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A self-shielding origin for the ^{15}N enrichment in meteoritic amino acids

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Introduction: Meteoritic amino acids are typically enriched by ~ 50 - 200 ‰ in $\delta^{15}N$, measured relative to Earth atmosphere N_2 [1]. However, this does not capture the full magnitude of the enrichment. Measurements of N isotopes in solar wind samples collected by the NASA Genesis mission reveal that inner solar system objects, including Earth's atmosphere, are enriched by ~ 400 ‰ compared to the bulk Sun [2]. Therefore, the enrichment in meteoritic amino acids, relative to the starting material from which the solar system formed (the bulk Sun), is ~ 450 – 600 ‰. We propose here that photochemical self-shielding of gas phase N_2 is responsible for producing such massive ^{15}N enrichments.

Methods: We have completed initial modeling of N isotopes in a vertically-mixed solar nebula model that includes N_2 self-shielding and HCN and NH_3 formation in a network of over 700 reactions involving ~ 100 species [3]. We find that NH_{3gr} (NH_3 on dust grains) is highly enriched in ^{15}N, with delta-values relative to Earth atmosphere ranging up to +800 ‰, demonstrating that N_2 self-shielding can easily achieve the ^{15}N enrichments observed in the inner solar system.

Amino acid formation: Amino acids in meteorites are formed primarily by aqueous phase reactions in their meteorite parent bodies. Strecker synthesis, Michael addition, and reductive amination all involve reaction of a carbonyl or nitrile with NH_3 [1]. NH_3 that is derived by grain formation and N_2 self-shielding in the solar nebula will contribute its substantial ^{15}N enrichment to amino acids formed by these formation mechanisms.

Conclusions: We argue here that the ^{15}N enrichment measured in meteoritic amino acids can be explained as a result of NH_3 production from N atoms liberated during N_2 self-shielding in the solar nebula. We conclude that photochemistry in the solar nebula was likely an important contributor to the inventory of prebiotic molecules in early Earth environments.

References: [1] Elsila J. et al. (2012) *MAPS*, 47, 1517. [2] Furi E. and Marty B. (2015) *Nat. Geo.,* 8*,* 515. [3] Garani J. and Lyons J. R. (2021) *52nd LPSC, abstract # 2571.*