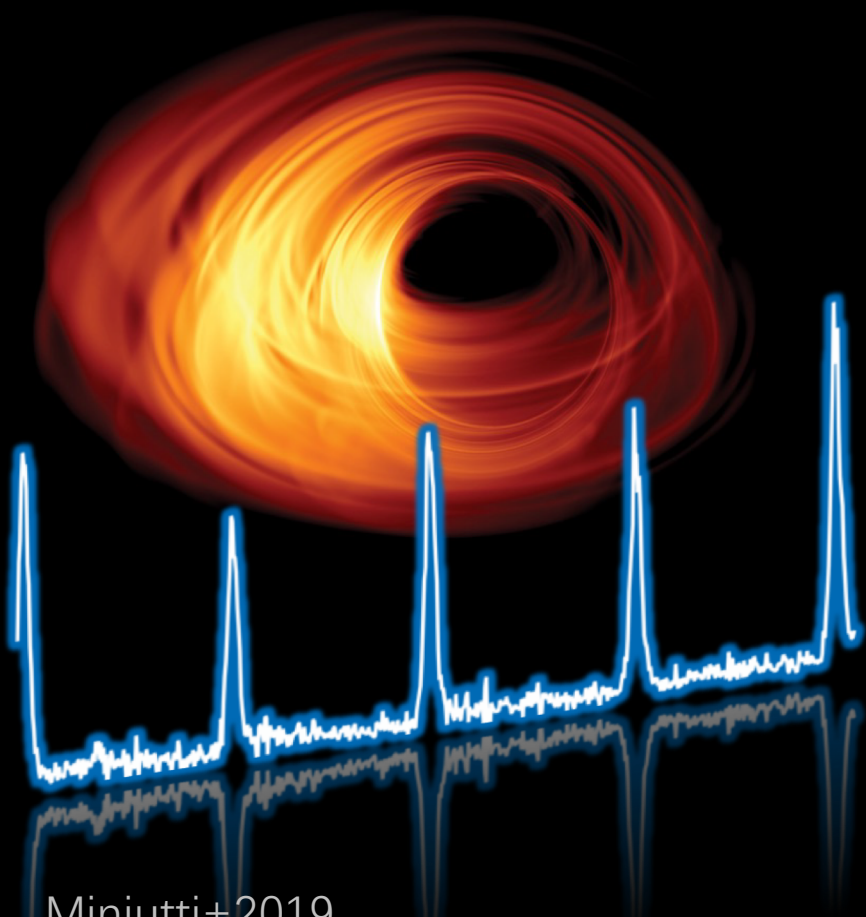


Two tales of X-ray QPEs



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安徽师范大学 (Anhui Normal University)

in collaboration with L.M. Sun(AHNU), T. G. Wang(USTC) , N. Jiang,
W. J. Zhang et al.

X射线天文学60周年及中国X射线天文研究 研讨会, 2022/06/17

Outline

- What are Quasi-Periodic Eruptions (QPEs)?
- How the QPEs were discovered?
- The properties of QPEs and models

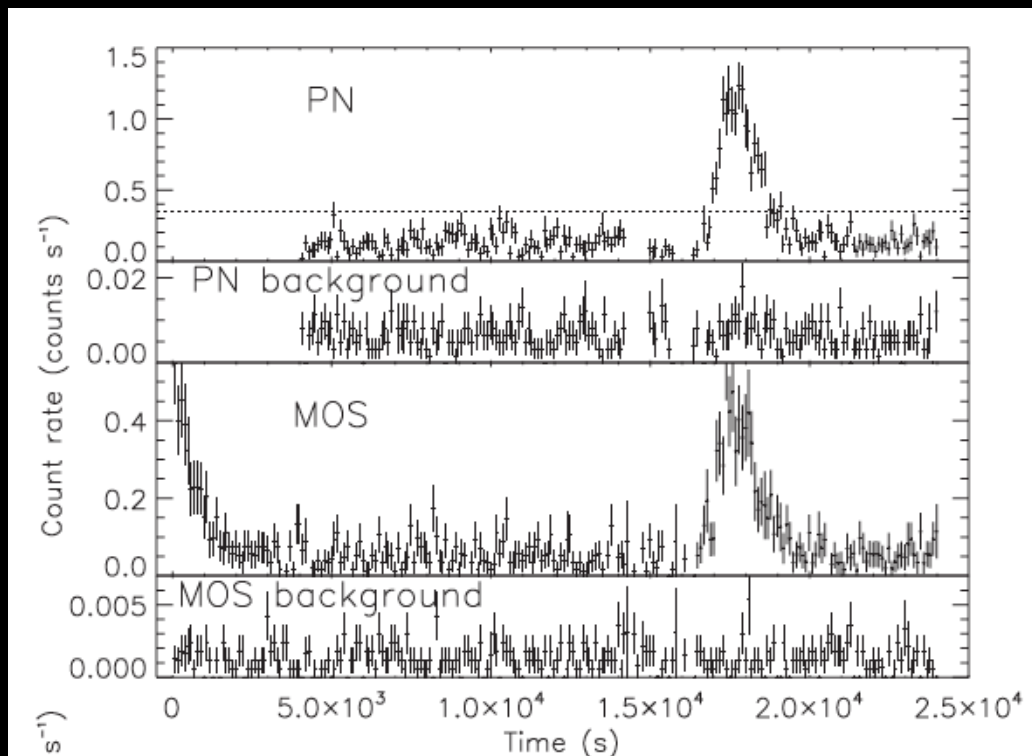
1. What are Quasi-Periodic Eruptions (QPEs)?

RX J1301.9+2747: A HIGHLY VARIABLE SEYFERT GALAXY WITH EXTREMELY SOFT X-RAY EMISSION

LUMING SUN, XINWEN SHU, AND TINGGUI WANG

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ABSTRACT

In this paper we present a temporal and spectral analysis of X-ray data from *XMM-Newton* and *Chandra* observation of the ultrasoft and variable Seyfert galaxy RX J1301.9+2747. In both observations the source clearly displays two distinct states in the X-ray band: a long quiescent state and a short flare (or eruptive) state which differs in count rate by a factor of 5–7. The transition from the quiescent to the flare state occurs in 1–2 ks. We have observed that the quiescent state spectrum is unprecedentedly steep with a photon index $\Gamma \sim 7.1$, and the spectrum of the flare state flatter with $\Gamma \sim 4.4$. X-rays above 2 keV were not significantly detected in either state. In the quiescent state, the spectrum appears to be dominated by a blackbody component of temperature about ~ 30 – 40 eV, which is comparable to the expected maximum effective temperature from the inner accretion disk. The quiescent state, however, requires

- Short-lived X-ray flares (1–2 ks)
- Supersoft X-ray spectrum (0.2–2 keV)
- Luminosity 10^{41-42} erg/s
- Periodic? ??

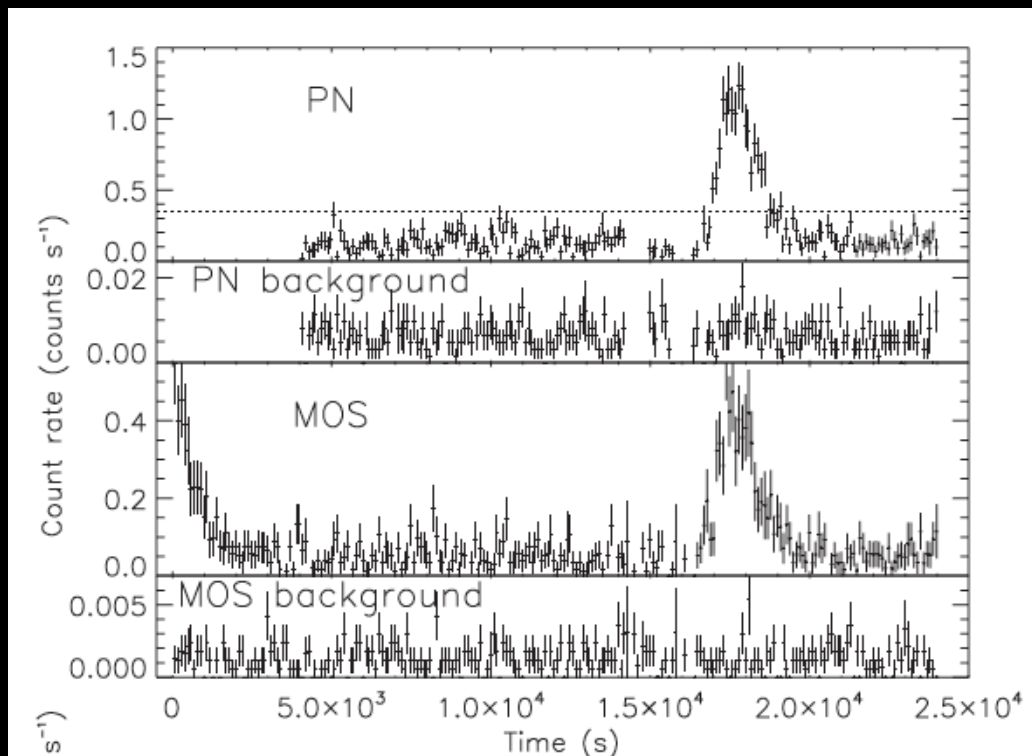
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XMM-Newton proposal:

"Explore the nature of a remarkable supersoft AGN with repetitive X-ray eruptions"

and having the proposal ID number:

最早用到eruptions

082317

PI: Shu, X,
2013-2017

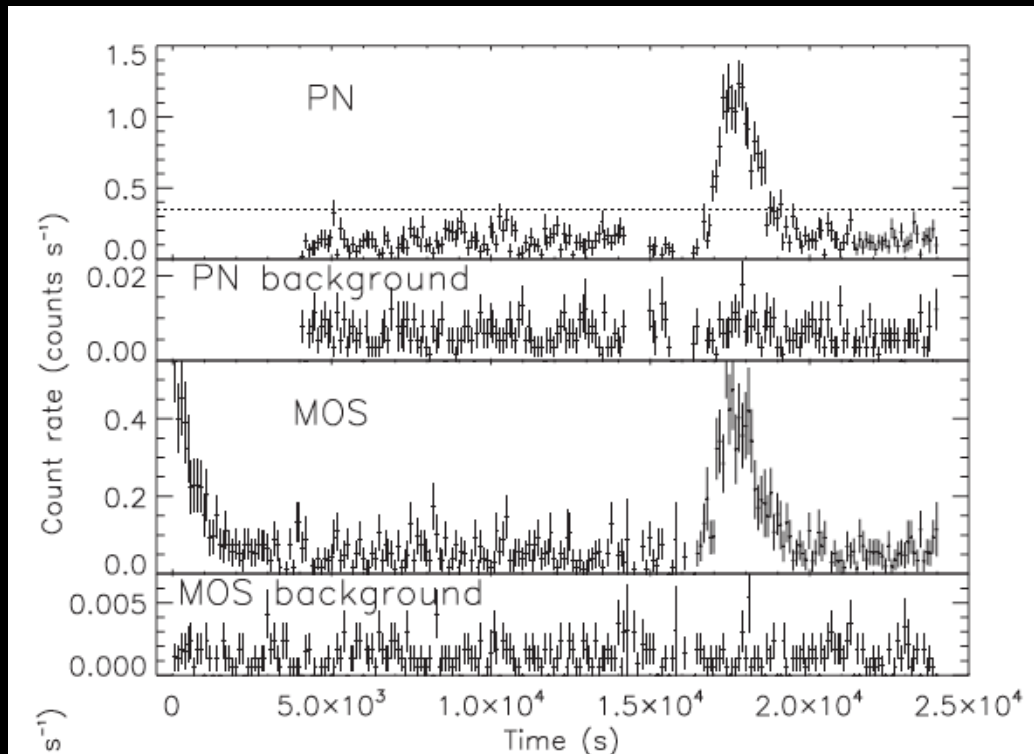
Your proposal has been allocated XMM-Newton observing time as detailed in the list attached below.

