Studying the stellar wind structure of Vela X-1 using *XMM-Newton*

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Alicante-ESAC-Bamberg

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Outline

Stellar Winds on Super-Giant X-ray binaries.

The system: Vela X-1.

The data: an unexpected XMM-Newton observation.

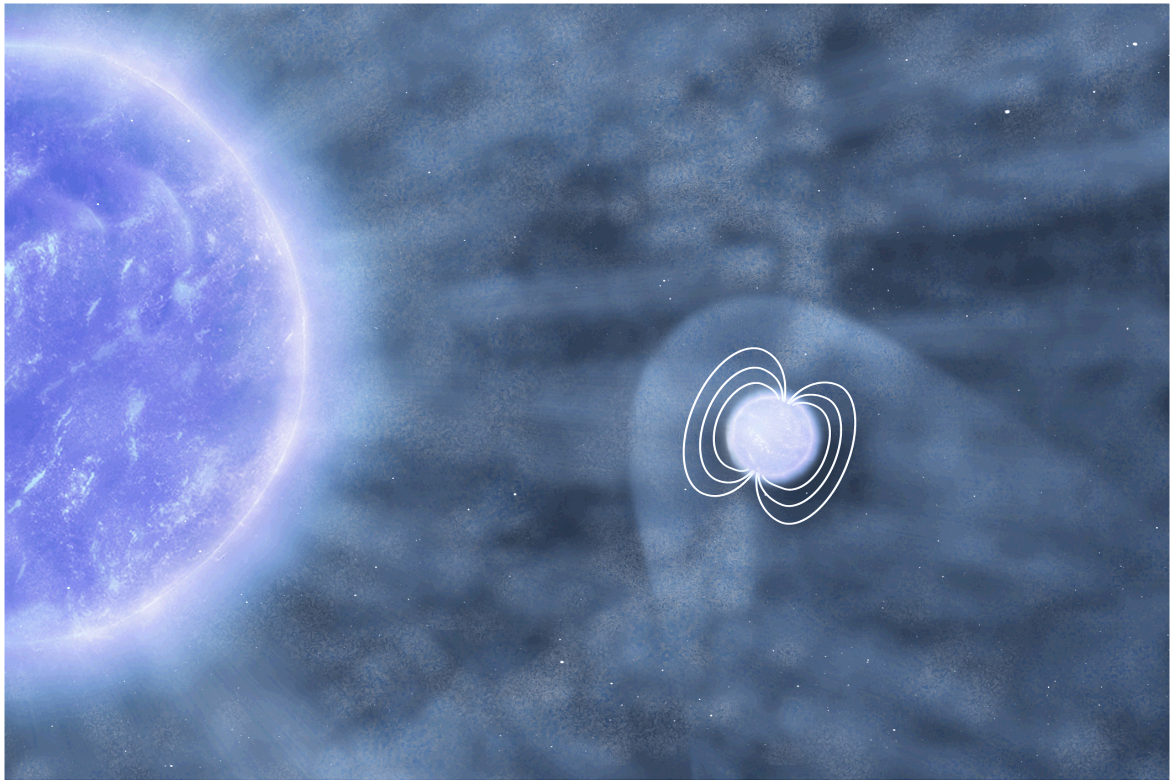
Stellar Winds on SGX

Three main reasons why real accretion differs from current theory:

-The wind of massive stars are highly structured.

-Accretion onto a NS is an unstable process.

-The magnetic field of NS affects the flow of material.



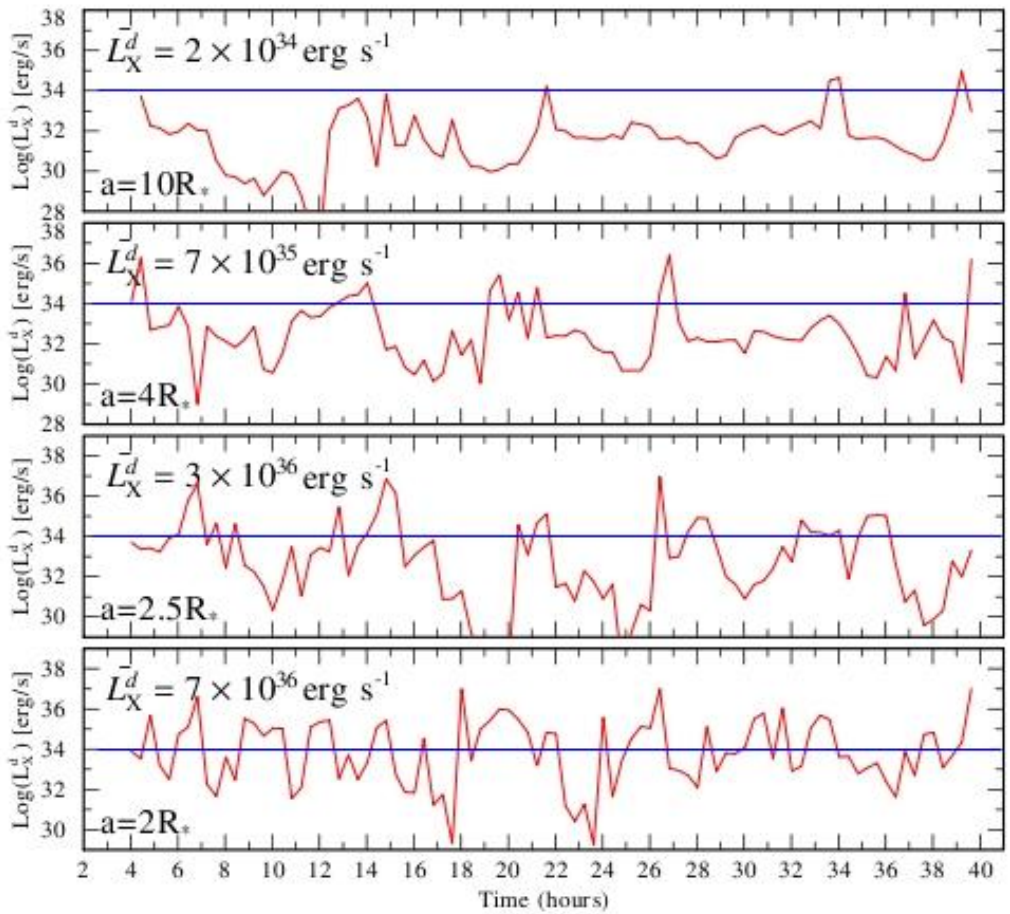
Bozzo et al . 2011

Stellar Winds on SGX

Oskinova et al. 2012:

Bondi-Holyle-Lyttleton accretion of a non stationary stellar wind onto a NS of $1.4M_\circ$.

The synthetic light curves are highly variable, with X-ray luminosity changing by up to eight orders of magnitude ! Due to the highly variable density and velocity of the clumping stellar wind.



Spectral type		O9.7Ib
Mass	M_*	$34\ M_\odot$
Radius	R_*	$24\ R_\odot$
Terminal speed	v_∞	1850 km/s
Mass loss rate	$\dot{M}$	$3 \times 10^{-6}\ M_\odot\ \mathrm{yr}^{-1}$

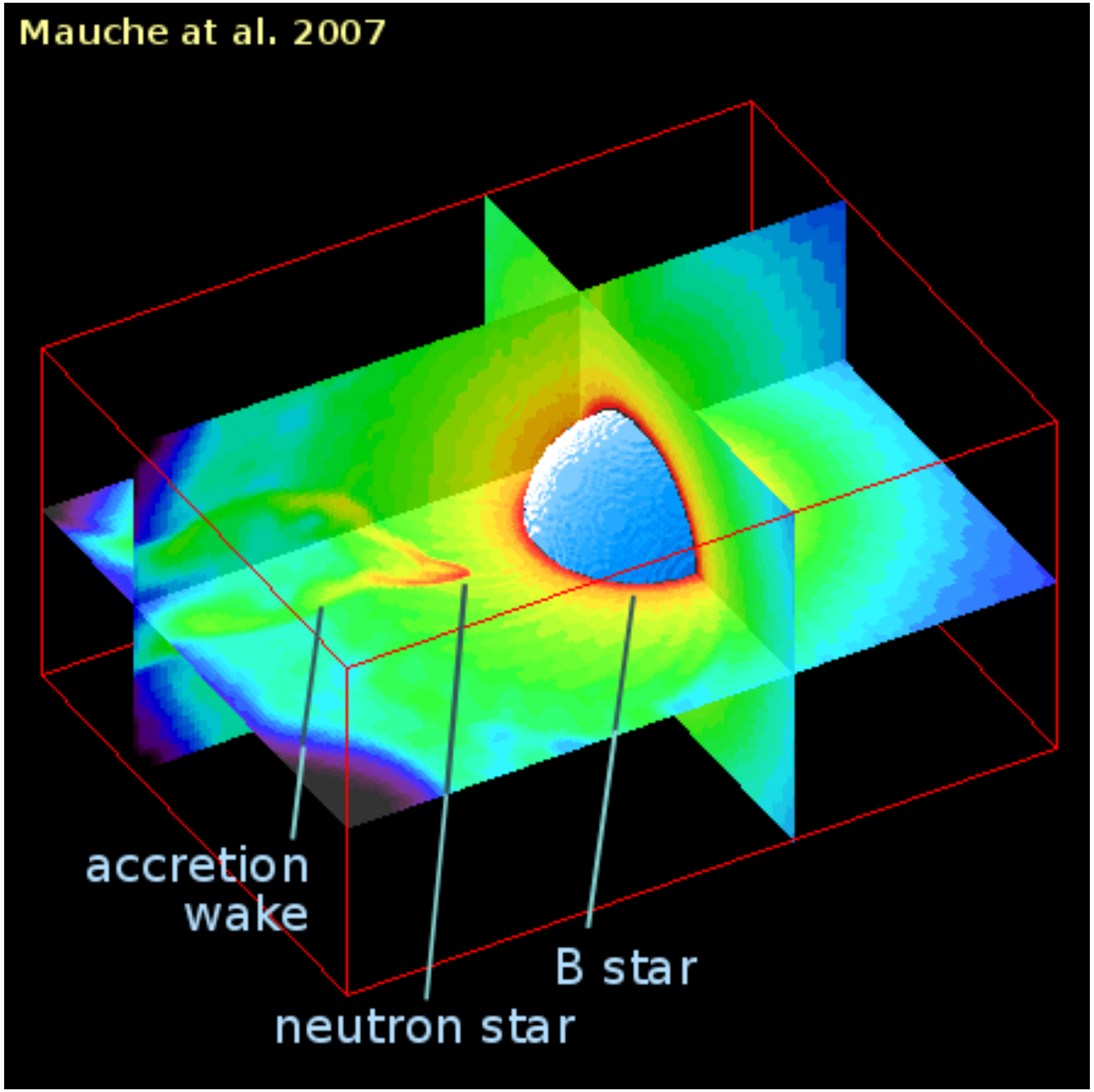
Blue line is the limit for current X-ray missions for a source at certain source distance

Stellar Winds on SGX

3D Monte Calor Flash snapshot simulation of Vela X-1 system.

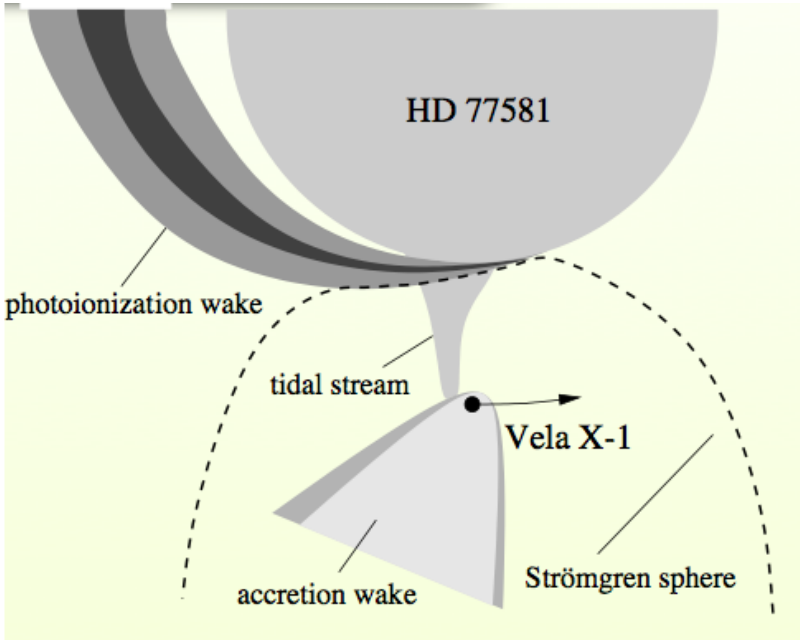
Bondi-Holyle-Lyttleton accretion of a smooth stellar wind.

