A deep HETGS observation of MCG-6-30-15 : a narrow view of the broad iron line

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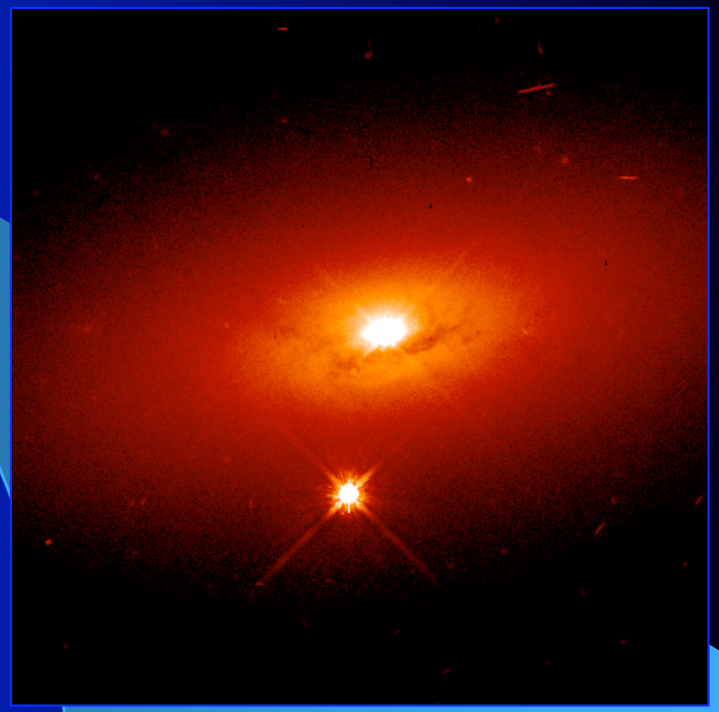
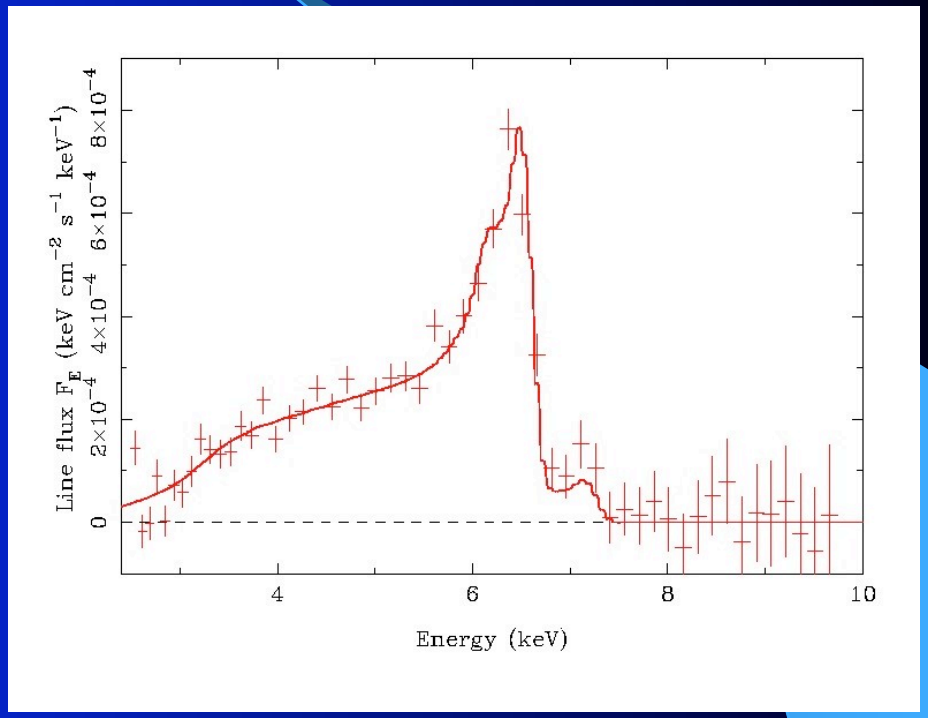


Outline

- Introduction to MCG-6-30-15
- Absorption lines from highly ionized outflows
- The robustness of the broad iron emission line

MCG-6-30-15

- Nearby (z=0.008) Seyfert 1.2 galaxy
- Borderline member of the NLS1 class
- Intensively studied because of its warm absorber and relativistic broad iron emission line



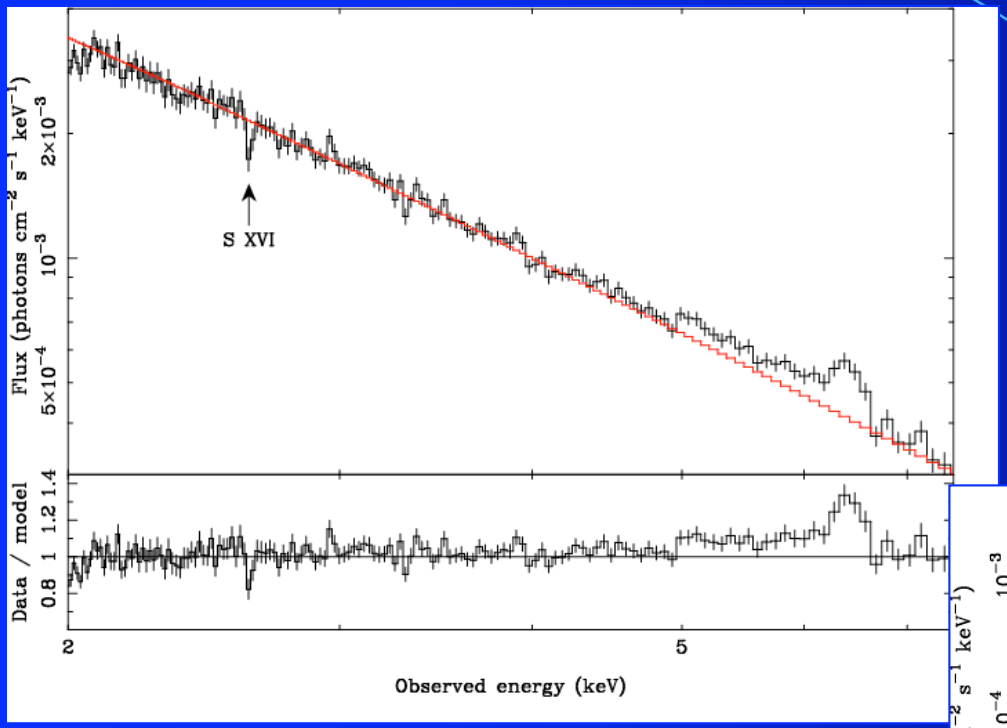
Fabian et al. (2002)

The deep HETGS observation

- Motivation
  - Detailed study of well-known warm absorber
  - First high s/n, high-resolution study of iron-band region of spectrum… assess role of absorption in confusing broad line studies
- Performed 19-27th May 2004
- 522ks good exposure time
- Will just discuss hard band (>2keV) results here.

