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RBS 1032: A TIDAL DISRUPTION EVENT IN ANOTHER DWARF GALAXY?

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ABSTRACT

RBS 1032 is a supersoft ($\Gamma \sim 5$), luminous ($\sim 10^{43}$ erg s^{-1}) *ROSAT* PSPC source which has been associated with an inactive dwarf galaxy at $z = 0.026$, SDSS J114726.69+494257.8. We have analyzed an *XMM-Newton* observation that confirms that RBS 1032 is indeed associated with the dwarf galaxy. Moreover, RBS 1032 has undergone a factor of ∼100–300 decay since 1990 November. This variability suggests that RBS 1032 may not be a steadily accreting intermediate-mass black hole, but rather an accretion flare from the tidal disruption of a star by the central black hole (which may or may not be intermediate-mass). We suggest that additional tidal disruption events may remain unidentified in archival *ROSAT* data, such that disruption rate estimates based upon *ROSAT* All-Sky Survey data may need reconsideration.

Key words: galaxies: dwarf – galaxies: nuclei – X-rays: bursts – X-rays: individual (RBS 1032)

1. INTRODUCTION

Most (if not all) galaxies are thought to host massive ($M_\bullet \gtrsim 10^5\, M_\odot$) black holes (MBHs) at their nuclei. An important consequence is that occasionally a star may pass within the tidal disruption radius (R_T) of the MBH and be disrupted. The tidal forces overwhelm the star's self-gravity, and the star is ripped apart in a tidal disruption event (TDE; Hills 1975; Rees 1988). The bound debris falls back onto the MBH, generating an accretion-powered flare whose evolution is (to first order) governed by the approximately Keplerian orbits and the energy spread of the debris. The flare itself is thought to typically be most luminous in X-rays and ultraviolet (e.g., Ulmer 1999) but may also produce a relativistic jet that emits hard X-rays and gamma-rays (Bloom et al. 2011; Burrows et al. 2011). The rate at which TDEs occur (γ_D) is furthermore important to models of galaxy formation and evolution, as γ_D is a function of the MBH population distribution and the stellar population in the central cluster of a given galactic nucleus.

Recent wide-field time domain surveys have proven particularly effective at detailing TDE light curves during their rise and decline (e.g., Gezari et al. 2012). Since soft X-rays are likely to contain the bulk of the bolometric luminosity, however, numerous X-ray searches at $kT \lesssim 2$ keV have long proven productive in finding TDEs (e.g., Maksym et al. 2010, 2013, 2014; Lin et al. 2011; Irwin et al. 2010; Saxton et al. 2012; Esquej et al. 2008). The earliest confident TDEs were detected using *ROSAT* (Bade et al. 1996; Komossa & Bade 1999), with one of the most convincing early cases being RX J1242.6-1119A (Komossa & Greiner 1999; Komossa et al. 2004). By extension, one of the most-cited observational determinations of γ_D was conducted by Donley et al. (2002) using data from the *ROSAT* All-Sky Survey (RASS; Voges et al. 1999). *ROSAT* continues to be useful in the identification of new TDEs, not only as a critical indicator of pre-flare upper limits, but also in the identification of at least one new flare whose extreme variability was undetected by *ROSAT*, but which became evident through later X-ray observations (Cappelluti et al. 2009).

RBS 1032 was a bright ($F_X[0.1\text{–}2.4\ \text{keV}] \gtrsim 10^{-12}$ erg cm^{-2} s^{-1}), ultrasoft X-ray source identified in RASS (Fischer et al. 1998). The optical counterpart was initially suggested to be a star by Zickgraf et al. (2003). Later work by Ghosh et al. (2006) using the Sloan Digital Sky Survey (Ahn et al. 2014), the Russian–Turkish 1.5 m telescope in Anatalya, Turkey, and the 6 m telescope of the Special Astrophysical Observatory in Russia, however, showed the most likely optical counterpart to be a dwarf galaxy at $z \sim 0.026$ without emission lines, SDSS J114726.69+494257.8. They considered, and rejected as unlikely, numerous possible explanations for the X-ray emission. They also suggested that the system may be a binary with an intermediate-mass black hole (IMBH) as the primary component and a star, possibly a white dwarf, as the secondary.

