10.2 ESA's Mission ExoMars 2016 and ExoMars 2018

A. Context and state of the art

Uwe Meierhenrich, member of the *Institut Convergence* is involved as Co-Investigator (Co-I) in the MOMA experiment of the ExoMars 2018 mission:

The Rosetta mission carried the first experiment ever sent outside Earth to investigate chirality, the COSAC experiment onboard the Rosetta Lander Philae. Meierhenrich is Co-I of the COSAC instrument and was in charge of its chirality part.

In the context of planet Mars, it is important to investigate whether or not organic species including chiral organic molecules can be identified and quantified on its surface and/or subsurface. Martian organic molecules might be relicts of stellar evolution brought to Mars via meteorites, they might be remnants of chemical evolution on Mars itself, but also remains of extinct (or present-day) life on the Red Planet. In order to distinguish between these three potential pathways of formation, the chirality of Martian organic enantiomers would be of high importance to study. Officials from the European and North-American Space Agencies ESA and NASA understood this immense research opportunity to be of outstanding interest. As a consequence, NASA's Mars Science Laboratory (MSL) payload of the Curiosity Rover has been equipped with a similar chirality module [1, 2]. The results of this module regarding the chirality of organics on Mars have not yet been reported.

B. Current activity

Driven by the importance to detect organic molecules on Mars, the European Space Agency ESA decided to design a mission to Mars ready to start in 2016. The mission is called ExoMars and is composed of two parts ExoMars 2016 and ExoMars 2018. ESA's ExoMars 2018 rover depicted in Figure 1 is equipped with a chirality-investigating instrument, the so-called Mars Organic Molecule Analyzer (MOMA) [3, 4]. MOMA combines a sophisticated gas chromatograph-mass spectrometer (GC-MS) with a Laser desorption mass spectrometer (LD-MS) system. The central part of MOMA is an ion trap mass spectrometer (ITMS) for the detection and identification of molecular ions. The source to be investigated will be Martian soil samples from the surface and maximum 2 m subsurface obtained from a specifically developed drilling system. In order to transfer molecules from the soil sample to the MS two methods are employed. Firstly, Laser desorption mass spectrometry (LD-MS) will be used, where the Martian sample will be subjected to intense Laser flashes producing molecules and ions directly, even from refractory material, but in a mixture. Secondly, in GC-MS, Martian samples will be heated (pyrolysed) or subjected to a combustion procedure. The evolving volatiles are transferred to a GC where the compounds are separated and then fed into the MS to be measured individually. The combination of methods to feed the MS in MOMA a) via GC and b) via LD-MS covers a wide rage of molecules from the very light (example: methanol) to medium sized (example: naphthalene) by GC-MS up to more complicated (example: peptides) by LD-MS. Rather low detection limits in the 20 ppb range for GC-MS and in the pico-mole range for LD-MS can be provided. The MOMA instrument will be designed and constructed by an international research team, the coordinator (PI) of which is Fred Goesmann at the Max Planck Institute for Solar System Research in Göttingen, Germany.

The ExoMars mission with its rover will be launched in 2018. Prior to the ExoMars Rover mission, the ExoMars Trace Gas Orbiter (TGO) and Schiaparelli, the entry, descent, and landing demonstrator, were successfully launched in Mars 2016 [5], arriving at Mars in October 2016. Meierhenrich is co-investigator of the MOMA instrument onboard the ExoMars 2018 rover. We expect first experimental data from this mission in 2018, in the mid of the here proposed *Institut Convergence* project.

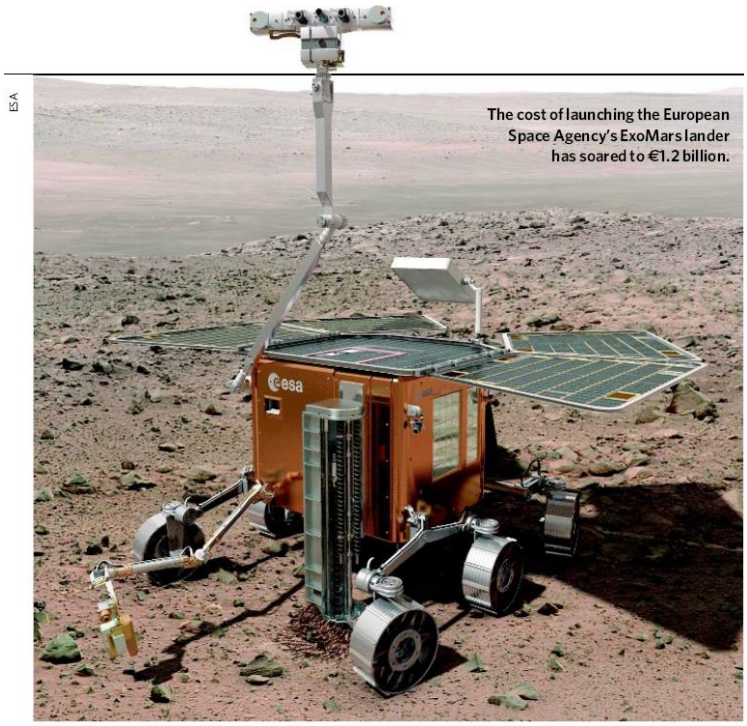

Figure 1. *Artist's impression of the ExoMars Rover drilling into the Martian surface [6]. Organic molecules are likely to be very rare on Mars. Furthermore, only a fraction of the conceivable organic molecules do have stereogenic centers. Hence, enantiomers will be even more rare. There is consequently a strong need for sample enrichment in order to improve detection limits for trace abundances of organic molecules. If – and this is promising – organic molecules will be detected in Martian surface and subsurface samples by the MOMA-instrument, we would like to learn about the organics' chirality by measuring enantiomeric excesses. Will there be any deviation from the racemic enantiomeric distribution expected for abiotic synthesis of organic molecules? The pathways of formation of eventual chiral organic molecules on Mars, biotic versus abiotic and extra-Martian versus Martian, might be deduced from the enantiomeric ratios in different families of organic molecules.*

