XMM-Newton's view of the multiple fluorescence lines of GX 301−2

Felix Fürst

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June 28th 2011
The X-ray Universe 2011

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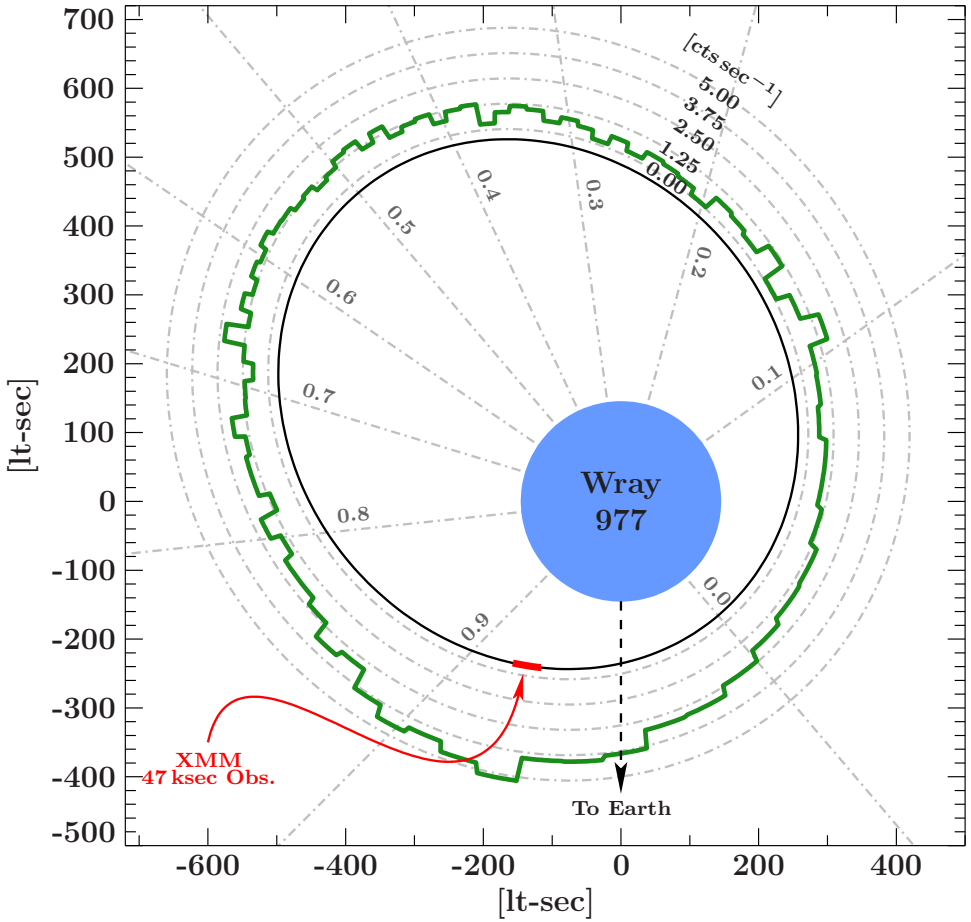
The system

- HMXB with $\gtrsim$40 $M_\odot$, B1 Ia+ companion (Kaper et al., 2006)
- very bright pre-periastron flare
- accretion stream (Leahy & Kostka, 2008)
- highly structured, dense medium
- eccentric orbit $e = 0.47$



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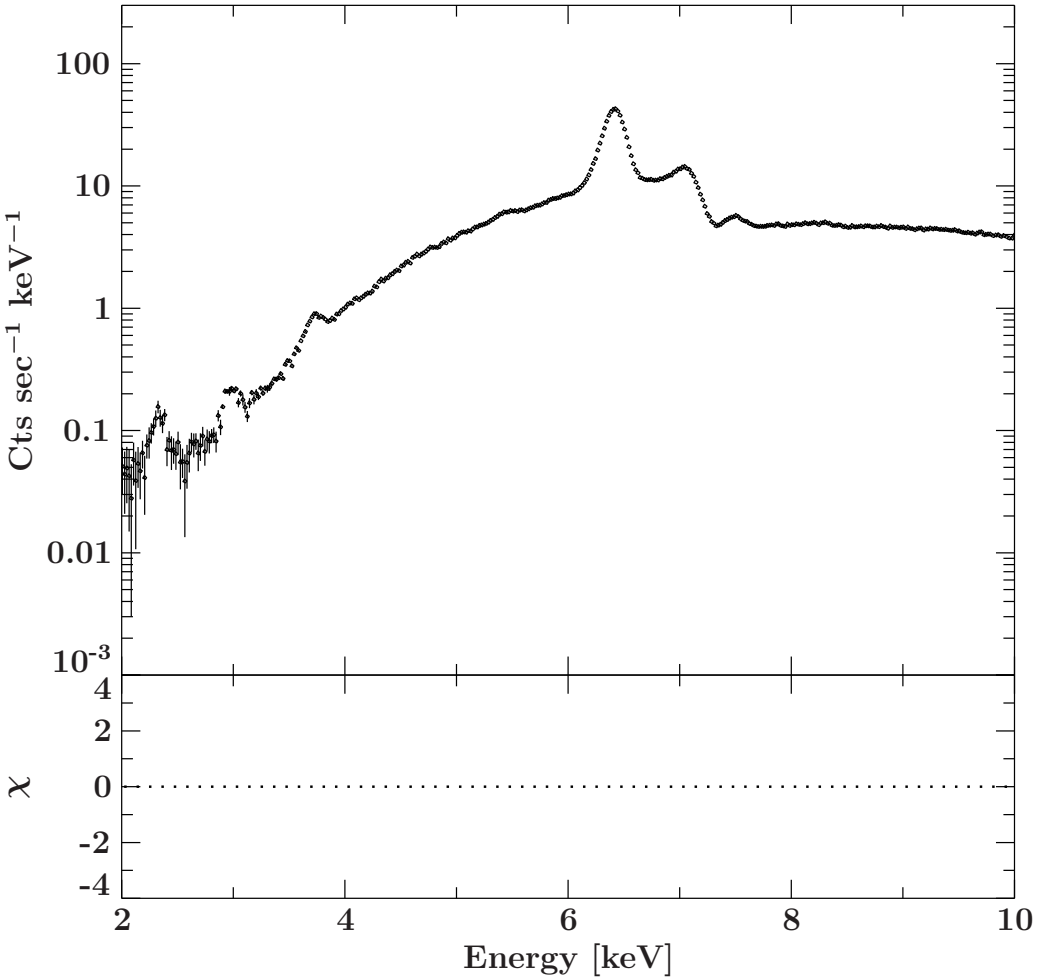
The overall spectrum



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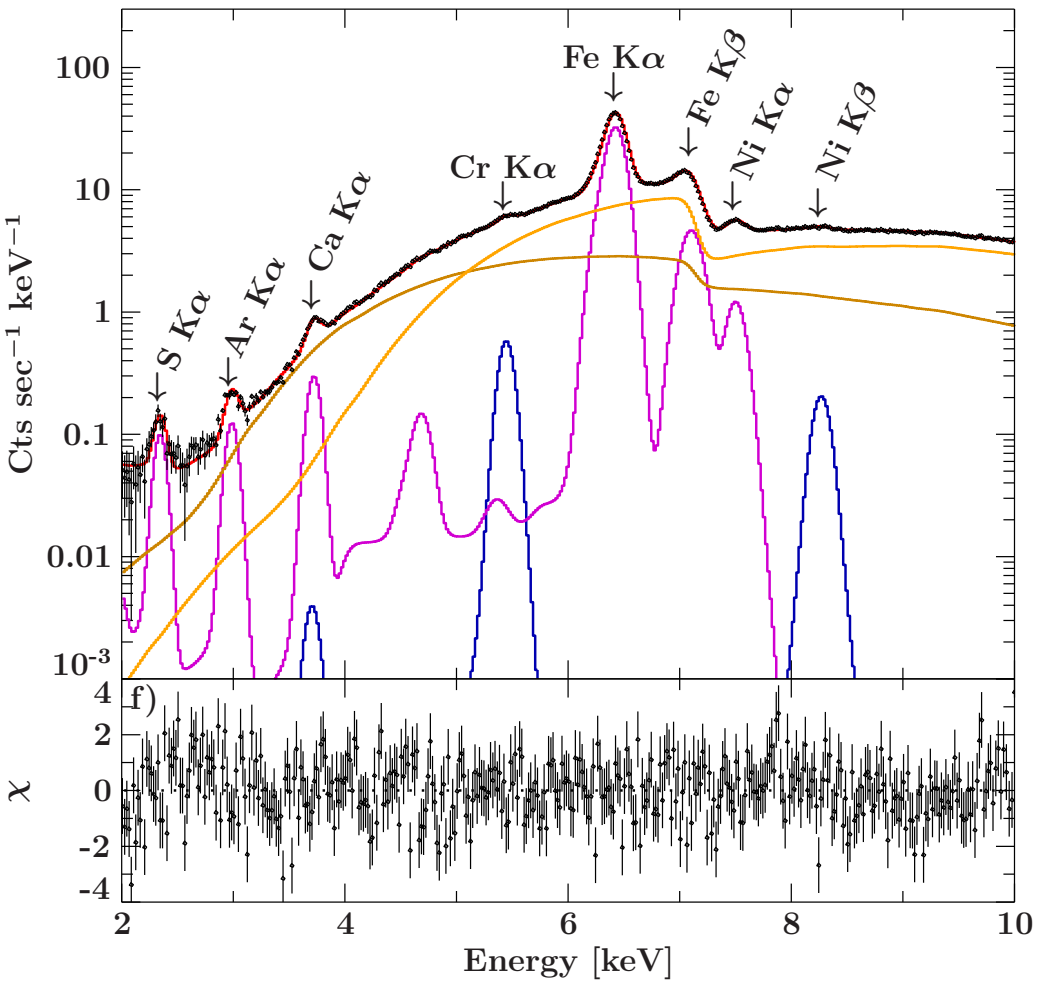

$N_{H,1} = 141(3) \times 10^{22}\,\mathrm{cm}^{-2}$

$N_{H,2} = 54(1) \times 10^{22}\,\mathrm{cm}^{-2}$

$\Gamma = 0.90(2)$

First evidence for

Cr Kα at 5.41 keV

Ni Kβ at 8.26 keV

best fit $\chi^2_{red} = 1.2$

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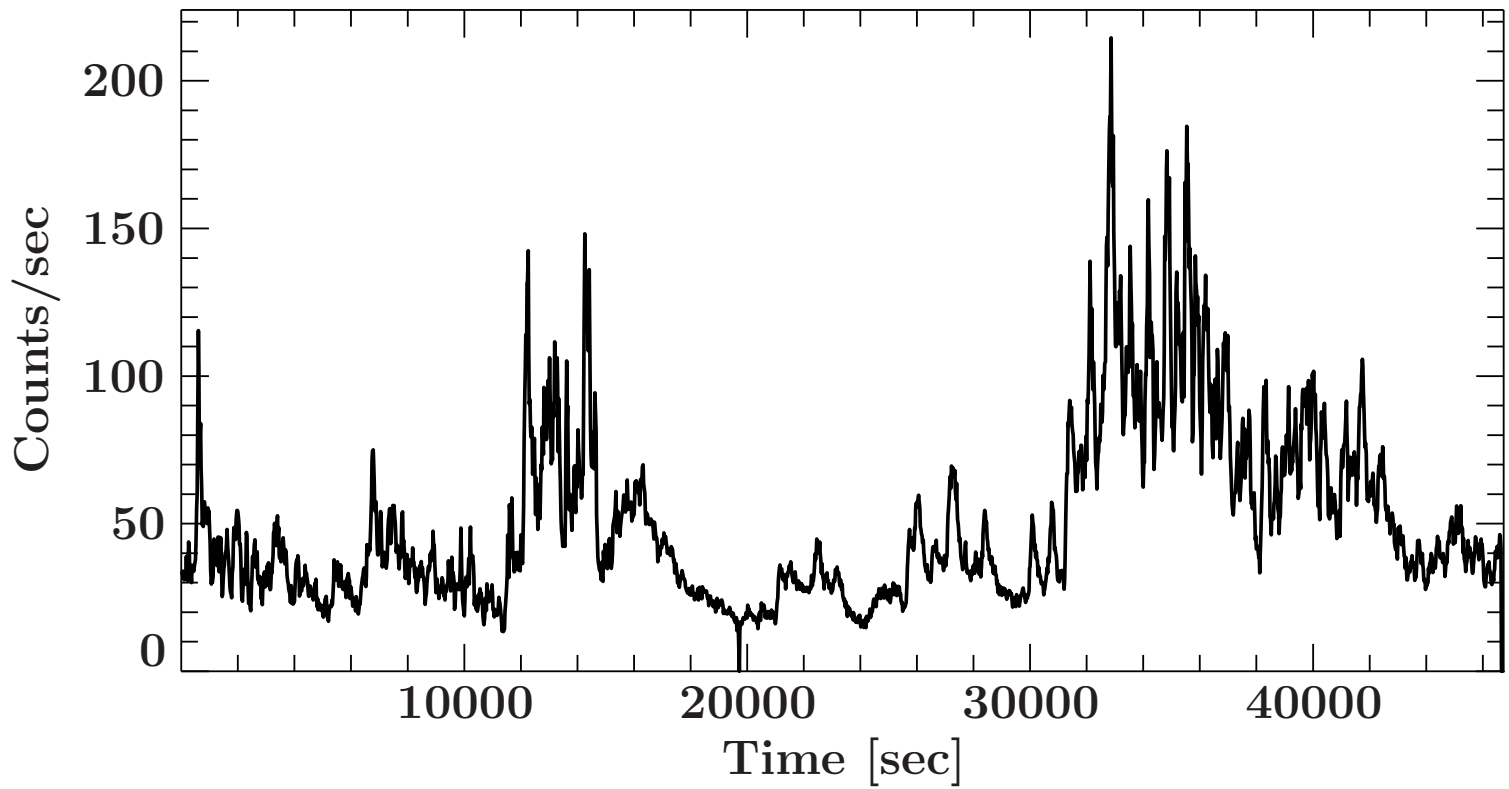
The lightcurve and the pulse profile



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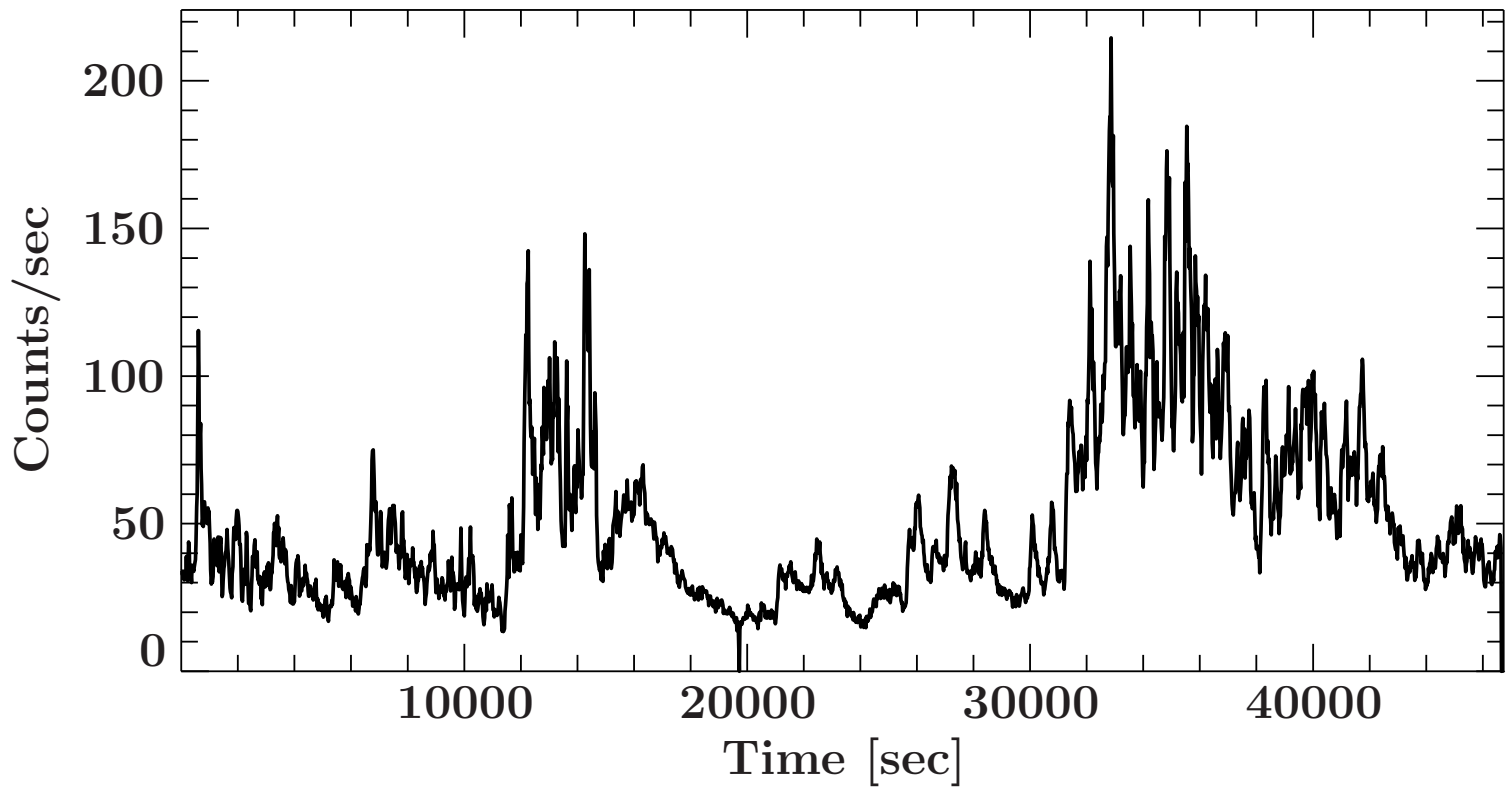

