Charged Particle Measurements in Mars Orbit from 2002 to 2006

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MRME & MRME

- MRME – The Mars Radiation Monitoring Experiment (follow-on to MARIE).
  - MARIE failed in Oct. 2003 SPE.
  - Repeated turn-on attempts have failed.
- Continuing measurements of energetic charged particles in Mars orbit using other Odyssey instruments.
  - GRS = Gamma Ray Spectrometer
    - Upper Level Discriminator is useful
  - HEND = High Energy Neutron Detector
    - Scintillation Block is useful
Odyssey Detectors With Sensitivity to Charged Particles

- **MARIE**: March 2002 – October 2003
- GRS ULD fires when $\Delta E$ in Ge crystal exceeds 10 MeV.
- HEND Inner Scint. is sensitive to neutrons from 300 keV up to about 10 MeV.
  - Most high-E neutrons created in spacecraft.
- Odyssey is in a 2-hour polar orbit about 400km up.
  - 5 p.m./5 a.m. local mean solar time.
  - Mars occupies 28% of $4\pi$. 
GRS and HEND Data

- Counts are collected every 19.7 sec.
- Relatively high rate in GRS ULD due to large geometry factor.
- Low count rate in HEND SB due to small geometry factor & low efficiency for conversion of incident charged particles to high-E neutrons.
2002 data used to determine average count rate for each detector during solar quiet time.
- This was close to solar max, GCR rates low.

Averages used to normalize all later data.
- MARIE & ULD data averaged in 10-minute intervals.
- SB data are 5-min. sums, averaged over 1-hour intervals due to lower statistics (still noisier than others).

Monthly plots of normalized data.
- With assumptions, convert counts to dose and dose equivalent monthly averages.
SPE Responses

- Typical: A1 most sensitive, followed by SB, followed by ULD.
- A2 not shown here...
SB matches A2 in this & several other SPE’s – but not all.
June 2002

- All 3 detectors show same trend but normalizations vary.
- HEND SB sees unexplained blip around day 155
July 2002

- MARI E coverage poor during big SPE.
- SB and A1 agree, at least for Day 198
- ULD below others despite adding back in rollovers → “Soft” spectrum SPE, proton threshold energy critical
- SB response < A1 when MARI E back on at Day 205
MARIE off for the most intense part of the event.

Interpolate MARIE data $\rightarrow$ integral $\sim$ agrees with ULD but not with SB.
Integration

- Time-integrated flux, dose, dose equivalent $\Rightarrow$ sum up counts.
- With MARIE, large gaps a problem.
- Time-integrated flux and dose are approx. proportional to sums.
- Dose equivalent not as trivial, but not too hard (rely on model input).
Relative Flux, Dose, Dose Equivalent

- For flux $J$ & dose $D$ use 2002 quiet time factors.
- $D = J \times \text{constants} \times \text{avg. LET}$
  - LET = linear energy transfer in water, i.e., $\frac{dE}{dx}$
  - If avg. LET constant, $D$ proportional to $J$
- Dose equivalent $H = D \times Q$
  - $Q = \text{average radiation quality factor}$
  - $Q = 1$ for protons (dominant in SPEs)
  - Model calculation: $Q = 5.38$ for GCR (time-dependent?).
- Recipe for $H$: GCR flux gets weight 5.38; SPE flux gets weight 1
  - Surprising result: modest SPE with Forbush decrease can cause net reduction in $H$.
- Final MARIE numbers will allow simple scaling to physical units.
Detector Responses

- GCR response of GRS is straightforward, HEND not.
- SPE responses complicated.
  - ULD always less sensitive than MARIE A1 or A2 – higher threshold energy.
  - SB varies, from most sensitive to least.
    - Caused by varying SPE proton energy spectra
  - Need model of SB response as a function of SPE spectrum.
2003 Relative Flux

For GCR, SB trends low starting in August.
2003 Relative Dose Equivalent

Log scale

Linear scale w/ cutoff.

Relative Dose Equivalent
Long Timeline Stripchart

- HEND SB (green) and ULD (red) only
- Log scale
Long Timeline GCR

- Zoom in around 1.0, see modulation
- Both mostly follow similar trends with a few unexplained differences (e.g., times near days 600, 1200)
More Detail – 2004 & 2005

2004
GRS ULD
HEND SB

coincidence mode

2005
GRS ULD
HEND SB

Day of Year
Cataloging SPE (Tricky)
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<th>MM/YY</th>
<th>DOY</th>
<th>A1 peak</th>
<th>ULD peak</th>
<th>SB peak</th>
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### SPE’s Seen by ODY post-MARIE

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* Peaks are relative to quiet-time avg. in days near SPE
Summary

- Lots of data in simple, standard form.
- Soon to be placed online for public availability (Planetary Data System = PDS).
- MARIE simulation will give final normalization constants, then normalize the rest.
- Data for HEND SB hard to understand without detailed response model.
  - Project soon to get underway using FLUKA and spacecraft model created for MARIE.