DISCOVERY OF A NEW KIND OF EXPLOSIVE X-RAY TRANSIENT NEAR M 86

P.G. Jonker 1,2,3, A. Glennie 4, M. Heida 1,2, T. Maccarone 5, S. Hodgkin 6, G. Nelemans 2,7, J.C.A. Miller-Jones 8, M.A.P. Torres 9, and R. Fender 3

ABSTRACT

We present the discovery of a new type of explosive X-ray flash in Chandra images of the old elliptical galaxy M 86. This unique event is characterised by the peak luminosity of $6 \times 10^{42}$ erg s$^{-1}$ for the distance of M 86, the presence of precursor events, the timescale between the precursors and the main event ($\sim 4000$ s), the absence of detectable hard X-ray and $\gamma$-ray emission, the total duration of the event and the detection of a faint associated optical signal. The transient is located close to M 86 in the Virgo cluster at the location where gas and stars are seen protruding from the galaxy probably due to an ongoing wet minor merger. We discuss the possible mechanisms for the transient and we conclude that the X-ray flash could have been caused by the disruption of a compact white dwarf star by a $\sim 10^5$ M$_\odot$ black hole. Alternative scenarios such that of a foreground neutron star accreting an asteroid or the detection of an off-axis (short) $\gamma$-ray burst cannot be excluded at present.

Subject headings: black hole physics— galaxies: individual M 86– galaxies: interactions — X-rays: individual XRT 000519

1. INTRODUCTION

The Universe is not static: optical, infrared, radio, X-ray and $\gamma$-ray observations reveal a rich diversity in variability and explosions. In the X-ray band the observed variability on time scales of hours to days has been attributed to exploding massive stars (Mészáros 2006), or the accretion of material on neutron stars, stellar-mass (Fender & Belloni 2012), or super-massive black holes in AGN with masses of $>10^9$ M$_\odot$ (Greene & Ho 2007) have been identified, black holes with masses of several hundred to a few thousand solar masses remain elusive. Ultra-luminous X-ray sources (ULXs) could harbor such black holes with masses in-between the stellar--mass black holes found in X--ray binaries and the supermassive black holes (SMBHs; $\gtrsim 1 \times 10^{7}$ M$_\odot$) found in the centers of galaxies. The ULX near ESO 243-49 is possibly the best intermediate-mass black hole (IMBH) candidate (Farrell et al. 2009).

Theoretically, the mass of a stellar--mass black hole, formed from the evolution of a massive star, depends on the initial mass of the progenitor, on the supernova explosion mechanism (Belczynski et al. 2010; Fryer et al. 2012) and on how much mass is lost during the progenitor’s evolution which, in turn, is a function of the metallicity of the black hole progenitor star. Mass is lost through stellar winds, the mass--loss rate strongly depends on the metallicity of the star. For a low--metallicity star ($\sim 0.01$ solar metallicity) it is possible to leave a black hole of $\lesssim 70 M_\odot$ (Belczynski et al. 2010). Thus, theories do allow for more massive stellar--mass black holes than have been found so far in our Galaxy (e.g. Özel et al. 2010).

In very massive stars ($\gtrsim 130 M_\odot$) production of free electrons and positrons, due to increased $\gamma$-ray production, reduce thermal pressure inside the core. This eventually leads to a runaway thermonuclear explosion that completely disrupts the star without leaving a black hole, causing the upper limit for a stellar black hole of $\sim 100 M_\odot$. It has been suggested that metal--free Population III stars could have had masses above this pair--instability limit and collapsed into intermediate--mass black holes (Madau & Rees 2001). It has also been suggested that SMBHs may form in the centers of dense stellar clusters via the merger of stellar mass black holes (e.g., Miller & Hamilton 2002), or from the collapse of merged supermassive stars in very dense star clusters (e.g., Portegies Zwart & McMillan 2002). These massive black holes could allow for the assembly of supermassive black holes early in the Universe (e.g. Volonteri 2010 Volonteri 2012).

