Glancing through the accretion column of a neutron star

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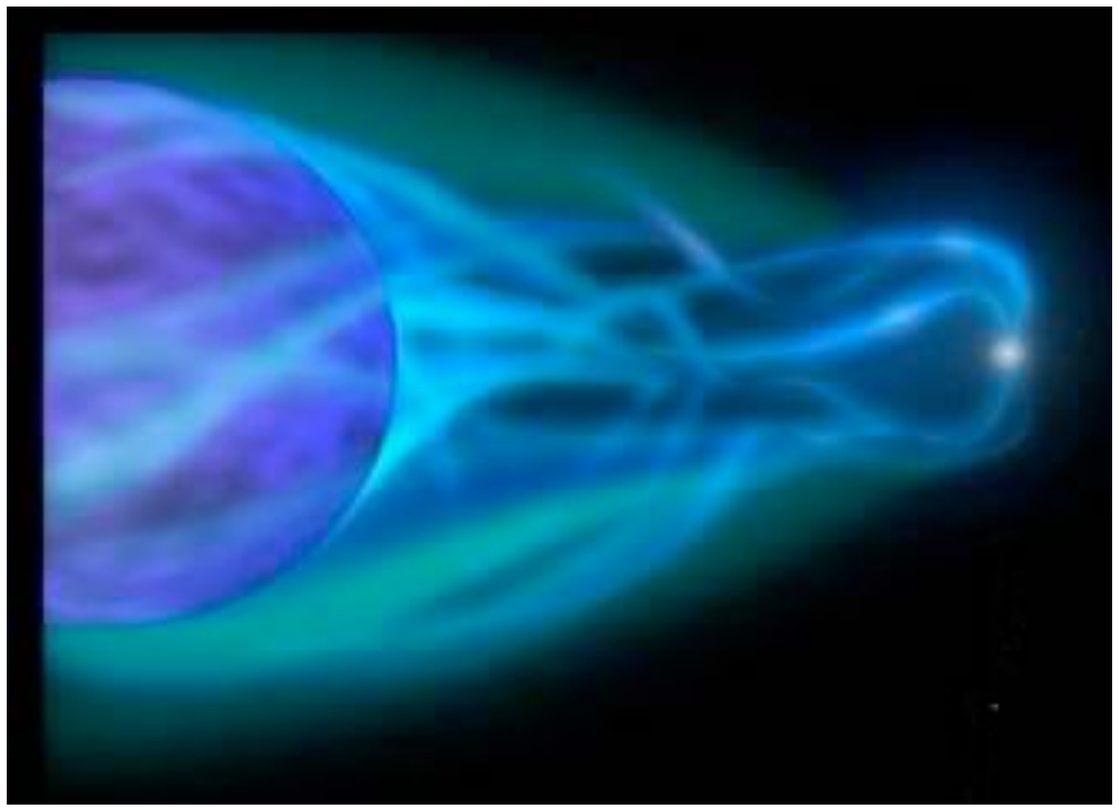
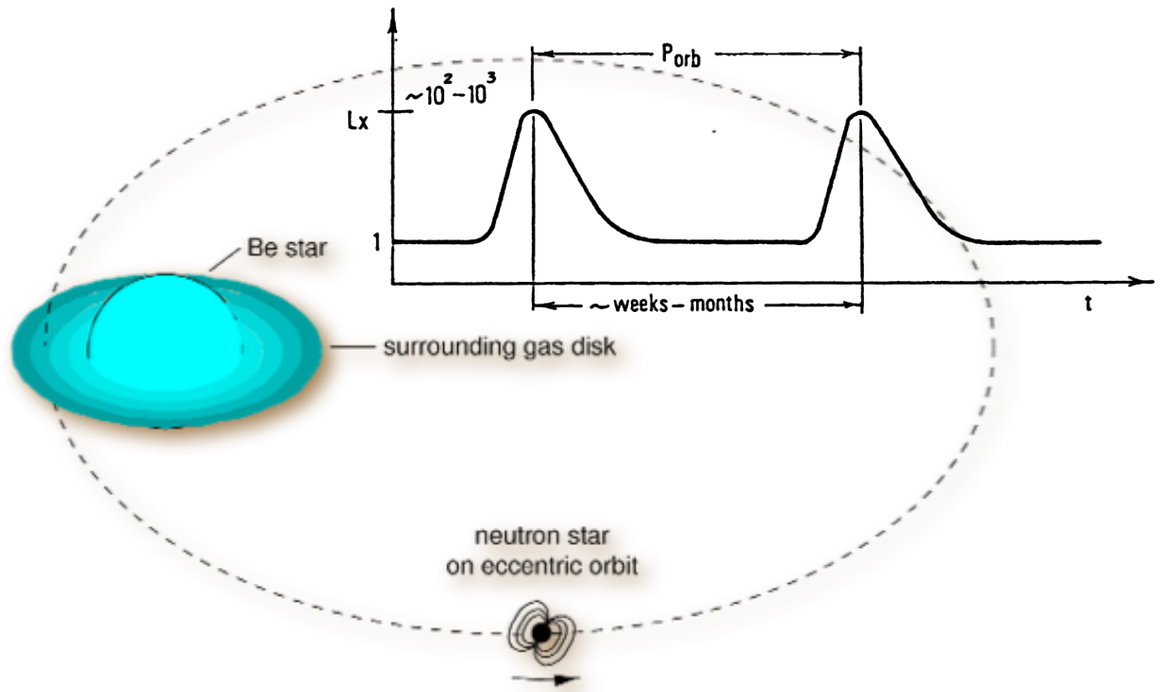
Introduction

- High mass X-ray binaries are normally young systems, in which a neutron star has a high magnetic field ($10^{12\text{-}13}$ G) and accretes from the wind of a (super)giant companion.



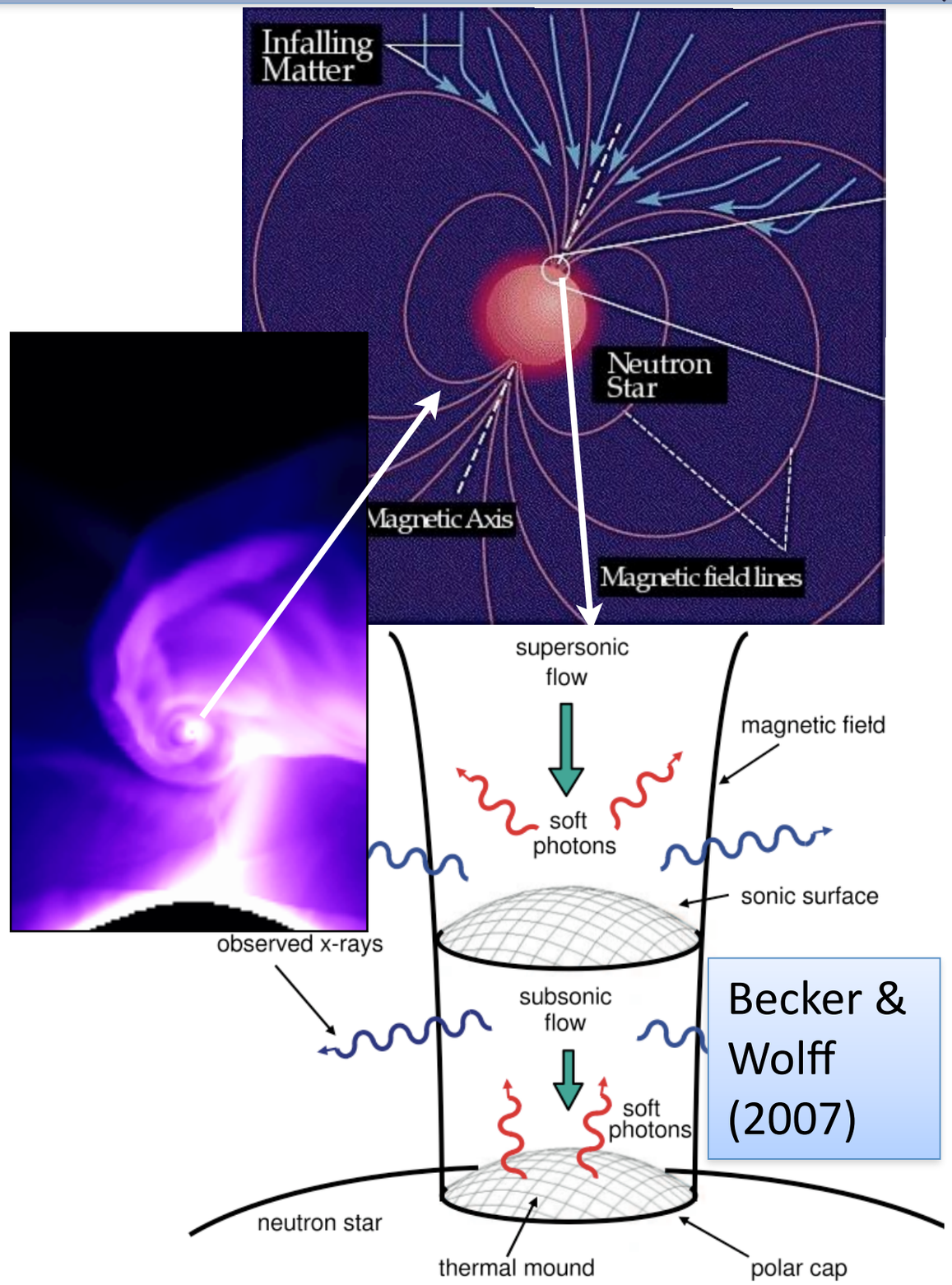
- Be/X-ray binaries: the neutron star undergoes outbursts at the periastron passage.



