# Observations of the accreting x-ray pulsar GX 301-2 with the *X-Calibur* hard X-ray polarimetry mission

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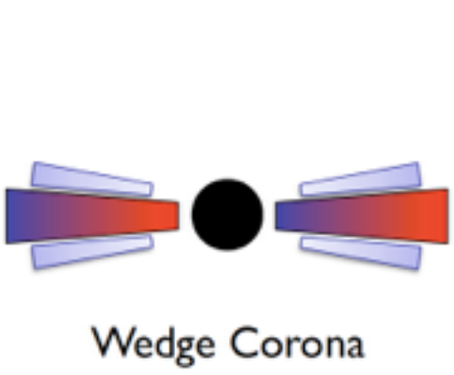
Multiwavelength Collaborators: K. Forster, F. Fürst, K. Gendreau, B. W. Grefenstette, V. Grinberg, P.  Jenke, H. Krimm, E. Kuulkers, J. Miller, H. Miyasaka, M. Nowak, C. Sanchez.

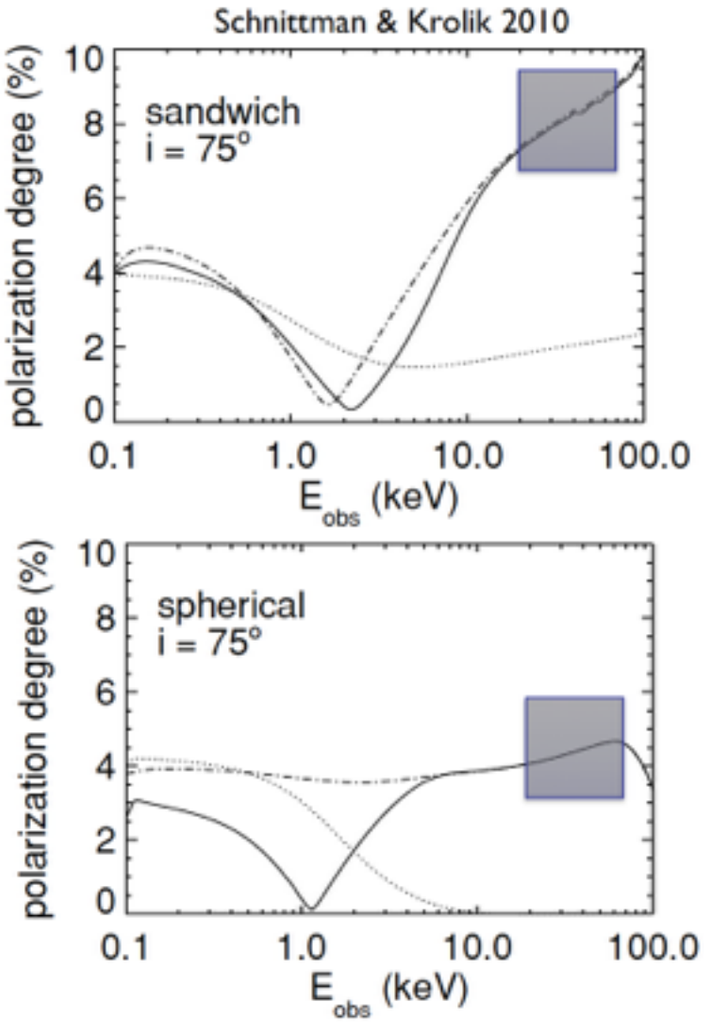

HEPRO VII

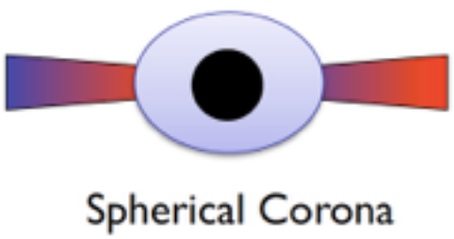
Barcelona, July 9-12 2019

# X-ray polarization

Accreting stelar-mass black holes



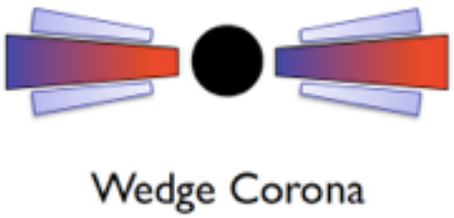



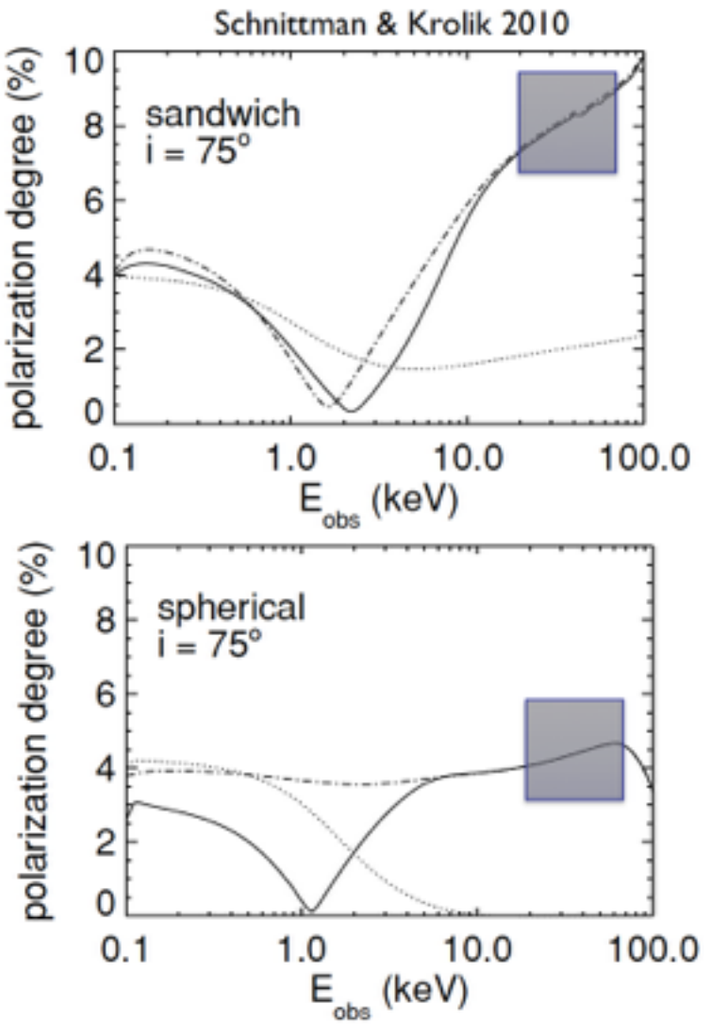



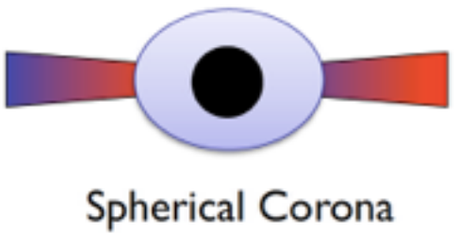

X-ray polarization observations can contain the geometry and location of the X-ray corona

# X-ray polarization

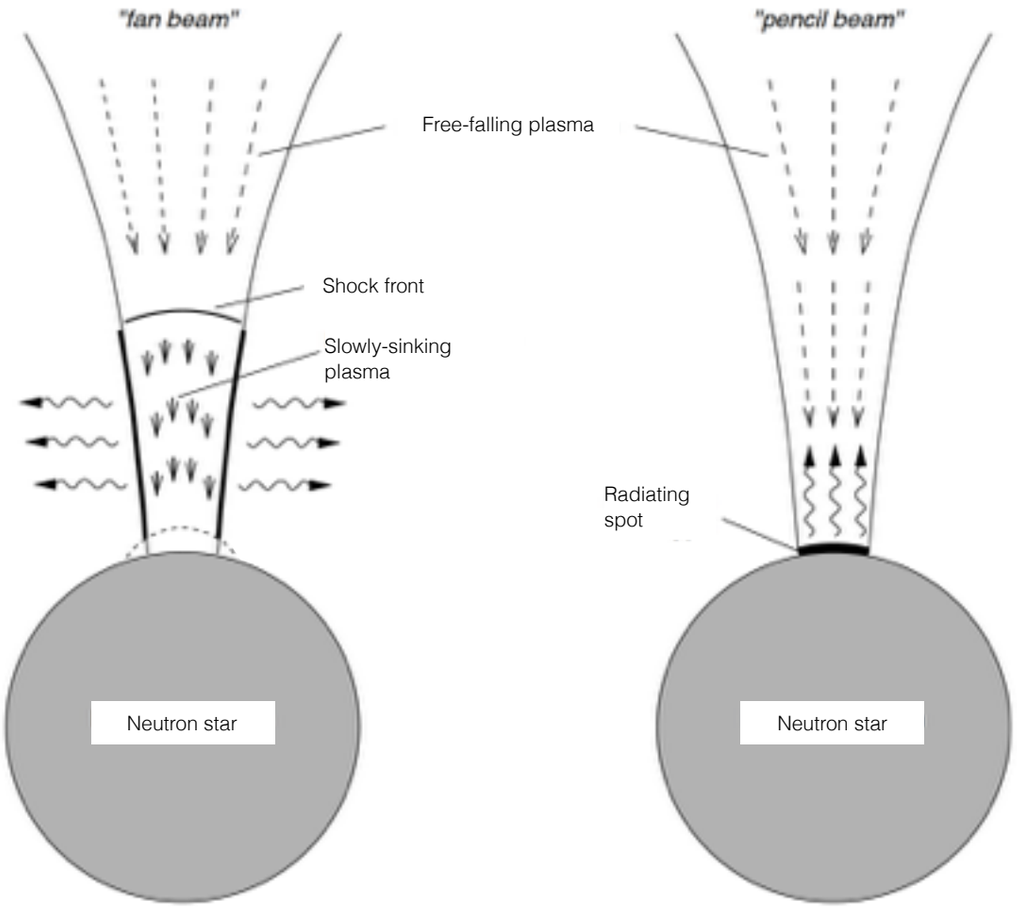
## Accreting stelar-mass black holes



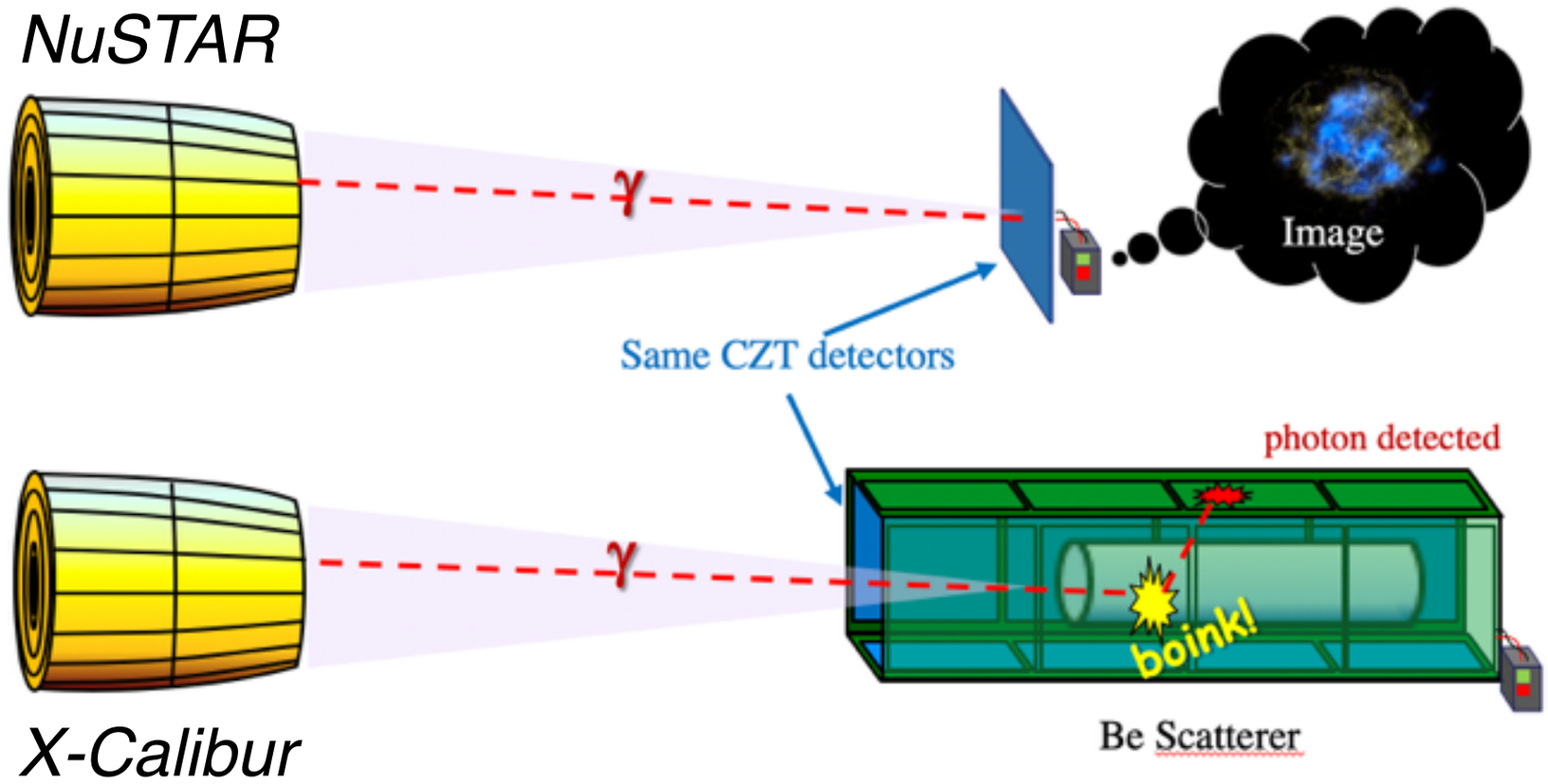

## Accreting neutron stars




X-ray polarization observations can contain the geometry and location of the X-ray corona

