

Line Profiles Radiated by Orbiting Matter Around Black Holes

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Abstract. Emission-line profiles from both narrow eccentric rings and an extended disk around a black hole are presented. In both cases, a black-hole signature appears when the inclination of the emitting orbit is larger than 80° .

1. Introduction

One of the information sources in favor of the accretion-disk model in active galactic nuclei (AGNs) and X-ray binaries is the profile of emission lines. It is well-known that emission-line profiles from a relativistic accretion disk around a black hole are characterized by double horns, with the blue horn always being stronger than the red one. The blue horn is attributed to emitting matter of the disk approaching the observer, whereas the red horn is caused by the matter receding from the observer.

Although some of the optical line profiles from AGNs (about twelve) have been well-fitted by the profiles resulting from relativistic accretion disks (e.g., Halpern 1990), there is still a considerable number of AGNs with optical line profiles that are quite different from those resulting from a disk. This implies that there exist other mechanisms that determine the line profile.

Here we present the line profiles from both relativistic eccentric rings orbiting a black hole and an extended accretion disk. The rings may be formed by the presence of a companion of the central body (as in the case of mass exchange in binaries), or by the debris released from the tidal disruption of a star by the supermassive black hole in an active galactic nucleus (Bao et al. 1996). Since the profile from a disk is well-known, we here just show the profiles from a highly inclined disk, where black-hole effects are strongest.

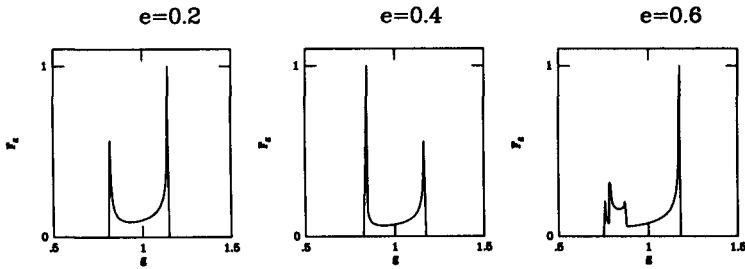


Figure 1. Line profiles from relativistic eccentric rings for three different values of eccentricity e . Frequency increases to the right.

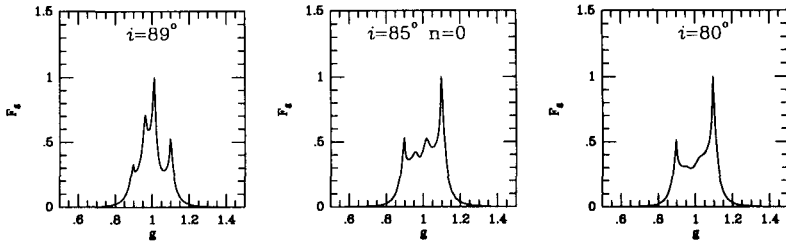


Figure 2. Line profiles for a relativistic disk with inner radius $3.5r_s$ and outer radius $50r_s$ for three different inclinations i .

2. Line Profiles

To illustrate the influence of the eccentricity on line profiles, several examples are given in Fig. 1. For small eccentricities, the lines are basically double-horned due to the fact that each ring element spends most of its orbital period close to the extremes of radial velocity. The blue peak is higher due to the Doppler enhancement. However, for higher eccentricities the intensity ratio of the blue and red peak can be reversed due to the faster motion in the blue-shifted periastron region (in Fig. 1, the inclination of the orbit $i = 50^\circ$, the periastron longitude $\omega \approx 180^\circ$, and the semi-major axis $a = 10r_s$).

Line profiles from a disk have been widely studied. Here we present several cases for strictly highly inclined disks. Figure 2 shows profiles from an extended disk from $3.5r_s$ to $50r_s$, with the inclination being 80° , 85° , and 89° , respectively ($n = 0$ means that only those photons coming directly to the observer are considered). For $i = 80^\circ$ the line has the famous double-horn structure with the blue peak being higher than the red one. As the inclination increases, some fine structure can be seen between the two horns. This is because of the gravitational-lensing effect of the central black hole, and can thus be regarded as a black-hole signature.

References

- Bao, G., Hadrava, P., & Østgaard, E. 1996, *ApJ*, 464, 684.
 Halpern, J. P. 1990, *ApJ*, 365, L51.