NANOSCALE DUST PRODUCTION AT 1 AU; IDENTIFICATION AND TRACKING WITH 12 SPACECRAFT. H.R. Lai[1], Y.D. Jia[1], M. Connors[2], C.T. Russell[1], [1] Earth, Planetary and Space Sciences, UCLA, 603 Charles Young Drive, Los Angeles, CA 90095-1567, USA, yyn@g.ucla.edu, [2]Centre for Science, Science and Technology, Athabasca University, 1 University Drive, Athabasca, AB T9S 3A3, Canada.

Interplanetary Field Enhancements are phenomena in the interplanetary magnetic field, first discovered near Venus [1], during an extremely long duration (12 hours) and large size (about 0.1 AU) passage across the Pioneer Venus spacecraft.

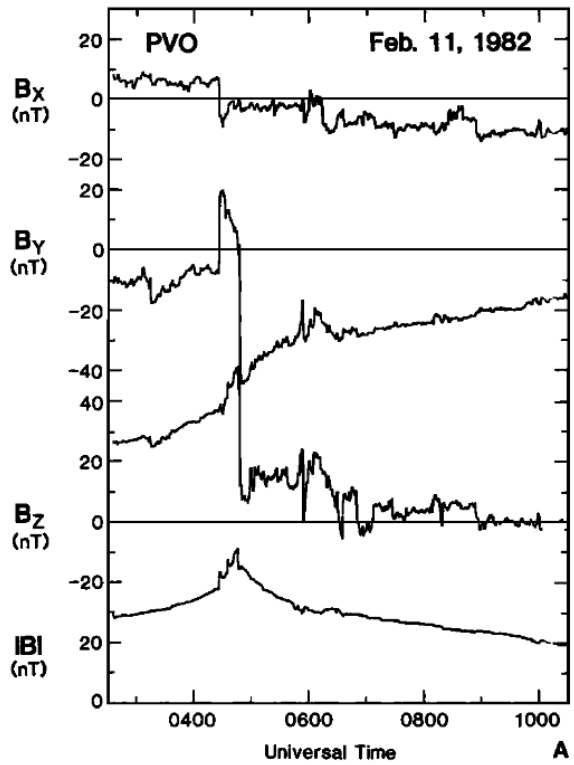


Figure 1. Pioneer Venus measurements in solar ecliptic coordinates.

Three and a half hours later and 21 x 10^6 km farther from the Sun, this structure, somewhat weaker and off to the side of the expected radial path of any solar initiated disturbance, was seen by first Venera 13 and then Venera 14, trailing behind V13 [2].

Since this discovery, many smaller such disturbances have been observed and attributed to collisions of small rocks in space at speeds of about 20 km/s at 1 AU and faster, closer to the Sun. All sightings with magnetometers and other space plasma instruments give very precise measurements of the radial structure (of usually the magnetic field), but the scale transverse to the solar radius is poorly defined, as is the temporal evolution of the structure from single spacecraft data.

