Technologies of Perception: Searches for Life and Intelligence Beyond Earth

by

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Scientists in the late 1950s in the United States gained technological capabilities to test for signs of extraterrestrial life. While exobiologists developed visual techniques to detect whether sites beyond Earth might harbor microbes, "biosignatures," radio astronomers searched for extraterrestrial intelligence (SETI) in the form of "technosignatures." This dissertation explores how scientists since the Space Age have constructed experimental assemblages to imagine, relate to, and investigate the alien and exotic microbes—unknown, indeed, as-yet-imperceptible, objects—through familiar sensory metaphors of *seeing* (exobiologists) and *listening* (SETI scientists).

From historical material gathered at various D.C. archives, the American Philosophical Society, and the National Library of Medicine, I show how exobiologists' technologies of vision rendered anew images of the Moon, Mars, Venus, and the Earth from afar and at surface, affording scientists the ability to conceptually anticipate relationships between their world and others. Through a epistemic pratice I call "gaze-scaling," they yoked the concept of "island" to "planet," casting extraterrestrial sites as fragile laboratories of life that beckoned exploration. I next draw from immersive participant observation since 2016 to engage ethnographic sonar on the SETI group Breakthrough Listen based at U.C. Berkeley, California. I analyze how they construct criteria of intelligence through "experiments of anticipation" that are parametrized to hear from a commensurable subject. I theorize "figures of listening" in both observational protocols and as a preemptive attunement to Other intention, acts that configure an alien who would be not just perceptible, but relatable.

If exobiologists envisioned universal standards of biochemistry that would map life's common *origins*, SETI astronomers have traded on imagined superhuman characteristics of the alien—more benevolent, wiser, and technologically superior—to suggest human *futures*. I outline how the alien has been imagined through three potent analogical figures: as *artifacts*, *animals,* and *angels*. Furnished by feminist epistemologies and queer theories of care around multispecies becomings—traditions that have persistently challenged ontological stability across species, gender, race, and spacetime—I theorize those analogies as acts of "reflexive alienation": a mode of world-making in which scientists imagine Others imagining them. Future-oriented extraterrestrial objects held in abeyance cultivate Earthly concepts of being.

Thesis Supervisor: David Kaiser
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Acknowledgements

This dissertation project was sparked by an astronomy internship at the SETI Institute I gained while at Vassar College over the summer of 2008. Debra Elmegreen and Fred Chromey, my undergraduate astronomy professors, taught me about galaxies, quasars, observational astronomy, and possible forms of life beyond Earth. Jennifer Church, my philosopher advisor there, introduced me to methods of inquiry I would stitch together with science studies in HASTS. As a result of their mentorship, I found an incredible community of scientists who quest for extraterrestrial life, especially Jill Tarter and Frank Drake. As founders of the SETI Institute, those two scientists generously nudged along my interpretation of their work. While I was living in Berkeley, California, Jill, who lives high in the hills there, was always open for coffee or an interview. I remain inspired by her tenacity and enduring passion to make contact.

If aliens were to descend to Earth and require, as part of their anthropological (or exo-logical?) research, a model of a perfect dissertation committee, I would recommend to them Profs. David Kaiser, Stefan Helmreich, and Sally Haslanger. I feel lucky to have been able both to tap their discipline-spanning knowledge (history of science, anthropology, and feminist studies) and also rely on their unflagging good nature, good humor, and grace. I met my advisor, Dave (see: OED, s.v., "mensch") as a prospective student in 2012, and left his office with the sure feeling I wanted to learn alongside him. Since then, he has lit the way for this project with warmth, encouragement, and sparkling wit. Dave has read endless drafts and fielded countless emails with buoying, calming, encouragement. Our intersecting interests in (astro)physics in the Cold War era have inspired this project, but it was a pure pleasure to read together back to the pre-Socratic philosophers during my exams. That experience made me feel like I was part of an honored intellectual club that extends back millennia, and there was no better guide. Stefan Helmreich's scalpel-like inquiry into all things

anthropological has pulled this project in wonderful, exciting new directions. With him, I know there is always another level to think on, a new theoretical connection to be gained; learning social theory with him was mind-bending. Sally Haslanger graciously joined my committee outside of the HASTS program. Wading into the philosophical tradition with her counsel, I have learned to carefully piece together language to make broader claims. She molded my STS-y approach around feminist topics with generous philosophical illumination, an approach I am excited to cultivate further. As I have immersed myself in the worlds of exobiologists of the Space Age and current SETI practitioners, I have often found myself asking: How would Dave characterize, relate, and theorize the circulation of knowledge practices here? What *bon mot* would Stefan proffer to unspool my ethnographic claims a little bit farther? How might approaching a gnarly topic with Sally's philosophical sharpness make more clear claims about gender, race, and being? This amazing trio thinks, reads, and writes with care and compassion, and I feel honored to have been mentored by them. My profoundest gratitude to these three.

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the world to remote telescope sites, joined backyard BBQs, drank coffees on campus, listened to live music, and clinked beers at Berkeley's Faculty Club. My collaboration with the team begins with this dissertation, and I look forward to ongoing projects with this marvelous group of comrades.

Alongside the Breakthrough Listen science team, I met and engaged with folks adjacent to SETI research who helped along this project, like the operators at the Green Bank Telescope, the Parkes Telescope, and the Allen Telescope Array. With the participants of the Making Contact Workshops, especially, Michael Oman-Reagan and Kathryn Denning, we engaged questions of being, species, and feminist theory around the alien, adding depth to this project. Thank you also to members of the Breakthrough Initiatives team—Pete Worden, Jamie Drew—and especially to Christian Reuwer, with whom I tackled the task of organizing the team's participation at the International Astronomical Congress 2019 in Washington, D.C.

My three dear friends—Emma Carmichael, Kelly Stout, and Molly Johnsen—dedicated our group chat name to my ABD status after my exams (subbing some words in that initialization) and I task them with now changing it. They shamelessly dole out my kudos to anyone who will listen. Having counted them as kin since my first week of college, they have bolstered me as I left Brooklyn, passed my exams, moved about twenty times, and completed this project. Not only have they been sounding boards for this project, introducing unexpected literary touchpoints, but with them, I find joy easily and often. Grady Chambers is a life-long friend who read my graduate school applications. He has urged me on, edited my writing, and made me braver since we were nineteen. Jesse Brooks and Maxine Speier, too, are friends who encouraged my dissertation. Galen Stolee is my anthropological kin. Kate Guadagnino and Hannah Shtein are my Shorewood posse whose Midwestern stalwartness and interest in my project has braced and inspired me over many years. Luke Stern is my college bud who has been a most loyal cheerleader. Amanda Waterhouse, soon to also claim her Ph.D. in history, is a generous and shrewd scholar. Brad and Katie are the coolest kids

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Many moments in this dissertation reference interspecies encountering that at times play out through colonial-laden analogy and imagery. I finally acknowledge my position as a white scholar who has benefited from institutions that are currently sited on lands dispossessed from Native peoples through the past and ongoing violence of settler colonialism. Acknowledgement is a small move toward undoing that great and cascading violence, but it pricks the consciousness of readers and this writer; it calls attention to the need for greater, braver acts.[1]

Cambridge, Massachusetts, is Nipmuck land.

Berkeley, California, is Chochenyo land and Ohlone land.

Washington, D.C., is Nacotchtank land and Piscataway land.

Philadelphia, Pennsylvania, is Lenni-Lenape land.

Baltimore, Maryland, is Piscataway land.

Parkes, Australia, is Wiradjuri land.

[1] Native Land Digital, "Native Land," accessed August 11, 2020, https://native-land.ca/. (H/t Elena Sobrino.)

Green Bank, West Virginia., is Calicuas land and Moneton land.

Hat Creek, California, is Atsugewi land.

Introduction: Technologies of Perception

I spent the summer of 2008 at NASA Ames Research Center near Mountain View, California, as an undergraduate intern at the SETI Institute, an organization whose scientific mission is the search for extraterrestrial intelligence. SETI hopes to discover signs of such intelligence by scanning the skies for radio signals carrying alien information or communication. Along with the other interns, I stayed in the stark dorms at Moffett Field, a hodgepodge of buildings that included scientific research facilities devoted to space engineering projects as well as a gargantuan airplane hangar, a relic of the site's past life as a Cold War-era naval base. At the peak of summer, we interns sojourned from the rigid, militaristic atmosphere of Moffett Field to the Allen Telescope Array (ATA) named after a major sponsor, Paul Allen, a co-founder of Microsoft in Hat Creek, California, for a fieldtrip to experience observational SETI research. The array remains partially built as a result of multiple funding shortfalls from both public and private sources (only 42 of the intended 350 radio telescopes were constructed).[2] Still, we were able to demonstrate the array's capacities by training the telescopes to track a television satellite across the sky. Jill Tarter, who had promulgated the search for extraterrestrials (ET) with a passionate, singular focus, and who co-founded the SETI Institute in 1984, accompanied us to the telescope array she had helped design, engineer, and build. In 2020, now retired from active research, Tarter remains an indefatigable veteran in a field she molded over forty years, a field whose aim is to achieve a mission that still eludes her: to find a radio transmission from an alien species, an event she and others in more recent years have called a "technosignature." That term first appeared in the literature in 2007, when Tarter wrote to the International Astronomical Union's General Assembly, "If we can find technosignatures—evidence

[2] Tom Pierson, "Status of the Allen Telescope Array," email to SETI Institute Supporter (April 22, 2011); see also, Stephen J. Garber, "Searching for the Good Science: The Cancellation of NASA's SETI Program," *Journal of the British Interplanetary Society* 52 (1999): 3-12.

of some technology that modifies its environment in ways that are detectable—then we will be permitted to infer the existence, at least at some time, of intelligent technologists."[3]

On the first night of that 2008 fieldtrip, I set up a tent near the array with a few other interns. The desert heat was oppressive and the arid air kicked up clots of dust. However, the fragrant night breeze caught pleasant scents from desert blooms as we watched Jupiter rise in the southern sky. As romantically minded teenagers, I suppose we cast ourselves as budding young scientists cosplaying a scene in one of my favorite movies at the time, *Contact,* adapted to film by Carl Sagan, the author of the book of the same name, and Ann Druyan.[4] Jodi Foster plays Ellie Arroway, a SETI scientist whose life closely parallels Tarter's: a headstrong and heterodox scientist whose drive to discover extraterrestrial radio transmissions could not be extinguished by closed-minded naysayers. Arroway, listening on the hood of her car alongside rows of radio dishes at the Very Large Array in New Mexico—a site much like the ATA, but larger and more flush with cash—hears an extraterrestrial signal thumping through her headphones. At the Allen Array, my fellow interns and I weren't "listening" for alien signals, though the array's turning dishes suggested to me that this might be the place where an alien transmission might someday arrive.

Tarter had alerted those of who were sleeping outside that evening that the dry conditions had prompted local officials to call an unusually high risk of wildfire warning for the area. Later that evening, an intensively incandescent orange light peeked above the black silhouette of a nearby mountain range. For a few seconds, groggy, discombobulated from waking outside in a strange place and without my glasses on, I briefly considered alerting Tarter to a forest fire. Reader: it was the Moon. As it rose, its sprawling, bloody hue on the ridge gave way to a sharp and focused sphere,

[3] Jill C. Tarter, "The Evolution of Life in the Universe: Are We Alone?" *Highlights of Astronomy*, 14 (IAU XXVI General Assembly, 14-25 August 2006), 20.
[4] Robert Zemeckis, dir., *Contact* (Los Angeles: South Side Amusement Company, 1997); Carl Sagan, *Contact* (New York: Simon and Schuster, 1985).

flooding the array with white light that glinted off the usually dull metal dishes. Sheepishly, I went back to my sleeping bag.

I recalled that incident while writing this Introduction twelve summers later because my momentary confusion that night illustrates how we parse events first through calling upon our senses; previously gathered information can prime our anticipations and interpretations. That moment, unfolding on hallowed SETI ground, now appeals to me as a flashpoint for major themes in this dissertation, a work that is centered around the ways that scientists such as Tarter make knowledge around elusive Others through calling upon familiar modes of sensing. The phrase "technologies of perception" refers to the instruments that scientists who search for life beyond Earth employ—technologies that are expensive to use, complexly engineered, and available only to highly trained experts. Technologies of perception bring into relief phenomena—real and imagined—that escape scientists' immediate sense-abilities.[5] These technologies create the possibility of *seeing* alien organisms through biological devices on the Moon or Mars or *listening* to extraterrestrials' electromagnetic messages via radio telescopes. The central question of this dissertation is: How are sensory phenomenological modes of sensing the world deployed and channeled through material technologies to scout for otherworldly technoscientific objects, lively organisms, and intelligent aliens?

Technologies of Perception: Searches for Life and Intelligence Beyond Earth is a historical and ethnographic dissertation whose theoretical orientations are informed by studies in science, technology, and society (STS), as well as feminist traditions that examine sensory apprehension, especially those modes that enlist seeing and hearing. My archival work charts a civilian group of scientists in the Space Age who called themselves exobiologists who sought life in an extraterrestrial

[5] Readers might recognize the resonance of this phrase with Jonathan Crary's "techniques of the observer" that describes modernity's construction of sight, seeing, and veracity: Jonathan Crary, *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century* (Cambridge: MIT Press, 1990).

context just as the possibility to explore nearby planets and the Moon shimmered into reality. Their use of *visual* technologies (spectroscopy, photometry, photography), I will argue, enabled them to "scale up" knowledge about Earthly forms life to pertain to possible alien life, an activity that has in turn brokered new visions of Earth itself. That is, conceptually moving between different expressions of life on their home planet and hoped-for others was diffracted through visual media afforded by views from, to, and in outer space. My ethnographic work follows radio astronomers' use of *listening* technologies and metaphors to tune to possible alien signals—ones that might not only be perceptible, but intelligible. Originating in the U.S. Cold War context, these civilian scientists' projects have been animated by an ethos of *hope*. If exobiologists envisioned that universal standards of biochemistry would illuminate life's common *origins*, SETI astronomers today imagine an alien—sagacious, superhuman, suspended across spacetime—who would suggest possible *futures*.

Complementing my archival research in multiple collections, including at the U.S. National Archives in Washington, D.C., the National Library of Medicine in Bethesda, Maryland, and the American Philosophical Society in Philadelphia, Pennsylvania, my project also benefits from access over four years of immersive fieldwork with the Breakthrough Listen collaboration, a SETI research group based at University of California, Berkeley. My ethnographic and participant-observation research with them anchors my account of this most robust search for technosignatures—radio artifacts of the extraterrestrial—ever performed. The team of astronomers, engineers, and data scientists uses a variety of instruments across the world, often equipped with a special hardware assemblage to record, store, and transfer data. Research trips and remote observing sessions at radio telescopes in West Virginia, Australia, and California, made possible in part by my undergraduate training in astronomy, constitute the ethnographic base for my theorizing scientific imaginations of ET intelligence around the metaphor of listening. I explore listening as an epistemic mode of expectation that informs the group's material, instrumental, and data analysis choices. In configuring

how the alien will "speak," the group devises the experimental conditions that would render the alien legible. Breakthrough's quest to lay the groundwork for how alien and human might meet on a plane of ontological similitude is a matter of expected, congruent technology, in other words, anticipated *commensurability*. "Commensurability" is a concept crucial to the SETI project: it is a mode of relation by which particular attributes are "measurable by the same standard or scale of values."[6] Although SETI practitioners have historically sought mere *technological* commensurability—as Jill Tarter has told me, "we are using radio technology as a *proxy* for intelligence"—I evaluate how the alien emerges in scientific imaginaries that construe ontological overlap (or blockage) between species.[7] In particular, I theorize the alien that surfaces in scientists' analogical comparisons to three figures: prehistoric humans' relics, non-human animals, and god-like entities. I further read Breakthrough's data analysis products as epistemic tools that encode anticipation; such programs are built to preemptively attune to *past* alien intention that had created noticeable signals arriving to Earth millennia in their *future*—perhaps, our soon-to-be-present.

That is, their data products are built to subvert what Tarter has called "the tyranny of lightspeed" in which ET, perhaps hundreds of thousands or even millions of years in past, would have transmitted a radio signal so as to be commensurable with our present technology.[8] As Karen Barad has theorized, such mishmashes of spacetime disrupt received notions of matter's and beings' ontological stability, and I similarly read Breakthrough's data manipulations as *queer* orientations tuned toward unknown, but anticipated, alien intention. As such, I make use of STS scholarship on regimes of perception and representation, extendable sensoria, non-human animals, and cultivations

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[6] *Oxford English Dictionary Online,* s.v. "commensurability," accessed February 2, 2020, https://www.oed.com/view/Entry/37042.

[7] Jill Tarter, in discussion with the author, March, 2018.

[8] Anthropologist Michael Lachmann and physicists M. E. J. Newman and Cristopher Moore have argued that, because an information-rich technosignature would be perceived as a one-dimensional blackbody spectrum, an extraterrestrial alien signal would be not legible. Riffing on Arthur C. Clarke, in other words, "any sufficiently advanced technology is indistinguishable from noise." See: "The Physical Limits of Communication *or* Why Any Sufficiently Advanced Technology is Indistinguishable from Noise," *American Journal of Physics* 72, no. 1290 (2004): 1290-1293.

of care. I extend such topics to analyze my interlocutors' shifting interpretations of objectivity, the Other, and outer space since the late 1950s. As objects that remain out of reach, the intelligent alien and extraterrestrial microbes disrupt and disharmonize Earthly categories of life, species, and mind in ways I parse through feminist and queer theory.

Seeing, Sounding, Sensing

STS scholars and historians and anthropologists of science have long examined how scientific instruments are called on to facilitate research regimes through their engineered capabilities to sense the world in ways different than those available to their human users. Steven Shapin and Simon Schaffer show how what they call "virtual witnessing" privileged certain kinds of sight that could be mobilized to give credence to experimental and philosophical "forms of life."[9] In particular, Robert Boyle's disciplining of his fellow elite experimenters' ways to see and replicate the air pump impelled his community to unveil discoverable, but hitherto hidden, "matters of fact"—acts that assured the moral certitude of reality the device provided.[10] Lorraine Daston and Peter Galison explain how images produced under the regime of "mechanical objectivity" at the *fin de siècle* sought to vanish the handiwork of the natural philosopher; "epistemology of the eye," wrought through technologies such as photography and microscopy, afforded scientists what they saw as a path to suppress an intervening, subjective (even dangerous) will that would cloud their ethical duty to represent nature most purely.[11] In these two cases, men of science sought to tamp down the deceptive and perilous tendencies of the senses to misrepresent, obfuscate, and confuse—effects

[9] Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and The Experimental Life* (Princeton: Princeton University Press, 1985), 150. (They make use of philosopher Ludwig Wittgenstein's concept, "forms of life.")
[10] Shapin and Schaffer, *Leviathan and the Air-Pump,* see especially, Chapter 2: "Seeing and Believing: The Experimental Production of Pneumatic Facts," 22-79.
[11] Peter Galison and Lorraine Daston, *Objectivity* (New York: Zone Books, 2007). Chapter 3, 115-190.

that might not only contaminate experimental results, but also ones that to them represented existential threats to glimpsing the core of the real. (René Descartes eschewed the senses altogether in *Meditations*; his *cri de cœur,* "Je pense, donc je suis," is a retreat to the inner mind as the only objective reality, as secured through God.[12])

How visual practices represent nature in Western empirical traditions extends to more recent applications. David Kaiser's tracing of physicist Richard Feynman's diagrams, meant as bookkeeping tools to keep track of pesky particles, was facilitated through communal dispersion in postwar America. As they morphed, the drawings inspired various articulations of quantum behavior, attesting to what Kaiser notes is the phenomenon of visual tools' at once ephemeral and lingering abilities to form and reform theory through practice; the scratching out of quick drawings that accounted for the day-to-day labor of physics gestured toward their practitioners' fundamental reworkings of quantum theories by which they understood but also constructed their universe.[13] Scaling up to outer space, Janet Vertesi looks to technologies of the camera to theorize how NASA scientists bridge the distance between their terrestrial labs and the robots they control and care for on Mars through an embodied practice she calls "technomorphing"—the cultivation of visual skills around unfamiliar ways of looking (in panorama and fish-eyes lens) and embodied gestures (translating human motions to robotic appendages) that discipline community-specific practices of "how to see like a Rover."[14] Their scholarship demonstrates how social practices (the dispersion of diagrams, the analysis of mechanically produced images) normed visual techniques to cultivate particular ways of seeing and understanding imperceptible or distant objects.

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[12] René Descartes, *Discourse on Method*, in *The Philosophical Works of Descartes*, trans. Elizabeth Haldane and G. R. T. Ross, vol. 1, 80-106, (New York: Cambridge University Press, 1978 [1637]).
[13] David Kaiser, *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics* (Chicago: University of Chicago Press, 2009).
[14] Janet Vertesti, "Seeing like a Rover: Visualization, Embodiment, and Interaction on the Mars Exploration Rover Mission," *Social Studies of Science* 42, no. 3 (2012): 400.

If objectivity's contestable avatar is the visual, then scholarly work on *sound* explores how technoscientific practices resonate subjectivity. Stefan Helmreich describes how the watery descent of the submersible *Alvin* to the sea floor of the Juan de Fuca Ridge is full of sounds that confuse inside and outside, creating an intimate, immersive experience in which cyborgian materials (human, water, machine) mesh.[15] Steven Feld's acoustemology (an imbrication of acoustics and epistemology) overflows with the sounds the Kaluli people of Papua New Guinea as they submerse themselves into the rainforest to navigate, hunt, and imbue recallable memories.[16] Their polyphonic singing enculturates senses of place and time; they layer their songs with ritual to create emotional soundscapes, ones that reverberate with the dense forest and the animals that live there. Or take Sophia Roosth's account of sonocytology, the science of making cell sounds audible. Scientific practices meant to gain auditory access to those cells is an act of calling upon them as living subjects, she argues, to create the experimental conditions in which they can be interpreted as responding though making sound (allegorized as "screaming").[17] These examples show how *sound* orchestrates listening *subjects* through various *emplaced* media (cyborgs in water, animals in the forest, cells in a milieu), and thus, as Roosth suggests, sound "floods space with time."[18] Ways of seeing and ways of sounding, then, are historically and culturally created framings. If vision lends itself to scientific inquiry to parse, delimit, and purify, sound, alternatively, is construed as immersive, interior, and connective. While sight is mobilized to freeze and pinpoint, listening is experienced as swimming and surfing through soundscapes.[19]

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[15] Stefan Helmreich, "Submarine Cyborgs: Transductive Ethnography at the Seafloor, Juan De Fuca Ridge," in *Alien Ocean: Anthropological Voyages in Microbial Seas* (Berkeley: University of California, 2009), 216-232.
[16] Steven Feld, "A Rainforest Acoustemology," in *The Auditory Culture Reader*, ed. Michael Bull and Les Back (Oxford: Berg Publishers, 2004): 223-240.
[17] Sophia Roosth, "Screaming Yeast: Sonocytology, Cytoplasmic Milieus, and Cellular Subjectivities," *Critical Inquiry* 35, no. 2 (Winter 2009): 332-350.
[18] Roosth, "Screaming Yeast," 346.
[19] For instance, technologies crafted in the 19th century, privileging particular virtues, wrought sights and sounds to be experienced as *modern*, see Crary, *Techniques of the Observer* or Emily Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900-1933* (Cambridge: MIT Press, 2004).

Seeing and sounding are thus distinct modes of abled sensing in the world that read out through technoscientific instruments, materials, and practices of meaning-making. My project engages *familiar* visual and aural phenomenological modes of perception that scientists since the 1950s have called upon to test theories around extraterrestrial life and intelligence—as yet *otherworldly*, unavailable objects. It explores how radio and optical astronomers, as well as biologists, engineers, and computer scientists since the postwar era, working within research universities and institutes of scientific inquiry in the United States, have constructed experimental systems to grapple with the related but distinct questions "Are we alone?" and "Where else is life?" This project queries technical methods that scientists use to span the epistemological space between working definitions of Earthly life and human intelligence and as-yet-unknown, but potentially commensurable, forms of Other life and Other intelligence.

To do so, this project probes the technological methods by which these scientists have extended human modes of sensing to try to perceive unknown Others. Over the past four years, I have followed the practices of exobiologists, a group of civilian scientists working in NASA's fledgling space biology programs from the late 1950s to the early 1970s, to today's SETI researchers, especially the Breakthrough Listen group based in U.C. Berkeley, to ask: How do radio and optical astronomers mobilize *technologies of perception* to build experimental systems toward future-oriented objects? Using optical methods like photometry and spectroscopy to "see" signs of life, or radio astronomy to "listen" for a signal from an intelligent alien, scientists, I contend, have made use of ways of sensing the *world* to orient toward *otherworldly* phenomena. Lacking extraterrestrial contexts of life and intelligence, scientists fall back on, but also pursue, familiar metaphors that describe human modes of sensing as they operate at the edges of knowledge.

Knowability Held in Abeyance

What instruments, theories, and practices hover at those edges? Scientists' sought-after objects—an encounter with intelligent alien or the detection of lively signs of Earthlike biology elsewhere in the solar system or beyond—have yet to surface. I explore in this dissertation how that irresolution sets up particular epistemic conditions for each group of scientists. Exobiologists seeking a universalized theory of biology and radio astronomers seeking commensurable intelligence have created experimental methods to anticipate forms of life that might arrive as perceptible, relatable, and understandable with and against definitions of liveliness, cognition, technology—even morality, as we shall see—on Earth. Searches for extraterrestrial life, whose objects are as yet unheralded but still poignantly sought, are *experiments of anticipation*. How scientists have oriented themselves to expect objects they believe exist but remain missing, elusive, or shrouded from perceptibility since the Cold War is the primary theme of this dissertation.

In historian of science Hans-Jörg Rheinberger's terms, "epistemic things" that are processed through experimental systems and then emerge through historically located and materially dependent scientific work never cohere into "technical objects," stabilized tools of technoscience that would command further utility. The reception of an initial technosignature has yet to inform methods to attune to the *next* alien transmission; the un-glimpsed microbial life forms on Mars cannot illuminate possibilities of other lively worlds.[20] By Rheinberger's reckoning, scientists in the lab proceed through "organized groping" to pinpoint scientific objects that only appear evident after the fact, like wandering inside the walls of an unplanned labyrinth. However, in the two scientific fields I explore here (to warp that metaphor further), those walls have not yet led Ariadne to Theseus.[21] For astronomers working to clarify universal theories of lively biochemistry or the

[20] Hans-Jörg Rheinberger, *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (Stanford: Stanford University Press, 1997), 29.
[21] Rheinberger, *Toward a History of Epistemic Things*, 56.

existence of a technologically commensurable alien, definitions of life and intelligence since the 1950s remain incomparable outside of their terrestrial contexts, reflexively refined within a self-referential echo chamber. New epistemic things that could cascade from technological objects are locked in a liminal abyss between existing proofs of life and intelligence on Earth and sought-after objects that could expand, derail, subvert, upend, or deepen such concepts. Extraterrestrial organisms and beings are epistemic things that indeed "derive significance from their future."[22] But it is unclear if, when, and how they will catch up to scientific expectations in that future.

Nevertheless, they remain potent objects around which scientists have mobilized gargantuan yet highly sensitive instruments, cleverly designed and increasingly sophisticated software codes, and billions of dollars of funding for telescope time and human labor. Scientists have devoted their careers to these objects, molding new experimental methodologies over the decades. My interlocuters in SETI have repeatedly told me about their openness to being surprised by the source of the longed-for technosignature. "I hope the LIGO guys would let us know if they find an alien message on a gravity wave," one astronomer at Breakthrough Listen remarked to me (referring to the Laser Interferometer Gravitational-Wave Observatory, an instrument designed for a decidedly different purpose: to uncover ripples in spacetime).[23] The research strategy Dan Werthimer, Chief Scientist at the Berkeley SETI Research Center, employs is to "try forty different small things" so as to increase the likelihood that one might be successful.[24] His experiments, and other SETI efforts, endeavor to tip unknowability to knowability, a move with potentially exponential consequences. Jill Tarter speculated to me that once N=2 is detected—in which the number of radio-competent species would move from [humans] to [humans plus one]—SETI practitioners would be able to figure the existence of thousands, if not millions, of other species with whom we could potentially,

[22] Rheinberger, *Toward a History of Epistemic Things*, 76.
[23] Howard Isaacson, in discussion with the author, April 2018.
[24] Dan Werthimer, in discussion with the author, July 2016.

eventually, interact.[25] Meanwhile, exobiologists in the 1950s imagined a plentitude of other habitable worlds like our own, an idea scientist Joshua Lederberg called the "evolutionary principle": that chemistry, biology, and even culture would have sprung up from the same stuff in the universe.[26] Astrobiologists working today, benefiting from Lederberg's legacy that first inscribed biology into NASA's beginnings, often narrate their field (as their predecessors did), as one on the cusp of discovery. At the Breakthrough Discuss 2018 conference, an invite-only workshop held in the Bay Area, scientists on the panel "Search for Life in our Solar System" engaged in good-natured speculation (and even professional ribbing about competition for NASA funding) about which extraterrestrial site—methane-filled Titan, icy Europa, or an old favorite, Mars—would pull ahead as the winning prize horse of discovery.

These examples point to acts of empirical *reaching*, a taut and fruitful site of anthropological inquiry. Lisa Messeri, in her work with exoplanetary astronomers, argues that scientists "make planets places" by familiarizing potential sites of life. Her concept, the "planetary imagination," describes, in part, how scientists create aspirational "beliefs and hopes from the past, present, and future of what planets *are* and thus what they would be like to occupy."[27] The planetary imagination mediates technical methods by which scientists emplace themselves on faraway worlds, Messeri argues, drawing closer together hoped-for discoveries on distant planets with familiar ways of being and seeing on Earth, modes that govern the shared production of knowledge. Her concept enacts what Helmreich and Roosth identify within the history and philosophy of science as "abductive reasoning," one they describe as a "future-oriented, even hopeful" epistemic framework by which

[25] Jill Tarter, in discussion with the author, March 2018. For a discussion on the social power of numbers, see: Will Deringer, *Calculated Values: Finance, Politics, and the Quantitative Age* (Cambridge: Harvard University Press, 2018).
[26] Joshua Lederberg, "Signs of Life: The Criterion System of Exobiology," *Nature* 207, no. 4992 (1965): 9.
[27] Lisa Messeri, *Placing Outer Space: An Earthly Ethnography of Other Worlds* (Durham: Duke University Press, 2016), 20.

scientists imagine life forms based on "premises that may or may not materialize."[28] In particular, the ubiquity of life in the universe that Lederberg envisioned unfolds in astrobiological practices today, in which, those anthropologists write, "life reaches toward forms as yet unencountered."[29] Consider, too, that term's linguistic sibling, "abduction," within the themes of this dissertation—the experience of being captured, probed, and experimented on by alien beings.[30] Anthropologists Debbora Battaglia, Susan Lepselter, and Jodi Dean, notably, have variously analyzed these stories as expressive of Americans' feelings of uncertainty, captivity, and tension (especially race relations) in the postwar era.[31] They explore how culture curls into space, only to reflect back what Battaglia describes as an "extraterrestrial uncannily familiar and concrete."[32]

This dissertation focuses instead on scientific imaginations of an alien unencountered yet yearned for, premised on projected ontological resemblance, which informs epistemic practices that "reach" toward other beings. Another sense of the word "abduction"—"the action of leading or drawing something away"—summons the image of some enticing entity shrouded in the distance, and this dissertation, in part, follows scientists who follow those beckoning extraterrestrial objects.[33] It plumbs the gap between the known and the unknown, delimiting a dynamic, communally wrought, interstitial epistemic space I conceptualize as *knowability held in abeyance*. Although scientific inquiry is, generally, directed toward the unknown, the interlocuters in this dissertation cast about

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[28] Stefan Helmreich and Sophia Roosth, "Life Forms: A Keyword Entry," *Representations* 112, no. 1 (Fall 2010): 28. They also describe two forms of reasoning that predate abductive logic around historically evolving ideas of life. Through *deductive* logic, the German term *Lebensform* linked habit, medium and living, marking a Kantian, inherent purpose of liveliness. By the mid-nineteenth century, life form had lost its "corseting hyphen" (39); unveiled with inductive reasoning, Darwinian mechanisms found material, not teleological, origins of life. Thus, "Life form," they write, "has moved from its origins as a term referring to abstract, idealized, aesthetic possibilities through reference to biogeographic and evolutionary possibilities to, today, conjectural and future possibilities" (27).
[29] Helmreich and Roosth, "Life Forms," 41.
[30] Plays on abduction / abductive logic were required.
[31] Susan Lepselter, *The Resonance of Unseen Things: Poetics, Power, Captivity, and UFOs in the American Uncanny* (Ann Arbor: University of Michigan Press, 2016). Debbora Battaglia, "Insiders' Voices in Outerspaces," in *E.T. Culture: Anthropology in Outerspaces*, ed. Debbora Battaglia, 1-37 (Durham: Duke University Press, 2005); Jodi Dean, *Aliens in America: Conspiracy Cultures from Outerspace to Cyberspace* (Ithaca: Cornell University Press, 1998).
[32] Battaglia, "Introduction," 1.
[33] *Oxford English Dictionary Online,* s.v. "abduction," accessed August 17, 2020, https://www.oed.com/view/Entry/250.

for scientific objects that are hoped to exist but escape hints as to their nature, origin, or form. Thinking with astrobiology's (exobiology's successor) expected *extreme* forms of life beyond Earth, Stefan Helmreich's "extraterrestrial relativism" nods to that curious epistemic conundrum, describing how "knowledge or truth about 'life' (or even its 'conditions') is imagined as relative to a 'nature' whose full character we do not yet know, whose outlines may lead us toward comparisons we cannot predict."[34] SETI is essentially an "anomaly detector" according to Steve Croft, a senior scientist at Breakthrough Listen; attuning to the unknown is what motivates him. "We might even just succeed by chance, we might get lucky," he remarked to me.[35] Foreshadowing animal analogies later in the dissertation, "You dip your net in the ocean and maybe you were fishing for tuna, but maybe you pull up an octopus," he said. "It turned out that the net was actually kind of good at catching other stuff." Croft described SETI as a pursuit as "pushing out into discovery space, motivated by an idea of what they [ET] might be doing."[36]

Experiments of expectation that scientists have conducted since the 1950s are modes to orient themselves toward unperceived objects, that, I will show, engender a self-reflexive care aligned with possible futures. The experiments have afforded scientists the ability to imagine Others in relation to themselves that boomerang back to Earth. Exobiologists' fears of contamination of other potential worlds by crafts of terrestrial origin in kind informed protocols to sterilize returning space probes so as to protect their own planet. SETI scientists' search for alien transmissions, because those signals would be arriving millions of years after their postage stamp, would be evidence of radio technology-using species' abilities to "tunnel over" into a category of long-lived populations—a

[34] Stefan Helmreich, "Extraterrestrial Relativism," *Anthropological Quarterly* 85, no. 4 (Fall 2012): 1130.
[35] Steve Croft, in discussion with the author, February 2020.
[36] Steve Croft, in discussion with the author, February 2020.

realization that would lend optimism to humans' capabilities to do the same, according to Tarter.[37] Care for imagined, future Others thus cultivates care for familiar, present selves.

Knowability held in abeyance, then, describes communal practices that orbit around expected Others whose existences are *unperceived* but not *inconceivable*. Exobiologists imagined that microbial life on the Moon, Mars, or Venus would confirm or torque their understanding of terrestrial biology—new evidence that would help the flesh out the thorny problems of life's origins. Radio message from ET would give shape to a commensurable technoscientific soundscape between listening species—those who expect the Other could speak and be heard. As such, imaginations of lively Others are read through experimental practices that gesture toward un-foreclosed, if undisclosed, futures in which species might meet. ET's properties remain suspended in what Astrid Schrader has termed "epistemic uncertainty" rather than "ontological indeterminacy"—they are imagined as beings whose existence and characteristics *could* be revealed even if they are, as yet, occluded from knowability.[38] Orientation toward these Others form what Daston and Galison call "scientific selves," attitudes and practices that are cultivated around historically moored "epistemic virtues."[39] The scientists in this dissertation rally around unknown, yearned-for objects that awe. They form communal practices that turn to face hoped-for futures of *imaginable* inter-species encounters. As astrophysicist Andrew Siemion, the Director of the Berkeley SETI Research Center and the Bernard M. Oliver Chair for SETI at the SETI Institute (the position Tarter had held before retirement) told me, SETI is the "pursuit to answer the most profound and fundamental question of humanity," that is, if humans are "alone in the universe."[40]

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[37] Jill Tarter, in discussion with the author, February 2020.
[38] Astrid Schrader, "Responding to Pfiesteria piscicida (the Fish Killer): Phantomatic Ontologies, Indeterminacy, and Responsibility in Toxic Microbiology," *Social Studies of Science* 40, no. 2 (April 2010): 275.
[39] Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2007), 18.
[40] Andrew Siemion, in personal communication with the author, July 2017.

Some Keywords Entries: Metaphor, Analogy, and Commensurable Species

Physicists Giuseppe Cocconi and Philip Morrison, then at Cornell University, penned a short paper in *Nature* in 1959, "Searching for Interstellar Communications," that would mark the modern beginning of a novel direction in radio astronomy. "Near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us," they wrote.[41] "To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence."[42] Their words prompted a young Frank Drake, a year later, then a staff astronomer at the Green Bank facilities in West Virginia, to tune to what Cocconi and Morrison had outlined as "the optimum channel" for radio communication. Many of terms used here—civilization, communication, intelligence—have outgrown their Cold War origins but nevertheless persist in scientific and popular rhetoric. Giuseppe Cocconi and Philip Morrison's prediction conjures expectant throngs of extraterrestrial beings waiting to welcome humans to the intergalactic fold—imagery that seems overripe, if not naïve. As David Kaiser writes, their language "combined hardheaded calculation with an almost giddy optimism, the 'can-do' and 'gee-whiz' spirit that often marked the early years of the space age."[43]

[41] Giuseppe Cocconi and Philip Morrison, "Searching for Interstellar Communications," *Nature* 184, no. 4690 (1959): 844.
[42] Cocconi and Morrison, "Searching for Interstellar Communications," 844.
[43] David Kaiser, *Quantum Legacies: Dispatches from an Uncertain World* (Chicago: University of Chicago Press, 2020), 206.

This dissertation engages the technical terms, profound concepts, and everyday words that my interlocutors use, sometimes interchangeably, as shorthand, casually, or simply as part of a practical lexicon within privileged communities of science (that sometimes butt up against popular interpretations), and thus I pause here to reflect on a handful of them. The "I" in SETI is "intelligence," a word that has rankled the field's practitioners, but nonetheless remains in that initialism.[44] Jill Tarter has patiently explained that SETI is really the searching for a very specific kind of technology—non-local radio artifacts—that would act as a proxy for presumed alien intelligence. "Life," exobiology's parallel term, eludes definitional stability because its context in the universe remains unresolved. As Lederberg put it, life "may be unique in the solar system, perhaps even the cosmos—howbeit, it is still parochial."[45] Or, according to Helmreich, the NASA Astrobiology Institute's stated mission to uncover "universal" forms of life is curious because it is unclear how biosignatures—"fingerprints of life" that would mirror terrestrial traces—would exactly distinguish vitality from abiotic activity with only one example to go on.[46]

SETI furthermore is a field that is often associated with providing some kind of communication line between alien and human. Drake's "Equation" that the astrophysicist first formed in 1960 estimates the "number of civilizations in the Milky Way Galaxy whose electromagnetic emissions are detectable" but has undergone criticism and revision by subsequent practitioners.[47] One term, f_c, is defined as the "fraction of intelligent civilizations that develop communication" that would be further clarified by the final term, L, the length of time for species to live and develop radio technology. The speed of light at which radio waves travel is sluggish when

[44] There is chatter of changing the name to simply "SI," but that has not materialized.
[45] Joshua Lederberg, "Origin and Extent of Life" (Notes for Terry Lecture, Yale University, April 6-7 and 13-14, 1989, Box 86, Folder 82, National Library of Medicine), 11.
[46] Stefan Helmreich, "The Signature of Life: Designing the Astrobiological Imagination," *Grey Room* 23 (Spring 2006): 66-95.
[47] SETI Institute, "Drake Equation," accessed August 14, 2020, https://www.seti.org/drake-equation-index.

one considers the maw of interstellar distances. Barring some exotic method to subvert it, "communication"—a two-way conversation between human and alien—would take hundreds of thousands, if not millions of years, to complete. Croft of the Breakthrough Listen team and I have many times discussed how f_c should really be the fraction of *commensurable* radio technology-using species: the overlap of humans' capabilities as radio astronomers to "listen" at the right place, in the right time, for a powerful technosignature, and ET's transmission. Commensurability—a common standard of measurement—is a concept that informs both epistemic experimental conditions (the how of searching for familiar forms of life) and ontological expectation (that aliens will be enough like to humans to be recognizable through technological media).

I use the terms "listening" and "seeing" in a variety of ways to plumb scientific practices. Perhaps most superficially, they refer to literal ways of sensing. Exobiologists gained new views of Earth, the Moon, and Mars from outer space, and Drake really did scan through frequencies as one would on a car radio at a Green Bank telescope (only to hear static). Those sensory terms are also figures of speech. Breakthrough Listen's very name attests to the enduring potency of the particular association of SETI with sound. The 1970 NASA Report "Life Sciences in Space" linked new technologies of bioinstrumentation with the expected ability to illuminate heretofore hidden corners of the universe: "We explore in order to see farther and more clearly than ever before, and because we are curious to know the unknown."[48] Finally, they are metaphors employed by my interlocuters, historical and present-day, to conjure connection. Technical ways of perceiving optical light (telemetry, photography, spectroscopy) facilitated outer space views by which exobiologists conceptually gazed between extra/terrestrial contexts. For SETI scientists today, preparing to listen qualifies the experimental conditions in which the alien might "speak" as a commensurable subject.

[48] Space Science Board, *Life Sciences in Space: Report of the Study to Review NASA Life Sciences Programs* (Washington, D.C.: National Academy of Sciences Press—National Research Council, 1970), 10.

Analogy, too, is a rhetorical mode that figures in this dissertation. As Messeri's work has richly shown, space scientists familiarize other places through the use of *analogies*—linguistic relations of comparison—and *analogs*, e.g. the Mars Desert Research Station, as viable modes to imagine life on the that planet, on Earth. Because their sought-after objects remain undetected, the scientists in the dissertation frequently retreat to, but also cultivate, analogy as an ineluctable, if unsatisfying, tool. Exobiologists, in the milieu of the Cold War's masculinist posturing, sometimes compared themselves to past voyagers in the sea of space on the cusp of "discovery" of "new" worlds. SETI scientists' imaginations of the alien, meanwhile, reference non-human forms of life in relation to a self-perceived human subject along the grain of hierarchized intelligence across species.

The Alien: Ultimate Other, Kindred Being

Put another way, cultural milieus inevitably inform scientific representations of the unknown. But searches for life beyond Earth seem especially pregnable to anthropocentric projections, because, according to Isaac Asimov, they are "science[s] in search of a subject."[49] As he put it in a 1967 essay in the *New York Times Magazine* on exobiology, "How do you speculate when you have nothing to go on, when there is not even the tiniest fragment of outside life to serve as a guide? The answer to that is we *do* have something to go on. We know of one planet that is thoroughly infested with life—our own."[50] Beset by a cosmic echo chamber or hall of mirrors (choose your own metaphor), scientists' retreat to anthropocentric figurations of the alien or terrestrial models of life seems to inevitably enfold historically specific, socially normed ideas. Michael Warner, in the introduction to *Fear of a Queer Planet*, explains how the images on NASA's

[49] Isaac Asimov, "A Science in Search of a Subject," *New York Times*, May 23, 1965: SM52.
[50] Asimov, "A Science in Search of a Subject," SM52.

Pioneer Plaques launched into space 1972 and '73 illustrate gender and racial stereotypes of the postwar era; legible to human interpreters, they prompt wondering if they could ever even be readable by aliens. Carl Sagan, Linda Salzman Sagan (his wife at the time), and Frank Drake designed a pictorial message meant to indicate physical properties of the universe and also human beings. The figures, intended to display an amalgamation of races (whatever that means) have no body hair (let alone textured hair), and where the man sports a polite penis, the woman is genital-less (NASA erased the line that would have depicted her labia). The paragon of heteronormativity—ironically sanitized as asexual (a Foucauldian field day)—the couple is a technoscientific Adam and Eve. "They are not just sexually different," Warner writes. "They are sexual difference itself."[51] Philosopher Sally Haslanger might wonder, how, if prescriptive gender norms cannot be understood without socially negotiated notions of "masculinity" or "femininity," an alien could possibly parse the senders' terrestrial notions of being, difference, and body.[52]

The Plaques are one of several messages that have been transmitted into space, perhaps one day to be received by some Others, that illustrate their makers' yearning for what Sagan called a "cosmic connection," a desire to be universally legible to some unknown Other mind.[53] In an oral history I conducted with Frank Drake at the SETI Institute offices in Mountain View, California, over the summer of 2016, he related to me scientists' ongoing struggle to anticipate how aliens would read those messages: of the images that were chosen for the Voyager space craft's Golden Record in 1977, Drake remembered that he worried a photograph of an Olympic hurdler might prompt aliens to think humans could fly.[54] Astrobiologist Nathalie Cabrol, Drake's colleague at the

[51] Michael Warner, "Introduction," in *Fear of a Queer Planet: Queer Politics and Social Theory,* ed. Michael Warner (Minneapolis: University of Minnesota Press, 1993), xxiii.
[52] Sally Haslanger, "On Being Objective and Being Objectified," in *A Mind of One's Own*, ed. Louise M. Anthony and Charlotte E. Witt (Boulder: Westview Press, 2001), 215.
[53] Carl Sagan, *The Cosmic Connection: An Extraterrestrial Perspective* (New York: Dell Publishing Co., Inc., 1973).
[54] Frank Drake, in discussion with the author, June 2016; see also, Jet Propulsion Laboratory, "Images on the Golden Record," https://voyager.jpl.nasa.gov/galleries/images-on-the-golden-record/.

SETI Institute, has proposed that, "to find aliens, we must become the aliens," but the epistemic steps to do so remain murky.[55]

Still, through experiments of anticipation, that is exactly what the interlocuters we will meet in the following chapters endeavor to do. This dissertation, in part, analyzes modes of care for those imagined others, practices I analyze through feminist scholarship in the Conclusion. Care outlines an affective orientation—an emotional attunement to hoped-for Others—but also epistemic working methods. A persistent question posed by feminists is *cui bono?*[56] Asking it of the scientists in this work attends not only to their philosophical stakes of finding extraterrestrial forms of life but also "scientific selves," that is, identities that ground and qualify their questions.[57] For instance, orienting around questions of care provides a framework to understand how Lederberg sought sterilization protocols for returning space crafts to ensure Earth's planetary ecologies. It also highlights how searches for life that purport to detect knowledge for the benefit of all humans are ones that have typically been performed by Western-educated, white, male, hetero, cis, elite experts trained in the so-called "hard sciences," fields that have historically shuttered women, Black, and Indigenous peoples' participation.

This dissertation integrates feminist theories of care with scientific experiments of anticipation around *imagined* technoscientific objects. "Care is a selective mode of attention: it circumscribes and cherishes some things, lives, or phenomena as its objects," Aryn Martin, Natasha Myers, and Ana Viseu write. "In the process, it excludes others."[58] Scientists' questions, their working methods that prune data in particular ways, and the imaginaries they construct have

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[55] Nathalie Cabrol, "Alien Mindscapes—A Perspective on the Search for Extraterrestrial Intelligence," *Astrobiology* 16, no. 9 (2016): 667.
[56] Susan Leigh Star, "Power, Technologies and the Phenomenology of Conventions: On Being Allergic to Onions," in *A Sociology of Monsters: Essays on Power, Technology and Domination*, ed. John Law (London: Routledge), 43.
[57] Daston and Galison, *Objectivity*, 18.
[58] Aryn Martin, Natasha Myers and Ana Viseu, "The Politics of Care in Technoscience," *Social Studies of Science* 45, no. 5 (October 2015): 627.

developed around particular versions of "intelligent" life I ask after in this work. Take Cocconi and Morrison's recommendation (that Drake followed) to search in the wide radio band, the "rational choice," in particular, at the 21 cm line, a "unique, objective standard of frequency, which must be known to every observer in the universe."[59] Or Drake's depictions of atomic numbers, DNA, a human, and the radio telescope, among other items, in the Arecibo message transmitted in 1974 intended to demonstrate universal properties of matter. Wrestling with how technologically savvy species might communicate invites questions situated within feminist traditions such as: Are notions like reason, rationality, and objectivity gendered or raced, as Sally Haslanger has asked?[60] How do objects that elude immediate sense-ability *queer* received phenomenologies of perception, as sketched by Karen Barad and Sara Ahmed?[61] Finally, what does it mean to *care* for inextant Others who, to be visible, would have to be culled to promissory ontological commensurability?

The dissertation makes use of feminist theory to analyze instruments and techniques of perception. Modes of seeing were diffracted through optical technologies so as to locate (potential) omnipresent life forms toward a universal theory of biology in the 1950s, paired with Space Age rhetoric to "probe" interstellar space, recalling colonial fantasies of the past. Meanwhile, what Hillel Schwartz calls the "indefensible ear" resonates with scientists' description of radio telescopes that they use to "passively listen," according to one interlocuter.[62] I analyze what has been narrated as complementary pairings of sight/objectivity/activity vs. sound/subjectivity/passivity through historical and contemporary technologies of perception with feminist theories of technoscience.

[59] Cocconi and Morrison, "Searching for Interstellar Communications," 844-845.
[60] Haslanger, "On Being Objective and Being Objectified," 209-253.
[61] Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, Duke University Press, 2007); Sara Ahmed, *Queer Phenomenology: Orientations, Objects, Others* (Durham: Duke University Press, 2006).
[62] Steve Croft, in discussion with the author, March 2020.

Chapter Outline

Chapter 2: Islands in Space

To begin, I narrate the history of the search for microbial life beyond Earth beginning around the creation of the National Aeronautics and Space Administration (NASA) in the late 1950s into the early 1970s. Civilian scientists and engineers, led by the Nobel Prize-winning microbiologist Joshua Lederberg, spearheaded the effort to search for basic forms of life on Mars, the Moon, and even Venus, in addition to NASA's planned missions in the upcoming decades. I show how exobiologists framed those places around a powerful analogy that linked exploration of the past with tantalizing discoveries of the future. By envisioning planets as *islands*, they called upon discursive strategies to concretize their emergent discipline with familiar watery metaphors (the sea of space, planets as oases of life). That vision followed long traditions in literature, philosophy, and geography in which islands had been narrated as fragile and bounded, even as they had also been staged as sites invitatory of exploration, even exploitation. From Lederberg's archive at the National Library of Medicine; other historical sources, including the NASA archives and material drawn from the American Philosophical Society; and accounts of seeing Earth from above in the Space Age, I argue that the conceptual dualities of islands—as enclosed and expansive—transferred to the way exobiologists came to consider planets and the Moon in outer space.

