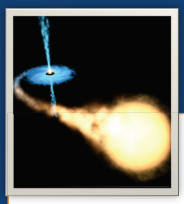
Suzaku Observations of GX 339 – 4 in the Low/Hard State



Yoshihiro Ueda & Megumi Shidatsu
Department of Astronomy, Kyoto University
Contact: ueda@kusastro.kyoto-u.ac.jp, shidatsu@kusastro.kyoto-u.ac.jp

Abstract

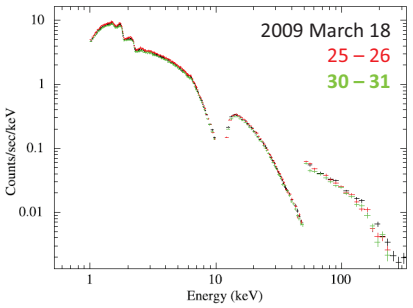
We present the results from X-ray and near-infrared observations of the Galactic black hole binary GX 339 – 4 in the low/hard state with Suzaku and IRSF in 2009 March. The spectrum in the 0.5 – 300 keV band is dominated by thermal Comptonization of multicolor disk photons, with a small contribution from a direct disk component, indicating that the inner disk is almost fully covered by hot corona with an electron temperature of ≈ 175 keV. The Comptonizing corona has at least two optical depths, $\tau \approx 1$ and ≈ 0.4. Analysis of the iron-K line profile yields an inner disk radius of 13.3 (7.3 – 19.7 at 90 percent confidence level) times the gravitational radius, with the best-fit inclination angle of ≈ 50°. This radius is consistent with that estimated from the continuum fit by assuming the conservation of photon numbers in Comptonization. Our results suggest that the standard disk of GX 339 – 4 is likely truncated before reaching the innermost stable circular orbit (for a non rotating black hole) in the low/hard state at ~1 percent of the Eddington luminosity. The one-day averaged near-infrared light curves are found to be correlated with hard X-ray flux with a power law slope of 0.45.
The reader is referred to Shidatsu et al. (2011, arXiv: 1105.3586) for the details of these observations and results.

1.1 Suzaku observations in the low/hard state

We performed three sequential ToO (Target of Opportunity) observations of the Galactic black hole candidate GX 339–4 with Suzaku on 2009 March 18, 25-26, and 30-31, each for a net exposure of ~40 ksec, when it became active and stayed in the low/hard state.

From the observations, we achieved the best quality broad-band (approximately 1-300 keV) spectra that have ever obtained in the low/hard state of GX 339-4.

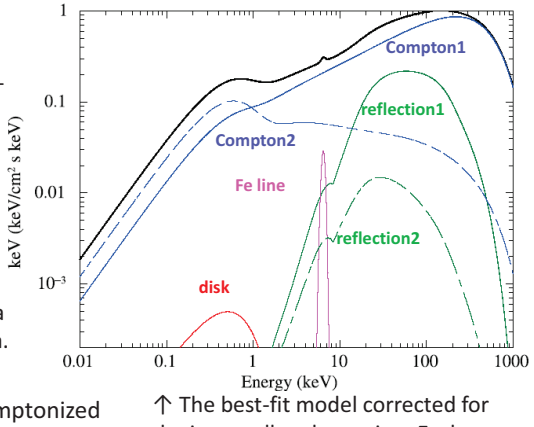
Time-averaged spectra in the three epochs



The three spectra exhibit almost the same shape, and therefore we co-added the data of the three observations to use for the analysis.

1.2 Analysis of the Suzaku spectra

To constrain the origin of the X-ray emission, the broad-band time-averaged spectrum was simultaneously fitted with a model of emission from a standard accretion disk and its thermal Comptonization by a spherical hot corona.



↑ The best-fit model corrected for the interstellar absorption. Each component is separately plotted.

