



Charged Particle Measurements in Mars Orbit from 2002 to 2006

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MARIE & 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 ΔE 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 4π .



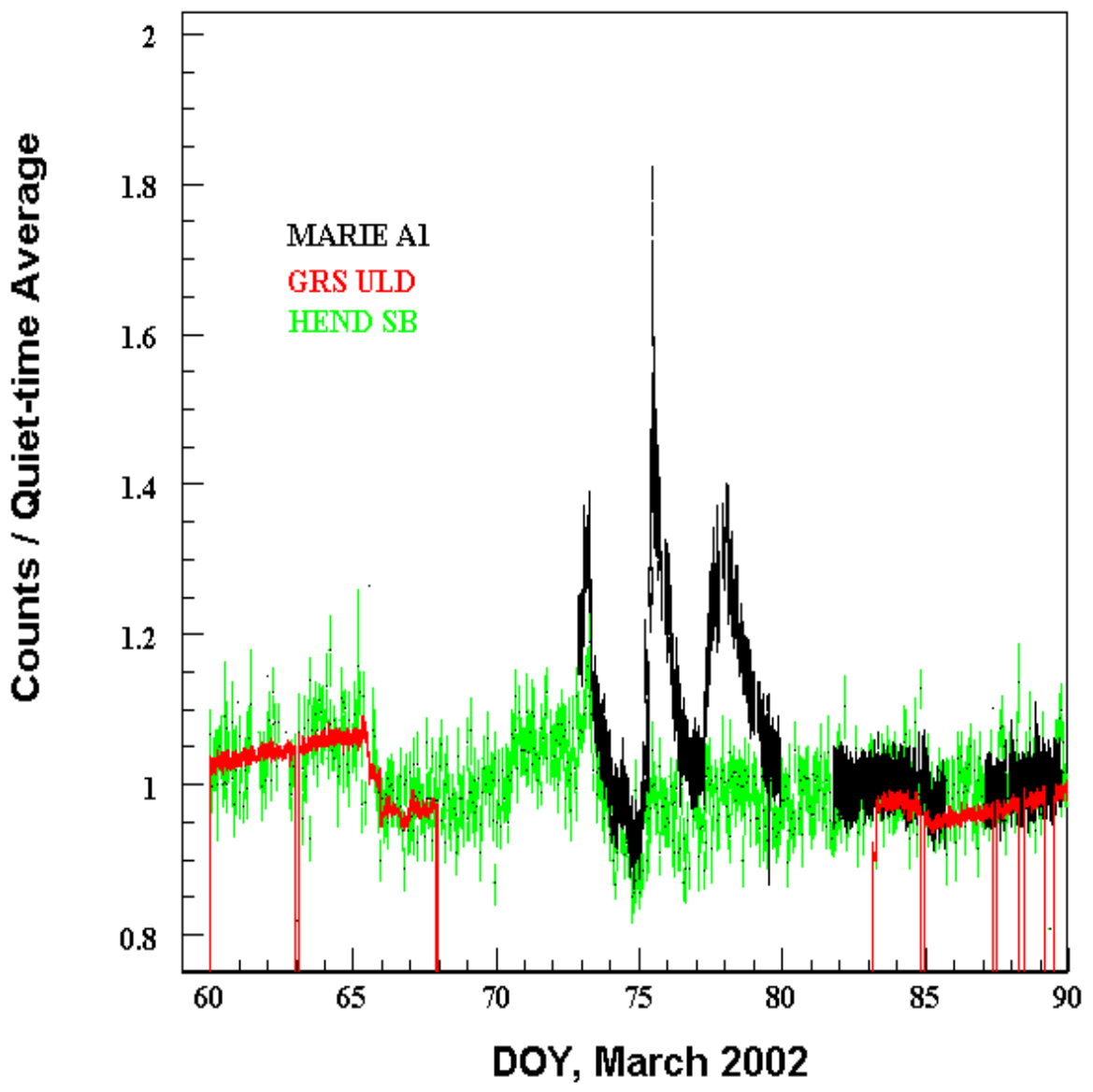
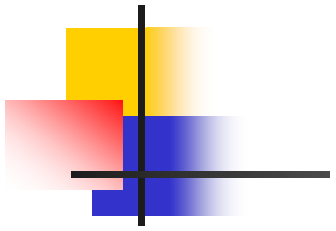
GRS and HEND Data

- 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.