Just as naturalists and conservationists had posited islands as closed systems that were ecologically rich yet vulnerable, exobiologists imagined planets, including their own, and the Moon as biospheres to be preserved. At the same time, they looked to those sites as ones that could possibly underwrite humans' future colonization of extraterrestrial locations. Such speculation was supported by a rich visual culture of technologically animated perception, from *Apollo 8*'s "Earthrise" photograph (1968), to *Mariner 9*'s (1970) televisual images, to the mapping of Mars in

greater resolution than ever before. Through the use of images to conceptually shift the gaze of planetary science back and forth between Earth and outer space, exobiologists' planets-as-islands imaginary forecasted a cosmic archipelago of universalized life in the post-World War II era.

Chapter 3. Sounds of SETI

This chapter conveys more than four years of fieldwork with the Breakthrough Listen team based in U.C. Berkeley, California. In 2015, the astronomy community was taken by surprise when Yuri Milner, the Silicon Valley billionaire announced a $100 million, ten-year project to fund SETI research.[63] Since that project took off in earnest in 2016 (dovetailing fortuitously with the start of my research), the team has grown and morphed as researchers have visited, postdocs have come and gone, and interns have taken on summer projects before returning to their home institutions in the fall. This chapter spans stories of observing, remote and on-site, at the Green Bank Telescope in West Virginia, and the Parkes telescope near Sydney, Australia; in-person immersion at the Breakthrough Listen labs for the better part of 2018; quick clarifications with the team over Slack, the productivity messaging app; presentations at professional astronomy meetings; conversations with scientists at Breakthrough Discuss workshops in 2018 and 2019; casual discussions and formal panels at the International Astronomy Congress in Washington, D.C., that I co-organized in my capacity as a Research Associate with Breakthrough Listen; the Making Contact Workshops, a social science intervention on SETI science I organized through Breakthrough Listen in 2018 and 2019; and other small gatherings I convened at Berkeley and over Zoom, the video conferencing platform.

This chapter explores the metaphor of "listening" and its aural accompaniments (sounding, hearing) as a rich epistemic mode that orients subjects to each other because the metaphor creates

[63] Breakthrough Initiatives, "Yuri Milner And Stephen Hawking Announce $100 Million Breakthrough Initiative To Dramatically Accelerate Search For Intelligent Life In The Universe," July 20, 2015, https://breakthroughinitiatives.org/news/1

conditions for who and what can be made to speak through experiments of anticipation. The chapter considers the following set of questions: How do astronomers partition what data is worth paying attention to, and what can be deleted? What makes a signal meaningful, and noise discardable? How do programmers write computer code to distinguish those categories—especially when they do not know if, when, and how ET will articulate a message? First, I outline "listening" as a figure of speech that SETI scientists often use to describe their research (e.g. a technosignature as a "cosmic dial tone") but whose utility as a metaphor—while poetic and evocative of interspecies communication—is epistemically paltry.[64] I then sound out two "figures of listening": first, an embodied metaphor by which I and other remote observers attune ourselves to radio telescopes through computerized bird song; second, as an epistemic mode that encodes particular technological parameters through which the alien might be rendered noticeable. Breakthrough's data analysis techniques are premised on the following: To listen begins with waiting for someone to speak; to wait is to manufacture the conditions that they will.

Chapter 4. Analogical Aliens

This chapter locates, illuminates, and theoretically structures moments when SETI practitioners and their scientific affiliates engage in speculation about a commensurable alien through three analogical figures: as *artifacts*, material relics of spacetime comparable to terrestrial prehistoric monuments; humans as pestiferous *animals* in relation to technologically advanced aliens; and as *god-like* beings—magical, benevolent, creators of life. The precession of those concepts—material, beastly, angelical—dovetails a scaling model of ontological virtue as narrated by the Western philosophical tradition predating Aristotle, employed here to reflect my interlocuters' invocations of analogical hierarchization. I first focus on an extraordinary object, KIC8462852, also

[64] Jill Tarter, in conversation with the author, July 2016.

known as Tabby's Star, that was wondered about, for a time, to be potential evidence of an alien megastructure. I describe in particular one experiment of anticipation: that aliens would have, thousands of years ago, imagined us noticing them, queerly bending space time so as to commiserate across interstellar distances. Next, flipping the script, humans are imagined as pestiferous critters in relation to an alien Other, a being so "advanced" they would not even notice us (we might be "brushed away like a wasp hovering over your beer"[65]). Inchoately immortal, the final alien of my tripartite is imagined as an Earthling, but extrapolated, extended, and amplified. I invoke philosophical concepts—Jacque Derrida's *différance* and the ancient Greeks' concept of *Eros*—to inquire how the alien, in SETI scientists' imaginations, tugs between the realms of mortal and divine.

Conclusion: Reflexive Alienation

I theorize scientists' turn toward these analogies as acts of "reflexive alienation," a mode of world-making in which SETI astronomers imagine Others imagining them, enchanting the familiar so as to assemble experiments of anticipation. I elaborate on themes of the preceding chapter to describe the process by which scientists analogize Other creations (though artifacts), Other beings (through animals), and Other capabilities (through immortals), in relation to themselves and their futures. Unrealized, but anticipated, scientists sketch ontological commensurability. To end, I concatenate themes of the previous chapters—life, intelligence, commensurability, communication, metaphor, analogy—around the concept of knowability held in abeyance. I describe how scientific searches of anticipation are ones of care for themselves and their futures. I cultivate feminist considerations of others who come to matter in various ways, including non-human animals and the environment, extended to imagined beings.

[65] Steve Croft, in conversation with the author, February, 2020.

Hopeful Futures around Unknown Others

Although the topics of this dissertation—microbial life forms and a conversant alien—are otherworldly, distant, and unperceived, writing about them in the time of COVD-19 calls them forth in unanticipated eerie resonance. Just like the potential extraterrestrial microbes that Lederberg and his cohort imagined might disrupt Earth's ecology, human health, and planetary stability decades ago, fear percolates around the unseen and frequently fatal novel corona virus today as it rips through fragile global health networks. While Lederberg and his companions advocated for planetary quarantine—that returning probes, and even men, should be isolated so as to protect a potentially vulnerable Earth from germs encountered on the missions—that word now has taken on a darker meaning, referring to practices of extreme social distancing afforded to those in privileged positions to protect ourselves and those we love from a microscopic but deadly virus.

It seems that scientists learn something new about the corona virus each day, and thus the virus dances ahead of comprehensibility—a dark twin to extraterrestrial microbes, similarly beyond grasp, but ones hoped to profoundly nurture theories of life's potential in an as-yet abiotic universe. I have wondered, wrapping up my chapter on the exobiologists with complementary material from the American Philosophical Society (APS), what Baruch S. Blumberg—the geneticist who shared the 1976 Nobel Prize in Medicine for his work on the hepatitis B virus and eventual vaccine that saved millions of lives, a member of the APS that houses his papers, and the first leader of the NASA Astrobiology Institute—would have thought of this travesty of public health. The virus is cast as a foreign invader by President Trump, whose repeated references to it as the "China virus" and even "kung flu" have stoked despicable racist attacks on Asian Americans.[66] His rhetoric calls to mind the

[66] David Nakamura, "With 'Kung Flu,' Trump Sparks Backlash Over Racist Language—And a Rallying Cry for Supporters," *Washington Post,* June 24, 2020 https://www.washingtonpost.com/politics/with-kung-flu-trump-sparks-

negative valences around the concept of "alien," the other unknown entity that haunts this project: suspicious, immigrant, non-native, outsider, hostile.

This dissertation alternatively explores hopeful visions for the future imagined by scientists whose desired objects of inquiry are often counterpoised as possible ameliorations against their contemporaneous terrestrial woes. In my archival and ethnographic work about and with scientists who search for life beyond Earth, I have often been struck by how palpably their imaginations of extraterrestrial microbes or alien Others embed hopes and anxieties of particular historical moments on Earth. Exobiologists working in the late 1950s feared a future in which the Soviets might detonate a "Red Star," a nuclear bomb visible from Earth, on the Moon, which spurred international collaboration.[67] In the face of the looming climate apocalypse, astrobiologists today reference the preciousness and precariousness of Earth's ecosystem as they search for universal aspects of planetary sustainability and habitability. A SETI scientist mused to me that ET could help humans "log on to the galactic internet," to receive blueprints to technical instruments that would harness the Sun's, and even the galaxy's, energy to solve food shortages, poverty, and dependence on foreign oil.[68] Due to the speed limit of light, any transmission scientists might obtain would have been sent from a distant, mature civilization—an event that would, SETI scientists reason, imply that ET had managed to avoid both nuclear and climate catastrophe.

As such, searches for life beyond Earth are hope-filled experiments of anticipation that shape Others as beacons that may light human futures, beings whose imagined existence populates an otherwise lonely, vacuous cosmos.

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backlash-over-racist-language--and-a-rallying-cry-for-supporters/2020/06/24/485d151e-b620-11ea-aca5-ebb63d27e1ff_story.html.

[67] Joshua Lederberg, interview by Barry Teicher, Tape No. 2, June 19, 1998 (Madison: University of Wisconsin-Madison Archives Oral History Project).

[68] Dan Wertheimer, in discussion with the author, March 2018.

Chapter 2: *Islands in Space*

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On Christmas Eve in 1968, U.S. astronauts William Anders, Frank Borman, and James Lovell became the first people to orbit the Moon on the *Apollo 8* mission. Anders took a photograph of Earth appearing to rise above the Moon's horizon, freezing one moment on their journey that almost skimmed the lunar surface. The Earth's seas glowed in vibrant blue hues while clouds swaddled its green and ochre continents. The planet appeared to float in stark contrast to the enveloping black void and the desolate grey Moon. Anders' photograph inverted the familiar experience of gazing skyward from Earth: the image miniaturized the planet to what the astronauts described as the size of a quarter—a cheerful, distant sphere in relation to the lifeless moonscape's horizon.[69] [Figure 1]. Decades later, in a 2018 *New York Times* documentary, the astronauts all commented that leaving Earth and experiencing what Anders described as "total immersion in the heavens" prompted profound feelings of preciousness and care for their home planet.[70] Borman remarked of seeing the Earth from afar, "When you're in a space craft, you think in terms of oceans, of islands."[71]

[69] *Earthrise*, dir. Emmanuel Vaughan-Lee (New York: The New York Times Op-Docs, 2018).
[70] *Earthrise*, Vaughan-Lee.
[71] *Earthrise*, Vaughan-Lee.

Figure 1. William Anders, *Earthrise* (NASA, reprocessed by Jim Weigang, https://apod.nasa.gov/apod/ap181224.html).

Borman's use of the word "island" continues a long discursive tradition that has deployed oceanic and insular imagery to describe and familiarize physically unreachable places in outer space. Think of 19th century Italian astronomer Giovanni Schiaparelli's description of Mars as an island, a planet whose geology he used to describe with words such as "isthmus, strait, channel, peninsula, [and] cape."[72] The National Aeronautics and Space Administration's (NASA) similarly plumbed this watery association between outer space and the sea in their naming of crafts like *Viking*, *Mariner, Magellan, Odyssey,* and *Ulysses* a century later. NASA Administrator Oran Nicks, who directed Lunar Planetary Programs and later served as the Deputy Director at the Langley Research Center, in a

[72] Cited in Robert Markley, *Dying Planet: Mars in Science and the Imagination* (Durham: Duke University Press, 2005), 55.

NASA publication *This Island Earth* further linked space missions to ocean voyages of yore, describing the 1969 Moon landing as "essentially similar to the paddling out by three valiant men in a dugout canoe to explore for the first time the nearest offshore island."[73] Finally, recall that astrophysicist Carl Sagan, standing on a cliff with the roaring waves below, opened the popular science television show *Cosmos: A Personal Voyage* with the evocative phrase, "the surface of the Earth is the shore of the cosmic ocean."[74]

How, historically, did the figure of the island come to structure scientific descriptions of distant planets in the Space Age? And how did terrestrial islands—depicted as sites where life flourished, evolved, and at times overwhelmed—vivify scientific hopes for expressions of life beyond Earth? I argue in this chapter that visual technologies and their interpretations were crucial. Images of planets, from afar and at surface, permitted scientists to conceptually anticipate relationships between their world and others, and in so doing, yoked the concept of "island" to "planet." New technologies of perception afforded views from space of other celestial bodies as well as Earth that scientists lighted on as they sought to articulate life in an extraterrestrial context. From the late 1950s to early 1970s, civilian scientists in the United States shaped the newly formed NASA's policies and space missions around space biology. Led by Nobel Prize-winning microbiologist Joshua Lederberg, "exobiologists," as they called themselves, worked between the disciplines of biology, geology, and chemistry. They endeavored to uncover life's particular attributes elsewhere in the solar system so as to establish a universal theory of life in the cosmos through new visual technologies.[75]

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[73] Oran Nicks, *This Island Earth* (Washington, D.C.: Scientific and Technical Information Division, Office of Technology Utilization, National Aeronautics and Space Administration, 1970), 4.
[74] *Cosmos: A Personal Voyage*, "The Shores of a Cosmic Ocean," dir. David Oyster, Richard Wells, Tom Weidlinger, et al., written by Carl Sagan, Ann Druyan, and Steven Soter, and presented by Carl Sagan, PBS, September 28, 1980.
[75] For an in-depth reading on the history of the search for life beyond Earth from the ancient Greeks to today's field of astrobiology, see urtexts by former NASA historian Steven J. Dick: *The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science* (Cambridge: Cambridge University Press, 1996); *Life on Other Worlds: The*

A month after witnessing Sputnik, the first artificial satellite that streaked across the evening sky on in October 1957, Lederberg was in Calcutta, India to visit his friend J.B.S. Haldane, a prominent biologist who had helped develop what became commonly known as the primordial soup model of the life's origins on Earth (he was also "notorious as a committed communist," according to Lederberg, speaking to the political landscape.[76]) Local celebrations marked the lunar eclipse, prompting the two men wonder whether the Soviets might "accent the military prowess signified by Sputnik" with the detonation of what Lederberg called "Red Star": a nuclear bomb visible from Earth—a back-of-the-napkin calculation revealed that this was indeed possible.[77] The encounter left Lederberg with "a determination…to do good, solid science" and propelled him to the forefront of NASA's new space biology program.[78] While at Stanford University, in 1958, Lederberg was named the Chairman of WESTEX, the National Academy of Science (NAS) Space Science Board's (SSB) West Coast group that studied exobiology, and was deeply involved with Committee on Space Research, COSPAR.[79] As evident in memos to NASA policy makers, community reports to NASA, and collaborations with his colleagues, Lederberg worked to ensure that the Moon and other planets' surfaces would be maintained for future scientific inquiry despite militarized, masculinist one-upmanship between the U.S. and the U.S.S.R. that defined the Cold War era.[80]

Ideological desires for manned missions that would demonstrate the U.S.'s technoscientific dominance coincided and conflicted with exobiologists' urgent messaging to NASA to conserve unexplored planets as potentially rich scientific sites. A 1961 SSB report envisioned a slow and

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20th Century Extraterrestrial Life Debate (Cambridge: Cambridge University Press, 1998); and, with James Strick, *The Living Universe: NASA and the Development of Astrobiology* (New York: Routledge, 2005).

[76] Joshua Lederberg, "Origin and Extent of Life" (Notes for Terry Lecture, Yale University, April 6-7 and 13-14, 1989), 9. Perhaps suggesting a microbiological *exo*

[77] Lederberg, "Origin and Extent of Life," 10; Joshua Lederberg, interview by Barry Teicher, Tape No. 2, June 19, 1998 (Madison: University of Wisconsin-Madison Archives Oral History Project).

[78] Lederberg, interview by Teicher, 1998.

[79] This group was originally called the Contamination by Extraterrestrial Exploration (CETEX) Committee.

[80] See Audre Wolfe, "Germs in Space: Joshua Lederberg, Exobiology, and the Public Imagination, 1958–1964." *Isis* 93, no. 2 (2002): 183-205.

careful integration of manned landings to Mars and elsewhere that would follow orbital television devices and unmanned space craft landings designed to first investigate planetary geological and potential biochemical properties.[81] Citing potential free radicals on the Moon that might cause explosions if they interacted with terrestrial material, the authors of the WESTEX report urged "great care be taken to exclude organic substances from space vehicles likely to impact on the moon."[82] The foresaw that outer space missions would take up the mantle of past oceanic exploration: "The early voyages of discovery can serve as useful analogies" to extraterrestrial inquiry, the report explained.[83] In the voluminous 1961 *Science in Space* Report, Lederberg and Nobel Prize-winning physiologist H. Keffer Hartline urged NASA to consider what they called the "cosmic distribution of life" to be equally important factor in their planning, not an afterthought to manned missions.[84] "This unique capacity of life which engages our deepest interest also generates our gravest concerns in the scientific management of missions beyond the earth," Lederberg would emphasis later in the report. "We are obliged to weigh the most productive experiments that we can do by remote instrumentation in early flights whether or not manned space flight eventually plays a role in scientific exploration."[85]

Exobiologists like Lederberg worried that "virgin planetary surfaces"—a phrase that calls to mind the perception of islands as untouched paradises—might host extraterrestrial life that would be compromised without international conservational efforts. Others involved in U.S. space science

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[81] Space Science Board, "Man's Role in the National Space Program," *31 March 1961 Letter Report to NASA* (Washington, D.C.: NAS, 1961), 2.
[82] Space Science Board, *Summary Report of WESTEX, February 21, 1959—September 26, 1959, Second Meeting of the ad hoc Committee on Contamination by Extra-terrestrial Exploration* (Washington, D.C.: National Academy of Sciences—National Research Council, 1959), 3.
[83] L. V. Berkner and Hugh Odishaw, "Dimensions and Problems: A General Review," in *Science in Space*, the Space Science Board (Washington, D.C.: National Academy of Sciences—National Research Council, 1961), 24.
[84] Joshua Lederberg and H. Keffer Hartline, "The Biological Sciences and Space Research," in *Science in Space*, the Space Science Board (Washington, D.C.: National Academy of Sciences—National Research Council, 1961), 2.
[85] Joshua Lederberg, "Exobiology-—Experimental Approaches to Life Beyond the Earth," in *Science in Space*, the Space Science Board (Washington, D.C.: National Academy of Sciences—National Research Council, 1961), 4.

took their cue from President Eisenhower's statement in March 1958 that outlined new directions for national space policy immediately prior to the formalization of NASA, in which he cited "the compelling urge of man to explore and to discover" driven by the "thrust of curiosity that leads men to try to go where no one has gone before."[86] Many of Lederberg's contemporaries privileged man's supposedly "innate drive to explore unknown regions," citing expansionist fantasies that traded on outer space as a harsh and extreme—but penetrable and irresistible—frontier of discovery.[87]

These competing attitudes toward expected planetary exploration rehearsed themes of past island voyages. Tropical islands have historically sited Western powers' conflicting ideologies: the Age of Discovery saw European companies' pursuit toward expansionism coupled with naturalists' enthrallment with novel flora and fauna: an intersection at which Western powers tussled with ideas of conservation vs. exploitation. Historian Richard Grove shows how European powers in the 17th-19th centuries both developed ecologically disruptive capitalist models of trade but also staged care-taking interventions as a result of new understandings of an equilibrating environment.[88] Those islands would later emerge as fragile, Edenic places primed to illuminate privileged, ephemeral, and profound insights on life's origin and evolution. As geographers Elizabeth Hennessy Amy McCleary explain, the Galápagos Islands where Charles Darwin developed his theory of natural selection are still perceived as pristine sites of nature in critical need of protection.[89] As such, historical

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[86] President's Science Advisory Committee, "Introduction to Outer Space" (Washington, D.C.: NASA History Division, 1958), 1.

[87] Space Science Board, *A Review of Space Research: The Report of the Summer Study Conducted Under the Auspices of the Space Science Board of the National Academy of Sciences at the State University of Iowa, Iowa City, Iowa, June 17-August 10, 1962* (Washington, D.C.: National Academy of Sciences—National Research Council, 1962), 1-21; More recently NASA, under the governance of the Trump administration, reanimates Cold War messaging around outer space. In a 2017 press release, Vice President Mike Pence, quoting President Trump, framed outer space as "next great American frontier" citing "our duty—and our destiny—to settle that frontier with American leadership, courage, and values." See: NASA, "New Space Policy Directive Calls for Human Expansion Across Solar System," accessed August 14, 2020, https://www.nasa.gov/press-release/new-space-policy-directive-calls-for-human-expansion-across-solar-system.

[88] Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600-1860* (Cambridge: Cambridge University Press, 1995).

[89] Elizabeth Hennessy and Amy L. McCleary, "Nature's Eden? The Production and Effects of 'Pristine' Nature in the Galápagos Islands," *Island Studies Journal* 6, no. 2 (2011): 131-156.

imaginaries around islands fertilize them as conceptual repositories that elicit conflicting ideological regimes of care and plunder, conservatorship and exploitation, hiddenness and discovery.

This chapter analyzes how mid-20th century scientists transported the island's fluid valences to their framing of the search for extraterrestrial life, in part through the development of new visual technologies. As the fledging NASA articulated how it would explore outer space, Lederberg and other exobiologists tapped into competing analytical dualities of the island imaginary to influence those policies. I explore in this chapter how islands—insular sites of enclosure that have historically beckoned exploration through promissory, novel forms of life—furnished scientific imaginations of extraterrestrial biology from the late 1950s to the early 1970s. I demarcate this time period to home in on experiments of anticipation that preceded the ambiguous, but ultimately disappointing, results of the *Viking* missions of the mid-70s, that, while leaving open the question of extraterrestrial life in the solar system, foreclosed the fount of funding for exobiological research (at least for several decades). As outer space became explorable in the 1960s, exobiologists in collaboration with engineers and NASA administrators developed visual devices such as high-altitude photography and televisual instruments mounted on space crafts, calling upon varying representations of the island to tack between imagined worlds and their own as they pursued extraterrestrial life. The chapter explores how the expected, and then realized, view from beyond the Earth's atmosphere mediated how scientists saw their planet, themselves, and the cosmos.

As exobiologists turned their gaze to outer space, imaging technologies made it possible for them and others to perceive their planet from above—a double vision that enabled the possibility to see if terrestrial expressions of life would be mirrored elsewhere. The *Apollo 8* astronauts' view from space afforded contemplative self-reflection about their place in the cosmos in part because it flipped the *gaze* and *scale* of Earth and extraterrestrial; this chapter further explores how visual technologies in the Space Age mediated articulations of being and living through acts that buoyed

sites unexplored sites in outer space. To "scale" references a movement between two points in space and in so doing illuminates emergent analogical relationships, in particular, islands and planets. What I call "gaze-scaling" reflects the conceptual toggling between the micro (microbes), meso (the Earth), and macro (the cosmos) facilitated by visual devices through which exobiologists emplaced (rather than displaced) to other planets the possibility of extraterrestrial life. The concept calls attention to exobiologists' use of technologies of visual perception to imagine celestial bodies as archipelagic islands—connected, relational, and possibly life-filled. *Specular* modes of perception enabled exobiologists' envisioning of *speculative* forms of life.

Literary and philosophical traditions have imagined islands along dueling edges: fecund yet fragile, Edenic yet dangerous, isolated but connective. They are exotic paradises that can harbor danger, according to Godfrey Baldacchino; miniature worlds that transform into macrocosms, so says Rebecca Lemov; far-flung specks of land on the periphery that are actually central to mainland concepts of nationhood and power, Ruth Oldenziel argues.[90] Conversely, performative acts of scaling, because they generate relational categories moored to particular times and places, offer safe harbor from islands' conceptual instability. Drawing concepts together, islands' putative dualities lensed by the stabilizing effect of scaling generates a taut analytical framework to elaborate how exobiologists articulated a sense of place and identity in their search for extraterrestrial life.[91]

In what follows I illuminate one particular pairing of islands' presumed polarity—enclosure vs. expansion—to demonstrate my claim that exobiologists analogized islands to planets through gaze-scaling, in part through image-based technology and media. I make use of historical documents

[90] Godfrey Baldacchino, "Editorial: Islands—Objects of Representation," *Geografiska Annaler: Series B, Human Geography,* 87 (2005): 247-251; Rebecca Lemov, *World as Laboratory: Experiments with Mice, Mazes, and Men* (New York: Hill and Wang, 2005); Ruth Oldenziel, "Islands: The United States as a Networked Empire," in *Entangled Geographies: Empire and Technopolitics in the Global Cold War,* ed. by Gabrielle Hecht, 13-42 (Cambridge: MIT Press, 2011).
[91] Riffing on David Kaiser's "drawing theories apart," *Drawing Theories Apart: The Dispersion of Feynman Diagrams In Postwar* Physics (Chicago: university of Chicago Press, 2005).

from the 1950s-1970s, primarily, memos, correspondence, and government studies from Lederberg's papers held at National Library of Medicine in Bethesda, Maryland; scientific reports to the NAS and NASA in Washington, D.C.; and historical material from the American Philosophical Society in Philadelphia, P.A. Cast as bounded, fragile "living laboratories," islands have offered evidence of life's *evolution* that exobiologists extended to the Moon, Mars, and Venus with hopes to unveil life's *origins*. Islands' utility as stepping stones of Western imperialism in the Age of Discovery transitioned to exobiologists' expectations that a cosmic archipelago of organisms connected through common biology would concretize universal principles of liveliness (dynamism, metabolism, evolution). I then turn to NASA's *Mariner 9*'s high resolution images of Mars that geographers stitched together to create a planetary concept. Perceiving that planet in a new way activated aspects of the island imaginary I have alluded to here (bounded, fragile, potentially lively) through transformative acts of gaze-scaling: miniaturizing Mars through mapping those images relationalized that it to Earth, bringing the two planets into lively reflection. To close I revisit those themes essential feminist theory of objective modes of perception associated with vision, sketching how the view from above situated a cosmic archipelago.

Dualities of the Island

According to literary critic Gillian Beer, it is "the double nature of the island" that foments its "imaginative attraction and makes it possible to play many nature/culture variations."[92] Islands' "discursive doubling" render attempts to locate what geographer Pete Hay dubs a "coherent theory

[92] Gillian Beer, "Discourses of the Island," in *Literature and Science as Modes of Expression*, ed. Frederick Amrine (Dordrecht: Kluwer Academic Publishers, 1989), 13.

of islandness" a slippery endeavor at best.[93] Even waves—islands putative edges—offer not delimitation, but instability and elusiveness, according to anthropologist of science Stefan Helmreich.[94] Perhaps because of such features, islands surface as staging grounds to ponder multiplicities of the self: in Gilles Deleuze's telling, the desert island's liminality invites impulses be alone and pull away, yet simultaneously, elicits an urge to cement the self through the discovery of one's origin.[95] As such, islands' analytical duality highlights them as sociotechnical objects useful to think "with."[96] Their mythic qualities layer their geographical ones, presenting a precarious ontology latent with imaginative projections, particularly, as expansive but also enclosed.

One definition of "insular" is "detached or standing out by itself like an island; insulated."[97] Those phonic siblings, insular and island, symbolically resonate with islands' discursive deployment as bounded and timeless. European naturalists in the Age of Discovery came to think of islands as "living museums" that had preserved nature in a "purer, more authentic form."[98] By the late 19th century, solidified in Charles Darwin's theory of evolution, islands were imagined as "closed domains in which the processes of variation and of natural selection may be observed" within "undisturbed historical continuity."[99] As such, naturalists considered islands as near-perfect biological sites to watch natural selection at work, whose ecosystems ought to be preserved for

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[93] Beer, "Discourses of the Island," 22; Pete Hay, "A Phenomenology of Islands," *Island Studies Journal* 1, no. 1 (May 2006): 20.
[94] Stefan Helmreich, "How to Hide an Island," in *New Geographies, 8*, ed. Daniel Daou and Pablo Pérez-Ramos (Cambridge: Harvard University Press, 2017), 82-87.
[95] Gilles Deleuze, *Desert Islands and Other Texts, 1953-1974*, trans. Mike Taormina and ed. David Lapoujade (Cambridge: Massachusetts Institute of Technology Press, 2004).
[96] Jonathan Pugh, "Island Movements: Thinking with the Archipelago," *Island Studies Journal* 8 no, 1 (2013): 9-24; Jennifer Chirico and Gregory Farley, *Thinking Like an Island: Navigating a Sustainable Future in Hawai'i* (Honolulu: University of Hawai'i Press, 2015).
[97] *Oxford English Dictionary Online,* s.v. "insular," accessed June 2, 2018, https://www.oed.com/view/Entry/97221; See also, "insularity," "the condition of living on an island, and of being thus cut off or isolated from other people, their ideas, customs, etc.," *Oxford English Dictionary Online,* s.v. "insularity," accessed August 14, 2020, https://www.oed.com/view/Entry/97223.
[98] John Gillis, *Islands of the Mind: How the Human Imagination Created the Atlantic World* (New York: Palgrave Macmillan, 2004), 131.
[99] Gillian Beer, "Writing Darwin's Islands: England and the Insular Condition," In *Inscribing Science: Scientific Texts and the Materiality of Communication*, ed. Timothy Lenoir (Palo Alto: Stanford University Press, 1998), 120.

scientific experiment. A century later, scientists mediated the imagination of islands as closed worlds in ecological terms: the concept of "island biogeography" emerged in the late 1960s to explain how islands' distance from the mainland rendered them as sensitive, self-tuning sites easily disrupted by invasive species.[100] Euro-scientific traditions from the late 15th century through the mid-20th century, then, have historically cast islands as fragile and enclosed domains crucial to the study of life.

On the other hand, islands' connectiveness as physical archipelagos, or as conceptual foils to the mainland, furnish them as symbolic nodes of relationality. Although imagined as exterior to the mainland, for instance, islands from the Caribbean to the South Pacific were actually essential for the U.S.'s self-conception as global Super Power through the construction of technological networks.[101] Acknowledging the expansive aspect of the island's analytical valence, geographers have urged "archipelagic thinking" a framework that "suggests relations built on connection, assemblage, mobility, and multiplicity."[102] Recently, critical geography studies have introduced the idea of the archipelago as a "performative geography" to move beyond the insular attribution to the island and instead think "between and among" island*s* as sites connected both physically and conceptually.[103] To wit, Craig Santos Perez's "terripelago" "foreground[s] territoriality as it conjoins land and sea, islands and continents."[104] His concept is cousin to geographer Elizabeth McMahon's "planetary archipelago," which she uses to underscore "multiplicity and inter-relations" between islands.[105] Such scholarly moves emphasize islands', island chains', and islanders', spatial, temporal, and cultural connections.

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[100] Robert MacArthur and E. O. Wilson, *The Theory of Island Biogeography* (Princeton: Princeton University Press, 1967).
[101] Oldenziel, "Islands," 16.
[102] Pugh, "Island Movements," 9; Elaine Stratford, "The Idea of the Archipelago: Contemplating Island Relations," *Island Studies Journal* 8, no. 1 (2013): 3.
[103] Lisa Fletcher, "'some distance to go': A Critical Survey of Island Studies," *New Literatures Review* 47-48 (January 2011): 18; Elaine Stratford et al., "Envisioning the Archipelago," *Island Studies Journal* 6, no. 2 (2011): 114.
[104] Craig Santos Perez, "Transterritorial Currents and the Imperial Terripelago," *American Quarterly* 67, no. 3 (2015): 619.
[105] Elizabeth McMahon, "Reading the Planetary Archipelago of the Torres Strait," *Island Studies Journal* 8, no. 1 (2013): 57.

Moored Scaling

The gerund scal*ing* is a dynamic act that "implies positioning and, hence, point of view: a perspective from which…modes of comparison are constructed."[106] Scaling sets up relational, cultural categories between the "here" of Earth and the "there" of space.[107] Anthropologist Lisa Messeri depicts how astronomers and geologists scale up Earth's qualities—its atmosphere, terrain, chemistry—to conceptualize exoplanets not as externalized objects but as embodied *places*, arguing that so doing "transforms the geographically alien into the familiar."[108] That the Earth becomes a reference point for other, perhaps similar, imagined sites, produces what anthropologist Valerie Olsen calls a "heliospheric ecology."[109] These viewpoints suggest that scientific acts of scaling, because they insist on particular points of relation, make distant or otherwise imperceptible objects not only comparable, but imaginable, relatable, and particular.

Moving between Earth and outer space is a process that scholars have argued cannot be narrated without calling into question the presumptive separation of nature and culture.[110] Channeling philosopher Henri Lefebvre, geographer Christy Collis writes that space is "never simply physical" but "always a jostling composite of material, imagined, and practiced geographies."[111]

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[106] Susan Gal, "Scale-Making: Comparison and Perspective as Ideological Projects," In *Scale: Discourse and Dimensions of Social Life,* ed. E. Carr Summerson and Michael Lempert (Berkeley: University of California Press, 2016), 91.
[107] See: Debbora Battaglia, David Valentine, and Valerie Olson, "Relational Space: An Earthly Installation," *Cultural Anthropology* 30, no. 2 (2015): 245–256.
[108] Lisa Messeri, *Placing Outer Space: An Earthly Ethnography of Other Worlds* (Durham: Duke University Press, 2016), 11-12.
[109] Valerie Olson, "Political Ecology in the Extreme: Asteroid Activism and the Making of an Environmental Solar System," *Anthropological Quarterly* 85, no. 4 (2012): 1027.
[110] See: Donna Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective," *Feminist Studies,* 14 no. 3 (Autumn 1988): 575-599; Denis Cosgrove, *Apollo's Eye: A Cartographic Genealogy of the Earth in the Western Imagination* (Baltimore: Johns Hopkins University Press, 2003): Benjamin Lazier, "Earthrise; Or, the Globalization of the World Picture," *The American Historical Review* 116, no. 3 (2011): 602–630.
[111] Christy Collis, "The Geostationary Orbit: A Critical Legal Geography of Space's Most Valuable Real Estate," *Sociological Review* 57, no. 1 (2009): 62; Jason Beery, "Unearthing Global Natures: Outer Space and Scalar Politics," *Political Geography* 55 (November 2016): 92-101.

Particular to my period of analysis, the post-Sputnik era saw outer space transformed into a contested environment as boundaries traditionally constitutive of nation-states projected skywards.[112] Scientists, politicians, and government officials deployed technological networks, satellites, and global positioning systems in outer space to embed political and ideological concerns.[113] The ways actors mobilized Cold War technologies dismantles the idea that outer space was ever a purely natural realm (and only a vacuum in a narrow astrophysical sense). It is by "examining the physical materialities and scalar politics of this period," geographer Jason Beery suggests, that one finds outer space's nature is cluttered with culture-making.[114] Acts of scaling vis-à-vis extension, projection, and imagination, then, attend to the entanglement and inseparability between the social and the natural. Inquiring after where one is looking *from*—be that viewpoint geographical or conceptual—marks a cultural space by highlighting the production of relations rather than singularity.

Evolution on Islands / Origin on Planets

In the 1920s, Russian biochemist Aleksander Ivanoch Oparin and British biochemist John Burdon Sanderson Haldane independently theorized that Earth's early atmosphere could have led to the formation of simple, inorganic molecules that in turn built complex, organic (carbon-based) molecules. In the 1950s, American chemists Harold Urey and his student Stanley Miller showed in the laboratory that in certain conditions, methane, water, hydrogen gas, and ammonia, along with sparks meant to simulate lightning in an early chaotic Earth, could give rise to the building blocks of

[112] Collis, "The Geostationary Orbit"; Beery, "Unearthing Global Natures."
[113] Lisa Parks. *Cultures in Orbit: Satellites and the Televisual* (Durham: Duke University Press, 2005).
[114] Beery, "Unearthing Global Natures," 99.

life.[115] These developments of biological theory in the decades leading up to the Space Age suggested how life *might* have formed on Earth, but they did not conclude if it had originated there—nor if it were a common emergence in the universe. As plans formed to explore the Moon and beyond beginning in the 1950s, scientists urged NASA to focus on experiments that would "shed light on the nature, origin, and evolution of the planetary system and of life within it" to address these uncertainties.[116] Evidence of microbes on the Moon, Mars, or Venus would point to a "cosmic distribution of life" and provide the basis for a universal, rather than terrestrial, theory of life's origin and subsequent evolution.[117] Scientists thus considered biology in space to be "most exciting, challenging and profound issue" of their time because it could point to signs of life in an as-yet lonely universe.[118]

Citing the preceding decades' biochemical research that had pushed back theories life's *evolution* by hinting at its *origin*, exobiologists saw themselves as scientists on the precipice of a new episteme: "It is not since Darwin—and before him, Copernicus—that science has had the opportunity for so great an impact on man's understanding of man," they wrote.[119] Exobiologists viewed their discipline as essential to refine and extend Darwin's theory of evolution: "Only the perspective of comparative biology on a cosmic scale could tell whether [natural selection] is an indispensable element of all life," Lederberg wrote in an SSB report.[120] Darwin's theory, developed on research on the Galápagos Islands, had upended the worldview that man was made in the image

[115] Stanley Miller, "Production of Amino Acids Under Possible Primitive Earth Conditions," *Science* 117, no. 3046 (1953): 528-529; Stanley Miller and Harold Urey, "Organic Compound Synthesis on the Primitive Earth," *Science*, 130, no. 3370 (1959): 245–51.
[116] Berkner and Odishaw, "Dimensions and Problems," 22.
[117] Lederberg and Hartline, "The Biological Sciences and Space Research," 2.
[118] Space Science Board, *A Review of Space Research*, 9-2–9-3.
[119] Space Science Board, *A Review of Space Research*, 9-2.
[120] Lederberg, "Exobiology," 5.

of God.[121] In parallel, exobiologists hoped their findings would have a similarly profound impact on humans' understanding of their place, and life in general, in the universe.

Conceptual connections between islands and planets begin to emerge. As Darwin had formed a theory of life's evolution on the Galápagos, exobiologists saw themselves as revolutionary scientists who looked to especially to Mars to articulate a theory of life's beginnings. If they could extend the theory of natural selection to other planets and identify common origins of life, it would, according to Lederberg, prompt a "self-understanding as well as…the comprehension of the external universe."[122] Just as islands have been represented as fraught sites to articulate philosophies of the self—for Deleuze, a site that circulated both *elan* and loneliness—exobiologists dreamed that life, perhaps intelligent life, was a common or at least multiple occurrence in a cosmos in which they were so far the sole example.[123]

As space travel began to materialize in the 1960s, the Moon, Mars, and Venus—"on the verge of meaningful accessibility"—transformed into *anticipated,* rather than *abstracted,* objects of potential life.[124] That is, exobiologists' expected ability to soon analyze nearby bodies facilitated how they imagined life beyond Earth in ways that shaped how they saw themselves. Around the Moon, Mars, and Venus, exobiologists created a particular, communally produced, form of social life: their technoscientific imaginary extended the identity of *islands* as sites of *evolution* to space, by which *planets* became potential sites of *origin*.

Planets as Insular "Living Laboratories"

[121] Janet Browne, *Charles Darwin: The Power of Place* (London: Jonathan Cape, 2002).
[122] Lederberg, "Origin and Extent of Life," 9.
[123] Deleuze, *Desert Islands and Other Texts,* 10.
[124] Berkner and Odishaw, "Dimensions and Problems," 22.

While past scientific efforts to identify life beyond Earth had failed (notably, astronomer Percival Lowell's misinterpretation of canals on Mars in the early 20th century, NASA's planned missions promised to grant scientists the first real opportunity to investigate if life existed beyond a terrestrial context. Exobiologists hoped to find "cosmobiota" and compare how microbes and even plants would have originated and evolved.[125] In a 1961 report, they wrote that "the origin of life under radically different conditions of environment and ecology is a subject of unprecedented significance to fundamental biology."[126] Exobiologists wondered: Had life evolved on other planets and the Moon, sites whose gravities, atmospheres, and temperatures were extreme by Earth standards? If so, had it evolved by the same mechanisms?[127] Just as islands have been imagined as precious sites to protect, might planets also host life forms that would be at risk from incautious intervention? If Earth was a control group where life was extant, previously unexplored planets and the Moon represented experimental laboratories.

Throughout the 1960s, Lederberg led the effort to prevent terrestrial space probes from disrupting potential biological sites because the Moon, Mars, and Venus might evince what he considered the "only potentially universal principle in biology": Darwin's evolution through natural selection.[128] The WESTEX group strongly urged NASA to develop precautionary procedures to sterilize exploratory spacecrafts that could potentially disrupt or even wipe out ecological systems on other planets and the Moon, a possibility they considered a "scientific catastrophe" and a "cosmic blunder."[129] Even a single terrestrial microbe could terraform a planet, and "destroy an inestimable

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[125] Melvin Calvin et al., "Panel on Extraterrestrial Life," minutes of the first meeting, Armed Forces-NRC Committee on Bio-Astronautics, July 16-24 1959, Woods Hole, Massachusetts. (Washington, D.C.: National Academy of Sciences—National Research Council, 1959), 4.
[126] Berkner and Odishaw, "Dimensions and Problems," 21.
[127] Space Science Board, *Summary Report of WESTEX, February 21, 1959 - September 26, 1959* (Washington, D.C.: National Academy of Sciences—National Research Council, 1959).
[128] Lederberg, "Exobiology," 5.
[129] Space Science Board, *Summary Report of WESTEX,* Ref.1, 2.

prize for the understanding of our own living nature."[130] As such, planets and the Moon emerged as sites to be preserved, cared for, and protected.

Microbiologist Wolf Vishniac, who designed life-finding prototypes for NASA, was the lead author of a paper for the Space Science Board report that hypothesized, "Mars, like Earth, cannot be populated by any single organism. Any model of a Martian ecology must describe a *community* of organisms the members of which compensate for each other's activities."[131] Vishniac and his co-authors, among them Carl Sagan, proposed measures to preserve Mars' potential "worldwide balance."[132] These exobiologists increasingly conceived of life as interconnected ecosystems rather than as solitary examples. They framed planets as bounded systems in which any interference would disrupt fragile, yet integrated, *ecosystems* of life. In this way, Mars became *worthy* of protection through its perceived *world-like* features.

Reports throughout the 1960s show how exobiologists came to care about imagined nearby planets as delicate, enclosed, laboratories of life: characteristics that have often been ascribed to islands. Because they arise *de novo* from the ocean; are often isolated from the mainland; and, host a limited number of species whose populations are sensitive to disruption, biologists often describe islands as *tabulæ rasæ* to witness evolution in real time.[133] They are living museums that preserve exotic specimens of flora and fauna, but whose populations are always perceived to be in danger of extinction, a notion that cultivates nostalgia about a lost age.[134] For instance, the Galápagos islands offered up to Darwin a "primal moment of observation" due to their curious and sometimes

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[130] Lederberg and Hartline, "The Biological Sciences and Space Research," 15.
[131] Wolf Vishniac at al., "A Model of Martian Ecology," in *Biology and Exploration of Mars: Report of a Study Held Under the Auspices of the Space Science Board*, ed. Colin Pittendrigh, Wolf Vishniac, and J.P.T. Pearman (Washington D.C.: National Academy of Sciences—National Research Council, 1966), 229.
[132] Vishniac at al., "A Model of Martian Ecology," 229.
[133] See: Christian Depraetere and Arthur Dahl, "Island Locations and Classifications," in *A World of Islands: An Island Studies Reader*, ed. Godfrey Baldacchino (Washington, D.C.: Island Studies Press), 57-105.
[134] See: Mark Barrow, "The Specter of Extinction: Taking a Long View of Species Loss," *Environmental History*, 16 no. 3 (2011): 428-432.

monstrous inhabitants that seemed immune to time's passage.[135] In fact, precisely the threats of encroachment and disturbance, imagined or real, prompt conservational efforts to deem islands as "natural laboratories" so that ecological and biological science may continue.[136]

In parallel, exobiologists' uses of phrases such as "virgin Martian material" and the "virgin surface of another planet" call to mind the idea of the island as pristine.[137] Lederberg and others tapped into the metaphorical resonance of the island as a closed site of exotic life to underscore what they perceived as the importance of as-yet-untouched nearby planets, and those sites' potential to define a comprehensive theory of biology. If Darwin's Galápagos islands represented "an evolutionary Eden," nearby planets were imagined as *technoscientific* Edens through which exobiologists would clarify life's origins, and by extension, humans' place in the cosmos.[138] The planets-as-islands concept scaled the scientific notion of the terrestrial island as a living laboratory—its boundedness, its preciousness, its outsize significance in biological theory—to extraterrestrial planets.

Contamination of Terrestrial Life

If a single terrestrial bacterium could wreak havoc on extraterrestrial biology, what effect might the reverse have? Allan Brown, a professor of botany at the University of Pennsylvania who was involved in many NASA committees in the 1960s, led the Space Science Board's 1964 "Conference on Potential Hazards of Back Contamination from the Planets" whose objective was to

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[135] Beer, "Writing Darwin's Islands," 122.
[136] Diego Quiroga, "Crafting Nature: the Galápagos and the Making and Unmaking of a 'Natural Laboratory,'" *Journal of Political Ecology* 16, no. 1 (2009): 123–140; McMahon, "Reading the Planetary Archipelago of the Torres Strait."
[137] Space Science Board, *Space Research: Directions for the Future; Report of a Study by the Space Science Board, Woods Hole, Massachusetts, 1965* (Washington, D.C.: National Academy of Sciences—National Research Council, 1966), 489; Space Science Board, *Conference on Hazard of Planetary Contamination Due to Microbiological Contamination in the Interior of Spacecraft Components* (Washington, D.C.: The National Academies Press—National Research Council, 1965), 3.
[138] Hennessy and McCleary, "Nature's Eden?", 140.

develop and recommend quarantine measures to NASA to prevent such a scenario. Although the chance of any life form surviving the return trip in a harsh environment of space was minuscule, the "failure to foresee a danger which might be avoided," the committee warned, could have catastrophic consequences for life on Earth.[139] They worried, "An organism, innocuous when in the hostile environment of a planet, might, when transported to the comparatively lush conditions of the earth, overgrow terrestrial life forms or alter the physical or chemical characteristics of the biosphere."[140] Brown asked: "If exotic life forms are introduced into our own biosphere, would they survive, propagate, infect terrestrial organisms, or bring harm directly or indirectly to our ecosphere?"[141] Just as planets and the moon were imagined as closed worlds to be preserved for the use of basic science, the committee imagined Earth as a bounded biosphere that should be protected and preserved.

In this scenario, extraterrestrial microbes were imagined not as objects of science that would unify a theory of biology, but as potential threats. In one context, unknowability invited empirical investigation; for exobiologists working on the issue of back contamination, life's unestablished qualities elicited fear. This reaction calls to mind another valence of the island imaginary: a site of danger. As "paradises, but also Gulags," islands have been sites of mystery, isolation, even madness.[142] For Darwin, too, islands' relatively exotic flora and fauna could be repulsive.[143] Exobiologists pictured a hypothetical scenario in which 'exotic soil organisms with unfamiliar metabolic capacities' could run wild on Earth, destroying terrestrial life forms in their wake.[144]

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[139] Space Science Board, *Conference on Potential Hazards of Back Contamination from the Planets* (Washington, D.C.: The National Academies Press—National Research Council, 1964), 4.
[140] Space Science Board, *Conference on Potential Hazards of Back Contamination from the Planets*, 5.
[141] Brown, "'Back Contamination' and Quarantine," 443.
[142] Baldacchino, "Editorial: Islands—Objects of Representation," 248.
[143] Beer, "Writing Darwin's Islands," 128).
[144] Space Science Board, *Conference on Potential Hazards of Back Contamination from the Planets*, 5.

Such language reflects the greater cultural milieu of the 1960s, in which Soviet attacks—nuclear but also chemical and biological—seemed to loom and science fiction films imagined nefarious extraterrestrial flora.[145] *Invasion of the Triffids* (1963) and *Mutiny in Outer Space* (1965) highlight how fecundity could turn feral and how planets could be perilous—anxieties exobiologists shared in that historical moment.[146] The issue of back contamination, then, reveals how exobiologists joined another resonance of the island—fear—to planets beyond. While both hinged on one aspect of the planets-as-islands imaginary—self-contained ecological systems whose purity was precarious—front contamination spoke to a care *for* imagined life on other planets, while back contamination evoked fear *from* (microbial) alien invaders.

Cosmic Archipelagos

Mars became a foil to Earth that would give scientists insight into their own planet, writing, "The two planets, taken together, would form a couple far more powerful in illuminating the general setting in which we live than the geology of the Earth…alone."[147] Mars' presumed properties were imagined to be 'intermediate between those of the Earth and the moon', reiterating a 19th century concept of the universe that hypothesized life in the solar system was fundamentally the same, just parceled out in different degrees.[148] Earth and nearby bodies functioned, in the minds of these exobiologists, as complementary components of a whole with exotic, but recognizable, variation.

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[145] Paul Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (Chapel Hill: University of North Carolina Press, 1985); Joshua Lederberg, "To Outlaw Biological Arsenals," *New York Times,* April 5, 1971, https://www.nytimes.com/1971/04/05/archives/to-outlaw-biological-arsenals.html?searchResultPosition=6.
[146] For an exploration of fears of nefarious proliferation by microscopic organisms—very of the moment in the time of COVID-19—see: Robin Scheffler*, A Contagious Cause: The American Hunt for Cancer Viruses and the Rise of Molecular Medicine* (Chicago: University of Chicago Press, 2019).
[147] Space Science Board, *Conference on Hazard of Planetary Contamination*, 15.
[148] Space Science Board, *Conference on Hazard of Planetary Contamination*, 4; Stéphane Tirard, "The Relationship Between the Origins of Life on Earth and the Possibility of Life on Other Planets: A Nineteenth-Century Perspective," in *Astrobiology, History, and Society*, ed. Douglas Vakoch (Berlin: Springer, 2013), 111.

This imaginary captured nearby bodies in a relational analytical framework by and transformed them into places to be cared for and protected precisely because of their imagined kinship with Earth.

Lederberg further articulated the concept of cosmic connectedness through what he called "the evolutionary principle," a term that indicated a hierarchy of similitude between eso (Earth-bound), and exo (beyond Earth), life.[149] A triad of sub-principles supported this principle: chemogeny (universal chemistry); biogeny (universal biological life); and, cognogeny, which he described as 'the evolution of the mechanisms of perception, computation, and symbolic expression and interpersonal communication, whereby tradition can accumulate [and] culture [can] unfold."[150] In this view, signatures of life—even, incredibly, culture—based on a terrestrial blueprint transformed into generalizable cosmic features. Beyond the next decade's exploration of nearby planets, Lederberg gestured to imagined beings beyond humans, based on expected commonality in an ordered universe.