We have investigated the most recent X-ray observation of RBS 1032 taken using *XMM-Newton*, and suggest an alternative explanation that RBS 1032 is certainly a transient source, and is a strong candidate for a TDE. If so, this adds to the list of TDEs reported in dwarf galaxies which may indicate the presence of IMBHs in dwarf galaxies, including WINGS J1348 in A1795 (Maksym et al. 2013, 2014; Donato et al. 2014) and GRB 060218 (Shcherbakov et al. 2013). Such IMBHs are important clues to the formation of the first black holes (Maksym et al. 2013, and references therein). Furthermore, we note that the discovery of new TDEs in archival *ROSAT* data has implications for γ_D as determined by Donley et al. (2002). We have conducted our analysis and arrived at this conclusion independently from the recent paper by Khabibullin & Sazonov (2014), who count RBS 1032 among their TDE candidates. We find that, with minor differences, our analysis is largely in agreement with theirs.

Throughout this Letter, we adopt concordant cosmological parameters[3] of $H_0 = 70$ km^{-1} sec^{-1} Mpc^{-1}, $\Omega_{m,0} = 0.3$, and $\Omega_{\Lambda,0} = 0.7$. All coordinates are J2000.

2. OBSERVATIONS AND DATA

2.1. *Previous ROSAT Work*

RBS 1032 was detected by *ROSAT* as part of RASS on 1990 November 5, and was re-observed with pointed PSPC observations on 1992 December 7 and 1994 June 05. For these epochs, Ghosh et al. (2006) determined an unabsorbed $F_X(0.1\text{–}2.4\ \text{keV}) = [6.0, 2.3, 1.1] \times 10^{-12}$ erg cm^{-2} s^{-1},

[3] Distances are calculated according to http://www.astro.ucla.edu/∼wright/CosmoCalc.html.

Table 1
Model Fits to *XMM-Newton* Data

Model	Parameter	Value	F_X (0.1−2.4 keV)	cstat/dof*
`zpowerlw`	Γ	3.42 ± 0.33	7.4 ± 3.1	20.69/20
`zbbody`	kT_{bb} (keV)	0.11 ± 0.01	2.0 ± 0.5	19.62/20
`diskbb`	kT_{bb}(keV)	0.15 ± 0.02	2.7 ± 0.7	19.23/20

Note. Fits use the Cash (1979) statistic (cstat) for given degrees of freedom (dof). N_H is fixed and assumed at Galactic (1.98×10^{20} cm^{-2}) as per `colden` (http://cxc.harvard.edu/toolkit/colden.jsp) and Dickey & Lockman (1990). F_X is in units of 10^{-14} erg cm^{-2} s^{-1}. F_X is unabsorbed, with 1σ uncertainties.

respectively,[4] assuming a blackbody with $kT_{bb} = 0.055$ keV and Galactic $N_H = 1.98 \times 10^{20}$ cm^{-2}, although they also fitted the data to a variety of models, including power law and multicolor blackbody disk models. In all epochs, they found the spectrum to be supersoft ($\Gamma_{pl} \sim 5$ or $kT_{bb} \sim 0.06$ keV).

2.2. XMM Observation

RBS 1032 was observed by *XMM-Newton* on 2009 November 21 for ∼17 ks (obs. id 0604020101, PI: K. Ghosh). The observation was badly contaminated by background flaring, leaving only [1.5, 4.7, 9.8] ks of usable [PN, M1, M2] data. Inspection of the pipeline-produced broadband image reveals a faint point source within the ∼30″ *ROSAT* PSPC PSF when compared to the location of RBS 1032 ($r \sim 6''.4$ separation). This source is also recovered by the *XMM-Newton* pipeline, with a corresponding UVW1 (∼2910 Å) source detected by the optical monitor pipeline at $m_{UVW1} = 20.3$ ($M_{UVW1} = -15$, $\nu L_{\nu,UVW} = 1.2 \times 10^{41}$ erg s^{-1}). This corresponds to the source 3XMM J114726.7+494257 ([α, δ] = [$11^h47^m26^s.73$, +49°42′57″.3], XMM-Newton Survey Science Centre 2013; coordinates are J2000 with 1σ error of 1″.45). This is the only such source within 30″. The next-closest pipeline source is at $\gtrsim 3'$ separation.

