Statistical and Comparison study of Forbush decreases at Mars and at Earth

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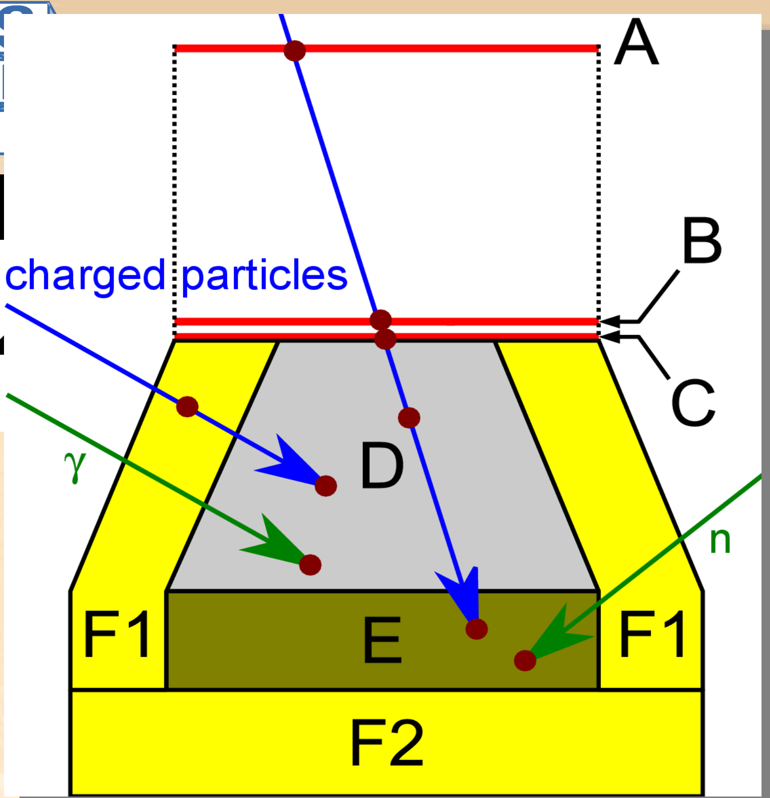
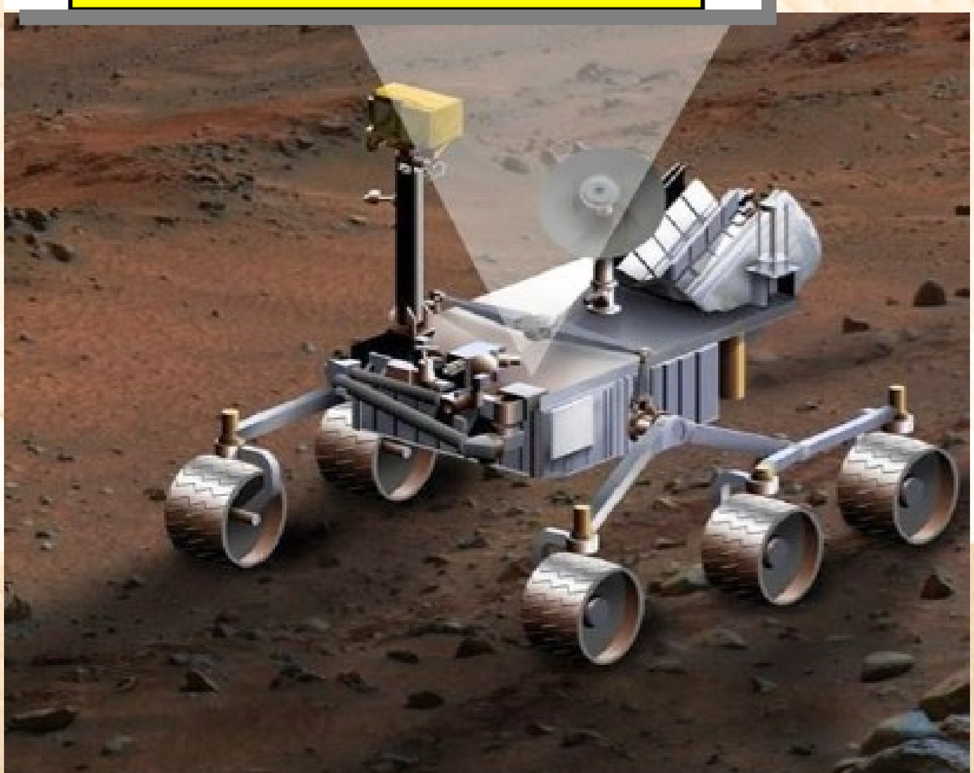
SSW, GOA, INDIA

25th Jan, 2016





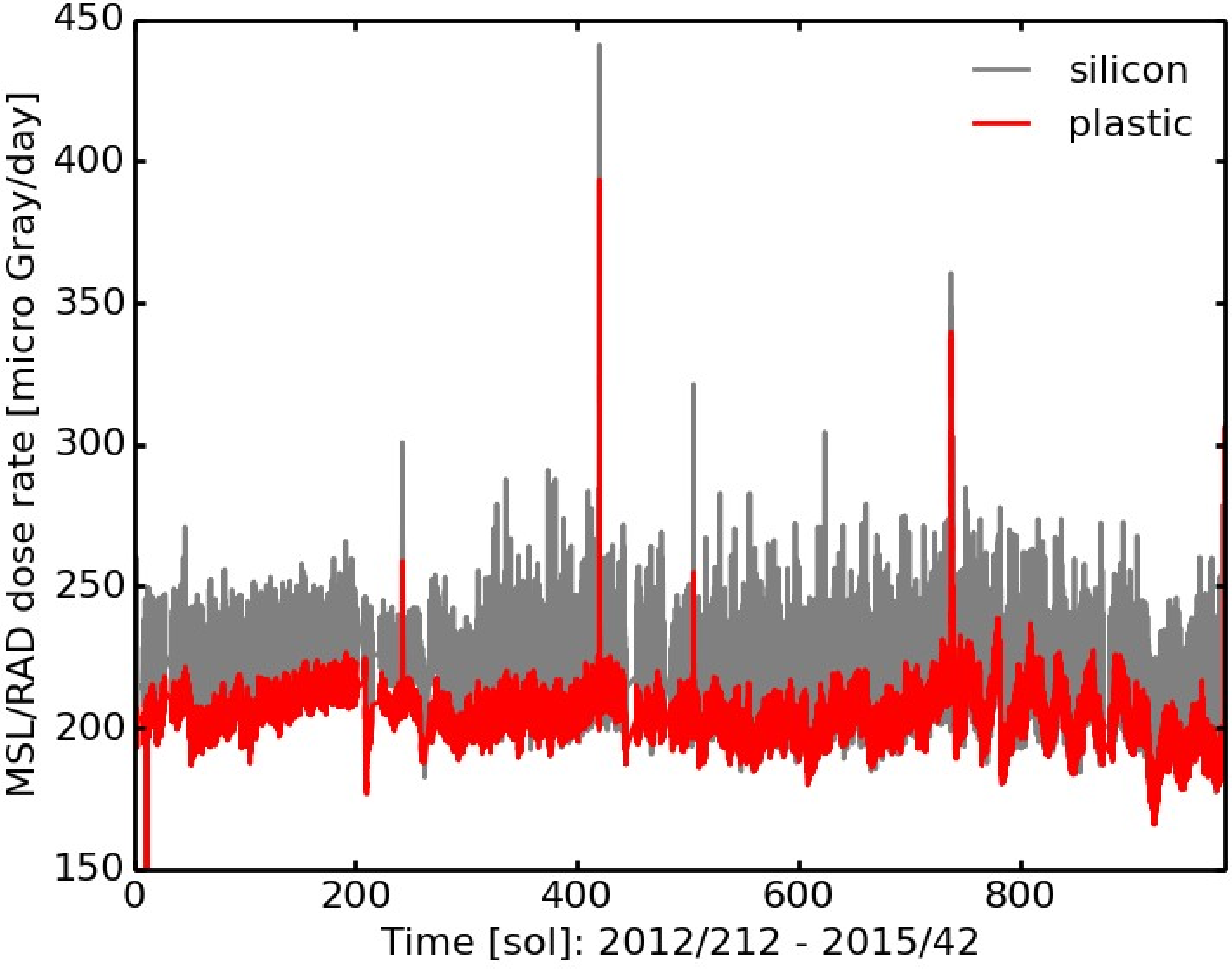
Radiation Assessment Detector (RAD) provides the first measurement of high energetic charged particle flux on the surface of another planet!

- RAD is an energetic particle detector designed to measure **galactic cosmic rays**, **solar energetic particles**, **secondary neutrons**, and other secondary particles.
- RAD contains six detectors, three of which (**A, B, and C**) are **silicon diodes** (each 300 micro meter thick) arranged as a telescope.
- The other three (**D, E, and F**) are **scintillators**.
  - **D**: 2.8 cm thick CSI, **gamma-ray** detection.
  - **E**: 1.8 cm thick hydrogen-rich plastic, efficient for **neutrons**
  - **F**: 1.2 cm thick plastic; **anti-coincidence**,
- Dose rates are measured in both silicon and plastic detectors.

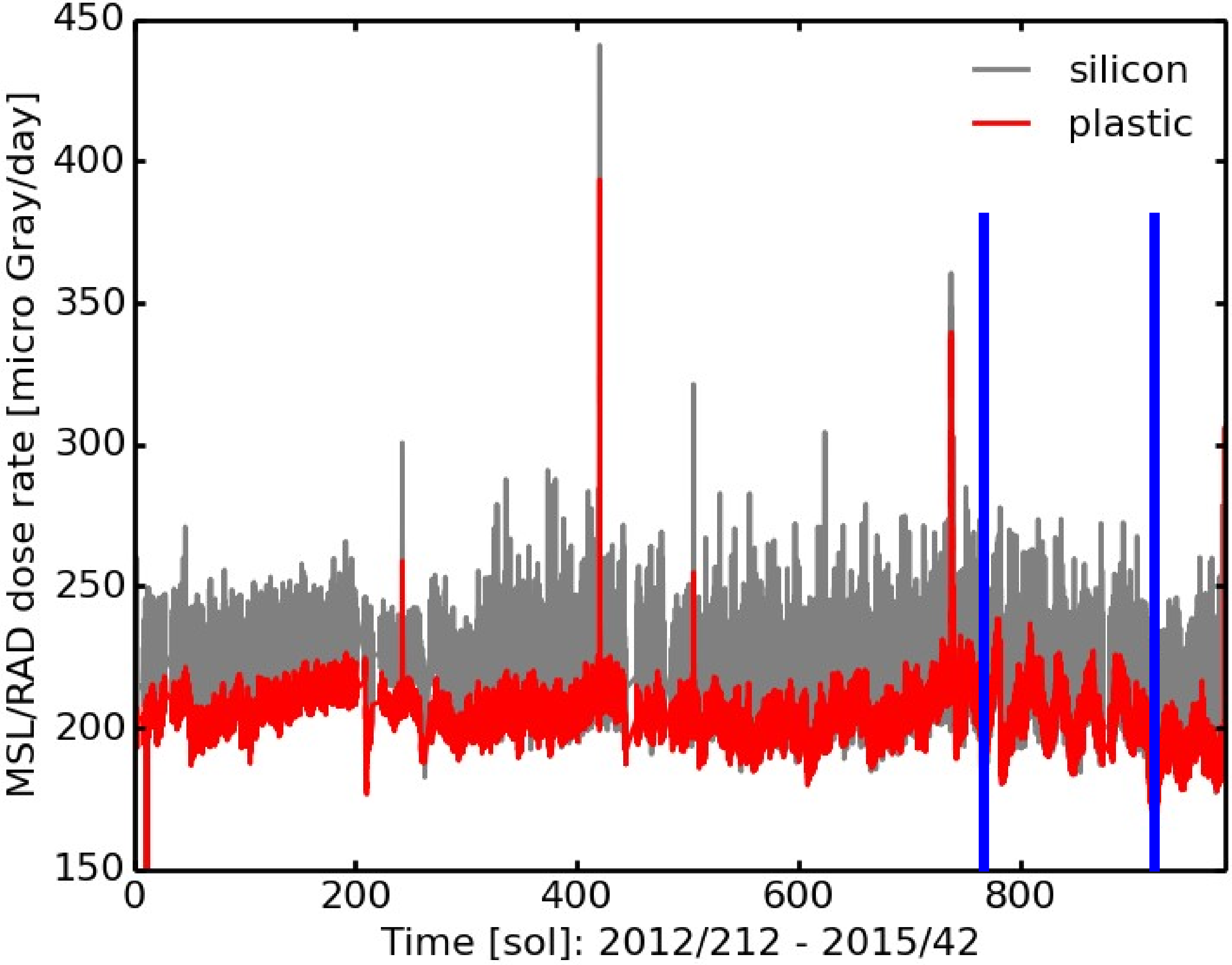
Motivation

- MSL/RAD has been sending back a wealth of data from the MSL landing since Aug 2012.
- We have seen the long-term variations caused by Martian atmospheric pressure changes and solar modulations (Guo et al 2015).
- However there remains frequent short-term variations that can be attributed to interplanetary disturbances like CIRs or ICMEs.
- We carry out a statistical study of events at Mars and compare the results with those from Earth.