Young et al., 2005, ApJ, 631, 733

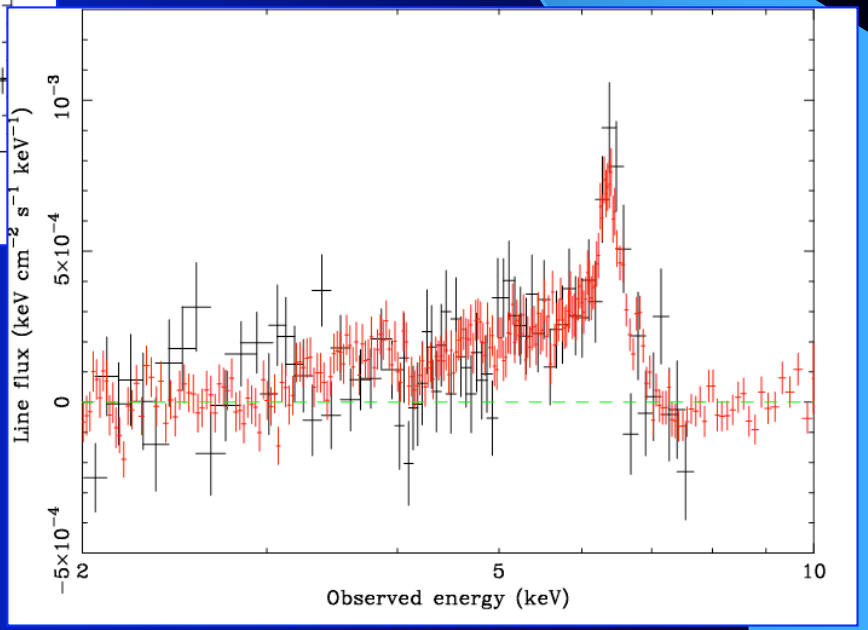
Binned spectrum



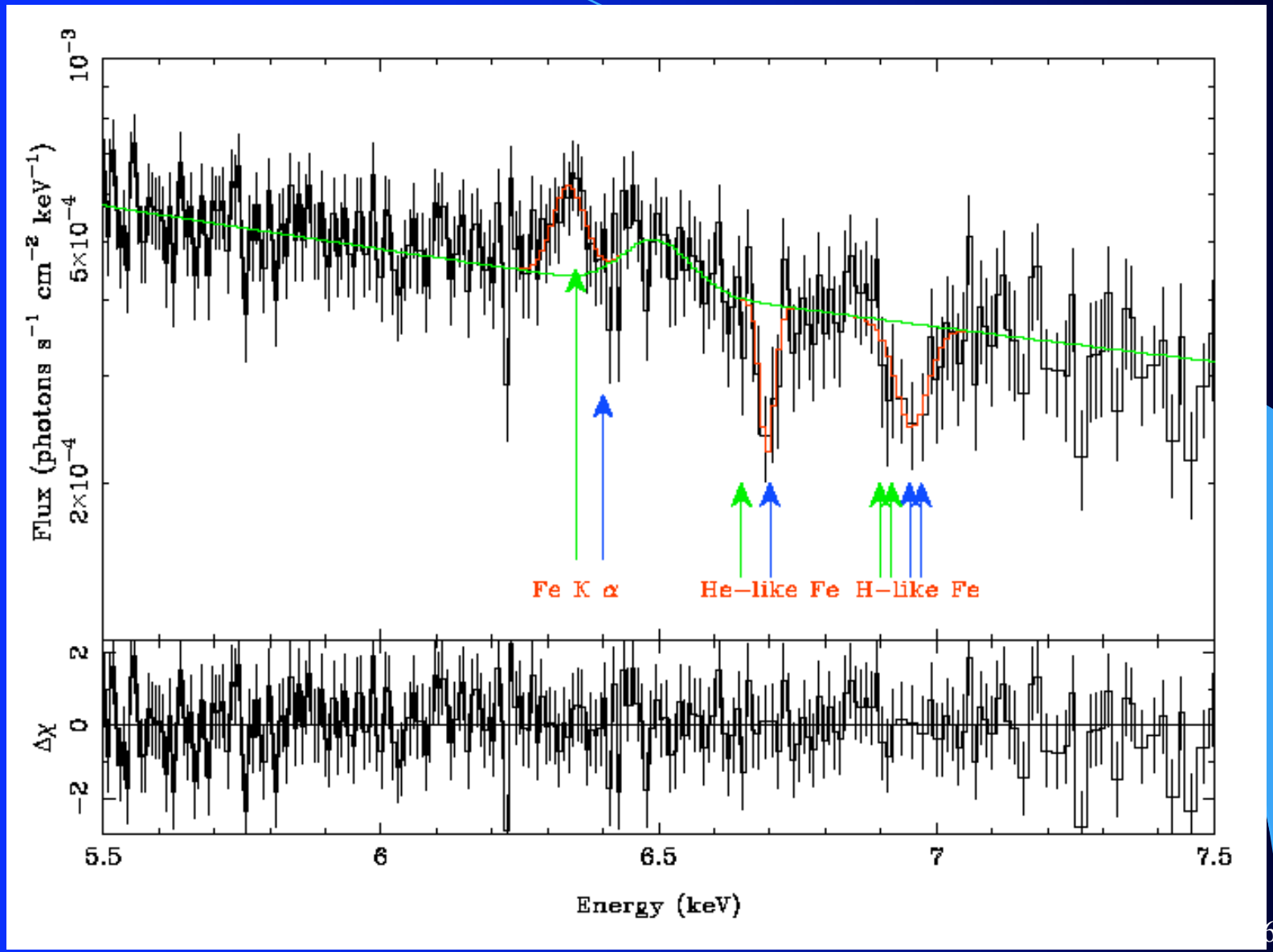
0.067A bins; powerlaw fitted from 2.25-2.5keV to 7-7.5keV

Can recover broad iron line (but not extreme red-wing)

