

# Charged Particle Measurements in Mars Orbit from 2002 to 2006



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# MARIE & MRME

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- 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

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- 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

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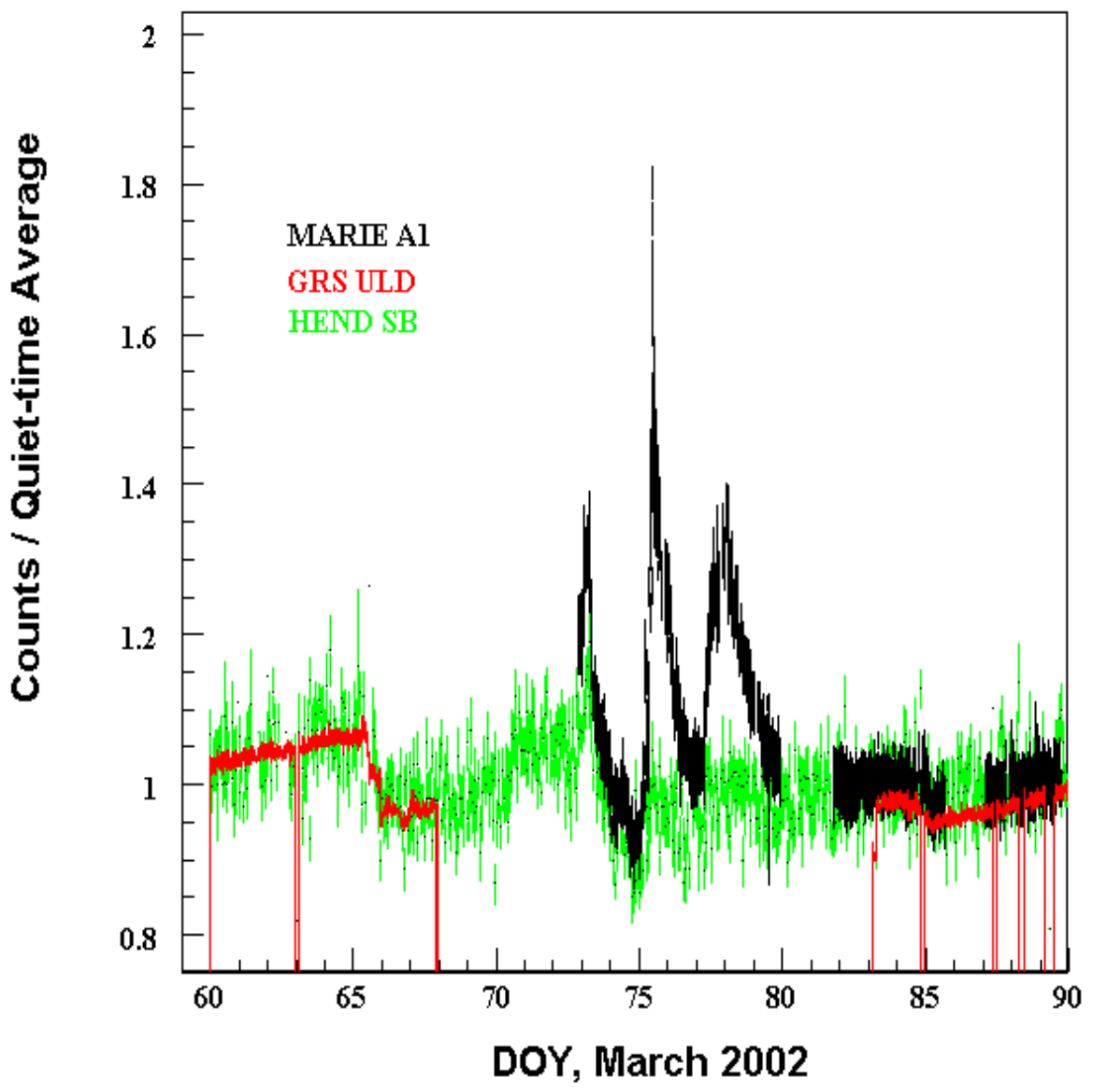
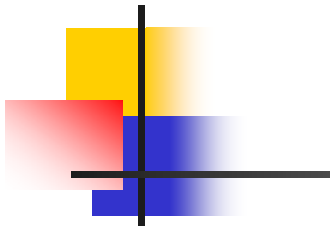
- Counts are collected every 19.7 sec.
- Relatively high rate in GRS ULD due to large geometry factor.
- Low count rate in HEND SB due to small geometry factor & low efficiency for conversion of incident charged particles to high-E neutrons.



