Constraining the neutron star equation of state using XMM

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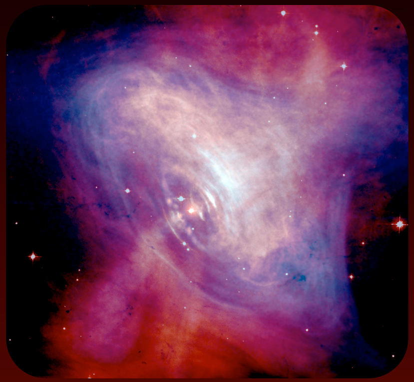
Why is the neutron star equation of state so important?

radius ~10 km
mass ~1.4 Msun

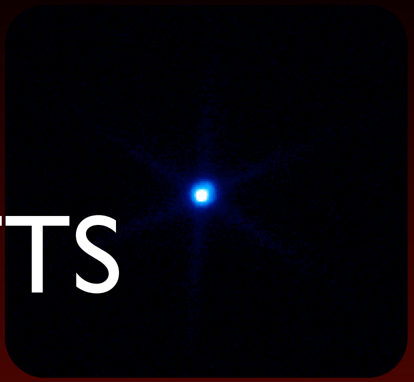
extreme density

Neutron stars in astronomy:

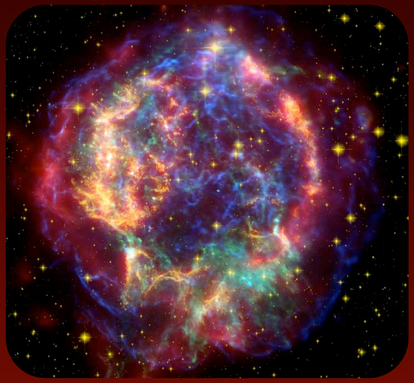
Pulsars



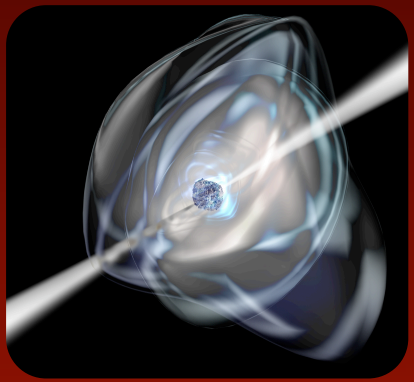
DINS
& RATTS



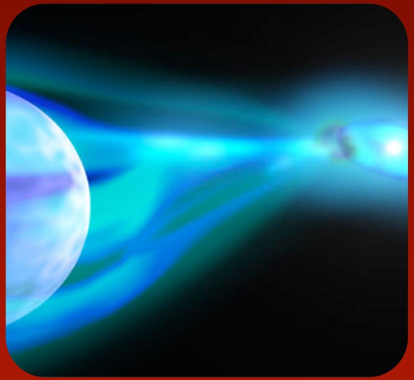
Compact Central Objects



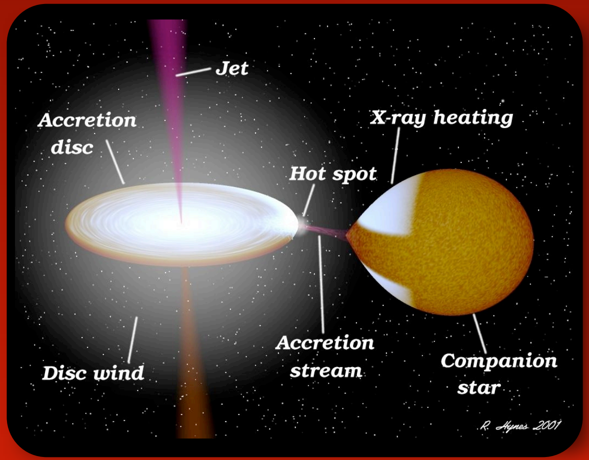
AXPs & SGRs



In HMXBs

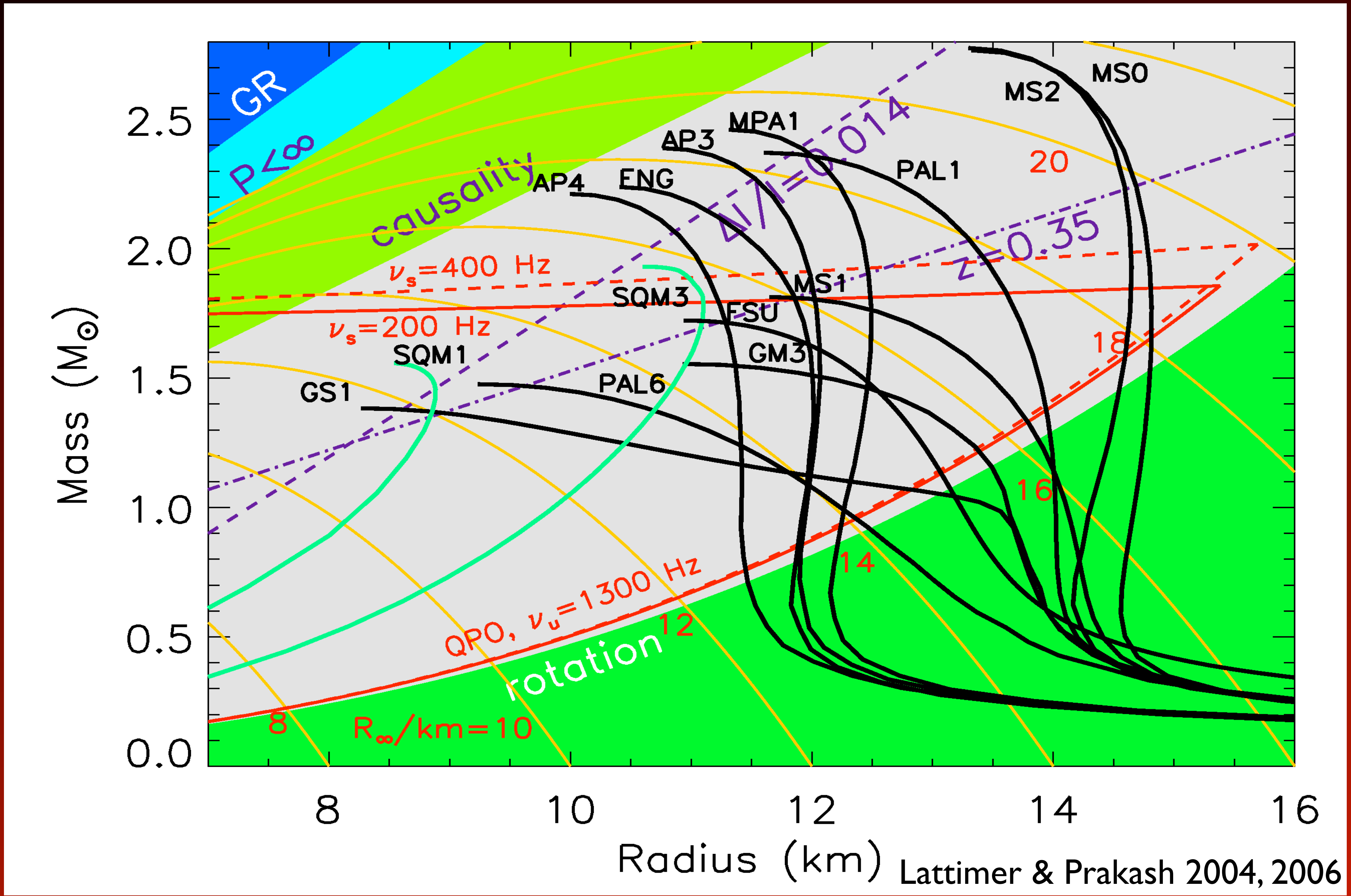


In LMXBs



In short γ-ray bursts (?)

