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Measuring the black hole parameters in the galactic center with RADIOASTRON

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Abstract

Recently, Holz and Wheeler (2002) [ApJ 578, 330] considered a very attracting possibility to detect retro-MACHOs, i.e., retro-images of the Sun by a Schwarzschild black hole. In this paper, we discuss glories (mirages) formed near rapidly rotating Kerr black hole horizons and propose a procedure to measure masses and rotation parameters analyzing these forms of mirages. In some sense that is a manifestation of gravitational lens effect in the strong gravitational field near black hole horizon and a generalization of the retro-gravitational lens phenomenon. We analyze the case of a Kerr black hole rotating at arbitrary speed for some selected positions of a distant observer with respect to the equatorial plane of a Kerr black hole. Some time ago Falcke, Melia, Agol (2000) [ApJ 528, L13S] suggested to search shadows at the Galactic Center. In this paper, we present the boundaries for shadows. We also propose to use future radio interferometer RADIOASTRON facilities to measure shapes of mirages (glories) and to evaluate the black hole spin as a function of the position angle of a distant observer.

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1. Introduction

Recently Holz and Wheeler (2002) have suggested that a Schwarzschild black hole may form retro-images (called retro-MACHOs) if it is illuminated by the Sun. We analyze a rapidly rotating

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Kerr black hole case for some selected positions of a distant observer with respect to the equatorial plane of the Kerr black hole. We discuss glory (mirage) formed near a rapidly rotating Kerr black hole horizon and propose a procedure to measure the mass and the rotation parameter analyzing the mirage shapes. Since a source illuminating the black hole surroundings may be located in an arbitrary direction with respect to the observer line of sight, a generalization of the retro-gravitational lens idea suggested by Holz and Wheeler (2002) is needed. A strong gravitational field approximation for a gravitational lens model was considered recently in several papers (Frittelli et al., 2000; Virbhadra and Ellis, 2000, 2002; Ciufolini and Ricci, 2002, 2003; Bozza, 2002, 2003; Bozza and Mancini, 2004a,b; Eiroa et al., 2002; Eiroa and Torres, 2004; Sereno, 2003, 2004). However, if we consider the standard geometry for a gravitational lens model, namely if a gravitational lens is located between a source and observer, then the probability to have evidences for strong gravitational field effects is quite small, because the probability is about $P \sim \tau_{\rm GL} \times R_{\rm G}/D_{\rm S}$, where $\tau_{\rm GL}$ is the optical depth for gravitational lensing and the factor $R_{\rm G}/D_{\rm S}$ corresponds to a probability to have a manifestations for strong gravitational field effects ($R_{\rm G}$ is the Schwarzschild radius for a gravitational lens, $D_{\rm S}$ is a distance between an observer and gravitational lens). Therefore, the factor $R_{\rm G}/D_{\rm S}$ is quite small for typical astronomical cases. However, these arguments cannot be used for the cases of a a source located nearby a black hole.

First, it is necessary to explain differences among the considered geometry, the standard geometry of gravitational lensing (when a gravitational lens is located roughly speaking between a source and an observer) and the model introduced by Holz and Wheeler (2002) when an observer is located between a source (Sun) and a gravitational lens that is a black hole. In this paper, we will consider images formed by retro-photons, but in contrast to Holz and Wheeler (2002) we will analyze forms of images near black holes but not a light curve of formed images as Holz and Wheeler (2002) did. In our consideration a location of source could be arbitrary in great part (in accordance with a geometry different parts of images could be formed),[1] for example, accretion flows (disks) could be sources forming such images. Since in such cases images formed by retro-photons are considered, we call it like retro gravitational lensing even if a source is located near a gravitational lens (a black hole) in contrast to a standard gravitational lens model.

The plan of the paper is as follows. In Section 2, we discuss possible mirage shapes. In Section 3, we analyze the most simple case of source and observer in the black hole equatorial plane. In Section 4, we consider the case of observer at the rotation axis of a spinning black hole. In Section 5, we consider observer in a general position with respect to the rotation axis. The basic characteristics of future space based radio interferometer RADIOASTRON were given in Section 6. In Section 7, we discuss Sgr A* as a possible target for RADIOASTRON observations to possibly observe such images near the black hole located in the object. In Section 8, we discuss our results of calculations and in Section 9, we present our conclusions.

2. Mirage shapes

As usual, we use geometrical units with $G = c = 1$. It is convenient also to measure all distances in black hole masses, so we may set $M = 1$ (M is a black hole mass). Calculations of mirage forms are based on qualitative analysis of different types of photon geodesics in a Kerr metric (for references see Young (1976), Chandrasekhar (1983), Zakharov (1986), Zakharov (1989)). In fact, we know that impact parameters of photons are very close to the critical ones (which correspond to parabolic orbits). One can find some samples of photon trajectories in Zakharov (1991a) and Chandrasekhar (1983). This set (critical curve) of impact parameters separates escape and plunge orbits (see for details, Young (1976), Chandrasekhar (1983), Zakharov (1986, 1989)) or otherwise the critical curve separates scatter and capture regions for unbounded photon trajectories. Therefore the

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[1] However, if a source is located between a black hole and an observer, images formed by retro-photons and located near black holes could be non-detectable.