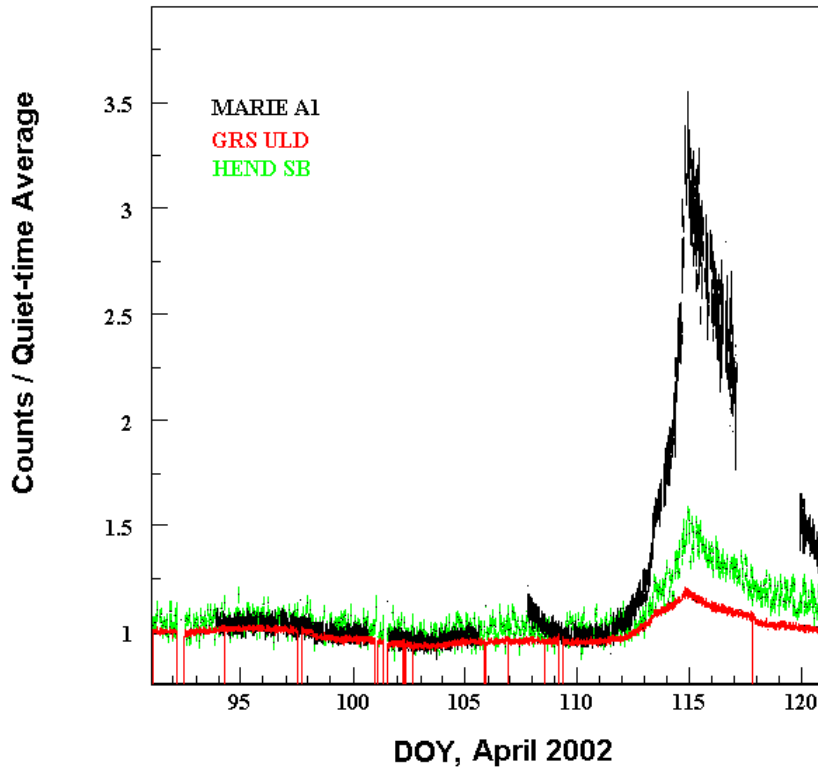
# Data Aggregation

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- 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.

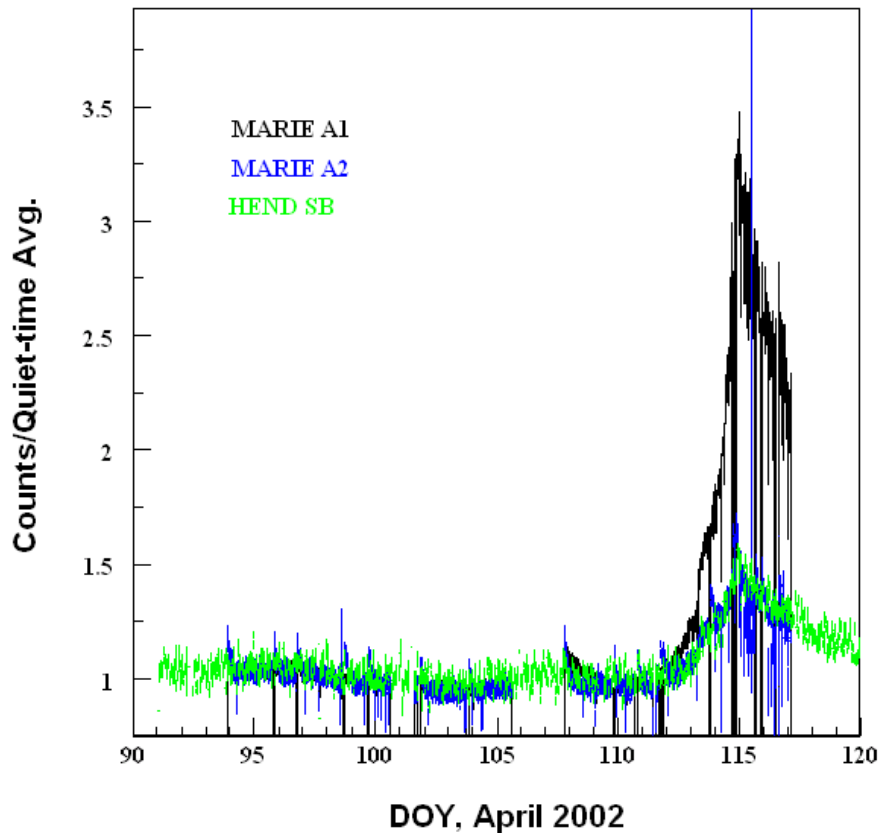


# SPE Responses



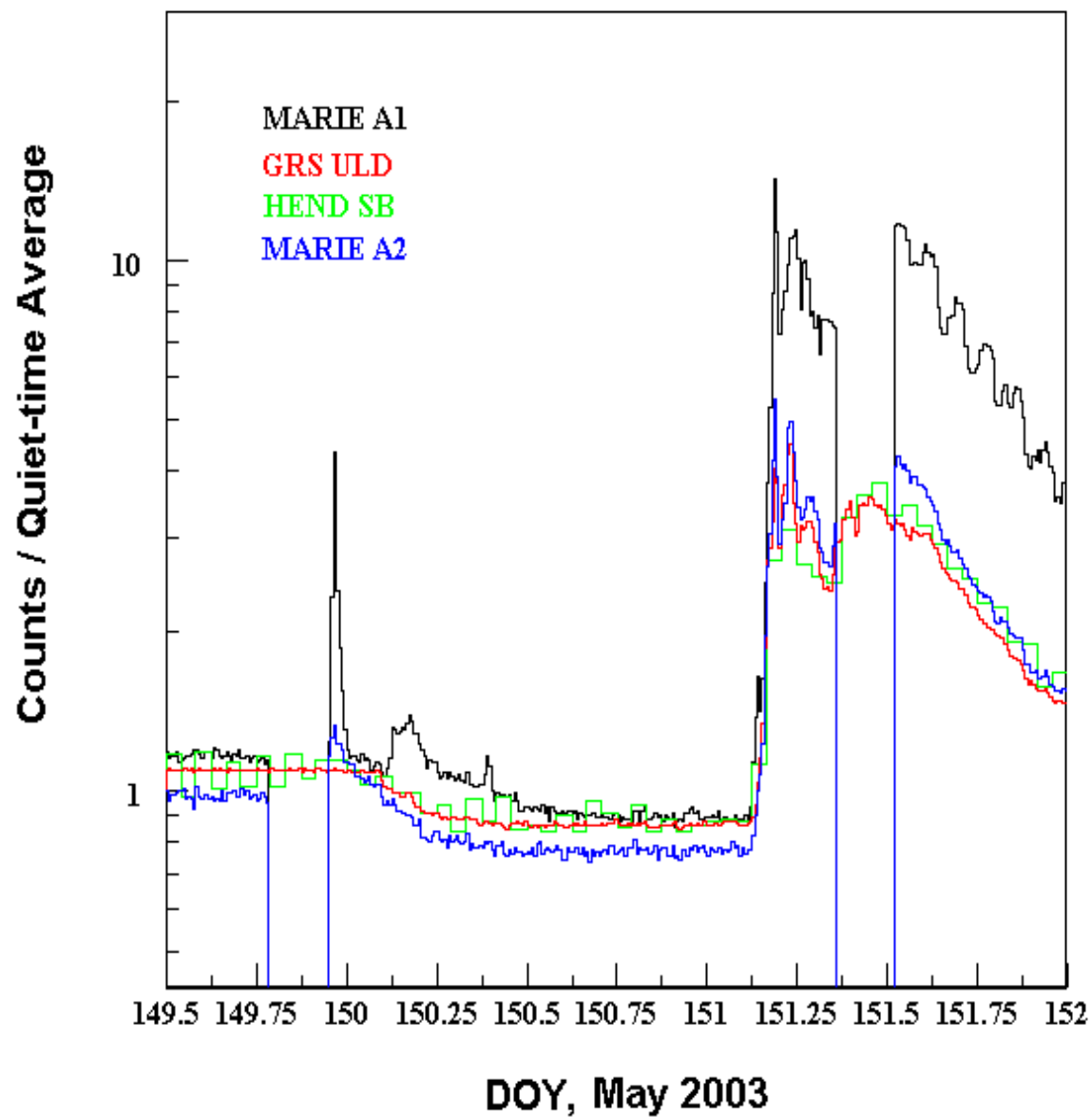
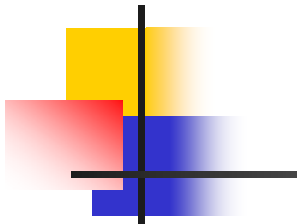
- Typical: A1 most sensitive, followed by SB, followed by ULD.
- A2 not shown here...

