Timing variability of Vela X-1 during a bright flare

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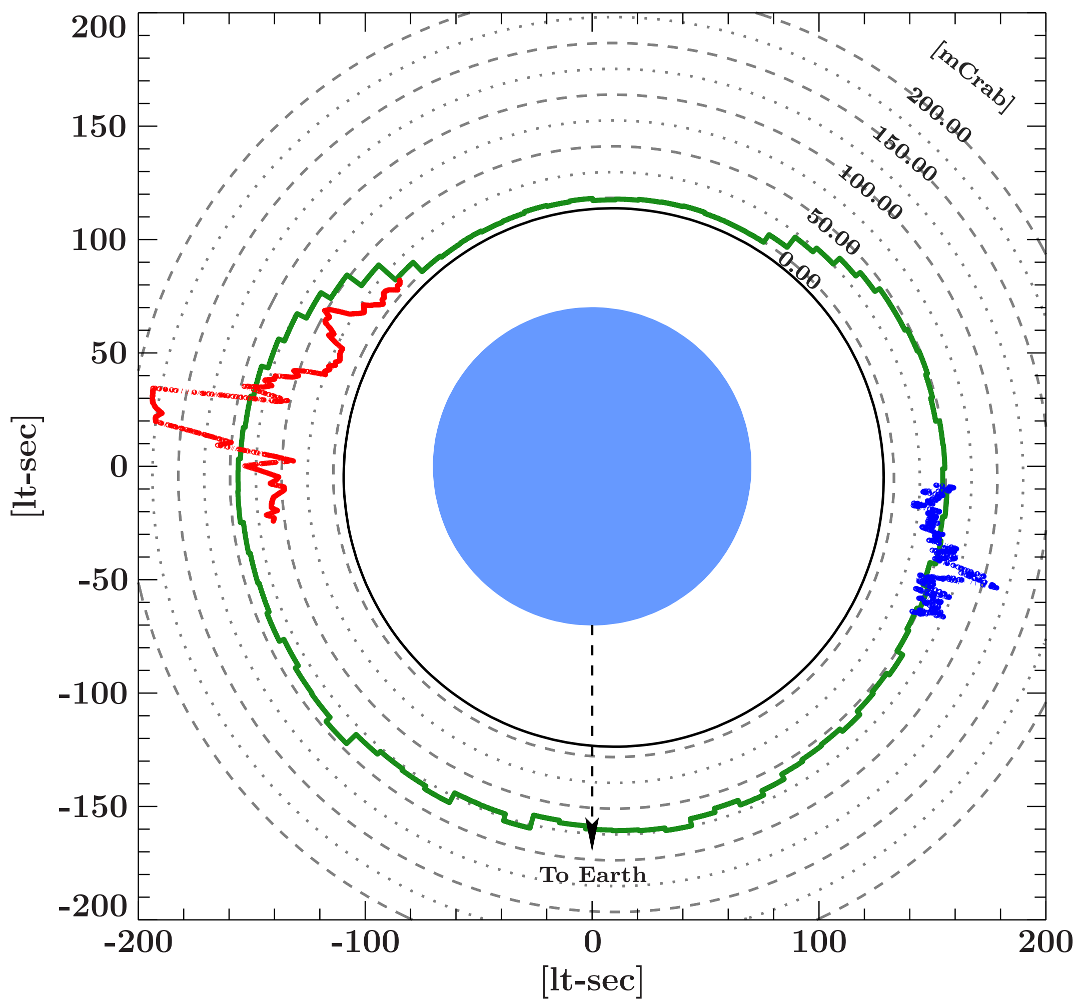
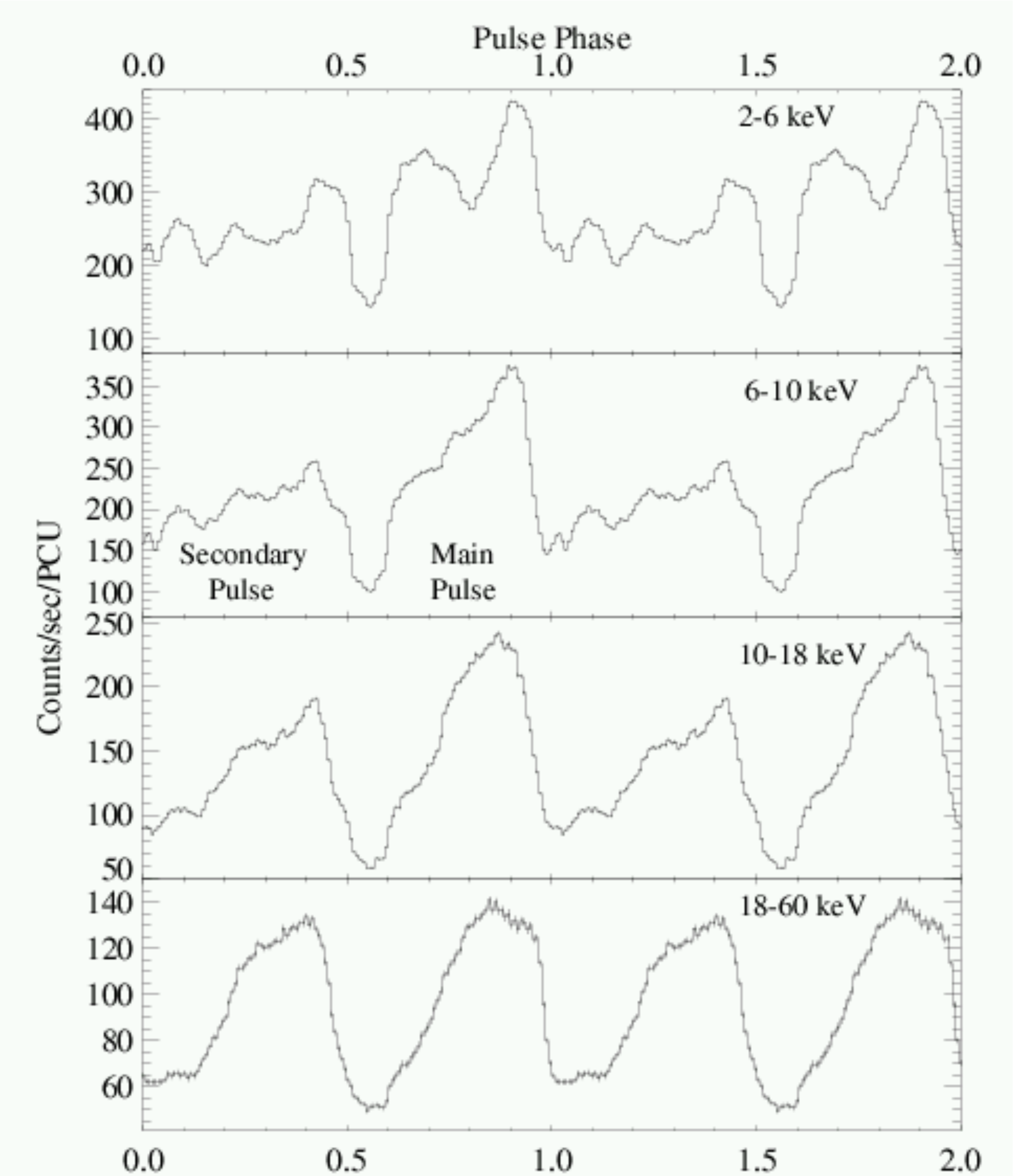
• Introduction



Green: RXTE 1.5 -12 keV average light curve
Red & Blue: XMM-Newton 0.5-12 observed light curve

- Supergiant B star and a neutron star
- Distance at periastron is only 0.6 stellar radii (a ~53 $R_\odot$)
- Neutron star is orbiting its companion every 8.964 days and remains eclipsed during almost 2 days
- 2 XMM-Newton observations at two different orbital phases
  - Observation 2000: 0.683-0.753 (~54 ks)
  - Observation 2006: 0.132-0.27 (~100 ks)