This XMM source is $r \sim 0''.8$ from SDSS J114726.69+494257.8, and within the 1σ error (1″.45 in [α, δ]), from the 3XMM catalog position. The next-closest SDSS source is at $r \sim 6''.0$ (comparable to the *XMM-Newton* FWHM) and 5.6 mag fainter. The UVW1 source is also coincident with SDSS J114726.69+494257.8.

2.3. Data Reduction

To perform our own spectral analysis, we reduced the data for 3XMM J114726.7+494257 using `XMM-SAS`.[5] As per standard procedure, we used `evselect` to filter the MOS and PN event files for periods of high background, and then to extract the spectrum for a region with $r = 15''$ and $\gtrsim 3$ counts per bin. We then similarly extracted a background spectrum from a nearby 33″ region. We then used `arfgen` and `rmfgen` to produce response matrix files.

We used `XSPEC`[6] to fit the spectra to `zbbody`, `zpowerlw`, and `diskbb` models, in order to compare to the analysis of *ROSAT* data by Ghosh et al. (2006). With only ∼17 net PN counts (32 total), meaningful constraint of N_H is not possible. We can, however, address the general shape of the spectrum and constrain the normalization of an assumed spectral type. We present the results of these fits in Table 1 and Figure 1.

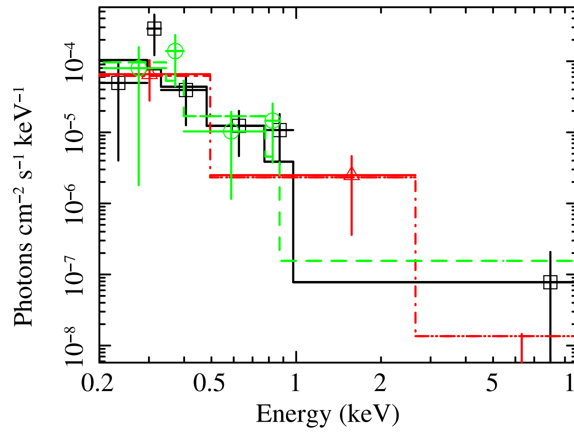

Figure 1. Best-fit power law model for *XMM-Newton* spectrum, as per Table 1. Data from [PN, MOS1, MOS2] are represented as [black square, red triangle, green circle] and fit simultaneously, with model values of a given bin represented as [solid, dot-dashed, dashed] lines. Data are fit in the 0.2–10 keV range.

3. LIGHT CURVE ANALYSIS

Depending upon the spectral model, F_X(0.1–2.4 keV) decreases by a factor of ∼100–300 from 1990 to 2009. Given the strong variability, the extreme luminosity ($L_X > L_{Edd}$ for $M_\bullet \sim 10^5\, M_\odot$), and the supersoft spectrum, we must therefore consider the possibility that RBS 1032 is a TDE. At a very basic level, we can examine the X-ray light curve to compare against the assumption that the X-ray luminosity tracks the accretion rate $\dot{M}$, for which $L_X \propto (t - t_0)^{-5/3}$ (to first order), where t_0 is the time of stellar pericenter.

We plot a variety of simple model fits to the light curve in Figure 2, assuming the best-fit value for `zpowerlw` in 2009. The data generally fit a simple $t^{-5/3}$ approximation, although the *XMM-Newton* data point is below the prediction of a $t^{-5/3}$ curve which fits only the *ROSAT* points. Unlike `zpowerlw`, the inferred luminosities from the `zbbody` and `diskbb` models are below all light curve fits in Figure 2. Lodato & Rossi (2011) suggest that the monochromatic flux from a TDE may pass through three major evolutionary phases ($t^{-5/12}$, $t^{-5/3}$, and exponential decay) as it cools, depending upon the relation of the bandpass to the peak emission wavelength. For X-rays, the $t^{-5/12}$ phase is not seen, whereas the $t^{-5/3}$ phase may last years. Maksym et al. (2013) suggest that there is some evidence for this late-time exponential decay. Simulations by Guillochon & Ramirez-Ruiz (2013) and Guillochon et al. (2014) paint a more complicated picture, as $\dot{M}$ may be affected by the retention of an intact stellar core and may asymptote to $t^{-2.2}$.

