

CNOC XII, Cefalù, 28 September 2022

Recurrent X-ray flares from an extra-galactic globular cluster: QPEs from an IMBH?

Andrea Tiengo



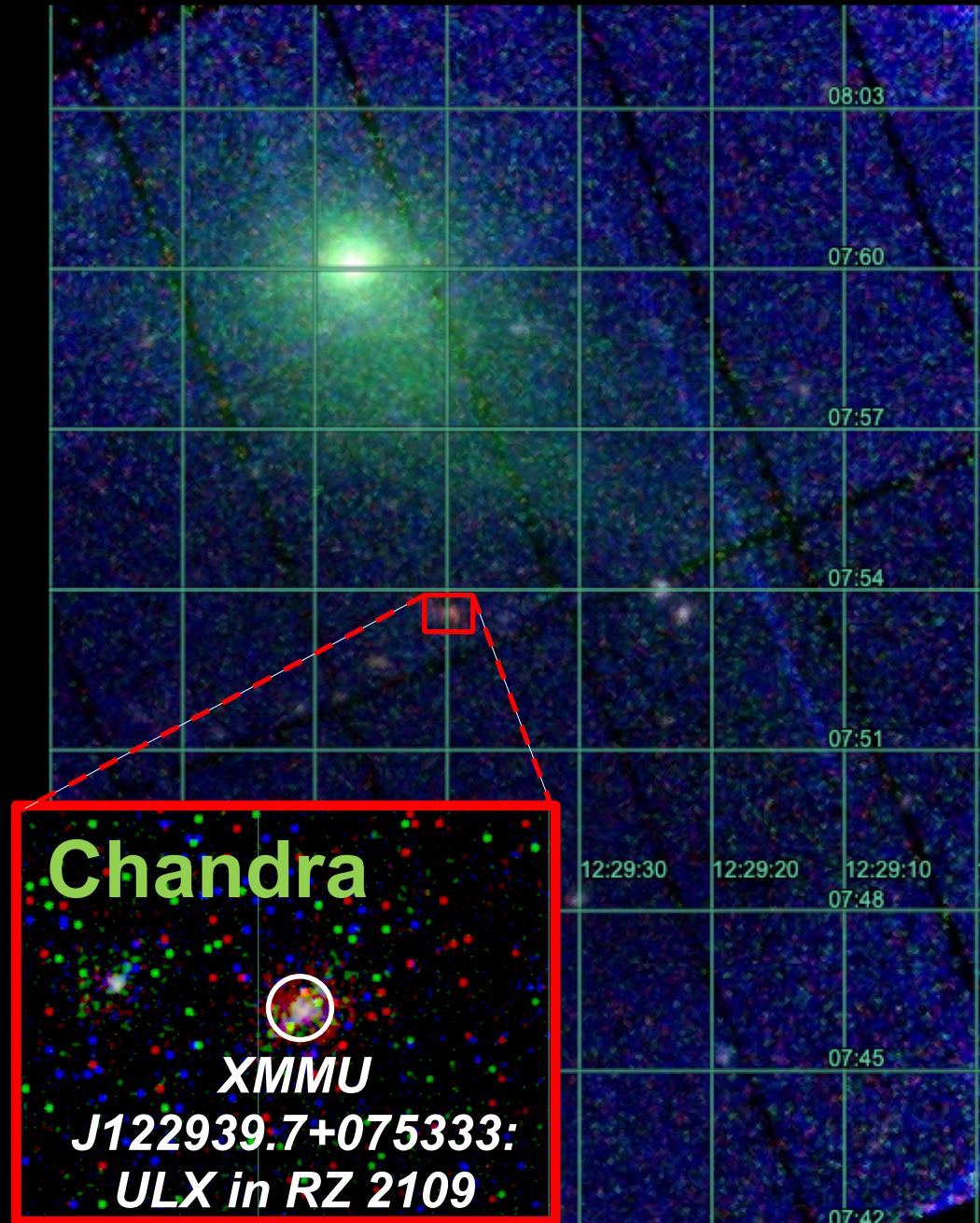
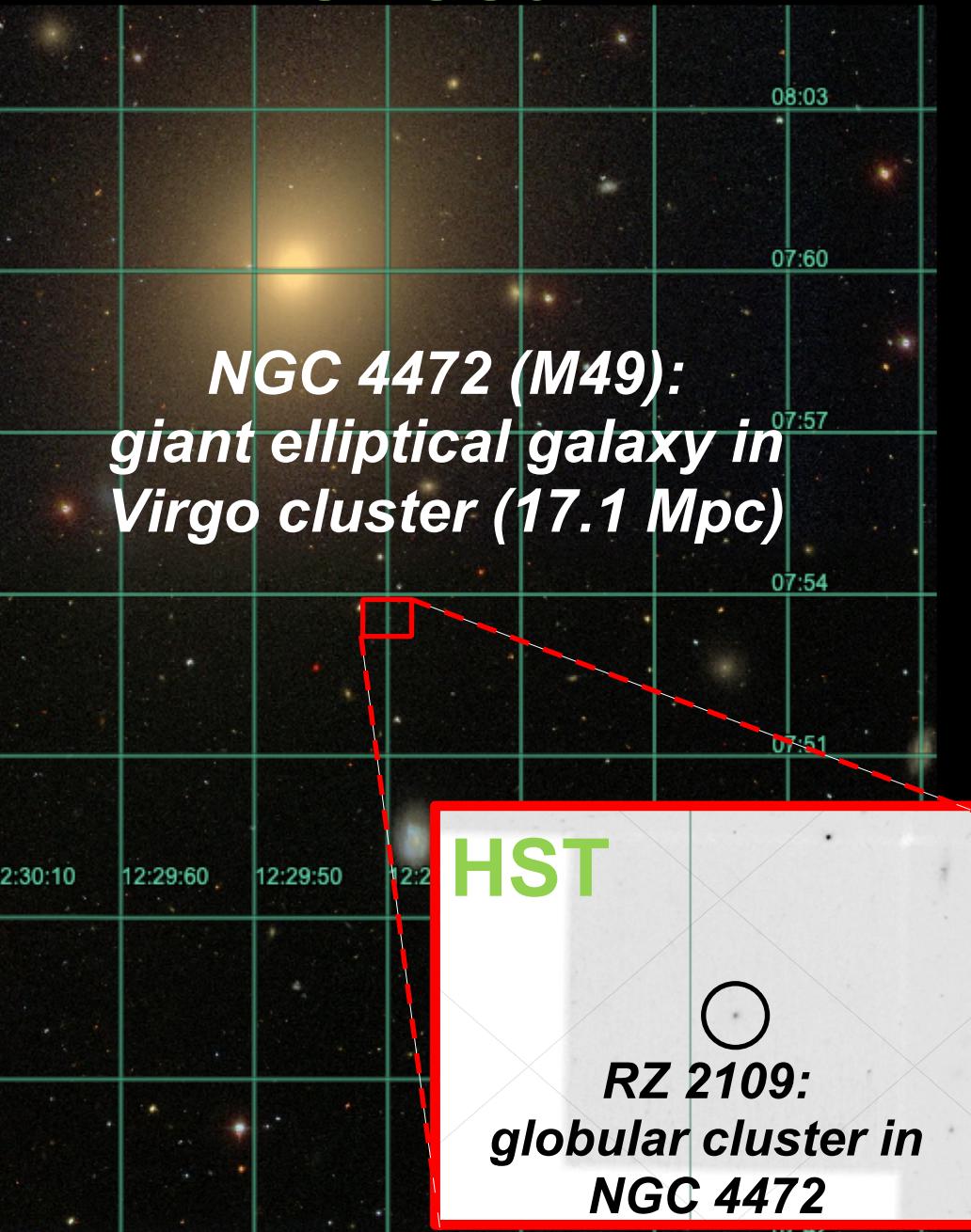
Paolo Esposito, Martina Toscani, Giuseppe Lodato, Manuel Arca Sedda, Sara Motta, Federica Contato, Martino Marelli, Ruben Salvaterra, Andrea De Luca

