Chandra and XMM Observations of the ADC Source 2S0921-63

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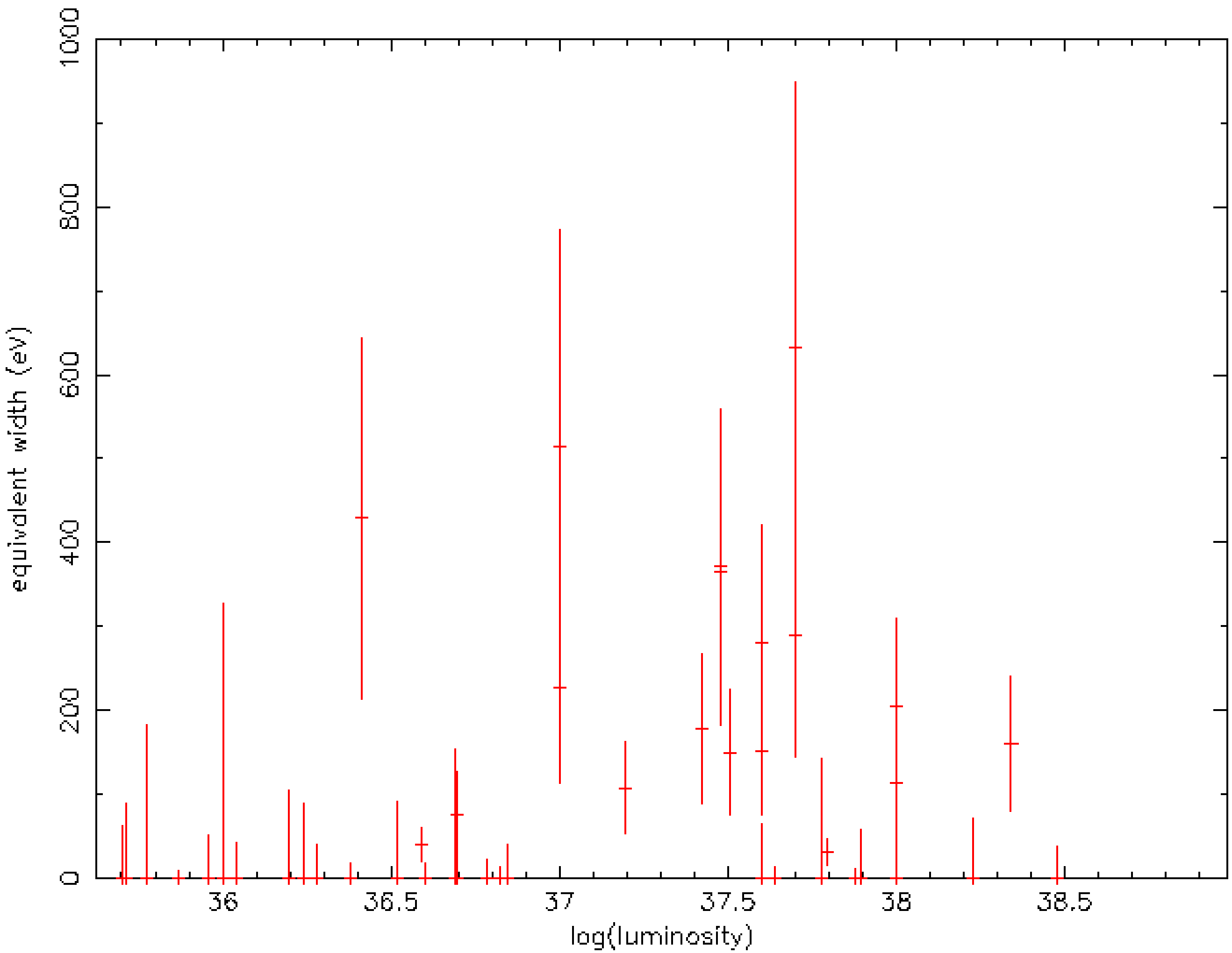
- **2S0921 is a 9.02 day binary with a K0 companion**
- **Distance estimate is D~7 kpc (Cowley et al. 1982) based on optical spectral type,**
- **This implies the X-ray luminosity is L~2.4 x 10^{35} erg/s**
- **L_x/L_{opt} ~1 implies intrinsic L_x is much greater than we observe .**
- **Mason et al (1987) fit X-ray light curve if i=75-90°**
- **The Fe K equivalent width is among the largest for LMXBs (Gottwald)**
- **We observed with Chandra HETG and XMM for 70 ks during X-ray minimum**

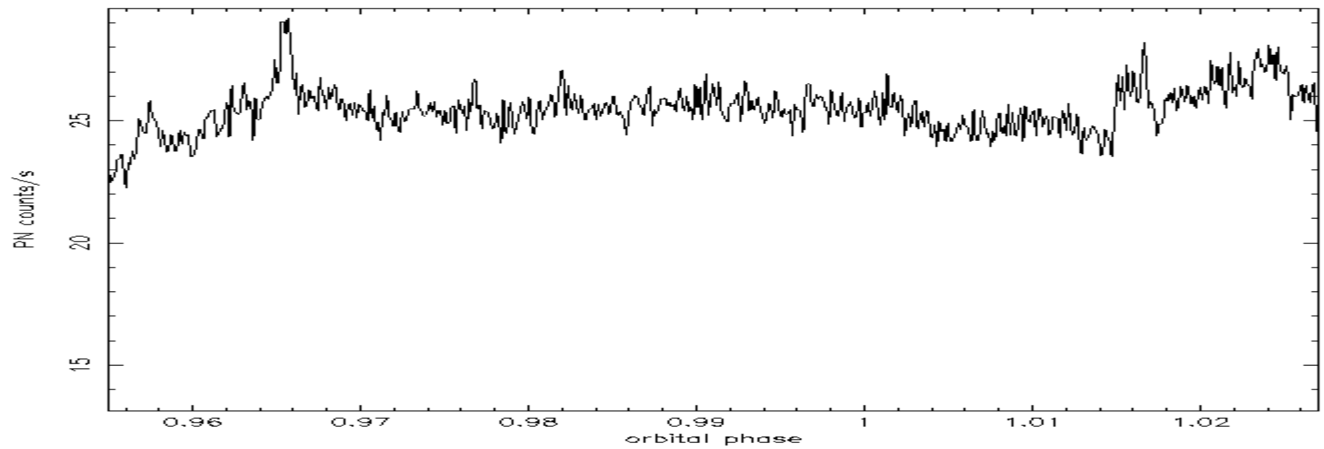
Accretion Disk Coronae

- Disks in X-ray binaries are expected to be heated to $\sim 10^7$-10^8K by Compton scattering of continuum photons from the compact object (Shakura and Sunyaev, 1971; White and Holt 1981; Begelman et al. 1982)
- Corona is expected to be marginally Compton thick, producing gradual light curves observed from high inclination sources.
- Intermediate ionization region is expected at base of corona
- If so, high inclination sources should have high intrinsic luminosities, and also large line equivalent widths
- Examination of existing equivalent width distribution (eg. Gottwald et al. , 1996) does not confirm this.

