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Banados-Silk-West effect with finite forces near different types of horizons: general classification of scenarios

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If two particles move towards a black hole and collide in the vicinity of the horizon, under certain conditions their energy Ec.m. in the center of mass frame can grow unbounded. This is the Banados-Silk-West (BSW) effect. Usually, this effect is considered for extremal horizons and geodesic (or electrogedesic) trajectories. We study this effect in a more general context, when both geometric and dynamic factors are taken into account. We consider generic axially symmetric rotating black holes. The near-horizon behavior of metric coefficients is determined by three numbers p, q, k that appear in the Taylor expansions for different types of a horizon. This includes nonextremal, extremal and ultraextremal horizons. We also give general classification of possible trajectories that include so-called usual, subcritical, critical and ultracritical ones depending on the near-horizon behavior of the radial component of the four-velocity. We assume that particles move not freely but under the action of some unspecified force. We find when the finiteness of a force and the BSW effect are compatible with each other. The BSW effect implies that one of two particles has fine-tuned parameters. We show that such a particle always requires an infinite proper time for reaching the horizon. Otherwise, either a force becomes infinite or a horizon fails to be regular. This realizes the so-called principle of kinematic censorship that forbids literally infinite Ec.m. in any act of collision. The obtained general results are illustrated for the Kerr-Newman-(anti-)de Sitter metric used as an example. The description of diversity of trajectories suggested in our work can be of use also in other contexts, beyond the BSW effect. In particular, we find the relation between a force and the type of a trajectory.

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