Ionized absorbers in Galactic Binaries

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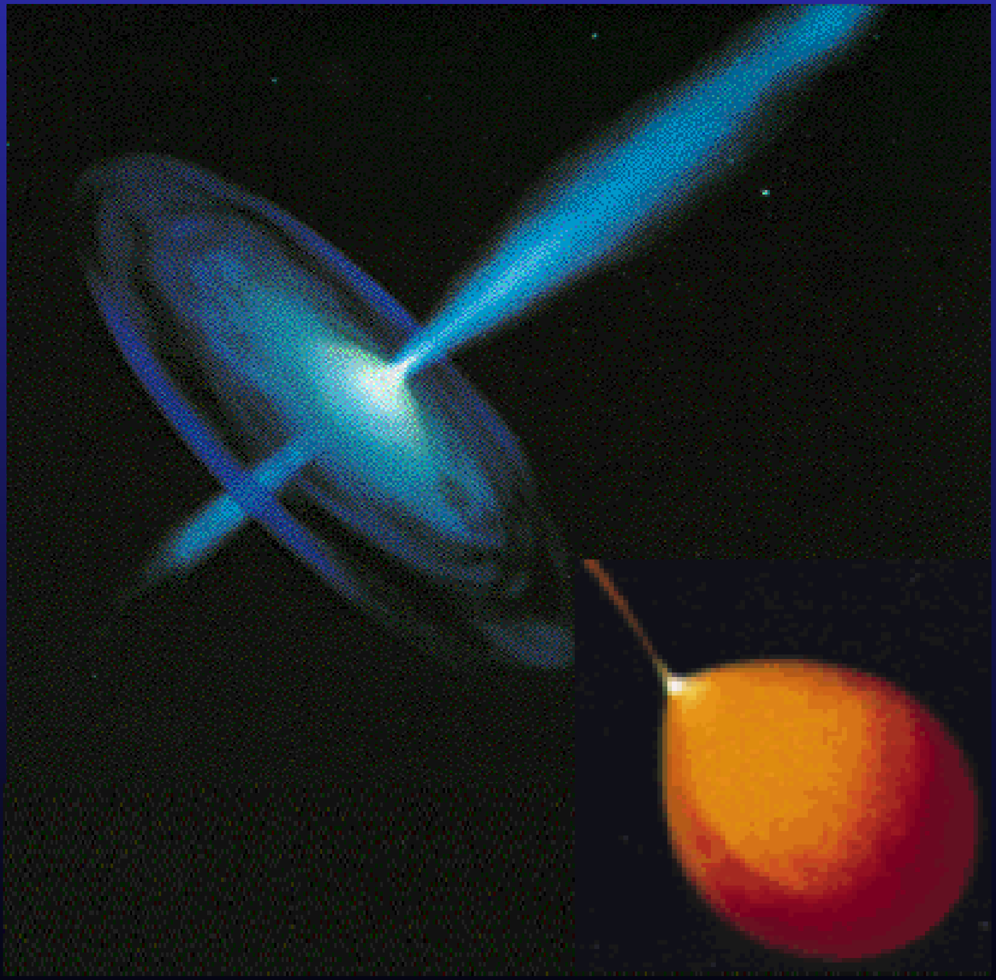
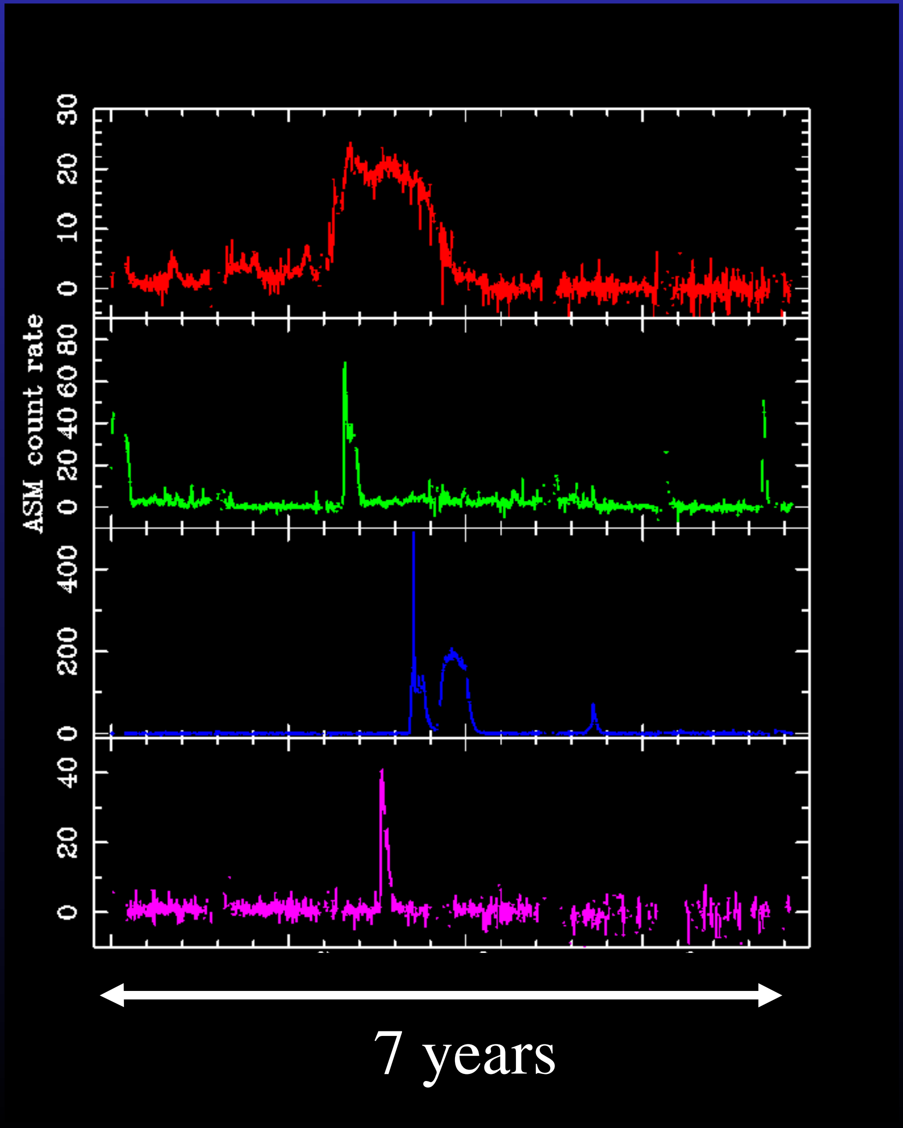
Black holes

- Appearance of BH should depend only on mass and spin (black holes have no hair!)
- Plus mass accretion rate – L/L_{Edd}
- 10^4-10^{10} M : Quasars
- 10-1000(?) M : ULX
- 3-20 M : Galactic black holes

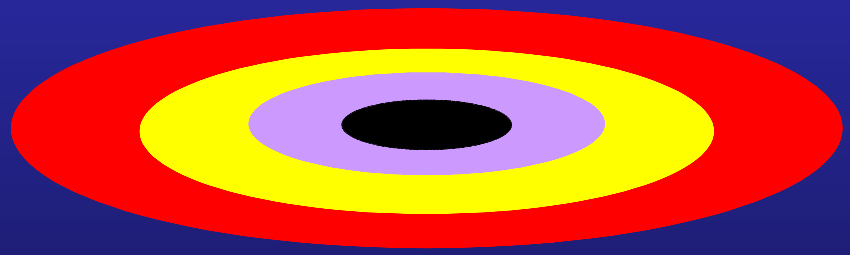


Galactic Binary systems

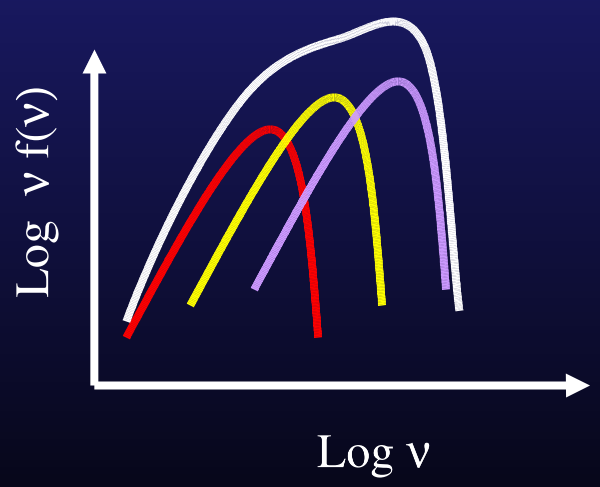
- Huge amounts of data
- Timescales
  - ms – year (observable!)
  - hours – 10^8 years in quasars
- Observational template of accretion flow as a function of L/L_{Edd} onto ~10 M BH



Spectra of accretion flow: disc

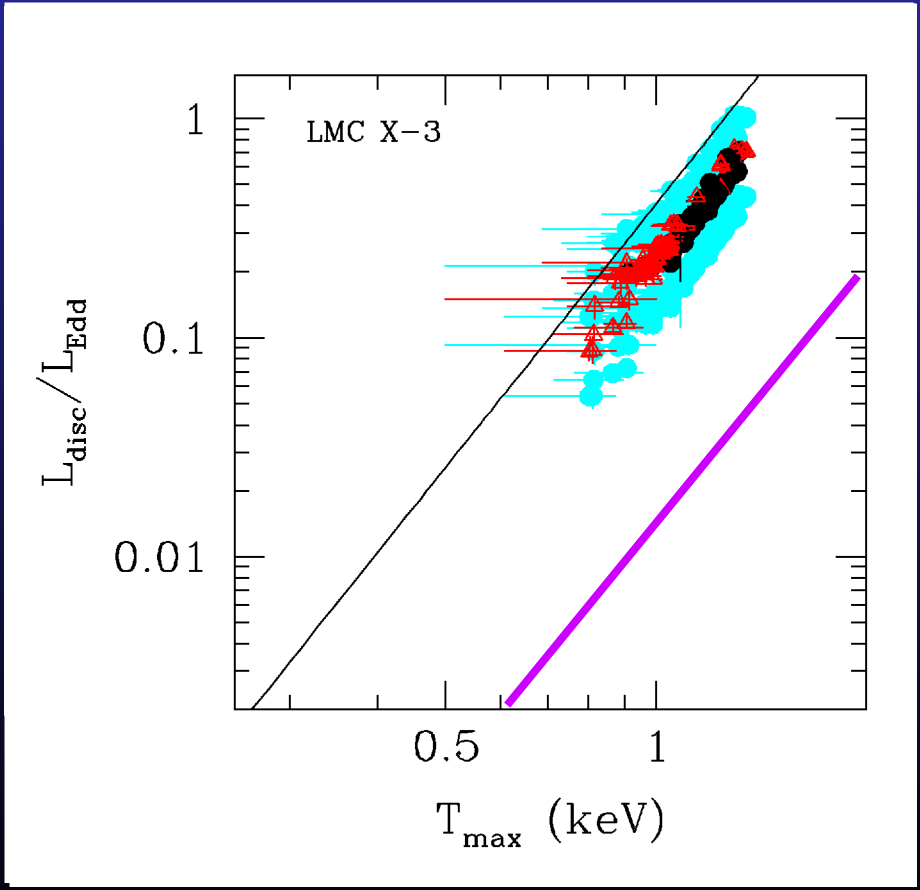


- Differential Keplerian rotation
- Viscosity B: gravity → heat
- Thermal emission: $L = A\sigma T^4$
- Temperature increases inwards
- GR last stable orbit gives minimum radius R_{ms}
- For a=0 and $L \sim L_{Edd}$ T_{max} is
  - 1 keV (10^7 K) for 10 M
  - 10 eV (10^5 K) for 10^8 M
- AGN: UV disc – more opacity than GBH, more powerful wind, less ionised so more noticeable



