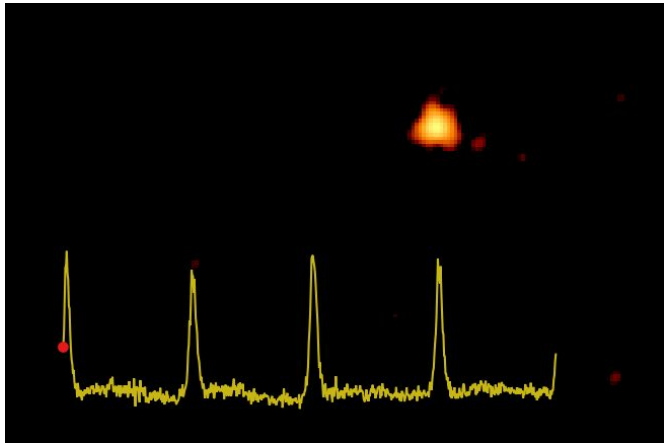
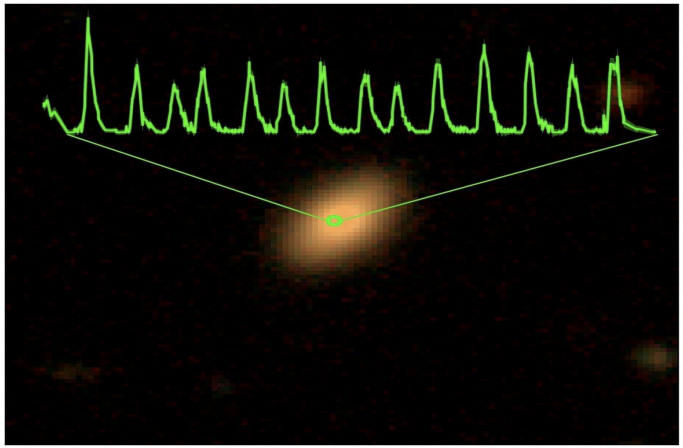
Quasi-Periodic (X-ray) Eruptions from Galactic Nuclei





Muryel Guolo

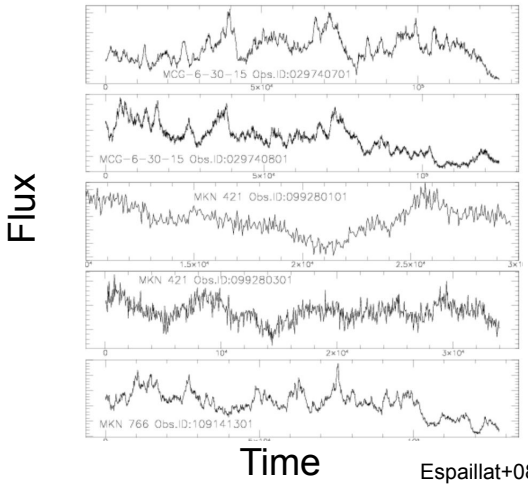
Johns Hopkins University

Dheeraj R. Pasham, Michal Zajacek, Eric Coughlin, Suvi Gezari, et al.

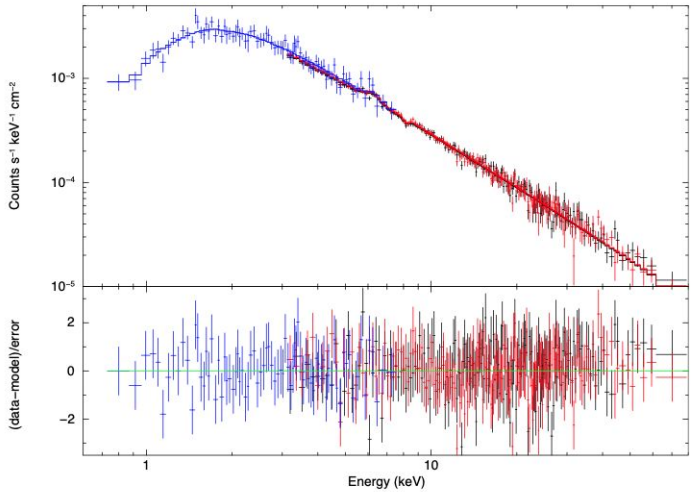
Nuclear Activity: **AGN** or TDEs

Typical Active Galactic Nucleus (AGN) in the X-ray band:

- 30-50% fractional variability; “aperiodic”, “random”, “stochastic”
- Power-law X-ray spectrum extending to hard X-rays