If describing of Mars and Earth as enclosed, bounded planets evokes islands, thinking of them together invites the idea of the archipelago: linked chains of islands which host commensurable variations of flora and fauna. "Envisioning the archipelago," geographers Stratford et al. write, theorizes islands beyond categorical binaries such inside / outside and land / water, and inquire more deeply after alternative "ontologies that illuminate island spaces as mutually constituted, co-constructed and inter-related."[151] By wresting the singular island from the mythic and instead "thinking with the archipelago" one is able identity "disjuncture, connection and entanglement *between* and *among* islands."[152] As exobiologists worked to clarify universal signs of life, they conceptualized other nearby planets, especially Mars, in a relational milieu with Earth. Even if

[149] Joshua Lederberg, "Signs of Life: The Criterion System of Exobiology," *Nature* 207, no. 4992 (1965): 9.
[150] Lederberg, "Signs of Life," 9.
[151] Stratford et al., "Envisioning the Archipelago," 124.
[152] Pugh, "Island Movements," 9; Stratford et al., "Envisioning the Archipelago," 124.

they found an object on Mars that was "obviously analogous to an Earthly plant, animal or microbe," their larger goal was to establish an empirical system of comparison based on physics and biochemistry that they could then extrapolate to the general cosmos.[153]

NASA Associate Administrator Homer Newell mused that the "solar system is becoming the neighborhood of man," a phrase that localized distant planets by placing them within explorable grasp.[154] Terms such as Perez's "terripelago," and McMahon's "planetary archipelago" focus an "archipelagic perspective [that] may provide a counter to the imagined fixity of islands" and the land / sea distinction because they highlight individual islands' connections to the global.[155] Further scaling up these moves, I suggest the idea of a "cosmic archipelago" as a tool to analyze how exobiologists in the 1960s began to frame their planet in relation to others, finding conceptual and geographic connections between and among them. Thinking with the idea of planets-as-islands, in particular, Mars, produced an anticipated cosmic archipelago by which exobiologists imagined regionally specific forms of exotic life that would nonetheless give evidence to universalized theories of biochemistry—even, in Lederberg's telling, culture.

Colonizing Island Planets

Despite exobiologists' calls for highly controlled manned missions, government officials were exuberant, citing the "compelling urge of man to explore and to discover" through 'the *thrust* of curiosity that leads men to try to go where no one has gone before."[156] Berkner and Odishaw anticipated that space missions would "*penetrate* directly into the interplanetary medium and to reach

[153] Lederberg, "Exobiology," 5.
[154] Paraphrased in Nicks, *This Island Earth*, 4.
[155] Perez, "Transterritorial Currents and the Imperial Terripelago," 620; McMahon, "Reading the Planetary Archipelago of the Torres Strait," 56.
[156] President's Science Advisory Committee, "Introduction to Outer Space," 1.

other bodies in the solar system."[157] The use of aggressive, almost violent, words suggests an expectation of ownership over soon-to be explored planets. That 1961 report also framed scientists' mandate to venture into space in line with a history of Western exploration and conquest: "The early voyages of discovery…fulfilled the need for adventure, glory, and personal and national aggrandizement," they wrote. "Manned adventure in space would fulfill the same objectives."[158] NASA administrator Oran Nicks in *This Island Earth* directly linked the "great navigators of the 15th century" and their "spirit of conquest" to NASA's upcoming space missions.[159] In these analogies, astronauts and scientists were ocean explorers, and by extension, planets became the islands on which they would land and later conquer.

Although Sagan championed efforts to protect nearby planets from potential contamination, he too imagined future missions of colonization: "It may…be desirable to deliberately introduce terrestrial organisms into the Cytherean [Venusian] environment," he wrote in a 1959 WESTEX Report, "either to modify the environment for human ends, or to extend the cosmic availability of the information contained in the terrestrial genetic material."[160] In Sagan's vision, colonization takes on a curious resonance—microbes, not man, would directly reshape Venus's biochemistry. Microbes would be proxy voyagers fulfilling a colonialist destiny to mold (perhaps literally) the planet.

Westerners' colonial imagination has long narrated islands as empty of people with unlimited, unclaimed, resources.[161] Uninhabited islands were "represented as empty of cultural or economic value yet full of potential" spurring colonial powers to use islands as both social and

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[157] Berkner and Odishaw, "Dimensions and Problems," 1.
[158] Berkner and Odishaw, "Dimensions and Problems," 24.
[159] Nicks, *This Island Earth,* 176.
[160] Carl Sagan, "Venus as a Planet of Possible Biological Interest," in *Summary Report of WESTEX, February 1959 – 26 September 1959* (Washington, D.C.: Space Sciences Board, National Academy of Sciences Press—National Research Council Report, 1959), 33.
[161] R. Gerard Ward, "Earth's Empty Quarter? The Pacific Islands in a Pacific Century," *The Geographical Journal*, 155, no. 2 (1989): 235-246.

ecological laboratories.[162] Even Lederberg, arguably the most adamant expert on contamination, framed the preservation of other planets as an interest to colonial efforts, writing, "It would be rash to predict too narrowly the ways in which undisturbed planetary surfaces, their indigenous organisms, their molecular resources may ultimately serve human needs."[163] Planets—while they were to be protected—were not immune, after their scientific value had been assessed, from future plans to exploit resources to serve Earth's residents. Although Lederberg and Sagan hoped, of course, to find evidence of life in the solar system, they nonetheless ascribed colonialist imaginations of islands—relatively empty sites to manipulated, transformed, and mined—to planets and the Moon.

In a memo dated in 1960, Caltech geneticist Norman Horowitz, Lederberg's friend and colleague who would go on to design the Viking Lander, questioned what he viewed as exobiology's perhaps overly restrictive sterilization protocols:

> The present situation may be likened to that which obtained in Europe in the decade before Columbus set forth on his voyage of discovery. If men had known then that Columbus would bring back with him a disease—syphilis—that was to plague Europe for centuries, they might well have prevented him from ever leaving Spain. Suppose, however, that they had known also of the tremendous benefits that were to flow from the discovery of the New World. Can there be any doubt what their decision would have been then?[164]

While Lederberg outlined a "stringent embargo," Horowitz envisioned "unhampered traffic with the planets."[165] In this vignette, Horowitz directly linked Christopher Columbus to Space Age explorers and privileged risk and glory over safety in a mission that might unveil the origin of life on

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[162] Uma Kothari and Rorden Wilkinson, "Colonial Imaginaries and Postcolonial Transformations: Exiles, Bases, Beaches," *Third World Quarterly* 31, no. 8 (2010): 1397; Rebecca Lemov, *World as Laboratory.*
[163] Lederberg and Hartline, "The Biological Sciences and Space Research." 15.
[164] Norman Horowitz, *Memorandum from Norman H. Horowitz to Joshua Lederberg [On Back-contamination and the Goals of Exobiological Research]* (Bethesda: Joshua Lederberg Papers, the National Library of Medicine), 1.
[165] Lederberg, "Exobiology," 33; Horowitz, *Memorandum from Norman H. Horowitz*, 1.

Earth. Horowitz's words evoke a brutalist colonial regime that placed discovery above all else, even if it came with the cost of disease. Conspicuously missing from his account is that infections were not just brought back to the continent, but inflicted upon Native peoples with devastating effects.

Gaze-Scaling Mars in a Cosmic Archipelago

As we have seen, exobiologists in the 1960s mobilized two aspects of islands' putative identities—enclosure and expansion—to recast unexplored planets. As living laboratories and bounded biospheres, planets including the Earth were imagined as fragile objects of scientific inquiry that should be cared from, protected, and preserved. Conversely, as archipelagoes of related life forms, planets invited exploration, even, possibly, exploitation. I move now from exobiologists' *imaginations* of planets in the late 1950s and early 1960s to *realized* explorations of space in the subsequent years. In particular, how did scientists, astronauts and NASA administrators mobilize photographic and televisual instruments to populate the planets-as-islands imaginary?

The *Mariner 9* was the first spacecraft to orbit Mars in 1971, which reached the planet during a dust storm. After it cleared, the craft took 7,329 photographs, covering 80% of the red planet's surface, at half a mile resolution.[166] It revealed a gargantuan canyon, Valles Marineris, that suggested massive tectonic activity—phenomena that might have stimulated a dynamic environment and led to biotic beginnings. Equipped with an advanced imaging system, an infrared radiometer, and two spectrometers, *Mariner* produced a cache of high-quality images. Sagan, Lederberg, and others studied what they called Martian "splotches" as possible indications of biochemistry.[167] Although

[166] Elizabeth Howell, "Mariner 9: First Spacecraft to Orbit Mars," *Space.com,* November 8, 2018, https://www.space.com/18439-mariner-9.html.
[167] Carl Sagan et al., "Variable Features on Mars: Preliminary Mariner 9 Television Results," *Icarus* 17, no. 2 (October 1972): 346.

Mariner 9 did not provide exobiologists with definitive proof of life on Mars, its sophisticated imaging technology allowed exobiologists to see another planet as never before.

For a publication meant for a popular audience from 1974, Sagan described how the television instrument data showed first "completely featureless" object due to "spectacular planetwide dust storm," that, as they storm cleared, transformed into a planet with striking geology and gargantuan mountains.[168] As the probe gained altitude, Sagan visualized how an "imaginary parcel of Martian air, rising along the slope of the mountain, expands and cools" and formed a mountain cloud.[169] Through storytelling and analogy, Sagan engaged what anthropologist Lisa Messeri would recognize as "place-making at a planetary scale."[170] Mars moved, analytically, from a remote planet to one that could be wondered about to one made more intimate and familiar, a scientific practice that "transform[ed] planets from *objects* into *places*" in Sagan's imagination.[171]

In 1973, NASA scientists at the Jet Propulsion Laboratory stitched together 1,500 images from *Mariner 9's* subsequent orbits around the Mars to form photomosaic globes, complete planetary images.[172] [Figure 2.] Each piece was carefully shaded, placed, and glued to give a consistent, cohesive, image.[173] These globes helped scientists and engineers make reasonable assumptions about Mars' geography to plan *Viking* landing sites later in the 1970s, ones they hoped would be near water.[174] Granular features added up to a planetary whole, an essential tool to conceptualize global features such as wind patterns, tectonic structures, and the distribution of geographic features.[175]

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[168] Carl Sagan, *The Cosmic Connection: An Extraterrestrial Perspective* (New York: Dell Publishing Co., Inc., 1974), 101.
[169] Sagan, *The Cosmic Connection,* 103.
[170] Messeri, *Placing Outer Space*, 12.
[171] Messeri, *Placing Outer Space*, 9.
[172] Smithsonian National Air and Space Museum, "Oran W. Nicks," accessed August 8, 2019, https://airandspace.si.edu/support/wall-of-honor/oran-w-nicks.
[173] The photomosaics were described as fish-scales, a playful yet inadvertent reference to both the ocean and scaling.
[174] Philip Stooke, Professor Emeritus and Adjunct Research Professor Department of Geography, and Centre for Planetary Science and Exploration, University of Western Ontario, personal communication, April 6, 2019.
[175] Philip Stooke, personal communication.

Figure 2. Jet Propulsion Laboratory map makers, *Photomosaic Globe of Mars* (Washington, D.C.: Smithsonian National Air and Space Museum, 1973).

JPL scientists thus performed labors of care to visually and conceptually gaze-scale between the microscopic, surface features, and the macroscopic planet as a whole. Moving and working between different scales (4-foot globes, 6-foot globes); highlighting different aspects (albedo, geological features); and gluing the pieces ("the most delicate step in the whole process"), scientists fostered an intimate, tacit understanding of the planet.[176] [Figure 3.] Scientists rendered Mars as *planetary,* that is, "something that can be navigated, whose dynamics can be observed, and from which lessons can be learned" in a way that further anticipated landed missions.[177] In this photograph, a lone scientist

[176] Staff of *Engineering and Science,* "Martian Map Makers," *Engineering and Science* 37, no. 1 (1973): 9.
[177] Messeri, *Placing Outer Space*, 12.

stands in a room full of Marses: a visual metaphor apropos for the biological islands exobiologists hoped to find in the coming decades in a cosmos in which they knew only one example of life.

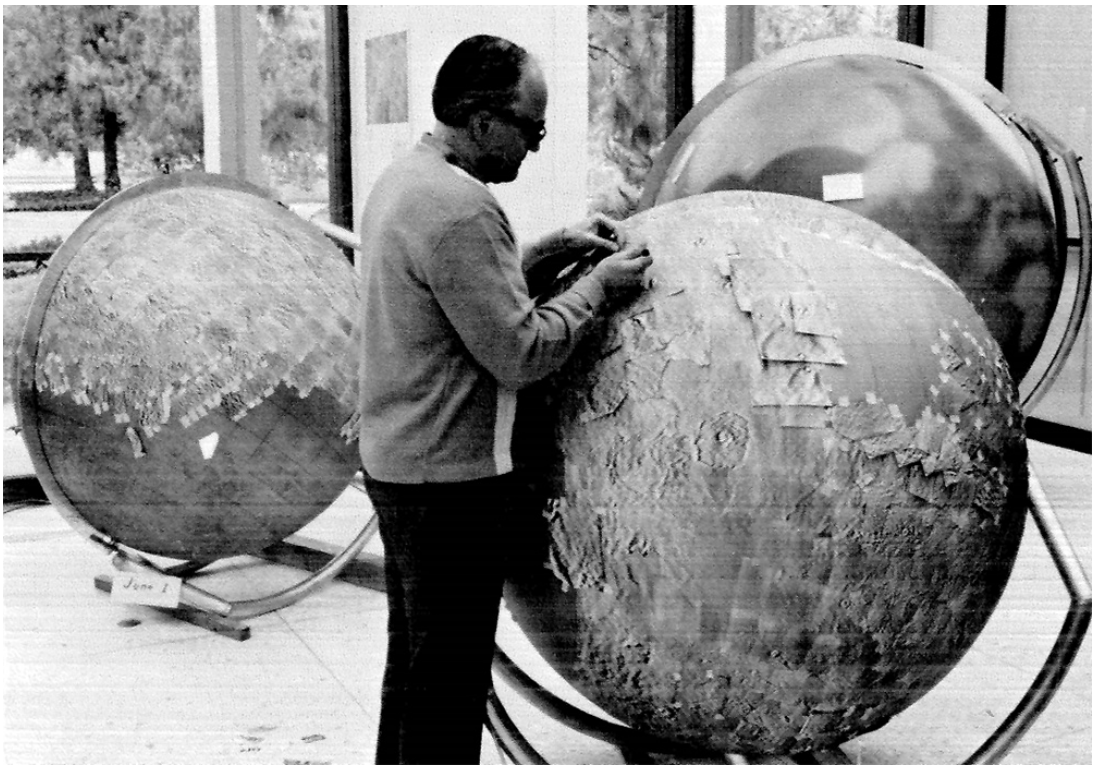

Figure 3: Earl Zimmerman and his coworkers made the *Photomosaic Globes of Mars*. See: Staff of Engineering and Science, "Martian Map Makers," *Engineering and Science* 37, no. 1 (1973): 9.

A Blue Agate

I return now to the *Apollo 8* space craft and the *Earthrise* photo, an image that NASA administrator Oran Nicks would argue was "the true perspective of our island."[178] Anders recalled, "I had trouble orienting myself, I didn't know which way was north, which end was up."[179] But, from the window on the space craft, working his "down" from the south pole, he identified the

[178] Nicks, *This Island Earth,* vi.
[179] *Earthrise*, Vaughan-Lee.

bulge of Africa to his "right," the "tongue of ocean down" at Florida and the Bahamas.[180] From the abstract to the specific—from a confounding swirl of colors, to recognizable continents, to the very state from which *Apollo 8* had launched—Anders regained a sense of place. By picking out recognizable features, and describing them using directions (down, up, right, left), astronauts' dynamic spatial reorientation linked the fantastic and overwhelming to the familiar and comforting.

Later, Anders would compare the experience of Earth from the ground to the view from space. Although one "subconsciously think[s] that the Earth is flat or at least almost infinite," he mused, the view from space in which Earth appeared spherical and bounded prompted him to instead think of his planet "as a fragile Christmas-tree ball which we should handle with considerable care."[181] Borman described the planet as a jewel: "The Earth was the only thing in the entire universe, all this inky black void, and Earth was there with a beautiful blue hue to it, a blue marble," he said. "That's what it looked like, a blue marble, a blue agate."[182] Casting Earth as a precious stone, the astronauts cultivated feelings of care for Earth as a result of seeing their home planet from space as no one had before. Like a life-filled island whose existence rebelled against the endless ocean, Earth became a contained and treasured jewel sparkling in the void of space. Seeing Earth in this way gestured to a novel analytical framework by which astronauts reconsidered their home planet: space became a place in which they developed a sense of care for Earth through the ability to leave the surface, an act never before possible. Ironically, the "escape" from Earth engendered a sense of protective care in Borman, for whom the view made poignant that 'our families, our countries, everything I held dear was back on that blue planet."[183] As the only known home of life in the universe, Earth's perceived vulnerability elicited an emotive longing. George Low, NASA's Acting

[180] *Earthrise*, Vaughan-Lee.
[181] Quoted in Nicks, *This Island Earth,* 14.
[182] *Earthrise*, Vaughan-Lee.
[183] *Earthrise*, Vaughan-Lee.

Administrator from 1969-1976, reflected that "it is somewhat paradoxical that man's new ability to fly above the atmosphere and voyage in space has provided him with a new and valuable way to appreciate Earth."[184] These comments reveal how the view from above joined a radical spatial orientation to the emergence of Earth as a precious object.

Scholarly analyses of this gaze from above have worried that an Archimedean viewpoint dislocates the human from the Earth because it invisibles artifice as a totalizing gaze, it exercises the last (acceptable) outpost of colonial imagination; or, that the 'conquering view from nowhere' is 'an illusion, a god trick' because it diminishes embodied situatedness.[185] I want to suggest that the astronauts' very moment of reorientation on *Apollo 8*, followed by a profound appreciation of their planet below, was an act of scaling that brought them emotionally closer to their home planet, a move of mooring rather than dislocation. Scal*ing* is action threading space and time by which Earth was made dearer, an exercise Lisa Fletcher might call "performative geography."[186] I expand this concept—what Stratford et al. summarize as a "tool to consider resonances of the island as a space of cultural production that insists on connectivity"—from islands to planets, in particular, Earth.[187] That is, in astronauts' effort to locate themselves in their craft in relation to Earth, care for their home planet sharpened and deepened. The performative act of gaze-scaling—locating, comparing, and analyzing particular geographies between spaces—coincided with astronauts' novel sense of Earth. In this way, the visual perception of Earth from above afforded the astronauts an ability to concretize one aspect of the planets-as-islands imaginary: Earth as fragile, bounded, and precious.

After clearing the atmosphere, *Apollo 8* escaped low-Earth orbit and swung around the Moon. Of the more than 150 photographs the astronauts took for NASA to analyze the moons'

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[184] Quoted in Nicks, *This Island Earth,* iv.
[185] See Lazier, "Earthrise"; and Peter Redfield, "The Half-life of Empire in Outer Space," *Social Studies of Science* 32, no. 6 (2002): 791-825; Haraway, "Situated Knowledges," 581.
[186] Fletcher, "'some distance to go'," p.18).
[187] Fletcher, "'some distance to go'," p.18).

service, including its far side (NASA, 1969), Anders' photograph of what came to be known as *Earthrise* became iconic. Yet, the idea that any one view represents an objective reality is contestable. In its original orientation, the image implies that the space craft is swinging around the Moon in flight. In its dissemination around the world, however, that view was turned ninety degree clockwise. [Figure 4.] The act of turning the original image was not an accident, and speaks to the use of visual manipulation to transmit a symbolic message.

Figure 4. William Anders, *Earthrise* (NASA, 1968); "Earthrise: Original," The Planetary Society, accessed June 2019, http://www.planetary.org/multimedia/space-images/earth/earthrise.html.

Following geographer Jonathan Beery's call to synthesize theories of the production of space, nature, and scale to more adeptly evaluate outer space as a socially constructed realm, the manipulated *Earthrise* image acculturates what had hitherto been a void.[188] It creates an imagined standpoint from Moon-to-Earth, anchoring the viewer to the surface there, an act that recalls yet inverts the familiar experience from Earth of watching the moon progress above the horizon.[189] Perceived this way, the image imposes a symmetrical relationship between the two sites by parallelizing the moon / the Earth as places that can be gazed at / gazed from. Viewers are asked to scale their gaze from an embodied, familiar experience on Earth to an imagined, alien experience from another surface. Half-shrouded in an almost Stygian blackness, with the grey moon "below," the twinkling blue and white swirl of Earth appears lively and dynamic, whose smallness endeared it to the astronauts and viewers of *Earthrise*.

Conclusion

Lisa Messeri conceptualizes a "planetary imagination" to describe how exoplanet hunters today light upon the "aspirational aspect of the imagination" to "capture beliefs and hopes from the past, present, and future of what planets *are* and thus what they would be like to occupy."[190] Exobiologists working in the Space Age exercised a sociotechnical imaginary centrifugally oriented around a goal that still eludes scientists today: the discovery of life beyond Earth. As a sociotechnical practice, the island imaginary structured exobiologists' visions for extraterrestrial life. The move to space in the late 1960s, first through scientific speculation about life on other planets, and then,

[188] Beery, "Unearthing Global Natures."
[189] A view anticipated the later *Apollo 11* mission in which astronauts Neil Armstrong and Buzz Aldrin actually Moon-walked.
[190] Messeri, *Placing Outer Space*, 21.

through visual technologies of perception in subsequent years, called upon analytical dualities of the island imaginary—as fragile, bounded sites, but also explorable, even exploitable—to conceptually refashion nearby planets and the moon. Often mobilized as repositories in myth, literature, philosophy, and geography, islands' modalities mapped to soon-to-be-explored nearby celestial bodies. As laboratories of nature, as sites of potential danger, and as archipelagoes of variations on life, planets, especially Mars, took on resonances of the island on the brink of NASA space missions.

Images taken from space concretized each polarity of the planets-as-islands imaginary: enclosure/fragility vs. exploration/connection. The astronauts' view from above in *Apollo 8*, and Ander's *Earthrise* photo taken on that mission, framed the Earth as a lively, lovely oasis in a bleak ocean of space. On the other hand, *Mariner 9's* pictures of Mars afforded scientists the ability to compare its geological features, its weather, and its surface material, to Earth's, placing the two planets in an analytical relationship and inviting moments of analogy and connection. If seeing Earth from above caused scientists to relate it to a single island, then comparing it to Mars invited further imagination toward a cosmic archipelago.

Visual technologies of perception facilitated scientists' and astronauts' act of gaze-scaling, that is, of cosmic reorientation by which they moved between images of Earth, the Moon, Mars, and outer space. Seeing Earth from *afar* made it emotionally *closer*; seeing Mars *closer up* put it in relation more acutely with Earth, scaling the planets toward the *cosmos in general*. Gaze-scaling is a kind of performative geography through which scholars better understand how points of view, abstracted or real, contribute to the social construction of outer space and its objects. It is a tool to map how geographical and literary imaginations of the island coalesce to produce planets and space as sites of cultural production. Gaze-scaling illuminates how the planet-as-islands imaginary cultivated scientific nature-cultures. Taken in tandem with the oppositions, enclosure and exploration, gaze-scaling is a social/scientific practice that produced the planets-as-islands imaginary in the Space Age. Such

concepts are analytical guideposts that clarify earthly scientific forms of life around a topic that continues to exist only in the realms of imagination and anticipation: unearthly life forms.

Further applications of the planets-as-islands imaginary alongside gaze-scaling could enrich anti-colonial and feminist STS scholarship in this moment when space exploration's future appears to move from ideologically driven national projects to capitalist-funded private ventures. Critical geographers have developed the idea of the archipelago—because it attends to islands', and islanders' roles, in shaping, subverting, resisting, and living with, imperial power— as an anti-colonial project. That is, thinking with the archipelago "may reveal multiple emancipatory narratives that enunciate exceptions to colonizing grammars of empire that rendered islands remote, isolated and backward."[191] Hitching these insights to the cosmic archipelago can open up critical reflection on the ecology of outer space, particularly, of Mars as an assumed site of imminent colonization. Billionaire-funded projects like Jeff Bezo's Blue Origin and Richard Branson's Virgin Galactic seek to make space travel frequent and accessible to the very rich, inviting questions nascent to the Cold War in a new context: Who owns space? What fundamental responsibilities are there to protect unexplored planets? How might capitalistic projects lend themselves to a colonial imagination that still haunts outer space?

Emerging work on feminist (space) studies around of embodied Otherness, descended from Donna Haraway's concept of situated knowledge are antidotes to well-worn stories of colonization and conquer rendered through the gaze. Gaze-scaling, an act of "doing and intervening" becomes a feminist epistemological exercise by which practitioners come to care for other things and places.[192] Extending the embodied aspect of Sagan's story about Mars, astronomer Dr. Sara Seager places

[191] Elaine Stratford, "The Idea of the Archipelago: Contemplating Island Relations," *Island Studies Journal* 8, no. 1 (2013): 4, paraphrasing McMahon.
[192] Maria Puig de la Bellacasa, "Matters of Care in Technoscience: Assembling Neglected Things," *Social Studies of Science* 41, no. 1 (February 2011): 89.

herself in the position of an alien observer, asking, "What would aliens see, looking at Earth from afar?" She muses, "If aliens, like humans, were curious and deductive, they could interpret how we live life on Earth."[193] Seager's speculative interaction with an alien rehearses exobiologists' cultivation of care for untold others. Seeing the planet as a curious, science-minded alien might invites a "care-ful" radical habitability because it links Earth to imagined worlds beyond.[194] Earth, and its features, become self-referential because it is, theoretically, already cosmically familiar. As missions to Mars loom, how might developing that planet in future decades modulate the gaze backward to Earth, and in turn, perceptions of humans' home planet? How might revisioning Earth from above generate a sense of cosmically oriented compassion in a moment when it the planet is under threat?

[193] Sara Seager, *Is There Life Out There? The Search for Habitable Exoplanets* (e-book: 2009), 6, http://seagerexoplanets.mit.edu/ProfSeagerEbook.pdf.
[194] Aryn Martin, Natasha Myers, and Ana Viseu, "The Politics of Care in Technoscience," *Social Studies of Science* 45, no. 5 (2015): 626.

Chapter 3: *Sounds of SETI*

The drive to the National Radio Astronomy Observatory's (NRAO) Green Bank Telescope (GBT) in the rural Allegheny Mountain Range in West Virginia disrupts a city-dweller's rhythms of sensation, perception, and time. After peeling off Washington D.C.'s beltway, landscapes unfurl in verdant hills, pleasant plots of farmland, and clotted forests. Such pastoral scenes are punctuated by artifacts of humans' industrial activities: rock faces blasted to bits reveal layers of geological time; vistas are blackened by abandoned coal mining projects; and one route to the telescope is even bisected by what seemed to me to be ghost town, strewn with relics from the 1950s. My cellphone always flickers through areas of service as I approach the telescope, and eventually falls off, and so I usually drive in silence for the last half-hour. On these trips, the sense of quiet that deepens as I approach the GBT has often prompted me to listen more attentively. On site, I am often jarred by sounds I would not otherwise notice: a car backfiring, bb gun shots, the thud of a volleyball being spiked on a make-shift court near the dorms where visiting researchers reside. On one such visit to the GBT in late June, 2016, I arrived at the site as twilight thickened into night. I struggled to locate my assigned dorm; the ranch style houses are nearly identical and not well-marked. After finding it and settling in, I woke up when humanlike screams curdled the night. The summer solstice had just passed, and so the witchy sounds seemed almost supernatural to me. As they faded into woods, I decided to slip back into an uneasy sleep. The next morning, one of the full-time operators told me the sounds were from red foxes who sometimes express themselves with surprisingly anthropomorphous shrieks.

If adjusting to these rural sounds opens up a new space of attention for an anthropologist usually immersed in the soundscape of city living (trash pick-ups, a neighbor's party, the wail of ambulances), the GBT is in turn dedicated to a special kind of "listening," hosting telescopes trained

to (astro)physical murmuring well beyond the range of abled human hearing. The GBT is located in what is called the National Radio Quiet Zone (NRQZ), an area of about 13,000 square miles that straddles West Virginia and Virginia.[195] The Federal Communications Commission (FCC) designated it as such in 1958 to restrict radio interference with the Green Bank instruments.[196] Cellphones, FM/AM transmitters, and ham radios, along with any other kinds of wireless communication, are banned or highly regulated (although telescope operators often either ignore or find clever work-arounds for these dictums). WiFi is out of the question, and so on research trips to the site, I have to excavate an Ethernet cord from a tangled ball of mostly defunct or outdated electronics. Researchers in the observing room use a Faraday cage, a metal box that acts as a bunker for electromagnetic signals, to microwave their lunches. The NRQZ is legally shielded from such pesky interference because errant signals blast the awesomely sensitive Robert C. Byrd Green Bank Telescope maneuvered and programmed just so, it can easily pick up the radio traces of the Voyager space crafts that launched from Earth in 1977, now careening beyond the lip of our solar system and transmitting power equivalent to that of a measly refrigerator lightbulb.[197]

Of course, Green Bank is not a hushed land slipped from time that happens to host a powerful, extraordinary instrument, but is populated by many people who visit it, use it from afar, and maintain it. Researchers are afforded precious telescope time to observe objects like fast radio bursts, galactic nuclei, and pulsars. Local West Virginians clean the cabins, prepare food at the Starlight Café, and manage the site's expansive acreage. On one trip in 2017, I visited during an extended period of maintenance in which painters, suspended on the telescope hundreds of feet in

[195] NRAO, "National Radio Quiet Zone," accessed July 16, 2020, https://Science.Nrao.Edu/Facilities/Gbt/Interference-Protection/Nrqz.
[196] NRAO, "National Radio Quiet Zone."
[197] There are other telescopes on at the NRAO site at Green Bank (the town) but the I refer hereafter that that particular instrument as the GBT, as the operators and astronomers do; Steve Croft, in conversation with the author, July 2020.

the air, refreshed the GBT's sparkling white finish (the 2,004 aluminum panels are scraped and repainted perpetually to maintain the shape the parabola). [Figure 1.]

Figure 5. Painters prepare to ascend, photo taken by Dave MacMahon, June 2016.

Ray Creager, an affable, middle-aged Senior Software Engineer with an impressive white mustache told me on that trip that his daughter, soon to graduate from Pocahontas County High School, would have her senior prom at the facility (it's the largest building for miles around).[198]

[198] Ray Creager, in conversation with the author, July 2017.

Meanwhile, the telescope's administrators spend much of their time cobbling together funding largely from the National Science Foundation to keep the world's largest fully steerable radio telescope operational. And, the GBT is an essential scientific site for the people who are the focus of this chapter: the Breakthrough Listen scientists who use it and other telescopes to search for radio transmissions from extraterrestrial beings.

The Breakthrough Listen team is based at U.C. Berkeley in Berkeley, California, and has a core group that is made up of astrophysicists, computer engineers, and data scientists. The Listen project is one arm of a privately funded foundation, Breakthrough Initiatives, whose billionaire sponsor Yuri Milner seeks to "explore the Universe, seek scientific evidence of life beyond Earth, and encourage public debate from a planetary perspective," according to the project's website.[199] Announced in 2015, Breakthrough Listen is the latest iteration of an eons-old tradition that has wondered if there are beings beyond Earth with whom humans could communicate, but one whose modern scientific start, coincidentally, began at Green Bank half a century ago. Frank Drake, then a 30-year-old radio astronomer working at the site, was inspired by Giuseppe Cocconi and Philip Morrison's 1959 paper in *Nature* that outlined a scientific mandate to employ radio technology to intercept an interstellar message. Over the spring and summer of 1960, Drake tuned the 85-foot Howard E. Tatel telescope at Green Bank to the 21 cm line—a wavelength the *Nature* paper suggested would coalesce with the "expectation of the operators of the assumed source," that is, alien beings on an extraterrestrial planet—a choice whose physical properties were framed to express anticipated ontological hallmarks I will presently explore in more depth.[200] Drake's experiment recorded only static, not a message from extraterrestrials that the scientist mused at the time might

[199] Breakthrough Initiatives, "About," Accessed July 16, 2020, https://Breakthroughinitiatives.Org/About.
[200] Giuseppe Cocconi and Philip Morrison, "Searching for Interstellar Communications," *Nature* 184, no. 4690 (1959): 845.

have taken the form of a series of prime numbers.[201] The noise Drake heard was deemed uneventful, while an extraterrestrial message he hoped for would have harbored some recognizability he imagined would be commensurable across species.

How do astronomers partition what data is worth paying attention to, and what can be deleted? What makes a signal meaningful, and noise discard-able? How do programmers write computer code to distinguish those categories—especially when they do not know if, when, and how ET will articulate a message? This chapter probes listening as a technology of perception by which SETI scientists, in particular, the Breakthrough Listen team, carve out epistemological practices to anticipate a noticeable, intentional, extraterrestrial signal. A cadence of edited volumes such as *The Auditory Culture Reader*, *The Sound Studies Reader*, and *Hearing Cultures: Essays on Sound, Listening and Modernity* give voice to scholars' tuning of attention from vision as a primary mode of perception to sound as a rich and underexplored epistemic regime in recent decades.[202] Taking my cue from them, this chapter sounds out how an anthropologist of science might "think with her ears" to ethnographically explore different valences of "listening" as an immersive metaphor for SETI science.[203] That is, my aim is enact an ethnographic sonar on Breakthrough's practice—their instruments, their observational methods, and their data analyses techniques—through what Michael Bull and Les Back call "deep" or "agile" listening, a mode of attunement that requires one "to listen again to multiple layers of meaning potentially embedded in the same sound."[204] I explore here the

[201] See: Carl Pomerance, "Prime Numbers and the Search for Extraterrestrial Intelligence," in *Mathematical Adventures for Students and Amateurs*, eds. David F. Hayes, Tatiana Shubin (Washington, D.C.: Mathematical Association of America), 1-4.
[202] Michael Bull and Les Back, ed., *The Auditory Culture Reader* (Oxford: Berg Publishers, 2004); Jonathan Sterne, ed., *The Sound Studies Reader* (New York: Routledge, 2012); Veit Erlmann, ed., *Hearing Cultures: Essays on Sound, Listening and Modernity* (Oxford: Berg Publishers, 2004).
[203] Michael Bull and Les Back, "Into Sound," in *The Auditory Culture Reader*, ed. Michael Bull and Les Back (Oxford: Berg Publishers, 2004), 2.
[204] Bull and Back, "Into Sound," 3.

larger phenomenology of listening as a layered metaphor, including but extending physically heard sounds.

The sonic framework, sound studies scholars frequently accent, is necessarily one of exchange. Of the Bosavi people's musical conversations with each other and the rainforest they inhabit, Steven Feld writes that "listening and voicing are in deep reciprocity, an embodied dialogue of inner and outer sounding and resounding built from the historicization of experience."[205] Of yeast cells that are made to "scream," Sophia Roosth argues that their sonification occurs as a result of scientific subjectification of what had hitherto been locked as a scientific object, a practice that "renders ambiguous the distinction between cells *speaking* and cells being *spoken for*."[206] Yet SETI scientists have no one to talk to; the subject they seek remains silent; the alien has no history, except that which is imagined by the practitioners who endeavor to excavate it.

Still, inspired by sound's "engulfing multi-directionality," I tease out "listening" as a multimodal metaphor that deepens as it abstracts.[207] In a general sense, like any anthropologist, I endeavor to ethnographically "listen" to the experts I have been immersed with, adjusting myself to their world-making.[208] First, "listening" peppers SETI as a figure of speech. Since Drake's initial experiment in 1960—which *was* actually was set up to produce audible output from receiver's loudspeaker as he scanned around the 21 cm line—"listening" has evolved from literal practice to a powerful expression that has encircled and explicated (and at times vexed) the search for extraterrestrial intelligence. Most obviously, perhaps, it emerges in Breakthrough Initiative's choice of title for their SETI program that purports to "*listen* for messages from the 100 closest galaxies to

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[205] Steven Feld, "A Rainforest Acoustemology," in *The Auditory Culture Reader*, ed. Michael Bull and Les Back (Oxford: Berg Publishers, 2004), 226. [223-240]
[206] Sophia Roosth, "Screaming Yeast: Sonocytology, Cytoplasmic Milieus, and Cellular Subjectivities," *Critical Inquiry* 35, no. 2 (Winter 2009): 333, emphasis in the original.
[207] Bull and Back, "Into Sound," 3.
[208] For more discussion on sound immersion and technical practices, see: Tom Rice, *Hearing and the Hospital: Sound, Listening, Knowledge and Experience* (Canon Pyon: Sean Kingston Publishing, 2013).

ours" using sensitive instruments that can "*hear* a common aircraft radar transmitting to us from any of the 1,000 nearest stars."[209] Or think of what (lack of) phenomenon that thwarts listening, the absence of a signal: silence. Physicist and popular science author Paul Davies's *The Eerie Silence* explores a paradox that physicist Enrico Fermi outlined that asks why, if the universe should be populated with life forms, some of which had developed radio technology, why humans haven't heard from ET.[210] Summarized succinctly: Where is everybody?

"Listening for ET" (and conversely not "hearing from" the alien) is thus an extensively rooted trope that continues to haunt the SETI project and sometimes annoy its practitioners. It remains a commonly heard-about mode to illuminate radio science to the public, even as scientists bristle at its limited utility to explain complex data collection processes they practice day-to-day. For instance, at what is called Cal Day in 2018, an annual springtime event where departments at U.C. Berkeley host an open house at which I volunteered, visitors to the Breakthrough Listen lab recalled the 1997 movie *Contact*. In it, the protagonist, radio astronomer Dr. Ellie Arroway, reposes on the hood of her 1965 Chevy Impala coupe convertible, listening passively on her headphones to the sonic output from the cluster of radio telescopes, when she intercepts what turns out to be an alien transmission.[211] In response to the visitors' fond memory, the Breakthrough scientists patiently explained that they do not spend all day listening for audible aliens. (Jill Tarter, too, has griped to me about the scientific inaccuracy of that scene—the walkie talkie Arroway used to alert the control room would have thunderously washed out any delicate extraterrestrial signal, like a microwave at

[209] Breakthrough Initiatives, "Listen," accessed July 31, 2020, https://breakthroughinitiatives.org/initiative/1, emphasis added.
[210] Paul Davies, *The Eerie Silence* (New York: Houghton Mifflin Harcourt, 2010). For a less succinct discussion on Fermi's paradox, see: Steven J. Dick, *The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science* (Cambridge: Cambridge University Press, 1999); John M. Smart, "Evo Devo Universe? A Framework for Speculations on Cosmic Culture," in *Cosmos and Culture: Cultural Evolution in a Cosmic Context*, ed. Steven J. Dick and Mark L. Lupisella (Washington, D.C.: NASA History Series, 2009); and "Fermi Paradox," SETI Institute, accessed September 2, 2020, https://www.seti.org/fermi-paradox.
[211] Robert Zemeckis, dir., *Contact* (Los Angeles: South Side Amusement Company, 1997).

the GBT.[212]) And yet, a Morse code transmitter and receiver that had been set-up on opposite sides of the Breakthrough Listen lab for visitors to try their ears at wireless communication seemed to me to rebel at the team's weary dismissal of listening as a viable metaphor of SETI's mission.

Figure 6. Poster at the GBT, photograph by the author October 2017.

Or, take the GBT's slogan on posters that line the facility's hallways and on banners that are rolled out for public events: "The universe it whispering to us." [Figure 2.] At the Galaxy Gift Shop

[212] In discussion with the author, July 2008.

there, a visitor can purchase a t-shirt, a magnet, stickers, and even a license plate emblazoned with that phrase. The GBT facilitates all kinds of radio observations, but the phrase clearly references the site's history of SETI research. That the universe would be softly murmuring evokes the image of someone straining—actively trying—to listen, as well as some source directedly provoking wanted attention. The GBT's catchphrase thus implies both an attentive listener and intentional speaker that will meet on a plane of similitude conjured through commensurable technology and assumed understanding. In kind, in *Contact,* Dr. Arroway lets the crackling static wash over her, until she "earwitnesses" a technosignature, thumping like a beating heart, that transforms her passive hearing into attentive listening.[213]

The movie is a work of fiction, and the GBT slogan is clever branding. But do the conditions that these examples posit necessary to perceive an alien message—the arrayed telescopes engineered to be sensitive in the radio, turned to the right place in the sky, "listened" to at the right time by a person who has wagered on the existence of extraterrestrials—translate to Breakthrough's processes of observation and data analysis that they create, adjust, and fine-tune to fit some unknown, but anticipated, alien broadcaster? That is, in more general terms, can listening, here described as a rhetorical device, transform to some other category that implicates it as an epistemic, embodied tool in technoscientific practice?

Scholarly work on sound studies, especially in the field of science, technology, and society (STS), speak together in a resounding "yes." Trevor Pinch and Frank Trocco's work on musical instruments centers material practices of knowledge-making, focusing on how developers of analog synthesizers in the 1960s "sculpted" sound to particular aesthetics.[214] For anthropologist Stefan Helmreich, "sounding" is a part of a dynamic scientific practice that vivifies matter through

[213] R. Murray Schafer, *The Soundscape: Our Sonic Environment and the Tuning of the World* (Rochester: Destiny Books, 1994), 8.
[214] Trevor Pinch and Frank Trocco, *Analog Days: The Invention and Impact of the Moog Synthesizer* (Cambridge, Harvard University Press, 2004).

transduction, that is, the transformation, deepening, and smoothing of meaning through changing media (sea water, bodies, cyborgian crafts that plumb ocean depths).[215] As Sophia Roosth has argued, "sounds are not inherently meaningful" but are made so by scientists who construct laboratory milieus to *listen.*[216] That is, listening is an epistemic mode that orients subjects to each other because it creates conditions for who and what can be made to speak, and relatedly, elevates that which is worth paying attention to. Meanwhile, historians like Emily Thompson and Jonathan Sterne have richly illustrated the cultural conditions for sounds to be crafted as particularly modern, from recording devices to concert halls to skyscrapers.[217] This chorus of scholars dials down the immediacy of the sensory mode that has dominated Western epistemology—sight—and instead attends to technoscientific practices that render sound (and its constituents: music, noise, silence, audibility) through a material, embodied, ideological regime, one that leans in to subjective immersion rather than objective delimitation (more on these differences soon).

In concert with these thinkers, in what follows I describe moments that transpose SETI's practices from the "figures of speech" described above to "figures of listening": how Breakthrough scientists assemble experiments by which they condition themselves to the prospect of "hearing from" ET. I explain how I partook in sonic tools through my participant observation as a remote observer at the Parkes Telescope in Australia, a single-dish radio telescope like the GBT, but with different technological capacities. *Computerized* bird songs disciplined my observational practices, and for others more in tune with the telescope, *natural* bird songs created moments of experiential conflation. I then sketch how listening richens and abstracts into an epistemic space of expectation

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[215] Stefan Helmreich, "Submarine Cyborgs: Transductive Ethnography at the Seafloor, Juan De Fuca Ridge," in *Alien Ocean: Anthropological Voyages in Microbial Seas* (Berkeley: University Of California, 2009), 216-232.
[216] Sophia Roosth, "Screaming Yeast: Sonocytology, Cytoplasmic Milieus, and Cellular Subjectivities," *Critical Inquiry* 35, no. 2 (Winter 2009): 335.
[217] Emily Thompson *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900-1933* (Cambridge: MIT Press); Jonathan Sterne, *The Audible Past: Cultural Origins of Sound Reproduction* (Durham: Duke University Press, 2003).

Breakthrough scientists create by programming experimental tools calibrated to alien *intention*. Through observational protocols, data collection and analyses, and hardware configurations, the Breakthrough team enacts particular experimental choices to best attune themselves to what they imagine to be extraterrestrials' behaviors. That is, Breakthrough's programming of anticipation for how the alien will emerge creates the conditions of attentive listening around assumed alien desires to make contact.

To listen begins with waiting for someone to speak; to wait is to manufacture the conditions that they will. This chapter follows how I and others manipulate observational data as it churns through a global pipeline through embodied, metaphorical, and abstracted practices of listening. It considers how Breakthrough scientists tease out "natural" noise from "artificial" signals. Like I heard the fox's seemingly otherworldly, but actually "natural" screams, Breakthrough observers seek parse what is disposable interference from what could be a meaningful "speech" from ET—a communicated, information-rich, message.[218] First, however, I explain key aspects of radio science as they bear on the search for extraterrestrial intelligence to later contextualize listening—a capacious, leaky, immersive, multi-channel technology of perception that sounds out practices by which Breakthrough teams expects the alien to signal.

Radio Dishes and SETI Science

Scientists interpret electromagnetic radiation (light) as waves that propagate through spacetime waves (more on light's queer behavior in the next chapter). Light's wavelength is measured in distance, such as millimeters. Like an ocean wave, wavelengths of light have crests and troughs. The frequency is expressed as how long it takes for light to make a complete cycle, from

[218] *cf.* Lachmann, Newman and Moore's "The Physical Limits of Communication."

crest to crest, say; for instance, hertz is a unit of measurement that is equal to one cycle per second. The electromagnetic spectrum characterizes electromagnetic waves based on their wavelength (or frequency). Microwave and x-rays are both light traveling at the same speed I in an unimpeded vacuum—almost 300,000,000 meters per second. The visible light that typically abled people see—the flaming red of a toreador's flag, the soft green of a plush Midwestern lawn, the sublime wine dark sea of Homer's ancient Greece—takes up a small part of that spectrum. Radio waves, at the lowest frequency / longest wavelength end of the spectrum, range from about a centimeter to a kilometer—wavelengths that correspond to frequencies of about 30 gigahertz (GHz) to 300 kilohertz (kHz). The GBT is an instrument designed to capture radio waves 3 m to 2.6 mm long (0.1 – 116 GHz).[219] Scientists use the resulting data to investigate astrophysical objects that radiate within that range, from pulsars (swiftly rotating, magnetic neutron stars), to gas clouds, to galaxies—even, perhaps, technosignatures from extraterrestrials.

There are a variety of reasons why SETI scientists have historically focused on certain parts of the broad radio part of the electromagnetic spectrum to expect alien communication. Dust and gas in the interstellar medium scatter and absorb electromagnetic waves in such a way that radio waves pass more efficiently over longer distances. Within the radio spectrum, the galaxy produces what has been described to me as a "hum" or a "hiss" of low frequency noise, while higher radio frequencies get absorbed by Earth's atmosphere (and presumably would also be absorbed by exoplanetary biospheres on which ET would transmit technosignatures). The "quiet" terrestrial microwave window, perched between is referred to as a "noisy" zone and a dead zone, sits between about 1 GHz to 10 GHz and has spurred SETI scientists to direct observations within those specifications. Notice how aspects of sound emerge here as metaphors refracted by embodied

[219] Green Bank Observatory, "Green Bank Telescope," accessed July 16, 2020, https://greenbankobservatory.org/science/telescopes/gbt/

listening. Sound waves, unlike light waves, require a medium to travel. It's not as if the universe "hisses" or is "noisy." In fact, in a vacuum, there is no medium for sound waves to propagate (cue complaints of physicists when they hear explosions in outer space in science fiction movies).[220] The point here is that scientists lean on analogies like "signal" and "noise" from the phenomenology of abled hearing, discourse that gets muddled as it propagates.

Figure 7. A view from the focus cabin at the GBT, photo by the author, June 2016.

SETI scientists also sometimes design experiments that bet that physical aspects of spectrum will be interpreted as universally significant, a move that transforms physical phenomena into commensurable cultural touchpoints. As electrons shift energy levels in atoms and molecules, corresponding wavelengths travel. A hydrogen (H) atom will emit at 21 cm, relating to 1420 MHz frequency. Here in the "most favoured radio region," Cocconi and Morrison wrote in the 1959 paper, "there lies a unique, objective standard of frequency, which must be known to every observer

[220] See also: James Wierzbicki, "The Imagined Sounds of Outer Space," *Journal of Sonic Studies* 8 (Sounds of Space 2014): 1-37.

in the universe."[221] Bernard Oliver, an electrical engineer who worked at Bell Labs and Hewlett-Packard and later became a SETI practitioner and funder, expanded on that intuition, famously coining the phrase the "water hole" as an attractive place to search for technosignatures.[222] A hydroxyl molecule (OH) will emit light at various energy levels that translate to 1612 MHz to 1720 MHz on the spectrum. Taken together—OH + H = H_2O—the so-called water hole encompasses the 1420-1720 MHz, what astrophysicists sometimes hedge will be universally recognized as a common meeting place. Radio astronomers use telescopes sensitive around these frequencies.

Figure 8. The Robert C. Byrd Green Bank Telescope, photo by the author, June 2016.

[221] Cocconi and Morrison, "Searching for Interstellar Communications," 845.
[222] SETI Institute, "Bernard M. Oliver (1916 – 1995)," accessed July 20, 2020, https://www.seti.org/bernard-m-oliver-1916-1995.

Both the Parkes and the GBT are single dish telescopes. The later section of this chapter explicates the particular experimental choices the Breakthrough Listen team has made to anticipate alien intention, located in the intensive data transformations *after* the observations taken using these sensitive and complex instruments, but it is helpful to sketch out the basics physical functions the two telescopes share. Because radio waves occupy the longest part of the EM spectrum, the larger the dish, the greater the range of wavelengths it can collect—but engineers have cleverly exploited the physics of each instrument for different purposes. At 100 meters across, the GBT is the largest fully steerable radio dish in the world.[223] [Figures 3 and 4.] But its shape is not uniformly parabolic; in fact, adjustable panels can morph the antenna (the dish) to reflect radio waves. They either reach the prime focus that sit on a moveable boom (a feature that has always looked to me like a flexing arm) and are then directed to a receiver sensitive to low frequencies/shorter wavelengths of radio. This set-up has the advantage that the aperture—the telescope's capability to collect radio waves, like the shutter in a camera—remains less obstructed during observations. When the boom gets retracted (a process that gobbles up a whole day of maintenance that occurs, roughly, about once a month), the radio waves can get directed to a secondary receiver positioned behind the reflector that is sensitive to higher frequencies. Breakthrough observers can tell the telescope to switch from C band to L band, for instance, within a single session.

[223] Take a virtual reality (VR) tour of the GBT: Breakthrough Listen, "Visit the Green Bank Telescope in VR (Part One)," uploaded June 29, 2017, https://www.youtube.com/watch?v=sobaAqgQWLY&t=3s.

Figure 9: On a plane ride with pilot Brett Preisig, the X at the Parkes Telescope (pictured here in the mid-left).

Meanwhile, the Parkes dish is 64-meters across and has been operational since 1961. Its claim to fame is that operators there, despite magnificent wind gusts that threatened the structure of the telescope, were instrumental in broadcasting Neil Armstrong and Buzz Aldrin's moonwalk during the Apollo 11 mission to the world in 1969.[224] Unlike the blinding white, flexible panels of

[224] Read the full story here by the Operations Scientist at Parkes Radio, John Sarkissian, "On Eagle's Wings: The Parkes Observatory's Support of the Apollo 11 Mission," last updated February 25, 2009, https://www.parkes.atnf.csiro.au/news_events/apollo11/; and, a movie that dramatizes these events: Rob Sitch, dir., *The Dish* (2000, Roadshow Entertainment).

the GBT, the Parkes' antenna is a strict parabola made of metal enringed by metal mesh. Although it is smaller (more limited in the range of radio wavelengths to which it is sensitive) and the focus cabin sit directly above the center of the dish (potentially blocking coverage), this telescope is equipped with thirteen (instead of the GBT's two) receivers that together create what are called multibeam observations. Dave MacMahon, the chief engineer for the Breakthrough Listen project, described the configuration as a disco ball, in which reflected light beams off of each panel.[225] The multibeam receivers can gather radio waves from 1.23 to 1.52 GHz—a smaller range of frequencies than the GBT—but can be used for multiple positions in the sky at once for surveys.