Disc spectra: last stable orbit

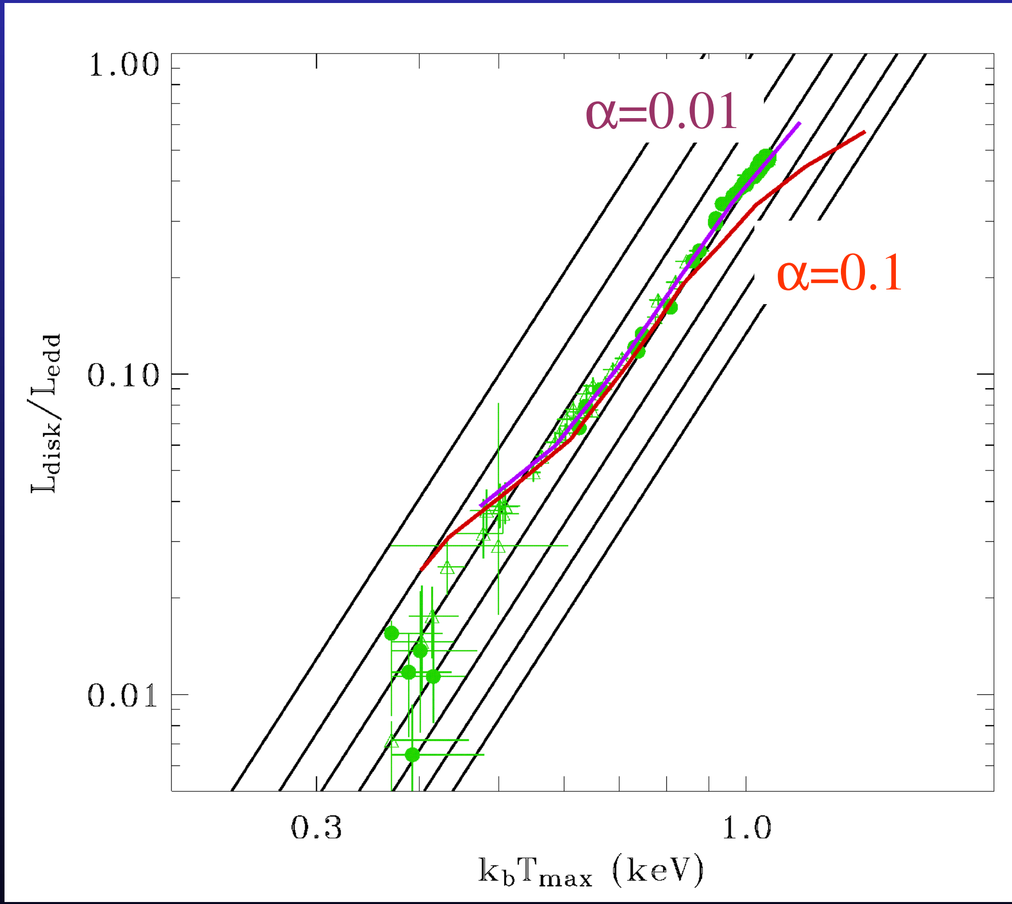
- Pick ONLY ones that look like a disc!
- $L/L_{Edd} \propto T^4_{max}$ (Ebisawa et al 1993; Kubota et al 1999; 2001)
- Proportionality constant gives R_{ms} i.e. a as know M
- Consistent with low to moderate spin **not** extreme spin **nor** extreme versions of higher dimensional gravity - braneworlds (Gregory, Whisker, Beckwith & Done 2004)



Gierlinski & Done 2003

Theoretical disc spectra

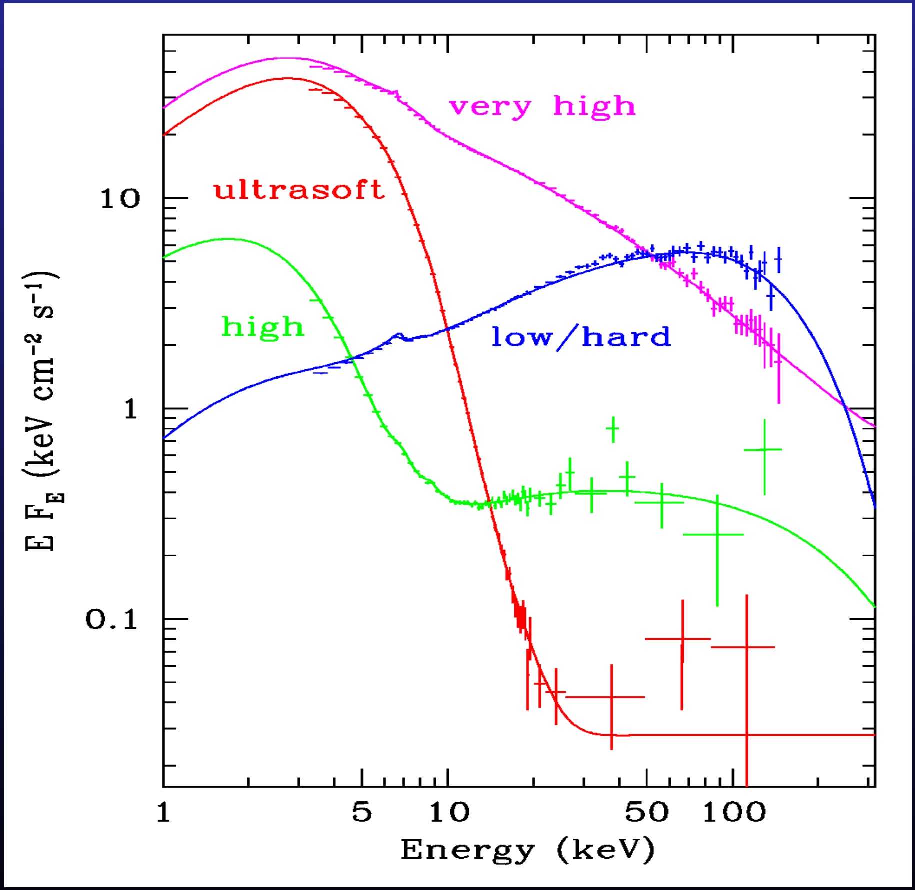
- ONLY works with disc dominated spectra
- Surely even disc spectra aren't this simple!!!!
- Best theoretical models say they can be! Hubeny LTUSTY code
- Metal opacity (not included in previous work) keeps photosphere close to top of disc so constant colour temperature correction (Davies et al 2005)



Davies, Blaes et al 2005

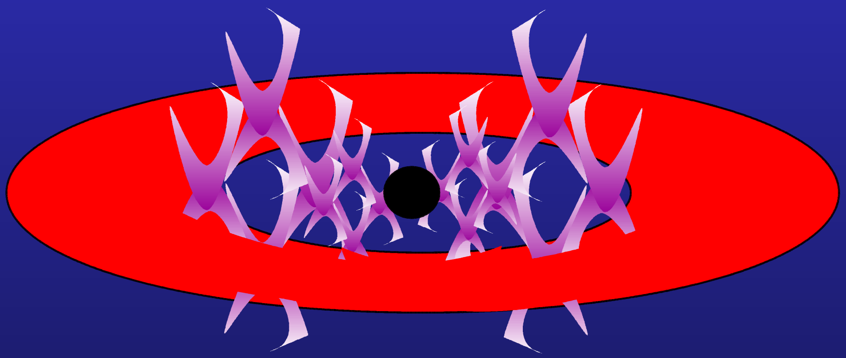
X-ray spectra are not simple…

- Bewildering variety of spectra from single object
- Underlying pattern
- High L/L_{Edd}: soft spectrum, peaks at kT_{max} often disc-like, plus tail
- Lower L/L_{Edd}: hard spectrum, peaks at high energies, not like a disc

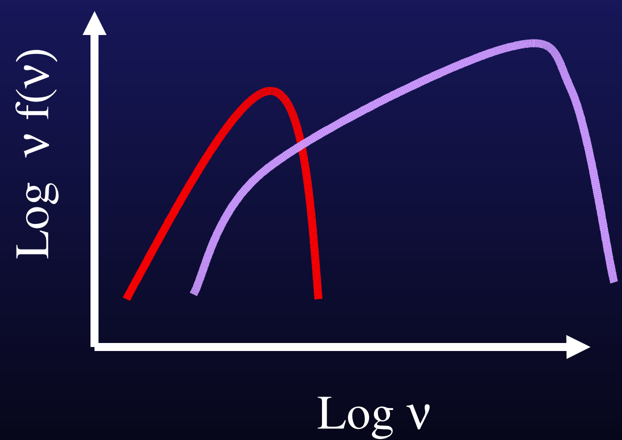


Done & Gierlinski 2003

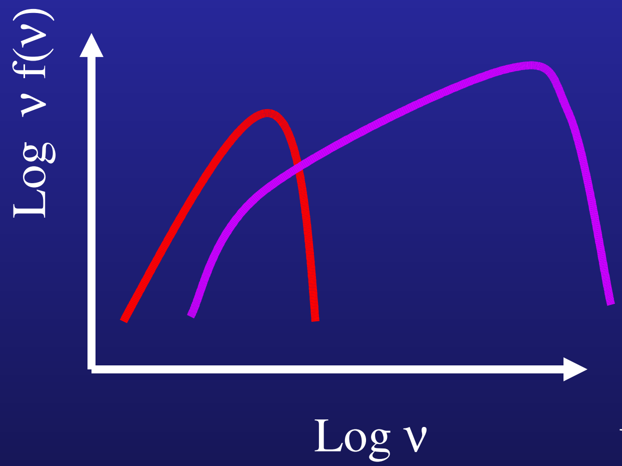
Accretion flows without discs

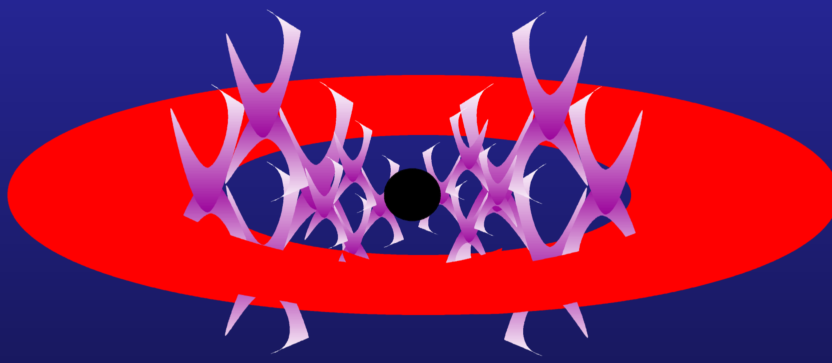


- Disc models assumed thermal plasma – not true at low L/L_{Edd}
- Instead: hot, optically thin, geometrically thick inner flow replacing the inner disc (Shapiro et al. 1976; Narayan & Yi 1995)
- Hot electrons Compton upscatter photons from outer cool disc
- Few seed photons, so spectrum is hard



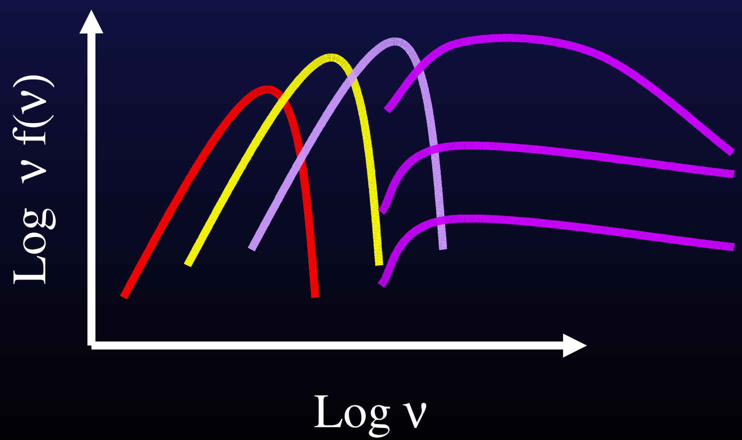
Qualitative and quantitative models: geometry