- Short-lived X-ray flares (1-2 ks)
- Supersoft X-ray spectrum (0.2-2 keV)
- Luminosity 10^{41-42} erg/s
- **Periodic? ??**

1. What are Quasi-Periodic Eruptions (QPEs)?

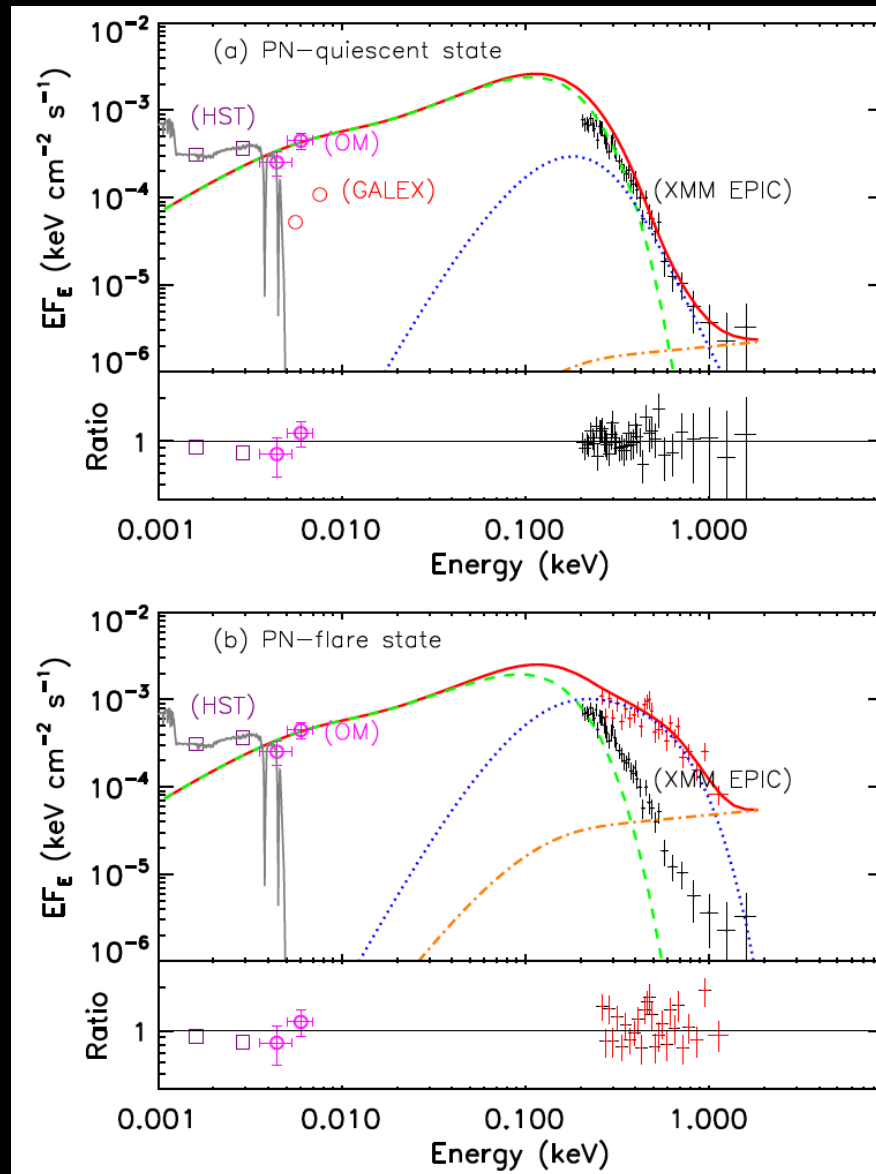
RX J1301.9+2746:

Origin of the supersoft X-ray emission:
AGN accretion disk+corona flares?



Sun, SXW & Wang 2013, ApJ

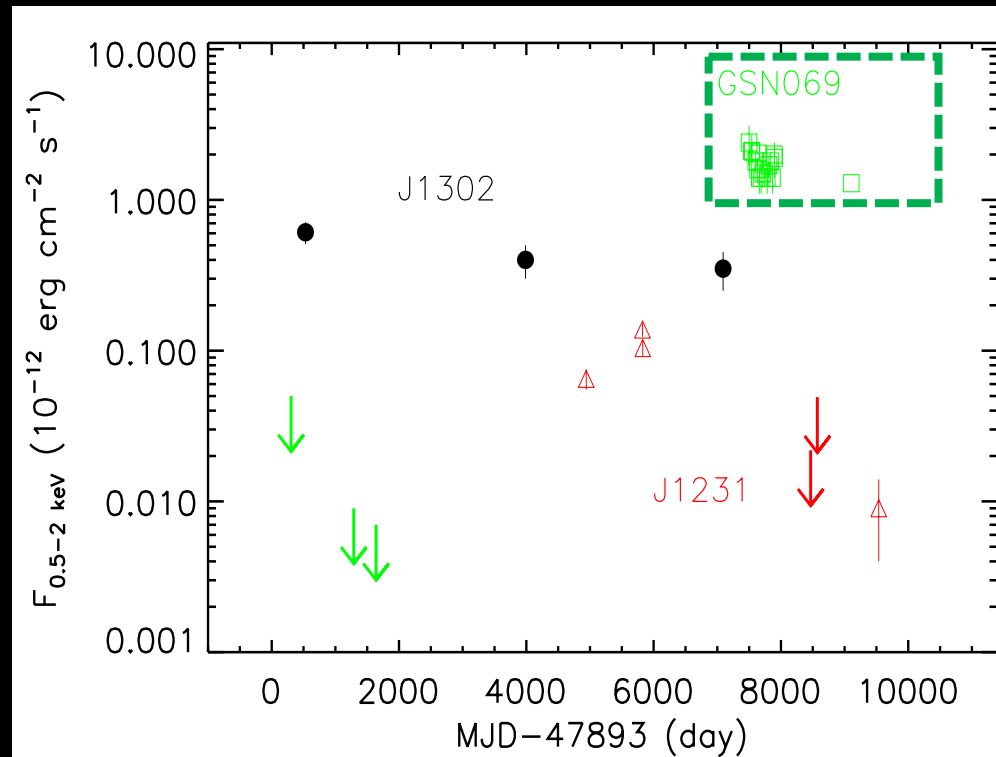
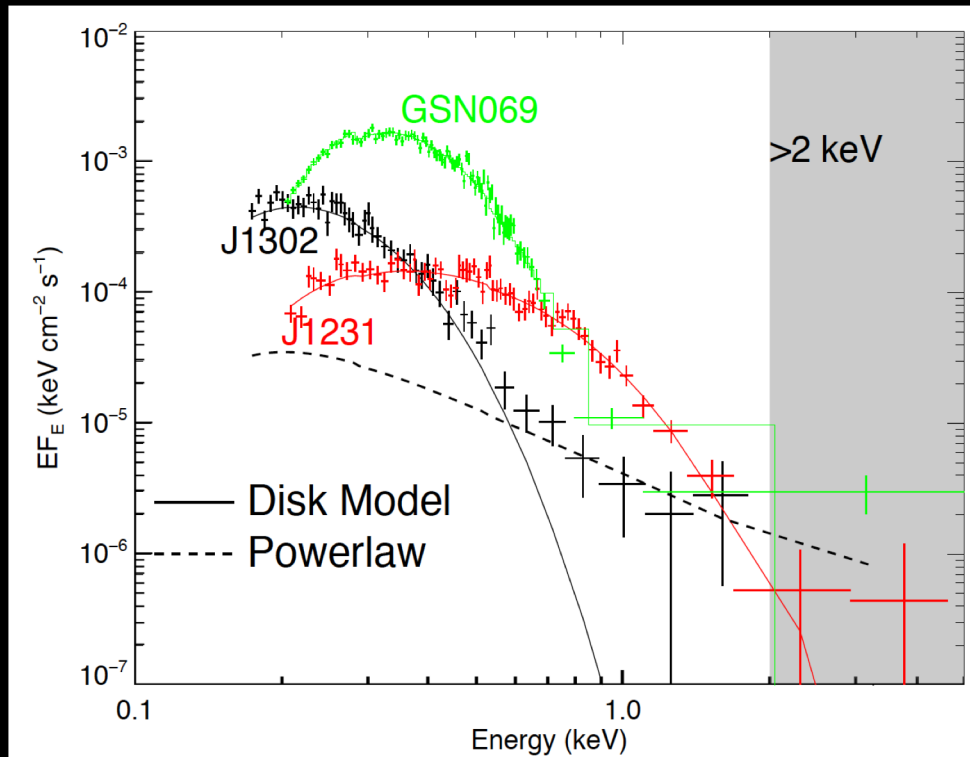
SXW et al. 2017, ApJ



