Highs and Lows of a transitional MSP

The ultimate campaign on PSR J1023+0038

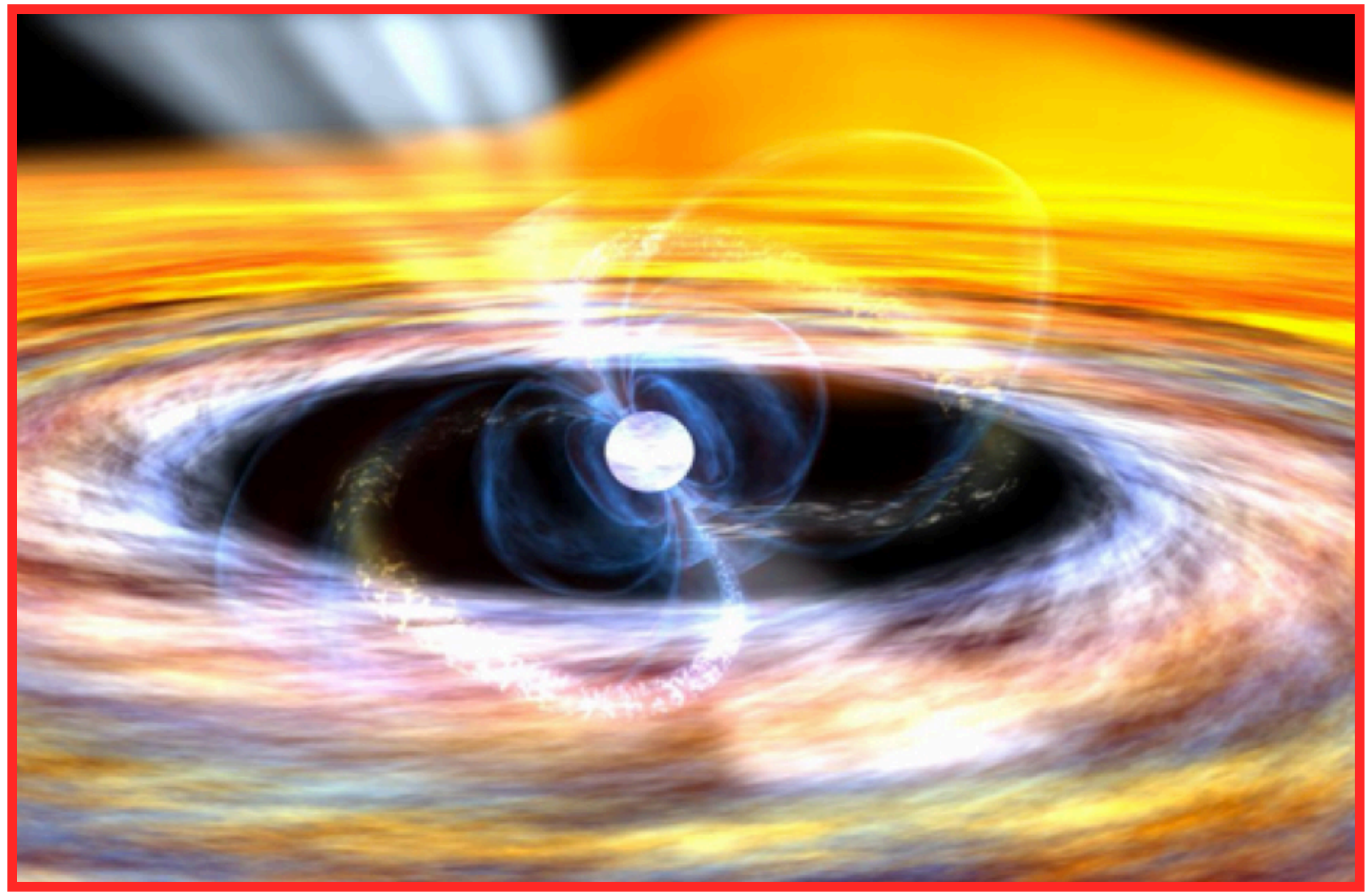
M. Cristina Baglio

New York University of Abu Dhabi
INAF- Osservatorio Astronomico di Brera (Merate)

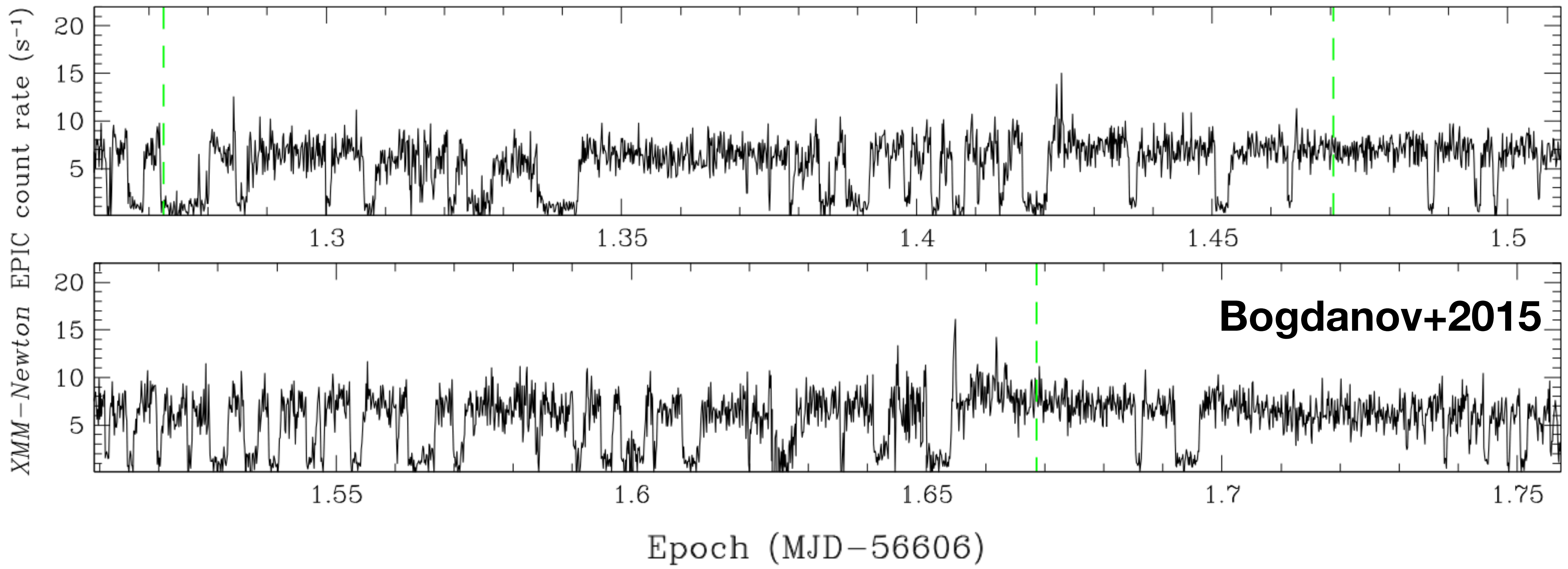
Collaborators: F. Coti Zelati (ICE, CSIC), S. Campana, P. D'Avanzo, S. Covino (INAF - OAB), A. Miraval Zanon, A. Papitto, P. Casella (INAF -OAR), D. M. Russell (NYU Abu Dhabi) ....

CNOC XII, Cefalù (PA), 27 September 2022

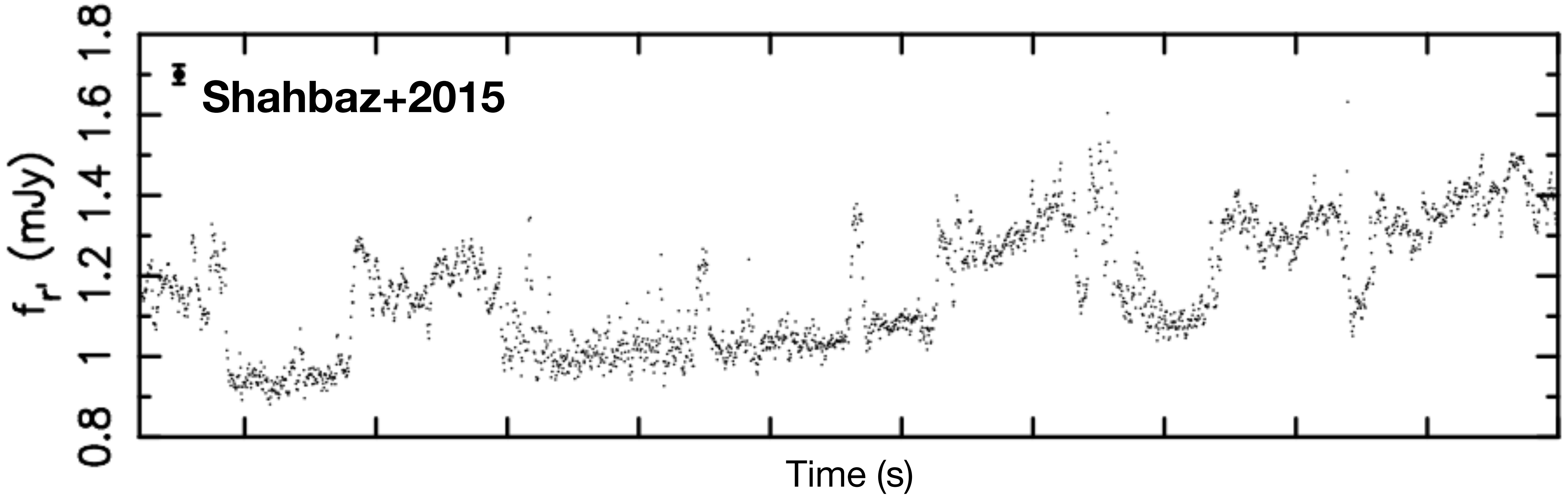
Accretion states in tMSPs

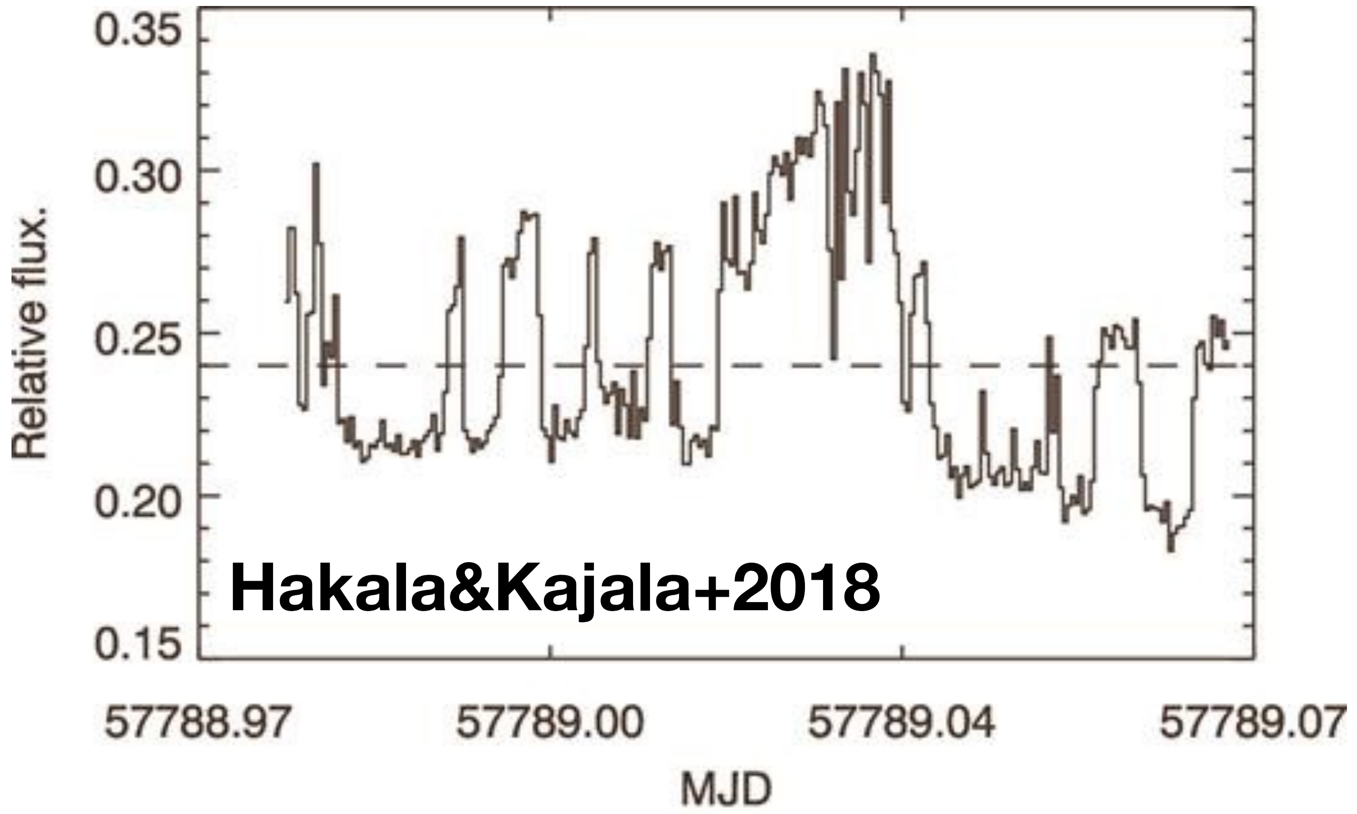


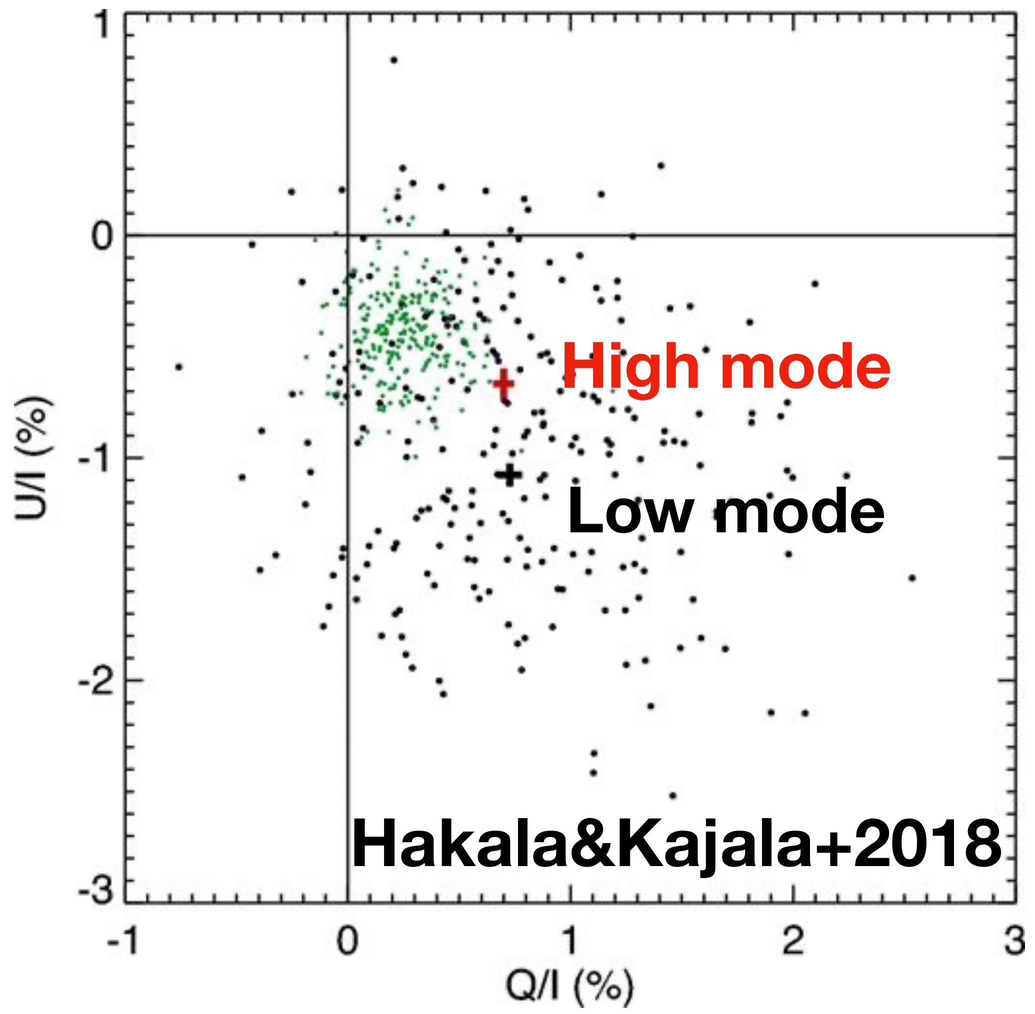
Both PSR J1023+0038 and XSS J12270-4859 show transitions on a timescale of ~10s between a *low* (L_x~10^{33} erg s^{-1}) and a *high* (L_x~$7x10^{33}$ erg s^{-1}) mode. Flares are also observed (L_x~10^{34} erg s^{-1}). Bogdanov+2015, Campana+2016



Pulsations detected during high modes only.
Similar transitions detected also in NIR, optical and optical polarization.