Strong flaring activity and pulse period of ∼685 sec evident
using orbital ephemeris by Doroshenko et al. (2010)

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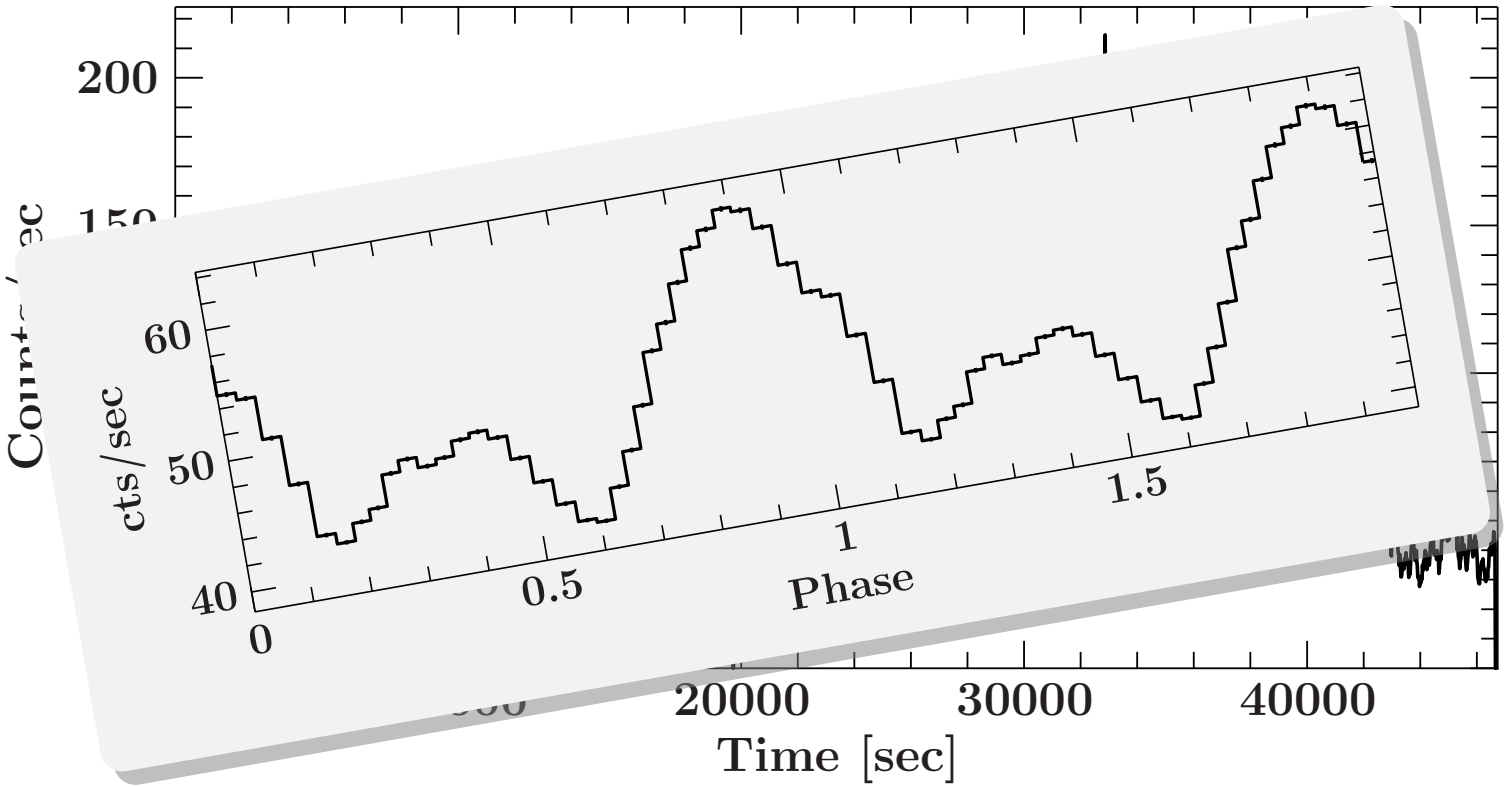

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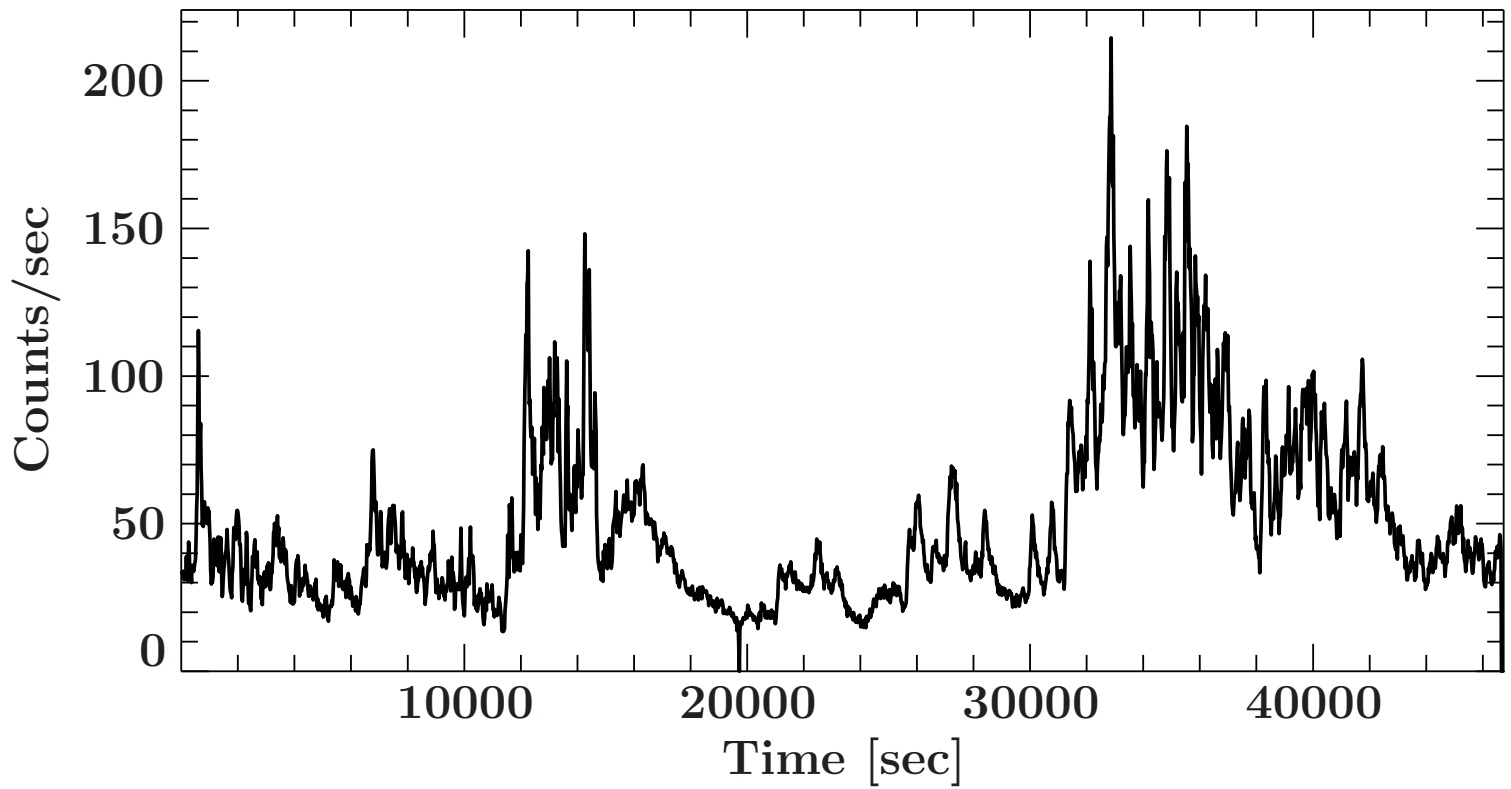

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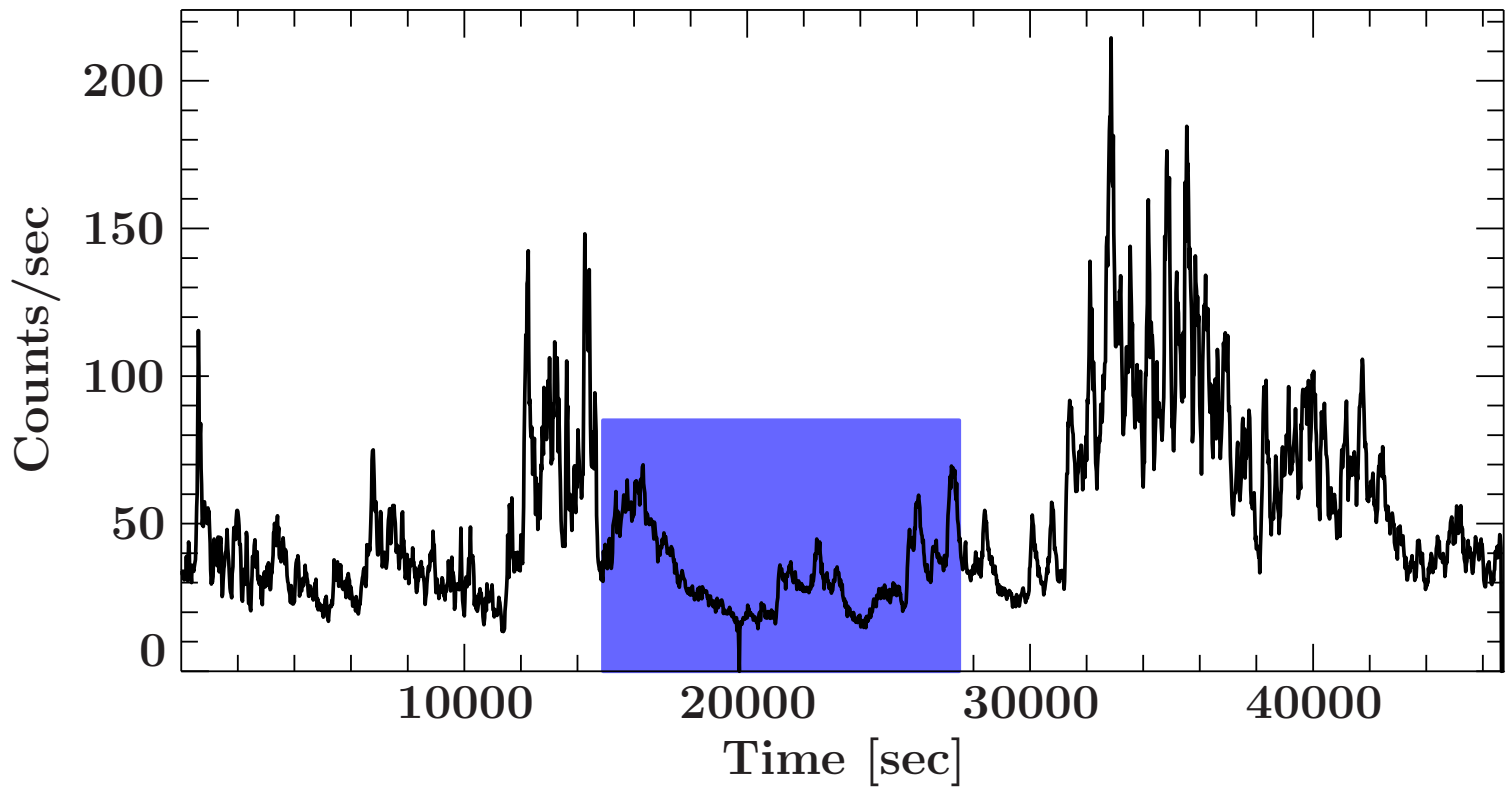

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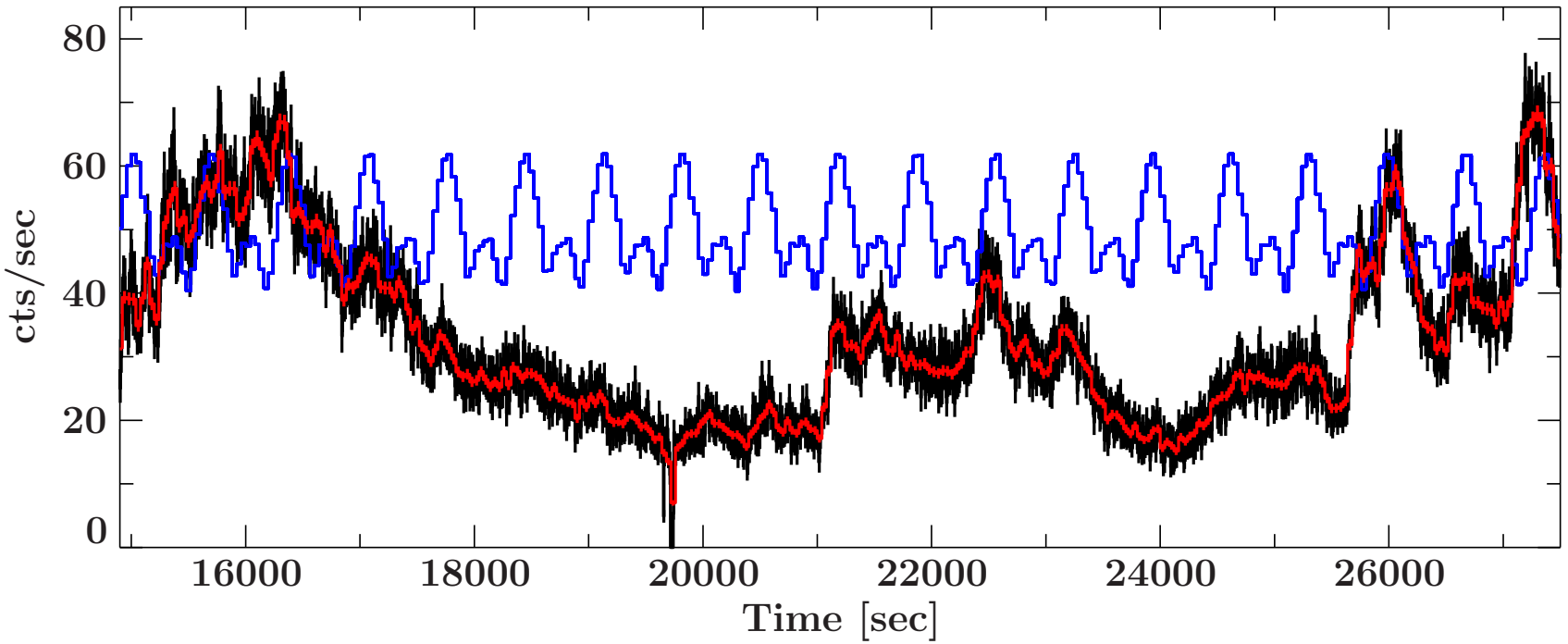
An Off-state



