Magnetically Aligned Dust as a Source of Chiral Symmetry Breaking via Spin-Polarized Electrons

Thiem Hoang[1,2]

[1]*Korea Astronomy and Space Science Institute, Republic of Korea*

[2]*Korea University of Science and Technology, Republic of Korea*

The homochirality of organic moleculessuch as amino acids and sugars is a defining biosignature of life on Earth, yet its origin remains a fundamental question in astrobiology. Spin-polarized electrons (SPEs) from the -decay of radioactive nuclei have been proposed as a possible mechanism for chiral symmetry breaking, though their role is still under debate. In this work, we propose a novel source of low-energy SPEs: magnetically aligned interstellar dust grains. These grains can emit spin-aligned electrons via the Barnett effect, triggered by interstellar UV radiation and cosmic rays (CRs). We focus on protostellar environments, where we demonstrate that icy grains can achieve magnetic alignment through a radiative torque mechanism enhanced by magnetic susceptibility. We then investigate how CRs produce thermal electrons via ionization of H_2 and CR-induced UV radiation, using an attenuated CR spectrum derived from a continuous slowing down model. These thermal electrons, initially unpolarized, become spin-polarized upon capture by aligned grains due to the Barnett effect, effectively converting them into secondary low-energy SPEs. We suggest that these SPEs, especially those emitted by superparamagnetic grains with substantial iron inclusions, can induce chiral asymmetry in prebiotic molecules formed within ice mantles, similar in effect to circularly polarized UV light. This mechanism offers a compelling pathway for the origin of molecular homochirality in the early stages of star and planet formation.

References:

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