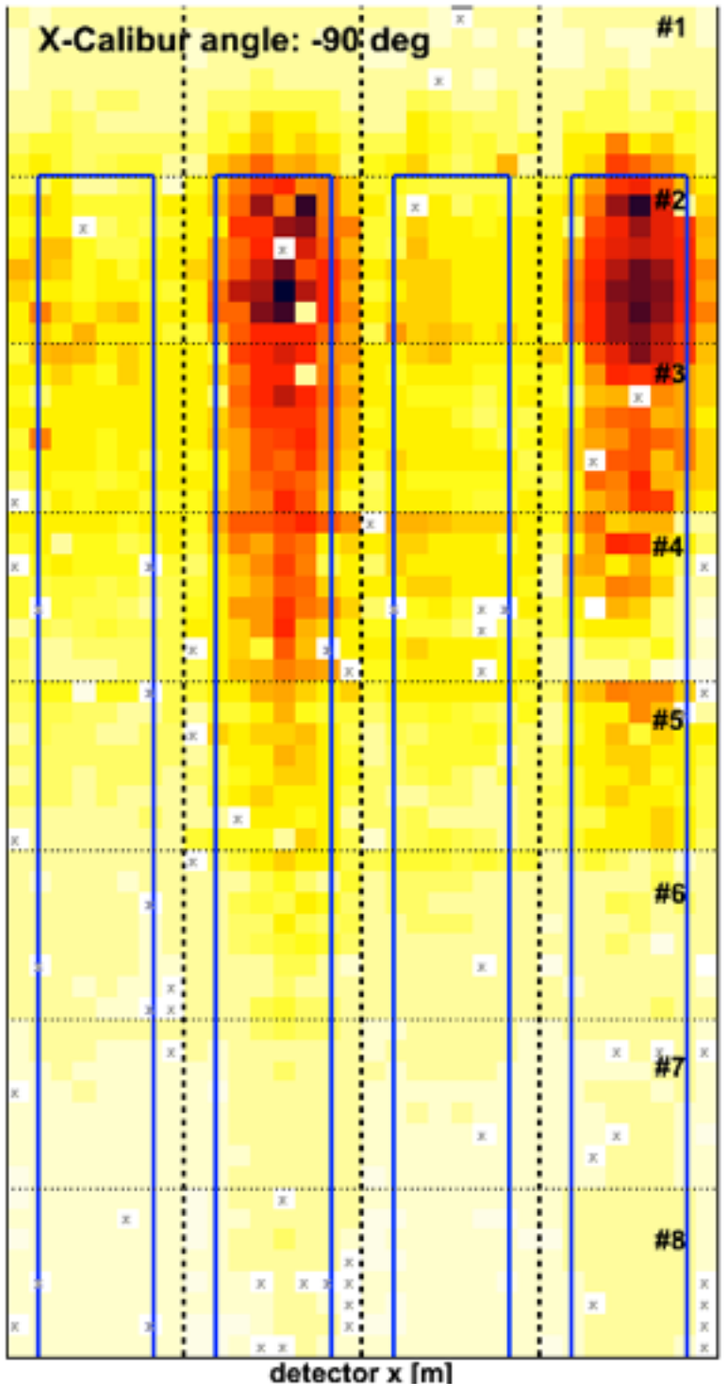
Discriminate between radiation models in accreting X-ray pulsars

# X-Calibur optics and scattering polarimeter

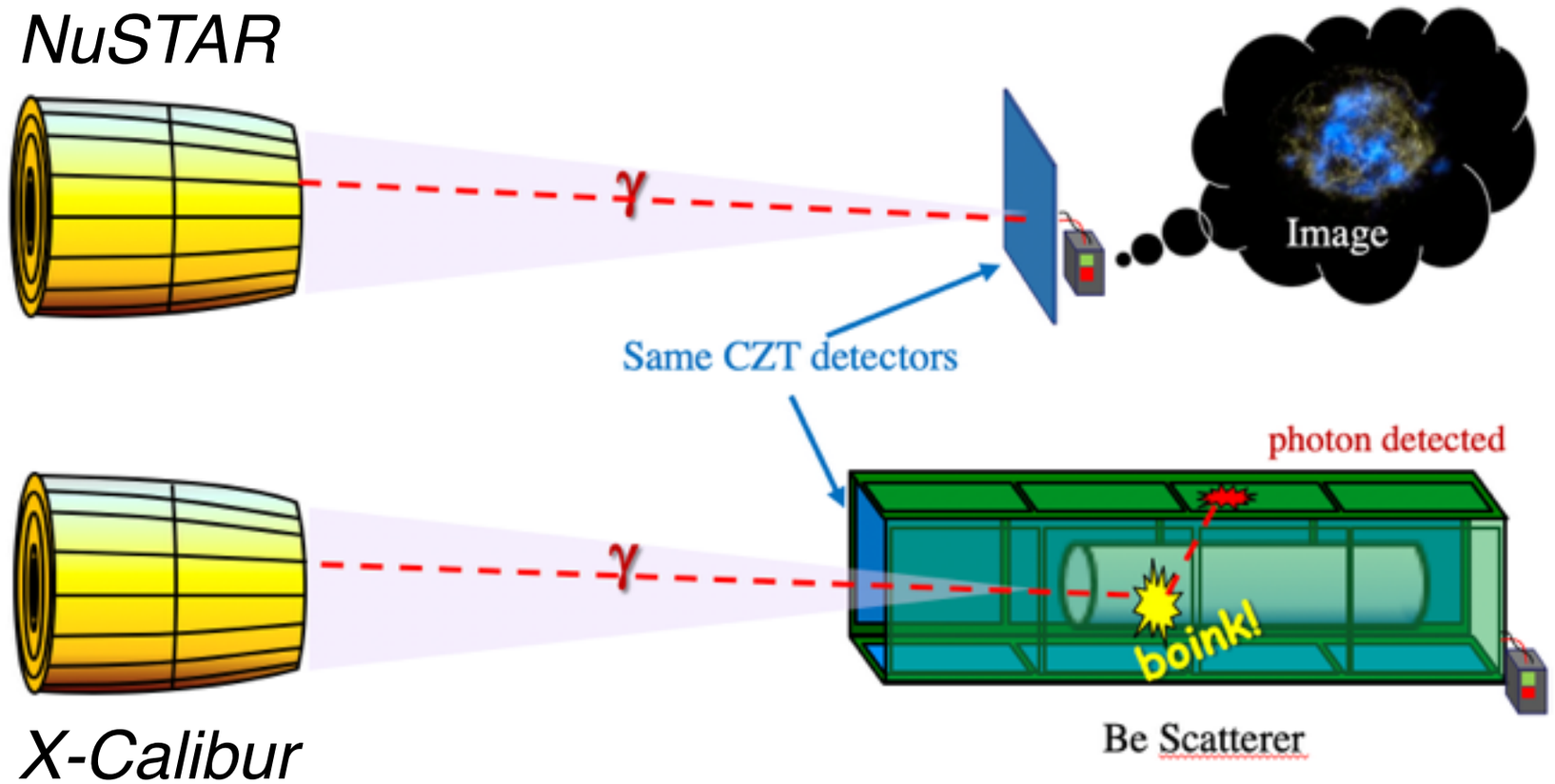



**Energy range:** 15 - 60 keV
**Effective area:** ~100cm$^2$ @ 20 keV
**Sensitivity to polarization (5σ):**
5% polarization on 1 Crab source in 10 days.
30% polarization on 200 mCrab source in 1 day.

# X-Calibur optics and scattering polarimeter




*Beilicke+2014*




*X-Calibur*

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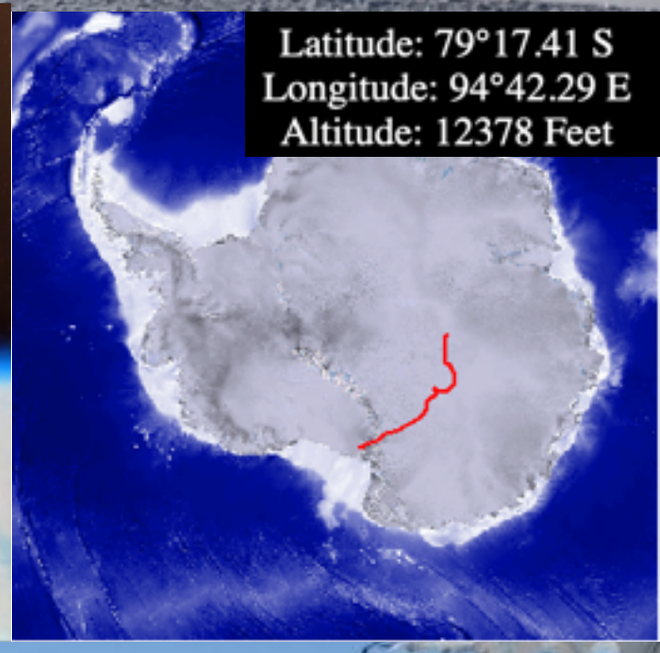
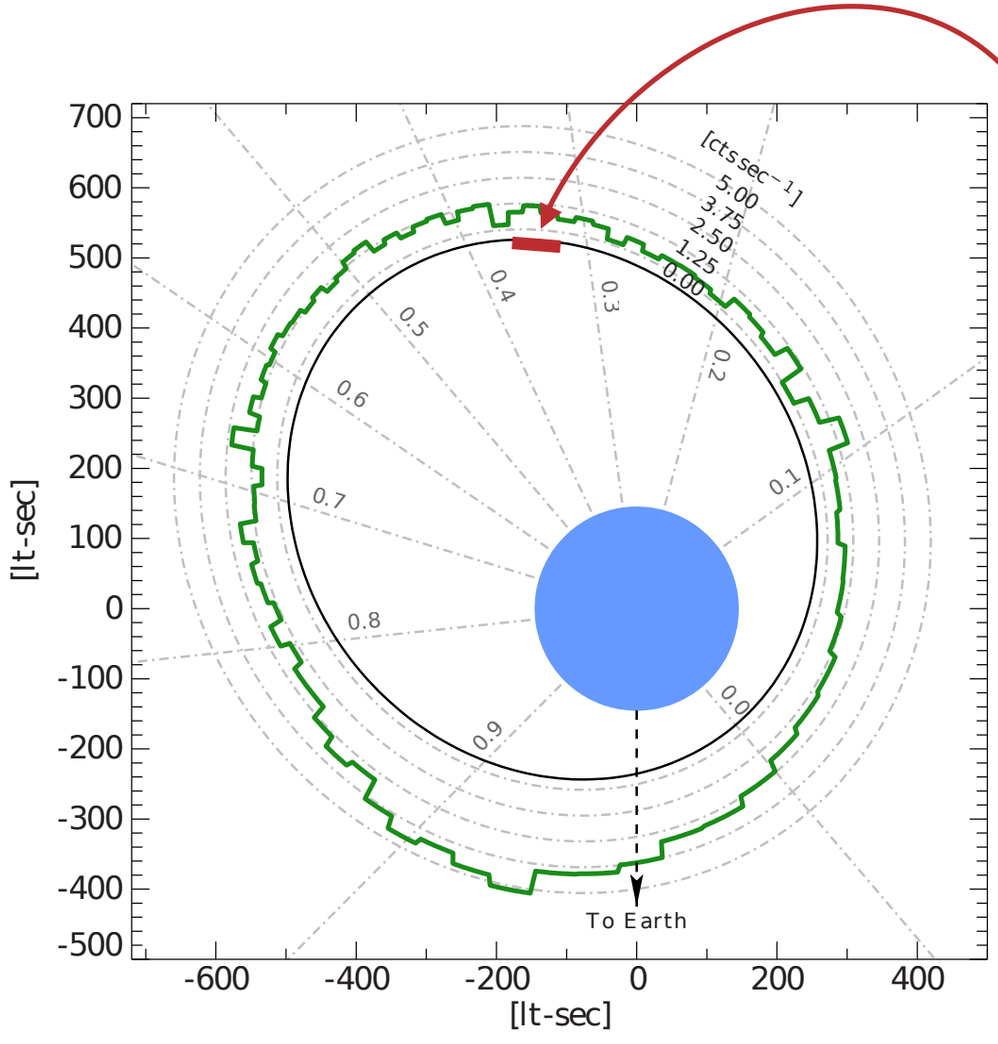




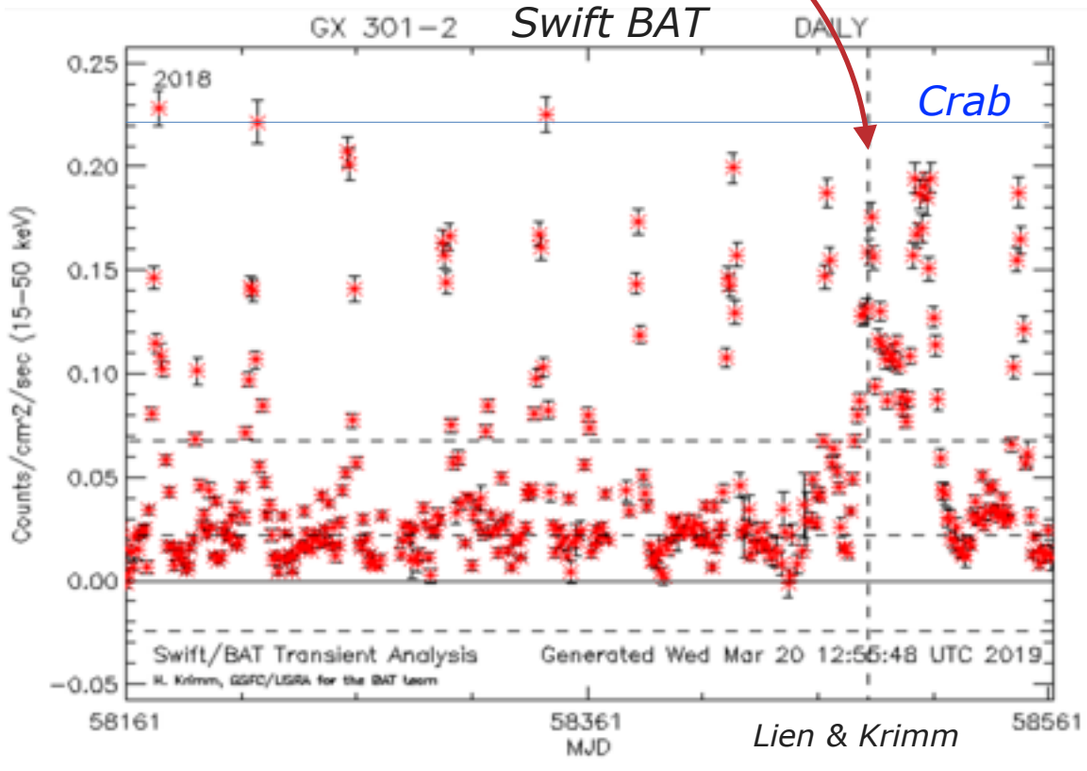
X-Calibur balloon payload launched on Dec 29th 2018 from McMurdo Station, Antarctica

