Radiation Monitoring at Mars Using the Odyssey Instrument Payload

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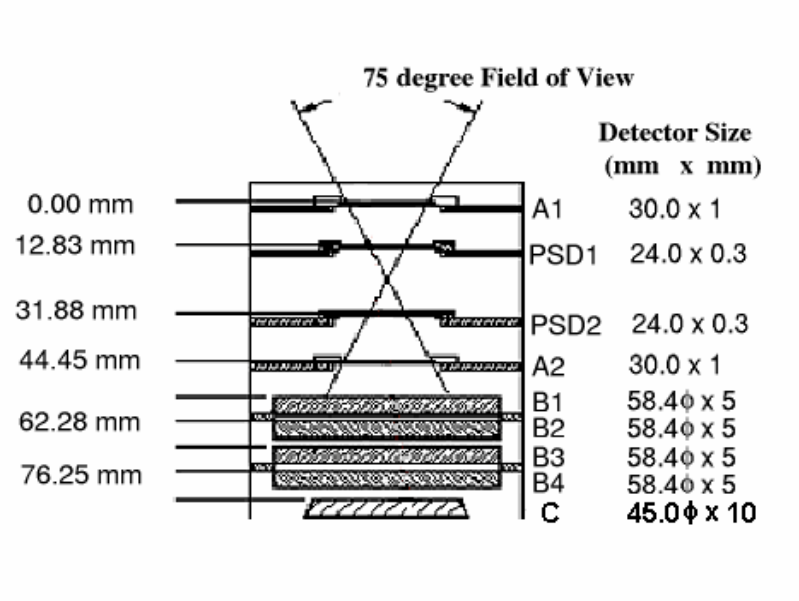
MARIE & MRME

- MARIE Status
  - MARIE failed in Oct. 2003 SPE.
  - Repeated turn-on attempts have failed.
  - Final attempt later this month.
- Mars Radiation Monitoring Experiment
  - 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

MARIE

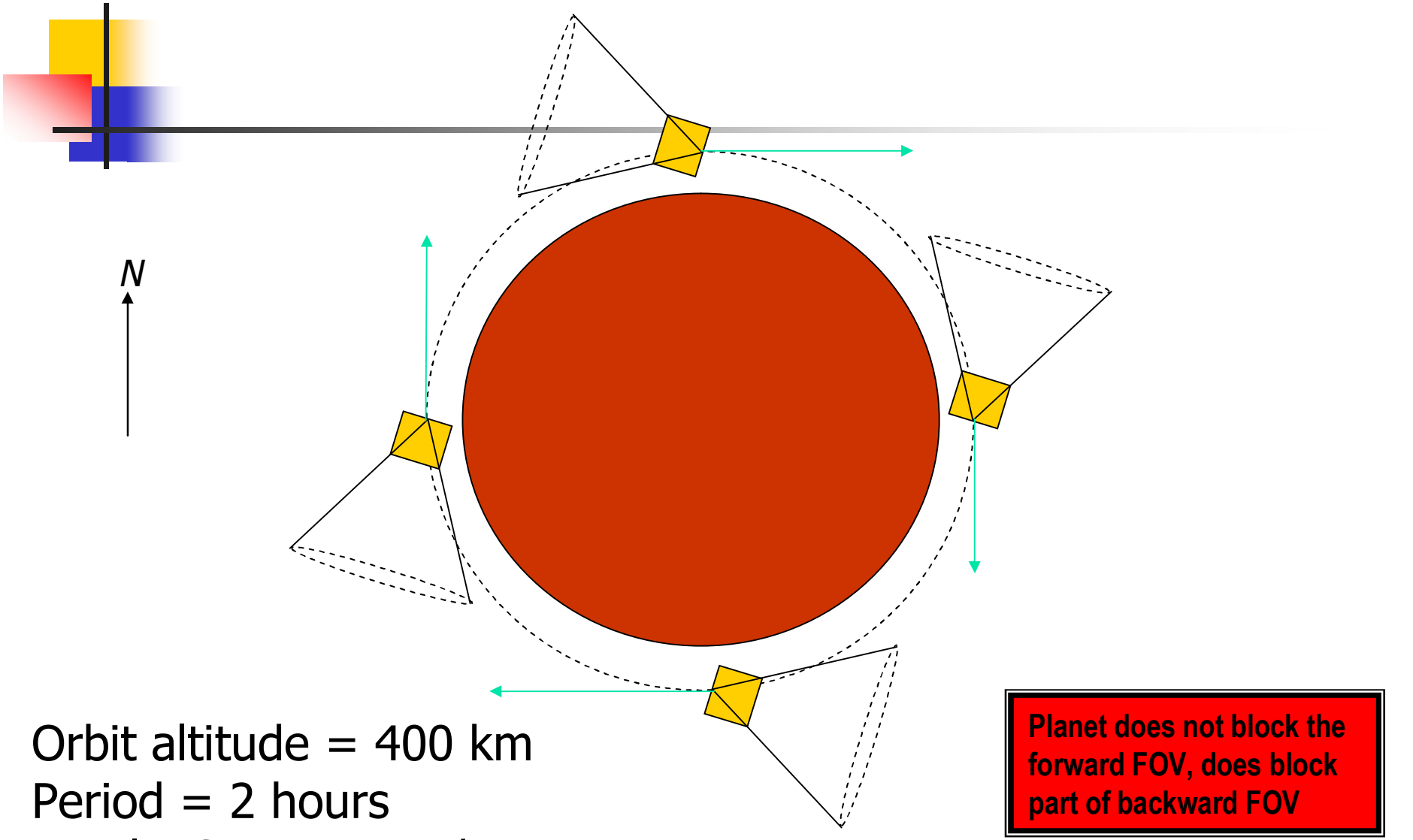


- Measured energetic charged particles
  - Silicon telescope with 2 "A" (1mm depth) and 4 "B" (5mm)
- Minimum proton energies:
  - > 20 MeV → count in A1
    - Counts recorded per minute
  - > 30 MeV for A2 count & PHA
  - Max stopping E_{proton} = 72 MeV
- Severe problems with PSDs and Cerenkov counter, those data not used in analysis.

MARIE Hardware Details

- Forward FOV points anti-velocity
- Nominal G = 3.2 cm^2 sr (forward only)
  - Backward FOV ~ 50% blocked by Mars
  - Unblocked half shielded by 10-20 g cm^{-2}
- A1*A2 → Pulse-height analysis but with large deadtime.
- Counters deadtime-free but rollovers seen in A1 during largest events.