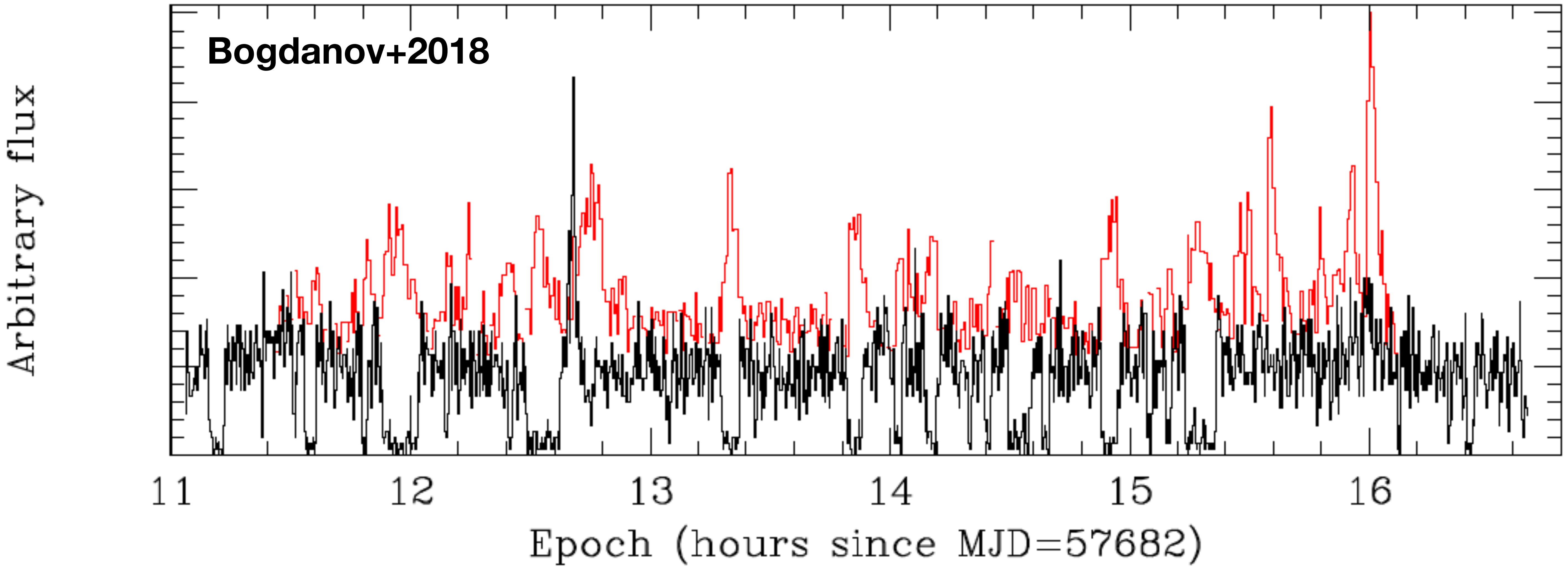




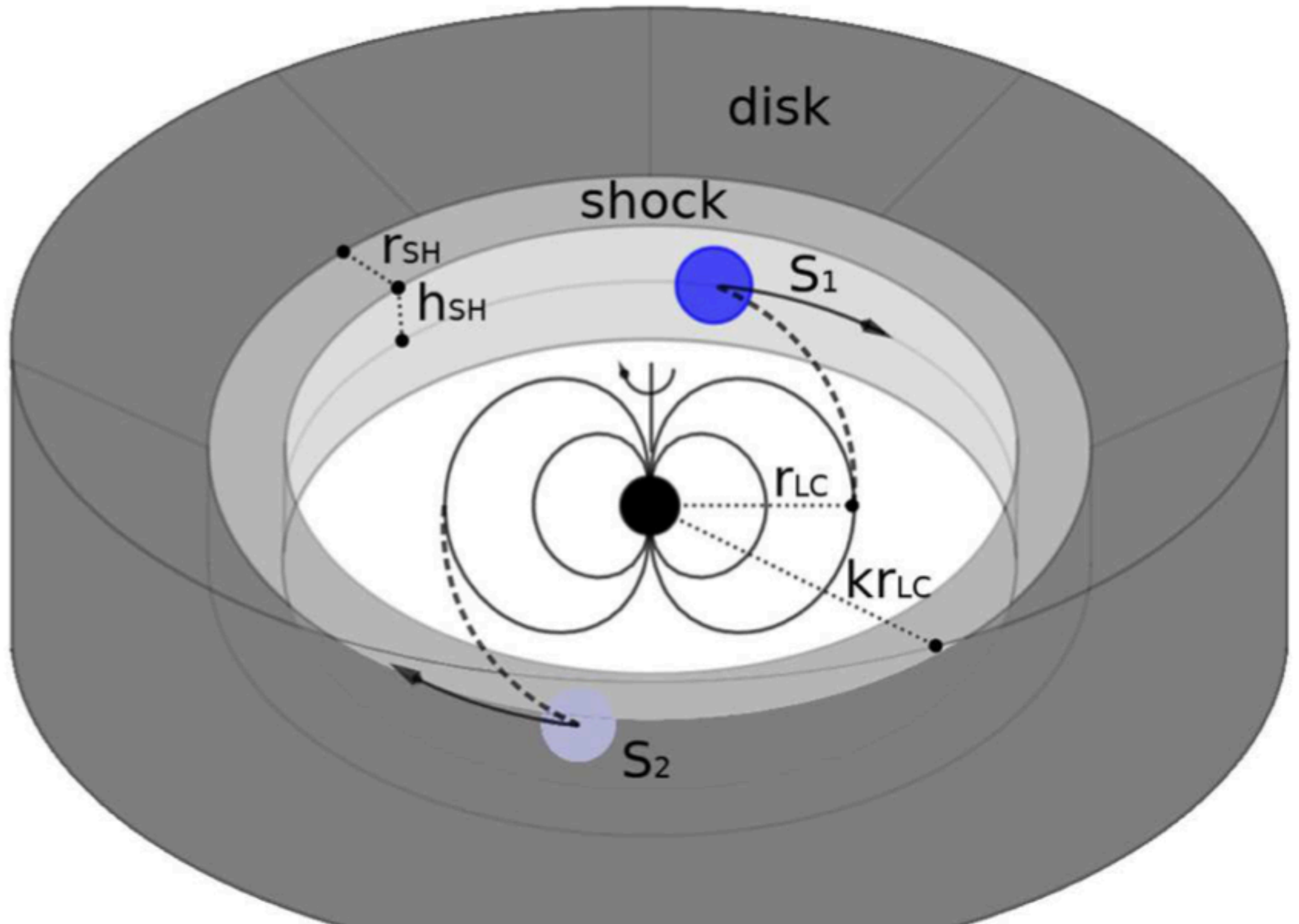
PSR J1023: what else we already know

RADIO continuum emission with flat spectral shape: possible compact self-absorbed jet (Deller+2015).

RADIO flares during low X-ray modes: possible ejection of optically thin plasmoids (Bogdanov+2018).



New important discovery: optical ms pulsations (see Filippo, Alessandro, Arianna talks) with SiFAP2 and Aqueye+



Papitto+2019

The radio pulsar is always active

HIGH MODE

The pulsar wind interacts with the disc

A shock is generated

Coherent pulsations from optical to X-rays are produced

LOW MODE

The shock moves outside the lc radius

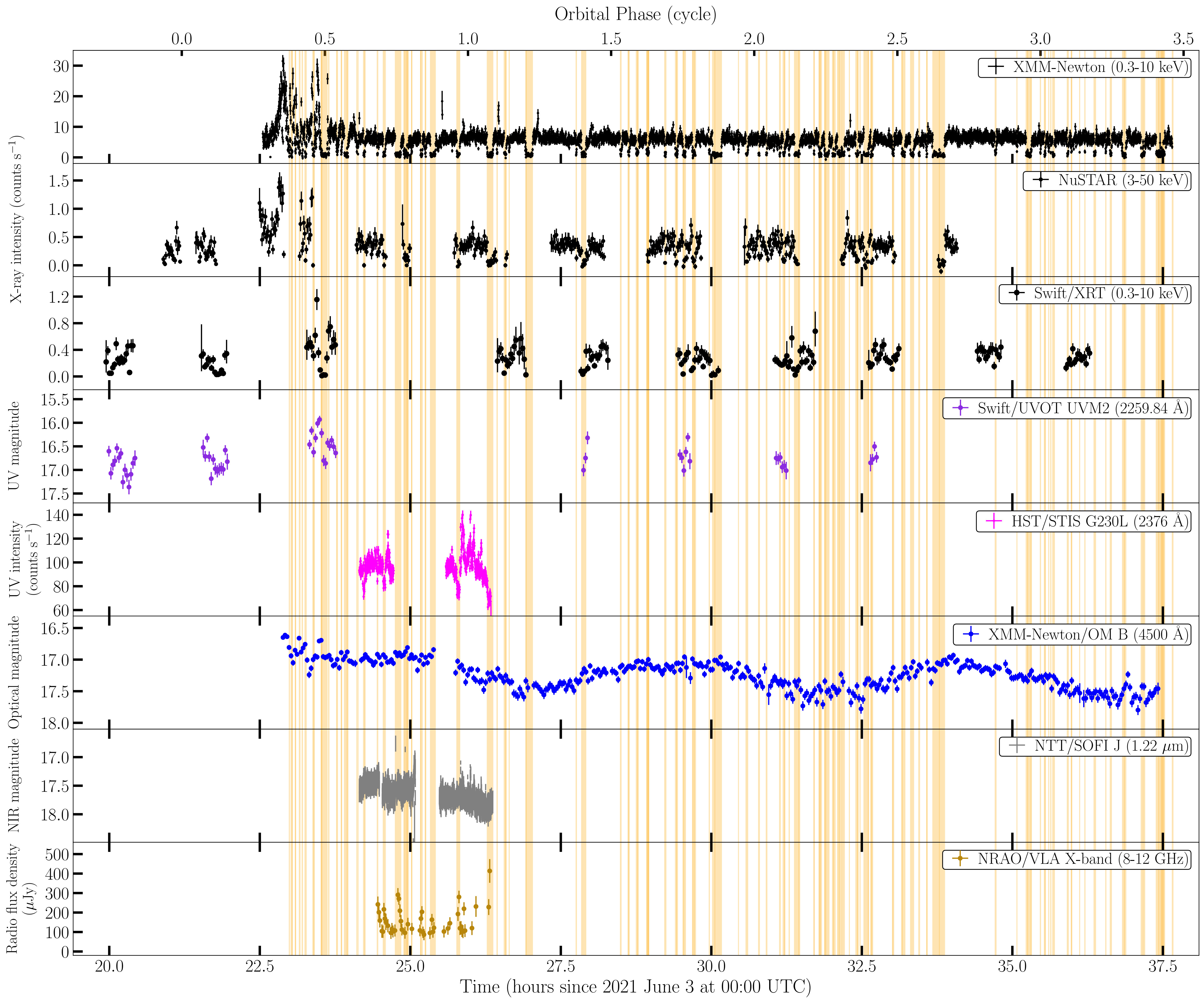
No pulsations are observed

FLARING MODE

The region of shock becomes bigger

The ultimate campaign!

2 nights of monitoring in June 2021, many facilities involved.



NIGHT1:

- **XMM-Newton (0.3-10 keV)**
- **NuSTAR**
- **Swift/XRT**
- **Swift/UVOT**
- **HST/STIS**
- **XMM-Newton/OM B-band**
- **NTT/SOFI J-band**
- **VLA X-band (8-12 GHz)**

Baglio, Coti Zelati et al. 2022 (in prep.)

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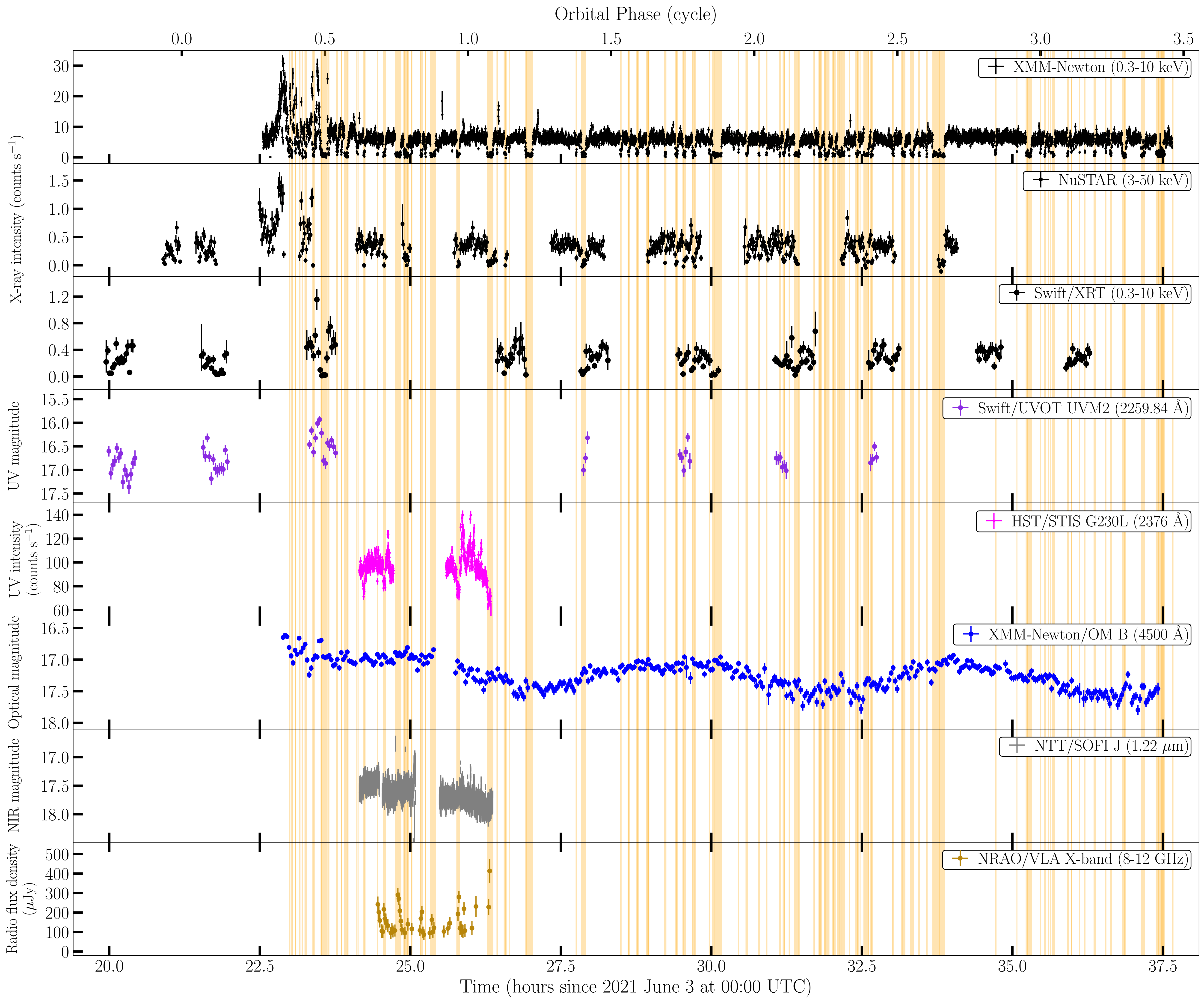

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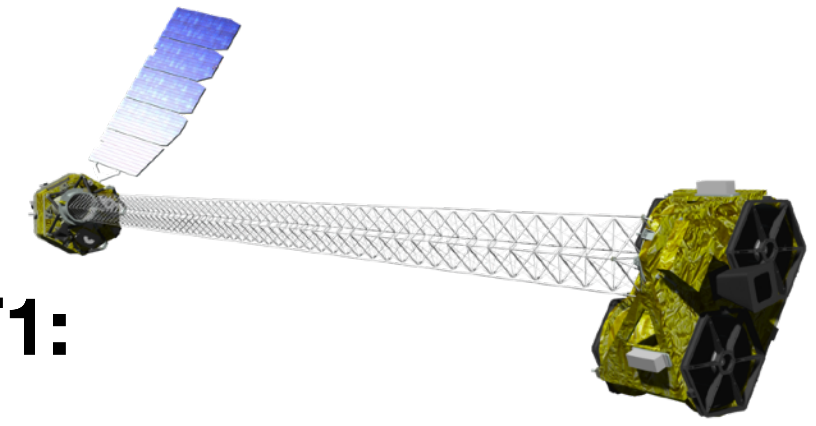
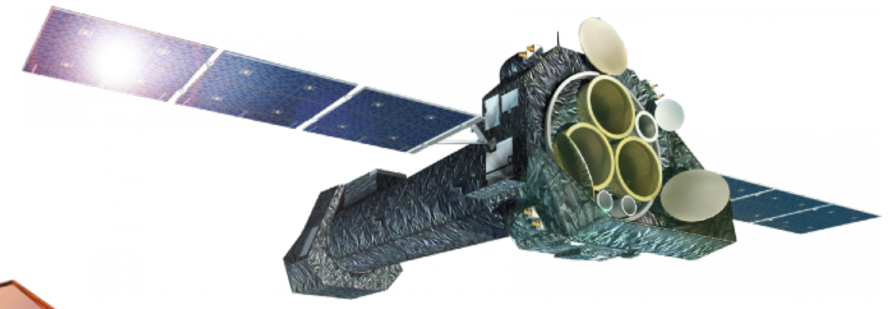
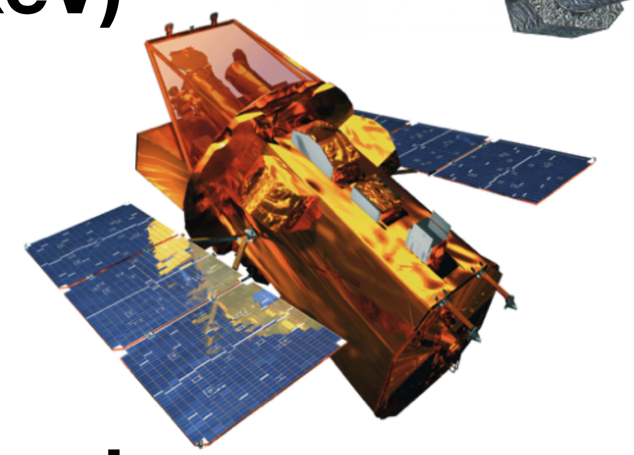