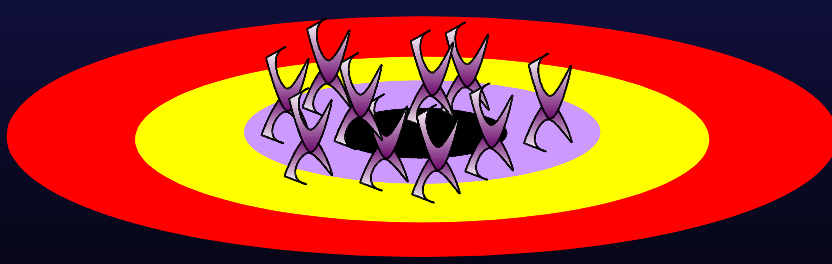




Hard (low L/L_{Edd})

Soft (high L/L_{Edd})





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Observed GBH spectra

- RXTE archive of many GBH
- Same spectral evolution $10^{-3} < L/L_{Edd} < 1$
- Truncated disc → R_{ms} qualitative and quantitative

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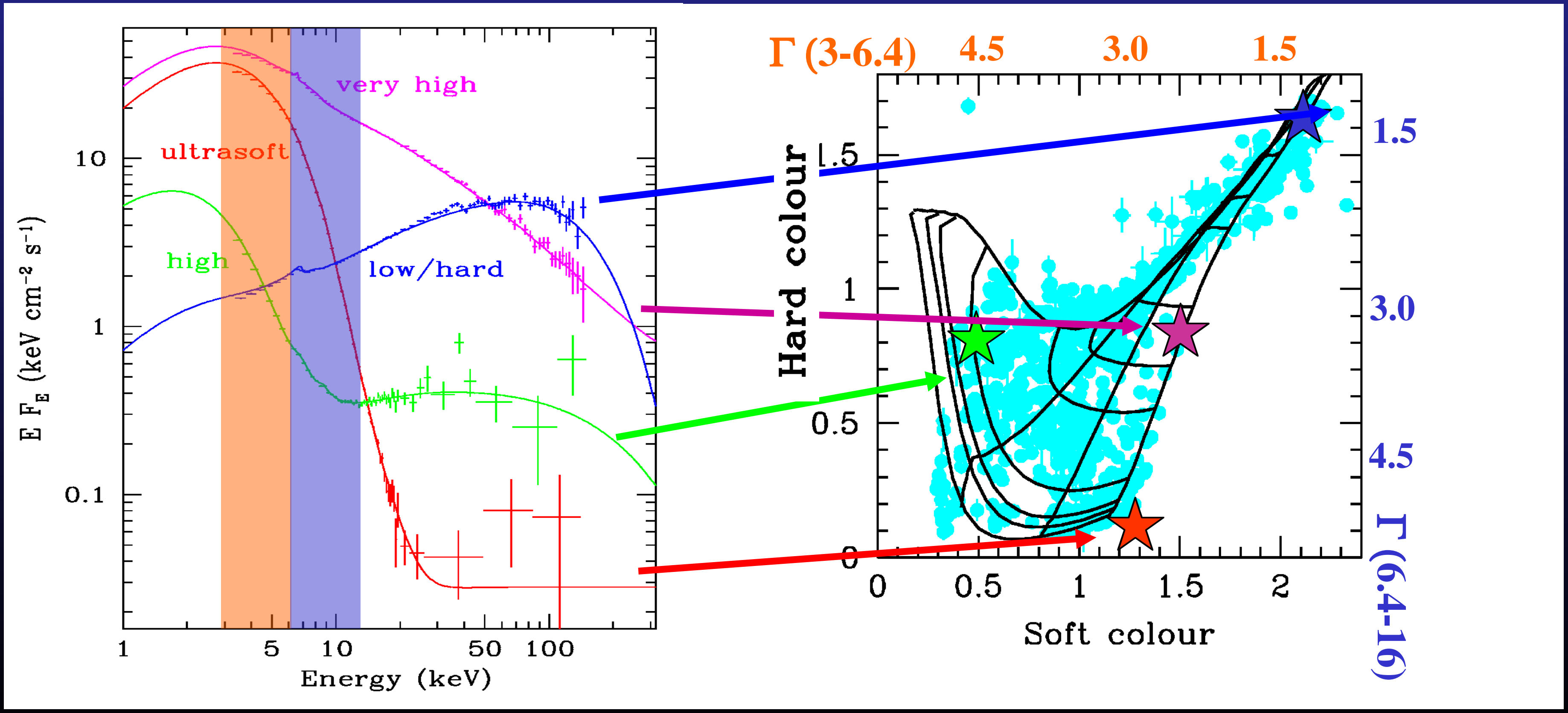
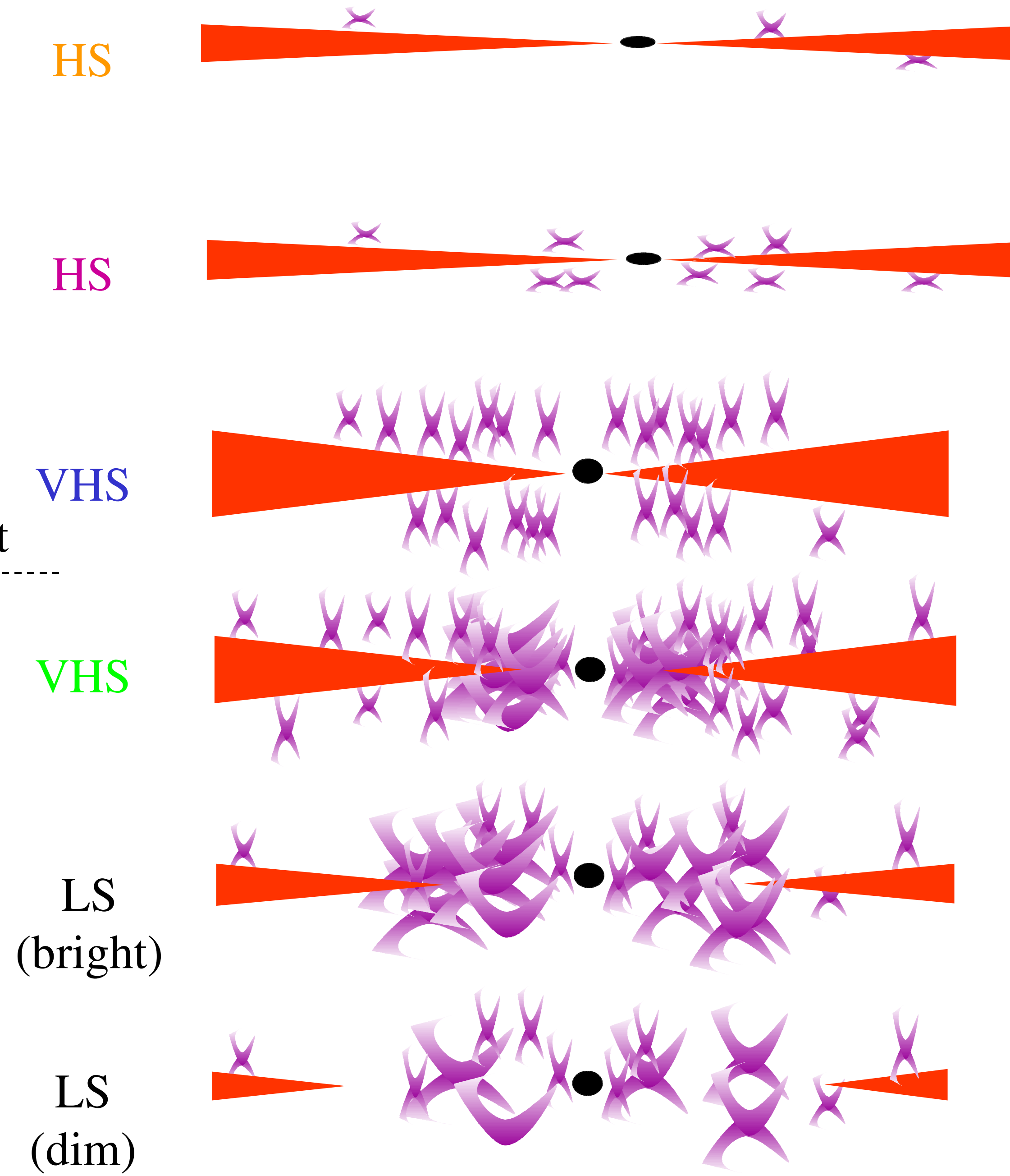


Decrease fraction of power in nonthermal reconnection above disc

Disc to minimum stable orbit

Decrease inner disc radius, and maybe radial extent of corona giving increasing LF QPO frequency

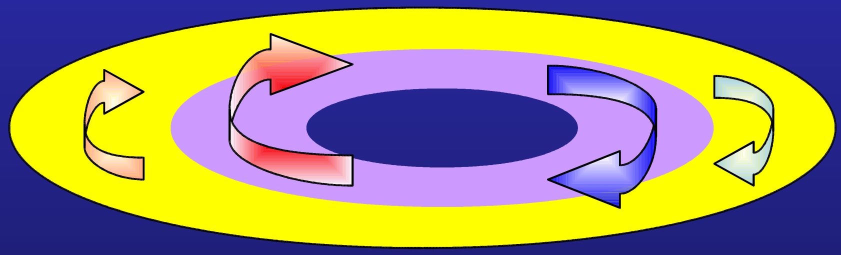
Jet gets faster, catches up with slower outflow, get flares of radio emission from internal shocks Fender (2004)

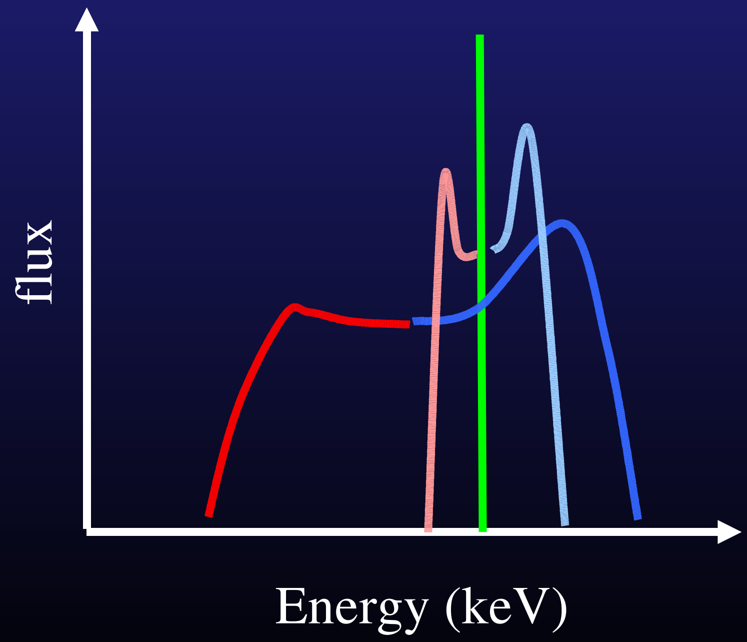


Kubota & Done 2004

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)
- Broadening gives an independent measure of Rin – so spin if ISO (Laor 1991)
- Models predict increasing width as go from low/hard to high/soft states

