There is Nothing Like the Present

(for X-ray Spectroscopy)

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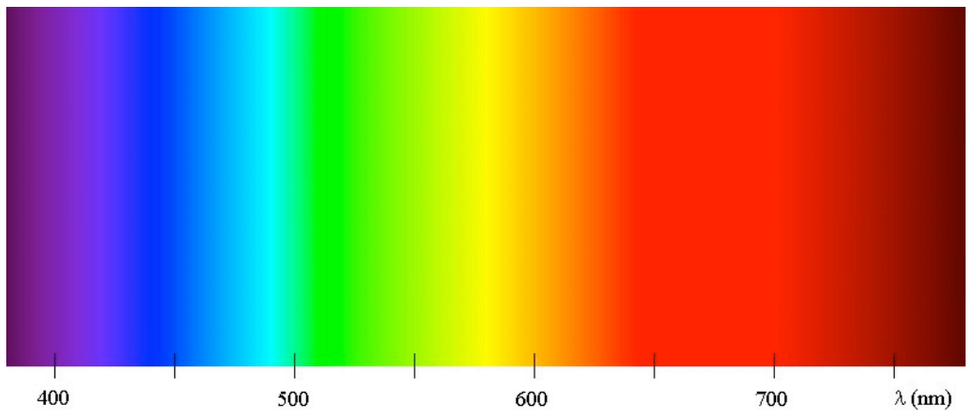
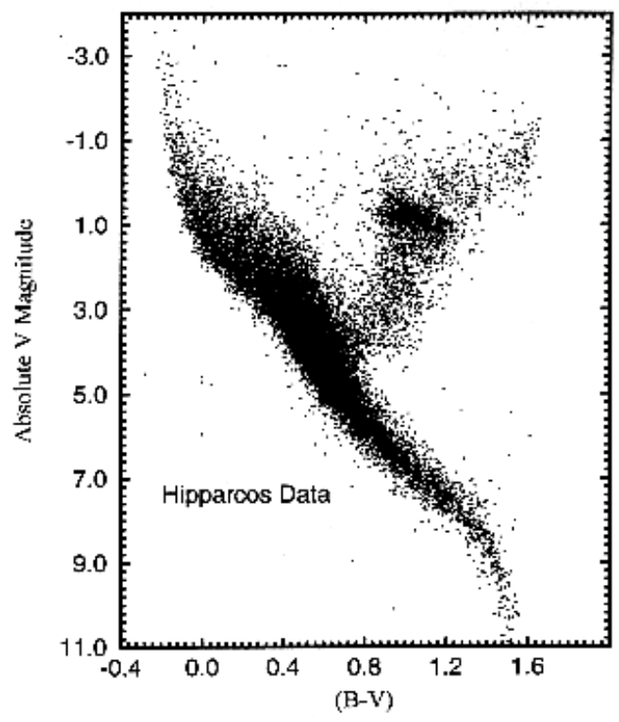
Columbia University and SRON/Utrecht
Cambridge, August 21, 2015

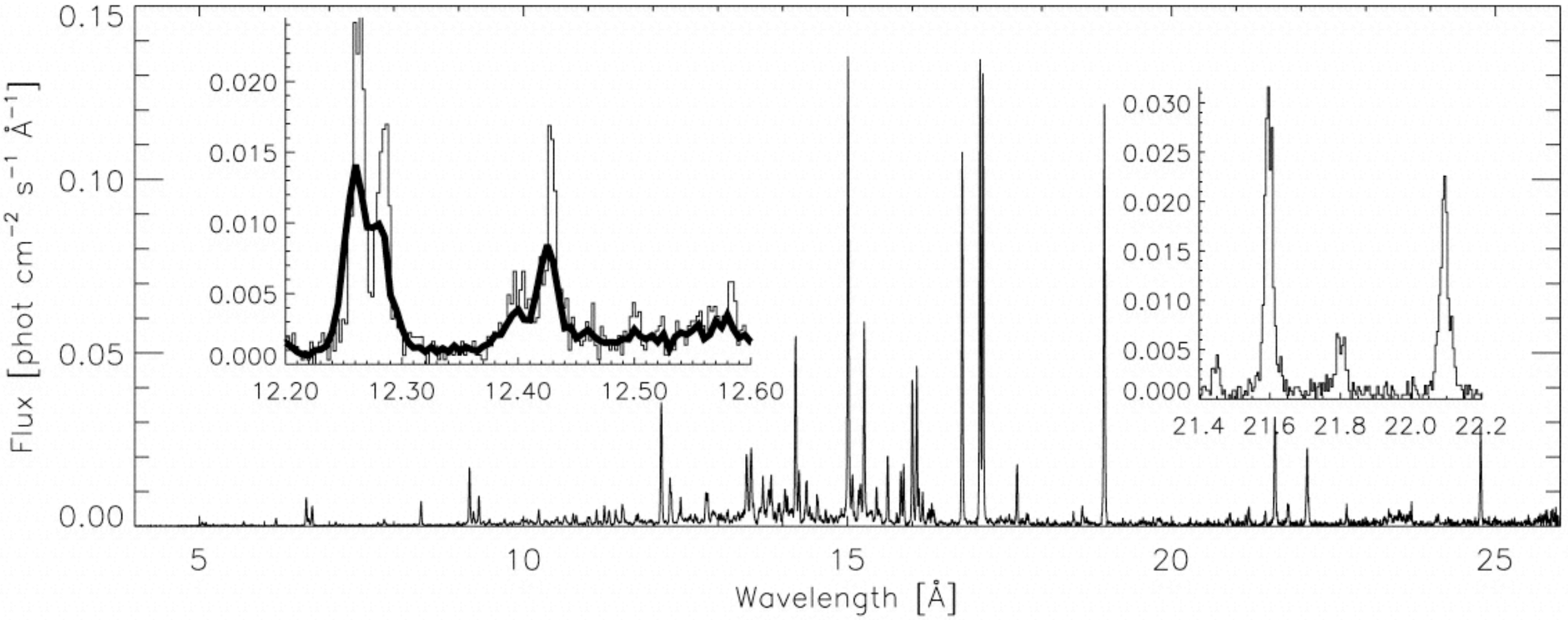
This is a great time for spectroscopy:

completing a revolution that has been completed in all other bands
(except γ nuclear line spectroscopy)

pre-*Chandra*:

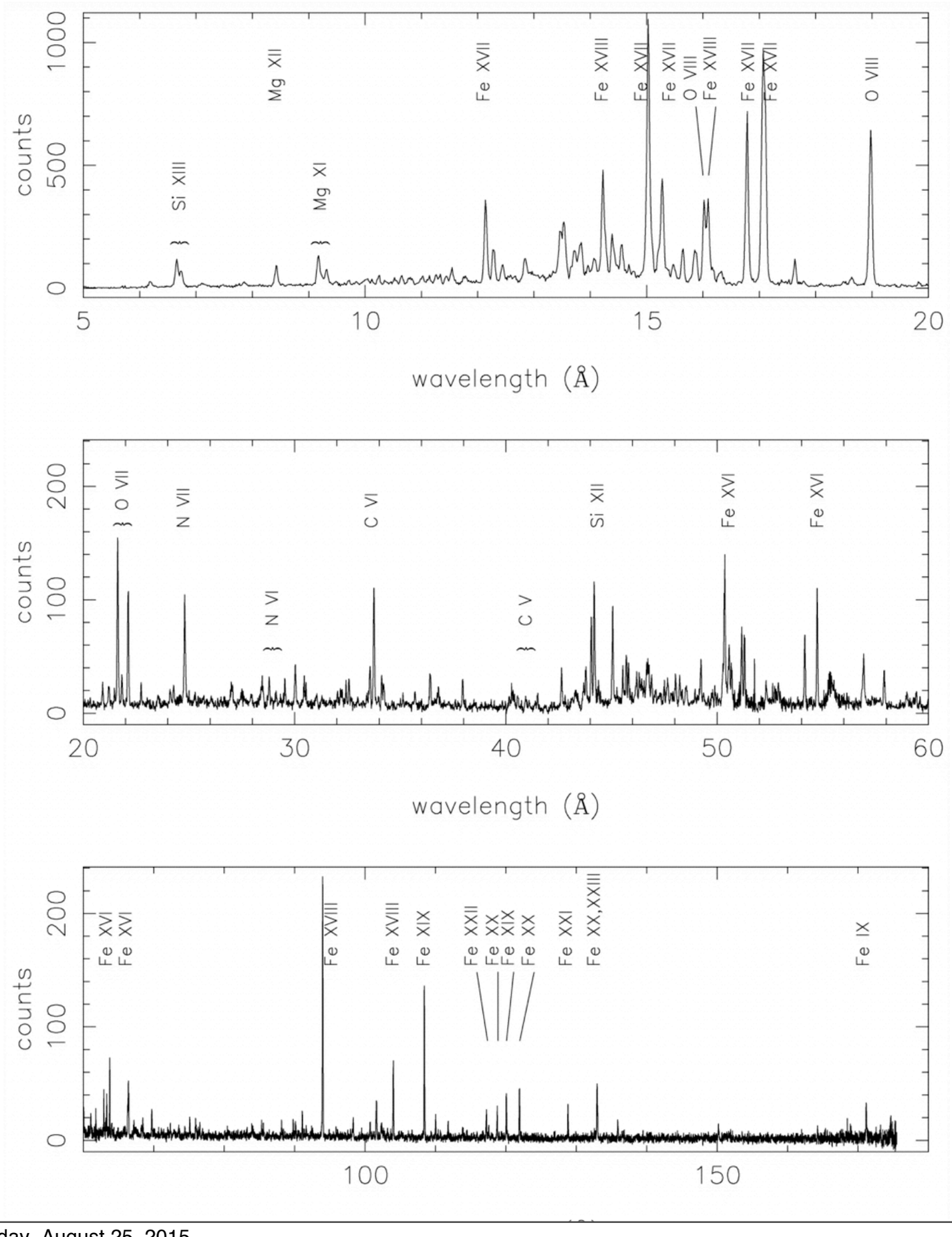






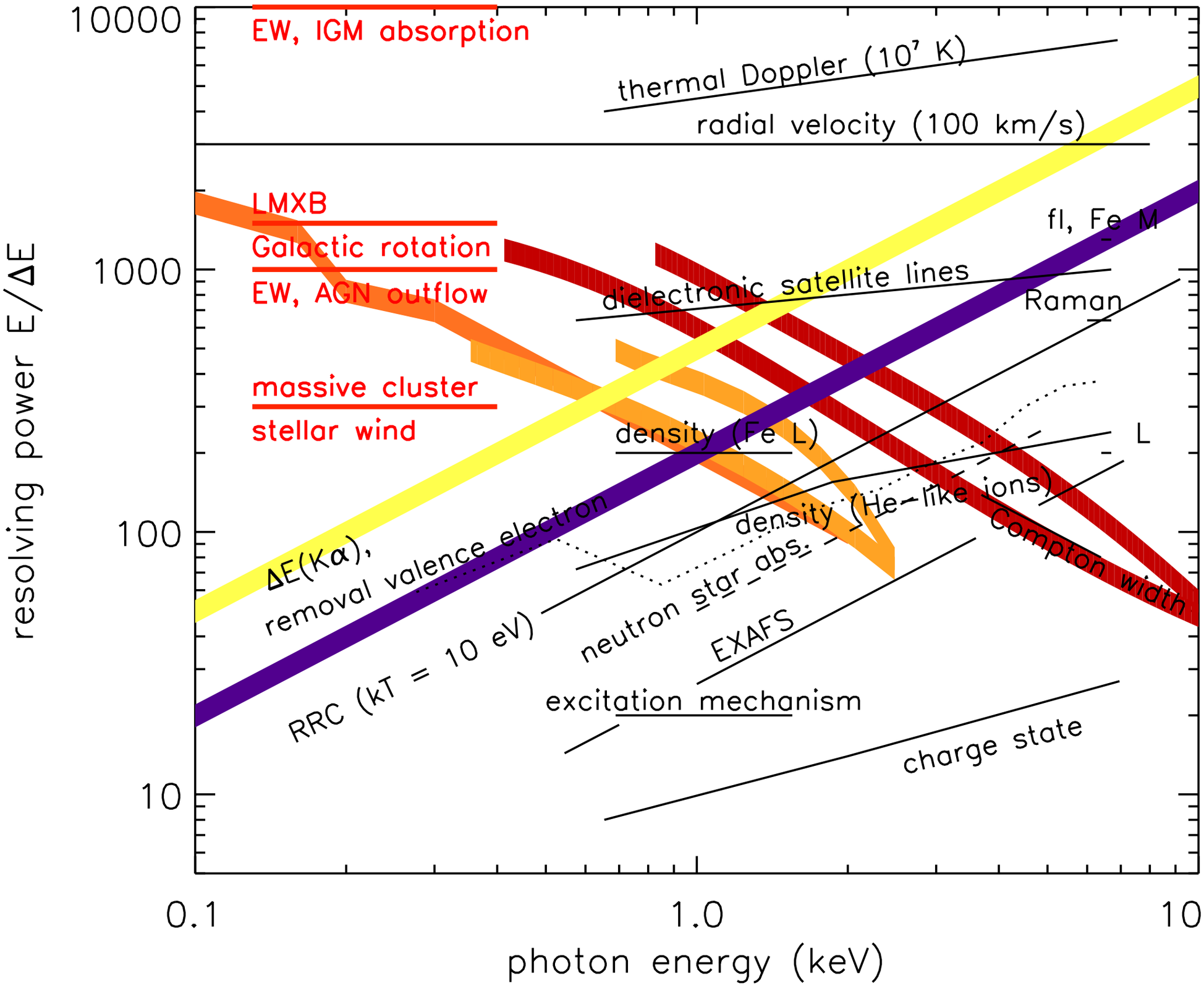
Capella, *Chandra*/HETGS; Canizares *et al.* 2000)

(but of course we had the intermediate step of CCDs)



Capella, *Chandra*/LETGS; Brinkman *et al.* 2000)

X-ray Spectroscopic Diagnostics



Among other things, we learned

how to identify the nature of the ionization balance (collisional/photon driven; RRC's)

how to use the He-like triplets to determine local plasma conditions *and* effects of large-scale radiative transfer

the same, with the Fe L spectrum

interpret the fluorescent spectra of Fe and Si

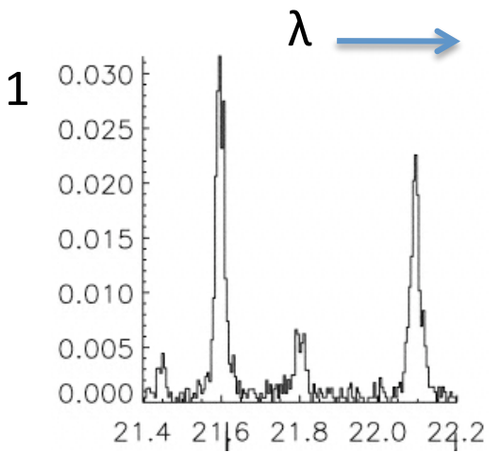
how to do absorption spectroscopy: physical chemistry of the MWG ISM (ionization, phase distribution), constrain the nature of dust grains, multiphase AGN outflows, stellar winds, XRB winds, ...

not only high resolution, but- it all worked(s) !

Quiz: A Gallery of He-like Triplets

What conditions produce these triplet spectra?

1



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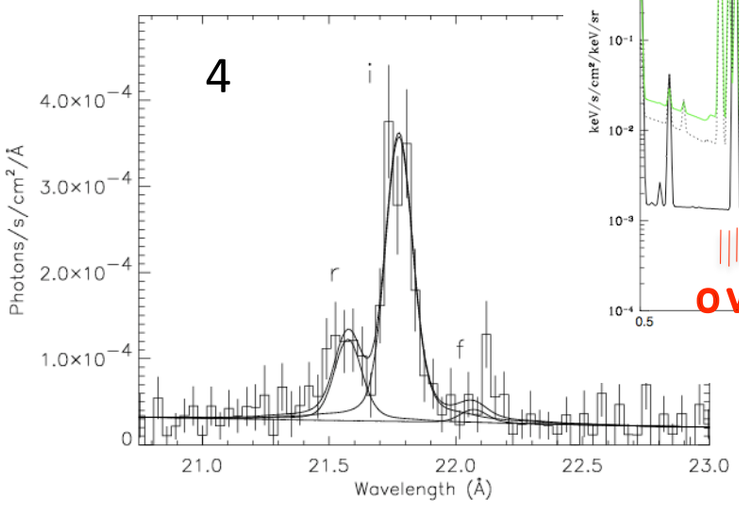

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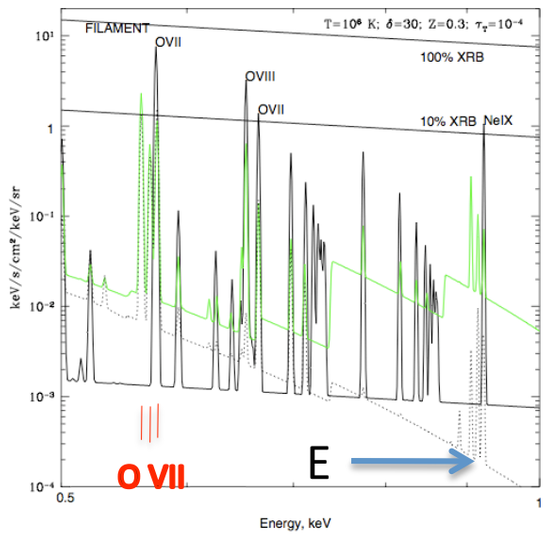
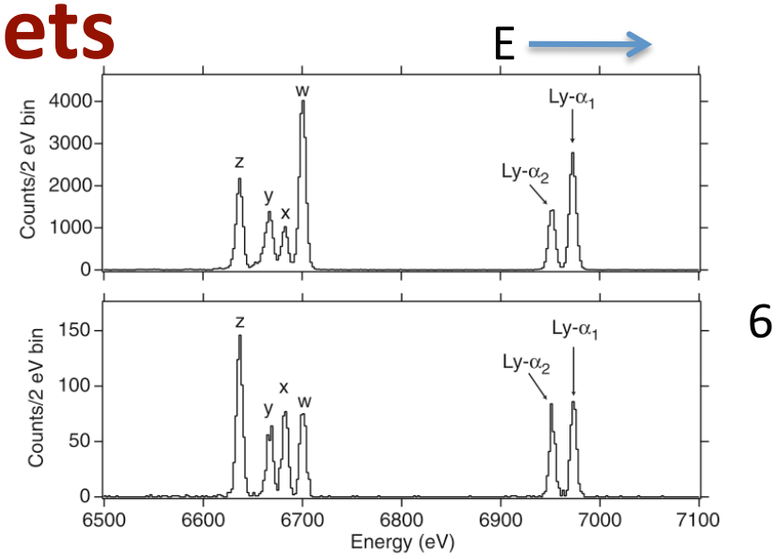


