Delivery of prebiotic material on the first generations of Milky Way planets

Was it possible ?

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Introduction

The possibility of delivery on Earth of prebiotic molecules assembled and processed in space has been demonstrated by several studies of meteorites [1,2,5].

The presence of L-type enantiomeric eccesses in extraterrestrial aminoacids found in some carbonaceous chondrite meteorites [1,2] suggests that prebiotic material delivered from space on the primitive Earth may have played a crucial role in the origin of terrestrial life.

In the present contribution we discuss whether or not interstellar organic material was also available at earlier epochs, well before the formation of the Solar System, for delivery on the first generations of Milky Way planets.

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Probing the early stages of interstellar organic chemistry

Observations of the Milky Way interstellar medium cannot probe the early interstellar chemistry because the time-scale of interstellar mixing is much shorter than time-scale of Galactic evolution.

Therefore, in order to cast light on the early interstellar chemistry, we consider different types of chemically unevolved environments, representative, to some extent, of the young Milky Way.

In practice, we investigate metal-poor galaxies of the local Universe and high-redshift, unevolved galaxies observed in absorption in the spectra of background quasars.

For these different types of environments we study the evidence of diffuse interstellar organic material.

The "extinction bump" at 217.5 nm

The extinction bump at 217.5 nm is a classic indicator of interstellar carbon-bearing material [3]. In nearby, metal-poor galaxies, such as the Small Magellanic Cloud, the extinction bump is known to be much weaker than in the Milky-Way. Searches for the extinction bump in unevolved galaxies of the distant Universe yield similar indications. In fact, attempts to detect the extinction bump in high-redshift absorption systems [10] generally give null results (Fig. 1), with a few exceptions.

The general lack of extinction bump in unevolved environments indicates a deficiency of organic molecules in the early stages of evolution of galaxies. It is reasonable to expect that <u>a deficiency of organic material was</u> also <u>present in the interstellar medium of the young Milky Way</u>.

