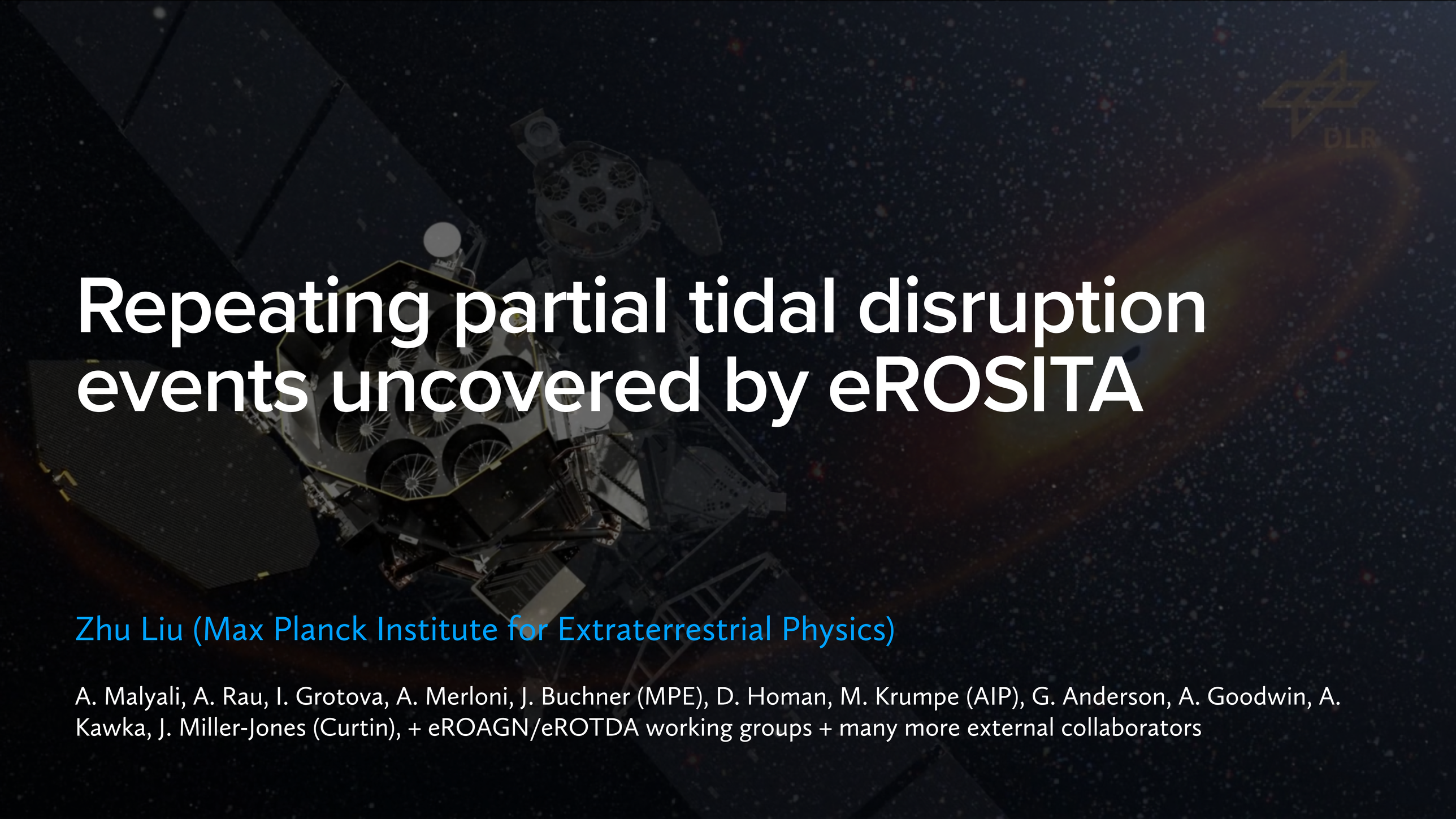


Repeating partial tidal disruption events uncovered by eROSITA

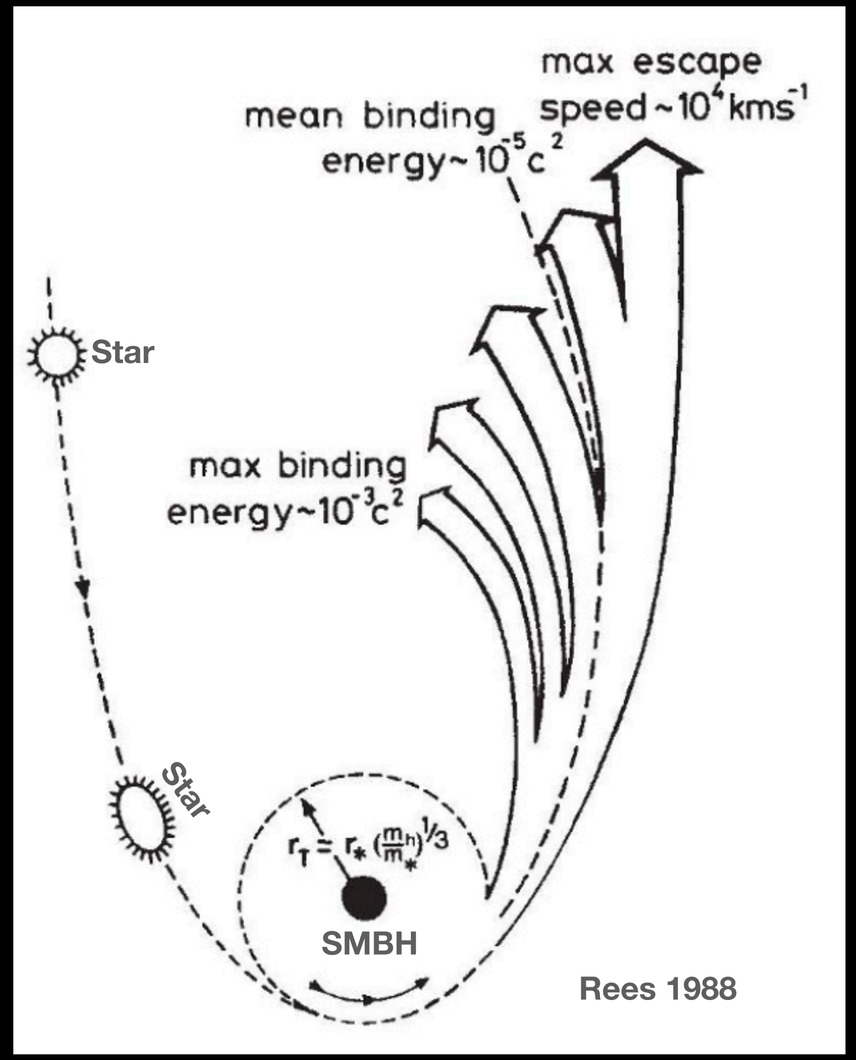
Zhu Liu (Max Planck Institute for Extraterrestrial Physics)

A. Malyali, A. Rau, I. Grotova, A. Merloni, J. Buchner (MPE), D. Homan, M. Krumpe (AIP), G. Anderson, A. Goodwin, A. Kawka, J. Miller-Jones (Curtin), + eROAGN/eROTDA working groups + many more external collaborators

Partial tidal disruption events (*p*TDEs)

Full disruption vs. partial disruption

- eROSITA: powerful in detecting TDEs (Grotova et al. in prep.)
  - ~**300 candidates** selected from eRASS1 and eRASS2
  - **25 super-soft**: golden TDE sample ($f_{0.2\text{-}2keV} \geq 10^{-13}$ erg/s/cm^2)
- Stars are not always fully destroyed
  - Impact factor: $\beta = R_T/R_p$ (R_T: tidal radius; R_p: pericenter)
  - Partial disruption if the impact factor is low
- Partial tidal disruption events (*p*TDEs)
  - Fainter and decay faster (e.g. Ryu et al. 2020)
  - Understand the TDE rate (e.g. Bortolas et al. 2023)
  - Repeating *p*TDEs: ideal for investigating the accretion & circularisation processes



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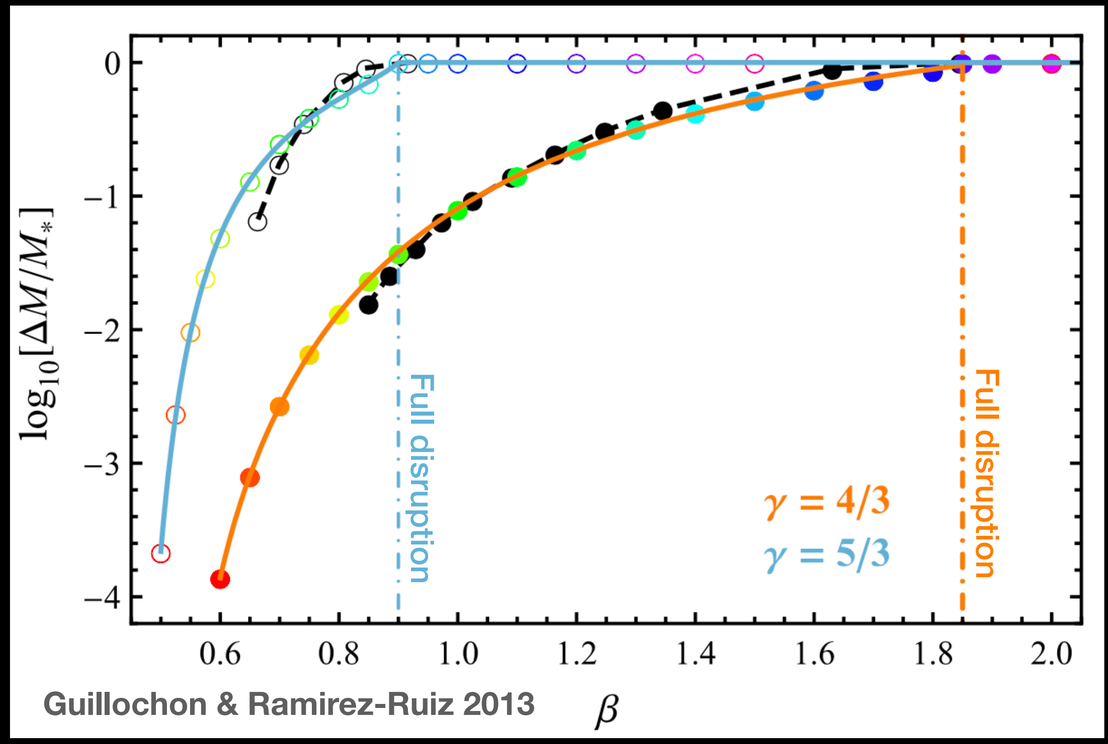