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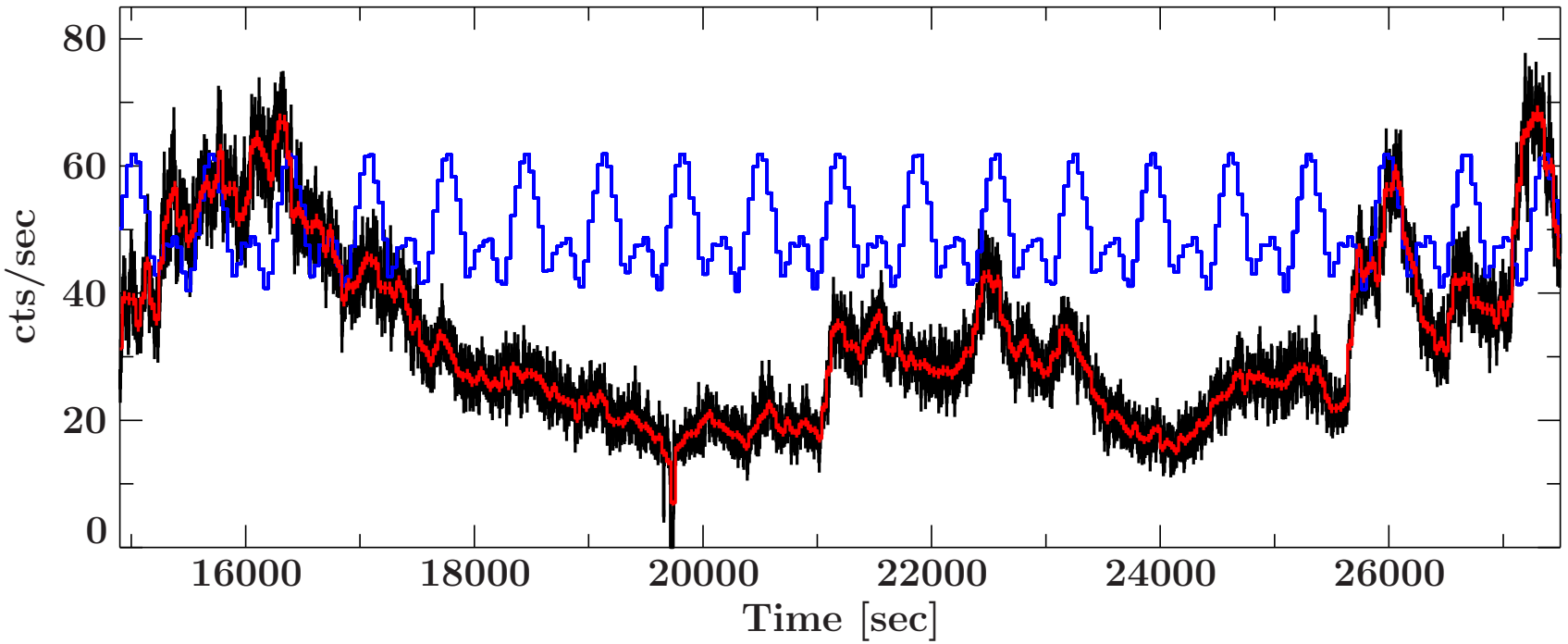

- ∼4 pulses are missing
- similar to the off-state seen by Göğüş et al. (2011)
- similar to Vela X-1 (Kreykenbohm et al., 2008)

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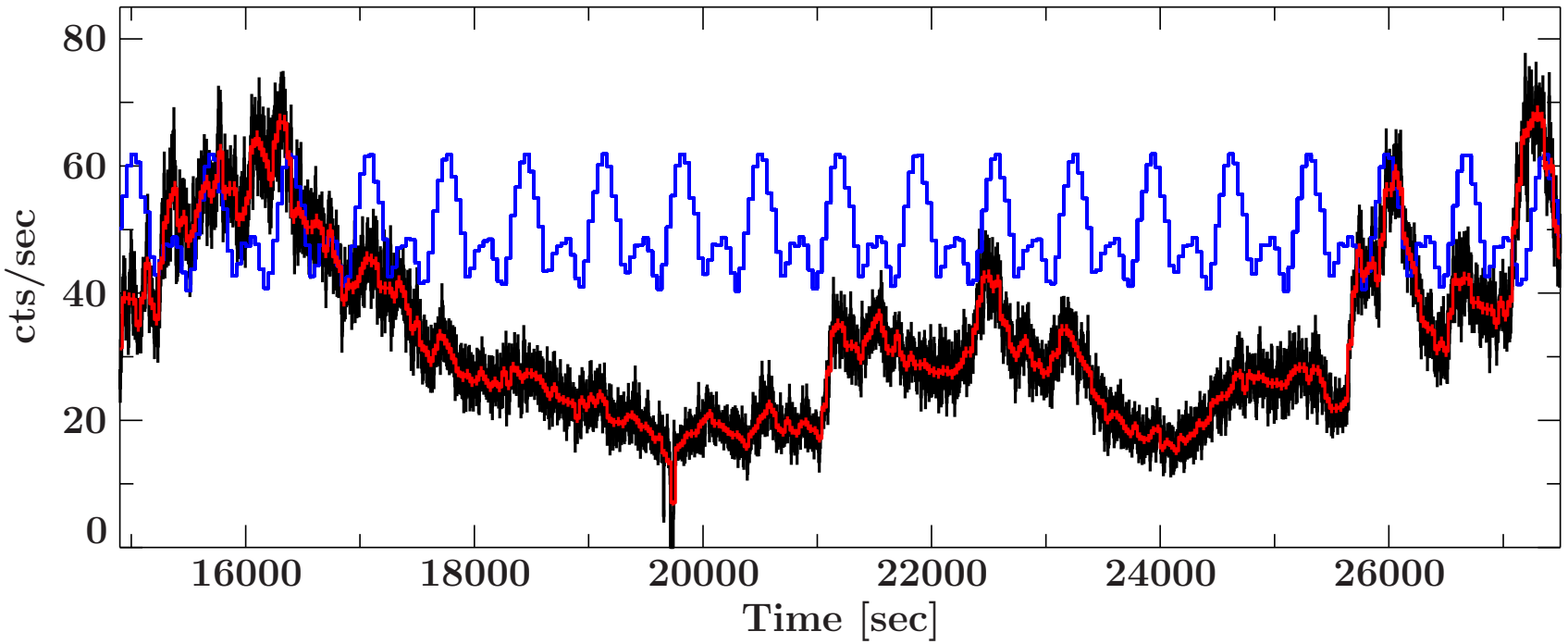

- source is still visible
- no pulsed flux $\Rightarrow$ no accretion
- larger region (> 2000 lt-sec) visible in X-rays

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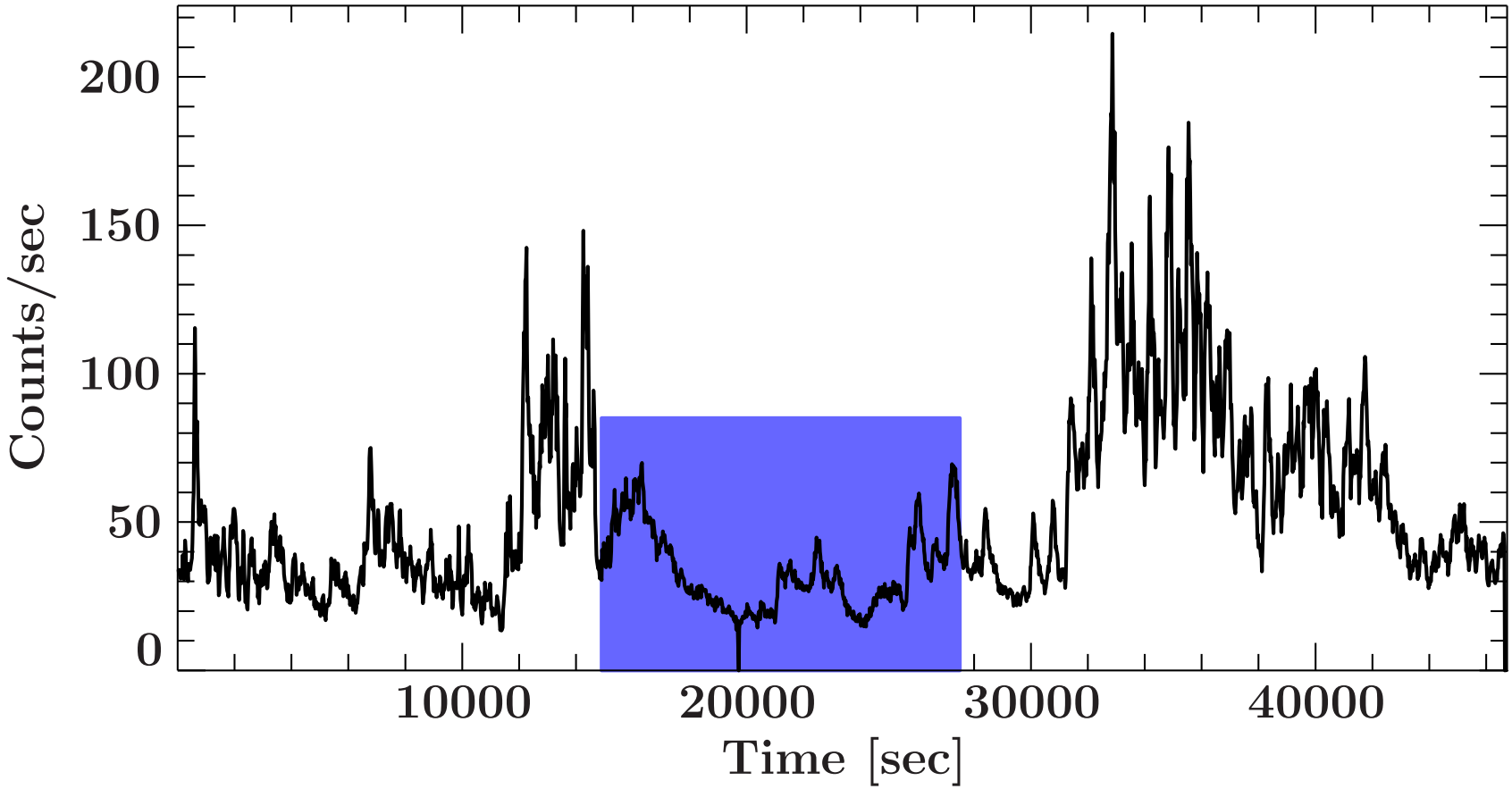
Divide data by states



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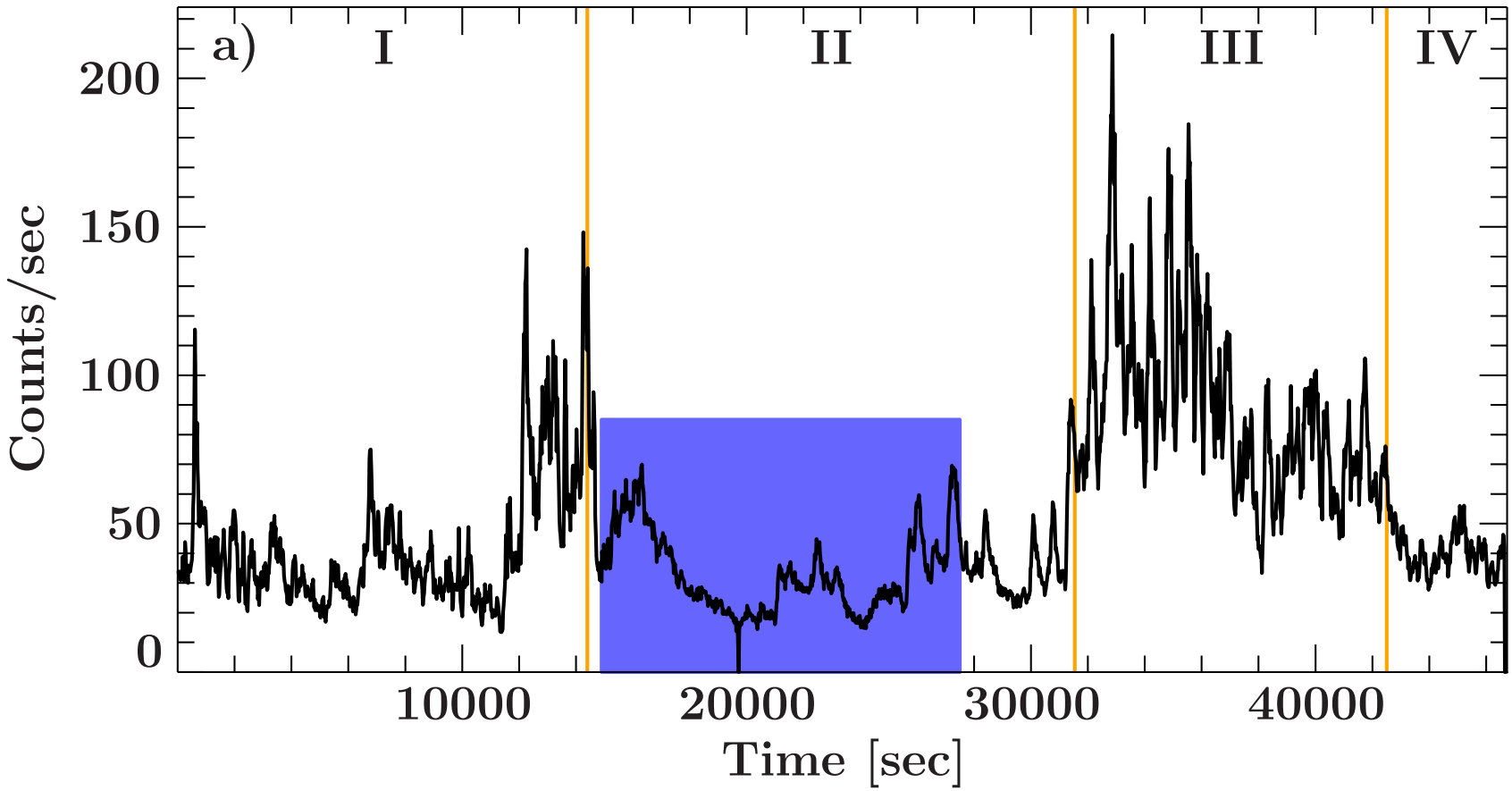
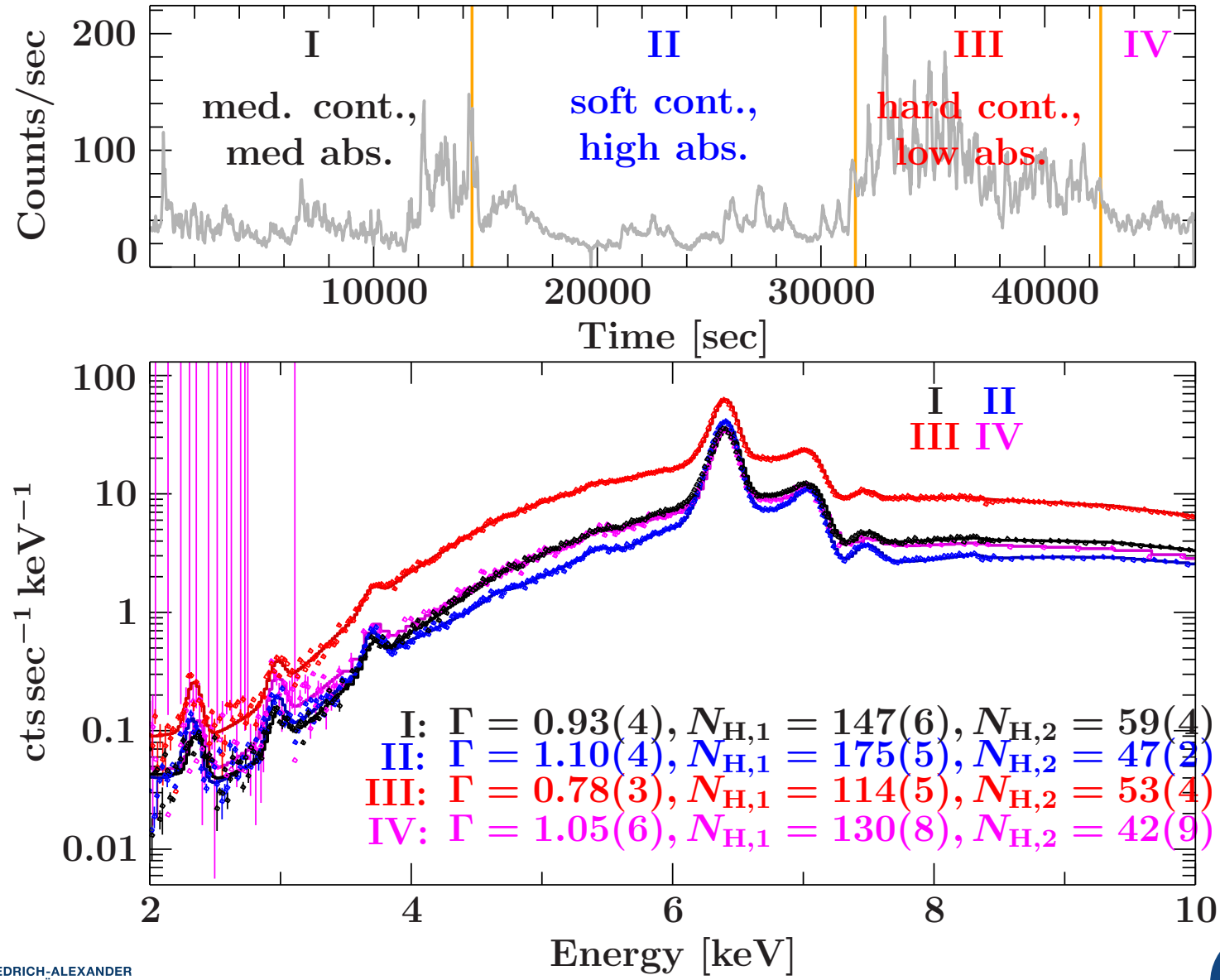