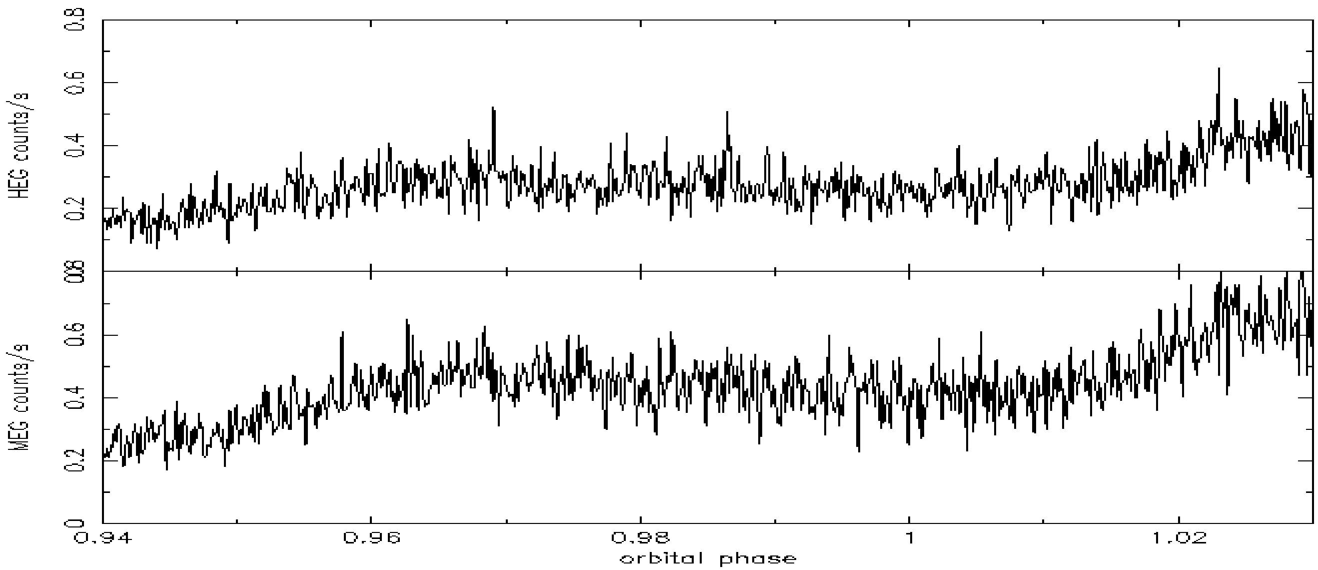
Fe K equivalent width vs. luminosity



Lightcurves

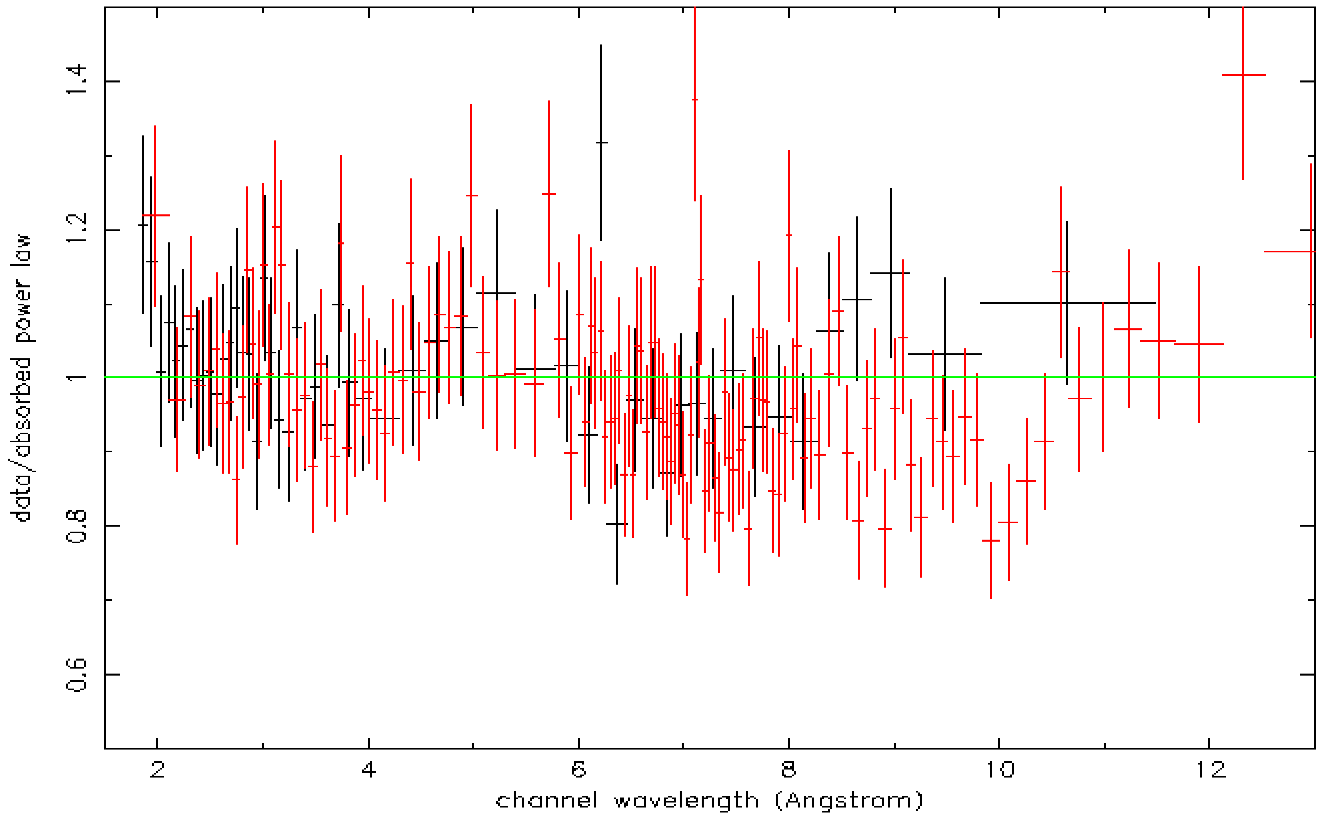


MOS

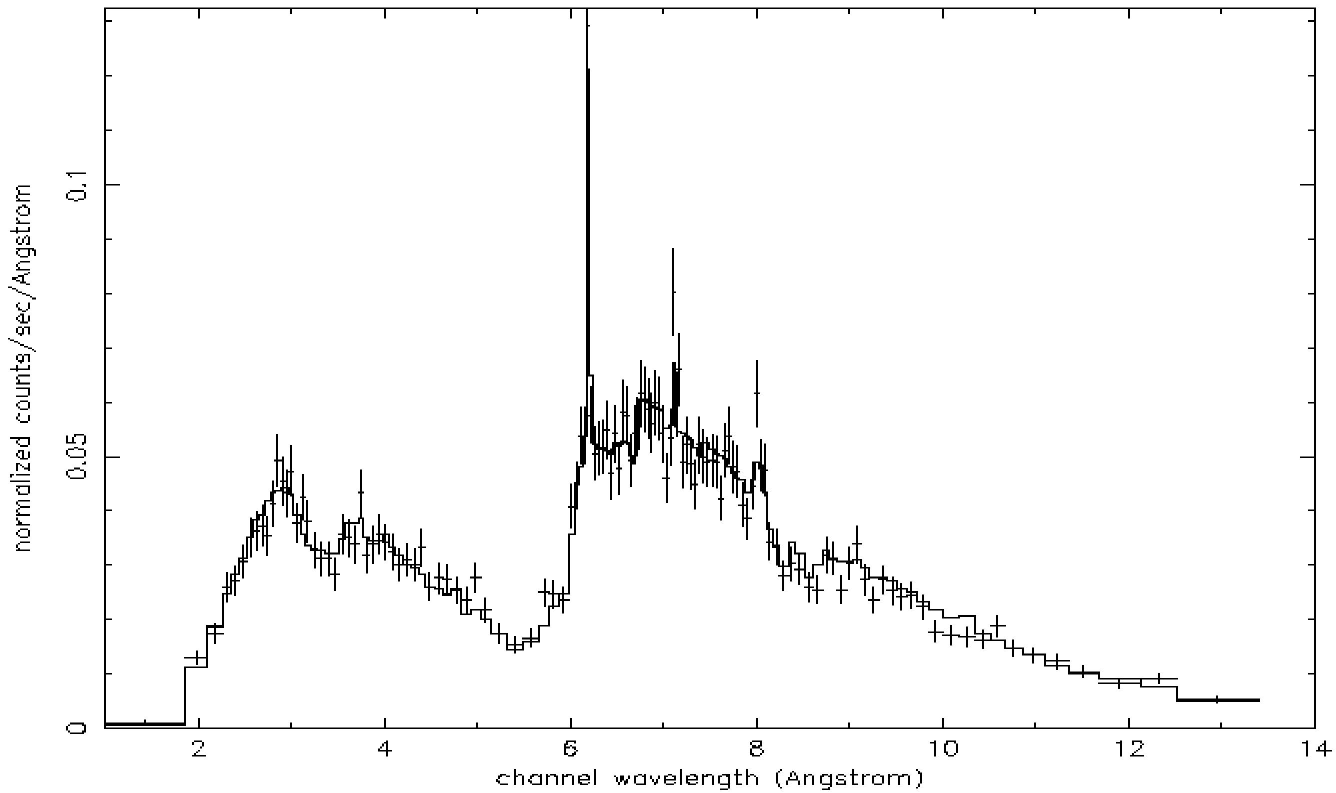


HEG

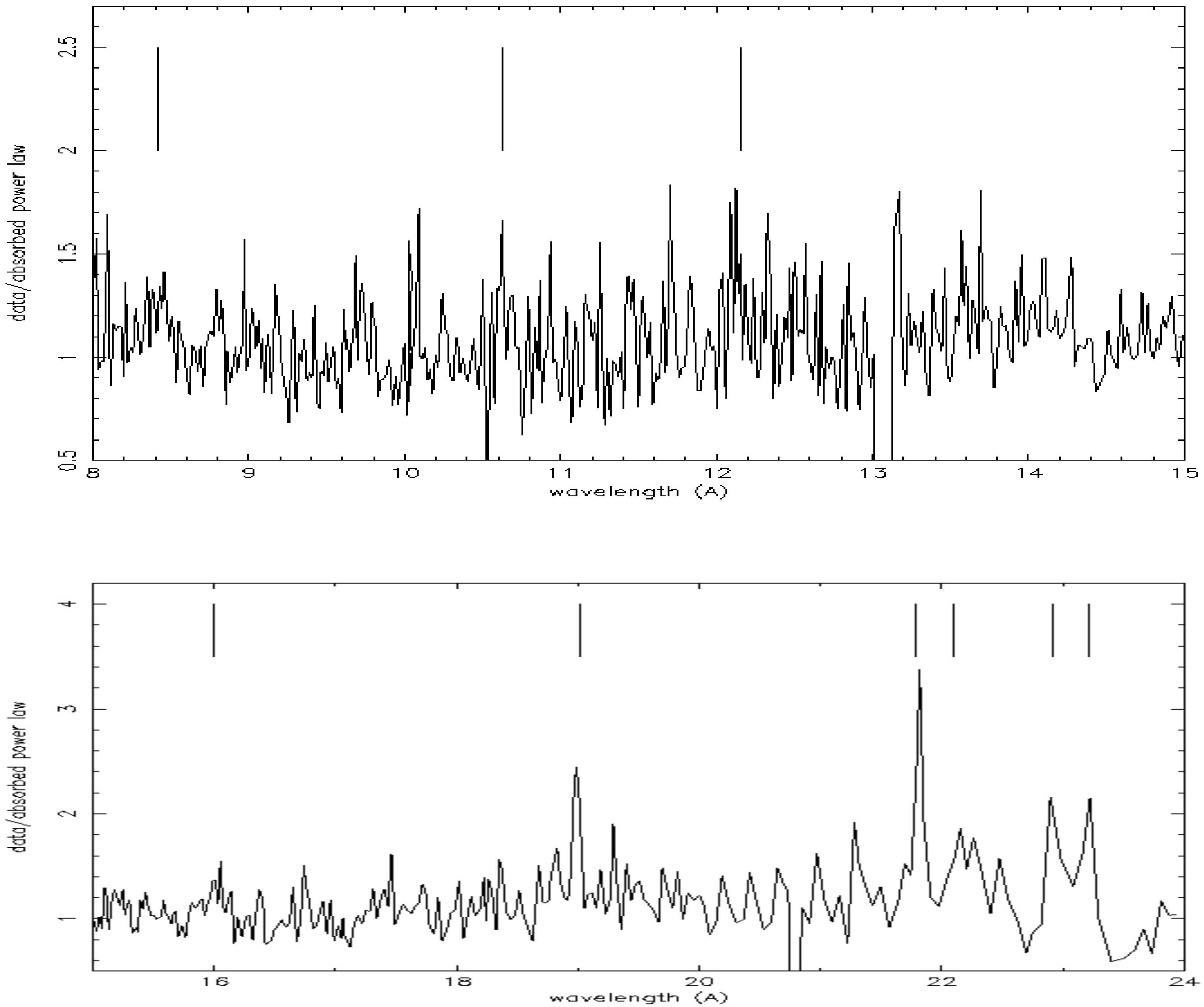
MEG



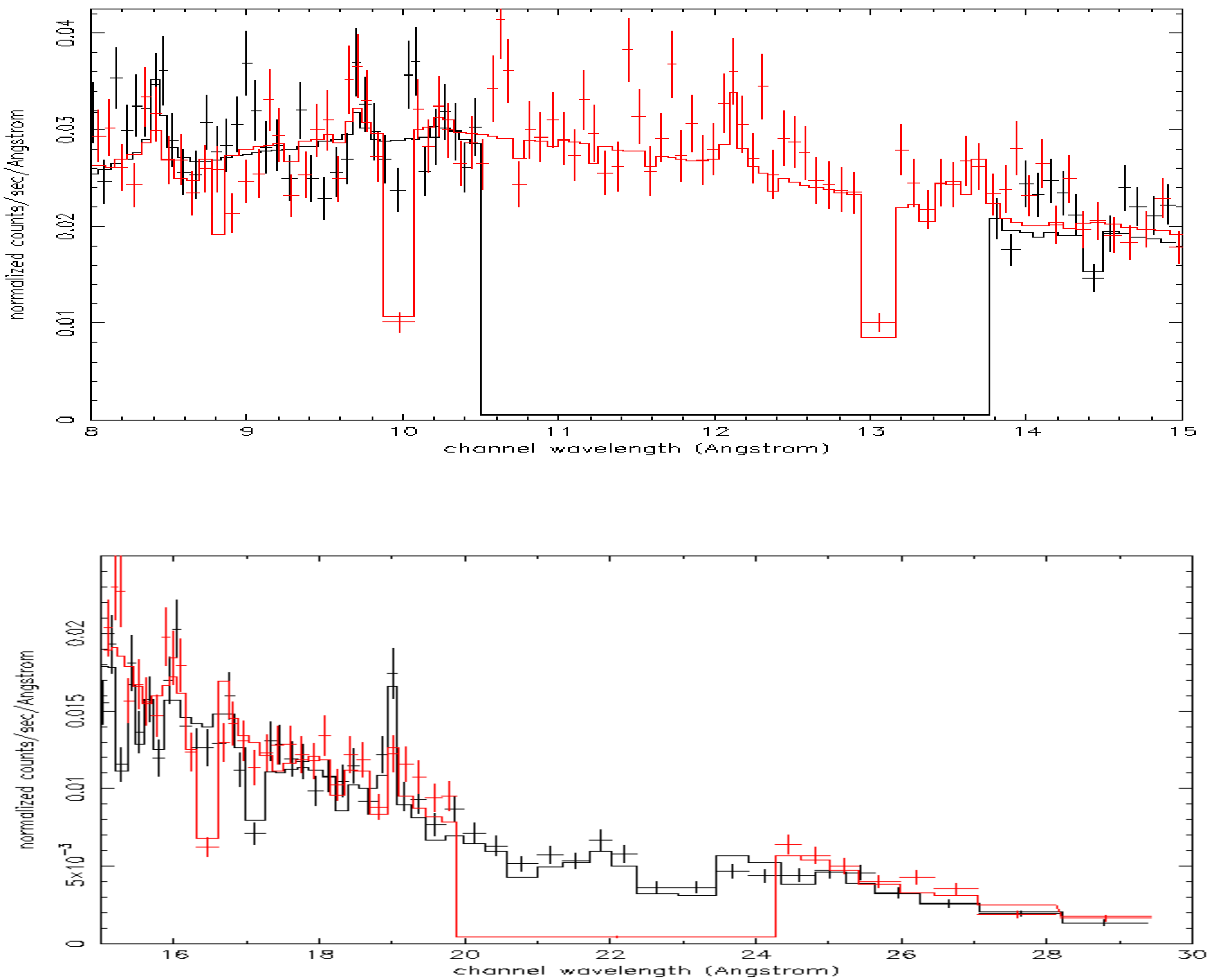
HEG and MEG residuals to power law



Xstar model fit to HETG spectrum



RGS residuals to power law



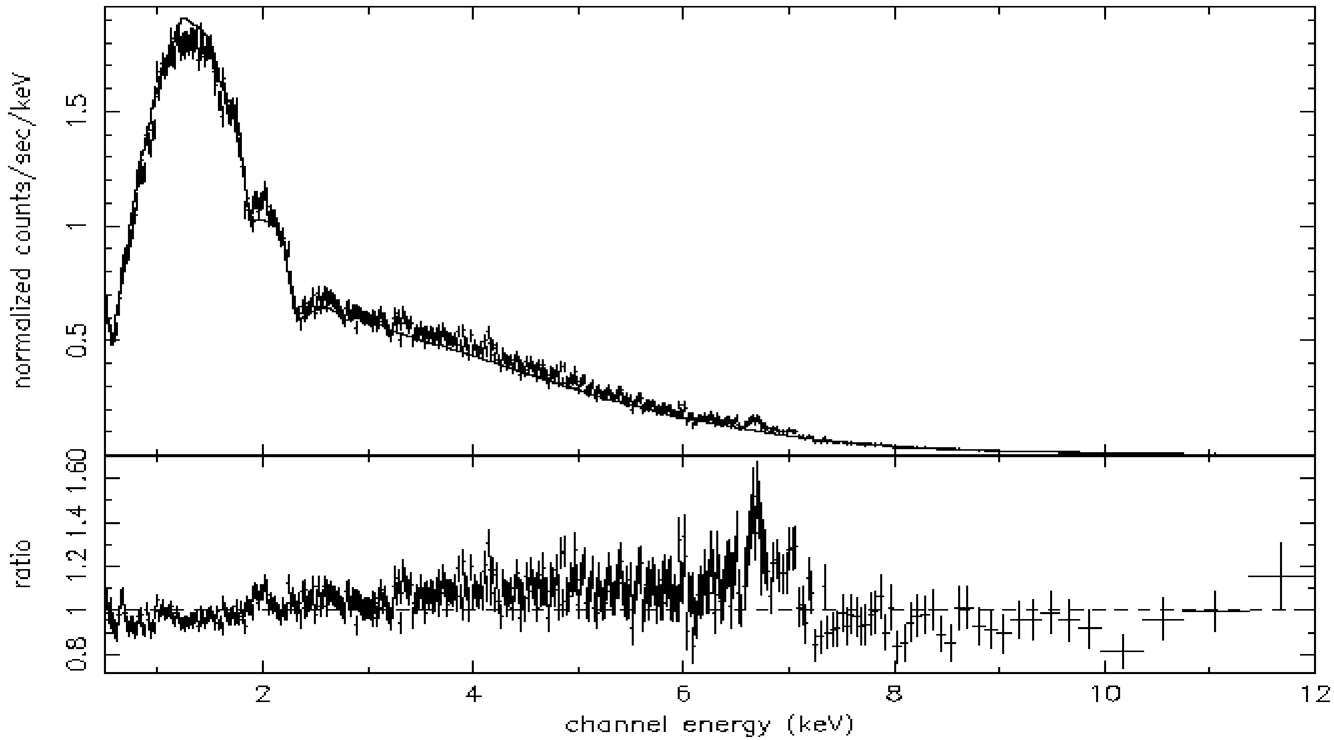
RGS fit to xstar model

HETG and RGS

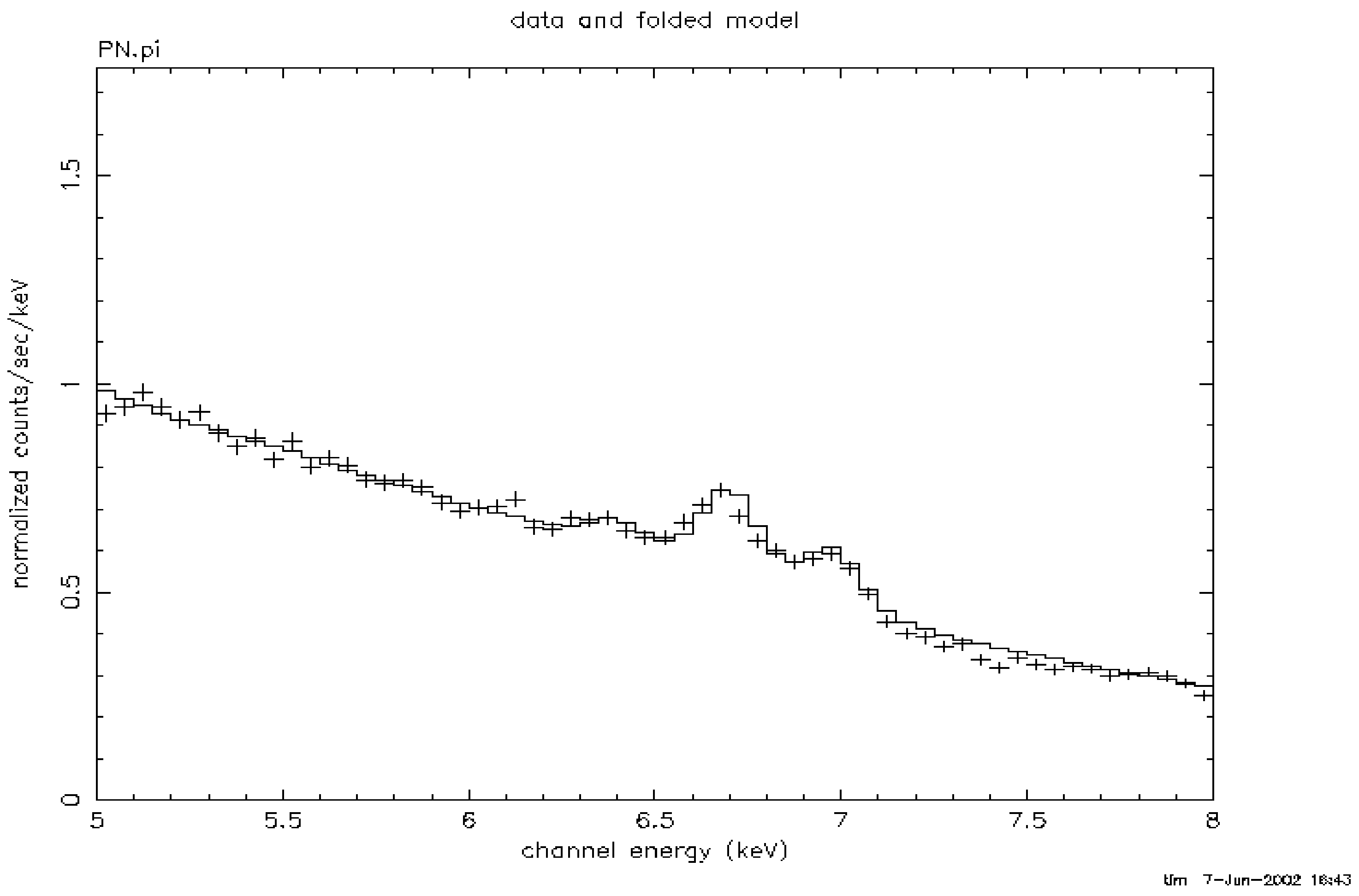
- Continuum fits to single absorbed power law
- Lines observed from H and He-like ions of abundant elements O-Fe.
- Line equivalent widths ~10-50 eV
- Lines are narrow, v<600 km/s