MARIE Orbital Geometry
(Viewed from the Sun)



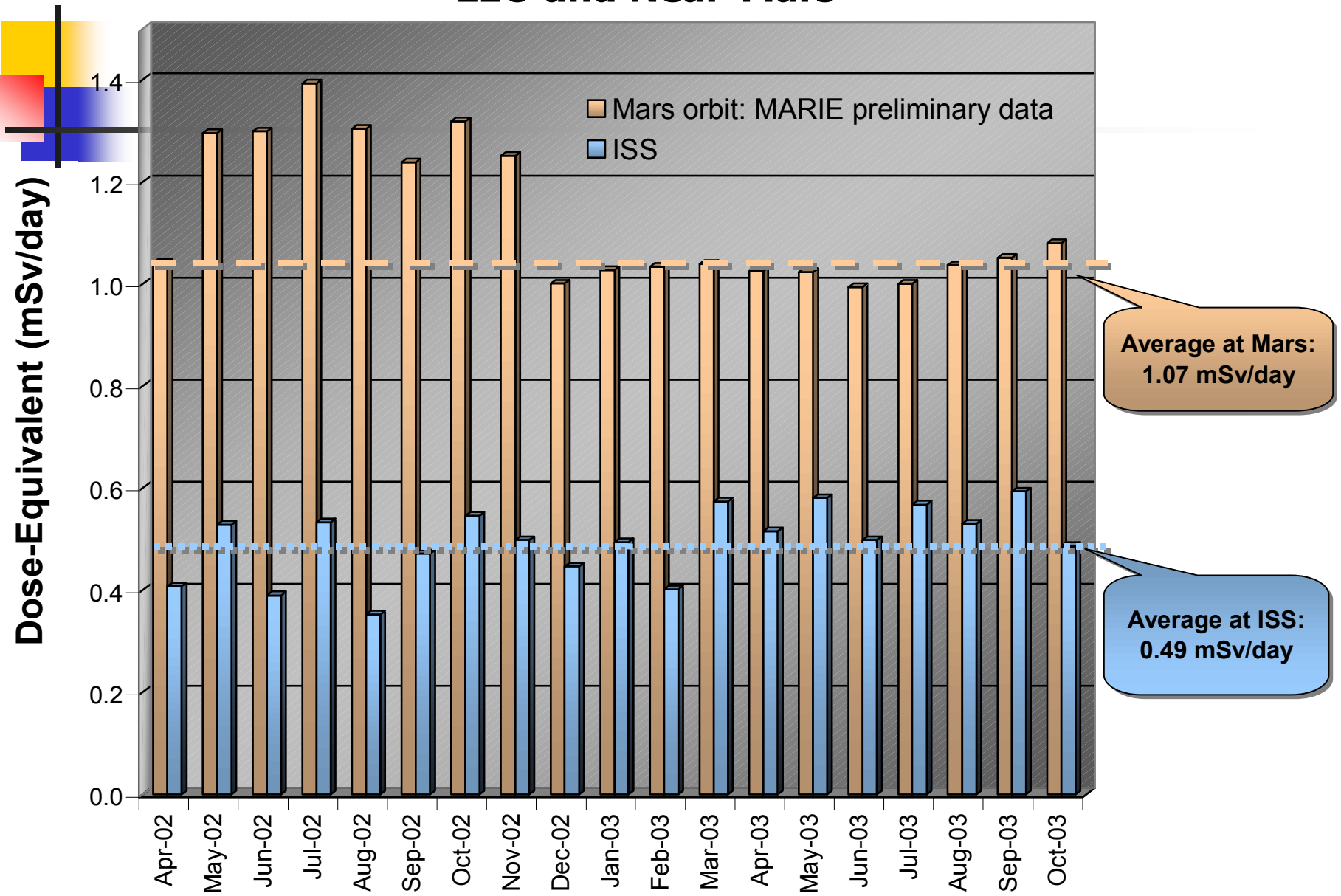
Orbit altitude = 400 km
Period = 2 hours
Local MST = 5 a.m./5 p.m.

Planet does not block the forward FOV, does block part of backward FOV

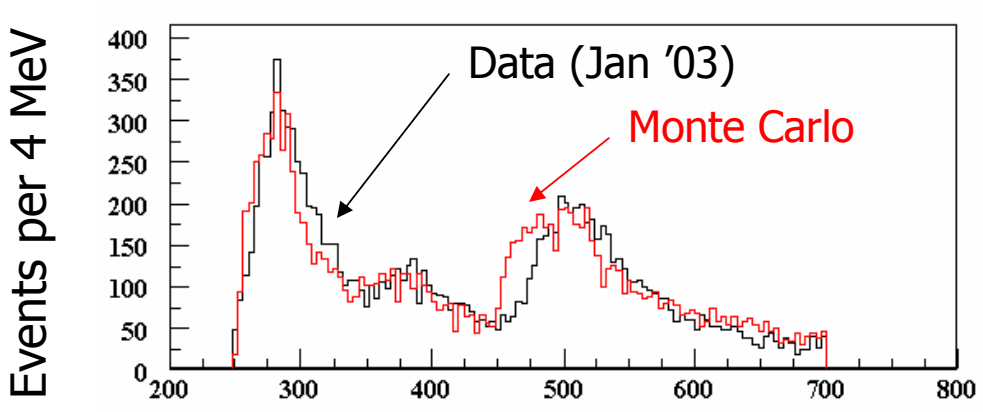
MARIE Problems

- Limitations (mostly acquisition-related)
  - PHA @ low rates only.
  - Small storage → gaps in time coverage.
  - Low efficiency for triggering on high-E protons.
  - Dynamic range limited (LET < 30 keV/μm)
  - No forward/back discrimination.
- Result: Large uncertainty in dose estimation ($\pm$ 30%), measurement of <Q> is poor.
  - Measured <Q> ~ 3.5, B-ON model gives ~ 5.

Unshielded Dose Equivalent (mSv/day)
LEO and Near-Mars



CNO Flux Result



- Spectral shape of MC looks about right.
  - MC based on newest B-ON model.
- Flux J = N / G*t*ε_1* ε_2 = 1.7 x 10^{-3} cm^{-2} sr^{-1} s^{-1}
  - G = $G_{nominal}$ x 1.5 x .907 (backwards-going & B4 correction)
- B-ON Model predicts J = 1.3 x 10^{-3} cm^{-2} sr^{-1} s^{-1}

