

# Opening a window on ICME related GCR modulation in the inner solar system

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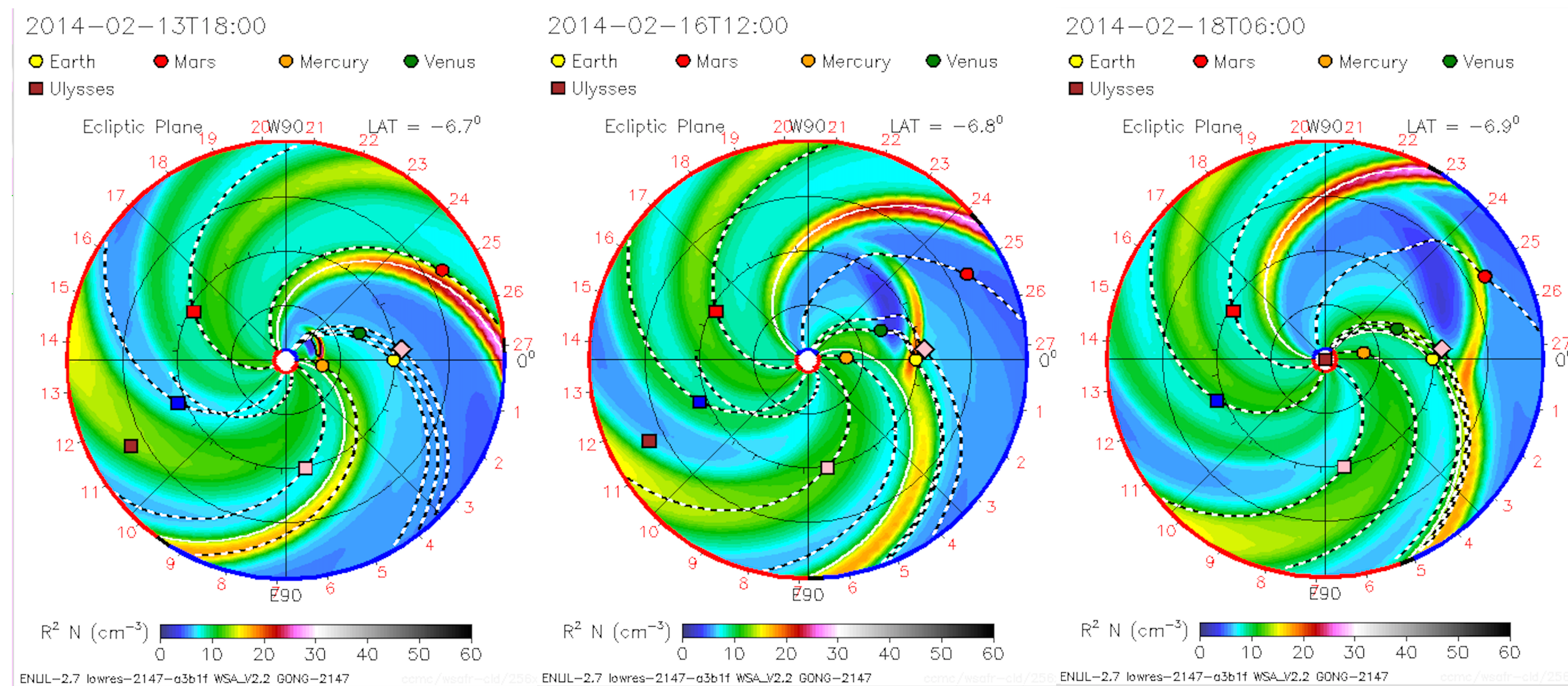


## 1. Summary

- Forbush decreases (FDs) in galactic cosmic ray (GCR) count rates indicate ICME related GCR modulation.
- FDs can be caused by a decrease in the particle diffusion coefficient in the turbulent ICME sheath, as well as by the closed field line geometry inside the magnetic ejecta.
- For the first time, we have observations of FDs associated with the same ICME event at three different planets in the inner heliosphere. This allows us to investigate changes with heliospheric distance in GCR modulation by ICMEs using data from MESSENGER, LRO, and MSL for the ICME observed in conjunction.
- Multipoint observations show depth of Forbush decrease diminishes with distance from Sun. Yields glimpse of environment we are about to explore with Parker Solar Probe and Solar Orbiter.