Stellar dynamical models predict that once every $10^3$–$10^5$ year a star in a galaxy will pass within the tidal disruption radius of the central black hole and thus will be torn apart by tidal forces (Wang & Merritt 2004). The fall-back of debris onto the black hole produces a luminous electromagnetic flare that is detectable in UV and X-ray light. Several UV transients coincident with the center of a galaxy have been detected (e.g. Gezari...
2. OBSERVATIONS, ANALYSIS AND RESULTS

2.1. Chandra X-ray observation

We identified a new type of X-ray transient in a Chandra observation that started on 2000 May 19 UT (universal time). We designate the name X-ray transient (XRT) 000519 to this event. The transient was discovered in Chandra images with Observation Identification number 803. The source position was covered by the S4 CCD of the ACIS-S array of CCD detectors (Garmire 1997). We reprocessed and analyzed the data using the CIAO 4.5 software developed by the Chandra X-ray Center and employing CALDB version 4.5.5.1. The data telemetry mode was set to very faint, which allows for a thorough rejection of events caused by cosmic rays.

The ACIS-S4 CCD is known to be suffering from an error in the readout where charge unrelated to the arrival of X-ray photons is deposited during read-out of the CCD. These events can be removed in the subsequent processing of the event file by using the DESTREAK command in the CIAO software suite provided by the Chandra X-ray Center (Fruscione et al. 2006). XRT 000519 is still detected at a very high significance level after we run the DESTREAK command. However, given that this tool also removes some charge from genuine X-ray photons when the X-ray source is very bright, we extracted the data from the peak of XRT 000519 without applying the DESTREAK step.

Using the WAVDETECT tool on the X-ray image allows us to locate the event at (J2000) right ascension 12\(^\text{h}\)25\(^\text{m}\)31.64\(^{\text{s}}\) and declination +13\(^{\circ}\)03'58.8" with an estimated 68 per cent confidence uncertainty in the position of 1\(^{\prime}\) due to the large angle of 13.37\(^{\prime\prime}\) between the optical axis of the Chandra mirrors and the location of the source on the detector. We investigated the point-spread function of the source by performing a MARX simulation for such an off-axis angle and we find that the observed point-spread function is consistent with that expected on the basis of the simulation. Due to the large off-axis angle the source photons were spread over hundreds of detector elements, making spectral distortion due to photon pile-up minimal.

The light curve of the main event, plotted at the maximum time resolution of 3.24 s, is double peaked (see Figure 1). The source flux rises within 10 s from being undetected to a peak count rate of 20 counts s\(^{-1}\), it decays more slowly over a period of 20 s to a count rate just above 1 count s\(^{-1}\), to rise again to the peak count rate of 24 counts s\(^{-1}\). The second peak has a flat top that lasts around 20 s, before gradually decreasing on a time scale of about 100 s, followed by a slow power law decay with an index of -0.3\(\pm\)0.1 that could be followed for 2\(\times\)10\(^4\) s until the end of the observation.

When investigating the X-ray light curve of the source we found evidence for the presence of a precursor event of 16 X-ray photons about 4,000 s before the main flare. In the same 1,000 s interval of time of the precursor, we find 4 photons due to the background in a source-free region with the same size as the source region, on the same CCD and at a similar off-axis angle as XRT 000519. Thus, the chance of finding 16 photons due to random variations in the background is less than 1 in 250,000. Interestingly, there is evidence for another precursor event, again about 4,000 s earlier. In that case, we find 11 photons in 1,000 s where 3.7 are found in an off-source region over the same time; this should happen by chance in less than 1 in 650,000 cases. Therefore, we conclude that these two precursor events are likely to be real. The small number of events (three) does not allow us to conclude that the 4,000 s time scale is periodic.

