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# WHAT IS LIFE? HOW MOLECULAR ASTROBIOLOGY AND SPACE EXPLORATION ARE BRINGING US CLOSER TO AN ANSWER

**Abstract**

A physicochemical description of life and its emergence is one of the greatest open problems in science. Life is made of molecules described most fundamentally by quantum theory. The identification of quantum effects in primitive organisms such as bacteria has resulted in the successful application of open quantum systems models to transfer processes in photosynthetic systems, as well as suggesting that quantum effects may have played an important role in the emergence of the very first living systems from the inanimate matter of which they are constituted.

Improvements in observational techniques have resulted in the detection of over 150 species of organic molecules in our galaxy to date, including a range of molecules likely to be precursors of life in interstellar regions. This suggests that the formation of the building blocks of life may not be as rare an occurrence as once imagined. Furthermore, a range of experiments have demonstrated the spontaneous generation of amino acids in diverse environments ranging from early Earth atmospheric analogues subjected to electric discharge, to interstellar ice analogues irradiated with UV light.

However, typically employed quantum chemical computational methods describing gas-phase phenomena cannot account for the variety of chemistry occurring in the interstellar medium, in particular, since a range of chemical processes take place on the surfaces of icy dust grains subject to incoming ultraviolet radiation. The theoretical study of the spontaneous generation of prebiotic molecules on icy dust grains in the interstellar medium is performed most fundamentally in the framework of open quantum systems.

Understanding the fundamental principles of the system-environment interaction resulting in the spontaneous formation of prebiotic molecules will allow the prediction of which as yet undetected complex molecules could have formed in regions ranging from interstellar space to specific locations in our solar system, as well as the prediction of general characteristics of environments where such molecules emerge. We report our progress on this topic, which would not be possible without ongoing ground-based observations of our galaxy from Earth, as well as flyby, sample return, robotic and crewed missions in our own solar system, to provide data on the richness of chemistry occurring there.