# Accreting X-ray pulsar GX 301-2

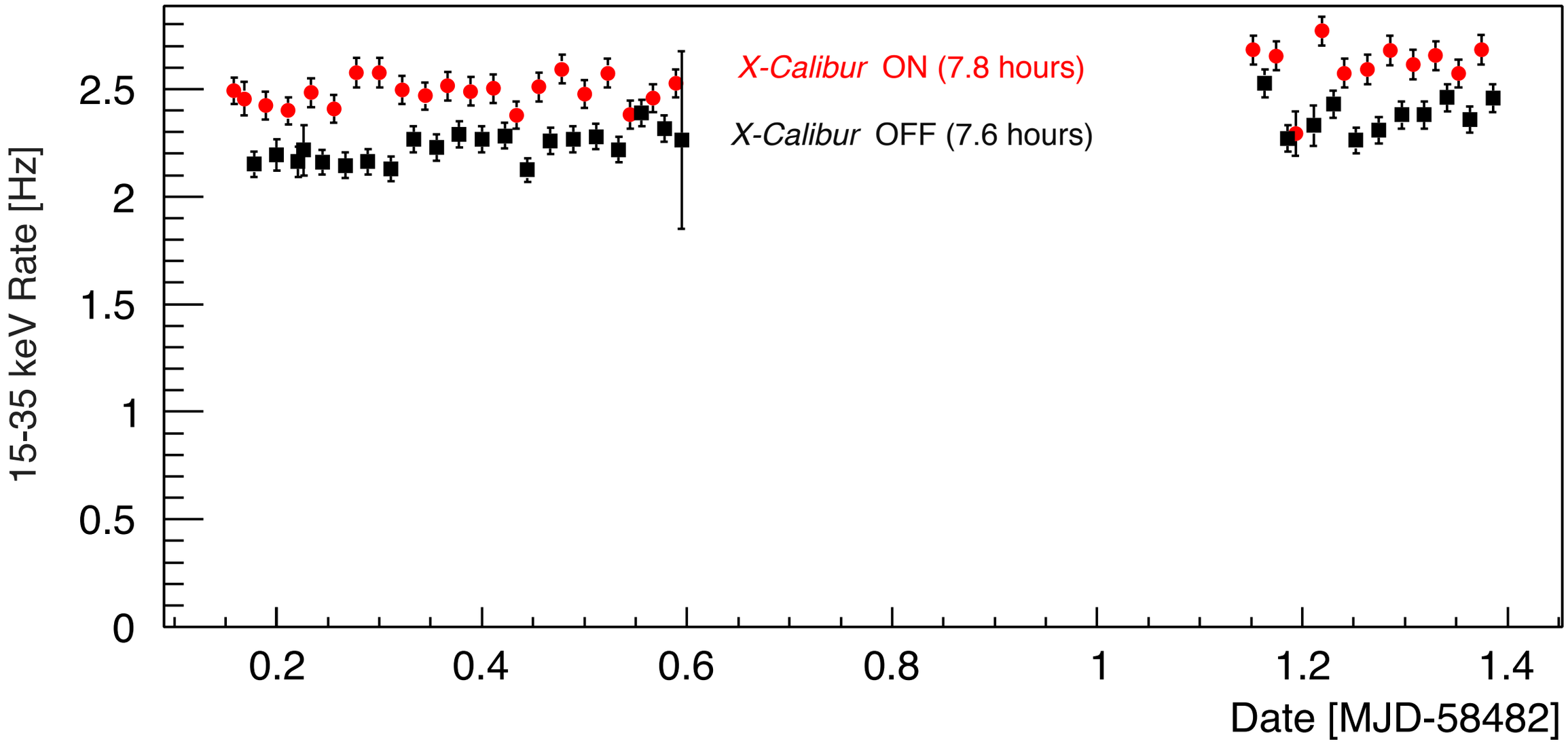
- Spin period: ~ 683 sec (White+1976)
- Orbits a B1 Ia Hypergiant, 40-60$M_\odot$.
- Orbital period: 41.5 days (Doroshenko+2011)
- 2-10 keV Luminosity: $10^{37}$ - $10^{38}$ erg/s (Lei+2018)
- $E_{CRSF}$ = ~35 keV and 50 keV (Fürst+2018)



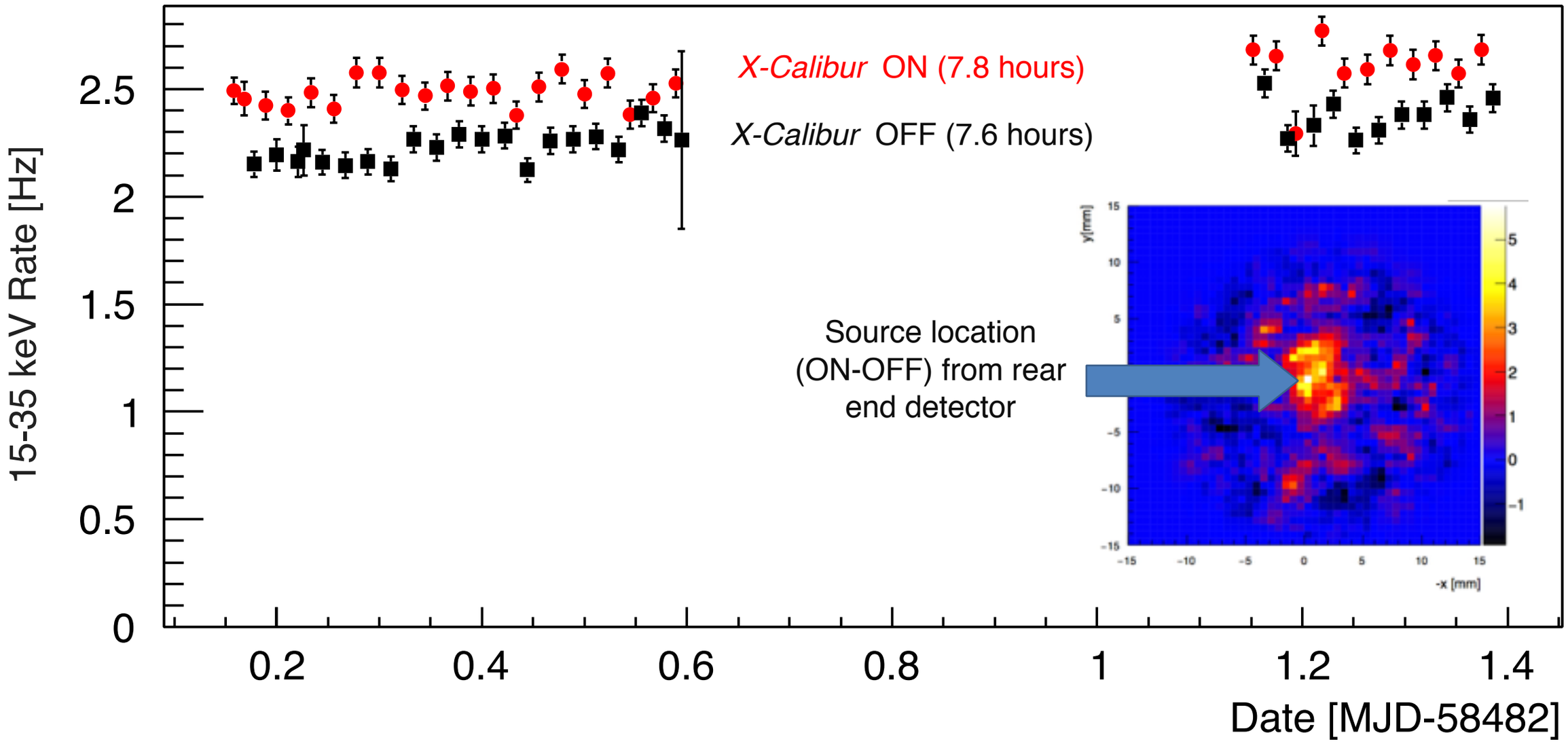

X-Calibur



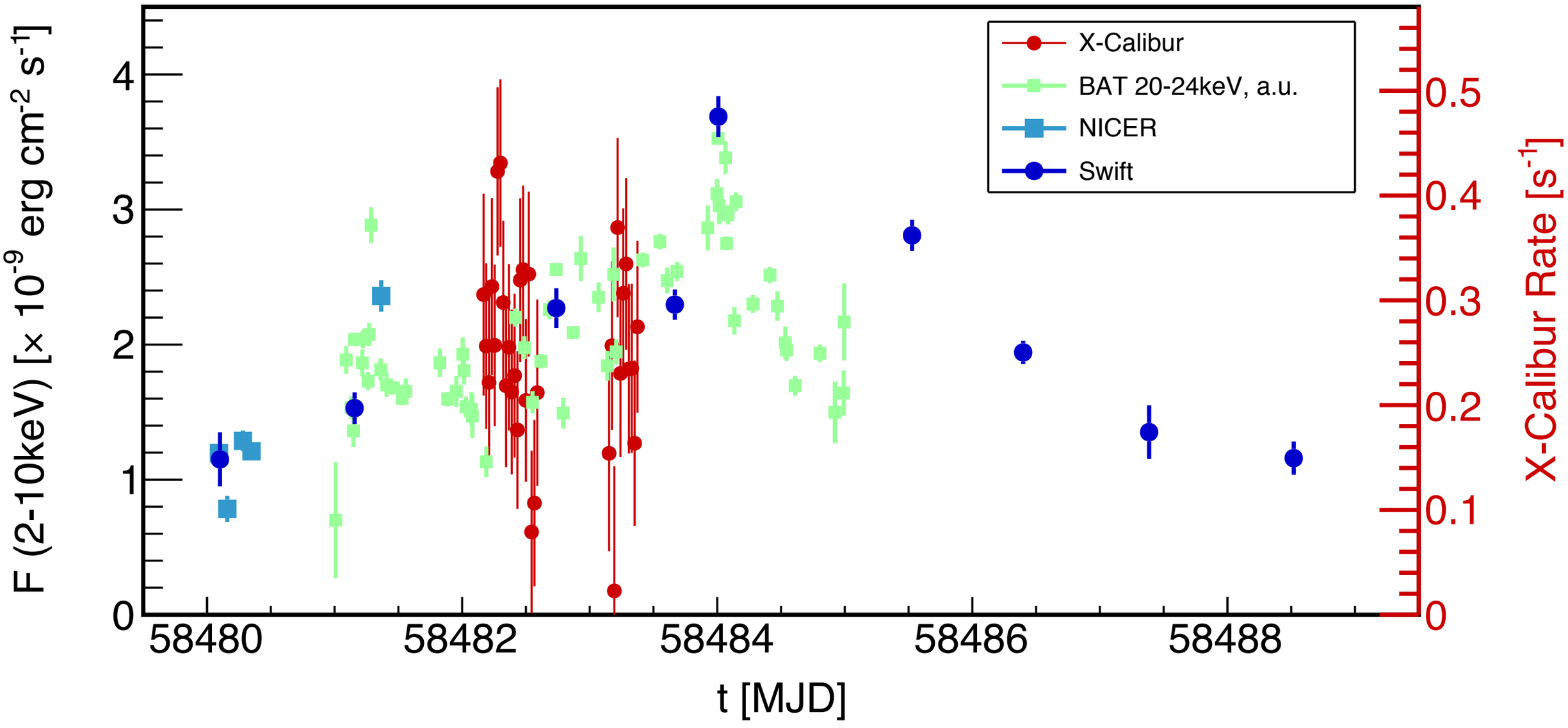
# X-Calibur 15-35 keV detection of GX 301-2



