Theory confronts observations AGN

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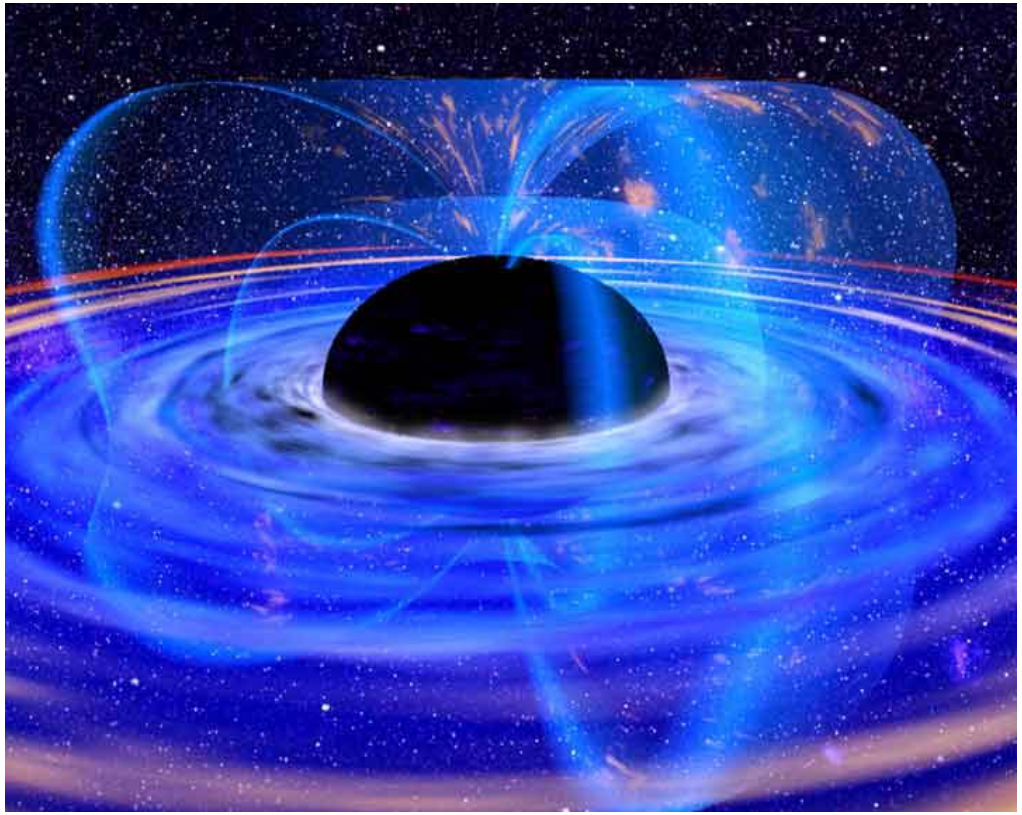
Black hole accretion flows

- Light up regions close to event horizon
- Probe strong gravity if and only if we understand geometry/dynamics of accretion flow!
- AGN feedback
- Radiative GR-MHD - wait 10+ years ?

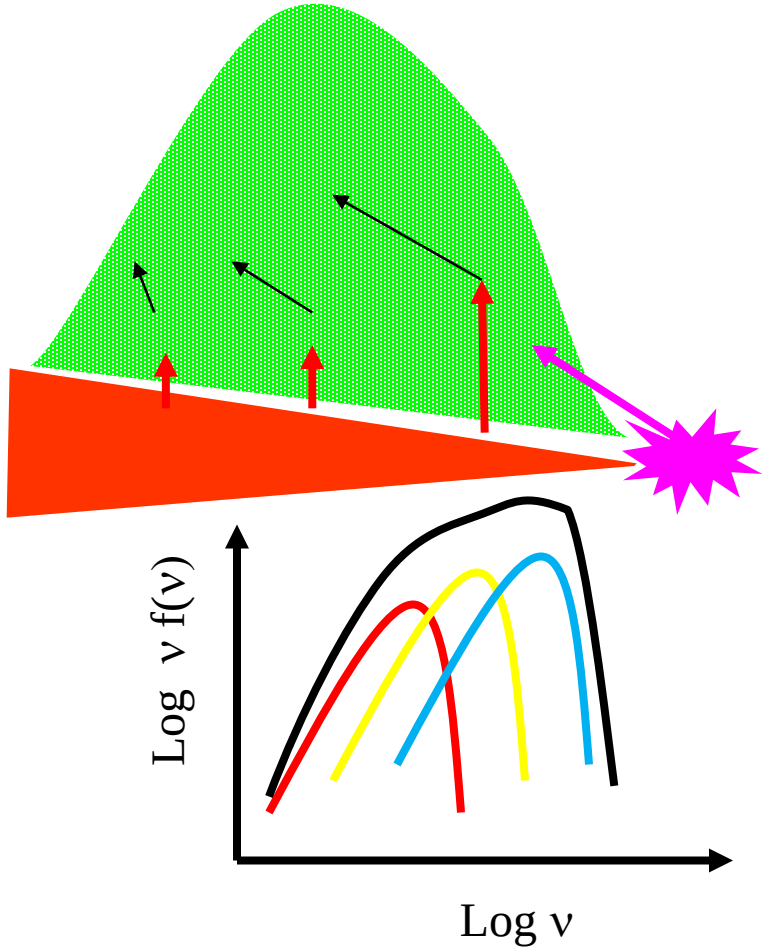


How do we get answers faster?

- Calculate what can be calculated!
- Disc winds – thermal, UV line driven, continuum driven
- Radiative mode AGN feedback
- All depend on SED

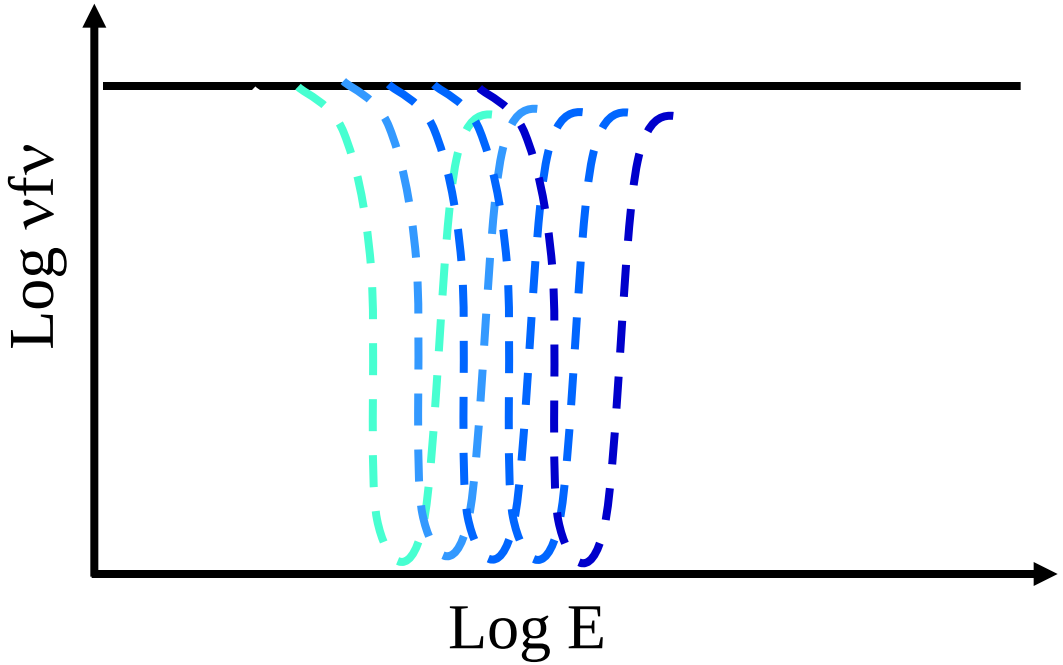
1: Continuum radiation driven Wind

- Effective gravity is balance of gravity and radiation pressure
- $(1- \tau/\tau_{es}\, L/L_{Edd})\ GM/R^2$
- If just electron scattering $L = L_{edd}$ gives continuum driven wind
- Exceeds L_{edd} in central regions of disc first so wind from inner disc!



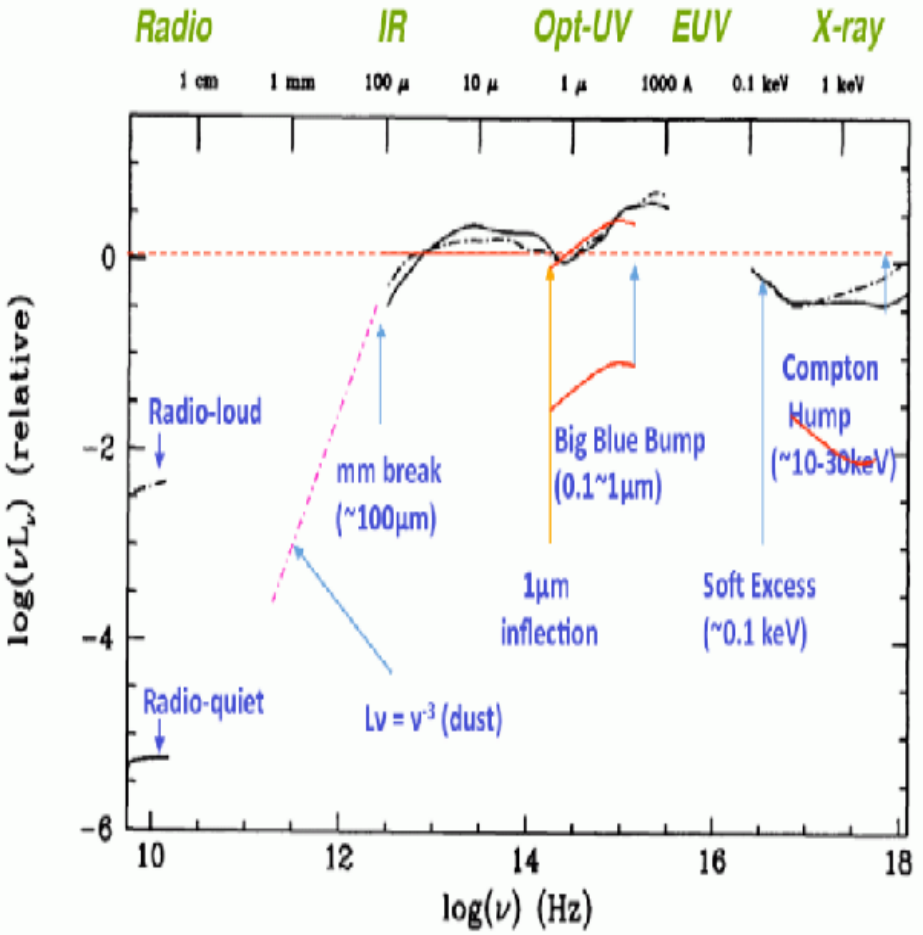
2: UV line driven Winds ?

- If substantial opacity: $\tau >> \tau_{es}$ so gravity $(1- \tau/\tau_{es}\ L/L_{Edd})\ GM/R^2$
- Most opacity in UV resonance lines
- Momentum absorbed in line accelerates wind so more momentum absorbed in line - UV line driving at $L << L_{Edd}$



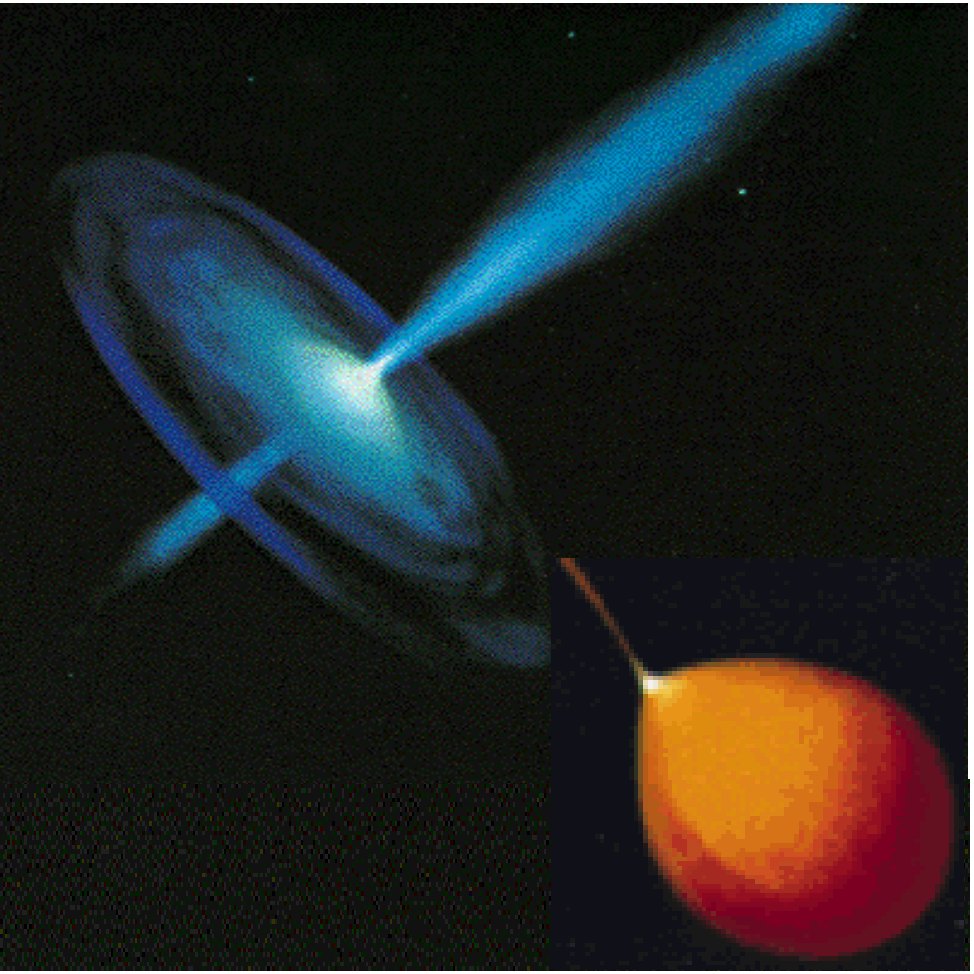
How do we get answers faster?

- Continuum SED – should depend on mass, mass accretion rate and spin!
- Complex – so scale up from binaries!
- Can we use the same physics for stellar and supermassive?

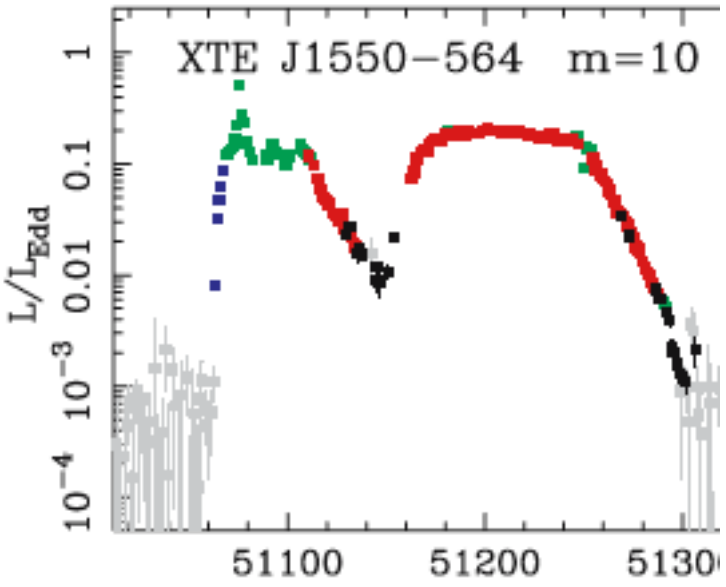


Elvis et al. 1994, ApJS, 95, 1

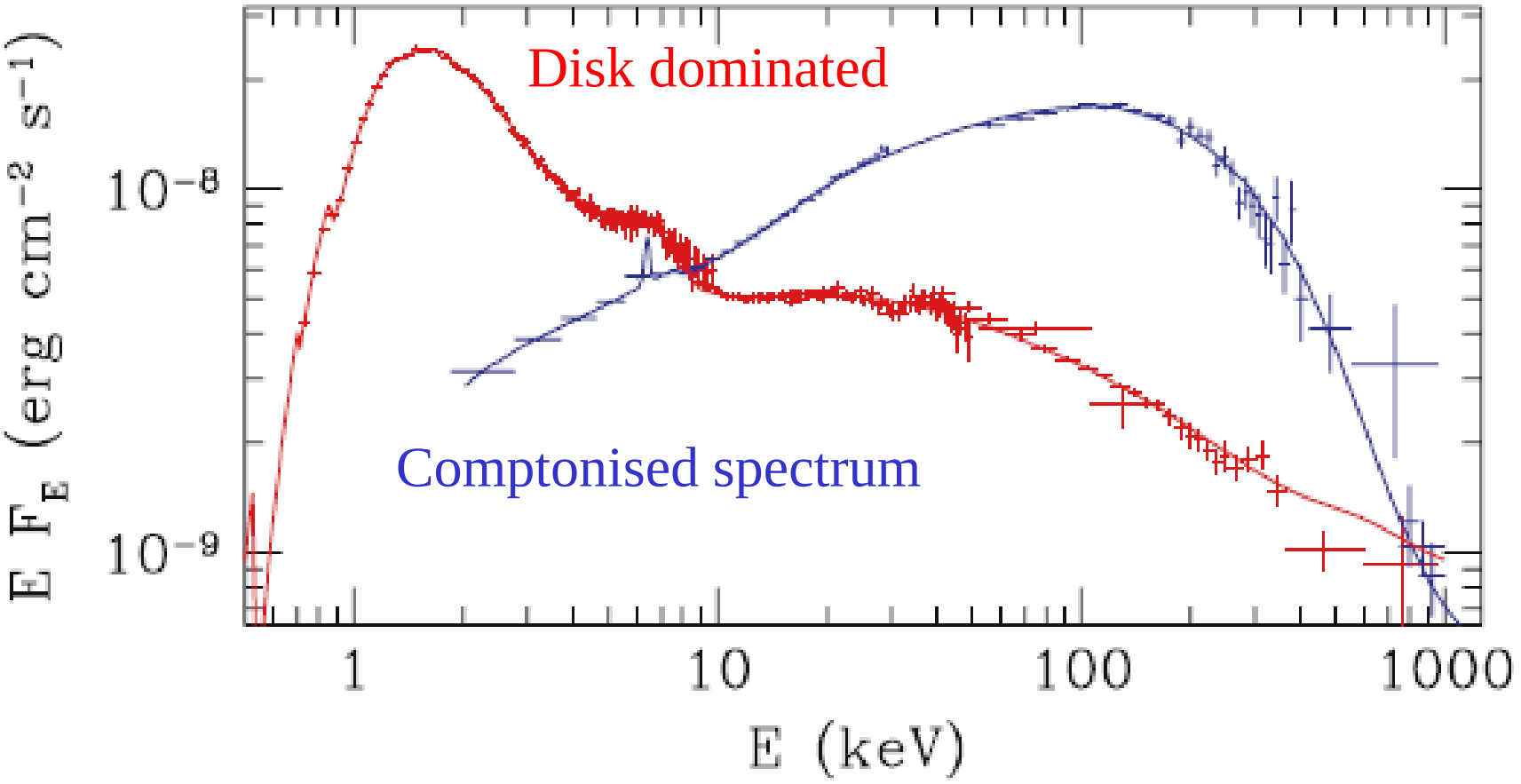
Understand the accretion flow: BHB



- Mass accretion rate onto central object changes in real time! Days-weeks-months

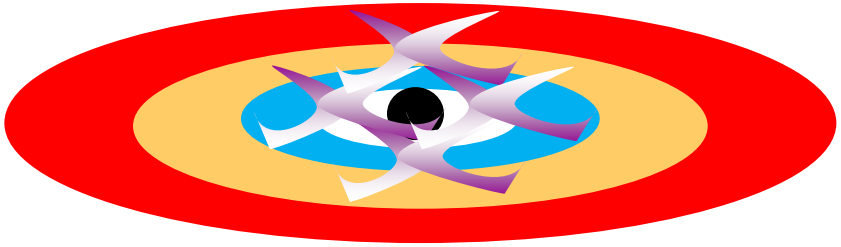


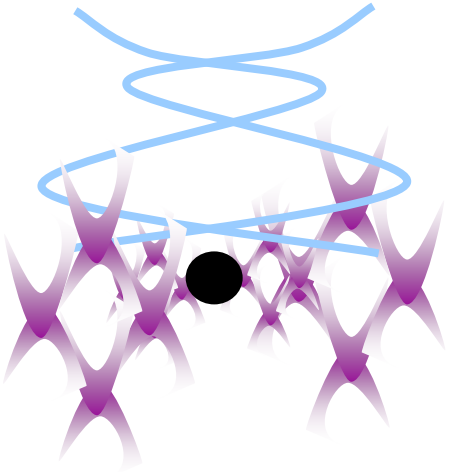
Spectral transitions in BHB



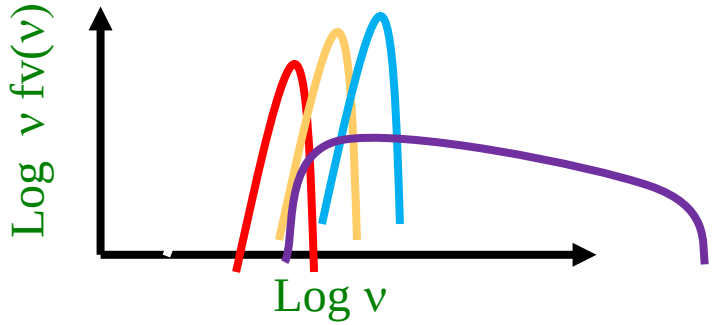
Gierlinski et al 1999

Theory of accretion flows



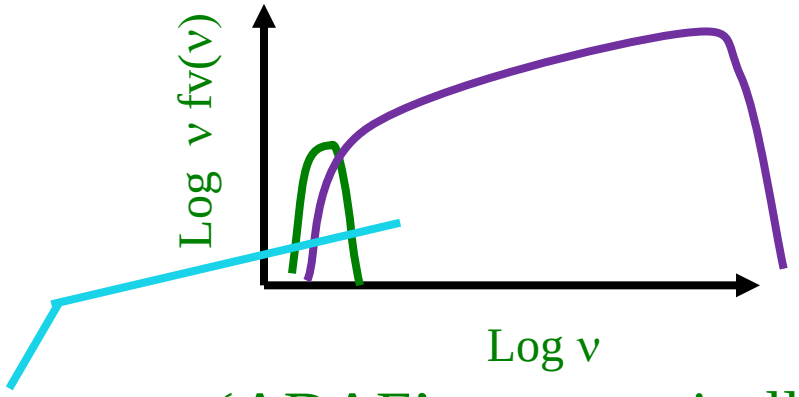


IR opt UV X-ray



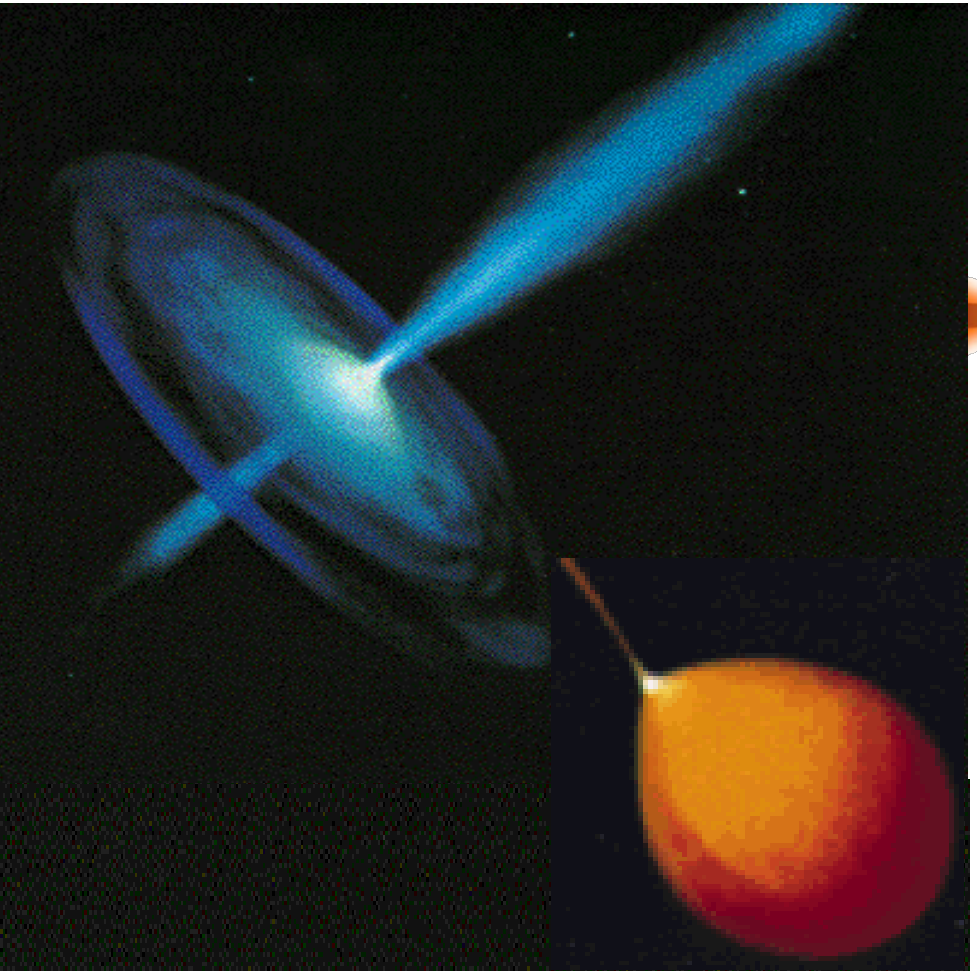
Discs – geometrically thin, cool, optically thick
Winds – thermal/Eddington