We extracted the source spectrum from photons in a circular region with radius of 30\(^{\prime\prime}\) centered on the source position of XRT 000519 in the energy range of 0.1–7 keV. Background events were extracted from an annulus centered on the position of the source with an inner radius of 60\(^{\prime\prime}\) and an outer radius of 105\(^{\prime\prime}\). Using xspec version 12.4.0a1 (Arnaud 1996), we have fitted the spectra of XRT 000519 using Cash statistics (Cash 1979) modified to account for the subtraction of background counts, the so called W–statistics\(^9\). We have used an absorbed power–law model (pegpwrlw in xspec) to describe the data. For the extraction of the X-ray spectral parameters we added an extinction of N\(_\text{H} = 2.6 \times 10^{20} \text{cm}^{-2}\) due to the Galactic foreground (Dickey & Lockman 1990). We did not detect enough counts to add a component to the fit function that could describe the influence of the potential presence of local material causing extinction in addition to that by the Galactic foreground. The X-ray spectrum of the first of the two bright peaks can be well described by a powerlaw with photon index 1.6\(\pm\)0.1 (68% confidence level) where we included the effect of the Galactic extinction in the direction of the source. The energy spectrum of the second of the two bright peaks is softer with a power law photon index of 1.95\(\pm\)0.05 (see Figure 2). The fact that the second peak has a higher peak count rate while it has a softer spectrum is in line with the inference that the X-ray spectrum is not dis-

---

A new kind of explosive X-ray transient

2.2. BATSE observations

XRT 000519 was not detected by the Burst And Transient Source Experiment (BATSE), although the source was in the BATSE field of view at the time of the event (including the precursor events). Extrapolating the best-fitting X-ray spectrum at peak would have the source falling a factor of \(\sim 50\) below the BATSE threshold for detection. The nearly steady emission during the second half of the Chandra observation falls a factor of a few below the occultation technique’s sensitivity limit.

2.3. XMM-Newton observations of the field

XMM-Newton X-ray observations of the region on the sky containing the position of XRT 000519 were obtained on 2002 July 1, 2004 December 27 and 2011 June 1 (the observation identification numbers for these observations are 0108260201, 0210270201, and 0673310101, respectively). Using the 2012 June 21 release of SAS, we cleaned the event lists for periods of enhanced background leaving 78 and 79 ksec for the MOS1 and MOS2 detectors in the 2002 observation, respectively. The source region falls off the pn CCD during the 2002 observation.

The 2004 observation yielded 18 ksec of cleaned pn exposure and 21.7 ksec for both MOS1 and MOS2. Finally, the 2011 observation has 40 ksec of cleaned pn exposure.

The source was undetected with a \((0.5-10\text{ keV})\) flux limit of \(\approx 4 \times 10^{-14}\text{ erg cm}^{-2}\text{ s}^{-1}\) for an assumed incident power law spectrum with index 1.7 for the first two observations and \(\approx 3 \times 10^{-13}\text{ erg cm}^{-2}\text{ s}^{-1}\) for the last observation, giving a luminosity upper limit of \(1 \times 10^{39}\) erg s\(^{-1}\) for the first two and \(9 \times 10^{38}\) erg s\(^{-1}\) for the third observation, respectively if the event took place at the distance of M 86 of 16.2 Mpc.

2.4. Ultra-violet, optical and near-infrared observations

We queried various data archives to search for archival ultra-violet, optical and near-infrared images of the field of XRT 000519.

The Galaxy Evolution Explorer satellite (GALEX) observed the field of the transient on 2006 March 20 for 15700 s with its near-ultraviolet camera and for 482 s with its far-ultraviolet camera. No source was detected in either the near-ultraviolet or the far-ultraviolet image down to a magnitude limit of 25.5 and 23.7, respectively.

We investigated a 999 s \(i’\)-band image \((\lambda_{central} = 7743\ \text{Å} , \Delta\lambda = 1519\ \text{Å})\) from the Isaac Newton Telescope (INT) at La Palma, Spain, obtained on 2001 March 22 (see Figure 2). We found a faint optical star at a magnitude of \(i’ = 24.3 \pm 0.1\) magnitude. The source is located at \((J2000)\) right ascension \(12^h25^m31.636^s\) and declination \(+13^\circ03’58.01”\), where the uncertainty in the position is 0.1 arcsec in both right ascension and declination. The angular difference between the X-ray position of XRT 000519 and the position of this faint \(i’\)-band source is 0.8 arcsec. This is within the 1” error circle of...
the \textit{Chandra} X-ray position of the source.

