INITIAL DETERMINATION OF THE ZENITH ANGLE DEPENDENCE OF THE MARTIAN RADIATION ENVIRONMENT AT GALE CRATER ALTITUDES. R. F. Wimmer-Schweingruber[1], J. Köhler[1], Donald M. Hassler[2,3], J. Guo[1], J. Appel[1], C. Zeitlin[4], E. Böhm[1], B. Ehresmann[2], H. Lohf[1], S. I. Böttcher[1], S. Burmeister[1], C. Martin[1], A. Kharytonov[1], D. E. Brinza[5], A. Posner[6], G. Reitz[7], D. Matthiä[7], S. Rafkin[2], G. Weigle[8], and F. Cucinotta[9], [1]Institute for Experimental and Applied Physics, University of Kiel, Germany (wimmer@physik.uni-kiel.de), [2]Southwest Research Institute, Boulder, Colorado, USA, [3]Institut d'Astrophysique Spatiale, Paris XI-Paris Sud, Orsay, Orsay, France, [4]Lockheed Martin IS and GS, Oakland, California, USA, [5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA, [6]NASA HQ, Washington, District of Columbia, USA, [7]Institute of Aerospace Medicine, DLR, Cologne, Germany, [8]Big Head Endian, Burden, Kansas, USA, [9]Department of Health Physics and Diagnostic Services, Las Vegas, Nevada, USA

Introduction: The galactic cosmic rays (GCR) outside the Martian atmosphere are approximately isotropic with small (< 1%) anisotropies. The interaction of the GCR with a planetary atmosphere leads to a change of the isotropic nature of the radiation field which, on Earth, results in a larger directional flux of particles from the zenith than from the horizon. Intuitively, this can be understood as due to shielding by the atmosphere which has a much smaller column density in the zenith direction than toward the horizon. In this work we report the first determination of this zenith angle dependence on the surface of Mars using data from the Radiation Assessment Detector (RAD) [1] which is part of the Mars Science Laboratory (MSL) payload [2].

Here we describe the zenith angle dependence of the radiation at ground level as $J(\theta) \sim \cos(\theta') \cos^{\gamma}(\theta)$ where θ' equals θ for a zenith-pointing detector. The first term describes the usual projection effect onto a plane surface, the second splits out the dependence on zenith angle. For an isotropic radiation field, $\gamma = 0$, at the Earths surface, $\gamma = 1$ is considered a standard value [3]. We find that the surface radiation on Mars at Gale crater altitudes is quite different from that at Earth, with a $\gamma = 0.18 \pm 0.07$.

Data Analysis: The Radiation Assessment Detector (RAD) is a very compact and versatile instrument which was optimized for operation on Mars [1] to asses the charged and neutral particle radiation environment. A simplified cross section of RAD is shown in Fig. 1. RAD is mounted inside Curiosity such that its field of view points along the normal to the rover deck. Thus, the inclination of RAD is the same as that of the rover which is known. For this study we used data from sol 525 to 806 when no changes were made to the RAD instrument settings. During theses sols, MSL's inclination angle varied between 0° and 15°, the most probable value being 6.5°, the mean and median were 5.8° and 6°, respectively. Times when the Dynamic Albedo of Neutrons (DAN) instrument [4] was active were excluded from our analysis to reduce background. Detailed modeling of RADs response to different zenith-angle distributions showed that the ratio of particles entering RAD through the outer segment of the front detector (A1) to those entering RAD through the inner segment of A (A2) depends on the zenith-angle dependence of the radiation field. We used this fact to obtain the exponent, γ, which characterizes this important property of the radiation environment on Mars. A more detailed description of the data analysis is given in [5].

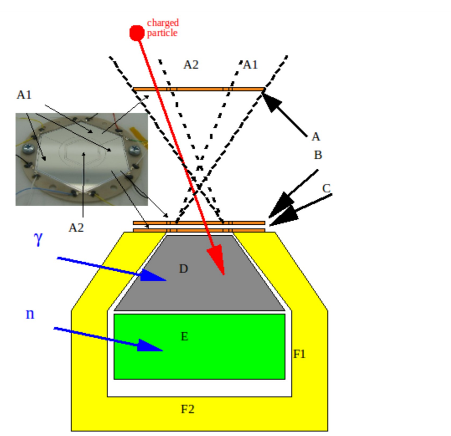

Figure 1: Schematic of the RAD instrument. The inset shows one of the segmented Si-solid-state detectors. The ratio of particles coming from the outer segments to the inner segments depends in their zenith-angle distribution.

Results: The results of our analysis are discussed in detail in [5] and summarized in Fig. 2 which shows hourly values of the ratio of counts of particles entering RAD through the A1 and through the A2 segments of the top SSD and triggering B (see Fig. 1), which we call A1/A2 in the following. In an isotropic field, $A1/A2_{iso} = 4.202 \pm 6.6\ 10^{-4}$, our measurements show $A1/A2_{Mars} = 4.173 \pm 0.012$, which differs from the isotropic case by 2.4 times the estimated error. Assuming underlying Gaussian errors, the chance that we are truly observing an isotropic distribution is

1.6%. As one sees in Figure 2, an underlying Lorentzian error distribution more closely resembles the data. Using this assumption and the corresponding fitted width of the distribution, we obtain a probability of $\sim$ 10% for an isotropic distribution “masquerading” as non-isotropic. Given these uncertainties, we may state that the radiation field coming from within zenith angles of up to $\sim 15^\circ$ at Gale crater is very close to isotropic and tends to show added shielding from larger zenith angles.

This result can be used to estimate the cos θ index, γ . Taking the values for the modeled ratio for A1 · B and A2 · B coincidences, we can interpolate in them to find the index, γ, corresponding to A1/A2 Mars = 4.173 ± 0.012. We thus found $\gamma_{Mars} = 0.18 \pm 0.07$. As expected from the discussion in the previous paragraph, this is not too different from the isotropic value $\gamma_{iso} = 0$ and indicates that the very thin Martian atmosphere provides only a small amount of shielding or that the shielding effect is partially compensated by the generation of second-day particles from the interaction of the GCR with the atmosphere.

Interpretation: We could show that the radiation coming from within some 15° from the zenith direction at Gale Crater on Mars is nearly isotropic and that shielding plays only a minor role in this range of zenith angles. Seasonal and diurnal pressure variations do not influence the A1/A2 count ratio [5]. While limited to a rather narrow range of zenith angles, this finding has implications for future human exploration of Mars and for investigations of the interaction of radiation with the Martian soil and the possible preservation of organic molecules. It is important to note that these observations were only made in a rather narrow range of zenith angles and our finding of a nearly isotropic radiation field should not be extrapolated to larger zenith angles. In future work, we will attempt to extend this range by adding newer data from RAD when Curiosity began climbing Mount Sharp and experienced somewhat higher inclination angles. This will require careful calibration of temperature effects and other possible configurations changes to RAD.

References:

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