2. How the QPEs were discovered?

Low-mass AGNs with Extremely Soft X-Ray Emission

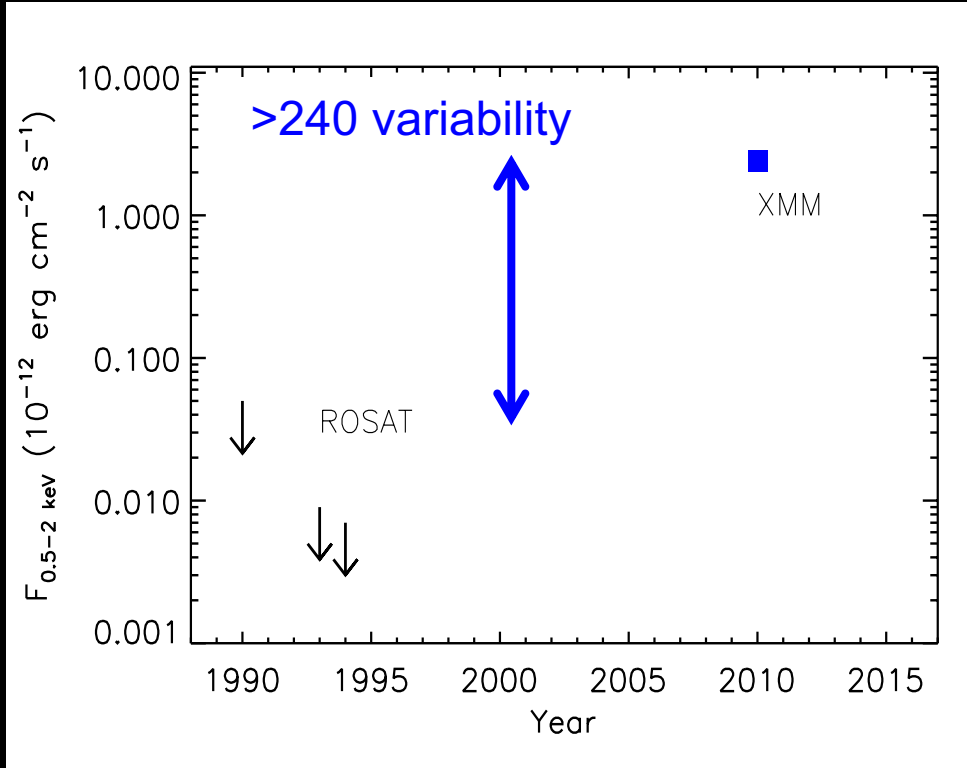
Name	Morph.	z	$\log(M_{\text{BH}})$ (M_{\odot})	Γ^{a}	$\log(L_{0.5-2 \text{ keV}}^{\text{a}})$ (erg s^{-1})	$\log(L_{\text{O III}})$ (erg s^{-1})	$\log(L_{1.4 \text{ GHz}})$ (erg s^{-1})	$\alpha_{\text{ox}}^{\text{a}}$	$\Delta\alpha_{\text{ox}}^{\text{b}}$
RX J1301–2746	disk	0.024	5.9	7.1(4.4)	40.45 (41.8)	39.64	37.6	−2.04 (−1.50)	−0.99 [10.67] (−0.46) [4.9]
2XMM J1231+1106	disk	0.119	5	4.8	42.13 (42.5)	40.22	...	−1.89 (−1.68)	−0.77 [8.33] (−0.57) [6.18]
GSN 069	...	0.018	6.08	6.7	42.08	40.32	...	<−2	−0.89 [9.53]



SXW +2017
Lin, D+2017
Miniutti+2013

2. How the QPEs were discovered?

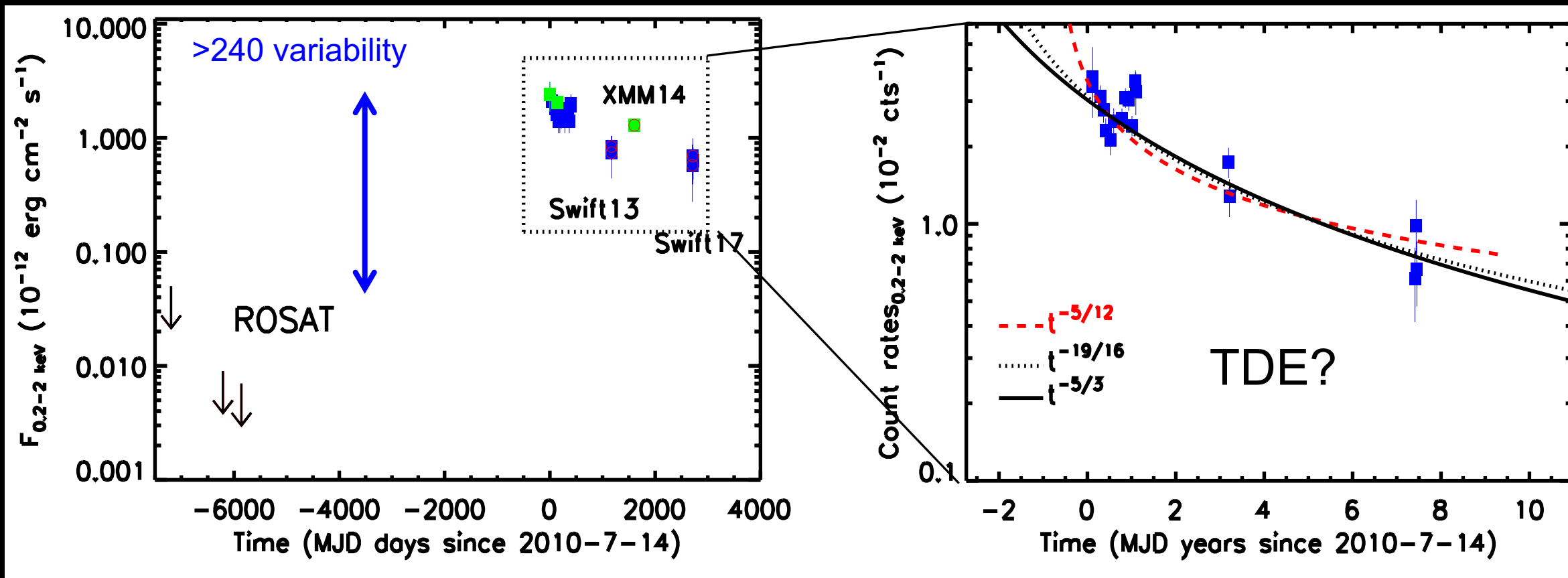
GSN 069



Miniutti+2013

2. How the QPEs were discovered?

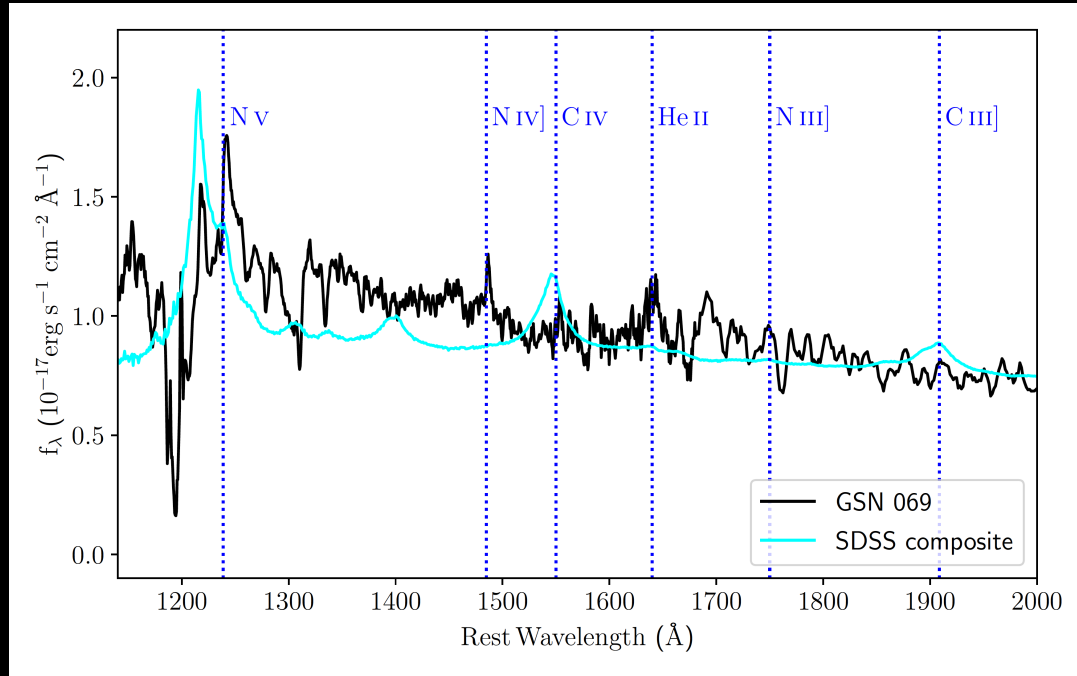
GSN 069



(NASA/Swift ToO proposal, PI : Shu)

2. How the QPEs were discovered?

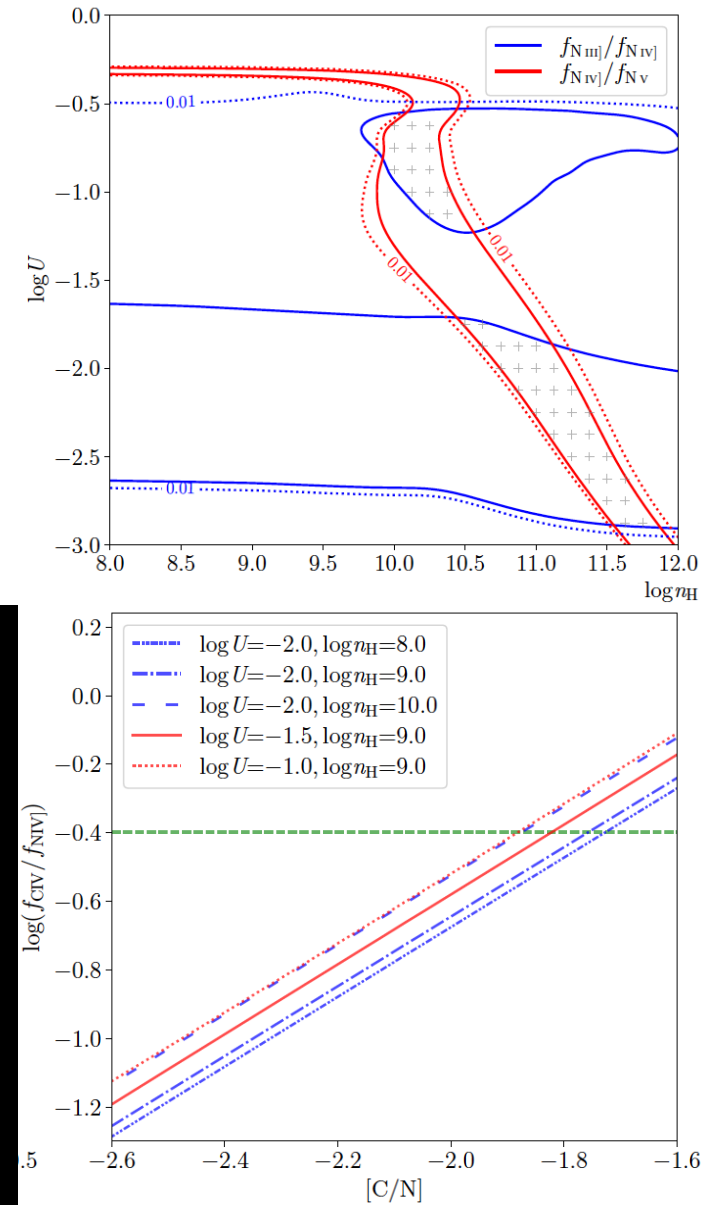
GSN 069 **Abnormal C/N abundance ratio**



