Was the soft X-ray flare in NGC 3599 due to an AGN disc instability or a delayed tidal disruption event?

R.D. Saxton1*, S.E. Motta1,2, S. Komossa3 and A.M. Read4

1 ESAC, Apartado 78, 28691 Villanueva de la Cañada, Madrid, Spain
2 University of Oxford, Dept. of Physics, Denys Wilkinson building, Keble road, OX1 3RU, Oxford, U.K.
3 Max Planck Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
4 Dept. of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, U.K.

Accepted 1988 December 15. Received 1988 December 14; in original form 1988 October 11

ABSTRACT

We present unpublished data from a tidal disruption candidate in NGC 3599 which show that the galaxy was already X-ray bright 18 months before the measurement which led to its classification. This removes the possibility that the flare was caused by a classical, fast-rising, short-peaked, tidal disruption event. Recent relativistic simulations indicate that the majority of disruptions will actually take months or years to rise to a peak, which will then be maintained for longer than previously thought. NGC 3599 could be one of the first identified examples of such an event. The optical spectra of NGC 3599 indicate that it is a low-luminosity Seyfert/LINER with $L_{\text{bol}} \sim 10^{40}$ ergs s$^{-1}$. The flare may alternatively be explained by a thermal instability in the accretion disc, which propagates through the inner region at the sound speed, causing an increase of the disc scale height and local accretion rate. This can explain the $< 9$ years rise time of the flare. If this mechanism is correct then the flare may repeat on a timescale of several decades as the inner disc is emptied and refilled.

Key words: X-rays: galaxies – galaxies:individual:NGC 3599 – accretion disc

1 INTRODUCTION

Tidal disruption events (TDE; Hills 1975; Luminet 1985; Rees 1988) occur when a stellar object is destroyed and subsequently accreted by a super-massive black hole (SMBH). Ten to twenty TDE (Hills 1975; Luminet 1985; Rees 1988) occur when a stellar object is destroyed and subsequently accreted by a super-massive black hole (SMBH). Ten to twenty years later, the galaxy shows weak, narrow, optical lines leading to the conclusion that the galaxy was already X-ray bright 18 months before the measurement which led to its classification. This removes the possibility that the flare was caused by a classical, fast-rising, short-peaked, tidal disruption event. Recent relativistic simulations indicate that the majority of disruptions will actually take months or years to rise to a peak, which will then be maintained for longer than previously thought. NGC 3599 could be one of the first identified examples of such an event. The optical spectra of NGC 3599 indicate that it is a low-luminosity Seyfert/LINER with $L_{\text{bol}} \sim 10^{40}$ ergs s$^{-1}$. The flare may alternatively be explained by a thermal instability in the accretion disc, which propagates through the inner region at the sound speed, causing an increase of the disc scale height and local accretion rate. This can explain the $< 9$ years rise time of the flare. If this mechanism is correct then the flare may repeat on a timescale of several decades as the inner disc is emptied and refilled.

The presence of a pre-existing accretion disc may enhance the tidal disruption rate (Karas & Subr 2007) and Merloni et al. (2015) have proposed that up to 10% of optically-selected AGN could be caused by stellar disruptions. On an individual level, large flares in persistent AGN present a certain ambiguity. The classic case is IC 3599 where a giant X-ray and UV flare, which repeated after 20 years, has been alternatively explained by tidal stripping of an orbiting star (Campana et al. 2015) or by an accretion disc instability (Grue, Komossa & Saxton 2015).

NGC 3599 ($\alpha_{2000} = 11^h15^m26.9^s, \delta_{2000} = +18^\circ06'37''$, $z=0.0028$) was discovered in an XMM-Newton slew from 2003 with a soft X-ray flux a factor $> 100$ higher than an upper limit from ROSAT (Esquej et al. 2007). Subsequent observations of the galaxy by XMM-Newton, Chandra and Swift revealed a strong decay in flux by a factor $> 100$ over the following years (Esquej et al. 2008, 2012). The galaxy shows weak, narrow, optical lines leading to its classification as a LINER or Seyfert 2 galaxy (Esquej et al. 2008).

