XMM-Newton
SURVEY SCIENCE CENTRE

X-ray Periodicities in the γ Cas Analogues

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Collaborators: Y. Nazé & N. Webb

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astrophysique & planétologie

What are the γ Cas Analogues ?

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Archetype - γ Cas first star to show Balmer Lines in 1866

Unusually high X-ray flux

$\log_{10}(L_X/L_{Bol}) \sim -5$

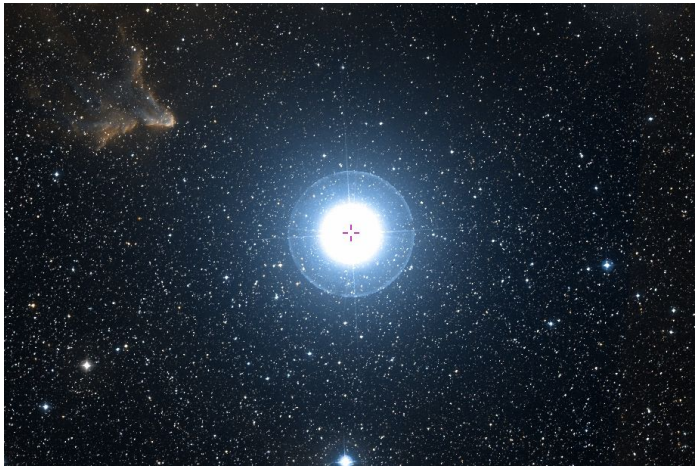
High variability across timescales

Luminosity $\sim 10^{33}$ erg s^{-1}

Spectrum

Multiple thermal components ~1 keV, >10 keV(, ~5 keV)

Fe Lines



DSS2 view of γ Cas. Credit: ESASky

What are the ɣ Cas Analogues ?

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Archetype - ɣ Cas first star to show Balmer Lines in 1866

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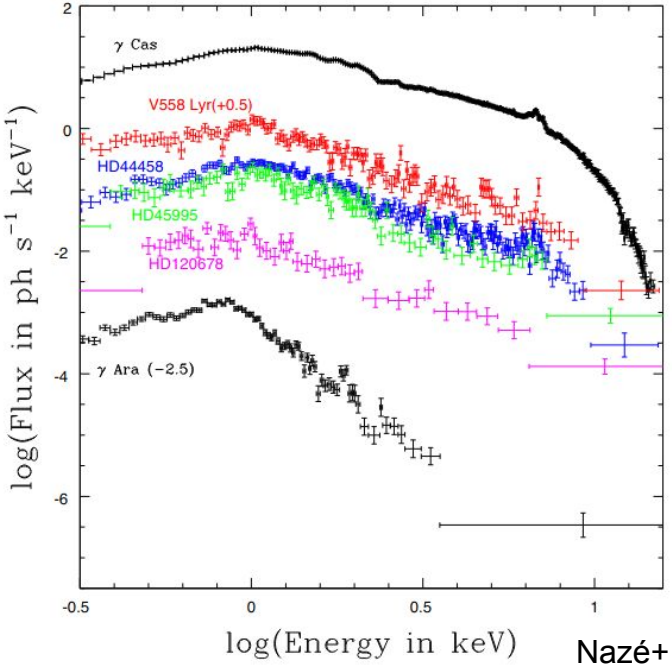

Nazé+ 2020

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What are the γ Cas Analogues ?

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Selection Criteria:

- Oe/Be class stars
- $\log_{10}(L_X/L_{Bol}) \sim -5$
- X-ray variability
- Hot plasma component in spectra

26 confirmed analogues, 2 candidates

How do they generate X-rays?