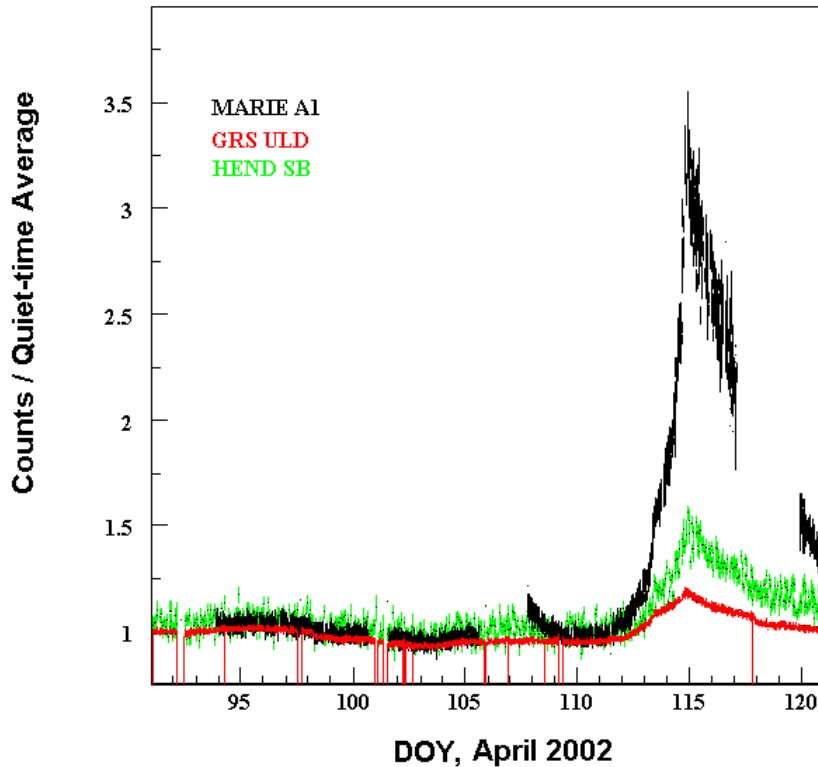


Data Aggregation

- 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.

