Origin of Chirality of the Amino Acids

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Half a century ago it was demonstrated by Miller [1] and Urey that at least some of the 20 amino acids on which we depend for life could be produced in a spark discharge in a chemical environment that may have existed early in the Earth's history. Thus the model of such an environment in a lightning storm became the accepted means for producing amino acids on Earth. However, the amino acids have been found to have a left-handed chirality, whereas the Miller-Urey mechanism produces equal numbers of left- and right-handed molecules. Furthermore, amino acids have been found in meteorites[2], and those that have a preferred chirality had more lefthanded molecules than right-handed molecules (at a level of 10%). Several mechanisms have been suggested as being the means by which the amino acid chirality is established. One widely accepted one involves circularly polarized light impinging on the molecules that are produced on Earth, although circularly polarized x-rays in the interstellar medium have also been suggested as a driver of chirality.

However, during the past several years, we have developed a model[3,4] for establishing amino acid chirality in the interstellar medium by selective molecular destruction of one chirality by neutrinos from a supernova. In this model, the strong magnetic field from the protoneutron star would orient the ^{14}N nuclei that are common to the amino acids to produce a significant fraction of those nuclei with their spins aligned with the neutrino spin. Neutrino helicity is a conserved quantum number, which is aways −1 for neutrinos and +1 for antineutrinos, namely the symmetry of left- or right-handedness is maximally broken in nature.

Angular momentum conservation requires that the $\nu + {}^{14}N \rightarrow {}^{14}C + e^+$ reaction (ν denotes an electron antineutrino) requires transfer of one unit of angular momentum from the neutrino wave function when the spins are aligned, whereas the reaction could proceed with no angular momentum transfer when the spins are not aligned. This inhibits the reaction by roughly an order of magnitude for the aligned case, skewing the magnetic substate distribution in favor of one ^{14}N spin configuration and, therefore, one molecular chirality[5]. The intense magnetic field also modifies the antineutrino cross sections, thereby creating an antineutrino flux that is asymmetric by 3%[6]. This combination of effects would create a small chirality preference; we estimate it to be a maximum of 1×10^{-6}.

While the Galactic supernovae are not capable of processing all the molecules in the galaxy, several mechanisms exist for amplifying this chirality preference, and for spreading it throughout the Galaxy. It is also believed[3,4] that once a chirality preference was established on Earth, more amplification would drive that preference to homochirality.

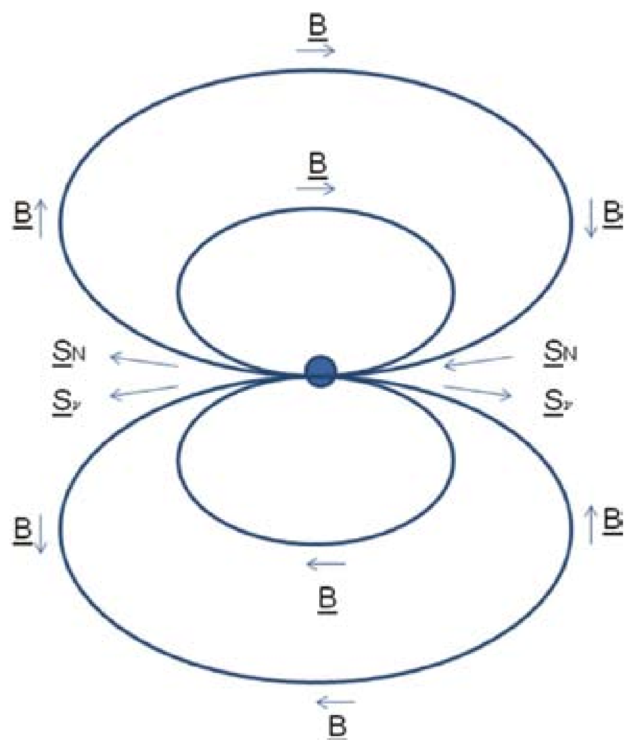

Figure 1: Schematic diagram of the magnetic fields, B, surrounding a nascent neutron star and the spins of the ^{14}N nuclei, S_N, and of the neutrinos, $S\nu$, emitted from the collapse of the supernova that created the neutron star.

References

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