• Introduction

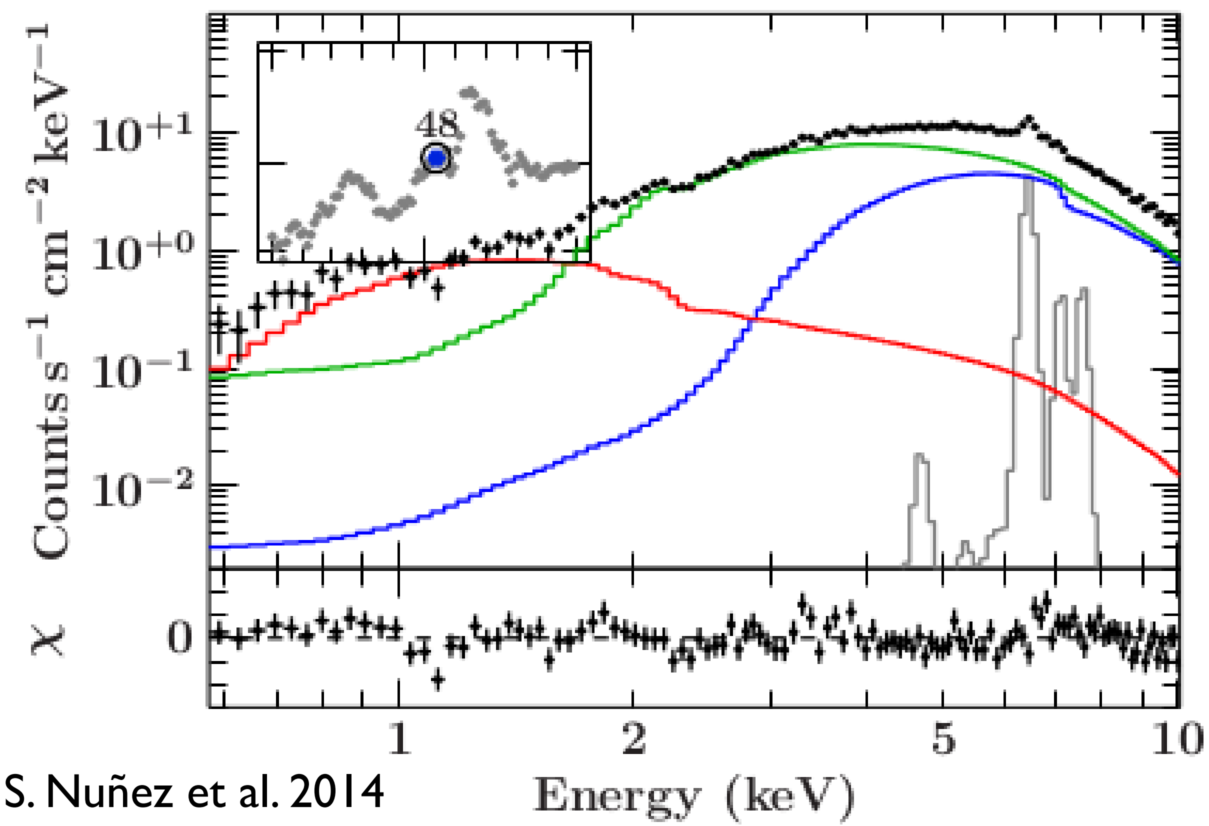


Raubenheimer 1990

- Period evolves quite randomly: 283.0-283.5 s
- Pulse to pulse variations
- Strong energy dependence of its pulse profile showing complex pulse profile at soft X-rays

• The spectrum

- 3 continuum components plus fluorescence lines (Fe-Kα @ ~6.4 keV)
- Evolution of the absorption component during the observation of 2006



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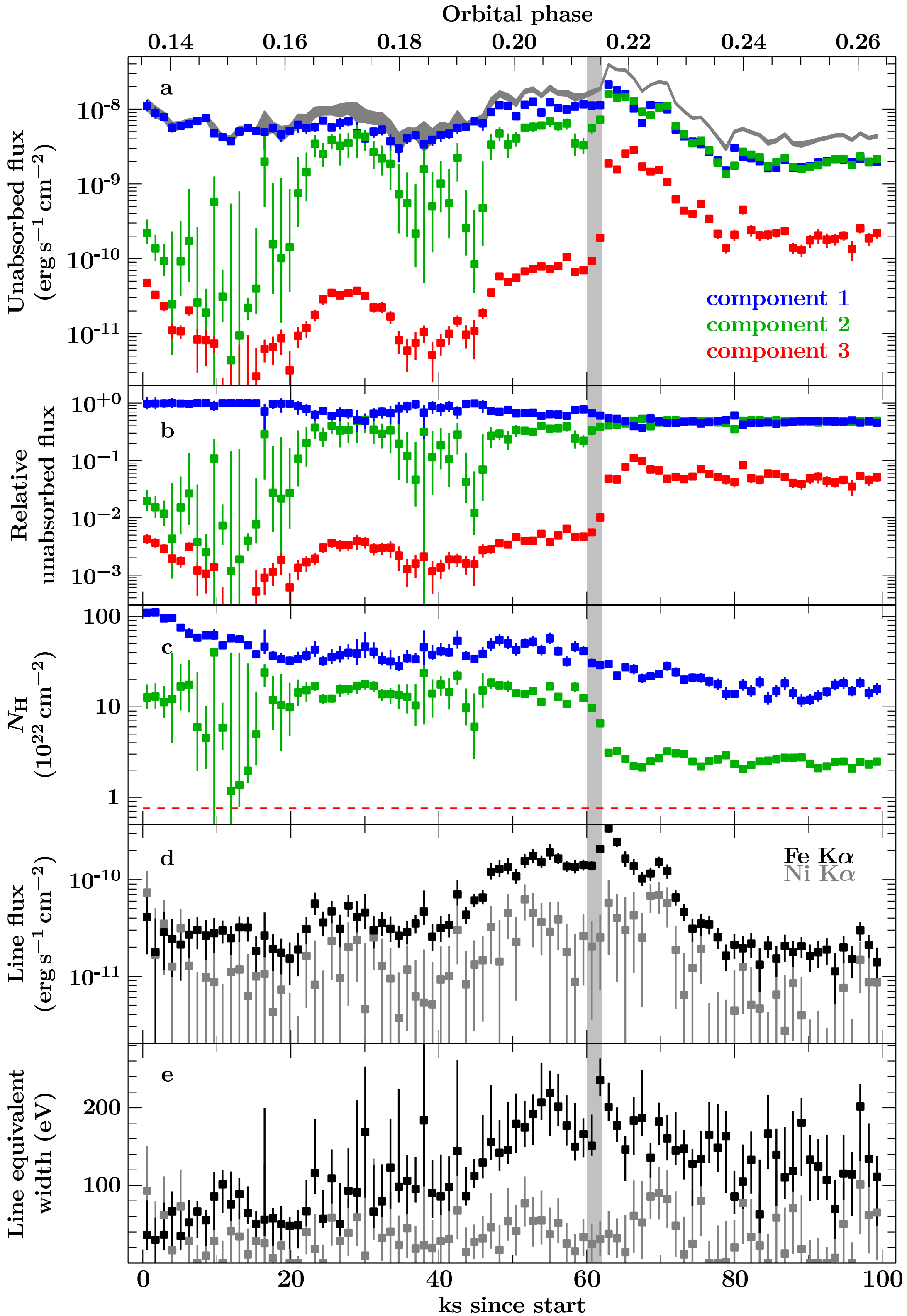