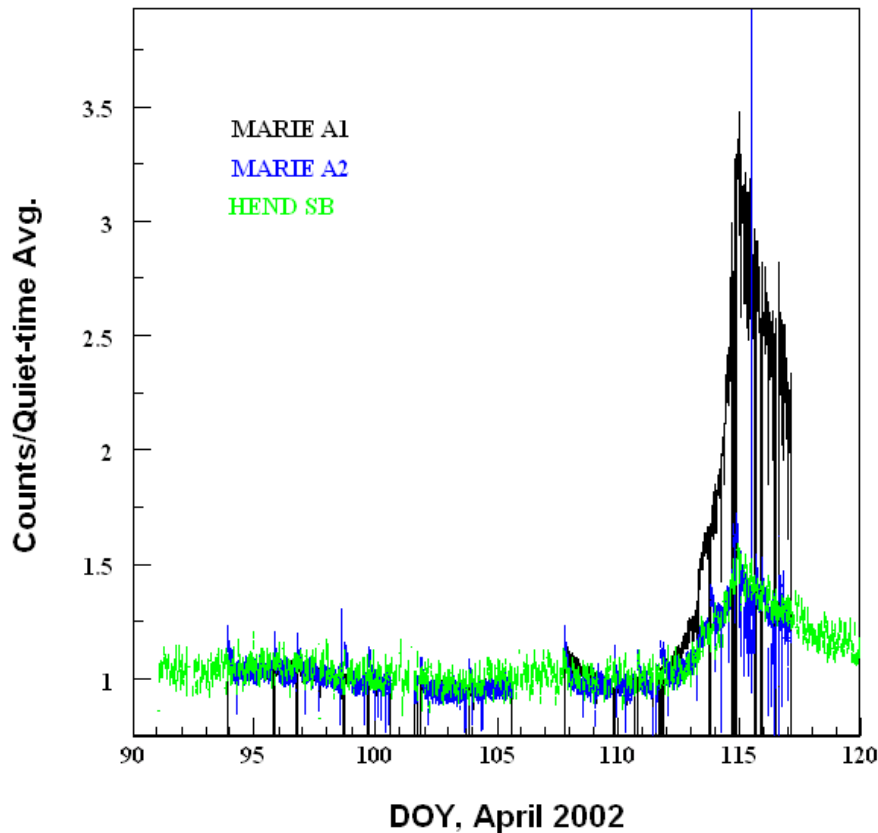


SPE Responses

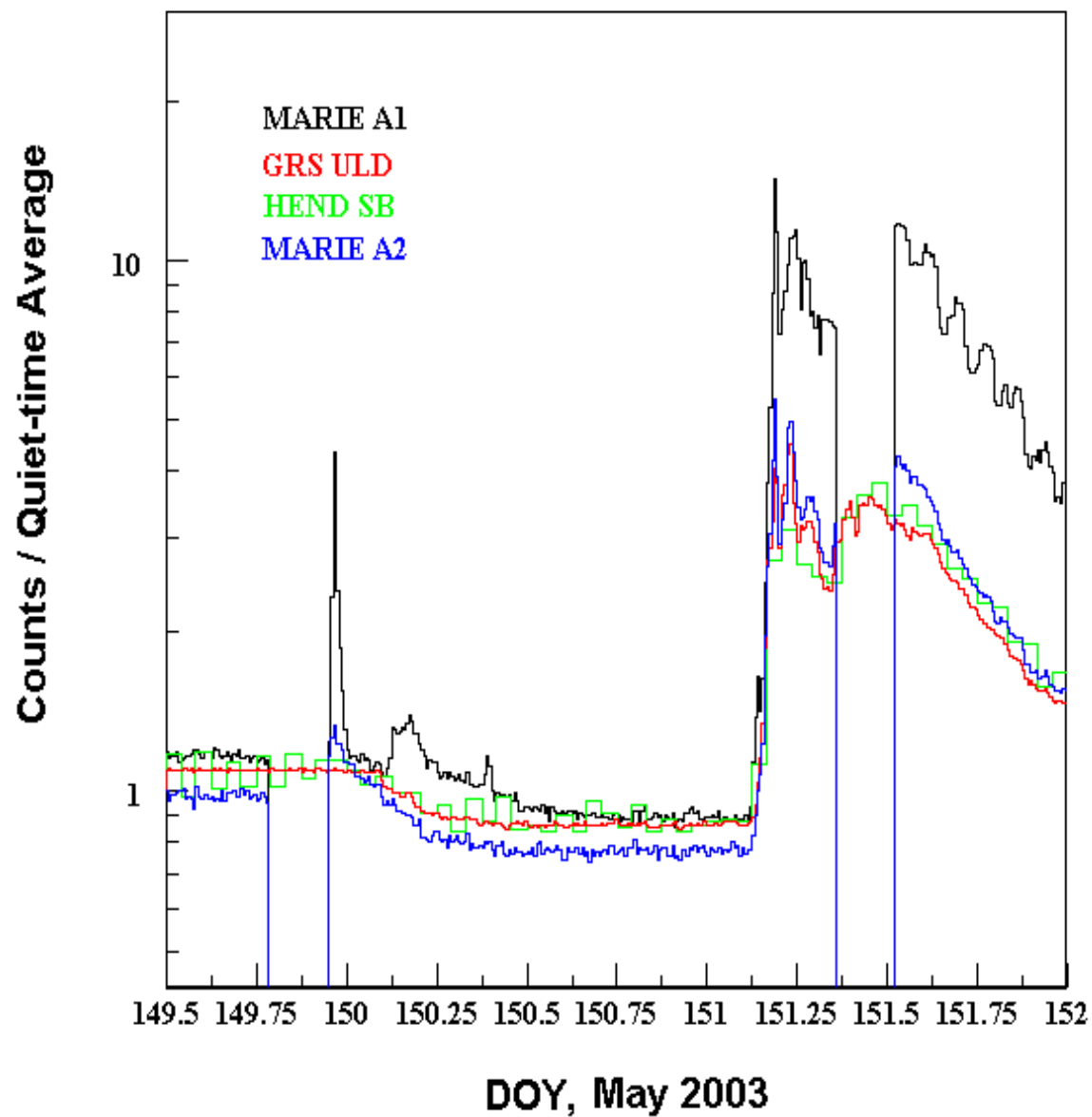
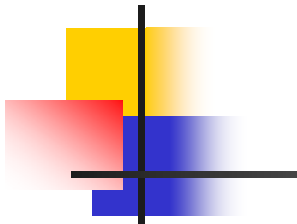


- Typical: A1 most sensitive, followed by SB, followed by ULD.
- A2 not shown here...

