Galactic Cosmic Rays variations which are not clearly related with heliospheric structures

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What are Cosmic Rays, and how do we detect them?

- Cosmic rays are high-energy particles from outer space.
- About 1000 cosmic rays per second strike each square meter area of Earth's atmosphere.

- Cosmic rays are produced in our galaxy by supernova explosions.
- CMEs and HSSs modulate the cosmic ray intensity, and they're a proxy for the magnetic fields and density

Ground-based detectors measure byproducts of the interaction of primary cosmic rays (predominantly protons and helium nuclei) with Earth's atmosphere.

Neutron monitor:

Typical energy of primary CR:

- ~1 GeV for solar cosmic rays.
- ~10 GeV for galactic cosmic rays.

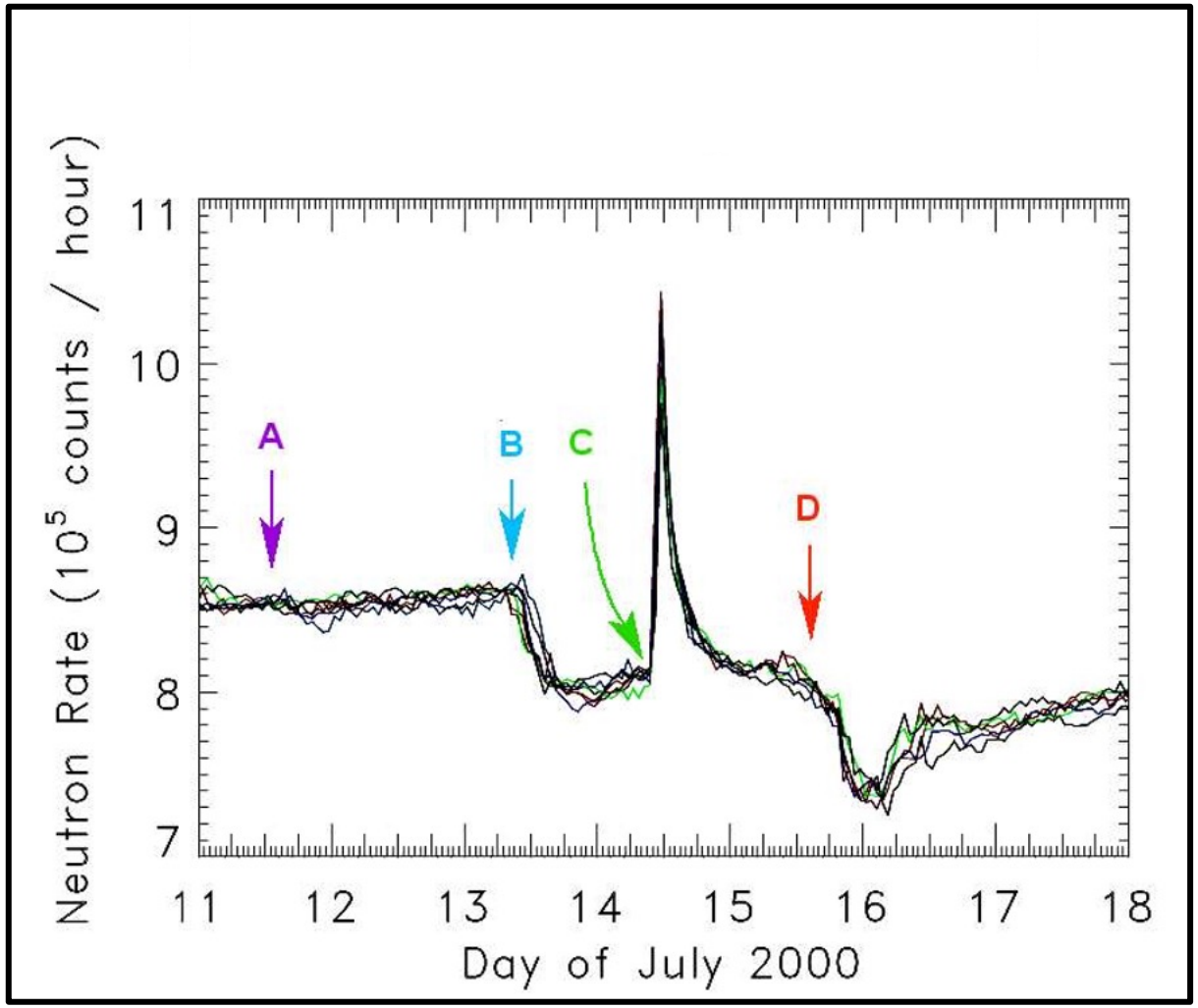
Cosmic ray variations

A. First *coronal mass ejection* (CME) at Sun.

B. First, CME arrives on Earth. Cosmic rays decrease suddenly – a "*Forbush Decrease*".

C. Second CME at Sun. This one accelerates high-energy particles that reach Earth minutes later. The sudden increase recorded by the neutron monitor is a "*Ground-level enhancement*".

