AGN as scaled up black hole binaries

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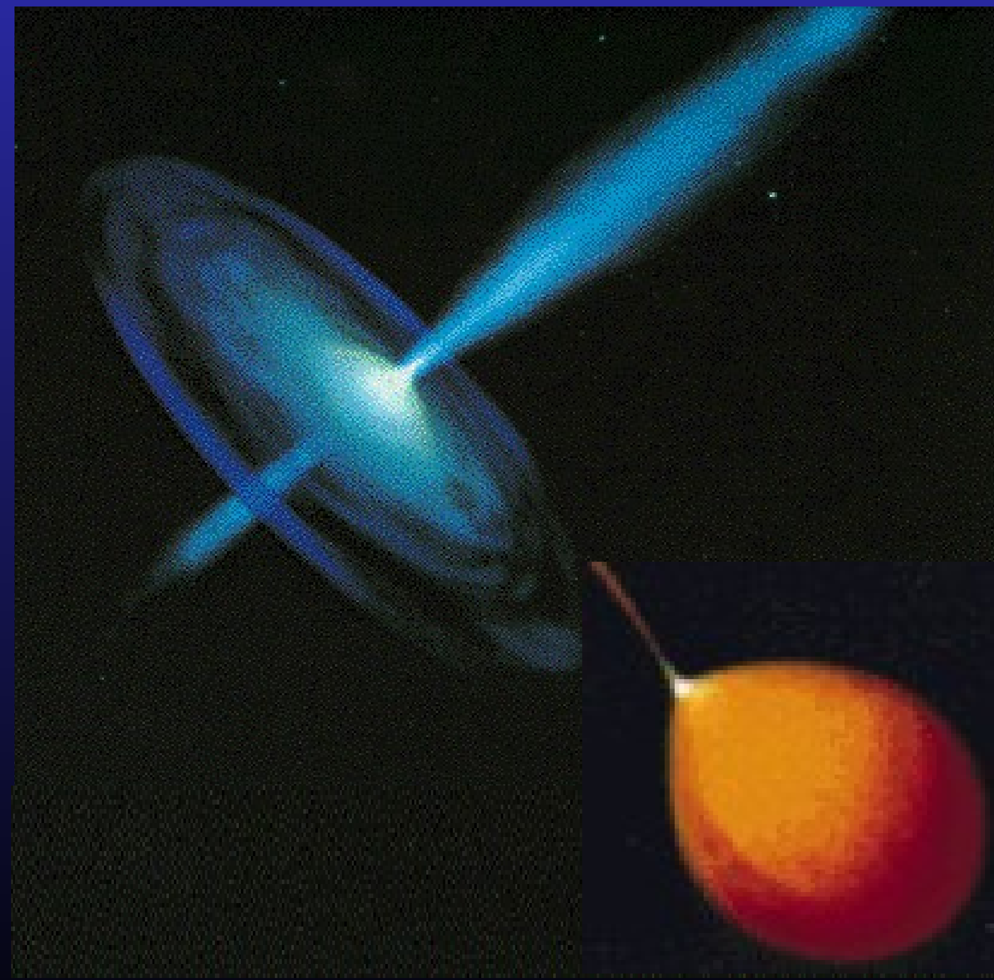
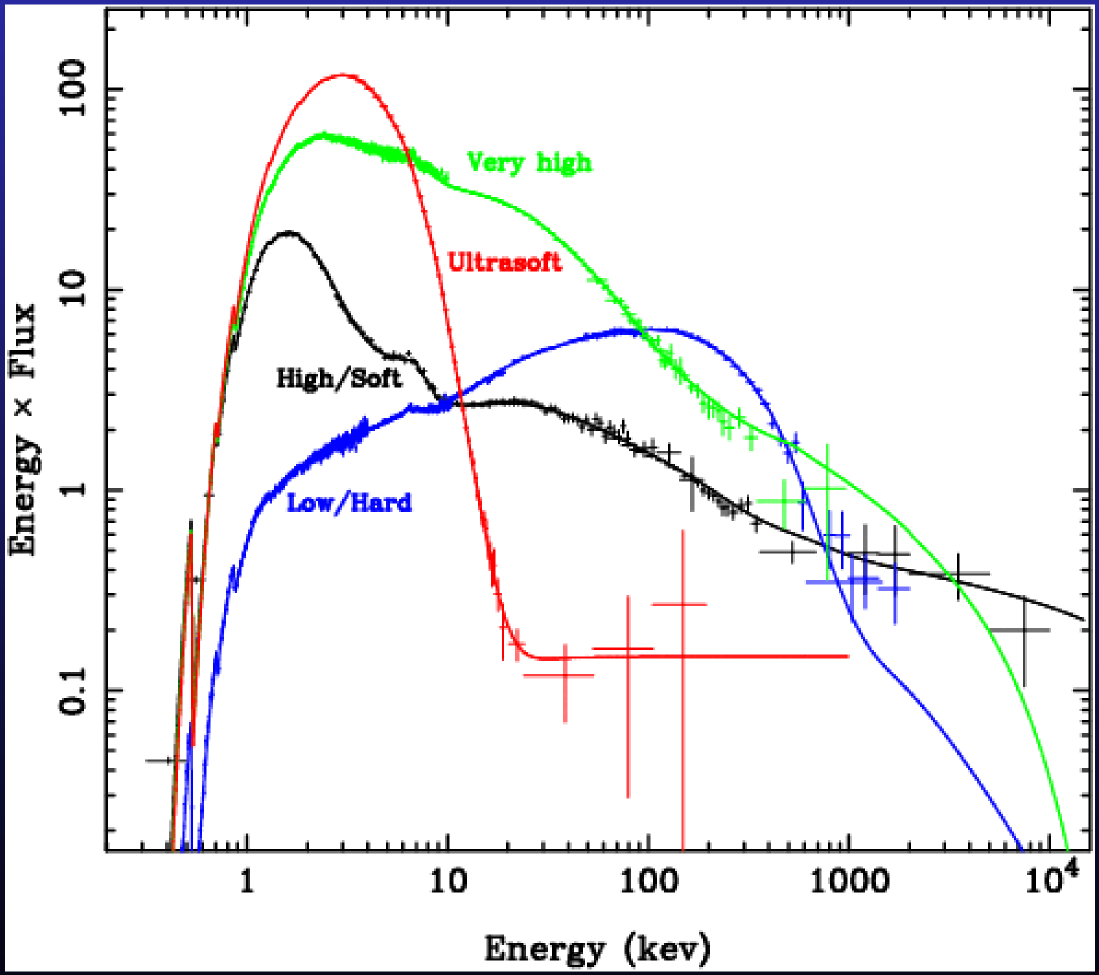
Stellar mass black hole binaries

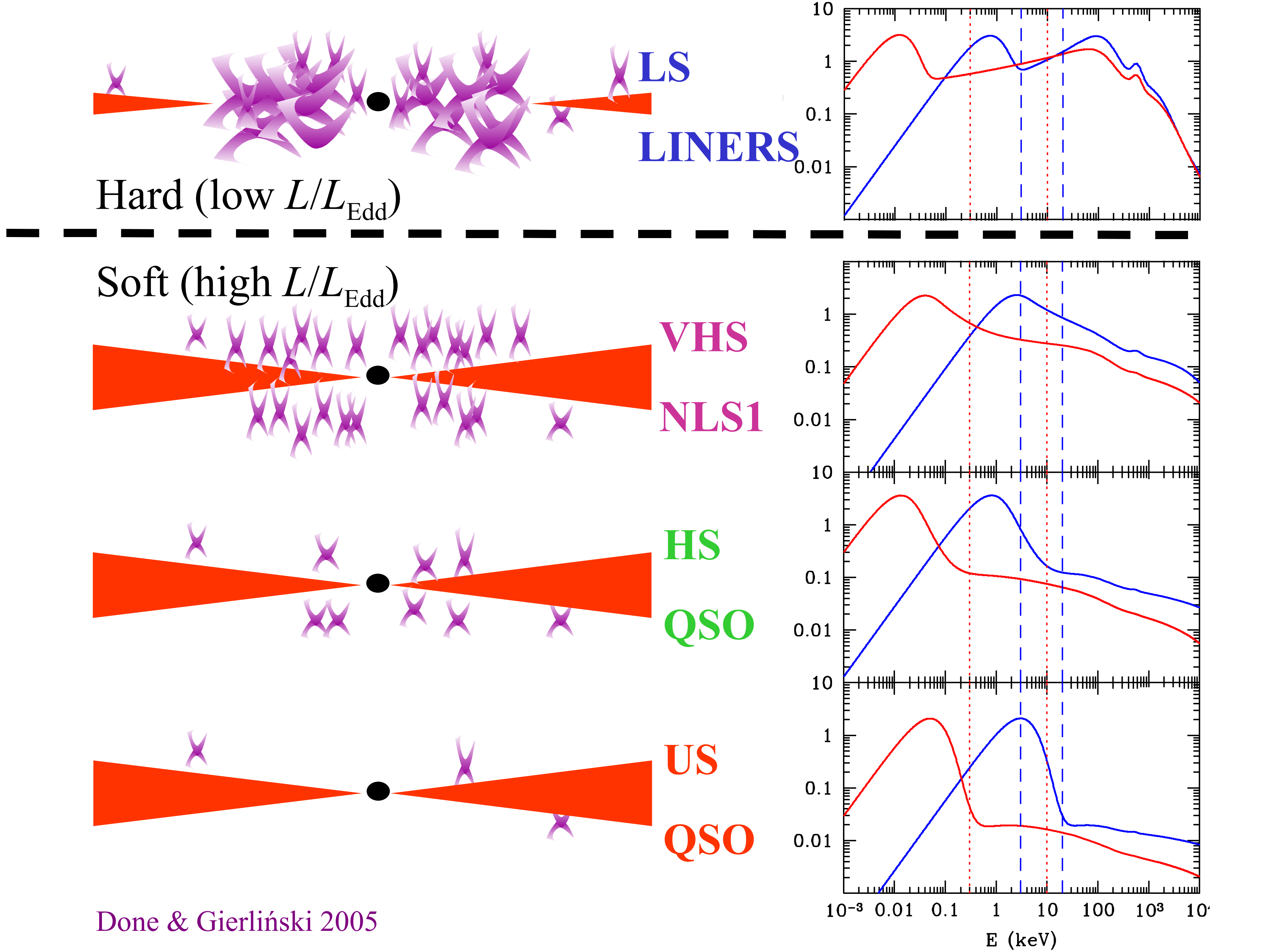
- Appearance of BH depends only on mass and spin (black holes have no hair!)
- M~3-20 $M_{\odot}$ (stellar evolution) - very homogeneous
- Form observational template of variation of flow with L/L_{Edd}
- Scale up to 10^6-10^9 M． AGN



Spectral states

- Dramatic changes in continuum – single object, different days
- Underlying pattern in all systems
- Low L/L_{Edd}: hard spectrum, truncated disc, hot inner flow
- High L/L_{Edd}: soft spectrum, peaks at kT_{max} often disc-like, plus tail
- BUT they don't tend to go superEddington….

