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MAXI J1820+070: a new black hole low-mass X-ray binary candidate

Jessymol K Thomas, David A. H. Buckley, Enrico Kotze, and Stephen Potter

South African Astronomical Observatory, P.O Box 9, Observatory 7935, Cape Town, South Africa, e-mail: jessy@saao.ac.za

Abstract. MAXI J1820+070, a new bright X-ray transient source, has been observed by a number of telescopes since its discovery on 11th March 2018. Based on multi-wavelength observations, MAXI J1820+070 has been identified as a new black hole candidate low-mass X-ray binary. Our high-speed photometry undertaken with the SHOC instrument on the SAAO 1-m telescopes, plus SALT slotmode observations, reveals high frequency variability in the range 0.01- 3 Hz. In addition we have obtained SALT spectra of the source which shows strong emission lines (Balmer series, HeII and [C III]/[N III]), which are clearly modulated on the proposed 17 h orbital period. These observations strongly support the black hole X-ray binary classification, as does the recent evidence for it entering a hard-to-soft X-ray transition state.

1. Introduction

Black hole X-ray binaries (BHXBs) are rarely detected astrophysical events which can provide information on accretion in the strong gravity regime and also about the stellar and binary evolution. The majority of known Galactic black holes reside in low-mass X-ray binaries. The low-mass black hole X-ray binaries (LBHXBs) are mainly characterized for the emission of X-rays from the accreted material close to the compact object and most of the optical emission in LBHXBs is expected to be from the accretion disk formed by the companion star.

MAXI J1820+070 was discovered by the Monitor of All-sky X-ray Image (MAXI) telescope on board the International Space Station on 11 March 2018 (Kawamuro et al. 2018) and identified as an outbursting low-mass X-ray binary in which the accreting object is a black hole (Baglio et al. 2018). For MAXI J1820+070, being a low-mass BHXB, the mass transfer take place via Roche lobe overflow. The system is located near to the Galactic plane at a distance of $\sim$ 3.3 kpc from the measured Gaia parallax (Gandhi et al. 2018; Kara et al. 2019) and it was observed to be an exceptionally bright source (>3.5 Crab) (Megumi et al. 2019). The orbital period of MAXI J1820+070 from photometry has been suggested to be ~17h (Patterson et al. 2018), although this could be a superhump period. Towards the end of March 2018 *Swift* has reported the detection of low-frequency QPOs at ~0.06 Hz (Wenfei et al. 2018) in the X-ray power spectra. The INTEGRAL has confirmed the presence of QPOs at 0.04 ± 0.01 Hz from the JEM-X monitor (Mereminskiy et al. 2018) and the observed shape of the power spectrum was typical of the low/hard

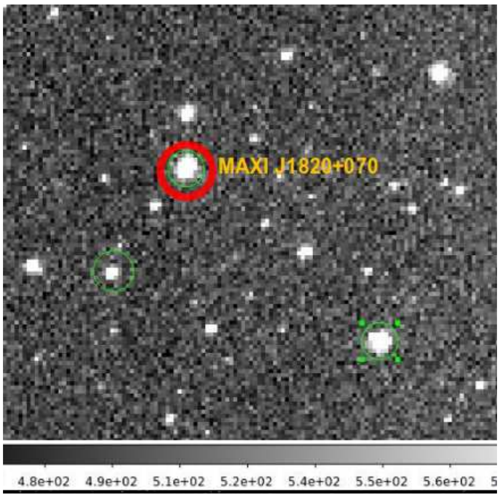

Fig. 1. The image of MAXI J1820+070 observed with SAAO 1m telescope with the SHOC CCD camera is shown in red circle.

or hard/intermediate states of black hole transients. NICER observations revealed that, following the initial hard state of its outburst, MAXI J1820+070 entered into the hard intermediate state in early July 2018 and then made a rapid transition towards a soft spectral state (Homan et al. 2018). The NICER observations revealed that the QPOs have increased in frequency from ~ 0.35 Hz on June 27 to ~ 3.0 Hz on July 5. MAXI, *Swift* and radio observations (Bright et al. 2018; Motta et al. 2018) indicate that the source transitioned towards a harder spectral state by the end of September 2018 and by the end of October 2018 MAXI 1820+070 has declined from the optical re-brightening following the soft to hard transition.

2. SALT and SAAO observations of MAXI J1820+070

Multi-wavelength observations of the target have been done by a number of space based telescopes and ground based telescopes. The optical observations of MAXI J1820+070 reported here have been done with Southern African Large Telescope (SALT) and other South African Astronomical Observatory (SAAO) telescopes from the time of its detection to the declination of its re-brightening towards end of September, over a time span of ~7 months. The spectroscopic and photometric analyses of these observations strongly support MAXI J1820+070 as a black hole X-ray binary.

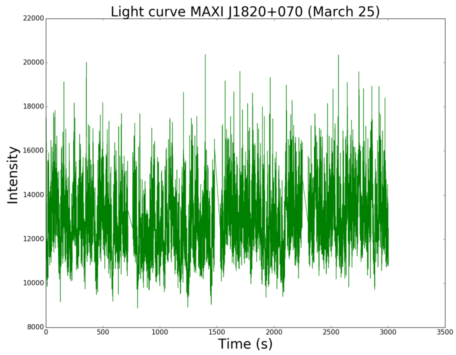

Fig. 2. The light curve of MAXI J1820+070 obtained with the SHOC camera on the SAAO 1m telescope on March 25, 2018.