E

6



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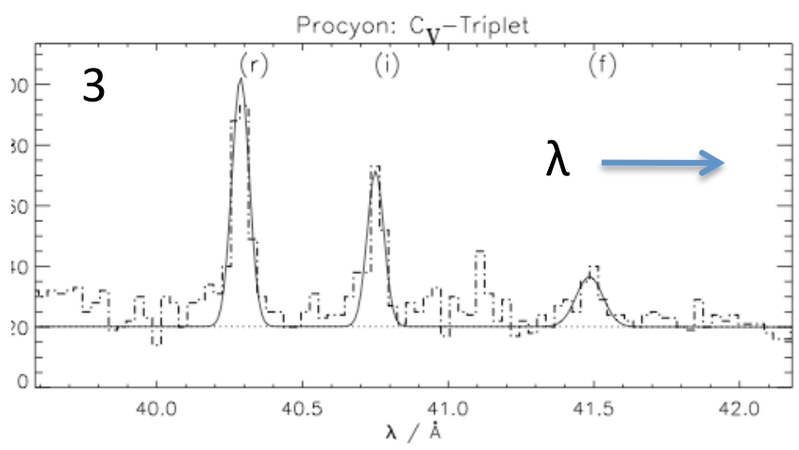

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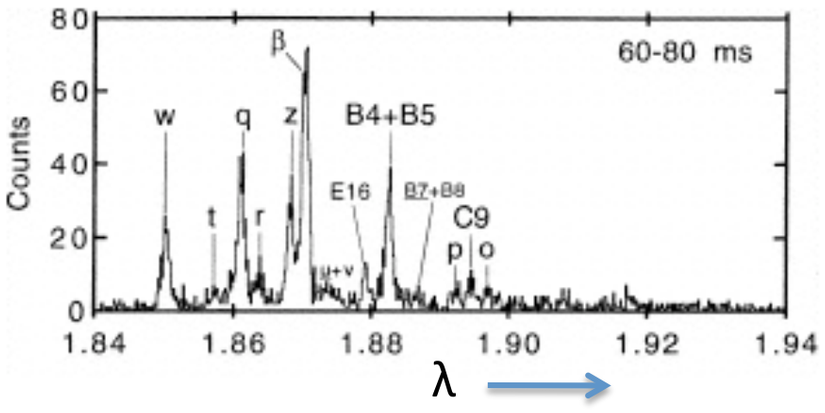

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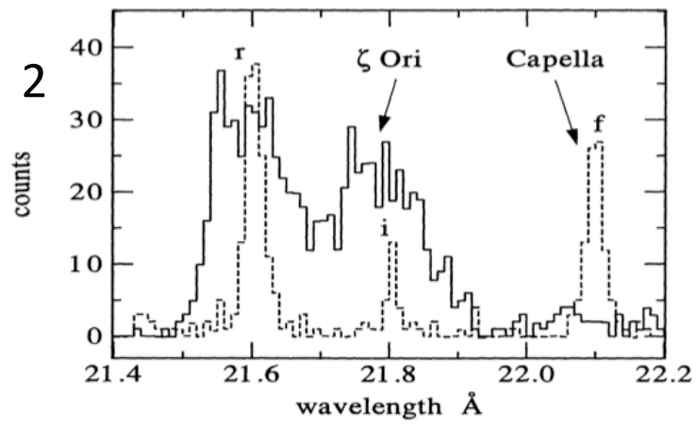
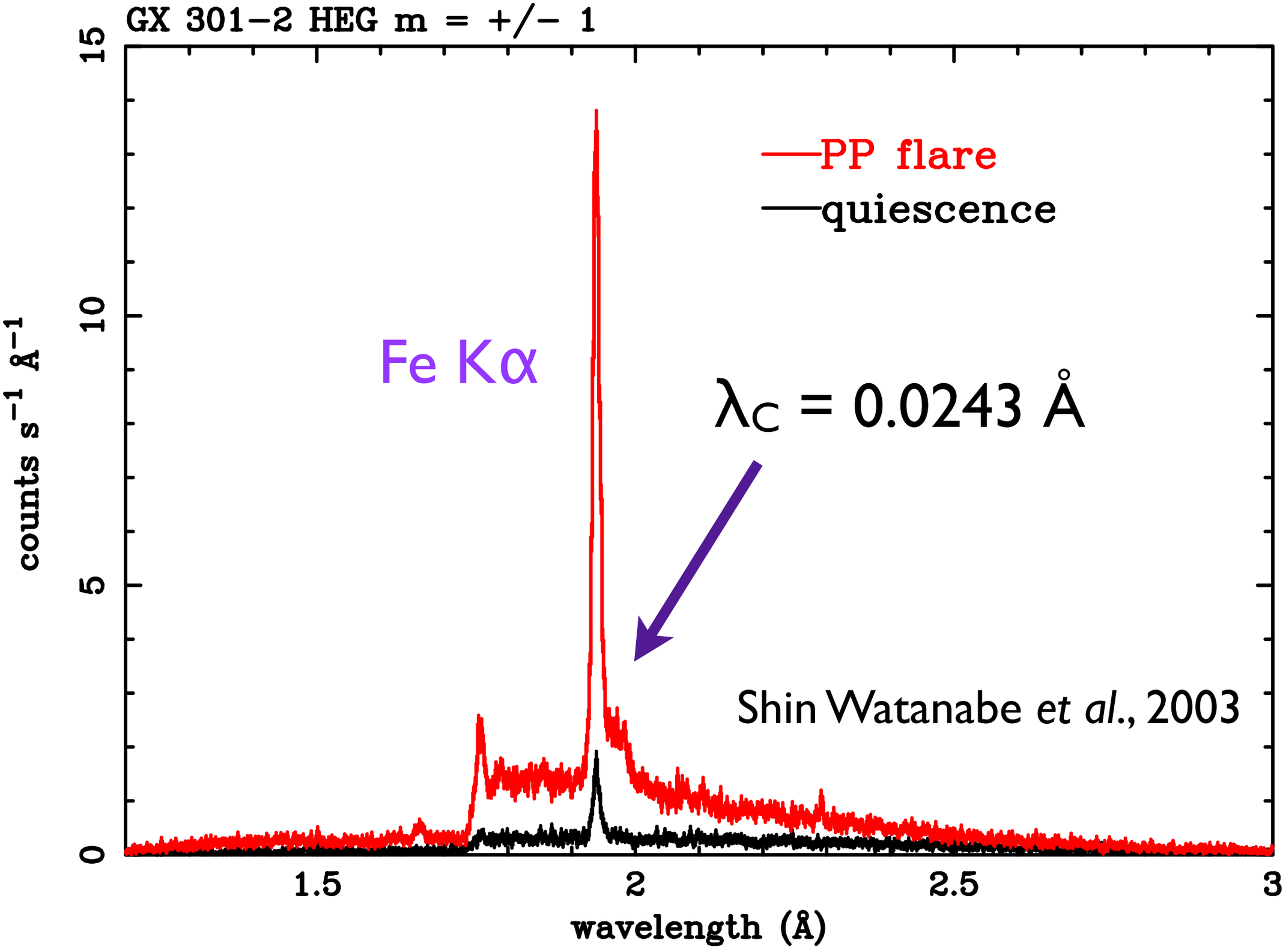
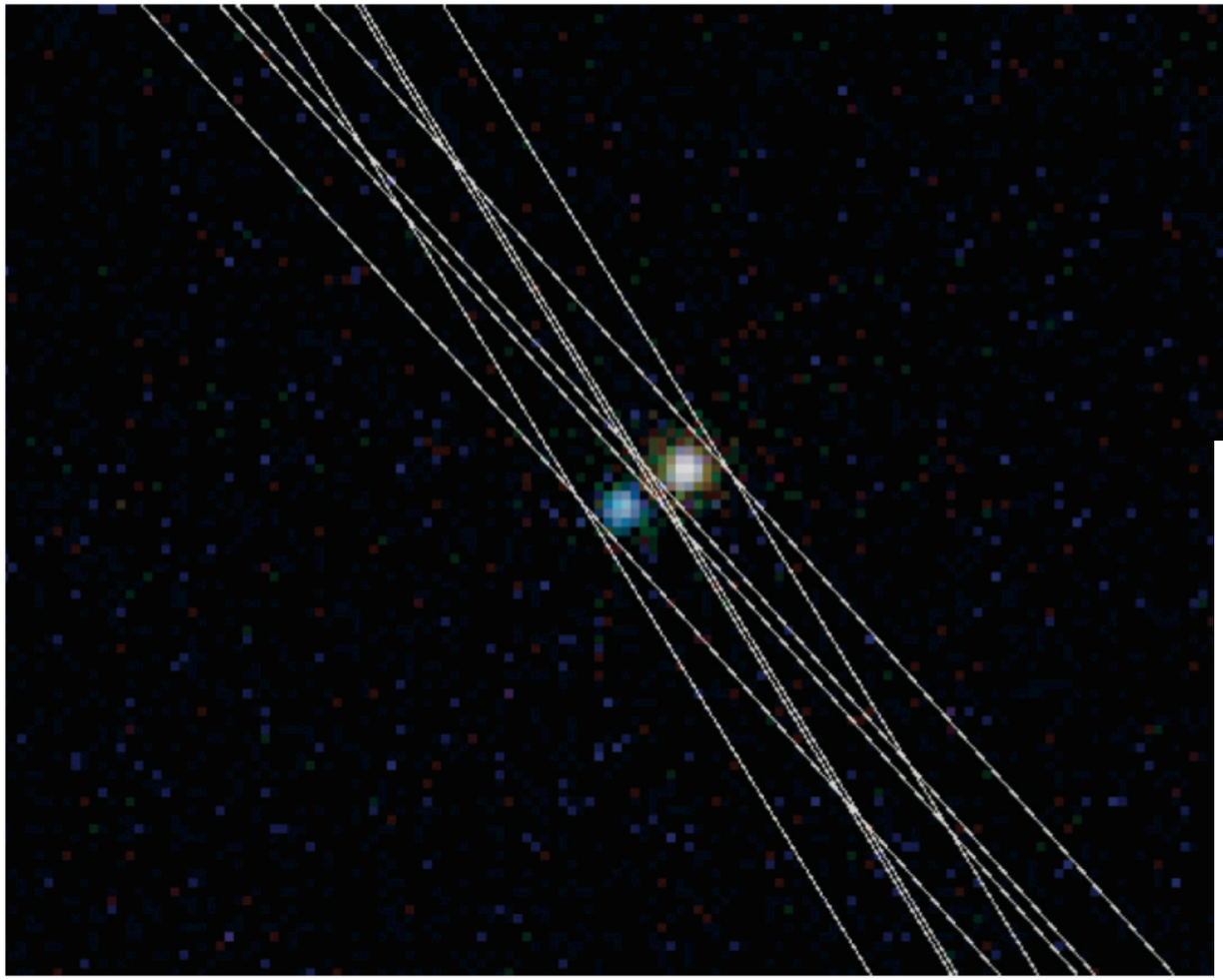