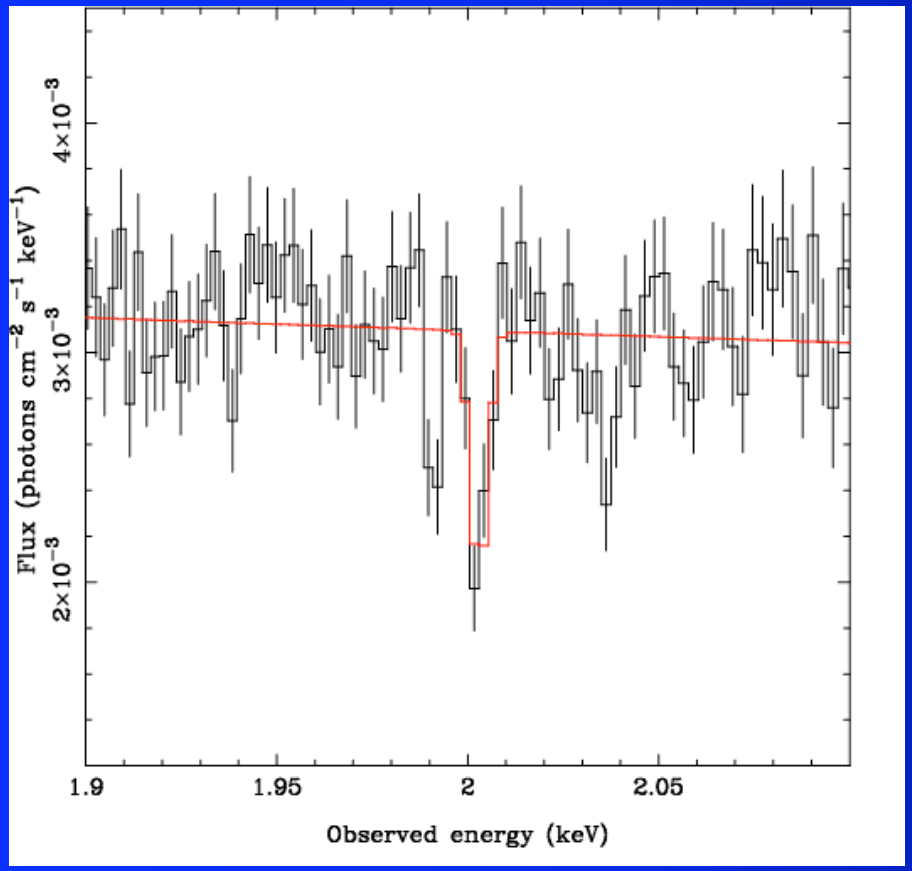
HETGS & EPIC-pn

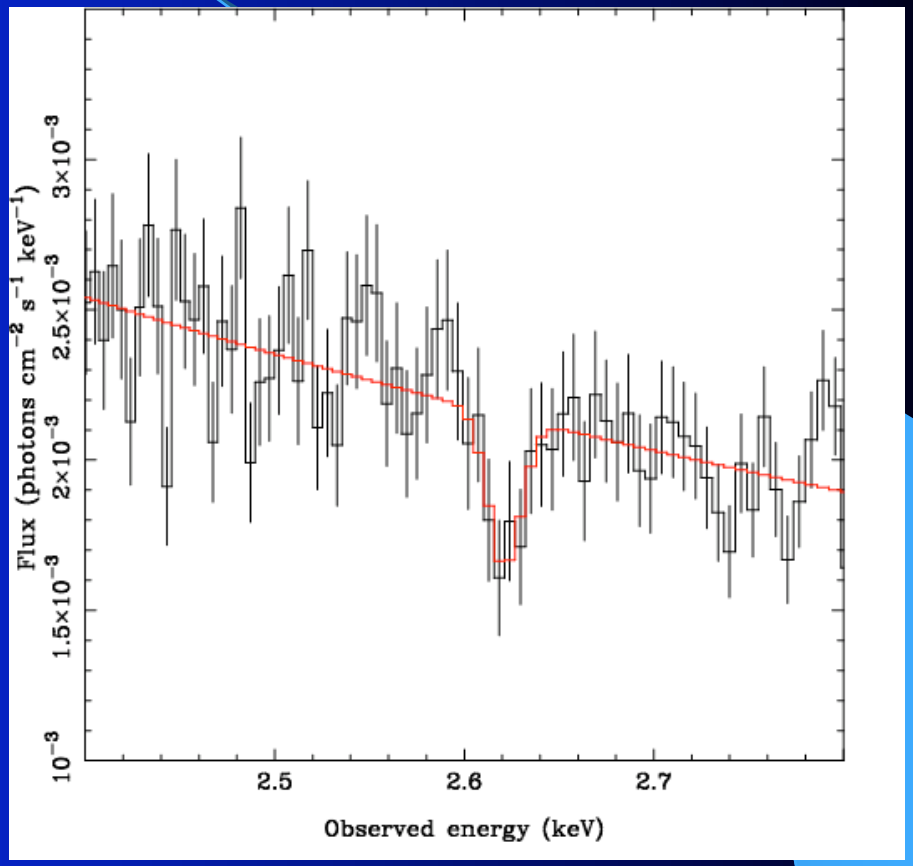


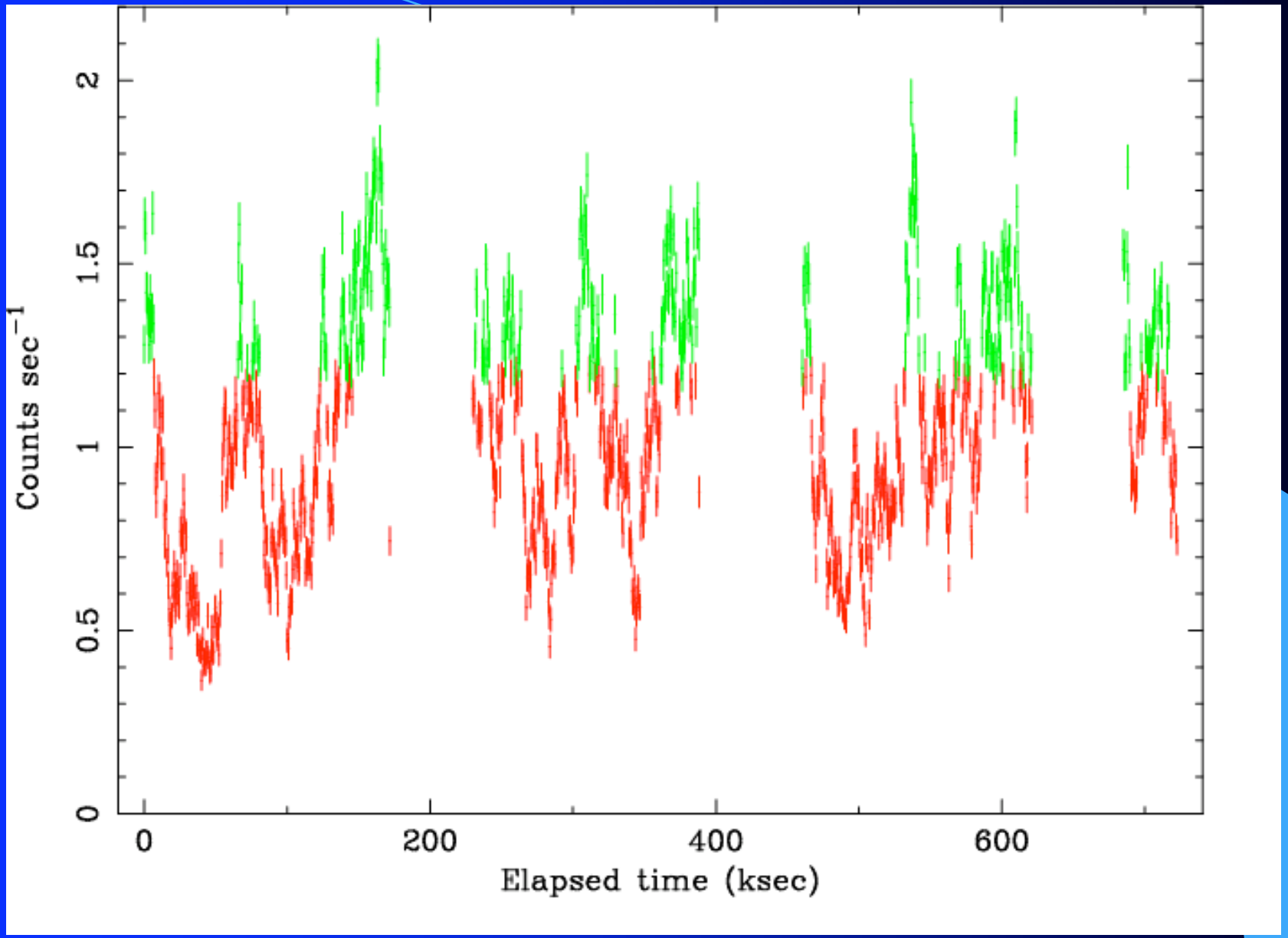
Full resolution spectrum

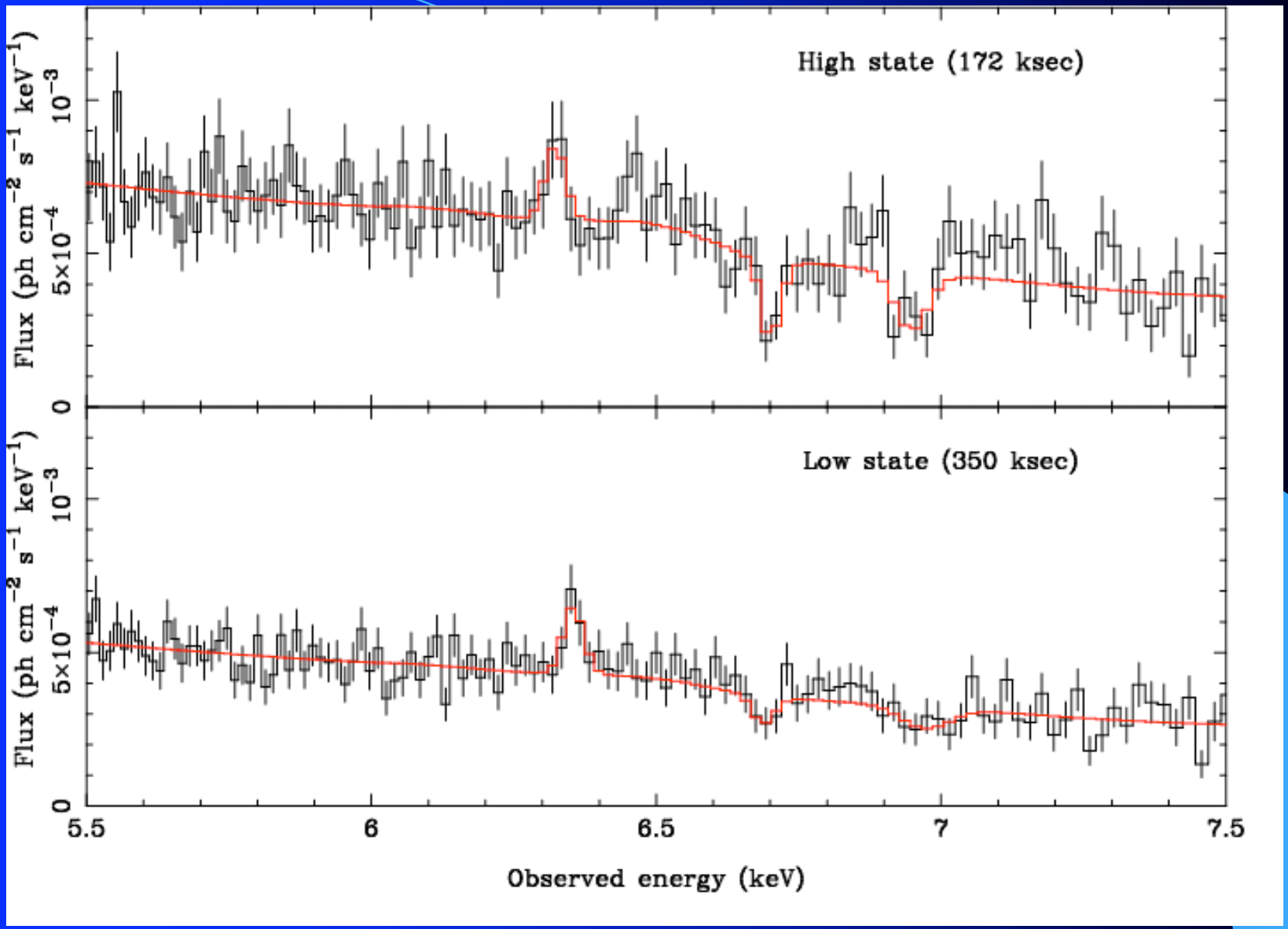


Other signatures of the same flow… SiXIV and SXVI






Counts sec^{-1}
0
0.5
1
1.5
2
0
200
400
600
Elapsed time (ksec)


High state (172 ksec)
Low state (350 ksec)
Flux (ph cm^{-2} s^{-1} keV^{-1})
0
5×10^{-4}
10^{-3}
5.5
6
6.5
7
7.5
Observed energy (keV)

The highly ionized WA

- 18±6eV Fe25 line; 21±10eV Fe26 line
- Column densities and velocities…
  - $N_{Fe25}=3\times10^{17}$-3×10^{18}/cm^2 (b=500-100km/s)
  - $N_{Fe26}=6\times10^{17}$-4×10^{19}/cm^2 (b=500-100km/s)