# Compare A2 Data

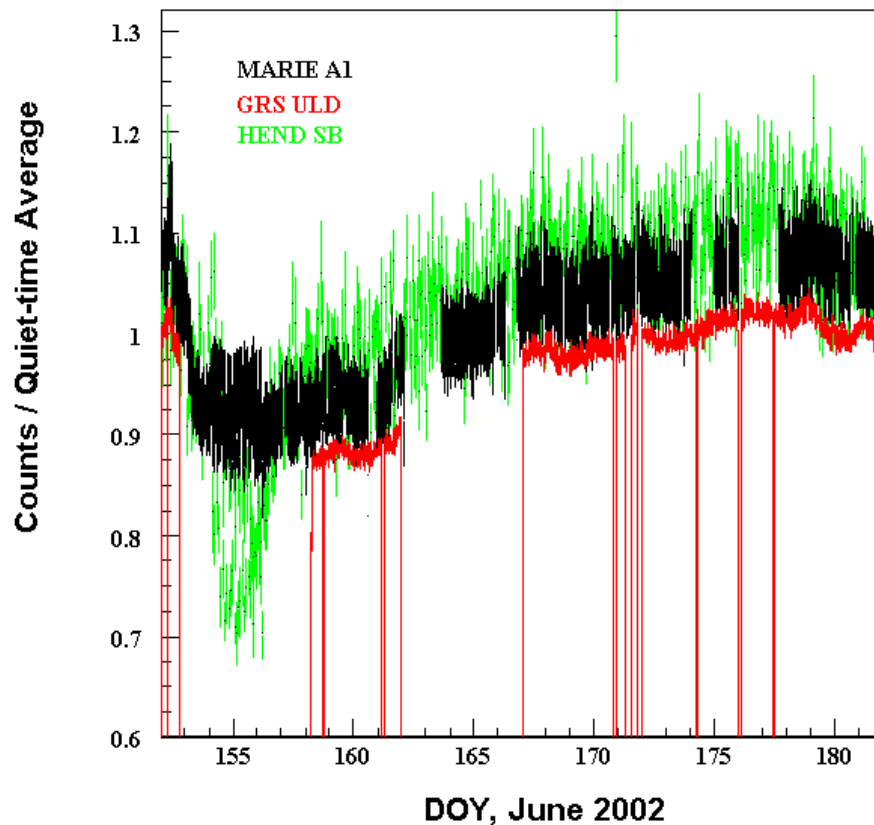


- SB matches A2 in this & several other SPE's – but not all.