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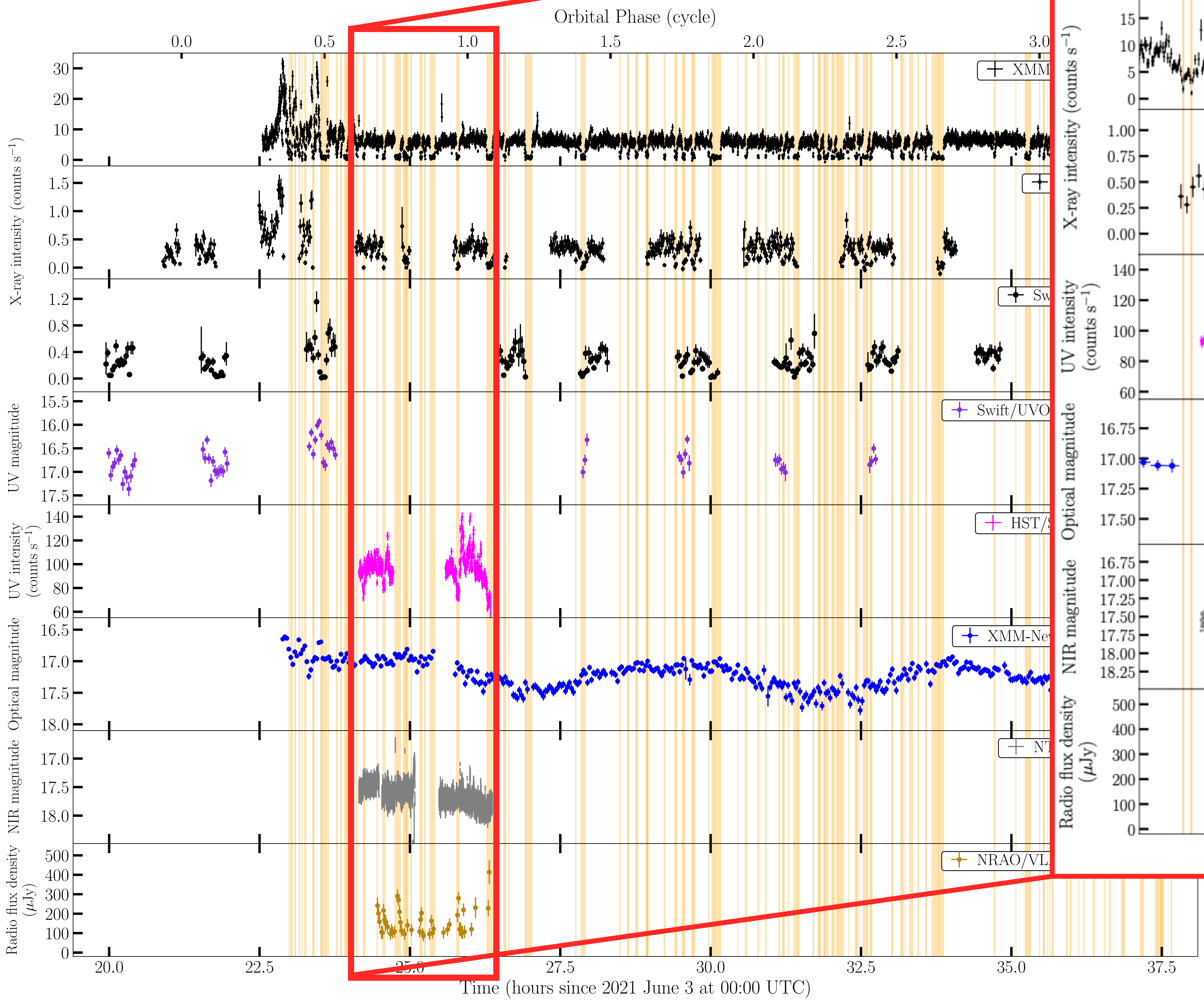

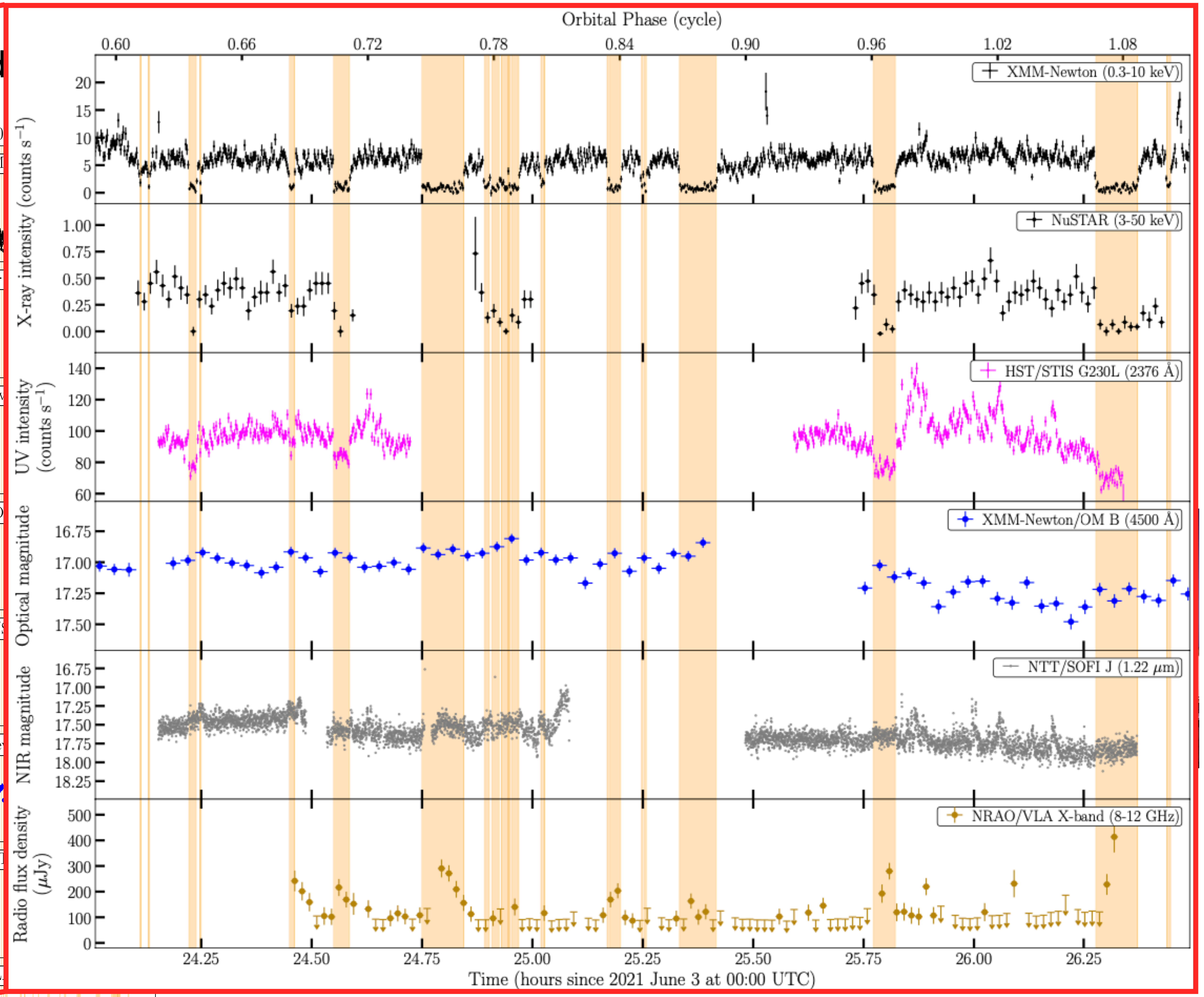

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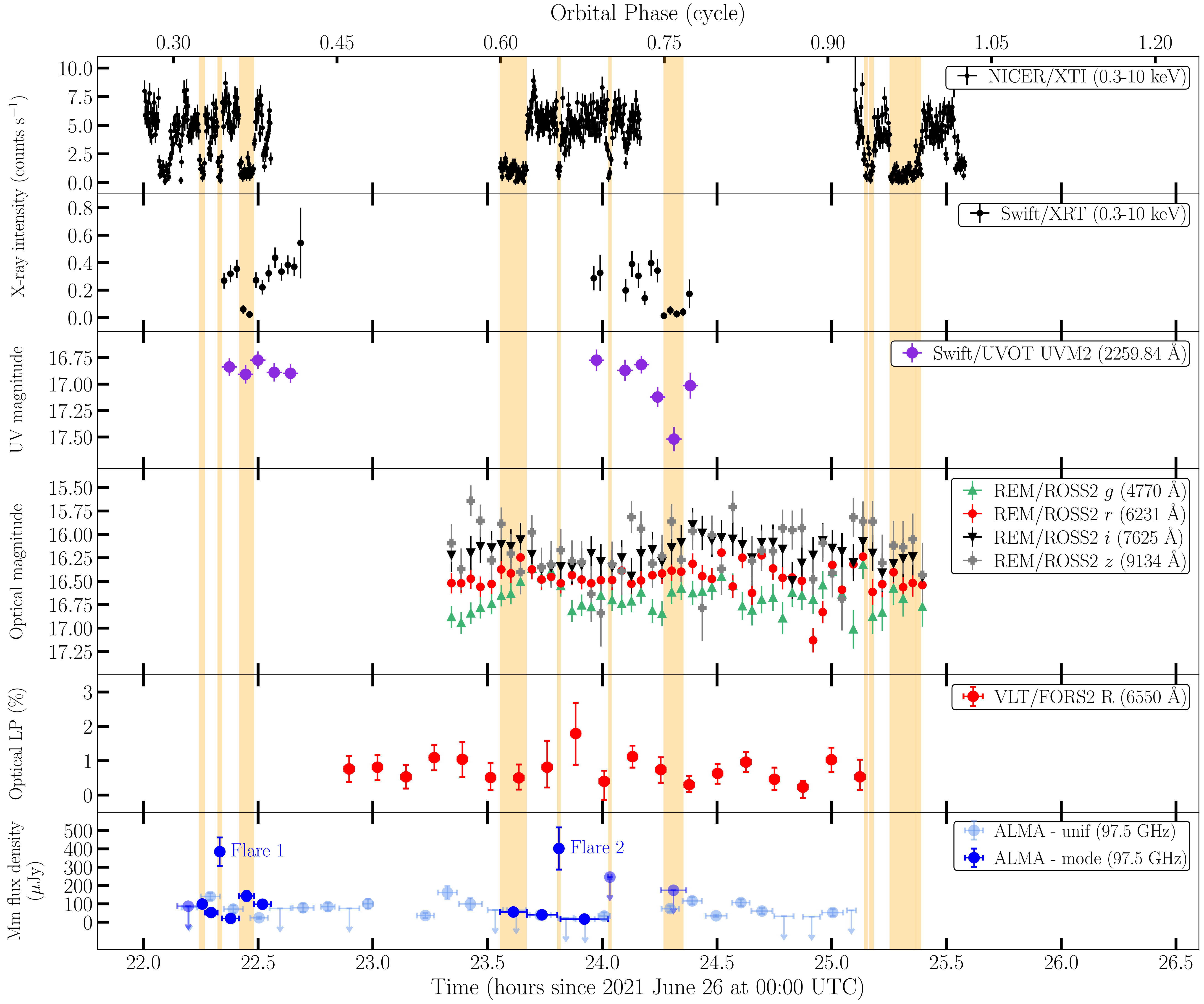

NIGHT2:

- **NICER (0.3-10 keV)**
- **Swift/XRT**
- **Swift/UVOT**
- **REM/ROSS2, REMIR**
- **VLT (FORS2 polarimeter)**
- **ALMA**

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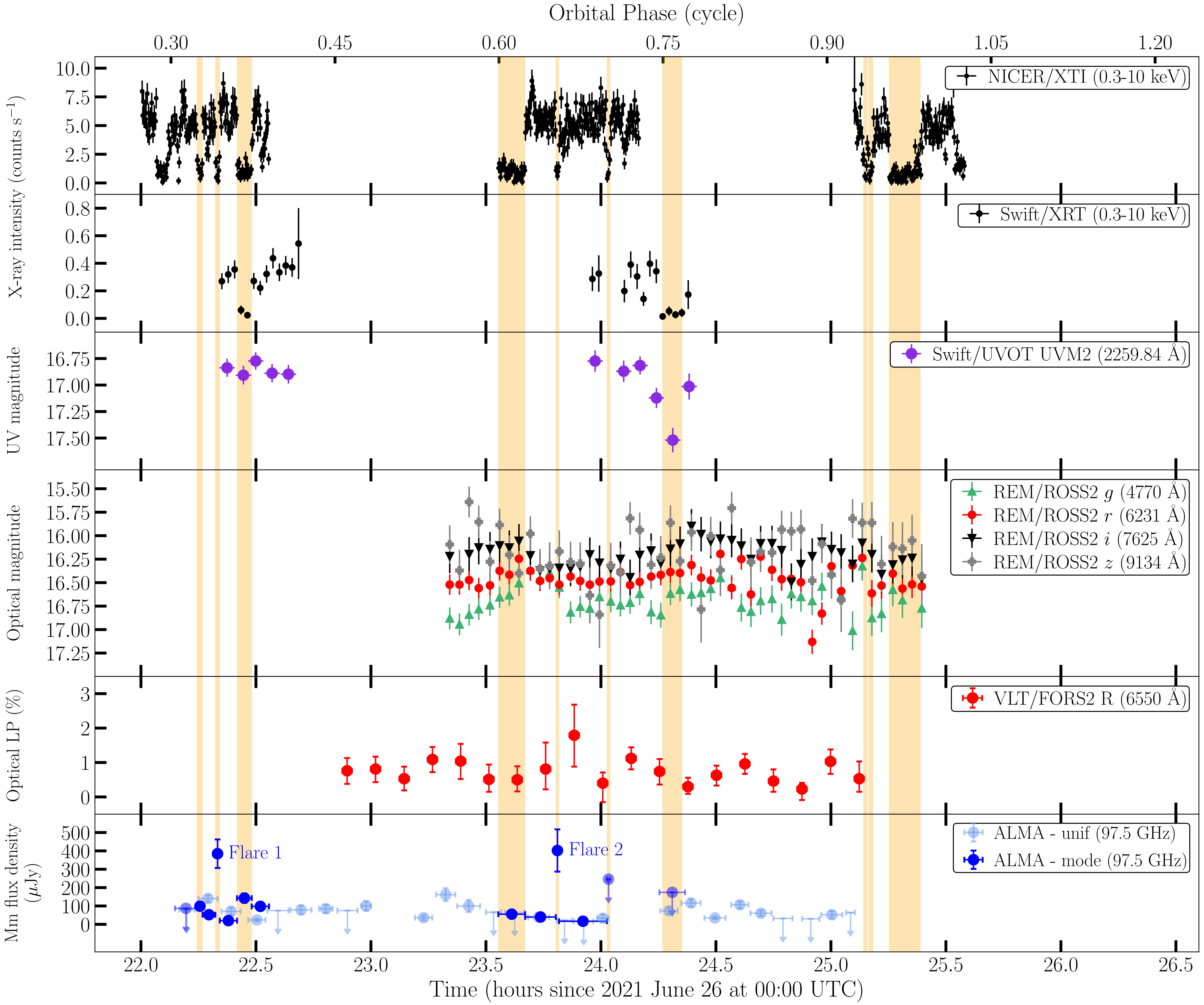

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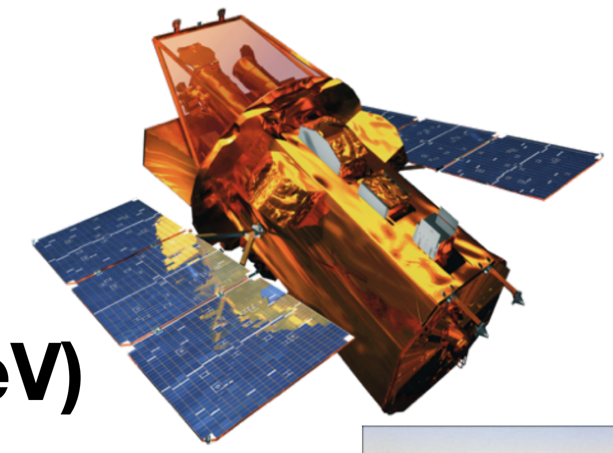