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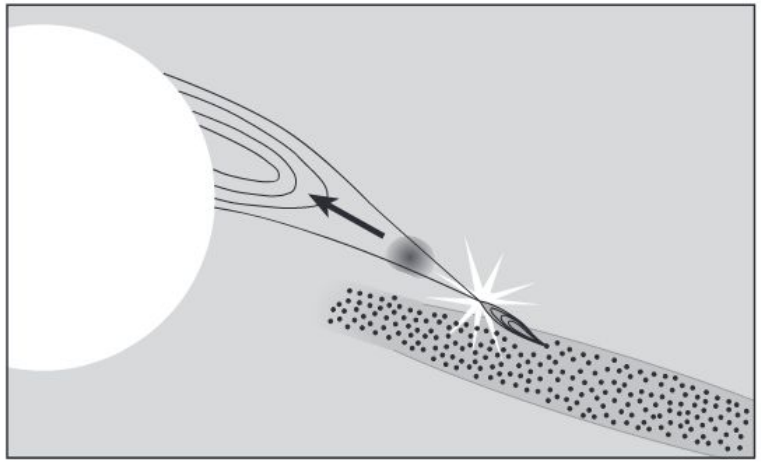
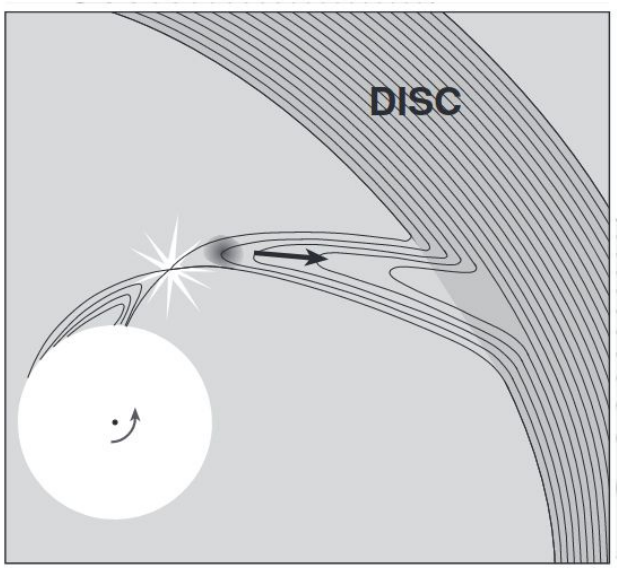
Magnetic Events

Smith & Robinson 1999





How do they generate X-rays?

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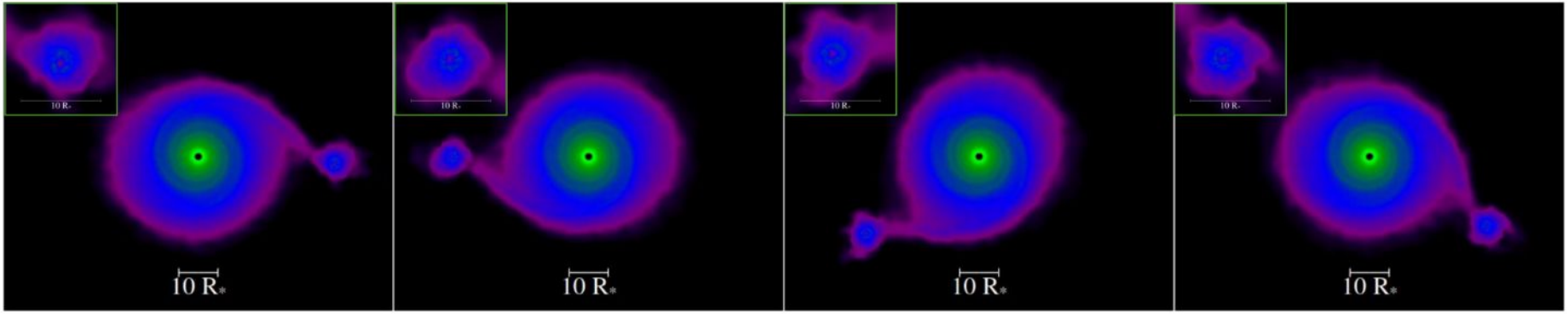
Accretion



