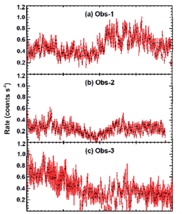
The Best Constraints on A Super-Eddington Accretion Flow: XMM-Newton Observations of An Intermediate-mass Black Hole

Chichuan Jin[1], Chris Done[2], Martin Ward[2]
[1]*Qian Xuesen Space Laboratory, China Academy of Space Technology, Beijing, China, 100094*
[2] *Department of Physics, Durham University, South Road, Durham, United Kingdom, DH1 3LE*

Abstract

We report the latest results from three XMM-Newton observations of an Intermediate-mass black hole RX J1140.1+0307. The black hole mass of this source is so small that the variable optical flux requires a mass accretion rate of L/L_{Edd}~10. Such high mass accretion rate would dramatically over-predicts the observed X-ray flux, unless either there is substantial energy loss through winds/advections which is, however, inconsistent with the X-ray spectral and variability properties, or the variable optical flux is predominantly from the reprocessed X-rays rather than the outer accretion disc.

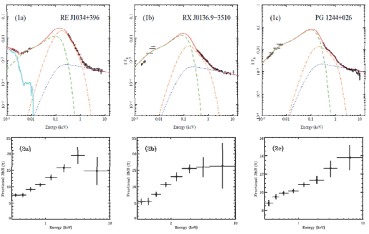
Source & Observations



(Fig.1: pn light-curves)

RX J1140.1+0307, also referred to as GH08, is amongst the original 19 IMBH sample of Greene & Ho (2004). It is a nearby NLS1 (z = 0.081) with both strong optical and X-ray variability. The HST images show a resolved disc component. We obtained the data from two recent XMM-Newton observations of this source and performed data analysis.

An Extremely Accreting NLS1 Group



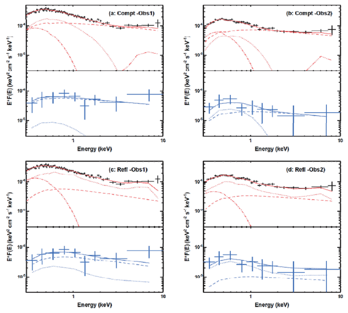
(Fig.5: 0.2-2 ks high-freq. RMS spectra and broadband SEDs based on XMM-Newton data of three NLS1s)

GH08 is a good example:

- ✓ prominent and featureless soft-excess (a huge **BBB**)
- ✓ strong X-ray variability
- ✓ high-freq. fractional **RMS** rises towards hard X-rays
- ✓ accreting near/above the Eddington limit

X-ray Spectral Fitting

Comptonisation and reflection fit the X-ray spectra equally well, but variability properties slightly prefer Compt. Model.



(Fig.6: Spectral de-composition for the mean spectra (red) and high-freq. covariance spectra (blue), based on Compt. & reflection models.)

The curvature of covariance spectra also reveals accretion disc emission in the soft X-ray.

(Table : Best-fit parameters in Fig.6)

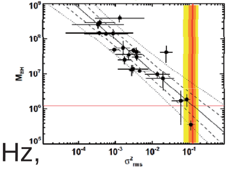
Comptonisation		Obs-1	Obs-2
DISKBB	Tin (keV)	135	135
NTHCOMP	Γ	2.26	2.26
CompTT	kT (keV)	0.38	0.21
CompTT	τ	10.9	19.2
$\chi^2_{reduced}$		**0.95**	**0.78**
Reflection		**Obs-1**	**Obs-2**
NTHCOMP	Γ	2.42	2.22
KDBLUR	Rin (Rg)	4.98	3.05
RFXCONV	Fe_{abund}	1.39	0.81
RFXCONV	Log ξ	3.37	2.86
$\chi^2_{reduced}$		**0.95**	**0.77**

Conclusions

- ◆ GH08 is most likely to be an IMBH with $M_{BH} < 10^6 M_\odot$
- ◆ GH08 is a typical example of extremely accreting AGN.
- ◆ For GH08, Comptonisation model appears slightly better than reflection in explaining X-ray spectra and variability.
- ◆ Broadband SED suggests energy loss via advections and/or winds and X-ray reprocessing may both emerge in GH08, then neither Comptonisation nor reflection is sufficient to explain the X-ray emission.