- Line spectrum fits adequately to xstar model or sum of two models, $\log(\xi)=1.5, 4$.
- From O VII f/i ratio, $n<10^{11}$ cm^{-3}.

Summary of Line fits

ID	Wave(A)	Energy (keV)		F(photon/cm^2/s		L (erg/s)	Width (keV)		EW (eV)	log(P)	Inst	V8	log(R)
?	23.22	0.53	+/- 0.01	5.3	+/- 7	2.5E+32	0.005	+/- 0.005	2.8	- 1.06	RGS	2.8	9.4
?	22.92	0.54	+/- 0.01	7.1	+/- 8	3.4E+32	0.005	+/- 0.005	3.5	- 1.34	RGS	2.8	9.4
O VII 1- 2 f	22.1	0.56	+/- 0.01	4.5	+/- 5	2.2E+32	0.005	+/- 0.005	2.2	- 1.15	RGS	2.7	9.4
O VII 1- 2 i	21.77	0.57	+/- 0.01	5.9	+/- 12	3.0E+32	0.005	+/- 0.005	3.3	- 2.27	RGS	2.6	9.4
O VIII Lα	19	0.65	+/- 0.01	7.6	+/- 2	4.4E+32	0.005	+/- 0.005	5.4	- 14.35	RGS	2.3	9.5
O VIII Lβ	15.97	0.78	+/- 0.0015	1.4	+/- 2	9.6E+31	0.005	+/- 0.005	1.2	- 0.84	RGS	1.9	9.7
