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Chiral effects from non-equilibrium left-handed neutrinos in core-collapse supernovae

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Recently, the anomalous transport phenomena of relativistic fermions associated with chirality induced by external fields have been greatly explored in different areas of physics. Notably, such phenomena are in connection with various quantum effects such as the chiral anomaly and spin-orbit interaction. These chiral effects like the chiral magnetic and vortical effects have been recently included for the study of lepton transport in core-collapse supernovae (CCSN). In particular, to delineate the chiral effects on neutrino radiation, a novel chiral neutrino radiation transport equation is derived from the chiral kinetic theory, which incorporates quantum corrections pertinent to magnetic and vortical fields in the collision term. Through this collision term for left-handed neutrinos near thermal equilibrium, the anisotropic energy current of neutrinos triggered by magnetic fields is found, which could have a potential application to pulsar kicks. We show such back reaction of left-handed neutrinos out of equilibrium on the matter sector induces an electric current proportional to a magnetic field even without a chiral imbalance for electrons in CCSN. This chiral electric current generates a strong magnetic field via the so-called chiral plasma instability, which could provide a new mechanism for the strong and stable magnetic field of magnetars. We also numerically study the physical origin of the inverse cascade of the magnetic energy in the magneto-hydrodynamics including this current. Our results indicate that incorporating the chiral effects of neutrinos would drastically modify the hydrodynamic evolutions of supernovae, which may also be relevant to the explosion dynamics.
References:
[1] Jin Matsumoto, Naoki Yamamoto, Di-Lun Yang, “Chiral plasma instability and inverse cascade from nonequilibrium left-handed neutrinos in core-collapse supernovae”, Rev. D 105, 123029 (2022).
[2] Naoki Yamamoto, Di-Lun Yang,”Magnetic field induced neutrino chiral transport near equilibrium”, Phys.Rev.D 104, 123019 (2021).
[3] Naoki Yamamoto, Di-Lun Yang, “Chiral Radiation Transport Theory of Neutrinos”, Astrophys.J. 895 (2020) 1, 56.

Is this abstract from experiment?

No

Name of experiment and experimental site

N/A

Is the speaker for that presentation defined?

Yes

Details

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https://www.phys.sinica.edu.tw/directory_en.php?directory=11&id_key=156

Internet talk

Maybe

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