The origin of the soft excess in AGN

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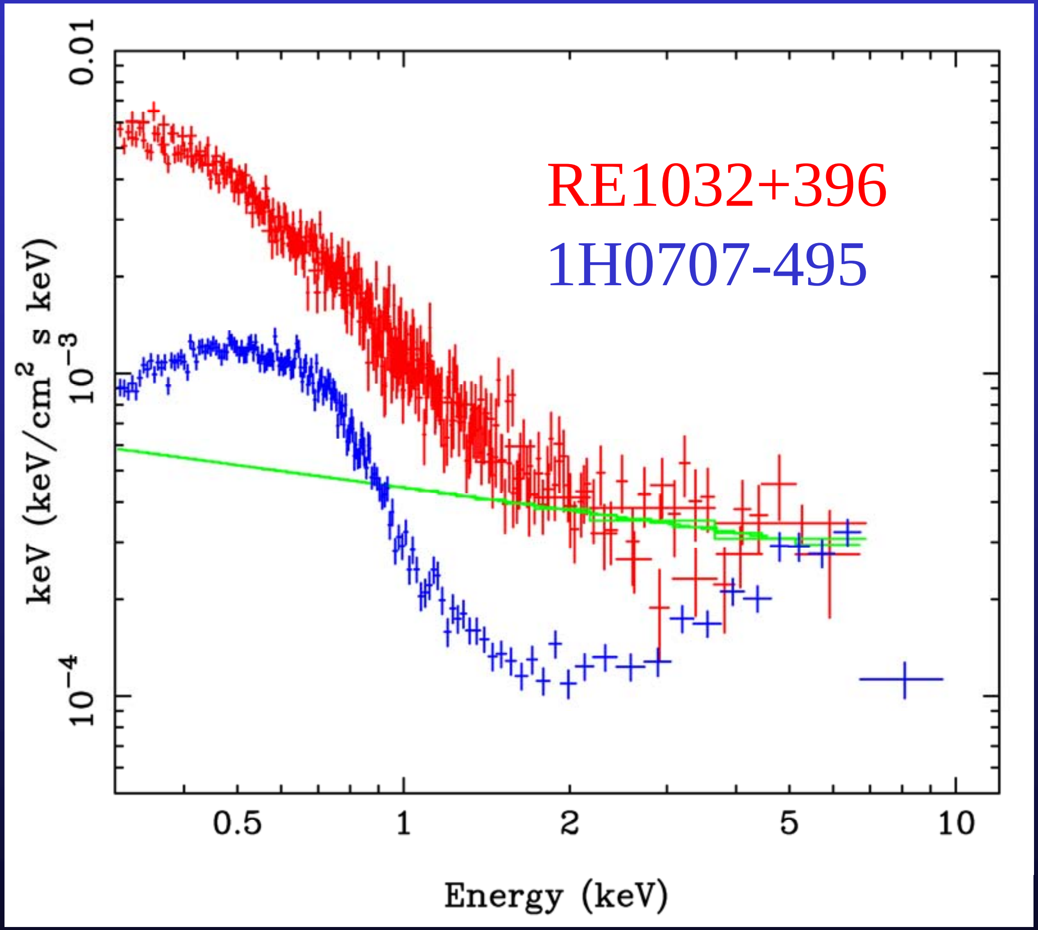
What is the soft excess?

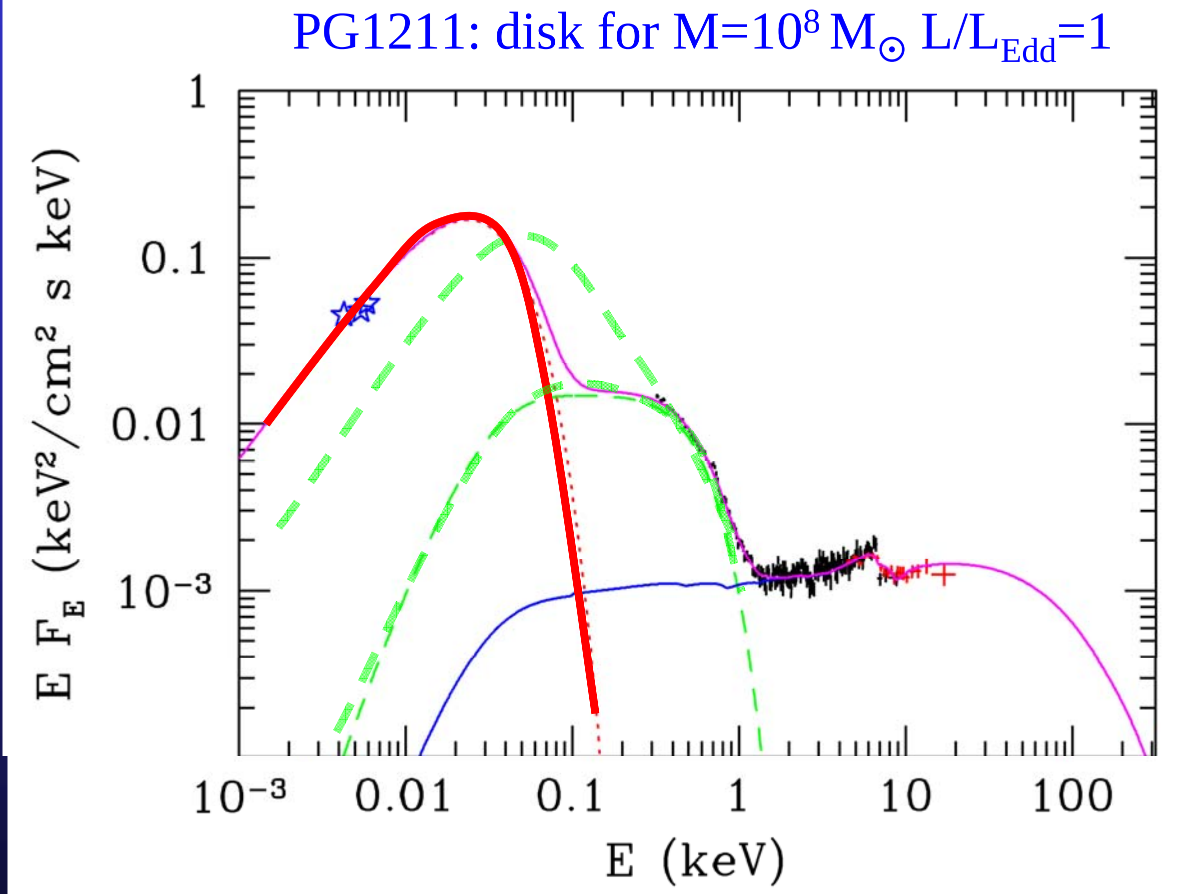
- Often see X-ray spectra with rise below ~1keV compared to 2-10keV
- Smooth spectral component – can't resolve it all into lines with gratings though there are some discrete emission/absorption features superimposed



NOT from the disc!

- NOT THE DISC - doesn't get close to rise in data at 1keV
- unless extreme spin and/or modified by advection – but disc tail very steep while SX gradual
- Compton scattering of disc by low T_e, high τ material?