Ne X Lα	12.16	1.02	+/- 0.0015	2.4	+/- 1.5	2.2E+32	0.0025	+/- 0.0025	6.65	- 19.2	HETG	0.7	10.5
		1.02	+/- 0.004	3.6	+/- 2.3	3.3E+32	0.005	+/- 0.005	3.8	- 2.17	RGS	1.5	9.9
Ne X Lβ	10.65	1.17	+/- 0.004	2	+/- 1.5	2.1E+32	0.005	+/- 0.005	2.9	- 3.09	RGS	1.3	10.1
		1.1	+/- 0.8	1.1	+/- 0.8	1.1E+32	0.0025	+/- 0.0025	3.52	- 7.74	HETG	0.7	10.6
Mg XII Lα	8.56	1.45	+/- 0.0025	7	+/- 5	9.0E+32	0.005	+/- 0.005	0.19	- 0.06	HETG	1.0	10.2
		1.47	+/- 0.004	4	+/- 2.7	5.1E+32	0.005	+/- 0.005	7.3	- 3.09	RGS	1.0	10.3
Si XIV Lα	6.18	2.01	+/- 0.004	1.95	+/- 0.2	3.5E+32	0.0025	+/- 0.0025	10.2	- 34.3	HETG	0.4	11.1
S XVI Lα	4.73	2.62	+/- 0.01	1.03	+/- 1	2.4E+32	0.0025	+/- 0.0025	13.2	- 4.09	HETG	0.3	11.4
