# What do we learn about AGN from galactic black holes?

Chris Done
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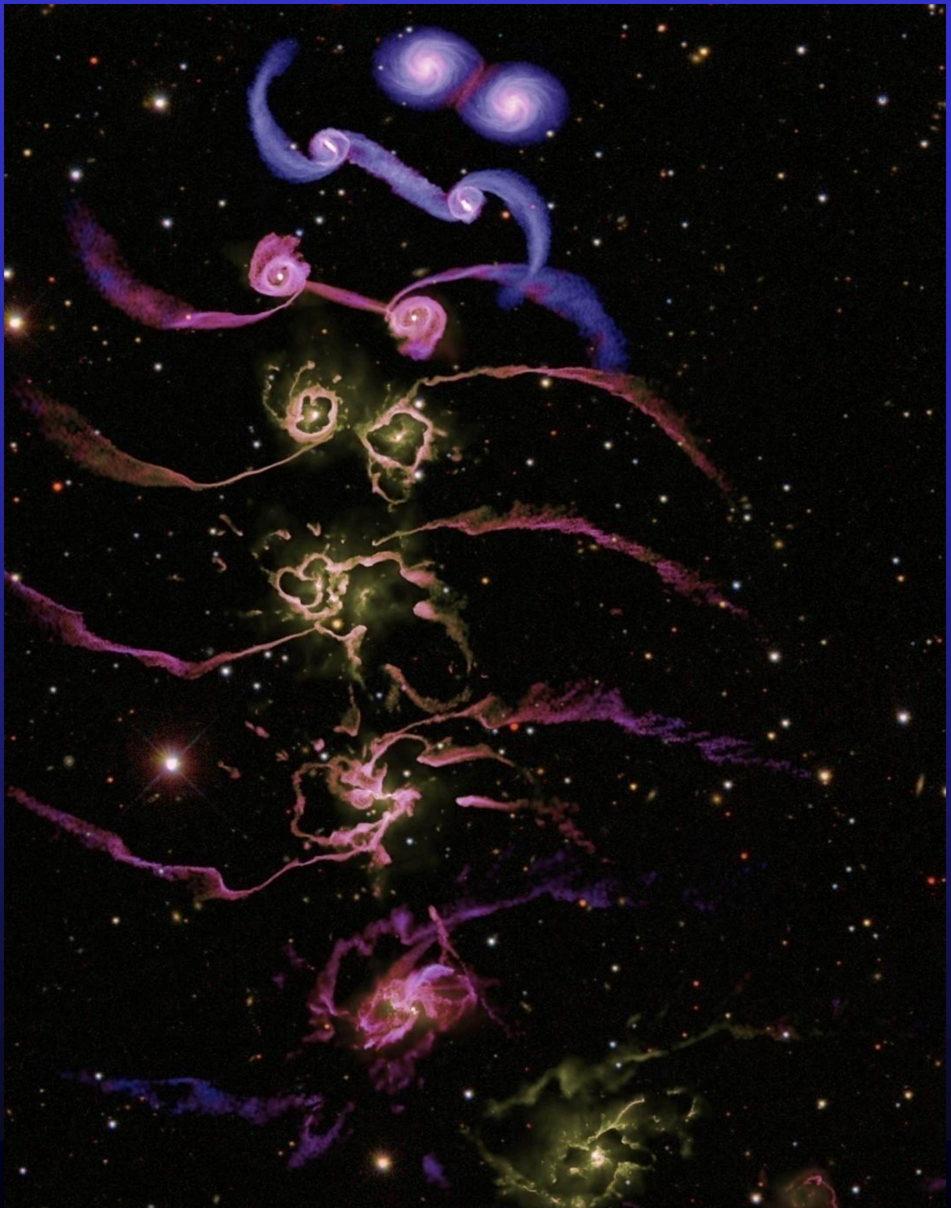
# Black holes in AGN grow by accretion

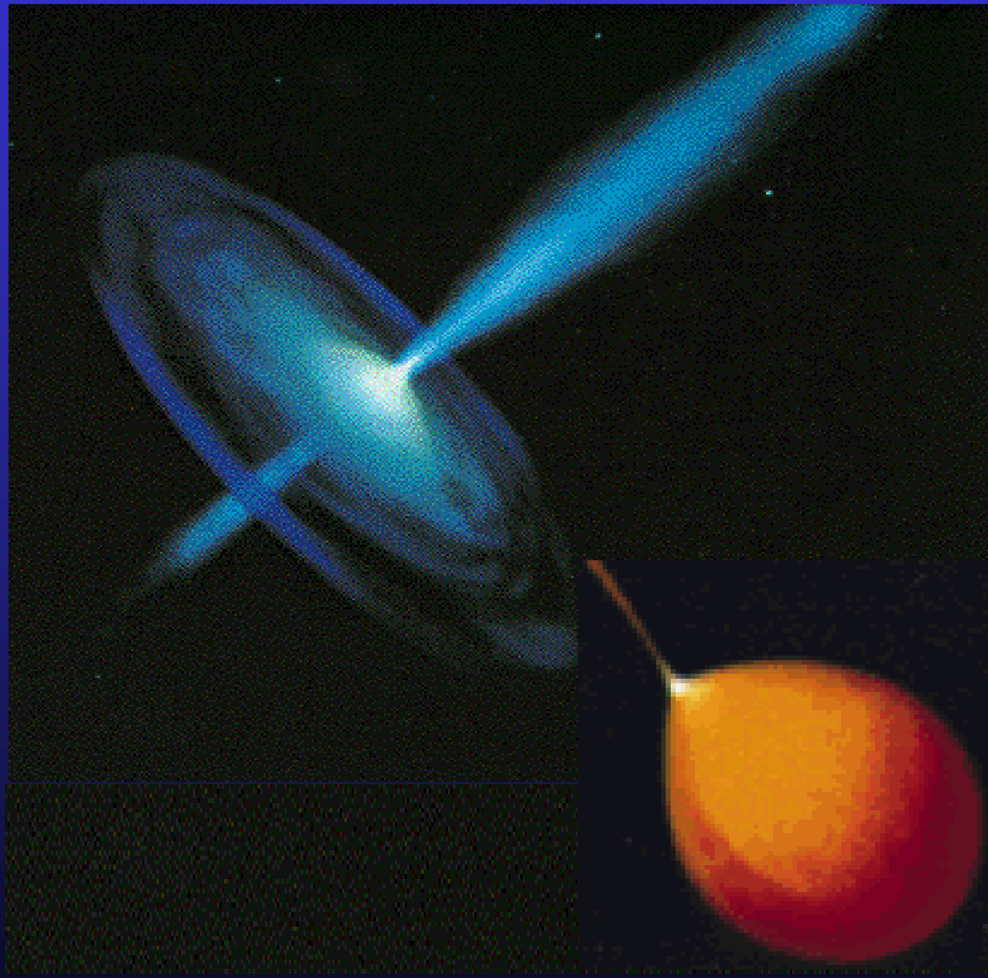
- Gas supply to nucleus
  - Galaxy disc instabilities
  - Major mergers
  - Minor mergers
  - Cooling flow of hot gas from halo
- Regulated by feedback
  - Supernovae
  - Kinetic energy from jet
  - Momentum from wind and/or radiation
- Need to understand accretion to understand feedback



Di Matteo et al 2005

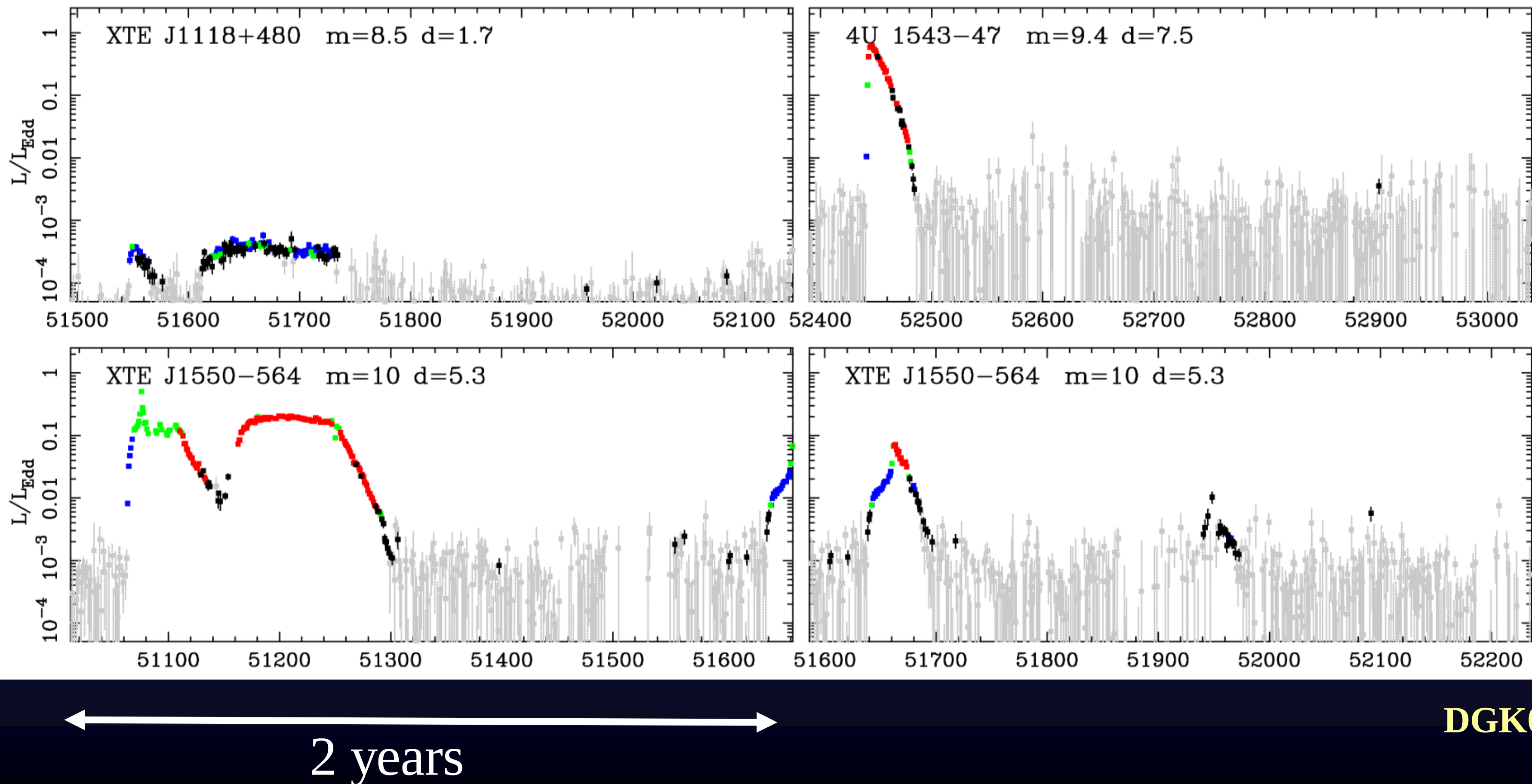
# Accreting black holes

- Appearance of BH depends only on mass and spin (black holes have no hair!)
- Black hole binaries (BHB)
- M~3-20 $M_\odot$ (stellar evolution) - very homogeneous in mass
- Form observational template of variation of flow with $L/L_{Edd}$
- Active Galactic Nuclei (AGN)
- M~$10^5$-$10^{10}$ $M_\odot$ (build through accretion and mergers) very inhomogeneous



# Transients

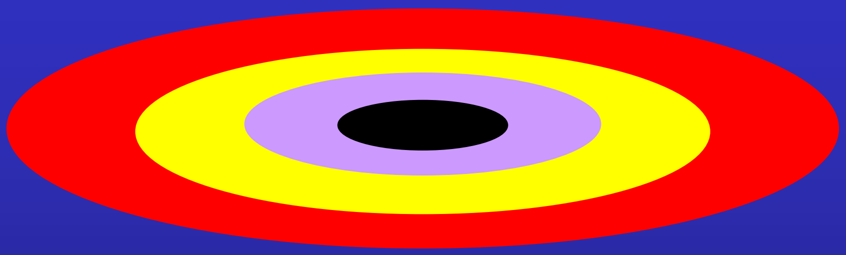
- Huge amounts of data, long term variability (days –years) in mass accretion rate (due to H ionisation instability in disc)
- Observational template of accretion flow as a function of $L/L_{Edd}$ onto ~10 $M_{\odot}$ BH