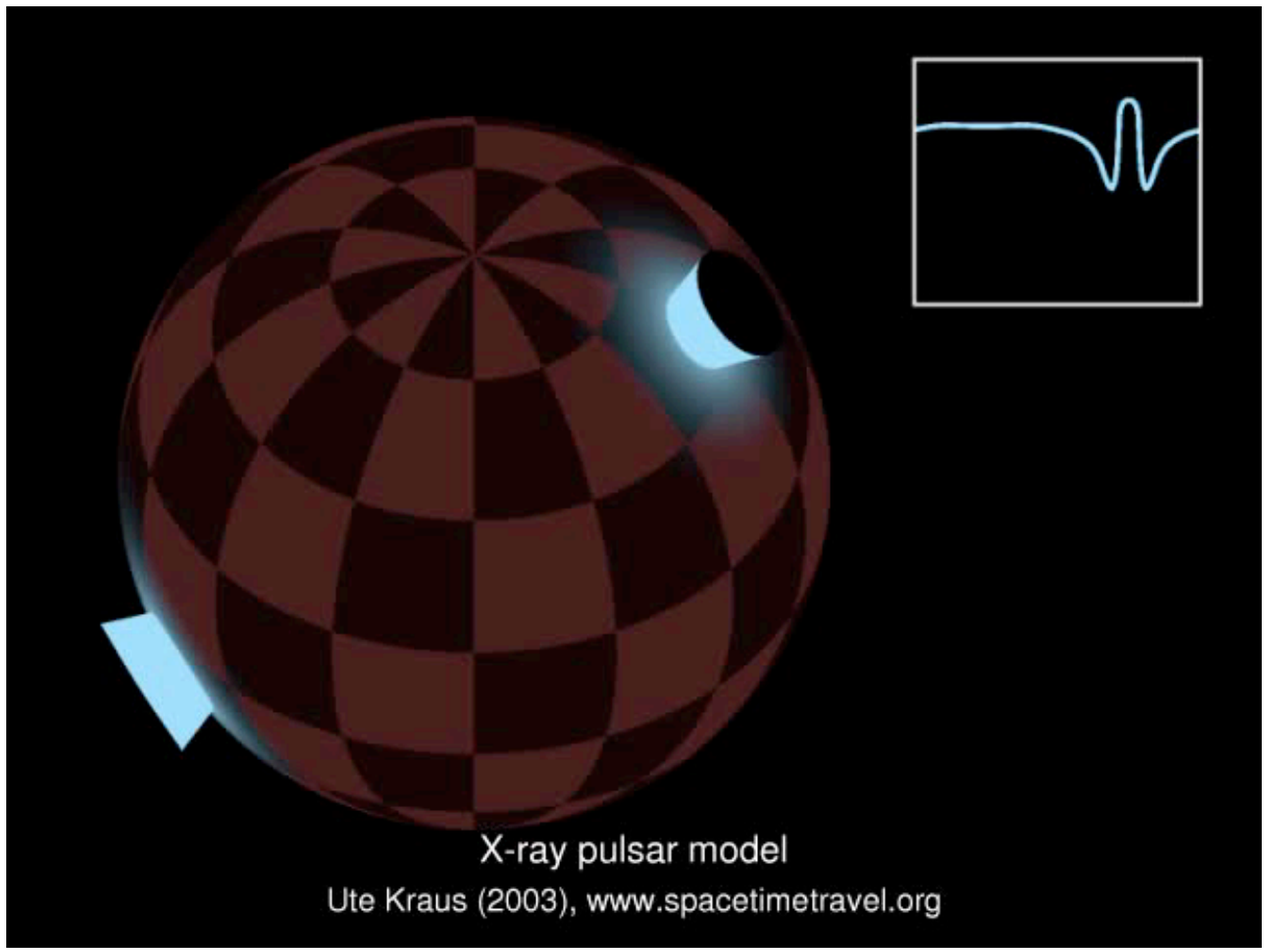
$$\frac{L_X^{outburst}}{L_X^{quiescence}} \sim 10^3$$

Emission mechanisms in a high magnetic field

- If the neutron star has a considerable magnetic field, the accreting matter is channeled along the field lines and accretes onto the magnetic poles.
- The flow acquires a high kinetic energy v~c/2 which is at least partially dissipated close to the surface and emitted in the form of X and Gamma-rays.
- For high accretion rates, radiation dominates: a radiative shock forms along the accretion column.
- Seed photons coming from thermal mound and electron breemstrahlung, in the high B-field, are Compton scattered.

