General relativistic mass and spin of a Kerr black hole in terms of redshifts

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Abstract. We derive closed general relativistic formulas for the mass M and spin a of a Kerr black hole (BH) in terms of observational data: the redshift of photons emitted by massive particles geodesically orbiting the BH, and their orbital radius. Given a set of two (three) stars revolving the Kerr BH, these formulas involve eight (twelve) observations: the redshift in six (nine) positions and the respective two (three) orbital radii. For a single star orbiting the BH we need four observational data to analytically determine M and a in closed form. Applications to astrophysical systems are briefly discussed.

The problem

1. There is a considerably increasing amount of astrophysical observations pointing out to strong dynamical evidence of the existence of black holes (BH) at the center of several spiral galaxies, including the Milky Way (SgrA*).

2. Most of the approaches that astronomers use to estimate or determine the mass M of these black holes rely on Newtonian dynamics while they estimate distances and measure an intrinsically general relativistic invariant quantity: the redshift of photons emitted by massive bodies revolving the BH, instead of their relative velocities (they identify $v = c\,z$). The spin parameter a is elusive in this classical mechanics approach.

3. An interesting question arises: How can one obtain information about the mass M and the spin parameter a of a Kerr black hole from observational data coming from diverse massive bodies (stars, gas, masers, etc.) orbiting around it using a completely general relativistic approach?

Solution to the problem and perspectives

1. One can derive closed general relativistic formulas for the mass M and the spin a parameters of a Kerr BH in terms of observational data: the redshift of photons emitted by massive particles geodesically orbiting the BH, and the corresponding orbital radii.

2. The complete information encoded in the redshift encompasses three aspects: the Doppler relative velocity, the gravitational redshift generated by the BH mass and the gravitational dragging due to the rotating character of the Kerr BH. Since we are living a precision era in astrophysics where the general relativistic effects are starting to show, we would like to invite the community to correctly interprete the measured redshift that comes from astrophysical systems, and stop thinking of it as a velocity entity.

3. We would like to consider more realistic elliptic trajectories of stars lying outside the equatorial plane when orbiting around rotating BHs in order to apply the method to SgrA* and other realistic astrophysical systems.