Espaillat+08

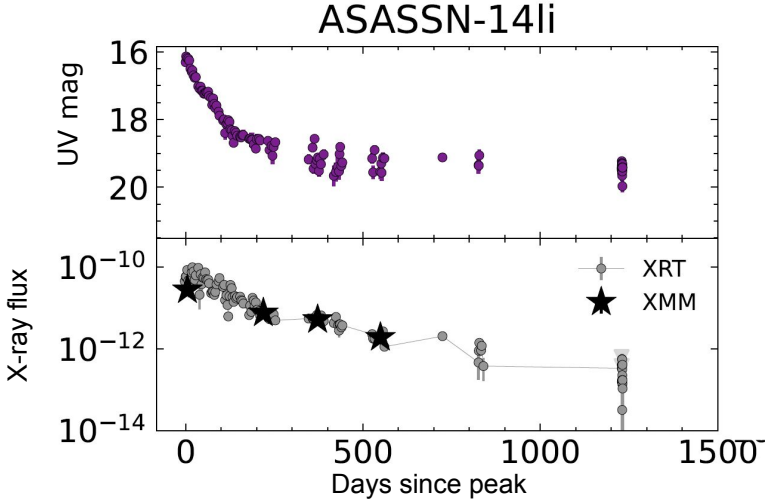


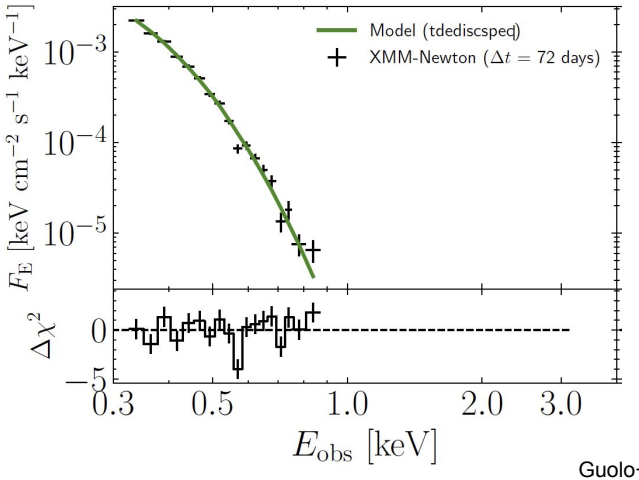
Marinucci+19

Nuclear Activity: AGN or **TDEs**

Typical Tidal Disruption Event (TDE) in the X-ray band:

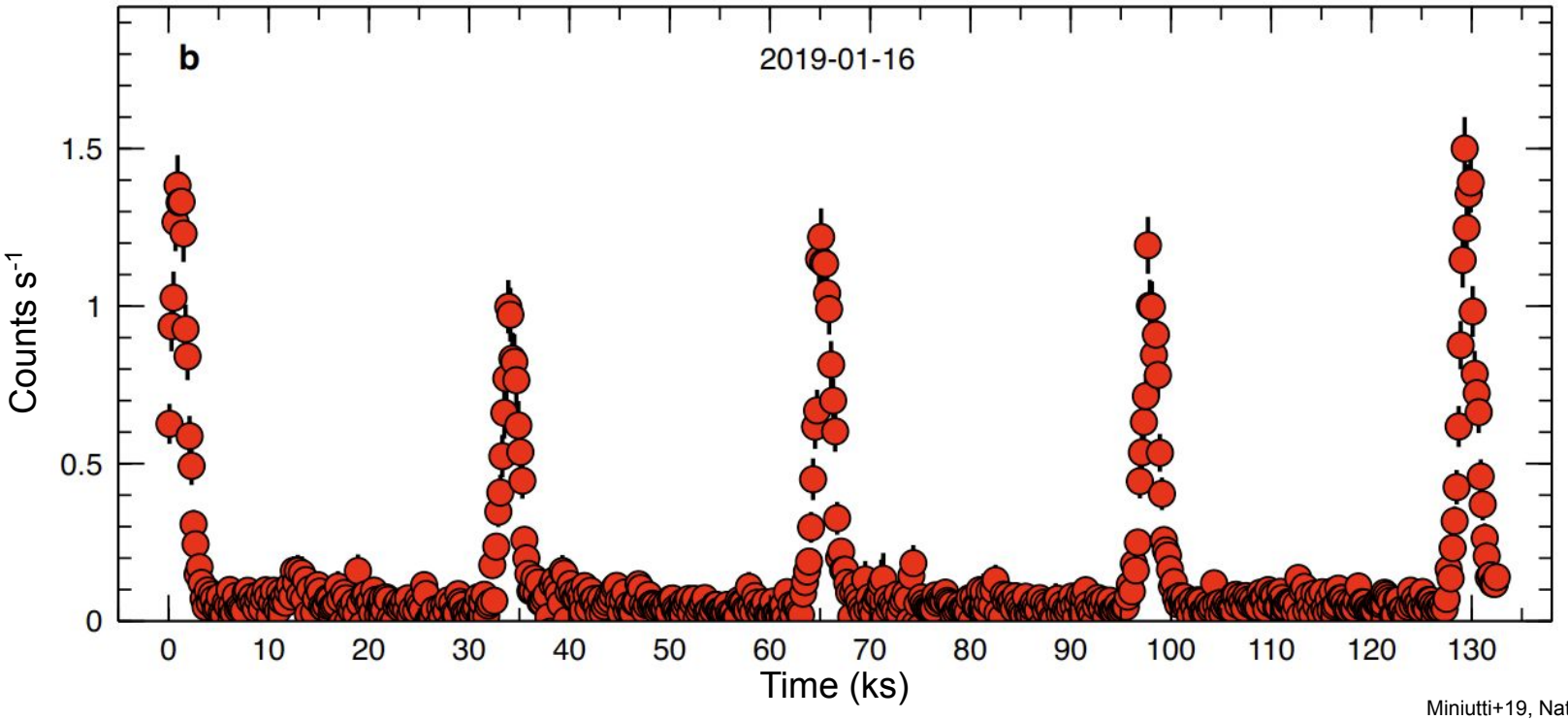
- Few years-long flare from a previously quiescent galaxy ($F_x \propto t^{-q}$), usually UV bright.
- Soft Thermal X-ray spectrum (T ~ 50-200 eV)