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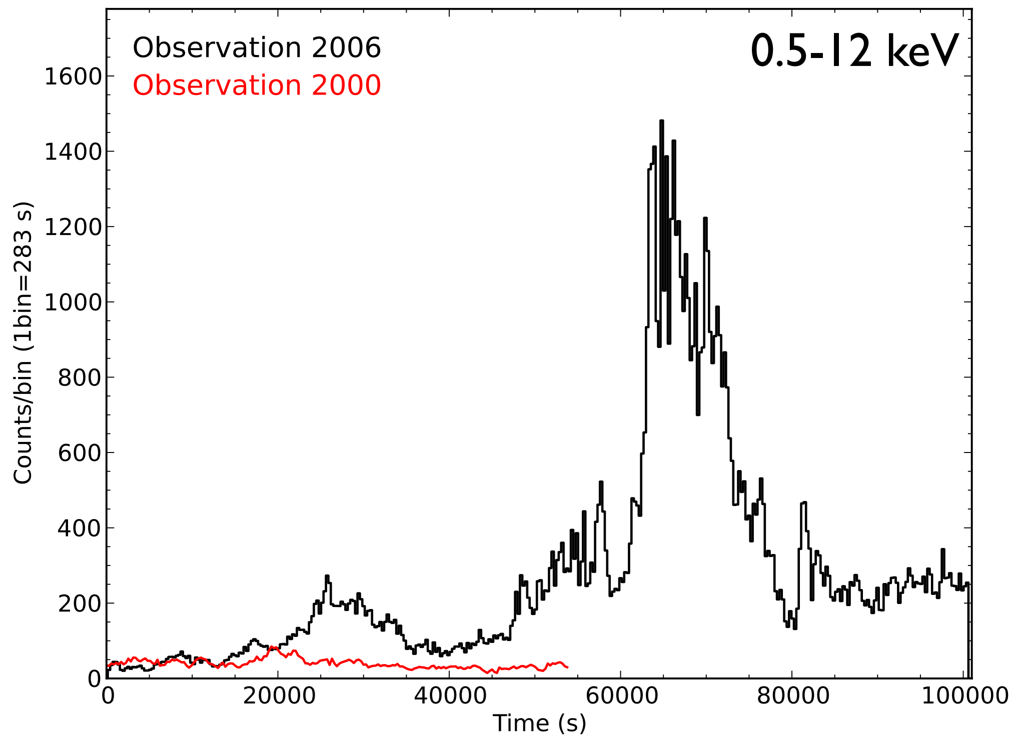
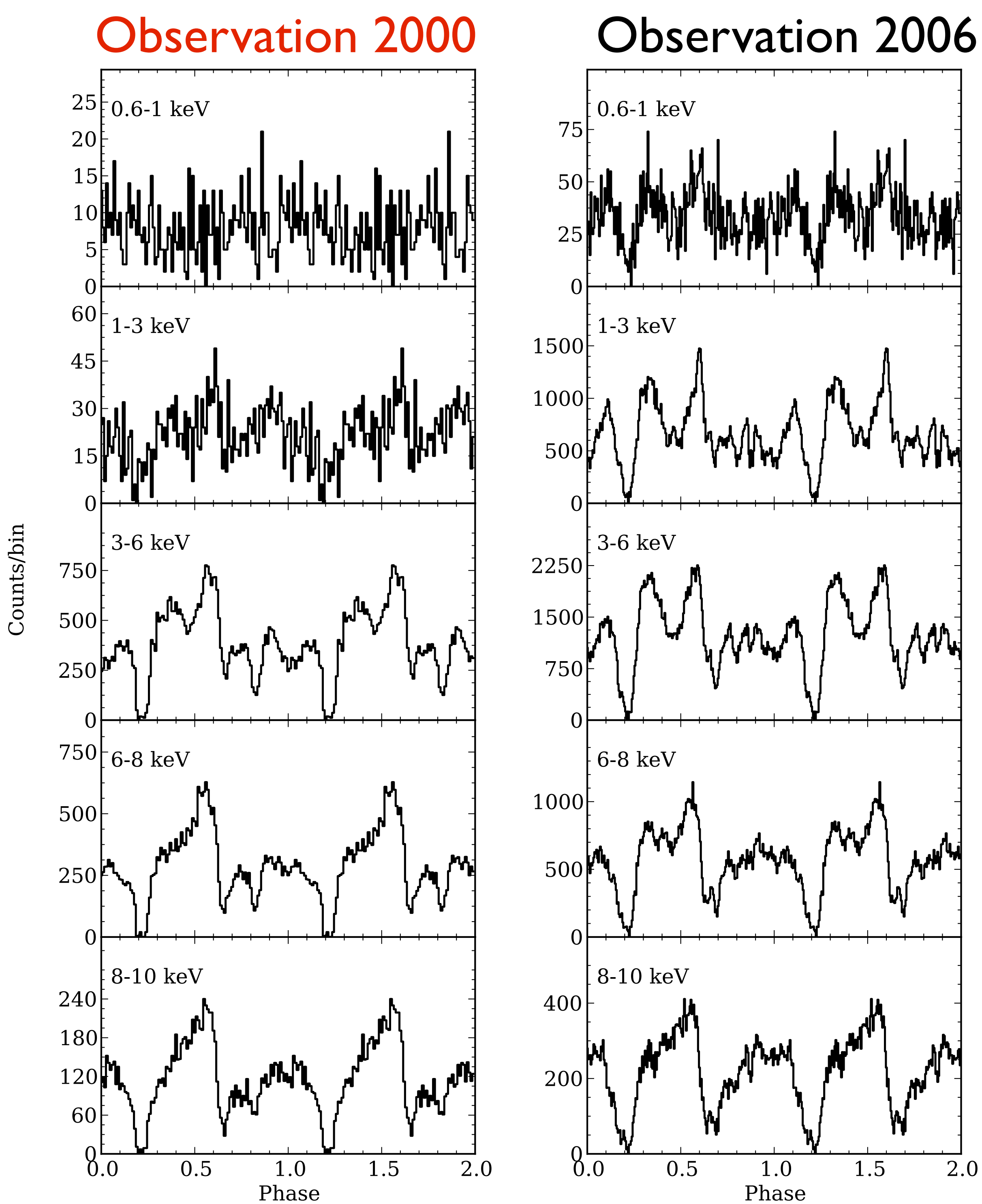
• XMM-Newton observations



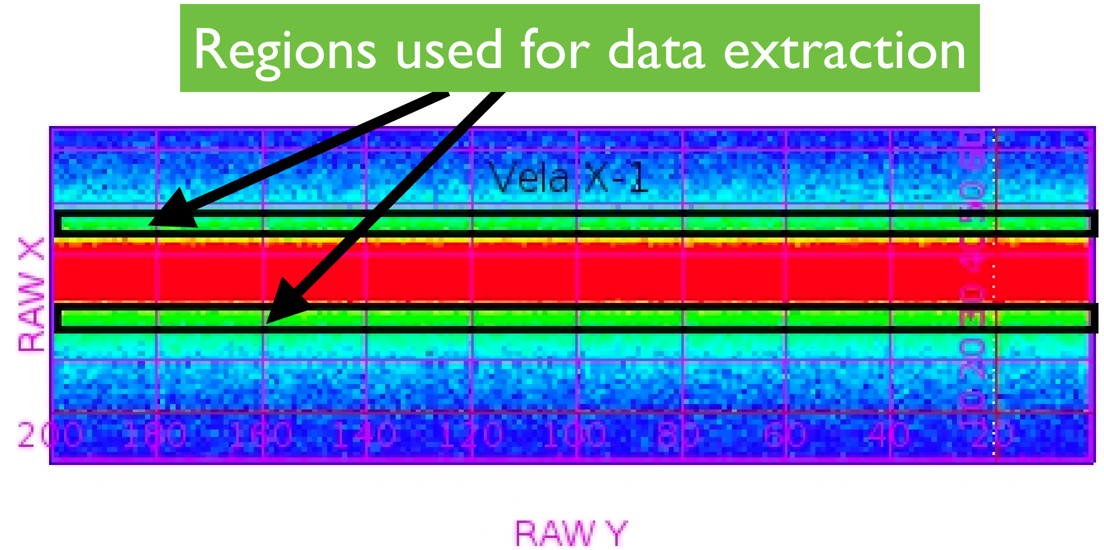


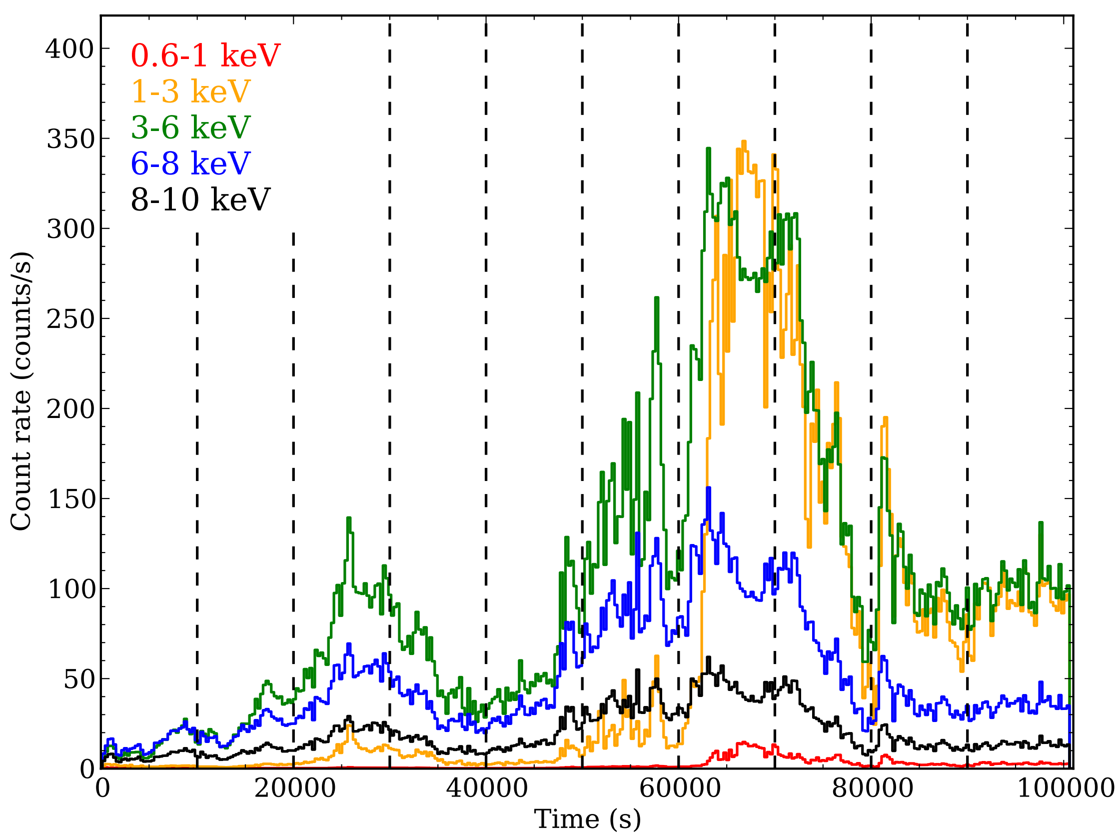
- Assuming a constant period:
  - Observation 2000: P = 283.523 ± 0.010 s
  - Observation 2006: P = 283.389 ± 0.004 s
- No significant variation seen in the pulse profile of the observation from 2000

