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REVEALING THE NATURE OF EXTREME CORONAL-LINE EMITTER SDSS J095209.56+214313.3

Lovro Palaversa[1], Suvi Gezari[2], Branimir Sesar[3], J. Scott Stuart[4], Przemyslaw Wozniak[5], Berry Holl[1], and Željko Ivezić[6]
[1] Observatoire astronomique de l'Université de Genève, 51 chemin des Maillettes, CH-1290 Sauverny, Switzerland; lovro.palaversa@unige.ch
[2] Department of Astronomy, University of Maryland, College Park, MD 20742-2421, USA
[3] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany
[4] Lincoln Laboratory, Massachusetts Institute of Technology, 244 Wood Street, Lexington, MA 02420-9108, USA
[5] Los Alamos National Laboratory, 30 Bikini Atoll Road, Los Alamos, NM 87545-0001, USA
[6] University of Washington, Department of Astronomy, P.O. Box 351580, Seattle, WA 98195-1580, USA
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ABSTRACT

Extreme coronal-line emitter (ECLE) SDSS J095209.56+214313.3, known by its strong, fading, high-ionization lines, has been a long-standing candidate for a tidal disruption event; however, a supernova (SN) origin has not yet been ruled out. Here we add several new pieces of information to the puzzle of the nature of the transient that powered its variable coronal lines: (1) an optical light curve from the Lincoln Near Earth Asteroid Research (LINEAR) survey that serendipitously catches the optical flare, and (2) late-time observations of the host galaxy with the *Swift* Ultraviolet and Optical Telescope (UVOT) and X-ray telescope (XRT) and the ground-based Mercator telescope. The well-sampled, ~10 yr long, unfiltered LINEAR light curve constrains the onset of the flare to a precision of ±5 days and enables us to place a lower limit on the peak optical magnitude. Difference imaging allows us to estimate the location of the flare in proximity of the host galaxy core. Comparison of the *GALEX* data (early 2006) with the recently acquired *Swift* UVOT (2015 June) and Mercator observations (2015 April) demonstrates a decrease in the UV flux over a ~10 yr period, confirming that the flare was UV-bright. The long-lived UV-bright emission, detected 1.8 rest-frame years after the start of the flare, strongly disfavors an SN origin. These new data allow us to conclude that the flare was indeed powered by the tidal disruption of a star by a supermassive black hole and that tidal disruption events are in fact capable of powering the enigmatic class of ECLEs.

Key words: black hole physics – circumstellar matter – galaxies: individual (SDSS J095209.56+214313.3) – galaxies: nuclei – supernovae: general – ultraviolet: galaxies

1. INTRODUCTION

The class of extreme coronal-line emitters (ECLEs) are distinct because they exhibit strong coronal lines, such as [Fe x] λ6376, [Fe ix] λ7894, and [Fe xiv] λ5304, that require a high-energy photoionizing continuum (Komossa et al. 2008; Wang et al. 2011, 2012). Additionally, as a class, ECLEs demonstrate coronal-line intensities that show strong variability with time, as well as complex Balmer-line profiles (Yang et al. 2013). While tidal disruption events (TDEs) have been proposed as the most likely source of the flaring UV-soft X-ray photoionizing continuum powering the iron-line light echoes in this class of objects, the light curve (LC) of the flare itself has never been detected to test this scenario directly.

For the first time, we report the LC of an ECLE, caught serendipitously by the optical time-domain Lincoln Near Earth Asteroid Research (LINEAR; Stokes et al. 2000) survey, and provide *Swift* UV follow-up observations that confirm the UV-luminous nature of the event. The paper is organized as follows. In Section 2 we describe the new and archival observations of SDSS J0952+2143 (hereafter SDSS J0952+2143), in Section 3 we present the implications for the TDE versus other origin scenarios, and in Section 4 we conclude that the coronal lines in SDSS J0952+2143 were indeed the light echo of a TDE in the gas-rich environment of a supermassive black hole (SMBH).

2. OBSERVATIONS

Here we describe our new observations of SDSS J0952+2143, which, together with the extensive multiwavelength data presented in Komossa et al. (2009), help solve the mystery of its origin. All magnitudes are in the AB system.[7] Unless otherwise noted, when reporting observed magnitudes, we do not correct for Galactic extinction toward the source ($E(B-V) = 0.028$ mag). However, the absolute magnitudes include the correction for Galactic extinction. Hereafter we use UT dates and assume a cosmology with $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$, and a luminosity distance of 360 Mpc.