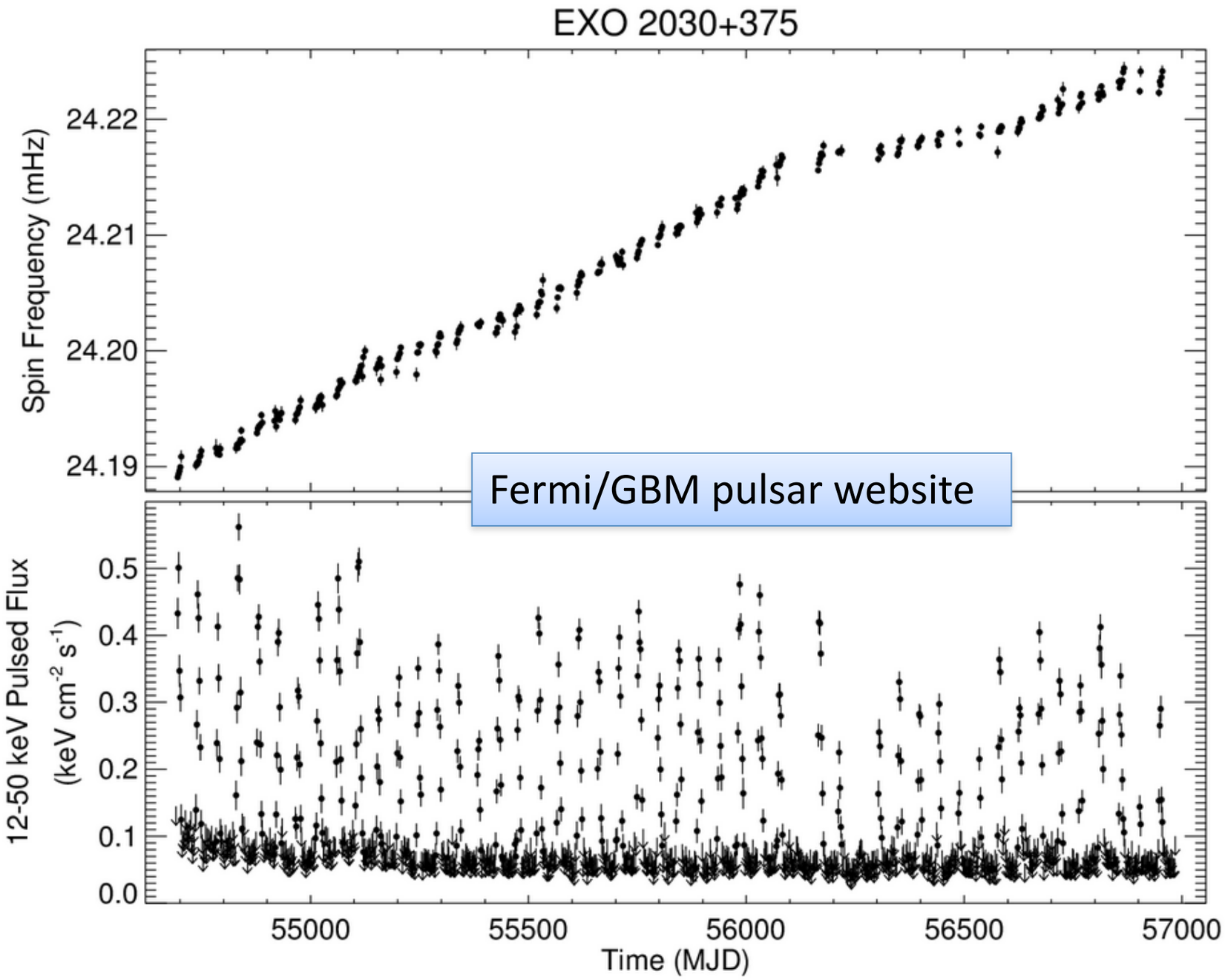


Possible self obscuration



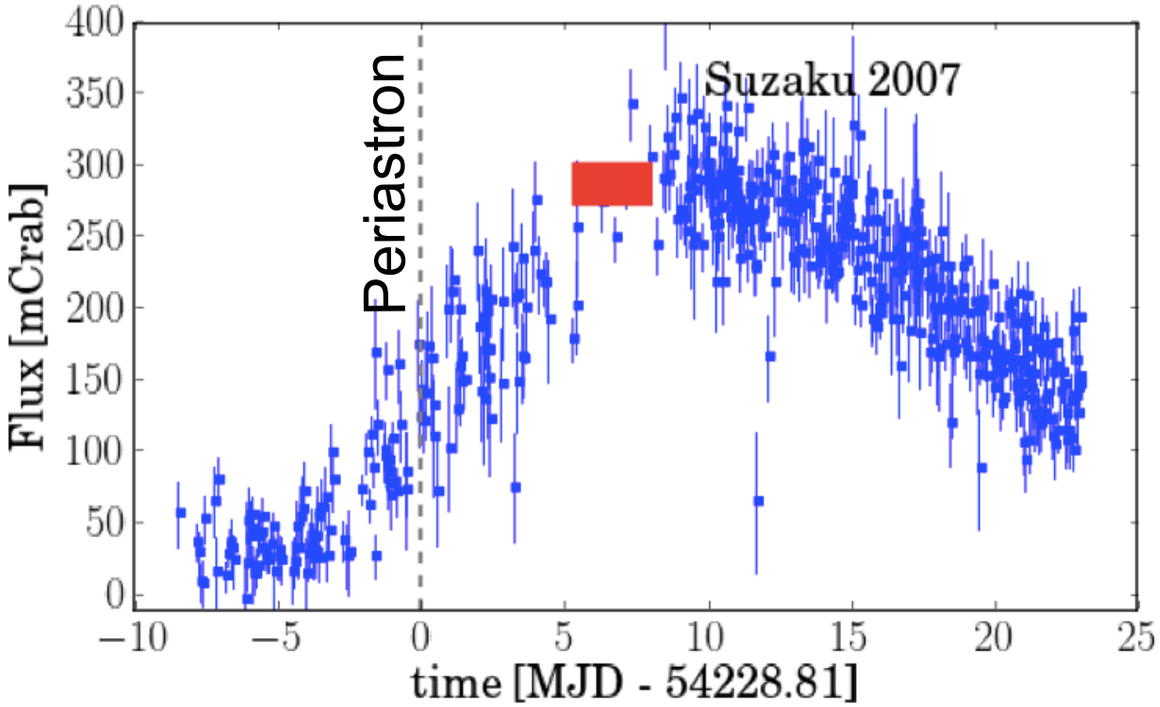
- Emission from the base of a filled column
- Sharp structures due to self-obscuration by the flow

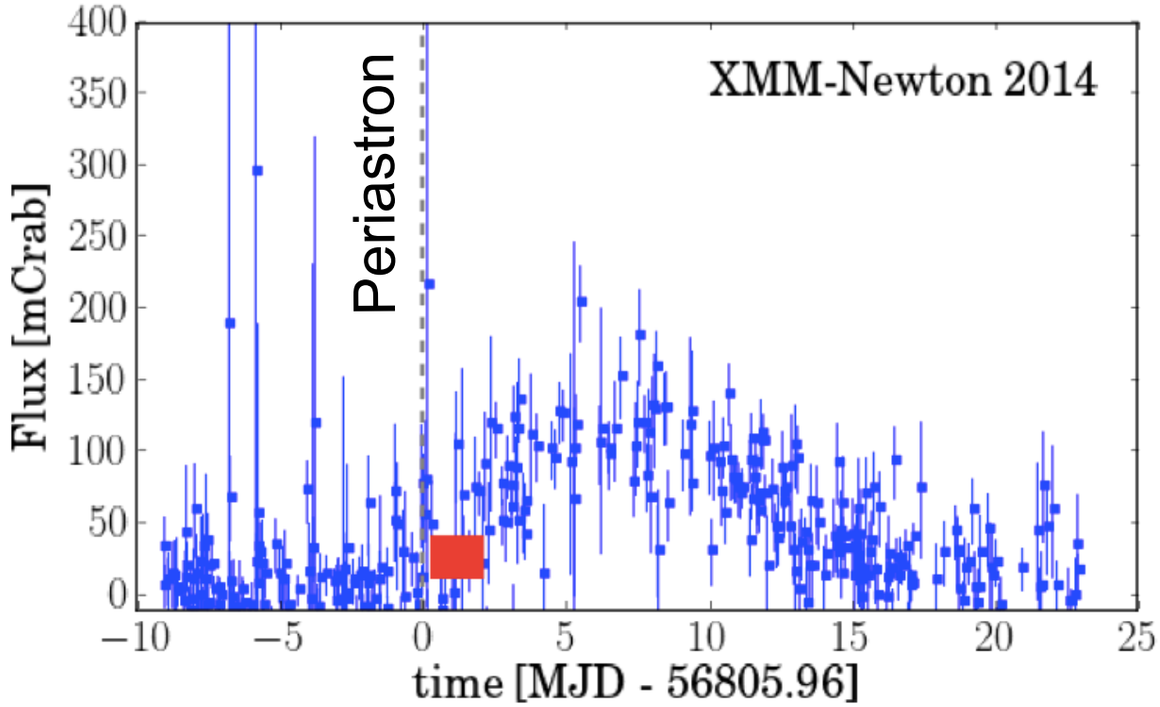
EXO 2030+375

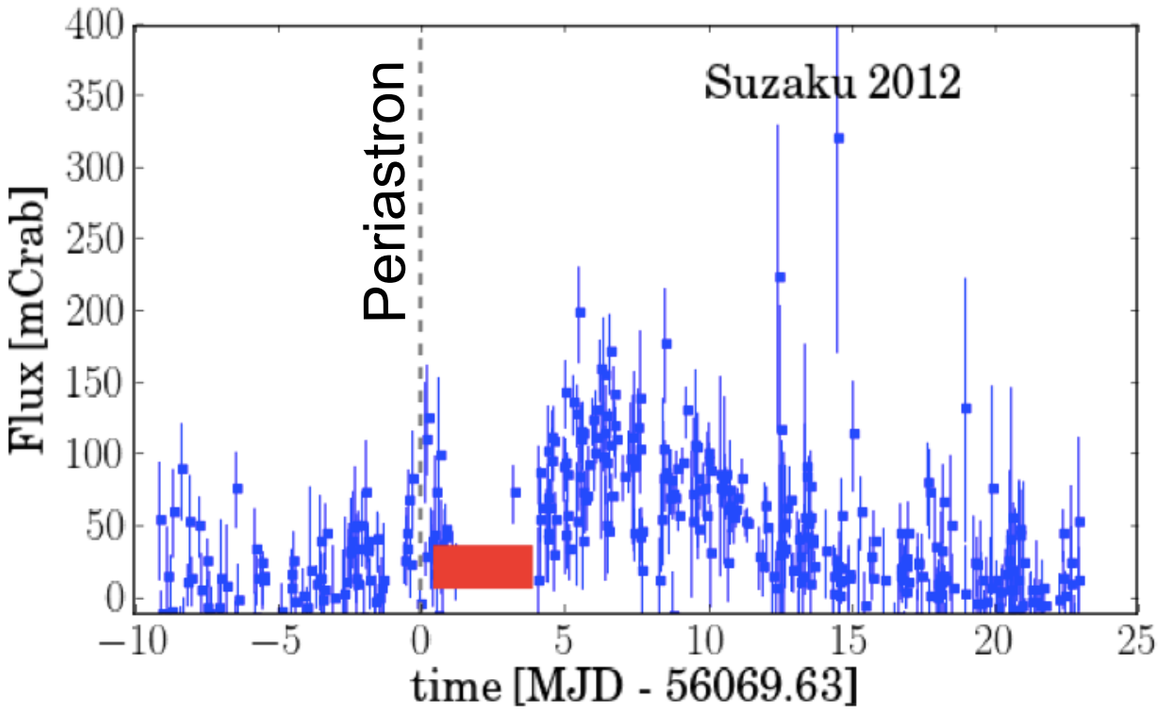


- Be/X-ray binary
- spin period 41 s
- orbital period 46 d
- eccentricity 0.4
- distance 7 kpc
- regular outbursts
- Possible cyclotron line at 64 keV
- Controversial broad-band spectrum
- Disc accretion during outbursts

Three observations

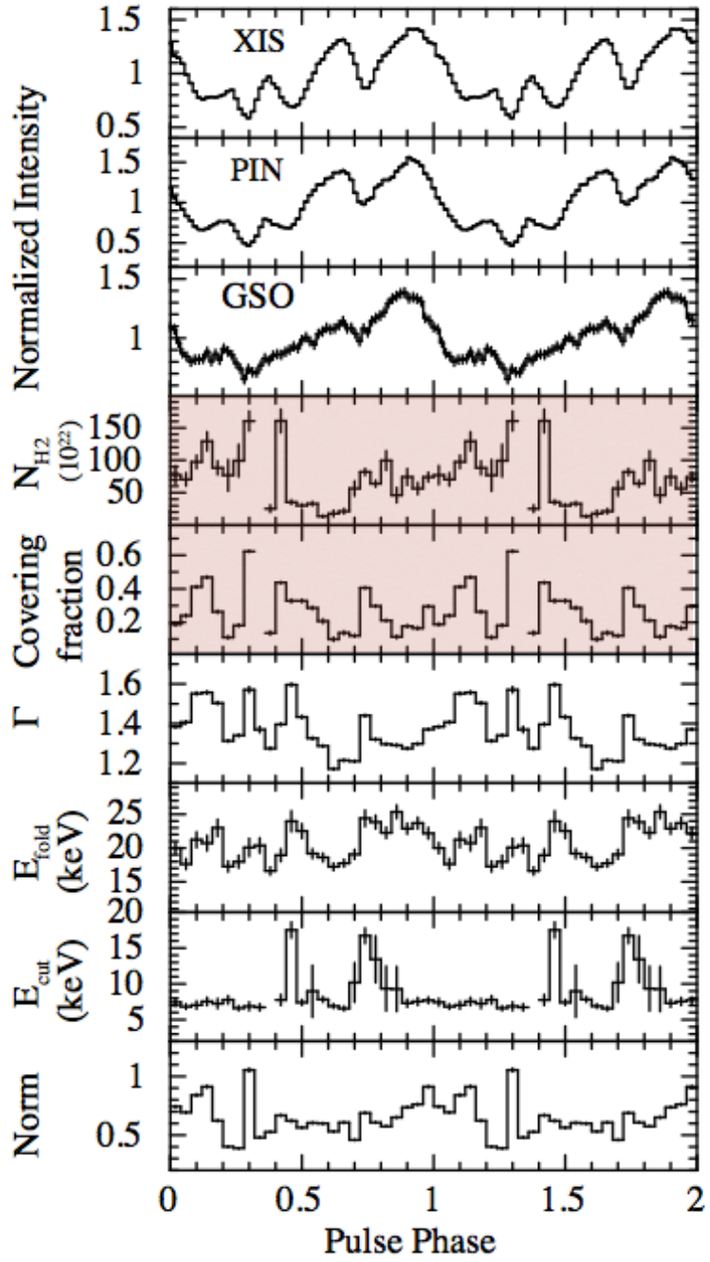






- Peak of the periastron outburst (2007)
- Setting off of the outburst (2012 and 2014)