Three scenarios were proposed at the time to explain the flare: a TDE, AGN variability and an ultra-luminous X-ray source (ULX; based on the relatively low X-ray luminosity, $L_X \sim 10^{41}$ ergs/s). In this paper we reassess these possibilities based on newly discovered high-state and more recent low-state data. In particular we investigate whether the flare could be due to an ac-

* E-mail: richard.saxton@sciops.esa.int
cretion disc instability, similar to that proposed for flares seen in certain galactic accreting binaries (Camenzind 1996; Belloni et al. 1997a). We also look at recent advances in numerical and analytical modelling of TDE lightcurves (Guillochon & Ramirez-Ruiz 2015; Hayasaki, Stone & Loeb 2015; Shiokawa et al. 2015; Piran et al. 2015), which show a generally slower rise to peak flux than that predicted by the classical model (Rees 1988).

A ΛCDM cosmology with ($Ω_M$, $Ω_Λ$) = (0.27, 0.73) and $H_0$ = 70 km s$^{-1}$ Mpc$^{-1}$ has been assumed throughout.

2 THE SOFT X-RAY FLARE IN NGC 3599

NGC 3599 was reported as a candidate tidal disruption event, based on an X-ray flare seen in an XMM-Newton slew from 2003-11-22 (Esquej et al. 2007). The source flux was ~ 150 times higher than that seen in a ROSAT pointed observation from 1993 (Esquej et al. 2012). The galaxy was sparsely monitored post-flare by XMM-Newton, Swift and Chandra revealing a decline in X-ray flux of a factor 100 from the peak value (Esquej et al. 2008, 2012) and a shape that can be reasonably fit by a canonical $t^{-5/3}$ curve, appropriate for the rate of return of tidal debris to the disruption radius (Rees 1988; Phinney 1989). A Chandra observation from 2008 pointed the emission to be within 60 pc of the nucleus (Esquej et al. 2012).

Optical spectra were taken in 2007 and 2008 and found to be consistent with a pre-flare spectrum (Caldwell et al. 2003; Esquej et al. 2008). After subtraction of the galactic contribution, weak, narrow, low-ionisation lines remain whose ratios lie on the border between LINER and low-luminosity AGN activity (Kauffmann & Heckman 2004; Esquej et al. 2008). The luminosity of the narrow [OIII]45007 line was $L_{\text{OIII}} = 1.1 \times 10^{48}$ ergs s$^{-1}$ implying a historical bolometric luminosity, $L_{\text{bol}}^\text{hist} \sim 10^{40}$ ergs s$^{-1}$ applying the standard correction factor for low-luminosity AGN (Lamastra et al. 2004). During the flare the soft X-ray luminosity was $L_{0.2-2} = 5.5 \times 10^{43}$ ergs s$^{-1}$. No simultaneous data are available from other wavelengths making the calculation of $L_{bol}$ at peak quite uncertain. Based on the reasonable assumption that the soft X-ray flux was dominated by thermal disc emission, as suggested by the very soft spectrum (Esquej et al. 2007), then a large fraction of the peak bolometric luminosity may be emitted in the soft X-rays. Even so this implies an increase in $L_{bol} > 50$ from the historical to the peak luminosity.

Improvements to the XMM-Newton science analysis software (SAS; Gabriel et al. 2003) have recently allowed some archival slew data to be processed for the first time. Amongst these was the slew 904510003, which passed over NGC 3599 in 2002-05-22. Analysis of this slew surprisingly reveals 19 photons from NGC 3599 in 4.0 seconds of effective exposure time, yielding a soft X-ray luminosity, $L_{0.2-2} = 4.8 \pm 1.1 \times 10^{43}$ ergs s$^{-1}$, consistent with the luminosity seen at the peak in 2003-11-22. The source, then, was already bright 18 months before the peak flux was measured and more than a year before the date of the presumed disruption itself, derived by fitting a canonical $t^{-5/3}$ curve to the X-ray measurements (Esquej et al. 2008). The historical light curve is plotted in Fig. 1 and includes the flux from 2002-05-22, a new upper limit from XMM-Newton slew 9081400004, taken on 2004-05-20, and an upper limit from a merge of 2 Swift observations made on 2010-10-23 and 2010-11-16. We have analysed the ROSAT observation of 1993-06-06 (rp600263n00) and identify NGC 3599 with the catalogued source, 1WGA J1115.4+1807, with a count rate of 0.0026 ± 0.0006 c/s. This equates to a flux 130 times lower than that seen in 2002-05-22.

