The underlying physics of the accretion flow – XARM

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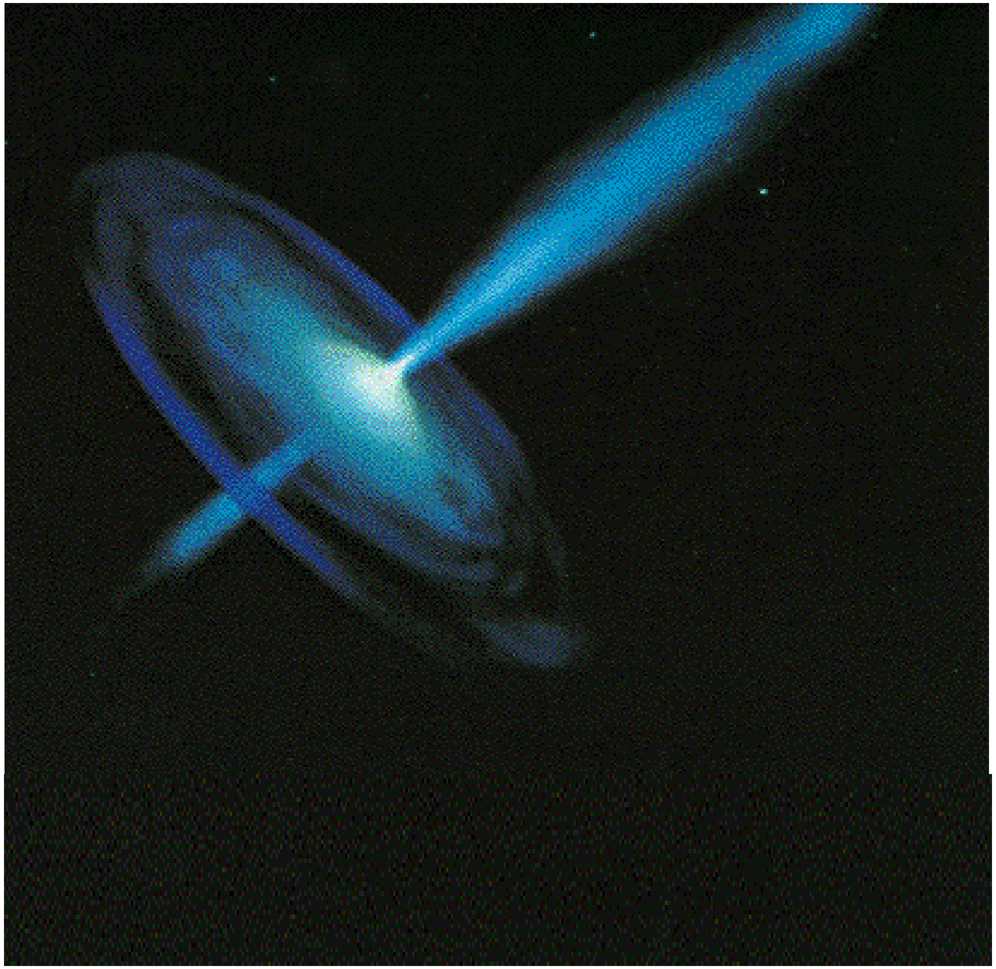
Hirofumi Noda…

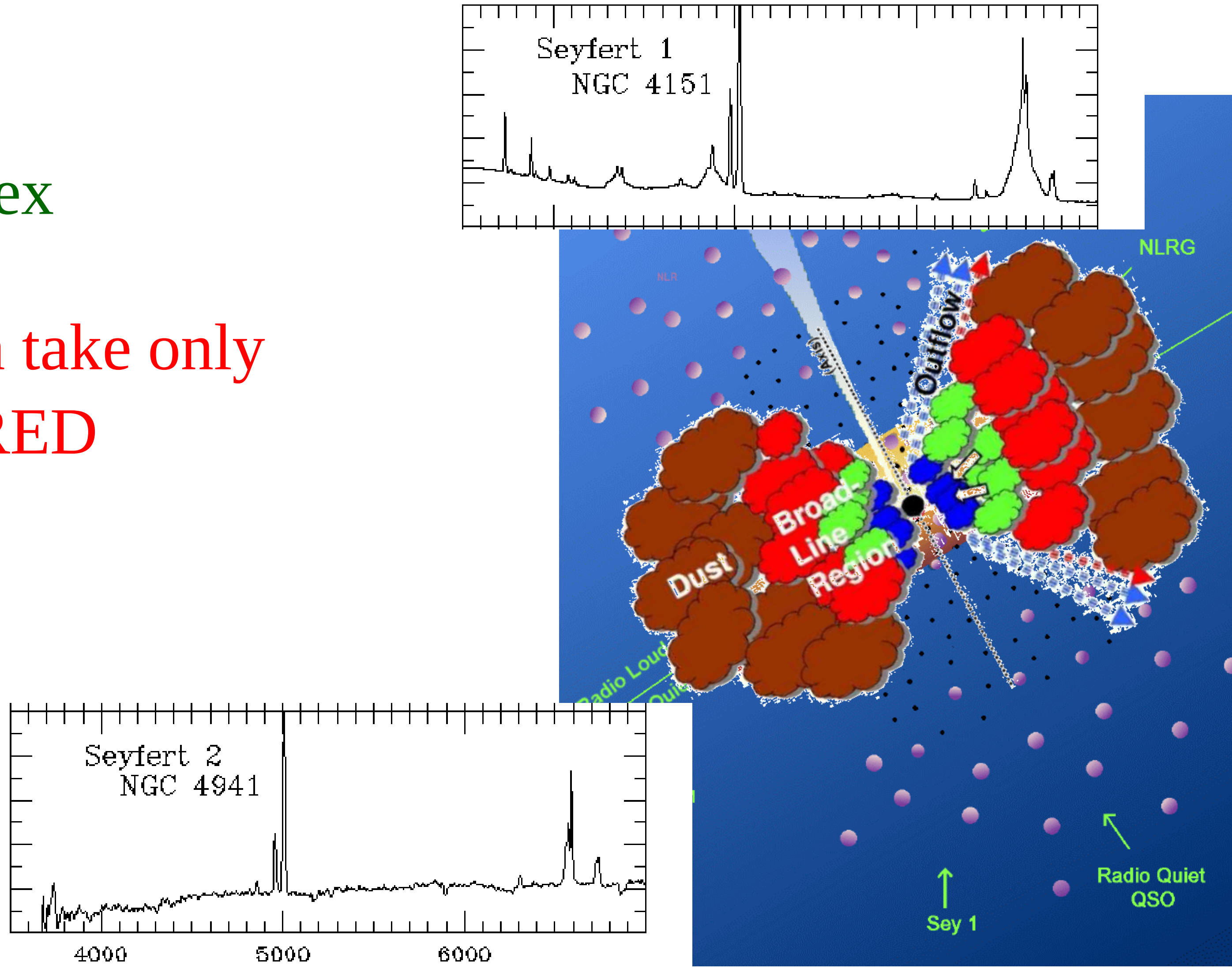
Black hole accretion and jets

- Black holes are the simplest possible objects
- Mass, spin
- See them through accretion – Mdot
- 3 fundamental parameters plus inclination



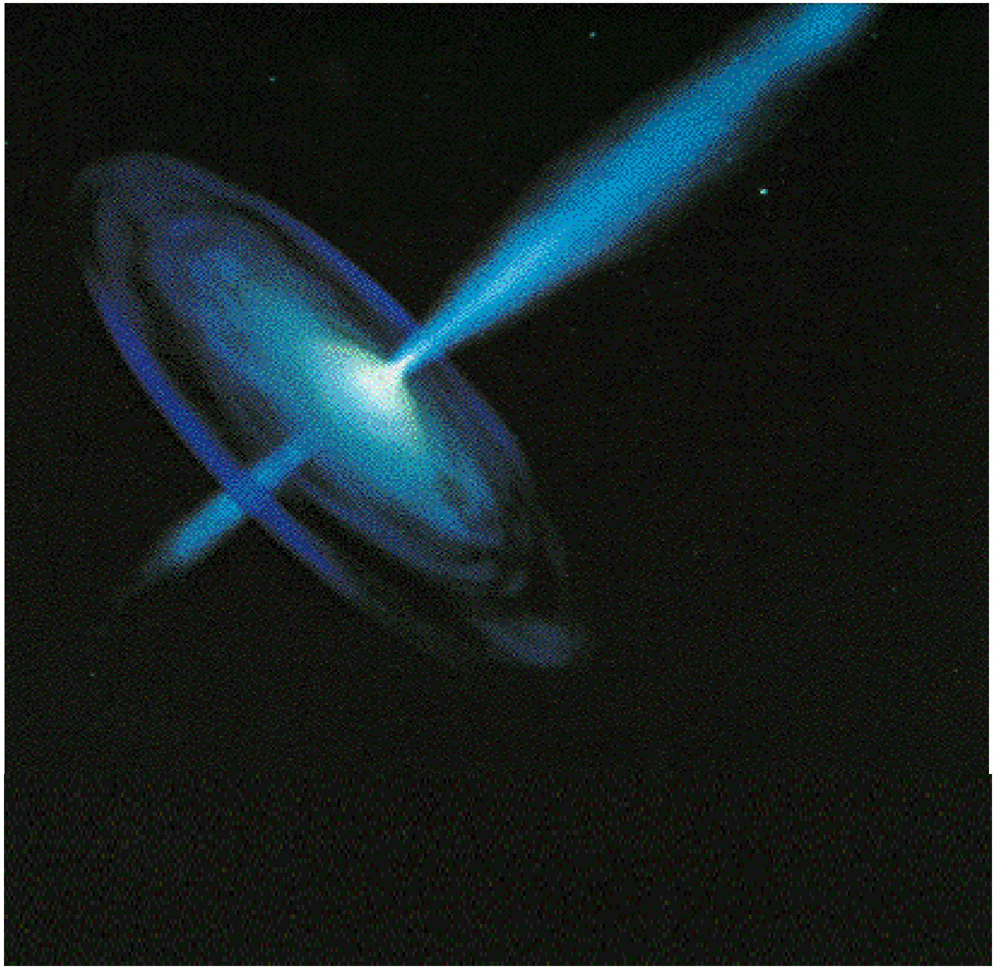
And Inclination

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



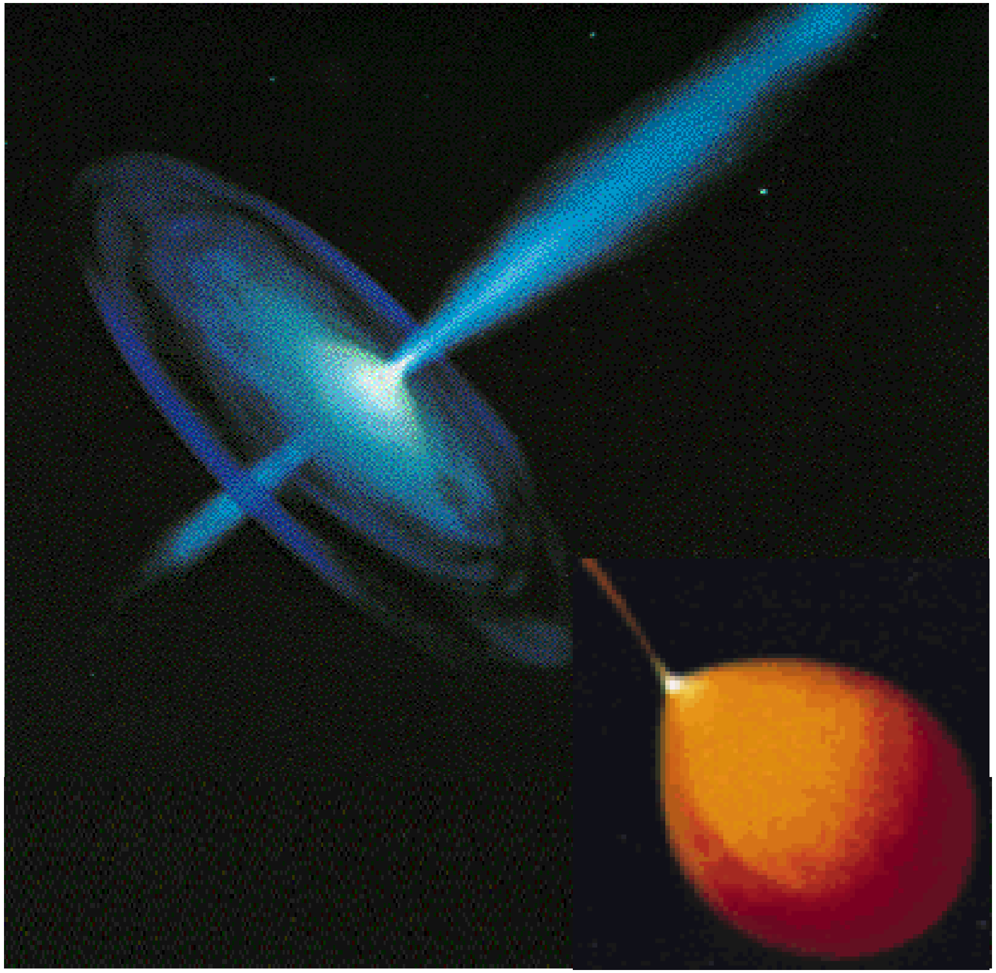
Black hole accretion and jets

- Understand origin of X-rays, jet, winds…
- Is the wind a key or consequence?
- 3 fundamental parameters
- Mass, Mdot, spin
- How hard can this be??

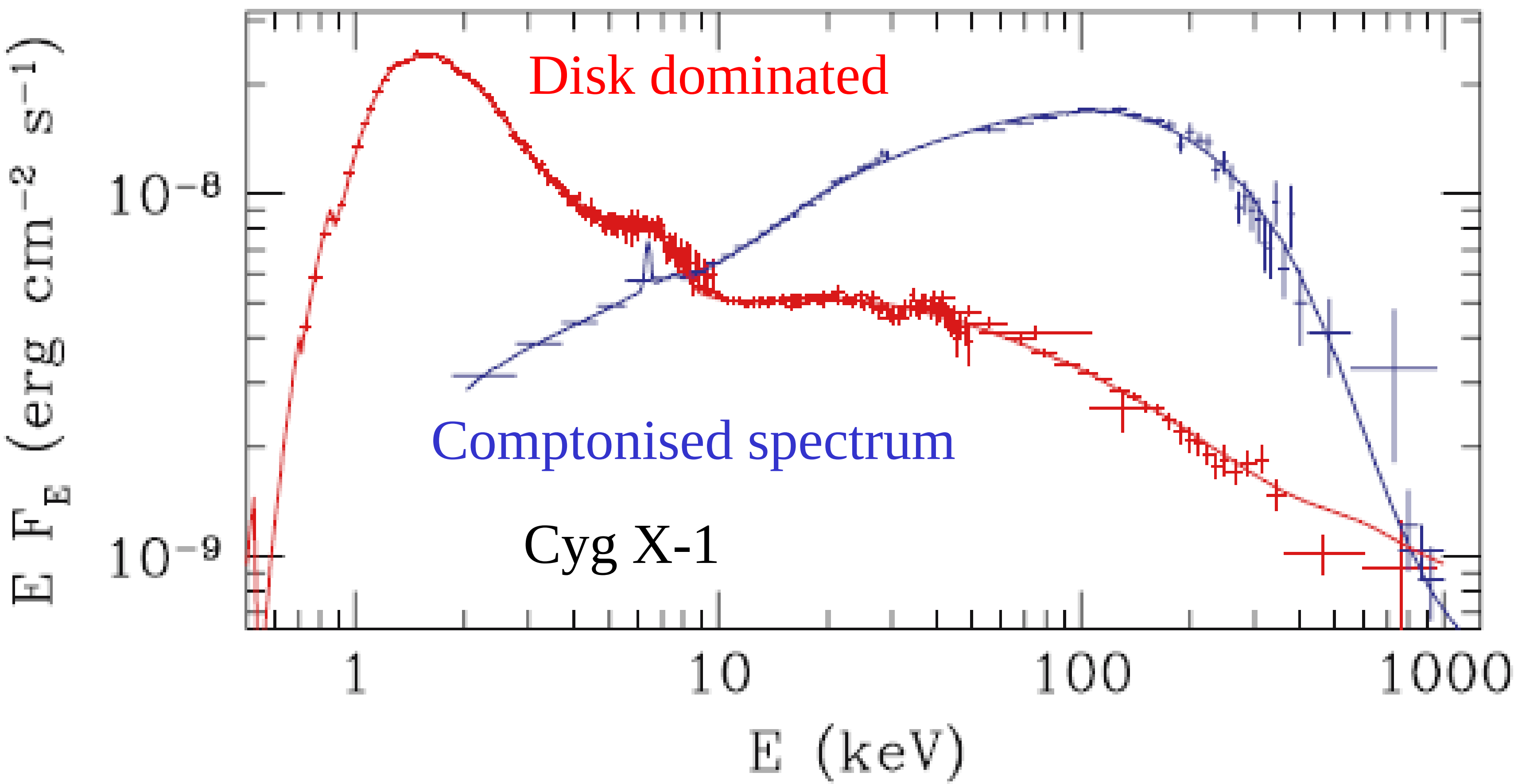


Scaling Black holes

- BONUS
- We get a test set!
- Stellar mass BHB
- All same mass (x2) – maybe also similar spin
- Observational template of how accretion flows behave with L/L_{Edd}

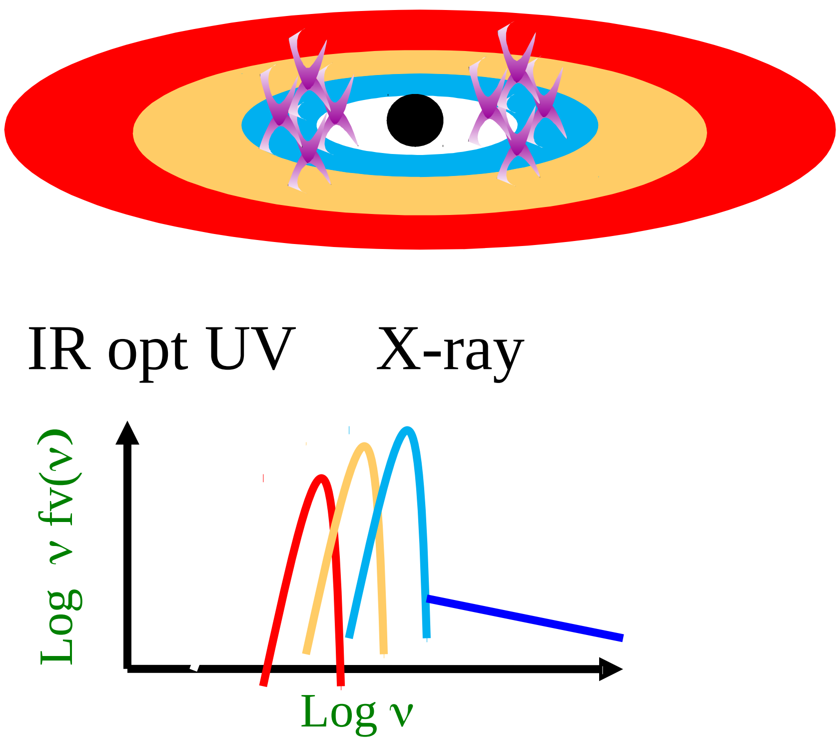


Two types of spectra in stellar BH

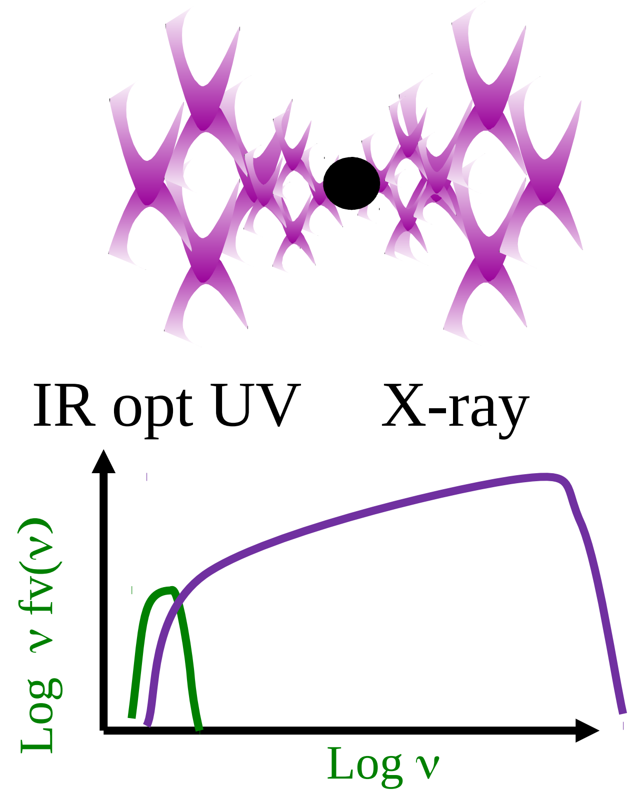


Gierlinski et al 1999

Theory of accretion flows



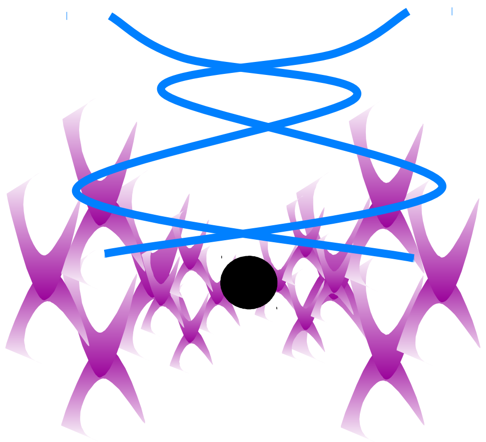
Discs – geometrically thin, cool, optically thick SS73
Plus X-ray tail/corona