Suzaku 2007 observation

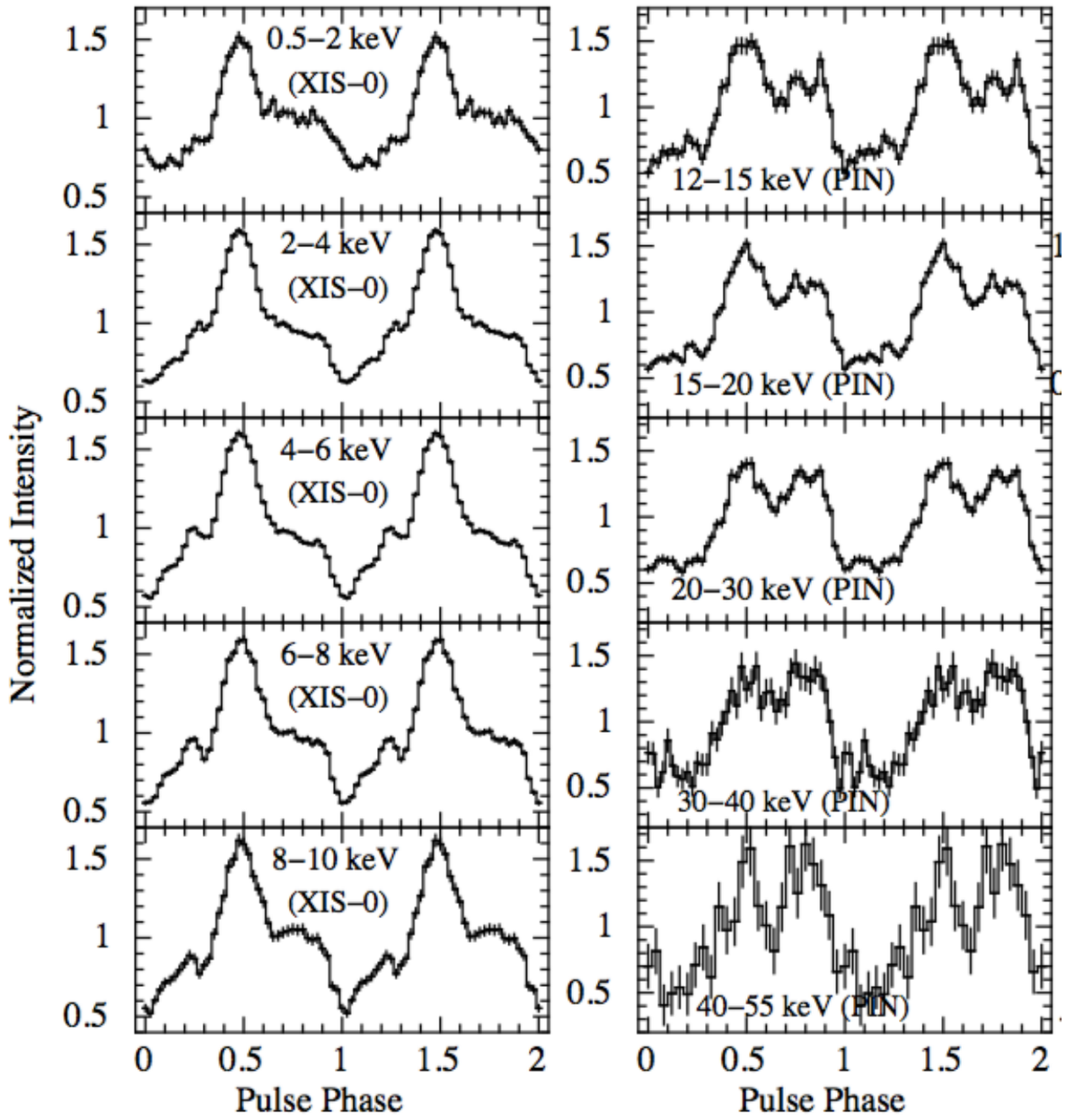


EXO 2030+375
Naik et al. (2013)

- Thanks to soft X-ray instruments, it is possible to correlate dips with enhanced absorption (column's self obscuration?).