# X-Calibur 15-35 keV detection of GX 301-2

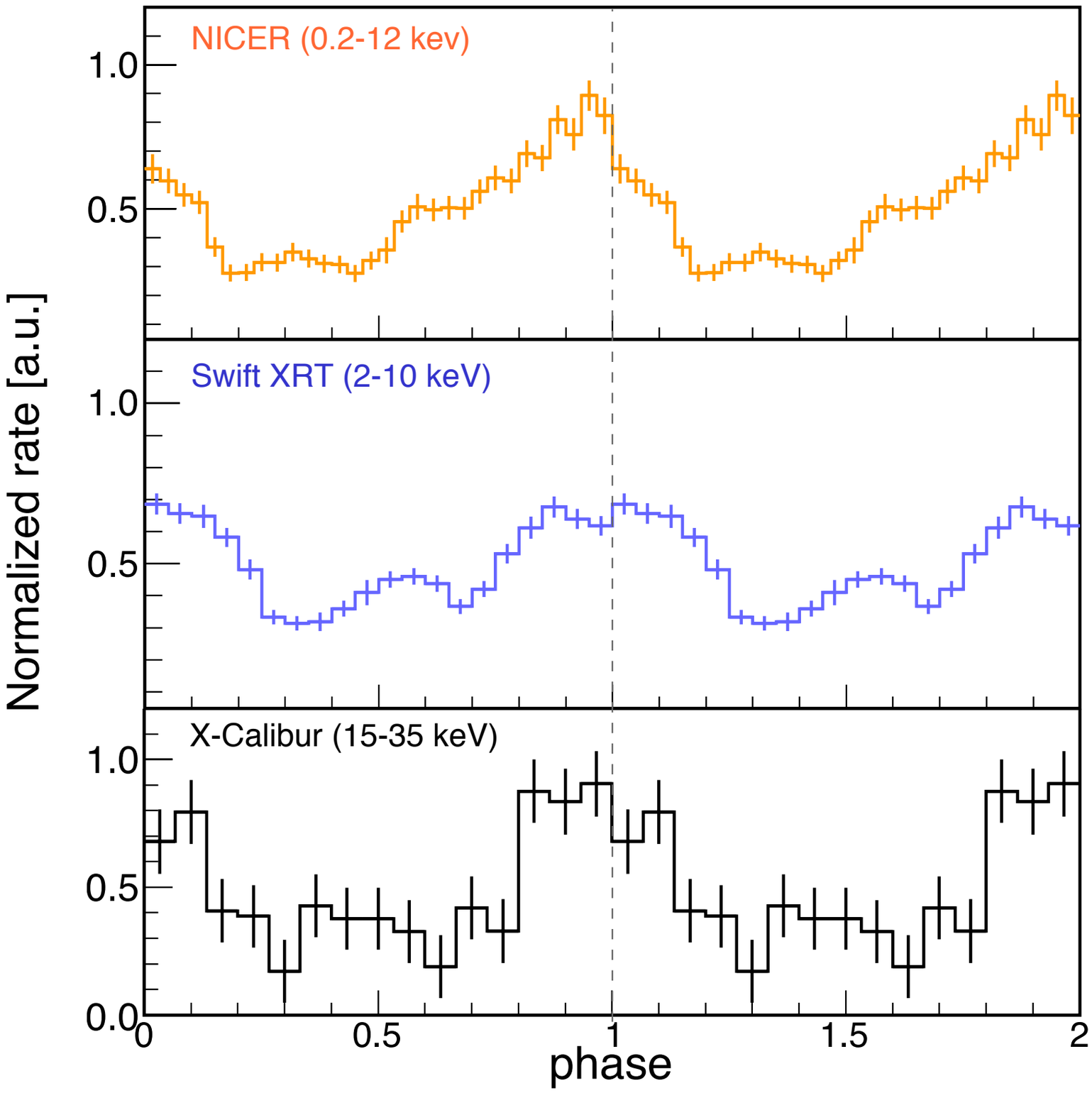


# X-ray light curve




*X-Calibur* light curve, with supporting Swift-XRT, Swift-BAT, and NICER observations

# Phase-resolved light curves

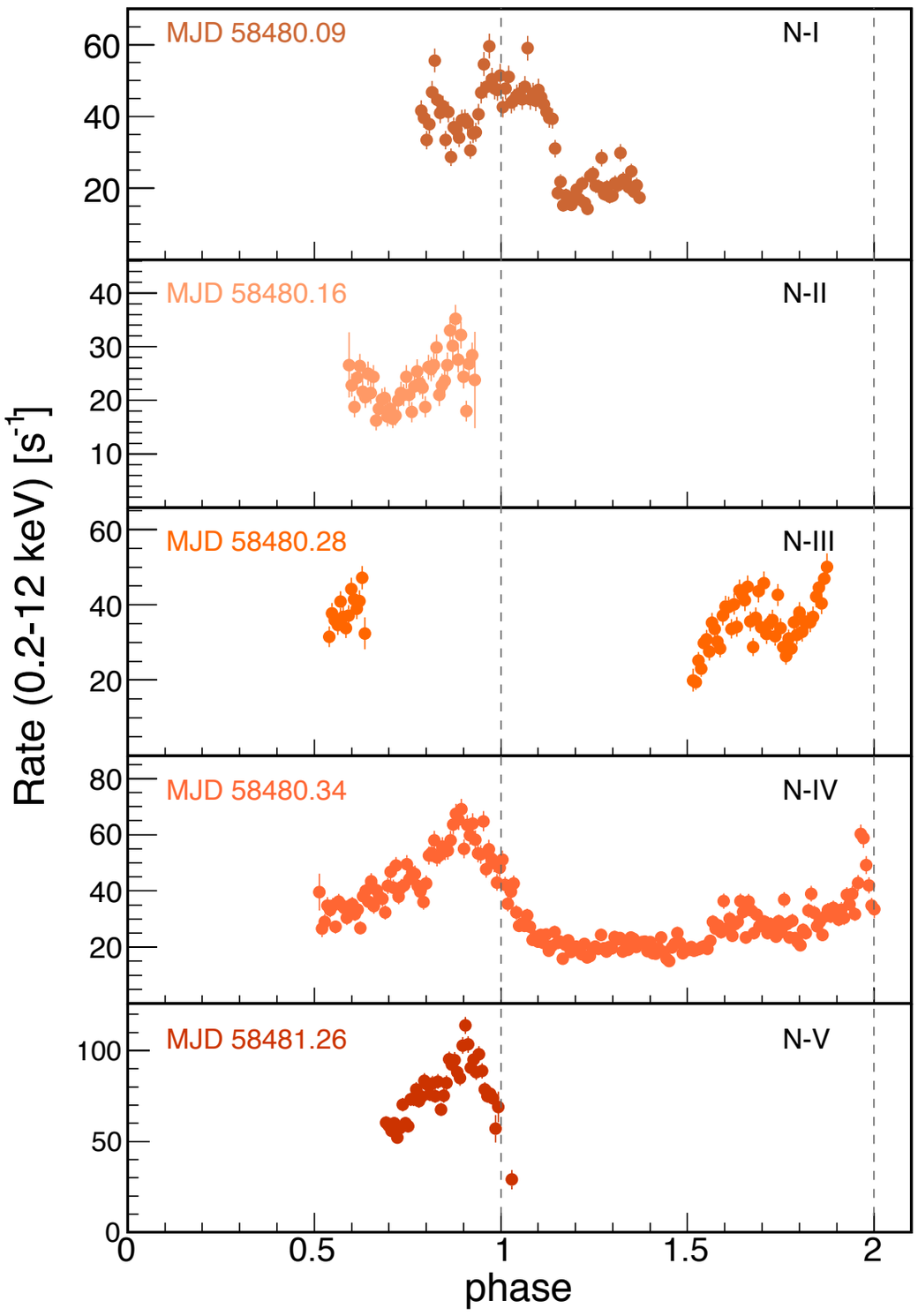



Light curves folded with the pulsar spin period of ~ 683s.

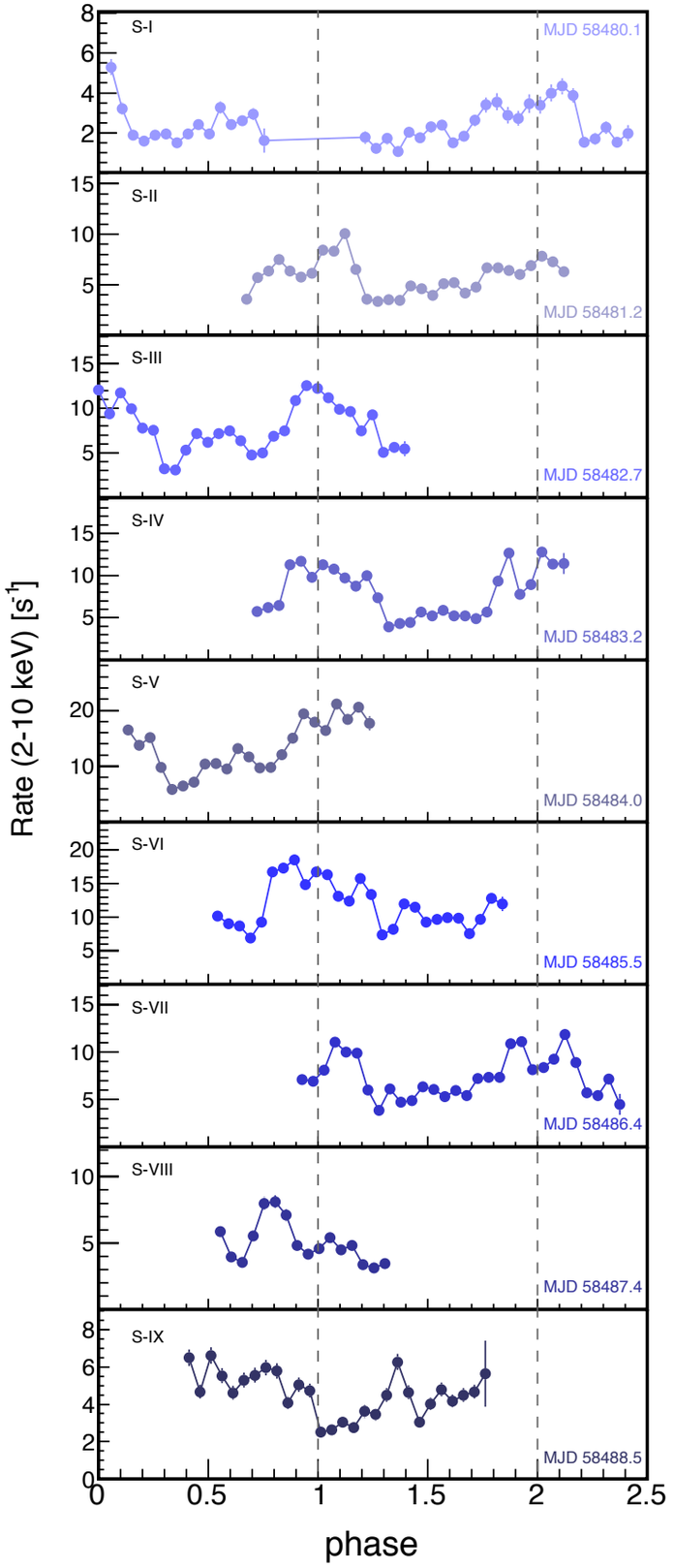
Ephemeris from Fermi-GBM by P. Jenke.