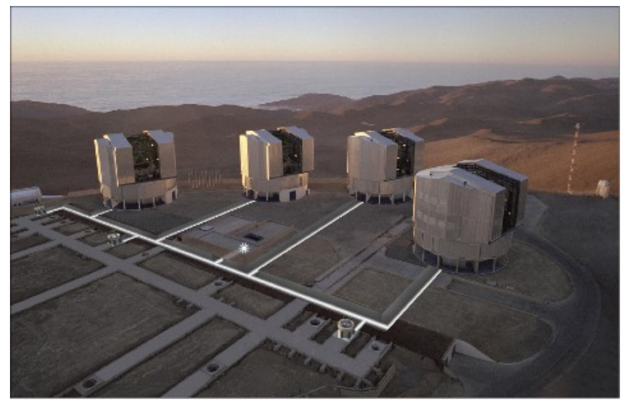

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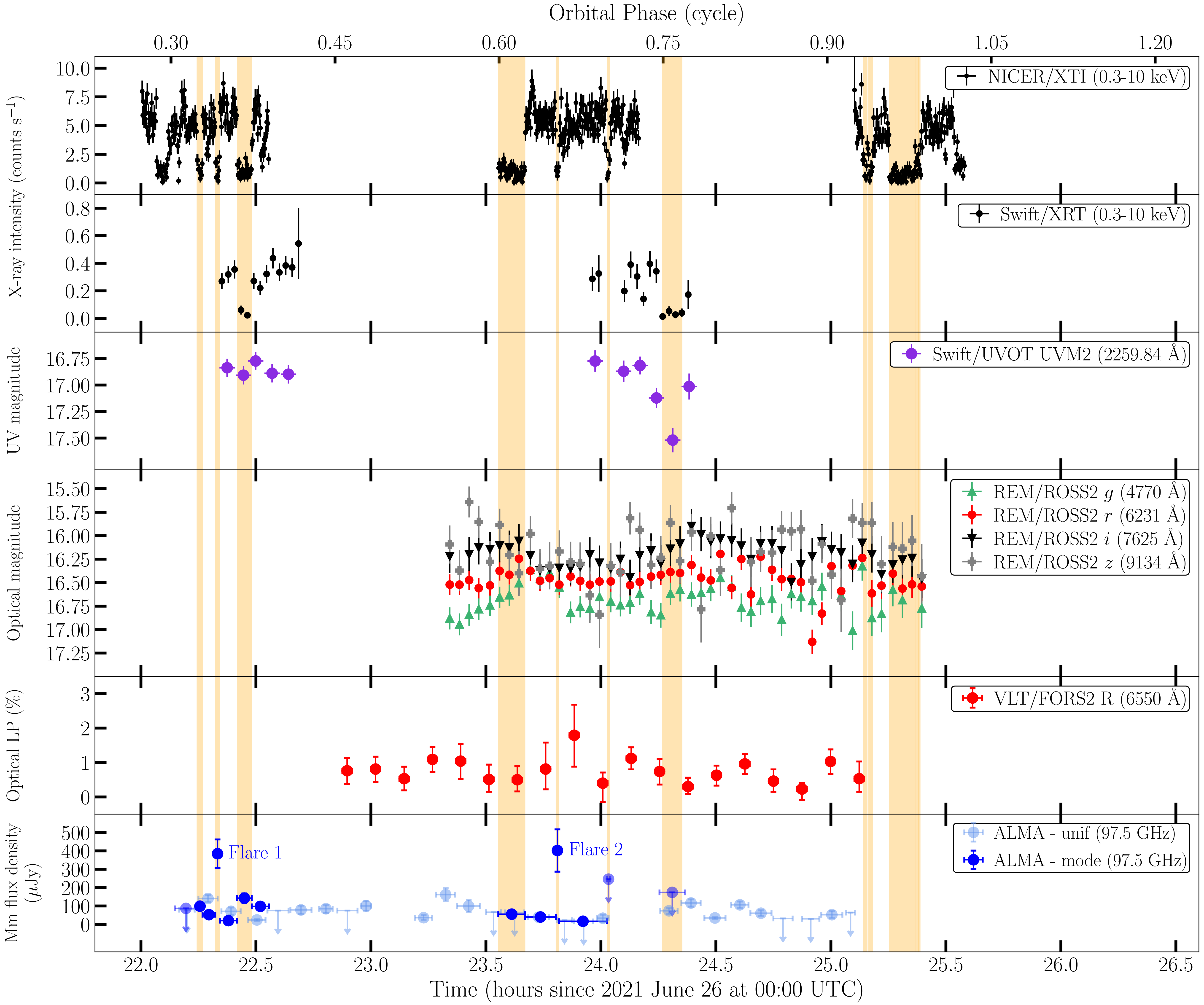

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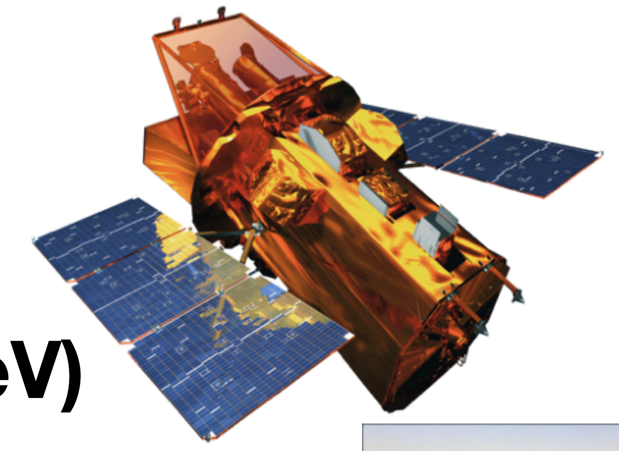

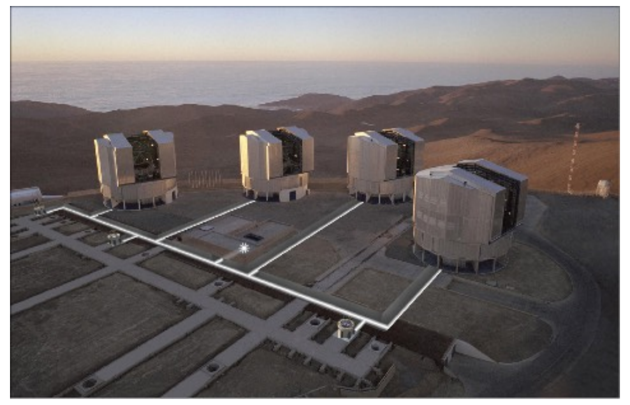

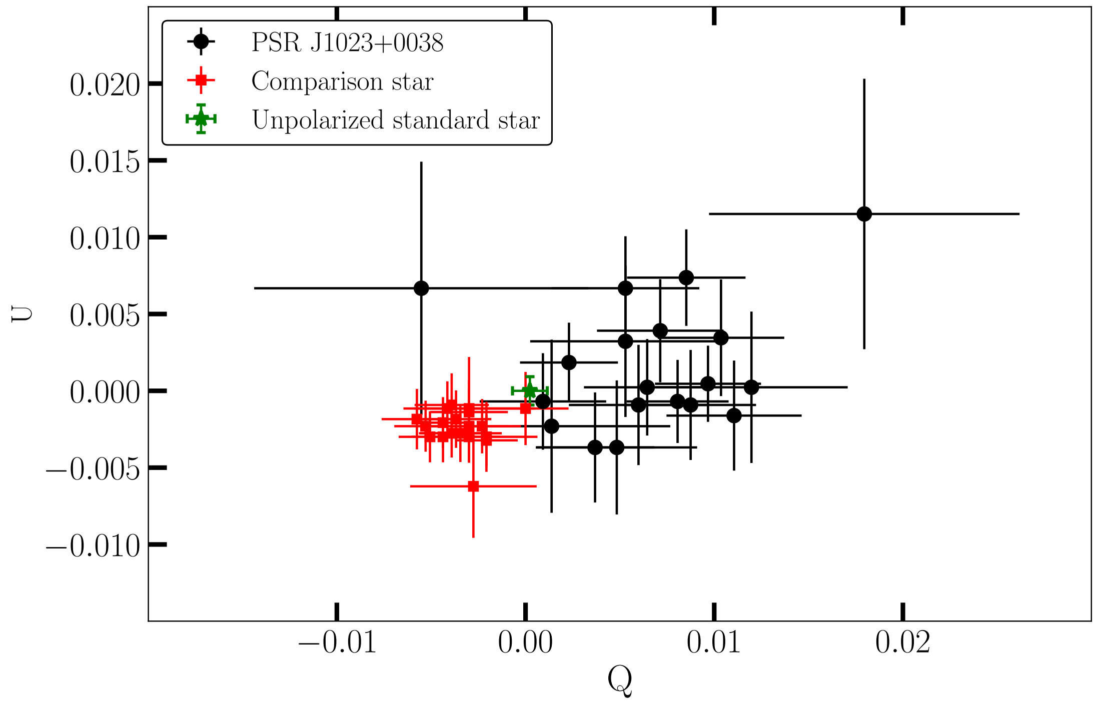

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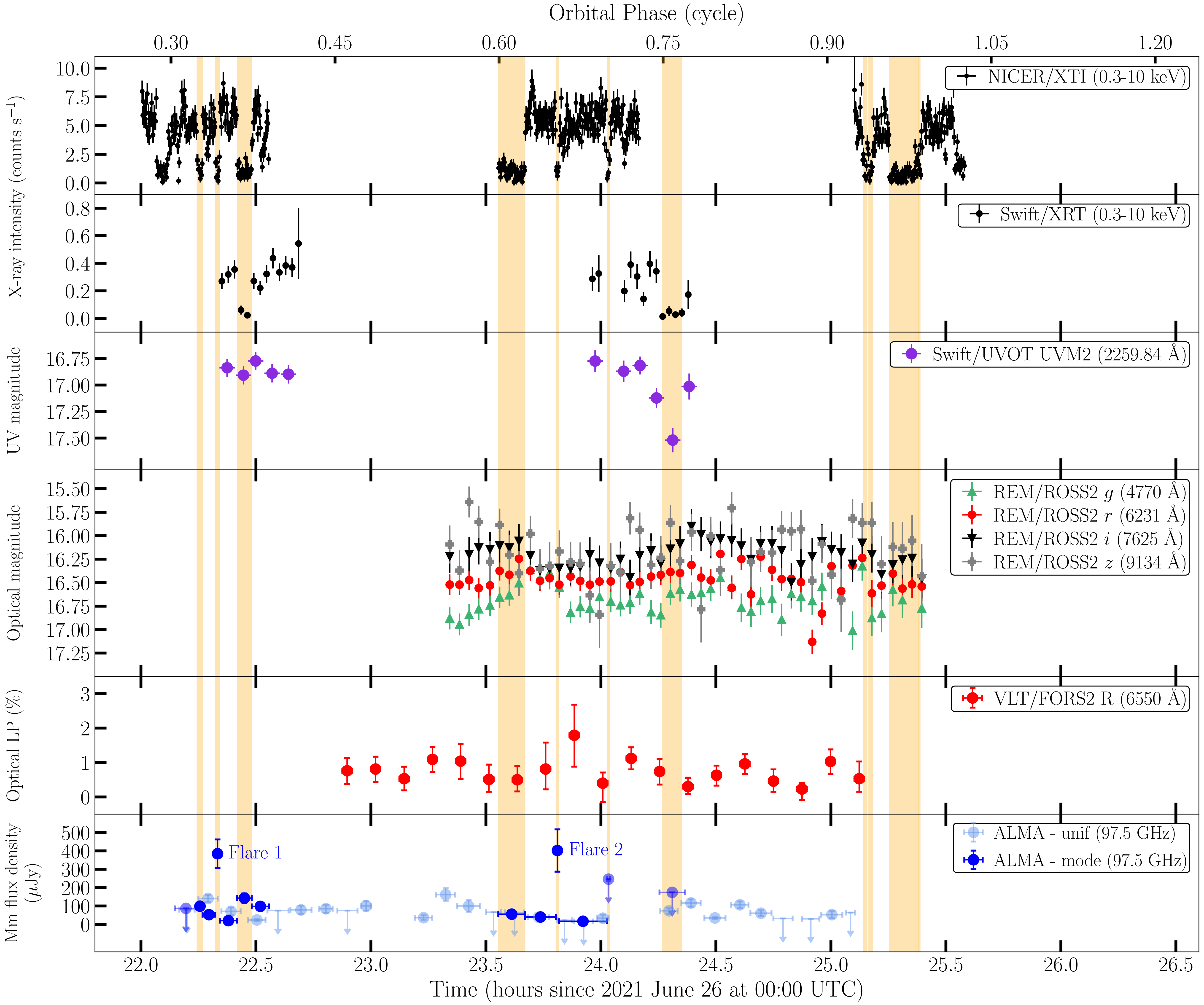

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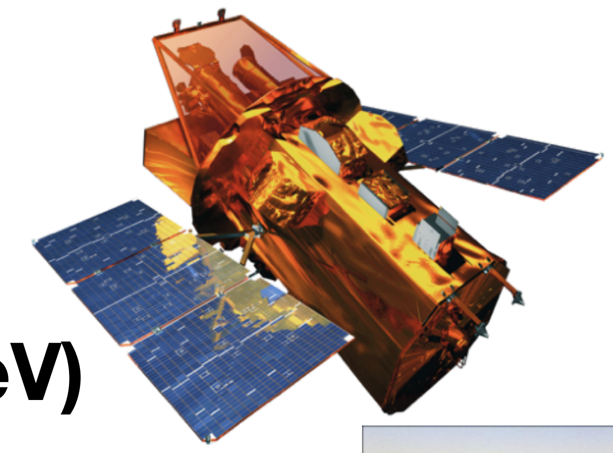