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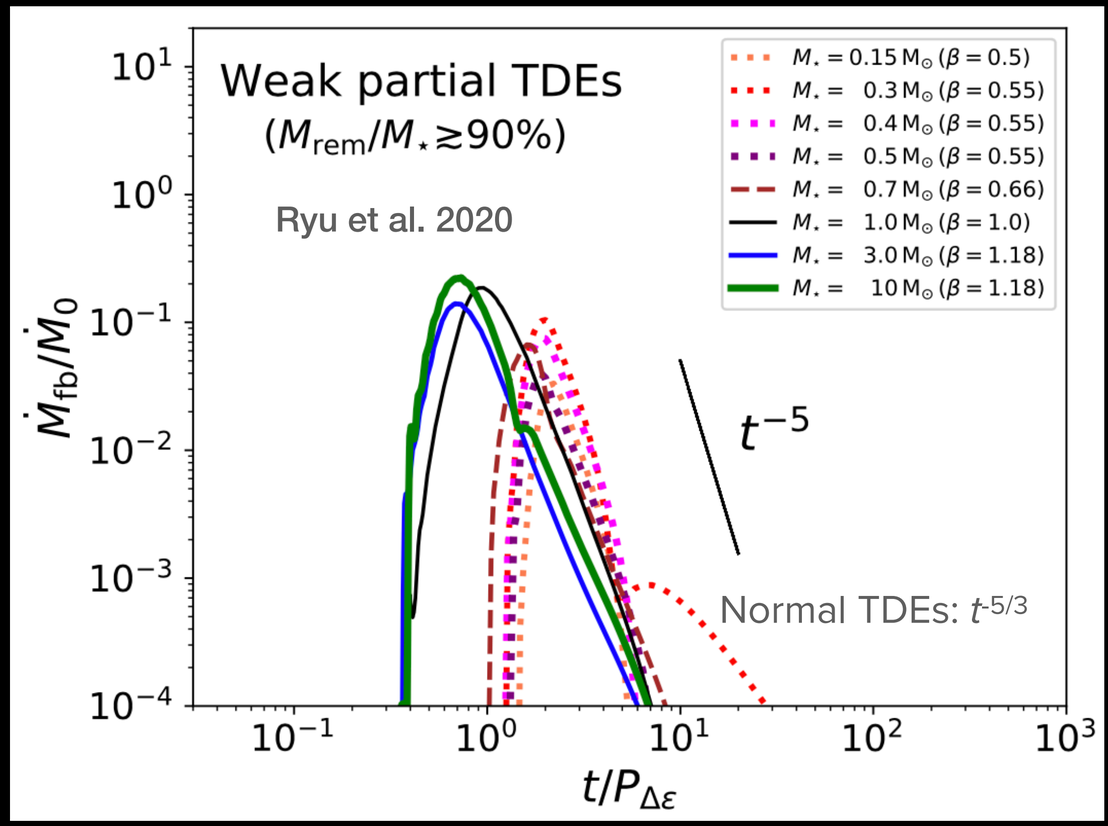
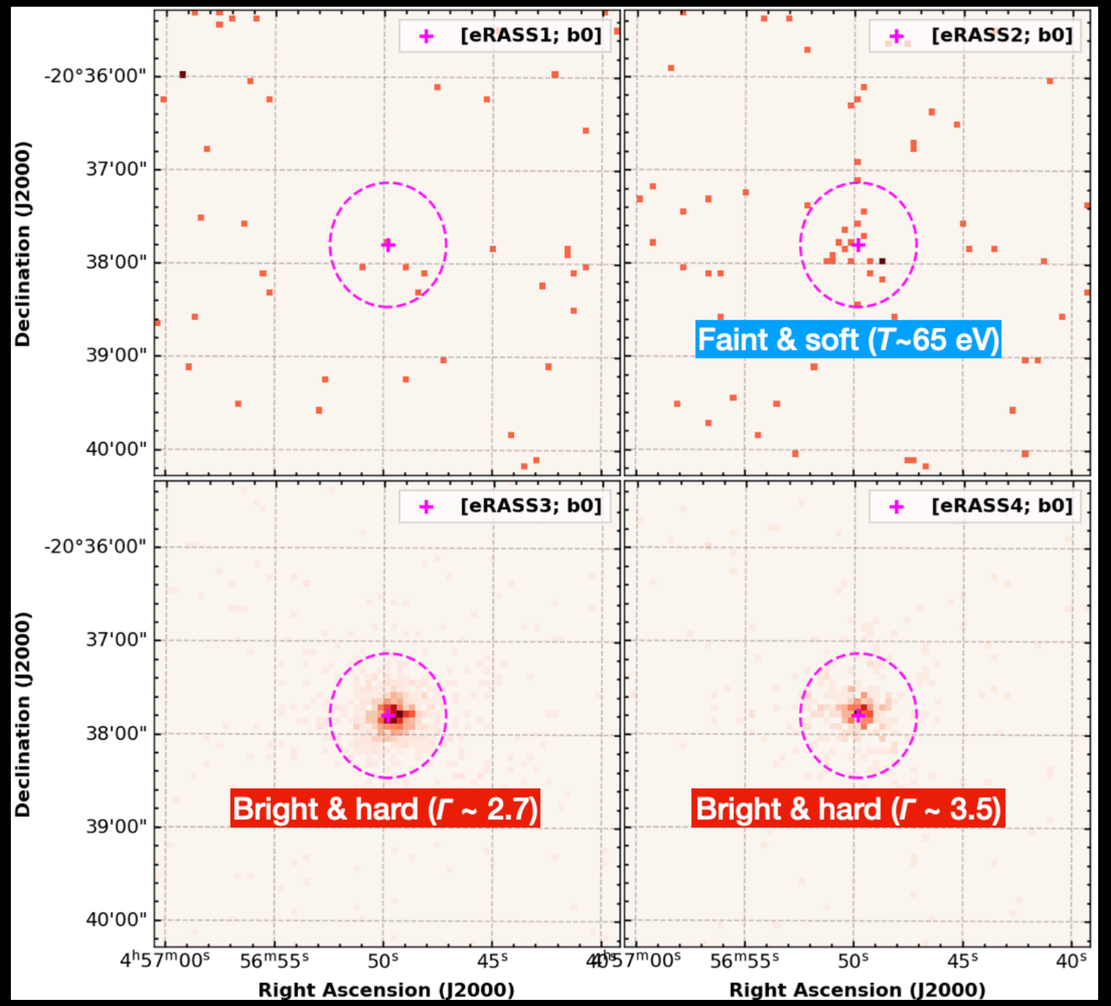


eROSITA discovery of repeating TDEs: J0456-20

Significant X-ray flux and spectral variabilities

- Very faint/soft in eRASS2
  - $f_{0.2\text{-}2.0\text{keV}} = 5.0 \times 10^{-13}$ erg/s/cm^2
  - Blackbody with T = 65 eV
- Much brighter/harder in eRASS3/4
  - $f_{0.2\text{-}2.0\text{keV}} = 9.5/5.0 \times 10^{-12}$ erg/s/cm^2
  - Power-law with index of 2.7/3.5
- Quiescent host galaxy (z=0.077)
- No significant optical variability



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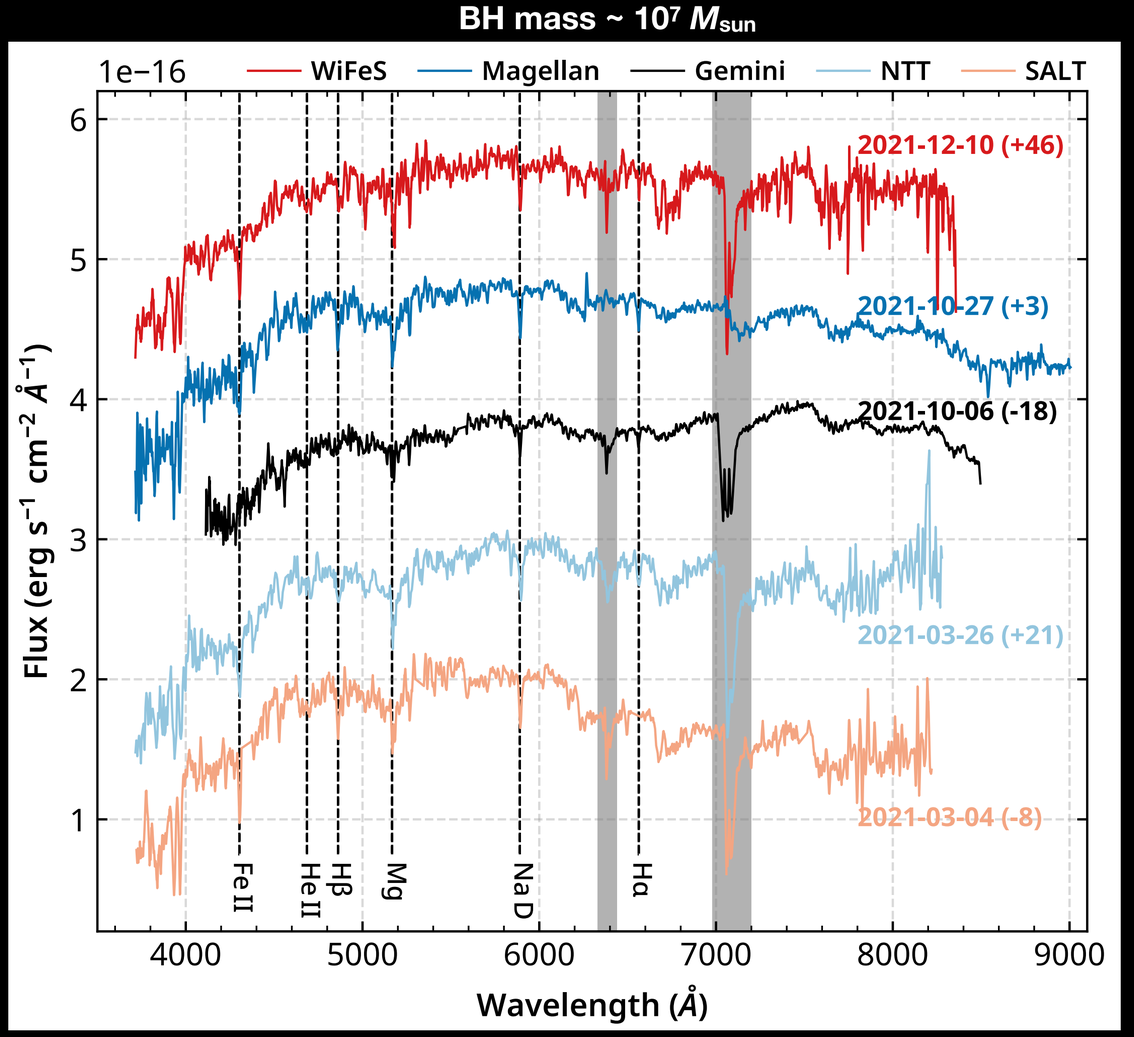
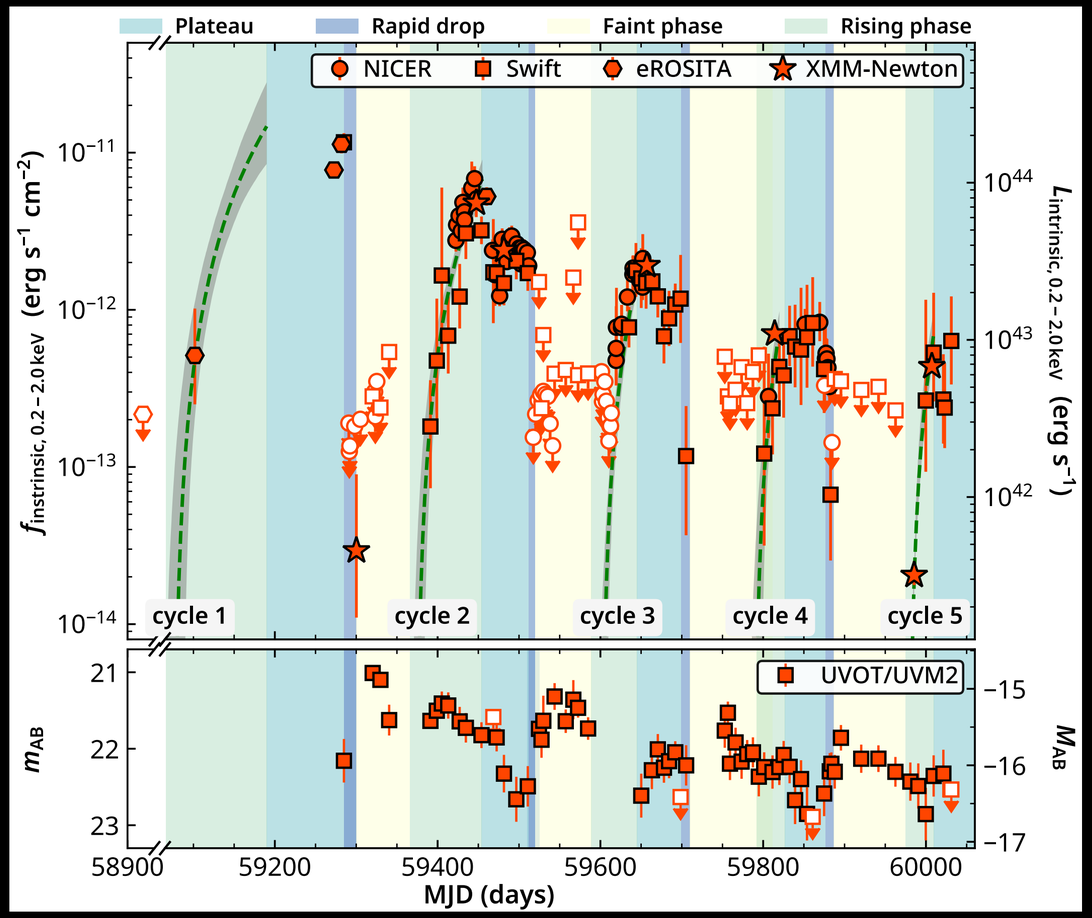


