4U 1909+07: a well-hidden pearl

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FOR ASTROPARTICLE
PHYSICS

Contents

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High Mass X-ray Binaries

- two stars in orbit: early type star and compact object
- in this case: neutron star
- X-rays produced through accretion of the stellar wind
- accreted matter channeled by strong magnetic field onto neutron star surface
- strong graviation, extreme magnetic fields, extreme physics!

Illustration: ESA (C. Carreau)

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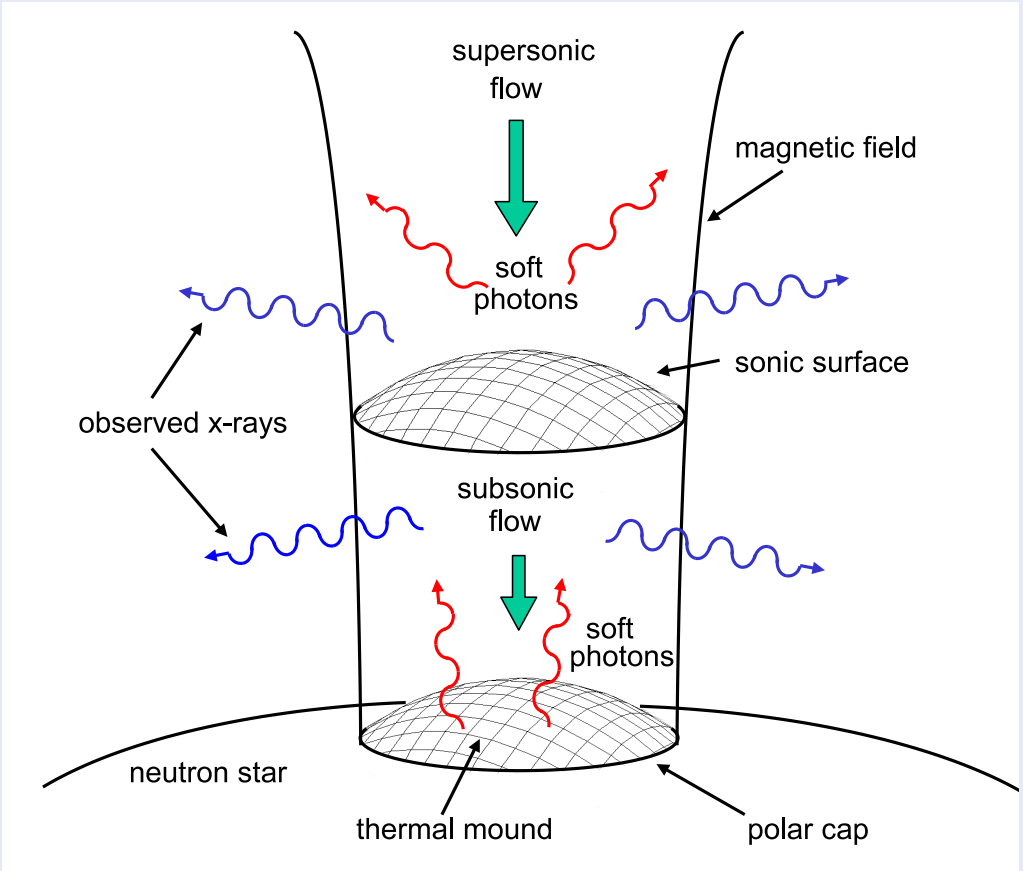
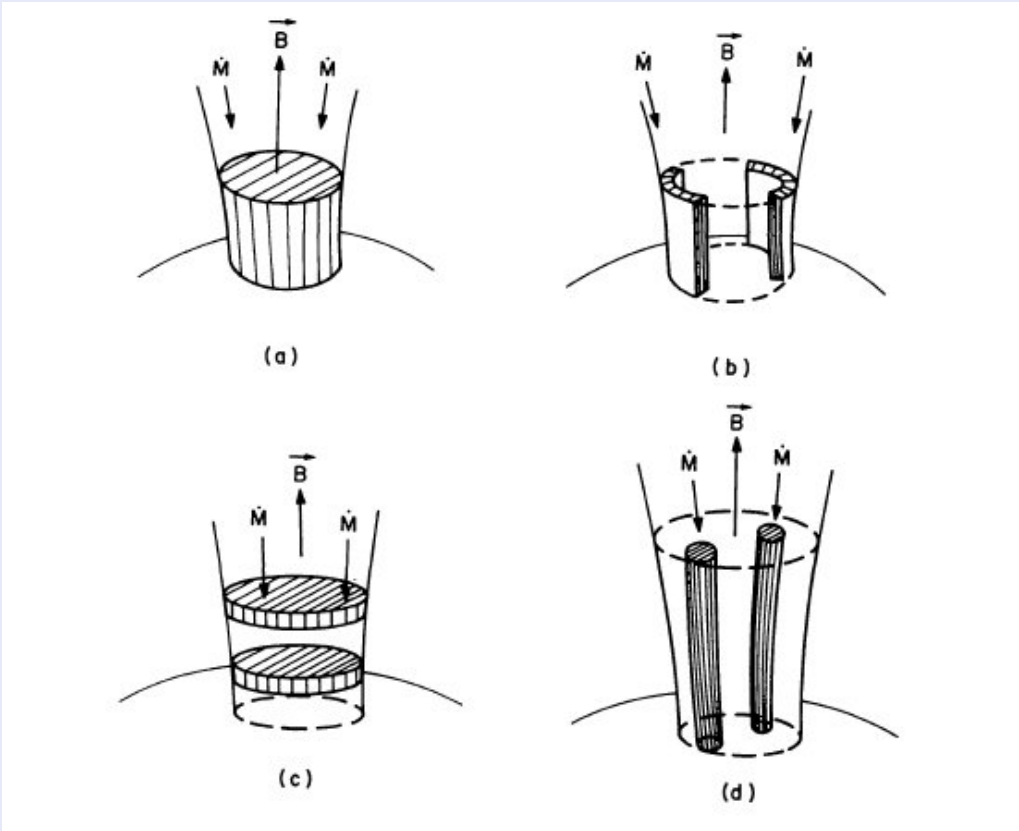
Accretion column



Becker & Wolff (2005)

Accretion column



Mészáros (1984)

History

Detection

- first detected with *Uhuru* in 1974 (Giacconi et al., 1974) as 3U 1912+07
- also known as X1908+075
- 4.4 d orbit detected with *RXTE* ASM in 2000 (Wen et al., 2000)
- 650 s pulse period detected with *RXTE* PCA (Levine et al., 2004)
- companion identified in infrared as OB star with $M_\star = 9\text{–}31\,\mathrm{M}_\odot$ (Morel & Grosdidier, 2005).

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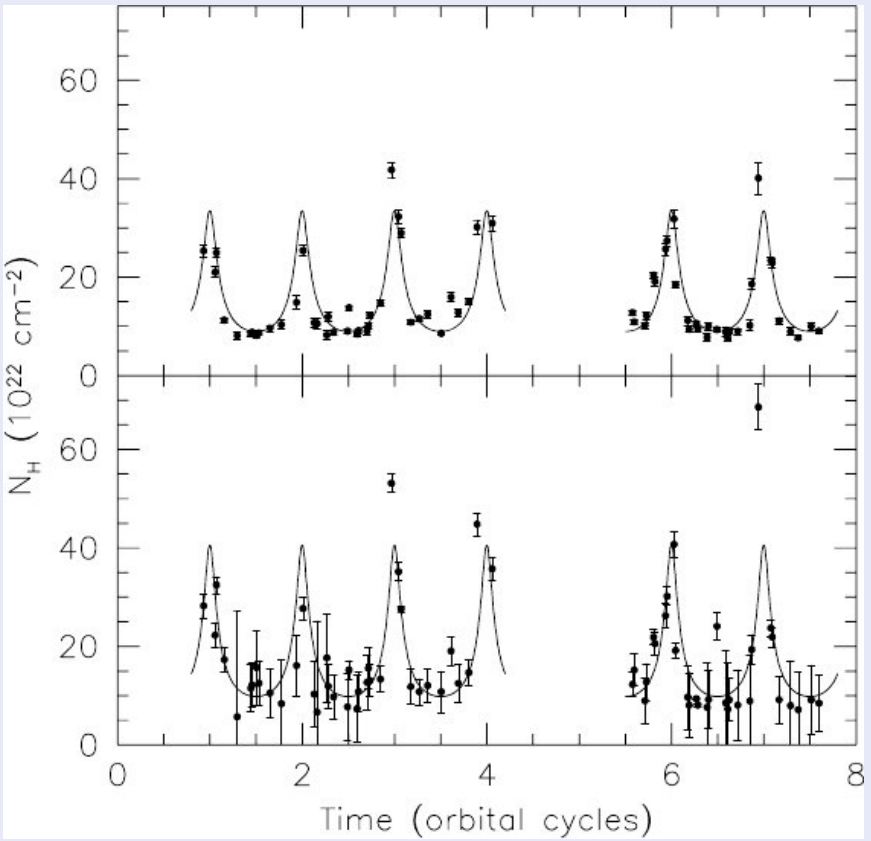
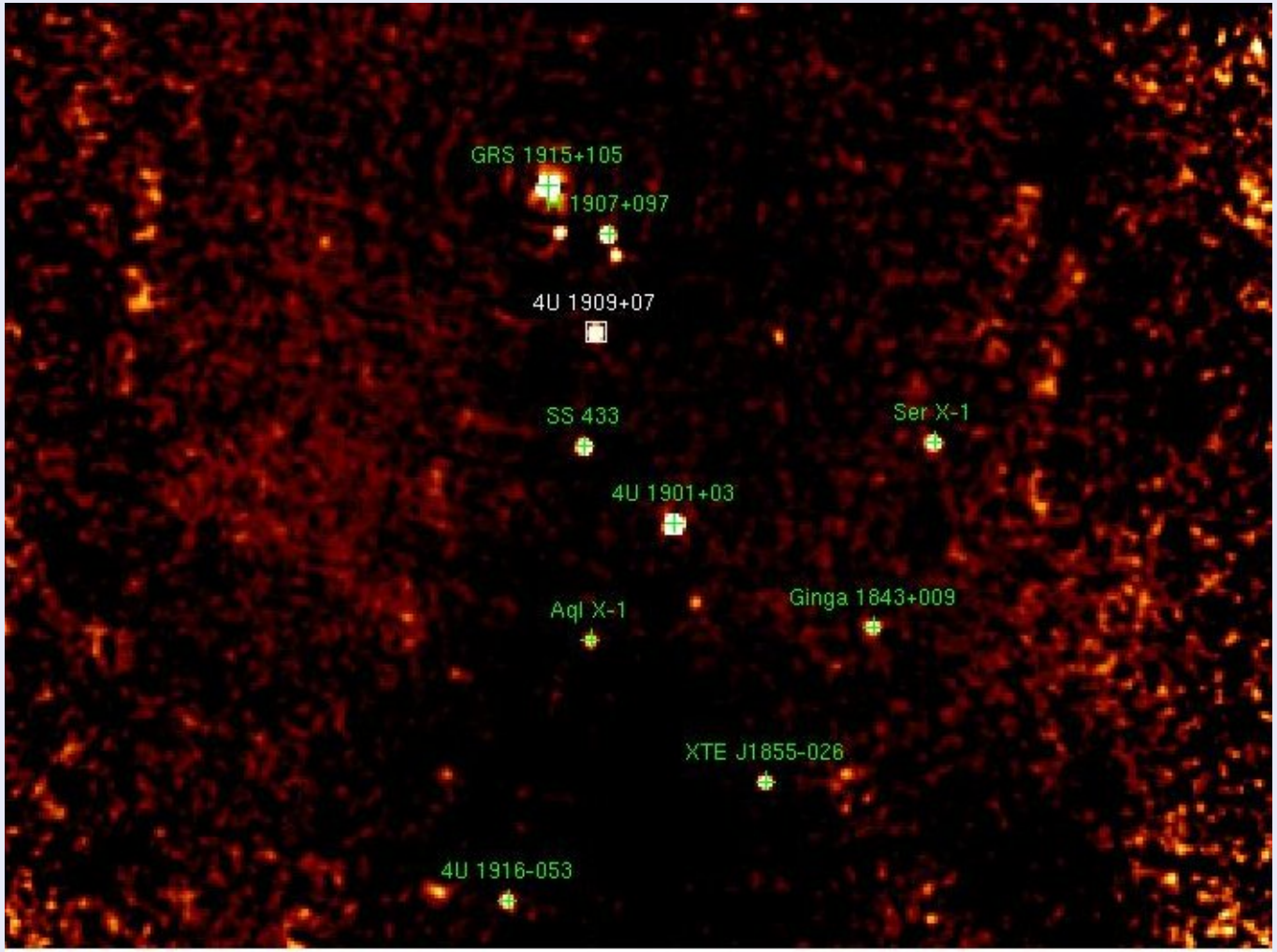
Orbital variation

