From Diffuse Interstellar Bands to comets: the organic connection

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Jean-Loup Bertaux (1, 2) and Rosine Lallement (3)
(1) LATMOS-UVSQ, Guyancourt, France; (2) Space Research Institute (IKI), Moscow, Russia, (3) GEPI, Observatoire de Paris, Meudon, France. (jean-loup.bertaux@latmos.ipsl.fr)

Abstract

The analysis of dust grains collected by *Rosetta* spacecraft from comet 67/P Churyumov-Gerasimenko has shown that they are constituted of about the same amount of minerals and large organic molecules (in mass ~45% organic, ~ 55% mineral, ([2], Bardyn et al. 2017). We suggest that the comet organic molecules are the same organic molecules that produce, in the Interstellar Medium (ISM), diffuse absorption features imprinted on stellar spectra (DIBs, Diffuse Interstellar Bands). The large molecules forming the DIBs are not yet identified, except for fullerene C_{60}^+, but are thought to constitute "… the largest reservoir of organic material in the Universe" ([7], Snow, 2014).

1. Introduction

The COSIMA instrument on board Rosetta collected dust grains escaping from the nucleus of 67P. Their composition was analyzed with a SIMS-TOF technique. They all show C^+, CH^+, CH_2^+, CH_3^+, which are fragments of much larger unidentified organic molecules ([6], Fray et al., 2015). We propose that they are the same large molecules producing the DIB absorptions in the ISM that agglomerate together in a condensing interstellar cloud which became eventually our solar system ([3], Bertaux et Lallement, 2017). Therefore, there is no need to invoke a massive fabrication of organics during the solar system. They were conserved from ISM during the formation of the solid comet nucleus, within the scenario established by [4] Davidsson et al. (2016) based on many arguments collected by *Rosetta*: a hierarchical scenario of gentle accretion of small interstellar grains to the final size of the nucleus. We back up our suggestion from both qualitative and quantitative arguments.

2. The ratio organic/mineral

A statistical analysis of the Equivalent Width (EW) of all known DIBs absorptions was performed. Assigning to all DIBs an oscillator strength equal to $C_{60}^+$and an average number of 60 C atoms per DIB carrier molecule, it is computed that at least 30% of ISM carbon is locked into a DIB carrier. It implies that in the ISM, the ratio organic/mineral is at least R_{ISM}=0.32, to be compared to R_C= 0.8±0.1 for the comet [2]. For the ISM, R_{ISM}=0.32 is a lower limit, since only those organic molecules which absorb are accounted for.

3. DIB carriers decrease within dense clouds

On the other hand, the sounding of some interstellar nebulae show that, when the Line-of-sight approaches the centre, the DIBs depths are levelling off while the dust extinction is still increasing, suggesting an accretion process for the DIB molecules. These organic molecules would agglomerate to form interstellar grains that will end up in the proto-solar nebula, then in comet nuclei.
As an example of such an accretion process in the ISM, the EW of an infra-red DIB has been compared to the dust extinction in the Barnard 68 nebula [5]. On fig.1 is represented the distribution of dust extinction (taken from [1]) which increases toward the center of the nebula. The dust extinction and corresponding H columns may be plotted as a function of distance to center (not shown here). They then may be inverted by an onion-peeling method to yield the *local* density distribution function of [H] as a function of distance to center (in arcsec, figure 2). The same method was applied to the EW of the IR band at 1527.3 nm, to derive a local volume density of this particular DIB carrier associated to this IR DIB.

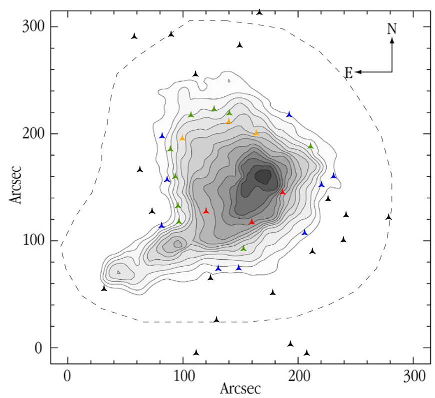

Figure 1: Target positions on the Barnard 68 extinction map from [1]. Solid contours correspond to 2 magnitude steps from extinction Av = 4 to 30 mag. The dashed line represents Av = 1:2 mag (taken form [5]).

While the local densities of both H atoms and DIB carriers are increasing toward the center of the nebula (figure 2), the increase of DIB carriers is much slower than the H atoms, as displayed by their ratio n(H)/n(DIB) which ***decreases*** toward center (blue curve of figure 2). This fact may be interpreted by an accretion process of DIB carriers molecules, either aggregating between themselves or accreting onto dust grains. Once these molecules are accreted, they can no longer absorb as they were when free-floating in space before accretion. Once formed, these grains (which could contain also minerals) would constitute the major fraction of the proto solar system from which condensed comet nuclei.

Conclusions.

It is often stated that early bombardment of comet nuclei on Earth could have facilitated the emergence of life on this planet by bringing organic material. Comet 67/P contains 3.5 billion tons of organic matter. Since the presence of DIBs is ubiquitous in our Galaxy, and in other galaxies, it is likely that organic material has been brought to all habitable exo-planets. How many of them have developed life, and intelligent life, are two other questions that would deserve large research investments, since they are related to the layman question: "Are we alone in the Universe ?"

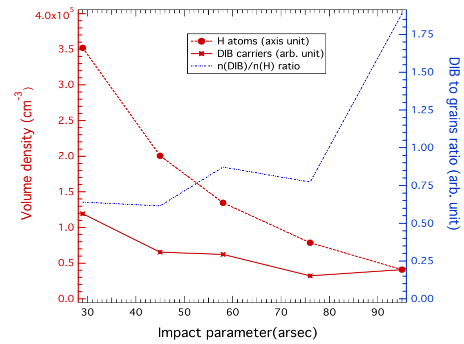

Figure 2: Volume density of DIB carrier n(DIB) based on the simplified inversion of EWs (left scale). Also shown is the inverted volume density n(H) based on Av data. The n(DIB) has been artificially scaled in such a way the two curves cross for the external layer at 96 arcsec. The ratio between the DIB carrier and H volume densities is also shown (right scale): it decreases toward center (taken from [5]).

Our proposed scenario of DIB connection with comets implies that a comet return-sample mission would not need to be much cooled to keep the double interest for comets and for Interstellar Medium studies, since the solid organic phase of the comet is not very volatile.

References

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