Long-term X-ray/UV variability of J0456-20

Extremely variable and repeatedly flaring



- Drastic X-ray flux drop: ~300 in 16 days
- Repeating X-ray and UV flares
  - ➡ X-ray: rising ➡ plateau ➡ drop ➡ faint
  - ➡ Recurrence time of ~220 days
- Transient radio emission
  - ➡ Decreased by a factor of a few in 2 weeks
- A repeating *p*TDE as the most plausible explanation (5 in total, Payne et al. 2021, Malyali et al. 2023, Wevers et al. 2023, Webb et al. 2023)

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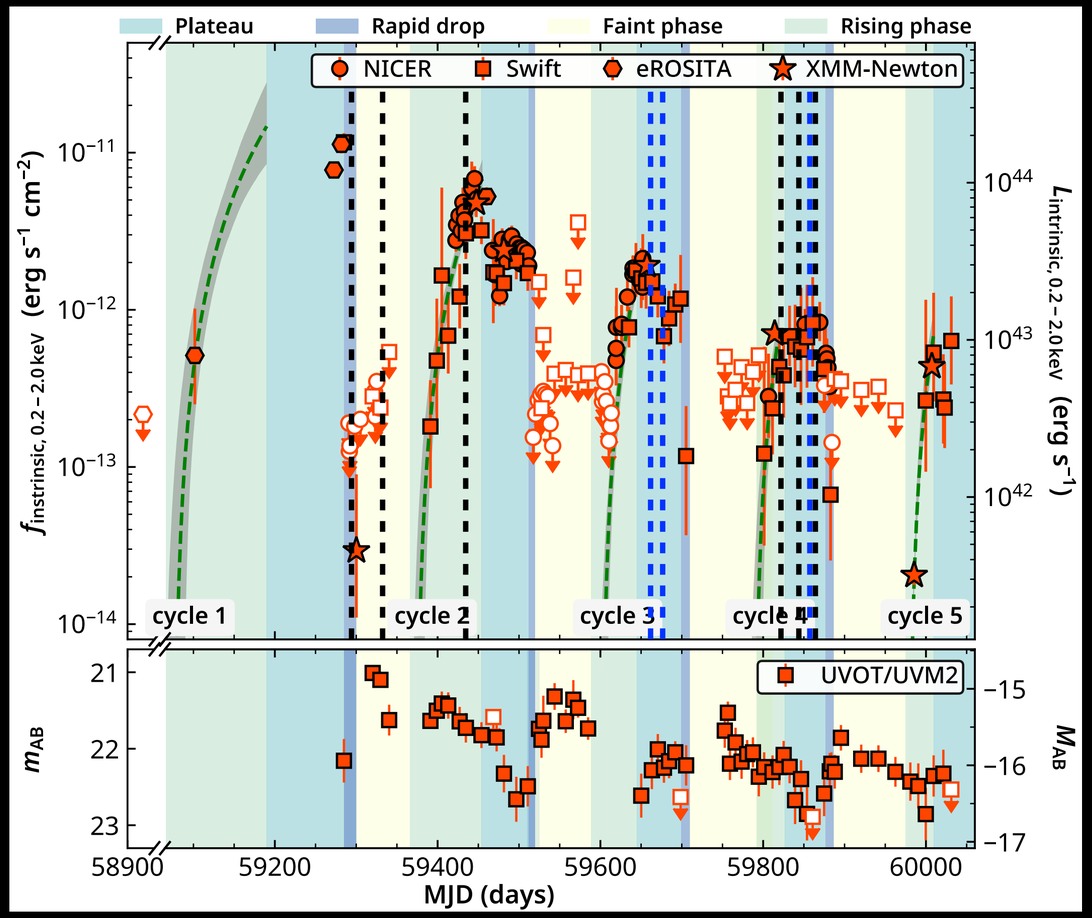

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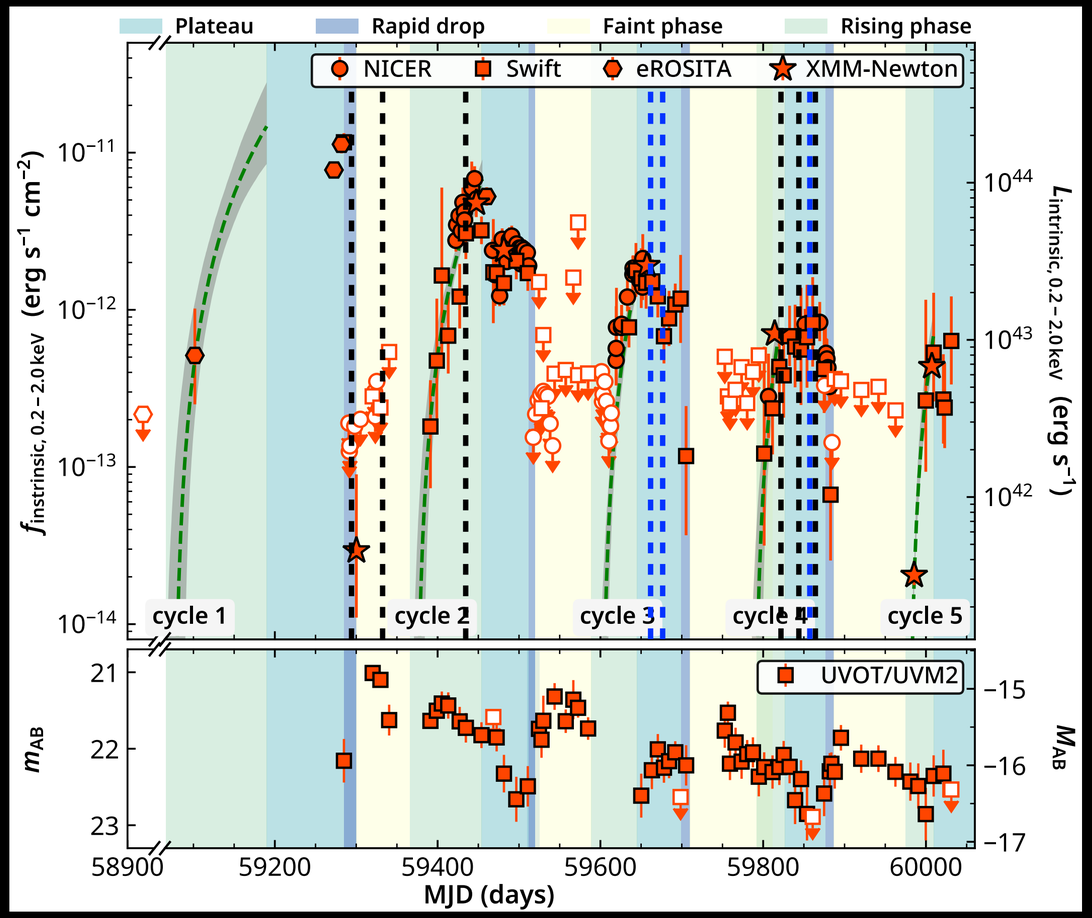