1000 Martian days of RAD data: Only 4 SEPs observed

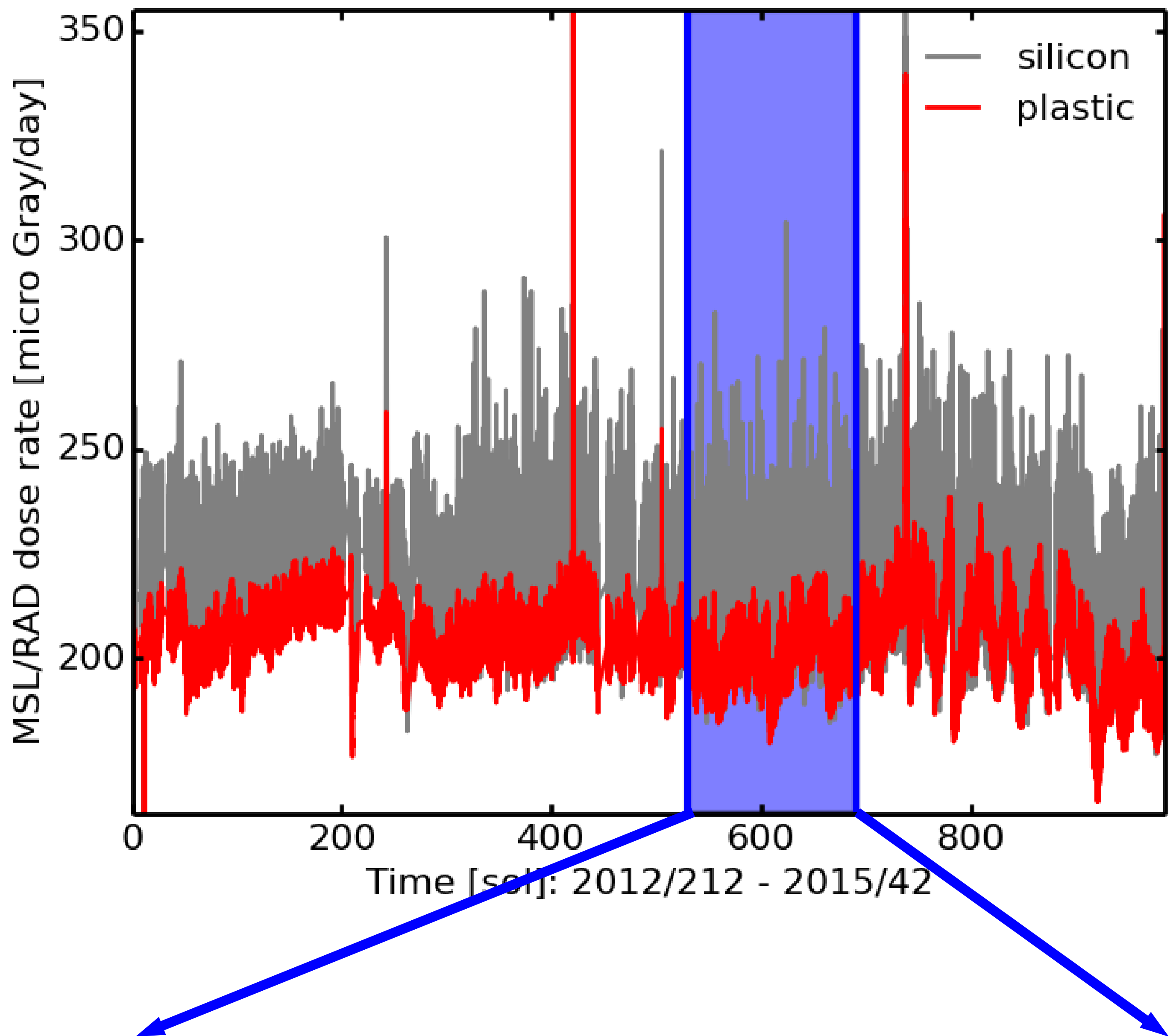


1000 Martian days of RAD data: ~100 sols (4 solar rotations) of CIRs

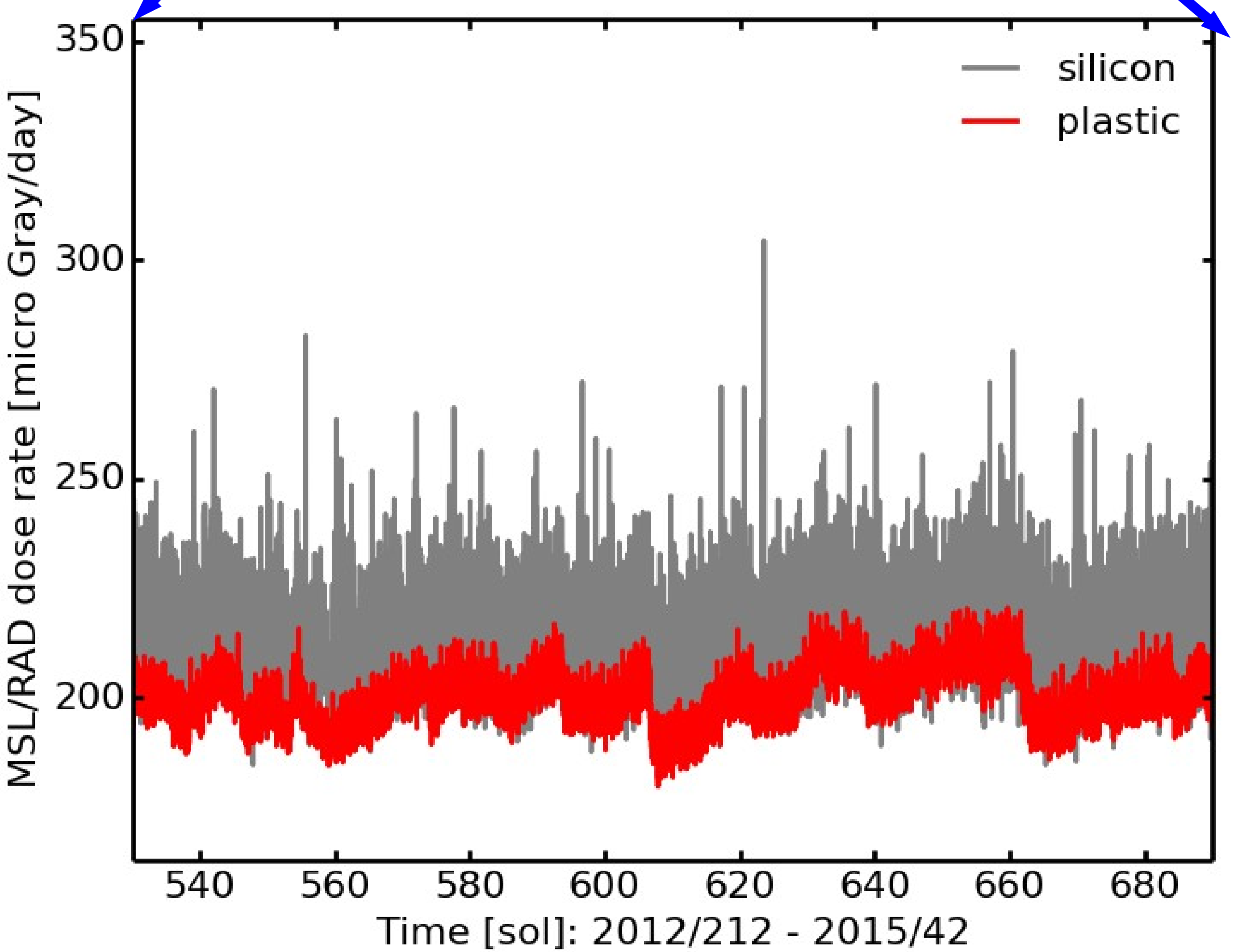


See Lohf poster

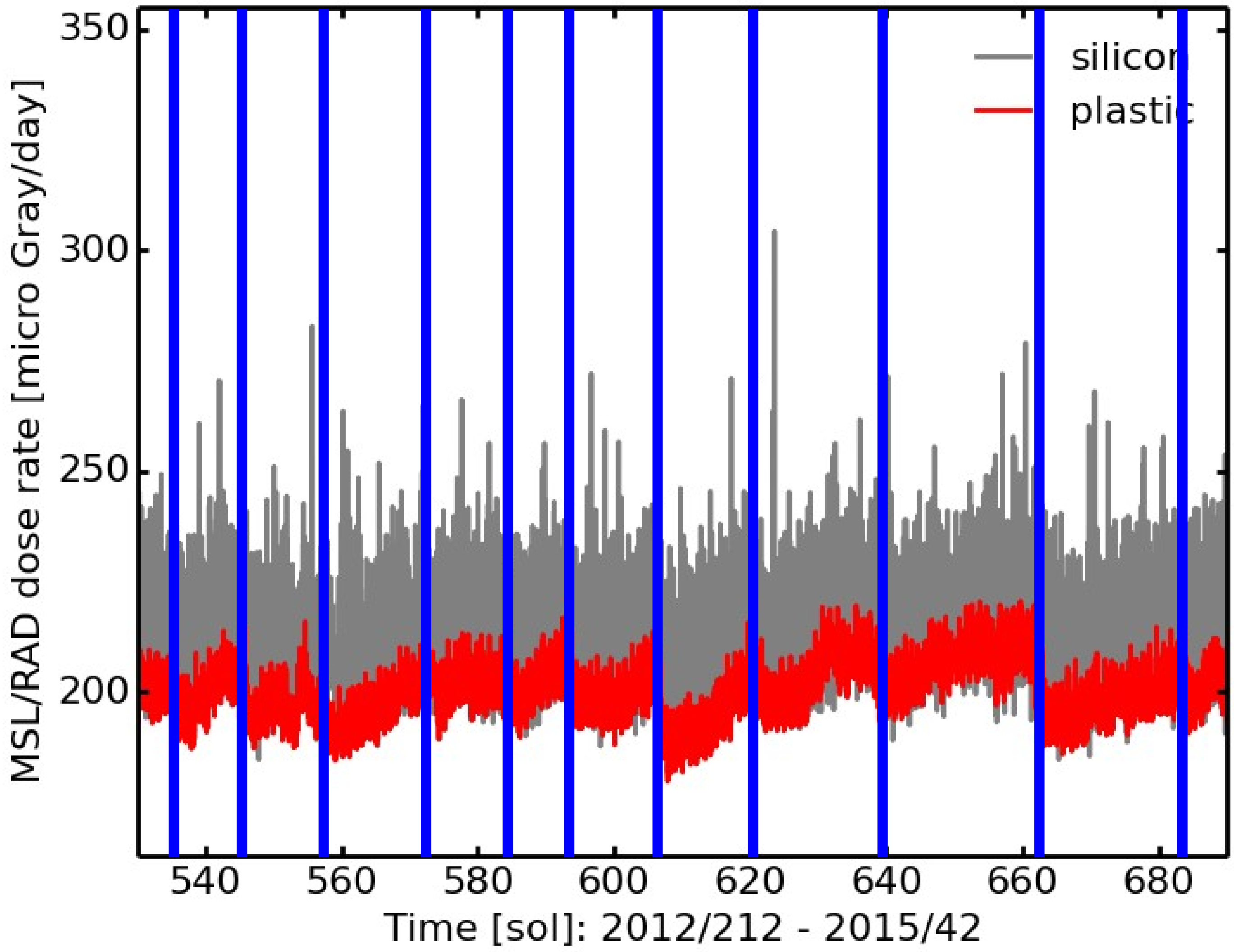
Let's just zoom in to a random period

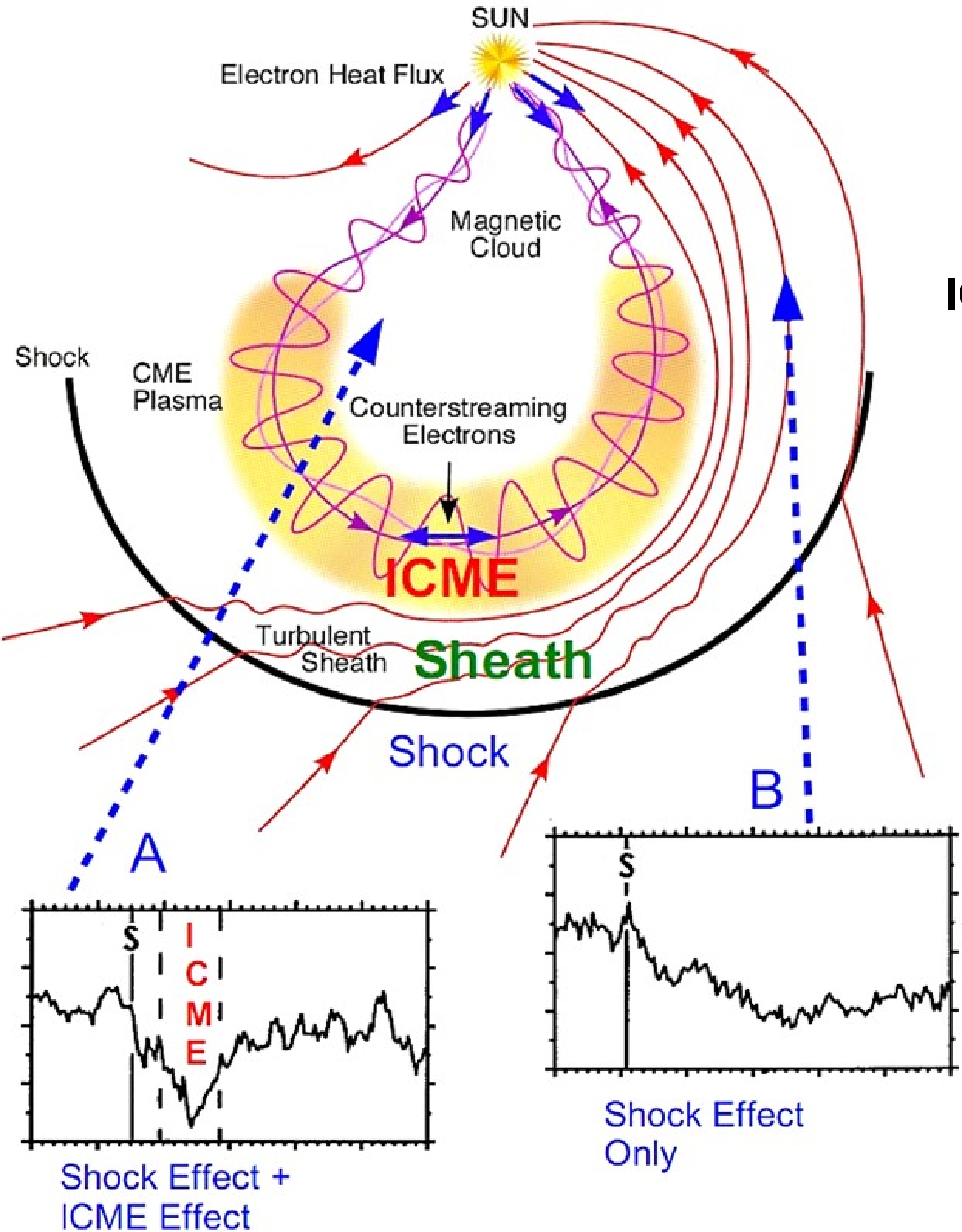


The GCR dose rate is varying all the time



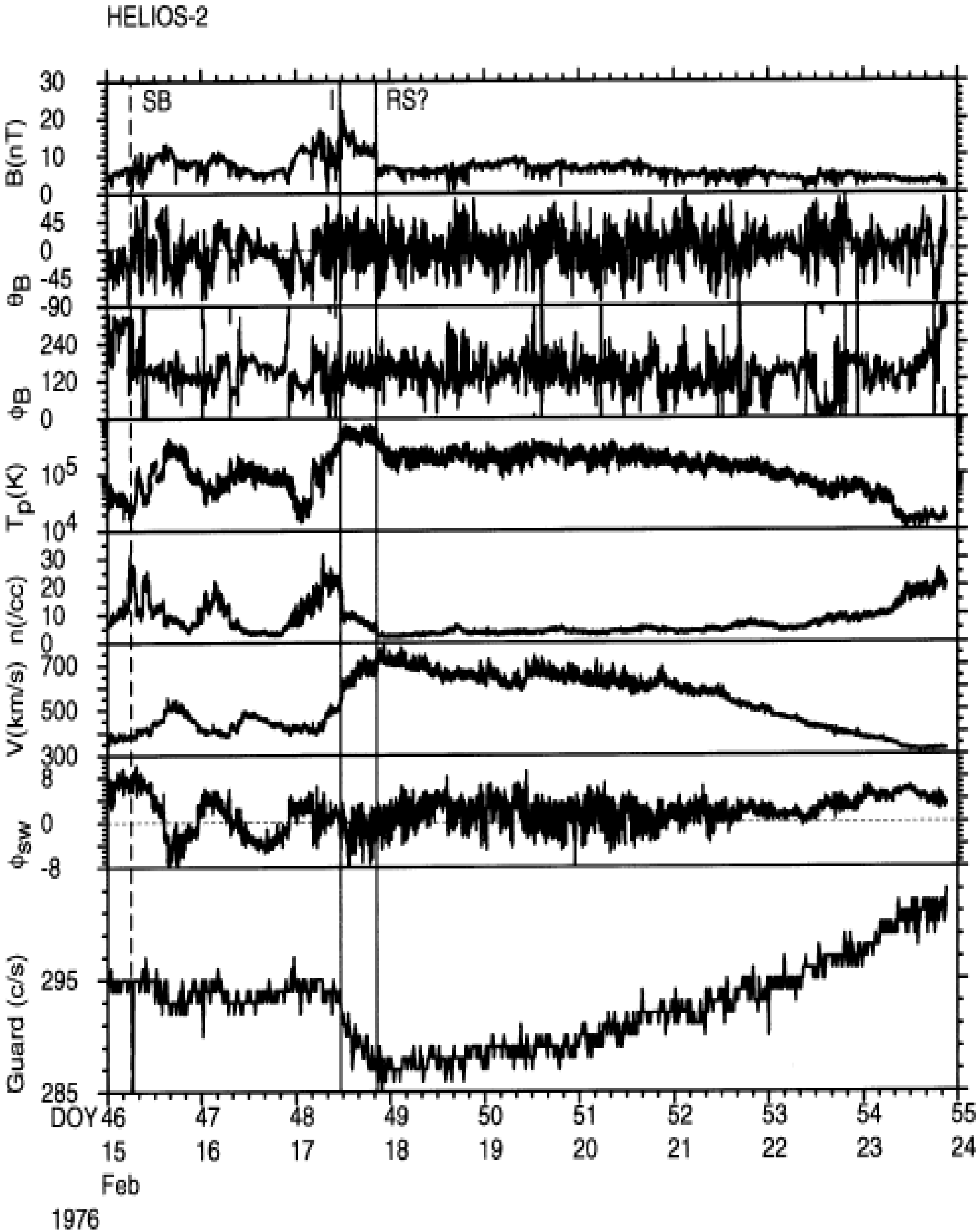
Many Forbush decreases





ICME related Forbush decreases

Associated variations in the GCR-intensity along trajectories that do (A) or do not (B) encounter the ICME (from Richardson and Cane, 2011)

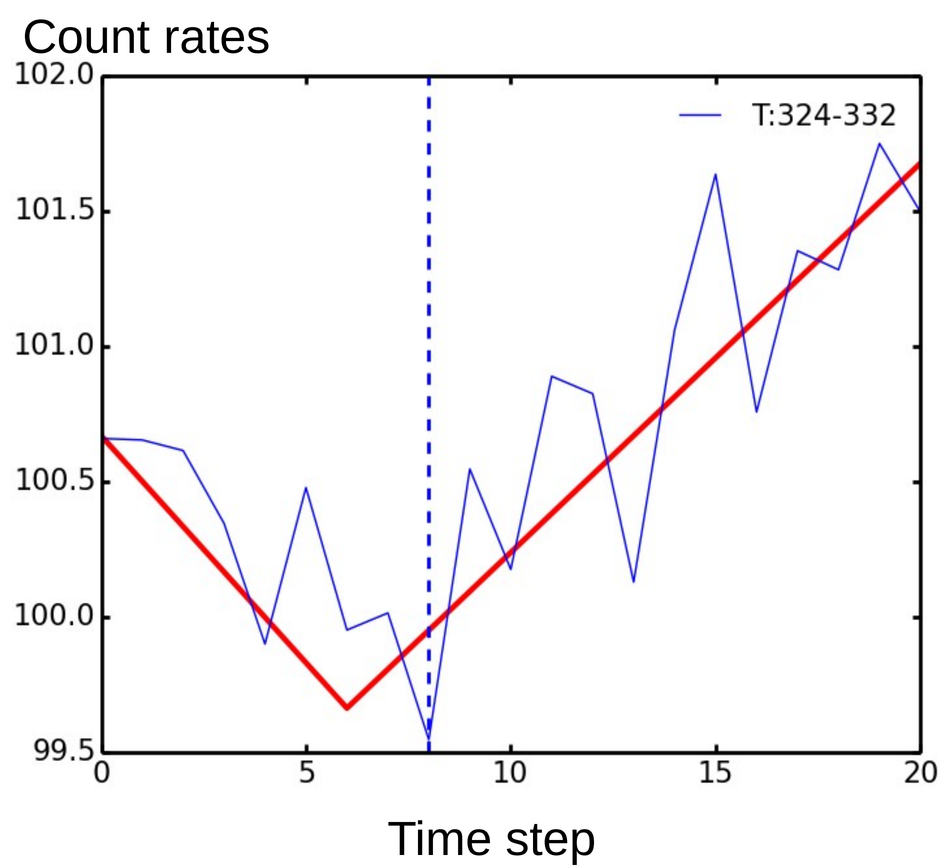


CIR related Forbush decreases

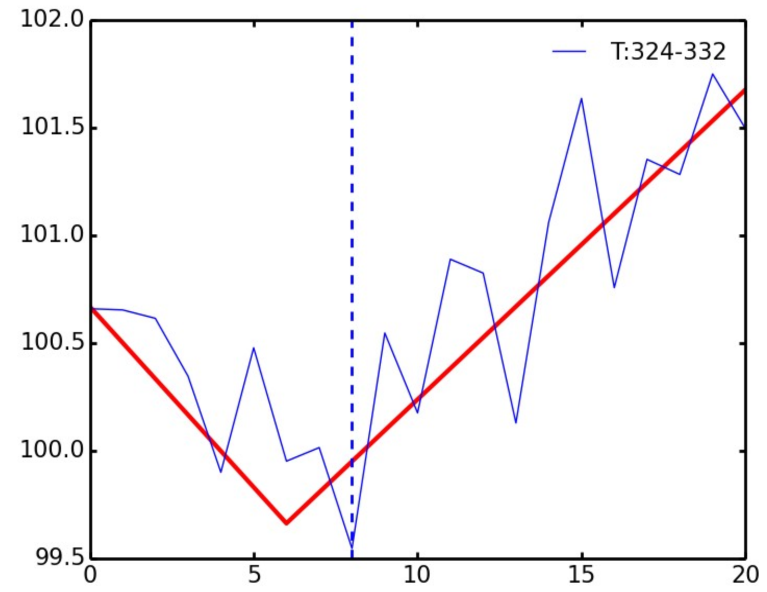
CIR associated variations in plasma and magnetic field and the GCR-intensity encountering a CIR (from Richardson 2004)

Automatic Detection of FDs in data

- 1, **Generate a Standard pattern** for a FD (**SFD**): by simply assuming a combination of two linear lines (first drop and then recovery). 3 parameters are considered during this process:
  - The total duration can change between **1 and 20 sols (p1)**.
  - The drop duration is between the highest resolution of the data (e.g., 0.25 sol for SOPO) and 1/2 **(p2)** of the total duration., i.e., the drop duration is shorter than the recovery duration.
  - The recovery ratio **(p3)** can be 1, 2, or 0.5
- 2, Use the **SFD** to go tl
  - have a correlation coeff
  - And the **depth ratio** ((l
  - The **first** point of the se ıer than its previous point
  - For such a candidate FI
  -
