Astronomický ústav AV ČR

Faculty of Mathematics and Physics
Charles University

Doctoral Thesis: **Evolution of Accreting Black Holes in X-ray Binaries**
M.Sc. **Anastasiya Yilmaz**

Thesis Supervisor: RNDr. Jiří Svoboda, PhD.

**Supervisor's report:**

The Thesis aims at the study of the evolution of accreting stellar-mast compact objects. The main part of the project consists in a comprehensive data analysis of a rich data set of X-ray spectra of two accreting black holes, GRO J1655-40 and LMC X-3, obtained with the RXTE X-ray mission. All the archival data were completely re-analyzed with the most recent calibration tools and spectra fitted with models including the thermal emission of the accretion disc and the Comptonisation component originating in the X-ray corona. The main focus was given on a comparison of the resulting spectral fitting parameters with the standardly-used non-relativistic models (such as *diskbb*) and more advanced fully-relativistic models. The different relativistic models were compared – the *kerrbb* model developed at MIT and the *kynbb* model developed at the Astronomical Institute. The latter model allows for the variable inner disc radius, providing an additional free parameter to the model. The analysis showed that the inner disc radius estimated from the normalization in the non-relativistic model is systematically offset and also corresponding maximum temperature is lower than the temperature peak derived from the relativistic model. One of the main goals of the project was the study of the luminosity – temperature relation, which was found to deviate from the standard relation at low luminosities with the non-relativistic models. Including the relativistic effects was not sufficient to explain this deviation. However, releasing the parameter for the inner radius in the *kynbb* model significantly decreased the measured deviations. The results were published in an extended research paper, published in a highly-ranked astronomical journal, *MNRAS*.

The second research part deals with the timing and spectral analysis of a newly discovered transient in a nearby galaxy M51. This galaxy has quite a rich ongoing star formation with several ultraluminous X-ray sources (ULXs) reported within the galaxy. ULXs are rather rare sources with a very high X-ray luminosity that can be best explained by the super-Eddington accretion on a black hole or a neutron star. The new transient reached the X-ray luminosity closely approaching the limit for the source classification as the ULX and based on the archival observations, the significant detection is limited only to a relatively short period, during which the source got into an outburst. Different physical interpretations of the source nature are discussed in the Thesis, with the most likely hypothesis pointing towards a highly

accreting stellar-mass black hole or neutron star. The results are ready for submission to the scientific journal.

During the PhD project, Anastasiya acquired the necessary skills to apply advanced analysis techniques (including Bayesian fitting methods) as well as to work with large data sets and thus perform the analysis in an automatized way with the PyXSPEC scripts. The Thesis is well structured. The first chapter contains a comprehensive introduction to the field. The following chapter describes the data reduction with different X-ray satellites and spectral analysis techniques. The other two parts contain the above-mentioned scientific results. The last chapter provides the final discussion and conclusions. The entire Thesis is also nicely enhanced by her own graphical images. Apart from the research presented in this Thesis, Anastasiya also significantly contributed to two additional scientific papers – one focused on the X-ray spectro-polarimetry analysis of LMC X-3 and the other on the application of a newly developed puffy-disc model on X-ray spectra.

In conclusion, the Thesis fulfills all the requirements put on the Doctoral Thesis at Charles University and I recommend it to be accepted to the PhD Thesis defense.

In Prague, on 19th of August 2024

**RNDr. Jiří Svoboda, PhD.**
Astronomical Institute of the Czech Academy of Sciences