D. Second CME arrives at Earth. Cosmic rays decrease again. This CME produces the largest geomagnetic storm in years.



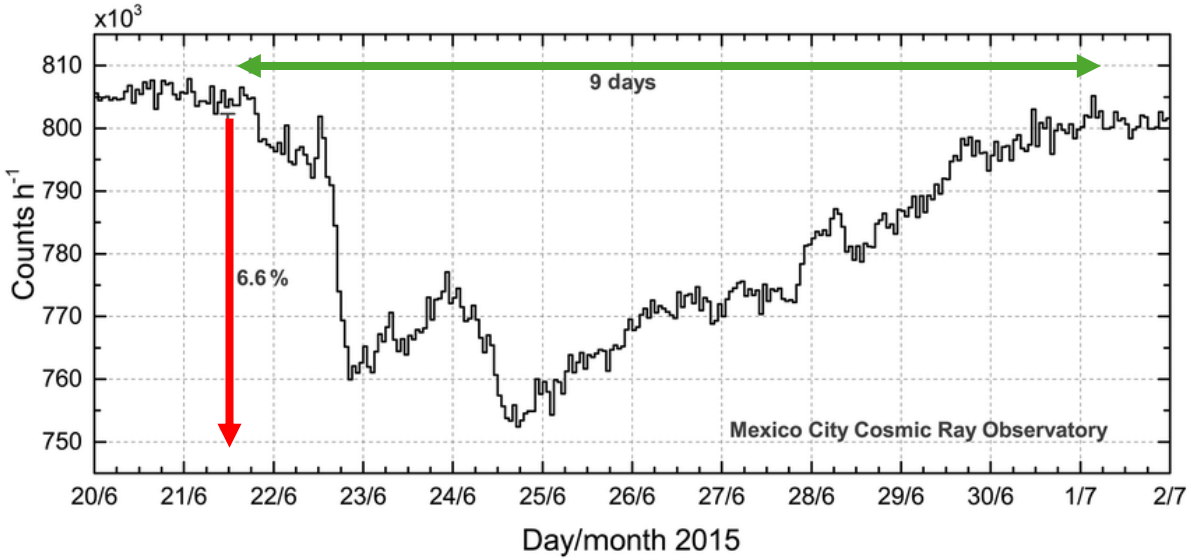
John W. Bieber, University of Delaware, Bartol Research Institute.

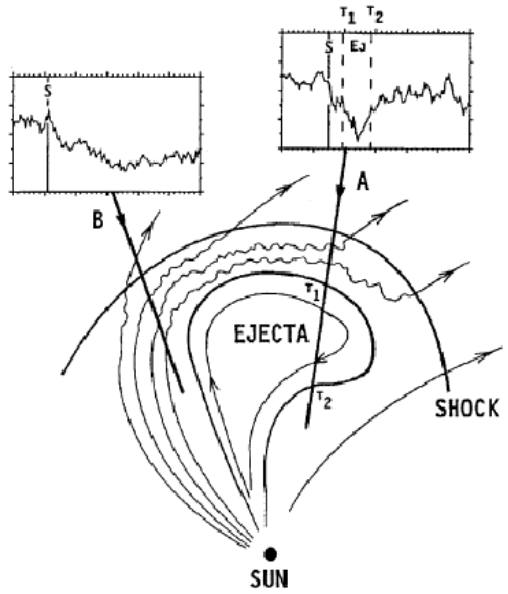
Forbush Decrease

- The *Forbush* effect is a temporary decrease in the intensity of cosmic rays that reach the Earth's atmosphere.

- The *Forbush* decrease occurs when a large eruption of solar material, known as *coronal mass ejection* (CME), occurs from the Sun. The CME can create a shock wave in the solar wind, a stream of charged particles flowing from the Sun. This shock wave can cause the Earth's magnetic field to become more efficient at blocking cosmic rays from entering the Earth's atmosphere.