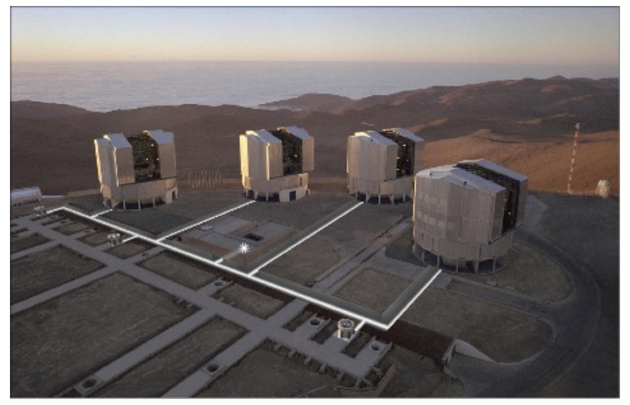

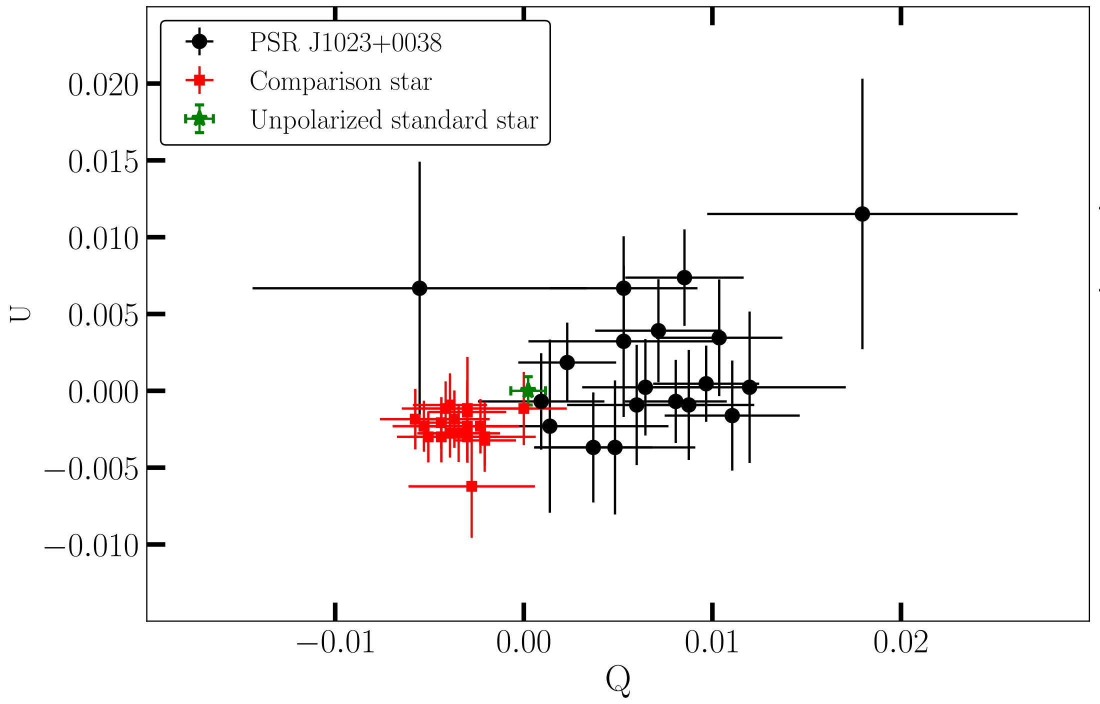

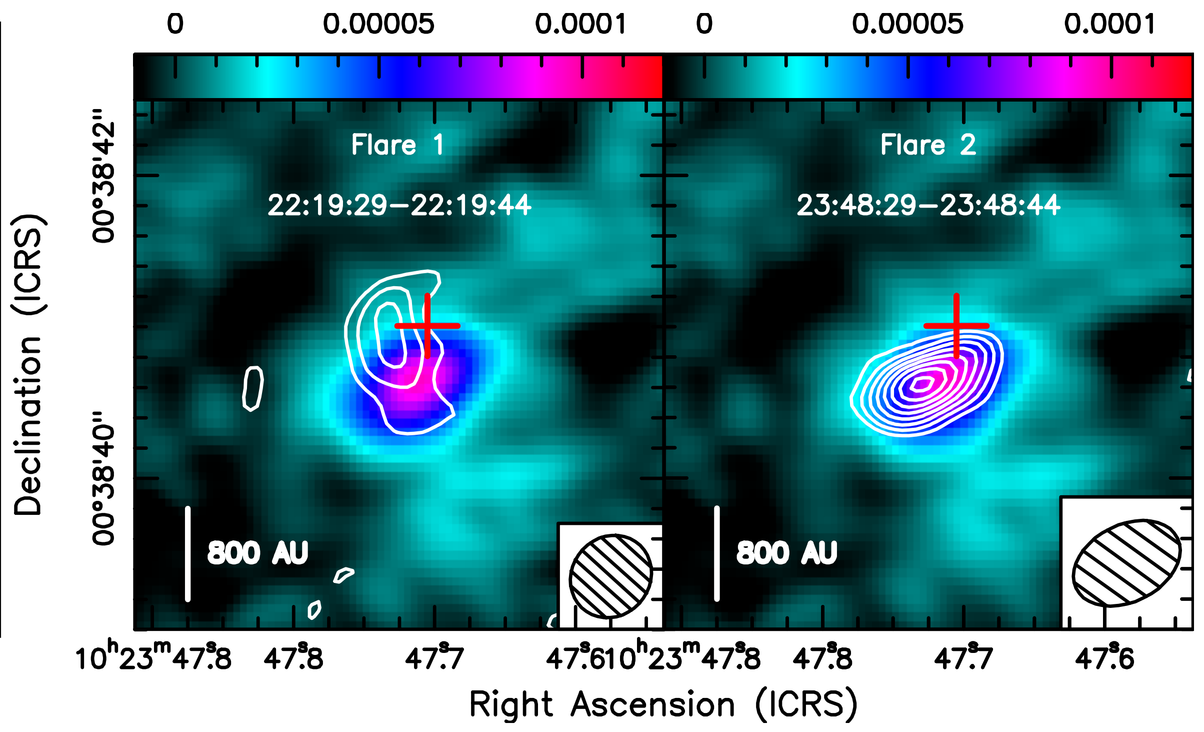

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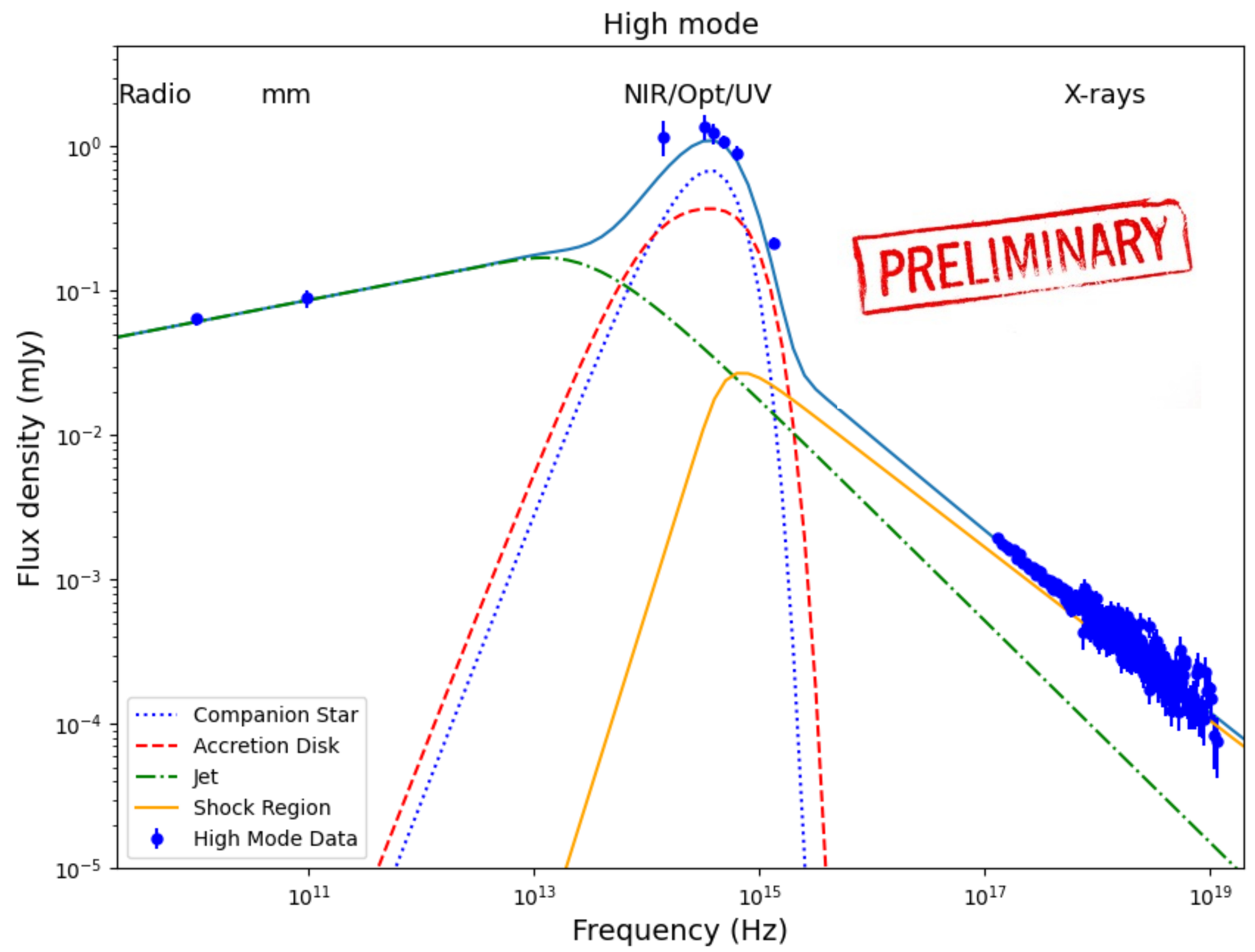
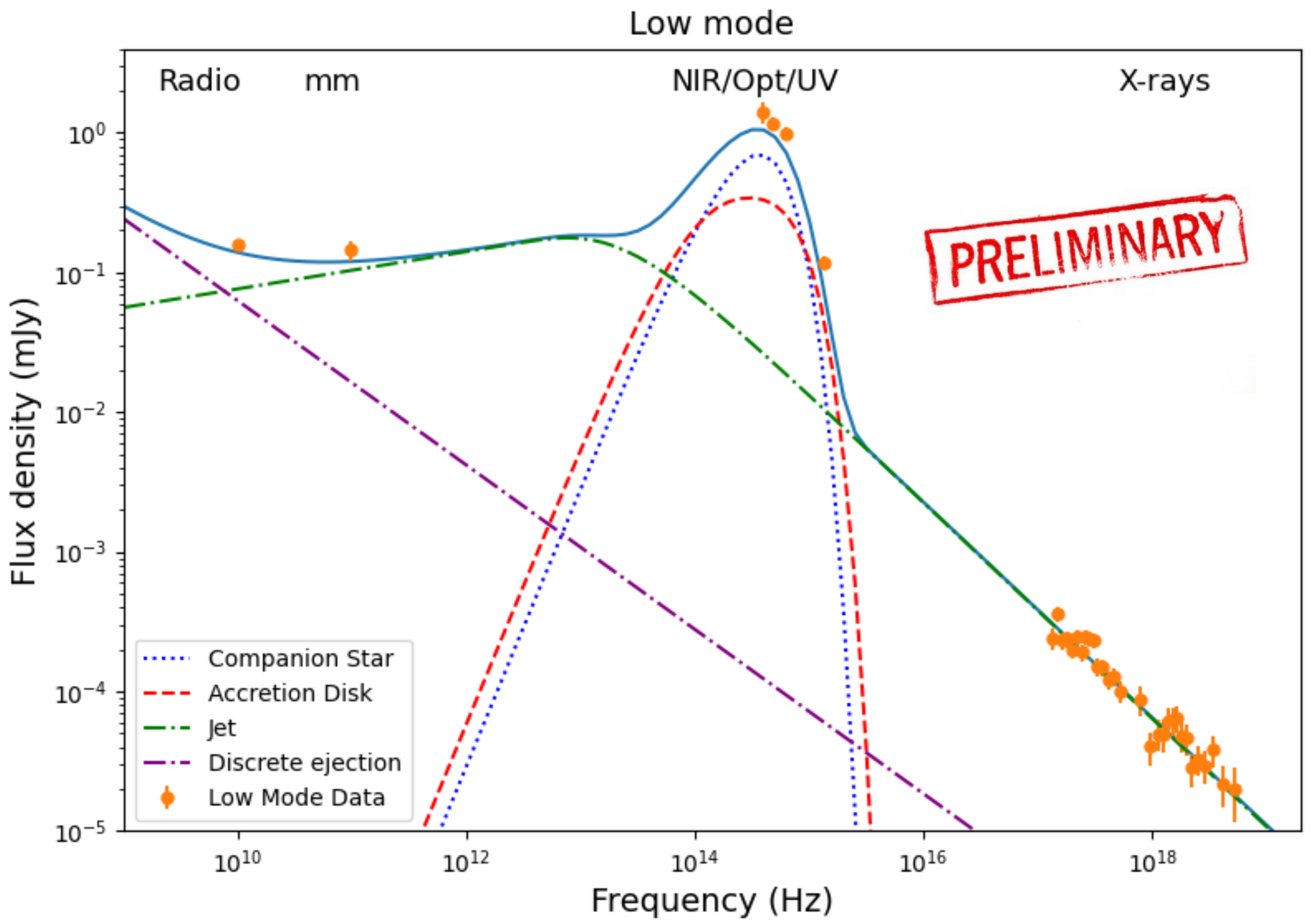
Highs and lows: a possible scenario





HIGH MODE

LOW MODE

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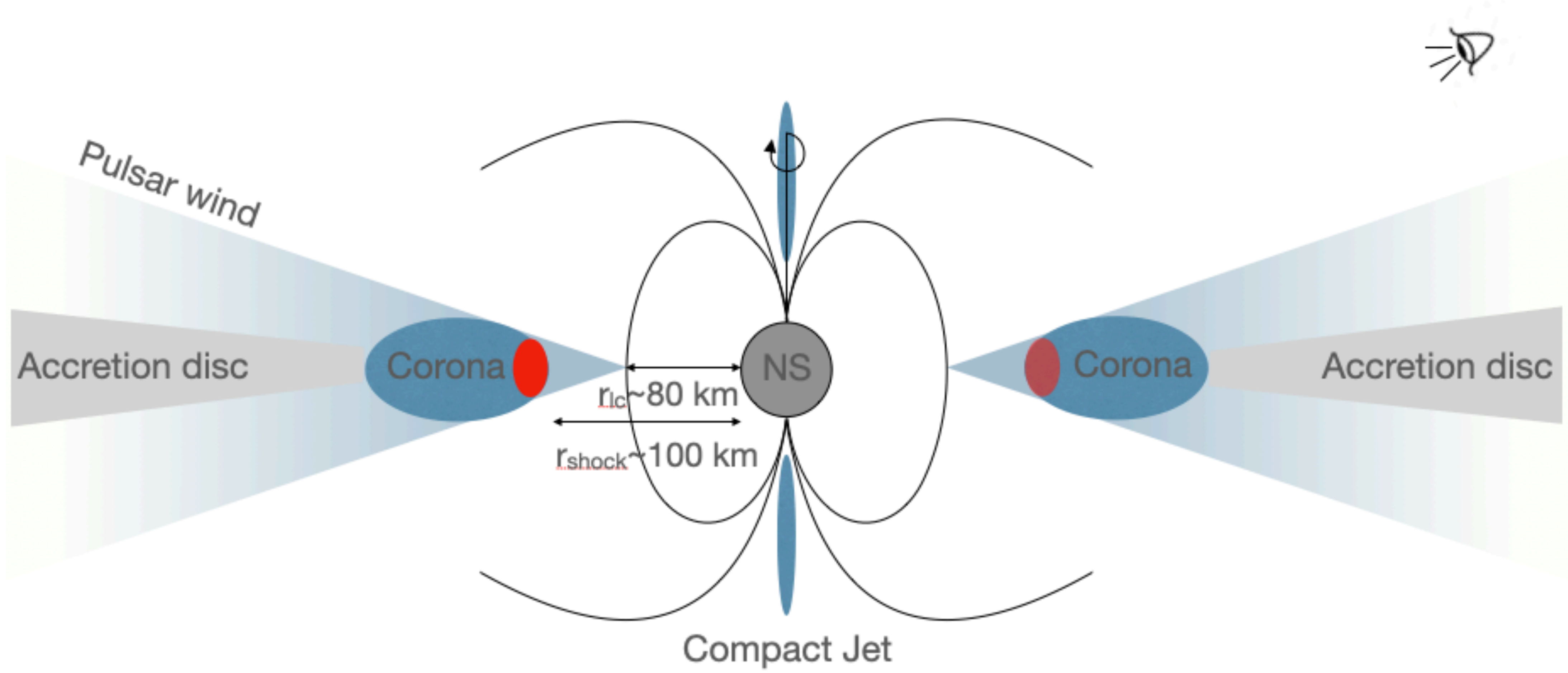
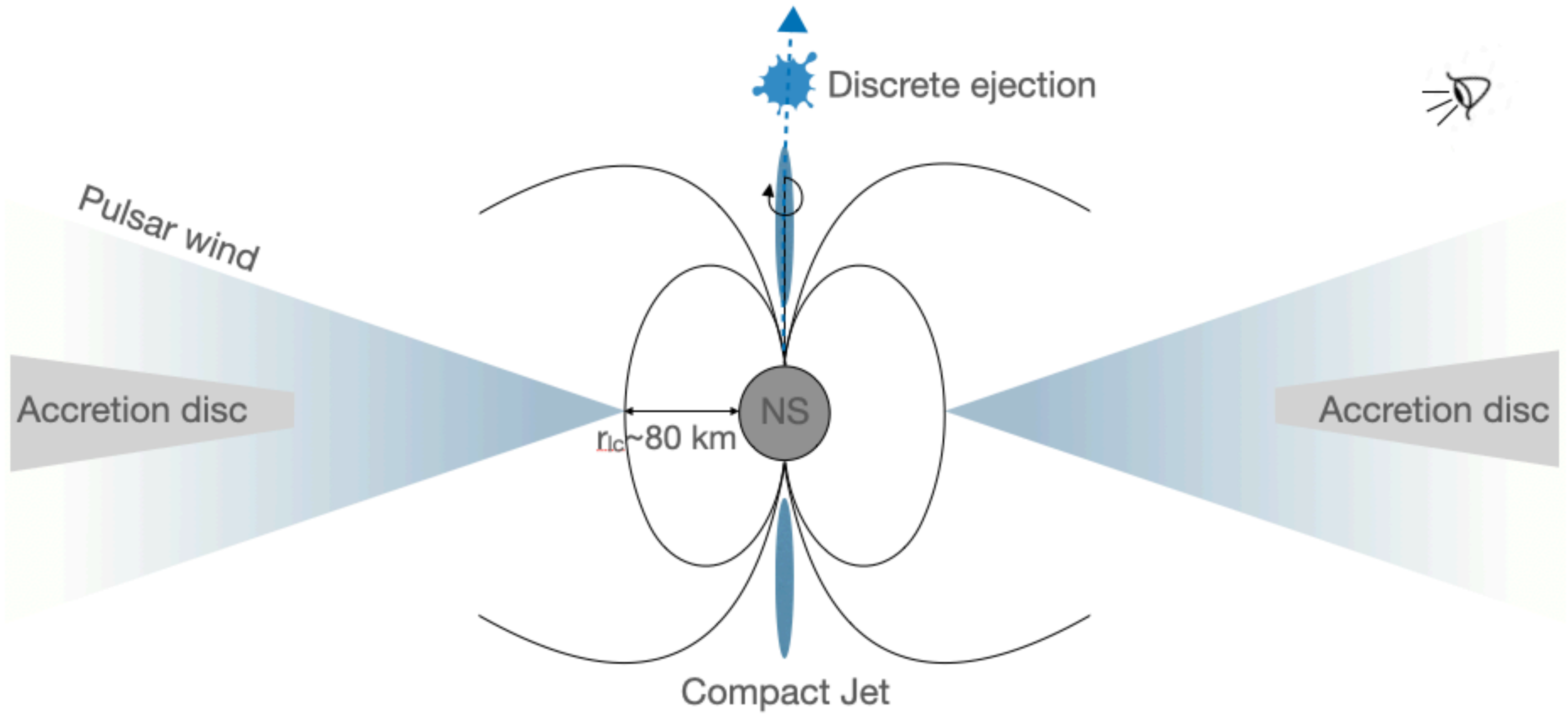
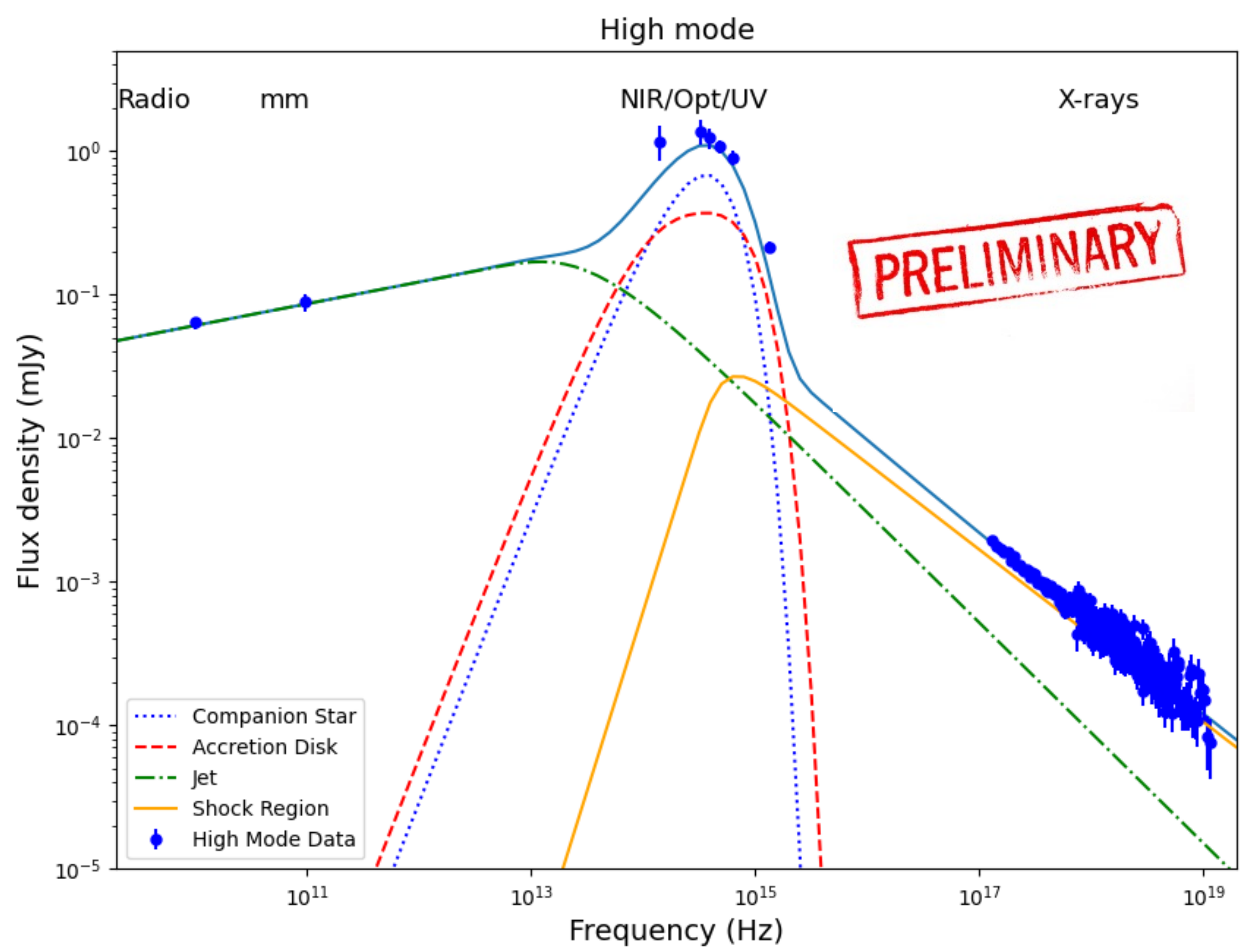
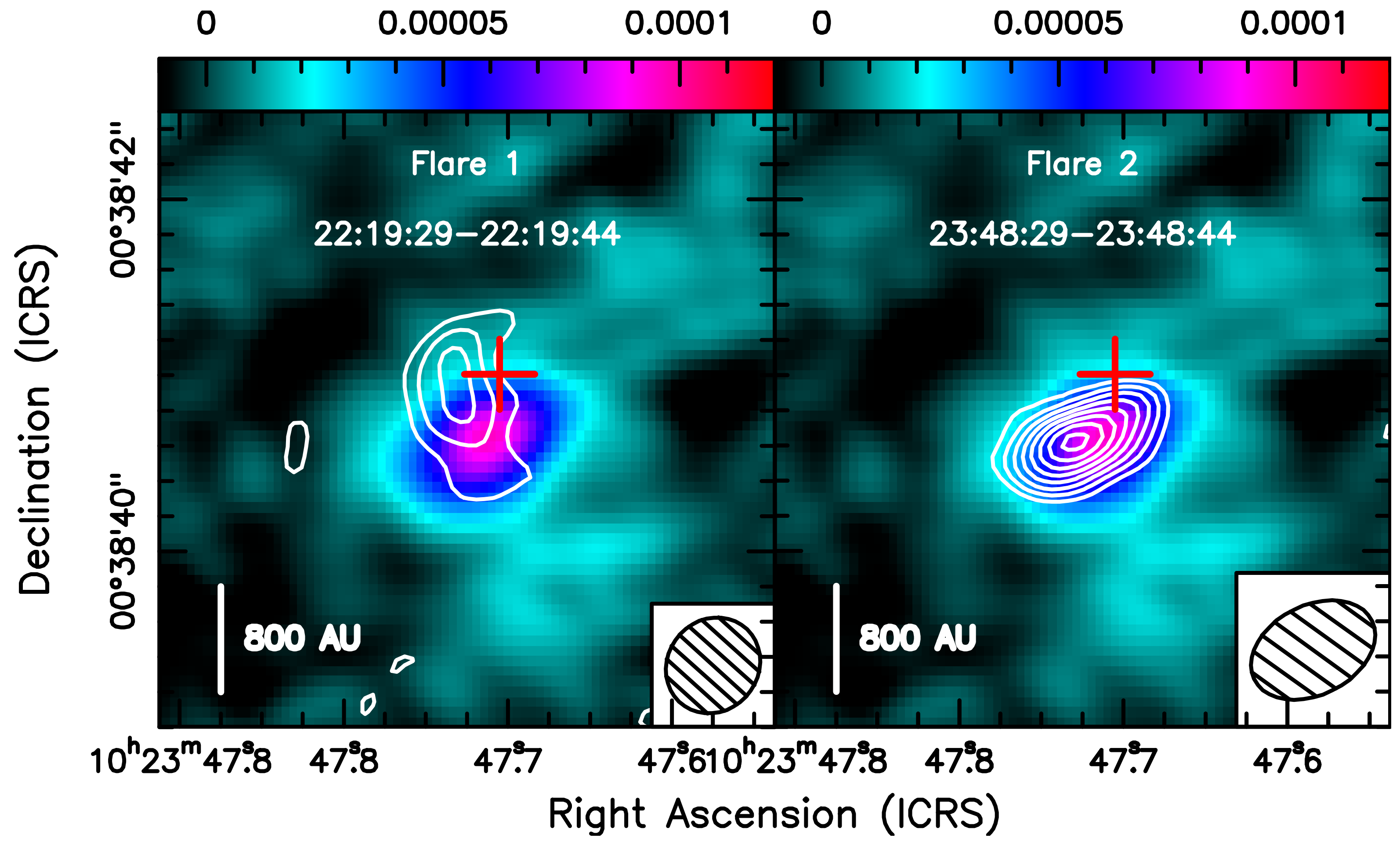