In order to evaluate the applicability of such decay models, we consider the plausible $M_\bullet$ range. Ghosh et al. (2006) suggest $M_\bullet \sim 5 \times 10^4\, M_\odot$ based on blackbody disk models, which requires sustained super-Eddington accretion in the 1990 epoch, given that $L_X \sim L_{Edd}$ implies $M_\bullet \gtrsim 10^5\, M_\odot$ for a bolometric correction of $\gtrsim 1.5$. We consider a plausible upper bound for $M_\bullet$, given the L_{bulge}–$M_\bullet$ relationship (e.g., Marconi & Hunt 2003; Kormendy & Ho 2013). The applicability of L_{bulge}–$M_\bullet$ in this regime is uncertain, and would be affected by the galaxy morphology (see, e.g., Kormendy & Ho 2013, and references therein), including the nature of any nuclear

[4] Ghosh et al. (2006) claim to have used the 1–2.4 keV band in their *ROSAT* analysis, but we believe this to be an uncorrected typographical error. The standard broad *ROSAT* band is 0.1–2.4 keV, which is consistent with flux values calculated using WebPIMMS (http://heasarc.nasa.gov/Tools/w3pimms.html) and the Ghosh et al. (2006) assumed spectral model.
[5] http://xmm.esac.esa.int/sas/
[6] http://heasarc.gsfc.nasa.gov/xanadu/xspec/

