Multiwavelength Observations of the Black Hole X-ray Binary MAXI J1820+070 in the Rebrightening Phase

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Abstract

We report the results of quasi-simultaneous multiwavelength (near-infrared, optical, UV, and X-ray) observations of the Galactic X-ray black hole binary MAXI J1820+070 performed in 2019 May 10–13, ~60 days after the onset of the first rebrightening phase. It showed a much larger optical-to-X-ray luminosity ratio (~8) than in the initial outburst epoch. The primary components of the spectral energy distribution (SED) can be best interpreted by a radiatively inefficient accretion flow (RIAF) spectrum showing a luminosity peak in the optical band. By comparison with theoretical calculations, we estimate the mass accretion rate to be $\dot{M}/(8L_{Edd}/c^2)$~10^{-3}, where c is the light speed and L_{Edd} is the Eddington luminosity. In addition to the RIAF emission, a blue power-law component is detected in the optical–UV SED, which is most likely synchrotron radiation from the jet. The optical spectrum taken at the Seimei telescope shows a weak and narrow Hα emission line, the emitting region of which is constrained to be ≳ 2 × 10^4 times the gravitational radius. We suggest that the entire disk structure cannot be described by a single RIAF solution but cooler material responsible for the Hα must exist at the outermost region. *Published as Yoshitake et al. (2022), PASJ, 74, 4*

1. Observations

We observed MAXI J1820+070 (Kawamuro et al. 2018) with Swift/XRT (X-ray), Swift/UVOT (UV), and OISTER (near-infrared to optical) on 2019 May 10–13. Optical spectroscopic observations were performed with KOOLS-IFU on Seimei telescope on 2019 May 11.

Figure 1 shows the long-term X-ray (MAXI) and optical (OISTER) light curve over three years since its discovery. Our multi-wavelength observation was performed in the last part of the decay phase of the first rebrightening, with the g′-band magnitude of ~16 mag. The optical-to-X-ray luminosity ratio (~8) is found to be much larger than those observed in an earlier outburst epoch when the source was in the LHS or HSS (Shidatsu et al. 2018; 2019), suggesting a very different disk structure.