Sheng, Wang, Ferland, SXW et al. 2021, supports TDE

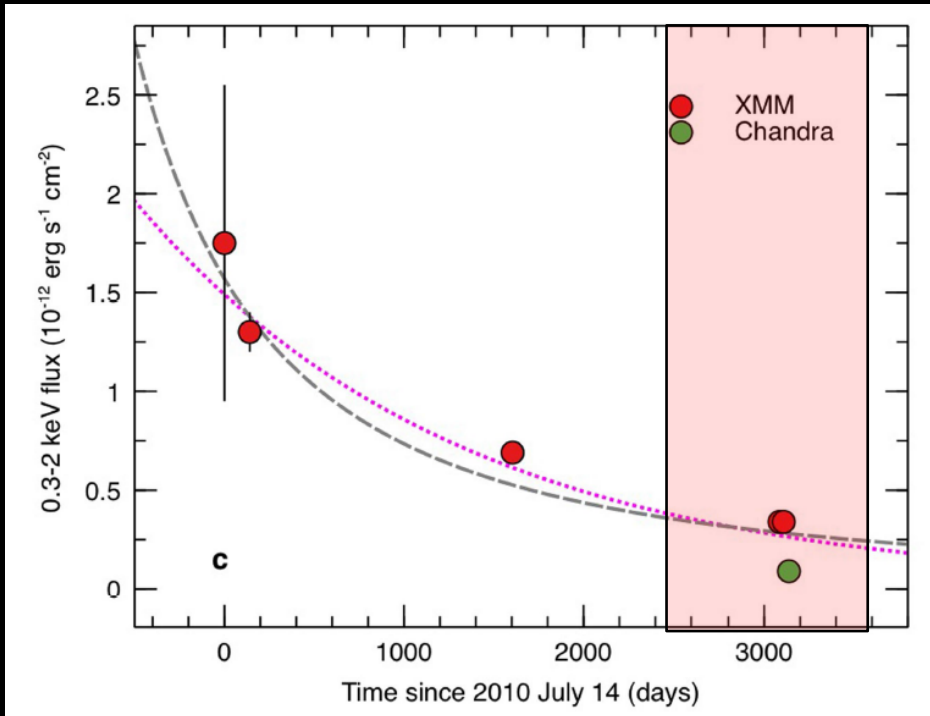
GSN069: $[\text{C}/\text{N}] \sim -1.8$

Normal QSOs: $[\text{C}/\text{N}] \sim -0.69$, Nagao+2006



2. How the QPEs were discovered?

GSN 069

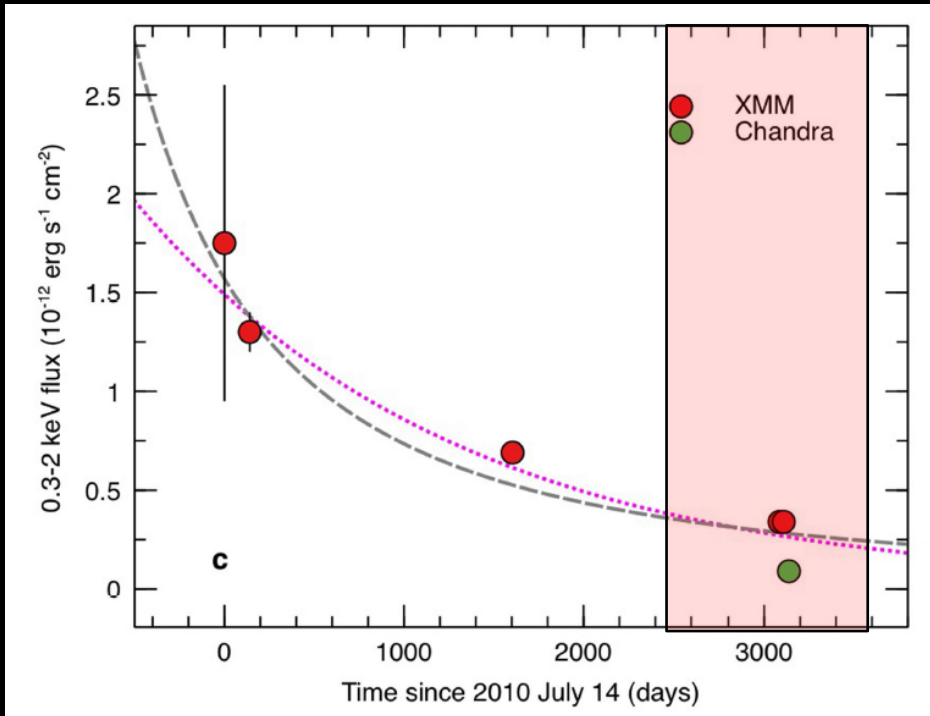


Long-term decay of X-ray emission

Miniutti et al. 2019, Nature

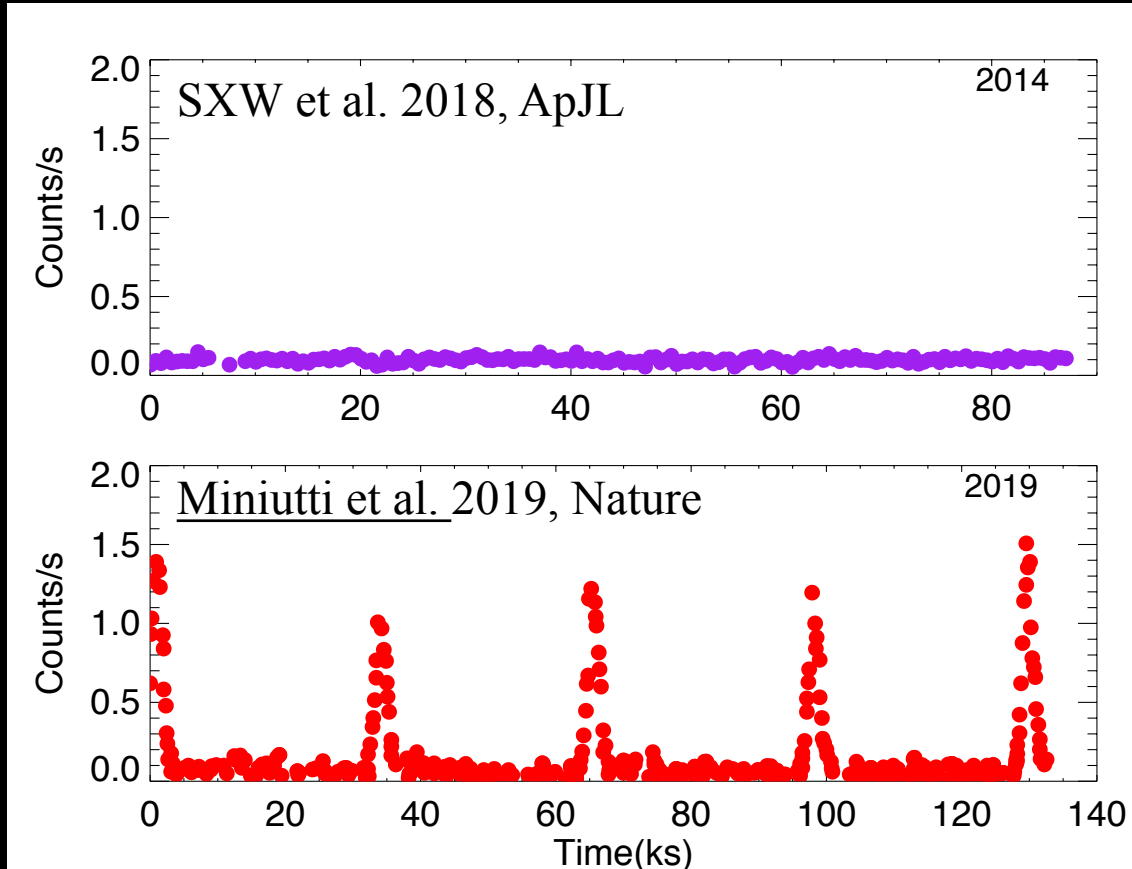
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GSN 069