Time resolved spectroscopy



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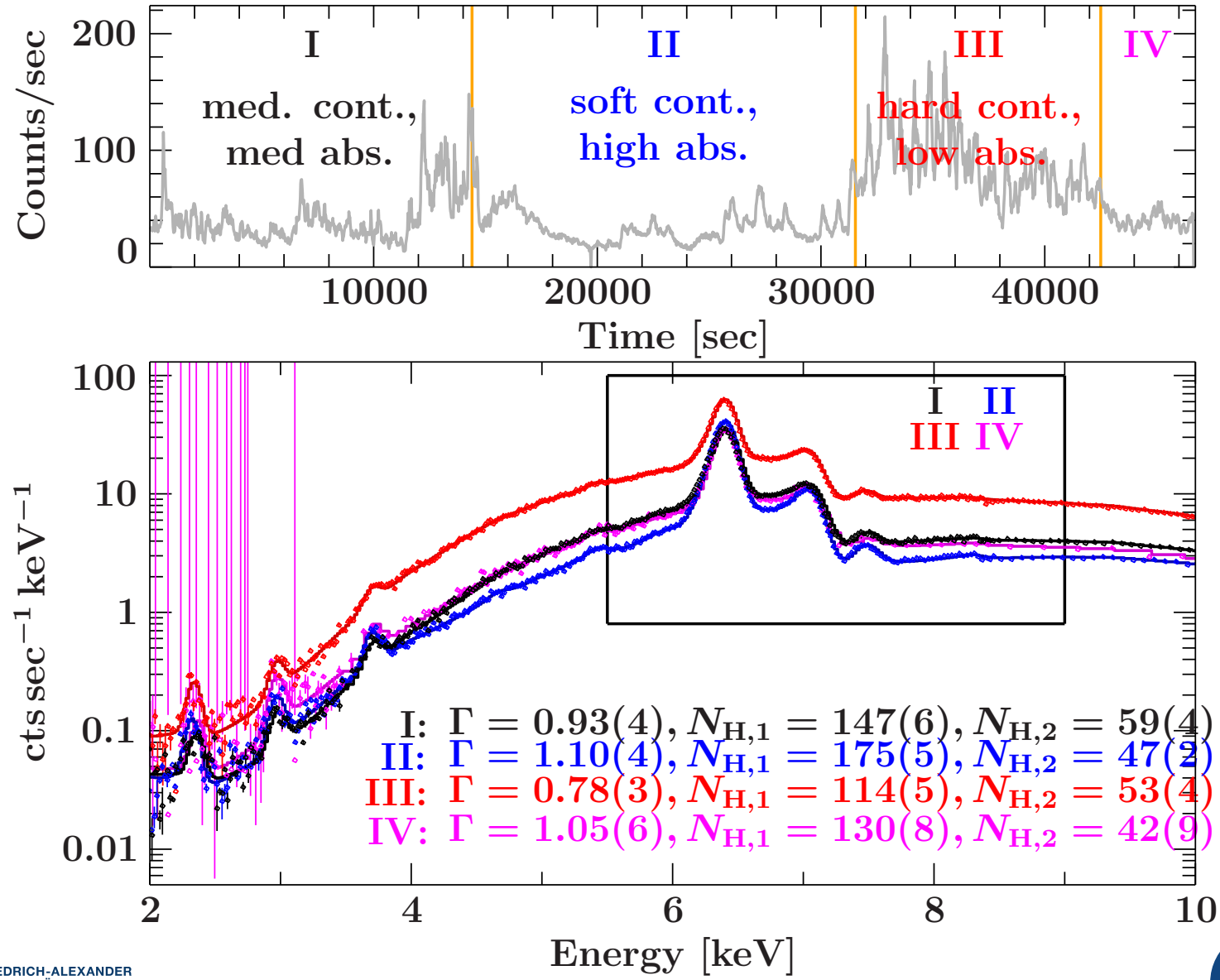

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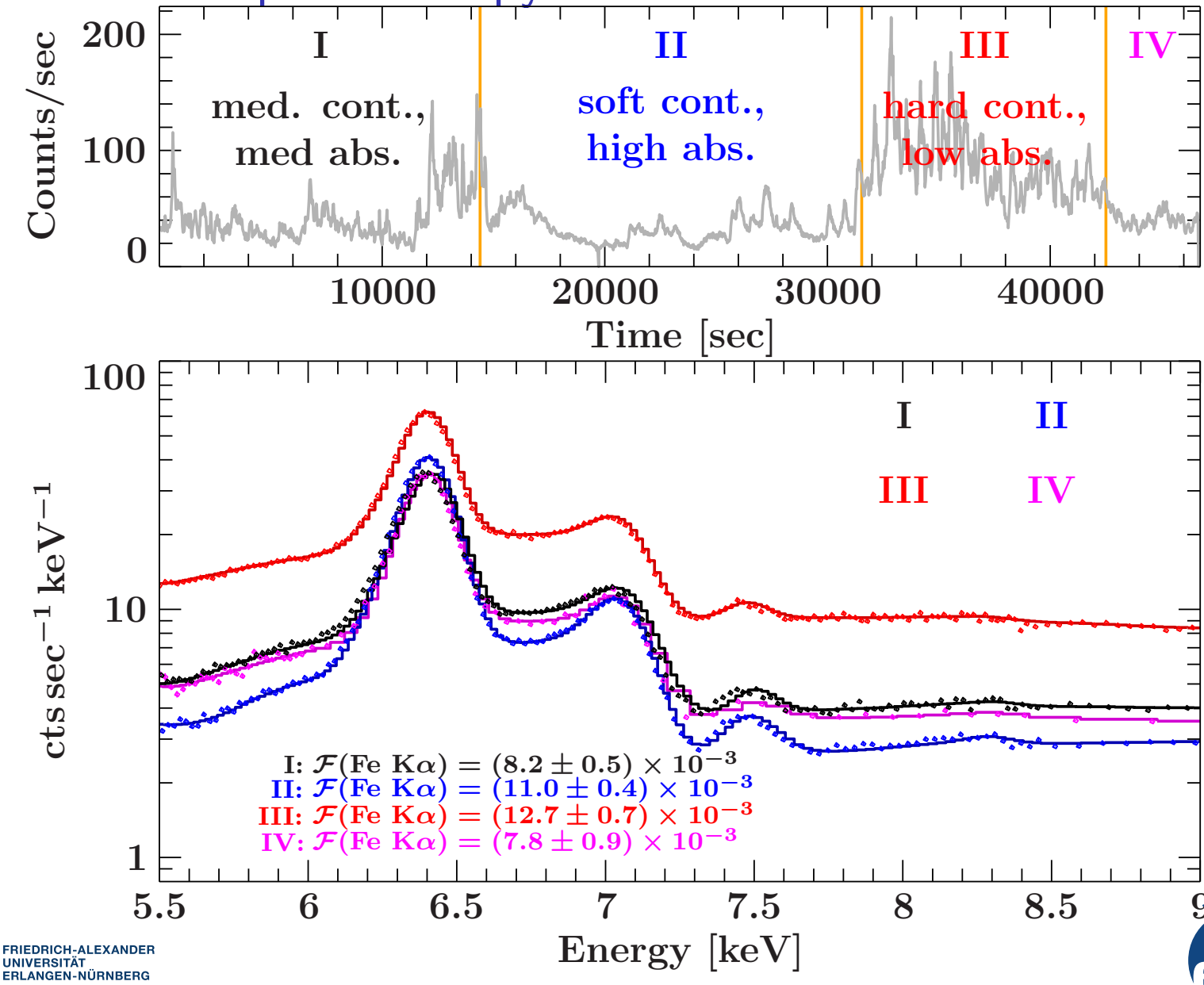

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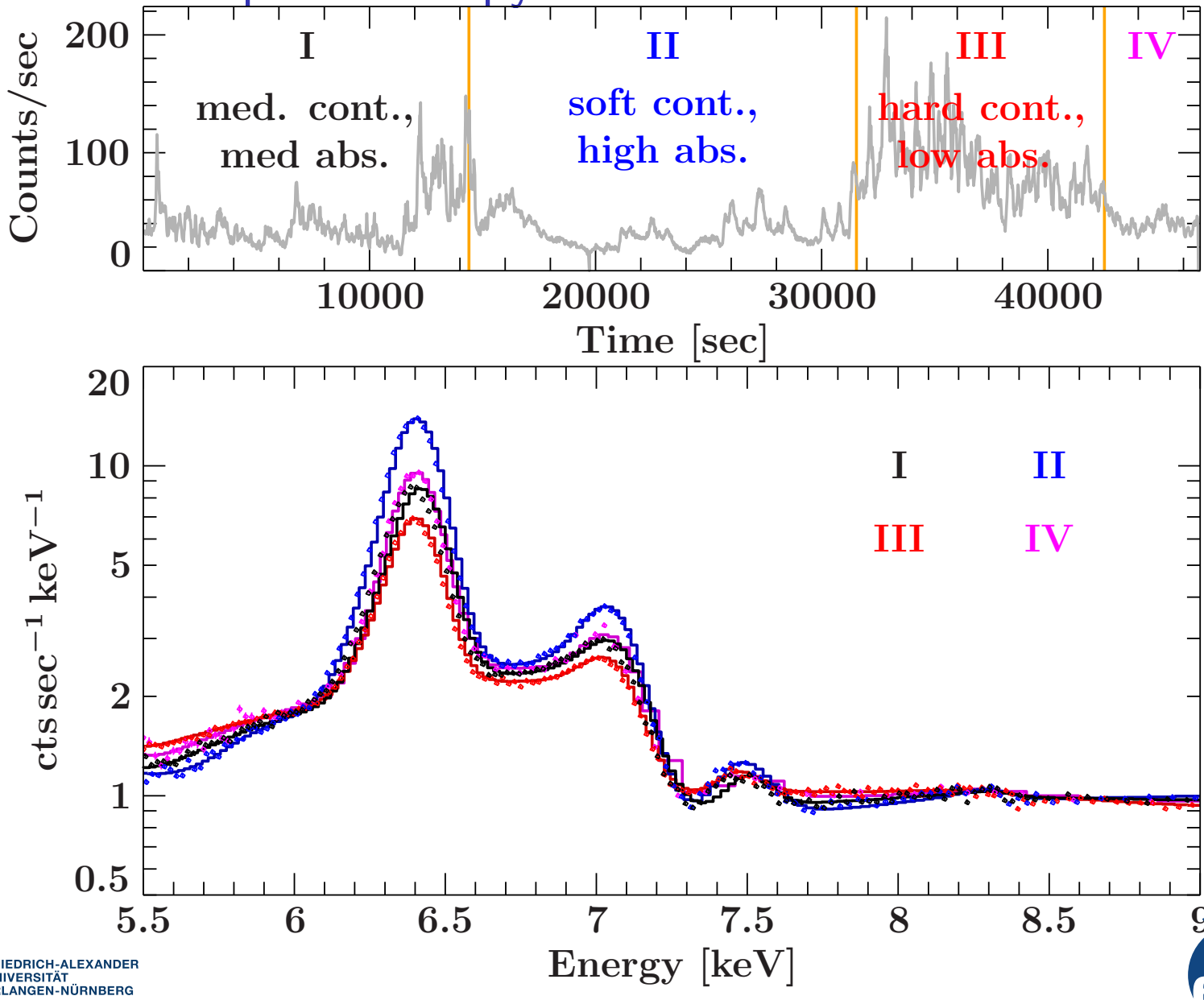
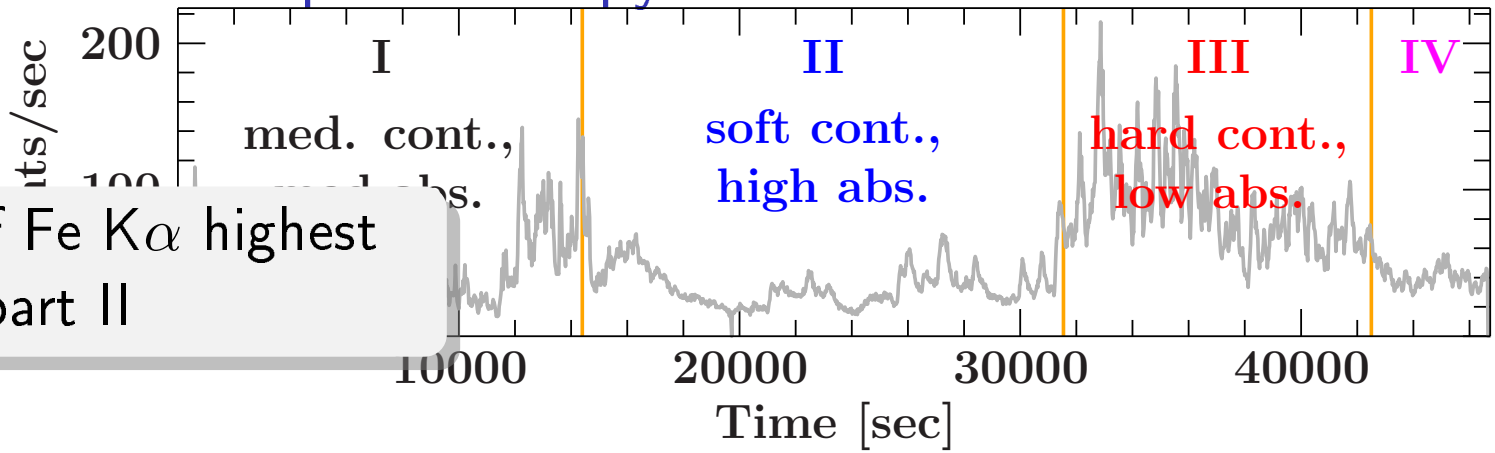
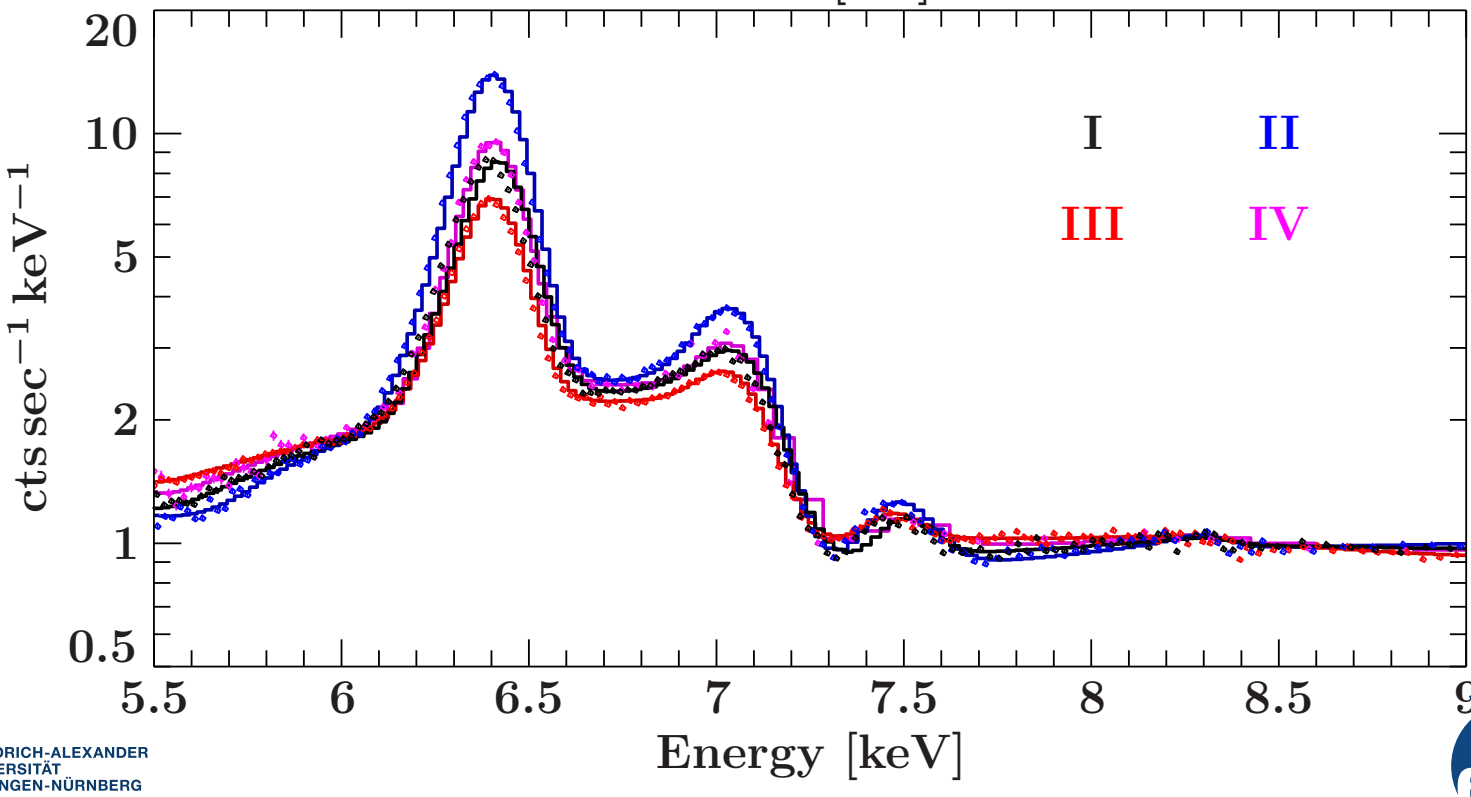