Rast+ 2025

Newest results

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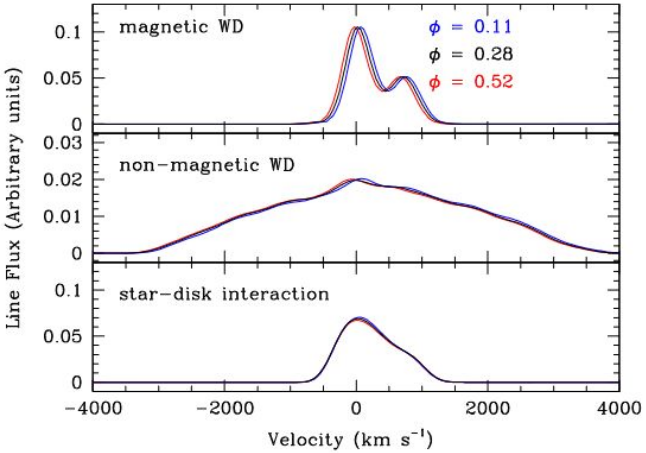
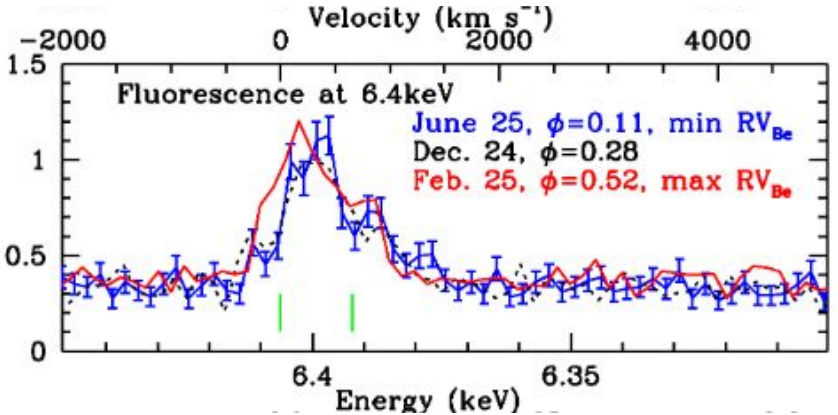
XRISM resolve measurements of Fe lines





Nazé+ 2026

Previously Reported Periodicities

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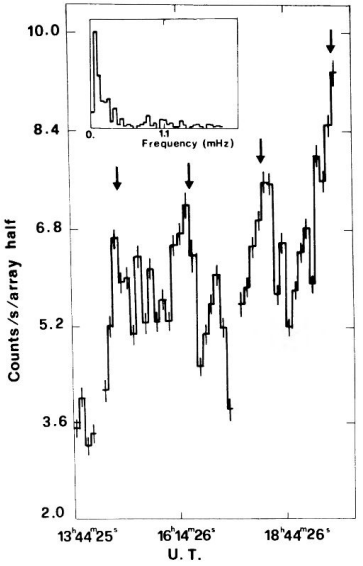
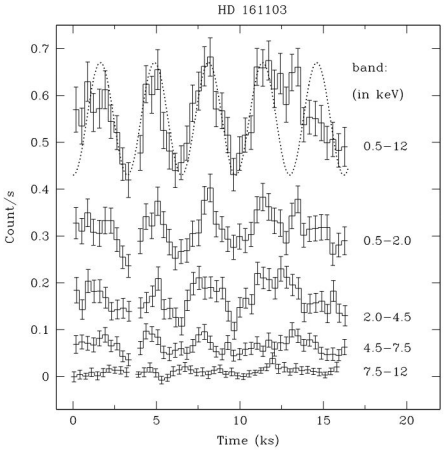
- Gamma Cas
  - EXOSAT, 6 ks (Frontera+ 1987)
  - ROSAT, 8.1 ks (Haberl+ 1995)
- HD161103
  - XMM-Newton, 3.2 ks (Lopes de Oliveira+ 2006)
- Zeta Tau
  - XMM-Newton, 3.7 ks (Nazé+ 2024)
- V771 Sgr
  - XMM-Newton, 4.1 ks (Mondal+ 2024)
- Pi Aqr
  - Chandra, 3.4 ks (Huenemoerder+ 2024)



