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X-ray iron line profiles from warped accretion discs

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Abstract. We present a method for calculating the relativistic iron line profile from warped accretion discs (twist-free and twisted), implementing and extending previous studies to various emissivity laws and to rotating black holes. We also discuss the consequences of modeling lines from warped discs using a priori a flat accretion disc geometry.

Key words. accretion disks – line: profiles – galaxies: active

1. Introduction

The observations of broad iron lines (Kα) in the X-ray spectrum of many active galactic nuclei (AGN) and, in particular, of Seyfert 1 galaxies, stimulated modelling of line profiles from accretion discs around black holes (see e.g. Fanton et al. 1997 and references therein). Indeed such lines are thought to originate in the innermost regions of the accretion flow, carrying information about geometry and dynamics of the gas within few gravitational radii and of the space-time geometry around the black hole (Fabian et al. 2000). In fitting the observed Kα line profiles, the standard assumption is that the accretion disc is geometrically thin and flat. However there are several reasons to consider different disc geometries, in particular warped accretion discs: (1) in some cases, the inclination of the disc inferred from the Kα line differs from the one inferred from other observations like radio jets, broad line optical lines etc; (2) the multiwavelength spectrum of some sources e.g. RE J1034+396 cannot be explained by a standard disc and flaring or warping of the disc is invoked (Puchnarewicz & Soria 2002); (3) the Lense-Thirring effect causes important changes in the geometry of an accretion disc around a rotating black hole.

We here present a method for calculating the relativistic iron line profile from warped accretion discs (twist-free and twisted), implementing and extending previous studies (Bachev 1999; Hartnoll & Blackman 2000) to various emissivity laws and to rotating black holes. We also discuss the consequences of modelling lines from warped discs using a priori a flat accretion disc geometry.

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2. From the disk to the line profile

Some results are presented in the figure (see electronic version of this contribution) for discs around a non-rotating (Schwarzschild) black hole. We consider twist-free discs (whose shape depends on two parameters that fix the magnitude of the warp and the curvature of the disc, and on the azimuthal angle Ω of the observer) and twisted discs (whose shape depends on one parameter that fixes the magnitude of the warp and on the azimuthal angle of the observer). All general relativistic and shadowing effects are taken into account. The following parameters are fixed: inner radius of the disc $R_{in} = 6R_g$, outer radius $R_{out} = 50R_g$; inclination angle of the disc $i = 30°$.

It is evident, even from the few examples presented here, that taking into account possible warping of the accretion disc produces a large variety of line profiles. The most important results to point out are: (1) the possibility of having lines with several narrow peaks; (2) there are profiles that are red-dominated or blue-dominated, depending on the azimuthal angle of the observer; (3) profiles can extend more to the blue and/or less to the red compared to a flat disc. Recalling that for flat discs the blue extent of the line depends mostly on the disc inclination while the red extent strongly depends on the radius of the innermost emitting region (and therefore also on the rotation of the black hole) it is obvious that assuming a priori a flat disc may lead to wrong conclusions in fitting observed Kα lines.

3. From the line profile to the disc

We here apply the method that we developed in Čadež et al. (2000) to invert the line profile and to obtain the best fitting inclination angle of the disc and the emissivity law (we restrict ourselves here to non-rotating black holes). We first construct artificial line profiles from warped discs, then we try to fit them assuming a priori that the disc is flat (see electronic version of this contribution). As expected, the best fitting values that we derive are in general not consistent with the original ones.

4. What if the black hole is rotating?

Deriving line profiles from warped discs in the case of an accretion disc around a rotating (Kerr) black hole is really a hard task. Indeed, apart from the complications of the space-time geometry and the loss of symmetry, the photon trajectories are now non-planar. We here present some preliminary results. Of course the introduction of another parameter – the angular momentum a of the black hole – gives rise to an even wider variety of line profiles. The images refer to a Kerr black hole with $a = 0.9998\,M$ and a disc with $R_{in} = 1.24\,R_g, R_{out} = 50\,R_g$.

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References

Bachev, R. 1999, A&A, 348, 71

Čadež, A., Calvani, M., Di Giacomo, C., & Marziani, P. 2000, New Ast, 5, 69

Fabian, A.C., Iwasawa, K., Reynolds. C. S., & Young, A. J. 2000, PASP, 112, 1145

Fanton, C., Calvani, M., de Felice, F. & Čadež, A. 1997, PASJ, 49, 159

Hartnoll, S. A., & Blackman, E. 2000, MNRAS, 317, 880

Puchnarewicz, E. M., & Soria, R. 2002, in New Visions of the X-ray Universe in the XMM-Newton and Chandra Era, ed. F. Jensen et al., ESA SP-488, in press (astro-ph/0202030)