Disk winds in stellar-mass black holes

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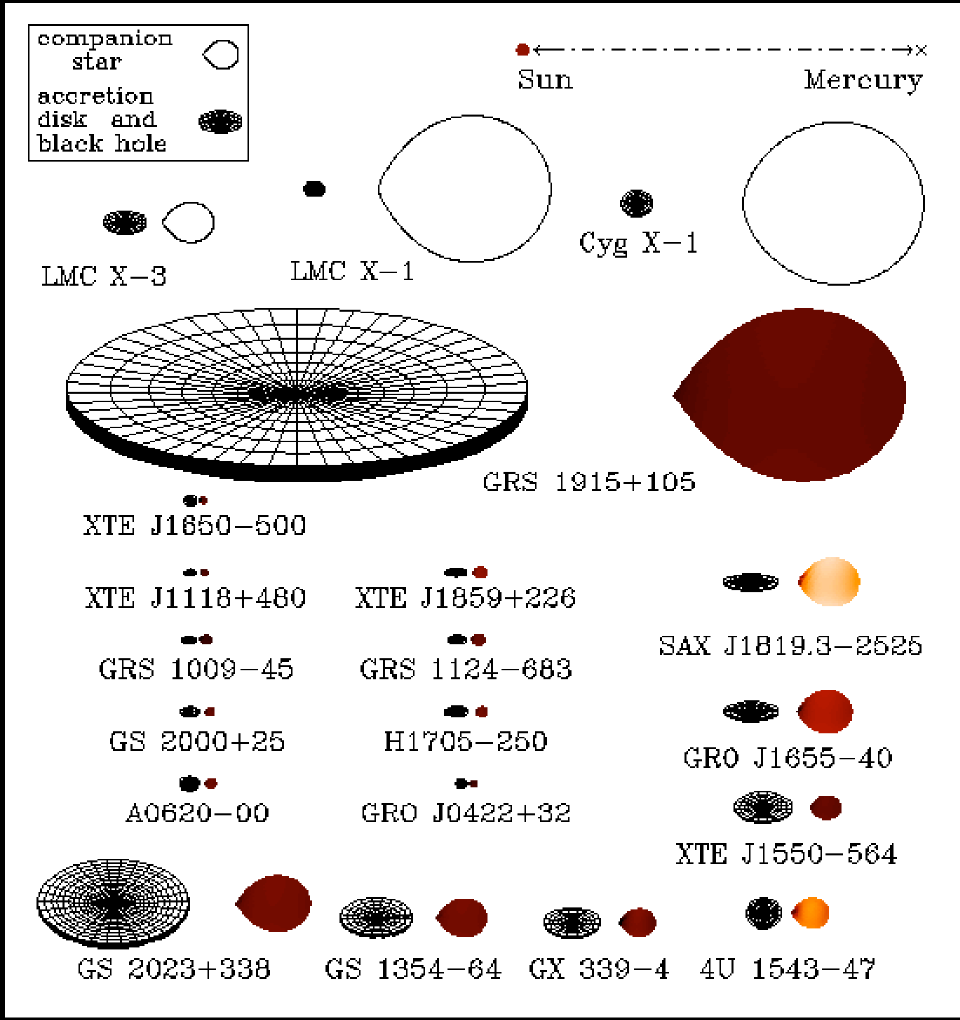
Four key ideas:

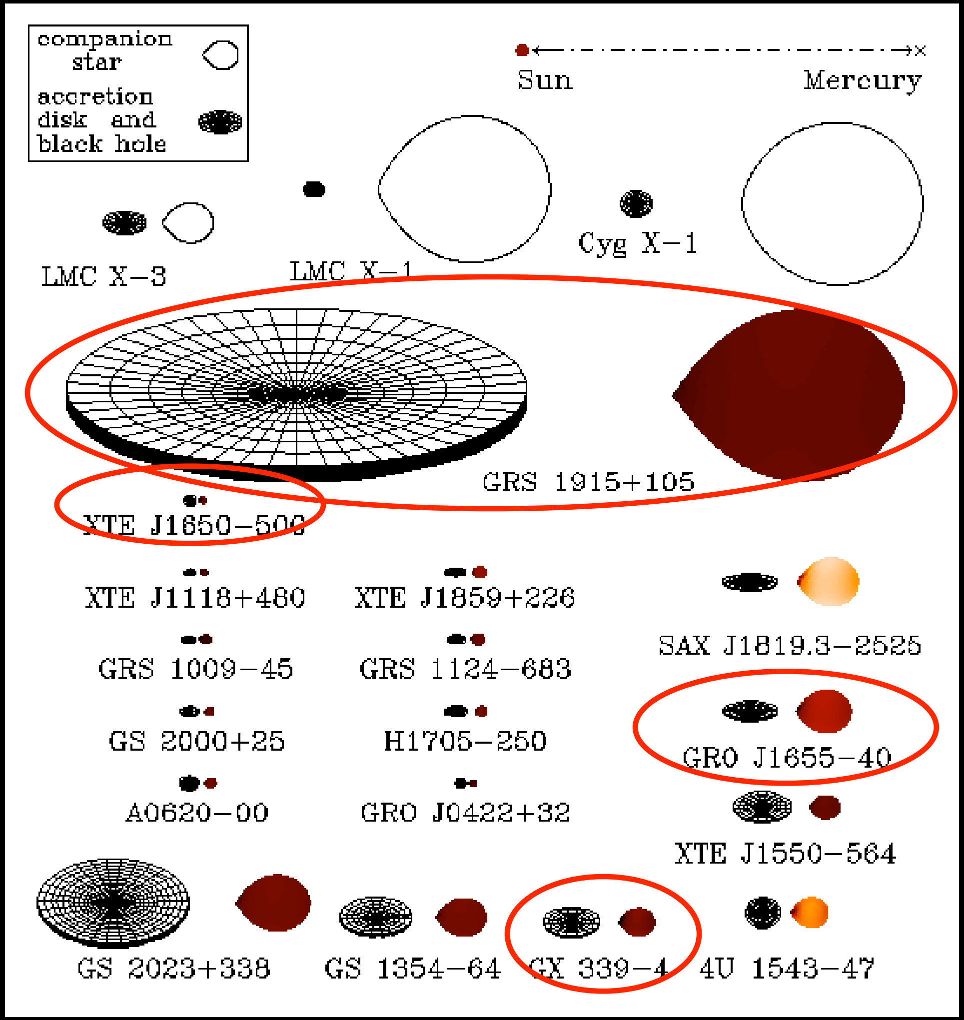
- Stellar BH disk winds are fairly common.
- Winds are seen in spectrally soft states.
- Magnetic effects may be important.
- Similar winds may be seen in Seyfert AGN.