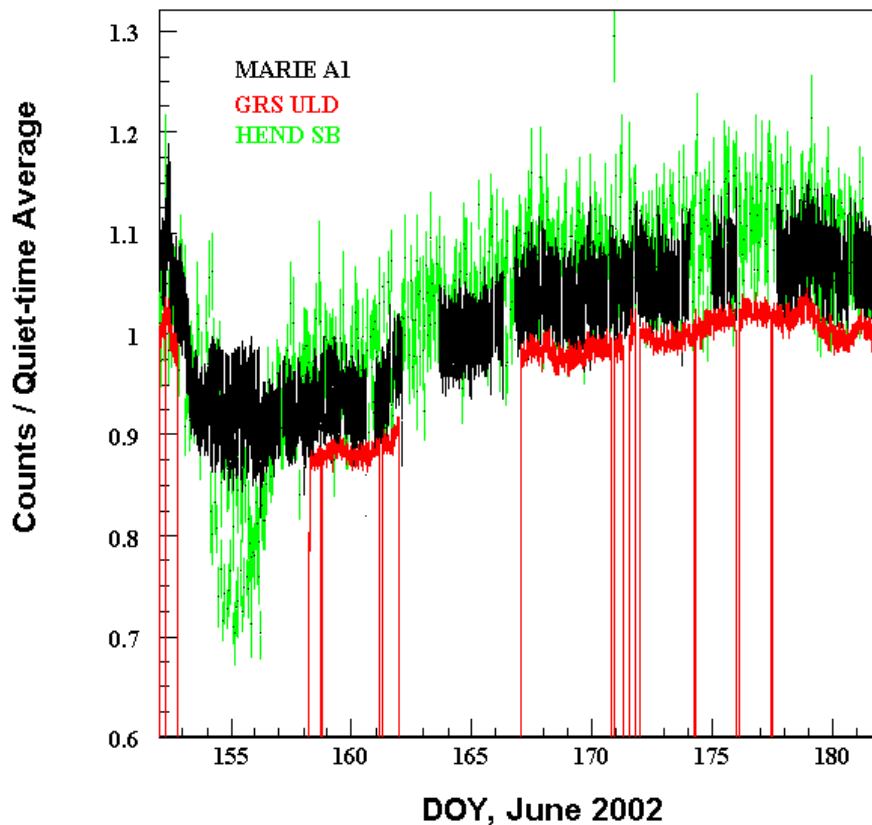
Compare A2 Data



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

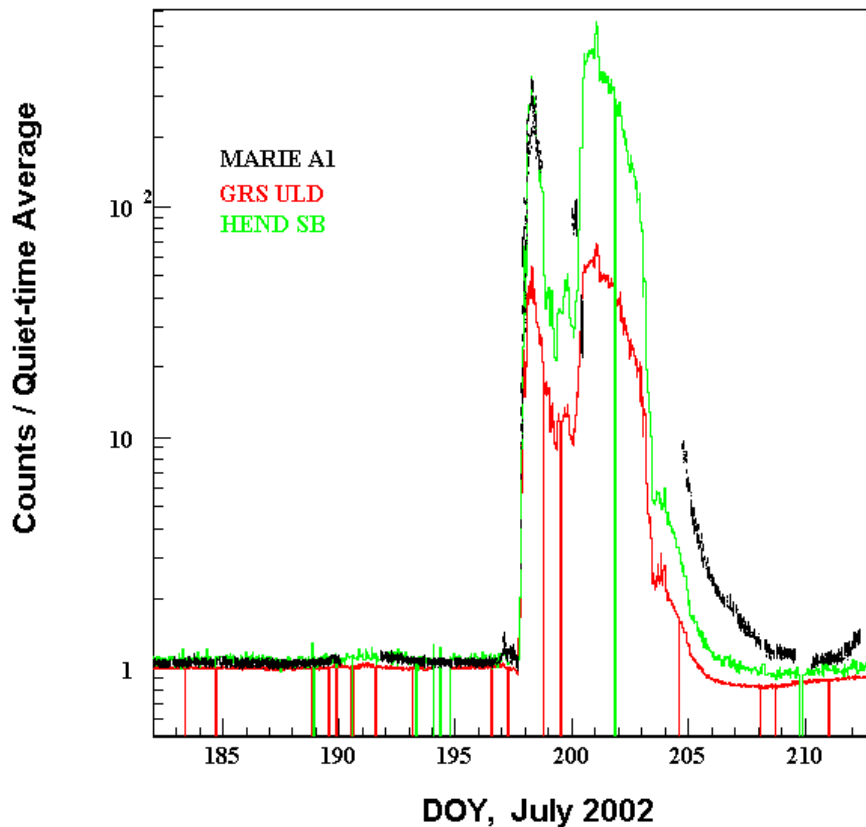


Quiet Month – GCR Only

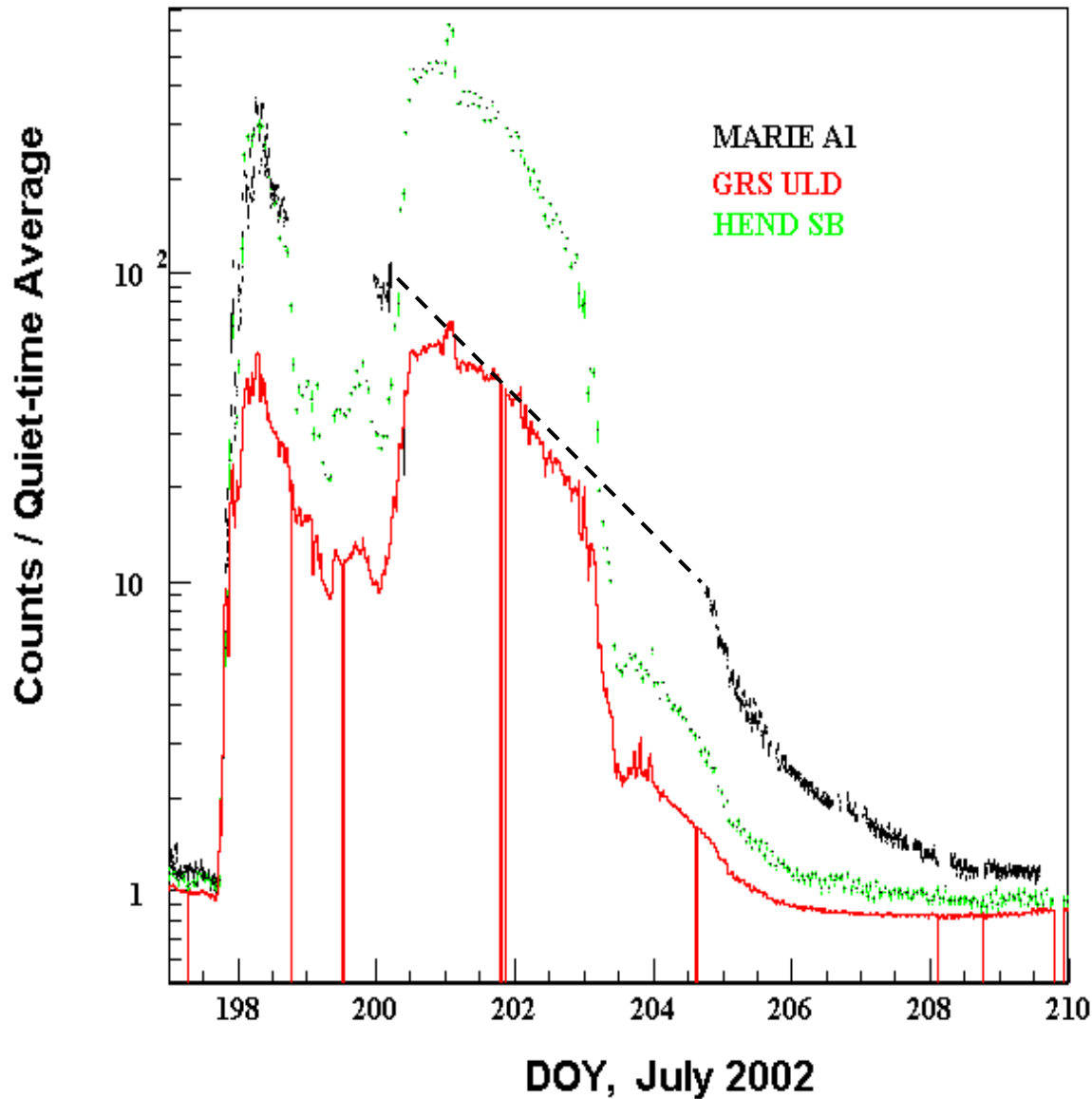


- June 2002
- All 3 detectors show same trend but normalizations vary.
- HEND SB sees unexplained blip around day 155