- 3, Repeat step1 to buil each SFD running through the whole data **ata set where more than 1/3 (p6) of the pc** selected where sub- small FDs have presen
- Overall, there are 6 adj ry among different data types.
- (*) This requirement of small drops can be well correlated with SF



Automatic Detection



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  - The total duration can change between **1 and 20 sols (p1).**
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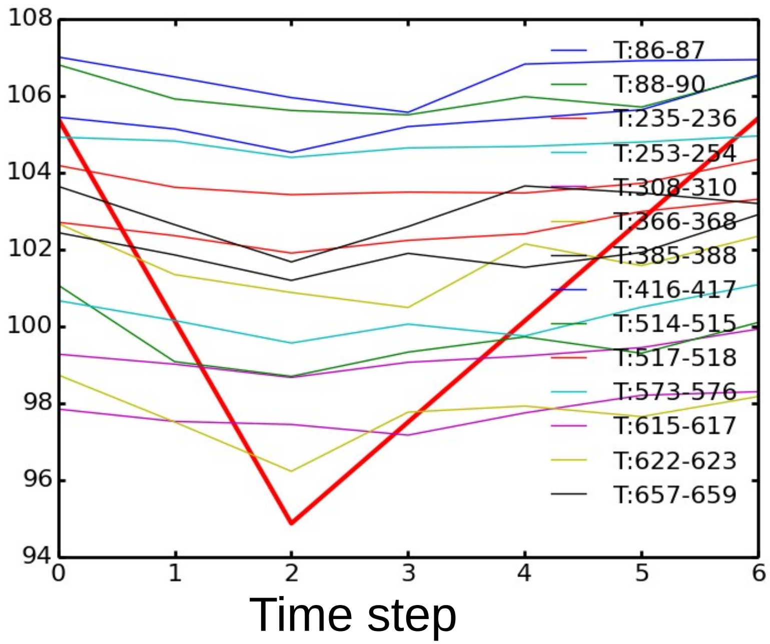
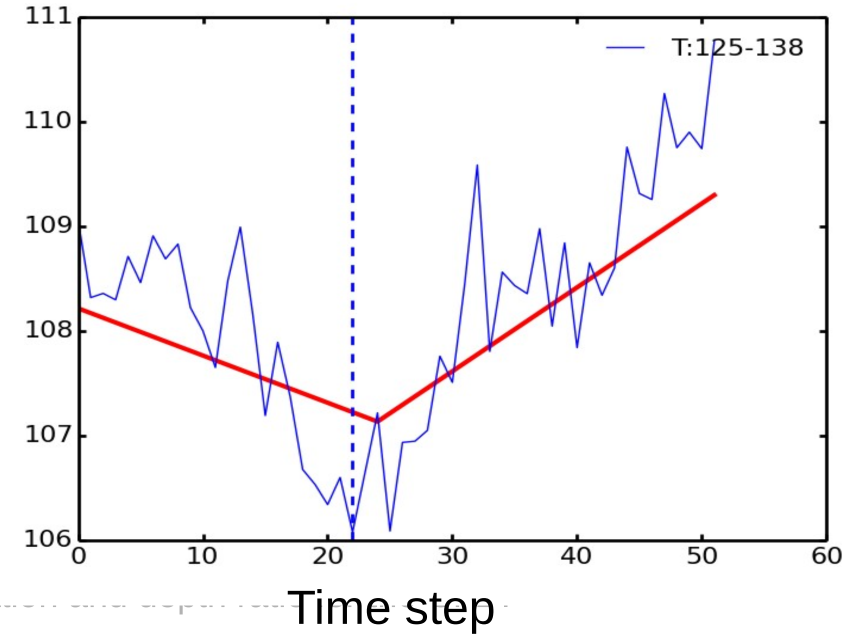
  - The recovery ratio **(p3)** can be 1, 2, or 0.5
- 2, **Use the SFD to go through the whole data sets and find a set of the data which**
  - **has a correlation coefficient with SFD of R > 0.85 (p4)**
  - **And the depth ratio ((beg-min)/beg) larger than 0.01 (p5)(*).**
  - **The first point of the selected set is the highest point during the drop duration and it is higher than its previous point**
  - For such a candidate FD (CFD), Mark down the time, duration and depth ratio for the CFD.
- 3, Repeat step1 to build SFD with different durations and drop durations; Correlate each SFD running through the whole data set and find more CFDs. Meantime, **avoiding selecting data set where more than 1/3 (p6) of the points have been registered as CFDs:** still allow a bigger FD selected where sub-small FDs have presented.
- Overall, there are 6 adjustable parameters and they are empirically defined and vary among different data types.
- (*) This requirement of min depth ratio is necessary; otherwise data with very very small drops can be well correlated with SFD as well.