Esquej et al. (2012) showed that the XMM-Newton and Chandra observations all had soft spectra and could be simultaneously fit with a black-body of $kT \sim 45$ eV plus a steep power-law, with $\Gamma \sim 2.7$, both absorbed by the Galactic column ($1.42 \times 10^{20}$ cm$^{-2}$; Kalberla et al. 2003). We fit this model, with free black-body temperature and power-law slope, to each individual observation, in Fig 2 and display the hardness ratio as a function of source flux.

The hardness ratio is defined in terms of the 1–5 keV and 0.2–1.0 keV fluxes as $H_r = (F_{1.5} - F_{0.2-1.0}) / (F_{1.5} + F_{0.2-1.0})$ and remains soft even in the lowest flux states.

![Figure 1](image1.png)  
**Figure 1.** The 0.2–2 keV X-ray luminosity light curve of NGC 3599. Points are from ROSAT, the XMM-Newton slew and XMM-Newton, Swift-XRT and Chandra pointed observations. The last upper limit has been made by combining Swift data from 2010-10-23 and 2010-11-16. Flare phases are marked as: quiescent (Q), rise (R; < 107 months), plateau (P; > 18 months) and decay (D; ~ 36 months).

![Figure 2](image2.png)  
**Figure 2.** The hardness-intensity diagram for NGC 3599, displayed as the ratio of the unabsorbed 1.0–5.0 keV flux to the 0.2–1.0 keV flux plotted against the total unabsorbed 0.2–5.0 keV flux.
3 DISCUSSION

3.1 A Tidal Disruption Event

The classical model of TDE predicts that, after the disruption, streams of debris will quickly shock, lose energy and accumulate most of the bound material at a radius, $2R_p$, where $R_p$ is the peri-centre of the stellar orbit (Rees 1988). From here it will accrete quickly causing a rapid rise in luminosity. The TDE candidates detected to date, which have been well-monitored before the peak, have all shown a short rise time consistent with this model. In NGC 5905, $t_{\text{rise}}$ was a few days (Bade, Komossa & Dahlen 2016), in PTF10iya, $t_{\text{rise}} \leq 0.03$ years (Cenko et al. 2012b), in PS1-10jh, $t_{\text{rise}} \sim 0.21$ years (Gezari et al. 2013) and in three other Palomar Transient Factory (PTF) candidates from $\sim 0.08$ – 0.14 years (Arcavi et al. 2014).

The time when the fallback maintains a peak accretion rate is also seen to be very short observationally (e.g. Bade, Komossa & Dahlen 2016; Cenko et al. 2012b; Gezari et al. 2013; Arcavi et al. 2014). At face value, the event in NGC 3599 plateaus between 2002-05-22 and 2003-11-22 and then declines sharply at a rate compatible with $\rho^{-5/3}$. This behaviour is quite different from the light curves of previous, well-monitored, TDE. In principle, the event in NGC 3599 could still be a tidal disruption event, similar to the ones previously observed, if the 2002-05-22 measurement lies on the rise of the luminosity curve and the 2003-11-22 measurement on the decline. Esquej et al. (2008) obtained a date for the onset of the monotonic decline of the luminosity curve, $t_0 = 2003.59 \pm 0.06$. If we adopt a minimum start date of 2003.53 then the new slew data predate the decline from peak by 1.14 years. If this were a tidal disruption, then the rise time, plus the time where the debris fall back rate is maintained near maximum, is $> 1.14$ years; significantly longer than seen in previous TDE candidates. This excludes the possibility that the flare in NGC 3599 was caused by a classical, prompt (fast-rising), TDE.

A slow, factor 5, flux decay in the TDE candidate, RBS 1032, was observed in ROSAT observations spanning 3.5 years (Maksym, Lin & Irwin 2014; Khabibullin & Sazonov 2014). These measurements may represent a flat, extended peak emission. They are, however, consistent with a canonical $t^{-5/3}$ decline curve first detected $\sim 1$ year after peak (Maksym, Lin & Irwin 2014).

