Report on the PhD Dissertation

High-frequency Quasi-Periodic Oscillations and Their Modulation by Relativisti Effects

Michal Bursa

The presented dissertation is a study of some aspects of high-frequency quasi-periodic oscillations observed in X-ray radiation coming from accreting neutron-star and black-hole binary systems, and can be separated into two parts. The first part (Chapters 1,2) is concentrated onto the observational phenomena related to kHz QPOs observed in black hole and neutron-star binary system and their interpretation in terms of the orbit resonance model developed by M. Abramowicz, W. Kluzniak and their collaborators. The second part (Chapters 3,4) concerns some theoretical models explaining the kHz QPOs in terms of the orbital resonance model, with attention being focused on the general relativistic phenomena modulating radiation of an oscillating torus in vicinity of the central object.

In the case of neutron stars, it is shown that frequencies of the twin-peak oscillations are remarkably correlated among all the observed sources and that this correlation can be described by a linear function. The same is valid if the sources are considered individually, when linear fits usually describe the individual frequency correlations with high accuracy. Then it is shown that the parameters of the linear fits, the slope and the shift, are anti-correlated, which means the source lines intersect close to a single point in the frequency-frequency plot. This point, notably, lies at the 3/2 line marked out by QPOs observations from four black hole (microquasar) sources, which brings to attention a possible connection between the neutron-star and black-hole QPOs, and suggests the idea that they all may arise from acting of the same mechanism.

There is a number of models constructed to explain the origin of QPOs. Among them, the epicyclic resonance model proposes a class of possible resonances between various combinations of frequencies connected with orbital motion. For each type of resonance, the model makes specific predictions about angular momentum of the three black-holes, whose masses are known. In the case of the source GRO J1655-40, for which also the angular momentum has been estimated recently by spectral fitting methods, the model predictions can be compared with the measured spin estimates. The autor concludes that currently none of the proposed resonances can satisfy the observational evidence coming from the spectrum. As a possible solution, a new type of resonance is proposed by the autor, namely the periastron precession resonance that gives the proper spin for the black-hole mass higher than 6Msun However, Beer and Podsiadlowski predict the hole mass smaller than 5. 7 Msun. If true, the periastron precession resonance model has to be excluded. The autor should comment, if some corrections of spin determination from spectra are allowed in such a situation.

In the second part of the thesis, the importance of relativistic effects on light propagation in an optically thin medium are studied using the ray-tracing approach. A toy model of a luminuous torus filled with an optically thin gas is constructed in order to investigate posibility of the observed flux modulation by global oscillations of torus body. The autor has shown that it is possible to modulate the observed signal sufficiently by relativistic effects such as light bending, lensing, and time delays. Effects of changing viewing angle, torus size, position, and of a presence of an outer thin disc are examined. The proper inclination and a close presence of the opaque disc is found capable to alter the distribution of power in the vertical and radial oscillation modes. The g-factor and the torus response to the radial pertubations have a major impact on the observed PDS power in the radial oscillation mode, while the power in the vertical mode oscillation is unaffected.

The autor has shown that the origin of hight-frequency QPOs may be related to a toroidal ADAF-type of accretion flow close to the marginally stable orbit, using the relatively simple torus model, but the results of the simple exact model are confirmed by extension of the ray-tracing method onto radiation emitted from a complex torus model treated by the MHD methods.

It can be concluded that the dissertation thesis brings very interesting, actual results in both its parts directed to the observations and their interpretation, and the theoretical models. The results were published in topical international journals (4 and 1 submitted) and conference proceedings (2) and have a relevant response in the international astrophysical community. The thesis is very well written, with deep insight into both the observational and theoretical aspects of the kHz QPOs phenomenon. The autor clearly demonstrates his high ability for scientific work. The dissertation thesis of Michal Bursa fully meets the necessary conditions on the PhD thesis. Therefore, I am recommending to accept the thesis as a PhD thesis and to award   the PhD to Mgr. Michal Bursa.

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