Guolo+in prep

2019: X-ray Quasi-Periodic Eruptions (QPEs) discovered in GSN 069

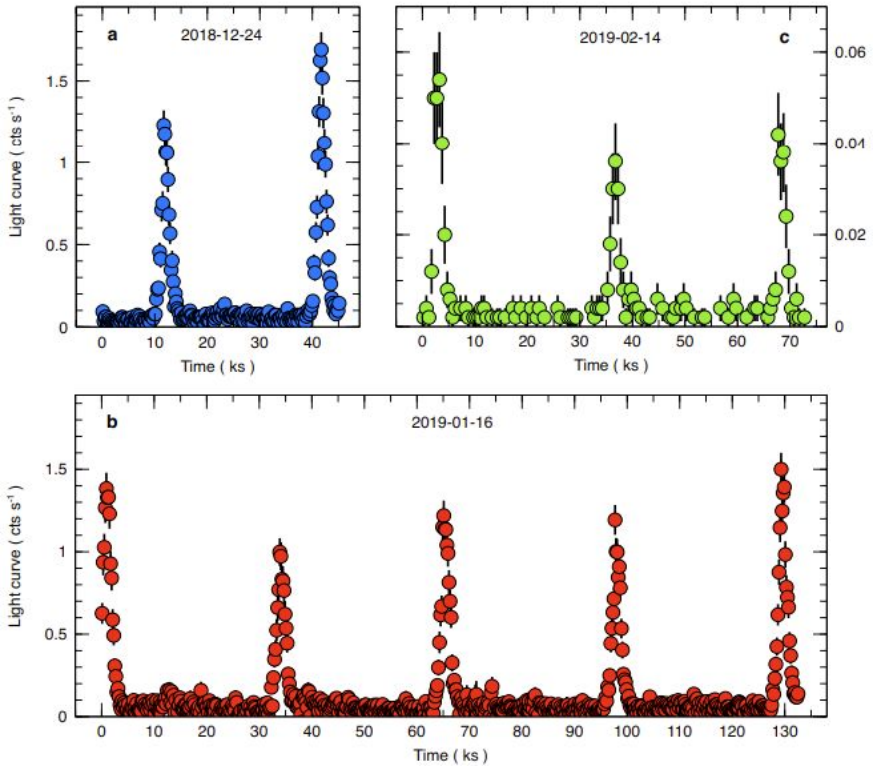


Miniutti+19, Nature.

Nuclear Activity: AGN or TDEs or **QPEs**

- 4 systems:
  - **GSN 069 (Miniutti+19)**
  - RX J1301 (Giustini+20)
  - eRO-QPE1 (Arcodia+21)
  - eRO-QPE2 (Arcodia+21)

- Recurrence times 2-20 hours
- Flare durations 0.5-8 hours
- Peak L_X= 10^{42}-10^{43} erg/s
- Amplitude 10-200
- No UV/optical counterpart
- M_{BH}= 10^{5}-$10^{6.6}$ $M_\odot$



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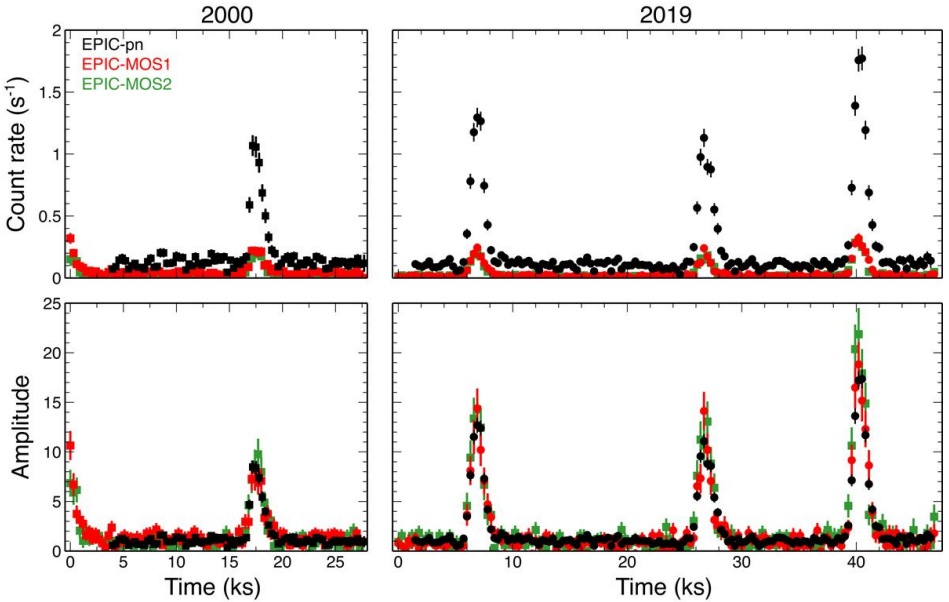

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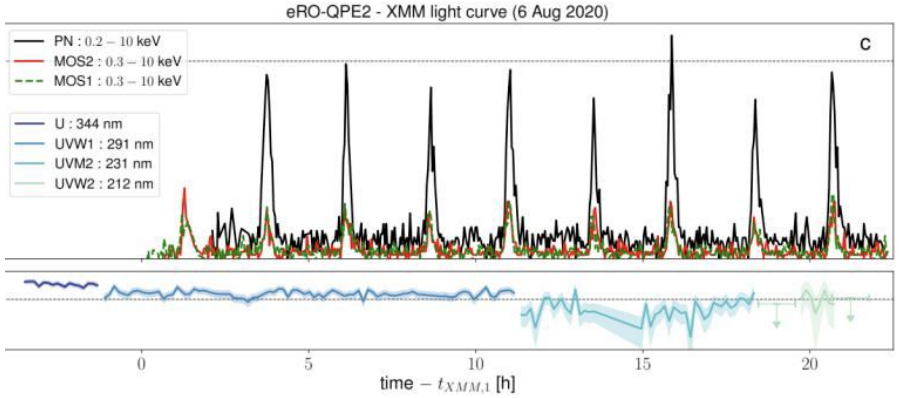
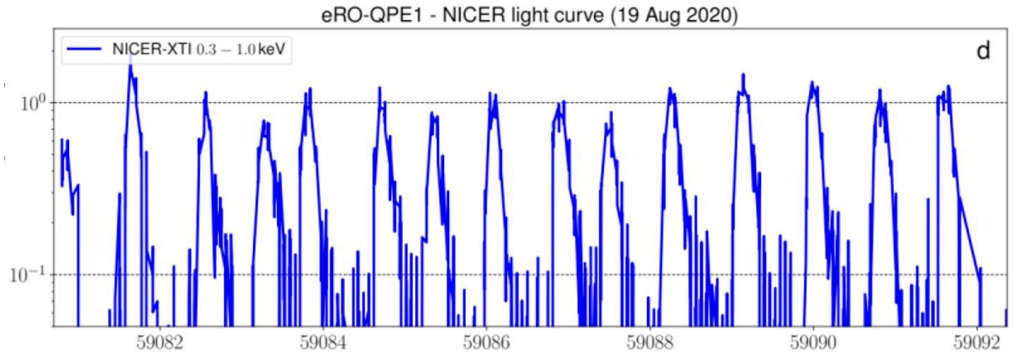
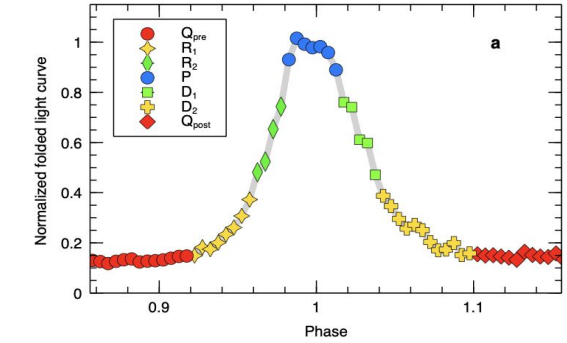
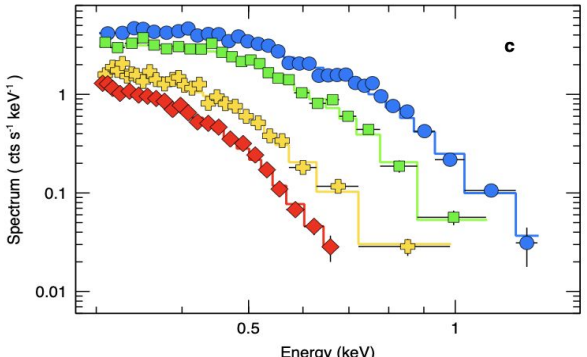