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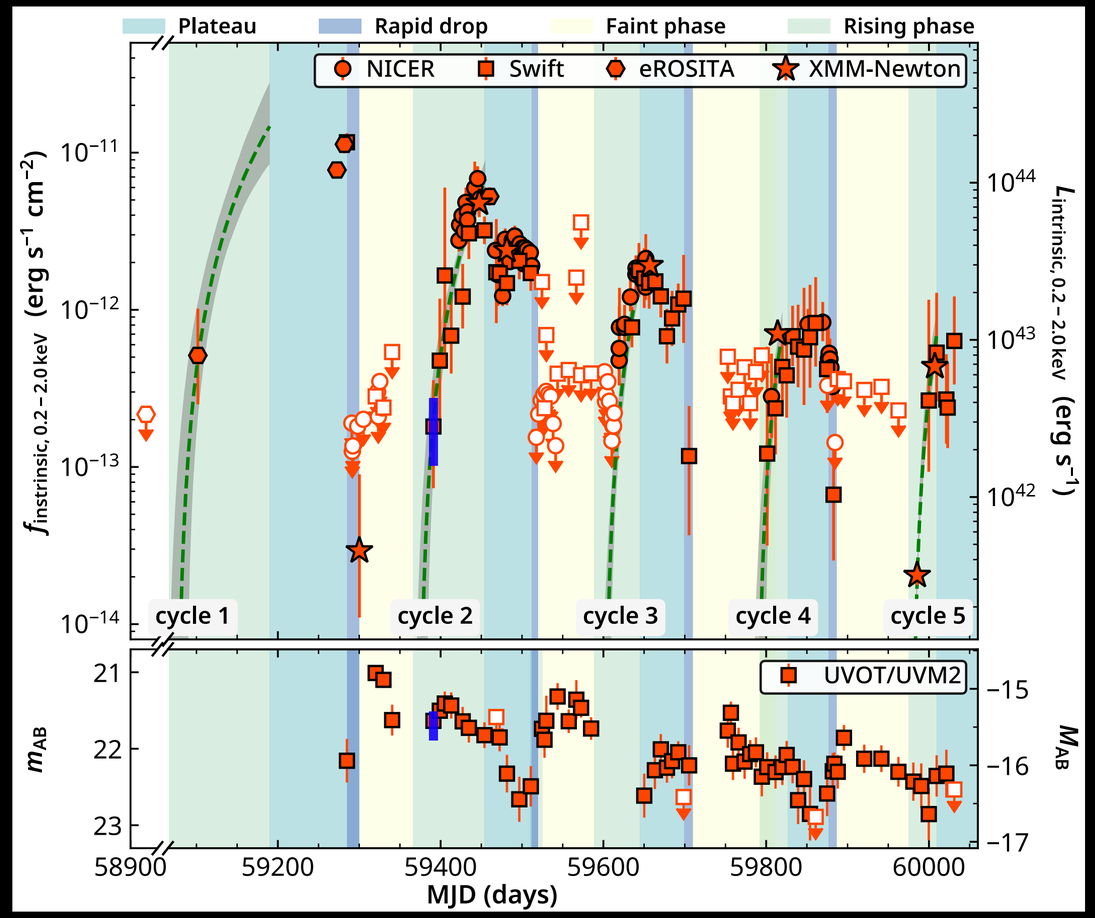
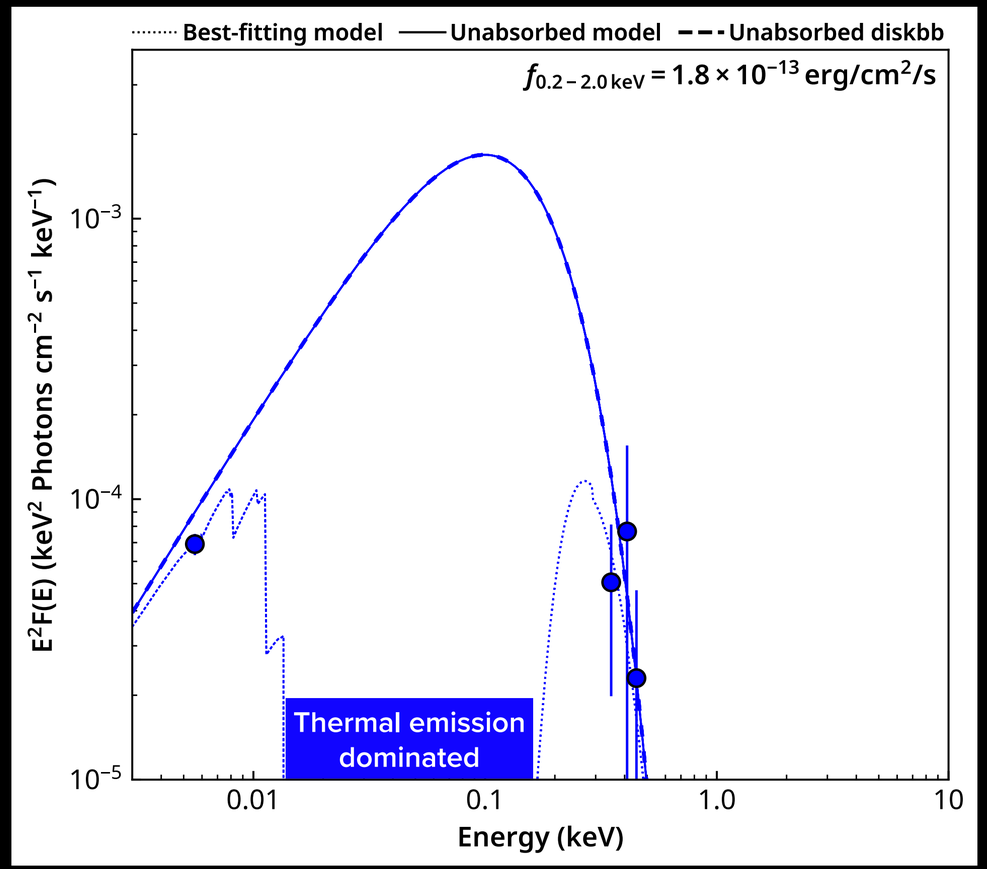
Evidence for accretion state transitions in J0456-20

X-ray rising phase: formation of the corona



Evolution of the UV-to-X-ray SED



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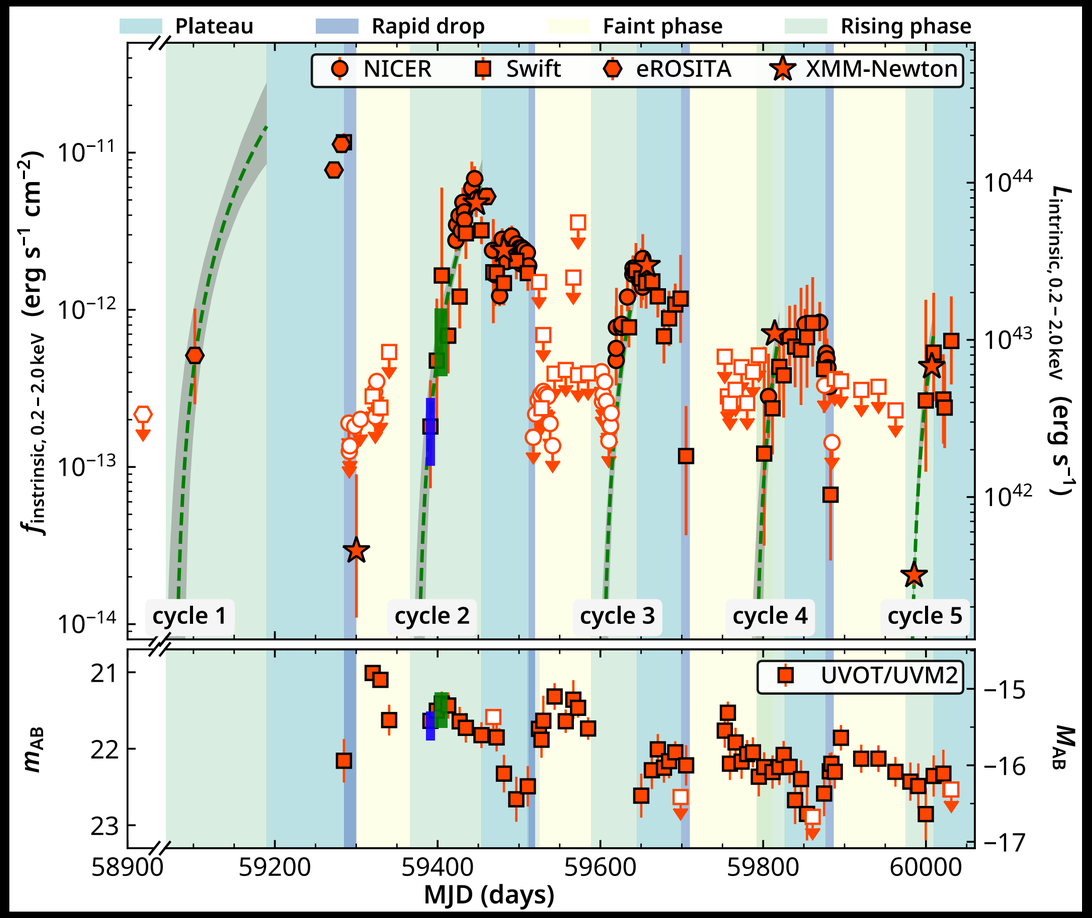

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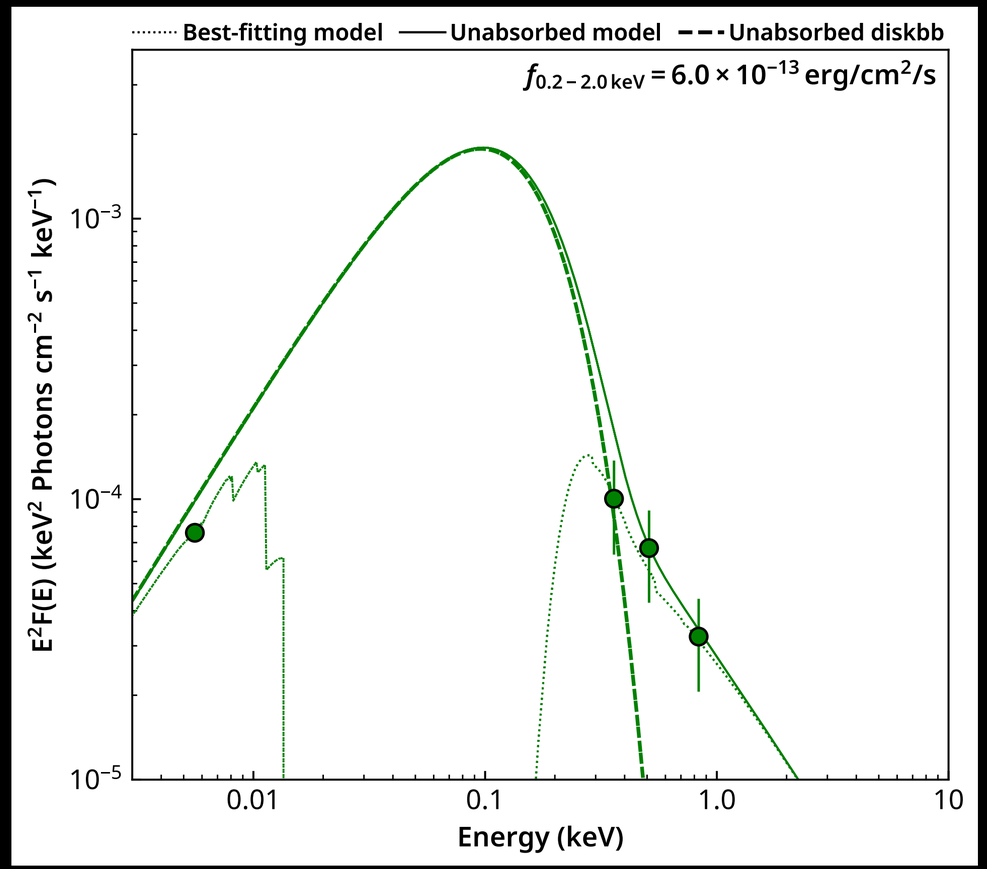

