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The Shape of the K_α Line as the Evidence for the Black Hole Existence

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Abstract. Observations of Seyfert galaxies in X-ray region reveal the wide emissive lines in their spectra, which can arise in inner parts of accretion disks, where the effects of General Relativity (GR) must be taken into account. A spectrum of a solitary emission line of a hot spot in Kerr accretion disk is simulated, depending on the radial coordinate r and the angular momentum $a = J/M$ of a black hole, under the assumption of equatorial circular motion of a hot spot. It is shown that the characteristic two-peak line profile with the sharp edges arises at a large distance, (about $r \approx (3 - 10)\ r_g$). The inner regions emit the line, which is observed with one maximum and extremely wide red wing. We present results of simulations for the isothermal and Shakura – Sunayev disks.

The general status of black holes has been described in a number of papers (see, for example, review by Zakharov (2000) references therein). As it was emphasized in these reviews the most solid evidence for an existence of black holes comes from observations of some Seyfert galaxies because we need a strong gravitational field approximation to interpret these observational data, so probably we observe manifestations radiation processes from the vicinity of the black hole horizon (these regions are located inside the Schwarzschild black hole horizon, but outside the Kerr black hole horizon, thus we should conclude that we have manifestations of rotational black holes).

Recent observations of Seyfert galaxies in X-ray band reveal the existence of wide iron K_α line (6.4 keV) in their spectra along with a number of other weaker lines (Ne X, Si XIII,XIV, S XIV-XVI, Ar XVII,XVIII, Ca XIX, etc.). The line width corresponds to the velocity of the matter motion of tens of thousands kilometers per second, reaching the maximum value $v \approx 80000 - 100000$ km/s for the galaxy MCG-6-30-15 (Tanaka et al. 1995) and $v \approx 48000$ km/s for MCG-5-23-16. In some cases the line has characteristic two-peak profile with a high "blue" maximum and the low "red" one and the long red wing, which gradually drops to the background level (Tanaka et al. 1995; Fabian 2001).

To simulate these shapes of the spectral lines we choose a minimal number of assumptions. We used the numerical approach based on the method, described earlier by Zakharov (1991, 1994, 1995).

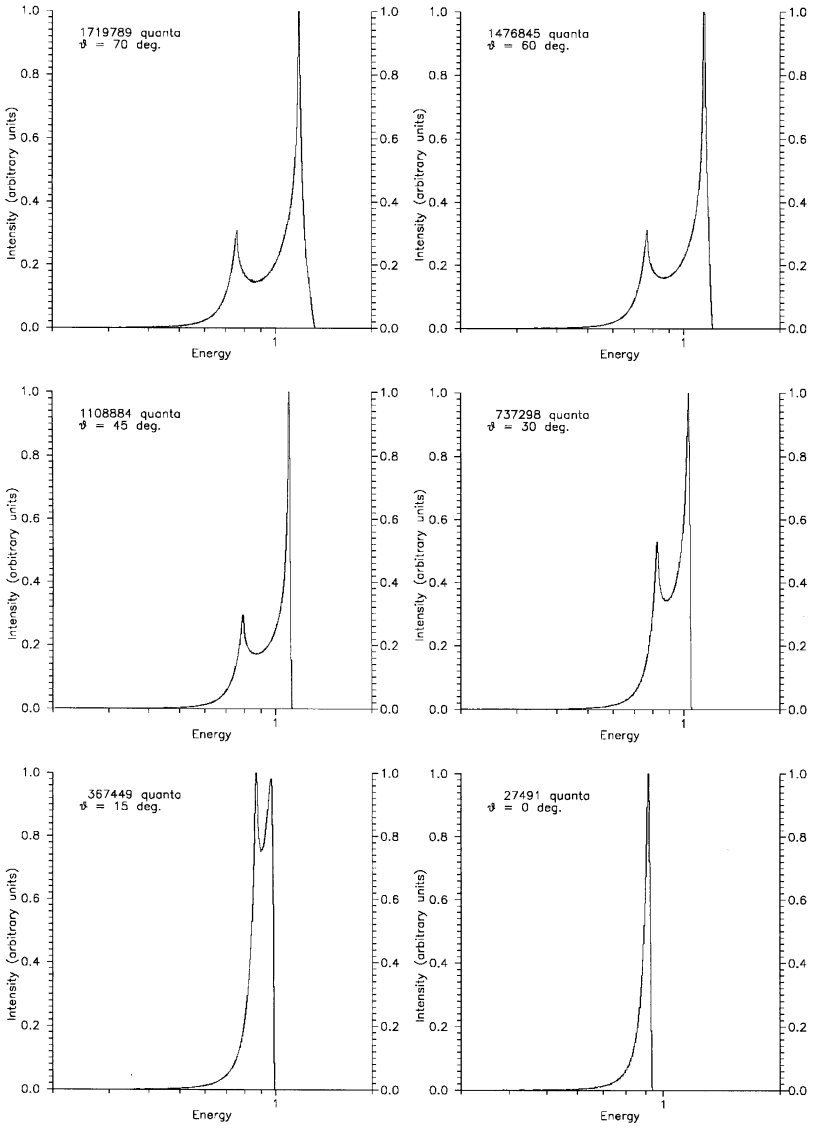

Figure 1. The spectral line shape for different θ angles. The emitting region is the wide ring and its inner boundary is the last stable orbit (for rotational parameter $a = 0.9$ this r-value is equal to $r = 1.16\,r_g$), its outer boundary corresponds to $r = 10\,r_g$.