Recently, numerical simulations and new analytical work have shown that the development of a TDE light curve is dependent on when the streams of tidal debris intersect each other (Guillochon & Ramirez-Ruiz 2015; Hayasaki, Stone & Loeb 2015; Shiokawa et al. 2015). Early interactions appear to be rare and in the majority of cases circularisation occurs late and at a large distance from the BH, 5–10 times further away than predicted by the classical model (Piran et al. 2015). This leads to a longer large distance from the BH, 5–10 times further away than predicted by the classical model (Piran et al. 2015). This may be the reason why they have not been seen yet in optical surveys or during the ROSAT mission. The comparison of XMM-Newton and ROSAT observations gives a baseline which currently stretches to 25 years and is hence not biased against slow-rising TDE. Khabibullin & Sazonov (2014) identified a small number of new TDE candidates by comparing ROSAT and XMM-Newton pointed observation source fluxes. Of these, only RBS 1032 (discussed above) had sufficient ROSAT observations to be able to detect a potential delayed TDE in NGC 3599 could then be one of the first detections of a delayed tidal disruption event.

3.2 A ULX

The peak luminosity of NGC 3599, $L_X = 5 \times 10^{41}$ ergs s$^{-1}$, falls within the range attained by ULX (Farrell et al. 2008). Some arguments against a ULX interpretation for the flare in NGC 3599 were presented in Esquej et al. (2012); we summarise these here and add new analysis.

A low-state Chandra observation revealed two X-ray sources within the galaxy. A brighter one, coincident with the nucleus, with a 90% confidence error of 60 pc, and a fainter source, with $L_X = 10^{39}$ ergs s$^{-1}$, at a distance of 250 pc. The XMM-Newton pointed observation of 2006 had a flux 6 times higher than the Chandra observation and is coincident with the nucleus with a 1-sigma error of 60 pc, excluding the possibility that the fainter Chandra source caused the variability. The luminosity of the Chandra nuclear source is consistent with that expected from the optical emission lines, hence it is highly likely that this represents the low-level AGN in its normal historical state. This Chandra source has an unusually steep spectrum, similar to that seen in the XMM-Newton observations (a power-law with $\Gamma = 2.7$ plus a black body of $K=44$ eV) (Esquej et al. 2012). Stellar-mass accreting binaries and ULX have significantly harder low-state spectra than this (e.g. $\Gamma \sim 2.7$ was found for the low-luminosity observations of HLX-1; Servillat et al. 2011). For these reasons we locate the flare in the galactic nucleus rather than from a nearby ULX.

3.3 A Highly Variable AGN

In section 2 we saw that NGC 3599 is a low-luminosity Seyfert/LINER and it is worth re-considering the possibility of an AGN flare in the light of the new data. Any AGN variability mechanism needs to explain the following characteristics of the flare in NGC 3599: (i) an increase of factor 130 in X-ray flux within $\leq 9$ years; (ii) an unusually soft peak spectrum ($\Gamma \sim 4 / K T \sim 90$ eV);
(iii) a spectrum which remained soft while the flux dropped by a factor 100 between 2003 and 2008.

No obvious intrinsic absorption was found in the low-state Chandra and XMM-Newton spectra (Esquej et al. 2008, 2012). As a further test, we investigated the possibility that the decline in flux in NGC 3599 is due to a variable warm absorber by fitting the two pointed XMM-Newton observations from 2006 and 2008 simultaneously, with a fixed power-law model and an ionized absorber (xzippf) which was allowed to vary. The best fit was poor, with χ² = 127/61, ruling out that the source variability is caused by a single phase absorbing medium. Warm absorbers, when looked at with sufficient spectral resolution, often appear to be multi-phased, containing gas at different distances and ionisation states (e.g. Longinotti et al. 2013). The NGC 3599 spectra have neither the spectral resolution nor statistics to be able to exclude variable multiple absorbers. However, such a scenario would not explain why the peak luminosity, during the XMM-Newton slew observations, was > 50 times higher than the historical bolometric luminosity nor why the spectrum remained soft while the flux reduced by a factor 100. From this we infer that the source experienced an increase in intrinsic emission rather than a variation in a patchy absorber.