Fe I- XVII Kα	1.94	6.4	+/- 0.01	1.1	+/- 2	6.2E+32	0.015	+/- 0.015	26.2	- 2.03	HETG	0.7	10.6
		6.38	+/- 0.1	1.4	+/- 0.15	7.9E+32	0.29	+/- 0.15	14	- 99	PN	13.6	8.0
Fe XXV 1- 2	1.87	6.65	+/- 0.01	1.4	+/- 2	8.3E+32	0.015	+/- 0.015	31.1	- 3.28	HETG	0.7	10.6
		6.68	+/- 0.03	5.7	+/- 0.2	3.4E+33	0.05	+/- 0.05	63	- 5.59	PN	2.2	9.6
		6.7	+/- 0.1	4	+/- 1.0	2.4E+33	0.05	+/- 0.05	1500	- 7.5	MOS	2.2	9.6
Fe XXVI Lα	1.8	6.9	+/- 0.01	1	+/- 1.0	6.1E+32	0.015	+/- 0.015	50.1	- 0.2	HETG	0.7	10.6
		6.96	+/- 0.07	4	+/- 0.1	2.4E+33	0.05	+/- 0.05	49	- 99	PN	2.2	9.6
		6.98	+/- 0.1	1.2	+/- 1.0	7.3E+32	0.05	+/- 0.05	288	- 1.95	MOS	2.1	9.6
?	1.59	7.8	+/- 0.1	1.3	+/- 0.3	9.0E+32	0.25	+/- 0.25	23	- 3.74	PN	9.6	8.3
?	1.51	8.2	+/- 0.1	1.4	+/- 0.3	1.0E+33	0.15	+/- 0.15	25	- 5.58	PN	5.5	8.8