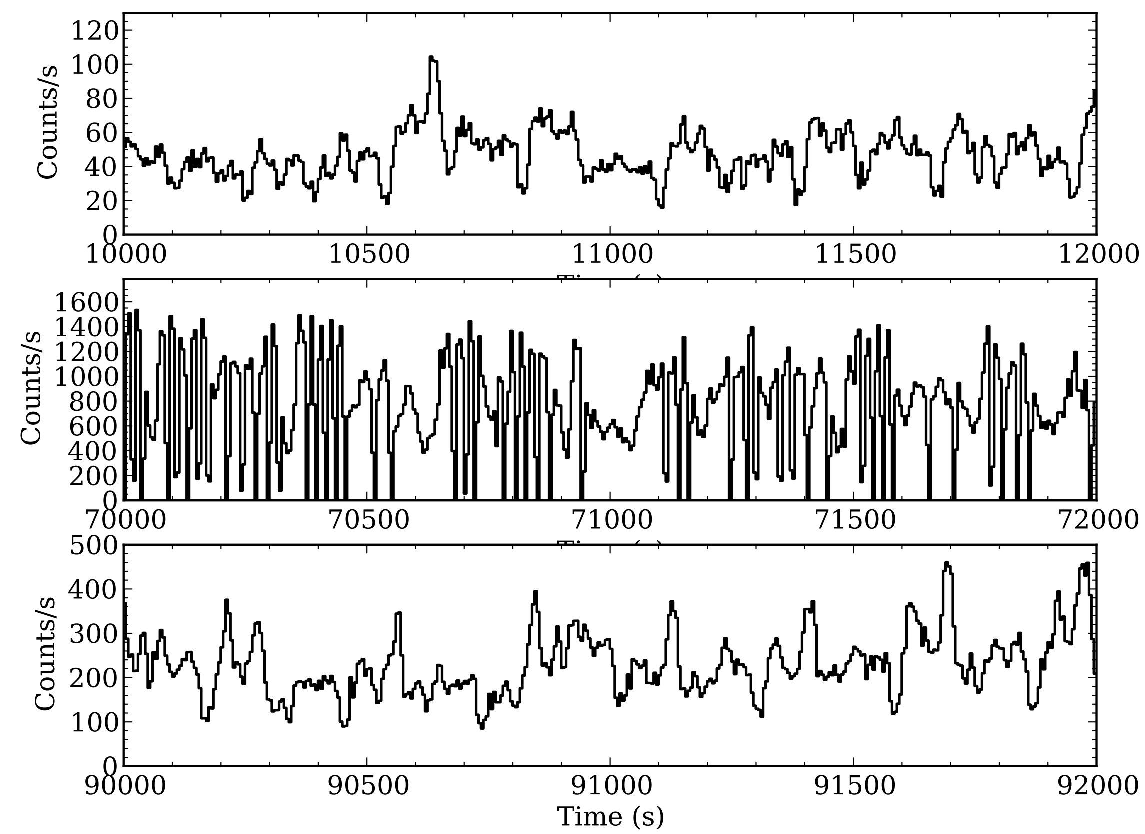
• The energy-resolved light curve of 2006

- Data contained pile-up and multiple telemetry gaps due to the bright flare observed

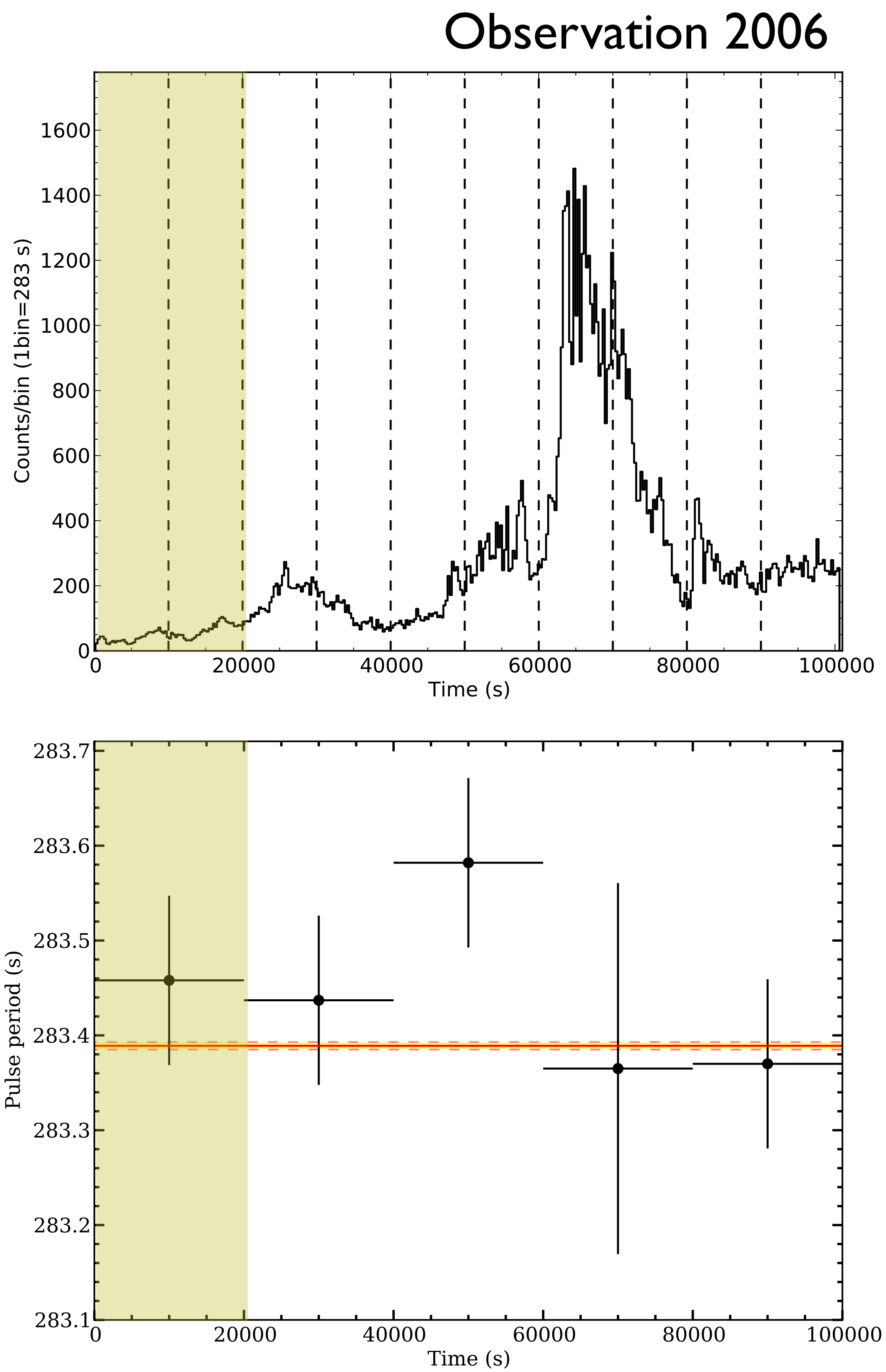
- The flare and post-flare emission is dominated by mid-energy emission (1-6 keV)