Frontera+ 1987

Lopes de Oliveira+ 2006



Searching for Periodicities - Methods

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Fourier Domain

- Power Spectral Densities (PSDs) from individual Good Time Intervals
- Generalised Fourier Algorithms (GFAs) from whole observations

Time Domain

- Epoch Folding Search
- Z^2_n Search

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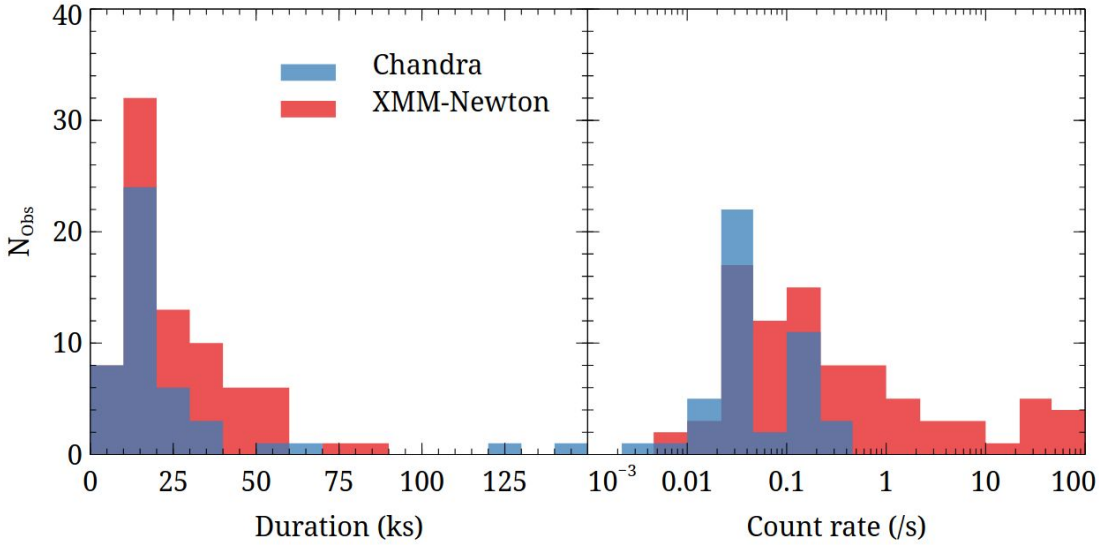
Searching for Periodicities - Data

77 XMM-Newton observations

45 Chandra observations



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Aperiodic Variability

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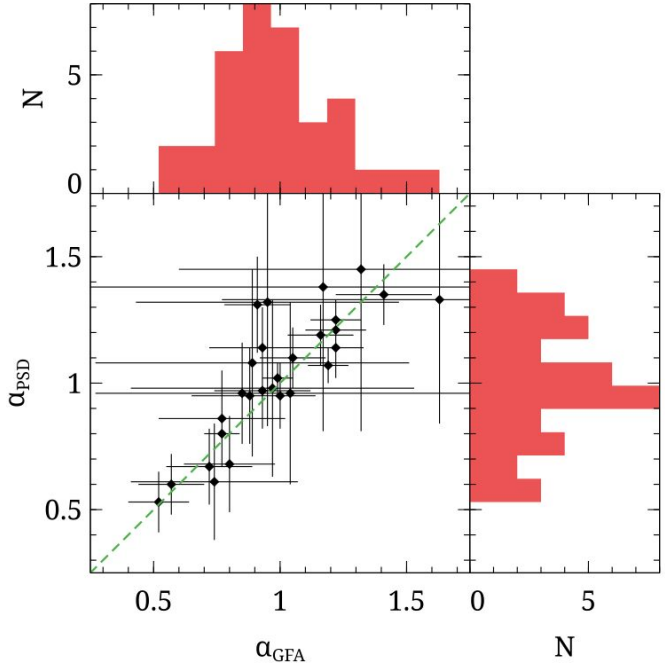