2.1. Archival Data

During a systematic search for emission lines in AGNs in SDSS DR6 (Sloan Digital Sky Survey Data Release 6; Adelman-McCarthy et al. 2008), Komossa et al. (2008, K08) identified unusual and variable emission lines of the host galaxy SDSS J0952+2143 and subsequently scheduled further observations with *Chandra X-ray Observatory* and the Gamma-ray Burst Optical/NIR Detector (GROND; Greiner et al. 2008) instrument mounted on the 2.2 m Max Planck Society telescope, as well as spectroscopic follow-up with the *Spitzer Space Telescope* Infrared Spectrograph (Houck et al. 2004), the OMR spectrograph at the 2.16 m Xinglong telescope, and the EMMI[8] instrument at the 3.5 m ESO New Technology Telescope (NTT; see Komossa et al. 2009, K09). More recently, Yang et al. (2013, Y13) acquired SDSS J0952

[7] Two Micron All Sky Survey (2MASS) and *Wide-field Infrared Survey Explorer* (*WISE*) magnitudes have been converted to the AB system according to Equation (5) from Blanton et al. (2005) and Table 5 from http://wise2.ipac.caltech.edu/docs/release/prelim/expsup/sec4_3g.html, respectively.

[8] See the EMMI user's manual at http://www.ls.eso.org/docs/.

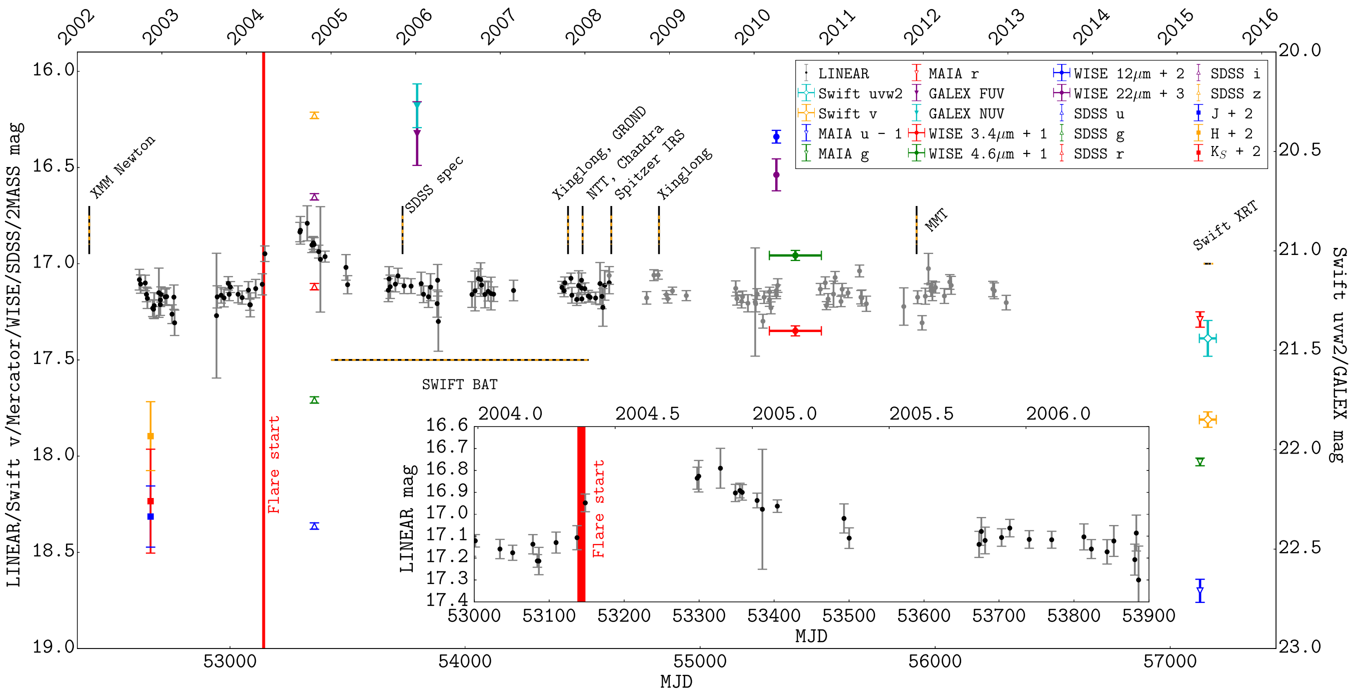

Figure 1. Evolution of the flare and overplotted observations (symbols according to the legend; note different scales on vertical axes). Time and duration of spectroscopic observations; *Swift* BAT and *Swift* XRT are designated by black and orange dashed lines, respectively. The red strip in the main panel and inset marks the limits on the onset of the flare (2004 May 18 ± 5 days). Note that the actual peak of the optical LC was not observed by LINEAR, and that earliest spectra (SDSS) were obtained more than a year and a half after the peak of the flare. Galactic extinction was not corrected for.