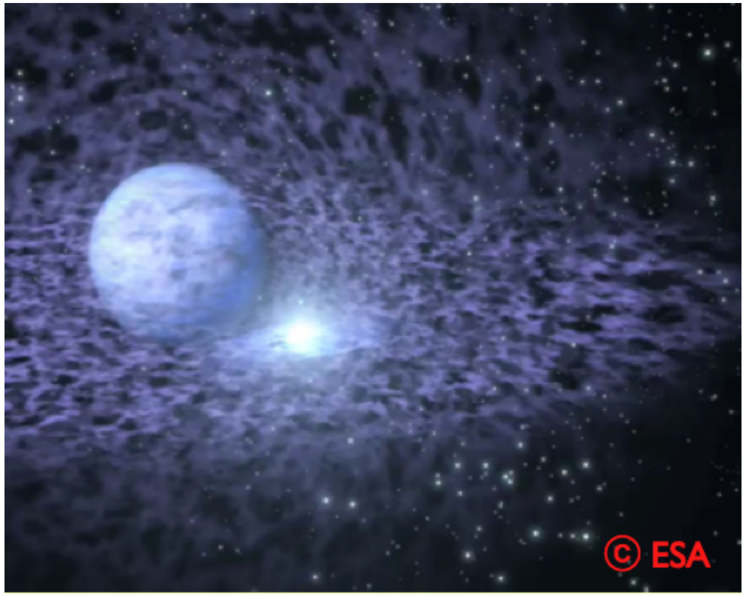
Colors indicate
log density (g/cm^3).



The system: Vela X-1

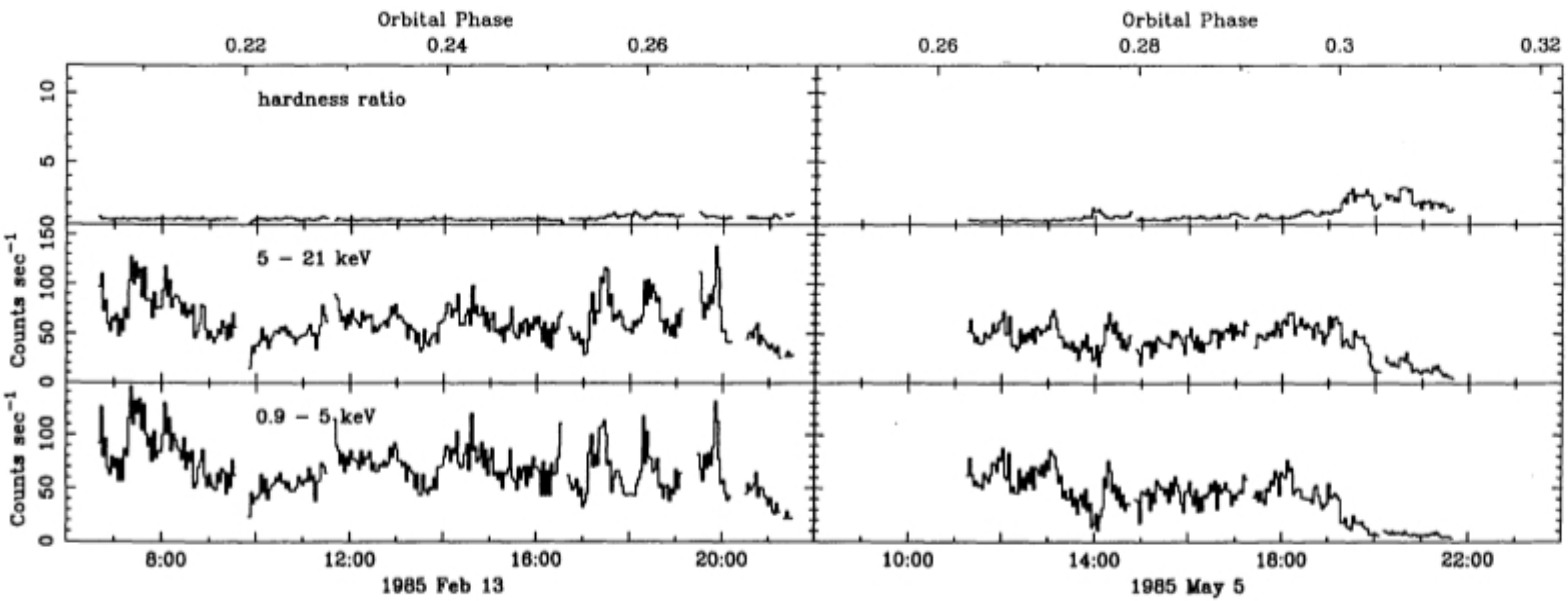
- NS (1.9-1.8M$_\odot$) + B0.5Ib supergiant companion.
- Orbital period: 8.96 d.
- Pulse period: 283 s.
- Eclipsing system.
- Mass loss rate: $\dot{M} = (1 - 6 \times 10^{-6} M_\odot)$





The system: Vela X-1

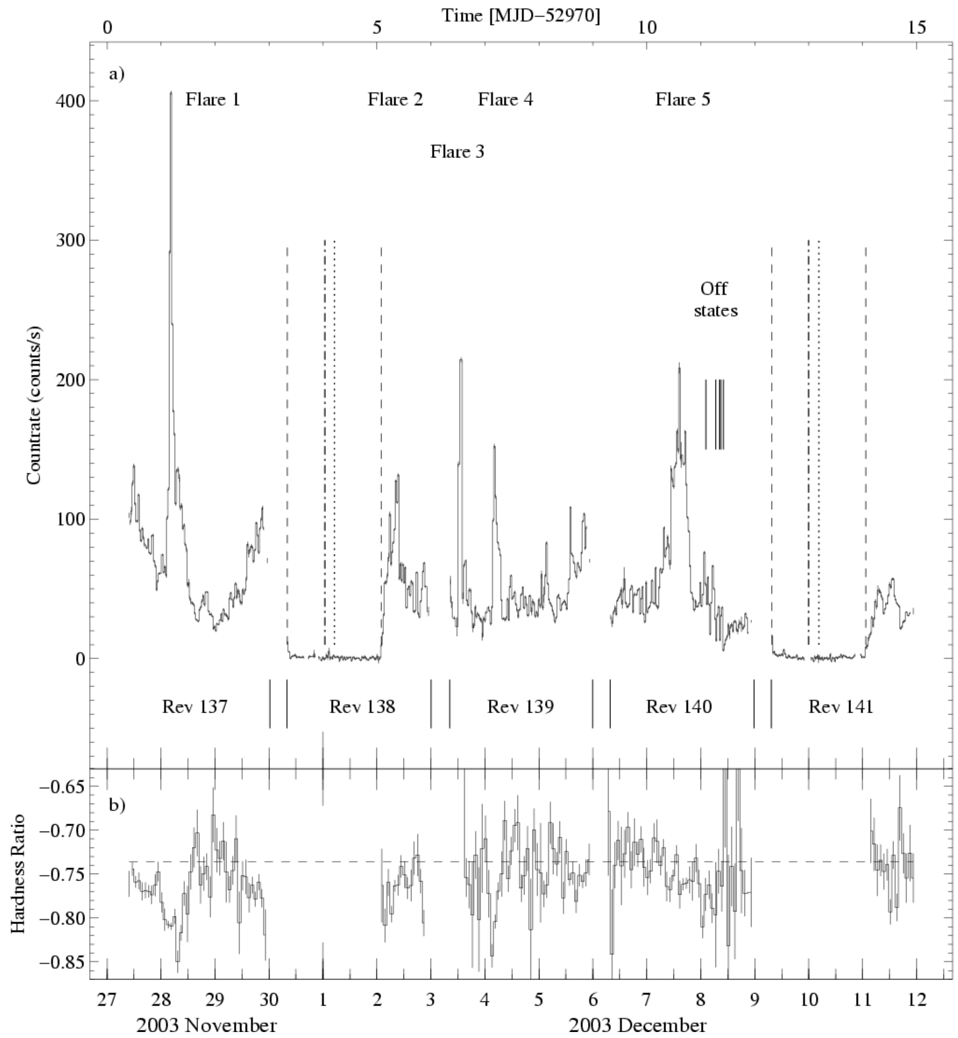
Haberl & White 1990: EXOSAT



The system: Vela X-1

Kreykenbohm et al. 2008 :
INTEGRAL/IBIS

Different types of flaring activity at different time scales



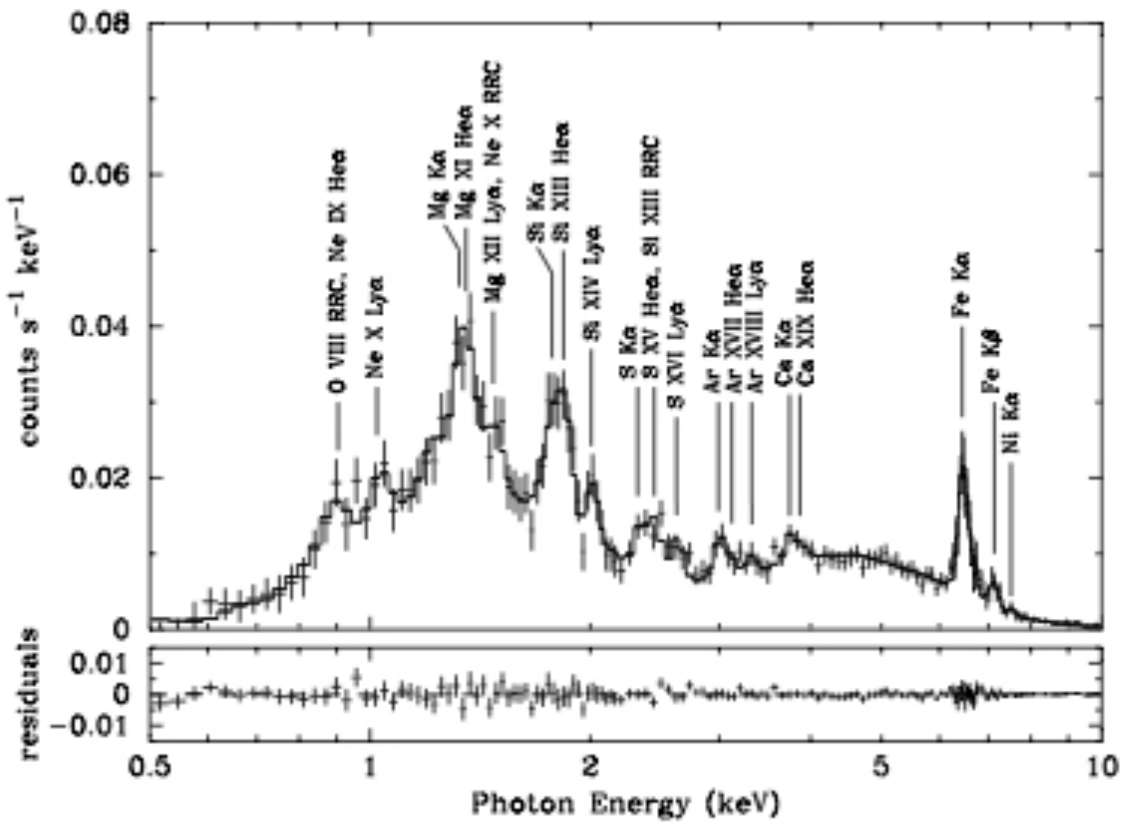
The system: Vela X-1

Sako et al. 1999: ASCA eclipse

Faint continuum: non-thermal emission: direct and scattered.