Automatic Detection of FDs in data





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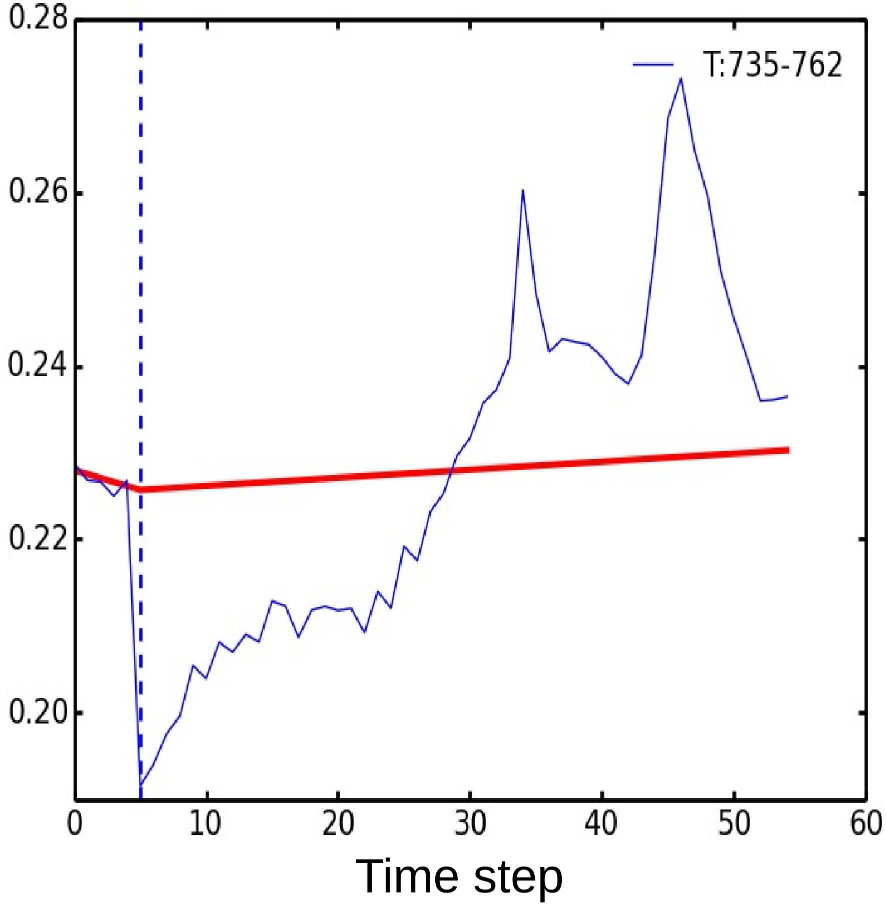
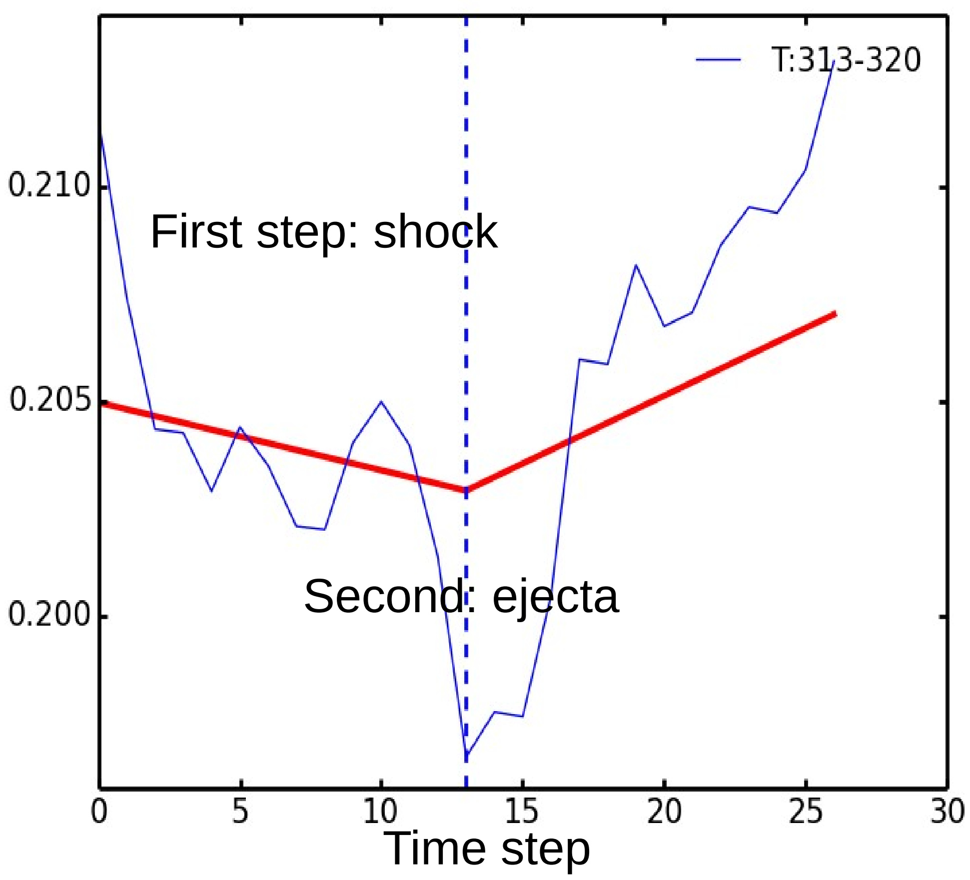
Two examples (EPHIN/SOHO at Earth, L1)

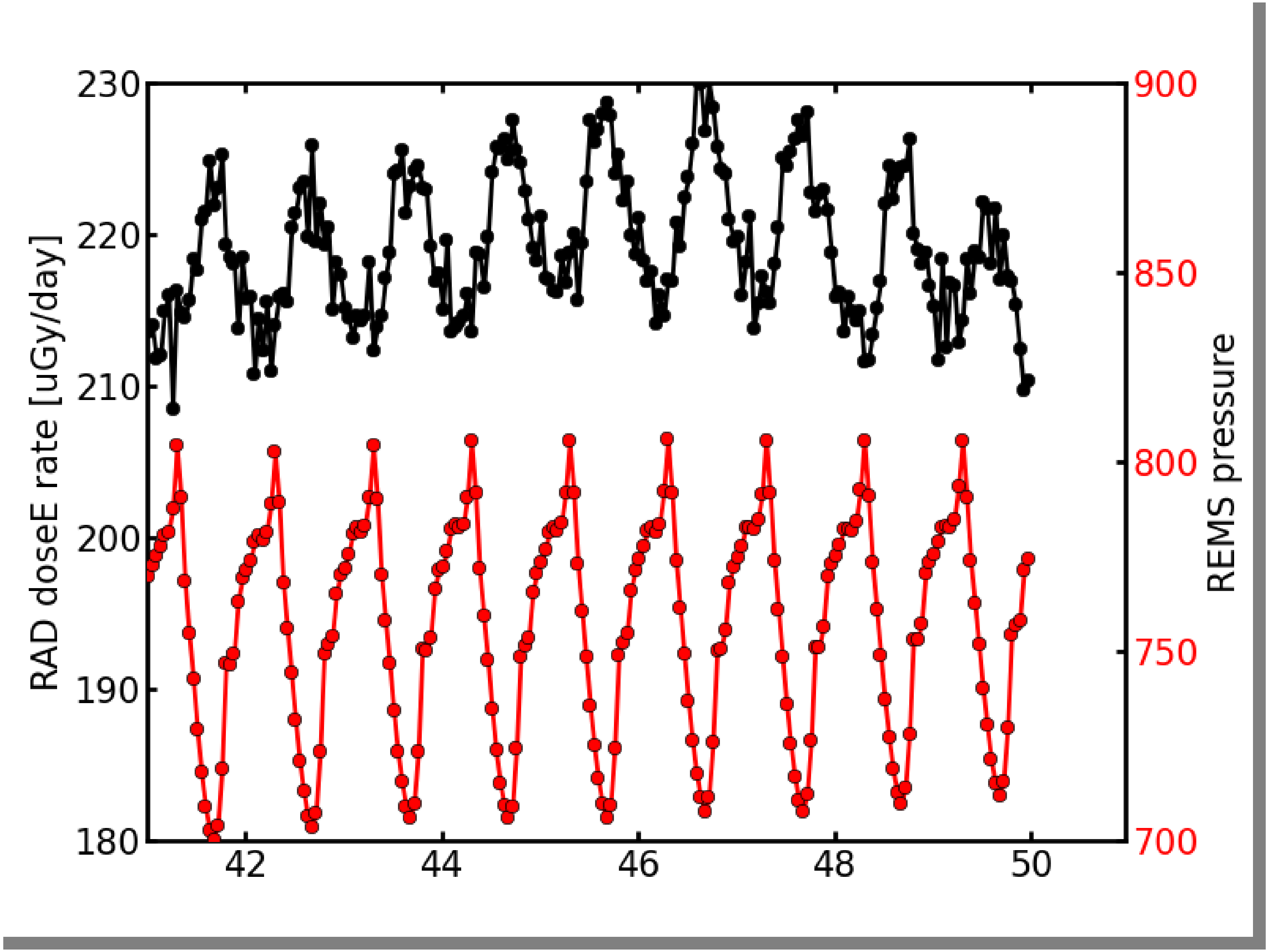
Fast drop



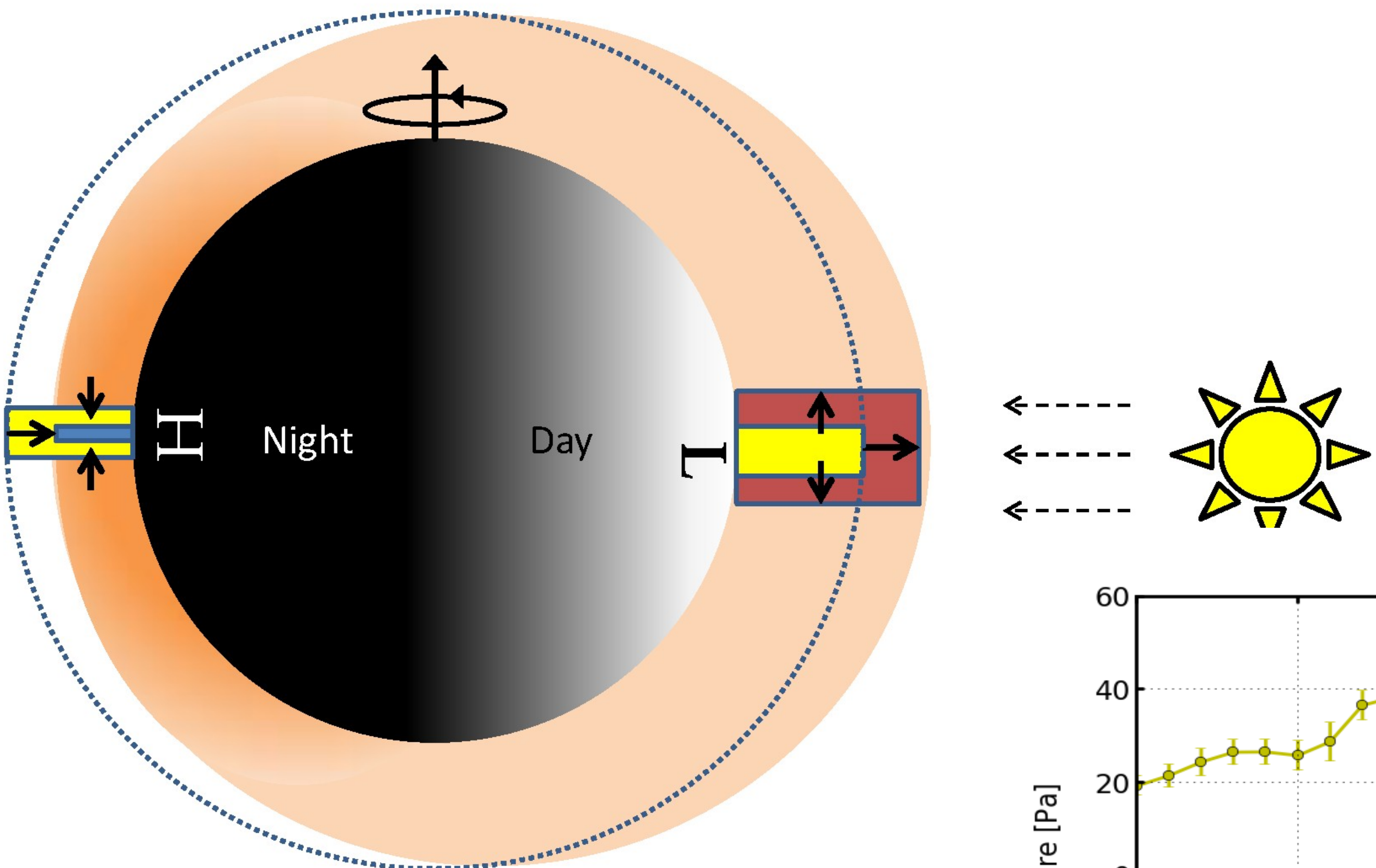
Two-step drop

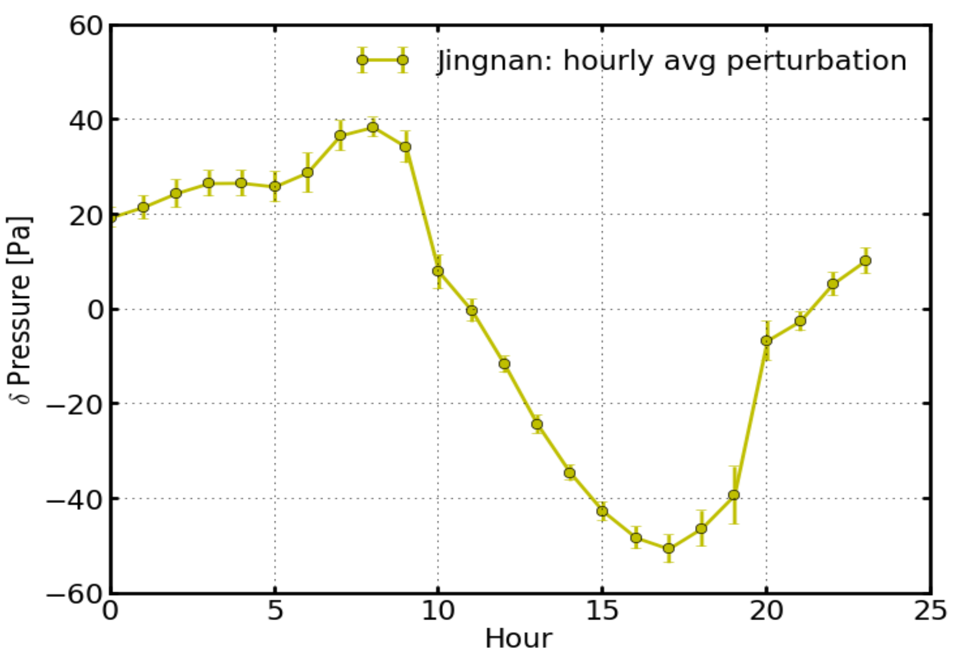


When applying the method to data from the surface of Mars...