# Phase-resolved light curves

*NICER*

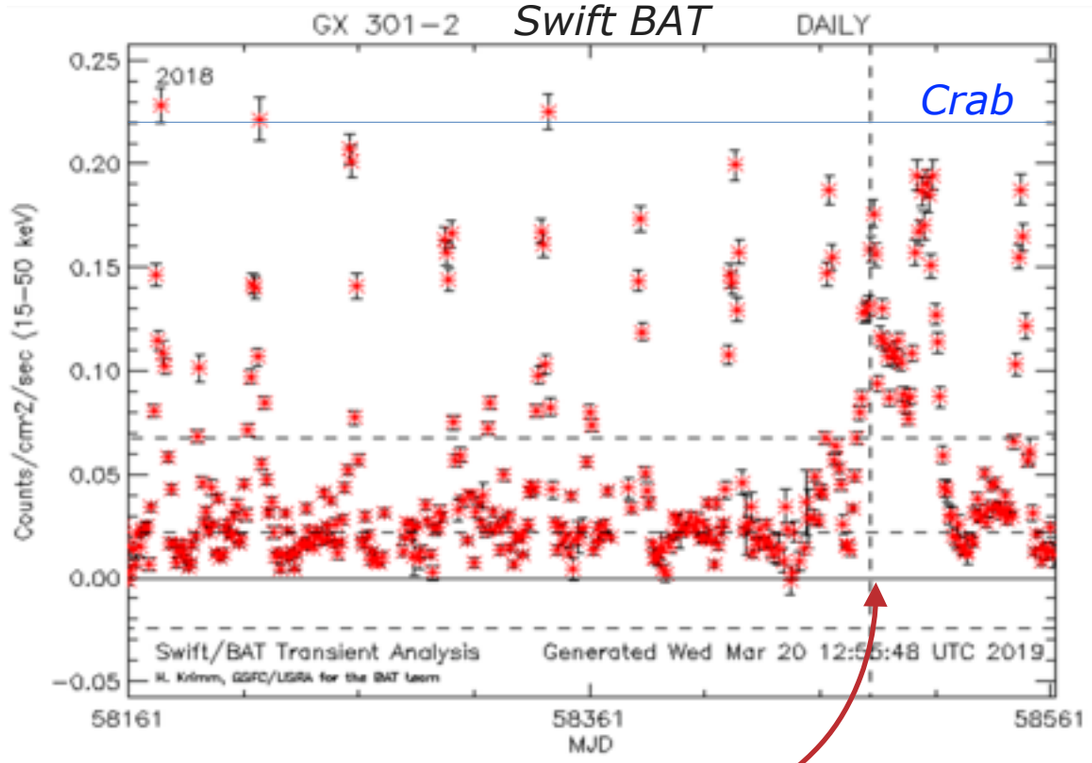



*Swift*-XRT

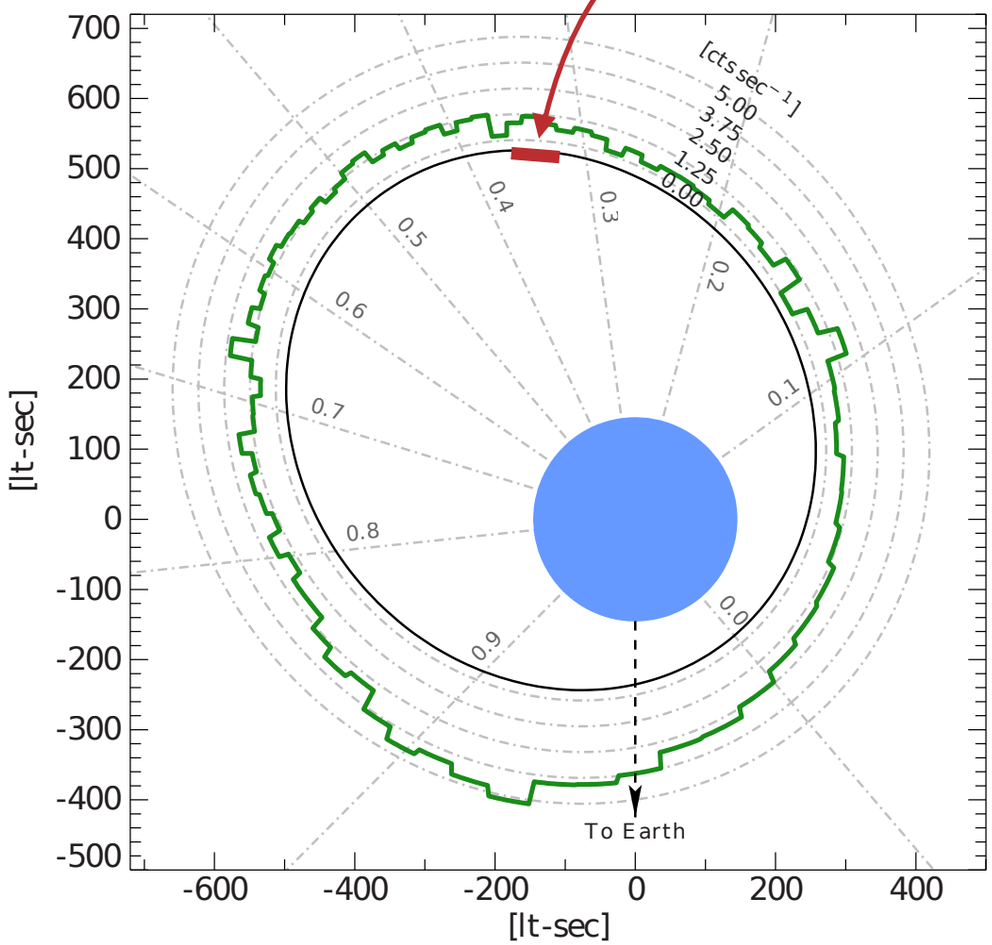


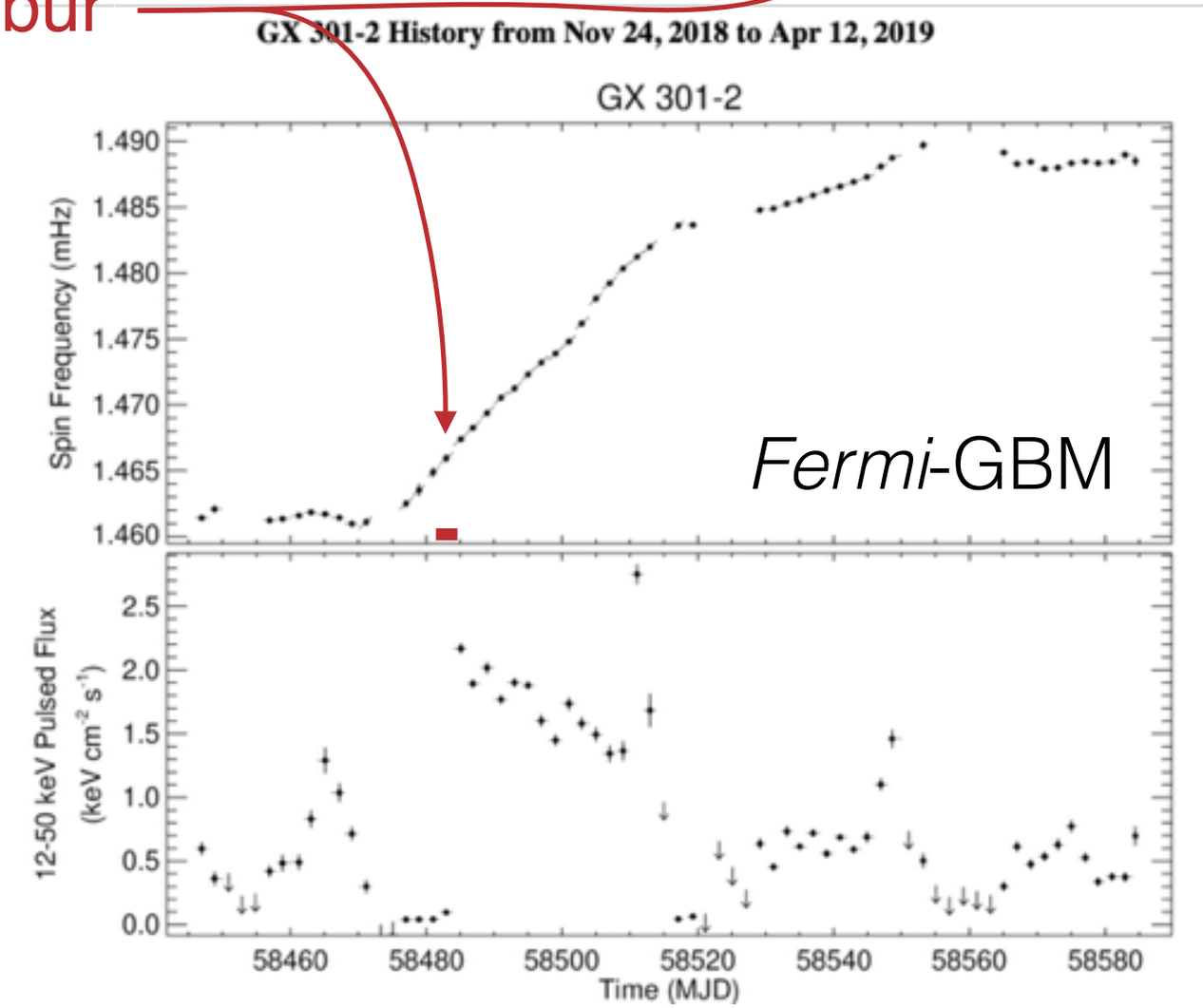
GX 301-2 underwent a rare pre-aphastron flare correlated with an (also rare) 35-day long spin-up period.

Formation of an accretion disk spinning up the pulsar?