Long-term decay of X-ray emission

Miniutti et al. 2019, Nature

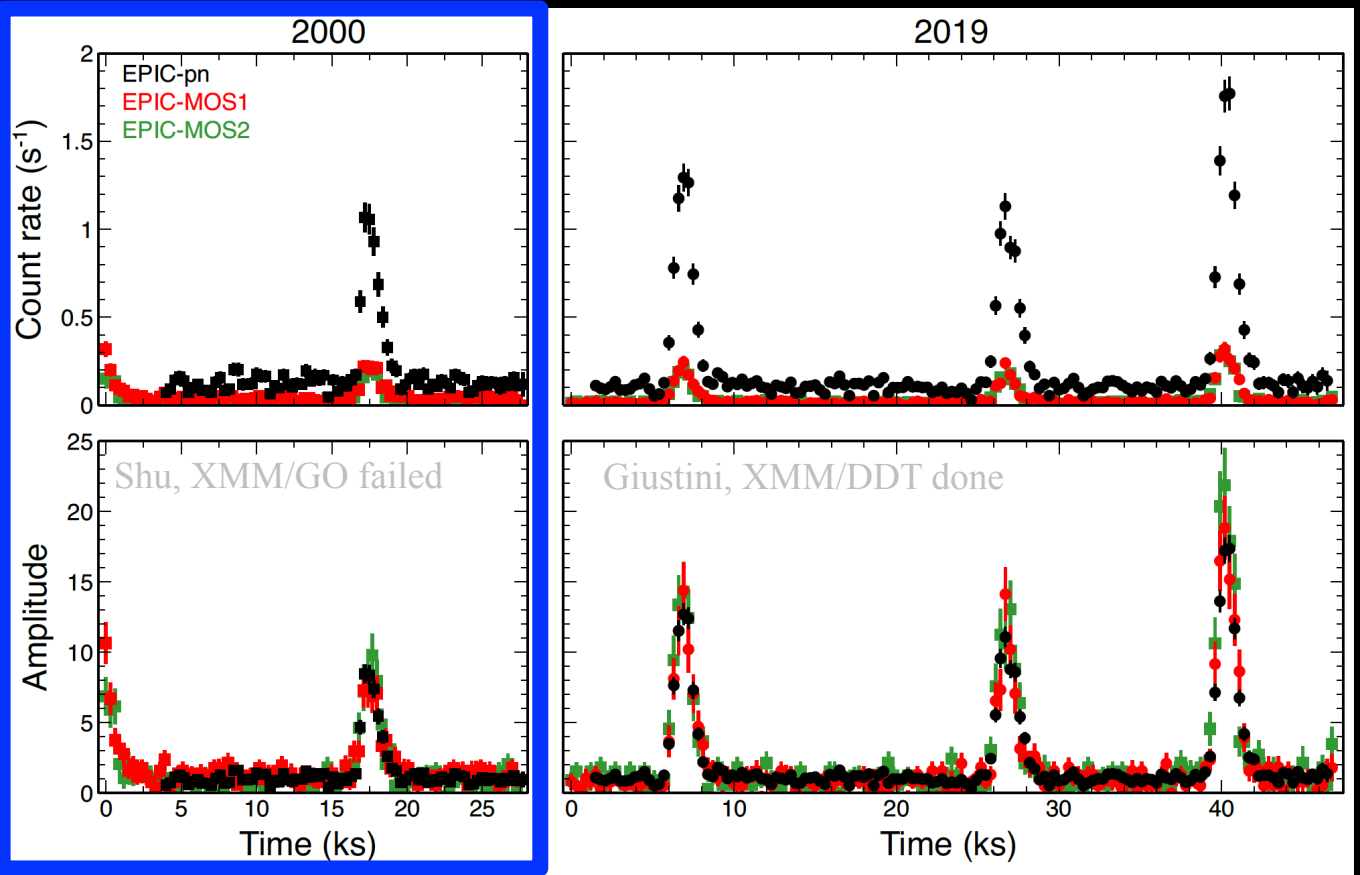
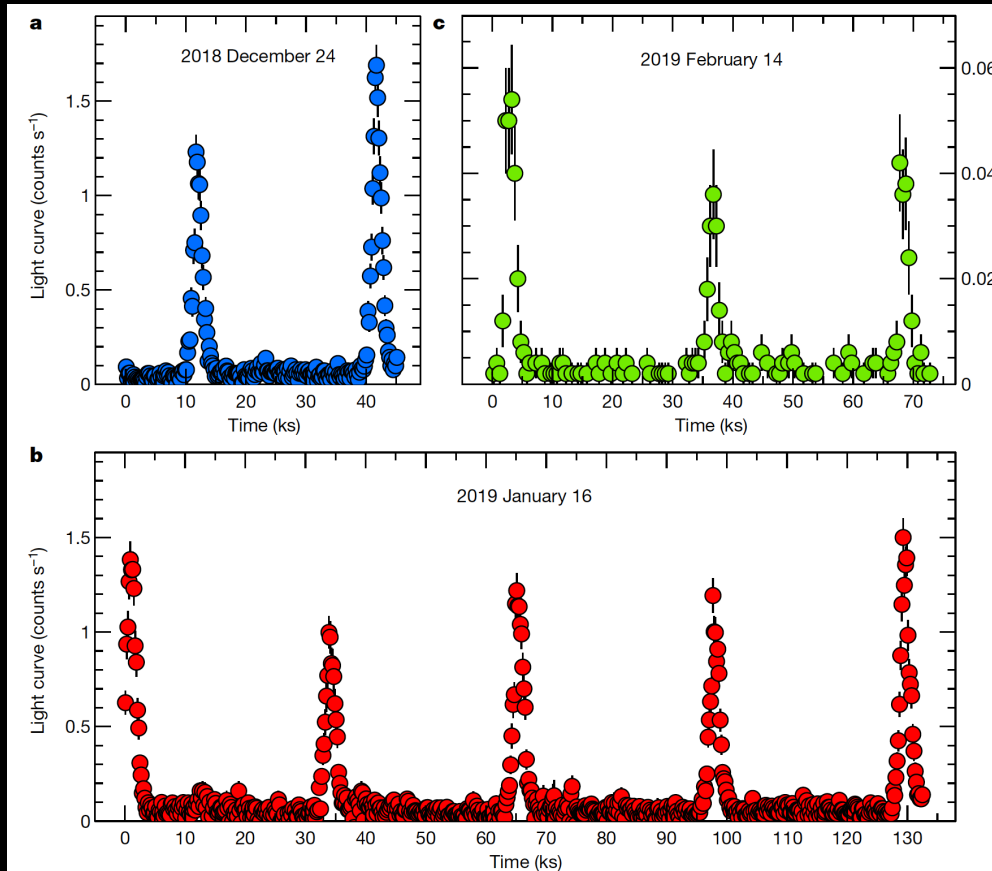