- As a result, the intensity of cosmic rays reaching the Earth's atmosphere decreases temporarily. The Forbush decrease can last for a few days to a few weeks, depending on the strength of the CME.



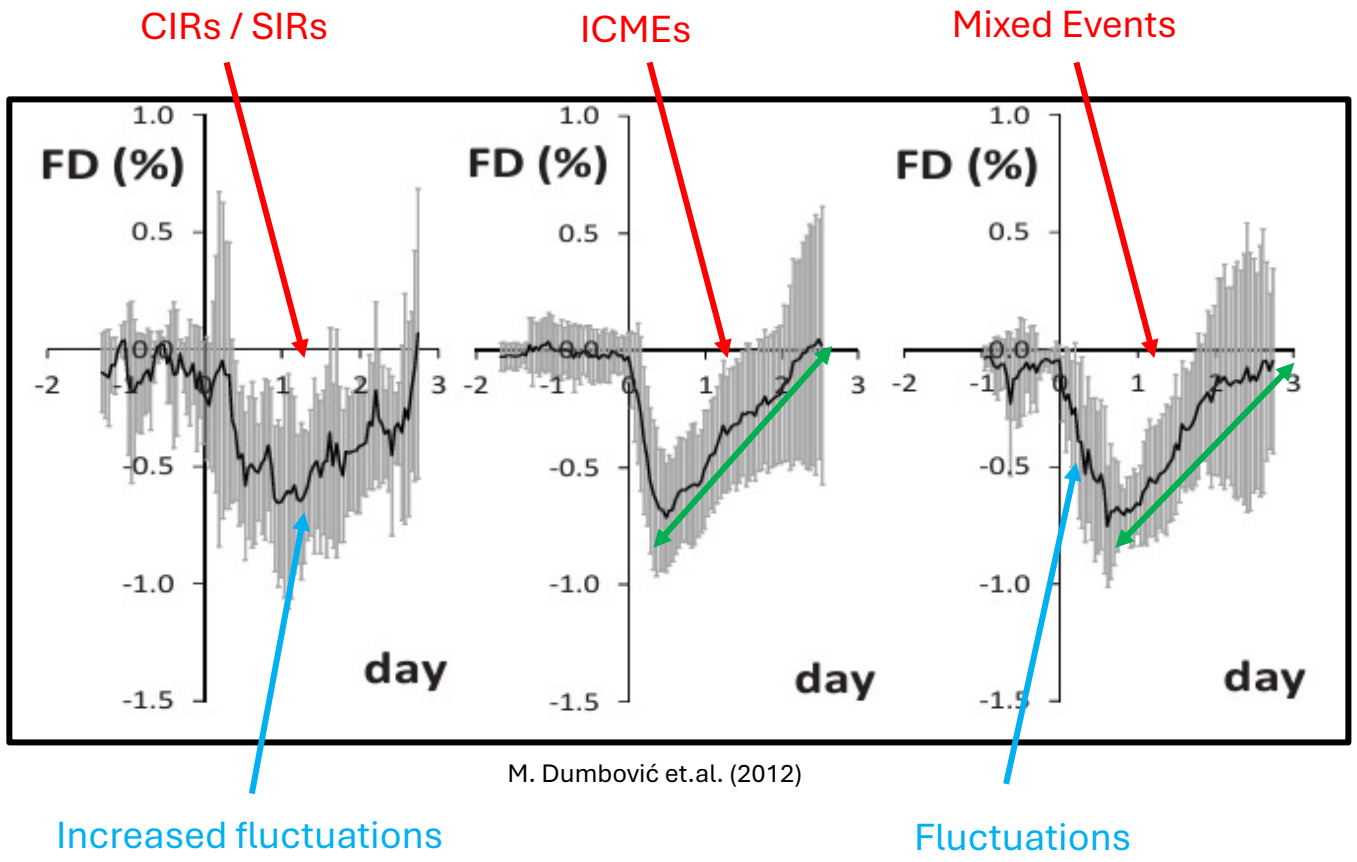


Solar wind structures and depressions in the intensity of cosmic rays

Forbush's decrease morphology, amplitude, and duration depends on the type of disturbance that caused the decrease.

- Unlike ICMEs, CIRs / SIRs and mixed events exhibit unique characteristics during the recovery phase of the decrease, including increased fluctuations.

This could indicate different mechanisms involved in cosmic ray modulation by ICMEs and CIRs / SIRs.