Many astrophysical processes, where the great energy release is observed, are assumed to be connected with the black holes. Because the main part of the astronomical objects, such as the stars and galaxies, possesses the proper

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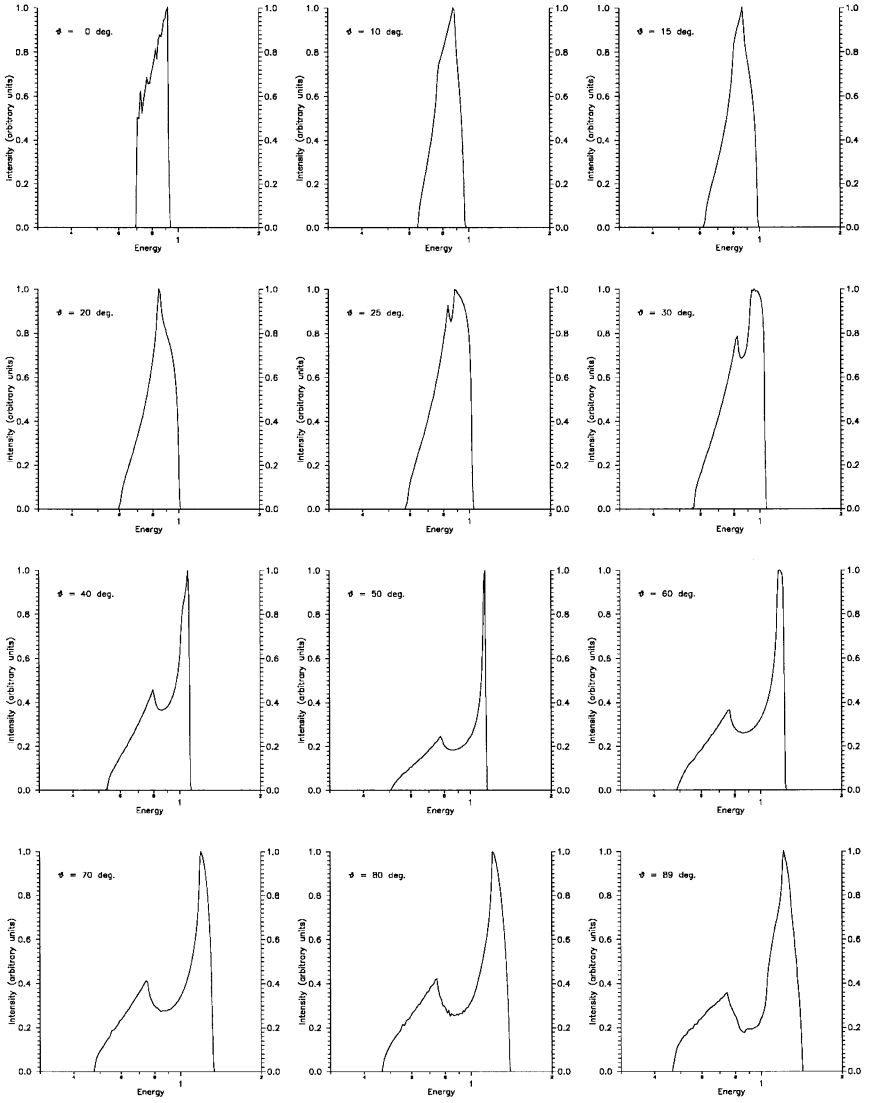

Figure 2. The spectral line shapes for an accretion disk with outer and inner radii ($r_{\rm in} = 3\,r_g$ and $r_{\rm out} = 10\,r_g$) in Schwarzschild black hole field for different position angles of a distant observer. The temperature is distributed according to the Shakura – Sunyaev model.

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rotation, then there are no doubts that the black holes, both stellar and supermassive, possess the intrinsic proper rotation too. Therefore we consider an emission of monoenergetic quanta near a Kerr black hole.

To analyze an influence of a disk width on the shapes of the line we consider the case of a wide accretion disk (in contrast to sharp accretion disks considered by Zakharov & Repin (1999) and it was shown that the shape of the spectral line retains its type with two peaks as it was shown by Zakharov & Repin (2002a, 2002b) (see Fig. 1). It is noted that the inner parts give the essential contribution into red wing of spectrum.

It is known that the standard disk models (like, for example, Shakura – Sunyaev and Novikov – Thorne disk models) hardly ever could be used to describe temperature distributions in accretion disks of Seyfert galaxies, however to show an influence of a temperature distribution on the spectral line shapes we use the standard disk model as a template. Fig. 2 demonstrates the shape of emitted monochromatic line in Schwarzschild black hole field with temperature distributed according to the standard α-disk model.

Details of computations and a full list of references could be found in papers by Zakharov & Repin (1999, 2002a).

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