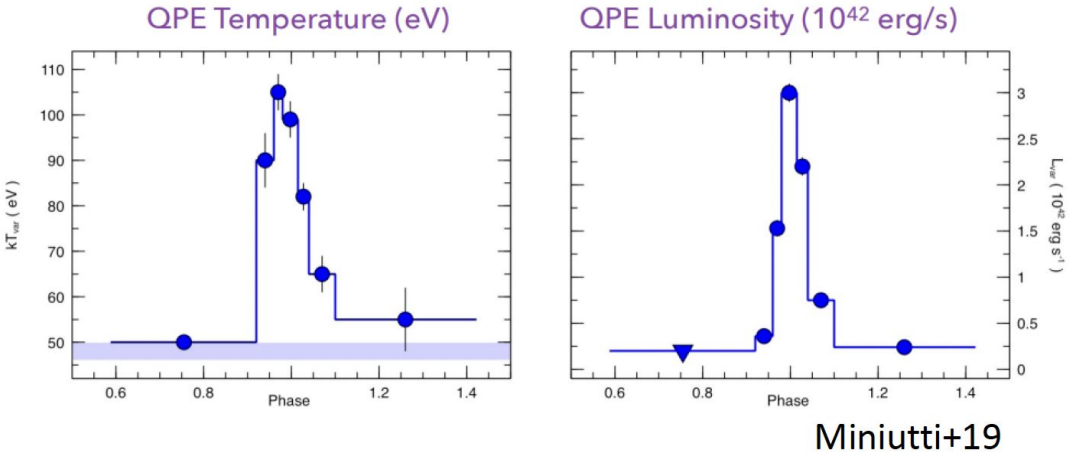


QPEs Spectra

- Blackbody or multi-temperature disk (*diskbb* on Xspec), T~50-200 eV







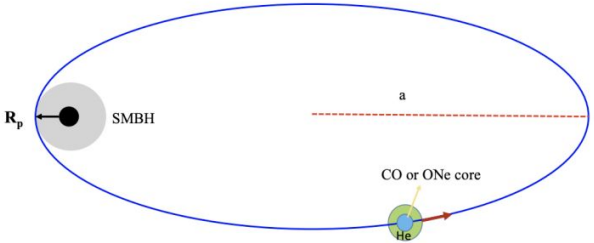
Miniutti+19

Models for QPE sources

- ~~Self-lensing black hole binary~~
- ~~Disk instabilities~~
- **Orbiting bodies?**
  - **EM counterparts of extreme mass ratio inspirals (EMRIs)**

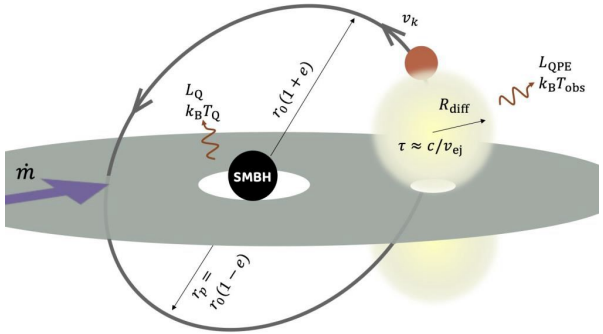
Repeating partial TDE of compact object or main-sequence companion(s)

(King 2020, 2022; Zhao et al. 2021; Metzger & Stone 2022)



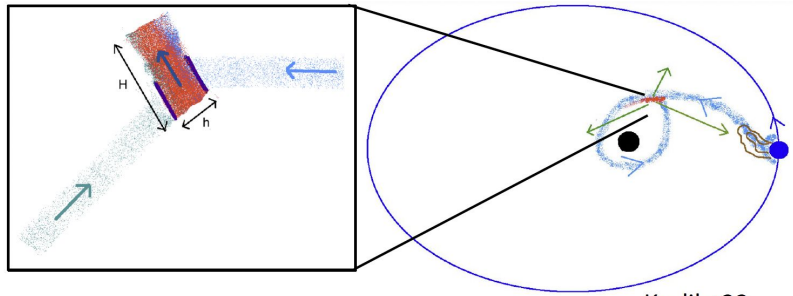
Star-disk (or ADAF) collisions/interactions