+2143 spectra from the Blue Channel Spectrograph on the Multi-mirror Telescope (MMT). The host SDSS J0952+2143 galaxy was also observed by the *ROSAT* all-sky survey in 1990 November (RASS; Voges et al. 1999), 2MASS (Skrutskie et al. 2006), *XMM-Newton* (Jansen et al. 2011), *Swift* Burst Alert Telescope (BAT; Markwardt et al. 2002; Ajello et al. 2008), and *GALEX* (Martin et al. 2005). The chronology of these observations is summarized in Figure 1.

The earliest ground-based spectrum, obtained by SDSS, exhibited unusually strong, high-ionization iron coronal lines with ionization states from [Fe VII] up to [Fe XIV] and complex Hα and Hβ profiles that can be decomposed into broad and narrow components with multiple peaks (see K08, K09, and Y13 for a thorough discussion of spectral lines). Subsequent NTT, Xinglong, and MMT spectra revealed a dramatic fading of the these lines, as well as a complex evolution of the broad-line profiles.

RASS (1990 November), *XMM-Newton* (2002 May 7), and *Swift* BAT (March 2005–2008) observations of the host galaxy did not make an X-ray detection and were only able to place upper limits on the X-ray luminosity of the host galaxy at L_X (0.1–2.4 keV) $< 10^{43}$ erg s^{-1}, L_X (0.2–10 keV) $< 8 \times 10^{43}$ erg s^{-1}, and L_X (15–55 keV) $< 10^{44}$ erg s^{-1}, respectively. However, a *Chandra* 10 ks observation initiated by K09 on 2008 February 4 detected faint X-ray emission, with L_X (0.1–10 keV) $\sim 10^{41}$ erg s^{-1}. The galaxy was detected as a luminous mid-IR source by *Spitzer*, which K09 attribute to relatively cold dust heated by the flare, or to a persistent starburst.

2.2. Lincoln Near Earth Asteroid Research

LINEAR (Stokes et al. 2000) operated two telescopes at the Experimental Test Site located within the US Army White Sands Missile Range in central New Mexico at an altitude of 1506 m. The program used two essentially identical equatorially mounted, folded design telescopes with 1 m diameter, $f/2.5$ primary mirrors equipped with 2560 × 1960 pixel back-illuminated, frame-transfer CCD cameras mounted in the prime focus. Cameras had no spectral filters and in combination with the telescopes produced a 1°60 × 1°23 (≈2 deg^2) field of view with a resolution of 2″25 pixel^{-1}.

The spectral response curve of the LINEAR system peaks at approximately 625 nm and covers an approximately 400–1000 nm wavelength range, broadly matching the range of SDSS *griz* filters. Sesar et al. (2011) described the LINEAR survey and photometric recalibration based on SDSS stars acting as a dense grid of standard stars (for the period from 1998 to 2009). In the overlapping 10,000 deg^2 of sky between LINEAR and SDSS, photometric errors range from 0.03 mag for sources not limited by photon statistics to 0.20 mag at $r = 18$ (where r is the SDSS r-band magnitude). LINEAR photometry of the SDSS J0952+2143 was obtained from SkyDOT.[9]

In order to supplement the existing photometry (for the period after 2009) and perform difference imaging, 622 7′55 × 7′55 (200 × 200 pixels) image cutouts were extracted from the LINEAR database. Aperture photometry was performed in the usual way using the IRAF[10] (Tody 1993) `apphot` task. Images were astrometrically registered (astrometry.net; Lang et al. 2010) and then visually inspected. Low-quality frames in the nonflaring state were removed, to

[9] http://skydot.lanl.gov/

[10] IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

give the final difference imaging sample of 299 images. Resulting good images were divided into groups containing pre-, post-, and flare data. Images satisfying $53{,}036 > \mathrm{MJD} > 53{,}750$ (2004 January 31 and 2006 January 14) were then corrected for distortions and co-added (SWARP; Bertin et al. 2002) to create a template image from which the co-added image in the flaring state ($53{,}148.2 < \mathrm{MJD} < 53{,}377.4$, 2004 May 22 to 2005 January 6) was differenced with HOTPANTS,[11] an implementation of the Alard (2000) algorithm.