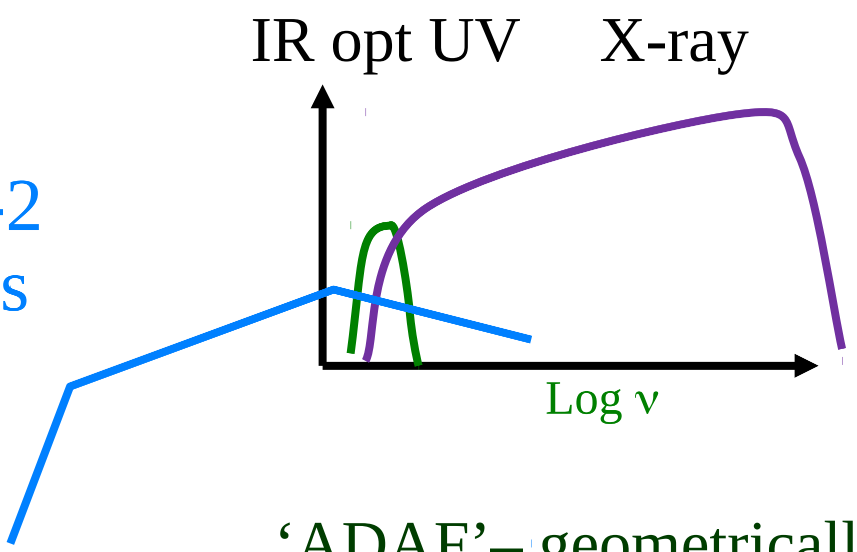


‘ADAF’– geometrically thick, hot, optically thin
Only low L/Ledd
Narayan & Yi 1995

Theory of accretion flows

- Low/hard state BHB
- Large scale height flow so large scale height B field…
- And jet!! L_R – Lx
- (Fender et al 2004)
- BUT NOT HIGHLY RELATIVISTIC Γ~1.5-2 NOT 10-20 as in Blazars

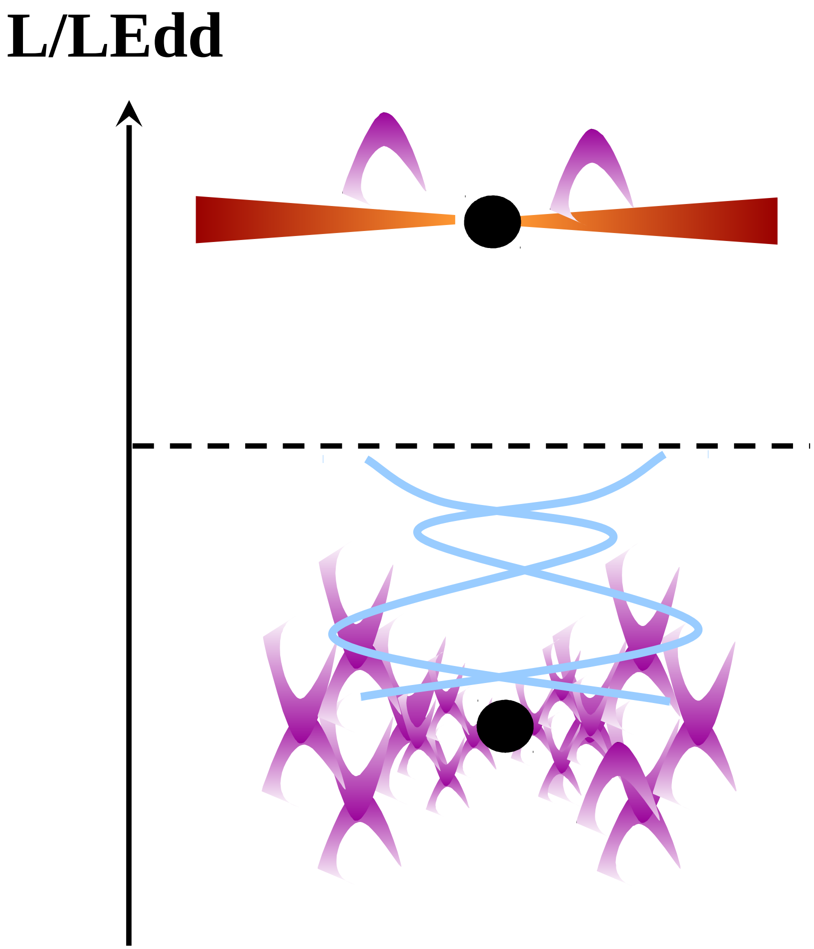




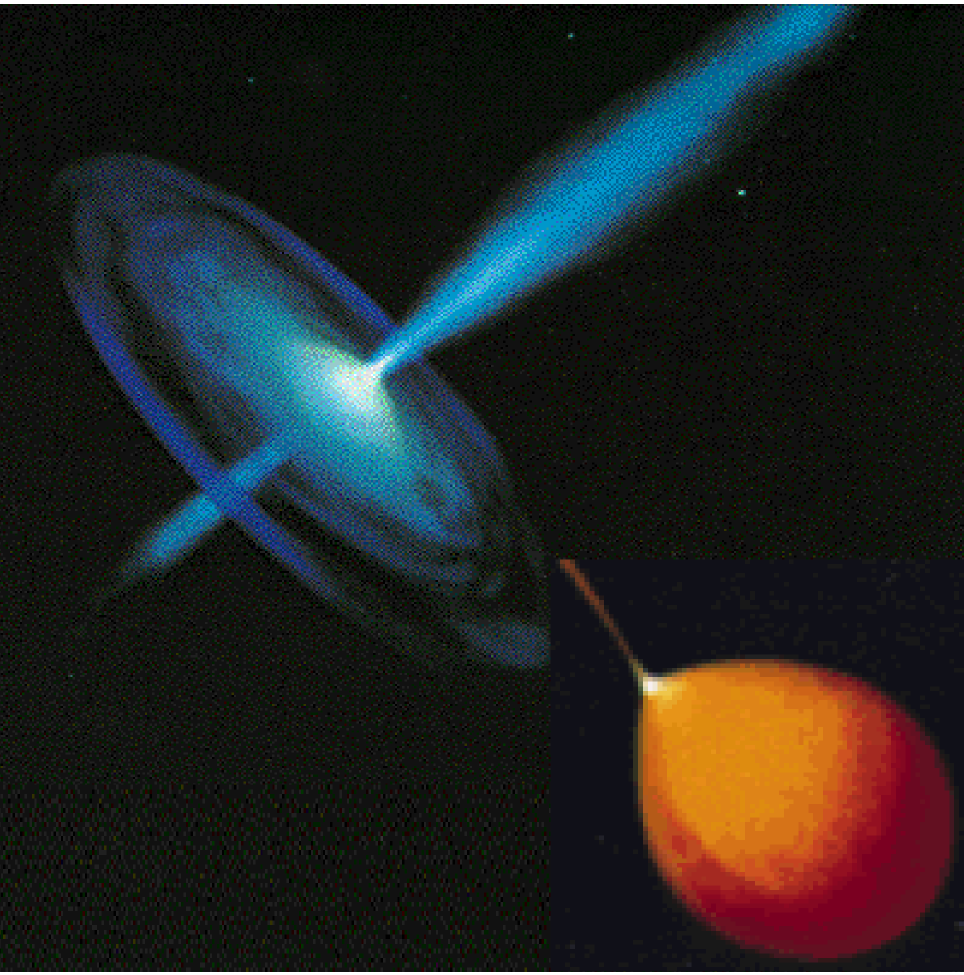
‘ADAF’– geometrically thick, hot, optically thin
Only low L/Ledd

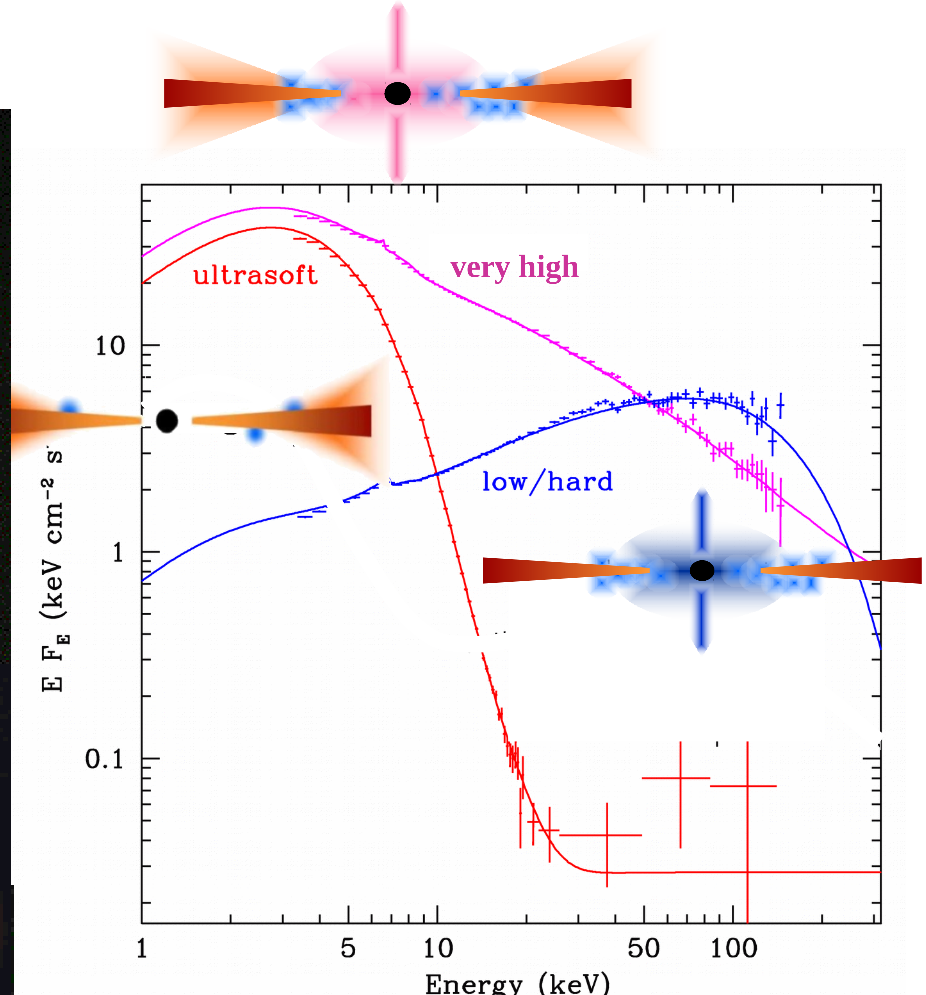
BHB accretion + jet

- Complex around Ledd?
- Disc dominated state – Shakura-Sunyaev disc equations!!
- X-ray corona and no jet
- Complex transition
- ADAF + steady compact jet bulk $\Gamma \sim 1.5\text{-}2$



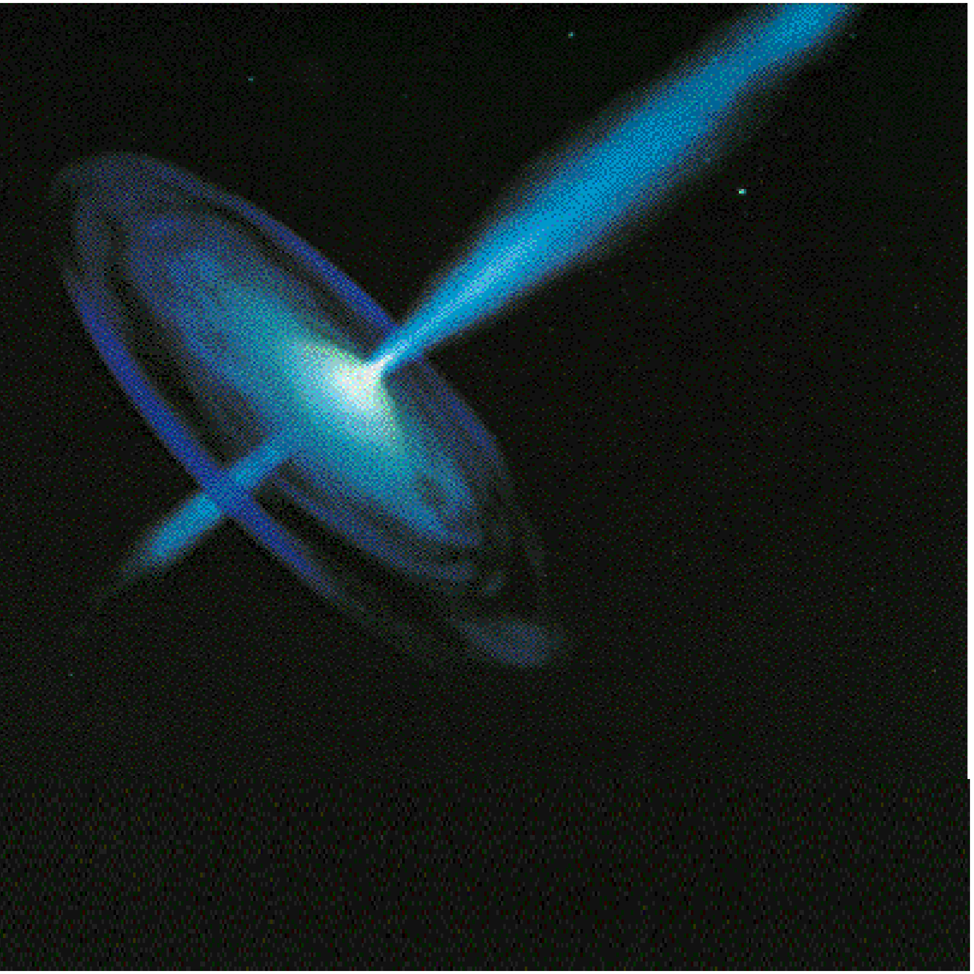
Spectral states - BHB





Gierlinski & Done 2003

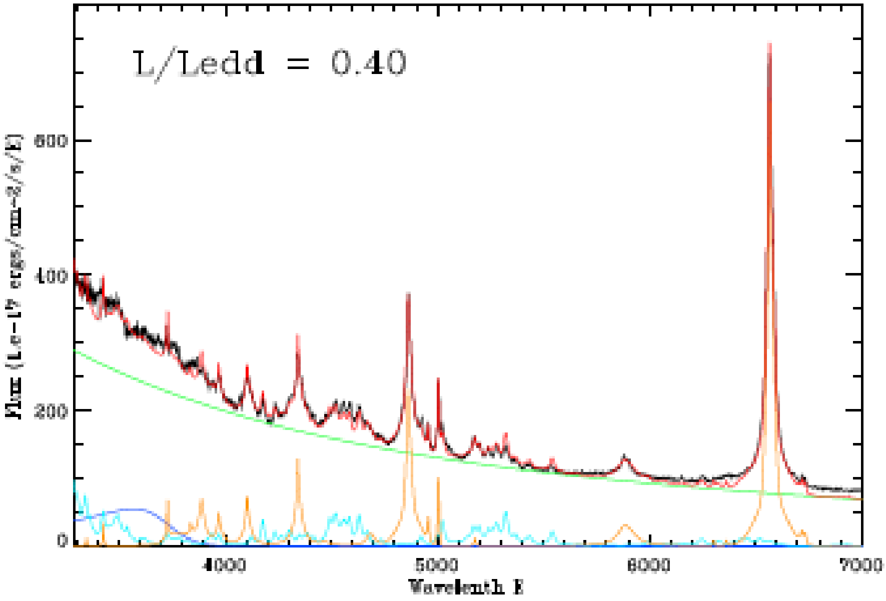
Scaling black hole accretion flow



- Scale up to AGN
- Bigger mass!
- Disc temp lower – peaks in UV (more power, but more area!)
- ATOMIC PHYSICS
- Radiation pressure dominant, smaller disc…
- Larger RANGE in mass –from 10^5-10^{10}M
- And maybe bigger range in spin??

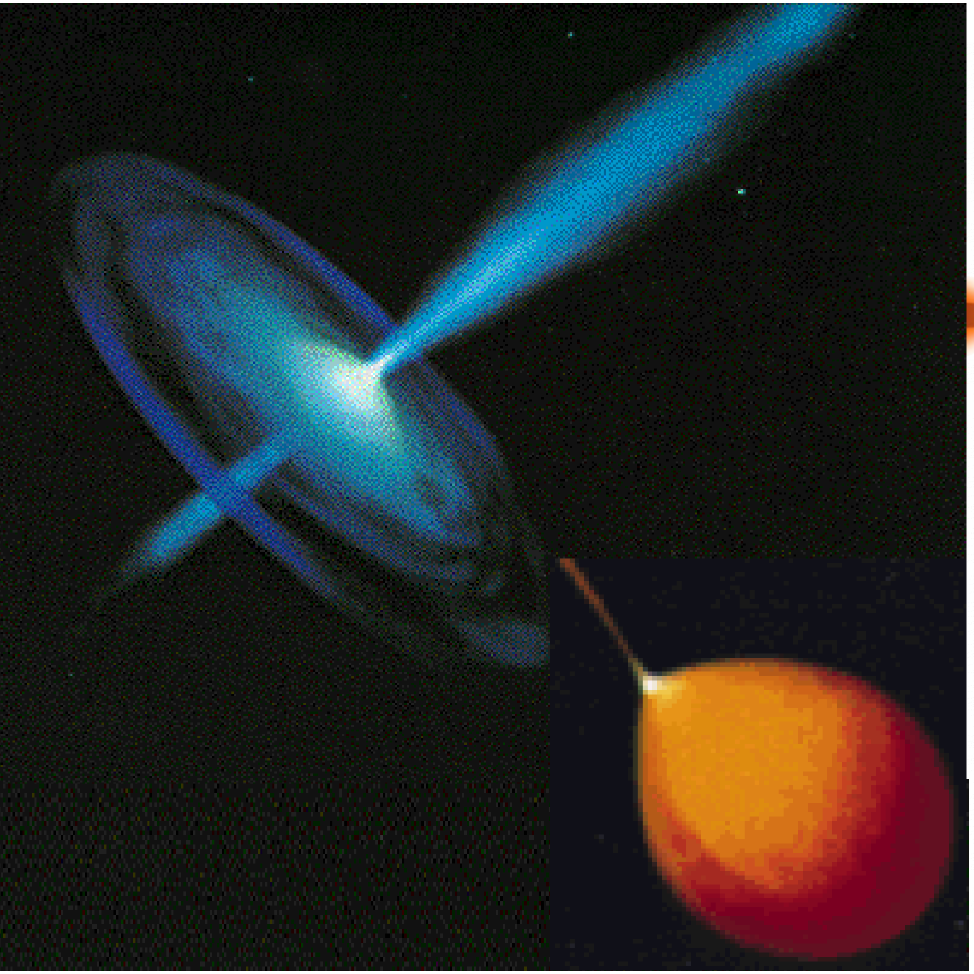
Need M and L/LEdd – SDSS!

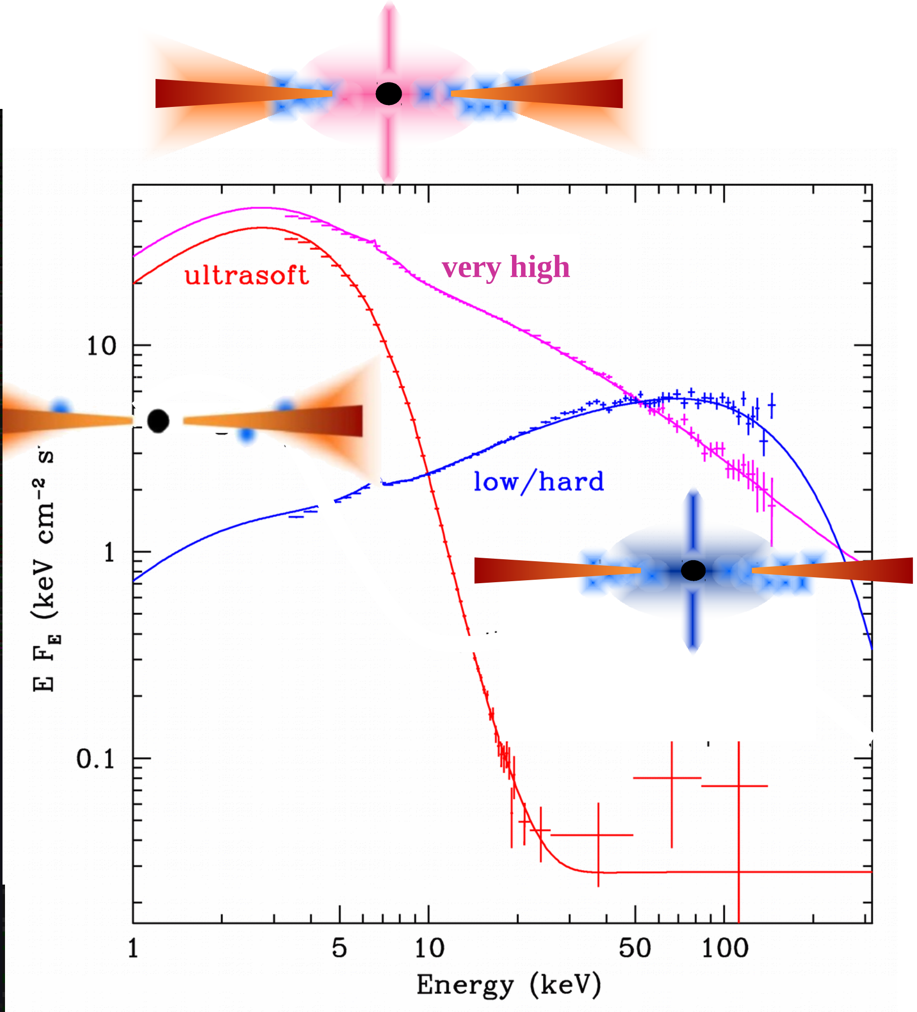
Jin, Ward, Done Gelbord 2012



- Mdot from optical spectra once know BH mass
- L_{5100} α (M Mdot)$^{2/3}$ cos i (SS73, Collin et al 2006 Davis & Laor 2011)
- Lbol =η Mdot c^2 α $L_{5100}^{1.5}$
- NOT α L_{5100}

BHB: template for SED L/Ledd?

