2 Polarized Radiation

(idea by A. Sadofyev)

Consider a hot rotating spherical body in vacuum. It radiates electromagnetic waves which are expected to be polarized. Find the spatial dependence of the polarization far away from the radiating body. You may find it convenient to start with a cylindrically symmetric rotating thermal radiation.

Solution:

Let us start with a cousin of the suggested problem and consider the polarization of a thermal fermionic radiation by a rotating body.This problem can be found in [1, 2, 3, 4], where a thermal radiation of a rotating black hole (BH) was studied. The equilibrium thermal emission rate of a rotating object (e.g. Kerr BH) takes the form

$$\frac{dN}{dtd\omega} = \frac{1}{2\pi} \sum_{j,m,\lambda} \Gamma_{\omega jm\lambda} \left(e^{\beta(\omega - m\Omega)} \pm 1 \right)^{-1} , \quad (1)$$

where β is the inversed temperature of the radiating body (which is related to the surface gravity in the case of BH), Ω is its angular velocity, two signs correspond to fermionic and bosonic particles, and Γ is the absorption coefficient for given quantum numbers. However, for our purposes we should also recover the angular distribution of emitted particles

$$\frac{dN}{dtd\omega do} = \frac{1}{2\pi} \sum_{j,m,\lambda} \Gamma_{\omega jm\lambda} f_{jm}(\theta) \left(e^{\beta(\omega - m\Omega)} + 1 \right)^{-1} , \quad (2)$$

where $f_{jm}(\theta)$ can be explicitly derived for each mode from equations of motion [1, 2, 4, 5]. In the case of one chiral fermion (say neutrino) and at low frequencies, the angular dependence is given by

$$\frac{dN}{dtd\omega do} \sim \sum_{\pm} (1 \pm L \cos\theta) \left(e^{\beta(\omega \pm \frac{1}{2}\Omega)} + 1 \right)^{-1} , \quad (3)$$

where $L = 1$ for neutrinos and $L = -1$ for antineutrinos. Interestingly, one may note that a Kerr BH radiates more neutrinos in one hemisphere and more antineutrinos in the other one. Completing this picture with the opposite chirality, we can easily come to the conclusion that the radiation is polarized – right and left particles are separated along the angular velocity. Since the spin direction is slaved with the momentum for massless particles it is equivalent to the overall spin polarization of the radiation.

Thus, considering fermions we have found that a thermal radiation can gain a polarization due to the spin-orbit coupling. Now the extension to the electromagnetic case is straightforward, for further discussion see [6, 7] and references therein.

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