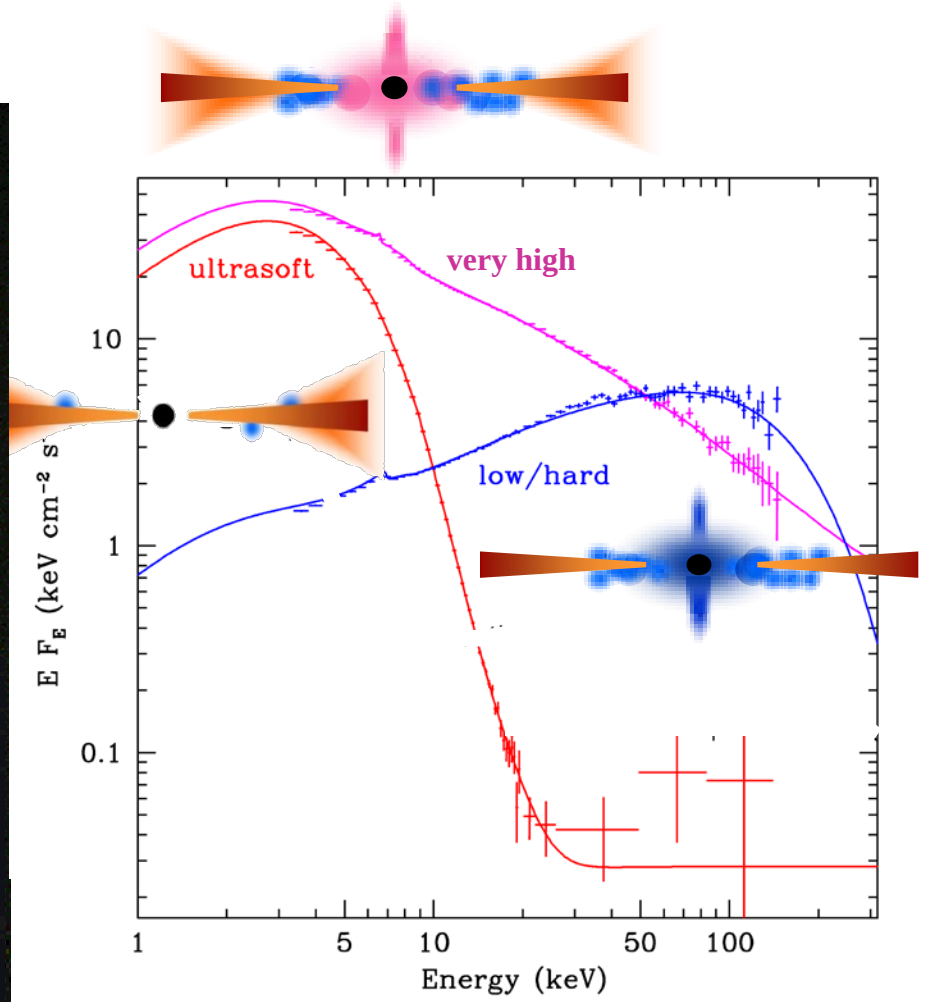
Radio IR opt UV X-ray



'ADAF'– geometrically thick, hot, optically thin
Only low L/Ledd + jet Γ<2

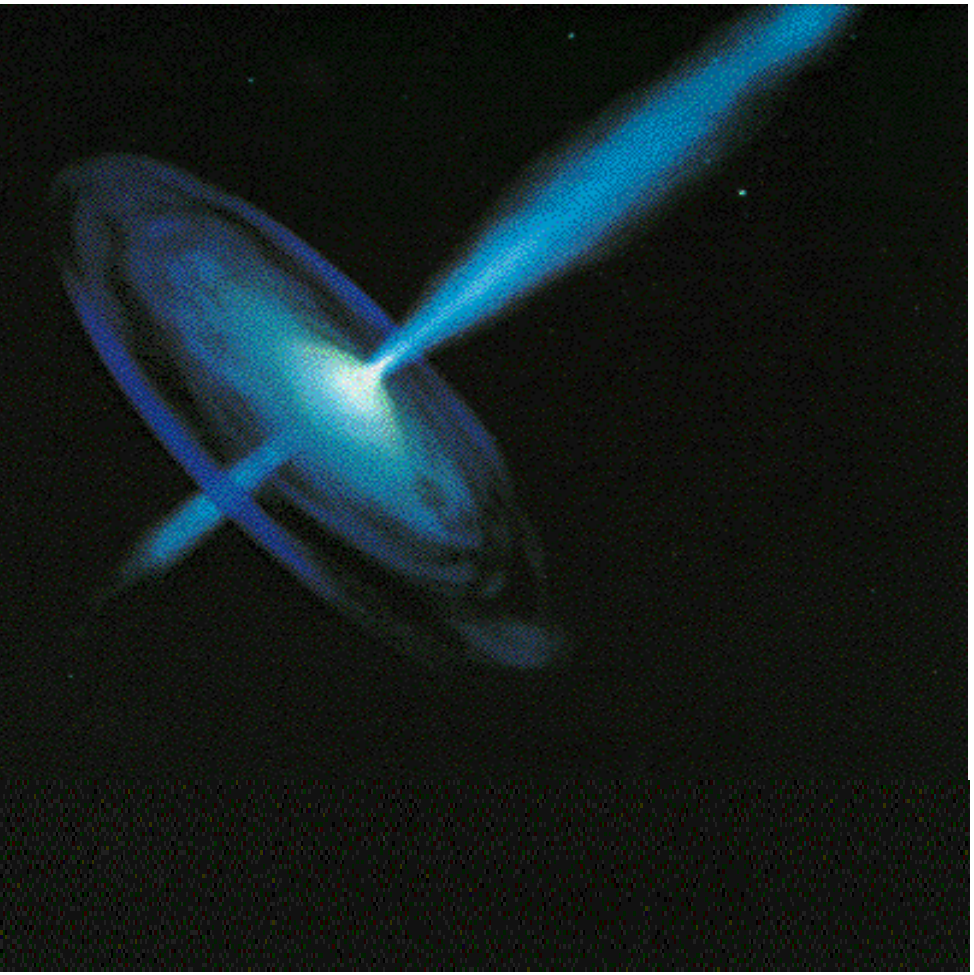
BHB: mass accretion rate L/LEdd





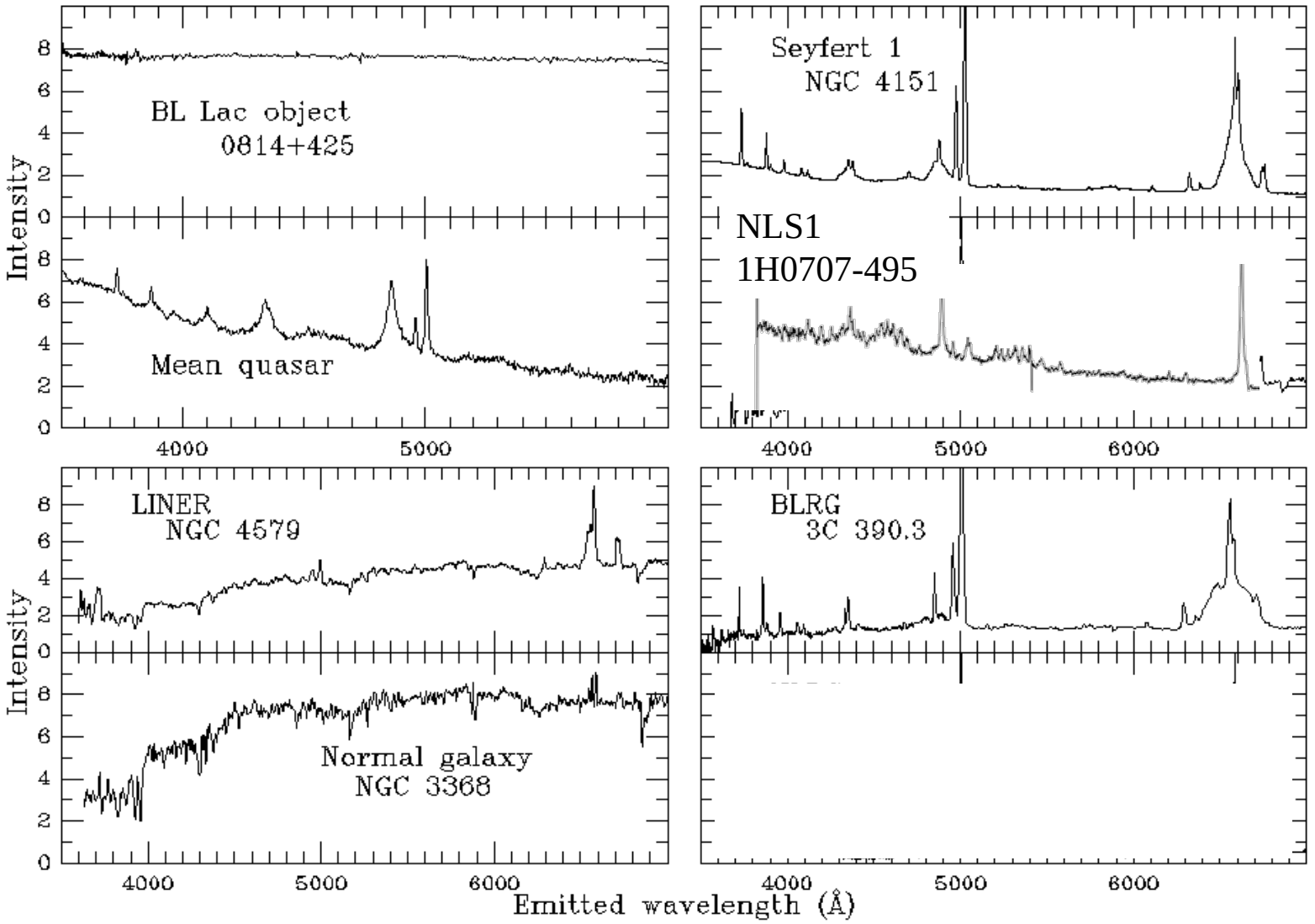
Gierlinski & Done 2003

Scaling black hole accretion flow



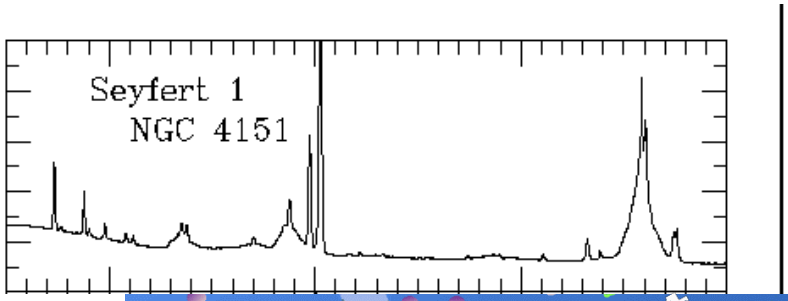
- Scale up to AGN
- Bigger mass!
- Disc temp lower – peaks in UV (more power, but more area!)
- ATOMIC PHYSICS
- Larger RANGE in mass –from 10^5-10^{10}M
- And maybe bigger range in spin??
- NOT SINGLE PARAMETER FAMILY – L, L/LEdd

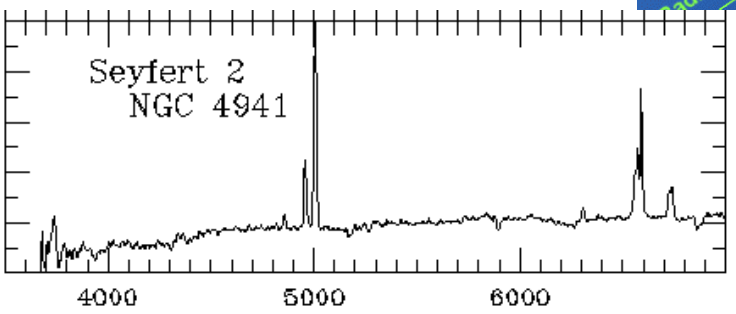
AGN/QSO Zoo!!! Optical

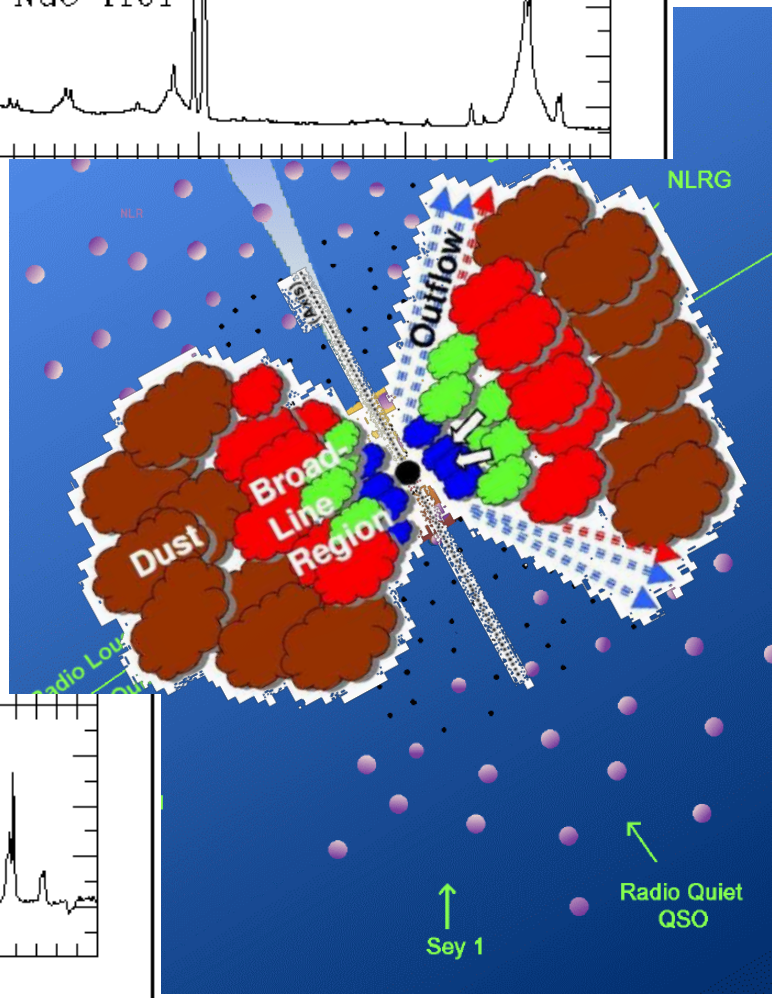


And Inclination

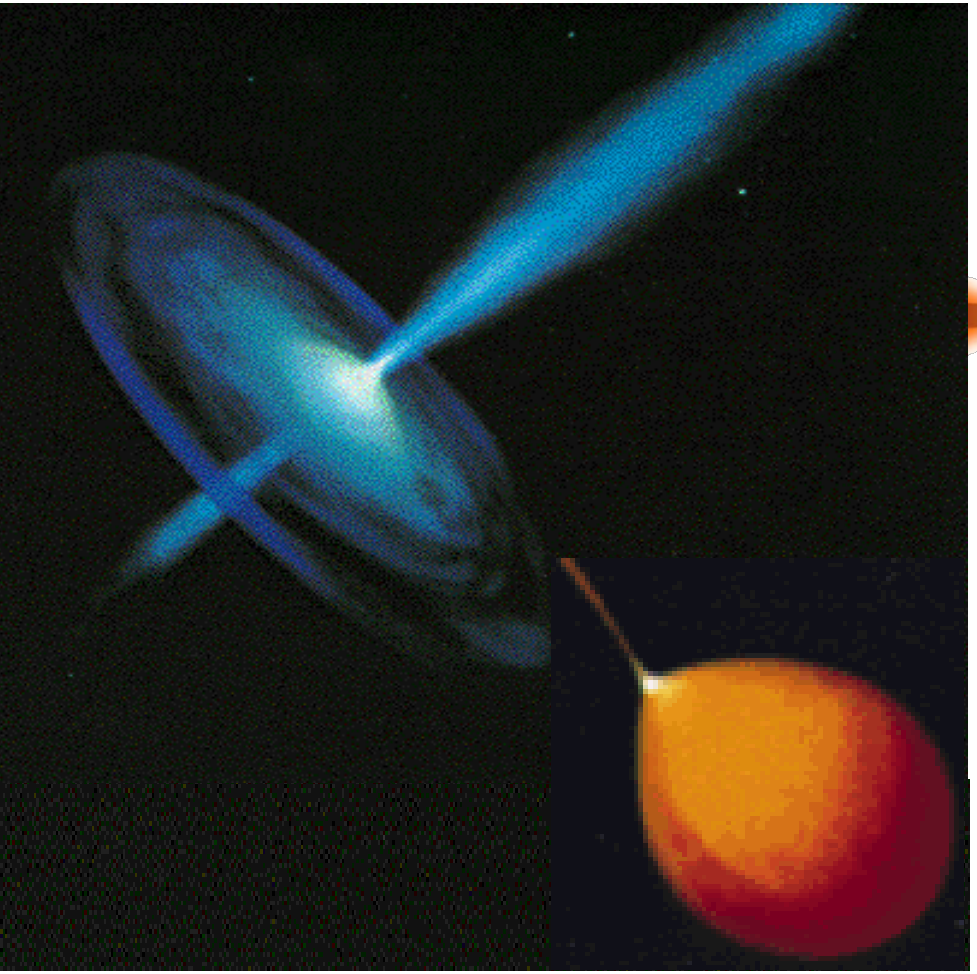
- AGN: complex environment
- From now on take only UNOBSCURED AGN

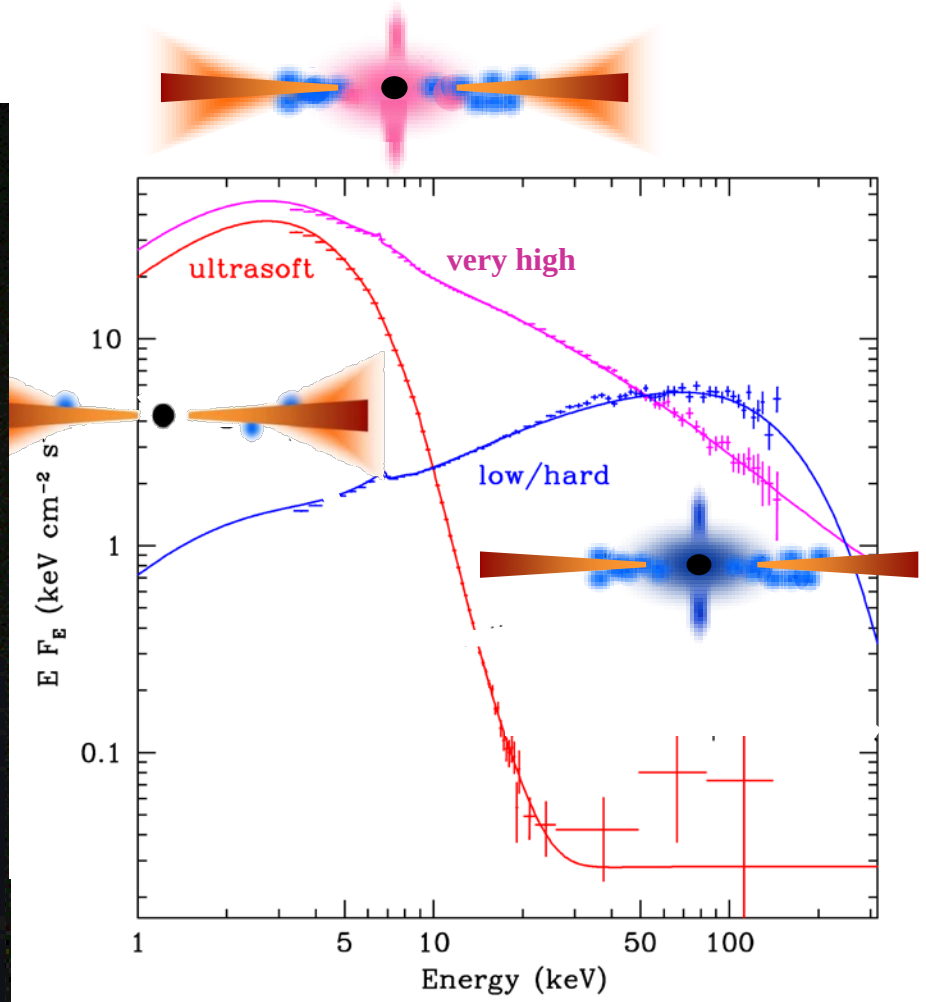






BHB: mass accretion rate L/LEdd

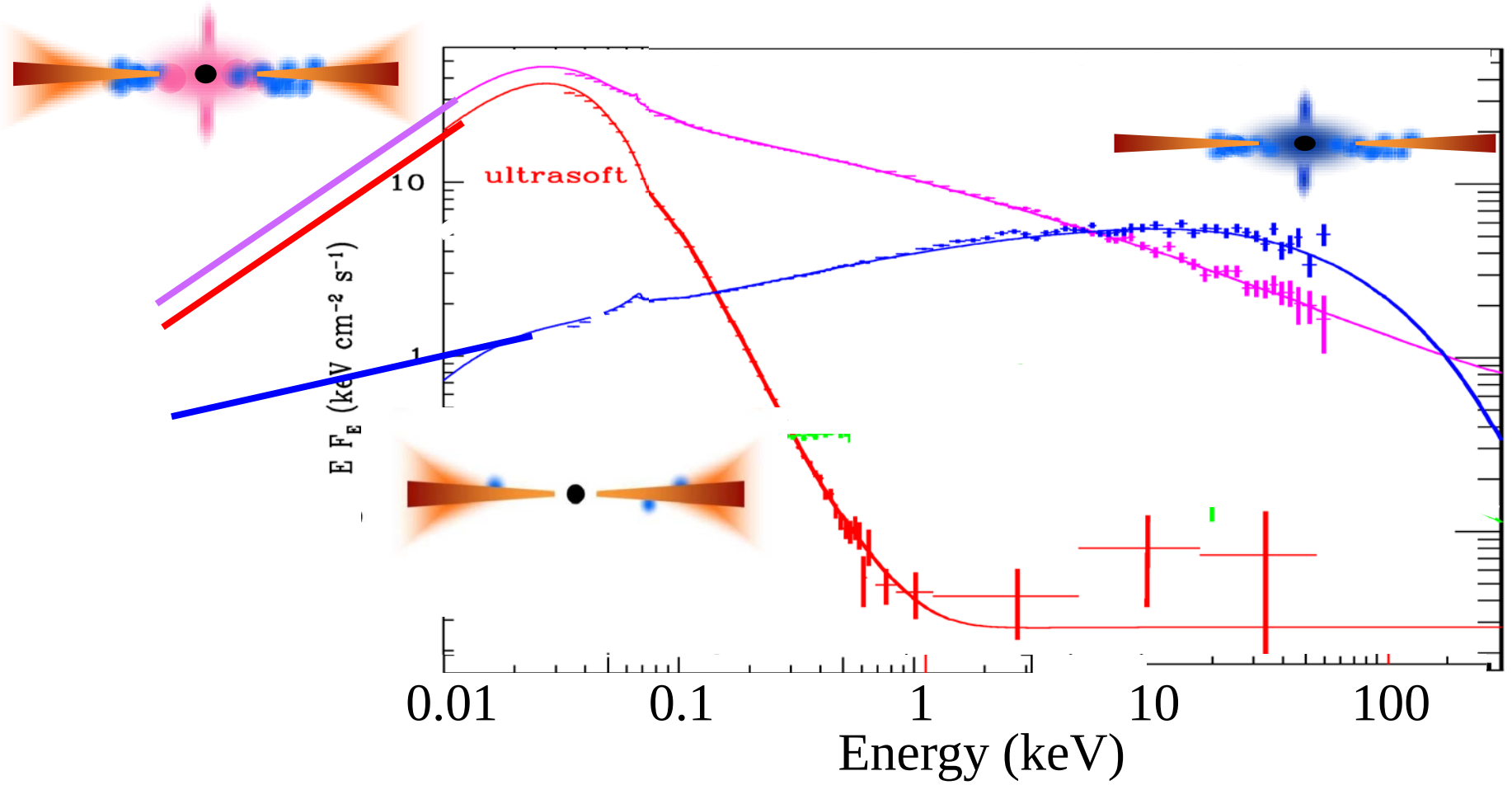




Gierlinski & Done 2003

‘Spectral states in AGN’

Disk below X-ray bandpass so use optical/UV to constrain disc.