  - Ionization parameter; log(ξ)=3.6
  - Equiv-H column $N_H=1.6\times10^{23}$ cm^{-2}
  - Outflow; V=2.0±0.8 × 10^{3}km/s
  - *[or, kinematically consistent with being local z=0 material; ala McKernan et al. 2004]*

Physical properties of the highly ionized WA…

- Constraints on location…

$$\xi = \frac{L_{\rm ion}}{nr^2} = \frac{L_{\rm ion}}{Nr}\left(\frac{\Delta r}{r}\right)$$

  - Must be close to central engine; R<0.02pc
- Constraints on mass outflow rate

$$\dot{M} = \Omega r^2 n v m_p = \Omega\left(\frac{L_{\rm ion}}{\xi}\right) v m_p$$

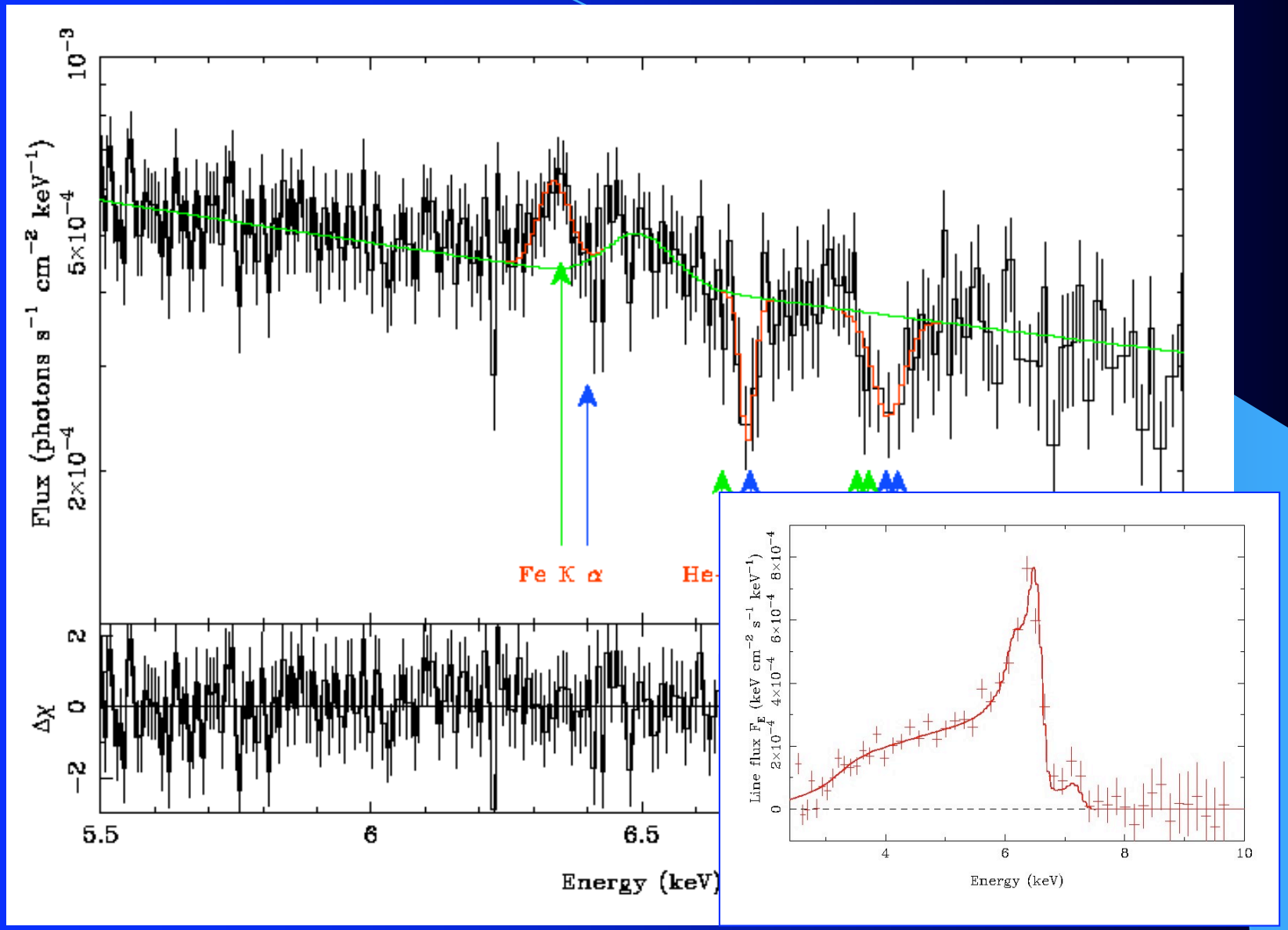
  - Mass flow rate = 0.3 ($\Omega/4\pi$) M_{sun}/yr
- Kinetic energy = $4\times10^{41}(\Omega/4\pi)$ erg/s

