DETECTING AND ANALYZING MOLECULAR CHIRALITY ON MARS

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Introduction: We propose to detect and analyze molecular chirality on Mars. The presence of homochirality is a necessity for biological activity[1], and the quantization of chirality yields information on when this activity would have occurred[2]. The measurement system that we propose has the ability to detect and identify known and unknown chiral organic compounds strongly linked to biological activity. This lightweight, low power, low cost detection system does not require consumables, providing detection and analytical abilities not limited by a finite stock of solvent or reagent. Together, these characteristics demonstrate that the proposed detection system presents an excellent opportunity to observe and analyze molecular chirality on Mars.

Molecular chirality on Mars:

Chirality. Chirality is the lack of reflection symmetry such as mirror planes, and is strongly associated with biological activity[1,2,5]. The origin of the overwhelming excess of L-enantiomer amino acids on earth has been a topic of heated discussion. While an interstellar origin has been suggested to explain the origin of this excess[3,4], biological activity at the very least amplifies this excess, creating a predominance of one enantiomer[5].

Measurement of chirality. Chirality can be detected by linear and non-linear optical characterization techniques. We propose to use optical rotation and circular dichroism to detect, quantify and analyze chirality. Both of these effects can only exist for chiral molecules, and as such no background signal is present in the measurements.

Detection system. We propose a low power, lightweight optical detection system, depicted in Fig. 1. The light source consists of a semiconductor diode with sufficient output in the biologically relevant middle UV spectral region. The polarization of the output light is modulated via a thin-film electro-optical modulator (EOM), requiring no moving parts, very little power and allowing for post-launch calibration and adjustment if necessary. Spectral detection can be achieved via various light detection systems depending on the chosen wavelength range, and need not be limited to semiconductor detection methods.

The collimated light will be channeled through an oven used to heat the soil samples. During heating only the organic molecules and fragments present in the soil

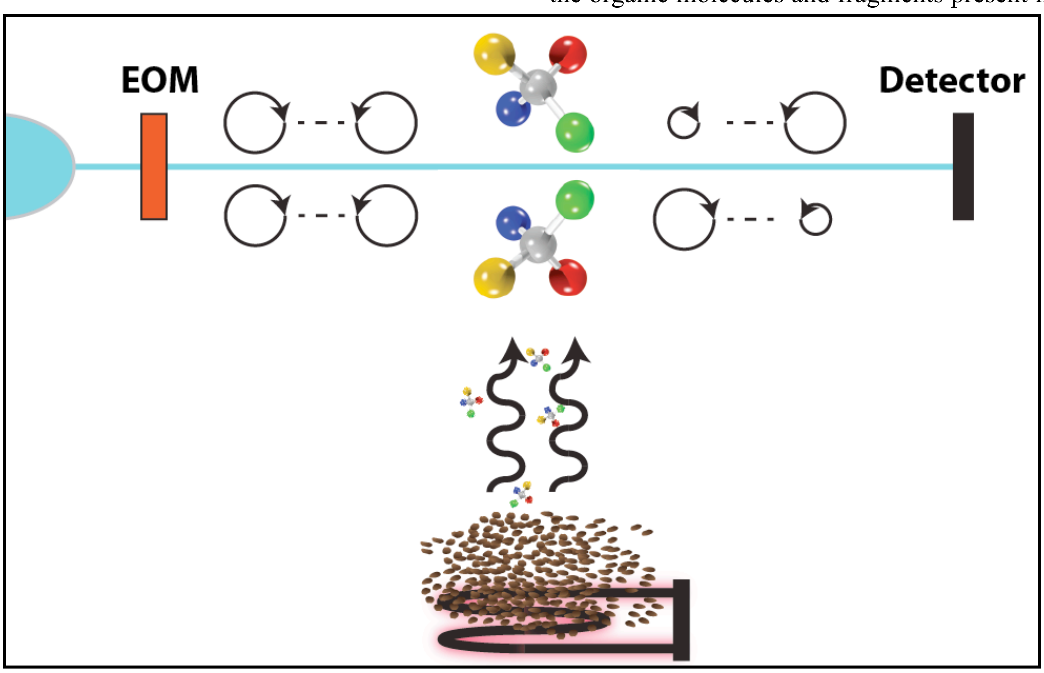

Figure 1. Depiction of the proposed detection system. A soil sample is heated, resulting in the transferal to the gas phase of the present organic material. A LED emits middle UV light, which is modulated by an electro-optical modulator (EOM). After interacting with the organic material, the light is detected and chirality can be detected.

sample will move to the gas phase. Subsequently, chirality can be spectrally detected in the gas, removing artifacts possibly induced by solid-state measurements. In the gas phase, chirality can be detected by means of optical rotation, circular dichroism and fluorescence circular dichroism. All three measurements can be performed with the same set of optical components. The only change necessary to switch between the three types of measurements consists of changing the voltage applied over the electro-optical modulator.

Optionally it is also possible to detect solid-state circular dichroism in fluorescence by focusing the light on the soil sample in the oven. This requires a secondary optical beam path and attention to the removal of anisotropy. Possible solutions include mechanical rotation of the soil sample. While this requires more mechanical manipulation, chirality in solid-state fluorescence can provide additional information on the chiral organic compounds present in the soil.

Analysis and obtained information. Measured optical rotation and circular dichroism spectra do not require extensive processing to interpret. The spectra can be compared to existing spectra in order to fully identify the compounds. Fluorescence circular dichroism spectra also provide information on biological activity, and the lifetimes of fluorescence and phosphorescence aid in organic molecule identification and provide information on their molecular environments.

All spectra can be used to determine the enantiomeric excess present in the sample. This enantiomeric excess can be used to date the biological activity, because the degree of racemization can be correlated to the time of biological activity[2].

A great advantage to using optical activity, both in transmission and in fluorescence, to detect chirality is that useful information can also be acquired on unknown compounds. With further investigation, this information can lead to the identification of the compound. This is an important characteristic, because while it is highly likely that non-terrestrial biological activity also exhibits chirality[1], it has been demonstrated that this does not need to be associated with the well-known chiral molecules such as DNA, RNA and amino acids[6]. Due to the high sensitivity of detection and the possibility for continuous measurement during the entire mission, if there is molecular chirality present on Mars this proposal provides an excellent opportunity to observe it.

Conclusion: Due to the strong association of biological activity with chirality, the measurement of chirality on Mars can provide a wealth of information on past and present biological activity. While the relevance of chirality has not escaped the scientific community[7], our instrument would be the first to perform continuous, sensitive and versatile chirality measurements. In addition to being low cost, lightweight and low power, our system can be used to identify unknown and unexpected compounds. Measurements can be performed for the entire duration of the mission because no material is consumed during the measurement. The lack of a background signal for the transmission measurements contributes to an excellent detection limit.

The measurement system we propose presents an excellent opportunity to detect and analyze chirality on Mars.

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