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Laboratory analogs for the development of space missions and their data treatments

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Abstract

All our approaches shows that laboratory simulation provides important information on the analysis of data coming from space missions (eg Rosetta). They are also useful in the preparation of future space missions either for determining the environments where such missions can be performed, or for giving information for the definition and the development of analytical tools of these missions. The last impact of laboratory simulation consists in testing these analytical tools before their shipping. By taking example of what we are developing in our laboratory, we will discuss about the different interests that could emerge by developing a close collaboration between ground experiments and space mission development laboratories.

1. Introduction

Understanding of the evolution of organic matter in astrophysical environments is a important field of research in astrobiology. It provides clues about its composition and on its availability throughout the Universe for leading ultimately in some environments to chemical systems which may precede the emergence of biochemical systems. For understanding this evolution , several approaches can be considered. The first approach consists in observing the different astrophysical environments from telescopes or satellites. These observations allow to get important information on physical and chemical processes that can occur in environments observed as well as on the understanding of the evolution of these objects. However, the information about the chemical evolution in these environments is restricted to simple chemical systems having only few atoms. For obtaining more information on the evolution of more complex chemical systems, another approach is the analysis of Solar system objects such as comets, asteroids, meteorites or planets. This can be done by in situ space missions whose objective is to meet (or even contact) some of these objects and analyze their composition (Rosetta space mission , Mission Hayabus , Mission Martian Curiosity , Cassini - Huygens mission). Characterizations of such object can also be performed by using sophisticated analytical methods on Earth as for meteorites or sample return. All these observational data allows us to compare different states of the natural organic matter and establish a first evolution of this material. However, they do not allow to trace the overall evolution of this material without the use of specific tracers of molecular evolution. That is why a complementary approach is the development of terrestrial experimental systems for simulating astrophysical environments. The interest of these simulations is to study simple systems (bottom-up approach describing the successive steps of molecular evolution) as well as complex systems (top-down approach, which consists in providing a refined description of extraterrestrial material analog). These simulations are used for example for understanding the evolution of the organic matter from interstellar grains to its incorporation within Solar system objects such as comets.

2. Implications of experimental simulation for space exploration

We believe that beyond the essential information that provide laboratory simulations for understanding the evolution of organic matter in astrophysical environments, experimental simulation can and must play an essential role in the development of instrumentations for future space exploration as well as data processing and data interpretation obtained from these space missions. Laboratory simulations may indeed have an essential impact in different stages (in chronological terms) of space programs through the points below:

1 - Refine the choice of environments in which space missions must be carried out ,
2 - Prepare the development of analytical devices,

3 - Test and qualify prototypes of space missions,
4 - Limit the risks associated with these missions,
5 - Develop and validate tools for analyzing data from space missions,
6 - Optimizing scientific return of space missions.

3. An example of experimental simulation

Our group develop experimental simulations for investigating the chemical reactivity and the chemical evolution that occur during star formation or in cometary environments. We develop two complementary approaches.

A bottom-up appraoch which consists in studying the reactivity that can lead to the formation of molecules in astrophysical environments. For instance, we were interested in the POM formation in cometary environments. POM is suggested to be an important component of comets, since it could be an extended source of formaldehyde by thermal degradation in cometary environment. It is one target of the COSIMA instrument of the Rosetta mission that will analyze molecular compound of cometary grains. However, a detail study of the reactivity that lead to the formation of POM in cometary conditions shows that only small POM (< 5 monomers) should form. Furthermore, we have shown that these small POM desorb from the grain surface as such without any degradation and at temperature lower than the temperature storage of grains in COSIMA. This imply that COSIMA could be not the best analyzer for POM, but rather ROSINA which can directly characterize these small POM in the gas phase[1,2].

The second approach that we are developing in the top-down one. In this case, we study the overall evolution of the organic matter in astrophysical environments and not anymore specific reactions as describe above. The first project consists in analyzing the whole compounds that sublime during the warming of a cometary ice analog[3]. This approach will give us important information of volatile molecules that could be detected by the Rosetta mission in the gas phase, and should thus improve the data treatment coming from this mission. An another approach consists in analyzing the whole residue that is formed after the warming of an ice analog. In this case, our aim is to find the best analytical method for obtaining a whole information of the evolution of these analogs. The aim is to obtain a mapping of this evolution that could then be compared to astrophysical objects such as meteorites.

We currently focus our investigation on high resolution mass spectrometry associated to the development of specific data treatment (collaboration with Roland Thissen, IPAG, Grenoble, France)[4]. The developed protocols can be then used for future space missions using high resolution mass spectrometry (e.g. orbitrap) as well as for the analyses of astrophysical objects on ground base.

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