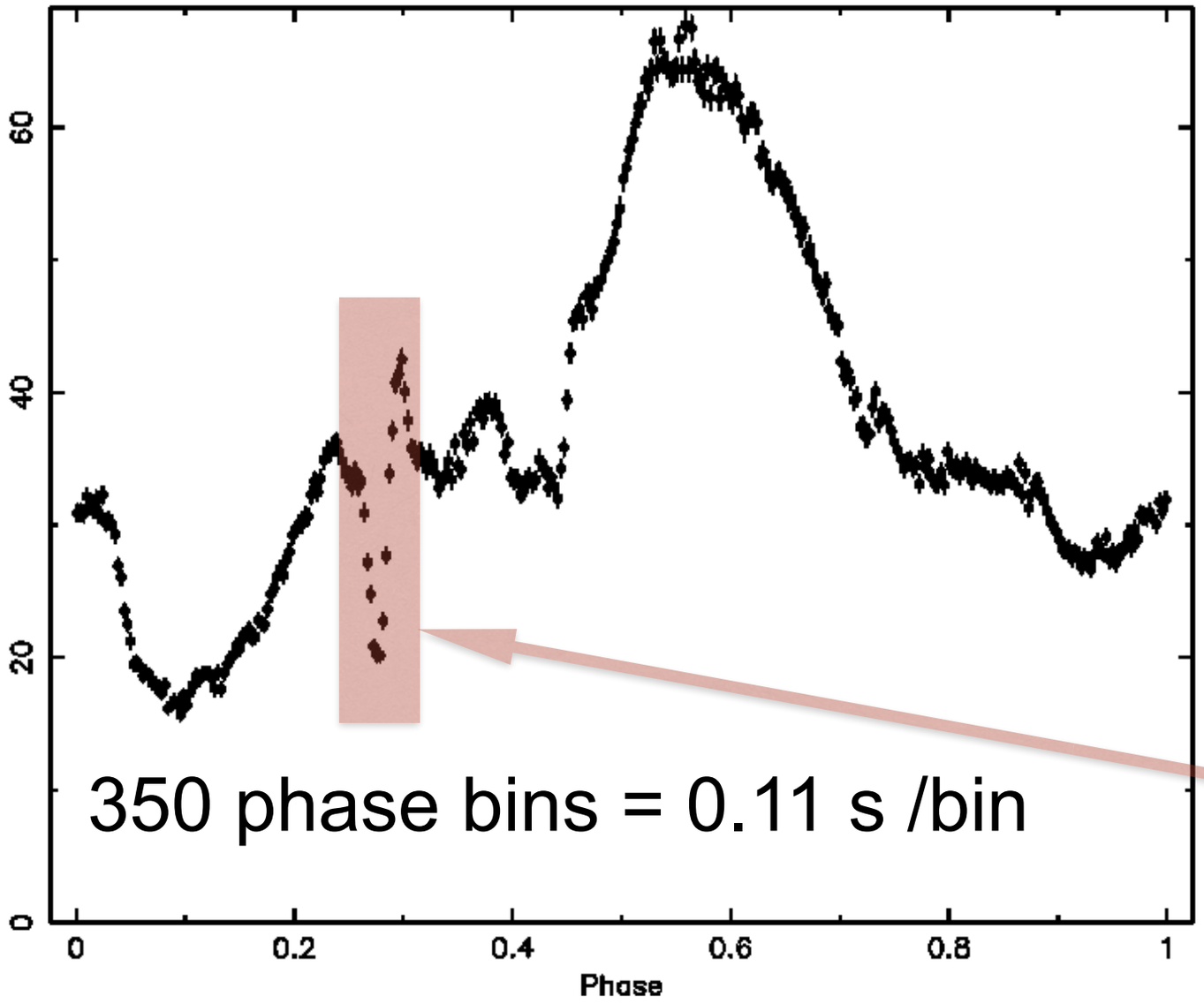
At lower luminosity

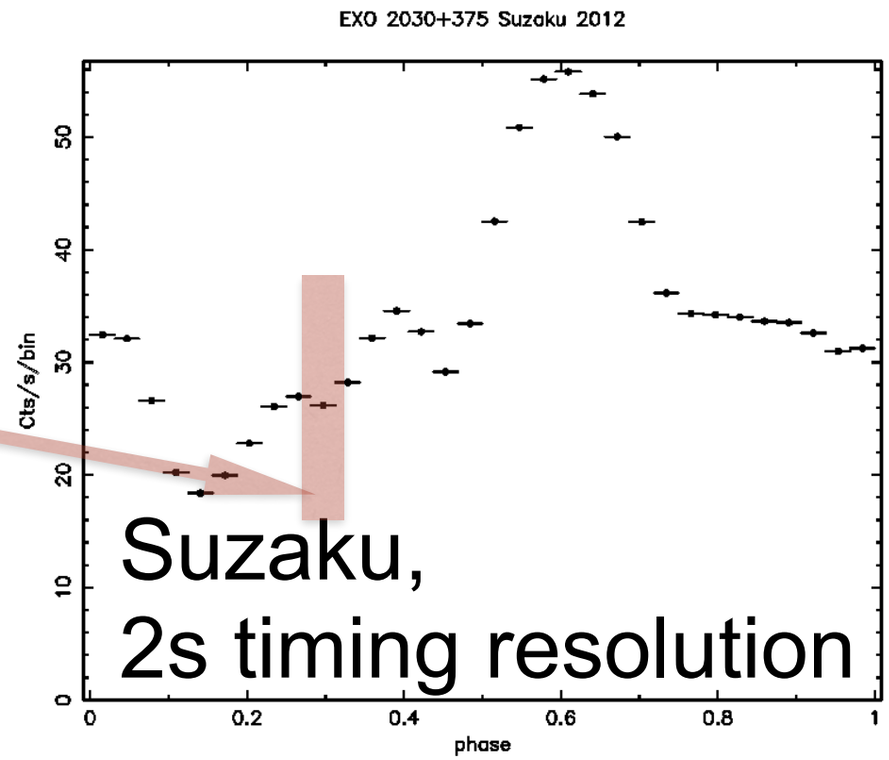
Nail et al. (2013)
Suzaku 2012



- Second pulse is suppressed at low energy: effect of absorption.

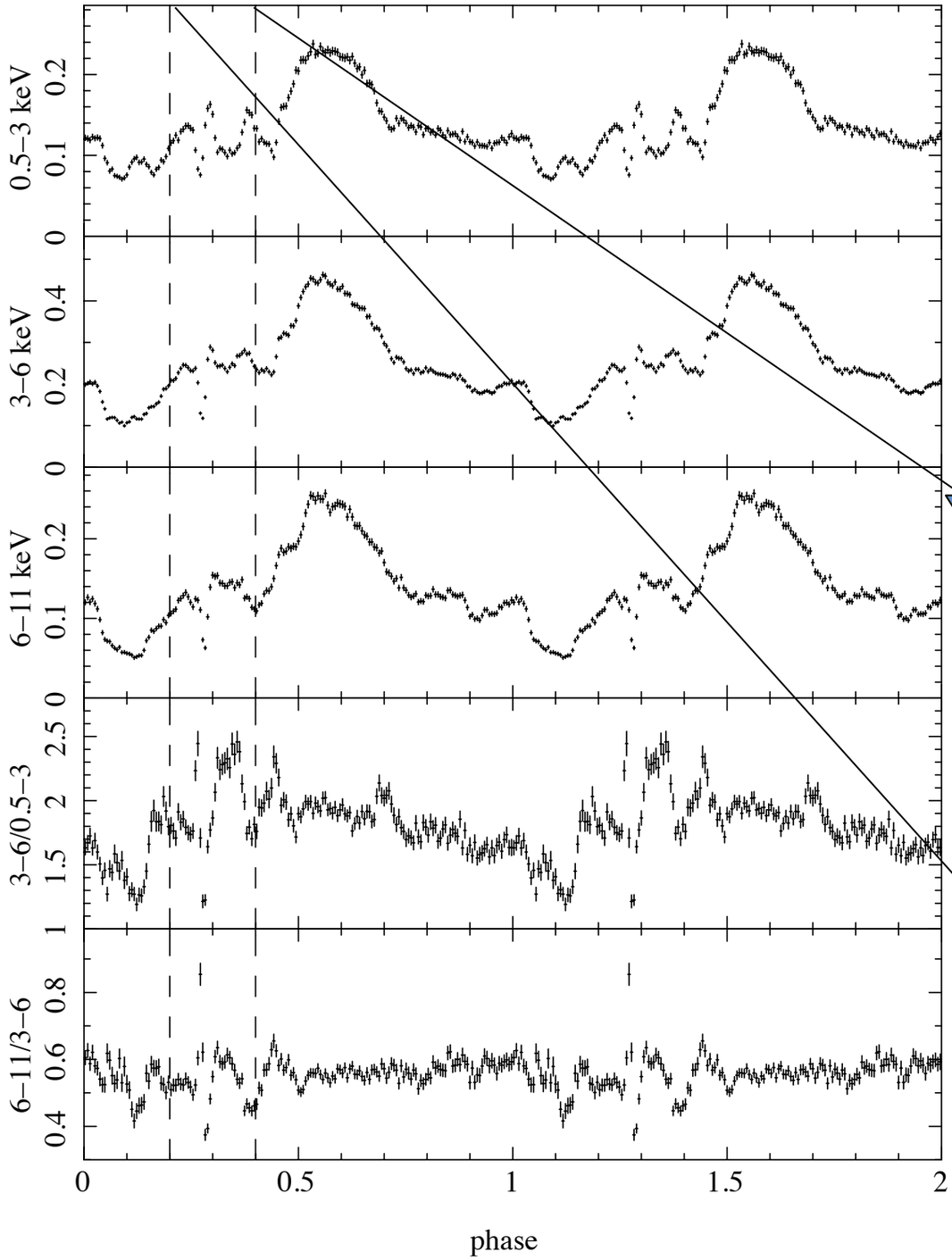
XMM-Newton 2014: a narrow dip !





- There is a very sharp structure, which appears only at the high time resolution of EPIC-PN in timing mode