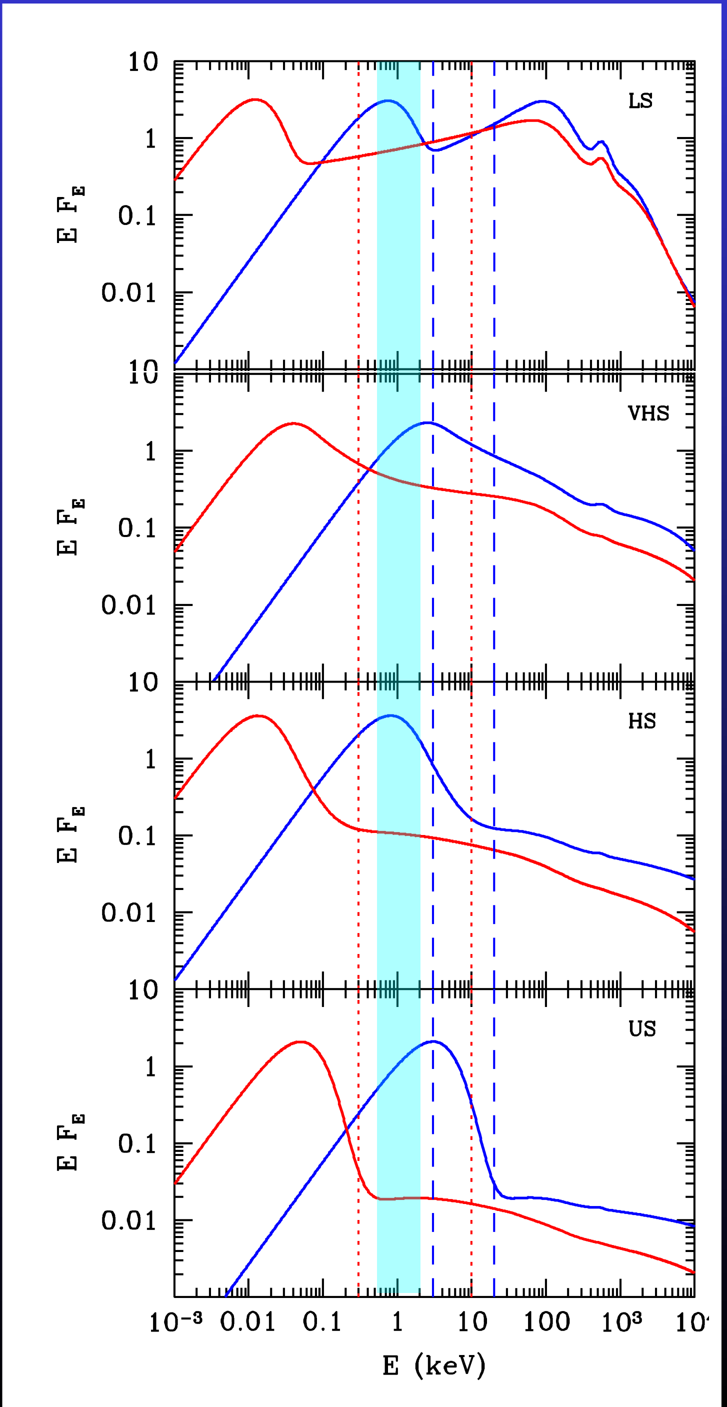




LS
LINERS
Hard (low L/L_{Edd})
Soft (high L/L_{Edd})
VHS
NLS1
HS
QSO
US
QSO
Done & Gierliński 2005
10
1
0.1
0.01
E (keV)

AGN spectral states

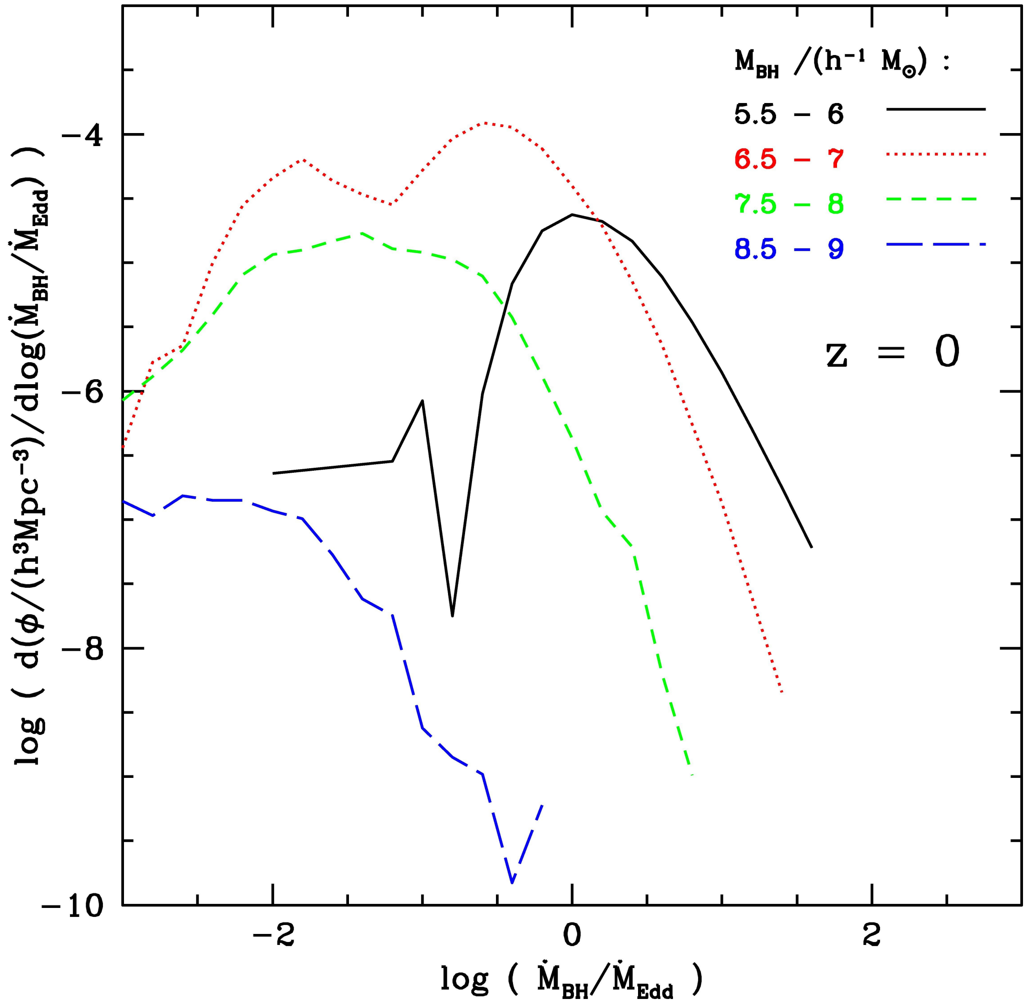
- Stretched out by lower disc temperature so not so obvious as in BHB
- BUT range in Lx/Lbol
- High mass accretion rates have lower Lx/Lbol
- Higher mass accretion rates have steep continua so redshift further reduces Lx(0.5-2)/Lbol
- High mass accretion rate objects progressively harder and harder to see at high redshift!