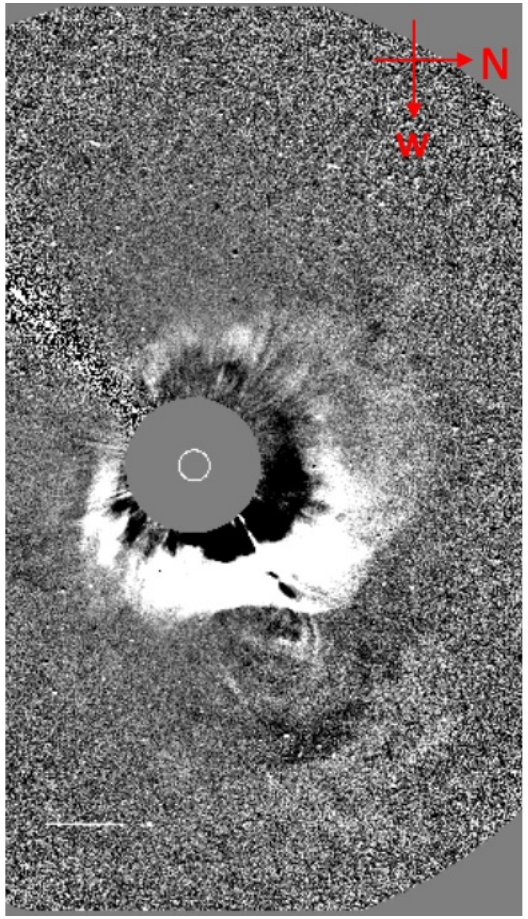


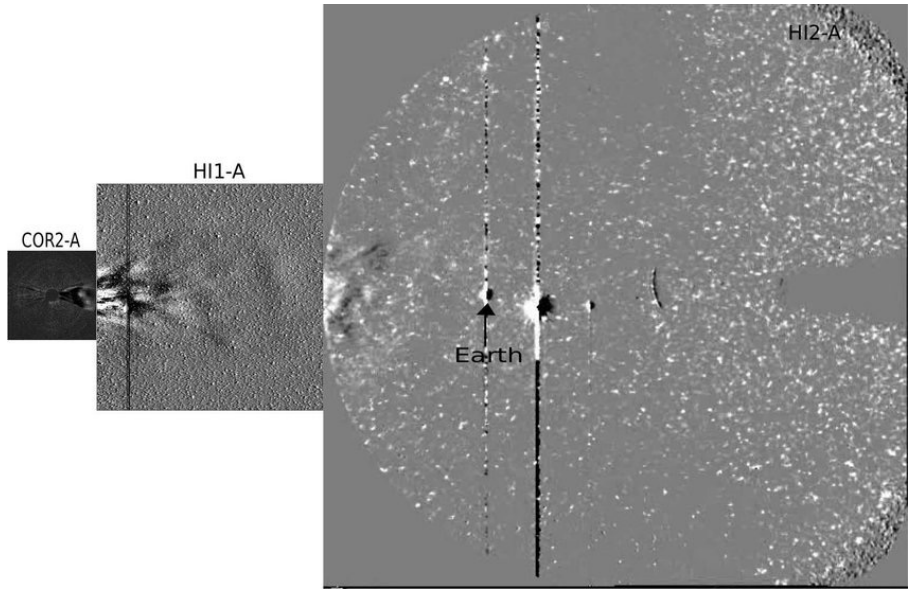
M. Dumbović et.al. (2012)

+ information: Dumbović, M., Vršnak, B., Čalogović, J., and Župan, R.: 2012, Astron. Astrophys. 538, A28.

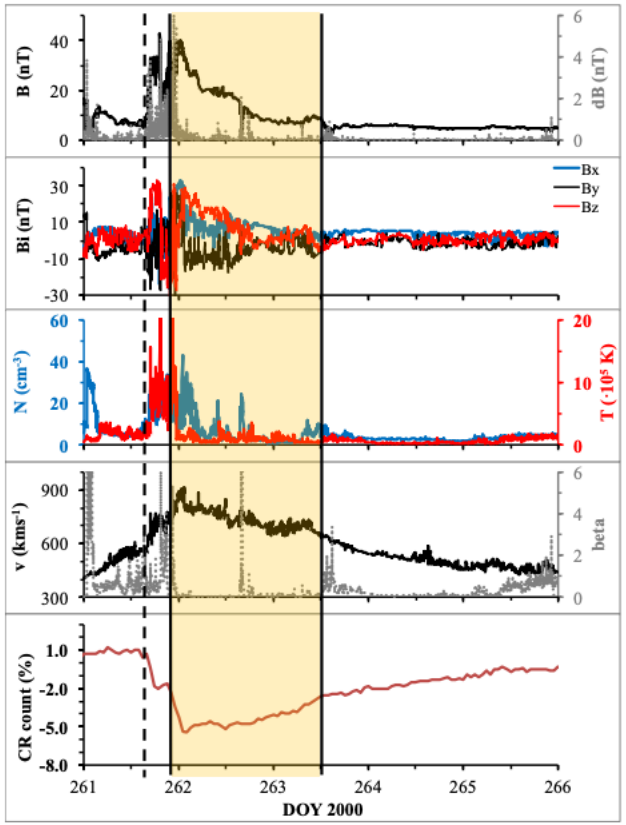
Heliospheric Imagers allow us to observe the region between the Sun and Earth in a manner that was never followed by imaging cameras continuously, allowing us to determine enhancements in density observed by heliospheric imagers that may explain cosmic ray decreases.