Differentiate between various EoS



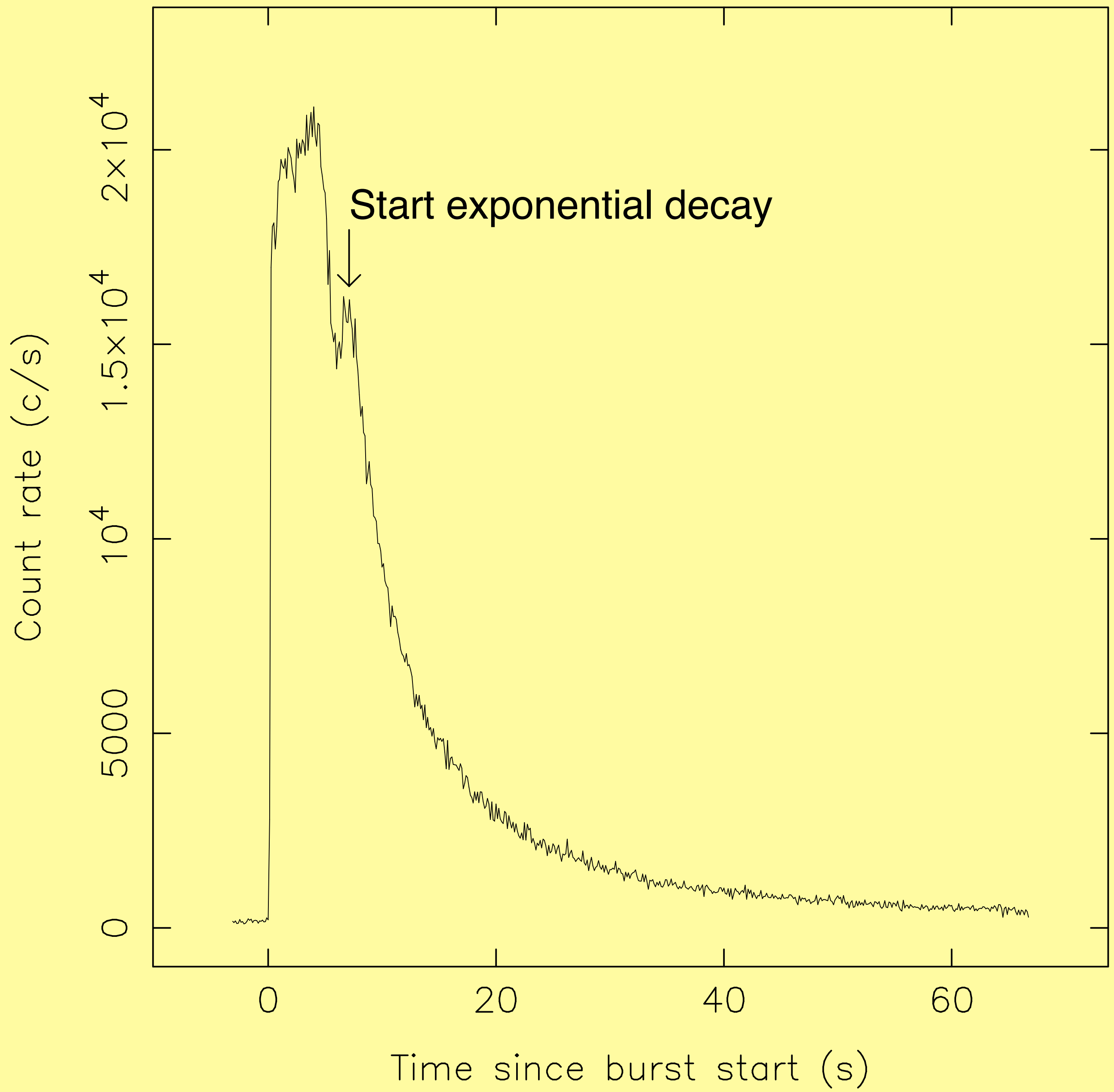
Measure at least 2 of:

mass, radius, spin frequency, gravitational redshift

New, deep XMM-Newton observations

- 1: High resolution spectroscopy during type I X-ray bursts
- 2: High resolution spectroscopy of quiescent systems
- 3: Determine inclination from X-ray light curve

1: High resolution spectroscopy during type I X-ray bursts



1: burning H + He, less bright EXO 0748-676, 2S 1826-238, 4U 1728-34

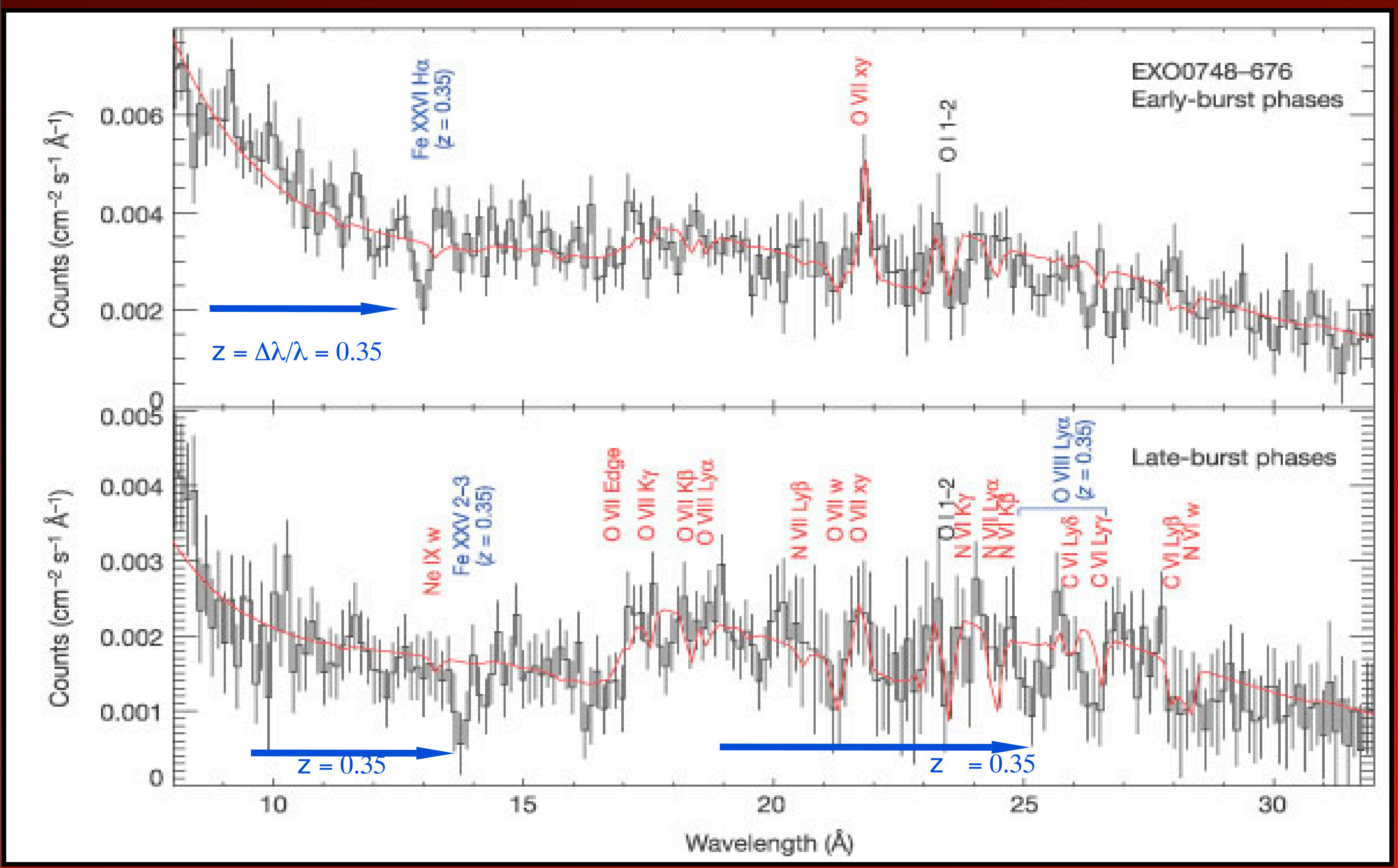
2: burning He, bright, short bursts

3: burning He, bright, long bursts → large fluence

4: super burst, burning C, very long, rare

Photospheric absorption during X-ray bursts

EXO 0748–676, a known X-ray burster
XMM-Newton observed it as a calibration target:
~ 335 ks with RGS cameras; 28 X-ray bursts.
~ 39 ks with EPIC simultaneous.