C. Future steps

Besides data interpretation of MOMA results expected in 2018, we propose to systematically contribute to a test campaign investigating Mars analogues in anticipation of the ExoMars 2018 mission. Meierhenrich is Associate Investigator of the Mars Analogues for Space Exploration (MASE) project and regularly received Mars analogue samples (http://mase.esf.org/mase-associate-investigators.html). These samples, for example from the Atacama desert, Regensburg and Iceland, are to be analyzed at UNS by multidimensional gas chromatography coupled to time-of-flight mass spectrometry (GCxGC/TOF-MS) in order to be best prepared for the MOMA experiment to be run on Mars in 2018 and 2019 by analyzing Mars subsurface samples. Figure 2 shows a typical Mars analogue sample as analyzed at UNS by GCxGC/TOF-MS.

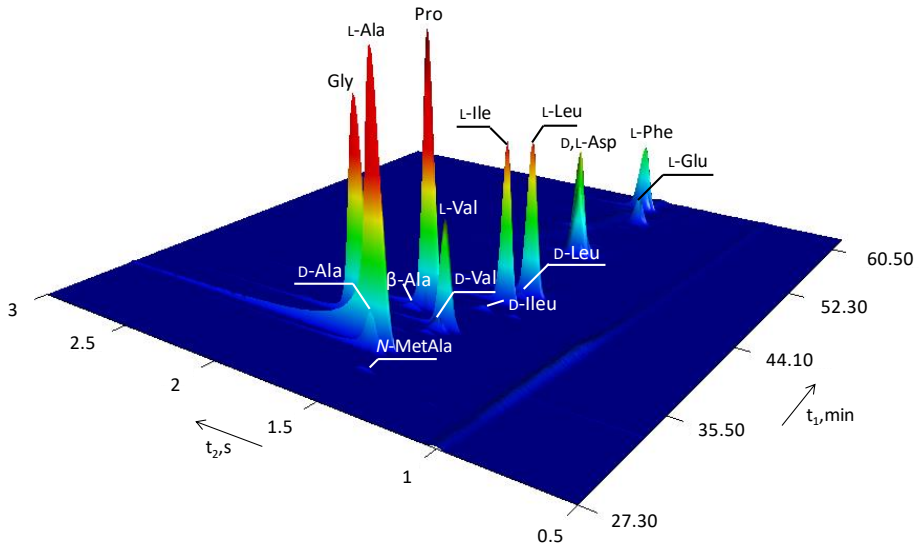

Figure 2. *Comprehensive two-dimensional enantioselective gas chromatogram [7, 8] depicting amino acids such as glycine (Gly), alanine (Ala), N-methylalanine (N-MetAla), β-alanine (β-Ala), proline (Pro), valine (Val), leucine (Leu), isoleucine (Ile), aspartic acid (Asp), phenylalanine (Phe), and glutamic acid (Glu) in the Mars-analogue 'Regensburg sample'. For most amino acids chiral species were resolved into enantiomers. Each point in the 3D chromatogram is accompanied by its individual mass spectrum. Atomic mass units 102, 116, 130, 144, 142, 158 and 330 were selected for the above representation using a modulation time of* P_m *= 3 s.*

We expect for the here proposed *Institut Convergence*, that new results from the space mission ExoMars 2016 and 2018 will provide profound insights into the formation of pristine organic molecules and the origin of biomolecular asymmetry. We further expect that the described research activities will result in multiple and interdisciplinary publications in high-impact journals.

References

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F. Most significant publications of the team

[1]W. Goetz, W. B. Brinckerhoff, R. Arevalo Jr., C. Freissinet, S. Getty, D. P. Glavin, S. Siljestroem , A. Buch, F. Stalport, A. Grubisic, X. Li, V. Pinnick, R. Danell, F. Goesmann, H. Steininger, N. Grand , F. Raulin, C. Szopa, U. Meierhenrich, J. R. Brucato, and the MOMA Science Team. MOMA: The Challenge to Search for Organics and Biosignatures on Mars. Int. J. Astrobiology, accepted for publication (2016).
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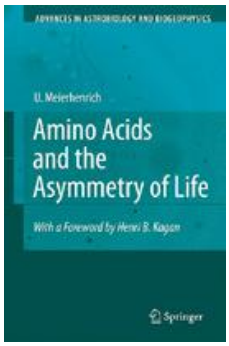

Short CV of participants

Uwe J. Meierhenrich studied chemistry at the Philipps University of Marburg. After completing his PhD at the University of Bremen by Prof. Wolfram Thiemann, he identified amino acids in artificial comets at the Max Planck Institute for Solar System Research in Gçttingen and at the CBM in Orléans in preparation for the Rosetta cometary mission. He is now professor 'classe exceptionnelle' at the University of Nice Sophia Antipolis. He was awarded the Horst Pracejus Prize by the GDCh in 2011 for his work on chirality and enantioselective chromatography.

Cornelia Meinert studied chemistry at the Universities of Rostock and Leipzig. After receiving her PhD at the Helmholtz Centre for Environmental Research by Dr. Werner Brack, she became a postdoctoral research fellow at the University Nice Sophia Antipolis, where she studied the asymmetric photolysis of amino acids and used GC_GC techniques for the enantioselective analysis of cometary and meteoritic matter. In 2013, she became a Chargé de Recherche of the CNRS. Her current research focuses on the origin of the homochirality of biomolecules.