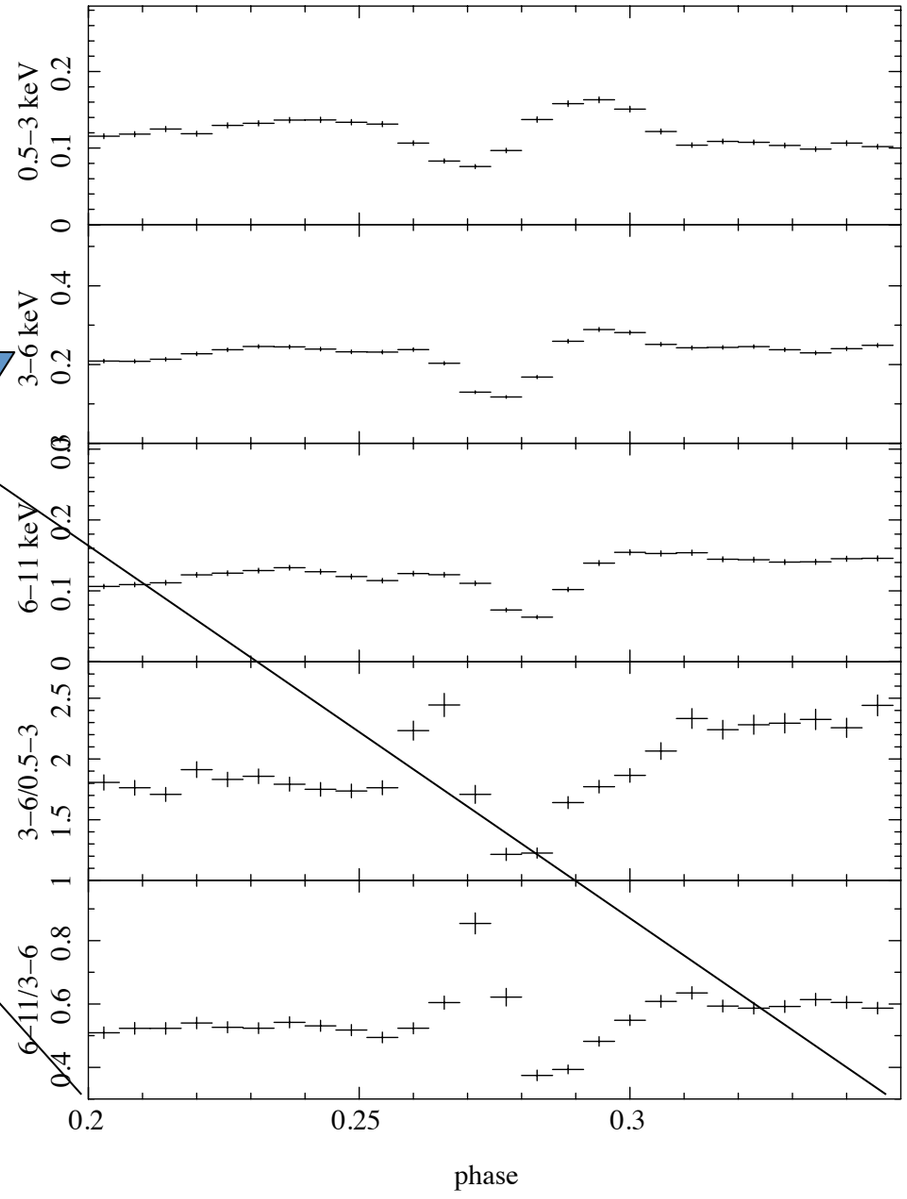
Sharp hardness variations



Energy

Hardness ratio

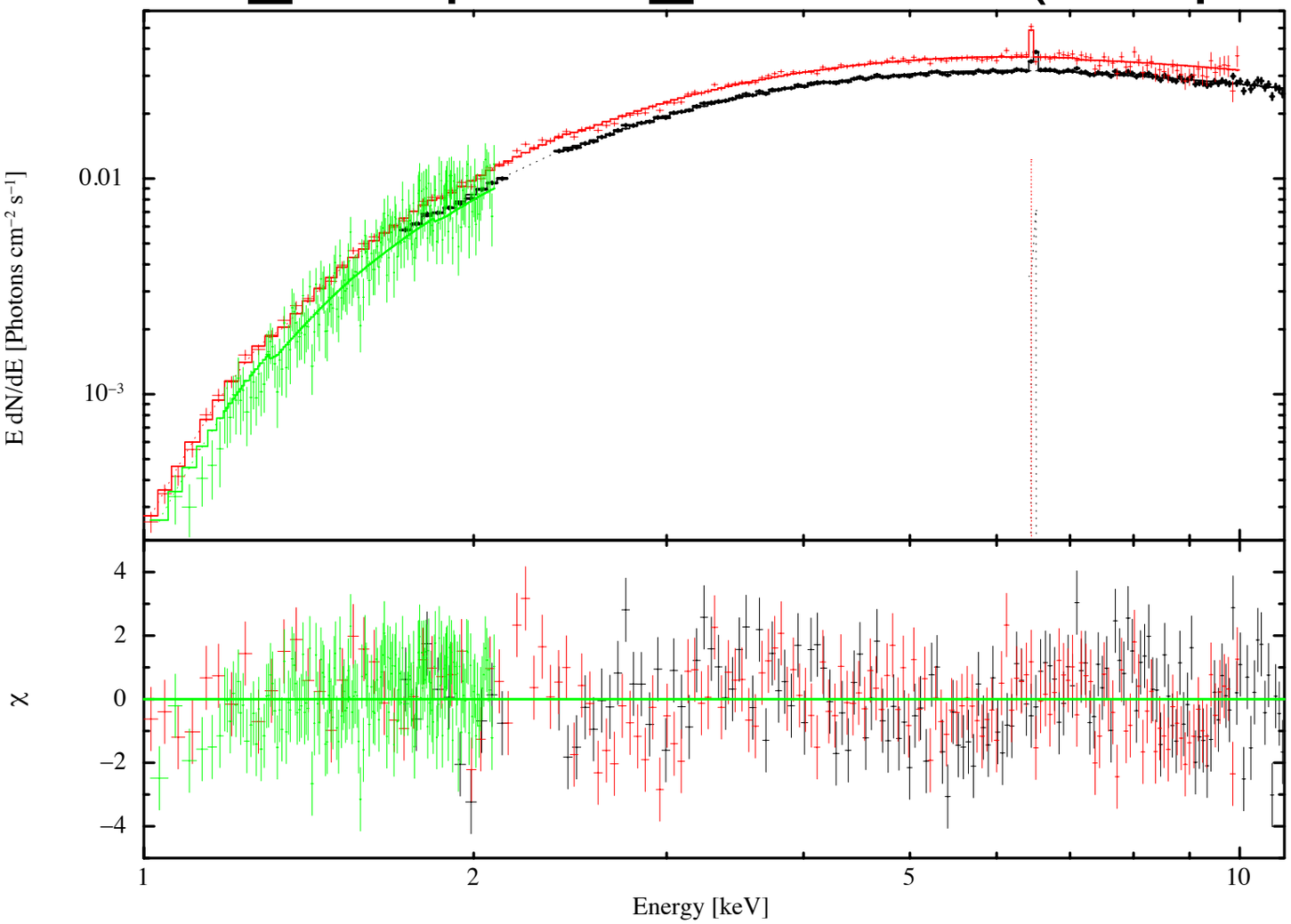
- Suggestive of a self-absorption effect.



Hardness ratio

Phase-averaged spectrum

Neutral_abs*partial_absorber*(comptb+2xGauss)

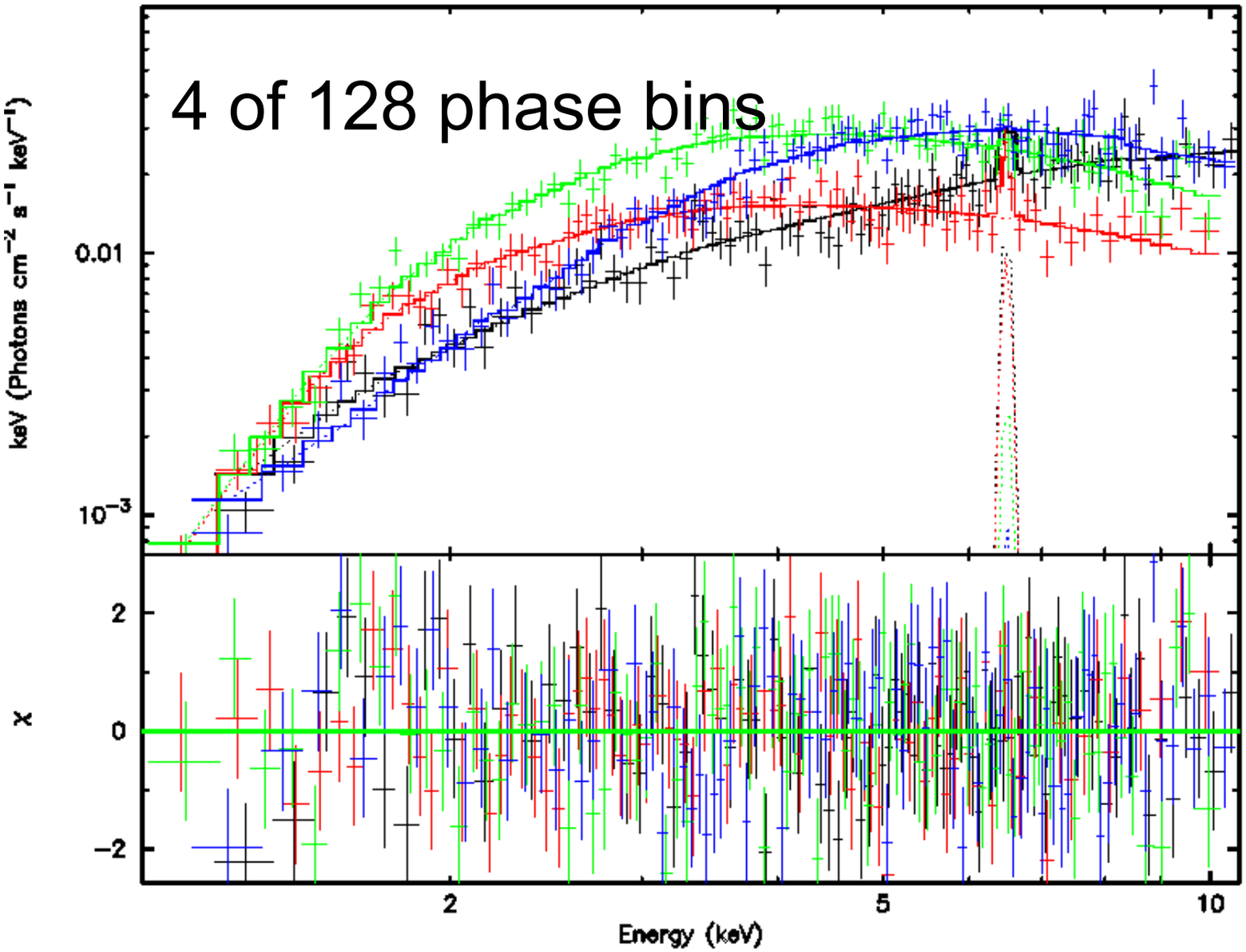


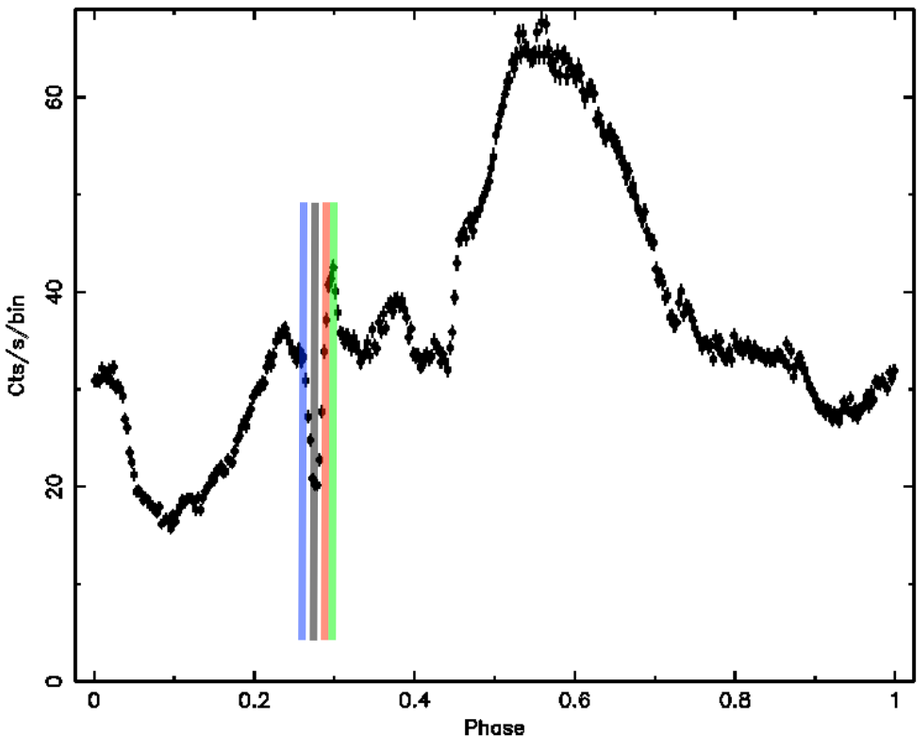
- CompTB model to use a seed photon spectrum with a custom functional form

$$S(x) = \frac{Cx^{\gamma}}{e^{T_e x/T_S} - 1}$$

- We determine the model on high S/N averaged spectrum.
- Tried ionised partial covering -> low ionisation, use neutral.