We found archival optical images in the $u'$, $g'$, $i'$ and $z'$-band obtained in 2009 and 2010 by the Canada-France-Hawaii Telescope (CFHT) using the MegaPrime instrument (see Table 1). In addition, we report on $r'$ images obtained on 2005 Jan. 17 with the same instrument–telescope combination. Using the Terapix data analysis results, we found no source down to the limiting magnitude of the images ($u' = 27.2$, $r' = 26$, $i' = 25.6$ and $z' = 25.3$). However, in the deep, median combined $g'$-band image totalling 3170 s of exposure obtained between 2009 May 22 and 25, under seeing conditions of 0.7 arcseconds, there is evidence for the presence of a faint unresolved source at a position of right ascension $12^h 25^m 31.56^s$ and declination $13^\circ 03' 59.2''$ with $g' = 26.8 \pm 0.1$ (see Figure 4). This source position is 1.2 arcsec away from the position of XRT 000519 and thus falls just outside the estimated error circle. The non-detection of the INT $i'$-band source in the deep CFHT $i'$-band image obtained a few years later in time (2009 May 14-15) down to a magnitude limit of 25.6 magnitudes, indicates that the source magnitude decayed by at least 1.2 magnitudes, strengthening the association of the INT optical $i'$-band source with XRT 000519.

Sloan Digital Sky Survey images (SDSS; Ahn et al. 2012) in the $u'$, $g'$, $r'$, $i'$ and $z'$-bands were obtained closer in time to XRT 000519 than the CFHT observations, namely on 2003 March 23 (see Table 1). In these images there is no evidence for a source in the error circle of the \textit{Chandra} X-ray image down to the limiting magnitude of the SDSS images.

The source region was observed on 2007 May 3 by the UK infrared telescope (UKIRT) as part of the UKIRT Infrared Deep Sky Survey (UKIDSS) (Lawrence et al. 2007) in $Y$, $J$, $H$, and $K$, but no source was detected in the error region of XRT 000519 down to the survey limit of 18.3 magnitudes in each of the bands. We obtained near–infrared $K$-band follow-up observations of the field of XRT 000519 in 2013 January using the 4.2 m William Herschel Telescope on La Palma. In 3750 s of exposure we find no source down to a limiting magnitude of $K > 20.3$.

2.5. Radio observations

We also investigated archival images obtained by the VLA on 2005 Aug. 15, 2009 Aug. 3 and on 2012 May 1-2 (see Table 2). Although the pointing of the observations was centred on M84, the primary beam of the VLA provides a response of 55% at the position of the transient (12.7 arcmin from the pointing centre). The last, most sensitive observation was taken with a total bandwidth of 256 MHz, split into two 128 MHz sub-bands centred at 1452 and 1820 MHz. The primary calibrator was 3C 286, and the secondary calibrator was J1254+1141. The flux scale was set according to the coefficients derived at the VLA by NRAO staff as implemented in the 31DEC13 version of AIPS and CASA version 4.1.0. Data reduction was carried out according to standard procedures within AIPS and checked using CASA data reduction procedures. Images were made using Briggs weighting with a robust value of 0, to reduce the sidelobes from M 84 (which has a peak of 130 mJy/beam) and no source was found at the transient position down to an upper limit of 0.18 mJy/beam (three times the root-mean-square noise of the image at the position of XRT 000519). For the upper limits of the other two observations see Table 2.