(from *Astro*-H Summer School at Minakami Onsen, 2010)

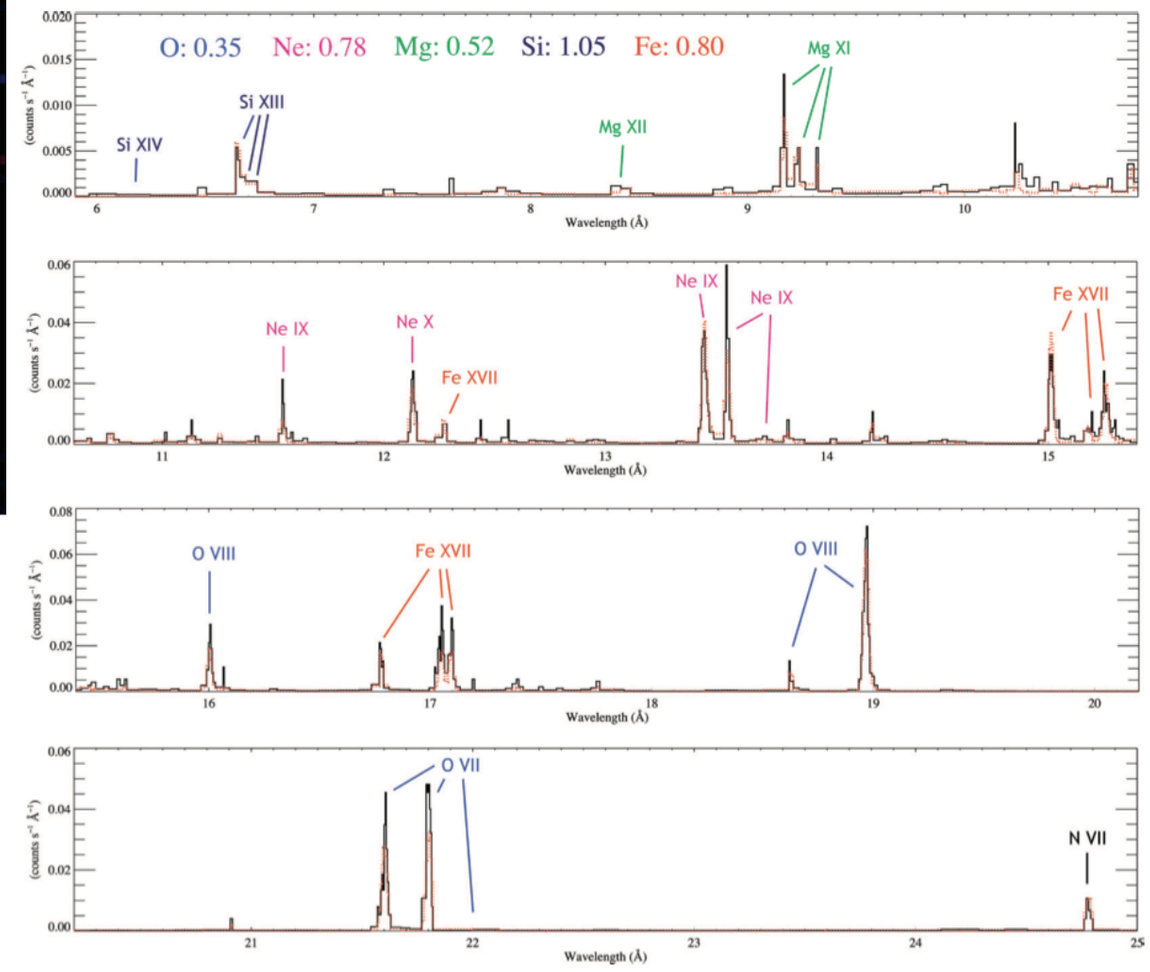
surprising stuff

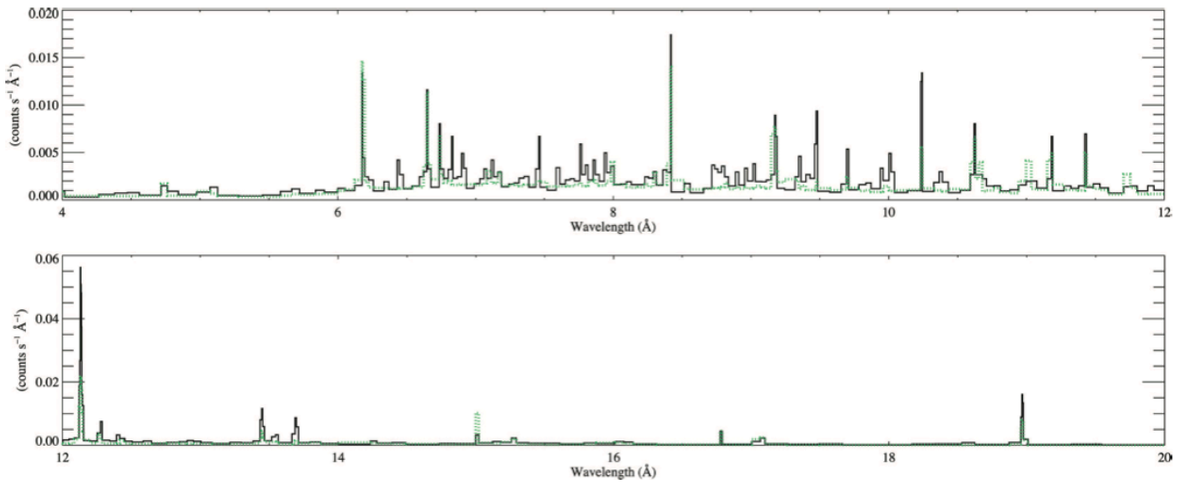
full Compton recoil spectrum!





β Crucis
Chandra HETGS
Cohen *et al.* 2009





β Cru (B0.5 III)

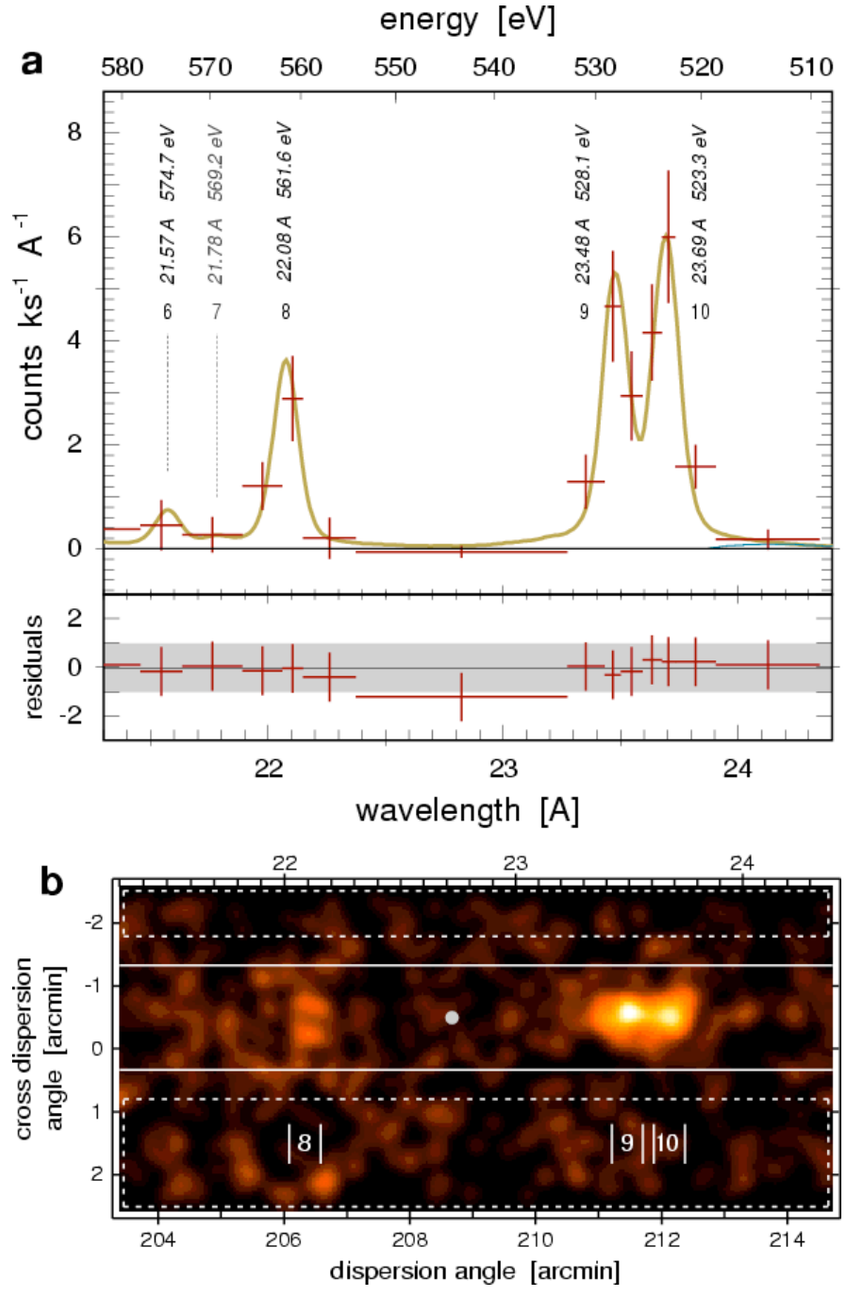
companion (PMS; L_X = 8.10^{29} erg s^{-1}; unknown optically)