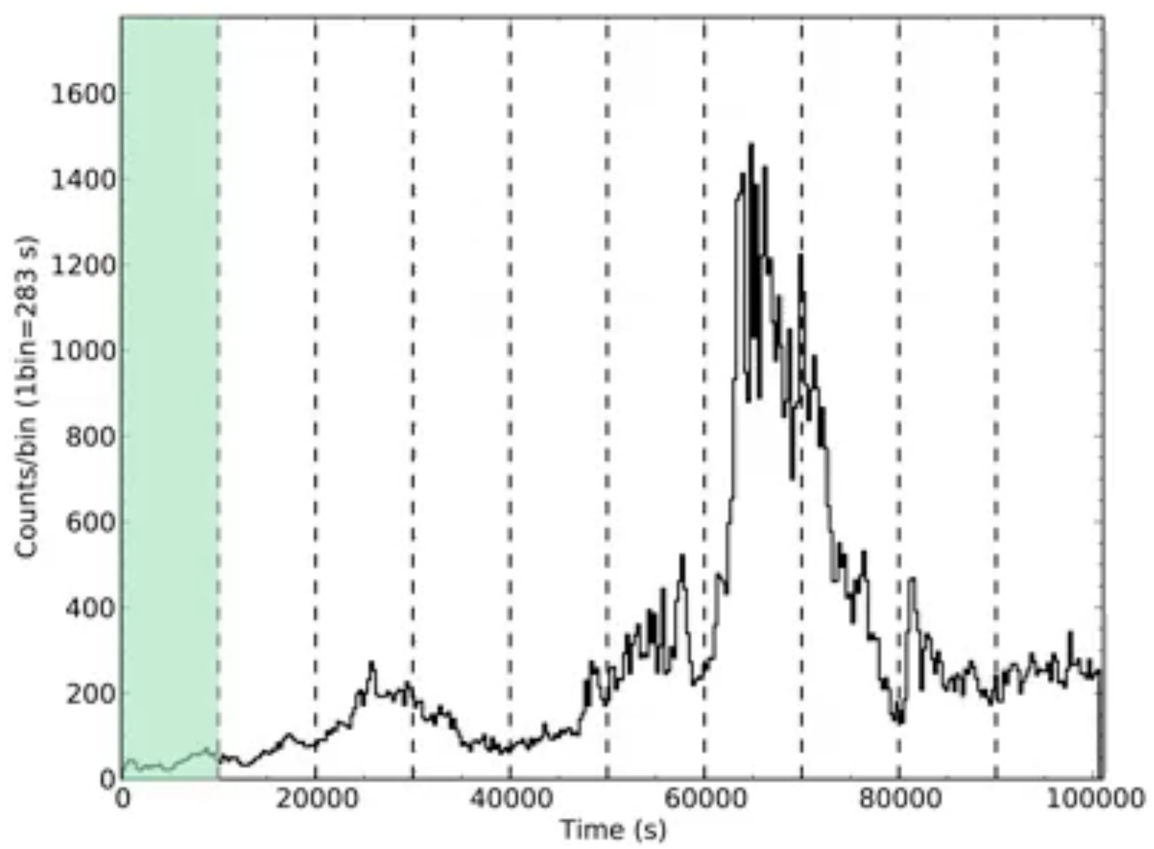
• Pulse period evolution

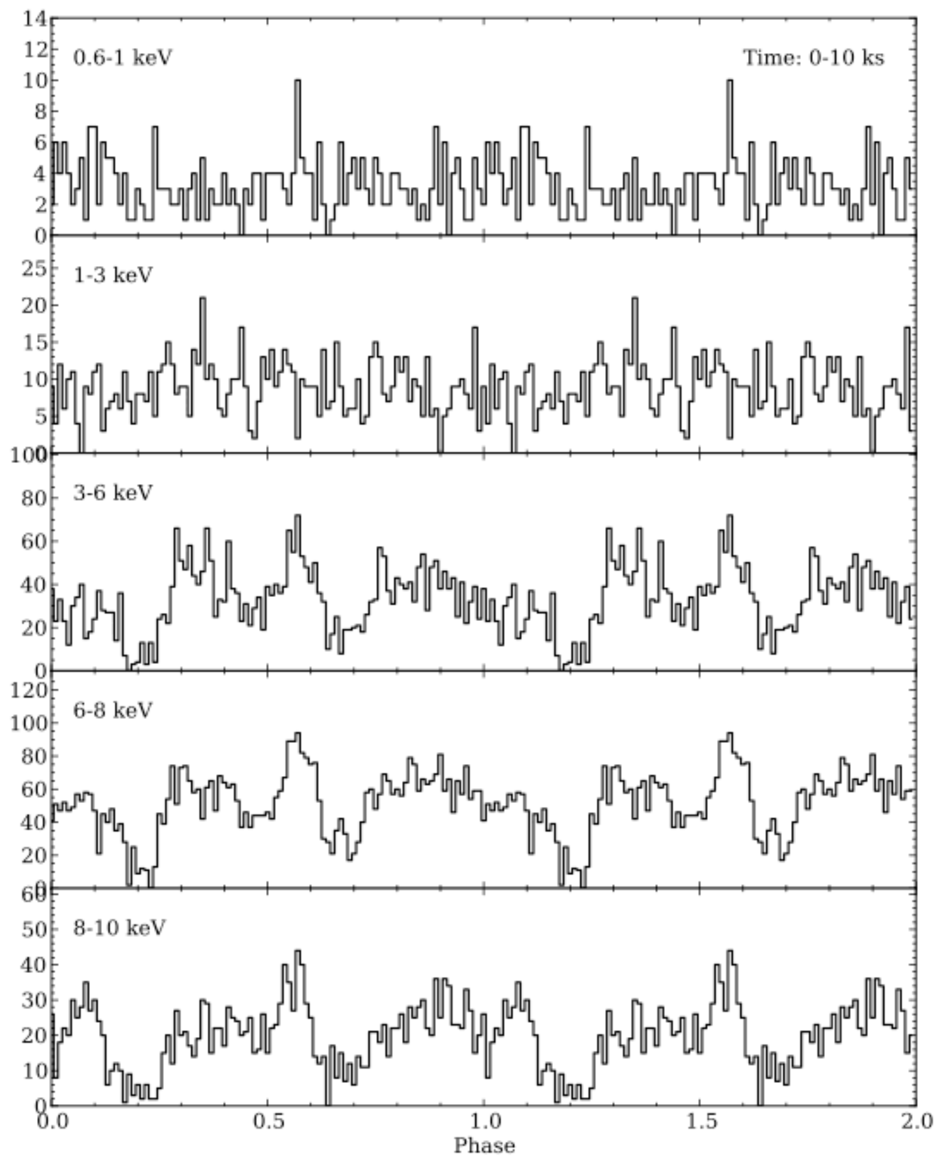


Indications of a possible spin-up after the flare

• Pulse profiles

