# X-rays from AGN in a multi-wavelength context

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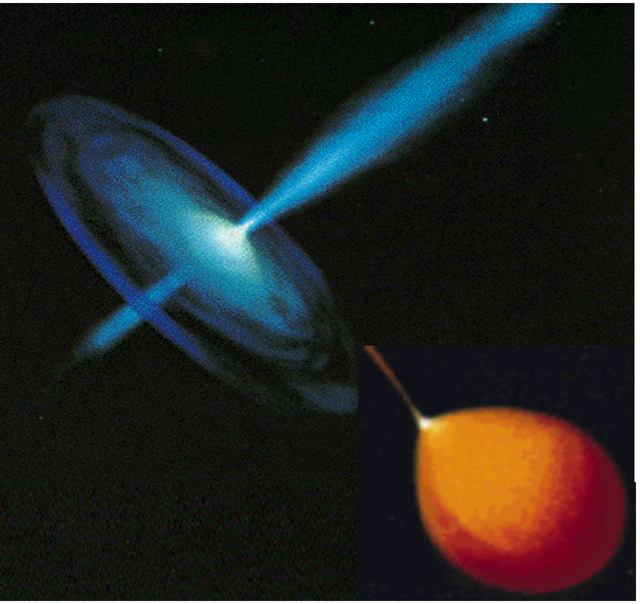
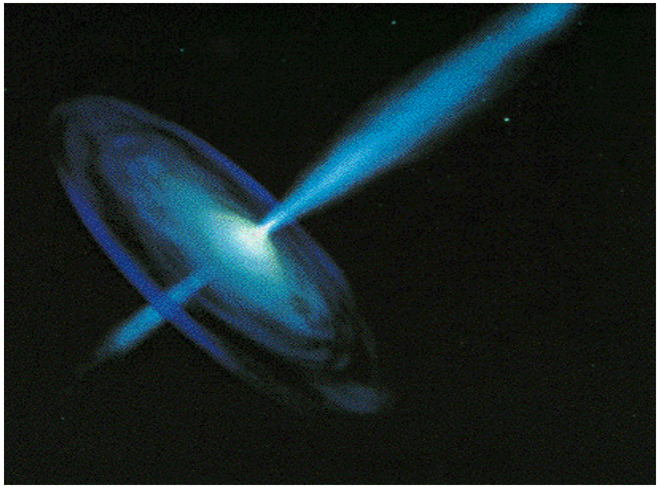
**Martin Ward, Chichuan Jin, Kouchi Hagino**

# Plan!



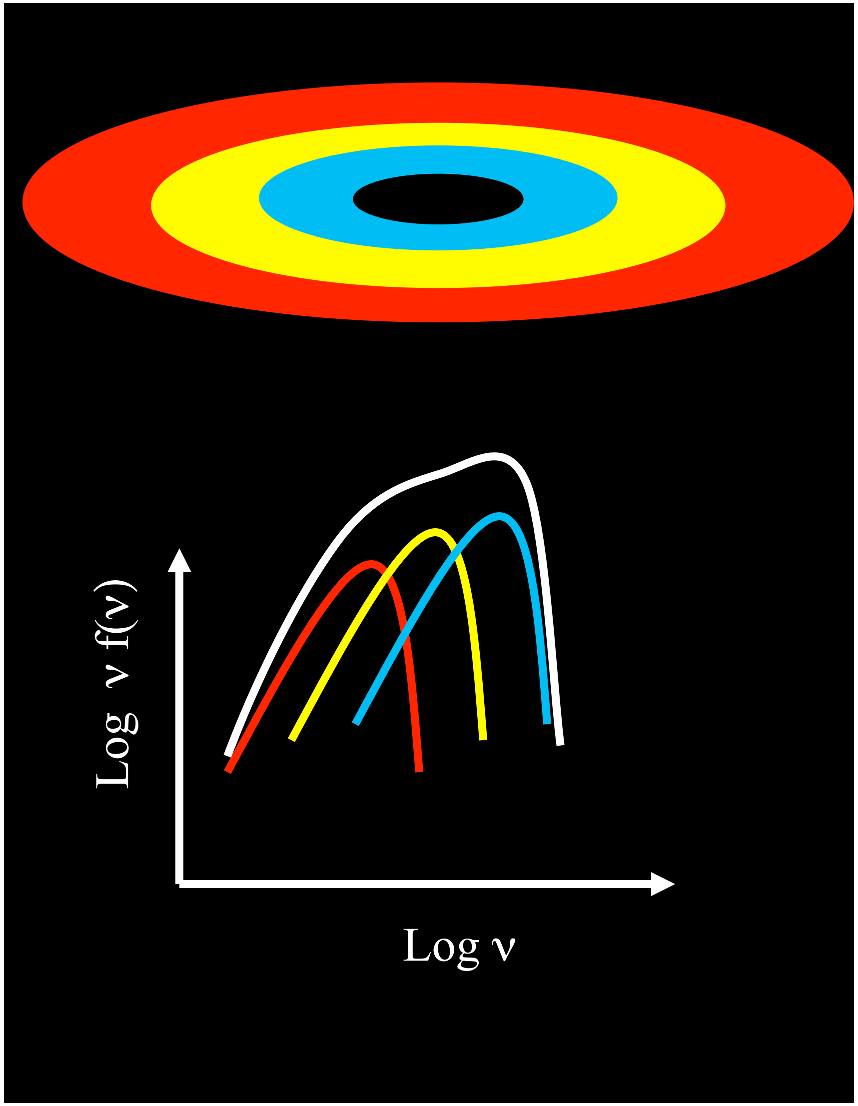
What can we learn about AGN variability from BHB?



What can we learn about tidal disruptions from AGN

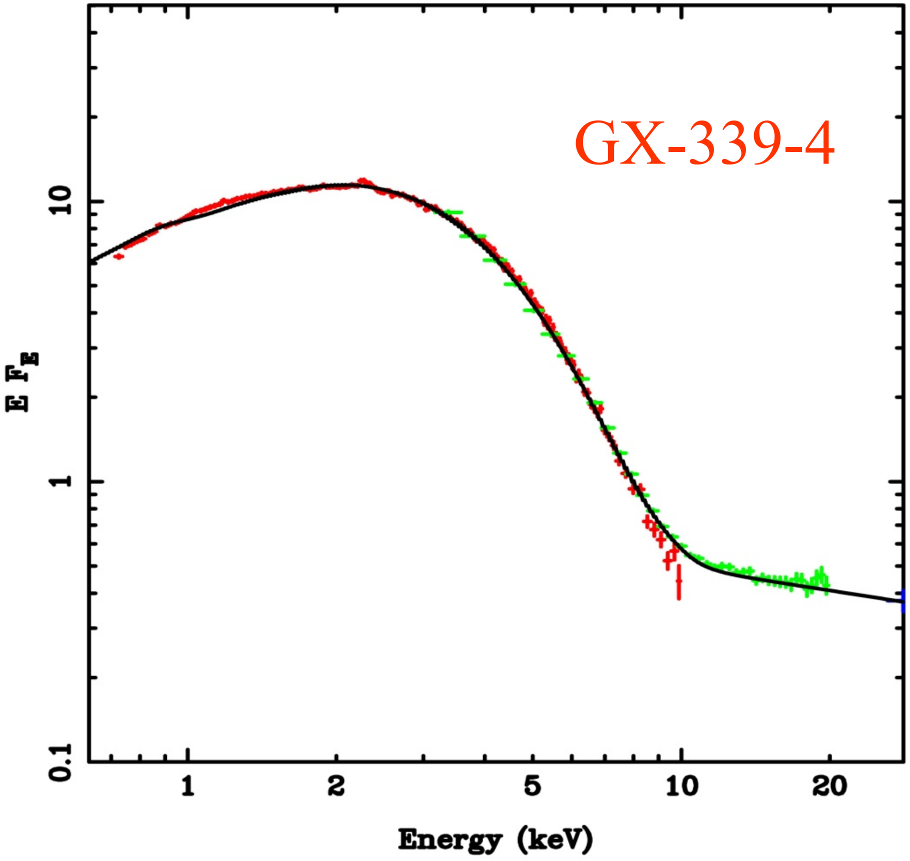
# Ultimately from accretion flow

- Differential Keplerian rotation
- MRI Viscosity: gravity → heat
- Thermal emission:
- $dL = dA\,\sigma\,T^4$
- 10 Msun, L=LEdd Tmax~1 keV



# Observed disc spectra in BHB!!

- Fit Shakura-Sunyaev disc (with GR and photosphere)
- WORKS WELL!!
- Small corona gives high energy tail



Kolehmainen et al 2010

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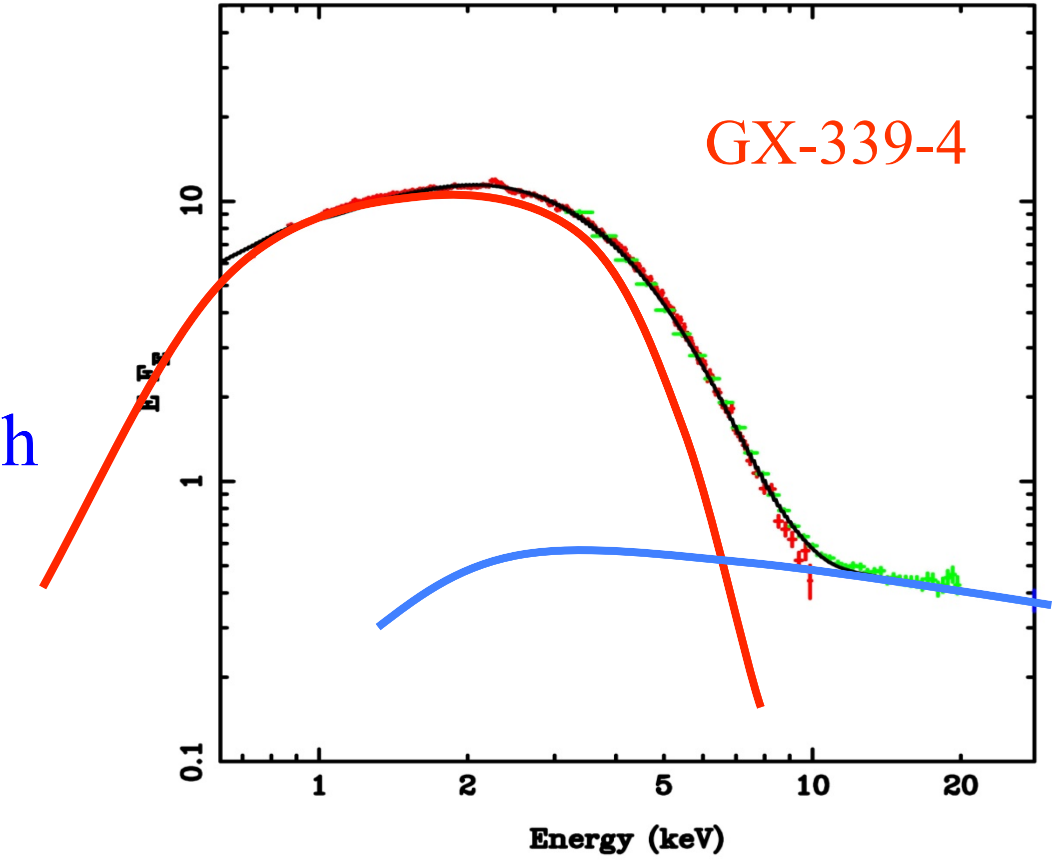
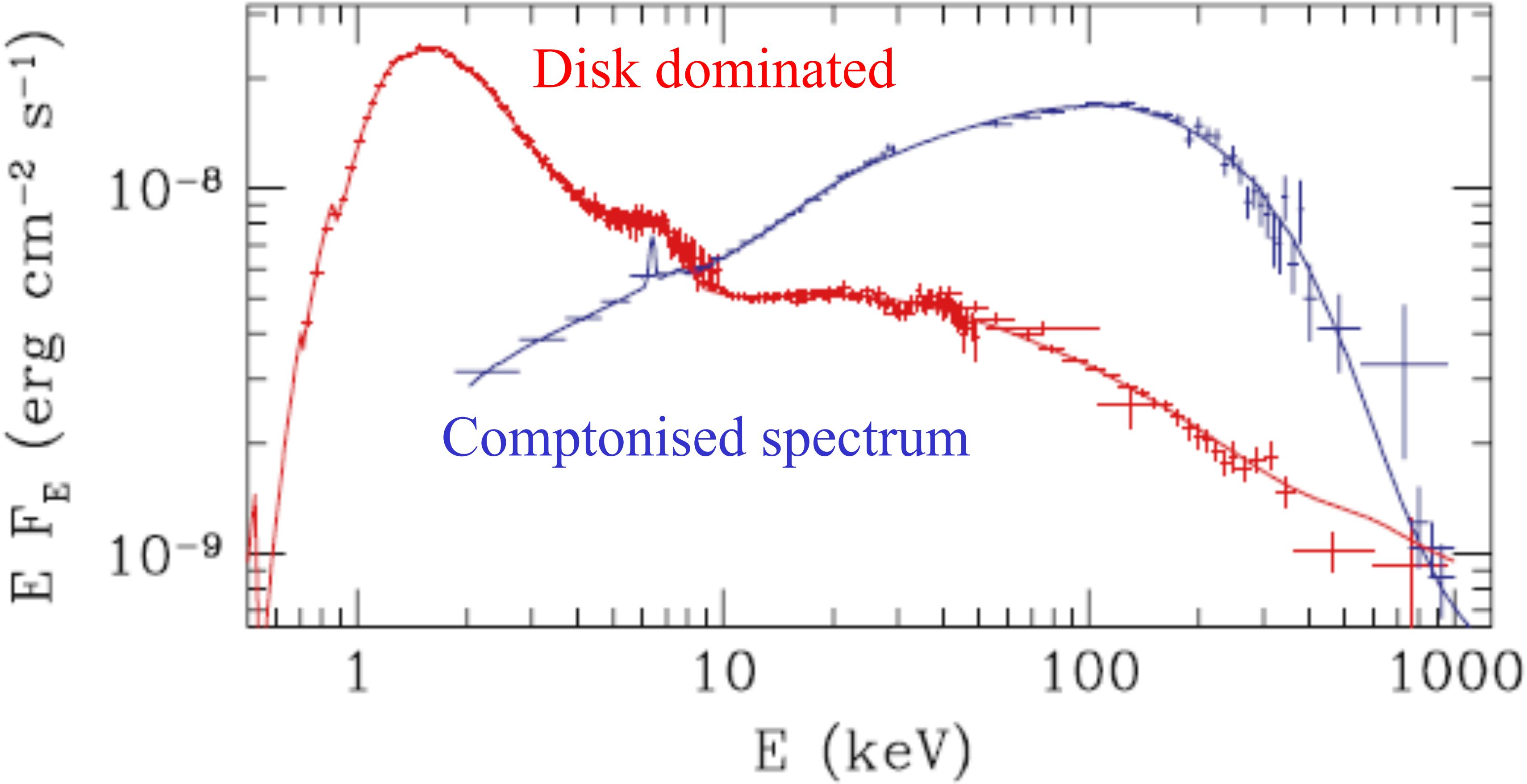


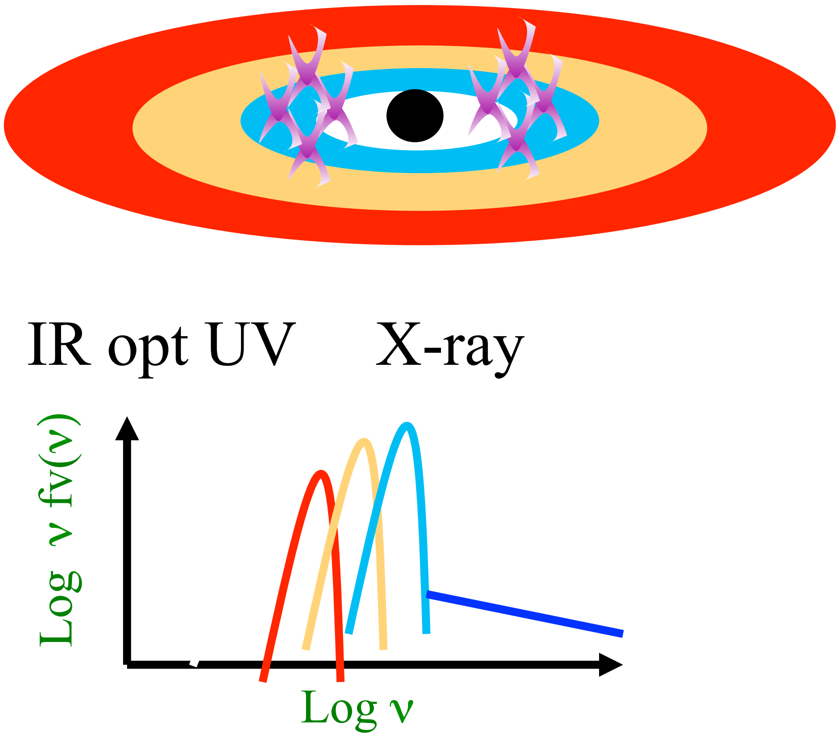
Kolehmainen et al 2010

# Two types of spectra in stellar BH

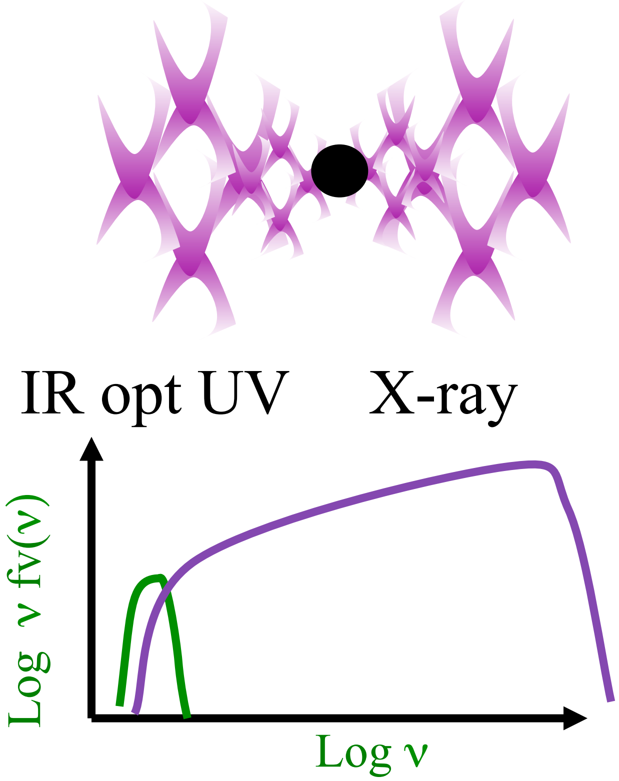


Gierlinski et al 1999

# Theory of accretion flows



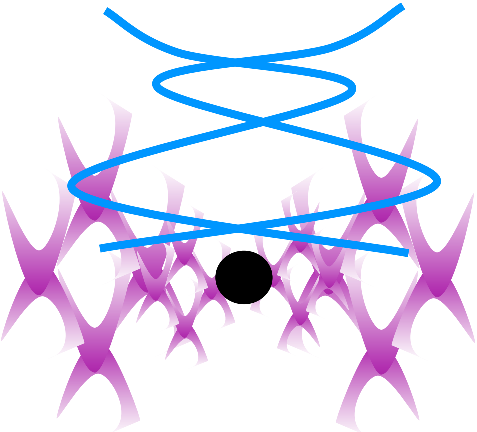
Discs – geometrically thin, cool, optically thick SS73
Plus X-ray tail/corona

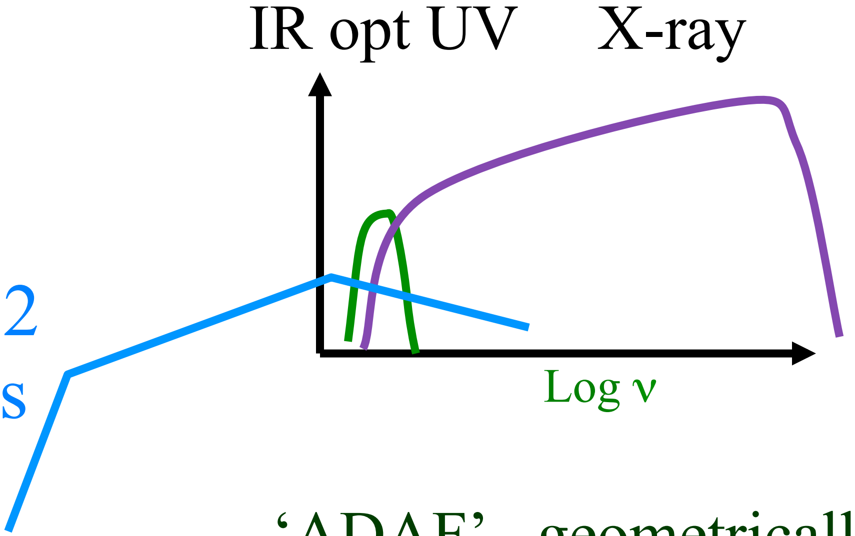


‘ADAF’– geometrically thick, hot, optically thin
Only low L/Ledd
Narayan & Yi 1995

# Theory of accretion flows

- Low/hard state BHB
- Optically thin (tau~1-2)
- We see the MRI directly!
- X-ray variability
- And jet!! $L_R$ – Lx
- (Fender et al 2004)
- BUT NOT HIGHLY RELATIVISTIC $\Gamma\sim1.5$-2 NOT 10-20 as in Blazars

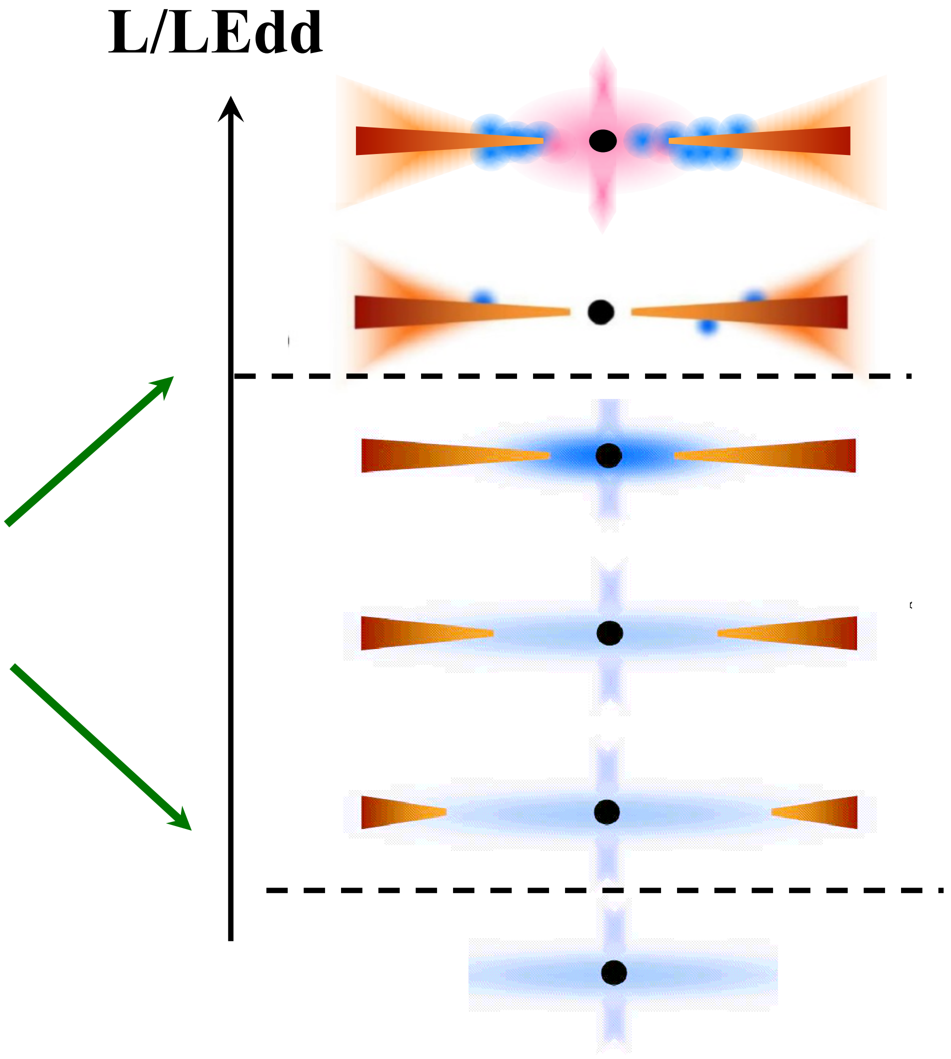




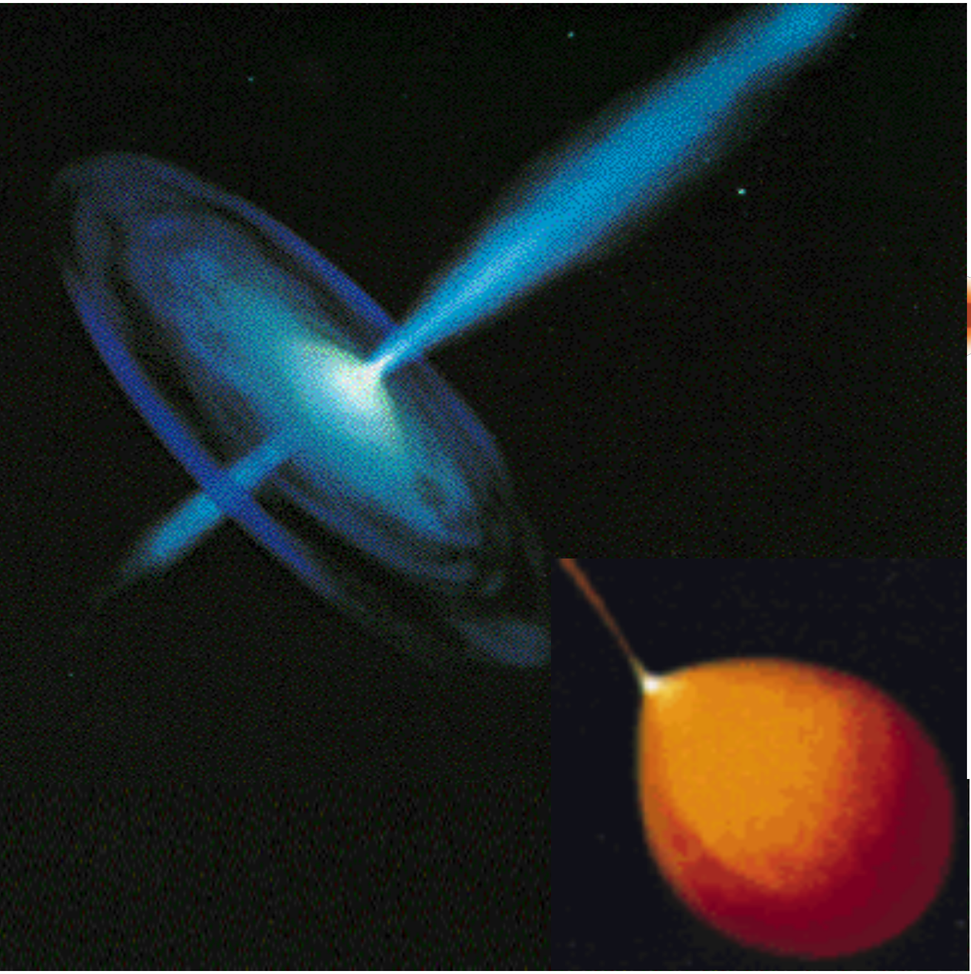
‘ADAF’– geometrically thick, hot, optically thin
Only low L/Ledd