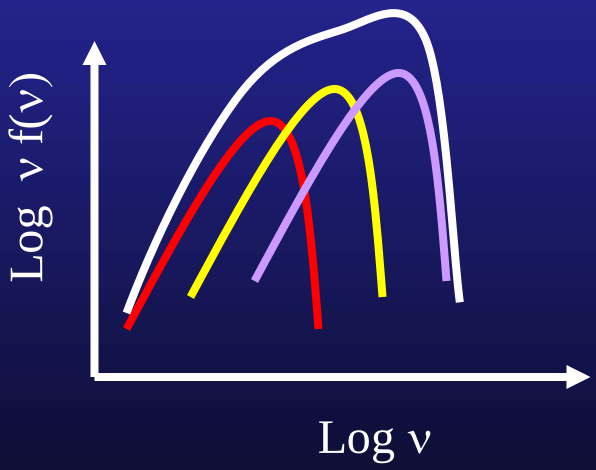



DGK07

# Spectra of accretion flow: disc

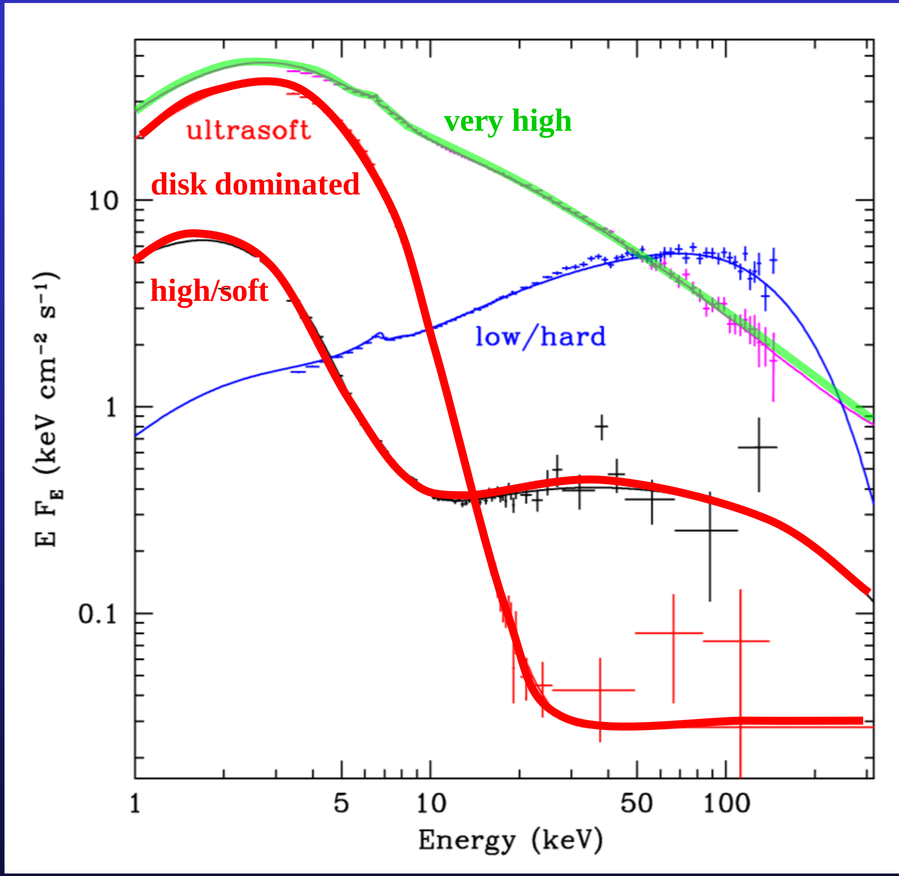
- Differential Keplerian rotation
- Viscosity B: gravity $\rightarrow$ heat
- Thermal emission: $L = A\sigma T^4$
- Temperature increases inwards until minimum radius $R_{lso}(a_*)$ For $a_*$=0 and $L \sim L_{Edd}$ $T_{max}$ is
  - 1 keV ($10^7$ K) for 10 $M_\odot$ (easy!)
  - 10 eV ($10^5$ K) for $10^8$ $M_\odot$ (hard as ISM absorption)
  - big black holes luminosity scales with mass but area scales with mass$^2$ so T goes down with mass





# Spectral states

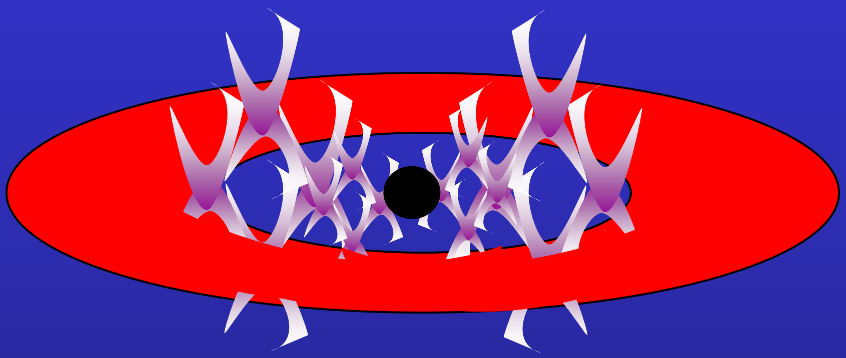
- Dramatic changes in continuum – single object, different days
- Underlying pattern in all systems
- High $L/L_{Edd}$: soft spectrum, peaks at $kT_{max}$ often disc-like, plus tail
- Lower $L/L_{Edd}$: hard spectrum, peaks at high energies, not like a disc (McClintock & Remillard 2006)

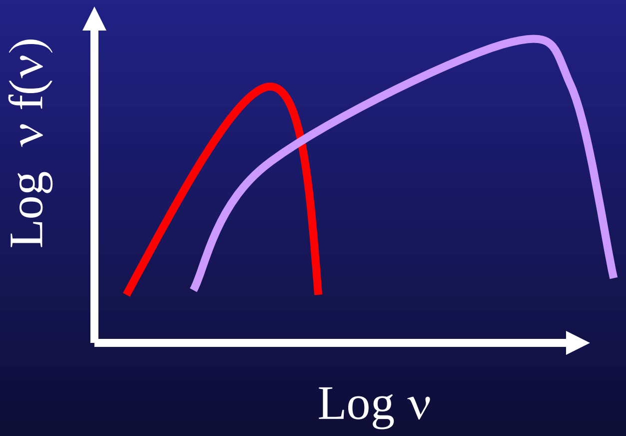



Gierlinski & Done 2003

# Accretion flows without discs

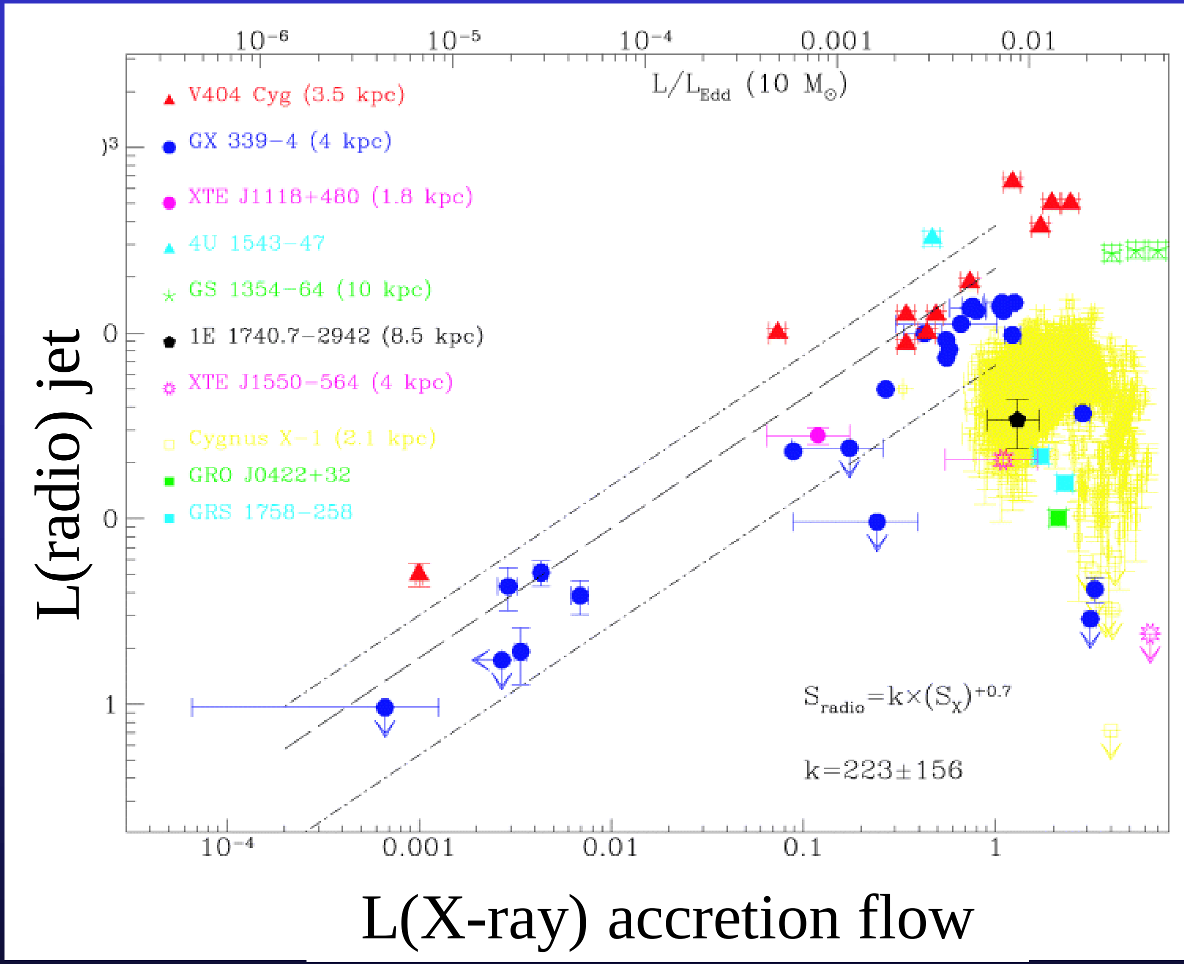
- Disc models assumed thermal plasma – not true at low $L/L_{Edd}$
- Instead: hot, optically thin, geometrically thick inner flow replacing the inner disc (Shapiro et al. 1976; Narayan & Yi 1995)
- Still somewhat controversial
- Hot electrons Compton upscatter photons from outer cool disc
- Few seed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





# And the radio jet… link to spin?

- No special μQSO class – they ALL produce jets, consistent with same radio/X ray evolution
- Jet links to spectral state – hard state has steady radio jet which gets brighter as the hard X-rays get brighter
- Then collapses as make transition to disc
- (Fender et al 2004)




Gallo et al 2003

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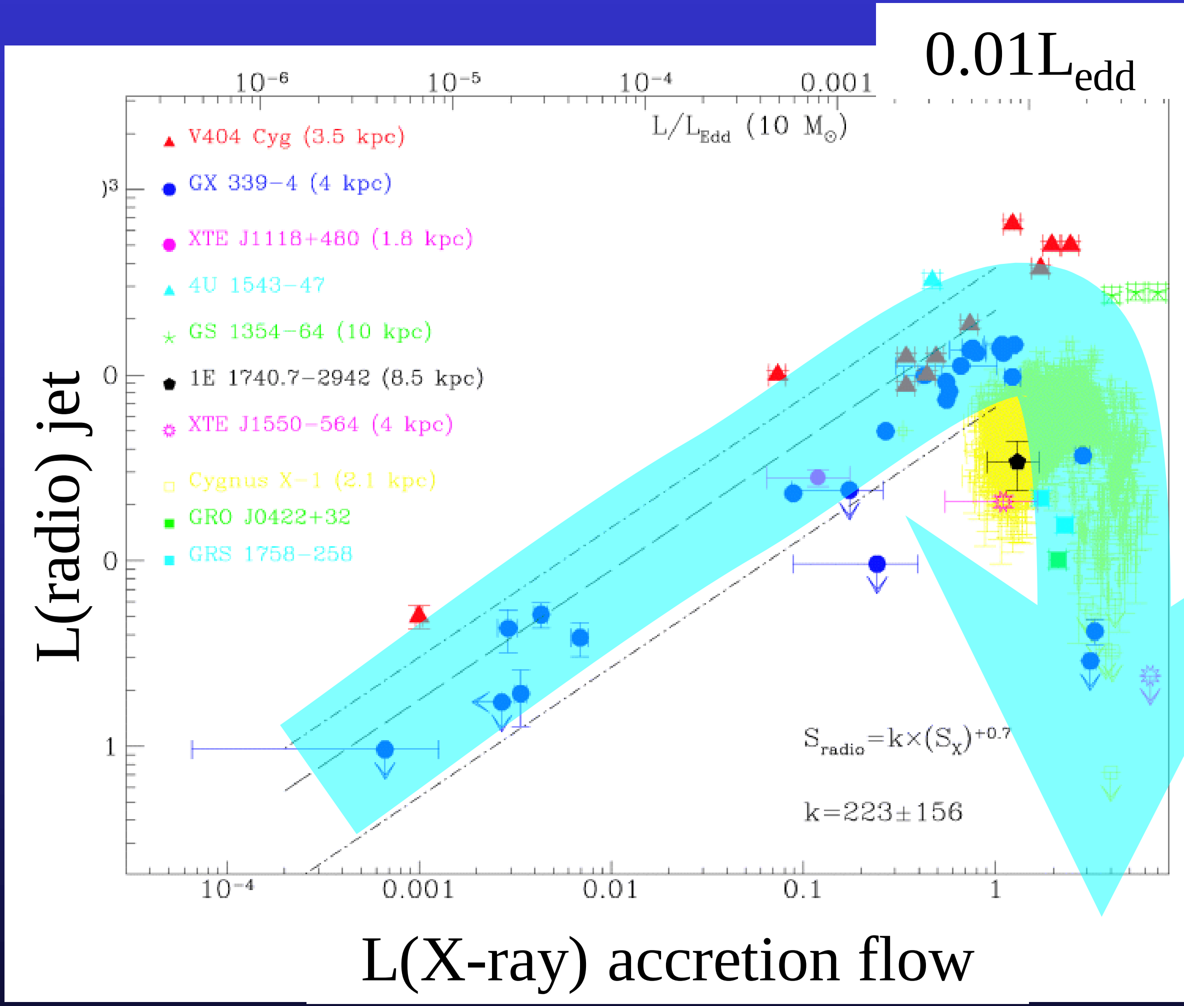