Discrete features: recombination (H and He lines produced by photoionization in wind) and fluorescence lines (circumsome medium).

Inhomogeneous wind, consisting on hundreds of cold dense clumps embedded in a hotter, more ionized gas.



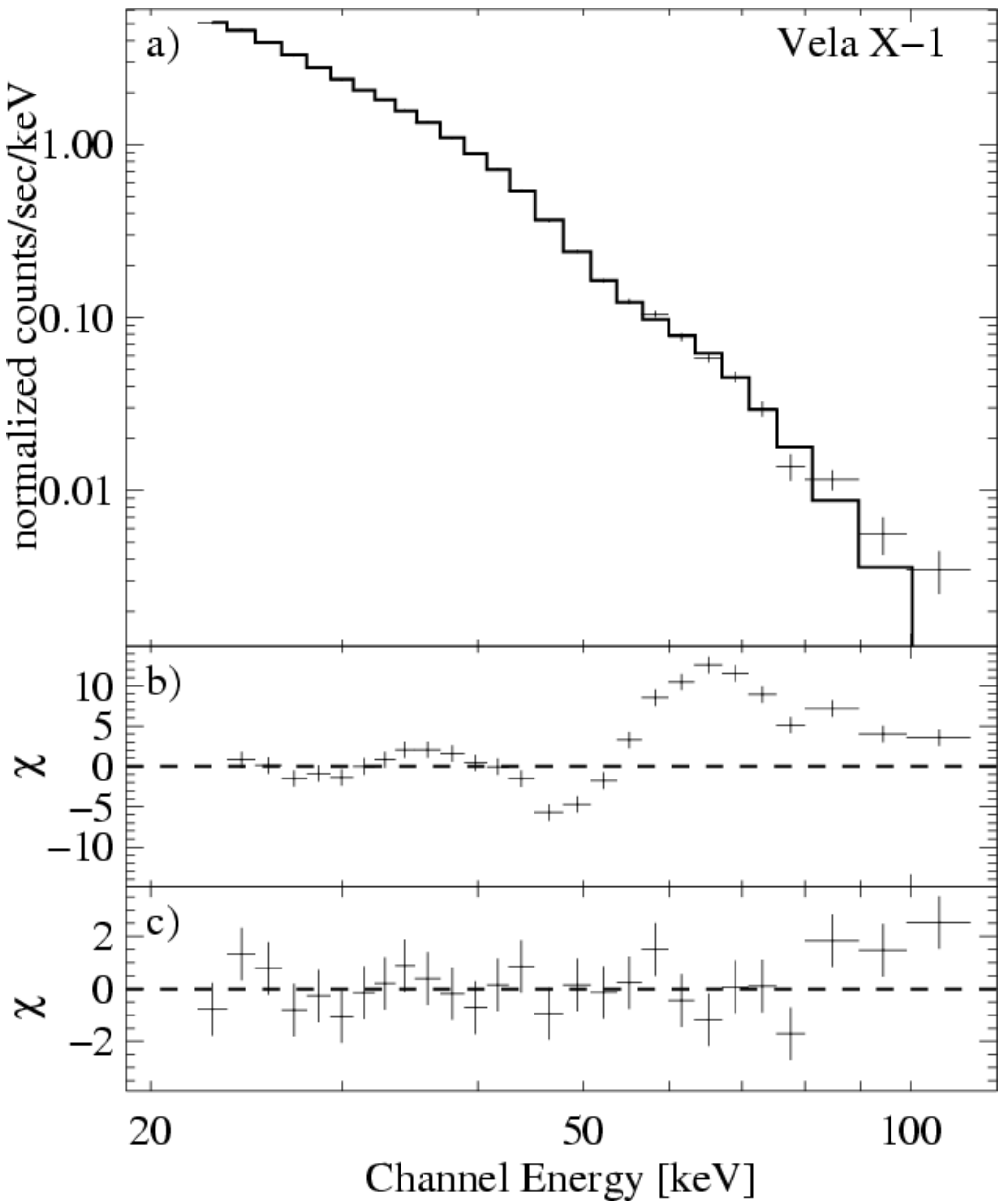
The system: Vela X-1

Kreykenbohm et al. 2008

INTEGRAL/IBIS

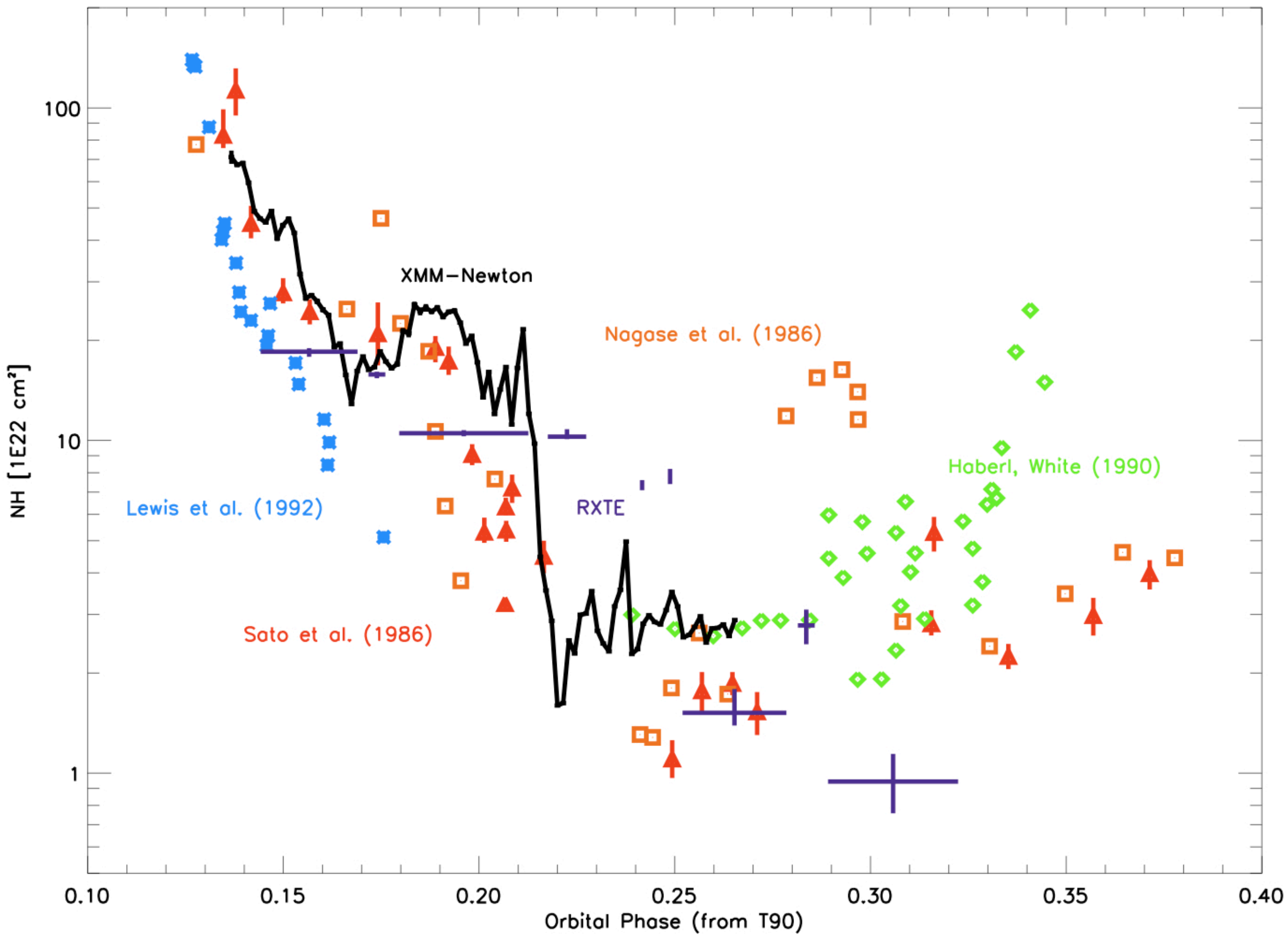
Cyclotron Resonance Features
at 25 keV and 50 keV

Magnetic field ~ 3 x 10^{12} G



The system: Vela X-1

After an initial decrease there is a phase of strongly variable absorption, while late orbital phases are always rather strongly absorbed.



The observation

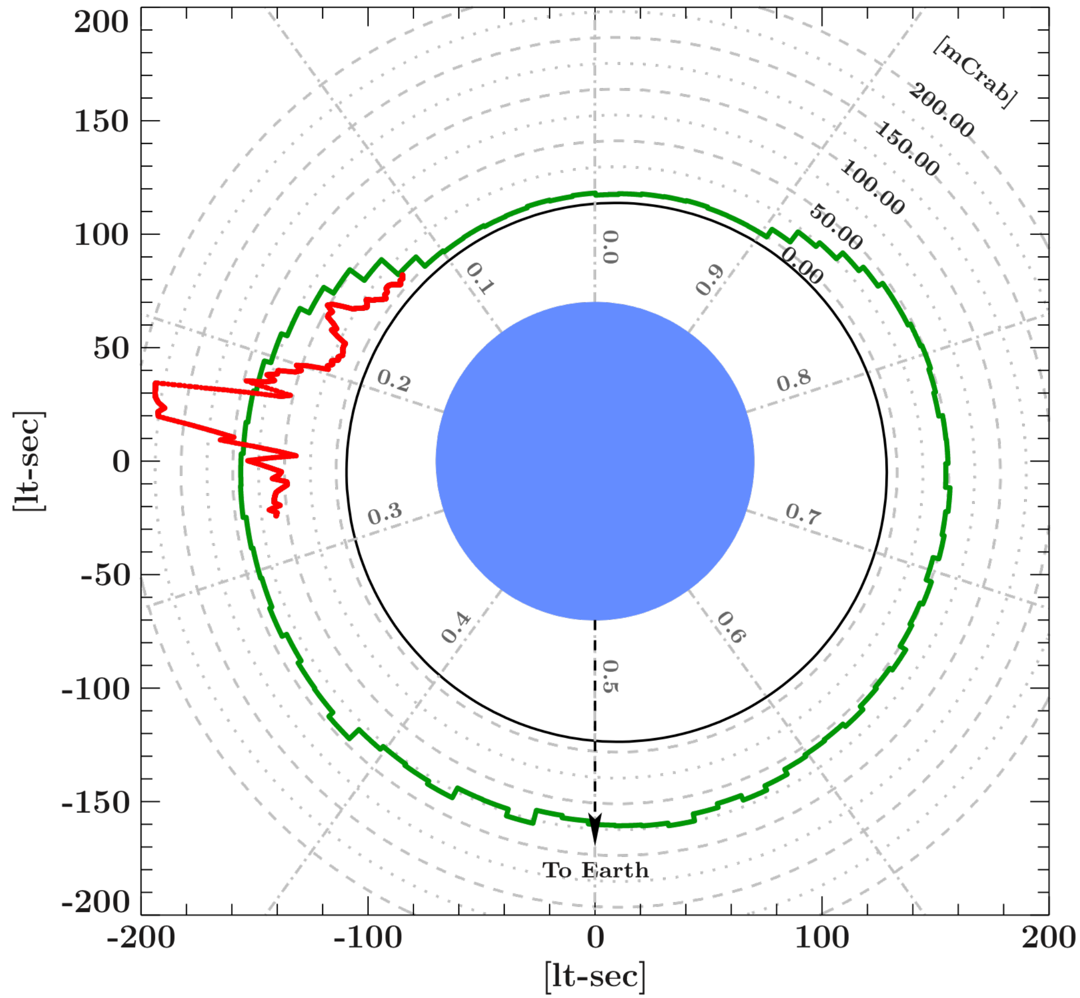
Orbit sketch of Vela X-1 using Kreykenbohm et al. (2008) ephemerides.

