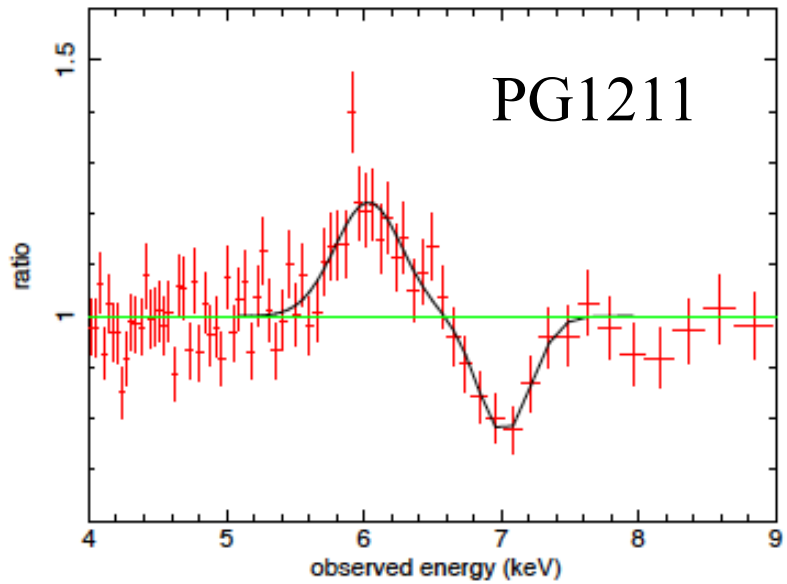
Winds from accreting black holes narrow features, good atomic data

Chris Done, University of Durham

Ryota Tomaru, Megumi Shidatsu, Aya Kubota
Misaki Mizumoto, Kouchi Hagino

Quasar mode (winds) feedback

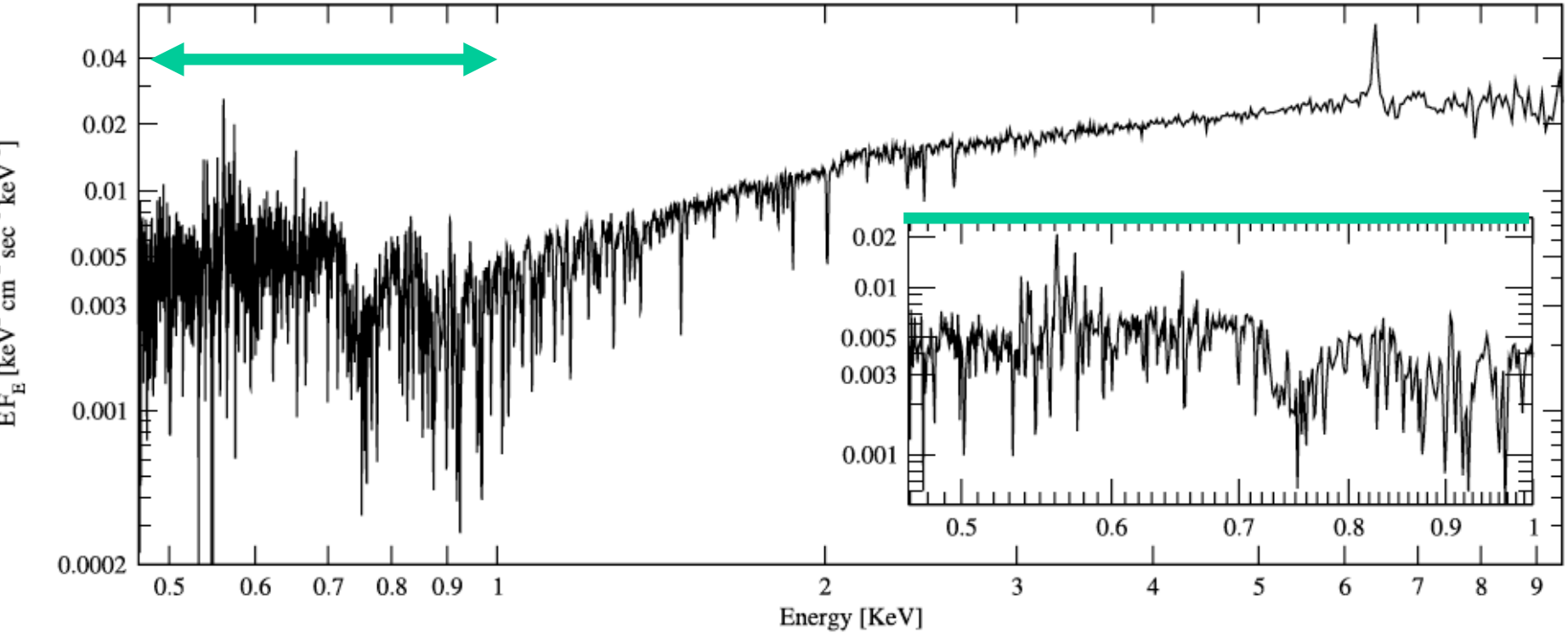
- AGN winds - absorption lines blueshifted!
- Ultrafast outflows! UFO
- v>0.05c, σ~v
- log ξ~4 (FeXXV+XXVI)



- AGN feedback!!
- Velocity outflow/broadening >>atomic data errors!!

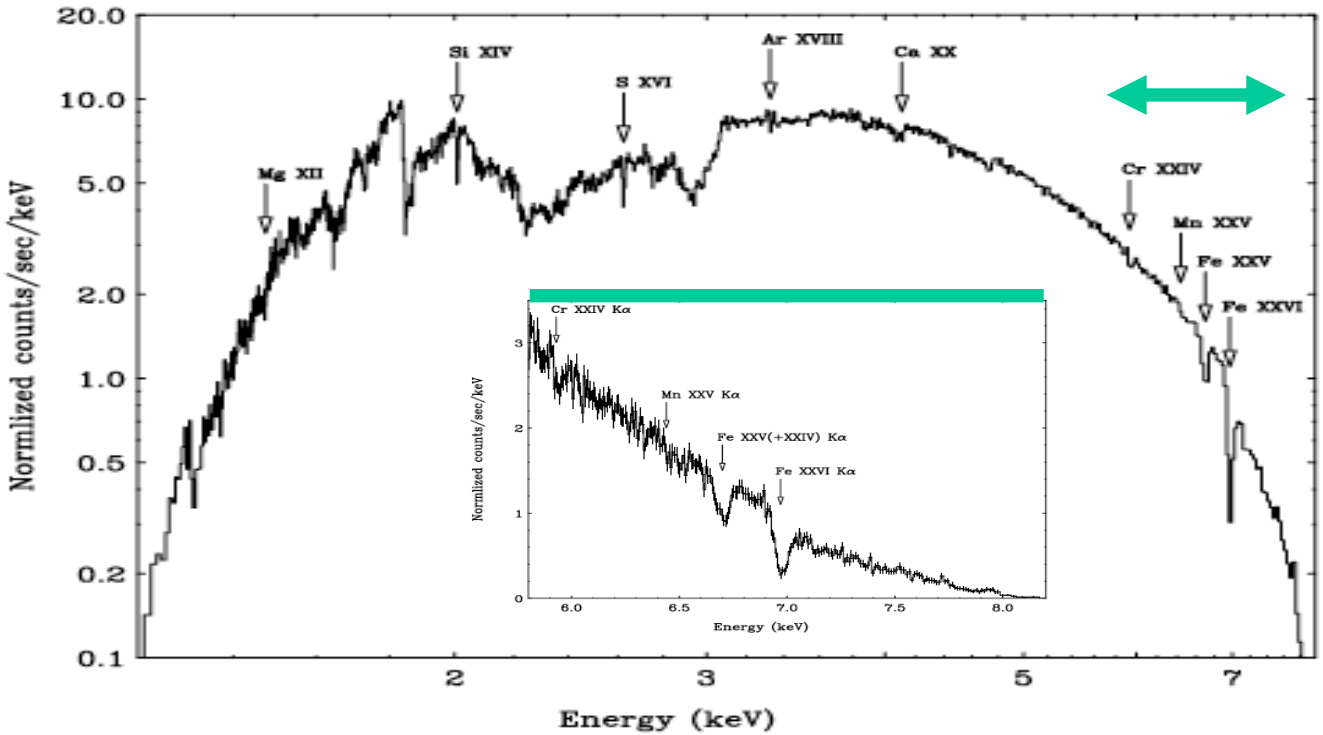
More winds in AGN

- Narrow lines, small v, σ - less KE but more Mdot!
- AGN warm absorbers log ξ ~2 (OVII/VIII and Fe L shell) v~500km/s (NGC3783: Kaspi et al 2002)
- Driving not known, so can't predict power or Mdot



And winds in binaries

- Galactic binary: LMXB Log ξ ~ 4 like UFOs but v~500 km/s like WA (GX13+1: Ueda et al 2004)
- Are binary winds the counterpart of WA (v) or of UFOs (log ξ)? Or something else entirely?

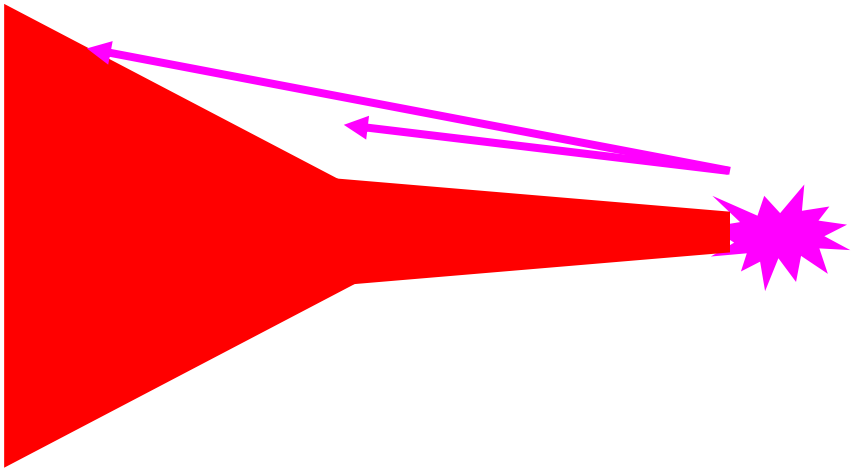


Wind mechanisms - LMXB

- Not stellar wind!
- Thermal pressure driven?
- Radiation driven?
  - L>Ledd for σ_T
  - L>σ/σ_T Ledd
- Magnetic?
- X-ray bright so $\sigma=\sigma T$ as ionised beyond high UV opacity
- L>0.1LEdd so radiation gives additional push…

Thermally driven Winds

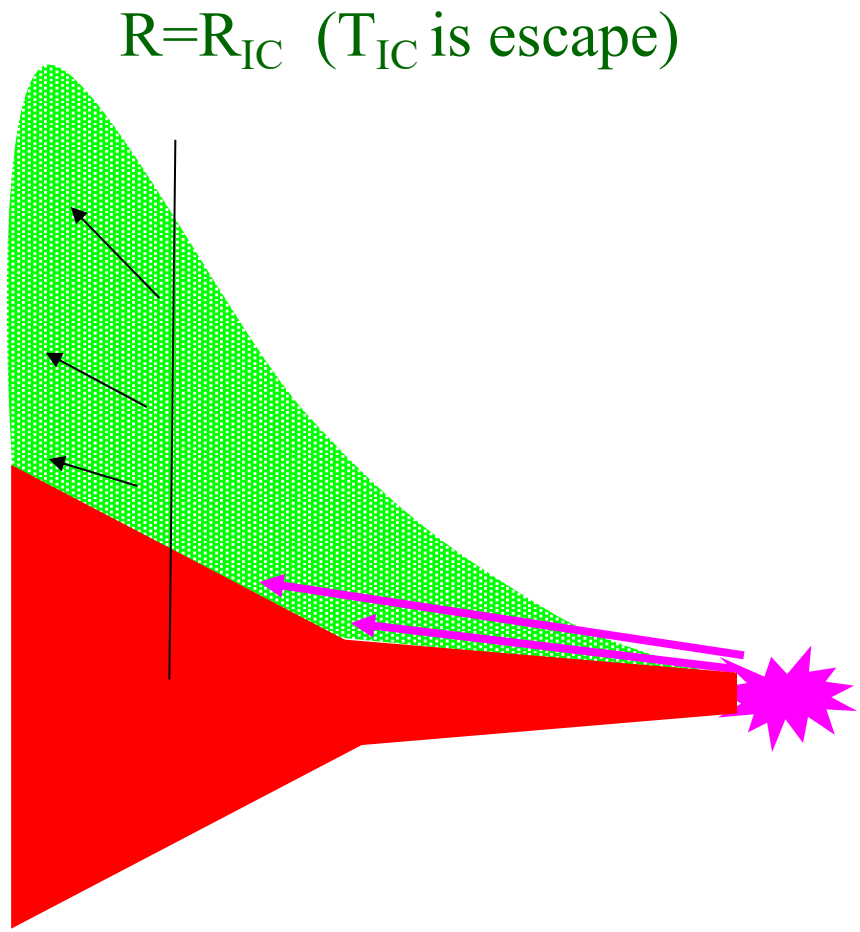
- X-ray source irradiates top of disc, heating it to Compton temperature
- T_{IC} depends only on spectrum



Begelman McKee Shields 1983

Thermally driven Winds

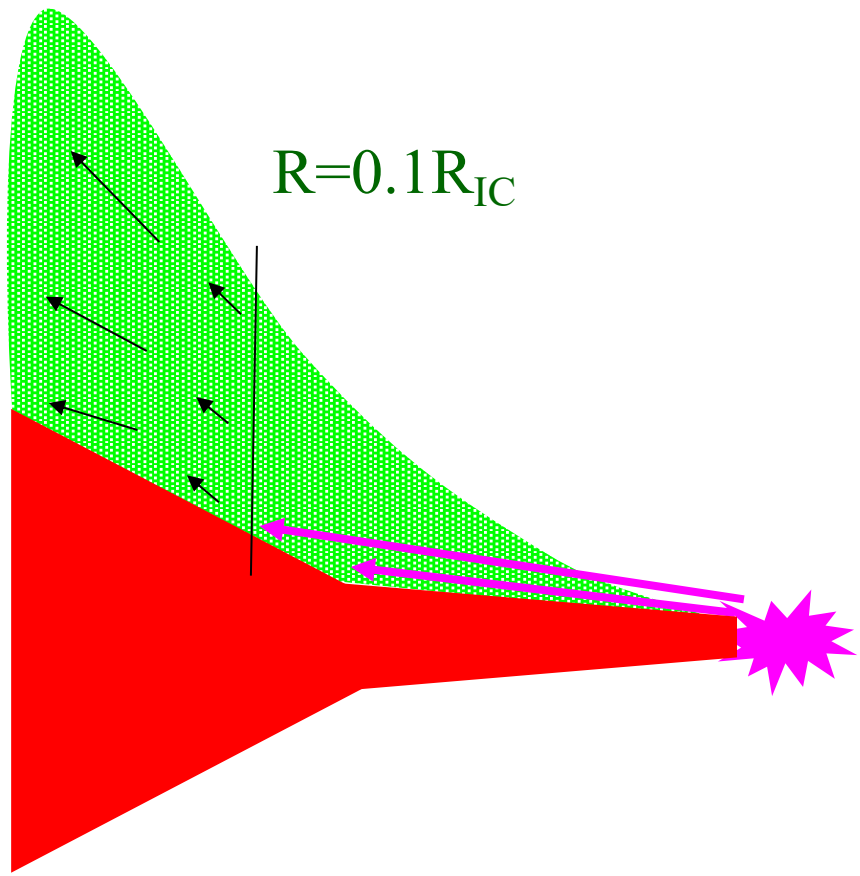
- Hot so expands
- Radius where thermal velocity is escape: RIC
- Wind for $R > R_{IC}$ driven by pressure gradient so $v_\infty = v_{esc}$ approx. constant