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

- 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

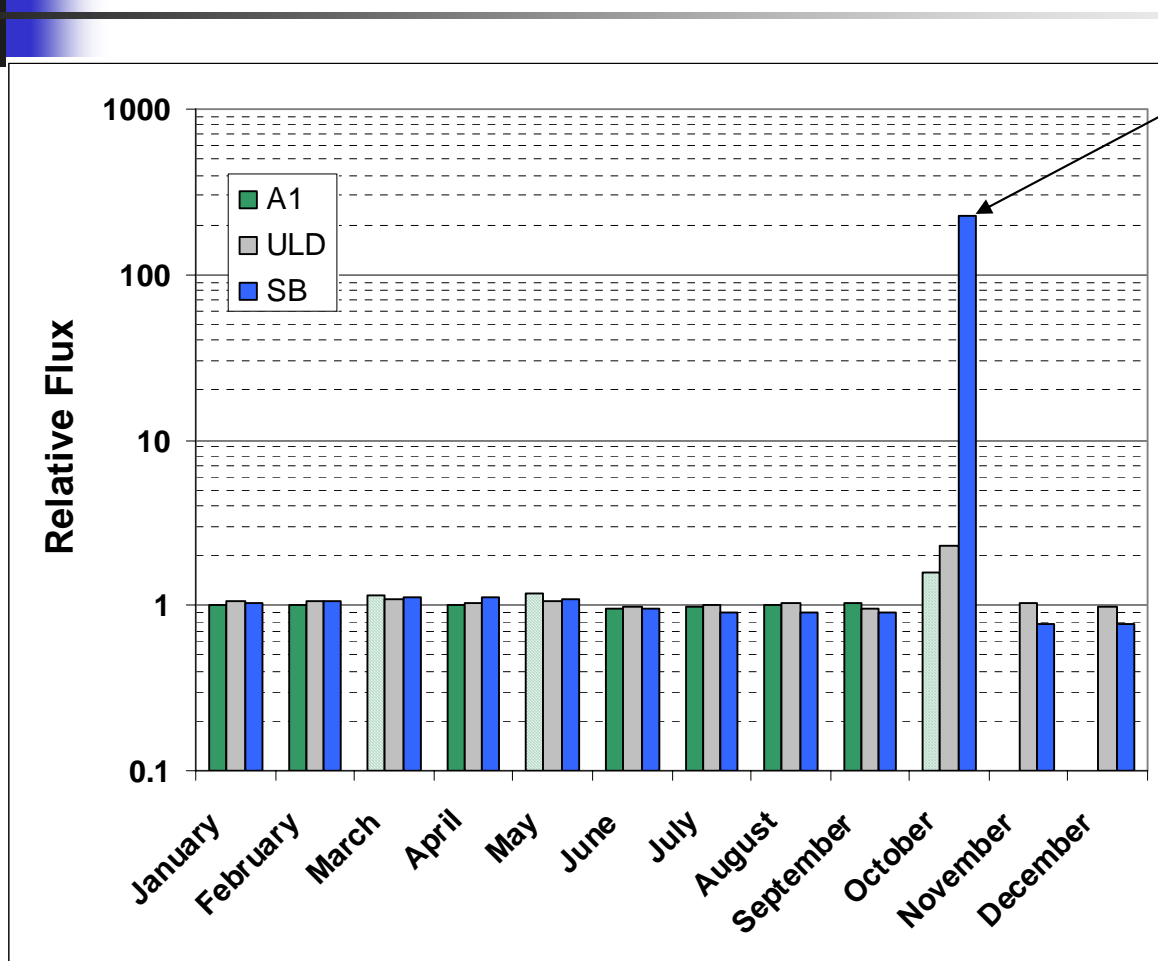
- For flux J & dose D use 2002 quiet time factors.
- $D = J * \text{constants} * \text{avg. LET}$
 - LET = linear energy transfer in water, i.e., dE/dx
 - If avg. LET constant, D proportional to J
- Dose equivalent $H = D * Q$
 - Q = average radiation quality factor
 - $Q = 1$ for protons (dominant in 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

- 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.