Range in SED is opportunity as range in optical line ratios

Unobscured AGN: LINERS-S1-NLS1

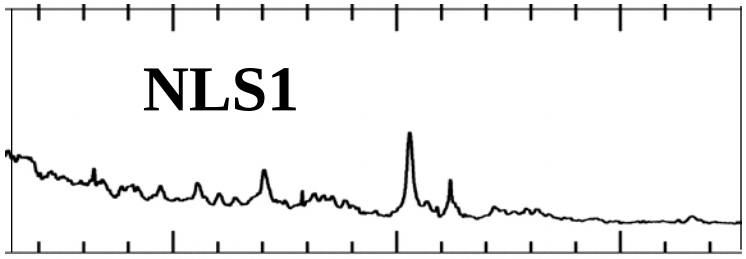
Similar mass.

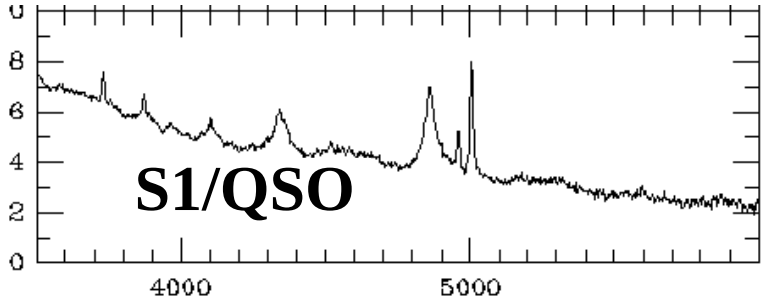
Different L/L_{Edd}

Different ionisation

Increasing L/L_{Edd}

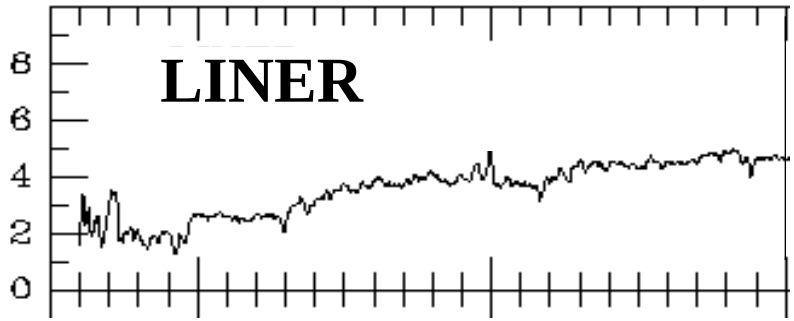
Boroson 2002

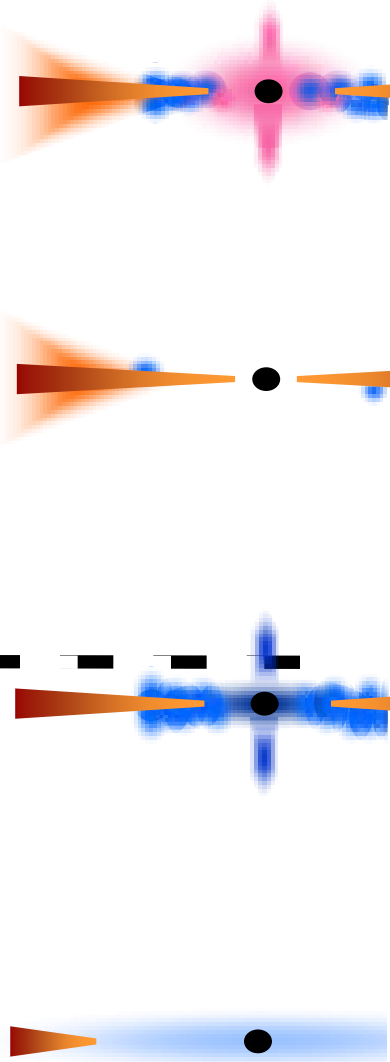




disc

Hot inner flow, no disc – true Seyfert 2s





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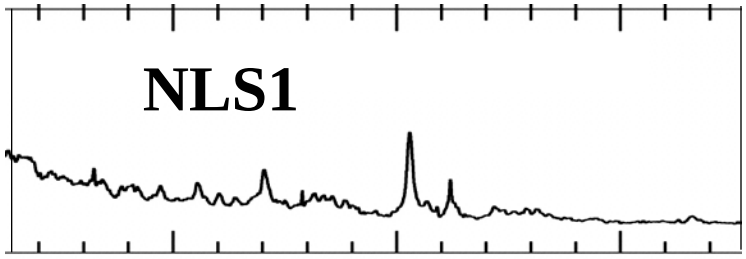

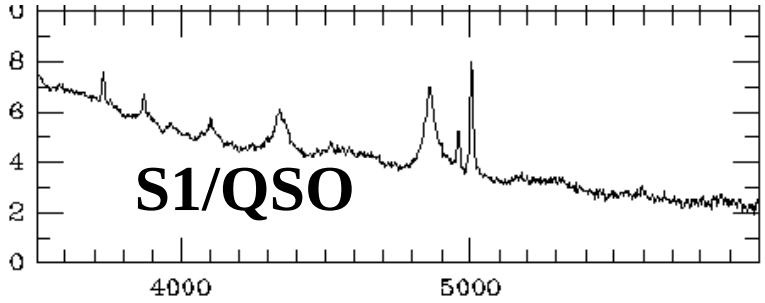

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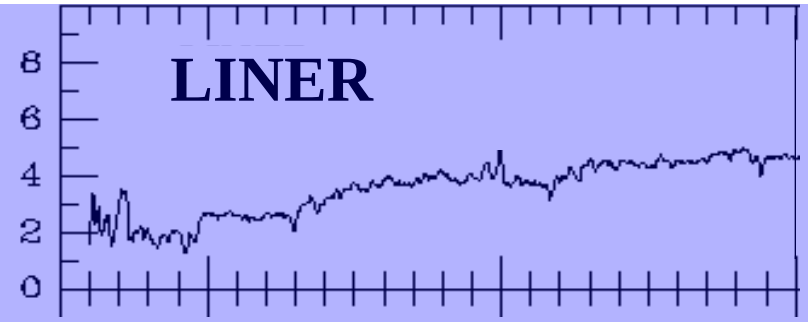
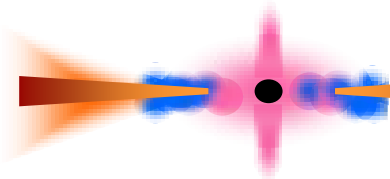
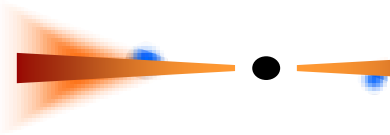
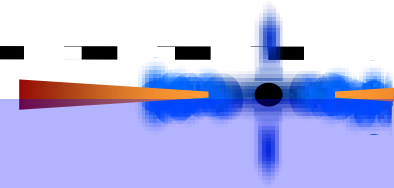
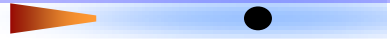




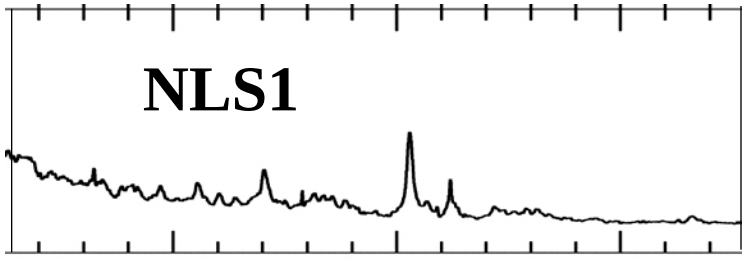


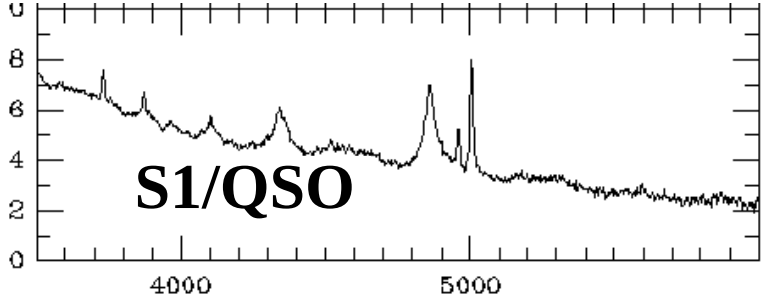




Unobscured AGN: LINERS-S1-NLS1

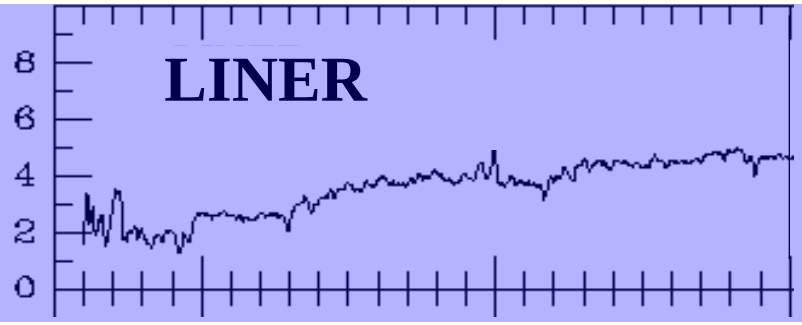
Similar mass.
Different L/L_{Edd}
Different ionising SED
Boroson 2002





Ljet

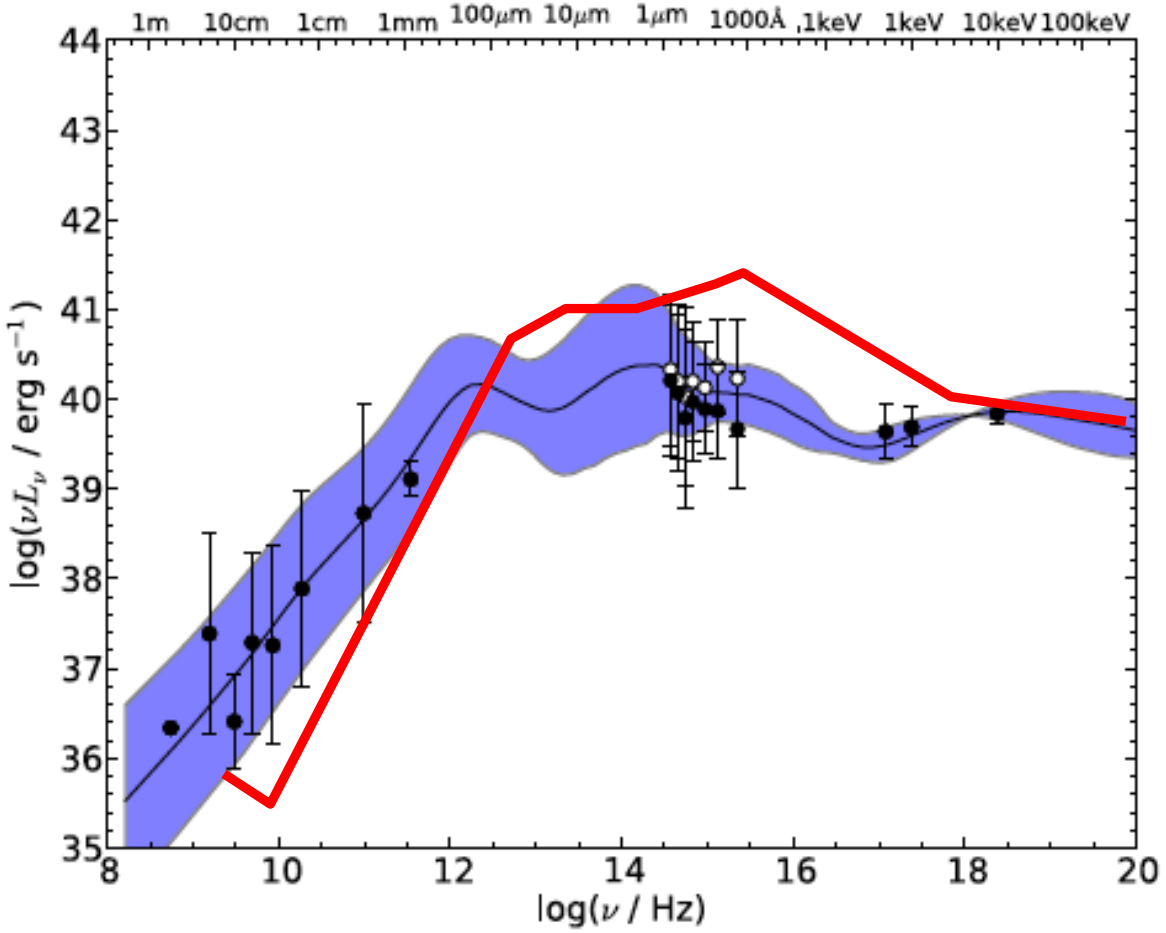
disc



Hot inner flow, no disc – true Seyfert 2s

AGN spectral states: LINERS

- Look like hot flow – truncated disc. SED has no strong UV bump from inner disc (Elvis et al QSO SED)



Nemmen et al 2014

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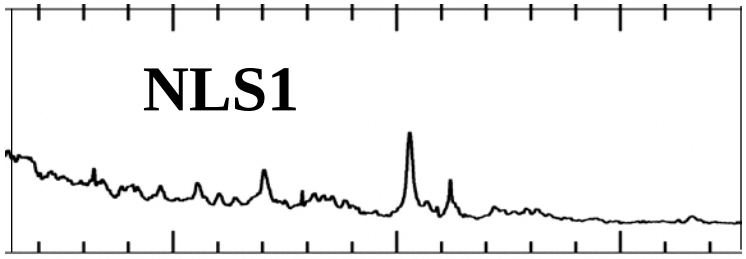

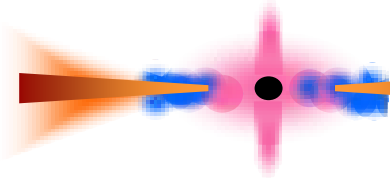

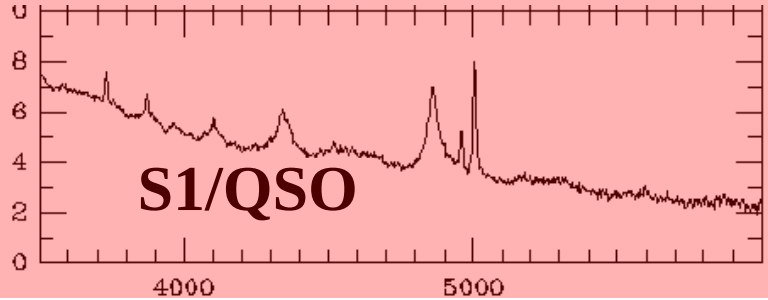

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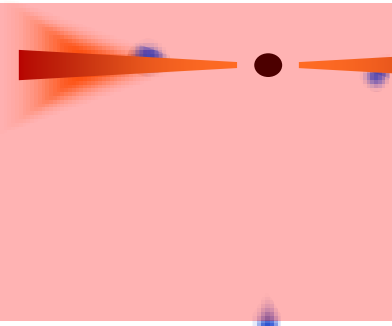
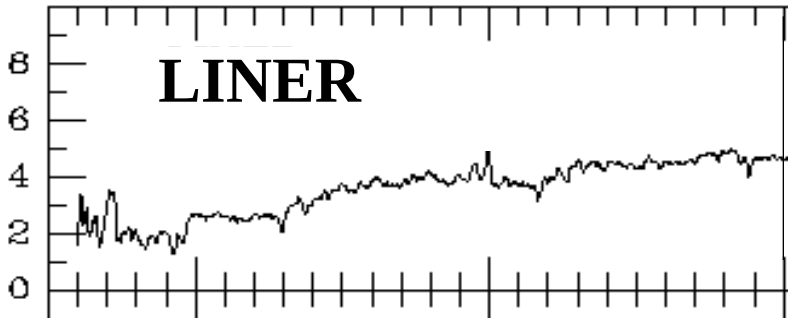
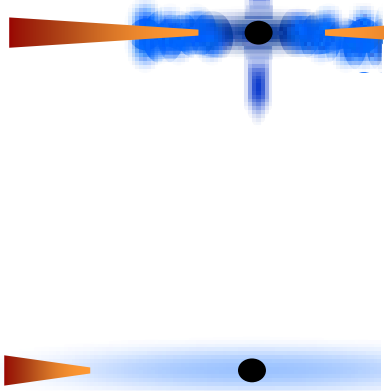


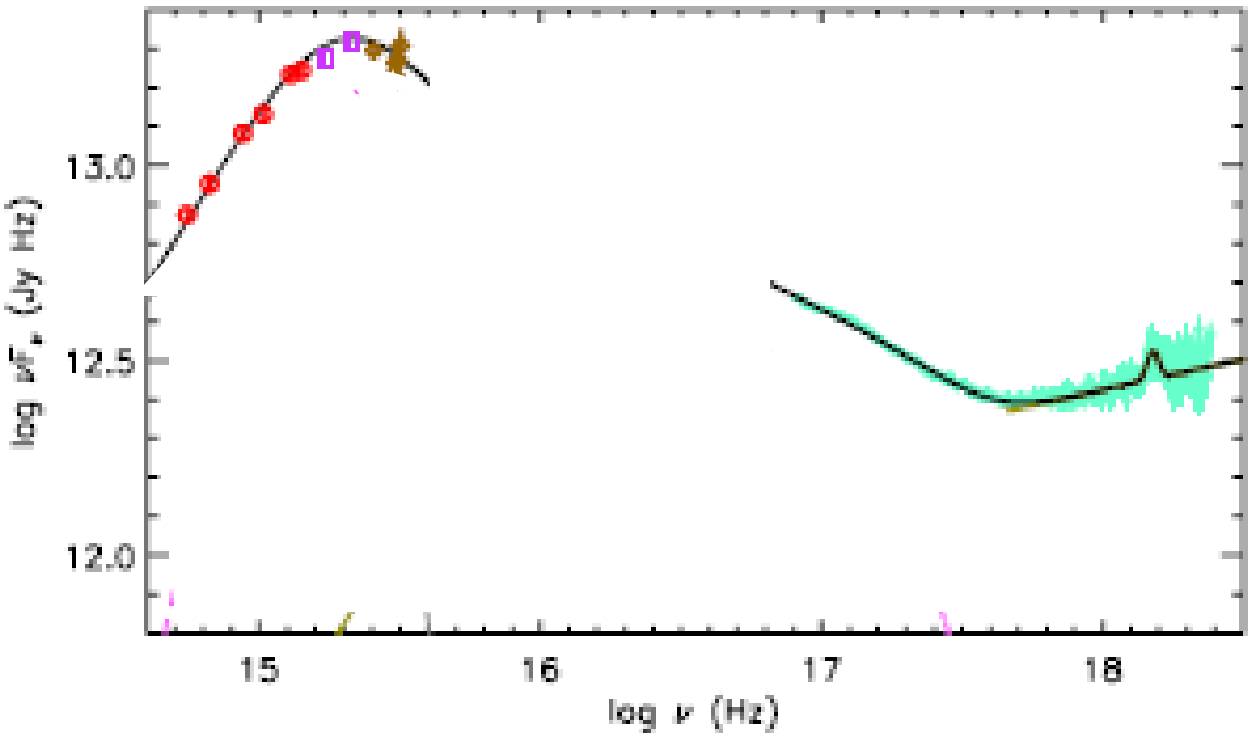




Hot inner flow, no disc – true Seyfert 2s

Classic QSO – most common shape

- Mkn 509 - 10^8M L/LEdd~0.1 (take out warm abs!)



Medhipour et al 2011

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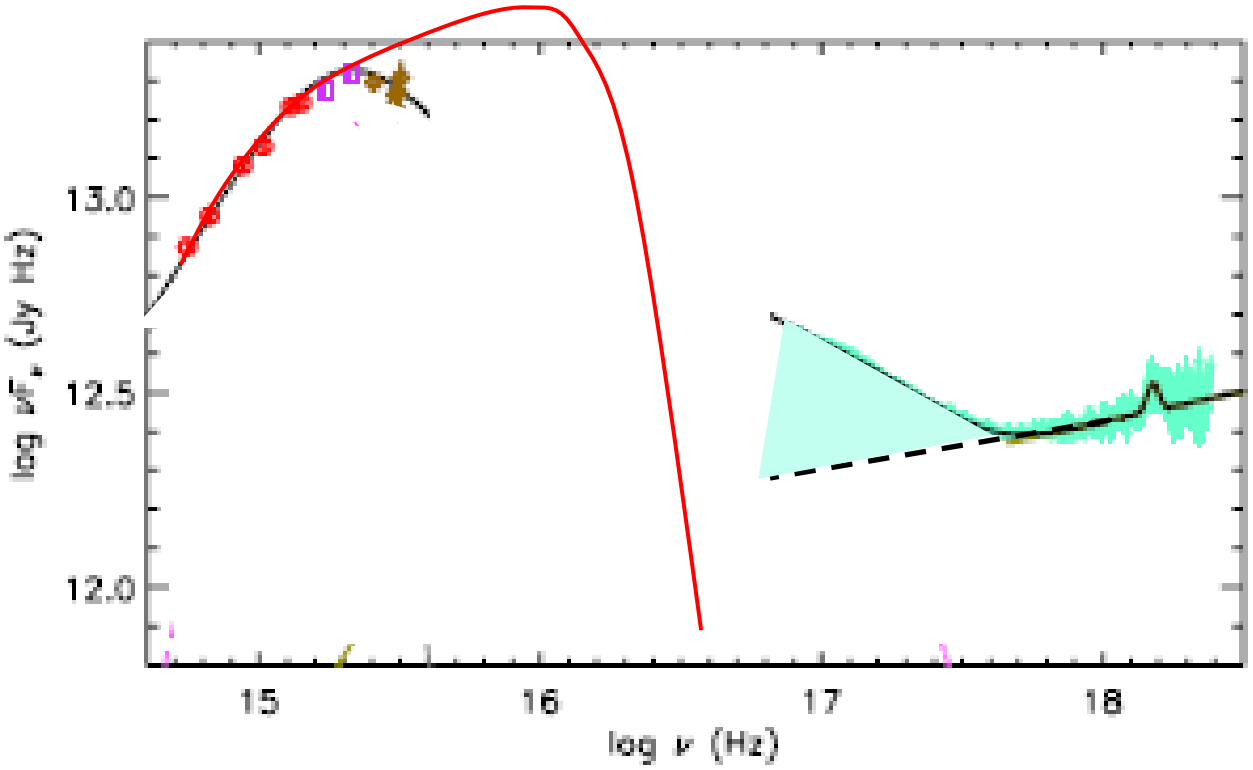
- Mkn 509 - 10^8M L/LEdd~0.1 (take out warm abs!)
- Not disc dominated - far too low temperature! Plus strange soft X-ray excess….What is this????