Remote observation



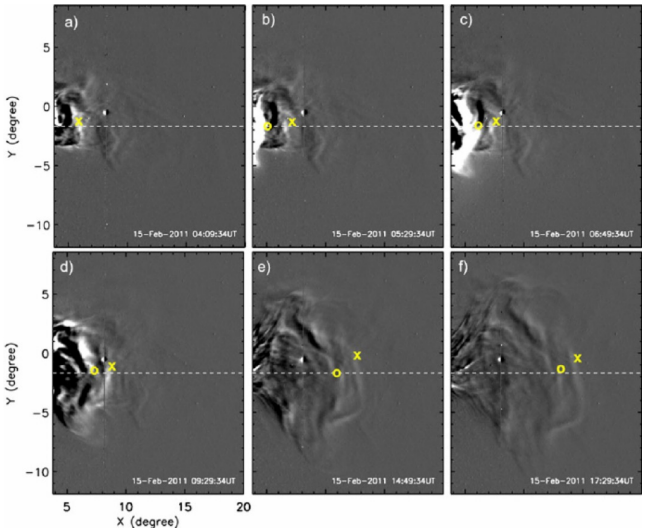


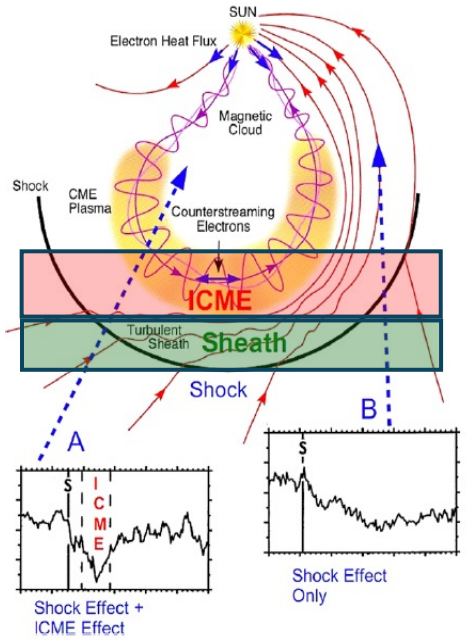
In-situ measurements

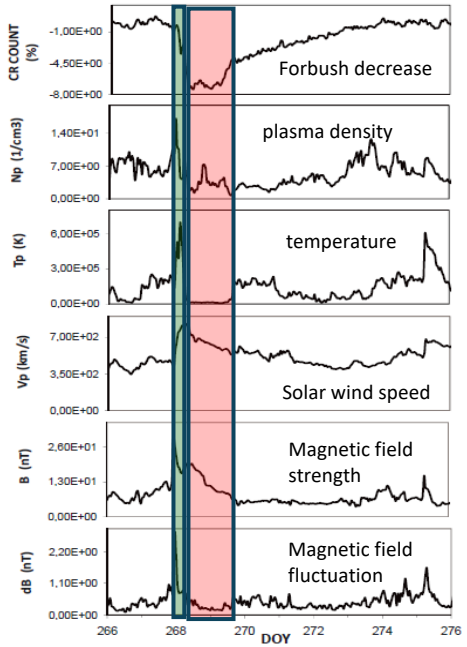


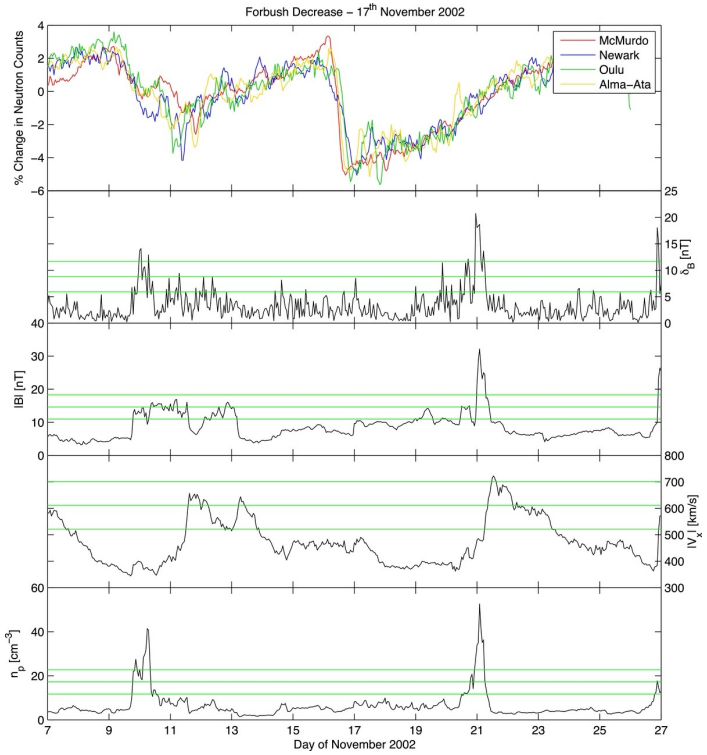
M. Dumbović et.al. (2012)

Thomas, et.al. (2015)