100 ks observation

Egress phase from 0.132 to 0.270

EPIC/pn timing mode

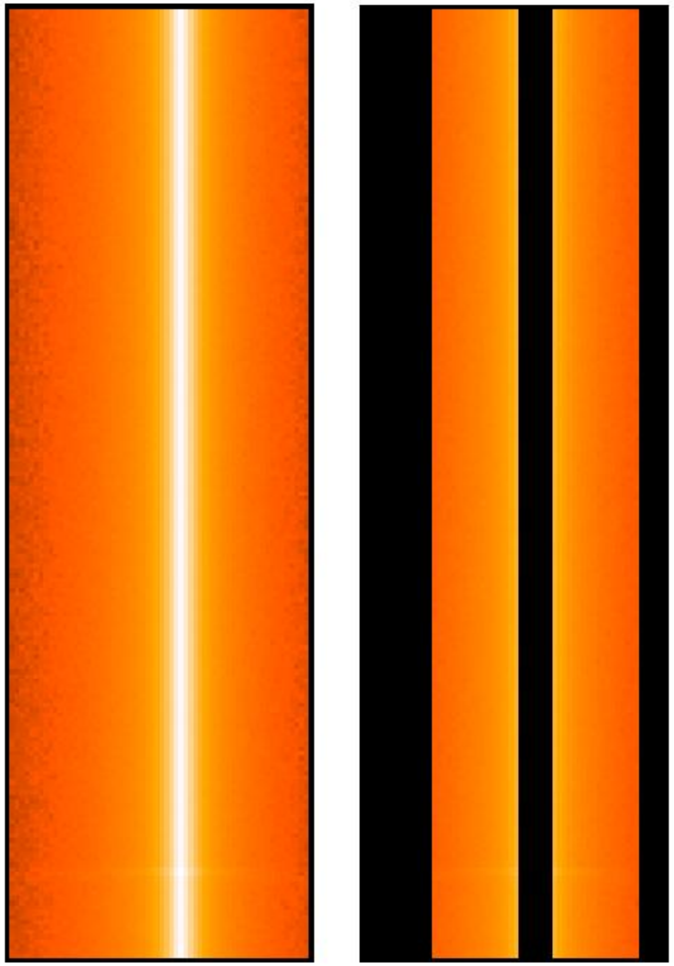
RGS

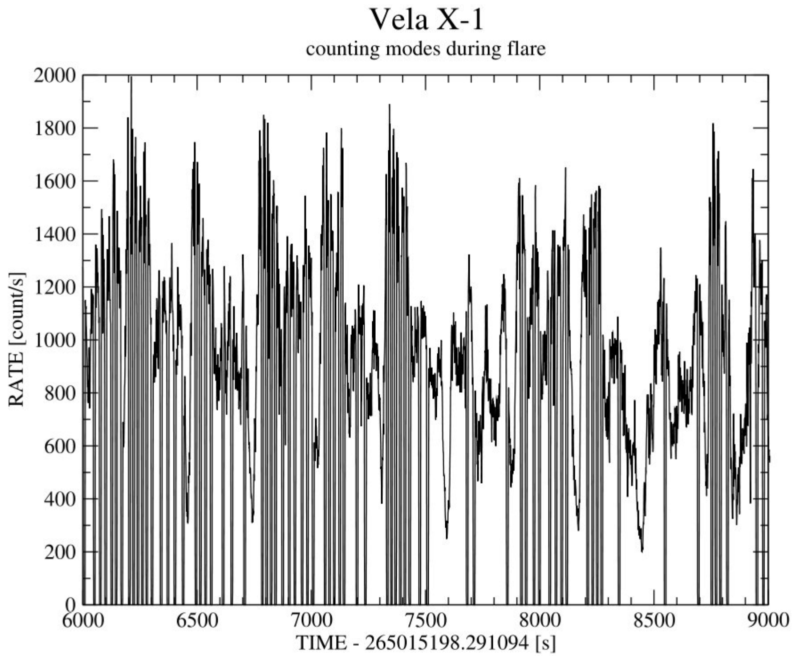


1.5-12 keV RTXE/ASM average light cuve

0.5-12 keV EPIC/pn light curve

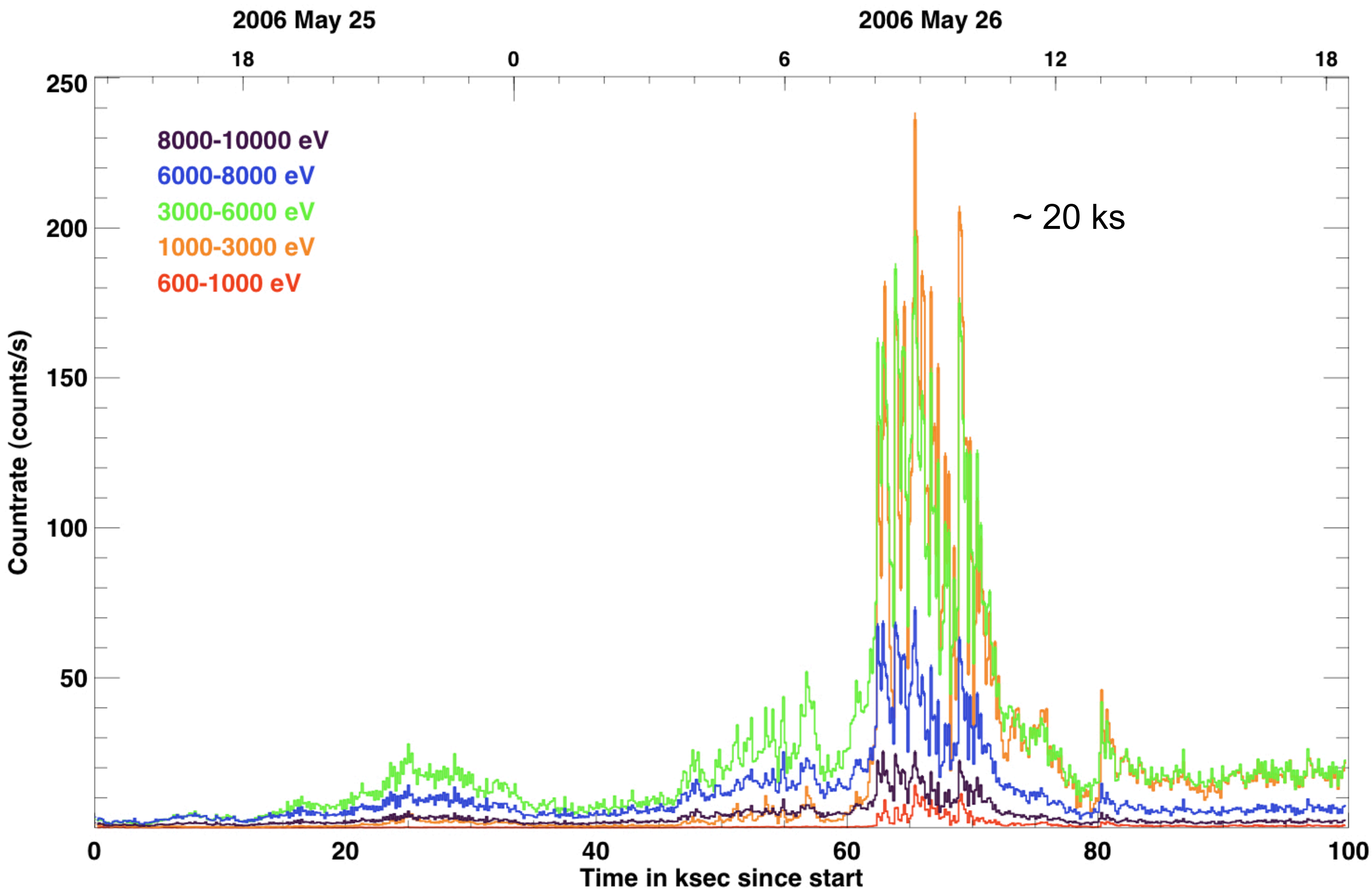
The observation



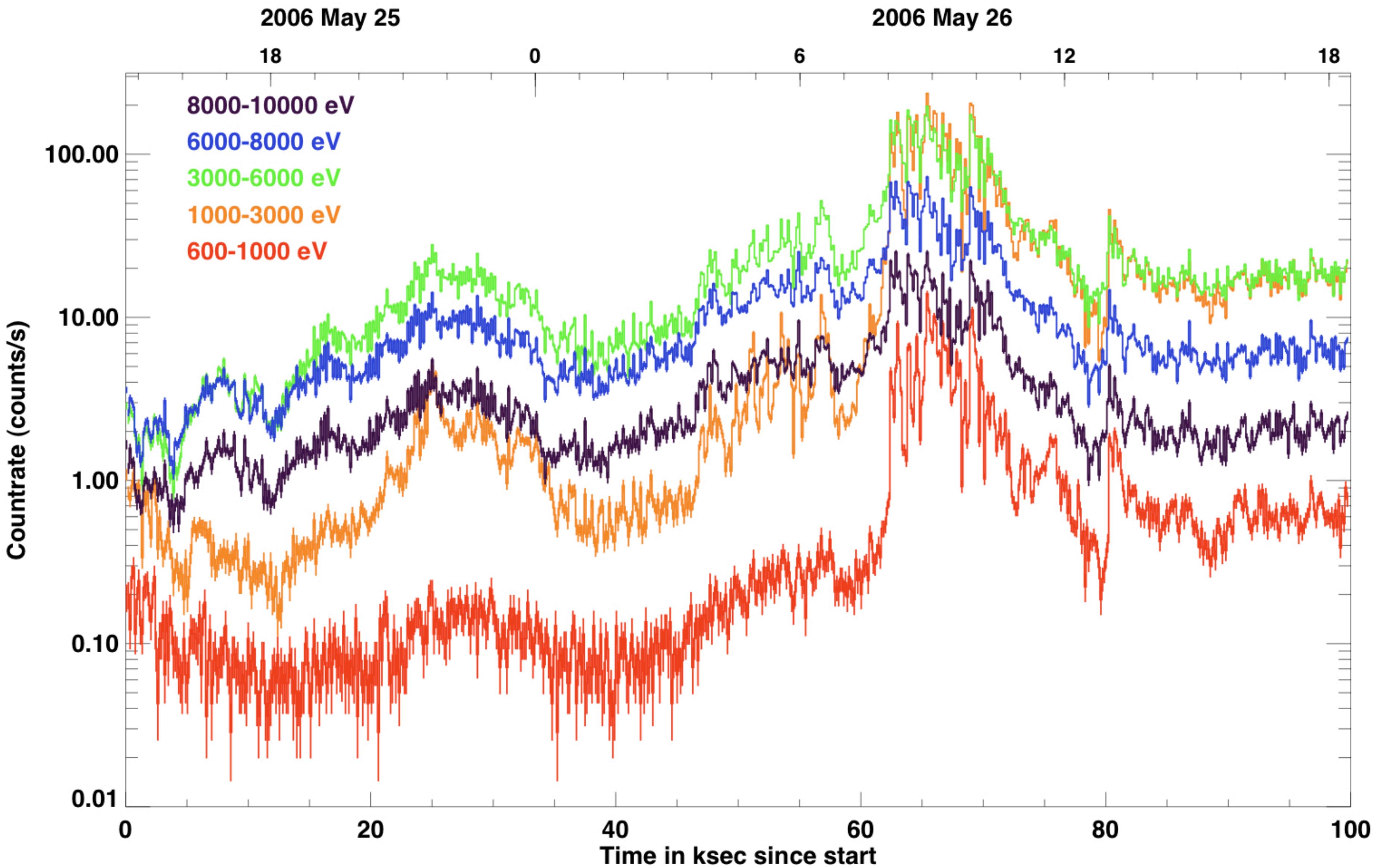


- Strongly piled up during most of the observing time.
- Extraction only in the wings of the PSF (70% of the photons rejected!)
- Applied to the whole interval to maintain homogeneity of extracted data.