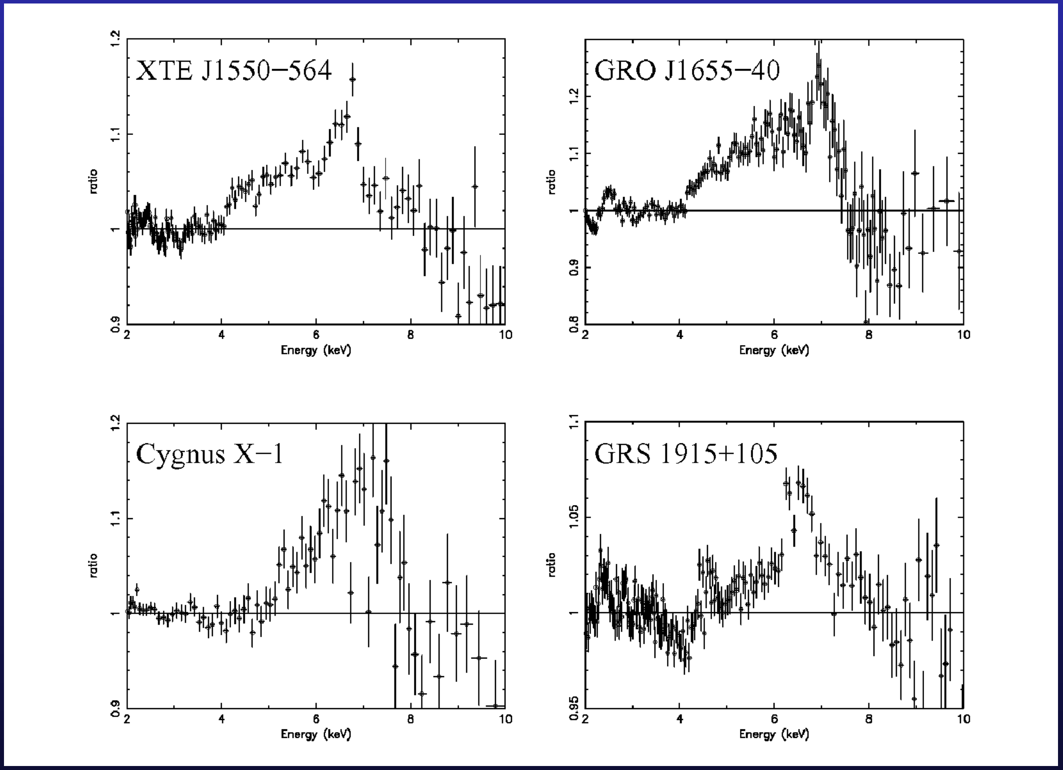




Fabian et al. 1989

Problems: extreme Fe lines

Miller et al 2004

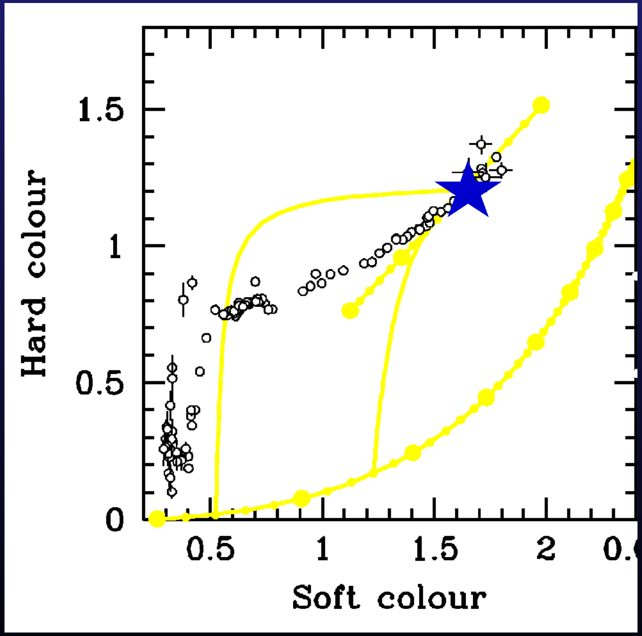


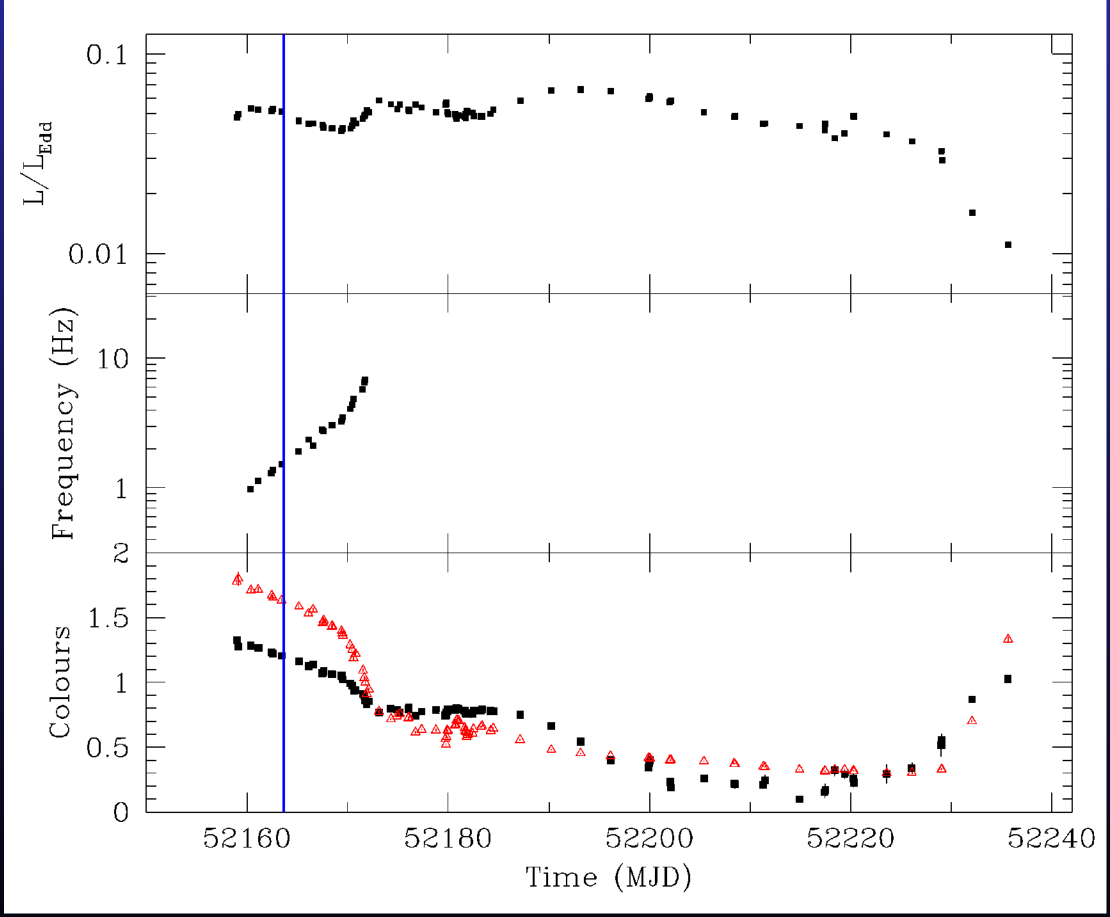
- Broad iron lines are common in GBH. Some indications of increasing width with spectral softness
- But some are *extremely* broad, indicating high spin (if disc to ISO) and extreme emissivity – tapping spin energy of black hole? (Miller et al 2002; 2003; 2004; Minuitti et al 2004)
- BUT these are the same objects for which a<~0.7 from disc spectra
- Mainly in VHS and softest low/hard states (intermediate states) flow extends below ISO? But truncated disc models!!!! Conflict!

XTE J1650-500

Done & Gierlinski 2005

- QPO and broadband data say that disc not down to ISO (RXTE)





Extreme line in bright LH state of J1650

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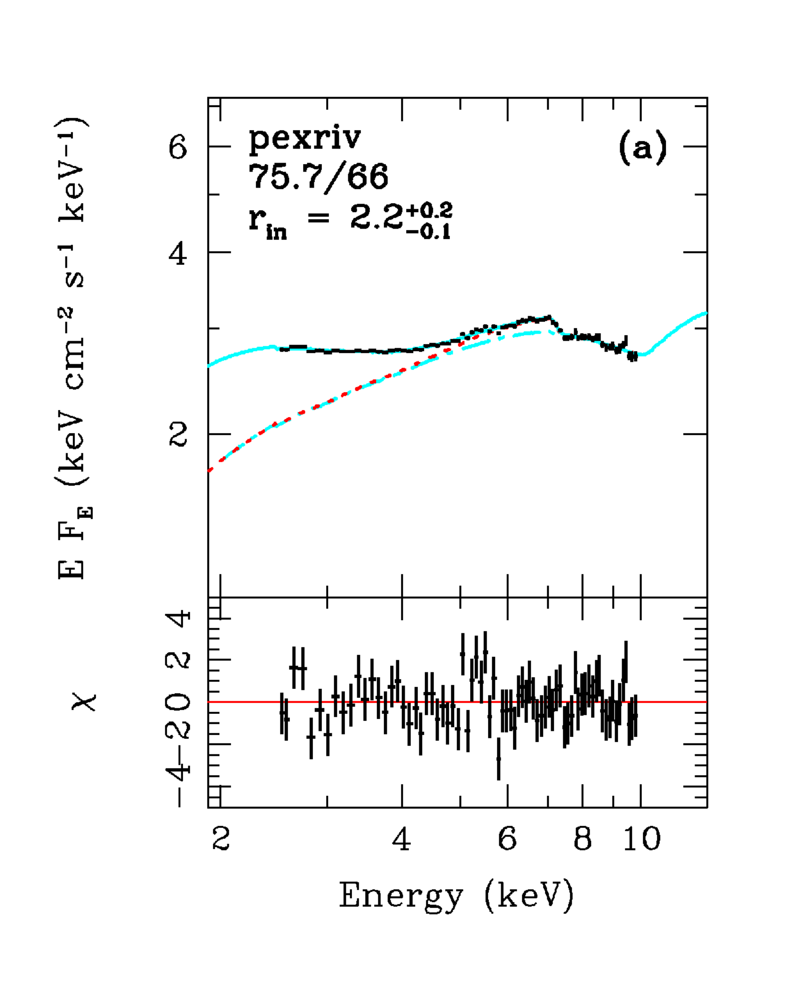
- MECS data (moderate resolution from BeppoSAX)
- pexriv+narrow line. Best fit is extreme spin (Rin=2) and emissivity q=3.5 (Miniutti et al 2004)
- But ionised reflection – line is intrinsically comptonised (Ross, Fabian & Young 1999)