- 4U 1909+07 shows strong orbital variability
- the N_H value rises by a factor of 3
- explainable by standard wind models
- resulting inclination $\sim 54° \leq i \leq 70°$



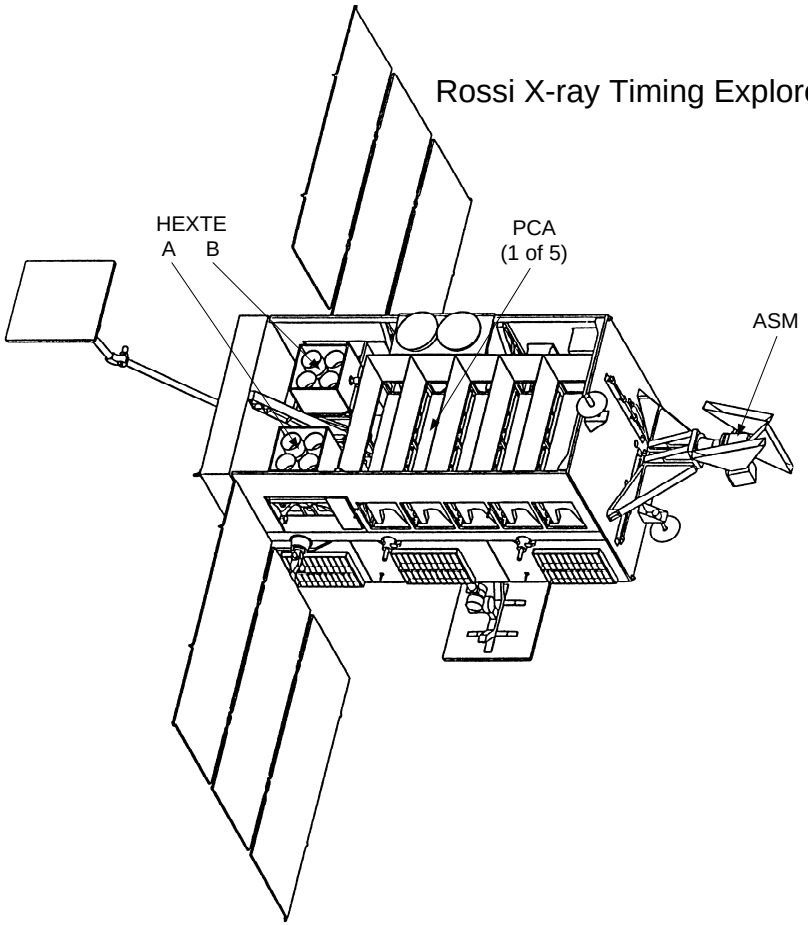
Levine et al. (2004)

Hard X-ray Image



Rossi X-ray Timing Explorer (RXTE)

- launched in Dec 1995
- small mission with 3 instruments:
  - Porpotional Chamber Array (PCA): 2–60 keV
  - High Energy X-ray Timing Experiment (HEXTE): 15–250 keV
  - All Sky Monitor (ASM): 2.5–10 keV
- no imaging capabilities, but high time resultion ($\sim \mu$s)



INTEGRAL

- launched in Oct 2002
- 3 X-ray instruments:
  - JEM-X: 3–35 keV
  - IBIS with ISGRI and PICsIT: 15 keV – 10 MeV
  - SPI: 20 keV – 8 MeV
- coded mask instruments, imaging of the hard X-ray sky

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Data

RXTE

- only short observations in 2000 and longer observations in 2004
- previously analyzed by Levine et al. (2004), but without phase resolved spectral analysis
- overall 180 ksec data with average countrate ∼50 cps

INTEGRAL

- no pointed observation (yet)
- 4U 1909+07 lies in ISGRI's FoV when observing GRS 1915+105
- ∼6.6 Msec data with ∼2.4 cps
- used first 100 days block for spectral analysis only

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Extraction

RXTE

- using standard HEASARC software v. 6.6
- extracted PCA lightcurves with 1 sec resolution
- extracted PCA and HEXTE spectra

INTEGRAL

- using OSA 7.0
- extraced ISGRI lightcurve with 20 sec resolution, using `ii_light`
- extracted ISGRI spectrum

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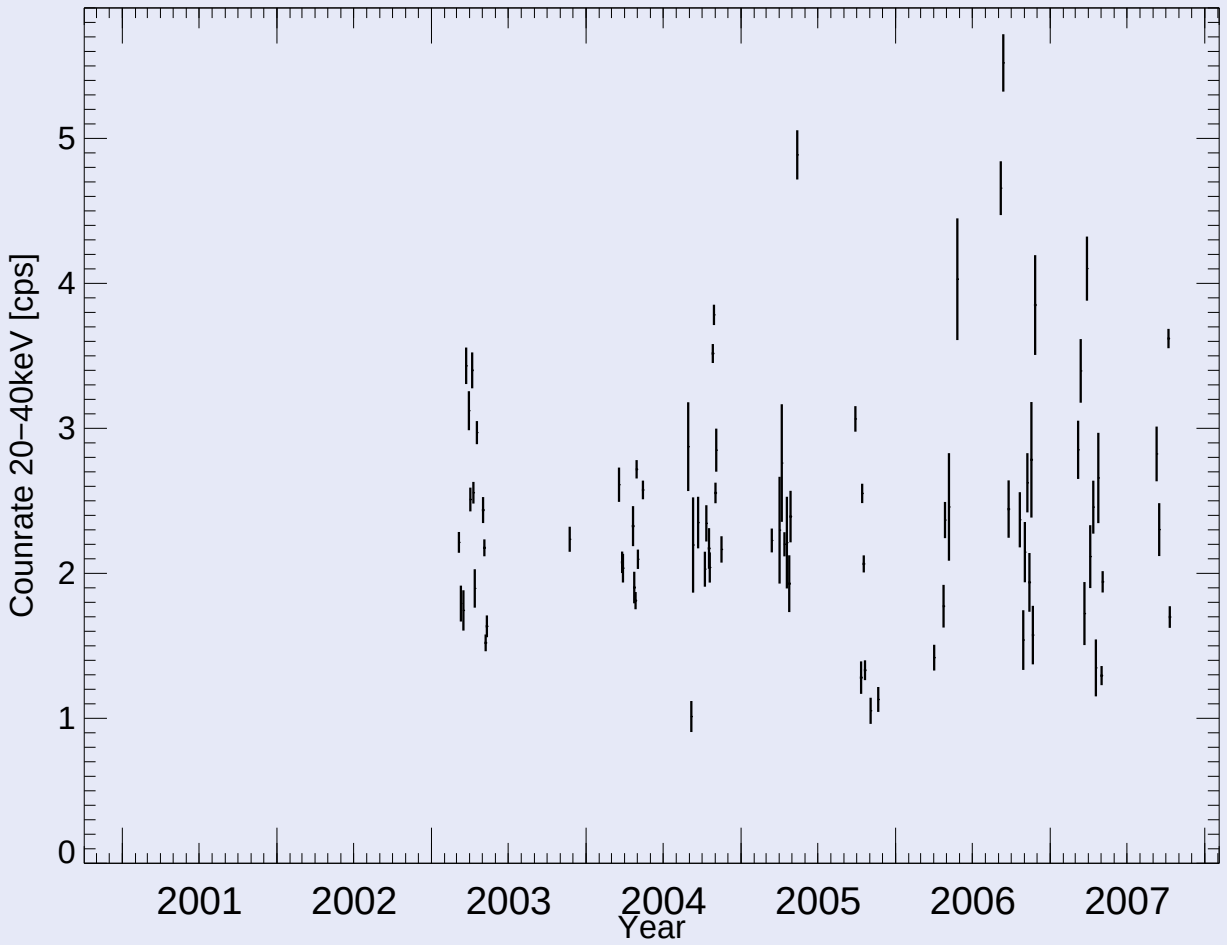
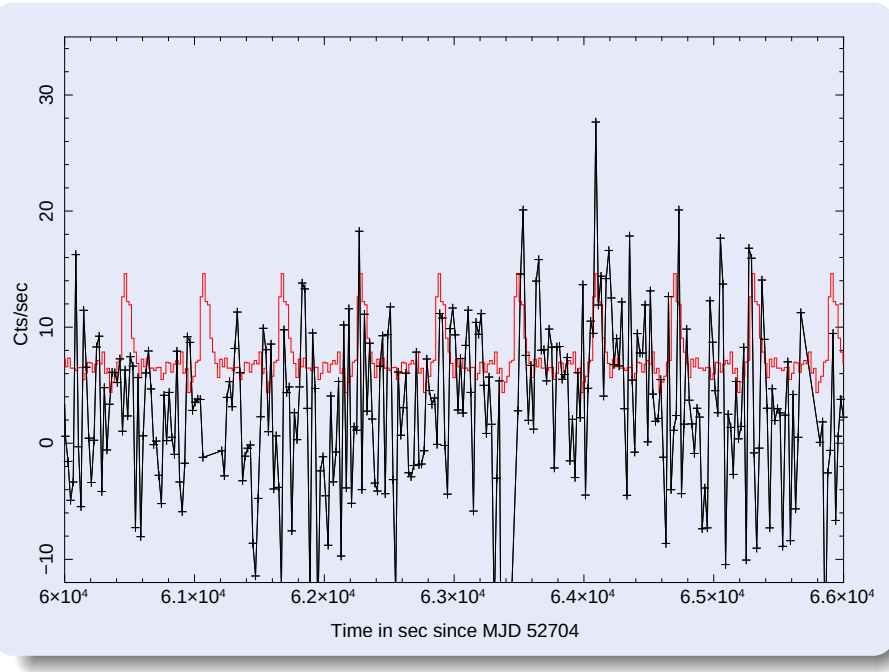
3 days average lightcurve



Pulse period search

- *INTEGRAL* data provides good sampling between 2003–2008
- *RXTE* measurements in 2000 and 2003
- stable pulse profile only after folding at least 500 pulses



