# Spectral Analysis of the Black Hole X-Ray Binary Maxi J1820+070 Using Astrosat/SXT Observations

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## ABSTRACT

MAXI J1820+070 is one of the brightest Galactic black hole X-ray transients discovered in recent years and has been extensively studied because of its remarkable spectral and timing behaviour. In the present work, we present timing (light-curve) and spectral analyses of MAXI J1820+070 using archival observations obtained with the Soft X-ray Telescope (SXT) onboard AstroSat. The analysis is based on a combined effective exposure of approximately 12 ks obtained from multiple orbital segments corresponding to Observation ID A05_142T01_9000002904. The source light curve exhibits significant variability, indicating active accretion processes around the compact object. Spectral fitting was performed in the 0.7–7.0 keV energy range using the model TBabs × (diskbb + powerlaw). The best-fit parameters are NH = $0.15 \times 10^{22}$ $cm^{-2}$ (fixed), inner disk temperature Tin = $0.145 \pm 0.011$ keV, and photon index $\Gamma = 0.94 \pm 0.15$. The fit yields $\chi^2 = 59.39$ for 38 degrees of freedom (reduced $\chi^2 = 1.56$), indicating an acceptable fit to the observed spectrum. The results indicate the presence of a relatively cool accretion disk together with a dominant hard X-ray component, suggesting that coronal emission contributes significantly to the observed X-ray spectrum. The observed variability and spectral characteristics are consistent with an active accretion state during the observation. These findings provide insight into the accretion geometry and X-ray emission mechanisms operating in MAXI J1820+070.

**Keywords:** AstroSat, SXT, MAXI J1820+070, Black Hole X-ray Binary, X-ray Spectroscopy, Accretion Disk

## INTRODUCTION

Black hole X-ray binaries (BHXBs) are among the most important laboratories for studying accretion physics under extreme gravitational conditions (Frank, King & Raine, 2002; Remillard & McClintock, 2006). In these systems, matter is transferred from a companion star onto a stellar-mass black hole through an accretion disk. The release of gravitational potential energy produces intense X-ray radiation, allowing the physical properties of the accretion flow to be investigated. Owing to their strong gravitational fields and rapid variability, BHXBs provide a unique opportunity to study the behaviour of matter under extreme physical conditions and to test theoretical models of accretion and radiation processes.

The observed X-ray spectrum of black hole binaries generally consists of two major components. The first is a thermal component originating from the optically thick accretion disk, while the second is a non-thermal component produced by inverse Compton scattering of soft photons by energetic electrons in a hot corona located near the compact object (Done, Gierliński & Kubota, 2007). The relative strengths of these components vary according to the accretion state of the source and provide important information regarding the structure and evolution of the accretion flow. The interaction between the accretion disk and the corona plays a crucial role in determining the spectral and timing properties of black hole systems.

Black hole X-ray binaries exhibit a variety of spectral states during their evolution, commonly classified as hard, soft and intermediate states (Remillard & McClintock, 2006; Belloni, Motta & Muñoz-Darias, 2011).

These states are believed to be associated with changes in the mass accretion rate and the geometry of the accretion flow. In the hard state, the X-ray spectrum is dominated by a power-law component generated through Comptonization in a hot corona, whereas the soft state is characterized by strong thermal emission from the accretion disk (Zdziarski & Gierliński, 2004). The study of spectral variability and state transitions therefore provides valuable information about the physical mechanisms governing accretion onto black holes.

MAXI J1820+070 was discovered on 11 March 2018 by the Monitor of All-sky X-ray image (MAXI) mission and was subsequently identified as a black hole X-ray binary candidate (Tucker et al., 2018). During its outburst, the source displayed remarkable spectral and temporal variability across multiple wavelengths, making it one of the most extensively studied Galactic X-ray transients in recent years. Multi-wavelength investigations revealed strong disk-corona interactions, rapid X-ray variability, jet activity and significant spectral state transitions during the outburst evolution (Buisson et al., 2019; Shidatsu et al., 2019; Kara et al., 2019; Fabian et al., 2020). MAXI J1820+070 is considered one of the most extensively monitored black hole transients of the modern era. Observations from X-ray, optical, radio and infrared facilities have revealed complex variability patterns, evolving disk-corona geometry and powerful jet ejections, making the source an excellent target for investigating accretion processes and spectral evolution in black hole X-ray binaries.