- two thermal Comptonized components, with the same electron temperature but different optical depths
- direct component of the disk emission is weak compared with Comptonization

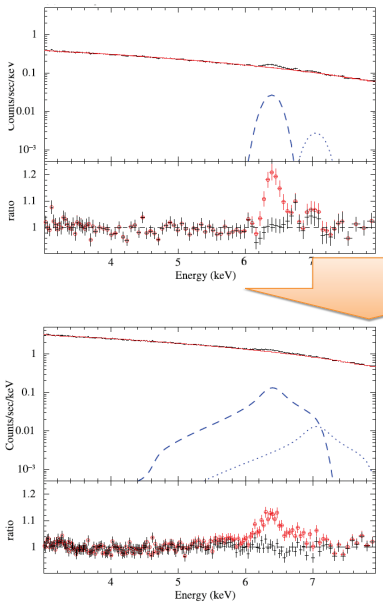
best-fit values

Component	Parameter	Value
Disk	kT_{in} (keV)	0.215±0.001
Corona	kT_e (keV)	172^{+4}_{-3}
	T	0.25±0.02, 0.91±0.02
Reflection	Ω/2π	0.43±0.01

➢ The Comptonizing corona has a more complex geometry than that assumed in a single zone, spherical model
➢ inner disk is almost fully covered by hot corona

1.3 Disk evolution in the low/hard state

We analyzed the 3–8 keV Suzaku spectra using a relativistic disk emission line model for the iron-Kα and Kβ fluorescent lines.



2008/09
(re-analysis of Tomsick et al. 2009)
$L_{1\text{-}100\text{keV}} \approx 0.0014\ L_{\rm Edd}$
$R_{\rm in} = 190^{+710}_{-90} R_{\rm g}$

2009/03
(our data)
$L_{1\text{-}100\text{keV}} \approx 0.02\ L_{\rm Edd}$
$R_{\rm in} = 13.3^{+6.4}_{-6.0} R_{\rm g}$

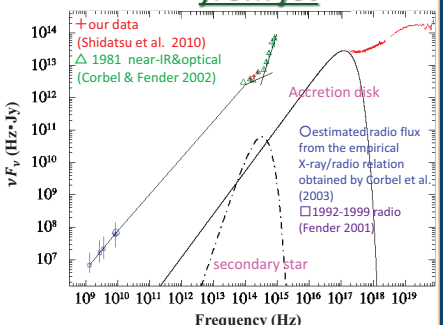
※$R_{\rm g}$: gravitational radius (GM/c^2)

➢ standard disk is truncated in the low/hard state
➢ Inner edge of the disk moves inward according to luminosity

2. Near-IR observations and results

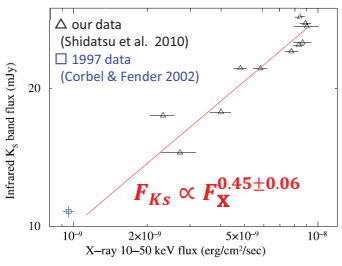
We carried out *JHKs*-band photometric observations on 11 nights over a period from 2009 Feb 27 to 2009 March 23, using IRSF (Infra-Red Survey Facility) 1.4 m telescope at the South African Astronomical Observatory (SAAO).

Synchrotron emission from jet



↑ Multi-wavelength SED corrected for interstellar absorption/extinction.

disk-jet coupling?



$F_{Ks} \propto F_{\rm X}^{0.45\pm0.06}$

↑ The relation between the one-day averaged X-ray (15–50 keV) and IR (*Ks*) fluxes of GX 339–4 with *Swift*/BAT and *IRSF*/SIRIUS in 2009 March, fitted by a power law.

Radio: Optically thick synchrotron
Near-IR: Optically thin synchrotron
Optical: Reprocessed thermal emission from irradiated disk

➢ The magnetic field and size of the jet base are ~10^4 G and ~10^9 cm, respectively
➢ Synchrotron self Compton component contributes < 0.4% of the total X-ray flux