The origin and evolution of organic matter in the solar system: the amino acid content of interstellar ices and the primitive carbonaceous chondrite Paris

Z. Martins[1], P. Modica[2,3], C. Meinert[4], B. Zanda[5], L.L.S. d'Hendecourt[2,6]

[1]ESE, Imperial College London, SW7 2AZ, UK; [2]CNRS, Université Paris XI, Institut d'Astrophysique Spatiale, ''Astrochimie et Origines'', 91405 Orsay Cedex, France; [3]Laboratoire de Physique et Chimie de l'Environnement et de l'Espace (LPC2E), CNRS/Université d'Orléans, 45071 Orléans, France; [4]Université Côte d'Azur, Institut de Chimie de Nice, UMR 7272 CNRS, 06108 Nice, France ; [5]Muséum d'Histoire Naturelle, CNRS, 75005, Paris, France; [6]Equipe ASTRO, Laboratoire de Physique des Interactions Ioniques et Moléculaires, UMR CNRS 7345, Centre de Saint Jérôme - case 252, Université d'Aix-Marseille, 13397 Marseille, France.

The organic matter present in carbonaceous chondrites reflects the physical and chemical reactions that occurred in the interstellar medium, solar nebula, and/or on their parent bodies [1, 2]. It is possible that organic matter synthetized in the initial molecular cloud survived the protosolar disk phase, was incorporated into planetesimals that would later form comets and asteroids, and finally experienced (aqueous or thermal) alteration on the parent body of carbonaceous meteorites [3]. Therefore, laboratory produced interstellar ice analogues, as well as primitive carbonaceous meteorites are precious samples that allow studying key steps into the origin and evolution of organic matter in the solar system. Amino acids, as well as many other complex organic molecules may be formed from ultraviolet irradiation and thermo-processing of interstellar icy grains, accreted into the parent bodies of meteorites [4-6], and finally witness aqueous alteration, which seems to influence their distribution and relative abundance [7-11].

In this study, we have analysed the amino acid content of laboratory organic residues produced by simulated photo- and thermo-processing of icy mixtures [12]. These have been considered as analogues for the organic material synthetized in interstellar or circumstellar icy grains [13-17]. We have also analysed the amino acid content of one of the most primitive CM chondrites, the Paris meteorite [6]. This meteorite is one of the least aqueously altered CM chondrites analysed to date [18-23]. Our results show that Paris has the lowest relative abundance of β-alanine/glycine (0.15 ± 0.02), which is the smallest β-alanine/glycine ratio observed in CM chondrites [6]. The relative abundance of β-alanine/glycine increases with increasing aqueous alteration, from the CM2.7/2.8 Paris to the CM2.0 MET01070. The isovaline detected in the Paris meteorite is racemic (corrected D/L = 1.03). This is a good indication that aqueous alteration may be responsible for extending an initial L-enantiomeric excess (Lee) of isovaline [6], but not responsible for creating an isovaline asymmetry [24-31]. Furthermore, our data shows that the laboratory organic residues have relative distributions of 4-carbon amino acids in agreement with that of the Paris meteorite, and that the relative β-alanine/glycine ratio is similar to that of Paris [12]. The analysis of the soluble organic content of carbonaceous meteorites and laboratory organic residues analogue to interstellar ices helps to increase our knowledge on the origin and evolution of organic matter in the solar system. It also shows that interstellar ice evolution may be an important source for organic matter in the solar system. This helps to build links between the different contributions for the formation of complex molecules, i.e. interstellar precursors, solar nebula, the incorporation in asteroids, and finally meteorite parent body alteration.

References

[1] Martins Z and Sephton MA (2009), In "Amino acids, peptides and proteins in organic chemistry", Wiley-VCH, pp. 3-42. [2] Martins Z (2011) Elements 7, 35. [3] Messenger S (2000) Nature 404, 968. [4] d'Hendecourt LB et al. (1982) A&A 109, 2, L12. [5] d'Hendecourt LB et al. (1986) A&A 158, 1-2, 119. [6] Elsila JE et al. (2007) ApJ 660, 911. [7] Glavin D et al. (2006) Meteorit. Planet. Sci. 41, 889. [8] Glavin D et al. (2011) Meteorit. Planet. Sci. 45, 1948. [9] Martins Z et al. (2007) Meteorit. Planet. Sci. 42, 2125. [10] Martins Z et al. (2015) Meteorit. Planet. Sci. 50, 926. [11] Elsila JE et al. (2016) 47th LPSC, Abstract 1533. [12] Modica et al. ApJ, submitted. [13] Muñoz Caro GM et al. (2002) Nature 416, 403. [14] Meinert C & Meierhenrich UJ (2012) Angew. Chem. Int. Ed. 51, 10460. [15] Myrgorodska I et al. (2015) Angew. Chem. Int. Ed. 54, 1402. [16] de Marcellus P et al. (2011), ApJL 727, 1, L27. [17] Modica P et al. (2014) ApJ 788, 79. [18] Bourot-Denise M et al. (2010) 41st LPSC, Abstract #1533. [19] Caillet Komorowski C et al. (2011) 74th Annual Meeting of the Meteoritical Society, Abstract #5289. [20] Caillet Komorowski C et al. (2013) 76th Annual Meeting of the Meteoritical Society, Abstract #5199. [21] Cournède C et al. (2011) 74th Annual Meeting of the Meteoritical Society, Abstract #5252. [22] Blanchard I et al. (2011) 74th Annual Meeting of the Meteoritical Society, Abstract #5322. [23] Zanda B et al. (2010) 73rd Annual Meeting of the Meteoritical Society, Abstract #5312. [24] Bonner and Rubenstein (1987) Biosystems 20, 99. [25] Bailey et al. (1998) Science 281, 672. [26] Lucas et al. (2005) OLEB 35, 29. [27] Meinert et al. (2012) ChemPlusChem 77, 186. [28] Meinert et al. (2014)

Angew. Chem. Int. Ed. 53, 210. [29] Modica et al. (2014) ApJ 788, 79. [30] Klussmann M et al. (2006) Nature 441, 621. [31] Glavin D et al. (2012) Meteorit. Planet. Sci. 47, 1347.