AstroSat, India's first dedicated multi-wavelength astronomy satellite, provides unique capabilities for studying accreting compact objects across a broad energy range (Singh et al., 2014). The Soft X-ray Telescope (SXT) onboard AstroSat is a focusing X-ray telescope operating in the soft X-ray energy range of approximately 0.3–8.0 keV. The instrument employs grazing-incidence optics and a CCD detector to provide imaging as well as spectroscopic capabilities. Its moderate spectral resolution and wide energy coverage make it particularly suitable for investigating thermal emission from accretion disks, absorption features and soft X-ray spectral components in compact accreting systems (Singh et al., 2017). By combining timing and spectral analyses, SXT observations can be used to probe the physical conditions of the accretion flow and the relative contributions of the disk and corona to the observed X-ray emission.

In the present work, we present timing and spectral analyses of MAXI J1820+070 using archival AstroSat/SXT observations. The objective of this study is to investigate the X-ray variability, determine the spectral characteristics of the source in the 0.7–7.0 keV energy range, and explore the nature of the accretion processes responsible for the observed emission. The results contribute to our understanding of disk-corona interactions, accretion geometry and the spectral behaviour of accreting black hole systems.

**Observation And Data Reduction**

The data used in this study were obtained from the Indian Space Science Data Centre (ISSDC). MAXI J1820+070 was observed with the Soft X-ray Telescope (SXT) onboard AstroSat in Photon Counting (PC) mode on 10May2019 under Observation ID A05_142T01_9000002904. The total effective exposure used for the present analysis is approximately 12 ks. Spectral analysis was performed in the 0.7–7.0 keV energy range, which provides reliable calibration and adequate photon statistics for investigating the spectral properties of the source.

The level-2 data products consist of several orbital segments corresponding to different AstroSat orbits. Although multiple datasets are present, all belong to the same observation ID and represent different segments of a single observation. These segments were combined to maximize photon statistics and improve the signal-to-noise ratio (S/N) for timing and spectral analyses.

Table 1. AstroSat/SXT observation of MAXI J1820+070 used in this study

| **S.No.** | **Observation ID** | **Orbital No.** | **Date of Observation** |
|---|---|---|---|
| 1 | A05_142T01_9000002904 | 19538 | 10-May-2019 |
| 2 | A05_142T01_9000002904 | 19539 | 10-May-2019 |
| 3 | A05_142T01_9000002904 | 19540 | 10-May-2019 |

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| | | | |
|---|---|---|---|
| 4 | A05_142T01_9000002904 | 19541 | 10-May-2019 |
| 5 | A05_142T01_9000002904 | 19542 | 10-May-2019 |
| 6 | A05_142T01_9000002904 | 19543 | 10-May-2019 |
| 7 | A05_142T01_9000002904 | 19544 | 10-May-2019 |
| 8 | A05_142T01_9000002904 | 19545 | 10-May-2019 |

The observation consists of eight individual orbital segments belonging to the same Observation ID. These segments were merged to obtain a total effective exposure of approximately 12 ks, thereby improving the statistical quality of the extracted light curve and energy spectrum.

The level-2 cleaned event files provided by the AstroSat Science Support Cell were used for further analysis. Source events were extracted from the cleaned event files, while the standard background files supplied by the SXT team were used for background subtraction. The corresponding response matrix file (RMF) and ancillary response file (ARF) were generated using the latest calibration database (CALDB). The extracted spectrum was grouped to ensure adequate photon statistics in each spectral bin before spectral fitting.

Spectral analysis was carried out using XSPEC version 12 (Arnaud, 1996). The fitting was restricted to the 0.7–7.0 keV energy range, where the calibration of the SXT instrument is well established and the signal-to-noise ratio is optimal for spectral studies.

**Timing Analysis**

Timing analysis was performed using the cleaned event files. A background-subtracted light curve was extracted with a time bin size of 50 seconds.

The resulting light curve, shown in Figure 1, exhibits significant variability throughout the observation. Several intensity fluctuations and short-term variations are visible, indicating changes in the accretion flow around the black hole. Such variability is commonly observed in black hole X-ray binaries and is often associated with variations in the disk-corona system. The presence of gaps in the light curve is due to the segmented nature of AstroSat observations. These interruptions arise from Earth occultation and satellite orbital constraints and are a normal characteristic of low-Earth orbit X-ray missions.

As shown in Figure 1, the source displays continuous intensity variations during the observation, suggesting that MAXI J1820+070 remained dynamically active with ongoing changes occurring in the inner accretion environment.