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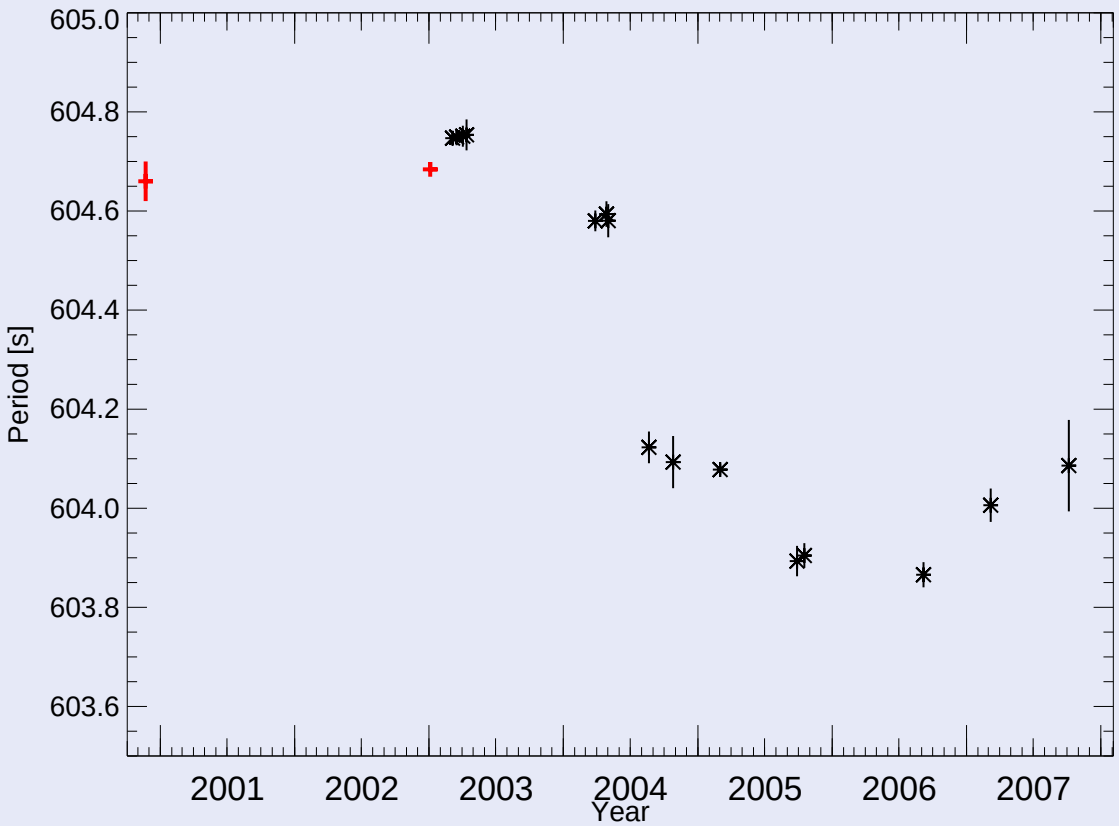
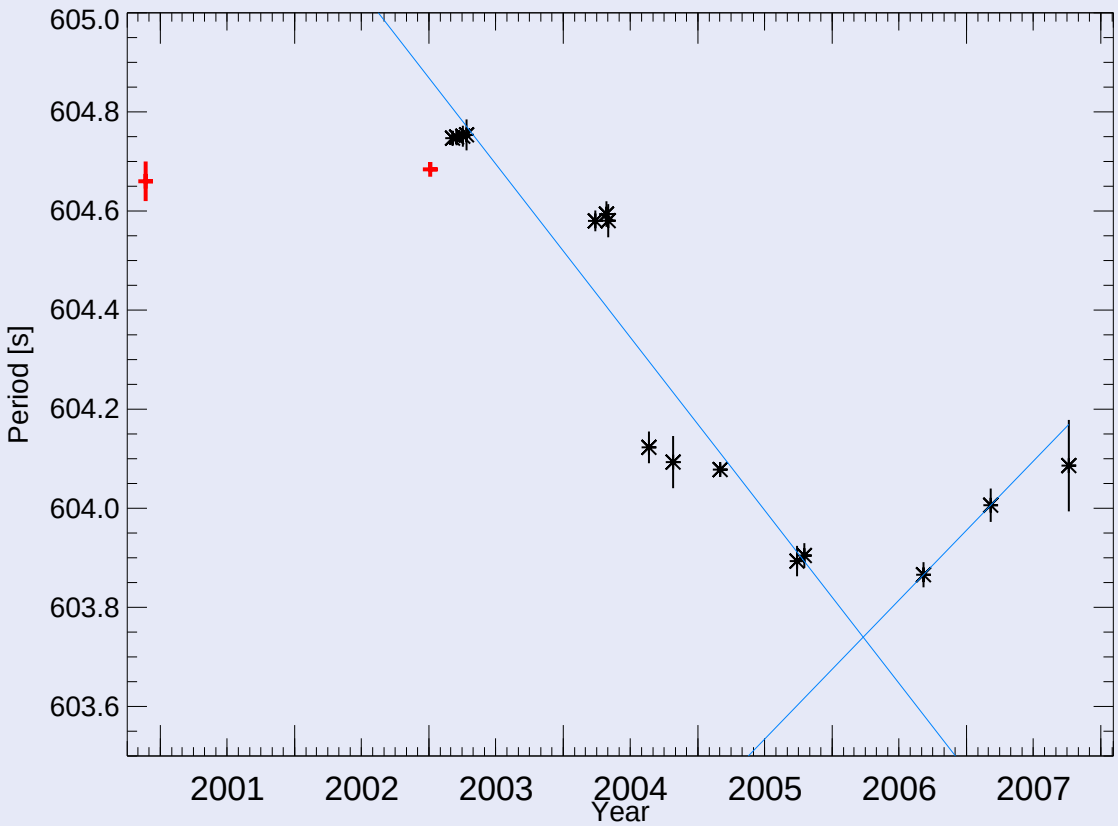
Pulse period evolution



Pulse period evolution



Pulse period evolution

- evolution could be torque reversal, as seen in 4U 1907+09 (Fritz et al., 2006)
- but also consistend with random walk

Random Walk?

- easy test proposed by de Kool & Anzer (1993)
- plot pulse period evolution in $\log \delta\omega - \log \delta t$ space
- perfect random walk shows powerlaw with index 0.5

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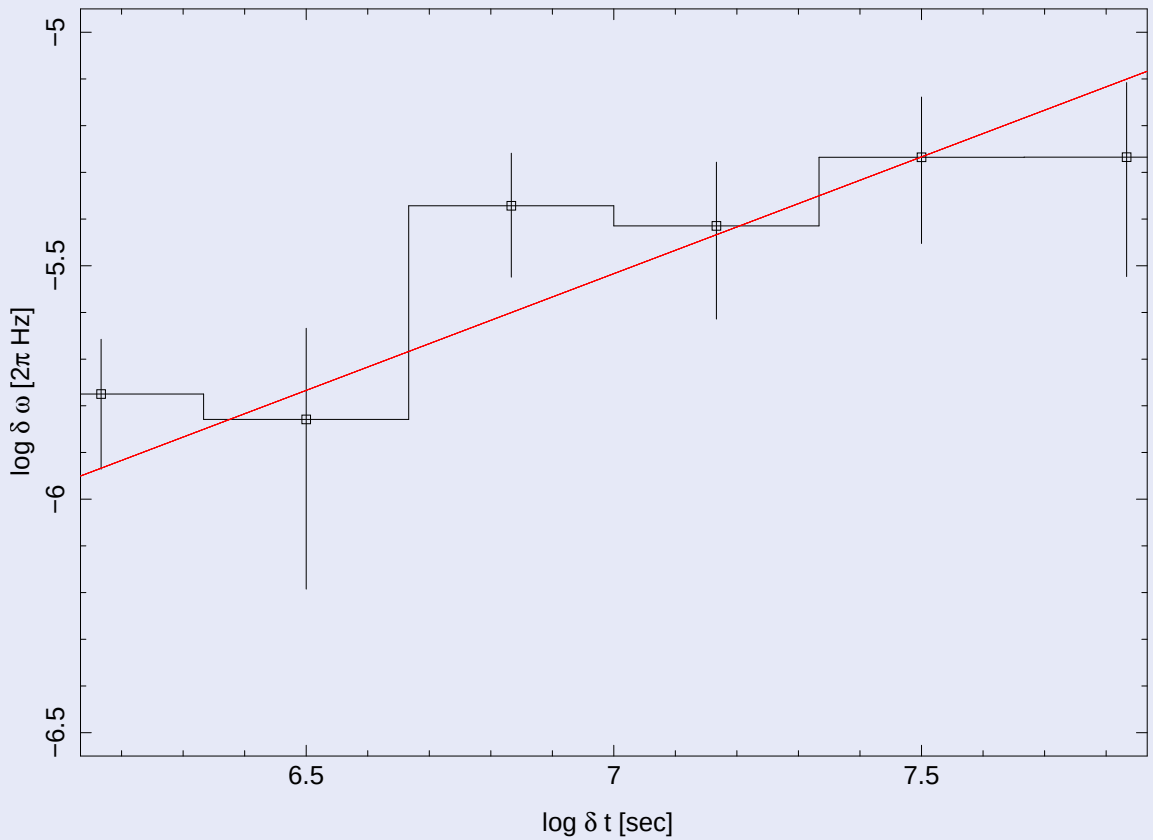
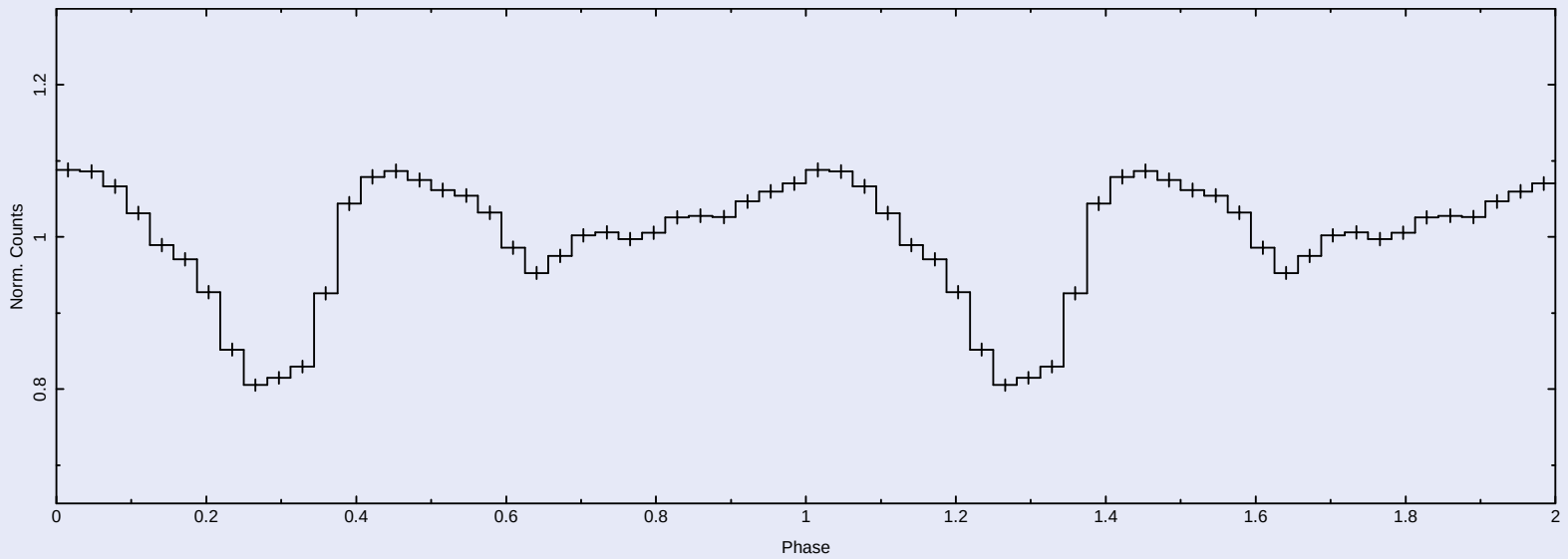
Pulse period evolution

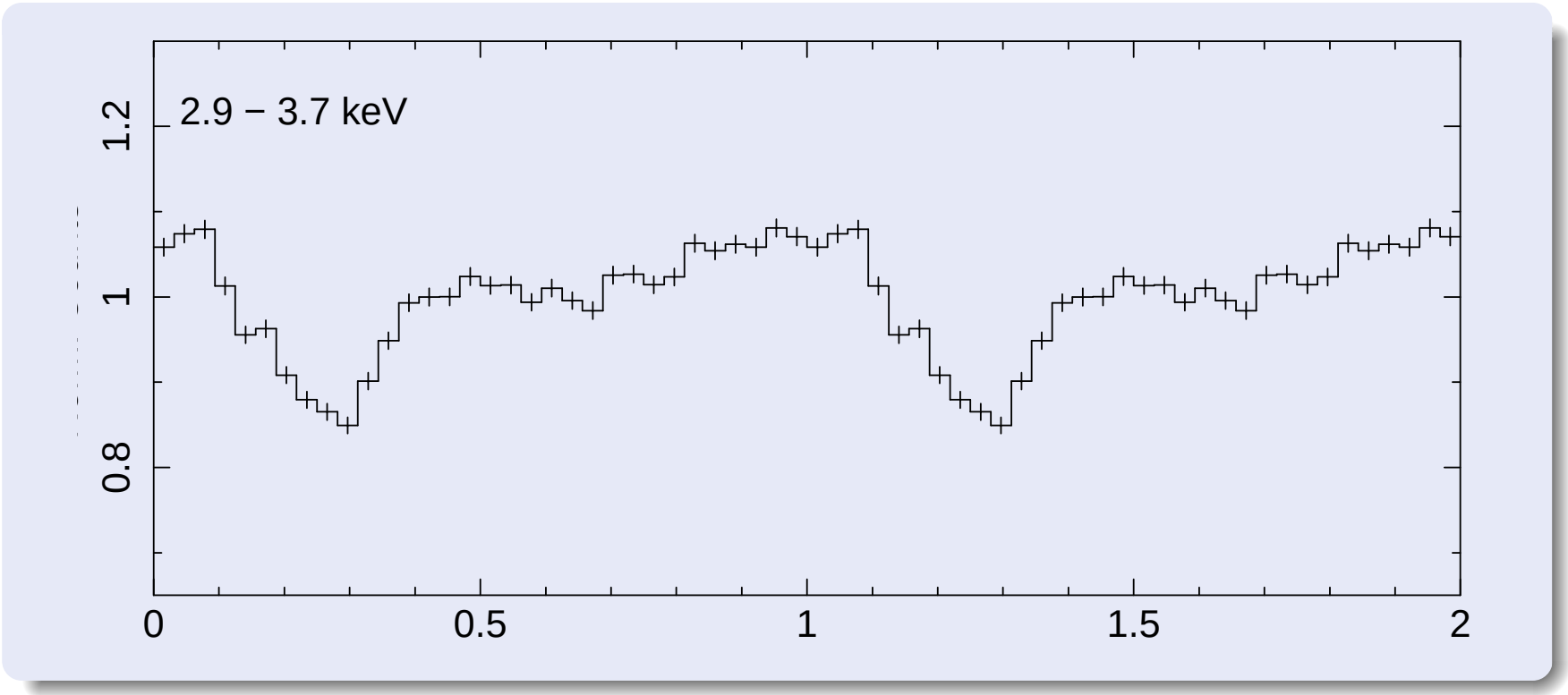


Pulseprofiles

- average 3.7–17 keV pulseprofile shows two-peaked shape (Levine et al., 2004).
- pulses are separated by deep minimum