AGN spectral states

- Downsizing means looking now at activity in predominantly $10^{7} M_{\odot}$ black holes
- Redshift 2 at peak of QSO (and SF) activity see more $10^{8} M_{\odot}$ black holes
- Redshift 6 dominated by the $10^{6} M_{\odot}$ black holes again, superEddington!
- Need to understand $L/L_{Edd} > 1$ onto $10^{6} M_{\odot}$

Malbon et al 2008



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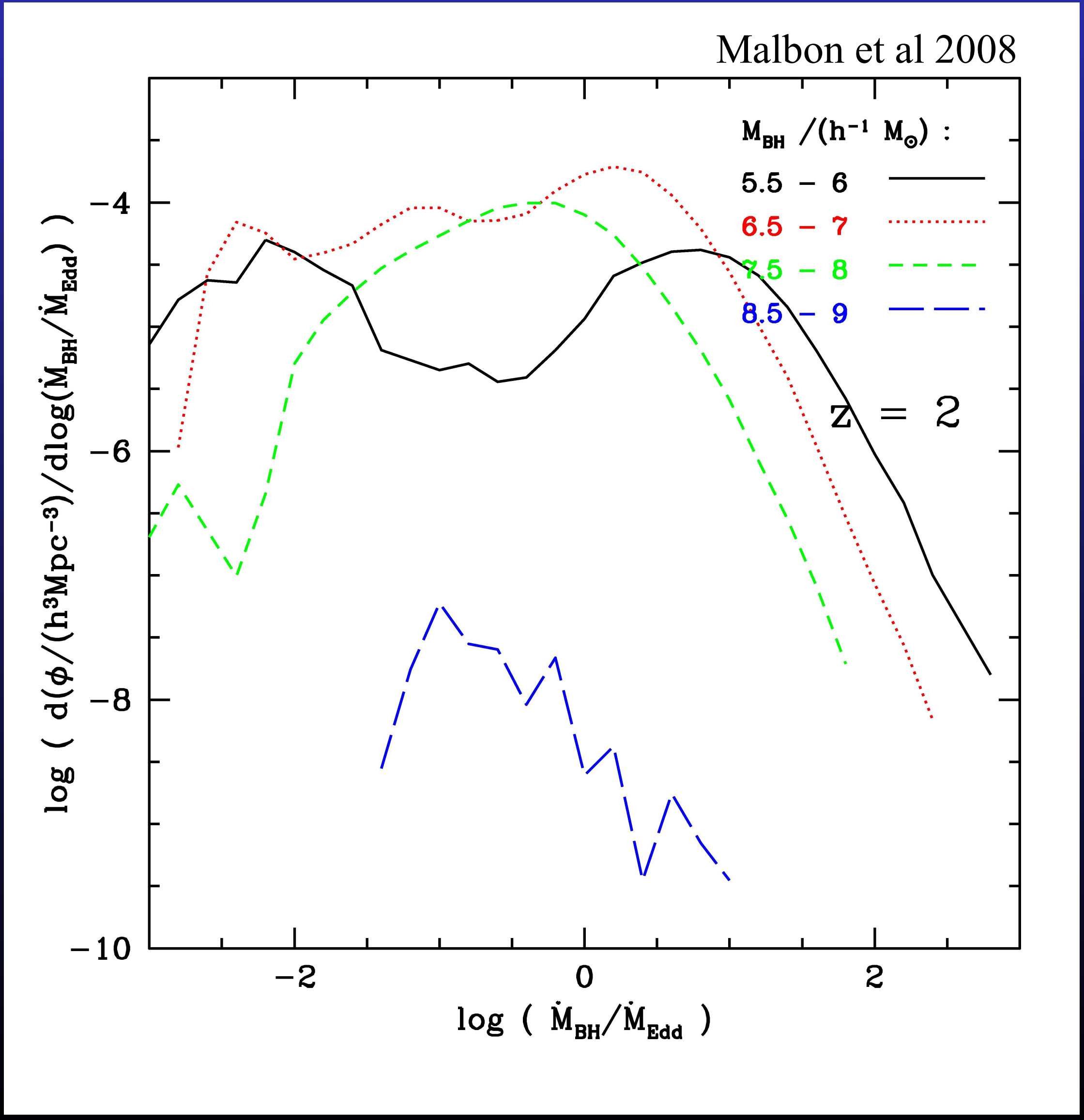

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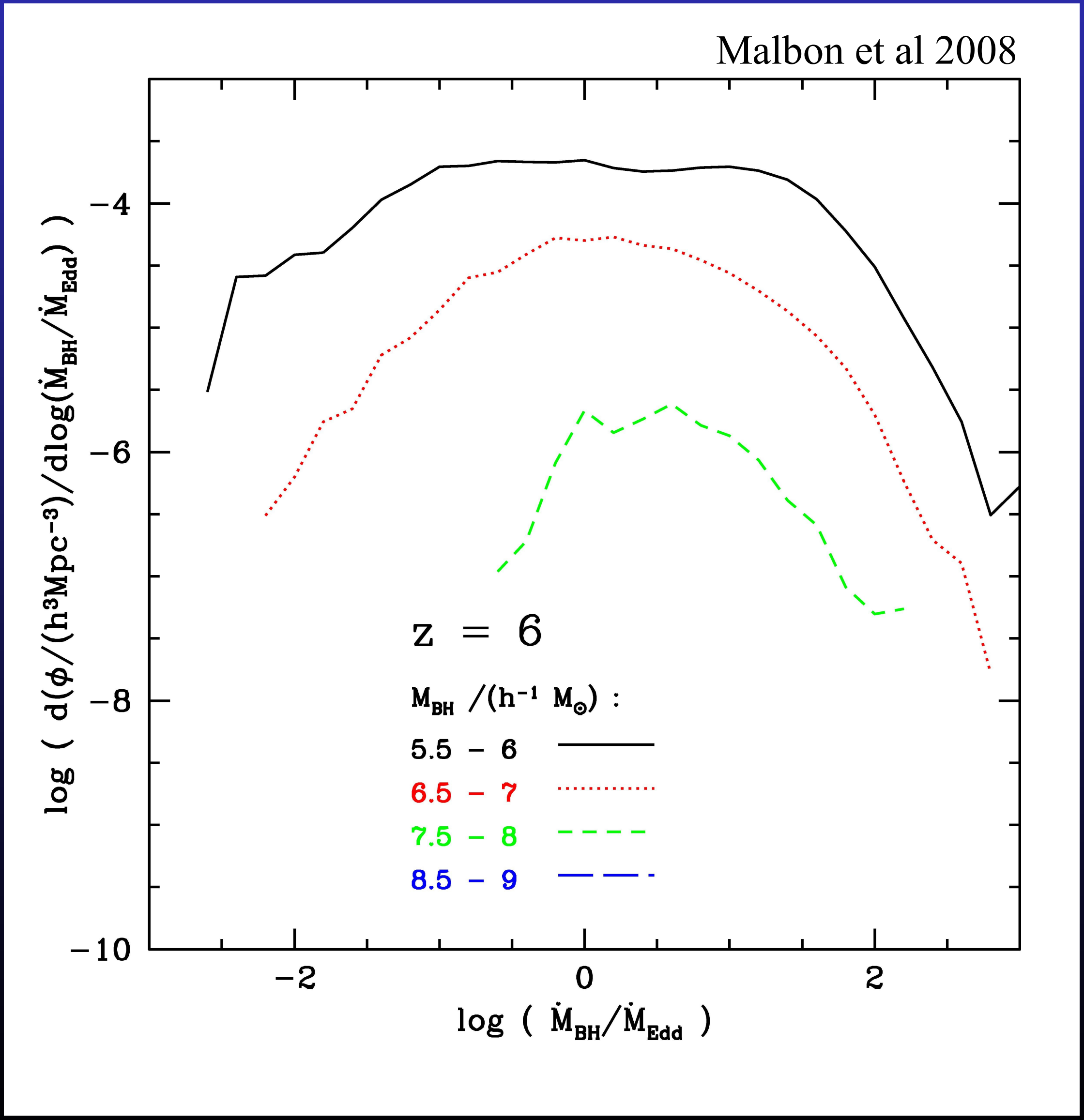
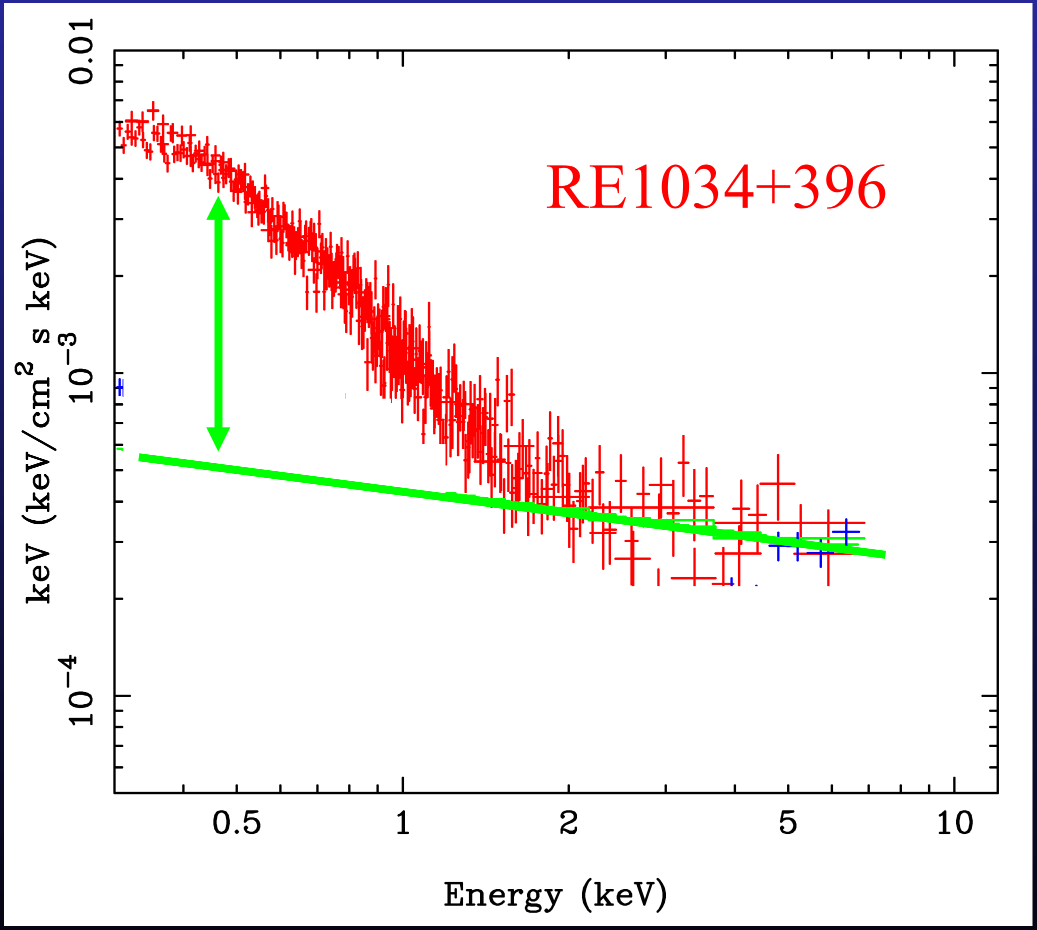