(Xian et al. 2021, Sukova et al. 2021, Linial & Metzger 2023)



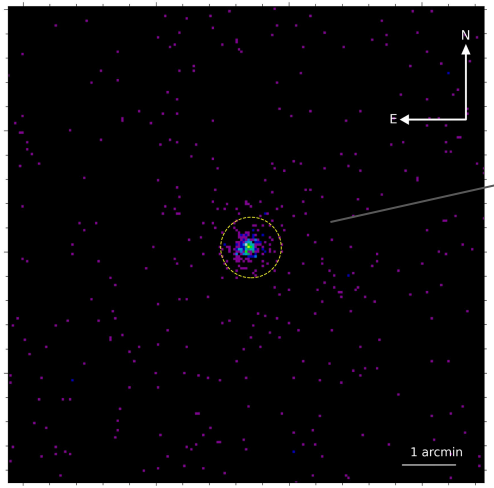
Linial & Metzger 2023

Shock-powered flares from a main-sequence companion (Lu & Quataert 2022; Linial& Sari 2022; Krolik & Linial 2022)

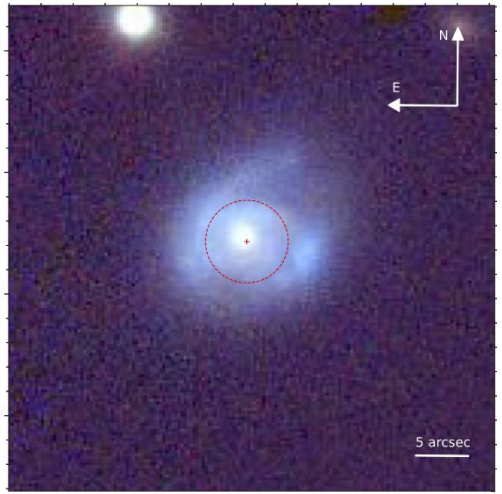


Krolik+22

Crazy Swift Source



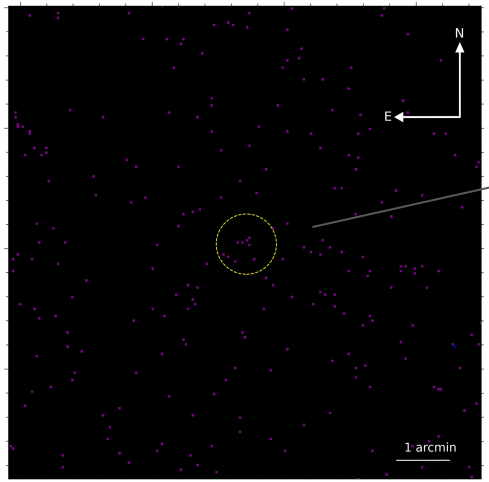
$F_x \sim 1 \times 10^{-12}$ cgs
$L_x \sim 5 \times 10^{42}$ cgs



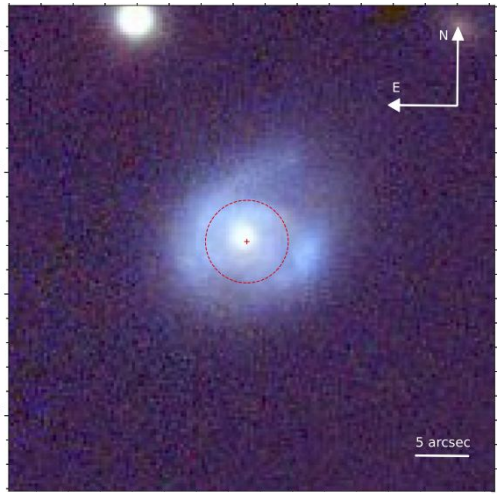
- Serendipitously discovered by Swift/XRT
- 35x brighter than previous upper limit
- Soft X-ray spectra all counts below 1 keV
- X-ray TDE candidate
- However….

Host: spiral galaxy at 165 Mpc (z ~ 0.036)

Crazy Swift Source



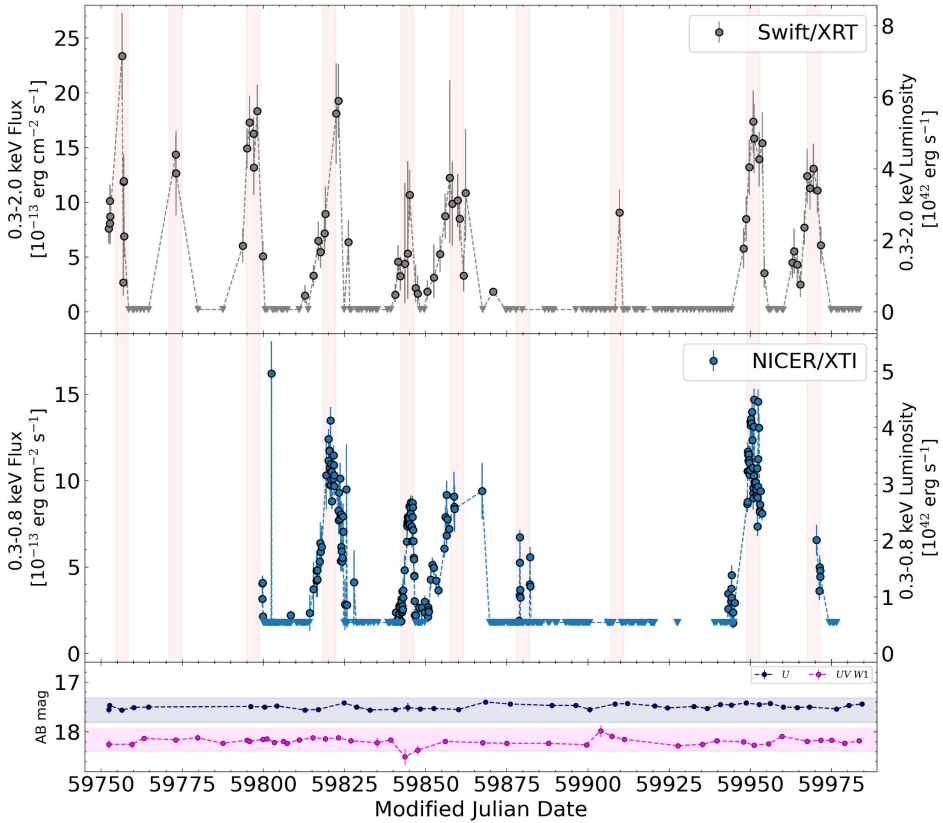
$Fx < 2 \times 10^{-14}$ cgs
$Lx < 1 \times 10^{41}$ cgs