2.3. Mercator Telescope

On 2015 April 15 we requested observations with the MAIA instrument mounted on the 1.2 m Mercator telescope.[12] MAIA is an efficient three-channel imager, capable of simultaneous three-band photometry. The optical system is built around three e2v 2k × 6k frame-transfer CCDs sourced from European Space Agency's canceled *Eddington* mission. The field of view of the system is 9′.4 × 14′.1, with image scale of 0″.276 pixel^{-1}. MAIA is equipped with three filters: *U, G*, and *R*. These filters are similar but not identical to the SDSS filter system. In particular, the *R* filter is an approximation of SDSS $r + i$ filters, while *U* and *G* are approximations of SDSS *u* and *g*. More details can be found in the technical paper by Raskin et al. (2013).

U-, G-, and *R*-band images were acquired simultaneously and under good conditions on 2015 April 15, with a 1 ks exposure in all three filters. Usual reduction steps were performed by a custom-built Python script (L. Palaversa & S. Blanco-Cuaresma 2015, private communication) that is used for reduction of *Gaia* Science Alerts[13] (GSA) follow-up observations obtained by the MAIA instrument. The photometric calibration and conversion to the SDSS system were performed by the Cambridge Photometry Calibration Server (also a part of GSA). The host galaxy was detected with $u = 19.70 \pm 0.06$ mag, $g = 18.03 \pm 0.02$ mag, and $r = 17.29 \pm 0.04$ mag. Comparison with SDSS photometry of 2004 December 20 ($u = 18.36 \pm 0.02$ mag, $g = 17.71 \pm 0.01$ mag, $r = 17.119 \pm 0.005$ mag, $i = 16.652 \pm 0.005$ mag, and $z = 16.23 \pm 0.01$ mag) reveals that the source became fainter in the *u*, *g*, and *r* bands and redder ($(u - g)_{\mathrm{SDSS}} = 0.66$, $(g - r)_{\mathrm{SDSS}} = 0.59$, $(u - g)_{\mathrm{MAIA}} = 1.67$, $(g - r)_{\mathrm{MAIA}} = 0.74$). All magnitudes are in the AB system.

2.4. Swift

We obtained follow-up imaging of SDSS J0952+2143 with *Swift* UVOT during the time period of 2015 April 12–June 23 with 4.96 ks in the *uvw*2 ($\lambda_{\mathrm{eff}} = 2246$ Å) filter and 4.79 ks in the *v* ($\lambda_{\mathrm{eff}} = 5468$ Å) filter. The host galaxy is detected with $uvw2 = 21.44 \pm 0.09$ mag and $v = 17.81 \pm 0.04$ in the AB system using heasoft software package `uvotsource` and a 5″.0 radius aperture. We find a negligible correction (<0.1 mag) between AB magnitudes in the *GALEX* near-UV (NUV) and *Swift uvw*2 bands using a comparison of four reference stars detected in both the *Swift* image and the 218 s *GALEX* All-sky Imaging Survey obtained on 2006 March 2. SDSS J0952+2143 is spatially extended in the *uvw*2 image in comparison to reference stars in the field of view (see cumulative flux distribution in Figure 2). We also measure a 3σ upper limit on the X-ray flux from a 6.82 ks *Swift* XRT exposure on 2015 June 23 using the heasoft software package `sosta` of $f_{0.3\text{–}10\,\mathrm{keV}} < 9.54 \times 10^{-14}$ erg s^{-1}, which for a Galactic column density of $N_{\mathrm{H}} = 2.79 \times 10^{20}$ cm^{-2} and a power-law index of $\Gamma = 1.9$ translates to $L_{\mathrm{X}} < 1.47 \times 10^{42}$ erg s^{-1}. This upper limit is consistent with the much more sensitive late-time *Chandra* detection of SDSS J0952+2143 on 2008 February 4.

2.5. Wide-field Infrared Survey Explorer

WISE (Wright et al. 2010) is a 0.4 m NASA infrared wavelength space telescope in Earth orbit that performed an all-sky survey in 3.4 μm, 4.6 μm, 12 μm, and 22 μm (hereafter designated as *W*1, *W*2, *W*3, and *W*4, respectively). *WISE* detected the host galaxy with $W1 = 16.349 \pm 0.026$ mag, $W2 = 15.957 \pm 0.026$ mag, $W3 = 14.340 \pm 0.033$ mag, and $W4 = 13.538 \pm 0.083$ mag, between 2010 May 08 and November 15.[14]

3. ANALYSIS

Ten-year-long monitoring enabled by the LINEAR survey, as well as late-time *Swift* and MAIA observations, allows us to uncover critical diagnostic information missing from the previous analyses of the mechanism responsible for the luminous flare in the SDSS J0952+2143 galaxy.