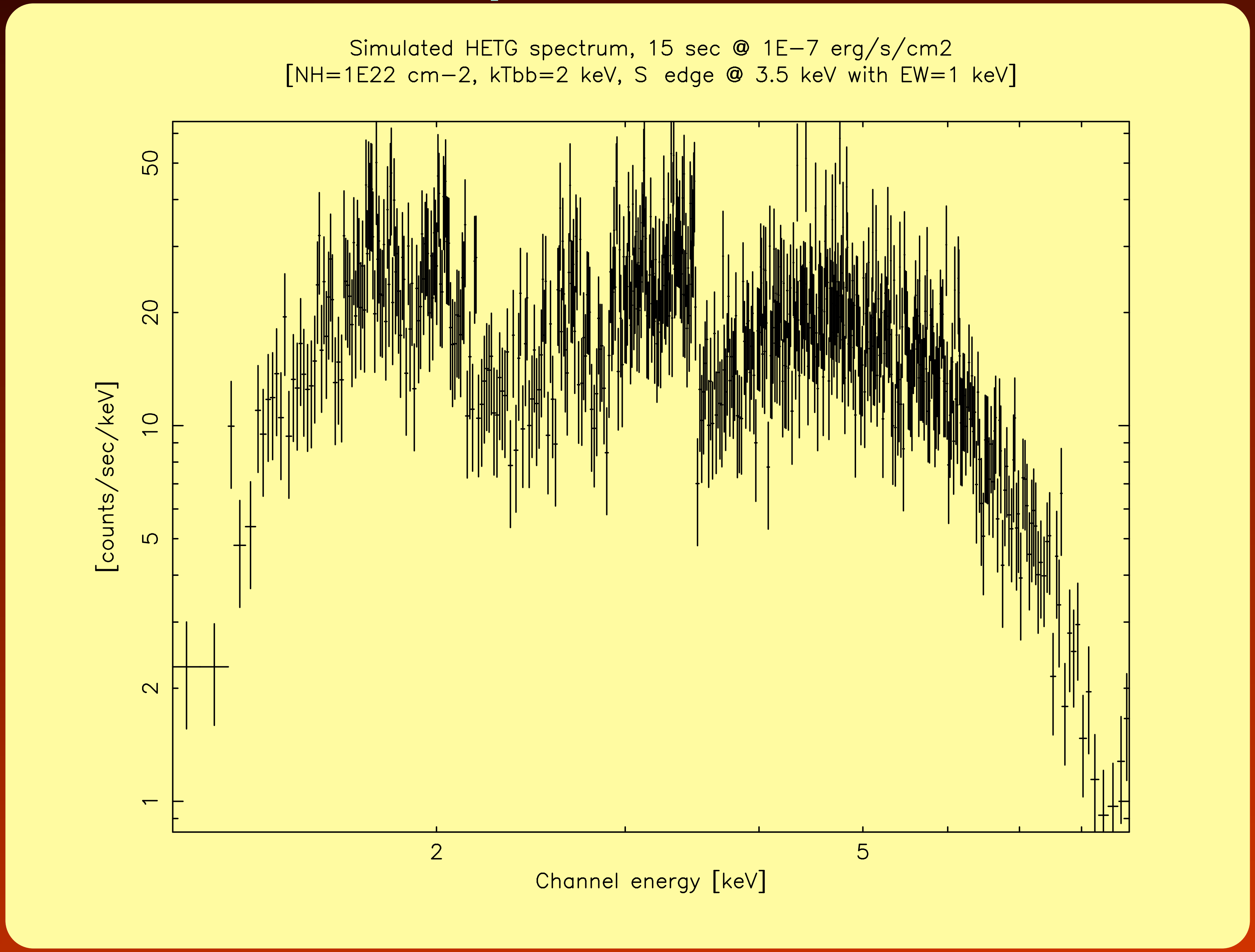
Absorption lines at 13.0Å and 13.7Å in the combined early- and late-burst spectra, respectively.

Fe XXVI Hα (n = 2–3) and Fe XXV Heα (n = 2–3), respectively, at the same redshift z = 0.350 ± 0.005.

The feature at 25.3 Å in the late-burst spectrum would then be consistent with O VIII Lyα.

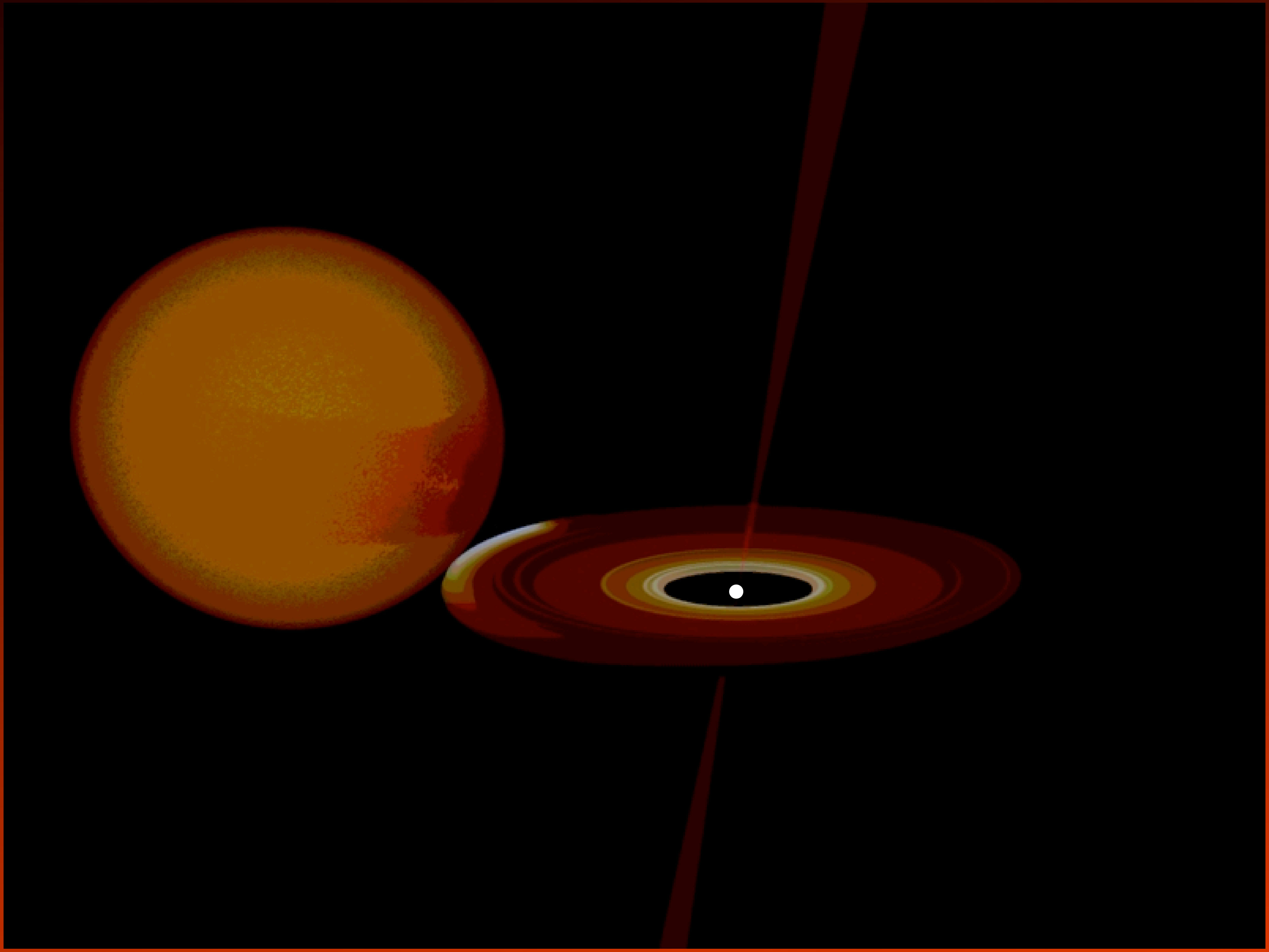
Cottam, Paerels & Méndez 2003

Perhaps better to focus on radius expansion
or
super bursts?