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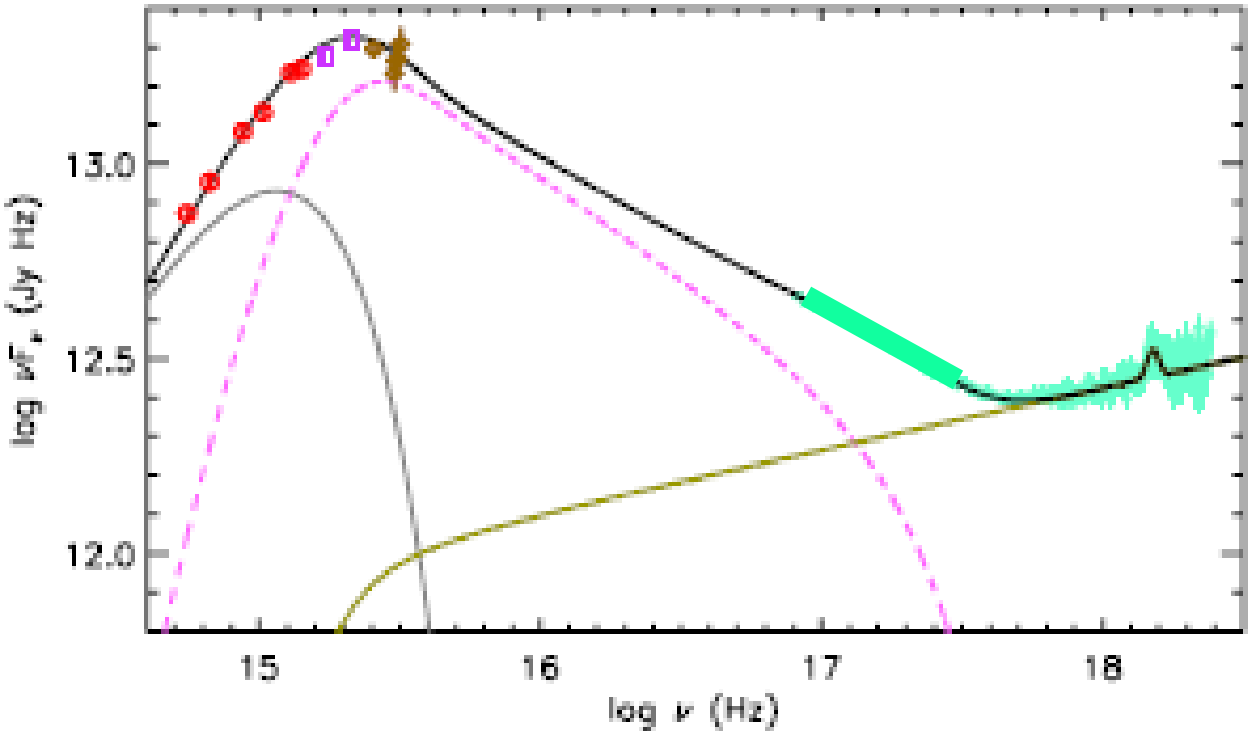
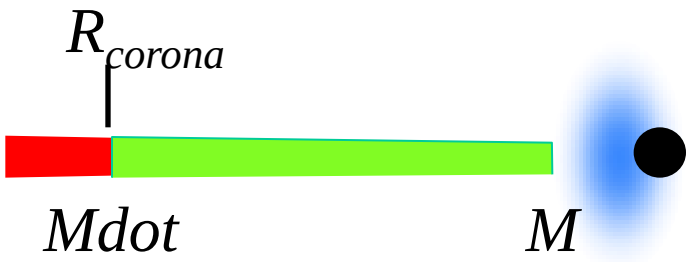
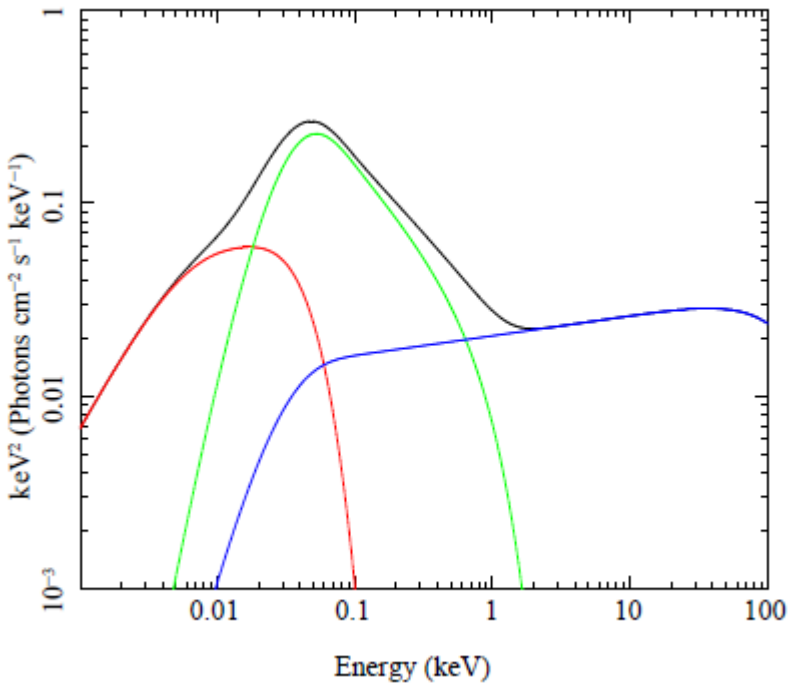


Medhipour et al 2011

Models conserving energy!!

- Outer standard disc with colour temp correction down to R_{corona}
- Then luminosity not completely thermalised to make soft X-ray excess ?
- Inner corona as in BHB
- XSPEC optxagn Done et al 2011 cf dkbbfth Done & Kubota 2006



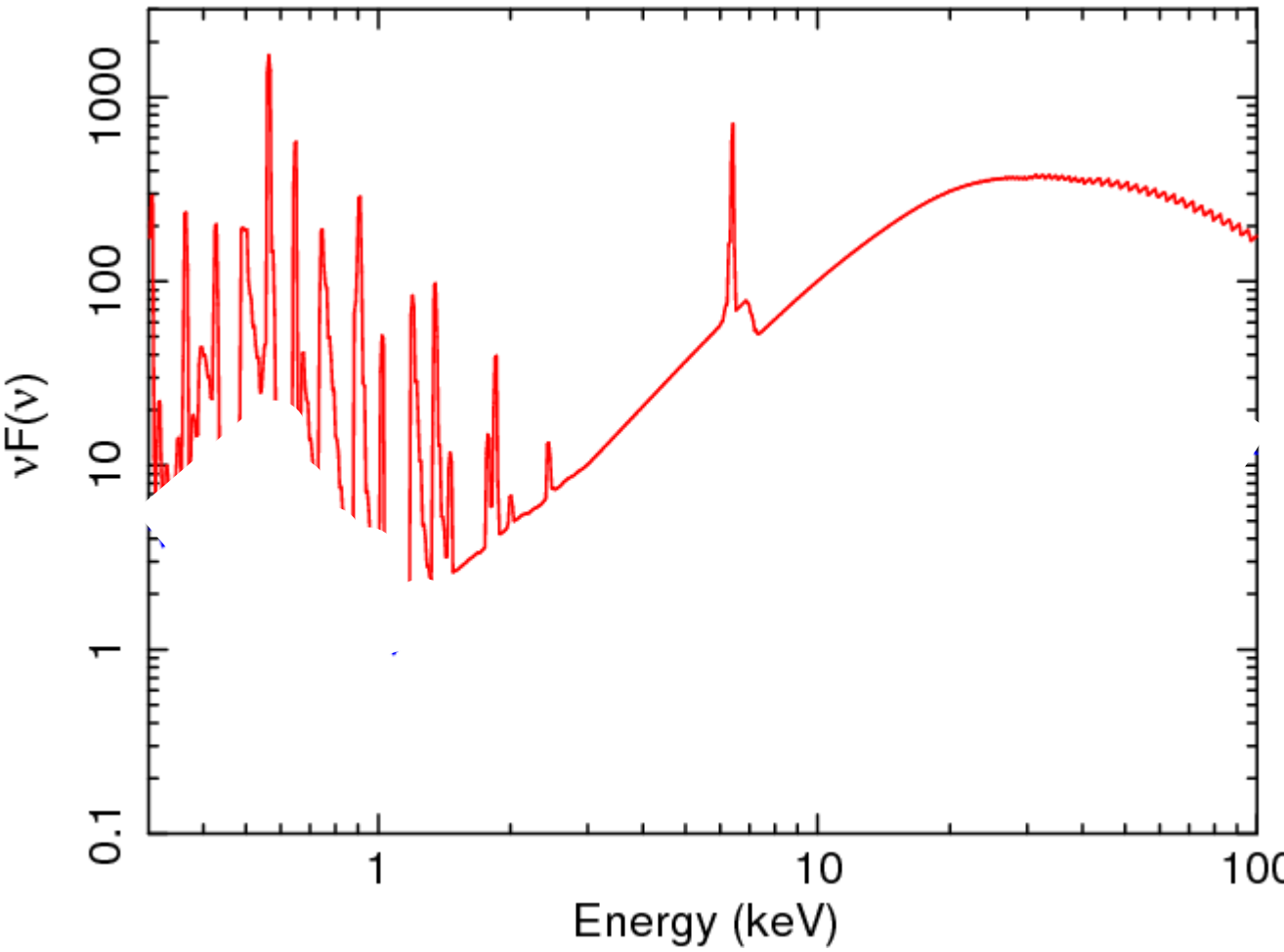


Done et al 2012

Soft X-ray excess

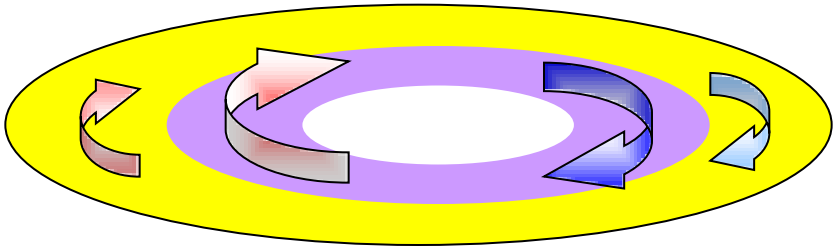
- Ionised reflection?
- Always big jump at 0.7keV
- Fiore et al 1995
- Accompanied by strong lines
- Not seen!

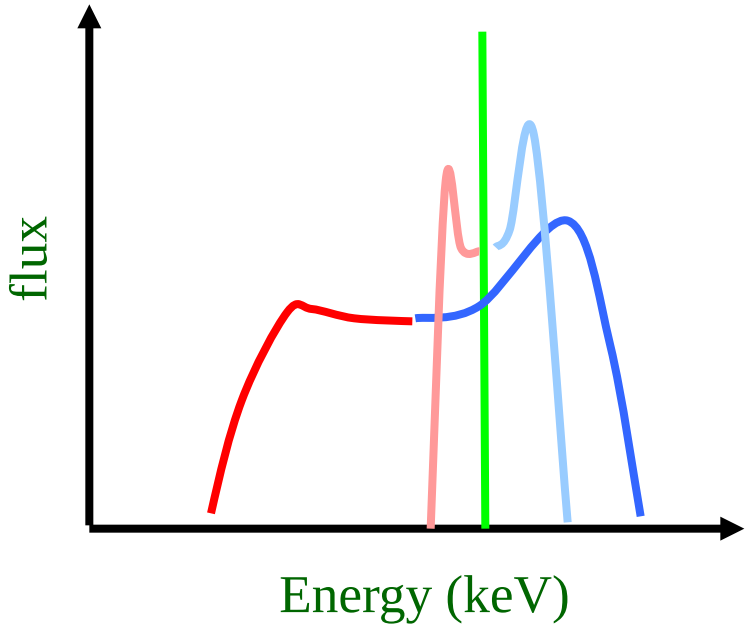
Reynolds et al 2012



Relativistic effects

- Relativistic effects (special and general) affect all emission (Cunningham 1975)
- Emission from the side of the disc coming towards us is blueshifted and boosted by Doppler effects, while opposite side is redshifted and suppressed.
- Also time dilation and gravitational redshift
- Broadens spectrum at a give radius from a narrow blackbody





Fabian et al. 1989

Soft X-ray excess

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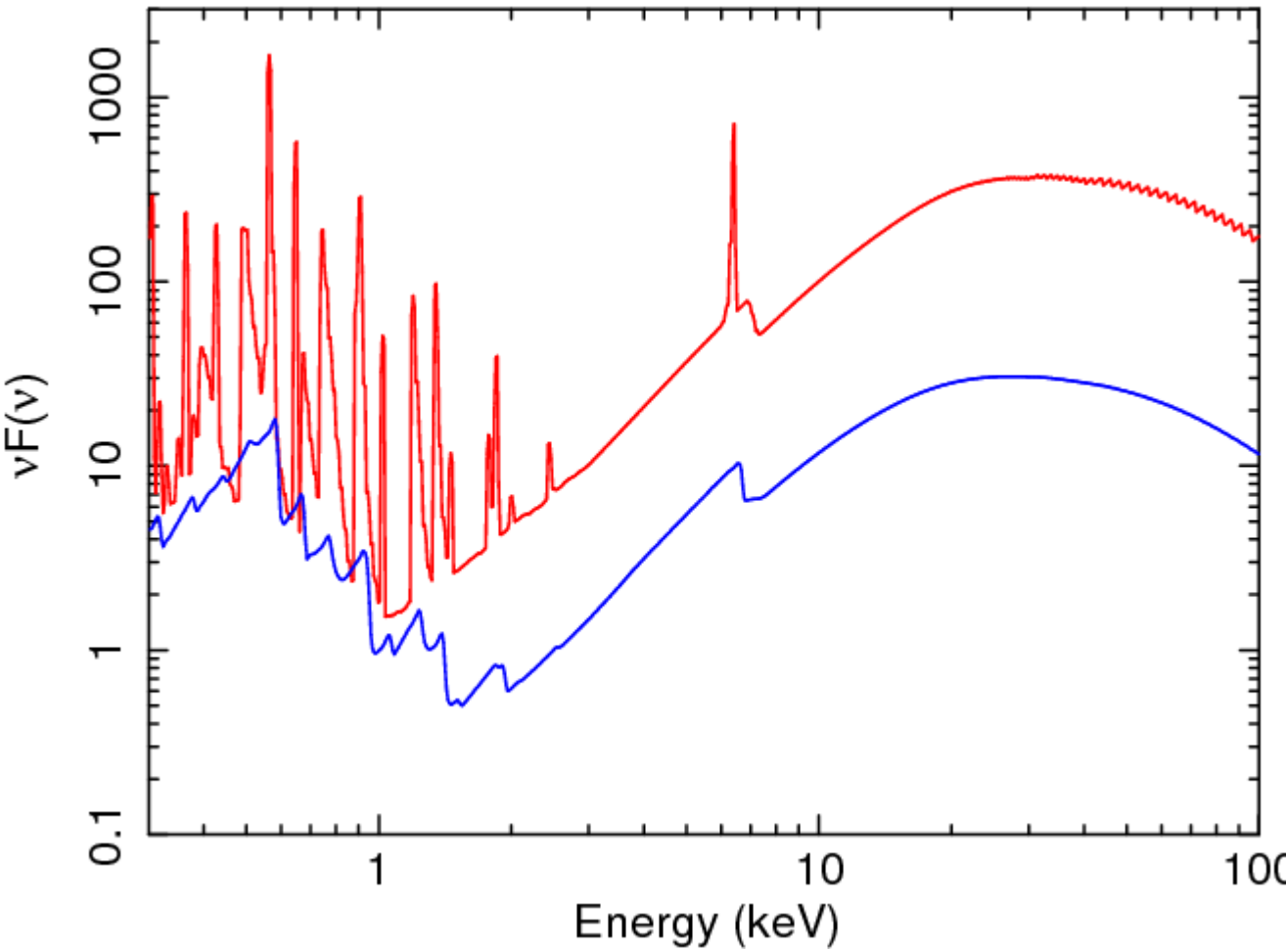
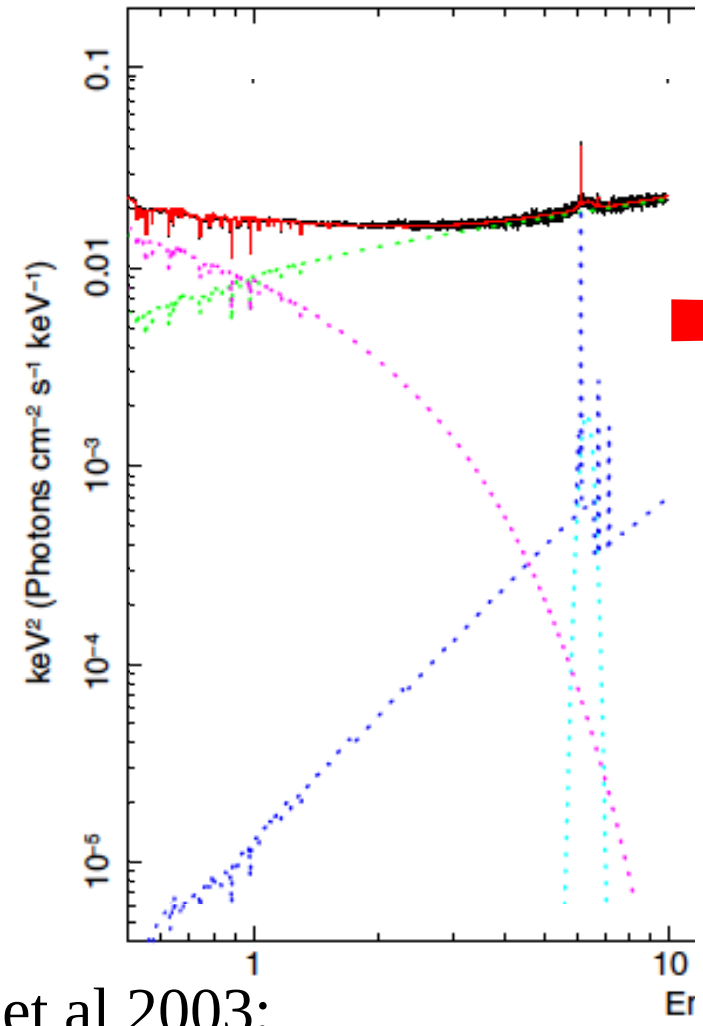
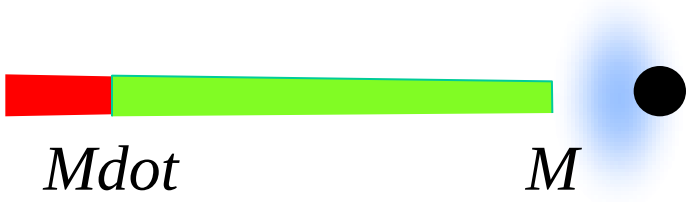
- Not seen! Very strong GR/SR smearing?? =High spin! Crummy et al 2006

Reynolds et al 2012



An additional component?

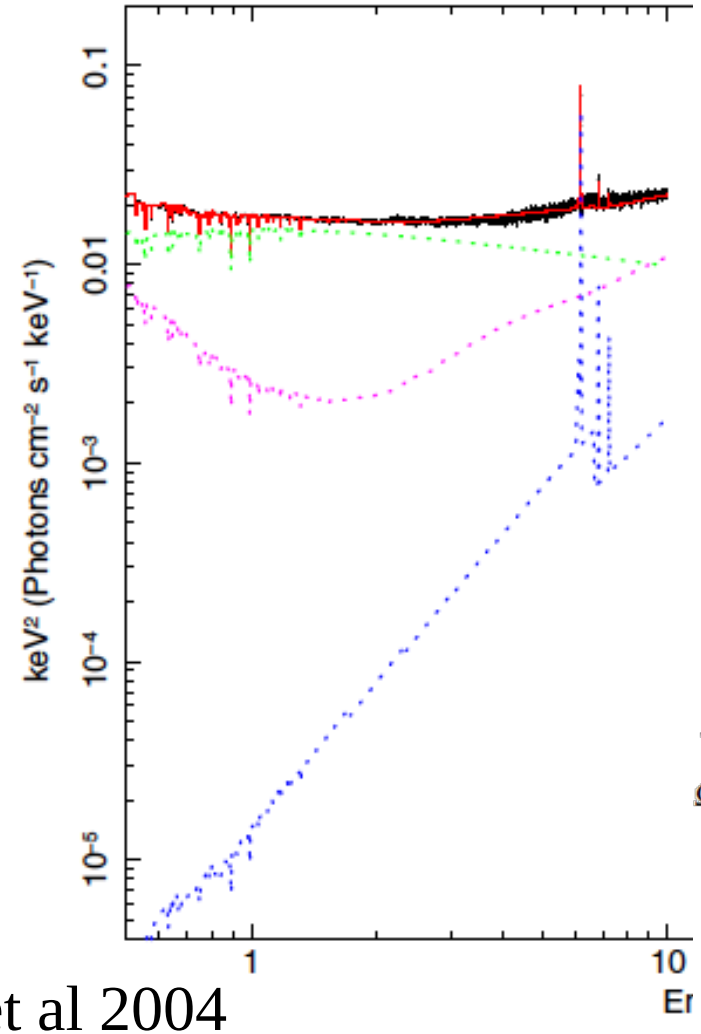




Porquet et al 2003;
Gierlinski & Done 2004;
Czerny et al 2003

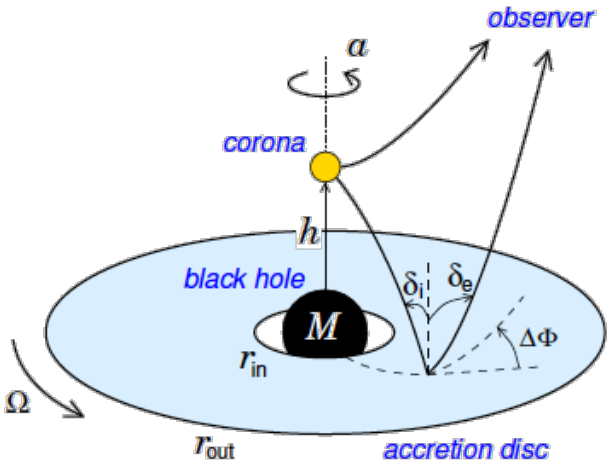
Boissay et al 2014

Reflected/smeared hard X-rays?



Fabian et al 2004

Crummy et al 2006



Boissay et al 2014

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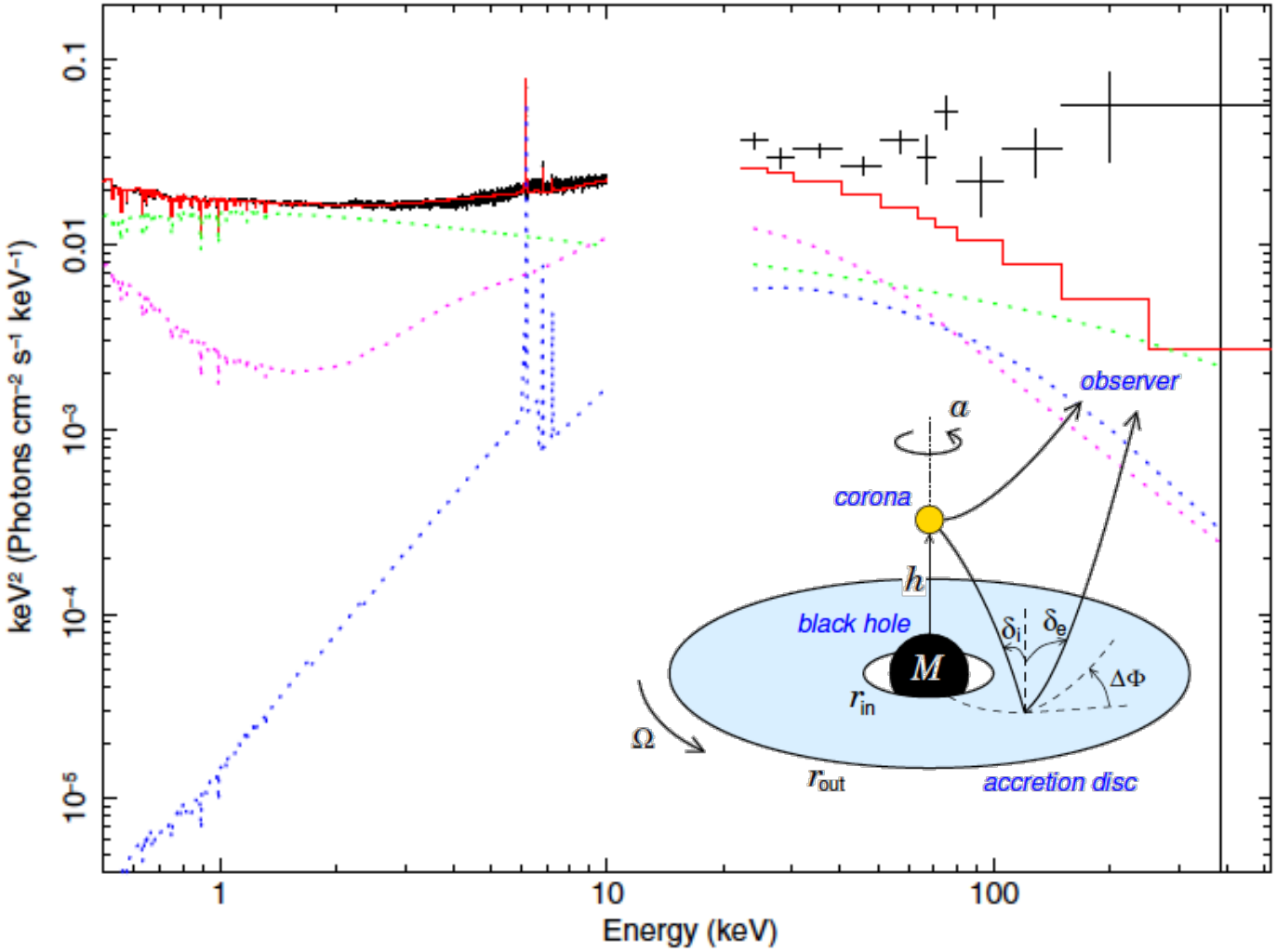

