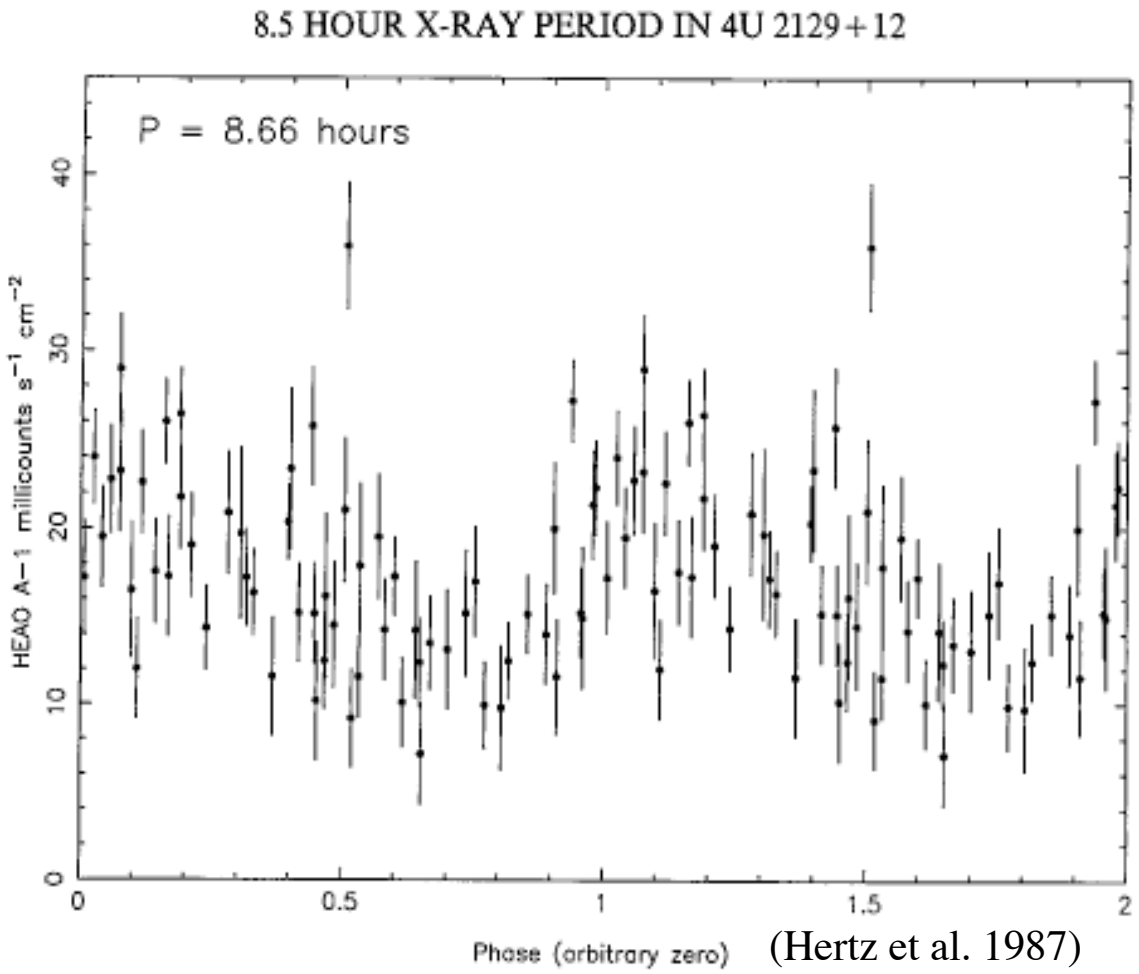
HETG Observations of AC211 in the Globular Cluster M15

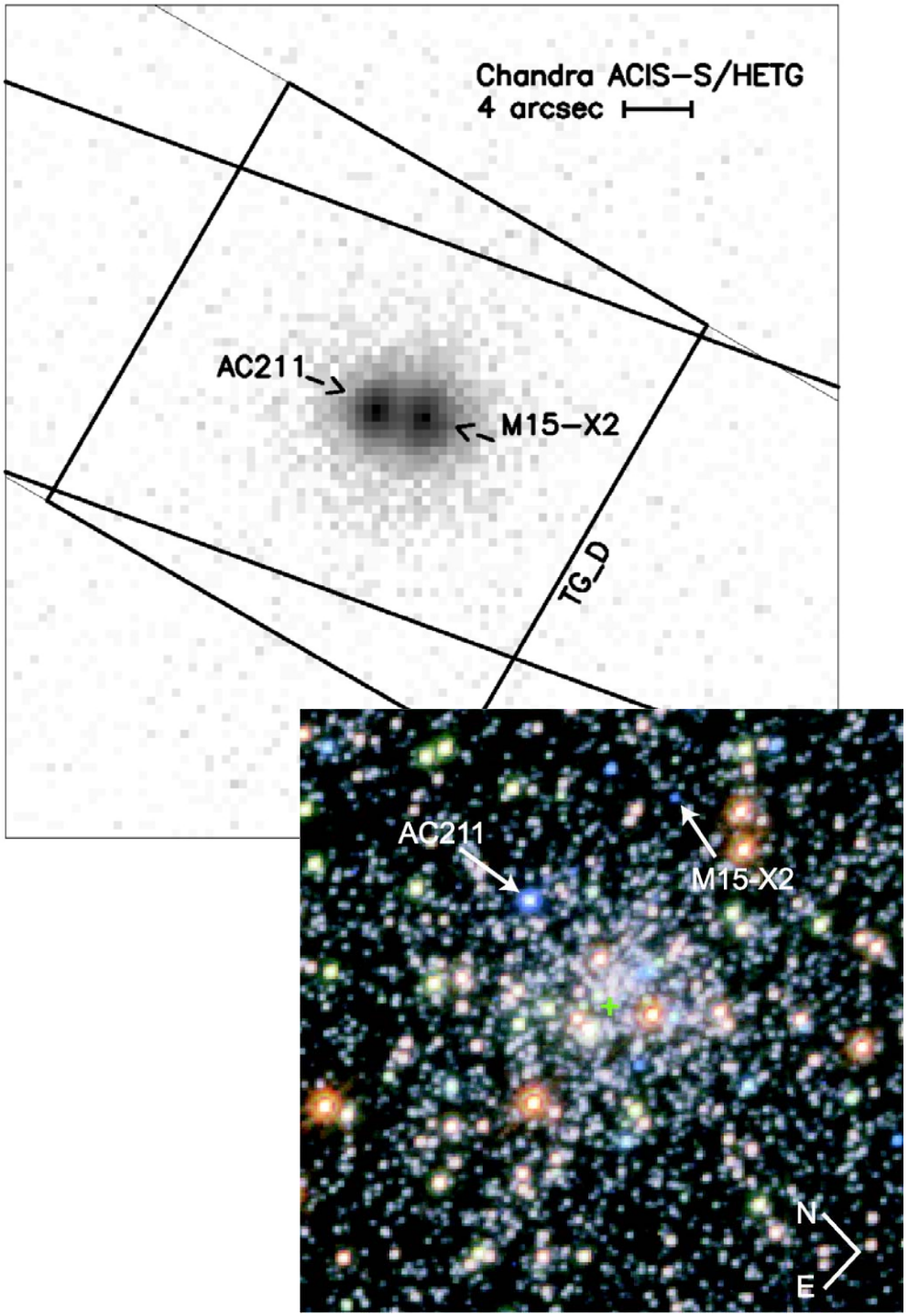
T. R. Kallman, L. Angelini, and N. E. White (NASA/GSFC), J. Sepinsky (NWU)

- 4U2129+119/AC211 associated with globular cluster source M15
- Light curve suggests accretion disk corona
- Period 17 hours
- Problem: type 1 X-ray bursts