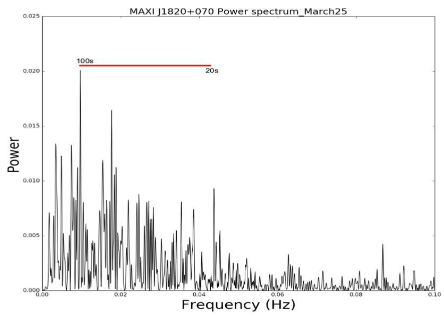

Fig. 3. The power spectrum with variability in the frequency range ~ 0.01- 0.2 Hz.

2.1. High speed photometry

The high speed photometry of the transient MAXI J1820+070 was done for 20 nights from March 25 to 29 September 2018 with the SHOC (Sutherland High Speed Optical Cameras) instrument on the SAAO

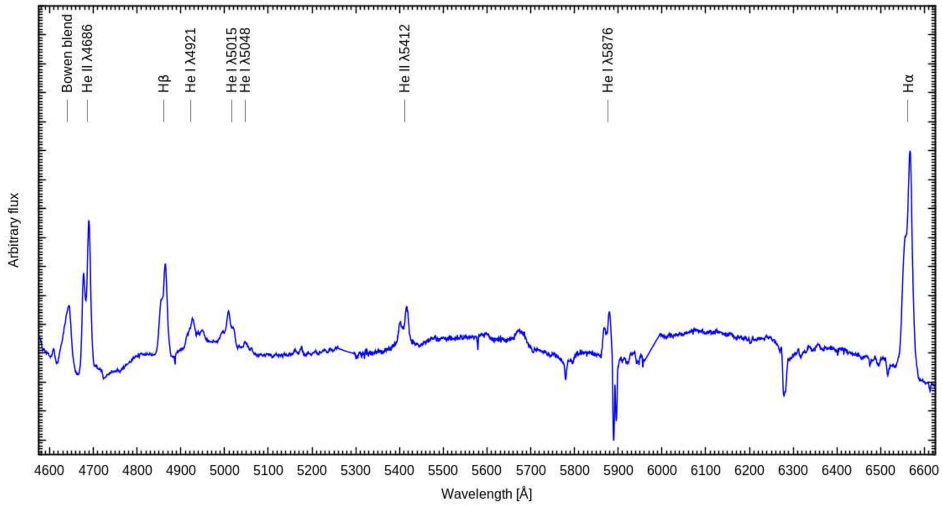

Fig. 4. SALT spectrum of MAXI J1820+070 observed on 12 May 2018.

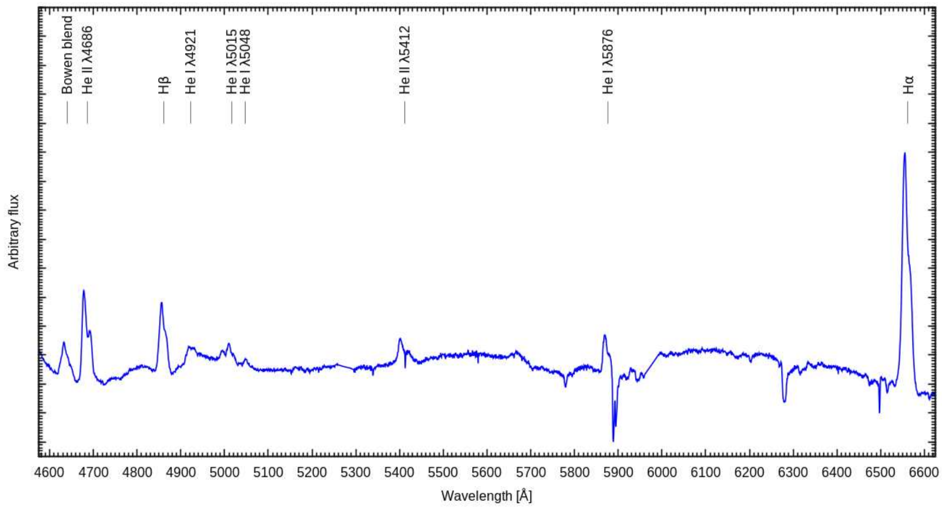

Fig. 5. SALT spectrum of MAXI J1820+070 observed on 13 May 2018.

1m telescope and SALT-RSS (Robert Stobie Spectrograph) slot mode photometry observations for 4 nights. Figure 1 shows the CCD image of MAXI J1820+070, which was a brightness in the order of ~13th magnitude. The most prominent characteristic of accreting systems, the fast timescale variability and the presence of quasi periodic oscillations (QPOs), are obvious in our observations. The variability observed in the target is noticeable in the light curve shown in figure 2 for the March 25 observation and the power spectrum in figure 3 shows the variability in the frequency range ~ 0.01- 0.2 Hz.

2.2. Spectroscopic observations with SALT

SALT spectroscopic observations of the transient were done for 5 nights from 22 April to 17 May 2018. The SALT spectra shows strong emission lines, the Balmer series, HeII and [C III]/[N III]. The visible double peaks in almost all the emission lines in figure 4 and 5 shows the motion of accretion disk towards us and away from us. Also, the velocity shifts over consecutive nights is consistent with the reported photometric period of ~17 hrs.

3. Summary

The high-speed photometric observations of MAXI J1820+070 show the variability in the transient target at characteristic timescale of $\sim 10^1$ to 10^2 s. SALT spectra have revealed strong emission lines, the Balmer series, HeII and the Bowen blend [C III]/[N III] from an accretion disk, which change in radial velocity. The motion of the accretion disk is in accordance with the changing ratio of the blue and red peaks of the double peaked emission lines. Also, the shift observed from night to night supports to claim of a ~ 17 hrs periodicity in the system, related to either an orbital or superhump period.

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