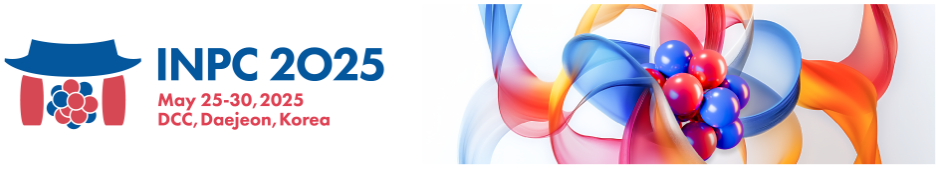

Contribution ID: **89** Type: **Contributed Oral Presentation**

Photonuclear Reactions by Photon Vortex with Bessel Waves in Astronomical System

Friday, 30 May 2025 11:15 (15 minutes)

Photon vortices are light that carry large orbital angular momentum (OAM) in quantum level [1]. They can be described by Laguerre-Gaussian or Bessel wavefunctions, which are waves being the eigenstates of the distinct angular momentum along their propagation direction . Unlike plane-wave photons, photon vortices interact differently with materials because their OAM changes the process where they transfer the relatively large angular momentum. In gamma-ray bursts (GRBs), photons in the keV range can become highly polarized due to strong magnetic fields.
We study the process that photon vortices form when electrons have spiral motion in magnetic fields as strong as 10^{12}-10^{13} G. Our results, which considered the Landau quantization, show that that these vortices are likely generated in places with extremely strong fields, such as magnetars or magnetized accretion disks around black holes [2]. Photon vortices can change the total angular momenta of compound nuclei transferred from the photon vortices when they interact with them. This is thought to play an important role in nucleosynthesis in the Universe. Liu et al. [3] 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 real system, however, we need to take the average of the reaction probabilities over the impact parameter.
Our results show that the photon vortices and the photons described by the plane-wave produce similar excitation probabilities [4]. However, the photon vortices allow transitions to states with a wider range of the magnetic quantum numbers, providing a unique perspective on the angular distributions of particle reactions. While these differences may not have a significant impact on stellar nucleosyntheses, they provide valuable insights into the properties of the photon vortices and open up an opportunity for experimental studies with control of the impact parameter to observe states which cannot be easily observed using the plane-wave photons.

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Primary author: MARUYAMA, Tomoyuki (Nihon university)

Co-authors: Prof. CHEOUN, Myung-Ki (Department of Physics, Soongsil University,); Dr HAYAKAWA, Takehito (National Institutes for Quantum and Radiological Science and Technology,); Prof. KAJINO, Toshitaka (4Beihang University, School of Physics, International Reserach Center for Big-Bang Cosmology and Element Genesis)

Presenter: MARUYAMA, Tomoyuki (Nihon university)

Session Classification: Parallel Session

Track Classification: Nuclear Astrophysics