4U 1812-12: 2 proposals XMM-Newton / Chandra ACIS + HETG, PI: In 't Zand

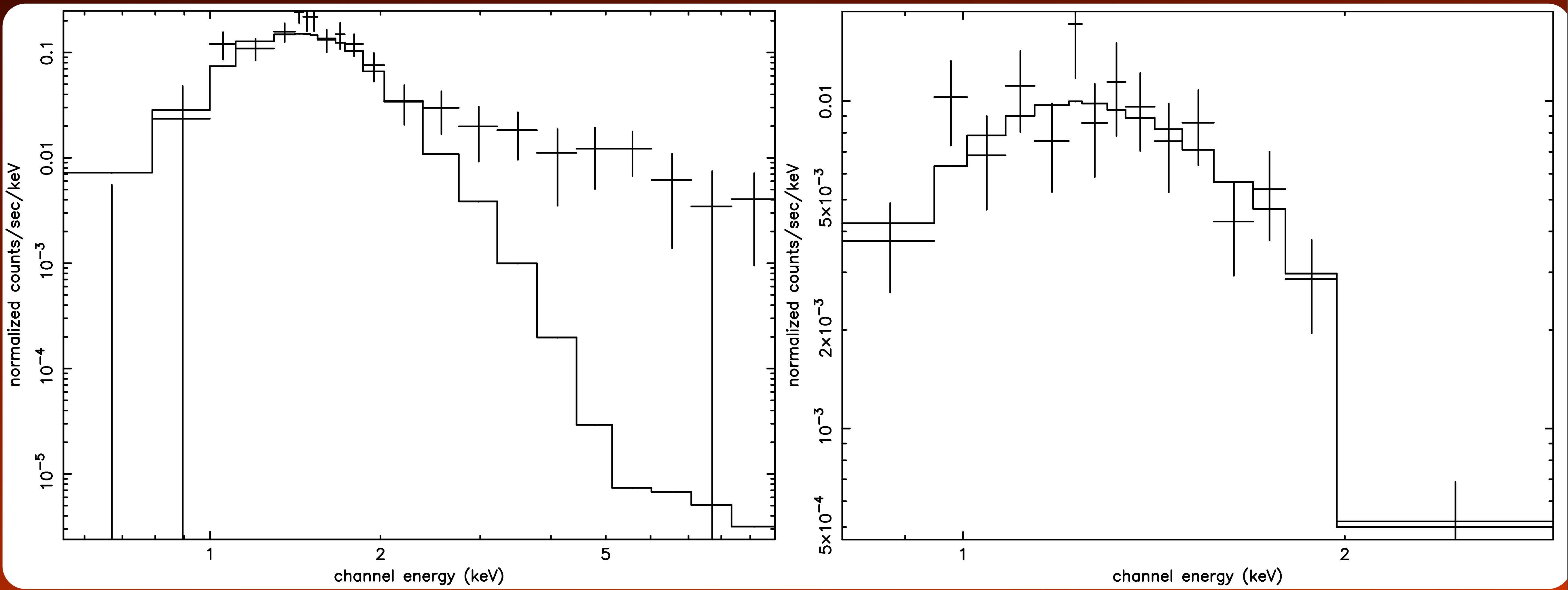
2: High resolution spectroscopy of quiescent systems



XMM-Newton and Chandra X-ray observations of quiescent LMXBs:

4U 1608-52 1H 1715-321

Absorbed NSA fit



T~1.26 million K

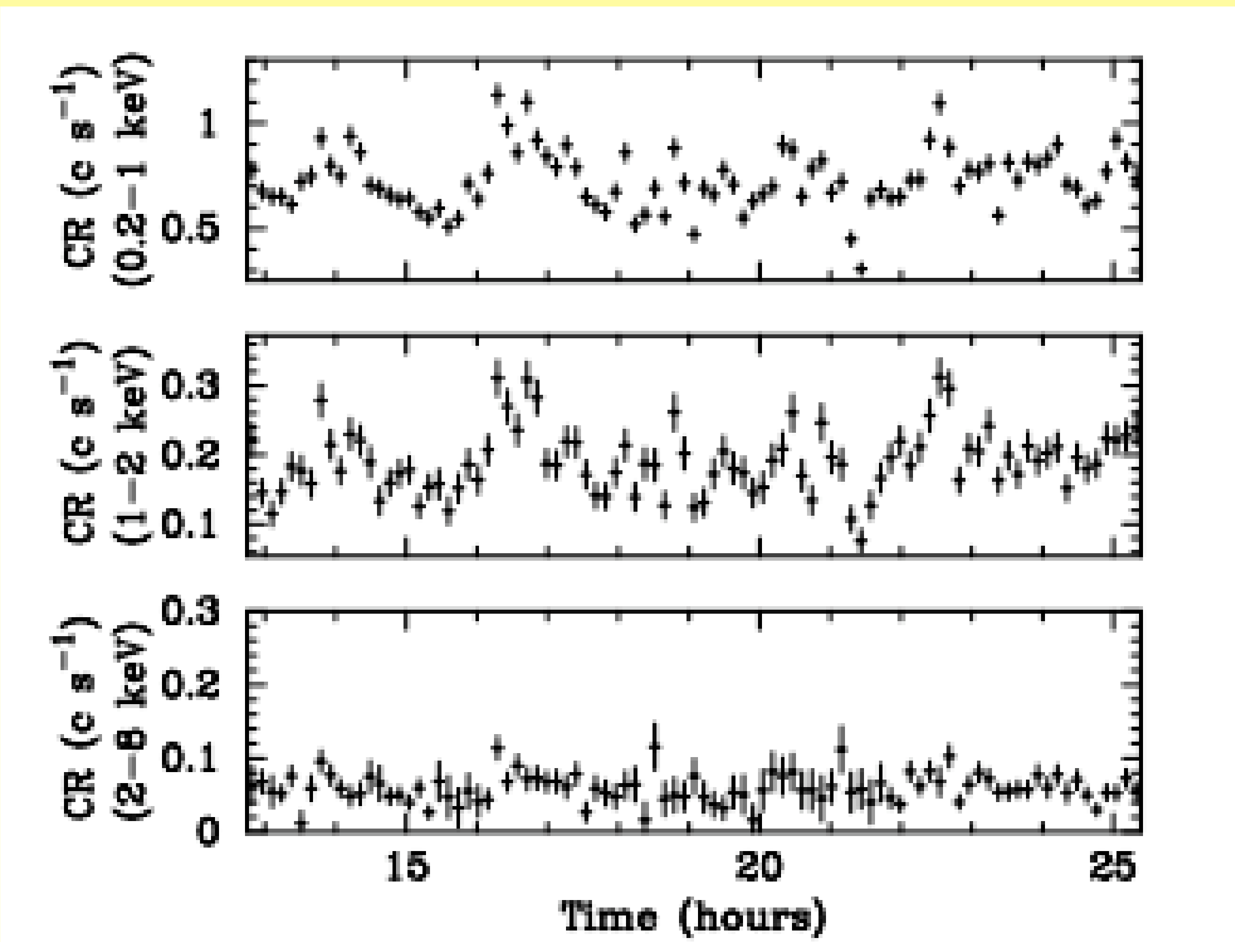
Altamirano et al. in prep.