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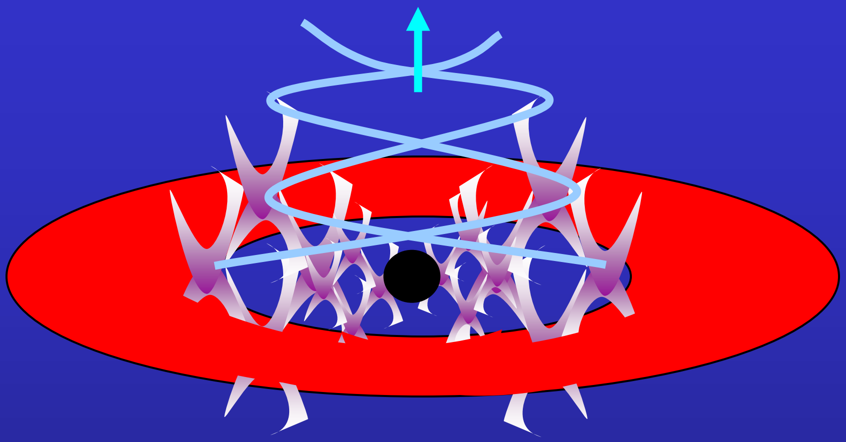
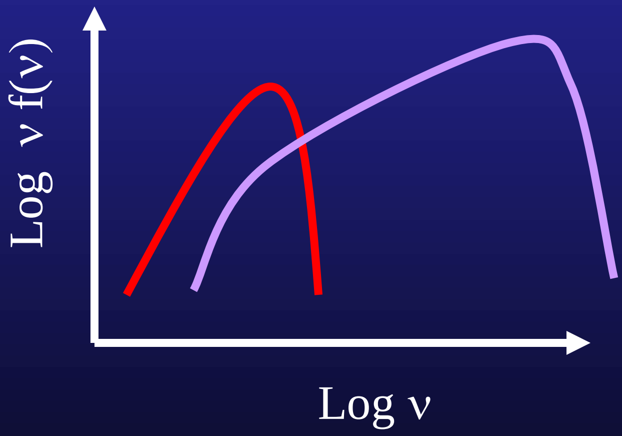
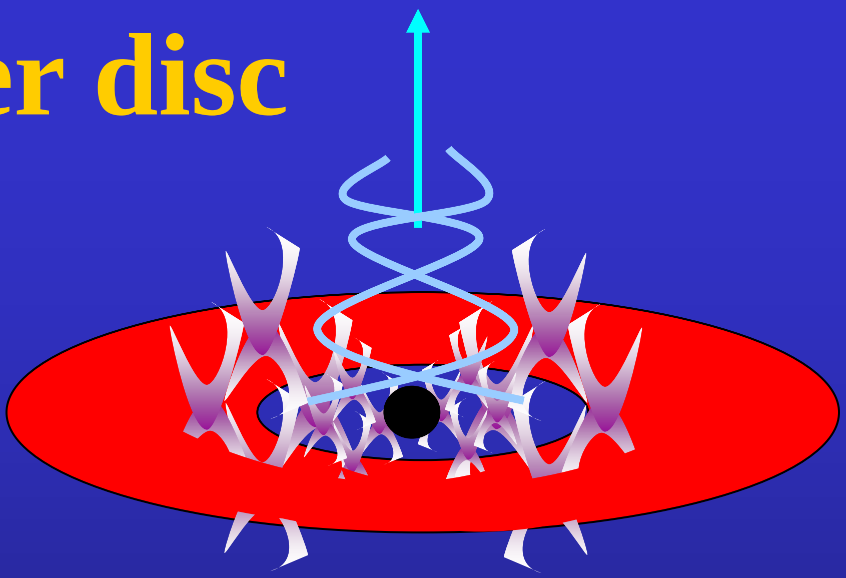




# No inner disc



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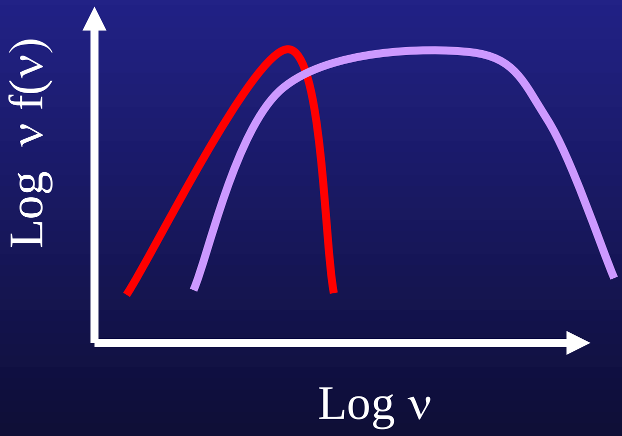

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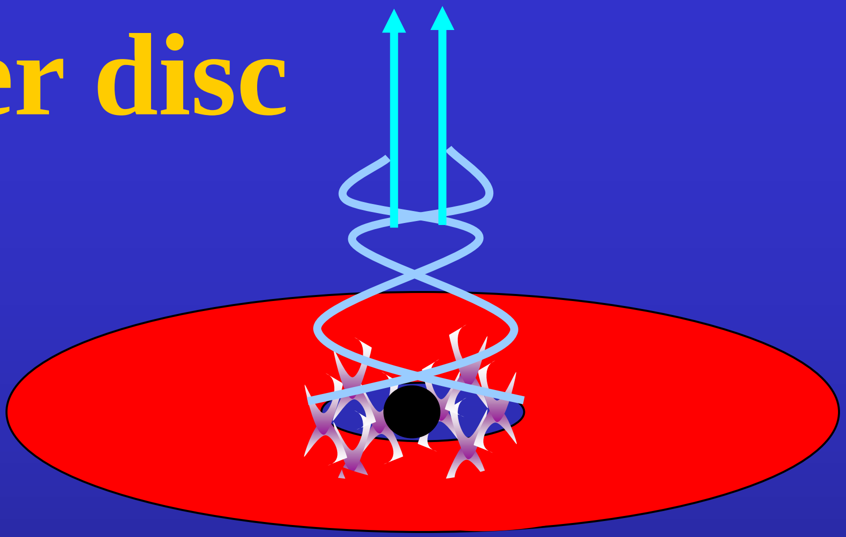

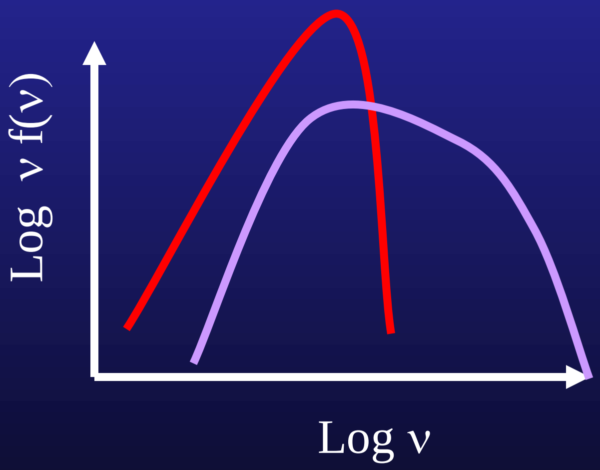

# Collapse of hot inner flow

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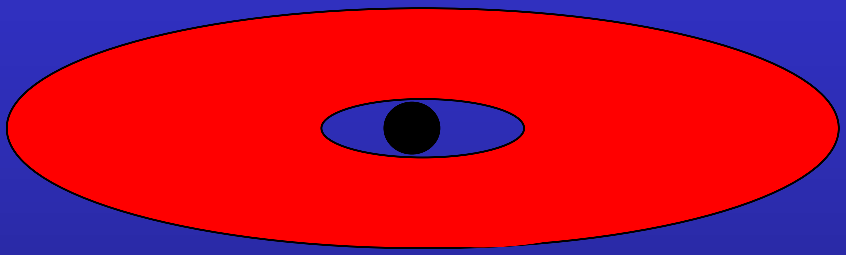
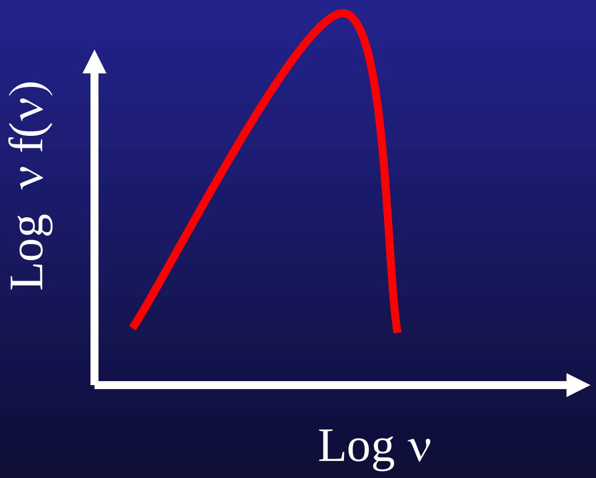
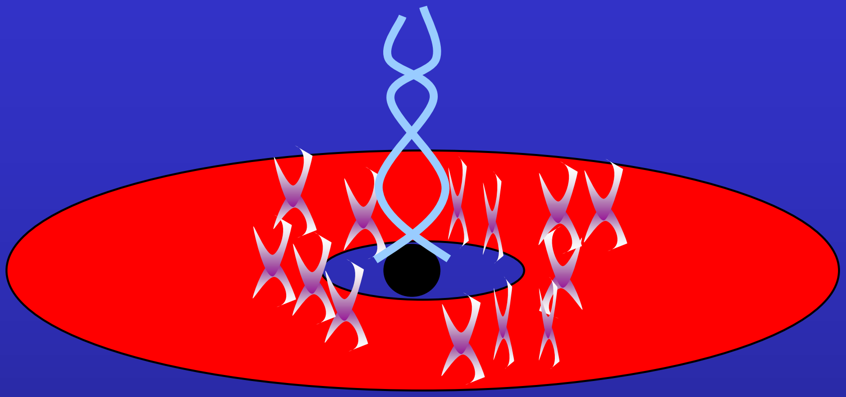
- Jet from large scale height flow collapse of flow=collapse of jet

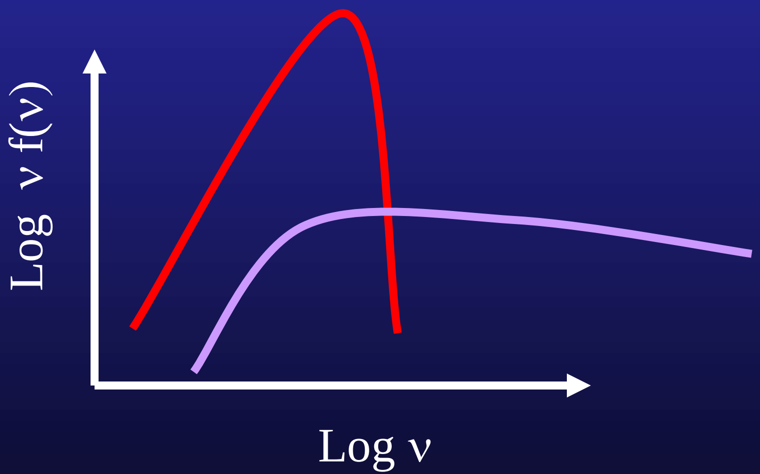




# remnant hot flow over disc

- But always see some tail to high energies
- Some X-ray hot plasma over the disc, probably has large scale height so get small residual jet
- Speculate!!! Jet faster, with smaller opening angle





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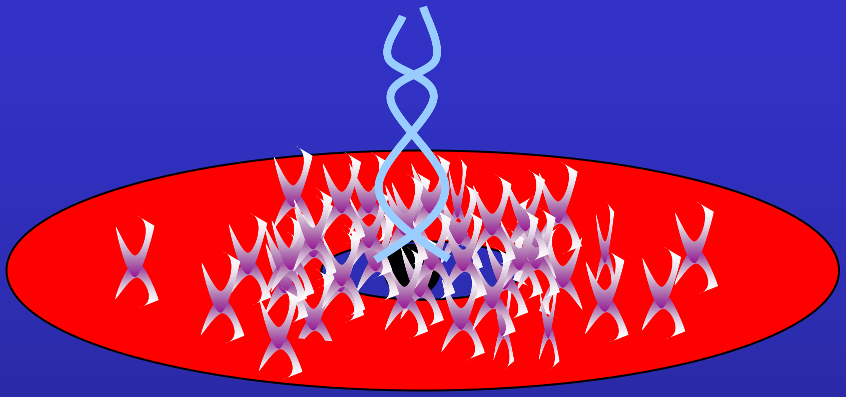
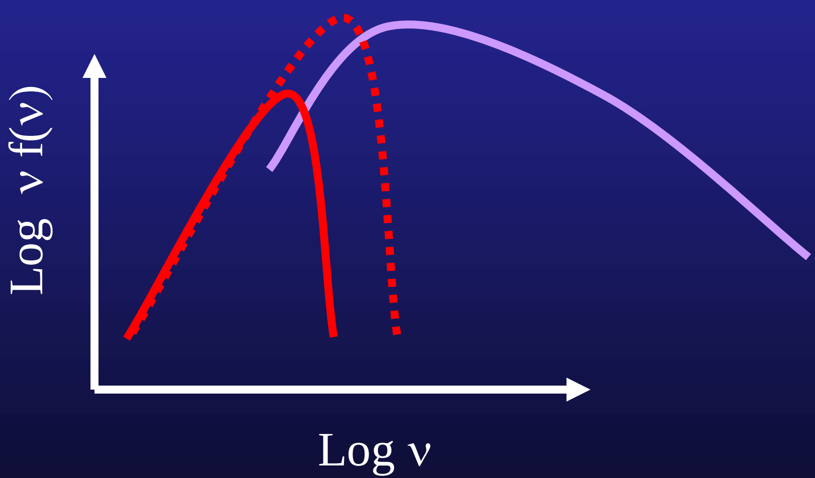
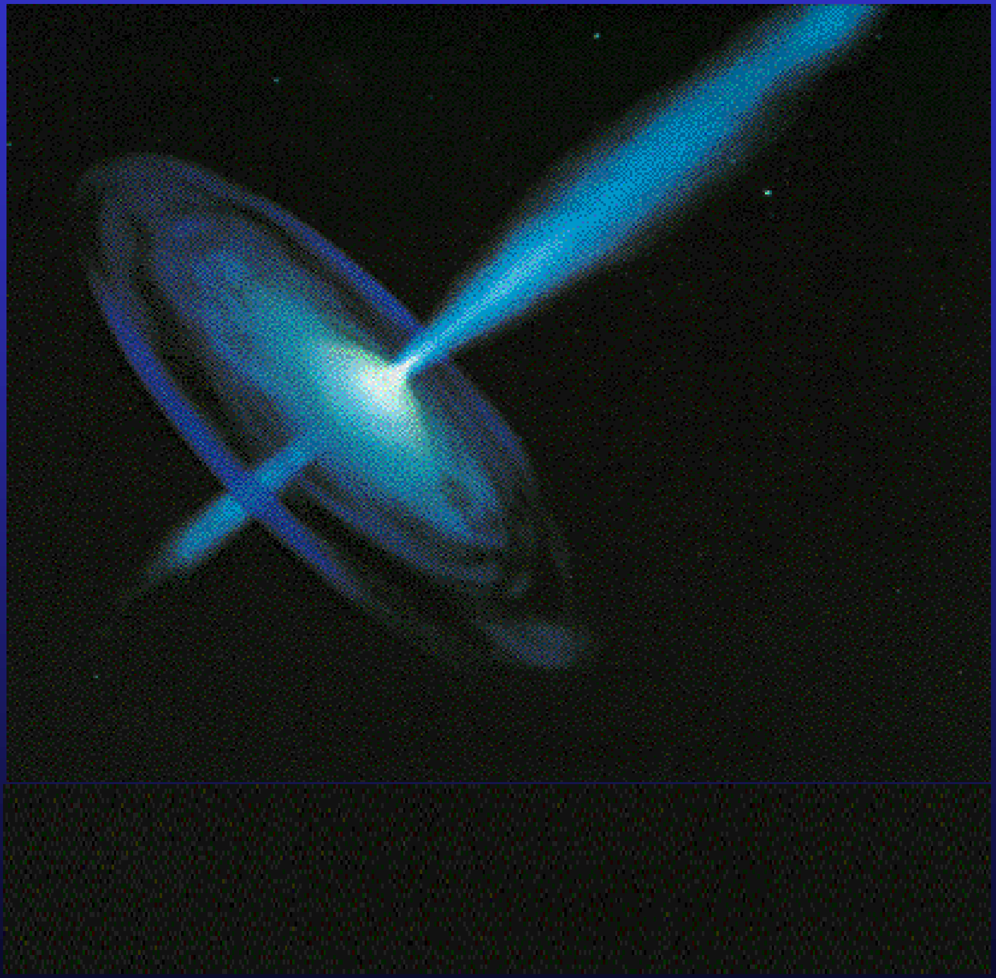