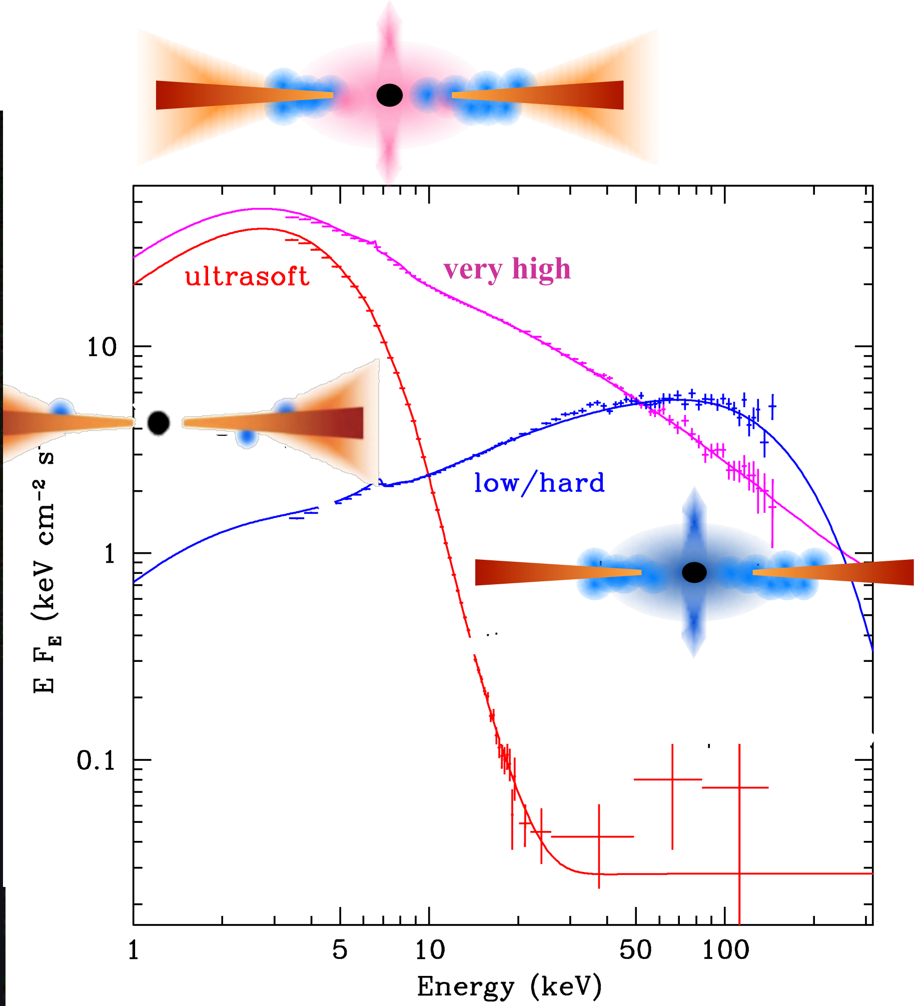
# Conclusions part 1 - BHB

- Disc dominated state – Shakura-Sunyaev disc equations!!
- TRANSITIONS – composite
- Truncated outer disc, inner hot thin flow
- ADAF - X-ray hot flow
- steady compact jet (bulk $\Gamma \sim 1.5\text{-}2$)



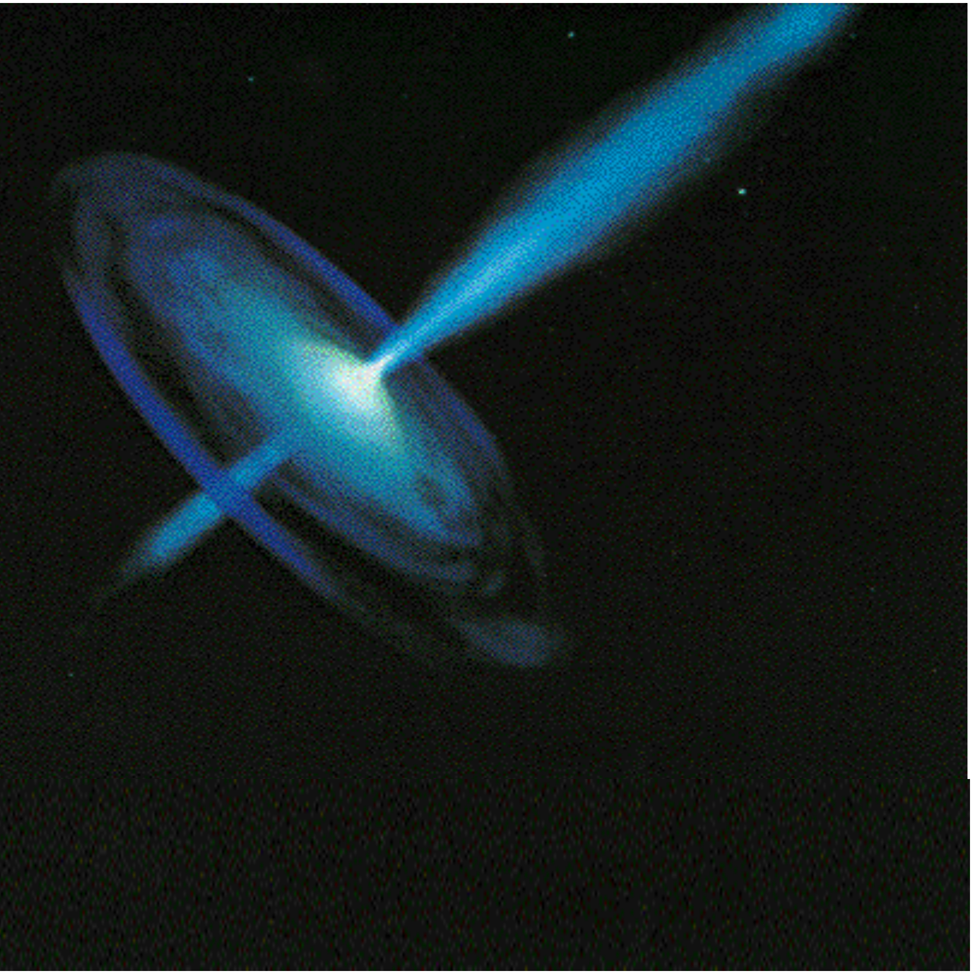
# BHB: template for SED L/Ledd?





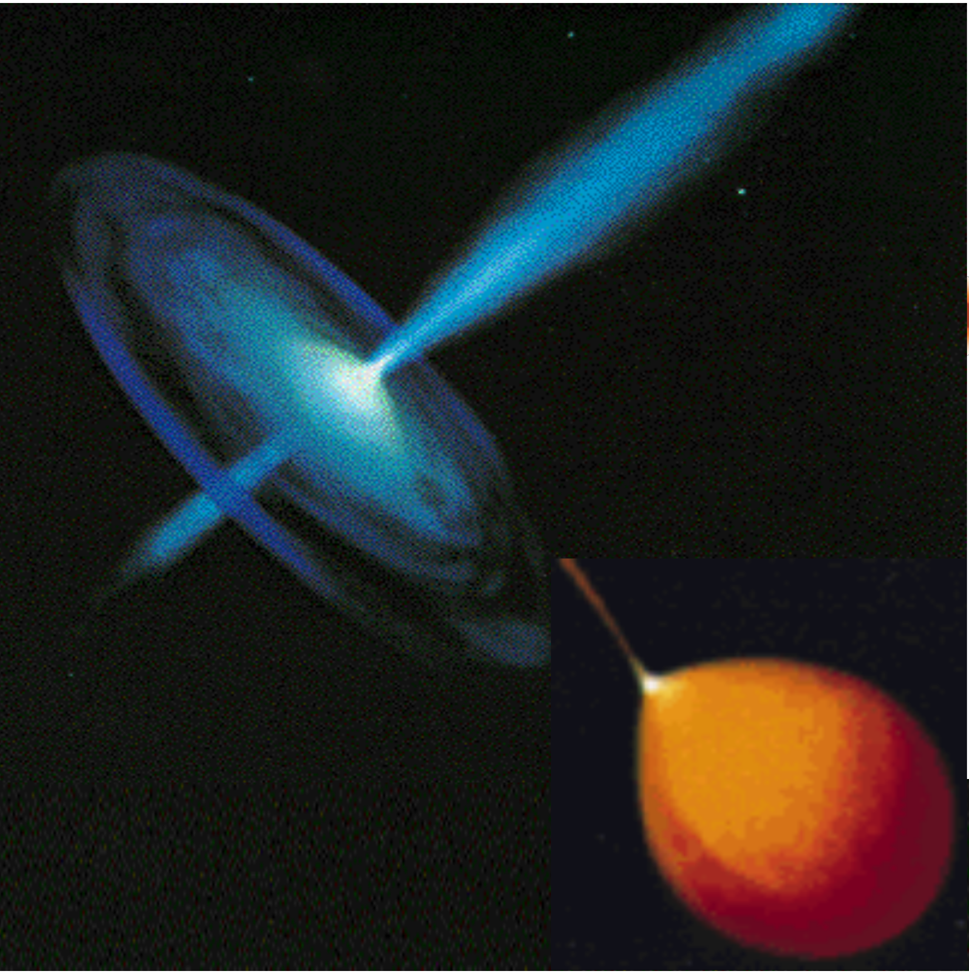
Gierlinski & Done 2003

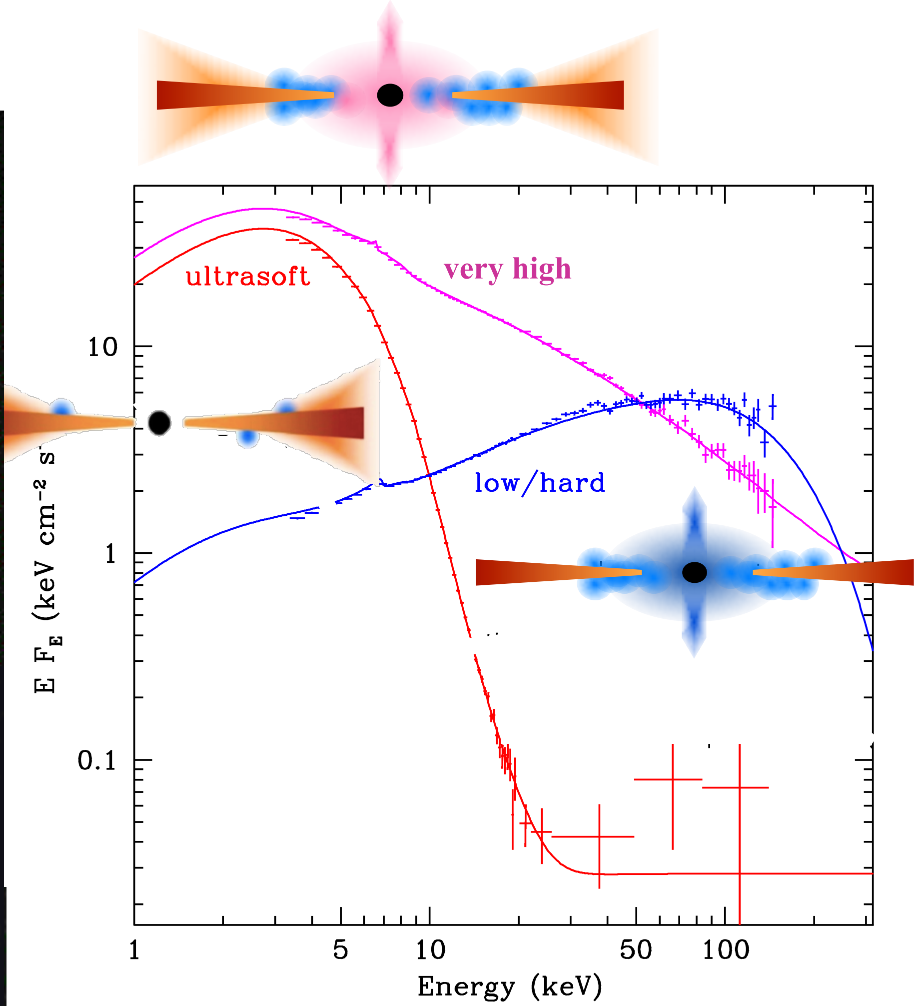
# Scaling black hole accretion flow



- 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??

# BHB: template for SED L/Ledd?

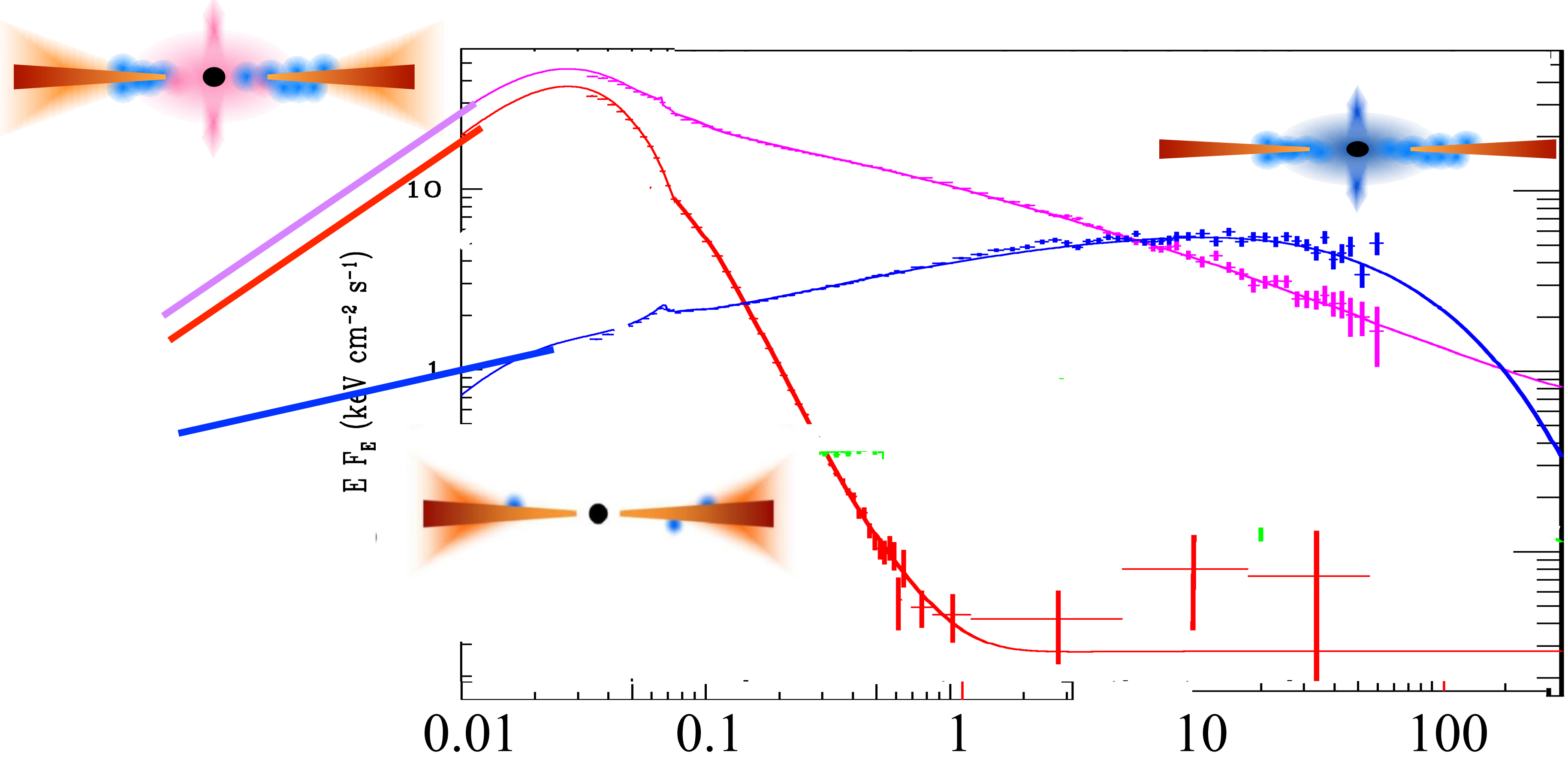




Gierlinski & Done 2003

# ‘Spectral states in AGN’

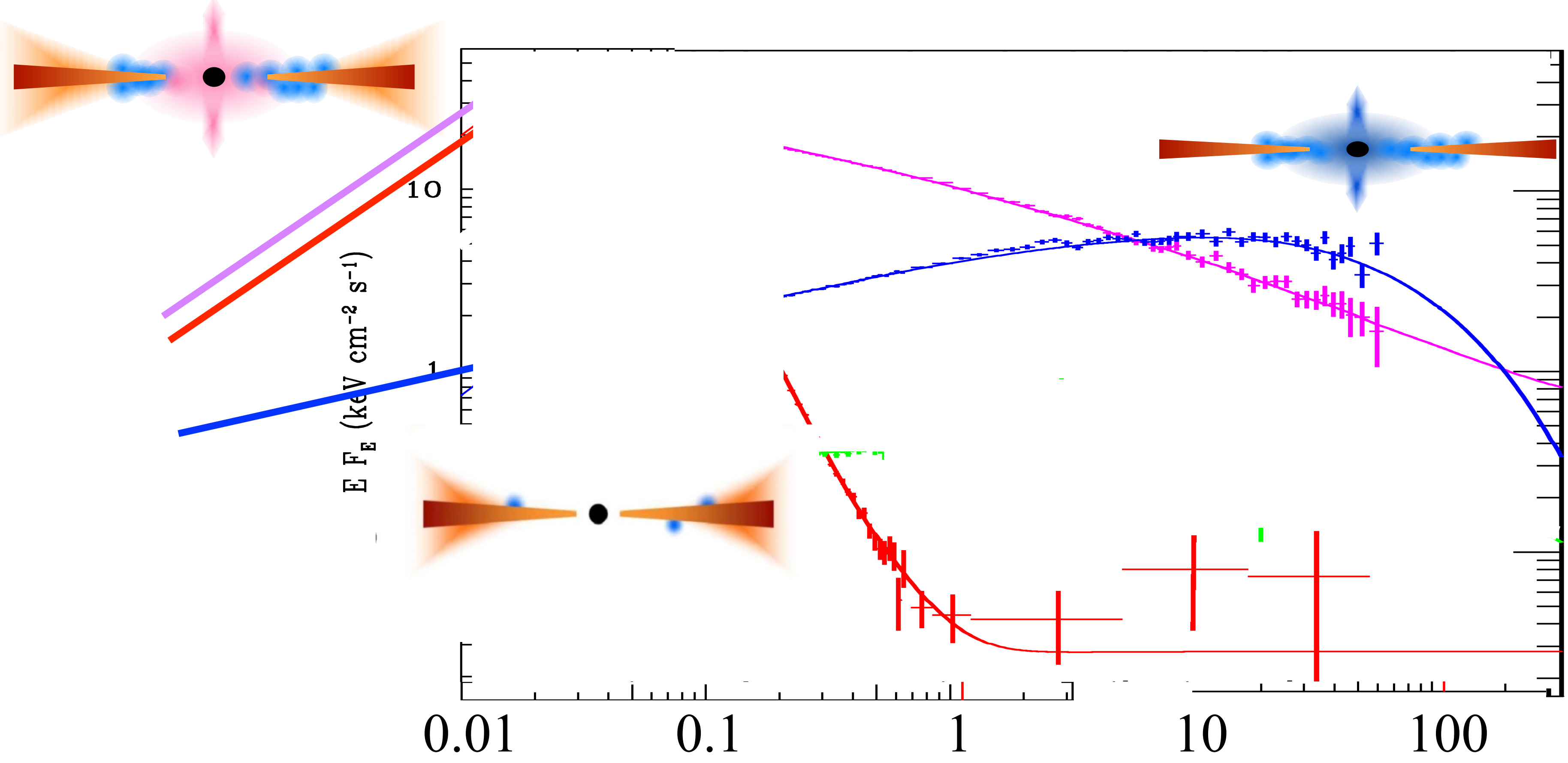
Disc BELOW X-ray bandpass. Peaks in UV – ATOMIC PHYSICS



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

# Interstellar absorption

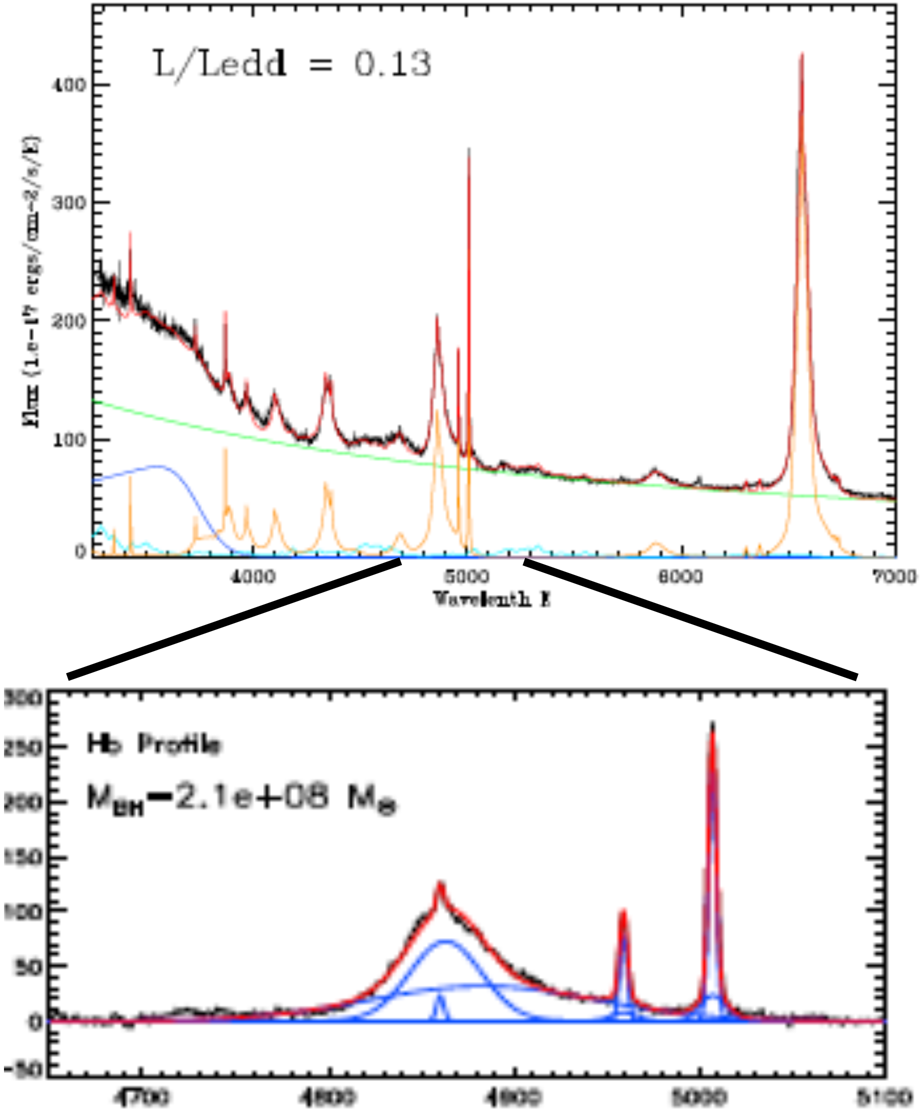
Disc BELOW X-ray bandpass. Peaks in UV – ATOMIC PHYSICS



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

# AGN L/LEdd ? SMBH Mass

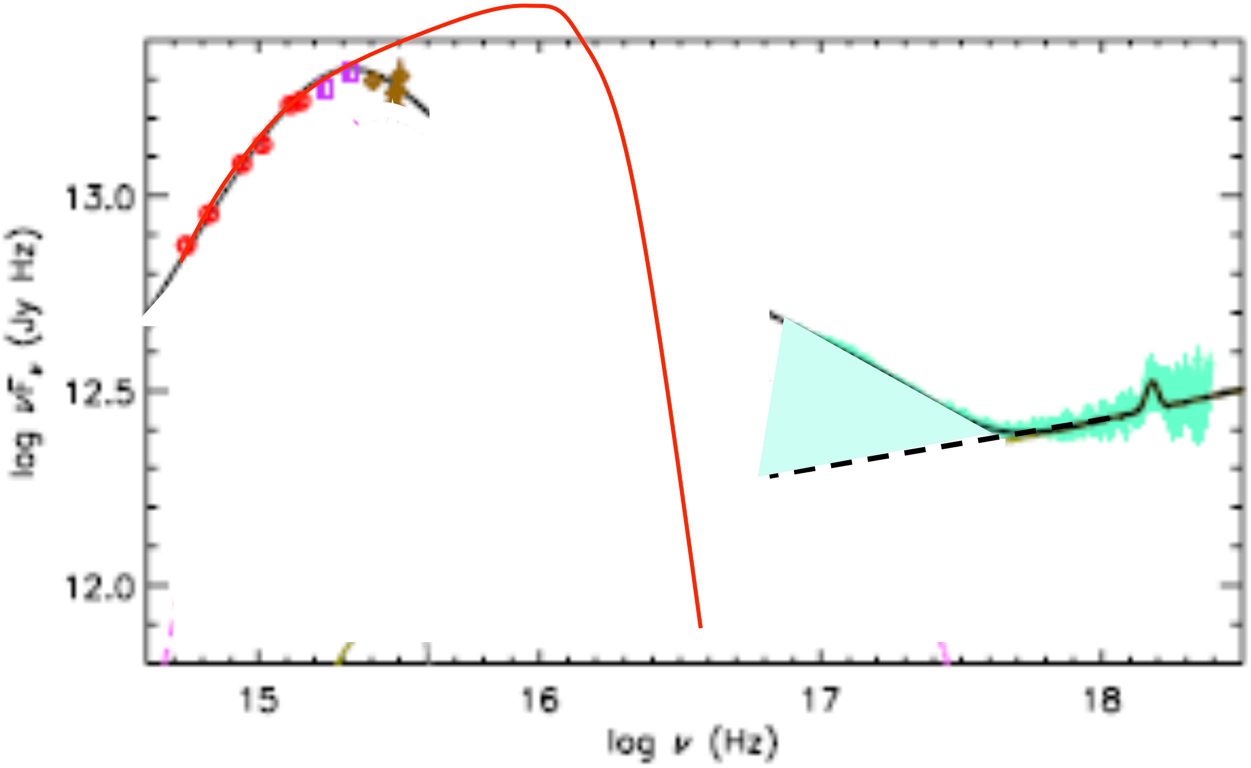
- Scaling relations for $M_{BH}$ in terms of Hβ FWHM and Fopt
- Based on BLR reverberation campaigns



# Full multi-wavelength spectrum

- De-absorb from galactic and intrinsic
- Model across unobservable 0.01-0.2 keV bandpass
- Lbol - know M so know LEdd so get Lbol/LEdd

- Mkn509
- $10^8$Msun
- 0.1LEdd
- Not disc!
- Soft X-ray XS

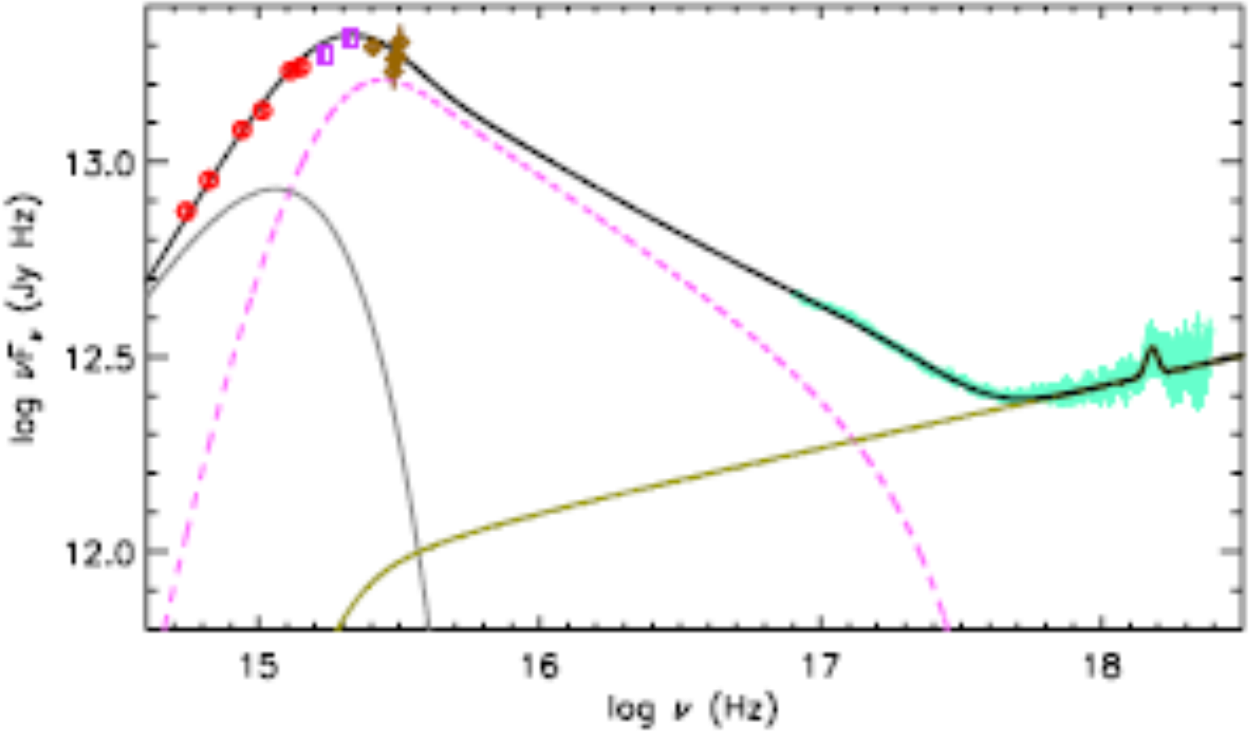


Medhipour et al 2011

# Full multi-wavelength spectrum

- De-absorb from galactic and intrinsic
- Model across unobservable 0.0136-0.2 keV bandpass
- Lbol - know M so know LEdd so get Lbol/LEdd