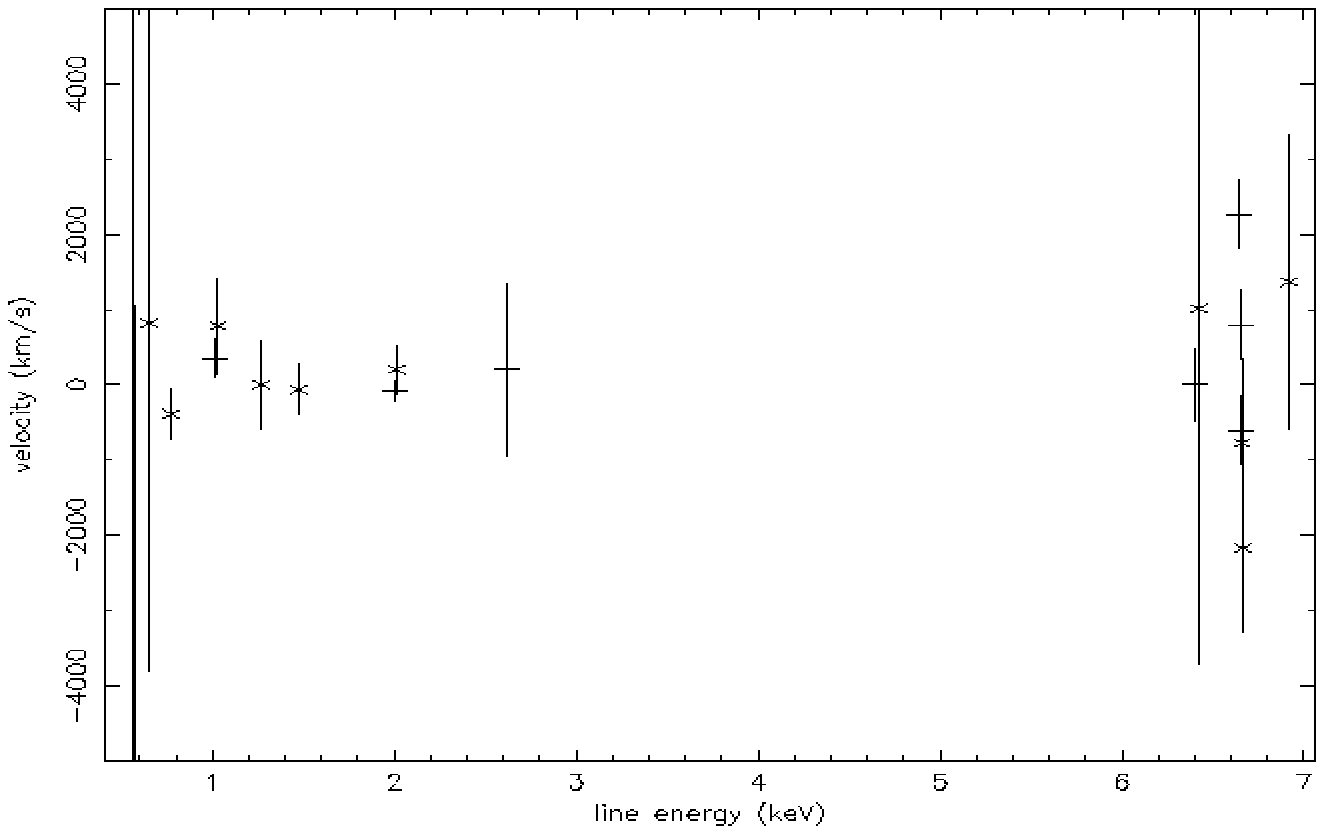
MOS Spectrum and power law fit



PN spectrum 5-8 keV

EPIC fits

- Lines: 3 components of Fe K: 6.4, 6.7, 6.97 keV.
- PN sets lower limit on Fe XXVI Lα width.
- PN continuum is not adequately fit by single power law
- Requires either cutoff power law, Ecut=7 keV, plus
- Or power law plus edges at 7.1 and 8.4 keV
- Curved continuum+Gaussians fits better due to narrow
- Similar to ASCA spectrum of 1822-37