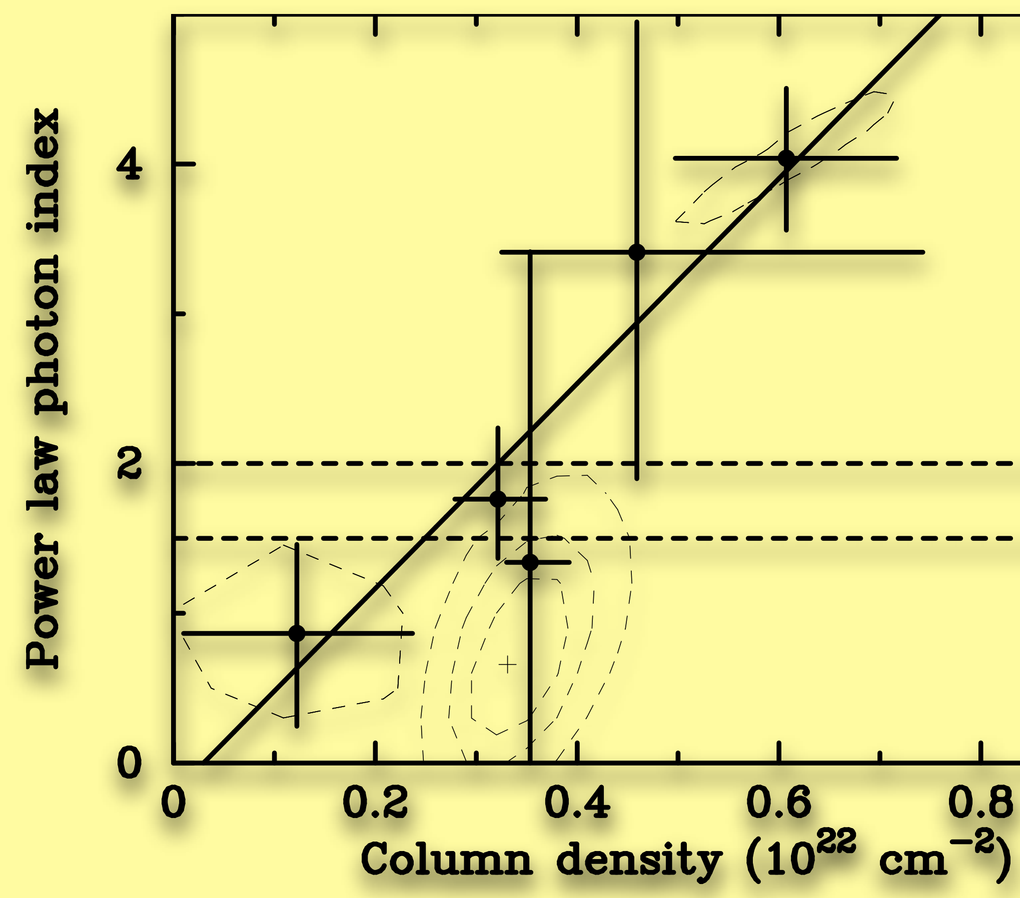
T~1.2 million K

Jonker, Bassa & Wachter 2007

Result of Webb & Barret 2007

Variation in quiescent emission of CenX-4 and AqlX-1

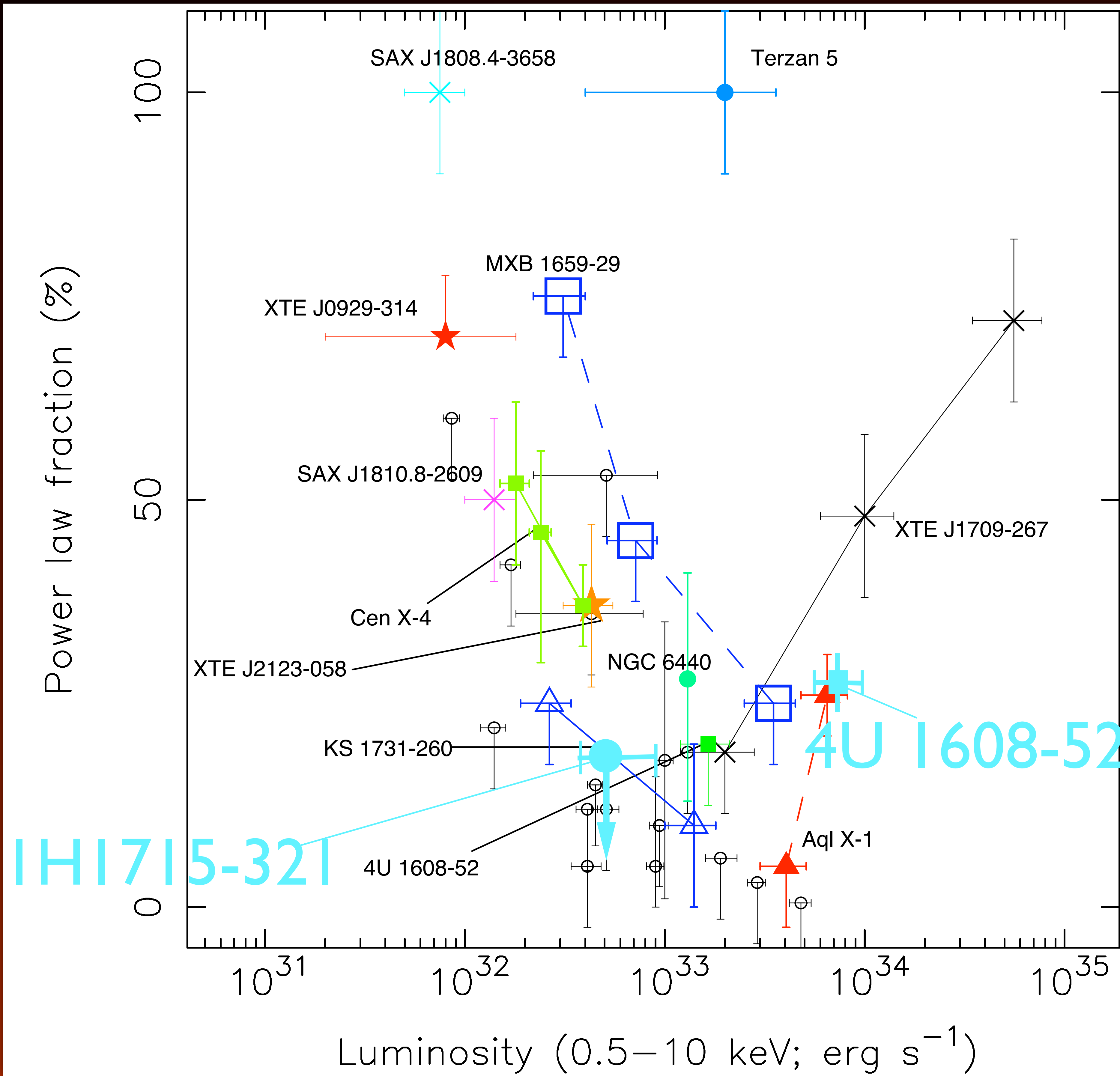




Variation in N_H from 5 to 10 x 10^{21} cm^{-2}

Campana et al. 2003, 2004

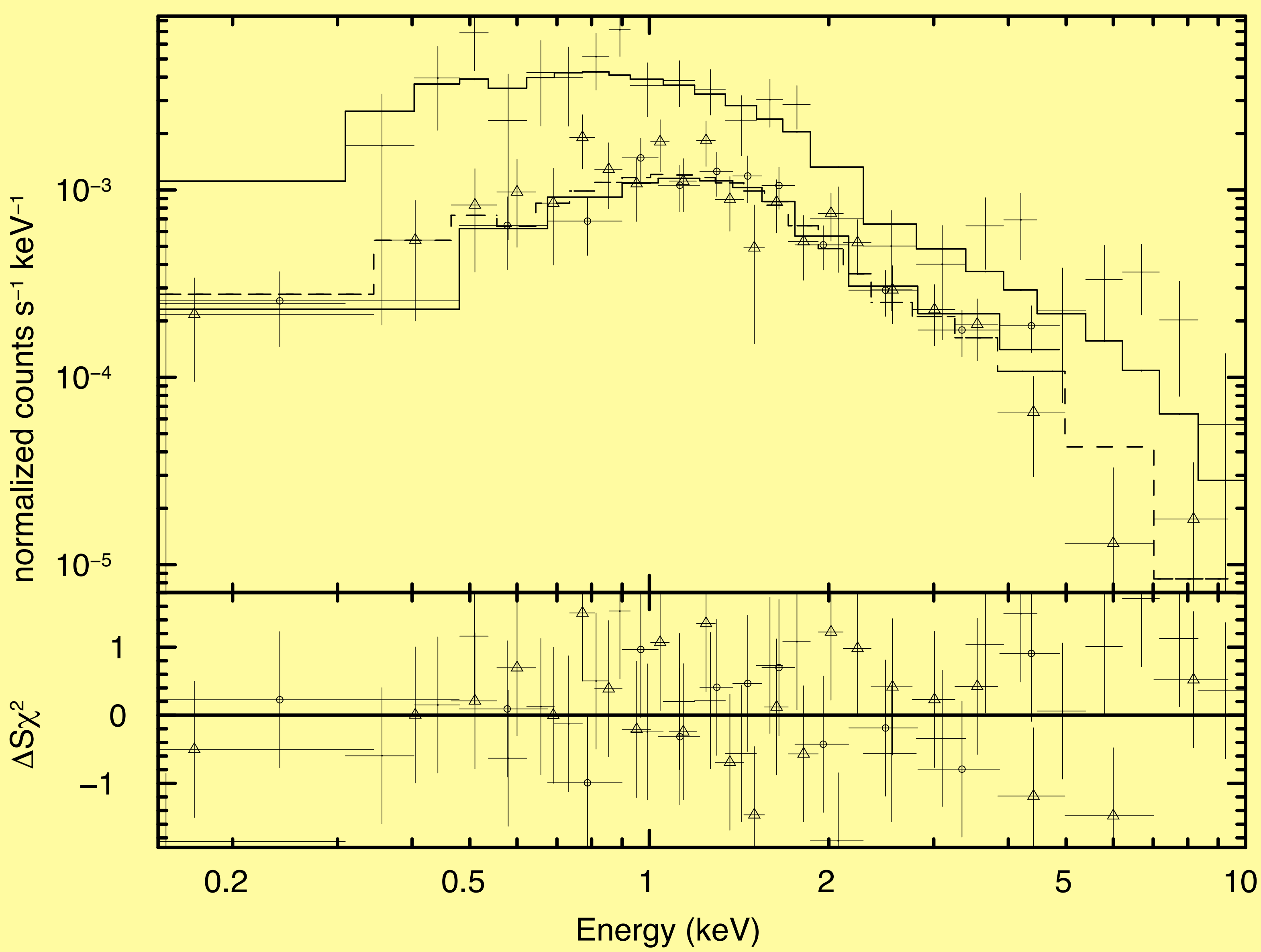
Observed quiescent properties



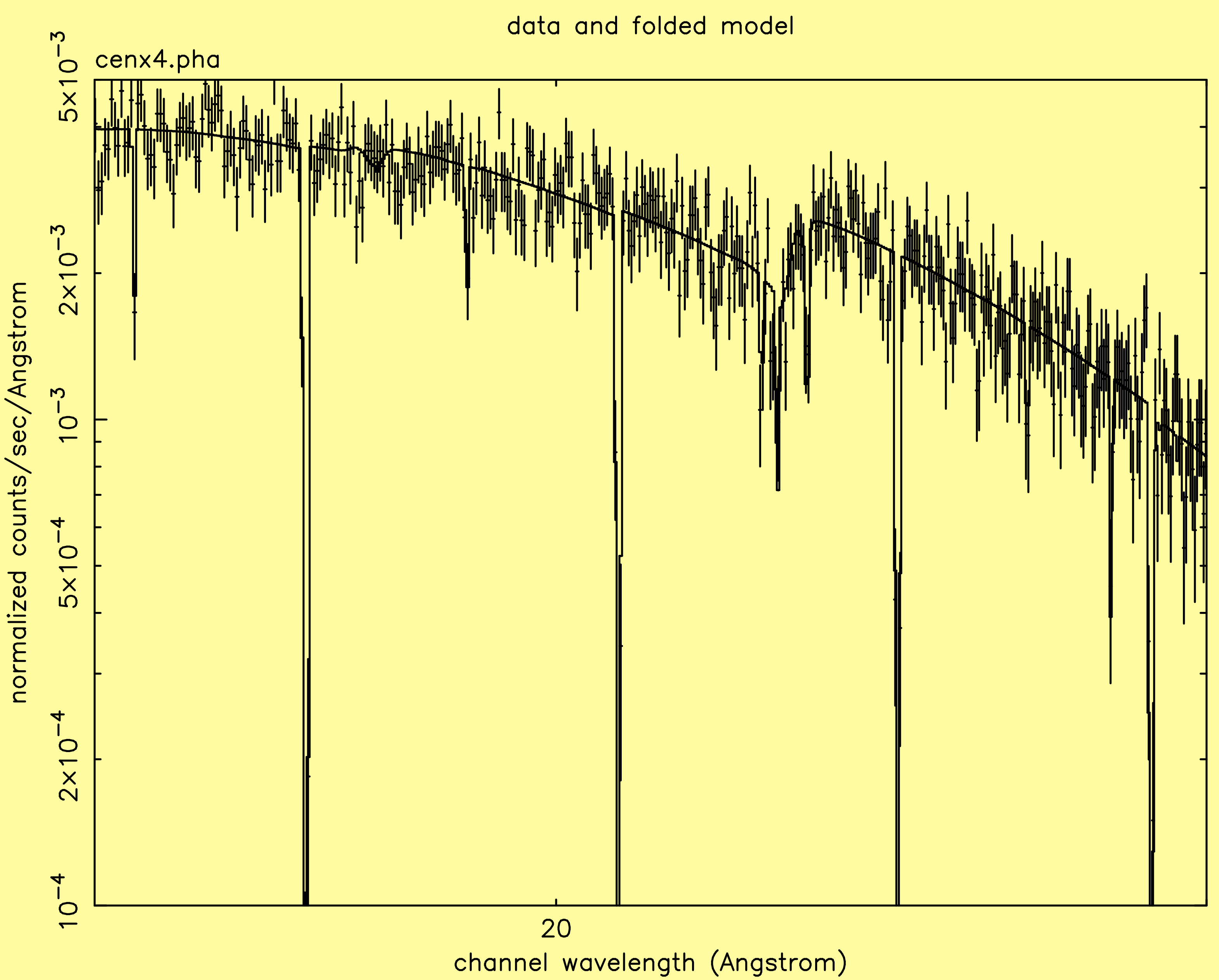
Jonker et al. 2004

Observations: Wijnands et al. 2001, 2002, 2005, Rutledge et al. 1999, 2001, 2002, Campana et al. 2002, Jonker