Boissay et al 2014

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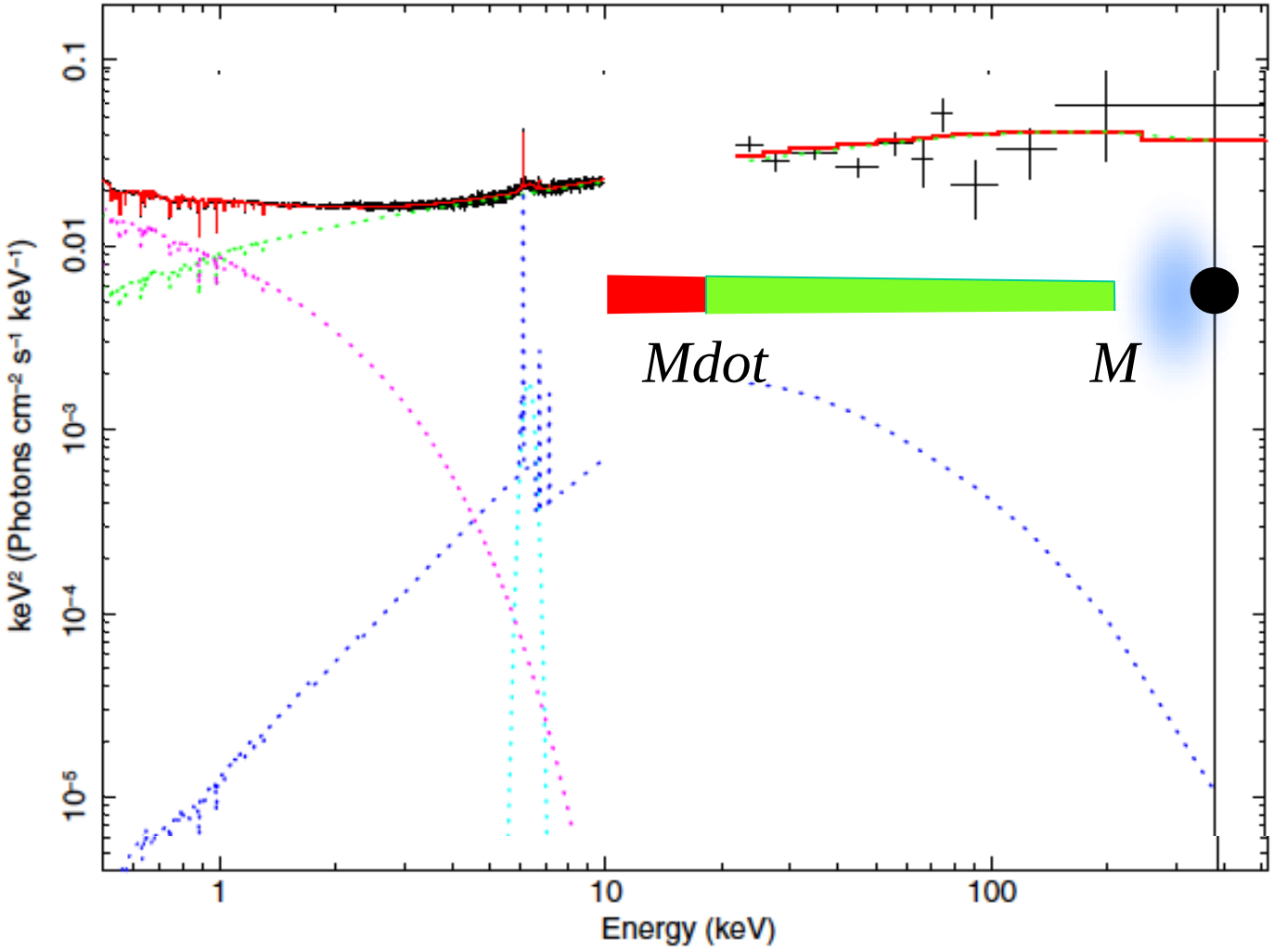
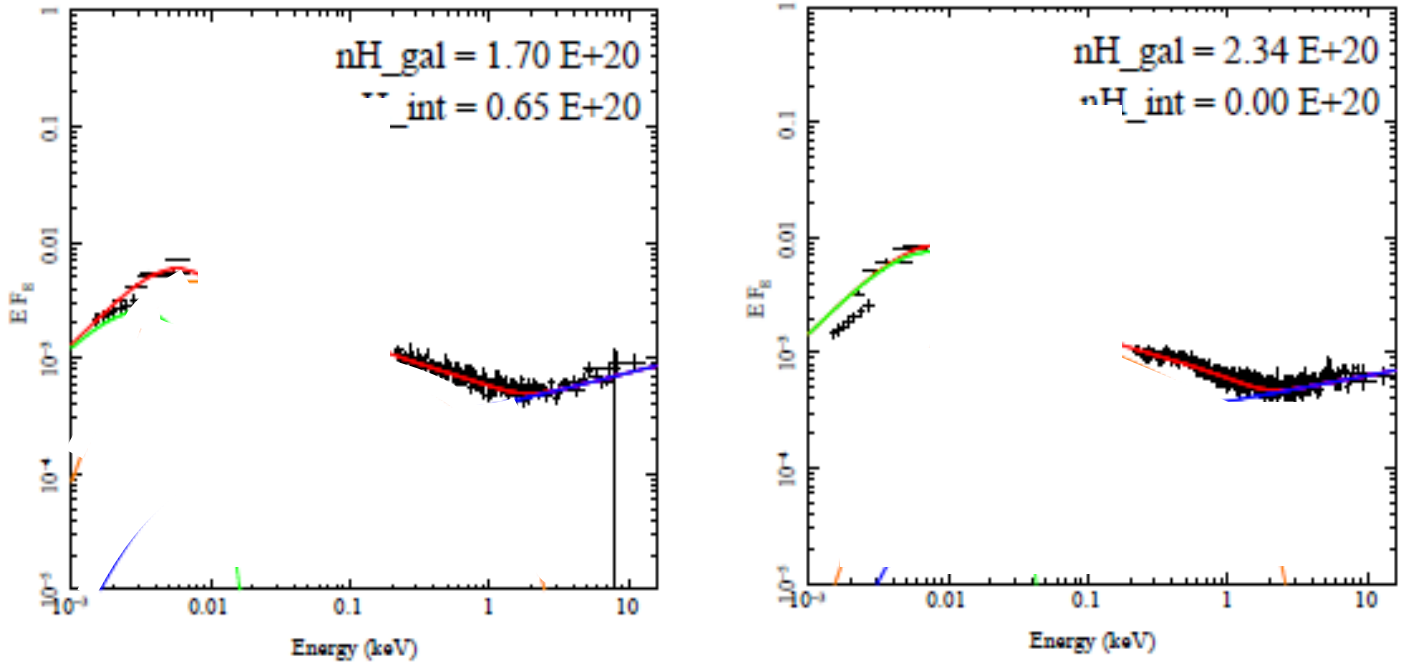


Boissay et al 2014

So what do AGN look like?

- More standard BLS1/QSO <M>~10^8, <L/LEdd>~0.1



Jin et al 2012

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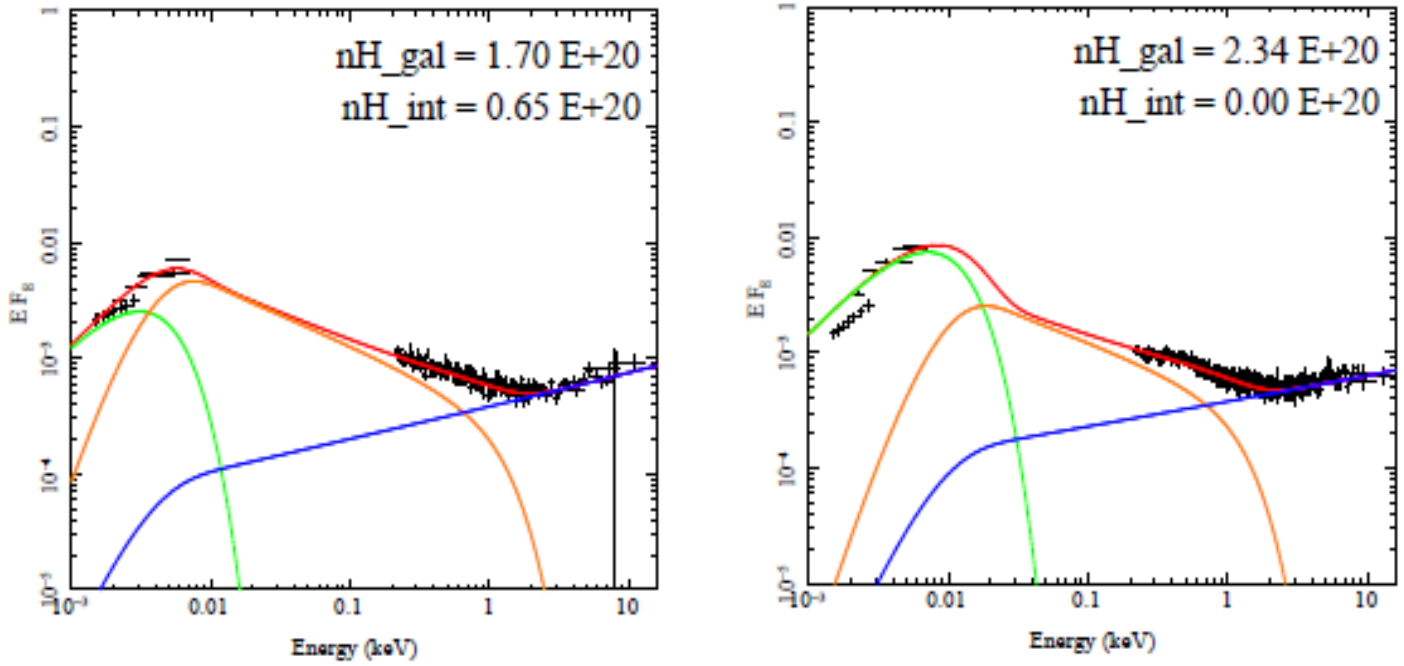
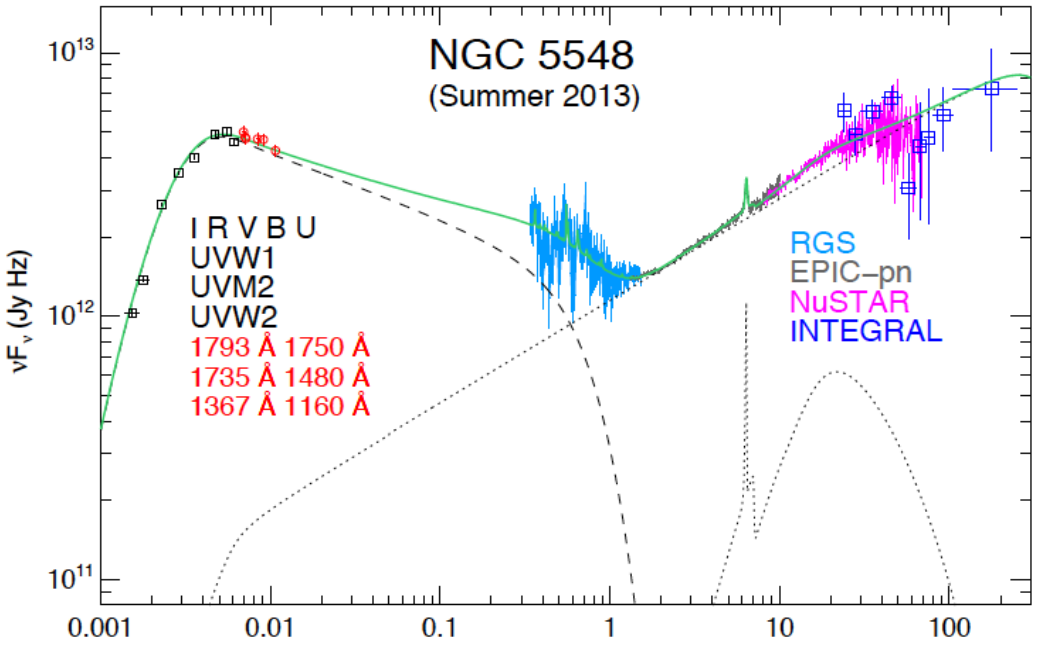
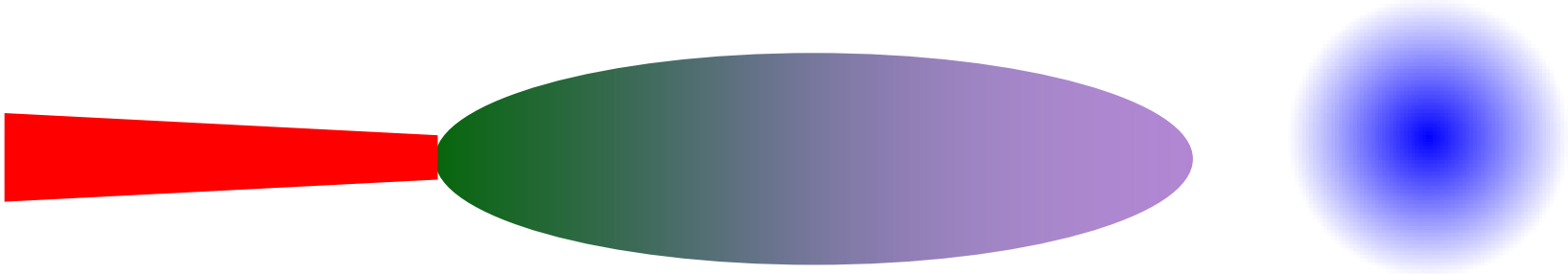


Jin et al 2012

Nature of soft excess region?

- Why??
- UV bright region of disc

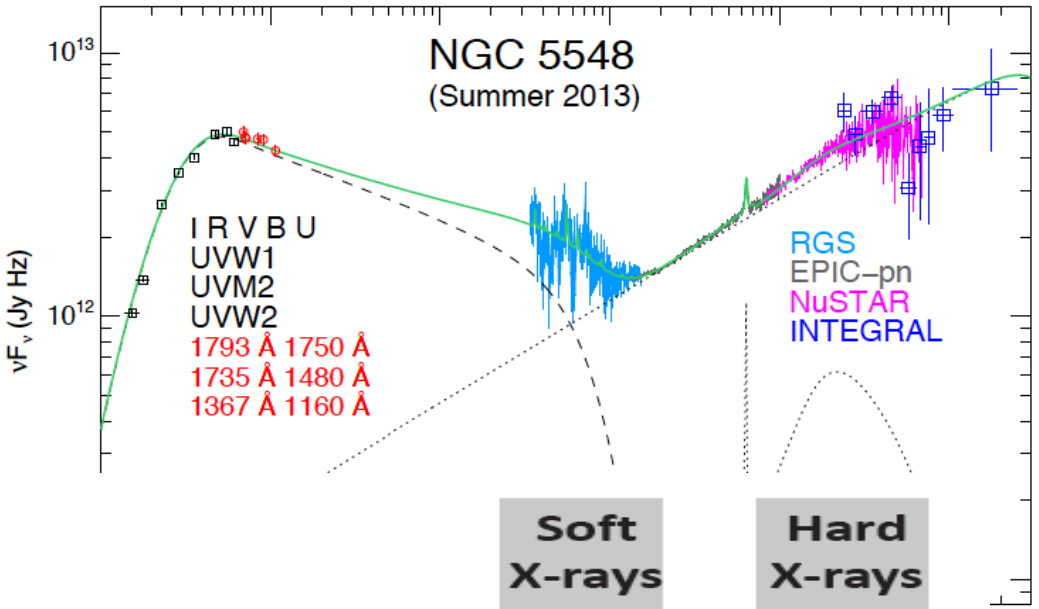


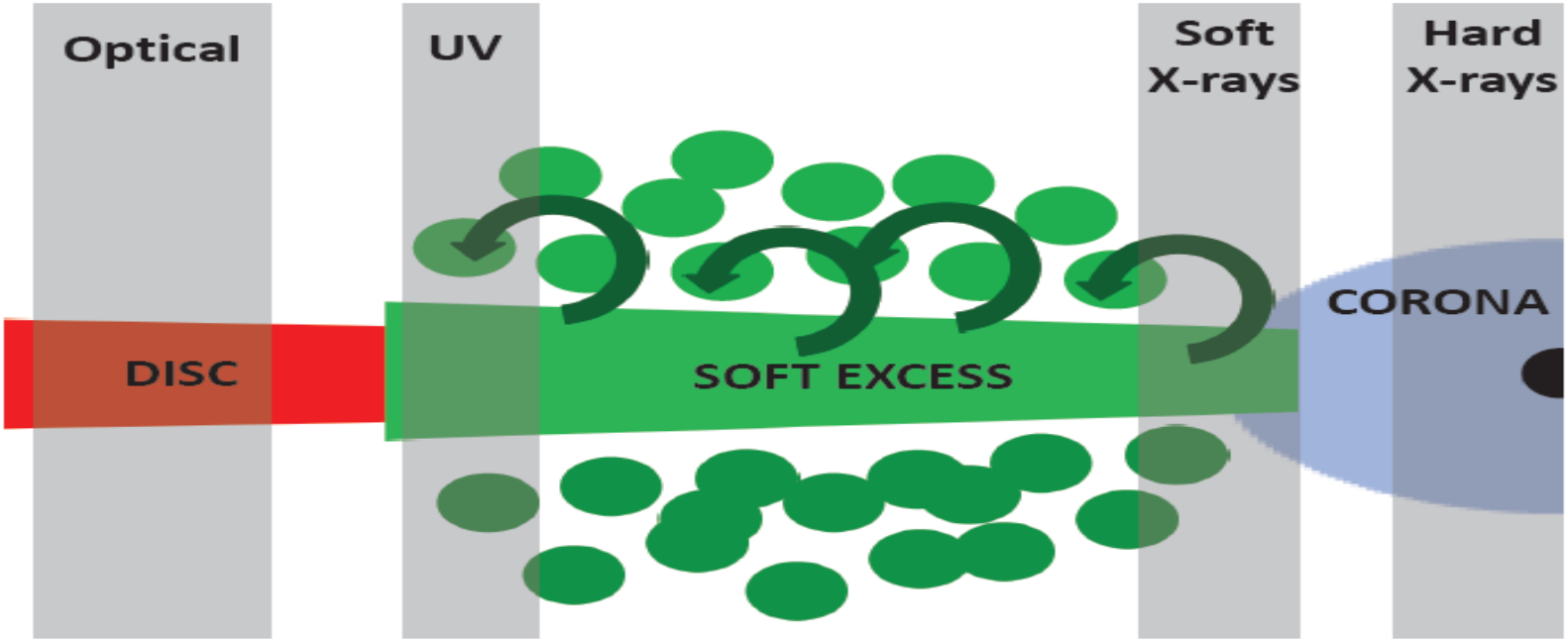


Optical UVW1

Nature of soft excess region?

- Why??
- UV bright region of disc
- Failed UV line driven wind?





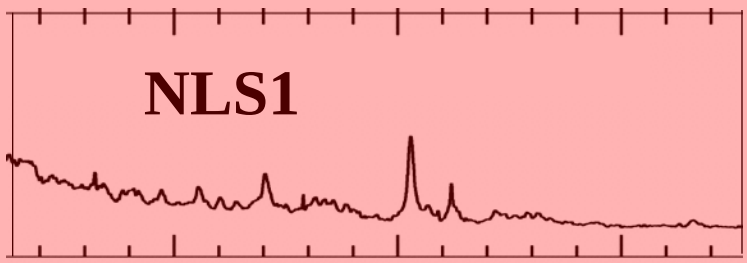
Unobscured AGN: LINERS-S1-NLS1

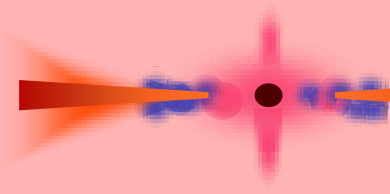
Similar mass.

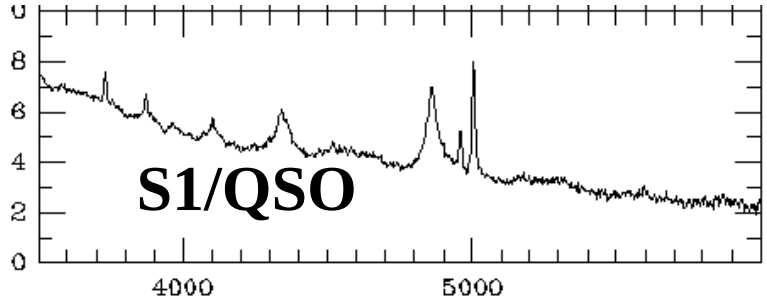
Different L/L_{Edd}

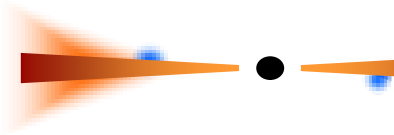
Different ionisation

Increasing L/L_{Edd}

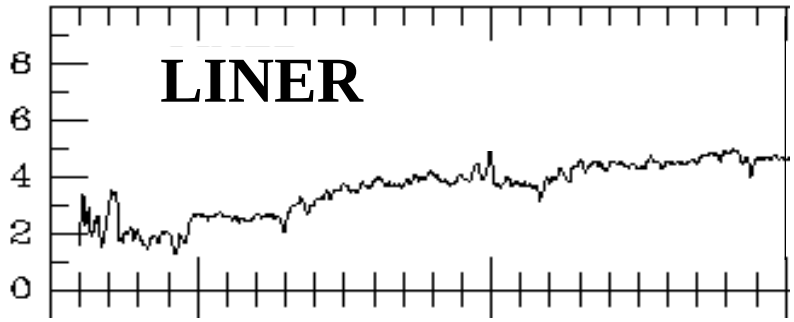


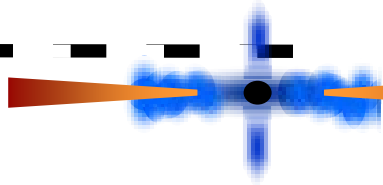






disc

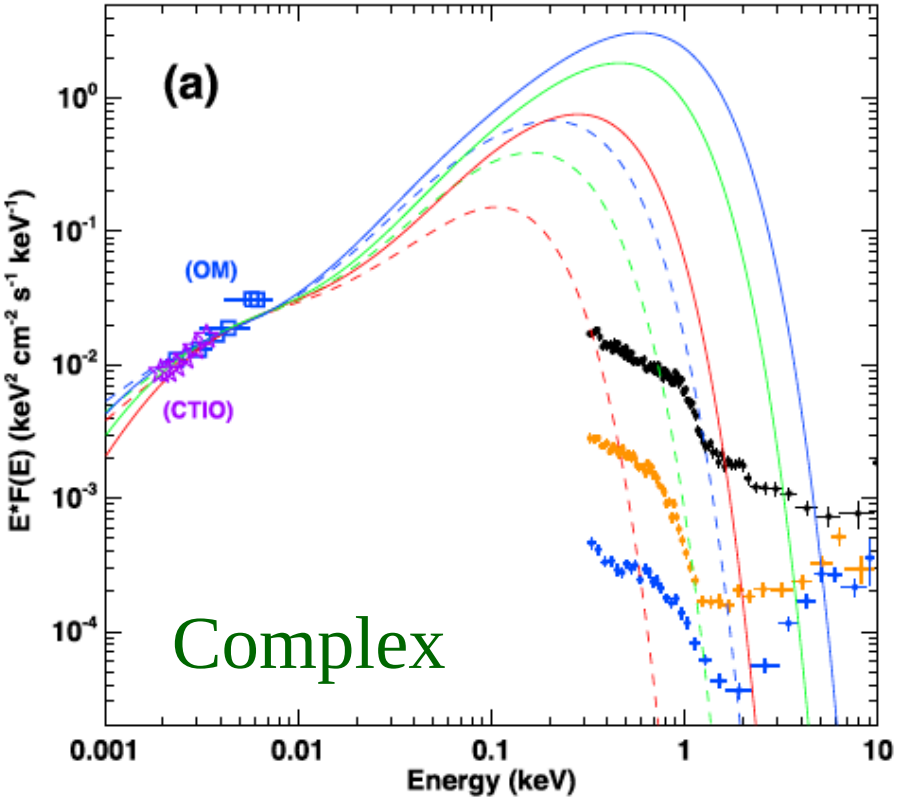


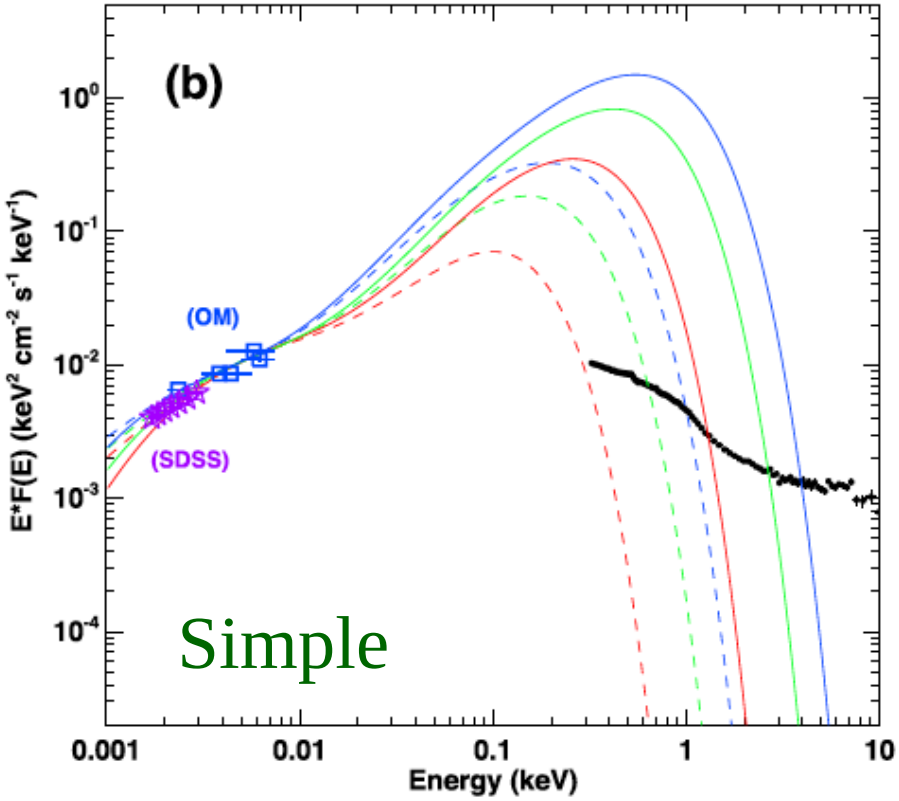


Hot inner flow, no disc – true Seyfert 2s

Boroson 2002

NLS1 come in 2 types!
Same M (low) and L/Ledd (high)