Diurnal Variations of Pressure: Column Mass Changes Due to Thermal Tide



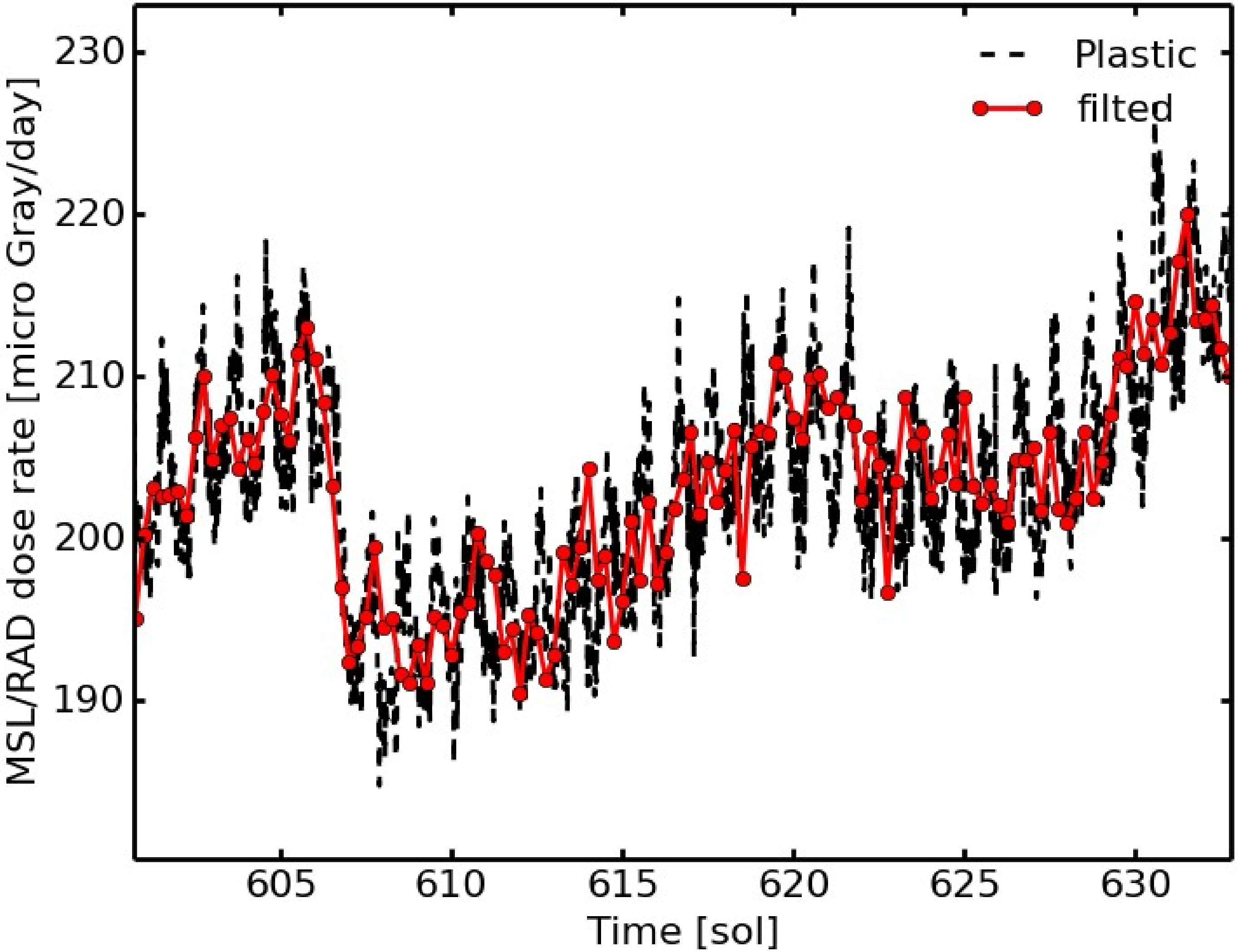


Rafkin et al. 2014

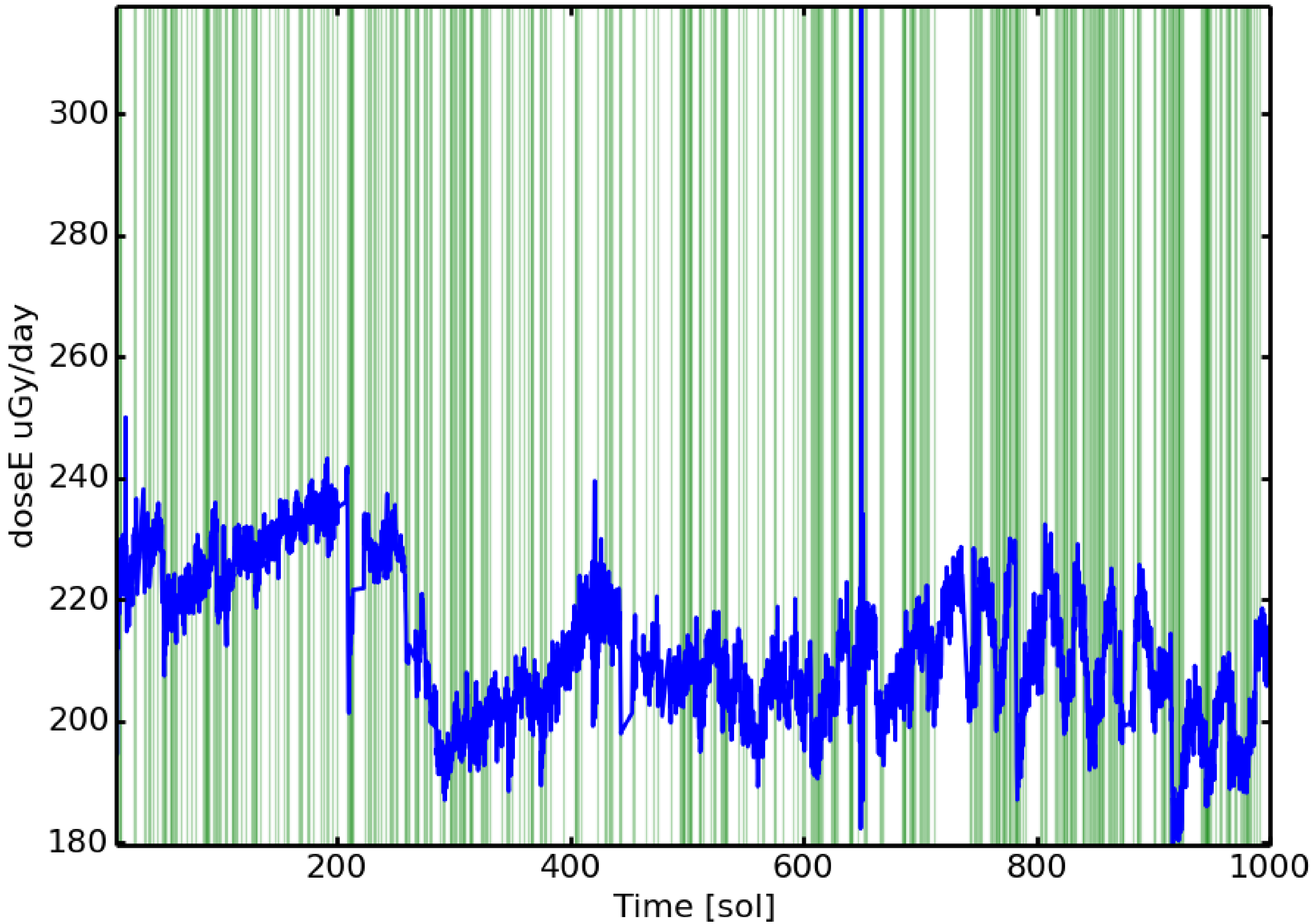
Crater circulations amplify the tide, leading to a stronger effect.

Need to filter out the diurnal signal

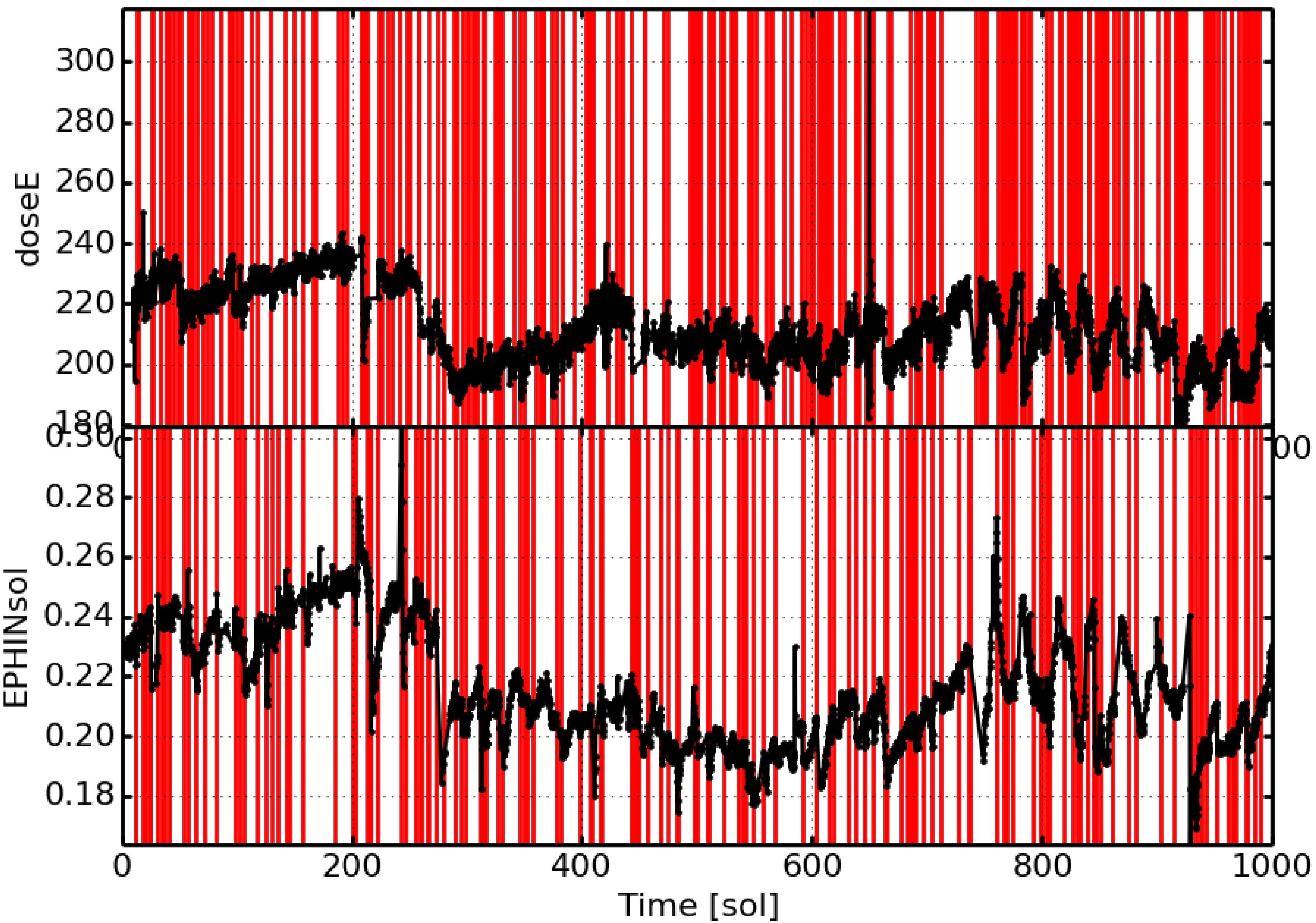
Since the frequency of the disturbance is known, a notch filter tuned to remove all the harmonics multiple of 1 sol can be used.