Begelman McKee Shields 1983

Thermally driven Winds

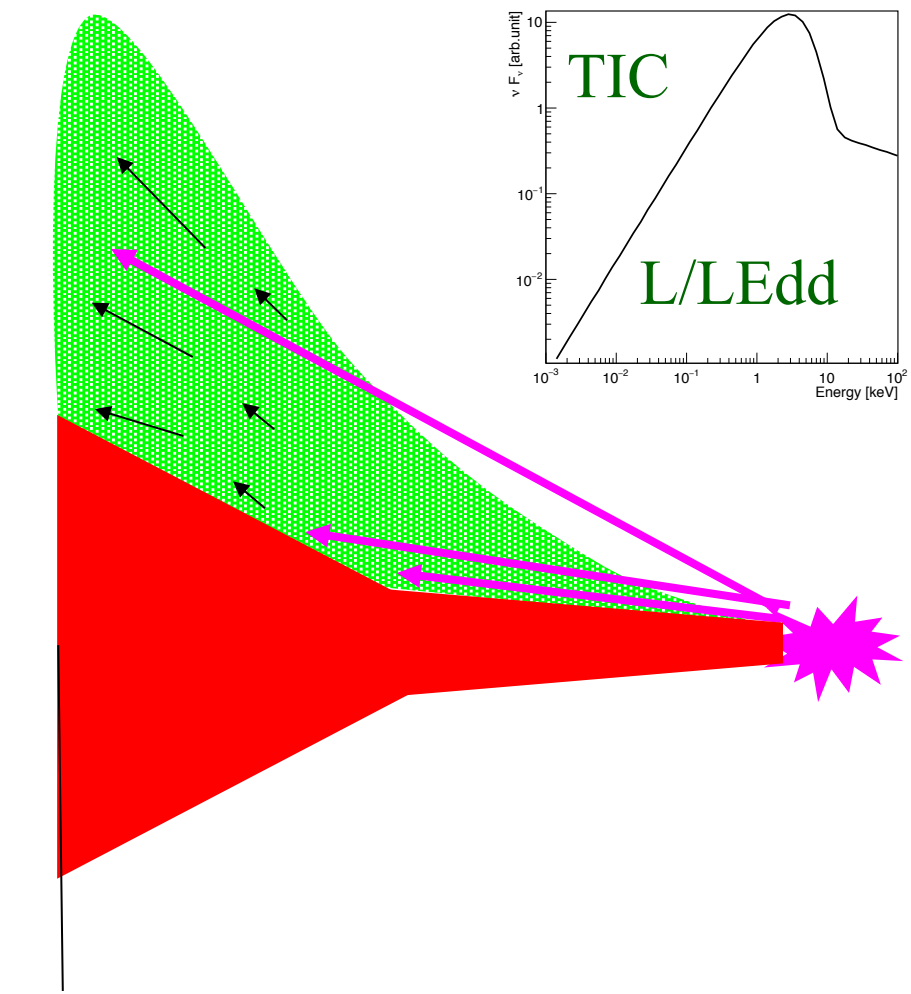
- Hot so expands
- Radius where thermal velocity is escape: RIC
- Wind for $R > R_{IC}$ driven by pressure gradient so $v_\infty = v_{esc}$ approx. constant
- NOT thermal wind if $R << 0.1\ R_{IC}$
- $\xi = L/nR^2$ – measure n from density lines – but often too highly ionised!



Begelman McKee Shields 1983

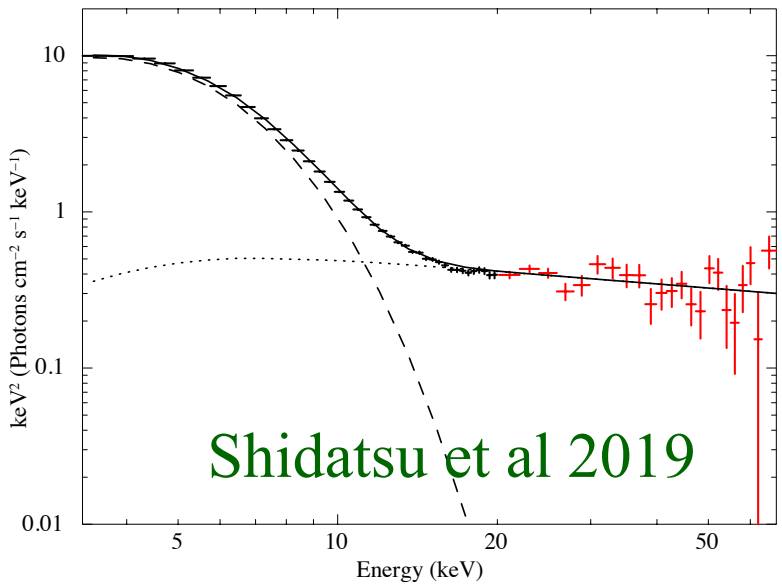
Predictive! No fudge parameters

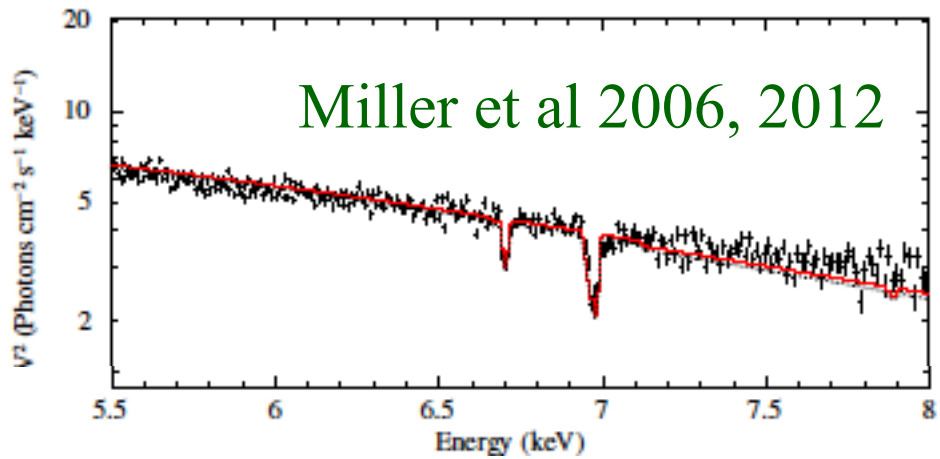
- Depends on spectrum! TIC sets RIC
- Depends on L/LEdd to heat the wind
- Depends on L/LEdd to give extra push from radiation pressure
- Depends on disc size Rout as more disc at R>RIC gives more wind
- Depends on inclination



Begelman McKee Shields 1983

Example: H1743 BHB





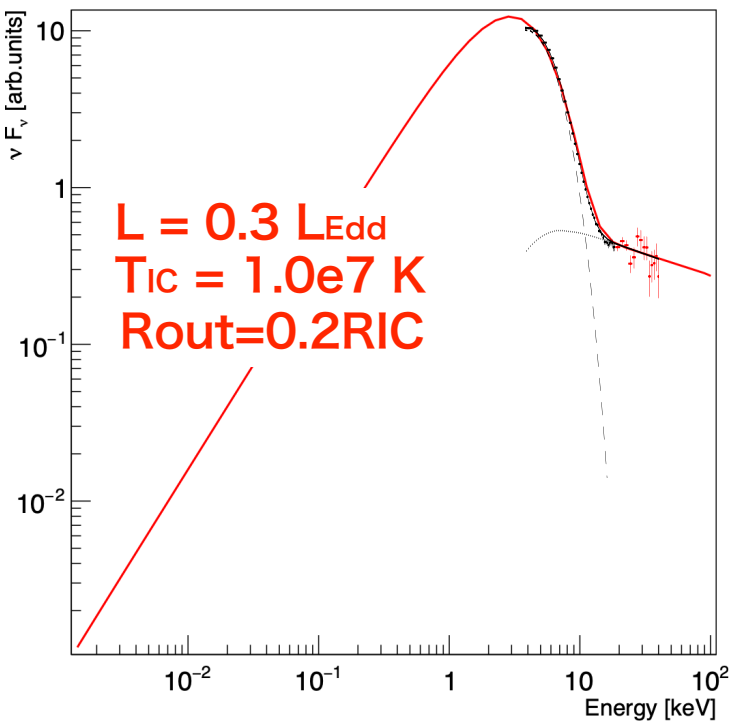
T_{IC} = 1.0e7 K

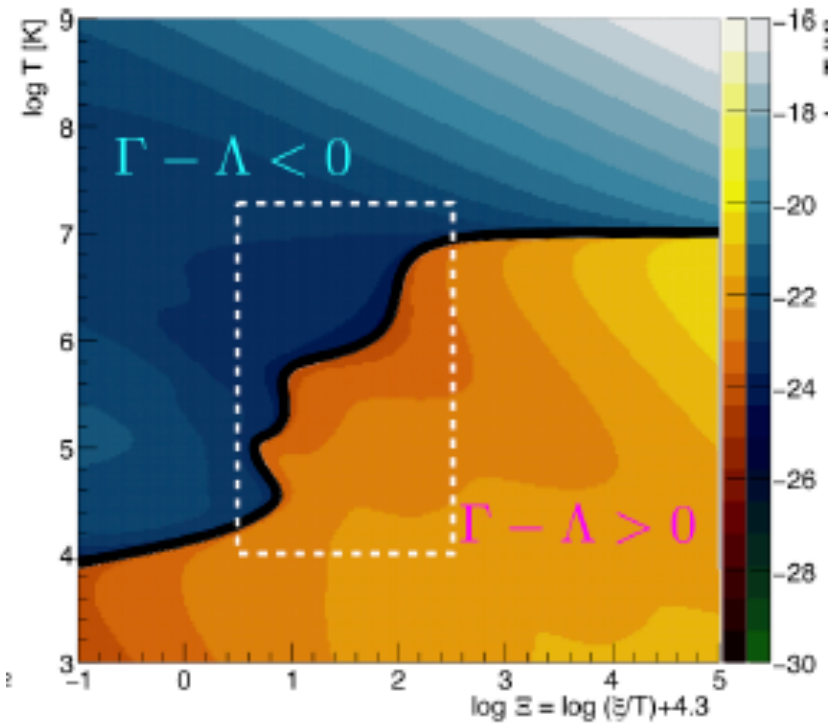
i=75

L = 0.3 L_{Edd}

Rout=0.2RIC

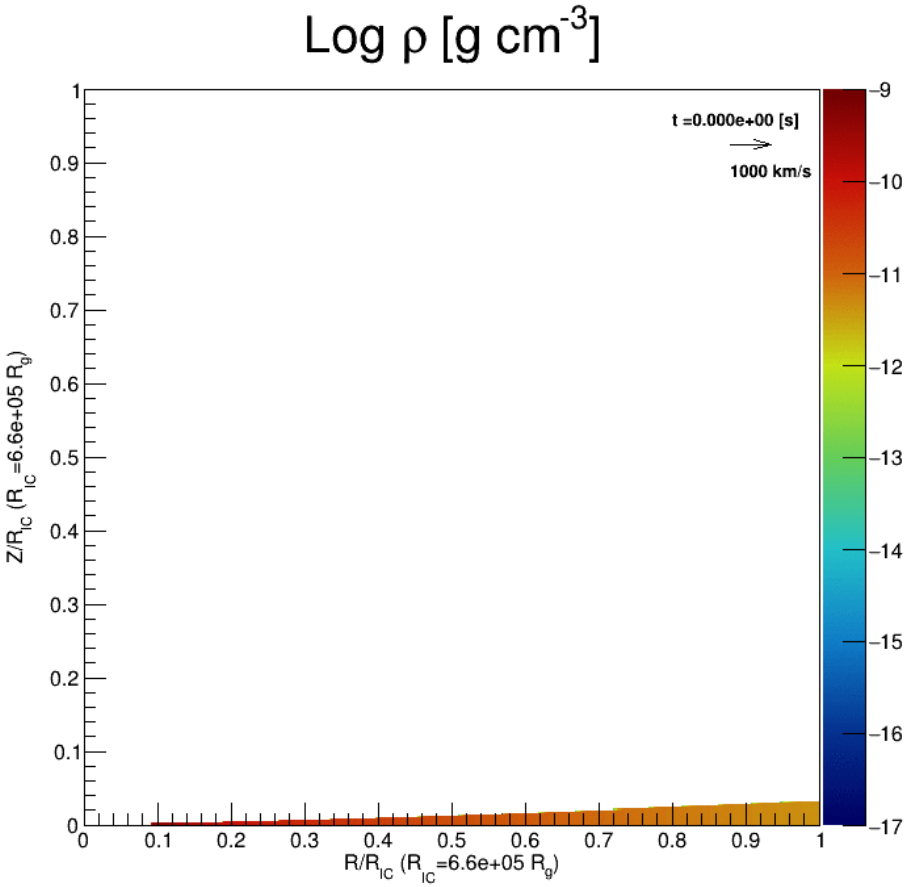
Simulation setup – H1743

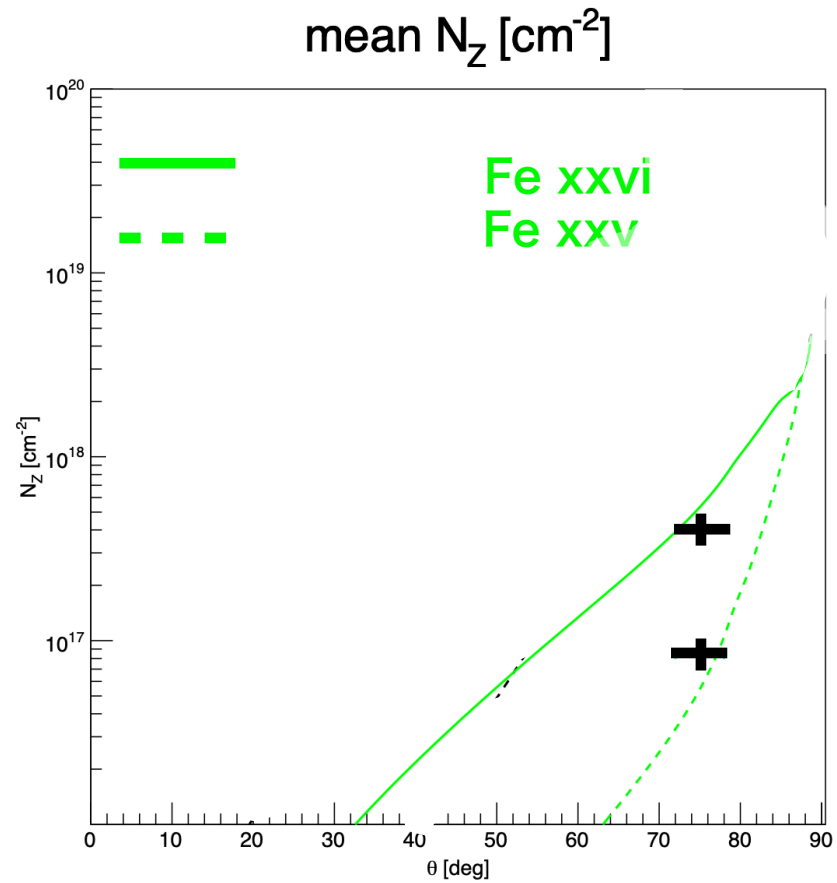




- Input to rad-hydrodynamics code (Takahashi & Ohsuga 13)

