Wave amplification in rotating reference frames

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In 1969 Penrose predicted that it is possible to extract energy from the angular momentum of a rotating black hole. This same idea was developed by Zel’dovich who predicted that the same effect could excite quantum fluctuations, a concept that eventually led to Hawking’s description of evaporation of non-rotating black holes. The amplification of waves from rotating black hole is often referred to as “superradiance” (not be confused with Dicke superradiance) and is actually a very generic effect, encompassing very rich physics that are still being investigated. Zel’dovich proposed a similar effect to occur for electromagnetic waves reflecting off a rotating metallic cylinder and recent measurements have uncovered a hydrodynamical analogue [1], also referred to in the literature as “over reflection”, where water waves are amplified in reflection from a vortex.

We will discuss opportunities for observing superradiance and amplification of waves with orbital angular momentum from rotating systems. We will discuss in particular two examples. The first is superradiance from a rotating 2D photon fluid. We have shown that it is possible to create an effective superfluid using light in defocusing media and this can in turn be shaped so as to form a vortex spacetime that exhibits both an ergosphere and a horizon for phonon modes (small amplitude oscillations) propagating in the transverse plane of the beam [2]. Numerical simulations also show evidence of superradiance through the formation of a negative (positive) current inside (outside) the ergosphere.

The second example considers an acoustic beam with frequency \( \omega \) and with OAM (winding number \( m \)) that is transmitted through a rotating, absorbing disk. This allows to probe the conditions envisaged by Zel’dovich, i.e. amplification of waves from a rotating cylinder when the angular rotation, \( \Omega \), rate satisfies \( \omega < m\Omega \). We show how this condition leads to an inversion of the material absorption to gain, i.e. energy extraction from the angular rotation energy of the system [3].

References