3. DISCUSSION

We found a new transient X-ray source in an archival \textit{Chandra} observation. The source position is 12.16 arcminutes from the centre of M 86, and it does not fall in the M 86 $\mu_B = 25$ magnitude per arcsec$^2$ isophote area (de Vaucouleurs et al. 1991) that has an approximate radius of 8.5 arcminutes in the direction of the XRT 000519 location. However, it was found that M 86 is falling into the Virgo cluster and that gas is stripped off the galaxy (Randall et al. 2008). The projected stripped gas lies close to the position of XRT 000519. Furthermore, the deep optical INT images we investigated show that stars, possibly stripped off the galaxy SDSS J122541.29+130251.2, follow the stripped gas, which suggests that M 86 shows signs of a recent minor merger (see Figure 5). The small projected distance on
the sky between the position of XRT 000519 and that of the stream of stripped stars strengthens the association between XRT 000519 and M 86. The stream of stars falls between the wedge-shaped hot gas structure visible in the X-ray images of the field (Randall et al. 2008), suggesting that some or all of the gas may come from the infalling galaxy, making this a wet minor merger.

Whereas the source location is in the direction of the early type galaxy M 86, the source could in principle be a foreground object located in our own Galaxy, it could indeed be located at the distance of 16.2 Mpc of M 86, or it could be located further away, well behind M 86. As the close proximity on the sky makes a scenario where it could be located at the distance of 16.2 Mpc of M 86, or a foreground object located in our own Galaxy, it could early type galaxy M 86, the source could in principle be the infalling galaxy, making this a wet minor merger.

In order for a star to be tidally disrupted by a black hole, it has to wander close enough. The rates for this to happen are low, except for instance in regions of high

### 3.1. A transient near M 86?

If the transient event took place at the distance of M 86 the peak luminosity would be $6 \times 10^{42}$ erg s$^{-1}$. The late time, slowly decaying, (0.5-10 keV) flux level is $4\times10^{-13}$ erg cm$^{-2}$ s$^{-1}$, which for the distance of M 86 would be $10^{46}$ erg s$^{-1}$. If we interpret the peak flux as the Eddington luminosity we derive a mass estimate of $4.6\times10^4$ $M_\odot$.

The time scale and luminosity of the event, and the occurrence in an old population, limit the potential interpretations. We only know a few classes of events that can release so much energy over a short timescale. We favor the scenario where XRT 000519 is due to a tidal disruption event (TDE) of a star by an intermediate-mass black hole near M 86. The (quasi-) periodic recurrence time of the precursors of $\approx 4,000$ s is potentially related to the orbital period of the stellar material present around the black hole after the tidal disruption, with subsequent passages of a partially disrupted star (Guillochon & Ramirez-Ruiz 2013) or with variations in the fall-back rate after the white dwarf has been disrupted. The latter is likely to occur as the white dwarf will be disrupted in a strong gravitational field regime where the orbits of the fluid elements are not closed giving rise to the possibility of multiple shocks, however, the current models are not yet calculated taking this into account (see the discussion in Rosswog et al. 2009). This short recurrence time of $\approx 4,000$ s and the inference that the peak flux is at or close to the Eddington luminosity, would imply a $\sim 10^4$ $M_\odot$ black hole tidally disrupting a white dwarf (see e.g. Rosswog et al. 2009; Lodato & Rossi 2011). In the two observed passages prior to the main event, some of the material of the white dwarf star is accreted by the black hole giving off X-rays with a peak luminosity of $\sim 6 \times 10^{39}$ erg s$^{-1}$. In a subsequent orbit the self-interaction of the accreting material increases the viscosity giving rise to the bright peaks, in line with modelling (Luminet & Pichon 1989; Rosswog et al. 2009). It is unlikely that the white dwarf detonates: a detonating white dwarf would appear as a bright Type Ia supernova and the absolute $i'$-band magnitude during the INT observation is too low to be consistent with a Type Ia supernova less than one year after the explosion (Stritzinger & Sollerman 2007). The observed tail in the Chandra observation would be associated with the accretion of part of the material falling back (at super-Eddington rates) towards the intermediate-mass black hole (Strubbe & Quataert 2009; Lodato & Rossi 2011). The luminosity may well be limited to be below the Eddington limit.