SDSS9

Optical/X-ray images

(from *ESASky*)

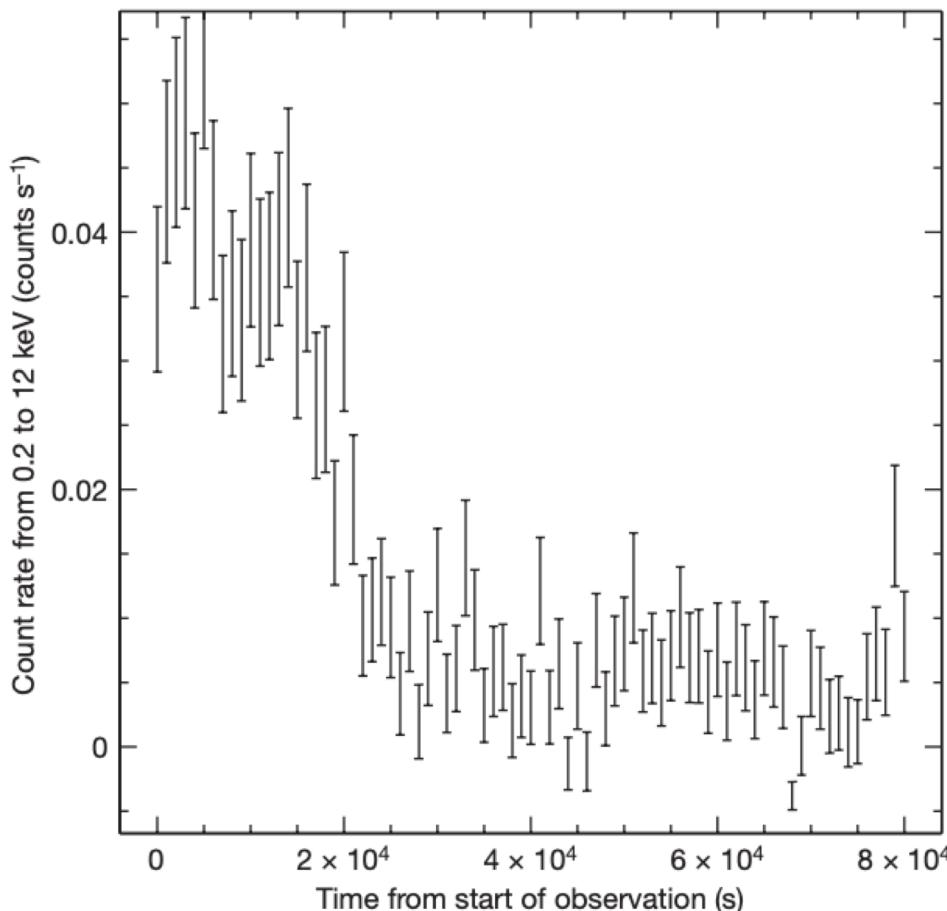
XMM-Newton



LETTERS

A black hole in a globular cluster

