We present an extended scheme for the calculation of the profiles of emission lines from accretion disks around rotating black holes. The scheme includes disks with angular momenta which are parallel and antiparallel with respect to the black hole’s angular momentum, as well as configurations assumed to be stable (King et al., 2005). Based on a Green’s function approach, an arbitrary radius dependence of the disk emissivity and arbitrary limb darkening laws can be easily taken into account, while the amount of precomputed data is significantly reduced with respect to other available models. We discuss line shapes for such discs and present a code for modelling observational data with this scheme in X-ray data analysis programs. Moreover the observability of these lines in current and future X-ray missions is discussed. A detailed discussion will soon be presented in a forthcoming paper (Dausser et al., 2010).

**Abstract**

Skew-symmetric, broadened Fe Kα emission lines are seen in many Active Galactic Nuclei (MCG−6−30−15). Galactic black hole binaries (Cyg X-1) and neutron star systems. Since the line shape depends on the spin of the black hole, α, and the emissivity and inclination of the surrounding accretion disk, the diagnostic power of relativistic lines is very high, as they provide one of the most direct ways to probe the physics of the region of strong gravity close to the black hole. As suggested by stochastic evolution models in the case of AGN (Volonteri et al., 2005) or a supernova kick in a galactic binary system (Brandt & Podsiadlowski, 1995), a strong misalignment between the angular momenta of the black hole and the accretion disk can and possibly become greater than 90°, i.e., the black hole has “negative spin”. As shown by King et al. (2005), both parallel and antiparallel alignments of the disk and black hole angular momenta are stable configurations; misaligned discs will evolve to one of them.

In fact, accretion onto rapidly spinning retrograde black holes may be of some importance for understanding the properties of powerful radio-loud AGN, as Garfalo (2009) argues that an accretion disk around a retrograde black hole is a particularly potent configuration for generating powerful jets, which might also explain the lack of radio-loud AGN (Garfalo et al., 2010).

**Line profiles for retrograde accretion disk**

The line profiles of a relativistic iron line at 6.4 keV with an emissivity (i.e., the intensity dependence on the radius) of \( r^{-2} \) are displayed in red. The maximal spinning black hole (\( α = +0.998 \)) is shown in black, and the blue line shows the broad emission line for maximal negative spin (\( α = −0.998 \)). In order to allow for a comparison of the pure frame-dragging effects, the inner edge of the accretion disk was set to \( r = 3r_g \) for all profiles.

The comparison shows that in this case the major difference between the different spins is the relative strength of the core of the line to the red wing, which decreases with decreasing \( α \). For this case of a large inner radius, the most significant differences in line shape are seen for low values of \( α \), while the red tails are virtually indistinguishable. The slight increase in line flux at the lowest energies is due to the increased Doppler boosting in the case of \( α < 0 \) (for a given radius, \( α \) increases with decreasing \( α \)).

The lower image is the change in energy shift between the image of an accretion disk producing the red line (positive spin) and the blue line (negative spin) in the profiles for an inclination angle of \( \theta = 40° \). In order to highlight the differences, the extreme case, meaning the difference between maximally positive and negative rotating black hole, was chosen. As the differences are highest close to the inner edge of the disc, a higher emissivity produces the deviations in the line profiles. Moreover this figure shows that for an accretion disk with an inner radius larger than \( 3r_g \), no significant differences are to be expected.

**Data Analysis: the relline model**

We implemented a model function, called relline, that can be added to data analysis software such as ISIS or XSPEC for spin \( −0.998 ≤ α ≤ 0.998 \) and inclination \( i < 90° \). Both an additive and a convolution model, which can be used for calculating relativistic smeering, are provided.

The figure shows a comparison of the relline model (blue) to models commonly used in X-ray astronomy (black) (Laird, 1991, Brenneman & Reynolds, 2006; Denulk et al., 2004). The comparison of the model with an exact numerical calculation in \( a \) that does not make use of precalculated quantities and interpolation shows that there is no significant deviation between both approaches.

**Observability of negative spin**

In order to study the question of observability in greater detail, we have performed simulations of observability of a relativistic line with the planned International X-ray Observatory (IXO). We performed the simulations using a line-fit to XMM-Newton data from MCG−6−30−15 in a typical state and set the equivalent width of the line to the observed 300 eV. The confidence contours in the figure are for a 50 keV observation and show that the next generation X-ray instrumentation will allow to separate even the difficult case of negatively spinning black holes.

**References**

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