Pulseprofiles



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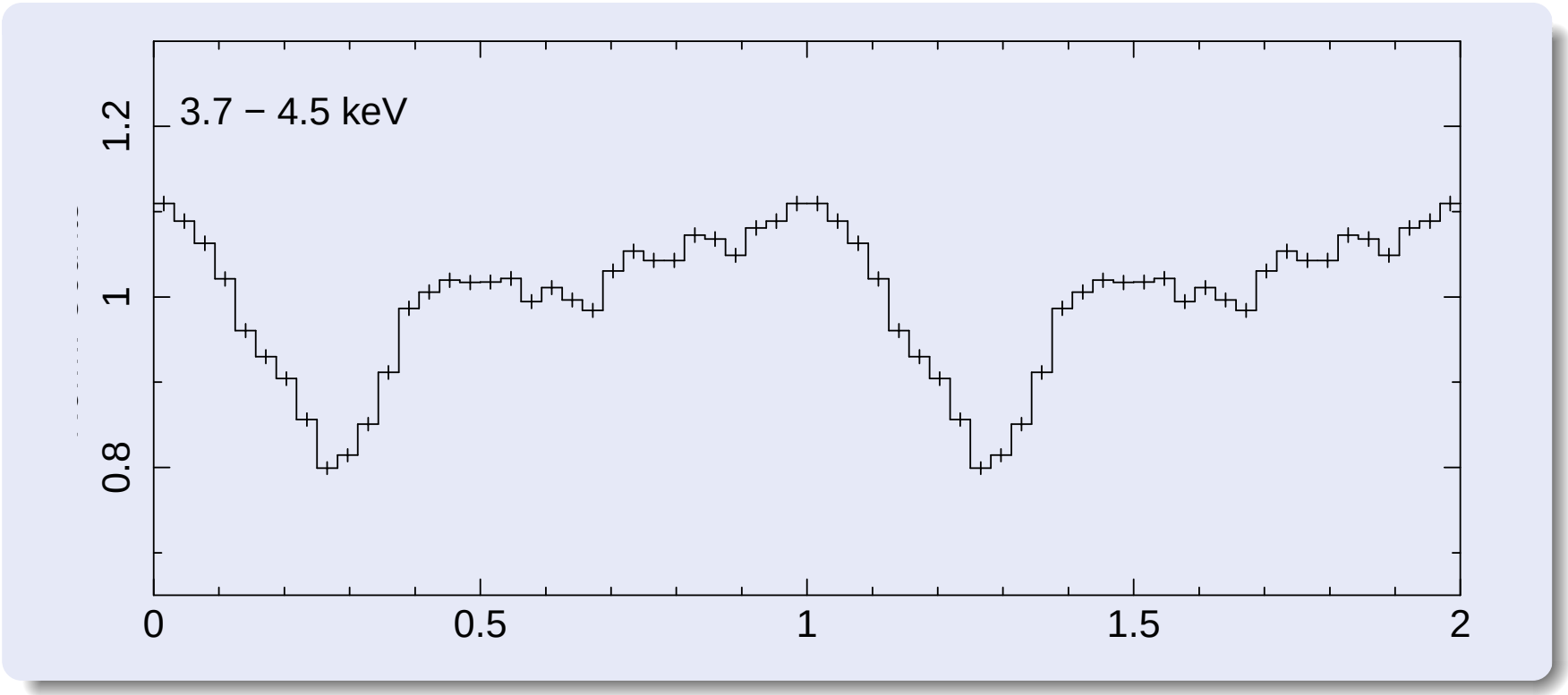
Pulseprofiles



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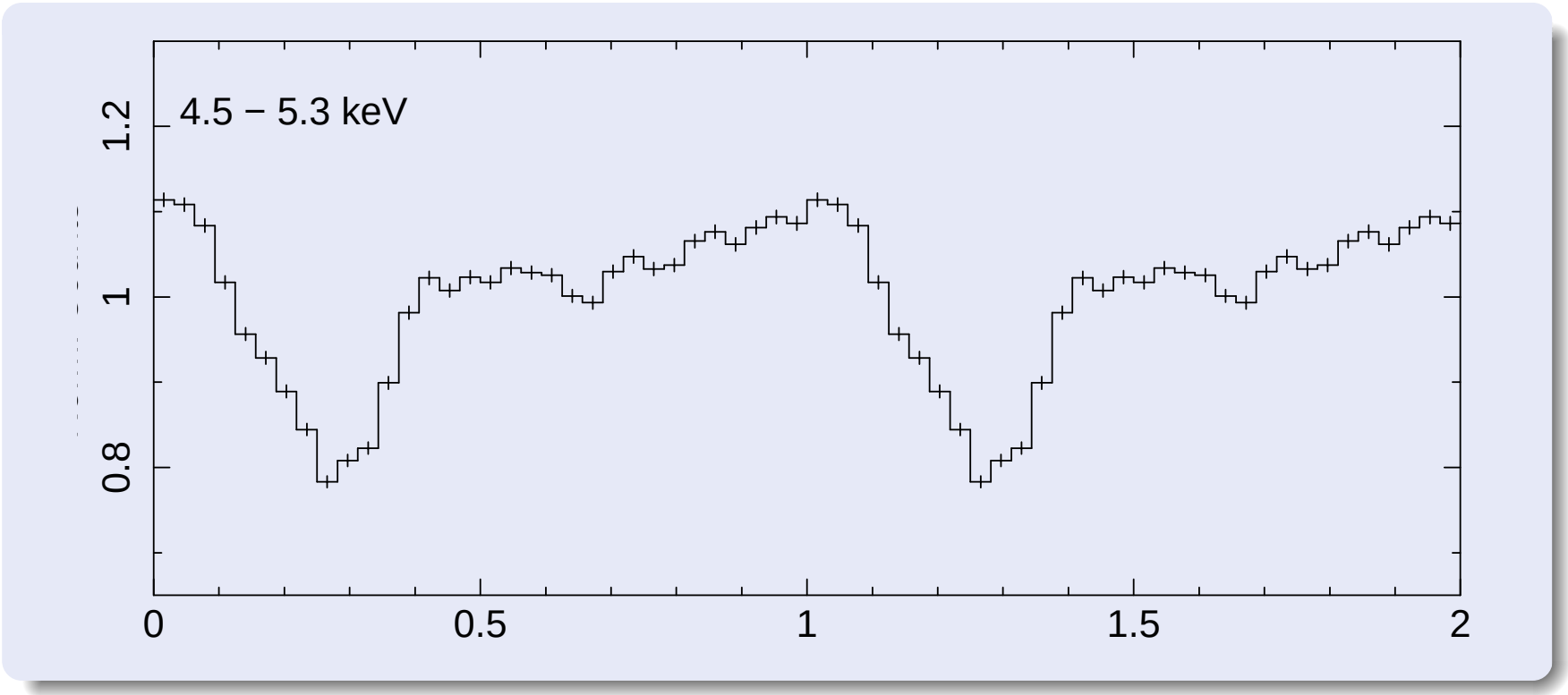

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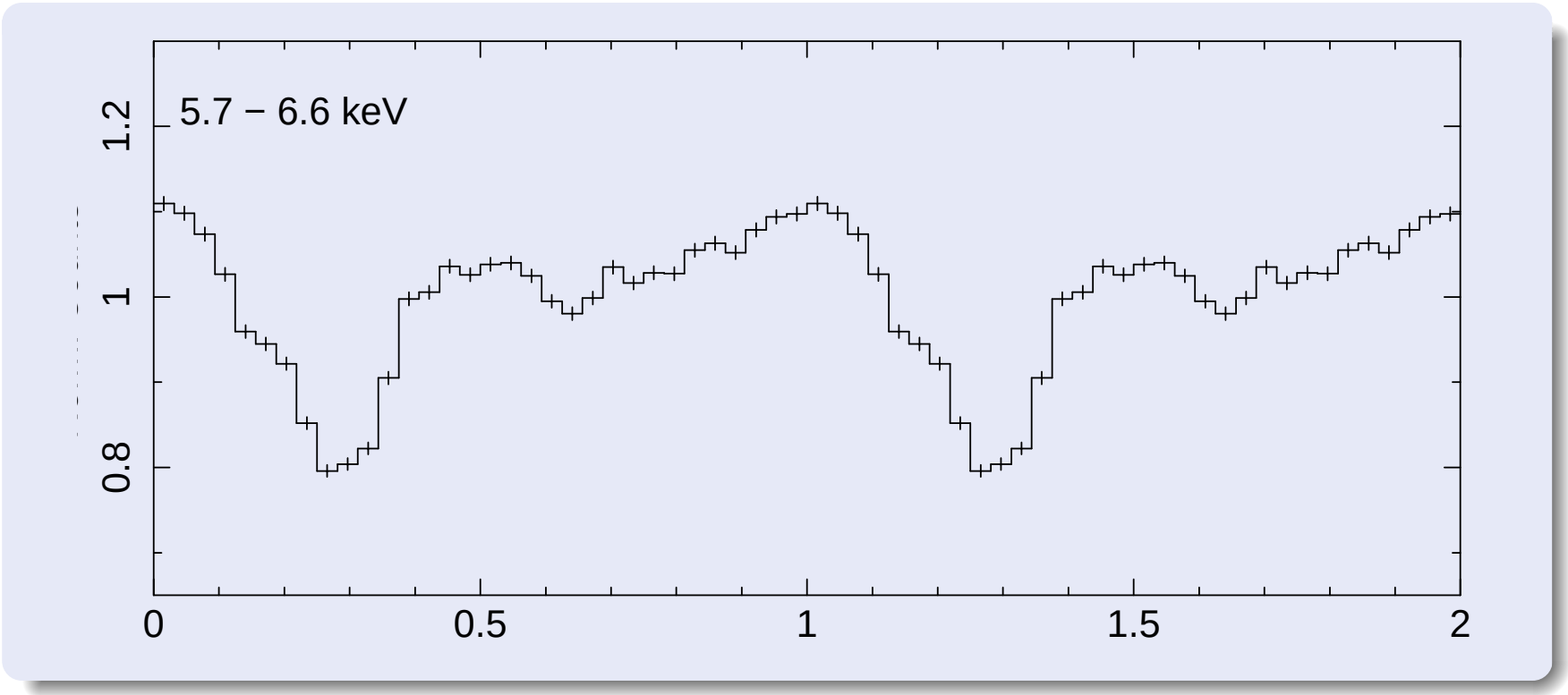