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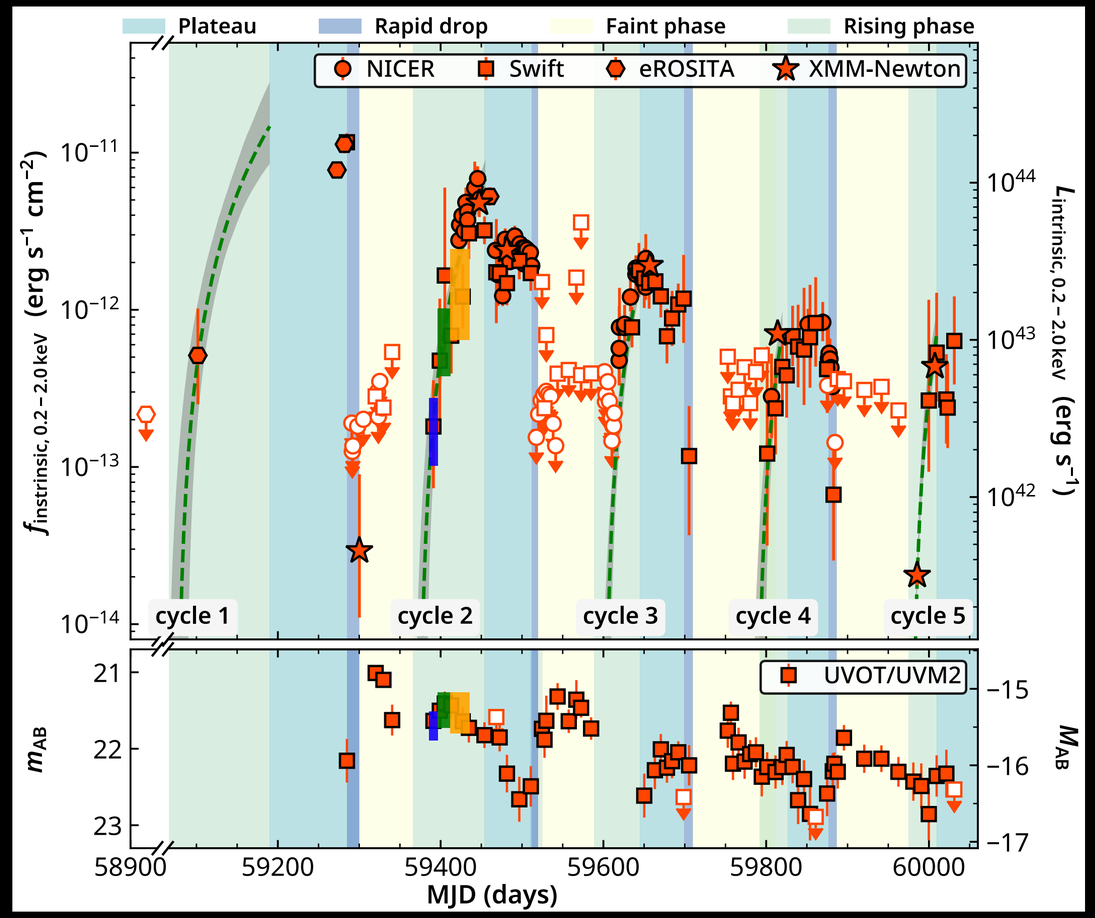

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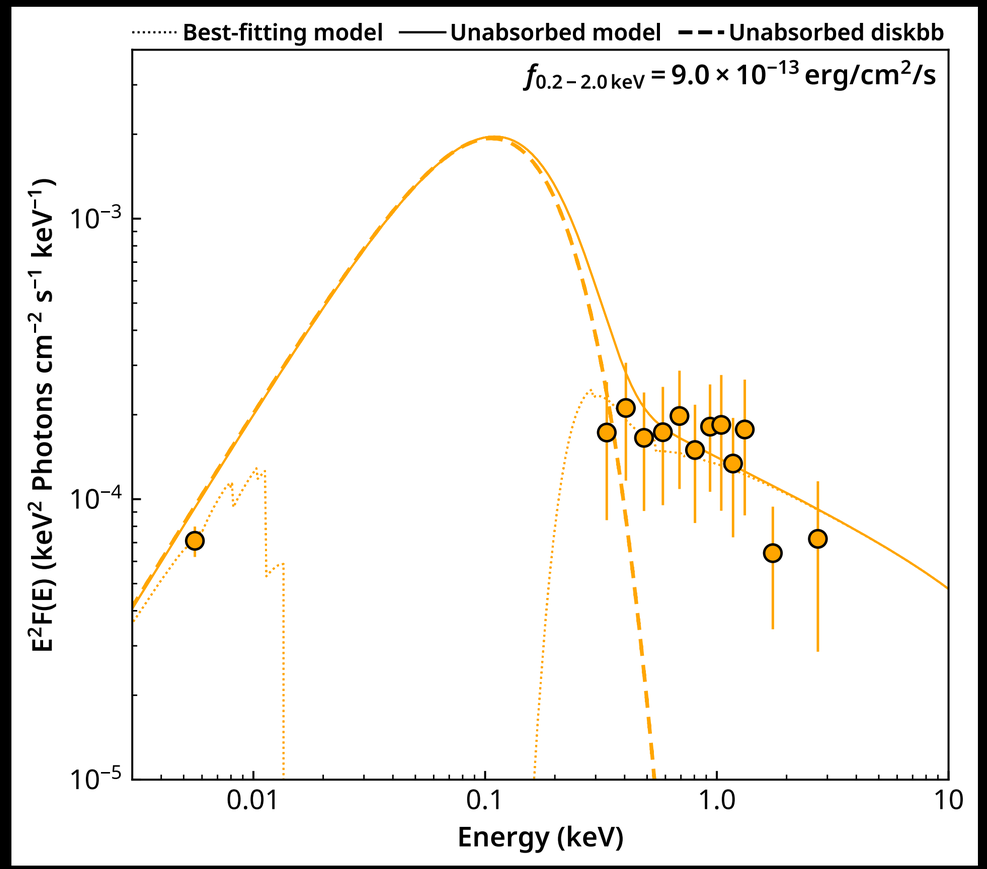

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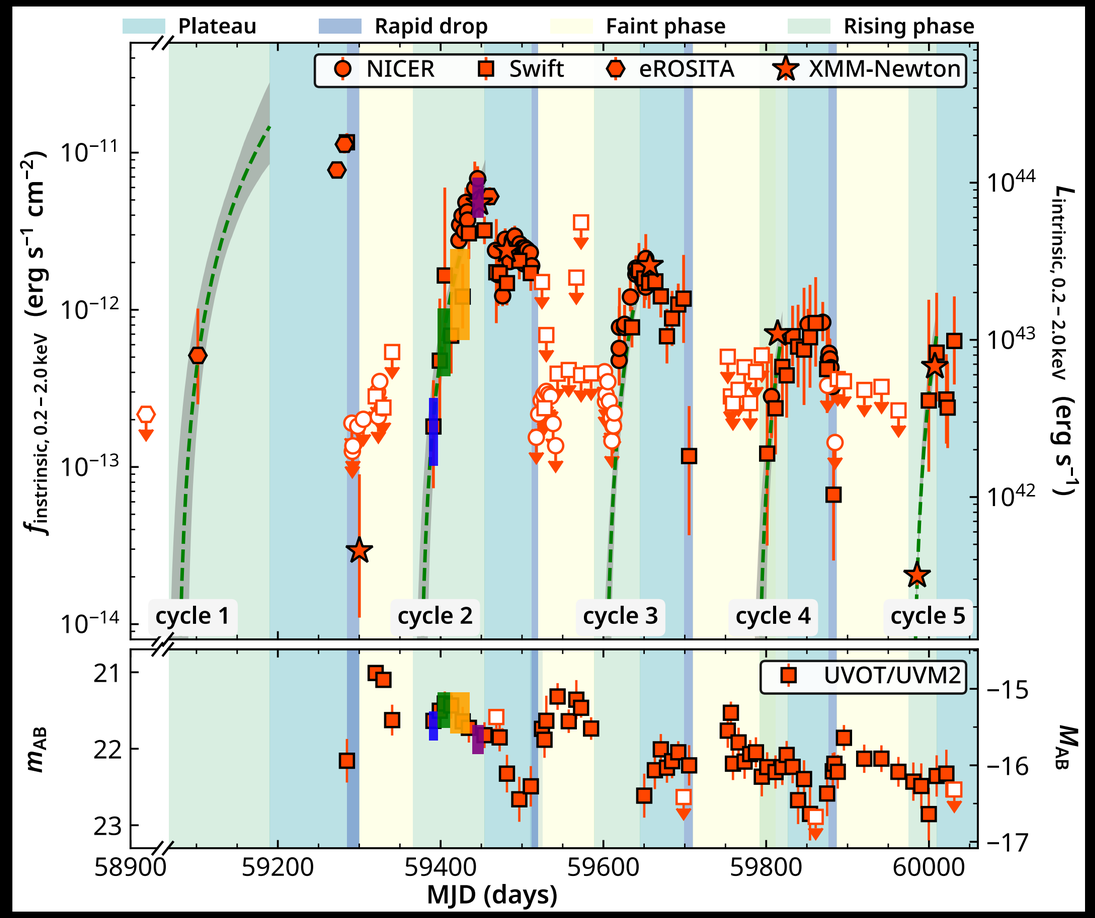