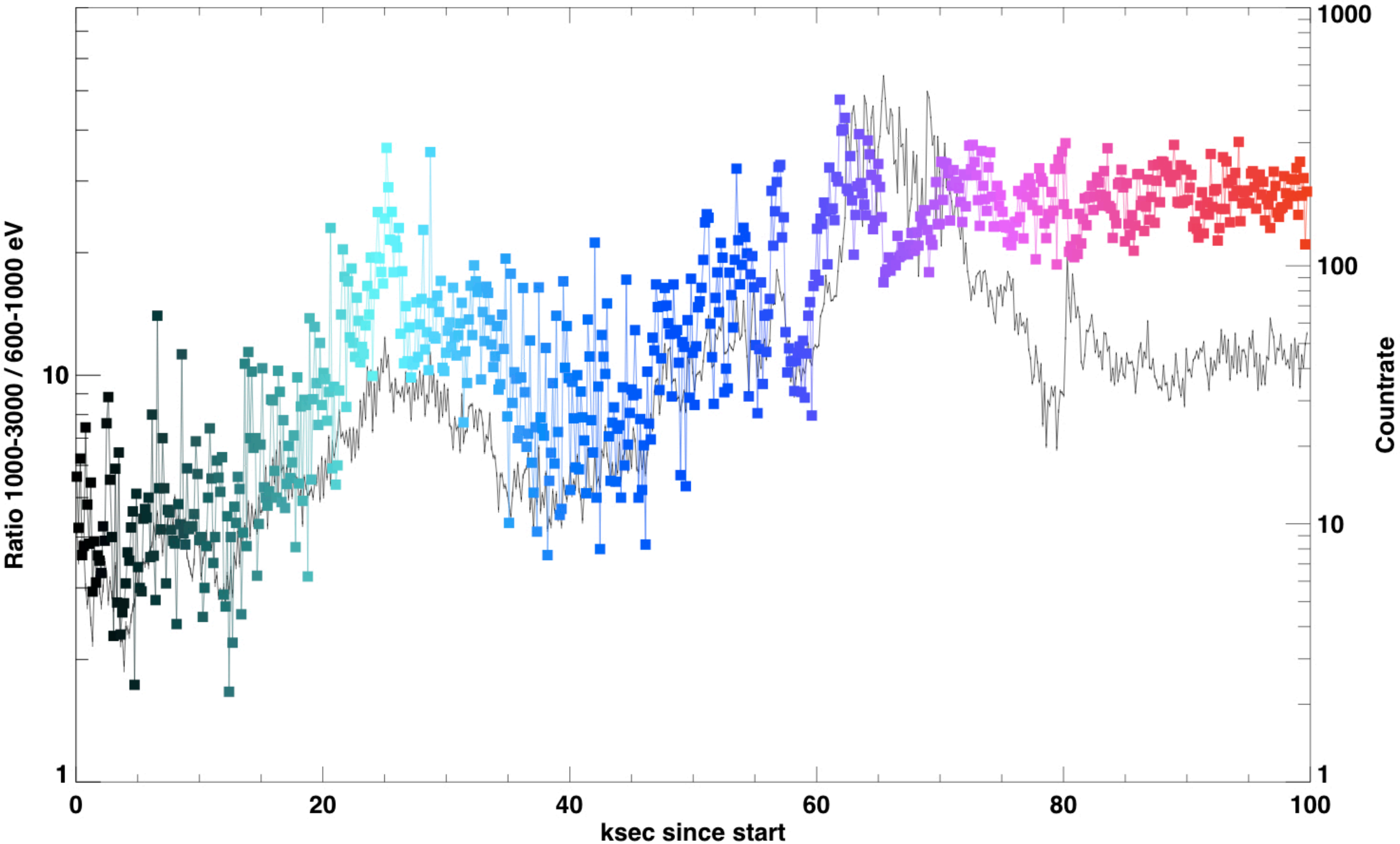
The observation



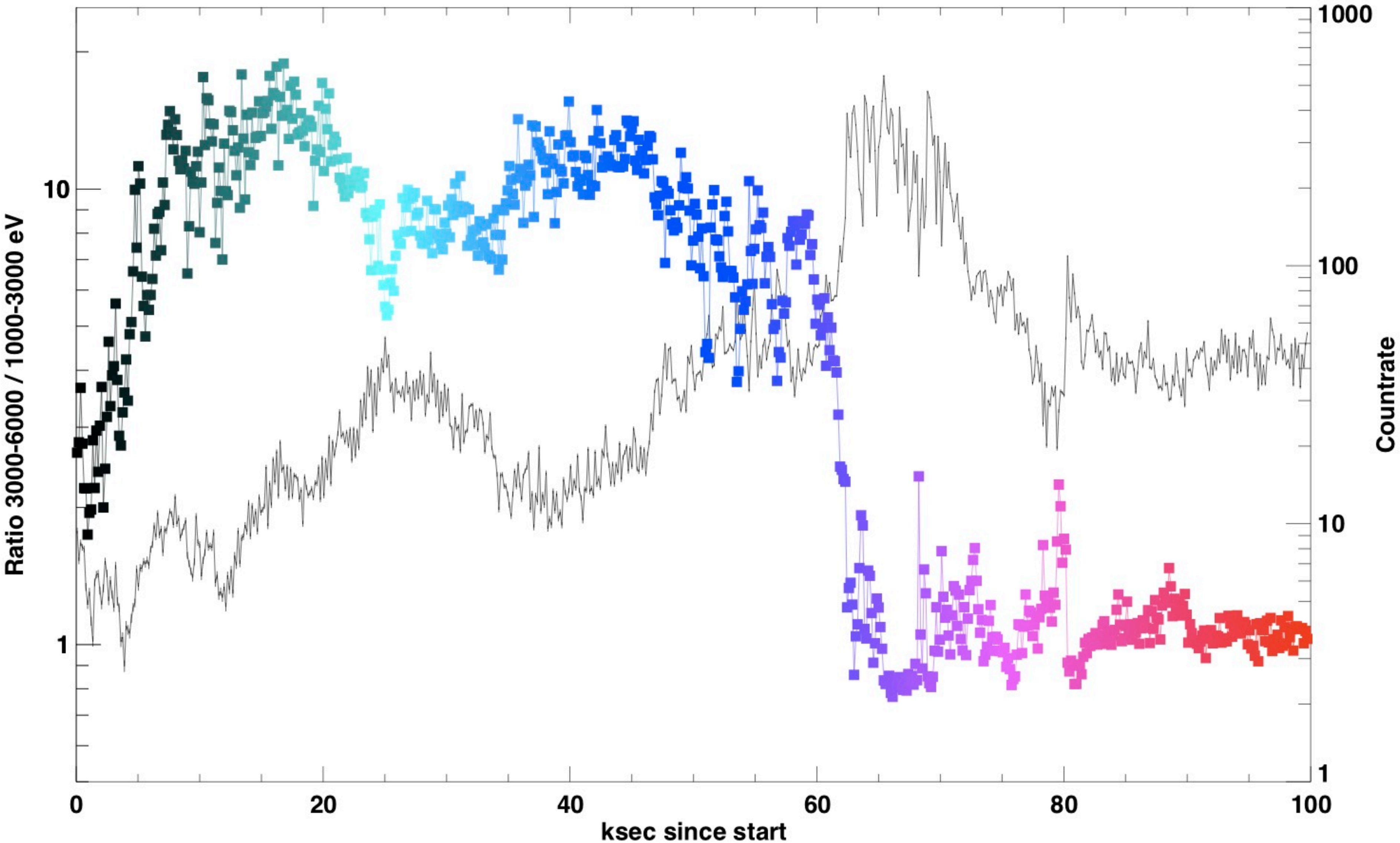
The observation



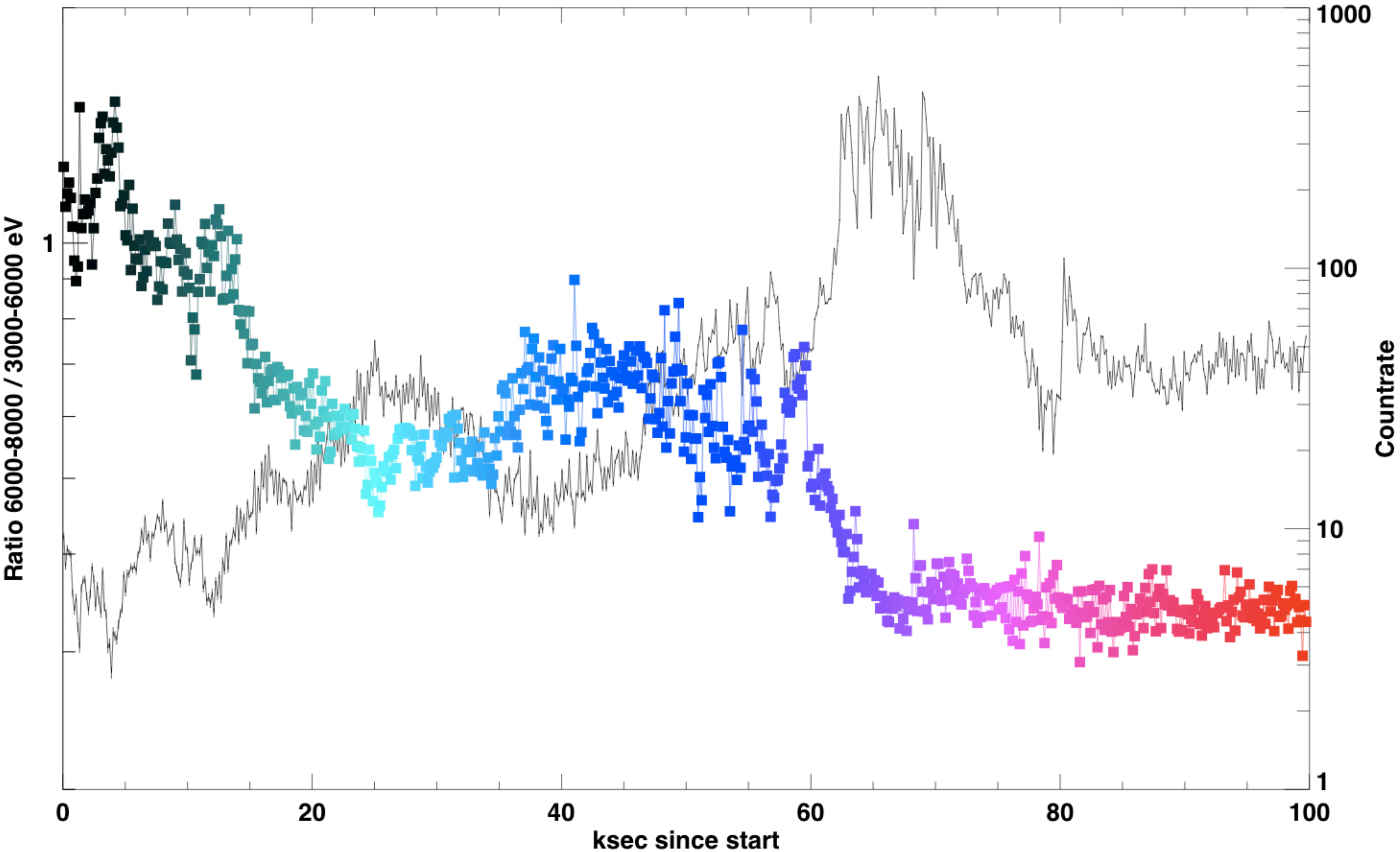
The observation



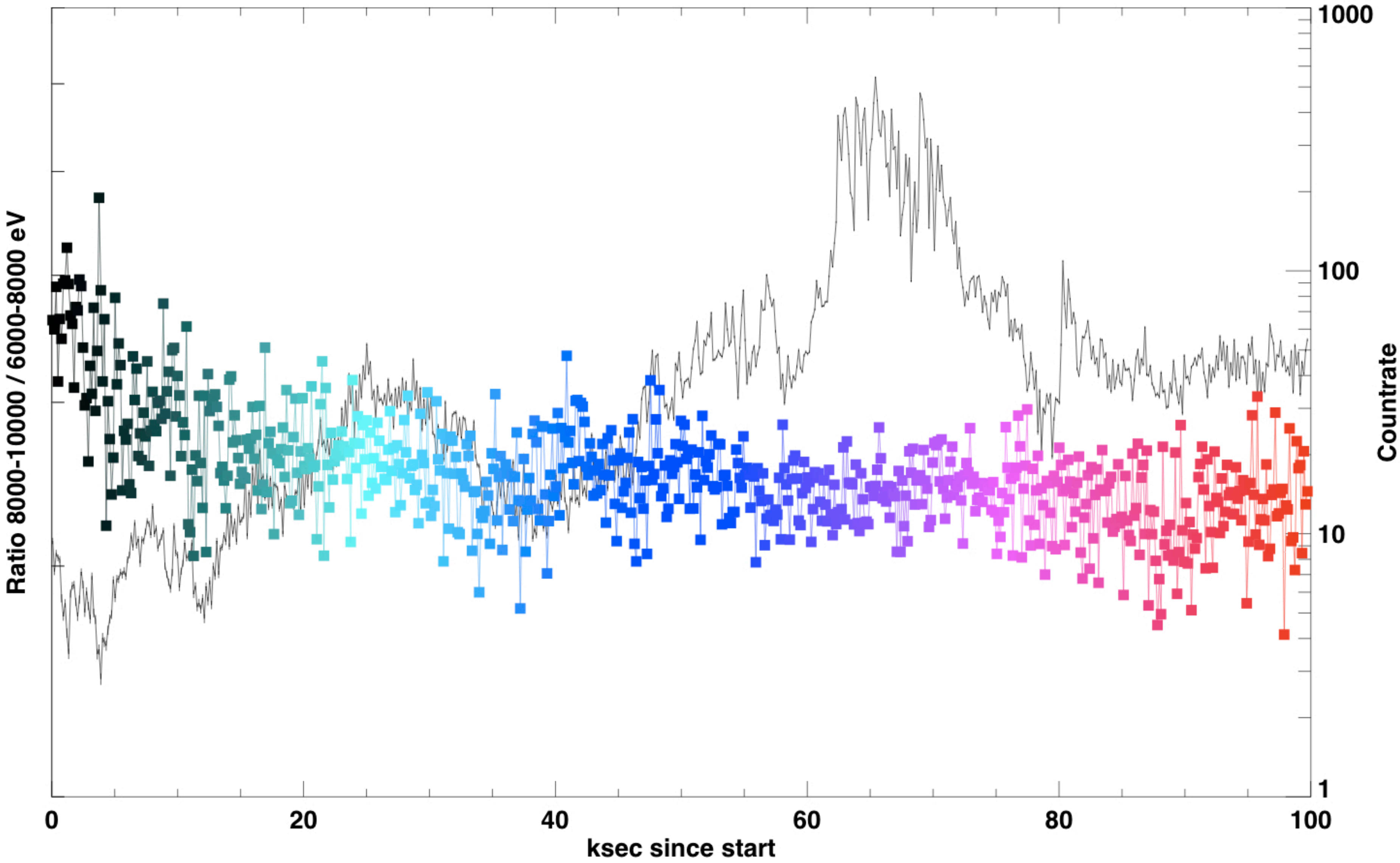
The observation