- But always see some tail to high energies
- Magnetic reconnection over disc? Comptonising some of disc flux out into tail
- Tail can be quite large at high L/LEdd, with Lx>Lx(max, ADAF) so THESE (strong disc plus strong tail) have brightest radio emission (GRS1915+104)
- but complicated in BHB as time variability



# Scale up to AGN

- AGN – much more massive so disc in UV



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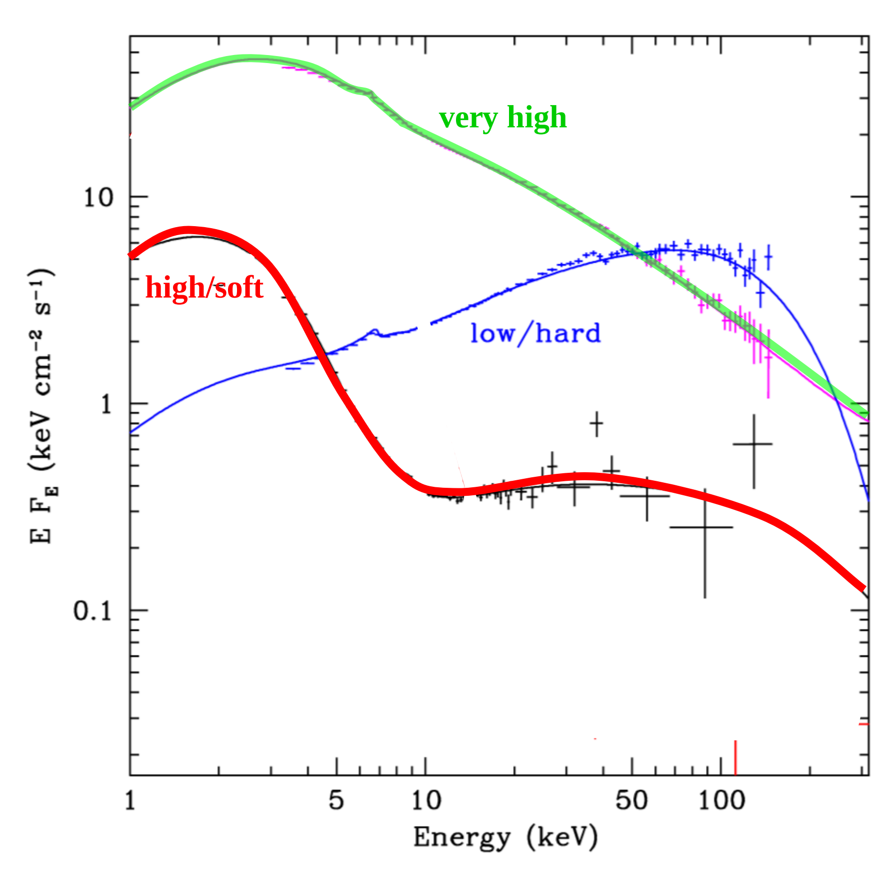
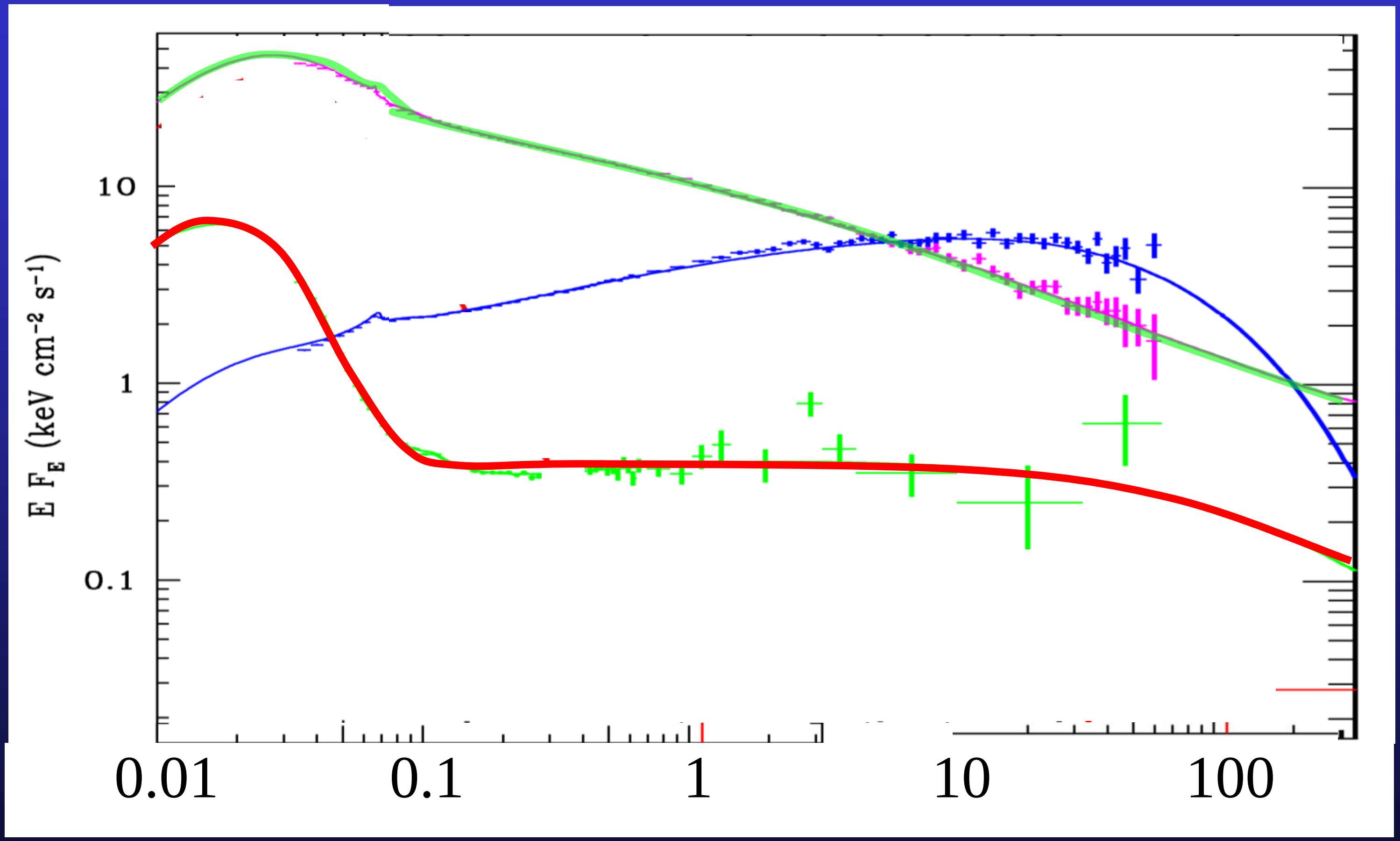



Gierlinski & Done 2003

# ‘Spectral states in AGN’

Disc BELOW X-ray bandpass. Only see tail




Intrinsic differences in spectrum (same M, different L/LEdd)

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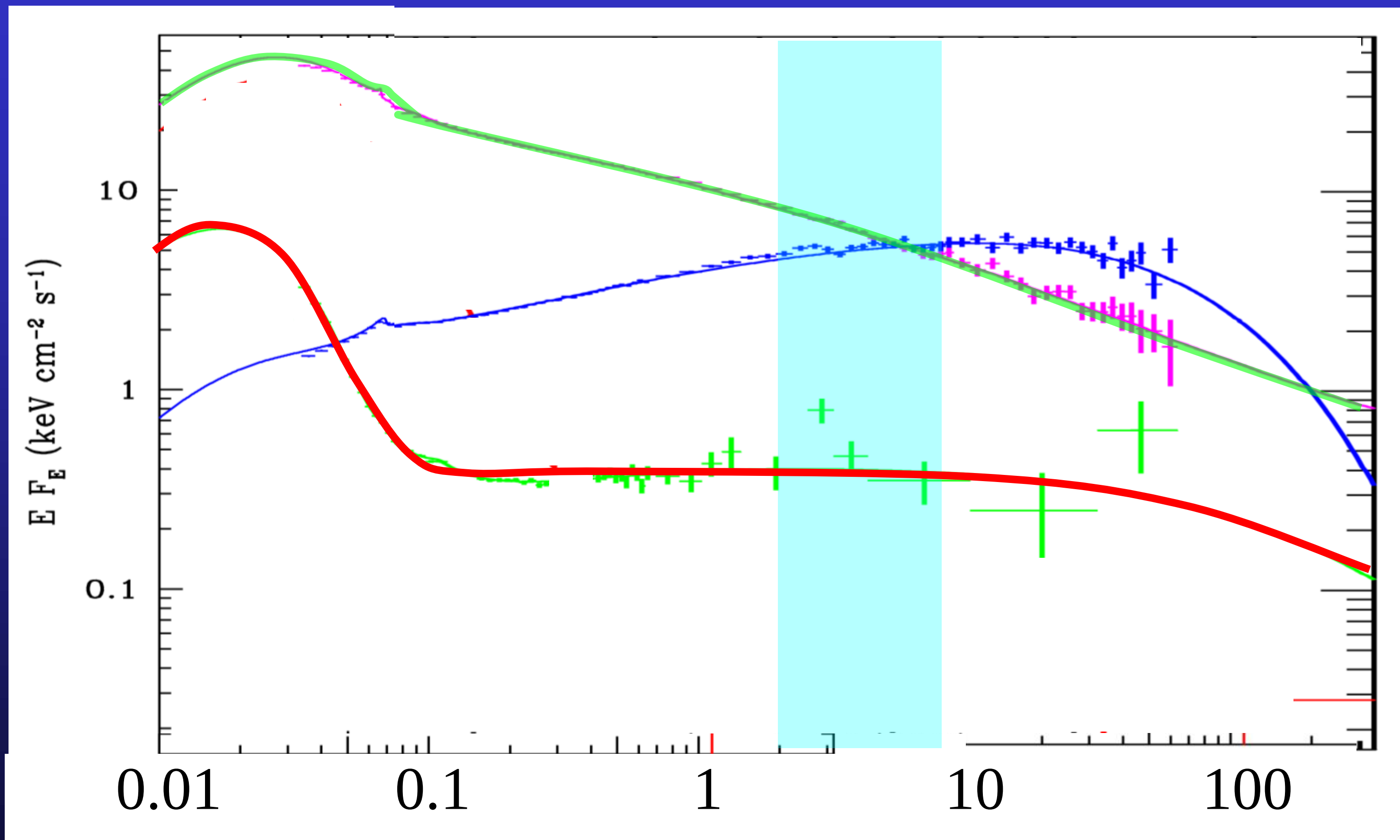
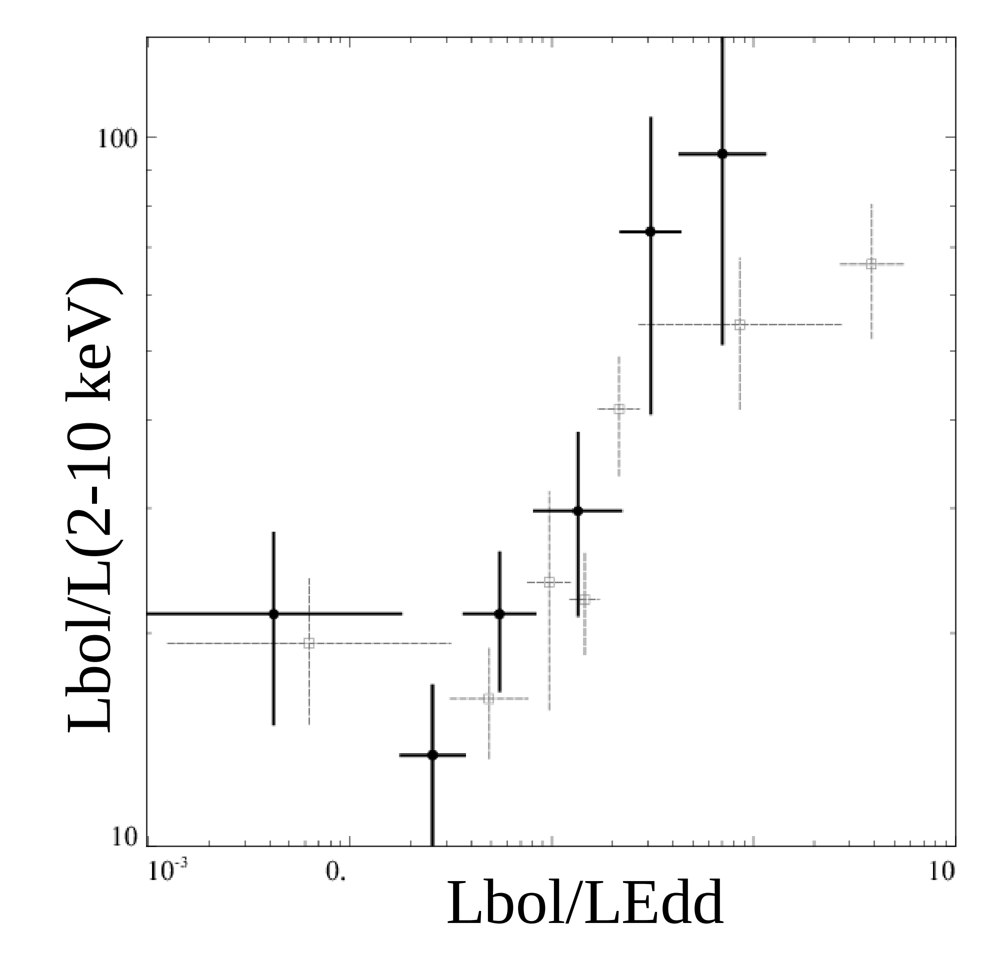