Time resolved spectroscopy

Eqw. of Fe Kα highest during part II





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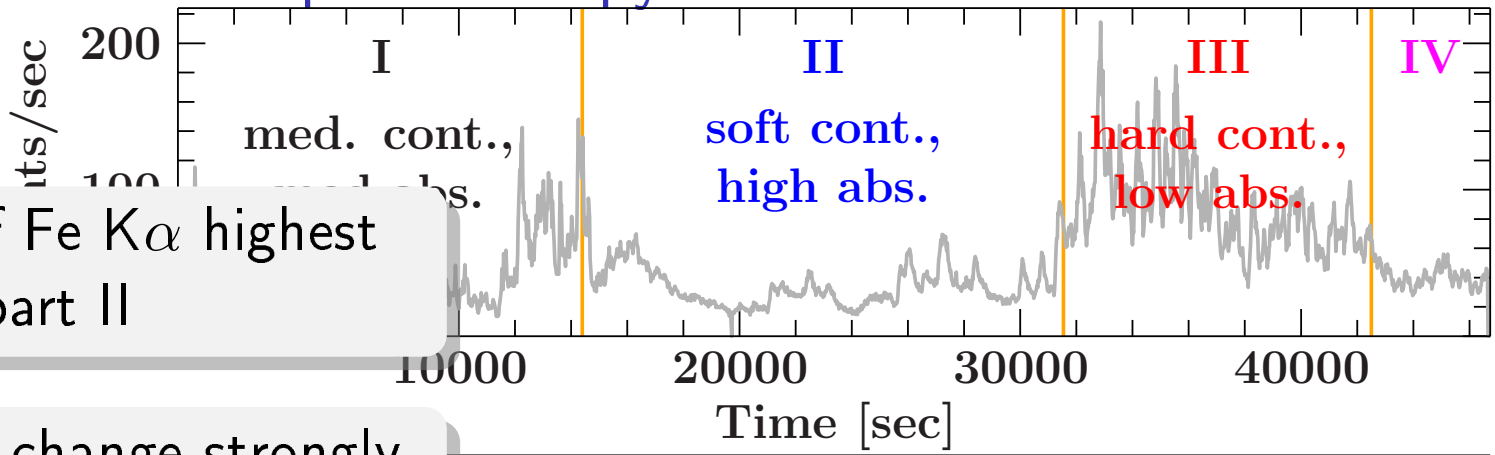
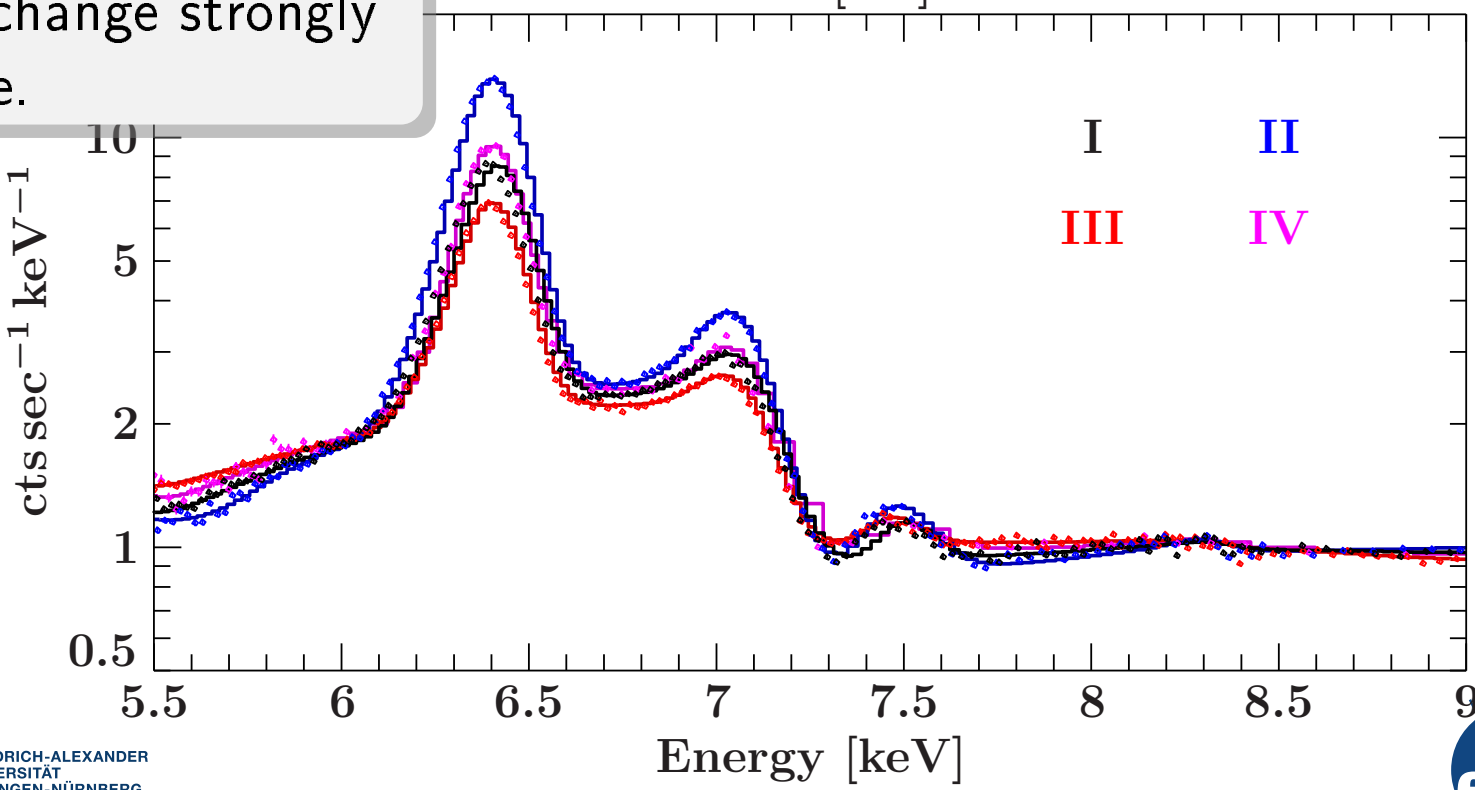
Time resolved spectroscopy

Eqw. of Fe Kα highest during part II

Spectra change strongly with time.





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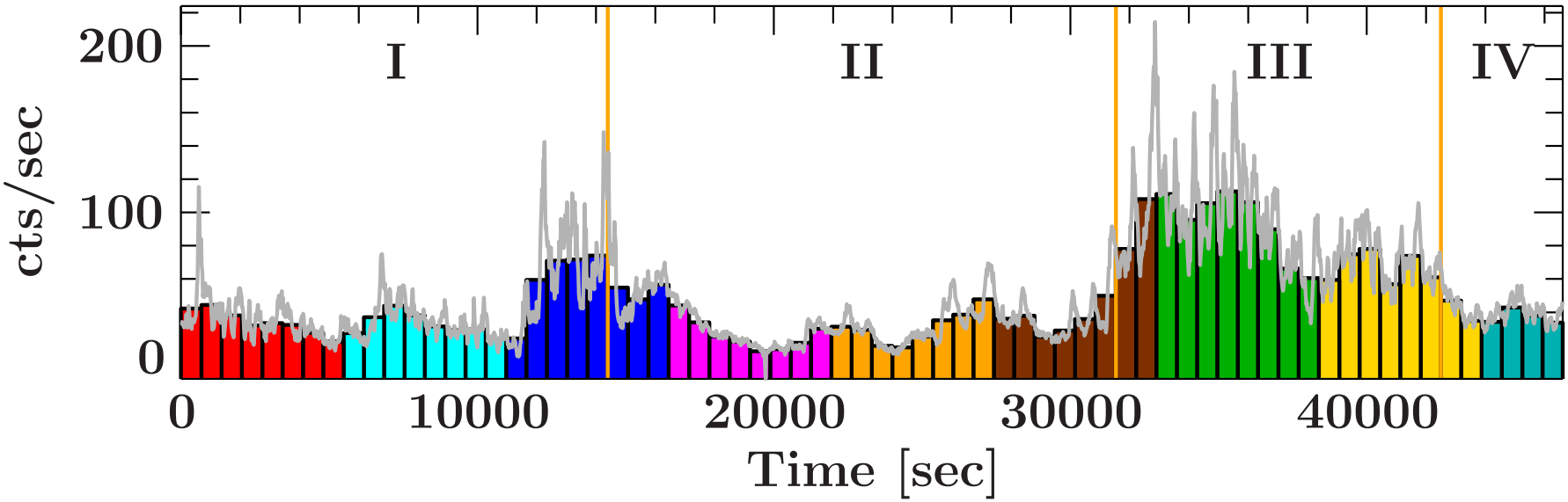
Pulse-to-pulse spectroscopy



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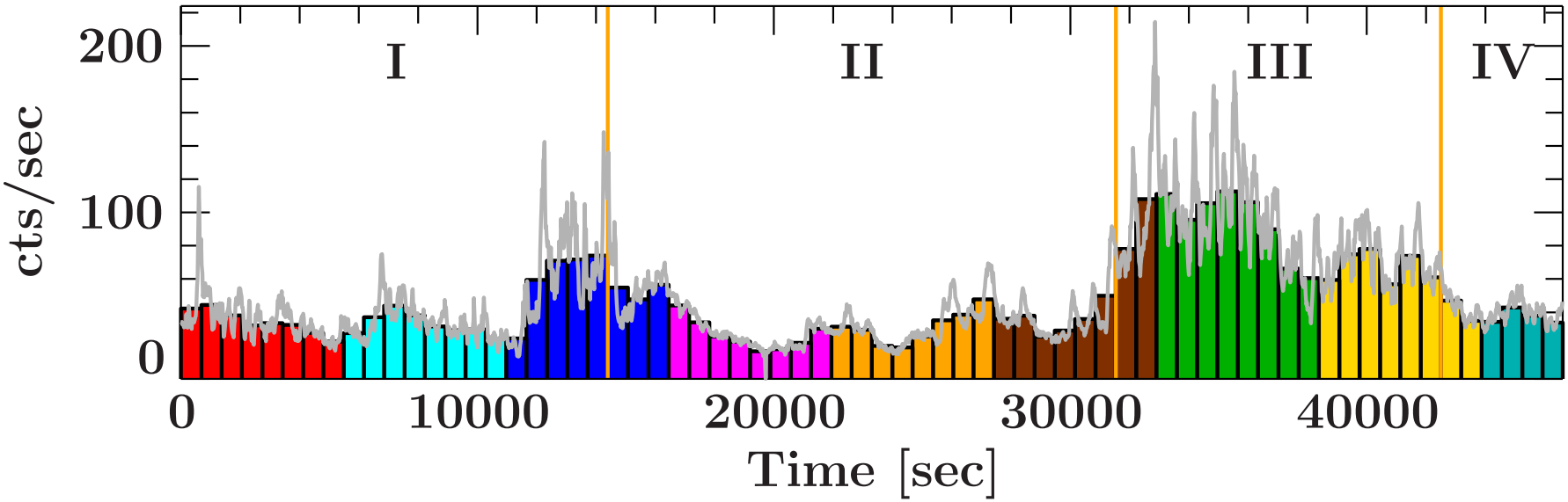

same model as for overall spectrum, but frozen $\Gamma = 0.90$ and $N_{\mathrm{H},2} = 5.27 \times 10^{23}\,\mathrm{cm}^{-2}$. Included only the Fe K$\alpha$, Fe K$\beta$, and Ni K$\alpha$ line.

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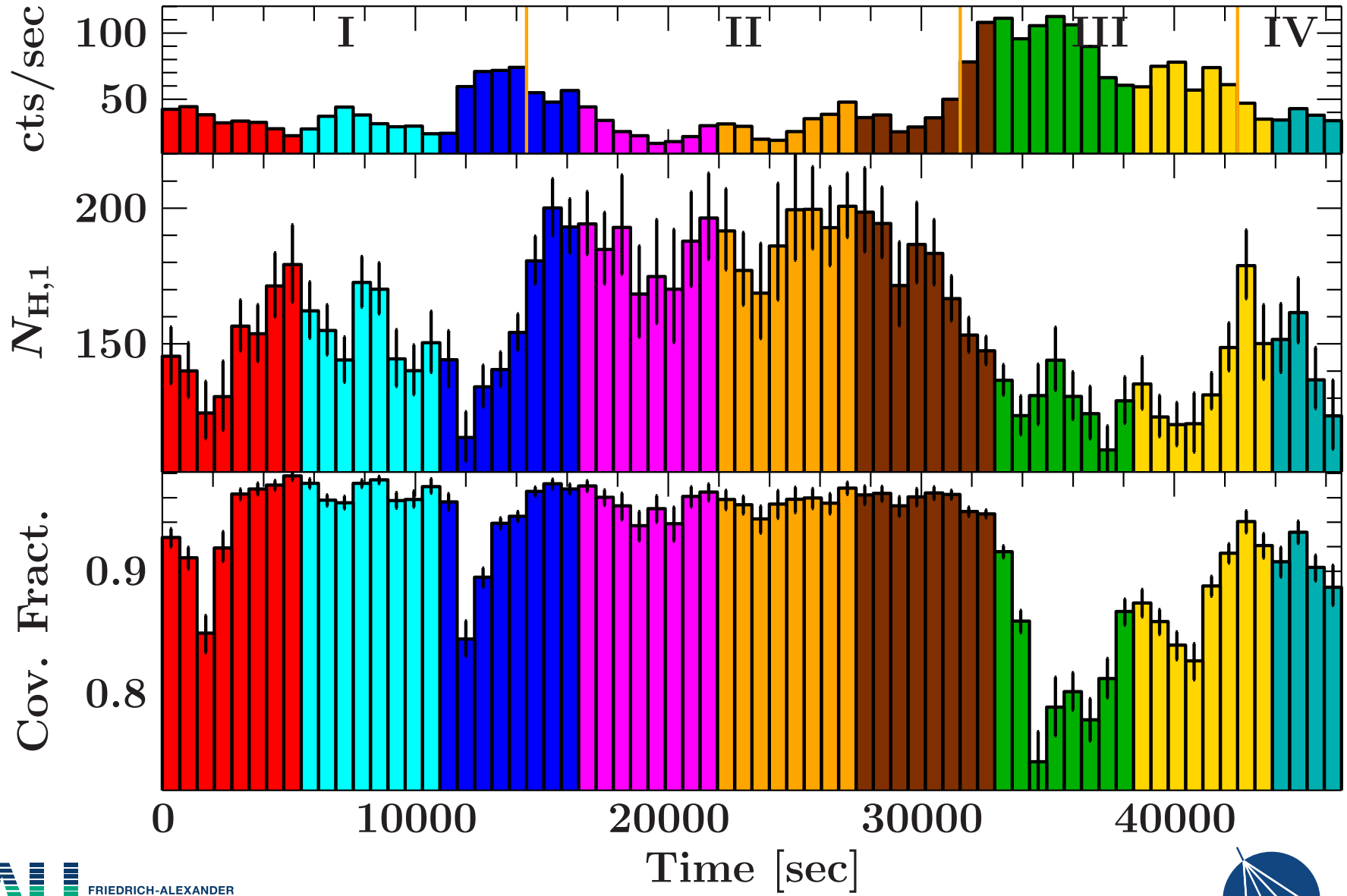