Magdziarz et al 1998, Czerny et al 2003

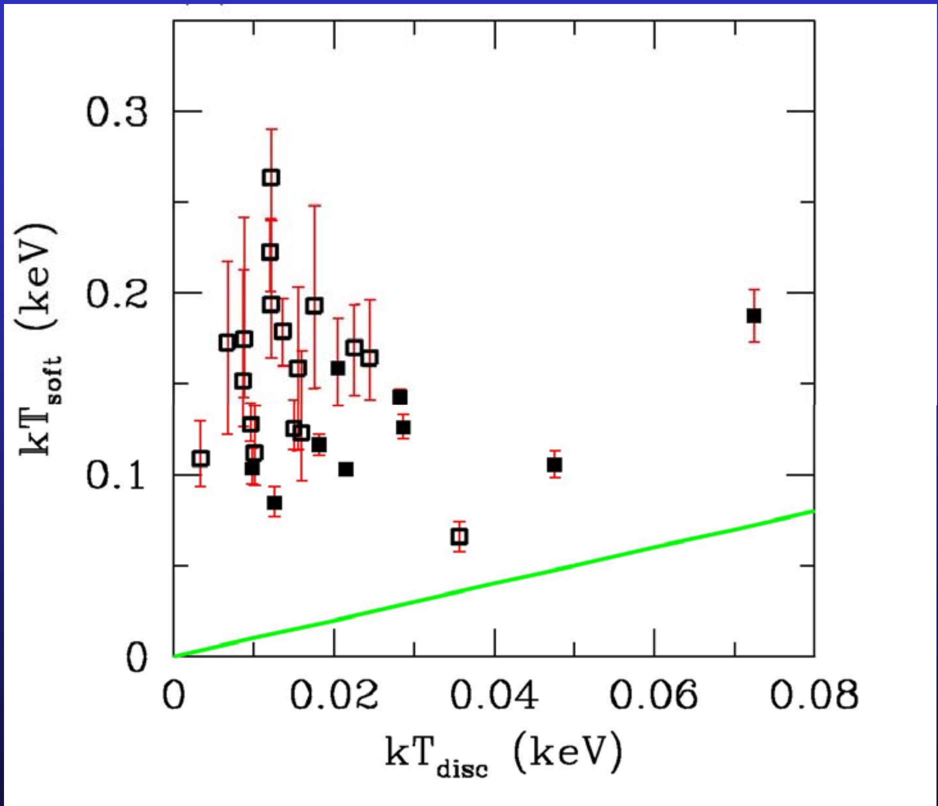


Gierliński & Done 2004

NOT from Comptonisation

- 30 PG QSO's already public in XMM database.
- ALL need soft excess
- Fit with comptonisation...
- ALL have same kT_e for soft excess!! Yet big range in expected disc kT (mainly M)
  Walter & Fink 1993, Czerny et al 2003, Gierlinski & Done 2004, Crummy et al 2006
- Expect electron temperature to change if seed photons from disc change – different efficiency of Compton cooling

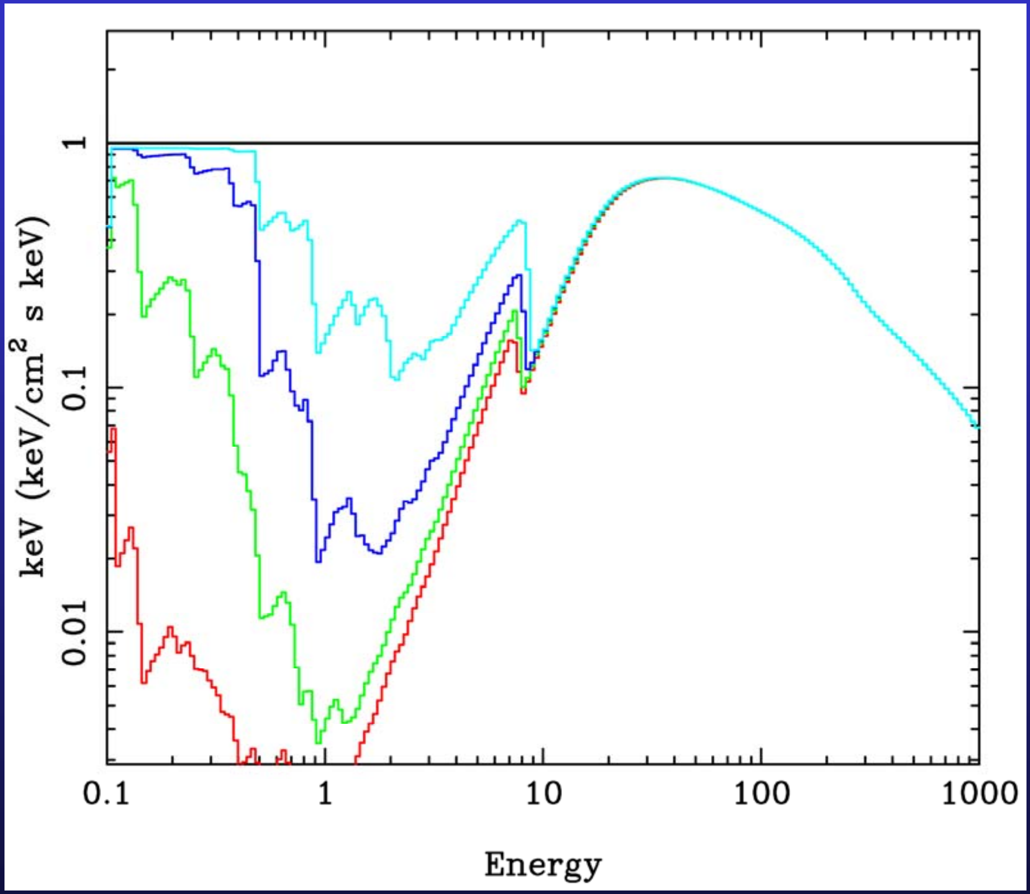
Gierlinski & Done 2004



- NOT COMPTON SCATTERING

Continuum Reflection

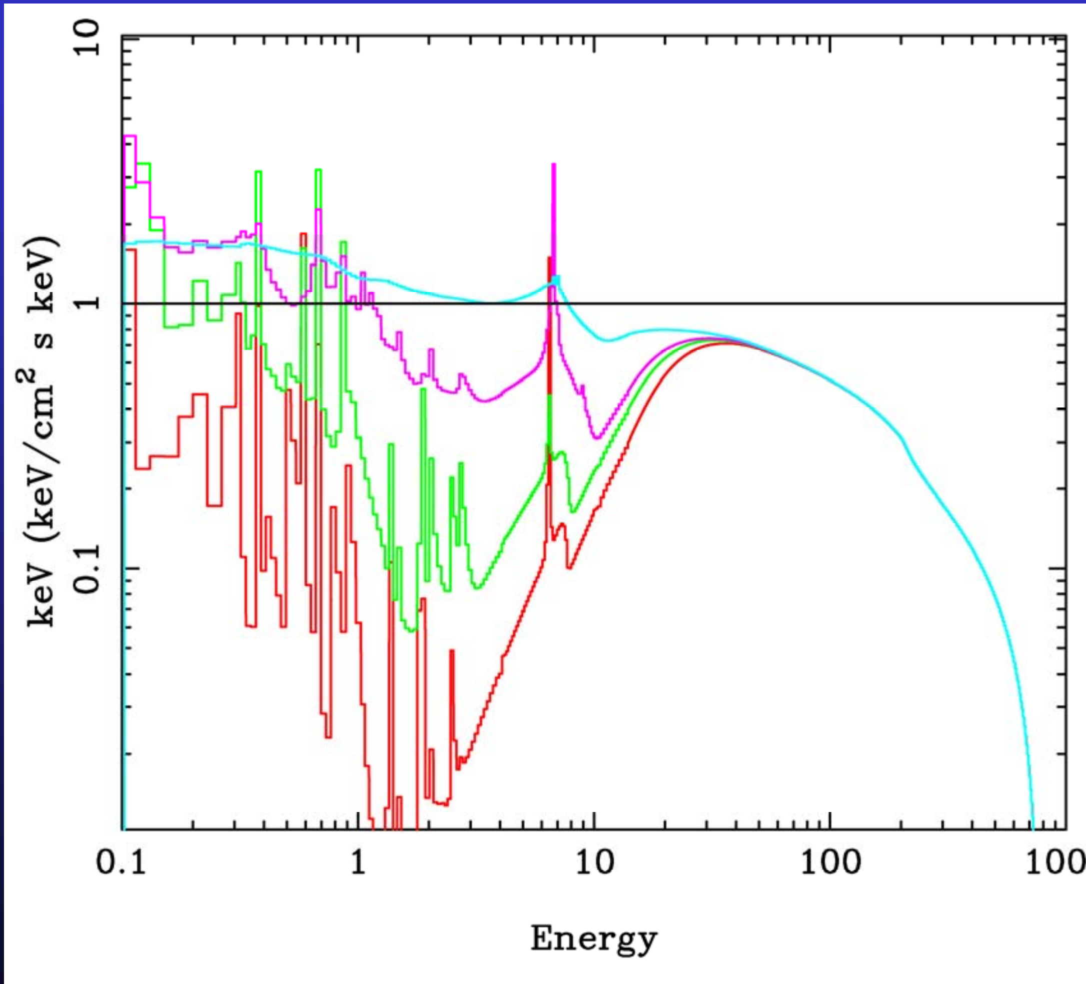
- Fixed temperature looks more like atomic!
- Big increase in opacity at 0.7-3 keV due to OVII/VIII and Fe L for $\xi = L/nr^2 \sim 1000$
- Partially ionised reflection?
- Increase in opacity between 0.7-3 keV gives dip in reflection probability as this is balance between scattering and photoelectric absorption
- Less reflection < 0.7 keV for lower ξ as more absorption from C, N as not ionised