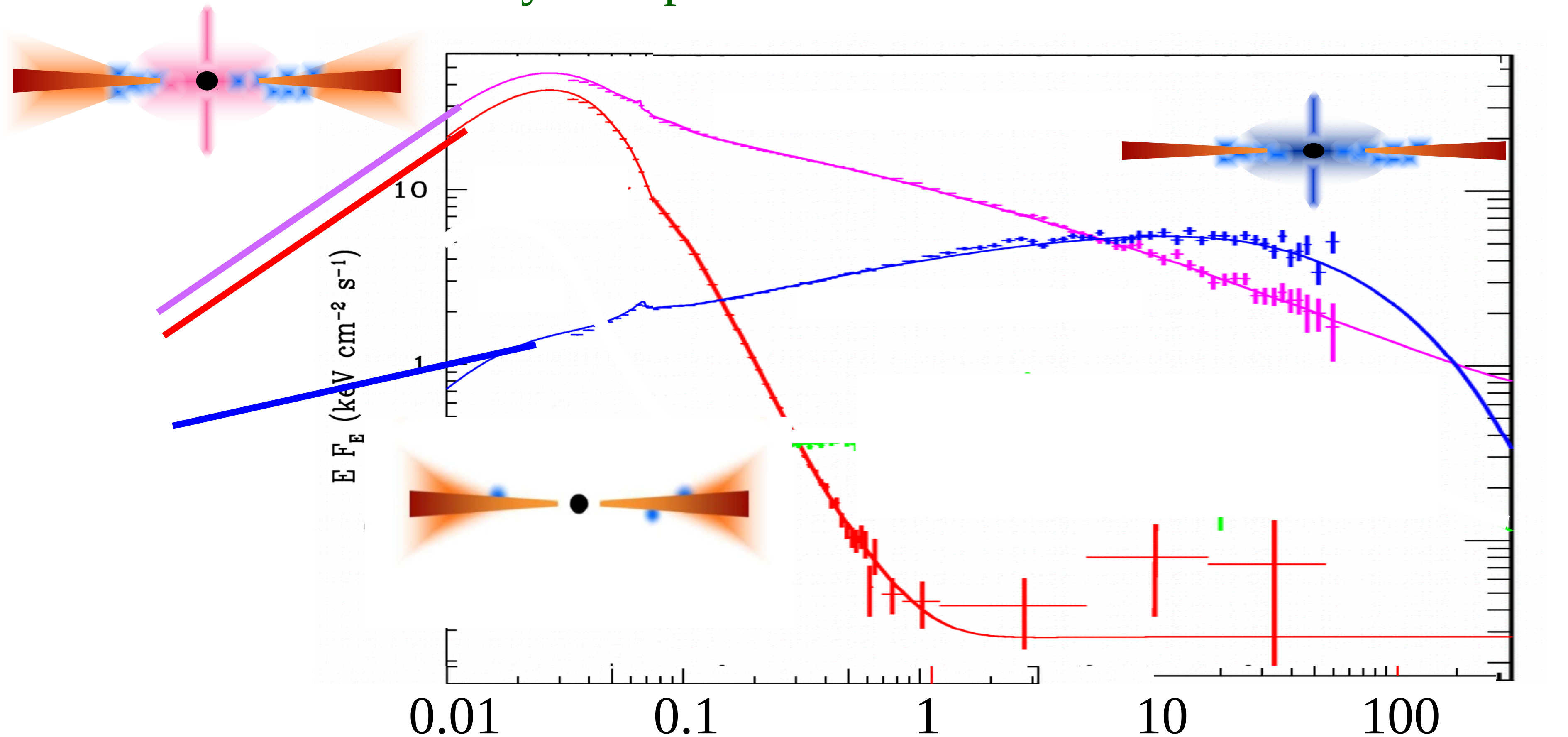




Gierlinski & Done 2003

‘Spectral states in AGN’

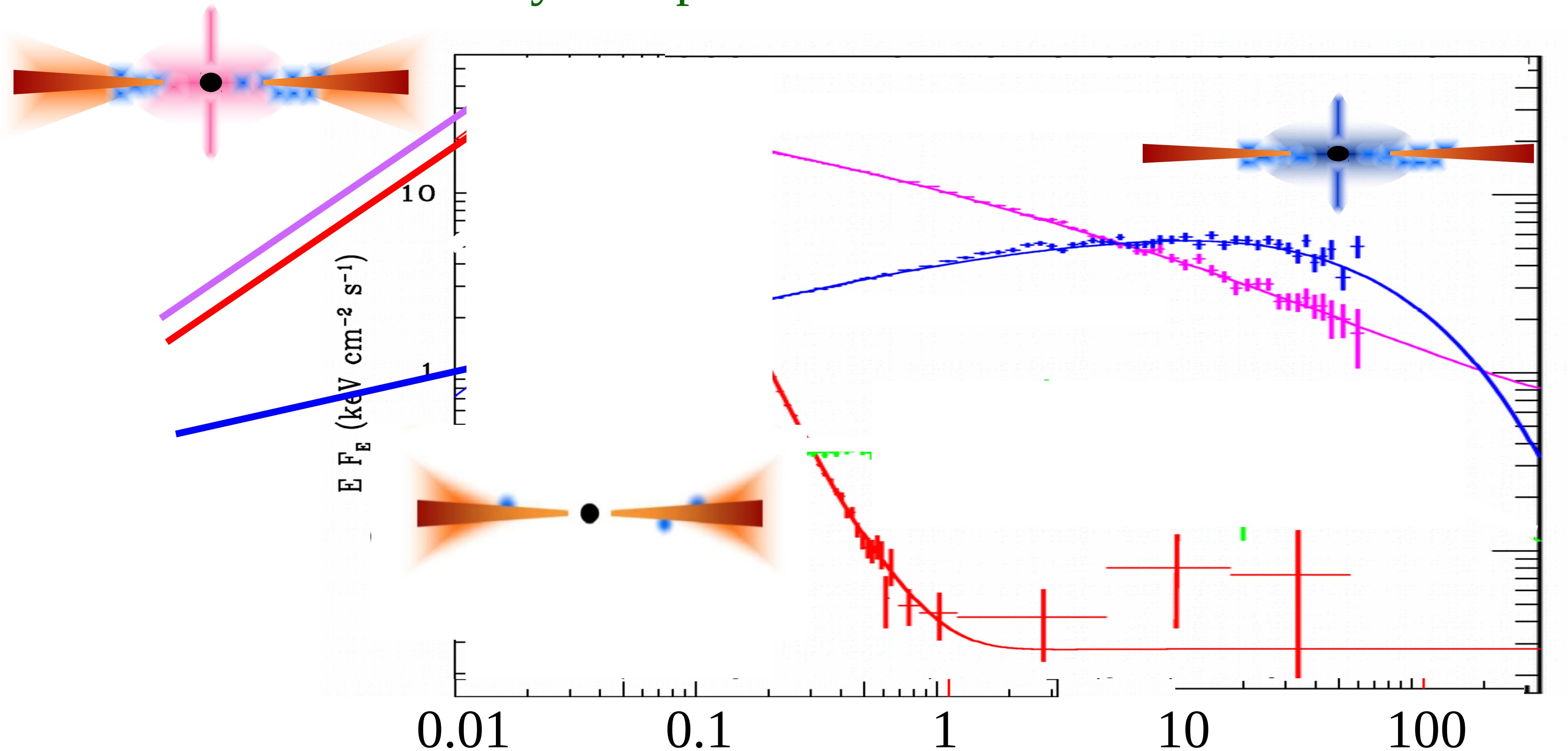
Disc BELOW X-ray bandpass. Peaks in UV – ATOMIC PHYSICS



XMM-Newton & SWIFT gives us simultaneous OM data ! Perfect

Interstellar absorption

Disc BELOW X-ray bandpass. Peaks in UV – ATOMIC PHYSICS

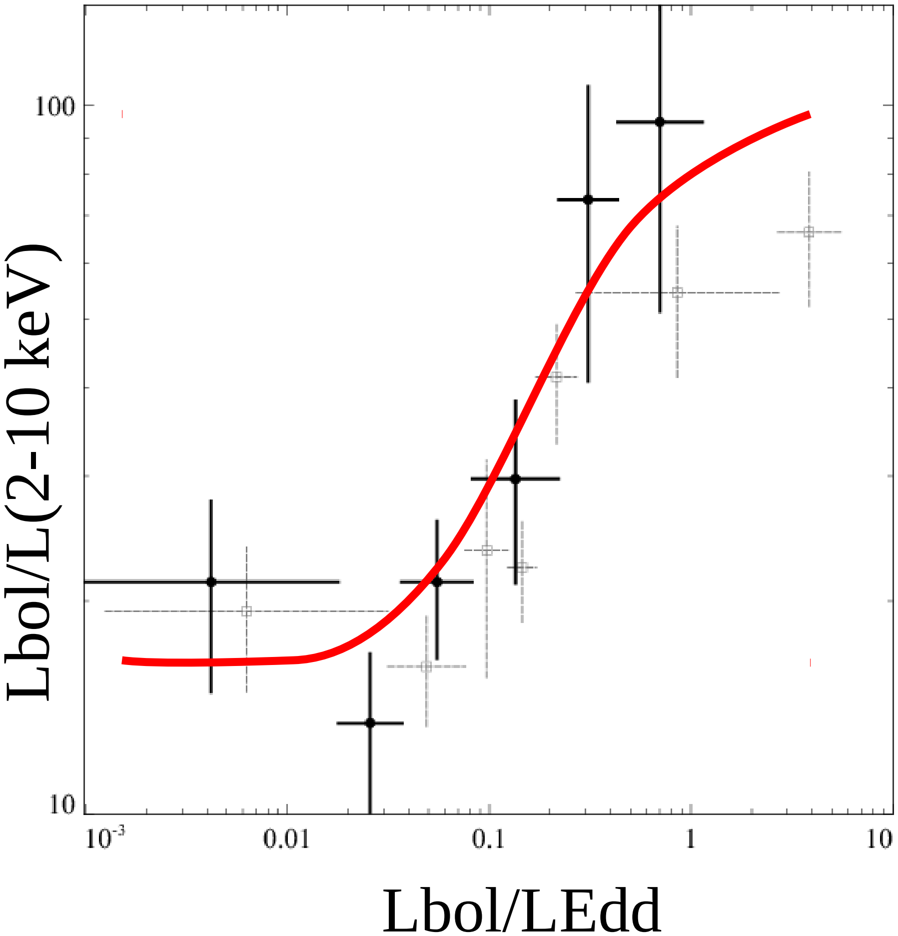


XMM-Newton & SWIFT gives us simultaneous OM data ! Perfect

AGN spectral states

Vasuvaden & Fabian 2008

- Big change in ratio of Lbol/L(2-10 keV) with Eddington ratio L/LEdd
- Looks good!!
- Changing SED means changing line ratios



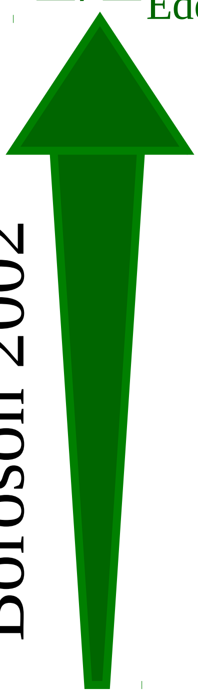
Unobscured AGN: LINERS-S1-NLS1

Similar mass.

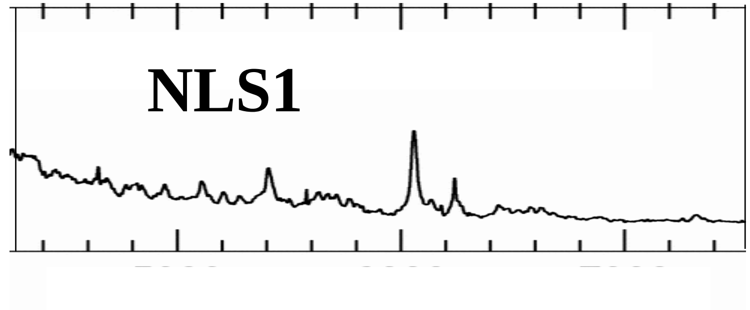
Different L/L_{Edd}

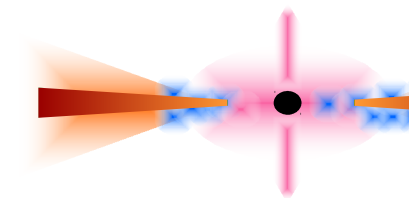
Different ionisation

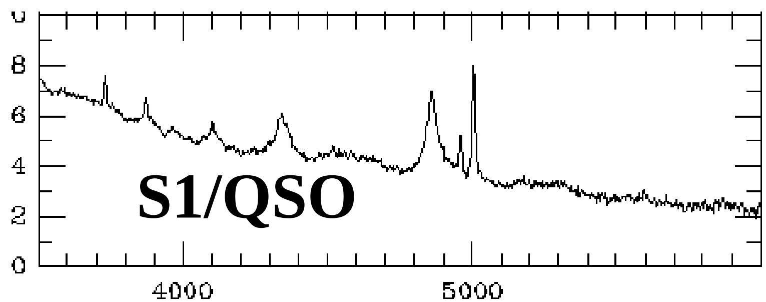
Increasing L/L_{Edd}

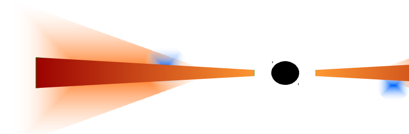


Boroson 2002

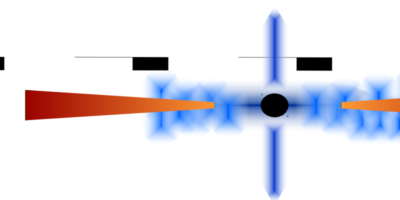




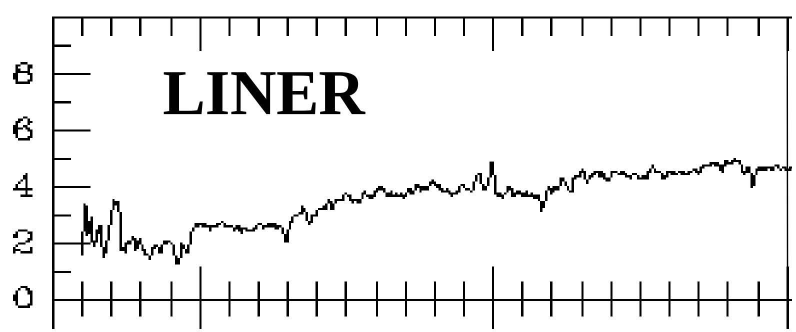




disc



Hot inner flow, no disc – true Seyfert 2s



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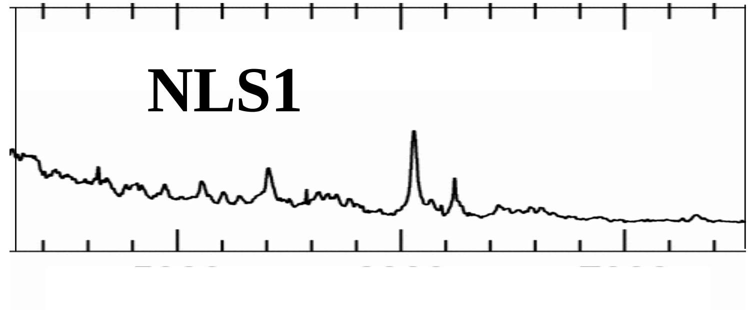
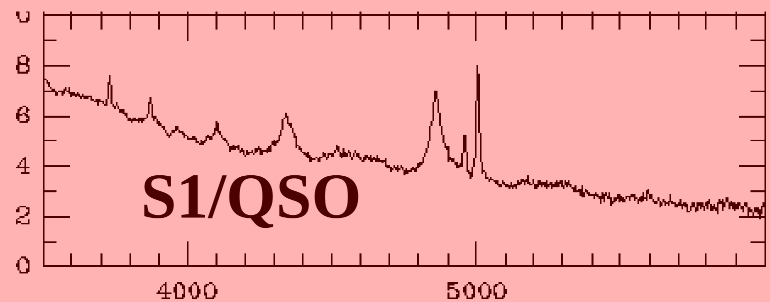
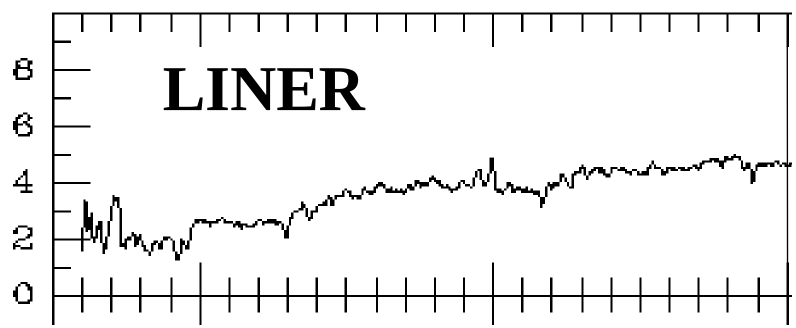
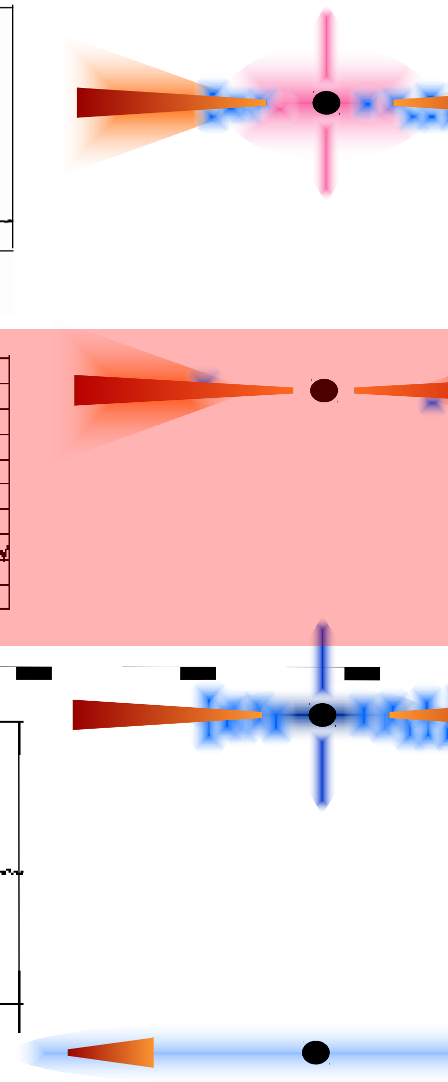




disc

Boroson 2002

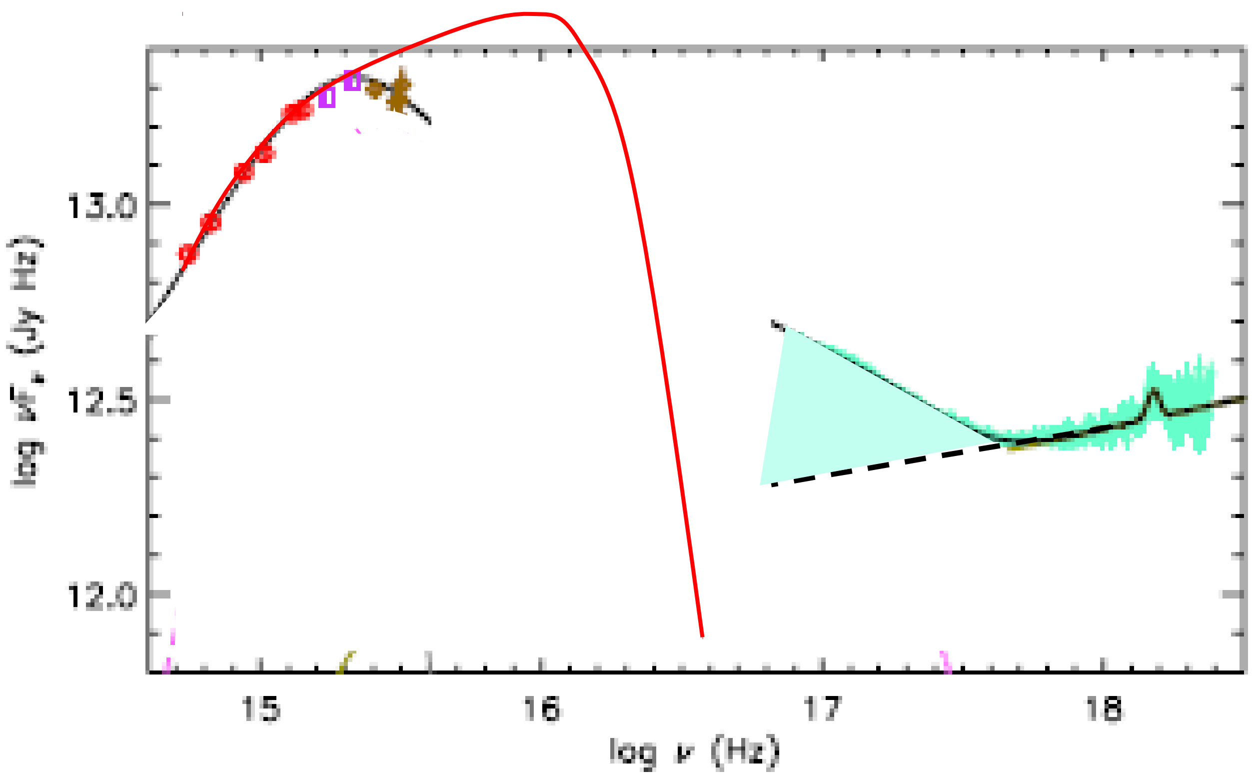




Hot inner flow, no disc – true Seyfert 2s

Classic QSO – most common shape

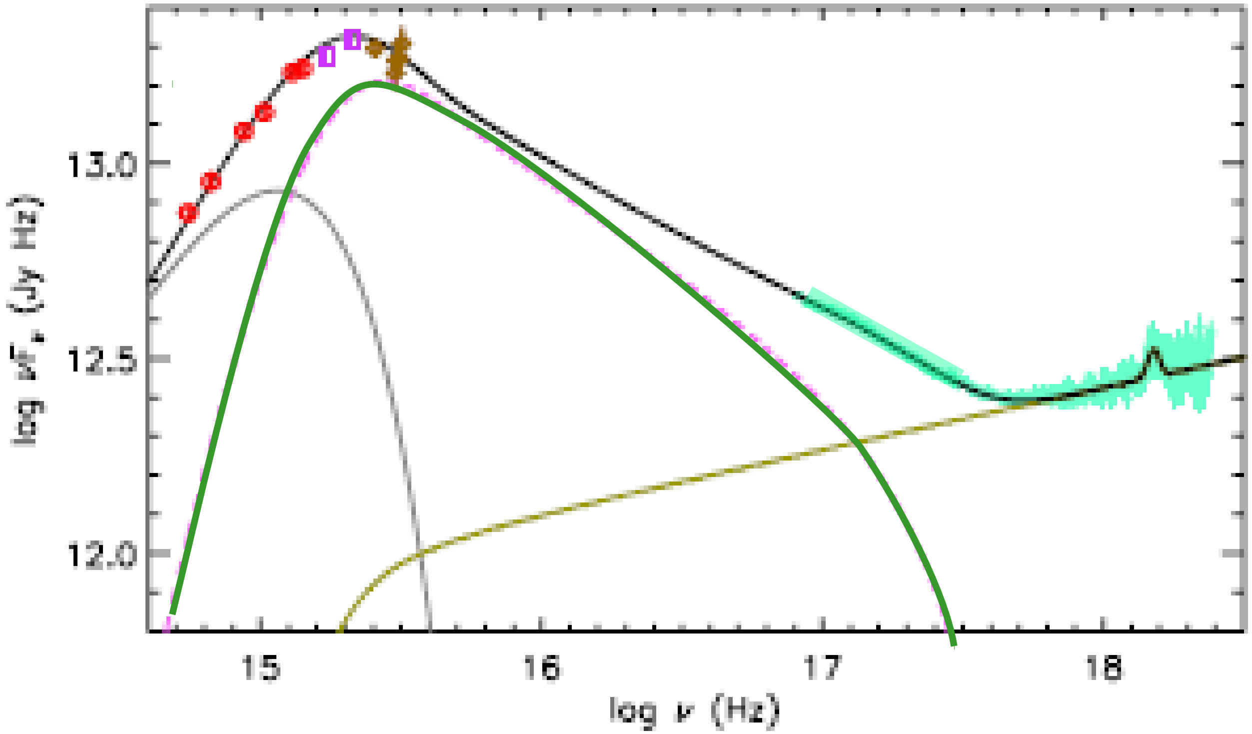
- Mkn 509 - 10^8M L/LEdd~0.1 (take out warm abs!)
- Not disc dominated - far too low temperature! Plus strange soft X-ray excess….What is this????