Black Hole Mass

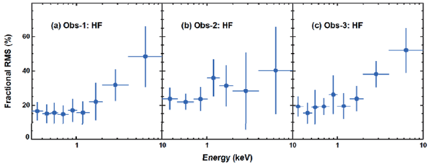
- ● Reverb. Mapping: $M_{BH} < 6 \times 10^5 M_\odot$
- ● Hβ FWHM (700 km s^{-1}), $L_{5100Å}$ (~10^{43} erg s^{-1}): M_{BH}~10^5-10^6 $M_\odot$
- ● $\sigma^2_{rms\ (2-10keV)}$ vs. M_{BH}: ≤10^6 $M_\odot$
- ● PSD shape: stay flat for $f < 2 \times 10^{-3}$ Hz, no high energy break found, implying $M_{BH} < 10^6 M_\odot$



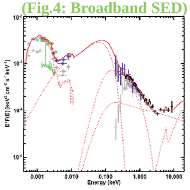
(Fig.2: σ^2_{rms} vs. M_{BH})

All studies confirm GH08 is an IMBH with $M < 10^6 M_\odot$

RMS Spectra & SED



(Fig.3: 0.2-2ks High-freq. RMS Spectra)



(Fig.4: Broadband SED)

The high-freq. **RMS** spectra indicate that the hard X-ray flux has more fast variability than the soft. The SED reveals a strong soft-excess and 'big blue bump' (**BBB**).

Best Constraints from Broadband SED

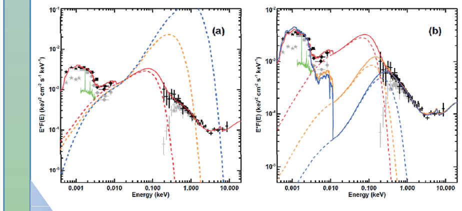


Fig.7a,b: Broadband SED of GH08 but with different masses: 9.6×10^6 $M_\odot$ (red), 1×10^6 $M_\odot$ (orange), 1.5×10^5 $M_\odot$ (blue). In Panel-a, the models primarily fit the UV points and have L/L_{Edd} = 0.17, 10 and 400 for disc emission outside 15 Rg. In Panel-b, the models primarily fit the X-ray spectra and have L/L_{Edd} = 0.17, 0.56 and 2.

BUT

Fig.7a, b show that for a mass of 10^6 $M_\odot$, either can the SED model fit the optical/UV flux with L/L_{Edd}=10, but over-predict the soft X-ray by more than a factor of 10, or it can fit the X-ray with L/L_{Edd}=0.56, but account for less than 10% flux in the optical/UV .

P1: M_{BH}~10^7 $M_\odot$, GH 08 is not an IMBH? Unlikely.

P2: Energy loss via advection/winds? As expected from high L/L_{Edd}, then both Compt. & Refl. models are wrong.

P3: X-ray reprocessing into the optical/UV? As expected from strong optical variability, but unlikely to dominate.

Maybe a better model is to combine **P2** & **P3**, so that GH08 has both wind and X-ray reprocessing by the wind.

References

[1] Done C., Davis S. W., Jin C., Blaes O., Ward, M., 2012, MNRAS, 420, 1848; [2] Greene J. E., Ho L. C., 2004, ApJ, 610, 722; [3] Jin C., Done C., Ward M., 2015, arXiv: 150406190J; [4] Jin C., Done C., Middleton M., Ward M., 2013, MNRAS, 436, 3173; [5] Miniutti G., Ponti G., Greene, J. E., Ho L. C., Fabian A. C., Iwasawa K., 2009, MNRAS, 394, 443; [6] Ponti G., et al., 2012, A&A, 542, A83