To explain the two-peak structure of the main event of XRT 000519 detailed hydrodynamical calculations have to be performed, which is beyond the scope of this paper.

For the transient event XRT 000519 near M 86 the most promising scenario is that of a tidally disrupted white dwarf star with a mass of $4.6\times10^4$ $M_\odot$. More data are needed to verify this interpretation.
stellar density such as the centers of galaxies or in globular clusters (Baumgardt et al. 2006; Ramirez-Ruiz & Rosswog 2009). The photometry we have is consistent with a scenario where XRT 000519 originated in a globular cluster, although the globular cluster would have to be at the faint end of the globular cluster luminosity function (Harris 1996, 2010 edition).

Below, we discuss alternative scenarios for XRT 000519. The time scale and luminosity of XRT 000519, and the occurrence in an old population, if located at the distance of M 86, suggests that XRT 000519 could for instance be due to two compact objects merging, such as a neutron star - neutron star merger. Given that we detect no hard X-ray or \( \gamma \)-ray emission, we would be observing the merger off-axis, unlike the short-hard \( \gamma \)-ray bursts (Rezzolla et al. 2011). Accretion from fall-back material onto the newly formed black hole would in this scenario account for the late time X-ray emission. The non-detection of the source in the radio down to 0.18 mJy on 2012 May 1−2 (Karl G. Jansky Very Large Array, central frequency 1636 MHz), thus nearly 12 years after the event, only loosely constrains the circum-stellar binary density in this scenario (for predictions for radio emission of off-axis \( \gamma \)-ray bursts see Nakar & Piran 2011 and van Eerten & MacFadyen 2011). However, the precursor events are hard to explain in this scenario, making it less likely.

An alternative, related, scenario involves a neutron star overflowing its Roche lobe onto a black hole or another neutron star. The neutron star mass donor will eventually drop below the minimum mass for a neutron star. At that point, the star should explode, and some of the debris should be captured by the other compact object (Blinnikov et al. 1990; Colpi et al. 1993). The optical source could in this scenario be interpreted as the late time fading counterpart at \( M_V = -6.7 \) for a Distance Modulus of 31 for M 86 (which converts to an \( i' \)-band luminosity of \( 8 \times 10^{37} \) erg s\(^{-1} \)). However, again the precursor events require a special explanation in this scenario.

If the source is in M 86 it could in principle be that we witnessed a Type Ia supernova shock break-out (Kasen 2010). A problem with this scenario is that the optical supernova was not discovered, which is unlikely given that the Virgo and M 86 region of the sky are well monitored (Akerlof et al. 2000) and given that Type Ia SNe have an absolute magnitude of −19 in the \( V \)-band (Hillebrandt & Niemeyer 2000) which means that the optical supernova would have reached \( V \sim 12 \), which is easily accessible also for amateur astronomers. The detection of the faint \( i' \)-band at \( M_{i'} = -6.7 \) also makes this scenario improbable as typical type Ia supernovae do not decay that fast in the \( i' \)-band within a year (Stritzinger & Sollerman 2007).

3.2. A foreground object?

One could also envisage a scenario where the source is nearby, e.g. in our own Galaxy. For instance, the brightening in X-rays and the \( i' \)-band could be due to an accretion event onto an isolated, old, neutron star.