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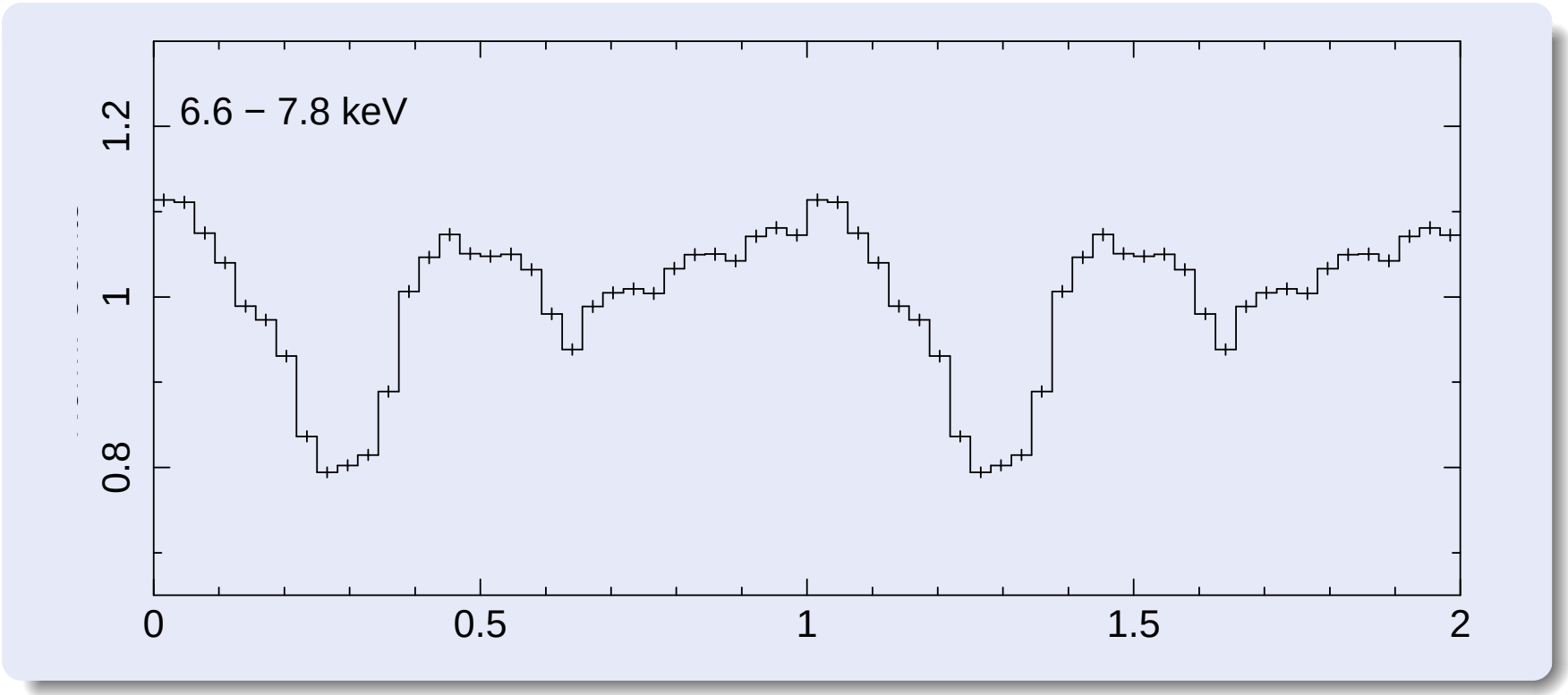

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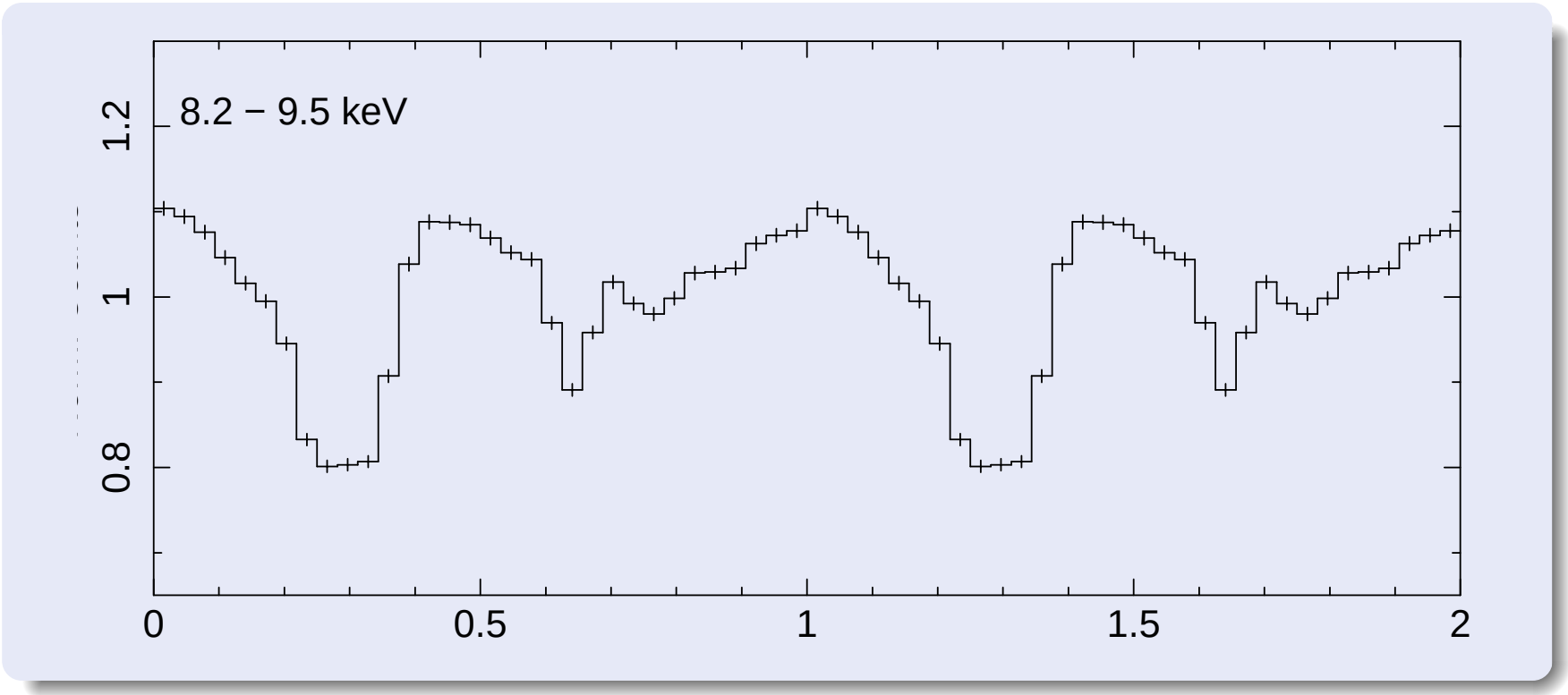

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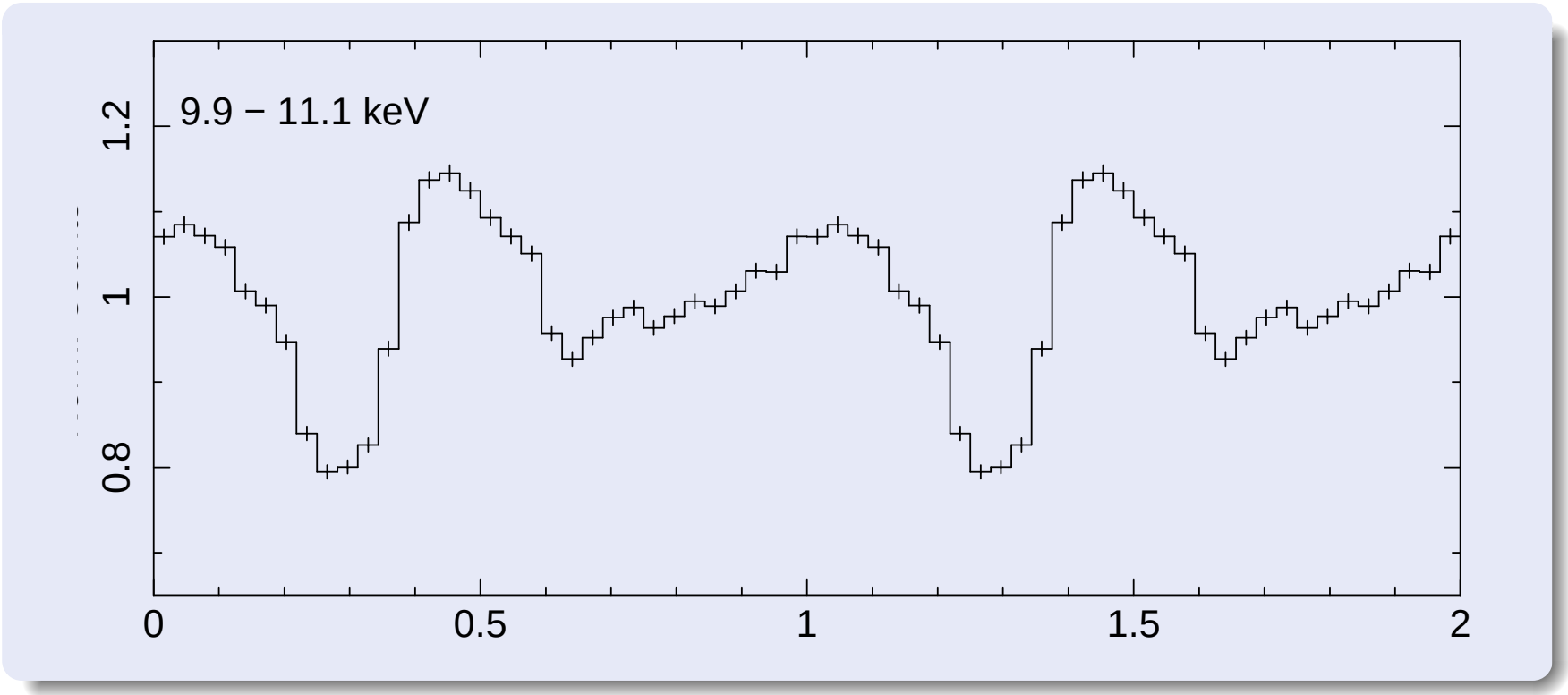

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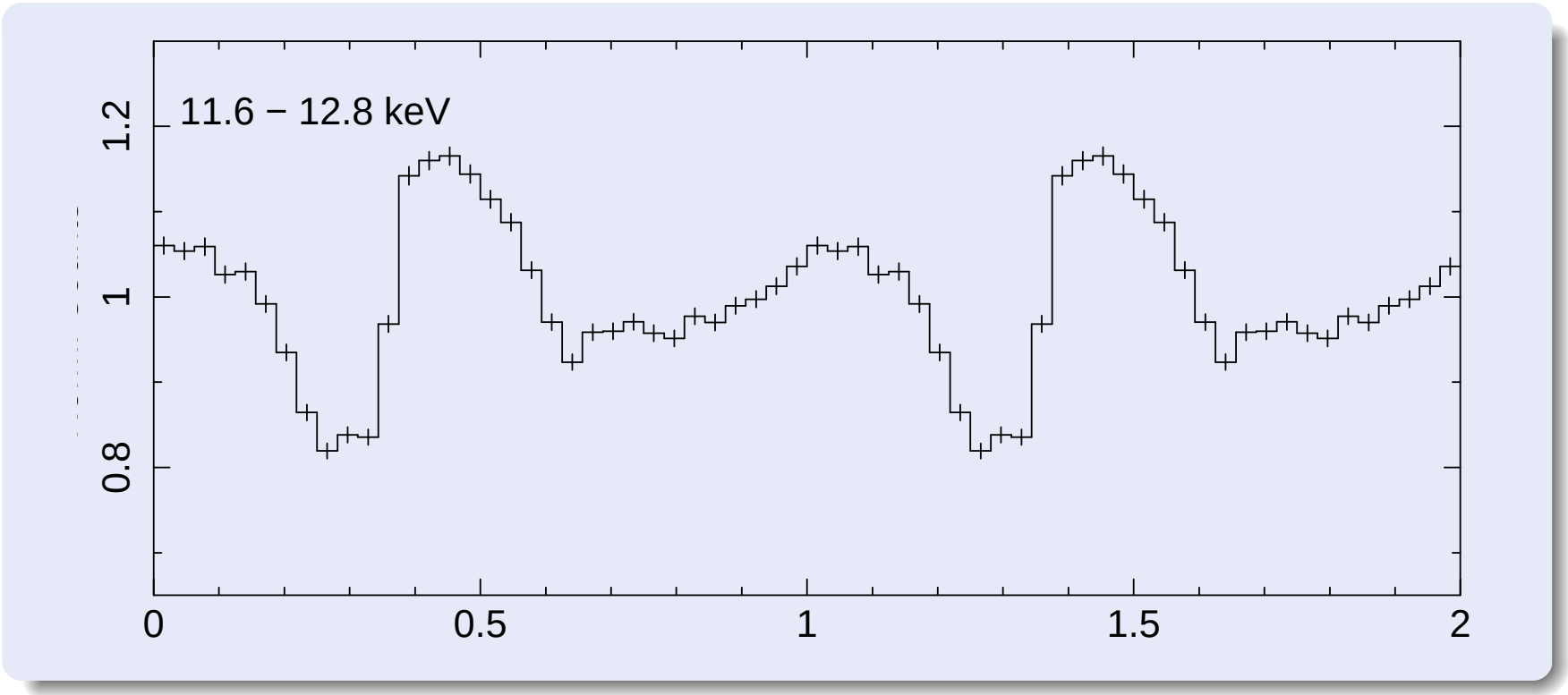