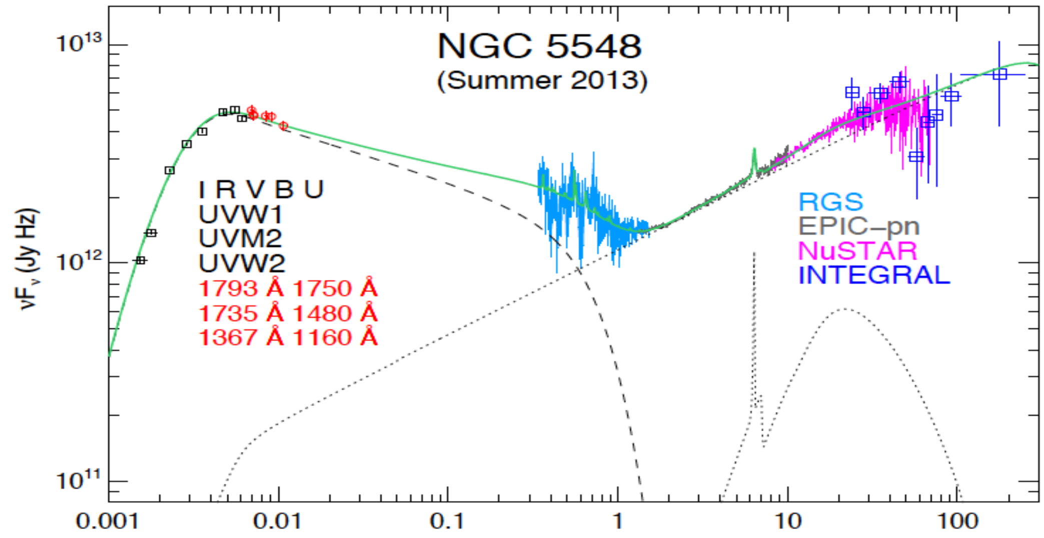
- Mkn509
- $10^8$Msun
- 0.1LEdd
- Not disc!
- Soft X-ray XS



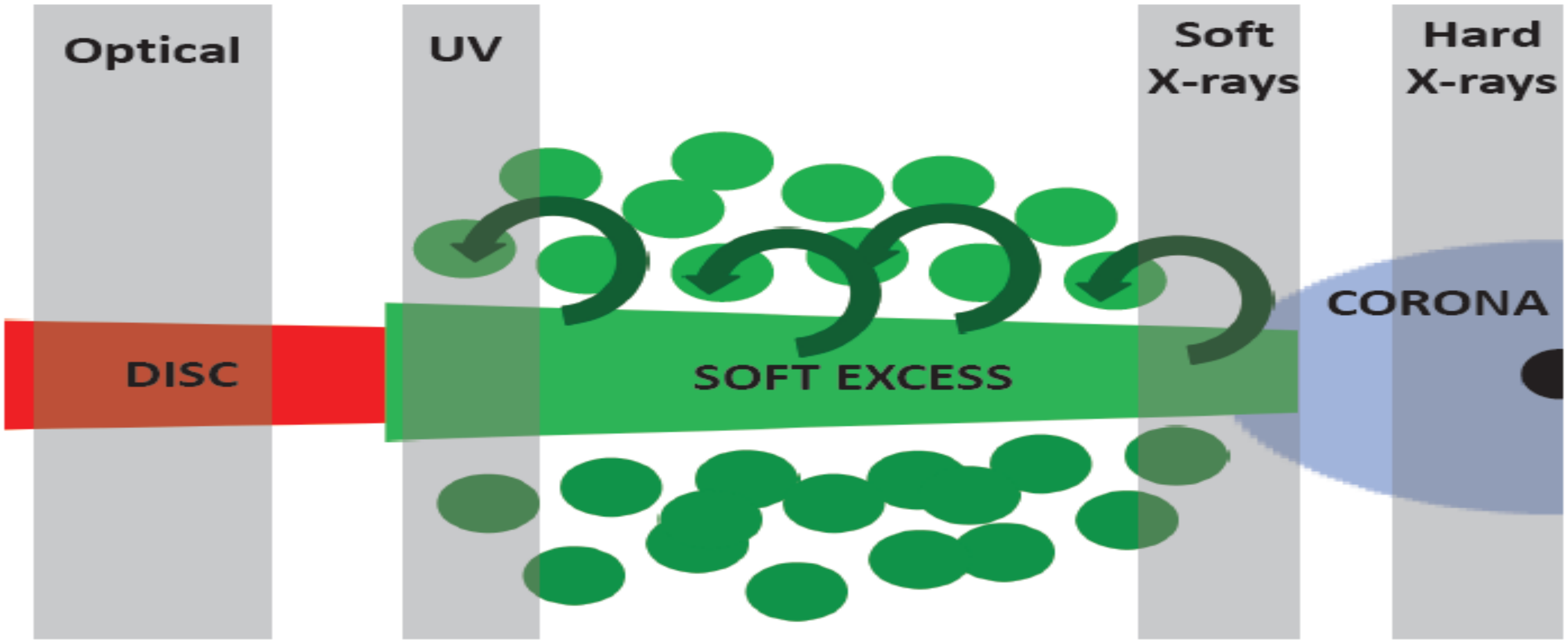
Medhipour et al 2011

# Nature of soft excess region?

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



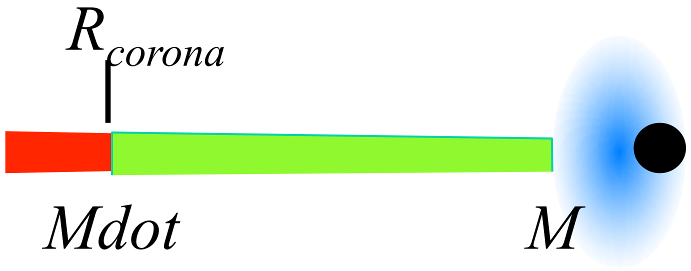
Mehdipour et al 2015

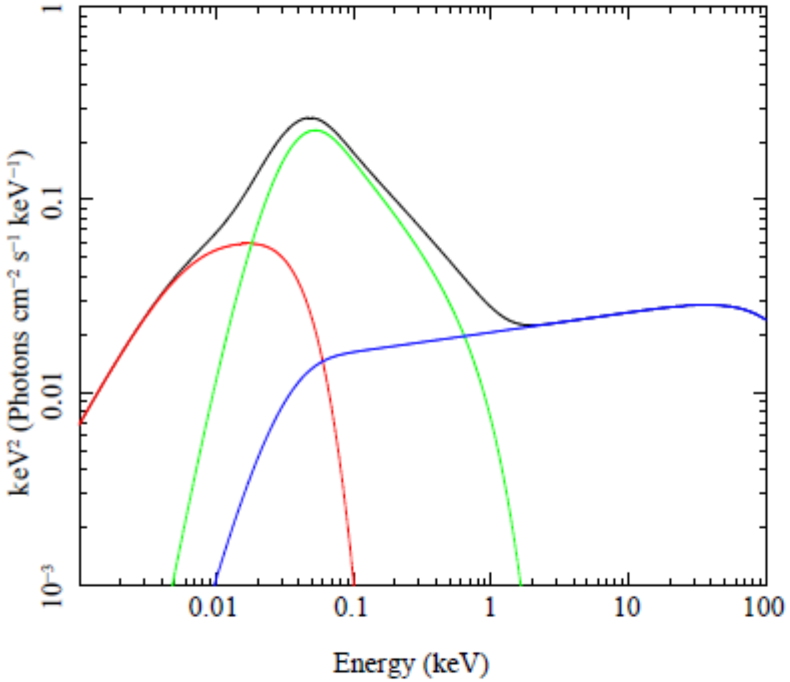


Gardner & Done 2017

# 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) α M Mdot /$R^3$
- Lbol=η Mdot $c^2$
- Inner corona as in hard state BHB (L/LEdd?)

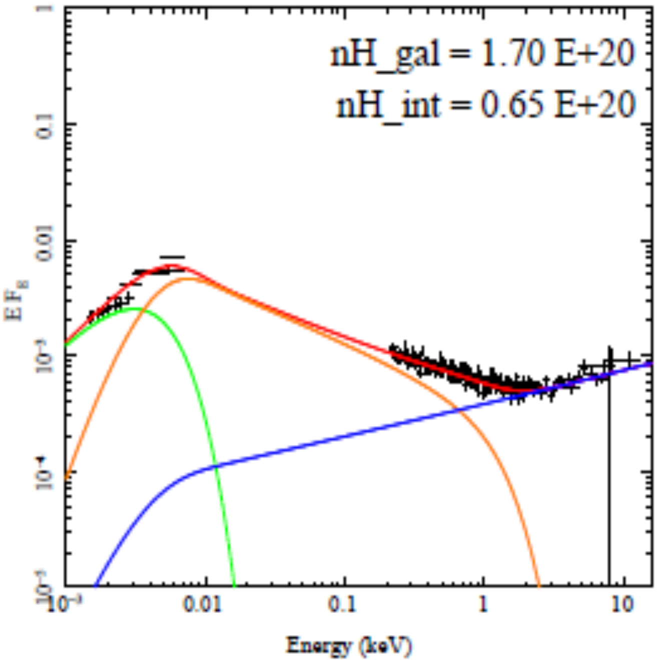


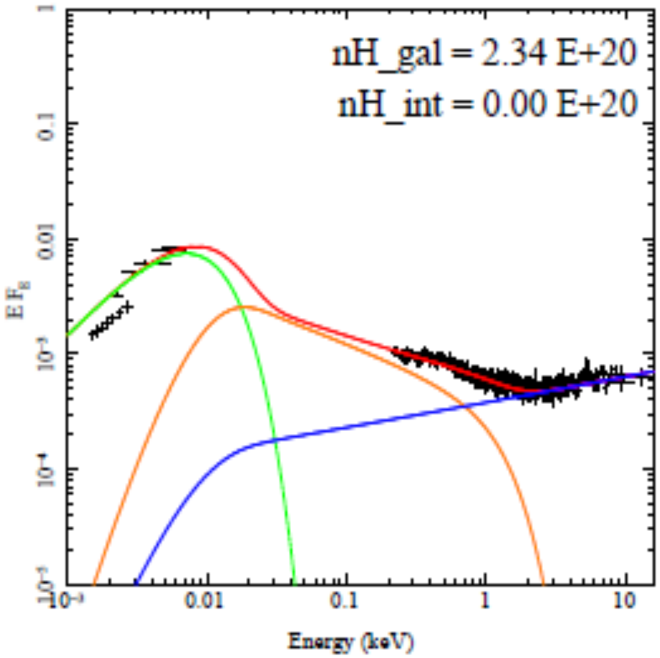


Done et al 2012

# 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

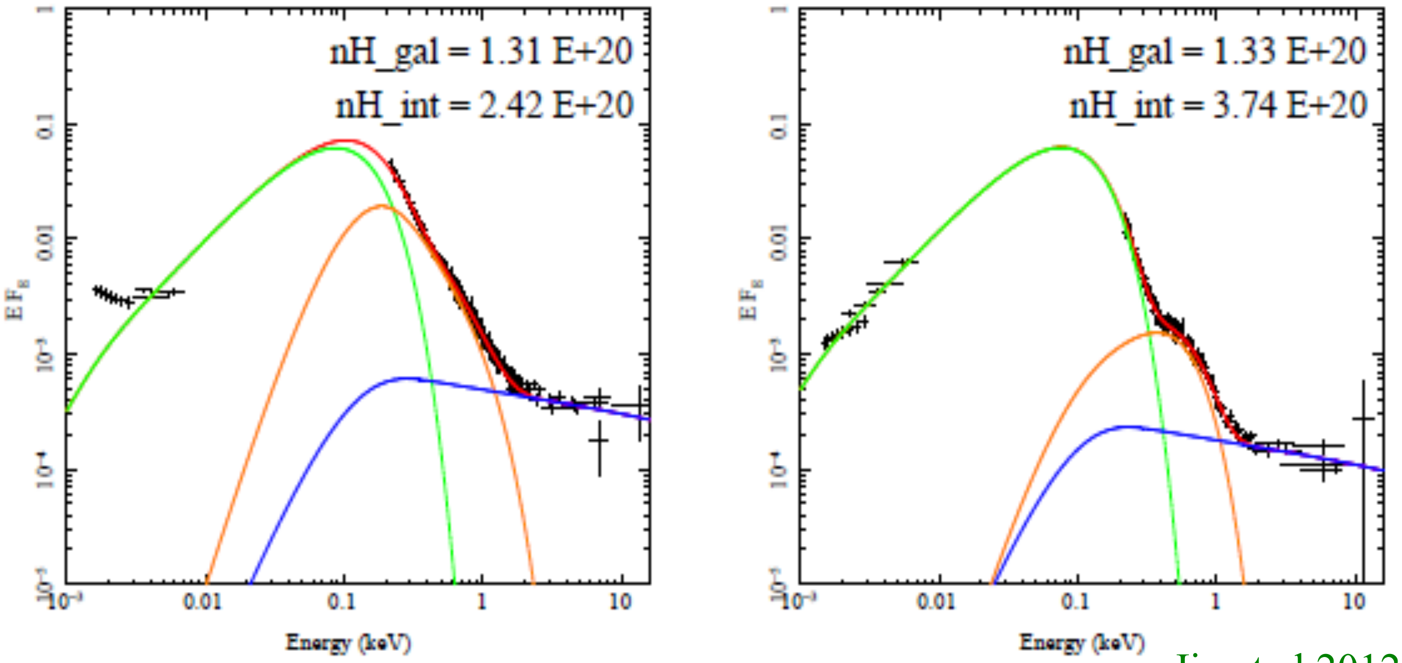




Jin et al 2012

# Very different to NLS1

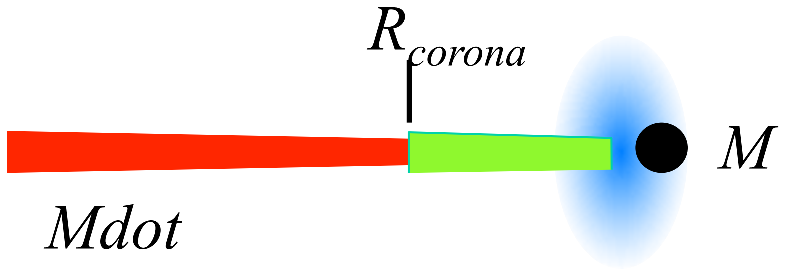
- <M>~$10^7$, <L/LEdd>~1 NLS1 in local universe
- Disc dominated, small SX, weak X-rays

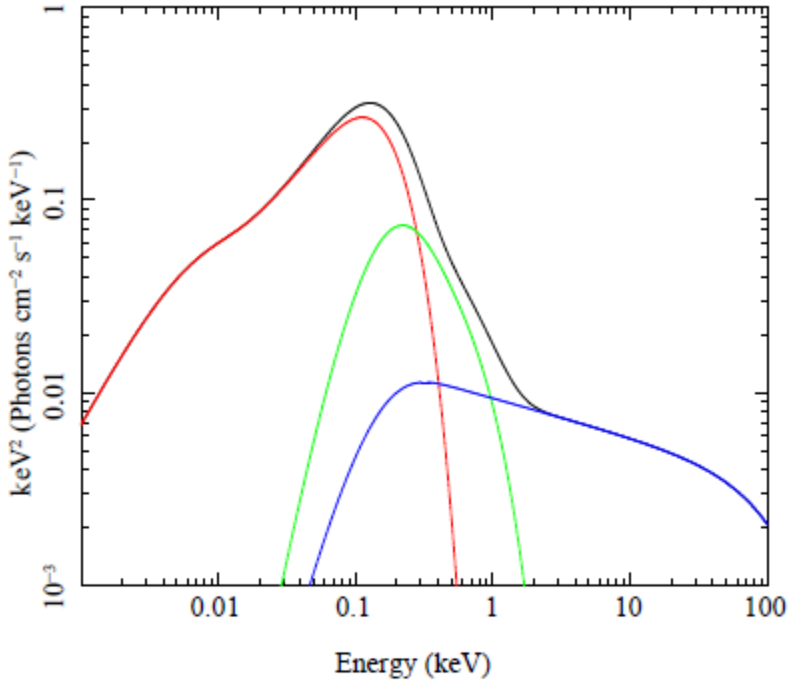


Jin et al 2012

# Models conserving energy!!

- Smaller $R_{corona}$
- Softer 2-10 keV corona
- Spectra are more disc dominated!
- Weak soft X-ray excess and weak corona
- X-ray bolometric correction CHANGES!!
- Vasudevan & Fabian 2007; 2009

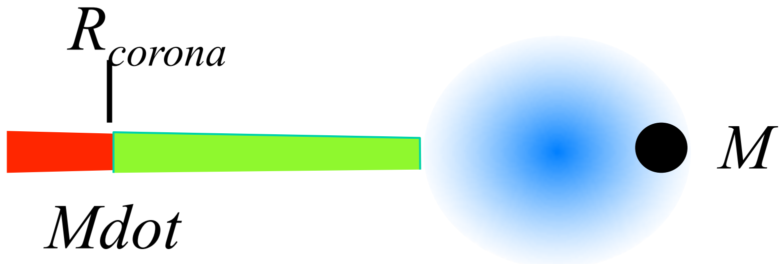


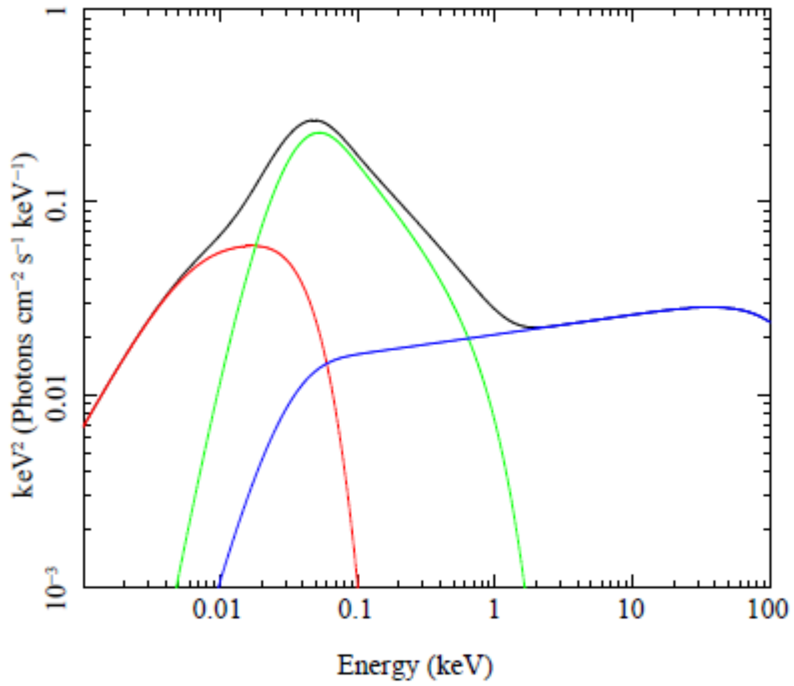


Done et al 2012

# Models conserving energy!!

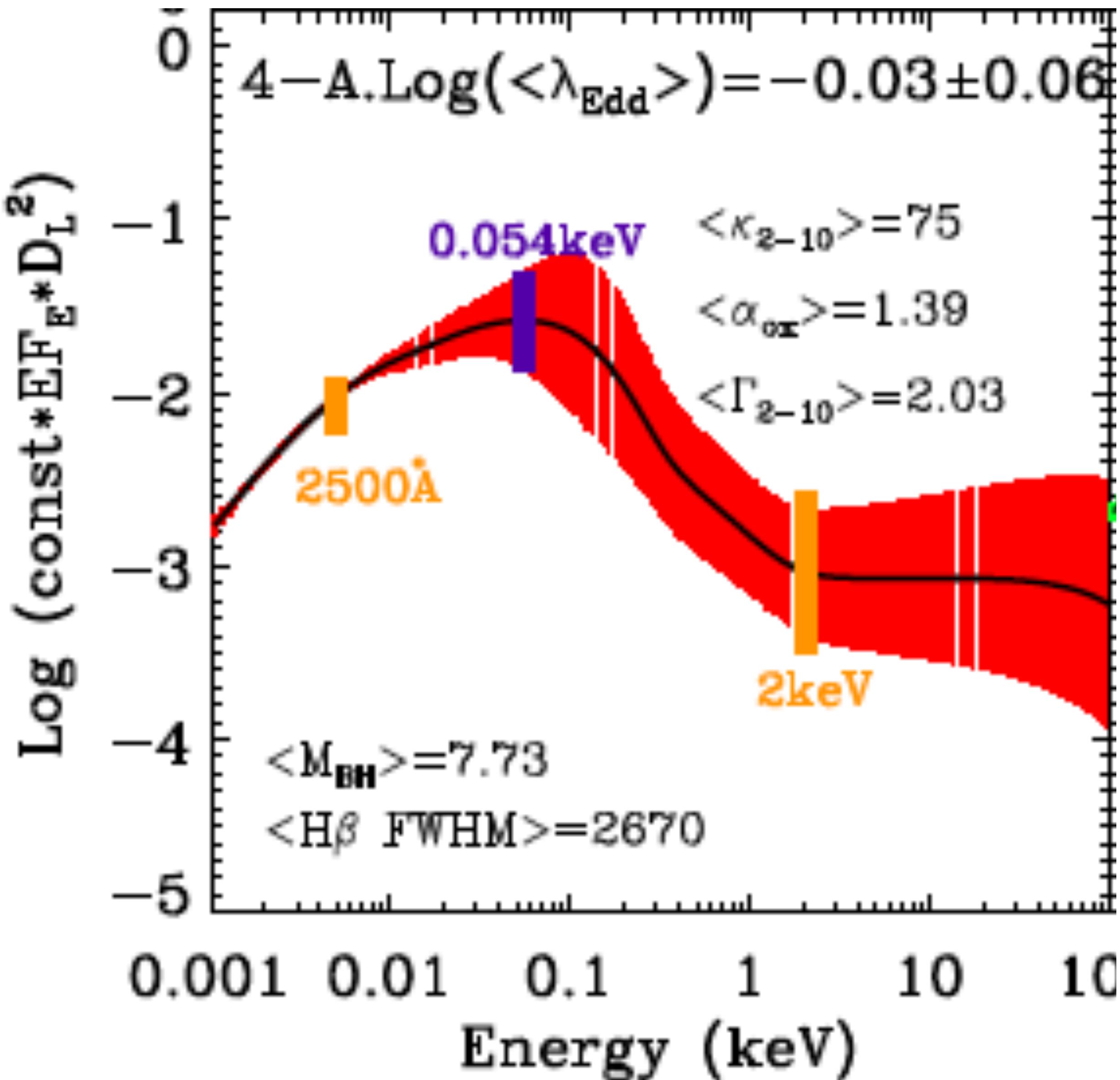
- Outer standard disc down to $R_{corona}$
- Then luminosity not completely thermalised to make soft X-ray excess ?
- Failed UV line driven wind? And/or H ionisation instability
- Inner corona as in hard state BHB (L/LEdd?)
- X-rays can affect optical more!!