Demographics



Wind Demographics

H 1743-322 4U 1630-47



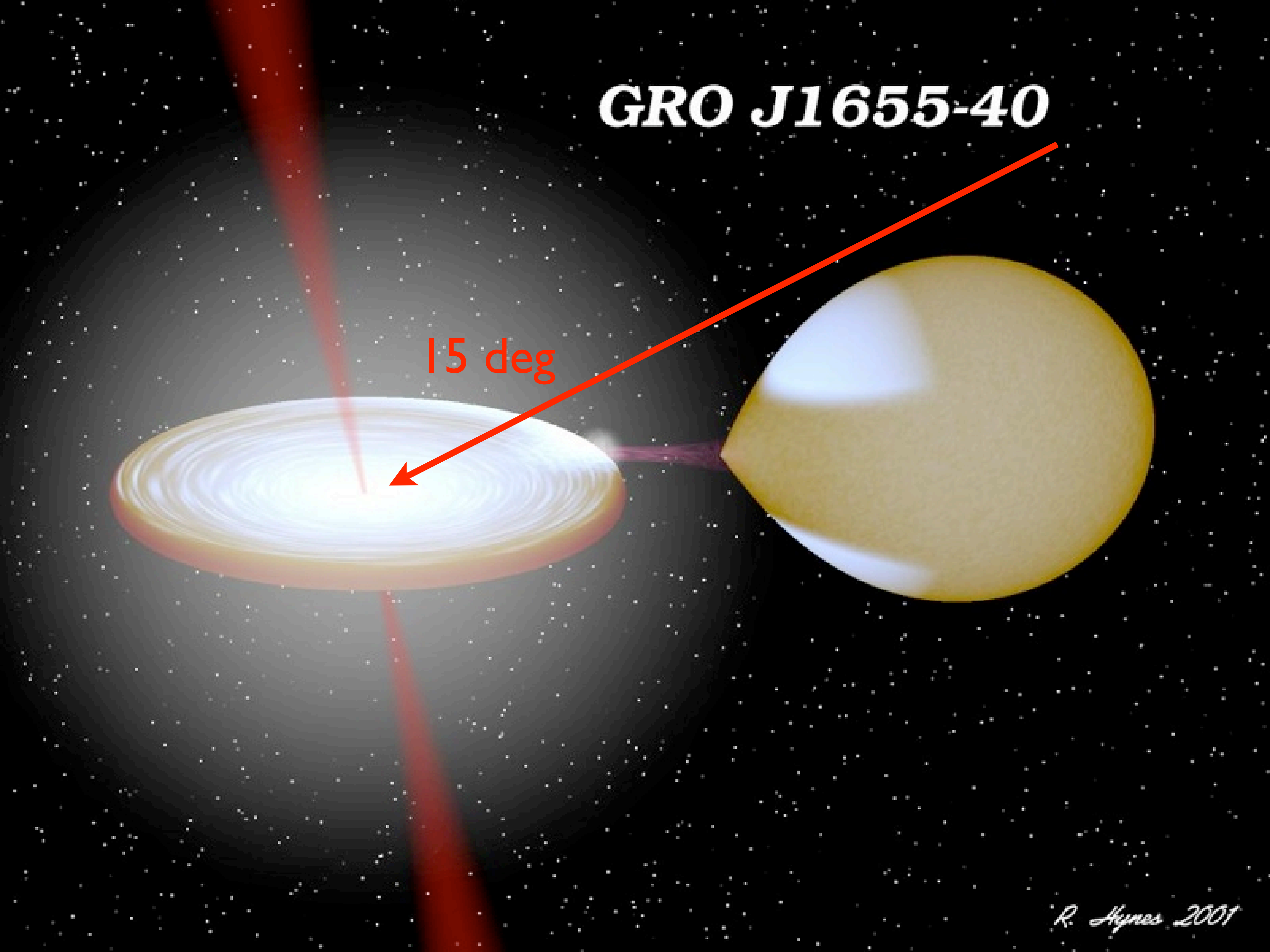
Common features:

high[?] inclination

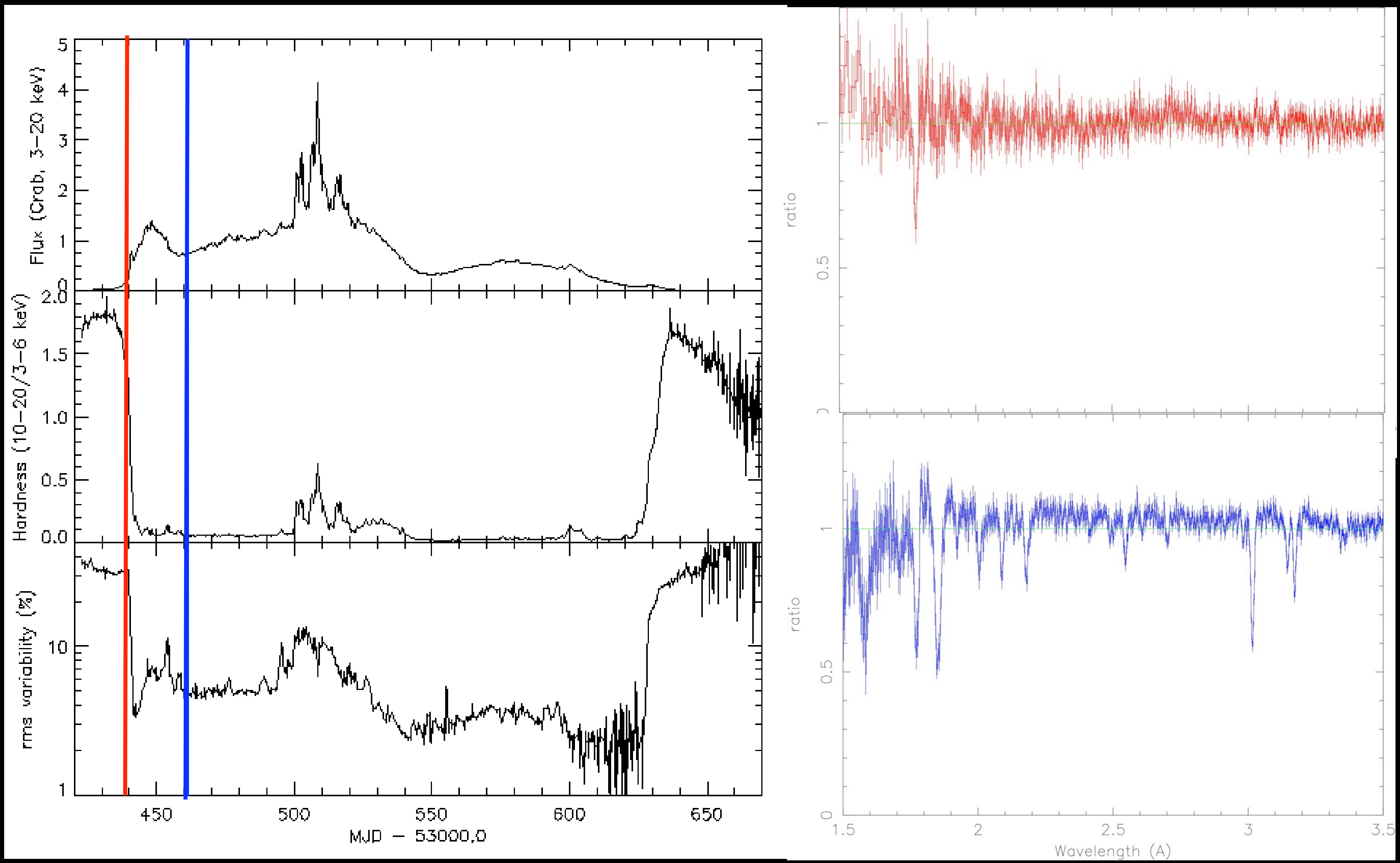
L > 0.01 Eddington

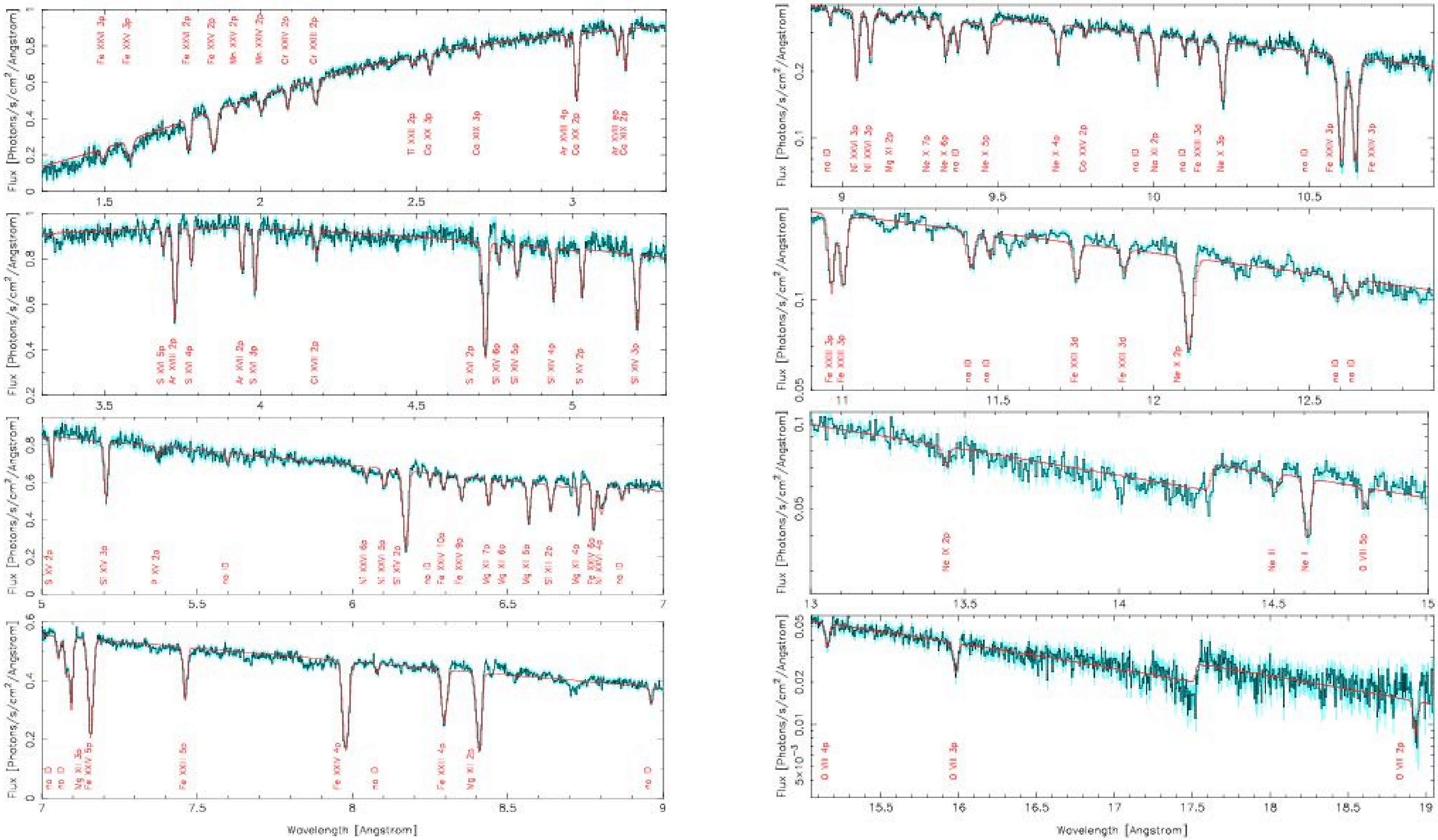
CXO, XMM, Suzaku

$\xi > 10^4$


GRO J1655-40
15 deg
R. Hynes 2001

“State” dependence





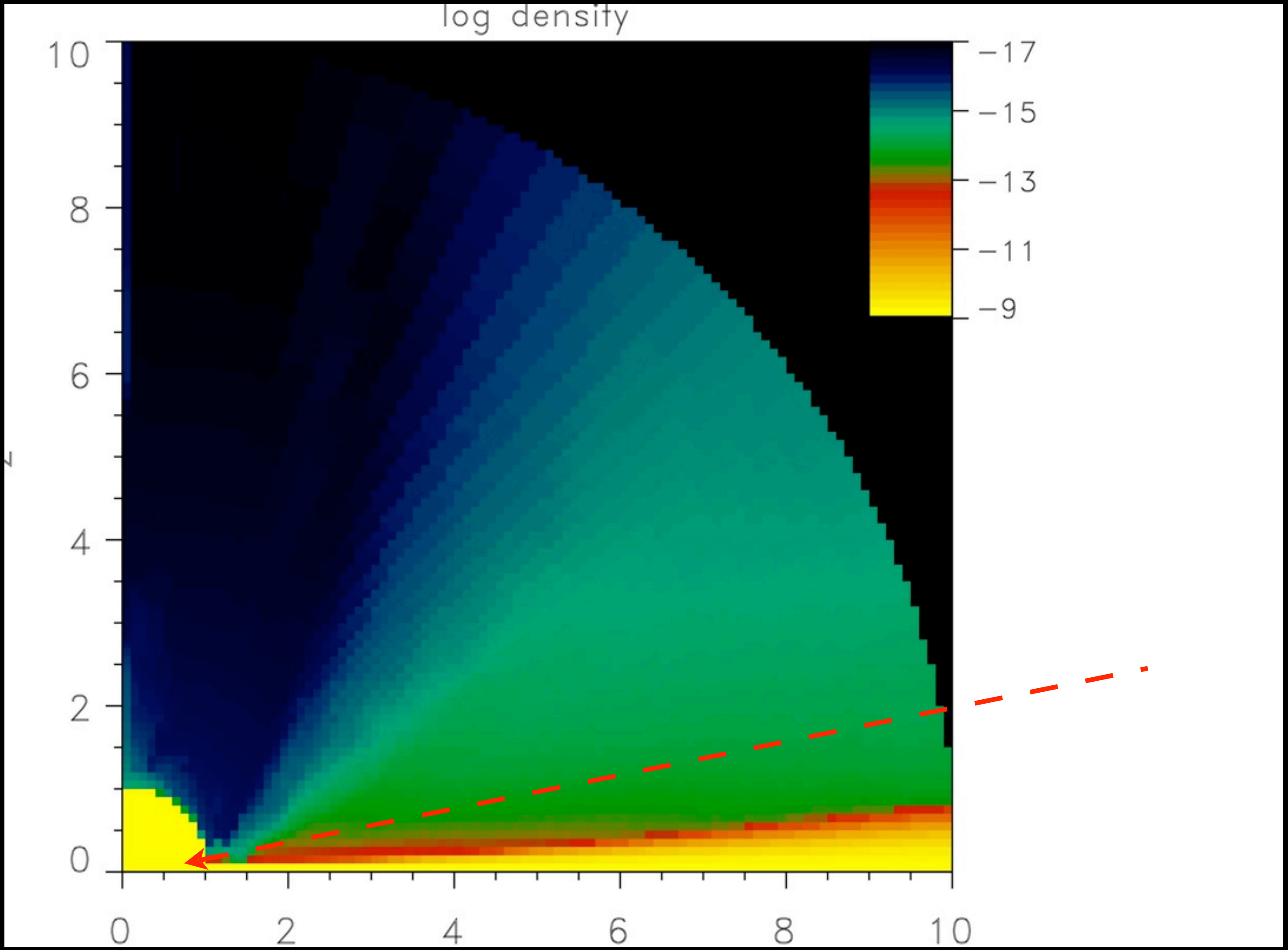
Flux [Photons/s/cm^2/Angstrom]
Wavelength [Angstrom]

Basic Properties

- v = 300-1500 km/s
- 90 lines, 76 easily identified, 32 charge states
- some first extra-solar detections in X-rays
- no significant emission lines

Early geometrical clue:

Proga 2003



What drives the wind?