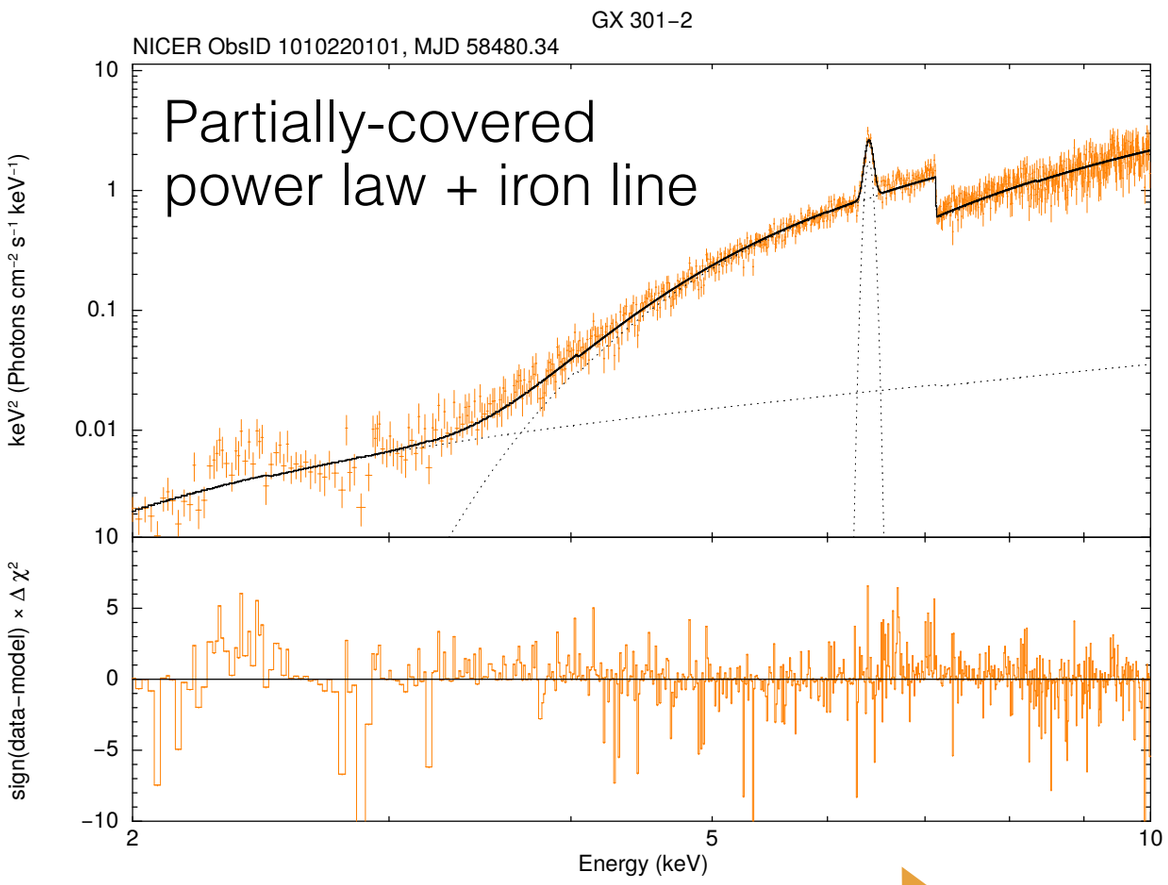


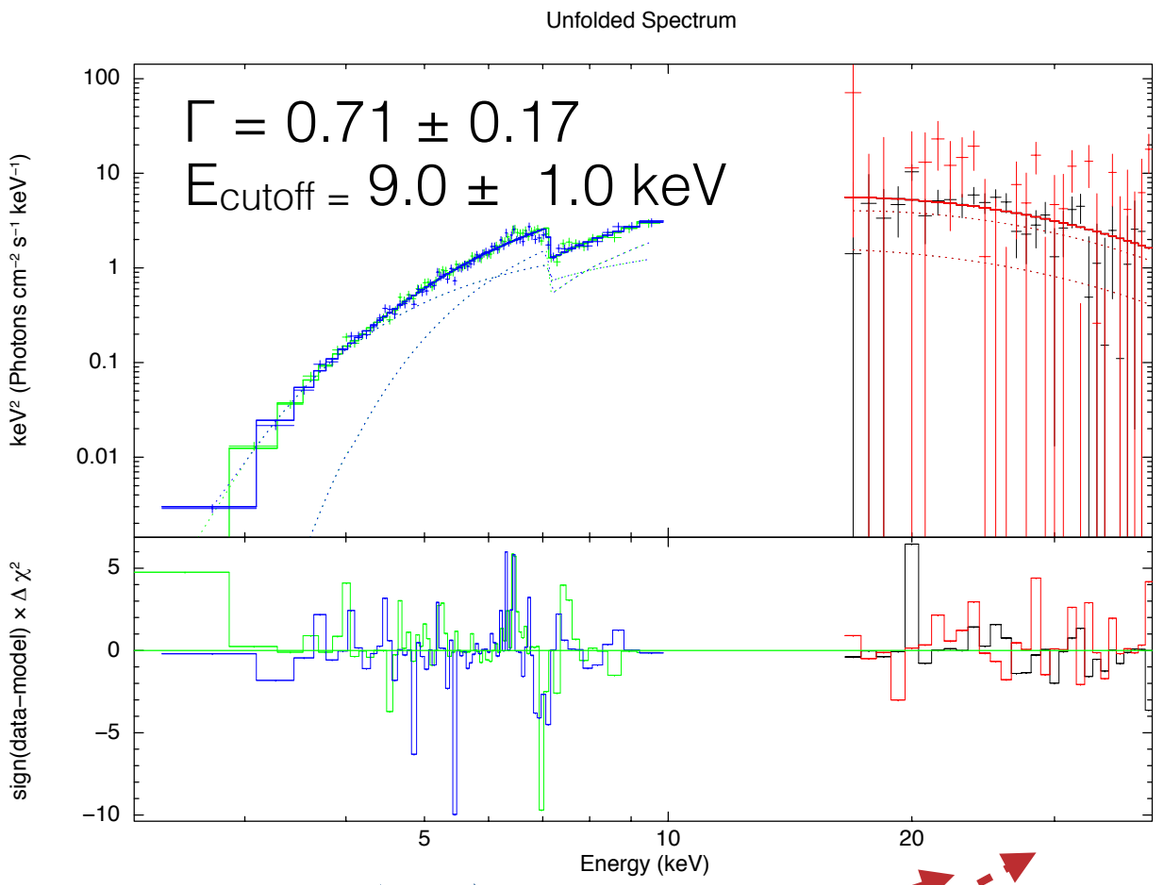

X-Calibur



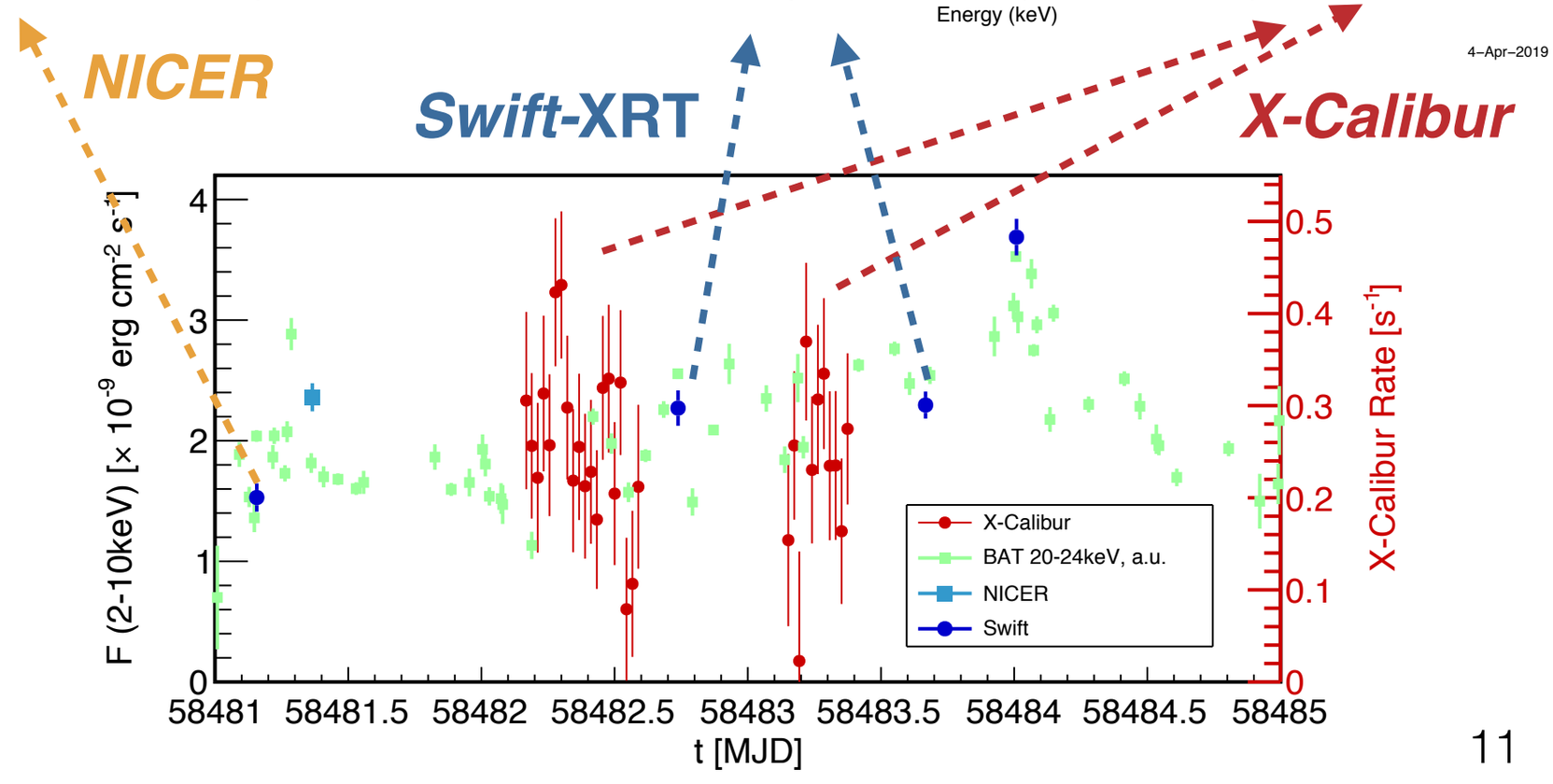



# Spectral analysis

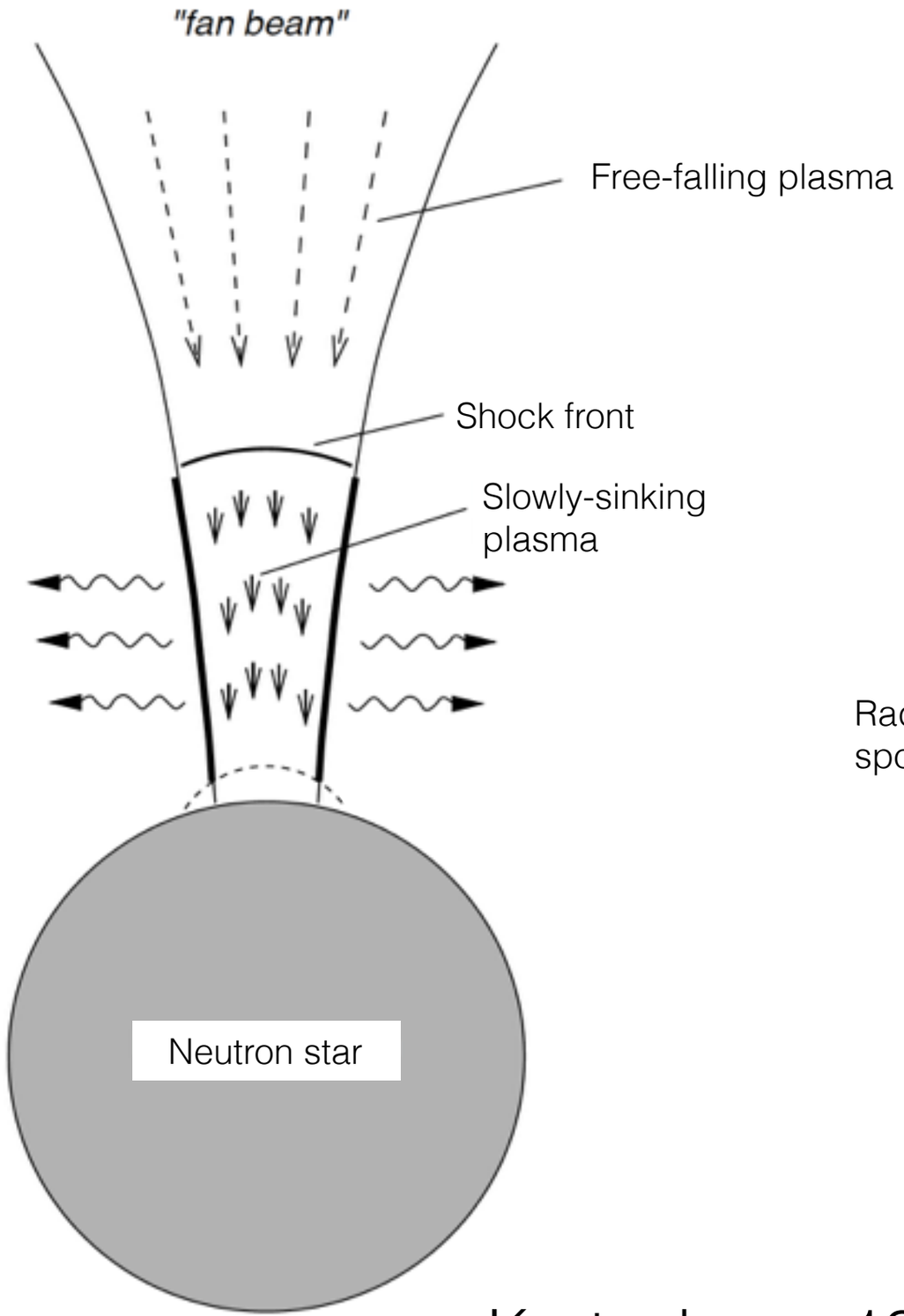


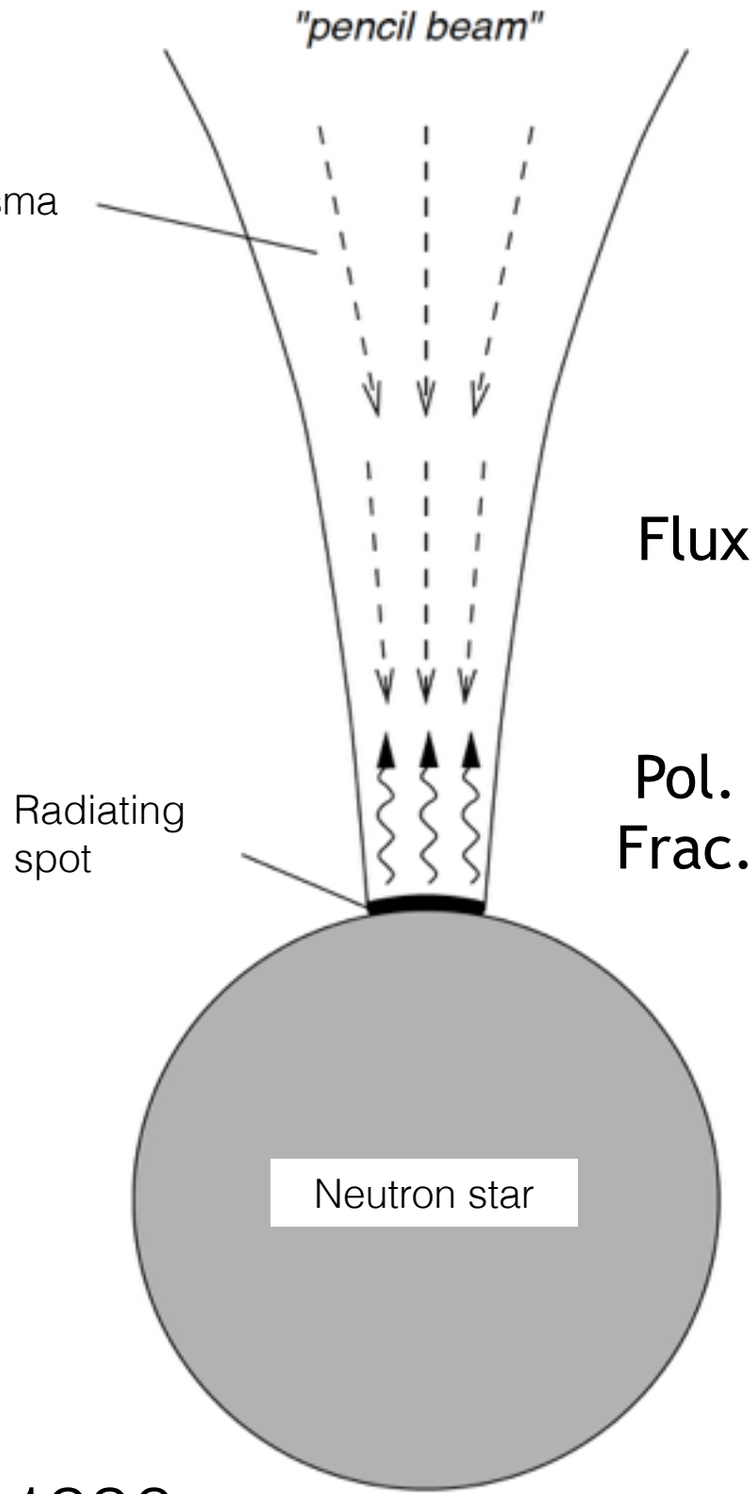

Spectral analysis indicates the presence of a thick, clumpy absorber, compatible with regular pre-periastron flares.