3.3.1 A change in the disc structure

A change in the distribution of matter, involving a filling and emptying of the inner accretion disc, has been invoked to explain long-lived changes in the emission state of solar-mass black-hole binaries (BHB; Esin et al. 1997).

The time τfill taken for material to migrate from a truncation radius and fill the inner disc up to the innermost stable circular orbit (ISCO) is governed by the viscous time scale and can be calculated from the mass of material in this inner region and the accretion rate, such that:

\[ \tau_{\text{fill}} = M_{\text{inner}}/M \]  

(1)

The mass of the inner disc being given by:

\[ M_{\text{inner}} = \int_{R_0}^{R_{\text{trunc}}} \rho(r) 2\pi r H(r) \, dr \]  

(2)

where \( R_0 \) is the radius of the ISCO, \( R_{\text{trunc}} \) is the truncation radius, \( \rho(r) \) is the disc density and \( H(r) \) its height.

For a Shakura-Sunyaev thin disc (Shakura & Sunyaev 1973), Frank, King & Raine (1992) give the disc density and height as

\[ \rho(r) = 3.1 \times 10^{-8} \alpha^{-7/10} M_{16}^{11/20} M_{1}^{5/8} R_{10}^{15/8} f^{1/5} g \text{ cm}^{-3} \]  

(3)

\[ H(r) = 1.7 \times 10^{-8} \alpha^{-1/10} M_{16}^{2/3} M_{3}^{-5/3} R_{10}^{2/3} f^{-1/3} \text{ cm} \]  

(4)

where \( R_{10} \) is the disc radius in units of 10^{10} cm, \( M_{1} \) is the mass of the black hole in solar masses, \( M_{16} \) is the accretion rate in units of 10^{16} g s^{-1} and \( \alpha \) is the viscosity parameter.

Converted to AGN scaled units (with the radius expressed in gravitational radii, \( R_{g} = GM/c² \)), the accretion rate in units of the Eddington-limited accretion rate, \( M_{\text{edd}} = 1.4 \times 10^{16} M_{⊙} \text{ g s}^{-1} \) and the black hole mass \( M_{bg} \) in units of 10^5 M_{⊙}, the inner disc mass is then given by:

\[ M_{\text{inner}} = 6 \times 10^{-4} \alpha^{-8/10} M_{6}^{11/10} M_{3}^{3/10} \left( \frac{R_{\text{trunc}}}{R_{g}} \right)^{5/4} \left( \frac{R_{0}}{R_{g}} \right)^{5/4} M_{bg} \]  

(5)

and the filling time \( \tau_{\text{fill}} \) by:

\[ \tau_{\text{fill}} \sim 0.33 \alpha^{-8/10} M_{6}^{5/4} M_{3}^{3/10} \left( \frac{R_{\text{trunc}}}{R_{g}} \right)^{5/4} \left( \frac{R_{0}}{R_{g}} \right)^{5/4} \text{ months} \]  

(6)

Note that \( \tau_{\text{fill}} \) is equivalent to the viscous timescale of a slim disc at the truncation radius.

In Fig. 3 we plot \( \tau_{\text{fill}} \) against the truncation radius for \( M_{bg} \) ranging between 10^8 and 10^9 M_{⊙}, assuming that the accretion rate is Eddington limited (\( M_{\text{edd}} = 1 \), \( \alpha = 0.1 \) and \( R_{0} = 3 R_{g} \)).

We see that it is possible to fill the inner disc in < 107 months for a limited range of \( M_{bg} \) and \( R_{\text{trunc}} \). To further constrain \( R_{\text{trunc}} \) we estimate the size of the inner disc which will have 130 times more thermal 0.2–2 keV flux than the outer disc, i.e. which would duplicate the change in flux between the 1993 ROSAT and the 2002 XMM-Newton slew observations. Here we used a Novikov-Thorne disc (Novikov & Thorne 1973) with colour corrections as described in Done et al. (2012). These constraints for \( 7 \times 10^8 < M_{bg} < 4.6 \times 10^9 M_{⊙} \), covering the range estimated for the nuclear black hole of NGC 3599, are shown in Fig. 3. No solution is possible for \( R_{\text{trunc}} \) and \( M_{bg} \), within the allowed mass range, which allows the flux to rise sufficiently quickly if the emission comes from a thin disc. The possibility of an off-nuclear, lower mass black hole, was discussed in section 3.2.