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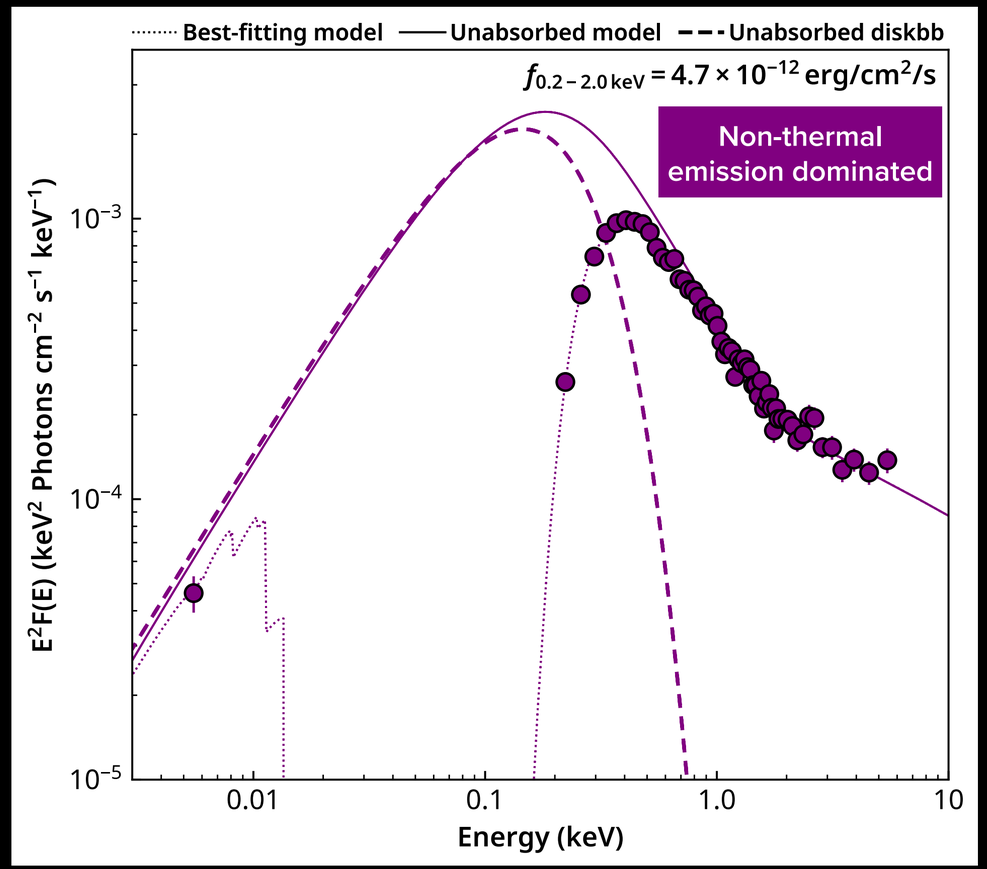

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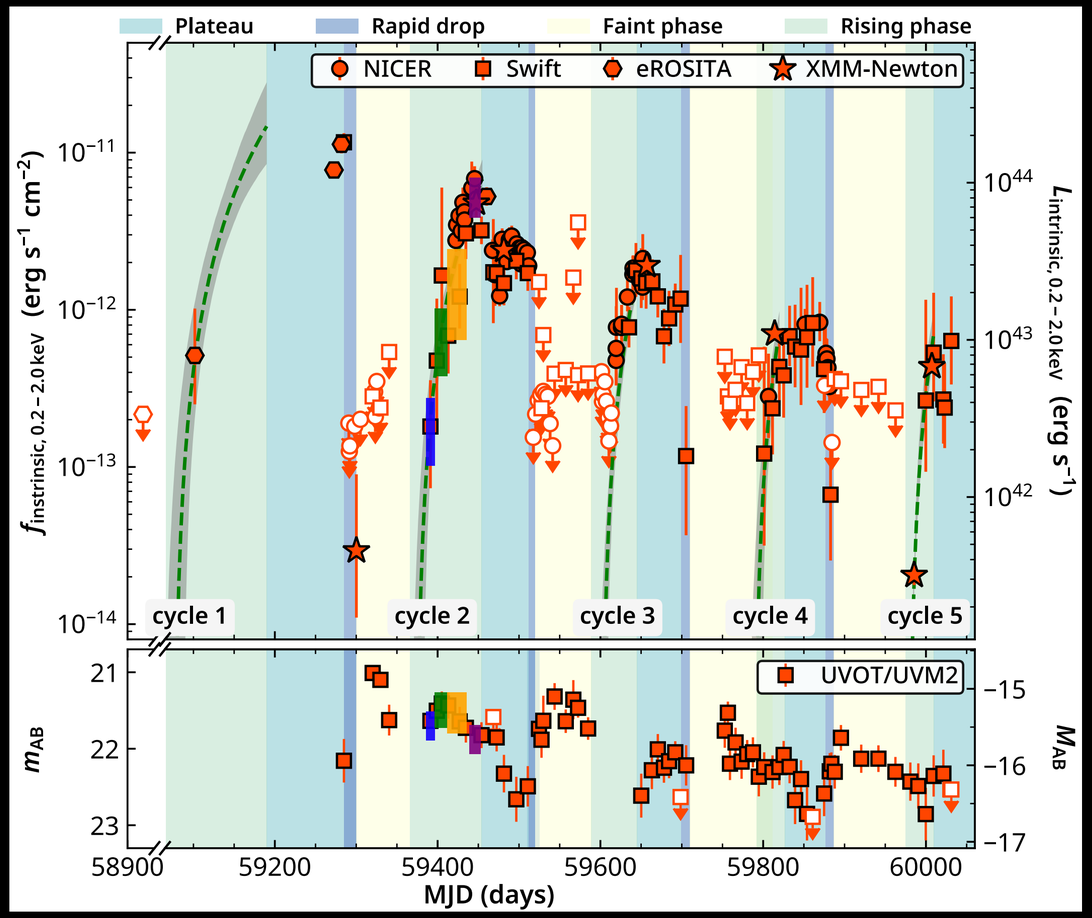

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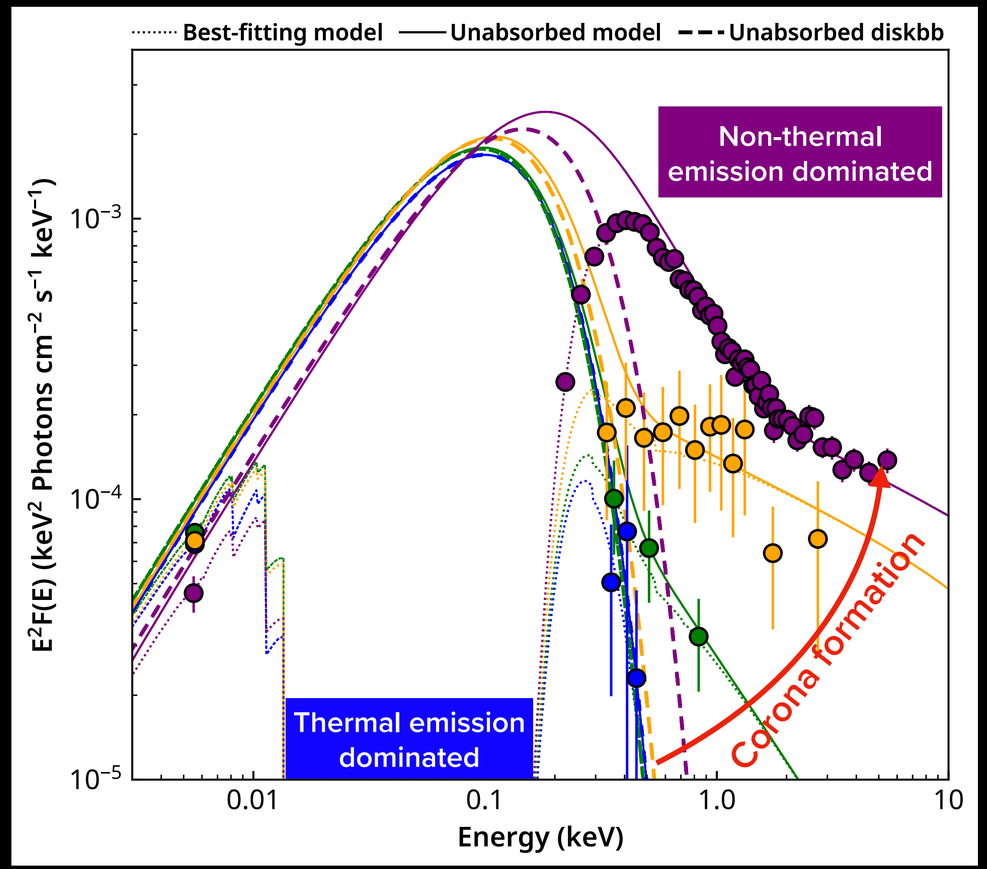
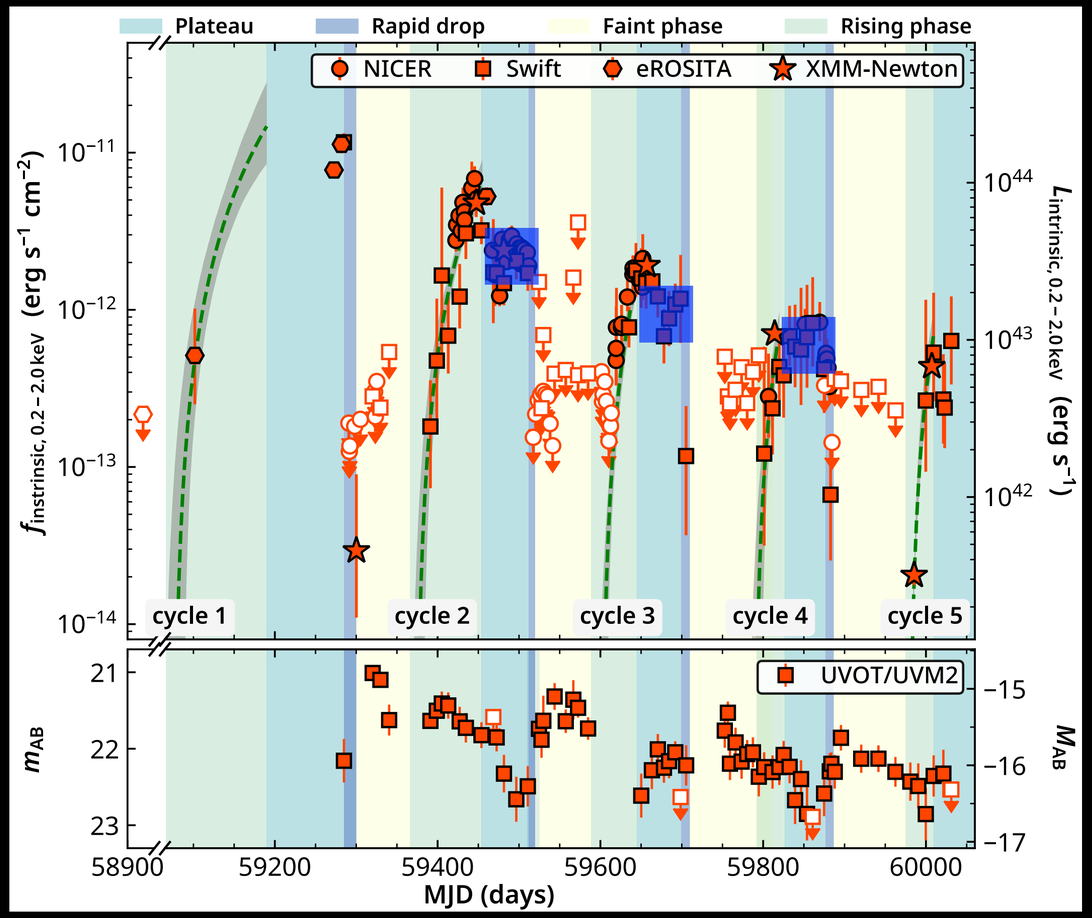


