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# From Astrochemistry to Astrobiology: a methodological approach

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## Abstract

Molecules are widely observed in the Interstellar Medium, particularly in dense regions of space, molecular clouds, out of which stars and planetary systems form. Although gas phase molecules are numerous, solid state ones, known as van der Waals solids or dirty ices are much more abundant and will play an essential role in the build-up of organic molecular complexity. These ices represent semi-volatile species that participate in a complex chemistry that can be simulated in the laboratory. These simulations allow the formation of complex organic residues that contain many potentially prebiotic molecules. The relevance to Astrobiology is thus rather suggestive and discussed here.

## 1. Introduction

The chemical evolution of our Galaxy is broadly understood: astration and star evolution provides for the elements and allow to define the cosmic abundances of them. At the end of their lives, supernovae explode, returning the elements in the ISM where new stars are formed, enriched in elements. Stars of intermediate masses, ending their lives in the AGB phase, provide the formation of dust grains that are released in the ISM by radiation pressure. These grains play a determining role in molecular formation, in particular through the formation of $H_2$. In the denser media where molecules do form, ices of known composition are then formed. The chemical evolution of these ices, particularly upon irradiation by energetic particles or UV photons allow for the formation of complex molecular species that remain protected by the grains on which they are adsorbed [1].

## 2. Cosmic abundances, depletions and the basic elements of life

Cosmic abundances are defined as the relative abundances of the elements in the photosphere of the Sun. However, when these abundances are measured in the ISM, analysing the light from distant stars, elements are missing from the gas phase. These elements are depleted, according to the refractory nature of the dust grains they are able to make in the envelopes of stars, such as oxides, carbides, silicates, amorphous carbon materials…However, the most abundant elements (H), O, C, N, S, P are also the less depleted for reasons that involve grain properties. These elements are thus available for a rich organic chemistry that will take place from the ice phase in molecular clouds. These elements are exclusive in biomolecules such as RNA and DNA which suggests strongly that life on Earth is a natural consequence of the chemical evolution of our Galaxy

## 3. The role of ices in the abiogenesis of organic matter

Laboratory simulations of inter/circumstellar ices have been undertaken in many laboratories. These simulations, based mainly in the ices irradiation by UV light duplicate the fate of interstellar ices. Starting with a representative mixture of ices (thus observed in the ISM), irradiation creates a complex network of radicals reactions leading to the formation of more complex molecules. At the end of the experiment, a complex soluble organic residue is always observed on the substrate. Chemical analysis of these residues, using sensitive techniques such as GC-MS reveals the presence of numerous amino acids [2] that can be compared with the composition of amino acids in meteorites. Other molecules such as glycolic acid, urea and glycerol [3], hydantoin [4] (a catalyst for the formation of oligopeptides) are also present in these residues whose complexity is attested through high resolution mass spectrometry.

## 4. The cycle of solid matter in the Galaxy

From the death of a star to the birth of new ones, solid state materials do evolve in the interstellar medium. Grains in the diffuse medium enter molecular clouds when they form and molecules and ices are formed and photochemical processes provide large amounts of organic matter. This constitutes a cycle. Gravitational collapse of the clouds will form stars and planetary systems, the debris of which (asteroids and comets) will fall on planets with the possibility to bring to telluric planets water and organic materials that may be necessary for the onset of prebiotic chemistry prior to the emergence of life.

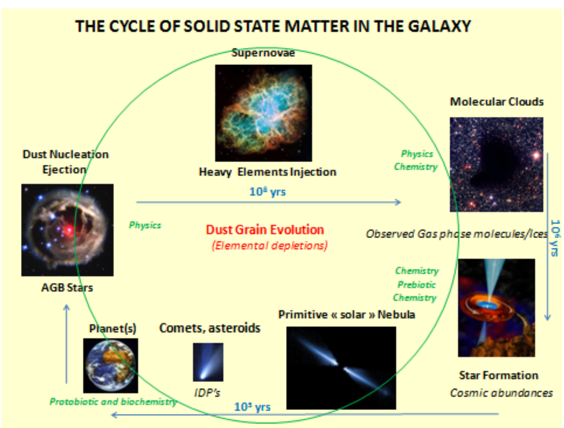


Figure 1 : The cycle of solid state matter in our Galaxy. Timescales are indicated.

## 5. Summary and Conclusions

Non directed experiments (simulations), taking into account certain characteristics of astrochemistry and in particular the chemistry of interstellar ices are able to reproduce huge quantities of abiogenic organic matter that may habeen decisive for the onset of prebiotic chemistry on the Earth (or on other telluric planets). However, if all these processes described above are indeed deterministic, the contingent nature of the chain of events leading to life is very far from being understood and the occurrence of life in our Galaxy remains unpredictable. Besides, it is by no means clear that the so-called prebiotic molecules discovered in meteorites did play a role in true prebiotic chemistry essentially because the chemistry from the ice irradiation and the organic composition of primitive meteorites do not present any selectivity and is driven to thermodynamic equilibrium that does not favour auto-organisation. Recent advances in prebiotic chemistry involve Systems Chemistry of replicators far from equilibrium that may provide selection and amplification of certain molecules or molecular networks, displaying auto-organisation and replication. The precise role of exogenous organic matter delivered to Earth by comets and asteroids remain an attractive but unproven hypothesis.


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