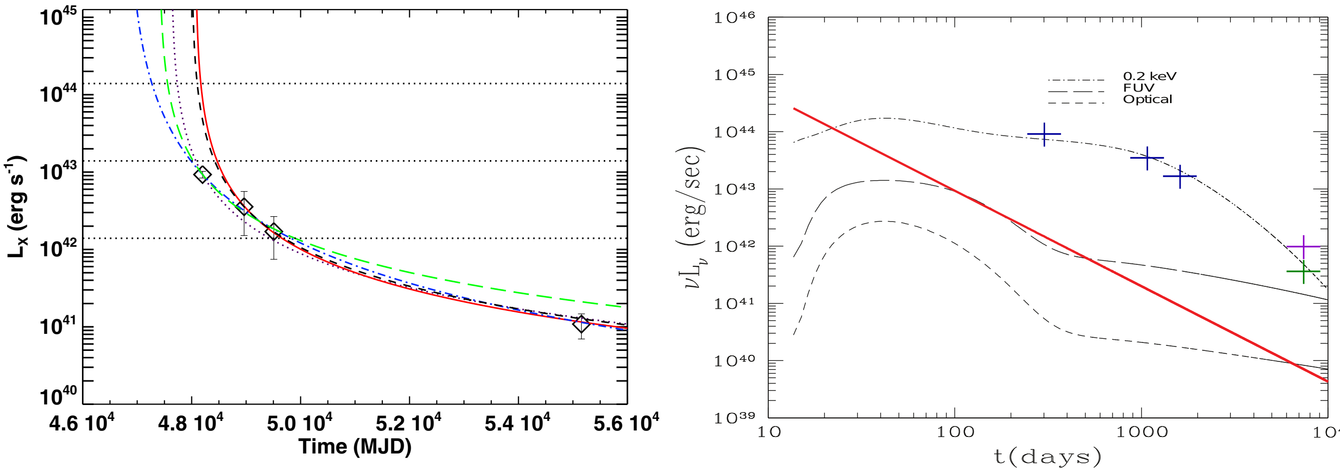

Figure 2. Left: light curve and models for RBS 1032. Except for free n (blue dot-dash; t_0 = MJD 46806), all curves are $t^{-5/3}$. Other models use a subset of observed points, to emphasize possible time-dependent deviations from the basic model, and the effect on the inferred pericenter date. Models are as follows: purple dotted (all; t_0 = MJD 47621), green long-dash (1,2,3; t_0 = MJD 47400), dashed black (2,3; t_0 = MJD 47995) and solid red (2,3,4; t_0 = MJD 48067). Horizontal dotted lines (from bottom to top) correspond to the Eddington luminosity for $M_\bullet = [10^4, 10^5, 10^6]M_\odot$. Right: Figure 7 from "Multiband light curves of tidal disruption events" by Lodato & Rossi (2011), modified to show RBS 1032 *ROSAT* data points (blue crosses), and the best *XMM-Newton* `zpowerlw` (purple) and `zbbody` (green) fits. Curves indicate predicted band-specific luminosities for $M_\bullet = 10^6\ M_\odot$ for a solar-mass star with pericenter R_T. The red line indicates $t^{-5/3}$ decay. Data are scaled such that νL_ν(0.2 keV; model)/L_X(0.1–2.4 keV; data) ~ 9.1 and assume t_0 = MJD 47900.

component in SDSS J114726.69+494257.8. Although Ghosh et al. (2006) label this galaxy as a nucleated dwarf spheroidal, the Galaxy Zoo morphology is uncertain (Lintott et al. 2008). Since $L_{\rm bulge} \lesssim L_{\rm total}$, we find $\log(M_\bullet/M_\odot) \lesssim 6.4$ for $I = 15.98$ (Ghosh et al. 2006), according to Jiang et al. (2011).

The 2009 observation of RBS 1032 is sufficiently late that it is likely to be in the Lodato & Rossi (2011) exponential decay regime for $M_\bullet \gtrsim 10^5\ M_\odot$, which is compatible with the observations. The *ROSAT* epochs may instead be described by a more gradual decay than $t^{-5/3}$ (see Lodato & Rossi 2011), if early accretion is significantly affected by stellar structure (Lodato et al. 2009) and $\dot{M}$ in the super-Eddington regime is strongly modulated by outflows (Dotan & Shaviv 2010). For example, Lodato & Rossi (2011) show that during the first ∼4 yr of a disruption where $M_\bullet = 10^6\ M_\odot$, L_X may vary by an amount comparable to the RBS 1032 *ROSAT* data. The super-Eddington phase may last $\sim 0.76(M_\bullet/10^7\ M_\odot)^{-2/5}$ yr (Ulmer 1999), or ∼4.8 yr at $M_\bullet \sim 10^5\ M_\odot$. Alternately, a disrupted red giant may exhibit similar slowly evolving $\dot{M}$ (MacLeod et al. 2012). When n for $L_X \propto t^{-n}$ is left free, we find $n = 2.5 \pm 1.3$, which is closer to the Guillochon & Ramirez-Ruiz (2013) suggestion of $t^{-2.2}$ for a surviving stellar core than to the Keplerian $n = 5/3$ value, but compatible with both.

4. DISCUSSION

The small separation between 3XMM J114726.7+494257 and RBS 1032, and the lack of other likely *XMM-Newton* counterparts to RBS 1032 both strongly suggest that they are the same X-ray source (see, e.g., the Donato et al. 2014 analysis of *EUVE* data for WINGS J1348). If so, the Ghosh et al. (2006) attribution of RBS 1032 to SDSS J114726.69+494257.8 is likely correct.

As with other X-ray selected TDE candidates (e.g., Maksym et al. 2010, 2013), the extreme luminosity ($L_X \gtrsim 10^{43}$ erg s^{-1}), supersoft spectrum $\Gamma \sim 5$ at early times, and extreme variability (a factor of ≳200 decay) make this a strong candidate for a TDE. This is not a surprising conclusion, given Wang & Merritt (2004) suggest significantly elevated γ_D for nucleated dwarf spheroidal galaxies. Other possible explanations can be rejected via arguments similar to those advanced by Maksym et al. (2010, 2013) and others. The X-ray spectrum is too soft for a gamma-ray burst (GRB). Supernovae may exhibit soft thermal spectra, but L_X would make RBS 1032 among the most X-ray luminous supernovae (Levan et al. 2013). RBS 1032 is, however, significantly softer at early times than the super-luminous supernova SCP 06F6 ($\Gamma \sim 5$ versus $\Gamma \sim 2.5$). The early X-ray emission in RBS 1032 is orders of magnitude too luminous for a stellar mass X-ray binary in SDSS J114726.69+494257.8. Ghosh et al. (2006) suggest a classical (and presumably Galactic) nova as possible but unlikely. In addition to their arguments, we suggest the high galactic latitude ($b \sim 64°$) makes a Galactic foreground object unlikely (Maksym et al. 2010, 2013). Classical novae in particular are rare at $b \gtrsim 30°$ (Imamura & Tanabe 2012).