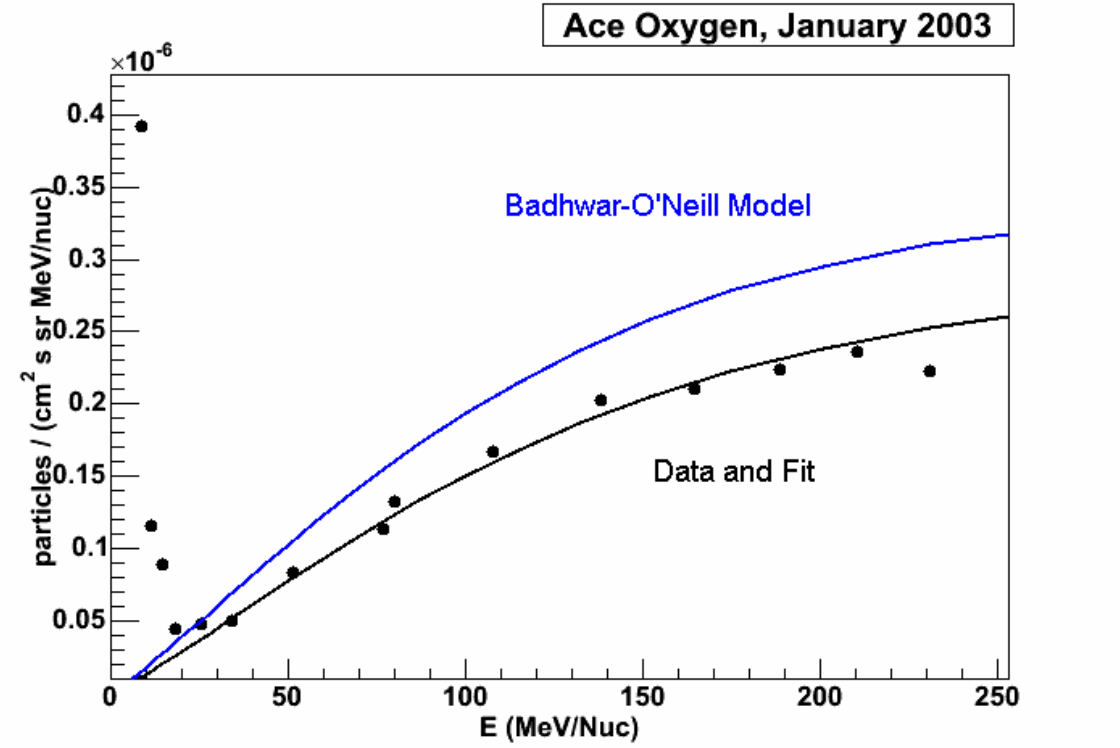
Gamma Ray Spectrometer

- PI: Bill Boynton, Univ. of Arizona
- Germanium crystal pointing slightly off nadir.
  - Right-circular cylinder, 67mm x 67mm DxL, so large geometry factor.
  - Discovered polar water (w/neutron detectors).
- Gamma spectrum taken in 19.7 sec intervals.
- GRS is away from spacecraft, on a boom 6m in length.

GRS ULD Flux

- Charged particles (mostly) produce hits in "ULD" = Upper-Level Discriminator channel.
  - Min-I proton in Ge with chord length=diameter = 67 mm deposits ~ 50 MeV, ULD threshold = 10 MeV.
    - Any charged particle with chord length > 20% of diameter gives a count in the ULD channel.
- 2002-3 ULD quiet-time J ~ 0.14 cm^{-2} sr^{-1} s^{-1}
  - Efficiency for GCR (chord lengths > 0.2 D) ~ 90%
- ACE/CRIS J = 0.16 cm^{-2} sr^{-1} s^{-1} 5/01- 9/03
- Badhwar-O'Neill model J=0.25 cm^{-2} sr^{-1} s^{-1}

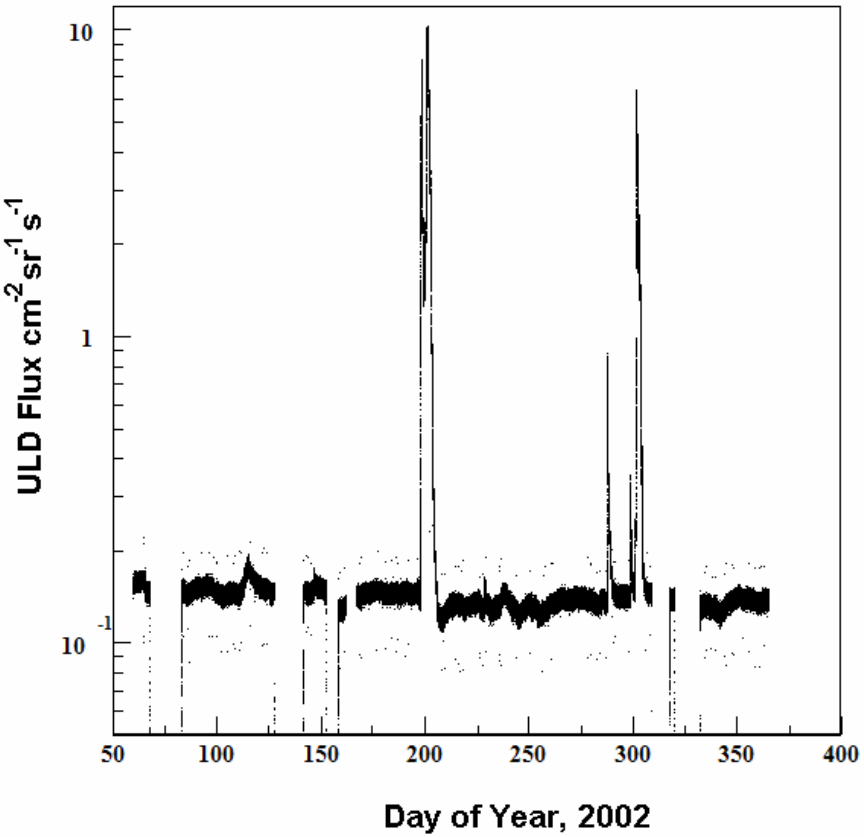
B-ON Model vs. ACE Data



Plot by Vic Andersen, UH

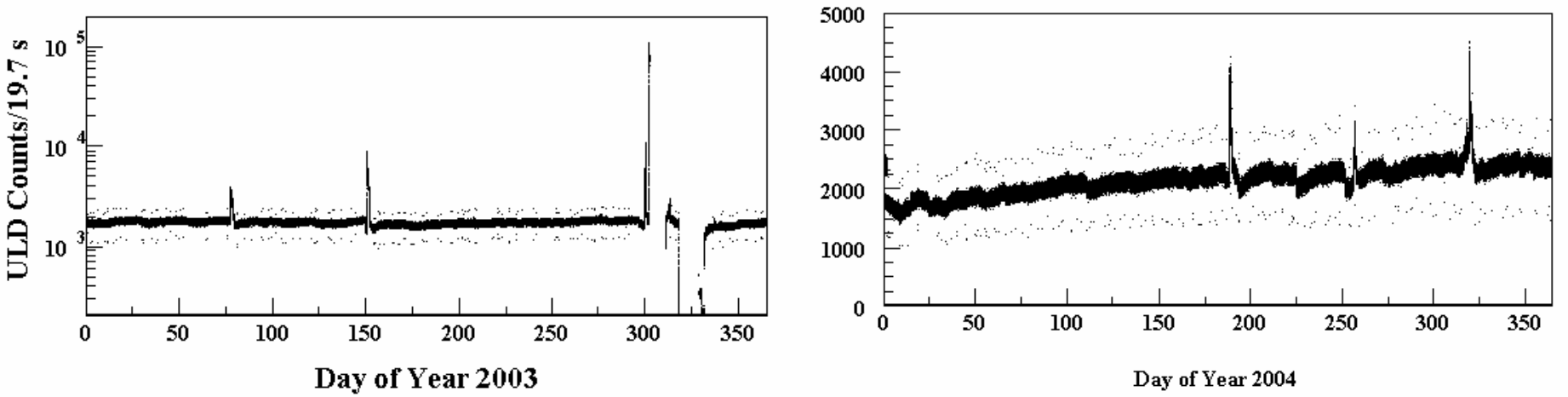
- Model tuned to ACE-CRIS but overshoots by ~ 30%.
- Total predicted flux → 0.25 cm^{-2} sr^{-1} s^{-1} also an overshoot compared to data (0.1 to 0.16 cm^{-2} sr^{-1} s^{-1}).

