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Geomagnetic Field Modulation of Prebiotic N-Carbamoylation

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The search for extraterrestrial life requires rigorous criteria to distinguish between abiotic chemical networks and authentic biosignatures. The evolution of complex macromolecules from simple precursors is a pivotal event in the origin of life. Pathways such as the Strecker synthesis and cyanate polymerization reactions elucidate the availability of building blocks. The role of the geomagnetic field (GMF) in shaping prebiotic chemical evolution has mainly remained underexplored. Here, we investigate the GMF as a potential regulator of the urea-mediated *N*-carbamoylation of amino acids, a crucial thermodynamic pathway for the formation of prebiotic peptides.

By simulating primordial planetary conditions, we systematically evaluated the reaction efficiency of all proteinogenic amino acids under GMF (~50 μT) and hypo-magnetic field (HMF, <20 nT) conditions. The yield of CAA production from most amino acids (14/20) is significantly higher under GMF. These results revealed a nuanced landscape of magnetic sensitivity. While statistically significant yield variations were observed between GMF and HMF environments, no uniform directional trend was evident across the amino acid spectrum. Instead, magnetic field effects were heterogeneous and contingent on specific side-chain characteristics.

These findings suggest that the GMF functions not as a dominant driver but as a subtle modulator of prebiotic synthesis. We hypothesize that the GMF likely influenced the distribution of early peptides, acting as an auxiliary variable that contributes to the complexity of prebiotic chemical evolution on Earth and potentially habitable exoplanets.