Medhipour et al 2011

Classic QSO?

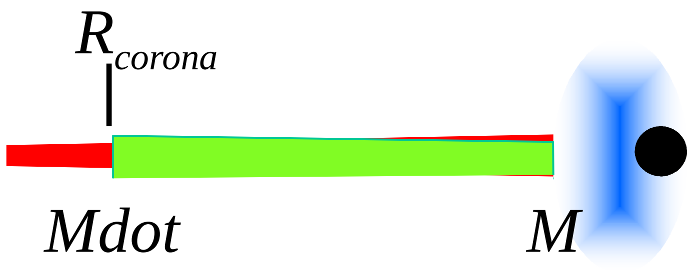
- Single low temperature, optically thick compton component connecting UV-SX(Mehdipour et al 2011)
- Correlated variability on months timescale

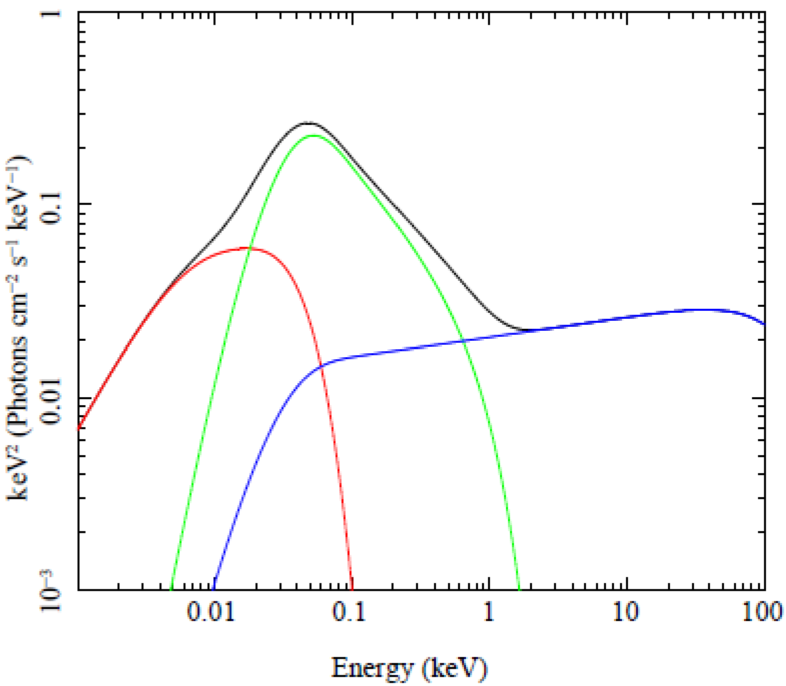


Medhipour et al 2011

Optxagnf: conserving energy

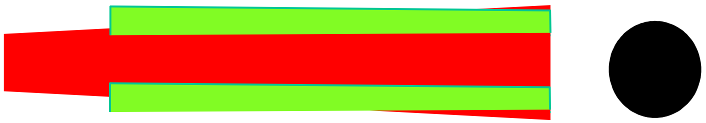
- Outer standard disc – gives Mdot - to R_{corona}
- Then luminosity not completely thermalised to make soft X-ray excess ?
- But Mdot same at all radii - Novikov Thorne $L(r) \alpha M\ Mdot / R^3$
- $Lbol = \eta\ Mdot\ c^2$
- Inner corona as in hard state BHB (L/LEdd?)



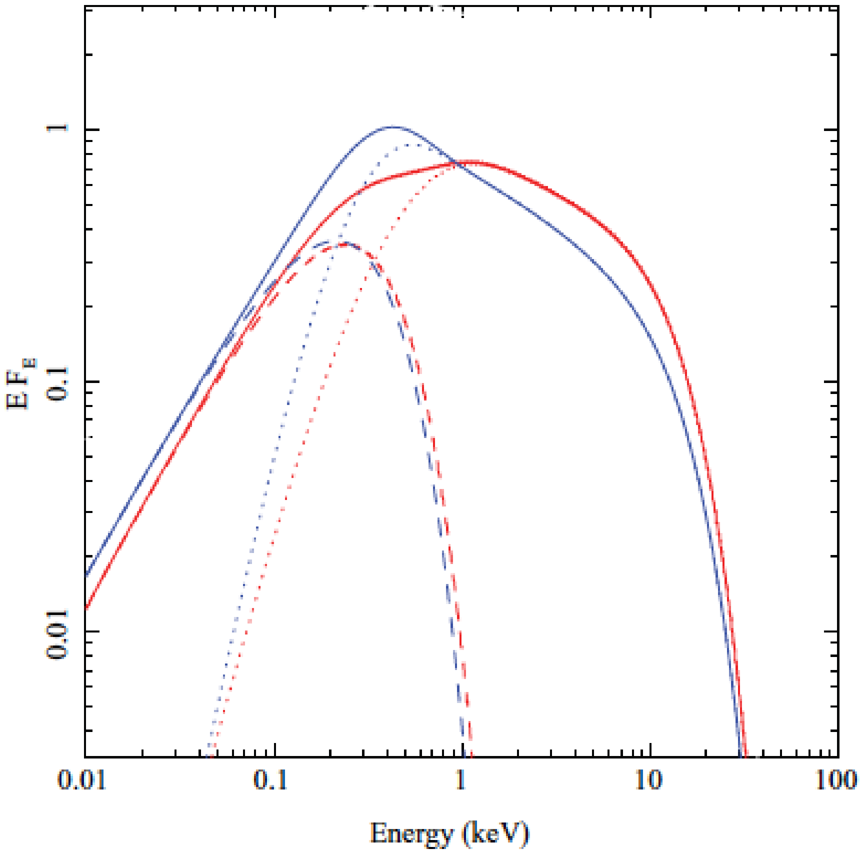


Done et al 2012

Seed photon for soft compton



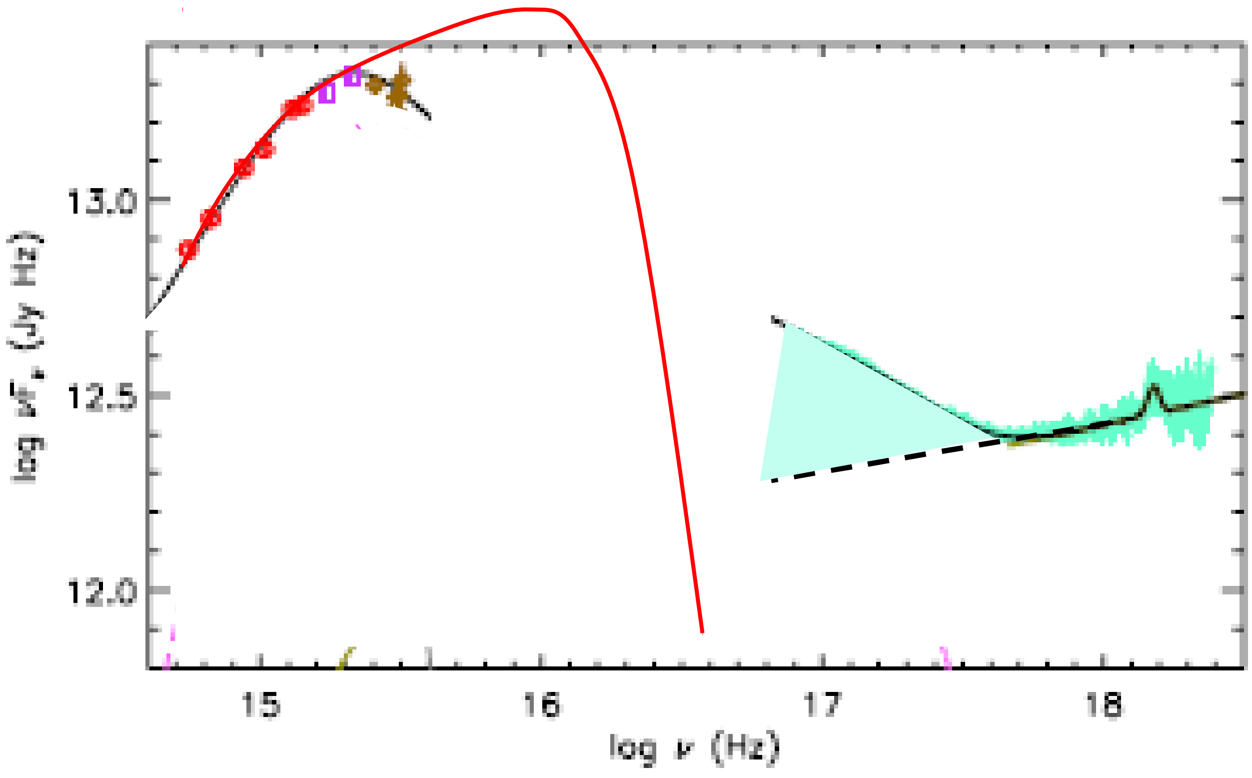
- Outer standard disc – gives Mdot - to R_{corona}
- Then luminosity not completely thermalised to make soft X-ray excess ?
- Seed photons from disc underneath the soft excess not the outer edge of standard disc….
- Petrucci et al 2018 – if disc underneath is passive then Γ_{SX}=2.7



Done et al 2012

Classic QSO – most common shape

- Soft excess as single soft compton – transition from standard disc always in unobservable EUV – NOT!!!



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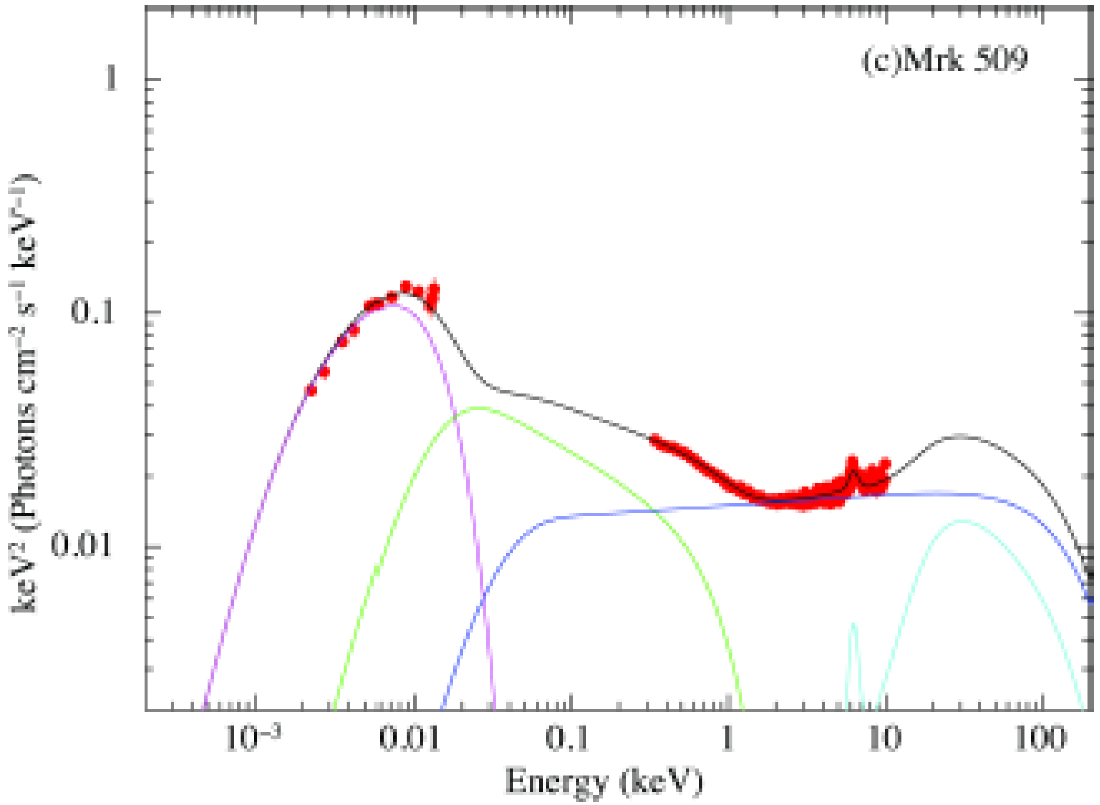
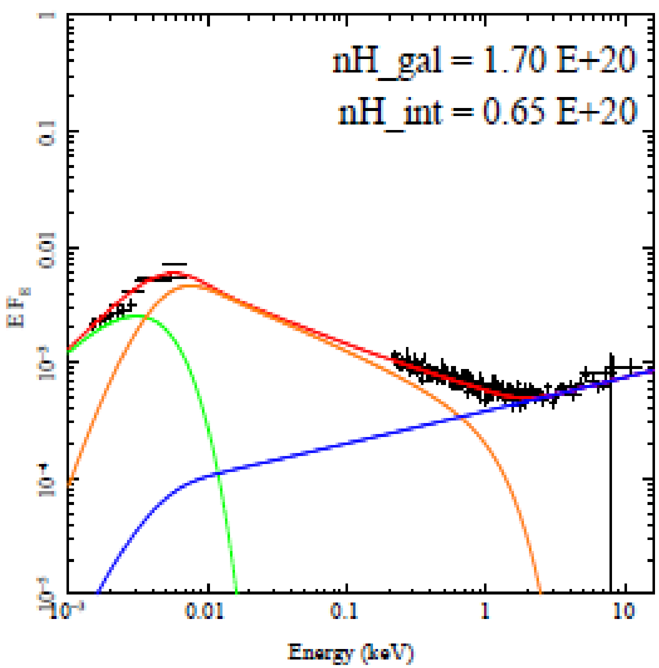
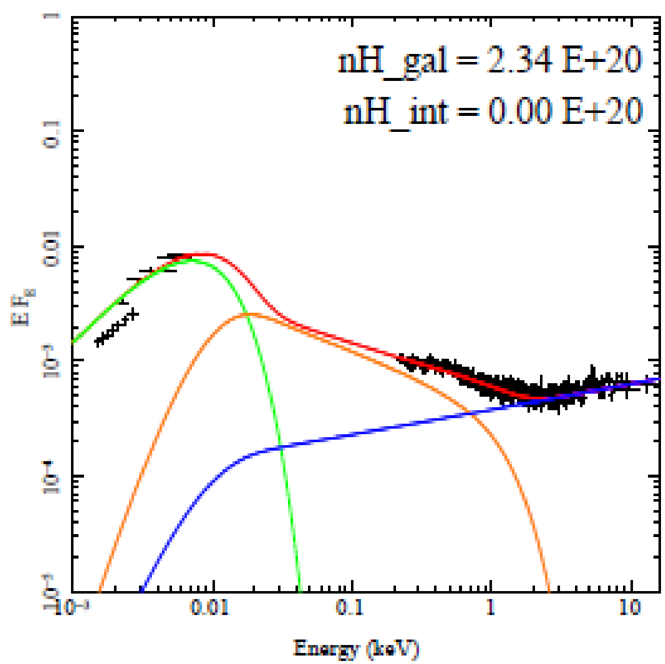


Kubota & Done 2018

Typical AGN SED

- Most standard BLS1/QSO <M>~10^8, <L/LEdd>~0.1
- Outer disc, strong UV peak from soft X-ray excess
- hard X-ray tail – supresses powerful UV line driving

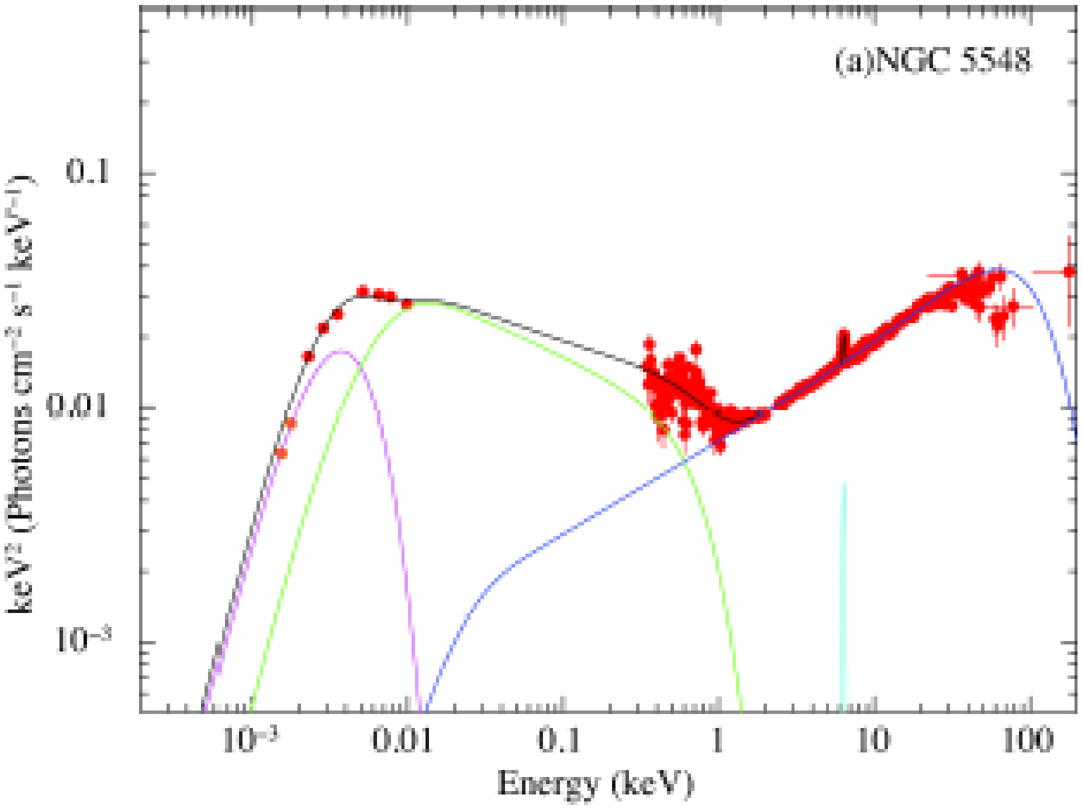




Jin et al 2012

Lower L/Ledd – more SX/HX

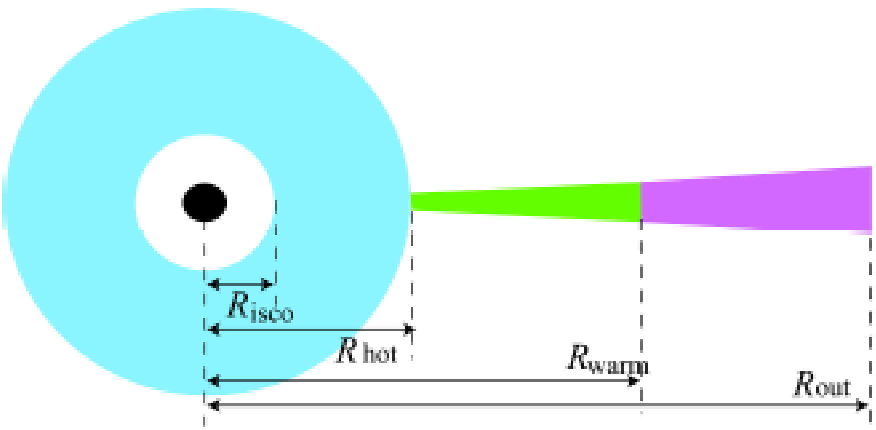
- Soft excess as single soft compton – transition from standard disc always in unobservable EUV – NOT!!!