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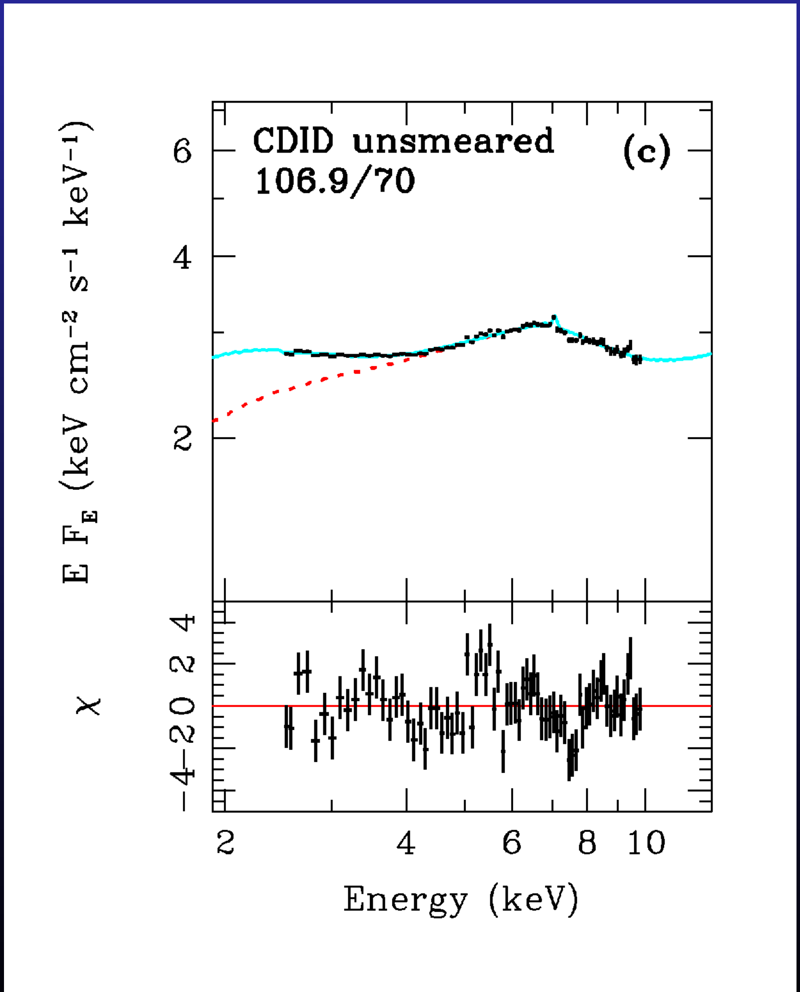
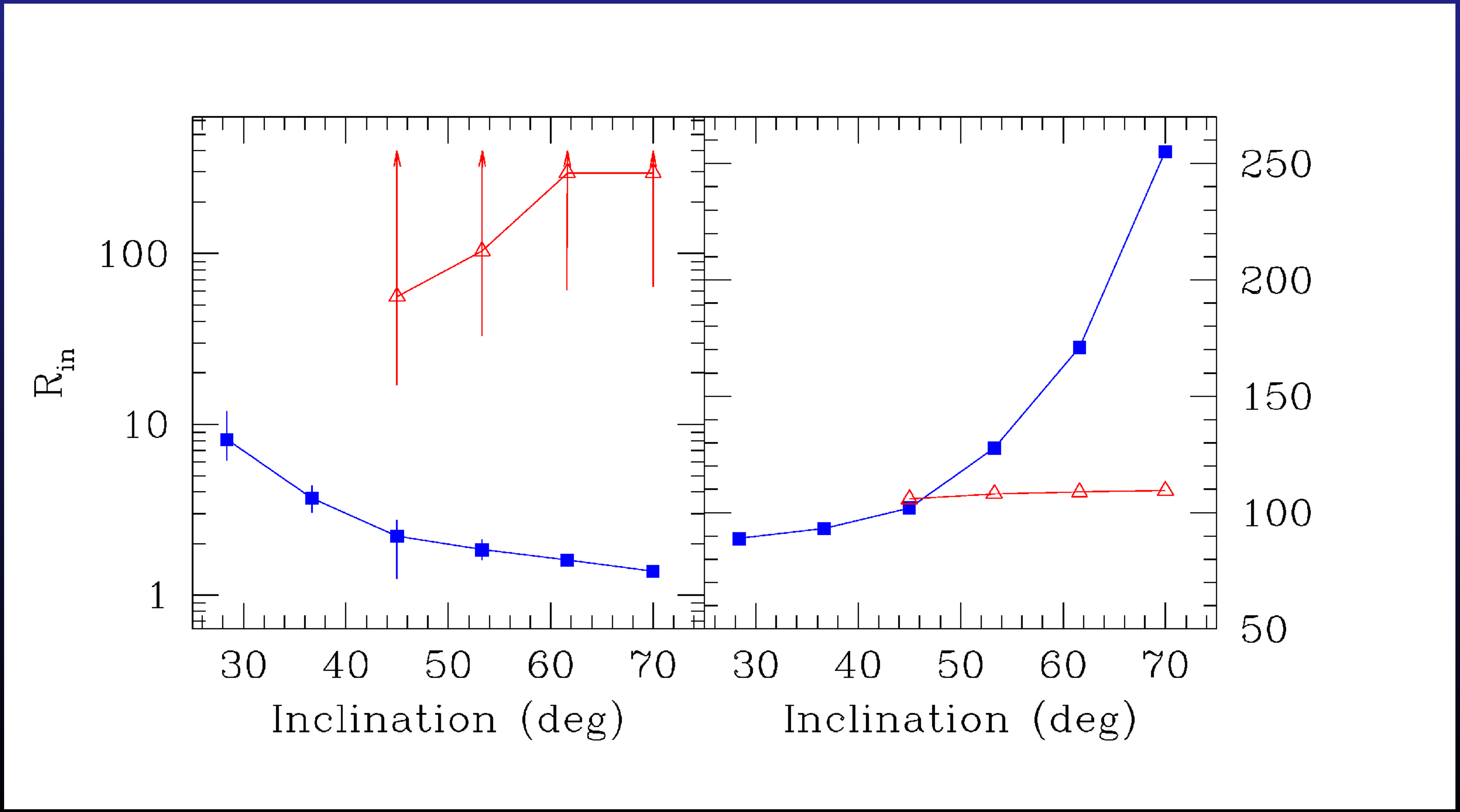
- Very different reflection shape – line and edge are broadened by Comptonisation (Ross, Fabian & Young 1999)
- Still extreme but relativistic effects only $\Delta\chi^2$=13 not 190 as for pexriv. Significance much reduced



Inclination

- Higher i so broader, bluer line.
- Need more gravitational redshift to get back to line peak at 6.7keV so smaller Rin and more centrally peaked emissivity (more extreme)



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Extreme line in bright LH state of J1650

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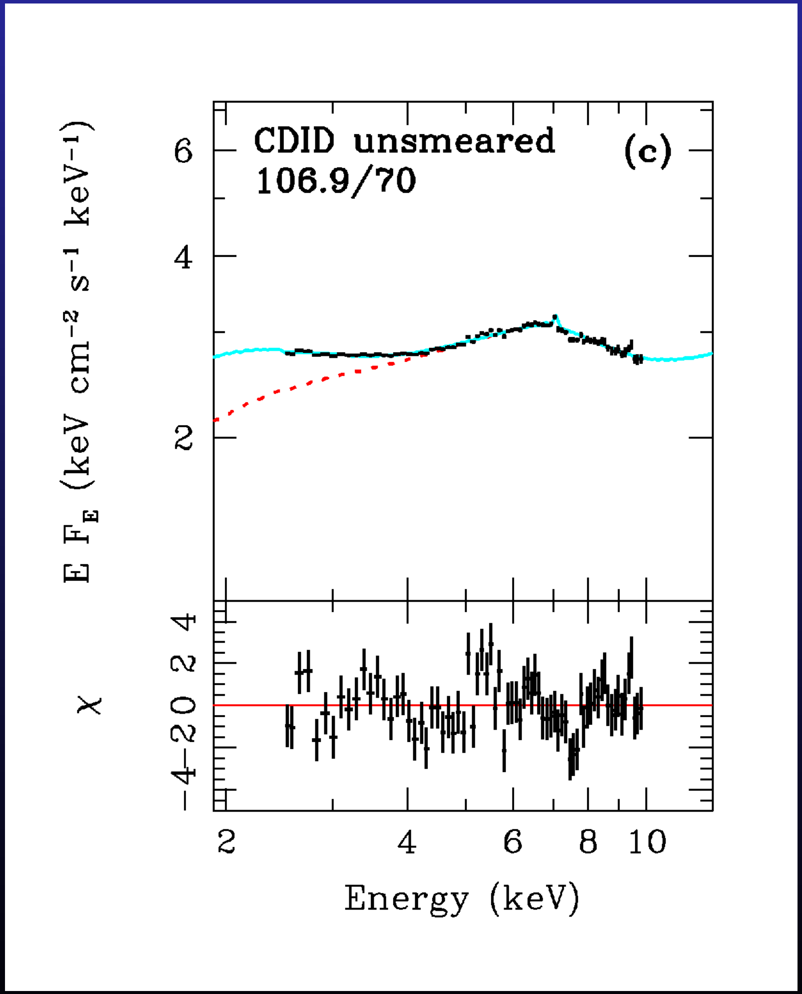
- Absorption lines – outflow?
- Rin~10 with normal emissivity. Nh~10, log ξ=2-3
- Absorption often seen in dipping LMXRB v~500km/s – line driven wind from UV outer disc? Boirin et al 2003, diaz Trigo et al 2005
- This is much faster v~0.1c.
- Link to jet? Max radio is close to time of this spectrum



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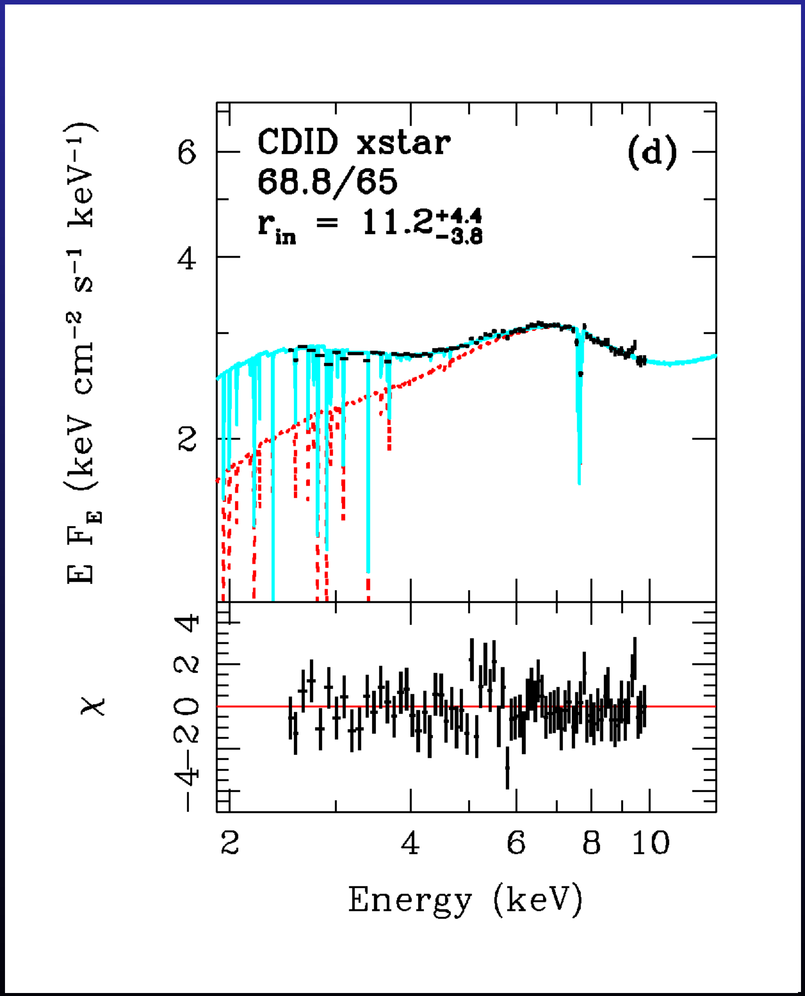