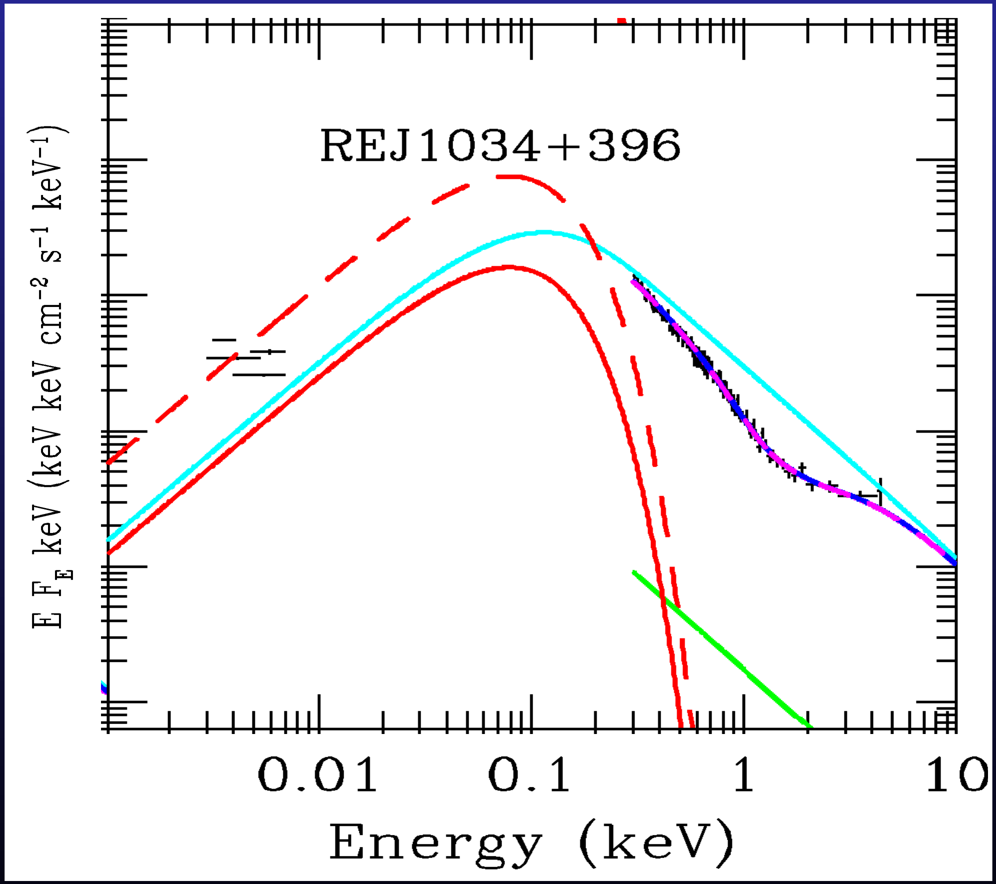
Narrow Line Seyfert 1s

- Typically few by 10^6 $M_\odot$ and L/L_{Edd}~1
- Often show soft excess - rise below ~1keV compared to 2-10keV
- Range in size but same 'temperature' Czerny et al 2003; Gierlinski & Done 2004
- No counterpart in BHB spectral states $L<L_{Edd}$



What is the soft excess?

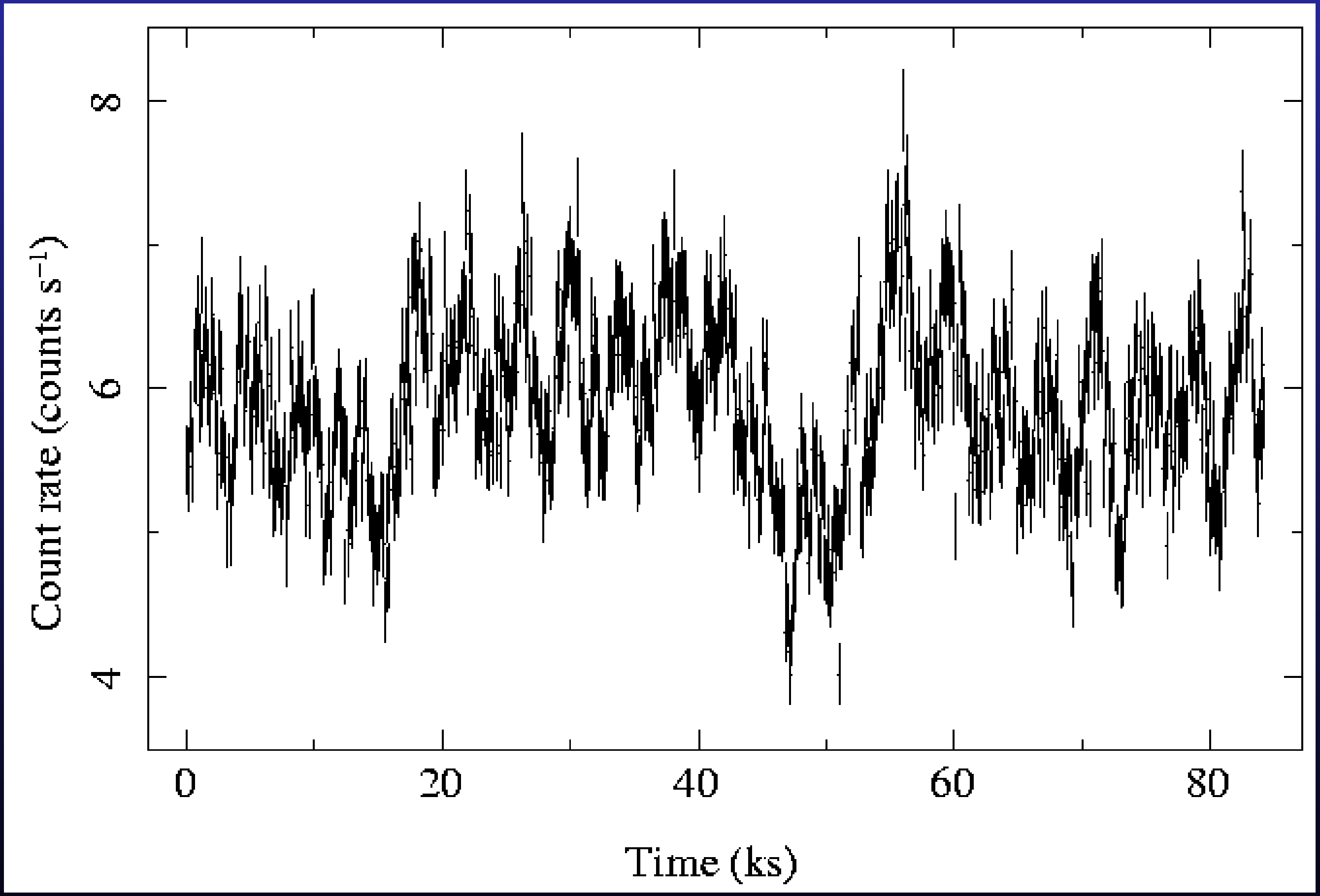
- Not the standard disc
- Smeared reflection? Fabian et al 2002 Miniutti & Fabian 2004 Crummy et al 2006
- Absorption (smeared or partial covering) Inoue 2000 Gierlinski & Done 2004 Miller et al 2007; 2008
- Advective disc ? Mineshige et al 2000, Wang & Netzer 2003, Haba et al 2008
- Deeper observation of one of the biggest soft excess sources to find out…



Middleton et al 2007

RE J1034+396: spot that period!!