ULD Data, 2002



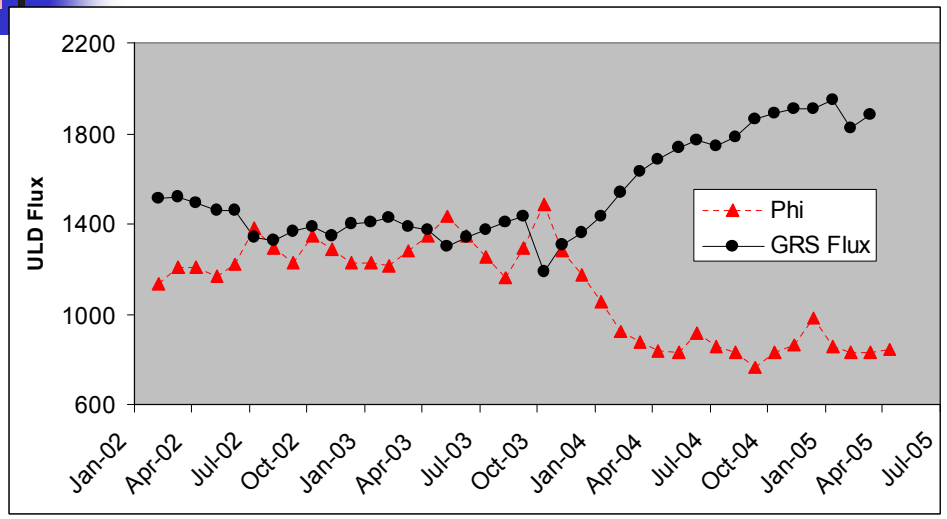
- Outages: annealing, boom deploy, Odyssey safe-mode entry (Nov.)
- GCR rate ~ flat in ’02.
- Counter is subject to rollovers during intense SPEs.
  - Rollover when flux exceeds 5 cm^{-2} sr^{-1} s^{-1}
  - Multiple rollovers possible

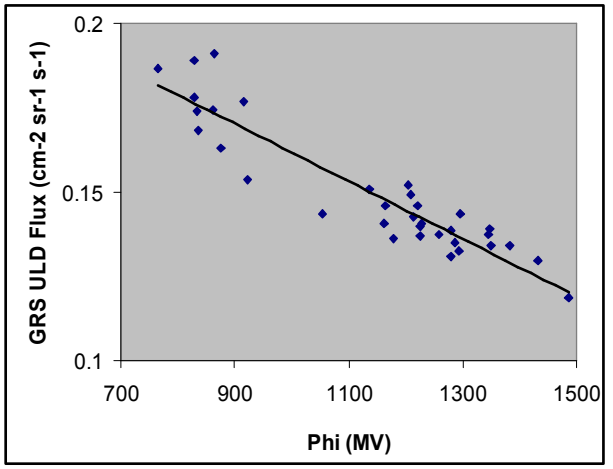
ULD Data 2003-4



- Modulation apparent starting in ’04.