et al. 2003, 2004, 2005, 2007, Tomsick et al. 2003, Heinke et al. 2003, 2006, Cackett et al. 2006

Powerlaw varies in SAX J1808.4-3658



Long XMM observation of e.g. CenX-4



500 ksec, RGS1, simulation

Variability in N_H, BB, and or powerlaw component??

RGS1: determined N_H=0.91± 0.05 x 10 ^{21} cm^{-2}

Campana et al. 2003, 2004

Variation from 5 to 10 x 10^{21} cm^{-2}

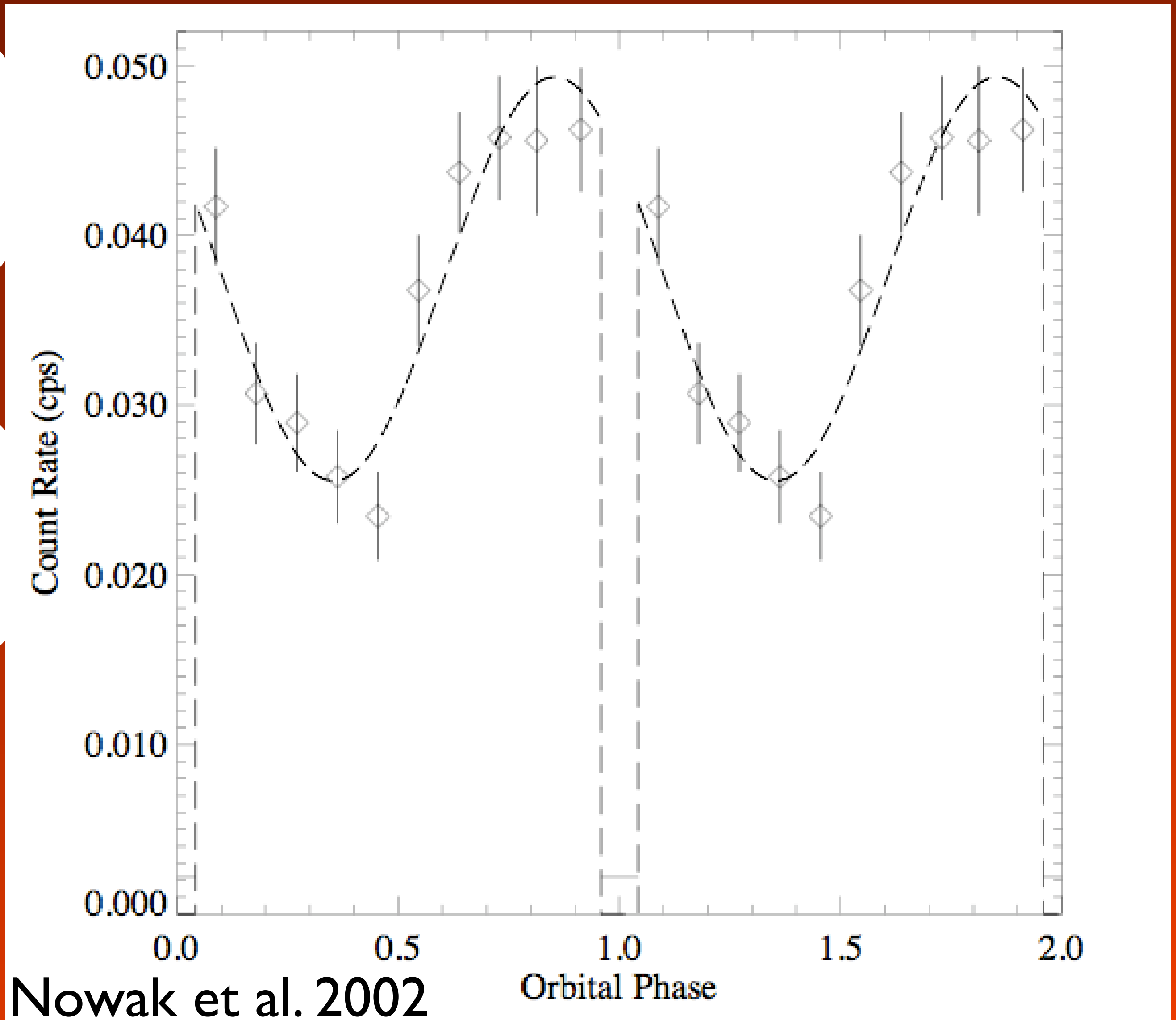
3: Determine inclination from eclipses in the X-ray light curve
Optical (VLT + X-shooter) + X-ray XMM-EPIC

