# *Peculiar outbursts of an ultra luminous source: Likely signs of an aperiodic disc-wind*

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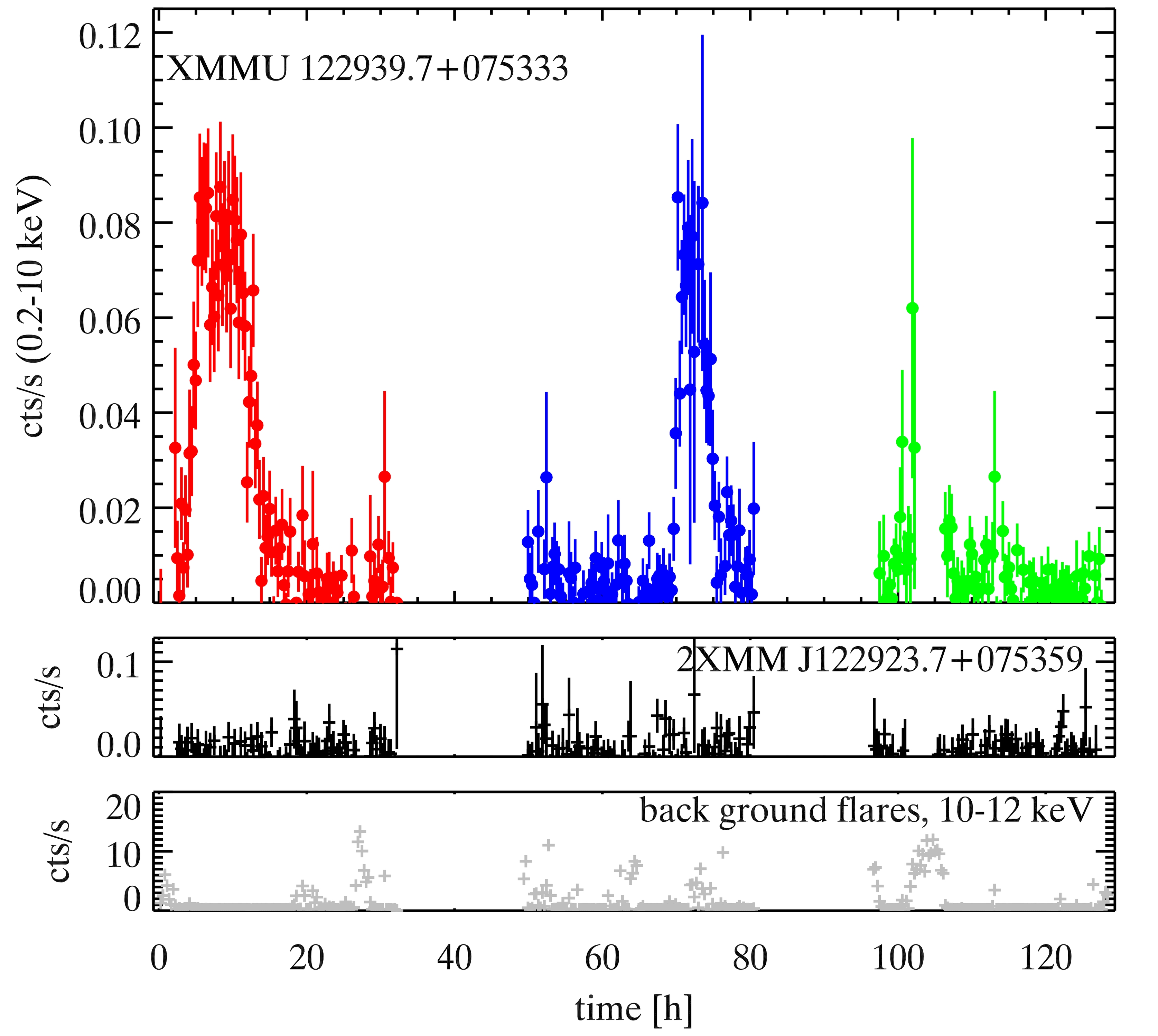
The ultra luminous X-ray source XMMU 122939.7+075333 is located in the metal rich globular cluster RZ 2109 in the massive Virgo elliptical galaxy NGC 4472 (M49) at a distance of 17.14±0.71 Mpc (Tully et al. 2008). Previous studies showed that this ultra luminous source ($L_{X;\ 0.2\text{-}10\ keV} \approx 3\times10^{39}$ erg $s^{-1}$) varies between bright and faint phases on timescales of just a few hours (Maccarone et al. 2007; Shih et al. 2008). Here, we present the discovery of two peculiar X-ray bursting events that last for about 8 and 3.5 hours separated by about 3 days. It is the first time that such a recurring X-ray burst-like behaviour has been observed. We show that type-I X-ray bursts or super bursts as well as outburst scenarios requiring a young stellar object are highly unlikely explanations for the observed light curve. Thus only an aperiodic disc-wind scenario driven by hyper-Eddington accretion remains as a viable explanation for this new type of X-ray flaring activities.

