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Photon vortex generation in the universe and its effect on stellar nucleosynthesis

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Abstract

Photon vortices are light that carry large orbital angular momentum (OAM) in quantum level [1]. The photon vortex can be described by wavefunctions based upon Laguerre-Gaussian or Bessel wavefunctions, which are waves being the eigenstates of the distinct angular momentum along their propagation direction. At present, photon vortices can be generated using laser or accelerators in the laboratory. However, generation of photon (optical) vortices in the universe has been discussed. In gamma-ray bursts (GRBs), photons in the keV and MeV range can become highly polarized due to strong magnetic fields. It has been predicted that optical vortex are generated by strong gravity fields around rotating black holes [2], and the optical vortex of Laguerre-Gaussian mode with frequency of approximately 200 GHz from the M87 black hole was measured [3]. We study the process that photon vortices are generated when electrons have spiral motion in magnetic fields as strong as $10^{12\text{-}13}$ G. The results show that these vortices are likely generated in places with extremely strong fields, such as magnetars or magnetized accretion disks around black holes [4].

One of the reparable features is that one can observe unique phenome caused by large angular momentum transfer in interactions with quantum object such as atoms, atomic nuclei, and elementary particles. Liu et al. [5] found that the amplitudes of low multipole giant resonances become weaker when a photon vortex interacts on a nucleus with a relatively small impact parameter. In this work, furthermore, we calculate the ratios of the photon absorption transition probabilities of photon vortices with Bessel wave to photons described by the plane wave [6]. The result shows enhancement of excitation of states with large total angular momentum by optimization of the divergence angle of the incident photon vortex in momentum space. However, the average cross section for the photon vortex turns out to be identical with that for the plane wave. We discuss the final result of the effect of photon vortex generation on stellar nucleosynthesis.

References
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