$$\frac{P_{orb}K^3}{2\pi G} = \frac{M_{NS}\, sin^3 i}{(1+q)^2}$$

$$\frac{v\ sin\ i}{K} = 0.46[(1+q)^2 q]^{1/3}$$

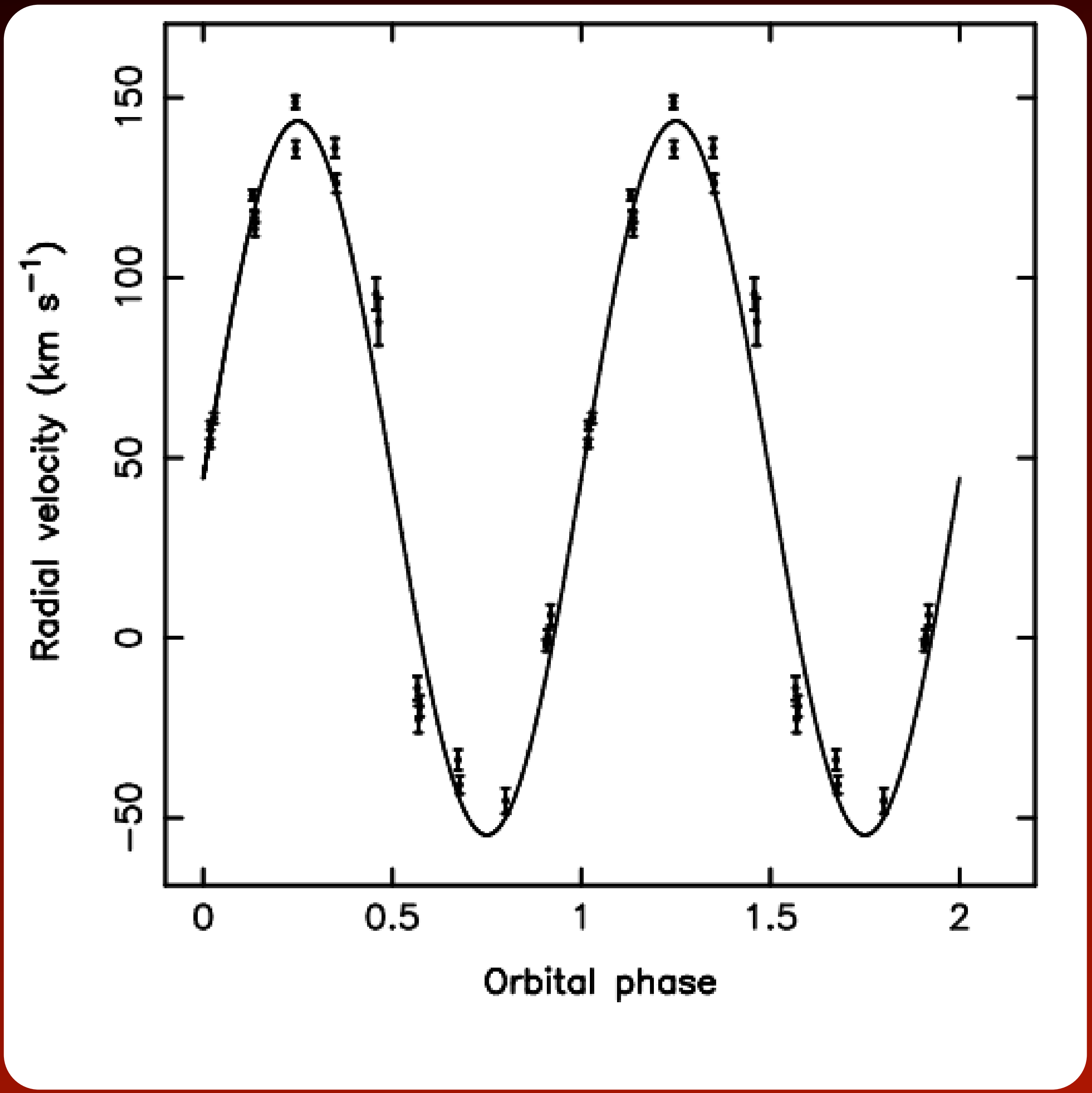
$$\Delta\phi^2 = \left(\frac{0.49\,q^{2/3}}{0.6\,q^{2/3}+\ln(1+q^{1/3})}\right)^2 - \left(\frac{\cos i}{1+q}\right)^2$$