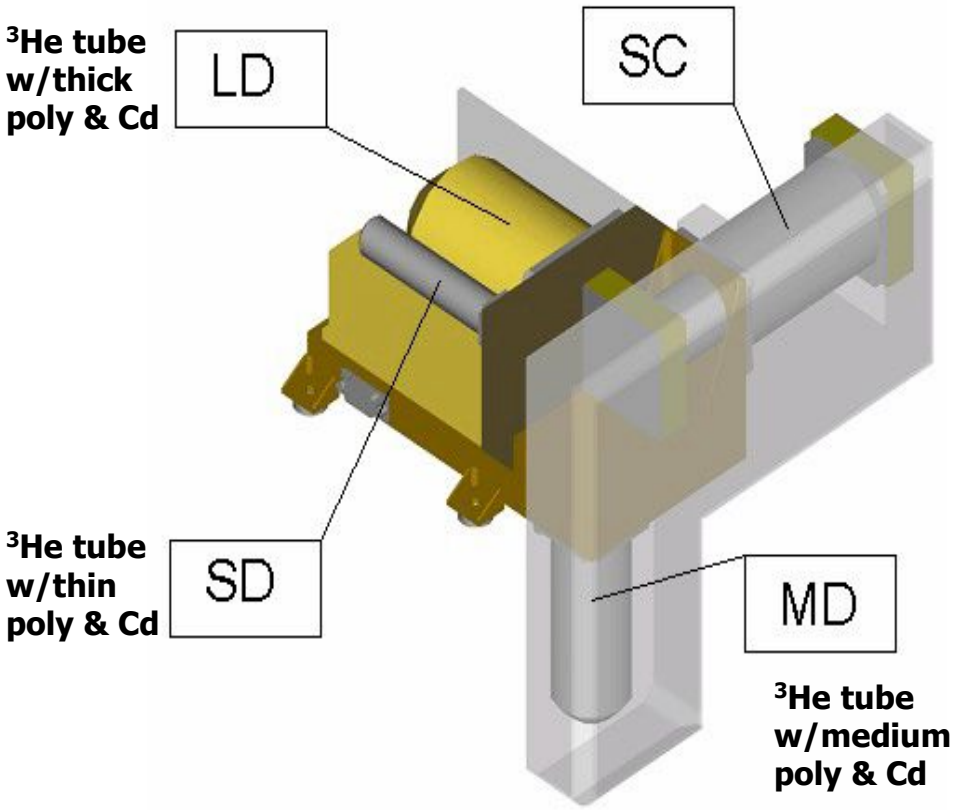
ULD GCR Flux vs. CLIMAX





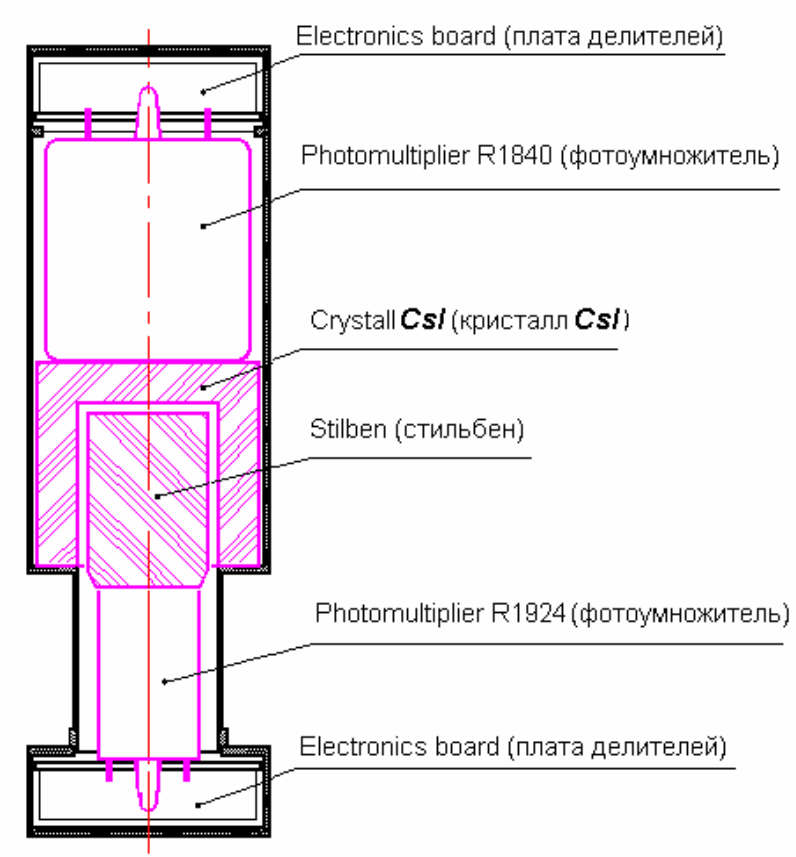
- ULD flux(particles m^{-2} sr^{-1} s^{-1}) vs. CLIMAX Φ(MV).
- Quiet-time only, SPEs excluded.
- Inverse relationship as expected.

High Energy Neutron Detector



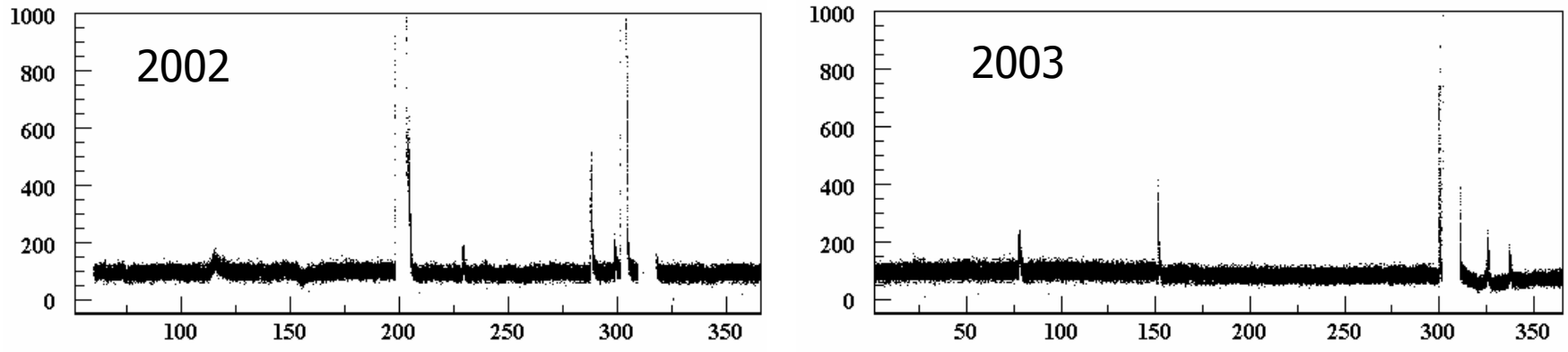
- PI: I. Mitrofanov, IKI, Russia
- Suite of neutron detectors covering 4 energy ranges.
- Counters see neutrons created in the spacecraft as well as those from Mars.

HEND Scintillation Block



- Outer CsI, inner Stilbene detectors.
- Stilbene measures high-energy neutrons, CsI provides veto against charged particles.

HEND – Inner Scint "High"

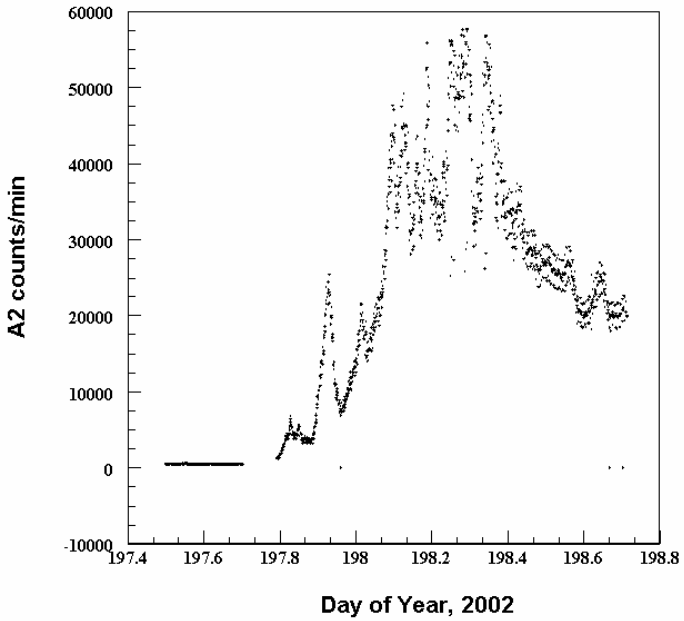


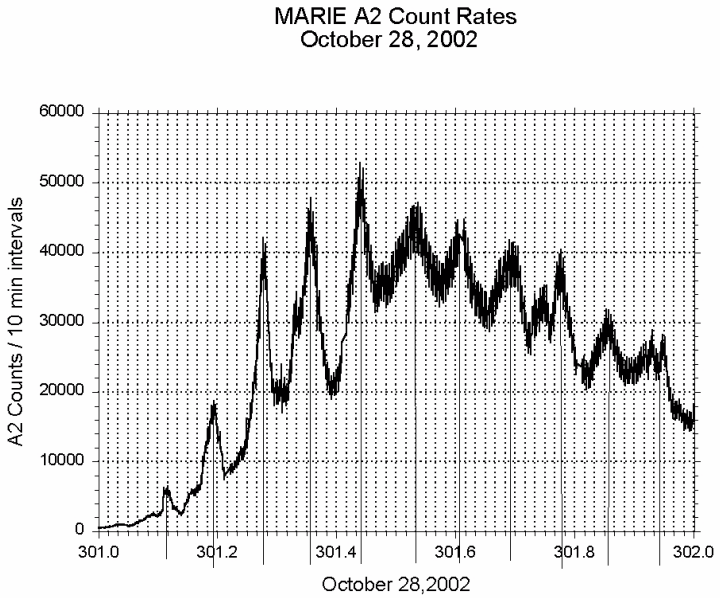
- All HEND sensors are read out through the GRS electronics box → same 19.7 sec sampling interval.
- Due to low count rate, sum over ~5 minute intervals.
- No counter rollovers.
- ODY safe mode entries in Nov. 2002, Nov. 2003

Cross-calibration

- GRS, HEND not built for charged-particle detection.
  - Sensitivities not optimized, not fully understood.
  - ULD preferred – geometry factor is calculable.
  - HEND detects secondary neutrons so G depends on many other factors.
- Comparisons to MARIE:
  - Fill in gaps in MARIE SEP coverage.
  - Improve understanding of HEND & ULD sensitivity.
- Ongoing project.