What are we looking at?

CMEs Kinematics

Arrival times

Evolution of CMEs, not solved

Propagation

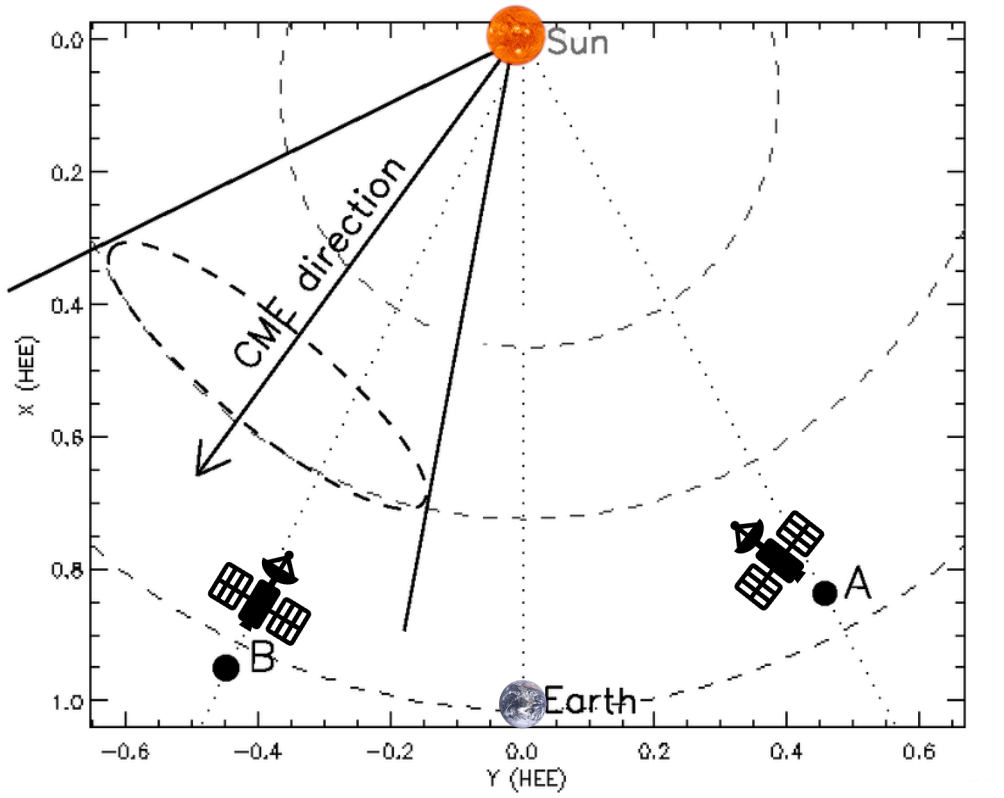
Magnetic field structure

Forbush Decrease physical mechanism, not solved

CMEs lead to disturbances in the solar wind and IMF.