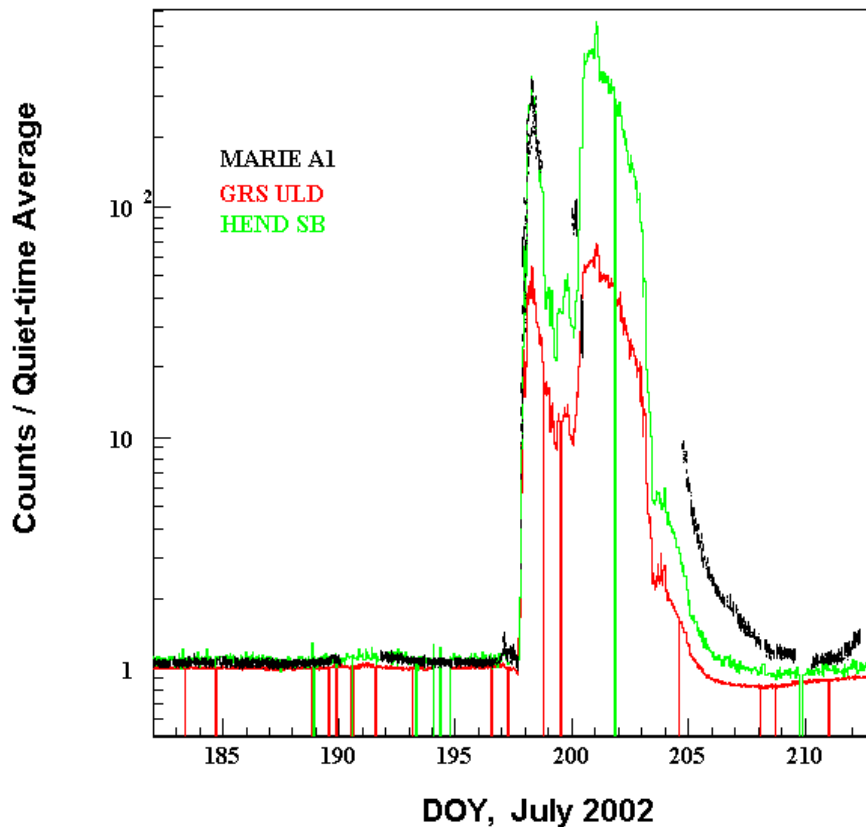


# Quiet Month – GCR Only

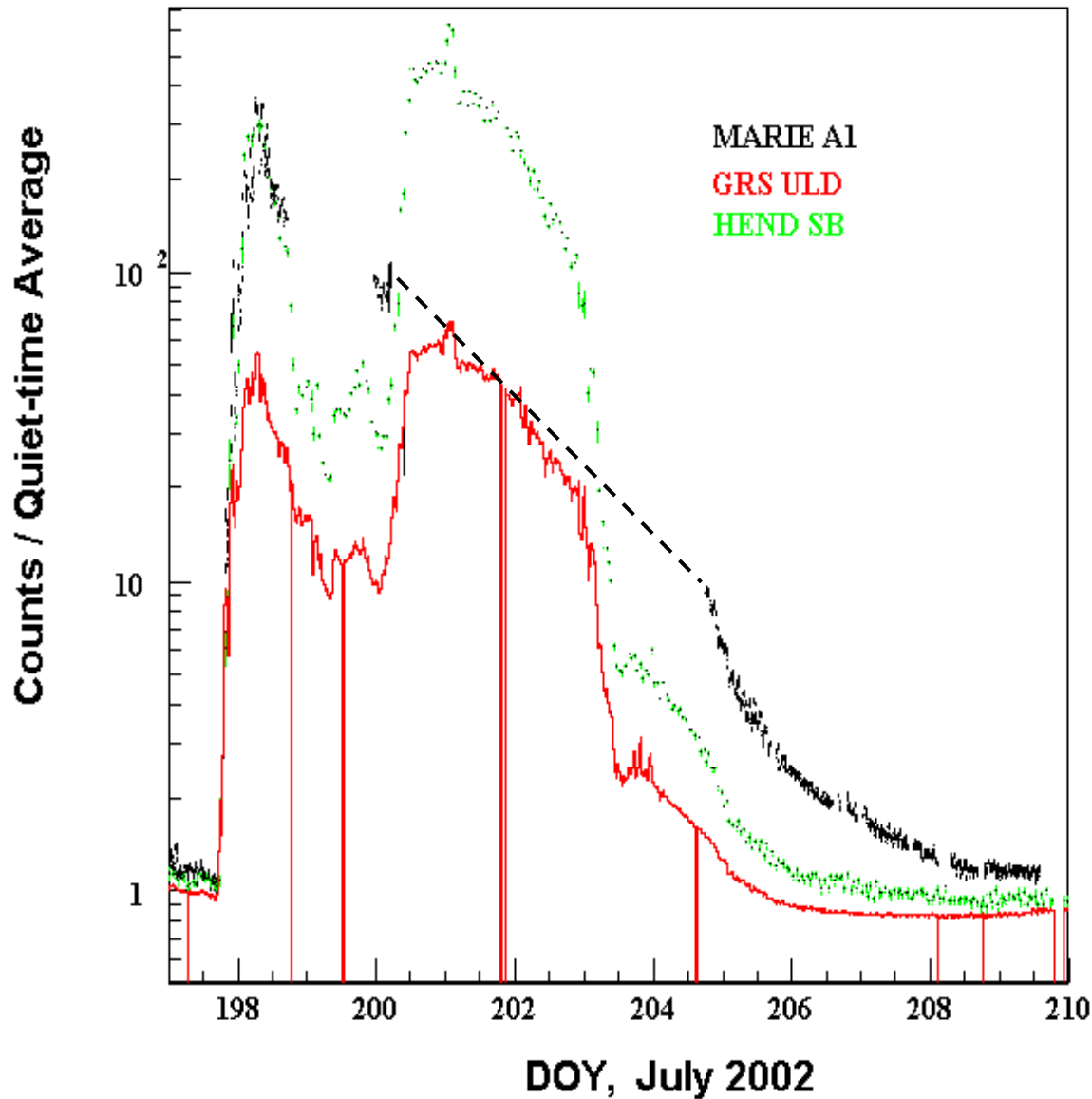


- June 2002
- All 3 detectors show same trend but normalizations vary.
- HEND SB sees unexplained blip around day 155

# July 2002



- MARIE 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 MARIE 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

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- 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

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- For flux  $J$  & dose  $D$  use 2002 quiet time factors.
- $D = J * \text{constants} * \text{avg. LET}$ 
  - LET = linear energy transfer in water, i.e.,  $dE/dx$
  - If avg. LET constant,  $D$  proportional to  $J$
- Dose equivalent  $H = D * Q$ 
  - $Q$  = 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.