Any evidence for this? L(2-10 keV) / Lbol bigger at low L/LEdd

# AGN spectral states

Vasuvaden & Fabian 2008

- Big change in ratio of Lbol/L(2-10 keV) with Eddington ratio L/LEdd
- Same as the BHB – whatever the stellar mass black holes are doing, AGN do as well!



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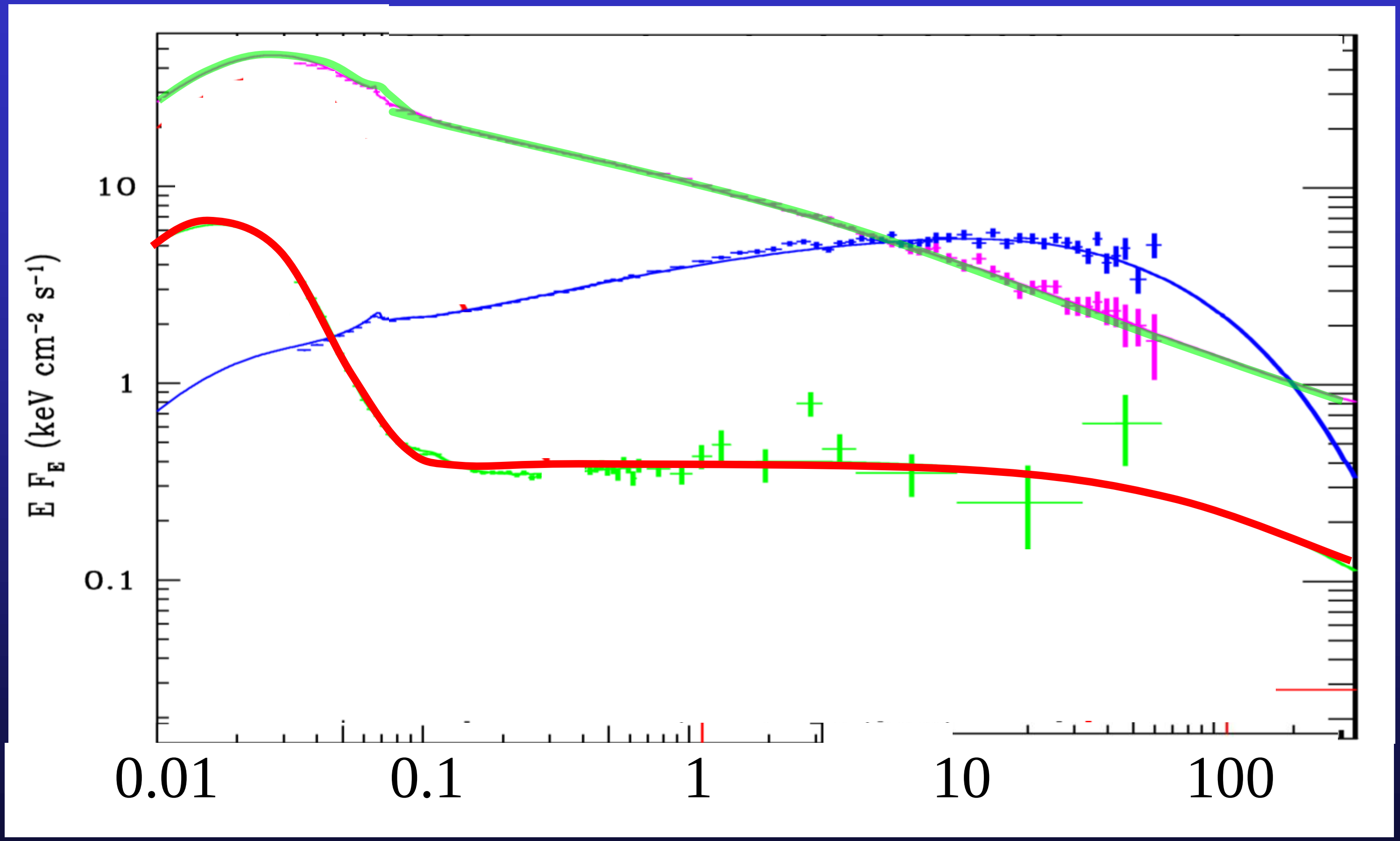



Intrinsic differences in ionising spectrum (same M, different L/LEdd)

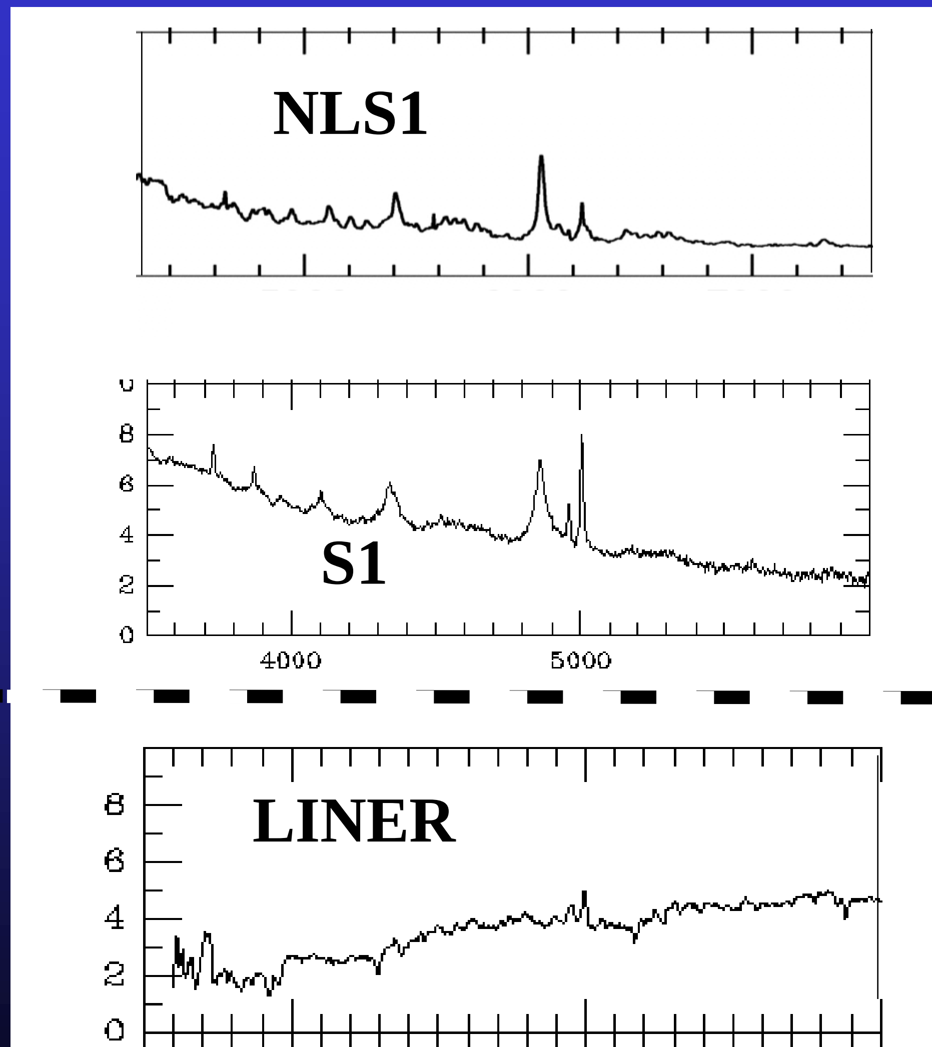
# LINERS-S1-NLS1

Similar mass.
Different $L/L_{Edd}$
Different ionisation

Increasing $L/L_{Edd}$

disc

Hot inner flow, no UV bright disc




Jester 2005; Leighy 2005; kording et al 2007

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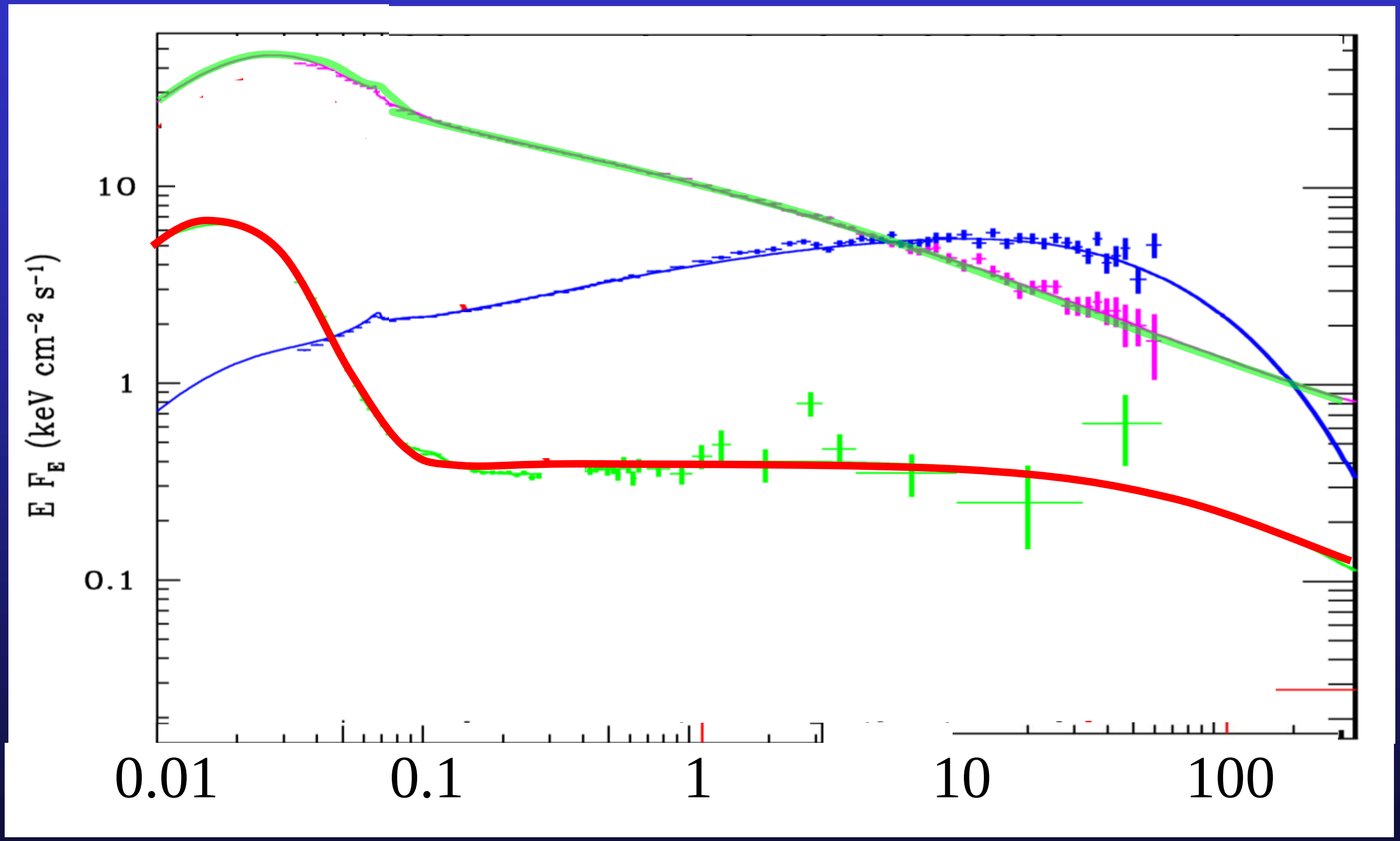


Should also correlate with jet!