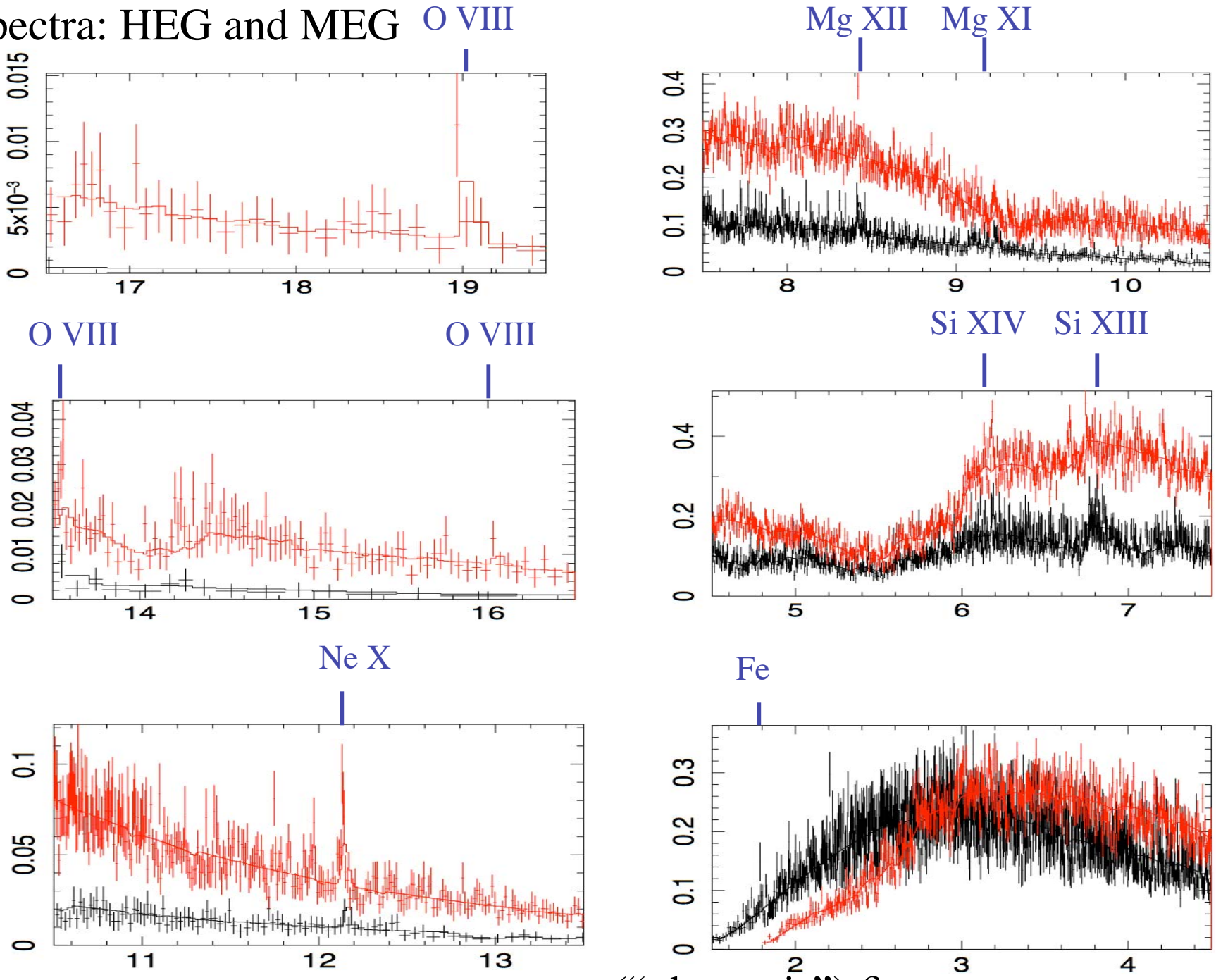


(Hertz et al. 1987)

- Discovered to be confused with another source 2.7” away (White and Angelini 2001)
- Using HETG zero order
- Observation roll angle was wrong for separating the components in the dispersed image
- We report on second observation, 60 ksec, in 2004
- GCs are nurseries for XRBs: Are GC X-ray binaries similar to field XRBs?



Spectra: HEG and MEG



+xstar ("photemis") fit

Strong lines detected: HEG and MEG

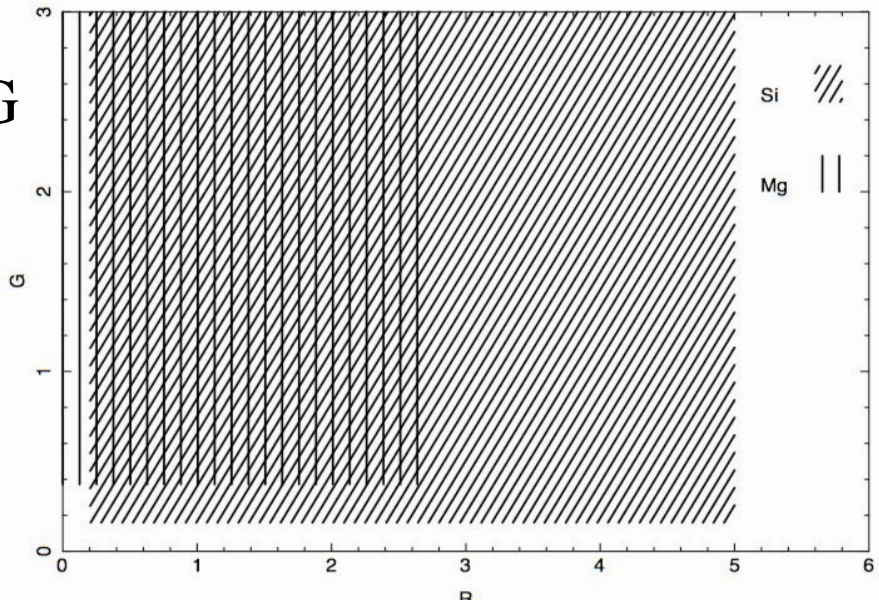
Energy	Wave	Id	Meg			Heg		
			Energy	flux	Redshift	Energy	flux	Redshift
0.6530	19	O VIII L alpha						
1.0210	12.1	Ne X L alpha	1.022	4.75E-05	6.17E-04	1.02	5.91E-05	-9.50E-04
1.3317	9.31	Mg XI He-like 1-2 f	1.331	2.14E-05	-8.07E-04	1.35	2.62E-05	1.33E-02
1.3433	9.23	Mg XI He-like 1-2 i	1.316	2.42E-05	-2.07E-02	1.34	2.62E-05	9.60E-06
1.3521	9.17	Mg XI He-like 1-2 r	1.352	1.95E-05	-2.19E-04	1.35	2.62E-05	1.75E-05
1.4730	8.42	Mg XII L alpha	1.474	2.08E-05	8.28E-04	1.47	1.98E-05	2.85E-04
1.8395	6.74	Si XIII He-like 1-2 f	1.839	8.58E-06	-1.61E-04	1.84	5.41E-06	-2.50E-05
1.8533	6.69	Si XIII He-like 1-2 i	1.868	7.73E-06	7.83E-03	1.85	5.41E-06	2.98E-06
1.8644	6.65	Si XIII He-like 1-2 r	1.865	1.11E-05	1.01E-04	1.86	5.41E-06	-2.26E-05
2.0060	6.18	Si XIV L alpha	2.008	2.11E-05	7.73E-04	2.01	1.70E-05	1.35E-04
6.3090	1.97	Fe K alpha	6.309	2.83E-05	7.13E-05	6.31	2.01E-05	-6.18E-05
6.9260	1.79	Fe XXVI L alpha ???	6.934	1.46E-05	1.11E-03	6.93	2.96E-05	2.74E-05

(flux=photons/cm^2/s)

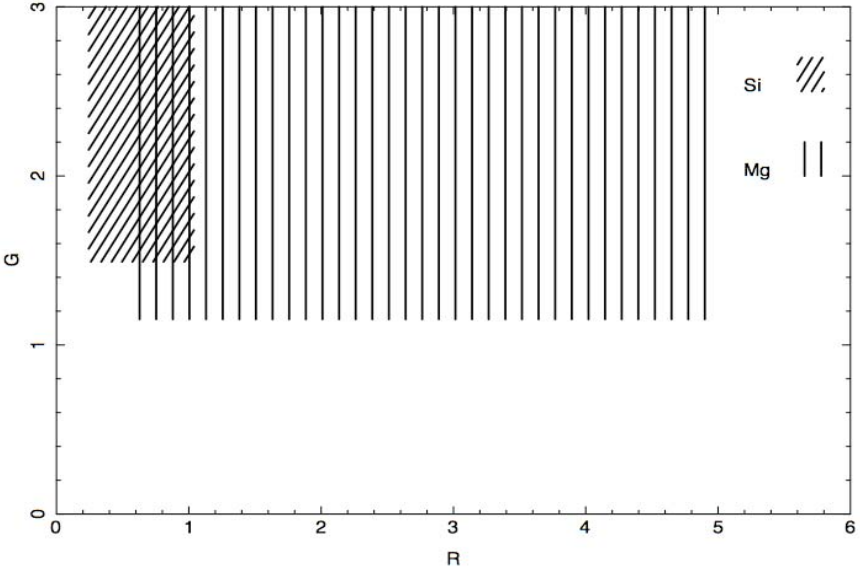
He-like line ratios

- R=f/i, G=(f+i)/r
- Best diagnostic information from Si XIII and Mg XI lines
- Figures show the allowed regions of R and G for the He-like Mg and Si lines.
- High density recombining models are favored, although the evidence from the HEG alone is not conclusive.