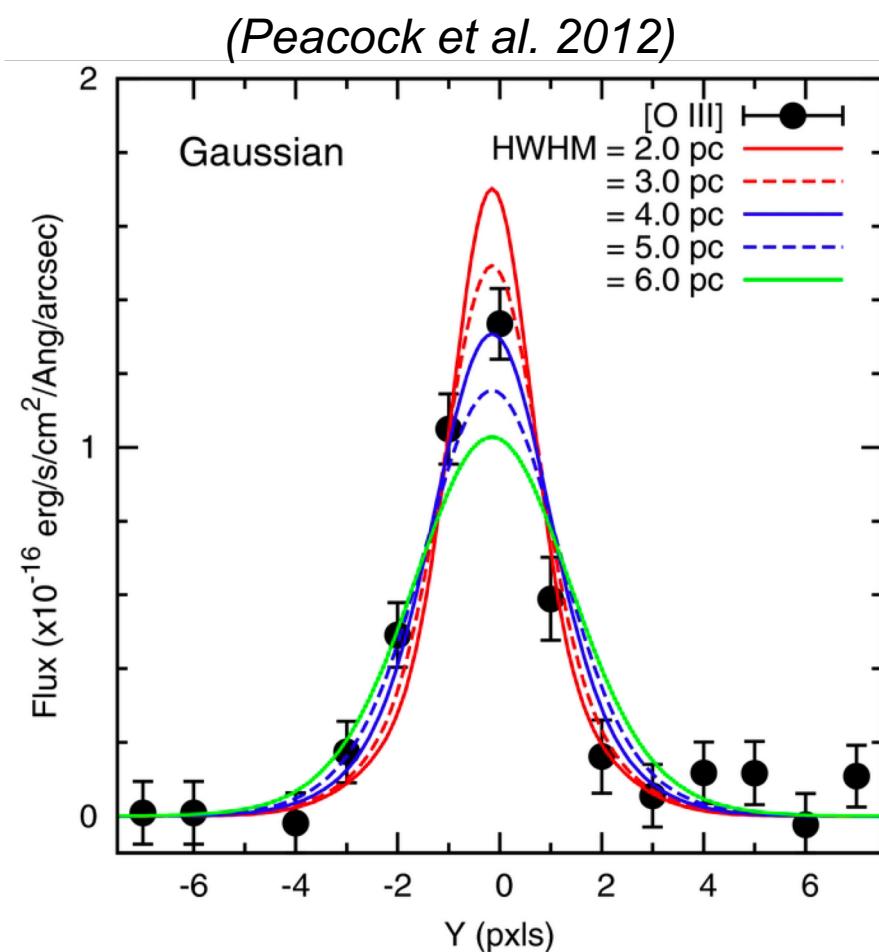
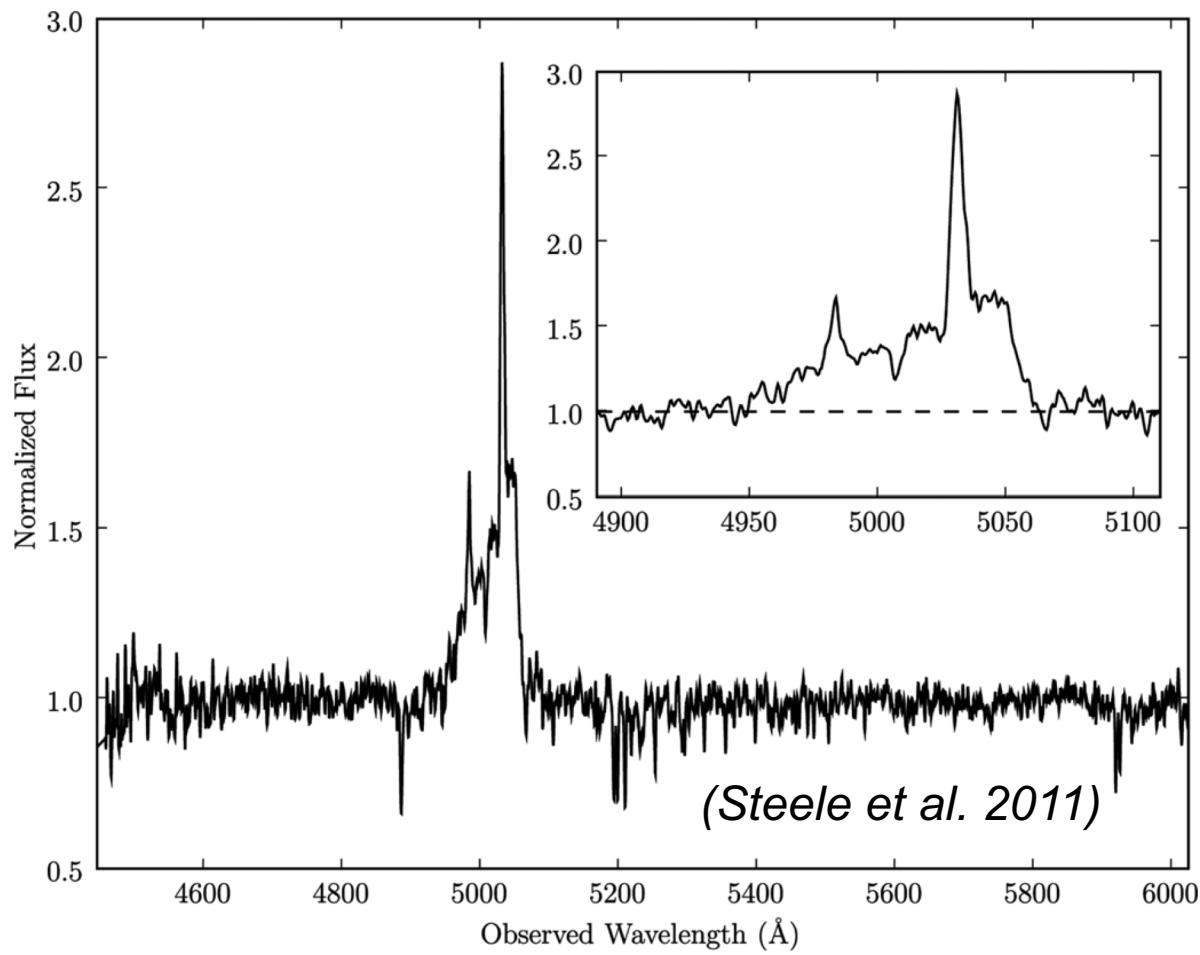
Thomas J. Maccarone¹, Arunav Kundu², Stephen E. Zepf² & Katherine L. Rhode^{3,4}