Most importantly, exact timing of the event and its evolution can now be constrained (see Figure 1). From the difference in time between the last point on the flat part of the LC prior to the flare and the first point on the rise, we estimate with a precision of ±5 days that the flare started on 2004 May 18. Unfortunately, LINEAR did not observe the peak of the optical LC, but we are able to determine that the flare could not have been fainter than $M_r \sim -20$ mag.

The LINEAR survey also allows us to establish the optical variability of the host galaxy SDSS J0952+2143 at a level of $\sigma < 0.08$ mag (outside of the flaring phase), removing the possibility of strong, unobscured active galactic nucleus (AGN) activity in the host. We also use the difference imaging described in Section 2.4 to localize the transient relative to the host galaxy nucleus. Figure 3 shows a contour of the difference image constructed from the flaring state images, overlaid on the host galaxy reference image. There is no significant offset detected, with the transient centroid measured from a Gaussian fit located within 1σ (0.2 pixels or 0″.45) of the host galaxy centroid. Assuming the SDSS value for redshift ($z = 0.079$), this translates to an offset from the core of less than 670 pc, thus not ruling out the TDE hypothesis.

Furthermore, the optical LC allows us to put other observations in context. We now know that the SDSS photometry (2004 December 20) and SDSS spectrum (2005 December 30) were taken approximately 210 and 580 days after the start of the flare. Therefore, only LINEAR and SDSS photometry were taken during the flaring phase. By the time *GALEX* photometry and SDSS spectra were acquired, the flare had already faded considerably (at least at optical wavelengths). Although the early part of the *Swift* BAT observations were taken during the declining phase of the flare, no detection

[11] http://www.astro.washington.edu/users/becker/v2.0/hotpants.html

[12] Located at Observatorio del Roque de los Muchachos on La Palma island (Spain) and operated by the Institute of Astronomy of KU Leuven (Belgium).

[13] http://gaia.ac.uk/selected-gaia-science-alerts

[14] *WISE* magnitudes in the Vega system are equal to $W1 = 13.666 \pm 0.026$ mag, $W2 = 12.638 \pm 0.026$ mag, $W3 = 9.098 \pm 0.033$ mag, and $W4 = 6.934 \pm 0.083$ mag.

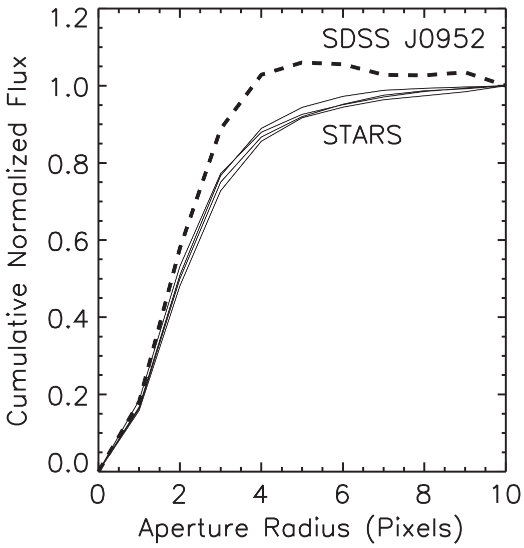

Figure 2. Cumulative flux as a function of aperture radius for SDSS J0952+2143 (dashed line) in comparison to reference stars (solid lines) in the *Swift* *uvw*2 image. The UV emission in SDSS J0952+2143 is clearly extended and is likely associated with star formation in the host galaxy. The *Swift* UVOT pixel scale is 0.″502 pixel^{-1}.