HEG



MEG



High <----------density ----------> low

Coronal/scattering <--->recombiinng

Photoionization model fitting

- Fitting to photoionization models gives: Ionization parameter: $\log(\xi)=2.1+/-0.1$, $\chi^2/\nu=1.224$ For simultaneous heg/meg fit.
- We measure $L=1.9 \times 10^{36} D_{10.3}$ erg/s (2-10 keV)

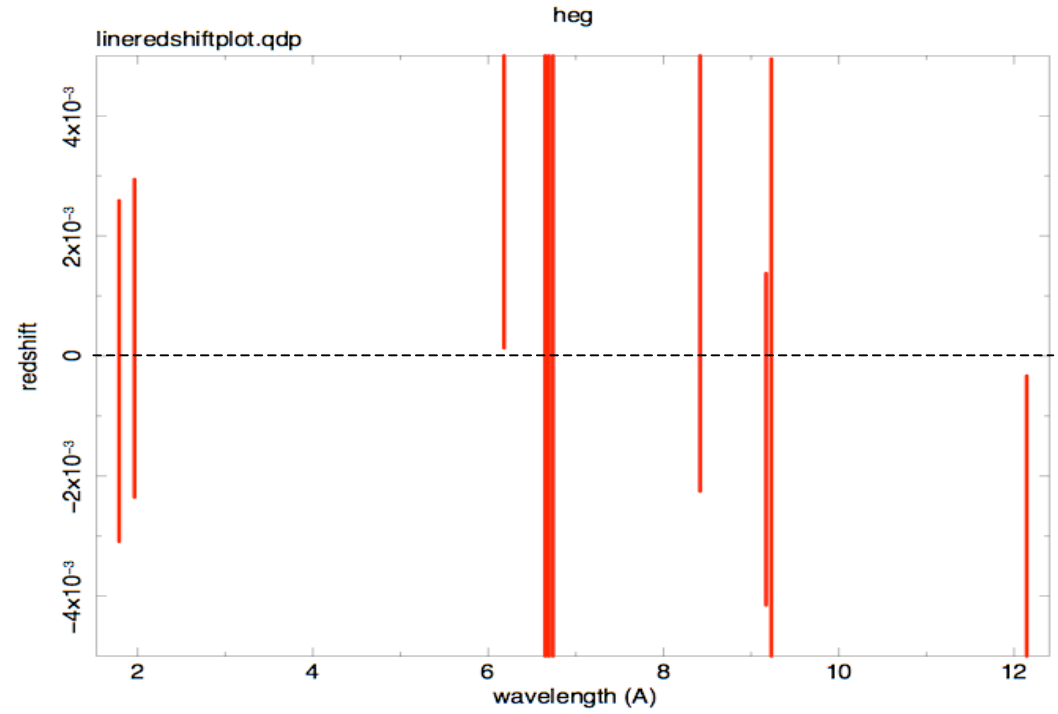
($\xi=L/(nR^2)$ (Tarter, Tucker and Salpeter 1969))

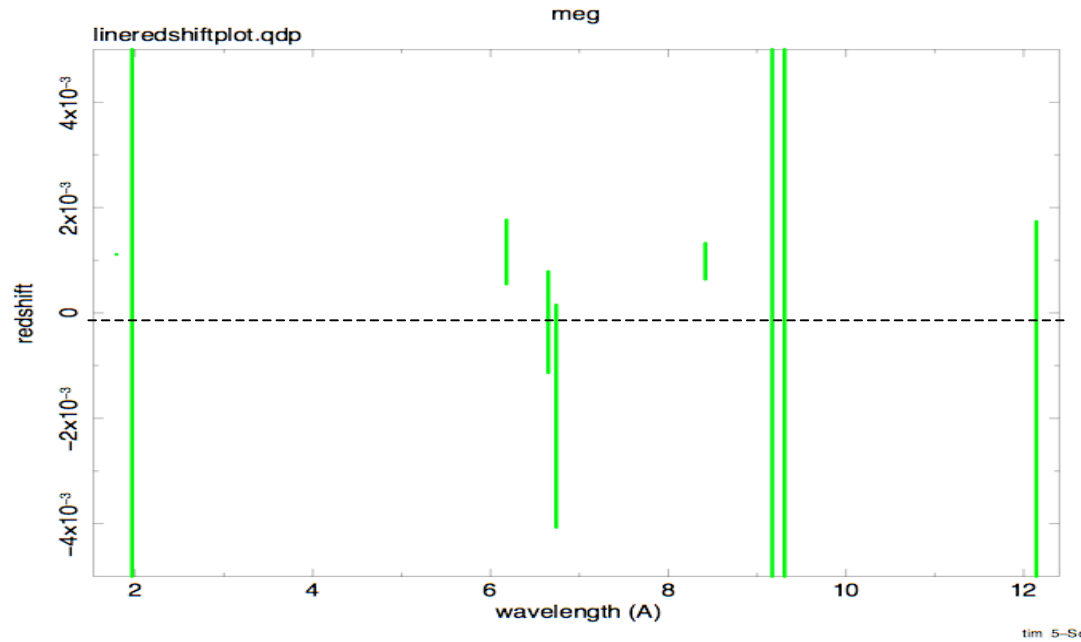
==> $R=10^{11} L_{36}^{1/2} n_{12}^{-1/2}$ cm

(big for P=0.6 days)

Line redshifts

- Consistent with being at rest.
- No systematic difference between HEG and MEG.
- Typical error ~100 km/s, comparable to AC211 radial velocity (Van den Bosch et al., 2005)