- **Variability** \Rightarrow single X-ray source in globular cluster
- **$L_x > 10^{39}$ erg/s** \Rightarrow black hole

However, pulsating ULXs
(Bachetti *et al.* 2014; Israel *et al.* 2017...) \Rightarrow neutron stars
with $L_x > 10^{39}$ erg/s

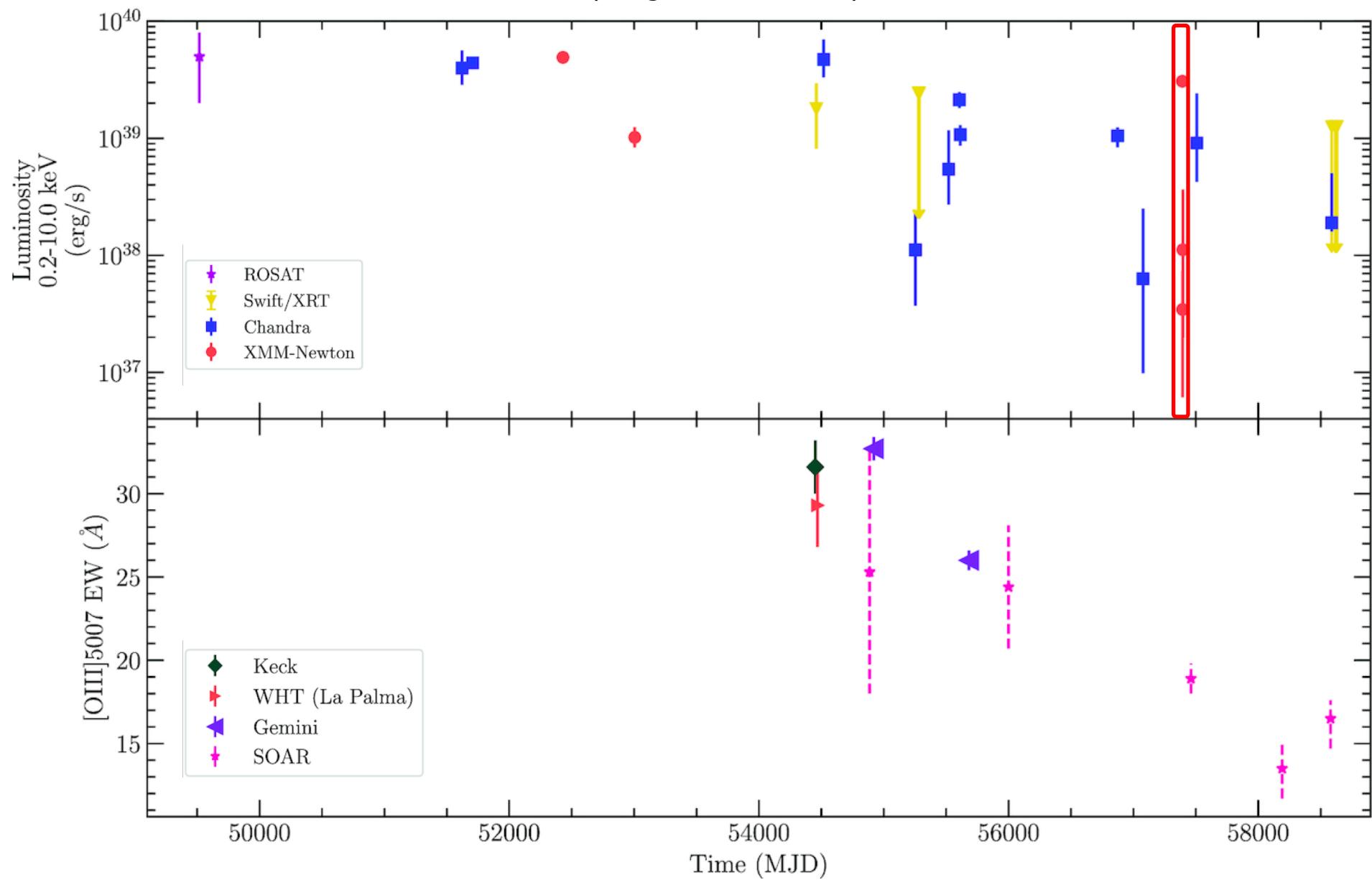
Optical [O III] line: broad, extended and variable



Bright, broad and extended (~ 4 pc) emission line \Rightarrow outflow ($v \sim 1600$ km/s) and Oxygen excess

