Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS 505, 713–725 (2021)
Advance Access publication 2021 May 10
doi:10.1093/mnras/stab1307

Broad-band spectral and timing properties of MAXI J1348–630 using *AstroSat* and *NICER* observations

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Accepted 2021 May 5. Received 2021 May 5; in original form 2021 January 11

ABSTRACT

We present broad-band X-ray spectral-timing analysis of the new Galactic X-ray transient MAXI J1348–630 using five simultaneous *AstroSat* and *NICER* observations. Spectral analysis using *AstroSat* data identify the source to be in the soft state for the first three observations and in a faint and bright hard state for the next two. Quasi-periodic oscillations at ∼0.9 and ∼6.9 Hz, belonging to the type-C and type-A class are detected. In the soft state, the power density spectra are substantially lower (by a factor >5) for the *NICER* (0.5–12 keV) band compared to the *AstroSat*/LAXPC (3–80 keV) one, confirming that the disc is significantly less variable than the Comptonization component. For the first time, energy-dependent fractional rms and time lag in the 0.5–80 keV energy band was measured at different Fourier frequencies, using the bright hard state observation. Hard time lag is detected for the bright hard state, while the faint one shows evidence for soft lag. A single-zone propagation model fits the LAXPC results in the energy band 3–80 keV with parameters similar to those obtained for Cygnus X–1 and MAXI J1820+070. Extending the model to lower energies, reveals qualitative similarities but having quantitative differences with the *NICER* results. These discrepancies could be because the *NICER* and *AstroSat* data are not strictly simultaneous and because the simple propagation model does not take into account disc emission. The results highlight the need for more joint coordinated observations of such systems by *NICER* and *AstroSat*.

Key words: accretion, accretion discs – black hole physics – X-rays: binaries – X-rays: individual (MAXI J1348–630).

1 INTRODUCTION

Black hole transients (BHTs) are usually discovered when they exhibit outbursts, which are characterized by distinct spectral and temporal states (see Remillard & McClintock 2006; Belloni, Motta & Muñoz-Darias 2011, for reviews). Based on the spectrotiming properties, four main states have been identified in BHTs: the hard state (HS), the soft state (SS), the hard and soft intermediate states (HIMS and SIMS). In the HS, the source is characterized by a hard spectrum with a typical photon index $\Gamma \sim 1.7$. The power density spectra (PDS) are dominated by strong broad-limited noise with typical root mean square (rms) values of ∼30 per cent (Belloni 2005) and occasionally exhibits type-C low-frequency quasi-periodic oscillations (LFQPOs) along with a sub-harmonic or second harmonic in the PDS. Type-C QPOs are characterized by a narrow peak with centroid frequency ranging from few mHz to ∼30 Hz (Remillard et al. 2002; Casella, Belloni & Stella 2005). The SS spectra are dominated by a thermal disc component and the variability amplitude reduces to a few percent. Weak QPOs with a frequency range of 6–8 Hz are sometimes detected in the SS, which belong to the so-called type-A category (Wijnands, Homan & van der Klis 1999; Casella et al. 2004; Motta et al. 2011; Motta 2016). In the HIMS and SIMS, the energy spectrum is a combination of soft and hard components, while the PDS contains type-C LFQPOs in HIMS and type-A and B in the SIMS.

From 1996 to 2012, the *Rossi X-ray Timing Explorer* (*RXTE*) was the workhorse in the field of rapid time variability of X-ray binaries. Now the Large Area X-ray Proportional Counter (LAXPC) onboard *AstroSat* has replaced *RXTE* and is contributing to the rapid time variability studies in the hard energy band. For example, *AstroSat* data have been used to study the spectral-timing properties of several black hole X-ray binaries, including Cygnus X–1 (Misra et al. 2017; Maqbool et al. 2019), Cygnus X–3 (Pahari et al. 2017), MAXI J1535–571 (Bhargava et al. 2019; Sreehari et al. 2019), Swift J1658.2–4242 (Jithesh et al. 2019), GRS 1915+105 (Belloni et al. 2019; Rawat et al. 2019; Misra et al. 2020; Sreehari et al. 2020), MAXI J1820+070 (Mudambi et al. 2020), and 4U 1630–472 (Baby et al. 2020). The soft X-ray (<4 keV) rapid timing properties of black hole X-ray binaries (BHXRBs) were largely unknown, which is now being explored using the X-ray Timing Instrument (XTI) onboard the Neutron star Interior Composition Explorer (*NICER*). *NICER* observations have provided unprecedented soft X-ray timing characteristics of several black hole systems, MAXI J1535–571 (Stevens et al. 2018; Stiele & Kong 2018) MAXI J1820+070 (Kara et al. 2019; Homan et al. 2020; Stiele & Kong 2020) and MAXI J1348–630 (Belloni et al. 2020; Zhang et al. 2020). However, broad-band (0.3–30 keV) fast timing properties of BHXRBs has been relatively less studied. There has been one such attempt to understand the broad-band spectral-timing behaviour of the transient BHXRB Swift J1658.2–4242 using simultaneous *Insight-HXMT*, *NICER*, and *AstroSat* observations (Xiao et al. 2019), where a QPO at ∼1.5 Hz was detected in all three satellites. The study further emphasizes the need for simultaneous

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