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X-ray Periodicities

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25 sources, 58 observations

PSDs - 9 detected periodicities: 0.27-9.72 mHz

GFAs - 26 detected periodicities: 0.09-1.41 mHz

Epoch Folding - 58 detected periodicities: 0.06-0.98 mHz

Z^2_n - 47 detected periodicities: 0.09-0.98 mHz

Persistent Periodicities

XMM-Newton SURVEY SCIENCE CENTRE

Periodicities observed in 25 sources

Consistent detections across methodologies

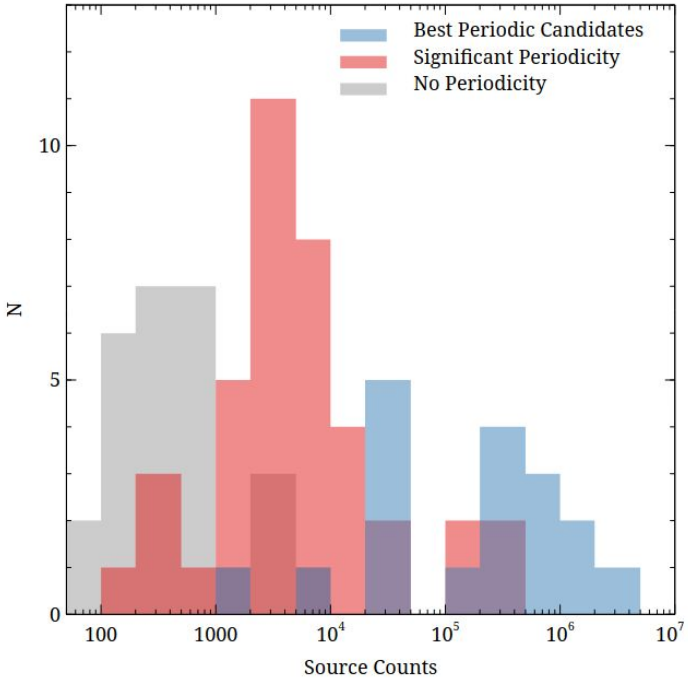
- 1 detection recovered through PSD, GFA, EF & Z^2_n
- 18 of 26 consistent between GFA and EF
- 31 of 47 consistent between EF and Z^2_n

8 sources with only one observation & detection

12 sources with intermittent detections. Some potentially spurious.

Persistent Periodicities

XMM-Newton SURVEY SCIENCE CENTRE



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Persistent Periodicities

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8 sources with only one observation & detection

12 sources with intermittent detections. Some potentially spurious.

5 sources with persistent, significant, periodicities across observations.

Gamma Cas

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10 XMM-Newton observations. Feb 2004 - Jan 2022

ObsID	Exp (ks)	Rate (cts s^{-1})	f_1 (mHz)	P_1 (ks)	PF_1 (%)	f_2 (mHz)	P_2 (ks)	PF_2 (%)
0201220101	71	48	0.56 ± 0.02	1.77 ± 0.07	6.5 ± 0.2	0.36 ± 0.01	2.77 ± 0.09	8.1 ± 0.2
0651670201	18	42	0.59 ± 0.05	1.70 ± 0.14	11.0 ± 0.4	–	–	–
0651670301	16	37	0.59 ± 0.09	1.70 ± 0.23	8.1 ± 0.5	–	–	–
0651670401	18	55	0.58 ± 0.04	1.72 ± 0.12	9.7 ± 0.4	0.45 ± 0.05	2.20 ± 0.25	15.0 ± 0.4
0651670501	24	37	–	–	–	–	–	–
0743600101	34	53	0.56 ± 0.03	1.78 ± 0.11	6.2 ± 0.4	0.41 ± 0.03	2.41 ± 0.16	10.6 ± 0.4
0840310101	20	21	0.66 ± 0.07	1.50 ± 0.15	8.7 ± 0.7	0.38 ± 0.04	2.63 ± 0.27	13.9 ± 0.6
0840310201	19	42	–	–	–	0.43 ± 0.08	2.33 ± 0.45	16.4 ± 0.6
0840310301	10	48	0.51 ± 0.09	1.98 ± 0.37	15.3 ± 0.7	–	–	–
0840310401	18	37	0.67 ± 0.05	1.50 ± 0.12	14.6 ± 0.7	0.42 ± 0.07	2.39 ± 0.41	15.9 ± 0.7