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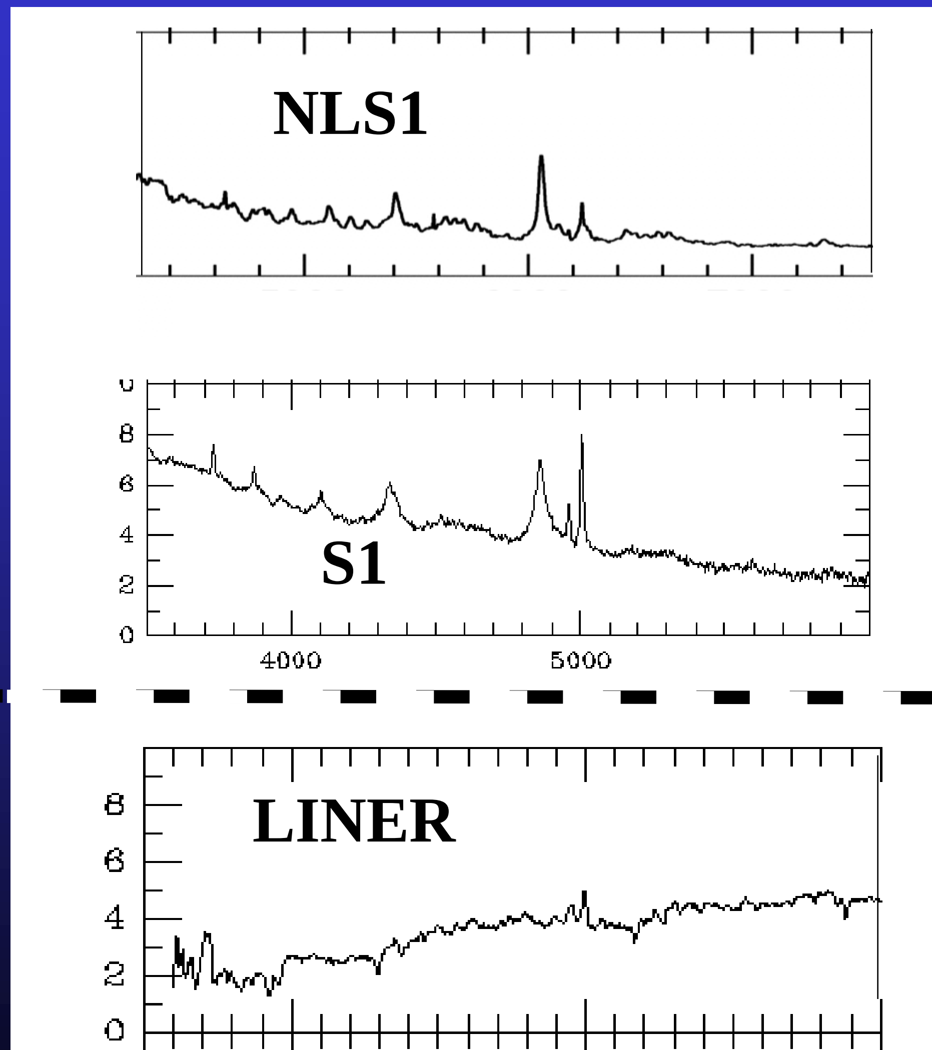



????

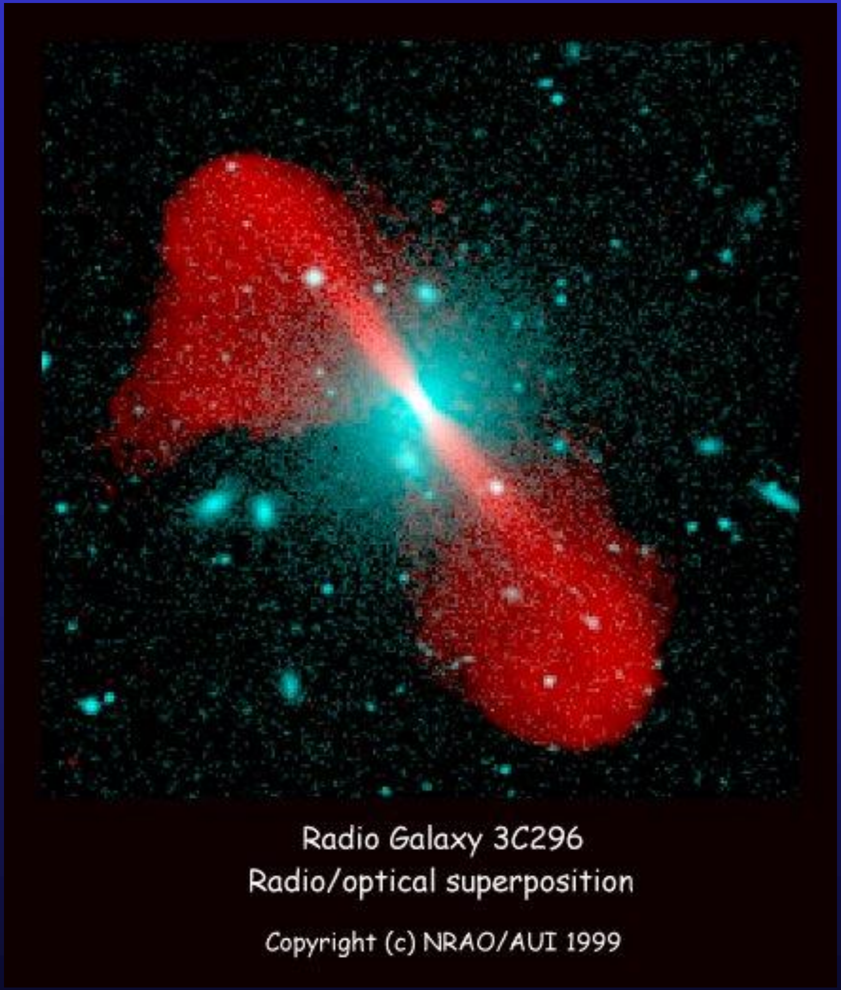
Radio quiet

Radio loudness

Jester 2005; Leighy 2005; Kording et al 2007

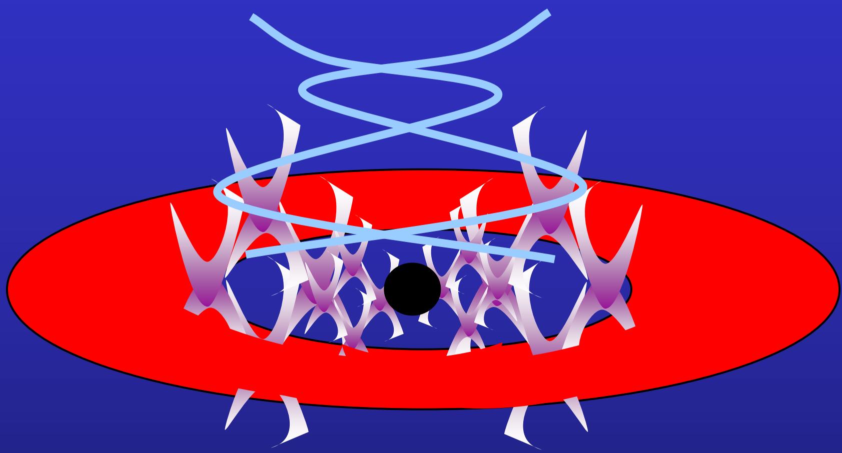
# But what about spin?

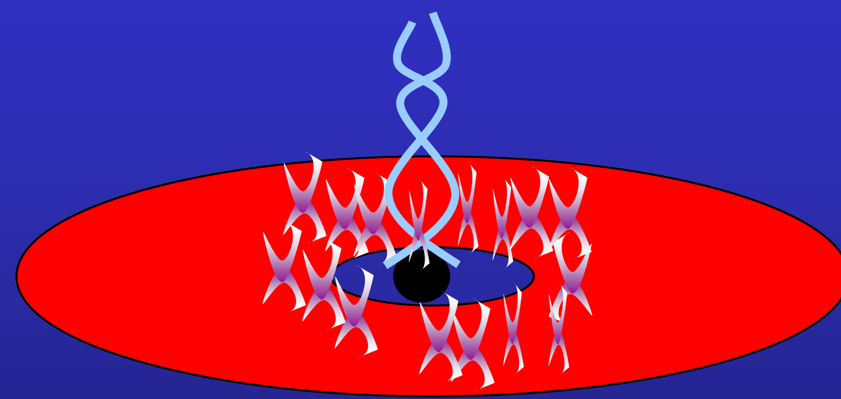
- Is this really enough to explain range in behaviour of radio jets?

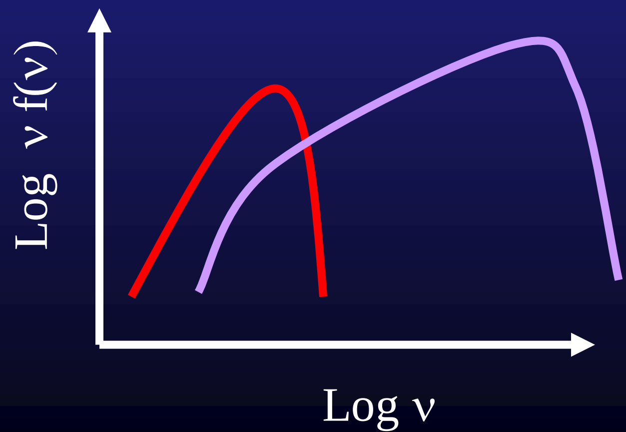


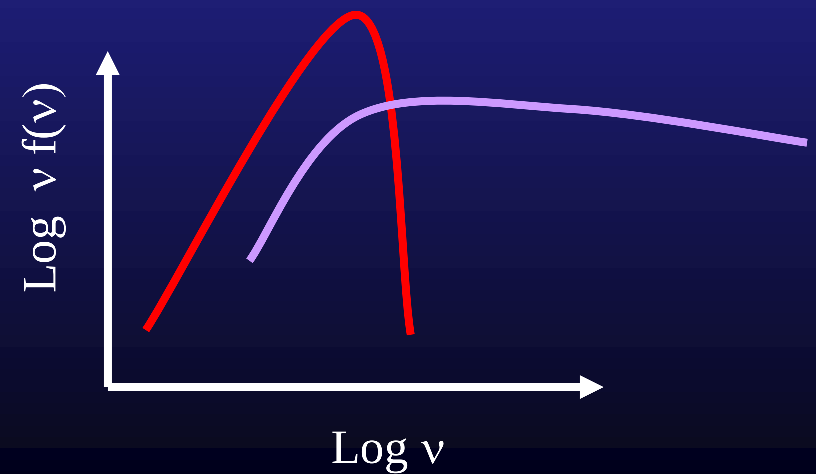
L/Ledd < 0.01 ADAF,
weak disk, low excitation
broader, slower jet, FRI

