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Towards Low Earth Orbit Exposure Experiments on the ISS -Designing a Simulation Setup for Mars Like Conditions

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Abstract

In the search for life, Mars is considered to be a major target due to its similarity and relative proximity to Earth, which makes it accessible for scientific investigation. Considering the past chemical, geological and physical environment on Mars, the planets surface might have been habitable to life during the so called Noachian[1]. The quest to identify complex organic molecules on the surface of Mars is an ongoing effort using instruments like SHERLOC onboard the NASA Perseverance Rover[2] or the SAM[3] and CheMin[4] instruments onboard the NASA Curiosity Rover. Other investigations of possible biosignatures on Mars are focusing on the search for chemical processes exclusive to life. Potential indicators are specific atmospheric gases like Methane or mineralogical signatures in composition or morphology that indicate past or present presence life. Recent measurements indicate not only the presence of frozen but also subsurface liquid water on Mars. Such water could only be stable on the planet in the form of highly concentrated brines. Halophilic organisms, that are known to survive environments with high salinity, have therefore become a focus for Astrobiology in the context of Mars[5].

The atmosphere of Mars mostly consists of CO2 (95%), but oxygen (0.174%) and water vapor (0.03%, variable) are also present[6] at an atmospheric pressure of around 6 mbar. The high abundance of CO2 blocks UV radiation below around 200 nm while any UV light at higher wavelengths reaches the surface of Mars. This is in clear contrast to solar radiation on the surface of Earth where UV light below around 300 nm is blocked from reaching ground level due to the higher concentration of oxygen and ozone. Additionally, the absence of magnetic shielding around Mars means that energetic particle radiation can reach the surface of Mars. The average surface temperature of Mars is considered to be around −63 ☐, reaching up to 20 ☐ in the equatorial regions and go as low as −153 ☐ at the poles, with daily variations often exceeding 80 ☐[7]. The surface of Mars is covered in a fine, unconsolidated regolith mostly originating from eroded volcanic rocks exhibiting a distinct red color caused by high abundances of iron oxides. Varying amounts of phyllosilicates have been found indicating the past presence of water[8]. To investigate the photochemistry of possible biosignatures in a laboratory or space born context it is necessary to reproduce these extreme conditions as accurately as possible.

A number of radiation exposure experiments under Mars-like conditions in Low Earth Orbit (LEO) involving organic molecules and other astrobiological samples have been performed or are currently under development. Considering high costs and limited availability of space born experiments we have developed a laboratory based Mars simulation setup. Our setup partly reuses concepts of LEO experiments while adding simulation parameters that are not yet possible to recreate in LEO due to their technical complexity. Specialized reaction cells have been developed for the NASA O/OREOS cube satellite experiments[9]. They hold samples, applied as thin films, in a sealed gas volume while being transparent to irradiation and spectroscopy measurements. These reaction cells are also planned to be used in the upcoming LEO experiments ExoCube Chem and OREOCube[10] outside the International Space Station (ISS). The reaction cells consist of a central stainless steel ring, sealed using indium rings with a sample window on either side The window materials are chosen to allow both irradiation and transmission spectroscopy from the UV up to the IR range. Using FTIR spectroscopy, we can show that the reaction cells lose less than 60% of CO2 gas content over a span of 18 months. The Radiation Background on Mars is complex and can not fully be recreated accurately. We therefore focus on simulating electromagnetic radiation as found on the surface of Mars. To do so we use a Xenon Arc lamp that produces a wide spectrum of light similar to solar radiation. It also produces significant amounts of UV radiation below 300 nm so that it can be used as an adequate radiation source for Mars Simulation. The setup has space for up to 10 reaction cells placed in a ring for the most uniform irradiation. The irradiance was checked at each sample spot with a relative variation in irradiance of less than 5%. The custom made sample holder can be cooled using liquid nitrogen (LN2). An off the shelf solenoid valve is used to control the flow of LN2 while the temperature is controlled using a PT1000 temperature probe in the same form factor as the reaction cells. In practice this system can be used to cool samples to temperatures between room temperatures and about −150 ☐. The custom PID control is not limited to a fixed temperature but also allows to perform temperature protocols (e.g. diurnal cycles). The variance in temperature from the setpoint using this temperature control is typically below 1 ☐.

FTIR spectroscopy is performed using the ARCoptix OEM FT-IR module which is also planned to be used in the ExoCube Chem LEO experiment. For UV-VIS measurements we use an Ocean Insight Flame-S UV-VIS spectrometer, which is planned to be used in the OREOCube LEO experiment. Both spectroscopy setups are placed on a xy-stage, measuring individual samples in transmission during the irradiation. The spectroscopic measurements are fully automated, such that only the exchange of liquid nitrogen has to be performed manually. The setup will be used in the context of the ExoCube Halo project to investigate photochemical processes involving halophilic organisms exposed to extreme Mars like conditions.

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References

1 https://doi.org/10.1089/ast.2013.1106
2 https://doi.org/10.1007/s11214-021-00812-z
3 https://doi.org/10.1016/j.pss.2016.06.007.
4 https://doi.org/10.1016/j.chemer.2020.125605.
5 https://doi.org/10.1038/s41550-020-1080-9
6 https://doi.org/10.1016/j.pss.2017.01.014.
7 https://doi.org/10.1029/1999JE001095
8 https://doi.org/10.1016/j.icarus.2018.08.019
9 https://doi.org/10.1016/j.actaastro.2012.09.009.
10 https://ui.adsabs.harvard.edu/abs/2022cosp…44.2758W