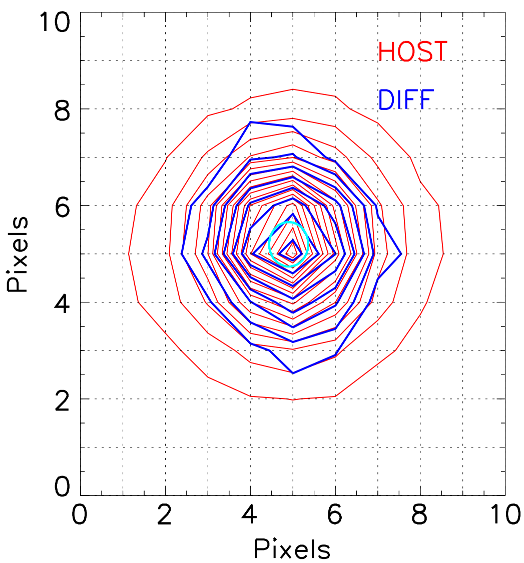

Figure 3. Contour image of the host galaxy detected by LINEAR constructed from the pre- and post-flare data (red), compared to the contour image of the difference image during the flare (blue). The cyan circle marks the 2σ error circle on the difference image centroid measured from a Gaussian fit. No significant offset is detected between the difference image centroid and the host galaxy nucleus. The LINEAR pixel scale is 2.″25 pixel^{-1}.

was made, suggesting that there was no significant hard X-ray emission. Remaining observations taken after mid-2006 could have measured only the echo of the flare in the surrounding medium.

The extended, persistent UV emission detected by *Swift* from SDSS J0952+2143 11 yr after the transient outburst has faded by 1.2 mag since the *GALEX* detection on UT 2006 March 02 and is likely associated with star formation in the host galaxy. Therefore, we can derive the UV flux intrinsic to the transient detected by *GALEX* to be $NUV_{trans} = 20.60 \pm 0.14$ mag, which corresponds to an absolute magnitude of $M_{NUV} = -17.4$ mag (corrected for Galactic extinction), 1.8 yr after the onset of the transient outburst. Our confirmation of transient UV emission associated with the event in 2006 March 2 contradicts the conclusions of Yang et al. (2013), who found that it is not necessary to add a nonstellar component to fit the blue end of the SDSS spectrum of SDSS J0952+2143 on 2005 December 30, which we now know was taken 1.6 yr after the start of the UV/optical flare. Note that a similar fading in the UV was detected in archival *GALEX* observations of ECLE SDSS J0748+4712 by Wang et al. (2012), confirming that it too was powered by a UV-luminous event.

Furthermore, the confirmation that the host galaxy is in fact a star-forming galaxy is important, since the continuum colors of the host galaxy measured by 2MASS, *WISE*, and MAIA, all of which were taken either before the flare or at least 6 yr after the optical LC reached its pre-flare level, and its narrow-line ratios measured in K08 are ambiguous and consistent with the regions populated by both AGNs and star-forming galaxies in the diagnostic diagrams (Baldwin et al. 1981; Obrić et al. 2006; Nikutta et al. 2014).

4. DISCUSSION

4.1. Nature of the Host Galaxy

LINEAR photometry spanning more than a decade does not exhibit behavior indicative of AGN activity (cf. stability of the optical LC in Section 3). This is corroborated by *XMM-Newton*, *Swift* BAT, *Swift* XRT, and *Chandra* X-ray observations, all of which were taken outside of the flaring phase (with the slight exception of *Swift* BAT observations). Only *Chandra* observations detected low levels of soft X-rays, approximately 3.5 yr after the start of the flare, and at a level well below that which is expected for normal AGNs. Our recent *Swift* photometry detected extended, persistent UV emission from SDSS J0952+2143, an indication of ongoing star formation. Given the fact that the *Swift* photometry was acquired ∼11 yr after the start of the flare, it is unlikely that there is a contribution to the late-time UV emission from the flare itself.

These measurements provide a contigous observational baseline of approximately 2 yr before the flare and 10 yr after the flare in which no activity characteristic of AGNs was detected. We also note that RASS observations in 1990 November did not detect significant X-ray emission (yet an 11 yr gap in observation exists between RASS and *XMM-Newton* observations). However, a longer baseline may be needed to definitively rule out an AGN. Seyfert 1.9 galaxy IC 3599, for example, showed two bursting episodes caught by *ROSAT* and *Swift*, respectively, separated by a time interval of 20 yr. While the Catalina Sky Survey data caught the second outburst in 2008 (Grupe et al. 2015), it shows no significant variability ($\sigma = 0.04$ mag) in the LINEAR data in the 6 yr preceding it (Figure 4). We do, however, note the difference in the LC shape of IC 3599 and SDSS J0952+2143, the latter of which is asymmetric, shows more abrupt change in luminosity, and has a larger optical amplitude (approximately 0.2 mag in the case of IC 3599 and 0.5 mag in the case of SDSS J0952+2143).