L/Ledd~1 Disc+tail
strong disk, high excitation
Narrower, faster jet, FRII







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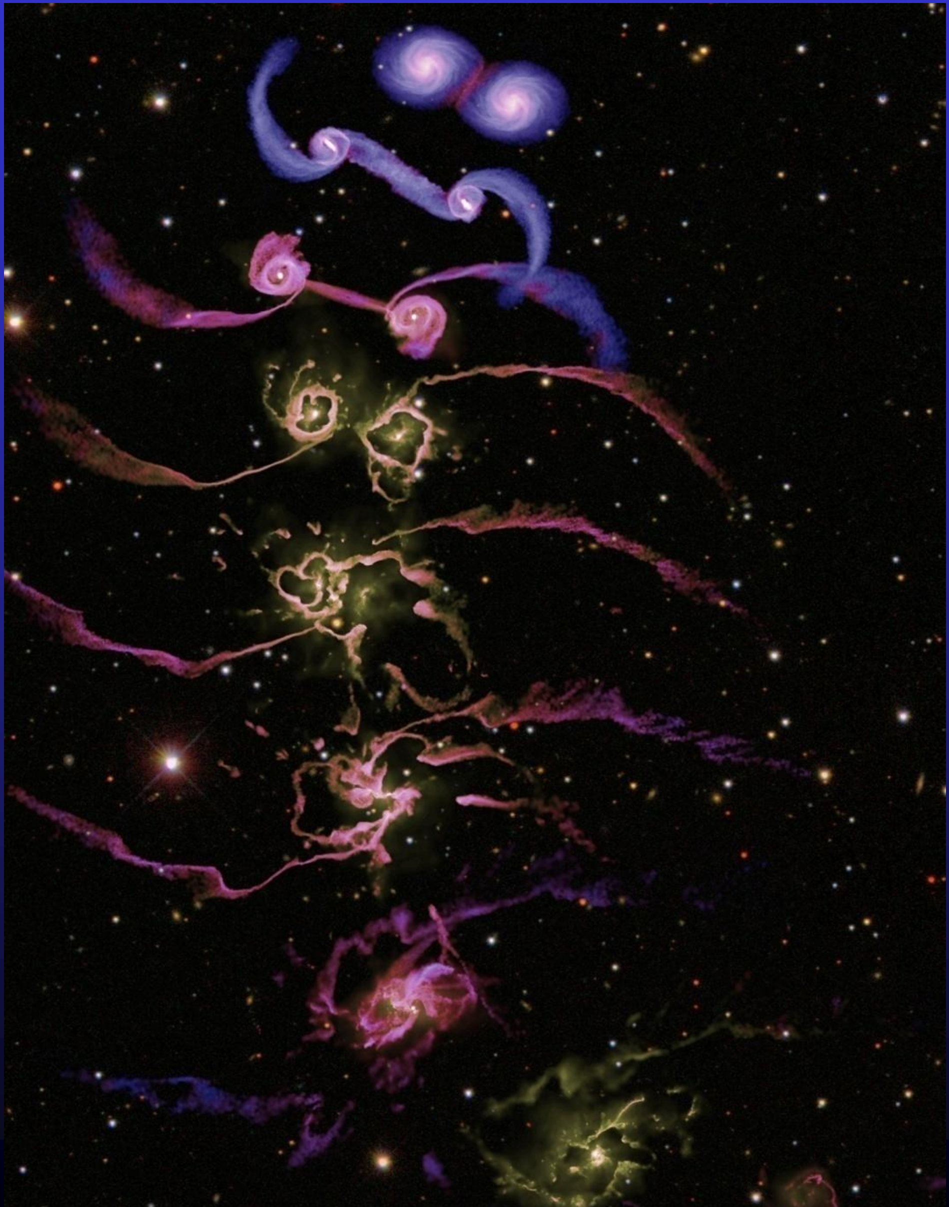
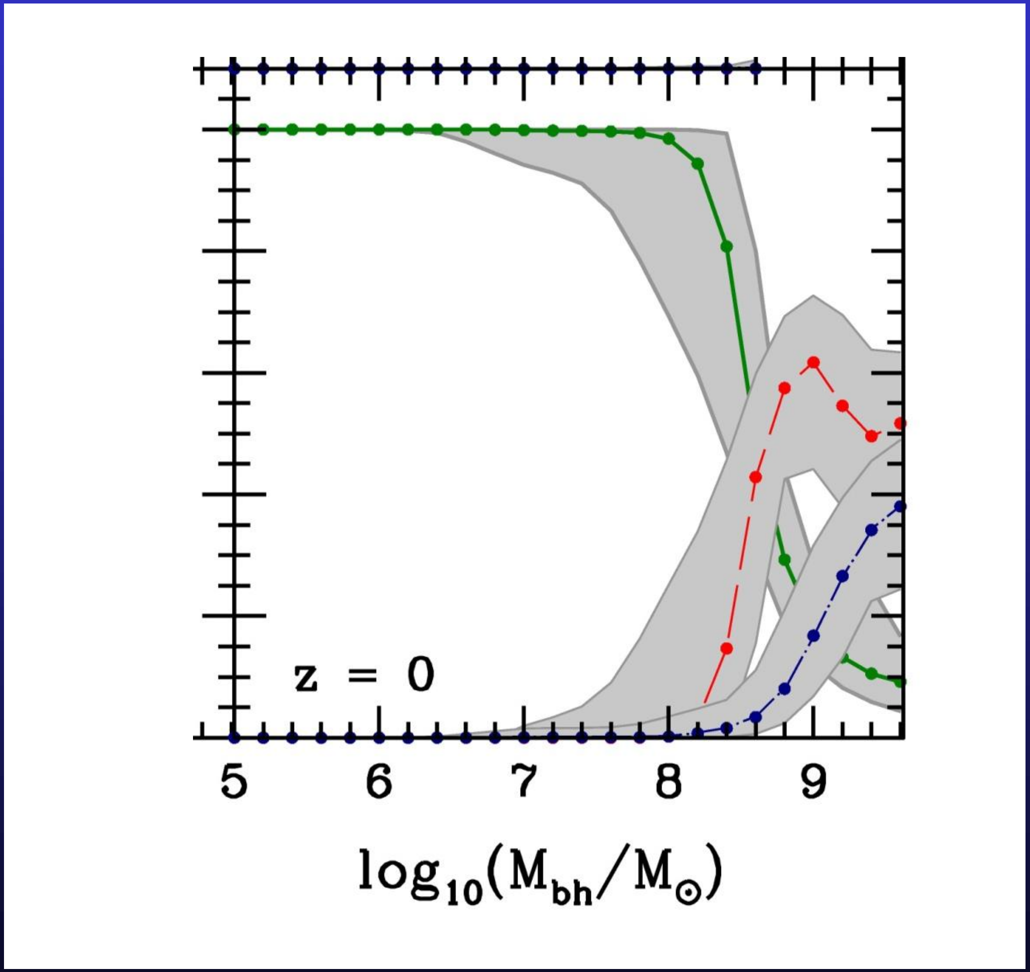


Di Matteo et al 2005

# Black hole mass

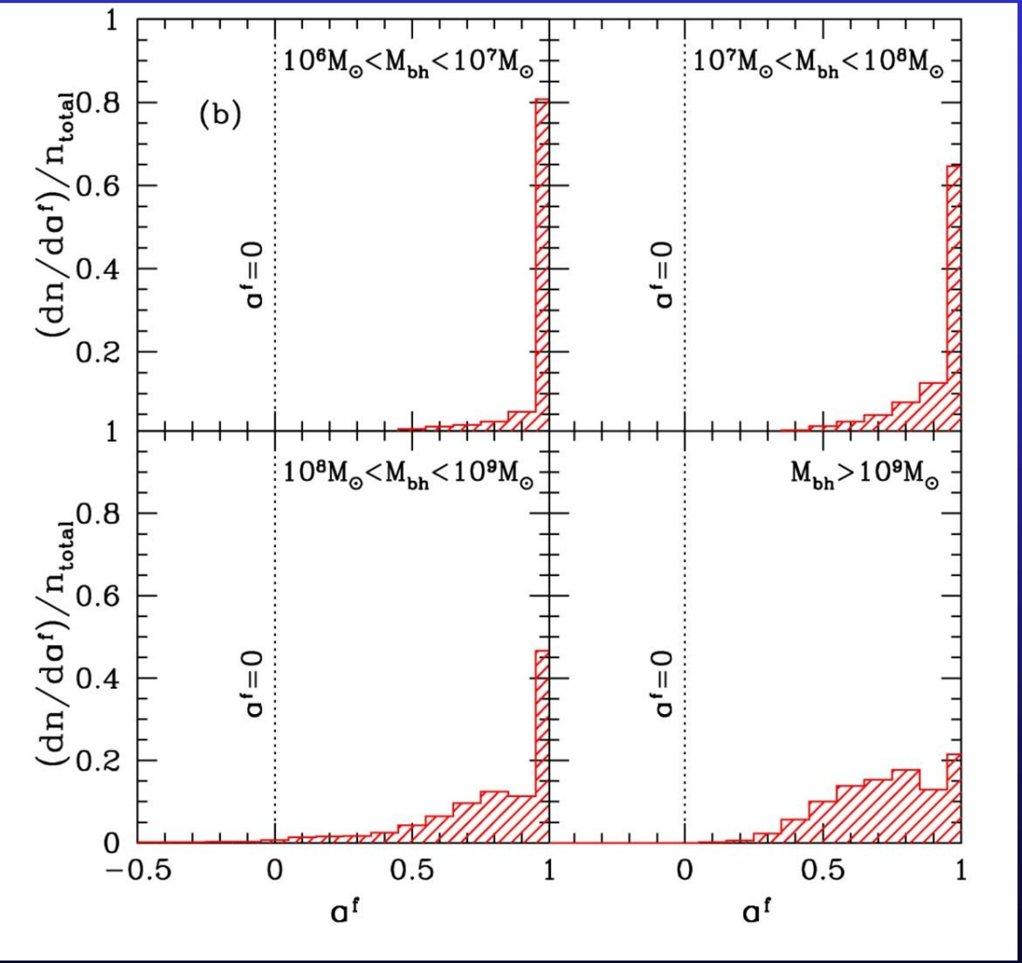
Fanidakis et al 2010

- SMBH grow by gas accretion and BH-BH mergers
- Mergers dominate only highest BH mass (> $10^9$ M) . Spin of 0.7-0.8
- Accretion  (thin disk) dominates for lower mass ($<10^8$ M)
- Accretion (hot flow) never really dominates



# Black hole mass and spin

Fanidakis et al 2010

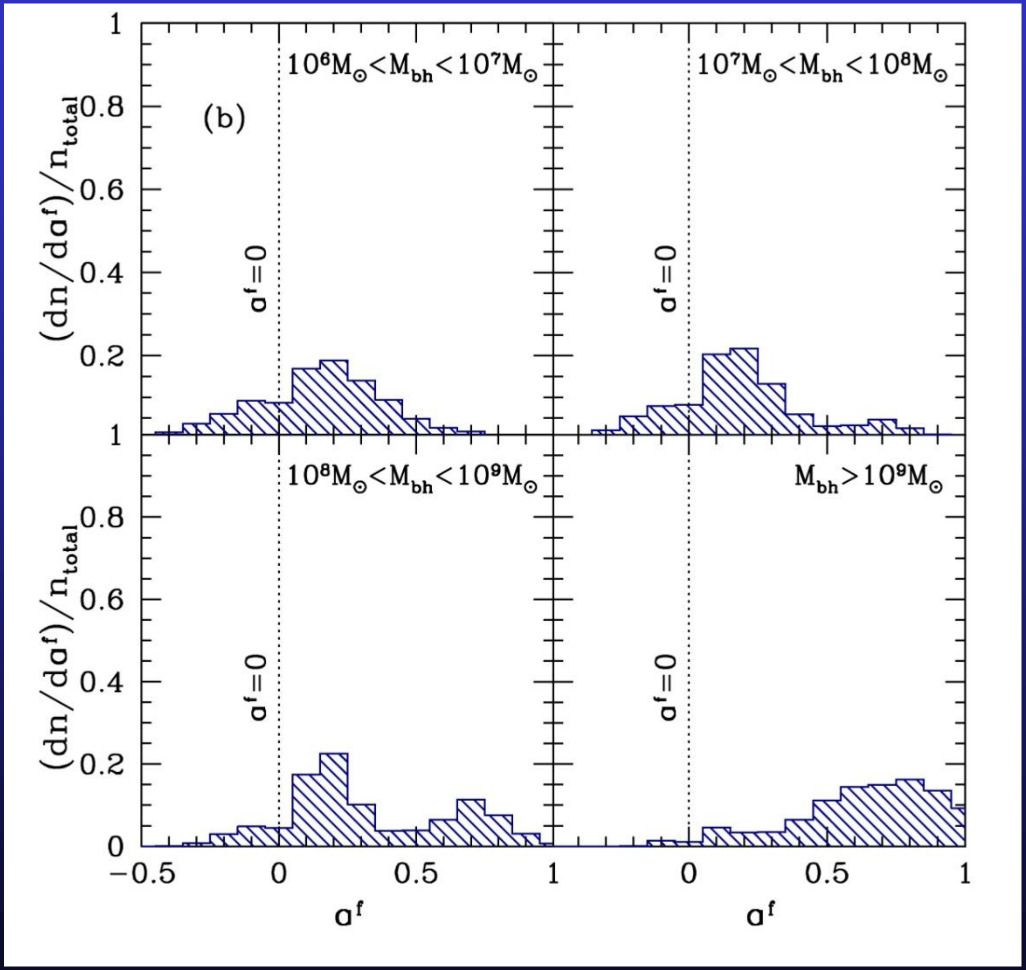



- Prolonged accretion?
- Typical mass available in each accretion episode is > $M_{BH}$ so spin BH up to maximal a ~ 1
- BH – BH mergers spin DOWN the most massive BH to 0.7

# Black hole mass and spin

Fanidakis et al 2010

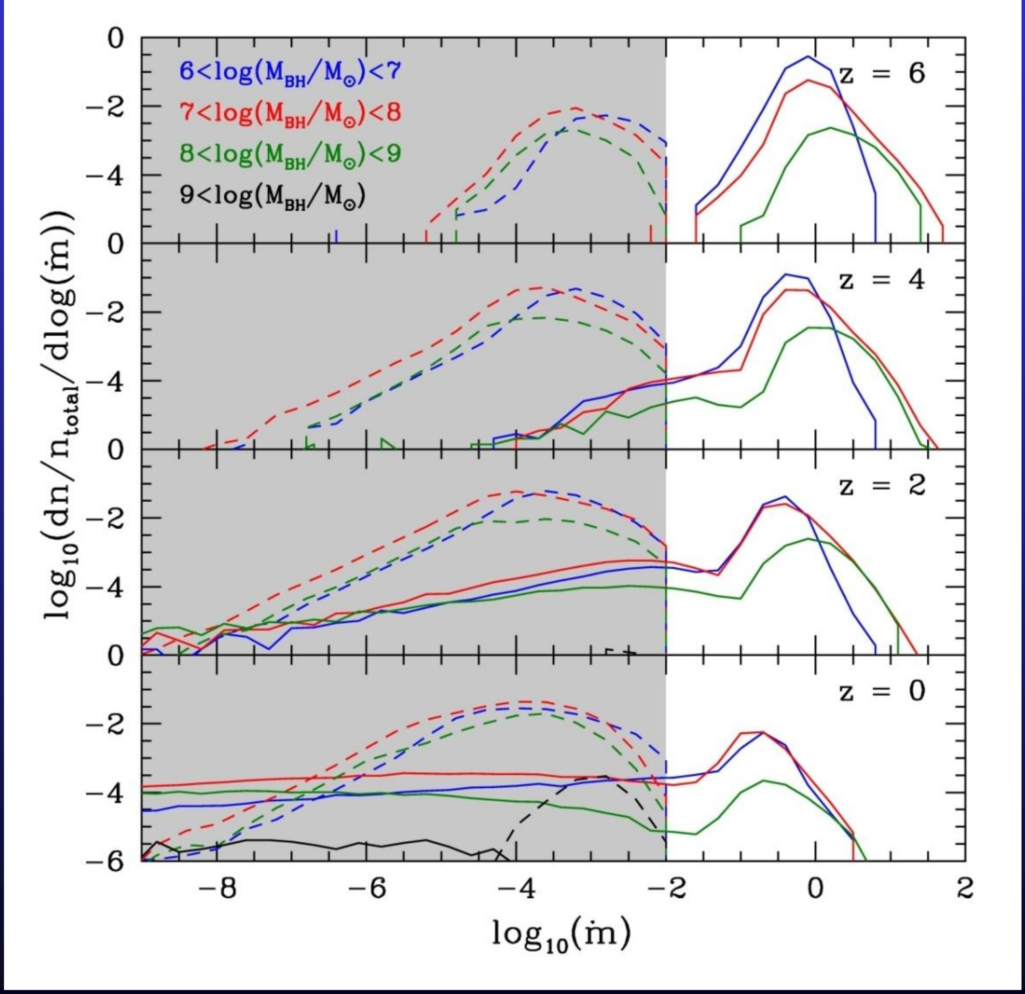
- Chaotic accretion?
- Mass of thin disc limited by self gravity to ~ (H/R) $M_{BH}$ (King et al 2008)
- Each accretion episode splits up into multiple events with randomised direction
- Low spin except for most massive BH where mergers spin UP



# Black hole mass accretion rate

Fanidakis et al 2010

- Now need a prescription to link M and L/Ledd to the jet kinetic power
- And another prescrition to link jet power to radio power (also depends on M and L/Ledd)
- Does it also depend on spin??