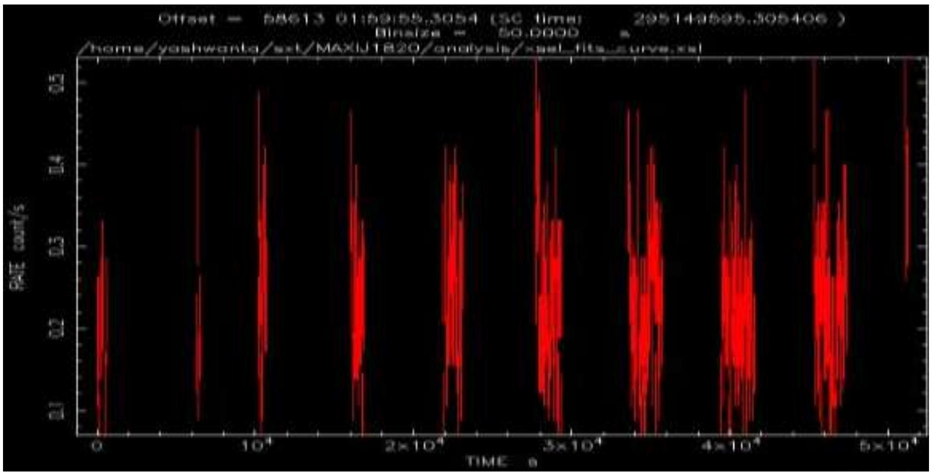


Figure 1. Background-subtracted AstroSat/SXT light curve of MAXI J1820+070 extracted with a time bin size of 50 s. The light curve shows significant variability throughout the observation, indicating active accretion processes in the source.

**Spectral Analysis**

The source spectrum was analyzed using XSPEC version 12 (Arnaud, 1996). Spectral fitting was restricted to the 0.7–7.0 keV energy range to avoid calibration uncertainties at the lowest and highest energies and to ensure reliable spectral modelling.

Initially, the extracted source spectrum was inspected to evaluate the count distribution as a function of detector channel. The spectrum exhibits a gradual decline in count rate with increasing energy, indicating that the majority of photons are concentrated in the soft X-ray band. Such behaviour is commonly observed in accreting black hole systems where both thermal disk emission and high-energy coronal emission contribute to the observed spectrum. The raw spectrum provides an initial indication of the spectral shape before model fitting.

