Selection of Amino Acid Homochirality in Stellar Environments

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Because they are asymmetric, amino acids (an example of which is shown in Figure 1) have two chiral states - or mirror images - referred to as "left-handed" and "right-handed" forms. With very few notable exceptions, nearly all life on earth utilizes only left-handed amino acids, a phenomenon referred to as biomolecular homochirality. Additionally, analyses of inclusions in meteoritic carbonaceous chondrites have revealed numerous amino acids. The discovery that *meteorites not only contain amino acids, but can have amino acids favoring left handed amino acids* is a possible indicator that amino acid chiral selection may have extra-terrestrial origins and has led to several hotly contested theories. Some of the amino acids so synthesized have an excess of a few percent of the left-handed chirality that is observed in earthly amino acids. It is generally accepted that if some mechanism can introduce an imbalance in the populations of the left- and right-handed forms of any amino acid, successive autocatalysis can amplify this enantiomeric excess to ultimately produce a single form. What is not well understood is the mechanism by which the initial imbalance is produced and the means by which it produces the left-handed chirality observed in the amino acids. *The origin of biomolecular homochirality is one of the top questions in science today* [1].

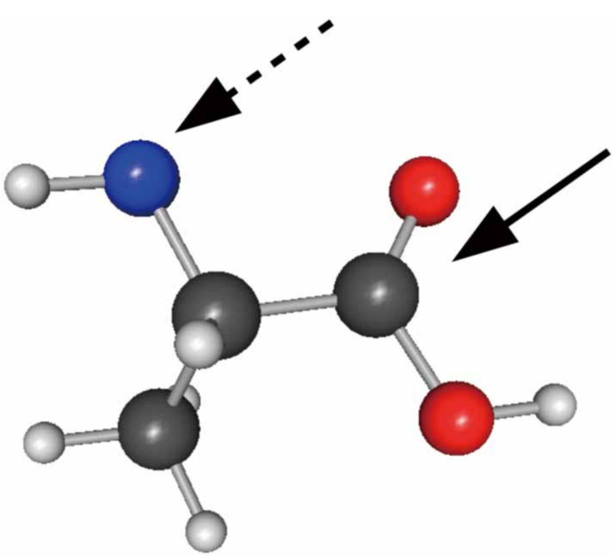

Figure 1: The left-handed enantiomer of the amino acid, alanine, L-alanine. The amine group is indicated by the dashed arrow and the carboxyl group by the solid arrow.

A model has been created which predicts the origins of amino acid homochirality in an emergent stellar phenomenon involving lepton interactions in magnetic fields [2]. Multiple sites capable of implementing this models have been proposed [3].

The results of an evaluation are shown in Figure 2 for the amino acid isovaline (in cationic form) for a scenario representing conditions of a meteoroid in the vicinity of a neutron star. The antineutrino reaction rates are given by the ratios $f = 0$, 0, 10^{-9}, 5×10^{-9}, 10^{-8}, 2×10^{-8}, and 5×10^{-8}, where f is defined as the ratio of the neutrino interaction rate to the nitrogen nuclear spin relaxation rate.

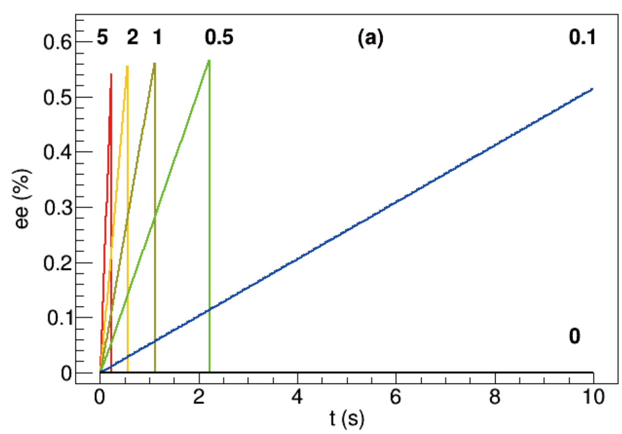

Figure 2: Enantiomeric excess of isovaline in a high-field, high flux environment for several different neutrino interaction rates.

In this figure, the relative amount by which one chiral state outnumbers another is given by the "enantiomeric excess," *ee*, defined as $ee \equiv (N_L - N_D)/(N_L + N_D)$ where N_L and N_D represent the number of left- and right-handed amino acids, respectively, of a specific type in an ensemble. The *ee*s computed in this model are similar to those found in meteorites. It is possible that amino acid *ee*s have their origin in space, while subsequent autocatalysis via chemical or biological means can increase the *ee* to the homochiral values observed today.

References

[1] Kennedy, D., Norman, C.: 2005, *Science*, **309**, 78.
[2] Famiano, M. A., et al.: 2018, *Astrobiology*, **18**, 190.
[3] Boyd, R. N., et al.: 2018, *ApJ*, **856**, 26.