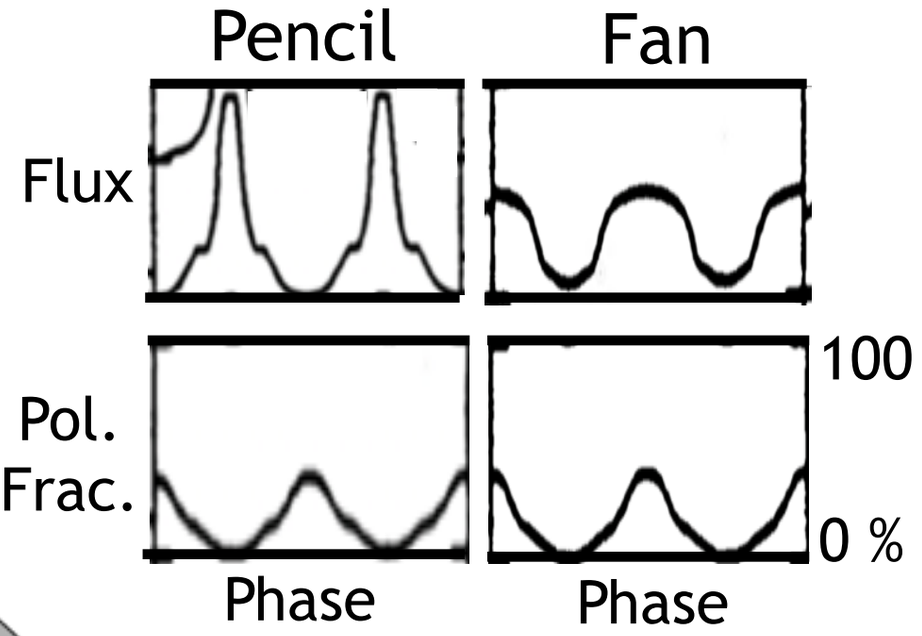


# Phase-resolved polarization: predictions




Kretschmar 1996

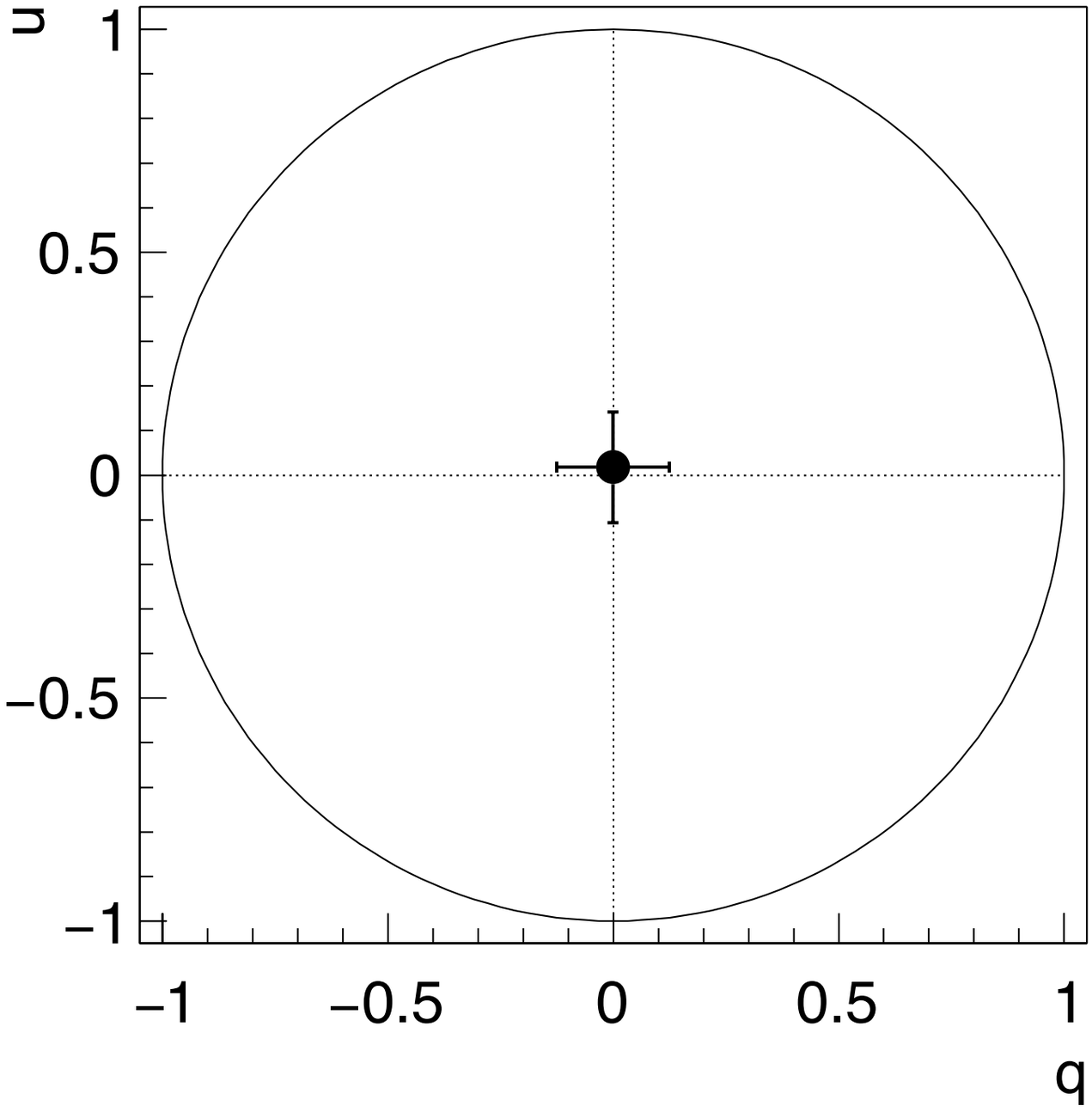


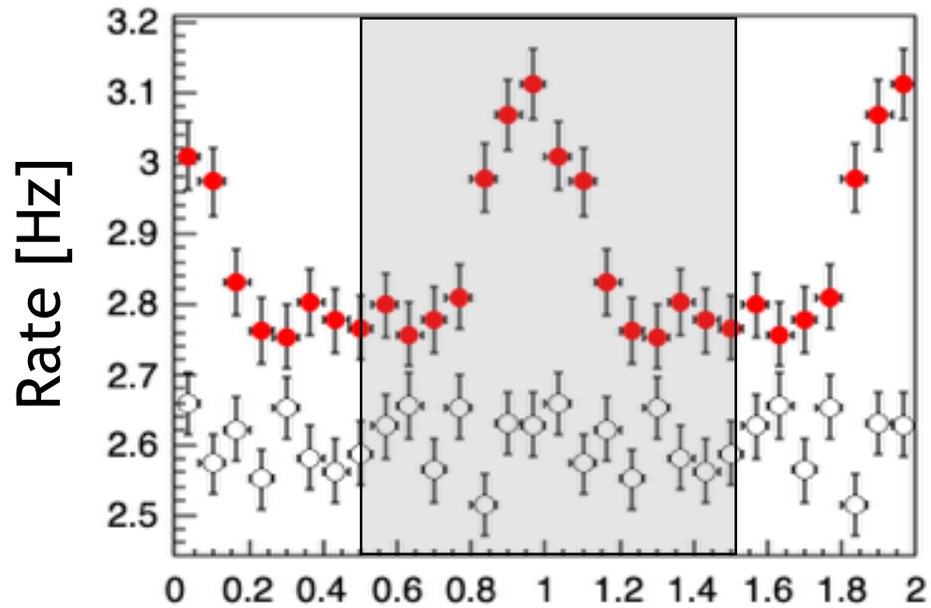




Mészáros+ 1988

# Phase-averaged polarization: results

*Preliminary*

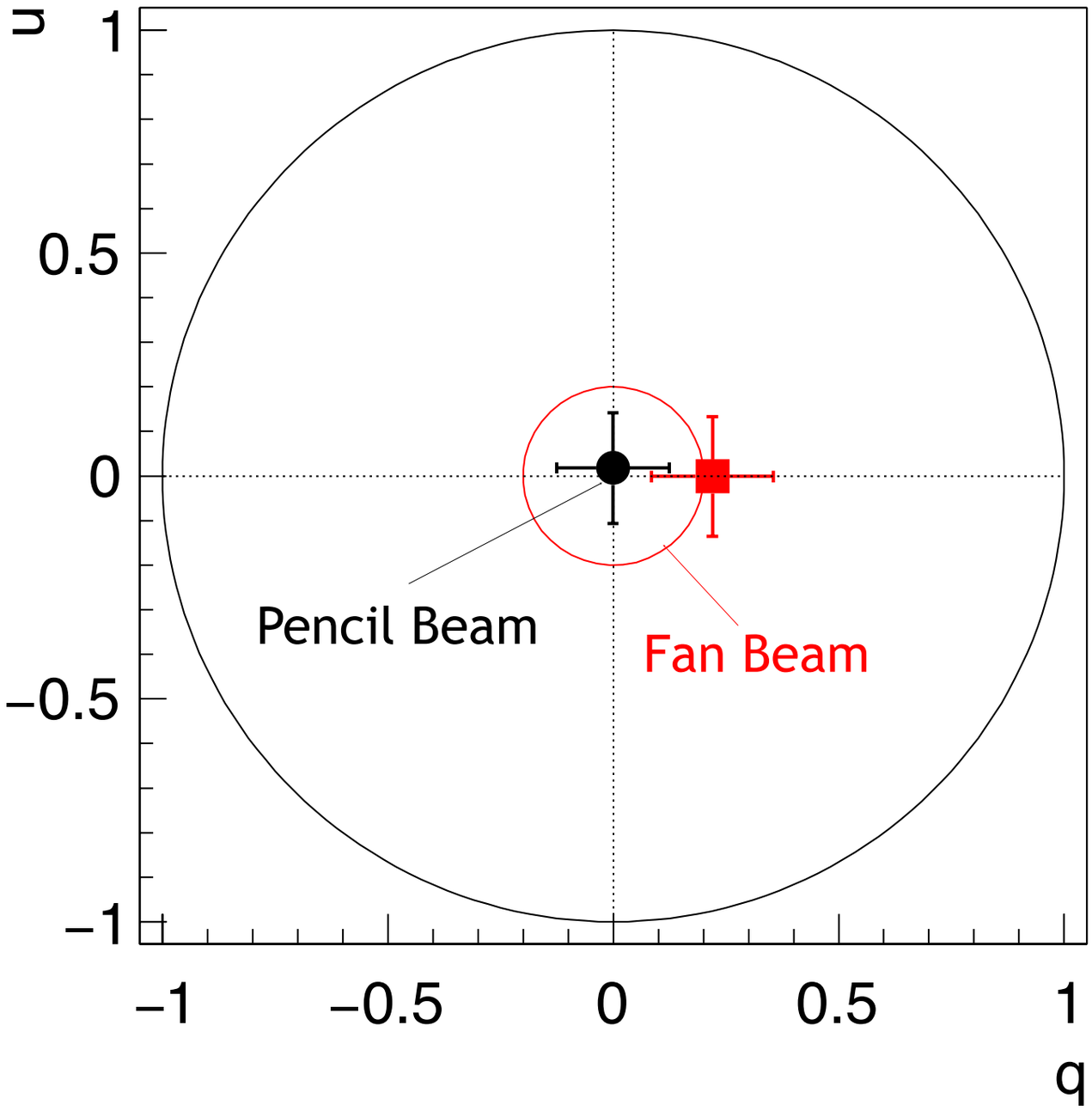


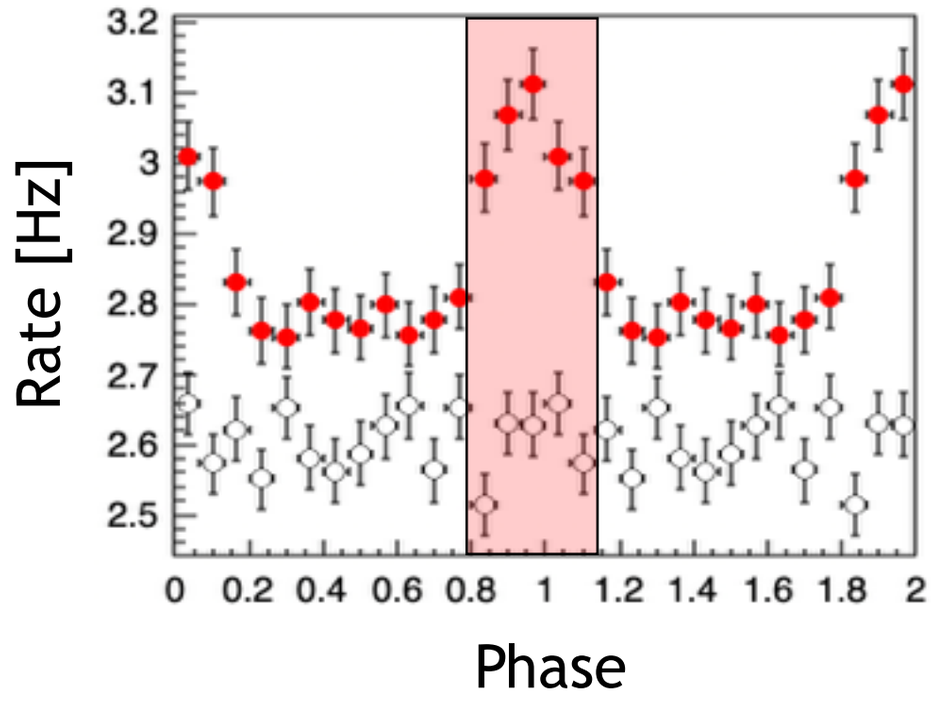




q = -(0.8 ± 12.4)%
u = (1.8 ± 12.4)%
Π = (1.8 ± 12.4)%

# Phase-resolved polarization: results

*Preliminary*

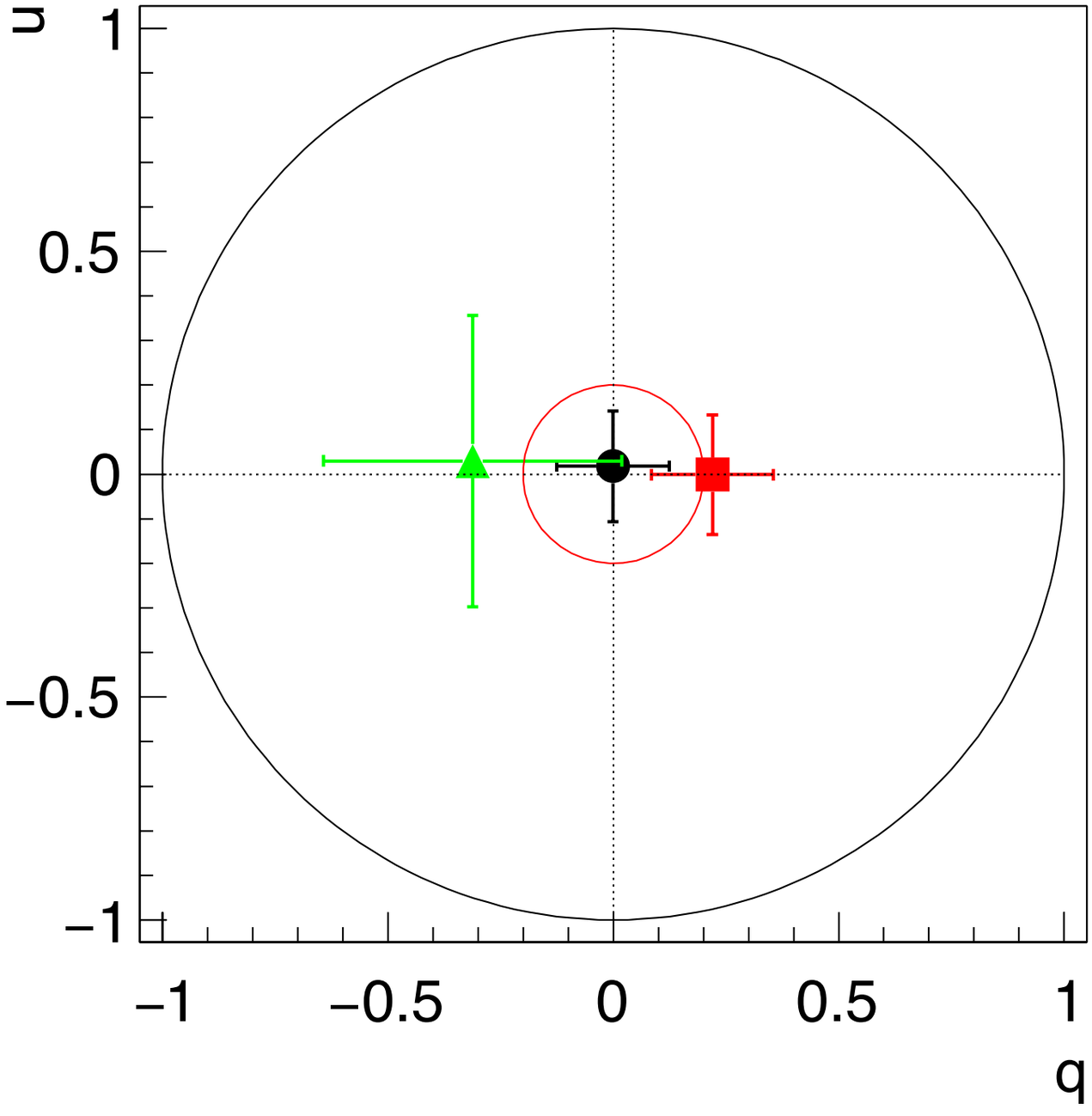


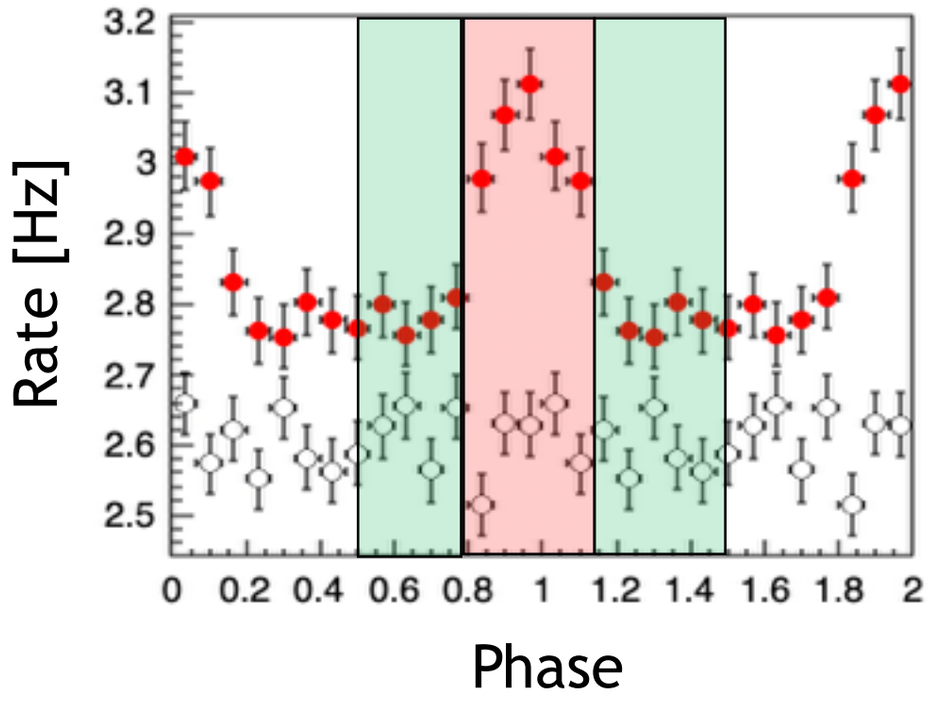




q = (22 ± 14)%
u = -(0. 1 ± 14)%
Π = (22 ± 14)%

# Phase-resolved polarization: results

*Preliminary*



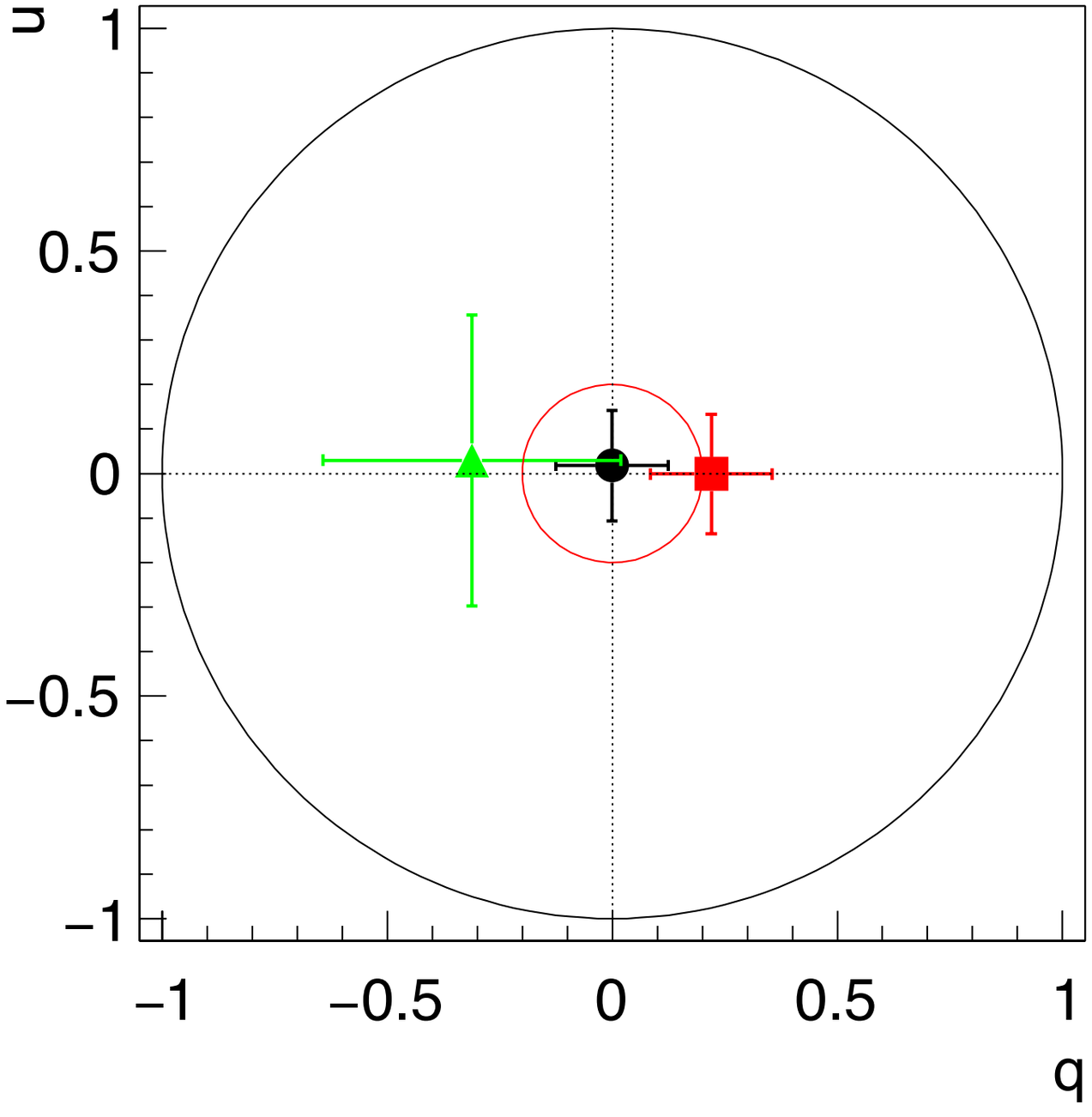



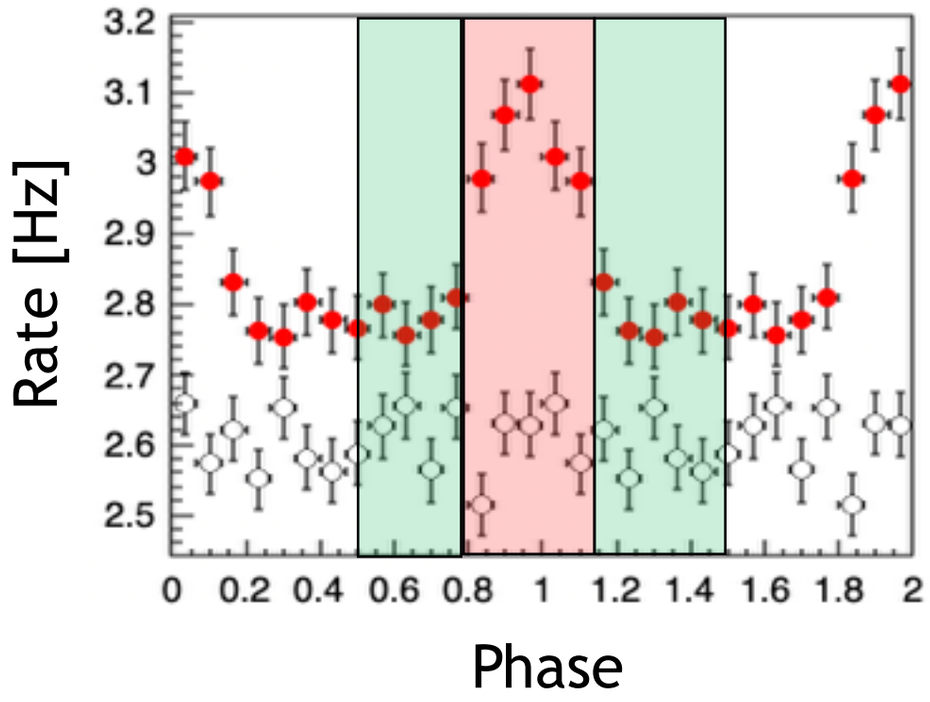

q = (22 ± 14)%
u = -(0. 1 ± 14)%
Π = (22 ± 14)%

q = -(32 ± 33)%
u = (3 ± 33)%
Π = (31+33-31)%

# Phase-resolved polarization: results

*Preliminary*

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u = -(0. 1 ± 14)%
Π = (22 ± 14)%

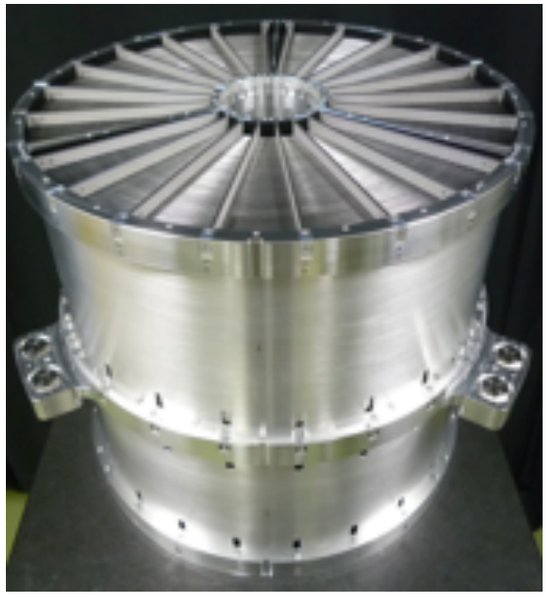