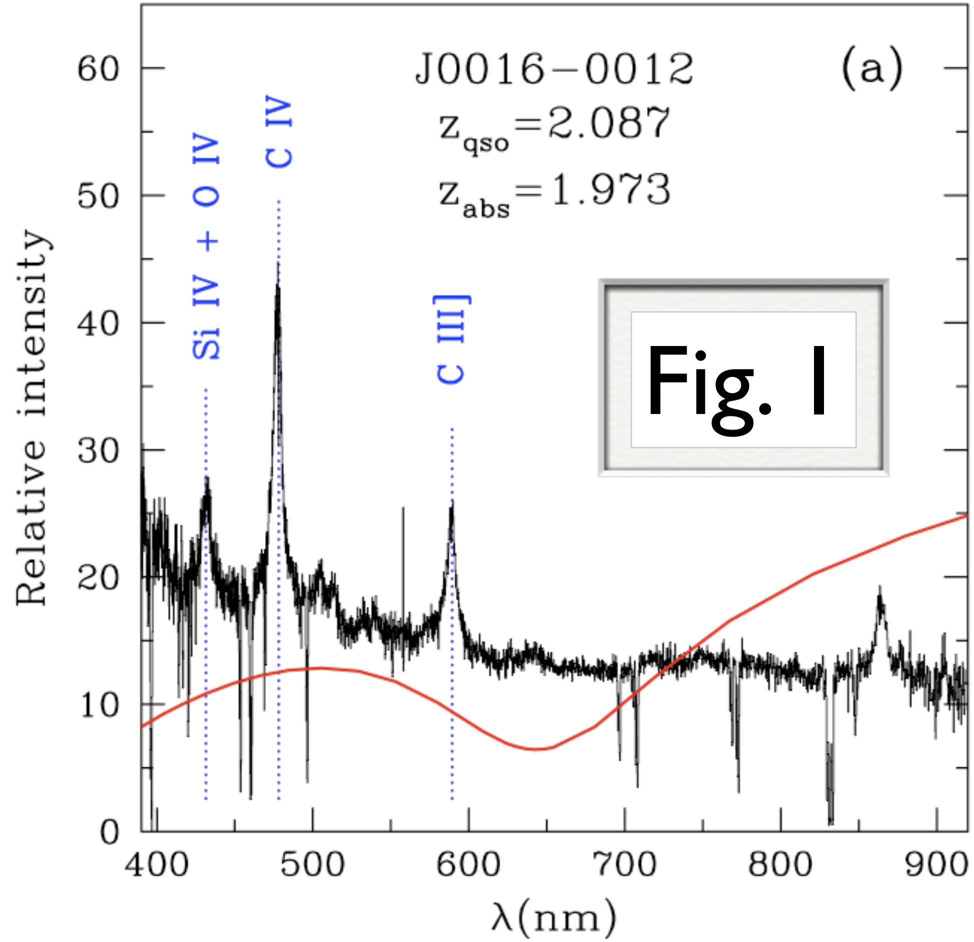

Fig. 1. Search for the 2175 extinction bump in a high-redshift absorption system [10]. Black line: observed spectrum of the background quasar. Red line: predicted Milky Way extinction curve at the redshift of the absorber. No extinction bump is detected.

Dust in chemically unevolved environments

It is well known that dust grains play a crucial role in interstellar chemistry. The abundance of dust at early stages of chemical evolution therefore provides an indication of the efficiency of the chemical network that may lead to the formation of complex, carbon-bearing molecules.

Observations indicate that the dust-to-gas ratio scales down with the level of metal enrichment. This result, already known for nearby, metal-poor galaxies, is now confirmed by studies of high-redshift absorbers (Fig. 2).

The low abundance of dust in unevolved environments negatively impacts the formation of complex organic molecules in two ways: (1) weakening the UV extinction shield that protects interstellar molecules from photo-dissociation and (2) reducing the catalytic effect of molecular formation on the surface of dust grains. Therefore the chemical pathways that lead to organic chemistry tends to become less and less efficient at low metallicity.

Carbon abundance at the early stages of Milky Way evolution

Also the abundance of carbon at the early stages of Galactic evolution is critical to determine the efficiency of the chemical pathways that may lead to the formation of organic interstellar material.

Observations of Milky-Way metal-poor stars indicate that, for most part of the early chemical evolution, the C/O ratio was lower than at the time of Sun formation [6]. The low C/O ratio might have favoured oxygen-rich, rather than carbon-rich chemical pathways [8]. Such pathways would be unfavourable to the formation of prebiotic material. We find evidence of oxygen-rich dust in high-redshift absorption systems, in line with the expectation of oxygen-rich chemistry at the early stages of galactic chemical evolution (Fig. 3). This argument lends support to the notion that organic chemistry would be less favoured than oxygen-based chemistry during the early stages of galactic chemical evolution.