265 Events at Mars with drop ratio > 0.01

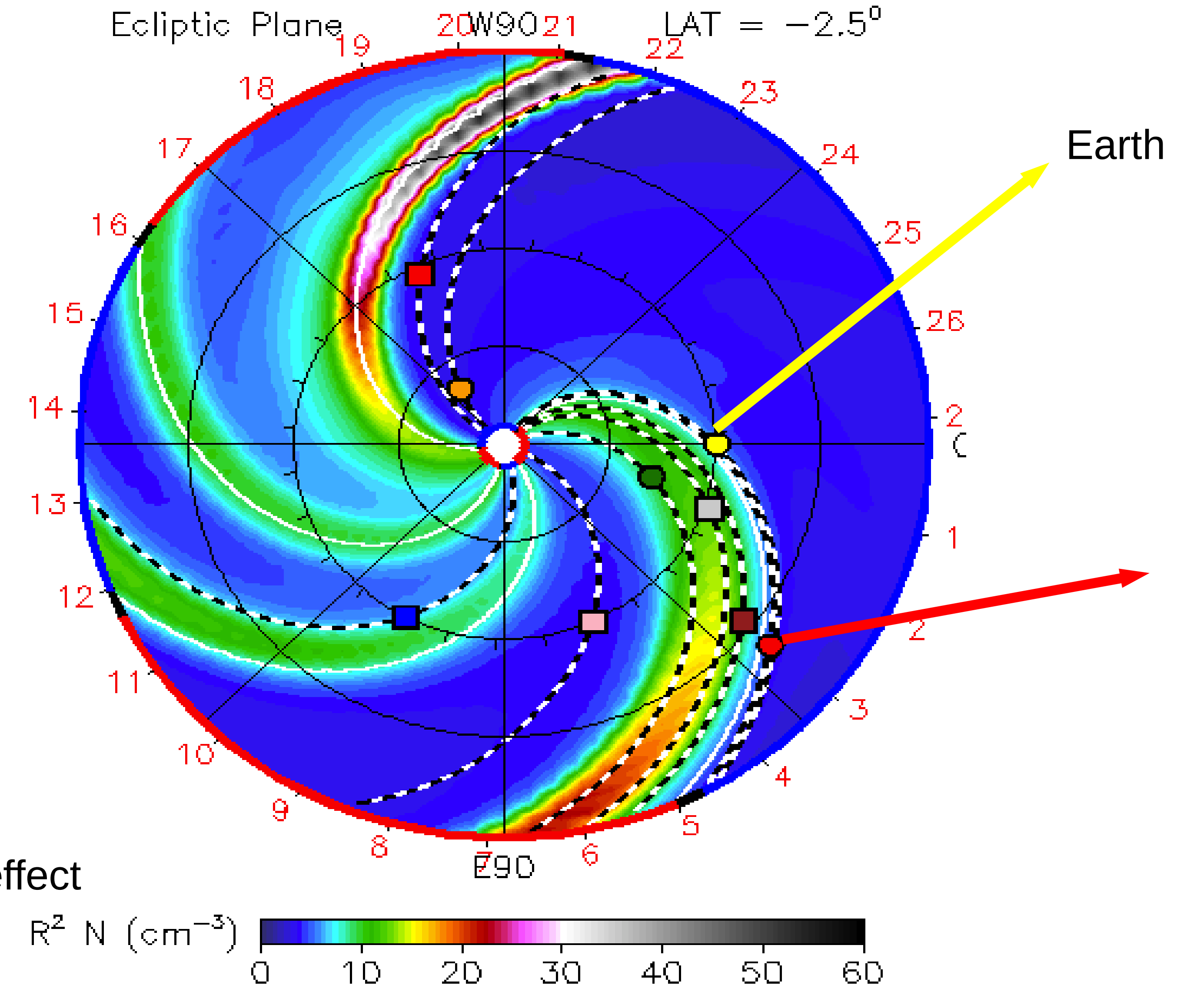


Mars (top) and Earth (bottom)
216 Events & 139 Events with drop ratio > 0.02

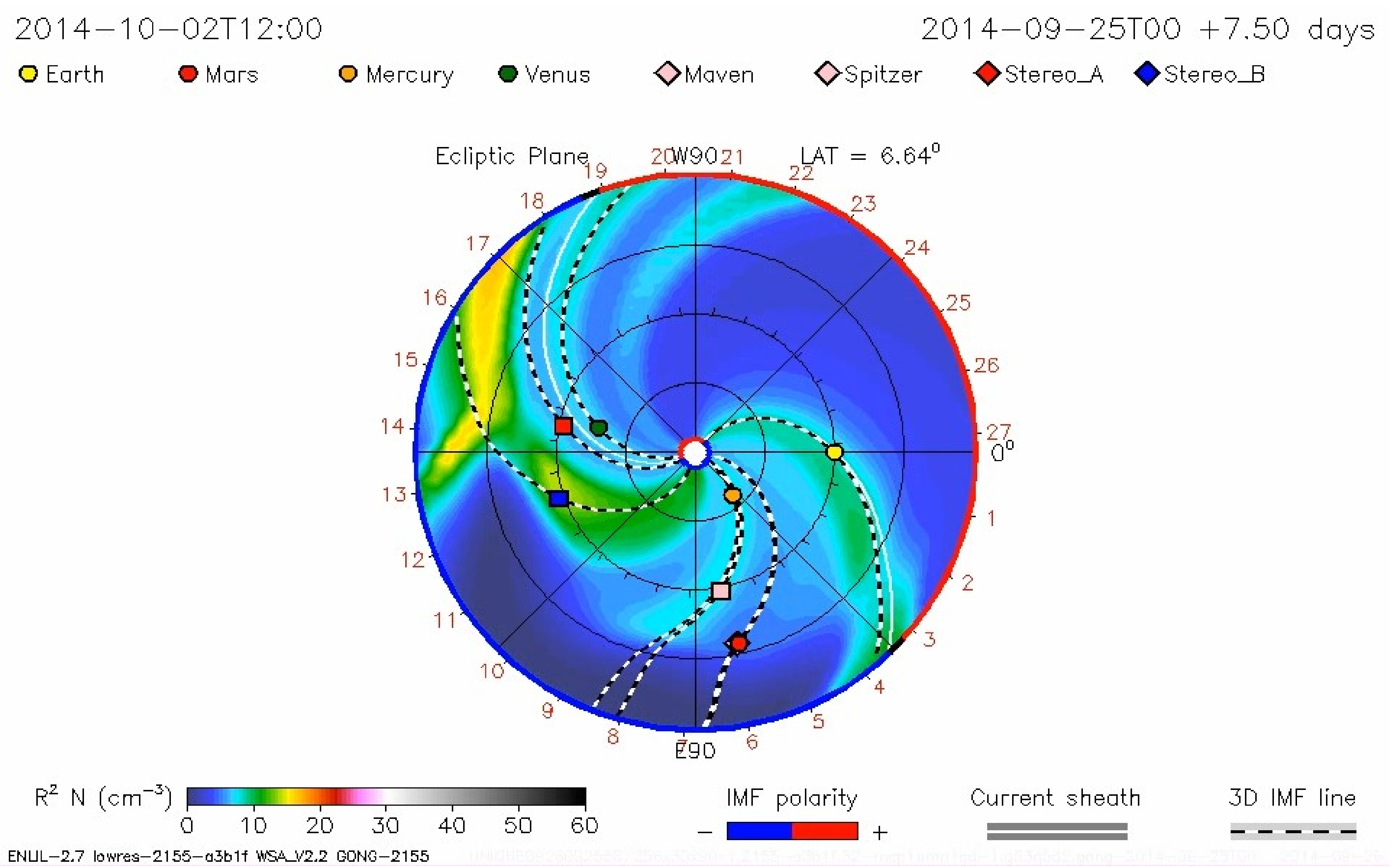


Parker spiral separation:

Most of the time, the two planets are **not** well magnetically connected...

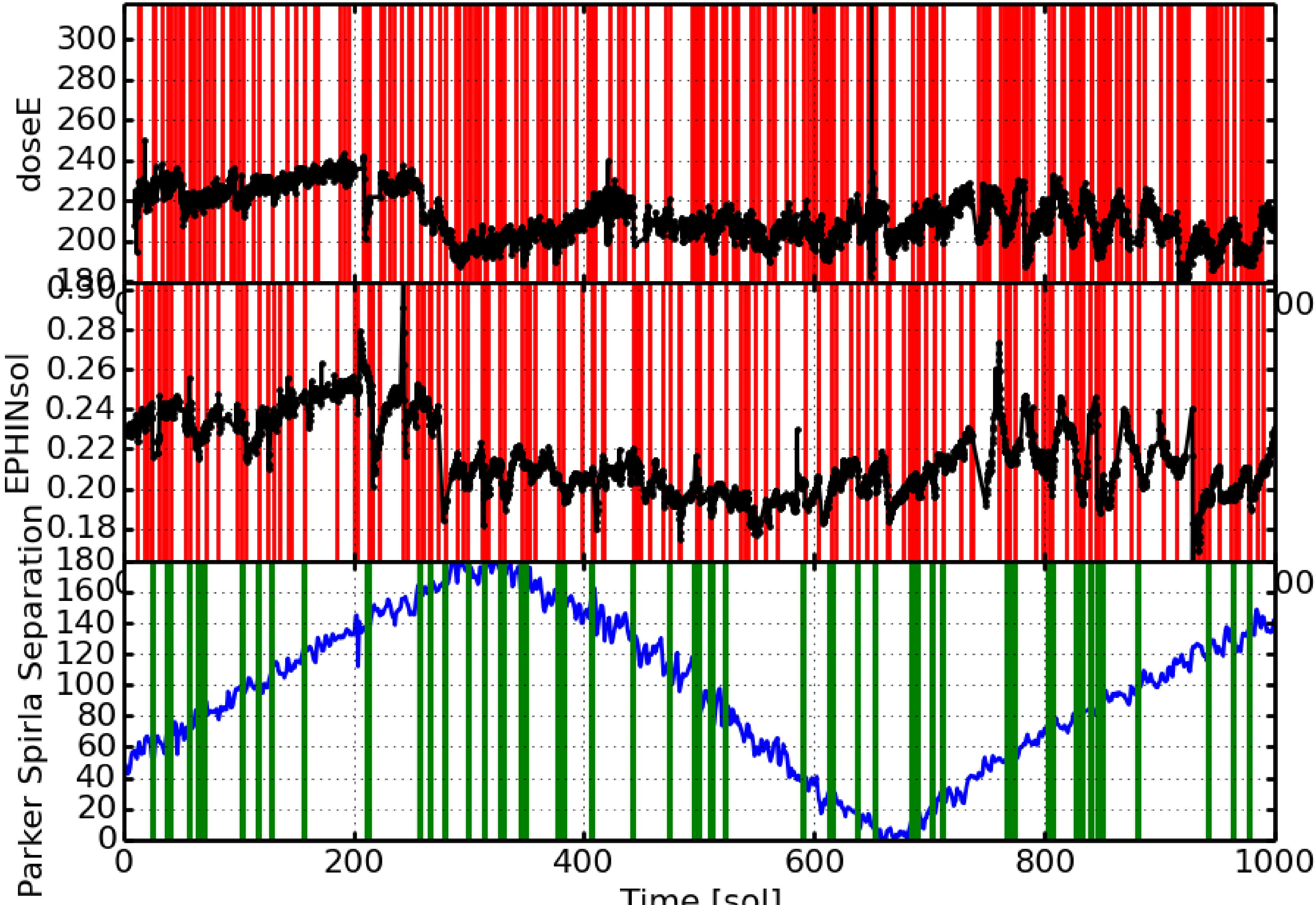


Homman-Parker effect
Posner et al 2013

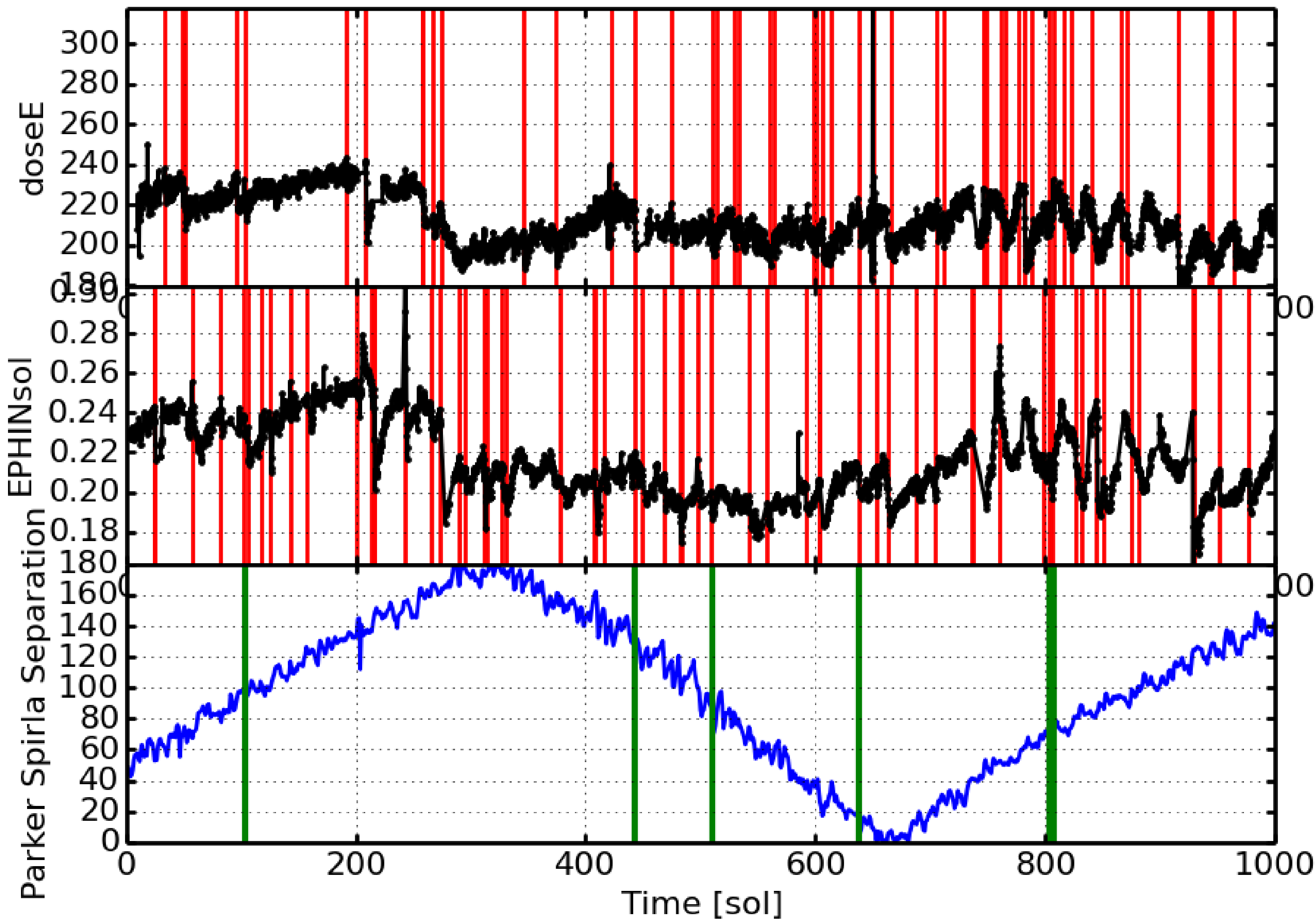


2014-10-02T12:00
2014-09-25T00 +7.50 days
Earth
Mars
Mercury
Venus
Maven
Spitzer
Stereo_A
Stereo_B
Ecliptic Plane
W90
LAT = 6.64°
E90
0°
R² N (cm⁻³)
0 10 20 30 40 50 60
IMF polarity
– +
Current sheath
3D IMF line
ENLIL-2.7 lowres-2155-a3b1f WSA_V2.2 GONG-2155