The telescope's concave shapes have always evoked for me the shape of a giant listening ear filling soundlessly with radio waves like water in a bathtub. As the Breakthrough Listen astronomers told the visitors at Cal Day, they do not literally listen for alien signals nor consider the telescopes' dishes to be like their ears, only more sensitive. Yet the metaphors around listening that SETI cultivates—the Big Ear telescope at Ohio State University is another example—attest to the resonance between that organ and radio telescopes, and thus it is worth pausing on that linkage.[226]

The ear has a history, so argues Hillel Schwartz. Since the 19th century, it has been pitied as the "vulnerable organ of perception," without lids or lips that might mediate its sonic encounters, described as a "passive receptacle" that was never fully "off."[227] Anatomical investigation of its delicate and sensitive workings, coiled in intimate interiority, strained the conceptual and phenomenological differences of cultural and scientific interpretations between hearing and

[225] In discussion with the author, July 2020.
[226] For further discussion on extendable sensing in STS, see Janet Vertesi, *Seeing Like a Rover: How Robots, Teams, and Images Craft Knowledge Of Mars* (Chicago: University of Chicago Press, 2014); Natasha Myers, *Rendering Life Molecular: Models, Modelers, and Excitable Matter* (Durham: Duke University Press); and, around feminist studies of sex and the body, Saray Ayala And Nadya Vasilyeva, "Extended Sex: An Account of Sex for a More Just Society," *Hypatia* 30, no. 4 (Fall 2015): 726-742.
[227] Hillel Schwartz, "The Indefensible Ear: A History," in *The Auditory Culture Reader,* eds. Michael Bull and Les Back (Oxford: Berg Publishers, 2004), 487.

listening.[228] As an embodied instrument accosted by modernity, the ear risked being beleaguered, overtaxed, and in a perpetual state of decline, all the while facilitating subtle cultural interpretations that sought to distinguish sound, noise, music.

Adding to Schwartz's litany of problems he bemoans that have troubled the ear ("Stop talking about the ear as defenceless" he commands[229]) is that the listening it facilitates is often diffracted through oppressive ideologies of gender.[230] Transposing John Berger's quip ("Men act and women appear"), men speak, and women listen, as any woman who has been "mansplained" to can attest.[231] (That portmanteau was rubberstamped by the OED in 2008, a testament to its contemporary cultural currency.[232]) Those links have been contested by feminist scholars, notably, in Emily Martin's classic essay "The Egg and the Sperm." She elucidates how gender stereotypes inform scientific narratives (even in the face of contradictory evidence): sperm are described as vigorous, powerful, swimmers that must brave a hostile environment to penetrate the ovum, its foil, imagined, conversely, as fragile, waiting, and still.[233] Particular to the anthropology of gender and speech, in Beth Semel's study of how practitioners diagnose and parameterize mental illness with

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[228] Schwartz, "The Indefensible Ear," 491-492.
[229] Schwartz, "The Indefensible Ear," 500-501.
[230] Composer and sound artist Miya Masaoka hypothesizes that "genital vaginal folds and flaps, like the bony pleats of the ear, create a layered and labyrinthian topography for listening, perceiving, and feeling," risking, perhaps, a theoretical move whose elision of the two organs risks objectifying (or at least essentializing) both (*The Vagina Is the Third Ear*, *TDR/The Drama Review* 64, no. 1 [Spring 2020]: 4). Her performance project remixing organs' spiritual currencies (eye, ear, vagina), invites participants to amplify the sounds of their vagina through "vaginated chairs" (2). (Meanwhile, women are socially conditioned that audible sounds mediated by the vagina ["queefs"] are excruciatingly embarrassing, from yoga to intercourse). Joe Davis, an artist who has been variously affiliated with Center for Advanced Visual Studies and the Biology Department at MIT, in 1986 transmitted ballerinas' vaginal contractions to Epsilon Eridani and Tau Ceti and other nearby star systems [Paul Gilster and Joe Davis "'Rubisco Stars' and The Riddle Of Life," *Centauri Dreams: Imagining and Planning Interstellar Exploration,* November 18, 2009, https://www.centauri-dreams.org/2009/11/18/%e2%80%9crubisco-stars%e2%80%9d-and-the-riddle-of-life/; W. Wayt Gibbs, "Art as a Form of Life," *The Gates of Paradise*, accessed July 30, 2020, http://www.thegatesofparadise.com/joe_davis.htm.] These examples show how the vagina is framed as interior, obfuscated, a passage point to an even more hidden, primordial realm, the womb; that it must be coaxed to speak references broader associations of female genitalia to feminine passivity.
[231] John Berger, *Ways of Seeing* (London: British Broadcasting Corporation and Penguin Books, 1972), 47.
[232] *Oxford English Dictionary Online,* s.v. "mansplain," accessed June 2, 2020, https://www-oed-com.Entry/59997929.
[233] Emily Martin, "The Egg and the Sperm: How Science Has Constructed a Romance Based on Stereotypical Male-Female," *Signs* 16, no. 3 (Spring, 1991): 485-501.

computerized techniques, she shows that the "very notion of what it means to be empathic—to listen empathically—is wrapped up in ideas about the relationship between speech and self, and mind and language, and [is] torqued by ideas about gender, race, ability, and class."[234] Take also Liz W. Faber's forthcoming study of how computerized helpers (e.g. Siri) are gendered.[235] That is, the performance of femininity is, in part, a culturally orchestrated performance of a particular kind of listener or speaker who is caring, passive, or comforting.[236] Extending such considerations to *sound waves*—how the ear hears—Stefan Helmreich suggests that the associations between femininity, the ocean, and waves, is coming undone (as he puts it, newly "at sea") as non-human considerations (like waves themselves) propogate ontological flux and instability.[237]

Following the electromagnetic signals captured by the radio dishes described above, I now turn to the material hardware process that Breakthrough Listen engineers have bootstrapped to wrestle with truly incredible amounts of data.

[234] Beth Semel, "Speech, Signal, Symptom: Machine Listening and the Remaking of Psychiatric Assessment," Dissertation (Massachusetts Institute of Technology, 2019), 25.
[235] Liz W. Farber, *The Computer's Voice: From Star Trek to Siri* (Minneapolis: Minnesota University Press, 2020).
[236] See also: Kenneth Lipartito, "When Women Were Switches: Technology, Work, and Gender in the Telephony Industry, 1890-1920," *The American Historical Review* 99, no. 4 (1994): 1075-1111.
[237] Stefan Helmreich, "The Genders of Waves," *Women's Studies Quarterly* 45, no. 1-2 (Spring/Summer 2017): 31.

Figure 10. The Parkes telescope from the ground, backlit by the afternoon sun, photo by the author, September 2016.

The Hardware

Along with the GBT, the Breakthrough Listen team has used the Parkes radio telescope just outside of Parkes, Australia in New South Wales, as a primary site for SETI research. It is run by the country's Commonwealth Scientific and Industrial Research Organisation (CSIRO), a federal agency

akin to the U.S.'s NSF, but the team has installed their own hardware. I accompanied Dave MacMahon, the chief engineer for the Breakthrough Listen project; Matt Lebofsky, the team's computer programmer and systems administrator; and Danny Price, then a postdoc, who now is based in Melbourne and works as the Parkes Project Scientist, to the Parkes telescope in September, 2016 as they worked to set up the hardware that would feed observations back to U.C. Berkeley. On this particular venture, I met the crew in Sydney before we made the five-hour drive NNW to Parkes. Our trip included a flat tire, an Elvis-themed hotel [Figure 7.] (Parkes hosts an annual festival honoring him, and the town seems to be inexplicably obsessed), an Airbnb stay in a converted vintage railroad car (where I learned to play Texas hold'em using quarters as poker chips), a waterfall hike in the Blue Mountains, and wine tasting in the Hunter Valley (Semillon is varietal in which the region excels).

Figure 11. Elvis at The Dish, photo by the author, September 2016.

Dave MacMahon is the chief engineer for the Breakthrough Listen project. I call MacMahon (part of) Team Chill because, at heart, he is a fixer; every problem is somehow calmly, cleverly, dealt with. There is always a solution to be found when conference logistics hit snags, computer parts go mysteriously missing, (my) glasses are lost at the GBT dorm, etc.[238] MacMahon has directed and built up Breakthrough's idiosyncratic hardware set-up on-site, called the backend, that he has assembled (with others) to intercept, transform, and compress the data before it gets analyzed back at Berkeley. Both backends at the GBT and Parkes are set up in basically the same way. The wire from the telescope receiver carries raw data as a series of voltages (the energy required to move a unit of charge) over increments of time. The data gets sampled at an extremely fast rate—3 gigasamples per second. MacMahon told me this would be like taking the temperature three billion times per second and scribbling down the degrees on a notepad; there is limited information but it builds up rapidly. The analog-to-digital converter (ADC) translates those voltages to digits. MacMahon compared converting sound from a record (in which a needle encounters grooves, wobbles, and the oscillations are amplified in a speaker system) to a CD (a compact disc that reflects a series of 1s and 0s).[239] Lebofsky offered a visual analogy: "The analog voltages are like seeing a person in real life," he told me, "and the channelized data are like a digital video of that person," in which the quality of the video (how many pixels, how many frames per second) is determined by the complexity of the data conversion.[240]

Next, in a field-programmable gate array (FPGA) MacMahon and the Breakthrough team have customized executes what is called a rough fast Fourier transform (FFT), an adjustable

[238] This nickname includes with a recent member of the Breakthrough team, postdoc Daniel Czech. The three of us worked intensively for Breakthrough's participation at the International Astronomy Conference in Washington, D.C., in October 2019. I felt lucky to be proximate to Team Chill, as I do not, admittedly, share the team's basic ethos.
[239] In conversation with the author, July 20, 2020.
[240] In conversation with the author, July 20, 2020.

algorithm that is widely used beyond radio projects.[241] In it, the algorithm is programmed to pick out sine waves from digitized data (more on this later), a process that whittles down the data products into more manageable sizes. The now-digital data gets channelized and packetized, that is, separated into segments of frequency ranges. Directed through what is called the switch—what MacMahon called the spine, or nervous system, of the assemblage—the data then "fans out" to individual compute nodes.[242] There, chunks of the data are processed independently and in parallel by what are called graphics processing units (GPUs). Highly efficient electronic circuits that were originally created for gaming, the GPUs MacMahon and other Breakthrough scientists have customized digest unfathomable amounts of data. All of this is choreographed by the head node—the brain of the system, according to MacMahon—that is programmed to communicate with each compute node through a network.[243] The storage node, as one might guess, holds the data after it undergoes another, finer-grained FFT I will soon explain. The manipulated data products, digitized and double FFT'd, are archived and then available for further analysis. As MacMahon summarized for me over Slack, "Telescope → ADC → FFT in FPGA → Switch → Compute Nodes (→ Storage Nodes) → Data Archive → Detection of ETI [extraterrestrial intelligence] → Nobel Prize."[244]

The Breakthrough team decided to piece together their experimental set-up on a smaller scale before adjusting it and bulking it up. When I visited the GBT in June, 2016, MacMahon was installing the first phase of the hardware, with a handful of compute nodes. Now, the GBT has 64 compute nodes that file down the data into eight storage nodes. Parkes' system is comprised of one head node, 27 compute nodes, and six storage nodes [Figure 8]. For reference, I am writing on a

[241] Lebofsky described the FFT algorithms as taking the raw voltage data and rotating it 90 degrees. According to physicist Dave Kaiser, "A Fast Fourier Transform identifies the dominant frequencies in a series of data over time. Those dominant frequencies indicate the characteristic waves, of specific frequencies, that contribute the most to the original signal." See also: William Press et al., "Fast Fourier Transform," in *Numerical Recipes: The Art of Scientific Computing*, 3rd ed., 600-637 (New York: Cambridge University Press, 2007).
[242] In conversation with the author, July 21, 2020.
[243] In conversation with the author, July 21, 2020.
[244] In conversation with the author, July 21, 2020.

2014 MacBook Pro laptop that runs on 16 gigabytes (GB) of memory and has about one terabyte (TB) of disk space; its computing and storage capacity seems paltry when compared to a single compute node that runs up to 92 GB and houses about 100 TB of storage. The computer room at the GBT is loud enough so that MacMahon and I have to raise our voices to talk; the compute nodes produce heat waste that has to be tamped down by whirring fans that are in turn cooled by a water system. (MacMahon has installed LED lighting that snakes around the tubes of the cooling system, cheerily changing color.)

Figure 12. I "help" Matt Lebofsky, center, and Dave MacMahon, right, install the backend at Parkes, photo by Brett Preisig, September 2016.

These hefty backends and the data that course through them are reminders that data collection is not neutral and the processes to coordinate them involves many resources—human labor, money, and time.[245] Logistical snags always impede any hardware assembly, and network

[245] For discussion on the materiality of machine assemblages from historical and STS approaches, see: Andrew Pickering, *The Mangle of Practice: Time, Agency, And Science* (Chicago: University of Chicago Press, 1995); Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997); Karin Knorr Cetina, *Epistemic Cultures: How the Sciences Make Knowledge* (Cambridge: Harvard University Press, 1999).

issues thwart continuous data collection. When I accompanied MacMahon, Lebofsky, and Price to the Parkes telescope in September 2016 to help install the compute nodes there, we were hampered by the discovery of asbestos in the computer room and had to wait days for an abatement team to give the all clear.[246] At the MeerKAT telescope array in South Africa where Breakthrough is currently assembling their unique data set-up (a site I have not yet visited), enterprising thieves, in search of copper wire, frequently tear out the fiber optic cables that run from Cape Town to Karoo. Baboons in the area often climb on the cables and rip the wires out too, probably, MacMahon guesses, because they like to eat the coating.[247] These disruptions prompt the operators at MeerKAT to rely on a backup cable system as often as once a week.

These details highlight the energy, materials, resources, and logistics that Breakthrough must maneuver to ensure the storage and movement of its data. Often unperceived or underappreciated by casual computer users, the ways in which unwieldy data are stored and transferred reflect particular ideological regimes. Nicole Starosielski's "network archaeology," for instance, excavates the intensively material processes by which underwater cables freight the Internet across oceans.[248] Their hubs are in unexpectedly disparate places that rub up against the seamless experience of accessing the Internet everywhere, anywhere, at any time; at these sites, construction and maintenance of cables' infrastructure can generate local resistance. Ruth Oldenziel, meanwhile, homes in on islands (often way-stations at which cables resurface) as nodes of networked power that the U.S. mobilized as connective tissue to shore up modernized, imperial heft after World War II—all the while, ironically, propagating an insular self-identity dependent on a myth of nationally

[246] Not to mention that on the drive from Parkes back to Sydney, on a not-that-populated, occasionally dirt road, we got a flat tire. The wine we stocked up on in the Pokolbin region, no doubt, which had replaced the heavy computer equipment on the way in, was unhelpful.
[247] Dave MacMahon, in conversation with the author, July 21, 2020.
[248] Nicole Starosielski, *The Undersea Network* (Durham: Duke University Press, 2015), 15.

bounded borders.[249] As such, historical and ethnographic accounts that follow the cables that are depended on to rapidly transmit data illuminate the jagged contours of globalization that have emerged since the Cold War.

Meanwhile, Breakthrough Listen's efforts to wrestle with incredible amounts of data are facilitated by private funding allocated to the project from Breakthrough Initiatives. Each compute node runs about $10,000, and each storage node, $15,000. It costs about $60,000 per petabyte (1,000 TB) to store the data that goes through these systems. While the data collection depends on which receiver is being used, in general, a six-hour session typical for Breakthrough at the GBT will collect about 75 TB an hour (approaching 500 TB over a typical six-hour session, or close to one petabyte (PB) over a longer 12-hour session. Copying and transferring a petabyte of raw data would take a month, and so what is originally collected gets reduced to about 30 TB (3% of the original) to filterbank data, files whose utilities I will soon explain. About 95% of the raw data gets deleted to clear disk space, saving the remainder for special projects that require it (for example, to observe a repeating fast radio burst). The topic of data storage comes up often at the weekly standing meetings on Monday afternoons, in which the Breakthrough team oscillates between thinking they should store it themselves or pay Google, Amazon or some other cloud service to store it for them.

Breakthrough Data: A Musical Analogy

Matt Lebofsky is a computer programmer and systems administrator who has been Breakthrough Listen's self-described "lead data wrangler" since the beginning of 2016, although he has been involved in various SETI projects around U.C. Berkeley for over 23 years. Lebofsky's

[249] Ruth Oldenziel, "Islands: The United States as a Networked Empire," in *Entangled Geographies: Empire and Technopolitics in the Global Cold War*, ed. Gabrielle Hecht (Cambridge: MIT Press, 2011), 13-41.

pursuits outside of computer science work are musical; he has toured the world as part of several bands, most recently as the keyboardist for Secret Chiefs 3, an experimental group that spans genres from Persian to death metal to Italian horror film music.[250] Perhaps because we share interests (I have been trained as a classical cellist, something we've talked about over the years), Lebofsky often reaches for musical analogies to explain the tortuous path that data takes before it ever gets dissected for technosignatures. He compared the Green Bank telescope picking up data the way that a microphone would pick up the human voice or other instruments. Both, he said, are just a series of voltages over time that are sensitive to various frequencies, but the telescope just has a much wider available range. If a typical microphone is sensitive from 20 Hz to 48 KHz, the GBT picks up frequencies that range from 0 to 100 GHz.[251]

Lebofsky describes himself as the drummer of the group. "Andrew [Siemion] dreams it up, Dave [MacMahon] makes it happen, and I keep it going," he told me.[252] "My job is keeping everything in time and holding everything together. Not to sell [myself] short; drummers are the most talented people in any band." We laughed. He envisioned MacMahon to be the bass player of the Breakthrough band: he "knows how to talk to the drummer and the guitarist" plus, he books all the gigs and he has the van with all the equipment. (Actually, MacMahon drives a 2014 silver Mazda Miata convertible that I have been angling for the past four years to drive; it can barely fit each of our suitcases in the trunk, let alone recording equipment. MacMahon plays music, too—he is a consummate guitarist who I've heard jam at a bar near Green Bank—and has to drive with the top down to fit an amp in the passenger seat.) "Dave [MacMahon] might not get all the glory," Lebofsky explained, "but he knows *everything*."[253] Lebofsky and I decided that the postdocs were the lead

[250] In discussion with the author, July 20, 2020.
[251] 1 Hz is one cycle of signal per second. 1 GHz = 1,000,000 KHz = 1,000,000,000 Hz.
[252] In discussion with the author, July 20, 2020.
[253] In discussion with the author, July 20, 2020.

singers of the band, doing flashy and experimental maneuvers on the data with novel AI and machine learning techniques.

As the conductor of the data pipeline, Lebofsky said, "I just have to keep the beat; I don't care if you're hitting wrong notes."[254] He oversees how they gets directed, reduced, trimmed, stored or deleted before it reaches Breakthrough scientists for analysis. Lebofsky compared data splicing how computers would be directed to analyze a singer's different octaves, multitasking to maximize time efficiency, before the reduced segments get concatenated. Meanwhile, data cleaning is like how musical sounds gets mixed in a recording studio, where specialized microphones are placed to pick up different instruments (e.g., a Neumann u87 for voice, a D112 for a bass drum microphone). Erroneous, low quality, or superfluous data gets trimmed away, saving further storage space. Through these processes and others, raw data (in the form of voltages and power) are compressed to what are called filterbank files (.fil) that take up far less computer storage space and can be more easily transferred down the pipeline for analysis.[255] The filterbank files encode essential frequency, time, and intensity data as spectra, but depending on which FFT they were directed to undergo, prioritize different aspects of the original data. As decisions about how to handle the unwieldy data have evolved since 2016, the team settled on what are now three data products, each configured into different formats ("We've been sailing the oceans while developing the ship," Lebofsky told me, calling upon another metaphor). One is fine-grained in the time domain with poor frequency resolution; the second embeds highly detailed frequency resolution, but is coarse in time; the third, "everyone's favorite," is a compromise of these two formats.[256]

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[254] In discussion with the author, July 20, 2020.

[255] In fact, much of that raw data gets discarded unless it is flagged for a special purpose; it is just written over. The GBT can record up to a petabyte of data over a typical six-hour observing block which would take over a month to transfer to Berkeley. Lebofsky estimates that 99% of it is immediately reduced to filterbank files.

[256] This tradeoff is *analogous* to what physicists call the uncertainty principle in quantum mechanics that states that one cannot know both the momentum and the location of a particle at any given time, but has a different sense in harmonic applications. As a result of a Fourier transform, precise time and frequency data of a signal, in principle, cannot be located simultaneously. Frequency and time are inversely proportional, so that f=1/t. In other words, zooming in on

I was trying to wrap my head around the differences between these files, and so Lebofsky conjured another musical analogy that resonated with me. The filterbank file, and the spectra they are used to create (depicted below), that has fine frequency resolution is like a piano in which "you can hear all 88 keys, but it's all whole notes." [Figure 10.] He made a vocal sound like "uuuuu," a single flat, sustained tone. Think of singing each note in "do-re-mi-fa-so-la-ti-do," but each tone is held for four seconds (a typical length of a whole note); there's no wiggle room to play each note for longer or shorter time lengths. In the file with fine time resolution, by contrast, the data would be all $1/64^{th}$ notes, rendering data in tiny temporal increments. [Figure 9.] (If a whole note is four seconds, $1/64^{th}$ notes scale to being played at sixteen times per second.) He made a sound like machine gun fire, rolling his tongue, something like "brrrrrrrrrrrr." This file sacrifices frequency gradation: "You have seven octaves [but] you can't tell what the different notes are within the octave," Lebofsky explained. He makes a blunt, watery, and deepthroated sound meant to evoke someone banging on the piano, "pbuvhh, pbuvhh, pbuvhh." Rounding up the analogy, in the filterbank file that compromises both frequency and time, "you can get quarter notes out and you can hear a pentatonic scale."[257] [Figure 11.] This would be equivalent to playing one-second notes that reveal quadruple the information over the same amount of time as a whole note, but the five frequencies of each note are more spaced out; they still complete a cycle, but one not as detailed as the

time requires zooming out in frequency, and vice versa. Achieving higher resolution in time—creating a spectrum that steps in tighter and tighter increments, e.g., one that is parsed in microseconds instead of minutes—dictates a loss of the ability to count how many cycles (how frequently) a sine wave can complete in that time segment. As I was trying to gain intuition about this relationship, I found YouTube to be particularly helpful resource to revisit physics fundamentals that had gone stale since college. One video used the analogy of two cars stopping at a red light with their turn signals on. As you pull up next to them, by chance, the lights appear to be blinking in unison. But it would take the full duration of the traffic light, perhaps the good part of a minute, to determine if the two blinkers had fallen out of sync. That is, the longer the time domain, the more confident you would be that they had the same frequency. (See: Grant Sanderson, "The More General Uncertainty Principle, Beyond Quantum," YouTube, uploaded February 24, 2018, https://www.youtube.com/watch?v=MBnnXbOM5S4&vl=zh-Hans.) Inverting the relationship in that analogy, you might imagine that, in the moment you see the two cars, you take a photograph that would allow you to closely examine aspects of the turn signals the instant that they blink (their color, how bright they are, etc.); but that snapshot would miss the counting aspect required to determine their syncopation.

[257] In discussion with the author, July 20, 2020.

heptatonic one (a seven-note scale plus the tonic that resolves the octave) I am used to hearing in Western classical music used by Beethoven and Brahms.

Prioritizing frequency resolution will reduce a gigahertz of bandwidth to a finely grained data product at three Hz per channel (frequency steps) at 100% power but only over an 18 second "bin" (simply, a discrete increment of value). A narrowband signal that ET would have transmitted over a shorter period of time would not be washed away, but scale linearly in power, that is, how intense or bright the signal is. For instance, a technosignature broadcast over a single frequency at 15 seconds say, has 15/18*100=83.3% of the power of the full bin. A signal that is a fraction of a second would get "lost in the noise," according to Lebofsky.

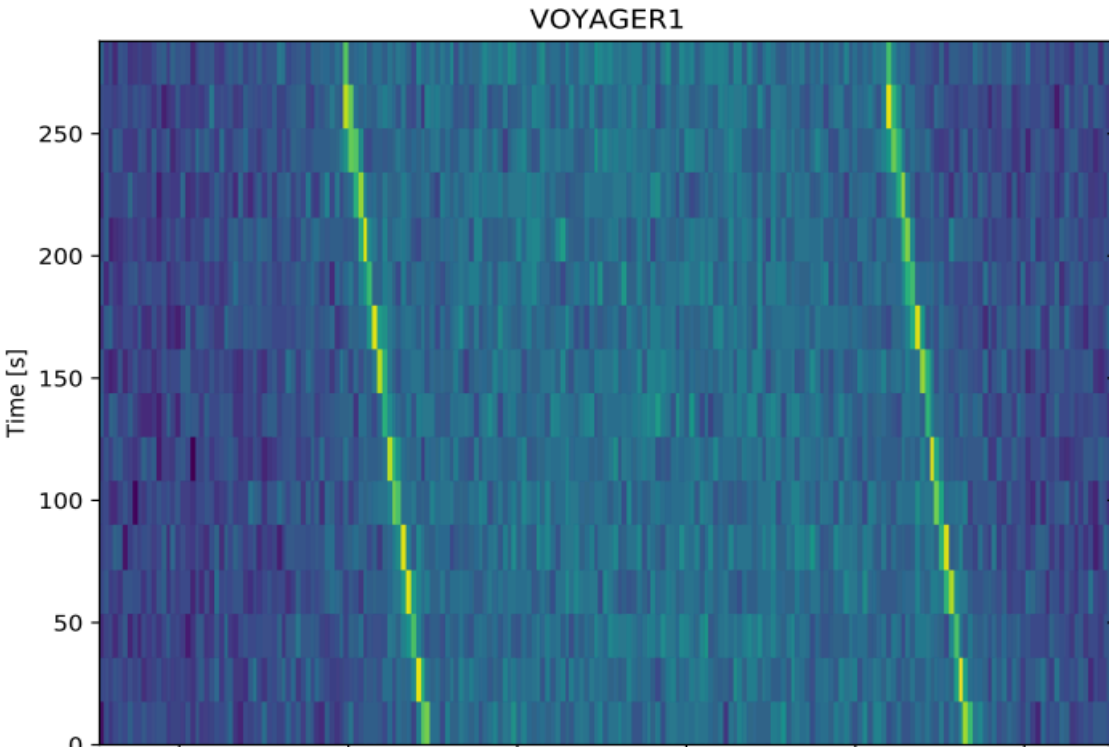

Figure 13. An example of fine frequency / coarse time resolution. Courtesy Matt Lebofsky, July, 2020.

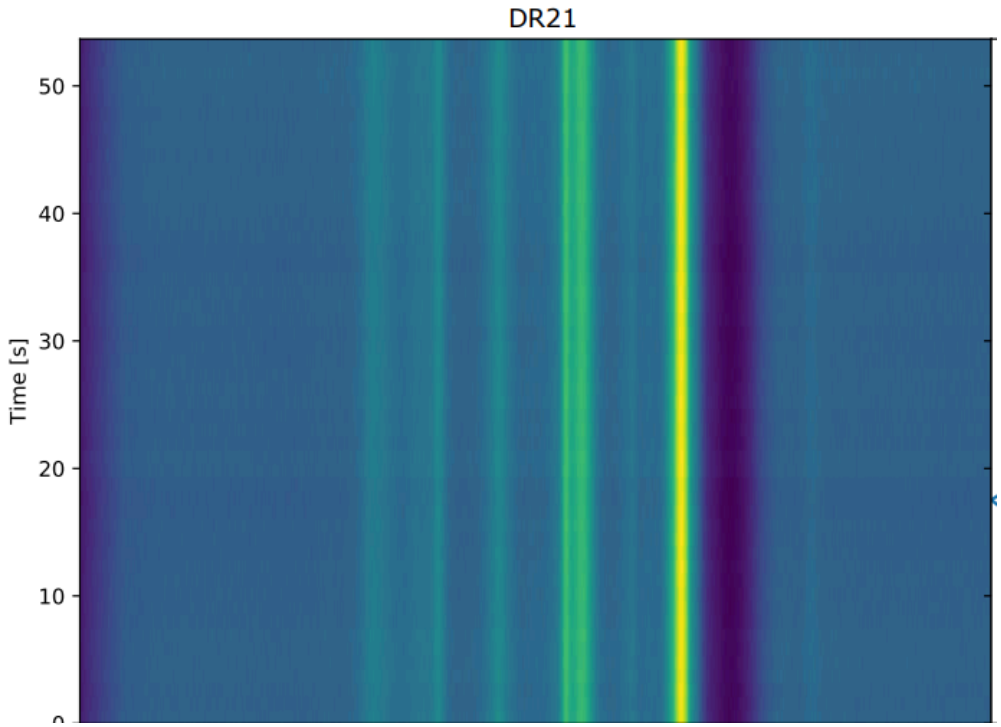

Figure 14. An example of Fine time / coarse frequency resolution. Courtesy of Matt Lebofsky.

Conversely, the filterbank file of the fine time frequency are incremented in 350 microseconds. The mixture of both is about one second in time over a kilohertz of frequency. Breakthrough scientists analyze this third kind of file first, and if they see something interesting, will go back and retrieve the other data. These intermediate, pre-analyzed data products, Lebofsky told me, are like making mp3s out of a master sound file; if a Breakthrough data scientist uncovers something interesting, they might want to "fine tune" their analysis by going back to the original.[258]

[258] In discussion with the author, July 20, 2020.

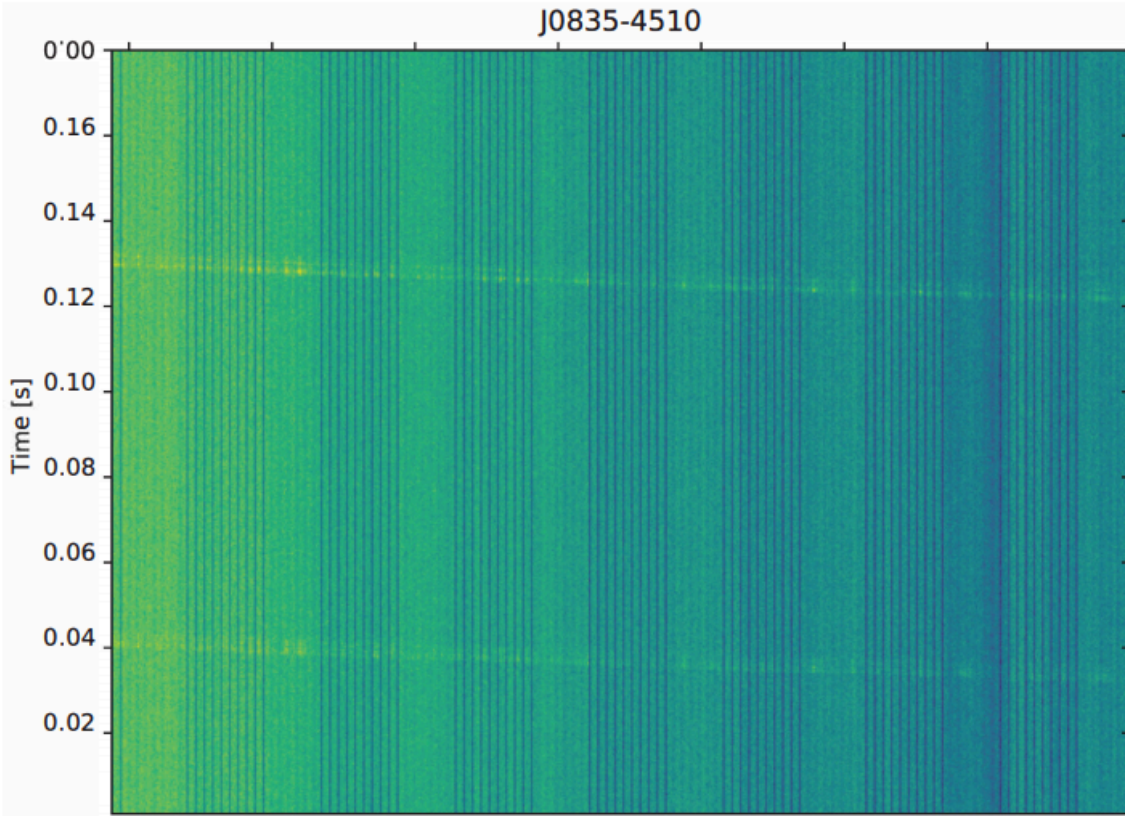

Figure 15. An example of the compromise of frequency and time resolution. Courtesy of Matt Lebofsky, July 2020.

Avian Figures of Listening at the Parkes Telescope

The three Americans on that trip (me, MacMahon, and Lebofsky) were impressed with the gargantuan and curious organisms we encountered on the five-hour drive NNW from Sydney, Australia, that included a pitstop to hike to a waterfall in the Blue Mountains: fragrant eucalyptus trees towered over us; huge birds glinted with iridescent plumage; and, tragically, dead, fuzzy wombats lay slain on the side of the road, casualties of car run-ins. On the way back to Sydney, at an AirBnB we stayed at, we were greeted by a throng of hushed, huge, kangaroos at sunset. (MacMahon and I were unsuccessful at trailing them later; they bounded noiselessly away on

muscular but springy haunches.) As I remarked to the group, living creatures seemed to be copy-pasted in Australia at 120%.

Back in Sydney, we stopped at a popular, gimmicky brunch place that Price had favorited when he had lived in Sydney. Corralled animals were gimmicks: a rotund pink pig lazed in the sun, and a wandering but flightless parrot even pecked the button off of MacMahon's shirt. That incident prompted Price to warn us about another pesky bird we'd seen and heard on the trip: clever magpies, black and white songbirds who can mimic other animals (including humans) and are known to "swoop" uncomfortably close—even injuring unsuspecting pedestrians and cyclists—if they feel threatened, especially when their eggs hatch in springtime (September in the Southern hemisphere). Although magpies are considered to be invasive species by ecologists, their unusual song-singing capabilities have endeared them to many Australians, and the birds are mascots for a number of sports teams. Their calls have even made their way into the Parkes telescope operating protocol, an auditory experience essential to correctly executing observations.

After that trip to the telescope, I got trained to run Parkes telescope observations remotely. The operators there work with Breakthrough to schedule blocks of observing time that are never wholly convenient to any particular time zone, so, living in Baltimore, Maryland in patches from 2017 and 2018, I sometimes picked up shifts that were morning for the east coast, middle-of-the-night for scientists based in Berkeley. Howard Isaacson, a Research Associate with Breakthrough Listen who is also affiliated with Berkeley's astronomy department, handled scheduling runs for the group. Price generated the list of targets to be observed, mostly culled from the Kepler exoplanet catalogue; for a while, though, the observers were running scripts aimed largely at the galactic center. Because the Milky Way is a spiral galaxy, its mass is centered on a pancake-like plane; astronomers reason that pointing the radio telescopes from our solar system, flung out on an arm in the galaxy,

toward the galactic center will have a higher probability of intercepting a technosignature as a result of the sheer density of stars there.

The observing protocol works like this: I open the Fantastic Remote Operations GUI (FROG), an interface that shows lets me quickly see the telescope status, the current observer in charge, the wind speed, and even a livestream trained on the telescope. [Figure 12.]

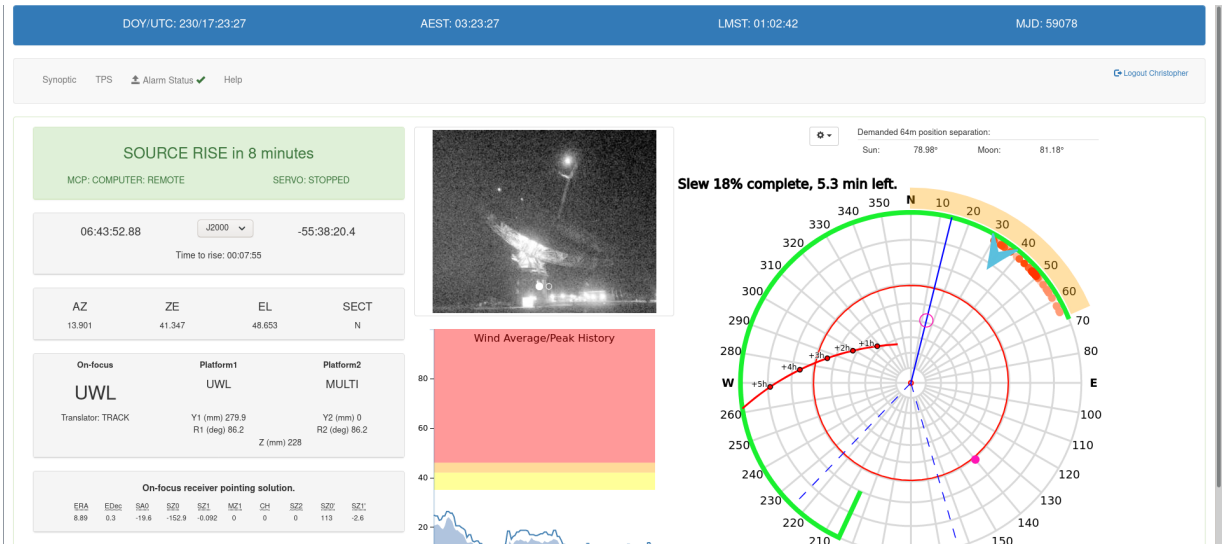

Figure 16. Screen shot of FROG, courtesy of observer Christopher Stevens, August 2020.

I also open PORTAL, Breakthrough's tailored user interface that lets me confirm that the data is being copied to the disk drives, see how much disk space is getting used, and check quick plots of the observational data. Then, I call up a Virtual Network Computing (VNC) program that lets my computer "see" the computer onsite at Parkes. (This an is unwieldy set-up that remote observers often grouse about; doing basic computer tasks like pointing and clicking is imprecise, almost as if one is operating under water, because one is interacting with a mirror of the computer there.) [Figure 13.]

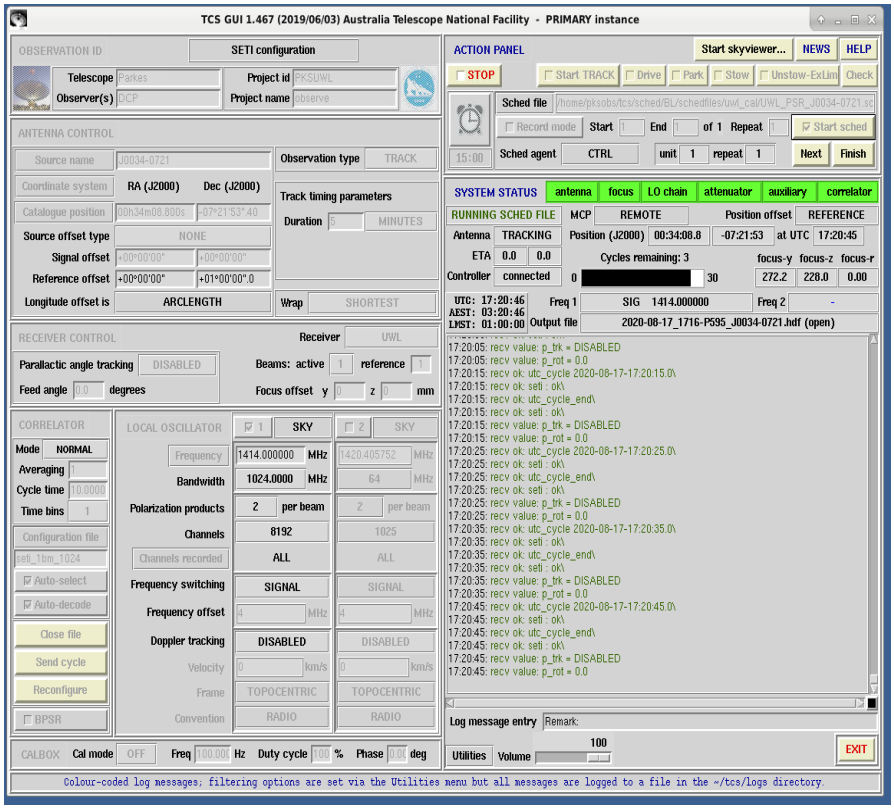

Figure 17. Screen shot of the VNC, courtesy of observer Christopher Stevens, August 2020.

Within the VNC, through the remote computer at Parkes, the observer in charge sets up the telescope to Breakthrough's specifications. I set it to "SETI mode," turn on system that links the antenna and the focus, and then turn on the multibeam function if the system is not already defaulted to it. More recently, Breakthrough has been using the ultrawide bandwidth (UWL) capability at Parkes that spans 704 to 4032 MHz.[259] The observer directs the telescope to a calibrator source to create a baseline (like checking the light levels before shooting a photograph) and a pulsar to test the instrument's data collection. Next, the observer runs a pre-generated script that tells the

[259] For detail, see: G. Hobbs et al., "An ultra-wide bandwidth (704 to 4032 MHz) receiver for the Parkes radio telescope," *Publications of the Astronomical Society of Australia* 37 (submitted November 2 2019), https://arxiv.org/abs/1911.00656.

telescope where to point and for how long. Price has preprogrammed these scripts, and so the observer in charge simply has to execute them in the VNC.

Maximizing observing time is crucial for SETI experiments. While I was observing Parkes remotely at Berkeley one evening over the spring in 2018, high winds forced the telescope to stow, and so, thinking I had the night off, went out to dinner with the team. The next morning, to my embarrassment, I learned that this had been the wrong move; the winds had calmed down and I had squandered a huge chunk of precious observing time. Howard Isaacson joked to me afterward that there should be a GUI in the VNC ticking off the money Breakthrough pays these facilities to use the telescope—at $1500 per hour of observing at the GBT works is $25 per minute, almost 42 cents per second. Such a feature, he reasoned, would inspire green observers (me, the summer interns) to run our scripts, tackle snags, or pay more attention to dynamic observing conditions (ahem) with more alacrity.[260]

A successful observing run is thus uneventful. Unlike Ellie Arroway in *Contact*, I was not locked in to my headphones scanning for technosignatures in real time, listening for what I determined were meaningful blasts amidst the noise of crackle. Yet sounds during the observing runs were crucial to conditioning scientific practice. I confess that after a few sessions, I felt relaxed enough after executing the automated observations that I would busy myself with other tasks: I'd chop onions to prepare for dinner, read a book, or even call my mom for a quick chat. The seasoned Breakthrough Listen observers who fill in shifts when no one else can (or wants to) run the programs at undesired times, say, midnight to 6 a.m. PST, often dozed off. But I learned to do what they do: keep my laptop awake, nearby, and with the volume up. I'd do this for an important reason: a dialog box in the program would alert me to changes in the observing session through a series of sounds I became intimately attuned to.

[260] In discussion with the author,

Observing the galactic center remotely over the fall in 2018, pleasant chirps assured me the telescope was slewing to its next point in the sky. I hadn't really thought too deeply about those sounds as indications of a "normal" session until, one time, I decided to take a shower but raced out dripping wet when I heard screeching from my laptop. Sharp and uneven, it sounded like an animal was clawing its way out my computer. The program was signaling me to an error in the observing session. It jarred me so that I became curious about the other sounds I had assumed were just computer-generated beeps and bops. I learned later that the screeching was programmed to be a cockatoo's call, one in a menagerie of bird sounds whose variety would pique an ornithologist's ears. Through FROG's chat capability—just like AOL's instant messaging (AIM) program popular in the early 2000s—I later asked an operator on a concurrent shift as me if there were other sounds. Dr. Jane Kaczmarek, then a CSIRO postdoctoral fellow on site, dug around for a bit to pull up what she called the "songlist" and emailed me a screenshot of this GUI (pronounced "gooey," a graphical user interface that is programmed to relay basic information to a computer user that can be called up within the terminal window) [Figure 14]:

Figure 18. GUI of the bird sounds at Parkes, image from Jane Kaczmarek , October 2018.

As I logged observation time, I became accustomed to many of these sounds, all from birds that live in Australia.[261] (We were unable to determine who had originally created and programmed this GUI.) The dipping "whoop" of the whip bird told me that the telescope had finished observing and tracking a particular pointing in the sky[262]; the sharp, but echoing, ringing of the bell miner signaled the activity of the correlator[263]; meanwhile, I wasn't sure of the "reminders" that the plaintive wail of pied butcher bird were meant to indicate.[264] Conditioning myself to these sounds made my observations more efficient. The cockatoo provoked tension and action ("Crap, I hope Howard is awake in Berkeley in case I can't figure out the problem and need to Slack him") while the whip bird prompted me to check in with the target list to gauge how far along to script was ("Let's eat dinner because this will be running for at least another hour"). The cockatoo's grating screech was chosen to alarm, not merely alert; the currawong's throaty, tooting, call was designed to perk the observer's attention to an observer sign-off. (I called up recordings of these birds in YouTube, and one commenter aptly wrote that the currawong sounded like "a Canada goose swallowed a bike horn."[265]) When I happened to be in the Breakthrough Lab when the Parkes observations were running, I'd often witness the scientists mumble in mild annoyance when they heard a sound that they had internalized was irrelevant ("Oh hush" to the noisy miner).

STS scholar Cyrus Mody shows scientists attune to, and are in turn conditioned by, sounds in their laboratories. Sounds are powerful, if often overlooked (underheard) components that influence laboratory practices that can be perceived to "contaminate" a scientific experiment or

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[261] For more birds in the laboratory, see: Joeri Bruyninckx, *Listening in the Field: Recording and the Science of Birdsong* (Cambridge: MIT Press, 2018).
[262] To listen, visit: Linda Hansbauer, "Whipbird Call 13 08 2016," *YouTube,* uploaded August 13, 2016, https://youtu.be/3vz7mqnrzZg?t=23.
[263] "Bell Miner (Manorina melanophrys) HD Video clip 1/1 Tim Siggs ABVC," *YouTube*, uploaded April 25, 2018, https://www.youtube.com/watch?v=5kjK_JRA9O8.
[264] PHOTONAUT, "Amazing Singing Performance by Four Pied Butcherbirds, Western Australia," *YouTube*, uploaded April 1, 2016, https://www.youtube.com/watch?v=Wr46I3568Hk.
[265] Birds of the Huon Tasmania, "Black Currawong call up close, *YouTube*, uploaded August 28, 2018, https://www.youtube.com/watch?v=ZEDmvni5yTk.

conversely be harnessed to "tune" and correct instruments.[266] Loud sounds emanating from instruments (and noisy but mundane machines like air conditioners) can be physically draining and even can evenly dangerously lead to hearing loss (Schwartz: "the ear's remorse and the ear's revenge."[267]) Scientists who use a transmission electron microscope (TEM) will be careful not to disturb their instruments with disruptive auditory vibrations that range from a clap to a conversation.[268] But besides avoiding or tolerating noise, scientists also harness sound in their experiments through what Mody calls "ear-work." TEM practitioners used sounds as a tool to assess whether or not their instruments are performing as expected; microscope builders often audibilize their instruments' output to finetune it to their liking.[269]

In kind, my attunement to the Parkes' bird songs deepened my competence as an observer. I gained what STS scholars call tacit knowledge—bodily practices that are difficult to explain to others, ones gained implicitly through *Fingerspitzengefuhl* (German for "finger tips feeling"). As summarized by Michael Polyani, it is the enactment of a feeling that "we know more than we can tell," and oft-cited examples are (most) humans' ability to recognize different faces and (some) humans' ability to ride bicycles; I can do both without thinking deeply about the cognitive or physics explanations behind those phenomena. I quickly gained an intuition for certain sounds that seemed "good" or "bad," and as I logged more hours, birdsongs prompted actions in ways that superseded rote processes (e.g., cockatoo=error=check the zenith gave way to a calm and ordered flow of action). That is, as time went on, I could turn the volume down on my laptop and did not necessarily need sustain a hypervigilant orientation toward the program. I enfolded particular sounds into a semi-conscious dimension, developing a keen awareness of the many levers required to

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[266] Cyrus Mody, "The Sounds of Science: Listening to Laboratory Practice," *Science, Technology, & Human Values* 30, no. 2 (Spring, 2005): 178-188.
[267] Schwartz, "The Indefensible Ear," 501.
[268] Mody, "The Sounds of Science," 179-182.
[269] Mody, "The Sounds of Science," 186-188.

execute remote observations. Cultivating intuition over the course of these observing runs mapped up to a deeper, different tacit knowledge that sociologist of science Henry Collins is concerned with, that is, one that requires not just skills-gathering but cultural inculcation into a community of experts.[270] For instance, I moved from what he describes as a state of incompetence to one of competence not only through learning the bird sounds, but also through adjusting to norms and expectations set by Breakthrough Listen scientists (e.g., becoming fluent in remote observing also meant learning that it was not acceptable to fritter away telescope time).

The observing manual stashed on Github, a repository that computer programmers use to store and share code and its documentation, indeed recommends that one "keep an ear open for bird noises" as the two preliminary observations are just a few minutes long. Kaczmarek and I were unable to find out who had programmed the sounds, but we agreed that the birds fit their intended message. As MacMahon would tell me when I asked him later for clarification of what each computerized bird song, he wrote, "I guess someone had to compile that list so that they could program the sounds to be played at the appropriate time, but as an observer I (and maybe you too?) I never read that list ahead of time and instead just learned which sounds were 'good' sounds (things proceeding normally) and which were 'bad' sounds (things not proceeding normally). It helps that the sounds are not randomly assigned."[271]

Beyond becoming immersed in these sounds, observers who have spent a significant amount of their time with or at the telescope described experiencing something more amplified than the tacit knowledge I glimpsed: a conflation between the computer-generated bird sounds and real-life bird sounds. On that 2016 trip to Parkes to install the compute nodes, MacMahon and Lebofsky were running a late night to early morning observing session out of a hotel room (I was thankfully

[270] Harry Collins, "What is tacit knowledge?" in *The Practice Turn in Contemporary Theory*, ed. Theodore R. Schatzki, Karin Knorr-Cetina, and Eike von Savigny (London: Routledge, 2001), 107-119.
[271] In discussion with the author, September 1, 2020.

spared), and so heard various bird sounds from the telescope control system for hours. Emerging from this sound bath for a quick nap before heading to the site, MacMahon recalled: "When I finally went back to my room at 5 a.m., I stepped outside and heard some of the same bird sounds irl [in real life]😂!"[272]

Jane Kaczmarek, the CSIRO postdoc who spent over two years in town and at the telescope site, experienced what MacMahon had but through more sustained immersion. She told me that she "now very much hate[s] cockatoos" on walks in the woods because when she hears them, she "will sometimes fret that something is wrong."[273] Kaczmarek, now in British Colombia as an astrophysicist at CHIME, the Canadian Hydrogen Intensity Mapping Experiment (astronomical, auditory metaphors seem to echo and follow her?) wrote to me in an email that she misses magpies the most, whose "amazing song" she associates with operating the telescope. A family of them used to nest in her backyard at Parkes and would sing from her roof, try to play with her chickens, and even bring her their young that had hatched in the spring. "Magpies are always pleasant—unless they're swooping you :D," she wrote. Meanwhile, bellbirds' calls became grating and even annoying to Kaczmarek. While on a three-day hike in the Blue Mountains, she wrote to me, their "constant, short calls, all the time" caused her to "go a bit nuts." She conflated their persistent sounds in nature with what she came to deem irrelevant sounds in Parkes observing. "Bellbirds mark the start of a new scan, and I still think, 'Ugh, so much unnecessary noise!'" she told me.[274]

Steeping myself in the bird sounds made me better able to adjust and respond to novel situations; MacMahon experienced a cacophonous overlap of bird songs both "irl" and through the mediated/digitized/programmed sounds of the telescope's operating program; for Kaczmarek, bird songs bled into different contexts due to her longer immersion with the telescope and life in Parkes.