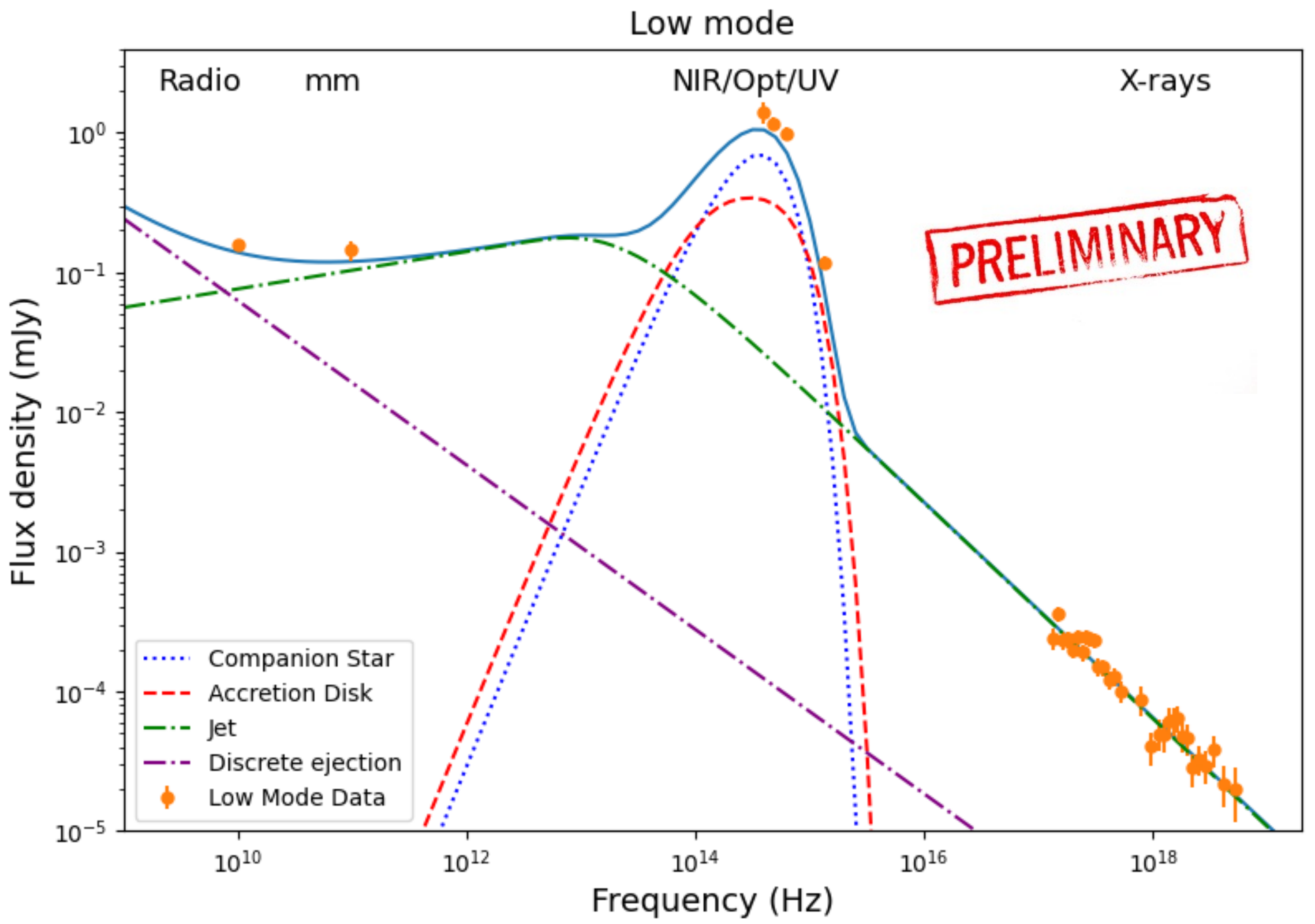


The shock moves out (of a factor ~20): its contribution in the X-rays is negligible.

Highs and lows: a possible scenario







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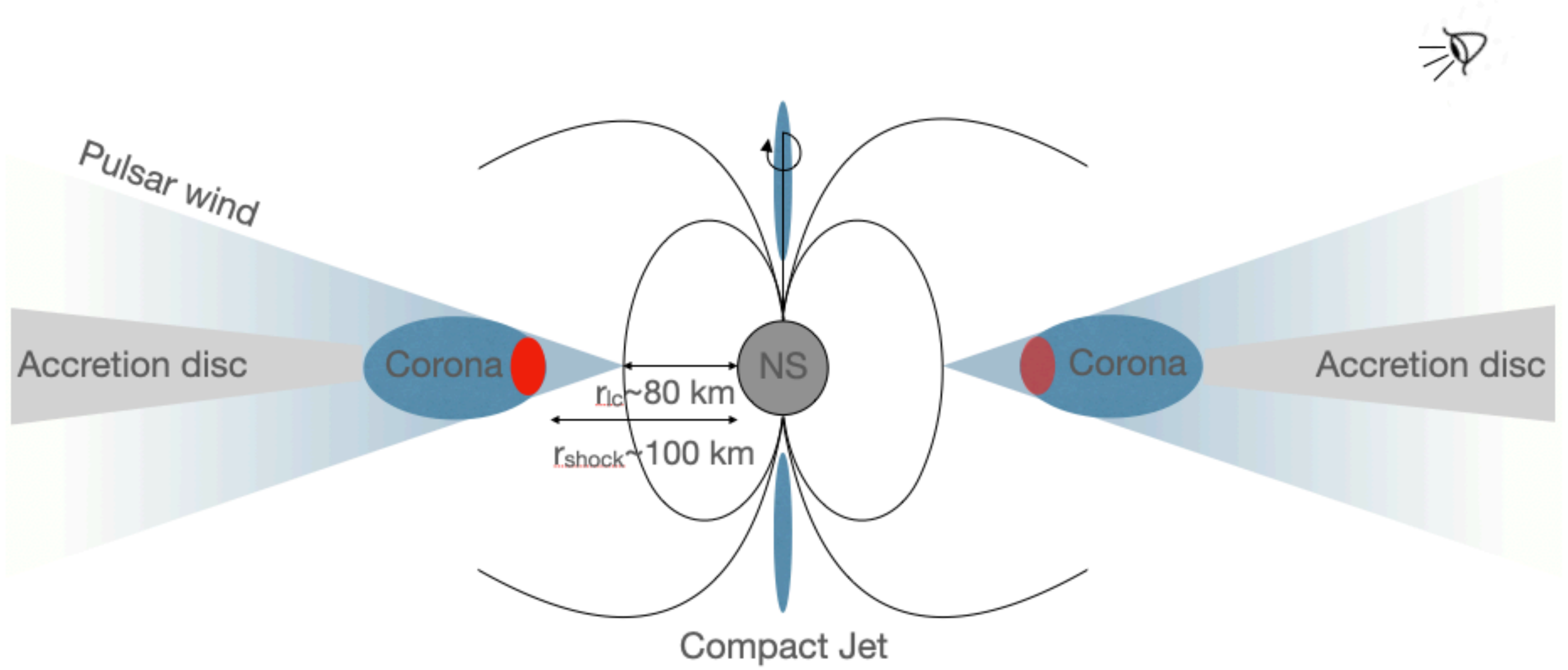

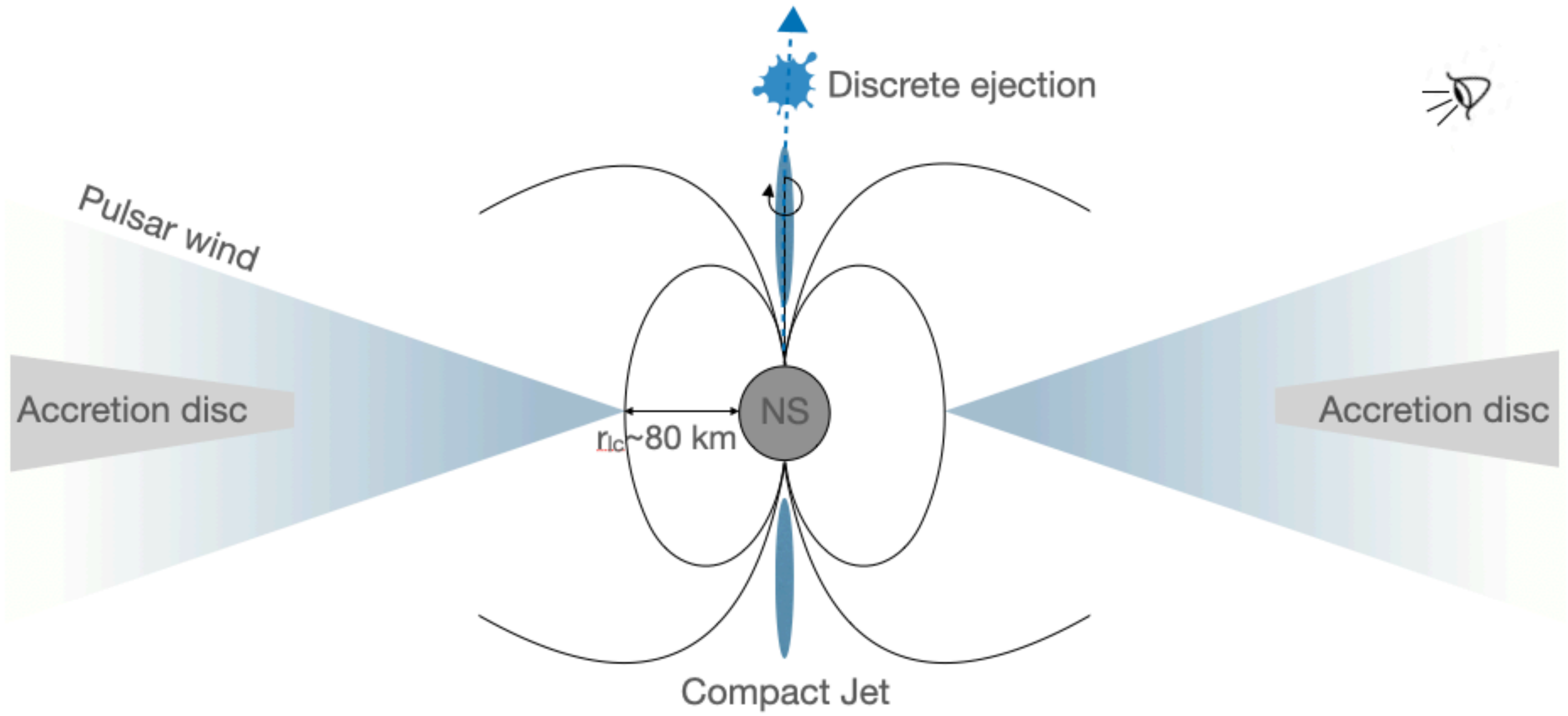

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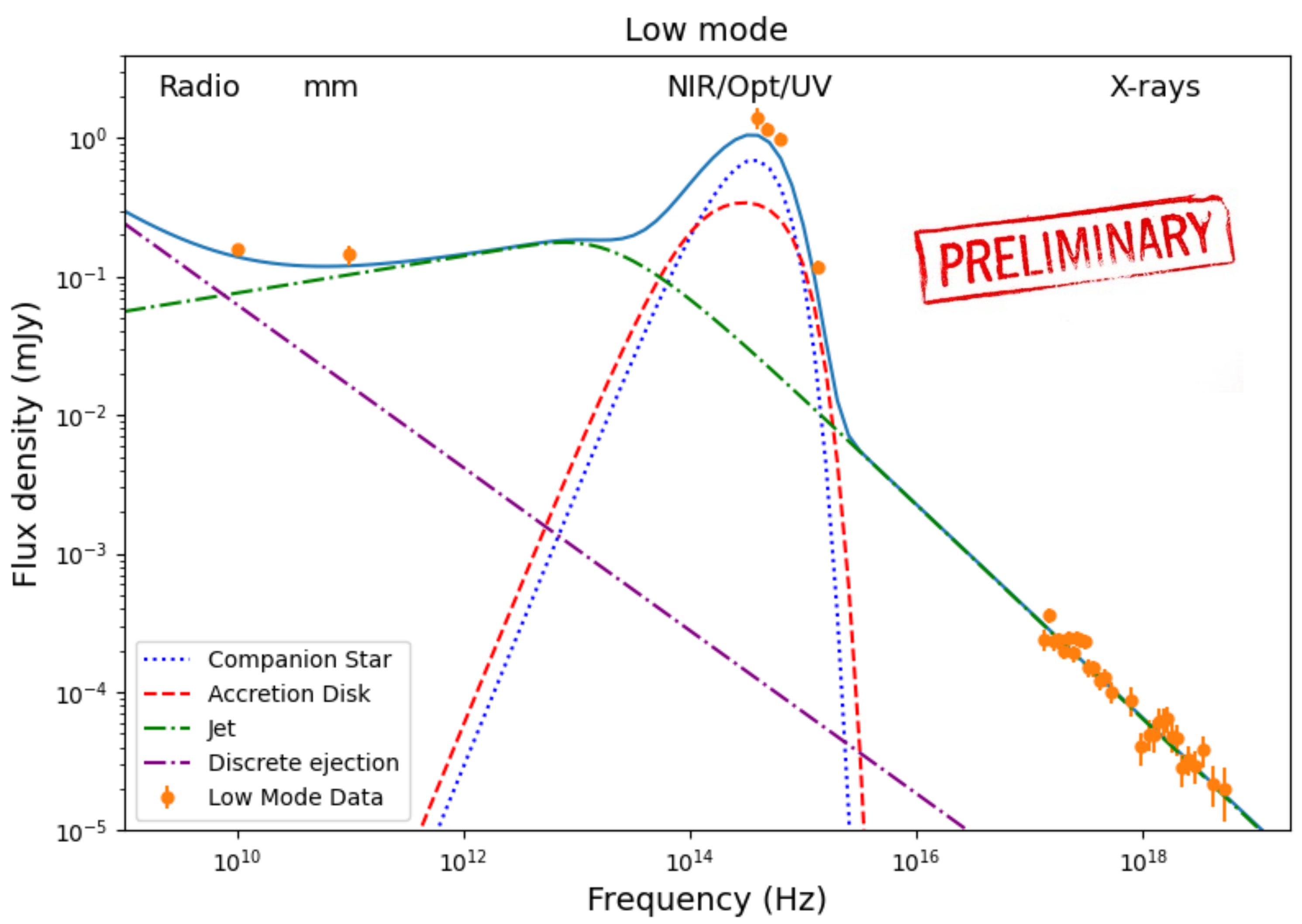
Polarization: possible origins & predictions

1 - Optically thin emission from the jet

Low average polarization (0.92%).
The compact jet is contributing up to 3% in r-band.
The jet would therefore be intrinsically polarized at 30%.
This would imply a highly ordered magnetic field at the base (~60%)

Prediction of X-ray LP due to the jet of ~12% in the IXPE band (in low mode) and 4% (in high mode): can be tested.