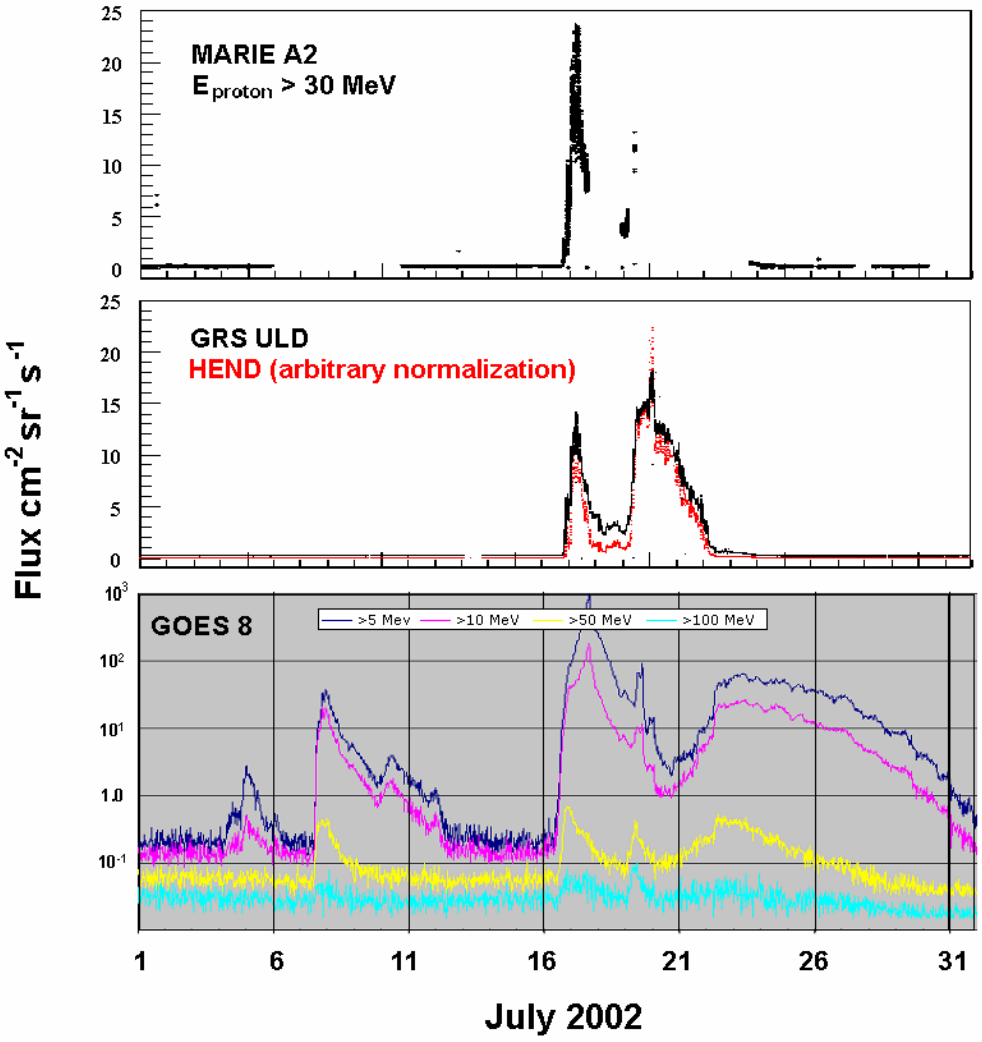
Oscillations in SPE Rates



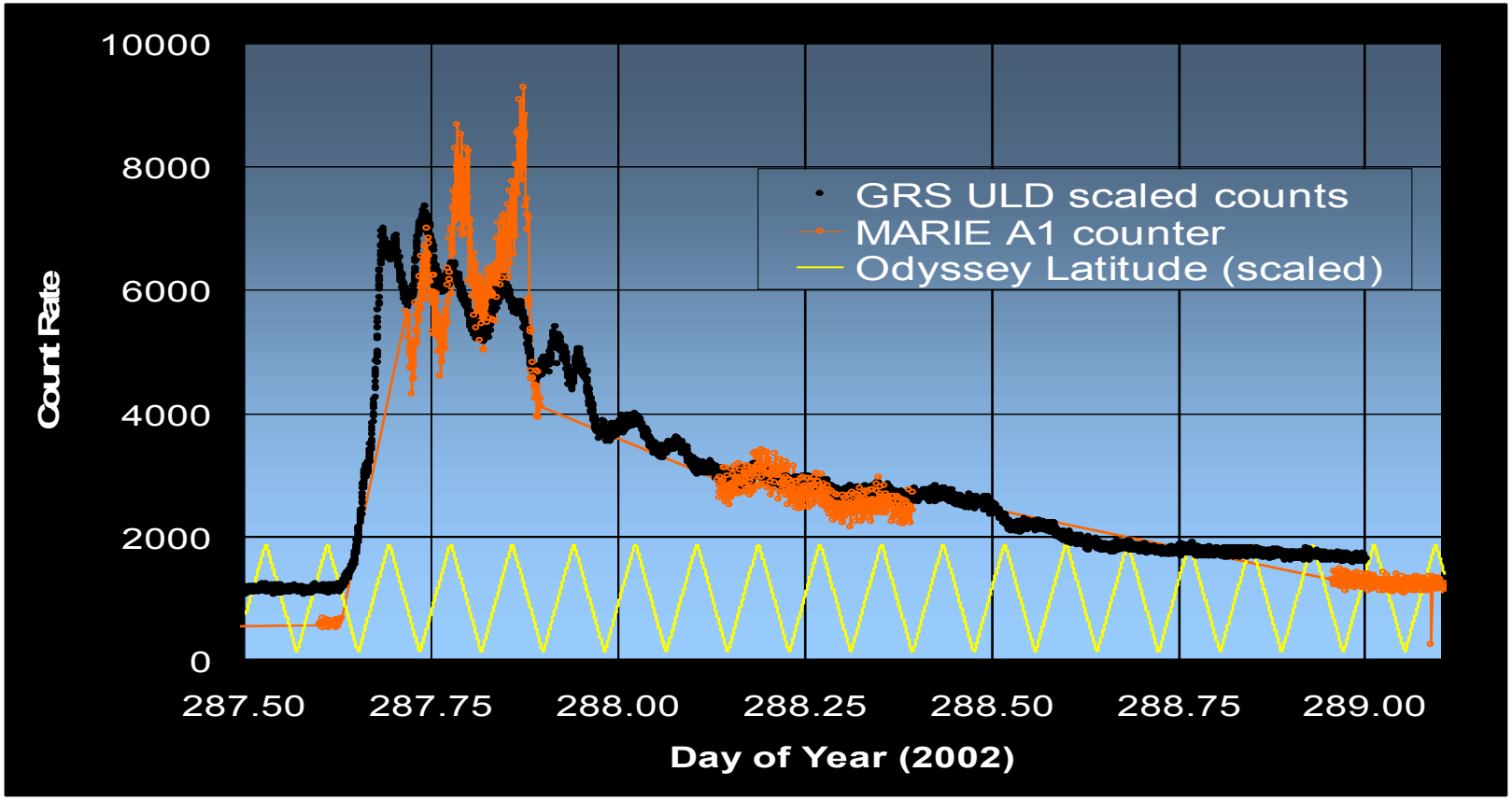


- Peaks when Odyssey is over North Pole.
- Not due to Martian crustal magnetic anomalies – fields are too weak.
- Seen by all instruments.