Lightman & White 1988, Done et al 1992; Madgziarz & Zdziarski 1995; Czerny & Zycki 1994

Continuum+lines/RRC Reflection

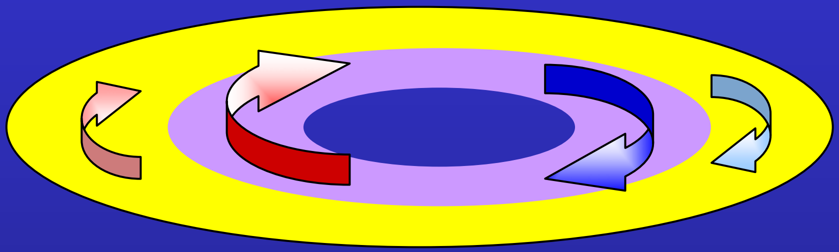
- Ionised material also has recombination lines as well as fluorescent lines (iron)
- Add to rise below 0.7 keV
- Is partially ionised reflection the origin of soft excess? Zycki et al 1994,
- No – smooth! These are line dominated except for very high ionisation not much lines and get Comptonisation smearing as well

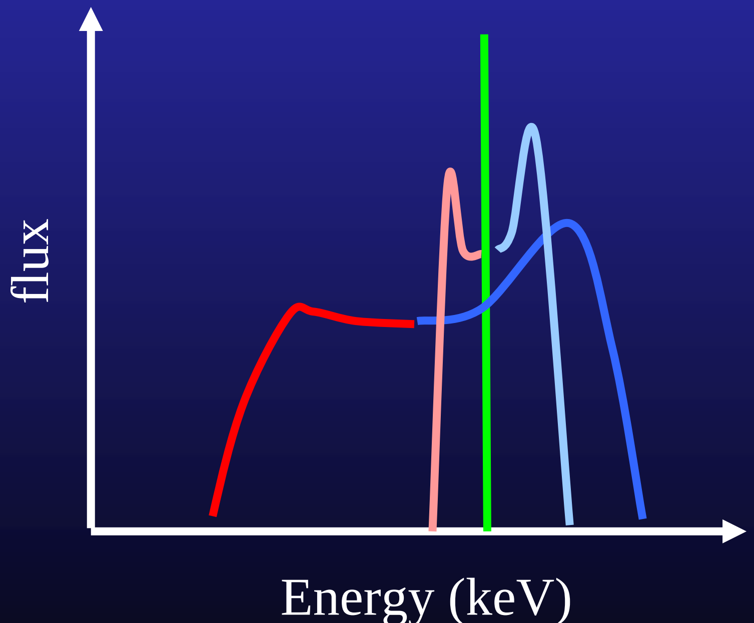


Matt et al 1991,1993,1996, Ross et al 1993,1996; Ballantyne et al 2004, Ross & Fabian 2006

Relativistic effects

- Relativistic effects (special and general) affect all emission (Cunningham 1975)
- Hard to easily spot on continuum components
- Fe Kα line from irradiated disc – broad and skewed! (Fabian et al 1989)
- But rest of spectral also – so all soft excess features also smeared
- Amount of broadening depends on Rin – so spin if ISO and emissivity profile (Laor 1991)