---

![Fig. 5.](image-url) The INT \( i' \)-band image around the field of the transient (which is indicated with the red circle). The cut levels are chosen to highlight the presence of the stream of stars (marked with dashed red lines on both sides of the stream of stars). Potentially, the stars are stripped from the galaxy SDSS J122541.29+130251.2 that in this representation is hidden in the glare of the stars of the outskirts of M 86 (but its position is shown by the white circle). SDSS spectroscopy of this galaxy shows that it is a starburst galaxy that could well be associated with M 86.
The isolated neutron star is then possibly detected in the late-time CFHT $g'$-band observation. The two detections are offset by 1.1 arcseconds in right ascension and by -1.2 arcseconds in declination giving a distance on the sky between the two positions of 1.6 arcseconds. This would yield a proper motion of 0.16 arcseconds per year with respect to the $i'$-band variable source detected in 2001. For a typical transverse velocity of an isolated neutron star of 200 km s$^{-1}$, we derive a distance of 250 pc for the source. At that distance the fluence of the event would imply the accretion of around $5 \times 10^{15}$ g onto the neutron star. The deep upper limits on the quiescent X-ray emission derived from the XMM-Newton observations imply a limit on the luminosity of $3 \times 10^{39}$ erg s$^{-1}$ for such a distance. This means that the quiescent neutron star luminosity is lower than what has been observed so far for isolated neutron stars (Page et al. 2004), however, the current observations favor young, hot neutron stars. Additionally, the cooler the neutron star, the more its emission peaks towards the soft X-rays or even the ultra-violet part of the energy spectrum. Additional, new, optical (e.g. Hubble Space Telescope) observations could test this scenario by checking whether the faint $g'$-band source indeed has a proper motion of 0.16 arcseconds per year.

In an alternative version of this scenario, where we do not ascribe the $g'$-band detection to the isolated neutron star, and thus we have no constraint on the proper motion or distance of the neutron star, we can place it at a larger distance. This would increase the total energy liberated in the transient event and thus the amount of accreted mass but it alleviates the constraint on the quiescent X-ray luminosity of the isolated neutron star. However, in both these isolated neutron star scenarios the precursor events and their 4,000 s time scale are difficult to understand. Furthermore, the accretion of asteroid-sized bodies onto a neutron star are thought to produce significant amounts of $\gamma$-ray emission (Campana et al. 2011), which is not detected from XRT 000519, implying that for reasons unknown, the $\gamma$-ray emission is much reduced in this case, making this scenario less likely.

3.3. A transient (far) behind M 86?

If we instead interpret XRT 000519 as coming from a redshift, $z$, between 0.23–1.5 in line with the $g'$-band non-detection of an unresolved faint dwarf galaxy of an absolute magnitude of $-14.5 > M_g > -19.5$ (Blanton et al. 2005), then the luminosity of XRT 000519 would be $3 \times 10^{46} - 3 \times 10^{48}$ erg s$^{-1}$.

Then, it could be potentially interpreted as an X-ray flash such as those found in X-rays and which are probably related to $\gamma$-ray bursts (Campana et al. 2006, Sakamoto et al. 2005). However, with a peak energy, $E_p$, of about 1.5 keV, the event has a softer X-ray spectrum than that of X-ray flashes known so far (Sakamoto et al. 2005). Nevertheless, if the event was indeed near $z=1.5$, thus at a luminosity of $L= 3 \times 10^{48}$ erg s$^{-1}$, then the peak energy $E_p$ of 1.5 keV and the isotropic peak energy at the peak flux, $E_{iso}$, are consistent with those expected extrapolating the $E_p$ and $E_{iso}$ correlation of X-ray flashes and $\gamma$-ray bursts to lower values (the Amati et al. 2008 relation). Whereas we cannot rule out that XRT 000519 was due to an event similar to an X-ray flash, extending the peak energies and the isotropic luminosities for those events a factor of several below those that have been found for this class of flashes until now (Sakamoto et al. 2005), the presence of the precursor events is never seen in X-ray flashes so far, making the association unlikely.