Solar wind and IMF modulate GCR flux.

"Phantom" Forbush



CMEs are widely accepted as a source of transient modulations in the galactic cosmic ray intensity, known as Forbush Decreases.

- Occasionally, Forbush decreases occur for which there is no readily associated solar wind structure in near-Earth space, the so-called Phantom Forbush (PFDs).
- STEREO-A (B) can identify large solar wind structures responsible for such structures using heliospheric imagers.
- STEREO allows observations from well-located points in the inner heliosphere to identify pre-existing heliospheric structures to create a magnetic barrier to modulate galactic cosmic rays.

+ information: Thomas, et.al. (2015)

Forbush Effects and Interplanetary disturbances

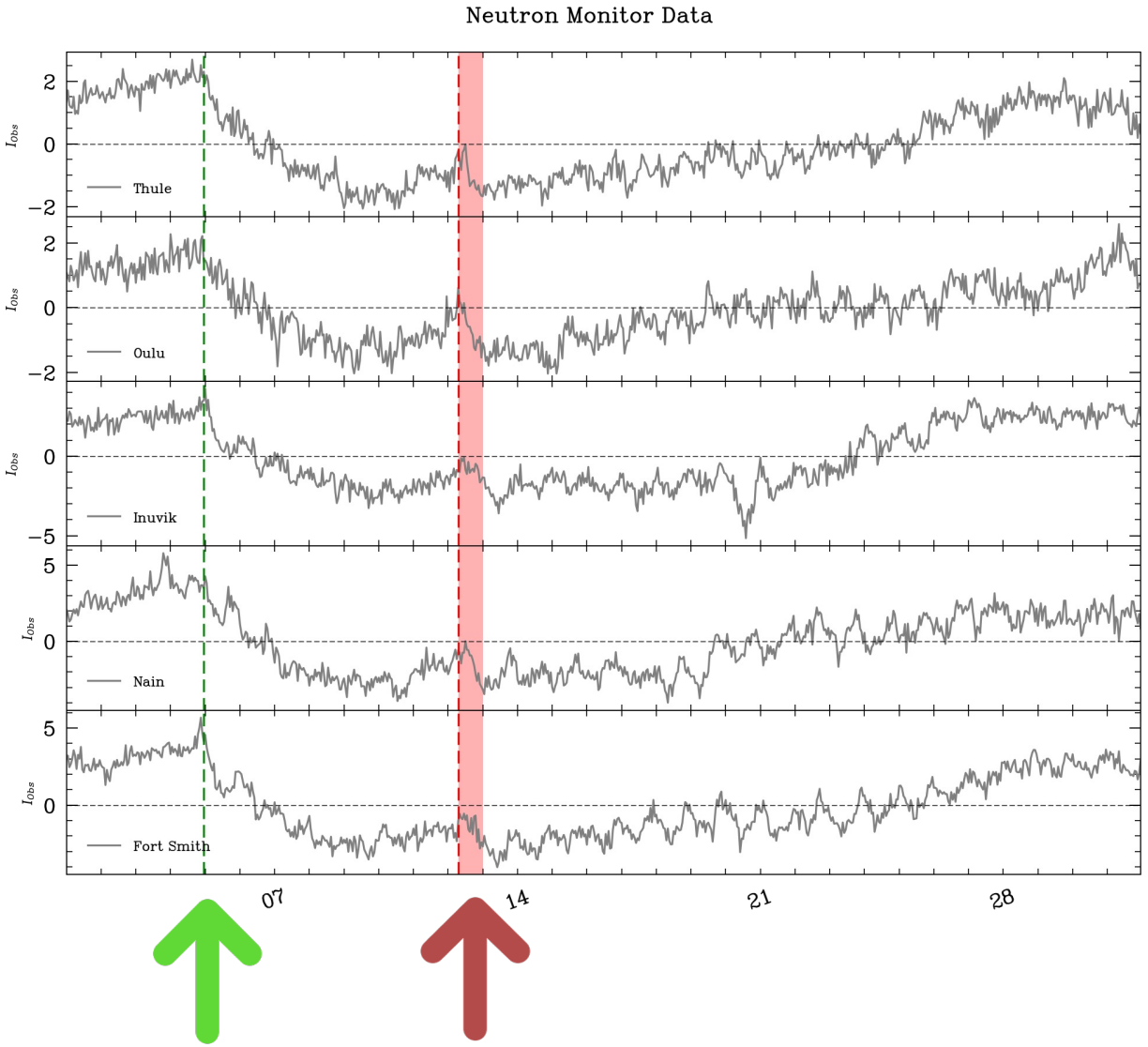
Date of Interplanetary Disturbance	Type of Interplanetary Disturbance
2008-01-04 22:50:00	(ICME) Interplanetary Coronal Mass Ejection
2008-01-12 07:00:00 not SIR Observed by STEREO-A or WIND	SIR Observed by STEREO-B
2008-01-25 01:00:00	(HSS) High-speed solar stream
2008-01-31 11:23:00	HSS1 (the first HSS from CHs in the interacting HSS1 + HSS2)
2008-02-01 08:00:00	HSS2 (the second HSS from CHs in the interacting HSS1 + HSS2)