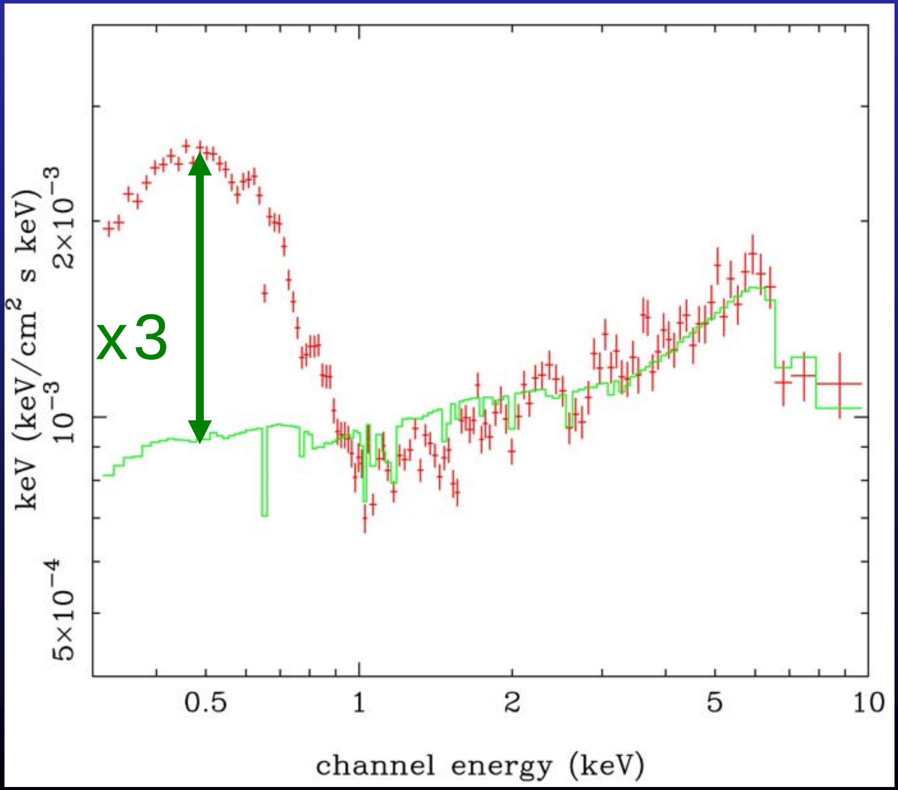


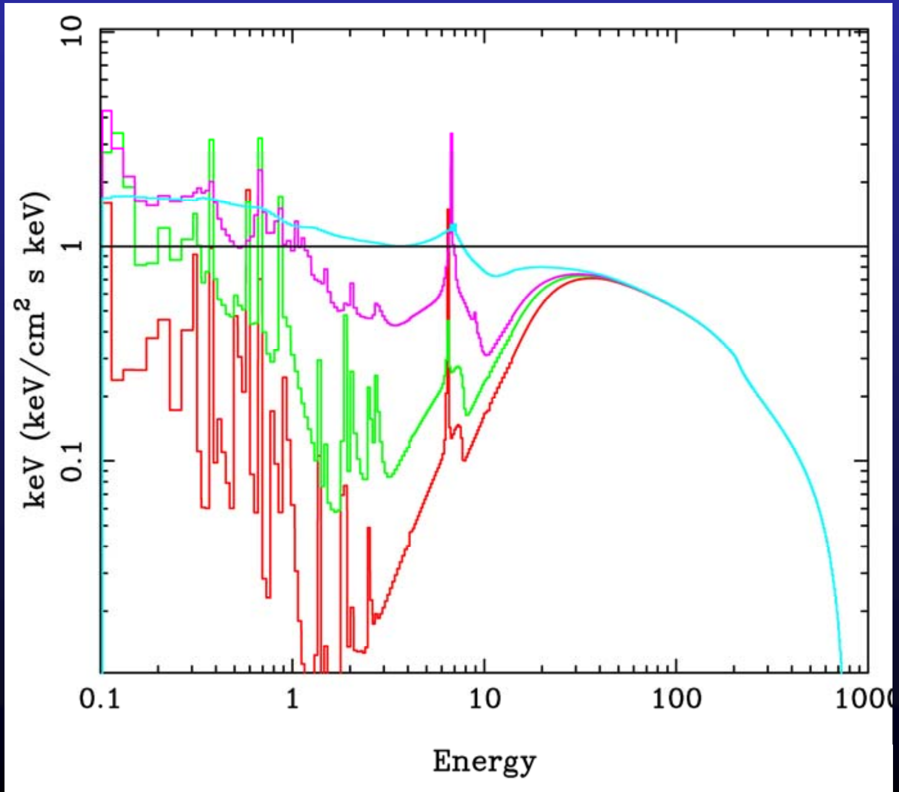


Fabian et al. 1989

Test reflection via size of the SX

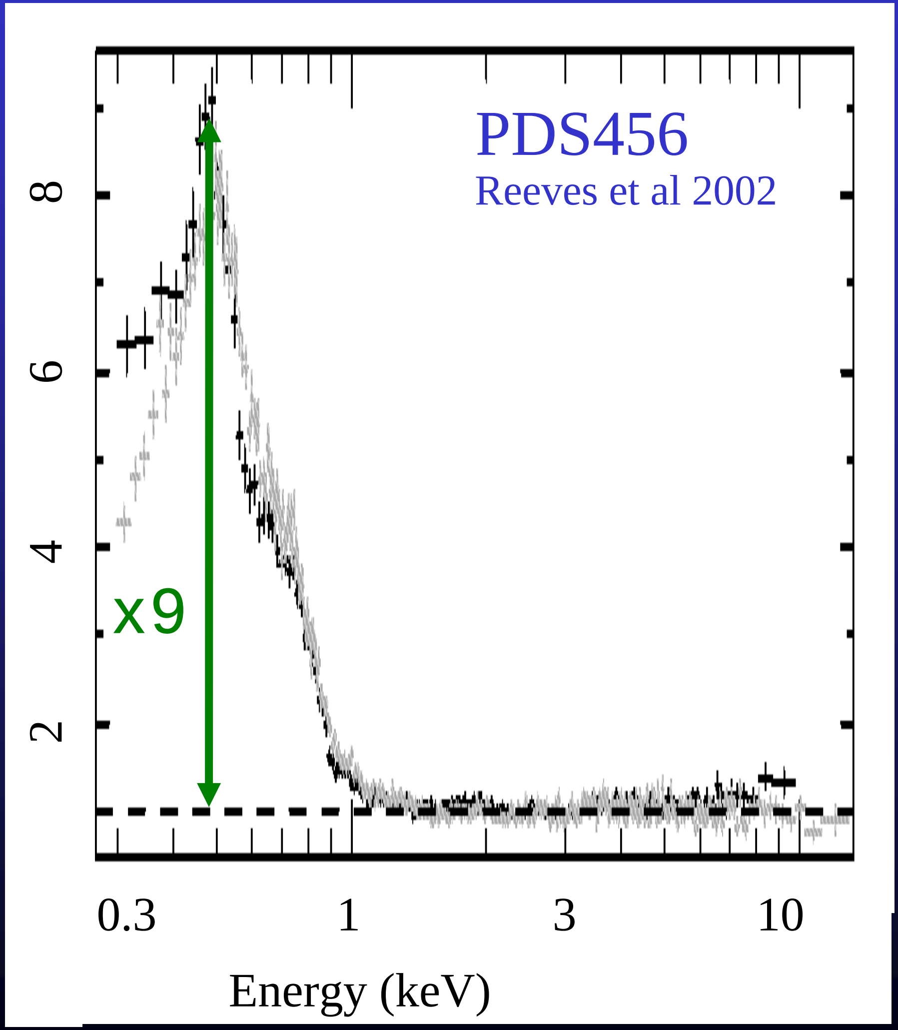
- Smeared reflection from a disc? Fabian et al 2002; 2004; 2005, Crummy et al 2006
- Size of SX: Extrapolate 2-10 keV spectrum and ratio data/model at 0.5 keV. Get 1.5-3 for most PG QSO's Porquet et al 2004
- For $\Omega/2\pi=1$ (isotropic) reflection gives maximum S<2-3 if reflection~incident below 0.7 keV and small in 2-10 keV i.e. ξ~1000



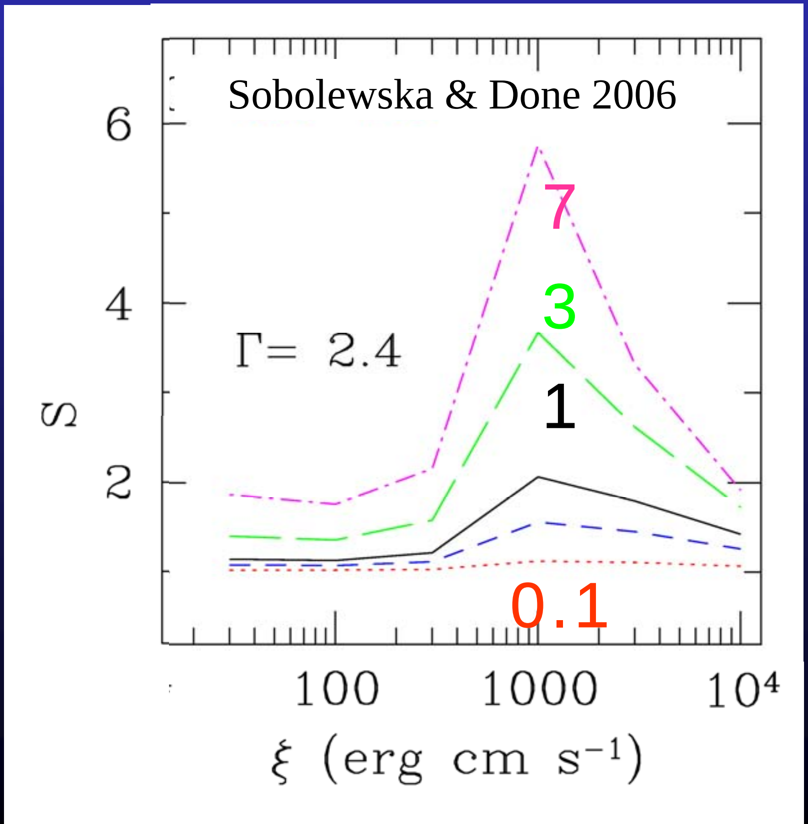


The size of the soft excess

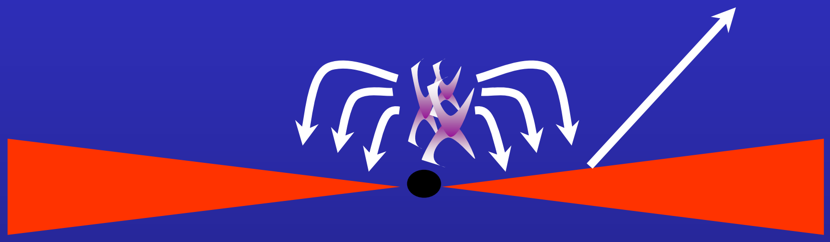
- Biggest soft excesses have S=10!! Tend to be NLS1's…



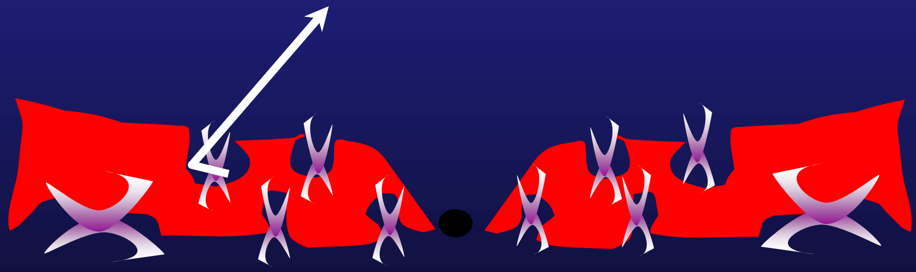
- Need reflection dominated spectra $\Omega/2\pi > 7$ so incident continuum supressed



