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Unraveling the chemical space of terrestrial and meteoritic organic matter

Philippe Schmitt-Kopplin (1,2), Mourad Harir (1), Norbert Hertkorn (1), Basem Kanawati (1), Alexander Ruf (1,2), Eric Quirico (3), Lydie Bonal (3), Pierre Beck (3), and Zelimir Gabelica (4)

(1) Analytical BioGeoChemistry, Helmholtz Zentrum Muenchen, Munich, Germany, (2) Analytical Food Chemistry, Technische Universität München, Munich, Germany, (3) Institut de Planétologie et d'Astrophysique de Grenoble, Grenoble, France, (4) Université de Haute Alsace, Mulhouse, France

In terrestrial environments natural organic matter (NOM) occurs in soils, freshwater and marine environments, in the atmosphere and represents an exceedingly complex mixture of organic compounds that collectively exhibits a nearly continuous range of properties (size-reactivity continuum). In these materials, the “classical” biogeosignatures of the (biogenic and geogenic) precursor molecules, like lipids, lignins, proteins and natural products have been attenuated, often beyond recognition, during a succession of biotic and abiotic (e.g. photo- and redox chemistry) reactions. Because of this loss of biochemical signature, these materials can be designated non-repetitive complex systems.

The access to extra-terrestrial organic matter is given i.e. in the analysis of meteoritic materials. Numerous descriptions of organic molecules present in organic chondrites have improved our understanding of the early interstellar chemistry that operated at or just before the birth of our solar system. However, many molecular analyses are so far targeted toward selected classes of compounds with a particular emphasis on biologically active components in the context of prebiotic chemistry. Here we demonstrate that a non-targeted ultrahigh-resolution molecular analysis of the solvent-accessible organic fraction of meteorite extracted under mild conditions allows one to extend its indigenous chemical diversity to tens of thousands of different molecular compositions and likely millions of diverse structures. The description of the molecular complexity provides hints on heteroatoms chronological assembly, shock and thermal events and revealed recently new classes of thousands of novel organic, organometallic compounds uniquely found in extra-terrestrial materials and never described in terrestrial systems. This high polymolecularity suggests that the extraterrestrial chemodiversity is high compared to terrestrial relevant biological and biogeochemical-driven chemical space.

(ultra)High resolution analytical approaches will be presented in their application to unravel the chemical nature and organic signatures in bio-geosystems and especially in selected chondritic (organic and ordinary) and achondritic meteorites. We will focus on thermal effects in CM types of materials and describe the effect of shock events on the changes in chemodiversity and the formation of unique novel organic compounds using high magnetic field ultrahigh resolution mass spectrometry (12 Tesla ion cyclotron resonance Fourier transform mass spectrometry – ICR-FT/MS) and nuclear magnetic resonance spectroscopy (Cryo 800MHz NMR).