[272] In discussion with the author, July 23, 2020.
[273] In discussion with the author, July 23, 2020.
[274] In discussion with the author, July 23, 2020.

As such, sound gets stitched into various epistemic practices by which I and others gained an *embodied* sense of listening around SETI observing. Building on Schafer's acoustic ecology, Steven Feld's "acoustemology"—a concepts that imbricates acoustics and epistemology—is infused with both "artificial" and "natural" sounds that constitute phenomenological world of the rainforest, a method to analyze that particular soundscape as a site of reciprocal, dynamic, experiences that locate actors in spacetimes. That is, acoustemology probes how "soundscapes are perceived and interpreted by human actors who attend to them as making their place in and through the world," Feld writes. "Soundscapes are invested with significance by those whose bodies and lives resonate with them in social time and space."[275] For Kaczmarez and MacMahon, especially, the layering of the computerized sounds with bird song "irl" created an immersive soundscape that remixed the digital and the natural—a phenomenon resonant with the astronomers' greater goal, that is, to untangle an artificial, alien *signal* from *natural,* cosmic *noise*. As such, embodied practices of observation molded site-specific avian figures of listening.

An Intermission: Metaphors, Analogies, and Representation

The following sections have loosely invoked various terms—listening, hearing, sound, music, attention, noise, silence—sounded through similarly loose rhetorical devices—metaphor, analogy, simile, whose uses, in practice, do "shade into one another."[276] Here I will be more careful, starting with a snapshot of my experience as a typically abled listener. Listening is a word deployed to describe the deepening of the physiological experience of (typical, abled) hearing, a micro-drama that enfolds in soft cacophony in the ear: soundwaves impact the eardrums; tiny bones vibrate; fluid in

[275] Feld, "A Rainforest Acoustemology," 226.
[276] Stefan Helmreich, "Gravity's Reverb: Listening to Space-Time, or Articulating the Sounds of Gravitational-Wave Detection," in *Cultural Anthropology* 31, no. 4 (2016): 487.

the inner ear agitates; cochlea hairs crook; electricity pulses up the auditory nerve to the brain. To listen, meanwhile, is to "hear attentively." It is an informed, relational, directed effort "to pay attention to" something, "to make an effort to hear something."[277] While writing, I tune in and out of listening. I *hear noises* I choose to ignore that crinkle my daily phenomenological experience in my apartment: the drone of the air conditioning, my neighbor downstairs assembling tools to bake sourdough bread (a fleeting thought before I relinquish my attention: I hope he drops some off later). Meanwhile, I choose to *listen* to *signals* and sustain attention because they require further contemplation, expectation, and sometimes action: a USPS worker delivers a book I am expecting, my sister jangles keys just outside the door (time for dinner), my 6-month-old puppy yelps quietly in her sleep as she enters a REM cycle (an indication, I've learned, that she'll wake up in a matter of minutes, bark, and want to go outside). Philosopher Don Ihde might describe my oscillations as semi-conscious mediation of "resistance to the maintenance of 'inner' focus and 'outer' sound."[278]

Lacking a referent—the alien—SETI swims in linguistic modes of metaphor, analogy, and representation. If "listening" is the metaphorical watchword in the field—think of the Big Ear Telescope in Ohio, Tarter's "cosmic dial tone," a "whispering" universe at the GBT—analogy is a structural enactment of gathered metaphor that elaborates comparisons between regimes of perception. I detour to scholarly interpretations of analogy and its linguistic compatriots (metaphor, representation) as yard sticks that inform my analysis of SETI's sensory leitmotif, listening. The philosophical, anthropological, and historical accounts I detail will triangulate the following questions: How do Breakthrough scientists engage rhetorical modes to relate to unknown entities? How do they map out experiments of expectation through those imagined relations? How is abled *listening* a mode by which SETI scientists *anticipate* ET?

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[277] *Oxford English Dictionary Online,* s.v. "listen," accessed July 2, 2020, https://Www-Oed-Com/View/Entry/109008
[278] Don Ihde, "Auditory Imagination," in *The Auditory Culture Reader*, ed. Michael Bull and Les Back (Oxford: Berg Publishers, 2004), 62.

The word "analogy" is derived from the ancient Greek *ἀναλογία* to describe "mathematical proportion, proportion in general, correspondence, resemblance, reasoning on the basis of parallel cases," and is a potent tool that scientists often invoke as a starting point to explain their theoretical models: the expanding universe is analogous to a balloon filling with hydrogen, Bohr's model of the atom, to the solar system, the shape of the spiral galaxy, to a pancake.[279] As such, analogies are approximate (near) tools to approximate (fashion) resonant imaginations that interleave the familiar with the unfamiliar. Yet, even though the above (probably recognizable) examples appeal as illustrative starting points to explain complex astronomical phenomena, I would bet that trained physicists would fuss over the applicability to their day-to-day practices. Analogies outlive their usefulness, or simply strain the relationship between the theory they are used to describe and the phenomena that pop up in experimentation. Nevertheless, they percolate as an ineluctable logical mode for both scientists and the STS scholars chart their epistemic world-makings. As shorthand, as sketches, analogies facilitate imaginations of that which is imperceptible *in relation* to that which is available.

In her classic treatise, *Models and Analogies in Science*, philosopher of science Mary Hesse sketches three typologies: positive analogies describe likeness between two things, such as, billiard balls that bounce off each other in random motion behave *like* gas molecules; the features the two objects *don't* share result in negative analogies; and neutral analogies gesture to an ambiguous space in which new phenomena can be compared against the previous types to refine and deepen the analogy.[280] Hesse further describes what she calls material analogies, that is, grouped properties that can be said to have both internal (vertical) causal relations, characteristics that, once abstracted, can be symmetrically mapped onto the other phenomena through what she calls similarity relations

[279] *Oxford English Dictionary Online,* s.v. "analogy," accessed July 2, 2020, https://www.oed.com/View/Entry/7030
[280] Mary B. Hesse, *Models and Analogies in Science* (Norte Dame: University of Norte Dame Press, 1970), 7-9.

(horizontal).[281] Apropos to the workings of radio astronomy, in which analogies often tend toward the visual, an example Hesse fleshes out compares properties of sound to properties of light: sound echoes, can be loud, has pitch, is detected by the ear, and propagates through the air (these are causal relations); analogously, light reflects, can be bright, has color, is detected by the eye, and propagates through the "ether" (also causal relations).[282] Taken together, the properties of light are horizontally mapped onto sound through similarity relations.[283]

How are analogies refracted, enacted, and distributed as tools in scientific practice? Anthropologist of science Graham Jones argues that the forging of anthropology and the making of modern magic operated in entwinement in the late 19th century, both relying on cultural calculations of similarities and difference.[284] French magic acts were, Jones writes, an ideological project premised on convincing Algerian locals that ritualized feats belonged to a category of primitive, base charlatanism *dis-analogous* (in Hesse's terminology, negatively analogous) to modern, empirical, and rational illusions that were framed as entertainment. Circumscribed within the bounds of polite modernity, the Western illusionists enacted a colonial regime that burnished their own reputations as revealers of truth from trickery, part and parcel of modernity's vigorous quest to disenchant the occult.

Meanwhile, the budding field of anthropology of the same era flexed analogies as a mode to engage cross-cultural comparisons around the practice of magic (and, its uneasy cousins, ritual, religion). Informed by contemporary anthropological theory, Jones depicts an analogical ladder to describe the ethnographic utility of such mappings.[285] He explains how ethnographers triangulate their (1) immersion in their field (2) with previous case studies (3) and anthropological theory to

[281] Hesse, *Models and Analogies in Science*, 57-87.
[282] Hesse, *Models and Analogies in Science*, 60.
[283] Hesse, *Models and Analogies in Science*, 60.
[284] Graham Jones, *Magic's Reason: An Anthropology of Analogy* (Chicago: University of Chicago Press, 2018).
[285] Jones, *Magic's Reason*, 129.

create conceptual abstractions by which analogical comparisons are refined through their analytical usefulness. Applied to anthropology of magic in particular, the ladder diagrams how the transference of anthropological concepts from one case to another depends both on bifurcation (rationality vs. the occult) and disanalogy (that which is not like), mappings whose jagged edges often grind the gears of any arrived-upon, static, apodictic anthropological theory (Jones' example: Is Trobriand magic *really* "like" the magic of Western advertising tricks, as Bronisław Malinowski quipped?)[286]

Historian of science David Kaiser traces the dispersion of what became known as Feynman diagrams—sketches representing relationships between subatomic particles—through pedagogical practices that American (and some Soviet) physicists in the mid-20th century transported and refined to tease out the gnarly world of the quantum. Kaiser's driving concern is with the material practices that institutionalized the now widely used diagrams as a matter of cultural, collective decisions: diagrammatic sketching that has become physicists' bread and butter, he argues, is not only a particular mode of calculation, but a fundamental way to construct—not merely interpret—the world.[287] Although analogies are not his focus, Kaiser's study of the diagrams parses conceptual similarities and differences between "representation" and "analogy," and how each regime torques any smooth descriptions meant to bridge "theory" and "practice."

Kaiser's story focuses on famed physicist Richard Feynman's diagrams that he used shorthand in the late 1940s to explain quantum behavior, but their status as a useful, almost universal tool, was not initially taken up; instead, their dispersion depended on personal contact, persuasion, and ultimately the careful, assiduous conditioning through training and skill-gathering by individual physicists that then propagated through communal usage. In particular, the diagrams'

[286] Jones, *Magic's Reason*, 129. 132.
[287] For more on mathematical formalisms and materialisms, see: Clare Seungyoon Kim, "The Subjects of Modernism: Mathematics, Art, and the Politics of Value in Twentieth-Century United States," dissertation (Massachusetts Institute of Technology, 2019).

constituent parts—their lines or squiggles (how the particles behaved) and vertices (the points in which particles interacted with each other)—were argued over not just for disparate pictorial conventions that sprang up in different places, but what they actually *represented*: How close to reality were they? As dynamic, porous, (literally) shape-shifting representations, the diagrams were decidedly *not* Latourian "immutable mobiles," Kaiser argues, migrating statically through various institutions. Instead, as *sets* of normed practices developed in particular contexts—emerging as what Kaiser, invoking philosopher Ludwig Wittgenstein, sees as "family resemblances"—they were transported as *analogously* to different applications, with varying successes (in particular, from quantum electrodynamics to meson-theories).[288] Stretching slightly to apply Hesse's terminology, the diagrams' verticals (their particular conventions around which *lingua francas* developed) got packetized and then horizontally transported as (sometimes uneven) analogies to subsequent subsequent theories of how particles behave. As such, Kaiser's focus on the pedagogical dispersion of the Feynman diagrams attends to their utility both as *representations* of reality (or not) through visual media, but also their valences as *analogies* to conceive possible structural comparison between various theories.

If analogy (and its equally potent antipode, as Jones agues, disanalogy) frame out structural modes of comparison, metaphors operate as the links that ornament, often poetically, those abstractions, but as Hesse writes, "metaphor is more than a decorative literary device and that it has cognitive implications whose nature is a proper subject of philosophic discussion."[289] Anthropologist of science Stefan Helmreich illustrates the value of metaphor through the material, experiential, and immersive metaphor "transduction," developed ethnographically to impact a bodily, watery description of the cyborgian submersible *Alvin* as it descends to the sea floor. Helmreich's

[288] Kaiser, "Family Resemblances," in *Drawing Theories Apart*, 208-249.
[289] Hesse, *Models and Analogies in Science*, 158.

deployment of transduction's tentacular senses—from acoustics, the transference of energy through different substances, and also, its usage in biology—capture the variegated phenomenology of watery submersion as rendered through sounding media, from the bubbling crackle of sonar transponders to the scientists' music playlists. To the reader, transduction is also in itself a meta-rhetorical device; as he leads us ethnographically from *Alvin*'s hub above water on the vessel *Atlantis* to hundreds of meters below the surface of the ocean and finally to the sea floor, so the metaphor itself develops overtones as it nets cultural and anthropological touchpoints in its wake. More than "decoration," transduction "adds the dimension of materiality," an embodied, cyborgian *submersion* into the ocean that leaks into theoretical *immersion*.

Electromagnetic Signals

One type of electromagnetic signal SETI scientists think they might detect is termed "leakage": imagined-to-be inadvertent technosignatures that drift into space like the television, radio, high frequency radio, and radar that Earthlings have transmitted at a high volume since World War II. A report from a 1978 NASA Ames conference "Life in the Universe" explained that "eavesdropping" on ET's technological by-products was indeed worth considering, given that Earth's television leakage, especially, would be perceptible to an alien observer.[290] The report noted that patterns of transmission signals reveal a great deal of information, if the alien observer could cleverly correlate certain frequencies with times and places (e.g. transmissions from the U.S. to Japan, or radio broadcasts that would appear Doppler-shifted depending on their longitude).[291] Dave MacMahon explained to me how astronomers might even observe leaky transmission *between* planets,

[290] Woodruff T. Sullivan III, "Eavesdropping Mode and Radio Leakage from Earth," in *Proceedings of the Conference on Life in the Universe*, ed. John Billingham (NASA Ames Research Center, June 19-20, 1979), 377-378.
[291] Sullivan III, "Eavesdropping," 386-387.

too: "You can imagine if they [ET] had colonized planets in the system, and they would be communicating back and forth with radio waves," he told me, "and that some radio would leak past the planet and come to us."[292]

The second type of extraterrestrial transmission scientists could intercept is called a "beacon," what Steve Croft has described to me as a rotating beam of a lighthouse: narrowband (transmitting within a tight range of frequencies) and bright against the night sky (high signal ratio compared to the ambient light of the environment).[293] Gerry Harp, a data scientist formerly of the SETI Institute who primarily worked at the Allen Telescope Array, wrote with other SETI scientists in a 2010 paper that a "beacon is an excellent choice to get alien attention" from afar.[294] Due to its relatively higher power, a beacon would pass easily through the cluttered interstellar medium (ISM), avoiding light dispersion and scattering, and would thus more easily be intercepted by terrestrial telescopes.[295] Think of a pulsing laser beam, rather than a low wattage, constantly emitting lightbulb, in a smoky room like a fog-filled dance club.

A 2010 paper by the Breakthrough team explains why SETI has traditionally searched for beacons: "An alien civilization wishing to make contact with others would broadcast a signal that is easily detected and easily distinguished from natural sources of radio emission" which they hypothesize ET would do by sending out a powerful, narrowband frequency pulses.[296] However, the amount of information that can be broadcast through a beacon is inversely related to both the range

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[292] In discussion with the author, July, 2016. Note: However, as Julia DeMarines, an astrobiologist and Research Associate at the UC Berkeley SETI Research Center, writes in a 2019 white paper with Sullivan and others for the "Moon Bounce Project"—a proposal that seeks to measure Earth's current technosignature reflected off of the Moon—Earthlings' growing reliance on fiber optics, "may cause the Earth's leakage to diminish in its detectability," a phenomenon that could "suggest that advanced extraterrestrial civilizations may inevitably evolve to a radio-quiet phase." See: Julia DeMarines, "Observing the Earth as a Communicating Exoplanet: A White Paper for the Astro2020 Decadal Review" (Breakthrough Listen, 2020), accessed May 20, 2020, https://113qx216in8z1kdeyi404hgf-wpengine.netdna-ssl.com/wp-content/uploads/2019/05/558_demarines.pdf.
[293] In discussion with the author, March, 2020.
[294] Gerald Harp et al., "A New Class of SETI Beacons that Contain Information," *ArXiv* (March 17, 2014): 1, https://arxiv.org/abs/1211.6470.
[295] Harp et al., "A New Class of SETI Beacons," 1.
[296] Andrew Siemion et al., "New SETI Sky Surveys for Radio Pulses," *Acta Astronautica* 67 (December 2010): 1343.

of a signal (how far it can travel, based on the power of the transmitter) and the range of frequencies (how much bandwidth it takes up). That is, a continuous, narrowband, far-reaching, extraterrestrial transmission is limited to one bit of information: that the alien civilization exists. A beacon is an event that Jill Tarter has described as a "cosmic dial tone."[297] The telephone works, but no one is talking on the other end.

SETI scientists' speculations about how ET might transmit an intentional signal (negative dispersion, a twice-sent signal, even a simple high-power, narrowband beacon) frame ET's noticeability as an issue of an alien broadcaster turning a *natural* phenomenon into an *artificial* event. ET would purposefully modify aspects of a carrier wave such as dispersion or frequency so that humans would take notice. As Jill Tarter has written, "If an extraterrestrial technology is deliberately broadcasting a signal, it is logical to assume that they will attempt to make the signal detectable," and one way they might do so would be to "generate a signal that violates the natural emission mechanisms of astrophysics so that it will appear to be an obvious technological artifact."[298] Tarter thus posits ET an intentional system to anticipate what they might do to become noticeable to her. Alien *intention* is speculated to spark human *attention* through the anticipated transformation of a natural occurrence to meaningful artifact.

A third class of electromagnetic signals SETI scientists have hypothesized could combine the attention-grabbing aspect of a beacon and the range of frequencies that wideband signals exhibit, potentially encoding both a flare and then a longer message. For instance, a "twice-sent" signal would first alert human observers (or the algorithms they've built) to take notice, and then a

[297] In discussion with the author, February, 2020.
[298] Jill Tarter, "The Search for Extraterrestrial Intelligence (SETI)," *Annual Review of Astronomy and Astrophysics* 39 (2001): 522.

superimposed secondary signal could transmit "complete works of Shakespeare or the complete embodiment of their society's knowledge."[299]

Alien Intention, Human Attention

Sound studies scholars I have mentioned in this chapter have explored how various scientific practices differentiate what counts as interesting or desirable *signals* and what should be discarded, tamped down, or ignored as distractive *noise* through the cultivation of (imagined) subjectivities. In her analysis of sonocytology—the scientific study of how cells "sound" through vibration—Sophia Roosth argues that the transformation of raw data (noise) into meaningful sound (signal) is contingent on the creation of a soundscape that implicates "listening bodies" and speaking subjects.[300] That is, she writes, "Parsing cellular signals from noise…is determined by scientists' understanding of cells as subjects capable of speaking to their conditions."[301] Germane to the topic of the alien, Stefan Helmreich notices how SETI scientists have often tailored their searches to expected extraterrestrial behavior, that is, they have chosen particular frequencies at which to *listen* for an anticipated subject.[302] In these two examples, how meaningful signals are determined—on what conditions sounds get counted as being worthy of being *listened* to—is an effect of scientific practices that craft a resonance between self and others framed as purposefully acting subjects. If listening is a practice of acknowledging or at least anticipating others' status as a subject, what is imagined to be "behind" that subject's actions might be described as intention.[303]

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[299] Harp et al., "A New Class of SETI Beacons," 15-16.
[300] Roosth, "Screaming Yeast," 335.
[301] Roosth, "Screaming Yeast," 337.
[302] Stefan Helmreich, *Sounding The Limits Of Life: Essays In The Anthropology Of Biology And Beyond* (Princeton University Press, 2016), 76.
[303] Sara Ahmed, *Queer Phenomenology: Orientations, Objects, Others* (Durham: Duke University Press, 2006), 36.

Philosophical debates on the quality, experience, and interpretability of intention inquire after possible links between mental states, belief systems, and actions. Following Sarah Ahmed's risk-taking to read philosophy "out of line" as a non-philosopher, I cautiously explore the connection between scientifically imagined alien artifacts to catalyze intentions.[304] Philosophers who inquire after intention consider questions such as: Does a person need to be conscious (self-aware) of their actions to do things with intention? Can objects harbor intention? What are the effects of ascribing the possibility of intention to others? Or, invoking John Searle, "What exactly is the relationship between Intentional states and the objects and states of affairs that they are in some sense directed at or about?"[305] Searle finds that speech acts *closely track* intentional states. Promises and sentiments ("I hope you win a prize," or, "I promise to meet you for lunch") carry illocutionary force that are freighted with intention, what Searle calls a "world-to-mind direction of fit": they "are supposed to bring about changes in the world so that the world matches the speech act."[306] That is, intentional speech acts, unlike statements or assertions ("The sun orbits the Earth") that can be evaluated using a metric of truth vs. false, express internally consistent psychological modes of desire, hope, sincerity, etc. Searle further states that only conscious beings are capable of having intention, writing, "A plant can literally be said to need water and to be harmed by the drought, but it cannot be literally said to desire water or believe that it is not getting enough."[307]

Meanwhile, for philosopher Daniel Dennett, an "intentional stance" describes a treating a person—or even an object like a thermostat!—as a rational agent with predictable behavior and mental states.[308] What he calls a "true believer" is a system whose behavior one can consistently

[304] Ahmed, *Queer Phenomenology*, 22.
[305] John Searle, "What Is an Intentional State?" *Mind* 88, no. 349 (January 1979): 74.
[306] Searle, "What Is an Intentional State?", 76.
[307] Searle, "What Is an Intentional State?", 92.
[308] Daniel Dennet, *The Intentional Stance* (Cambridge: MIT Press, 1998), 15.

anticipate.[309] One can attribute desires to such a system; agents *ought* to act in predictable ways and thus desire and action are linked through rational behavior. Another category of explaining phenomena in the world, what he calls the physical stance—e.g., a Newtonian description of thrown ball used to accurately predict its landing place—is a level of abstraction insufficient to describe patterns behavior (why the ball was thrown).[310] An intentional stance, however, is a powerful tool of prediction that relates mental states to actions (the thermostat wanting a room to be warmer explains its behavior). It is a strategy that considers "the object whose behavior you want to predict as a rational agent with beliefs and desires and other mental stages exhibiting… intentionality."[311]

To illustrate this point Dennett devises a story of a Martian observer trying to predict a man picking up a bottle of wine on his way home from work. Without first taking for granted that humans are rational beings, the Martian would not be able to accurately anticipate the man's behaviors (getting out of the car at the shop, slowing down at an intersection, getting back in the car and heading home).[312] An Earthling's seemingly uncanny ability to predict these actions, on the other hand, would appear magical to the Martian.[313] Dennett uses this thought experiment to claim that the intentional stances starts with *buying in* to others' rational behavior through anticipating and correctly interpreting predictable actions (most of the time). Importantly, unlike Searle, who draws a bright line that divides subjects who *intend* from objects or organisms that don't on the basis of possessing cognitive states, Dennett's assignation of intention *starts with the subject adopting an intentional stance* with regards to others. According to him, that is the only criteria for assigning the capability of intention to others.

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309 Dennett, *The Intentional Stance,* 15.
310 Dennett, *The Intentional Stance,* 26-27.
311 Dennett, *The Intentional Stance,* 15.
312 Dennett, *The Intentional Stance,* 27.
313 Dennett, *The Intentional Stance,* 27.

Without wading too far in to such philosophical disagreements about the emergence of intention vis-à-vis conscious beings, organisms, and objects, I suggest here that words and concepts SETI scientists use to imagine how ET might operate presuppose the simple *existence* of *some* alien intention. I home in on Dennett's intentional stance as a framework to understand how SETI scientists assume aliens to be rational beings with predictable patterns of behavior, around which they use instruments like telescopes, build software codes, and anticipate particular technosignatures distinguishable from noise. Although, according to Dennett, assumptions about ET's rationality, prediction, anticipation, etc. are identical to attributing logical actions to a thermostat, I deploy his intentional stance here to get beyond Breakthrough's constrained premise that alien technology will merely be technologically commensurable—they will send a transmission legible to humans' radio technology—but that their intentions *behind* those actions imply some glimmer of ontological overlap. That is, although Jill Tarter's insistence that she is simply looking for *technology* not *intelligence*—a notion that has been recycled in various iterations by my interlocuters throughout my fieldwork—SETI scientists' imagined ET is expected to behave *like enough* to how humans would: they would *want* to be noticed by humans by sending out a noticeable-by-us technosignature. As Stefan Helmreich has written, Breakthrough "listens" for particular signals that would "twin human cognition."[314]

Because the alien exists in a suspended state of expected but uncertain emergence, imaginations of alien intention are brought forth through *words*. ET would "deliberately" send out a signal (Tarter); they might "wish" to make contact (Breakthrough); they would "choose" to get alien attention (that is, our attention, Breakthrough); they would "intentionally" create an artificial, noticeable signal (Breakthrough). Such words imply a desire, a motivation, or intended actions that would have produced imagined technosignatures. Electromagnetic signals aimed at Earth are not

[314] Helmreich, *Sounding The Limits Of Life*, 76.

understandable without first anticipating an alien *intention* "behind" those transmissions.[315] Applying Dennett's philosophical framework, a physical stance could explain the near-infinite necessary levers that would have had to coincide to produce characteristics of what scientists think would be a technosignature (how the universe formed, a natural object that would produce an anomalous narrowband pulse, the advent of terrestrial radio technology to perceive it). But it would not explain the *why* behind a technosignature. The intentional stance skips over the unimaginably laborious description the physical stance dictates, instead providing a philosophical scaffolding to explain the actions of a rationally acting being, even if those actions are alien (in more than one sense!).

Dennett continues this thought experiment, writing that Martians who fail to predict human behavior nevertheless act with intentions themselves.[316] "If they observe, theorize, predict, communicate, they view *themselves* as intentional systems," he writes.[317] "Where there are intelligent beings, the patterns must be there to be described, whether or not we care to see them."[318] That is, for Dennett, beings that act rationally must have internally consistent *modi operandi* that render them as intentional systems even if those actions are incomprehensible to others. Steve Croft imagined that a technosignature would not be understandable, but it would still indicate that it was sent intentionally: "The only thing that we're going to comprehend is that there is some volition there," he told me.[319] "Basically, they're [ET] doing something intentional. The idea that we'll be able to understand the motivations of a civilization that's had technology for 50 million years and what they're up to seems unlikely. I think we'll see them doing something that's obviously artificial."[320]

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[315] Ahmed, *Queer Phenomenology,* 36.
[316] Dennett, *The Intentional Stance,* 28.
[317] Dennett, *The Intentional Stance,* 28, emphasis in original.
[318] Dennett, *The Intentional Stance,* 28.
[319] In discussion with the author, March 2020.
[320] In discussion with the author, March 2020. Philosopher Sally Haslanger has brought up to me how, in taking Dennett's view that thermostats, and by extension, robots, AI, etc., have volition and act intentionally, how scientists might parse the transmitters' ontology based on the event of a technosignature. "Would it be sufficient for the signals to be coming from machines? Would it be sufficient if the machines were a cosmic accident, not designed by an intelligent being?" she asked of a draft of this manuscript. In response, I offer that for my Breakthrough Listen interlocuters, it

Dennett's intentional stance is a mode to explain how Croft takes for granted that ET will have purposefully sent a signal without necessarily needing to understand the alien "behind" it—but that there is a rationally acting agent who might do things human might do, too. An alien imagined to possess a desire to be noticed and who acts to garner human attention through an "obviously artificial" transmission is assumed to be a rationally acting agent whose behavior Croft endeavors to predict—even if the only thing that is evident of that alien intention is the event of a technosignature.[321] According to Dennett, this assumed incomprehension does not foreclose Croft's recognition of *some kind of intention*, what Dennett writes is "*the unavoidability of the intentional stance with regard to oneself and one's fellow intelligent beings*."[322] The physical stance remains a valid option to explain behavior, "but not to the exclusion of maintaining at the same time an intentional stance with regard to oneself at a minimum, and one's fellows *if* one intends, for instance, to learn what they know."[323] In other words, to regard others as intentional systems and pursue observations to explain their behavior is to first consider one's self as an intentional system.

To draw out the assumed-to-be ontological partition between human and alien, Croft considered how his dog, Laika, does not comprehend his actions. Croft told me: "We won't understand a technosignature any more than [my dog understands] when I open the back door for her to go outside. [Laika] is like, 'I want to go outside, I want to go lie on the patio, or I want to go pee in the yard,' or whatever. She doesn't have any conception of the fact that somebody hung the door with some hinges and you know, put some screws in there."[324] Staging an imaginary interview

might not matter. In discussion in August 2019 with Vishal Gujjar, a postdoc there, he speculated that a technosignature might not be of biological origin. He imagined a future in which AIs—both extraterrestrial and made by humans on Earth—might be the only artifacts made by organic life that would have the time and technological capabilities to communicate across interstellar distances. ET might, in the end, be a machine. I plan to explore these topics soon with the folks at the Berggruen Institute.

[321] In discussion with the author, March 2020.

[322] Dennett, *The Intentional Stance,* 27, emphasis in the original.

[323] Dennett, *The Intentional Stance,* 27, emphasis in the original.

[324] In discussion with the author, March 2020.

with Laika, Croft asked his dog, "Where do humans go after they drop you off at daycare in the morning? Where does the food appear from? What do you understand about distribution chains and long-distance trucking and the economic system and capitalism?"[325] In Croft's analogy, humans trying to understand a technosignature would be like Laika trying to understand human socioeconomics.

I read Croft comments here through Dennett's intentional stance. First, Croft posits Laika as an intentional system with desires he views as logical (eat, pee, sleep). According to Dennett, imagining her imagining explanations to his behavior (letting her out, using a door with hinges, operating in a capitalist framework) necessitates Croft *a priori* positing *himself* as an intentional system (no matter that Laika does not comprehend the intent behind his actions). Finally—and this is crucial—Croft sets up an imagined relationship in which he, an intentional system, *analogically transforms* into the alien in comparison to Laika. In this way, the analogy momentarily operates as a hypothetical bridge between alien/human actions that are both considered to be driven by intention. A technosignature will appear to be "obviously artificial" as understood by two presumably intentional systems (human/alien). While the quality of that intention might be indecipherable for dog/human in an equivalent way Croft imagines it will be for human/alien, Dennett's framework helps understand how intention emerges *reflexively*; imagining it exists for others necessitates a point of origin by which Croft reifies his position as an intentional system that subsequently gets projected onto others, backward (dog) and forward (alien).

I present a final example of imagined-to-be-shared intentional actions from a conversation with Howard Isaacson, a Research Associate with the Breakthrough Listen team. Wrapping up my fieldwork with the team in early 2020, I was curious to gather meatier speculations about how scientists imagined the alien in relation to themselves. I asked Isaacson if he thought an anticipated

[325] In discussion with the author, March 2020.

technosignature would give any indication of what an alien was *like* mentally or physically. Like Croft, Isaacson limited ET's knowability to the intention behind a technosignature:

> In addition to probing for intelligence with technosignatures, I think we're also probing for curiosity. We emit a laser guide star in the pursuit of knowledge of the stars around that area of the sky. A lot of our radio goes out to communicate with spacecraft[s]. And those spacecrafts are put out there to help us learn about the solar system and places beyond the solar system…It's a pursuit of knowledge that causes our own technosignatures to go out, so maybe it's the same for an alien culture.[326]

Curiosity—another word that signals intention—is, to Isaacson, a motivating force for producing electronic artifacts for both humans and aliens. (Even leakage would be intentionally sent out, although not directed at us.) Through an imagined-to-be-shared pursuit of knowledge, Isaacson enacts a reflexivity by which his science team's act of learning about others and trying to predict their behavior recognizes ET as intentional systems *a priori*. Through speculating on how ET might make themselves noticeable through various kinds of electromagnetic signals, Croft and Isaacson not only cast ET as beings that possess intention, but whose intentional actions are rational, and therefore epistemologically commensurable, because they are imagined to create technosignatures, too.

TurboSETI

The filterbank files that have been constituted at the backend of the telescope arrive at the Breakthrough Listen server. These files store time, frequency, and power data that can be manipulated through further analysis to try to uncover technosignatures. I turn now to two of these programs to explore how astronomers endeavor to anticipate signals from ETI. Because they do not

[326] In discussion with the author, March 2020.

know exactly how that signal will be entangled in the data, Breakthrough scientists develop computer algorithms that are tweaked communally and then published to the wider SETI world. I read these programs as documentation of experimental choices that are constructed to first slough off contaminated data—local radio frequency interference, RFI—but then migrate to decisions around the data that have been described to me as "somewhat arbitrary" and even "intuitive." These two programs, called TurboSETI and SPANDAK, are tools whose inner workings shed light on how Breakthrough scientists program *anticipation*. More than literal (listening to bird sounds), something other than analogy (radio astronomy is *like* playing or recording music), I develop a third sense of "listening" in the final section of this chapter. Here, listening is a concept to parse scientific actions are centered around waiting and expectation. Through the development of these data analysis products, Breakthrough guesses and hedges how a future-oriented ET will have behaved in the past to transmit a signal that human could intercept in the present. Doing so catalyzes a time-bending practice of epistemic conditioning that eludes fulfilment in which scientists place themselves to be in an anticipatory state to perceive those signals. Listening for ET is a dynamic state of self-attunement enacted through the development of data analysis programs to predict alien intentions.

Jesús Emilio Enríquez Rascón was visiting from Radboud University Nijmegen in the Netherlands to finish his Ph.D. in SETI astronomy at Berkeley when I arrived at the Breakthrough Lab in March 2018. (From Chihuahua, Mexico, he goes by the shortened familial moniker Emilio Enríquez). His primary focus there was to develop a data analysis technique in the programming language Python he called TurboSETI, named because it was intended to churn through observational data far faster than previous techniques (it still takes six to ten hours to run the code). The kind of signals that TurboSETI was designed to sift for are powerful, narrowband frequencies—what the field of SETI has primarily searched for since Drake's Project Ozma

experiment at the GBT in 1960. TurboSETI is an algorithm specifically designed to flag narrowband signals: bright transmissions at powers significantly higher than the surrounding data over a short range of frequencies. TurboSETI was created around two primary assumptions: that an alien signal will be moving through space and time because it is emanating from an extraterrestrial, non-local source; and, that it would be bright enough against the backdrop. The first concept is explained by what scientists call Doppler drifting.

The signal would also have to have been transmitted from a source whose power (intensity, brightness) statistically exceeds that which scientists call noise, a class of disposable data that includes both random fluctuations of electromagnetic radiation inherent to the instrument as well as superfluous, artificial disturbances. The analysis, which takes hours of computing time to run for each observing block, works by pulling aspects of the filterbank files to determine what are assumed to be two primary characteristics of a potential alien signal: a non-zero drift-rate produced by a non-local source and signal to noise ratio (SNR) that passes some threshold (below which is assumed to be RFI). How these two aspects are programmed into TurboSETI are the result of experimental choices initiated by Enríquez and refined by other Breakthrough astronomer that presuppose characteristics about extraterrestrials. Before considering how such decisions encode assumptions about alien intention, I will blaze through the code that gets run on GBT filterbank files as a flashpoint of general data analysis techniques afforded by TurboSETI.

Breakthrough does targeted searches on specific sources through what are called ON/OFF observations at the GBT.[327] The scripts that Price writes point the antenna toward a source for set time (twenty seconds, say), and then direct the dish to slew slightly away from it for the same amount of time. Those steps get repeated three times before moving on to a new source, and the

[327] (Parkes' thirteen beams make it possible there for astronomers to discriminate which signals are terrestrial vs. extraterrestrial. They use the multibeam function to point to multiple sources at once and do surveys on large swaths of the sky, such as the galactic plane.)

whole process cycles for the duration of an observing block (six or twelve hours). Each ON/OFF observation produces a set a six filterbank files in what is called a cadence—a musical nomenclature defined as "rhythm, rhythmical construction, measure," touching on how deeply the sound analogy resonates in SETI science—but here references, in shorthand, alternating "ABACAD" observations, in which A is the source, and B, C, and D are off-target pointings.[328]

TurboSETI is programmed to analyze each cadence for powerful, narrowband signals in filterbank files that only appear in the A segment. In practice, it gets marked for further review if it exceeds two parameters set by the coder: SNR and drift rate. Both are parsed through an algorithm enacted by the code line find_events.py. The script works by grinding through filterbank file A: it starts at a particular frequency and adds up all the power in that vertical time bin. The program determines if that line is statistically brighter than the bins around it, and then moves on to the next bin. TurboSETI sets as its default a SNR of 10, that is, the ratio of noise around a potentially powerful signal in a certain time or frequency domain must be at least $1/10^{th}$ as faint. A potential signal must also pass through another threshold set by Enríquez, the drift rate. Recall that non-local radio frequencies will be Doppler-shifted…

If the integrated power exceeds both threshold of signal to noise ratio (SNR), it is pinned in the data analysis as what Enríquez has termed a "hit." If an intense (powerful), narrowband (spanning a tight frequency, say, 3 Hz) line appears in the ON files and not the OFF files, the data becomes more interesting to the Breakthrough astronomer running TurboSETI. If the same signal (same frequency, same time period, not Doppler-drifted) appears in both the ON/OFF files, it is assumed to be RFI—locally interfering signals like satellites, military planes spewing radar, even an errant cellphone—that are local to Earth and are then discarded. A "hit" is a single strong

[328] *Oxford English Dictionary Online,* s.v. "cadence," accessed August 1, 2020, https://www.oed.com/view/Entry/25947.

narrowband signal in an observation, and the occurrence of multiple hits in the ON (A) observations becomes an "event."

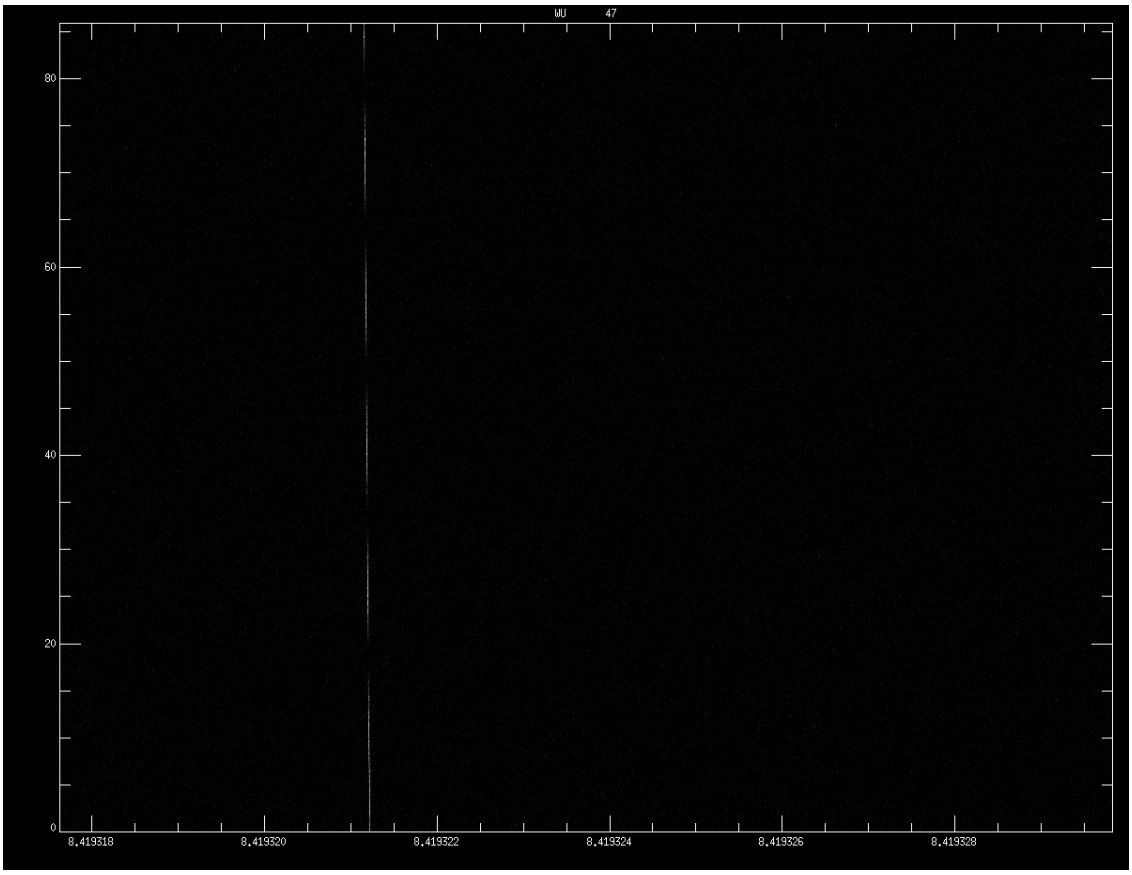

Figure 19. Waterfall plot of Voyager 1 in December, 2015, by Breakthrough Listen at the GBT, see: Berkeley SETI Research Center, "The Technology," accessed August 2020, https://seti.berkeley.edu/listen/tech.html.

Waterfall plots are visualizations of the filterbank files—arrays that encode digitized data that are produced at the telescope's backend—that graph integrated power as a function of frequency and time. [Figure 15.]. Frequency is plotted in GHz on the x-axis, and time in seconds runs on the y-axis. (The convention in radio astronomy inverts how scientists usually plot time on the x-axis.)

These signals are powerful spikes in the spectra—like a technosignature is expected to appear—in comparison to noise. The image below is one such plot: it shows a bright white line flowing or cascading through time. That line is the signature of the Voyager 1 space craft, which Breakthrough chose to observe first at the project's first light at the GBT on December 30, 2015: *SPANDAK*

Another method of encoding information that SETI scientists imagine ET could attempt is the process called modulation. Modulating the frequency is what happens when one tunes in to an FM radio station to hear anything from classic rock to opera to Christian programs. As Gujjar explained to me, ET, tinkering with the phase, amplitude, and frequency of a sinusoidal wideband wave, could produce a noticeable, meaningful, and information-rich technosignature. Like a human might change her voice to a higher pitch, speak faster, or yell, Gujjar explained, a listener would learn much about her intent and meaning.[329]

Breakthrough Listen has begun to consider how ET might have produced noticeable wideband beacons in addition to narrowband signals SETI has traditionally searched for. As radio waves travel through space, they often encounter ionized media like clouds of gas and dust; this ionization disperses the light waves, that, if they were originally sent across a range of frequencies (wideband) would arrive at the observer's instrument at different timestamps. "Natural" astrophysical phenomena, say, the Crab Nebula, produce wideband spectra in which higher frequencies arrive sooner, and lower frequencies, later. However, the Breakthrough team has speculated that "a civilization intentionally creating a beacon for extraterrestrial astronomers would choose to create 'pulses' which have a negative DM [dispersion measure]."[330] Vishal Gajjar, a

[329] In discussion with the author, August 2019.
[330] Siemion et al., "New SETI Sky Surveys for Radio Pulses," 1343.

postdoc with the Breakthrough team, explained the assumed difference between an artificial alien technosignature and a naturally occurring dispersion measure. ET would have had to intentionally manipulated what their transmission that that lower frequencies are recorded at an earlier timestamp and "would stand out as obviously artificial."[331]

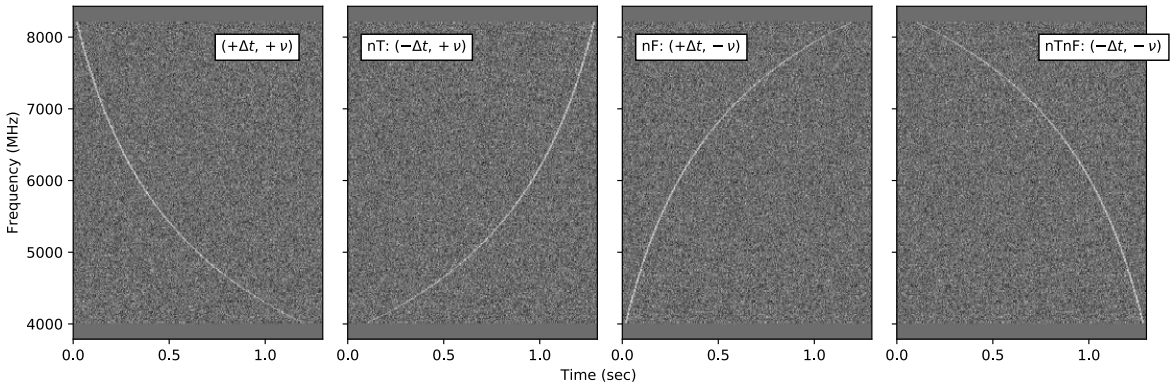

Figure 20. Negative Dispersion in images 2, 3, and 4. Forthcoming publication by Vishal Gujjar and the Breakthrough Listen team, 2020.

Gujjar's SPANDAK experiment is one of expectation, attuning to what alien might do so as to be noticed by humans' technology. [Figure 16.] It also gets at the central crux of SETI science: the distinction between what is natural vs. what is artificial, as I alluded to at the beginning of this chapter. As TurboSETI is programmed to winnow possible technosignatures (hit>event>candidate signal), SPANDAK, too, is the result of particular experimental choices to delimit different data, a process that happens through the programming anticipation of alien intention.

Listening, thus, a trimodal metaphor deployed and enacted by the Breakthrough team. SPANDAK and TurboSETI are experiments of expectation that ET will behave intentionally and utter their presence through commensurable technology. In these two cases, tuning parameters like

[331] Siemion et al., "New SETI Sky Surveys for Radio Pulses," 1343.

signal to noise ratio and dispersion measurements are ways to figuratively listen for the alien because they create the experimental condition to actively *wait* for noticeable, recognizable activity.[332]

[332] See also Stefan Helmreich's essay, "Gravity's Reverb: Listening to Space-Time, or Articulating the Sounds of Gravitational-Wave Detection," *Cultural Anthropology* 31, no. 4 (2016): 464–492. In it, he discusses "preverberations": the anticipation of a cosmic chirp rendered through hearable audio. Unlike scientists' auditions of gravity waves whose characteristics were mapped out before physicists confirmed their existence, Breakthrough's technosignatures are imaginable, but the whole point is that the particular conditions that would call them forth are unknown, and thus, the subject behind a transmission also eludes articulation.

Chapter 4: Analogical Aliens

Artifact: *On a visit to the Green Bank Telescope (GBT) in 2018, Dave MacMahon and I browsed the site's gift shop after sandwiches at the Starlite Café. We each bought a toy, a friendly looking lime green alien about the size of my palm. Later, in the equipment room, where computers whir away amidst a jungle of wires, MacMahon wound the alien's appendages into a cord so that it appeared to be waving like a rock climber suspended on the face of a cliff where millions of dollars of hardware impress the visitor with how much physical material is mobilized to potentially catch an alien artifact. We left the alien figure to the cool, dark computer room, ready to be excavated to the surprise a future visitor.*

*

Animal: *Ray Creager, an operator at the GBT in rural West Virginia, has kept bees on his property for the last twelve years. In the fall, the field blooms with thick stalks of ambrosial goldenrod, a haven for insects. As the winters have warmed and agriculture has waxed, filling up jobs that have replaced the dying coal mining industry, Creager told me he has noticed that fewer and fewer species populate his field each year. His compassionate caretaking of these endangered insects stands in contrast with the region's popular Roadkill Festival, an annual holiday to the GBT's local operators and a curio to visiting scientists. There, dishes might include "squirrel gravy over biscuits, teriyaki-marinated bear, quail meatballs, snapping turtle, and iguana."*[333]

*

Angelic: *The Robert C. Byrd telescope at the GBT site is a blinding bright white, clocking in at seventeen million pounds, and, with a receiver attached to a retractable boom that scrapes the sky at 485 feet, to me resembles a flexing bicep that defies aliens to send a technosignature. Stripped of its context, such an awesome technological assemblage might, according to astronomer Avi Loeb who is a Breakthrough Listen collaborator, appear as "magic" to some prehistoric people. Inverting that scenario, as Steve Croft, a senior scientist at Breakthrough Listen, remarked to me, alien technology, to us, might be "sufficiently advanced [to be] indistinguishable from God."*

Commensurable Analogies

Pondering possibilities of interspecies communication, Steve Croft at the Breakthrough Listen labs at Berkeley remarked, "It would be surprising if a technosignature is comprehensible to us… we won't understand what that is any more than when I open the back door for the dog to go out. She has no comprehension of how the house was built, [or] why there's an inside and an

[333] "West Virginia Roadkill Cook-Off," Pocahontas County Chamber of Commerce, accessed February 15, 2020, https://pccocwv.com/wv-roadkill-cook-off/; "Roadkill Festival 2020," RAD Season, accessed February 15, 2020, https://radseason.com/event/roadkill-festival-marlinton-west-virginia/.

outside. She has just enough ability to communicate with me. And we're closely related!"[334] The group laughed. Croft continued: "We have a universal common ancestor, some shrew that emerged some 165 million years after the asteroid hit."[335] Croft is here making a pronouncement about what SETI scientists call *commensurability:* a mode of relation by which particular attributes are "measurable by the same standard or scale of values."[336] Although ET might flit between dimensions, have evolved into a cyborgian mashup, or have sprung from silicon instead of carbon, confirmation of its existence through a technosignature need only be readable by Breakthrough Listen's current instruments and algorithms.[337] As Jill Tarter of the SETI Institute has often remarked to me, SETI merely seeks alien technology as a stand-in for the alien itself. In a 2018 interview with *Space.com*, she suggested that it was time for a rebranding that would clarify the field's goal as a search for technosignatures, not intelligence.[338] In that 2020 discussion at the Breakthrough lab, Croft considered interspecies communication through the idea of commensurability, looking to his husky Laika (apropos, named after the dog that orbited Earth in a Soviet space missions in the 1957) as a being with whom he might be able to communicate on some level, but his understanding of her—like hers of him—would be stymied. Through her, he posited an ontological chasm between humans and ET: an alien transmission, like a canine-human interaction, would be recognizable as communication, but its deeper meaning would be ungraspable. Croft's lighthearted comment here points to a question that has dogged me throughout four years of participant observations with this science team: If Breakthrough received what the community calls a technosignature, would it be even be necessary to know who—or what—was behind it?

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[334] Steve Croft in discussion with the author, March 2020.
[335] Steve Croft in discussion with the author, March 2020.
[336] *Oxford English Dictionary Online,* s.v. "commensurability," accessed February 2, 2020, https://www.oed.com/view/Entry/37042.
[337] Such possibilities were discussed at the Making Contact 2019 Workshop at Berkeley, California.
[338] In discussion with the author, 2017. Calla Cofield, "'Search for Extraterrestrial Intelligence' Needs a New Name, SETI Pioneer Says," accessed May 16, 2020. https://www.space.com/39474-search-for-extraterrestrial-intelligence-needs-new-name.html.