Reflection dominated geometries



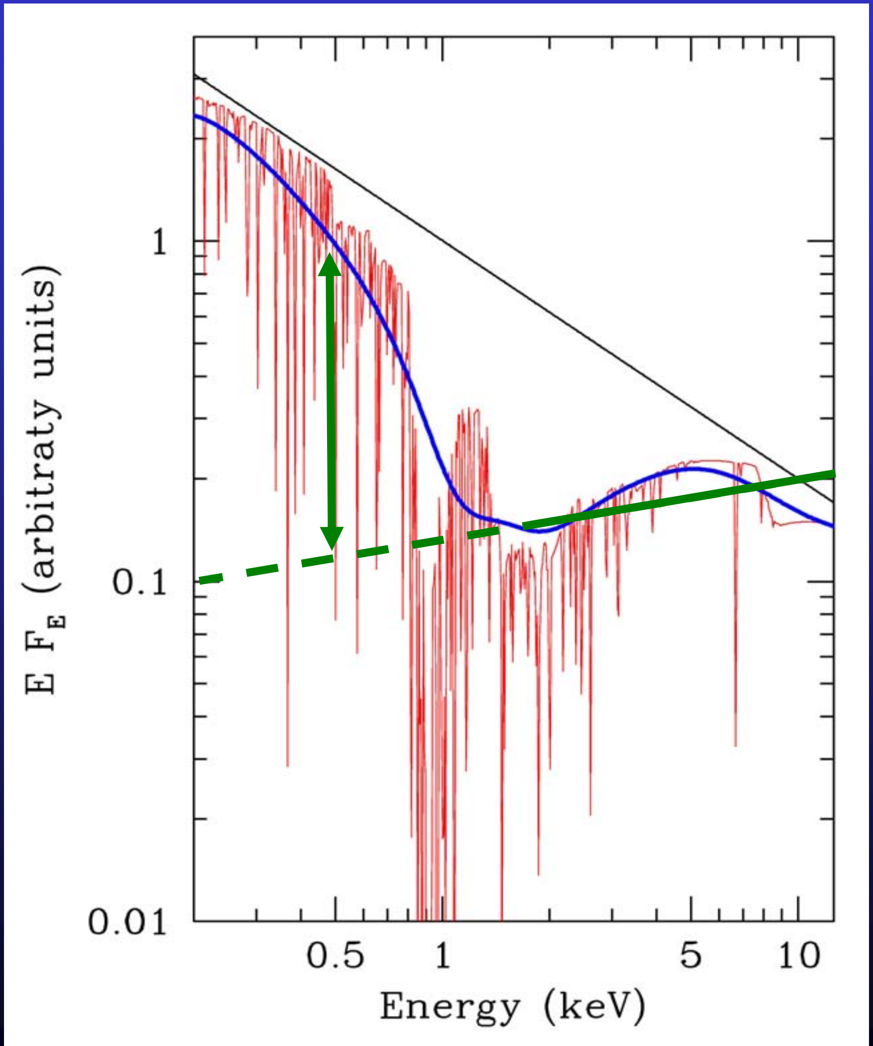
General relativistic lightbending enhancing illumination of disc and suppressing direct continuum flux? Fabian et al 2002



Disc fragments into inhomogeneous regions which hide a direct view of most of the intrinsic emission? Fabian et al 2004; 2005

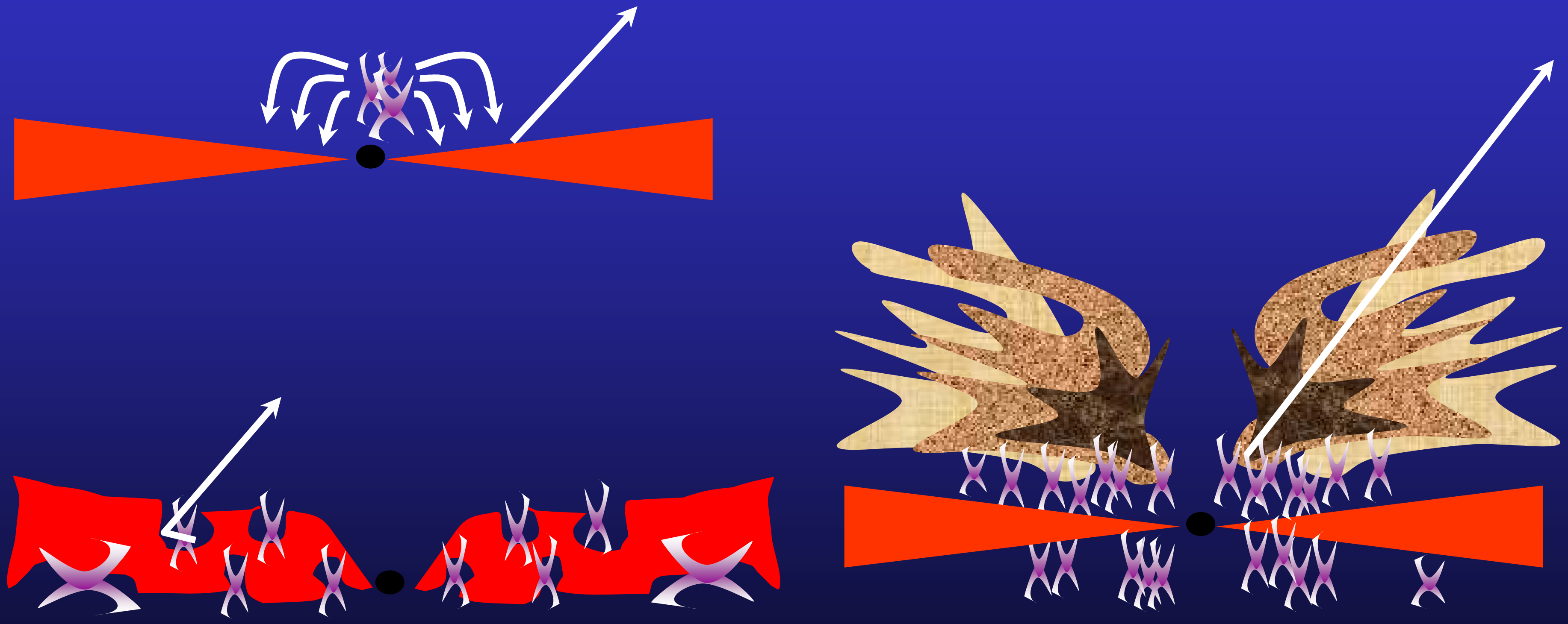
An alternative? Absorption

- Opacity jump could also work for material seen in absorption
- Again need to smear as no characteristic atomic features seen in soft excess
- Should be moving – wind/outflow ? Smearing NOT from Keplarian motion so can't translate into Rin and hence spin.
- Unknown wind velocity structure – try Gaussian!



