PARAMETERS OF RELATIVE MOTION OF A BINARY STAR MOVING IN EXTERNAL GRAVITATIONAL FIELD OF A BLACK HOLE FROM IT'S REDSHIFT

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The various approaches for studying the time evolution of the redshift of light of star in external gravitational field are presented in many papers (see, e. g., [1, 2, 3, 4]). They investigate the influence of trajectory of motion of the source on redshift, that can be used for future tests of various theories of gravity, for example, by applying the results to sources in the vicinity of the Galactic Center. Certain of the cited papers provide approaches for solution of inverse problem: calculating of the parameters of motion of the source using observable characteristics of radiation, such as redshift and intensity (see, e. g., [3, 1, 4]).

In the present work we describe a method that allows to solve inverse problem for the source in binary star that moves in external gravitational field of supermassive Kerr black hole using the redshift data only. With contrast to the case binary motion in absence of strong external gravitational field the results of our investigation show that presence of the field gives possibility to find all parameters of the orbit of relative motion of the stars in binary.

The presented method is illustrated on the example of mathematical model of the system that compose point masses m_1 and m_2, moving in external Kerr gravitational field. The mass of the emitter is m_1. The world lines for propagation of electromagnetic radiation of emitter are calculated as isotropic geodesics in Kerr metric in certain approximation (linear to Kerr parameter a/M, where a is the angular momentum of the black hole and M it's mass). Then the redshift can be found from [5]:

$$z(\tau) = (1 + z_0(\tau)) \left(1 - \frac{1}{c} \frac{\mathrm{d}}{\mathrm{d}\tau} (n_{(\alpha)} X_1^{(\alpha)})\right) - 1 + O\left(\frac{\rho^2}{M^2}, \frac{v^2}{c^2}\right), \tag{1}$$

Here $z(\tau)$ is the redshift of received light as function of proper time of the source τ. $X^{(\alpha)}$ is Fermi coordinates of the source star in the frame of the center of mass of the system, $n^{(\alpha)}$ is components of the unit vector of the light ray in Fermi coordinates, c is speed of light, $\rho \sim X^{(\alpha)}$, v is the relative velocity of the stars. $z_0(\tau)$ is redshift of the imagine source in the center of mass of the binary.

Parameter	Model value	Calculating value
Eccentricity, e	0.68	0.58
Period of relative motion, T	20.268 Mc^{-1}	20.264 Mc^{-1}
Mass function, M_2	0.0062 $M^{1/3}$	0.0066 $M^{1/3}$
Pericenter longitude, ω_r	1.56 rad	1.32 rad
Orbital inclination, i	1.55 rad	1.31 rad
Position angle, ζ	1.72 rad	3.05 rad

Table 1. The model parameters characterising relative motion of the components of the binary and the calculating ones from the solution of inverse problem.

The numerical results for the solution of inverse problem are presented in Table 1. Mass function in the presented data is defined by $M_2 = \sin(i) m_2/(m_1 + m_2)^{2/3}$.

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