THE SEARCH FOR CHIRAL ASYMMETRY AS A POTENTIAL BIOSIGNATURE IN SAMPLES FROM MARS. D. P. Glavin¹, A. S. Burton², J. E. Elsila¹, J. C. Aponte^{1,3,4}, E. T. Parker¹, H. L. McLain^{1,3,4}, D. N. Simkus^{1,3,4}, H. V. Graham¹, and J. P. Dworkin¹, ¹NASA Goddard Space Flight Center (GSFC), Greenbelt, Maryland (<u>daniel.p.glavin@nasa.gov</u>), ²NASA Johnson Space Center, Houston, Texas, ³Catholic University of America, Washington DC, ⁴Center for Research and Exploration in Space Science and Technology, NASA/GSFC, Greenbelt, Maryland.

The search for evidence of extraterrestrial life in our solar system has been guided by our understanding of terrestrial biology and its associated biosignatures. The observed homochirality in all life on Earth, that is, the predominance of "lefthanded" or L-amino acids and "right-handed" or D-sugars, is a unique property of life that is crucial for molecular recognition, enzymatic function, information storage and structure, and is thought to be a prerequisite for the origin or early evolution of life. Therefore, the detection of L- or D-excesses of chiral amino acids or sugars could be a powerful indicator of extant or extinct life on Mars or other habitable environments in our solar system. However, studies of primitive meteorites have revealed that they contain extraterrestrial amino acids and sugar acids with large enantiomeric excesses (60% and higher) that resulted from non-biological processes [1], complicating the use of chiral asymmetry by itself as a definitive biosignature.

The exploration of habitable environments on Mars, including an assessment of the preservation potential for complex organics of either abiotic or biological origin, is an objective of both current and future Mars missions. Now with the unambiguous detection of indigenous organic matter in sedimentary rocks by the Sample Analysis at Mars (SAM) instrument suite on Mars [2-5], NASA's Curiosity rover has found evidence of the preservation of potential chemical biosignatures in the martian near surface. Although amino acids have not yet been identified by in situ measurements on Mars [5], indigenous achiral amino acids have been identified in one martian meteorite [6]. It is expected that amino acid racemization would be very slow and any chiral or isotopic signatures from an extinct martian biota could be preserved for billions of years, given the extremely cold and dry surface conditions [7]. The ESA/Roscosmos ExoMars mission scheduled for launch next year includes the Rosalind Franklin rover designed to acquire samples from a depth of ~2 m and deliver them to a suite of instruments, including the Mars Organic Molecule Analyzer (MOMA). The MOMA instrument contains a wet chemistry experiment designed specifically for the detection of amino acids and measurement of their enantiomeric compositions [8].

The complexity and limited duration of spaceflight operations, and the known analytical challenges associated with in situ extraction and characterization of trace reduced organic compounds in ancient rocks, make it challenging to determine the origins of martian organic matter found to date. Coordinated state-of-the-art laboratory measurements of returned samples from Mars that include spatially resolved chemical, mineralogical, bulk and molecule-specific isotopic, and enantiomeric measurements will be required to firmly establish whether the complex organic matter detected on Mars derives from biotic or abiotic processes. Ultimately, Mars Sample Return of rock cores collected by NASA's Perseverance rover may be our best chance of identifying chemical biosignatures, including any chiral amino acid asymmetry resulting from a past or present martian biota, if one ever existed on Mars.

Here we review our current knowledge of the distributions, and enantiomeric and isotopic compositions of amino acids found in meteorites compared to terrestrial biochemistry. We also propose a set of measurement criteria that should be used to help establish the sources of any amino acids detected in samples returned from Mars using state-of-the-art gas and liquid chromatography mass spectrometry techniques [1].

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