Horne 1985

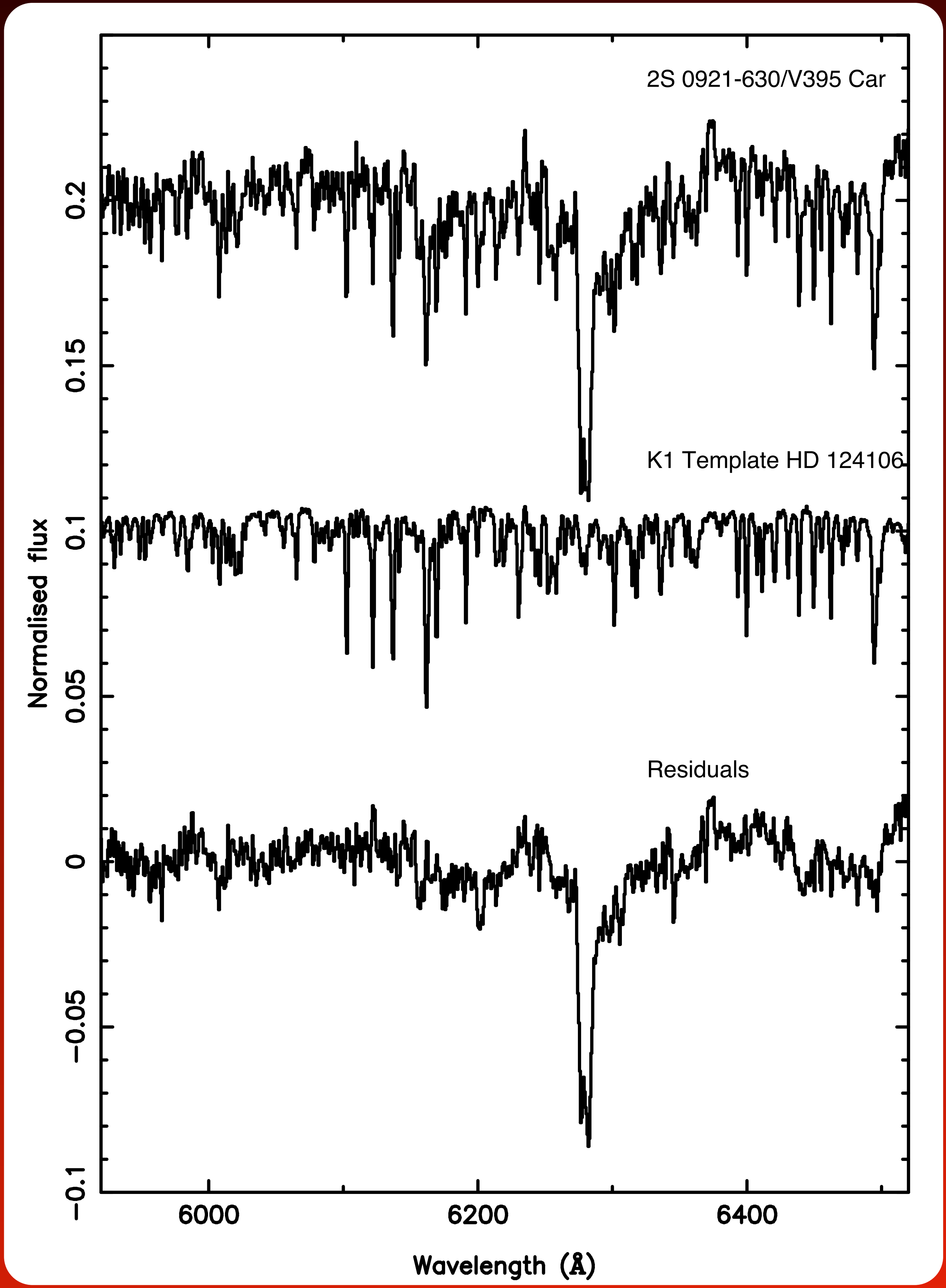


Nowak et al. 2002

Optical spectroscopic observations

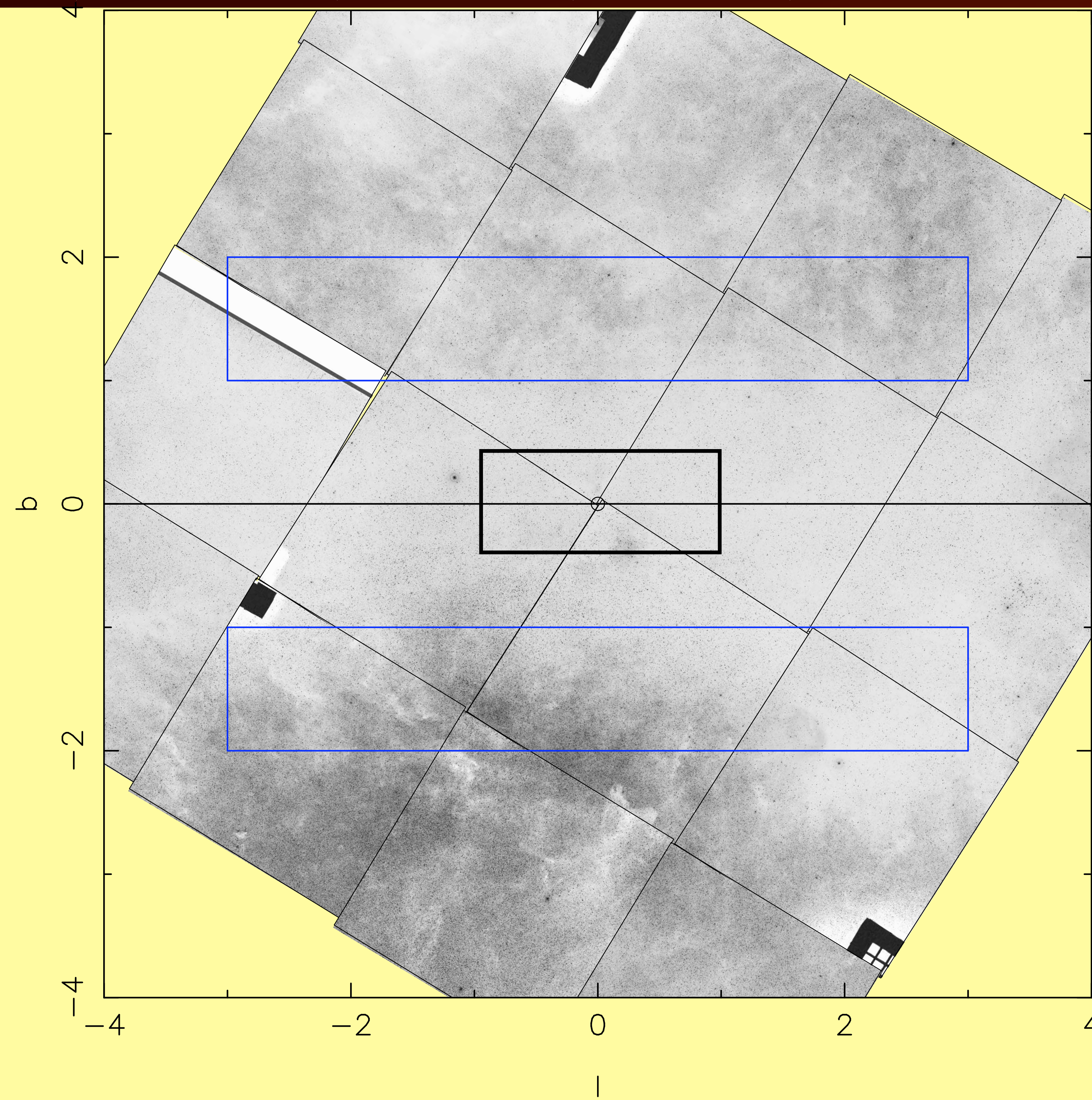


Jonker et al. 2005



Galactic Bulge Survey

PI: Jonker, Co-I's: Bassa, Maccarone, Nelemans, In 't Zand eo



Predictions:

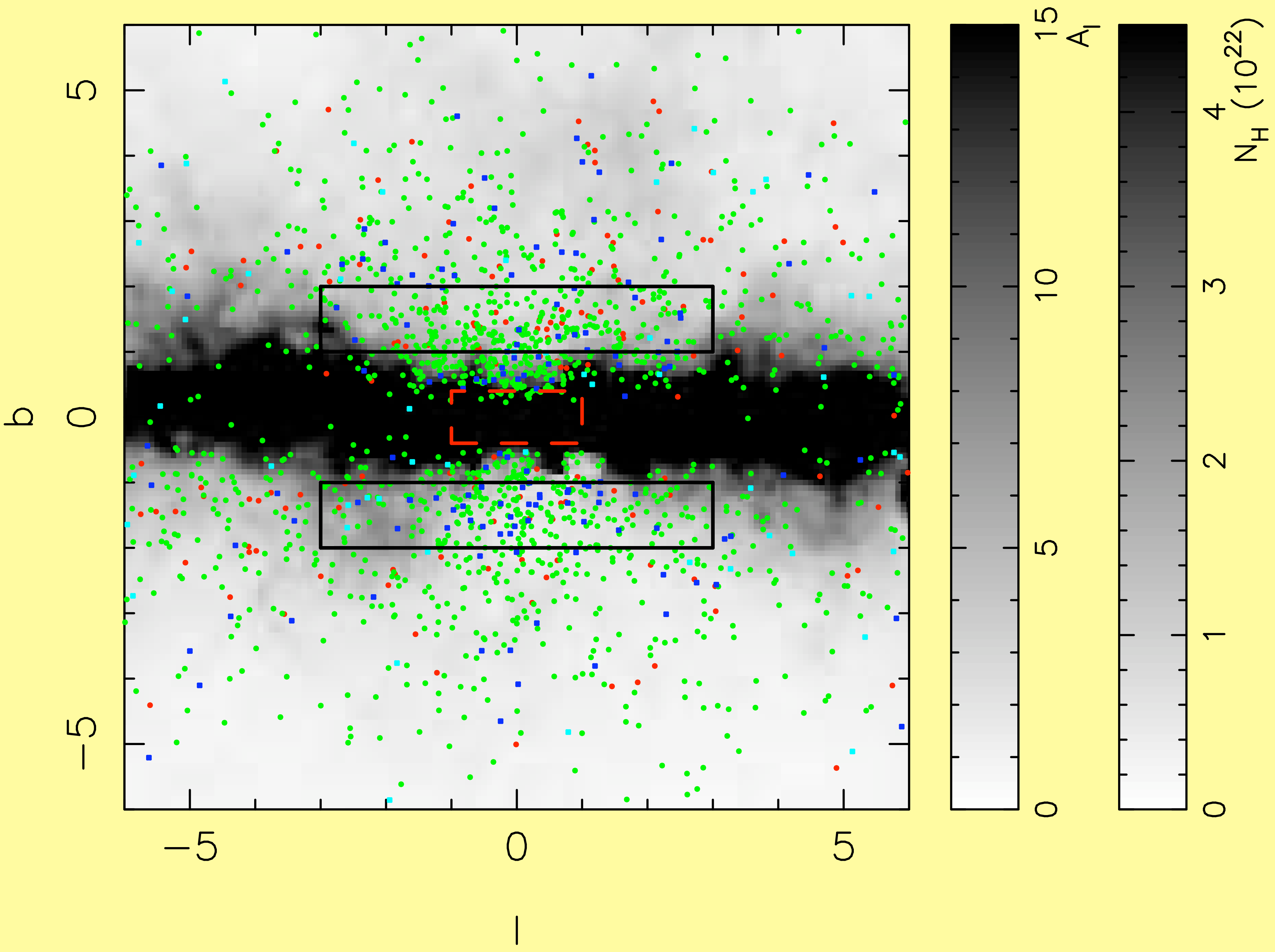
500 LMXBs

detectable in optical!

≳10 eclipsing qLMXB

Search for quiescent, eclipsing LMXBs with the Galactic Bulge Survey or eRosita

Galactic Bulge Survey:



Optical images in hand: area covered with VISTA, UKIDDS, EGAPS (optical/NIR)

Conclusion:

XMM has a vital role in our attempts to constrain the neutron star equation of state

Ideally need spacecraft dithering