This final chapter analyzes how SETI scientists conjure aspects of an imagined alien ontology along these two edges: *commensurability* and *analogy*, concepts I have explored in previous chapters.[339] Nailing down scientists' imaginations of the alien beyond boiler-plate, media-ready soundbites has proven to be an elusive anthropological task. Since my time as a summer intern at the SETI Institute in 2008 to my fieldwork with Breakthrough Listen from 2016-2020, I have noticed how the word "alien" is sparsely used. Scientists have seemed wary to indulge in unbridled speculation about *who* the alien would be or what physical shape it might take. When scientists do refer to the alien, it is as "ET," the initialism for "extraterrestrial"—a linguistic shortening that further distances scientists from an embodied subject whose existence they seek.[340]

This final chapter locates and theoretically frames moments when SETI practitioners and their scientific affiliates *do* engage in speculation about the character of the alien. While the previous chapter charted *epistemic* practices of "how" SETI scientists practice listening as a resonant mode of perception, this chapter maps the *ontological* "what" of the scientifically emergent alien.

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[339] Readers attentive to social studies of science will note that the concept of "commensurability" and its converse "incommensurability," have complex histories within the philosophy of science since the mid 20th century. Paul Feyerabend, contesting scientific practice as a linear, teleological uncovering of facts, instead advocated to investigate its social character. He argued that scientists' dependence on theoretical positions was the driving force behind experiment and empiricism; theories continuously change and eventually become *incommensurable* (see: "An Attempt at a Realistic Interpretation of Experience," *Proceedings of the Aristotelian Society*, 58 (1958): 143–170). Thomas Kuhn, especially in *The Copernican Revolution* (Cambridge: Harvard University Press, 1957) and *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962), developed the idea of incommensurability to explain how irreconcilable differences in scientific understandings shift worldviews, words, and concepts (a Keplerian vs. Ptolemaic solar system, Lavoisier's oxygen vs. Priestley's phlogiston). Such revolutions, he argued, occurred through social processes, and not always seismically. Kuhn argued that normal science, in the face of mounting inconsistencies, would eventually trigger a paradigm shifts so that a new theory was incommensurable with the old. Nodding to these profound contributions in the history of science, I use the word "commensurable" in a less technical, more generous sense that takes its cues from how my interlocuters strive for technological, and even, as we shall see, ontological commensurability—that is, overlap, not indistinguishability—between alien and human.

[340] SETI scientists are careful to delineate their pursuit of what they view as possible science fact from popular images of aliens in science fiction. A quick Google search for "alien" is filled with images of the maleficent being from the film franchise that spawned from Ridley Scott's *Alien* in 1979, while Steven Spielberg's vulnerable "E.T." figure from the 1982 film evokes fuzzy feelings of protection. For more discussion, see Klara Capova, "The Charming Science of the Other: The Cultural Analysis of the Scientific Search for Life Beyond Earth," Dissertation (Durham University, 2013). And, for a fun, exo-zoological field guide of extraterrestrial figures in science fiction, see Wayne Barlowe, Ian Summers, and Beth Meacham, *Barlowe's Guide to Extraterrestrials*: *Great Aliens from Science Fiction Literature* (New York: Workman Publishing Company, 1979).

Commensurability, including but also beyond that concept's technological sense, is the centrifugal force that orients how scientists imagine the alien. I propose that SETI practitioners relate to ET through three powerful figures: as *artifacts*, as *non-human animals*, and as *god-like* beings. The procession of those analogical touchstones—material, beastly, angelical—maps onto a scaling model of ontological virtue as narrated by a Western philosophical tradition going back at least to Aristotle, articulated eloquently by Arthur Lovejoy.[341]

The chapter draws from over four years of ethnographic material with Breakthrough Listen, including the 2018 and 2019 Making Contact Workshops that took place at U.C. Berkeley, a series hosted by Breakthrough Listen that I organized and moderated. It draws upon formal interviews I conducted in person (at conferences, in corridors, over meals) as well as over Skype or Zoom, and stars Steve Croft of the Breakthrough group. Croft's philosophical musings on ET are paired with his astute technical ability as an astronomer: an ethnographer's delight. I depend, too, upon books, essays, and scientific papers by SETI scientists.

The first figuration of the alien, as *material*, understands aliens as legible through the material artifacts they are assumed to have produced. In my discussion below, I focus, with respect to this figuration, on an extraordinary object, KIC8462852, also known as Tabby's Star, whose light curve stumped astrophysicists in 2016. Inexplicable for a time, it caused astronomers to wonder if it was the result of alien interference: a *physical*, rather than *electromagnetic*, technosignature. As a confounding, "half-glimpsed" event that initially eluded obvious astrophysical explanations, KIC8462852 activated scientific imaginations of ET's ontological character.[342] That a star can exhibit "weird behavior," prompting scientific interest, surprise, and novel research, summons scholarly

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[341] Arthur O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Cambridge: Harvard University Press, 1936). See also: Eustace M. Tillyard, *The Elizabethan World Picture: A Study of the Idea of Order in the Age of Shakespeare, Donne and Milton* (New York: Vintage Books, 1942).

[342] For the "half-glimpsed," see Sara Ahmed, *Queer Phenomenology: Orientations, Objects, Others* (Durham: Duke University Press, 2006), 4.

considerations of objects' ability to *express*.[343] The field of object-oriented-ontology (OOO) contests the primacy of a Kantian anthropocentrism, delving instead into "what it's like to be a thing."[344] It is a tool to foreground objects—say, an alien artifact, or an alien capable of producing, or even becoming, an artifact—and what might be *behind* them. Feminist revisions to that field offer up ways to consider objects' affect without giving up with critical theories of subjectivity, interiority, the body, and humans' ethical responsibilities to Others. As Katherine Behar writes in the Introduction to *Object-Oriented Feminism*, "Shifting focus from feminist subjects to feminist objects extends a classic tenet of feminism, the ethic of care, to promote sympathies and camaraderie with nonhuman neighbors."[345]

I work through Jane Bennett's "vibrant matter," Sarah Ahmed's "queer phenomenology," and Karen Barad's "agential realism," to explore assemblages, enmeshments, and connections through human/non-human knowledge-making of which experience, emotion, and experiment are essential elements.[346] I ask: What if the object of knowledge is not only not readily *perceptible*—here, I am thinking of Barad's atoms that are part of what she calls meaningful "material-discursive intra-actions"—but exists in an imagined state of being?[347] If feminist new materialisms welcome queer considerations around matter, I endeavor to push that scholarship into an even queerer space of *speculative* alien/human becomings that, within a Baradian framework, bridles classical concepts of space and time. I aim in this chapter to hold on to the critical groundwork afforded by feminist inquiry around materialisms but extend to inextant objects (like aliens and their artifacts) that may

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343 Tabatha Boyajian, in discussion with the author, July 2020.
344 Ian Bogost, *Alien Phenomenology, Or, What it's Like to Be a Thing* (Minneapolis: University of Minnesota Press, 2012). See also, Graham Harman, *Tool-Being: Heidegger and the Metaphysics of Objects*; and, Timothy Morton, *Hyperobjects: Philosophy and Ecology after the End of the World* (Minneapolis: University of Minnesota Press, 2013).
345 Katherine Behar, "An Introduction to OOF," in *Object-Oriented Feminism*, ed. Katherine Behar, (Minneapolis: University of Minnesota Press, 2016), 8.
346 Jane Bennett, *Vibrant Matter: A Political Ecology of Things* (Durham: Duke University Press, 2010); Ahmed, *Queer Phenomenology*; Karen Barad, "Agential Realism: Feminist Interventions in Understanding Scientific Practices," in *The Science Studies Reader*, ed. Mario Biagioli (New York: Routledge, 1999), 1-11.
347 Barad, "Agential Realism," 7.

invite inter- and intraspecies (human-directed) hope and care, themes on which I elaborate in the Conclusion.

The second figuration I consider is the animalization of a perceived Other in relation to possible human/alien becomings.[348] Fleshy, bloody, and at times present to the point of pestilence, terrestrial animals may be "good to think with"—and against—as they spur novel considerations of humor, play, justice, and ethics. SETI scientists' analogies that bind animals, humans, and the alien suggest that ET is a generative, if absent, "companion species" in the field.[349] If Donna Haraway's driving question in *When Species Meet* is, "How is 'becoming with' [other species] a practice of becoming worldly?", I sketch the epistemological space where species *have not yet met,* and propose that non-human others also offer up ways to practice becoming *other*-worldly.[350] Here I focus in particular on how Steve Croft flips the analogical script, comparing humans to insects in relation to a presumed-to-be superior alien being who might exterminate, or simply ignore, us. His self-deprecating comparison reverses the science fiction trope of aliens-as-bugs.[351]

The third figuration of the alien is akin to an angel. Jill Tarter has mused to me that ET will have evolved *beyond* humans' appetite for war, aggression, and resource plundering.[352] Another scientist involved with the SETI project and on Breakthrough Initiative's board, Avi Loeb at Harvard University, explicitly imagines ET as a divine being who could create life.[353] As a figure that has surpassed, or is simply beyond, humans—not just biologically or technologically, but morally as well—the final alien of my triumvirate is one I have dubbed the *god-like alien*. Inchoately immortal,

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348 Jacques Derrida, *The Animal that Therefore I Am*, ed. Marie-Louise Mallet and trans. David Wills (New York: Fordham University Press, 2008), 112.
349 Levi Strauss, *Totemism*, trans. Rodney Needham (Boston: Beacon Press, 1963), 89; Donna Haraway, *The Companion Species Manifesto: Dogs, People, and Significant Otherness* (Chicago: University of Chicago Press, 2003).
350 Donna Haraway, *When Species Meet* (Minneapolis: University of Minnesota Press, 2003), 3.
351 See, for example, Robert A. Heinlein's *Starship Troopers* (New York: G. P. Putnam's Sons, 1959), and the film it spawned of the same name (dir. Paul Verhoeven, 1997).
352 In discussion with the author, December 2017.
353 In discussion with the author, March 2020. For a physicist's claimed proof of God, see: Frank J. Tipler, *The Physics of Immortality: Modern Cosmology, God and the Resurrection of the Dead* (New York: Doubleday, 1994).

this alien is imagined as an Earthling, but extrapolated, extended, and amplified: sagacious, superhuman, suspended across spacetime. I invoke philosophical concepts—Jacque Derrida's *différance* and the ancient Greek concept of *Eros*—to inquire into how the alien, in SETI scientists' imaginations, mediates the realms of mortal and divine.[354]

While the three figures—artifact, animal, god—I have identified are not monolithic, they are ones that have nevertheless consistently surfaced in my ethnographic fieldwork with SETI communities, in scientific papers, and in popular science articles. Lacking evidence of ET's existence and characteristics, scientists tap rich analogical repositories that wend their way around the alien's ontological outline and expand the concept of commensurability beyond its (historically used) technological sense. Throughout the chapter I preview a concept I call "reflexive alienation" that I detail further in the Conclusion: for now, I outline it as an exercise of estranging oneself through analogy as a way to imagine how aliens might see us, and even behave (in part to execute experiments of anticipation), but in a process that ultimately loops back, *nolens volens*, to terrestrially bound concepts of epistemology (scientific practices that leverage current understandings of astrophysics) and ontology (anthropocentric as of yet).

The Artifactual Alien

In 2015, the citizen science group the Planet Hunters, using data from Kepler space telescope, noticed that KIC8462852, a star much like our sun although slightly hotter, exhibited strange fluctuations in brightness over time. They elevated its peculiarities to the attention of astrophysicist Tabatha Boyajian, then a postdoc at Yale. Boyajian et al.'s subsequent paper on the

[354] Jacques Derrida, "Difference," in *Speech and Phenomena: And Other Essays on Husserl's Theory of Signs*, Jacque Derrida, trans. David Allison (Evanston: Northwestern University Press, 1973), 129-160; Plato, *The Symposium of Plato*, trans. Suzy Q. Groden, ed. John A. Brentlinger, ill. Leonard Baskin (Amherst: University of Massachusetts Press, 1970).

object, "Where's the Flux?", interrogated the star's uneven, dramatic dimming, and the star emerged as confounding object: no astrophysical explanation seemed to fully account for its behavior.[355] Astronomer Jason Wright, a Breakthrough collaborator, and others at Pennsylvania State University began to wonder whether the eponymous Tabby's Star was occluded by a Dyson swarm: a hypothetical, artificial megastructure that physicist Freeman Dyson had first proposed in 1960 would encircle a star and provide a massive amount of energy for a species to leverage on their home planet.[356] The astronomy community, including SETI scientists, launched a massive observing campaign when an additional "weird dimming phase" occurred in 2017.[357] Although further observations have pointed to oblong clumps of dust irregularly impinging on what is presumed to be the star's "normal" flux, Tabby's Star persists as an enigmatic object whose light curve has yet to be definitively characterized.[358]

How did SETI scientists go about interrogating KIC8462852's status as a potential alien creation? After Boyajian et al.'s initial analysis, a flurry of scientific activity framed Tabby's Star as an object oscillating between two senses of the word "artifact": it was posed, alternatively, as an "object made or modified by human [or, more aptly, alien] workmanship" *or* one that could be classified as "a spurious result, effect, or finding in a scientific experiment," that is, a plausible, if strange, astrophysical object.[359] At a discussion at the Breakthrough Listen Labs in March, 2020, Andrew Siemion remarked on what he views as that word's ironic use in SETI terminology. "I've always had

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[355] Tabitha S. Boyajian et al., "Planet Hunters X. KIC 8462852—Where's the Flux?" *Monthly Notices of the Royal Astronomical Society* 457, no. 4 (January 2016): 3988–4004, https://arxiv.org/abs/1509.03622. Note: The article's title, "Where's the Flux?" refers also to that object's nickname: the "WTF star," a name the reader can recognize as a double entendre.
[356] Jason T. Wright et al., "The Ĝ Search for Extraterrestrial Civilizations with Large Energy Supplies. IV. The Signatures and Information Content of Transiting Megastructures," *The Astrophysical Journal* 816, no. 1 (December 2015): 19.
[357] Seth Shostak, "Has Tabby's Star Mystery Finally Been Solved?" *NBC News*, September 1, 2017, https://www.nbcnews.com/mach/science/tabby-s-star-mystery-still-hasn-t-been-solved-ncna797741.
[358] Bradley E. Schaefer et al., "The KIC 8462852 Light Curve From 2015.75 to 2018.18 Shows a Variable Secular Decline," *Monthly Notices of the Royal Astronomical Society* 481, no. 2 (June 2018): 2235.
[359] *Oxford English Dictionary Online,* s.v. "artifact," accessed July 1, 2020, https://www-oed-com.libproxy.mit.edu/view/Entry/11133.

this problem with the word 'artificial,'" he said, because it refers to something that was made by a human. "We [SETI scientists] sort of use it in a different way: made by something that's not natural," he continued. "Which is sort of weird. At the end of the day, what is it that separates humans from nature? We are no more or no less natural than a rock or a planet. There's some sort to interesting connection between that and the separation of very advanced technology and nature."[360] Siemion's comments speak to SETI's gnarled task to not only program separations between what is construed as natural (noise) from what is artificial (a signal), but the increasing precariousness of received ontological categorizations noticed by feminist materialisms.[361]

The star's activating qualities point to objects' proposed abilities to *affect*, a characteristic that has historically been assigned to speaking, acting subjects, but on that has more recently been theorized in new materialisms as a possible capacity of objects. For instance, Karen Barad's "agential realism" centers on the material "intra-actions" among scientists, their instruments, and the objects of their inquiry to describe how phenomena are inseparable from the conditions of experimentation.[362] Barad suggests that phenomena that rupture spacetime may profitably be described as "queer" or as "queering."[363] Queer objects may be said to *dis*orient, according to Sarah

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[360] In discussion with the author, July 7, 2020. On this topic, see: Martin Heidegger, *The Question Concerning Technology, and Other Essays*, trans. William Lovitt (New York: Harper and Row, 1954); and, for a review, Josef Barla, "Technology/Technicity/Techné," *New Materialism Almanac*, March 18, 2018, https://newmaterialism.eu/almanac/t/technology-technicity-techne.html.

[361] Siemion's comments call to mind a torque of Arthur C. Clarke's third "law,": that sufficiently advanced technology is indistinguishable from *nature* (and as I later discuss, Steve Croft's additional proposition that sufficiently advanced technology is indistinguishable from God or magic). I wonder, too, how Siemion's feeling of being unsettled by the elision of nature with technology as it bears on SETI's conceit—to delimitate the two—relates to the pursuit of biomimicry that, alternatively, seeks to conjoin the two. If biomimicry's (potentially profitable) aim is to, as closely as possible, cultivate technoscience's imitation of nature's form, Siemion here might be pointing to SETI's opposite e striving. For more on the field of biomimicry, see: Richard Fadok, "The Nature of the Copy," *Platypus: The CASTC Blog,* April 2, 2019, http://blog.castac.org/2019/04/the-nature-of-the-copy/. And, for artistic projects around the digital and material, see: Marie-Pier Boucher et al., *Being Material* (Cambridge: MIT Press, 2019).

[362] Karen Barad, "Agential Realism: Feminist Interventions in Understanding Scientific Practice," in *The Science Studies Reader*, ed. Mario Biagioli (New York: Routledge, 1999), 2.

[363] Karen Barad, "Nature's Queer Performativity," *Qui Parle* 19, no. 2 (Spring/Summer 2011): 149.

Ahmed, because they contort what should be normal.[364] Artifacts in the double sense—things *made* and things *imagined*—may impress themselves on those human subjects who encounter them. Stacy Alaimo posits that such impressions reveal "thinking as stuff of the world."[365]

Here I am thinking *with* stuff of *other* worlds on a plane of speculation, articulated by my interlocuters in Breakthrough Listen, rather than humans' realized enmeshment with worldly beings and materials. The first framing of the alien I identify—the "artifactual alien"—examines scientific practices to uncover, and their assumptions around, anomalous objects.[366] While the previous chapter explored scientific thresholds for classifying naturally occurring astrophysical *events* vs. purposefully produced artificial *phenomena*, this section explores (future-facing) human predictions about (eons-old) ET transmissions, considering the time-bending dimensions of intention-loaded alien objects. Alice Gorman has argued that outer space is a culturally rich archaeological site; it is perhaps, as Vicky Walsh has suggested, even bestrewn with "exo-artifacts."[367] While Gorman's work focuses on material cultures that have emerged since the Space Age (and the defunct, forgotten, or

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[364] Sara Ahmed, *Queer Phenomenology: Orientations, Objects, Others* (Durham: Duke University Press, 2006), 3.
[365] Stacy Alaimo, "Thinking as the Stuff of the World," *O-Zone: A Journal of Object-Oriented Studies* 1 (2014): 13.
[366] For more on xenoarchaeology, I offer up two more touchpoints. The "Black Knight" conspiracy asserts that a photo taken on the first Space Shuttle mission in 1998 shows an alien surveillance craft orbiting Earth (it was a blanket that had come loose from the International Space Station) (David Crookes, "The Black Knight Satellite: A Hodgepodge of Alien Conspiracy Theories," *Space.com*, October 22, 2019, https://www.space.com/what-is-the-black-knight.html.). Yet the theory that ET might have sent probes to communicate, or watch, Earthlings, is one that scientists have seriously considered. Stanford radio astronomer Ronald Bracewell entertained what became known as the "sentinel hypothesis" in a 1960 paper in *Nature*: that aliens might have sent "feelers" to potential life-filled solar systems, perhaps even our own ("Communications from Superior Galactic Communities," *Nature* 186, no. 4726 (1960): 670. Having been programmed to detect radio transmissions, the probes, Bracewell speculated, would then be triggered to ping Earthlings, learn a common language, and impart an alien message (671). Physicist James Benford reanimated this concept in a paper that I chatted with him about at the 2019 Breakthrough Discuss Conference in Berkeley, California, Benford argues that SETI should search for probes that Bracewell describes on what are called "co-orbitals," rocky objects that are only recently perceptible due to Earthlings' increasingly fine-grained imaging technology ("Looking for Lurkers: Co-orbiters as SETI Observables," *The Astronomical Journal* 158, no. 4: 1-5). Such objects gravitationally flirt with Earth's orbit and often remain stable and near for centuries. Benford reasons that such co-orbitals would be ideal sites for ET to have planted probes which they would have then used to surveil Earth without our noticing. These probes would be able to repair themselves and broadcast information back to their makers' planets over very long time scales. Benson and asks, "what message would draw them out of their passive state to interact with us?" (4).
[367] Alice Gorman, "The Archaeology of Space Exploration," in *The Oxford Handbook of the Archaeology of the Contemporary World*, ed. Paul Graves-Brown, Rodney Harrison, Angela Piccini, 409-424 (Oxford: Oxford University Press, 2013); Vicky Walsh, "The Case for Exo-Archaeology," in *Digging Holes in Popular Culture: Archaeology and Science*, ed. Miles Russell, 122 (Oxford: Oxbow Books, 2002). For further discussion on the intersection of archaeology and SETI, see, *Archaeology, Anthropology, and Interstellar Communication,* ed. Douglas A. Vakoch (Washington, D.C.: NASA History Office, 2013).

discarded human-made objects that litter Earth's orbit), I excavate imagined objects farther afield, ones uneasily suspended across space and time.[368]

I focus on scientific interpretations of KIC8462852's and briefly touch on 'Oumuamua (a perplexing asteroid whose "magical" properties I zoom in on later in the chapter) as *queer objects*. Analyzing them as such affords analysis as to how both were, for a time, not-quite-comprehensible phenomena that tilted betwixt natural and artificial definitude. Next, I mobilize queer and feminist applications of OOO to describe ways that scientists relate to future-oriented, unruly artifacts by calling upon concepts of long-gone eras.[369] Toggling through time, alien archeological pasts temporarily transubstantiate into possible human futures.

Tabby's Star

In 1960, Freeman Dyson hypothesized that extraterrestrials could build a shell to encompass their planet's host star, harnessing its energy to supply massive engineering projects.[370] Citing a teleological drive to expand and grow populations, Dyson predicted that extraterrestrials would exploit their energy-rich star, and that the resulting megastructure's waste heat would be perceivable in the infrared.[371] (Dyson clarified that he envisioned an artificial "biosphere," a "loose collection or swarm of objects traveling on independent orbits around the star."[372]) The idea for such a structure

368 Alice Gorman, "The Archaeology of Orbital Space," in *Australian Space Science Conference* (Melbourne: RMIT University, 2005), 338-357.
369 I venture that this moves not only turns the concept of "deep time" skyward, but also remixes geological burrowing that has pursued linear excavation, instead queerly bending and dipping through time. For discussion on deep time, see: Martin J. S. Rudwick, *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World* (Chicago: University of Chicago Press, 1995); and, Alison Laurance, "Afterlives of Extinction: The Politics of Display in the Modern United States," Dissertation (Massachusetts Institute of Technology, 2019).
370 Freeman J. Dyson, "Search for Artificial Stellar Sources of Infrared Radiation," *Science* 131, no. 3414 (June 3, 1960): 1667.
371 Dyson, "Search for Artificial Stellar Sources of Infrared Radiation," 1667.
372 Freeman J. Dyson, "Artificial Biosphere," *Science* 132, no. 3421 (July 22, 1960): 252-253.

populates science fiction, perhaps most notably in Larry Niven's classic 1970 novel *Ringworld* in which a crew travels from Earth to investigate the alien relic that encircles a star.[373] Dyson's mandate for theorizing such structures from an experimental perspective was an imagined, projected path not (yet) broached by Earthlings, writing, "Taking our own solar system as the model, we shall reach at least a possible picture of what may be expected to happen elsewhere."[374] Soviet astrophysicist Nikolai Kardashev classified such imagined extraterrestrials who could build Dyson swarms as a "Type II civilization," ones who would use the star's entire radiation.[375] Since Dyson's 1960 paper, astronomers have sketched out how those hypothetical spheres would be engineered, taking the form of orbiting rings, shells or even, as astrophysicist Robert J. Bradbury proposed, "Matrioshka Brains" (after the Russian nesting dolls): a series of nanocomputers that would form a megastructure and enshell a star.[376] Anticipating what he viewed as the inevitable marriage of hardware and wetware, Bradbury imagined that the gargantuan neurological computer would have inexhaustible thinking power and would be "essentially immortal."[377] Astronomers have reasoned that shells/swarms/brains would be perceptible to terrestrial telescopes because those engineered objects would partially occlude the light from an otherwise typical star. Or, using instruments sensitive to radio waves, scientists would find narrowband pulses originating from artificially produced alien communication in the area.

KIC8462852's aperiodic, irregular dimming and variations in flux flummoxed astronomers, piquing speculation that that star might be evidence of such a Dyson swarm. After Boyajian et al.'s

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[373] See: Larry Niven, *Ringworld* (New York: Ballantine, 1970).
[374] Dyson, "Search for Artificial Stellar Sources of Infrared Radiation," 1667.
[375] Nikolai Kardashev, "Transmission of Information by Extra Terrestrial Civilizations," *Soviet Astronomy* 8, no. 2 (September-October 1964): 219. Note: According to Kardashev's classification scheme, Earthlings are a type I, or planetary, civilization as we use a fraction of our sun's radiation; meanwhile, Type III are imagined to exploit the energy of a galaxy (219).
[376] Robert J. Bradbury, "Matrioshka Brains," (1997-2000), accessed July 2, 2020, https://web.archive.org/web/20080918090527/http://www.aeiveos.com:8080/~bradbury/MatrioshkaBrains/MatrioshkaBrainsPaper.html.
[377] Robert J. Bradbury, "Matrioshka Brains."

initial paper detailed uneven, days-long dips in brightness, astronomer Bradley Schaefer used the Harvard Observatory's archival astronomy plates dating back to 1890 and found observed long-scale dimming over a century—a trend he described as "completely unprecedented" for that type of star.[378] As a follow-up to this crisis, two of Boyajian's colleagues dug deep into the space telescope's data (examining calibration frames that are normally ignored) and found a dimming of 3% over four years—a breathtaking outlier.[379] The long-term dimming (a century, years) combined with short-term dips (days, weeks) simply didn't match up with astronomers' expectations of what appeared to be an otherwise typical object.[380] As Boyajian told me later, KIC8462852's double-dimming is "just not something that stars do."[381] The object was both "remarkable" for its anomalous flux patterns and yet "unremarkable" as it behaved like other "normal" F-type stars by Boyajian's reckoning; it was "superficially ordinary" according to her colleagues.[382]

Over a Skype conversation in July 2020, Boyajian talked me through how the Dyson swarm explanation gained traction after she and collaborators checked off an increasingly frustrating laundry list of typical astrophysical possibilities that the star thwarted. Boyajian and others investigated how exocomets or transiting planetesimals could explain the dips, yet their analyses found that the star's behavior did not match such expected patterns; besides, the comets would have had to number in the hundreds or even thousands for a sustained period to account for the star's dip in brightness, an event that seemed extremely unlikely.[383] Boyajian explained how the star did not

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[378] Bradley Schaefer, "KIC 8462852 Faded at an Average Rate of 0.164 ± 0.013 Magnitudes per Century from 1890 to 1989," *The Astrophysical Journal Letters* 822, no. 2 (2016): 7.
[379] Benjamin T. Montet and Joshua D. Simon, "KIC 8462852 Faded Throughout the Kepler Mission," *The Astrophysical Journal* Letters 830, no. 2 (October 4, 2016).
[380] In addition to Boyajian et al., "Where's the Flux?", see Eva Bodman et al., "The Variable Wavelength Dependence of The Dipping Event of KIC 8462852," *ArXiv*, submitted June 22, 2018, https://arxiv.org/abs/1806.08842.
[381] In discussion with the author, July 7, 2020.
[382] Boyajian et al., "Where's the Flux?", 15.
[383] Boyajian et al., "Planet Hunters X. KIC 8462852—Where's the Flux?", 15-16; Eva H. L A Bodman and Alice Quillen, "KIC 8462852: Transit of a Large Comet Family," *The Astrophysical Journal Letters* 819, no. 2 (2016): 1; M. A. Thompson et al., "Constraints on the Circumstellar Dust Around KIC 8462852, *Monthly Notices of the Royal Astronomical Society: Letters* 458, no. 1 (February 2016): L39; Breakthrough Listen, "Berkeley SETI Live Chat from Green Bank about Tabby's Star observations," October 26, 2016, https://www.youtube.com/watch?v=Ijyn0kAMTL8.

appear to have spots (dark areas on its surface of lower temperature), nor circumstellar material (dust, orbiting planets) to account for the aperiodic dimming.[384] Nor did the star seem to be pulsing (an effect of some physical inability to produce luminosity).[385] Spectra gathered over a period of time also did not show what is called red or blue shifting: when a body near a star is large enough to noticeably affect its gravity, say, Jupiter acting on our Sun, it tugs the star in a way that elongates or shortens perceived wavelengths of light.[386] "I can't wrap my head around how any of these [explanations] would work," Boyajian told me.[387] Perhaps the most perplexing aspect of KIC8462852 was that what seemed to be the most probable cause—dust occluding the star in the optical part of the electromagnetic spectrum—did not also produce a telltale "glow," an excess of light in the infrared.[388] The effect of putting more and more dust in front of the star—an explanation for its dramatic 20% flux dip—would be something "hard to hide" in the infrared, Boyajian explained. As a 2016 follow-up astronomy paper put it, "There is no known or proposed stellar phenomenon that can fully explain all aspects of the observed light curve."[389] As difficulties mounted to explain KIC8462852 "naturally," Jason Wright and other researchers at Penn State's Center for Exoplanets and Habitable Worlds wrote that the star's "transit signatures [are] consistent with a swarm of artificial objects" and urged SETI astronomers to take notice.[390]

At the Green Bank Telescope over the course in February 2016, Boyajian, who had moved on to Louisiana State University as an Assistant Professor, Jason Wright, and Andrew Siemion did just that. Their observations took place as I was preparing for my general exams and before my extended fieldwork with Breakthrough Listen, but Tabby's Star's many unusual properties inspired

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[384] In discussion with the author, July 7, 2020; see also: Jason T. Wright and Steinn Sigurdsson, "Families of Plausible Solutions to the Puzzle of Boyajian's Star," *The Astrophysical Journal* 829, no. 1 (September 2016): L3 (1-15).
[385] In discussion with the author, July 7, 2020.
[386] Montet and Simon, "KIC 8462852," 13.
[387] Boyajian in discussion with the author, July 7, 2020.
[388] Boyajian in discussion with the author, July 7, 2020.
[389] Montet and Simon, "KIC 8462852," 13.
[390] Jason T. Wright et al., "The Ĝ Search for Extraterrestrial Civilizations with Large Energy Supplies," 19.

me to revisit the object with the science team there, as well as Penn State PhD candidate Sofia Sheikh, who later took on the GBT observations' data analysis. The science team devoted an inordinate amount of time to KIC8462852. Although Breakthrough often trains the telescope on targeted sources, usually from the Kepler catalog (as opposed to sky surveys), for a maximum of thirty minutes (half of which is spent looking at the off-source), Tabby's Star commanded 25 hours of telescope time over several observing sessions. Breakthrough usually observes in one "band" of frequency that covers a particular range of the radio spectrum, but in this case, utilized the telescope's entire capability, collecting data from 1 GHz through 23 GHz that spanned the L, S, C, X, and even experimental K and K_a bands.

Not only that: the observations garnered a whopping *600 terabytes* of data that Breakthrough, in another atypical protocol, opted to keep. As explained in the previous chapter, raw data files representing all aspects of the observations stored at the Green Bank Telescope's backend typically are discarded because they take up too much diskspace, clogging the system as data from new observations roll in. (Reduced filterbank files that represent essential frequency and time data are passed down the pipeline to Breakthrough for further analysis.) For observations of KIC8462852, all the raw data was saved and then transferred to a data storage facility that Breakthrough rents from Penn State, taking up more real estate than any other project there by far.[391] KIC8462852's extraordinary behavior elicited extraordinary attention from these astronomers; as Sheikh remarked to me, "Because we thought it was special, we took observations in a special way."[392]

In a livestreamed Q&A before the observations on October 26, 2016, the three astronomers at the GBT fielded questions about the odd object. A possibility for the observations, Wright remarked, was to "catch it in the act of deep dimming," that is, a dip in flux that would exceed 5%,

[391] For context, the maximum amount of storage on the iPhone 11 Pro is 512 gigabytes; Breakthrough's observations of Tabby's Star account for almost 1,118 iPhones worth of storage.
[392] Sheikh in discussion with the author, July 3, 2020.

reaching 10, 15, or even 20%.[393] Asked about what kind of observations would strengthen the case that Tabby's Star could be a Dyson swarm, Wright explained that seeing identical dimming across all wavelengths would be exciting. Because different materials absorb, scatter, and emit light at different wavelengths, particular patterns are a fingerprint of a particular substance. An opaque alien megastructure would occlude Tabby's Star's light mostly evenly across all wavelengths. Siemion, in a later conversation with me, was careful to tell me that the observations were not driven by a strong expectation that they would detect evidence of extraterrestrial activity. "It's an interesting star with strange behavior," he remarked, "So why not observe it the moment that the strange thing is happening?"[394] Still, the point here is that the object's enduring strangeness elicited intense attention and left room for interpretations that the light curve was impacted by artificial activities. As Wright remarked, "Almost all natural explanations have to invoke something super rare. Of more than a hundred thousand stars that the Kepler gathered data about, Tabby's Star is still unique among all of them…It's something we've never seen before."[395] (Recall Siemion's noticing of linguistic tumblings of artifact/artificial objects vs. that which is parsed as natural.)

Tabby's Star preceded another unusual object that Breakthrough scientists would study a few years later: 'Oumuamua, the first observed interstellar object—one whose origin was of a different solar system than our own—with its own quirks. Likely to have been formed through astrophysical phenomena "different from the familiar," 'Oumuamua's murky "peculiarities" continue to confound.[396] Harvard astronomer and Breakthrough Initiative board member Avi Loeb compared the object to a "surprise guest for dinner from another country," who "appeared to be weird and

[393] BerkeleySETI, "Berkeley SETI Live Chat from Green Bank about Tabby's Star Observations," accessed July 2, 2020, https://www.youtube.com/watch?v=Ijyn0kAMTL8.
[394] In discussion with the author, July 7, 2020.
[395] BerkeleySETI, "Berkeley SETI Live Chat."
[396] Abraham Loeb, "6 Strange Facts about the Interstellar Visitor 'Oumuamua," *Scientific American Blog*, November 20, 2018, https://blogs.scientificamerican.com/observations/6-strange-facts-about-the-interstellar-visitor-oumuamua/.

unlike anything we have seen before."[397] Now rocketing out of the solar system and away from Earth, the thought-to-be-asteroid is frustratingly "already out the door" (like Laika?) and increasingly unavailable for more intense investigation.[398] As phenomena said to exhibit unruly behavior that effect, slip away, or have to be pinned down, how might Tabby's Star and 'Oumuamua be theorized as dynamic objects that excite?

Astrophysicists' descriptions of them as odd phenomena not immediately explainable point to objects' animating effect in the people who observe and study them, a characteristic Jane Bennet in *Vibrant Matter* describes as "thing-power": material things' "strange ability" to "exceed their status as objects and to manifest traces of independence and aliveness, constituting the outside of our own experience."[399] To explain, Bennet describes a motley still life on a street in Baltimore, Maryland, in which seemingly mundane objects clutter a storm drain. Yet through examination, contemplation, and wondering about their origins, Bennet finds the objects both elicit an emotional response and connect up to larger forces at play in the world. Linguistically knitting through hyphenation, the "glove-pollen-rat-cap-stick" assemblage she encounters transforms, for her, into "vivid entities" with "energetic vitality."[400] Objects act *on* and *with* her. Or, consider anthropologist Hugo Reinert considering sieidi, sacred stones of Scandinavia that prompt him to ask, "What kind of critter might a stone be? Does it have a life, or something like it?"[401] For Bennet, objects usually passed over, discarded, or simply unseen (power grids, food, metal) are reconsidered as participatory assemblages by which politics, bodies, and even myths are formed and reworked.[402] For Reinert, sieidi articulate "networks of relation" that both structure human behavior through ritual, and more recently,

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[397] Loeb, "6 Strange Facts." See also, David Kaiser's section, "Guess Who's Coming to Dinner," on SETI: *Quantum Legacies: Dispatches from an Uncertain World* (Chicago: University of Chicago Press, 2020).
[398] Loeb, "6 Strange Facts."
[399] Jane Bennet, *Vibrant Matter: A Political Ecology of Things* (Durham: Duke University Press, 2010), xvi.
[400] Bennet, *Vibrant Matter*, 5.
[401] Hugo Reinert, "About a Stone: Some Notes on Geologic Conviviality," *Environmental Humanities* 8, no. 1 (May 2016): 96.
[402] Bennet, *Vibrant Matter*, 20.

emerge as sites that can be vulnerable and harmed—phenomenological states usually attributed to feeling subjects.[403]

Such objects, Bennet and Reinert propose, are not merely flashpoints *around* which politics are enacted and stories are told. Rather, they claim, objects activate contestations of the life/object divide because they prompt displacements of humans' historical assignations of their inscrutability, vacuity, and disposability.[404] If scholarship on multispecies ethnography pursues human/animal becomings, investigations of human/object relationships further radically reevaluate the conditions of knowledge-making, pushing epistemic potency beyond organisms and onto things' capacities to provoke subjects who encounter them.[405] While Bennet and Reinert engage with objects at hand (sacred stones, debris) imagined alien artifacts are inchoately graspable yet similarly provoke curiosity, speculation, and further observations. As Boyajian told me, KIC8462852 slipped away from easy scenarios and provoked increasingly unlikely explanations; she had even considered its behavior the result of "starquakes," events previously reserved for modeling neutron stars.[406] Tabby's Star is an "exotic" object that remains "mysterious," enshrouded by dust (probably) and

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[403] Reinert, "About a Stone," 99.

[404] Here I am writing against certain practitioners of OOO that theorize things as, uninterestingly, ontologically obstructed. If a major criticism of Michel Callon's polarizing yet generative 1984 article, "Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay" (in *Power, Action and Belief: A New Sociology of Knowledge*, ed. John Law, 196- 233 [London: Routledge and Kegan Paul, 1986]) was that it theorized different *lively* stakeholders (fisherman, marine biologists, and the scallops themselves) on the same ontological plane with the same agential capacities, the field of (OOO) goes further. Its stringent rejection of anthropocentrism postulates what Levi Bryant calls a "flat ontology" that places paper towels, super novae, and carrots *in line with* lively bodies (*The Democracy of Objects* [London: Open Humanities Press 2011], 246). In conversation with Bryant, Ian Bogost's brand of OOO is one he calls *alien phenomenology*, a practice that encounters limits of knowability in the identical ontological locations in which objects "recede interminably into themselves" (*Alien Phenomenology, or What it's Like to Be a Thing* [Minneapolis: University of Minnesota Press, 2012], 9). Confusingly, Bogost's book title still promises to actually explain "what it's like to be a thing." As Stacy Alaimo points out, Bogost's approach "reinstalls a humanist and masculinist sense of a disembodied subject" through the atomizing of objects and suppressing their potential to express, impress, and activate "Thinking as the Stuff of the World," *O-Zone: A Journal of Object-Oriented Studies* 1 [2014]: 15).

[405] Whereas Ian Bogost working within OOO might claim these are properties of objects themselves that, pointing to a state of being in which they "exist not just *for us* but also *for themselves* and *for one another,* in ways that might surprise and dismay us" (*Alien Phenomenology,* 50-51), Behar's OOF reinstalls feminist concerns about interactions between humans and objects. She reminds us: "Not only the object or artifact is of import here; tantamount is the sense of orientation. The thing, not the maker, explains the world; so orientating or listening to things begets ontology" (*Object-Oriented Feminism,* 19).

[406] In discussion with the author, July 7, 2020.

also from full comprehension.[407] Although the Breakthrough team did not uncover narrowband pulses emanating from 'Oumuamua, many of that object's characteristics remain unaccounted for (shape, trajectory, origin) leaving open various possibilities of explanation. It remains, according to Loeb, a strange dinner guest that "must be chased down the street" before it disappears into the shadows of the solar system.[408]

Like 'Oumuamua, Tabby's Star's unruly behavior bucks standing models of astrophysical phenomena. As Jason Wright contemplated in the live stream, "When we list everything we can think of, and none of those fit…we start trying to think of something new…I always worry it's going to end up being something mundane, but I can't imagine what."[409] Left unsatisfied by explanations that either cobbled together disparate causes or that shoehorned its characteristics into obvious, but unfitting, models, astrophysicists developed new ones.[410] Participating in anthropologist Michael Oman-Reagan's call to "queer outer space," I call upon that capacious concept to frame KIC8462852 as a queer object.[411] Queer is disjointed, unfitting, elusive, jagged. It shimmers between binaries; it confounds. Queer slithers away from shackling allocations of smooth or stable existence. Choosing to read Tabby's Star as queer is itself a performative scholarly act of queer*ing* because doing so particularly calls attention how scientists, through their descriptions and speculations of anomalous objects, bestow on them agential aspects beyond the *160nthropos*, indeed beyond the *bios*. The GBT observers have variously described KIC8462852 as a "very weird" object whose "bizarre" light curve fluctuations remain "mysterious" and prompt further astrophysical observation, models,

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[407] L. Neslušan and J. Budaj, "Mysterious Eclipses in the Light Curve of KIC8462852: A Possible Explanation," *Astronomy & Astrophysics* [manuscript], accessed July 1, 2020, https://arxiv.org/pdf/1612.06121.pdf.
[408] Loeb, "6 Strange Facts."
[409] BerkeleySETI, "Berkeley SETI Live Chat."
[410] In discussion with the author, July 7, 2020.
[411] Michael Oman-Reagan, "Queering Outer Space," *SocArXiv* [manuscript], submitted January 22, 2017, osf.io/preprints/socarxiv/mpyk6/.

and theory.[412] For an object to behave badly and pique attention, queerly acting objects inspire experimentation and technological innovation.[413]

I detour to Sara Ahmed's "queer phenomenology" to next plumb KIC8462852's status as a queer object. Ahmed seeks to render "strange" everyday interactions with objects "at hand" (in particular, she focuses on the writing desk that has also haunted philosophers Edmund Husserl and Martin Heidegger) which, she explains, are composed of meaning-laden *orientations*.[414] How objects are made to "arrive"; the conditions of their functional usefulness (and failure); and the "background" of actions taken and options foreclosed to form particular configurations of objects extended through space and time, afford contours for political, racial, sexual, and material relations to emerge, be noticed, and affect.[415] As Ahmed explains, matter *matters* because it is "shaped by the directions taken that allows things to appear in certain ways."[416] We orient objects and they orient us through experiential negotiations that privilege or discard particular glimpses. Orientations are Ahmed's mode to explore how bodies and objects "face" each other through material, performative repetitions that sometimes adhere to and at other times contravene normed situational positions.[417] Homosexual "orientations" deviate from an assumed heterosexuality socially imposed to secure a "straight," patriarchal, reproductive "line."[418] White bodies are better enabled to "extend their reach"

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[412] Andrew Siemion, in discussion with the author, July 6, 2020; BerkeleySETI, "Berkeley SETI Live Chat"; Tabatha Boyajian, in discussion with the author, July 7, 2020.
[413] Here I am reading queer theory generously into an extraterrestrial object, and pointing merely to humans' interest in, and knowledge practices around, matters' curious ability to "excite" (nodding to Natasha Myers, *Rendering Life Molecular: Models, Modelers, and Excitable Matter* [Durham: Duke University Press, 2015]). For feminist critiques of modern science's narration of nature as violable and pursuable, see Evelyn Fox Keller's reading of Francis Bacon chasing nature as heterosexual conquest (*Reflections on Gender and Science* [New Haven: Yale University Press, 1985]); and, Carolyn Merchant's description of a transformed experience of nature though the eye of the Scientific Revolution (*The Death of Nature: Women, Ecology and the Scientific Revolution* [New York: Harper Collins Publishers, 1990]).
[414] Ahmed, *Queer Phenomenology,* 91; on the writing table, 29-31 and 45.
[415] Ahmed, *Queer Phenomenology,* on objects' "arrival," 37-44; on their "background," 31-38, also, 62-63; on deviant orientations, Chapters 2 and 3.
[416] Ahmed, *Queer Phenomenology,* 165.
[417] Ahmed, *Queer Phenomenology,* esp. 1; 31; 170.
[418] Ahmed, *Queer Phenomenology,* Chapter 2.

through time and space through the reproduction of inheritance of possessions, history, and affirmations in ways that dispossess and subsume Others' grasp of objects.[419]

A *queer* phenomenology—the experience of objects and the world that perhaps *dis*orient—is a performative examination of objects and bodies thought to be out of line, out of the ordinary, disturbing, strange, misbehaving, ones that fail their purpose, are beyond reach, collapse at the horizon of visibility, or are expressed on a diagonal slant rather than a straight line. Wresting queer bodies' and objects' "background" to the forefront of contemplation is an act of queering (the white, male, European, heteropatriarchal) philosophy of perception. It carves out a space whose aim is not to "reorient" or "straighten" deviants (lesbians, Black people), but instead to cultivate "an orientation toward what slips, which always what slips to pass through, in the unknowable length of its duration."[420] For Ahmed, analyzing rhetoric around queer bodies and things precipitates novel reformulations that (dis)orient us to weird yet wonderful ways by which we are affected by, and affect, disruptive matter.[421]

KIC8462852 was at once "remarkable" and "unremarkable," both "normal" and "mysterious" by Boyajian's reckoning; it was a peculiar object unlike anything Wright had observed before and thus triggered extraordinary conditions for the GBT observations.[422] Yet Tabby's Star is not queer merely because it was odd or inexplicable; but rather, as something that oscillated *between* opposing characterizations—long-term dimming/short-term dips, exocomets/not exocomets, dust/no IR glow—it eluded ontological stability. Applying Ahmed's parlance, even interpreted as a "natural," object, Tabby's Star "slipped away" from astrophysical models "at hand," and thus "failed" to "face" astronomers as a humdrum F3 type star. Even if it were a result of typical

[419] Ahmed, *Queer Phenomenology,* 132.
[420] Ahmed, *Queer Phenomenology,* 172.
[421] By "we," in concert with Ahmed, I mean especially queers and Others for whom philosophy and theory around the body, sexuality, and the mind holds different stakes than those on the "inside," to use her parlance.
[422] Boyajian et al., "Where's the Flux?"; BerkeleySETI, "Berkeley SETI Live Chat."

astrophysical occurrences (as astronomers now hesitantly agree it is), it is still "super rare," according to Wright.[423] If *not* natural, KIC8462852 could be evidence of an alien megastructure whose existence would be "a momentous discovery" of a "profound subject" according to Siemion.[424] Ahmed writes, "Queer becomes a matter of how things appear, how they gather, how they perform, to create the edges of space and worlds" in strange and wonderful ways.[425] Queer things like Tabby's Star are such because they incite new evaluations previously not thought possible. Surfacing as a confounding star whose unpredictable behavior had to be "caught in the act," KIC8462852 harbors activating properties that acted *on* the scientists who study it. Hiding from definitive classification, Tabby's Star provoked these scientists to consider not only how astrophysical matter "gathers" in weird and dynamic ways, but also the aliens who might be "behind" it, to orient with Ahmed's terminology.

I next consider Sofia Sheikh's speculation of that "background" through exploration of another queer aspect animated through Tabby's Star: I move from the material unfixity of the *star*, to the temporally disjointed *alien* imagined to be potentially "behind" it.

Artifacts Between Spacetimes

In another twist, the star could act as cosmological signaling device, like a firefly in a field intermittently glowing on a hot summer evening: its blinking light could be seen by people in the dark field who would not necessarily see each other. In the Q&A session, Wright credits Siemion with the idea that observing the star during the dipping would "trigger" attention, perhaps beyond Earth. "If you don't know when to look," Wright said, "You should choose a time when something

[423] BerkeleySETI, "Berkeley SETI Live Chat."
[424] BerkeleySETI, "Berkeley SETI Live Chat."
[425] Ahmed, *Queer Phenomenology,* 167.

is passing between you and the target because you can both agree that that's a special time."[426] The "you" here refers to both humans and potential extraterrestrials who would mutually take notice of Tabby's Star's bizarre behavior. An extraterrestrial near to the star might choose to send out electromagnetic transmission. In that case, ET might be hoping that observers, paying special attention to the star, would uncover a technosignature sent at the same time. At 1400 light years away, Tabby Star's light is a snapshot of the past.

MIT professor Philip Morrison—a coauthor of the 1959 *Nature* paper that inspired Frank Drake to embark on SETI research—famously dubbed the field the "archaeology of the future."[427] A light signal indicating ET's presence (either in the form of a directed beacon, or a star's light curve affected by some alien artifact like a Dyson swarm) would have propagated through spacetime at a restricted velocity. That technosignature, then, would indicate the age of the alien who had sent it. As Jill Tarter put it at a presentation at NASA Ames in 2016, SETI "is really archaeology because it's telling us about their [ET's] past" but at the same time, the advent of a technosignature would hint that "it's possible to become an old technology…[and] that it's possible to have a long future."[428] Morrison's adage tugs time in dual directions: archaeology, the study of the past through the interpretation of made objects collides with anticipated (even, for Tarter, hoped for) paths that humans might take. Invoking Morrison's quip at the GBT, Siemion explained that "any civilization we might detect is much more advanced that we are, probably, statistically speaking. We're seeing them as they were, 1,400 years ago. We're seeing our own future, perhaps, as a technological civilization by looking at another civilization's past."[429] Alien pasts foreshadow human futures, but

[426] BerkeleySETI, "Berkeley SETI Live Chat."
[427] Quoted by Jill Tarter, that phrase has migrated beyond Morrison's original symbolic association of space with science *fiction*, now often invoked to poetically describe SETI science. "Searching for ET: An Investment in Our Long Future," filmed July 31, 2014 at NASA Ames, Mountain View, CA, video, https://www.nasa.gov/ames/ocs/2014-summer-series/jill-tarter.
[428] Tarter, "Searching for ET."
[429] BerkeleySETI, "Berkeley SETI Live Chat."

are perceived in our present. Worlds collide through spacetime, drawn on the arc of anticipated technosignature.