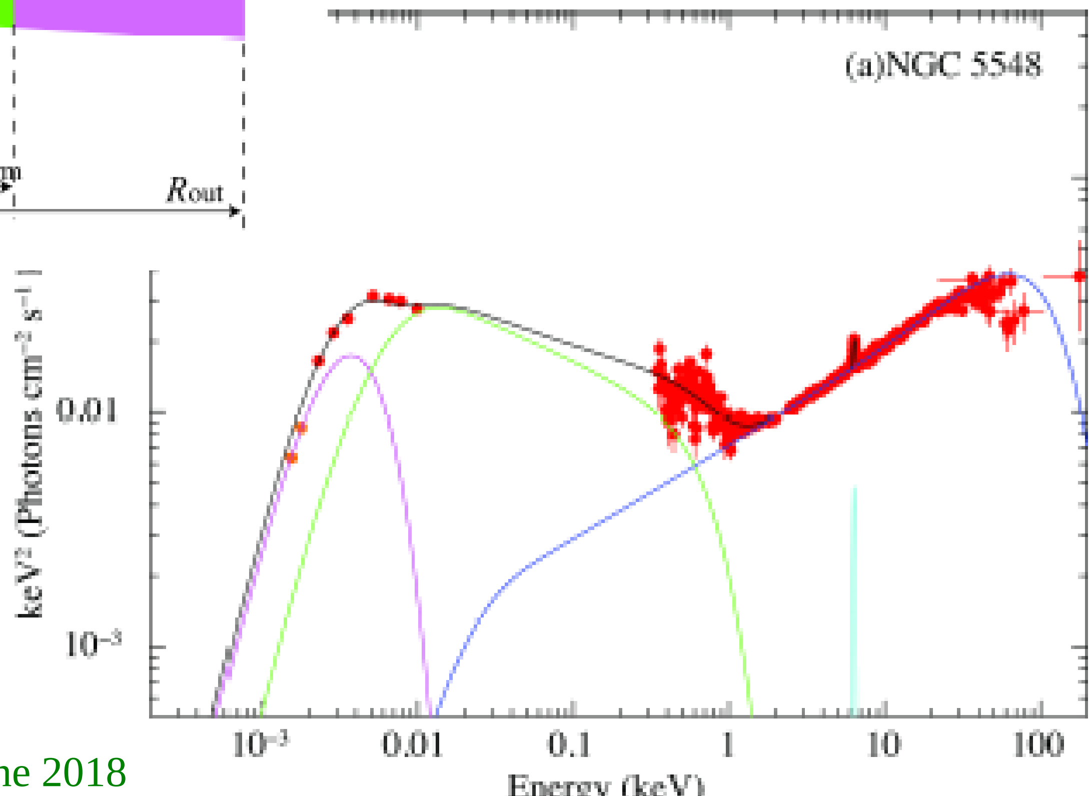


Kubota & Done 2018

Lower L/Ledd – truncated disc

- G<1.9, kT>50 keV needs photon starved geometry

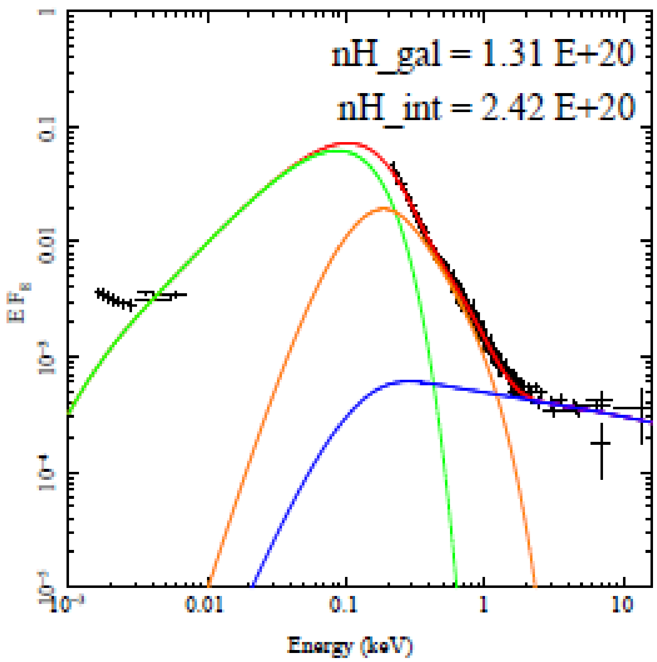


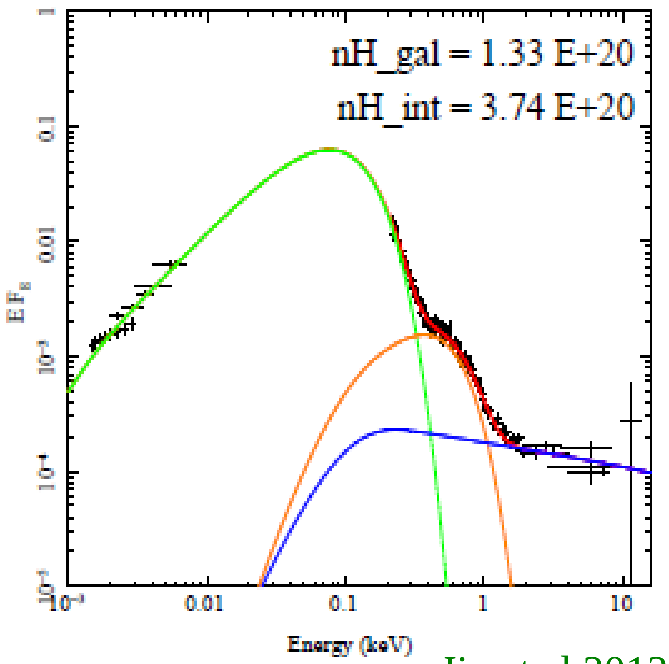


Kubota & Done 2018

Very different to NLS1

- <M>~10^7, <L/LEdd>~1 NLS1 in local universe
- Disc dominated, small SX, weak X-rays

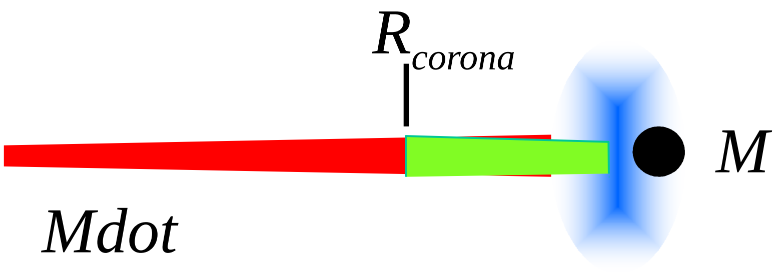


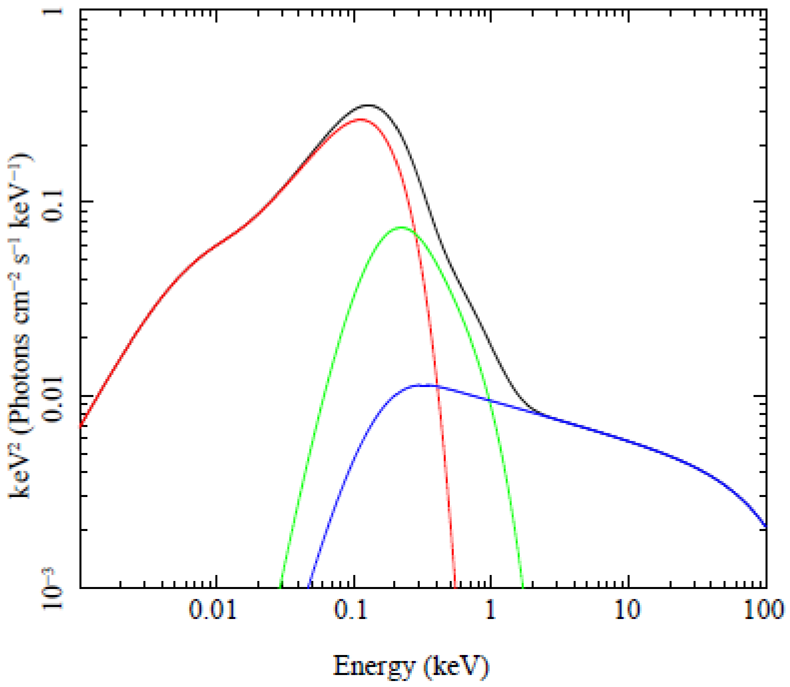


Jin et al 2012

Models conserving energy!!

- Smaller R_{corona}
- Softer 2-10 keV
- Spectra are more disc dominated!
- Weak soft X-ray excess and weak and soft hard X-rays
- Can be corona over disc or truncated disc

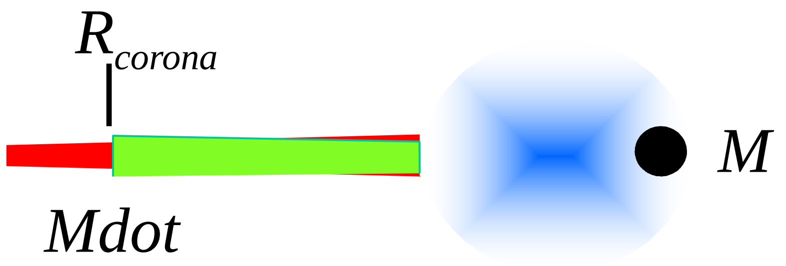


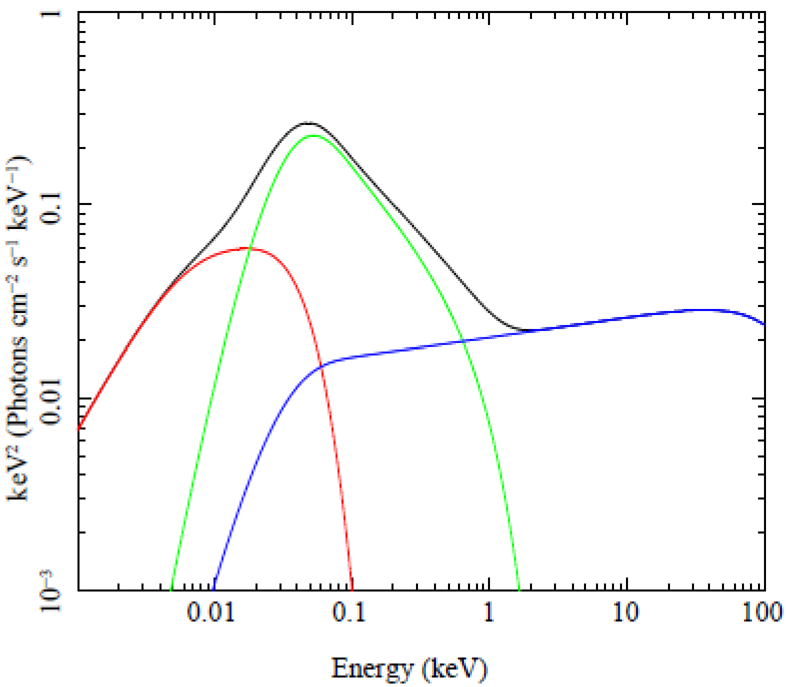


Done et al 2012

Models conserving energy!!

- Larger R_{corona}
- Harder 2-10 keV
- Spectra are dominated by SX/HX
- Strong SX and strong and hard HX
- Inner corona as in hard state BHB (L/LEdd?)
- X-rays can affect optical more!!

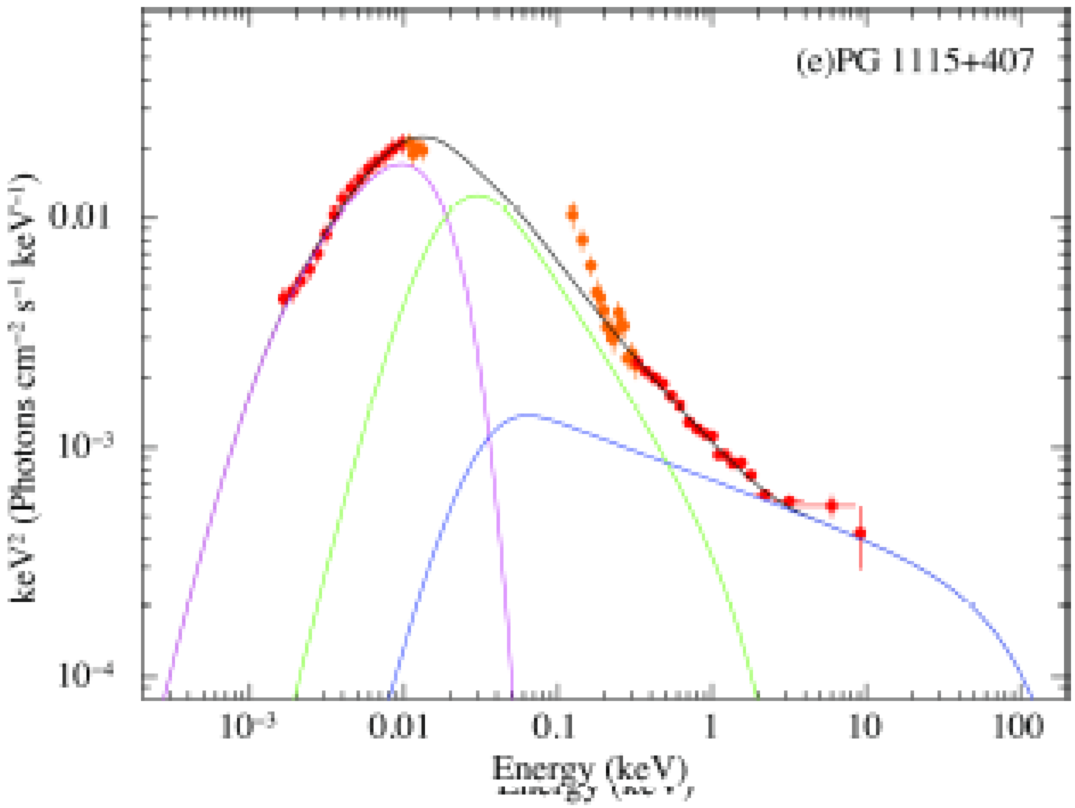




Done et al 2012

higher L/Ledd – less SX/HX

- Soft excess small, disc is large



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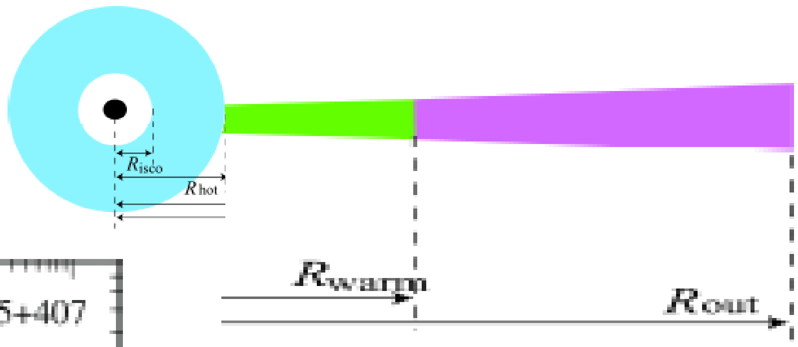
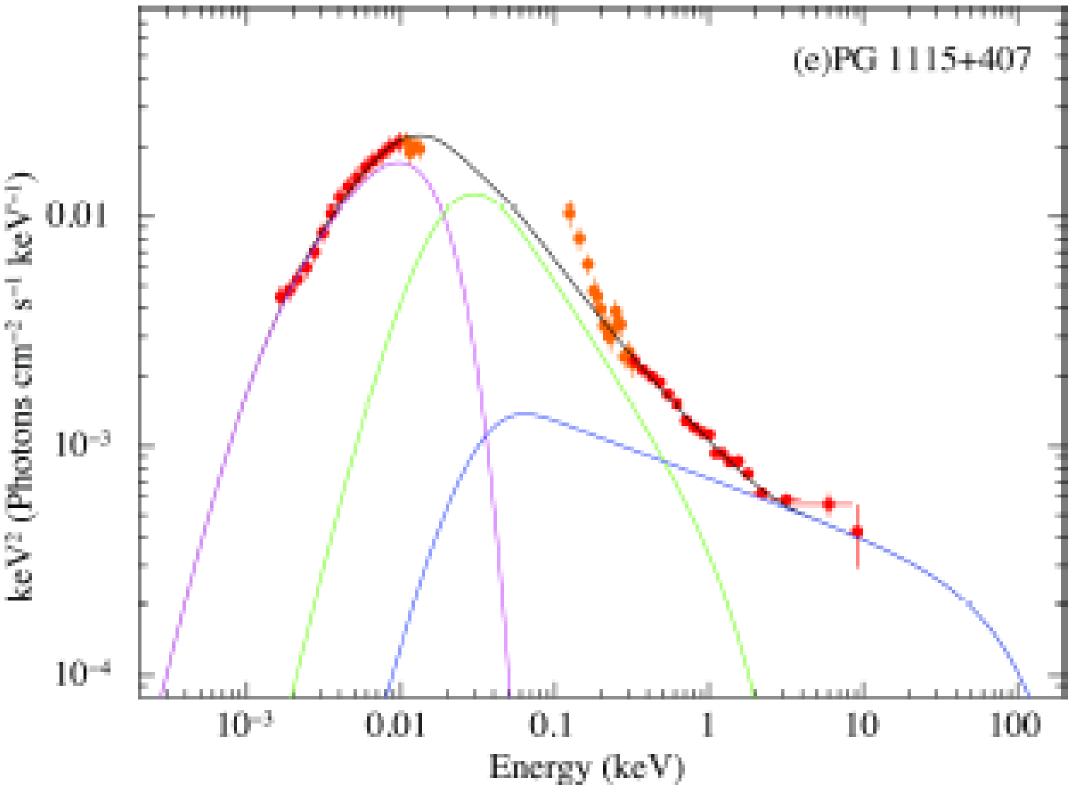
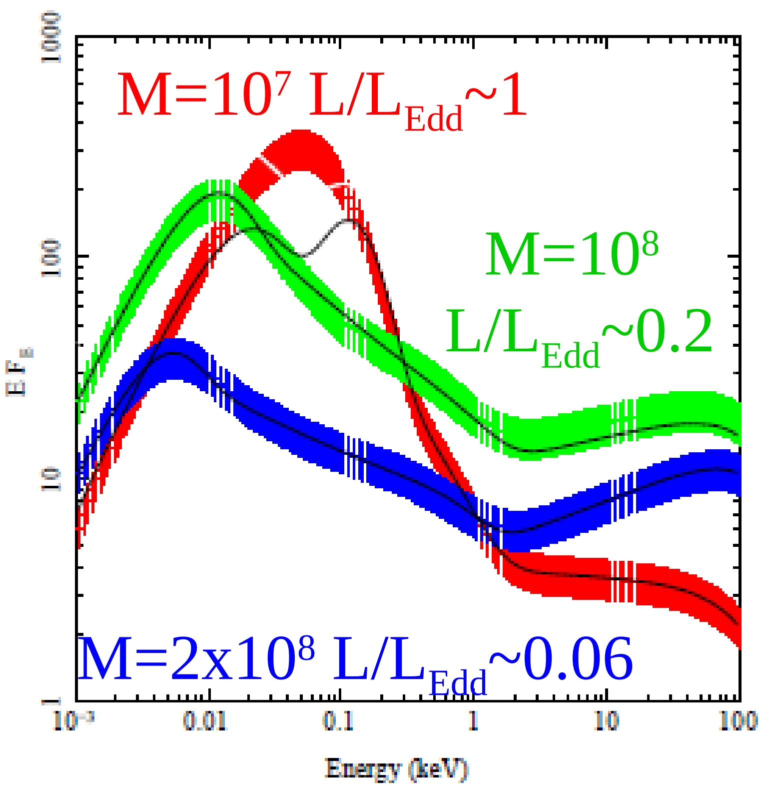


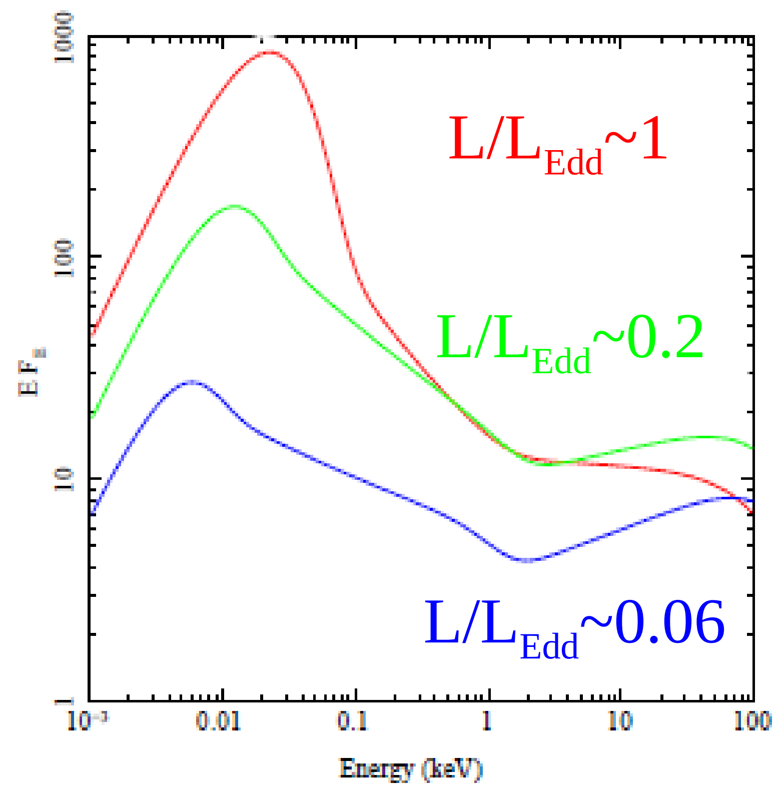


Kubota & Done 2018

INTRINSIC changes in SED

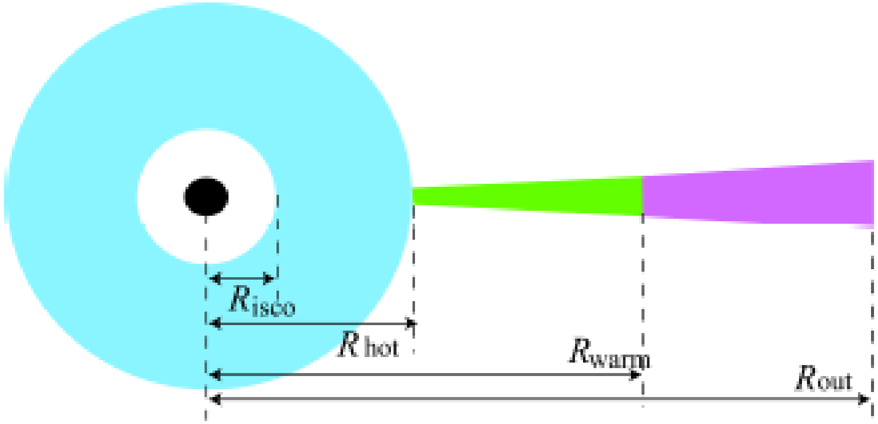
- Co-add models in 3 bins of L/L_{Edd}
- Correlates with M due to galaxy formation. high mass objects have low L/L_{Edd} in local Universe – downsizing
- Physical model so shift to same mass $M=10^8$ to compare with BHB