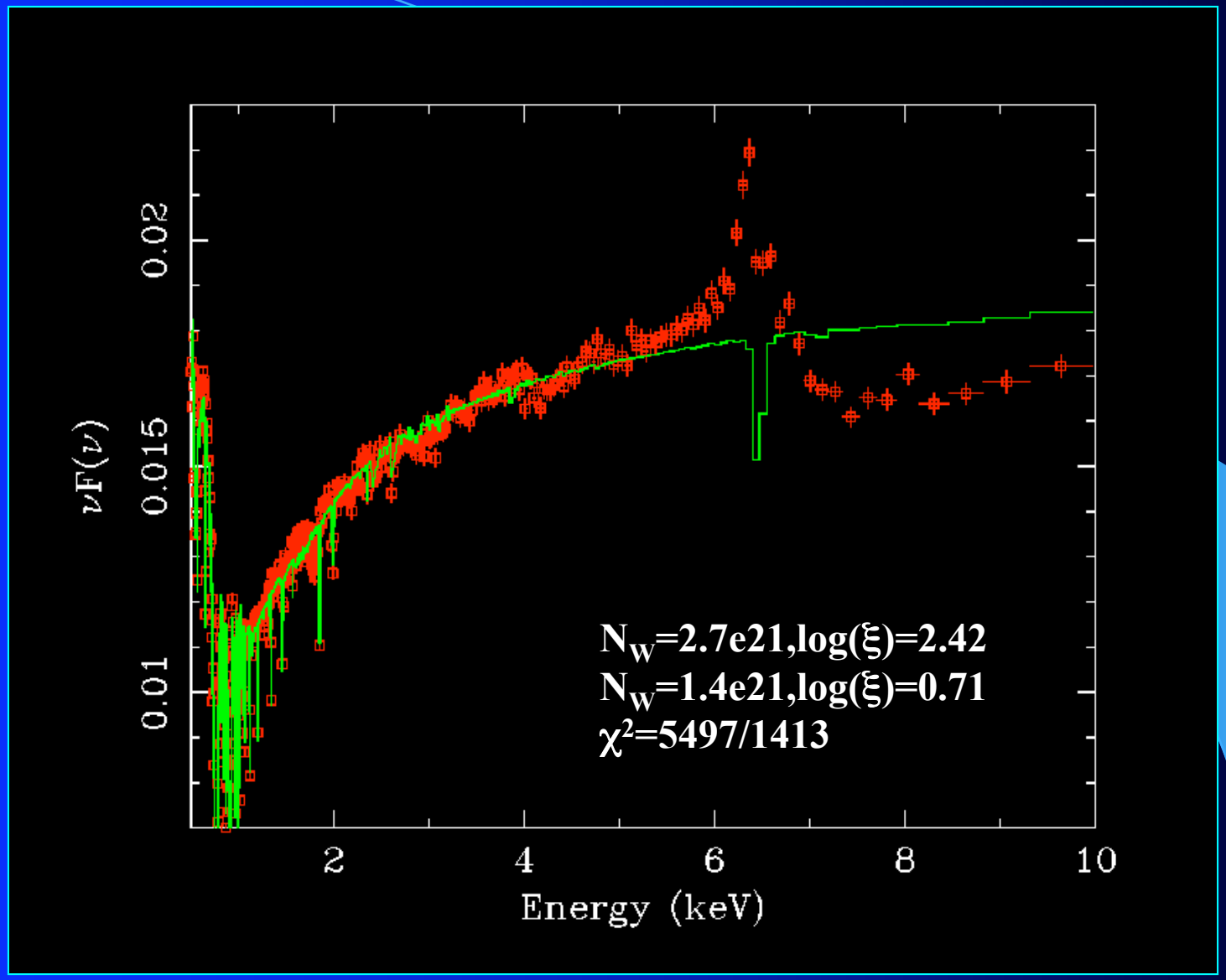
All mass and energy fluxes are for $\Omega=4\pi$

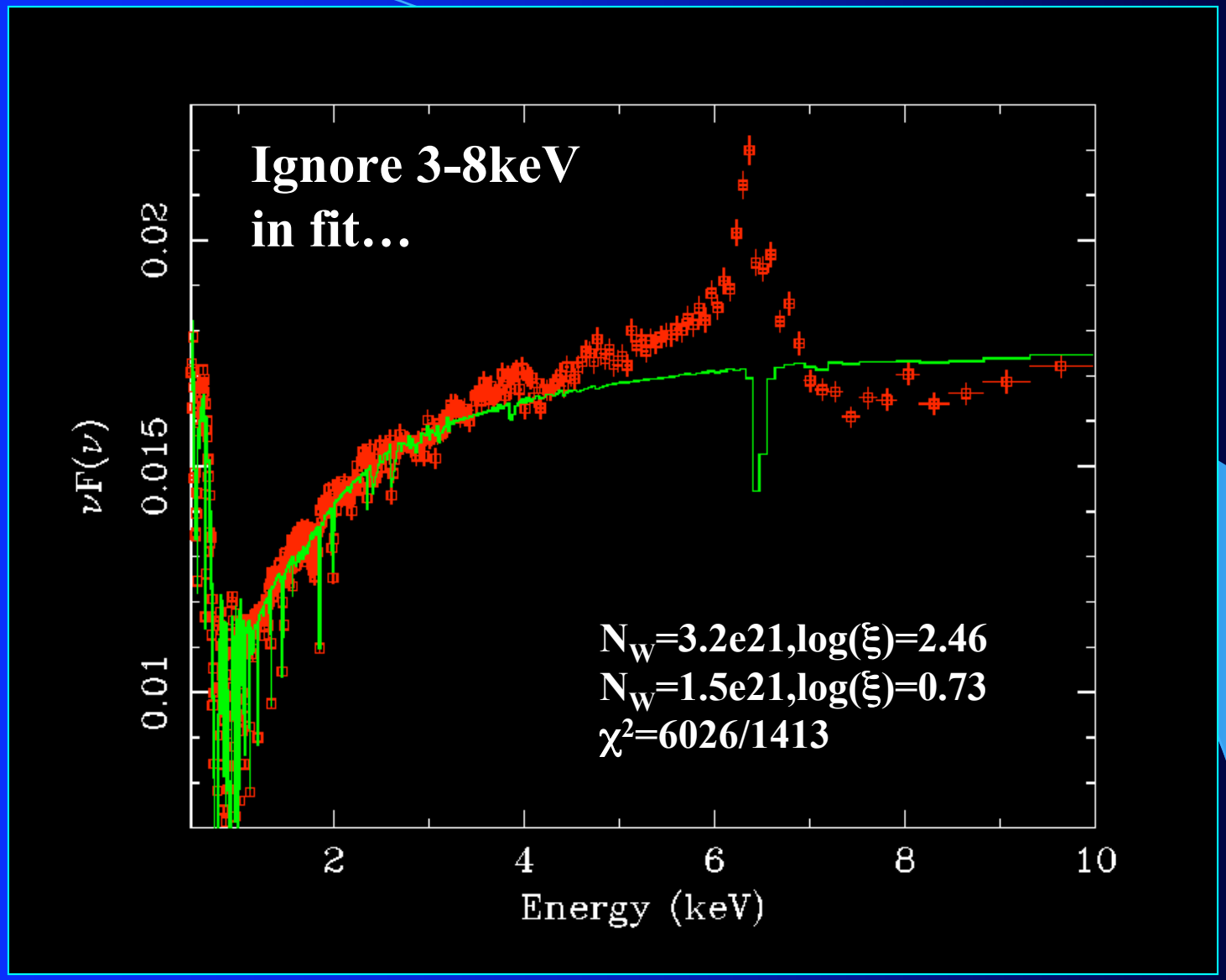
	Maximum Radius (pc)	Mass Flux (M_{sun}/yr)	Energy Flux (erg/s)
log(ξ)=3.6 V=2000km/s	0.02	0.16	2×10^{41}
log(x)=3.4 V=1600km/s	0.14	0.30	2×10^{41}
log(x)=2.1 V=200km/s	19	0.75	9×10^{39}
log(x)=0.2 V=200km/s	1400	60	8×10^{41}