## Light curve




Light curves of three XMM-Newton EPIC/pn observations taken in January 2016 with a good (although not complete) coverage of 5.7 days. Two flares within about 70 hours with durations of 7.78 and 3.42 hr, respectively, and luminosities of ≈$3\times10^{38}$ and ≈$2\times10^{38}$ erg $s^{-1}$, respectively, are detected. The persistent luminosity is ≈$1\text{-}2\times10^{37}$ erg $s^{-1}$. The flares in XMMU J122939.7+075333 are not related to flaring in the background rate and are intrinsic to the source. If flares occur periodically, onset of next flare ≈12.5 hr after end of third observation.

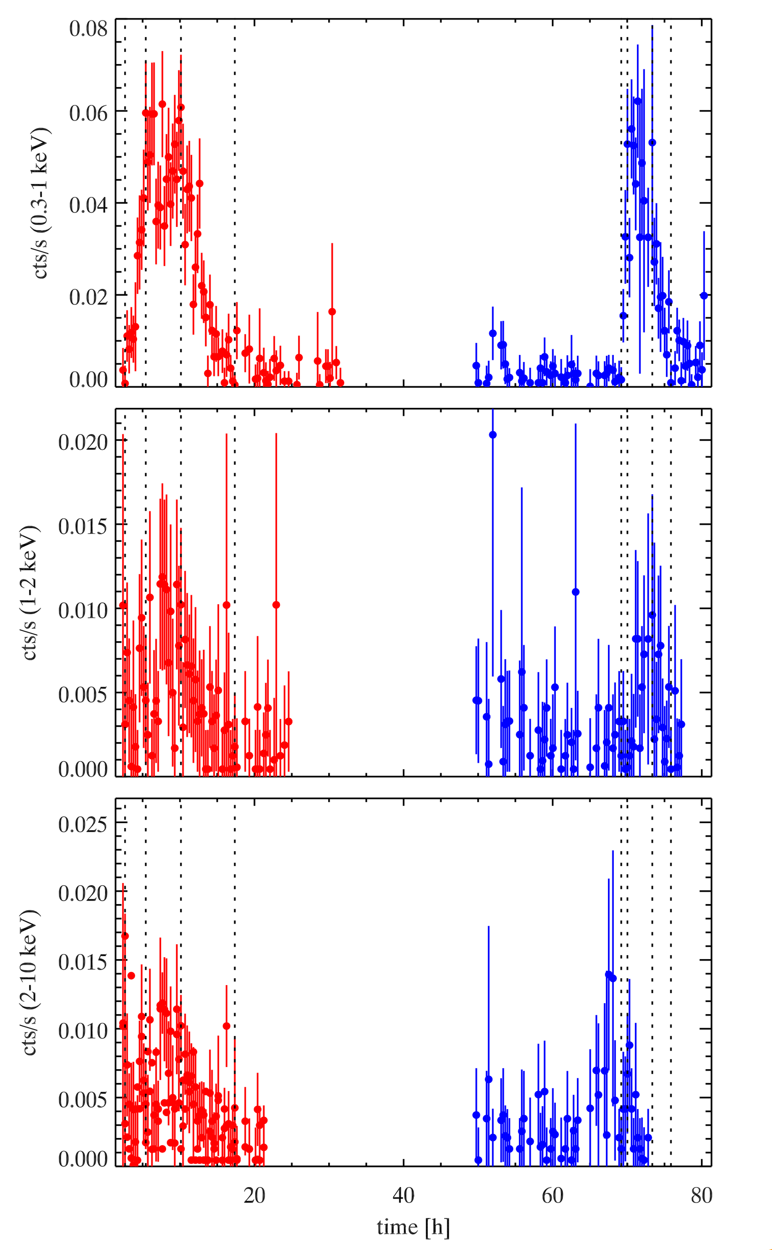
## Spectral properties

- Fit averaged spectra of flares and persistent emission in the 0.3 – 10 keV band
- Flare spectra:
  - Thermal disc emission
  - O VIII line
  - Comptonised component in first observation (simpl); no photons > 2 keV in second observation
- Values of parameters consistent within errors, apart from disc normalisation which is much smaller in second observation
- Disc temperature (≈150 eV) agrees well with values from pervious studies (Maccarone et al. 2007; Joseph et al. 2015)
- Persistent emission:
  - Thermal disc emission
  - First observation: + O VIII line
  - Alternative: 2 + 3 obs.: power law
- Foreground absorption in the persistent emission higher than during flare (Maccarone et al. 2007; Joseph et al. 2015)
- Models to fit flares do not give acceptable fits of persistent emission, as they contain components that are not required to fit persistent emission
- Fast-rise-exponential-decay outburst profile similar to type-I X-ray bursts of neutron star XRBs
- Fit flare spectra using best-fit persistent spectra + additional blackbody component (+ Comptonised component (up scattering of added blackbody component) and free O VIII normalisation in first observation)
