Report on the PhD Dissertation

Looking into the inner black hole accretion disc with relativistic models of iron line

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Studies of the accretion processes in the field of black holes represent one of the crucial topics of recent interplay between theoretical physics and observational astrophysics. The presented dissertation brings some very important contributions to this area of recent science that could be of high relevance in the future, when new observational instruments orbiting the Earth will be launched, especially the prepared international X-ray satellite IXO. The PhD thesis by Mgr. Svoboda is related to the most actual research related to relativistic phenomena in deep gravitational potential well in vicinity of the black hole horizont, namely to the profiled spectral lines. Fitting of the observational data representing the iron lines generated around rotating holes with the sophisticated models gives one of the best possibilities of measurement of the black hole spin, the most important parameter for understanding the character of physical processes around rotating holes and thein evolution in the Universe.

The thesis is separated into 6 parts. Two introductory parts give basic information on the properties and classification of accretion discs and the continuum spectra and spectral lines, both emission and reflection, generated by accreting matter near the horizon. These introductory parts are very usefull for two reasons – first, they present good overview of the accretion phenomena, second, a detailed comparison of two frequently used numerical models of line profile calculation is presented, with deep physical insight. The last two parts present conclusions and prospects for the future work.

The central part of the Thesis, devoted to very detailed study of the role of the emission directionality in the profiled iron line calculations is the crucial one. It brings a lot of new and very interesting results that were published in relevant impacted journals. It gives a study of the role of both the limb-brightened and limb-darkened angular profiles of the line emission in computing the line profile. It is shown that the limb-darkening law favours higher values of the spin and steeper radial dependence of the line emission, while the limb-brightening law prefers lower values of the spin and flatter radial profiles of the emission. The results of the approximate limb-brightening law were confirmed by simplified realistic model of the emission. In the numerical calculations the Laor model and KYRLINE model (developed by the Prague research group) were used and their results were compared. It is concluded that the Laor approximate model using modification of the innermost stable circular orbit due to the changing spin is precise enough in the present state of the observational instrument precision, but is not precise enough for the forthcoming instruments as the planned IXO is. The numerical models were also applied in fitting real observational data related to the Galactic black hole X-ray binaries and Active galactic nuclei. Two well studied sources were chosen for the data fitting, namely the microquasar GX 339-4 and the well known Seifert galaxy MCG-6-30-15. The corrected models developed in the work presented in the Thesis confirmed previously published estimates of the high-valued spin in MCG-6-30-15, but shifted the spin estimates of GX 339-4 from high to intermediate values. Clearly, new research and comparison to the results of other methods of spin estimate (as the polarimetry, or high-frequency quasi-periodic oscillations) is necessary. The main conclusion can be given by the statement that the emission directionality represent one of the most important clues in

understanding the accretion phenomena and in fitting the observational data on the line profiles with the theoretical models.

In the 4th chapter of the Thesis the author presents very useful discussion on the data analysis, namely on the data reduction and the spectral analysis. The discussion is concentrated on the data coming from the recently most sophisticated XMM-NEWTON satellite. The reduction and re-binning of the data is studied and the goodness of the fits by appropriate statistical methods is given. The data related to the discussed objects GX 339-4 and MCG-6-30-15 are summarized and newly treated. The corrected data are then applied in the confronting of the observations with the profiled line models and their implications for the black hole spin estimates.

I will comment mainly the theoretical parts of the work, leaving aside the observational aspects of the work. I can state that the Thesis is very well written and clearly demonstrates the deep insight of the author both to the theoretical and observational aspects of the work. It brings interesting and relevant results that were published in respected international journals and can be considered as very important for further development of the relativistic astrophysics in the field related to accretion discs orbiting black holes. The modeling of the line profiles is crucial for the black hole spin estimates and the understanding of the accretion phenomena in strong gravitational fields. I have only few comments.

1. In the introductory parts, there is a number of misprints and incorrect formulations, e.g. one can find in p.5 a sentence
…This means that it is released more energy…
Fig.1.3 - Eddington.
In Fig.1.7 - the angles denoting the relative position of WHIM has to be corrected (35-40),
In Fig.1.8 - The text is not corresponding to the figure.
In p.22 it could be useful to say where the Eq.(1.56) can be found.
P.31 – the sentence above (2.21) should have cancelled “coordinates”.

2. The statement that the r_ms grows for a growing above 1 is not true – it decreases down to r_ms = 2/3 and then grows again.

3. It could be useful, if the author will present some comments on the line profiles related to accretion discs orbiting low mass X-ray binary systems containing neutron (quark) stars.

I would like to conclude that Mgr Svoboda clearly demonstrates high ability for scientific work of high quality. His Thesis fully meets the necessary conditions on the PhD thesis. Therefore, I am recommending to accept the thesis as a PhD thesis and to give the PhD award to him.

In Opava 15.4.2010

Professor Zdeněk Stuchlík