The Laboratory Production of Complex Organic Molecules in Simulated Interstellar Ices

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Much of the volatiles in interstellar dense clouds exist in ices surrounding dust grains. Their low temperatures preclude most chemical reactions, but ionizing radiation can drive reactions that produce a suite of new species, many of which are complex organics. The Astrochemistry Lab at NASA-Ames studies the UV radiation processing of interstellar ice analogs to better identify the resulting products and establish links between interstellar chemistry, the organics in meteorites, and the origin of life on Earth. Once identified, the spectral properties of the products can be quantified to assist with the search for these species in space.

Of particular interest are findings that UV irradiation of interstellar ice analogs produces molecules of importance in current living organisms, including quinones, amphiphiles, and amino acids. Quinones play a variety of roles including electron transport and are used by all organisms. Studies show that quinones should be made wherever polycyclic aromatic hydrocarbons are irradiated in interstellar ices (Bernstein *et al.,* 2001). Amphiphiles are also made when mixed molecular ices are irradiated. These amphiphiles self-assemble into membrane-walled vesicles when put in liquid water (Dworkin *et al.,* 2001). Ice irradiation can also produce (Bernstein *et al.,* 2002) and destroy amino acids (Ehrenfreund *et al.,* 2001).

Many of the same processes thought to make organics in space should yield products highly enriched in deuterium (D) (Sandford *et al.,* 2001). The high D/H ratios in some interstellar species, and the knowledge that many of the organics in primitive meteorites are D-enriched, suggests that such linkages do exist. By using D as a tracer, we expect to learn more about the different chemical processes occurring in space and their relative importance in the production of different organic compounds and delivery to planetary surfaces.

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Acknowledgments:

This work was carried out with the assistance of NASA's Origins of Solar Sustems, Astrobiology, Exobiology, and Long Duration Astrophysics Programs.