Evidence for accretion state transitions in J0456-20

X-ray plateau phase: transitioned to the steep power-law state



- Similar to peak of rising phase
  - ➡ Componization by two coronae: a warm plus a hot corona
  - ➡ $T_{\rm in}$ ~ 60 eV for multi-colour disc
  - ➡ Γ ~ [2.5, 3.0] if fit with power-law
- Reminiscent of the steep power-law state in BHXRBs (e.g. Fender et al. 2004)
  - ➡ Transient radio emission
  - ➡ But a flat radio spectrum

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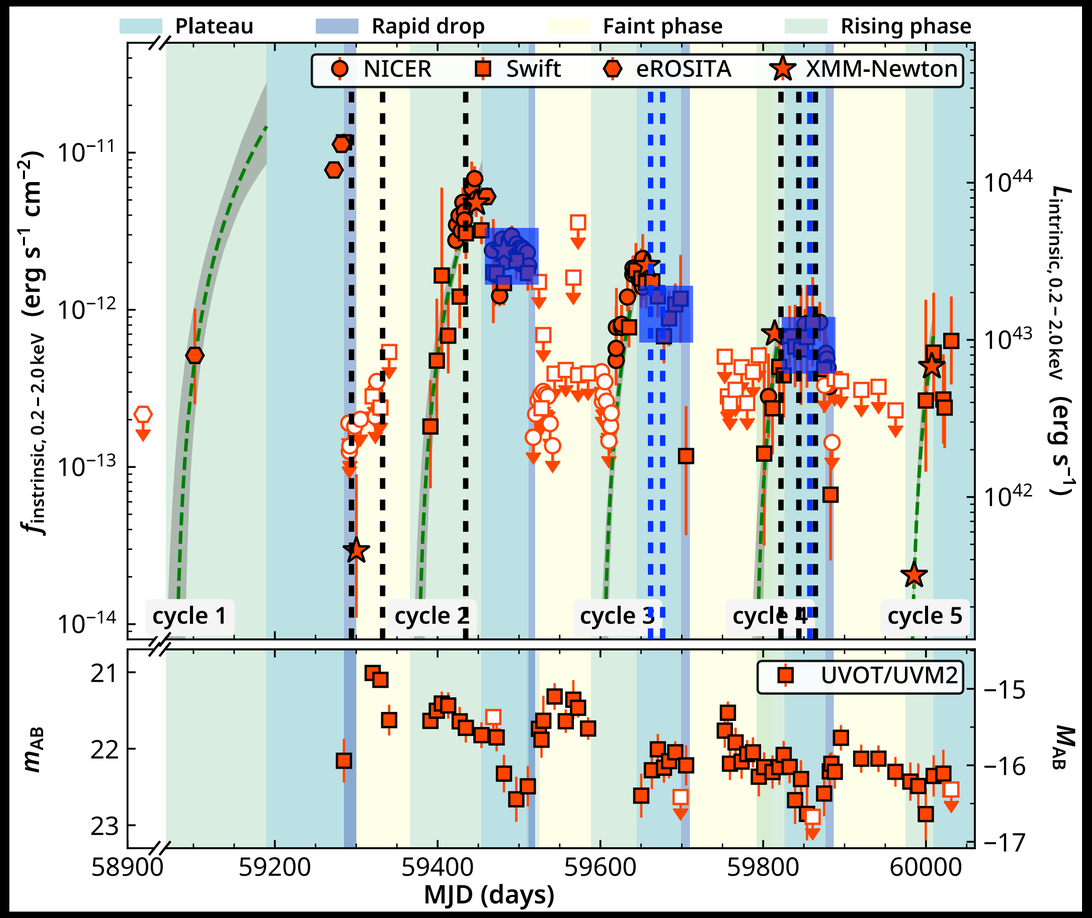

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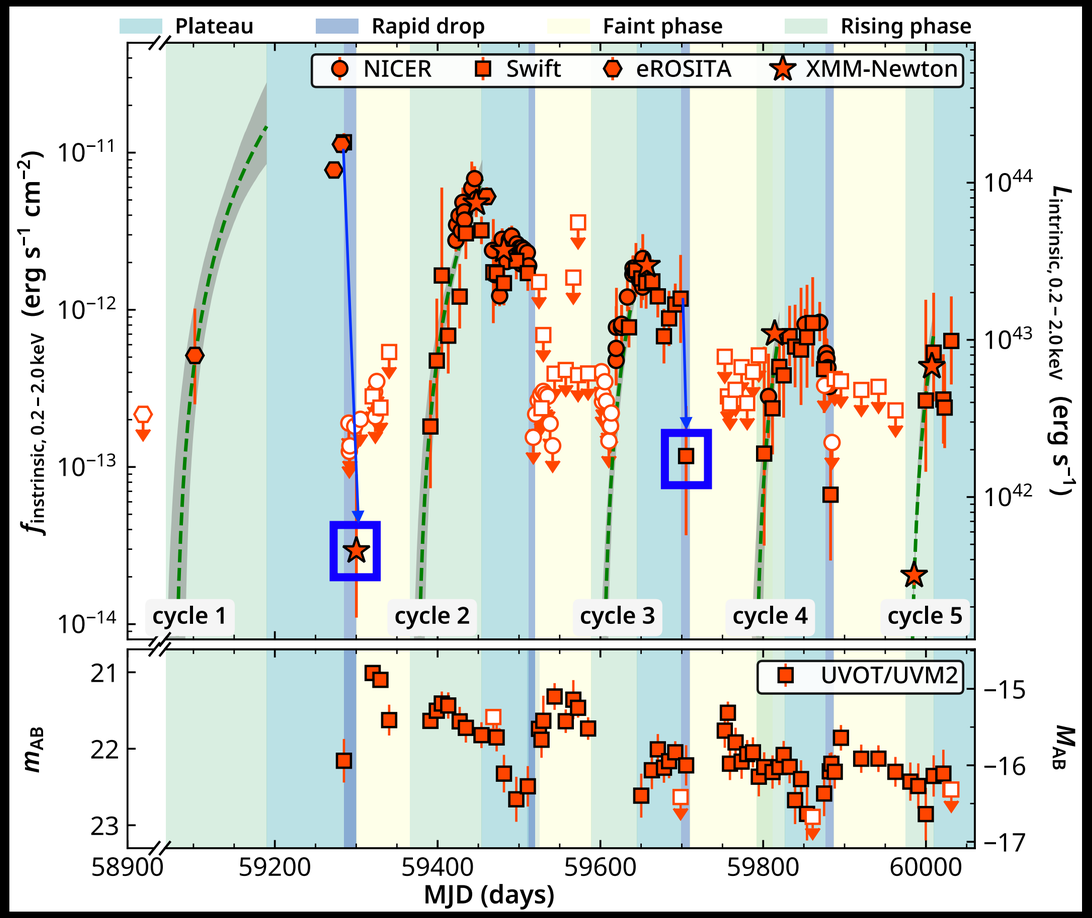
Evidence for accretion state transitions in J0456-20

Rapid X-ray drop: back to thermal state with destruction of the coronae?



- Drastic change in X-ray spectra
  - Become soft again (T_{in} ~ 100eV)
  - A hard component is not required
  - Indication of disappearance of the coronae
- Time-scale: flux decreased by a factor of > 10 in 3 days (Yao et al. 2022, Ricci et al. 2020)

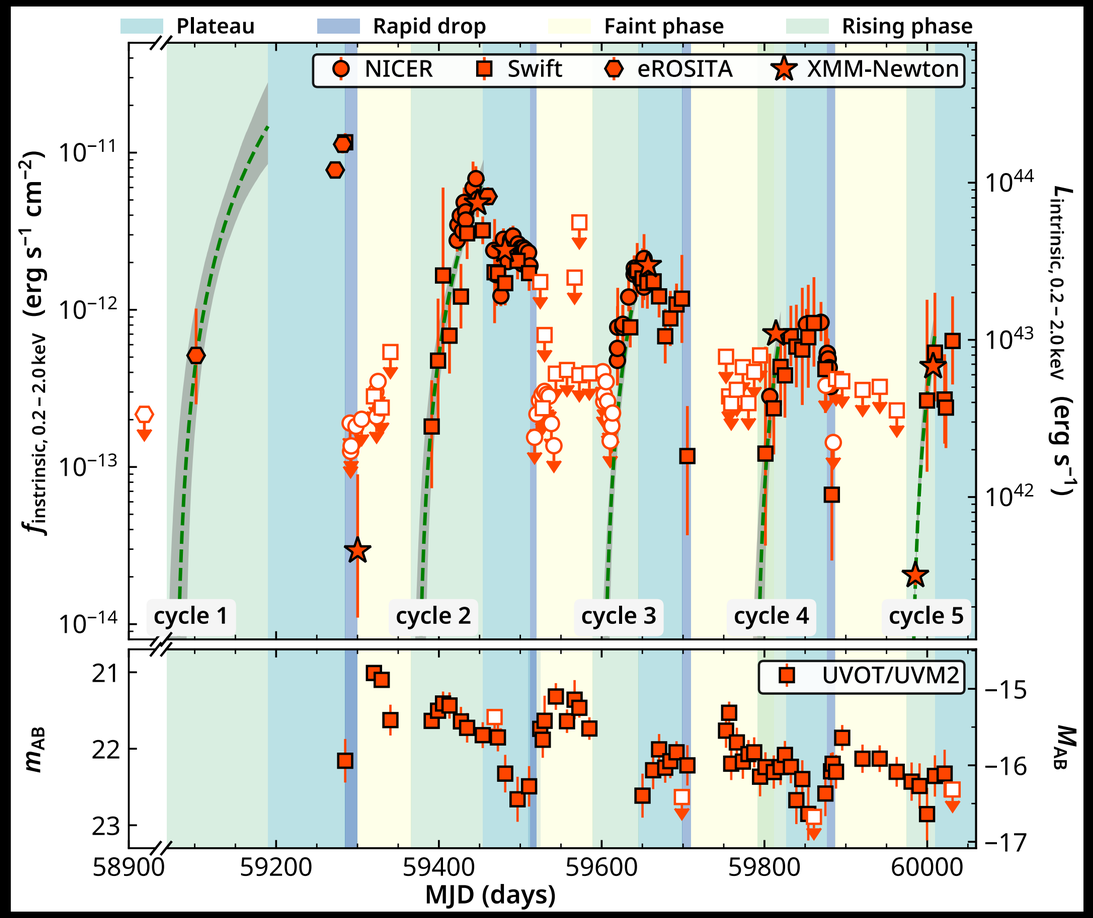
X-ray spectral evolution provides strong evidence for accretion state transitions

Rapid evolution of the recurrence time in J0456-20

Exploring the stellar/gas dynamics around SMBHs beyond the Milky Way?