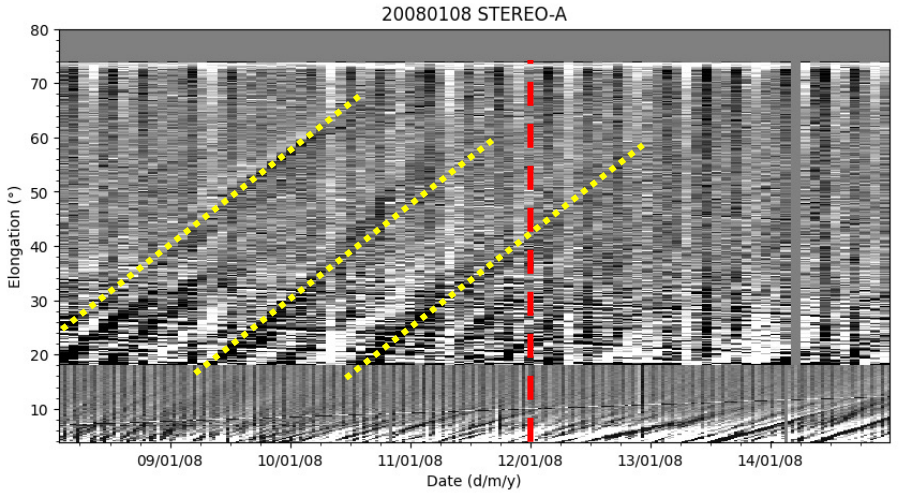
And more events …

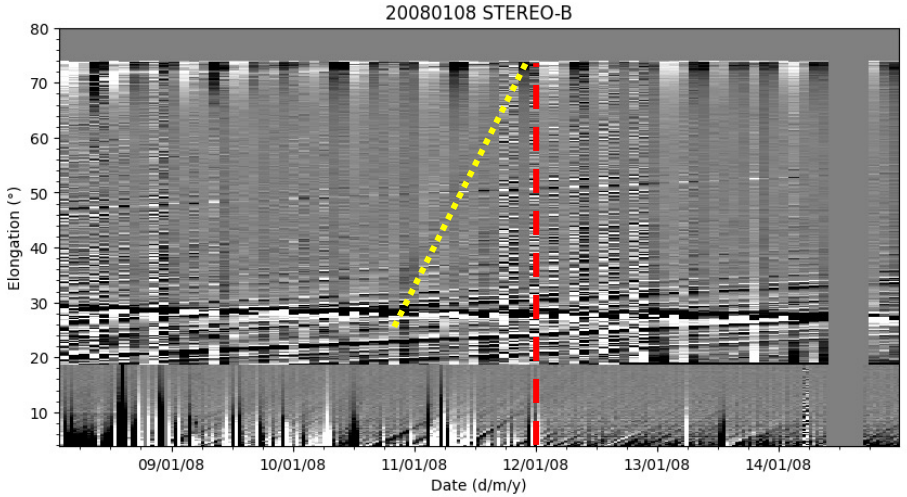
In 2008, we had 42depression not associated with a heliospheric structure in GCR flux observed by NMs.

For example, in 2008 (**80** Interplanetary disturbances were observed by NMs)
> High-Speed Streams (HSS)

Preliminary results







Forbush event

Depression in CR flux, what caused this?

Summary

- Only the images from HIs observations can identify this structure candidate (a SIR), which is not observed in situ by any of the other 2 missions available (STEREO-A or WIND).
- Remote sensing of heliospheric structures using STEREO Heliospheric Imagers during Forbush Decreases and GCR depressions.
- Features in the GCR can be closely related to structures in the local solar wind observed by spacecraft observations.
- Give a more global view of the physical mechanism of Forbush Decreases or GCR depressions.

Thanks for your attention !

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