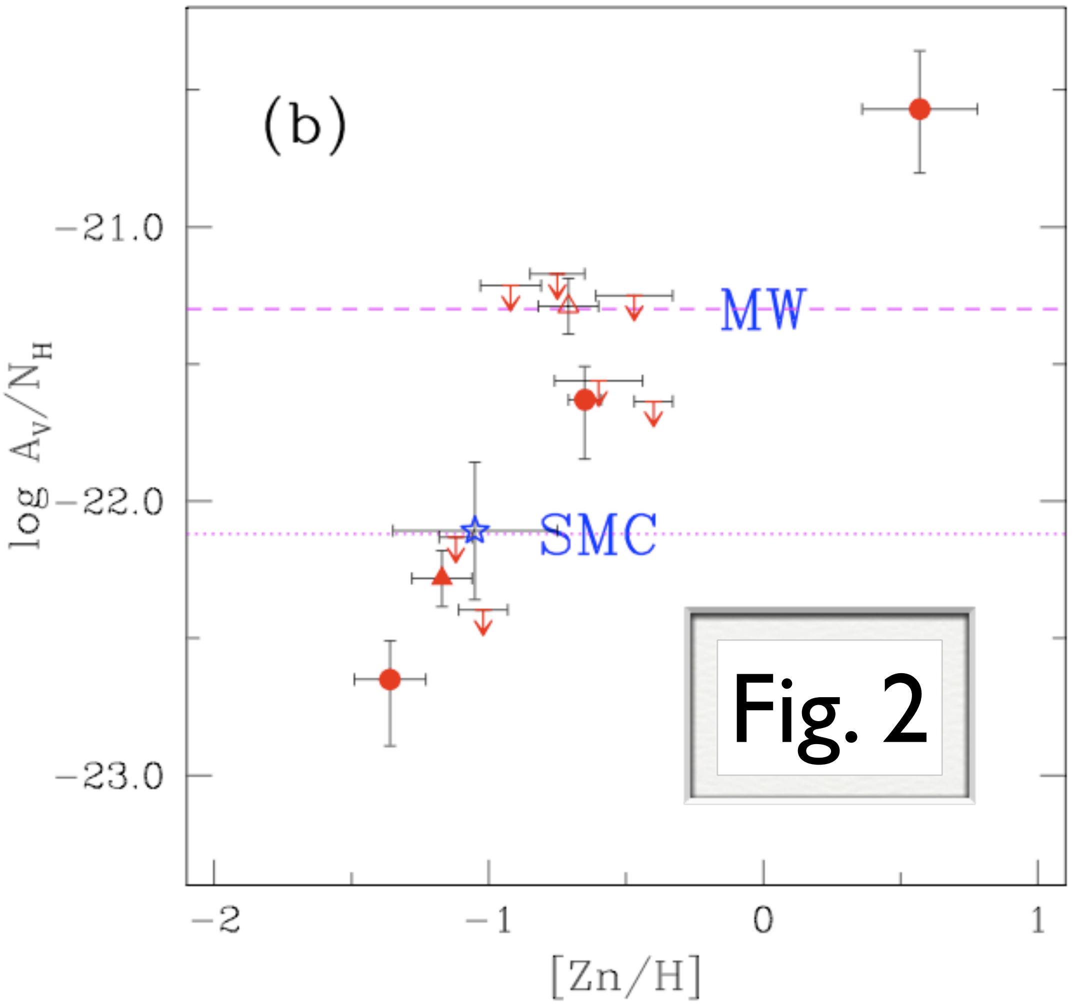

Fig. 2. The extinction per unit H column density, A_V/N_H, is an indicator of the dust-to-gas ratio. Comparison of A_V/N_H in metal-poor galaxies of the local and distant universe (blue and red symbols, respectively) consistently indicate that dust is less abundant in the early stages of chemical evolution [10].

From the diffuse medium to the proto-planetary nebula

The above mentioned arguments refer to the presence of organic material in the diffuse interstellar medium at early epochs of galactic chemical evolution. However, in order to assess the possibility of delivery of prebiotic material onto planets, we should also investigate the chemistry that took place at the stage of planetary formation.

Unfortunately, it is hard to investigate the presence of organics in proto-planetary clouds in past epochs of our Galaxy. In fact, the chemistry of pre-stellar clouds and planetesimals is poorly known even in the present-day Milky Way [4]. The lower abundance of dust and the lower C/O ratio at low metallicity suggest that, during the early evolutionary epochs, organic chemistry might have been inefficient also at the stage of proto-planetary formation.

Conclusions

Different, indipendent arguments consistently suggest that interstellar organic chemistry was less efficient in the early stages of the Milky Way evolution, before the formation of the Solar System. As a result, space *delivery of organic material might have played a minor role in the first generations of exoplanets*.

Future work is required to probe this scenario. In particular, a major effort is required to cast light on the chemical processing that occurs during the stages of planetesimal formation.

If this scenario will be confirmed by future studies, the assemblage of prebiotic material on early planets, if any, should have taken place *in situ*, through chemical pathways a la Urey-Miller.