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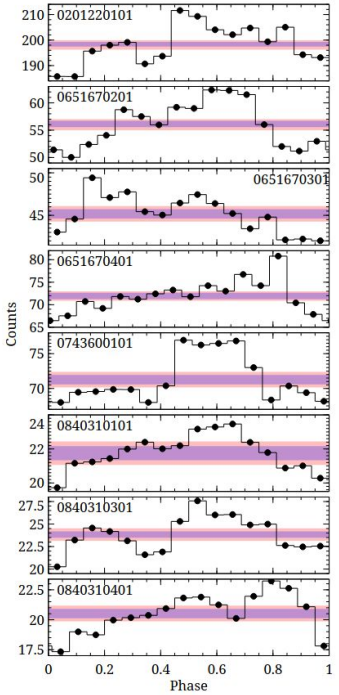

Gamma Cas

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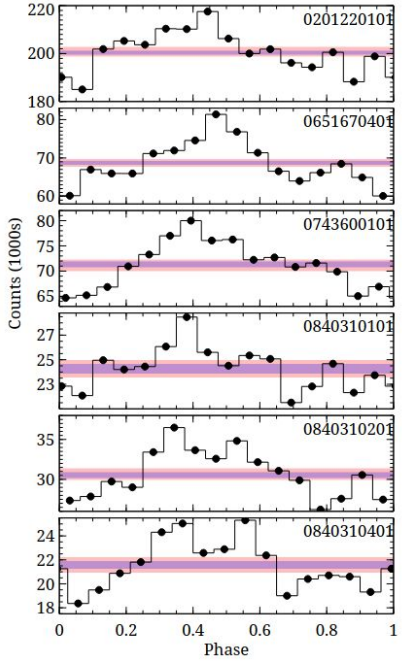

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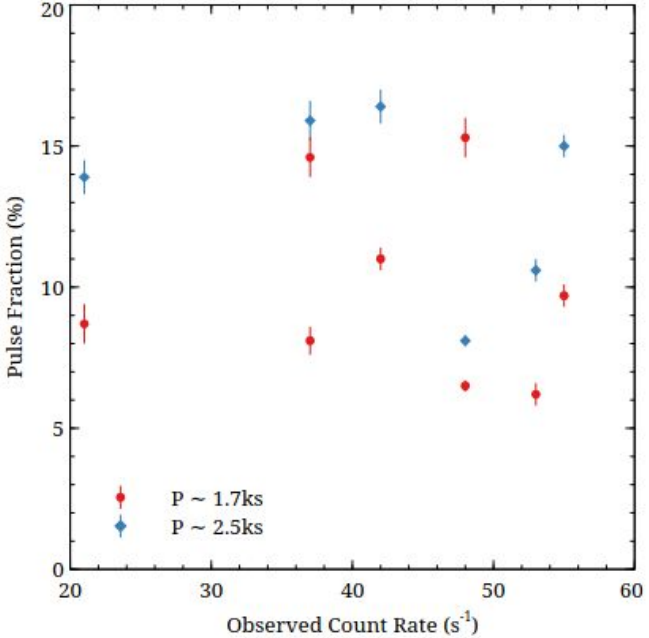