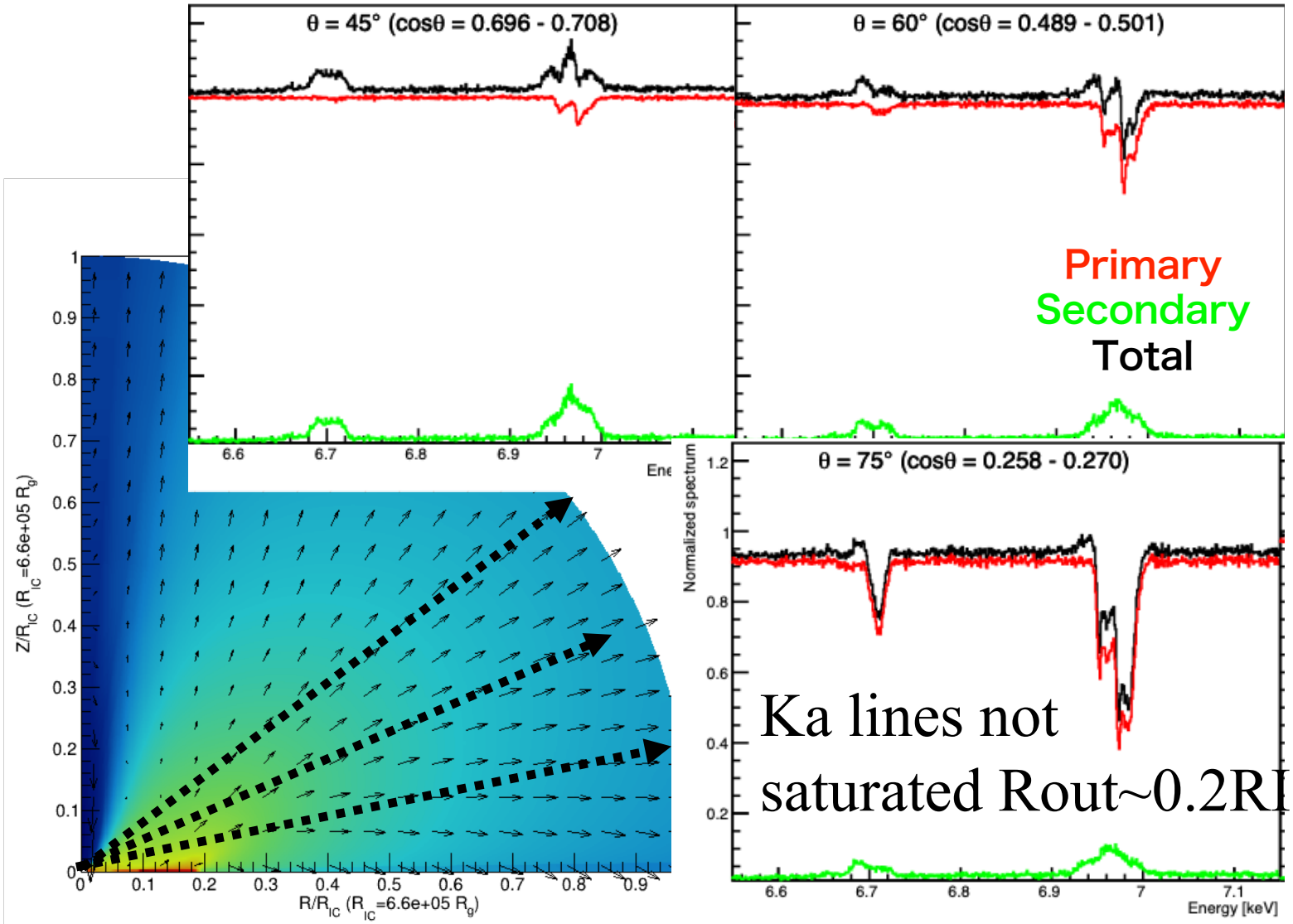
Simulation of H1743



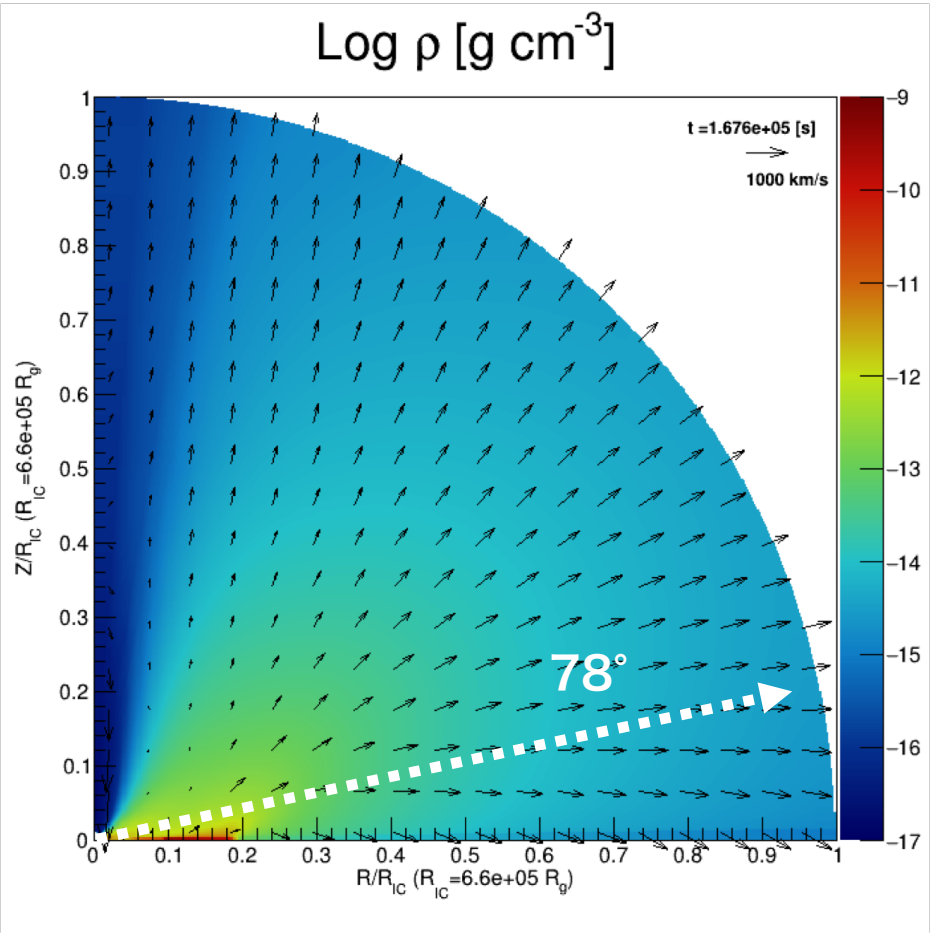


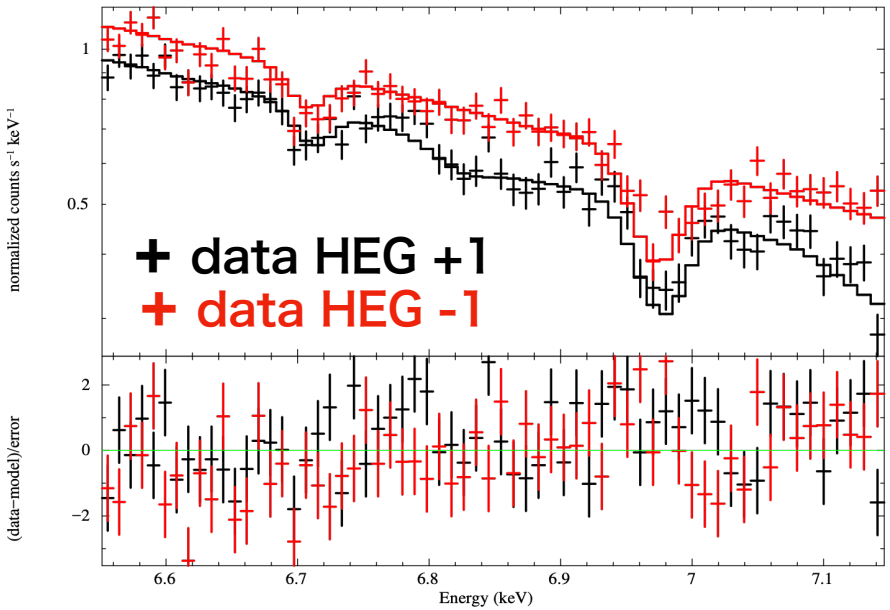
- Xstar - Ion columns, consistent with observation.
- Tomaru et al 2019,2020a