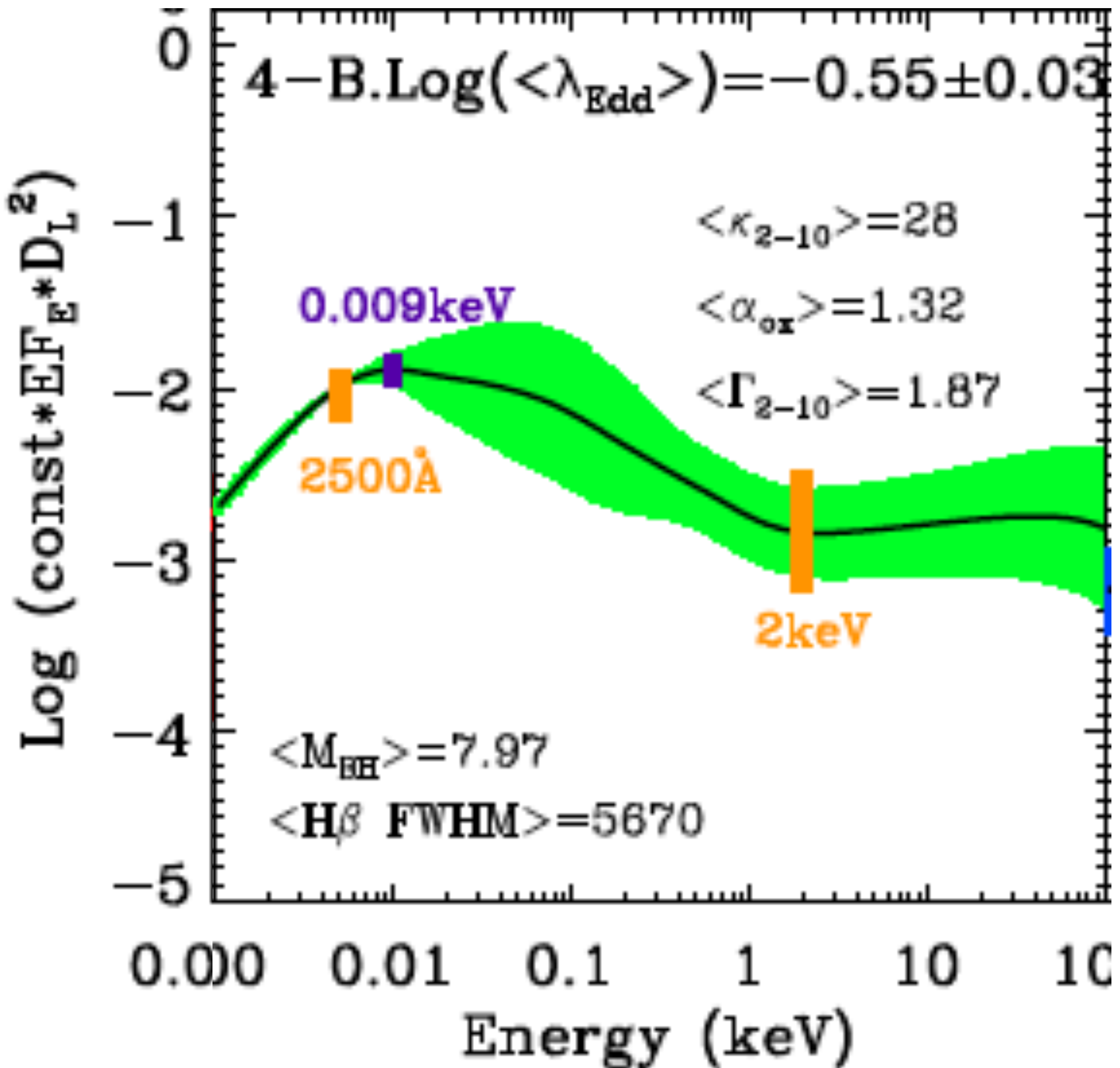
Done et al 2012

# AGN spectral states



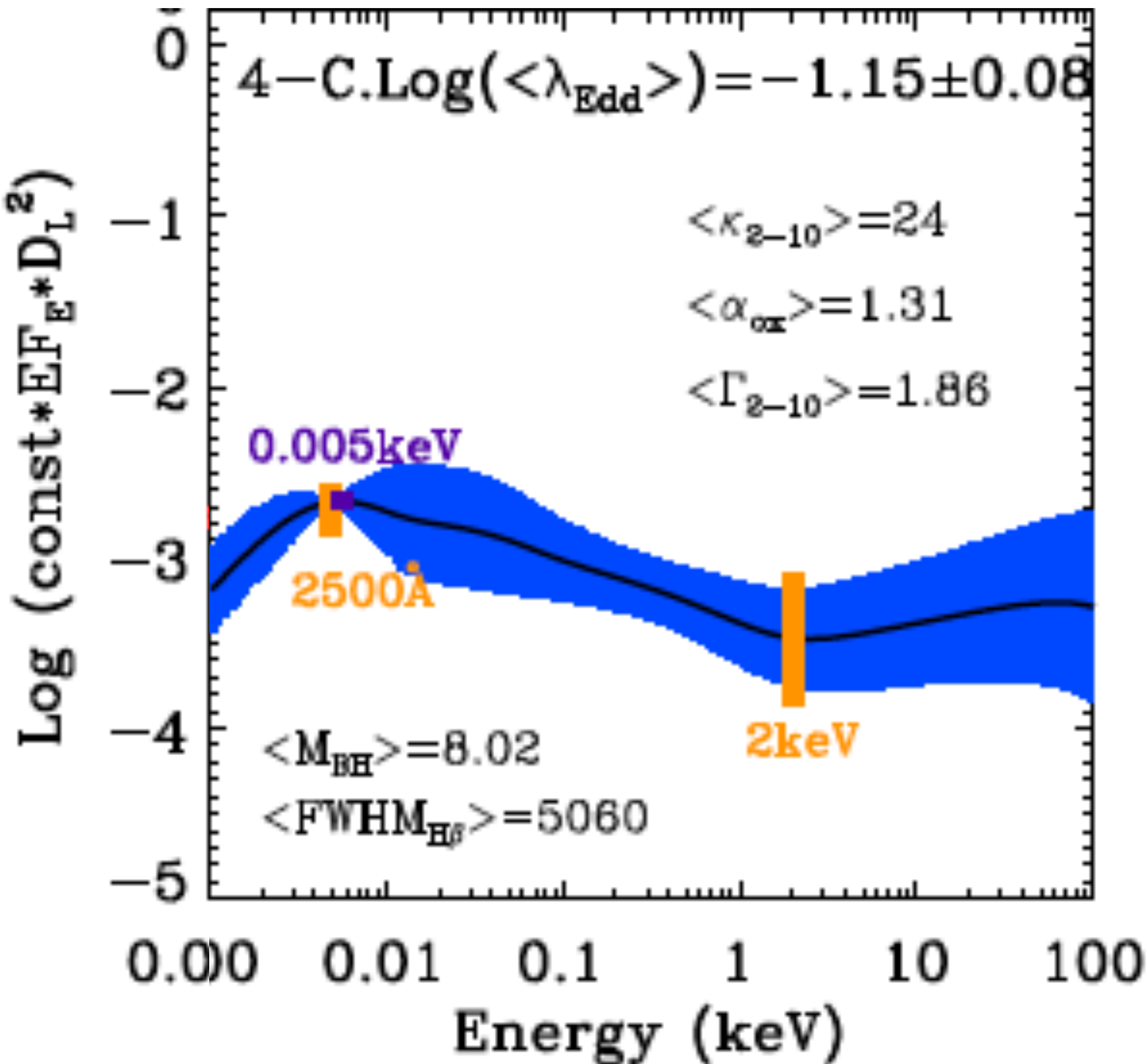
Jin, Ward, Done 2012

# AGN spectral states



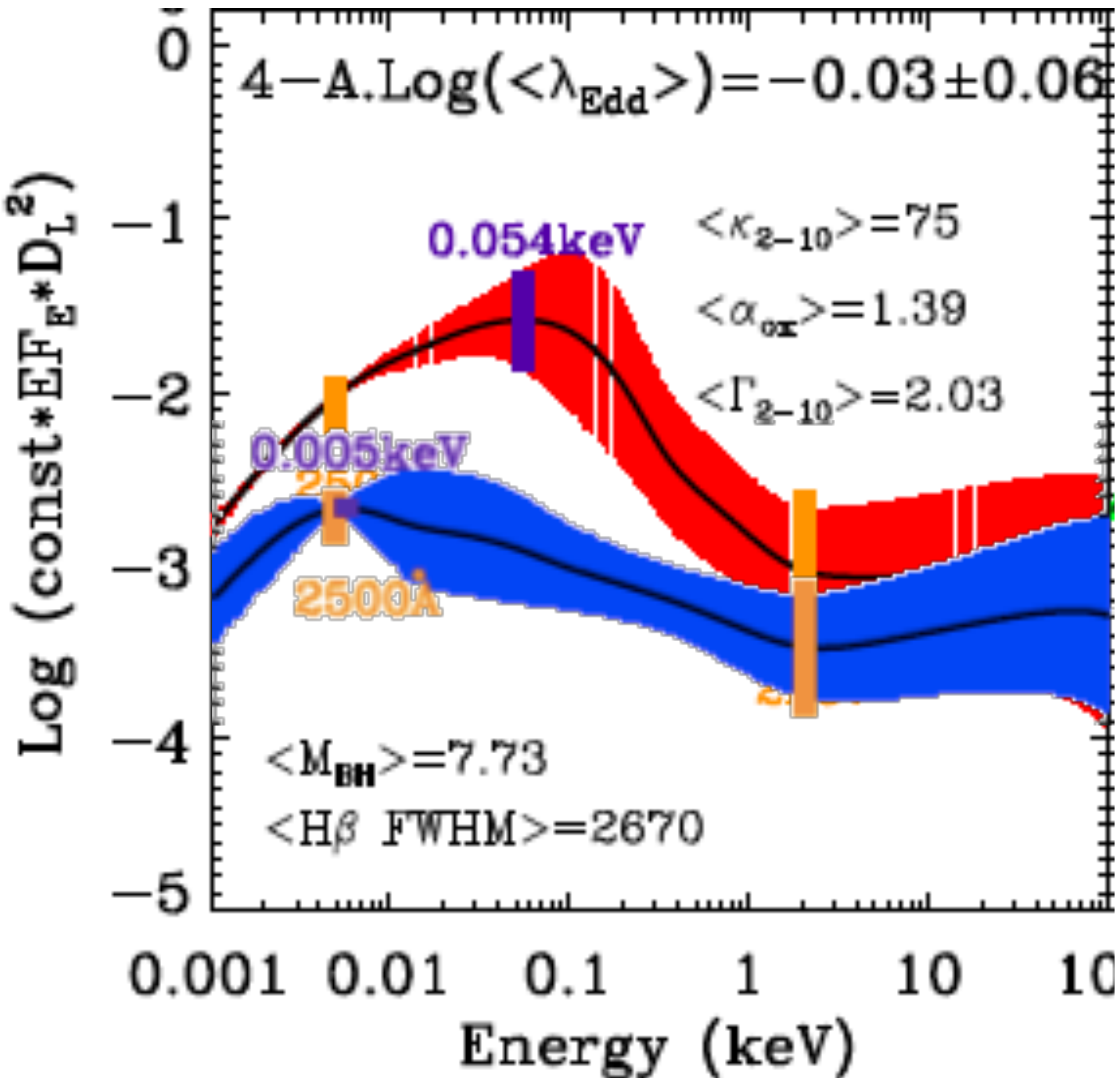
Jin, Ward, Done 2012

# AGN spectral states



Jin, Ward, Done 2012

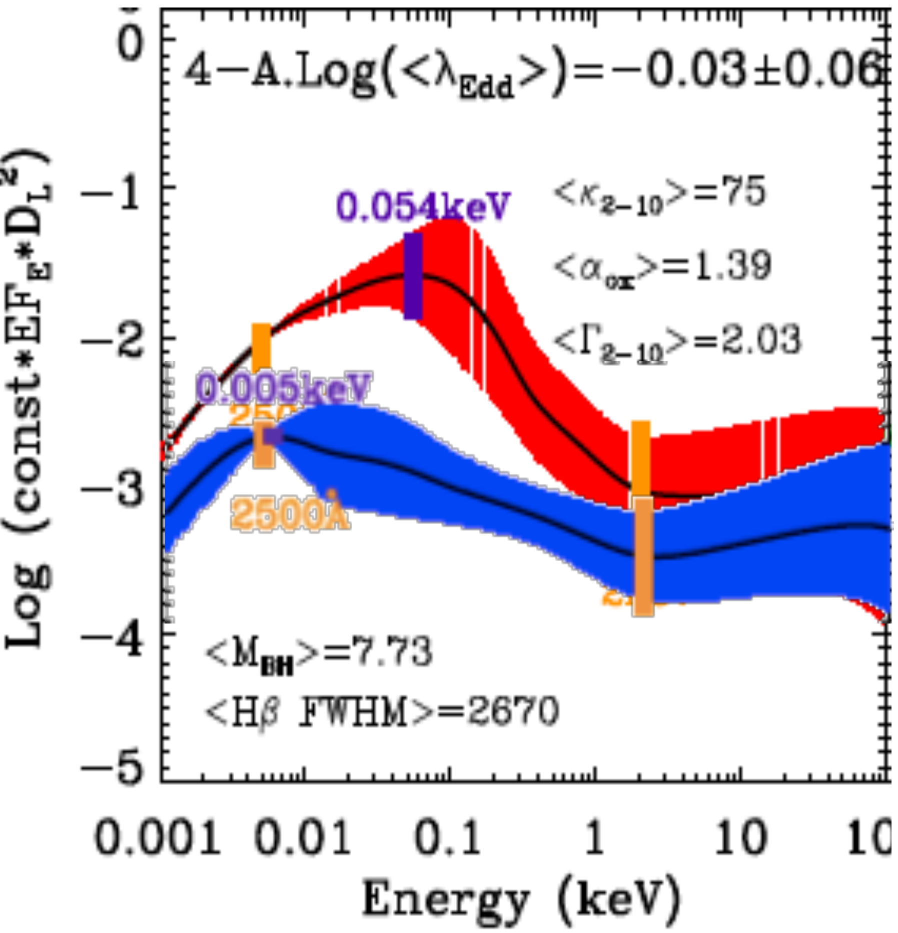
# X-ray/Lopt BIGGER small L/LEdd



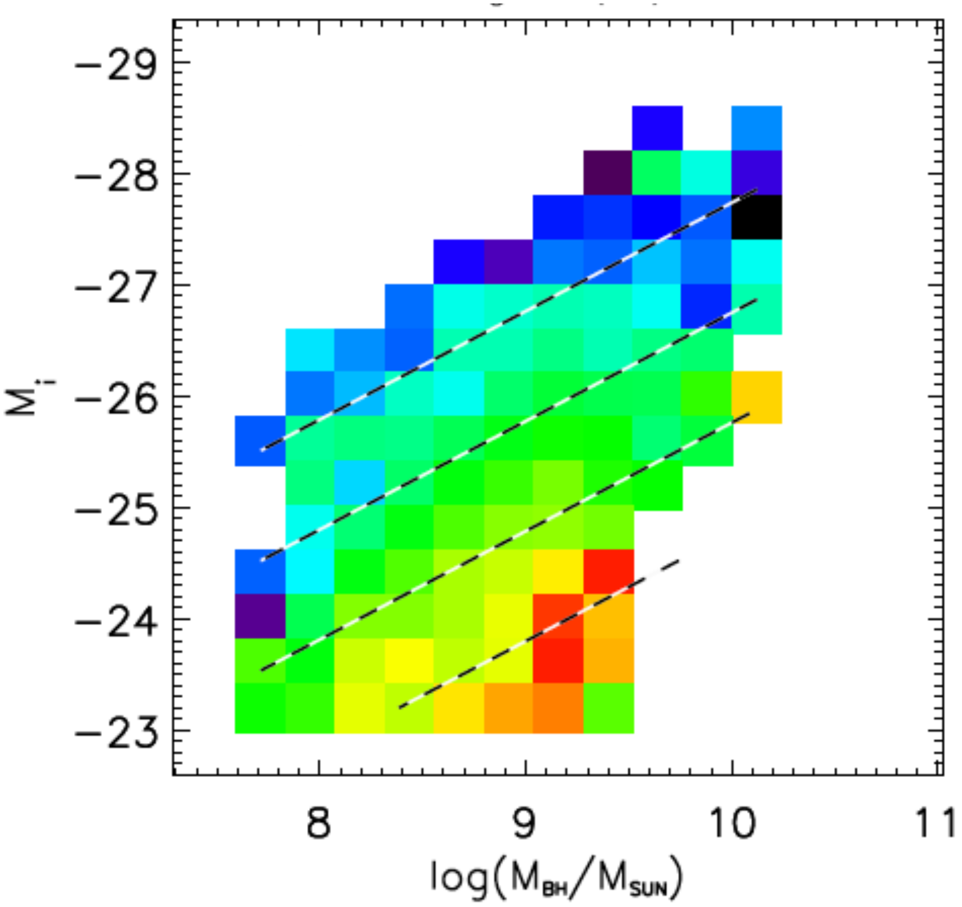
Jin, Ward, Done 2012

# Lx/Lopt big at low L/LEdd – more reprocessed (fast) optical variability

Jin, Ward, Done 2012

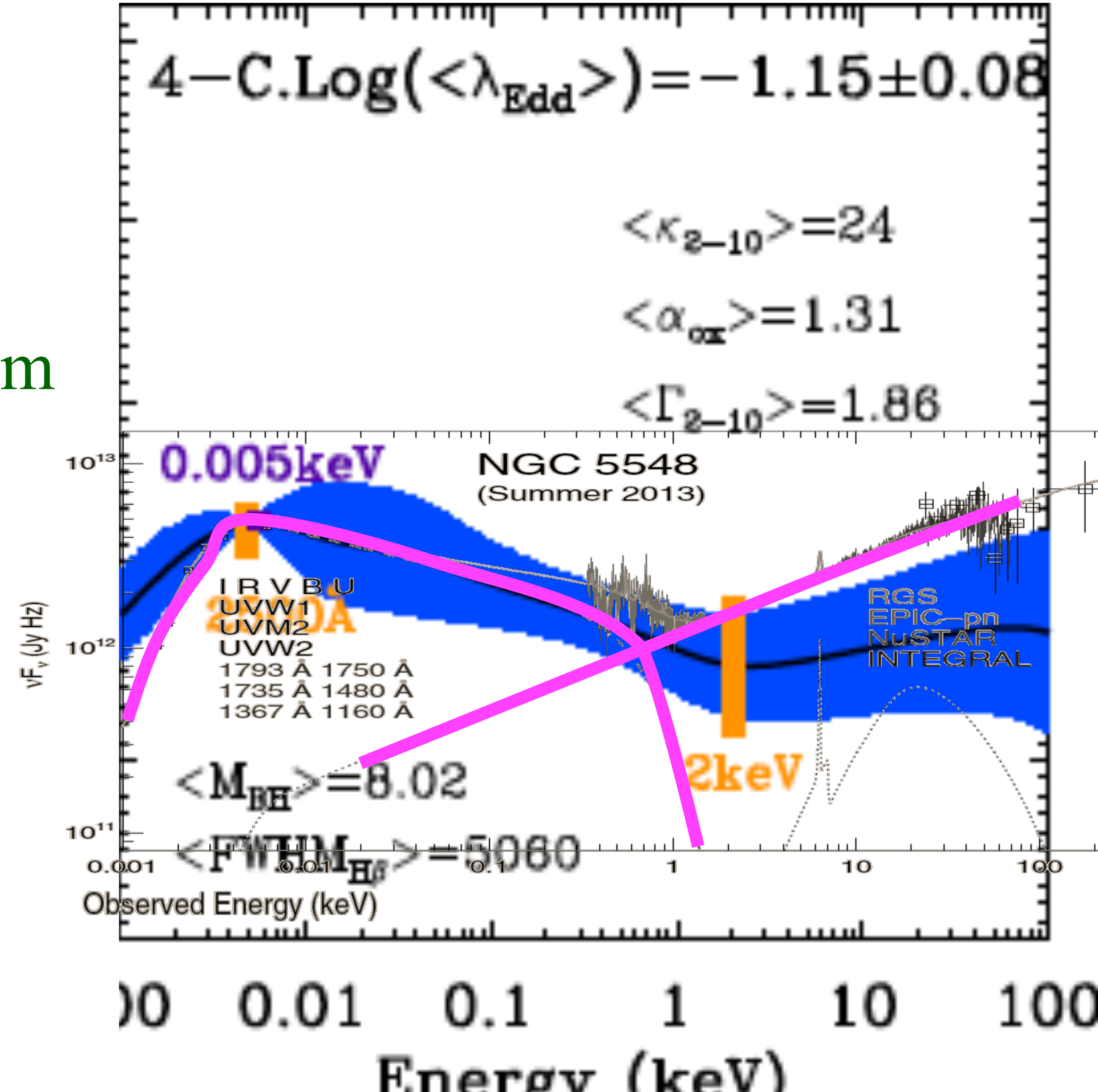


MacLeod et al 2010



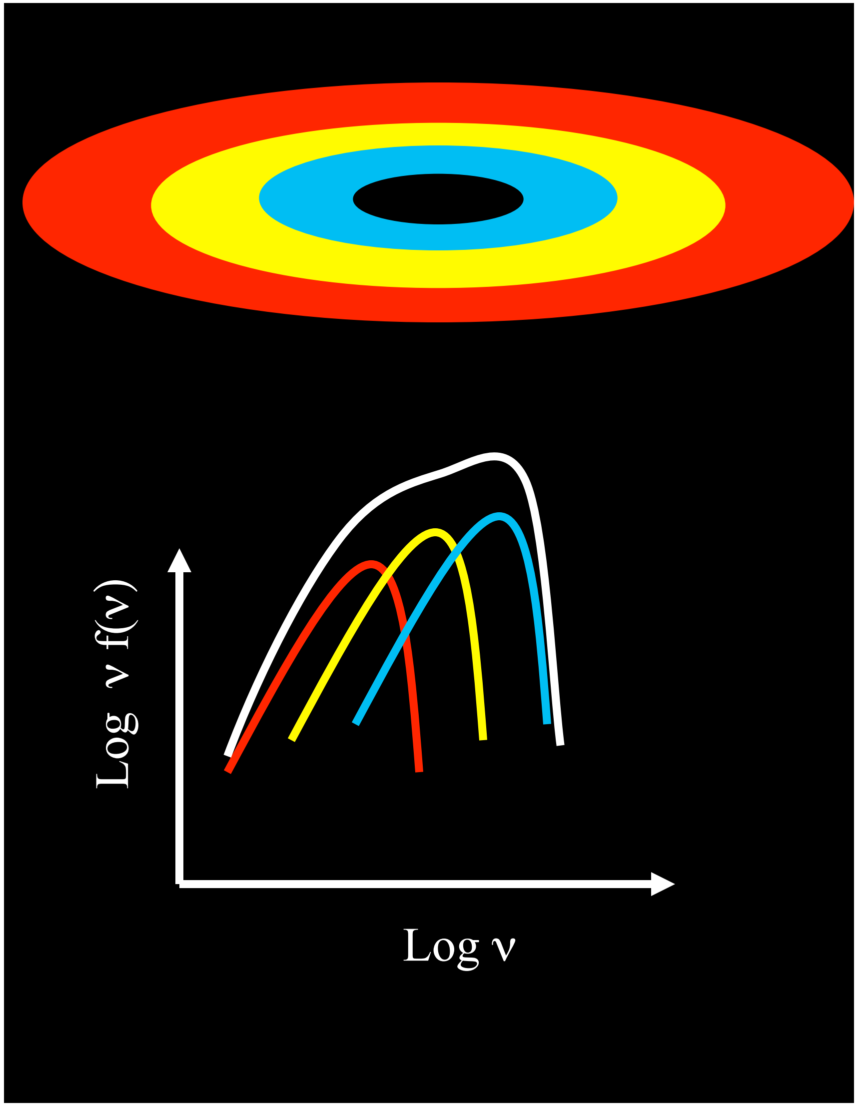
# Optical variability campaigns biased to low L/Ledd AGN

- Low L/Ledd means Lx/Lopt is highest
- larger amplitude optical variabilty from X-ray reprocessing
- NGC5548
- L/Ledd~0.02
- Hard X-ray survey (BAT) also biased to these objects!!



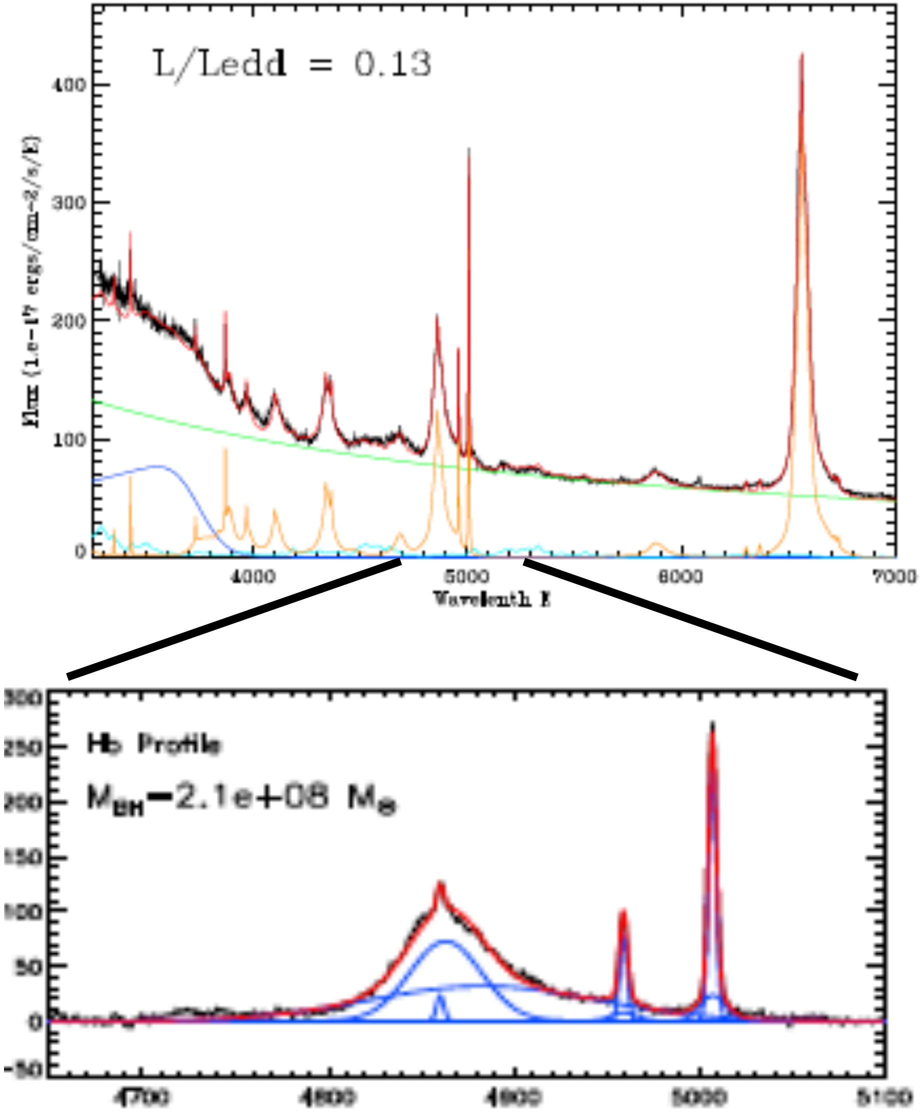
# Ultimately from accretion flow

- Thermal emission:
- $dL = dA\,\sigma\,T^4$
- 10 Msun, L=LEdd
  Tmax~1 keV
- hν<kTmax: integrates to
  Fopt α $(M\,\mathrm{Mdot})^{2/3}$ cos i
- So <Mdot> α Fopt $^{3/2}$/ M
- Davis & Laor 2011



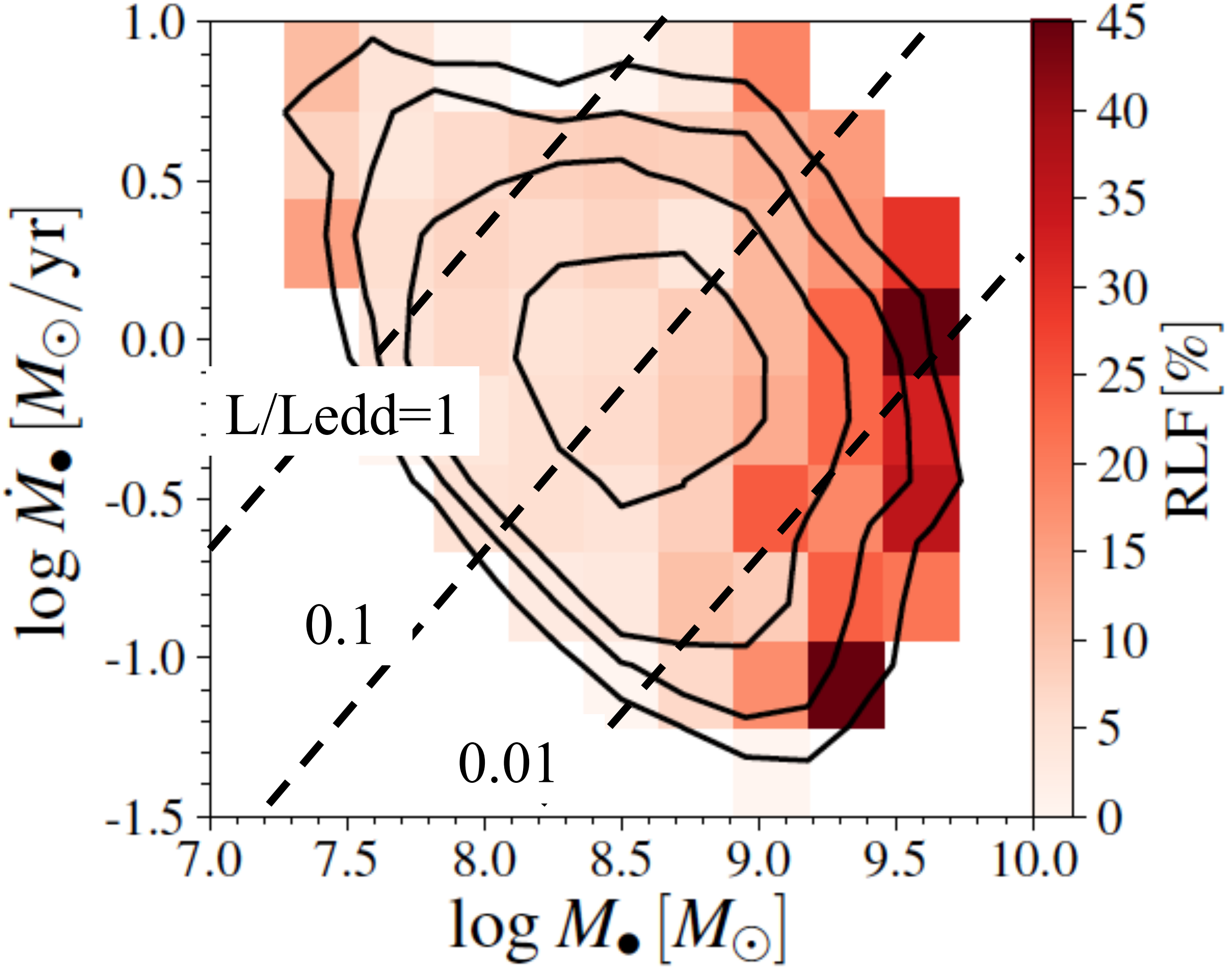
# Get M and L/Ledd from single spectrum!!!