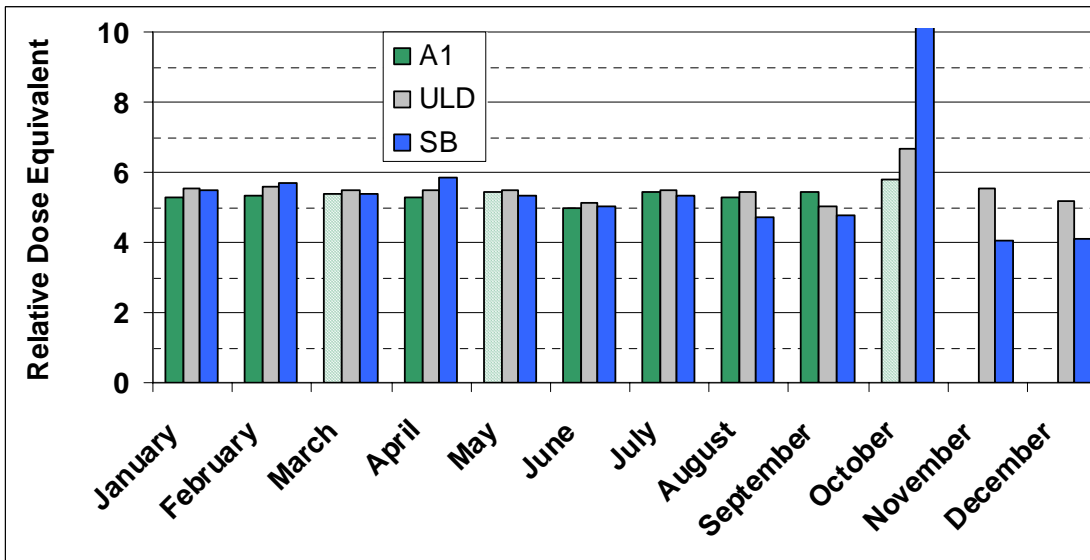
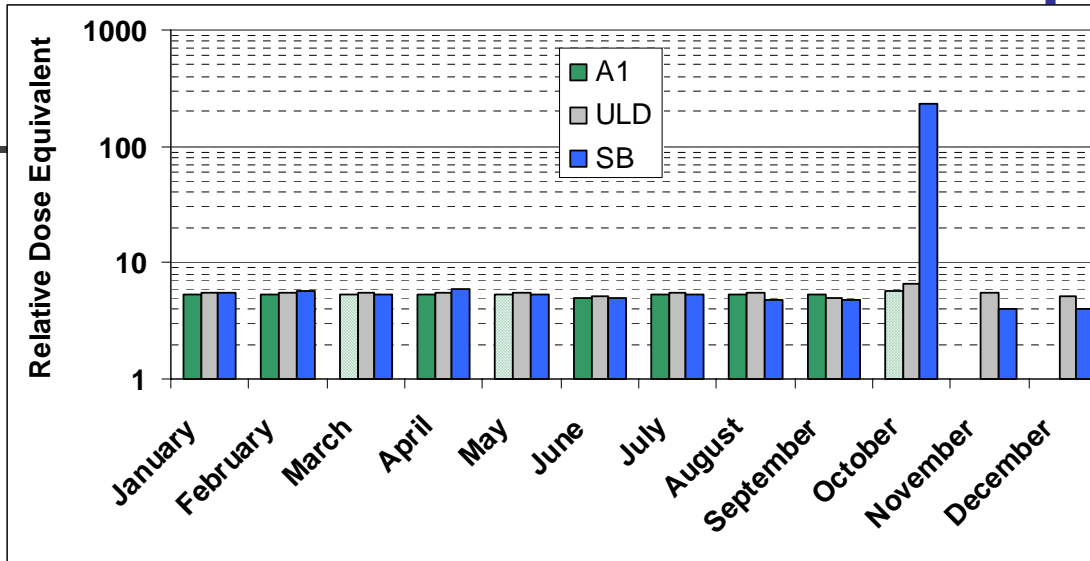
2003 Relative Flux



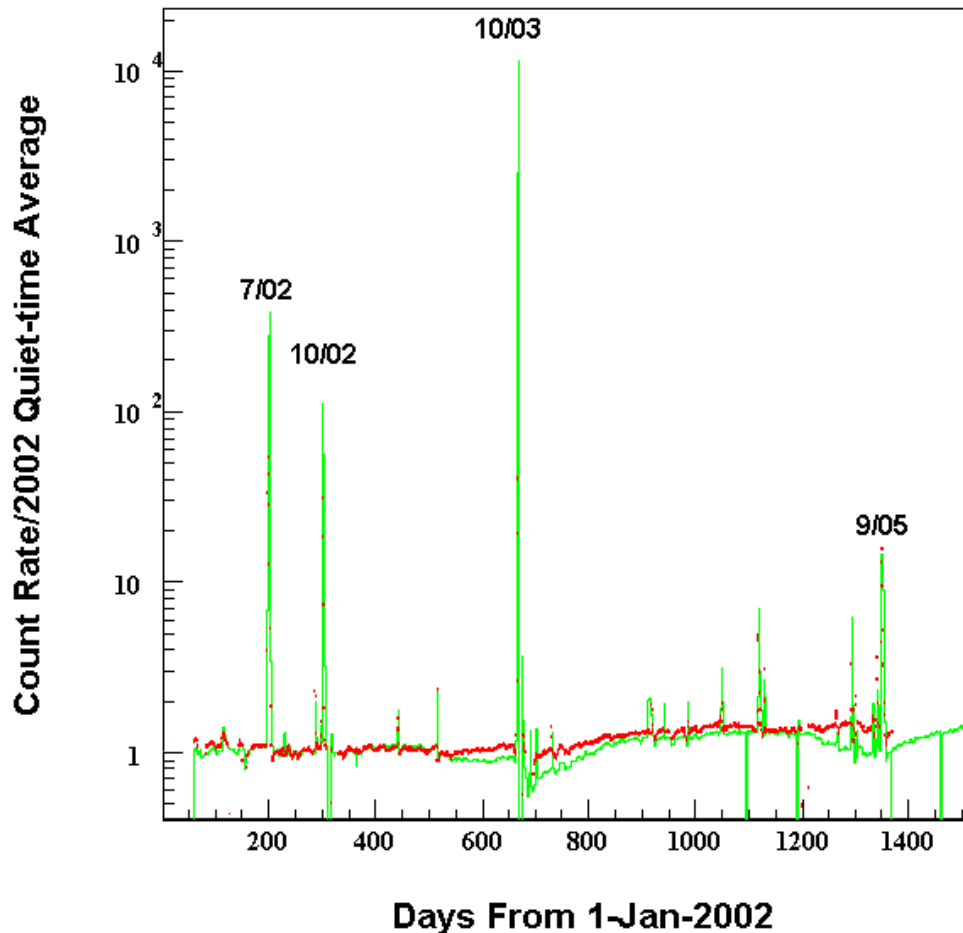
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For GCR, SB trends low starting in August.