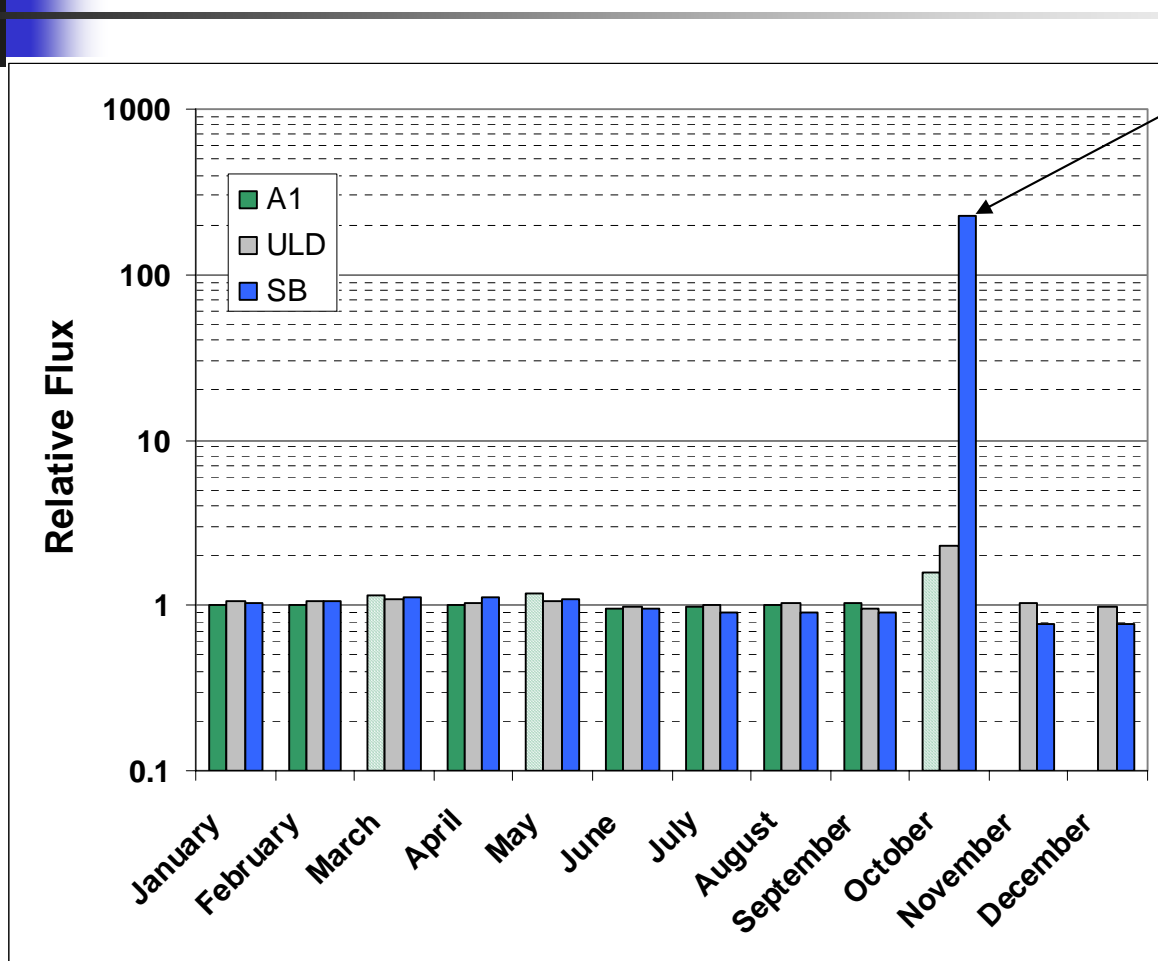


# Detector Responses

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- 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