Monte Carlo RT simulation



Comparison with obs

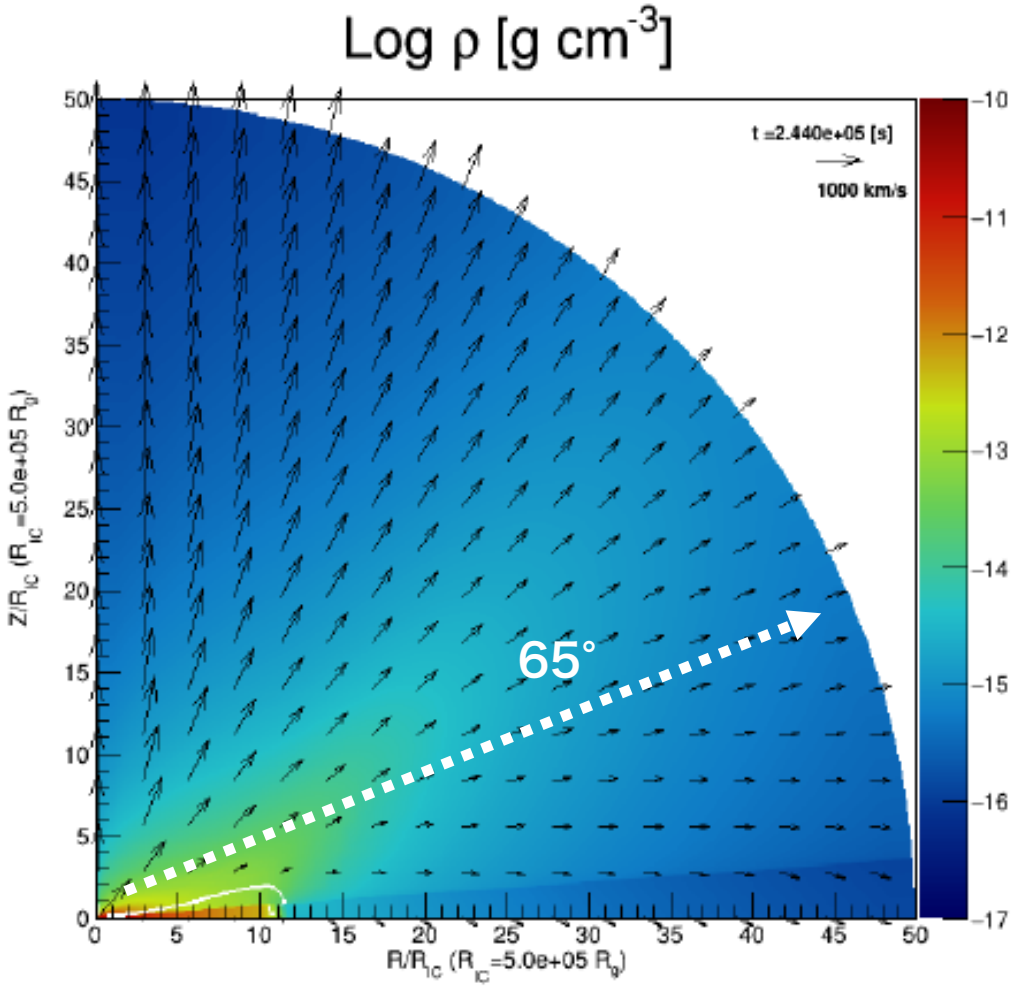


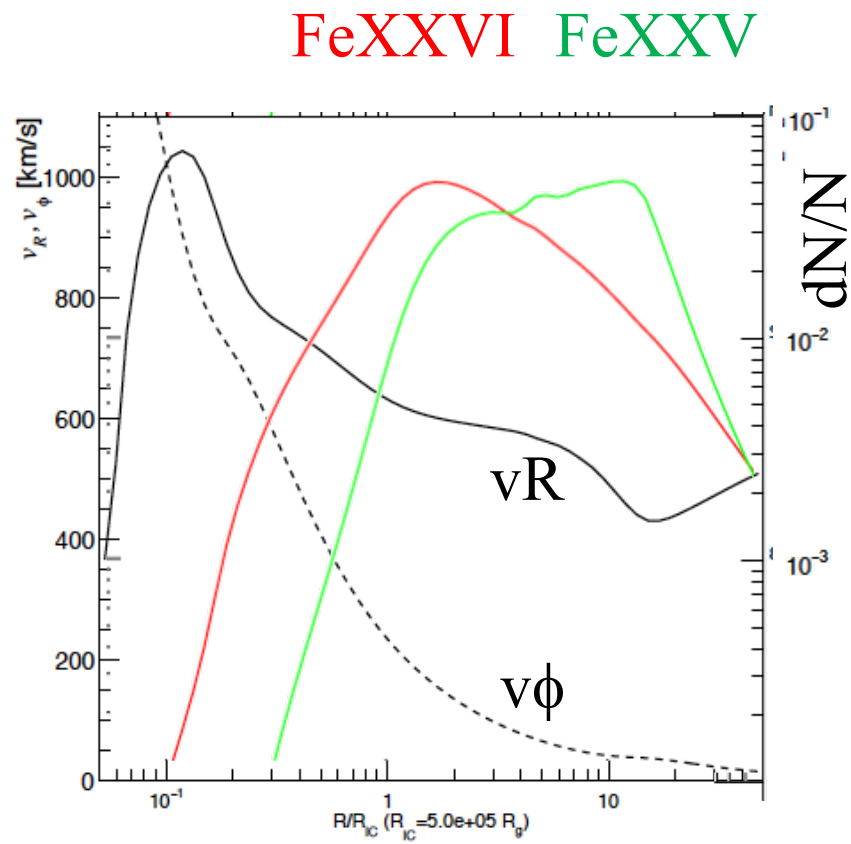


H 1743-322 soft-state

- Fits the data! Tomaru et al 2019, 2020a

Bigger disc, brighter source! GX13+1



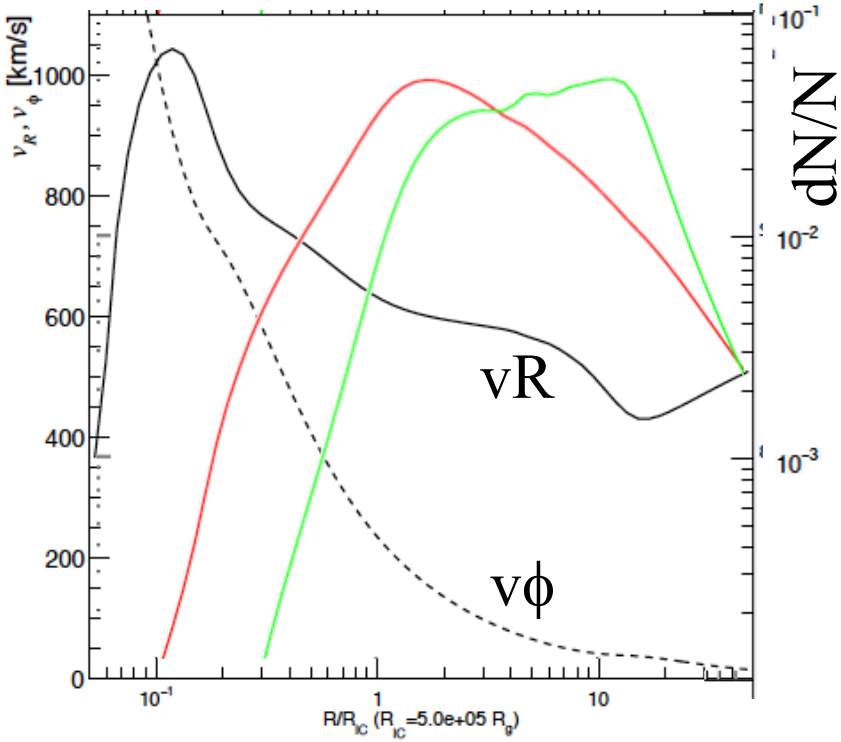


Tomaru et al 2020b

- TIC~10^7 as before, Rout =10 RIC, L=0.5LEdd, i=65

MUCH Bigger disc!!!

FeXXVI FeXXV

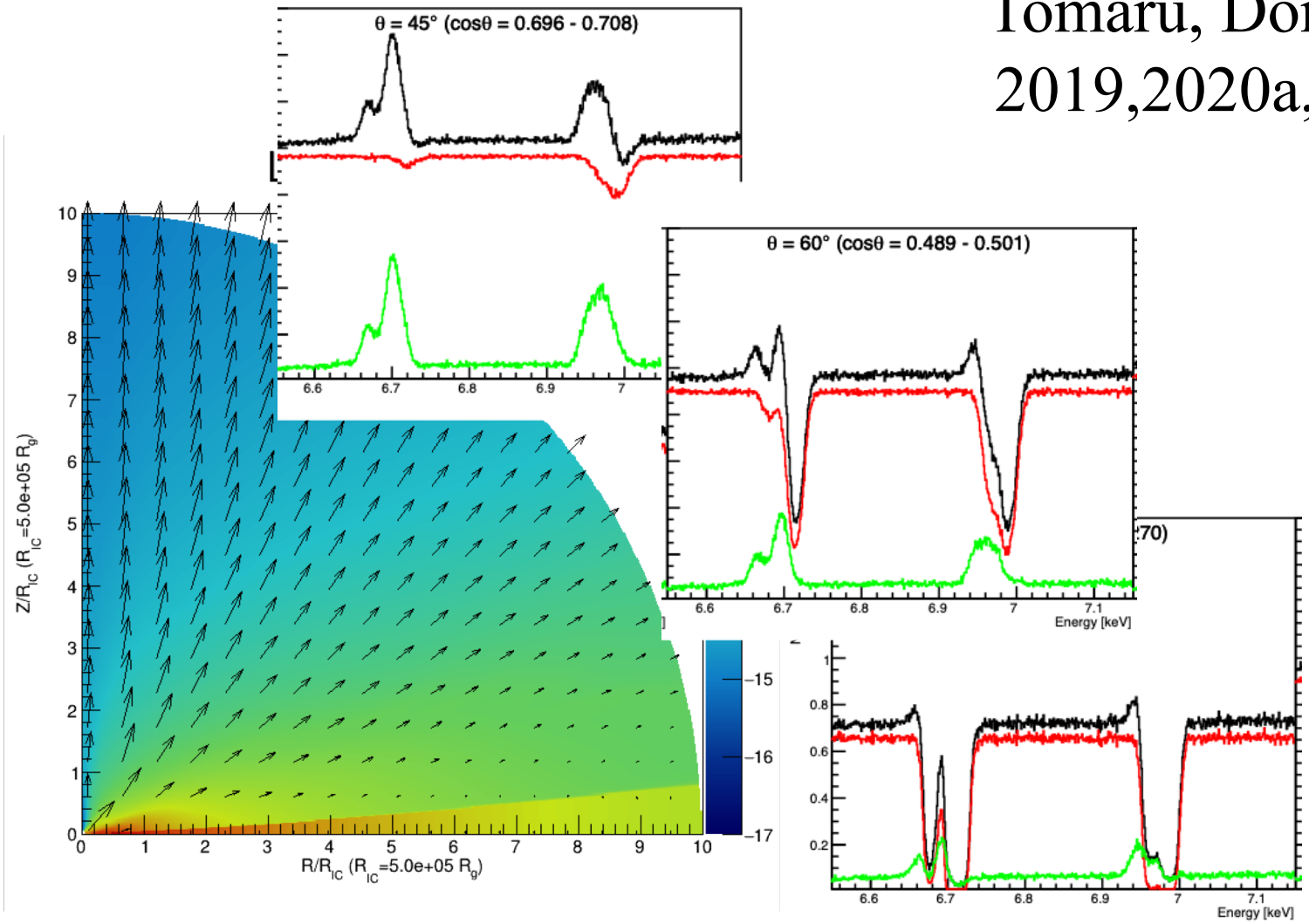


Tomaru et al 2020b

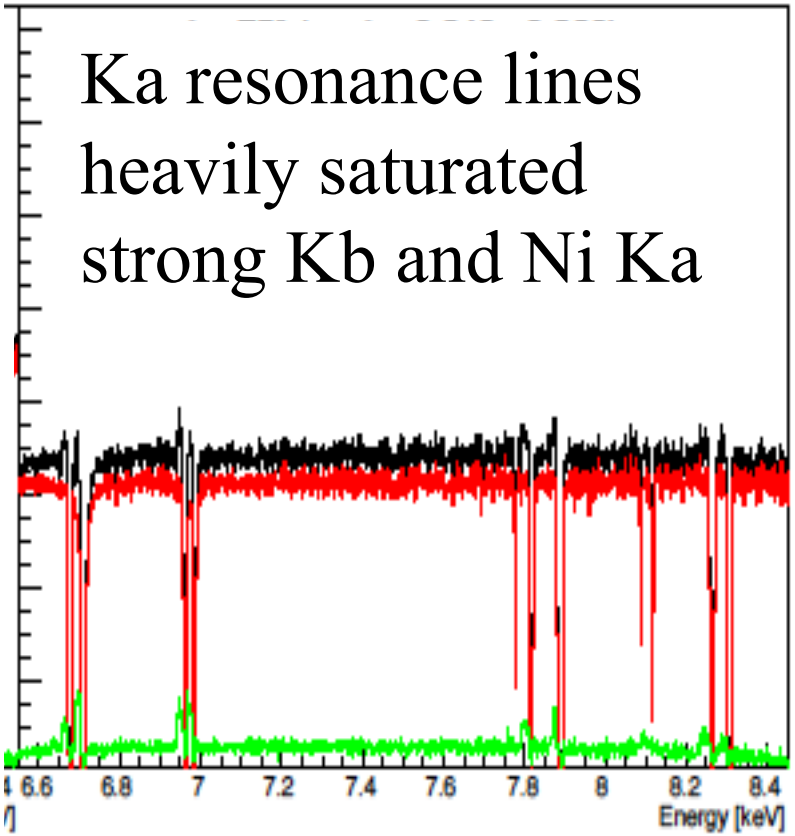
- TIC~10^7 as before, Rout =10 RIC, L=0.5LEdd, i=65

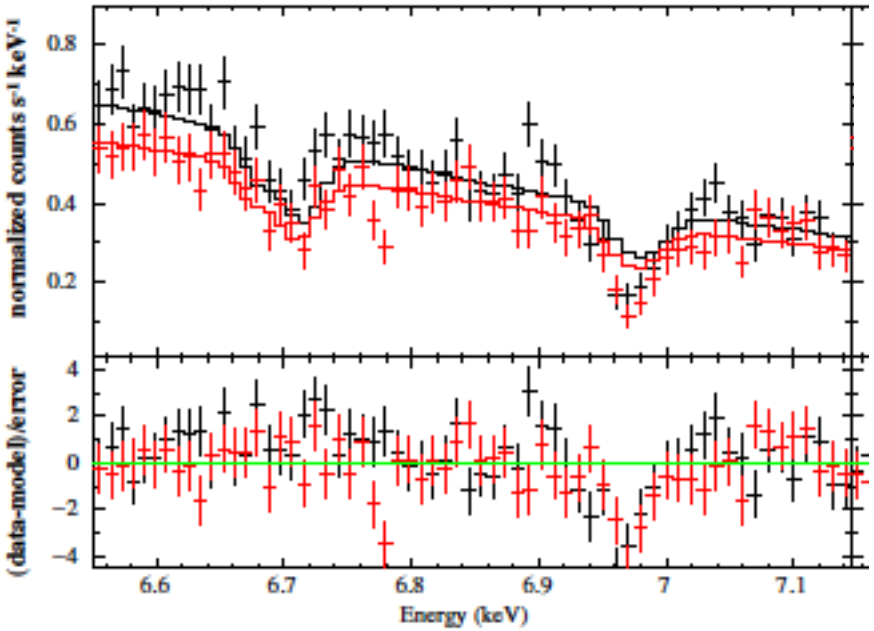
Monte Carlo RT through hydro

Tomaru, Done et al 2019,2020a,2020b



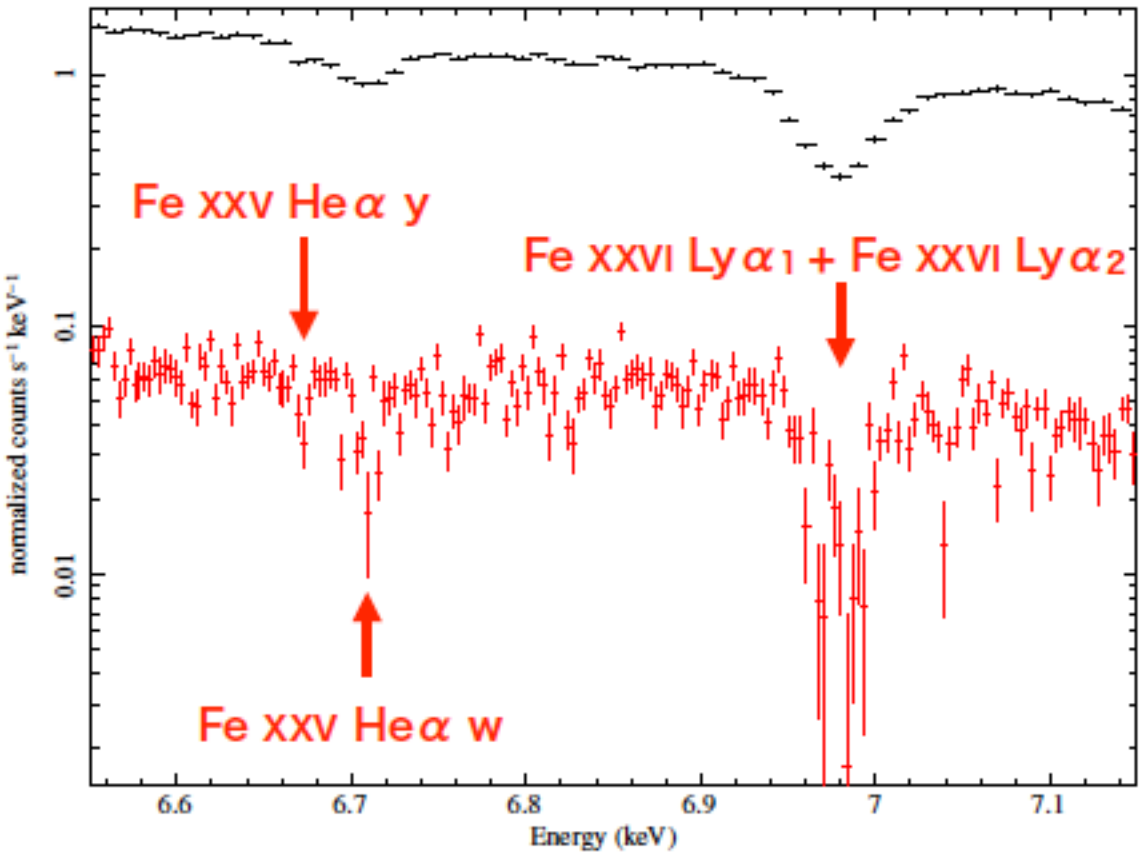
Bigger disc, brighter source! GX13+1





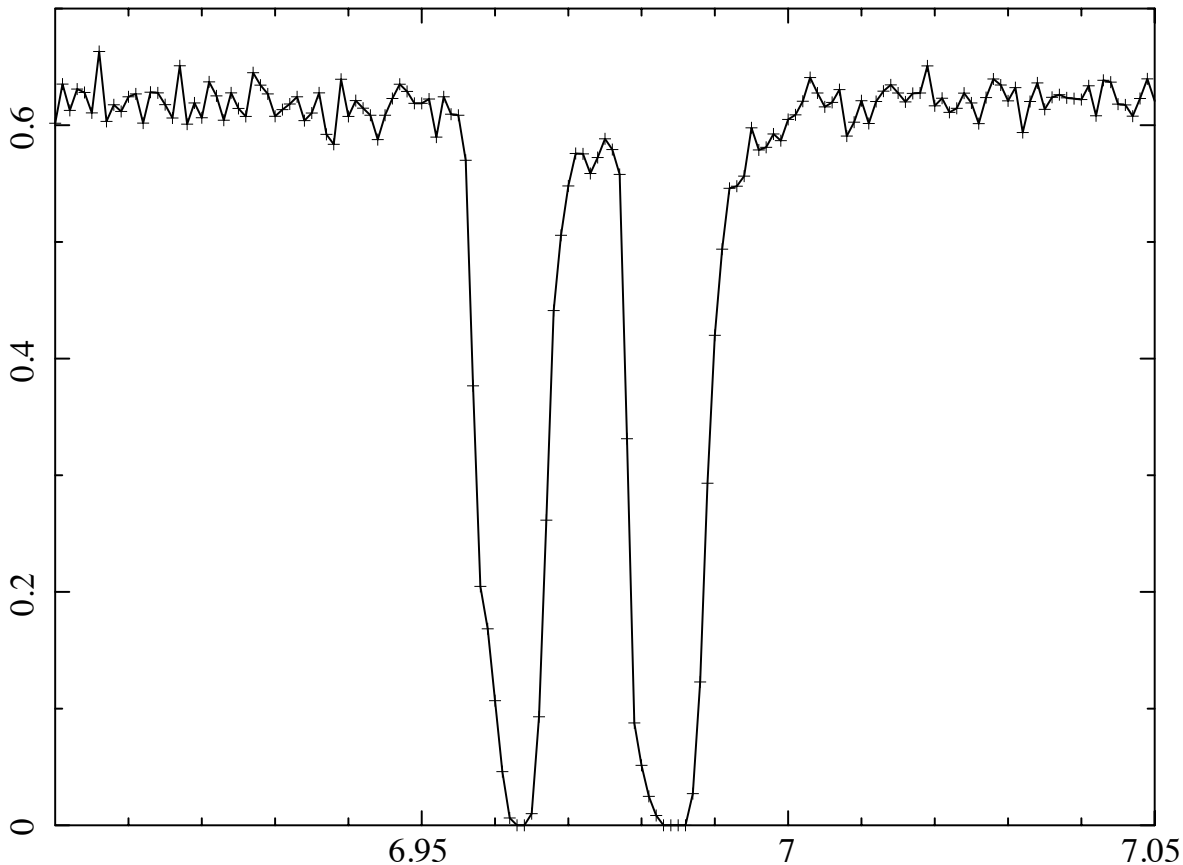
- But HETG only Ka. but it fits! (more or less!)
- No additional turbulence from disc surface, or stream impact, and neglects scattered flux

Chandra 3rd order!!!



