

XI. GRAVITATION RESEARCH

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M. I. T. Sloan Fund for Basic Research
National Science Foundation (Grant MPS75-04033)

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Our research objective is to make an experimental investigation of the gravitational interaction, embracing both terrestrial experiments and astrophysical observation. The research covers four broad areas: Null experiments to test fundamental principles, study of post-Newtonian gravitational effects to distinguish among relativistic theories of gravitation, search for gravitational radiation, and measurement of cosmological observables.

At present, our major project is construction of an interferometric broadband gravitational antenna. This antenna was described in some detail in Quarterly Progress Report No. 105 (pp. 54-76). Briefly, the basis of the design is to use virtually free masses for the antenna elements and to sense interferometrically the differential gravitational wave strain induced in orthogonal directions. The configuration is a Michelson interferometer with multipass arms. The prototype antenna that is being assembled has arm lengths of 9 meters each storing approximately 300 beams. In the frequency range 30 Hz to 10 kHz, the antenna will be limited by the Poisson (shot) amplitude noise of the light, and hence will permit measurement of gravitational wave strains of the order $\Delta\ell/\ell \approx 10^{-19}/\tau^{1/2}$, where τ is the integration time. Although this appears to be a very small strain, it is not small enough to detect the gravitational flux incident on the Earth from astrophysical sources on the basis of reasonable estimates. For example, a supernova explosion in our galaxy could produce measurable strains of $10^{-17} - 10^{-19}$ lasting 10^{-3} second but occurring only once in 30 to 100 years. The rate from the Virgo cluster of galaxies is $\sim 10^4$ higher but the strains are 10^3 smaller. An upper limit for the most promising pulsar source, the Crab pulsar NP0532, is $\Delta\ell/\ell \sim 10^{-24}$ at 60.4 Hz. This is also an impossible measurement with this antenna, since it would require 1000 years of integration.

The question is then, Why bother with the project? The answer is that it gives promise of success if it is carried out with longer baselines, in particular, if it is put into orbit in space either around the Sun or at one of the stable Earth-Moon Lagrangian points. For a fixed strain the integration time is proportional to the square of the baseline length as long as the dominant noise source in the antenna does not grow with the baseline, which is the case for a space antenna. At periods longer than ~ 100 s the dominant noise is the stochastic force of cosmic-ray protons; at shorter periods photon shot noise dominates. A 1-km interferometric baseline antenna could measure the gravitational wave strain of $\Delta\ell/\ell \sim 10^{-21}$ of the fast stellar binary WZ Sge at a 40-min period in 10 days of integration. It would also set $\Delta\ell/\ell \sim 10^{-24}$ as a limit for the Crab pulsar in 10 days.