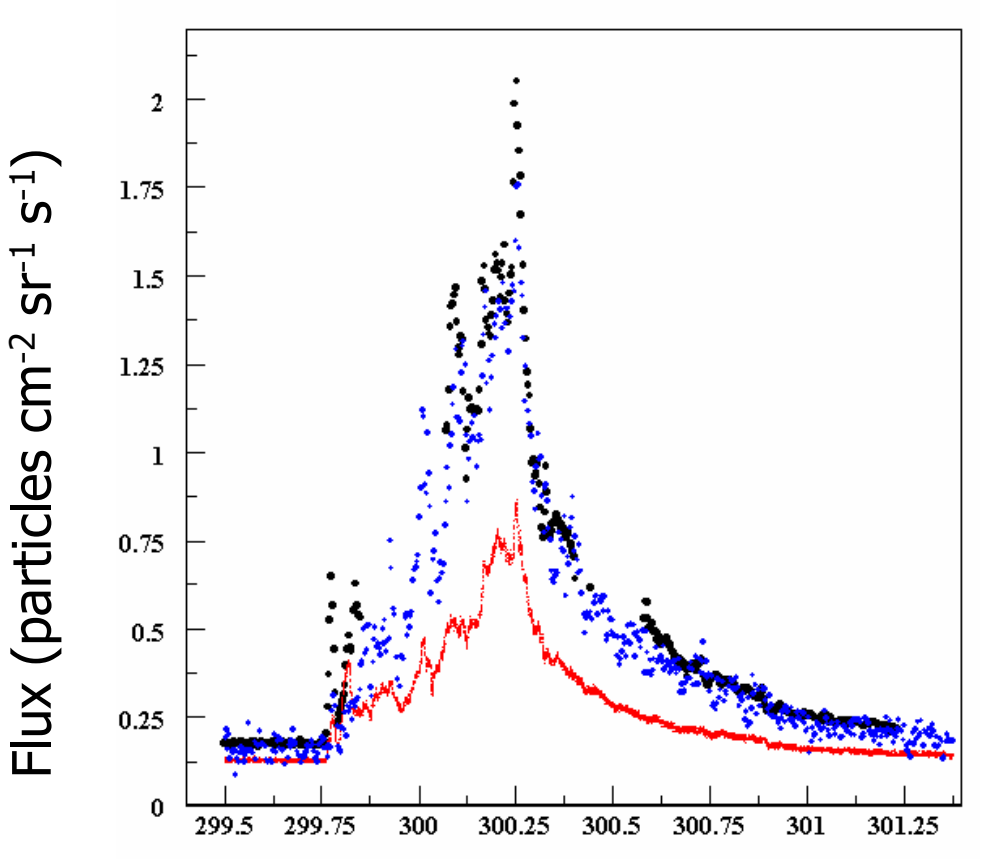
July 2002 SPE



MARIE and GRS, Oct. 2002

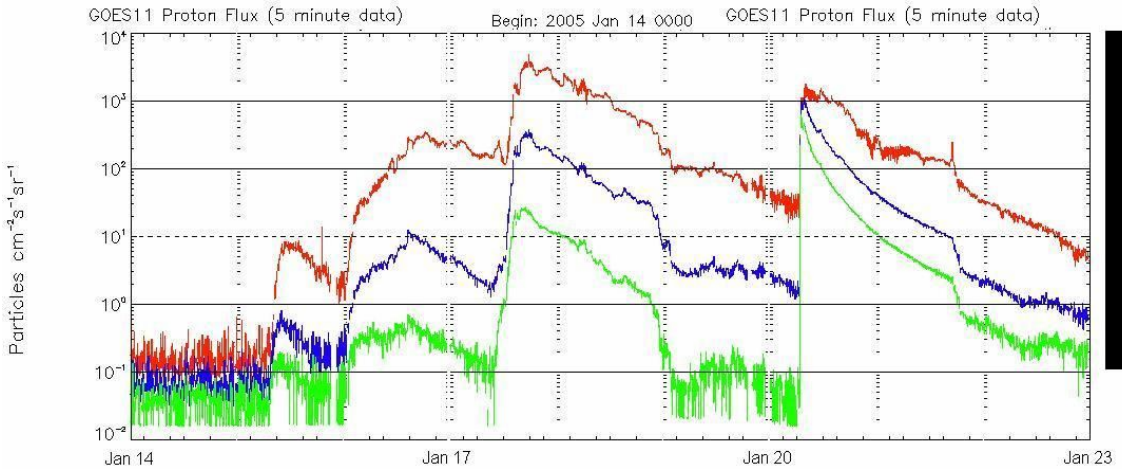


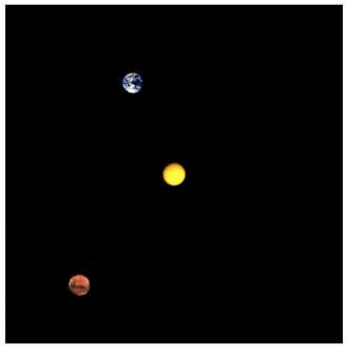
MARIE and ULD SPE Data Normalized to Flux