Since those observations at the GBT of Tabby's Star, the astronomy community has formed a tenuous consensus that the object's odd light curve is an effect of dust, albeit strangely behaving dust.[430] Yet, because the object was suspended in uncertainty as an alien megastructure, the resulting enormous data compiled by Breakthrough's observing run makes it possible to do special kinds of analysis that Sophia Sheikh has proposed. The raw voltage data, in contrast to the collapsed data products Breakthrough usually works with, embeds much more information. In particular, they represent time-domain data that usually gets jettisoned in the Fourier transform (as discussed in the previous chapter) and thus saves the powers at each individual frequency, a method called "coherent de-drifting" I will presently detail. These particular characteristics will allow Sheikh to apply the data in an unusual way, what she calls an "observation of opportunity": to ascertain an intentionally sent, Earth-directed extraterrestrial technosignature that—*before being transmitted—will have already pre-assumed human attention.* It would work like this:

The terrestrially grounded GBT telescope moves, within a cosmological framework, with both the rotation of the Earth as well as the Earth's orbit around the sun. As discussed in the previous chapter, radio frequency interference (RFI) like a cellphone, an Earth-orbiting satellite, or a plane passing overheard, is easy to distinguish not only because it is powerfully bright against the radio background, but also because it too is produced locally. What scientists understand as its Doppler shift is relatively easy to identify. Think of an ambulance speeding by: relative to an observer standing still on the street, the siren's wail is higher pitched because the wavelengths get contracted as they propagate through the medium, the air; as the ambulance passes, it sounds lower

[430] Bradley Schaefer et al., "The KIC 8462852 Light Curve From 2015.75 to 2018.18 Shows a Variable Secular Decline," *Monthly Notices of the Royal Astronomical Society* 481, no. 2 (June 2018): 1.

in pitch to that observer (a basso takes over from a soprano). Like locally produced RFI, the telescope's observational data is Doppler shifted relative to an outside observer, but those characteristics are well-understood; given that observers know GBT's latitude and longitude and clock the time of the observations, scientists have the ability in their data processing to eliminate those effects as they sift for potential non-local technosignatures. How would this correction bear on a SETI experiment?

Electromagnetic radiation transmitted from a far-away source will, roughly, add to what is termed the drift rate relative to receiving telescope. In astrophysical terms, the drift rate, an effect of Doppler shifting, is measured in units of frequency over time (for instance, megahertz per second). The drift rate, as perceived by someone observing a rotating or orbiting signal, will be *less* (fewer megahertz per second, resulting in more inclined slope) if that observer corrects—that is, subtracts out—their own Doppler shift (which, remember, they will have characterized thoroughly). The scenario works equally well in reverse: the transmitting source could instead, correct out *their* Doppler shift prior to transmission and the perceived drift rate by the observer would be equivalent. Here is where Sheikh's *gedankenexperiment* gets "spooky."[431] If *both* parties "pre-correct" their Doppler effects, then the drift rates, after running the observational data through analysis, would render zero: a vertical line with no slope. That is, the signal would appear to stay at the same frequency the entire time it was being observed. As she explained, "You assume that whoever is operating the transmitter has done the same thing for their system. They know where their transmitter is. They know how their planet rotates. They know how their planet orbits. Theoretically they [ET] could do the same thing [I do] on the other side."[432] The "pre-correcting" of the GBT's Doppler effect is one

[431] Here, of course, I am invoking Albert Einstein's description of quantum mechanic's queer ability to thwart causality, what he described in a letter to physicist Max Born as "spukhafte Fernwirkung," popularly translated from the German as "spooky action at a distance." See: Albert Einstein and Max Born, *The Born-Einstein Letters, 1916-1955: Friendship, Politics and Physics in Uncertain Times*, trans. Irene Born (New York: Macmillan Press Ltd., 1971), 158.
[432] In discussion with the author, July 3, 2020.

component of mutually inflected phenomena in which aliens' visibility hinges on her assumption that "the alien transmitter has done the same thing: that they've corrected out their motion."[433] Sheikh's experiment pre-assumes that extraterrestrials would *also pre-assume the same thing*. That is, ET would also pre-correct—"de-drift"—their Doppler drift to intentionally get the attention of Earth's observers. As she explained, "As we correct the things about the receiver that we know easily, and we hope they do the same for the symmetric things about their transmitter that they know easily."[434] Here's how the three scenarios would play out, according to an illustration Sheikh created and sent me:

[433] In discussion with the author, July 3, 2020.
[434] In discussion with the author, July 3, 2020.

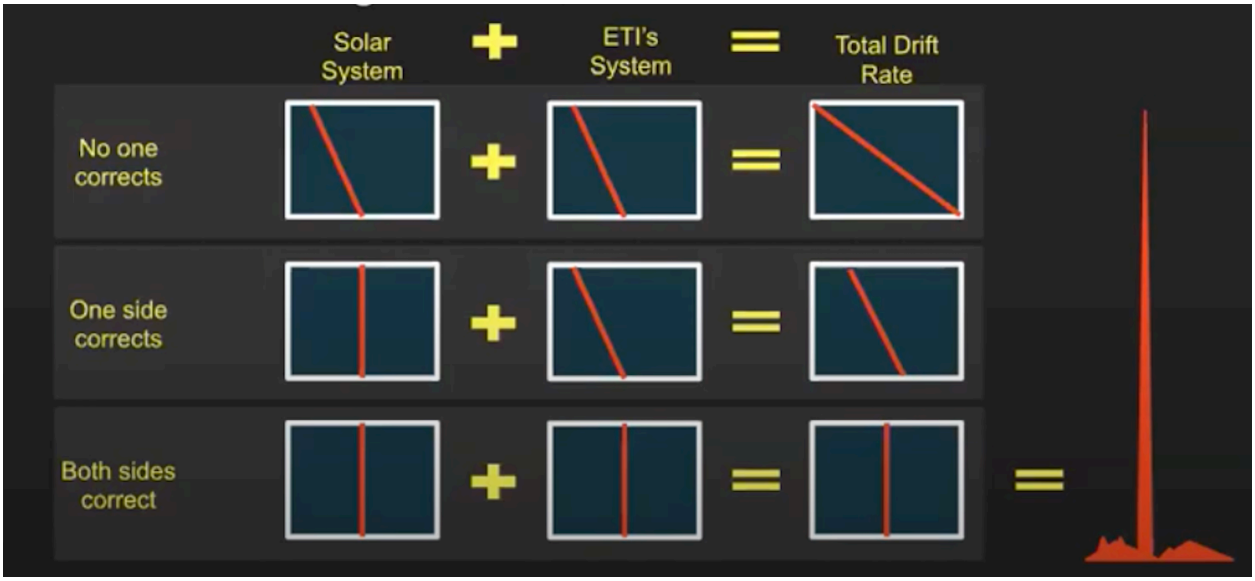

Figure 21: Diagram courtesy of Sofia Sheikh that explains the de-drifting scenarios.

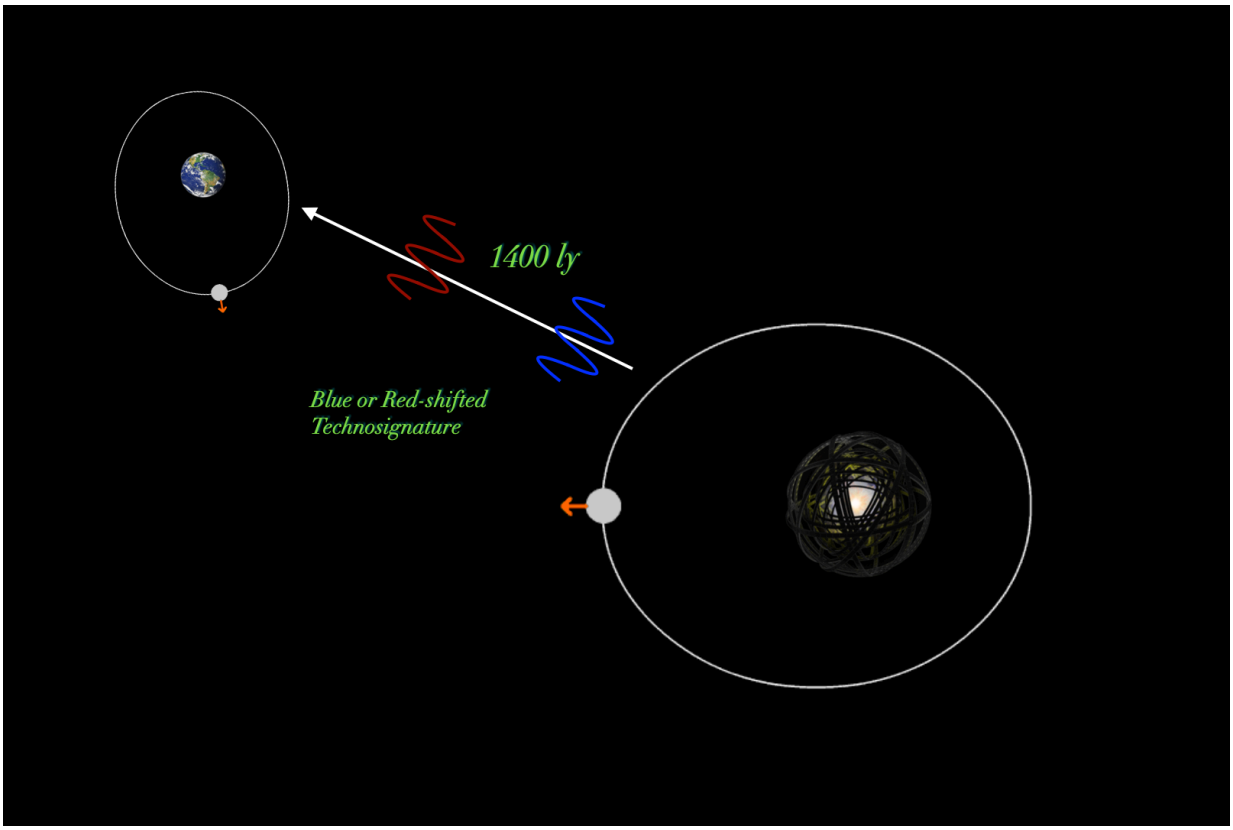

Figure 22: A schematic of Sheikh's experiment of anticipation. Illustration by the author.

Queer characteristics emerge around this particular experimental set-up. Like other SETI experiments, success—the interception of a technosignature—depends on human observers both being in the line of sight of the extraterrestrial signal (location-dependent) and catching it the moment it arrives (time-dependent). Yet Sheikh's hypothetical de-drifting phenomena could only occur if ET was sending out signals to Earth *specifically*.[435] An omni-directional technosignature broadcasting to various parts of the sky would not be visible with usual SETI methods that don't save the .raw datafiles. Sheikh's set-up is premised on ET intentionally acting to signal Earth *in particular* which raises weird assumptions about time and space. Recall that Siemion hypothesized that even without the Dyson swarm accounting for its unusual light curve, Tabby's Star could be considered to be so odd that it would garner *universal* attention and thus trigger an opportunity for aliens proximate to it to take action to be noticed by others. But Sheikh's set-up proposes an additional conundrum. The light the GBT collected arrived 1,400 years after it left its source, raising this question: Why would ET have *intentionally directed a narrowband, de-drifted signal to Earth then?* By that logic, ET will have had to either known, through some faster-than-light way, that humans exist now with technology capable of both noticing Tabby's Star and also intercepting a signal; or, would have seen what Sheikh told me was some interesting biosignatures or atmospheric technosignature (pollution from Roman silver smelting around 600 A.D.?) and then *predicted, betted, or hedged* that humans *would have* developed that technology by the time the star's light and their technosignature reached Earth in 2015.[436]

Sheikh is quick to point out to me that her speculations grew from a very particular "observation of opportunity": that Tabby's Star was simply interesting enough to collect swaths of

[435] Spacetime manipulated messages like the one Sheikh is after recall two recent films, *Interstellar* (dir. Christopher Nolan, 2014) and *Arrival* (dir. Denis Villeneuve, 2016).
[436] Sheikh mentioned this possibility to me; more here from the Director of The Planetary Society, Jason Davis: "Is There Anybody Out There?", October 25, 2017, https://www.planetary.org/blogs/jason-davis/2017/20171025-seti-anybody-out-there.html.

data that will allow her to test software code and data analysis techniques that might be applied to other SETI projects.[437] Nevertheless, the de-drifting experimental set-up catalyzes a scientific imagination of the alien Other in ways that are, crucially, profoundly queer because, not only do they disjoint spacetime, but do so *while relying on ontological similitude*. That ET would have similarly considered Tabby's Star anomalous and attention-getting; that they could have foreseen humans' technological development *from* the past; that they would "pre-correct" their own relative Doppler shifting to carve out a space of reflexively predicted noticeability, are extraordinary assumptions that both interrupt conceptions of past/present/future *while simultaneously sketching interspecies-congruency*.[438]

Karen Barad's investigations into queerly behaving phenomena similarly kick against classical interpretations of the physical world in which concepts of time, matter, and experiment are radically upended. Their task is not to merely enfold non-humans (stingray cells, lighting, electrons) into posthumanist scholarly inquiries, but rather to investigate the material, performative conditions for differentiating them, that is, to see how agential "cuts" made through experimentation destabilize presumed ontological boundaries.[439] Elements of the instrumentation/experimenter/matter bricolage get "continually reconstituted through our material-discursive intra-actions," through particular experimental choices, enactments, and opportunities.[440] Barad trains our attention to the queer aspects of quantum mechanics, that, without miring the reader in technical details, reveal noggin-scratching properties: electrons "leap" from discrete, bounded energy levels that nonetheless produce a photon that must have come from somewhere/somewhen; light can behave as both a wave (continuous propagation through spacetime that produces *interacting* diffraction patters) and as

[437] In discussion with the author, July 3, 2020.
[438] Subtly, perhaps, they are also queer because, invoking Ahmed here, ET transmitters would first have to be *aligned* with terrestrial instruments, and then for the resulting zero drift rates to be in a *vertical* line (rather than a slant). That these "straight" orientations reveal something further queer—literally alien, anomalous, extraordinary—activates another ironically queer level, linguistically.
[439] Karen Barad, "Nature's Queer Performativity," 124.
[440] Barad, "Agential Realism," 7.

a particle (discrete entities that cannot take up the same location); whether quantum entities behave as either a particle or a wave is determinable *after* the experiment.[441] Queer quantum agitations contradict, uproot, and escape concepts of causality, determinacy, and ontological fixity through conditional assemblages of instruments, experimenter, and quantum materials. "Phenomena are not located in space and time," Barad writes, "Rather, *phenomena are material entanglements enfolded and threaded through the spacetimemattering of the universe*."[442] Such phenomena are not merely strange, but in fact queer: they fundamentally upend notions of here/there, then/now/later and before/after.

Sheikh's experimental set-up adds an inter-active participant to Barad's observed/observed/instrument assemblage that already cultivates queerly unfolding phenomena*:* an alien Other. This co-conspirator flickers even beyond the edges of the material-discursive; here, *imagined intentionally* "cuts" across not only space but also time. The experiment presumes data manipulated *before* it was sent, torqueing linear time. It furthermore requires a foreshadowed reciprocation of that manipulation by an alien Other (in this case, the aliens are humans) to render a technosignature visible (zero drift rate). Humans hope that aliens hope humans will de-drift their data *prior* to transmission and *after* data collection. Simultaneously, the set-up presumes mutual *attention* to a provisionally agreed-upon astrophysical phenomenon (Tabby's Star) as well as mutual *intention* of transmitting/receiving a radio technosignature, thus pre-excavating a future-oriented ontological affinity. Past alien presuppositions curl into their version of human futures—what is our now. Imagining aliens (the de-drifting experiment) imagining us (predicting our technological capabilities) imagining them (both being drawn to a universally noticeable event) is a performance of reflexively imagining how aliens would have acted. That is, Sheik's experiment of expectation

[441] Karen Barad, "Nature's Queer Performativity," 136-146.
[442] Karen Barad, "Nature's Queer Performativity," 145-146, emphasis in original.

attempts to hurdle lightspeed by assembling commensurable conditions that notice the alien noticing us noticing them, an epistemic loop-de-loop oriented toward some unknown Other.

I close this section on the artifactual alien with comments by Steve Croft, whose graduate education in southern England steeped him in the landscape strewn with prehistoric peoples' megalithic structures across Salisbury Plane like Avebury Stone Circle, West Kennet Long Barrow, and, of course, Stonehenge. Recall from the previous chapter how Croft looks to these structures as evidence of some kind of intention, even if they are uninterpretable—much as he anticipates alien technosignatures would emerge. "If you're wandering through the landscape—and this is my point—you would recognize Stonehenge or… or any of these prehistoric monuments…as being intentional," he told me. "You might not be able to figure out what their purpose was. You might not be able to figure out the anthropology of them, but you'd [say], 'Somebody built this. God knows what was in their head at the time, but they built this."[443]

Here I focus instead on those ancient monuments' ability to evoke a cosmological sense of time for Croft. Newgrange, a mound near Dublin, Ireland, thought to have been constructed around 3200 BC, was built and oriented so that its inner tomb floods with light during the solstices. The site, Croft told me, made him "feel like [he is] part of a continuum of human history that extends before and beyond [his] short time on this planet" because it bears on enduring themes of "life and death, the seasons, the movement of astronomical objects."[444] A structure attuned to an inherited cosmos, oriented to signal mutually agreed upon notice-worthy signs threads human millennia and extends into the future represents, for Croft, "a lineage right through…to Breakthrough Listen using an 8,000-ton telescope in the middle of a meadow to try to find out if there are minds up there in

[443] Croft in discussion with the author, February, 2020.
[444] Croft in discussion with the author, July, 2020.

the sky."[445] He reflexively connects prehistoric pasts to human presents to future-oriented alien technosignatures, themselves relics of some an alien past.

If Newgrange is an evocative object that enfolds temporal continuity, it also weirds the familiar. That is, for Croft, Neolithic monuments like it "feel more alien to [him] than the cathedrals that embody the Christian tradition into which [he] was born."[446] Croft continued:

> The idea that there were previous cultures that we only know through what they left behind does connect…with the idea [that] ETI artifacts would be even more 'alien' (in the sense of 'Other') but [would] also still maintain a degree of familiarity. It's a bit like traveling to another country and meeting someone from a different culture where you share no language, but it brings a smile to both of your faces when you make a connection over something and develop some shared understanding.[447]

Croft situates himself between prehistoric, human-made artifacts of the past and future-oriented, extraterrestrial ones that both "feel," by different degrees, alien. According to Croft, technosignatures—like the prehistoric objects—are signs of *minds* at work, which would "help us know ourselves better."[448] In this way, imagined ontological familiarity arising from artifacts extends backward and forward through time and flows through species. Looking back to these monuments of the past leavens lively alien artifacts of the future.

The Human Animal

Engaging with, ignoring, hunting, and eating animals in Green Bank Telescope (GBT), West Virginia is a daily fact of life for the operators and scientists in the facility there, a rural town in the

[445] Croft in discussion with the author, July, 2020.
[446] Croft in discussion with the author, July, 2020.
[447] Croft in discussion with the author, July, 2020.
[448] Croft in discussion with the author, July, 2020.

Allegheny Mountain Range that has a permanent population of only 257 people.[449] At one of the few research sites that is committed to prolonged, enduring SETI research into life *beyond* Earth (Breakthrough claims about 20% of the telescope's time) earthly creatures proliferate, from the flies in spiders' webs that choke the dorms on site to the deer that stalk the woods surrounding the facilities.[450] If the immediacy of these non-human animals at the GBT brings to the fore anthropological exercises of multispecies theorizations, then, at the SETI science site, one might extrapolate those considerations to possible, future-oriented extraterrestrial-human interactions.[451]

In late July of 2016 I was with the Breakthrough team on a research trip at the GBT and we gathered for beer in the late afternoon on the lawn by the dorms where visiting researchers bunk. In the liminal space between day and night, my colleagues speculated about the uncertainty, perhaps the unknowability, of the alien. They wondered: If we received a signal, would we know what it meant? Would it be a blueprint to build a device that defied our understanding of the laws of physics? Would it be a hostile message from extraterrestrial colonizers, demanding compliance? Steve Croft remarked: "We might be like the ants."[452] He gestured to cracks in the sidewalk, where insects scurried in the waning day. "I can observe them and guess that they might be intelligent: they have certain patterns of behavior and they seem to communicate with each other. Yet no matter how many times I wave my arms, *I* can't communicate with *them*. I could only step on them—I guess that's a kind of communication."[453] We all laughed. For Croft, the ants transformed into a temporary reference point to highlight the barriers of cross-species communication. Through thinking with bugs and insects like the ants, Croft frames an analogical scaffolding to articulate humanness in

[449] "ACS Demographic and Housing Estimates," United States Census Bureau, accessed May 15, 2020, https://data.census.gov/cedsci/table?q=green%20bank%20west%20virginia%20population.
[450] Personal communication with the author, Dave DeBoer, Feb. 5, 2020
[451] See the "Special Issue: Multispecies Ethnography" in *Cultural Anthropology* 25, no. 4 (November 2010): 545-687.
[452] Croft in discussion with the author, July 2016.
[453] Croft in discussion with the author, July 2016.

relation to Otherness: aliens might see us the way he sees the ants. His comment illustrates how SETI scientists grope for a meaningful way to talk about the object of their scientific inquiry—the alien—and often look to non-human animals to set up imagined comparisons.

As workhorses of philosophical articulations of difference and subjectivity, animals "bear the burden of symbolic weight," writes Mel Chen, but also, according to Derrida, are "immobilized…within the snare of the imaginary," and thus "depriv[ed]…of any access to the symbolic."[454] Even as they operate in a symbolic economy for humans to refine and deepen their own sense of subject-hood, animals are often barred from the symbolic order, an effect of what Derrida argues has historically been judged their assumed incapacity for language. Western knowledge traditions shaped by René Descartes and Jacques Lacan, among other philosophers, Derrida maintains, have "conceded to the animal some aptitude for signs and for communication," yet ultimately "always denied it the power to *respond*."[455] Croft's analogy posits that humans, like the ants, might be stymied from meaningful communication with ET. An unbreachable difference might block humans' capacity to respond, to use Derrida's word: we would just be squished underfoot without comprehending our doom from some alien foot. Yet, Croft's use of analogy—a "correspondence between two things"—provokes questions about how, invoking Derrida again, thinking "after," "alongside" and "near" non-human animals furnish scientific imaginations of ET.[456] The alien—like the animal, historically theorized as beings of "absolute alterity"—is nevertheless fleshed out through analogical comparison, inviting possibilities of interspecies

[454] Mel Chen, *Animacies: Biopolitics, Racial Mattering, and Queer Affect* (Durham: Duke University Press, 2012), 98; Derrida, *The Animal That Therefore I Am*, 120.
[455] Derrida, *The Animal That Therefore I Am*, 33.
[456] *Oxford English Dictionary Online,* s.v. "analogy," accessed May 18, 2020, https://www.oed.com/view/Entry/7030; Derrida, *The Animal That Therefore I Am*, 10.

correspondence through electromagnetic signaling, premised on hoped-for, mutual capacities to *respond.*[457]

What is it Like to Be an Alien?

On trips to the GBT, I would often go running with Dave MacMahon, who was in charge of the group's computer assemblages. In the lush hills and adjacent woods to the telescopes there we would come across artifacts like defunct machine parts and the skeleton of an old water tower. Over that same research trip in 2016 we explored an old, abandoned house. Thirty years ago, it was probably used as boarding for visiting scientists. (Now we stay in the characterless dorms.) The house's white panels flaked like old bones, entombing ancient computer carcasses that once were used to process observational data. Picking our way up the dilapidated staircase, I tripped and almost fell through the floor, scaring a lone bat who frantically circled our heads before escaping through a window. MacMahon remarked to me that he felt bad we had interrupted its slumber, and how the bat must have used echolocation to reorient itself in front of two "weird creatures."[458] Even if MacMahon could not know what it's like to be a bat, he considered a non-human animal considering us as a moment that elicited pathos, one he projected onto an animal Other.

This event calls to mind philosopher Thomas Nagel's famous essay "What is it Like to Be a Bat?" not only because of its subject, but also because it asks if it is possible to translate human consciousness into other species' experiences, a provocation I have posed to SETI scientists about aliens in my ethnographic fieldwork.[459] In the essay, Nagel challenges a materialist position that posits that mental states can be reduced to physical phenomena; rather, he argues, subjective

[457] Derrida, *The Animal That Therefore I Am*, 11.
[458] MacMahon in discussion with the author, July 2016 and March 2020.
[459] Thomas Nagel, "What Is It Like to Be a Bat?" *The Philosophical Review* 83 no. 4 (1974): 435–450.

consciousness, is irreducible to how the brain assembles sensations.[460] He writes that consciousness "no doubt…occurs in countless forms totally unimaginable to us, on other planets in other solar systems throughout the universe. But no matter how the form may vary, the fact that an organism has conscious experience *at all* means, basically, that there is something it is like to *be* that organism."[461] Nagel writes that while humans can objectively state that bats possess sensory equipment such as sonar, it is impossible to imagine what is like to subjectively *experience* echolocation.[462] For MacMahon, Nagel would argue, the bat's phenomenological experience would be utterly opaque.

Nevertheless, Nagel writes, there is no doubt that a kind of un-experienceable bat consciousness—even alien consciousness—exists, writing, "The fact that we cannot expect ever to accommodate in our language a detailed description of Martian or bat phenomenology should not lead us to dismiss as meaningless the claim that bats and Martians have experiences fully comparable in richness of detail to our own."[463] At the 2020 American Astronomical Society meeting in Honolulu, Hawai'I, Jason Wright echoed Nagel's argument over lunch with me. "I presume that dolphins' thought process make a lot of sense to them," he said.[464] "As far as their epistemology, I can't figure it out because of who I am—not because it's in some weird state that's unknowable in principle."[465] If different species' experiences are not "fully comparable," Nagel's essay and Wright's comment prompt considerations about how SETI scientists navigate unknowability of the alien through appealing to various plays of non-human animals even if alien phenomenology remains ultimately occluded.[466]

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[460] Nagel, "What Is It Like to Be a Bat?", 447-450.
[461] Nagel, "What Is It Like to Be a Bat?", 436.
[462] Nagel, "What Is It Like to Be a Bat?", 438.
[463] Nagel, "What Is It Like to Be a Bat?", 440.
[464] Wright in discussion with the author, January 2020.
[465] Wright in discussion with the author, January 2020. Note: Here, phenomenology, rather than epistemology, might be a better word.
[466] Nagel, "What Is It Like to Be a Bat?", 440.

I brought up Croft's ant example at the Making Contact 2019 workshop, a small group of anthropologists and the Breakthrough Listen team I had organized to discuss this question: "How might thinking about non-human Others generate productive ways to enrich, diversify, and broaden SETI science?"[467] Elaborating, Croft told the group that the ants "don't really bother me until they start moving into the house at night. I worry a little bit. As somebody who's not particularly in favor of METI [messaging extraterrestrial intelligence], we may be the equivalent of the ants moving into [my] house. We might become a problem that would need to be dealt with. It's like, then you're actually agitating."[468] His comments call to mind the alien avatar that haunts science fiction media, whose bugged out eyes, overly large head evokes insects' features. In Orson Scott Card's science fiction novel *Ender's Game,* humans battle aliens they have nicknamed the "buggers."[469] The battle royale to save Earth from alien colonization depends on defeating the extraterrestrial queen who controls her subjects with a hivemind.[470] In the computer strategy game *StarCraft*, the insectoid Zerg Swarm evolves by cannibalizing other species' desired genetic traits.[471] Such aliens make the skin crawl, depicted as antipodal to humans' likeness and values. At that Making Contact workshop, Croft recalled hearing about an experiment in which researchers painted pheromones on ants to trigger them to rip each other's heads off.[472] Speaking as the ants who turned on their fellow colony members, he joked to the group, "You're no longer one of us, you've become the Other."[473]

STS scholar Clapperton Mavhunga explores how those in power objectify other humans through defining them as pests, especially insects. Mavhunga argues that British colonial forces in what was then Rhodesia during apartheid in the mid-20th century relegated humans to vermin to

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467 "Making Contact 2019," Making Contact, accessed May 2020, https://www.makingcontact2019.org/.
468 Croft in discussion with the author, August 2019.
469 Orson Scott Card, *Ender's Game* (New York: Tor, 1985).
470 Orson Scott Card, *Ender's Game* (New York: Tor, 1985).
471 Chris Metzen and James Phinney, *StarCraft*, multimedia game (Irvine: Blizzard Entertainment, 1998-present).
472 Croft in discussion with the author, August 2019.
473 Croft in discussion with the author, August 2019.

sanction policies of elimination.[474] White Rhodesians extended of the stereotype of Black Africans as simians to killable guerilla terrorists.[475] Conflating undesired human beings with pests in nature (unwanted animals, invasive plants), military British cadres justified dosing people with pesticides (anthrax-laced cigarettes, food tins contaminated with thallium, wells polluted with cholera).[476] In this way, material practices of domination mobilized the "descent of human beings into human game (animals hunted for food and sport but not normally domesticated, or that which is 'fair game') and even further, into a *vermin being* (pestiferous being in need of elimination)."[477] Mavhunga further argues that guerilla resistance fighters did not remain "mute" as they found ways to resist colonial rule, such as acting to subvert land mines intended for them.[478] In fact, he argues, colonialists' very framing of the resisters as pests "is to acknowledge their resistance or that they simply moved about in ways the colonial regime saw as resistance."[479] That is, "pestilence is a means and description of the kinetics of escape" because it calls attention to the ways in which the guerillas protested and were consequently categorized as vermin.[480]

To be constituted as a pest, then, according to Mavhunga, is to not be "mute," implying the capacity to "speak." In what way is the power of speech linked to agential worth? In a sprawling lecture series, Jacques Derrida in "The Animal that Therefore I Am" similarly addresses animals' possible ways of "speaking." Inspired by the shame he feels confronted by his cat witnessing him naked, Derrida endeavors to "follow" the animal, that is, trace its tracks, to uncover its potency in structuring philosophies of the human in relation to the Other.[481] (In French, *je suis* doubles as "I

[474] Clapperton Mavhunga, "Vermin Beings: On Pestiferous Animals and Human Game," *Social Text 106* 29, no. 1 (Spring 2011): 156-159.
[475] Mavhunga, "Vermin Beings," 161-162.
[476] Mavhunga, "Vermin Beings," 160-168.
[477] Mavhunga, "Vermin Beings," 152.
[478] Mavhunga, "Vermin Beings," 155-164.
[479] Mavhunga, "Vermin Beings," 152.
[480] Mavhunga, "Vermin Beings," 154.
[481] Derrida, *The Animal That Therefore I Am*, 39.

am" and "I follow.") Derrida points to the "abysmal rupture" that distinguishes the "so-called" man from animal, a Cartesian cut that ignores a "heterogeneous multiplicity" of living creatures.[482] He problematizes other philosophers' denials of animals' "power to respond—to pretend, to lie, to cover its tracks or erase its own traces" by pointing out that such a delineation drives man's self-conception actually toward the Other he purports to disavow; that is, man's adjudication that animals lack the ability to respond actually "confirm[s] not only the animality that he [man] is disavowing but his complicit, continued and organized involvement in a veritable war of the species."[483] If Descartes's "*Je pense donc je suis*" is the *cri de cœur* that established an I/Other opposition through *thinking* and *declaring* through an appeal to God and a rejection of Nature, Derrida's tracking and sniffing out of various philosophical scents produces a persistent "critical uneasiness" that never fully resolves.[484] Still, he offers up *animot*—a play on the French words *mot* (word) and *animaux* (animals)—a concept that pluralizes the monolithic animal Other, embedding it with an un-hearable difference from its written form.[485] This subversion calls attention to "neither a species nor a gender nor an individual," but instead, an "irreducible living multiplicity of mortals…a monstrous hybrid."[486]

Derrida's insistence to take animals seriously—especially attending to their capacity to suffer—suggests powerful ways that the Other matters when humans conceptualize, refine, and contemplate themselves.[487] While Derrida demurs from further philosophizing gender and sexuality (qualities often contingent on the construction of Otherness) alongside the animal, feminist and multispecies scholars, unsettled by theoretical moves that trap the animal—and its associates,

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[482] Derrida, *The Animal That Therefore I Am*, 31.
[483] Derrida, *The Animal That Therefore I Am*, 31-33.
[484] Descartes, René. 1978 [1637]. *Discourse on Method*, in *The Philosophical Works of Descartes*, trans. Elizabeth Haldane and G. R. T. Ross, vol. 1, 80-106. New York: Cambridge University Press.
Derrida, *The Animal That Therefore I Am*, 33.
[485] Derrida, *The Animal That Therefore I Am*, 41.
[486] Derrida, *The Animal That Therefore I Am*, 41.
[487] Derrida, *The Animal That Therefore I Am*, 27.

women and nature—in linguistic loops, now emphasize materialisms to root critical analyses of human/animal becomings. Consider a handful of many rich examples: In Donna Haraway's practice of "material-semiotics" that merges matter with signs, dogs and human communicate and train each other, correlating "ontics and antics of significant otherness."[488] Deborah Slicer jokes, teases, and laugh with a "cool, middle-aged guy"—that is, Kip, a sixteen-year-old black quarter horse.[489] Eva Hayward's enmeshment with cup corals, and their decidedly un-human-like modes of sensing through what she calls "fingeryeyes" is "navigated by constantly accessing the medium of the meeting and the accompanying beings and things."[490] For these writers and others who have prodigiously catalogued how all manner of creatures come to materially matter to humans, interspecies engagements are crucial to new conversations about, and configurations of, ethics, agency, selfhood, difference, and Otherness.

In what way does the alien matter? It cannot be eaten, caressed, fed, caged, slaughtered, snuggled, brushed, squashed. It cannot be sacrificed to a god for safe passage, domesticated to apartment living, nor pulverized into deli meat. Does this lack of immediate materiality circumvent theorizations of humans' moral responsibility to them or assignations of agency of them? I refer to ET uneasily as "it," unable to avoid entrapping the alien statically in the singular—a seemingly unavoidable blunder that Derrida attempts to subvert, if not solve, with his neologism *animot*. SETI scientists potentialize the alien with a capacity for language, but it has yet to "speak": they have yet to capture the alien's "tracks" through a technosignature.[491] Evading specificities of time, materiality, and language, how do scientists make meaning around the alien being?

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[488] Haraway, *When Species Meet*, 165.
[489] Deborah Slicer, "Joy," in *Ecofeminism: Feminist Intersections with Other Animals and the Earth*, ed. Carol J. Adams and Lori Gruen (New York: Bloomsbury, 2014), 61-69.
[490] Eva Hayward, "Fingeryeyes: Impressions of Cup Corals," *Cultural Anthropology* 25, no. 4 (2010): 580.
[491] Derrida, *The Animal That Therefore I Am*, 33.

I contend, to use Derrida's phrase, that alien mattering is "a question of words," in particular, scientists' use of analogies to imagine themselves in relation to an as-yet-silent being.[492] In Croft's example, humans are "like" the ants, and aliens would be "like" the humans. I wanted to reexamine Croft's comments at the GBT and the Making Contact 2019 workshop, so we spoke over Skype in February 2020. He again revisited the ants to imagine how humans might matter to ET, but added more insects to his analogical menagerie:

> I am somebody who kind of moves insects out of the way, generally speaking, [but] a mosquito will die [if it's] in my house. I get pretty good at like hitting them with my slipper…Maybe [I'm] leaving too many like slipper marks on the wall…I'm also pretty good at getting fruit flies out of midair in my hand. If you're going to bug me, if the ants get in the sugar, then you know, I'm sorry, all bets are off.[493]

Croft's model adds another species-being—the alien—to an echeloned model of worthiness foundational to the Western canon's obsessive impulse to catalogue, categorize, and differentiate, a tradition that originated from ancient Greek philosopher Aristotle's *scala naturae*. Philosopher Arthur Lovejoy's definitive lectures at Harvard in 1933 describe how a Great Chain of Being ranked all matter in levels of perfection.[494] What Lovejoy terms an "ontological scale" ascended from rocks "to the rational characteristic of man" and then to "possibly another kind superior to his."[495] Minerals, plants, animals, man, ethereal beings (angels), and finally god (later cemented as the Judeo-Christian God) each occupied a unique place on the ladder. Lovejoy roots Aristotle's *scala naturae* in that ancient philosopher's predecessor Plato's *plenum formarum*, the idea that the universe is filled with an awesome abundance of creatures and materials in which "difference of kind [was] treated as

[492] Derrida, *The Animal That Therefore I Am*, 33.
[493] Croft in discussion with the author, Feburary 2020.
[494] Lovejoy, *The Great Chain of Being*, 58.
[495] Lovejoy, *The Great Chain of Being*, 58-59.

necessarily equivalent to difference of excellence."[496] That is, according to Lovejoy, tenets of the ancient cosmos—"plenitude, continuity, gradation"—imbued all materials with specific moral meaning through ontological hierarchization.[497]

Croft's imagining of humans as possible pests in relation to the alien reinstalls aspects of the Aristotelian Great Chain of Being that cycled through Christian doctrine for millennia. In analogical form, ET: human :: human : animal—in particular, possible pests. Humans would be less worthy—killable, even—because we would be so much less sophisticated, according to Croft:

> Maybe the answer to the Fermi paradox is that we haven't gotten to be so annoying yet. You know, it's not the zoo hypothesis [either] where they're watching us and they don't care about us. It's like, if you get into sugar, then they're going to come along and you know, terminate with extreme prejudice. Maybe we should be careful…[498]

(Here, Croft is referring to two theories within SETI lore about why humans have not yet intercepted a technosignature. Italian physicist Enrico Fermi's paradox, discussed earlier, boils down to the question, "Where is everybody?"[499] Meanwhile, the zoo hypothesis, a possible explanation to the paradox posits that technologically skillful aliens know about Earthlings, but we are like animals caged in a zoo with a one-way mirror: gawked at, or merely tolerated by them, and unaware of their gaze.)

Dave DeBoer, the Project Manager at Breakthrough, elaborated on Croft's comment—humans are inconsequential until we "bug" the aliens—at the Making Contact 2019 workshop. I was setting up a presentation for the group when DeBoer recalled a scene in the sci-fi movie *Contact* (many in the SETI community attest that the main character of Carl Sagan's book that was adapted

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[496] Lovejoy, *The Great Chain of Being*, 64.
[497] Lovejoy, *The Great Chain of Being*, 183.
[498] In discussion with the author, March 2020.
[499] For an in-depth discussion of the Fermi paradox, see Chapter 6 in Paul Davies' *The Eerie Silence: Renewing Our Search for Alien Intelligence* (New York: Houghton Mifflin Harcourt, 2010).

into that movie is based on Jill Tarter). DeBoer summarized for the group how Dr. Ellie Arroway, the protagonist who first intercepted an alien radio communication, advocates for building the machine aliens had designed.[500] At a high-level meeting at the White House, Arroway bristles at the suggestion that the machine would be dangerous to use. "There is no reason whatsoever to believe the ETI's [extraterrestrial intelligence's] intentions are hostile," she tells the President of the United States.[501] "We pose no threat to them—it would be like us going out of our way to destroy microbes on a beach in Africa."[502] (Note that microbes, even lower than a bug, perhaps, on the *scala naturae,* are further diminished by their location.) The group at Making Contact laughed, and we moved on with the next presentation.

In conversation with me over Skype, Croft imagined a similar scenario: "It's not that they [ET] don't like what you have to hear. You might be something so inconsequential to them that they'll brush you away. Like you would brush away, you know, a wasp that's trying to get into your beer."[503] Not only might humans be a fleeting nuisance to aliens, we might simply be utterly beneath notice or care: "The idea that they're going to be at all interested with, you know, supplying us with the blueprints for the hyperdrive or like helping us solve human longevity or climate change or whatever," Croft continued, "seems to me about as realistic as that we're going to take time out of our day to go and like, help the ants out."[504]

I revisited the movie *Contact* after DeBoer mentioned it at the workshop. In that same scene, the character Dr. David Drumlin—Arroway's foil who outmaneuvers her to gain the single spot on the alien machine that indeed gets built—replies, "Interesting analogy. And how guilty would we feel

[500] In discussion with the author, August 2019.
[501] Robert Zemeckis, dir., *Contact* (Los Angeles: South Side Amusement Company, 1997).
[502] Zemeckis, *Contact*.
[503] Croft in discussion with the author, February 2020.
[504] Croft in discussion with the author, February 2020.

if we happened to destroy some microbes on a beach in Africa?"[505] (His implication is: not guilty at all.) Croft offered a different reply to Drumlin's unanswered question, drawing instead on another bug example to clarify his point. He felt bad about a spider in the shower he had declined from rescuing from a watery death—"It was going to be a whole rigmarole," he said, sighing.[506] He would have had to pause his shower, get a towel, scoop it up, take it outside, etc.[507] As he reflected on this event over the next couple of days, Croft began to compare himself to a "potential beneficent super intelligence not reaching down and helping [the spider]."[508] A week later, another spider appeared in the shower. "Maybe we have a spider infestation or something," he told me, chuckling.[509] Thinking, "I don't want to go through that again!" Croft bore the hassle of helping it, and rescued it by taking it out of the shower.[510] (Perhaps philosophical musings while naked, like Derrida with his cat, should be considered its own genre?)

Croft need not imagine what it is like to be a spider, ask if it wants to be rescued, or admonish it from future watery adventures, in order for that critter to kindle remorse in him in such a way that affected his actions in the future. It was worth his effort, in that second instance, to elevate the spider's worthiness to avoid what might have been even more intensified guilt over its otherwise likely death later. Anthropologist of science Luísa Reis Castro describes how humans assign different valances of care to another bug, the mosquito, through a concept she terms "becoming without."[511] The mirror of Donna Haraway's "becoming with" that examines meaning-making emergent from human/dog encounters, Reis Castro's "becoming without" inversely highlights human/pest "non-encounters," a reordering that destabilizes received notions of species-

[505] Zemeckis, *Contact*.
[506]Croft in discussion with the author, February 2020.
[507] Croft in discussion with the author, February 2020.
[508] Croft in discussion with the author, February 2020.
[509] Croft in discussion with the author, February 2020.
[510] Croft in discussion with the author, February 2020.
[511] Luísa Reis Castro, "Becoming Without: The Rearing and Release of Transgenic Mosquitoes in Brazil" (under review, June 2020), 8.

worthiness.[512] Her ethnographic fieldwork with scientists in Brazil narrates how the state's quest to exterminate the disease-carrying mosquito *A. aegypti* ironically depends on the cultivation of its transgenic counterpart, a sterile version that, when released into cities, will inhibit the species' overall reproducibility. As they work toward the pest's eradication, lab workers engage in exercises of care, such as selectively breeding males that "wild" *A. aegypti* females would find more desirable, and even giving mosquitos tastes of human blood (the critters prefer it to the usual goat blood).[513] Reis Castro theorizes that "mosquitoes are made valuable through the expectation that transgenic mosquitoes will *become with* their wild conspecifics, so that humans can *become without* them."[514] Croft's delimitations of which insects' lives are worthy of being saved, dependent not only on which species he is encountering (or choosing to *not* encounter), but his mood, and how far they edge in to particular spaces (his house, his shower, the sugar bowl). Reis Castro's concept of "becoming without" is a tool to evaluate imagined and promissory species-worthiness for pests iterated beyond the present moment (such as: future-oriented sterile populations of *A. aegypti* or potentially pestilent humans that aliens might "non-encounter," to use her term).[515]

Close examination of Croft's remarks reveals contradictory, contextual, and complicated attitudes towards insects and bugs. Musing over beer at the GBT, he might recognize ants as possibly intelligent, but "disavows" them from the capacity to communicate (and live).[516] Later, he tolerates ants, mosquitos and flies to a degree, but has no compunction exterminating them if they migrate into his house. A wasp barely registers and is brushed away, a momentary inconvenience that could result in its harm (although inadvertently). In the last example, a spider once considered burdensome triggers a feeling of guilt and elicits a different response from him the next time. These

[512] Reis Castro, "Becoming Without," 4.
[513] Reis Castro, "Becoming Without," 10.
[514] Reis Castro, "Becoming Without," 4.
[515] Reis Castro, "Becoming Without," 4.
[516] Derrida, *The Animal That Therefore I Am*, 31.

considerations are then extended into alien analogies: we might be *like* the unaware ants / the invasive spider / hungry fruit flies / a beer-guzzling wasp in relation to the alien Other. These critters generate feelings of insouciance, annoyance, animosity, and guilt in Croft—responses that he speculates, reflexively, Earthlings might evoke in aliens.

Crucially, in these analogies, alien, animal, and human are briefly confused in Croft's speech, taking up each other's places on hierarchical levels of value in subsequent sentences and even phrases. The "you" getting into the sugar bowl, a bottle of beer, or inside the house bounces between different beings sometimes in the same breath. In this way, Croft wades in to imagining an alien whose certain cultural norms and priorities would inform their qualitative judgements of Earthlings' perceived worthiness depending on our particular behaviors. Insects are ignored or tolerated until they are pestilent and transform into killable vermin—just like the humans Croft imagines might bug aliens. The spider offers the possibility of a reversal of initially assigned pestilence. In the shower, imagining himself as the spider in relation to the alien, Croft takes on the role of a super-intelligent ET who, he anticipates, would feel an *obligation* to help out a lesser being.

The God-like Alien

In her 1966 science fiction novel *Rocannon's World*, the essential Ursula K. Le Guin created a device called the ansible, "which can speak instantly to other worlds, with no loss of years."[517] Orson Scott Card used a similar device in *Ender's Game* and other books of his beloved series as a way to keep track of characters who, although they experience the passage of time unevenly as they move through the universe at relativistic speeds, can communicate instantaneously through quantumly

[517] Ursula K. Le Guin, *Rocannon's World* (New York: Ace Books, 1966), 29.

entangled ansibles.[518] Unless ET has planted such a device as an Easter egg in our local solar system, humans are stuck with trying to intercept messages from ET that will have left their source thousands, if not millions, of years ago.[519] Electromagnetic signals arrive with a timestamp as a result of what Tarter has called in our conversations "the tyranny of lightspeed."[520] A quasar's light from the early universe is only just now reaching Earth ten billion years after photons started the trek across spacetime. Light from the sun's closest neighbors, the Alpha Centauri system, takes over four years to reach terrestrial telescopes. If the sun were to defy the laws of physics and wink out of existence, it would still take humans over eight minutes to notice. For observers on Earth, then, light paints a portrait of the past.

Earthlings have only been competent in radio technology for a little over a century, when Italian inventor Guglielmo Marconi patented a wireless telegraphy system in 1901.[521] SETI scientists only sent a high-intensity, intentional message in 1974, when Frank Drake and Carl Sagan directed the "Arecibo Message" to globular cluster M13.[522] Today, if Tarter were to use the Allen Telescope Array to intercept a deliberately transmitted message from ET, those photons would have been sent, say, tens of millions of years ago. If that transmitting ET mirrored human development, then they would be millions of years older relative to Earthlings at the timestamp of the technosignature—with, perhaps, futuristic technology. SETI scientists must also take into account the lifetime of an alien species as a factor of their observability. This premise is sketched out in the Drake equation's L value: "The length of time [alien] civilizations release detectable signals into space."[523] If ET developed radio technology 50 million years ago but only transmitted for a few hundred years,

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[518] Orson Scott Card, *Ender's Game*, 3rd ed. (New York: Tor, 1991).
[519] The deduction bars exotic, surprising technosignatures, such as those speculated to be embedded in human DNA, or encoded into a gravity wave.
[520] In discussion with the author, May 2018.
[521] "Guglielmo Marconi," The Nobel Prize, accessed May 2, 2020, https://www.nobelprize.org/prizes/physics/1909/marconi/biographical/
[522] Steven J. Dick, *The Biological Universe* (Cambridge: Cambridge University Press, 1996), 440.
[523] "Drake Equation," SETI Institute, accessed May 1, 2020, https://www.seti.org/drake-equation-index.

scientists using radio telescopes today would have a slim chance of temporally overlapping with ET's commensurable technology. Historian of science David Kaiser reads Drake's L term as a byproduct of the Cold War era. If Cocconi and Morrison's 1959 paper imagined that lively, benevolent beings would develop radio technology, he writes, Drake's L term was, by contrast, "stand-in for all-out nuclear war."[524] If Earth at 1960 was a predictive model, it stamped an expiration date on any species' lifetime.

This deduction correlates aliens' biological lifetimes with SETI's probability of ascertaining a technosignature. As Steve Croft explained to me at the Breakthrough Listen lab, "If L is small, we're not likely to find them. If L is big, then we have more of a chance. Thinking with…statistics, if we find [ET], they're probably long-lived, because your chances of drawing a 100-year old civilization out of a distribution that goes from zero to 100 million years is small; you're going to find ones that have technology for 50 million years on average."[525] Tarter elaborated on this view over a Skype conversation in February 2020. She told me she "often thinks about the distribution of the ages of technological civilizations as probably being bimodal: there are a whole lot that are short-lived. We'll never contact them because they won't overlap with us."[526]

Considering that a technosignature would more likely come from an older source, how do SETI scientists conceptualize humans' possible L value to anticipate a long-lived alien? On a trip to the Allen Telescope Array in 2016 with the SETI Institute interns, Tarter repeated a well-worn phrase in the SETI community while we were chatting after a presentation: scientists are "searching for ourselves."[527] Yet over tea in 2018 at her house nestled high in the Berkeley hills, Tarter revised that mission statement. In sifting for technosignatures, she told me then, "We're basically looking

[524] David Kaiser, *Quantum Legacies: Dispatches from an Uncertain World* (Chicago: University of Chicago Press, 2020), 209.
[525] Croft in discussion with the author, March 2020.
[526] Tarter in discussion with the author, February 2020.
[527] Tarter in discussion with the author, July 2016.

for humans on steroids because we're not very good at envisioning something we can't conceive. We're looking for a highly advanced version of ourselves that makes the same kinds of technology."[528] I look to Tarter's two phrases—ET as "ourselves" but also, a "highly advanced version of ourselves"—to parse a scientifically imagined god-like alien that is both human-esque but *beyond* humans morally, technologically, and biologically.

Versions of the alien who are marked as god, god-like, or god-adjacent are found in science fiction and other cultural reference points. In the 1994 film *Stargate*, archaeologists tunnel into an alternate version of ancient Egypt, in which the aliens appear as deities Ra (the sun-god) and Anubis (god of the after-life).[529] Ron L. Hubbard's controversial and eccentric religion Scientology, which counts actors John Travolta and Tom Cruise among its devotees, teaches that a "thetan"—an immortal being in a human body—has experienced past lives as an extraterrestrial.[530] In their 1966 book *Intelligent Life in the Universe*, astrophysicists Iosif Shklovsky and Carl Sagan, although they assiduously specified that such an event is improbable, leave room for the hypothesis that ET could have visited Earth.[531] This idea, in part, spurred the concept of "ancient astronauts," perhaps most famously explored in Erich von Däniken's 1968 book *Chariots of the Gods? Unsolved Mysteries of the Past* that argues that artifacts like the Moai of Easter Island, Egyptian pyramids, and Neolithic structures such as Stonehenge were alien structures (or created by humans with alien help).[532] Also within that genre, notably, author Zecharia Sitchin has proposed that the ancient Sumerian gods, the Anunnaki, were actually extraterrestrials who created that civilization.[533]

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[528] Tarter in discussion with the author, April 2018.
[529] Roland Emmerich, dir., *Stargate* (Paris: Canal+, 1994).
[530] Lawrence Wright, *Going Clear: Scientology, Hollywood, and the Prison of Belief* (New York: Alfred A. Knopf, 2013).
[531] Iosif Shklovsky and Carl Sagan, *Intelligent Life in the Universe* (San Francisco: Holden-Day, 1966).
[532] Erich von Däniken, *Chariots of the Gods? Unsolved Mysteries of the Past* (New York: Putnam, 1968). See also historian of science Michael D. Gordin's discussion of von Däniken's work in *The Pseudoscience Wars: Immanuel Velikovsky and the Birth of the Modern Fringe* (Chicago: University of Chicago Press, 2012). A study in the social levers that delineate "real science" from conspiracy theories, Gordin briefly contrasts von Däniken's popular success of *Chariots of the Gods*—what the author would proclaim was a work of fiction—with scientists' damning assessment of Velikovsky's work (176-178).
[533] Zecharia Sitchin, *The 12th Planet* (New York: Stein and Day, 1976).

