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Time resolved spectroscopy of a GRS 1915 + 105 flare during its unusual low state using *AstroSat*

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ABSTRACT

Since its discovery in 1992, GRS 1915 + 105 has been among the brightest sources in the X-ray sky. However, in early 2018, it dimmed significantly and has stayed in this faint state ever since. We report on *AstroSat* and *NuSTAR* observation of GRS 1915 + 105 in its unusual low/hard state during 2019 May. We performed time-resolved spectroscopy of the X-ray flares observed in this state and found that the spectra can be fitted well using highly ionized absorption models. We further show that the spectra can also be fitted using a highly relativistic reflection dominated model, where for the lamp post geometry, the X-ray emitting source is always very close to the central black hole. For both interpretations, the flare can be attributed to a change in the intrinsic flux, rather than dramatic variation in the absorption or geometry. These reflection dominated spectra are very similar to the reflection dominated spectra reported for active galactic nuclei in their low flux states.

Key words: accretion, accretion discs – stars: black holes – stars: flare – stars: individual: GRS 1915 + 105 – X-rays: binaries.

1 INTRODUCTION

Black hole (BH) X-ray binary (XRB) system consists of a BH and its companion which is a normal star, orbiting around their common centre of mass. The BH accretes matter from its companion via a geometrically thin, optically thick accretion disc (Novikov & Thorne 1973; Shakura & Sunyaev 1973). Depending on the mass of the companion, those having a less massive companion ($M \leq M_\odot$) usually accrete via Roche-lobe overflow and are referred as low mass X-ray binaries (LMXBs) while those having a more massive companion ($M > 10\ M_\odot$) usually accrete through stellar winds and are referred as high mass X-ray binaries (HMXBs; Petterson 1978; Blondin, Stevens & Kallman 1991; Liu, van Paradijs & van den Heuvel 2007; Tan 2021). The majority of BH-XRBs are observed as X-ray transients (Corral-Santana et al. 2016; Tetarenko et al. 2016) and most of them are LMXBs. LMXBs spend most of their lives in a quiescent state where there is a steady mass transfer from the companion onto the compact object. An increase in the temperature of the disc is believed to initiate thermal viscous instabilities that prompt a fast outflow of material from the companion onto the BH resulting in an X-ray outburst. (Shakura & Sunyaev 1976; Hameury, King & Lasota 1990). The outburst duration in a BH-XRB can range from several months to a few years. State changes are a common feature in BH-XRBs. During a typical outburst, they evolve in their spectral and timing properties, leading to the classification of various spectral states. (Remillard & McClintock 2006; Belloni & Motta 2016). Typically, an outburst begins with a low/hard state, progresses to a high/soft state, and ultimately reverts back to a low/hard state towards the end of the outburst. Intermediate states are often observed around the time of state transitions (Belloni et al. 2000).

Three main radiative components are often present in the X-ray spectrum of BH-XRBs. The black-body radiation from the accretion disc dominating the emission in the soft X-ray band (Shakura & Sunyaev 1973), power-law like component caused by inverse Compton scattering of the disc photons from the region near the central BH, typically referred to as *corona*, dominating the emission in the hard X-ray band (Shakura & Sunyaev 1976; Sunyaev & Titarchuk 1980; Lightman & Zdziarski 1987). The lower and upper cutoffs of this power-law component is determined by the temperature of the seed photons and electrons, respectively. The third component arises due to the fraction of the coronal photons irradiating the disc and being scattered into our line of sight. These photons are reprocessed in the disc's atmosphere and produce reflection spectrum with characteristic features. The scattering produces a broad Compton hump peaking around ~20–30 keV (Lightman & White 1988; Fabian et al. 1989) and many spectral lines, the strongest being a broad emission line at ~6.4 keV due to iron (George & Fabian 1991; Ross & Fabian 2005). The line profile is set by special and general relativistic effects.

GRS 1915 + 105 is among one of the most well studied BH-XRBs, discovered in 1992 as an X-ray transient with the *WATCH* instrument onboard International Astrophysical Observatory *'GRANAT'* (Castro-Tirado, Brandt & Lund 1992). GRS 1915 + 105 hosts a BH of mass $12.5^{+2.0}_{-1.8}\ M_\odot$, located at radio parallax distance of $8.6^{+2.0}_{-1.6}$ kpc with disc inclination of 60° (Reid et al. 2014). GRS 1915 + 105

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