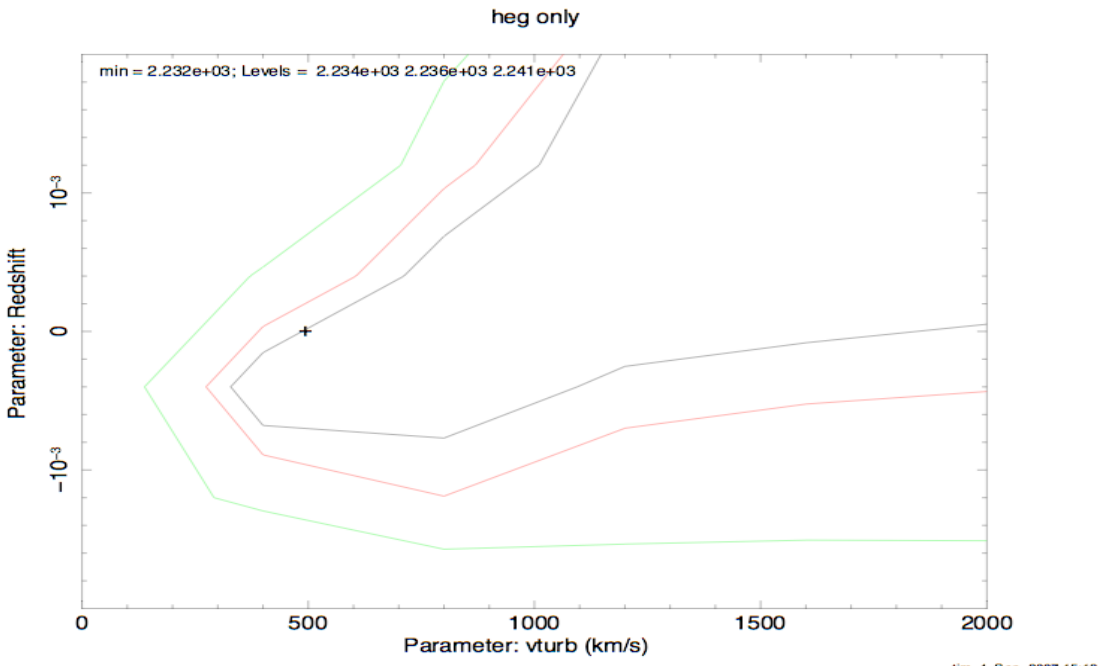


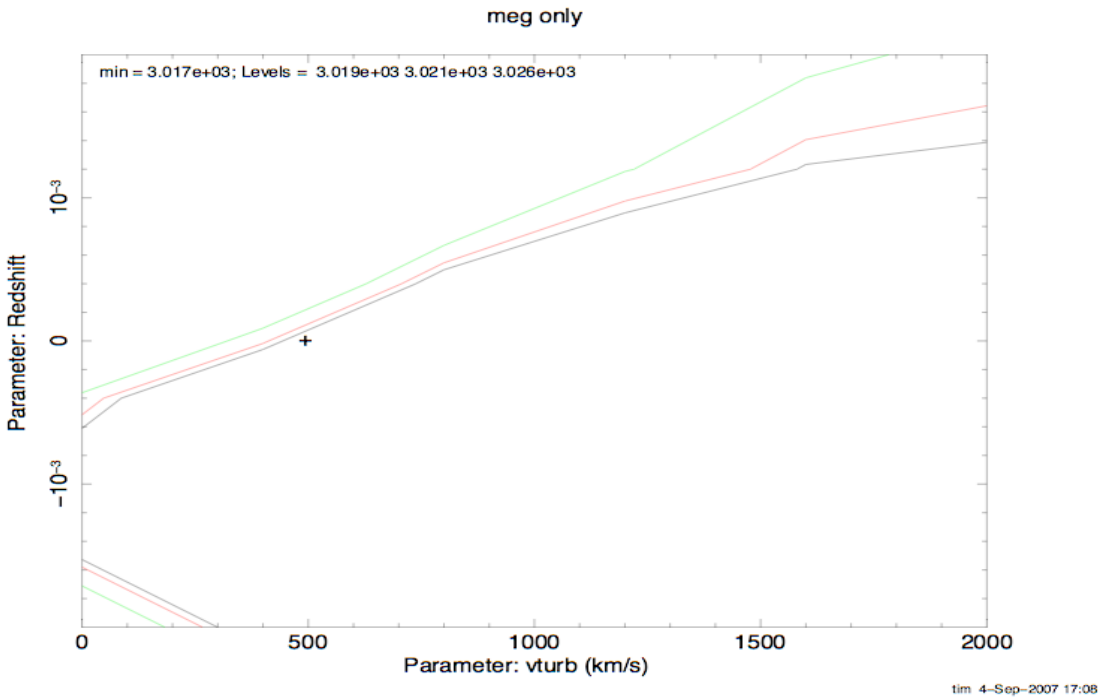
Line width

- Figures show χ^2 contours for redshift and line width for the photoionized model fits to the two detectors separately.
- Best fit is v_{turb}=550 km/s

If virial:

$R=10^{11.5}(M/M_{sun})v_{500}^{-2}cm$





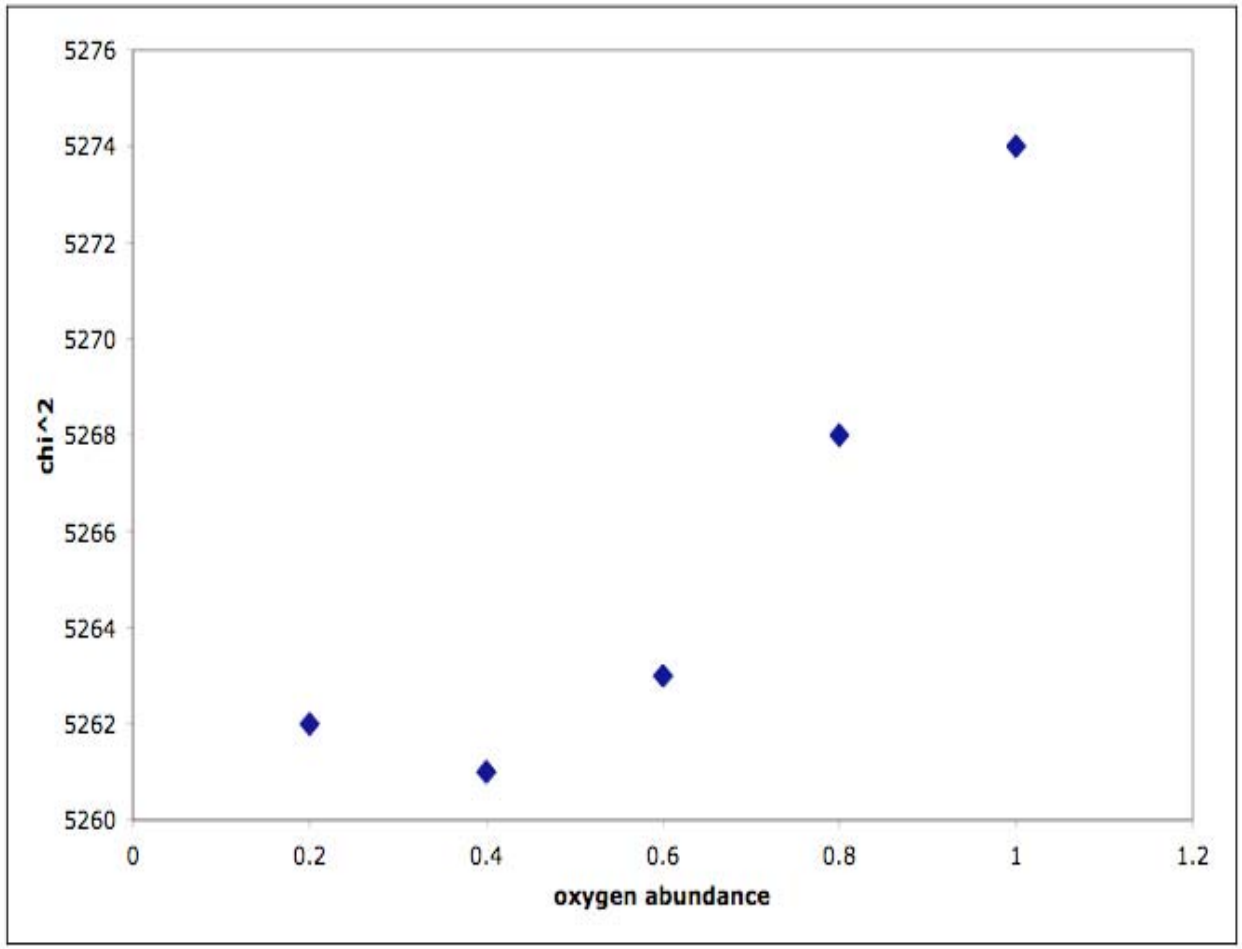
Abundances

best fit:

Ne=0.5 solar

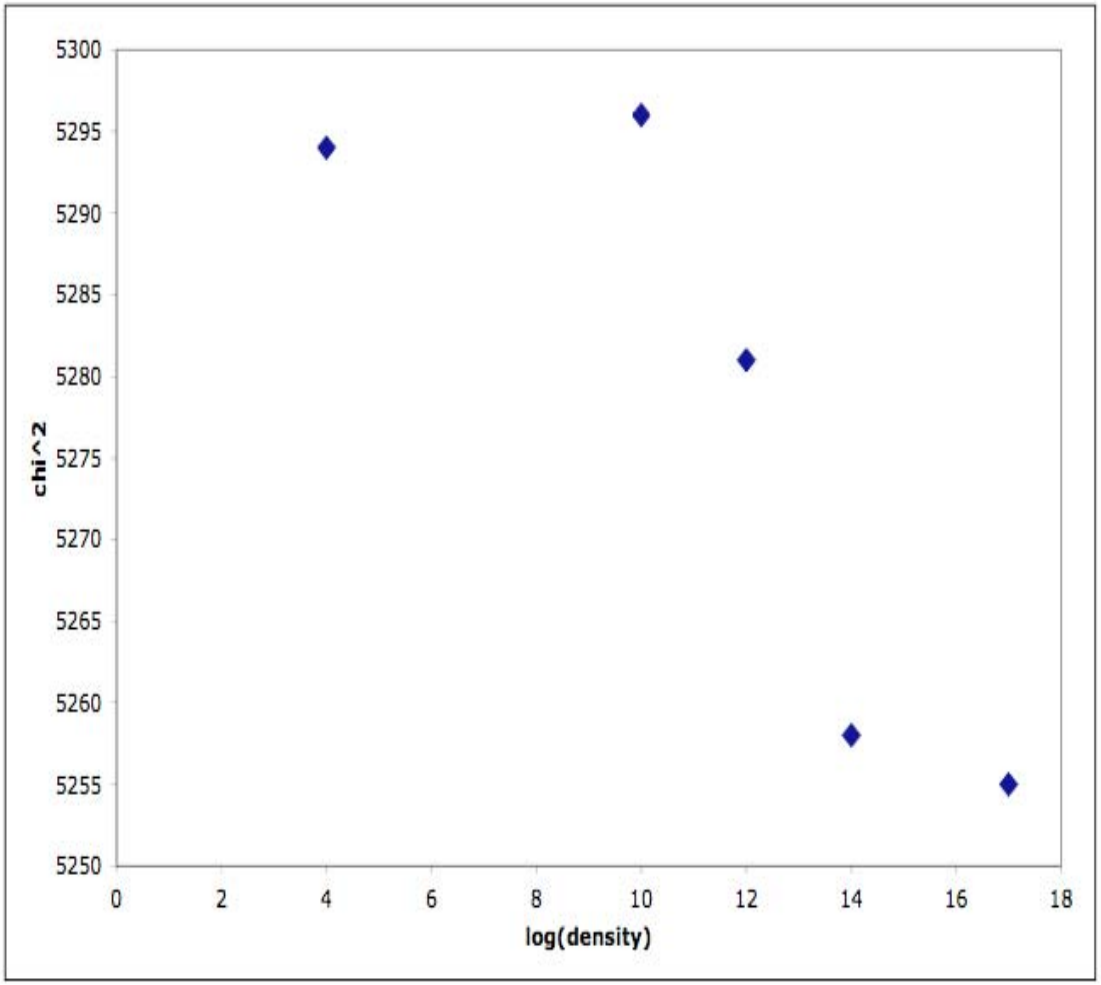
O< 0.4 solar

Other elements
= solar



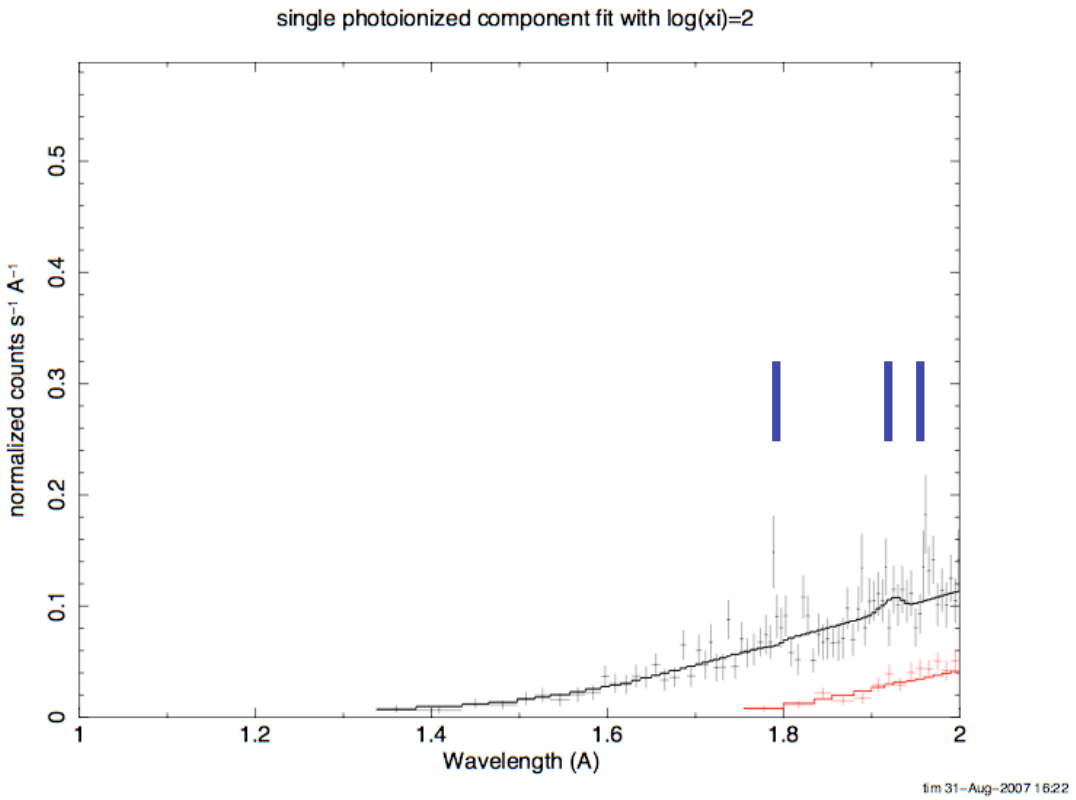
density

- best fit has high density, n> 10^{12} cm^{-3}.
  - The recombination model can produce the resonance components in the Si and Mg He-like triplets.
- Scattering component is not required by the statistics.



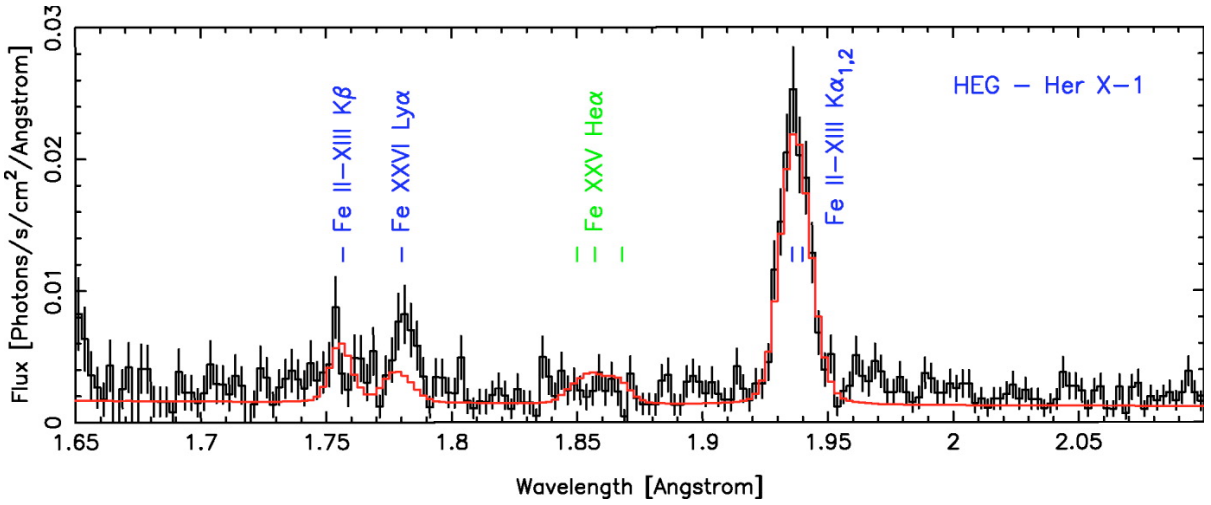
Iron line

- Best fit model does not produce the iron K fluorescence line near 1.96 A, or the hot line near 1.8 A. It produces an intermediate ionization line near 1.92 A but very weak. Figure shows this region with the iron abundance increased by 100 in order to illustrate the line.
- In order to fit the 1.8 A feature, another component is required, with $\log(\xi) > 4$. This reduces χ^2 by a marginal amount ($\chi^2/\nu = 5252.6/4306$ vs. 5267/4307).
- There is no He-like line, near 1.85 A (6700 eV).
- The Fe Kα line is unusually weak for an ADC source (EW<20 eV)