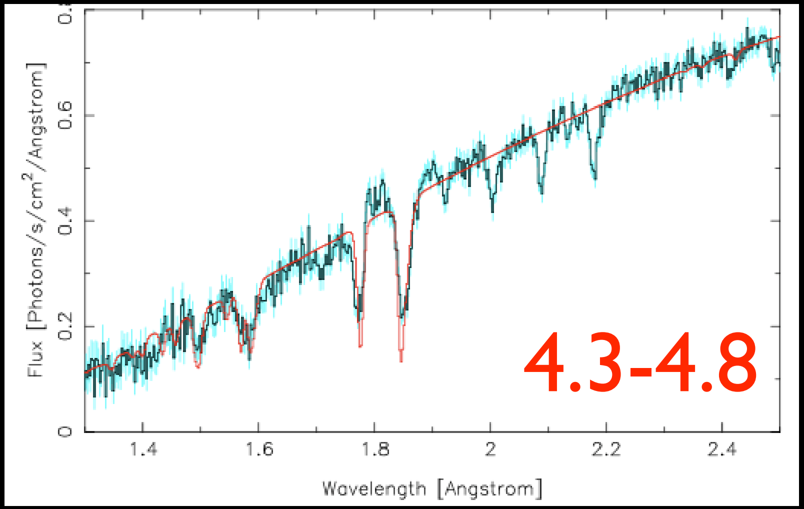
- High ionization rules out radiative driving.
- Thermal driving may be possible.
- TD models predict inner radius, m-dot.
  r* = 11.7 cm; 0.1 r* might be possible
  $6*10^{-6}$ g/cm/s is the maximum m-dot
- Thermal solution suggested by Netzer 06.

The analysis:

- Two seminal thermal driving references. *Analytical*: Begelman 83, *Numerical*: Woods 96.
- "Chianti" used to calculate Fe XXII populations.
- Three independent photoionization codes: Raymond, XSTAR, Cloudy.
- Direct fitting of XSTAR, Cloudy in 3 ways: total bandpass, narrow slices, specific ranges.