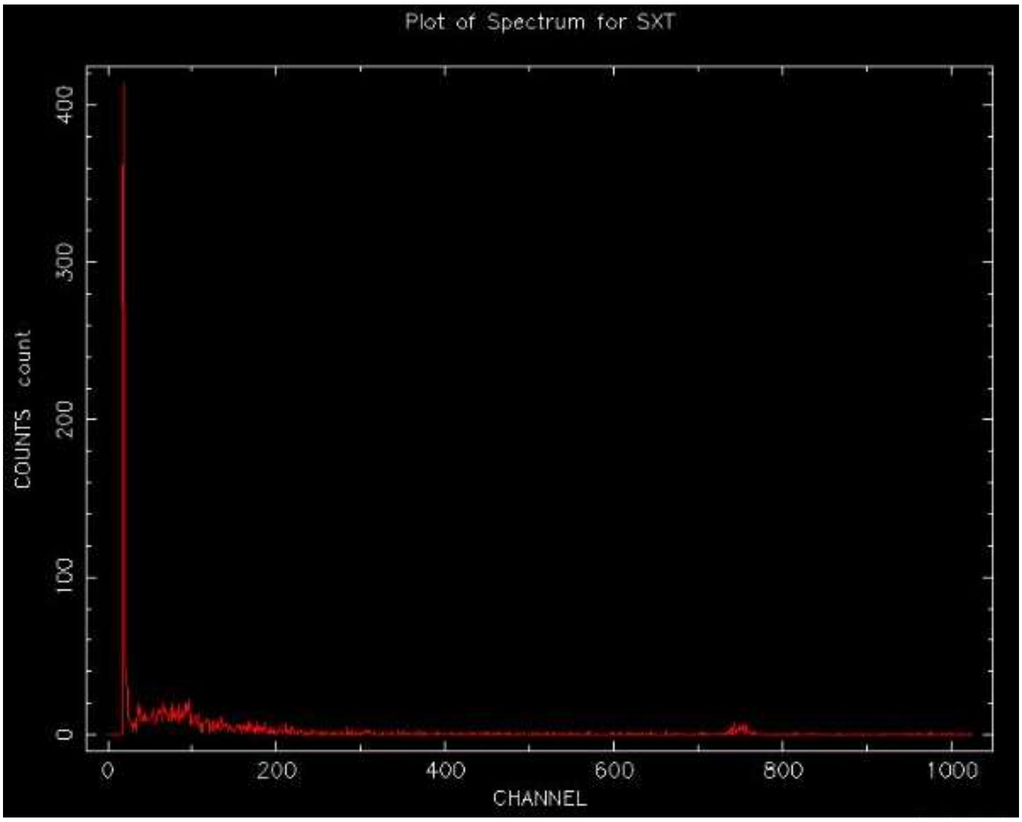


Figure 2. Source spectrum of MAXI J1820+070 showing count distribution as a function of detector channel prior to spectral fitting.

**Spectral Fitting**

The spectral fitting was performed using the model TBabs × (diskbb + powerlaw), where TBabs accounts for interstellar photoelectric absorption along the line of sight (Wilms et al., 2000), diskbb represents multi-temperature blackbody emission originating from the geometrically thin and optically thick accretion disk (Mitsuda et al., 1984), and the powerlaw component describes non-thermal Comptonized emission produced in a hot corona surrounding the compact object (Done, Gierliński & Kubota, 2007). This phenomenological model is widely used to investigate the spectral properties of black hole X-ray binaries and to estimate the relative contribution of thermal and non-thermal emission components.

The best-fit model successfully reproduces the overall spectral shape and provides an acceptable description of the observed spectrum. The spectrum and residual distribution indicate that the adopted model adequately represents the observed data. Most residuals remain within acceptable statistical limits across the fitted energy range, suggesting that the major spectral features are reasonably described by the model.

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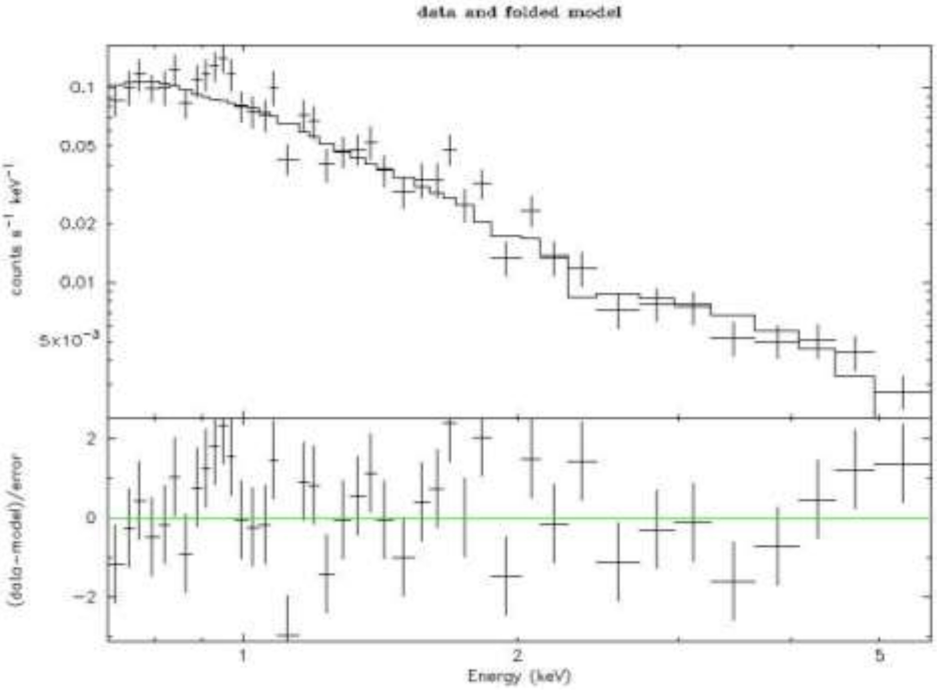


Figure 3. AstroSat/SXT spectrum fitted with the model TBabs × (diskbb + powerlaw) in the 0.7–7.0 keV energy range. The lower panel shows the fit residuals.