Optical [O III] line: broad, extended and variable

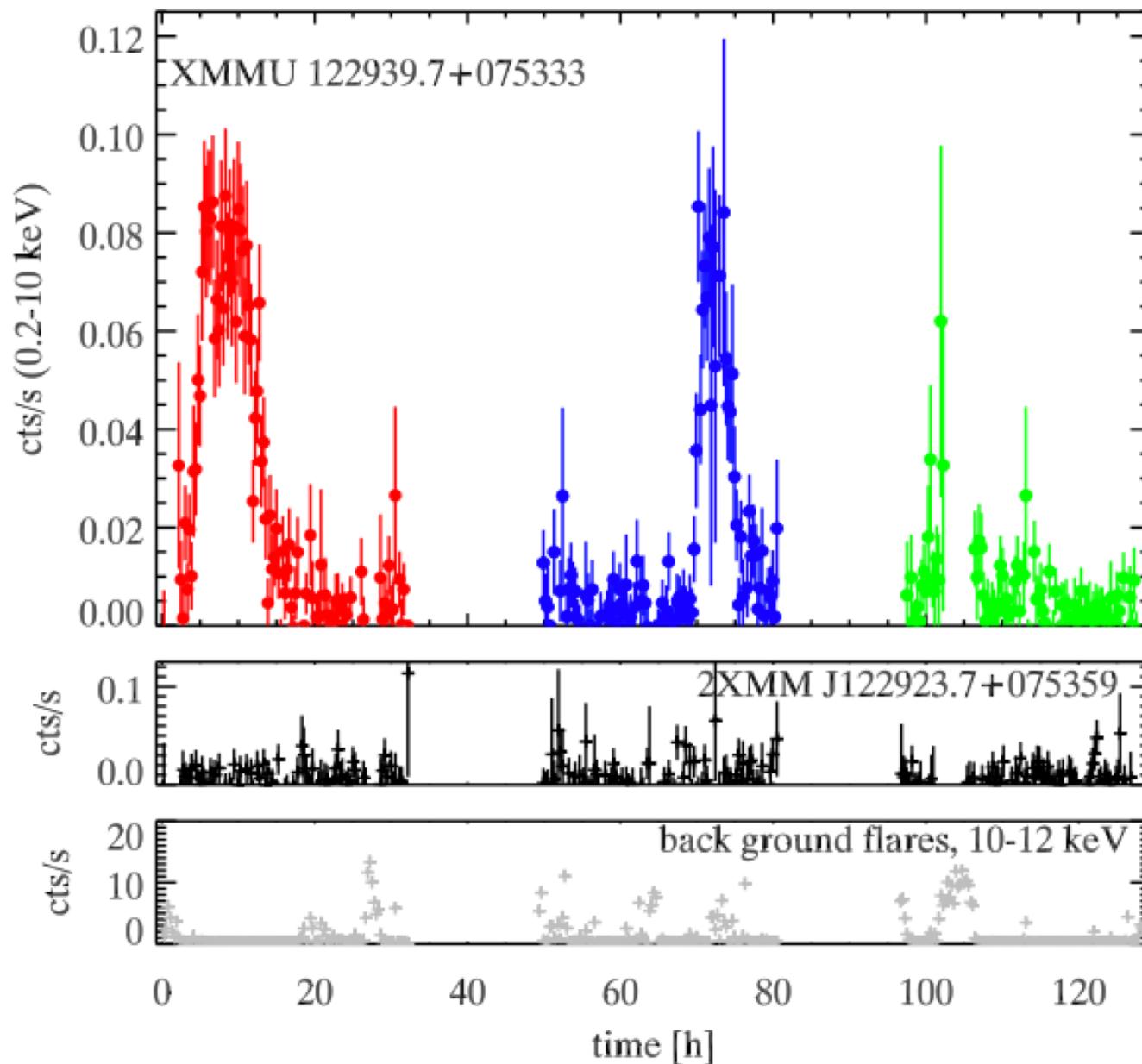
(Dage et al. 2018)





Peculiar Outbursts of an Ultra-luminous Source: Likely Signs of an Aperiodic Disk-wind

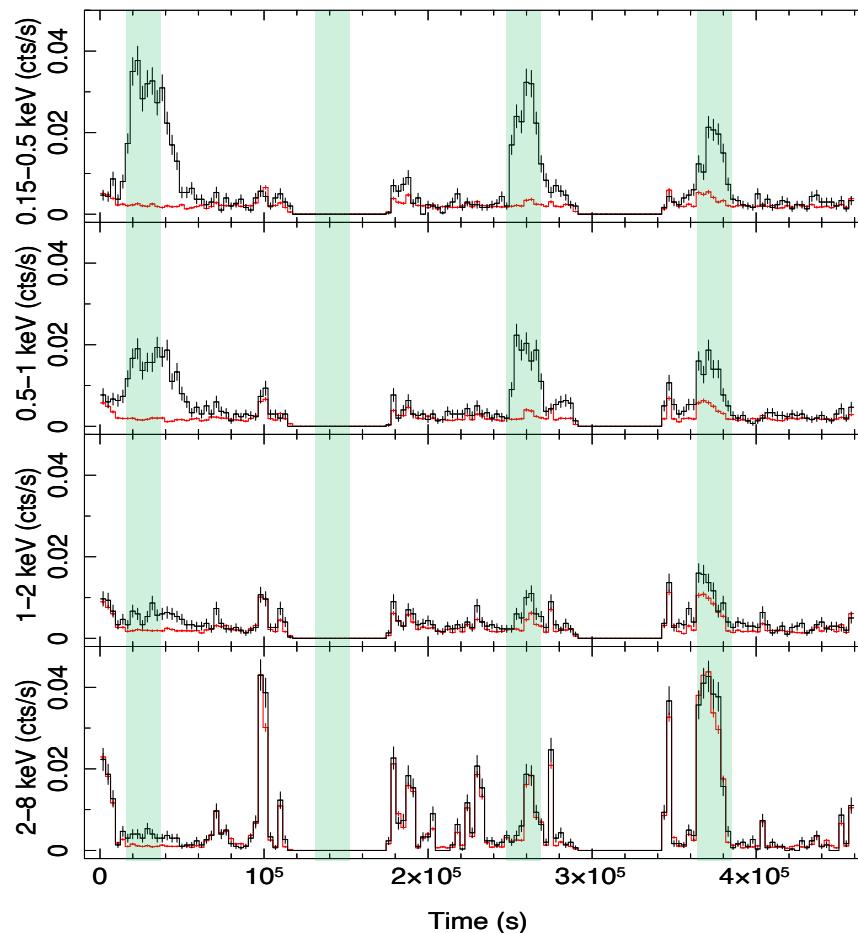
H. Stiele and A. K. H. Kong



Recurrent X-ray flares of the black hole candidate in the globular cluster RZ 2109 in NGC 4472