Zeta Tau

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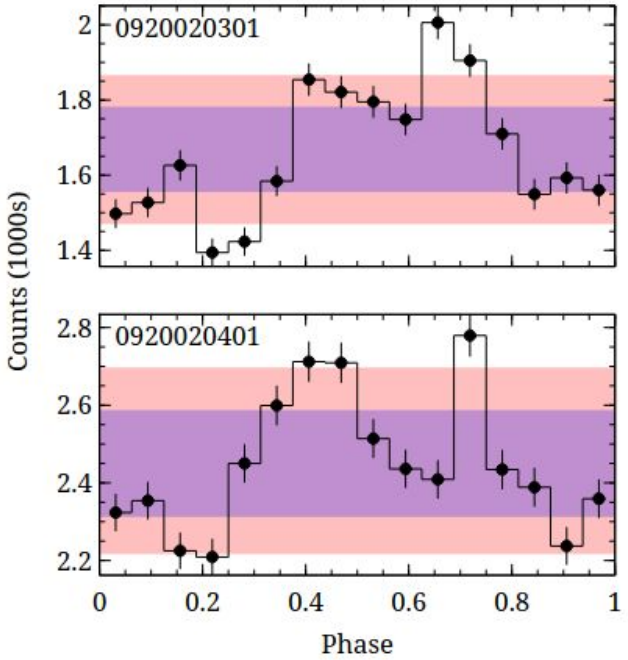
O1: Mar 2023. 17 ks, 1.5 cts/s.

P = 1.28 ± 0.07 ks , PF 18%

O2: Oct 2023. 22 ks, 1.7 cts/s.

P = 1.14 ± 0.10 ks , PF 11%



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HD45314

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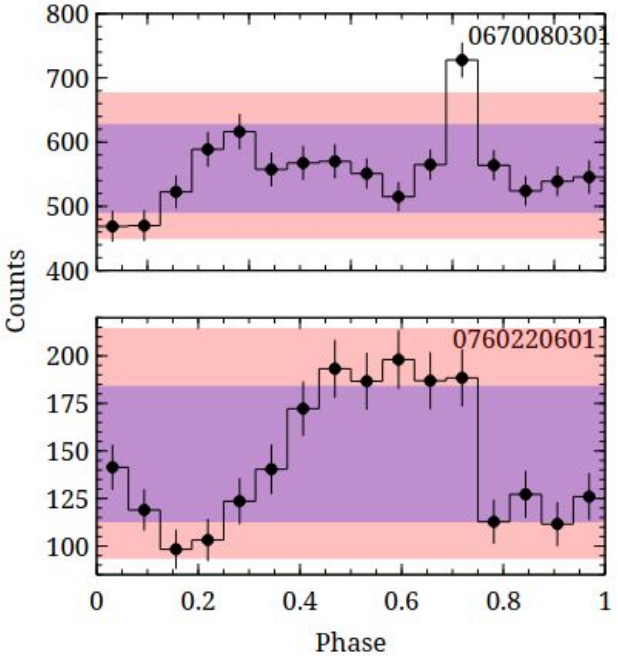
O1: Apr 2012. 26 ks, 0.2 cts/s.

P = 5.48 ± 0.41 ks , PF 22%

O2: Mar 2016. 31 ks, 0.04 cts/s.

P = 5.43 ± 0.95 ks , PF 34%



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V771 Sgr

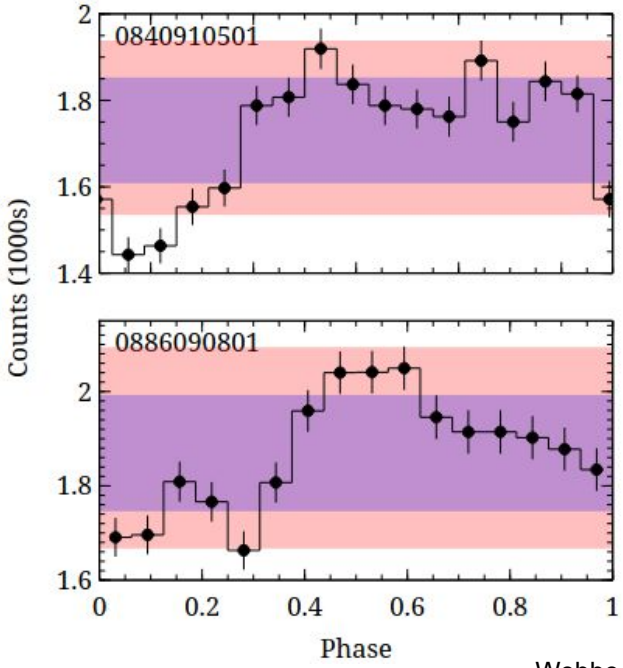
XMM-Newton SURVEY SCIENCE CENTRE

O1: Mar 2019. 20 ks, 0.9 cts/s.