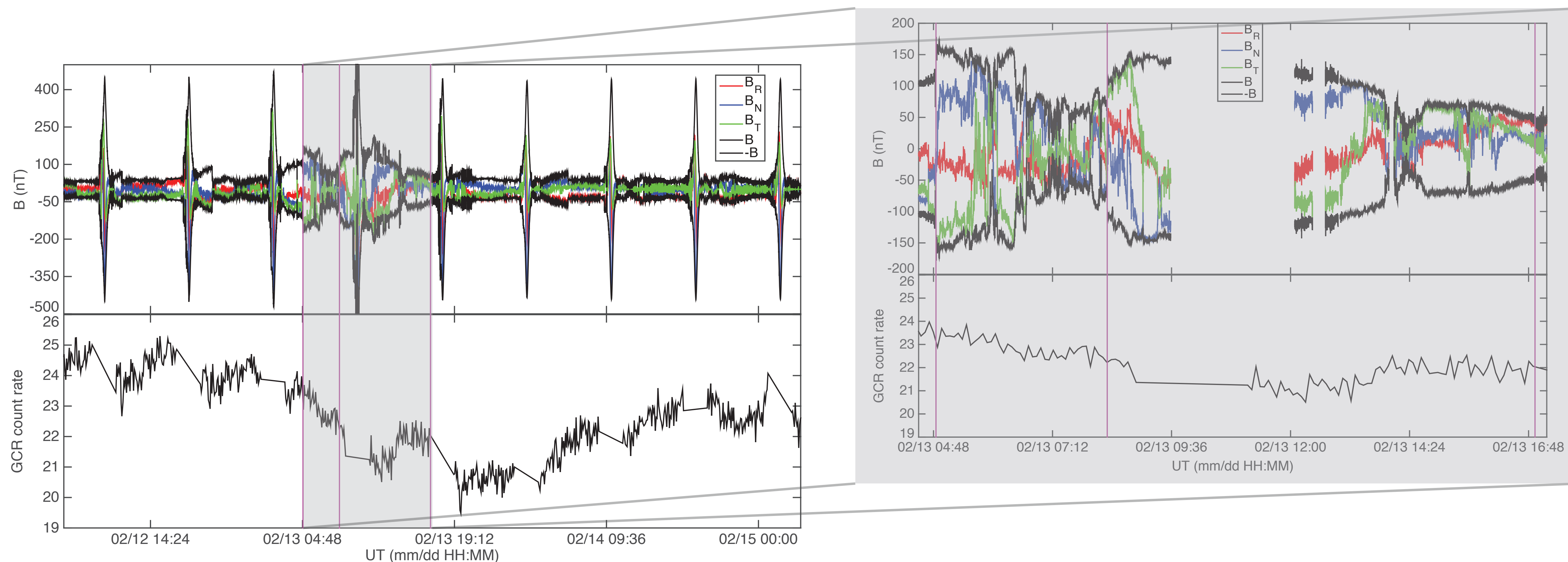
## 2. 12 February 2014 ICME event

- ICME launched on 12 Feb 2014 – it reached Mercury on 13 February, Venus on 14 February, Earth on 15 February, and Mars on 18 February. ENLIL with cone extension model simulation shows ICME reaching all 4 planets.