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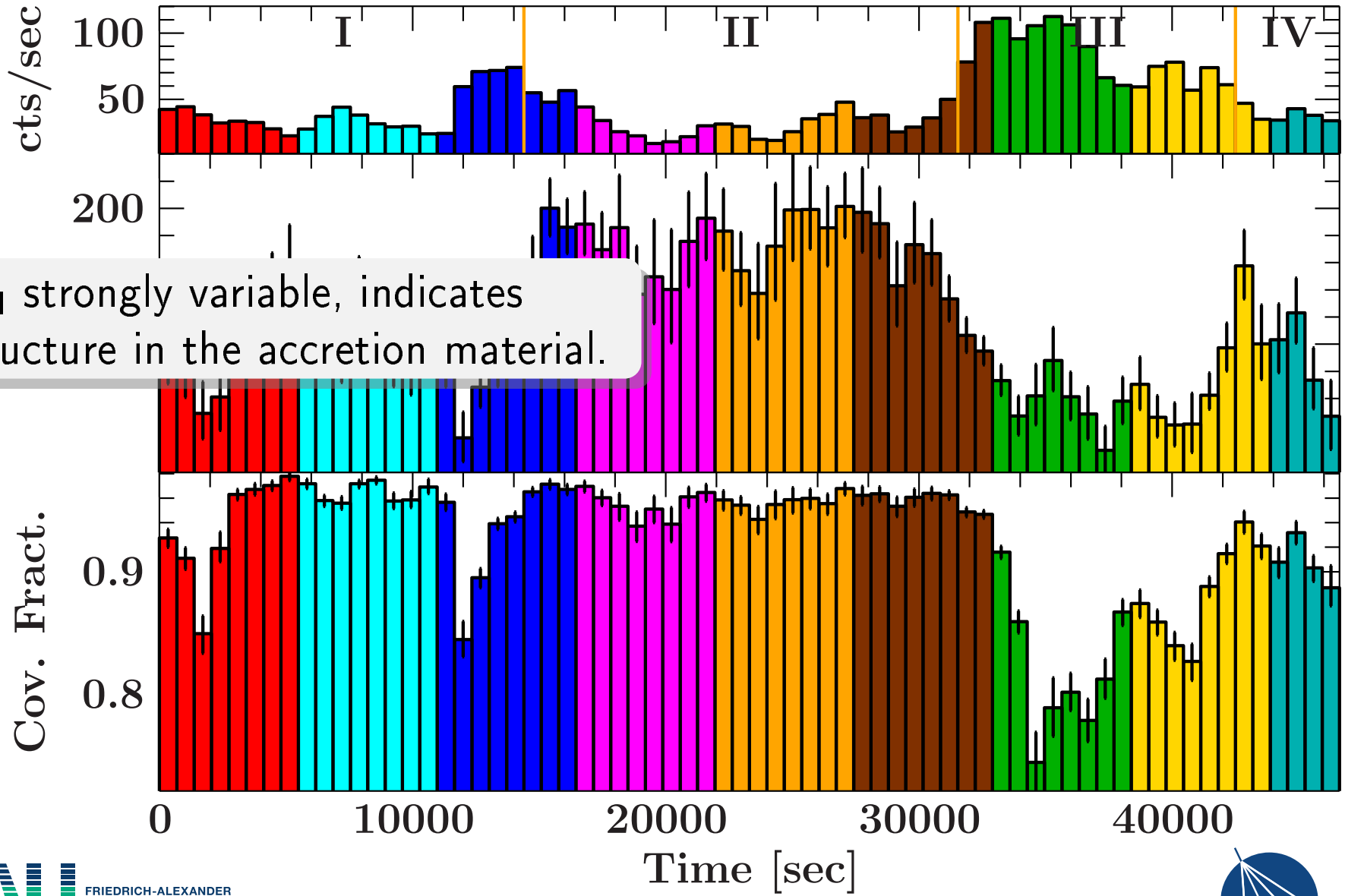
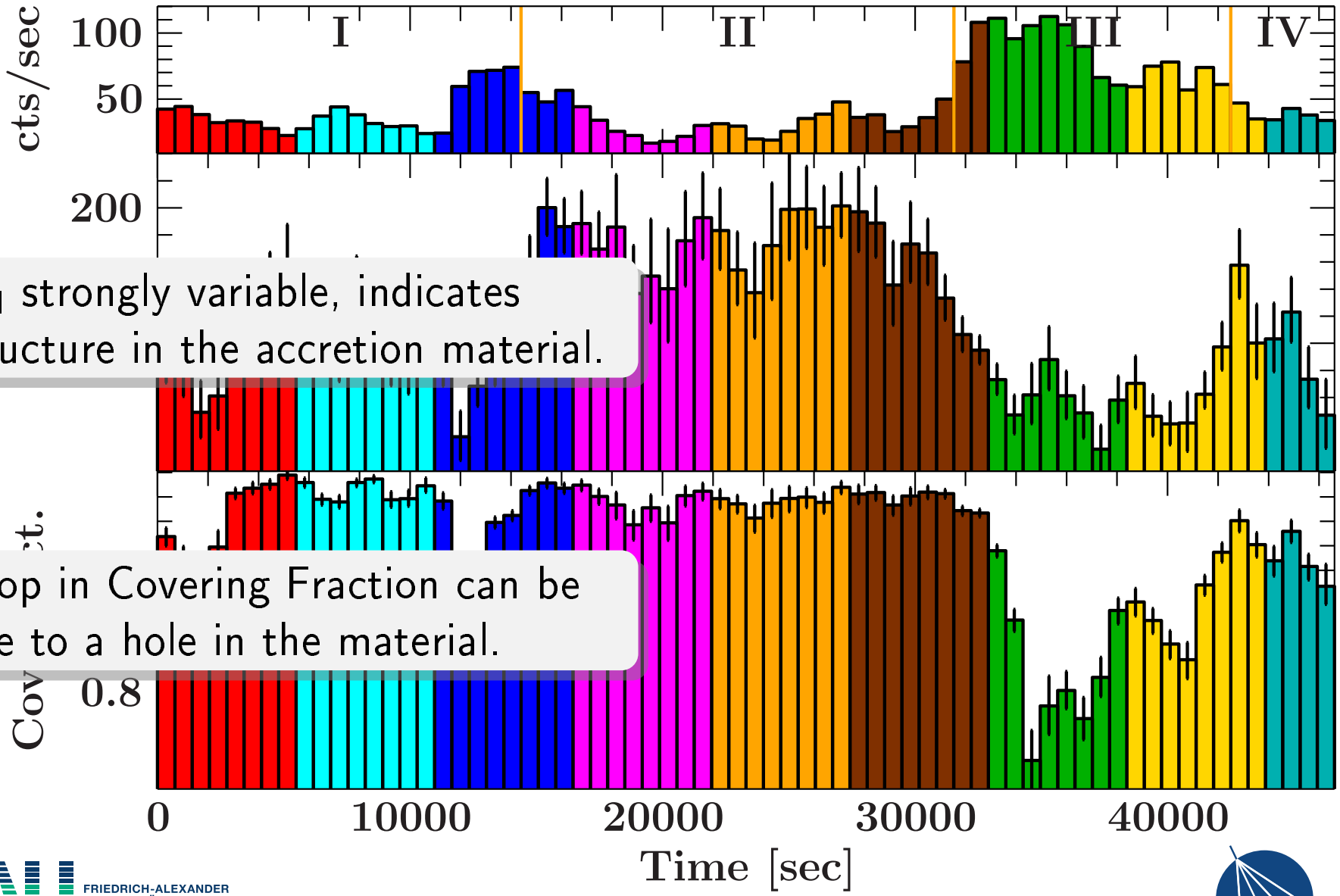


N_H strongly variable, indicates structure in the accretion material.

Pulse-to-pulse spectroscopy



N_H strongly variable, indicates structure in the accretion material.

Drop in Covering Fraction can be due to a hole in the material.

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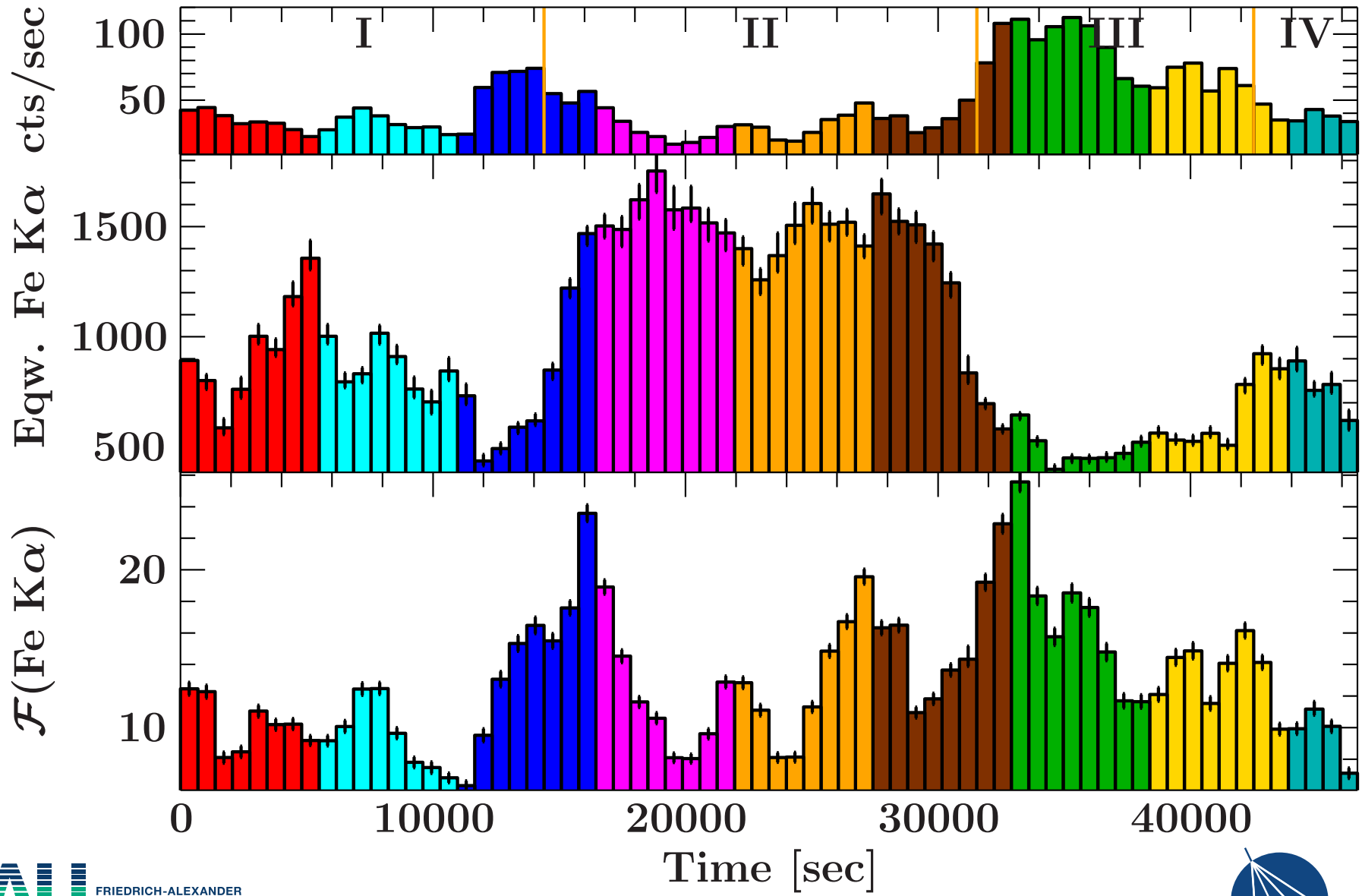

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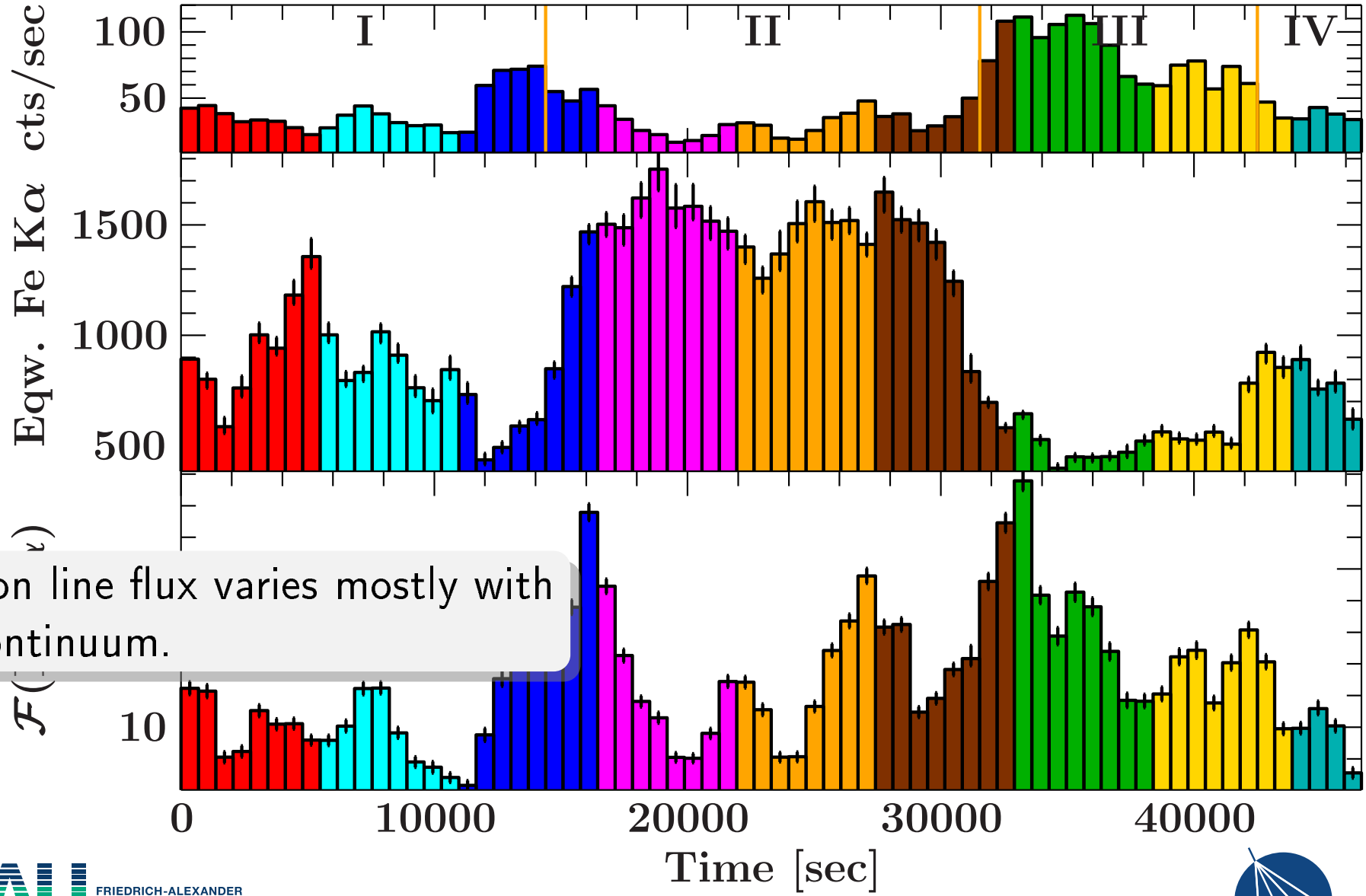
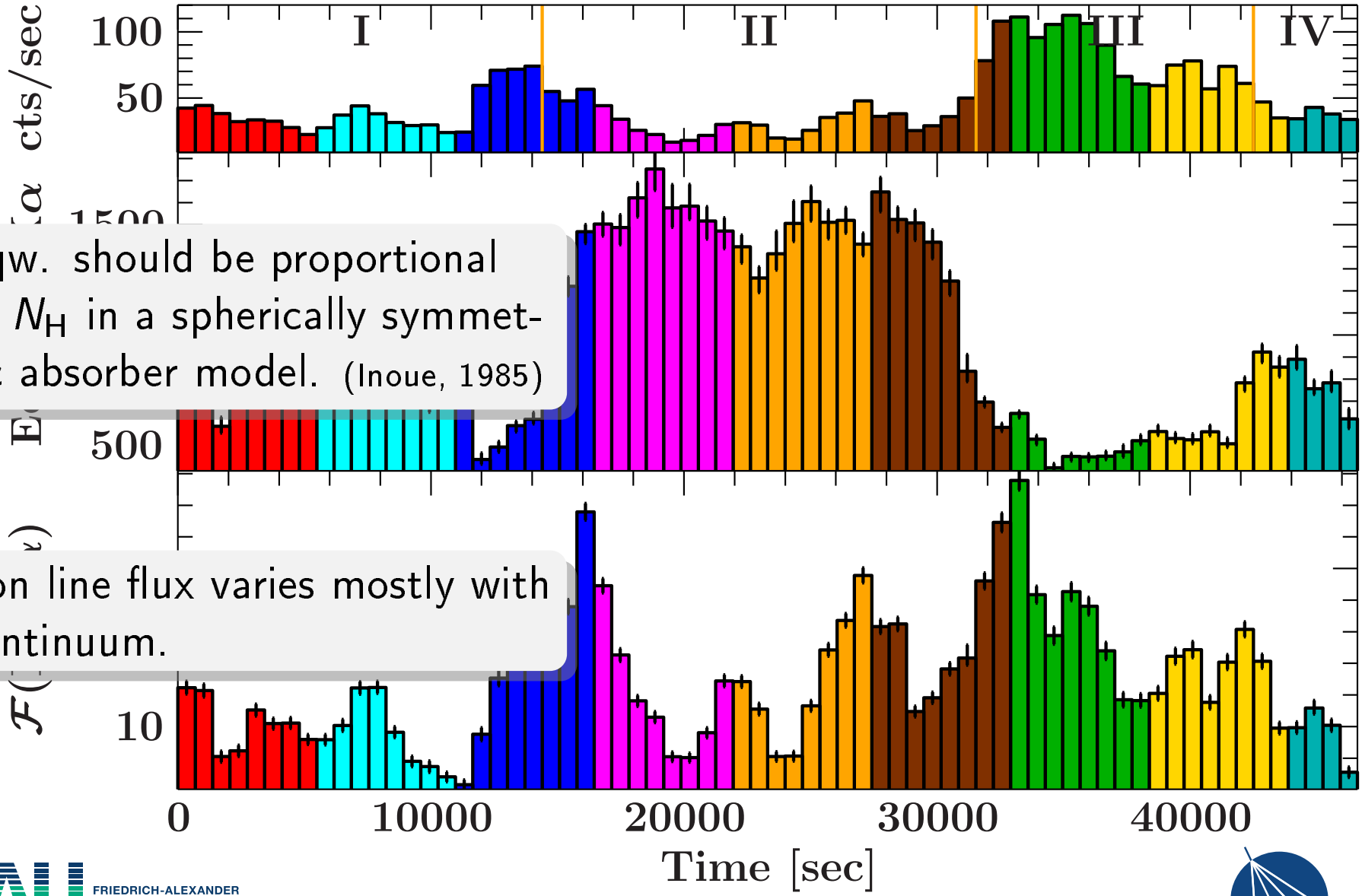


Iron line flux varies mostly with continuum.