In the BHB, GRS 1915+105, soft flares are seen with a rise and decay time of seconds, an order of magnitude too fast to be explained by a complete filling and emptying of an inner disc on the viscous time scale, even though spectrally this is a very attractive solution (Belloni et al. 1997a). To explain these very fast spectral/flux variations, the Lightman-Eardley (LE) disc instability has been invoked (Lightman & Eardley 1974; Cannizzo 1993; Belloni et al. 1997b). In this scenario, each flare (preceded by a quiescent phase) constitutes a cycle with different phases.

- **Quiescent phase**: during this phase the disc is truncated at a certain radius, with the central region either empty or filled with gas whose radiation is too soft to be detected. Slowly, the disc is refilled by a steady accretion rate \( M_{0} \) from the outer regions.
- **Rise phase**: at some point the radiation pressure in the inner disc exceeds the gas pressure. This causes a chain reaction (due to the LE disc instability) that switches on the inner disc (that has now refilled and has the form of a slim hot disc). During this phase the flux from the source rises quickly and becomes much softer.
- **Outburst phase (plateau)**: now the disc extends down to an orbit that is very close to or coincident with the innermost stable circular orbit (ISCO) and a smaller hot radius can be observed. During this phase the emission is dominated by the thermal contribution from the disc, that is now hot and bright. The time-scale governing this phase is unknown, even though Belloni et al. (1997b) noticed that the duration of the outburst phase correlates with the duration of the quiescent phase.
- **Decay phase**: eventually the inner disc runs out of fuel (because it is accreted onto the black hole faster than it is replenished) and switches off, either cooling and jumping back to an accretion rate smaller than \( M_{0} \) or emptying completely, leaving a new hole in the disc. The flux will therefore decay very quickly, bringing the source back to the quiescent phase.

The temporal development of the LE instability is compatible with that of the flare seen in NGC 3599. The instability begins when the radiation pressure becomes comparable with the gas pressure. A heating wave is generated at the inner edge of the disc.
The soft X-ray flare in NGC 3599

Figure 3. Time needed to fill an inner accretion disc previously truncated at $R_{\text{trunc}}$. This assumes an innermost stable orbit at $3R_g$ and Eddington-limited accretion. The dashed horizontal line shows the upper limit on the rise time for the flare in NGC 3599 (107 months). The diagonal dashed line indicates the truncation radius where thermal emission from the inner disc is 130 times greater than that of the outer disc in the 0.2-2 keV band, for the range of possible masses inferred for the nuclear black hole of NGC 3599. The time needed to produce the measured flux rise is always greater than the observed rise time for this range of black hole masses.

which propagates backwards through the disc at the sound speed ($c_s$). The heating increases the local viscosity, scale height of the disc and the local accretion rate (Cannizzo 1996). At this point the disc is no longer a thin Shakura-Sunyaev disc but still emits as a thermalised plasma. The time taken to fully heat the inner disc gives the rise time of the flare:

$$\tau_{\text{rise}} \geq \frac{R_{\text{trunc}}}{c_s} \sim 1.5 \times 10^9 \left(\frac{R_{\text{trunc}}}{R_g}\right) M_6 \text{ seconds}$$

about a month for $R_{\text{trunc}} = 100 R_g$.

When the disc is emptied, as the hot radiating matter is accreted into the black hole more quickly than it is replenished (Belloni et al. 1997a), the flare decays (decay phase). The time $\tau_{\text{decay}}$ required to empty the inner disc (or to let it go back to a tenuous plasma regime) cannot be shorter than the dynamical timescale, therefore it is given by:

$$\tau_{\text{decay}} \geq 6M_6 \left(\frac{R_{\text{trunc}}}{R_g}\right)^{3/2} \text{ seconds}$$

a few hours for $M_{\text{BH}} \sim 10^6 M_\odot$ and $R_{\text{trunc}} = 100R_g$. We note here that our estimates are stringent lower limits, based on the assumption that the accretion rate is Eddington limited. However, it is important to notice that, given the timescales discussed above, the rise time being longer than the decay time is a necessary condition for our interpretation to hold. Our results show that the rise time ($\lesssim 107$ months) is consistent with being longer than the decay time ($\sim 36$ months), therefore this constraint is not violated.