- Absorption of added component above Galactic foreground absorption, but much lower than the one needed to fit persistent emission
- Temperature of blackbody component does not change between both observations
- Its value (≈110 eV) is close to the one of the disc temperature observed during flare
- Emission area in second observation seems to be smaller

## Energy resolved light curves

- Flares visible in softest band (0.3 – 1 keV)
  - Rising part: power law
  - Decay part: exponential decay
- Harder bands: statistically consistent with steady source
- Duration of rise ≅ light-crossing timescale ➜ 1.2 – 7.3x$10^8$ $M_\odot$ (Neronov & Vovk 2011); supermassive black hole
- Ruled out as source is associated with a globular cluster

| obs. 1 | obs. 2 |
|---|---|
| rise; power law | |
| $\Gamma = 1.38^{+0.20}_{-0.18}$ | $\Gamma = 1.63 \pm 0.37$ |
| $\chi^2/dof : 6.19/14$ | $\chi^2/dof : 0.27/2$ |
| decay; power law | |
| $\Gamma = -0.45 \pm 0.04$ | $\Gamma = -0.53^{+0.11}_{-0.09}$ |
| $\chi^2/dof : 52.85/19$ | $\chi^2/dof : 8.50/8$ |
| decay; exponential | |
| $\alpha = (-1.2 \pm 0.1) \times 10^{-4}$ | $\alpha = (-2.1 \pm 0.6) \times 10^{-4}$ |
| $\chi^2/dof : 25.34/19$ | $\chi^2/dof : 5.84/8$ |




## Discussion

### Disc wind? ✔

- Occurs on aperiodic time scales
- **Viable** explanation for the light curve of XMMU 122939.7+075333
- Radius of thermal emission area and its temperature seem consistent with hyper-Eddington black hole winds (King & Muldrew 2016)

### Type-I X-ray bursts? ✘

- Time scales highly inconsistent; type-I bursts last for at most a few minutes
- Regarding duration, super bursts seem better explanation, but
- Recurrence time incredible short (Keek et al. 2006), temperatures obtained from energy spectra much too low (Strohmayer & Bilsten 2003; Kuulkers 2004)
- Radius of thermal emission area is $10^3$ – $10^4$ km, much larger than neutron star