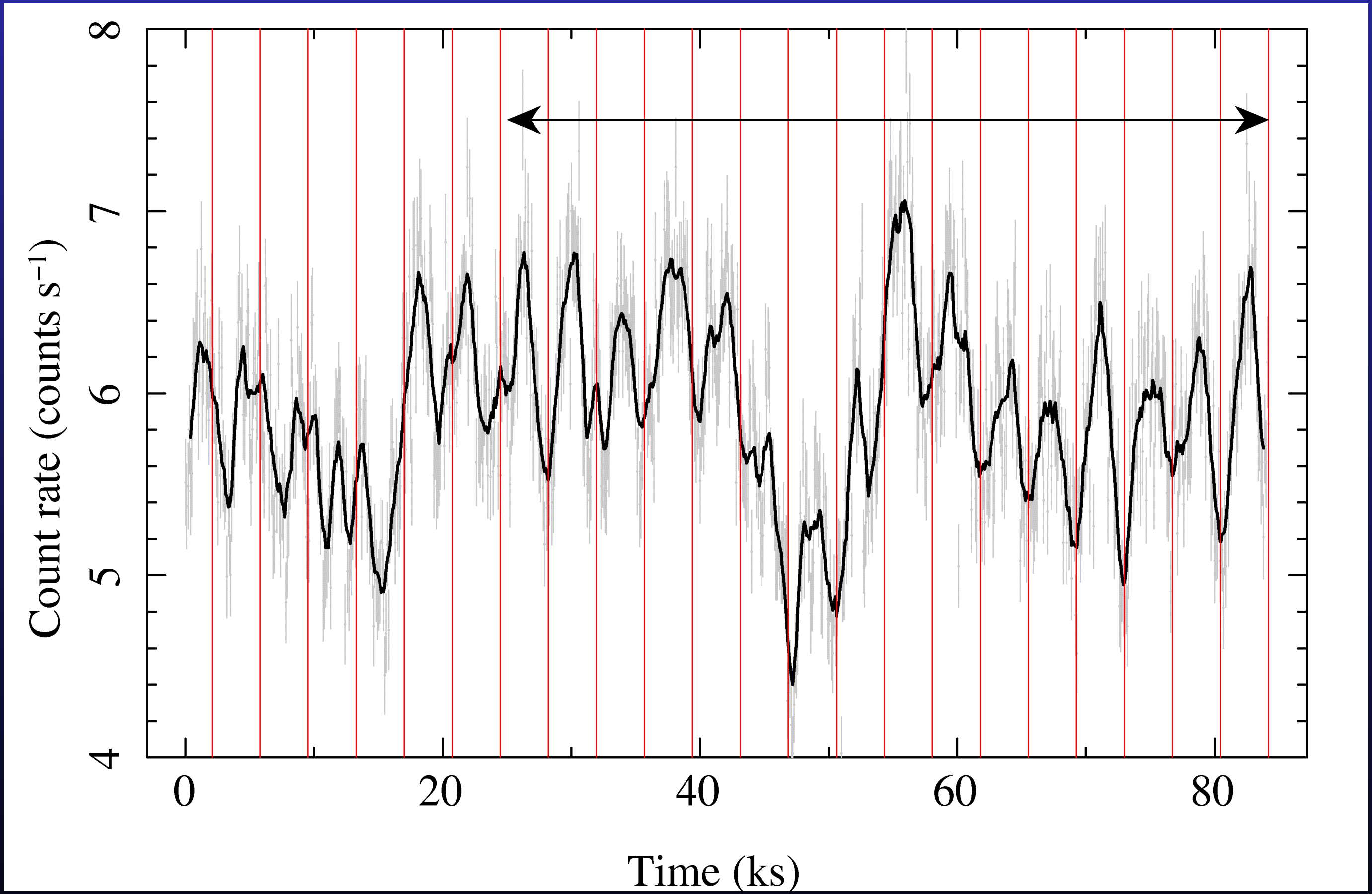
100ks of XMM-Newton data, co-adding MOS1, 2 and PN data



Gierlinski, Middleton, Ward & Done 2008

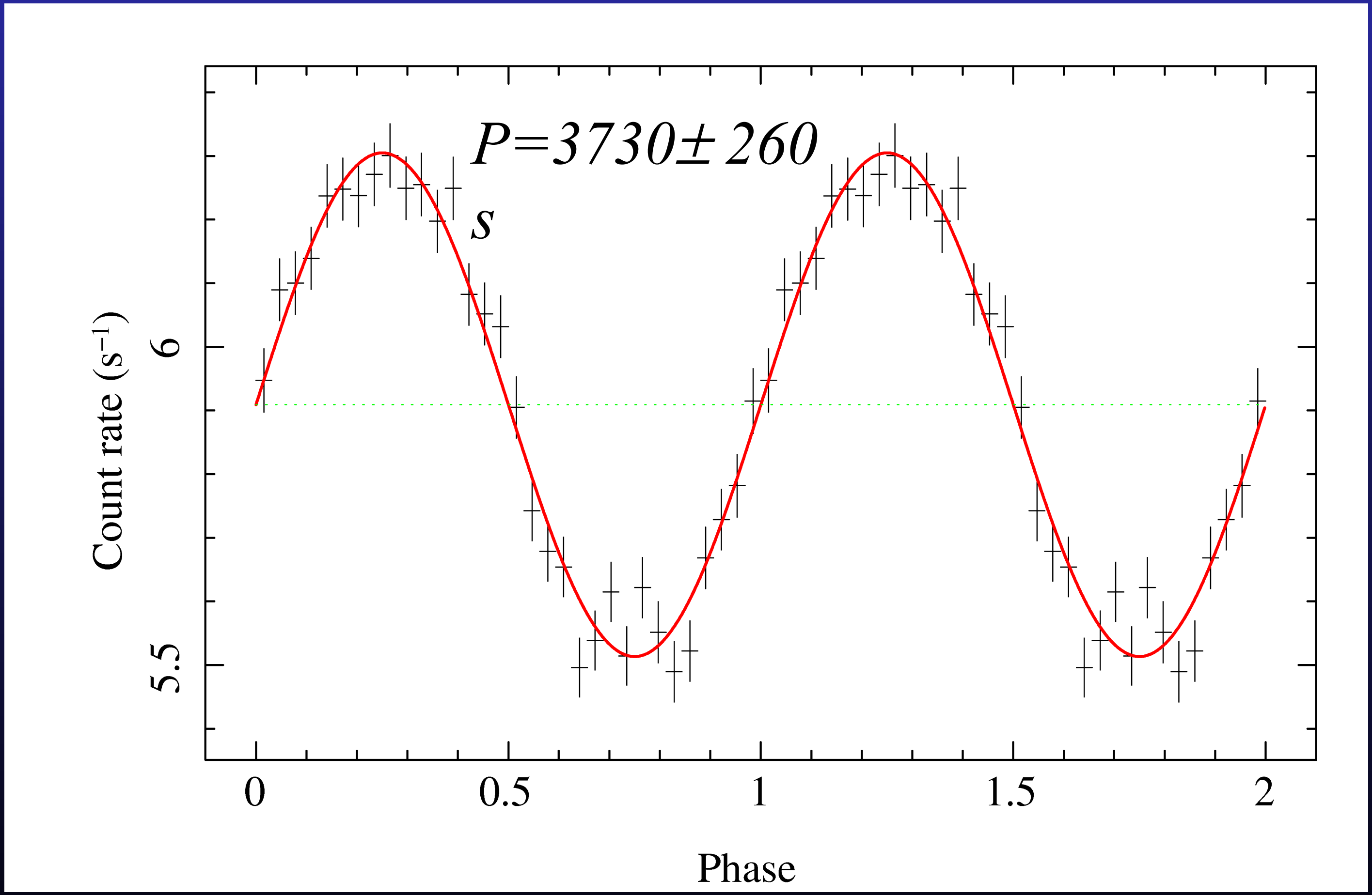
Smoothed lightcurve

Period much clearer in last ~60ks – almost periodic $Q = \upsilon/\Delta\upsilon > 16$