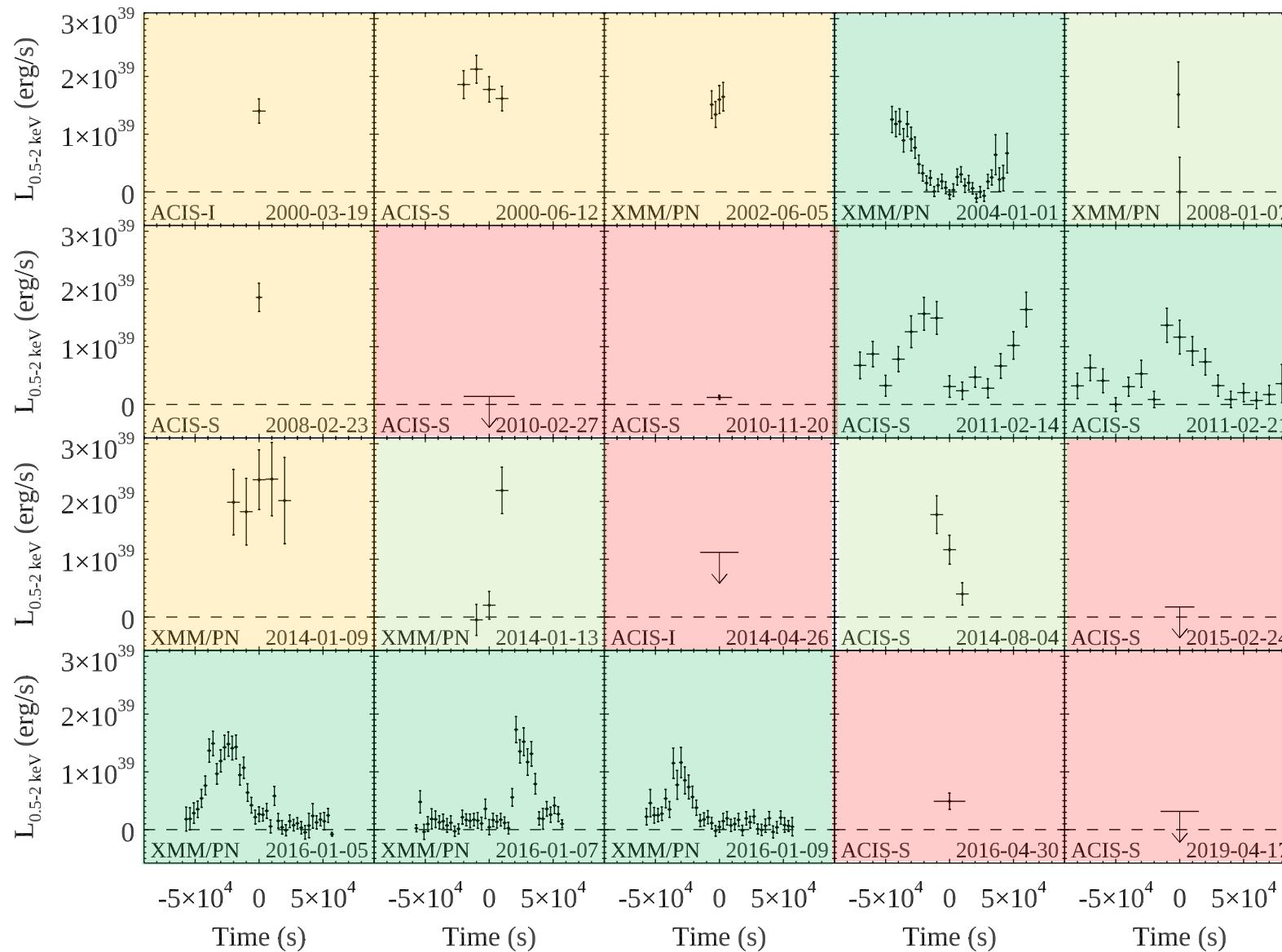
A. Tiengo^{1,2,3} , P. Esposito^{1,2} , M. Toscani^{4,5}, G. Lodato⁴ , M. Arca Sedda⁶ , S. E. Motta⁷ , F. Contato⁸ , M. Marelli² , R. Salvaterra² , and A. De Luca^{2,3} 

Bin time: 3000. s



- X-ray flares are very **soft**
⇒ clear detection of **flare**
also in 3rd orbit, even
during (hard) particle flare
- Possible recurrence time:
~112 ks (flare during data
gap at satellite perigee?)