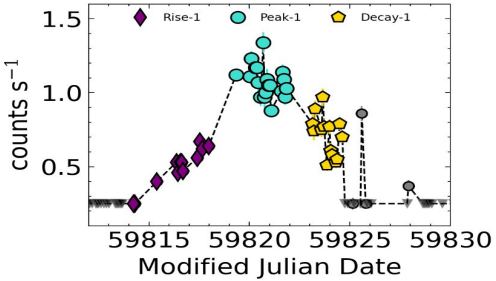
- Serendipitously discovered by Swift/XRT
- 35x brighter than previous upper limit
- Soft X-ray spectra all counts below 1 keV
- X-ray TDE candidate
- However…. GONE TWO WEEKS LATER!

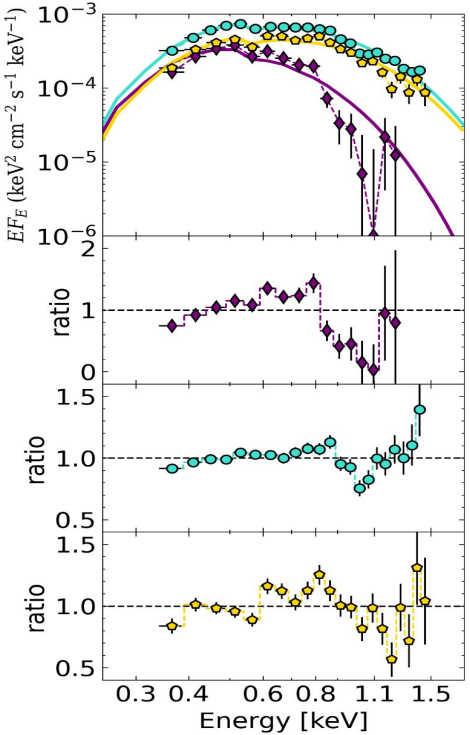
Host: spiral galaxy at 165 Mpc (z ~ 0.036)

Crazy Swift Source



- Few days long X-ray eruptions each ~20 days, but gaps…
- No detections during quiescent Fx < 2 x 10^{-14} cgs
- Amplitude > 100
- No UV optical Counterpart
- No clear AGN in the host galaxy (from X-ray, Radio, optical nor IR), but BPT/WHAN indicates a low-luminosity AGN.
- log M_{BH}= 6.6 +/- 0.4 $M_{\odot}$



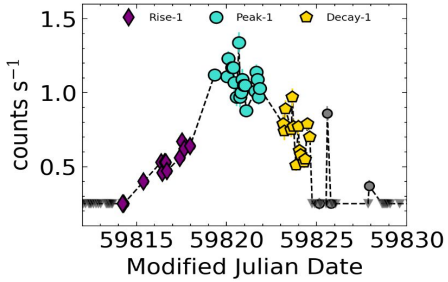


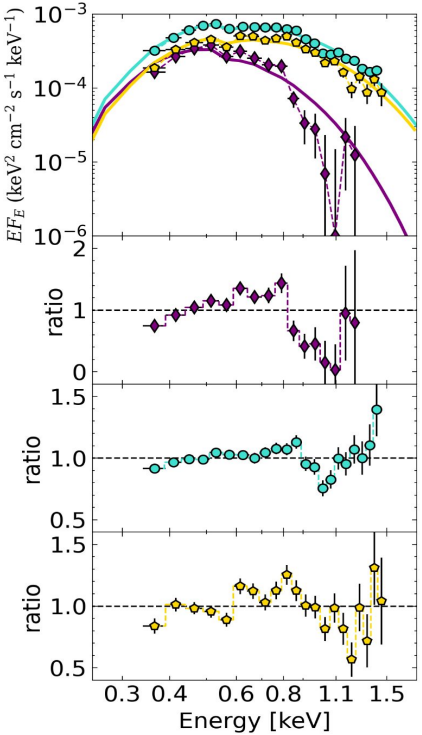
Crazy Swift Source: Spectra

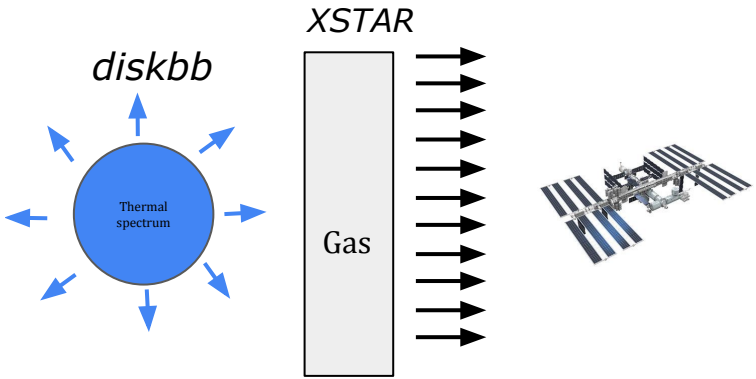
- Soft/Thermal X-ray spectrum T ~ 100-250 eV
- Strong residuals 0.9-1.1 Kev