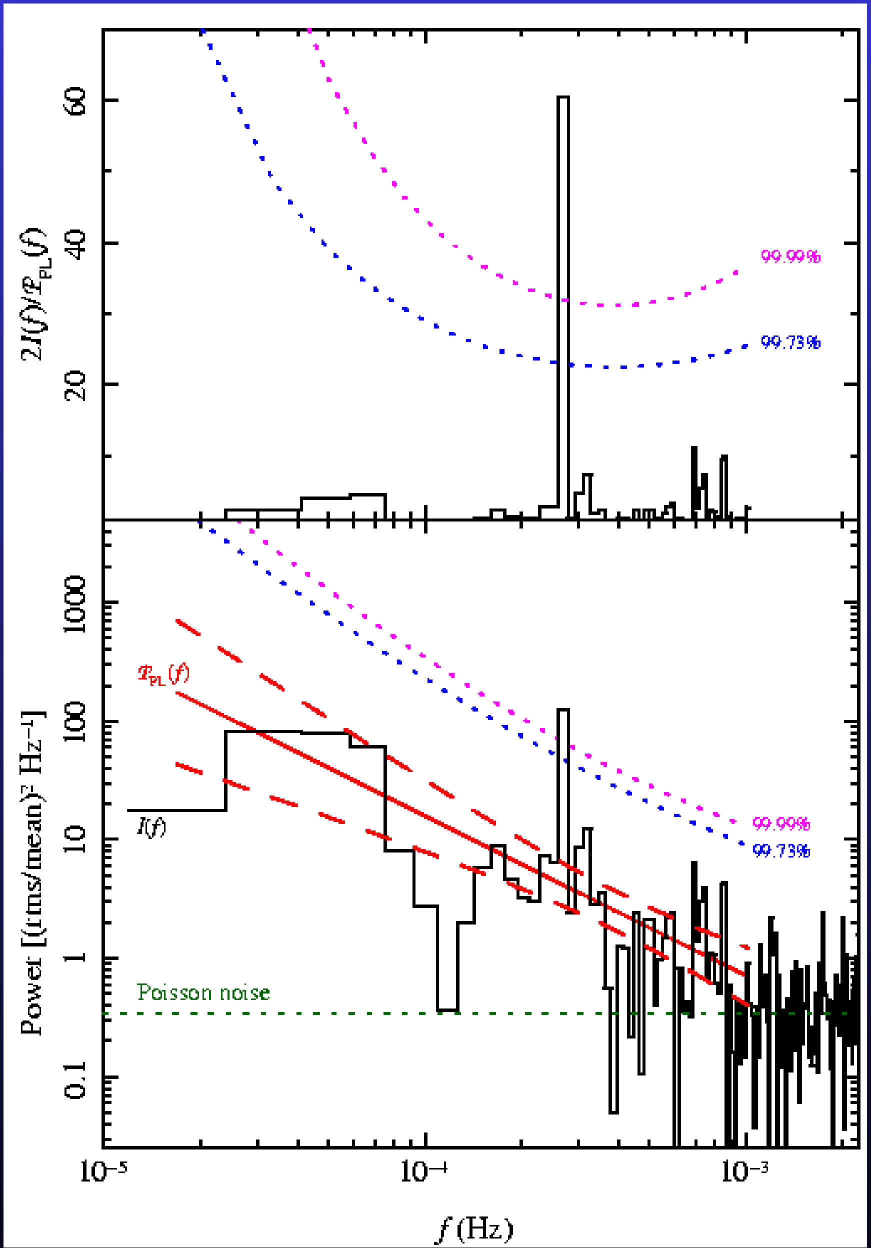
Gierlinski, Middleton, Done & Ward 2008

Folded lightcurve



Gierlinski, Middleton, Done & Ward 2008

Power spectrum



Gierlinski, Middleton, Ward & Done 2008

Even sampling so analytic

Power law $P_{PL} \propto f^{-\alpha}$

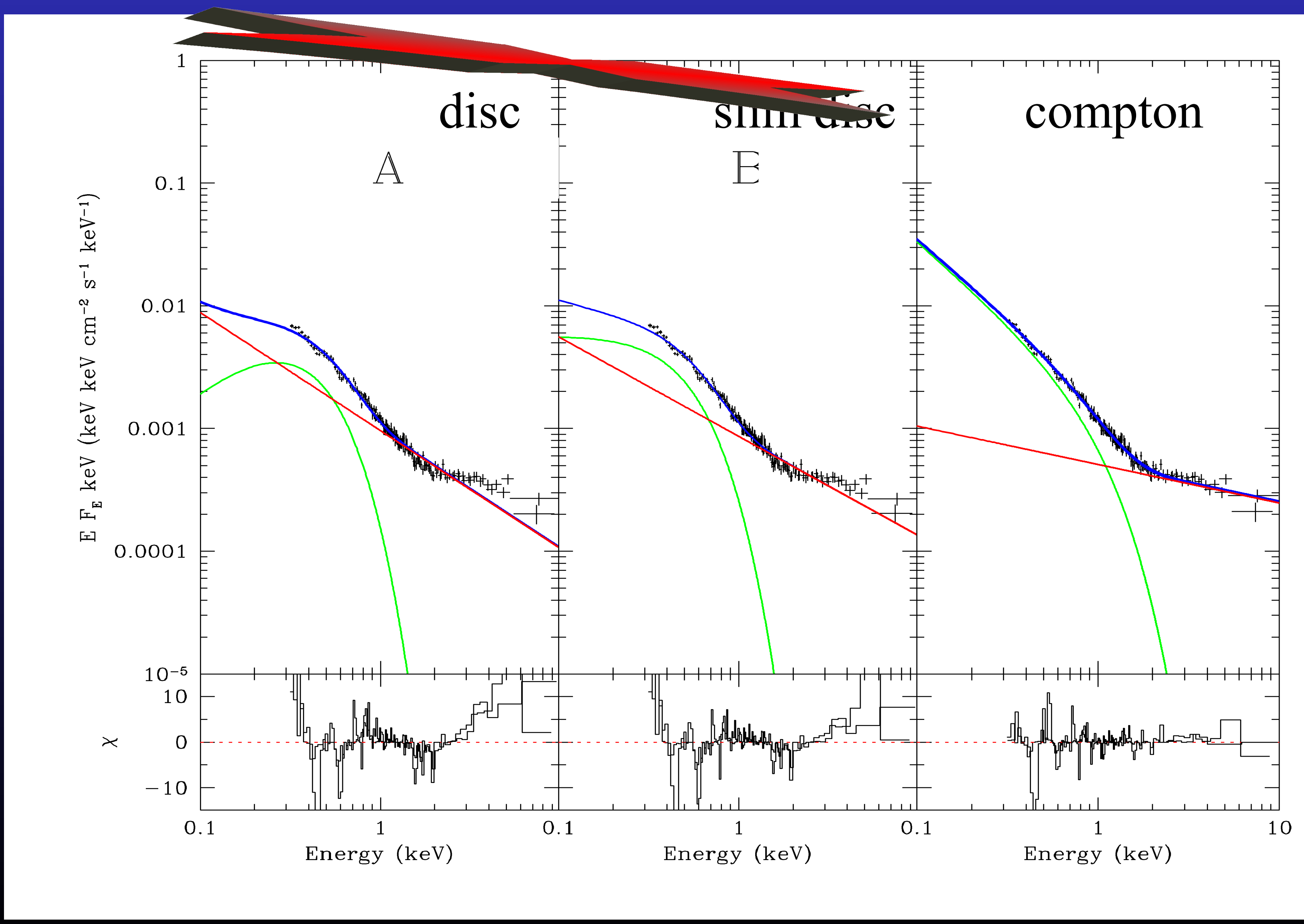
$\alpha = 1.35 \pm 0.18$

$f_{QPO} = 2.7\text{x}10^{-4}$ Hz (=3700 s)

Much bigger than 99.99% significance (chance probability is 10^{-7})

Derived from same methods used to reduce significance of previous claims *Vaughan et al. 2006*

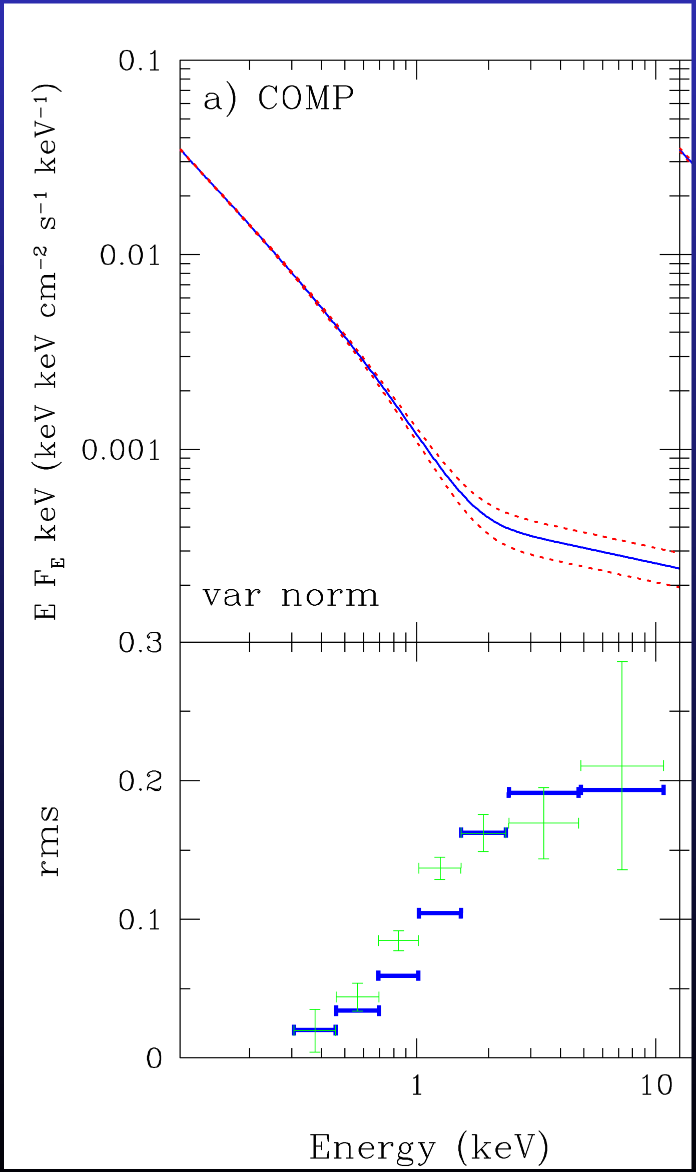
REJ1034: separate soft component



Middleton et al 2008

REJ1034: separate soft component

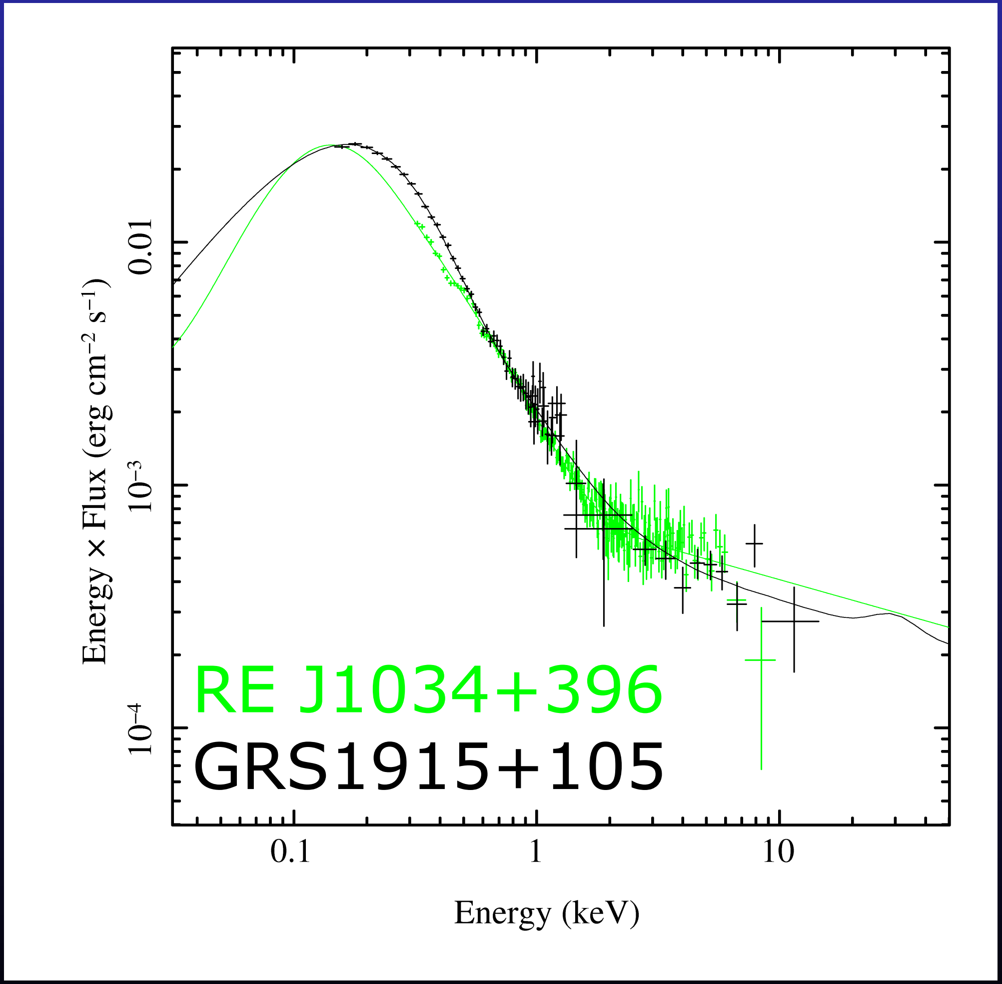
- Reflection and absorption also work to fit spectra but energy dependence of rapid variability most easily interpreted in low temperature compton model
- Vary power law norm, keep comptonised disc constant!!
- Like in BHB, QPO is in tail, not disc!
- Use this as template then 0.5-2 keV flux at z=5 (ie 3-12 keV rest frame) is ~10^{-17} ergs s^{-1} FAINT!!!