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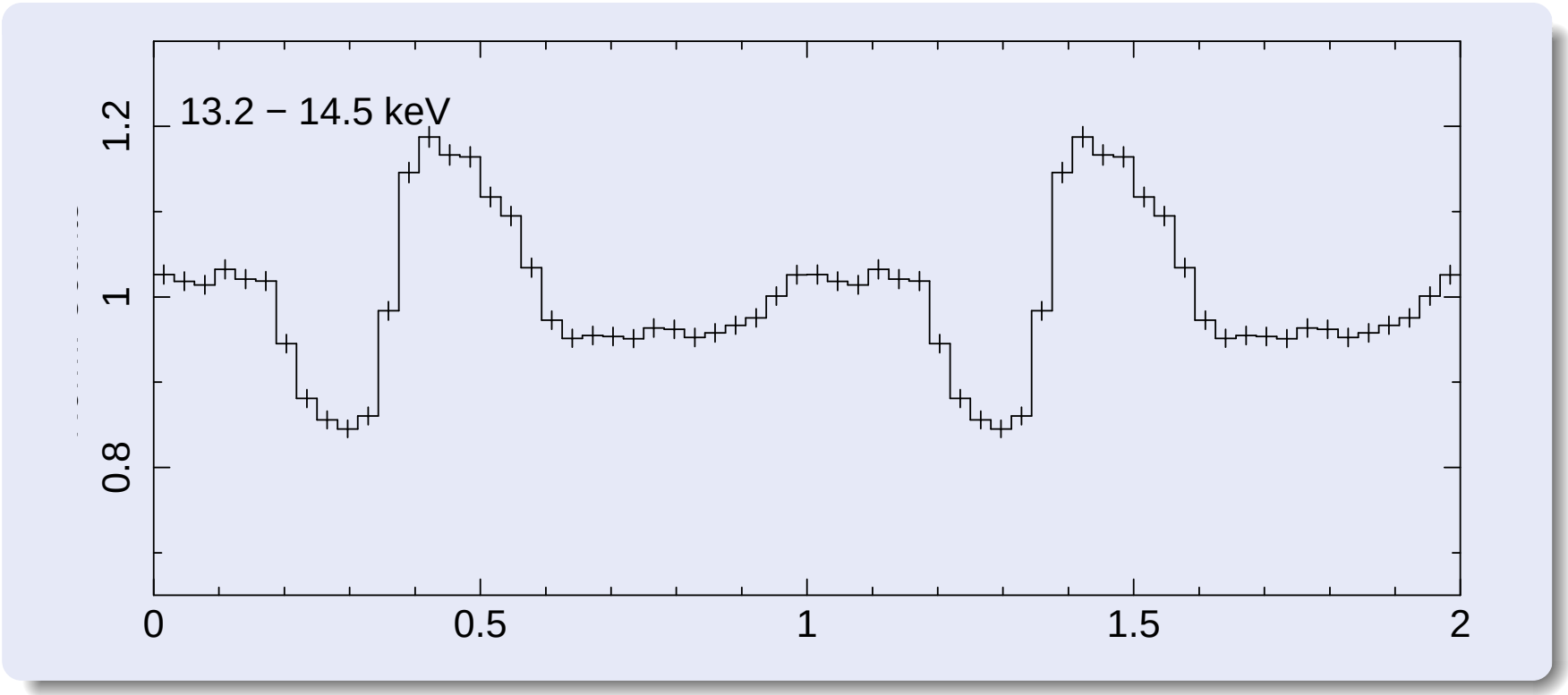

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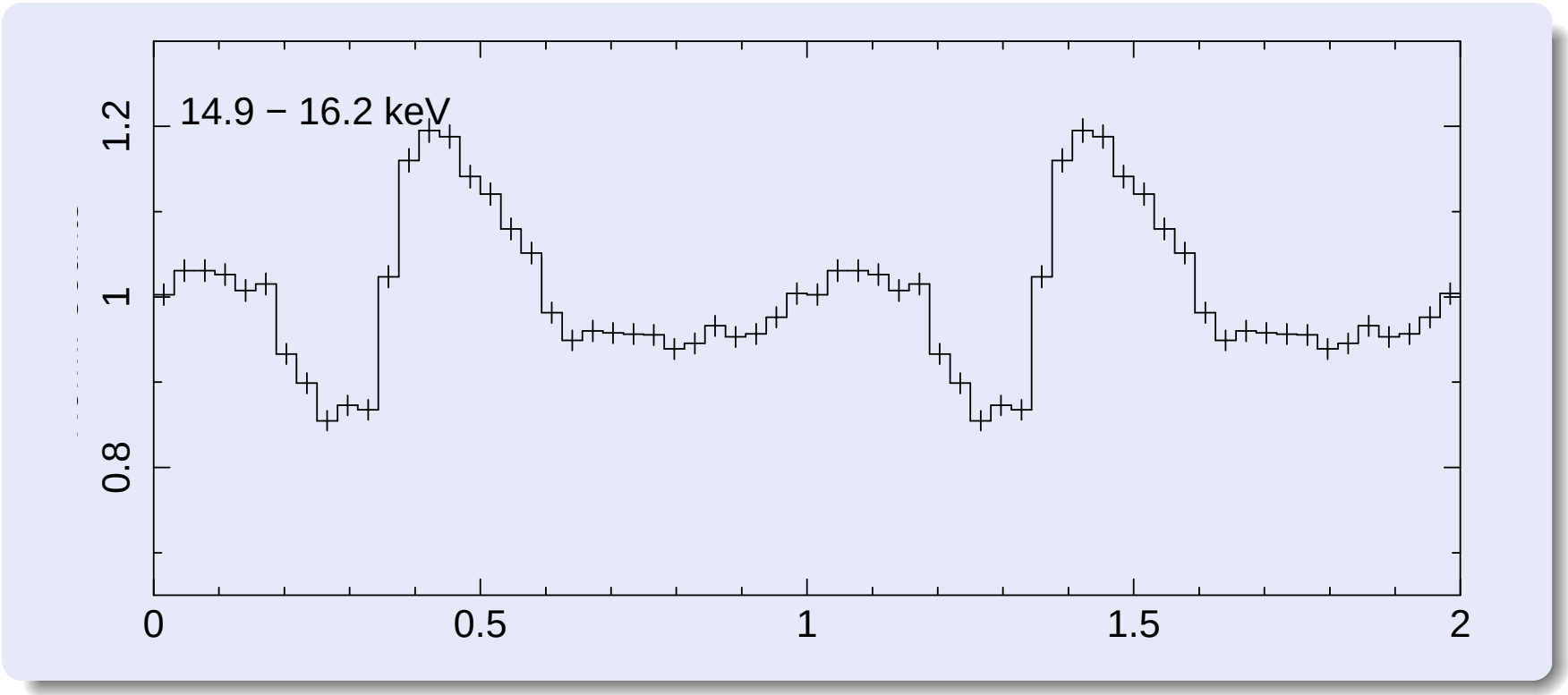

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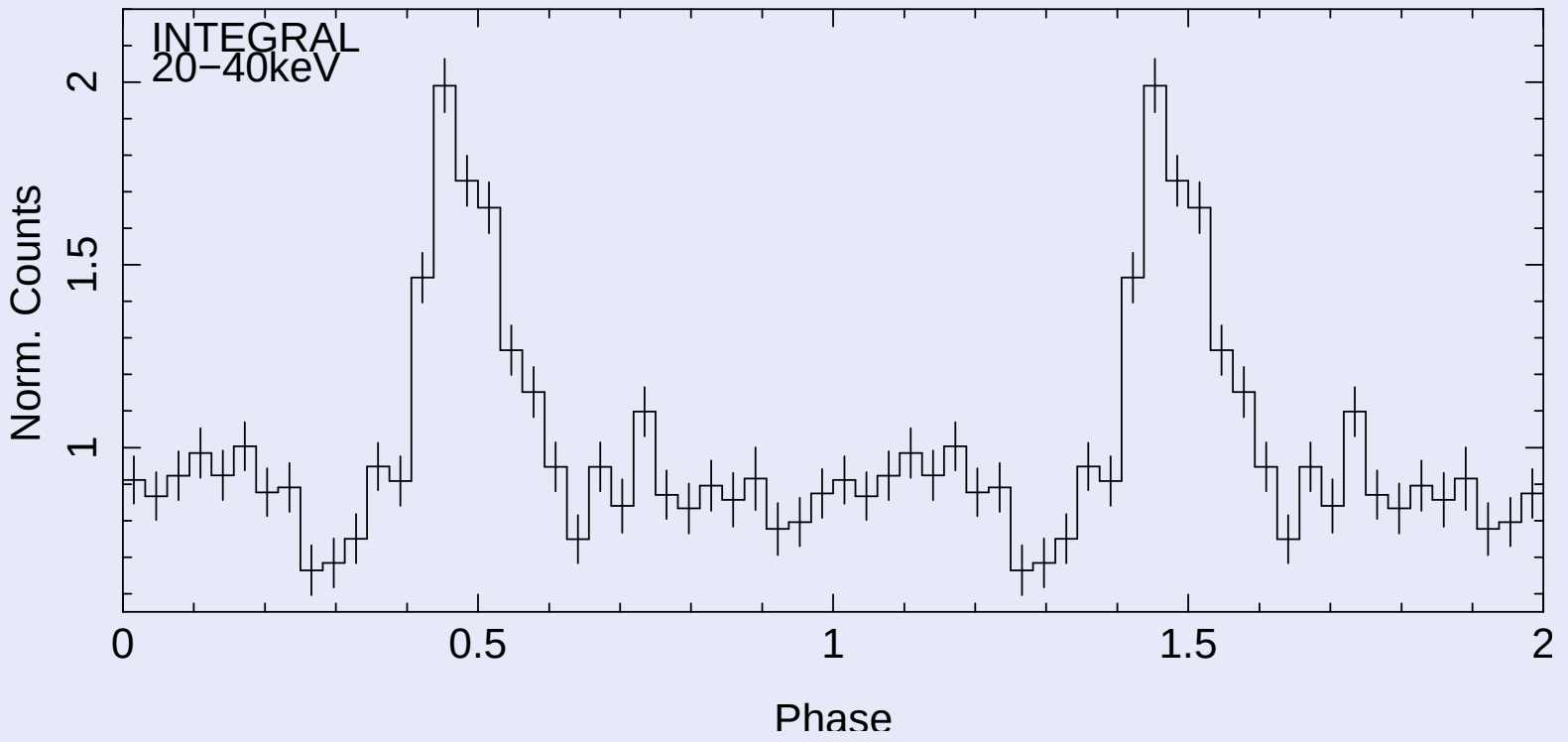
Pulseprofiles