Ghosh et al. (2006) suggest that RBS 1032 may be an IMBH binary, possibly with a white dwarf secondary component. At least one other IMBH binary has been suggested, ESO 243-09 HLX-1 (Lasota et al. 2011 suggest a donor giant star). As with ESO 243-09 HLX-1, an eccentric orbit could mimic the extreme variability seen in RBS 1032. Additional X-ray monitoring observations could verify or disprove such an explanation.

Given that both Narrow-Line Seyfert 1 (e.g., Grupe et al. 1995) and Seyfert 2 (Saxton et al. 2011) galaxies may exhibit extreme supersoft X-ray variability on timescales similarly short to TDEs, an AGN origin is typically the most difficult explanation to dismiss for an X-ray source with these characteristics. Variability in such a case may be attributed to change in $\dot{M}$ or N_H. Ghosh et al. (2006) demonstrate, however, that RBS 1032 has no significant emission lines. Steady accretion by an AGN is therefore disfavored. TDEs may temporarily excite emission lines (e.g., Bogdanović et al. 2004; Clausen & Eracleous 2011; Gezari et al. 2012), but such lines might not be visible at $t_0 \gtrsim 15$ yr.

The *XMM-Newton* spectrum is harder than previous epochs ($\Gamma \sim 3$ versus ∼5). Such evolution has been seen in X-ray observations at $t_0 \gtrsim 10$ yr (Halpern et al. 2004). This could be a state change due to a lower $\dot{M}$, or a weak "hard" physical component only visible when the soft component subsides. The lack of emission lines indicates little star formation or nuclear activity. Contamination due to hot gas or X-ray binaries is thus likely to be small ($\lesssim$few $\times$ 10^{39} erg s^{-1}).

Given the importance of RASS for determining γ_D, Donley et al. (2002) remains an important reference for discussion of the observed γ_D. At $\gamma_D \sim 10^{-5}$ galaxy^{-1} yr^{-1}, this also remains one the most conservative γ_D values in the literature. The discovery of a single RASS flare would not have a major impact on Donley et al. (2002) even given they only assume three outbursts from inactive galaxies. However, the presence of other unidentified flares (undetected due to long periods of shallow evolution, for example) might require a re-evaluation of Donley et al. (2002) and its applicability to TDEs. Donley et al. (2002) assume that any flare which varies by $\gtrsim$20 during RASS and the preceding ~six months would be detected by their study. This assumption was reasonable according to TDE theory at the time, and was confirmed by all known TDEs identified by *ROSAT*.

RBS 1032, though observed by *ROSAT* three times over ~4 yr, only varied by ~5 and thus was not selected. Under certain models, however, TDEs may have relatively shallow X-ray light curves for years at a time. In particular, certain models (e.g., Lodato & Rossi 2011) may have relatively shallow X-ray light curves for years. But even with modest deviations from best-fit $t^{-5/3}$ decay, RBS 1032 could fall within the Donley et al. (2002) window. As a result, we expect that not all RASS TDEs had been detected. The TDE in A3571 identified by Cappelluti et al. (2009) also complicates the Donley et al. (2002) rate estimation, as the RASS F_X upper limit falls earlier than their best-fit t_0, but is also above their earliest detected X-ray flux. Given the flare's proximity to the diffuse intracluster X-ray emission from A3571, and the likely importance of galaxy clusters in TDE production (Wang & Merritt 2004; Cappelluti et al. 2009; Maksym et al. 2010, 2013), such cluster background may be important to any RASS-derived γ_D.