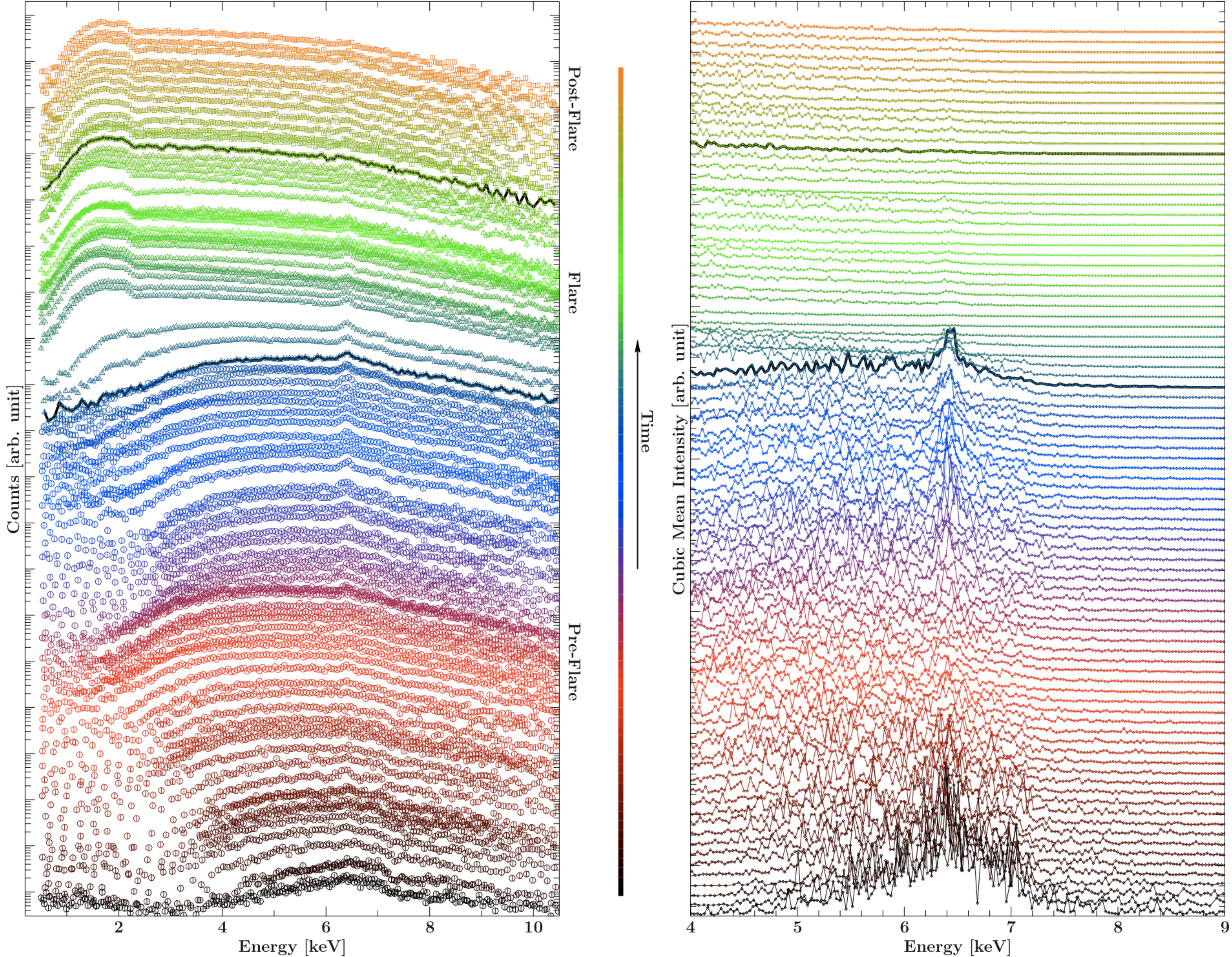


The observation



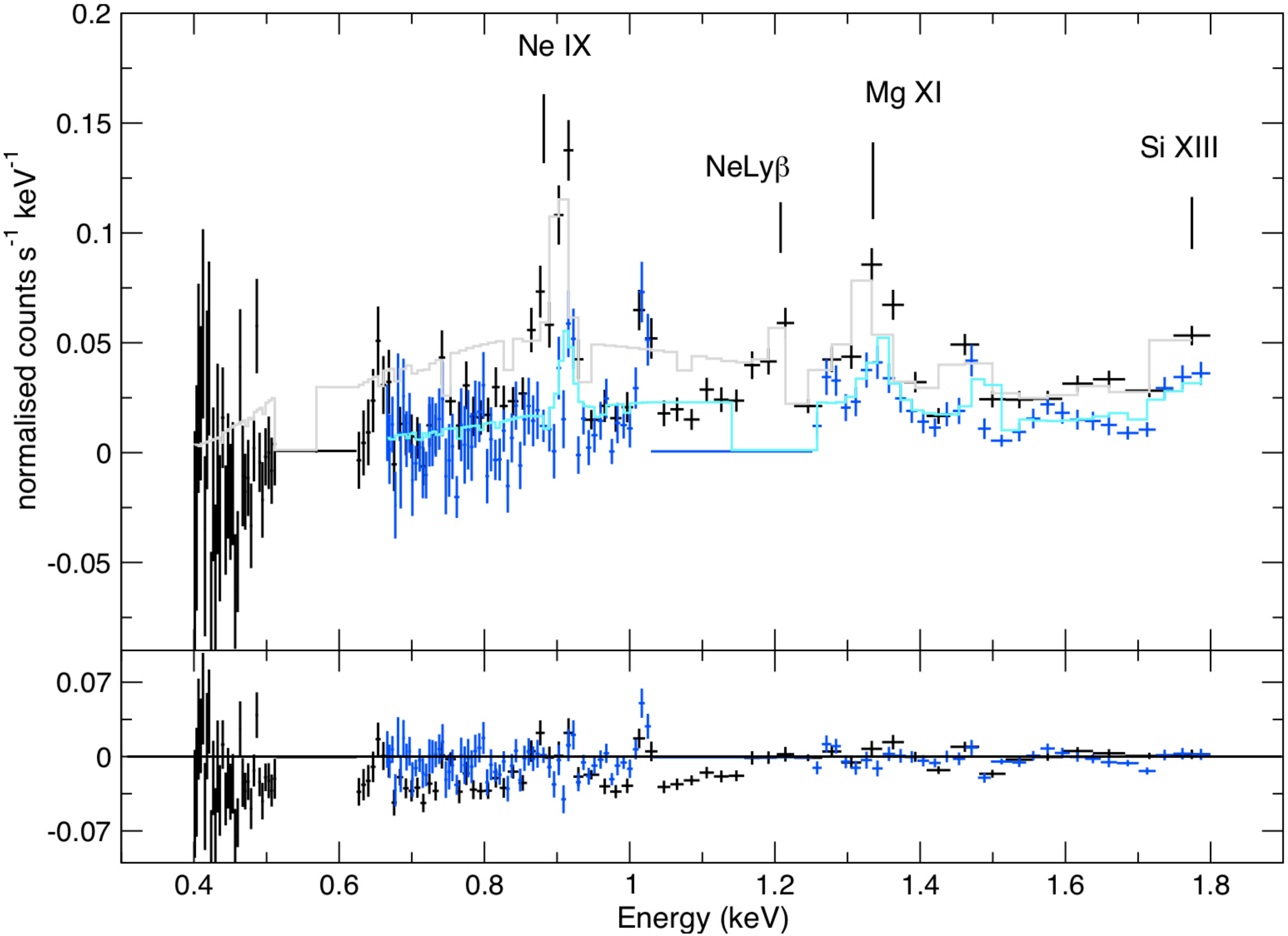
The observation





Counts [arb. unit]
Energy [keV]
2
4
6
8
10
Post-Flare
Flare
Pre-Flare
Time
Cubic Mean Intensity [arb. unit]
Energy [keV]
4
5
6
7
8
9