### Young, high-mass object? ✘

- Like Wolf-Rayet X-ray binary, magnetar, or high-mass donor star
- Does not seem to be viable explanation, as we do not expect to find a young, high-mass donor star in the old population of a globular cluster

### Grazing eclipse? ✘

- Excess absorption can be caused by a grazing eclipse by the donor star, a disc wind from the accretion disc, or a grazing eclipse by a precessing, warped accretion disc (Shih et al. 2008)
- Eclipse by donor star **cannot** explain change in X-ray flux (Shih et al. 2008; estimate orbital period based on light-curve properties ➜ orbital period unphysically long ≈ $10^9$ hr)
- About 90 day precession period for warped disc (Shih et al. 2008)
- Super-orbital periods in systems such as Her X-1, SS433 and LMC X-4 are several tens to hundreds of days (Jurua et al. 2011) ➜ observed ≈ 70 hr variability in XMMU 122939.7+075333 **inconsistent** with time scales expected for a precessing, warped accretion disc

### Ultra luminous flares? ✘

- From globular clusters or ultra compact dwarf companions of nearby parent elliptical galaxies, reaching luminosities of $10^{39}$ – $10^{41}$ erg $s^{-1}$ have been observed (Sivakoff et al. 2005; Irwin et al. 2016)
- However, rise times are less than one minute, and flares decay over about one hour
- Much shorter time scales than in XMMU 122939.7+075333

### Tidal disruption event? ✘

- Slope of power law fitted to decay of burst (~-1/2) is much flatter than the -5/3 decay characteristic for tidal disruption events (Rees 1988; Phinney 1989; Evans & Kochanek 1989)
- Partial disruption could help explain why we would see two events within ~3 days, but we should observe an even steeper slope (Guillochon & Ramirez-Ruiz 2013)
- Pervious optical studies have already considered tidal disruption events an unlikely explanation for the observed variability (Zepf et al. 2008; Steele et al. 2011)

### O rich gas? ✘

- Presence of OIII, OVIII lines ➜ some O rich gas in vicinity of compact object, irradiated by X-ray emission
- If gas fuels outburst it must be replenished quite regularly
- If it obscures the compact object it must be diluted from time to time (bright phase)
- Dilution can be caused by e.g. irradiation of the gas by emission from compact object ➜ absorbing gas must be replenished
- Outburst of XMMU 122939.7+075333 with luminosities >$10^{39}$ erg $s^{-1}$ observed for more than 14 years ➜ source of gas must be long-lasting
- Gas rich in O ➜ must be processed material containing few H and He, like white dwarf
- RCB star can be source of O rich gas (Maccarone & Warner 2011), but such stars eject part of envelope on time scales of years (Clayton 2012), hence **cannot** replenish gas on time scales observed in XMMU 122939.7+075333

## Literature

- Clayton 2012, JAVSO, 40, 539
- Evans & Kochanek 1989, ApJL, 346, L13
- Guillocho & Ramirez-Ruiz 2013, ApJ, 767,25
- Irwin et al. 2016, Nature, 538, 356
- Joseph et al. 2015, MNRAS, 447, 1460
- Jurua et al. 2011, MNRAS, 418, 437
- Keek et al. 2006, A&A, 455, 1031
- King & Muldrew 2016, MNRAS, 455, 1211
- Kuulkers 2004, NuPhS, 132, 466
- Maccarone et al. 2007, Nature, 455, 183
- Maccarone &Warner 2011, MNRAS, 412, 1389
- Neronov & Vovk 2011, MNRAS, 412, 1389
- Phinney 1989, IAU symp. 136, 543
- Rees 1988, Nature, 333, 523
- Shih et al. 2008, MNRAS, 386, 2075
- Sivakoff et al. 2005, ApJL, 624, L17
- Steele et al. 2011, ApJ, 739, 95
- Strohmayer & Bilsten 2003, Compact Stellar X-ray sources, 113
- Tully et al. 2008, ApJ, 676, 184
- Zepf et al. 2008, ApJL, 683, L139