A narrow dip !

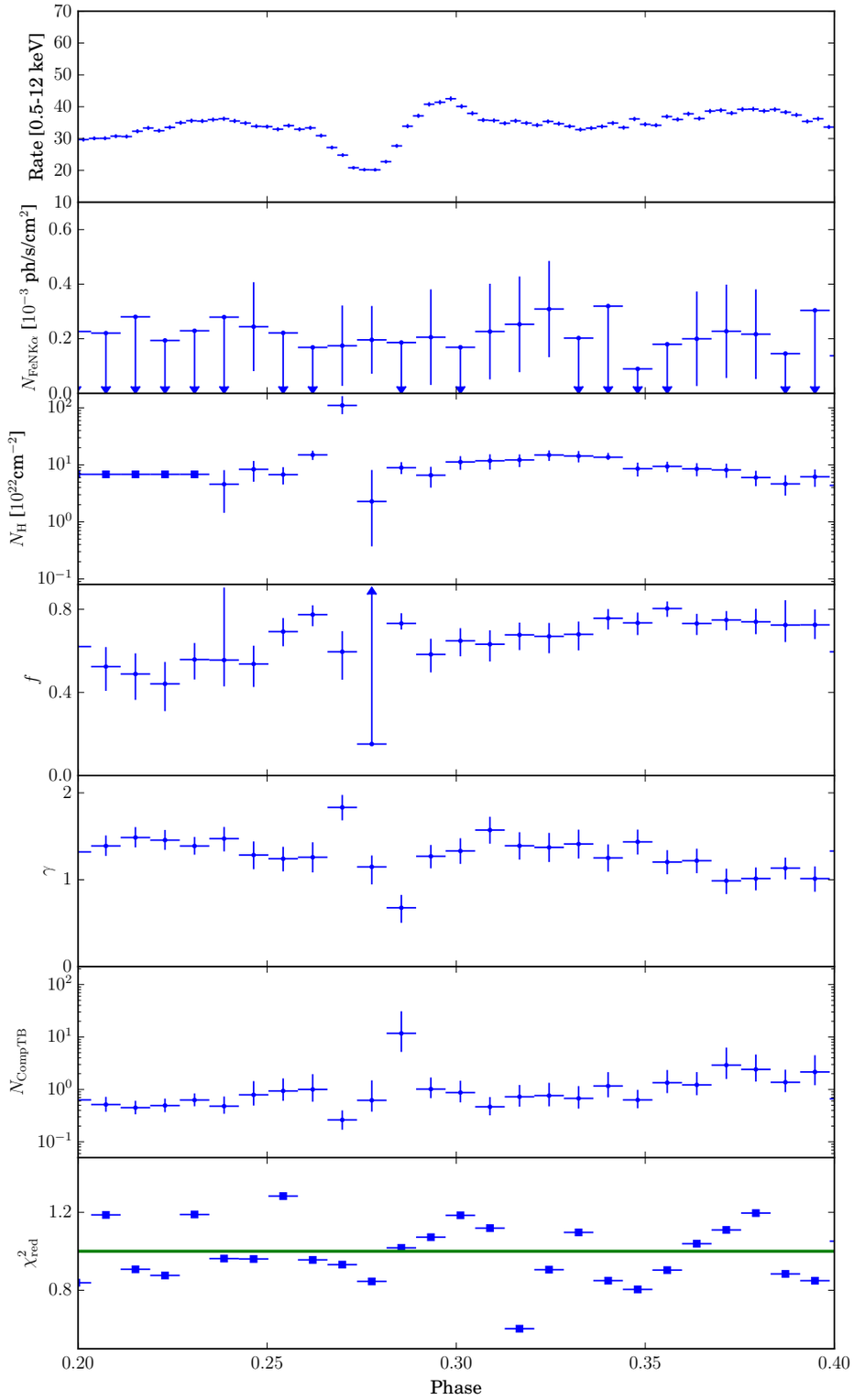




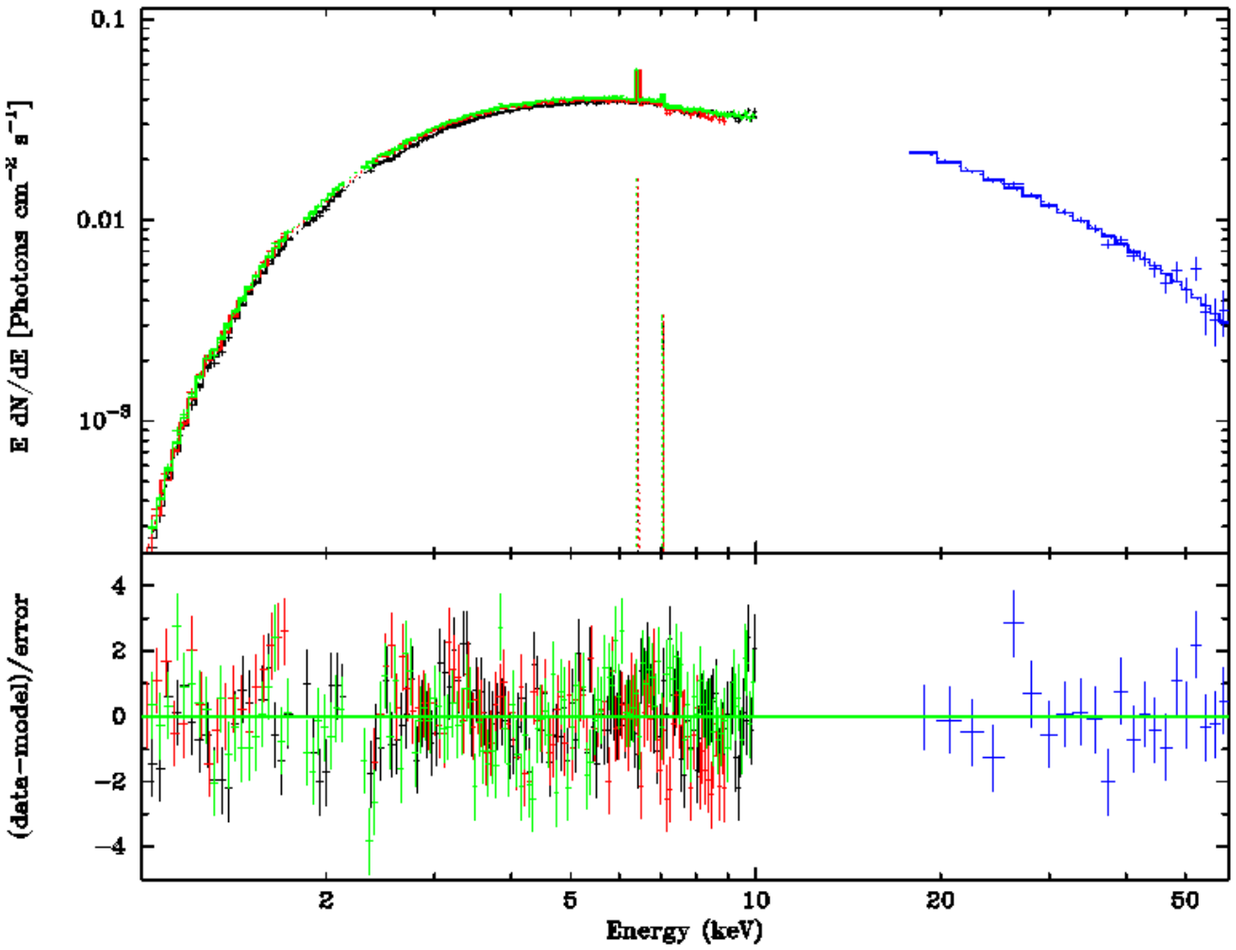
- Dramatic spectral change. Partially covered Comptonization model.