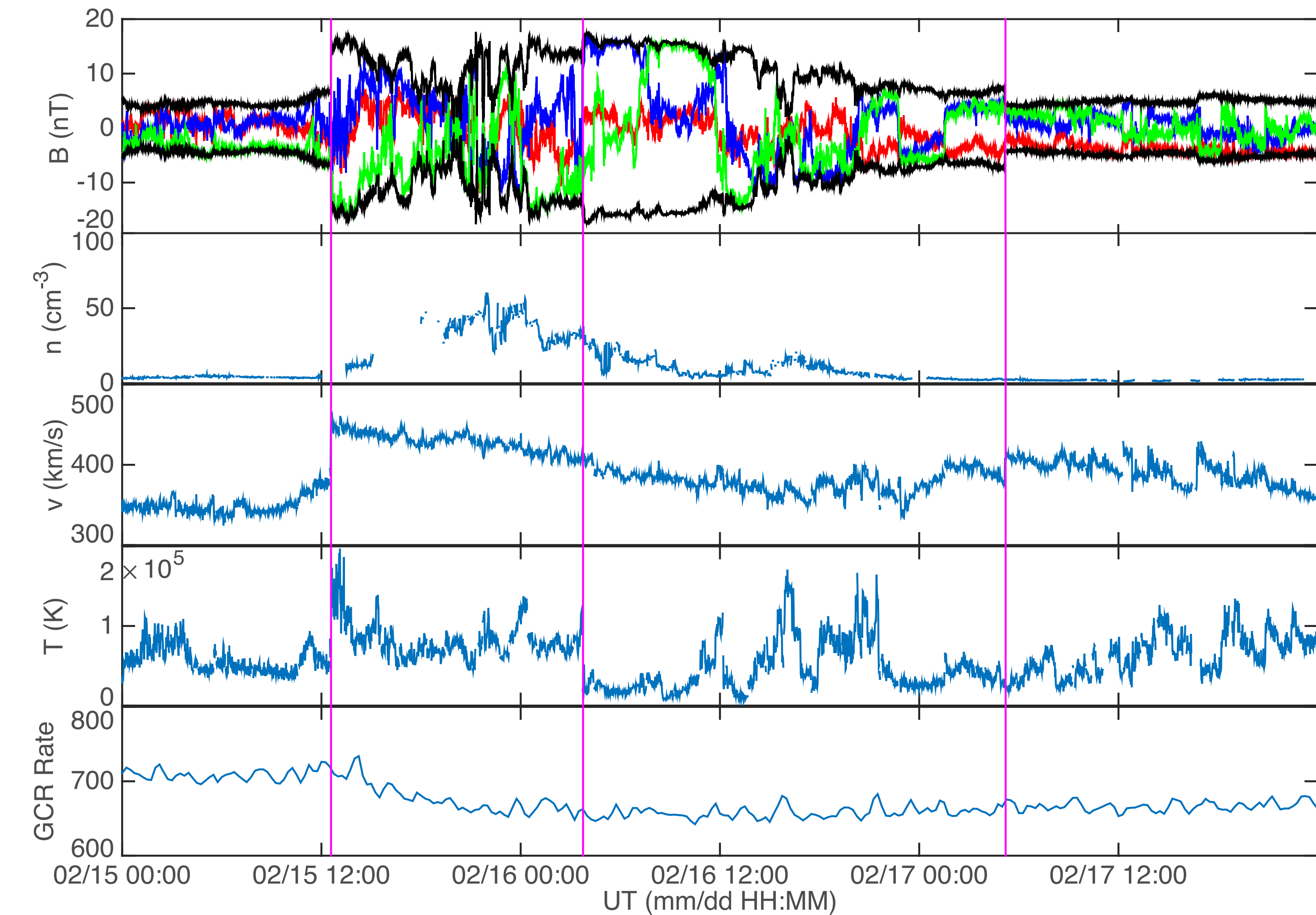
## 3. ICME at Mercury

- MESSENGER magnetic field and neutron spectrometer (NS) data is available. NS is sensitive to GCRs > 125 MeV.
- ICME shock reached Mercury with a speed of ~800 km/s; decrease in GCR flux is noted immediately after shock arrival. Two-step FD likely at Mercury, second decrease in flux noted after magnetic ejecta arrival.



## 4. ICME at Earth/Moon

- We use ACE magnetic field and plasma data of the ICME, and LRO-CRaTER GCR observations. To match the GCR energy range from MESSENGER as closely as possible, we used CRaTER GCR data >100 MeV. Only a 1-step FD is noted at the Moon.



## 5. Forbush Decreases at Mercury, Earth/Moon, Mars

- At Mars, used MSL GCR data at the surface. Modeling was conducted to account for Mars' atmospheric effects on the GCR fluxes. Estimated a factor of 1.4 decrease in FD size due to the atmosphere - corrected the FD observed at surface to obtain value above atmosphere for comparison with other planets.
- FD decreases with distance from the Sun, although decrease in FD between Mercury and Earth much larger than between Earth and Mars. This is largely due to the factor of ~7 ICME magnetic field decrease between Mercury and Earth compared to the factor of ~2 decrease between Earth and Mars,  $B \sim r^{-2.09}$  for this ICME.

