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Pair Creation of Neutral Dirac Fermions by Frame Dragging in the Ultracold Kerr–de Sitter Geometry

Abstract

Near a rotating black hole, space is dragged around the axis, and this dragging alone is known to create particle pairs even at zero temperature. In this work we identify the mechanism. We consider a neutral Dirac field on the near-horizon geometry of the ultracold Kerr–de Sitter black hole, where the three horizons coincide and the Hawking temperature vanishes. First, we find that the Dirac equation separates and that the radial equation has the same structure as the Dirac equation for a charged field in a uniform electric field: the dragging shifts the energy of each mode by $\tilde{k}\, m_q\, r$, in proportion to its azimuthal number m_q and to the position r, so that positive and negative energy levels cross. In the Schwinger effect the rate is set by the product eE of the charge and the field strength and by the mass; in our equation the product $\tilde{k}\, m_q$ of the dragging coefficient $\tilde{k}$ and the azimuthal number takes the place of eE, and the angular eigenvalue λ takes the place of the mass. Then, in coordinates rotating with the dragged space, the time dependence reduces to an equation of the Landau–Zener type, which gives the pair creation probability $\exp(-\pi\lambda^2/|\tilde{k}\, m_q|)$ per mode and the rate per unit volume. We also introduce charge in order to examine how the pair creation responds when the rotation is varied: with charge, the Einstein–Maxwell equations can be satisfied with the three horizons kept coincident while the rotation varies, and the resulting family of ultracold Kerr–Newman–de Sitter solutions returns to the Kerr–de Sitter geometry at zero charge. Since the Dirac field is neutral, the change of the pair creation along the family comes from the geometry, not from the charge. As expected, the rate increases with the rotation. We regard this as a rotational version of the Schwinger effect.