Nuclear Photonics 2025
October 6 - 10, 2025 in Darmstadt, Germany

Contribution ID: **27** Type: **Oral presentation**

Nuclear Excitation in Photonuclear Reactions by Photon Vortex with Large Angular Momentum in Astrophysical System

Thursday, October 9, 2025 2:15 PM (20 minutes)

Photon vortices are light carrying large orbital angular momentum (OAM) at the quantum level [1]. They can be described by Laguerre-Gaussian or Bessel wave functions, which are waves that are eigenstates of the total angular momentum along their propagation direction. Unlike plane-wave photons, photon vortices interact differently with materials because their OAM affects the way they transfer angular momentum.
In gamma-ray bursts (GRBs), keV photons may become highly polarized due to strong magnetic fields. This raises the question of whether similar polarization or angular momentum structures may occur in strongly magnetized environments. We have studied the process by which photon vortices form when electrons undergo spiral motion in magnetic fields as strong as 1012-1013 G, using Landau quantization. Our calculations show that such vortices are likely to be generated in environments with extremely strong fields, such as magnetars or magnetized accretion disks around black holes [2]. These results support the possibility that photon vortices are not rare, but rather abundant in high-field astrophysical systems.
Liu et al [3] found that the amplitudes of low-multipole giant resonances are suppressed when a photon vortex interacts with a nucleus at relatively small impact parameters. This suggests that photon vortices may change the isotopic abundances in nucleosynthesis processes in the Universe.
In this paper we calculate the ratios of photon absorption transition probabilities for Bessel-type photon vortices compared to plane-wave photons [4]. Our results show that excitations of nuclear states with large total angular momentum are enhanced by optimizing the divergence angle of the incident vortex in momentum space. This implies that photon vortices could selectively excite high angular momentum states. However, the average absorption cross section remains the same.

[1] L. Allen, et al. Phys. Rev. A 45, 8185 (1992).
[2] T. Maruyama, et al. Phys. Lett. B826. 136779 (2022).
[3] Z.-W, Lu, et al., Phys. Rev. Lett. 131, 202502 (2023).
[4] T. Maruyama, et al. Astrophys. J. 975, 51 (2024).

Primary author: MARUYAMA, Tomoyuki (BRS, Nihon university)

Co-authors: Dr HAYAKAWA, Takehito (Kansai Institute for Photon Science, National Institutes for Quantum Science and Technology); Prof. CHEOUN, Myung-Ki (Department of Physics, Soongsil University,); Prof. KAJINO, Toshitaka (Peng Huanwu Collaborative Center for Research and Education, International Reserach Center for Big-Bang Cosmology and Element Genesis)

Presenter: MARUYAMA, Tomoyuki (BRS, Nihon university)

Session Classification: Session III