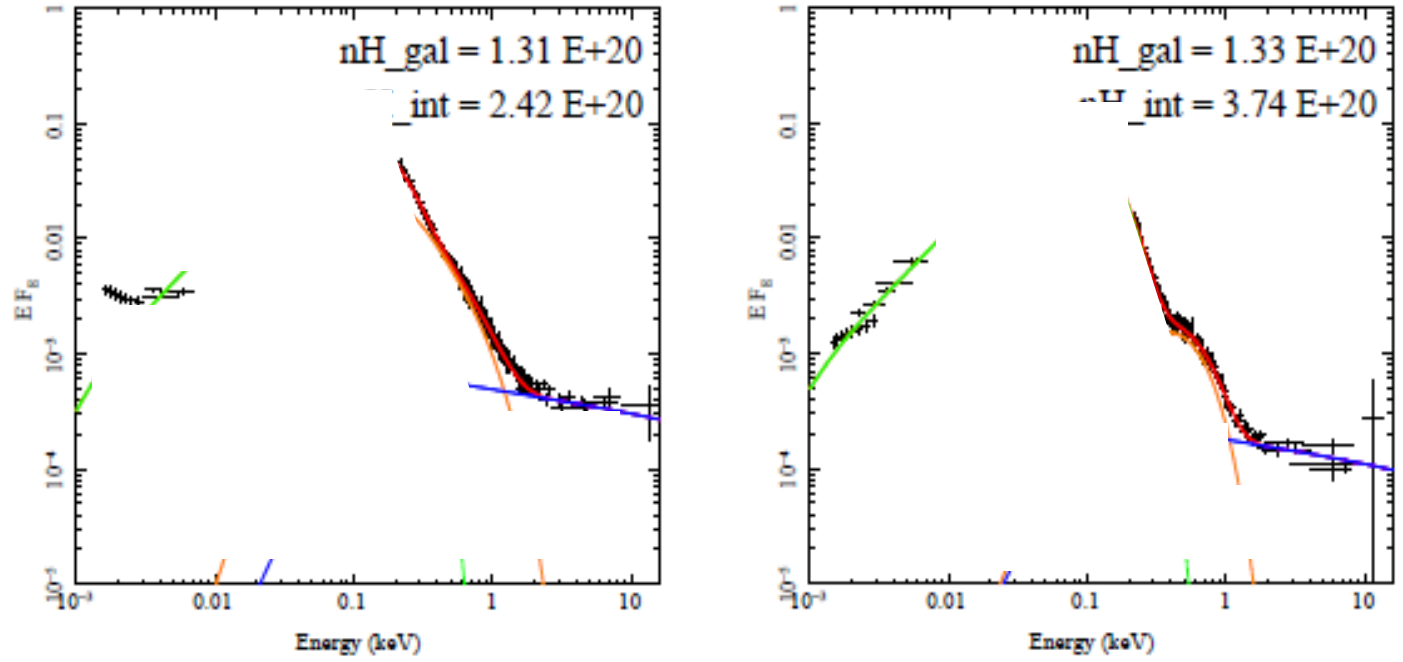




Gallo 2006; Done & Jin 2016

Simple NLS1

- Same L but lower M, higher L/LEdd (10^7, $L \sim L_{Edd}$)



Jin et al 2012

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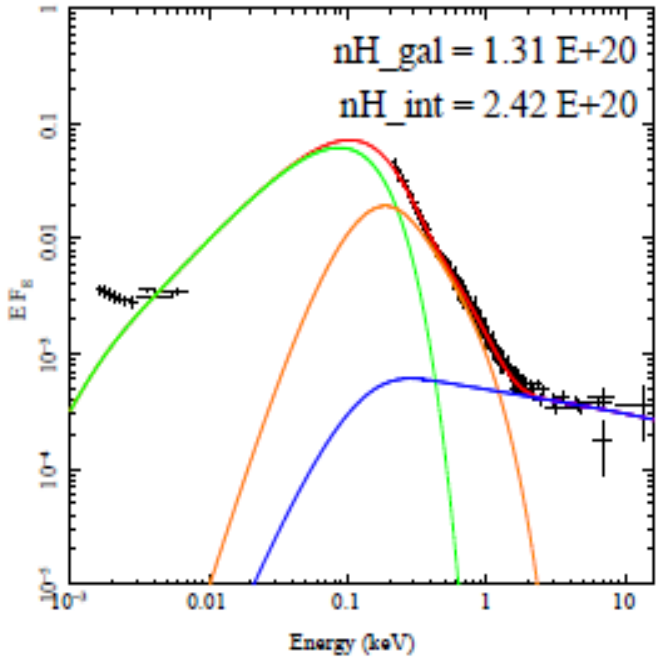
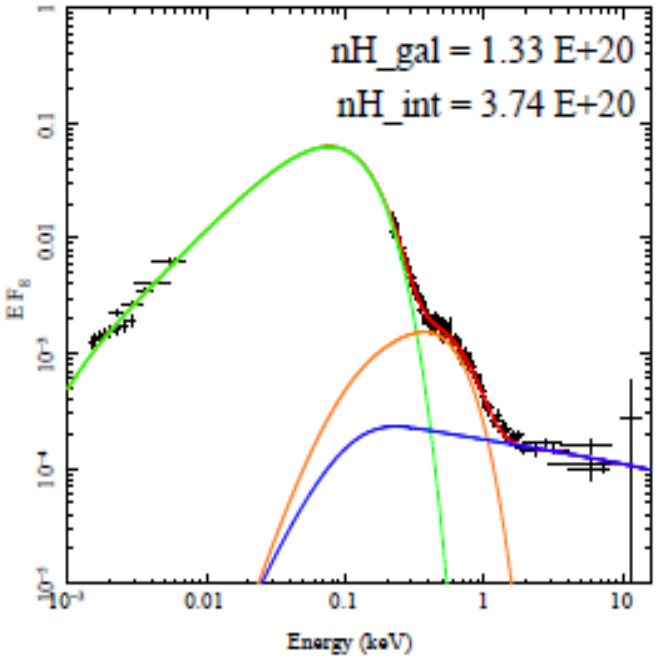
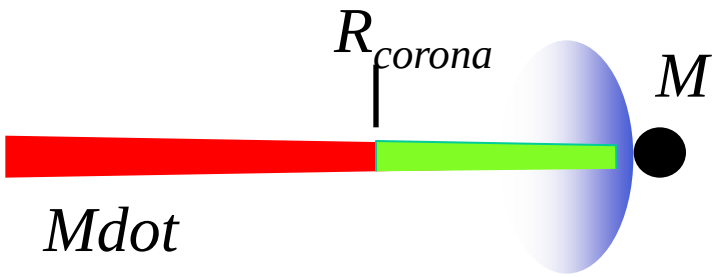


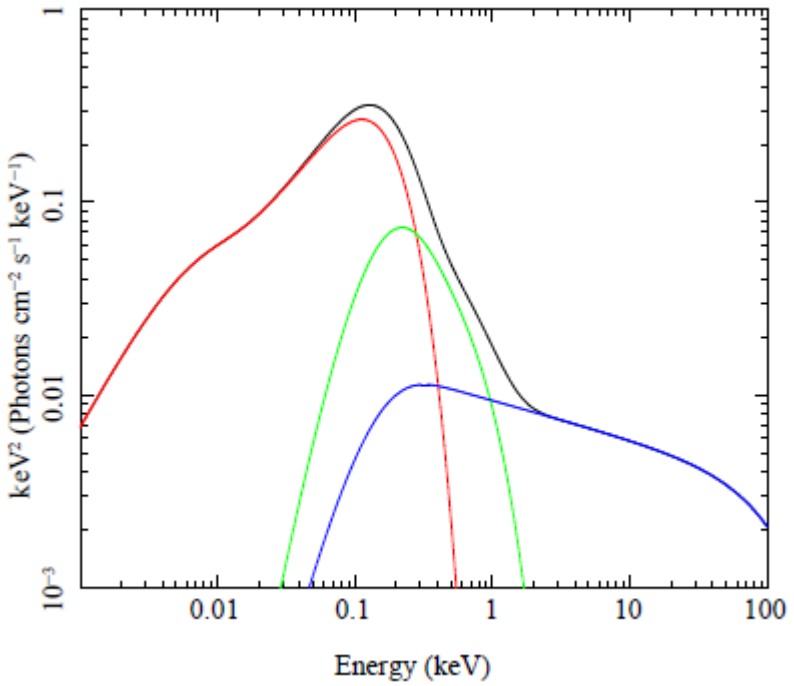


Jin et al 2012

Models conserving energy!!

- Outer standard disc with colour temp correction down to R_{corona}
- Then luminosity not completely thermalised to make soft X-ray excess ?
- Inner corona as in BHB
- Difference is R_{corona} smaller and Γ steeper for higher L/L_{Edd}

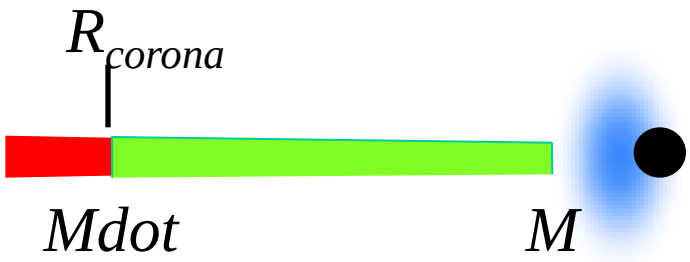


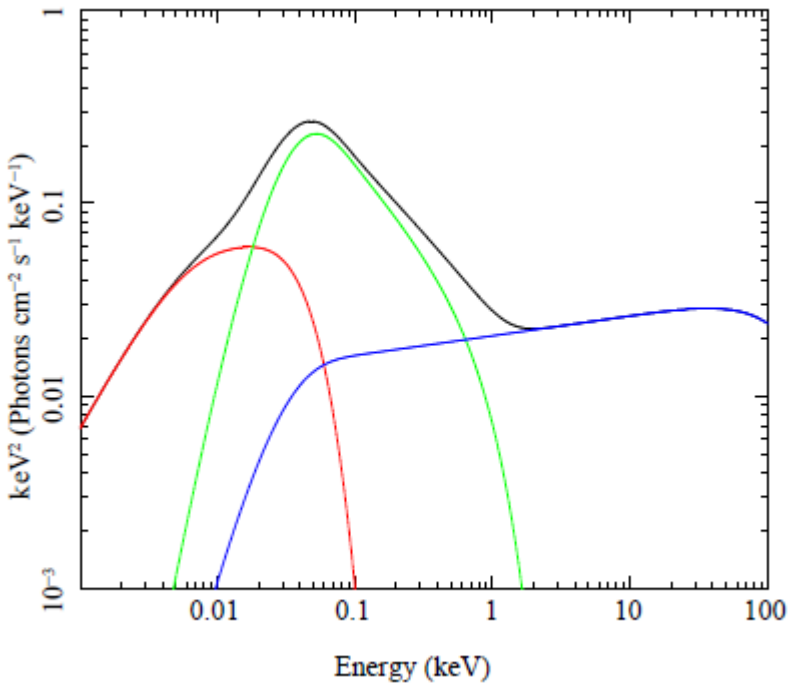


Done et al 2012

Models conserving energy!!

- Outer standard disc with colour temp correction down to R_{corona}
- Then luminosity not completely thermalised to make soft X-ray excess ?
- Inner corona as in BHB
- XSPEC optxagn Done et al 2011 cf dkbbfth Done & Kubota 2006



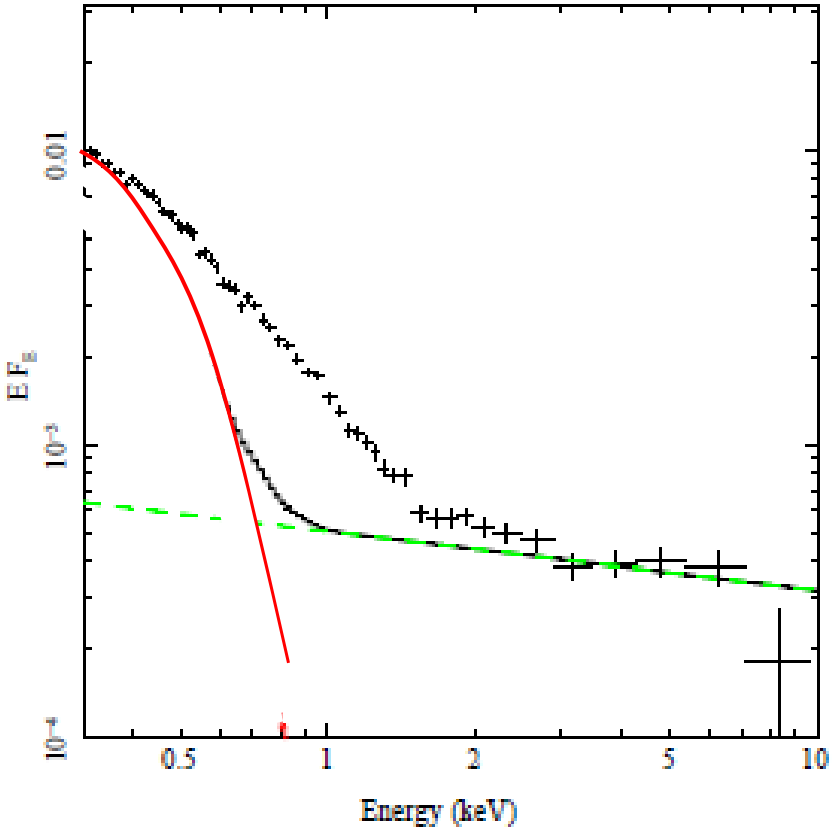


Done et al 2012

Disc spectra 2x10^6 M L/L_{Edd} ~1

Done, Davis, Jin, Blaes Ward 2011

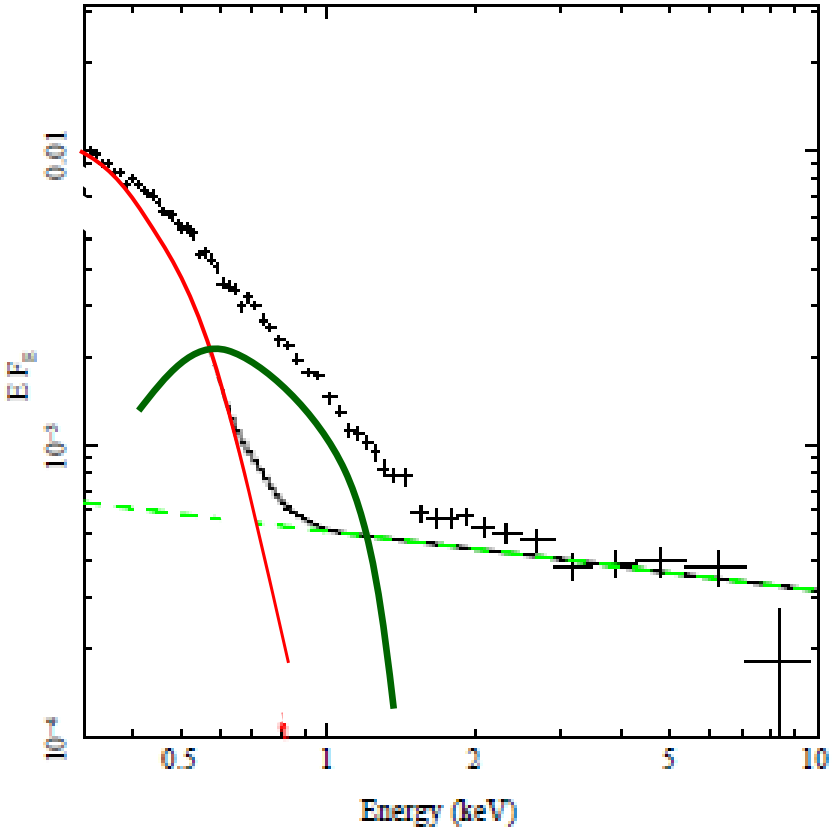
- Low M and high L/LEdd so highest AGN disk temperature
- Model 10^6, L~L_{Edd}
- REJ1034 2x10^6, L~LEdd – scale up by factor 2!
- No! mostly the disc!



Disc spectra $2x10^6$ M L/L_{Edd} ~1

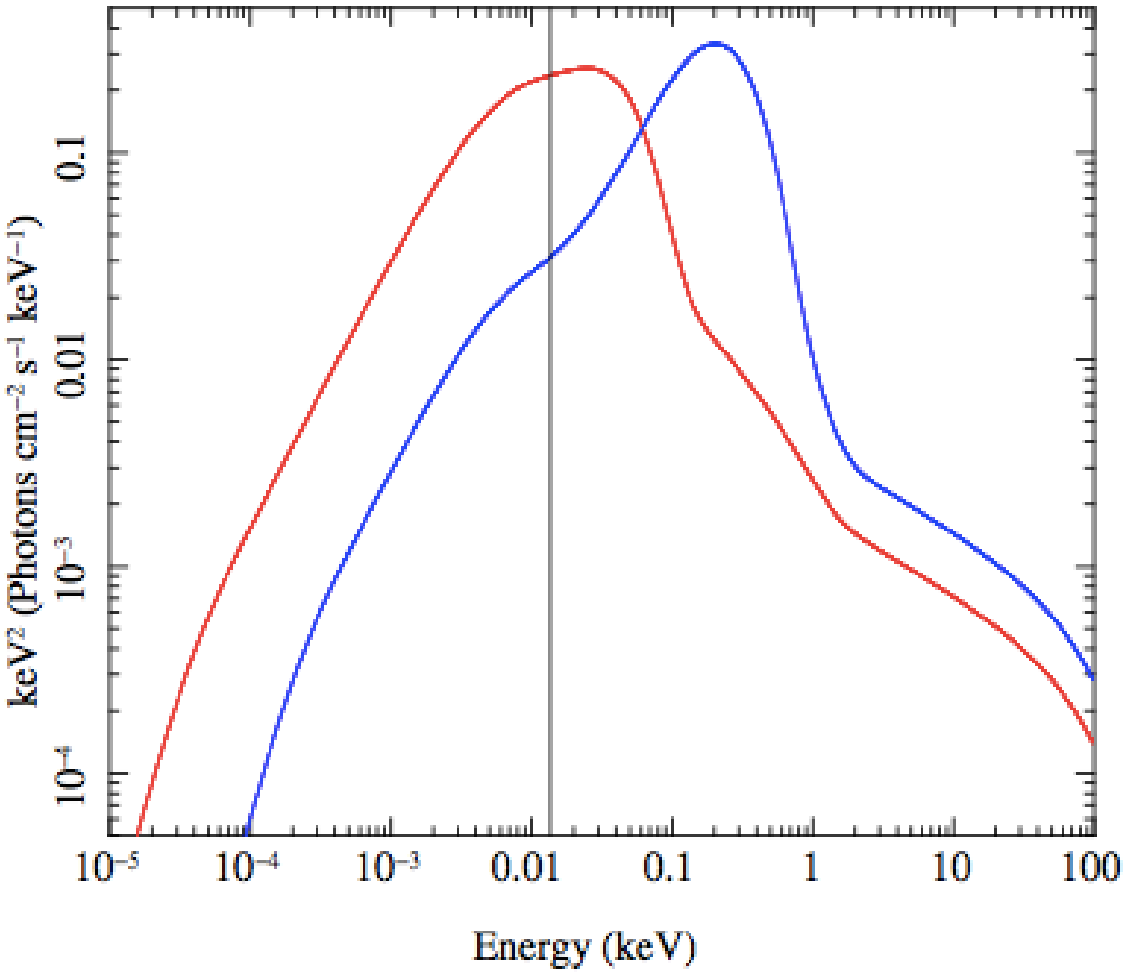
Done, Davis, Jin, Blaes Ward 2011

- Enormous soft excess in REJ1034?
- No – mostly disc!
- Plus a little soft X-ray excess
- Is this the same soft excess component or is it bulk turbulence or wind at Ledd??



10^6 versus 10^9 M

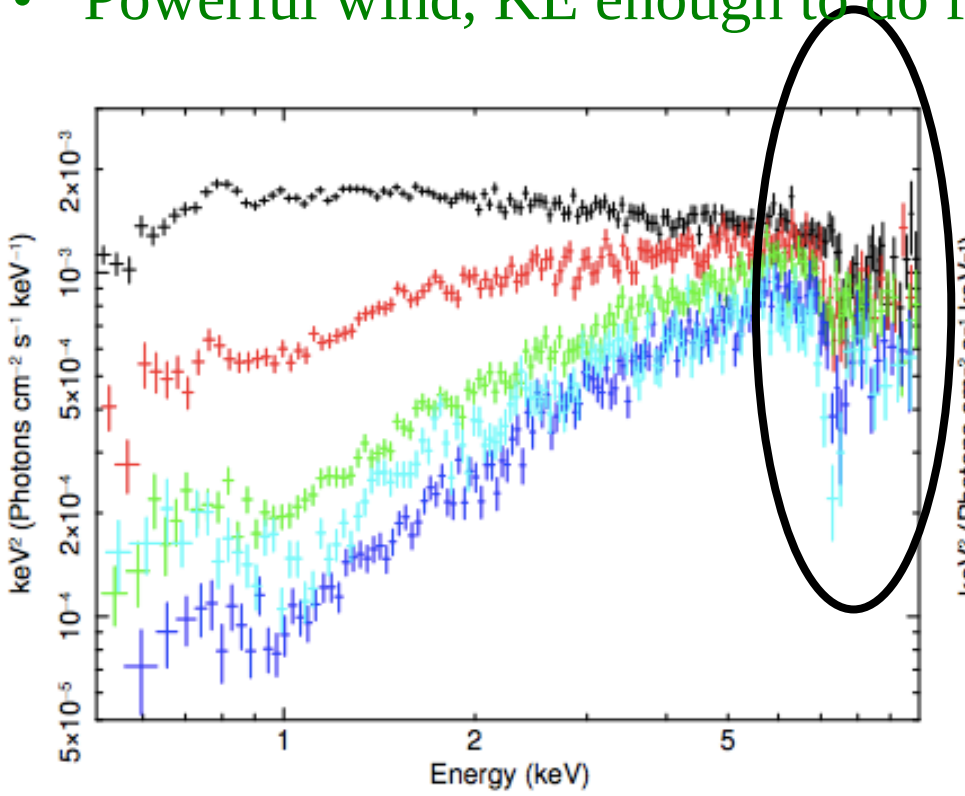
- Disk is bright, X-rays are weak
- High mass L~Ledd – UV AND continuum driving!! PREDICTON

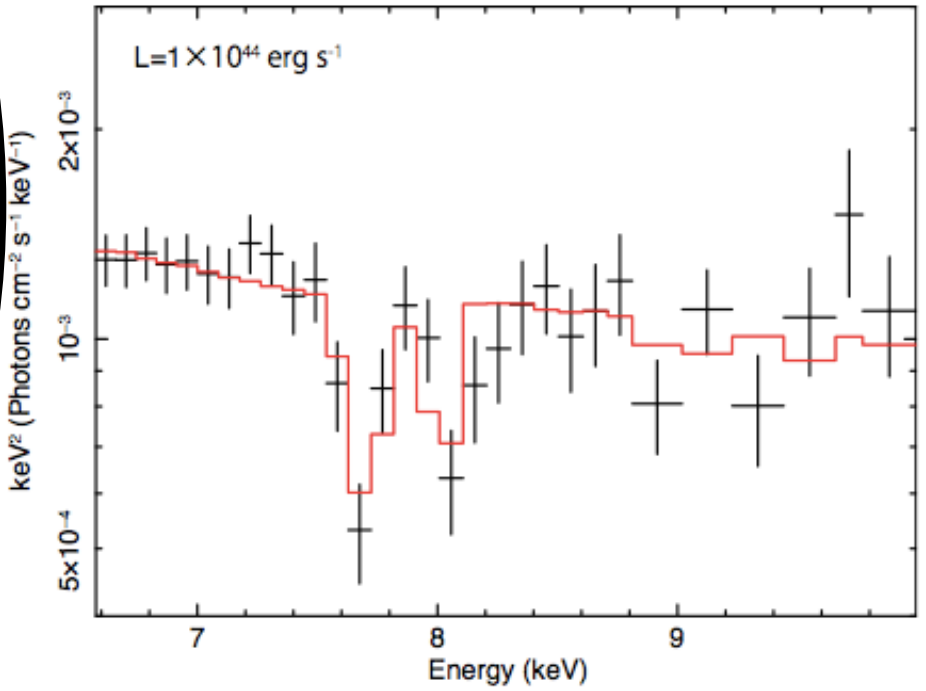


Hagino et al 2014

Evidence for Winds in AGN: UFOs

- PDS456 M~1-2 x 10^9 L~Ledd
- Powerful wind, KE enough to do feedback, high column, v=0.2c