2003 Relative Dose Equivalent

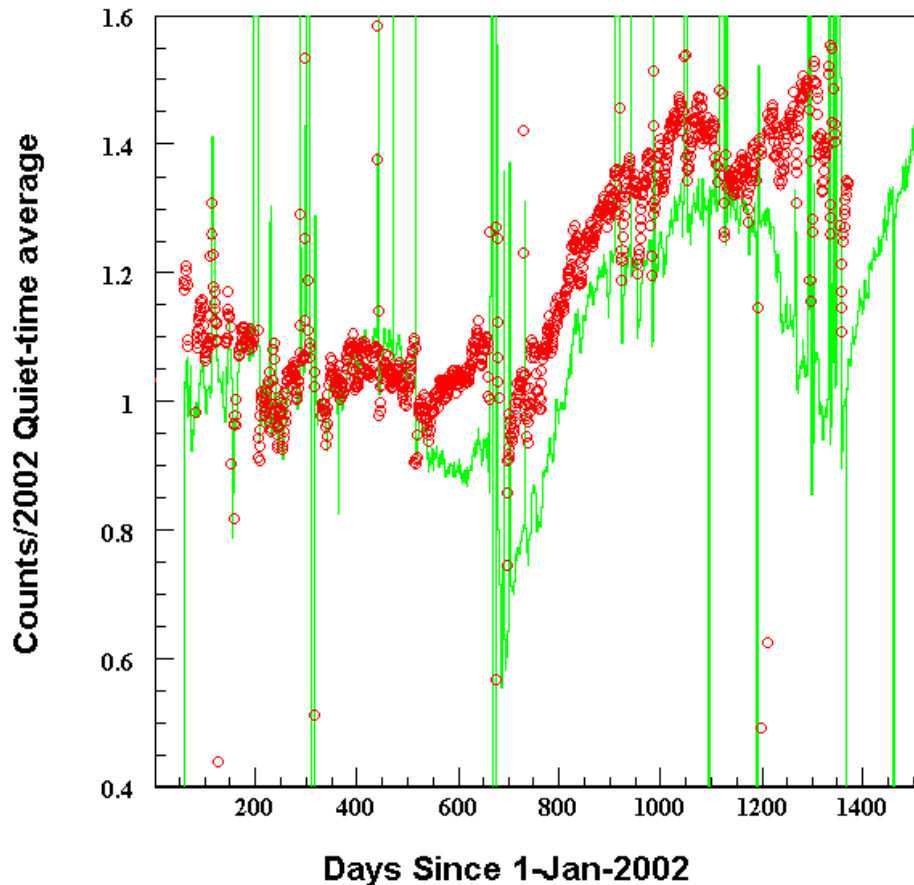


Long Timeline Stripchart



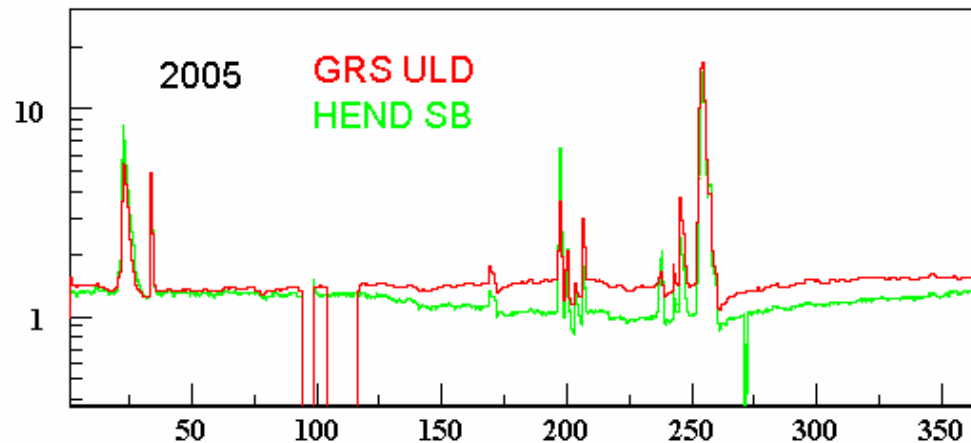
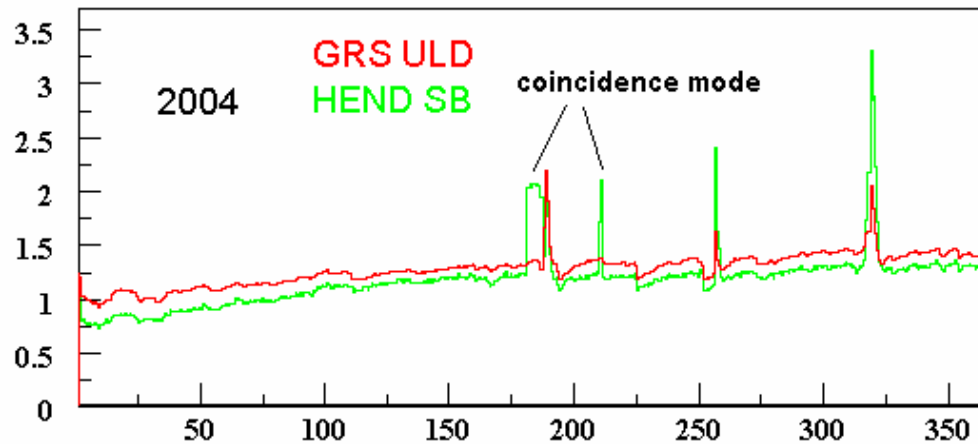
- HEND SB (green) and ULD (red) only
- Log scale