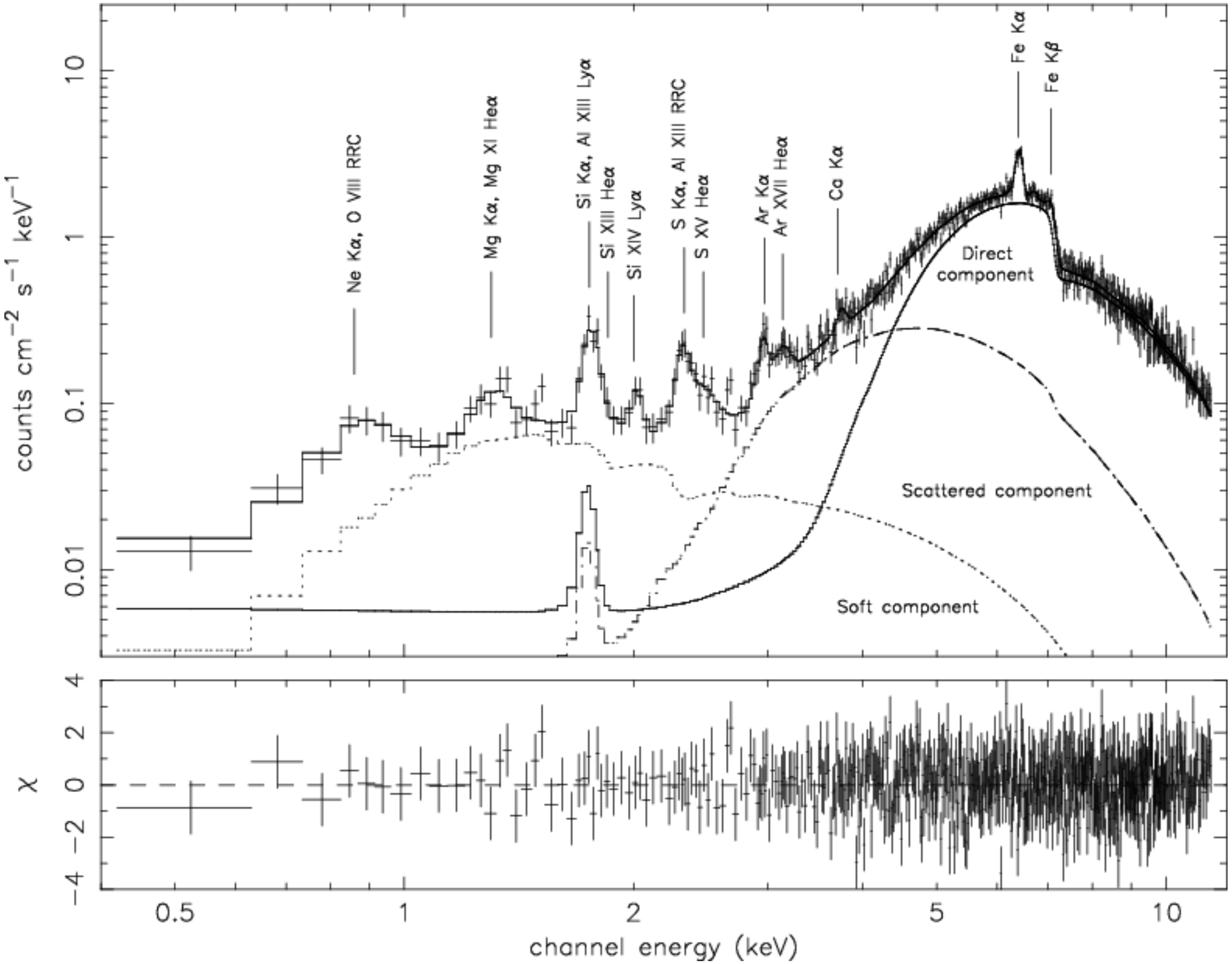
Spectra: RGS



Ne IX
NeLyβ
Mg XI
Si XIII
normalised counts s^-1 keV^-1
0.2
0.15
0.1
0.05
0
-0.05
0.07
0
-0.07
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Energy (keV)

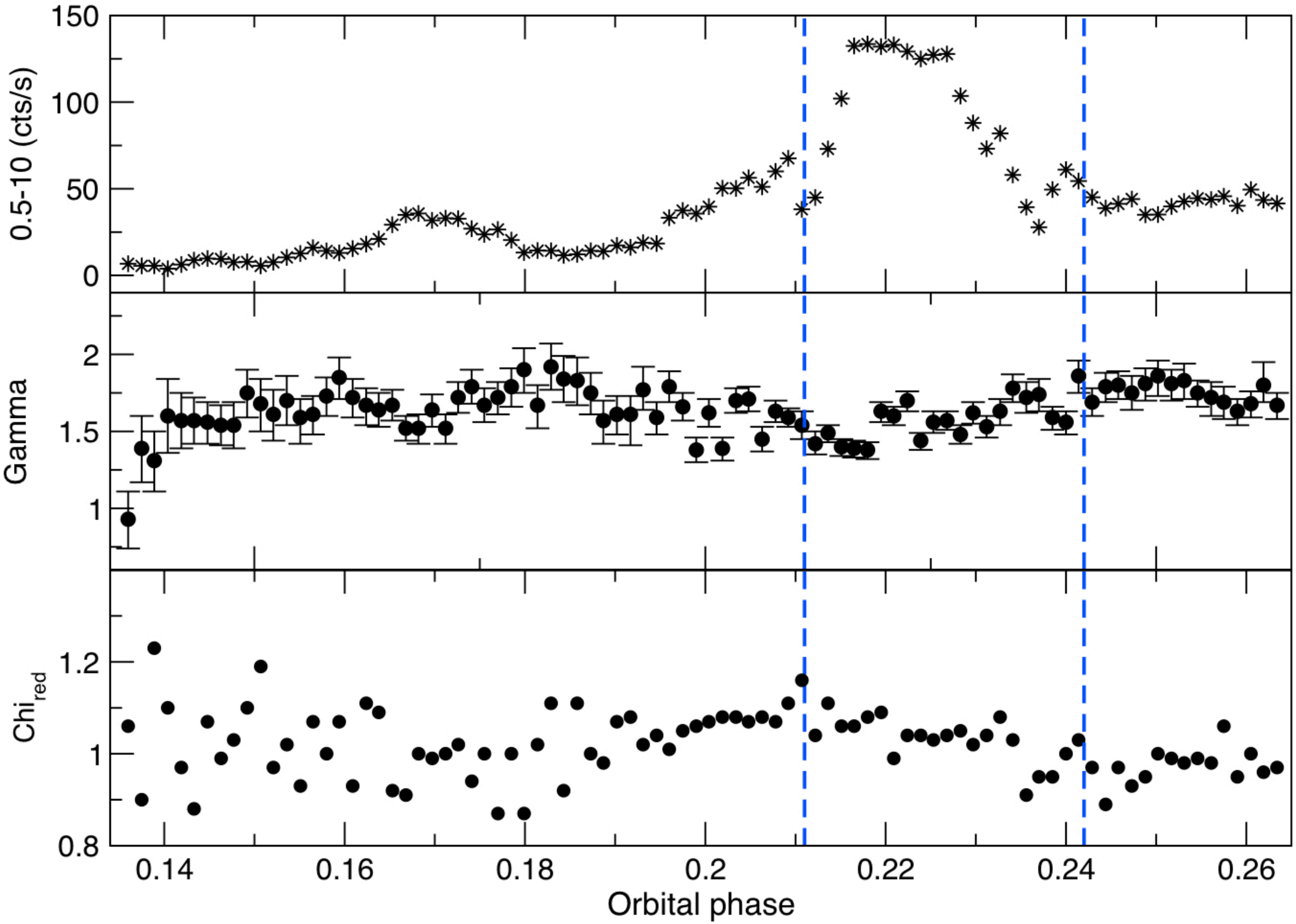
Phenomenological model

- Direct: originates near surroundings of the NS.
- Scattered: Thomson scattering of electrons in the stellar wind.
- Soft: originates in the outskirts or a blend of emission lines.

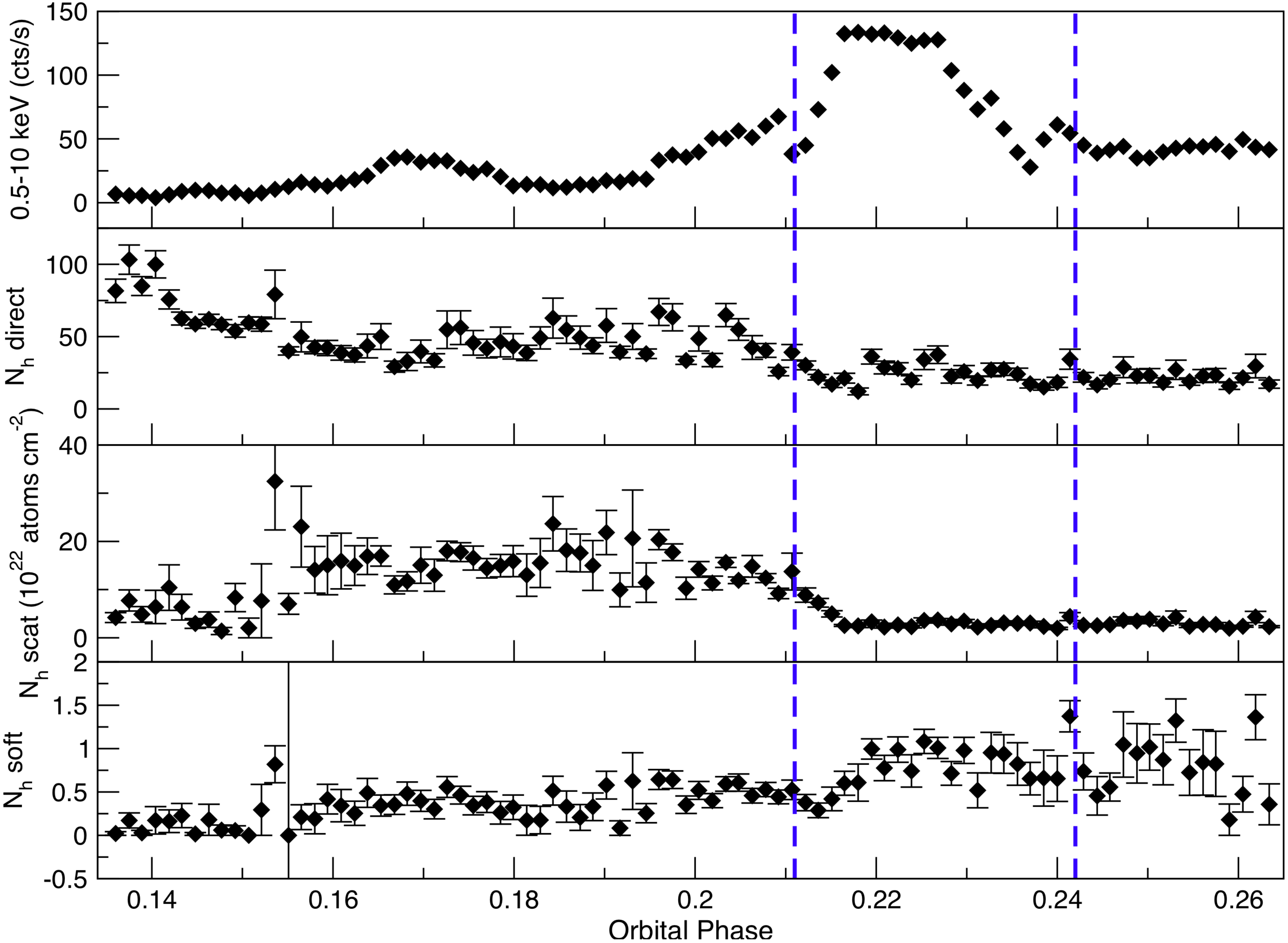


Van der Meer et al., 2005

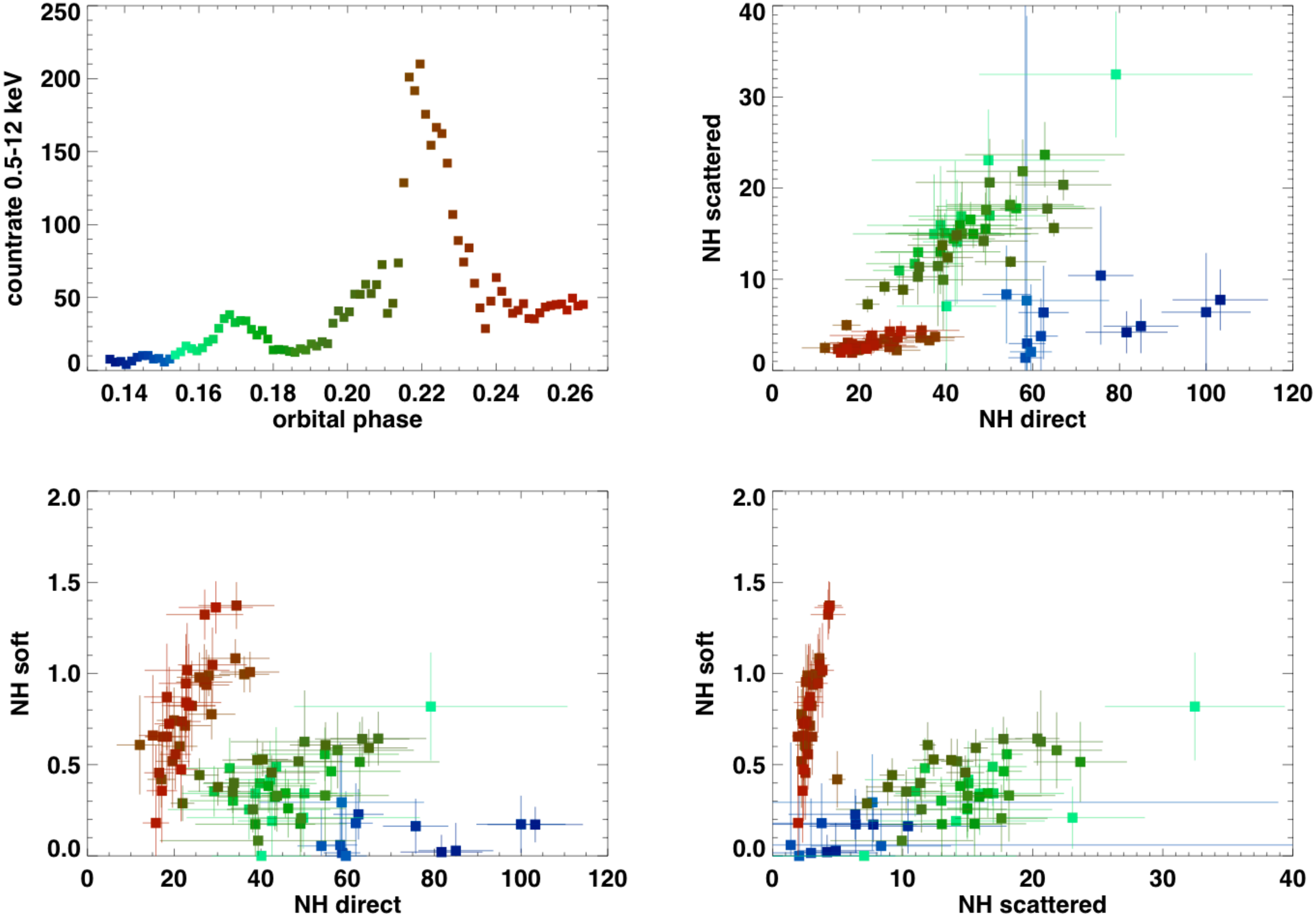
Orbital phase resolved spectroscopy: power law index