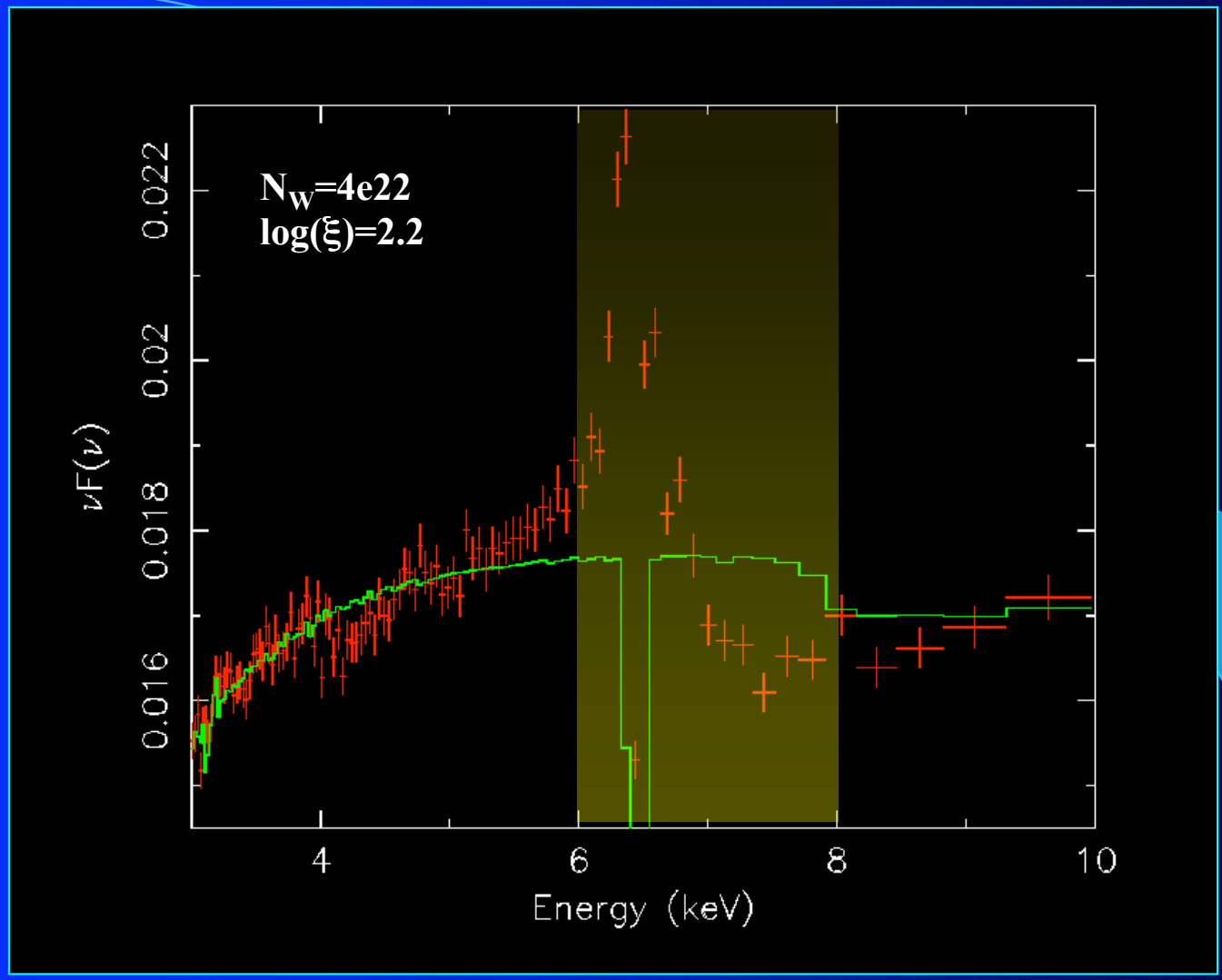
Last three rows from McKernan, Yaqoob & CSR, submitted