Comparison: the iron line region of other ADC sources

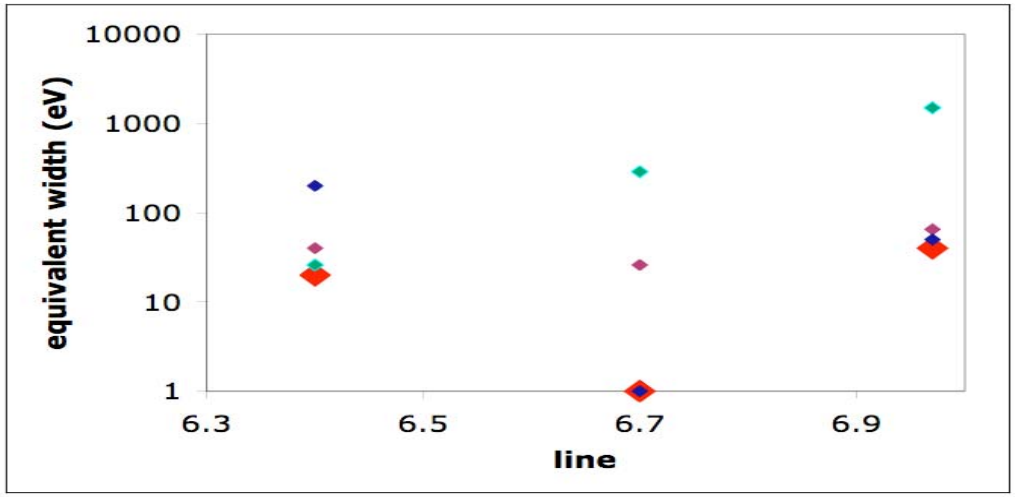
Her X-1: Strong iron Kα+ Fe XXVI Lα



(Jimenez-Garate et al. 2005)

Other objects

object	6.97	6.7	6.4
ac211	40	1	20
x1822	65	26	40
her x-1	50	1	200
0921-63	1500	288	26



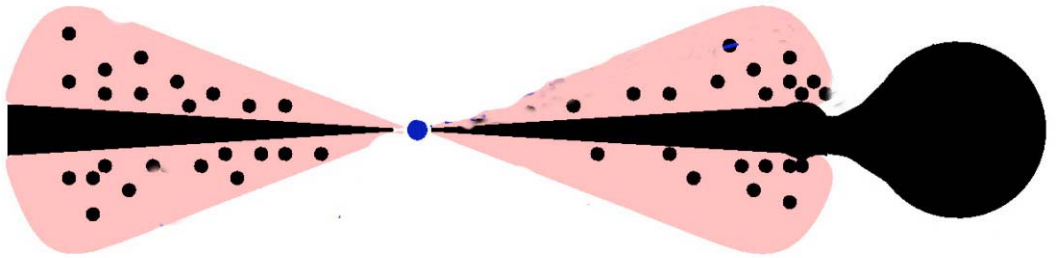
How much gas?

- An accretion disk corona is levitated by heating from X-rays from the central compact object
- An exponential atmosphere forms with scale height
- The amount of gas is determined by the amount of heating (L) and the gravity (M)
- The distribution of emission measure vs. ionization parameter is determined by:

$$\frac{dEM}{d\xi} = n^2 \frac{dV}{d\xi}$$

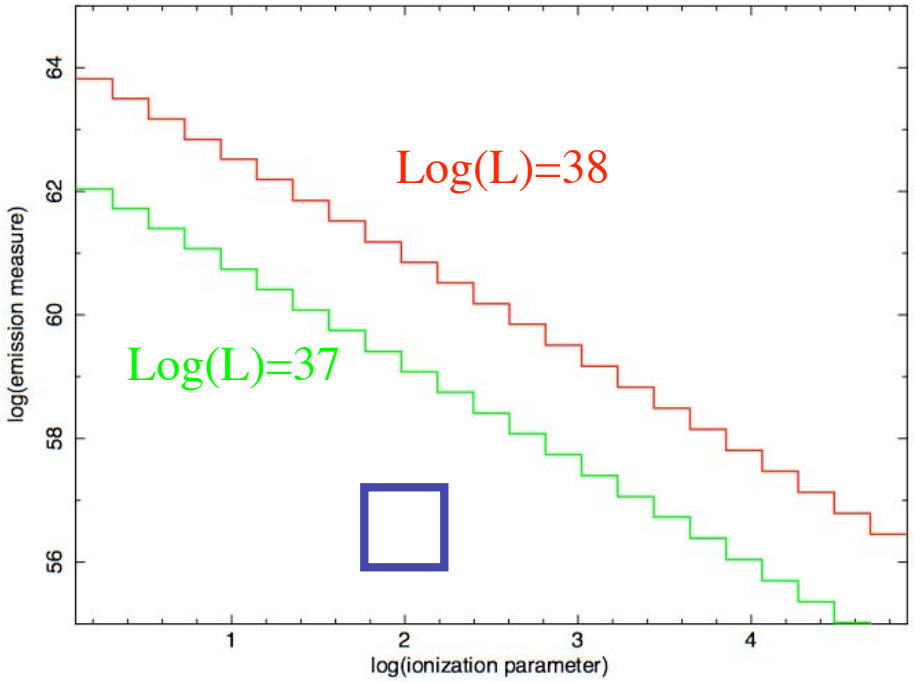
$$\simeq \xi^{-3} \left(\frac{kT}{GMm_H} \right)^{1/2} \frac{L^2}{R_i^{3/2}}$$

$$\simeq 2.5 \times 10^{65} \xi^{-3} L_{38}^2 R_{i7}^{-3/2} T_4^{1/2}$$



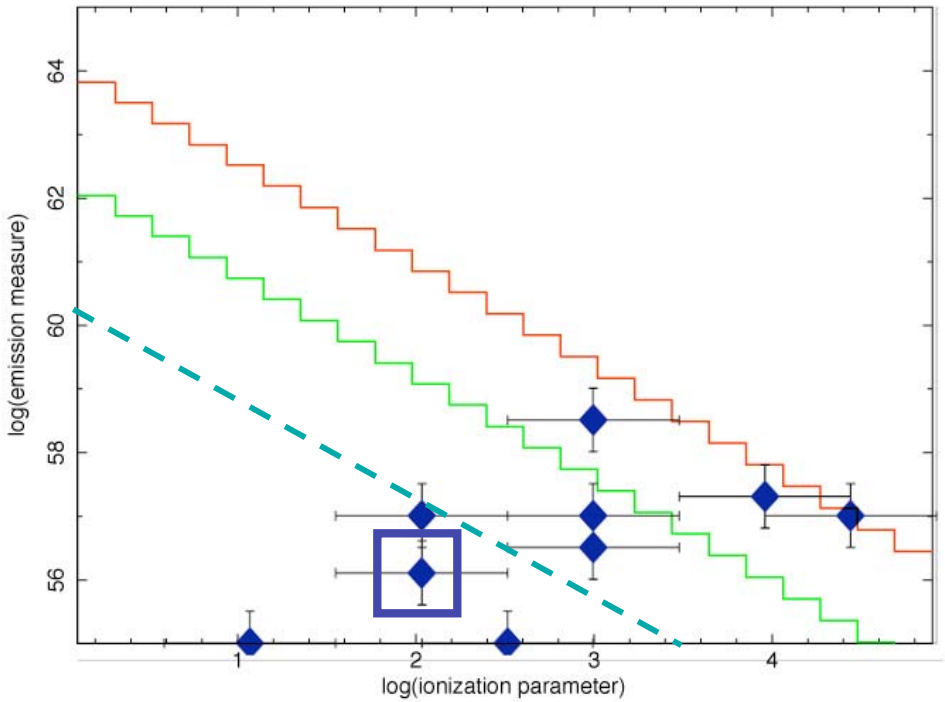
How much gas?

- The model normalization corresponds to an emission measure $\log(n^2\ V)=56.1$.
- This can easily be produced by an ADC.
- A numerical calculation gives results similar to the analytic estimate



Comparison with other adc sources

- most adc sources have emission measures within the range allowed by the Eddington limit
- Some have emission measures implying hidden continuum



object	log(xi)	EM
ac211	2	56.1
x1822	3	56.5
cir x-1	3	58.5
her x-1	4	57.3
	3	57
	2	57
0921-63	4.5	57
	2.5	55
	1	55

What can we learn from ac211..