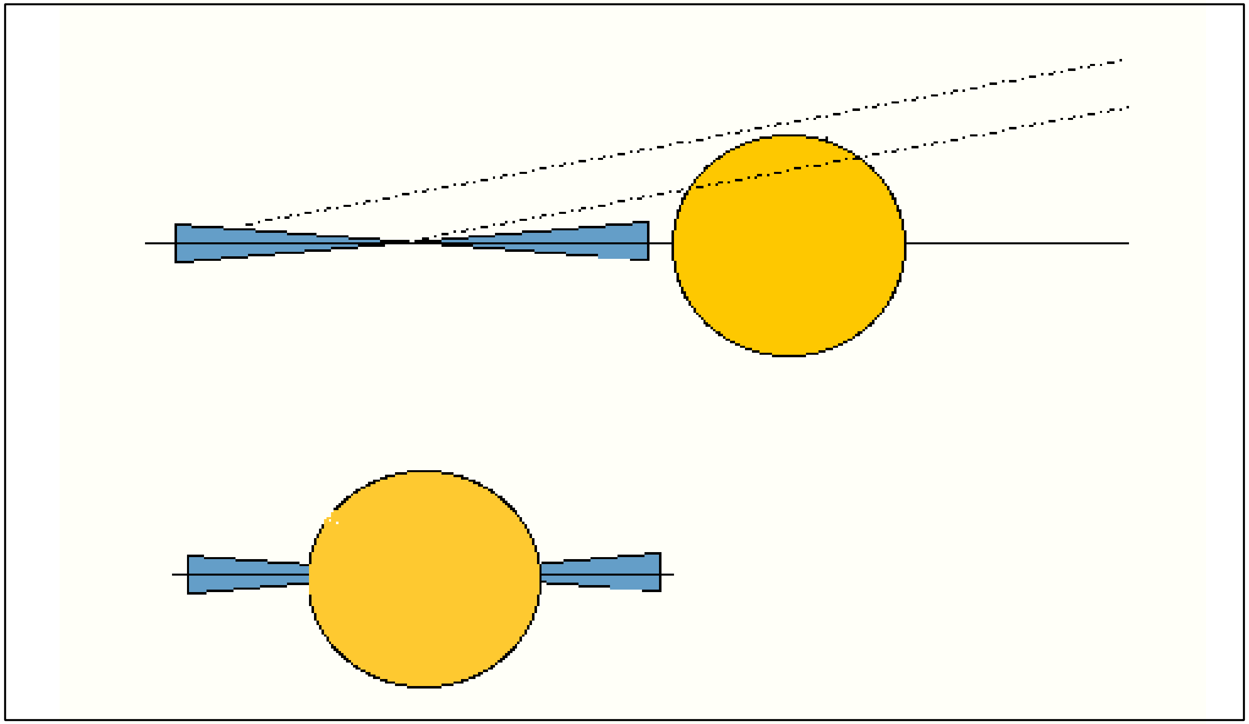


Line velocities

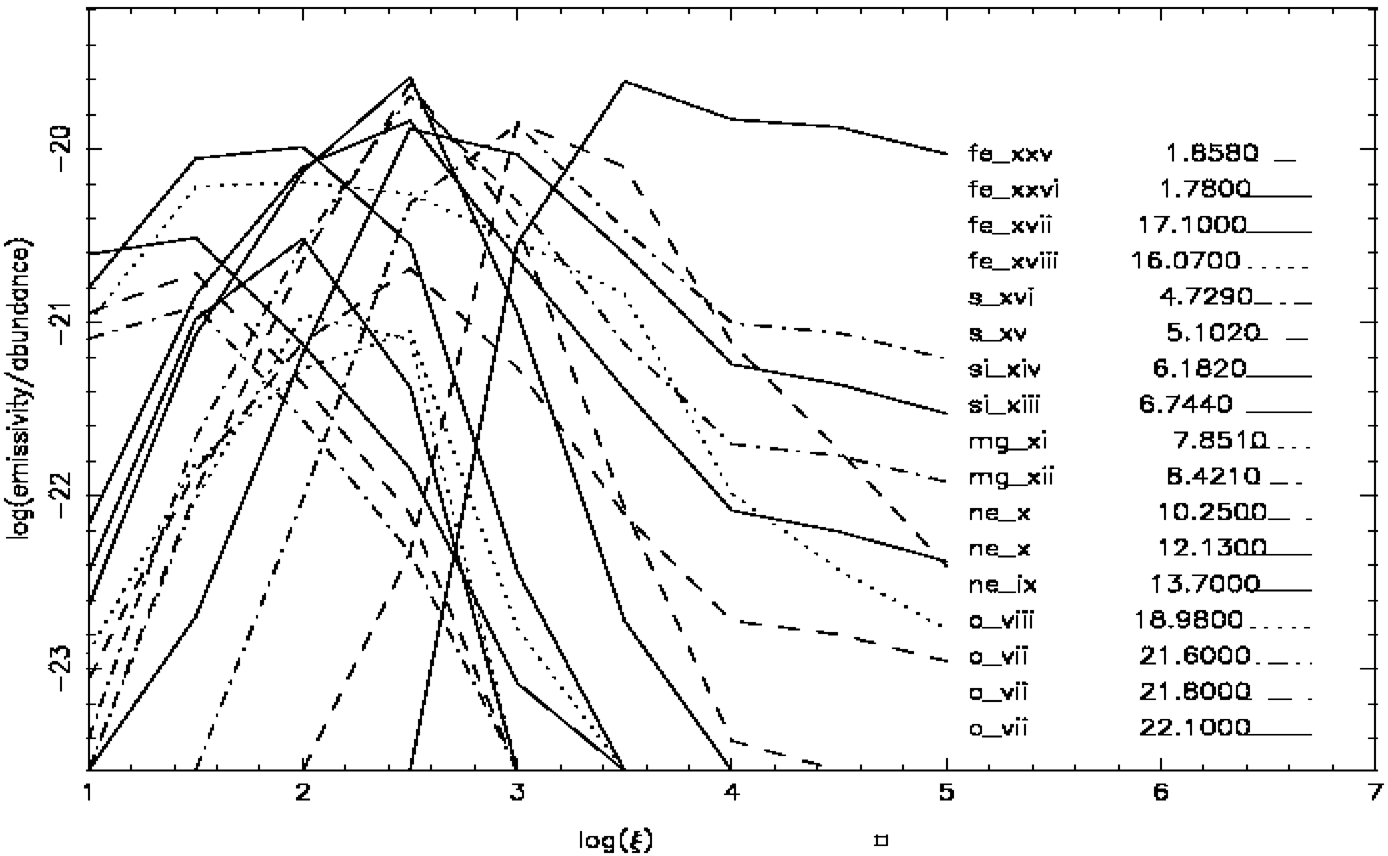
Line Widths

- Grating spectra give limits on line widths corresponding to Dopper velocities v < 600 km/s for the HETG (eg. SiXIV Lα).
- For emission from a Keplerian disk at 90^{o} inclination with a 1.4 solar mass primary, this corresponds to R > 5.2 x 10^{10} cm
- Using the PN data, the Fe XXVI Lα line width is measured to be in the range 430 km/s < v < 3900 km/s.
- This corresponds to radii 1.2 x 10^{9} cm < R < 1.0 x 10 ^{11} cm
- For comparison the primary Roche lobe size is ~1.1 x 10^{12} cm, and the secondary size is 6.75 - 7.2 x 10^{11} cm.