- Scaling relations for $M_{BH}$ in terms of Hβ FWHM and Fopt
- Based on BLR reverberation campaigns
- <Mdot> α Fopt $^{3/2}$/ M
- Lbol=η Mdot c$^2$
- η depends on BH spin
- Lbol/Ledd α Lbol / M



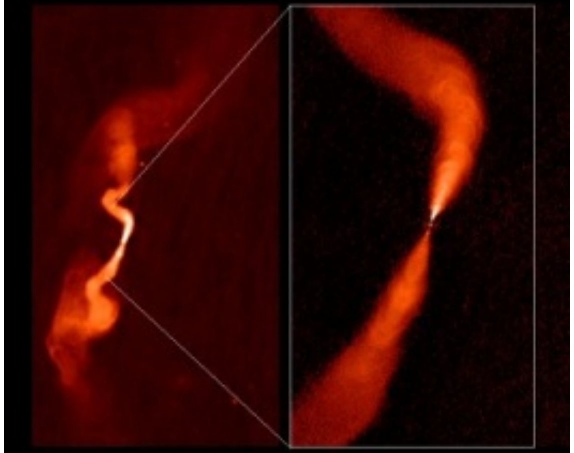
# SDSS Quasars: radio loud (R>10)

- ADAF flows RL
- Something else also
- High M are more RL
- high spin? BH-BH mergers?
- Shultze, Done et al 2017

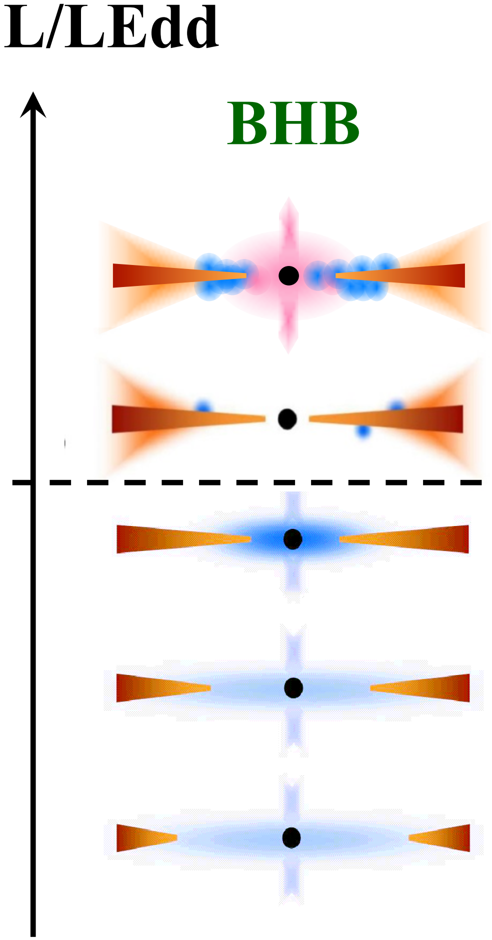


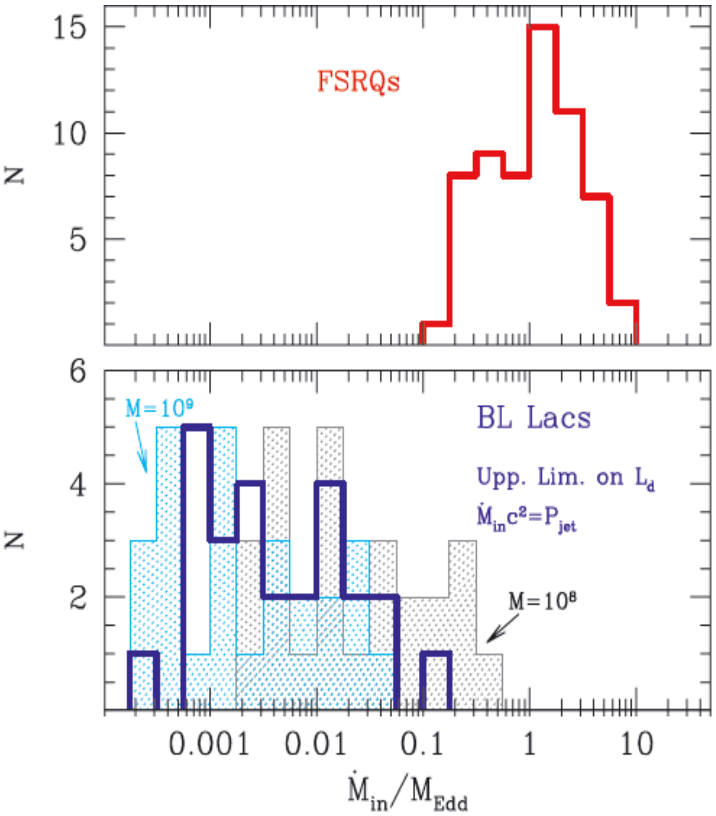
# FRI is top of ADAF branch (low/hard state BHB) but Γ=15!

FR Class II source: quasar 3C175



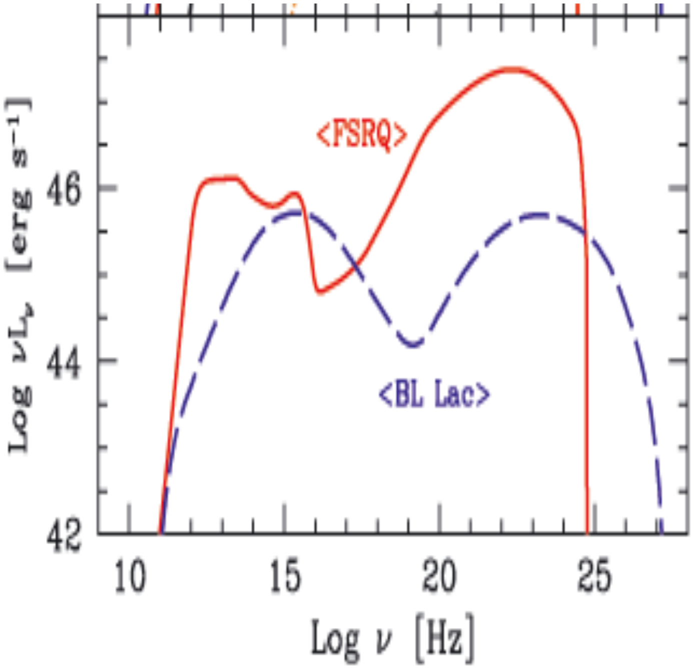
FR Class I source: radio galaxy 3C31

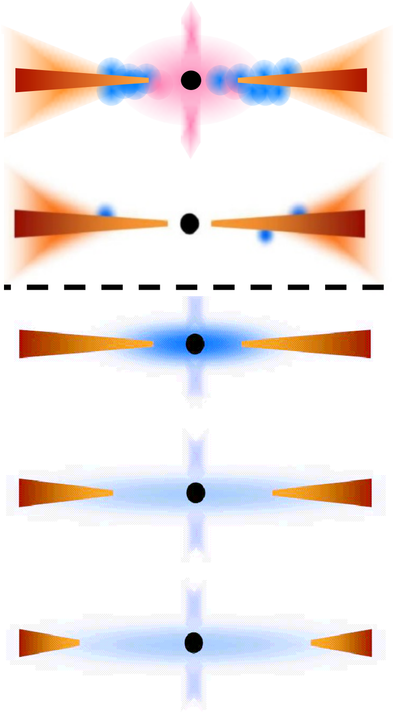


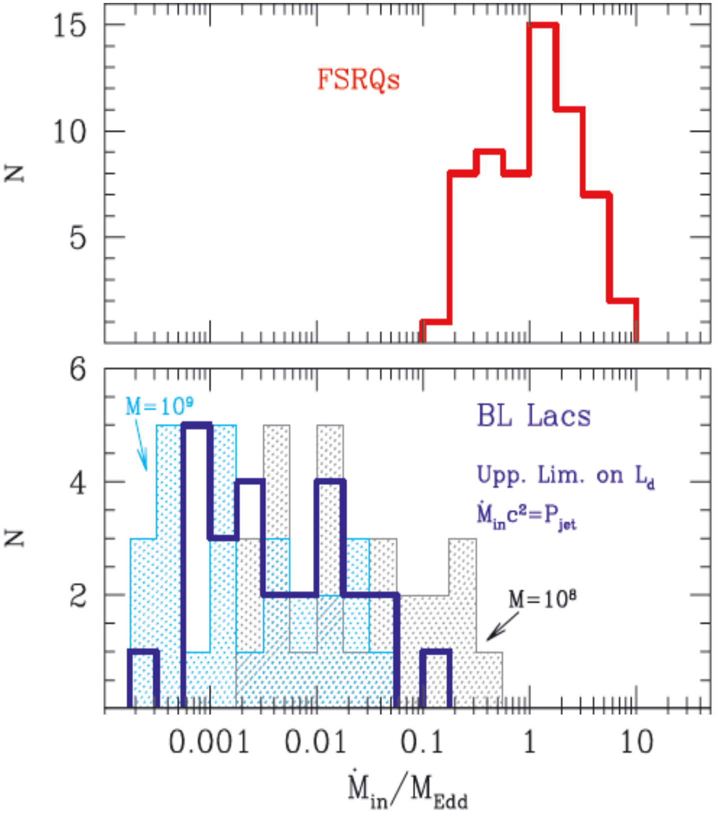


Ghisellini et al 2010

# FRI/BL Lacs is top of ADAF branch (low/hard state BHB) but Γ=15 BH spin? BZ effect?

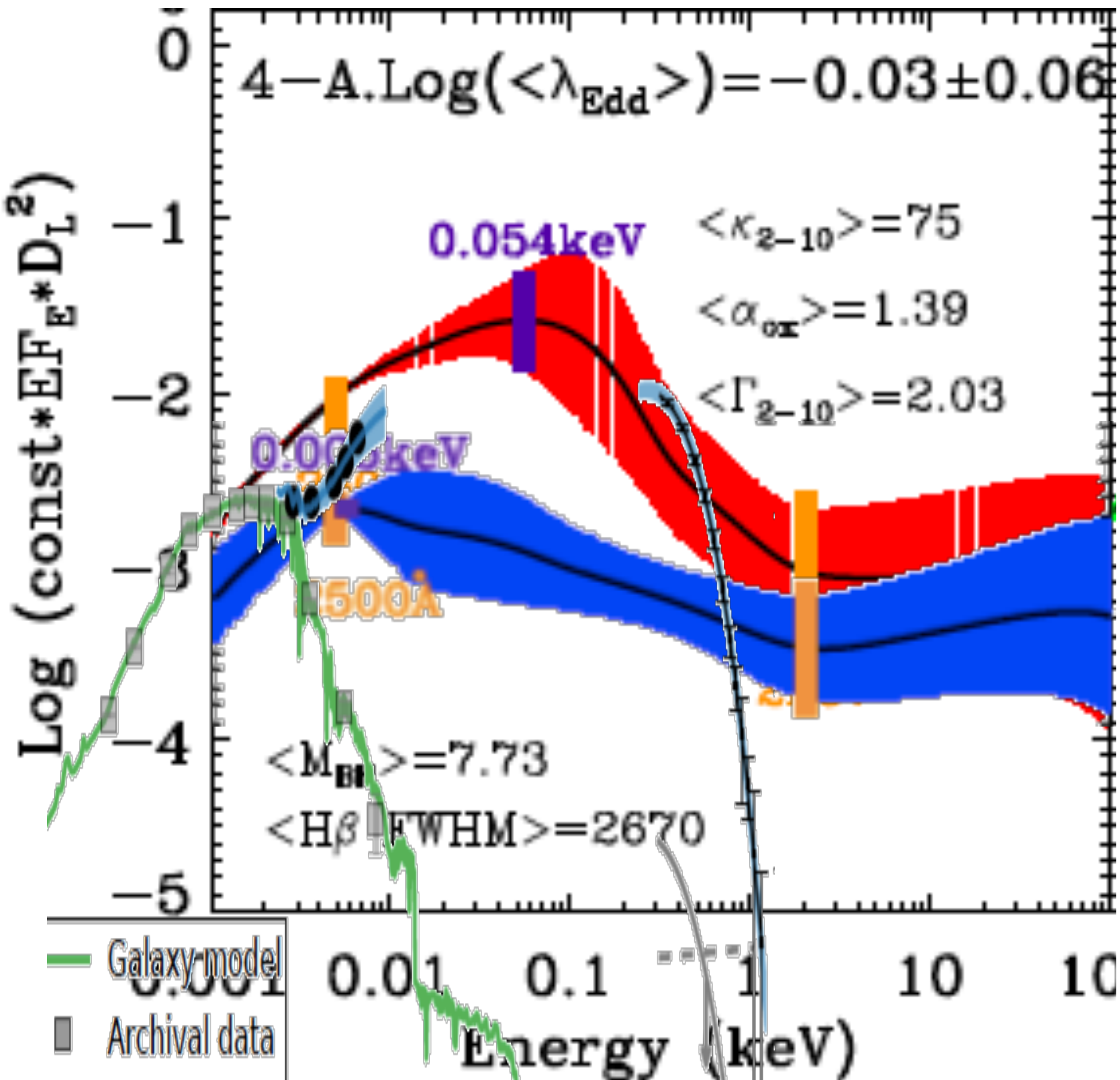






Ghisellini et al 2010

# Tidal disruption NOT like AGN

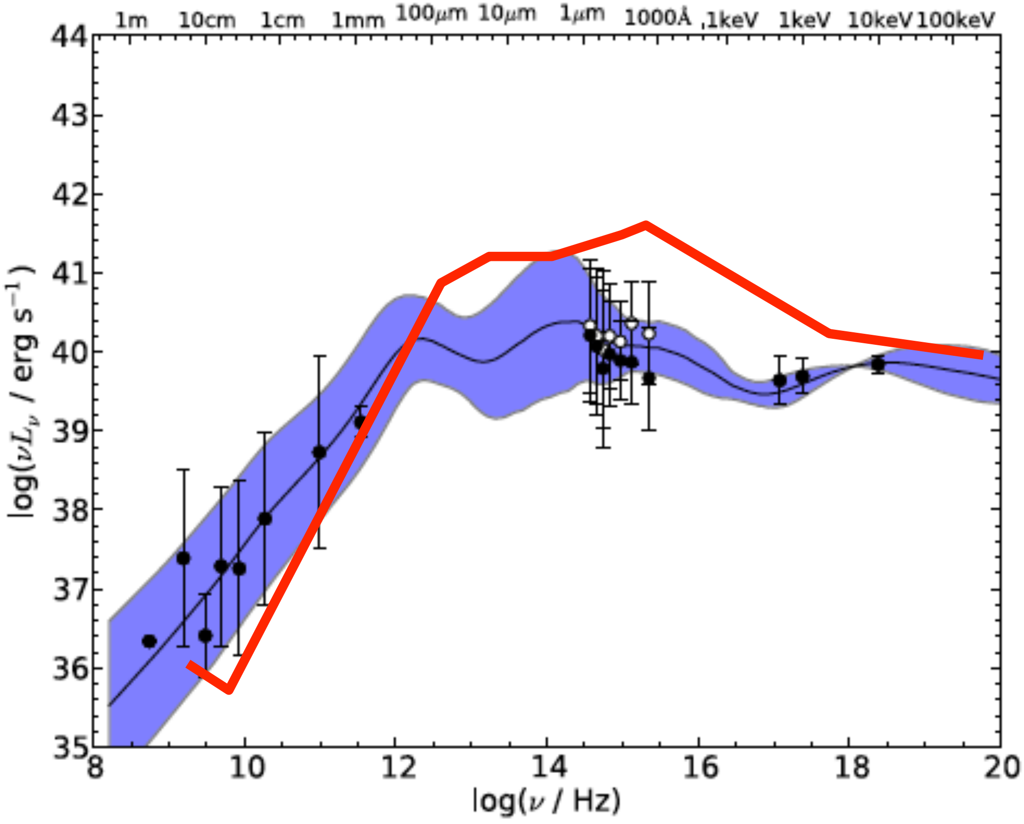


Val velzen et al 2016

Jin, Ward, Done 2012

# AGN spectral states: LINERS

- Look like hot flow – truncated disc. SED has no strong UV bump from inner disc (Elvis et al QSO SED)
- And does have stronger radio (NOT bulk 10-15 jet)



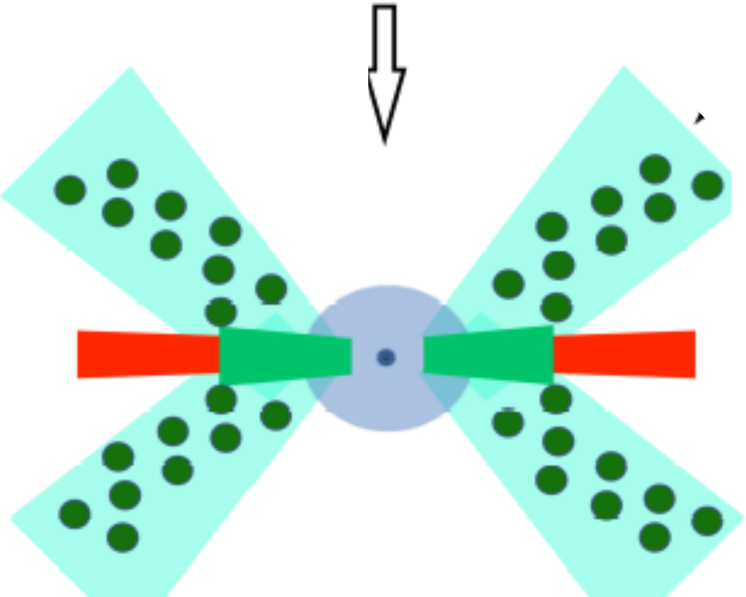
Nemmen et al 2014

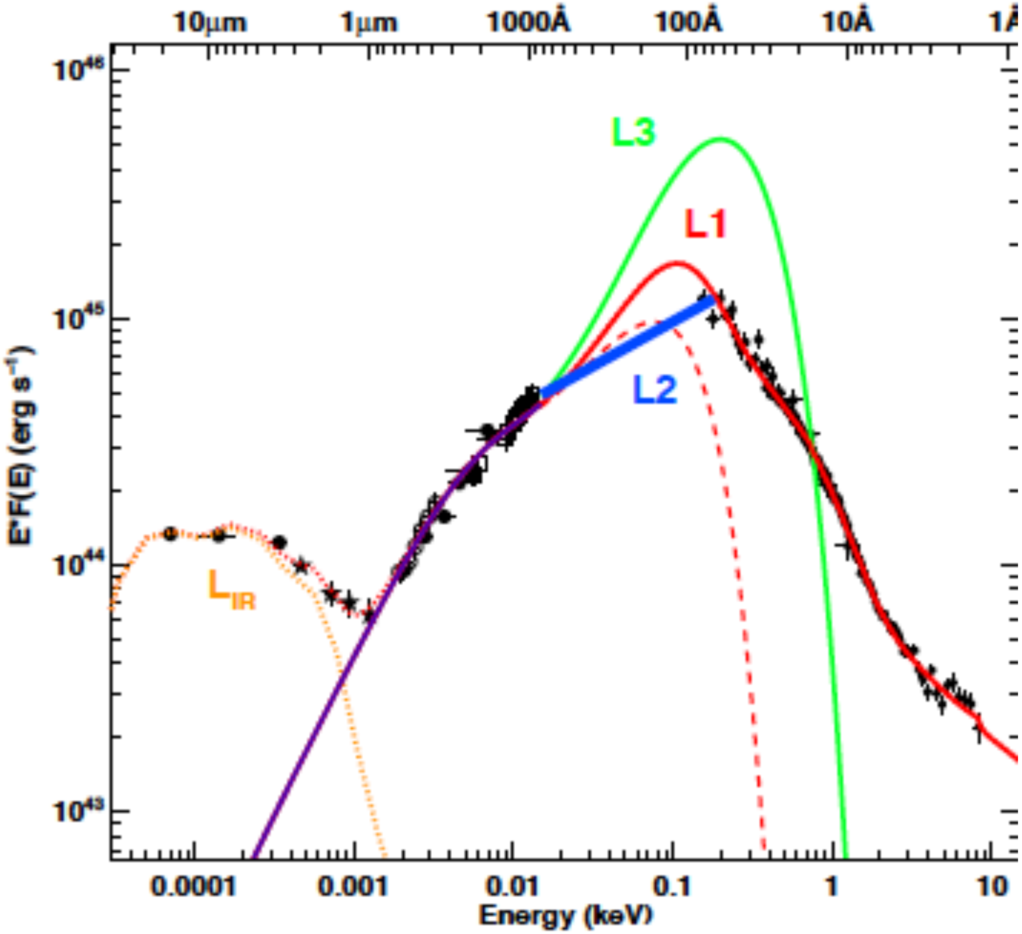
# Conclusions

- LINERs look like low/hard ADAF state
- Standard AGN/QSO all either high state or transition but don’t look exactly same as BHB – atomic physics?
- USE optical spectra to get BOTH M and L/LEdd from outer disc models NOT from bolometric correction!
- RL correlates with L/Ledd in BHB and AGN – ADAFs are more RL than discs… but also something different, most massive AGN have ‘proper’ jets – BH spin??
- Tidal disruptions DO NOT LOOK LIKE AGN!! No hard X-rays yet L/LEdd~0.1

# SuperEddington flows!

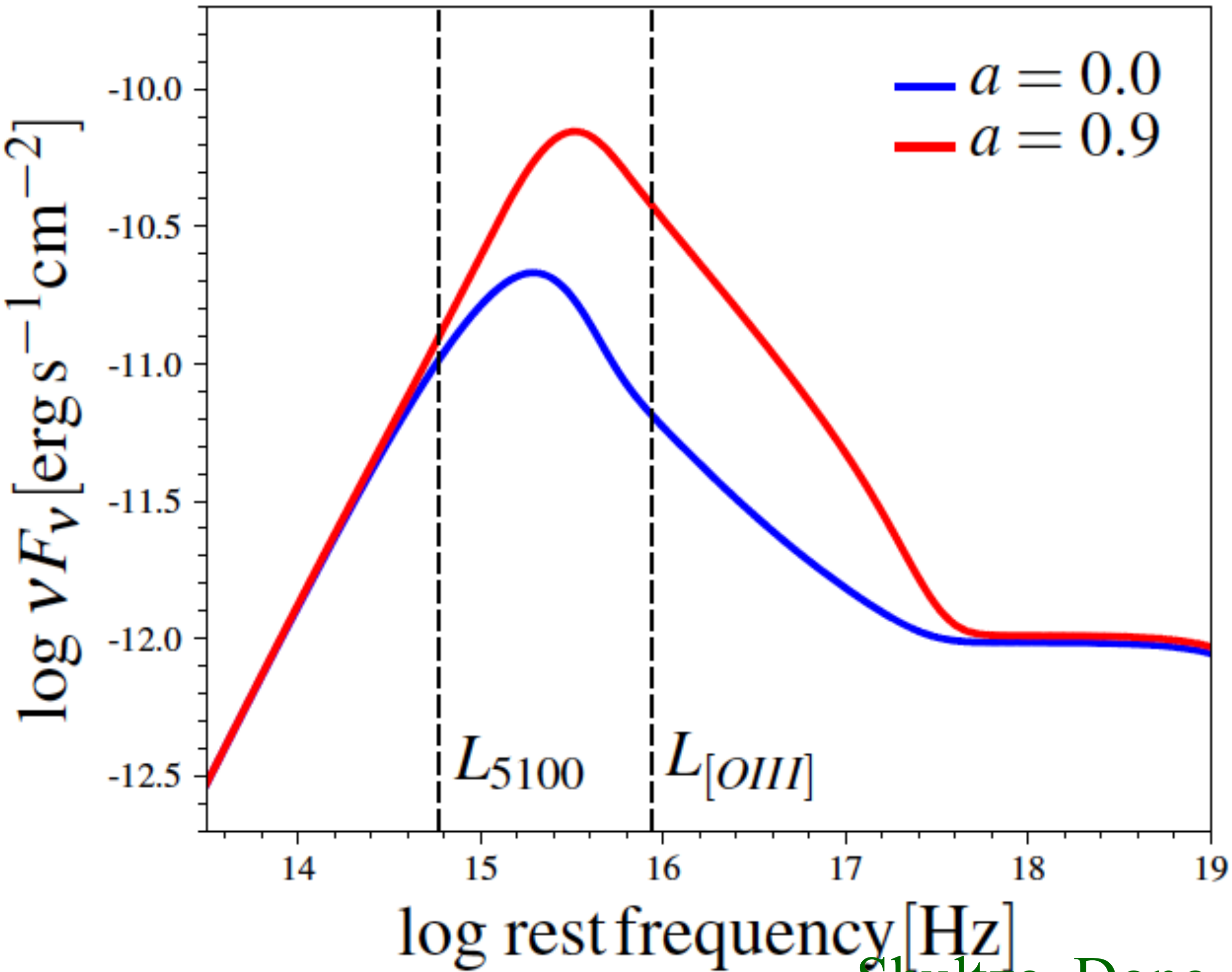
- Mdot=12MdotEdd
- Lobs=4.6LEdd wind and/or advection
- No absorption features– face on ??