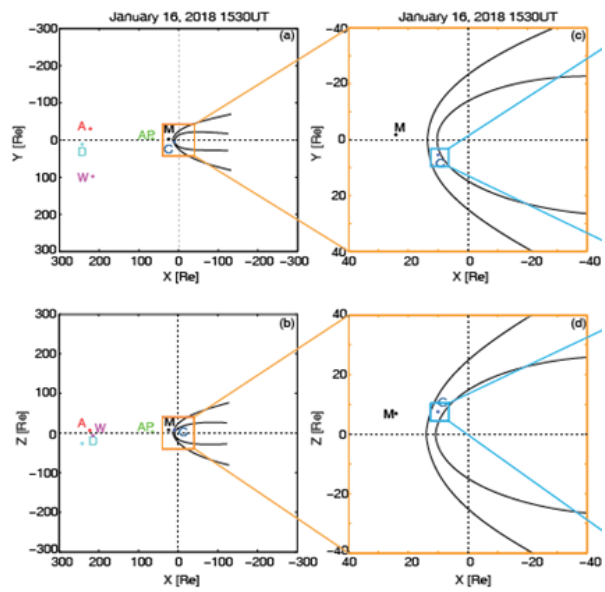


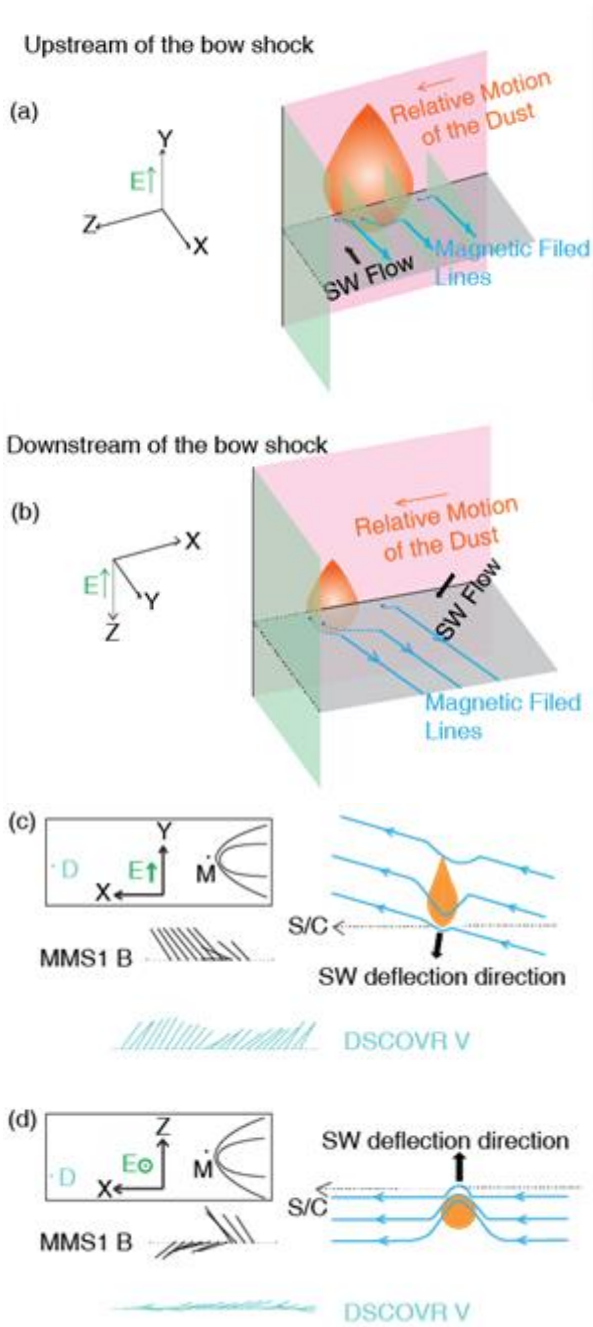
Figure 2. Locations of the spacecraft when the IFE was detected. This GSE coordinate system has its X axis towards the Sun, Z axis perpendicular to the Earth's orbit plane, and Y axis completing the right-handed coordinate system. The abbreviations are: A for ACE, D for DSCOVR, W for Wind, AP for ARTEMIS P2, M for MMS, C for Cluster, and numbers 1 to 4 for Cluster 1 to 4, respectively.

On January 16, 2018, near Earth, 12 spacecraft equipped with plasma spectrometers and magnetometers observed the passage of a single Interplanetary Field Enhancement [3]. The locations of these 12 spacecraft are shown in the ecliptic plane (top) and perpendicular to the solar direction (bottom) in Figure 2. From left to right, the scale expanse so that the separations of the closely spaced sites can be seen. From left to right, the scale expands a factor of 200. The temporal resolution of the data fortunately increased from left to right a similar amount, avoiding any ambiguity in timing. The magnetic field profiles and the four 1 AU spacecraft are very similar. The profiles were obtained at different times appropriate to their locations, and then aligned in this display [3].

The 4 Cluster spacecraft were closer to the Earth and in a region in which the solar wind had slowed down because of the Earth's bow wave (shock) in the solar wind. However, the disturbance in the shocked solar wind occurred at the time expected if the IFE structure had not been slowed by the plasma, but rather had proceeded with the momentum it had prior to the

shock crossing. If the disturbance causing particles are small bits of rock (not protons), then they should have kept most of their momentum in crossing the bow shock, as illustrated in Figure 3.

We view this as a complete test of the dust producing collisional origin of these Interplanetary Field Enhancements, and a clear demonstration of how the solar wind clears out the dust in the inner solar system produced by the continuing destructive collisional process.



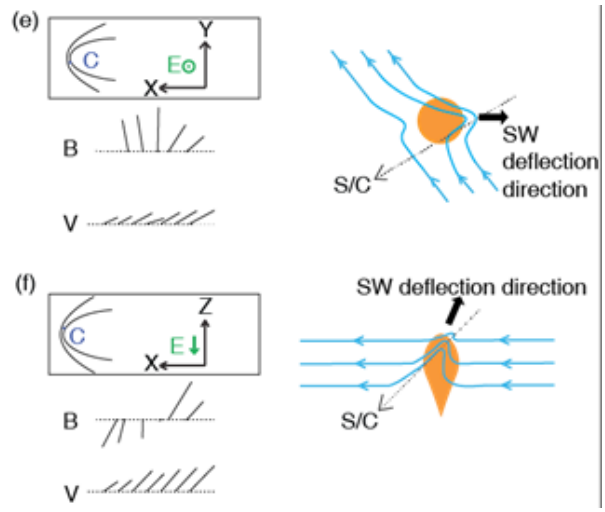


Figure 3. Cartoon illustrating the proposed interacting geometry of the IFE travelling across the bow shock. The blue lines are magnetic field lines consistent with the observation. The yellow shade marks the location of the dust cloud with an unconstrained shape. All plots are in GSE coordinate system. Panels (a) and (b) show the three-dimensional picture and panels (c) to (f) show their two-dimensional projections. The magnetic field and solar wind velocity vectors as well as the spacecraft locations are also illustrated in Panel (c) to (f). We use DSCOVR velocity in the solar wind because it has better coverage. To show the velocity variation better, -380km/s in X direction has been removed when generating the projections of the velocity.

References:

[1] C.T. Russell et al. (1983) *Nature*, *305*, 612-615.

[2] C.T. Russell et al. (1985) *Geophys. Res. Lett.*, *12*, 476-478.

[3] H.R. Lai et al. (2020) *Geophys. Res. Lett.*, in press.