Observation 2006

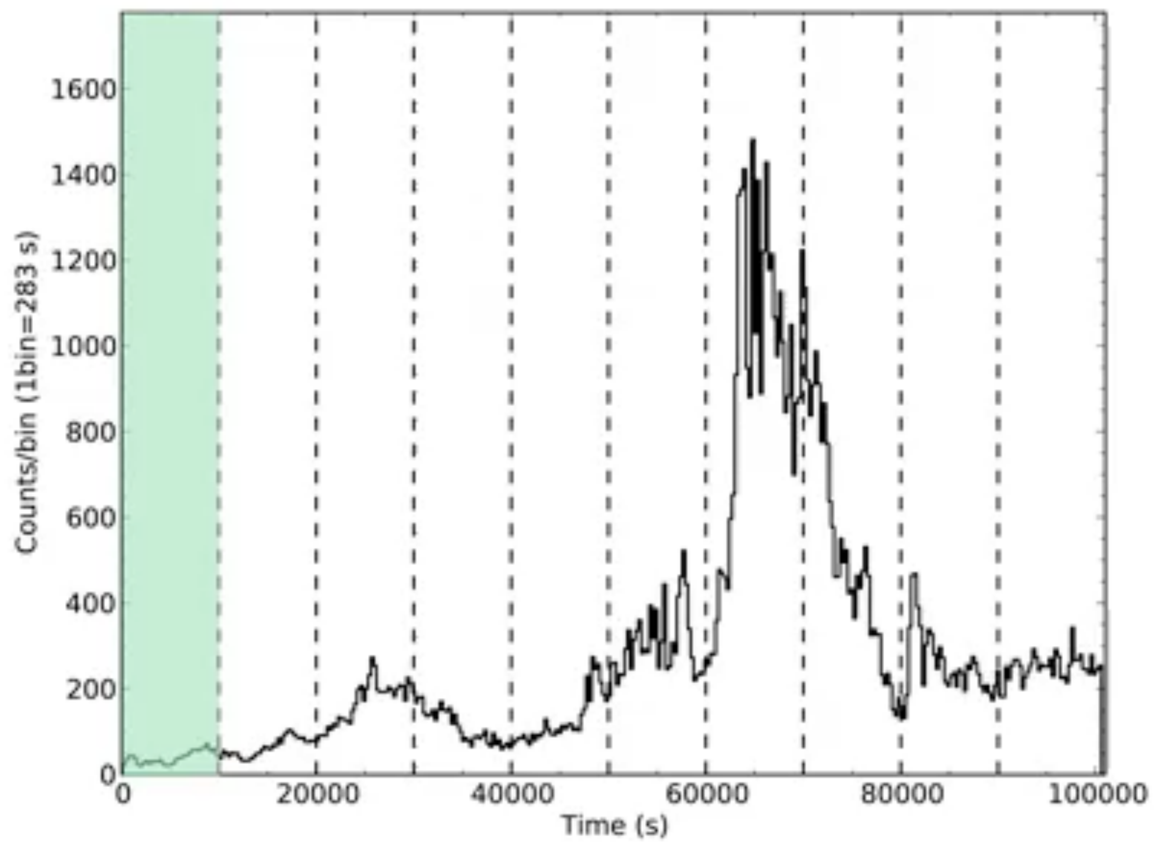


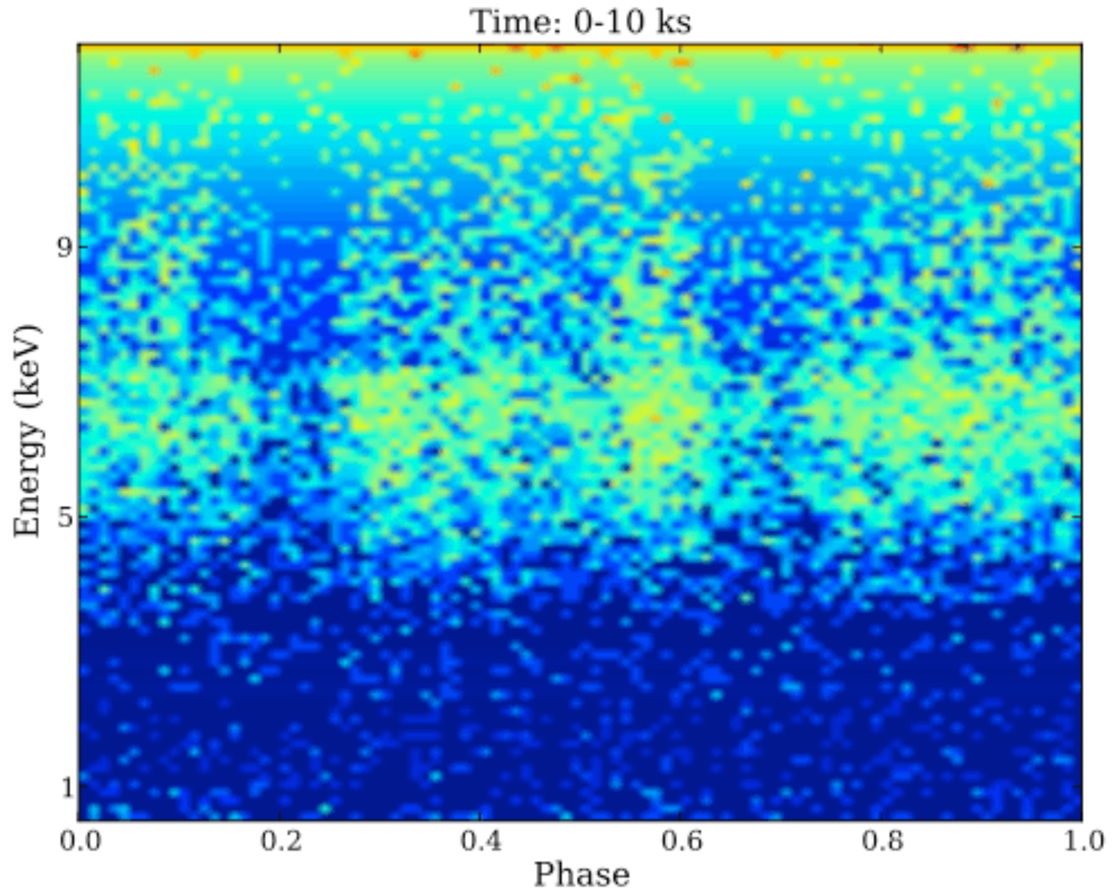


Strong variability of the first horn of main pulse (phase~0.35) and the secondary pulse