Given this state of affairs, we therefore argue that the results of Donley et al. (2002) should be considered a lower limit to γ_D, and that long baseline X-ray studies (such as may use RASS and *Chandra*, *XMM-Newton*, *Swift*, or *eROSITA*) are necessary to investigate the occurrence of TDEs which may display such gradual evolution. This assertion is supported by the recent work of Khabibullin & Sazonov (2014), who found several *ROSAT* flares in combination with the *XMM-Newton* archive (as predicted by Donley et al. 2002). Observations to follow up bright *ROSAT* sources may yield additional TDEs. Also, long-baseline studies of TDE candidates from other systematic surveys (such as the three as-yet-unfollowed candidates from Esquej et al. 2007) may prove helpful in better determining γ_D and the long-term X-ray behavior of TDE light curves.

5. CONCLUSIONS

By comparing archival *XMM-Newton* observations with previous work by Ghosh et al. (2006), we confirm that RBS 1032 is associated with the dwarf galaxy SDSS J114726.69+494257.8. We suggest that RBS 1032 is also likely to be a TDE. Its peak luminosity ($L_X \gtrsim 10^{43}$ erg s^{-1}), softness ($\Gamma \sim 5$), and extreme variability (factor of ~200) in a quiescent galaxy are typical of X-ray selected TDEs. Via the absence of AGN emission lines, Ghosh et al. (2006) have already demonstrated that an AGN is an unlikely explanation. Other explanations, such as GRBs, supernovae, and X-ray binaries are disfavored. Although the nuclear black hole could be an IMBH, a more massive black hole ($\gtrsim 10^6\ M_\odot$) would be consistent with the host galaxy luminosity, depending upon its morphology. Higher-resolution images, such as with the *Hubble Space Telescope*, would allow more thorough analysis of the host galaxy's morphology and properties.

We have not ruled out an explanation similar to Ghosh et al. (2006), that RBS 1032 may result from an IMBH binary. If so, the extreme variability may imply an eccentric orbit, as suggested for ESO 243-09 HLX-1 (Lasota et al. 2011). Additional X-ray monitoring observations would constrain this scenario. If RBS 1032 remains weak or undetected, the TDE scenario would be favored.

The discovery of a new TDE candidate in archival *ROSAT* All-Sky Survey data supports the idea that, as per Donley et al. (2002), additional TDEs may yet be discovered in RASS via X-ray follow up of bright *ROSAT* sources, and in comparison with *Chandra* and *XMM-Newton* archives. RBS 1032 also implies that the variability constraint of $\gtrsim$20 may leave some X-ray selected TDEs undiscovered, such that the outburst rate in Donley et al. (2002) should be taken as a lower limit for the true tidal disruption rate. Further RASS follow-up may help determine whether recent disruption rates of ~5–10 $\times$ 10^{-5} galaxy^{-1} yr^{-1} (e.g., Maksym et al. 2010, 2013; Esquej et al. 2008) are more reasonable. This is consistent with more recent models of multi-band TDE light curve variability (e.g., Lodato & Rossi 2011). Recent work by Khabibullin & Sazonov (2014) using archival *ROSAT* and *XMM-Newton* data already points to a higher rate (~3 $\times$ 10^{-5} galaxy^{-1} yr^{-1}). More generally, targeted X-ray follow-up of otherwise inactive galaxies that demonstrate bright X-ray activity may be fruitful in exploring the full range of TDE phenomena.

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Facilities: XMM-NEWTON, ROSAT, SDSS

REFERENCES

Ahn, C. P., Alexandroff, R., Allende Prieto, C., et al. 2014, ApJS, 211, 17
Bade, N., Komossa, S., & Dahlem, M. 1996, A&A, 309, L35
Bloom, J. S., Giannios, D., Metzger, B. D., et al. 2011, Sci, 333, 203
Bogdanović, T., Eracleous, M., Mahadevan, S., Sigurdsson, S., & Laguna, P. 2004, ApJ, 610, 707
Burrows, D. N., Kennea, J. A., Ghisellini, G., et al. 2011, Natur, 476, 421
Cappelluti, N., Ajello, M., Rebusco, P., et al. 2009, A&A, 495, L9
Cash, W. 1979, ApJ, 228, 939
Clausen, D., & Eracleous, M. 2011, ApJ, 726, 34
Dickey, J. M., & Lockman, F. J. 1990, ARA&A, 28, 215
Donato, D., Cenko, S. B., Covino, S., et al. 2014, ApJ, 781, 59
Donley, J. L., Brandt, W. N., Eracleous, M., & Boller, T. 2002, AJ, 124, 1308
Dotan, C., & Shaviv, N. J. 2010, arXiv:1004.1797
Esquej, P., Saxton, R. D., Freyberg, M. J., et al. 2007, A&A, 462, L49