This section, meanwhile, explores the implications of SETI scientists' reasoning that a technosignature they might intercept will be from an alien that they will have followed, exceeded, and improved humans' evolutionary trajectory. Elaborating on Tarter's comment, and employing the logic of the Drake Equation that Croft laid out, ET becomes an idealized version of humanity—ET is us, iterated into the future. I emphasize the term god-*like* to attend to that figure's middle position between mortal and immortal domains. According to SETI scientists, what I name the god-like alien is beyond humans but represents a future that humans *could* achieve: peaceful, with magical technology could even create life.

More Peaceful

Avi Loeb offered a reason for why scientists might not find technosignatures from short-lived societies in interview in *Spiegel International*: "Most civilizations might be very short-lived," he said.[534] "In other words: I'm afraid that they don't take good care of their home planet and that in the end they will destroy themselves—by nuclear wars, by interventions in the climate, by environmental destruction."[535] How could ET have avoided this outcome? Tarter told me over that Skype conversation, "Some of them [ET] may manage to surmount some kind of barrier. Some of them [may] figure out how to tunnel over into that other population of long-lived and essentially become infinite in their lifetime, probably as long as the universe allows."[536] I asked Tarter: "What kinds of barriers was she referring to? What would ET have had to overcome for us to receive a signal, other than creating and manipulating radio instruments?" She replied:

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[534] Johann Grolle, "Avi Loeb on the Mysterious Interstellar Body 'Oumuamua," Spiegel International, July 1, 2019, https://www.spiegel.de/international/zeitgeist/astronomer-avi-loeb-on-the-interstellar-body-oumuamua-a-1246803.html
[535] Grolle, "Avi Loeb."
[536] Tarter in discussion with the author, February 2020.

> Look around you. Look at all of these existential problems that we're facing. Hunger, food security, water security, climate change, nuclear proliferation, I guess Space Force now? All of those challenges need to be solved globally. It does no good for America to ensure its water supply [while] the rest of the planet is drying up. I think that the one really good thing about searching for technosignatures [is that]…it has to put [people] in a different frame of reference. They have to understand themselves in a cosmic perspective. That's great groundwork for then being able to see themselves as an Earthling and work with other Earthlings to find solutions to these challenges. That's my sense of optimism.[537]

Think back to Joshua Lederberg's fears of nuclear destruction in the Cold War era, and how anxiety informed his advocacy for policies for missions to the Moon and Mars to prevent contamination *[chapter 1]*. Today, an additional concern, climate apocalypse, gets mapped onto potential extraterrestrial organisms. If Lederberg envisioned that uncovering extraterrestrial life would allow exobiologists to theorize a universal biology, Tarter's same "cosmological perspective" is one that could connect technologically commensurable species. Moreover, this perspective could cultivate ways for humans to be more peaceful, more just, and more equitable.

This benevolent ET might even play a nurturing role for wayward humans, teaching us to use technology for good. In an interview with me, Dan Wertheimer, a Senior SETI scientist at Berkeley (but not affiliated with Breakthrough group), remarked in 2016, "I do really buy into the '60s view that advanced civilization worth its salt has stopped killing. [Maybe] they're interested in helping young, emerging civilizations."[538] He told me ET might help us log onto some kind of "galactic internet" so we could "start talking to everybody."[539] Still, Werthimer does not advocate for sending a message out into the void; in his mind, it would be too great a risk to attract alien

[537] Tarter in discussion with the author, February 2020.
[538] Wertheimer in discussion with the author, March 2018.
[539] Wertheimer in discussion with the author, March 2018.

attention. On a shuttle ride from Campbell Hall to his other office across campus, he imagined that ET, if they surmised Earthlings' presence, might "want to come and take our niobium."[540]

In the February 2020 Skype interview, Tarter disputed this risk, linking ET's large L value, their technology that would have developed past humans', and their imagined-to-be peaceful intentions. If Norm Horowitz invoked Christopher Columbus to justify exobiologists' mandate to explore other worlds in the 1960s, Tarter invokes the trope of European explorers standing in for alien Others with a hopeful spin:

> Opposed to Stephen Hawking, who famously said [exploration] didn't work out very well for the Natives when Columbus showed up, I think these alien Columbuses, if they have the technology to get here, may in fact not be a problem for us. Because in order to get to be old and stable and still be technological, I think they've had to outgrow all of the wildness and aggressive behaviors that probably helped us to become intelligent in the first place…you know, the better nature of us.[541]

In this moment, Tarter sets up a hierarchical analogy measured by technological capabilities, linked to longevity and developed empathy. Despite the squishiness of the Drake Equation, her comments underscore the L term's deep implications for scientific imaginations of the alien. For her, a *findable* ET is one for whom technology *and* morality would have progressed linearly and in tandem. Aliens would not only be older, but also wiser, gentler, and fluent in technology humans have not yet developed. Through imagining beings who are "infinite in their lifetime," but also embody "the better nature of us," Tarter invokes a god-*like* alien. Enduringly peaceful and technologically "advanced" in their ability to travel to Earth, ET is imagined as humanity's good aspects distilled and stretched across spacetime.

Creators of Life

[540] Wertheimer in discussion with the author, June 2018.
[541] Tarter in discussion with the author, February 2020.

Avi Loeb advocated in a 2018 *Scientific American* blog post that humans should leave Earth to "compile a sociological census of billions of exoplanets," and could potentially find "faith-based alien cultures" that would illustrate "the diversity of galactic interpretations of the concept of God."[542] Loeb's explicitly religious language around the alien is unusual among SETI scientists. In another blog post a year later, he argued that "members of [an alien] civilization would appear to us as a pretty good approximation to God."[543] Although Loeb and I have both attended SETI Breakthrough Listen conferences and events, we had never met, and so I proposed an interview. In a phone conversation I did with him in March 2020—we had planned to meet in person at the annual Breakthrough Discuss Conference in Berkeley that was canceled due to the coronavirus—I asked Loeb to explain his view of the intersection of intelligence, technology, and divinity, based on those blog posts. He told me: "It's possible that life was planted on Earth by another civilization. They're watching us, and I'm sure if they are they are quite disappointed by their failed experiment. But in that case, whatever attributes were assigned to God in creating life can be given to its experimentalists. And in that sense, they [ET] serves as God if they independently created life."[544]

In Loeb's imagining, ET is not the Judeo-Christian God—singular, immaterial, enduring forever—but divine-like in the sense that they can create life, as in the origin story of the Bible, Genesis. Like that God, ET is "watching us," their creation.[545] ET does not operate as Old Testament God—demanding blood sacrifice, jealous of false idols, handing down laws from on high—but instead as a powerful experimenter, with humans in a cosmological petri dish.

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[542] Abraham Loeb, "Are Alien Civilizations Technologically Advanced?", *Scientific American Blog,* January 8, 2018, https://blogs.scientificamerican.com/observations/are-alien-civilizations-technologically-advanced/.
[543] Abraham Loeb, "Advanced Extraterrestrials as an Approximation to God," *Scientific American Blog,* January 26, 2019, https://blogs.scientificamerican.com/observations/advanced-extraterrestrials-as-an-approximation-to-god/.
[544] Loeb in discussion with the author, March 2020.
[545] Loeb in discussion with the author, March 2020.

Approximal divinity, according to Loeb, is marked by technoscience rather than spirituality. Loeb told me:

> We might ourselves create life at some point in our laboratories. I cannot exclude the possibility that we will understand cosmology or the emergence of our universe well enough to the point that we will be able to create a universe in the laboratory, just like we create life in the laboratory. Our universe [might have been] created inside the laboratory of another civilization. We will create one once we become sufficiently advanced. It's just like a mother having a baby and the baby having another baby. Even though each generation would live for a finite amount of time, you end up getting continuation of universes, one born inside another. And in that case, we are playing the role of God not just in creating life, but also creating the first chapter of Genesis in the Old Testament in the Bible.[546]

His retelling of the creation myth wrests reproduction out of the realm of the body and finds it instead in the laboratory. Loeb's speculation transposes motherhood to technological genesis, an act we could read through feminist scholar Susan Bordo's analysis of the masculinization of nature through modern experimentation. Analyzing Rene Descartes's *Meditations*, Bordo describes his epiphany—"je pense, donc je suis"—as an declaration of selfhood that strictly separated outside (chaotic, unknowable nature) from inside (spiritual, objective, God-given).[547] This epistemological cleavage, what she calls a "flight from the feminine" is wrought through the "re-birthing and re-imaging of knowledge and the world as masculine."[548]

Loeb analogically transplants divine ability to alien experimenters, and finally to an imagined path that humans might take. Two decades earlier, in a 2001 paper that reviewed the history and directions of SETI, Tarter also imagined alien creators that would produce communicative technology that would outlive their biological creators: alien who were short-lived but who would have "disperse[d] a large number of effectively-immortal [sic] robotic emissaries."[549] Advanced alien

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[546] Loeb in discussion with the author, March 2020.
[547] Susan Bordo, "The Cartesian Masculinization of Thought," *Signs* 111, no. 3 (Spring 1986): 441.
[548] Bordo, "The Cartesian Masculinization of Thought," 441.
[549] Jill Tarter, "The Search for Extraterrestrial Intelligence (SETI)," *Annual Review of Astronomy and Astrophysics* 39 (2001): 520.

science would "approximate"—but not equal—God's role in creating life (Loeb); it could produce technology that would be "effectively immortal" (Tarter), but evade immortality itself. In this way, the alien emerges as god-*like*.

Magical

The "interstellar interloper" 'Oumuamua, first seen at the Haleakalā Observatory in Hawai'I on October 19, 2017, was the first observable object to have traveled between solar systems.[550] Although SETI scientists tracked it in the radio spectrum to see if it might be "alien artifact," they did not uncover any technosignatures.[551] Still, the evocative object caused Loeb to wonder in a 2019 paper he coauthored with Harvard postdoc Shmuel Bialy whether 'Oumuamua "might be a fully operational probe sent *intentionally* to Earth's vicinity by an alien civilization."[552] Other anomalies—the object's unusual and varying brightness and its rocket-like trajectory incongruent with those of comets or asteroids—spurred Loeb in that paper to consider all possible explanations of its origin. He even suggests in a 2018 *Scientific American* blog post on the subject that 'Oumuamua could act as a "buoy," a signaling device for ET in the sea of space.[553]

In this case, 'Oumuamua—geological but artificially manipulated—would appear "magic" according to Loeb in a 2019 *New Yorker* article in which he expanded on the scientific paper and

[550] "'Oumuamua," NASA, accessed May 1, 2020, https://solarsystem.nasa.gov/asteroids-comets-and-meteors/comets/oumuamua/in-depth/.
[551] Matija Ćuk, "The Three Surprises of 'Oumuamua," January 30, 2018, https://www.seti.org/three-surprises-oumuamua.
[552] Shmuel Bialy and Abraham Loeb, "Could Solar Radiation Pressure Explain 'Oumuamua's Peculiar Acceleration?", forthcoming in the *Astrophysical Journal Letters*, posted on Arxiv November 8, 2018, https://arxiv.org/pdf/1810.11490.pdf: 4.
[553] Abraham Loeb, "6 Strange Facts about the Interstellar Visitor 'Oumuamua," *Scientific American Blog*, November 20, 2018, https://blogs.scientificamerican.com/observations/6-strange-facts-about-the-interstellar-visitor-oumuamua/.

blog post.[554] Calling upon influential writer Arthur C. Clarke's adage—"Any sufficiently advanced technology is indistinguishable from magic"—Loeb imagined an ancient human looking at a cellphone:[555]

> An advanced technological civilization is a good approximation to God. Suppose you took a cell phone and showed it to a caveperson. The caveperson would say it was a nice rock. The caveperson is used to rocks. So now imagine this object—'Oumuamua—being the iPhone and us being the cave people. We look at it and say it's a rock. It's just an unusual rock. The point of this analogy is that, for a caveperson, the technologies we have today would have been magic. They would have been God-given."[556]

As Tarter does, Loeb forms a hierarchical sequence of being based on technological prowess, and in this instance, ET is so advanced in comparison to humans that alien technology would seem to have supernatural origin (rather than morally advanced).

Along those lines, ET might even resemble a god. Often joking that the Breakthrough team must be like the aliens to me, the resident anthropologist, Croft commented in a group discussion in 2020, "It strikes me that when the Spanish arrived, like Cortés, Aztecs thought he was Quetzalcoatl because he came from the East and was white-faced and he vaguely fit the description and they shoe-horned him into [it]: 'He vaguely fits our scriptures! The God from the East is back!' [Cortés] took advantage of that and destroyed [the Aztec] civilization. Maybe there's a lesson there."[557] The scientists chuckled. In Croft's half-hearted joke—Let's hope ET is not like Cortés!—he places himself, however briefly, in the frame of mind of the Aztecs witnessing something supernatural. I present his comment not as a deeply functioning analogy that Croft engages to do SETI science, but

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[554] Avi Loeb, "Have Aliens Found Us? A Harvard Astronomer on the Mysterious Interstellar Object 'Oumuamua," interview by Isaac Chotiner, *The New Yorker,* January 16, 2019, https://www.newyorker.com/news/q-and-a/have-aliens-found-us-a-harvard-astronomer-on-the-mysterious-interstellar-object-oumuamua.
[555] Arthur C. Clarke, *Profiles of the Future: An Inquiry into the Limits of the Possible* (New York: Harper and Row, 1977), 76, epub.
[556] Loeb, "Have Aliens Found Us?"
[557] Croft in discussion with the author, March 2020.

to illustrate Croft's willingness to venture into unfamiliar conceptual territory with me, and also to summon exobiologist Norm Horowitz's memo to Joshua Lederberg that related voyages of the past to future explorations of outer space. While Horowitz envisioned potential riches on extraterrestrial sites, comparing exobiologists to Columbus, Croft here offers another lesson: that humans might approach a magical-seeming alien with caution. Taken together, these moments witness a recalibration of imagined relations between self and Other, vulnerability and conquest.

Loeb and Croft's association with ET as magical calls to mind anthropologist of science Stefan Helmreich's question if the concept of "weirdness"—whose etymology he links to the supernatural—might apply to SETI's quest for intelligence.[558] "Weird" is a watchword in astrobiology; for instance, the 2015 NASA Astrobiology Strategy devoted a section to its report that asked how "'weird life'…may have alternative biochemistry or alternative habitability constraints."[559] Helmreich notes how "weird" is not equivalent to the "strange"—what is "outside," "external," and "foreign"—that "indicates the past, the origin of things."[560] Helmreich links "weird," instead, to the three witches in William Shakespeare's *Macbeth*, and their "supernatural power to confront destiny."[561] Helmreich writes, "What the weird indicates is the future, where things could lead…The strange can be made familiar, traced and explained. The weird is still awaiting explanation."[562] As an answer to his provocation, ET might occupy both weirdness *and* strangeness through Loeb and Croft's figurations of the god-like alien. Like the Shakespearean sisters, who themselves refer back to the three Moirai—ancient Greek beings who wove, apportioned, and ended mortals' destinies—the

[558] Stefan Helmreich, "Weird Intelligence: Astrobiologie et Attribution d'Intelligence," trans. Emmanuel Grimaud and Anne-Christine Taylor, *Persona, Étrangement humain* (2016): 61.
[559] "Nasa Astrobiology Strategy 2015," NASA, October 2015, https://nai.nasa.gov/media/medialibrary/2016/04/NASA_Astrobiology_Strategy_2015_FINAL_041216.pdf: 147.
[560] Helmreich, "Weird Intelligence," 61.
[561] Helmreich, "Weird Intelligence," 61.
[562] Helmreich, "Weird Intelligence," 61.

magical alien is imagined to presage humans' possible future through their advanced technology as creators of life (Loeb), or as a stranger in a god's supernatural semblance (Croft).

Between Human and God

I read the speculative ontological space that nests the alien between human presents/god-like futures through elements of French philosopher Jacque Derrida's deconstructivist philosophy, in particular, his focus on churning dynamics of linguistic oppositions. In his essay "Difference," he proposes that the verb "to differ" *[differer]* offers up "distinction," but also "delay, the interval of a *spacing* and *temporalizing* that puts off until 'later' what is presently denied, the possible that is presently impossible."[563] "Différance" is a riff on the French *difference,* yet the two words are pronounced the same. Thus, I's silent "a" marks an un-hearable, but readable, *difference* that refers both to that word's and others' distinction and delay between any sign and its referent. Derrida writes that any sign is a placeholder for the thing itself; it is a deferred presence of that thing. Derrida's différance is a "possibility of conceptuality" that inhabits spatial and temporal deferment of the sign ever being fully read.[564] As a sign always deferred into the future, the alien's magical, god-like qualities are narrated as desirable for humans but presently unavailable.

Différance calls attention to words' "nested oppositions," that is, a hidden, yet powerful, hearkening call to a word's twinned, contravened concept.[565] An utterance of any word invites contemplation of that word's opposite; it embeds a trace antithetical to that word. For instance, "woman" conjures its opposite, "man." An example that comes to mind is Adam and Eve, a pair that represents the paragon of sexual difference and composes the enduring archetype of

[563] Derrida, "Difference," 129.
[564] Derrida, "Differance," 140.
[565] Jack M. Balkin, "Nested Oppositions," *The Yale Law Journal* 99, no. 7 (May, 1990): 1671.

heterosexuality. Yet God made Eve from Adam's rib; lurking in Eve's essence, that masculine element deconstructs the very essentialism of the sexes that the West has relied on to distinguish, diminish, and devalue femininity in contrast to masculinity. Difference's dialectic, then, what Derrida describes as "incessant synthesis that is constantly led back upon its assembled and assembling self," underscores a play between opposites that can never fully resolve.[566] Words are always instead cascading allusions to other senses, by which those nested oppositions always demure from any pure meaning and instead exist only in relation to other (opposing) signs. The word "human" could be understand within a Derridean web of signs. Pulling between animal and God, it oscillates between loaded meanings of Western tradition: In Aristotle's words, man, distinguished from beast, is a "political animal" who possesses speech, and yet, according to biblical texts, was created in God's own image.[567]

The god-like alien I posit similarly swims between nested oppositions not only of being but of time. It cannot exist without bending scientific imaginations of human futures, and at the same time, is deferred to a space of unknowable precarity. It is always a step ahead of human presents, temporally and ontologically. If the word "alien" has typically evoked what is strange, foreign, and Other, its sought-after existence haunts SETI scientists' expectations for their own futures. Reading the god-like alien concept of différance articulates how SETI scientists mentioned here cyclically oscillate between human possibilities and unguessed alien acts. That is, ET is a figure whose anticipated appearance structures scientific speculation for futuristic technology and an evolved sense of morality and justice that is beyond the human; at the same time, the alien is a figure that never fully escapes the orbit of anthropocentrism's pull.

[566] Derrida, "Differance," 152.
[567] Aristotle, Politics 1253a.1; Genesis 1:27 (New Revised Standard Version).

If différance points to disjuncture in words' meanings, it does so through moving, unsettled, between them; if différance distorts categories of *being*, then reflexively imagining aliens' pasts toward human futures warps *time*. Neither concept stays still; searching and seeking, they dynamically act and activate. They "animate" a space of speculation, to use Mel Y. Chen's word.[568] I call upon the Greek concept of Eros—love—to explain this interstitial space of moving between opposites; that is, SETI scientists' configuration of the alien is an act of *reaching* toward human futures through inspired by potential artifacts of alien pasts. Moving backward through human time to the fourth century B.C., Plato's *Symposium* tells the story of a drunken party among friends in ancient Athens who pontificate on the quality of Eros. Does it require an object? Is love equivalent with lust? Is it a sensation, a figure? Agathon, the party's young and beautiful host, identifies with Eros in self-exultation, imagining a god with a "beauty of his skin [that] shines for the life he lives with the flowers."[569] However, Socrates refutes the poet's superficial and naïve conception of love. Socrates forces Agathon to admit that Love is not characterized wholly by beauty, but instead by a perpetual "longing" to secure and restore the "existence of those things [that are beautiful] in the future, preserved, provided always."[570] Love thus operates in a *lack*, straining for the beautiful and the good.

Socrates himself learned the true nature of love, he revealed, after having been chastened by a wise woman, Diotima. We learn that from his mother, Poverty, Eros is "always impoverished…always in need," but from his father, Resource, is at the same time "a schemer for beautiful and good things."[571] Diotima tells Socrates that Eros is "neither immortal nor mortal," but instead, a "daemon" caught between those realms, always reaching for the divine.[572] The wise woman specifies that Love is not statically contained in a vessel of the beloved, but a dynamic

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[568] Chen, *Animacies*.
[569] Plato, *The Symposium of Plato*, 195b-c; 196b.
[570] Plato, *The Symposium of Plato*, 200d.
[571] Plato, *The Symposium of Plato*, 203c-e.
[572] Plato, *The Symposium of Plato*, 202e; 203e.

"lov*ing*," an performance that strives toward the divine.[573] Mortals enact Eros by "giving birth," Diotima explains, to access the "eternal and immortal element" and desire "the good." That is, truth, virtuousness, and beauty are eternal elements brought forth *through* Eros, a liminal daemon who reaches for immortality.[574] Humans touch immortality first through progeny, but, the greater version of forging of beauty is wrought through the pursuit of knowledge.[575] The group is amazed by Socrates' description of Love, and, many of them sated and sleepy with wine, head to bed.

The god-like alien of SETI I have outlined, like the daemon Eros, exists between a Derridean pairing of signs, mortal vs. immortal. ET has progressed beyond self-destructive, technologically adolescent growing pains so as to appear magical, or take on god-like qualities. Eros is also a figure who appropriately *reaches* toward the divine, just the angelic alien sketched by the interlocuters in this chapter who are imagined as models for hopeful human futures. That is, to circle back to Stefan Helmreich and Sophia Roosth's interpretation of abductive reasoning (a mode of originally coined by Charles Sanders Peirce), SETI scientists' invocation of the god-like alien is thus a *presage* to human's future: (n.) an "indication or foreshadowing of a future event; an omen, a sign, a portent"; "a prophetic or anticipatory perception of the future"; and as an act, (v.) "to constitute a supernatural sign of (a future event)."[576] I call upon the *pre* part of that word to assert that the god-like alien operates in scientists' minds as a sign not only of an ET anticipated to emerge, but also as a foreshadow to humanity's future they hope will bear out. As a supernatural, otherworldly figure, the -*sage* marks SETI practitioners' reasoning that the ET they might encounter

[573] Plato, *The Symposium of Plato*, 204c.
[574] Plato, *The Symposium of Plato*, 206e-207a.
[575] Plato, *The Symposium of Plato*, 209b-c.
[576] *Oxford English Dictionary Online,* s.v. "presage," accessed April 30, 2020, https://www.oed.com/view/Entry/150584.; *Oxford English Dictionary Online,* s.v. "presage," accessed April 30, 2020, https://www.oed.com/view/Entry/150585.

will be long-lived, benevolent, with futuristic technology: a "fore*shadow*" of humanity's possible and hoped-for future.[577]

[577] Abductive reasoning was a mode originally coined by Charles Sanders Peirce, see: Sami Paavola, "Abduction Through Grammar, Critic, and Methodeutic," *Transactions of the Charles S. Peirce Society* 40, no. 2 (2004): 245–270.

Conclusion: Reflexive Alienation

I conclude by sketching moves toward feminist and queer theories of *care* around the unknown objects sought by scientists who populate this dissertation, expanding themes from the last chapter and my interlocuters' discussions of Others. Scholars have extended theories on multispecies knowledge-making beyond proximate or domesticated non-humans such as dogs (Donna Haraway), fungi (Anna Tsing), forests (Eduardo Kohn) and even fermenting microorganisms (Heather Paxson).[578] Theorizations of the last chapter portrayed a cat (Jacques Derrida), pests (Clapperton Mavhunga), and transgenic mosquitos (Luísa Reis Castro), and I move now to elaborate on how SETI scientists reflexively imagine how ET—an absent, but haunting, companion species—might view *them*. Breakthrough's experiments of anticipation orbit how they might trace ET by pre-guessing unknown intentionality, an epistemic position that plays out on a plane of *future-oriented* human/Other relations, and, despite analogies' missing referent, the alien. The alien is not available to catalyze human/non-human becomings central to scholarly theorization of interspecies knowledge production, but I suggest that compassionate entrées to thinking with Others may engender ethical alien/human enmeshments toward possible futures.[579]

Analogies found in this work (islands/planets; piano chords/spectra; aliens/angels) enact linguistic processes of assigning likeness as a way of explanation, but also of experimental practice. These analogies are not merely a matter of words; they are also matters of meaning-making. As Mel

[578] See: Anna Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (Princeton: Princeton University Press, 2017); Eduardo Kohn, *How Forests Think: Toward an Anthropology Beyond the Human* (Berkeley: University of California Press, 2013); and, Heather Paxson, "Post-Pasteurian Cultures: The Microbiopolitics of Raw-Milk Cheese in the United States," *Cultural Anthropology* 23, no. 1 (February 2008): 15-47.

[579] Indeed, this was the topic of the Making Contact 2019 Workshop held at U.C. Berkeley, California I organized and moderated with the support of Breakthrough Listen. For further discussion of these topics, see: Chelsea Haramia and Julia DeMarines, "The Imperative to Create an Ethically-Informed METI Protocol," in *Theology and Science* 7, no. 1 (January 2019): 38-48. (They were both participants of that workshop). And, it is a topic I look forward to exploring further in terms of creating a IRB-like statement of ethics *toward* the alien as well as post-detection protocol in collaboration with Andrew Siemion and the Breakthrough Listen team.

Y. Chen argues throughout *Animacies: Biopolitics, Racial Mattering, and Queer Affect,* words animate matter.[580] They reflect hierarchies of matter's and beings' presumed liveliness and inertness along cultural fault lines such as sexuality, race, and gender. A stone is low on the cline of mattering, while an able-bodied, white, heterosexual male matters most.[581] The seemingly innocent mechanics of language belie deep-seated cultural norms. Invoking racial stereotypes and even certain colors (such as yellow, deployed alongside someone's presumed Asian ethnicity), Chen writes, people deploy particular words to transform human subjects into abject objects with depressed animate capacity; rhetoric shapes ideologies of power.[582] When liveliness and subjectivity linearly scale upward (and deadness and objectivity oppositely de-cline), Chen explains, how words animate beings can be a matter of living and dying. As such, attention to animacies' effects "activates new theoretical formations that trouble and undo stubborn binary systems of difference, including dynamism/stasis, life/ death, subject/object, speech/nonspeech, human/animal, natural body/cyborg."[583]

In the previous chapter, Steve Croft, Jill Tarter, and Norm Horowitz invoked (with very different intentions) the following analogical relationship: Native Americans : European conquistador :: humans: aliens. For Avi Loeb, Neanderthals : current-day *Homo sapiens* :: humans: aliens. Such positioning invites further critical consideration about how ontological worthiness and agential capacity in regards to race, ethnicity, indigeneity, and species are borne out through analogical frameworks, a formulation that has historically privileged some (white/male/Western) while oppressing others (Black/Brown/Native/female/non-Western)—fundamental topics for the future of this project. For now, I note how such rhetoric recalls Space Age conceptualizations of

[580] Mel Y. Chen, *Animacies: Biopolitics, Racial Mattering, and Queer Affect* (Durham: Duke University Press, 2012).
[581] Chen, *Animacies,* 26.
[582] Chen, *Animacies,* 30-33.
[583] Chen, *Animacies,* 3.

human/alien "races," registering in dissonance with contemporary critical attention that resists totalizing characterizations.[584]

Endeavoring to transpose culturally loaded terms to unknown Others who have been framed as "advanced" and at times likened to Western colonizers is a move that further roils intersecting terrestrial categories, ones that have been reworked and reevaluated in scholarship on technoscientific practices of race and gender.[585] As philosopher Sally Haslanger has put it, questions like "What is X?" (sub X with a silverfish, fire, or, race) have been approached with semantic, biological, and constructivist strategies and have consequently yielded historically located, socially normed, symbolically deployed—*tout court*, different—answers.[586] As such, retreating to some kind of

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584 A quotation by astrophysicist John Strong, a contemporary of Joshua Lederberg, stitches together the themes of abductive logic, reflexive alienation, and technologies of perception. Strong helped develop telescope mirrors and other optical devices for space missions that would detect water vapor in Venus's atmosphere in 1964. In a 1961 NASA report, "Observations with Satellite-Substitute Vehicles," Strong wrote: "Because our knowledge of the planets is still so imperfect, we cannot bring ourselves to *believe* that these planets are *not* inhabited by some sort of life. We prefer to establish for ourselves a position of agnosticism. To illustrate our position, let us imagine a race of man, like us, on a planet somewhere, like ours, who might not yet know that fishes or birds exist. In such an instance, if life in water, or in air, was proposed to them we would expect them to think that the fishes might drown, and that the birds might flop rather than fly-because neither water nor air could support 'life as they know it'" (*The Atmospheres of Mars and Venus*, eds. William Kellogg and Carl Sagan (Washington, D.C.: The National Academies Press), 87.

585 The breadth of scholarship on the intersections of science studies and concepts of race/gender/ethnicity/indigeneity warrants a much, much, fuller list, but for now, see: Cecilia Åsberg and Nina Lykke, "Feminist Technoscience Studies," *European Journal of Women's Studies* 17, no. 4 (November 2010): 299–305; Ruha Benjamin, *Race After Technology: Abolitionist Tools for the New Jim Code* (Cambridge: Polity Press, 2019); Nadia Abu El-Haj, "The Genetic Reinscription of Race," *Annual Review of Anthropology* 36 (2007): 283-300; Sarah Franklin, *Dolly Mixtures: The Remaking of Genealogy* (Durham, NC: Duke University Press, 2007); Catharina Landstom, "Queering Feminist Technology Studies," *Feminist Theory* 8 (April 2007): 7–26; Jennifer S. Light, "When Computers were Women," *Technology and Culture* 40, no. 3 (July 1999): 455-483; Annemarie Mol, *The Body Multiple: Ontology in Medical Practice* (Durham, NC: Duke University Press, 2002); Michael Rodríguez-Muñiz, "Bridgework: STS, Sociology, and the 'Dark Matters' of Race," *Engaging Science, Technology, and Society* 2 (2016): 214-226; Sophia Roosth and Astrid Schrader, eds., "Feminist Theory Out of Science," *differences*: *A Journal of Feminist Cultural Studies* 23, no. 3 (Fall 2012); Londa Schiebinger, ed., *Women and Gender in Science and Technology* (Abingdon-on-Thames: Routledge, 2014); Kim TallBear, "Beyond the Life/Not Life Binary: A Feminist-Indigenous Reading of Cryopreservation, Interspecies Thinking and the New Materialisms," in *Cryopolitics: Frozen Life in a Melting World,* ed. Joanna Radin and Emma Kowal (Cambridge: MIT Press, 2017), 179-202. Also, some classic texts on feminist epistemology, intersectional with feminist STS: Elizabeth Anderson, "Feminist Epistemology: An Interpretation and Defense," *Hypatia* 10, no. 3 (Summer 1995): 50-84; Donna Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective," *Feminist Studies* 14, no. 3 (Autumn 1988): 575-599; Sandra Harding, *Sciences from Below: Feminisms, Postcolonialities, and Modernities* (Durham, NC: Duke University Press, 2008); Sally Haslanger, "On Being Objective and Being Objectified," in *A Mind of One's Own*, ed. Louise M. Anthony and Charlotte E. Witt (Boulder: Westview Press, 2001), 209–252; Evelyn Fox Keller, "Feminism and Science." *Signs* 7, no. 3 (1982): 589-602; Helen Longino, "Can There Be a Feminist Science?" *Hypatia* 2, no. 3 (Autumn 1987): 51-64; Londa Schiebinger, *The Mind Has No Sex? Women in the Origins of Modern Science* (Cambridge: Harvard University Press, 1991).

586 Sally Haslanger, "Tracing the Sociopolitical Reality of Race," in *What is Race?: Four Philosophical Views,* by Joshua Glasgow, Sally Haslanger, Chike Jeffers, and Quayshawn Spencer, 4-37 (Oxford: Oxford University Press, 2019).

hunch that the answer to the question "What is race?" might simply "depend on us" to find a latent, but stable, formulation is a move that risks losing sight of social constructions of race that intersect heavily with other concepts like justice and personhood.[587] Instead, she writes, "the adequacy of our theory [of what race is] is not to be judged simply by reference to 'the facts,' but also by its responsiveness to our prior understandings."[588] The philosophical stakes that Haslanger outlines here caution against tendencies to subsume categories (ethnicity, race) into concretized blocks that Space Age rhetoric and imagery was prone to do—think back to the Pioneer Plaque's pan-ethnic human figures. Consider, too, NASA Administrator's Robert Frosch's introductory remarks at a 1979 Conference, "Life in the Universe," that framed exobiology and SETI's quests to find extraterrestrial life as an antidote to Cold War fears of nuclear destruction: "How and why should we bother to save the race unless we seek to understand where we came from, who we are, and what the universe around us is about?"[589] Edging close to Aristotle's Great Chain of Being, Frosch proposed that the search for life beyond Earth could connect the "distant past…present…and distant future" through a "chain of logic" that would inform how to best "seek our siblings."[590] He gestures to how an unspoken but particular "we" here—white, American, men of the Space Age—would face similar cosmic kin. One alternative to the rhetoric that totalizes Earthlings as one "race"—a move that depends on collapsing ways to best see, and then be critical of, social systems of oppression—might be addressed by what Ruha Benjamin lays out as (science) speculative fictions, generative alternatives to can "expand our own visions of what is possible."[591]

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[587] Haslanger, "Tracing the Sociopolitical Reality of Race," 6.
[588] Haslanger, "Tracing the Sociopolitical Reality of Race," 6.
[589] Robert Frosch, "Introduction, *Life in the Universe: Proceedings of a Conference Held at NASA Ames Research Center, Moffett Field, California, June 19-20, 1979* (Washington, D.C.: NASA History Office, 1981), 1.
[590] Frosch, "Introduction," 1.
[591] Ruha Benjamin, "Racial Fictions, Biological Facts: Expanding the Sociological Imagination through Speculative Methods," *Catalyst: Feminism, Theory, Technoscience* 2, no. 2 (2016): 1-28.

Considering remixes on ontological categorizations since the Cold War era, how can we approach objects and beings that elude description and certitude, but that nevertheless potently animate hopes, fears, and longings—scientific objects of inquiry whose knowability is held in abeyance? In this dissertation, I have made use of historical materials and participant observation to parse my interlocutors' imaginations and descriptions of if, how, and when extraterrestrial forms of life might be detected through various modes of perception—listening and seeing—and for now, objects whose description often hinge on metaphorical and analogical framings.[592] Lisa Messeri has argued that analogical thinking is a crucial starting point through which scientists broach unknown or distant objects. In an essay that followed *Making Planets Places,* she explicates ethnographic moments with exoplanet astronomers who hope to observe an Earth-like planet. Those scientists, Messeri writes, suspend Earth in the unfamiliar as a way to imagine distant worlds.[593] Describing a moment in which planetary geologists uncover rocks in a Utah desert whose morphology they would have expected to find on Mars, the scientists experience what Messeri identifies as the affective practice of "resonance."[594] Resonance—"a shift from difference (differing states of motion) to sameness (taking on another's precise attributes)"—captures and relates not merely the familiar and the distant, but also, the scientist as a participating "excited element."[595] The phenomenon triggered by identifying the rocks and "recognizing the alien in the familiar" moves beyond analogy: the experience of resonance "brings into harmony the familiar and the strange and captures that breathless moment when the alien is intimate, recognizable, and knowable."[596] (Her use of "alien"

[592] "Meanings are not simply constituted by what we believe, yet we are situated within a tradition of linguistic practices that have already shaped our meanings and our world." Haslanger, "Tracing the Sociopolitical Reality of Race," 7.
[593] Lisa Messeri, "Resonant Worlds: Cultivating Proximal Encounters in Planetary Science," *American Ethnologist* 44, no. 1 (February 2017).
[594] Messeri, "Resonant Worlds," 132.
[595] Messeri, "Resonant Worlds," 133.
[596] Messeri, "Resonant Worlds," 131-132.

here refers to something geologically strange but recognizable, flagging too SETI scientists' quest to find a *being* who might provoke a similar response.)

Messeri's use of that "resonance" also calls to mind anthropologist Susan Lepselter's exploration of that term in her cultural study of Americans' feelings of captivity that she shows has haunted modern life, playing out in descriptions of alien abductions and UFOs she has collected and analyzed. Emerging from these stories and experiences, resonance describes the "intensification produced by the overlapping, back and forth call of signs from various discourses," for instance, how people cultivate affective memories (of alien abduction) that they claim had lain latent, worked through in communal searches for identity.[597] She goes on to write that resonance "is not an exact reiteration" of a past event: "rather it's something that strikes a chord, that inexplicably rings true, a sound whose notes are prolonged. It is just-glimpsed connections and hidden structures that are felt to shimmer below the surface of things…[it] gives rise to the partial sense of familiarity that makes an experience classically uncanny, where the strange leads back to what you already knew."[598] The interlocuters in this work would be quick to delineate their search for ET from Lepselter's informants' beliefs, but I invoke her here to call attention to how just-glimpsed objects—perhaps like Sara Ahmed's half-glimpsed ones—not only lend form to that is out of reach but provoke emotive responses of care.

SETI scientists, unlike the exoplanetary astronomers such as the ones Messeri mentions who are incentivized by a growing catalogue of increasingly Earth-like planets, lack physical objects such the Mars-like rocks by which to affect a resonance with alien-like technology. There is no opportunity to "confuse the familiar and the alien," in Messeri's words.[599] Note that in the last

[597] Susan Lepselter, *The Resonance of Unseen Things: Poetics, Power, Captivity, and UFOs in the American Uncanny* (Ann Arbor: University of Michigan Press, 2016), 4.
[598] Lepselter, *The Resonance of Unseen Things*, 4-5.
[599] Messeri, "Resonant Worlds," 133.

chapter, ET *approximates* God if their technology *appears* magical (Loeb); ET is "humans on steroids" or "*effectively* immortal (Tarter); humans could *mistake* ET for God (Croft).[600] The god-like alien in these scientists' utterances is not a conflation between the familiar (human) and the strange (alien); they are not "confused" through the resonance Messeri and Lepselter show which brings forth empathy and understanding.[601] This discrepancy invites the question: What does it *matter* to take seriously words of the interlocuters in the preceding chapters about extraterrestrial aliens and microbes, objects that so far lack form? In what ways do the imaginaries around such objects elicit emotional responses, gesturing to a desire not only to detect beings or objects who are non-human, but also, articulating senses of what it means to be human?

In the last chapter, note how Croft's phrases migrated from "we" the humans to "you" the humans. As foreshadowed there, I now seize upon his linguistic layering to unravel the concept I call reflexive alienation. To be reflexive is to be "capable of turning, deflecting, or bending," by which one might be "reciprocal, correspondent."[602] (It is also a much mulled-over word over in anthropological theory and practice.[603]) I have paired that term with one that ushers in opposite associations in the spirit of Derridean *différance*: "alienation," the "the state of being estranged."[604] Together, they invite a doubled movement of pulling away and getting closer, an activating exercise practiced by the scientists in this work. Reflexive alienation is a mode of imagining how and why ET (the alien Other) might behave by finding interspecies resonance around notions of shared intention:

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[600] Loeb in discussion with the author, March 2020; Tarter in discussion with the author, April 2018; Croft in discussion with the author, March 2020.
[601] Messeri, "Resonant Worlds," 133.
[602] *Oxford English Dictionary Online,* s.v. "reflexive," accessed September 3, 2020, https://www.oed.com/view/Entry/26130955.
[603] An incomplete list: Paul Rabinow, *Reflections on Fieldwork in Morocco* (Berkeley: University of California Press, 1978); *The Cracked Mirror: Reflexive Perspectives in Anthropology*, ed. Barbara Myerhoff and Jay Ruby (Philadelphia: University of Pennsylvania Press, 1982); *Writing Culture: The Poetics and Politics of Ethnography*, ed. James Clifford and George E. Marcus (Berkeley: University of California Press, 1986); *Anthropology as Cultural Critique*, ed. Michael M. J Fisher and George E. Marcus (Chicago: University of Chicago Press, 1986); *Women Writing Culture,* ed. Ruth Behar and Deborah Gordon (Berkeley: University of California Press, 1992).
[604] *Oxford English Dictionary Online,* s.v. "alienation," accessed September 3, 2020, https://www.oed.com/view/Entry/4999.

this constructs a philosophical stance called up by concepts such as curiosity (Howard Isaacson), shared pursuit of knowledge (Sofia Sheik), and deliberate actions (Jill Tarter). That is:

Programming how an alien in the past might have considered human activity of the future, Sheik imagines ET imagining her imagining them.[605] Vishal Gujjar's SPANDAK, in a similar vein, *presupposes* alien *intention* with regard to human *attention.* Emilio Enriquez's TurboSETI relies on characteristics (drift rate and signal to noise ratio) of *extant* astrophysical objects (that Sheik hopes to add to) to parametrize as-yet-*inextant* objects that would be legible—glimpsable—through commensurable technology. These experiments of anticipation forecast interspecies intention and noticeability. Placing themselves in an *alienated* epistemic position to suppose how ET might interact with them, these Breakthrough scientists must also *reflexively* depend on inescapable anthropocentric assumptions, deployed, I have argued, through various technologies of perception that align with familiar modes of abled human sensing. Now: How is reflexive alienation a "matter of care"?[606]

Concepts of care can be played in many ways.[607] In this dissertation, that term has first referred to scientists' commitment to care deeply about detecting the objects they seek, inspiring practitioners like Frank Drake, Jill Tarter, and Carl Sagan to devote their lives to the pursuit of a technosignature. Vishal Gujjar, Andrew Siemion, and Steve Croft and other members of the team described in a white paper that Breakthrough Listen's pursuit of SETI's driving question—"Are we alone?"—is a "quest to answer our most profound question about the universe and our place within

[605] For an audible articulation of this imagining, hear: SETI-X, *Scrambles of Earth: The Voyager Interstellar*, released October 2, 2010, compact disc.
[606] Maria Puig de la Bellacasa's phrase here is a feminist play on Bruno Latour's "matters of concern": "Matters of Care in Technoscience: Assembling Neglected Things," *Social Studies of Science* 41, no. 1 (2011): 85–106.
[607] For instance, culturally constructed notions of femininity have historically unevenly distributed to women both physical and emotional labor, see: Ruth Schwartz Cowan, *More Work for Mother: The Ironies of Household Technology from the Open Hearth to The Microwave* (New York: Basic Books, 1983); for discussion of in care in medicine, see, Annemarie Mol, *The Logic of Care: Health and the Problem of Patient Choice* (Abingdon: Routledge, 2008); and for a Foucauldian interpretation of Weight Watchers, see, Cressida J. Heyes, *Self-Transformations: Foucault, Ethics, and Normalized Bodies* (Oxford: Oxford University Press, 2007).

it."[608] Exobiologists of the Space Age positioned themselves as vanguard scientists whose discoveries could fundamentally impact human knowledge as Copernicus and Darwin had done.

The practitioners in this dissertation have also practiced a *care*fulness in their approach to unknown, potentially harmful, beings and objects. Through one figuration of the island—bounded, fragile, precious—exobiologists cultivated care for imagined extraterrestrial forms of life whose detection might be thwarted by unsterilized space crafts. The 1959 WESTEX report authors urged that "great care be taken to exclude organic substances from space vehicles likely to impact on the moon," and Carl Sagan, later in that report, underlined that "the consequences of biological contamination are clearly very grave, and great care should be taken to sterilize and decontaminate all space probes likely to impact on Venus."[609] Others like Joshua Lederberg cautioned against the inverse scenario, back contamination, by which extraterrestrial forms of life could proliferate and overwhelm Earth's biosphere.[610] As Allan Brown speculated of Martian microbes, "If exotic life forms are introduced into our own biosphere, would they survive, propagate, infect terrestrial organisms, or bring harm directly or indirectly to our ecosphere?"[611] Approaching extraterrestrial objects with wariness was also to care for oneself and fellow Earthlings, as they voiced the importance of preparation and thoroughness on an international scale.

By that coin, Croft has imagined that interfering alien Others might swarm and destroy Earth. In the last chapter, Croft's "we" (Earthlings) could have not yet gotten to be pestilent to aliens, until "you"—speaking as an alien to a human *and/or* as a human to pests—become bothersome. Species swapping through analogical imagining is an exercise of *reflexive alienation* of

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[608] Vishal Gujjar, Andrew Siemion, and Steve Croft, et al., "The Breakthrough Listen Search for Extraterrestrial Intelligence," *Astro2020 Activity, Project or State of the Profession (APC) White Paper* no. 223 (September, 2019): 1. – 13.
[609] Second Meeting of the ad hoc Committee on Contamination by Extra-terrestrial Exploration, The Hague, March 9 - 10 1959); Carl Sagan, Organic Matter and the Moon," Carl Sagan Ref. 14, 22.
[610] For further discussion of such themes—multispecies, enclosure, and the precariousness of life in the Space Age—see, Leah V. Aronowsky, "Of Astronauts and Algae NASA and the Dream of Multispecies Spaceflight," *Environmental Humanities* 9, no. 2 (November 2017): 359-377.
[611] Allan H. Brown, "Back Contamination and Quarantine: Problems And Perspectives," 443.

opposite movements. Croft *alienates* himself by imagining humans as pestilent creatures—lower on a chain of being—an annoying or simply inconsequential Other in relation to super-intelligent aliens. He *reflexively* imagines himself as higher being in relation to the insect/bug examples he draws from. Reflexive alienation is an act of both pulling away and coming closer, a retreat *from* the imagined alien through self-Othering (toward terrestrial pests) and movement *toward* it through self-aggrandizing (away from those pests). Reflexive alienation is a doubled movement akin to which Clapperton Mavhunga (*unmute* vermin), Jacques Derrida (*avowed animot*), and Luísa Reis Castro (*cared for* pests) theorize: the pestilent Other occupies an unstable ontological category whose resonances are brought forth through various capacities to respond.

Analogy creates a bridge by which Croft can momentarily inhabit an imagined Otherness. Moreover, it structures the kind of science he chooses to do. Reflexive alienation through analogical exercise directs what he calls "passive listening" through searching for technosignatures rather than "shouting into the void," that is, broadcasting with the intention of being noticed by ET, risking transforming himself and Earth into pestilent matters to be dealt with or taken *care* of.[612] Without the direct experience of knowing what it is like to be an alien—and thus, also without the ability to surmise if that alien would view Earth as a site to colonize, to brush away, or simply ignore—analogy is a linguistic mode by which terrestrial creatures come to stand in for humans that come to stand in for the imagined Other. Reflexive alienation through analogy troubles the human/animal distinction, creating, briefly, a mode for Croft to consider the aliens considering him.

More hopefully, ET is a projected/amplified/improved human by way of analogical extrapolation into the future. *Bon mot*, the "extra" in "extraterrestrial," means "beyond the ordinary degree."[613] The god-like extraterrestrial I outlined in the previous chapter is an *extra*ordinary

[612] In discussion with the author, March 2020.
[613] *Oxford English Dictionary Online,* s.v. "extra," accessed May 13, 2020, https://www.oed.com/view/Entry/67075.

terrestrial: "beyond," "additional to," humans, whose "exceptional" qualities would "exceed" our own.[614] The alien is the best of humanity, but deferred into the future: as a supernatural sign, the god-like alien is a potential portent for human's path, morally and technologically. SETI scientists Avi Loeb and Jill Tarter do not process an alien through resonance; instead, reflexive alienation is a mode of extending hopes and fears about humans and the Earth through imagining alien beings. This is not an epistemological anthropocentric hamster wheel; it is a driving "motivation" for doing SETI (Tarter) that offers a "lesson" (Croft) to speculate about human's technological future (Loeb).

Reflexive alienation is a reaching for "an advanced version of ourselves," in Tarter's words. It is act in which imagination of the alien object conjures human subjectivity. The god-like alien is a daemon who spawns progeny, both technological (emissaries and universes) and intellectual (directing humans toward a more hopeful future). Tarter, Croft, and Loeb all invoke an echeloned analogical mode of imagining ET, in which alien's magic-seeming technology, their limitless peaceful nature, and ability to create life are indications of that alien's relative status as divine-like in comparison to humans. Importantly, the scientists also coil their analogies onto imagined futures for humans' future. For Croft, Earthlings might learn from them (be domesticated?); for Tarter, humans might unite to become more peaceful themselves; for Loeb, humans might develop life-creating technologies that aliens had done before. This referential, analogical dynamism—projecting and returning from human to ET to immortals and back again—is an enactment of reflexive alienation: a mode of meaning-making through attention to both a speculative ET and Earthly desires for peace and a wondering of futuristic technology.

I have referred in this dissertation to feminist and queer scholarship on the more-than and other-than human that re-roots lived, acted, performed, and embodied materialisms, pushing

[614] *Oxford English Dictionary Online,* s.v. "extraordinary," accessed May 13, 2020, https://www.oed.com/view/Entry/67124.

ontological limits of things and beings. Such entanglements offer novel ways to see and critique systems of power, scientific practices, and modes of knowledge-making. As Stacey Alaimo writes, post/non-human models such as Karen Barad's intra-actions "scramble conventional notions of subjectivity that separate the rational human from an external environment."[615] Nature is found to be surprisingly queer, disorderly, messy, agitating, and out of line. The alien—as yet unfound—can be said to be queer for a variety of reasons: it exists out of time, yet is imagined as a foil for human futures; it is the ultimate Other, but flirts with anthropocentric foundations; it pulls between ontological delineations, in the last instance, upward to the divine. The alien queerly eludes discrete analogical comparisons, appearing unevenly as artifact that muddles human time, as a higher organism, and as a figure that, when squinting, appears immortal. In this looping space of analogical exercise, reflexive alienation is a mode to escape and return to speculative interspecies commensurability on the plane of imagination.

Reflexive alienation is an imaginative mode of world-making that swims in a space of knowability held in abeyance, often in ways that orient to a desire to be seen and heard, or, to see and hear, Others, beings, and objects. This concept skirts the limits of scientific knowledge and basks in unorthodox, even unknowable, ways of operating in an uncertain world.

[615] Alaimo, "Thinking as Stuff of the World," 17.

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