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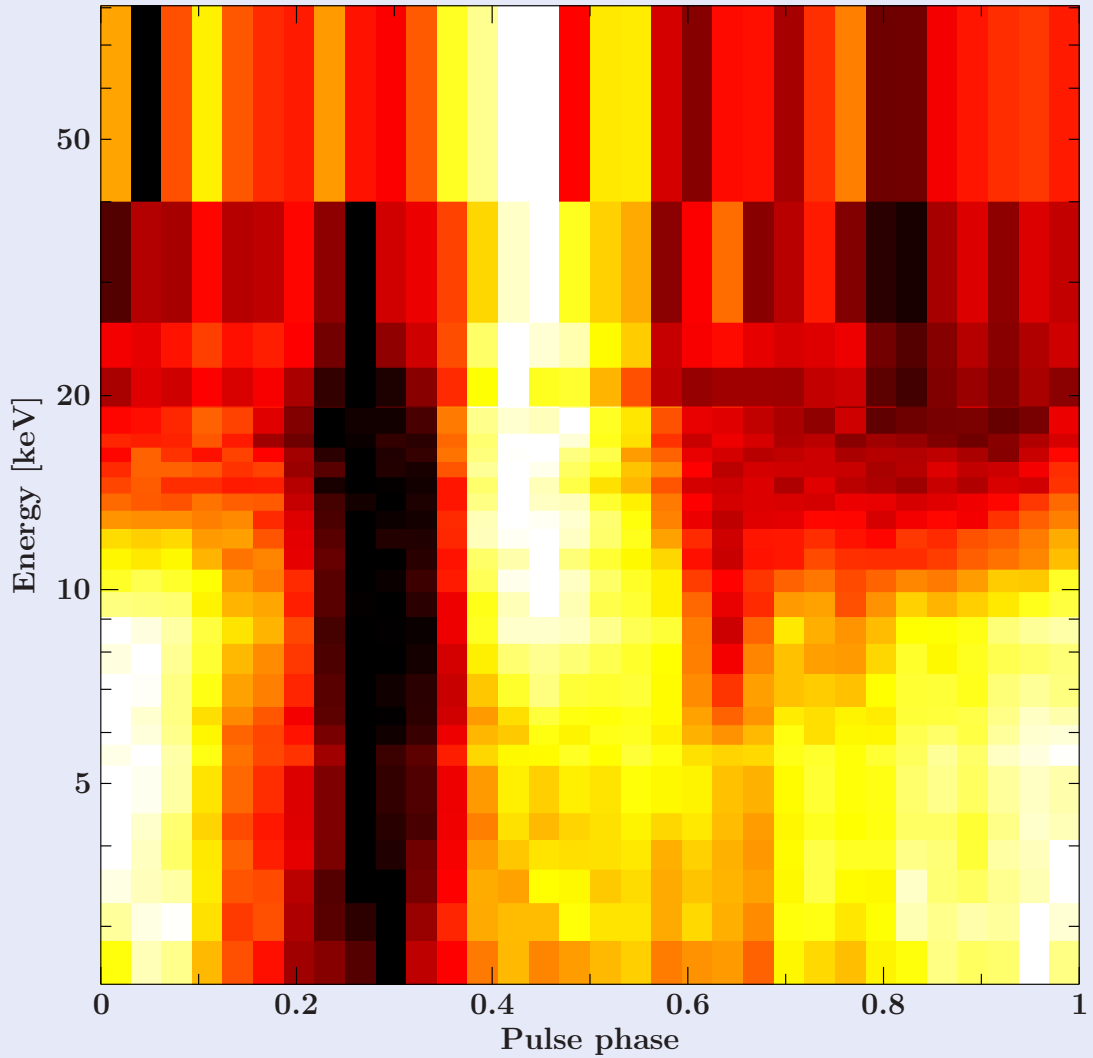
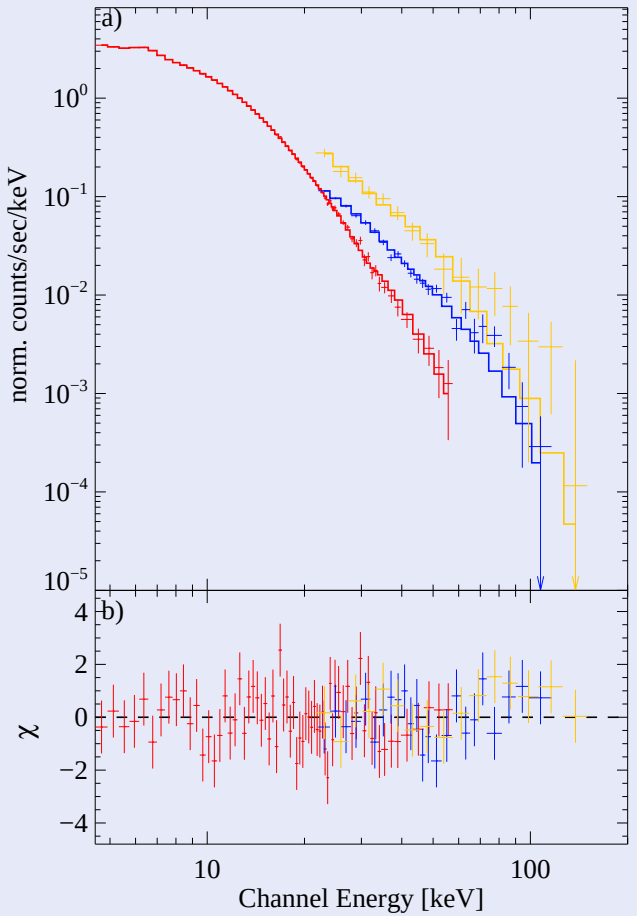
Landscape Pulseprofiles



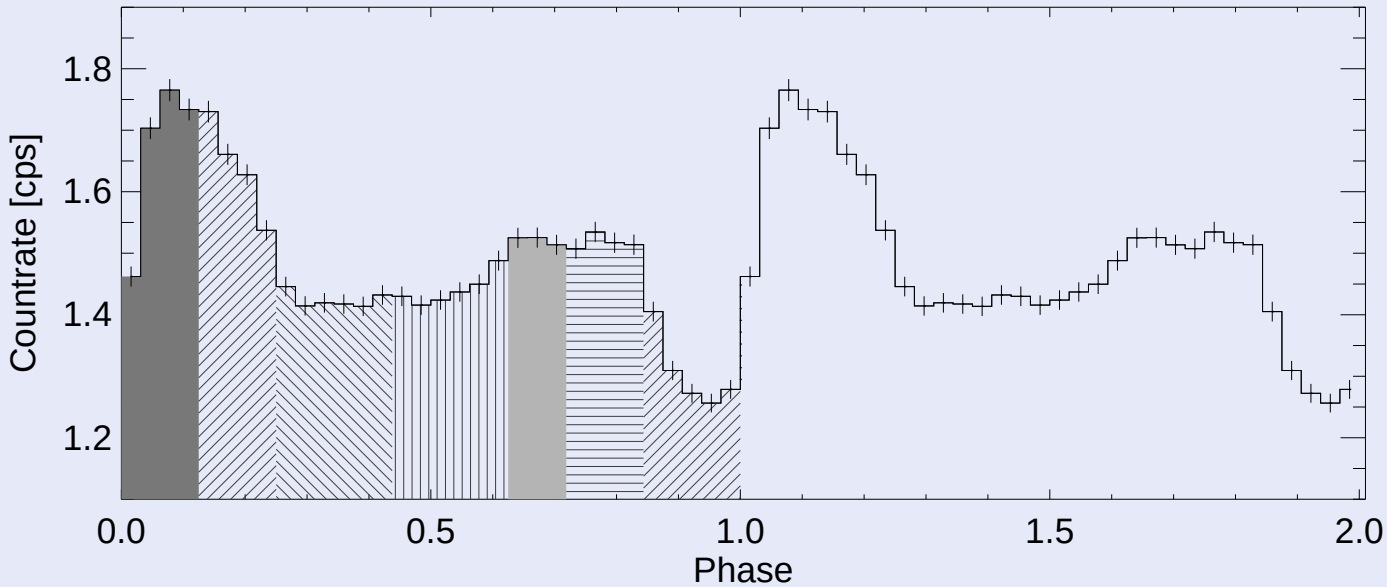
Phase averaged spectrum

- *RXTE* PCA, HEXTE, and *INTEGRAL* ISGRI fit simultaneously
- cutoff powerlaw with photoabsorption and iron line
- additionally black body to model soft excess
- no evidence for a Cyclotron Resonance Scattering Feature (CRSF)
- $\chi^2_{\mathrm{red}} \approx 1.01$ for `cutoffpl` + `bbody`

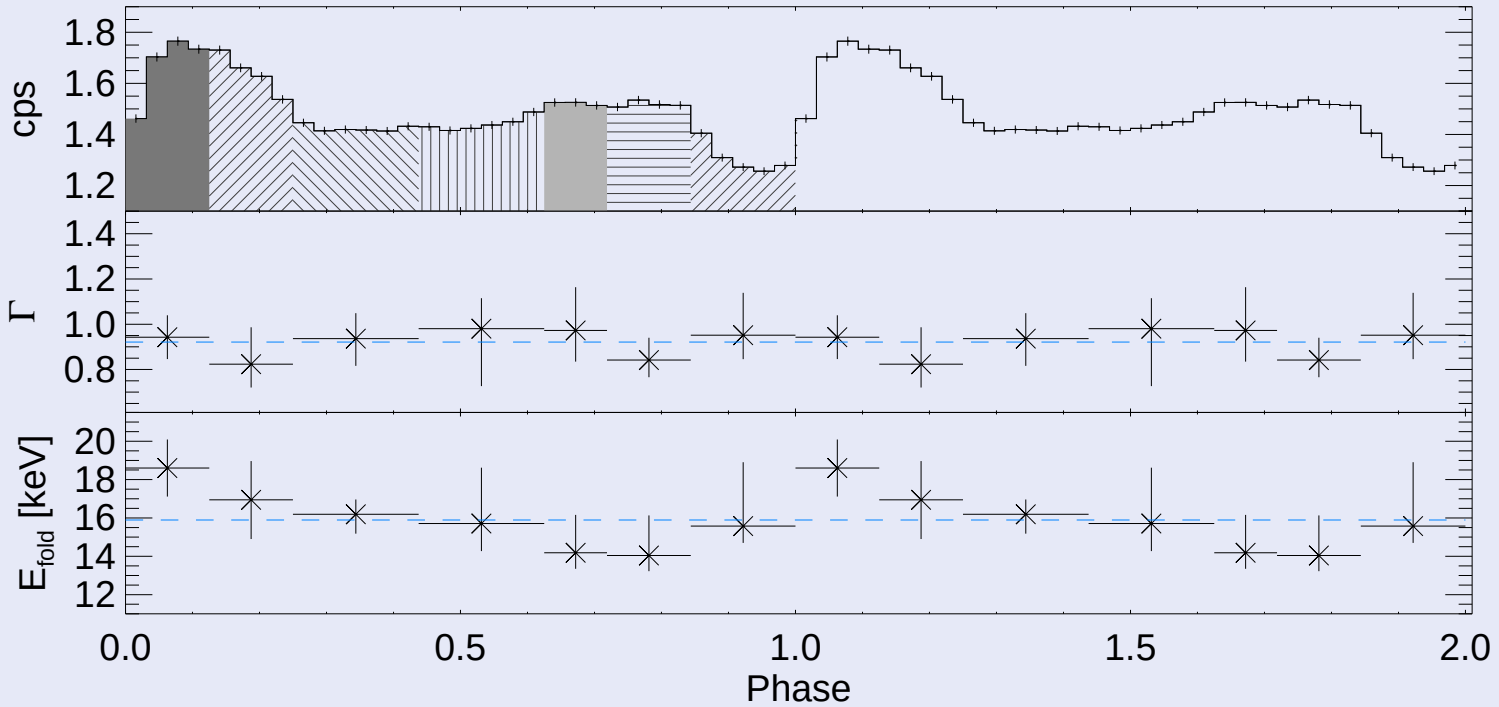


Phase resolved spectrum

- phase resolved analysis only for *RXTE* data
- analysis performed in 7 phasebins
- χ^2_{red} in all bins ≤ 1.4



Powerlaw parameters



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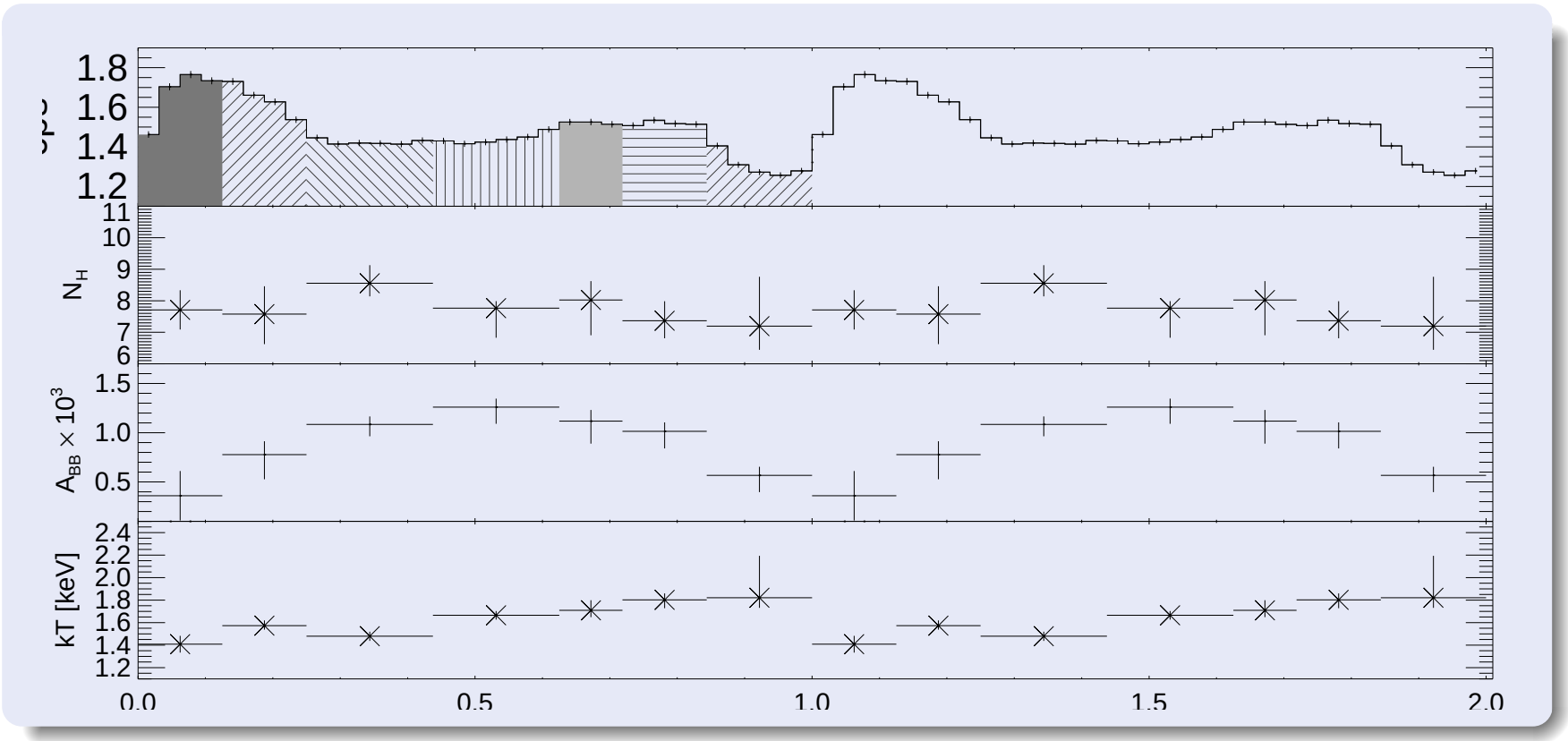
Soft components