Middleton et al 2008

REJ1034+396: Comptonised disc

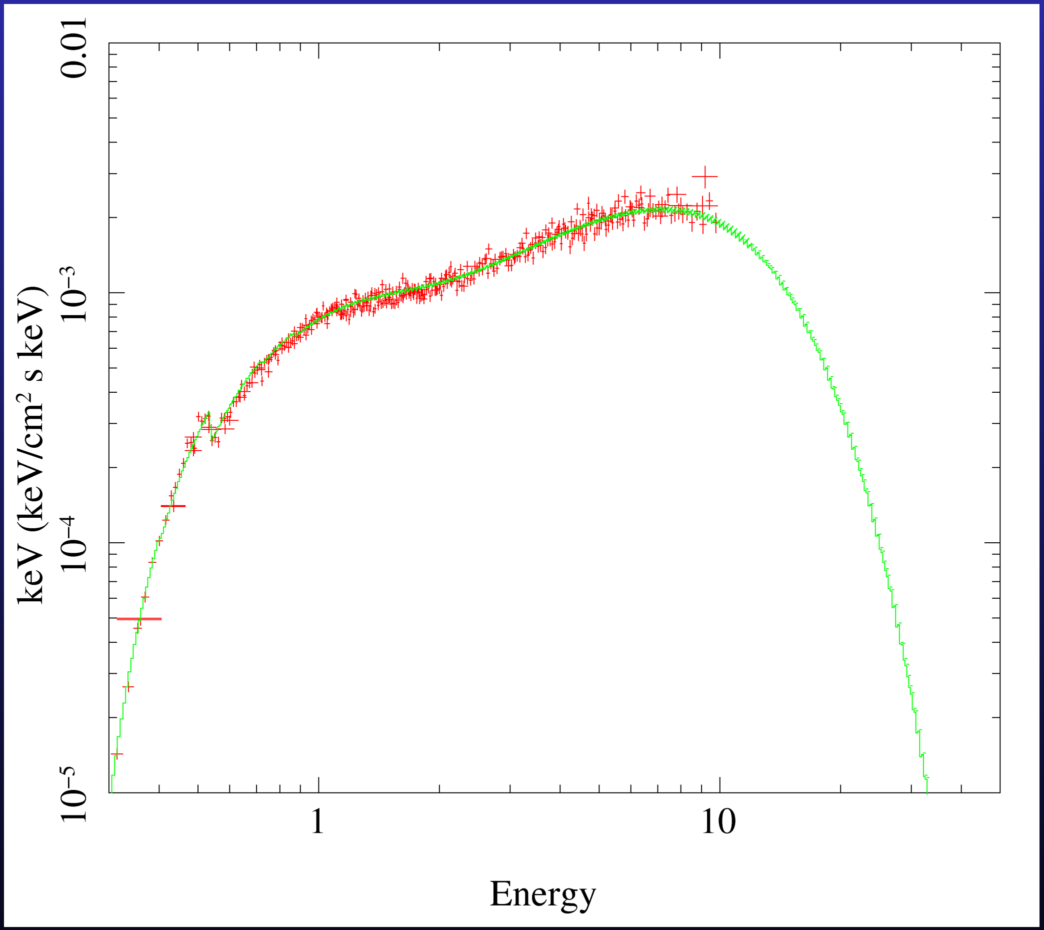
Middleton et al 2008



- Similar to $L>L_{Edd}$ BHB GRS1915+105
- $L \propto M$ and temp $\propto M^{-1/4}$ shift energy scale by ~20 and luminosity by 20^4 => mass of $\sim 2\times10^6\ M_\odot$
- Low temperature Comptonisation of disc in GRS1915+105 – distorts spin estimates Middleton et al 2006

ULX state ?

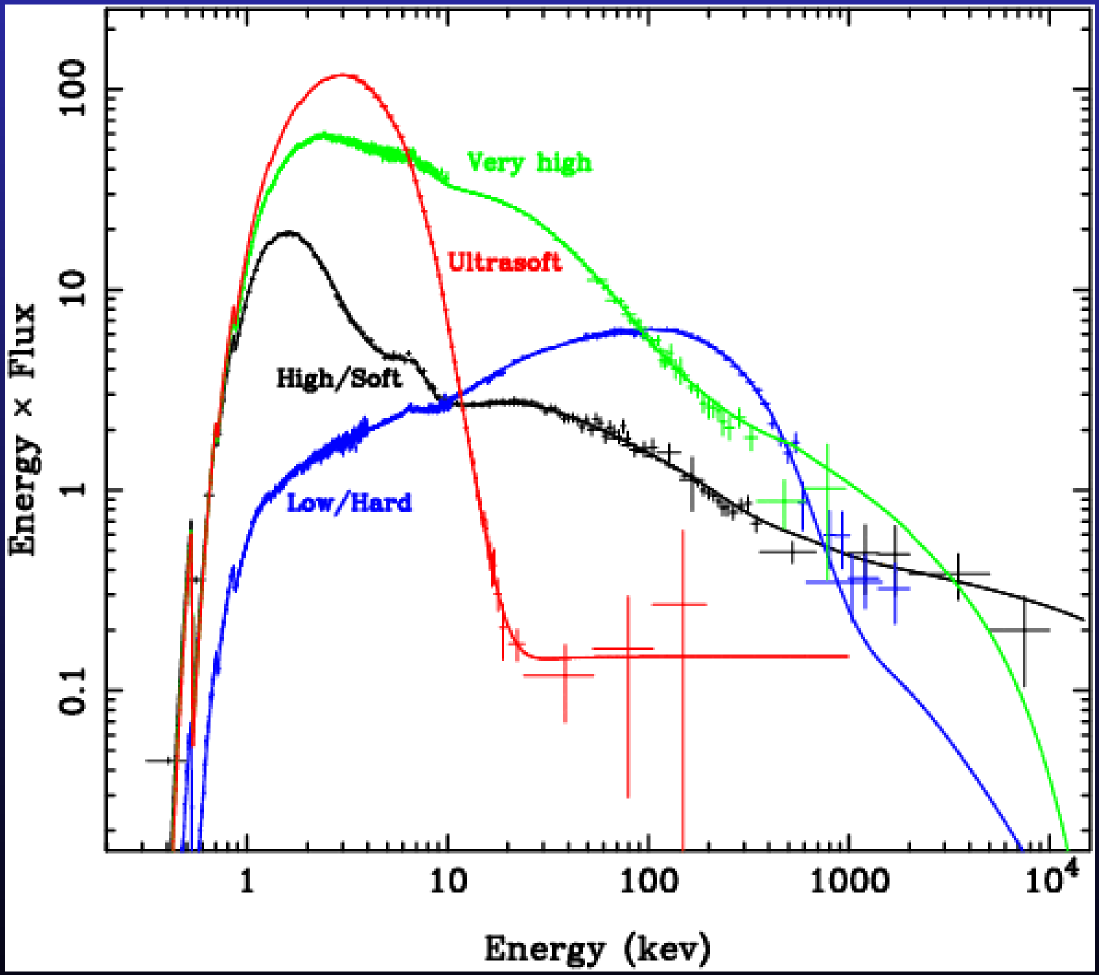
- Also similar to $L>L_{Edd}$ ULX
- Use the VHS models of Done & Kubota 2006 to the ULX
- Fits well for higher optical depth/lower electron temperature
- More extreme version of VHS?