Esquej, P., Saxton, R. D., Komossa, S., et al. 2008, A&A, 489, 543
Fischer, J.-U., Hasinger, G., Schwope, A. D., et al. 1998, AN, 319, 347
Gezari, S., Chornock, R., Rest, A., et al. 2012, Natur, 485, 217
Ghosh, K. K., Suleymanov, V., Bikmaev, I., Shimansky, S., & Sakhibullin, N. 2006, MNRAS, 371, 1587
Grupe, D., Beuerman, K., Mannheim, K., et al. 1995, A&A, 300, L21
Guillochon, J., Manukian, H., & Ramirez-Ruiz, E. 2014, ApJ, 783, 23
Guillochon, J., & Ramirez-Ruiz, E. 2013, ApJ, 767, 25
Halpern, J. P., Gezari, S., & Komossa, S. 2004, ApJ, 604, 572
Hills, J. G. 1975, Natur, 254, 295
Imamura, K., & Tanabe, K. 2012, PASJ, 64, 120
Irwin, J. A., Brink, T. G., Bregman, J. N., & Roberts, T. P. 2010, ApJL, 712, L1
Jiang, Y.-F., Greene, J. E., & Ho, L. C. 2011, ApJL, 737, L45
Khabibullin, I., & Sazonov, S. 2014, MNRAS, accepted (arXiv:1407.6284)
Komossa, S., & Bade, N. 1999, A&A, 343, 775
Komossa, S., & Greiner, J. 1999, A&A, 349, L45
Komossa, S., Halpern, J., Schartel, N., et al. 2004, ApJL, 603, L17
Kormendy, J., & Ho, L. C. 2013, ARA&A, 51, 511
Lasota, J.-P., Alexander, T., Dubus, G., et al. 2011, ApJ, 735, 89
Levan, A. J., Read, A. M., Metzger, B. D., Wheatley, P. J., & Tanvir, N. R. 2013, ApJ, 771, 136
Lin, D., Carrasco, E. R., Grupe, D., et al. 2011, ApJ, 738, 52
Lintott, C. J., Schawinski, K., Slosar, A., et al. 2008, MNRAS, 389, 1179
Lodato, G., King, A., & Pringle, J. 2009, MNRAS, 392, 332
Lodato, G., & Rossi, E. M. 2011, MNRAS, 410, 359
MacLeod, M., Guillochon, J., & Ramirez-Ruiz, E. 2012, ApJ, 757, 134
Maksym, W. P., Ulmer, M. P., & Eracleous, M. 2010, ApJ, 722, 1035
Maksym, W. P., Ulmer, M. P., Eracleous, M. C., Guennou, L., & Ho, L. C. 2013, MNRAS, 435, 1904
Maksym, W. P., Ulmer, M., Roth, K., et al. 2014, MNRAS, accepted (arXiv:1407.6737)
Marconi, A., & Hunt, L. K. 2003, ApJL, 589, L21
Rees, M. J. 1988, Natur, 333, 523
Saxton, R., Read, A., Esquej, P., Miniutti, G., & Alvarez, E. 2011, in Narrow-Line Seyfert 1 Galaxies and their Place in the Universe, ed. L. Foschini et al. (Proceedings of Science), 8
Saxton, R. D., Read, A. M., Esquej, P., et al. 2012, A&A, 541, A106
Shcherbakov, R. V., Pe'er, A., Reynolds, C. S., et al. 2013, ApJ, 769, 85
Ulmer, A. 1999, ApJ, 514, 180
Voges, W., Aschenbach, B., Boller, Th., et al. 1999, A&A, 349, 389
Wang, J., & Merritt, D. 2004, ApJ, 600, 149
XMM-Newton Survey Science Centre. 2013, yCat, 9044, 0
Zickgraf, F.-J., Engels, D., Hagen, H.-J., Reimers, D., & Voges, W. 2003, A&A, 406, 535