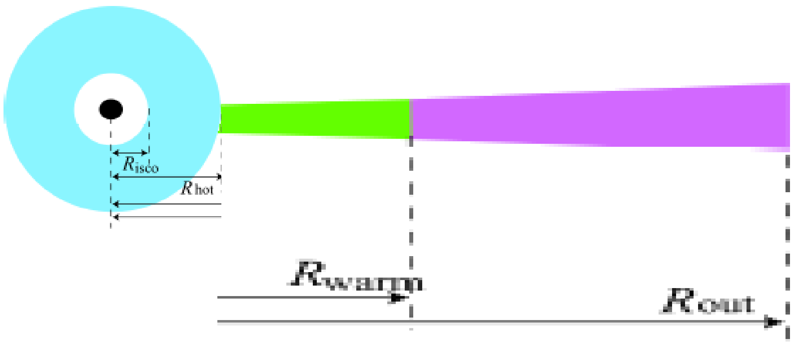




Done et al 2012

Lx- 0.02LEdd!! Lseed/Lx sets Γ





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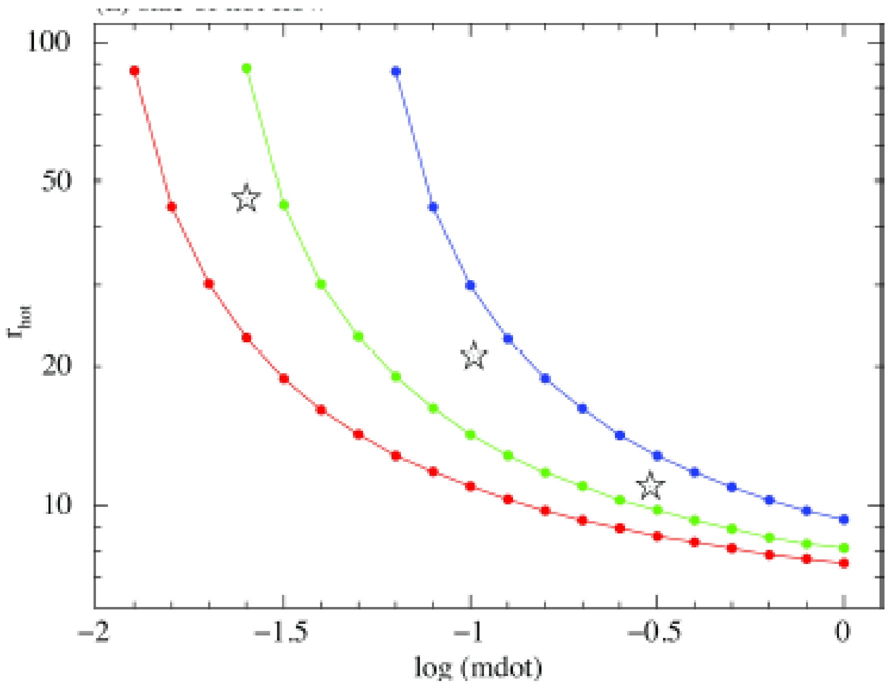
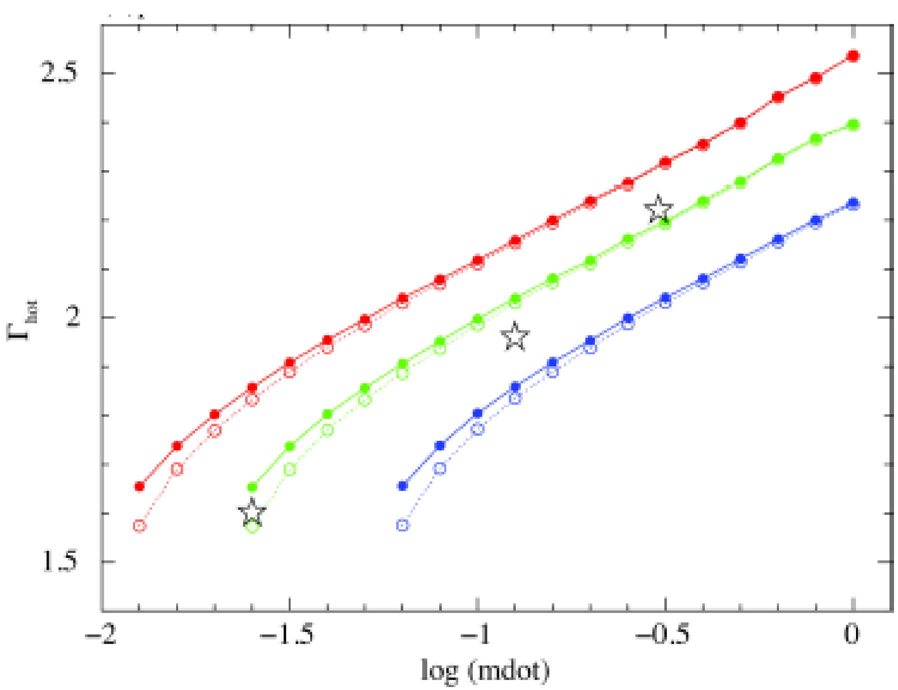
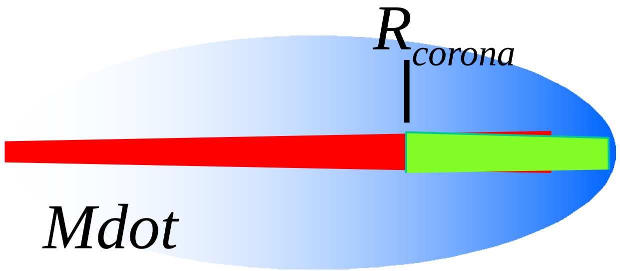
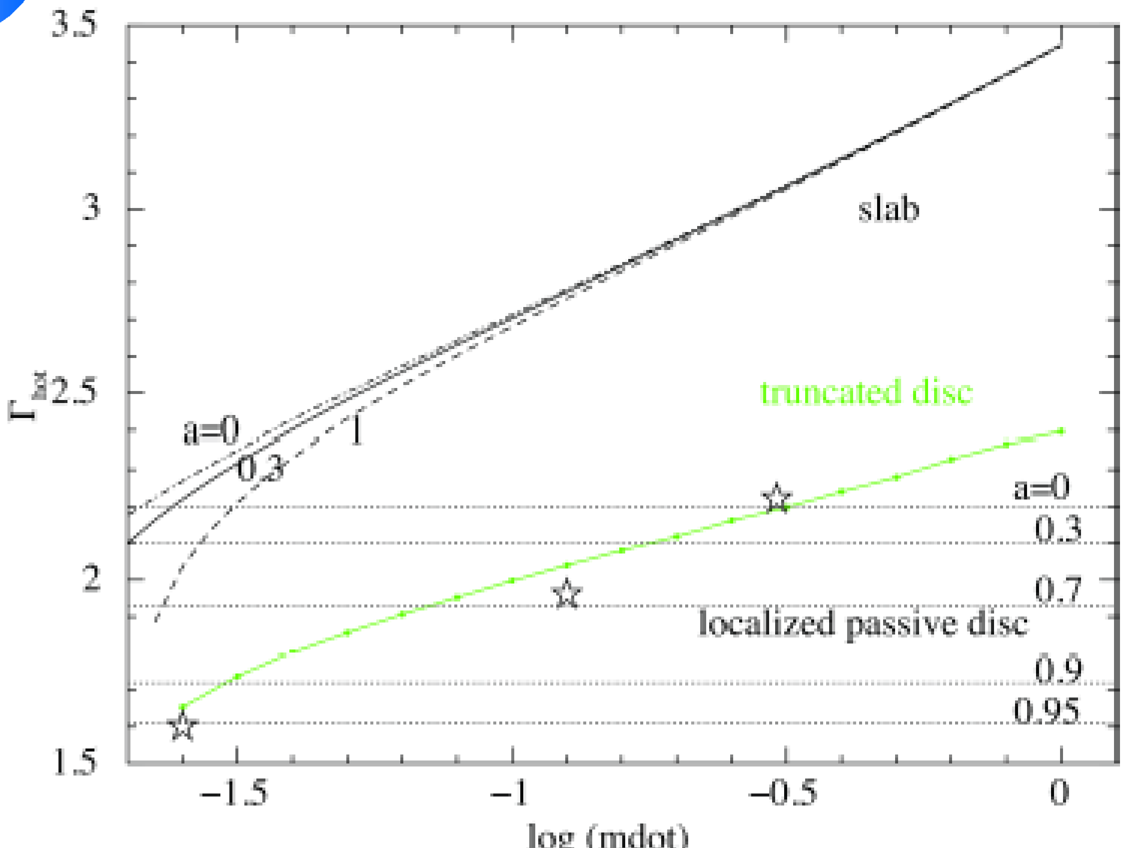


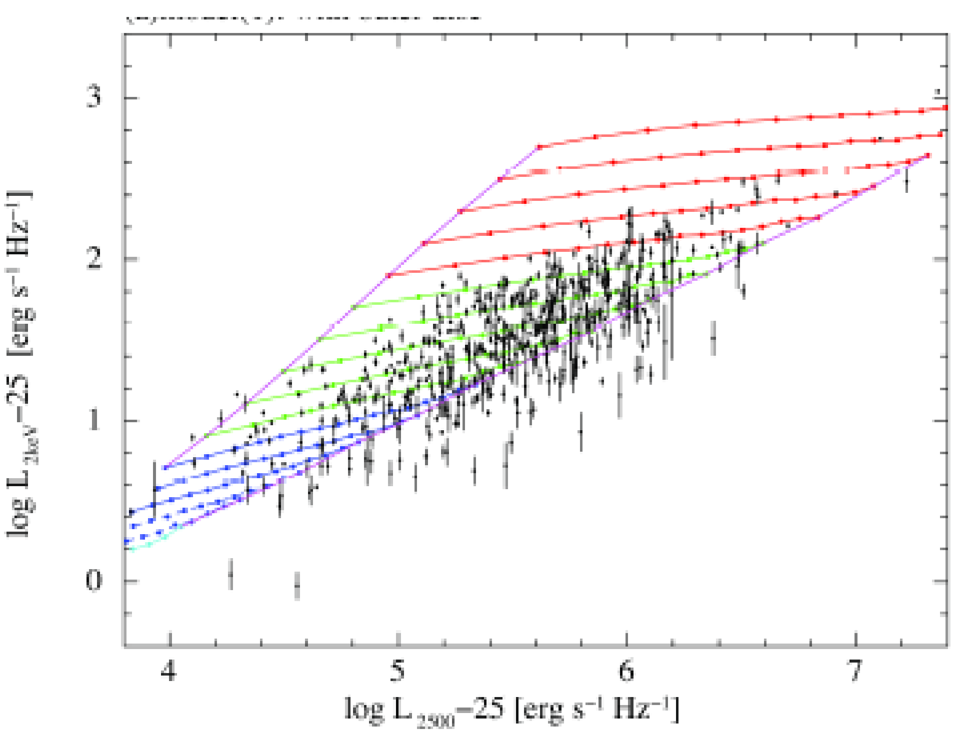


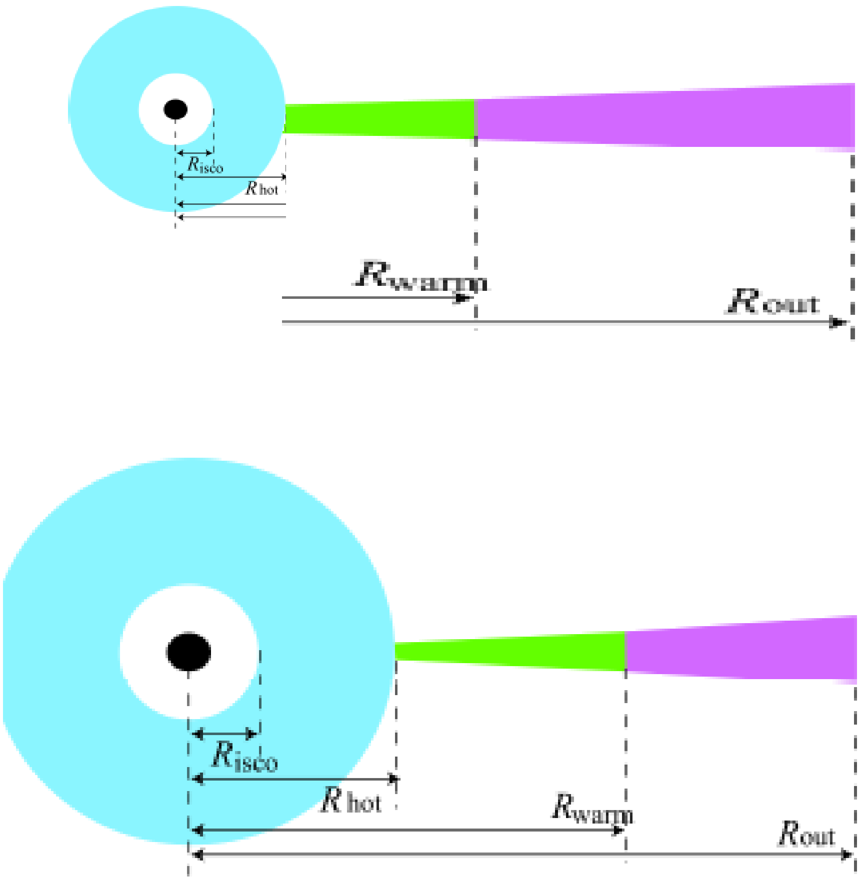
Lx- 0.02LEdd!! Lseed/Lx sets Γ





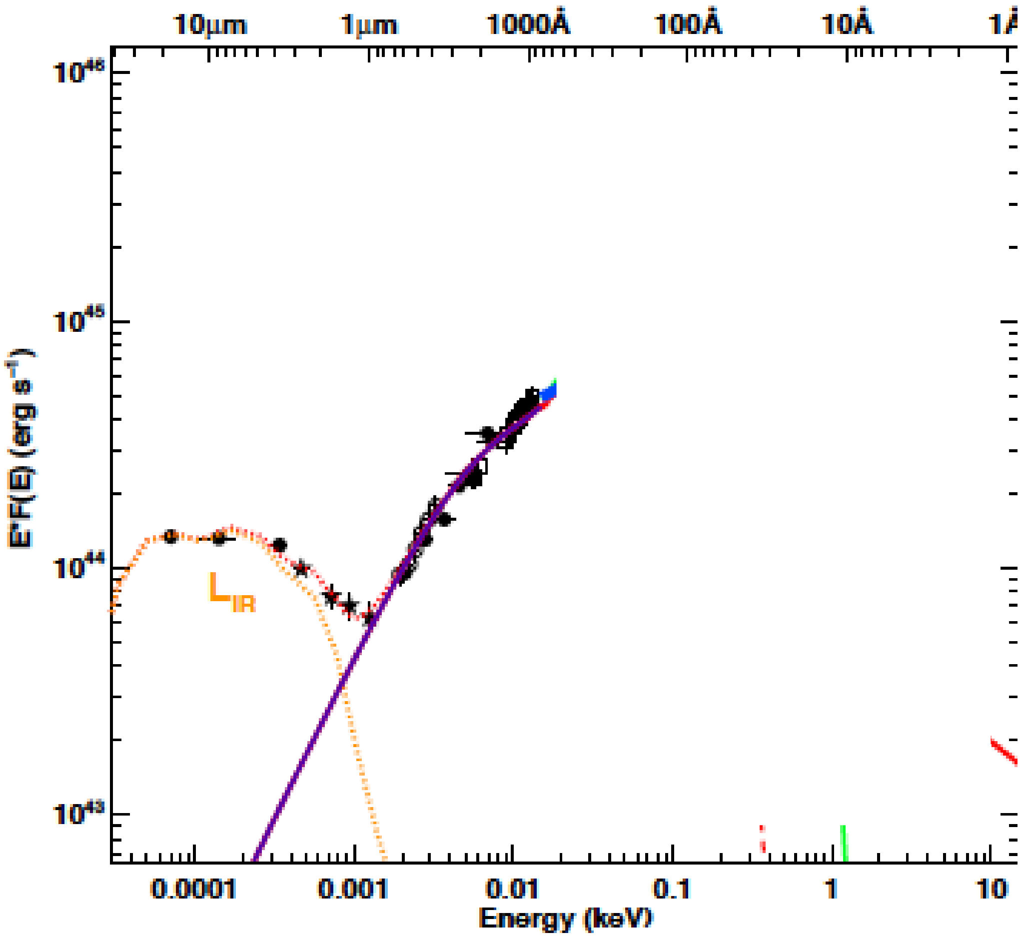
Lx- 0.02LEdd!! Lseed/Lx sets Γ gets Lusso & Risaliti





L/Ledd >1: NLS1 RX0439

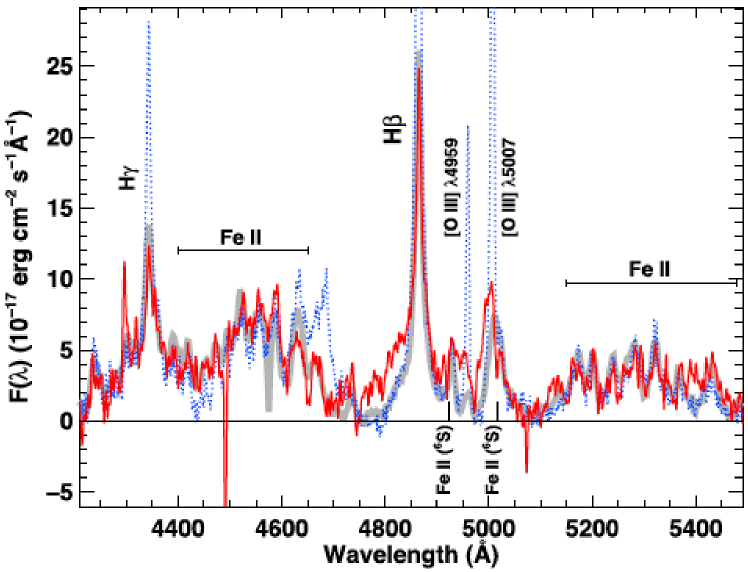
- $M=7x10^6$ Msun
- Mdot though outer disc is 12x Eddington for zero spin (bigger if high spin!!)