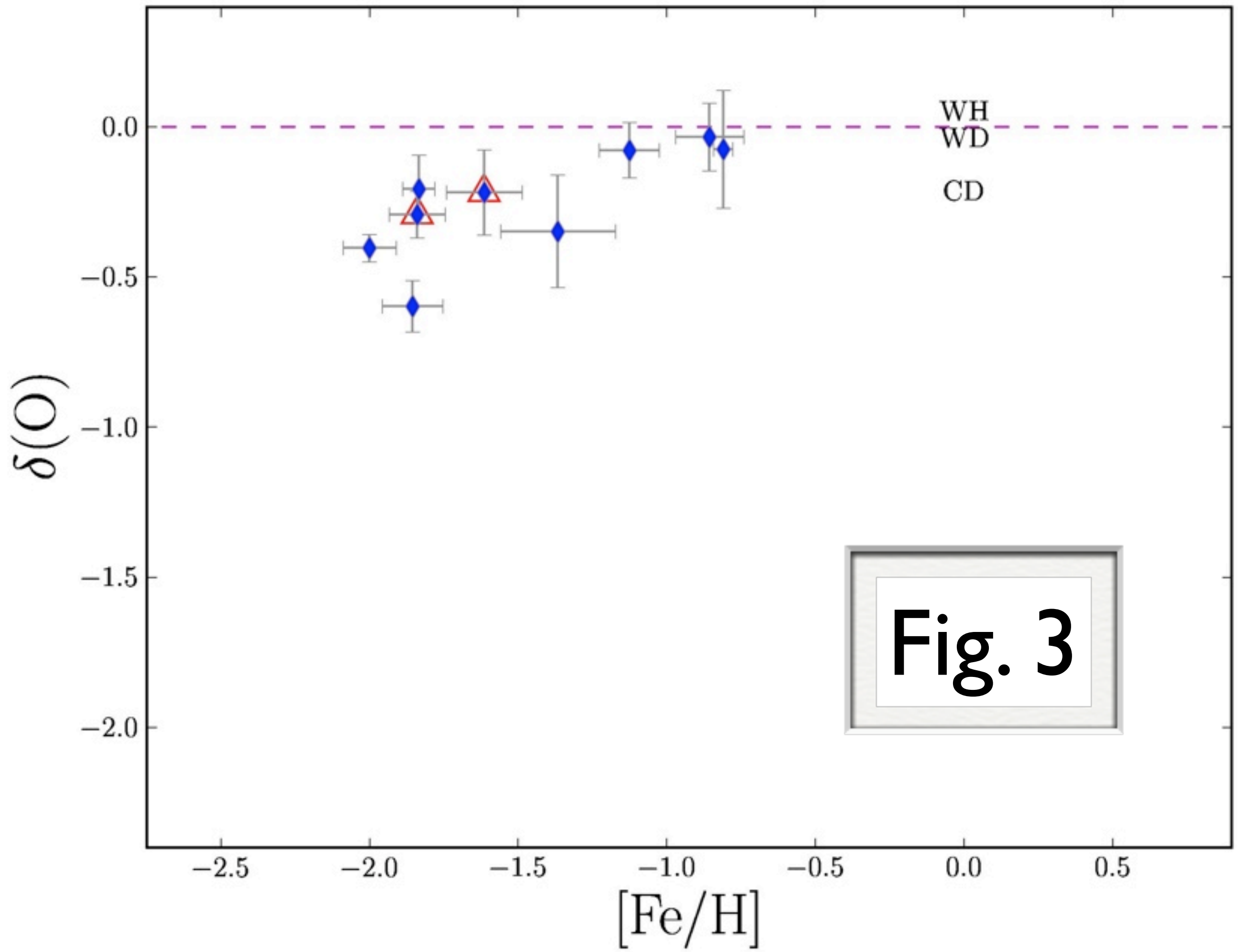

Fig. 3. Evidence of oxygen depletion in metal-poor absorption systems (Vladilo et al., in preparation). Oxygen is undepleted in present-day interstellar clouds. This result suggests that oxygen-rich chemistry was important at early stages of chemical evolution, characterized by a low C/O ratio.

Future work

Study the abundance of other tracers of organic material, such as PAHs and infrared bands [4], in different types of environments, in order to corroborate the trend of carbon deficiency at low metallicity inferred from the observations of the 2175 nm extinction bump.

Improve our understanding of the chemistry that takes place at the time of planetary formation. This can be done by modelling the chemical and physical properties of minor bodies of the Solar System [7]. Observational results should be used to constrains model calculations of the chemical pathways that build up prebiotic material at metallicity and dust-to-gas ratio lower than in the case of the solar nebula.

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