Spectral and timing properties of black-hole low-mass X-ray binaries

Alabarta Jativa, Kevin

DOI:
10.33612/diss.194779577

Publication date:
2021

6 Thesis summary and future prospects

You want to know how I did it? This is how I did it, Anton:
I never saved anything for the swim back
– Vincent Freeman, Gattaca –

6.1 Conclusions chapter by chapter

In this thesis, we focus on the study of the spectral and timing properties of BH LMXBs. In the following paragraphs, we summarise the main results of each chapter:

- **Chapter 2. Failed-Transition outbursts in Black hole low-mass X-ray binaries**

  In this chapter, we studied the observational differences between full and FT outbursts in X-rays and O/IR wavelengths. Using a sample of 56 BH LMXBs undergoing 128 outbursts, we found that 36% of these BH systems underwent at least one FT outburst and that 33% of the outbursts of the sample are FT outbursts. From all the available data from *RXTE*/PCA, *Swift*/BAT and MAXI, we found that full and FT outbursts cannot be distinguished from their X-ray light curves, HIDs and variability in the first 10–60 days of the outburst. This result suggests that FT and full outbursts are driven by the same physical mechanism. A potential interpretation for this result is that, during FT outbursts, the outer part of the accretion disc is more massive than the inner part, preventing the source to start a state transition. We studied the O/IR data of FT and full outbursts of GX 339–4 and found that this BH system is brighter before the onset of an FT outburst. One possibility is that the mass accretion rate is higher before the onset of an FT outburst or that the size of the O/IR emission regions is different for FT and full outbursts. We also found that the O/IR light curves of the FT outbursts of GX 339–4 are similar to those corresponding to inside-out outbursts.

- **Chapter 3. X-ray Spectral and Timing evolution of MAXI J1727–203 with *NICER***

  In this chapter, we studied the evolution of the spectral and timing properties of the BH system MAXI J1727–203 during its 2018 outbursts using *NICER* data. By studying the energy spectra in the 0.3–10 keV, we found two spectral components: a soft thermal and a hard Comptonised component. The contribution of these components to the energy spectra shows that the source evolved through all the spectral states typical of BH LMXBs. We found that the soft (disc) component was detected almost until the end of the outburst with temperatures from $\sim$0.4 keV in the HSS to $\sim$0.1 keV in the LHS near the end of the outburst. The power spectra in the LHS and intermediate states show broadband noise up to 20 Hz without the presence of QPOs. The broadband fractional rms amplitude increases with energy except in the LHS, where it remains constant with energy, suggesting that the variability is produced in the corona. For the first time, we studied the energy dependence of the fractional rms of the broadband noise at energies below 2–3 keV and found that the fractional rms follows the same trend as at higher energies. The evolution of the spectral and timing properties of MAXI J1727–203 was very similar to that observed in other BH systems, suggesting that the compact object in this system is a BH.

- **Chapter 4. A NICER look at the state transitions of the black hole candidate MAXI J1535–571 during its reflares**

  In this chapter, we studied the spectral and timing properties of the reflares of the BH LMXB MAXI J1535–571 during its 2017 outburst using *NICER* data. We found that the source underwent state transitions during the reflares that were observed in the hysteresis loops on the evolution diagrams and the spectral parameters. These results show that MAXI J1535–571 evolved through all the spectral states during the reflares. If we take the most probable distance to this source of 4 kpc, we found that the luminosities at which the state transitions occurred in the reflares of this BH system are the lowest luminosities for a state transition ever reported. The similarities between the evolution of the spectral and timing properties of the reflare and the main outburst of MAXI J1535–571 suggest that both the reflares and outbursts are driven by the same physical mechanisms.

- **Chapter 5. Variability and phase lags of type-C quasi-periodic oscillations of MAXI J1348–630 with *NICER***

  In this chapter, we studied the timing properties of the type-C QPOs that were observed during the 2019 outburst and its first reflare of MAXI J1348–630. This is the first time that type-C QPOs are studied during a reflare and we found that the properties of the type-C QPOs during the reflare are similar to those at full outbursts in other BH LMXBs. This result supports the idea that both outbursts and reflares are driven by the same physical mechanism. Moreover, we studied the energy dependence of the fractional rms amplitude and phase lags of the type-C QPOs and found that both increase with energy. This behaviour can be explained in terms of Comptonisation.

6.2 Future prospects

Fortunately, the completion of this thesis does not represent the end of the road for the study of the spectral and timing properties of BH LMXBs. On the contrary, all the projects presented here are the starting point for new studies that will go deeper in the understanding of the physical mechanisms driving BH LMXBs.

In the upcoming years, we will continue studying the observational differences between full and FT outbursts. We have already planned three lines of research. The first one will be the study of the optical data of FT and full outbursts during quiescence. As we present in Chapter 2, GX 339–4 was brighter in O/IR wavelengths before the onset of an FT outburst than before a full outburst. We will work with data from the LCO telescopes (of both new and old outbursts) to go deep in the difference between FT and full outbursts in optical wavelengths during quiescence. The second line of research will be the study of the difference in the energy dependence of the fractional rms amplitude and phase lags of type-C QPOs observed during FT and full outbursts. In order to do that, we will fit the rms and lags spectra with the model proposed by Karpouzas et al. (2020). This will allow us to study the evolution of the properties of the corona in full and FT outbursts and see if there is any difference between them. Finally, we will extend our study of FT and full outbursts to neutron star low-mass X-ray binaries.

In Chapter 5 we studied the energy dependence of the fractional rms amplitude and the phase lags of type-C QPOs of MAXI J1348–630. Based on the shape of both the rms and lag spectra, Comptonisation appears as the most probable radiative origin of type-C QPOs. The next step will be to fit the rms spectra and the lag spectra with the model developed by Karpouzas et al. (2020) to study the evolution of the coronal properties during the reflare.

Finally, thanks to *NICER* capabilities, in chapters 3 and 4, we have been able to detect the disc component at energies below 0.5 keV for MAXI J1727–203 and MAXI J1535–571, respectively. The fact that the emission from the disc component could be detected at low luminosities during the LHS at almost the end of the outburst offers the opportunity to study the truncation of the accretion disc in the LHS directly from the emission of the accretion disc. In the near future, we will study the X-ray properties with *NICER* of BH LMXBs during the LHS (both at the rise and the decay of the outburst) to estimate the truncation radius of the accretion disc. This study has the potential to break the degeneracy between the different models of the geometry of the accretion disc.