Full resolution spectrum

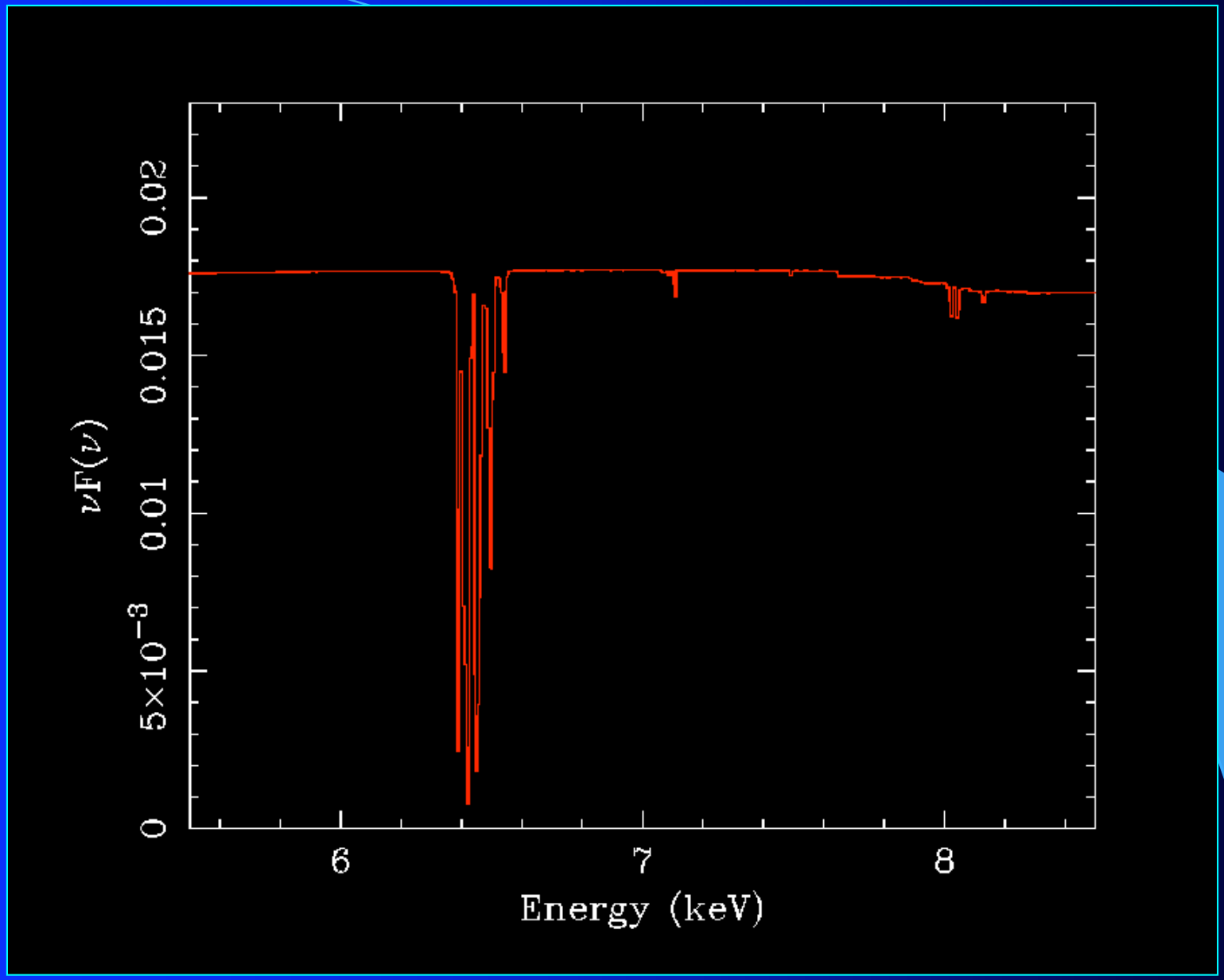



νF(ν)
0.01
0.015
0.02
2
4
6
8
10
Energy (keV)
N_W=2.7e21,log(ξ)=2.42
N_W=1.4e21,log(ξ)=0.71
χ²=5497/1413

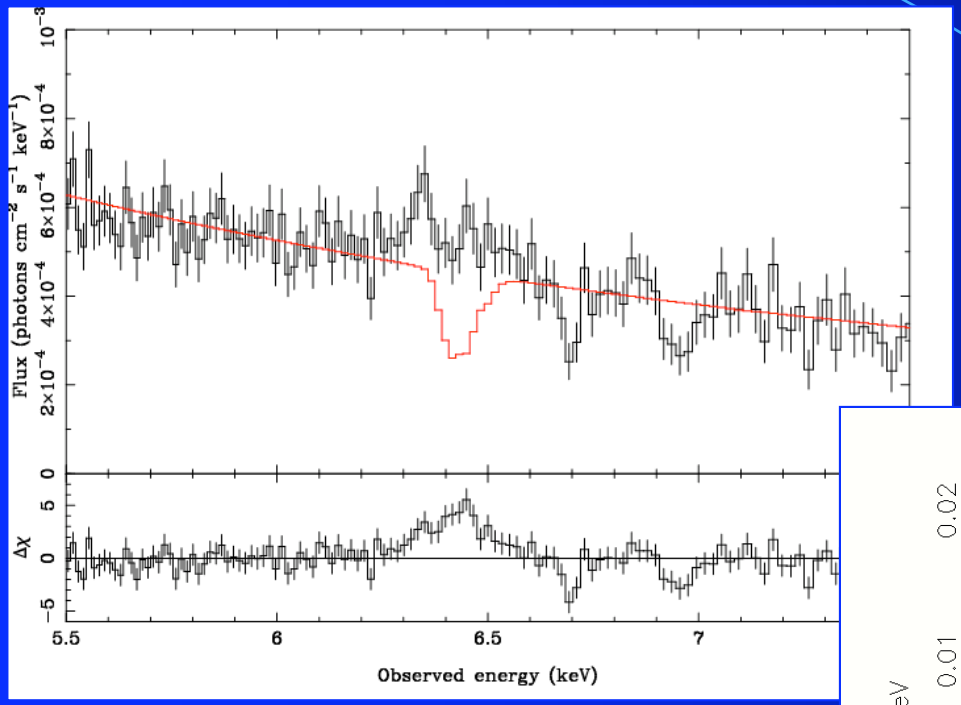

Ignore 3-8keV
in fit…
N_W=3.2e21,log(ξ)=2.46
N_W=1.5e21,log(ξ)=0.73
χ^2=6026/1413
νF(ν)
0.01
0.015
0.02
2
4
6
8
10
Energy (keV)

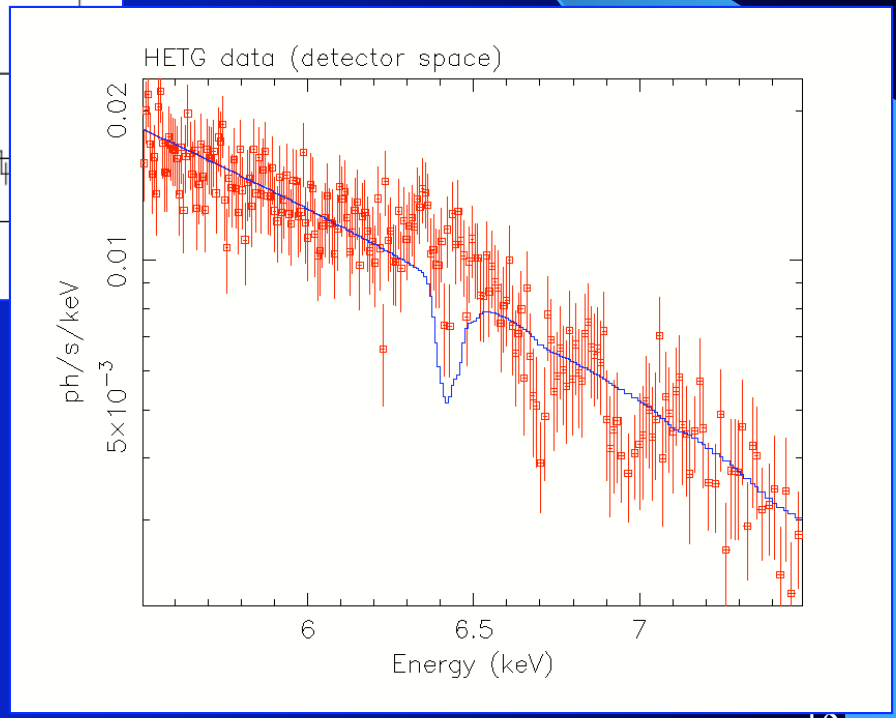


- Fitting 3-6keV and 8-10keV band, can reproduce “red-wing”curvature from iron-L absorption (Kinkhabwala 2003; PhD thesis)
- Generic prediction - significant iron K line absorption from FeXVII-FeXXIII (~6.4-6.6 keV)


νF(ν)
0
5×10⁻³
0.01
0.015
0.02
6
7
8
Energy (keV)

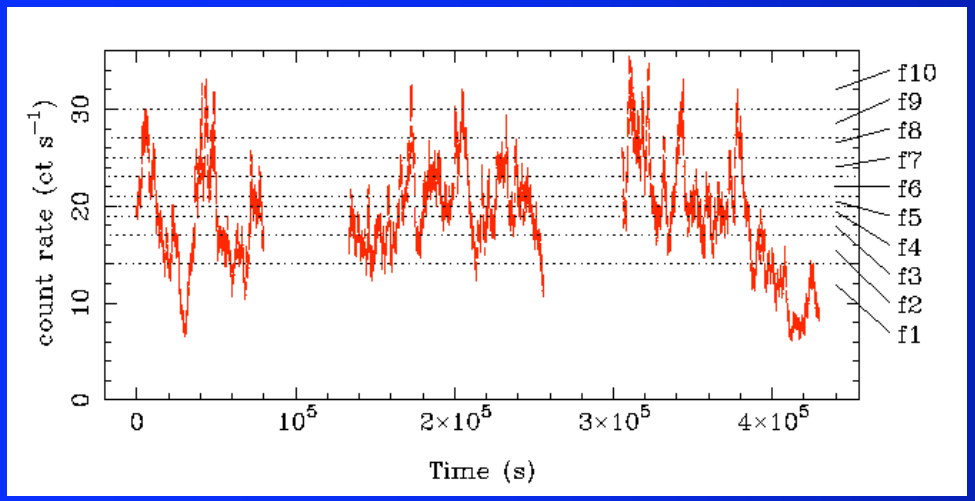
A broad line mimicking WA?