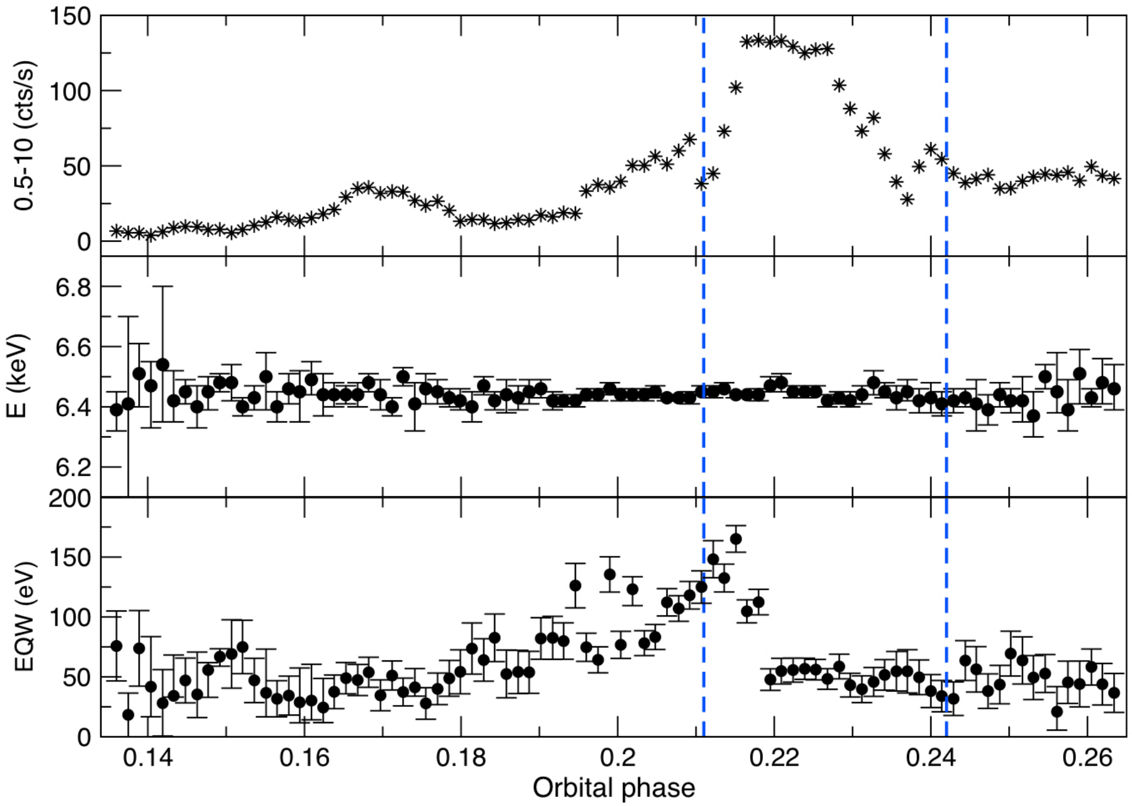
Orbital phase resolved spectroscopy: absorption columns



Absorption columns correlations



Orbital phase resolved spectroscopy: the Fe line



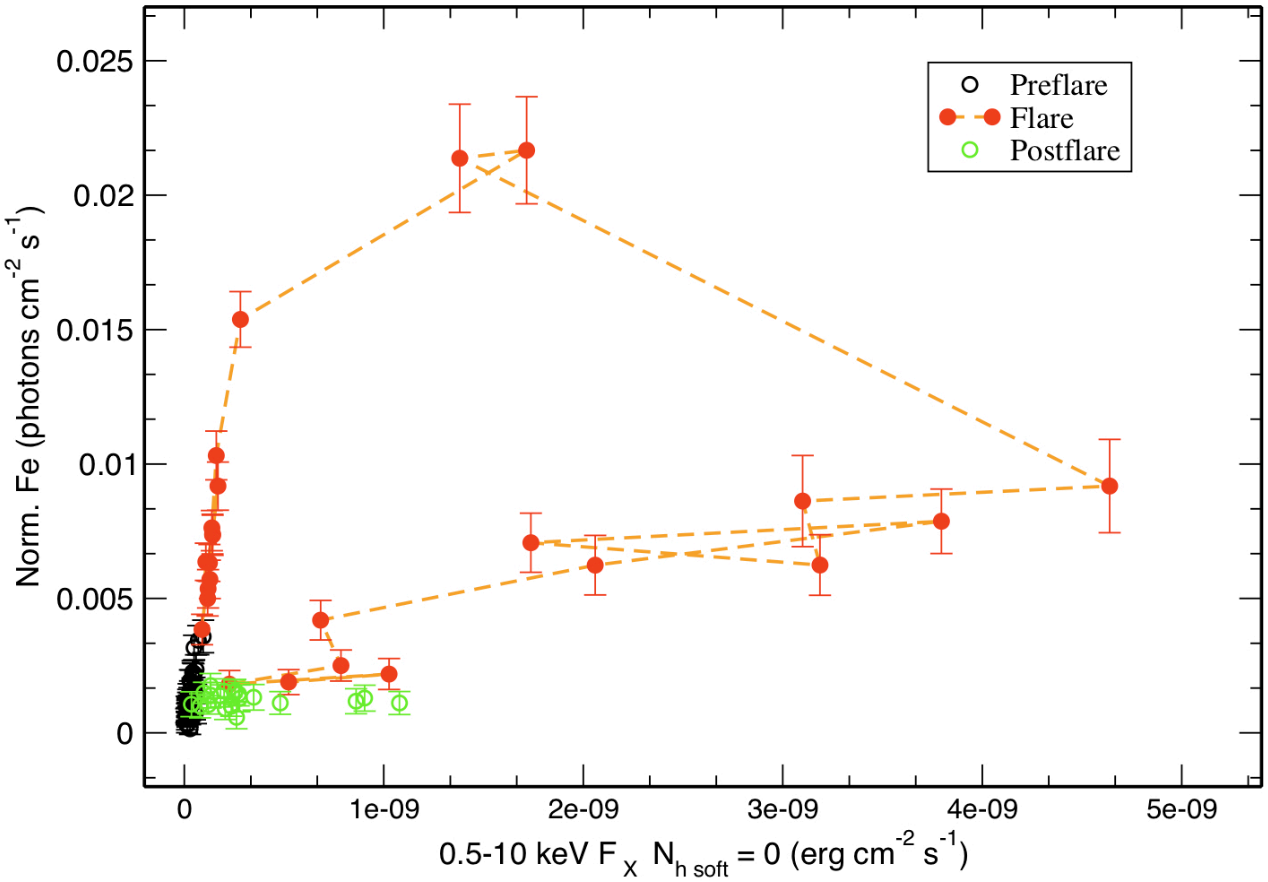
Despite dramatic changes from bin to bin and source brightness, Fe line always compatible with Kα transition from neutral Fe.

No signs of ionized Fe.

Fe Kα fluorescence must come from cool dense clumps.

Turning point at the beginning of the flare may indicate accretion of clumps.

Orbital phase resolved spectroscopy: the Fe line



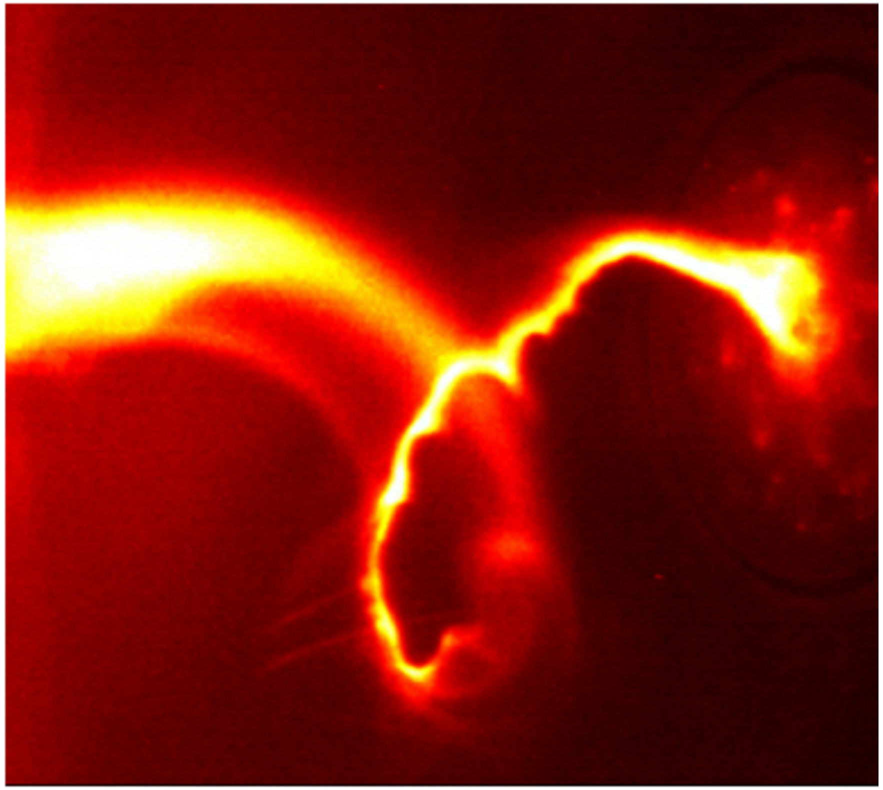
The Fe Kα line flux and soft component flux are strongly correlated: hysteresis cycle.

Conclusions

- Rich behaviour:
  - Source varying on all timescales.
  - Dramatic flare.
  - Time variable absorption.
  - Recombination lines at the beginning of obs.
  - Iron line Kα: equivalent width variable.

- Data explained by a phenomenological model: lack of physical models.

- Turning point in every spectral parameter and color at the beginning of the flare: two different accretion environments!



An argon plasma jet forms a rapidly growing corkscrew, known as a kink instability. This instability causes an even faster-developing behavior called a Rayleigh-Taylor instability, in which ripples grow and tear the jet apart. This phenomenon, the Caltech researchers say, has never been seen before and could be important in understanding solar flares and in developing nuclear fusion as a future energy source. Watch the plasma in action here.

[Credit: A. L. Moser and P. M. Bellan, Caltech]

- Identification of components with physical processes still pending
- Valuable input for wind/wind accretion models.
- Need for improved wind 3D models that reproduce the observation.

Thanks for your attention !!