Pulse-to-pulse spectroscopy



Eqw. should be proportional to N_H in a spherically symmetric absorber model. (Inoue, 1985)

Iron line flux varies mostly with continuum.

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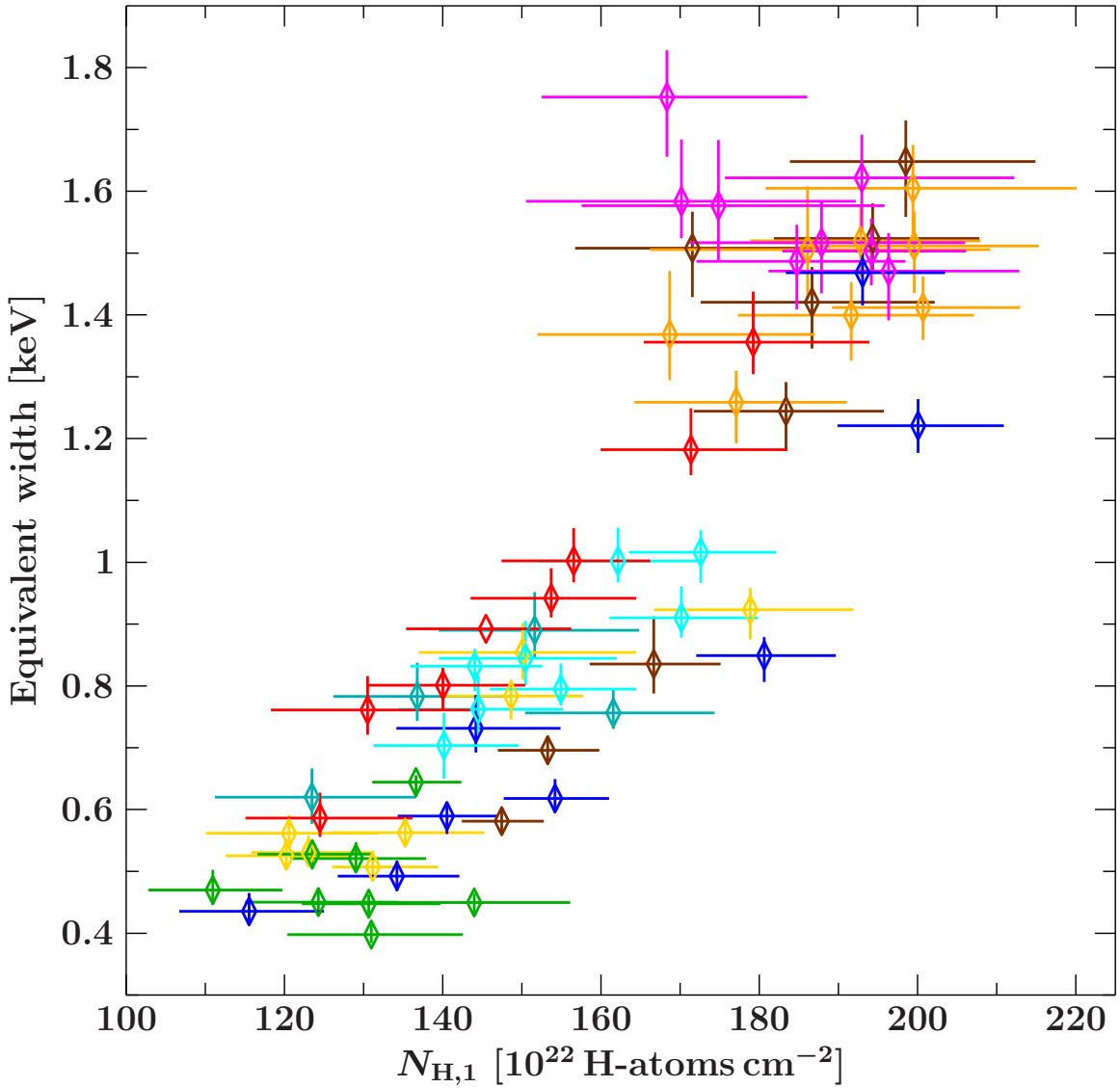
Iron line behavior



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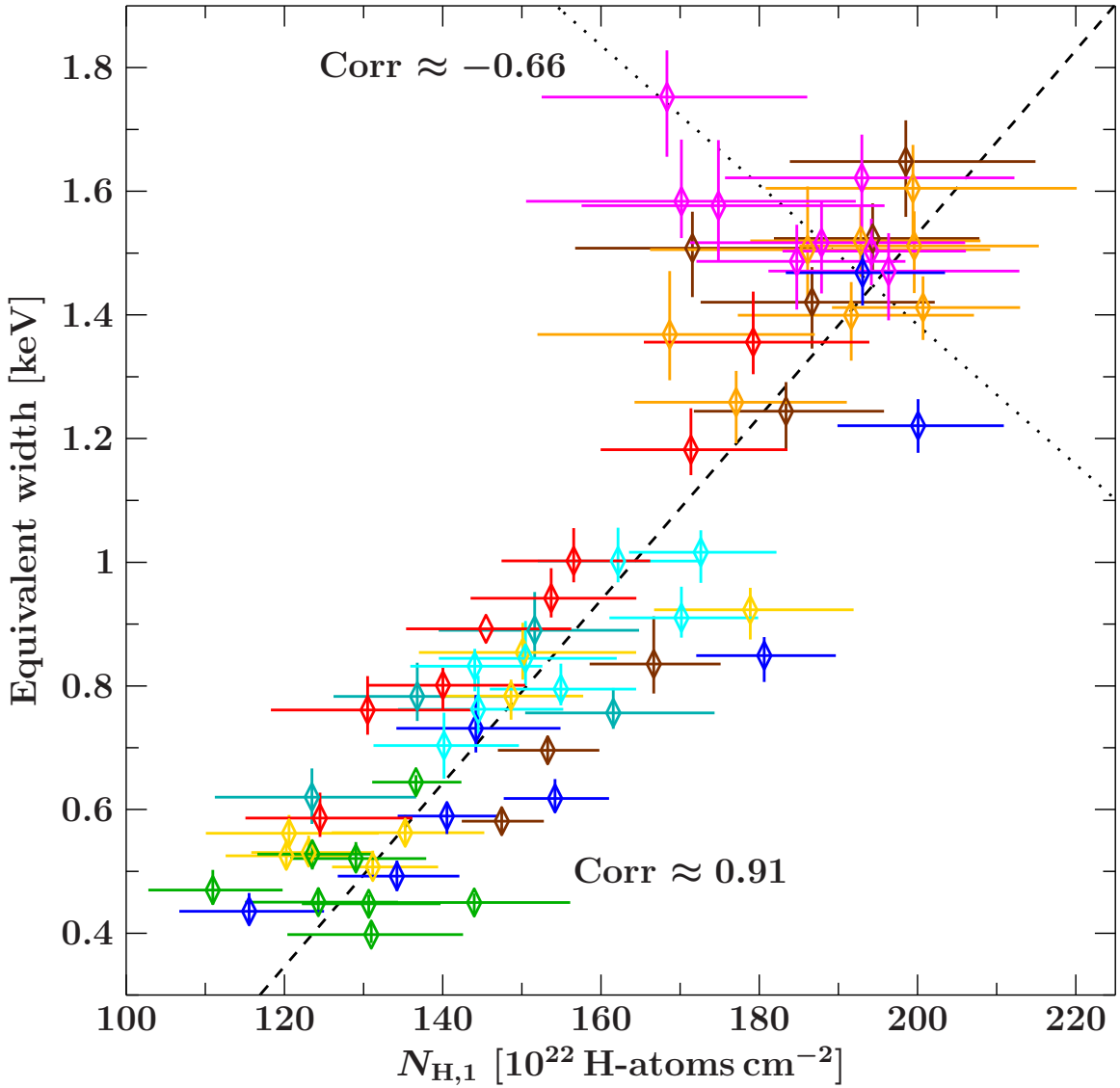
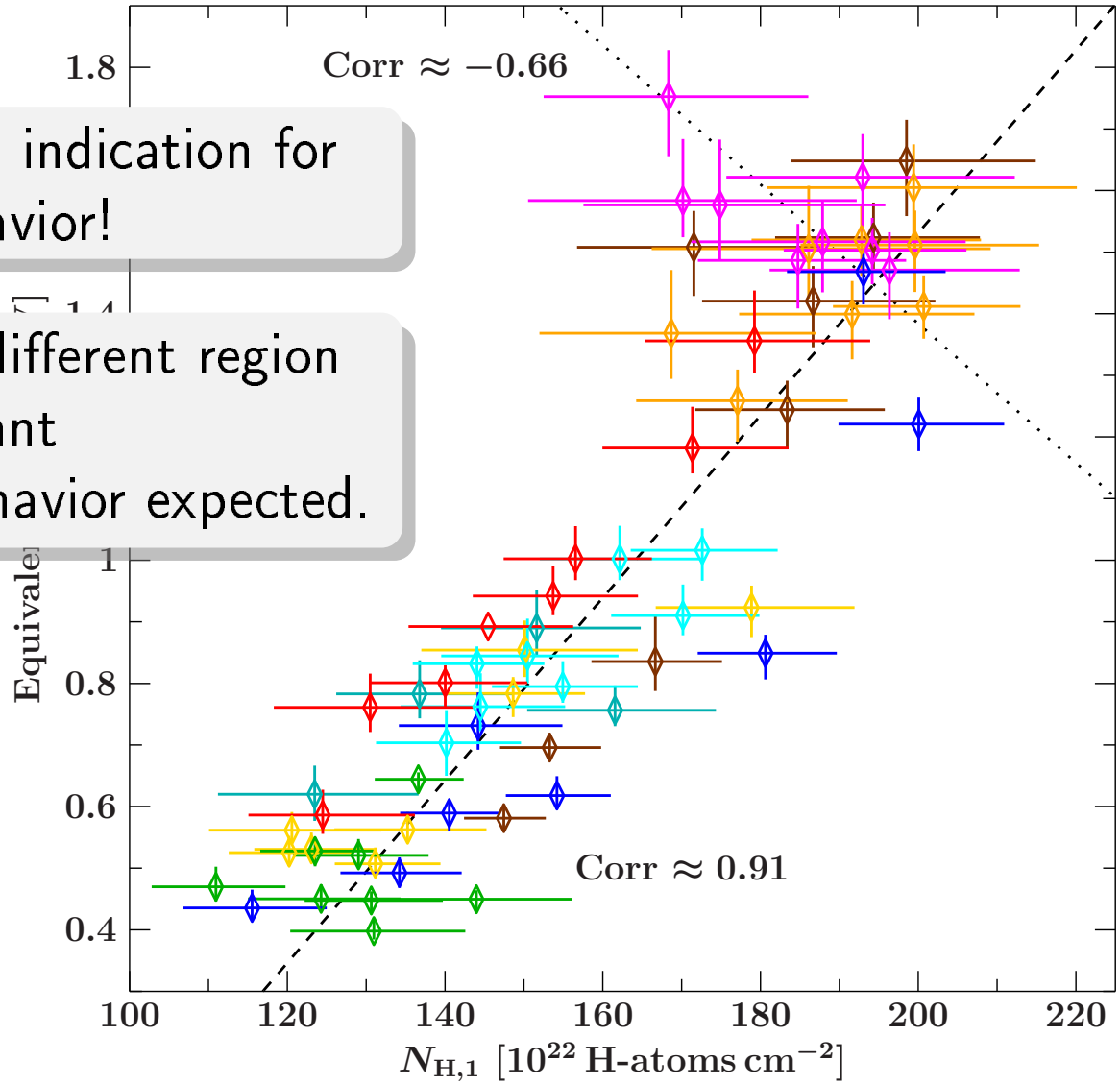


Iron line behavior

Off-state shows indication for a different behavior!

X-rays from a different region become dominant
⇒ different behavior expected.



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Summary

- partially covered spectrum with $10^{24}\,\mathrm{cm}^{-2}$ and expected fluorescence lines (including Cr Kα)
- highly variable flux and N_H
- off-state due to cessation of accretion (residual flux is not pulsed)

$\Rightarrow$ accreted material must be strongly structured

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Off-state and absorber geometry

two absorbers with two fluorescence regions:

main component very close to the neutron star, following the continuum

secondary component farther away and more independent of the momentary continuum flux

measured N_H not necessarily a good tracer for amount of fluorescence material as it is highly structured

see also Fürst et al., 2011, A&A, Suchy et al., 2011, ApJ, to be submitted

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Bibliography

Doroshenko V., Santangelo A., Suleimanov V., et al., 2010, A&A 515, 10

Göğüş E., Kreykenbohm I., Belloni T.M., 2011, A&A 525, L6

Inoue H., 1985, Space Sci. Rev. 40, 317

Kaper L., van der Meer A., Najarro F., 2006, A&A 457, 595

Kreykenbohm I., Wilms J., Kretschmar P., et al., 2008, A&A 492, 511

Leahy D.A., Kostka M., 2008, MNRAS 384, 747

Makino F., Leahy D.A., Kawai N., 1985, Space Sci. Rev. 40, 421

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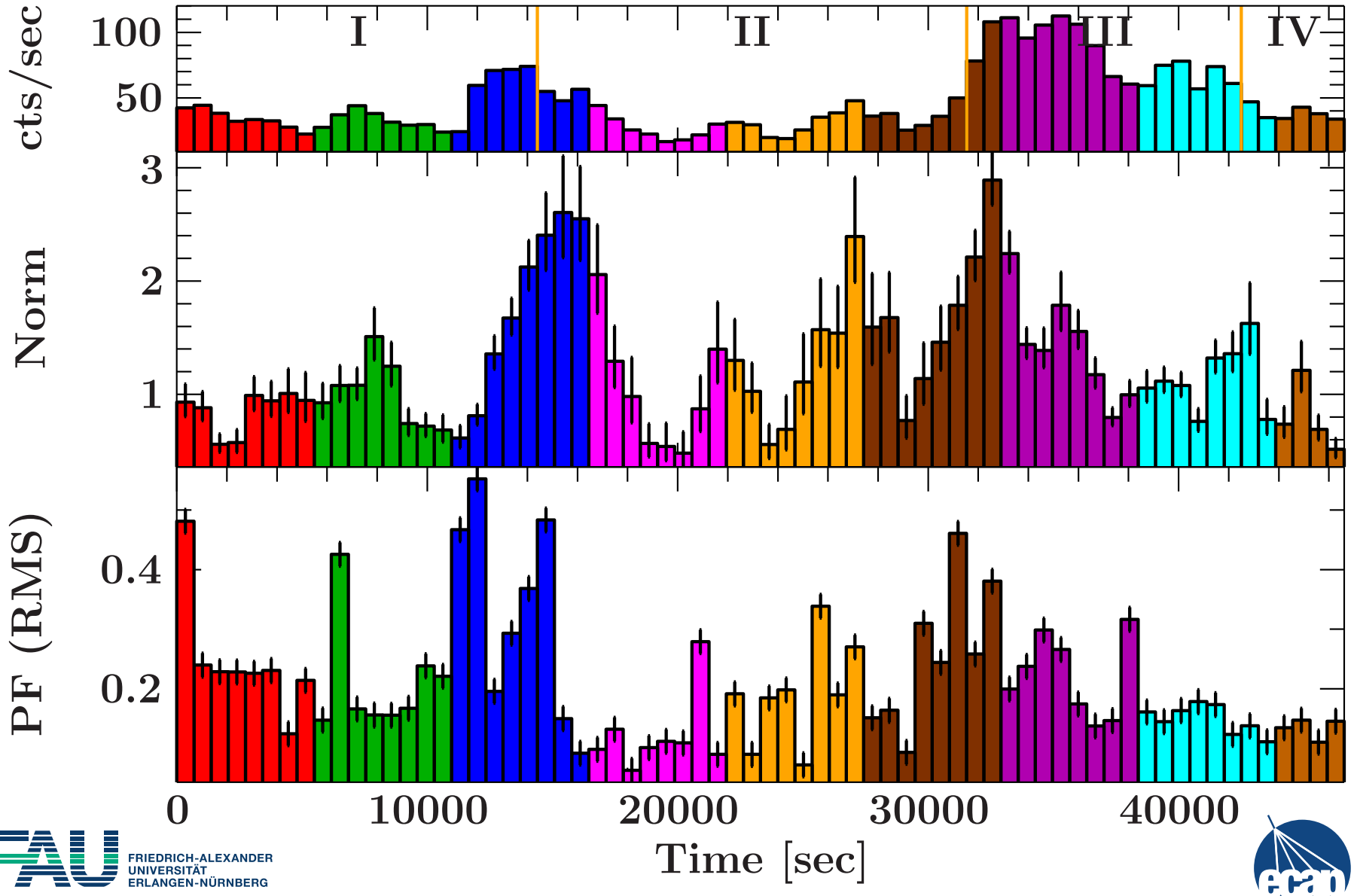
Pulse-to-pulse spectra