q = -(32 ± 33)%
u = (3 ± 33)%
Π = (31+33-31)%

With better statistics, measurement of ~20% polarization fraction in phase with main pulse of the pulsar favor fan-beam scenario.

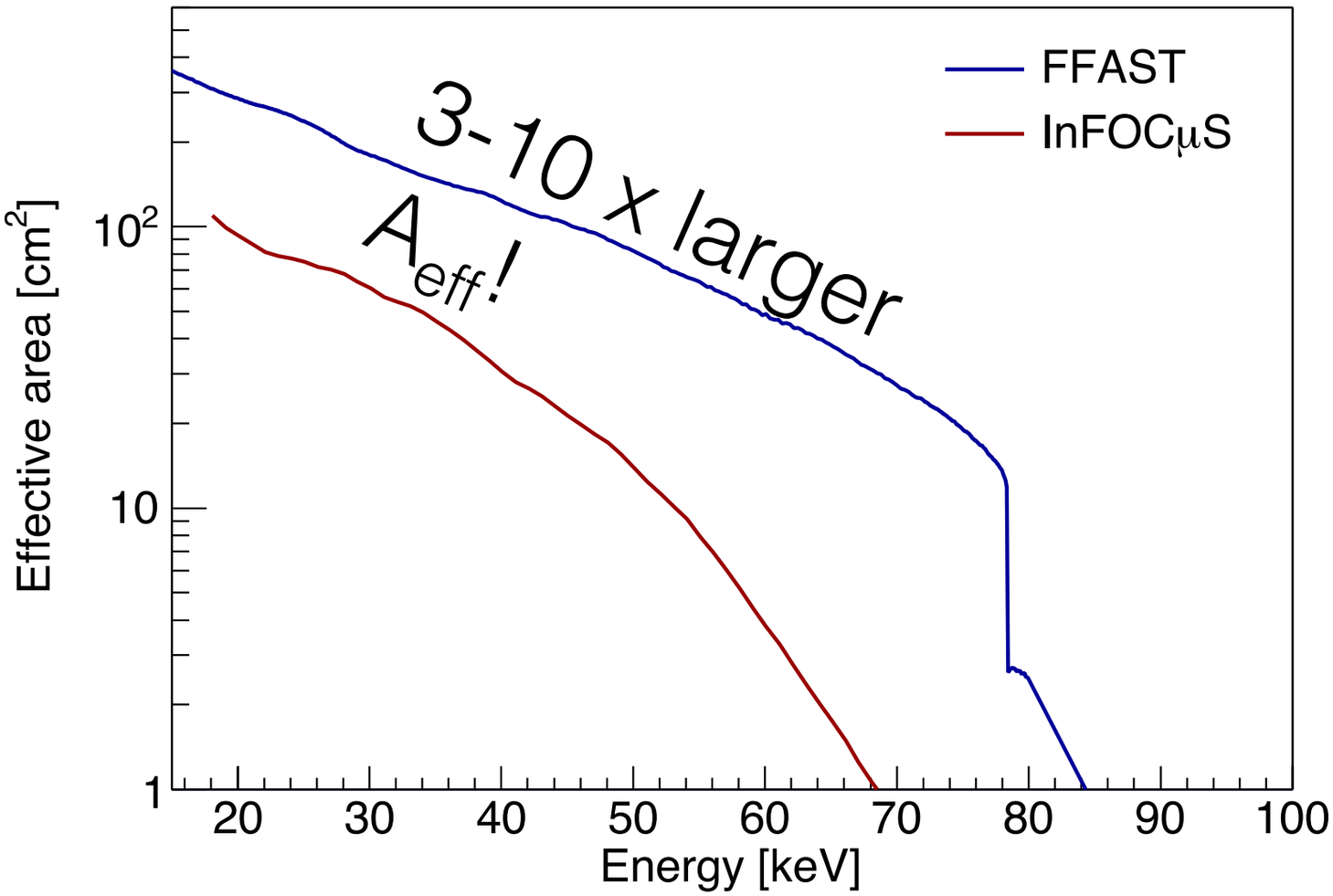
# Summary

- Accretion powered X-ray pulsar GX 301-2 was observed by the X-Calibur hard X-ray polarimeter during a rare pre-apastron flaring state.
- No evidence of a new spectral component linked to the spin-up of the pulsar.
- X-Calibur provides first linear polarization constraints on the X-ray emission, although the statistics does not amount to a significant detection of non-zero polarization.
  - overall: q=-(0.8±12.4)%, u=(1.8±12.4)%;
  - main pulse: q = (22±14)%, u= (0.1 ± 14)%.

# Future: XL-Calibur



Hitomi Spare Mirror, Maeda+




Thinner CZT detectors, neutron shield
➔ factor >4 lower background.

6-10 times better signal-to-noise
$MDP_{day}$ (500 mCrab)= 10% ➔ 1.5%.

Proposed flights in 2021, 2022 & 2024!

IXPE (2-8keV) launch expected in 2021.

# Thanks!

# Expected sensitivity