Gierliński & Done 2004

Alternative geometries for partially ionised, smeared material



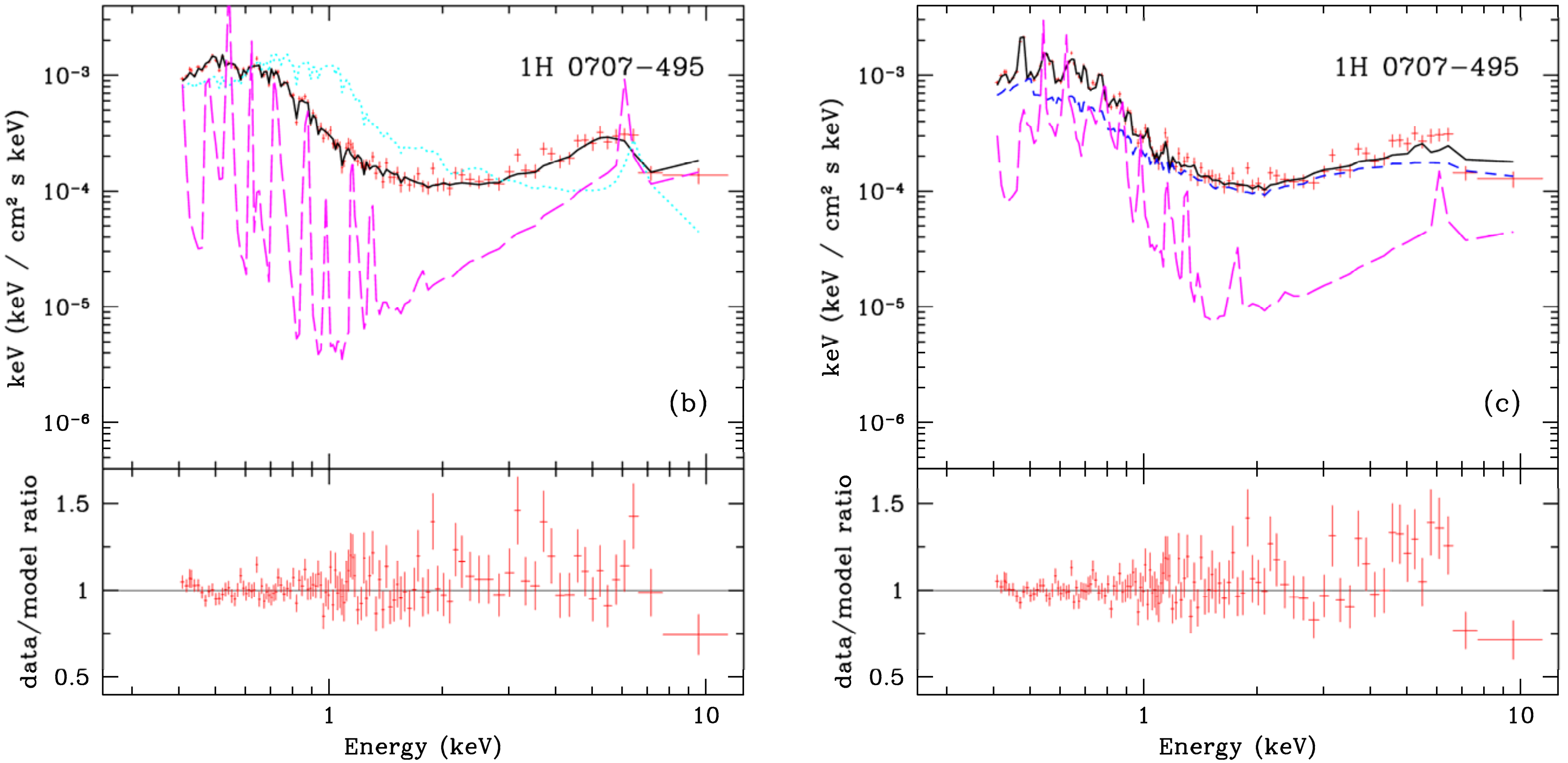
Reflection   Absorption

And does it fit ? 1H0707 huge SX

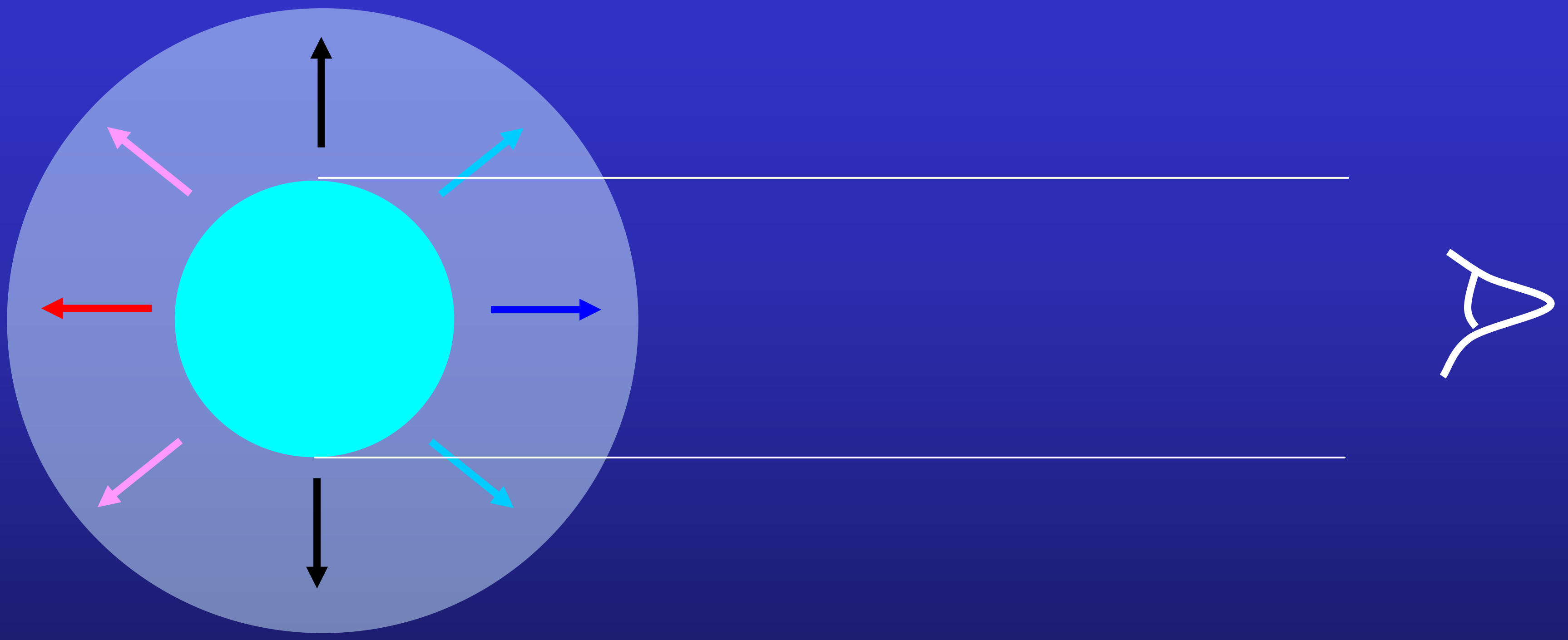
Reflection: $\Omega/2\pi >> 1$ dominates extreme smearing

Absorption. Still some reflection but $\Omega/2\pi < 1$, not extreme smearing! BUT problem round line