Thanks to the LINEAR LC, [N II]/Hα and [O III]/Hβ line ratios can now be used more safely in the context of the BPT diagram, in which the host galaxy is placed in the SF region, but near the AGN/SF division. Similarly, 2MASS, MAIA, SDSS, and *WISE* color–color diagrams locate the host galaxy

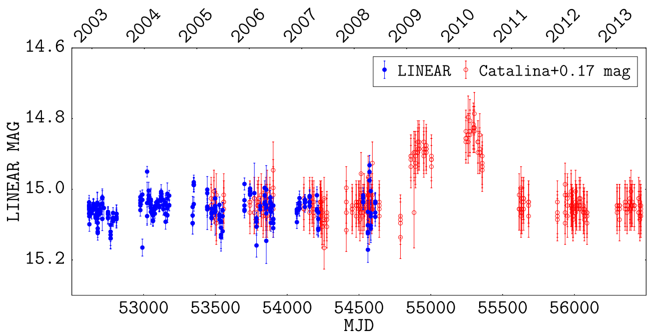

Figure 4. IC 3599 optical LC. Blue open circles correspond to the LINEAR data and red open circles to CSDR2 data (Drake et al. 2009), shifted by 0.17 mag, i.e., the difference of the median LC values between LINEAR and CSDR2 data, outside the flaring phase. Please note that SDSS J0952+2143 is ~2 mag fainter than IC 3599 and actually near the faint limit of the LINEAR survey.

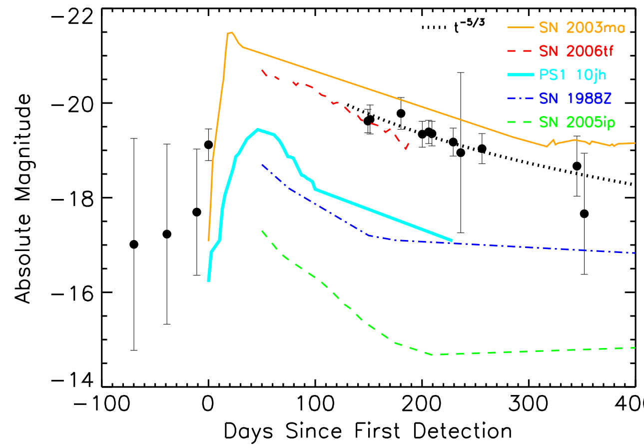

Figure 5. Comparison of LINEAR difference imaging LC, converted to absolute magnitudes, to known extreme interacting SNe SN 2005ip (unfiltered), SN 1988Z (M_z), SN 2006f (M_r), SN 2003ma (M_r), and the prototypical TDE candidate PS1-10jh (M_r). Correction for Galactic extinction is included.

within the clusters occupied by AGNs and star-forming galaxies. Motivated by these clues (and by GROND imaging that shows spiral structure in the host galaxy; K09), we conclude that the flare probably happened in a nonactive, star-forming galaxy.

4.2. Nature of the Flare

There are several possible explanations for the outburst in SDSS J0952+2143: a tidal disruption of a star by an SMBH in the center of the host galaxy, an extreme SN IIn, or AGN-like variability. Similarities in the spectral line responses of the former two scenarios require that we look at the photoionizing flare itself to ultimately uncover its origin. In Figure 5, we compare the LINEAR LC converted to absolute magnitude with the LCs of extreme interacting SNe in the r band (SN 2003ma, Rest et al. 2011; SN 2006tf, Smith et al. 2008; SN 1988Z, Turatto et al. 1993; SN 2005ip, Smith et al. 2009) and the best-observed TDE candidate PS1-10jh (Gezari et al. 2012). While the decline rate in the optical of 0.57 mag/(100 days) at >150 days from the start of the flare is similar to the behavior of SN 2003ma and SN 2006tf, this decline can also be fitted with a $t^{-5/3}$ power law evident in the optical LC of PS1-10jh. MAIA photometry obtained ~10 yr after SDSS photometry shows that the largest change in brightness happened in the bluer bands ($\Delta u \sim 1.3$ mag and $\Delta g \sim 0.6$ mag), indicating that the flare itself was much bluer than the host galaxy.