Table 2. Best-fit Spectral Parameters and Fit Statistics

| **Component** | **Parameter** | **Unit** | **Best-fit value** |
|---|---|---|---|
| TBabs | NH (fixed) | $10^{22}$ cm$^{-2}$ | 0.15 |
| diskbb | Tin | keV | 0.145 ± 0.011 |
| diskbb | Normalization | _ | 3569.88 ± 1922.35 |
| powerlaw | Photon Index (Γ) | _ | 0.94 ± 0.15 |
| powerlaw | Normalization | Photons keV$^{-1}$ cm$^{-2}$ s$^{-1}$ | $(6.61 \pm 1.04) \times 10^{-4}$ |
| Fit | $\chi^2$ /dof | _ | 59.39/38 |
| Fit | Reduced $\chi^2$ | _ | 1.56 |

The best-fit spectral parameters indicate the presence of both thermal and non-thermal emission components. The fitted disk temperature of approximately 0.145 keV suggests a relatively cool accretion disk, while the power-law component contributes significantly to the observed X-ray emission. The obtained photon index and the dominance of the power-law component indicate the importance of coronal emission in shaping the observed spectrum. The reduced $\chi^2$ value of 1.56 indicates an acceptable fit to the observed data, supporting the suitability of the adopted model for describing the spectral characteristics of MAXI J1820+070 during the observation.

## RESULTS AND DISCUSSION

The spectral analysis reveals the presence of both thermal and non-thermal emission components. The derived disk temperature of approximately 0.145 keV indicates a relatively cool accretion disk. Such low temperatures are typically associated with weak disk emission or a disk whose inner regions contribute only modestly to the observed soft X-ray spectrum.

The power-law component dominates the observed spectrum, indicating that Comptonized emission from a hot corona contributes significantly to the observed X-ray flux. Similar spectral behaviour has been reported in previous studies of MAXI J1820+070 during phases where coronal emission was prominent (Buisson et al., 2019; Fabian et al., 2020). The photon index obtained from spectral fitting ($\Gamma \approx 0.94$) indicates a very hard X-ray spectrum. However, the limited energy range (0.7–7.0 keV) used in the present analysis prevents a definitive spectral state classification.

The timing analysis supports this interpretation. The strong variability observed in the light curve suggests rapid changes in the accretion flow and coronal activity. Variability of this type is commonly observed in black hole X-ray binaries and is often linked to fluctuations in the inner accretion region and dynamic disk-corona interactions.

The spectrum and residual distribution demonstrate that the adopted model provides a reasonable representation of the observed data. Most residuals remain within acceptable statistical limits, indicating that the overall spectral shape is adequately described by the chosen model. The reduced $\chi^2$ value of approximately 1.56 suggests an acceptable fit to the observed spectrum.

The combined timing and spectral results indicate that the source was observed during a phase in which coronal emission dominated the X-ray output while the thermal disk contribution remained comparatively weak. These findings are consistent with scenarios in which a significant fraction of the accretion power is released through Comptonization processes in the corona rather than through thermal emission from the accretion disk.

The obtained spectral properties are broadly consistent with previous studies of MAXI J1820+070. The present work is primarily focused on AstroSat/SXT spectral analysis; therefore, only light-curve variability was investigated, while detailed timing analyses such as PDS and QPO searches were beyond the scope of this study.

## CONCLUSION

We have performed timing and spectral analysis of the black hole X-ray binary MAXI J1820+070 using AstroSat/SXT observations obtained on 10 May 2019. The analysis was based on approximately 12 ks of effective exposure obtained by combining multiple orbital segments belonging to the same observation. The light curve exhibits strong variability, indicating active accretion processes around the black hole. Spectral fitting in the 0.7– 7.0 keV energy range using the model TBabs × (diskbb + powerlaw) yields a cool disk temperature (Tin ≈ 0.145 keV) and a dominant hard power-law component ($\Gamma \approx 0.94$). The fit is statistically acceptable with $\chi^2 = 59.39$ for 38 degrees of freedom (reduced $\chi^2 = 1.56$).

The results indicate that the observed X-ray emission is dominated primarily by coronal processes, while the thermal contribution from the accretion disk appears comparatively weak within the analysed energy range. However, owing to the limited SXT energy coverage (0.7 —7.0 keV), a definitive spectral state classification cannot be established from the present analysis alone.

The present study demonstrates the capability of AstroSat/SXT to investigate the spectral behaviour of transient black hole X-ray binaries. The timing and spectral characteristics obtained for MAXI J1820+070 indicate the presence of a cool accretion disk together with a dominant hard X-ray component originating from a hot corona. Future broadband studies combining SXT, LAXPC and CZTI observations, together with advanced spectral models, are expected to provide a more comprehensive understanding of the accretion geometry, spectral evolution and state transitions in this source.

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