X-rays from AGN in a multi-wavelength context

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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, \( L = LEdd \)
  \( T_{\text{max}} \approx 1 \text{ keV} \)
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
Observed disc spectra in BHB!!

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Kolehmainen et al 2010

![Graph showing observed disc spectra in BHB with fit to Shakura-Sunyaev disc (with GR and photosphere). The graph indicates that small corona gives high energy tail.](image)
Two types of spectra in stellar BH

Disk dominated

Comptonised spectrum

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!! $L_R \sim L_x$
- (Fender et al 2004)
- BUT NOT HIGHLY RELATIVISTIC $\Gamma \sim 1.5-2$
- 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 $\Gamma \sim 1.5-2$)
BHB: template for SED $L/L_{edd}$?
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?

- Dramatic changes in continuum – single object, different days
- Underlying pattern in all systems
- High $L/L_{edd}$: soft spectrum, peaks at $kT_{\text{max}}$ 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
‘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
Scaling relations for $M_{\text{BH}}$ in terms of H$\beta$ FWHM and $F_{\text{opt}}$

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
Full multi-wavelength spectrum

- De-absorb from galactic and intrinsic
- Model across unobservable 0.0136-0.2 keV bandpass
- $L_{\text{bol}}$ - know M so know $LEdd$ so get $L_{\text{bol}}/LEdd$

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

Medhipour et al 2011
Nature of soft excess region?

- Why??
- UV bright region of disc
- Failed wind??
Optxagnf: conserving energy

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

Done et al 2012
Typical AGN SED

- Most standard BLS1/QSO $<M> \approx 10^8$, $<L/LEdd> \approx 0.1$
- Outer disc, strong UV peak from soft X-ray excess
- Hard X-ray tail – suppresses powerful UV line driving

Jin et al 2012
Very different to NLS1

- $\langle M \rangle \sim 10^7$, $\langle L/LEdd \rangle \sim 1$ NLS1 in local universe
- Disc dominated, small SX, weak X-rays

Jin et al 2012
Models conserving energy!!

- Smaller $R_{\text{corona}}$
- 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 $R_{\text{corona}}$
- 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!!
AGN spectral states

\[ 4 - A \log(\langle \lambda_{Edd} \rangle) = -0.03 \pm 0.06 \]

\[ \kappa_{2-10} = 75 \]
\[ \alpha_{ox} = 1.39 \]
\[ \Gamma_{2-10} = 2.03 \]

\[ \langle M_{BH} \rangle = 7.73 \]
\[ \langle H_\beta \ FWHM \rangle = 2670 \]
AGN spectral states

$4 - B \cdot \log(\langle \lambda_{\text{Edd}} \rangle) = -0.55 \pm 0.03$

$\langle \kappa_{2-10} \rangle = 28$

$\langle \alpha_{\text{ox}} \rangle = 1.32$

$\langle \Gamma_{2-10} \rangle = 1.87$

$0.009 \text{ keV}$

$2500 \text{ Å}$

$2 \text{ keV}$

$\langle M_{\text{BH}} \rangle = 7.97$

$\langle H\beta \text{ FWHM} \rangle = 5670$

Jin, Ward, Done 2012
AGN spectral states

$4-C. \log(<\lambda_{Edd}>) = -1.15 \pm 0.08$

$<\kappa_{2-10}> = 24$

$<\alpha_{ox}> = 1.31$

$<\Gamma_{2-10}> = 1.86$

$0.005 \text{ keV}$

$2500 \text{ Å}$

$<M_{BH}> = 8.02$

$<\text{FWHM}_{H\alpha}> = 5060$

$2 \text{ keV}$

Jin, Ward, Done 2012
X-ray/Lopt BIGGER small L/LEdd

$A \cdot \log(\langle \lambda_{Edd} \rangle) = -0.03 \pm 0.06$

$\langle \kappa_{2-10} \rangle = 75$
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$\langle M_{BH} \rangle = 7.73$
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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 variability 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:
  \[ \text{d}L = \text{d}A \sigma T^4 \]
- 10 Msun, \( L = L_{\text{Edd}} \)
  \( T_{\text{max}} \sim 1 \text{ keV} \)
- \( h\nu < kT_{\text{max}} \): integrates to
  \[ F_{\text{opt}} \propto (M \text{ Mdot})^{2/3} \cos i \]
- \( \text{So} < \text{Mdot} \propto F_{\text{opt}}^{3/2}/M \)
- Davis & Laor 2011
Get $M$ and $L/L_{edd}$ from single spectrum!!

- Scaling relations for $M_{BH}$ in terms of H$\beta$ FWHM and $F_{opt}$
- Based on BLR reverberation campaigns
- $<M_{\text{dot}}> \propto F_{opt}^{3/2}/M$
- $L_{bol}=\eta M_{\text{dot}} c^2$
- $\eta$ depends on BH spin
- $L_{bol}/L_{edd} \propto L_{bol}/M$
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 $\Gamma=15$!

Ghisellini et al. 2010
FRI/BL Lacs is top of ADAF branch (low/hard state BHB) but $\Gamma=15$ 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)
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/Leedd 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!

- $\dot{M} = 12 \dot{M}_{\text{Edd}}$
- $L_{\text{obs}} = 4.6L_{\text{Edd}}$ 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 $L \text{[OIII]}$ RL and RQ for same BH $M$ and $M_{\text{dot}}$!!

- 7000 SDSS QSO with Hb mass. Get $M_{\text{dot}}$
- Radio from FIRST $R= f_{5\text{GHz}}/f_{\text{opt}}>10$
- 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 $[\text{OIII}]$ 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 paradigm for highly relativistic jets!!??

Shultze, Done et al 2017
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
- 2-4x10^6
- $L/L_{edd} = 11, 40, 70$ (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
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!!
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

• Quantitative 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!!

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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
Reflected/smeared hard X-rays?

Boissay et al 2014
An additional component?

Boissay et al 2014