All available uninterrupted X-ray light curves



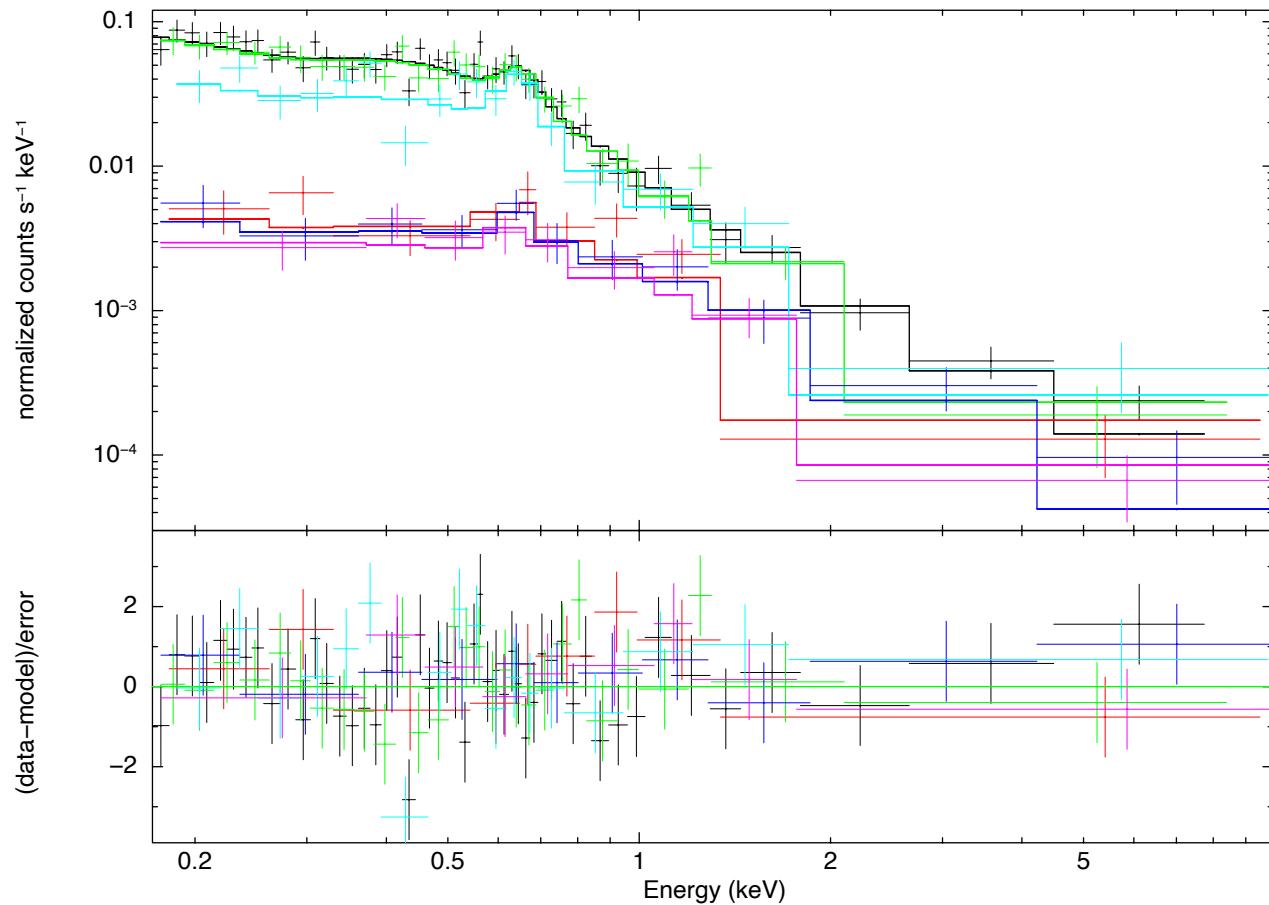
Significant variability

Possible variability

High luminosity

Low luminosity

X-ray spectrum: 2016 XMM observations

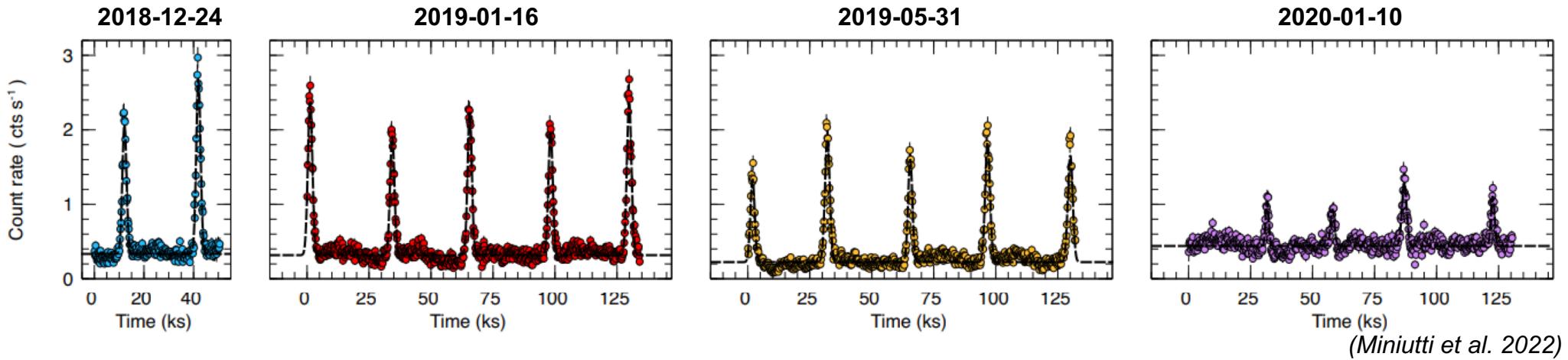


- **Flares** have same spectrum: diskbb+PL+OVIII line
- **Quiescent** spectrum is harder: no diskbb and much fainter line
- If inner disk radius \sim ISCO of non-rotating BH with $i=45^\circ$ \Rightarrow **$\sim 1,000 M_\odot$** black hole

	obs1F	obs1Q	obs2F	obs2Q	obs3F	obs3Q
Γ	$1.9^{+0.1}_{-0.2}$	1.9^a	1.9^a	1.9^a	1.9^a	1.9^a
PL flux ^b ($10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}$)	3.7 ± 0.4	1.5 ± 0.3	3.3 ± 0.7	1.4 ± 0.2	3.3 ± 0.9	1.1 ± 0.2
T _{in} (eV)	143 ± 7	143^a	143^a	143^a	143^a	143^a
R _{in} ^c (km)	6400^{+800}_{-600}	< 1100	6300^{+800}_{-600}	< 1100	4200 ± 600	< 900
O VIII norm. ^d ($10^{-6} \text{ photons cm}^{-2} \text{ s}^{-1}$)	4.2 ± 1.0	0.6 ± 0.4	4.3 ± 1.2	0.5 ± 0.3	5.7 ± 1.3	0.4 ± 0.3