- Short recurrence time (<300d)
  - ➡ Cannot produced via two-body scattering
  - ➡ Star initially in a binary system?
- Rapid evolution of the recurrence time
  - ➡ Decreased by >20d in the first three cycles
  - ➡ Much faster than the other repeating *p*TDEs
  - ➡ Physical origin is unclear

Repeating *p*TDEs could be effective probes to study stellar/gas dynamics around SMBH!



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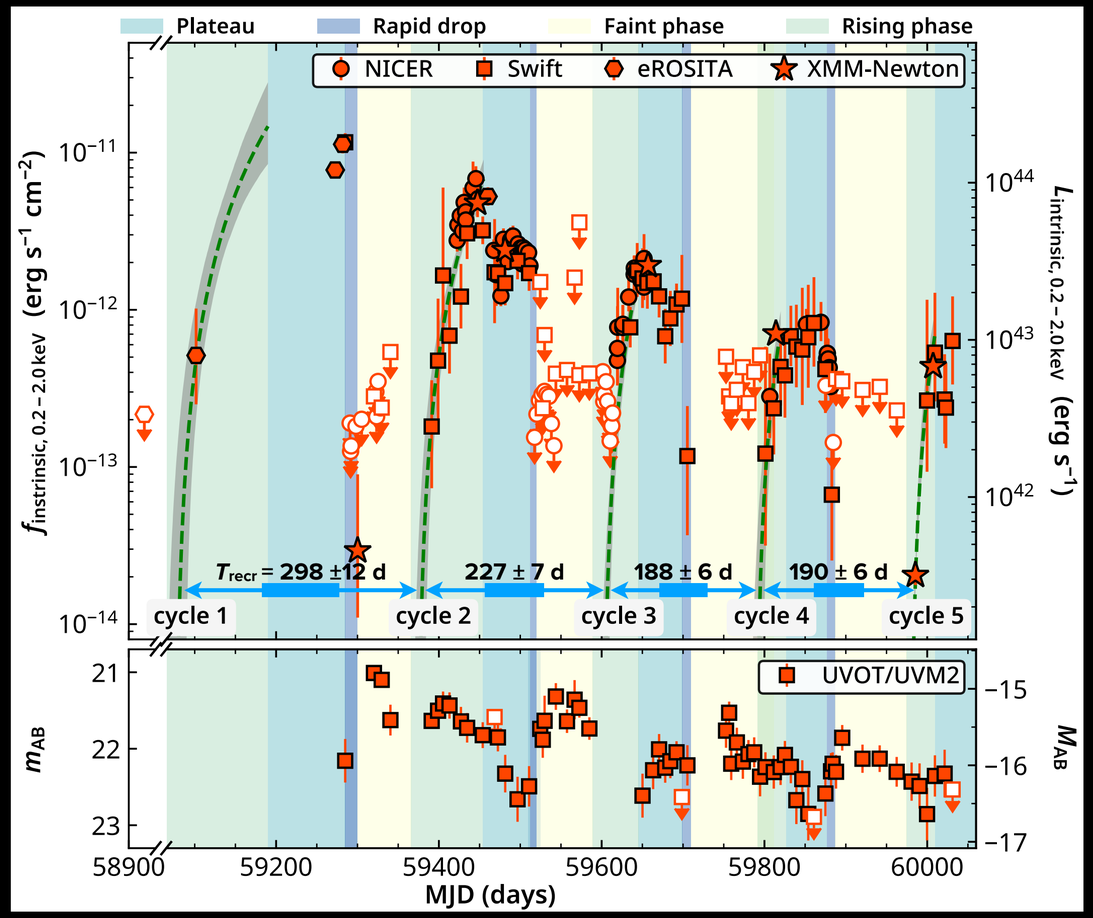
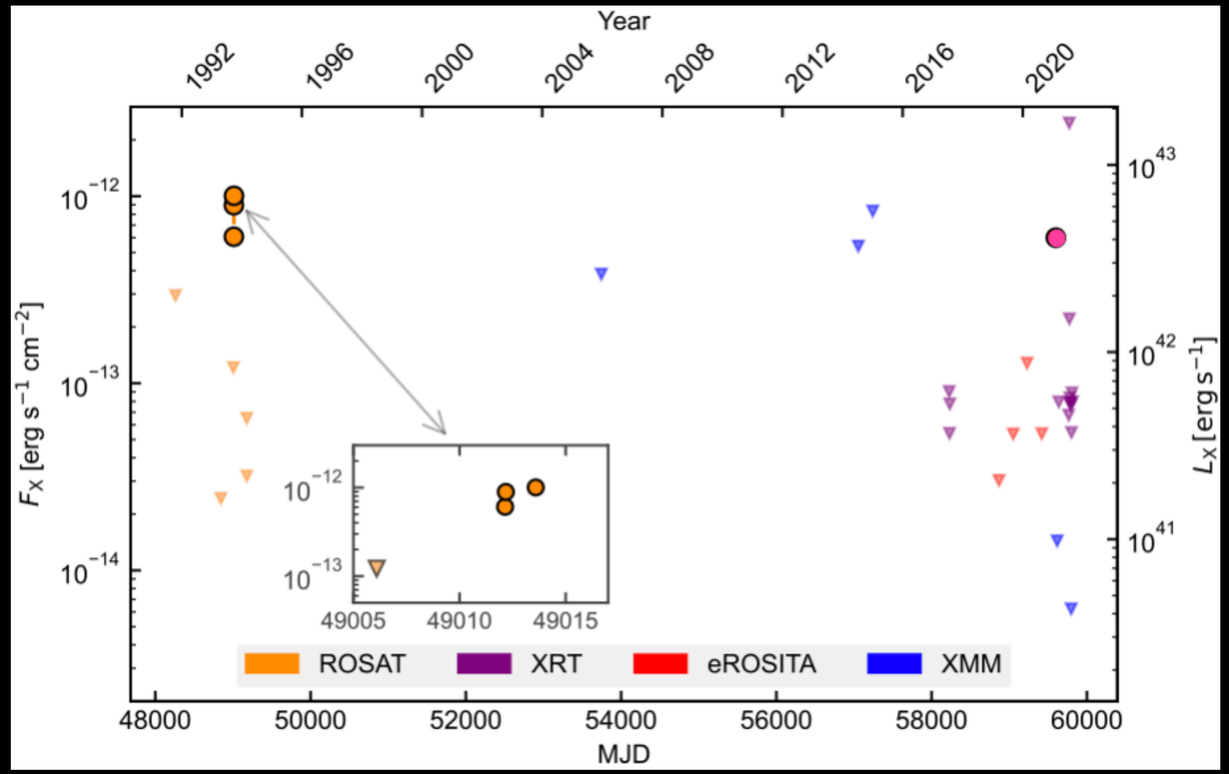
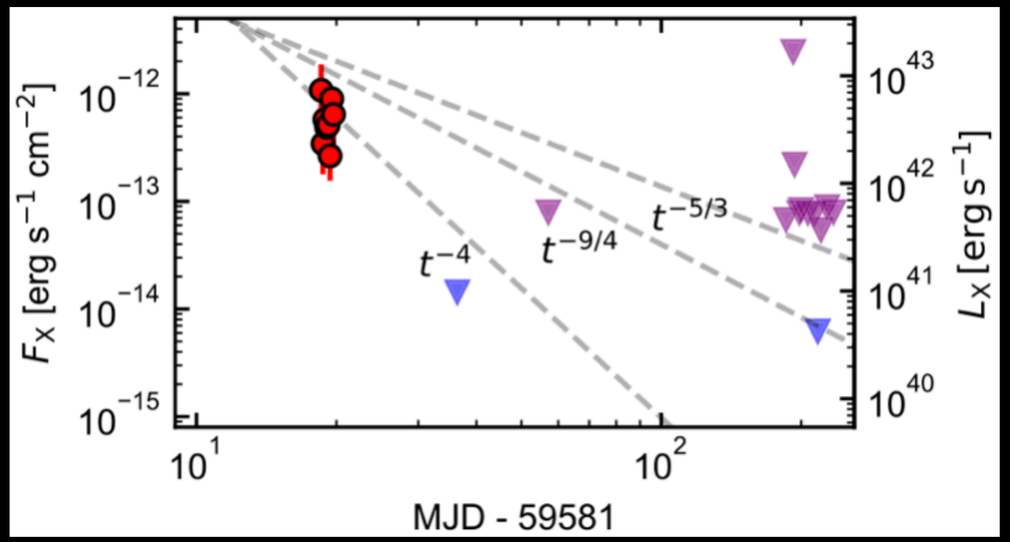


Malyali et al. 2023, MNRAS, 520, 3549–3559

Reawakened ROSAT TDE: J1331–32



- eRASS5 discovery >30yr after ROSAT reported TDE (z=0.052, Reiprich & Greiner 01; Hampel+22)
- Decay by a factor of >40 within ~17d revealed by XMM-Newton
- No associated transient optical/UV emission



- 2nd TDE extremely unlikely (<5x10^{-6})
- Favoured interpretation: partial, repeating TDE
- Steep decay suggests a star on an elliptical orbit, in agreement with theory (Ryu et al. 2020)

Repeating *p*TDEs detected by eROSITA

Step beyond the main stream TDE picture

- Indicates the existence of repeating *p*TDE
  - ➡ Impact on the rate of TDE (e.g. Bortolas et al. 2023)
- Accretion state transitions can occur in SMBH
  - ➡ Studying the poorly understood corona
  - ➡ Corona: formed within months (Masterson et al. 2022)
  - ➡ Corona: destroyed within weeks (Ricci et al. 2020)
- Long-term monitoring is crucial (eg., Einstein Probe, UVEX, ULTRASAT)
- Repeating *p*TDE could be used to probe the stellar dynamic around SMBH