Reeves et al 2009
Hagino et al 2015
Matzeu et al 2016

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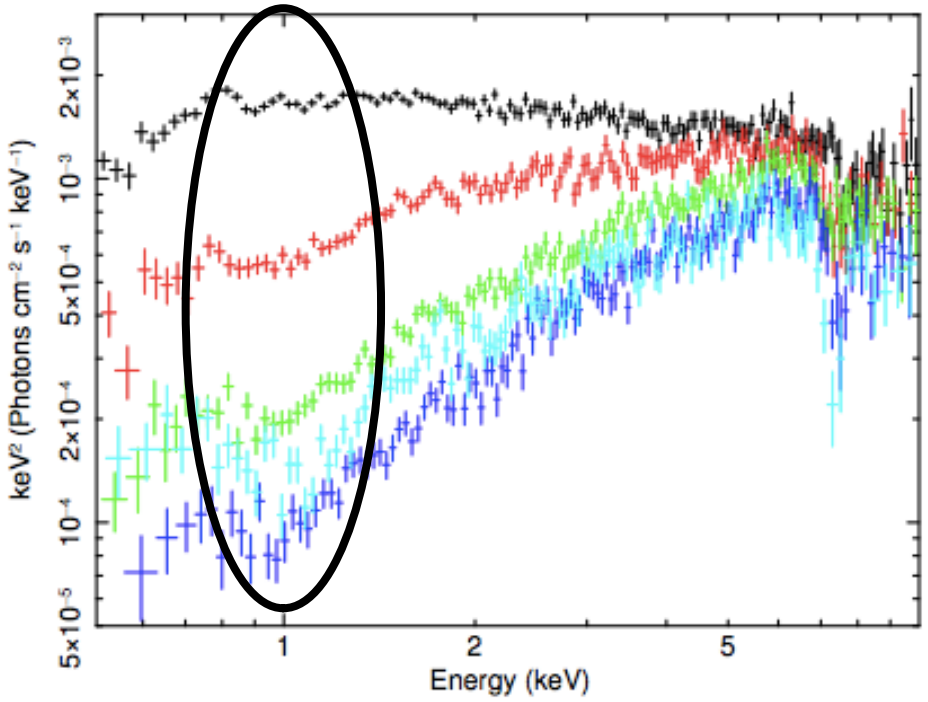
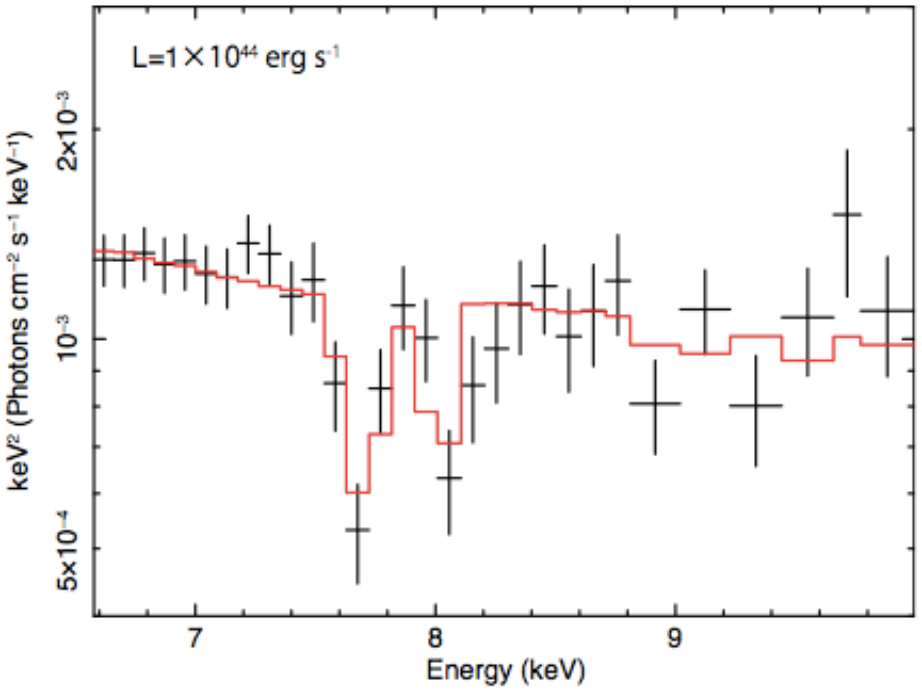


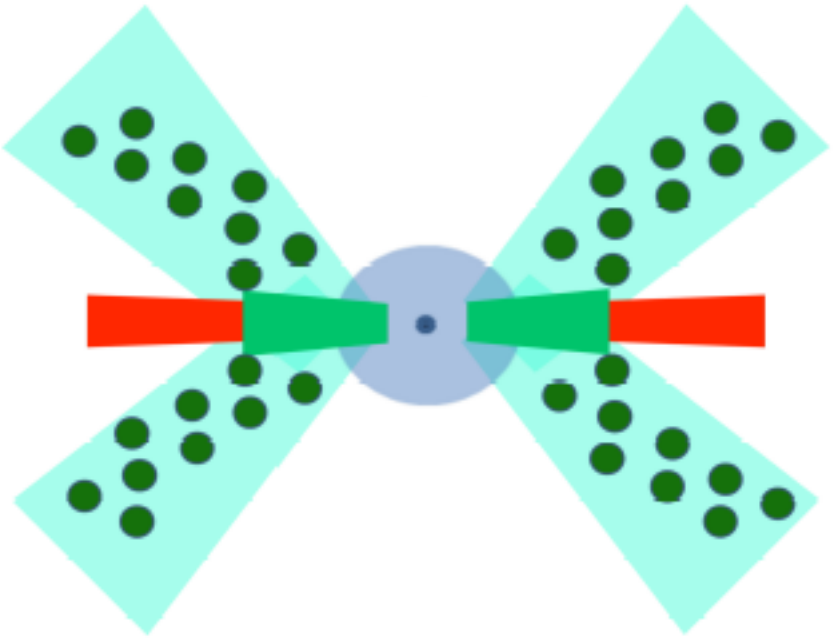


- Clumpy wind to have high ionisation lines AND low energy absorption

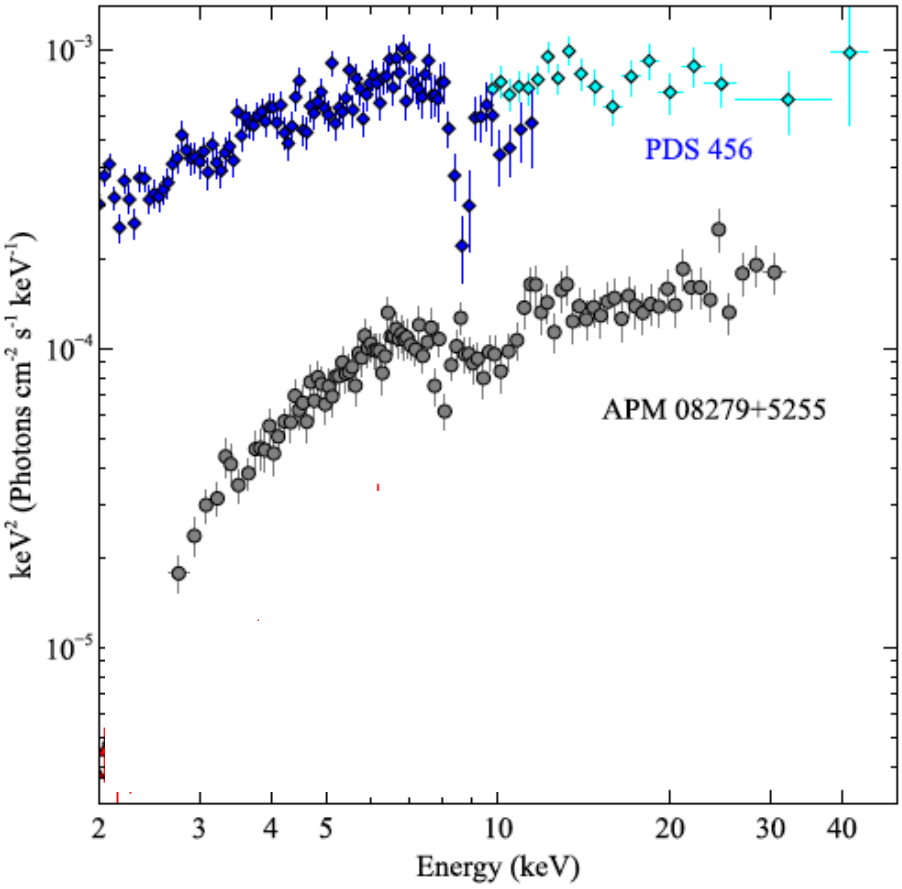
Reeves et al 2009
Hagino et al 2015
Matzeu et al 2016

Evidence for Winds in AGN: UFOs

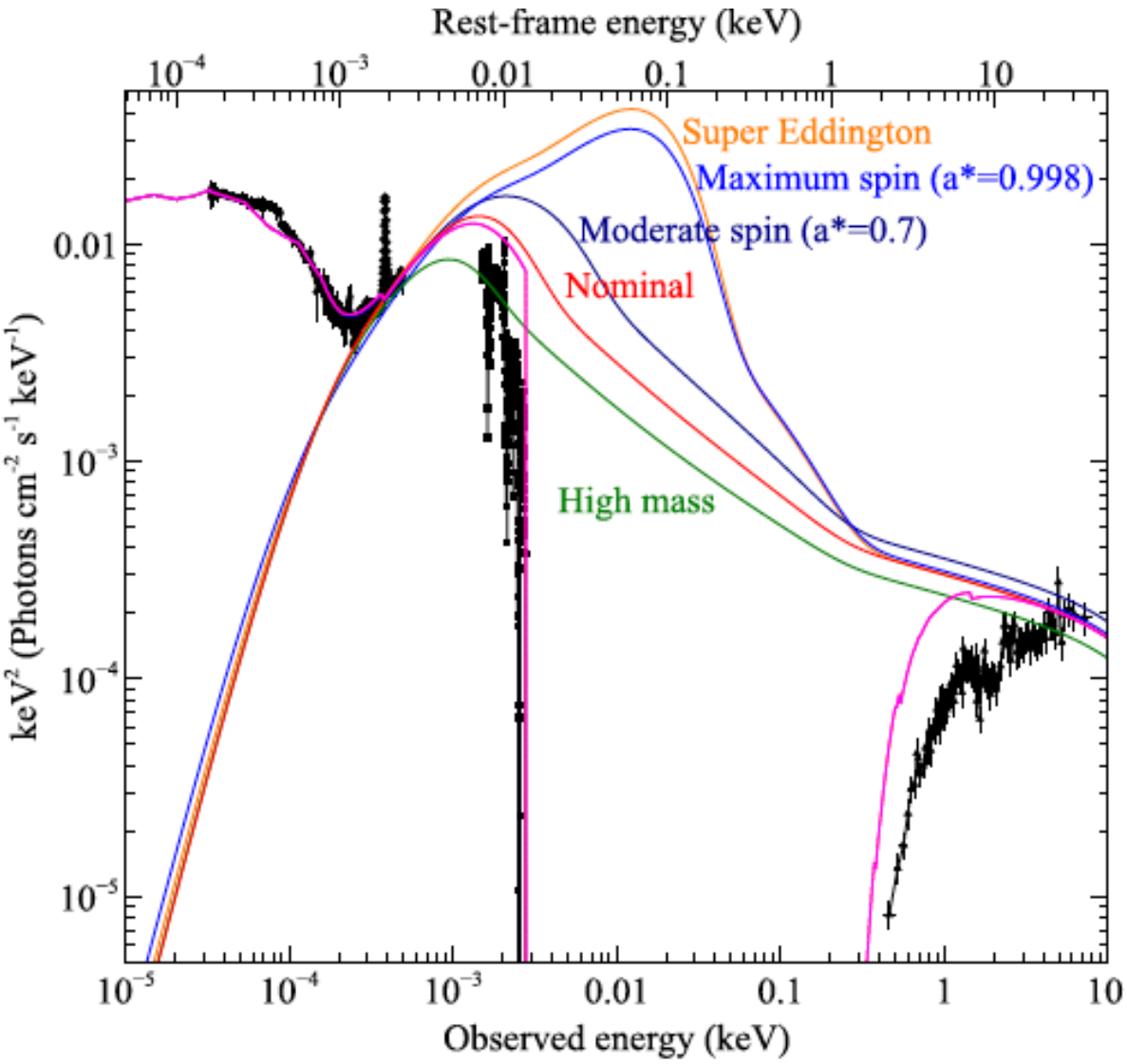
- APM08279+5255 M~1-2 x 10^{10} L~Ledd
- Powerful wind, KE enough to do feedback, high column,
- v=0.2c hot + cold. Hagino et al 2016 OR v=0.2c+0.6c hot wind….Chartas et al 2009



Done & Jin 2016



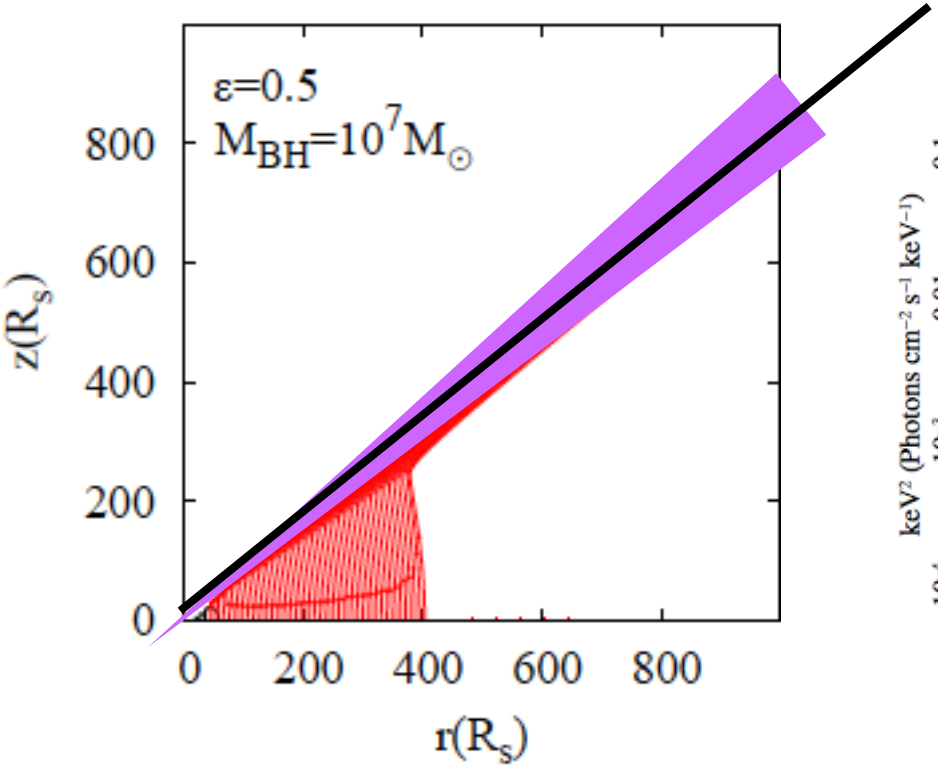
APM08279+5255

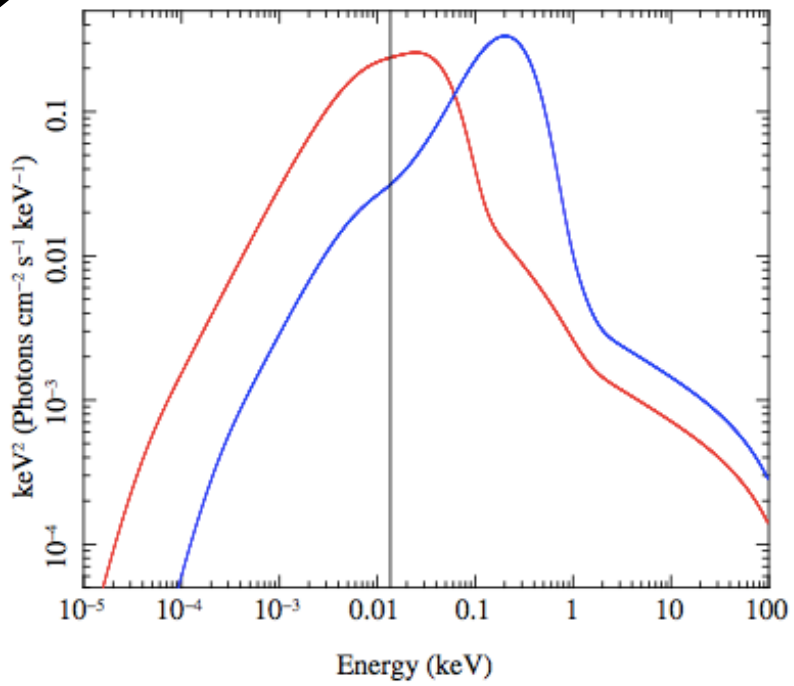


Hagino et al 2016

10^6 versus 10^9 M

- Disk is bright, X-rays are weak
- High mass L~Ledd – UV AND continuum driving!! PREDICTON
- But the winds we see are so ionised….
- Launch close to disc, then ionise??



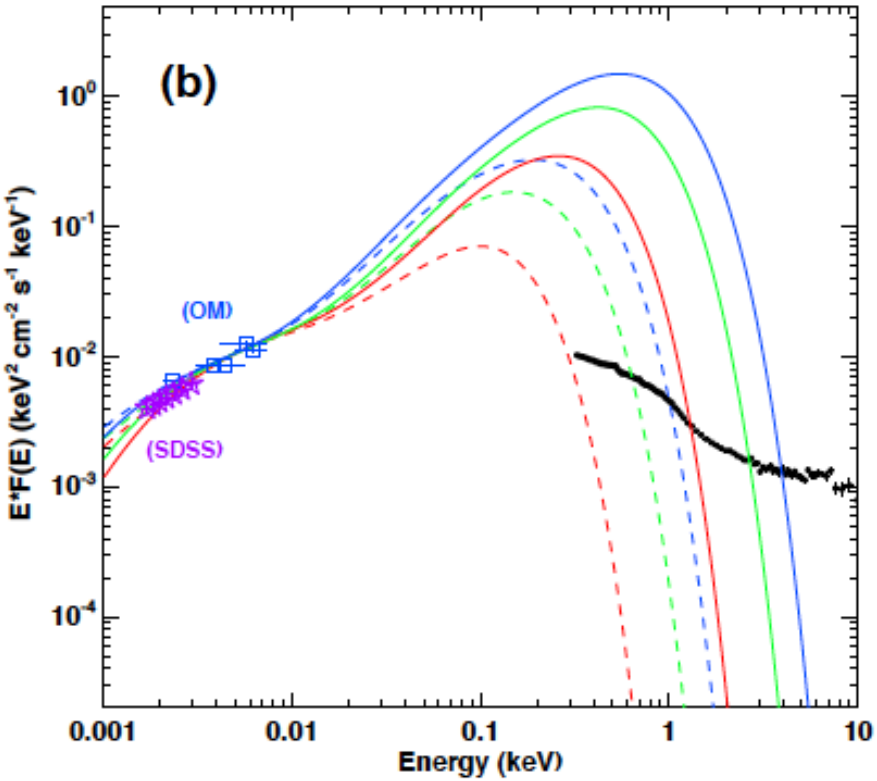


Hagino et al 2014

Supereddington PG1244

- M=2e6
- Mdot though outer disc is 13x Eddington and zero spin
- Lobs=4LEdd
- Losing lots of power!
- Winds/advection?

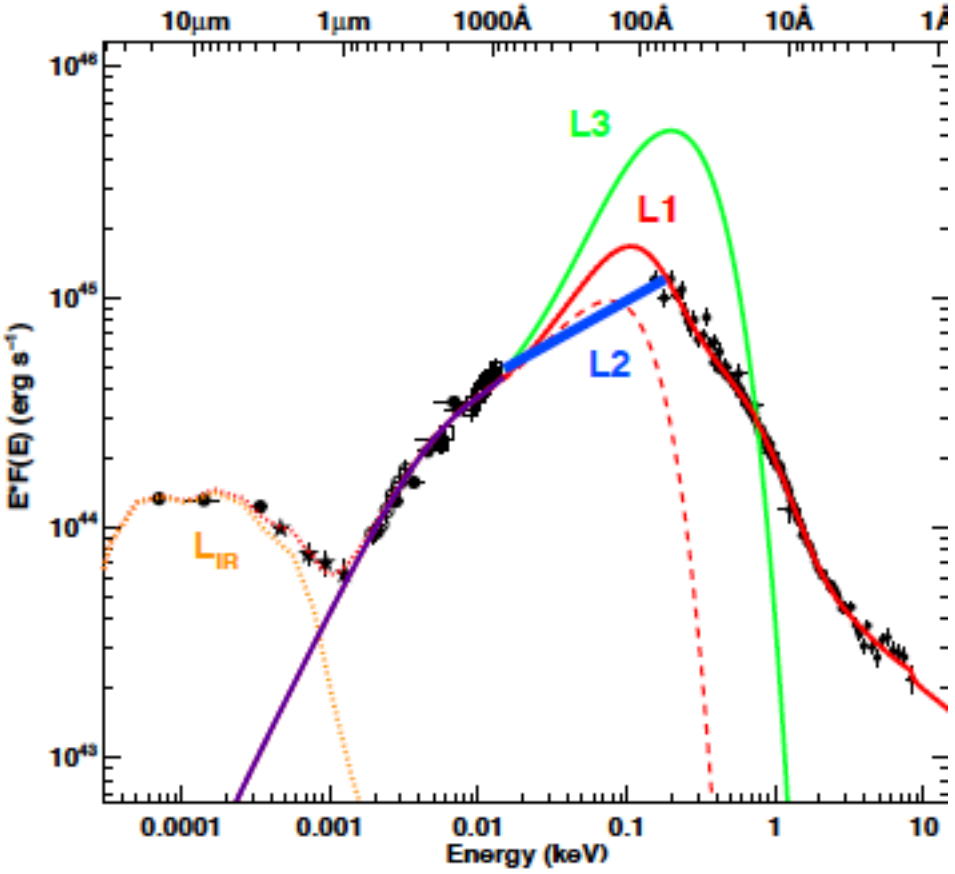
Done & Jin 2016

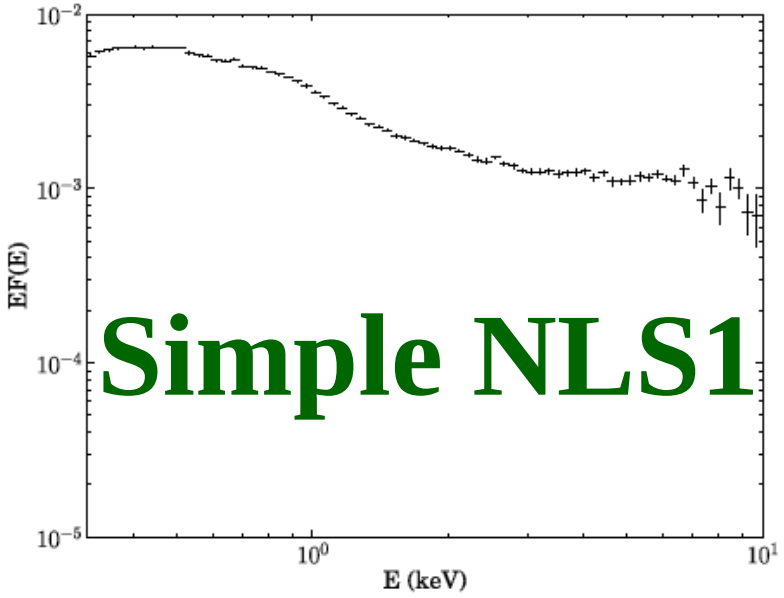


Supereddington RX0439

Jin et al 2017

- M=7e6
- Mdot though outer disc is 12x Eddington and zero spin
- Lobs=4.6LEdd
- Losing lots of power!
- Winds/advection?