Quasi-Periodic Eruptions (QPEs)
Discovered serendipitously

2. How the QPEs were discovered?

GSN 069

RX J1301.9+2746

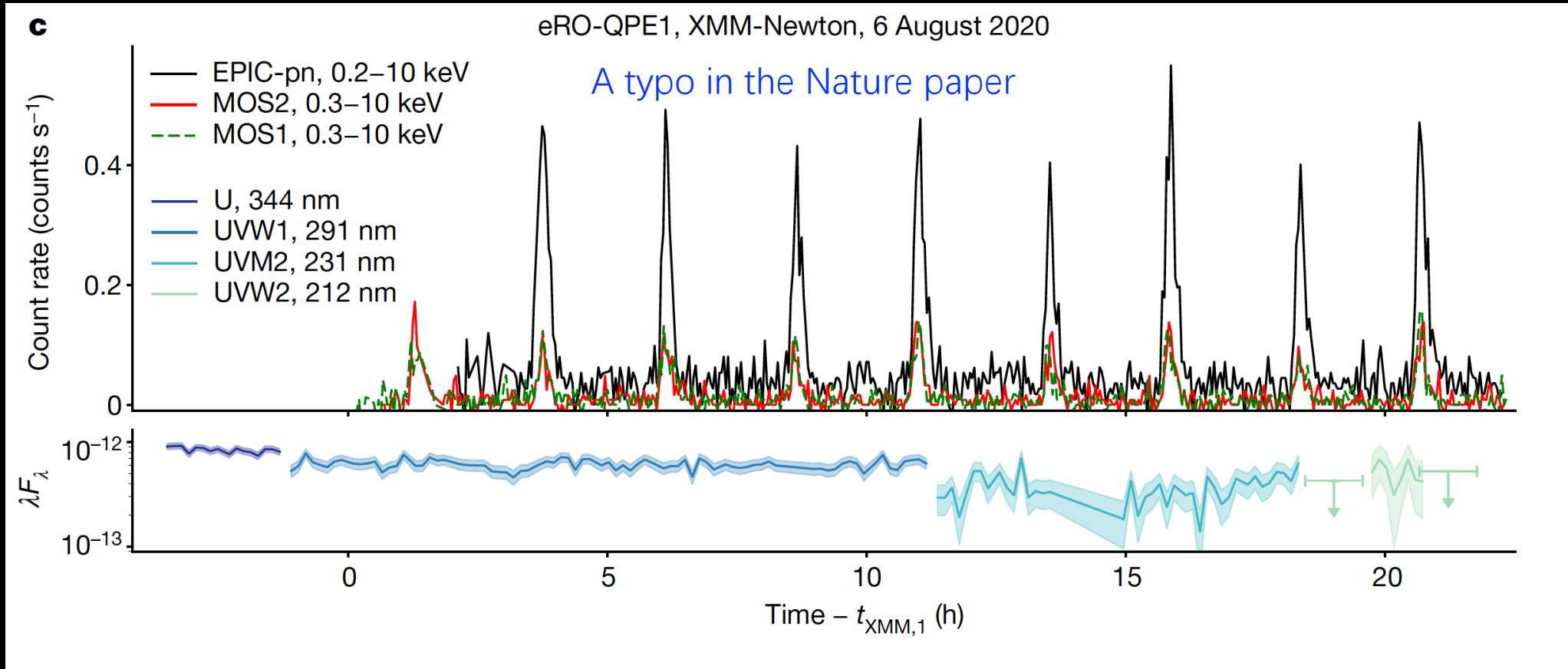


Miniutti et al. 2019, Nature

Sun, SXW & Wang 2013, ApJ
Giustini et al. 2020, A&A

2. How the QPEs were discovered?

eROSITA QPE 2

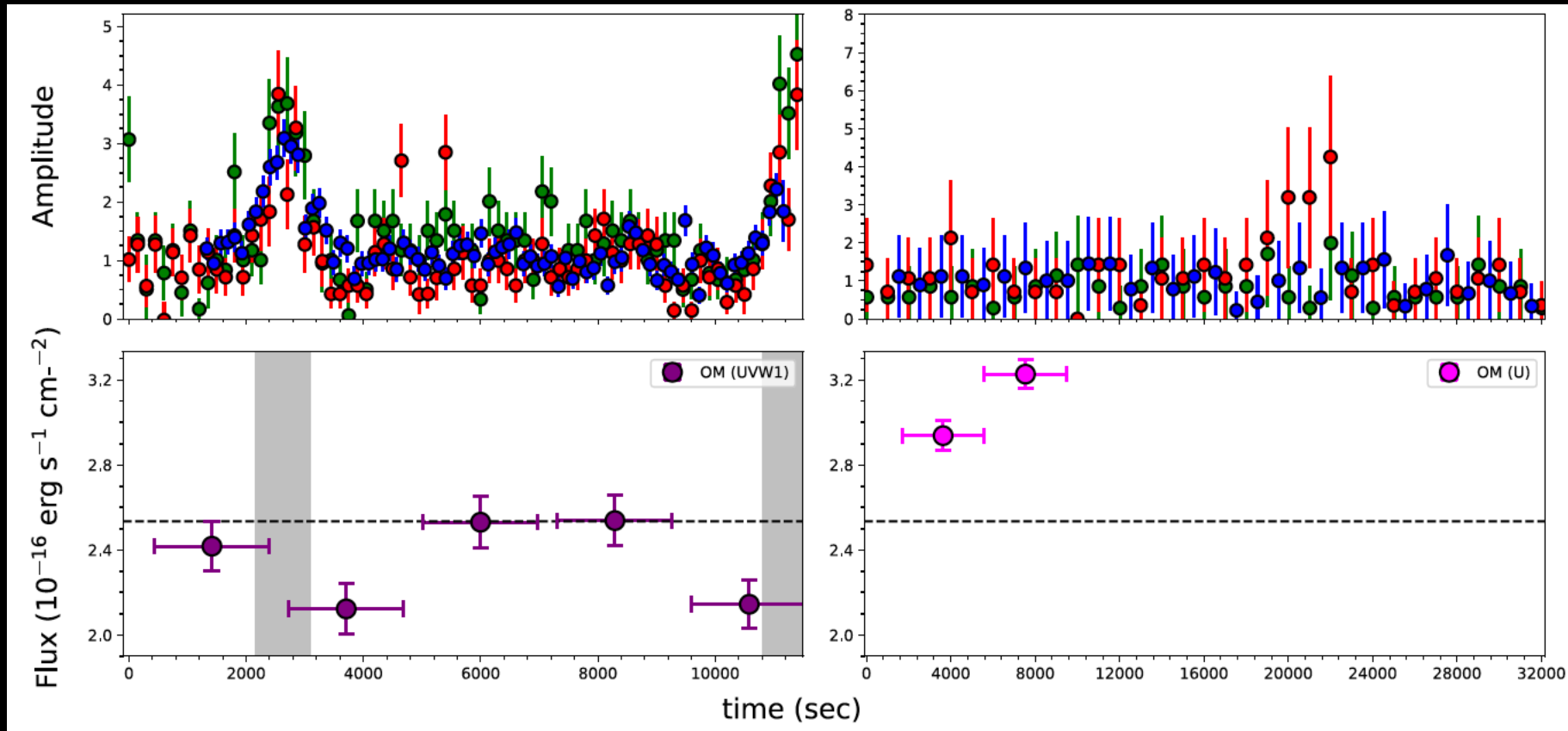


Arcodia et al. 2021, Nature

See also the talk by A. Merloni

2. How the QPEs were discovered?

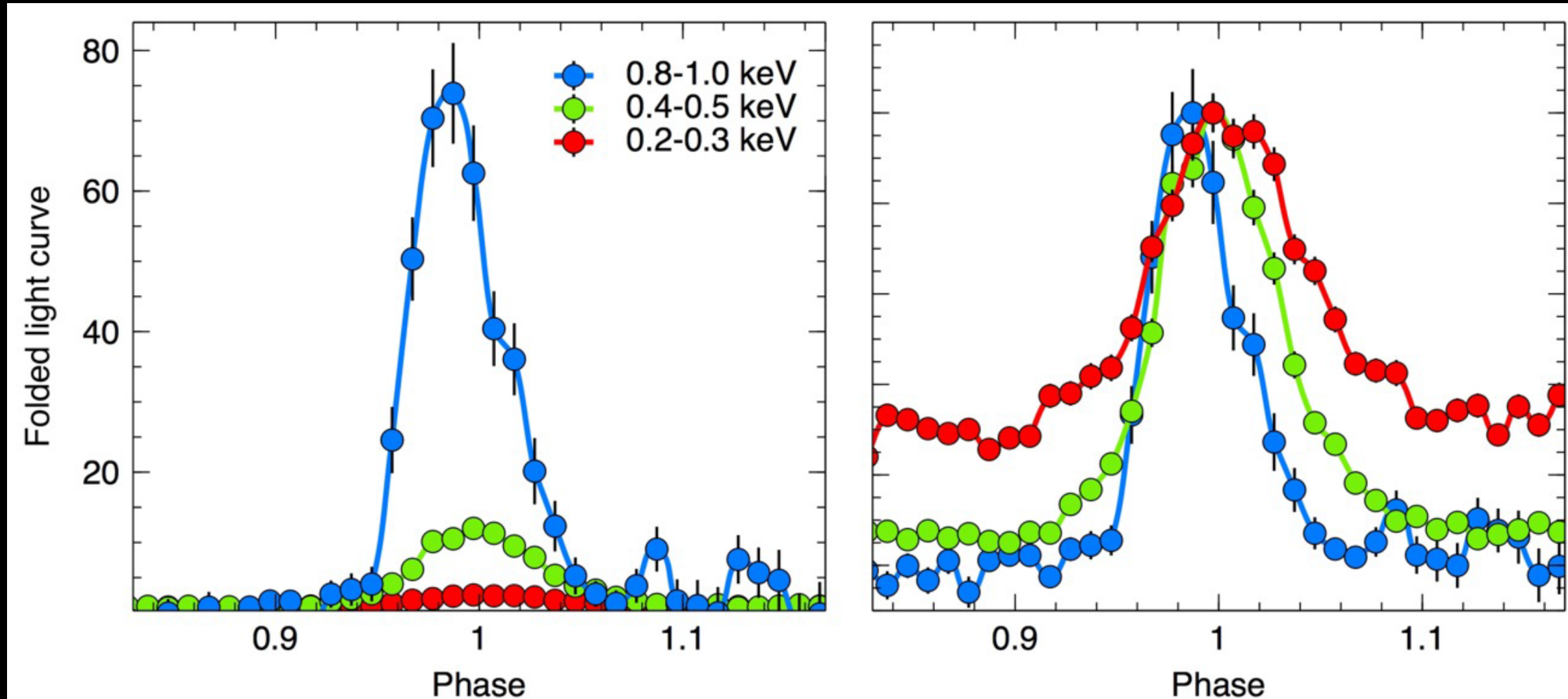
Possible QPEs in the TDE XMMSL1 J0249-0412