Gladstone, Roberts & Done 2008

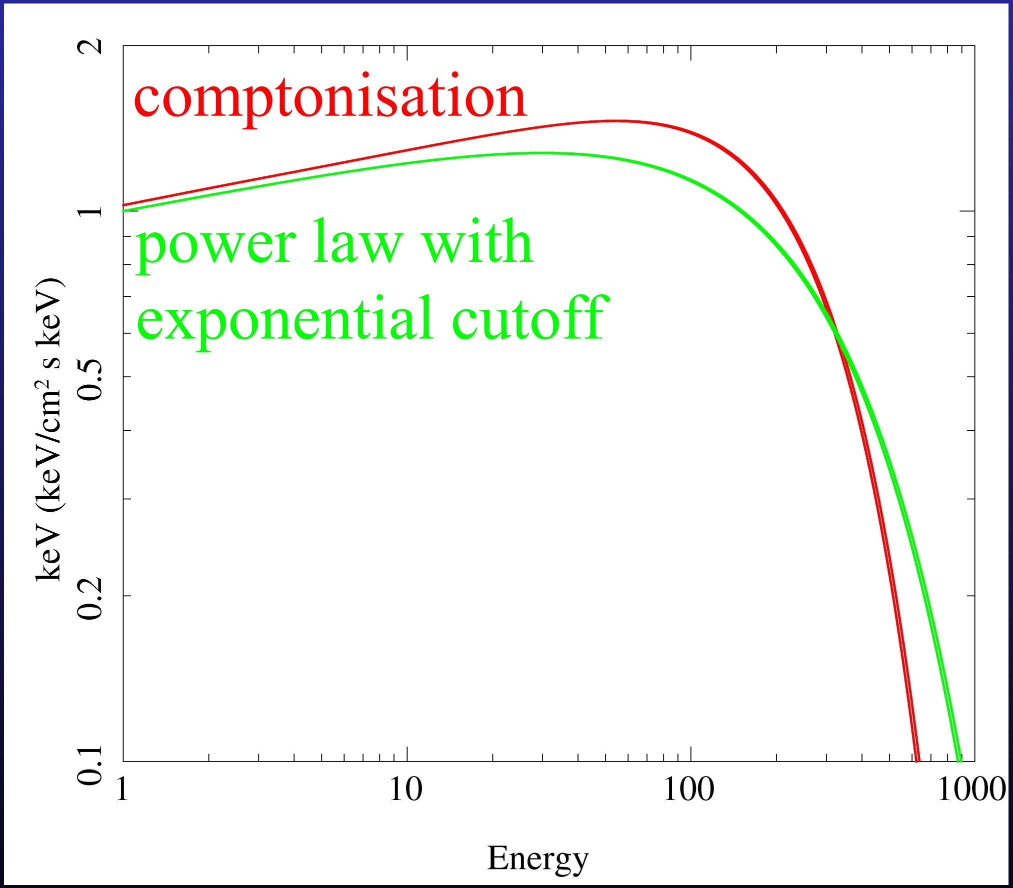
Spectral states and the CXB

- Dramatic changes in continuum – single object, different days
- Hard X-rays dominated by low/hard state but contributions from other states too!!
- Even with just low/hard state its NOT exponential cutoff power law!!



Cosmic X-ray background

- Power law with exponential cutoff NOT a good approximation to a real comptonised spectrum – rollover is less sharp.
- Makes difference to predicted shape of CXB
- So changes number of highly obscured AGN required



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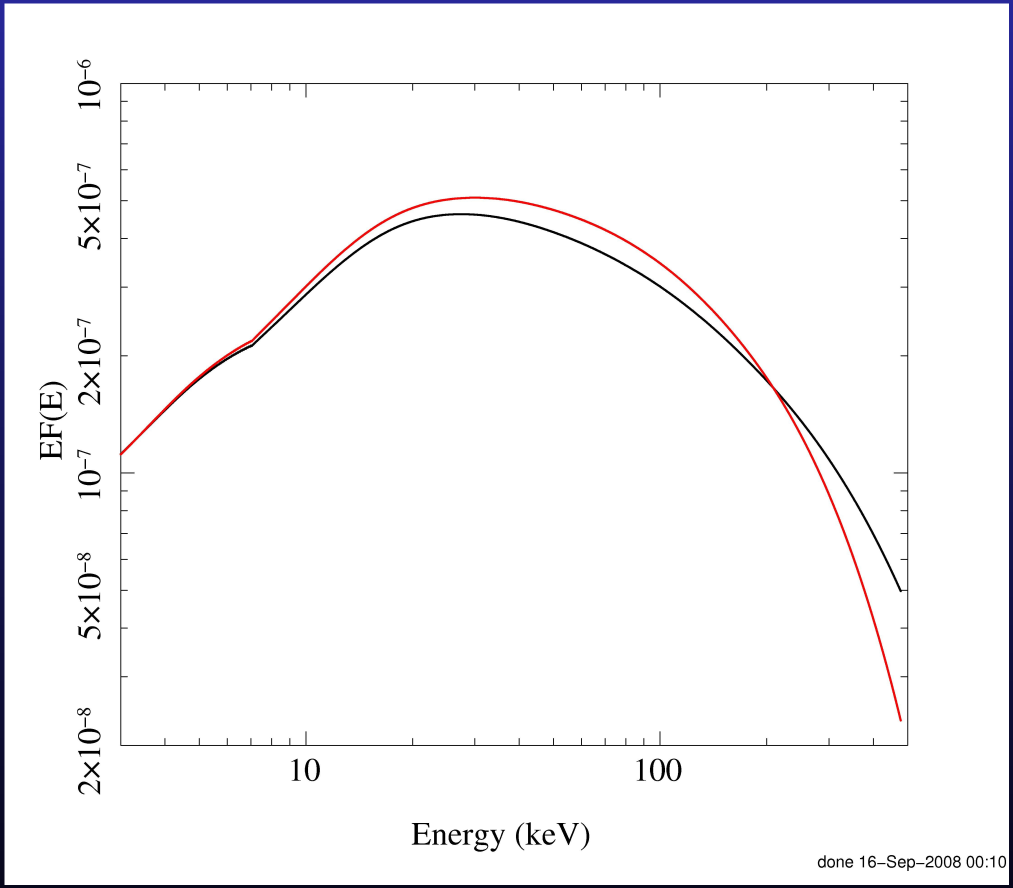

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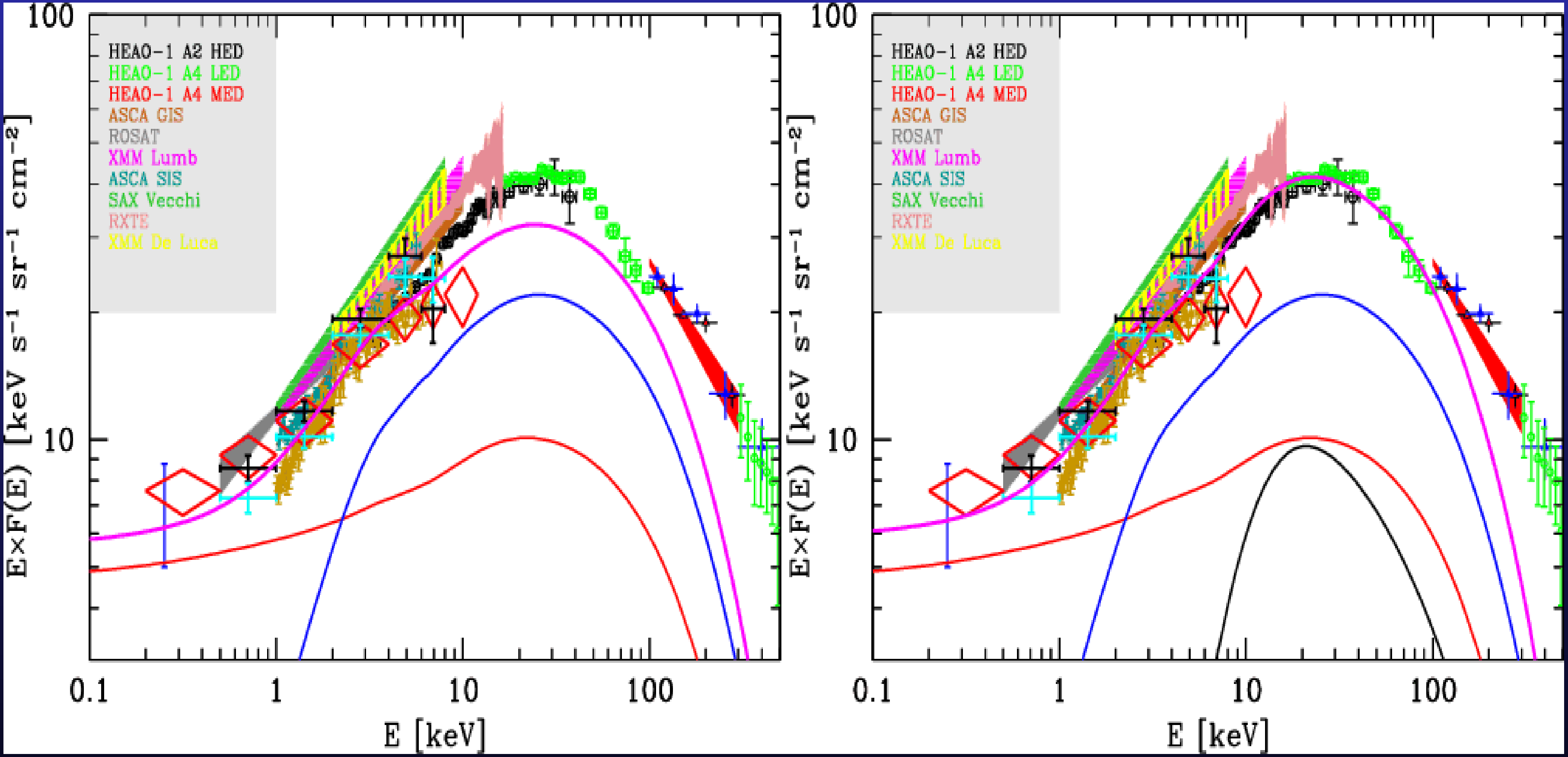

Gilli et al 2007

Conclusions

- BHB show us accretion physics (need IXO observations!)
- Spectra change as function of L/L_{Edd} – so AGN should also! We need to include this in IXO simulations!
- Models show mass and L/L_{Edd} change with redshift
- High redshift (z>5) dominated by $L/L_{Edd} > 1$
- See in uniquely luminous BHB GRS1915+105 and in AGN with X-ray QPO RE J1034+39 and probably ULX
- Optically thick, low temperature Comptonisation and fairly steep tail (Γ ~2.2)
- Hard state probably dominates CXB, but rollover NOT exponential! Makes a difference to number of Compton thick objects required to fit peak of CXB