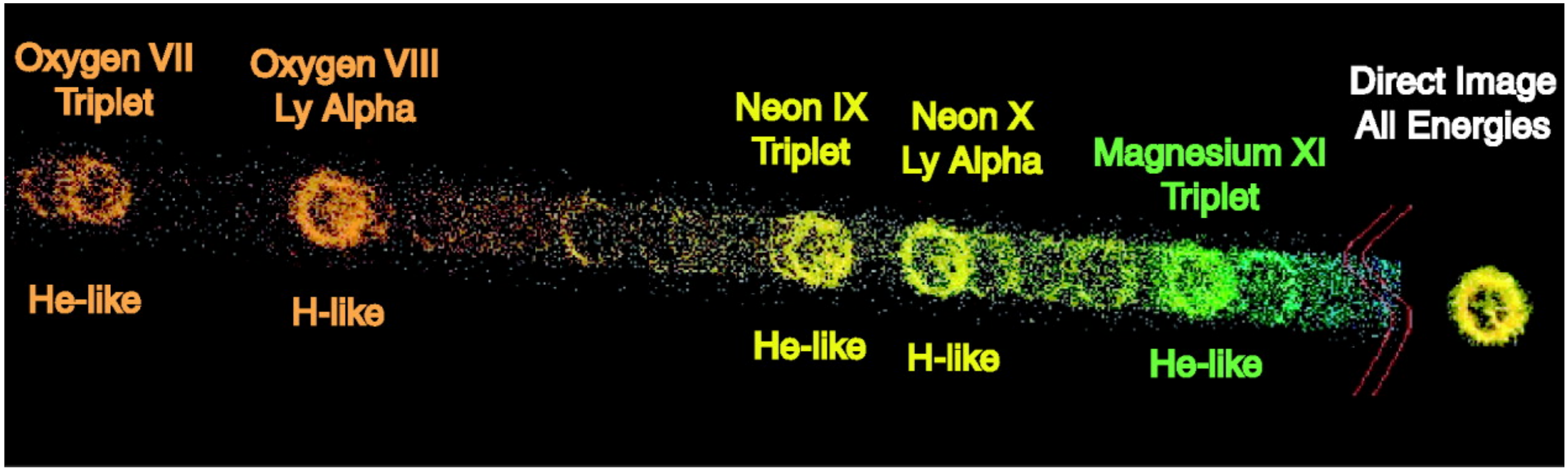
We now know how to handle:

stellar coronae (PMS, MS)
stellar winds (single; in XRB)
XRB (including weirdest cases, like GX301, Vela X-1;
Fe K in BHB)
Solar System (planets, comets- Mars!!)
compact objects photospheres (WD, NS)
ULX
supernova remnants (RGS; 1E0102 HETGS)
interstellar and circumgalactic gas and dust
and intergalactic gas too-
but not the Bok Globule near Cyg X-3...
cool cluster cores and Groups (O VII!?)
galaxies
AGN (huge variety)

cosmic explosions and cataclysms:
GRB afterglows
novae
supernovae (*e.g.* SN87A)
TDE!

Mars with RGS;
Dennerl *et al.* 2006

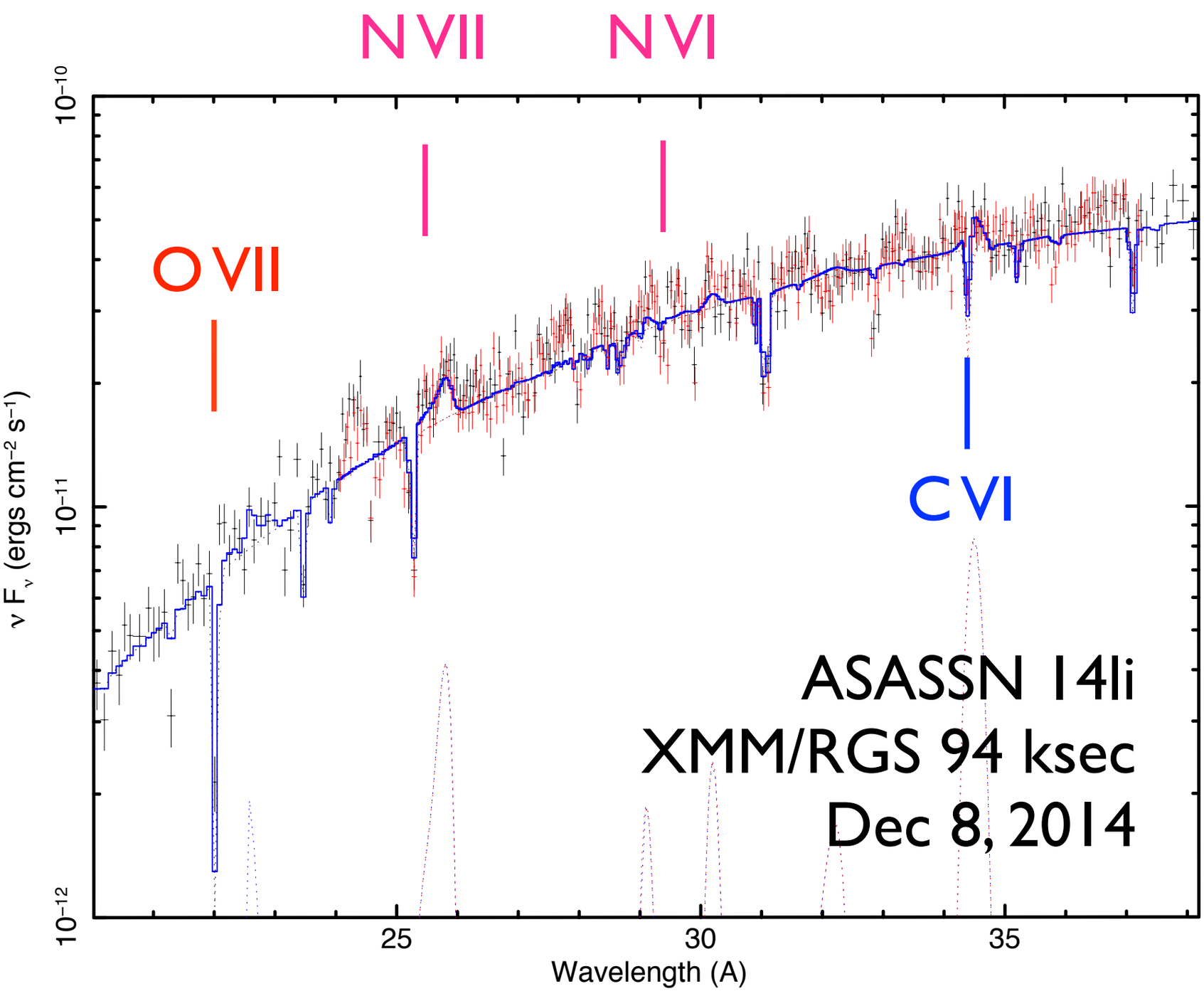




1E0102.2-7219/HETGS; Flanagan *et al.* 2004

and it keeps coming:

see Peter Maksym's poster!