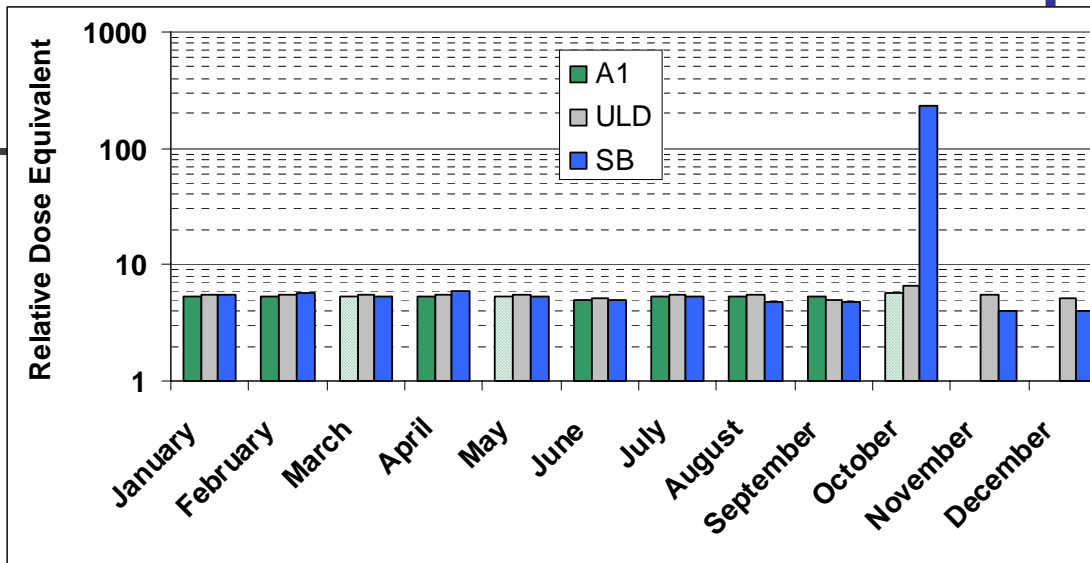


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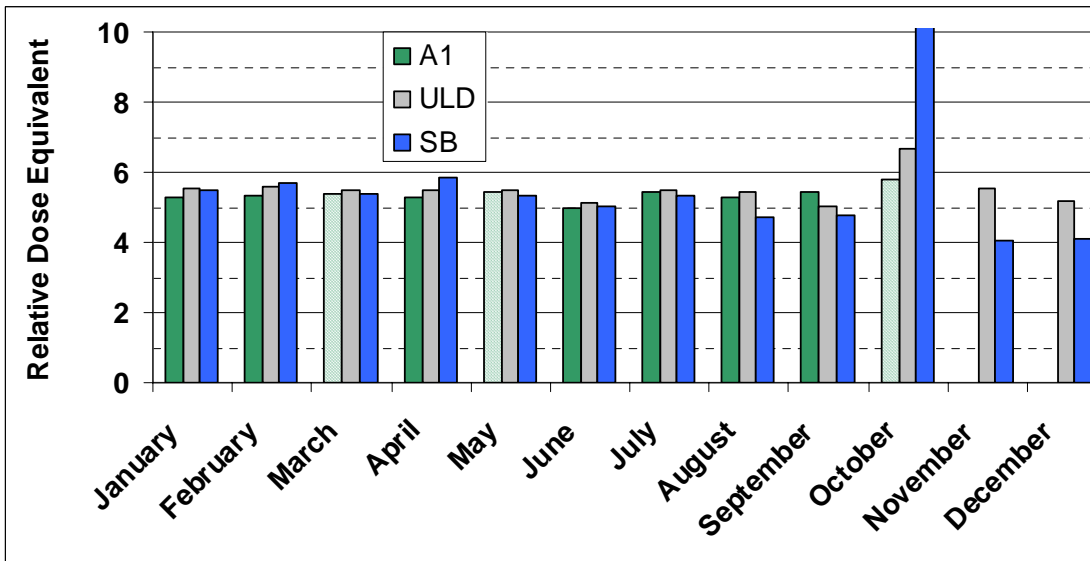
For GCR, SB trends low starting in August.