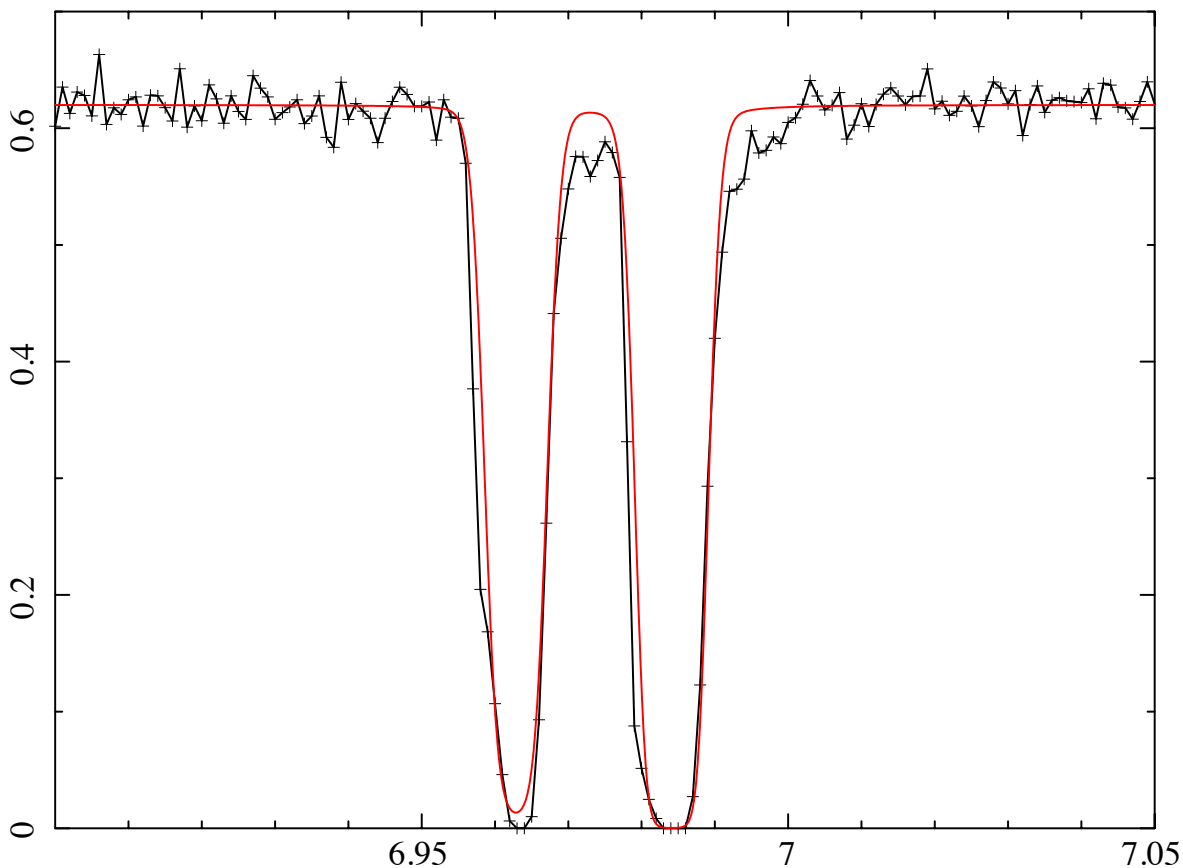
- First order – Ka components blended
- 3rd order – components resolved!
- FeXXVI doublet - 21 eV separation

FeXXVI is cleanest line



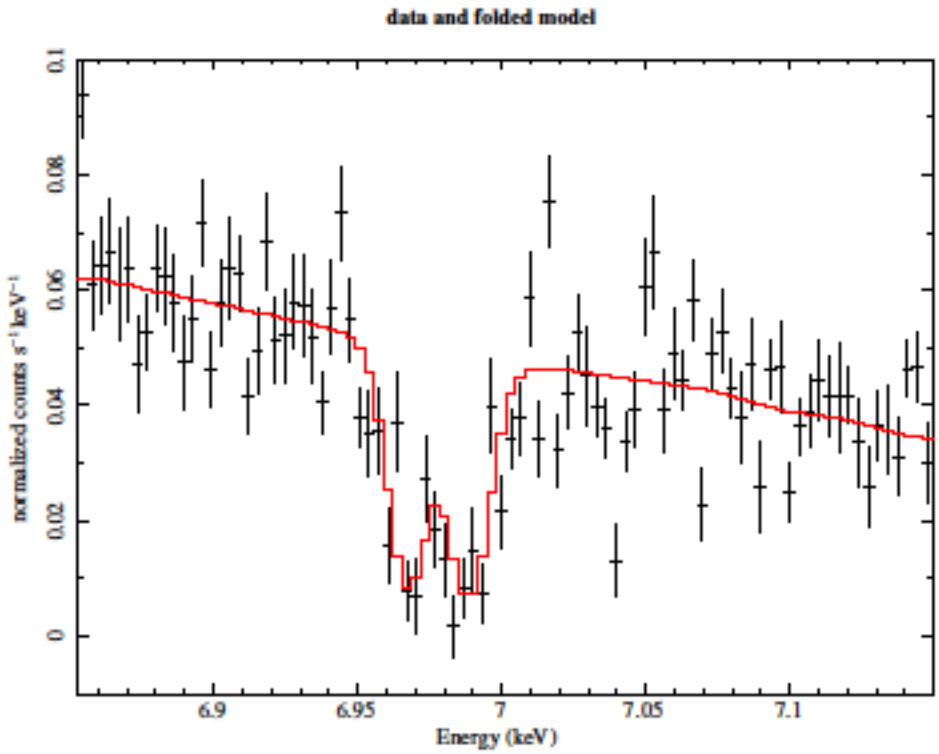
- Thermal winds ~ constant v so NARROW!

FeXXVI is cleanest line



- Voigt profile kT=5.7 keV (sim has T=1 keV so radial velocity change is 150 km/s) – quite symmetric

FeXXVI is cleanest line

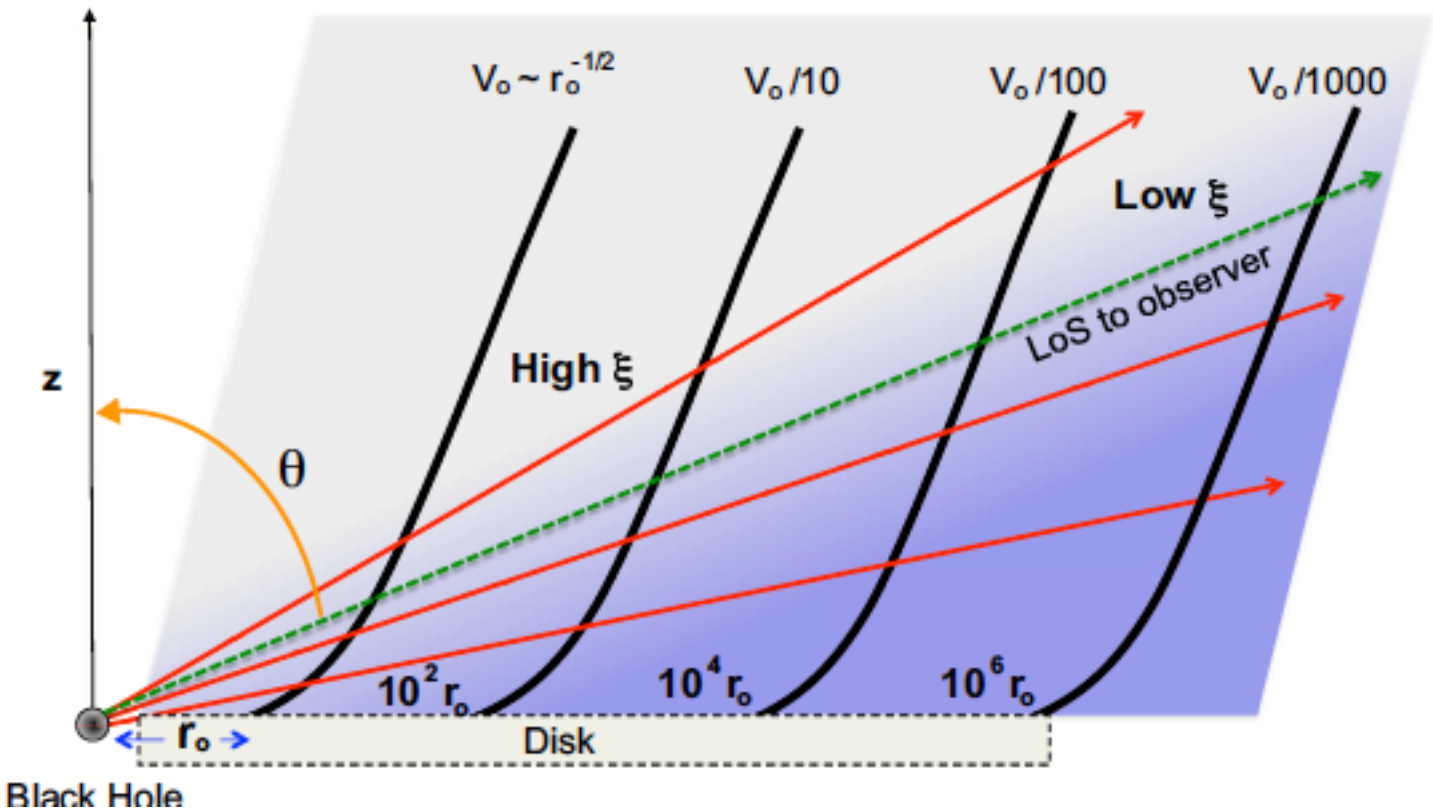


- Fit 3rd order FeXXVI with Voigt profile kT=5.7 keV
- But systematics – point to point scatter…chip edges