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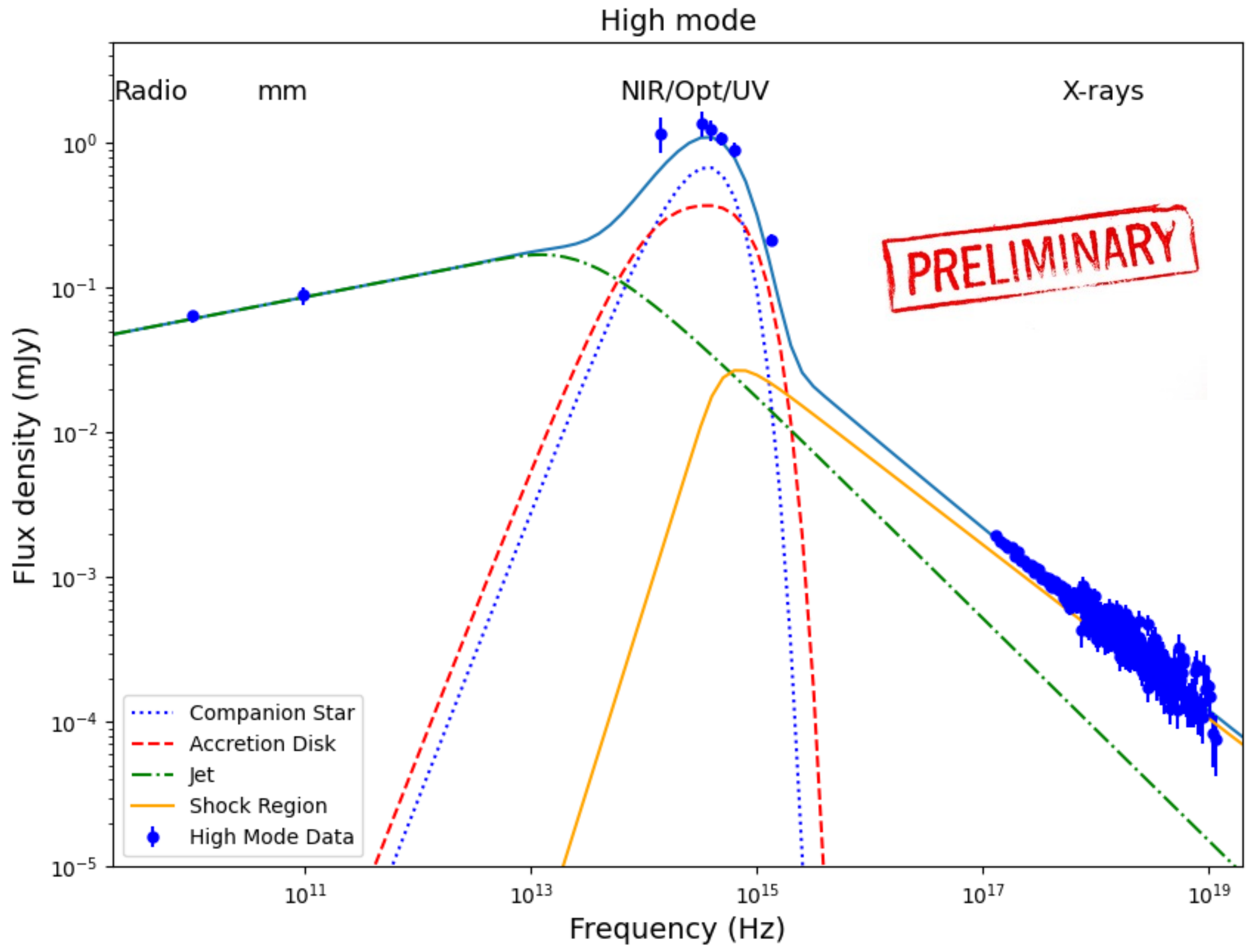

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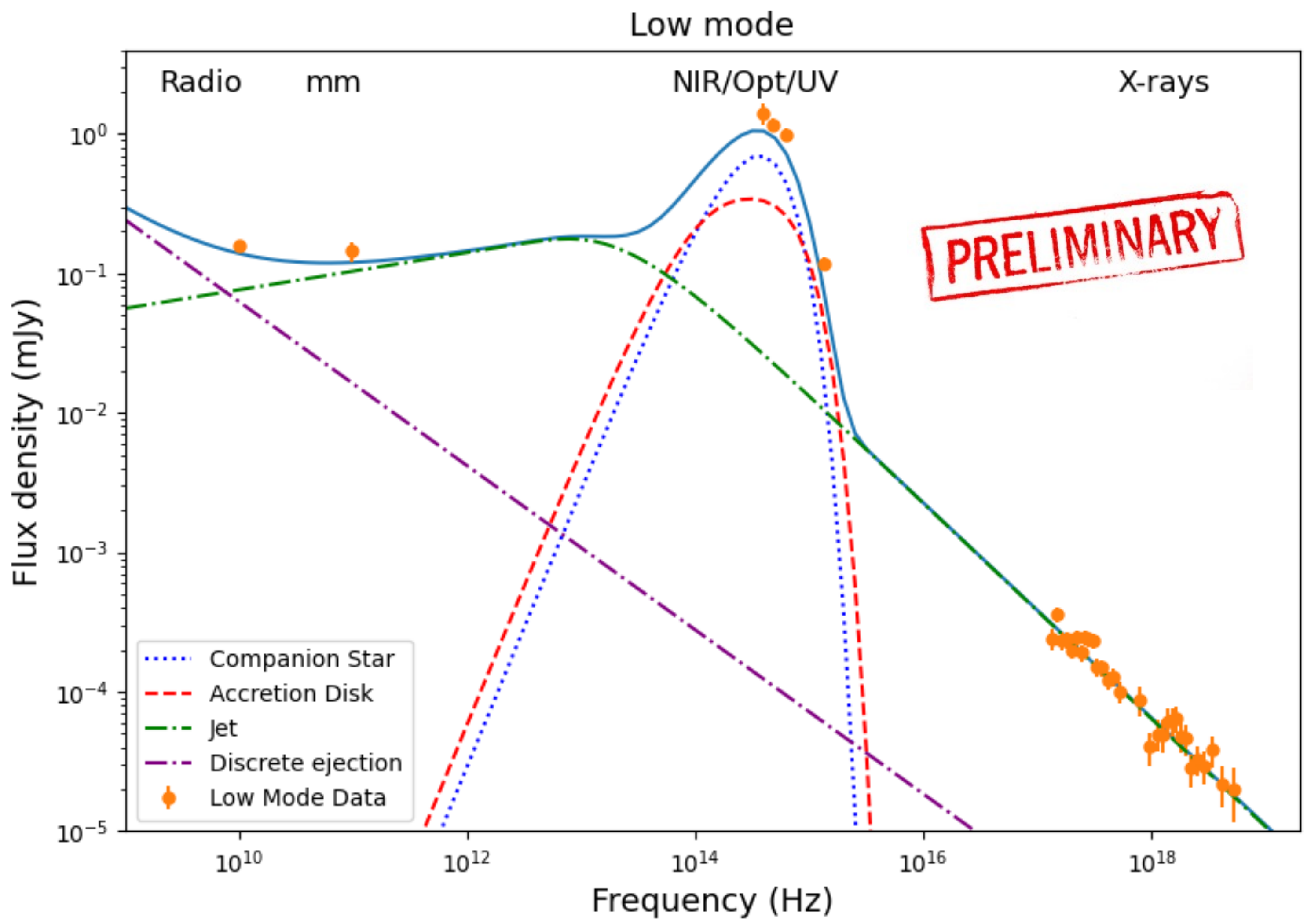
2 - Synchrotron in the region of shock

Scenario consistent with the ~lower P in low mode

$$P_{\text{low}} = (0.36^{+0.27}_{-0.35})\% \quad P_{\text{high}} = (0.65^{+0.43}_{-0.42})\%$$



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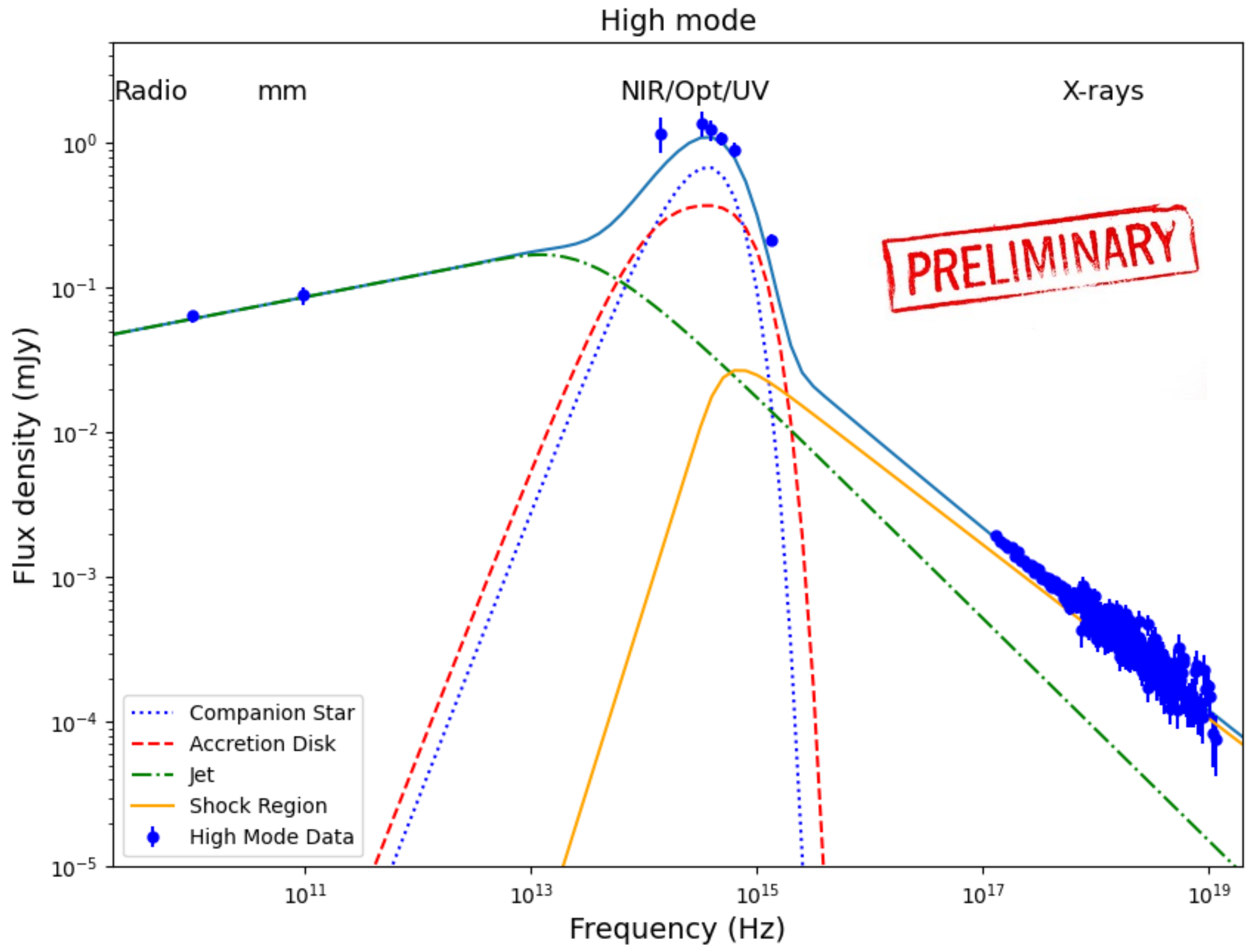

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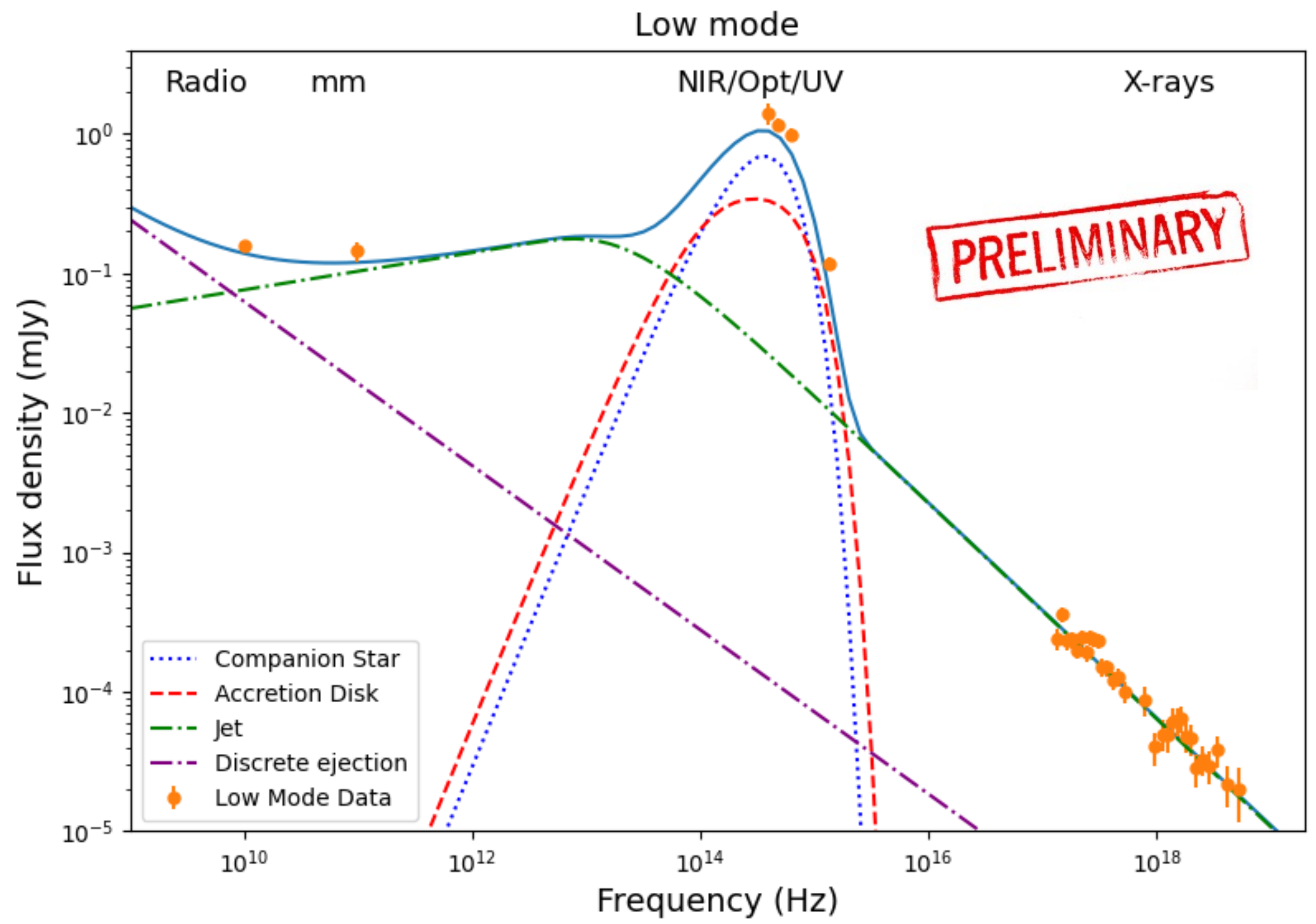
Shock contribution in r-band ~2.7%: intrinsic LP of ~23% in high mode.

<u>If polarization is due to the impulse only (1% of total)</u>, then the pulse will be ~90% polarized!

This can be tested with high time-resolution optical polarimetry.

Shock contribution of ~83% in X: X-ray pol of ~19% with IXPE.