- Abundances: oxygen deficiency a pattern?
- Adc: look for hidden flux? Not required
- Density: high (10^{12} is lower limit)
- Iron line: weak fluorescence line

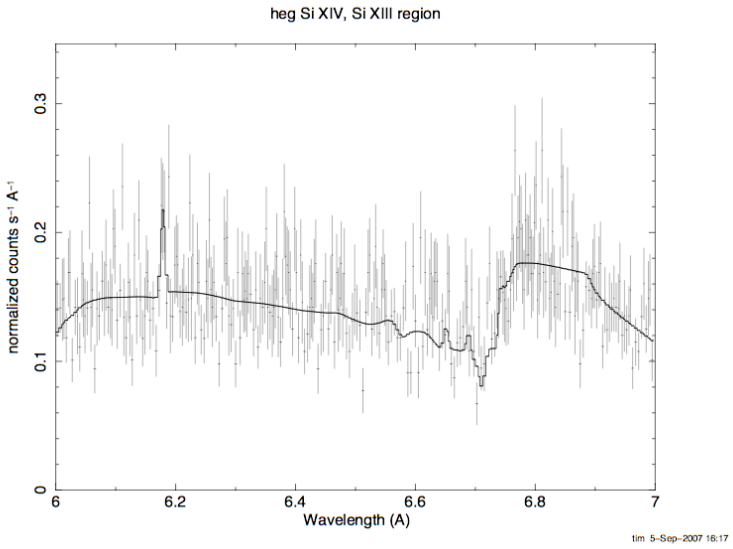
  ==> compact ADC? low Fe abundance?
- Line widths: v<600 km/s

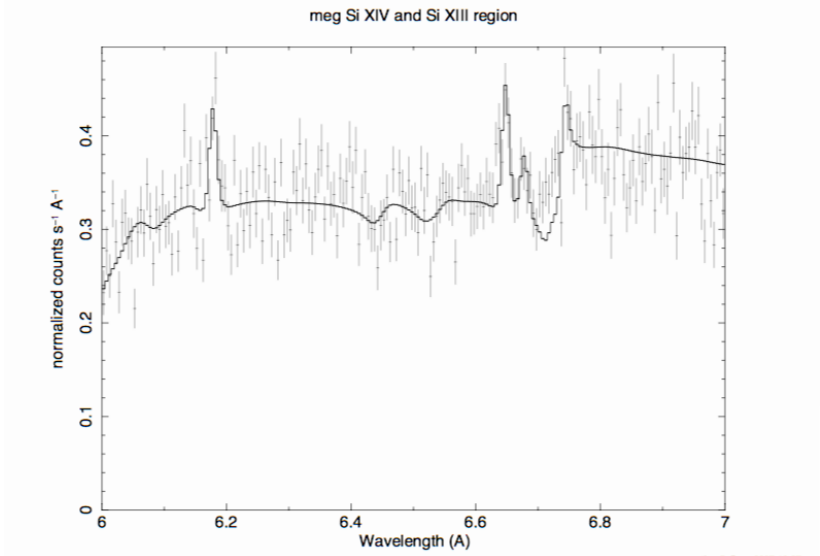
  ==> R>$10^{10.5}$ (M/M_{sun}) cm

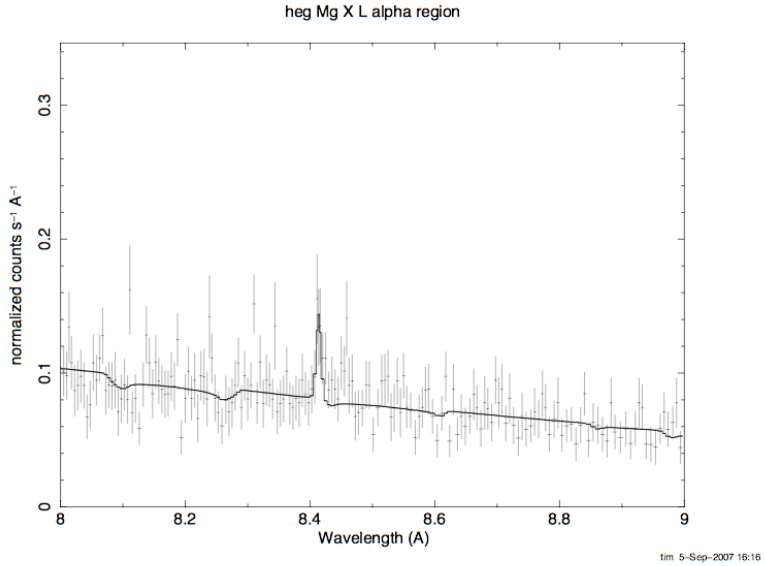
The end

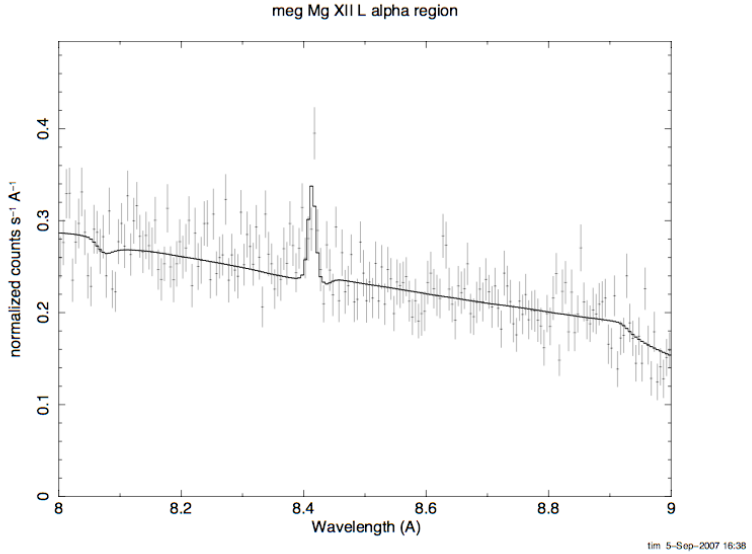
Extra slides

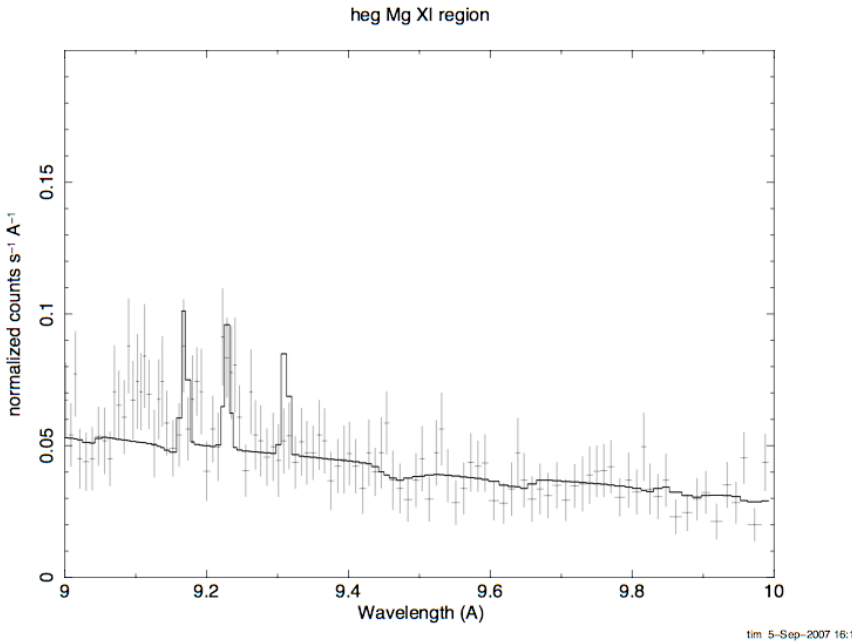
Line detections and parameters from Gaussian fits:

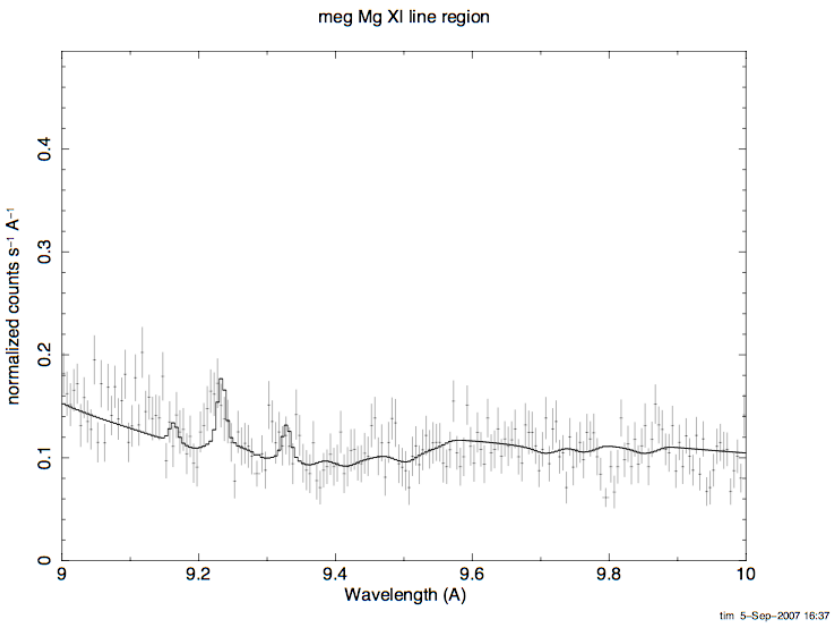


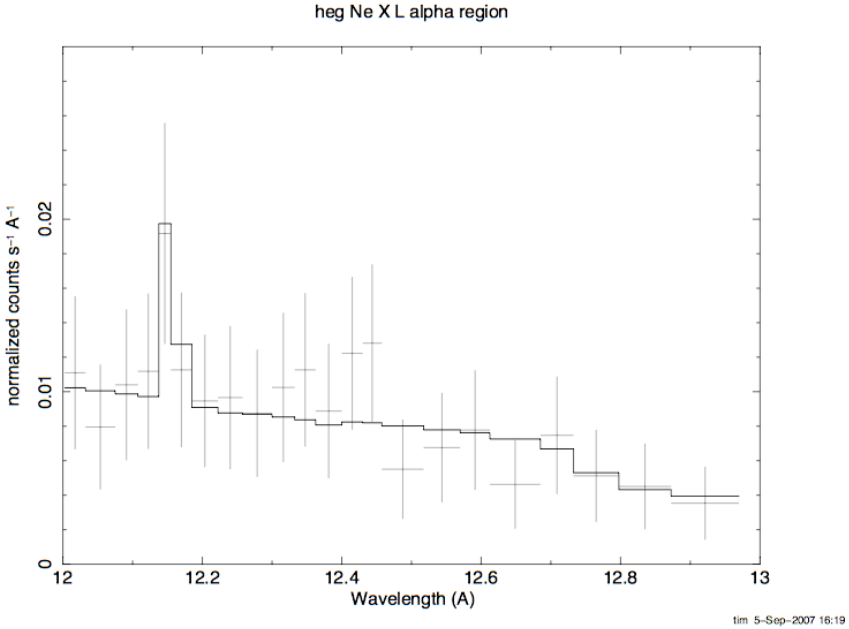


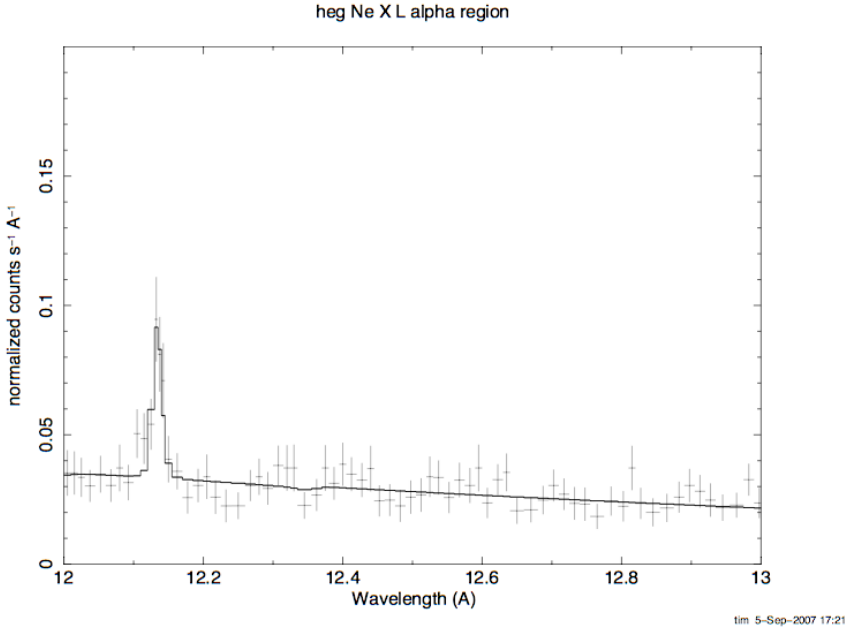


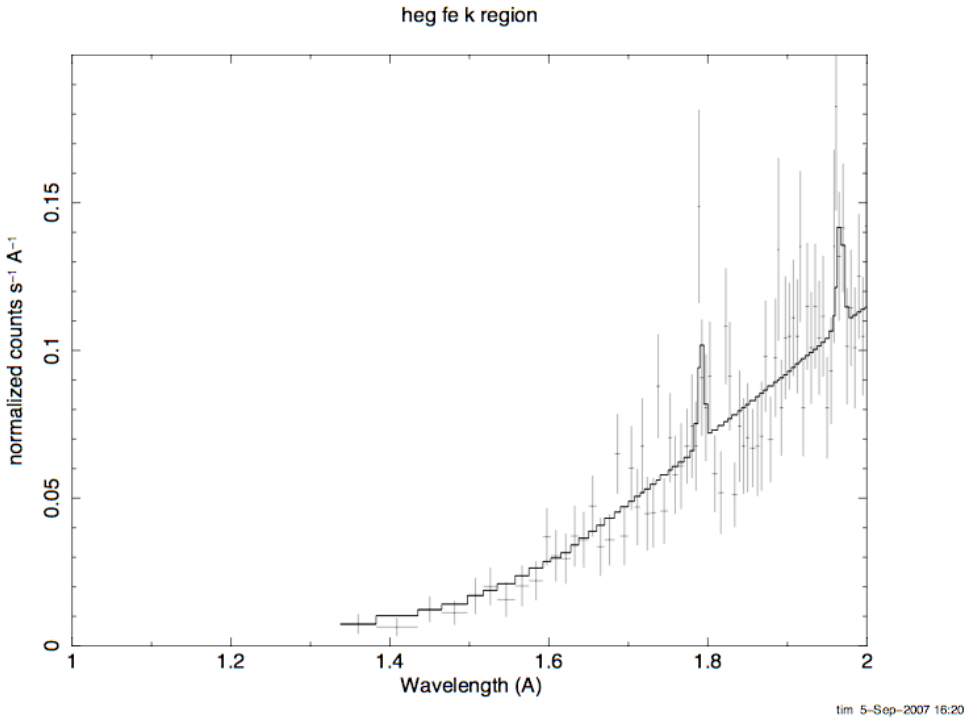



heg Mg XI region
normalized counts s⁻¹ A⁻¹
0
0.05
0.1
0.15
9
9.2
9.4
9.6
9.8
10
Wavelength (A)
tim 5-Sep-2007 16:1


meg Mg XI line region
normalized counts s⁻¹ A⁻¹
0
0.1
0.2
0.3
0.4
9
9.2
9.4
9.6
9.8
10
Wavelength (A)
tim 5-Sep-2007 16:37


heg Ne X L alpha region
normalized counts s⁻¹ A⁻¹
0
0.01
0.02
12
12.2
12.4
12.6
12.8
13
Wavelength (A)
tim 5-Sep-2007 16:19


heg Ne X L alpha region
normalized counts s⁻¹ A⁻¹
0
0.05
0.1
0.15
12
12.2
12.4
12.6
12.8
13
Wavelength (A)
tim 5-Sep-2007 17:21


heg fe k region
normalized counts s^{-1} A^{-1}
0
0.05
0.1
0.15
1
1.2
1.4
1.6
1.8
2
Wavelength (A)
tim 5-Sep-2007 16:20

HETG Observations of AC211 in the Globular Cluster M15.

T. R. Kallman, L. Angelini, and N. E. White (NASA/GSFC), J. Sepinsky (NWU)

We report on a 60 ksec observation of the low mass X-ray binary AC211/4U2127+119 in the Globular CLuster M15 using the Chandra HETG. The presence of the confusing source $\sim$3 arc-seconds away necessitates careful observation planning and analysis to disentangle the two spectra. The observation spans approximately one binary orbity, and the HETG spectrum shows emission lines from highly ionized Si, Mg, Ne, and O, and also features which correspond to the K lines of iron. The ratios of the helium-like lines from Mg and Si provide a lower limit on the density or the UV radiation field in the line emitting region. The relative strengths of the H- and He-like lines are consistent with photoionization equilibrium, with a narrow range of allowed ionization parameters. This provides an upper limit on the distance of the line-emitting gas from the source of X-ray continuum. The line emission is crudely consistent with that expected from an accretion disk corona, although there are important differences between this source and other likely ADC sources. One example is the strength of the iron line. We discuss these differences, and interpret them in the context of other information about this source: its orbital parameters and the nature of the companion star.