Chakraborty et al. 2021, ApJL

3. The properties of QPEs

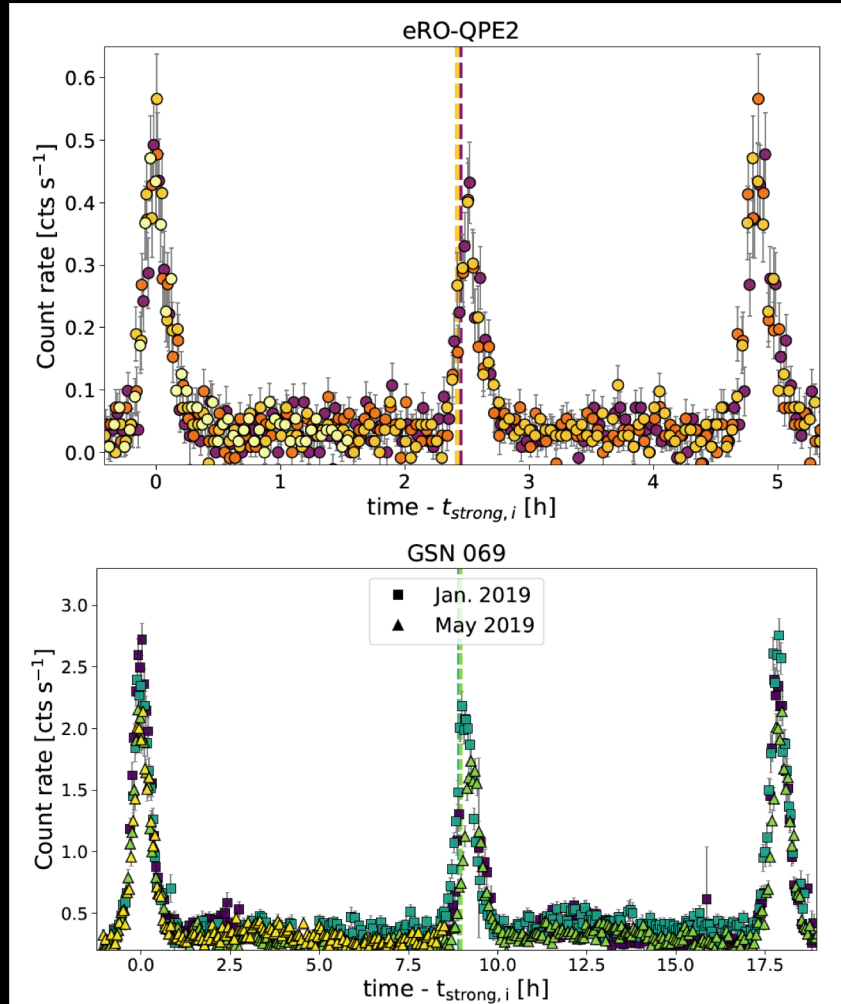
- QPE amplitude energy-dependence



Miniutti et al. 2019, Nature

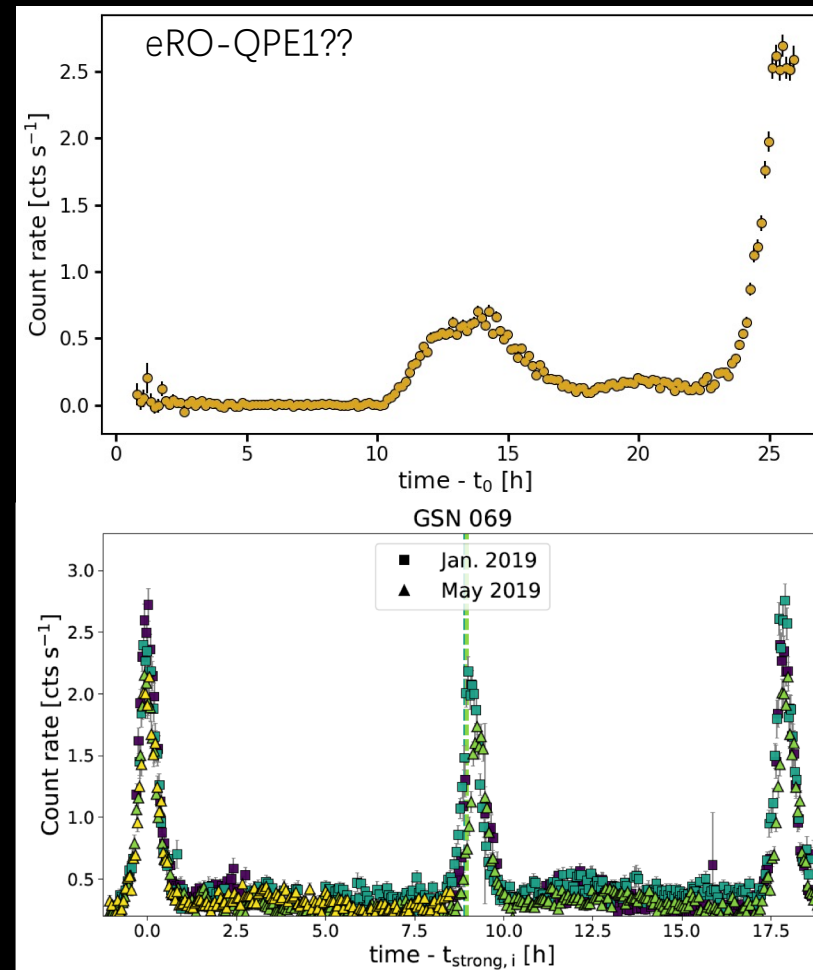
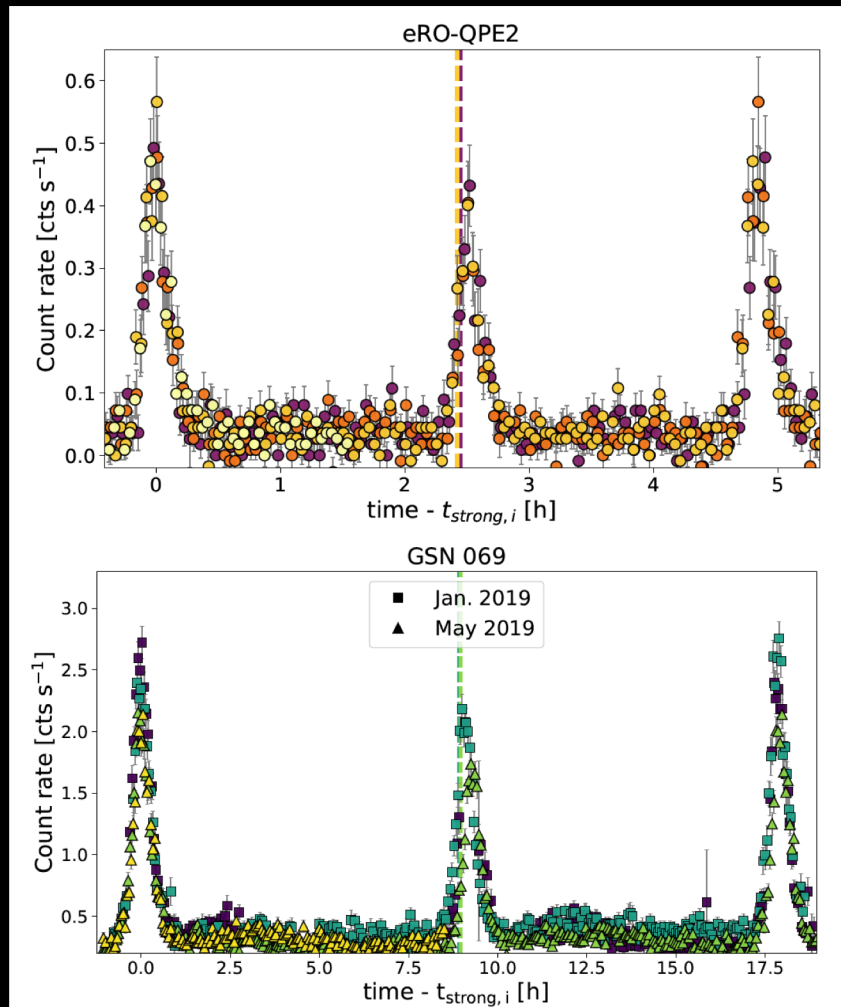
3. The properties of QPEs

- Two populations of QPEs? Alternating long/short and strong/weak



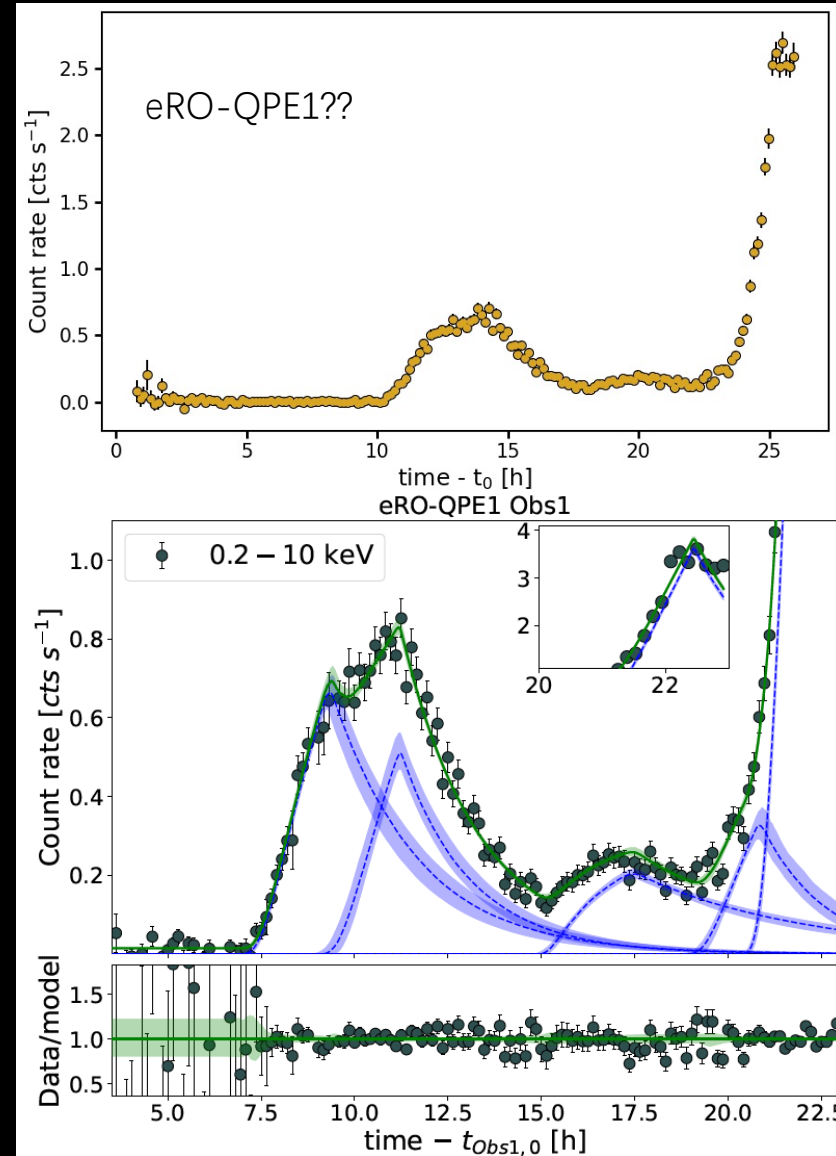
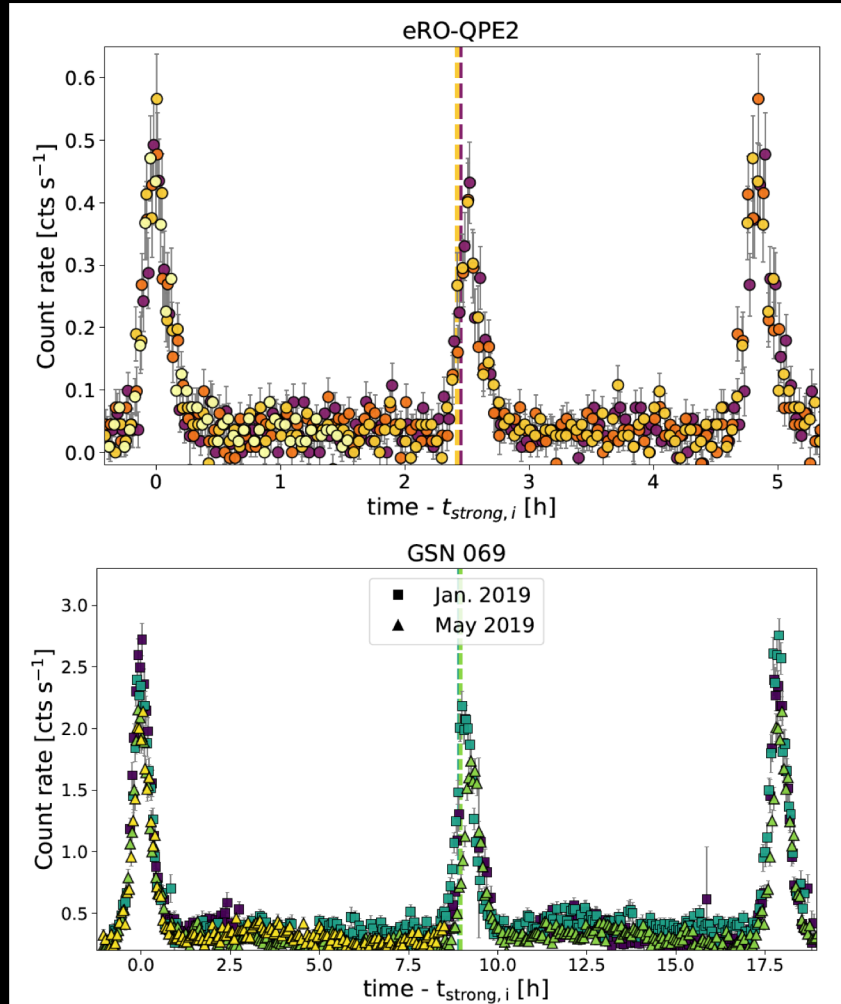
3. The properties of QPEs