P = 2.2 ± 0.2 ks , PF 14%

O2: Oct 2023. 23 ks, 1.3 cts/s.

P = 2.1 ± 0.2 ks , PF 10%



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Pi Aqr

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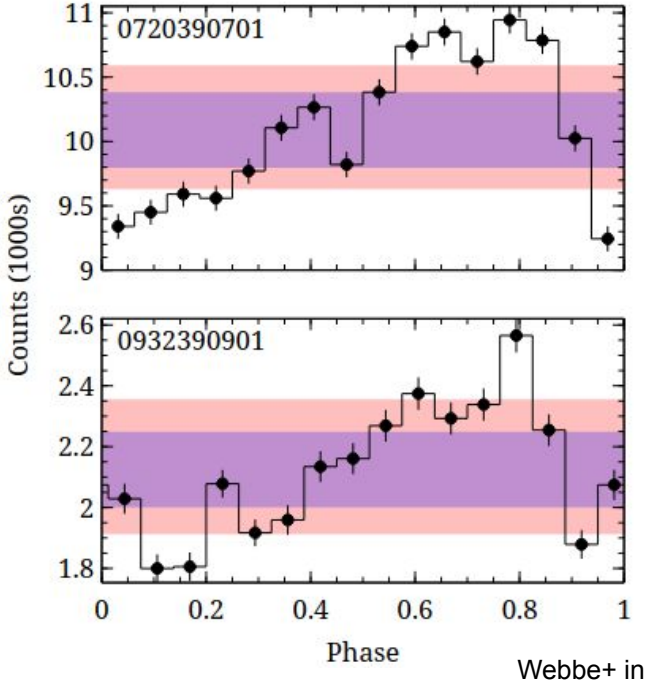
O1: Nov 2013. 55 ks, 2.3 cts/s.

P = 1.8 ± 0.1 ks , PF 8%

O2: Nov 2023. 10 ks, 3.0 cts/s.

P = 1.6 ± 0.3 ks , PF 18%



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Outlook for NewAthena et al

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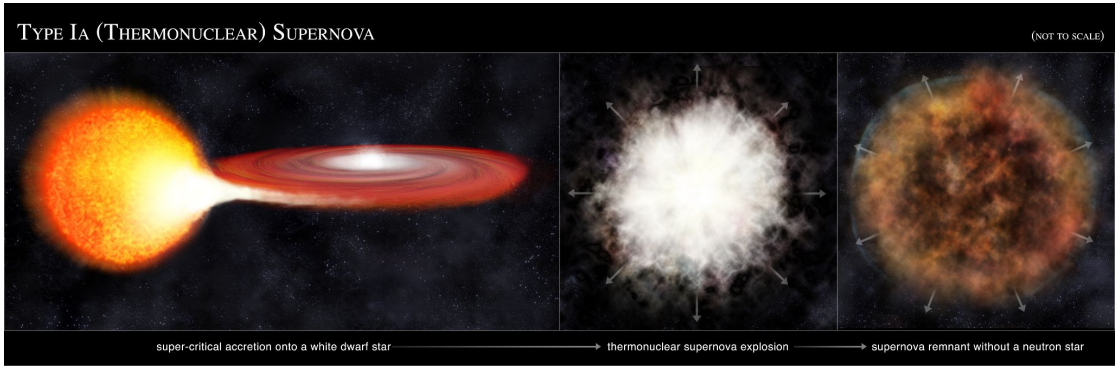
Higher effective area

Increased spectral sensitivity

Progenitors of Type I SN events

Credit: NASA/CXC/M.Weiss



Summary

Aperiodic variability consistent with White Dwarf and accretion disc models

Persistent periodicities found in five γ Cas sources

Several other sources with detected periodicities, but unconfirmed persistence.

Potential new population of Be+WD binaries!

Paper to be published very soon!