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Kerr black hole energy extraction, irreducible mass feedback, and the effect of the captured particles charge

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We analyze the extraction of the rotational energy of a Kerr black hole (BH) endowed with a test charge and surrounded by an external test magnetic field and ionized low-density matter. For a magnetic field parallel to the BH spin, the electric field accelerates electrons outward(inward) and protons inward(outward) in a region around the BH poles(equator). For zero net charge, the polar region comprises roughly 60 degrees from the polar axis and the equatorial 30 degrees from the equator. We recall the system has axial and equatorial reflection symmetry. Polar(equatorial) protons(electrons) that can be captured by the BH have positive(negative) energy and angular momentum. We show that a gain of positive charge makes the polar region shrink and the equatorial region enlarge. Thus, the BH could experience a cyclic behavior for an isotropic particle density. Starting from a zero charge, it accretes more polar protons than equatorial electrons, gaining net positive charge, energy, and angular momentum. Then, the shrinking(enlarging) of the polar(equatorial) region makes it accrete more equatorial electrons than polar protons, gaining net negative charge, energy, and angular momentum. In this phase, the BH rotational energy is extracted. The extraction process continues until the new enlargement of the polar region reverses the situation, and the cycle repeats. We show that the process produces a relatively low increase of the BH irreducible mass compared to gravitational mechanisms like the Penrose process. Hence, it provides a first step towards electrodynamical, efficient mechanisms for extracting the BH rotational energy. Consequences in the context of gamma-ray bursts are discussed.

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