The coronal-line formation, however, was a response to intense X-ray radiation created by the event. Since the *Chandra* spectrum was taken ~3.5 yr after the peak of the flare, it is reasonable to expect that the X-ray luminosity of SDSS J0952+2143 could have been orders of magnitude larger (assuming the $t^{-5/3}$ decay predicted for TDEs). Such high levels of X-ray luminosity are unusual for SNe. The inferred UV luminosity for SDSS J0952+2143 at 1.8 yr after the start of the flare is comparable to the late-time UV luminosity inferred for TDE candidate PS1-10jh at a similar phase (Gezari et al. 2015a), and much more luminous than would be expected for an interacting SN at such late times. UV observations of SNe show a dramatic fading in the NUV on the timescale of days to weeks (Brown et al. 2009; Gezari et al. 2015b), owing to the expansion and cooling of the SN ejecta. Even in interacting SNe, sustained NUV emission on the level observed for SDSS J0952+2143 on the timescale of 1.8 yr after explosion would be unprecedented.

A possible explanation for the outburst in the SDSS J0952+2143 could be AGN variability, such as an accretion disk instability (e.g., Grupe et al. 2015). Thanks to the LINEAR and Catalina surveys, we are able to directly compare the optical LC of SDSS J0952+2143 to the LC of the bursting AGN IC 3599. This comparison indicates shorter rise times in SDSS J925+2143, more consistent with the TDE scenario than a disk instability (Saxton et al. 2015) and a decline with the $t^{-5/3}$ rate (unlike the case of IC 3599). Furthermore, while the ionization lines up to [Fe x] have been reported in the case of IC 3599, the extreme coronal lines with ionization up to [Fe xiv] were not detected. We find that the reported X-ray and UV flux levels, combined with the LCs, suggest the AGN scenario to be less likely than a TDE for SDSS J0952+2143. However, a longer observational baseline of optical monitoring (to be provided by, e.g., Pan-STARRS, *Gaia*, and LSST) could shed more light on this question.

Interestingly, the peak optical luminosity of the transient is >1 mag brighter than PS1-10jh (Gezari et al. 2012), but in the range of some other optically selected TDE candidates reported in the literature (van Velzen et al. 2011; Arcavi et al. 2014). This could be attributed to a more energetic event, possibly resulting from the efficient accretion of a larger fraction of the bound stellar debris. This larger luminosity could also translate to a stronger light echo in its surrounding gaseous environment, thus resulting in a detectable ECLE. Given the optical luminosity of the host galaxy measured by *Swift* and the Mercator telescope and its stellar velocity dispersion, a central black hole with a mass of $7 \times 10^{6}\,M_{\odot}$ (Komossa et al. 2008) is well within the range of black hole masses capable of disruption of a solar-type star outside the event horizon, and in a mass range where the peak accretion rate of the stellar debris would not be limited by the Eddington luminosity of the central SMBH.

5. CONCLUSIONS

We present archival LINEAR observations and late-time *Swift* and Mercator observations that add new pieces of the puzzle to the nature of the flare that powered the extreme coronal line emission in SDSS J0952+2143. In particular, our

Table 1
Compatibility of the Observations with Two Competing Scenarios (a TDE, an Interacting Supernova, or an AGN)

Property	TDE	SN	AGN
Proximity to host core	Y	Y	Y
UV luminosity	Y	N	Y
X-ray luminosity	Y	U	N
LC shape	Y	Y	U

Note. "Y" indicates "yes," "N" indicates "no," and "U" indicates "unlikely."

observations reveal the blue color and strong late-time UV luminosity of the flare and constrain its location within the errors to the nucleus of the host galaxy, both disfavoring an SN origin. Furthermore, if the flaring event is indeed associated with the galaxy's central SMBH, then the lack of variability detected by LINEAR before and after the flare is best explained by an impulsive accretion event, as would be expected from the tidal disruption of a star, as opposed to stochastic variability associated with a persistently accreting AGN. In Table 1 we summarize the evidence for the nature of the flaring event that powered the light echo in SDSS J0952+2143 and conclude that the most likely scenario that explains all of its properties is a TDE. Ultimately, it is the UV brightness, not the LC shape, that makes us confident that the TDE scenario is favored over the SN scenario.

This case of SDSS J0952+2143 demonstrates the importance of archived all-sky, time-domain surveys: LINEAR was originally an asteroid survey that was recycled as a project searching for variable stars. However, this resulted in a highly valuable archival, decade-long, time-domain survey covering a large fraction of the sky. In the future era of synoptic surveys, the recovery of the LCs of ECLEs discovered in spectroscopic surveys should be even easier and allow one to relate the detailed energetics of the TDE powering the flare, to its subsequent light echo in the gaseous environment of the SMBH.

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