Magnetically driven Winds

- Unknown!!
- Need specific B field geometry

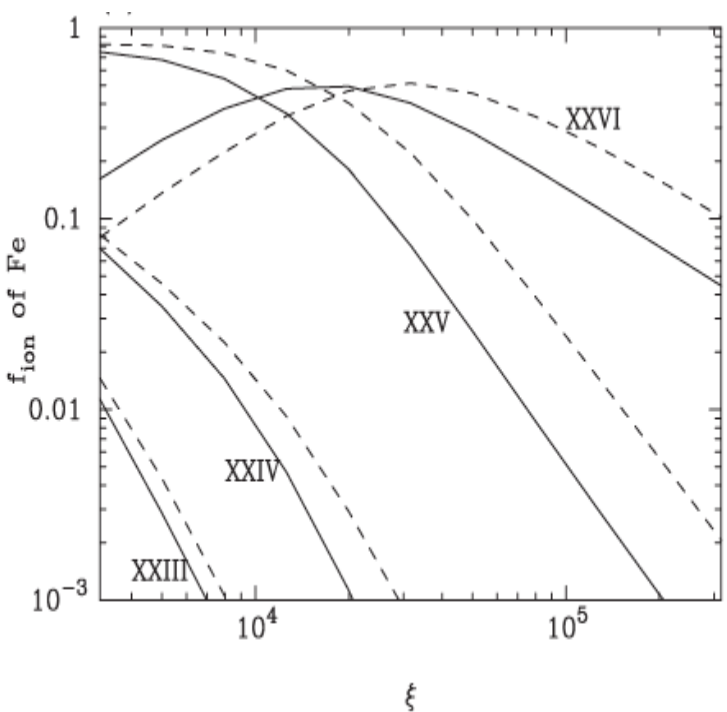
Fukumura et al 2010, 2014, 2017

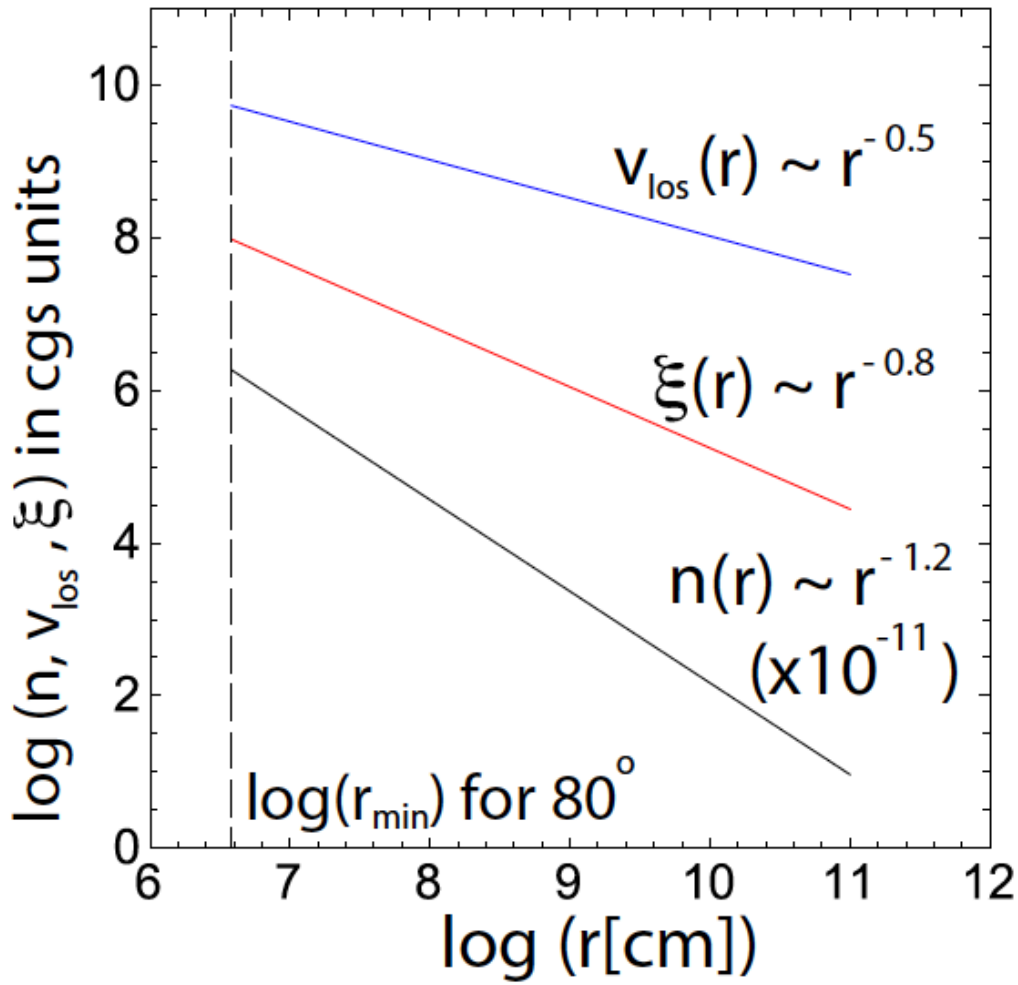


Magnetically driven Winds

Fukumura et al 2017

- Fukumura et al show density/ξ/v profile
- Combine with ion fraction with ξ

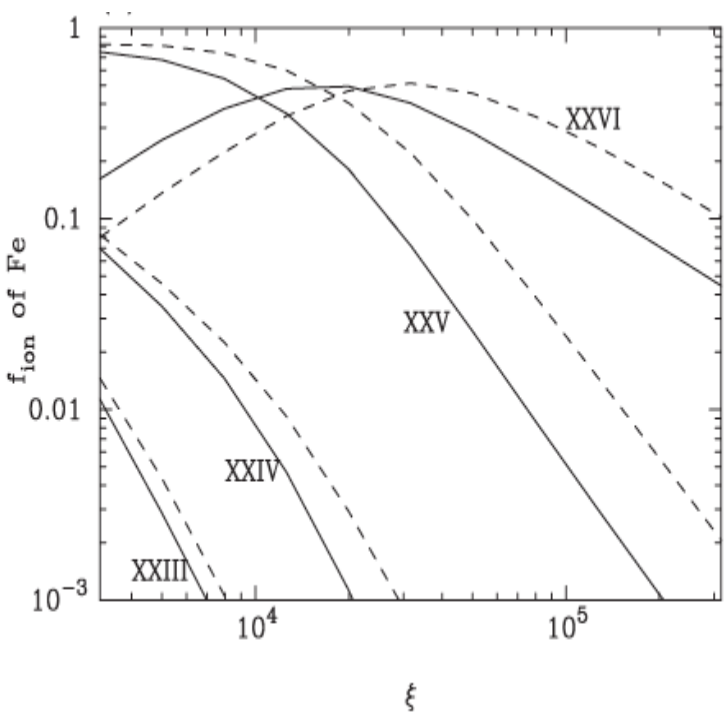


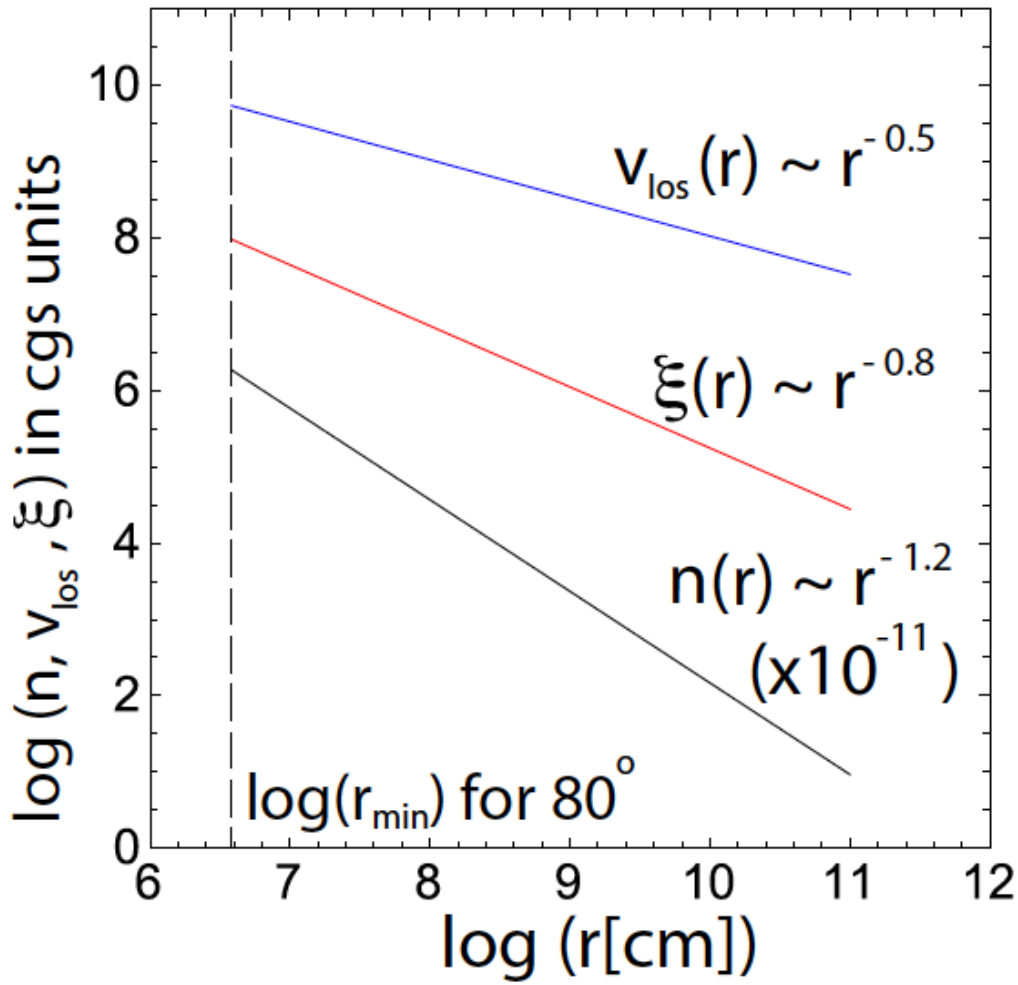


Magnetically driven Winds

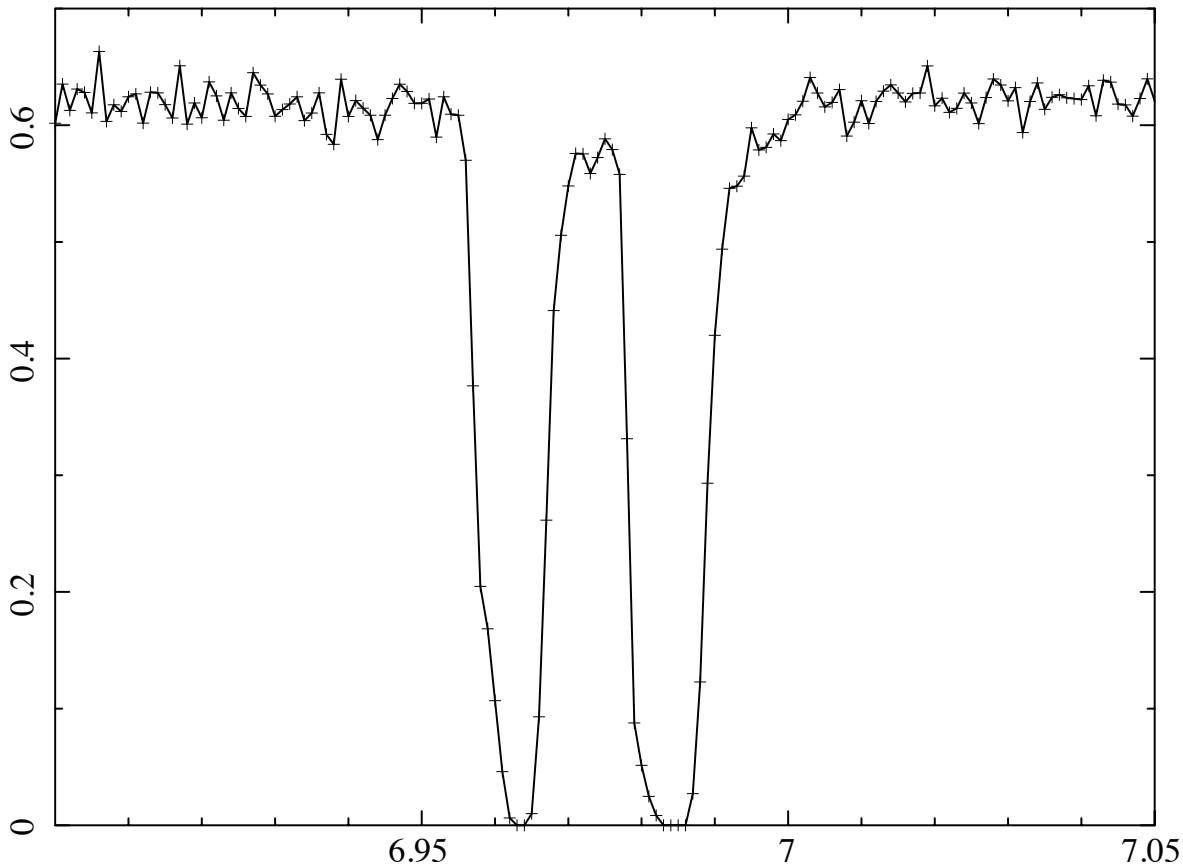
- Set n0 from peak FeXXVI at v=vobs (Kubota et al 2007)

Fukumura et al 2017



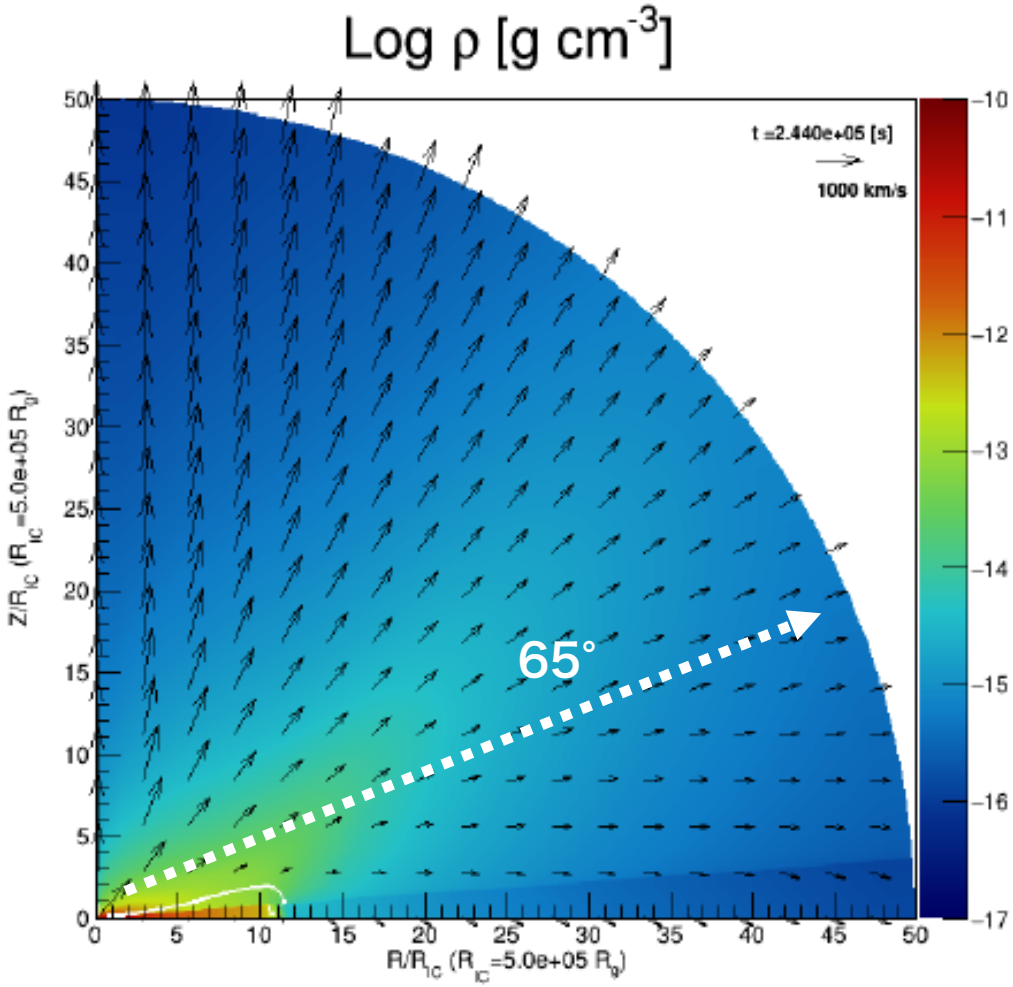


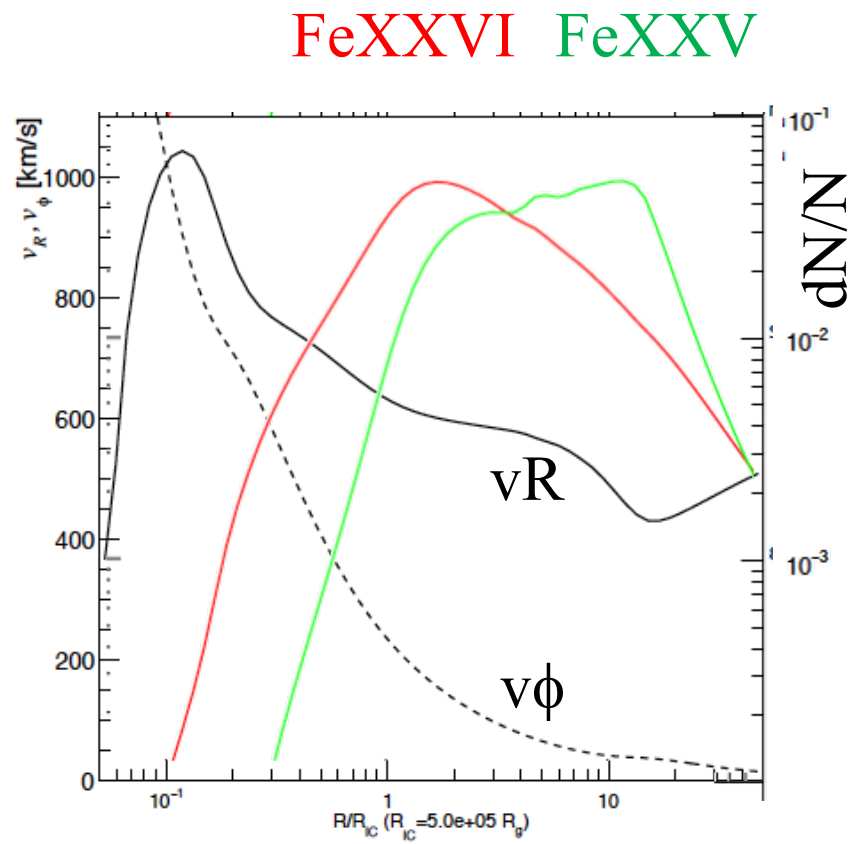
FeXXVI is cleanest line



- Thermal winds ~ constant v so NARROW!