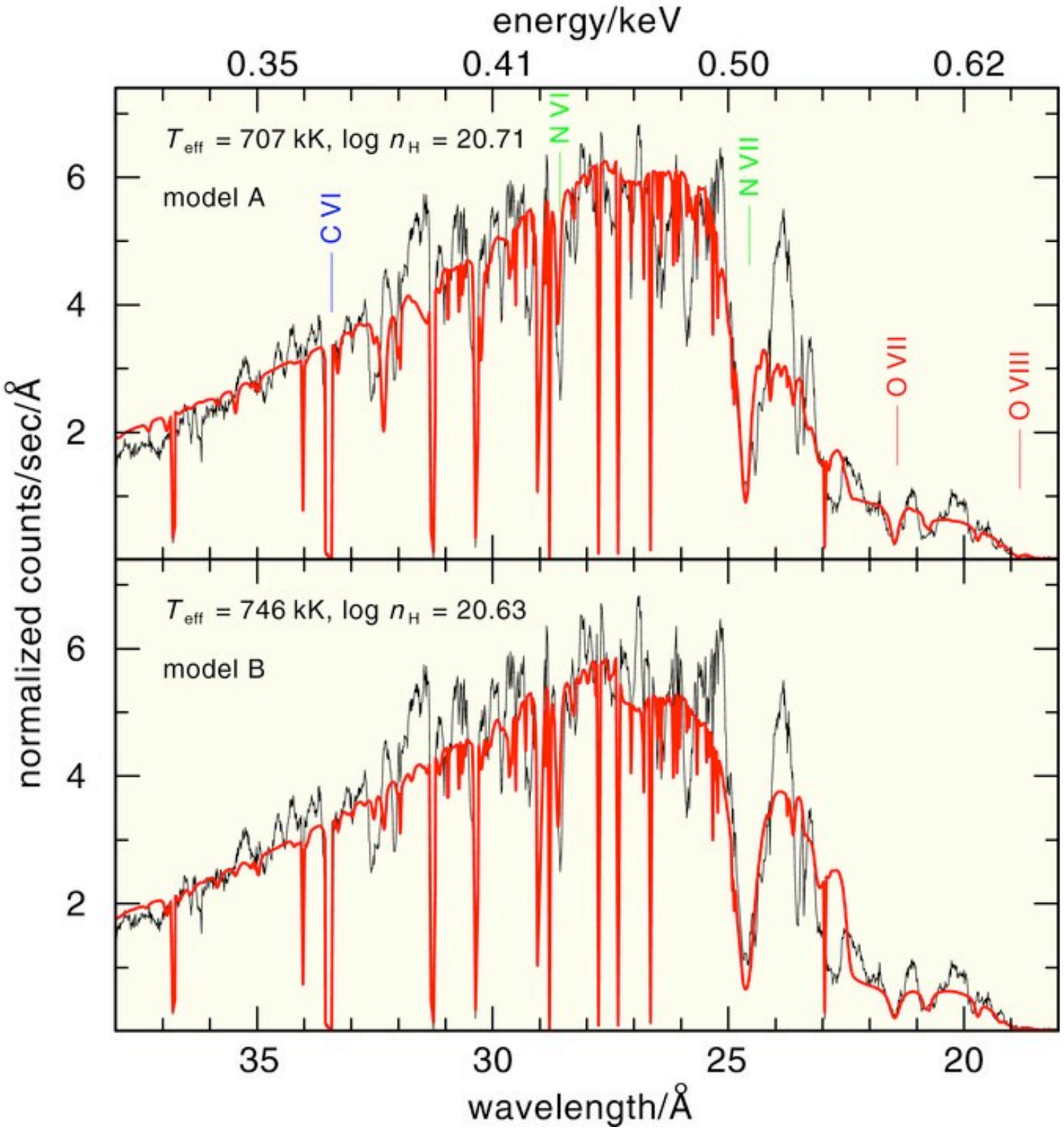


continuum: ~blackbody, $kT_{BB} \approx 53$ eV

superimposed absorption from a massive wind?

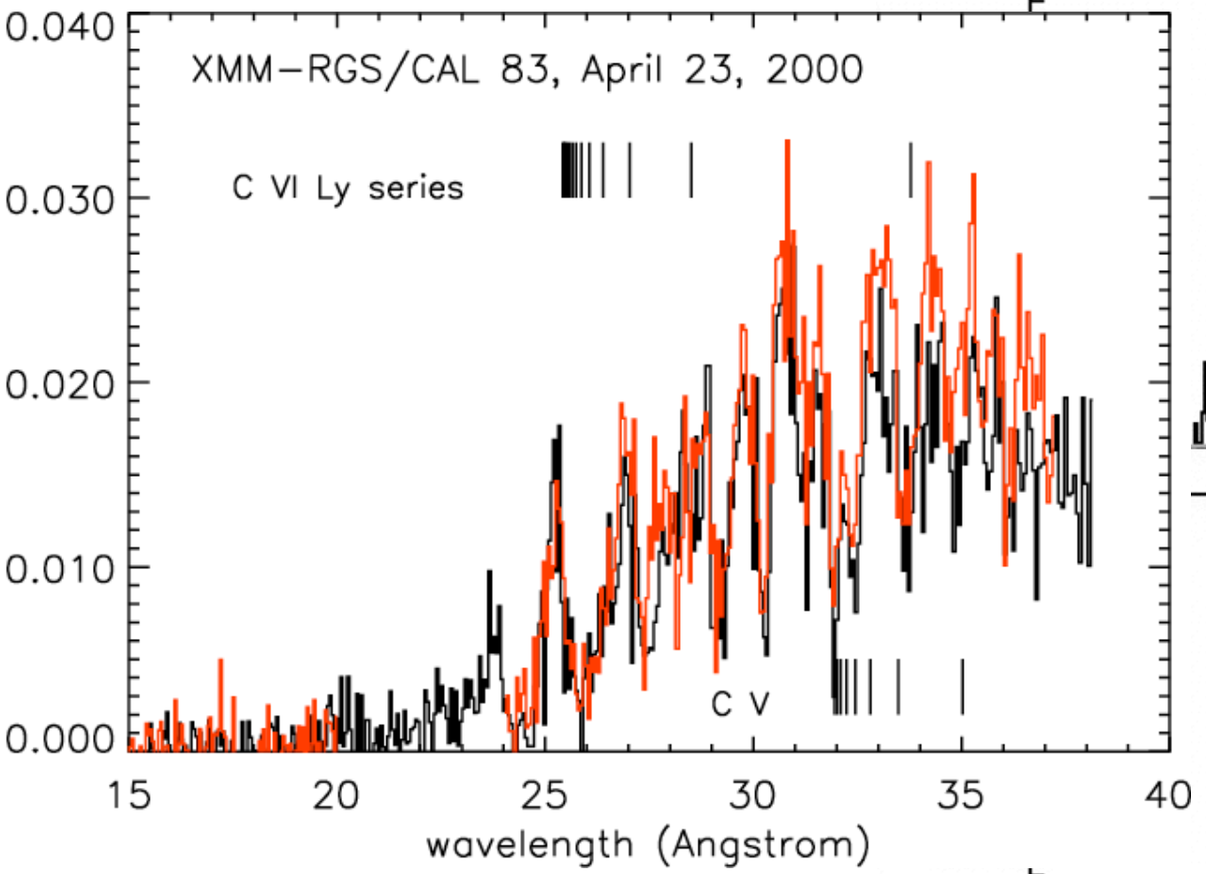
pseudophotosphere?

inner accretion disk? ($M_{BH} \sim 10^6 M_\odot$) (sin i = 0??)



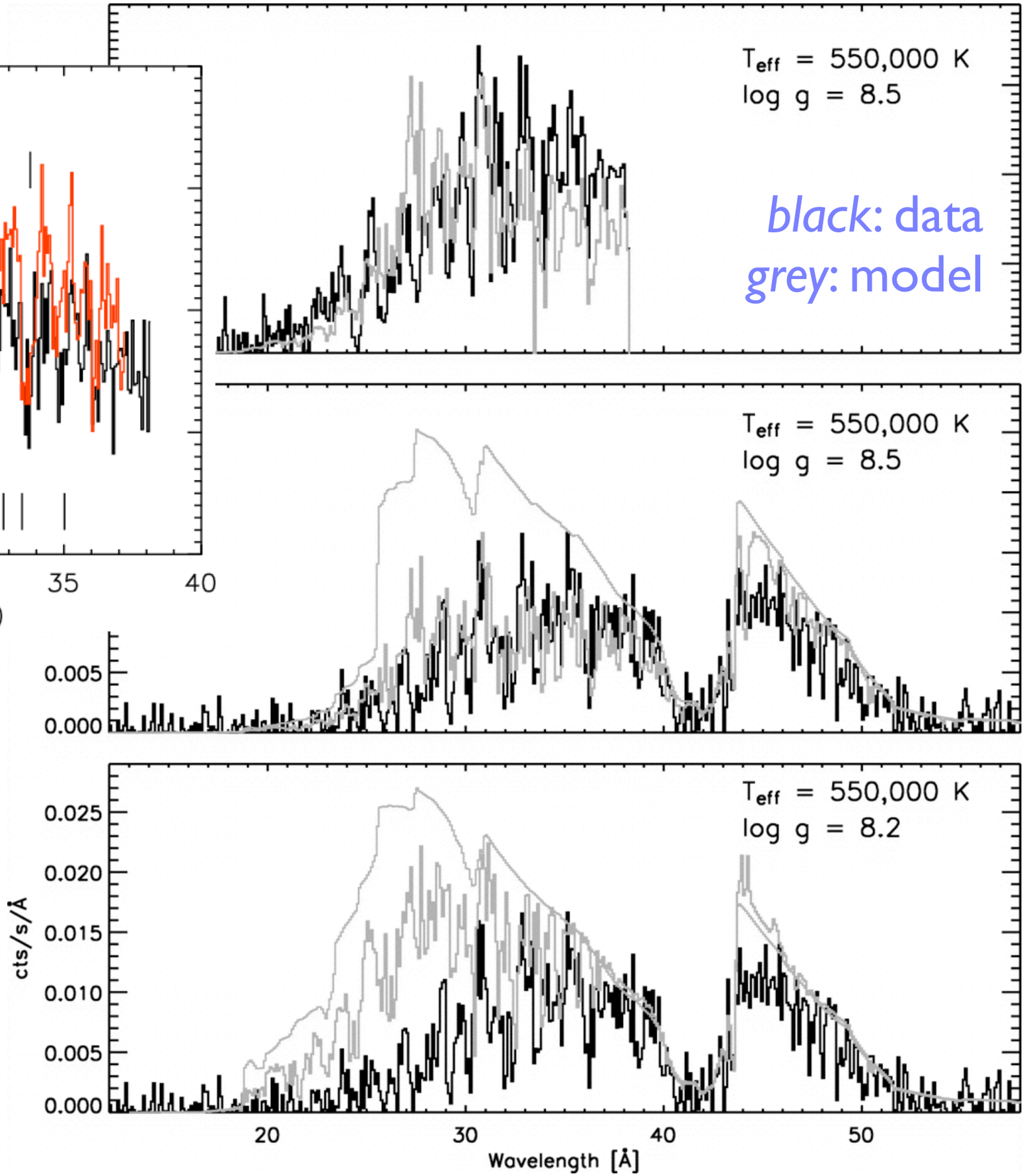
looks like a nova?

