ROMA TRE
UNIVERSITÀ DEGLI STUDI

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To: **Prof. RNDr. Zdeněk Němeček, DrSc.**
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Object: *report on the thesis "Looking into the inner black hole accretion disk with relativistic models of iron line", submitted by Mgr. Jiří Svoboda as his doctoral thesis.*

Dear Prof. Němeček

I have read with great interest the thesis "Looking into the inner black hole accretion disk with relativistic models of iron line", submitted by Jiří Svoboda as his doctoral thesis. The thesis concerns a topic in High Energy Astrophysics which is of great importance for the entire astronomical community, i.e. the use of the iron emission line in Active Galactic Nuclei (AGN) and in Galactic Black Hole Binary Systems (GBHS) as a probe of General Relativity effects in the vicinity of a black hole, and thence in the strong-field regime.

The profile of the iron line emitted in the innermost regions of the accretion disk – which is believed to form around black holes in both AGN and GBHS - is affected by General and Special Relativity effects, which modify it in a characteristic way. It is well known that the exact shape of the profile depends on the inner and outer radius of the disk, its inclination angle, and the spin of the black hole – the latter mainly via its dependence on the innermost stable orbit of the disk. These parameters can therefore in principle be derived, once a line profile is observed and studied. Indeed, such lines have been observed in a number of AGN and GBHS, but the estimate of the disk and black hole parameters, and in particular of the black hole spin, has proven very difficult to achieve. This is due primarily to the limited quality of the data, and to the difficulty to separate the line from the underlying continuum, but also to the inevitable simplifications in the models used to fit the data and to derive the abovementioned parameters.

The thesis is composed both by a theoretical and an observational part. The theoretical part deals with the problem of the correct estimate of the black hole spin I mentioned above. In particular, the effect of directionality of the emitted radiation is discussed in detail. The angular law of the emission depends on several unknown geometrical and physical parameters, and it is usually parametrized with simple laws like e.g. isotropic emission, limb darkening emission, or limb brightening emission, It is shown then, when real data are fitted (here the XMM-Newton data of the AGN MCG-6-30-15 – possibly the best data available at the moment), an incorrect choice of the angular law may result in an incorrect estimate of the black hole spin, while not affecting significantly the statistical quality of the fit. Fortunately, the errors are rather modest, when compared with statistical errors. More relevant errors – compared to statistical ones - are found, not surprisingly, when the same procedure is applied to simulated data of next generation X-ray satellites, like the International X-ray Observatory (IXO). The problem is even worse when the data were simulated using an angular emissivity derived from Monte Carlo simulations. None of the three simple angular laws reproduces satisfactorily the data, and give the correct value of the black hole spin, highligthing the importance of fitting the data with a “realistic” law.

The observational part of the thesis consists in the analysis of the X-ray spectra (all taken by XMM-Newton) of three interesting sources. GX339-4 is a GBHS and one of the brightest X-ray sources in the sky. The presence of a strong relativistic iron line was claimed in the past, with a high value for the spin. In the thesis, the same spectrum is reconsidered with a much careful analysis of the pile-up (i.e. the arrival of more than one photon per read time which occurs at high count rates and can significantly distort the spectrum). It is shown that taking into acount pile-up effects the evidence for a broad lines becomes inconclusive. A careful reanalysis of MCG-6-30-15 has instead basically confirmed previous results. Finally, the AGN IRAS 05078+1626 was analysed spectroscopically for the first time in X-rays. The main result is that no evidence for a relativistic line does exist, implying that the accretion disk should be truncated (inner radius at least 10 times larger than the innermost stable orbit for a non rotating black hole).

The results outlined above are certainly original and interesting. The discussion on the directionality effect will have an impact on the way in which present and, especially, future data will be used to estimate the black hole spin. The data analysis on GX339-4 has shown the importance of dealing correctly with pile-up effects in bright sources, while the analysis on IRAS 05078-1626 has shown one more case challenging the simplest picture of accretion disks extending down to the innermost stable orbit.

The thesis is well written, easy to read and well balanced in the various parts, with all necessary figures and tables. The bibliography is ample and up-to-date. I do not have major comments or criticisms.

In my opinion the quantitative and qualitative level of the thesis are certainly adequate for a doctoral thesis, and Mgr. Jiří Svoboda has proved his ability for creative scientific work. I have therefore no hesitations in recommending to admit Mgr. Jiří Svoboda to the defence of the thesis, and to grant to him the Ph.D. degree if the defense will be successful.

Sincerely yours,

Giorgio Matt

Prof. Giorgio Matt

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