- Two populations of QPEs? Complex flares



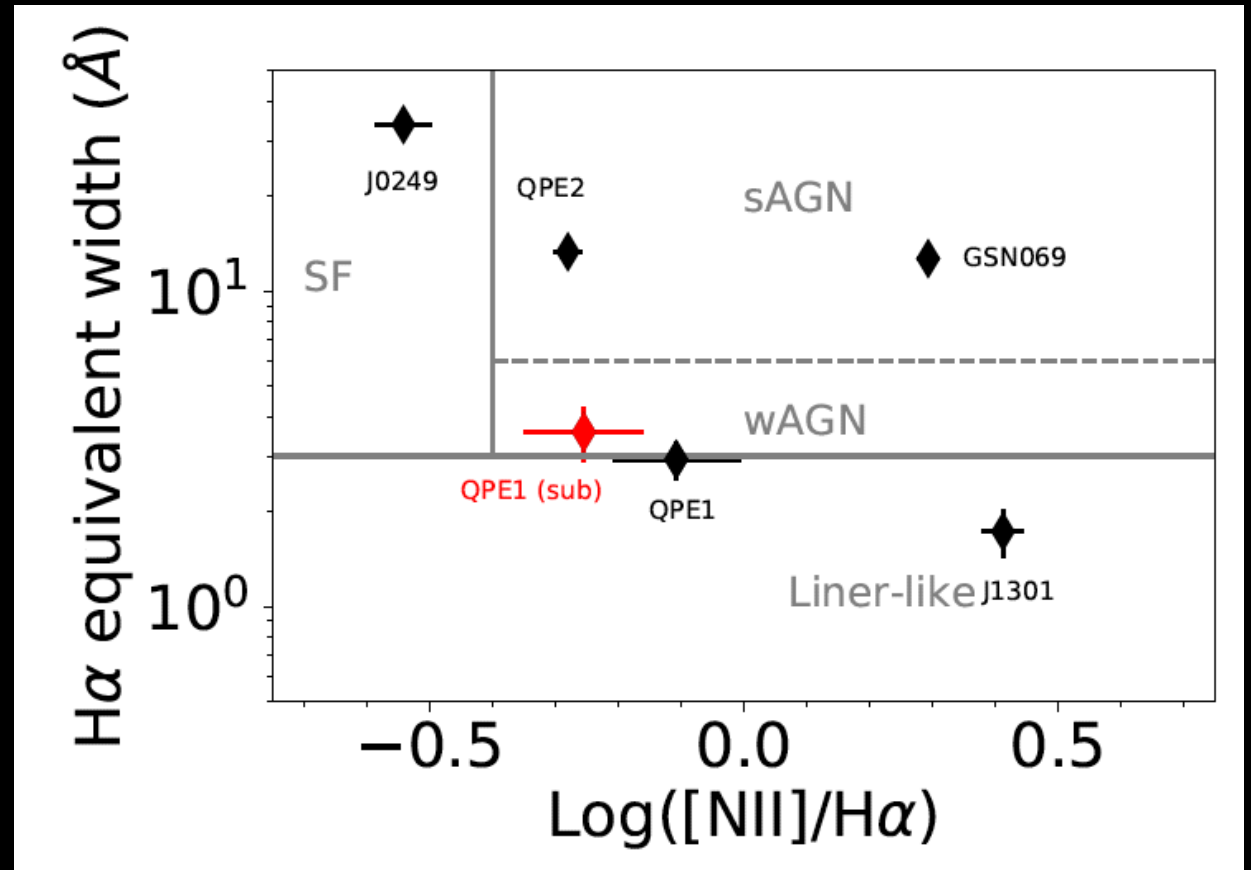
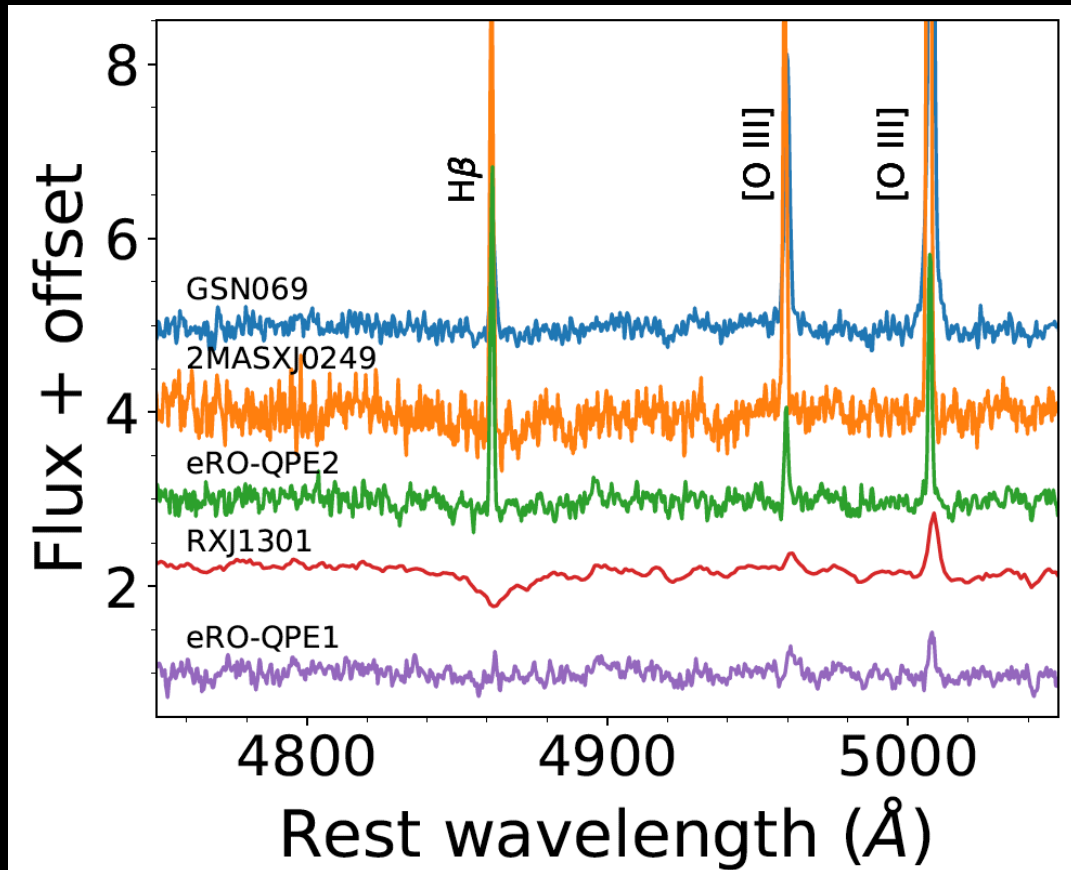
3. The properties of QPEs

- Two populations of QPEs? Complex flares



3. The properties of QPEs

- Host galaxies of QPEs

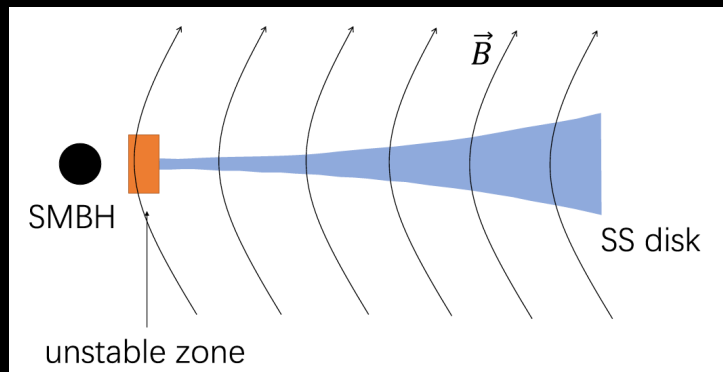


3. The models of QPEs

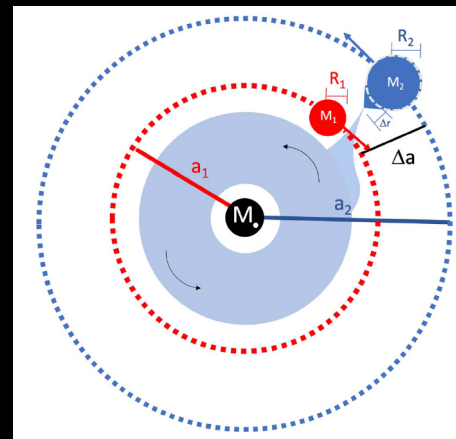
- More than the number of QPEs

Possible origins:

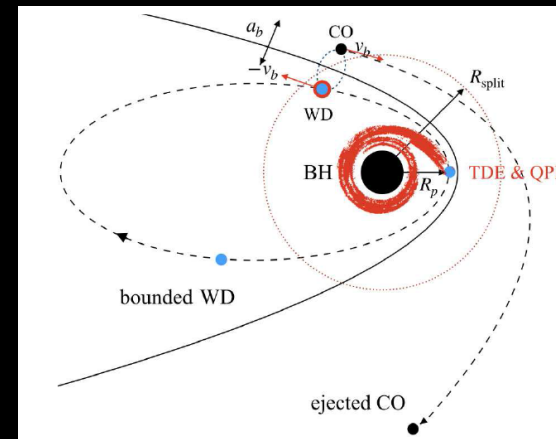
- Radiation pressure instabilities in disk (Miniutti et al. 2019; Pan et al. 2022)
- Tidal disruption of a red giant, WD or He-star (King et al. 2020, 2022; Zhao et al. 2022; Wang et al. 2022)
- Interactions with a secondary orbiting object (Arcodia et al 2021; Xian et al. 2021)
- Interacting stellar extreme mass ratio inspiral , EMRI (Metzger et al. 2022)
- SMBH binary mini disk and self-lensing (Ingram et al. 2021)
- 2 body, 3 body, ...



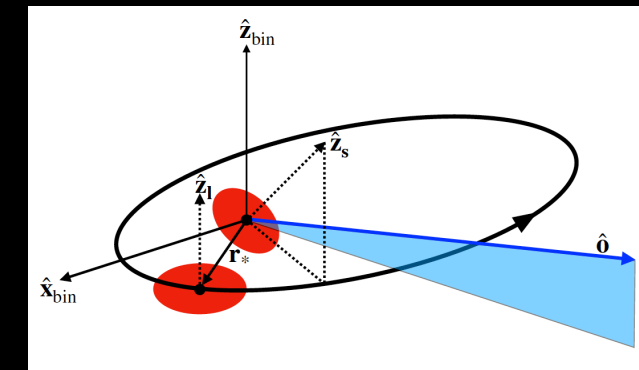
Pan et al. 2022



Metzger et al. 2022



Wang et al. 2022



Ingram et al. 2021

Summary

- QPEs are a new cosmic phenomenon
 - Short-lived X-ray flares (1-2 ks)
 - Supersoft X-ray spectrum (0.2-2 keV)
 - Luminosity 10^{41-42} erg/s
 - recurrence time: 13-30 ks (5-10 hours)
- What makes QPEs?
 - $M_{\text{BH}} \sim 10^5 - 10^6 M_{\text{sun}}$, type II AGN
 - No UV flares
 - Involving TDEs? Long-term LC
 - Transient or repetitive?
 - Diversity or impostors? irregular X-ray flares

