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Mars Science Laboratory (MSL) and the future missions to Mars

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Abstract. After their formation, and for almost 0.5 Gyr, Mars and Earth evolved in the same manner. On Earth, life occured very early, around 3.6 Gy ago. Then, the hypothesis that life might have occured also on Mars, and be extinct, is not unrealistic. If this is true, then complex molecules could be present, representing an early state of life-building blocks. Missions to Mars (Viking 1-2, Phoenix) have carried instruments capable to search for molecular indicators, although up to now, no positive detection has been obtained. Future missions to Mars (MSL-NASA, Exomars-ESA) will use enhanced experiments to try to end this quest.

In 1976, Viking 1 and 2 were very ambitious missions to search for life on Mars. Unfortunately, all the experiments devoted to this goal failed to reveal any organic molecules, even the most simple, Klein, 1977. Nevertheless, molecules could have been missed by Viking (Navarro-Gonzalez *et al.* 2006). In 2008, Phoenix lander performed evolved gas analysis experiments which, again, gave no result (phoenix.lpl.arizona.edu/index.php). The odd thing in these two missions is that they should have observed some of the 2 to 3.10^8 grams of organic matter that comes to Mars each year via micrometeorites (Flynn, 1995). Benner *et al.* (2000) showed that complex organic molecules may be transformed, under the effect of oxidants, into refractory molecules that cannot be analyzed by conventional means (pyrolysis, followed by gas chromatography and/or mas spectrometry), then experimental devices have to be rethought. Methane was detected recently in the atmosphere, new results (Mumma *et al.* 2009), showing CH_4 plumes containing dozens of ppbs, require a better understanding of its apparent lifetime (much less than predicted) and sources (serpentinization, H_2O-CH_4 clathrates, ...?).

In 2011, NASA will send a rover to Mars – MSL (Mars Science Laboratory) – with a 70 kg science payload to explore Mars during about 2 terrestrial years (one Martian year) and roll on about 20 km. MSL science payload consists in ten instruments (marsprogram.jpl.nasa.gov/msl/). One of them, SAM (ael.gsfc.nasa.gov/marsSAM.shtml – PI: P. Mahaffy, GSFC-NASA), will analyze atmosphere and powdered rock and soil delivered by MSL's sample acquisition and processing system. SAM consists of the association of a Gas Chromatograph (GC, six columns devoted to the detection of inorganic gases, light or heavy organics, and chirality), a Quadrupole Mass Spectrometer (MS, from 2 to 535 Da) and a tunable UV Laser Spectrometer (TLS : H_2O, CH_4, C and O, especially devoted to isotopy). Part of SAM investigations will be devoted to the study of the atmosphere (CH_4, and other trace species, noble gases, down to the ppb ; isotopy down to 10 per mil). Analysis by coupling pyrolysis at T = 1000°C and GC, MS and TLS, will allow to know what happens to powdered soil samples when heated up to 1000°C (Viking heated at about 500° C), as well for possible delivery of organic molecules inbedded into the sample, as well as of for gases issued of the decomposition of minerals that may be linked to the presence of such molecules (clays, carbonates, sulfates, were formed in the first ages of Mars and release their structural gases H_2O, CO_2, SO_2 at known temperatures). Organic molecules might be decomposed into CO_2 during heating, or fully refractory. Consequently, wet chemistry will be performed on soil samples by some of the 74 ovens of SAM. Cooking at low temperature organic molecules with a devoted reagent transforms these molecules into vaporizable ones, this is the so-called derivatization process. One may hope that, using pyrolysis and/or derivatization, one might detect down to some 10^{-12} mole of chemical species in the sample.

Mars exploration will also be performed by the European Space Agency (ESA). The July 2009 session of MEPAG foresaw an ESA-NASA association, in which NASA would simultaneously launch in 2018 its mid-size rover MRR and the ESA Exomars rover. MRR is intended to prospect Mars and cache samples to be brought to Earth by Mars Sample Return mission in 2022-24, whereas Exomars (www.esa.int/esaMI/ExoMars/) will continue the Exo-Astrobiological prospection started by MSL. Exomars, with its proposed 14 kg science payload will move on Mars surface for 1/4 Martian year. Compared to MSL, it has the advantage of drilling the soil down to 1 m ; its main differences with MSL are also the presence of a subsurface radar (WISDOM) and of a Raman-LIBS (Laser Induced Breakdown Spectroscopy) that allows an other way to detect and analyze organic molecules into a mineral mixture. In Exomars, one also finds MOMA (www.mps.mpg.de/en/projekte/exomars/moma/ – Team coordinator: F. Goesmann, MPS-Germany), which works the same way as SAM; a Laser Diode Mass Spectrometer has been added to the Pyro-Deriv-GC-MS analysis complex, that extracts molecules from their substrate. Other instruments have been proposed for future missions, among them UREY (Bada *et al.* 2008), in which a sub-critical water extractor will allow to identify organic molecules by means of capillary electrophoresis.

Orbiters, landers and rovers currently procure detailed informations that help to specify geology, geochemistry and evolution of Mars since its formation. Concerning the search for life, new developments of complex techniques, a better understanding of the chemical-geochemical processes on Mars will allow to answer the puzzling question of "life on Mars". In 2011, this will be implemented with the next vehicle on the surface of Mars – MSL with its complex instrumentation – followed by MRR and Exomars in 2018.

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