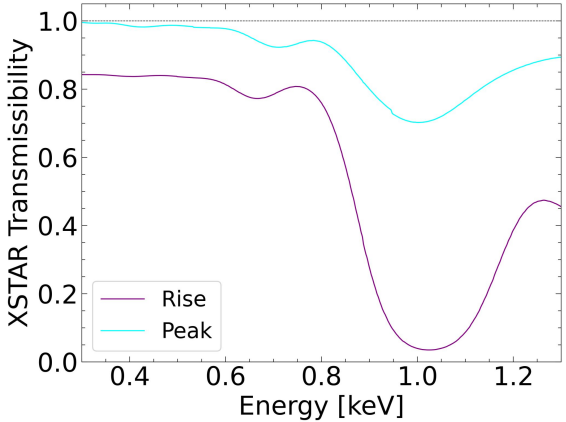
Crazy Swift Source: Spectra

- Soft/Thermal X-ray spectrum T ~ 100-250 eV
- Strong residuals 0.9-1.1 Kev -> **Ultra Fast Outflow (UFO), v ~ 0.1c**

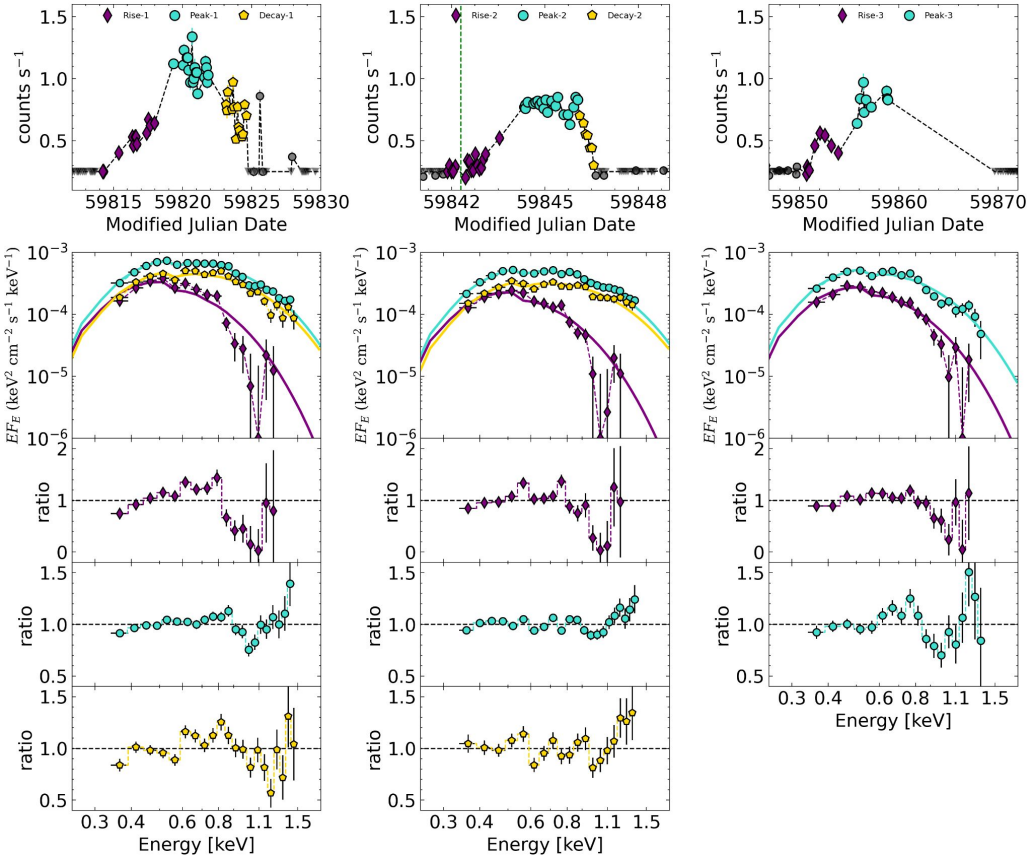






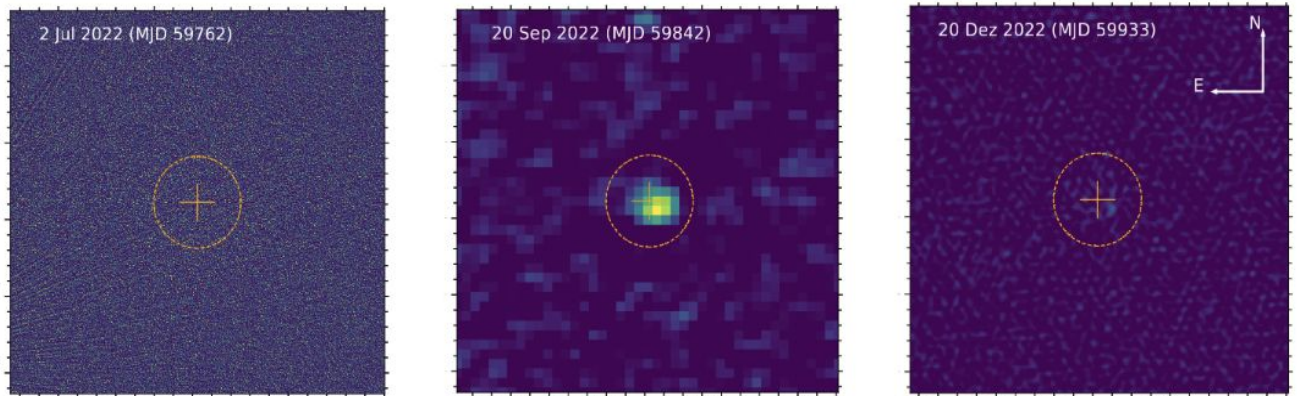


Outflow X-rays



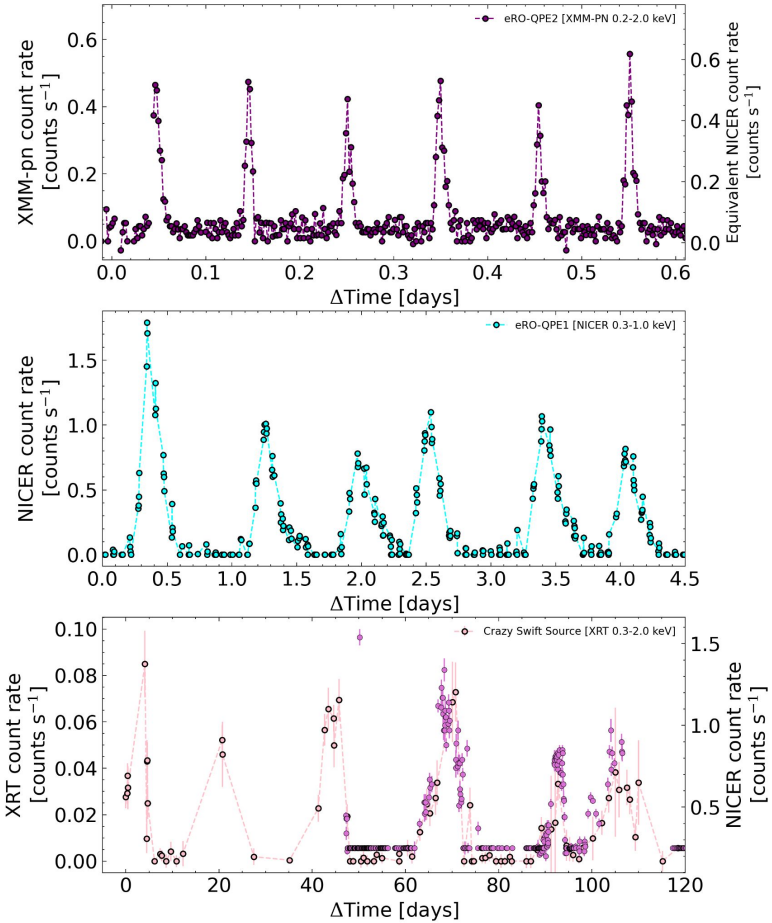
- **Soft/Thermal X-ray spectrum T ~ 100-250 eV**
- **Ultra Fast Outflow (UFO) v ~ 0.1c during the rise of the eruptions**

Outflow: Radio



Transient radio (VLA) detection during one of the X-ray eruptions

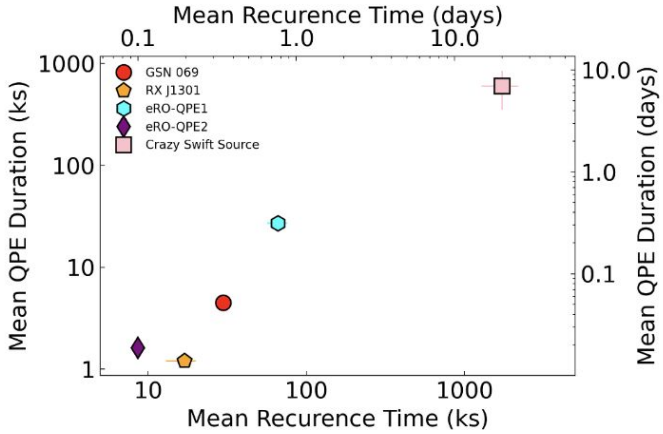