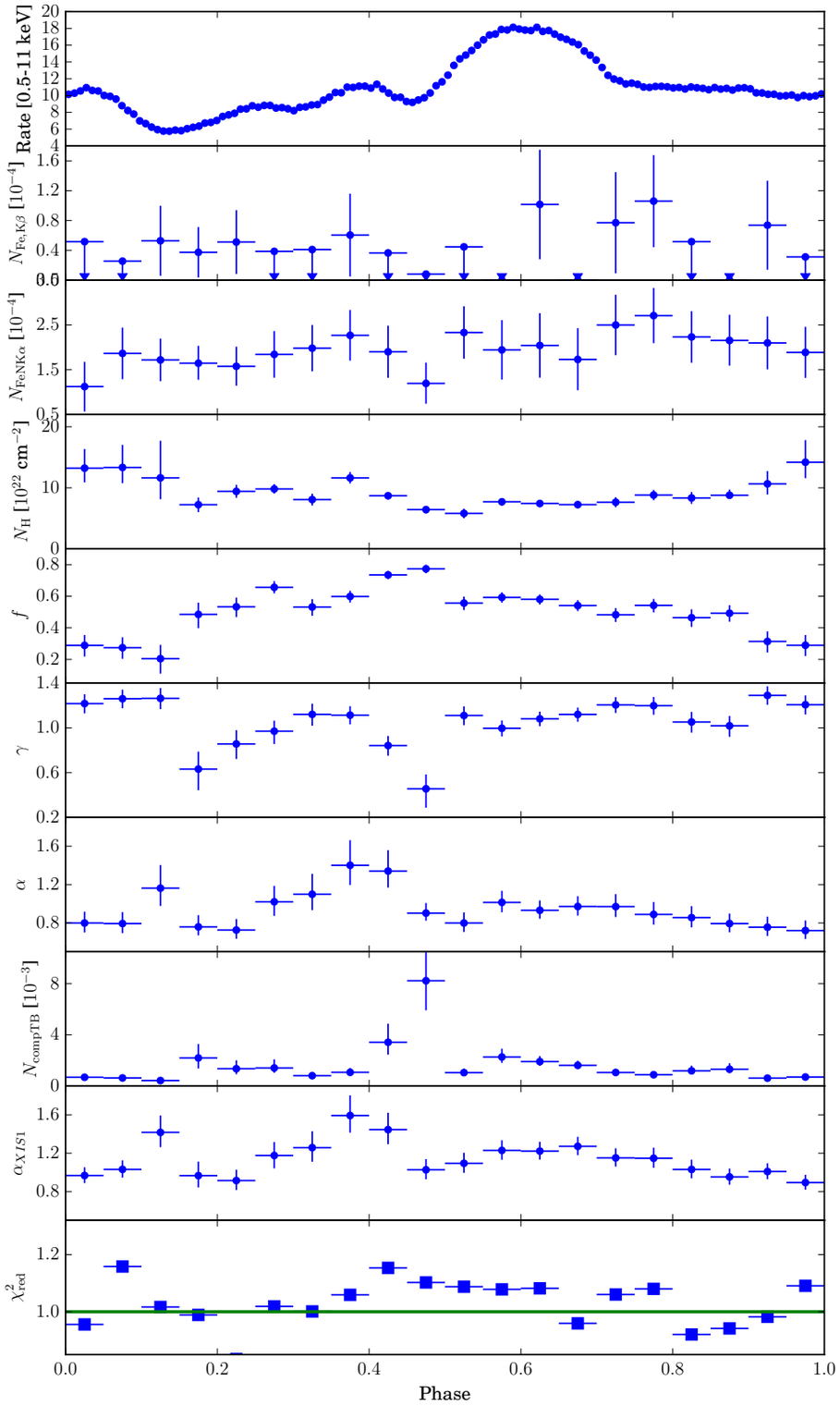
Phase resolved

- We describe the phase-resolved spectra by letting a subset of parameters free to be determined.
- Choice of fixed parameters is driven by general considerations and “trial and error”.
- Fix neutral column's density, iron line energy and width,fix kT_B continuum parameter.
- Both absorption jump and continuum variations around the dip



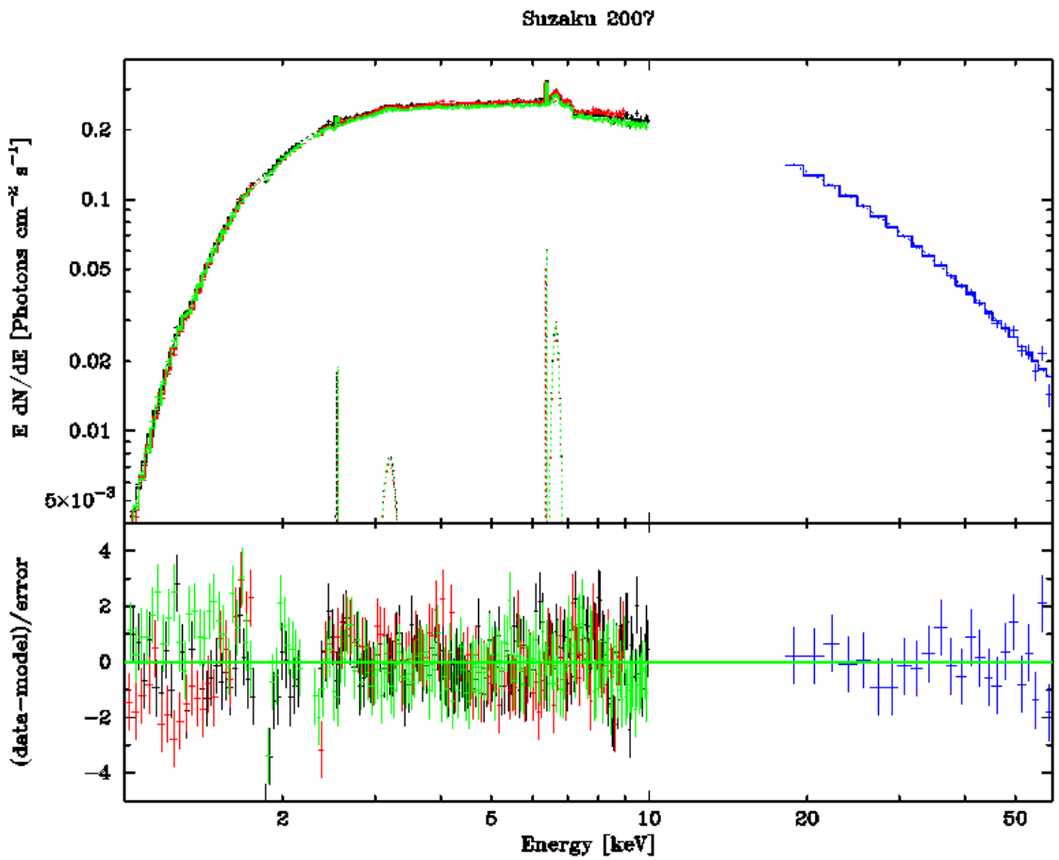
Suzaku 2012 (2x luminosity)



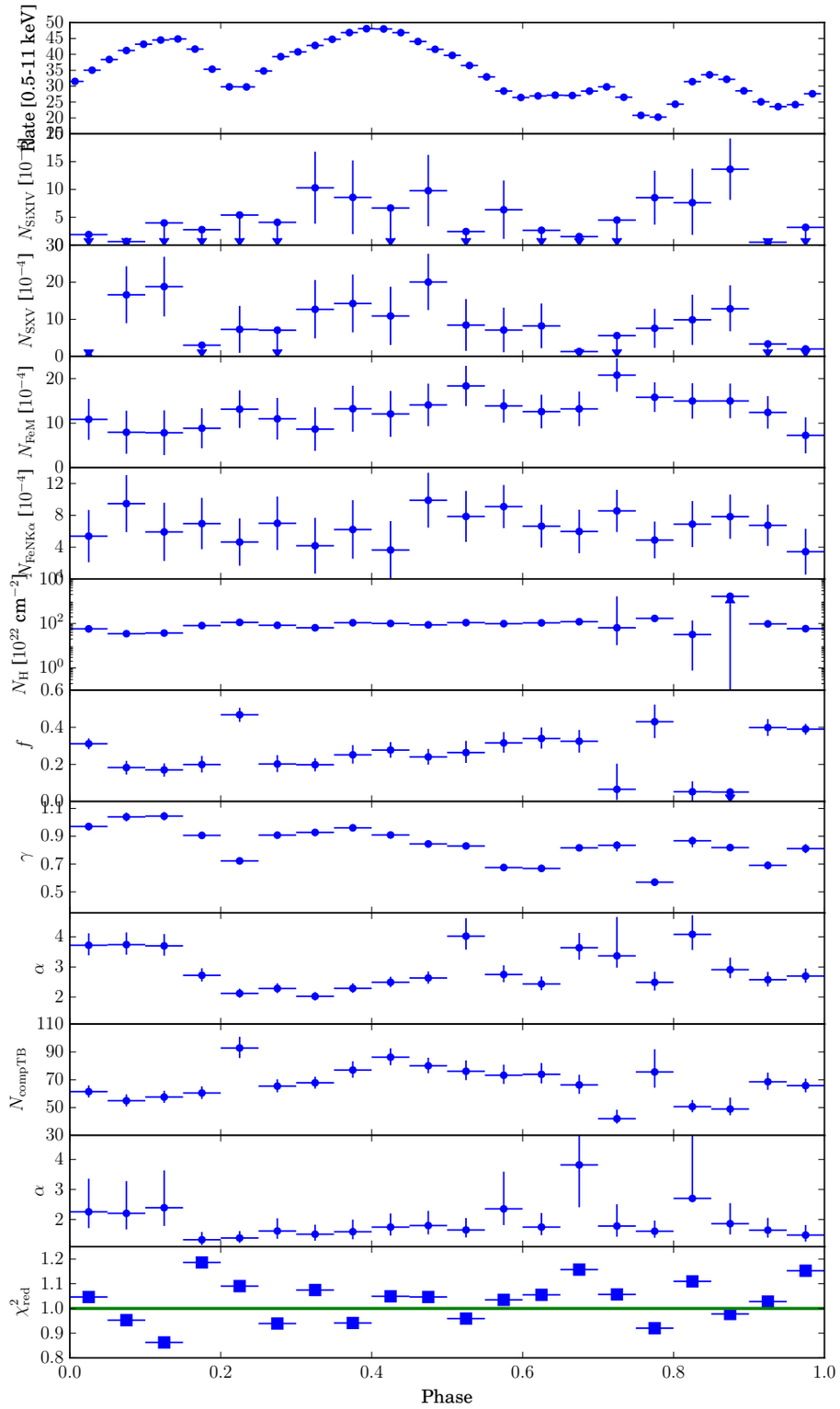


- Same model works and similar pattern in phase-resolved spectra.

Suzaku 2007 (10x luminosity)



- Same model works, absorber and continuum change over phase: not possible to disentangle effects clearly-> hint of enhanced absorption in dips.



Conclusions

- We found a peculiar structure in the pulse profiles of EXO 2030+375.

- Model with Comptonization by customised seed photon distribution and neutral partial absorption.

- We argue that self-obscuration of the accretion stream causes the dip in the XMM spectrum and this is enlarged at higher luminosity in the 2007 Suzaku data.