Jin et al 2017

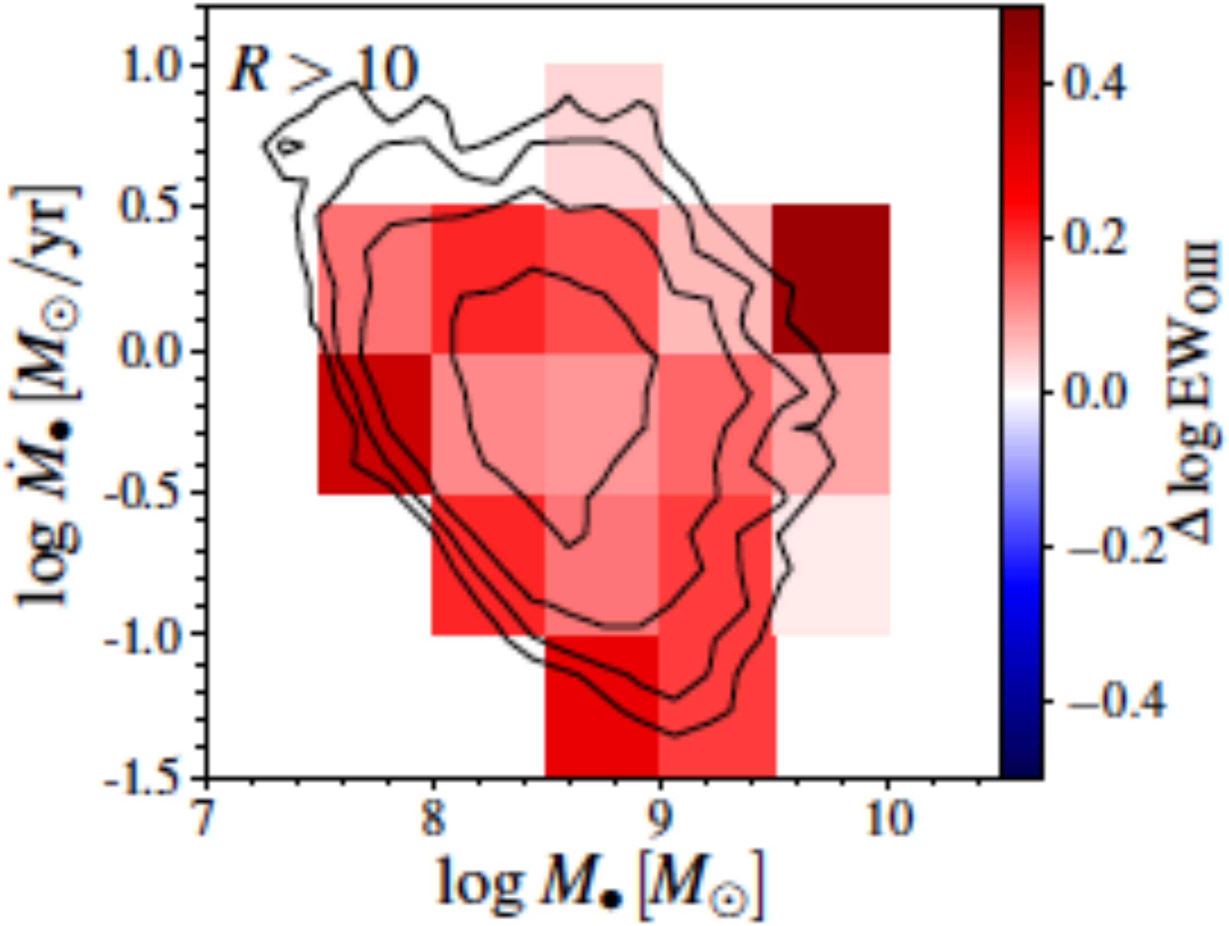
# More ionising luminosity for same Mdot



Shultze, Done et al 2017

# Compare L [OIII] RL and RQ for same BH M and Mdot!!

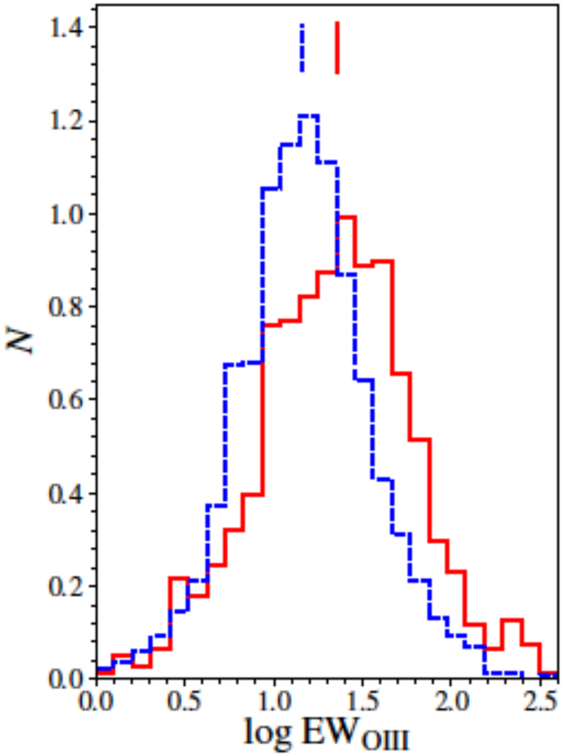
- 7000 SDSS QSO with Hb mass. Get Mdot
- Radio from FIRST R= $f_{5GHz}/f_{opt}$>10
- stack RL and RQ in each bin
- Measure OIII for RL/RQ
- All bins are RED More OIII in RL than RQ

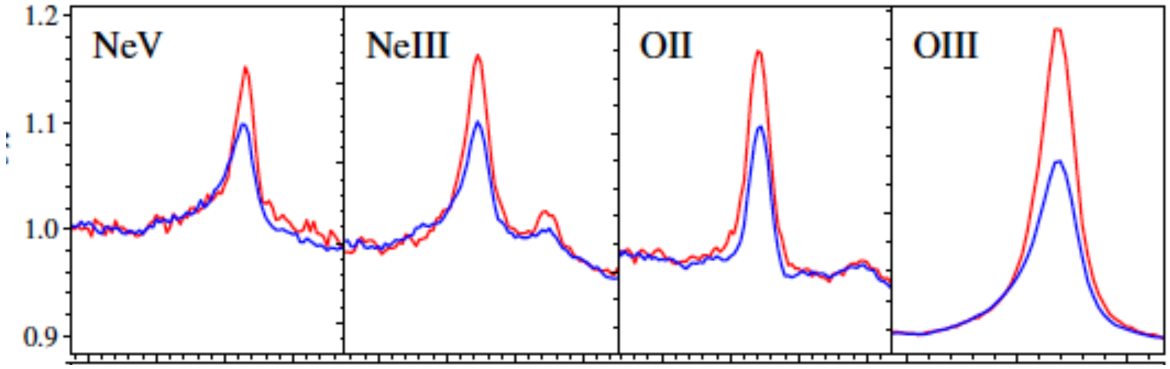


Shultze, Done et al 2017

# Compare L [OIII] RL and RQ for same BH M and Mdot!!

- Highly significant - Reject same distribution at $10^{-19}$
- not kinematically disturbed component as OIII profile same
- Spin paradijm for highly relativistic jets!!??





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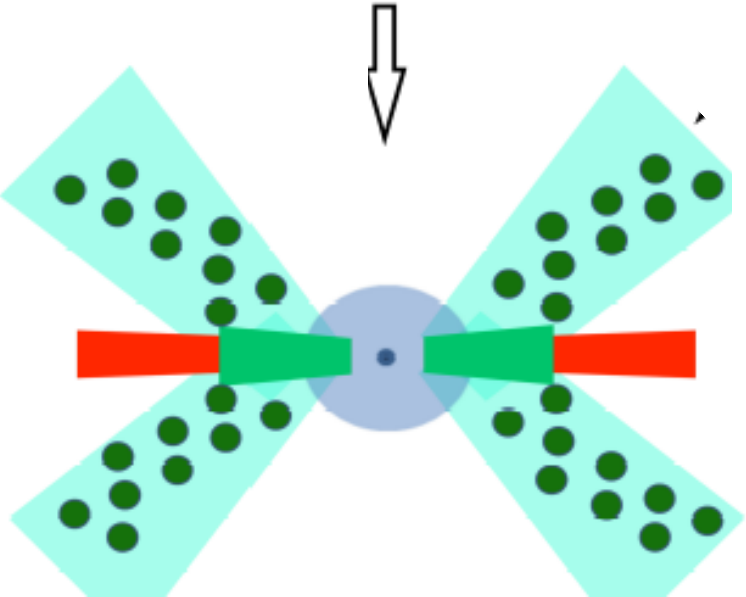
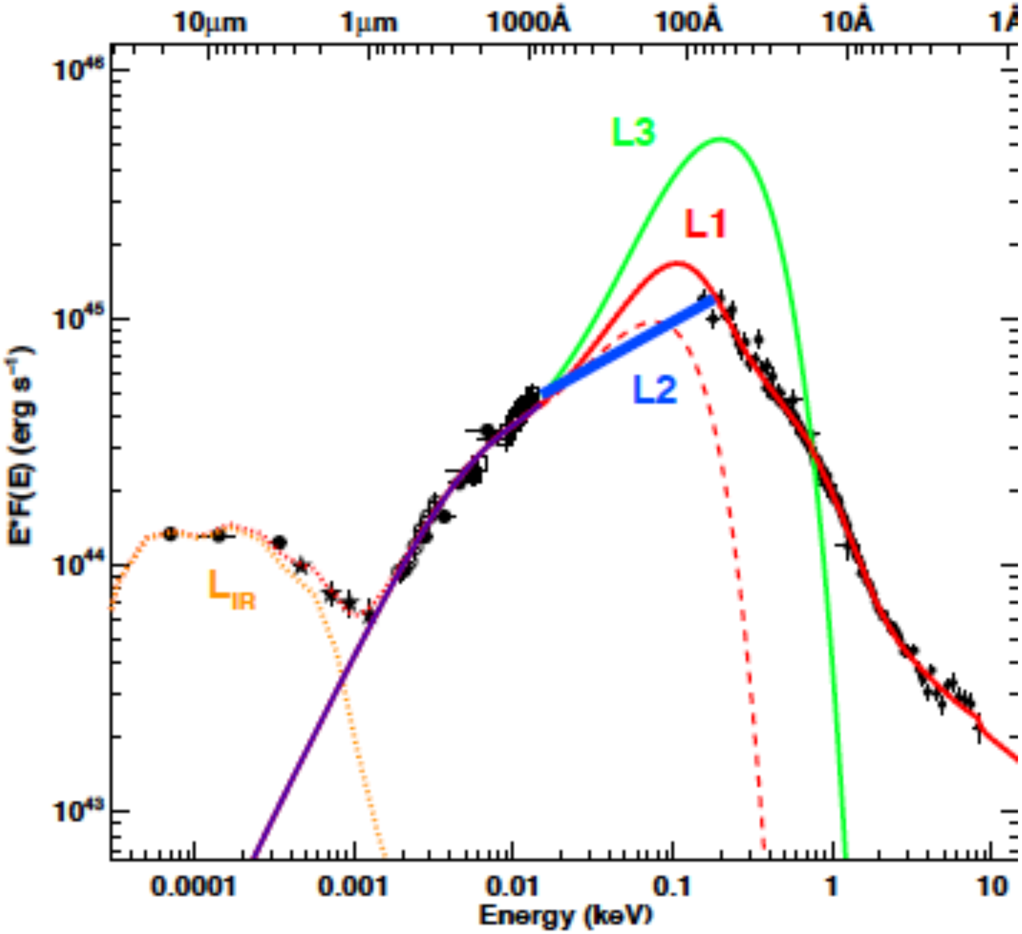
# Extreme NLS1 RX0439

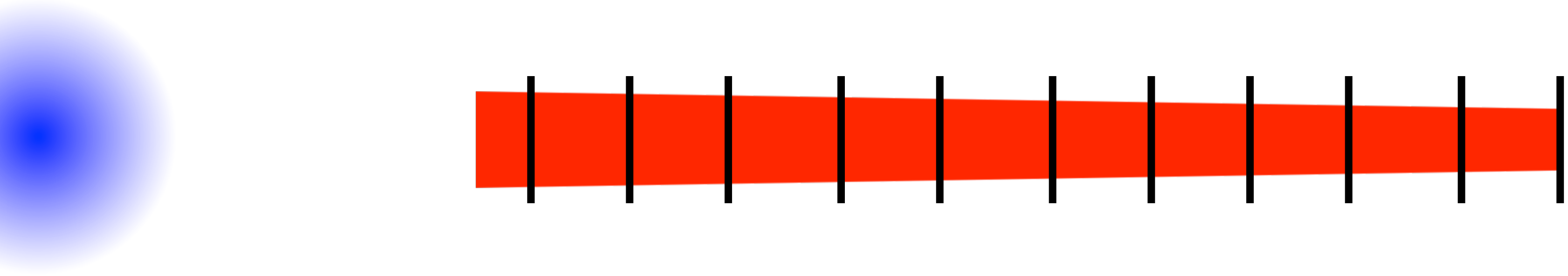
- Mdot=12MdotEdd
- Lobs=4.6LEdd wind and/or advection
- No absorption features– face on ??

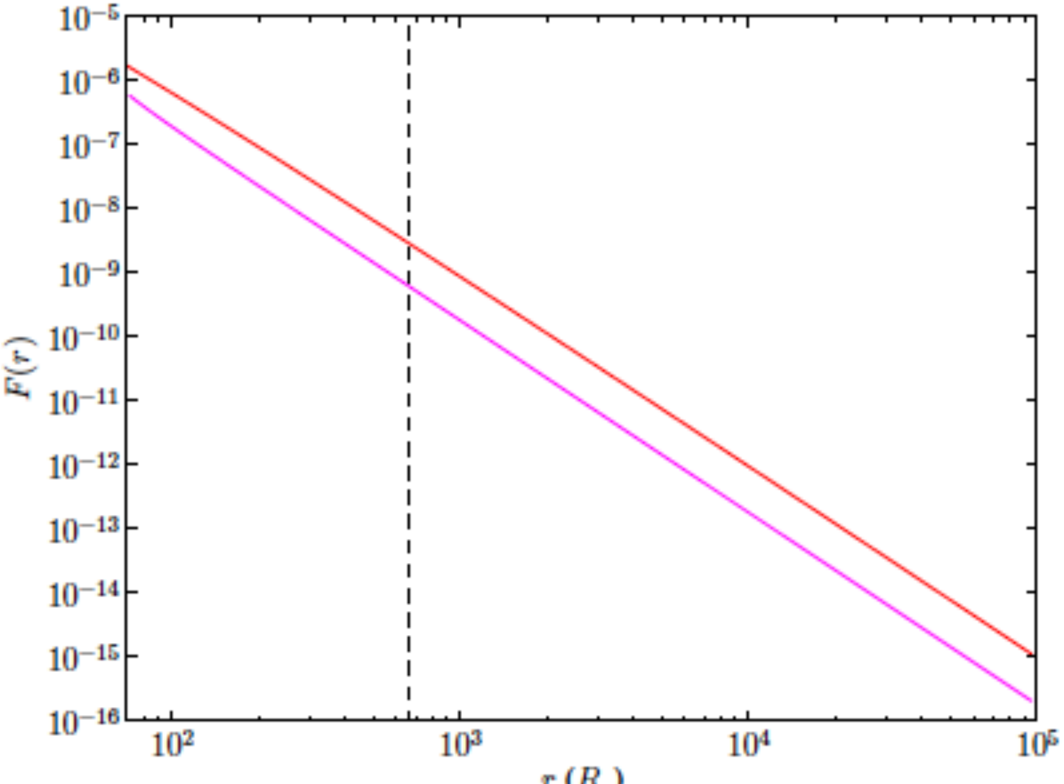




Jin et al 2017

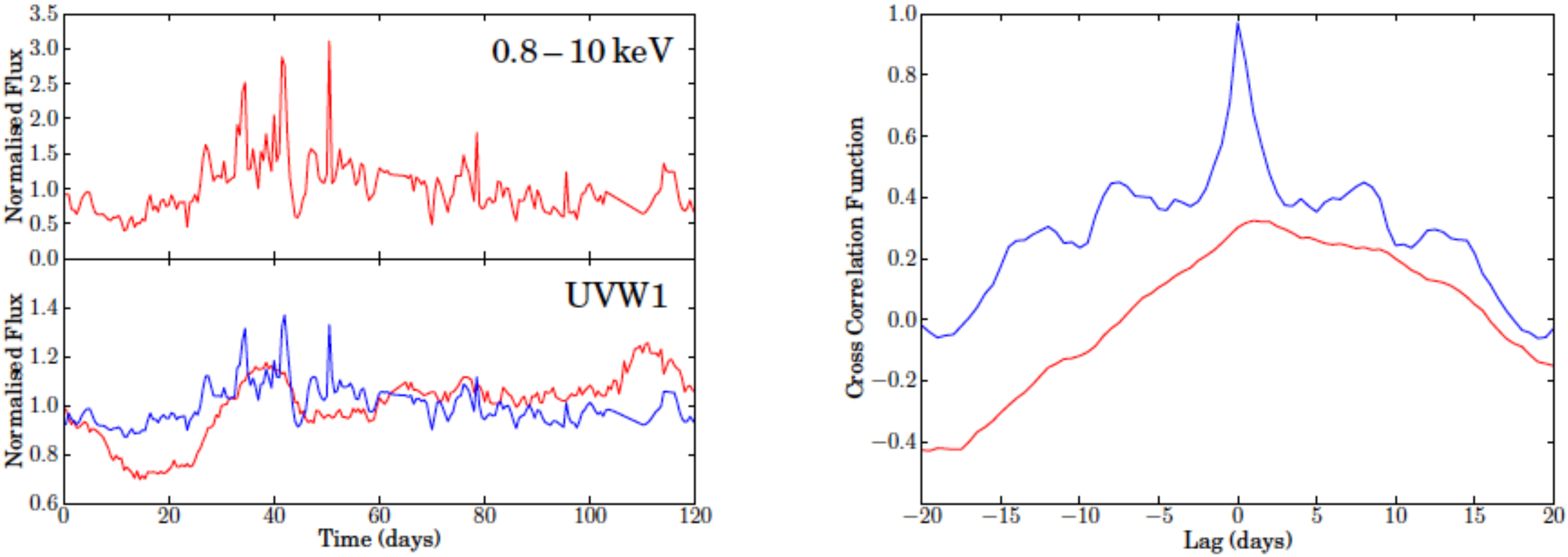
# Source and disc geometry





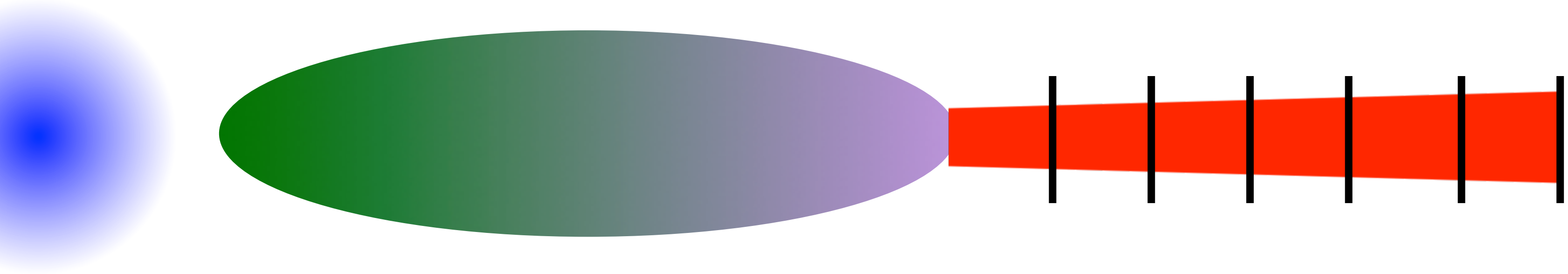
# X-ray illumination - appalling

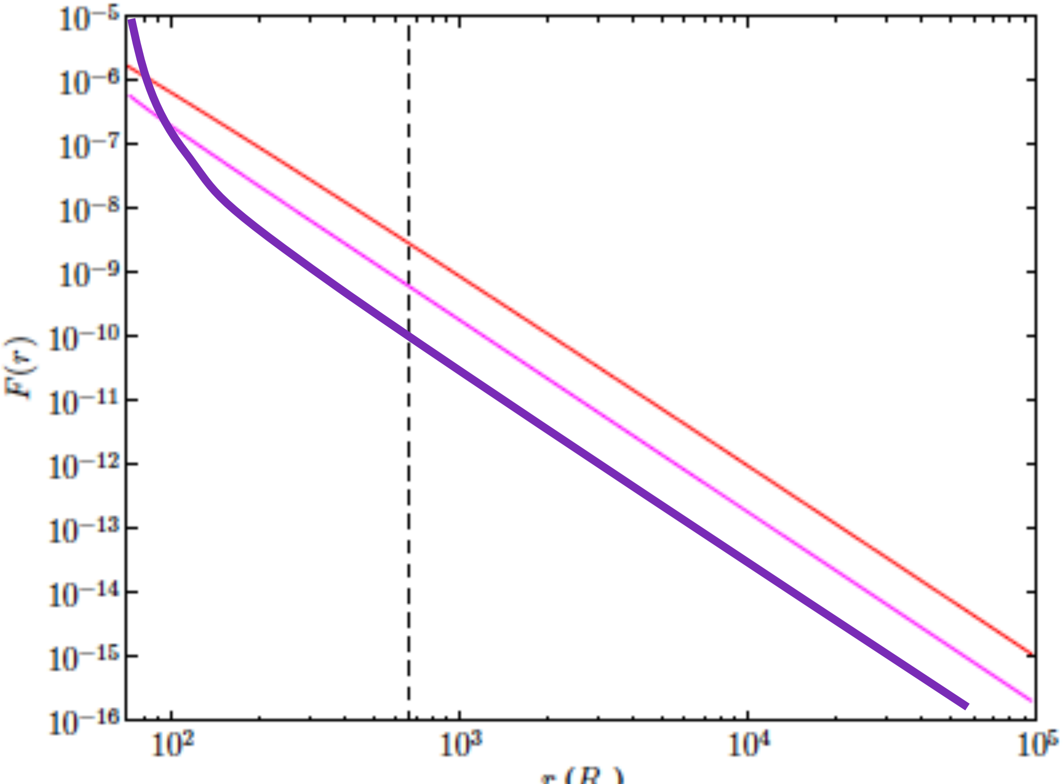
**Use observed X-rays, irradiate the disc to make UVW1**
**FAR too much fast UVW1 variability**
**70 Rg is 3 hours. UVW1 timescale 15-20 days**



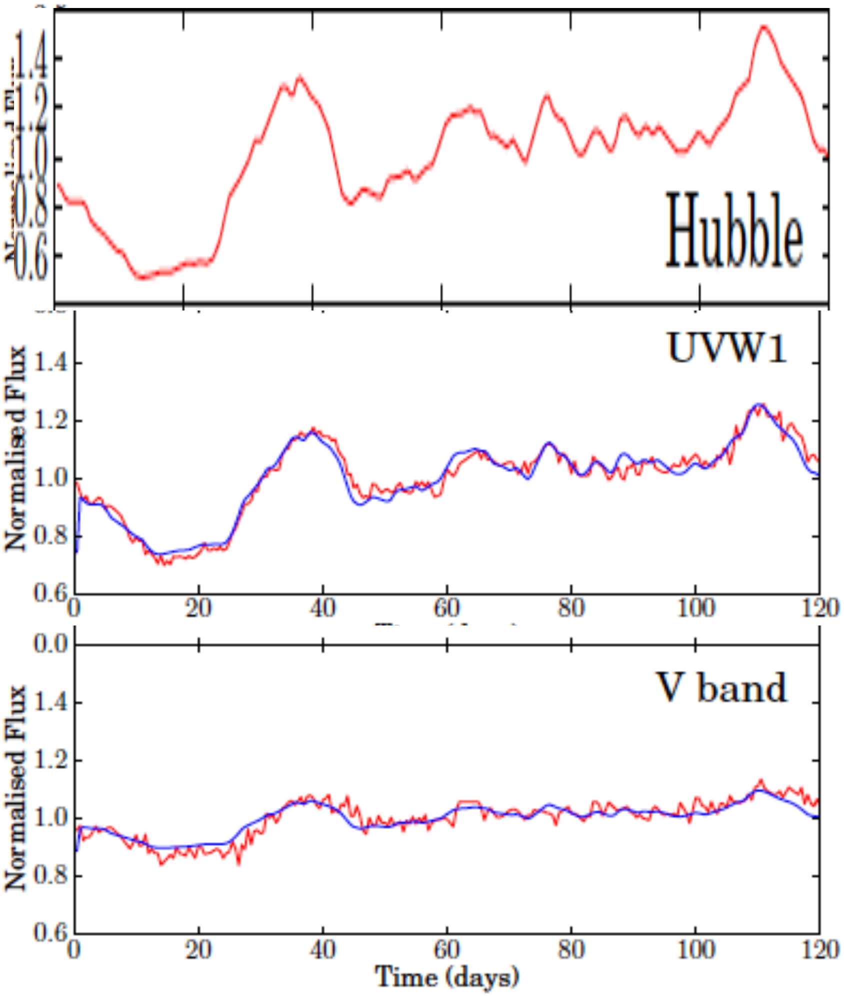
**Model UVW1 looks like X-rays! Data does NOT!!!**

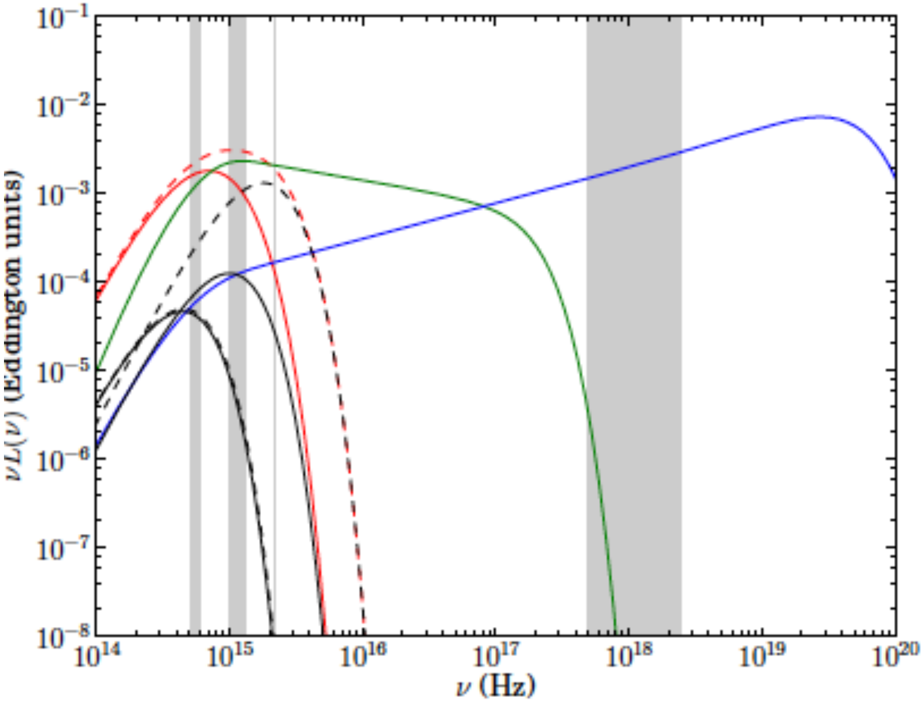
# Source and disc geometry



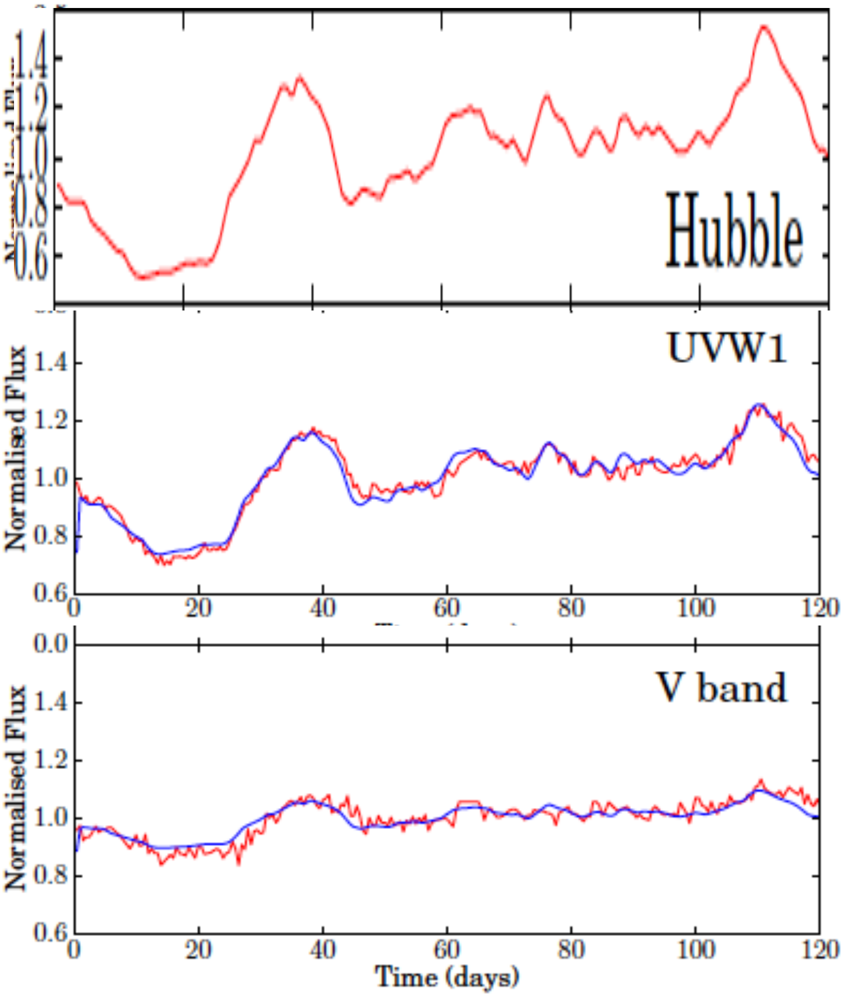


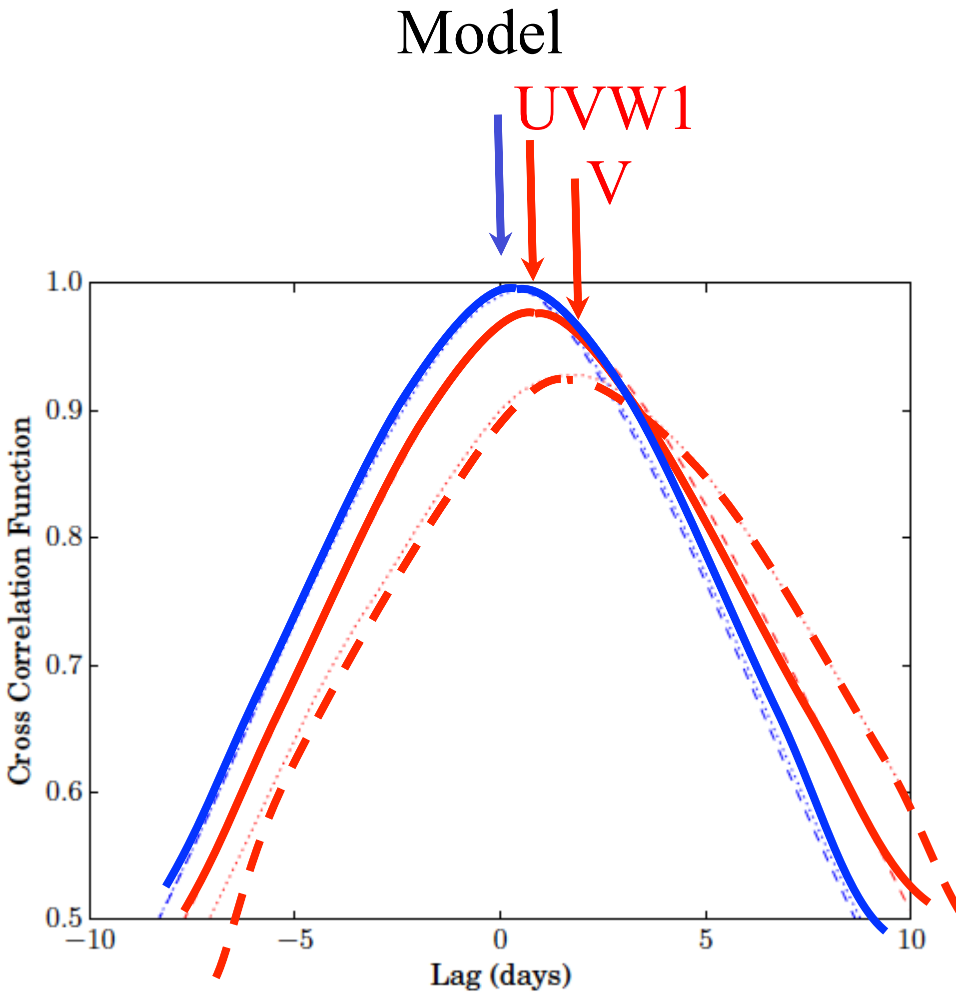
# UV illumination - Fantastic!!