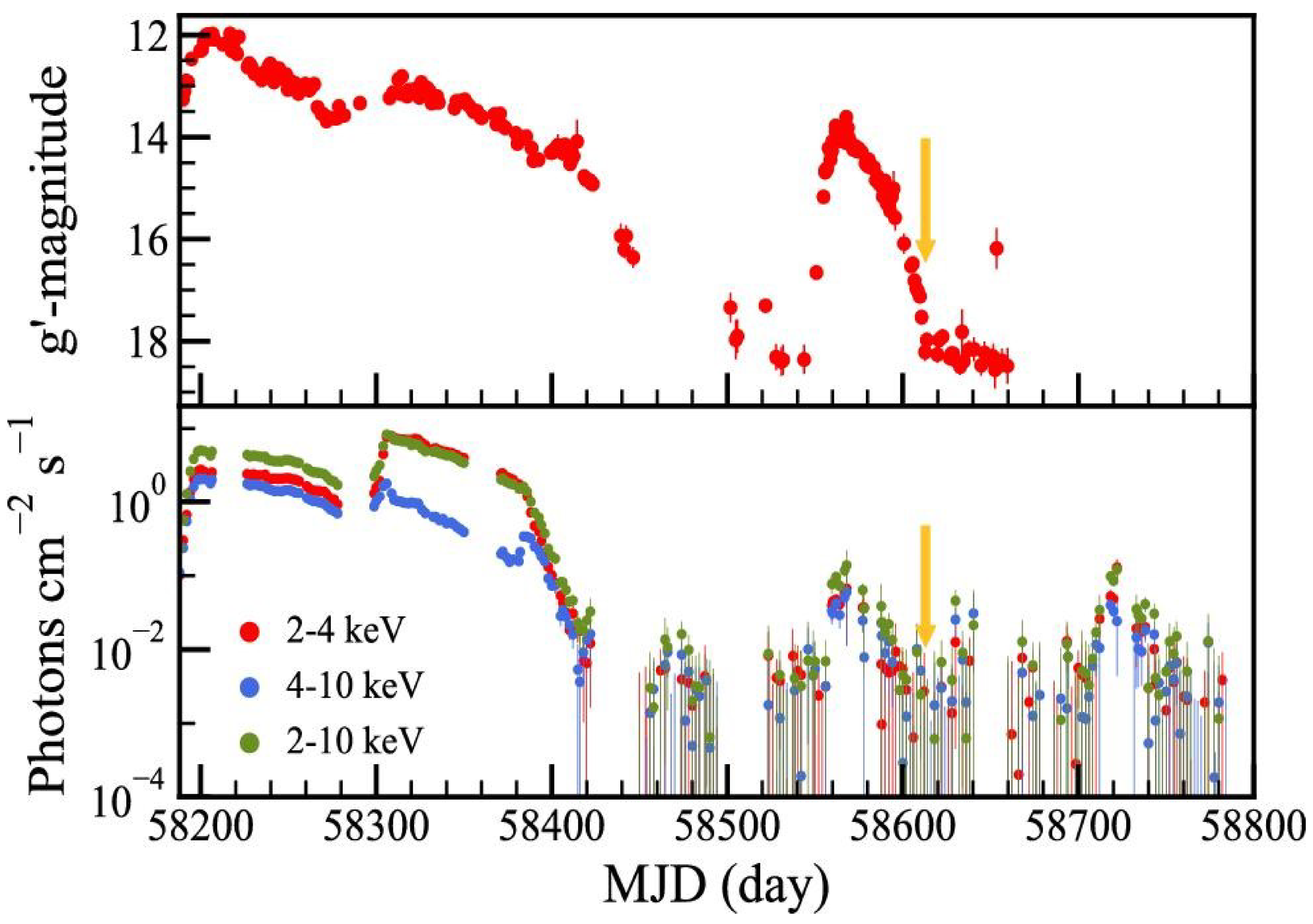

Fig. 1. (Top) g′-band optical light curve of MAXI J1820 from the OISTER collaboration (R. Adachi et al. in preparation). (Bottom) X-ray light curve in 2–10 keV from the MAXI/GSC. MJD 58200 corresponds to 2019 March 23. The yellow line presents our observation epoch (2019 May 11 = MJD 58614).

2. Multiwavelength SED

We considered two possibilities as the primary origin of the IR-to-UV SED: (Model 1) RIAF and (Model 2) truncated hot standard disk. In addition to the primary component, a blue power-law component dominating the UV flux was detected (see also Özbey Arabaci et al. 2022). We interpret that this is produced by synchrotron radiation by non-thermal electrons in the jet, as suggested by its rapid variability (R. Adachi et al. in preparation).

Model 1 (RIAF)

The primary components of the optical and X-ray SED can be best interpreted by an RIAF spectrum (Figure 2), showing a luminosity peak in the optical band (via thermal synchro-cyclotron) and a power-law in the X-ray band (via thermal bremsstrahlung). By comparison with theoretical calculations (Manmoto et al. 1997; Mahadevan 1997), we estimate the mass accretion rate to be $\dot{m}$ ($\equiv \dot{M}c^2/8L_{Edd}$) ~$10^{-3}$, which reproduces the observed optical and X-ray luminosities within factors of 6.