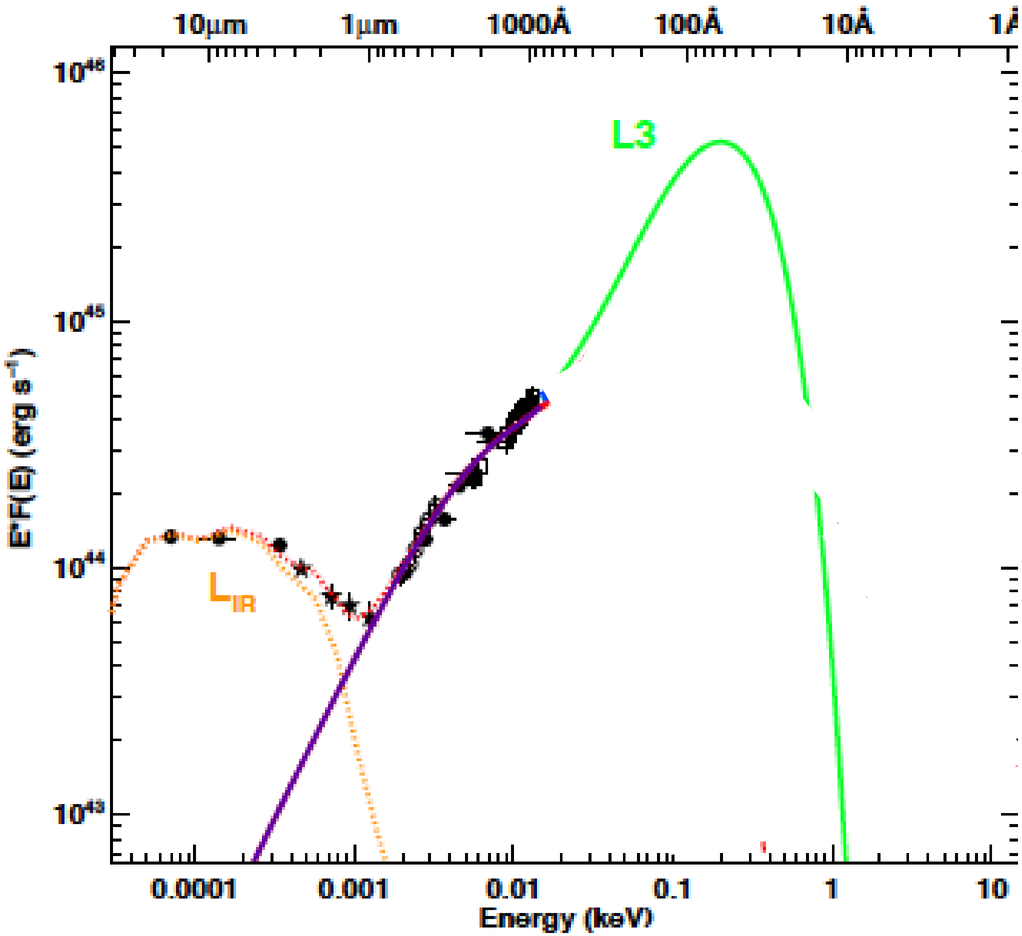


Jin et al 2017

L/Ledd>1: NLS1 RX0439

- Mdot=12MdotEdd

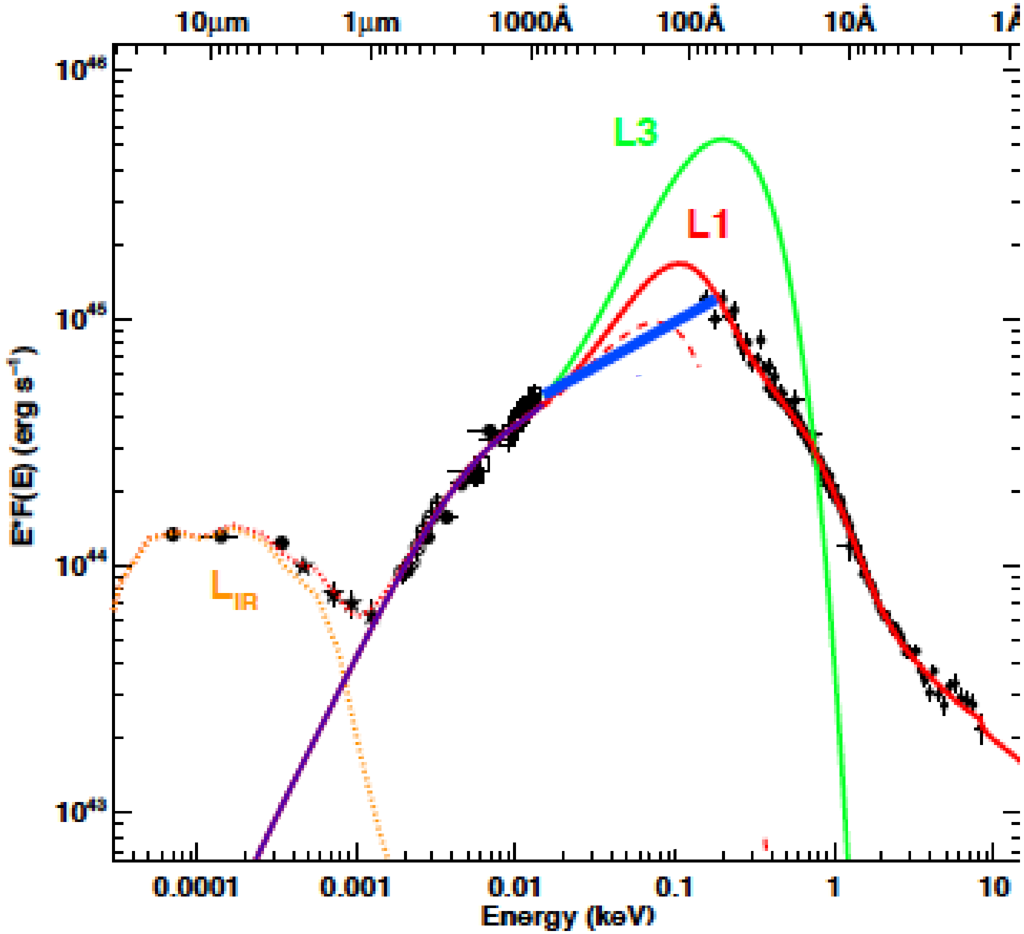




Jin et al 2017

Extreme NLS1 RX0439

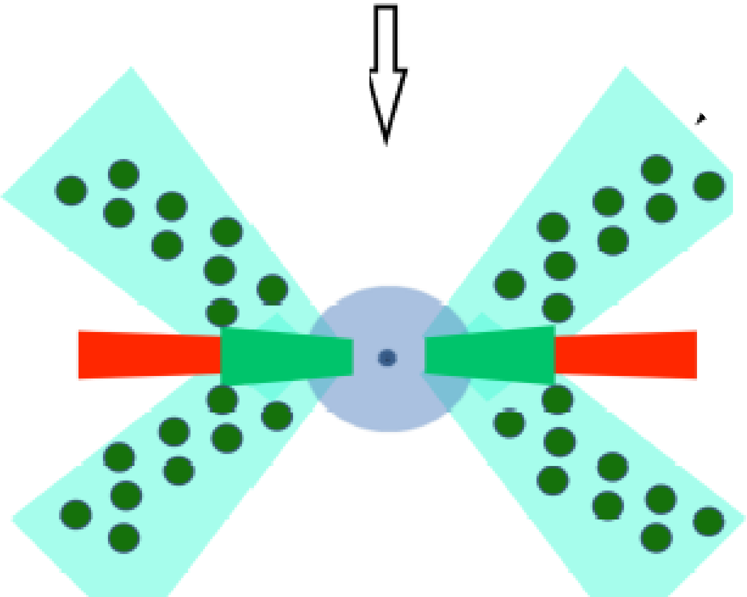
- Mdot=12MdotEdd
- Lobs=4.6LEdd wind and/or advection
- Lose ½ of accretion power

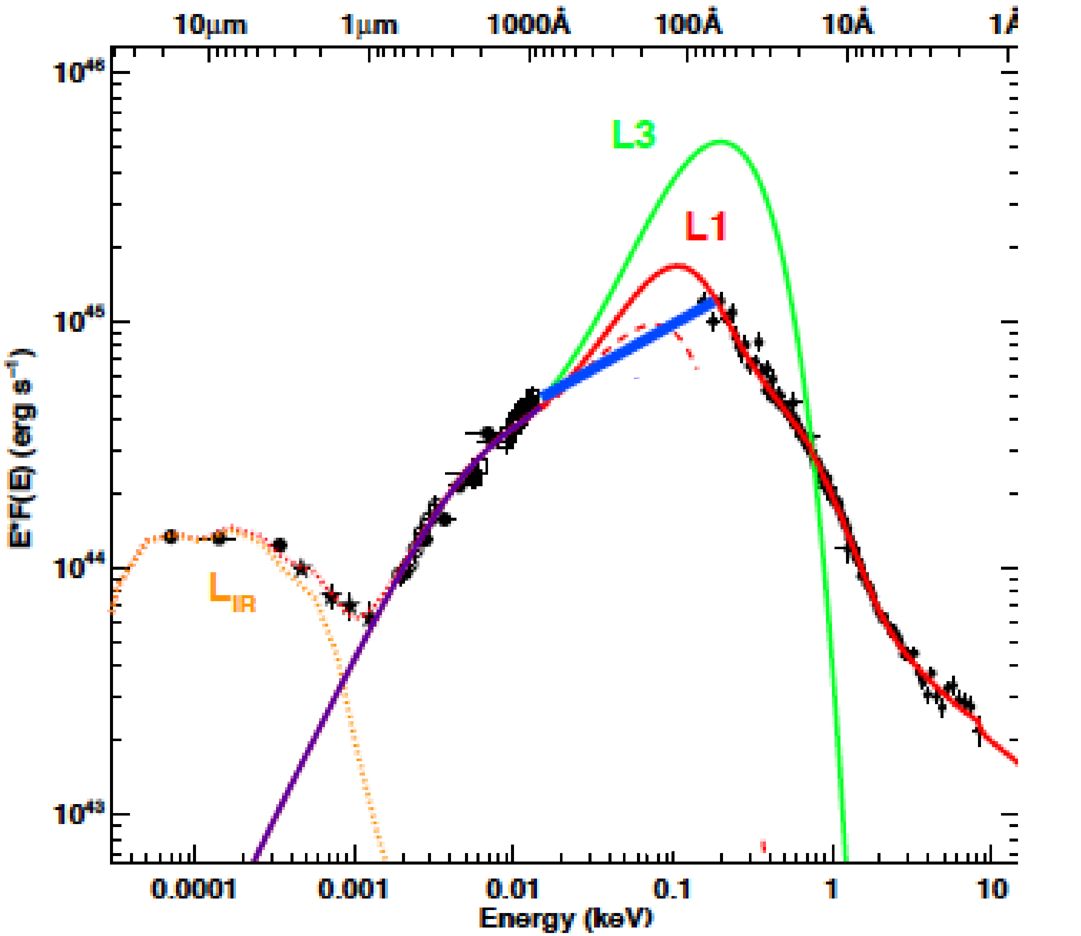


Jin et al 2017

Extreme NLS1 RX0439

- Mdot=12MdotEdd
- Lobs=4.6LEdd wind and/or advection
- Lose ½ of accretion power WINDS??

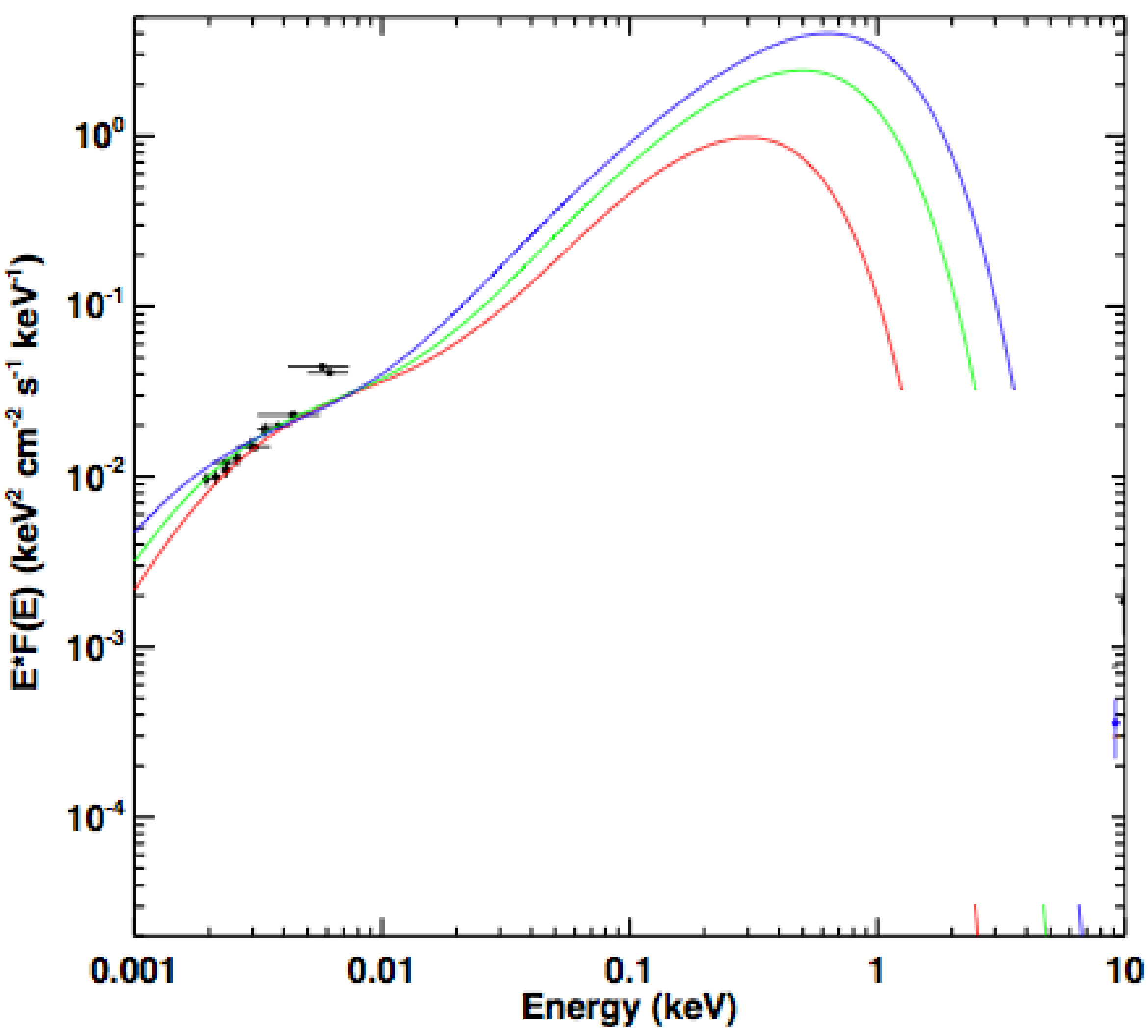




Jin et al 2017

1H0707-495 Extreme NLS1

- 1H0707
- 2-4x10^6
- L/Ledd = 11, 40 70
  (60 degrees)
- superEddington



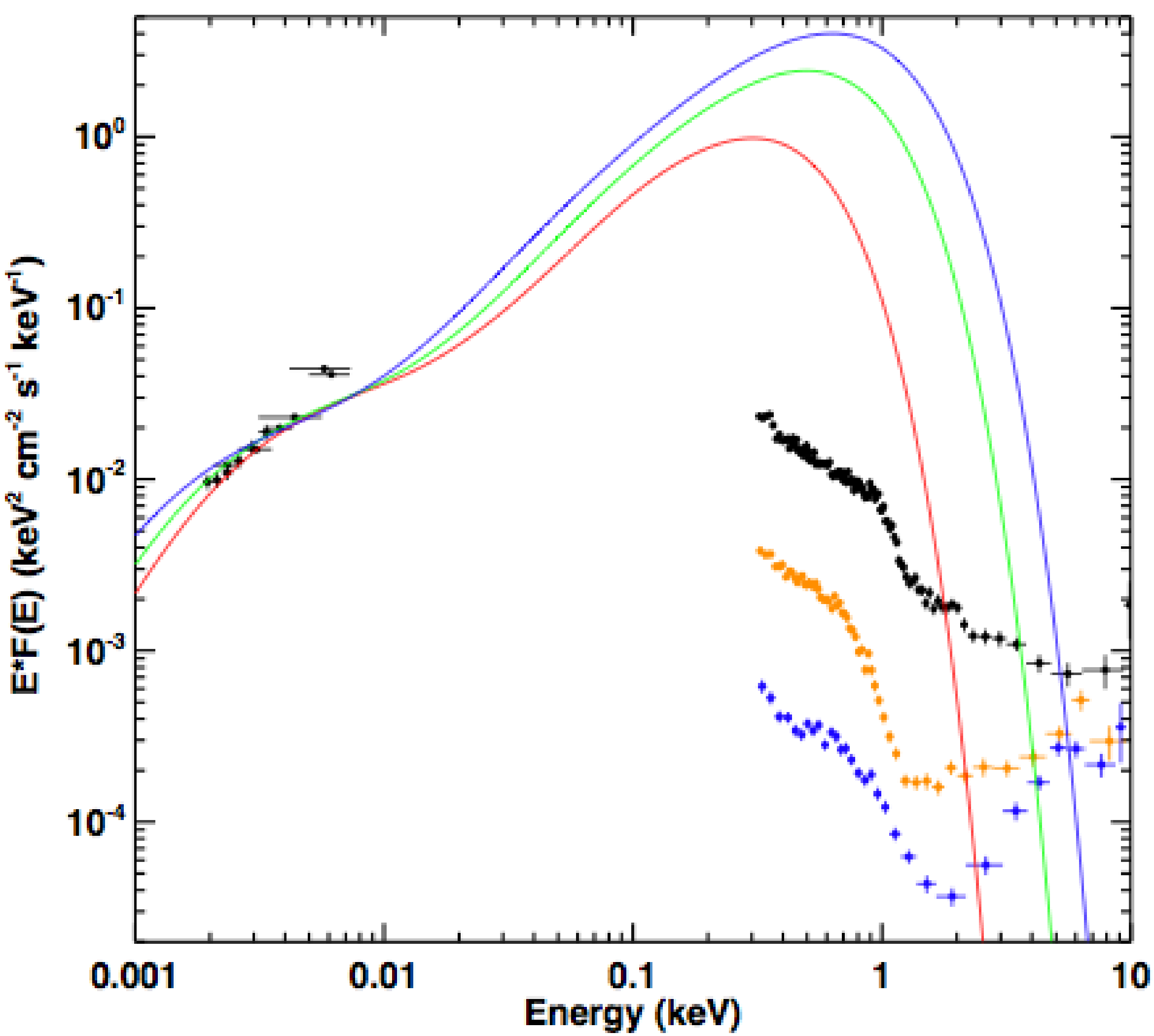
Done & Jin 2016

1H0707-495 Extreme NLS1

- 1H0707
- 2-4x10^6
- L/Ledd = 11, 40 70

  a=0 0.9 0.998

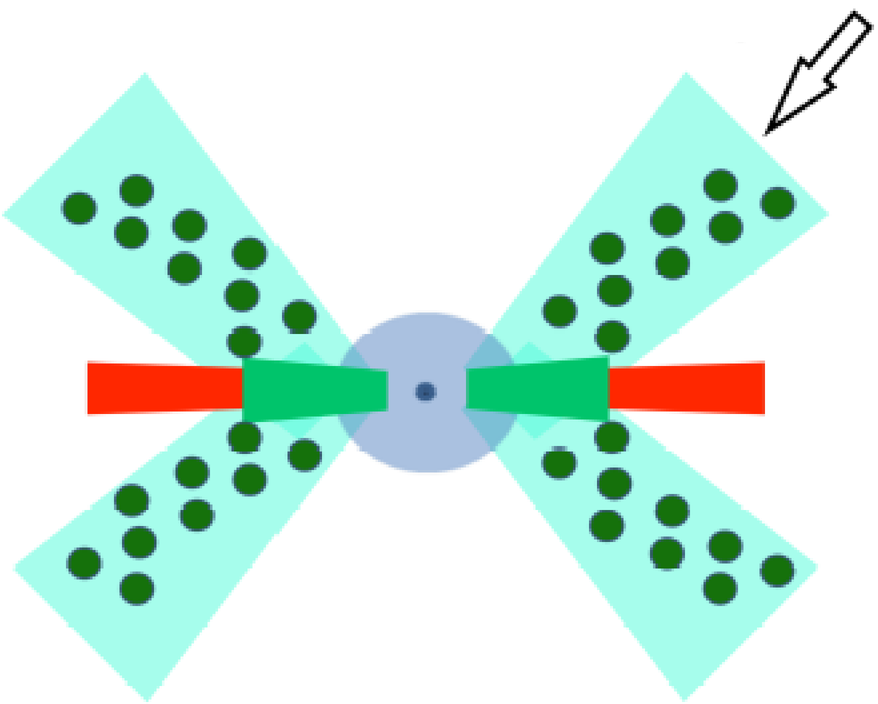
  60 degrees 4x10^6
- superEddington
- Strong wind, losing energy so not all potential power radiated



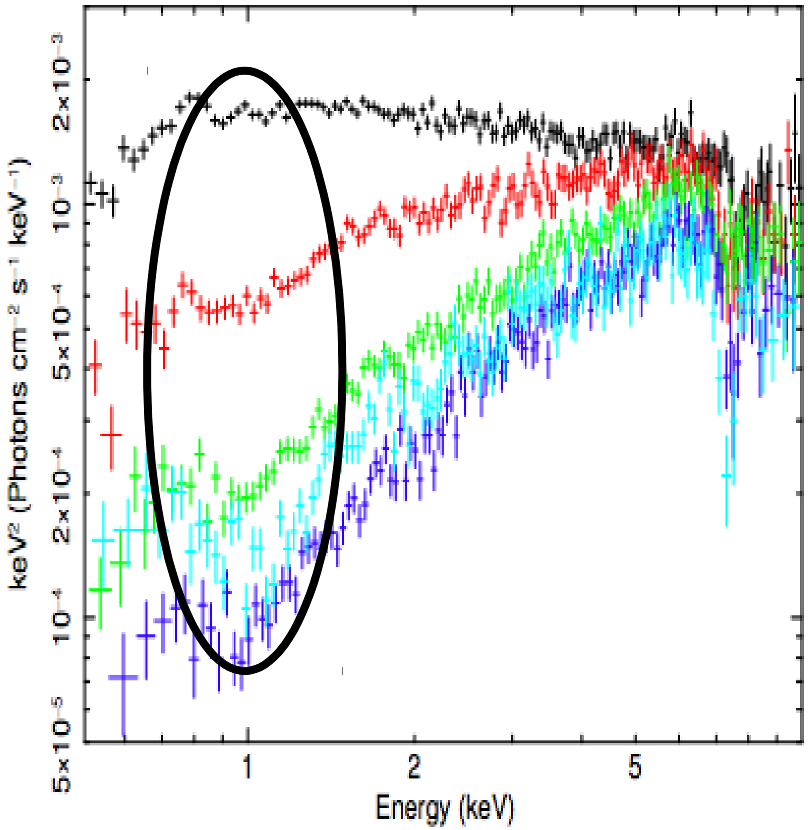
Done & Jin 2016

PDS456: L/Ledd~1
UFO wind is clumpy

- High ionisation lines AND low energy absorption



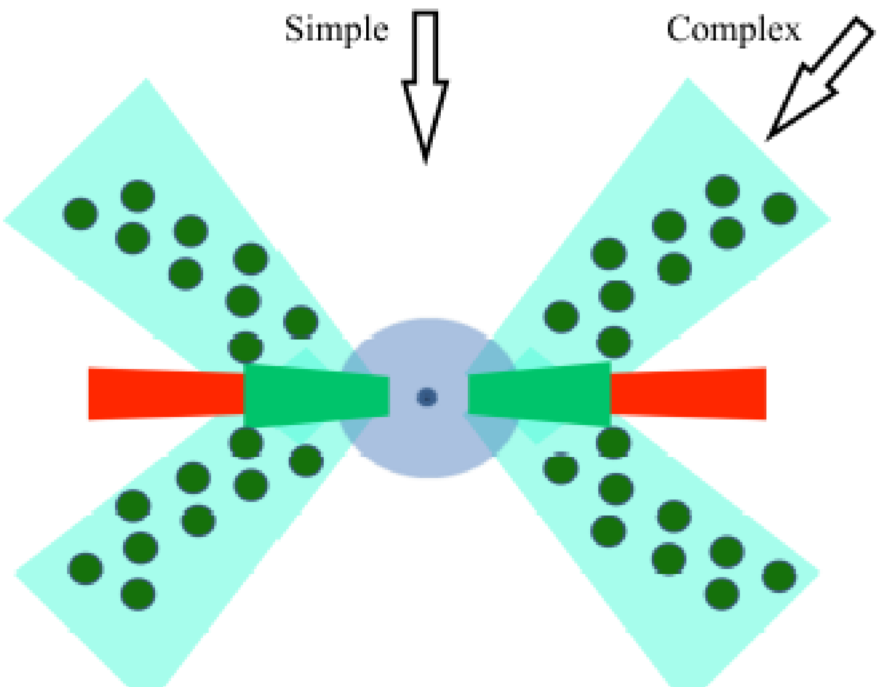
Done & Jin 2016



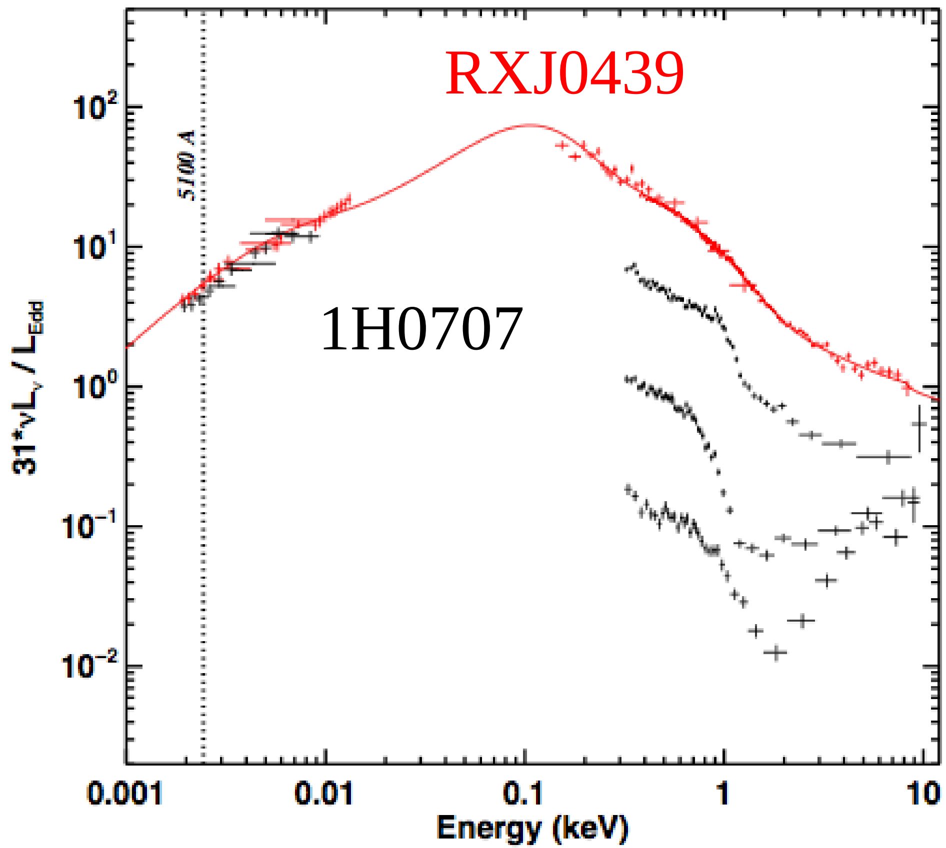
Reeves et al 2009
Hagino et al 2015
Matzeu et al 2016

Extreme NLS1 – simple / complex

- RXJ 0439 'simple' NLS1
- 1H0707 'complex' NLS1 so see wind absorption - UFO?