There does not seem to be more '**common events**' during good magnetic connections



49 events for Mars and 60 events for Earth with drop ratio >= 0.05



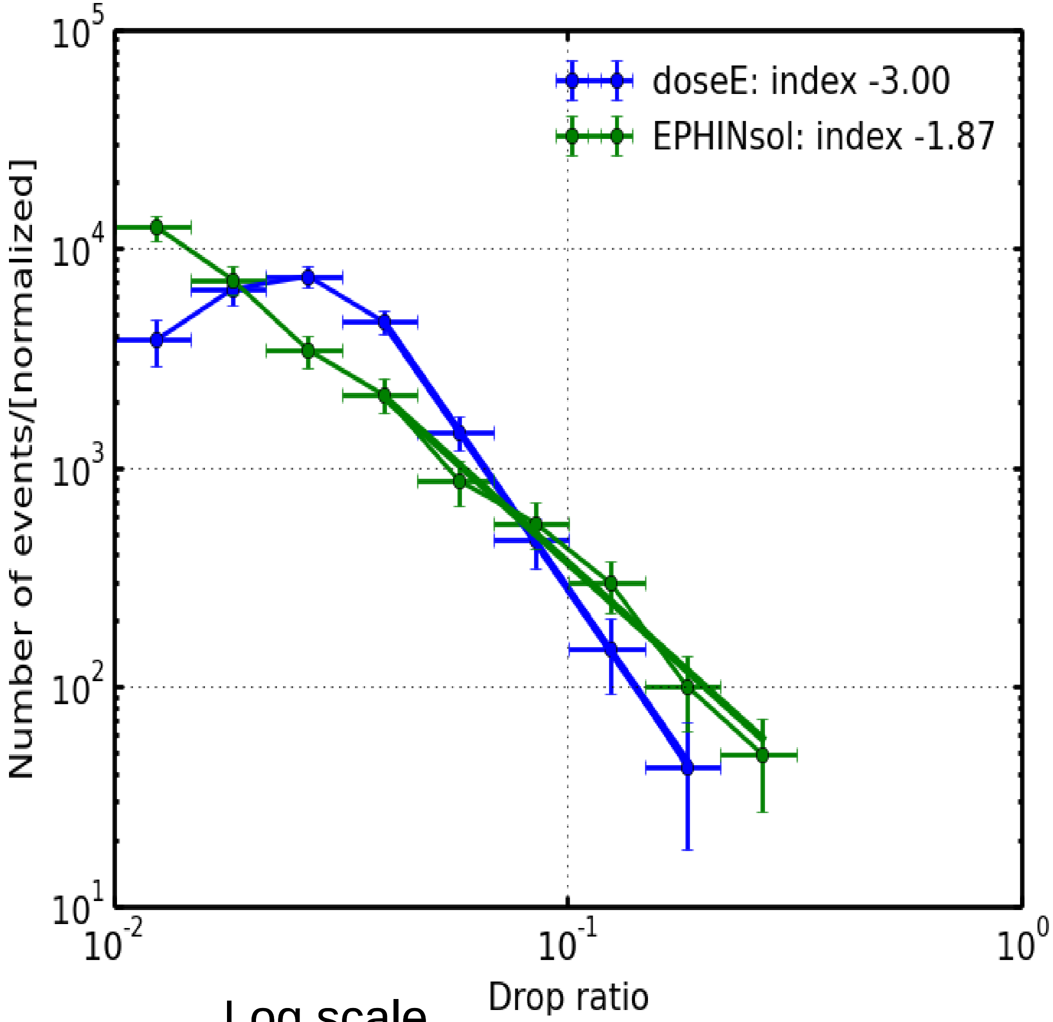
There is no obvious enhancement of 'common events' during good magnetic connections... may be because...

1, they do not coincide with the same CMEs

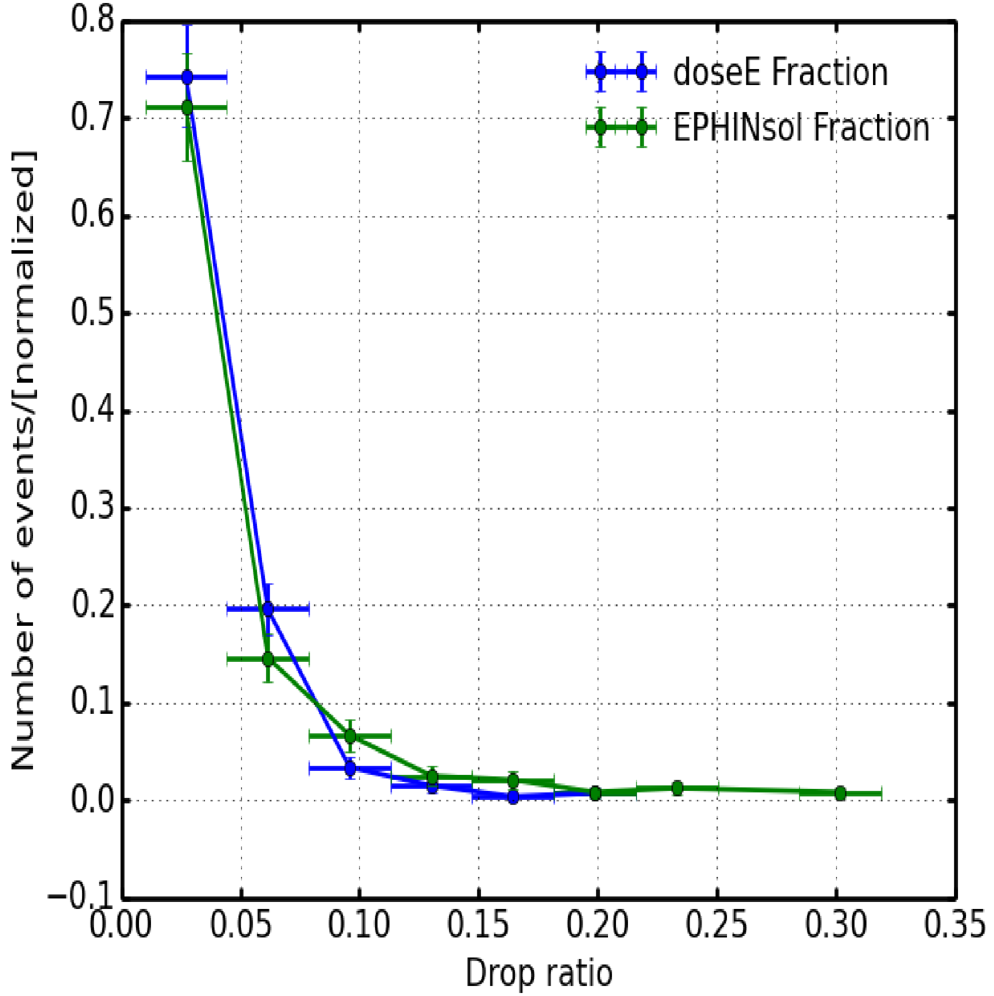
2, the time delay of a CME from Earth to Mars has to be more carefully considered

3, the GCR spectra may be altered first before being transported widely into the planetary space?