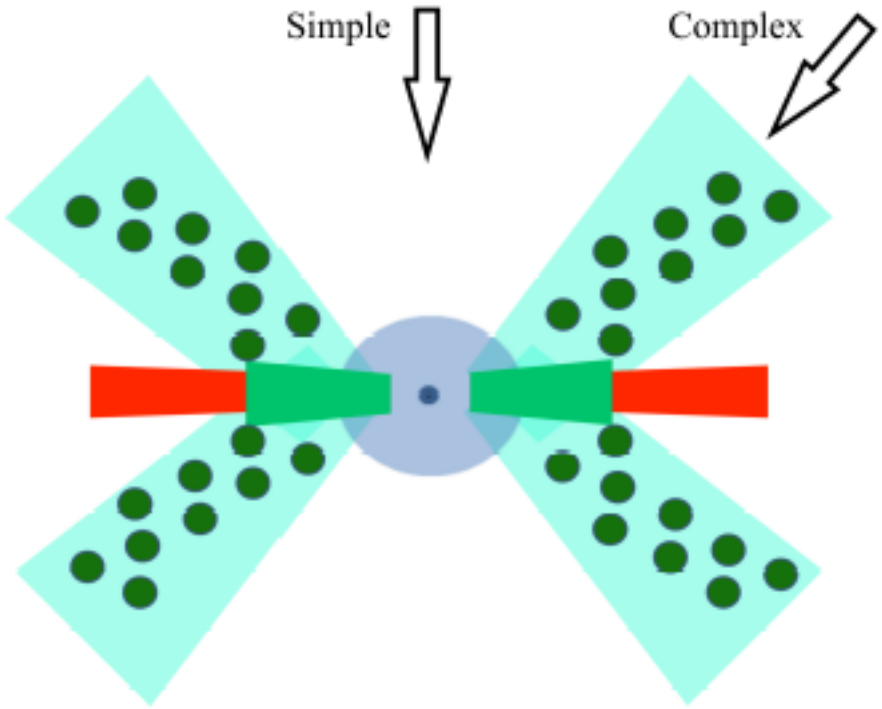


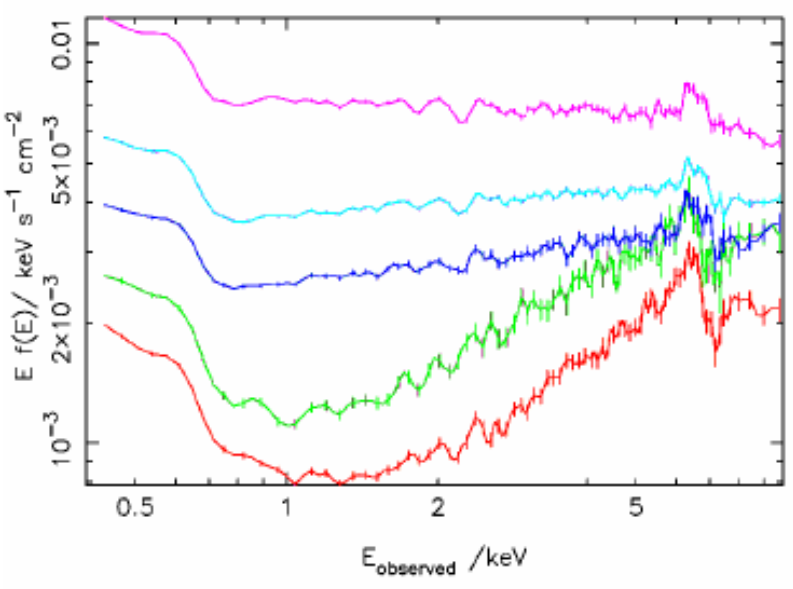


Simple NLS1

Supereddington winds

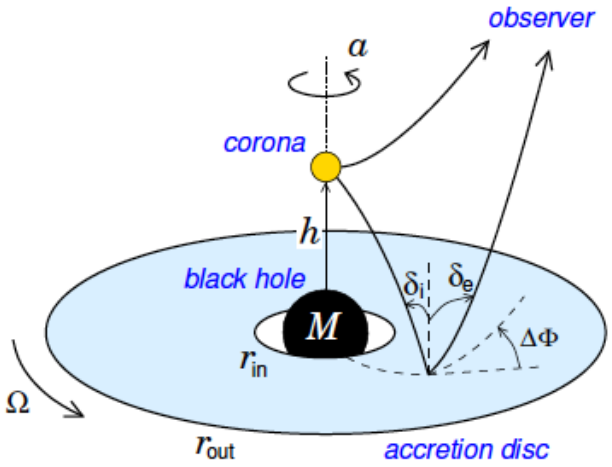
Complex NLS1

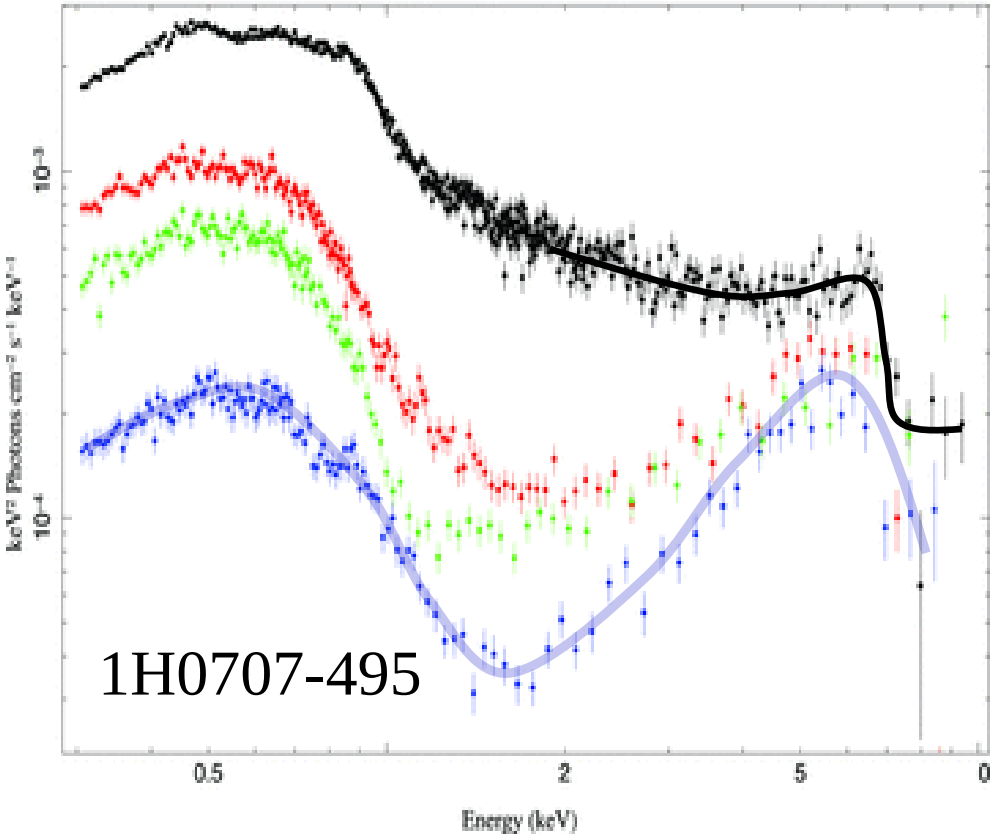




Complex NLS1 – X-ray view

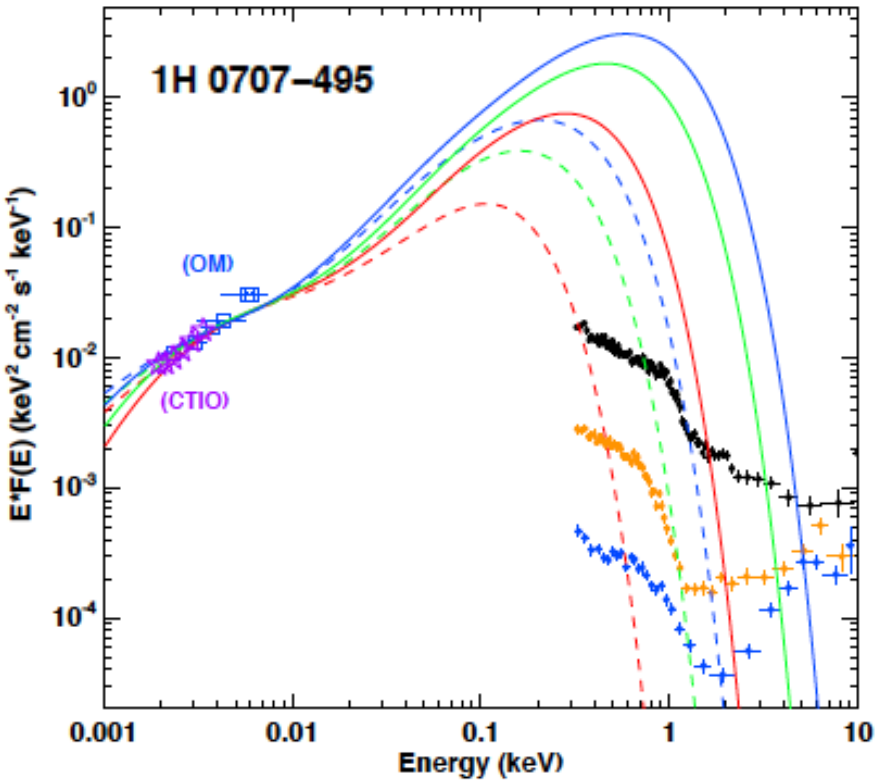
- ‘Complex’ NLS1 (Gallo 2006) eg 1H0707-495
- Deep dips – hard spectra, large Fe features



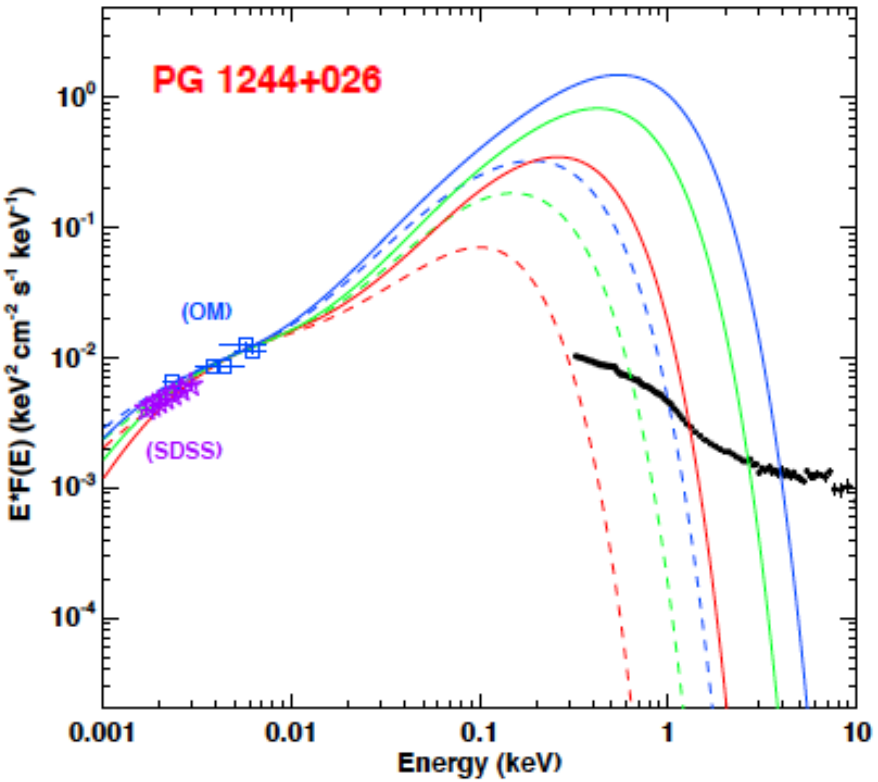


Fabian et al 2009

Multiwavelength view!



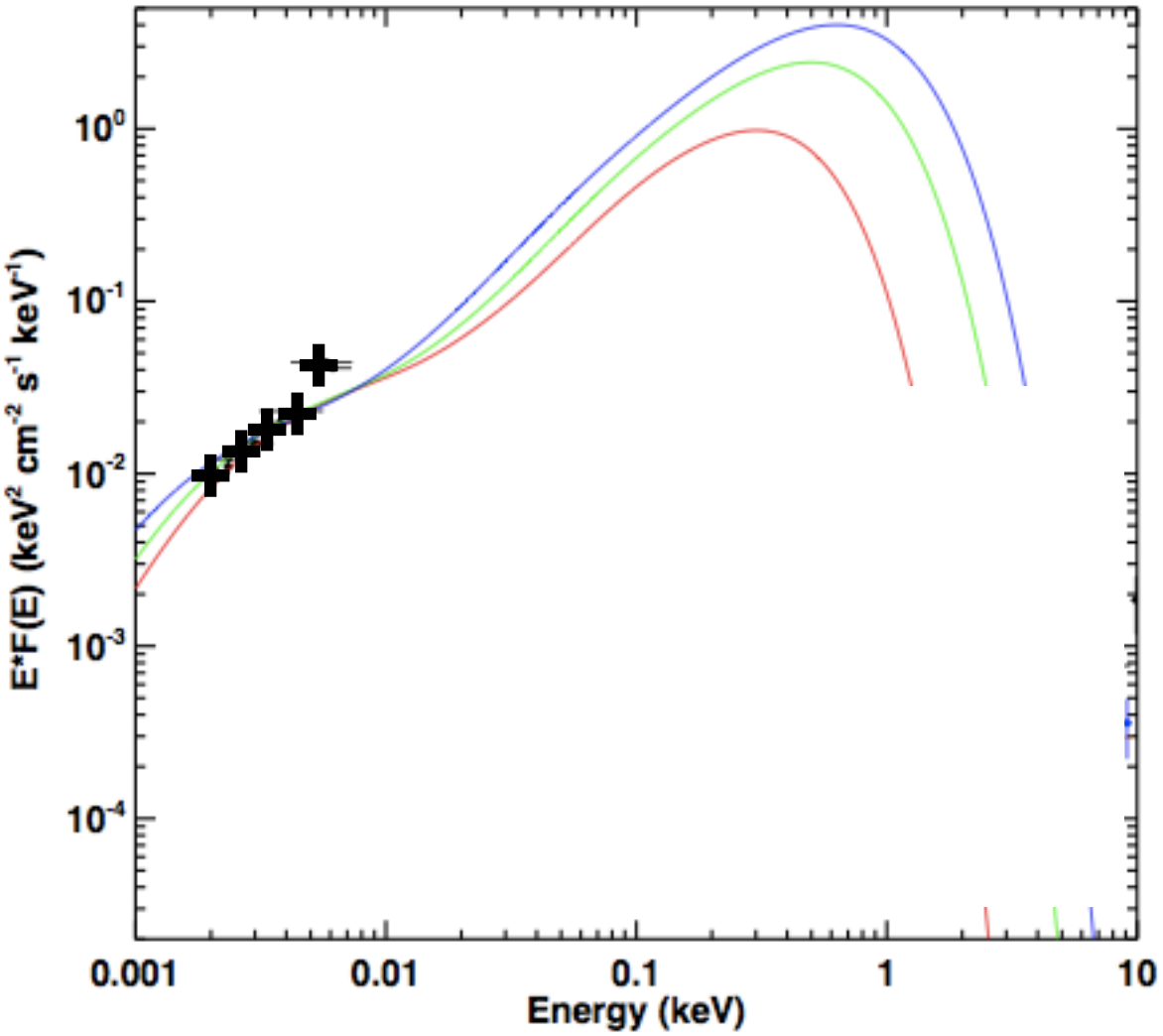
Fe 7-20
Maximal spin
Height small
i~60



Fe 2-3
maximal spin
height larger
i~30

Do we have a clean view - Winds

- 1H0707
- 2e6M a=0, 0.9, 0.998
- L/Ledd = 20, 63 150 (30 degrees)
- L/Ledd = 44, 123 270 (60 degrees)
- Done & Jin 2016
- Clean disc??



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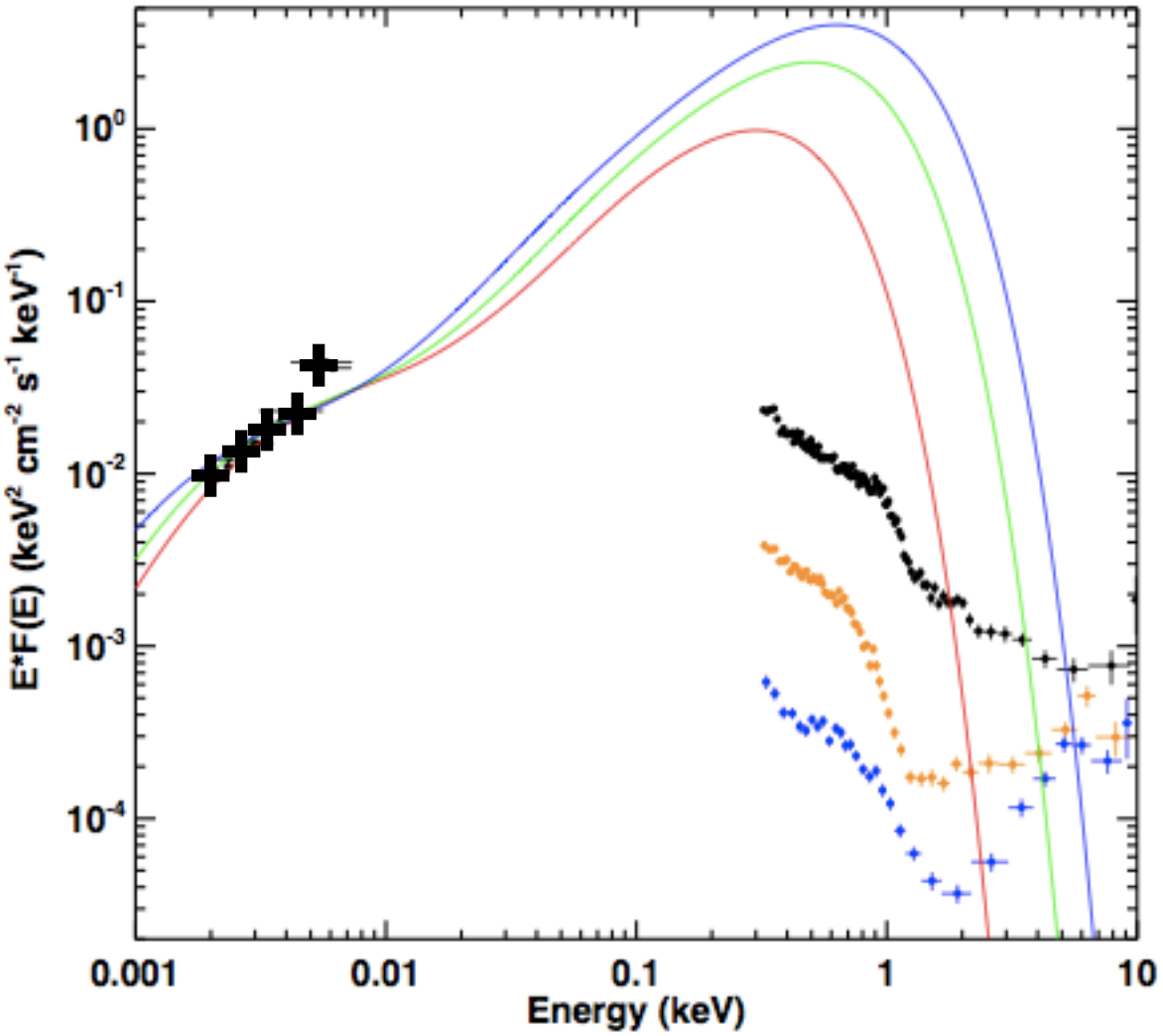
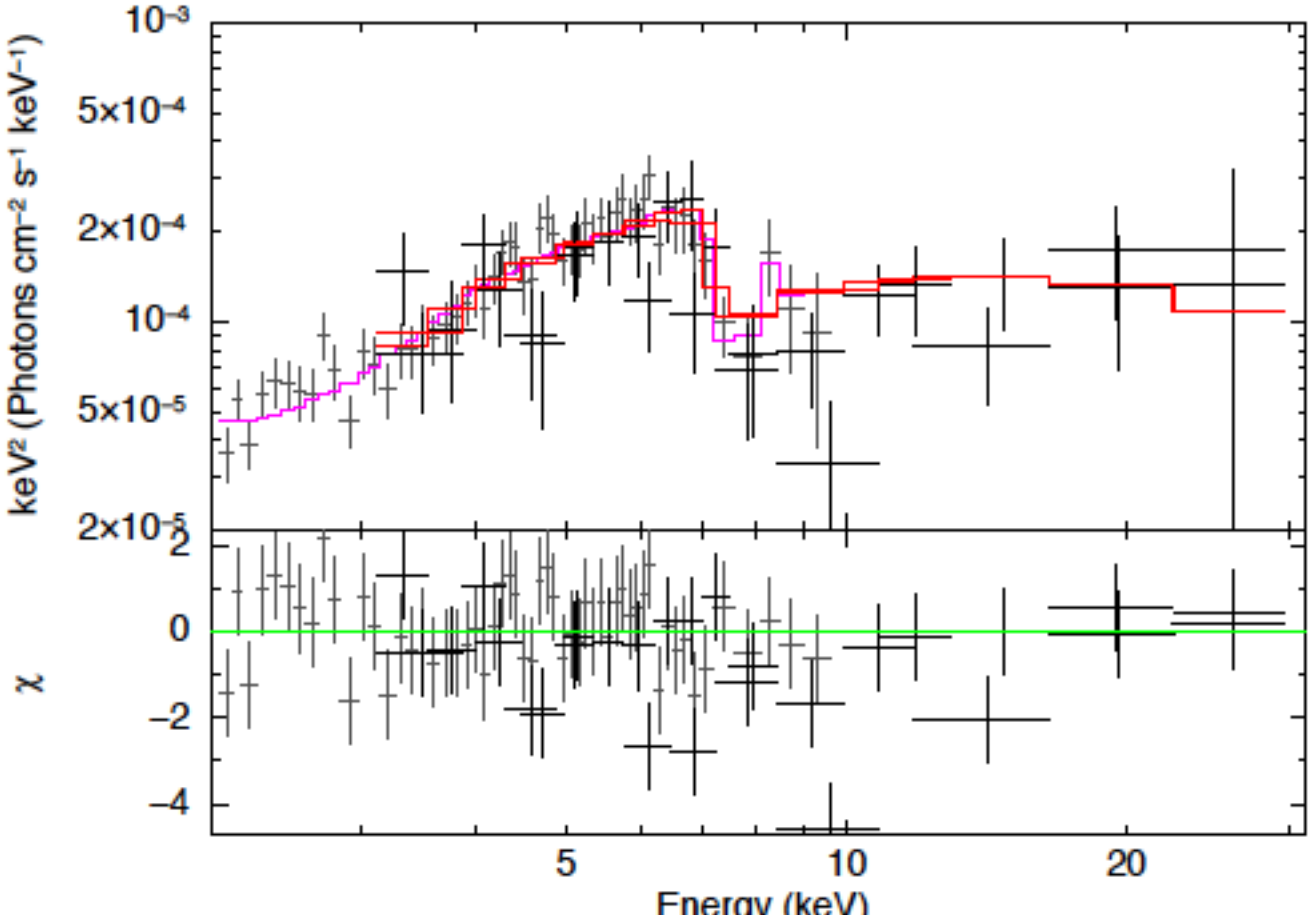
- 1H0707
- 2e6M a=0, 0.9, 0.998
- L/Ledd = 20, 63 150 (30 degrees)
- L/Ledd = 44, 123 270 (60 degrees)
- Done & Jin 2016
- Clean disc??

- SUPEREDDINGTON
- Strong winds???



Wind models for Ka line in 1H0707

- Means no need for high spin in radio quiet NLS1
- Could go back to high spin=highly relativisitic jet models!! Done & Jin 2016



Hagino et al 2016

Conclusions

- Zoo of AGN must be based on mass, mass accretion rate, spin and inclination
- Scale from BHB to AGN – disc peaks UV so atomic physics much more important! Breaks scaling
- Maybe produces the soft X-ray excess in BLS1
- Low L/Ledd scale as still plasma physics from hot inner flow: LINERS – look like hot flow
- NLS1 look quite like disc dominated BHB – weak X-rays. So high L/Ledd HIGH MASS are UV bright and x-ray weak – most favourable condition for UV line driven disc winds.
- Supereddington NLS1 – Eddington winds!

How do we get answers faster?

- what happens to disc structure when we use full opacities, DIM, failed UV line driven discwinds…soft excess region?
- Disc winds – thermal, UV line driven, continuum driven – depends on SED!! Put in realistic SED and calculate mass loss/power loss rates AGN feedback

- GR MHD – low/hard state. Nature of variability, nature of accretion powered jet from flow, hysteresis

- Radiative GR MHD jets – FSRQ