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 \( \tau \) material?

Magdziarz et al 1998, Czerny et al 2003

PG1211: disk for \( M=10^8 M_\odot \) \( L/L_{\text{Edd}}=1 \)

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)
- Expect electron temperature to change if seed photons from disc change – different efficiency of Compton cooling

- NOT COMPTON SCATTERING

Gierlinski & Done 2004
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 \( \xi = L/nr^2 \approx 1000 \)
• 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 \( \xi \) as more absorption from C, N as not ionised

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

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

- 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. $\xi \sim 1000$
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 suppressed
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!
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
P Cygni line profiles

symmetric emission + blueshifted absorption = P Cygni profile
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!
- $N_H \sim 3 \times 10^{24} \text{cm}^{-2}$ for $\tau_1 = 1$

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 $\xi$
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 $\xi$?
• 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 $L/L_{\text{Edd}}$ 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 $L/L_{\text{Edd}}$ AGN should be MESSY with strong winds. Need to understand these to understand first QSO’s