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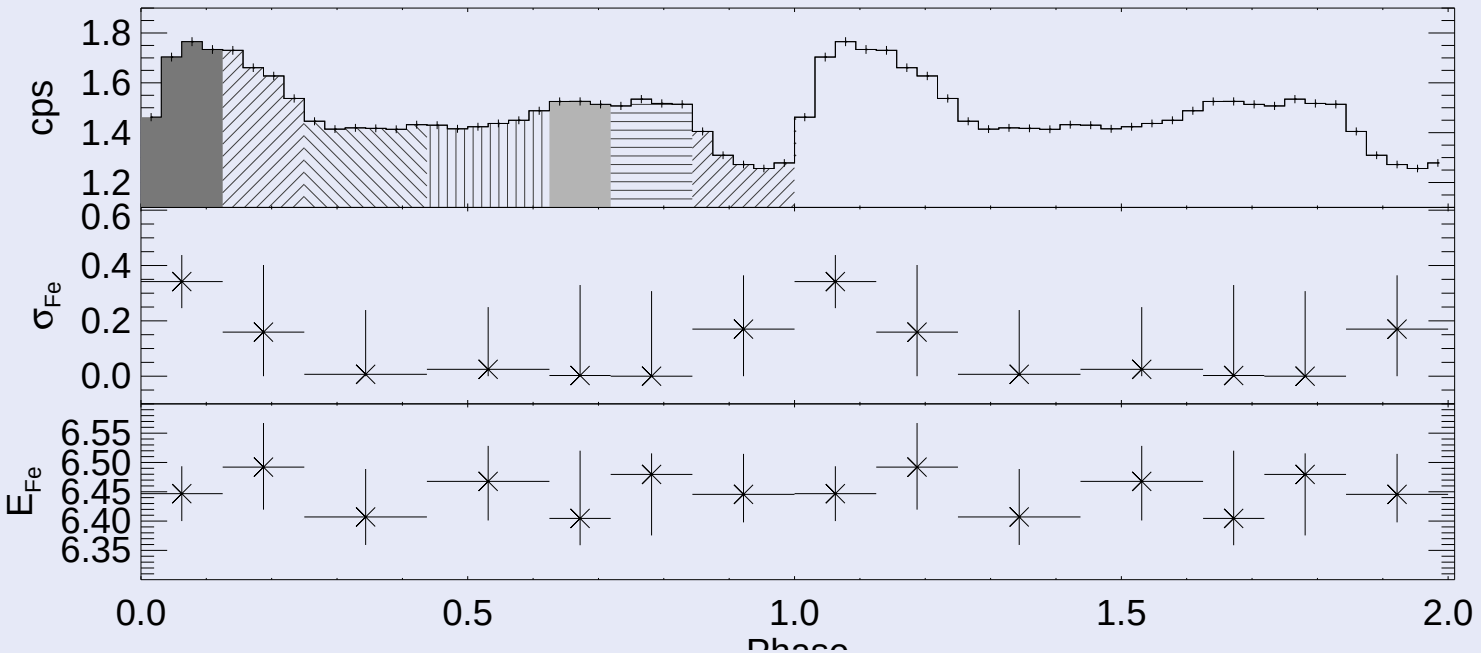
Iron line



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Results

- Pulse period changes compatible with a random walk
  $\Rightarrow$ no stable accretion disk (Ghosh & Lamb, 1979)
- Spectra show no evidence for a CRSF
  $\Rightarrow$ strong magnetic field still possible, as CRSFs can be missed due to various effects (Schönherr et al., 2007)
- Pulsed flux indicates strong magnetic field

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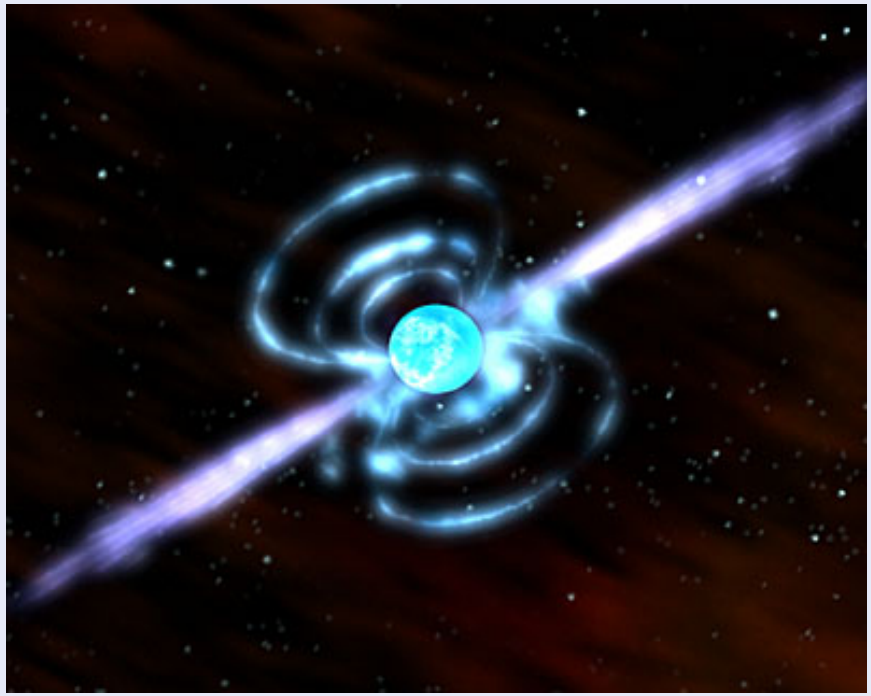
Results

- Pulse profiles shows two peaked structure
  $\Rightarrow$ orignating from the two magnetic poles?
- different spectral parameters in the two peaks
  $\Rightarrow$ different environment above the two poles?



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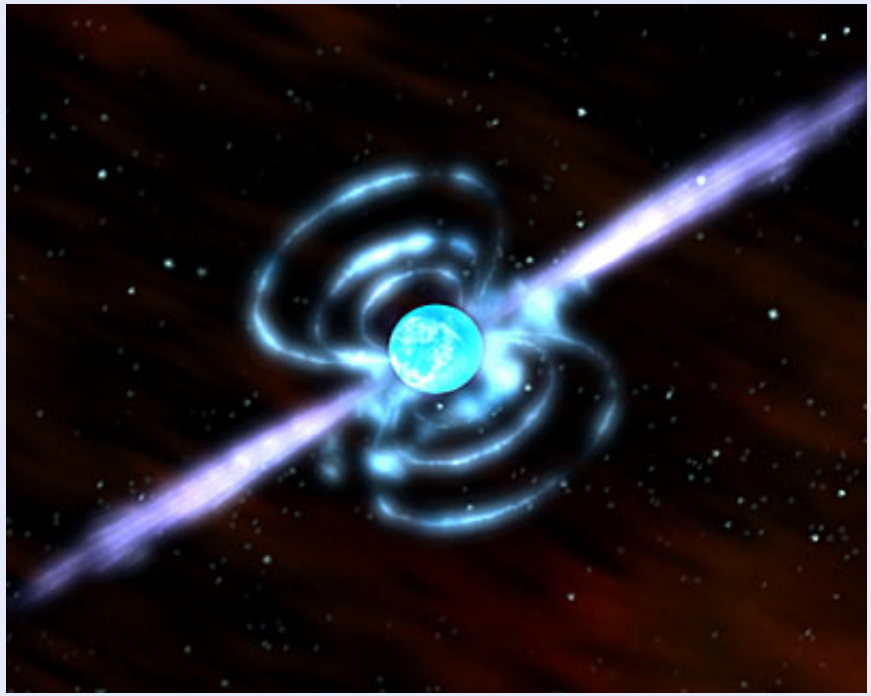
Results

- Maybe accretion column above one pole is colder and consequently can not Comptonize photons to hard X-rays
  $\Rightarrow$ change in E_{fold} explainable



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Outlook

- archival *Chandra* data are currently analyzed
- more observations with different satellites necessary
- especially soft energy range to study the iron complex
- in the hard X-rays: more thorough search for CRSF

Further reading: F. Fürst et al, Proceedings of the 2009 Fermi Symposium, astro-ph:0912.3702a
and soon publication in A&A

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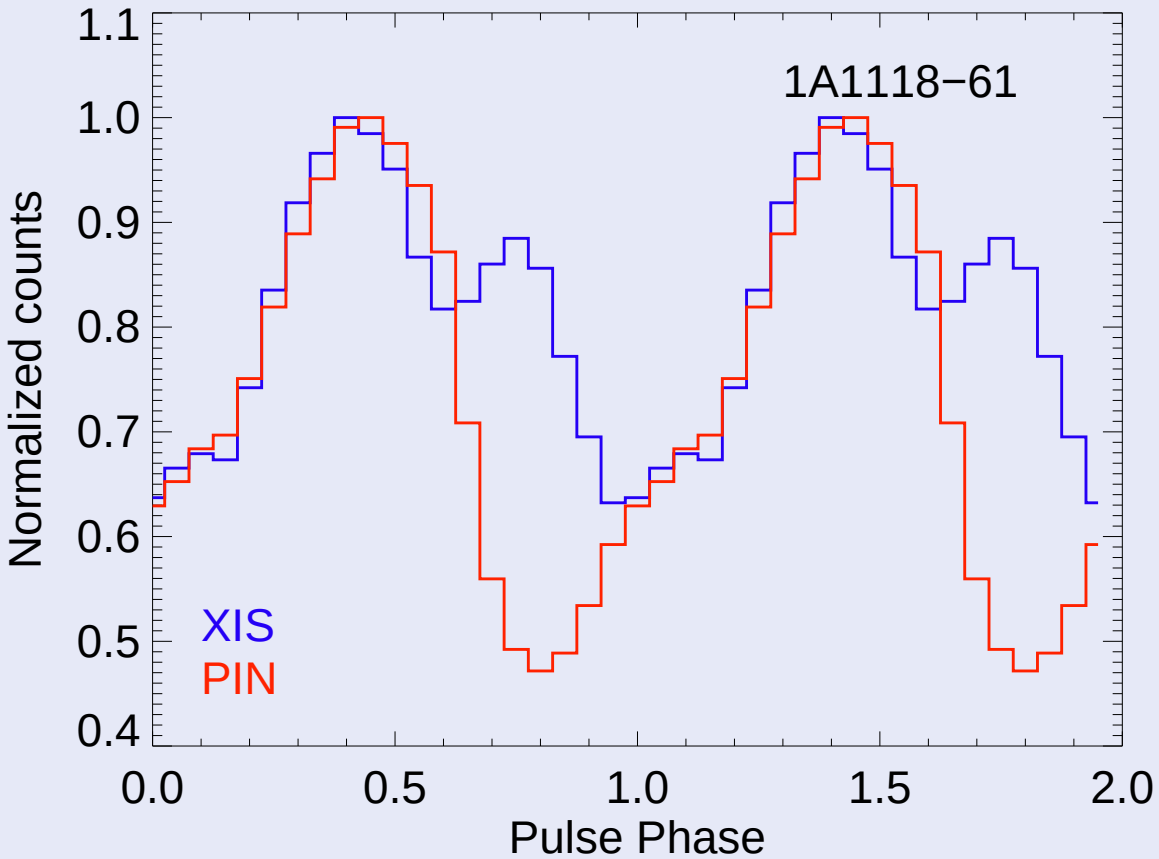

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