Energy extraction from an extremal rotating electrovacuum black hole through charged particle collisions

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ABSTRACT

Collisional Penrose process received a lot of attention after Bañados, Silk and West (BSW) pointed out the possibility of the centre-of-mass collision energy being unlimited for near-horizon particle collisions involving fine-tuned (so-called critical) particles moving around extremal black holes [1]. This setup was further refined when Schnittman showed that imperfect fine-tuning may result in the collision being heads-on in the radial direction [2]. Even though this led to significant revision of expected maximum efficiency of the collisional Penrose process, strict unconditional upper bounds on the extracted energy and on the efficiency were found using analytical methods [3]. Nevertheless, an electrostatic analogy of the BSW effect exists for extremal Reissner-Nordström black hole [4], and for this counterpart process, no unconditional analytical bounds were found [5]. Moreover, it was later shown that the electrostatic version of the BSW effect can exist also for black holes closer to astrophysical situations, and even be intermingled with the original, centrifugal variant [6]. Thus, it is of interest to study the energy extraction also in the generalised case of rotating electrovacuum black holes. In the present work, we confirm that for charged particle collisions, there are no unconditional kinematic bounds on the extracted energy even for extremal Kerr-Newman black holes with an arbitrarily small value of charge. Furthermore, the same framework can be likewise applied to exact solutions describing black holes in strong external magnetic fields, whose near-horizon regions were studied in [7]. In those models, "Wald's charge" arises naturally due to interaction with the external field. However, as the escaping particles in the collisional Penrose process can be produced only in specific kinematic regimes, it has to be examined carefully whether these are compatible with properties of the interactions responsible for the emission of the particles.

References

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