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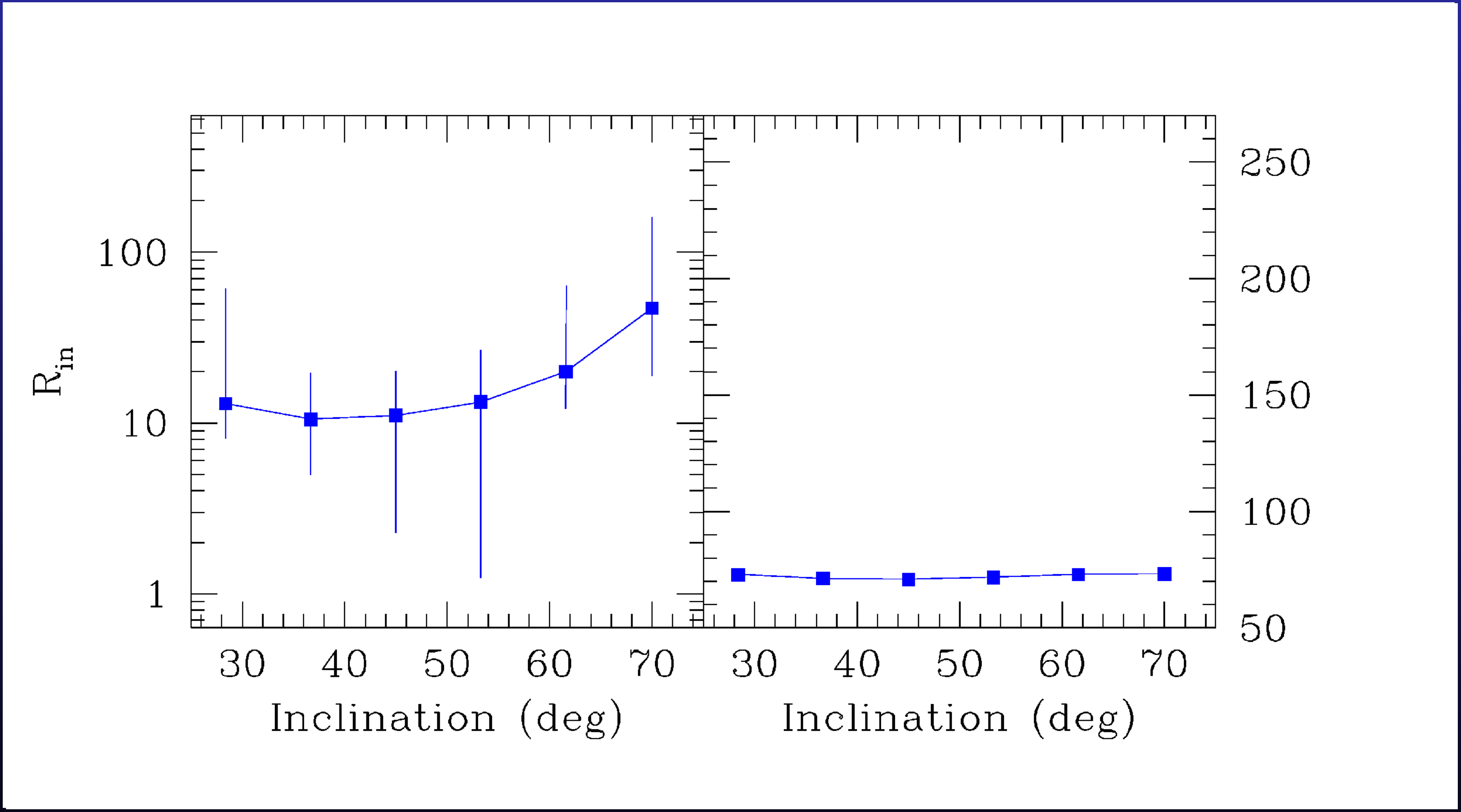

Broad band data

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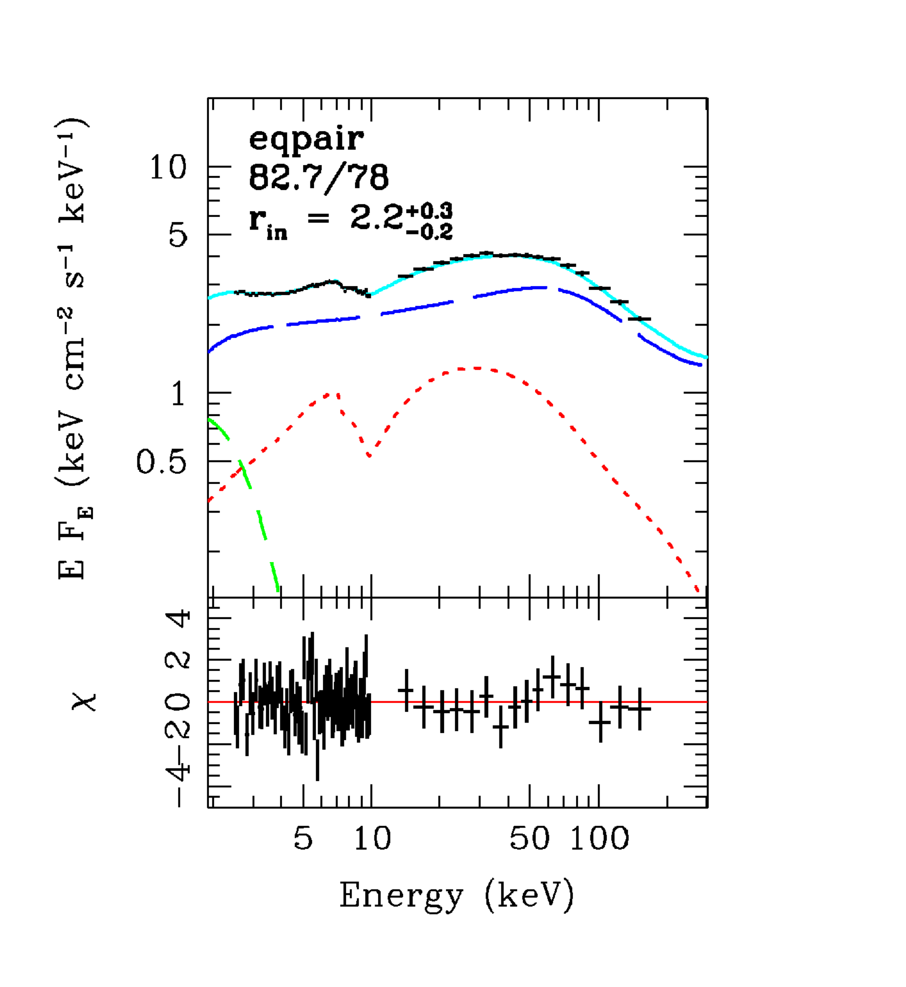

- So not consistent with truncated disc as reflection dominated with CDID
- But not with pexriv
- CDID reflection – photoionised but models for AGN temperatures.
- GBH have higher T so more collisional – less irradiation
- hence lower T from photoionsation? 1.5-2 keV versus 0.6 keV

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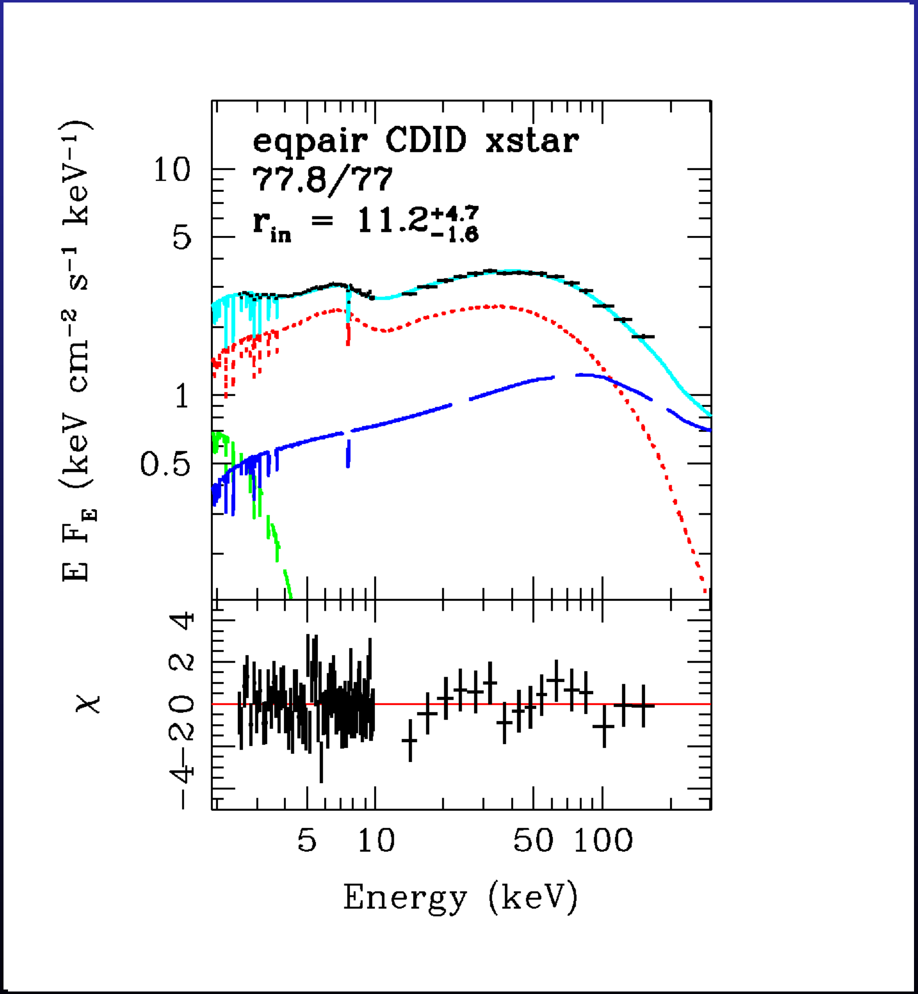