Crazy Swift Source: as a super-long QPE

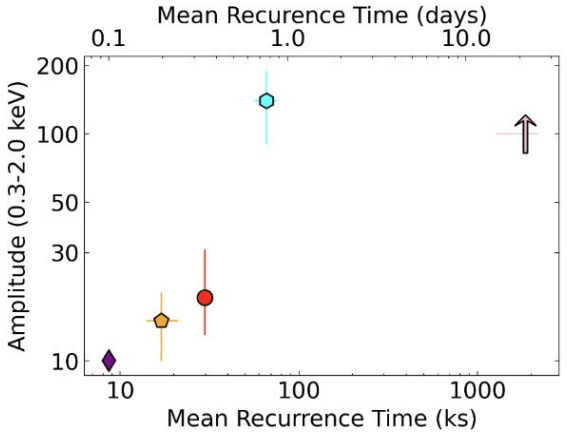


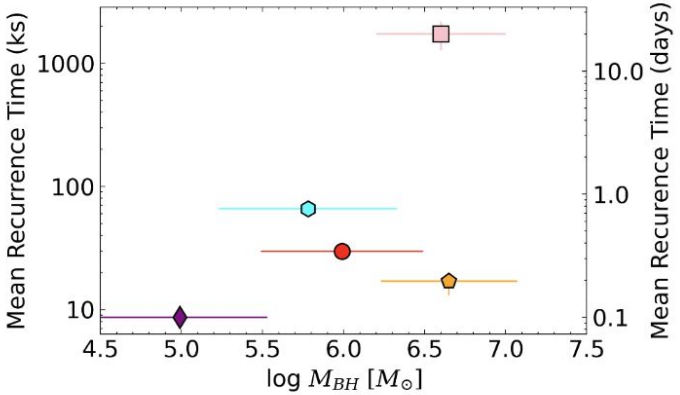
All characteristics of a QPE source, however…

- Recurrence time 25x longer than longest known QPE (eRO-QPE1 ~ 20 hours)

Crazy Swift Source: as a super-long QPE







Conclusions

- We discovered a new QPE candidate, the fifth and with longest recurrence time.
- It opens an unexplored time-scale for QPEs and nuclear transient
- First QPE with evidence for outflows.
- Theoretical understanding of QPEs is still incomplete, many possible scenarios, but should be scalable from 3 hours to 20 days.