V4743 Sgr (Rauch *et al.* 2010)



P *et al.* 2001

or a SSS?
Cal 83



Lanz *et al.* 2005

next developments:

(1) integral field spectroscopy with cryogenic spectrometers: *Astro*-H, Athena

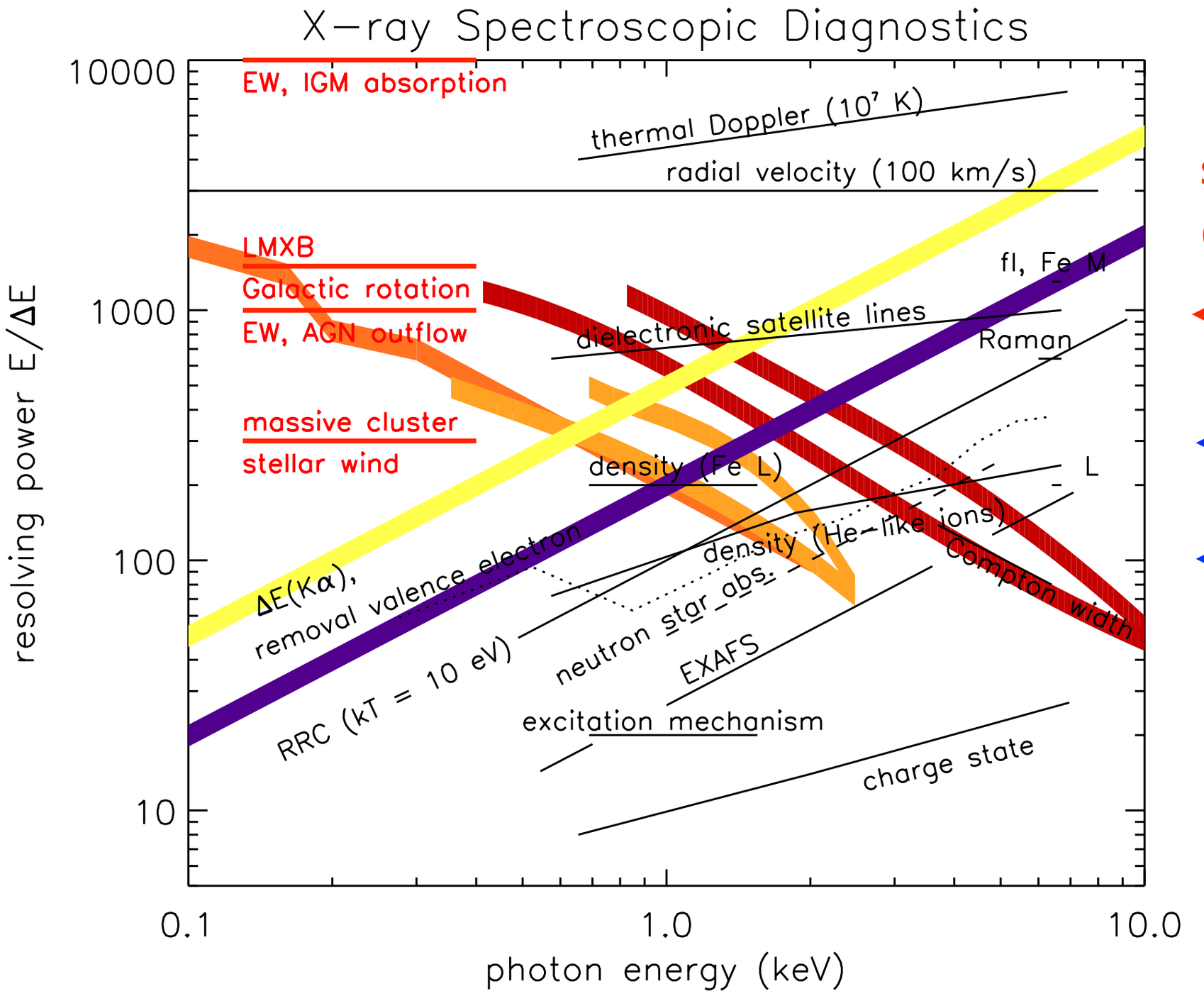
(caveat: resolution point sources already beaten at low energies!)

(2) dedicated very high resolution MIDEX (diffraction gratings)

(3) velocity spectroscopy[*]

[*] will be crucial if we ever want to get around the foreground CX!

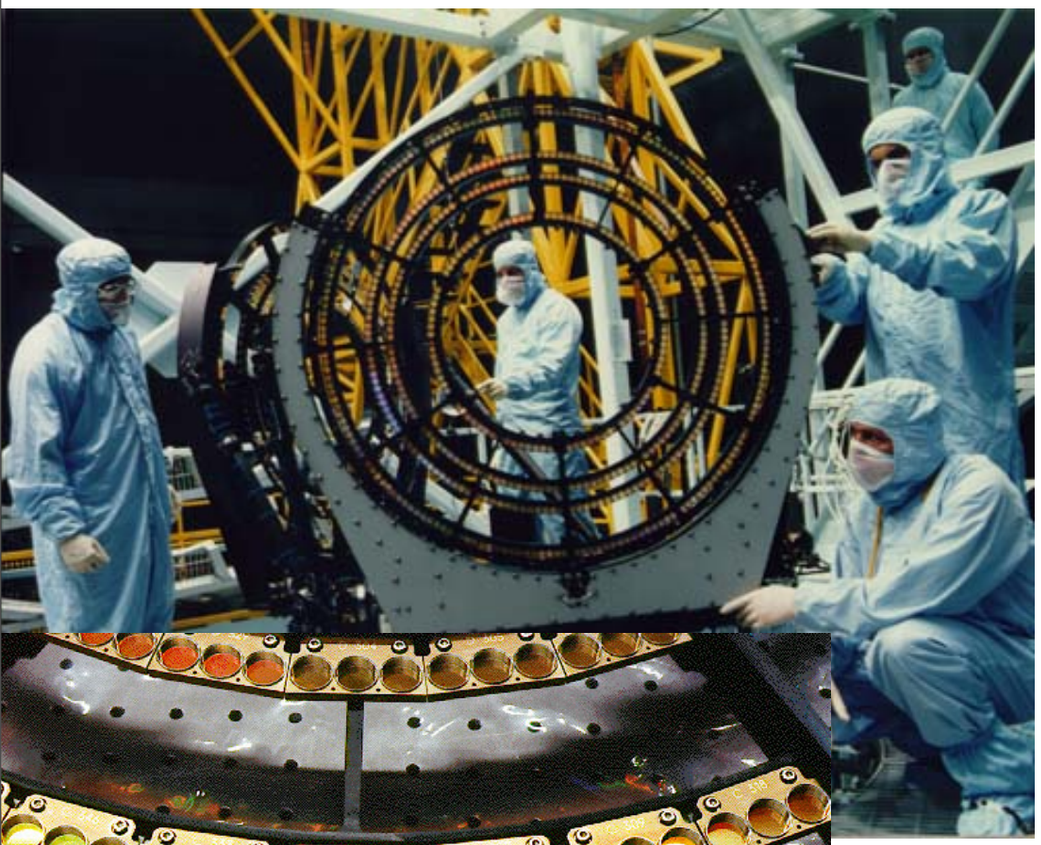
Possibly sombre note on velocity resolution/blurring