Ionization Parameter

$$\xi = \frac{L_X}{nR^2}$$



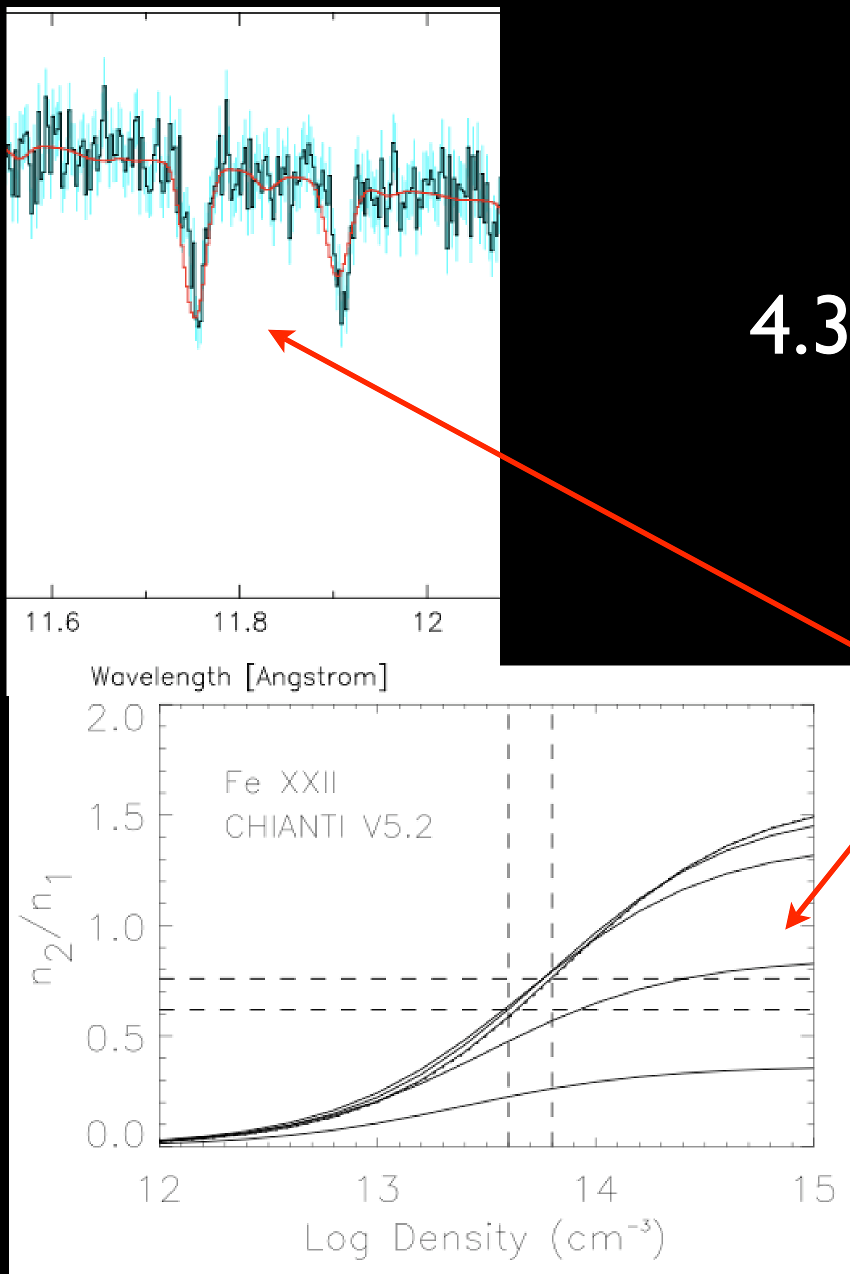
$$\xi = \frac{L_X}{nR^2}$$

4.3-4.8

5.0 E+37 erg/s

$$\xi = \frac{L_X}{nR^2}$$

Fe XXII: Mauche 2003



4.3-4.8   5.0 E+37 erg/s

$$\xi = \frac{L_X}{nR^2}$$

4.3-4.8 5.0 E+37 erg/s

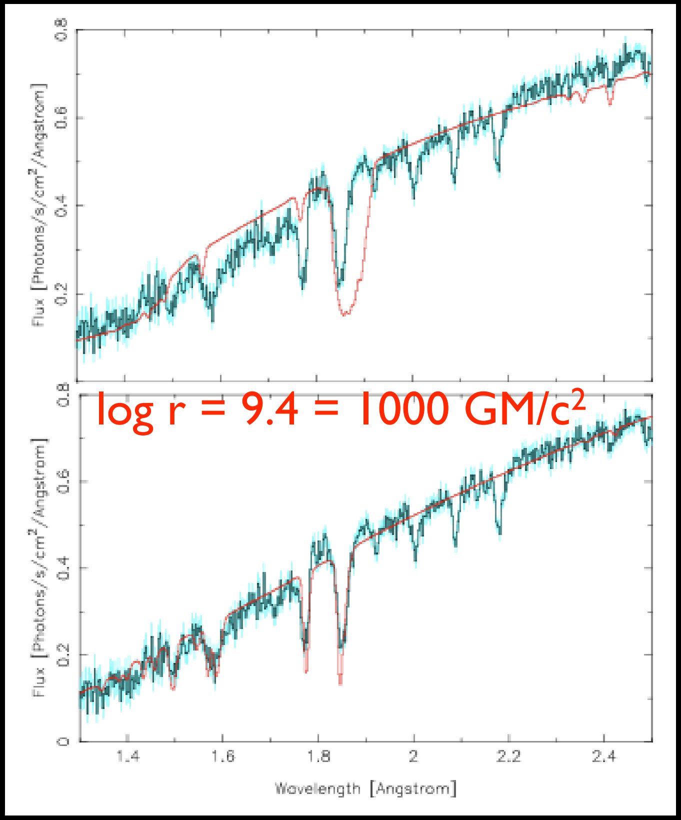
$$\xi = \frac{L_X}{nR^2}$$

n = 13.7-14.0

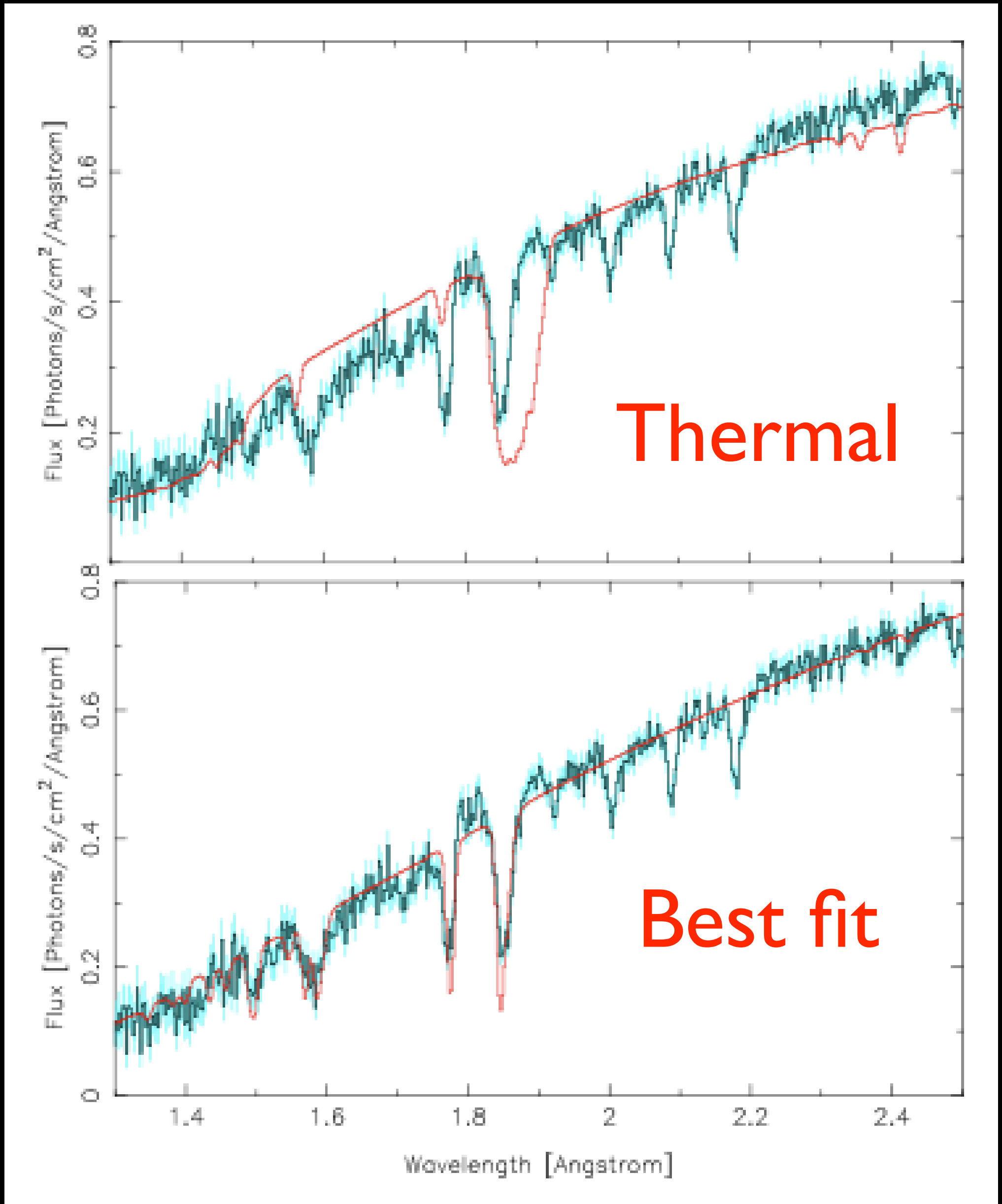
4.3-4.8 5.0 E+37 erg/s

$$\xi = \frac{L_X}{nR^2}$$

n = 13.7-14.0

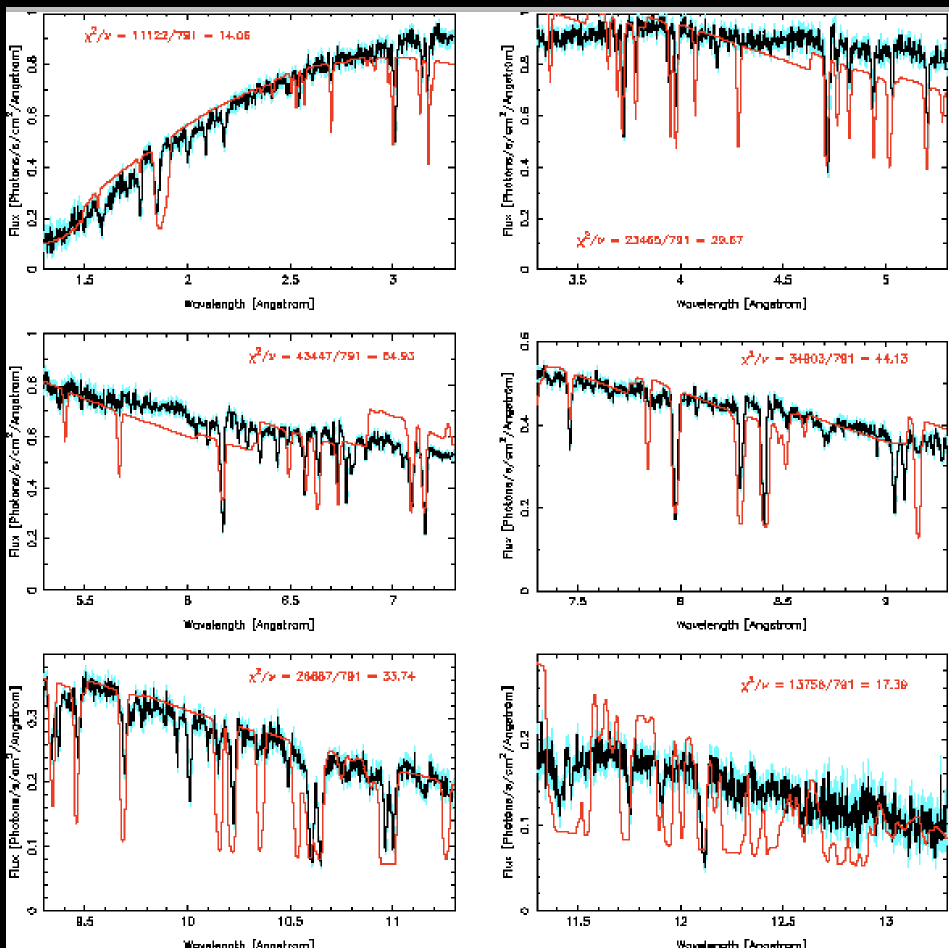


Specific ranges:

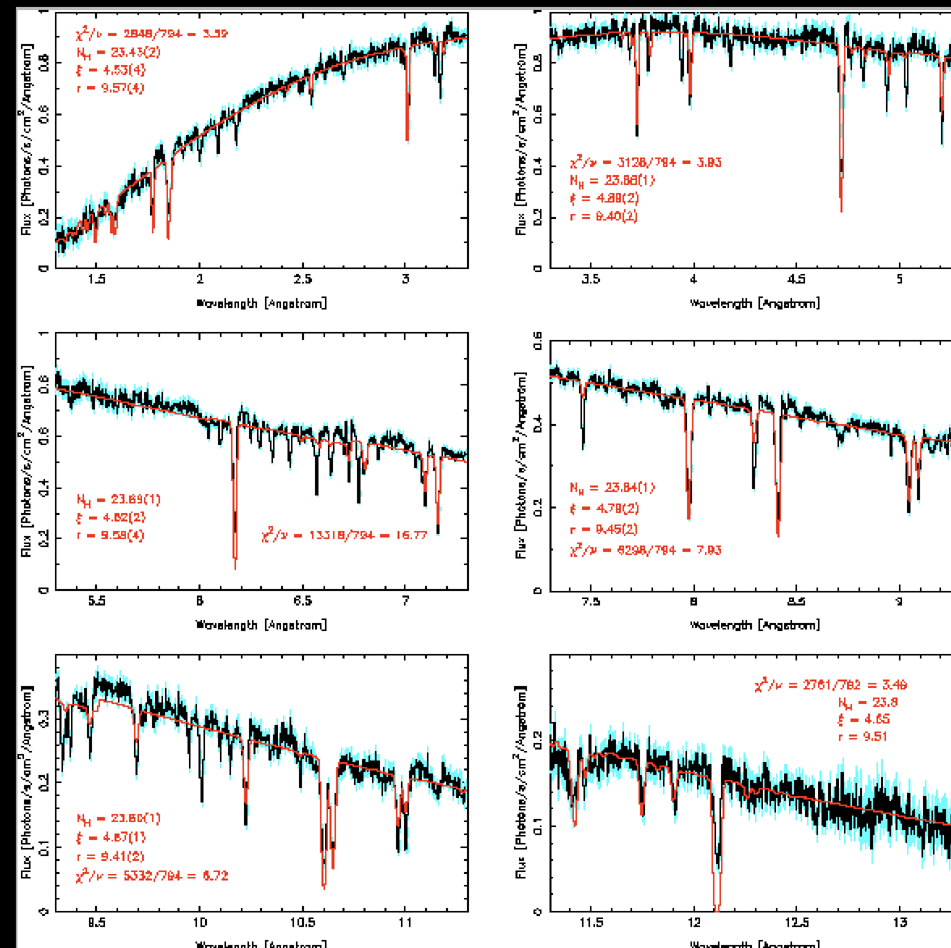


Specific ranges:

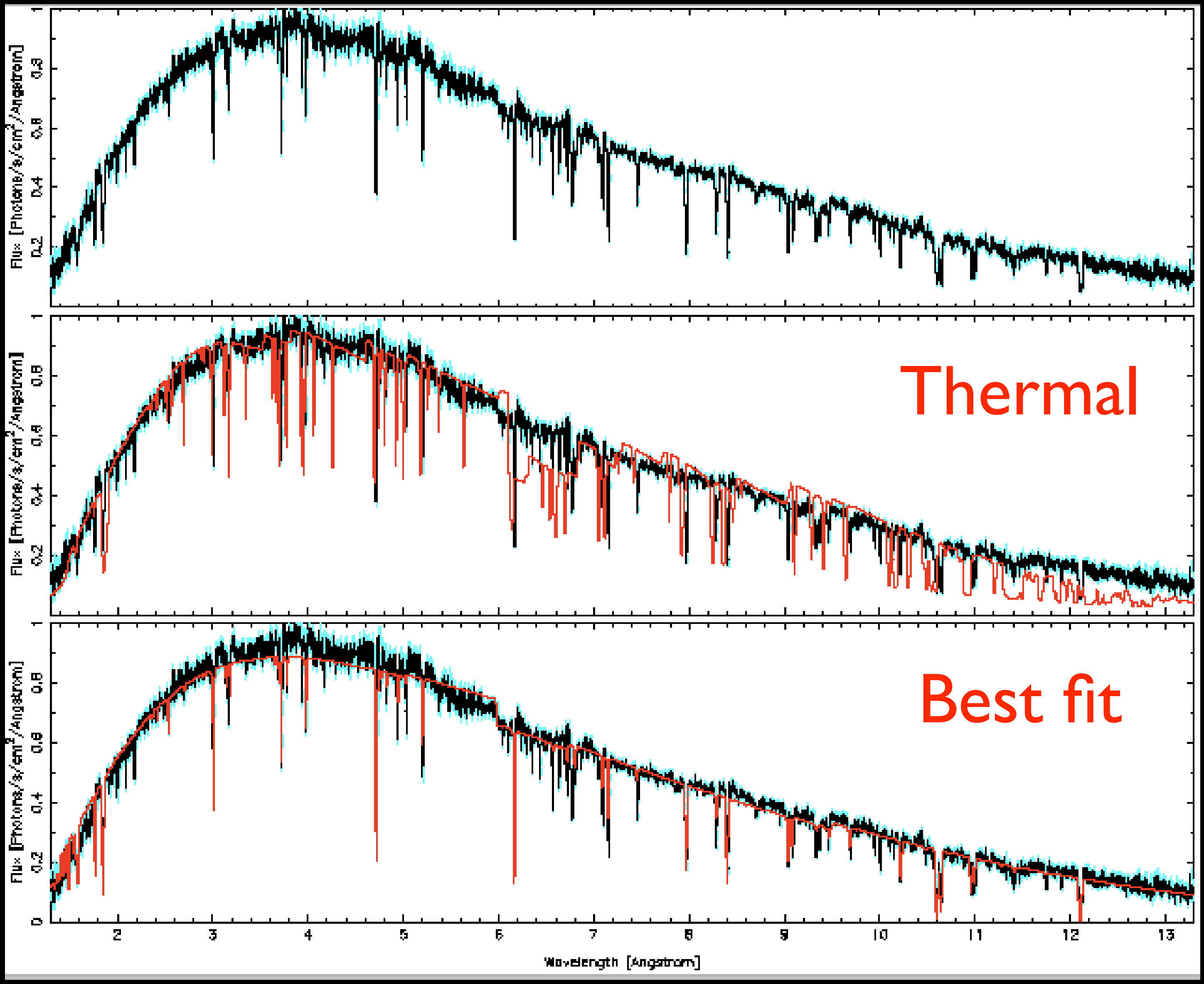
Thermal



Best fit



Total spectrum:



Results

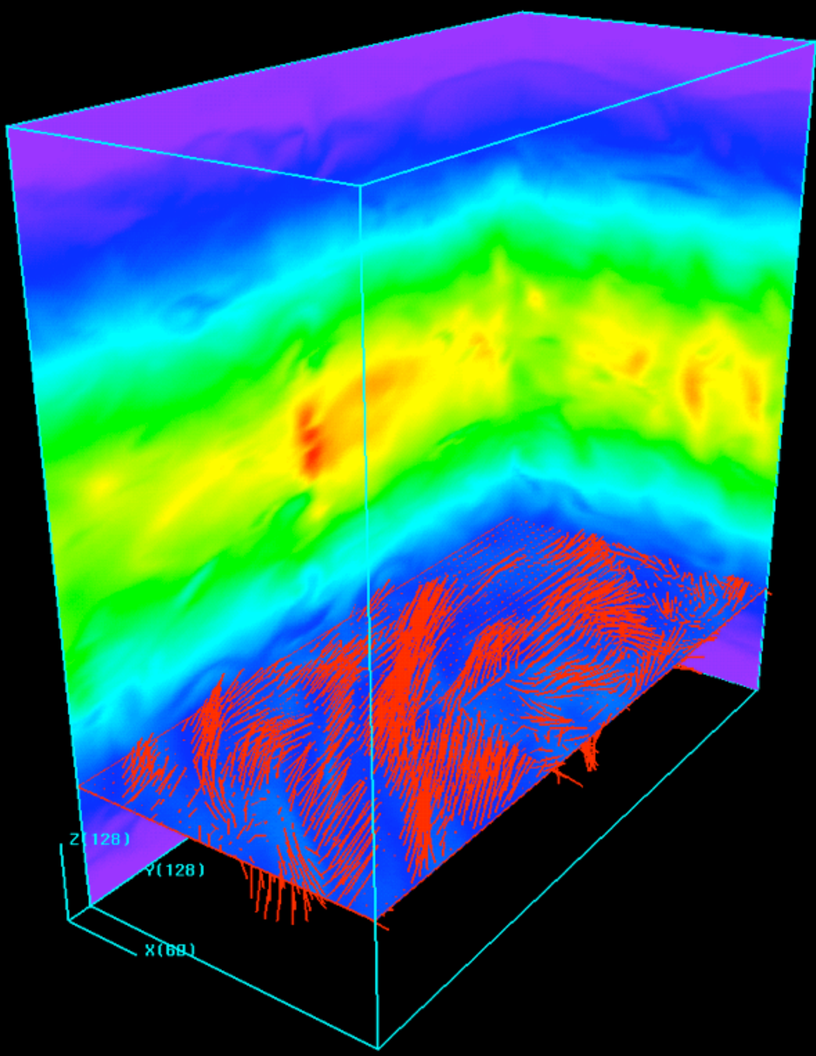
Best-fit	Thermal
$\log(n) = 13.8\text{-}14.0$	
$\log(N) = 23.1\text{-}23.6$	
$\log(\xi) = 4.3-4.8$	
$\log(r) = 9.4-9.7$	$\log(r) = 11.7$, maybe 10.7
$\log(\delta r) < 9.7$	
M-dot $= 10^{-2}$ g/cm^2/s	M-dot $= 6 * 10^{-6}$ g/cm^2/s

What drives the wind?

- Radiative driving is ruled out.
- Thermal driving models predict radii that are 10-20 times larger, m-dot 1000 times less.
- *Magnetic* processes might be the answer.

- FU Ori, T Tauri stars: Calvet et al. 1993.
- OY Car: Mauche & Raymond 2003.
- NGC 4151: Kraemer et al. 2005.

Can B do it?



KE flux: 3-6*10^{14} erg/cm^2/s

VE flux: 8*10^{16} erg/cm^2/s

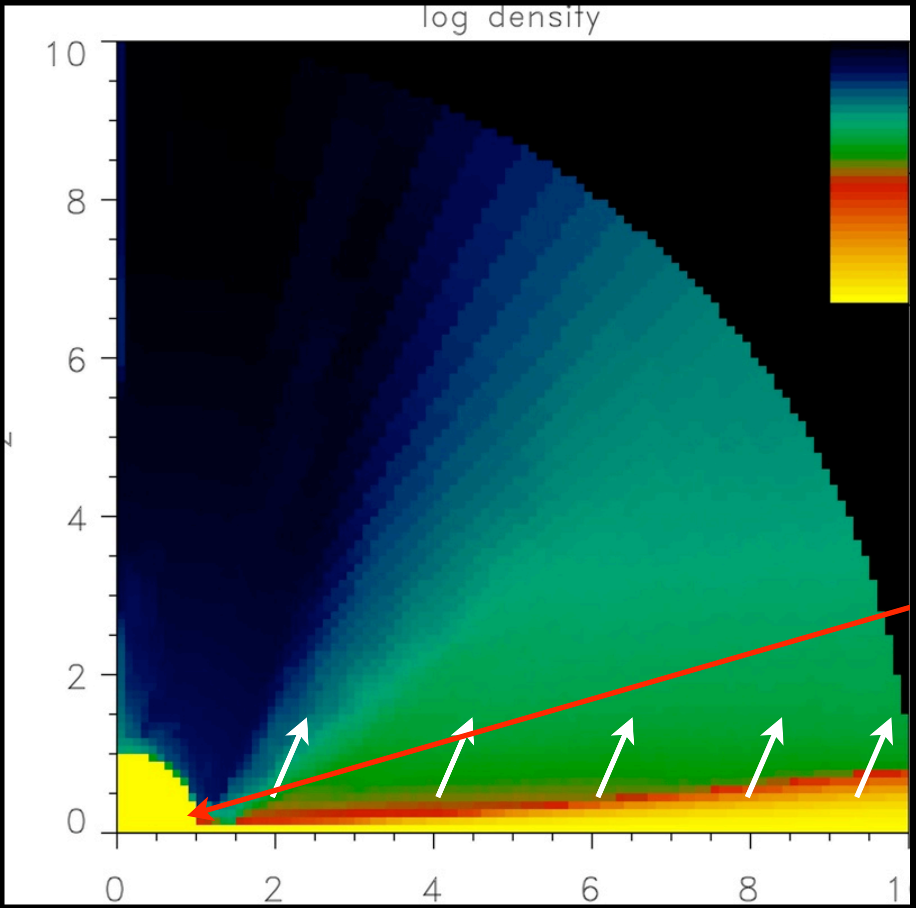
Miller & Stone 2000
Blaes 2007

--> Magnetic energy flux more than enough to supply the KE flux needed.

Proga 2003

--> Observed wind is very similar to simulations, even vel.

Can B do it?