• Phase-energy profiles

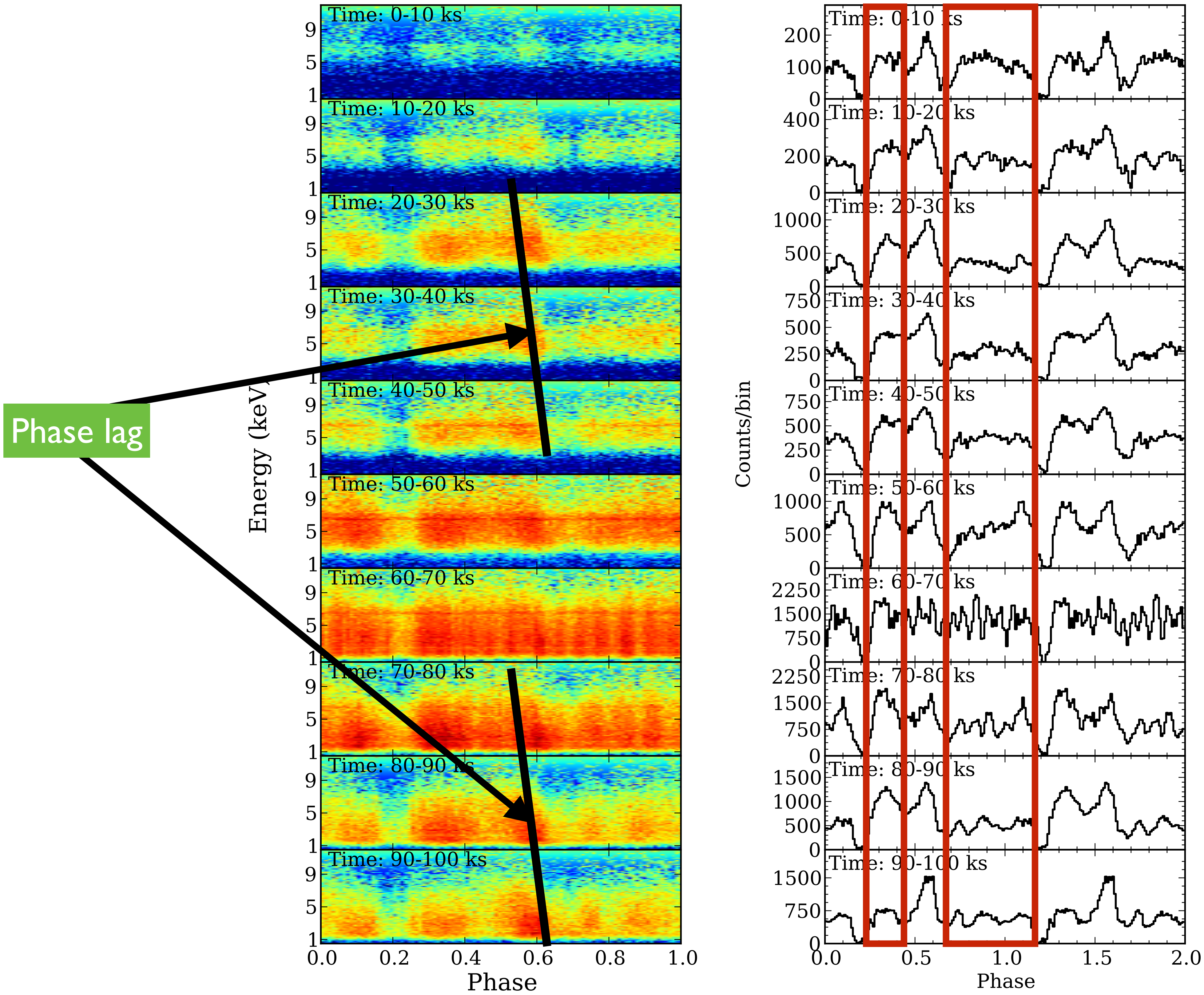
Observation 2006



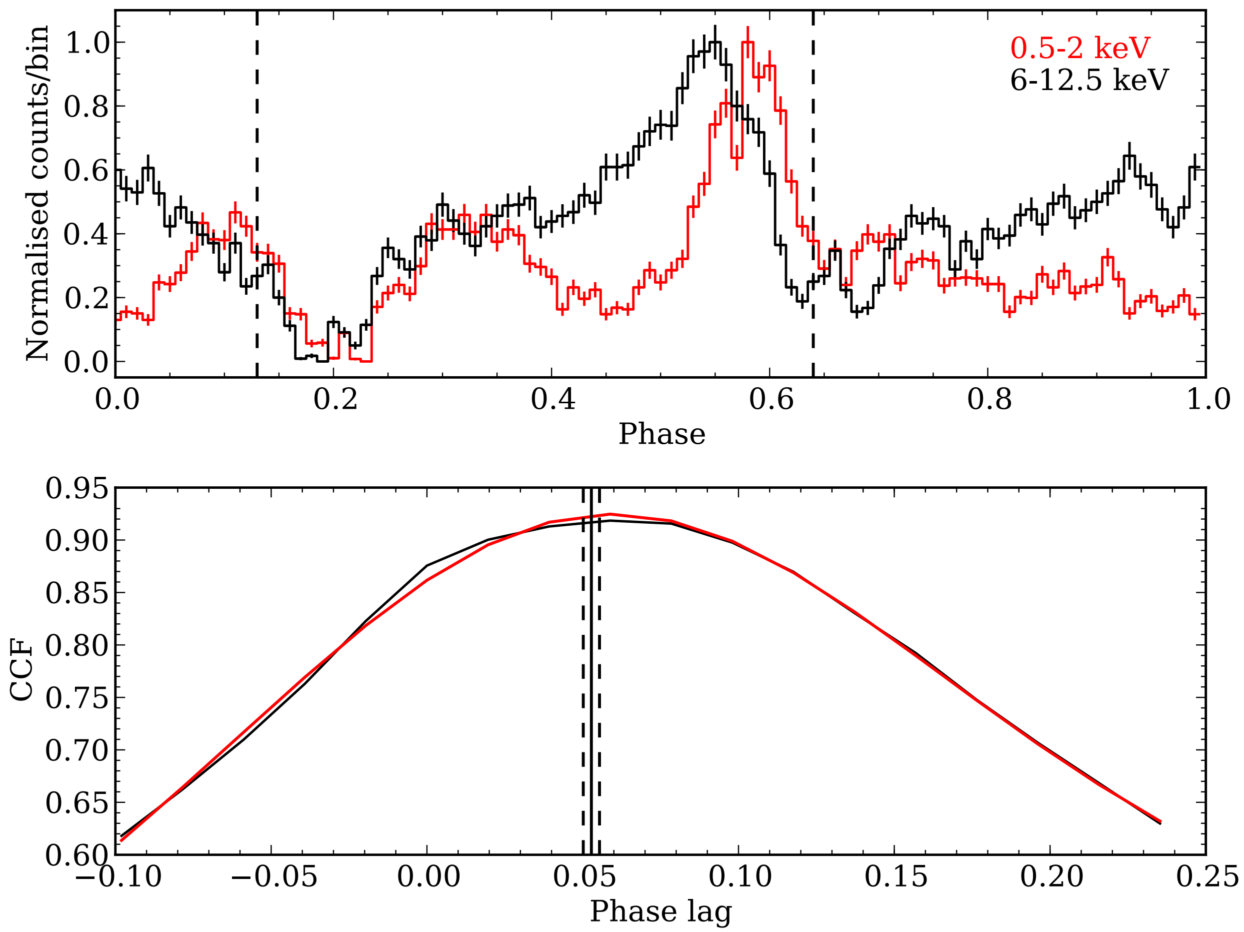


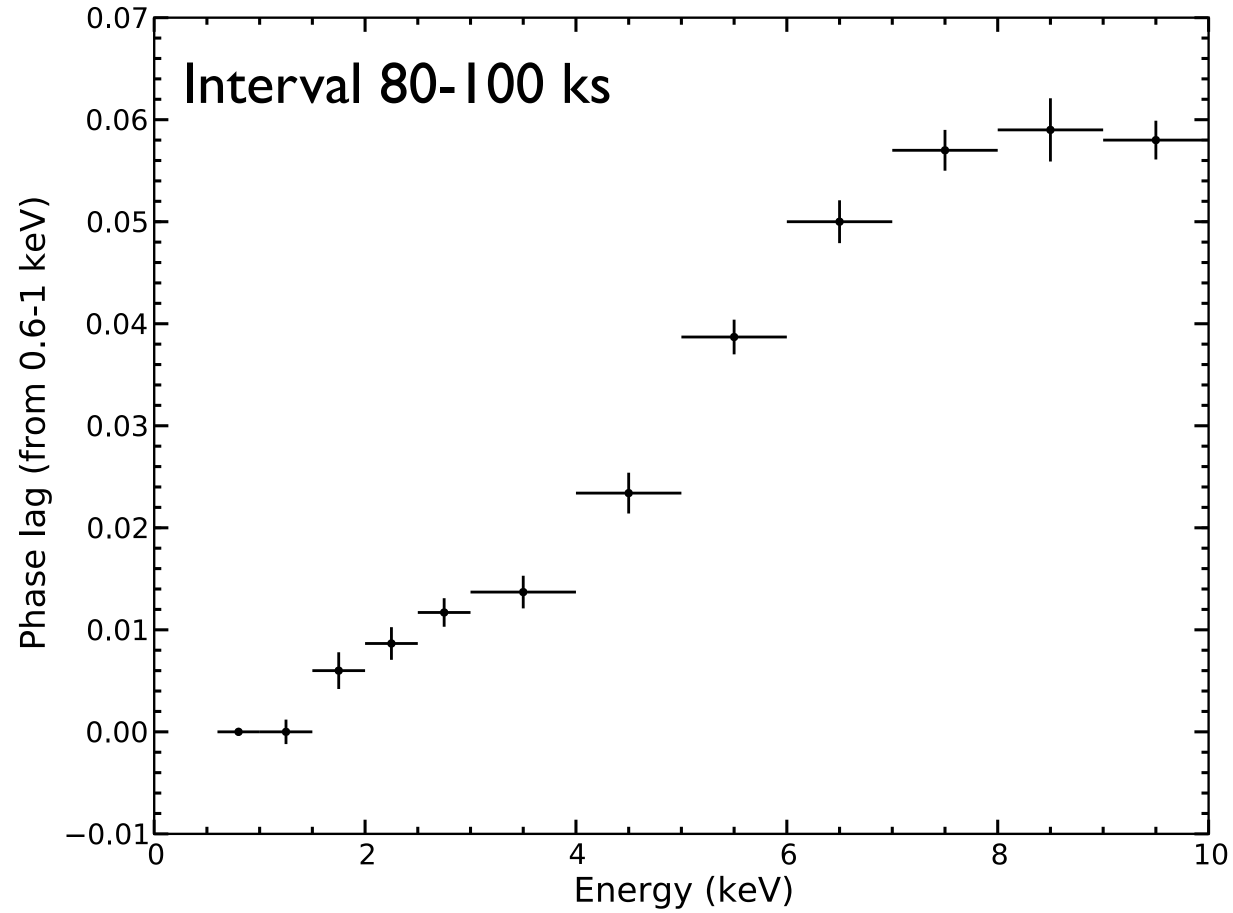
Pulsed emission dominated by soft energy photons after the flare