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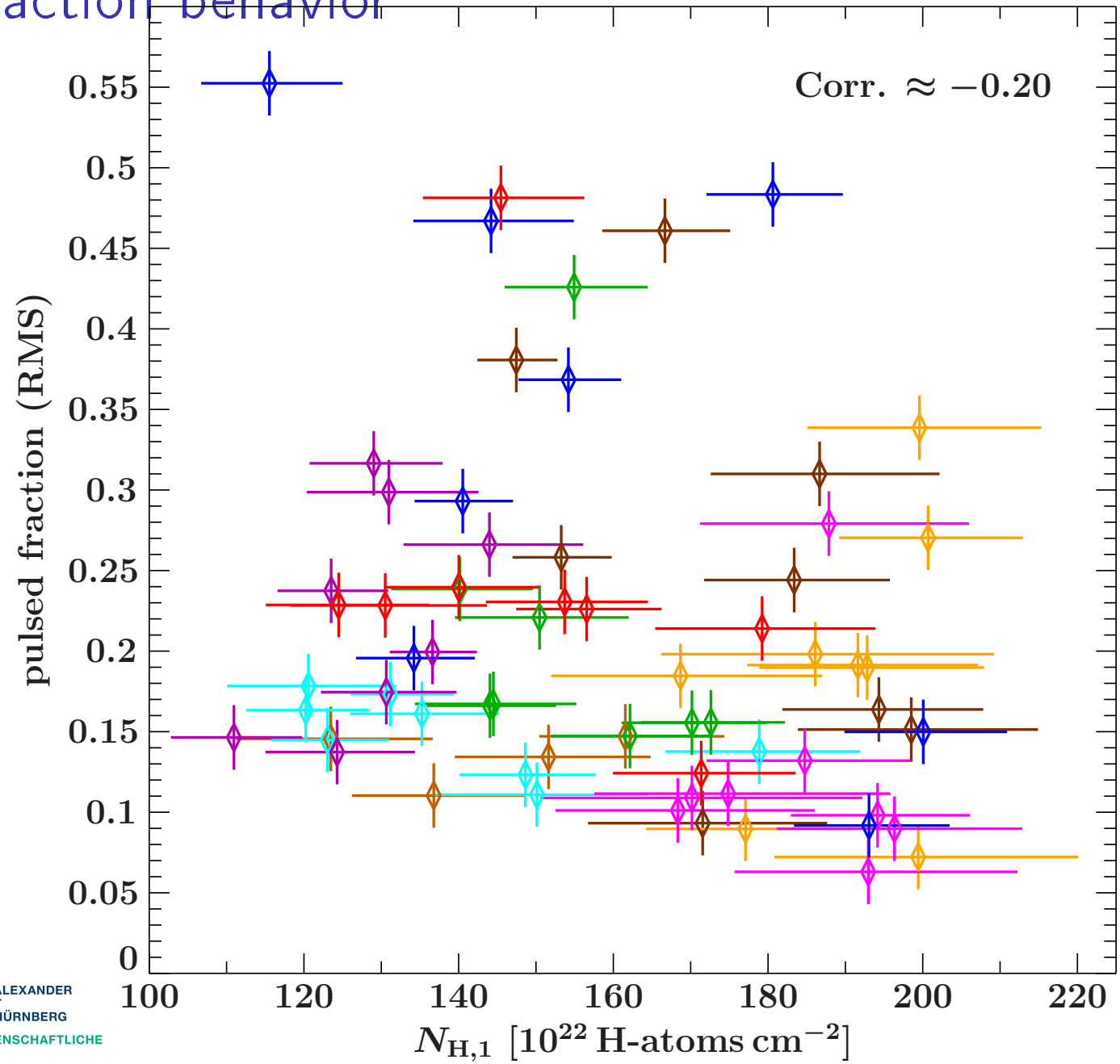
Pulsed fraction behavior



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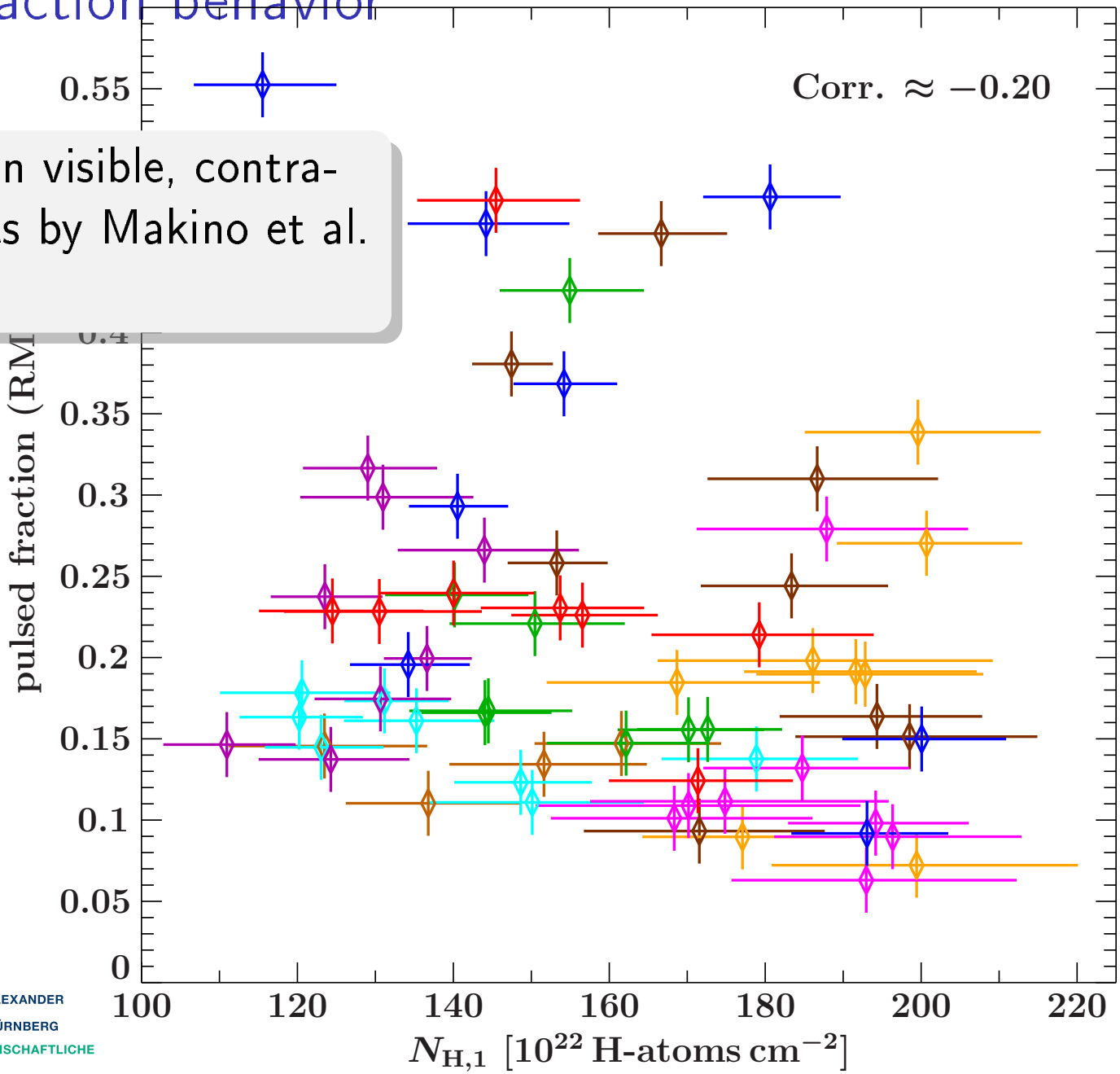
Pulsed fraction behavior

No correlation visible, contradicting results by Makino et al. (1985).



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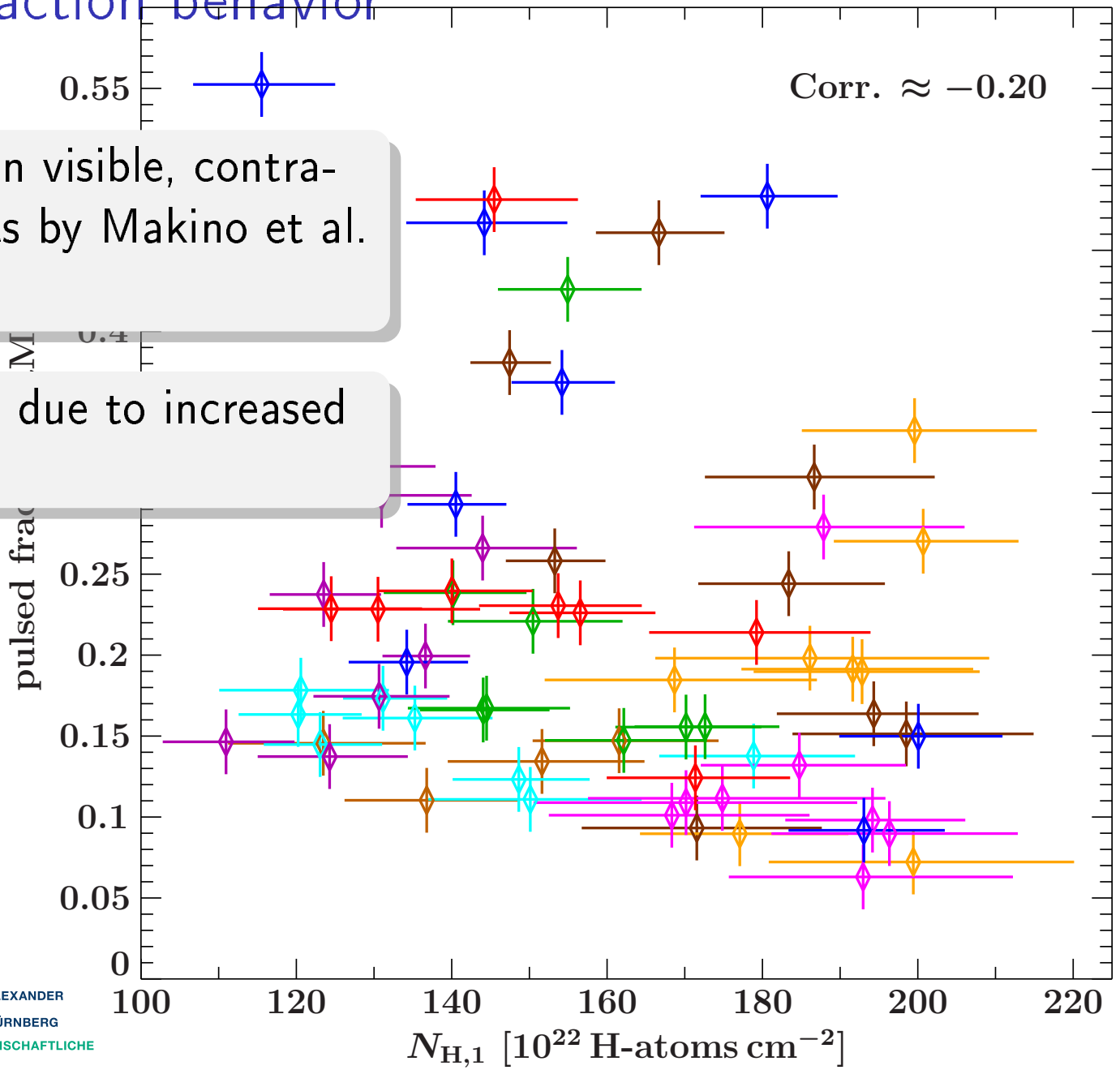
Off-state not due to increased N_H.



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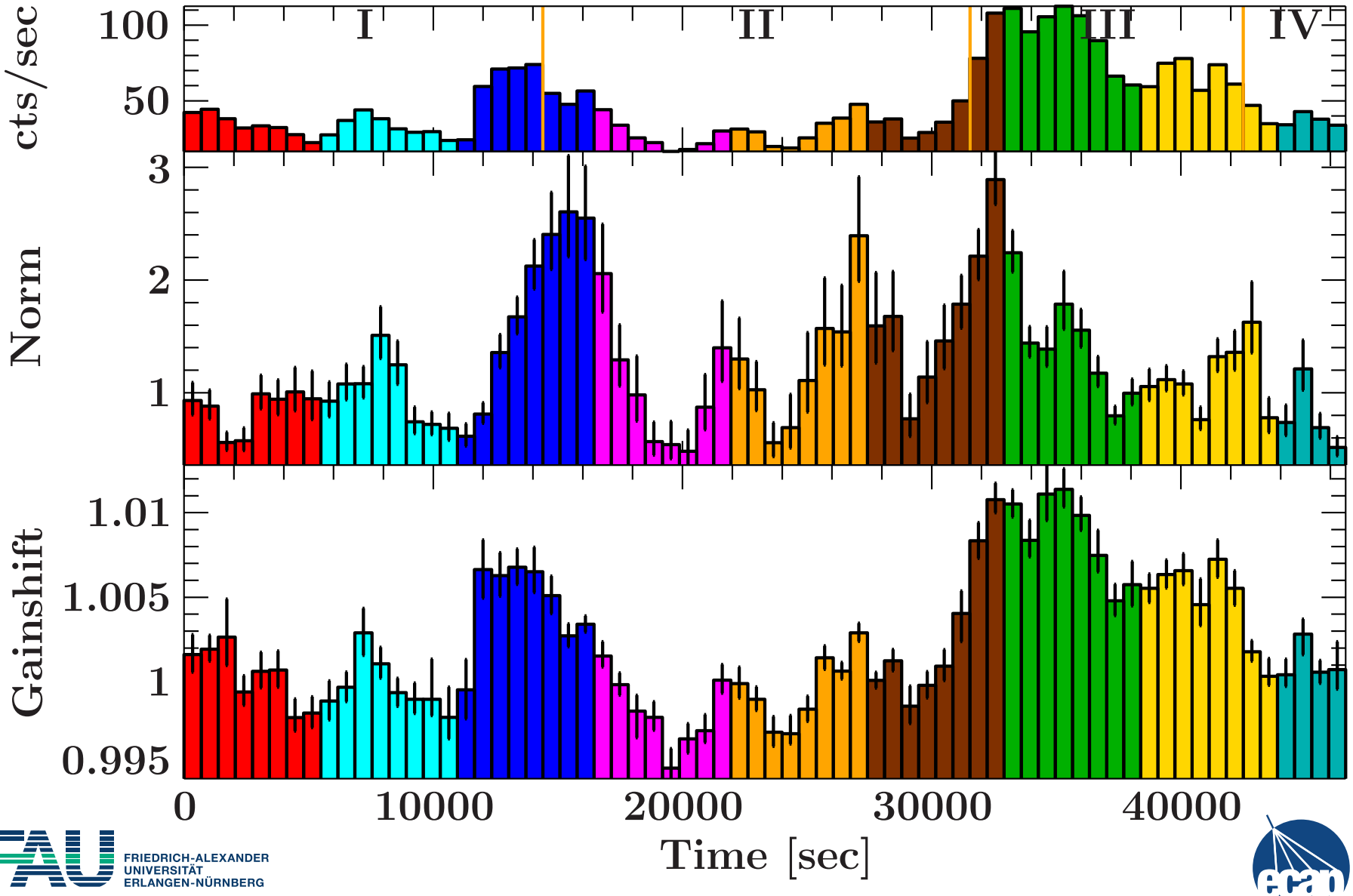

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