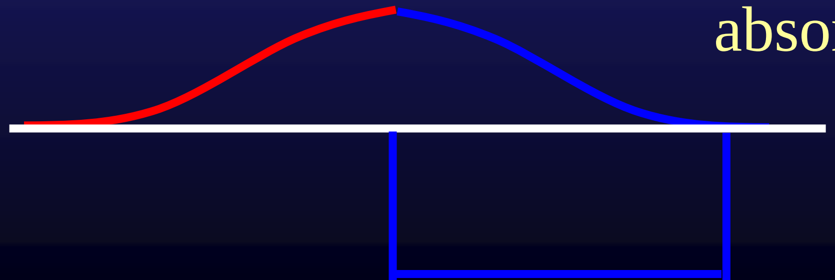
Sobolewska & Done 2006

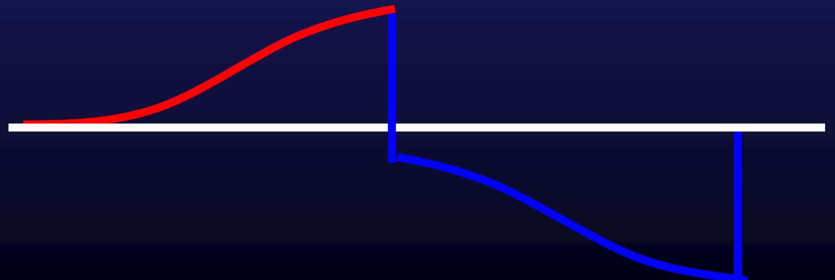


P Cygni line profiles



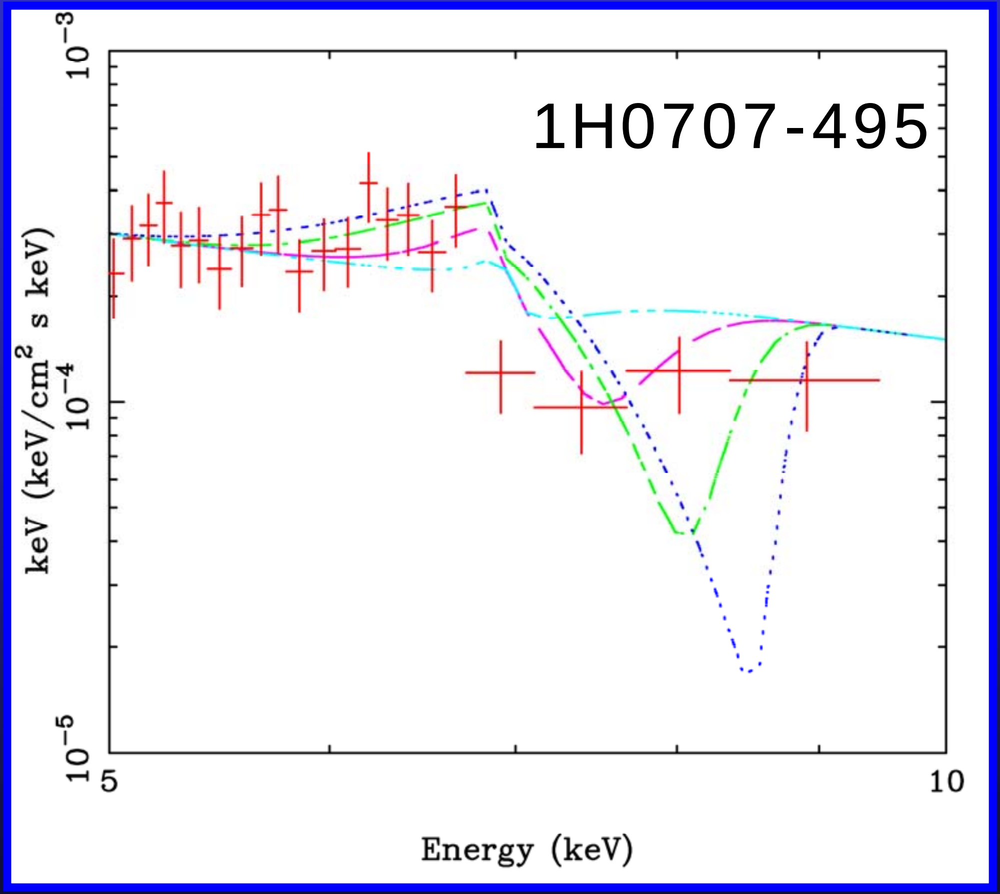
symmetric emission + blueshifted = P Cygni profile
absorption





P Cygni line profiles

- Classic P Cygni has maximum absorption at maximum velocity
- Doesn't really look like the 'edge' features we see
- BUT get this IF line is very optically thick – like all UV resonance lines
- Optical depth probably <1 for He and H like iron Kα
- This looks like the data !
- N_H~3x10^{24}cm^{-2} for τ_l=1



Done et al 2006

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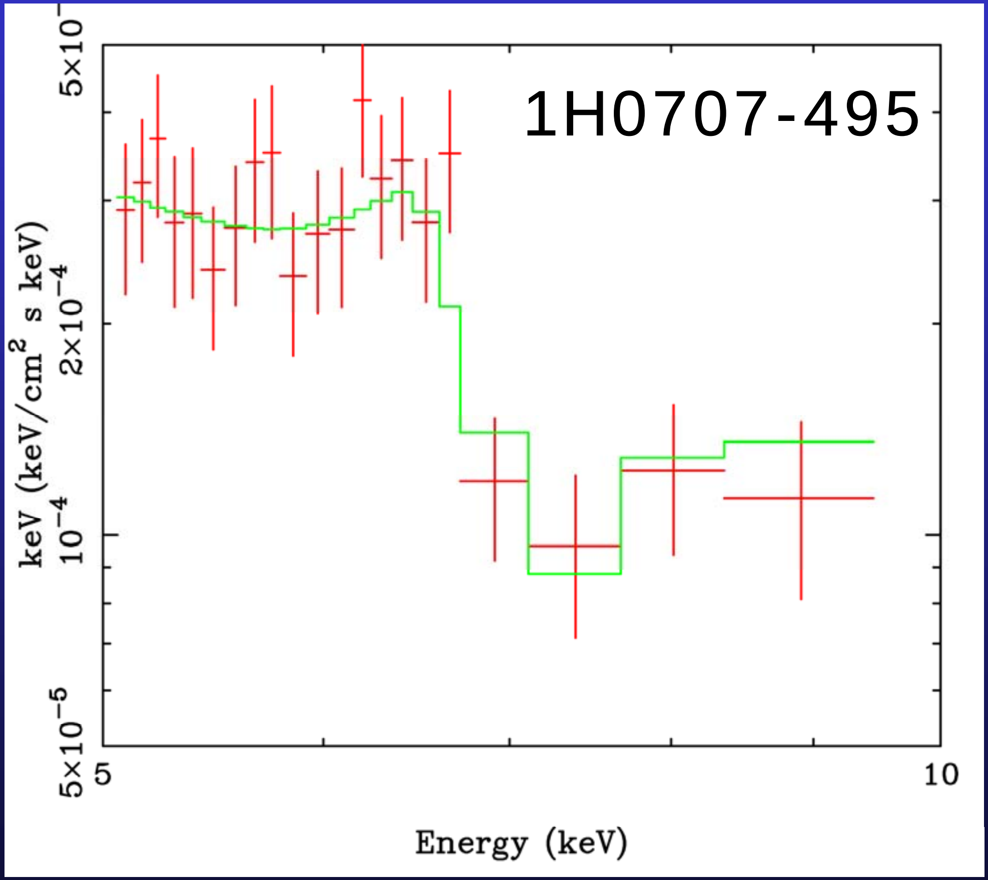
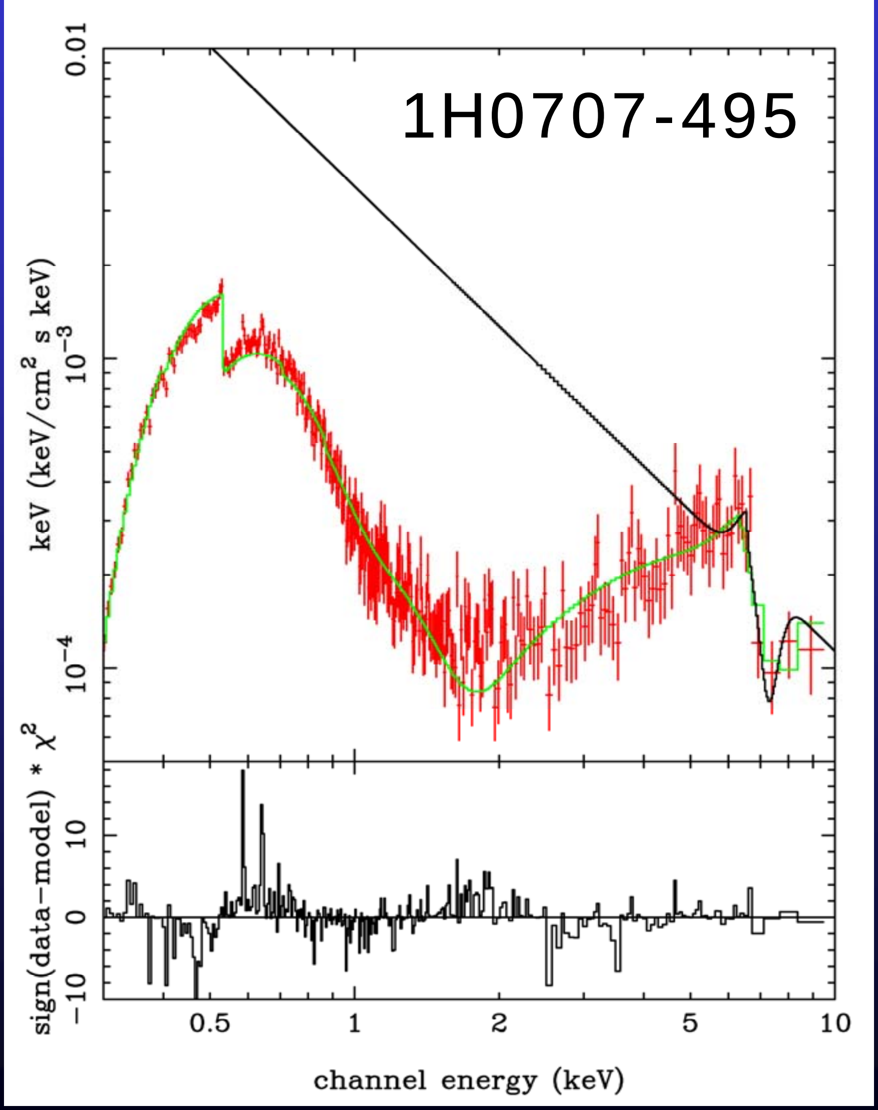