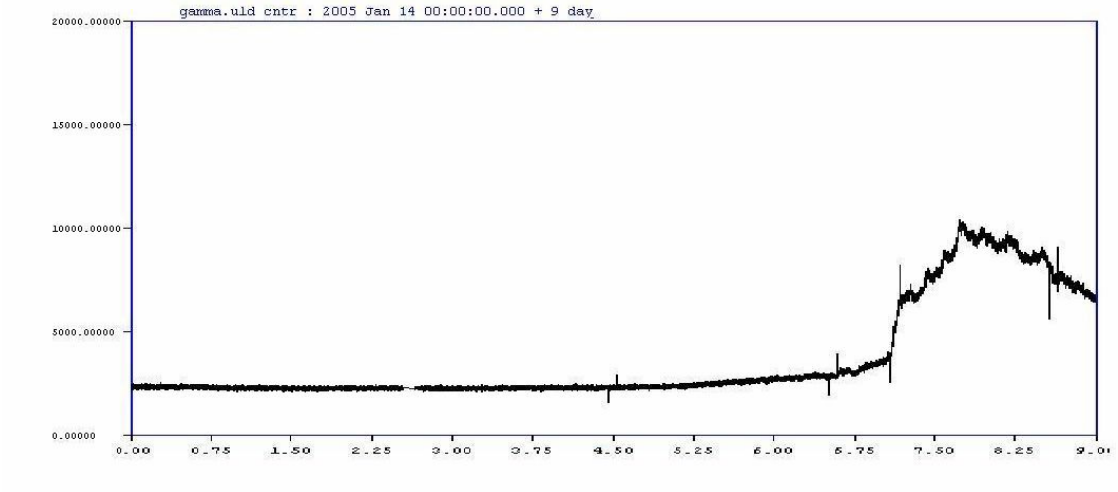


HEND data scale with MARIE E > 30 MeV data

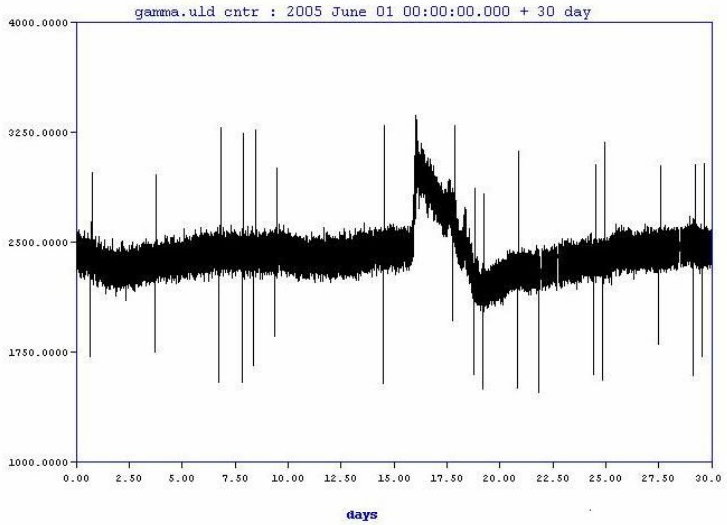
Recent SPEs: January 2005

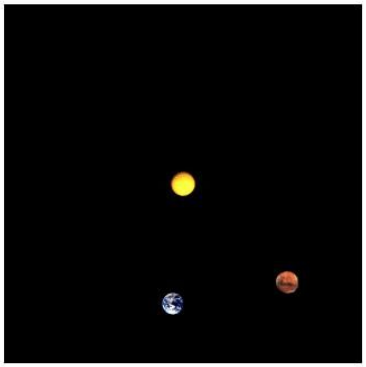




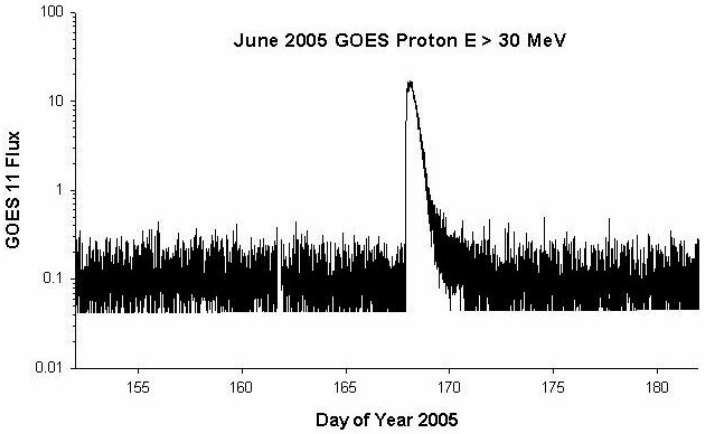


June 2005

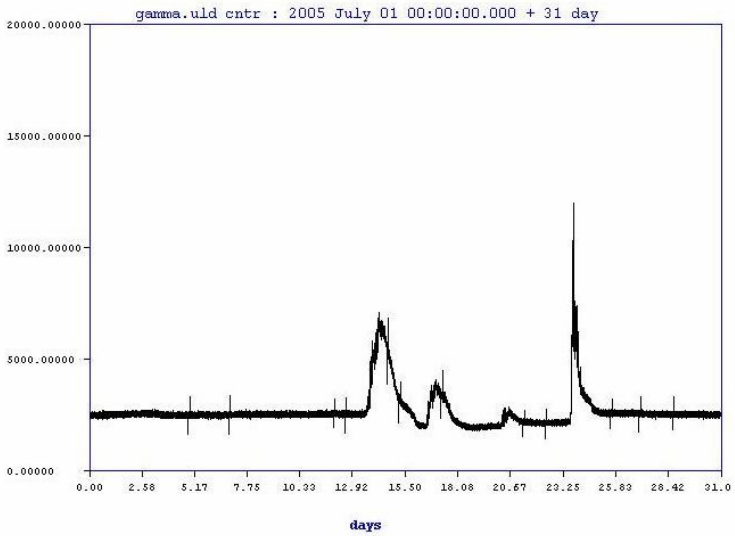


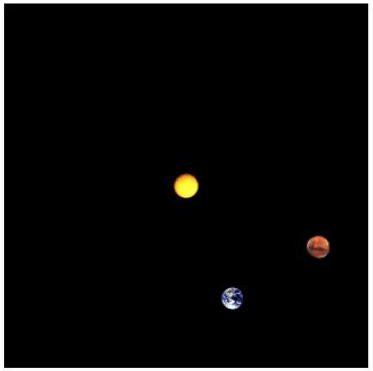


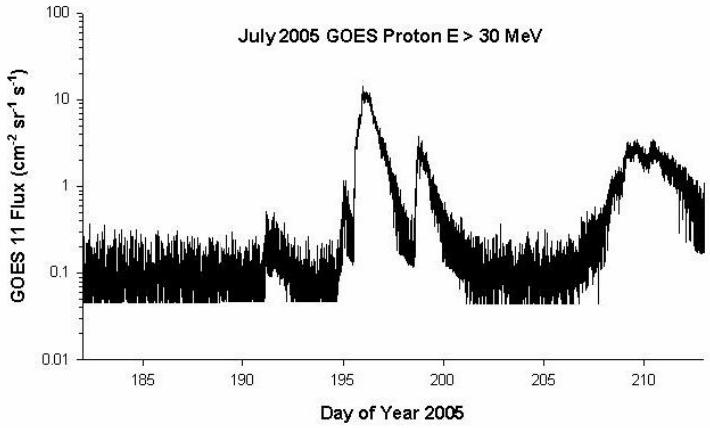
Well-connected at Earth,
not at Mars



July 2005


gamma.uld cntr : 2005 July 01 00:00:00.000 + 31 day
20000.00000
15000.00000
10000.00000
5000.00000
0.00000
0.00
2.58
5.17
7.75
10.33
12.92
15.50
18.08
20.67
23.25
25.83
28.42
31.0
days




July 2005 GOES Proton E > 30 MeV
GOES 11 Flux (cm-2 sr-1 s-1)
100
10
1
0.1
0.01
185
190
195
200
205
210
Day of Year 2005

Summary

- Radiation monitoring at Mars continues despite loss of MARIE.
- GRS ULD can provide an absolute flux, normalization not completely settled.
  - With model input, can calculate dose.
- HEND Inner Scintillator most useful during intense SPEs.