# 2003 Relative Dose Equivalent

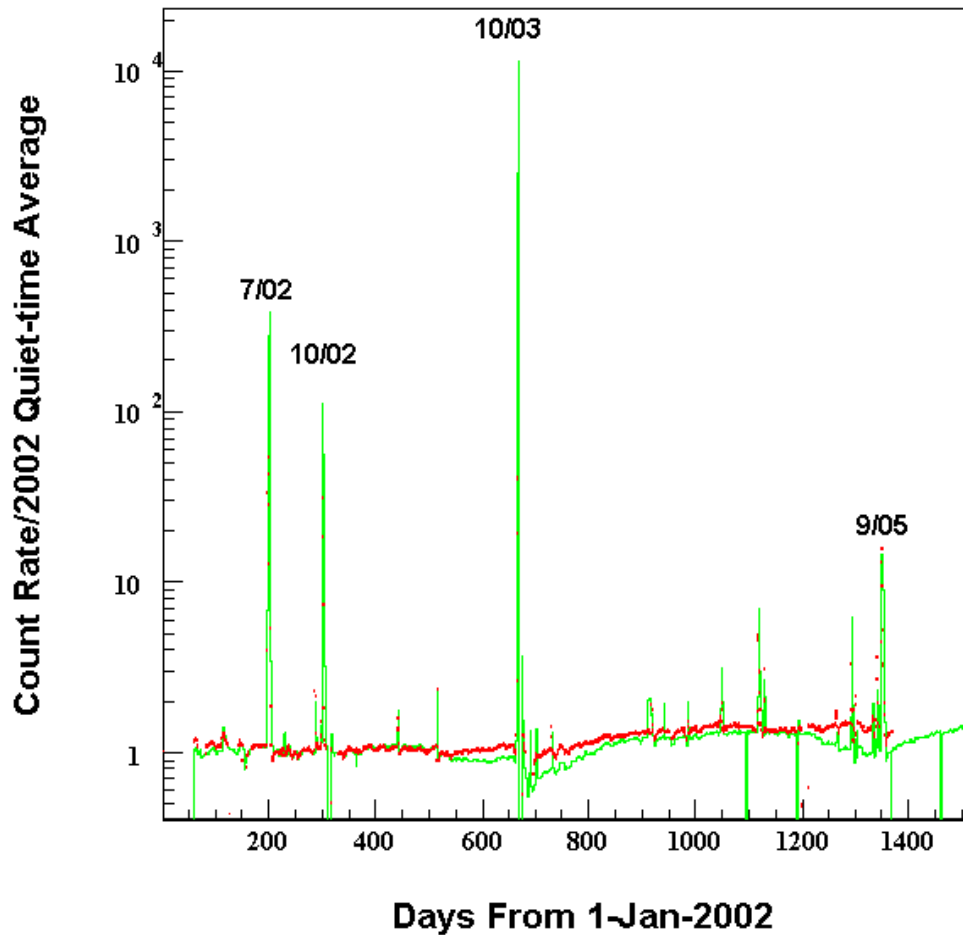


Log scale



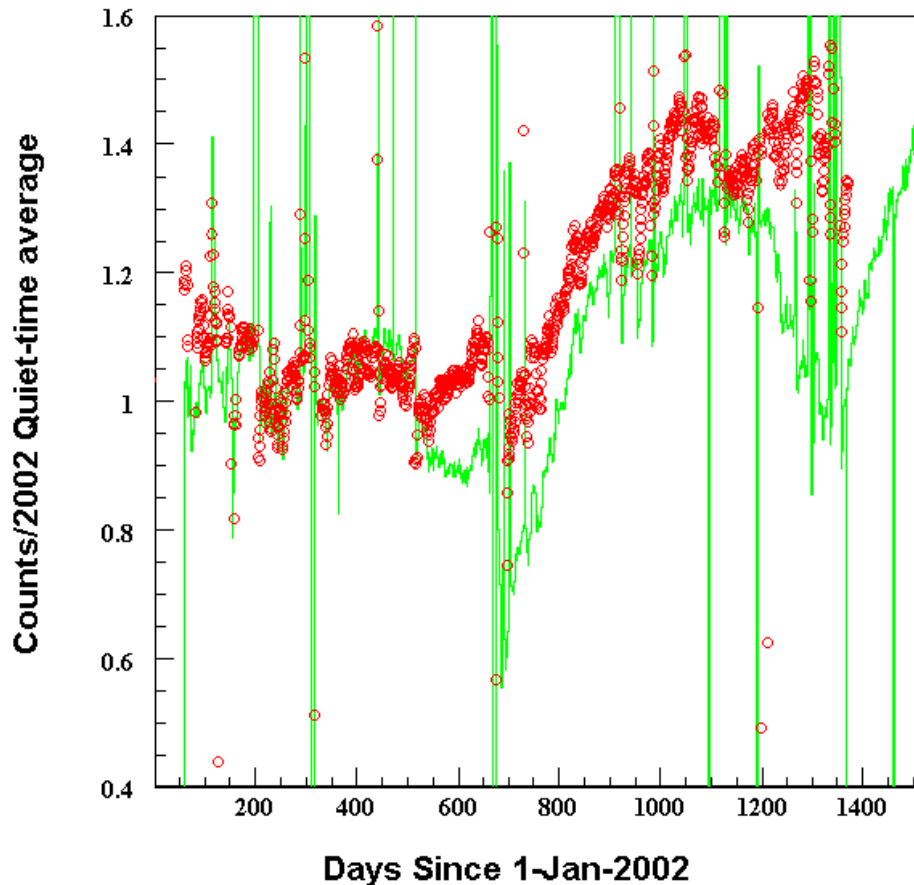
Linear scale  
w/cutoff.

# Long Timeline Stripchart



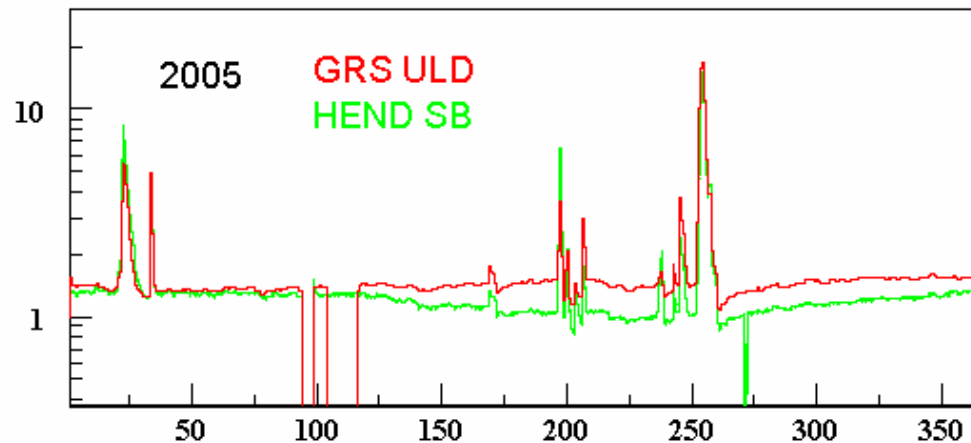
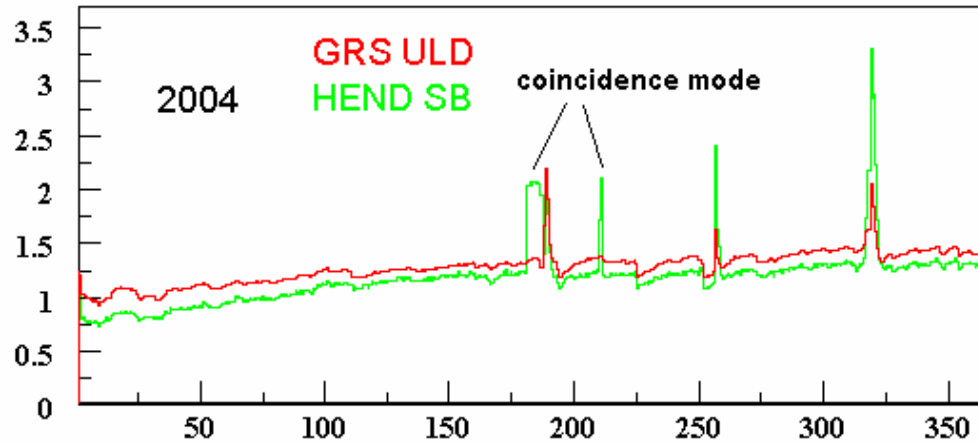
- HEND SB (green) and ULD (red) only
- Log scale