# Black hole radio emission??

Fanidakis et al 2010

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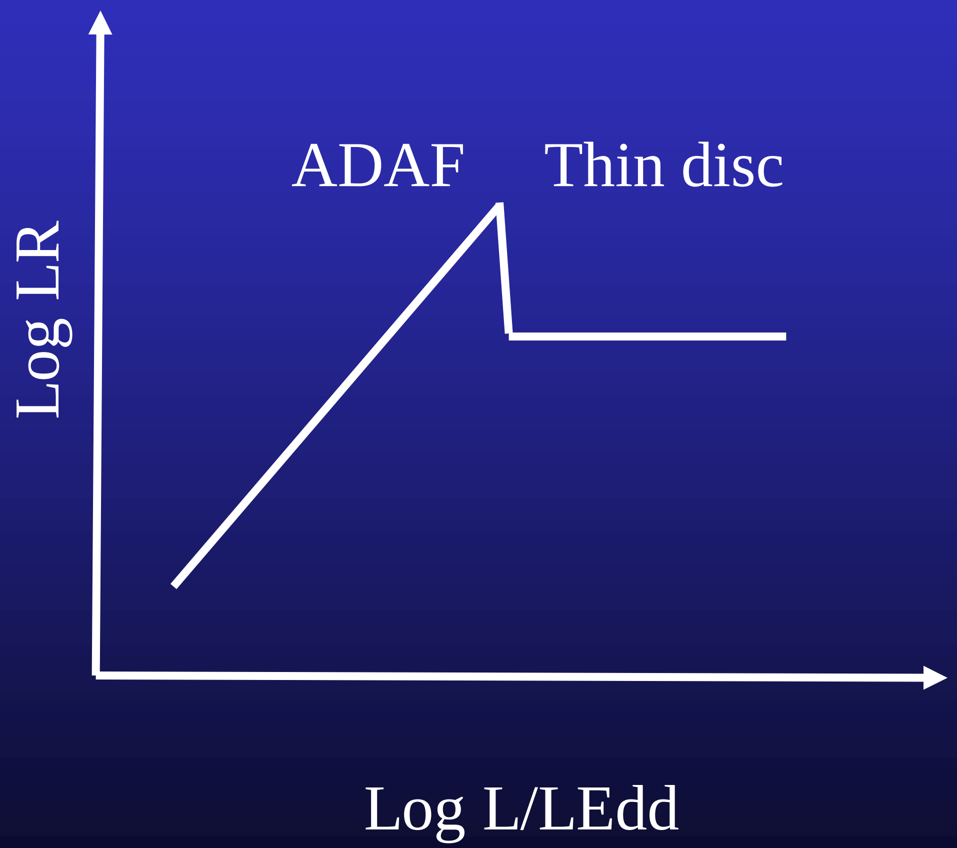
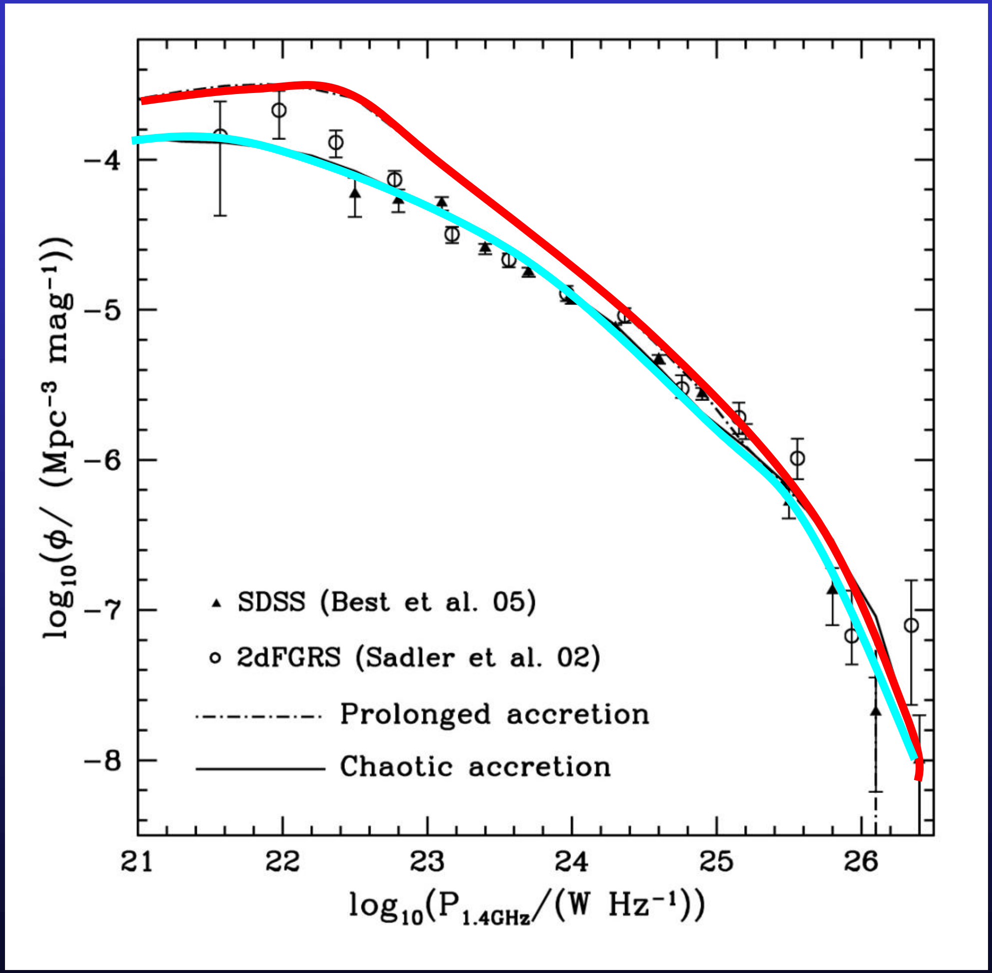


# Radio luminosity function

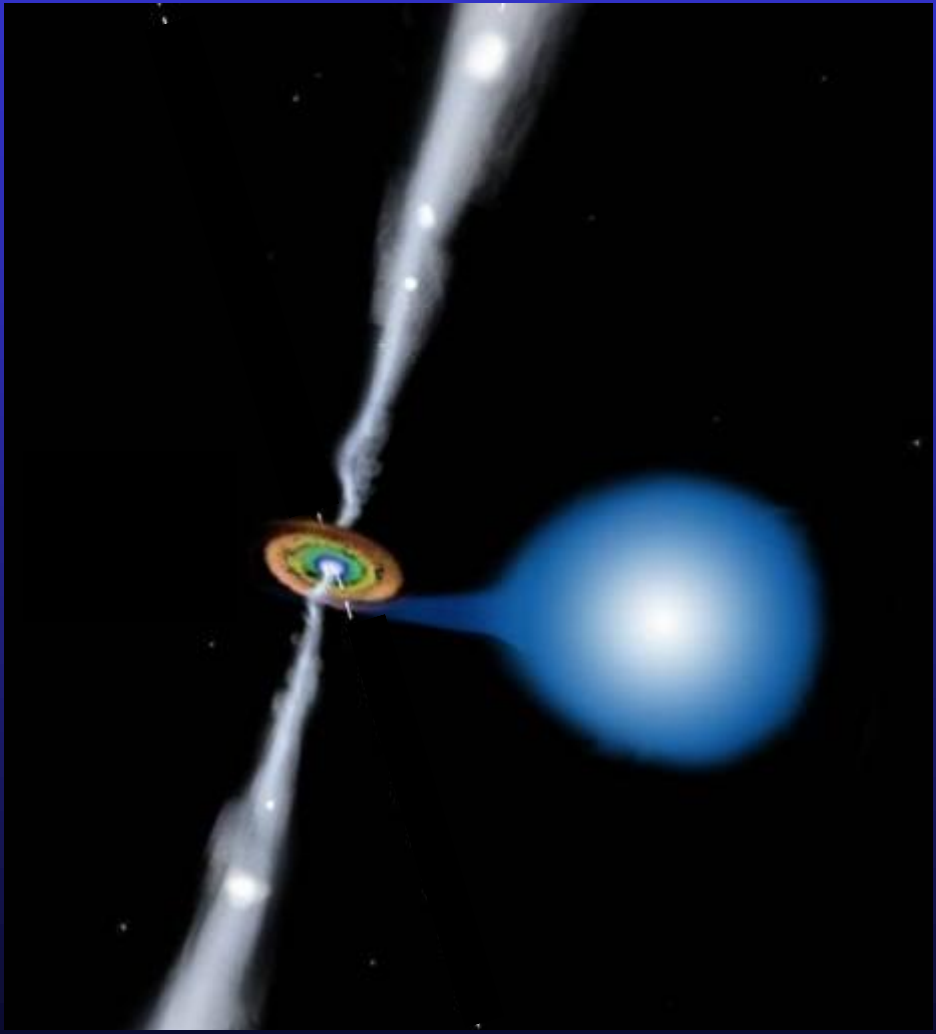
Fanidakis et al 2010

- BZ power $\propto$ $a^2$
- Prolonged model, almost everything has same spin so BZ makes little difference – too many objects at low radio power
- Similar to models with NO dependence of jet power on spin!!
- Chaotic model, low mass BH have lower spin so lower radio compared to higher mass, higher spin



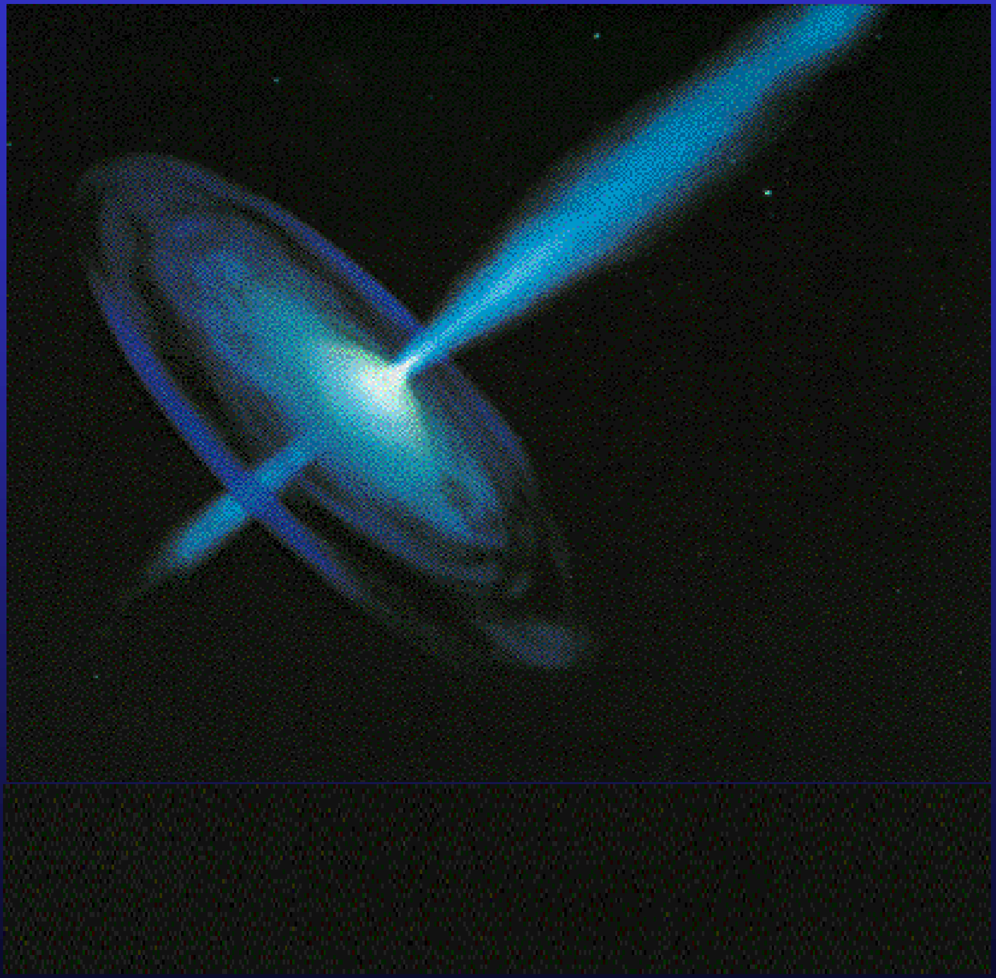
# Environment ??

- Brightest radio jet in BHB is Cyg X-3
- High mass companion star – strong stellar wind
- Jet emerging in much denser environment than in standard low mass x-ray binaries so radiates a bigger fraction of its kinetic energy



# Environment ??

- Brightest radio jets in AGN are in most massive galaxies (Mclure & Dunlop 2005)
- These live in most massive dark matter halos, have the biggest hot gas halos
- Jet emerging in much denser environment than in lower mass systems so radiates a bigger fraction of its kinetic energy



# Conclusions: BHB-AGN

- Use BHB to understand (characterize) accretion
- See disc at high L/Ledd – but always accompanied by tail (high/soft and very high states). Disc probably progressively recedes at L/Ledd<0.01 (low/hard state)
- Scale to AGN and should have different ionising spectra for same M at different $L/L_{Edd}$ – LINERS - S1 - NLS1 as well as standard obscuration dependence S1-S2, and mass dependence S1-QSO
- Should also link to radio jet properties! ADAF jet brightest just before collapse of hot flow (broad – FRI)
- Also when strong disc plus strong tail at close to Eddington (narrow, faster – FRII)
- Environment also determines radio/kinetic!!!