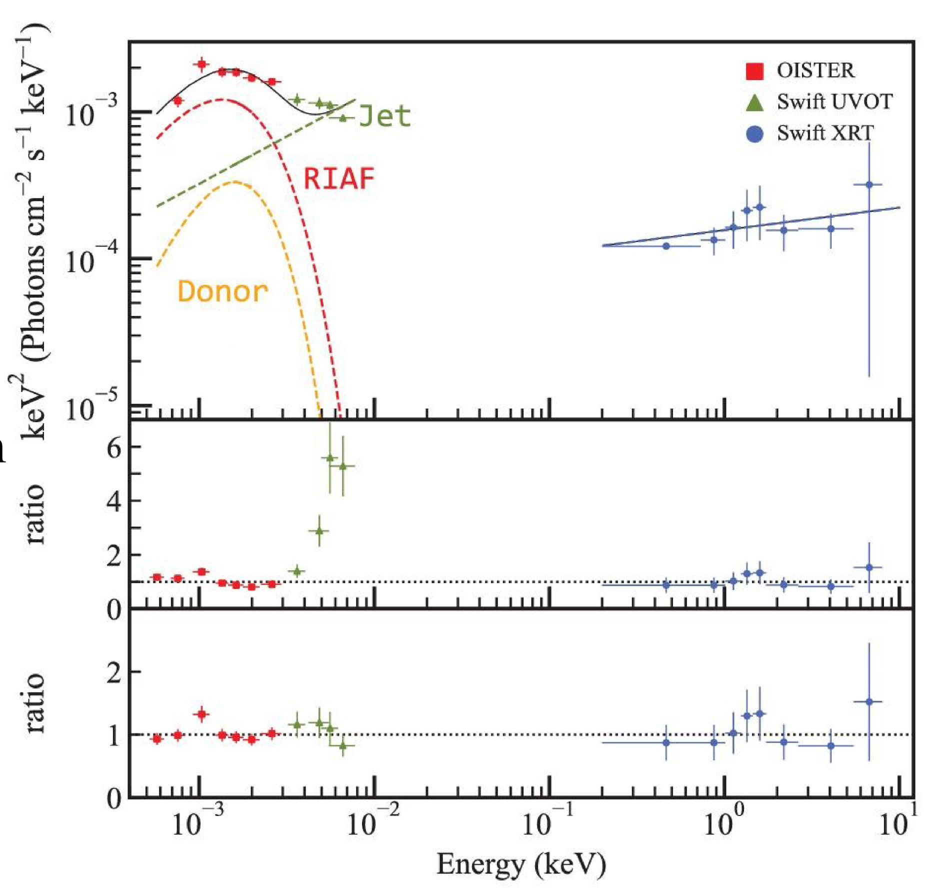

Fig. 2. Top: SED data with the best-fitting redden*(powerlaw+cutoffpl+bbodyrad) model (Model 1) in the NIR to UV band and the unfolded spectrum with the best-fitting TBabs*power-law model in X-rays, all corrected for the interstellar absorption and extinction. The individual components are separately plotted. Middle: the data versus model ratio of the redden*(cutoffpl+bbodyrad) model (in the infrared to UV band) and the TBabs*power-law model (in the X-ray band). Bottom: Same as the middle panel, but with the redden*(powerlaw+cutoffpl+bbodyrad) model in the infrared to UV band.

Model 2 (Truncated Hot Standard Disk)

As an alternative model, a major part of the optical SED could be reproduced by optically thick emission from a standard disk truncated at a very large radius (~10^4 r_g, where r_g is the gravitational radius, Figure 3). We conclude that this "truncated hot standard disk" scenario is unlikely, because the inferred mass accretion rate from the multi-color disk model, $\dot{m}$ ~0.04, is too large to explain the observed optical and X-ray luminosities, assuming that the inner accretion disk becomes RIAF.

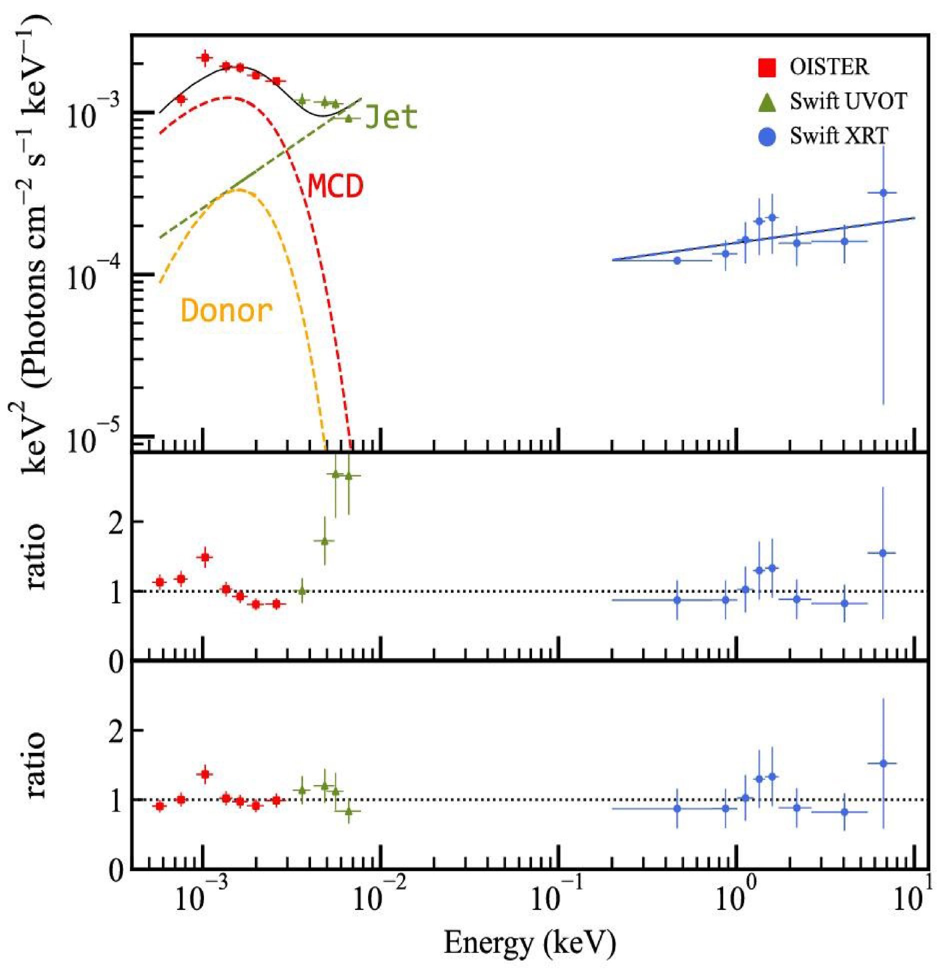

Fig. 3. Same as Figure 2, but for the redden*(diskbb+bbodyrad) model in the middle panel and for the redden*(powerlaw+diskbb+bbodyrad) model (Model 2) in the top and bottom panels, in the NIR to UV band. The bbodyrad model (common to Fig. 2) represents the blackbody emission from the companion star (K4V star; Torres et al. 2020), whose temperature and radius are assumed to be 4700 K and 0.65 solar radius, respectively.