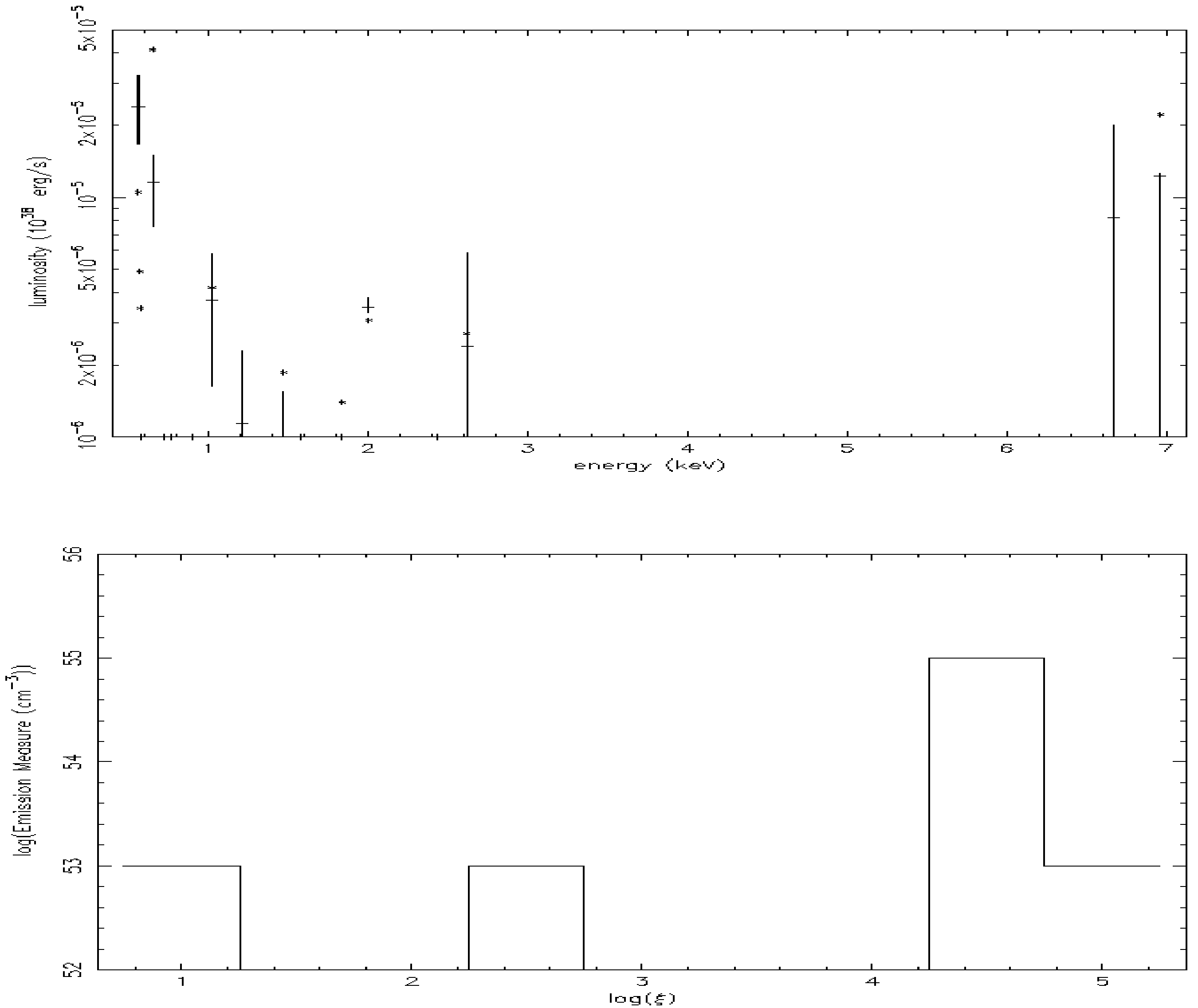
System Geometry



During eclipse we see only the outer disk



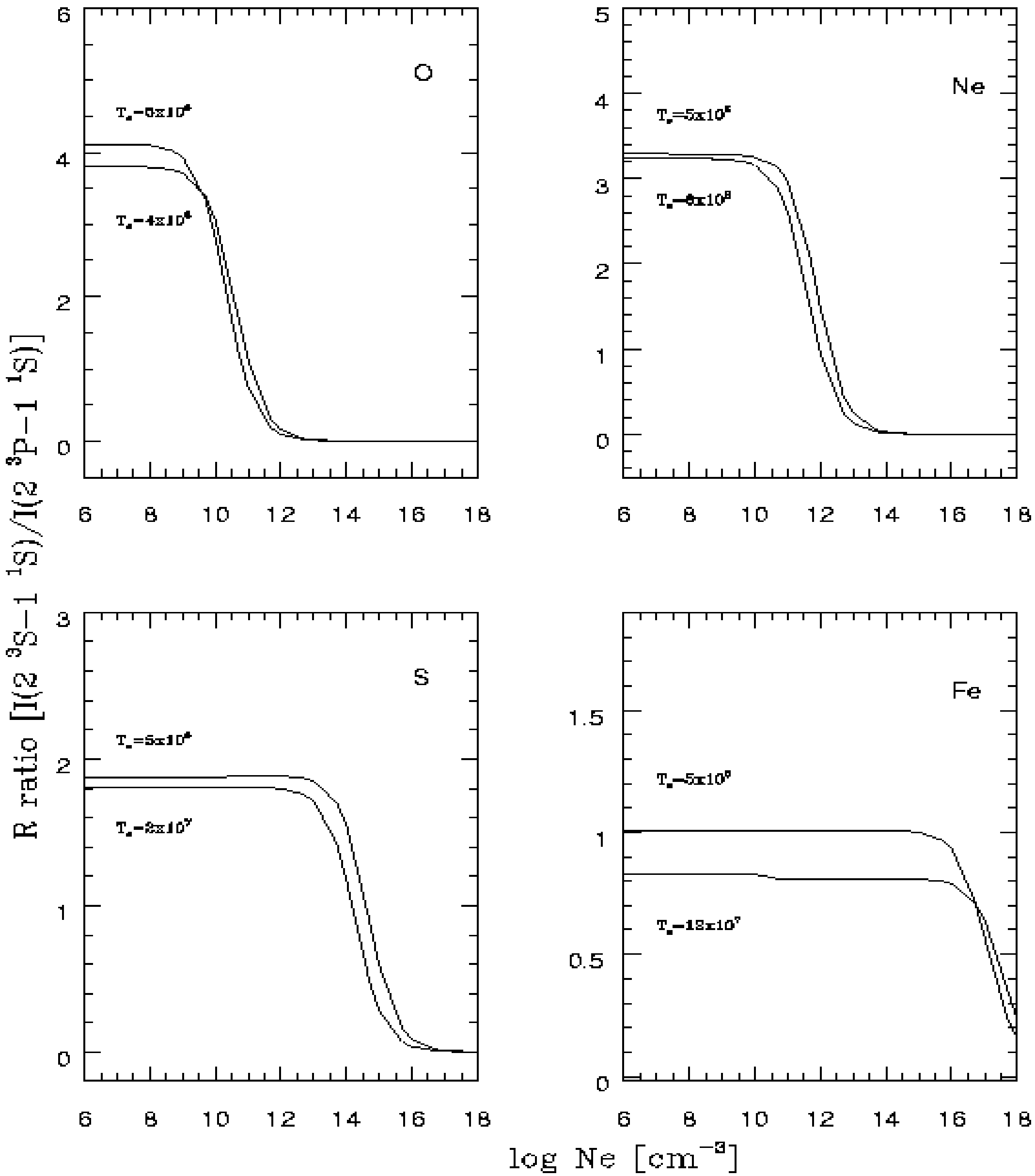
Emissivity curves for observed lines



DEM fit to measured line strengths

Line Luminosities

- Optical distance estimate is D ~ 7 kpc. If so, typical line luminosities are $\sim 10^{32}$ -10^{34} erg/s
- For log(ξ)~1-4, typical emissivities are j $\sim 10^{-24}$ erg cm^3 s^{-1}, so that the emission measure must be $\sim 10^{56}$ cm^{-3} .
- DEM analysis is consistent with this.
- Xstar model fits imply total emission measure $\sim 10^{55}$ cm^{-3} if $L_x \sim 10^{35}$ erg/s.



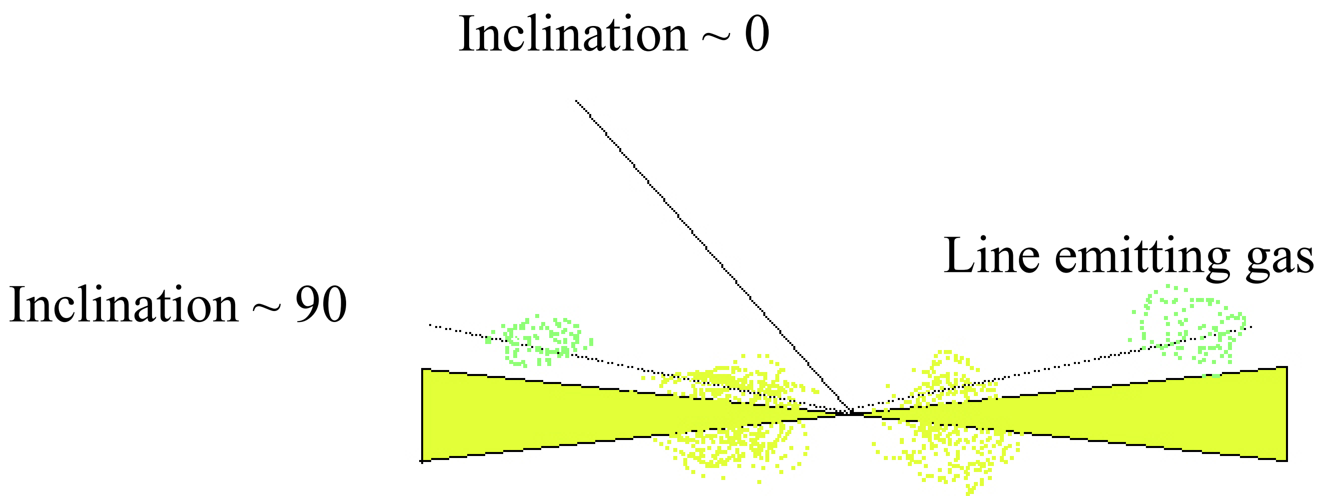
He-like line density diagnostics

Gas Density and Ionization Parameter

- From O VII f/i line ratio we infer density $n<10^{11}$ cm^{-3}.
- O VII recombination emission is most efficient for log(ξ)<2.
- The primary Roche lobe size is $R \sim 10^{12}$ cm.
- If the emission comes from within this region then the ionizing luminosity impacting the O VII gas must be $L< 10^{35}$ erg/s.
- This conflicts with the traditional arguments about ADC sources, eg. $L_x/L_{opt} \sim 1$.

What does this mean for otherLMXBs?

- Systems with larger intrinsic luminosities have line equivalent widths less than ~ a few eV
- Could ~10^{34} erg/s lines could be hiding in these spectra?
- Maybe the reason we observe lower luminosities from "ADC" sources is that the occultation is happening in the inner region of the disk.
- If so, all Z sources should be ~low inclination.


Inclination ~ 0
Line emitting gas
Inclination ~ 90