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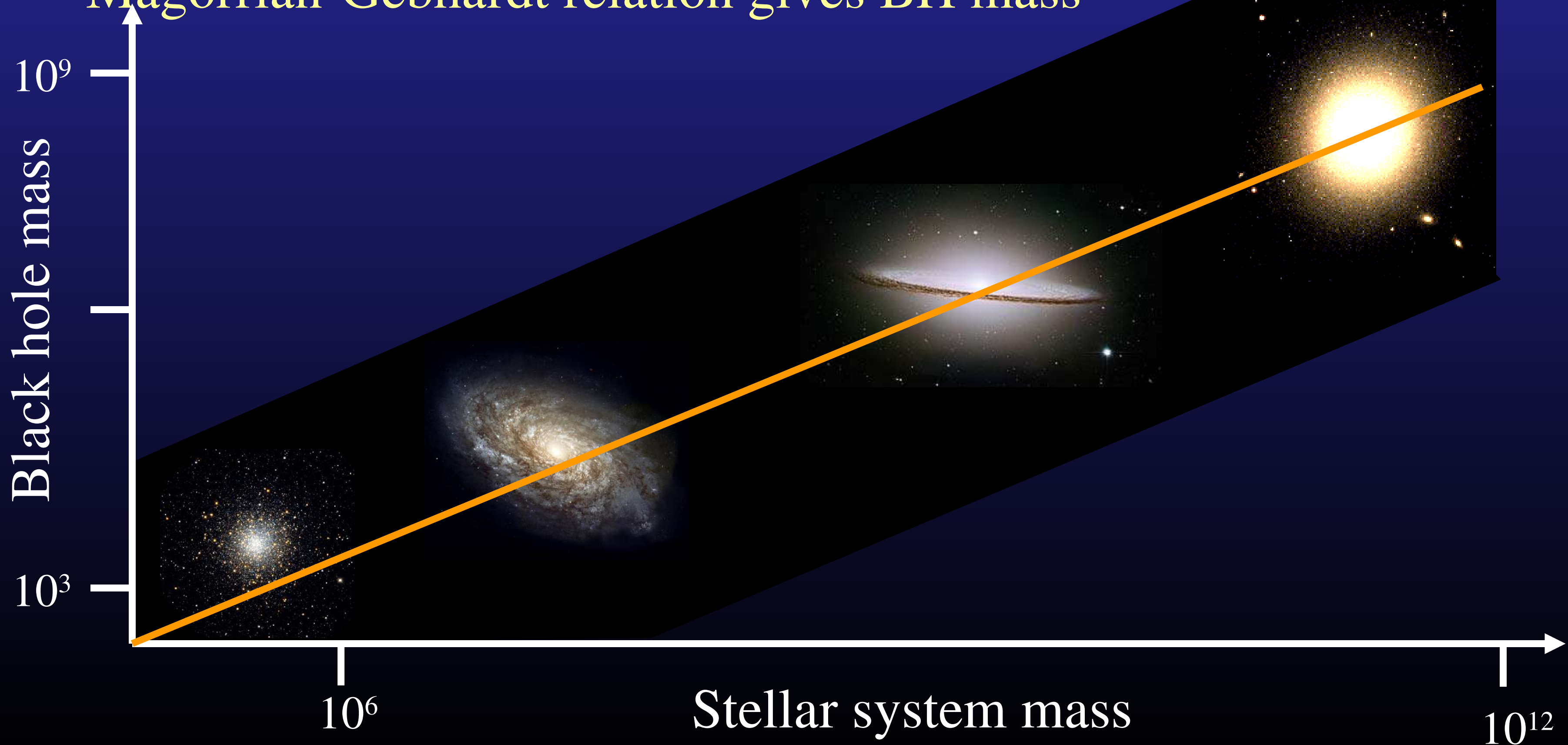
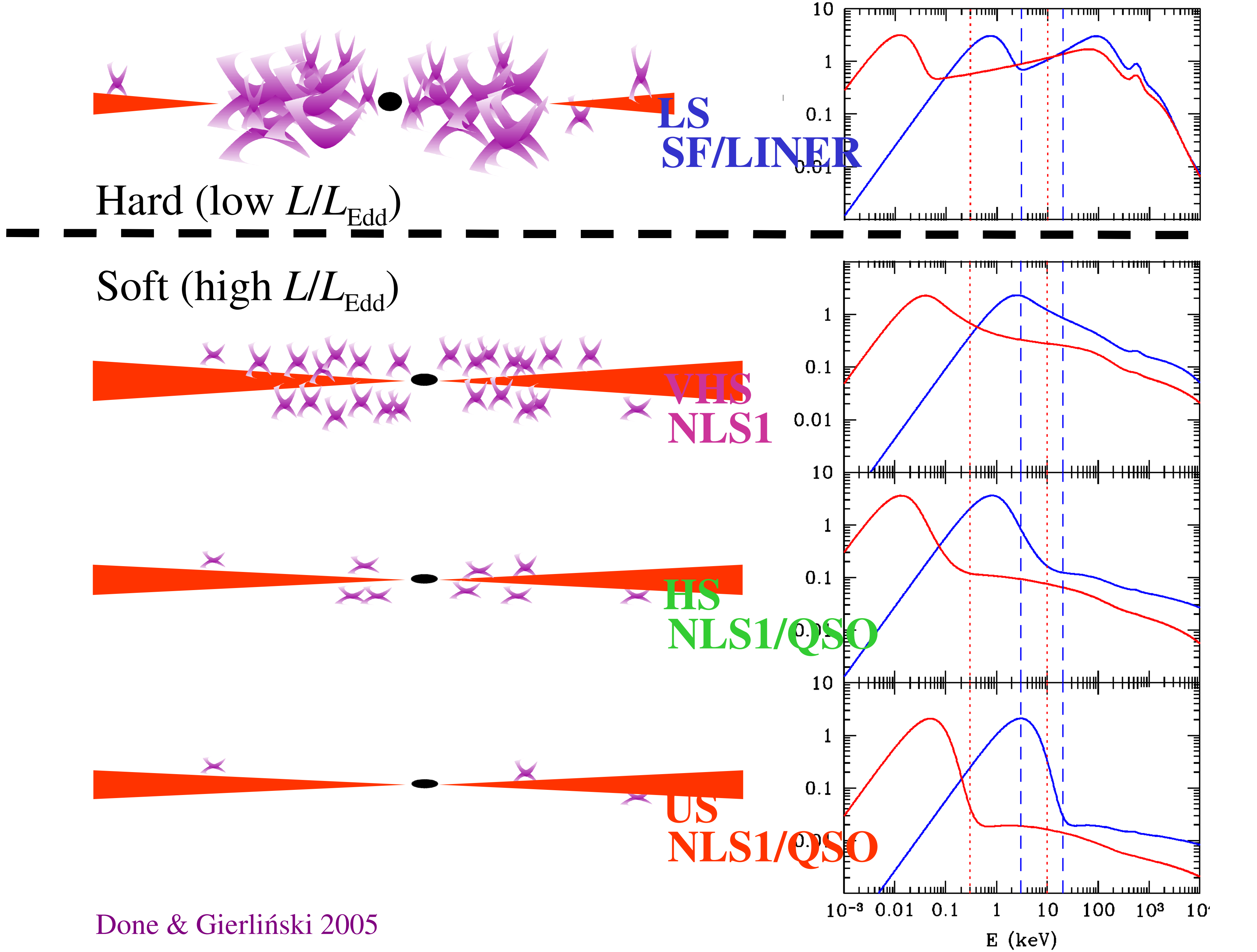
Scale up to AGN/QSOs

- Same accretion flow onto higher mass black hole (?)
- Spectral states with L/L_{Edd}
- $T_{max} \propto M^{-1/4}$ – disc emission in UV, not X-ray
- Magorrian-Gebhardt relation gives BH mass





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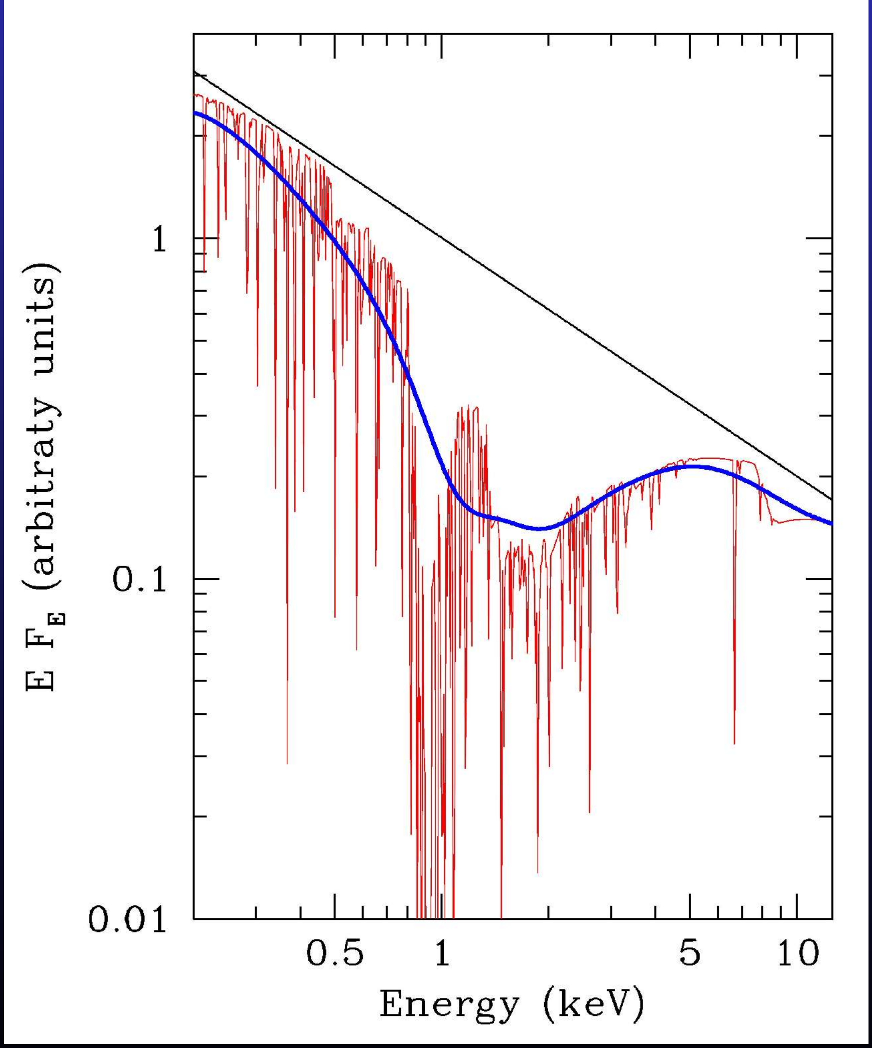
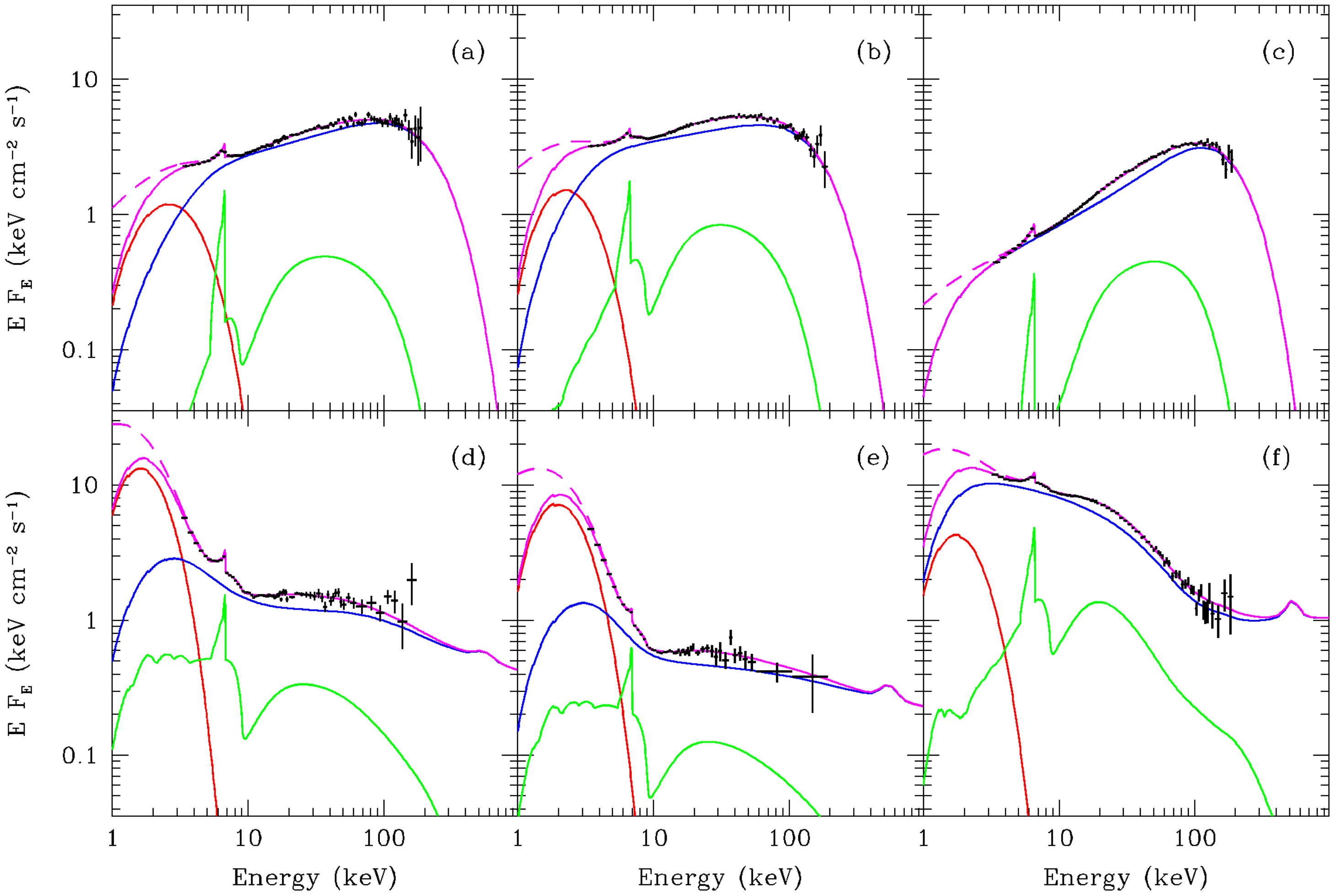
Spectral correspondance?

