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Modelling the Martian subsurface radiation environment and implications for astrobiology

L. R. Dartnell (1), A. J. Coates (2), J. M. Ward (3)

(1) CoMPLEX (Centre for Mathematics & Physics in the Life Sciences and Experimental Biology), University College London, UK (l.dartnell@ucl.ac.uk); (2) Mullard Space Science Laboratory, University College London, UK; (3) Department of Biochemistry and Molecular Biology, University College London, UK

Surface life on Earth is protected from solar and cosmic ionising radiation by a global dipole magnetic field and thick atmospheric column. Present day Mars receives limited protection from either, and these energetic particles, which are extremely damaging to life, impact directly onto the surface. Primordial Mars, however, is believed to have possessed a dense carbon dioxide atmosphere, and there is evidence from crustal magnetic anomalies that Mars had a global dipole ˜4 billion years ago. Warmer wetter primordial environmental conditions support the prospect of the development of Martian life, and continued survival in underground refuges to this day. We investigate the extent to which the Martian present and past atmosphere, magnetic anomalies, and surface rock attenuate the radiation environment and the potential effect on the distribution of life.

The damaging effect of ionising radiation is one of the prime limiting factors on the survival of life in potential astrobiological habitats. The Martian topsoil is thought to have been rendered completely sterile by oxidising conditions created by UV radiation, but the penetration of high energy particles far exceeds this depth. A computer model of radiation penetration has been built using Geant4, a simulation toolkit for particle physics. This Monte Carlo model tracks the propagation of primary particles, and the generated secondary cascades, through both the Martian atmosphere and regolith in order to calculate the radiation flux as a function of depth underground. Both cosmic galactic rays (CGR) and solar energetic particles (SEP) over a wide energy range are considered. The deflection of lower energy charged particles by the magnetic anomalies is also modelled. The persistence times of living cells, metaboli-

cally dormant spores, and organic molecule biomarkers at different depths can then be calculated. Comparison of this radiation map to other astrobiologically-relevant data, such as distribution of permafrost water, geothermal hotspots and locations of methane seepage, will determine the most likely refuges of subsurface Martian microbes. Such analysis will be invaluable in the planning of sample-return missions.