Done et al 2006

Unsaturated P Cygni line profiles

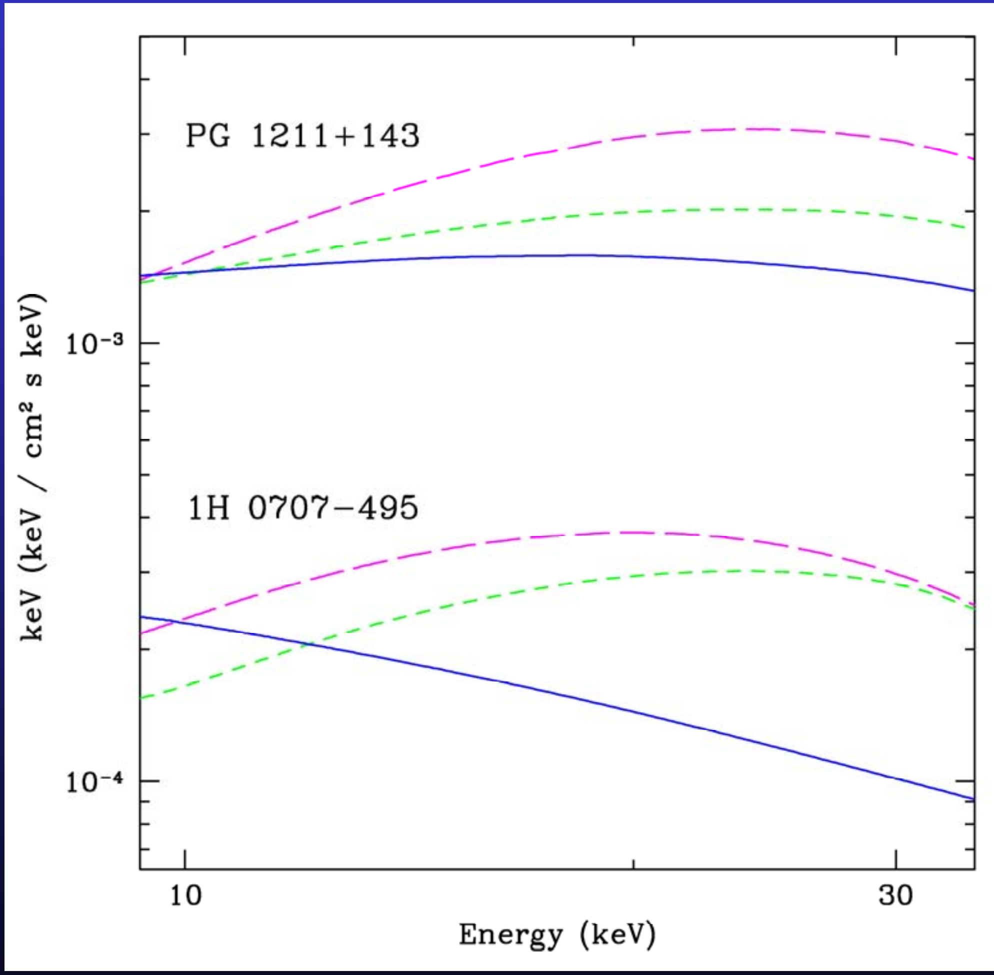
- Intrinsic spectrum is steep!
- No soft excess
- Fit with smeared absorption models to get 'hole'
- Matches broad spectral curvature well
- NOT good models as yet: gaussian for smeared absorber plus P Cygni
- Working on proper models: P Cygni in all resonance lines and scattering (reflection) from wind – but its hard!
- Probably needs stratified column not single ξ



Done et al 2006

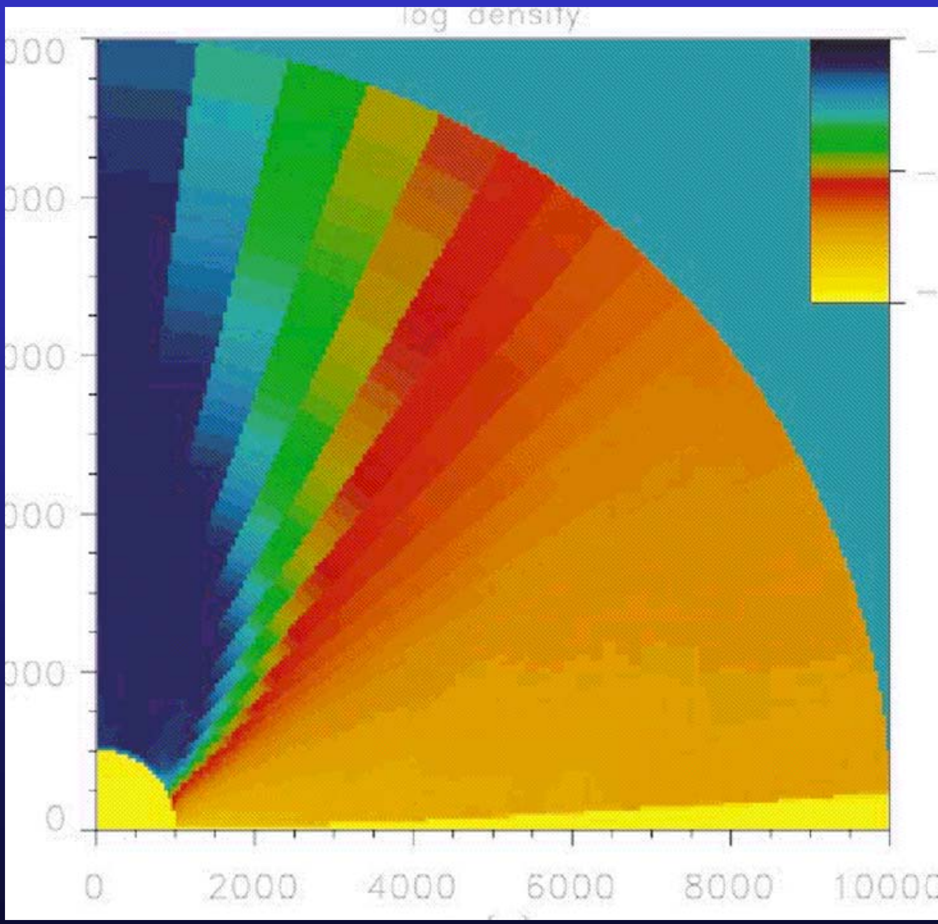
How to tell the difference ?

- BOTH reflection and absorption can fit the 0.3-10 keV spectra
- BOTH can also fit variability! Ponti et al 2006; Gierlinski & Done 2006
- Observations below 10 keV not helping – especially as models uncertain: range of ξ ?
- Some difference in 10-30 keV – maybe Suzaku can get first constraints ? But may get reflection from wind!!!



How to tell the difference ?

- Maybe go to physical plausibility
- BOTH require some extreme parameters:
- Reflection needs intrinsic continuum suppressed and extreme spin and/or extreme disc emissivity
- Absorption needs extreme velocity shear in wind >0.2c
- BUT we expect wind at high L/L_{EDD} especially AGN as disc peaks in UV so get line driving
- Need something faster than BAL outflows though!



Proga & Kallman 2002

Conclusions

- Soft excess seen everywhere in high L/L_{Edd} AGN. Fixed temperature unlikely to be disc or Comptonisation
- Biggest SX (NLS1) have sharp drop at 7-8 keV
- Can make both from partially ionised reflection but need reflection dominated geometry, extreme smearing
- OR make SX from absorption. No constraints on spin. Should still have some reflection but not extreme
- With P Cygni wind structure can also make 7 keV drop
- So both models fit spectra and variability below 10 keV
- Maybe high energy (10-30 keV) spectra can distinguish?
- High L/L_{Edd} AGN should be MESSY with strong winds. Need to understand these to understand first QSO's