3. Optical Spectrum

The optical spectrum observed with KOOLS-IFU on the Seimei telescope (Figure 4) shows a weak Hα emission line with an FWHM of ~5.3 ×10^2 km s^{-1}. The inner radius of the Hα-emitting region is constrained to be ≳ 2 × 10^4 r_g. We suggest that the entire disk structure cannot be described by a single RIAF solution but cooler material must exist at the outermost region.

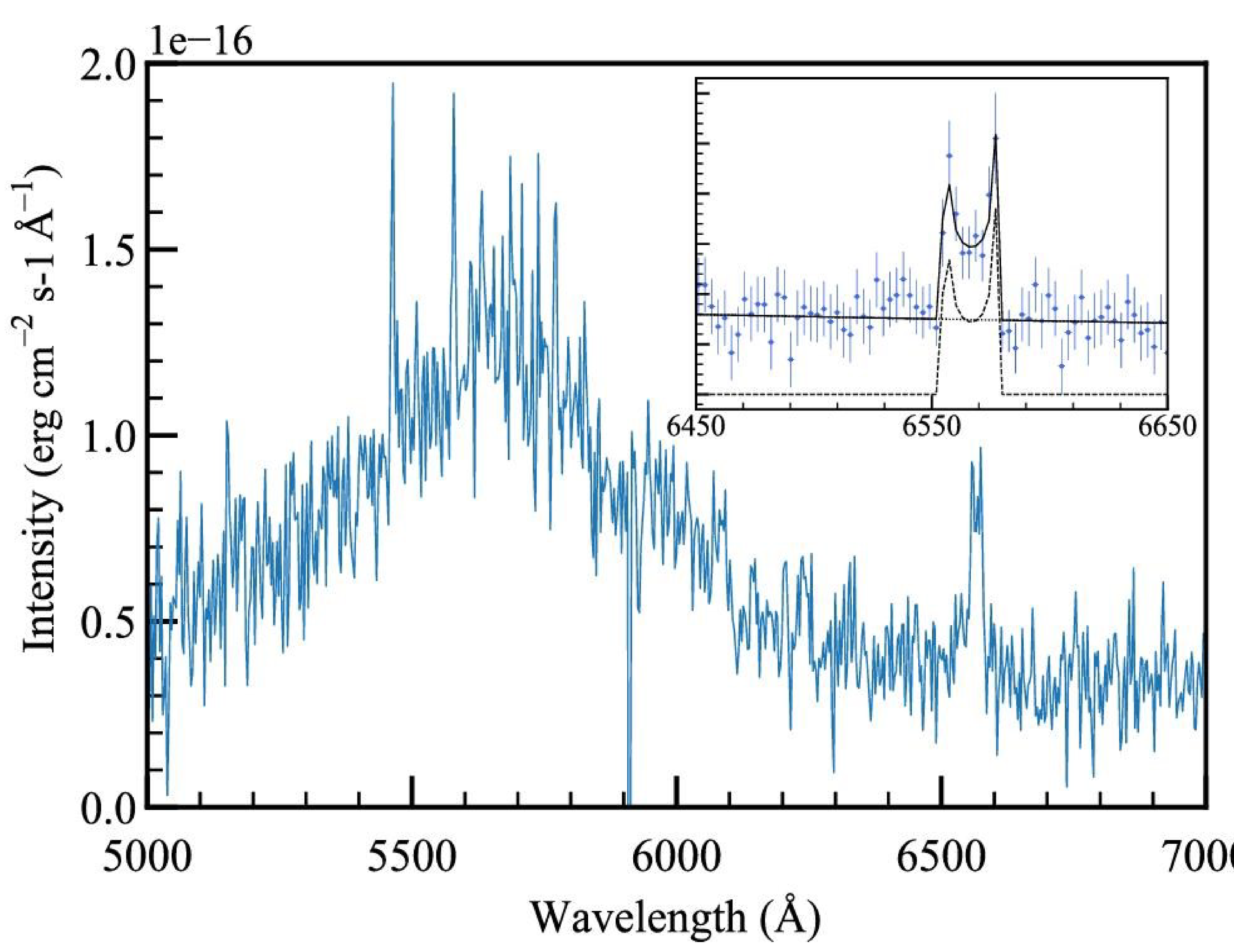

Fig. 4. Seimei/KOOLS-IFU spectrum of MAXI J1820, taken on 2019 May 11. The magnified image presents the Seimei spectrum around the Hα line and the best-fitting diskline model.

4. References

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[2] Kawamuro et al. 2018, ATel 11399, 1
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