Bigger disc, brighter source! GX13+1

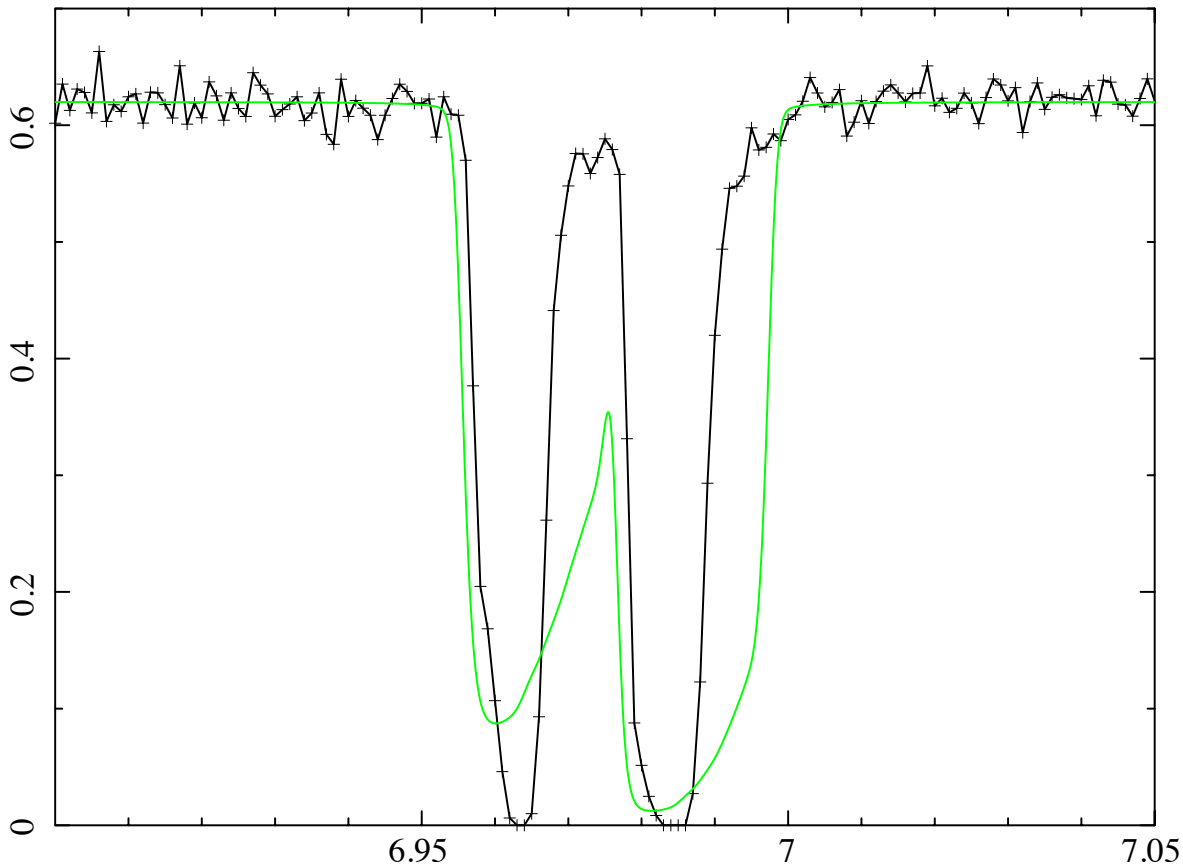




Tomaru et al 2020b

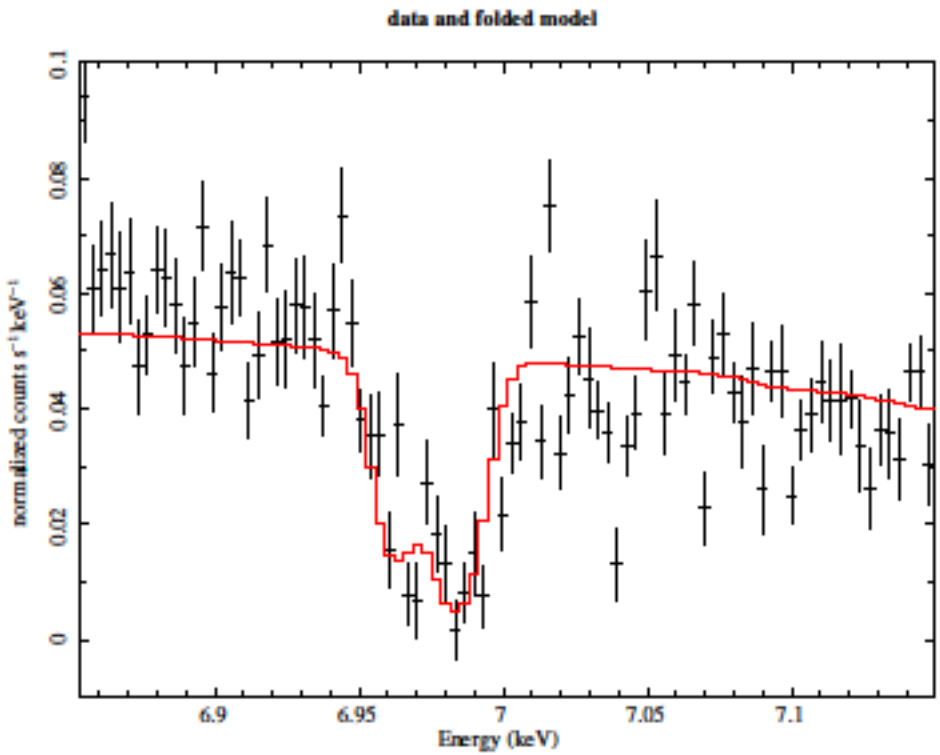
- TIC~10^7 as before, Rout =10 RIC, L=0.5LEdd, i=65

FeXXVI is cleanest line



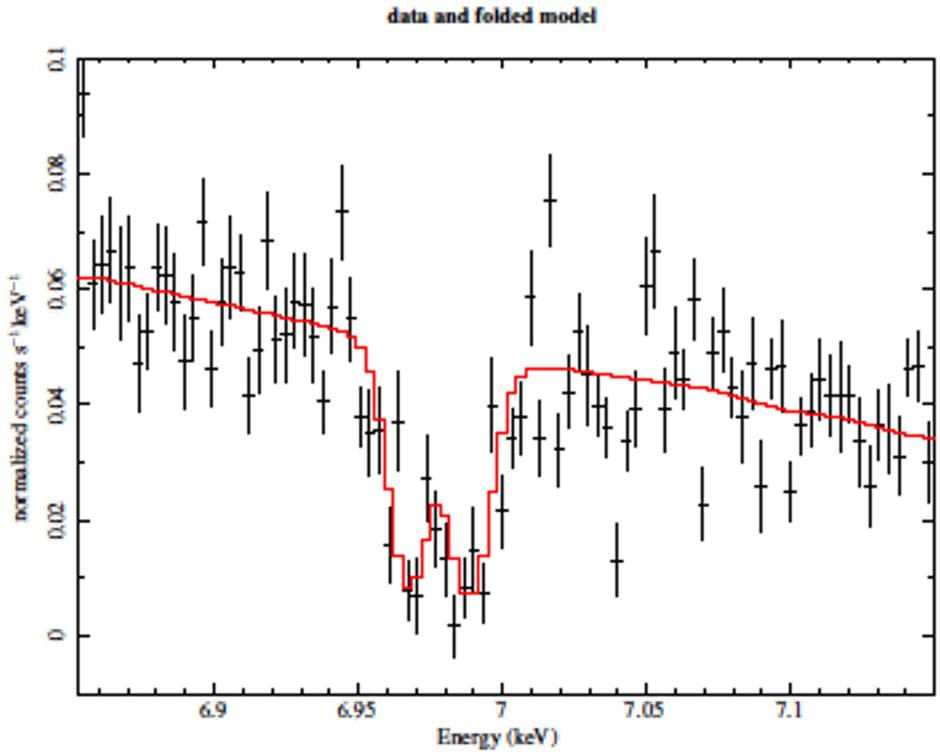
- B winds convert azimuthal to radial – broader range in v

FeXXVI B wind



- Fit 3rd order FeXXVI with B wind….

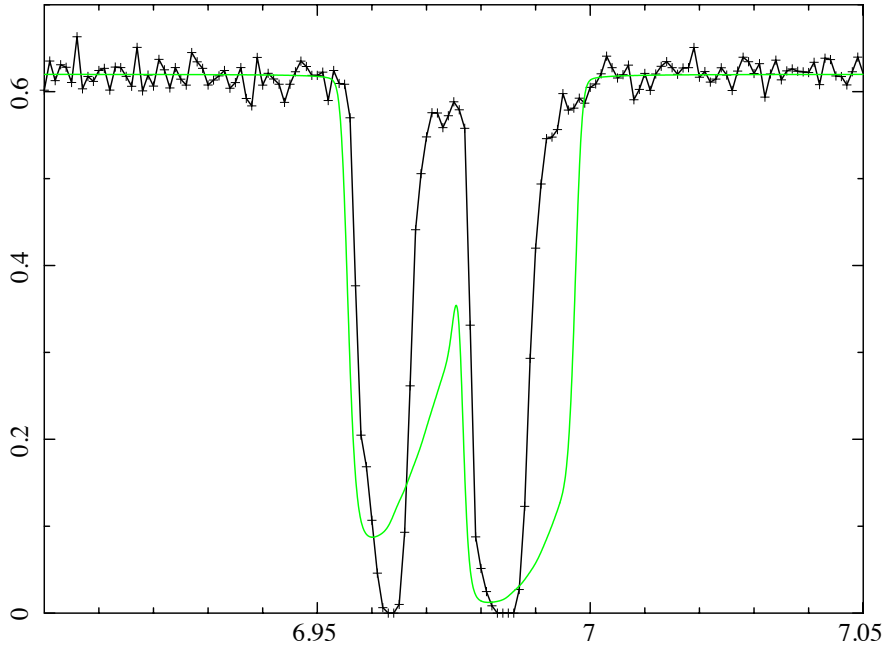
FeXXVI Thermal-radiative



- Fit 3rd order FeXXVI with Voigt profile kT=5.7 keV
- Better by eye, but Cstat wants broader Kabs line!! Sys..