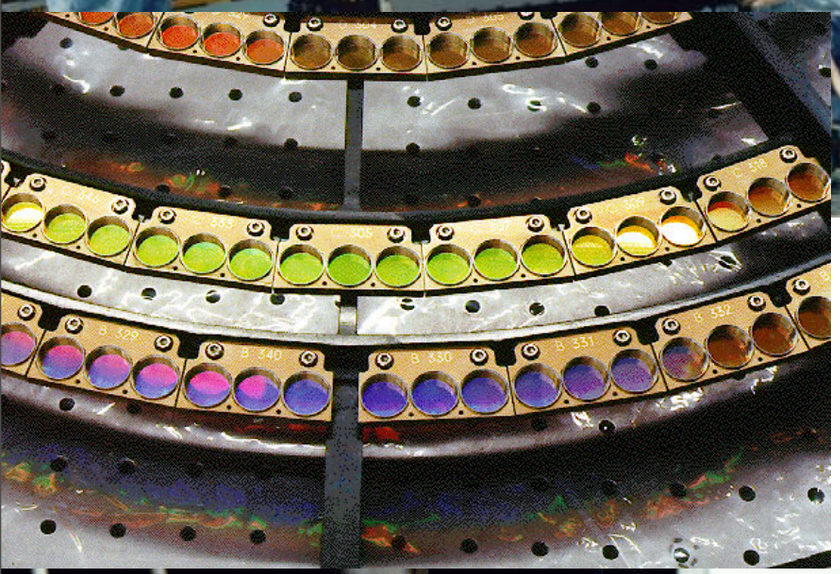


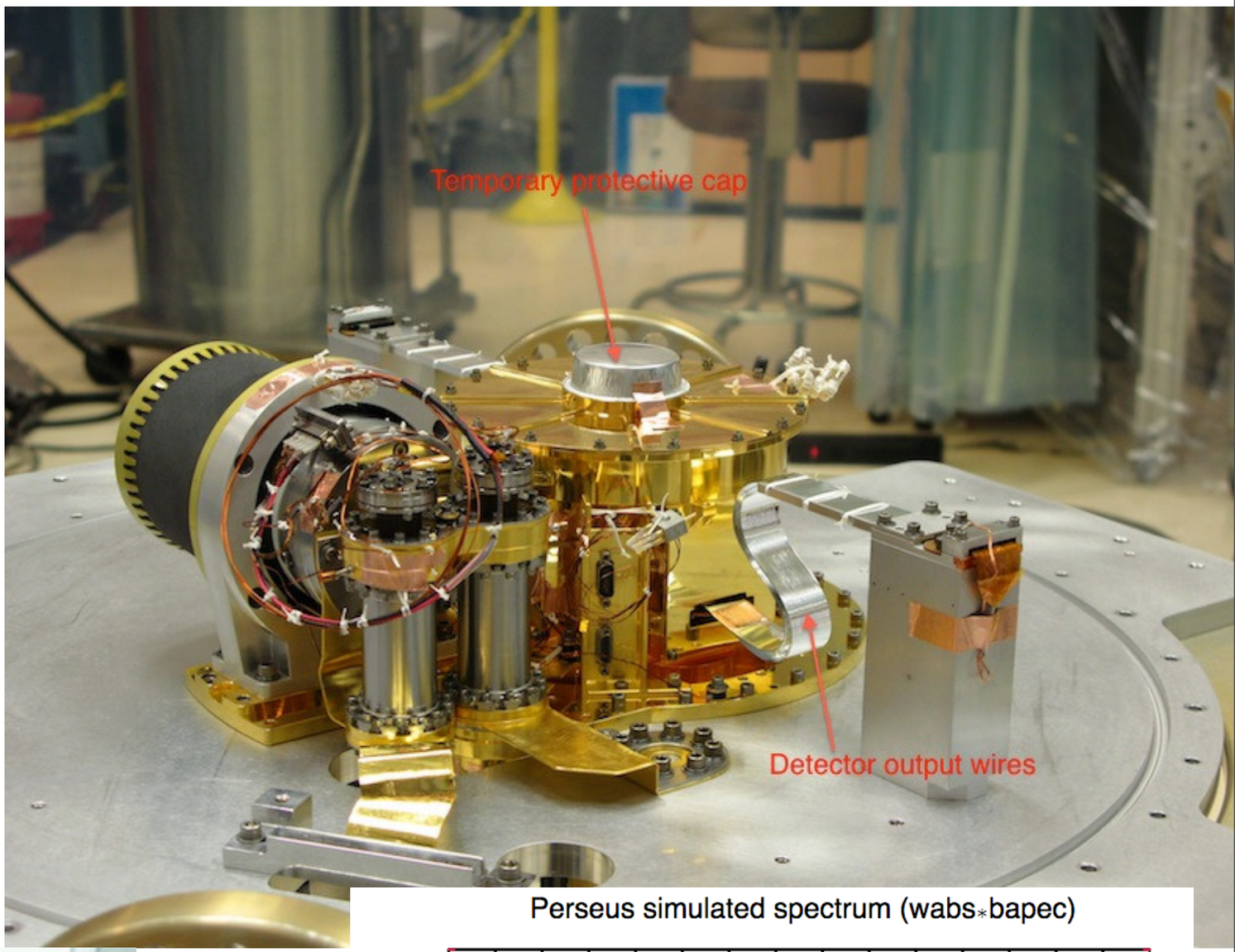
satellite spectra (DR, IE) (equilibrium, kT_e)

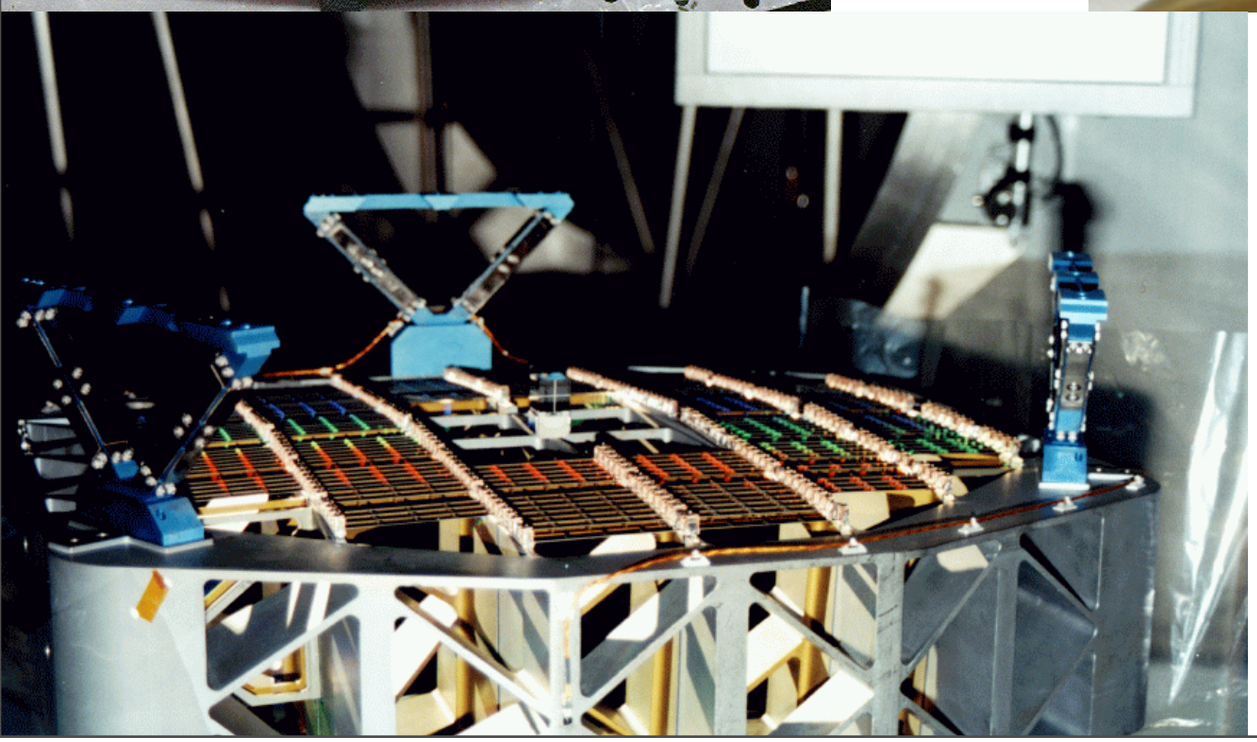
clusters

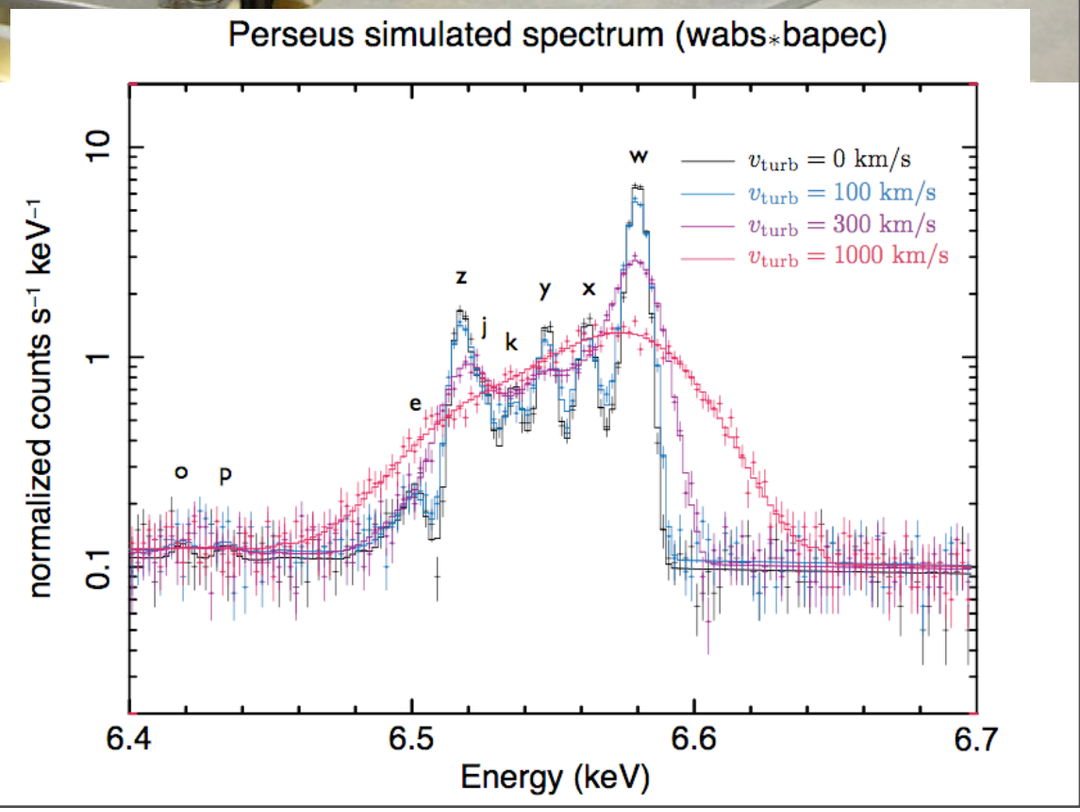
SNR






Temporary protective cap
Detector output wires




Perseus simulated spectrum (wabs*bapec)
normalized counts s⁻¹ keV⁻¹
Energy (keV)
6.4
6.5
6.6
6.7
0.1
1
10
o
p
e
j
k
z
y
x
w
v_{turb} = 0 km/s
v_{turb} = 100 km/s
v_{turb} = 300 km/s
v_{turb} = 1000 km/s

Extrapolation

so would we have done things differently?
should we be doing things differently?

clearly, the most challenging thing will be making spatially resolved (but convolved) spectroscopy work

while we

use *Chandra* and XMM for long spectroscopic exposures as much as we can