Although, the latter could be due to the reduced sensitivity of the satellites that detected the X-ray flashes so far, compared with the Chandra sensitivity. A potential problem with this scenario and a distance of $z=1.5$ is that even at 10 months after the event the absolute $i'$-band magnitude $M_i$ would still have to be -20.9 magnitudes. Furthermore, the projected co-location on the sky of an ongoing minor merger event and the X-ray transient would be a chance alignment in this scenario. Interestingly, Scherbakov et al. (Scherbakov et al. 2012) describe the X-ray flash reported by Campana et al. (2006) as a TDE of a white dwarf by an intermediate-mass black hole. This shows that the properties of these two classes of objects, X-ray flashes associated with stellar-mass black hole formation and X-ray flashes associated with TDEs by massive or intermediate-mass black holes, overlap. The main reason for this is that TDEs cover X-ray luminosities ranging from as low as $10^{38}$ erg s$^{-1}$ (Esquej et al. 2008, Gezari et al. 2008) up to $10^{48}$ erg s$^{-1}$ for the Blazar-like TDE Swift J1644+57 (Levan et al. 2011). The observed peak luminosity of XRT 000519 is in the range of distances we consider here. Thus, the properties of XRT 000519 are also consistent with a TDE in a dwarf galaxy at a distance between approximately 1.1 and 11 Gpc provided the emission is strongly beamed towards us as in Swift J1644+57 (Krolik & Piran 2011, Scherbakov et al. 2012), although again the optical $i'$-band magnitude would favor distances closer to 1.1 Gpc over one close to 11 Gpc.

4. CONCLUSION

We discovered a peculiar transient (XRT 000519) in the direction of M 86. Furthermore, we found evidence for an ongoing wet minor merger between M 86 and the galaxy SDSS J122541.29+130251.2. This activity makes it conceivable that the transient is located at the distance of M 86. If so, its properties are consistent with a scenario where the transient is due to the tidal disruption of a white dwarf by an intermediate-mass black hole. Alternative scenarios such that of a foreground neutron star accreting an asteroid or the detection of an off-axis (short) $\gamma$-ray burst cannot be fully excluded at present. Future, high resolution and deep Hubble Space Telescope imaging should reveal the host galaxy if it was due to an event in the background of M 86 such as a tidal disruption event at larger distance or an off axis $\gamma$-ray burst.

REFERENCES

ACKNOWLEDGMENTS

PGJ acknowledges the hospitality of the Institute of Astronomy, Cambridge where much of this work was done and PGJ also acknowledges discussions with Elena Rossi and Sjoerd van Velzen. Based on observations obtained with MegaPrime/MegaCam, a joint project of CFHT and CEA/IRFU, at the Canada-France-Hawaii Telescope (CFHT) which is operated by the National Research Council (NRC) of Canada, the Institut National des Science de l’Univers of the Centre National de la Recherche Scientifique (CNRS) of France, and the University of Hawaii. This work is based in part on data products produced at Terapix available at the Canadian Astronomy Data Centre as part of the Canada-France-Hawaii Telescope Legacy Survey, a collaborative project of NRC and CNRS. Based on observations obtained with MegaPrime/MegaCam, a joint project of CFHT and CEA/IRFU, at the Canada-France-Hawaii Telescope (CFHT) which is operated by the National Research Council (NRC) of Canada, the Institut National des Science de l’Univers of the Centre National de la Recherche Scientifique (CNRS) of France, and the University of Hawaii. This work is based in part on data products produced at Terapix available at the Canadian Astronomy Data Centre as part of the Canada-France-Hawaii Telescope Legacy Survey, a collaborative project of NRC and CNRS.

Funding for SDSS-III has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Science Foundation, and the U.S. Department of Energy Office of Science. The SDSS-III web site is http://www.sdss3.org/.

SDSS-III is managed by the Astrophysical Research Consortium for the Participating Institutions of the SDSS-III Collaboration including the University of Arizona, the Brazilian Participation Group, Brookhaven National Laboratory, University of Cambridge, Carnegie Mellon University, University of Florida, the French Participation Group, the German Participation Group, Harvard University, the Instituto de Astrofisica de Canarias, the Michigan State/Notre Dame/JINA Participation Group, Johns Hopkins University, Lawrence Berkeley National Laboratory, Max Planck Institute for Astrophysics, Max Planck Institute for Extraterrestrial Physics, New Mexico State University, New York University, Ohio State University, Pennsylvania State University, University of Portsmouth, Princeton University, the Spanish Participation Group, University of Tokyo, University of Utah, Vanderbilt University, University of Virginia, University of Washington, and Yale University.