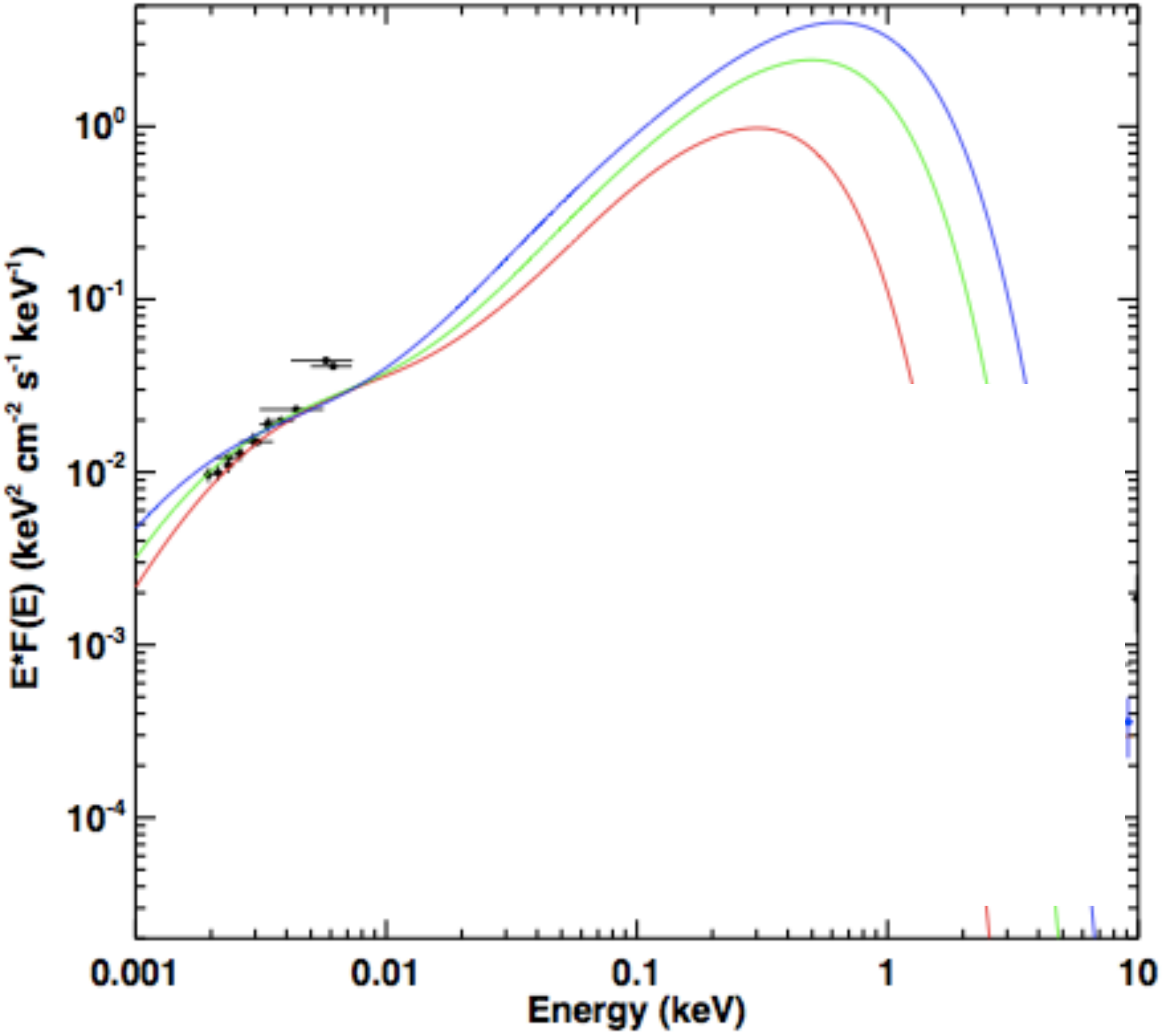
# Errr……not so fantastic!





# 1H0707-495 Extreme NLS1

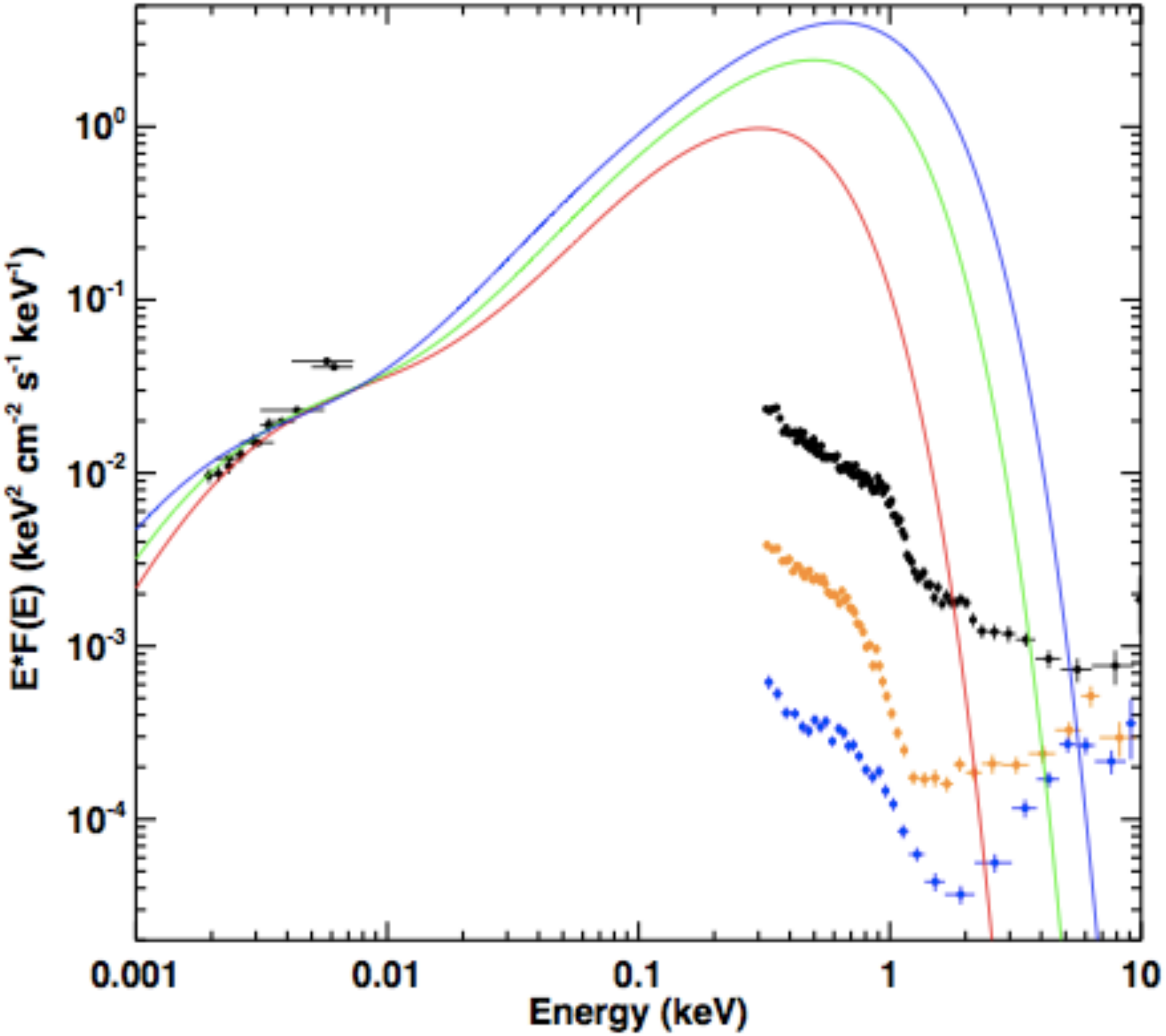
- 1H0707
- 2-4x$10^6$
- L/Ledd = 11, 40 70
  (60 degrees)
- superEddington



Done & Jin 2016

# 1H0707-495 Extreme NLS1

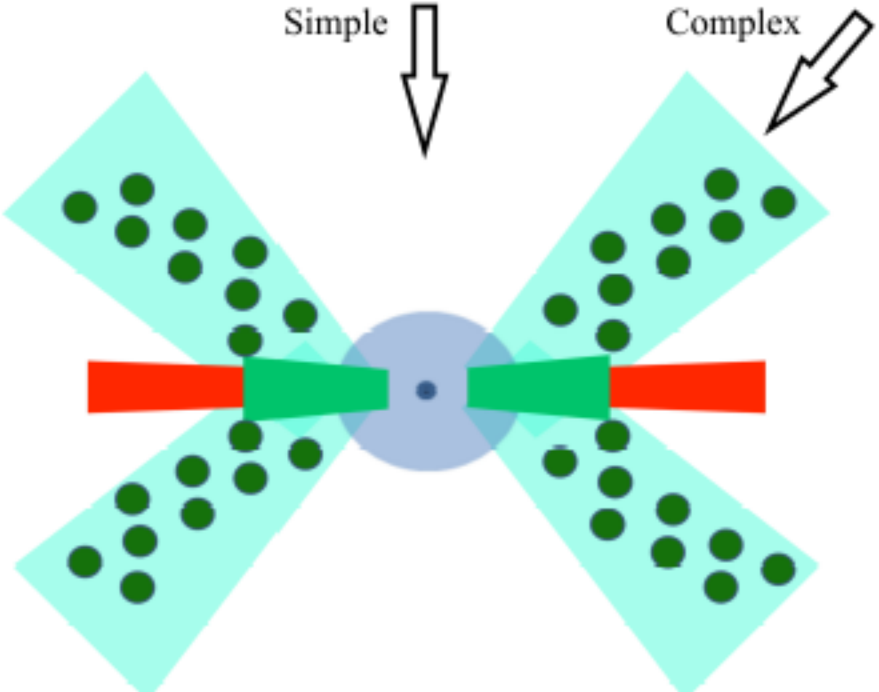
- 1H0707
- 2-4x$10^6$
- L/Ledd = 11, 40 70
  - a=0 0.9 0.998
  - 60 degrees 4x$10^6$
- superEddington
- Strong wind, losing energy so not all potential power radiated



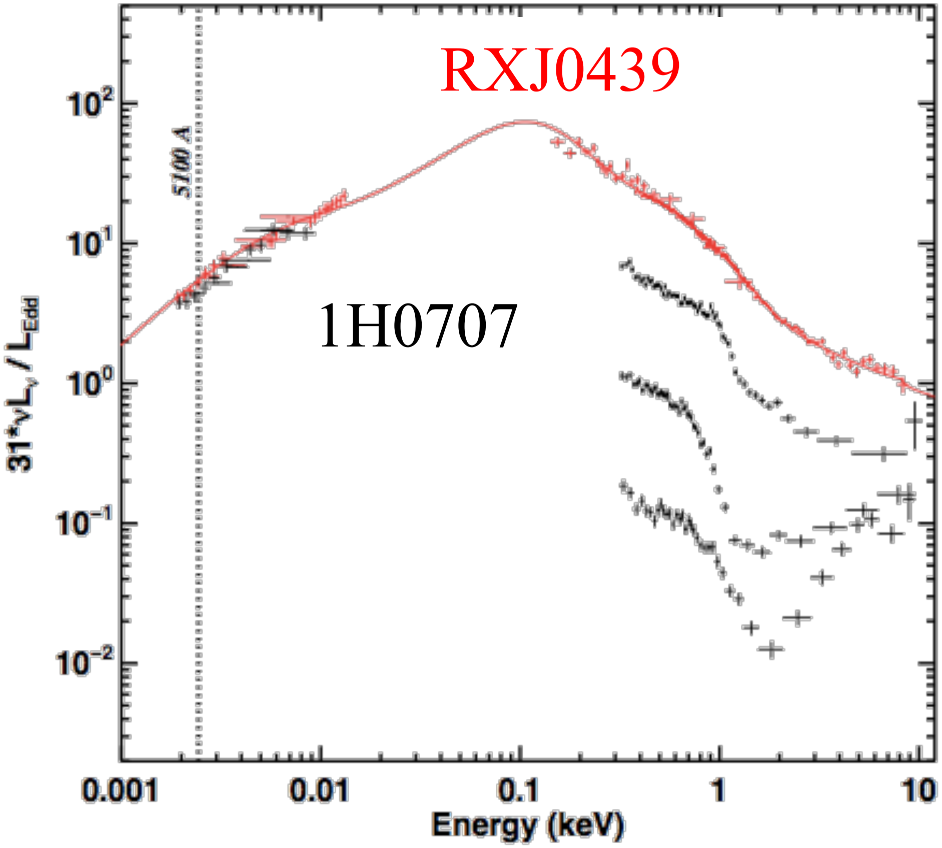
Done & Jin 2016

# Extreme NLS1 – simple / complex

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



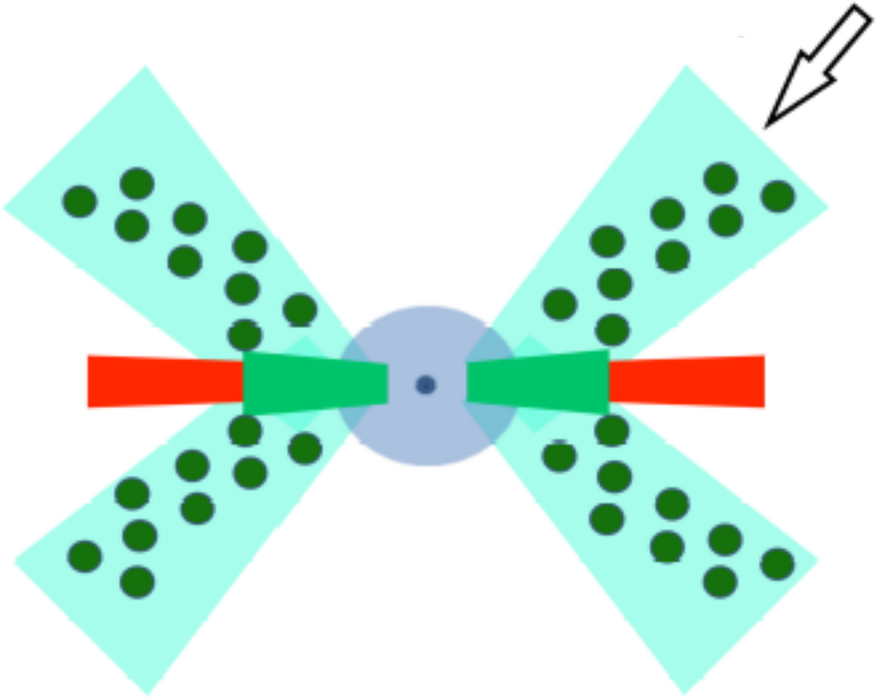
Done & Jin 2016



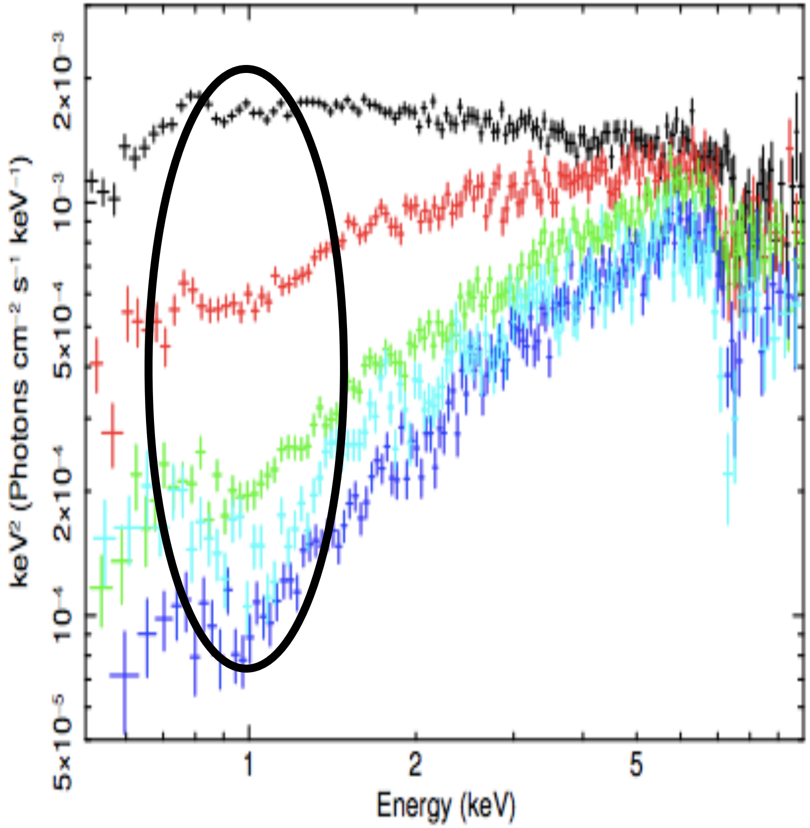
Jin et al 2017

# PDS456: UFO wind is clumpy

- High ionisation lines AND low energy absorption



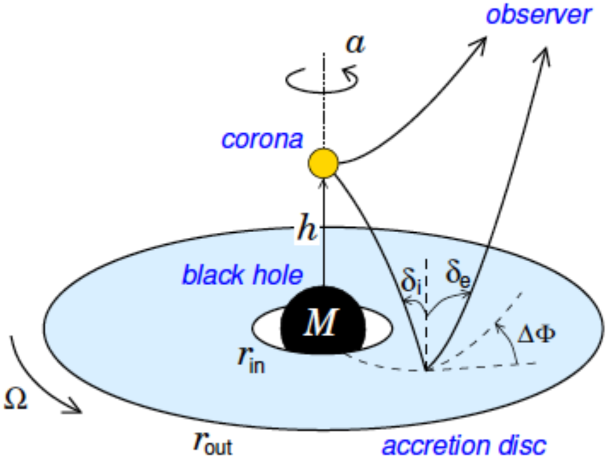
Done & Jin 2016

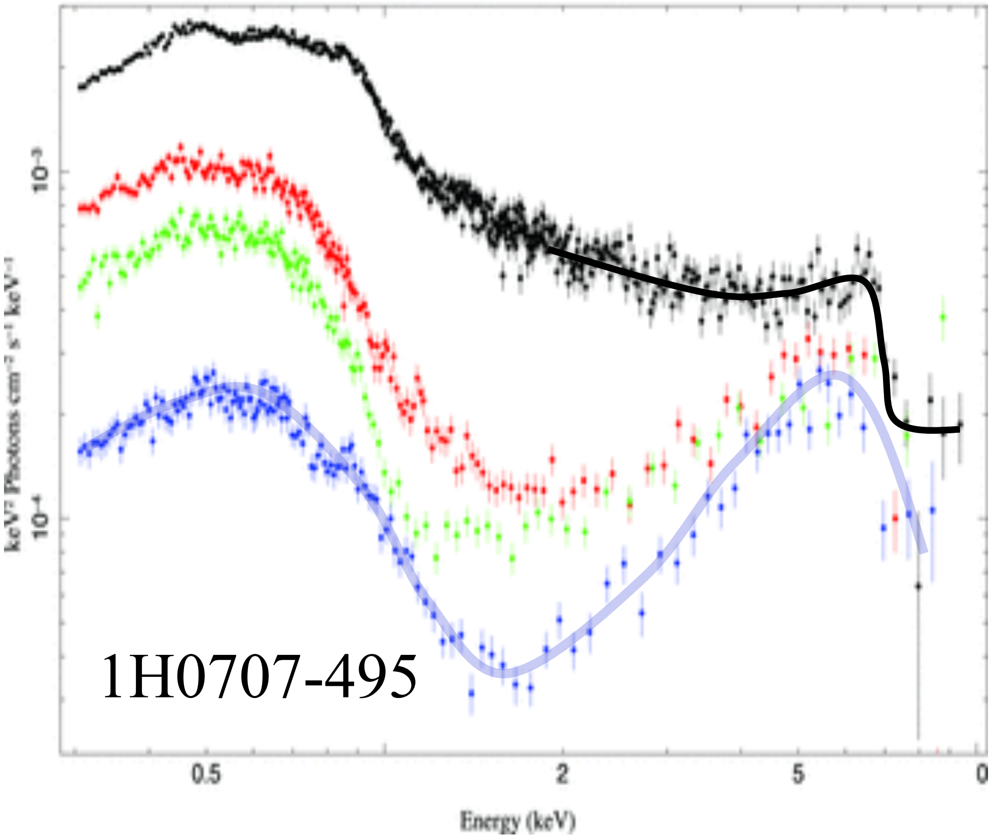


Reeves et al 2009
Hagino et al 2015
Matzeu et al 2016

# Complex NLS1 – X-ray view

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

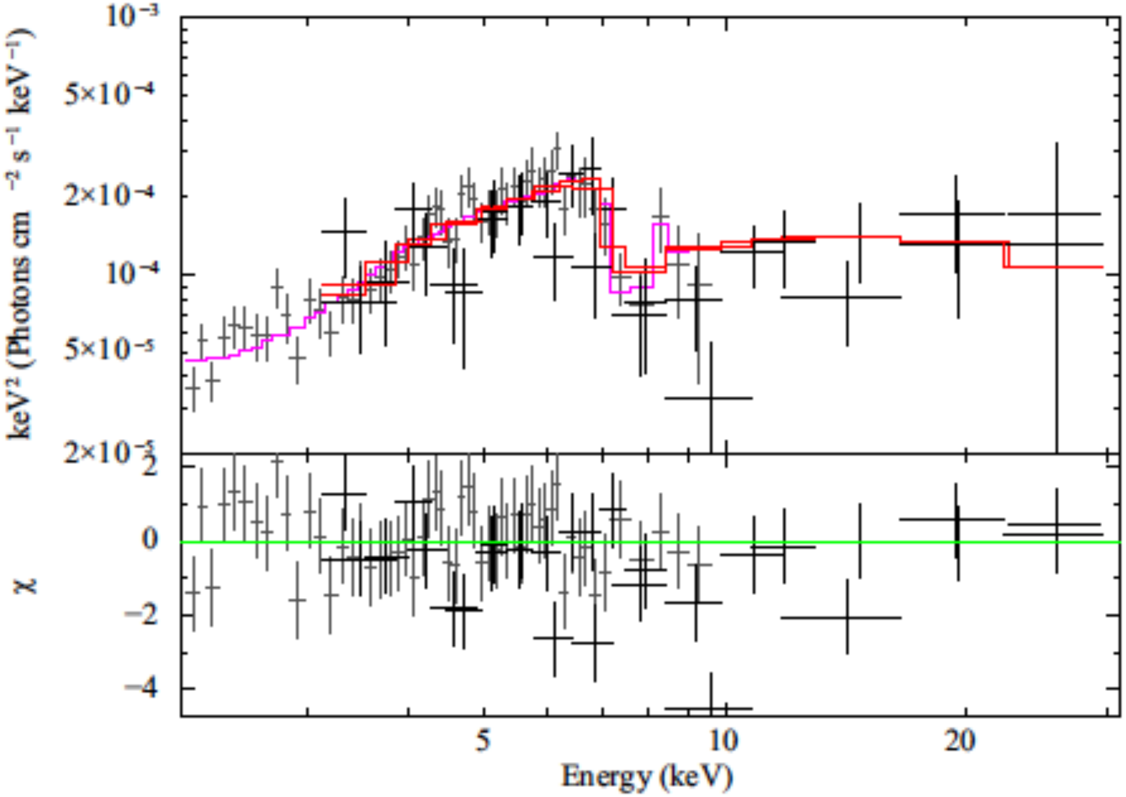




Fabian et al 2009

# Complex NLS1 – X-ray view

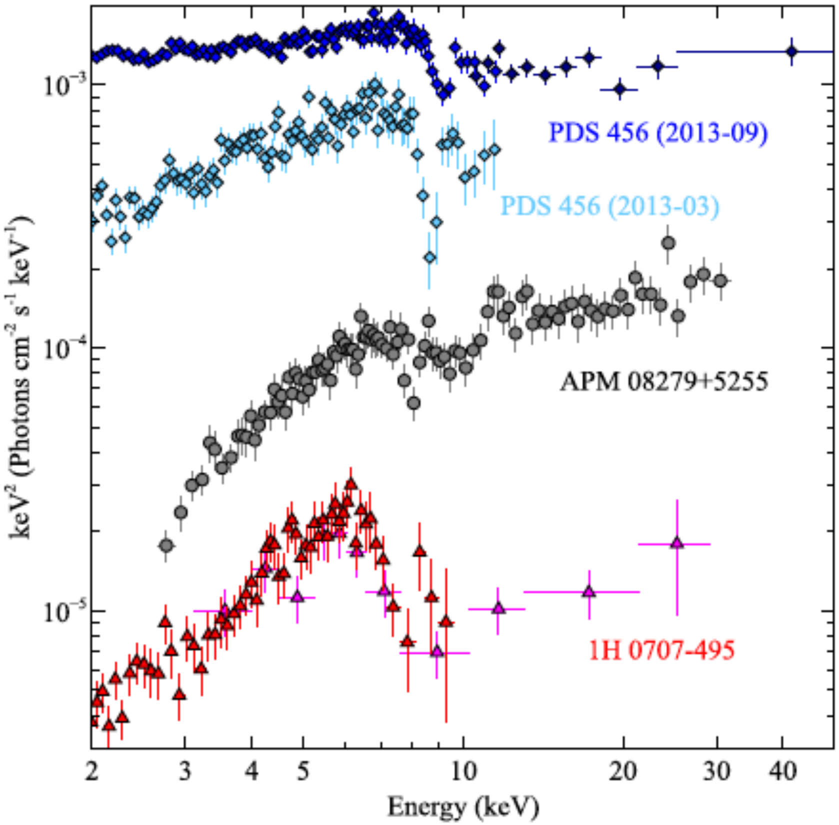
- Extreme spin with reflection from flat disc
- Or superEddington wind absorption with no constraints on spin!!