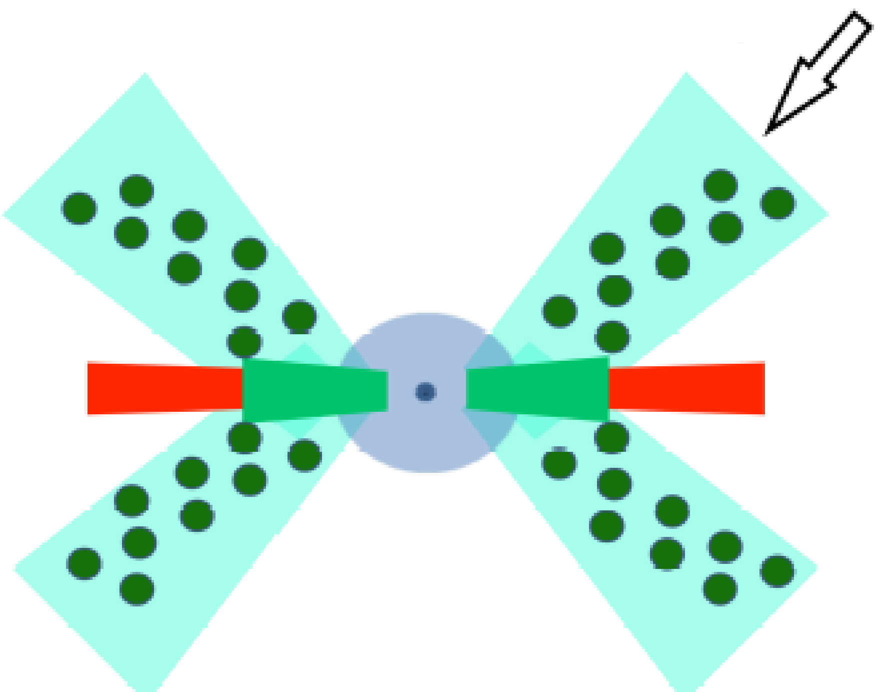
Done & Jin 2016



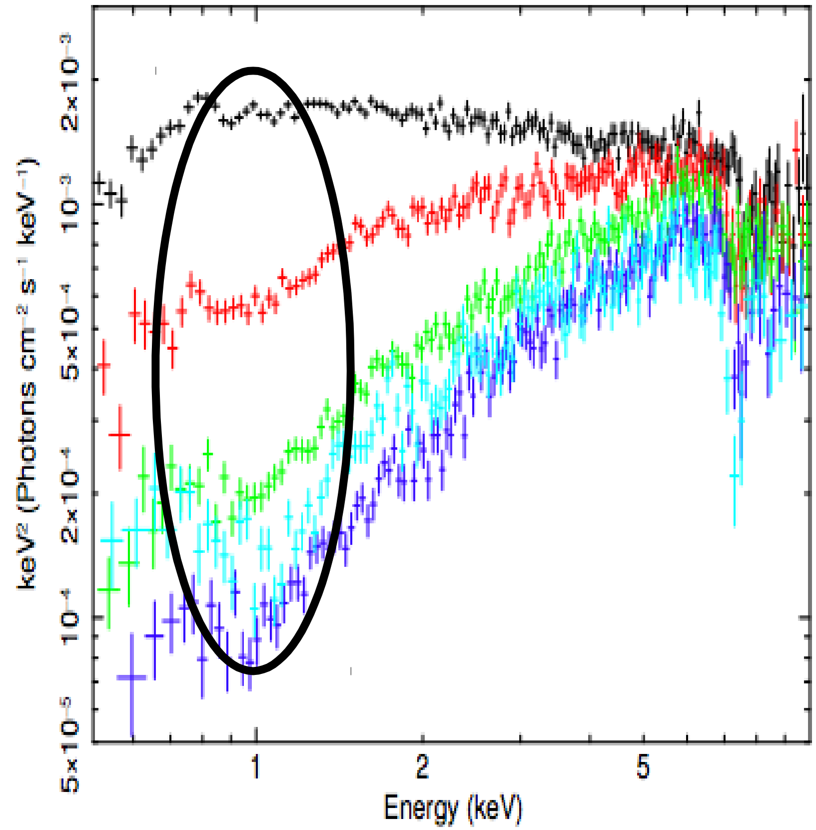
Done & Jin 2016
Jin et al 2017

PDS456: UFO wind is clumpy

- High ionisation lines AND low energy absorption

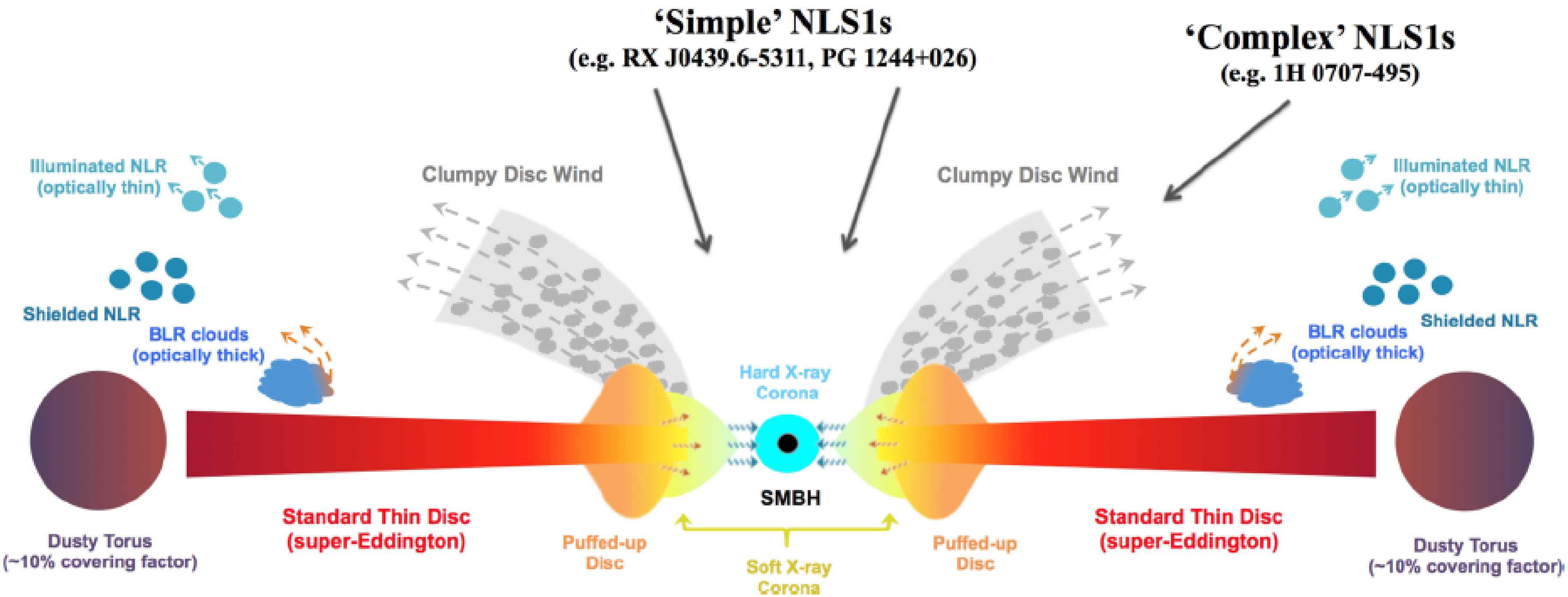


Done & Jin 2016



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

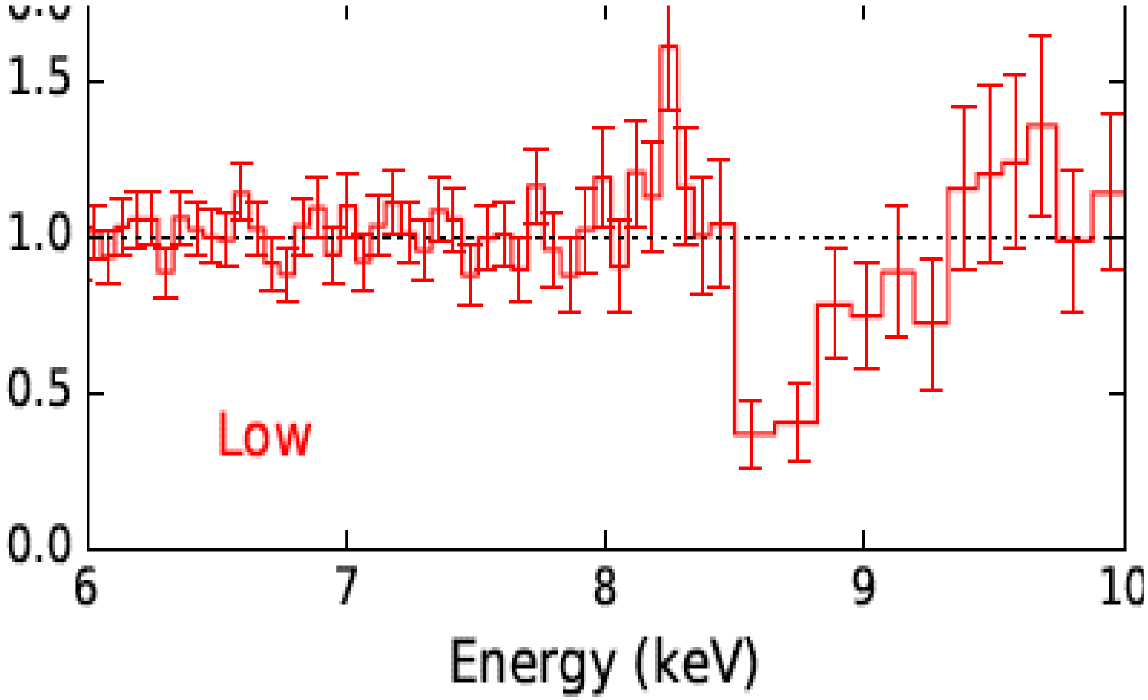
Super-Eddington Narrow-Line Seyfert 1s



Jin et al 2017

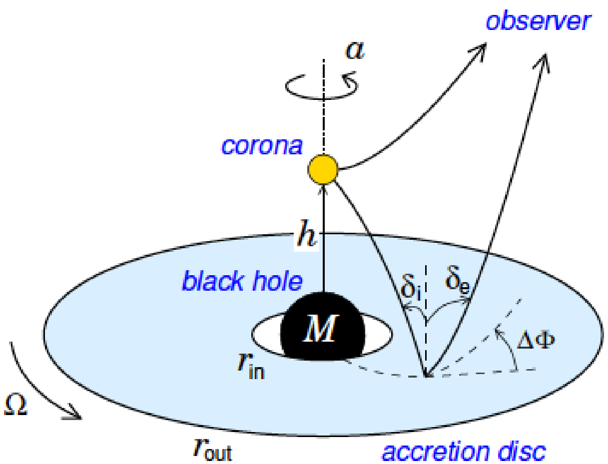
IRAS13224

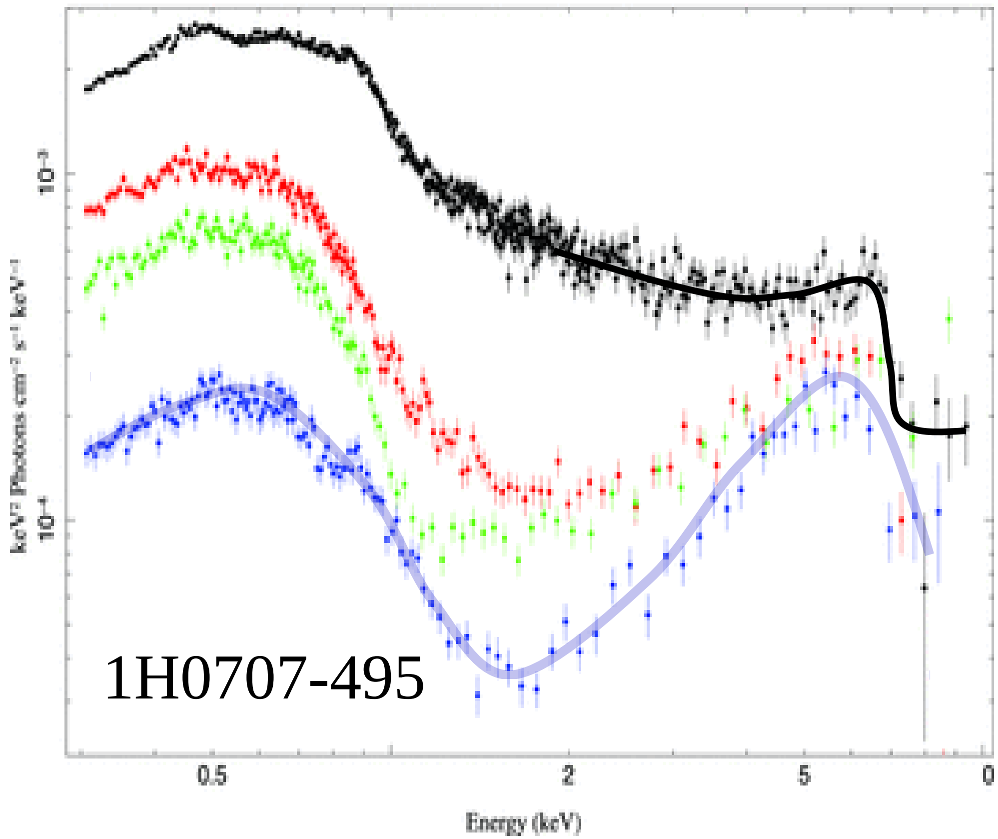
- IRAS13224 Parker et al 2017
- Called ‘twin’ of 1H0707 (Ponti et al 2009) – probably similarly superEddington (Leighly 2004)



Complex NLS1 – X-ray view

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

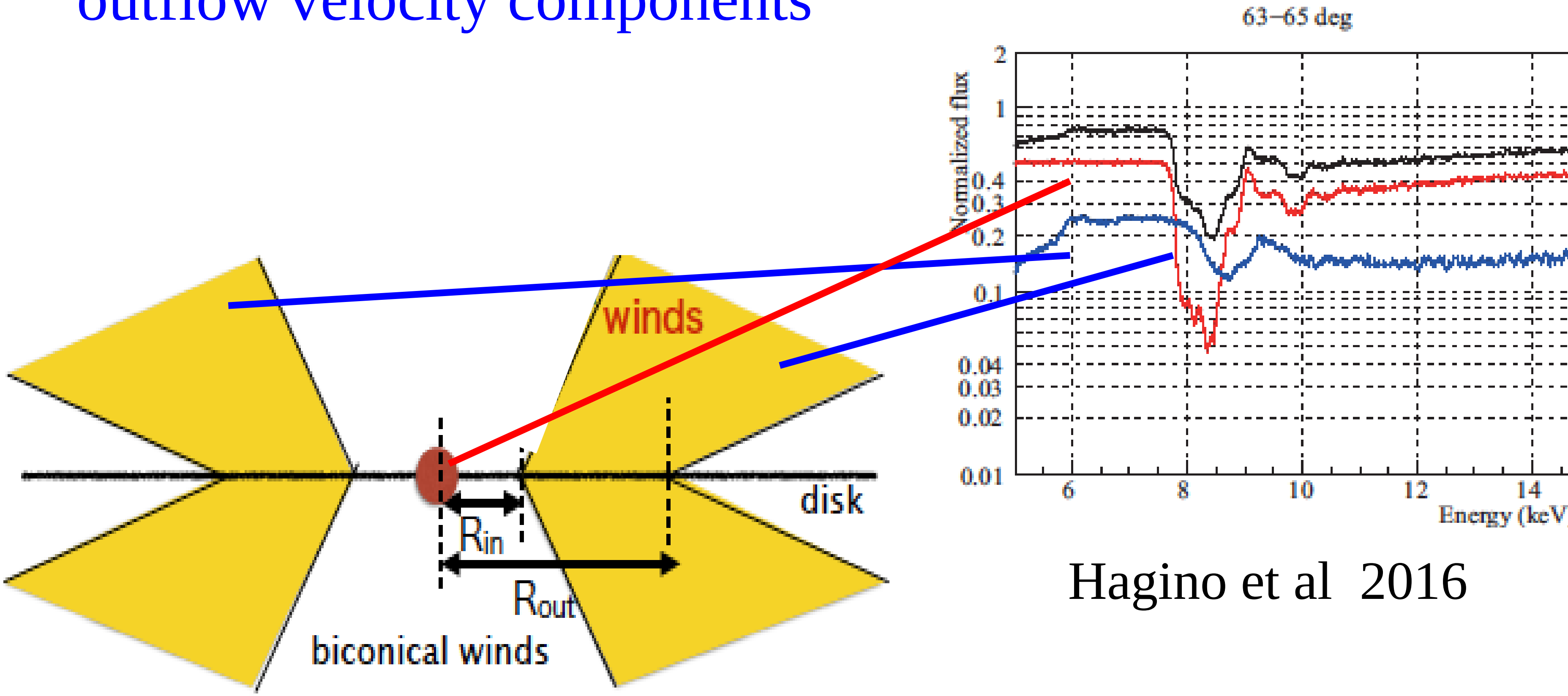




Fabian et al 2009

Complex NLS1 – X-ray view

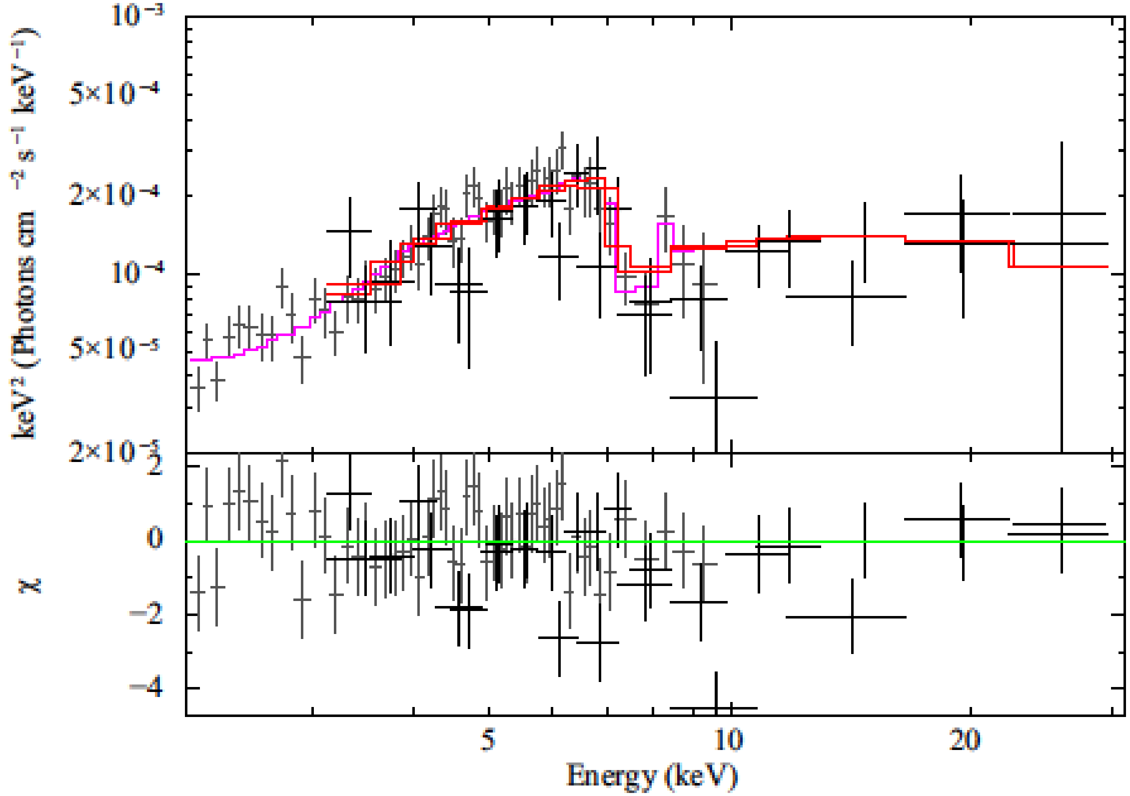
- Absorption on line of sight – blueshifted
- Emission from all wind – blue and redshift, rotation plus outflow velocity components



Hagino et al 2016

Complex NLS1 – X-ray view

- Extreme spin with reflection from flat disc
- Or superEddington wind absorption with no constraints on spin!!



Hagino et al 2016

Conclusions

- AGN should depend on mass, L/Ledd and spin.
- M and L/Ledd can be estimated easily from single optical spectrum. Define on these parameters!!
- 0.02<L/Ledd<1 see Lx~0.02LEdd!! Γ steepens 1.6-2.2 – requires truncated disc at low L/Ledd, fits nicely at higher L/Ledd
- L/Ledd > 1 – strong energy losses (unsurprising!). Winds and/or advection. Winds give difference between simple and complex NLS1
- Can fit lag-frequency results as well – no extreme spin required – spin-jet paradijm for blazar jets???