Drop Ratio: Mars and Earth

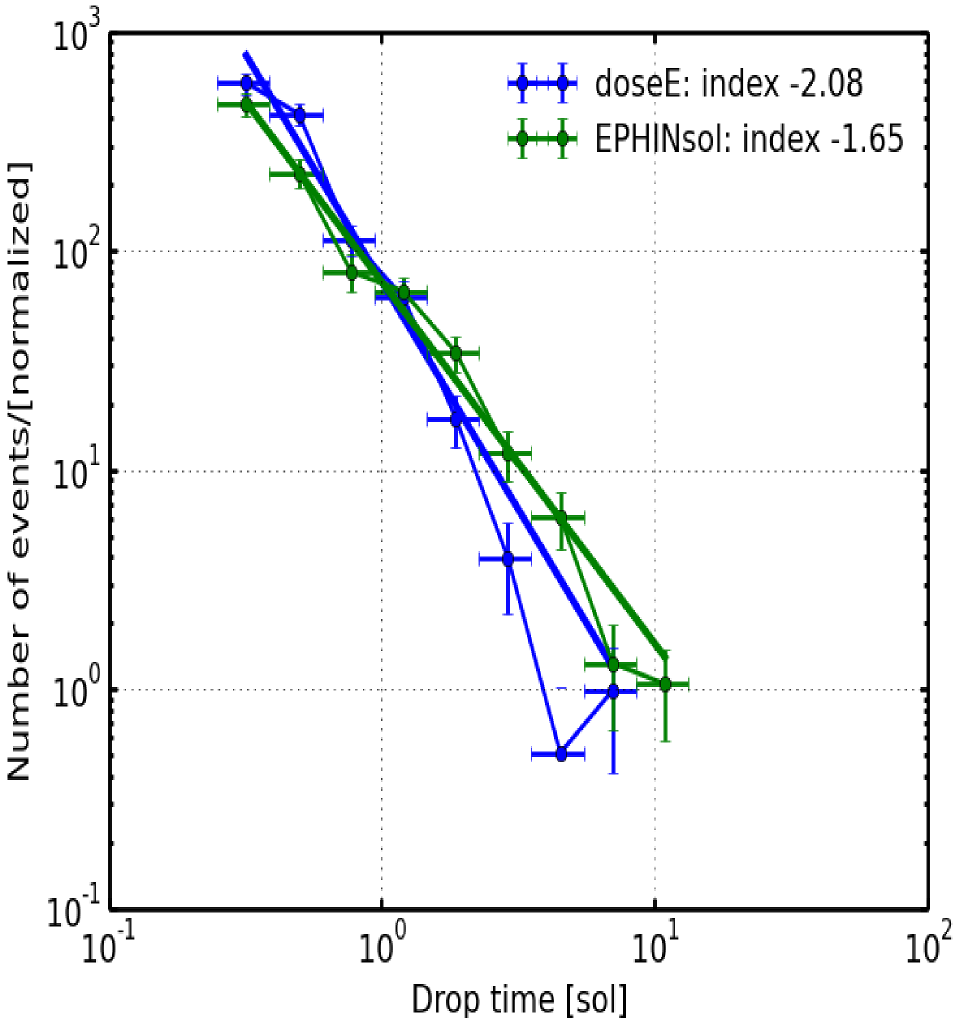


Log scale

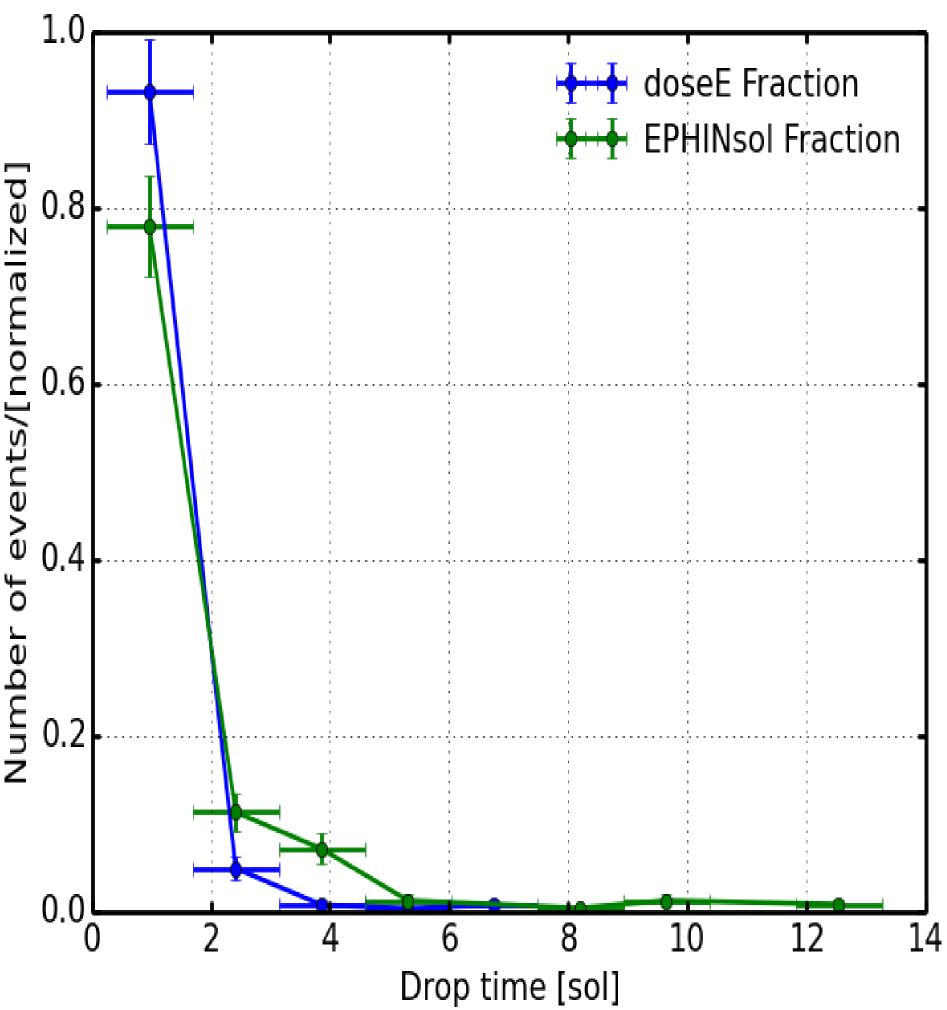


Linear scale

Drop time: Mars and Earth

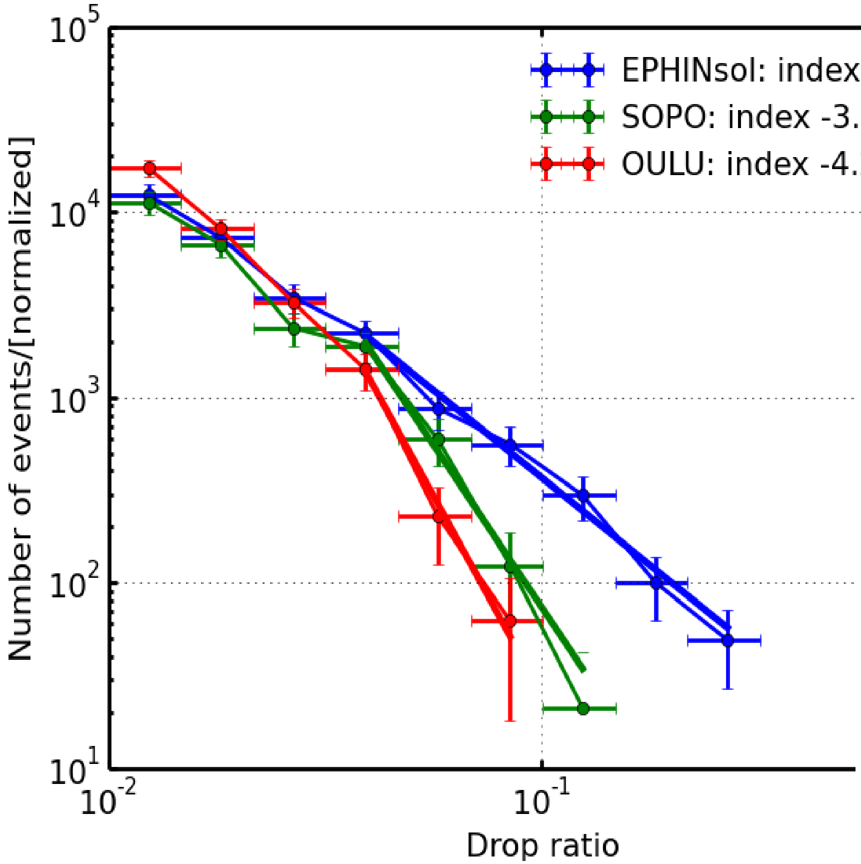


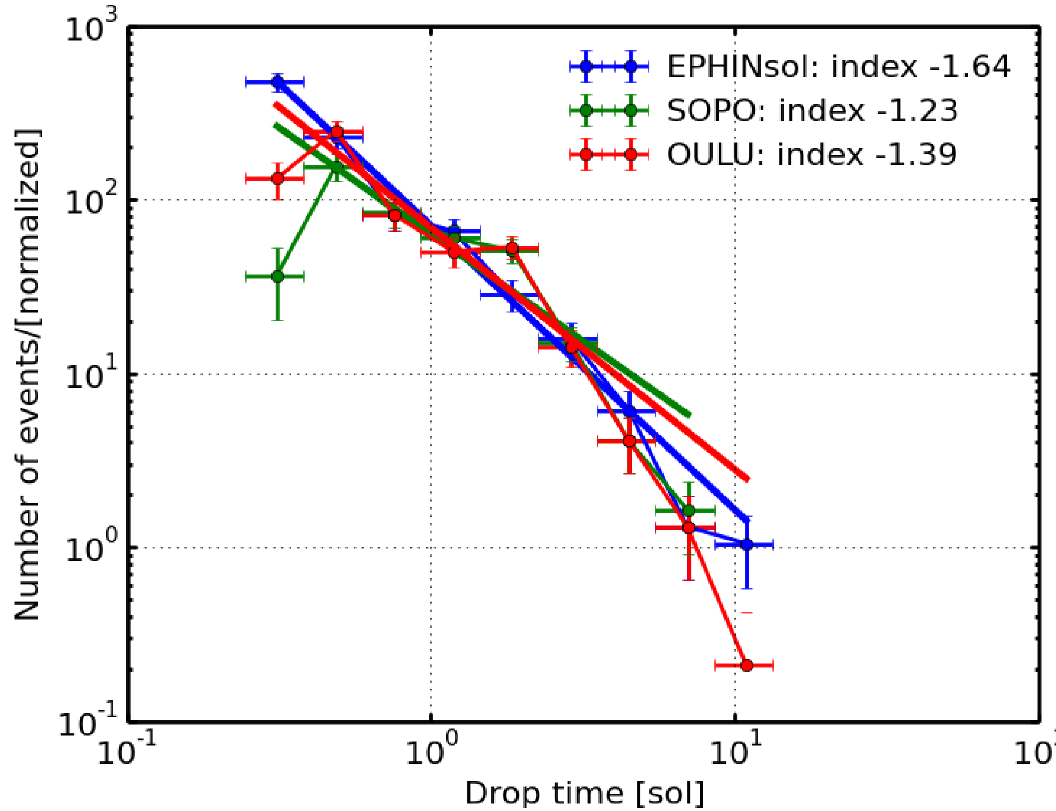
Log scale

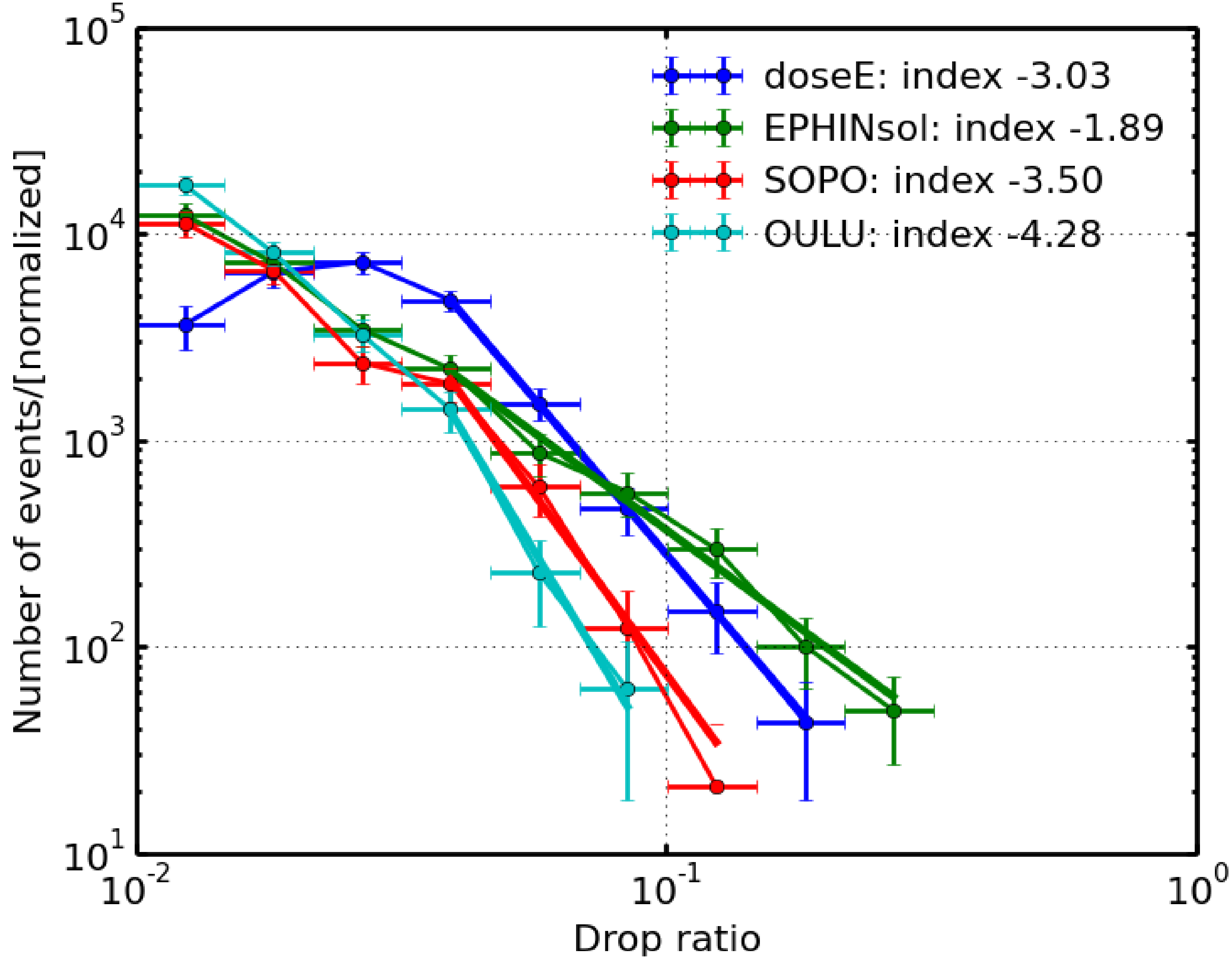


Linear scale

EPHIN compared to Neutron Monitors at Earth surface

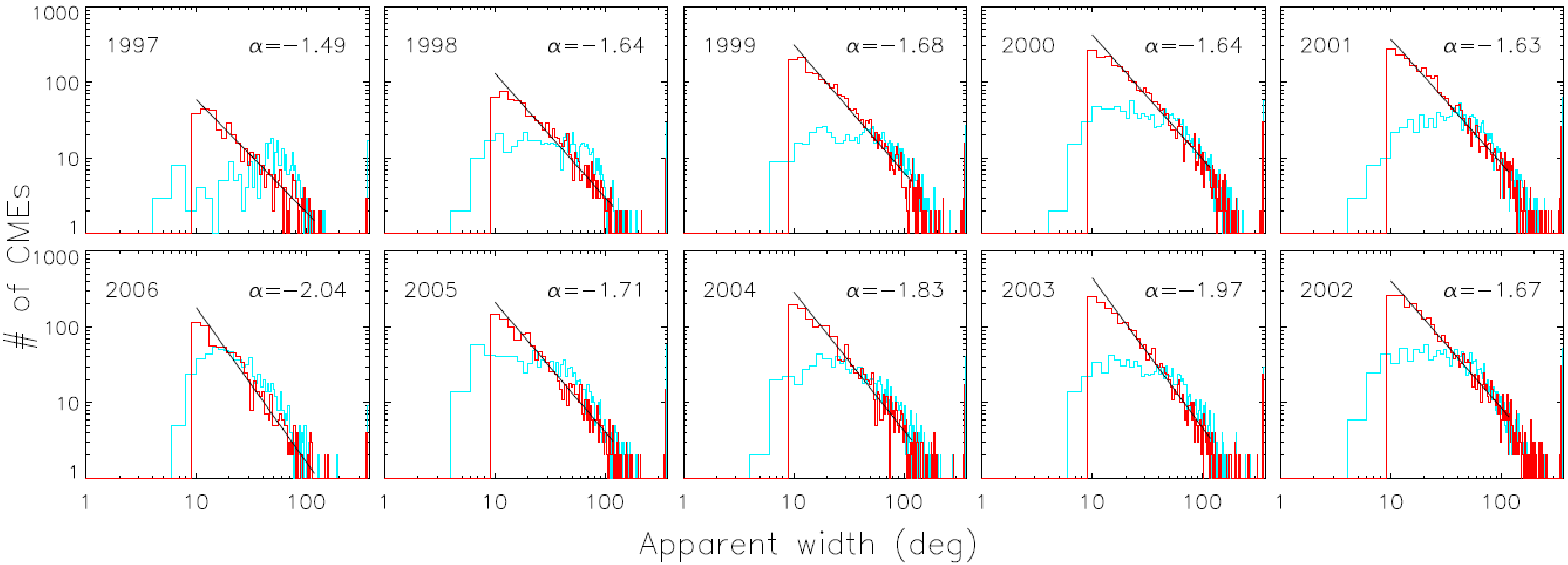






doseE: index -3.03
EPHINsol: index -1.89
SOPO: index -3.50
OULU: index -4.28
Number of events/[normalized]
Drop ratio
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{-2}
10^{-1}
10^{0}

CME widths



Robbrecht, E., Berghmans, D. and van der Linden, R.A.M., 2009a, Astrophys. J., 691, "Automated LASCO CME cata-log for solar cycle 23: Are CMEs scale invariant?"

Discussions

- The statistical study of FDs at Mars and Earth seem to show that there are more Forbush decreases (particularly the small ones) at Mars compared to at Earth, maybe due to the broadening and weakening of the CMEs as they propagate outside.
- There are however fewer big events at Mars compared to what EPHIN sees due to (1) the Martian atmospheric shielding and (2) the weakening of the CMEs during the propagation.
- We still have more events at Mars than at Neutron Monitors on Earth since Mars has a much thinner atmosphere and no rigidity cutoff.
- The power-law distribution of the FD sizes is a reflection of the CME size and strength distribution.
- Pairing the individual CMEs selected at Mars and Earth seems to show no better correlation during good magnetic connections...

To-do list

- Use the catalog of ICMEs from Wind and ACE Data during 2001 − 2009 to compare with EPHIN data during the same period.
- For a few events, compare observations with models (ENLIL) predicting the arrival time.
- Correlate the EPHIN FDs with ACE magnetic and solar wind properties.
- Use more points: STEREO A and B
- Correlate RAD doserates with MAVEN data.