SOLAR PARTICLE EVENTS OBSERVED BY THE ODYSSEY MARIE INSTRUMENT AT MARS: DOSE AND MODEL CALCULATIONS.

T. F. Cleghorn[1], P. B. Saganti[2], C. J. Zeitlin[3], and F. A. Cucinotta[1]

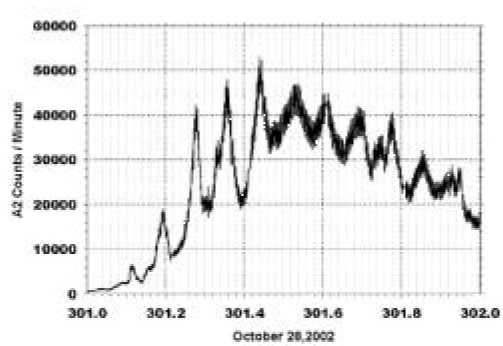
[1] NASA Johnson Space Center, 2101 NASA Road 1, Houston, TX, 77058
[2] Lockheed Martin Space Systems, 555 Forge River Rd. Suite 200, Webster, TX, 77598
[3] Lawrence Berkeley National Laboratories, One Cyclotron Road, Berkeley CA, 94720

Introduction: One of the primary concerns prior to human exploration of Mars is the need to accurately characterize the charged particle radiation environment both for the surface stay, and for the transit period to and from the planet. The Odyssey spacecraft, currently in Mars orbit includes a charged particle radiation detector, MARIE, which can measure particle fluxes with energies above ~30 MeV and charges between 1 and 10. Two classes of particles are of particular interest: the Galactic Cosmic Rays, (GCR), and those charged particles associated with Solar Particle Events, (SPE). The GCR are present continuously throughout the solar activity cycle, and their numbers vary inversely with the level of solar activity. They are characteristically more energetic than those particles originating from solar activity, and hence less influenced by the solar magnetic field
Because Mars lacks a global magnetic field, the GCR arrive isotropically. Thus a directional particle telescope such as MARIE can point in any direction, so long as it does not view Mars itself, and it can measure the GCR intensity at that particular time in the solar cycle. Particles associated with SPE, however, provide a different set of problems. SPE can occur randomly throughout the solar cycle, although they tend to occur near the peak(s) of solar activity. Predicting characteristics of SPE is one of the major unsolved problems. The timing, size, energy and charge distributions are unique to each event. However, the particles are usually less energetic than the GCR, and hence more influenced by the solar magnetic field. They tend in many cases to stream along field lines: the "garden hose effect". This can result in significant directional anisotropies in the particle environment, particularly early in a large event. A particle telescope pointed in the wrong direction can miss significant numbers of particles, and hence underestimate the intensity, and corresponding radiation dose. The MARIE instrument has been described extensively elsewhere, [1-3].

The Data: Since MARIE was successfully reactivated in March 2002, several major SPE have been observed by the instrument, as well as a number of smaller events. The events during the first six months have been discussed elsewhere, [4]. Notable in this data set was the July 16/17 event, which continued until July 27. It was sufficiently large that the standard A1*A2 counter event trigger was saturated, and the instrument was taken out of data collection mode as a safety precaution. However, the count rate monitors for some of the individual detector elements were kept running, which allowed an estimation of the dose rate. During the first six month period of operation in Mars orbit, the relative positions of Earth and Mars were such that Earth led Mars in their orbits by between ~105 ^{0} and ~195 ^{0}. Thus an event seen at Mars would have a very high probability of being observed at Earth as well. All of the events observed at Mars during this period were observed by the GOES 8 satellite in Earth orbit. However, by October 2002, Mars had lagged so far behind Earth, that there was a significant chance that an event originating on or behind the east limb of the Sun would be observed at Mars, but would not be seen by detectors in Earth orbit. This in fact happened three times in October, and two of the events were large enough to saturate the A1*A2 event trigger. The dose rate, and total dose for these three events were estimated using the A2 count rate.

Results: The October 2002 events provided some significant insights into the operation of the MARIE instrument, as well as how SPE behave at distances from the sun greater than 1 A.U. The two large events, starting October 14^{th} and October 28^{th} respectively, showed planetary shadowing, i.e.: the A2 count rate dropped dramatically as the spacecraft passed behind the planet. This indicated that the particles were arriving at Mars anisotropically, and in the case of the October 28^{th} event, it was possible to see the anisotropy decay later in the event, as would be expected, (Fig. 1). The count rate data gave total dosages for these events as ~500 mrads, and > 1 rad respectively. By comparison, the July 16 event gave an estimated dose rate of > 1 rad as well. The other October event, (October 25) provided a chance to compare the A2 count rate dose estimation with that derived from the A1*A2 event trigger rate. The former gave an estimated total dose of 52.6 mrads, as opposed to 66.7 mrads for the A1*A2 method. A lower dose estimation is to be expected for the A2 count rate method, due to the additional shielding around that detector. The dose rate due to GCR during this period was 24.5 mrads/day, so it is estimated that this medium-sized SPE would provide about one day's additional exposure. However, the two large events, and the large July event would each have provided significant additional dosage. In addition to providing insight to SPE behavior outside of Earth's orbit, the MARIE instrument is able to provide GCR flux data, which can be compared to the models of solar modulation [5]. While not much variation is expected to be seen between Earth and Mars orbit, it is noted that a decrease in GCR dose rate occurred late in 2002, in agreement with the HZETRN model predictions[6].

Figure 1



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