- Fixed temperature: atomic
- OVII/OVIII ionised absorption
- Features broadened if wind - no longer easily identifiable
- Continuum: hard spectrum with ‘thermal’ soft excess component as same `temperature’ in all objects
- AGN: UV disc – more opacity than GBH, more powerful wind, and less ionised so more noticeable.
- Schurch, Sobelewska etc



Gierliński & Done 2004

Variability scaling GBH-AGN



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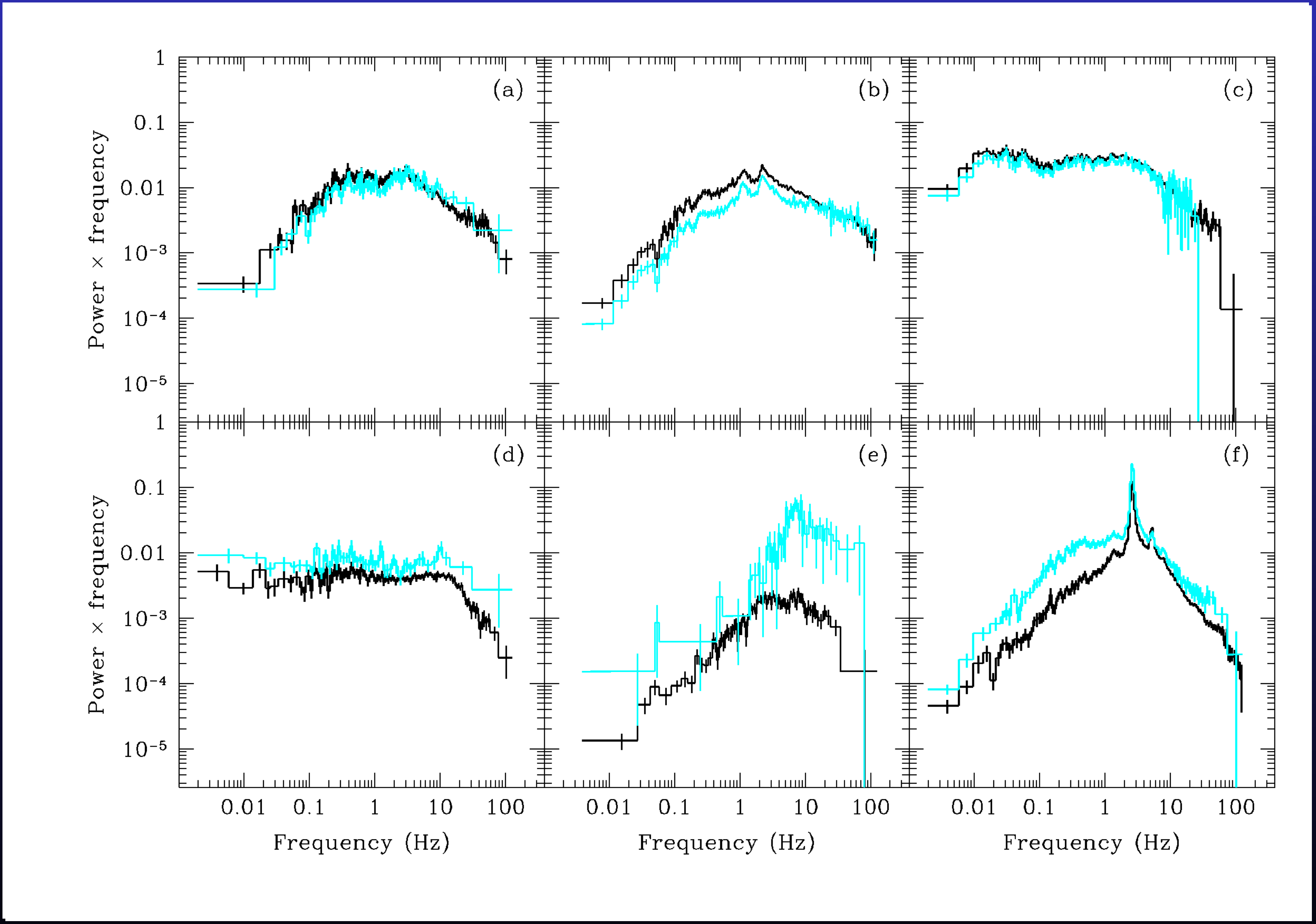
Variability GBH-AGN



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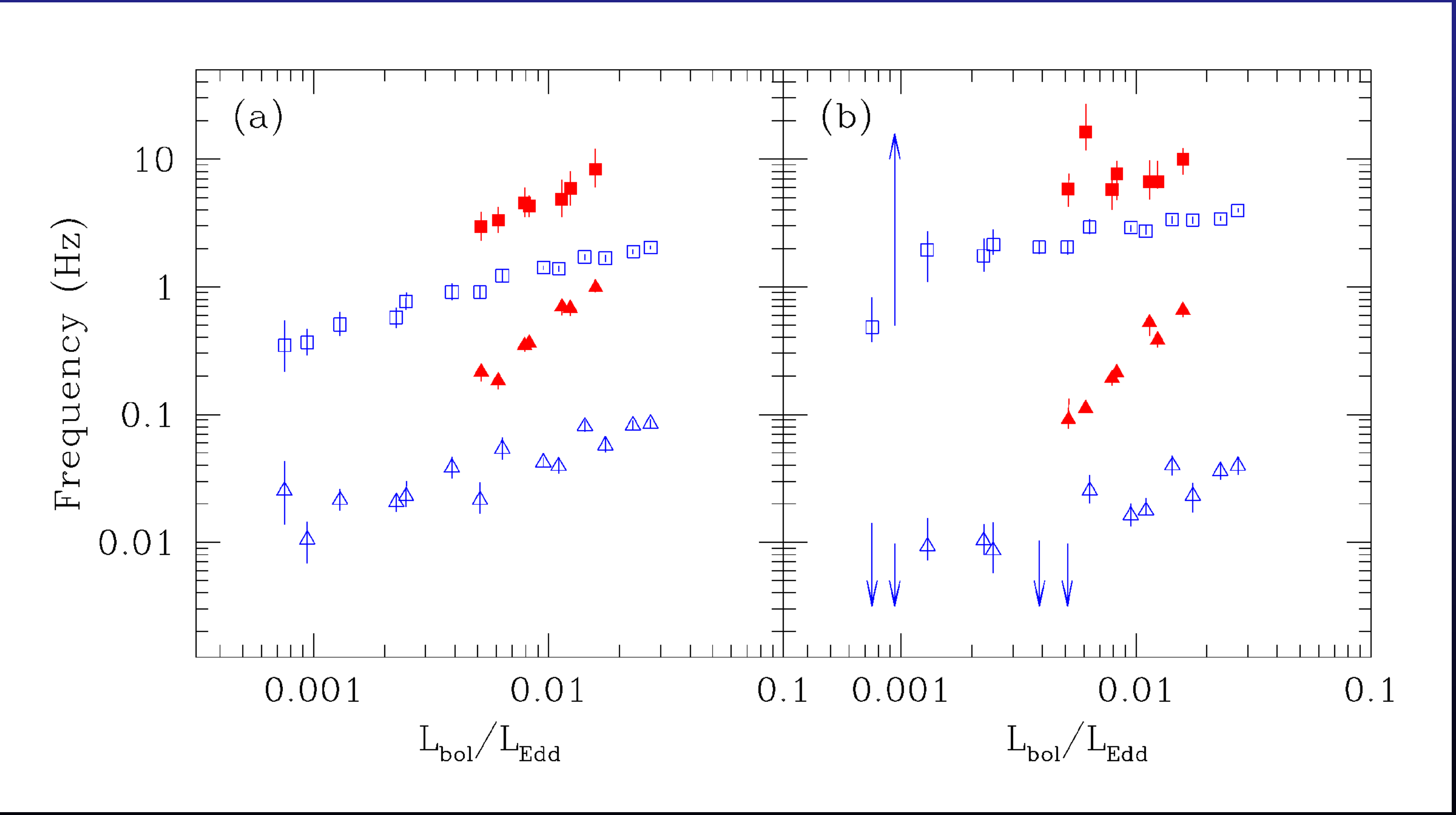
Variability within low/hard

- Lorentzians (GBH)
- f changes so NOT M

- Broken power law (AGN)
- some relation to Mdot but not unique 1:1 McHardy et al. 2004



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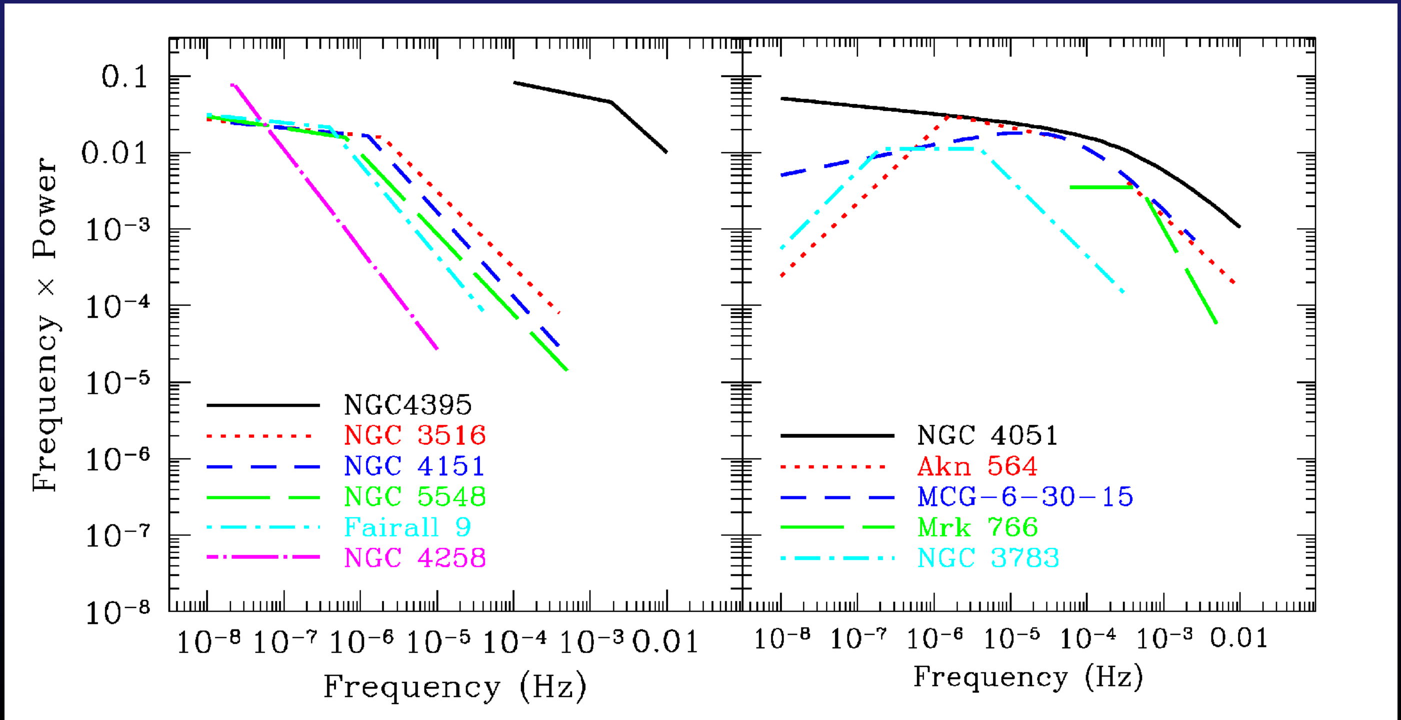
Variability GBH-AGN

- L/Ledd < 0.2 (~0.05 except for 4395 and 4258 0.001)
- M~$10^{7\text{-}8}$ except for 4395
- Break (sort of) scales with M, Mdot McHardy et al. 2004

- L/Ledd > 0.2 (VHS and HS)
- M~$10^{6\text{-}7}$
- VHS or HS is OK. for NLS1



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Conclusions

- Test GR - X-rays from accreting black holes produced in regions of strong gravity
- Event horizon (compare to NS)
- Last stable orbit (ONLY simple disc spectra) $L \propto T^4_{max}$
- Corrections to GR from proper gravity must be smallish
- Accretion flow NOT always simple disc – X-ray tail!
- Strong tail at high L/L_{Edd} (very high state) – sucking energy from disc so lower T_{max} than expect from L.
- Apply to ULX – low T_{max} can be 30-50 M not 1000 M
- Apply to AGN – breaks for some high L/L_{Edd} objects. Either missing some accretion physics OR discwind
- ASTROPHYSICS ↔ PHYSICS