As the inner disc is emptied and refilled, the flares should repeat on a timescale which is governed by the filling or viscous time at the truncation radius, i.e. decades for $M_{\text{BH}} \sim 10^6 M_\odot$. A similar large flare in the Sy 1.9 galaxy IC 3599, which may have been produced by the same mechanism, repeated after 20 years (Grupe, Komossa & Saxton 2015).

Numerical simulations by Xue et al. (2011) show that the magnitude of the flare produced by an instability in the standard disc model is strongly influenced by the BH spin, while the timescale primarily depends on $M_{\text{BH}}$ and viscosity. Their simulations found a short flare with a duty cycle $\lesssim 3\%$ which would imply a long ($\gtrsim 50$ year) quiescent phase for NGC 3599. Nevertheless, analytical work by Nayakshin, Rappaport & Melia (2000) and Janiuk & Czerny (2005), which include the effects of a compaction zone, jet and non-standard viscosity, and produce longer flares compatible with those seen in GRS 1915+105, would allow a shorter repeat time.

4 SUMMARY

Based on new data we have shown that it is difficult to reconcile the rise time of the soft X-ray flare seen in NGC 3599 with its previous classification as a classical, fast-rising, short plateau, tidal disruption event. It does, however, fit into the emerging scheme of a disruption which has led to a late, distant, circularisation where the rise is flatter and the peak lasts longer or alternatively to the tidal stripping of a red giant star.

If the factor 100 soft X-ray flare is interpreted as a change in the accretion from a persistent AGN, we find that the rise time of $\lesssim 9$ years is too short to be explained purely by the bulk motion of disc material about a $10^6 M_\odot$ BH. The observed timescales are compatible with the Lightman-Eardley instability which boosts the thermal soft X-ray emission by heating the inner disk and raising its scale height. This mechanism predicts that flares will repeat on the viscous timescale of the truncation radius, i.e. every few decades. The behaviour of NGC 3599 would then be analogous to flares seen in certain Galactic binary systems, but is too rapid to be equivalent to the state changes which are seen in those systems.

ACKNOWLEDGMENTS

We thank the anonymous referee for useful comments which improved the paper. RDS and SK would like to thank Giuseppe Lodato, Elena Rossi and the European Science Foundation for hosting the Tidal Disruption conference in Favignana. RDS would also like to acknowledge Giovanni Miniutti and Margarit Giustini for interesting and helpful discussions and Pilar Esquej for providing the optical spectrum. SEM acknowledges the ESA research fellowship program and the Violette and Samuel Glasstone foundation.

REFERENCES

Arcavi, I., Gal-Yam, A., Sullivan, M., Pan, Y.-C., Cenko, S. et al., 2014, ApJ, 793,38
Bade, N., Komossa, S., Dahlem, M. 1996, A&A, 309, L35
Belloni, T., Mendez, M., King, A., van der Klis, M., van Paradijs, J., 1997, ApJ, 479, L145
Belloni, T., Mendez, M., King, A., van der Klis, M., van Paradijs, J., 1997, ApJ, 488, 109
Bloom, J et al., 2011, Sci, 333, 203
Burrows, D., Kennea, J., Ghisellini, G. et al., 2011, Nat., 476, 421
Caldwell, N., Rose, J., & Concannon, K., 2003, ApJ, 125, 2891
Campana, S., Mainetti, D., Colpi, M., Lodato, G, D’Avanzo, P., Evans, P.A., & Moretti, A., 2015, A&A submitted
Cannizzo, J., 1996, ApJ, 466, L31
Cappelluti, N., Ajello, M., Rebusco, P. et al., 2009, A&A, 495, L9
Caramete, L., Biermann, P., 2010, A&A, 521, 55