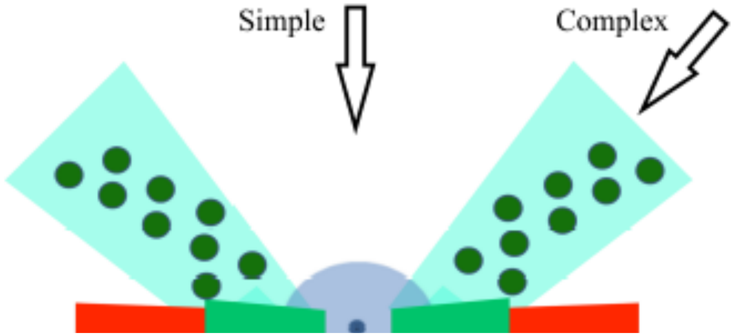


Hagino et al 2016

# Conclusions – most powerful winds

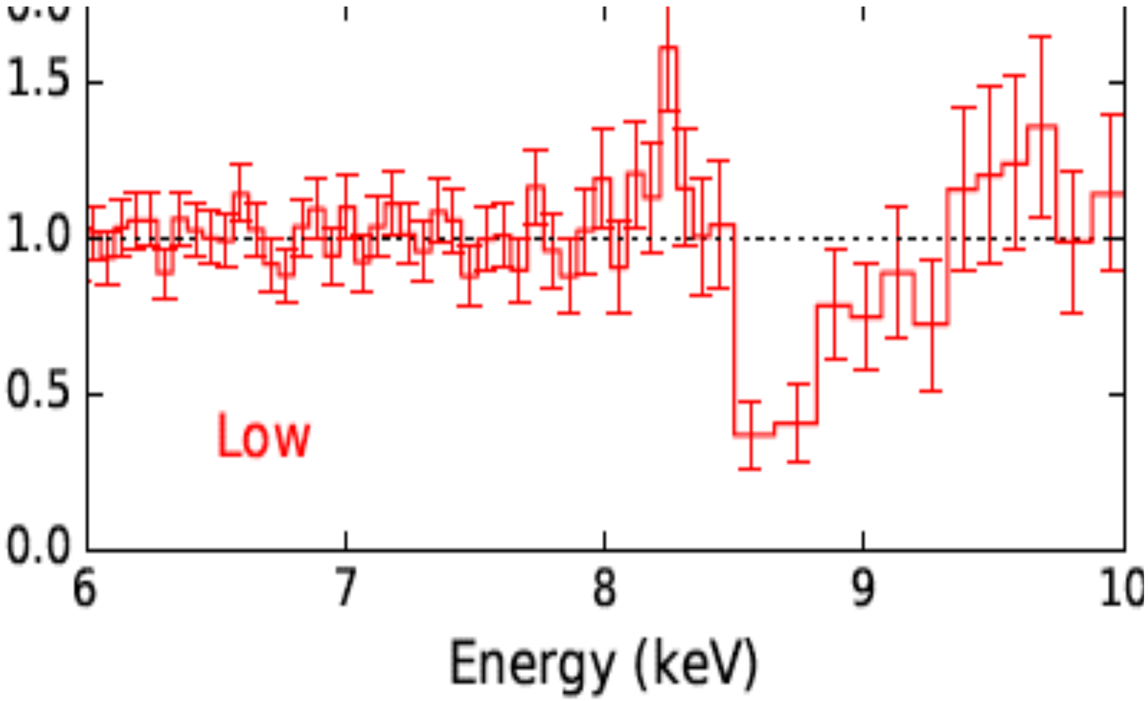
- Quantatative AGN feedback
- SED – L/LEdd and M
- high M, L~LEdd UV bright, X-ray weak, UV driving
- Eddington wind L>LEdd
- Both at z~2-3 QSO epoch
- Clumpy, complex - los



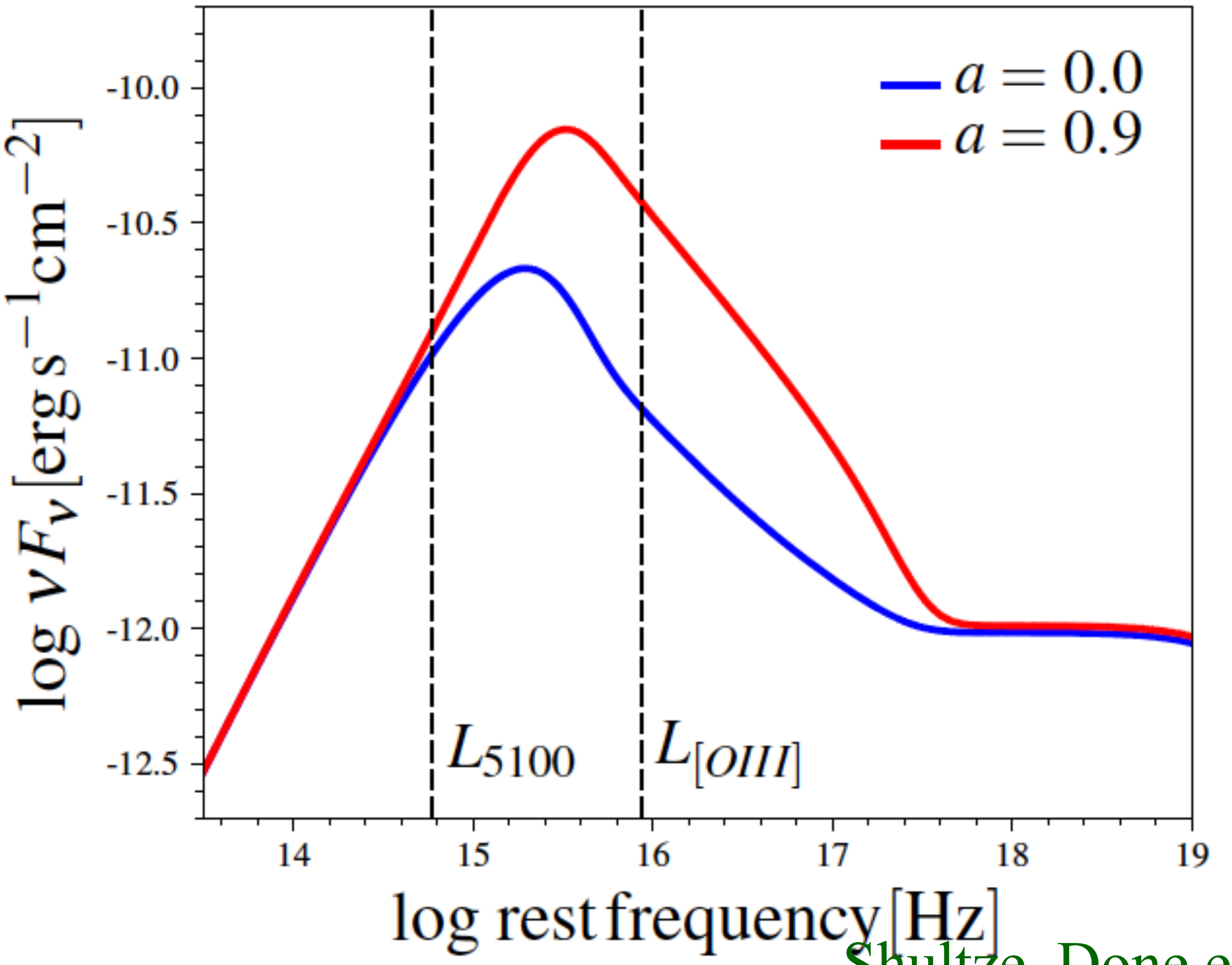


# IRAS13224

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



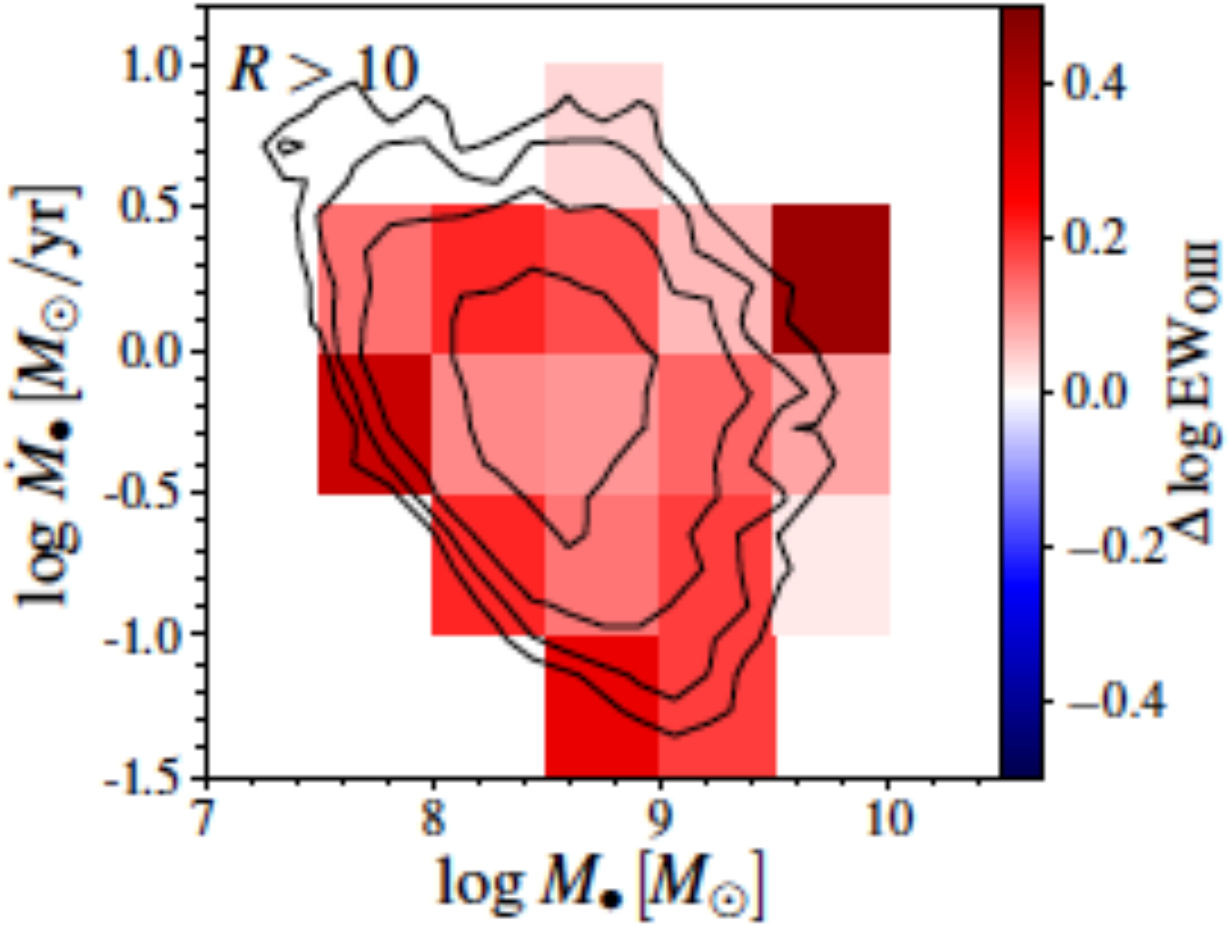
# More ionising luminosity for same Mdot



Shultze, Done et al 2017

# Compare L [OIII] RL and RQ for same BH M and Mdot!!

- 7000 SDSS QSO with Hb mass. Get Mdot
- Radio from FIRST R= $f_{5GHz}/f_{opt}>10$
- stack RL and RQ in each bin
- Measure OIII for RL/RQ
- All bins are RED More OIII in RL than RQ



Shultze, Done et al 2017

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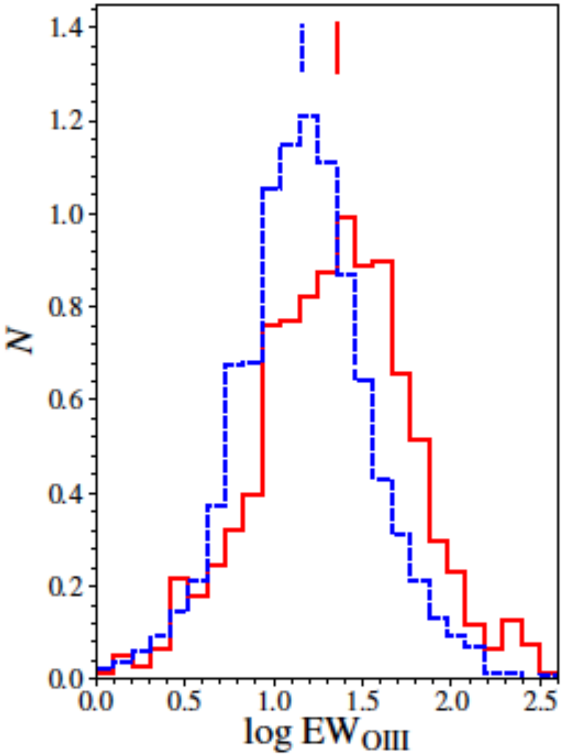
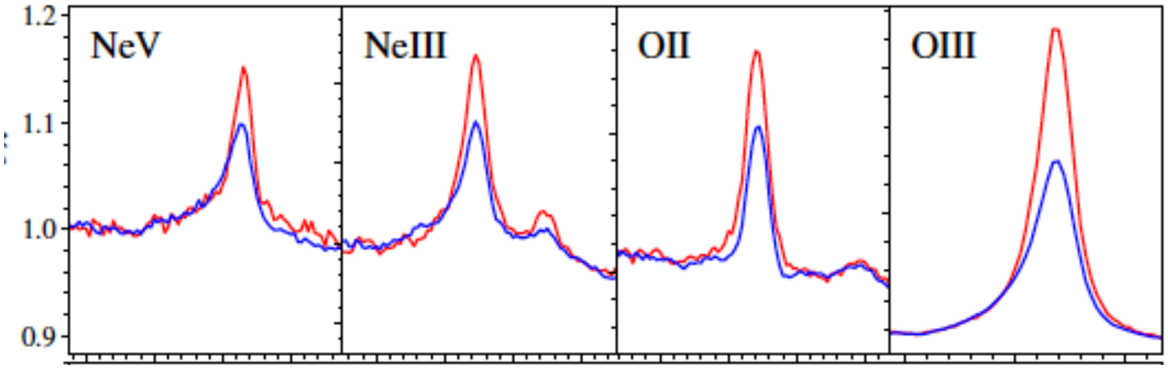
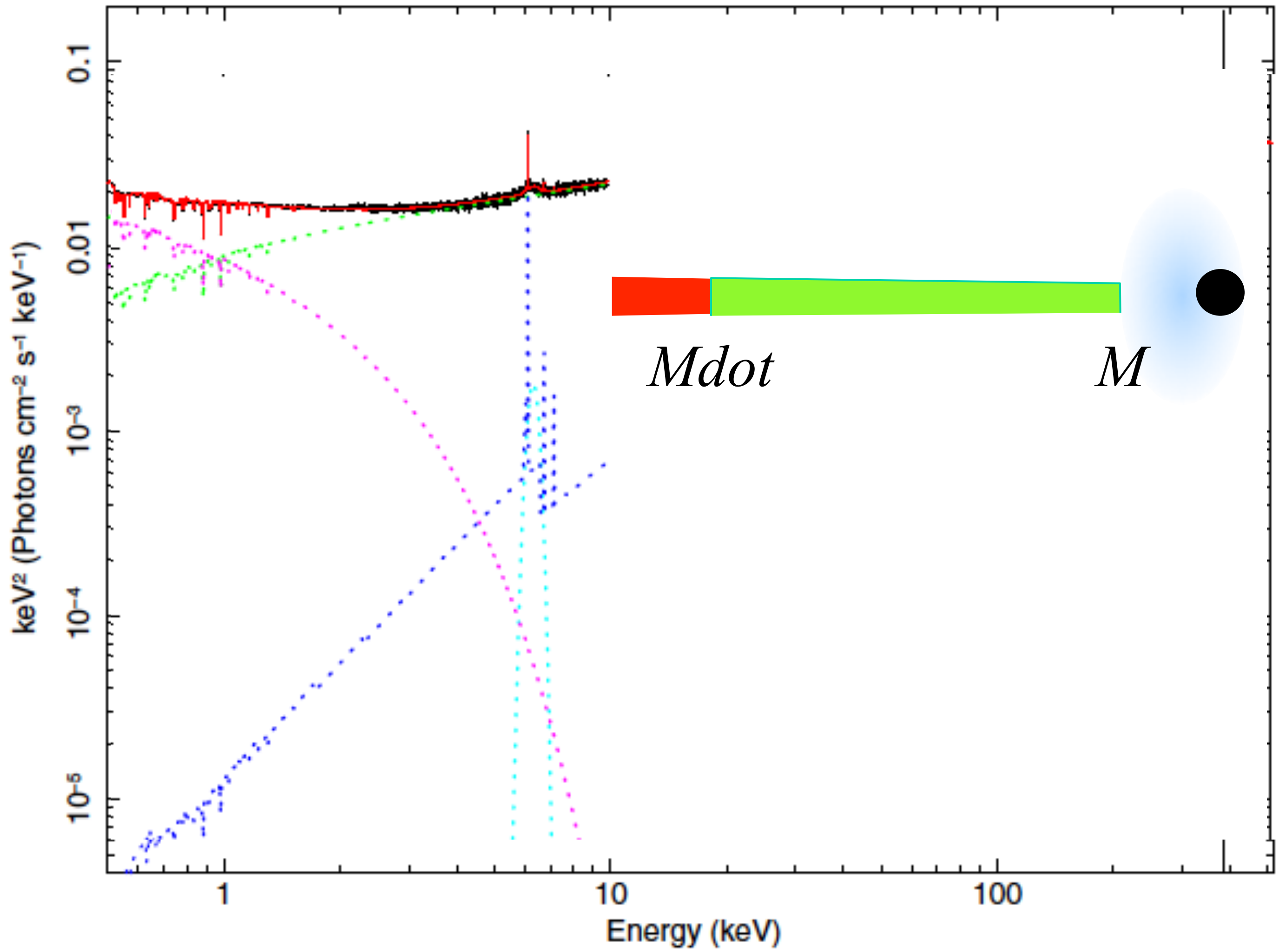




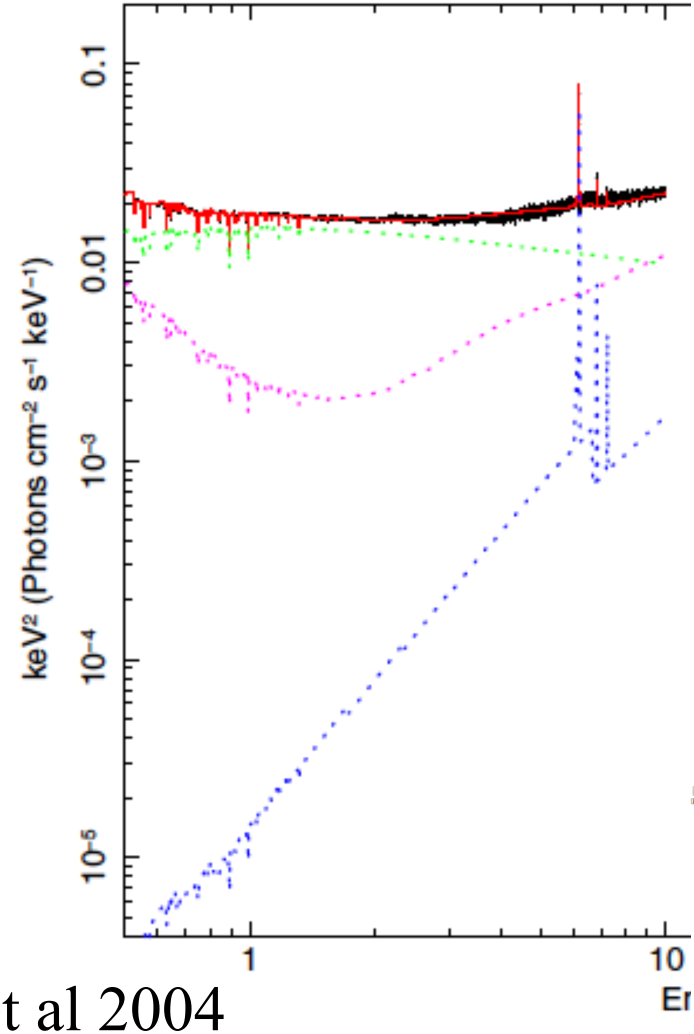
Shultze, Done et al 2017

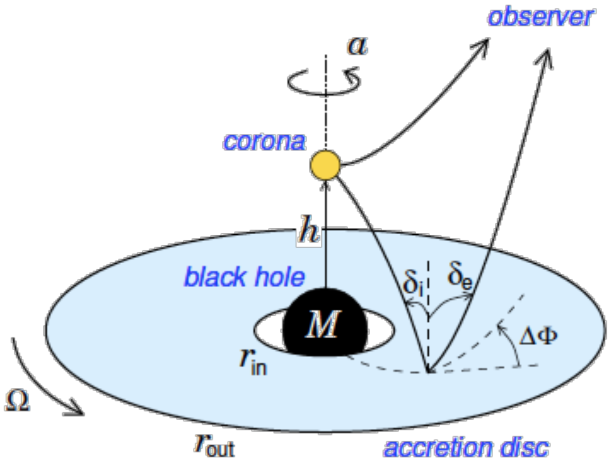
# An additional component?



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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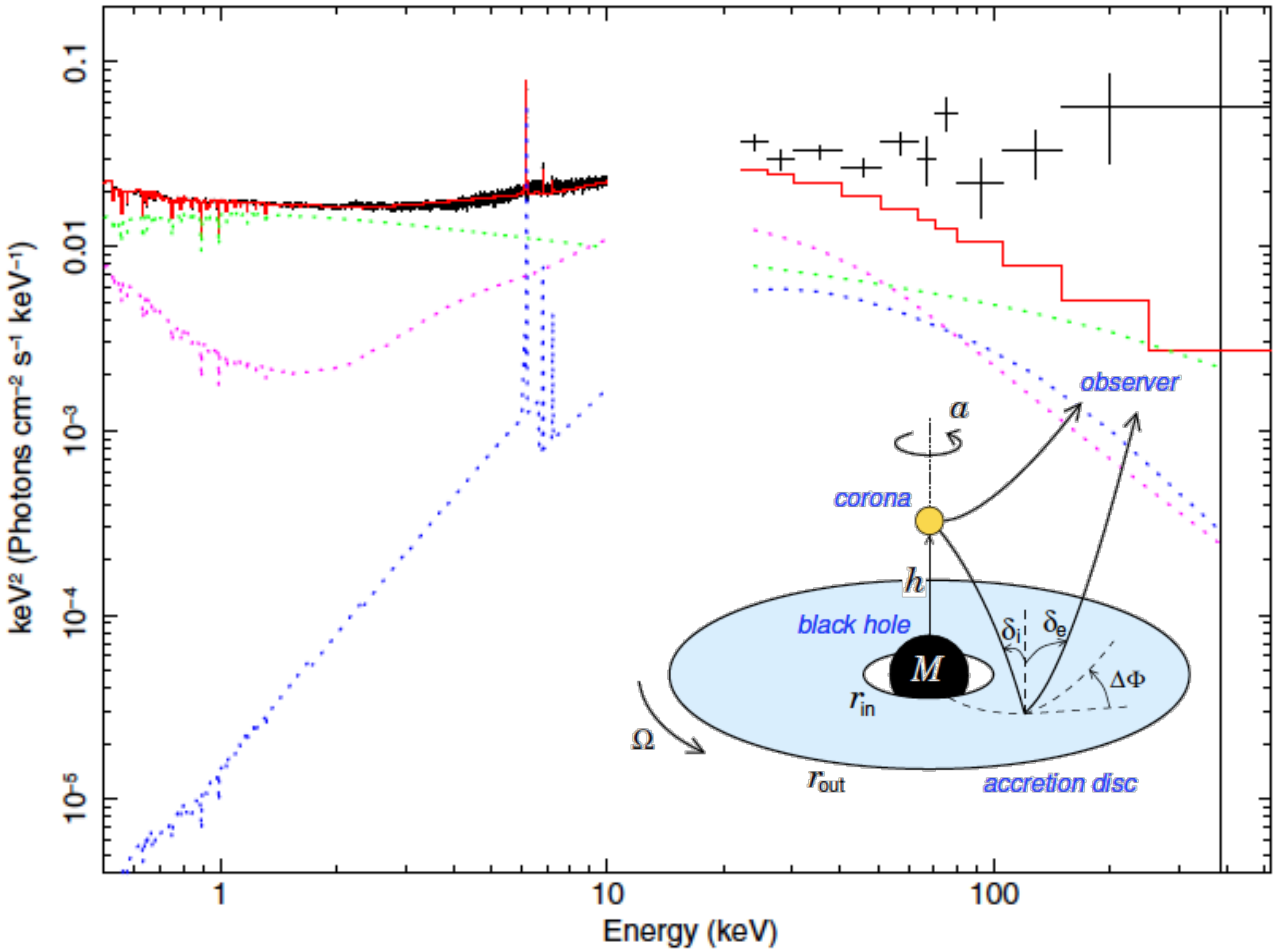

Boissay et al 2014

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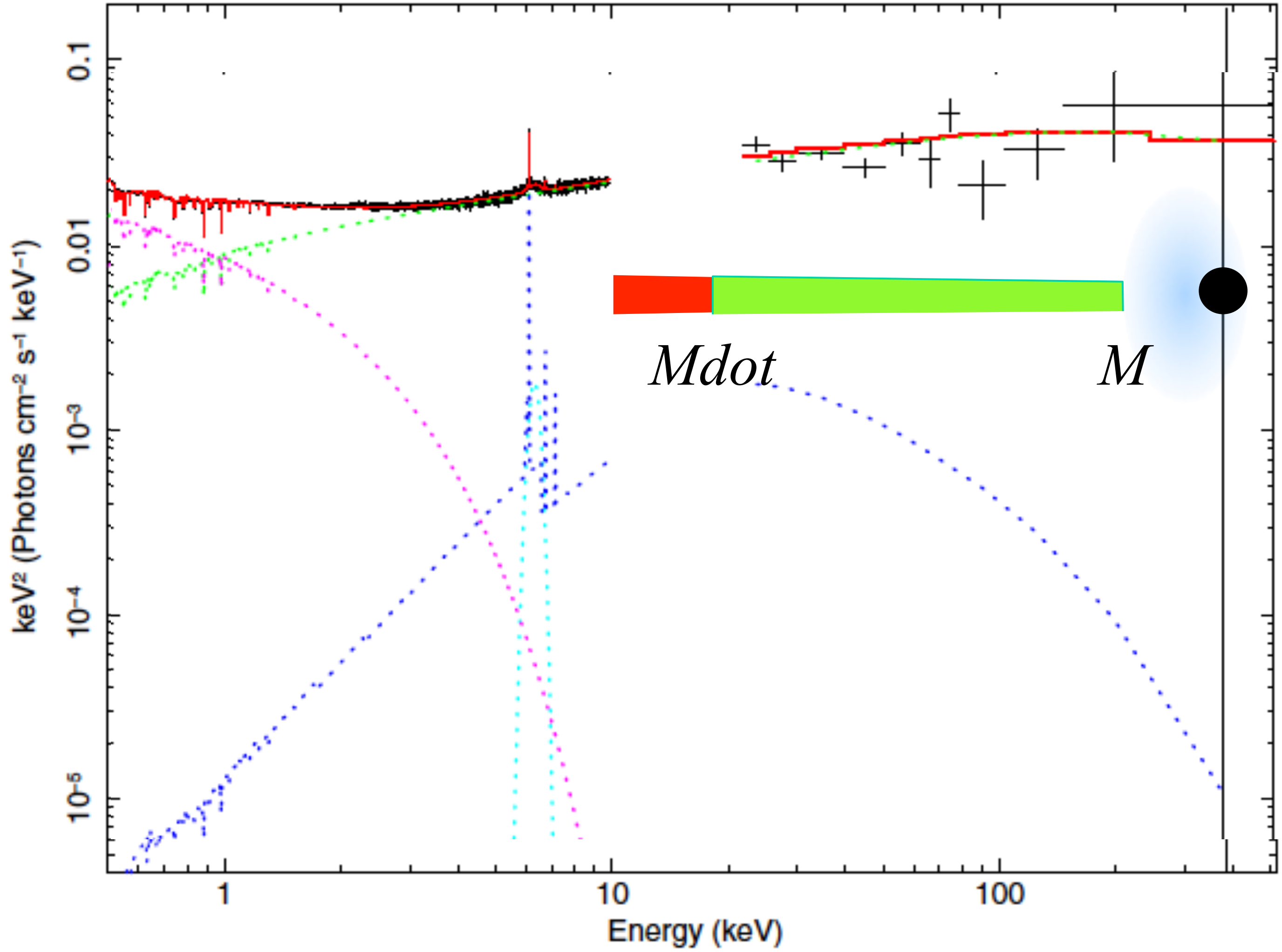

Boissay et al 2014