Apparent problem:
v < escape velocity

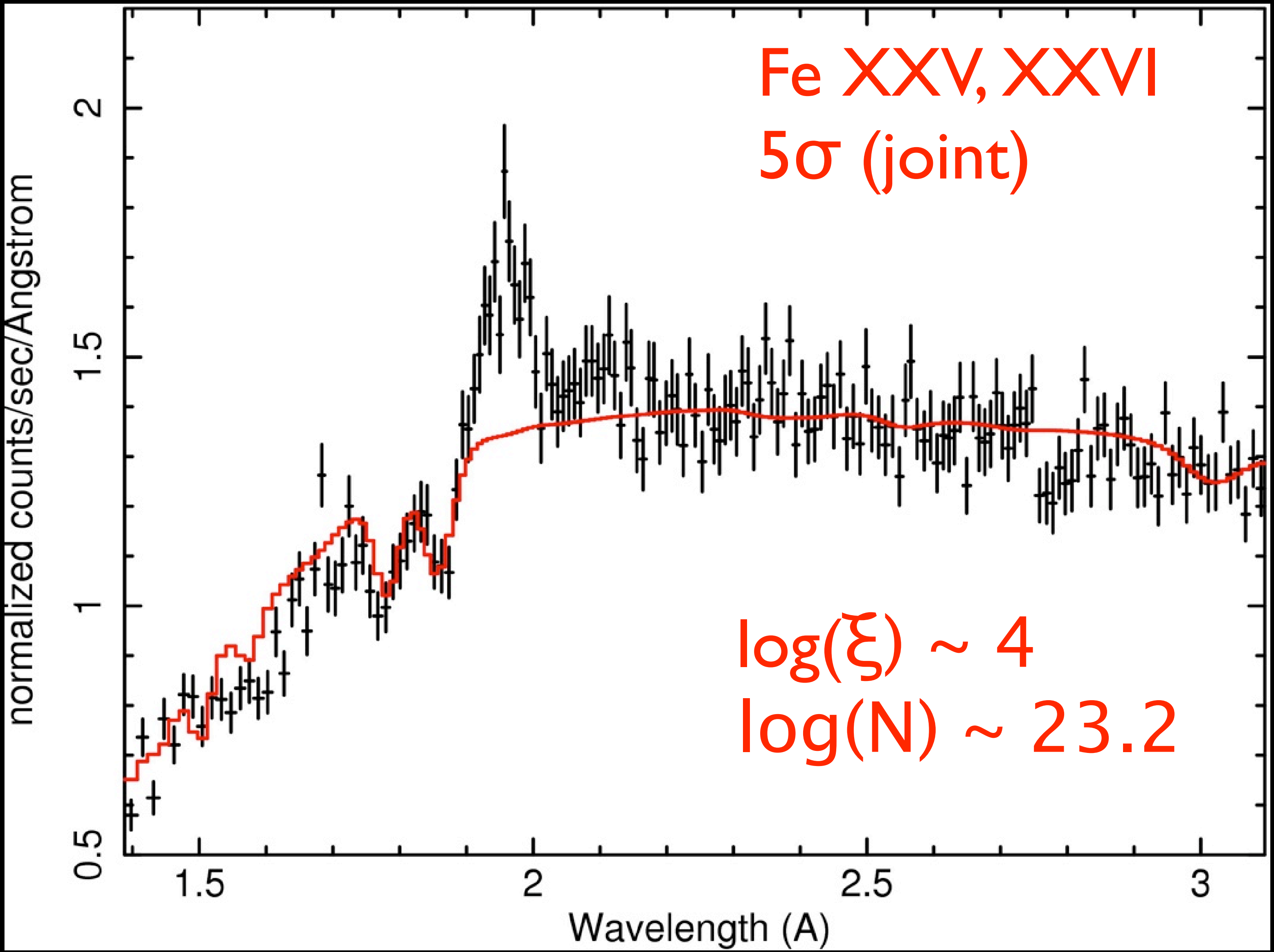
No sensitivity in Z.

No sensitivity in ϕ.

Blandford & Payne 82.

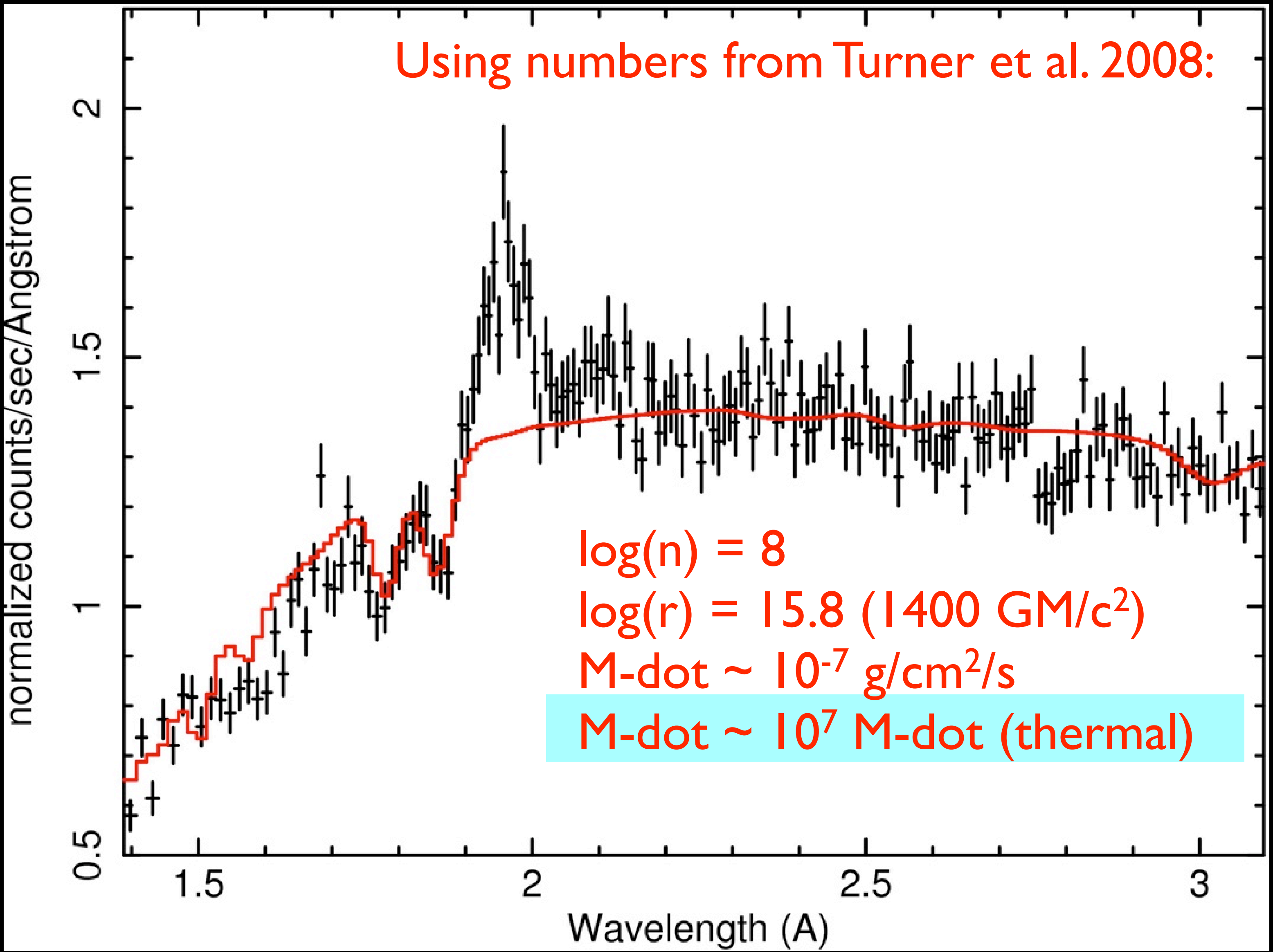
Does these results impact AGN?

NGC 3516



Fe XXV, XXVI
5σ (joint)
log(ξ) ~ 4
log(N) ~ 23.2
normalized counts/sec/Angstrom
Wavelength (A)
0.5
1
1.5
2
2.5
3

NGC 3516


Using numbers from Turner et al. 2008:
log(n) = 8
log(r) = 15.8 (1400 GM/c^2)
M-dot ~ 10^{-7} g/cm^2/s
M-dot ~ 10^7 M-dot (thermal)
normalized counts/sec/Angstrom
Wavelength (A)
0.5
1
1.5
2
1.5
2
2.5
3

Summary:

- Stellar BH disk winds are fairly common.
- Winds are seen in spectrally soft states.
- Magnetic effects may be important.
- Similar winds may be seen in Seyfert AGN.

for more info, see Miller et al. 2006, Miller et al. 2008