• Phase-energy profiles



• Phase lag

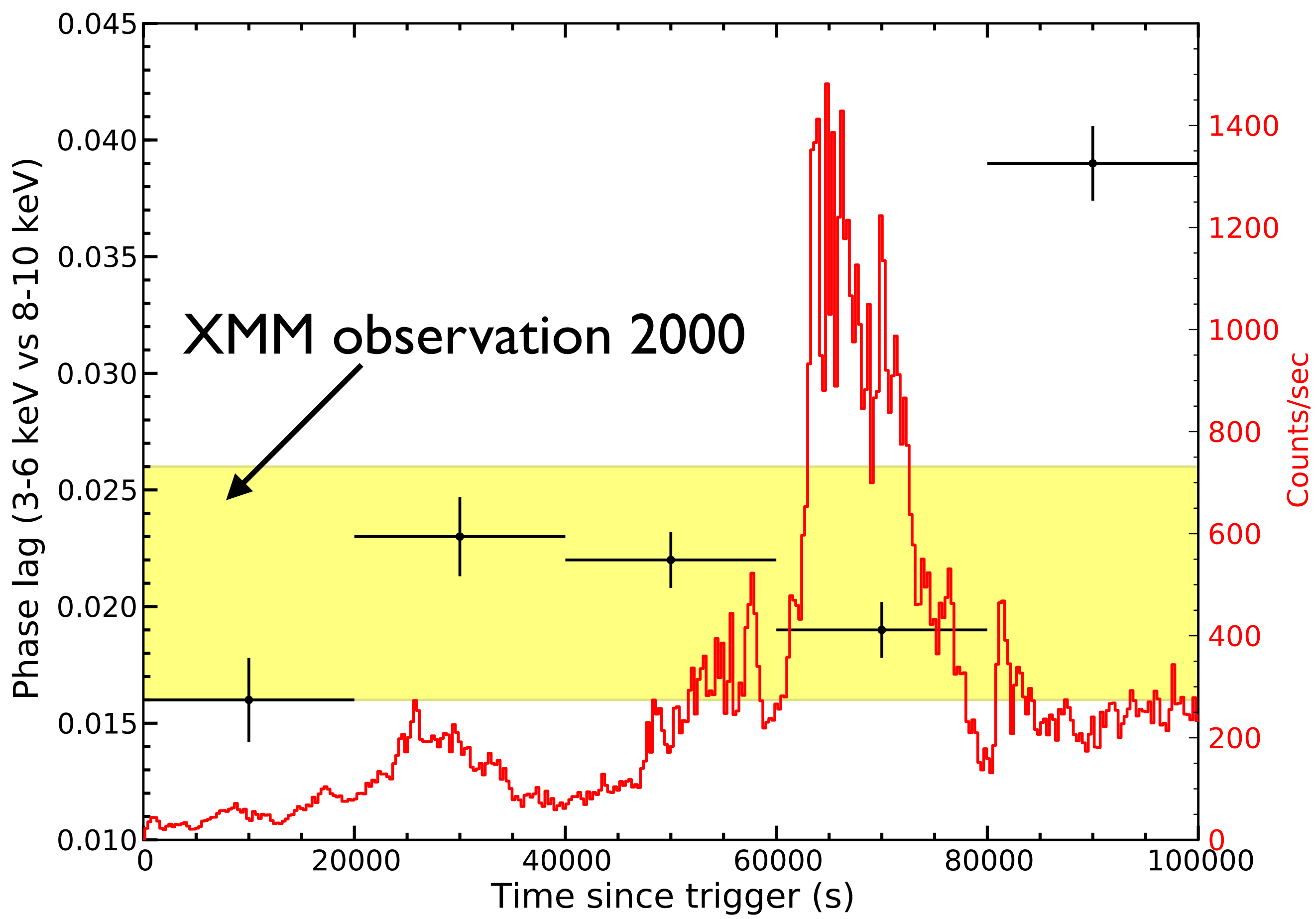


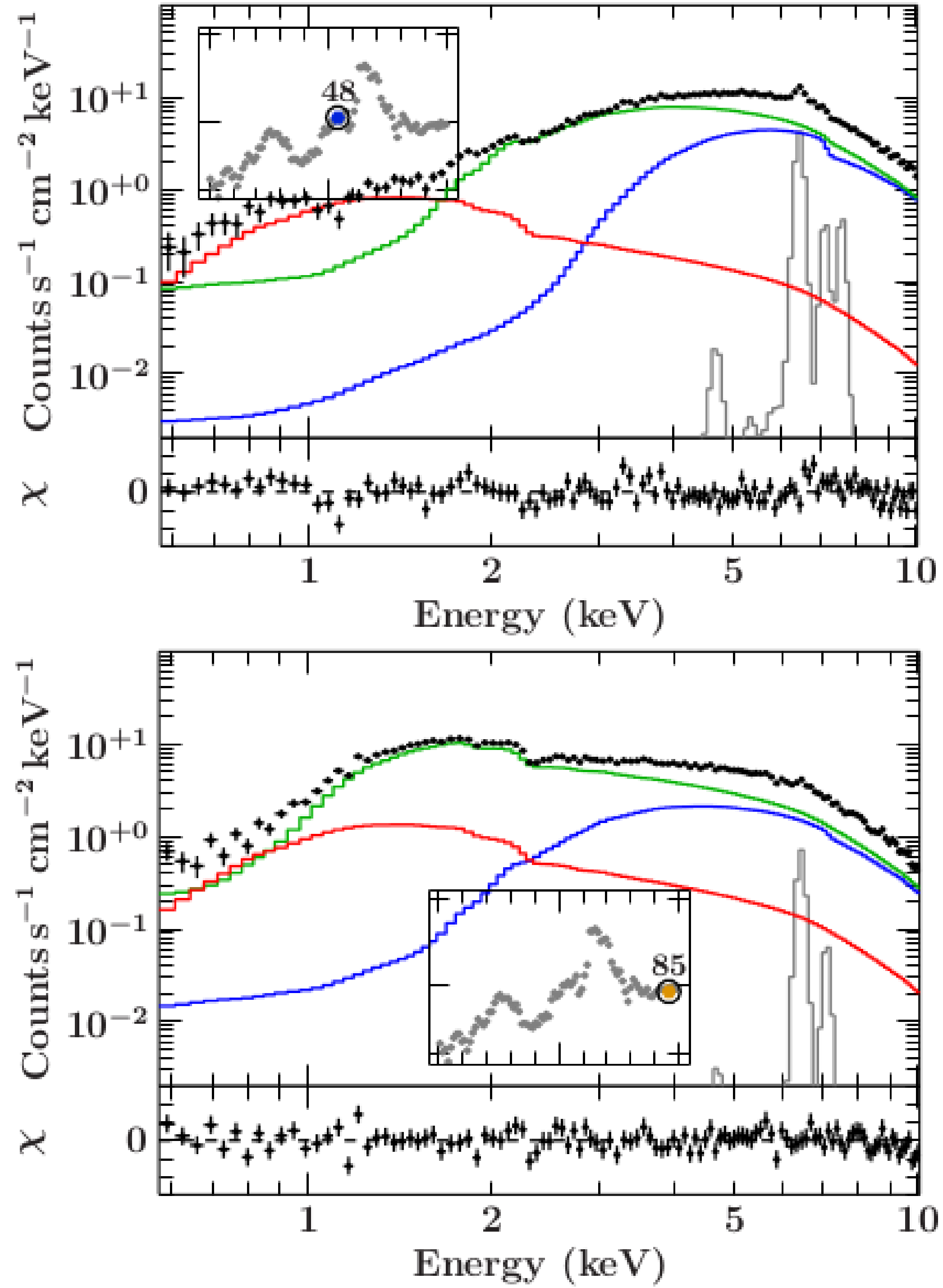


The high energy emission leads the softer emission

0.05 phase units = 14.17 sec ~ 4×10^{11} cm or 4 Mkm
Possible explanations: Geometrical effect
Compton-down scatter in the accretion column
Energy dependent intrinsic beaming

• Phase lag: evolution





Green spectral component responsible for the observed phase lag evolution?

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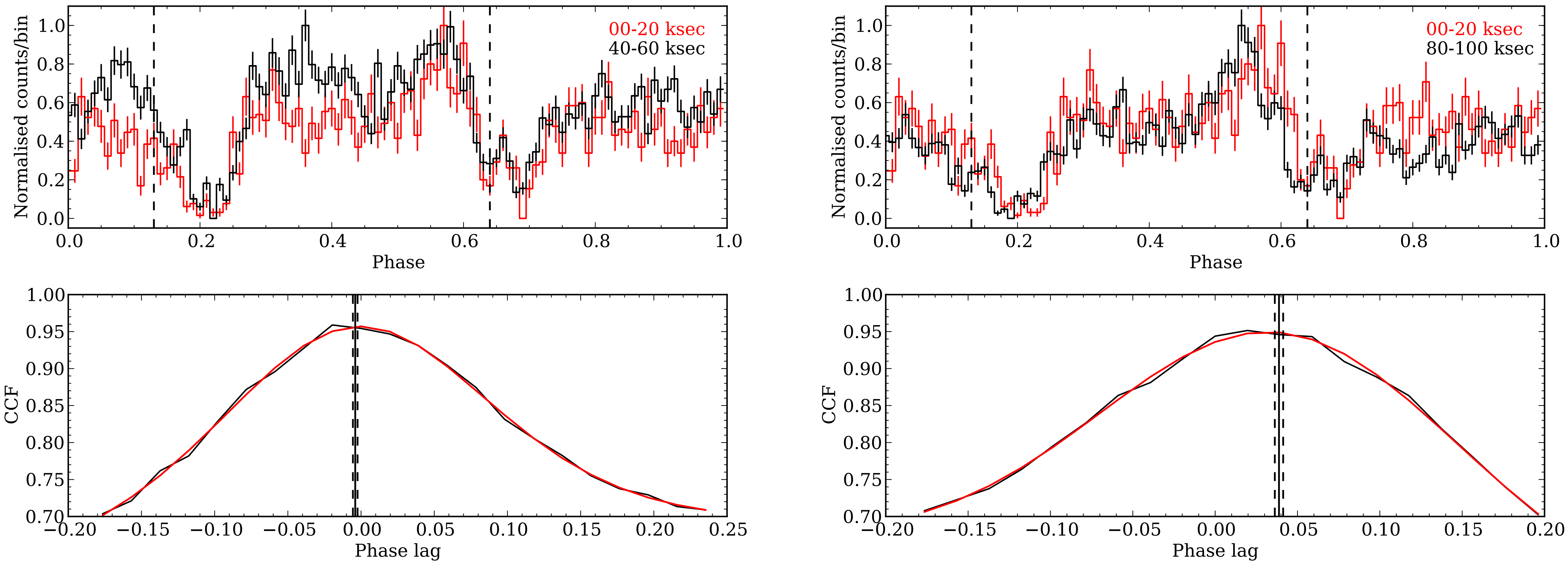
• Phase lag: iron line

- Fe-Kα line (6.2-6.6 keV) is used to study possible changes on the pulse period comparing its arrival time at two different intervals



Assuming a constant pulse period, the Fe-Kα before and after the flare shows a significant lag suggesting a **spin-up**

• Conclusions

- Strong pulse profile variations have been observed in Vela X-1 during a bright flare observed with XMM-Newton, especially at soft energies where pulsed emission is clearly detected after the flare.

- A sudden increase in the pulse period at the beginning of the flare followed by a spin-up after the flare has been observed, which could be related to a decrease on the friction between the neutron star and the surrounding wind (i.e. wind clump in the accretion disk).

- A phase lag between the softest and harder band has been observed, with the latter leading the pulse emission, and possibly caused by geometrical effects (?).

- Phase lag evolution likely correlated with the spectral evolution