Update on the Worsening Particle Radiation Environment Observed by CRaTER

Radiation Hazards, Interactions

- Galactic Cosmic Rays (GCRs)
  - Steady Background
  - Career limit in ~ 1-3 years
- Solar Energetic Particles (SEPs)
  - Acute Sources
  - ESPs versus impulsive component
  - Time-dependent response
McComas et al., 2008

ACE & Ulysses Comp.

Reduced Density and Dynamic Pressure

Proton speed

Normalized density

Normalized temp

Dynamic pressure

Dynamic Pressure ($\frac{R}{R_s^2} [nPa]$)

Ulysses Latitude

McComas et al., 2008
Schwadron and McComas, 2008
There is a 2-phase depletion of open field lines: first during the “normal phase” of solar min when ICME activity is small, and then later when ICME activity is virtually zero.

More recent theoretical considerations are predicting a lower flux floor.

Continued Decay of Magnetic Flux in the Dalton-like Minimum

Strong Reduction in Field Possible – Much Higher GCR Flux

Rahmanifard et al., 2016
Highest GCR doses in space age in recent cycle 23 solar minima
Continues trend observed by Ulysses, ACE
Lunar Surface Dose Rate (cGy/yr)

Year


Sunspot Number

ACE

CRaTER

Model

Sunspot Number

Schwadron et al., Space Weather, 2017
SEP Events During 2012: Indicators of Larger SEP Events in the New Cycle (24)

- Shown here are the major SEP events of 2012 and the comparisons between CRaTER observations (blue) and predictions (red and green).
- Agreement reveals overall accuracy of models, while deviations likely reveal heavy ion contributions to dose observed by CRaTER.

Jan. 23rd, 2012 Event

Jan. 23rd, 2012 Event

CRaTER (blue) EMMREM (red)

DOY 60 65 70 75 80
Dose Rate (uGy/hr)
CRaTER (blue) EMMREM (red)

DOY 60 65 70 75 80
Dose Rate (uGy/hr)
CRaTER (blue) EMMREM (red)
Schwadron et al., 2017

Lunar Dose Rate (cGy/day)

CRaTER D1D2

CRaTER D3D4

CRaTER D5D6

CRaTER Microdosimeter

Year

Dose in 1 g/cm² H₂O

Dose in 10 g/cm² H₂O

Schwadron et al., 2017
• Example of a large event during decline of cycle 24
• Note importance of seed population

Schwadron et al., 2017
• First event had clear shock, and ESP
• Second event shows prompt acceleration

Schwadron et al., 2017
Conclusions

- Radiation levels continue to increase due to weakening solar activity
- Dose rates even higher than predicted in 2014
- Large events (Sep 2017) in decline of cycle 24 indicate that weak activity does not exclude large SEP events
- Overall, SEP event probabilities still quite low during cycle 24