Long Timeline GCR



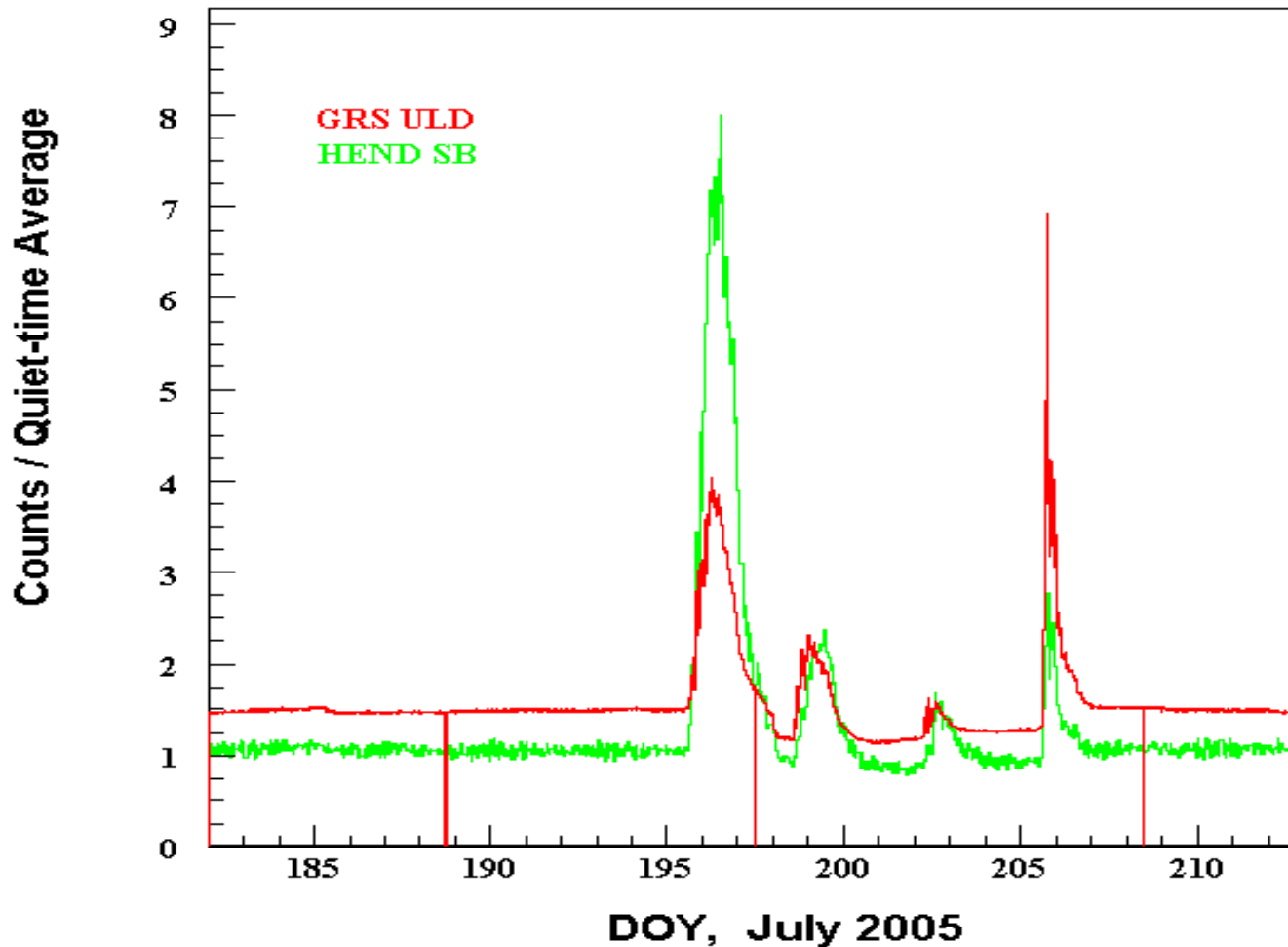
- Zoom in around 1.0, see modulation
- Both mostly follow similar trends with a few unexplained differences (e.g., times near days 600, 1200)

More Detail – 2004 & 2005

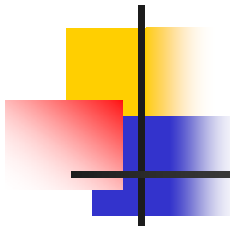


Day of Year

Cataloging SPE (Tricky)

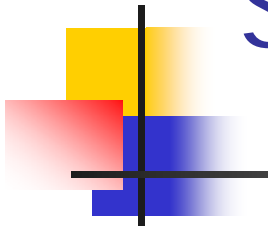


SPE's Seen by ODY incl. MARIE



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

- 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.