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Report on Marta Aleksandra Dziełak's doctoral dissertation

In her PhD dissertation Marta Dziełak adresses the issue of the structure and geometry of the accretion flow onto black holes in X-ray binaries. Her methodology is based on a detailed comparison of X-ray observations to physical models.

Indeed, the study of the X-ray emission from these systems informs us on fundamental accretion processes that are expected to operate similarly in a wide range of astrophysical objects, including accreting supermassive black holes in Active Galactic Nuclei (AGN). The advantage of X-ray binaries is that they are usually much easier to observe and study than AGN owing to their much shorter distances and variability time-scales.

The question of the geometry of the accretion flow onto a black hole is a longstanding problem that has been the subject of intense controversies for many years.

The main question is to decide whether the non-thermal X-ray emission observed in the so-called 'hard' spectral state arises from:

- a 'lamppost' located at some height above an accretion disc which extends close to the black hole down to the Innermost Stable Circuler Orbit (ISCO), or
- some form of hot accretion flow surrounded by a standard 'cold' accretion disc. The truncation radius which marks the transition between hot and cold accretion would then be located at distances significantly larger than the ISCO and would vary together with the evolution of the X-ray luminosity of the source.

Different authors analysing the same data sets have repeatedly reached very different conclusions. In her works, Marta Dziełak revisits these data and models with a very rigorous and systematic approach. She fits spectral data consistently and uniformly with the different spectral models that are currently available. She also applies innovative and powerful spectral-timing techniques that allow her to extract additional information from the fast variability properties of theses sources. She shows that despite the model degeneracies, once one takes into account all the available information, the truncated disc plus hot flow scenario is strongly favoured. Moreover her detailed modelling allows to infer some more stratification in the properties of the accretion flow: several emitting zones with different properties are required. Her timing analysis allows her to constrain this complex structure.

The dissertation is presented in the form of a thematically consistent collection of articles published in scientific journals. It starts with a broad introduction of the subject. This part, which is both concise and to the point is followed by three published papers.

The first paper is entitled 'Comparison of spectral models for disc truncation in the hard state of GX 339–4' and was published in the Monthly Notices of the Royal Astronomical Society (MNRAS), Marta Dziełak is the lead author. It presents the spectral analysis of a spectrum obtained by averaging 4 observations, made with the RXTE/PCA instrument, of the prototypical X-ray binary GX 339-4 in the bright hard state. Marta Dziełak compares 6 different models to this data set and estimate their relative statistical likelihood. She finds that the statistically and physically favoured model requires the disc to be truncated.

The second paper is entitled 'Accretion Geometry in the Hard State of the Black Hole X-Ray Binary MAXI J1820+070'. It is published in the Astrophysical Journal with Marta Dziełak as second author. It focusses on the hard X-ray spectra obtained with the NuSTAR telescope during 4 observations of the source MAXI J1820+070. This source is interesting because all previous spectral and timing studies had favoured lamppost-like geometries and disc extending close to ISCO. This study confirms that such models are formally consistent with the observed spectra, but it also points out that they require the system to be observed with a low inclination angle which is inconsistent with the independent measurements of large jet and orbital plane inclinations. On the other hand, it shows that a model involving at least two distinct Comptonizing regions and a truncated disc geometry would be consistent with the observed large inclination. It proposes a scenario involving a truncated flared disc observed at large inclination, a central hot flow producing hard X-ray emission, and a warm corona covering the inner parts of the truncated disc and producing a softer Comptonization component. Such a geometry can explain the puzzling spectral properties exhibited by this source and how they evolve during the hard state.

The third paper is entitled 'A spectrally stratified hot accretion flow in the hard state of MAXI J1820+070'. It was published In MNRAS with Marta Dziełak as lead author. In this paper, Marta Dziełak uses NICER spectral-timing observations of MAXI J1820+070 and explores the constraints brought by the fast variability of the source. She fitted the X-ray power spectra in terms of a sum of Lorentzians functions and then extracted the energy spectrum of each of these Lorentzians. The Lorentzian energy spectra where simultaneously fitted with disc and Comptonization models. This allowed her to confirm that the accretion flow of MAXI J1820+70 is stratified and to refine the geometrical scenario already outlined in paper II. The stratified hot flow surrounded by a truncated accretion disc can therefore explain both the time average spectra and the fast rms variability properties of this source.

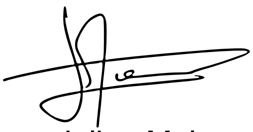
All these findings are of course interesting and relevant. Marta Dziełak has accumulated very convincing evidence in favour of a stratified hot accretion flow in a truncated disc geometry. Only time will tell if this definitely closes the controversy on the geometry of accretion flows around accreting black holes X-ray binaries in hard state.

Besides the important results, the articles also demonstrate that Marta Dziełak has mastered complex data reduction and analysis techniques of various X-ray instruments, and has an excellent understanding of the physical processes and current theoretical models. Such a breadth of skills is rare at PhD level and should be noted.

Finally, the papers are very clear and nicely written, the relevant literature is adequately referenced and the results are critically discussed.

Summing up, thanks to her methodical approach combining both spectral and timing information, Marta Dziełak managed to make substantial progress on an old problem. I therefore consider the doctoral thesis of Marta Aleksandra Dziełak to be a valuable contribution and to meet the criteria prescribed by the law for a doctoral dissertation. Therefore, I request that this dissertation be admitted to a public defense.

Toulouse, 15 November 2021,



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