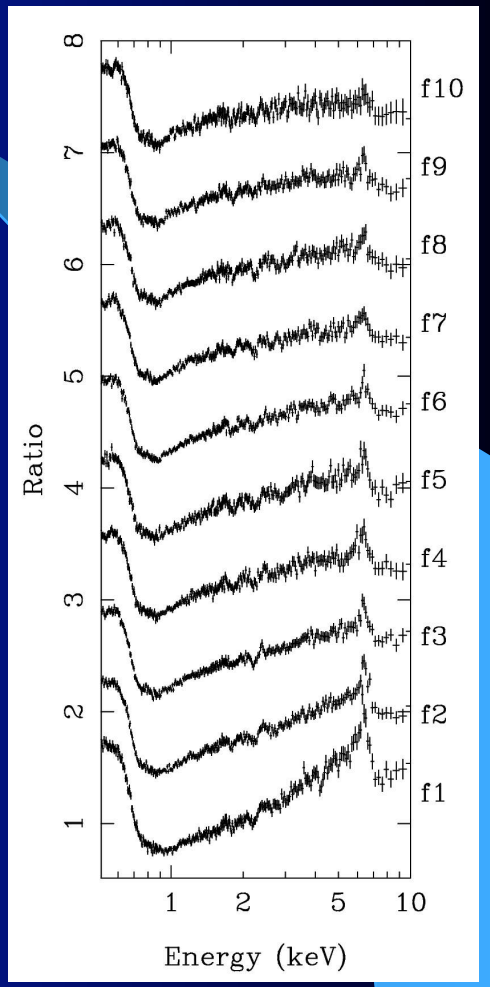




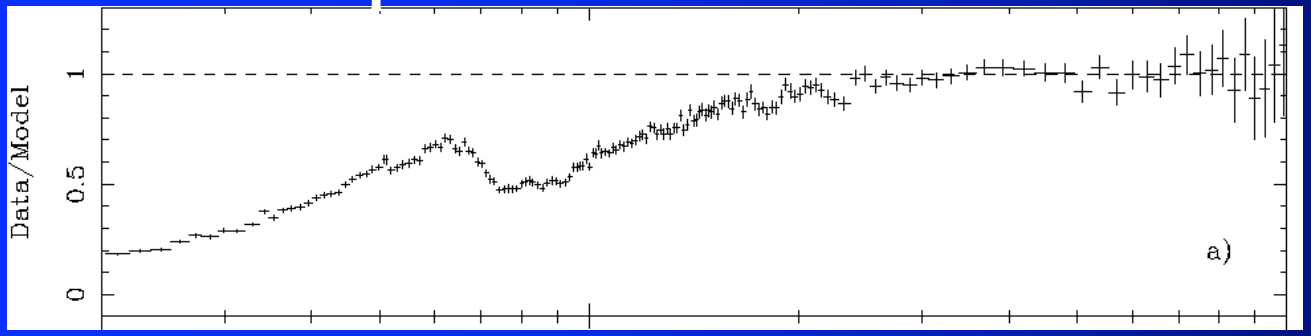
We clearly do not see the iron resonance absorption lines created by the species required to mimic the extended red-wing of the iron line

Consistent with XMM spectral variability…





Difference spectrum

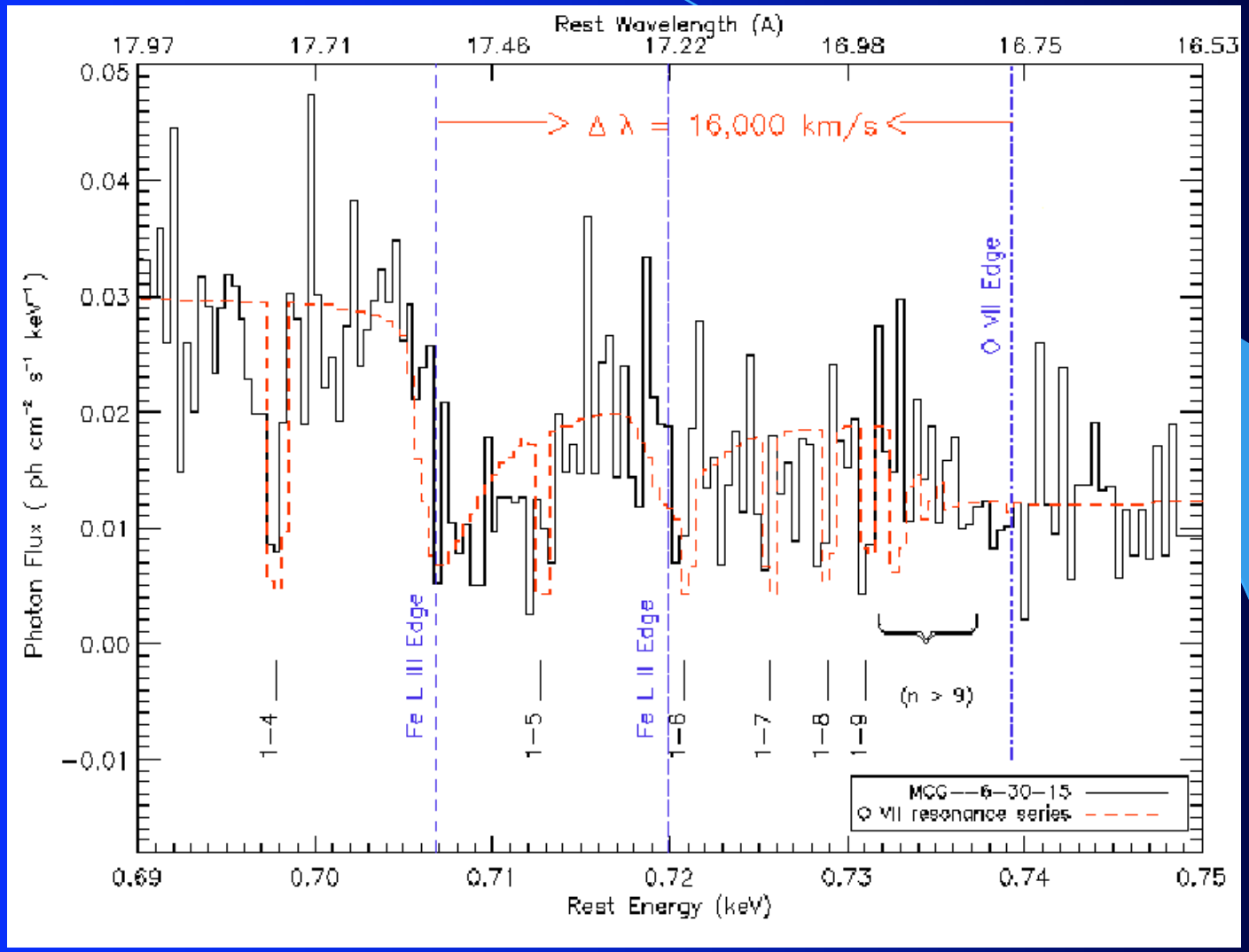


1keV 3 6

Conclusions

- Presented results from a deep (522ks) Chandra grating observation of MCG-6-30-15
- Reveals signatures of a highly ionized wind, possibly carrying significant energy flux
- Rules out presence of a “broad Fe line mimicking warm absorber”… predicted resonance absorption lines are plainly absent.
- Highlights importance of DEEP AGN spectroscopy

Dusty warm absorbers



Lee et al. (2001)