Quasi Periodic Eruptions (QPEs)

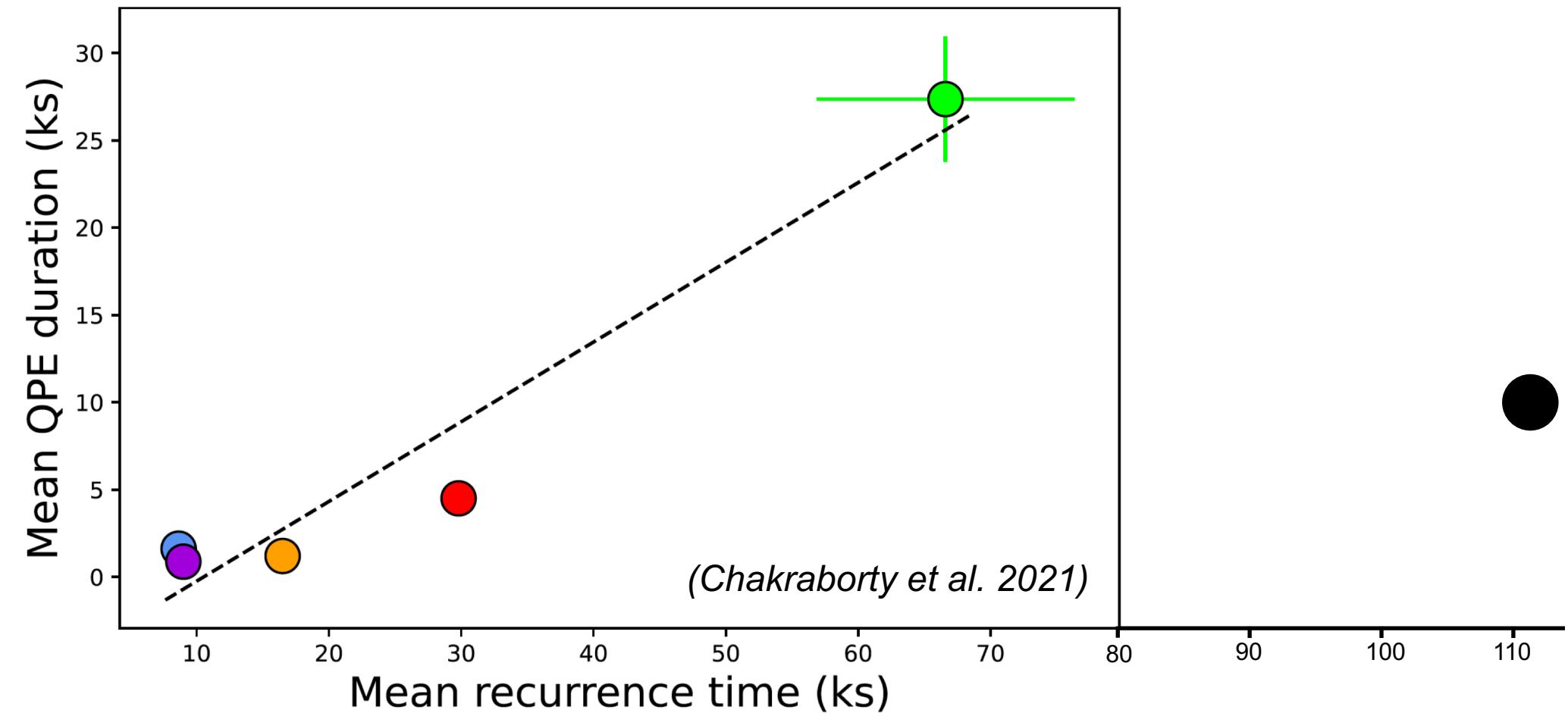
- First QPE X-ray source discovered in **AGN** GSN 069 with **XMM-Newton** (*Miniutti et al. 2019*)



- Other 3 (+1 candidate) QPE sources in (active or quiet) **galactic nuclei** with **XMM-Newton**, **Chandra**, **NICER** and **eROSITA** (*Giustini et al. 2020; Arcodia et al. 2021; Chakraborty et al. 2021*)
- Possible interpretation: recurrent **partial tidal disruption** of a star in **eccentric orbit** around a (small size: $\sim 10^{5-6} M_{\odot}$) **SMBH** (*King 2020, 2022; Zhao et al. 2022; Nixon & Coughlin 2022*)

Similarities (and differences) with QPEs

- Flare duration (~10 ks) longer than most QPEs, but larger separation (~112 ks) \Rightarrow similarly short duty cycle (shortening with time?)



Analogies (and differences) with QPEs

- Flare duration (~10 ks) longer than most QPEs, but larger separation (~112 ks) ⇒ similarly short duty cycle (shortening with time?)
- Spectrum: flare is very soft (similar to QPEs), but no significant spectral evolution during flare and hard quiescent emission (with no disc component)
- Crowded environment: globular cluster favours close stellar encounters ⇒ TDE or pTDE
- If pTDE and $M_{BH} \sim 1,000 M_{\odot}$: white dwarf, grazing encounter ($0.45 < \beta < 0.55$) and very eccentric orbit ($e > 0.95$)
- [O III] and O VIII lines from photoionization of unbound debris from Oxygen-rich white dwarf

If similarities confirmed by further observations of XMM1229 (or other similar systems) ⇒ a scaled-down (and nearby) version of QPE sources might help us to interpret them