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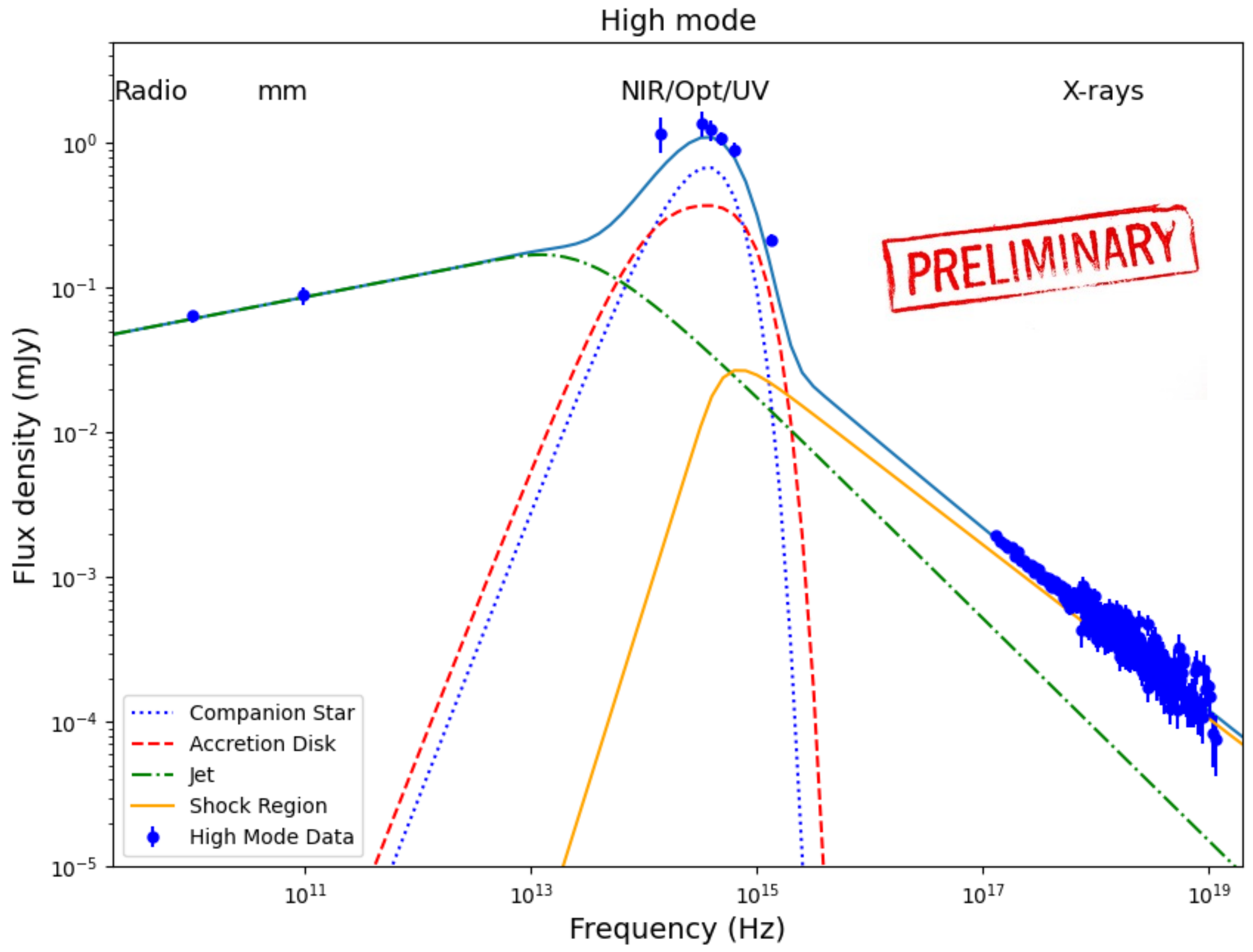


Conclusions

The ultimate campaign on PSR J1023 performed in 2021 was extremely successful.

We put together a new scenario which can explain most of the phenomenology:

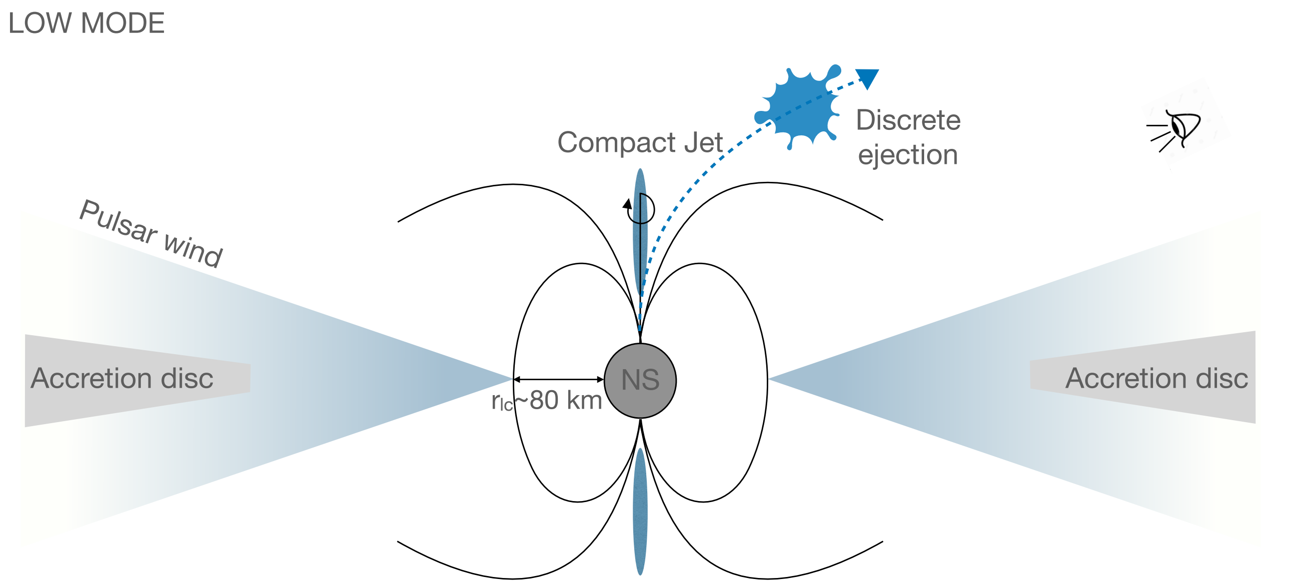
- **Radio/X-ray anti-correlation**
- **Flares in the mm at the high/low mode switching**
- **Mode switching in the X-rays**
- **Optical - to - X-rays ms pulsations**
- **Polarization in the optical**

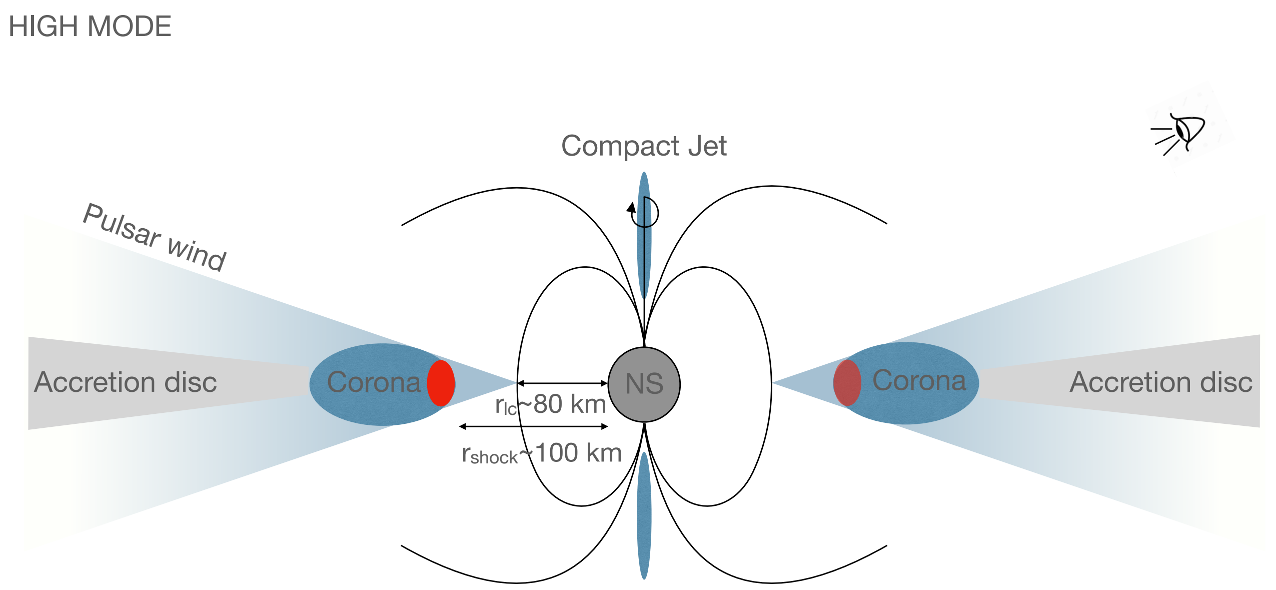
We report on the first observations in the mm of a tMSP.

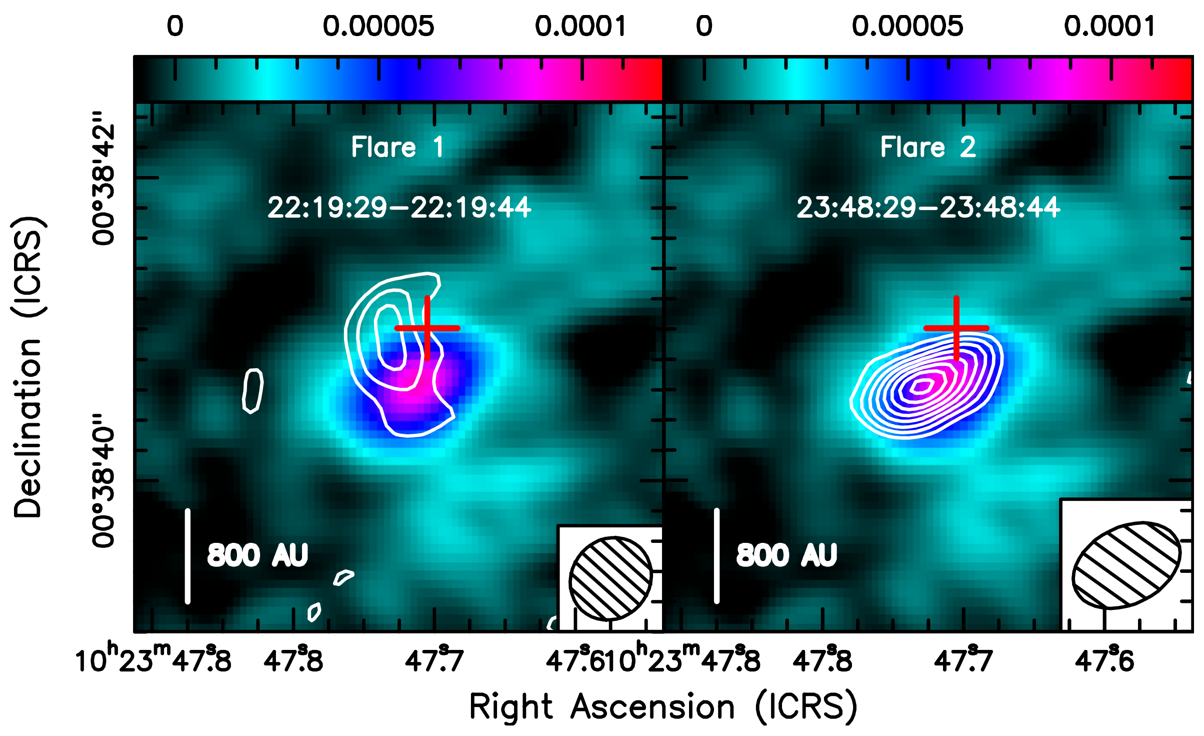
We explain why 1023 has an anomalous behavior on the radio/X-ray luminosity plane.

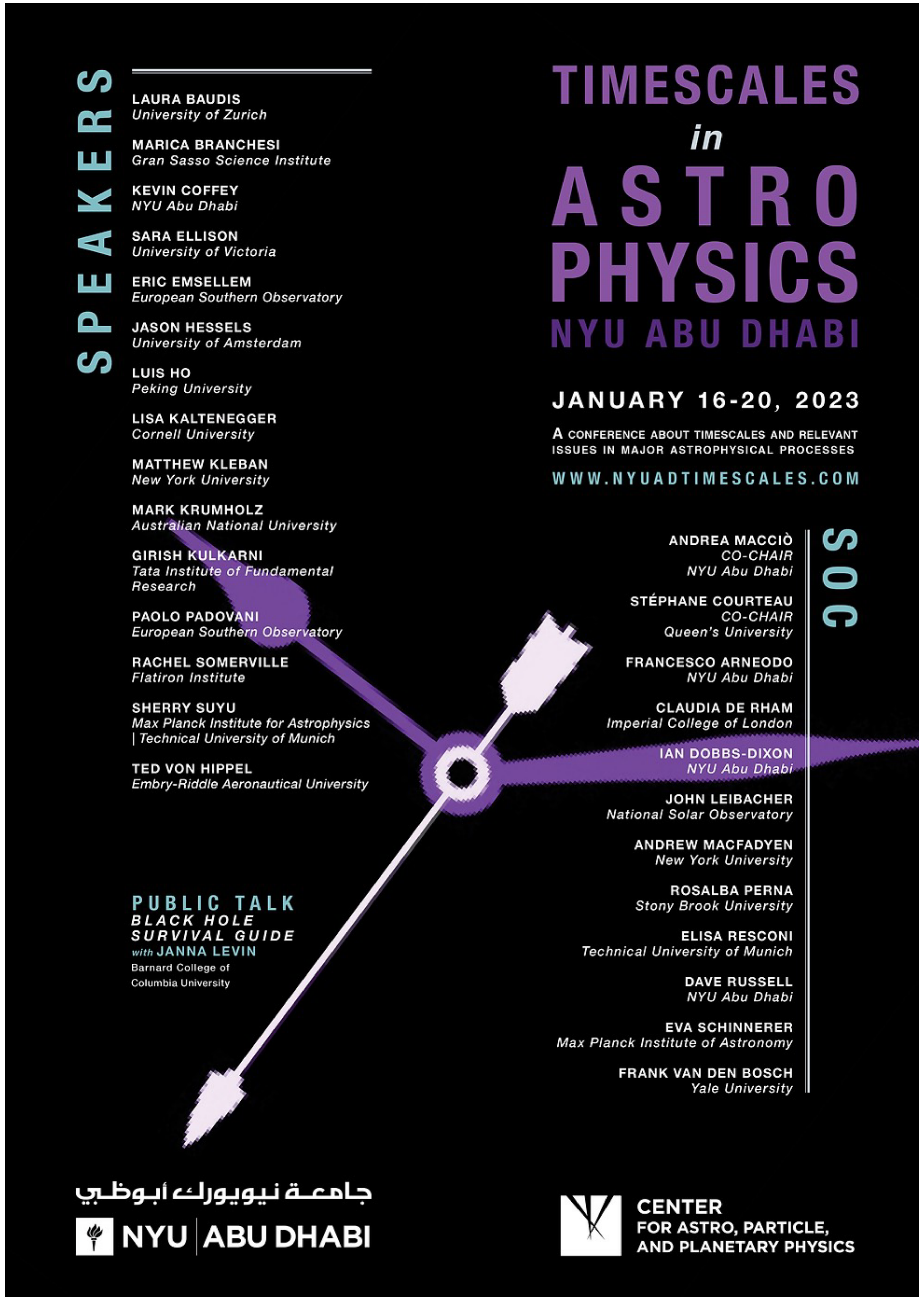
We could make predictions for X-ray polarization and high time-resolution optical polarimetry.

Future missions/instruments/campaign will be able to test the predictions and possibly confirm the scenario.



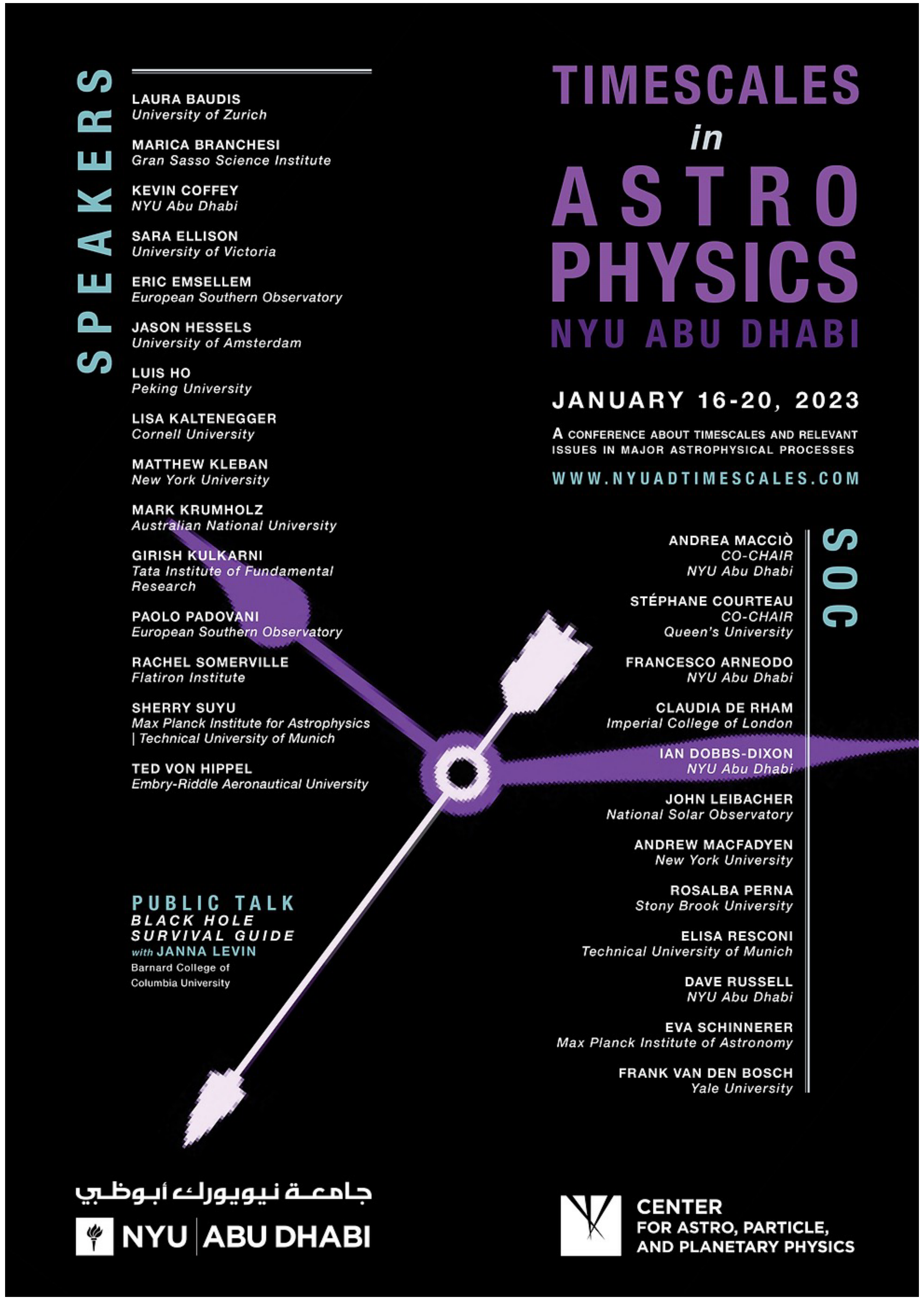






SAVE THE DATE!

THANKS!



SAVE THE DATE!

16-20 January 2023, Abu Dhabi (NYU campus)

Deadline for abstract submission extended: 9 October 2022

THANKS!