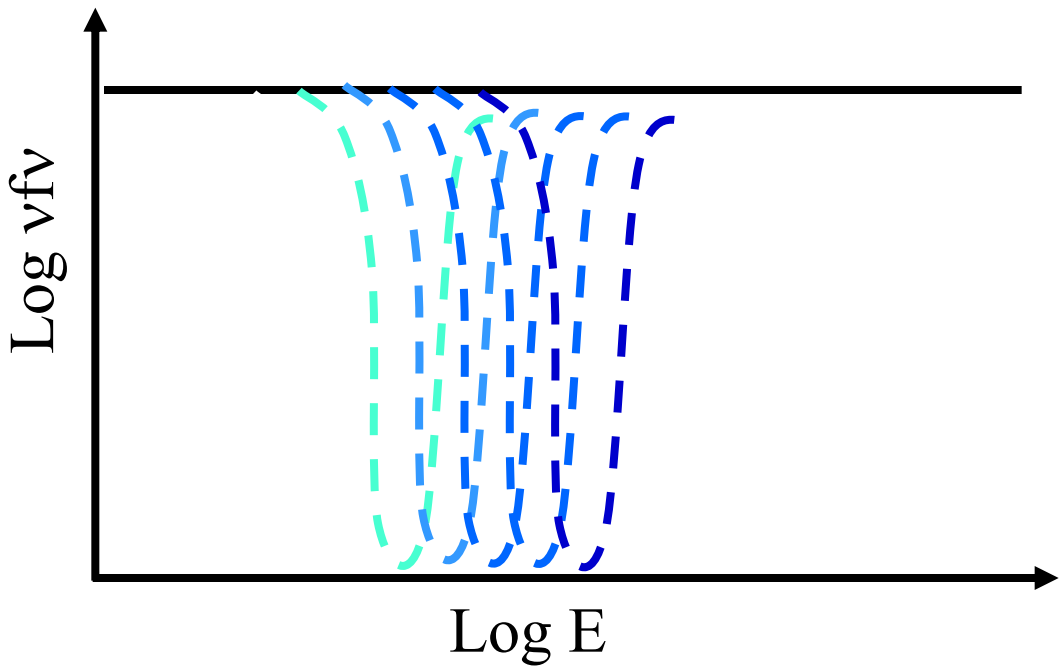
Conclusions

- PHYSICS of WIND LAUNCHING
- B field
- Thermal-radiative
- LMXB + XRISM/Athena



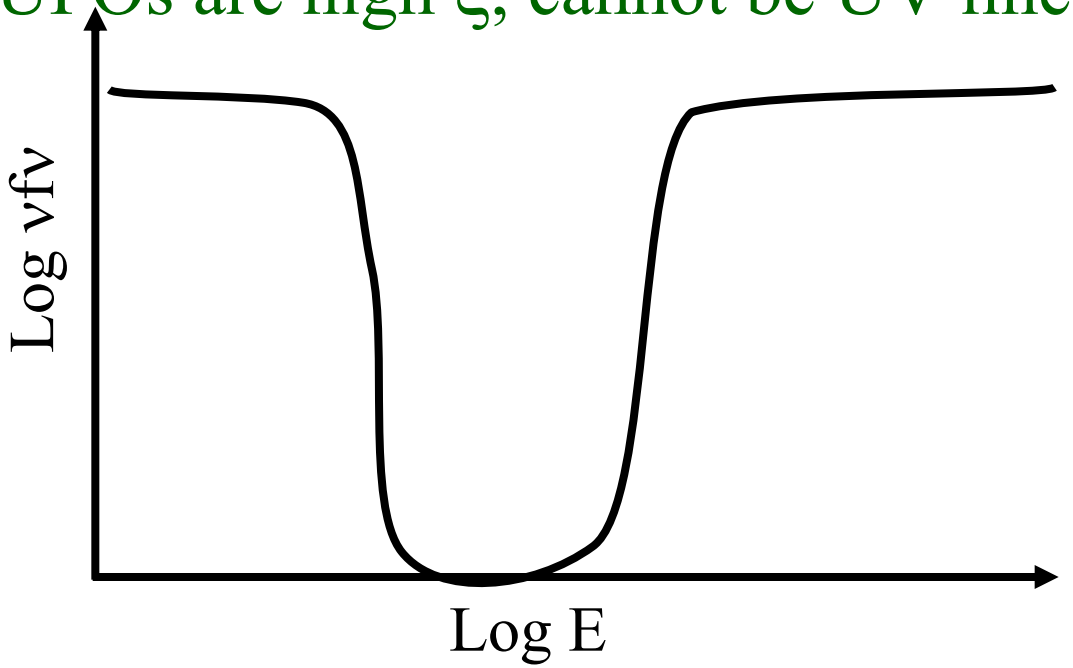
2: UV line driving

- Momentum absorbed in line accelerates wind so more momentum absorbed in line



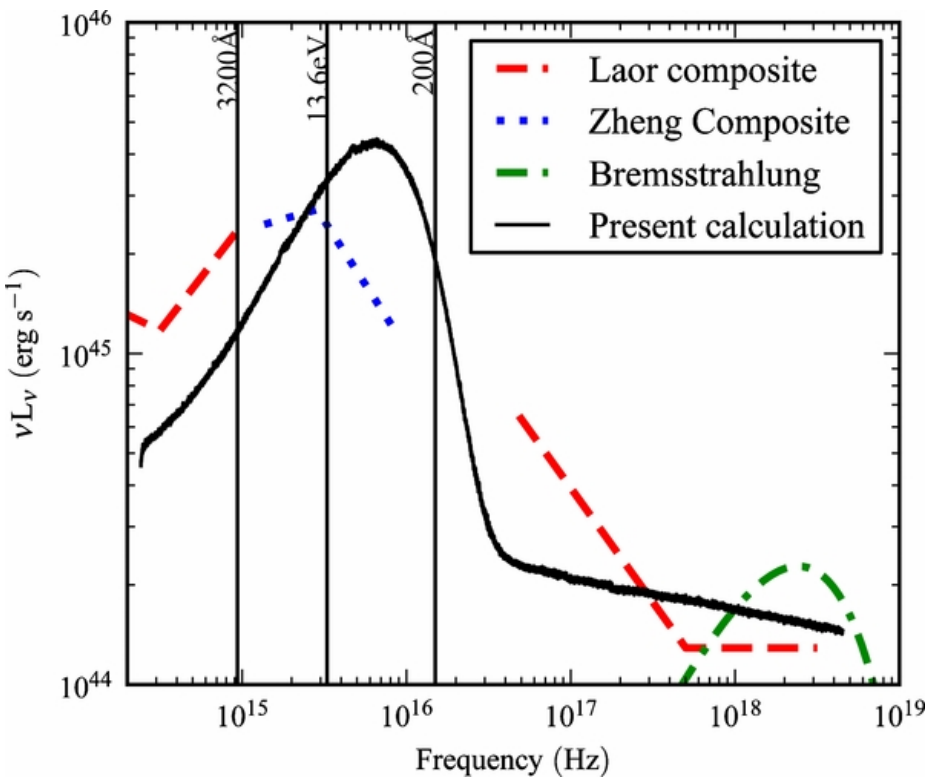
UV line driven Winds ?

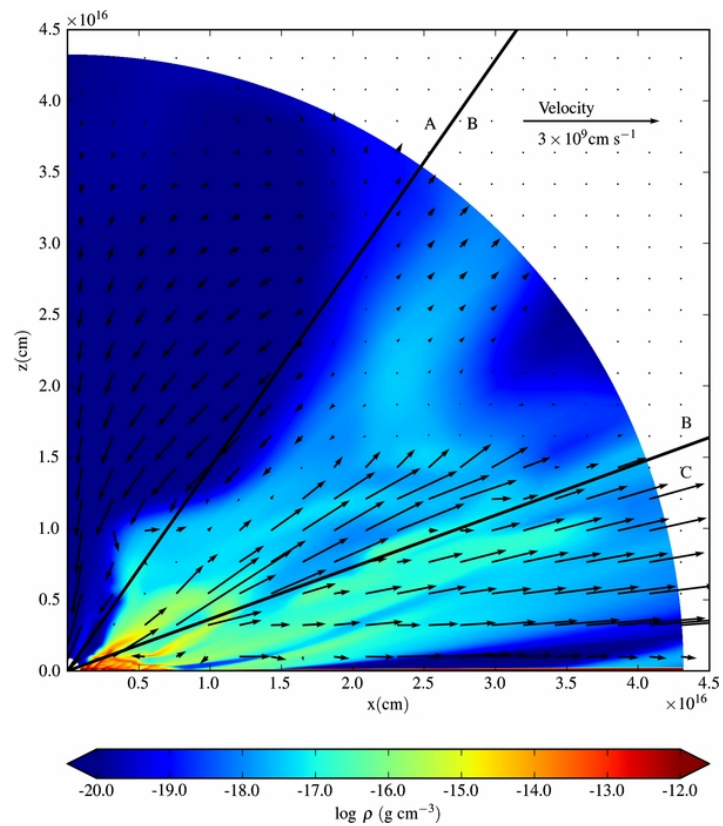
- Momentum absorbed in line accelerates wind so more momentum absorbed in line
- Requires UV transitions, so only works at low ξ
- UFOs are high ξ, cannot be UV line driven! Or can they?



UV line driven Winds ?

- Clumpy, complex
- 10^8 Msun, L/Ledd = 0.5 BUT wind depends on SED and AGN not pure discs. Lx ionises: Proga & Kallman 2004,

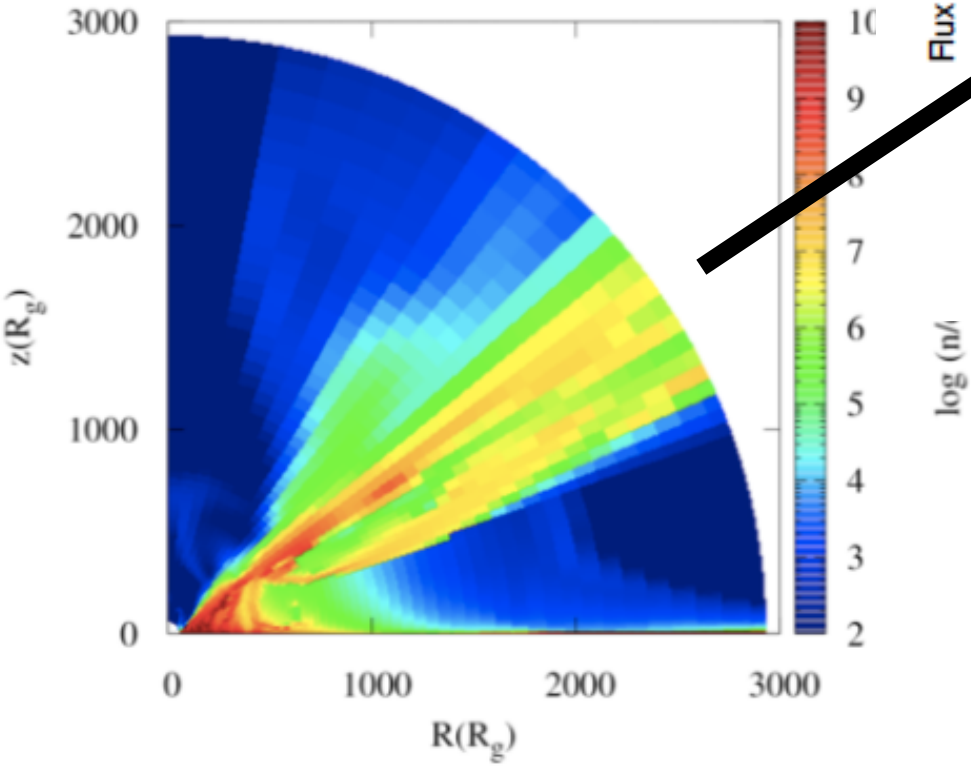


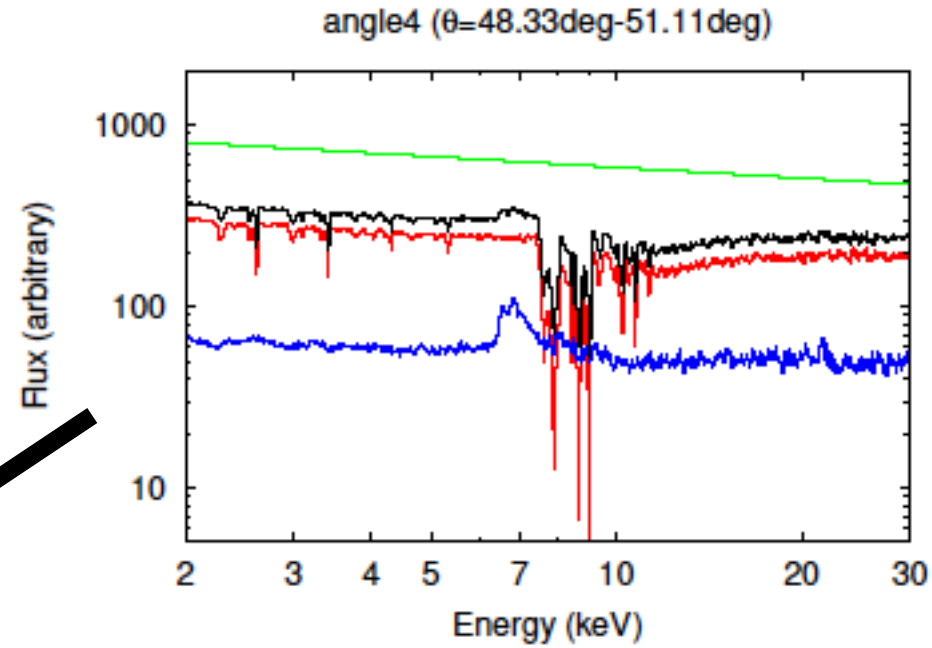


Higginbottom et al 2014

AGN: Ultrafast outflows UFOs!!

Modern UV line driven disc wind hydro sim Nomura et al 2019 fx=0.1



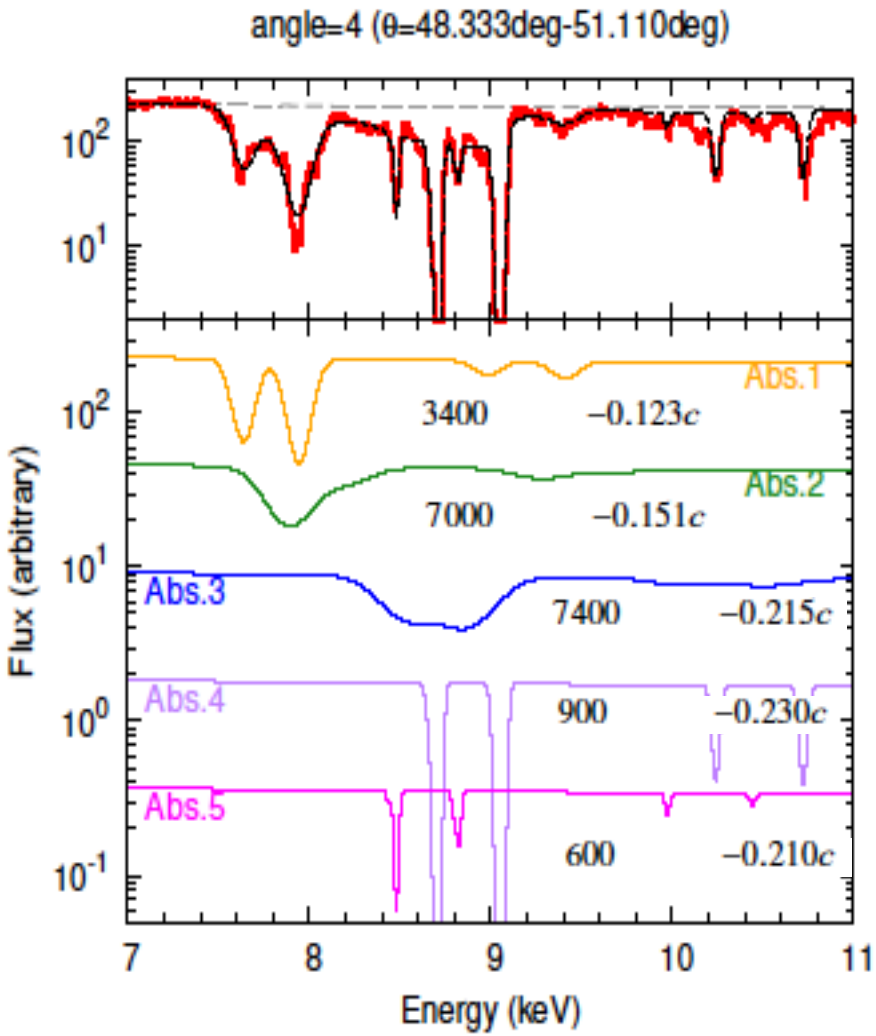


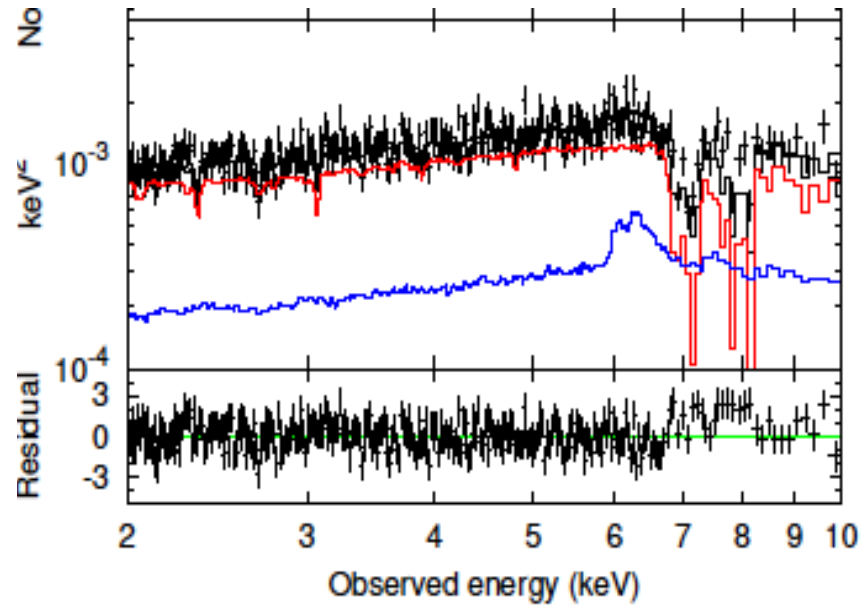
Some los only high ξ

UV driving works on low ξ close to disc, then ionised by central source

Mizumoto et al 2020

AGN: Ultrafast outflows UFOs!!





Not bad fit to real data
from PG1211
Mizumoto et al 2020