# Long Timeline GCR



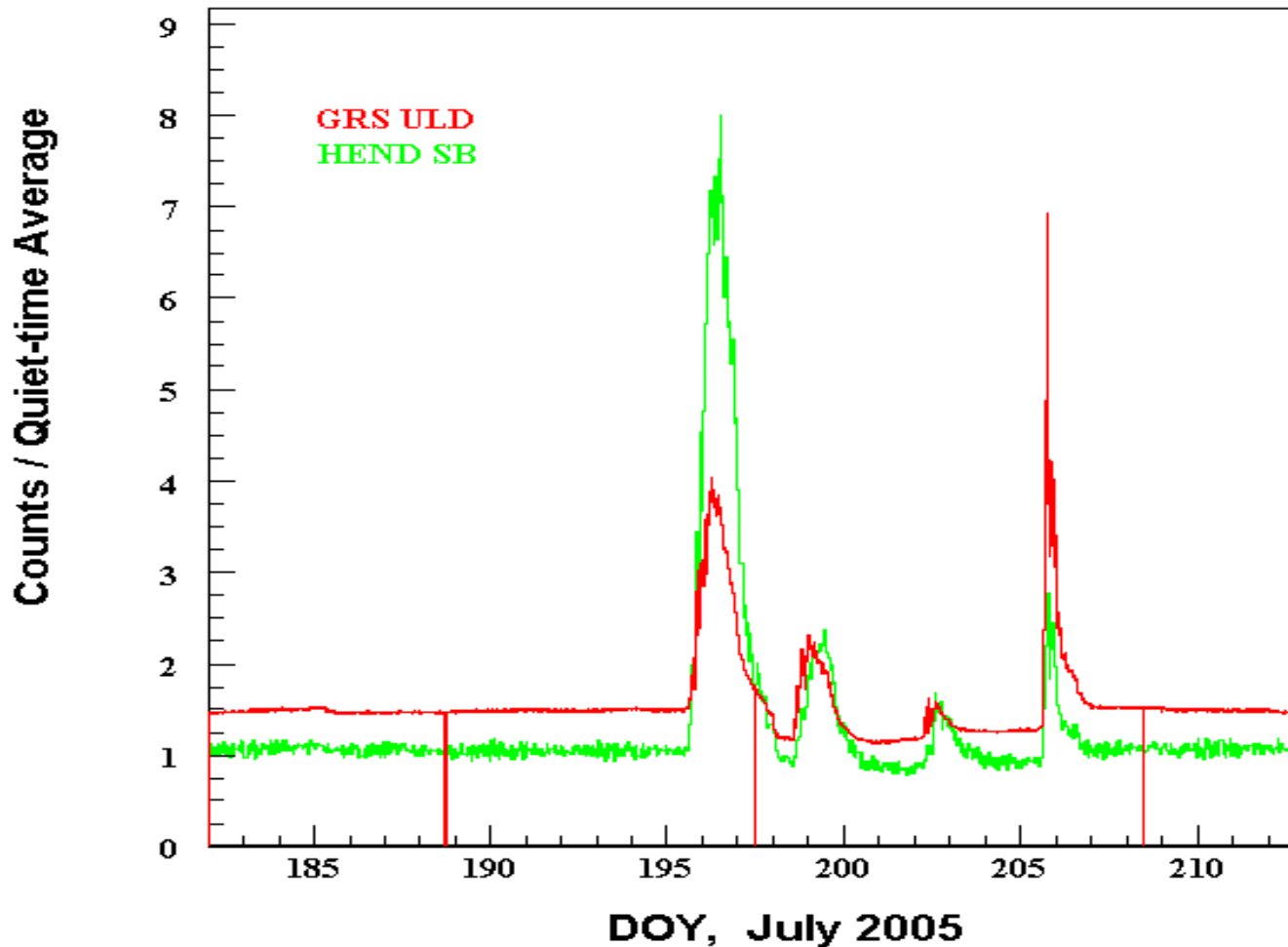
- Zoom in around 1.0, see modulation
- Both mostly follow similar trends with a few unexplained differences (e.g., times near days 600, 1200)

# More Detail – 2004 & 2005

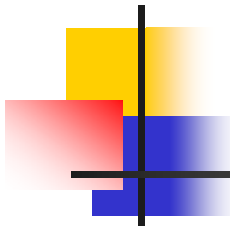


Day of Year

# Cataloging SPE (Tricky)

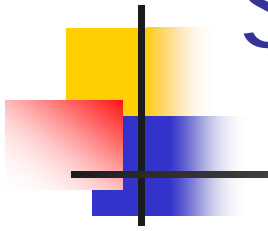


# SPE's Seen by ODY incl. MARIE



MM/YY	DOY	A1 peak	ULD peak	SB peak
04/02	115	3.5	1.2	1.5
04/02	147	1.55	1.1	1.25
07/02	198	350	50	350
07/02	200		10	40
07/02	201		70	600
08/02	229		1.2	1.8
08/02	238	1.15	1.1	1.1
09/02	250	1.3	1.0	1.1
10/02	288	14	6	5
10/02	299	4	2	2
10/02	302	240	40	250
03/03	78	6	2	2
10/03	300	50	6	7
10/03	302		75	10000

# SPE's Seen by ODY post-MARIE



MM/YY	DOY	ULD peak*	SB peak*
12/03	337	1.2	2.4
07/04	190	2.4	2.2
09/04	227	1.8	3.3
11/04	319	2.4	3.8
01/05	22	5.5	9.3
02/05	33	6.8	5.5
06/05	169	1.3	1.2
07/05	196	2.7	7.5
07/05	199	1.8	2.3
07/05	203	1.2	1.5
07/05	206	4.7	2.8
08/05	236	1.2	2.0
08/05	237	1.3	2.3
08/05	242	1.5	1.4
09/05	253	13.3	18.5

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



# Summary

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- 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.