Comparison of Molecular Complexity Between Chondrites, Martian Meteorite and Lunar Soils

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Introduction: Meteorites and comets bear organic molecules ranging in size from one single to an arbitrarily large number of carbon atoms. This contrasts with the limited size of free molecules detected in space environments[1]. Understanding the organic matter cycle in the solar system requires to identify the time and place where the molecule are formed and destroyed.

The High Resolution Mass Spectrometry technique has been used for almost a decade to characterize extraterrestrial material[2]. The technique only accesses the soluble part of the samples and is used both with and without liquid chromatography for molecular identification[3]. Several authors have proposed an origin for the sample mixtures. For instance, aqueous alteration has been invoked to explain the growth of N-bearing molecules[4] in Murchison.

During the last years, the IPAG group has developed a tool dedicated to the interpretation of the polymerization degree of any sample. We highlighted a peculiar pattern in meteorites extract that can be only reproduced with highly reducing gas phase polymerization experiments[5]. This is interpreted as a protoplanetary disk origin.

The work presented here is a comparison between the typical protosolar pattern and the features found or not in Martian meteorites and lunar soils.

Method: We extracted the organic mixtures from 4 lunar soils and from the NWA7533 "black beauty" Martian meteorite[6] by maceration in Toluene and Methanol for 1 week at room temperature. We did the same for several carbonaceous chondrites including Orgueil, Murchison, 4 CR class samples. Laboratory experiment residues produced from ionized gaz[7], [8], photon irradiated ices [9] or photon irradiated liquids[10] were also analyzed to provide comparison to well constrained synthesis environments. Mass spectra were acquired with a Thermo LTQ Orbitrap XL at its highest resolving power, coupled with Electrospay ionization (ESI) source.

Results: The Orbitrap mass spectrometry provides the mass distribution of mixtures with resolution and precision high enough to undoubtfully identify polymeric patterns. In every sample, CH_2 patterns are detected. A CH_2 family has only molecules with $R\text{-}(CH_2)_n$ formula. From each CH_2 family, the free parameters of the Wesslau model [11] for polymerization can be adjusted to match the distribution. Each sample has from 3 to 15 CH_2 families with up to 30 members. In the synthetic samples, the parameters depend mainly on the precursors mixture. The meteorites exhibit larger variations of the polymerization parameters than synthetic samples. We discuss the relevance of the various candidates for the emergence of molecular diversity of asteroids.

Polymeric patterns in the NWA7533 involve C, H and O. Only CH_2, C_2H_2 and C_2H_4O patterns seem to be responsible of the molecular complexity. Heteroatomic (O-bearing) pattern is the major difference between chondritic and Martian organics. Another major difference is the absence of nitrogen in any cations observed whereas it was a key feature in Murchison.

The patterns in lunar soils are highly variable. Some soils exhibit very little polymerization patterns, if any. One has a pattern comparable to the asteroidal one and one has a peculiar mass distribution that doesn't match any other extraterrestrial sample. The latter is the most exposed to solar wind and the mass range of its mixture is the most extended. We will discuss the interpretation of such feature in terms of origin and possible evolution of the organic matter delivered to the moon.

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