Interacting CMEs from the Sun to 1 AU: What can we learn from relating heliospheric images to in situ data?

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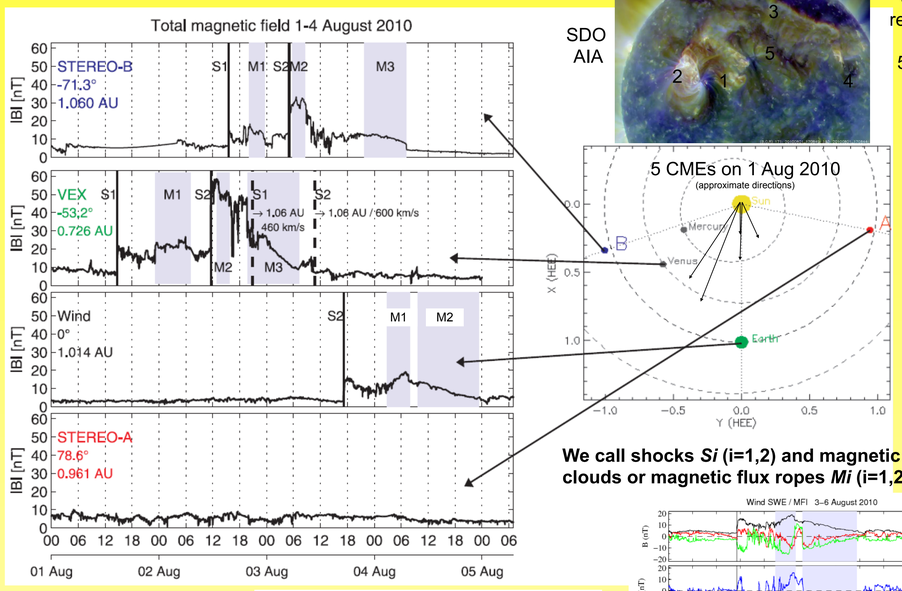
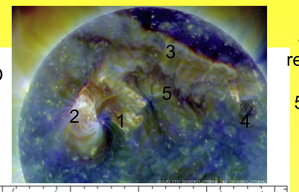
CONTEXT

- **Following coronal mass ejections from the Sun to Earth** has become possible with the Solar Mass Ejection Imager (SMEI) and the STEREO - Heliospheric Imager instruments. Here we **investigate two cases where CMEs were seen interacting in the STEREO-HI** fields of view (pointing 4-88.7° away from the Sun) and which were **subsequently observed by spacecraft measuring the solar wind in situ,** giving us detailed information on magnetic fields and plasma bulk parameters.
- **So far, the HI - in situ link has been achieved for isolated CMEs.** (e.g. Davis et al. 2009, GRL; Liu et al. 2010 ApjL; Möstl et al. 2009 ApjL / 2010 GRL).
- Both events caused moderate geomagnetic storms.
- Papers are in preparation.

August 1-4 2010 events

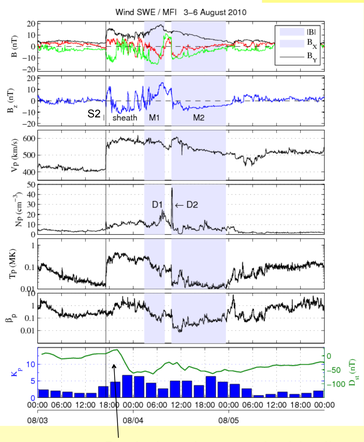
- On 1 August 2010, various instruments (SDO/SOHO/STEREO) monitored repeated coronal mass ejections from the Sun **originating within tens of degrees** from disk center.
- We **compare and contrast their imprints** on three widely separated spacecraft, namely STEREO-B (71° east of the Earth, at 1.06 AU), Venus Express (53° east, at 0.72 AU) and Wind in front of Earth (at 1.01 AU). **ICMEs and shock timing, location and parameters** set strong constraints on the propagation directions and speeds of multiple CMEs leaving the Sun on 1 Aug 2010.
- For Jplots and CME and kinematics please look at the **poster Z122 by Rollett et al.**

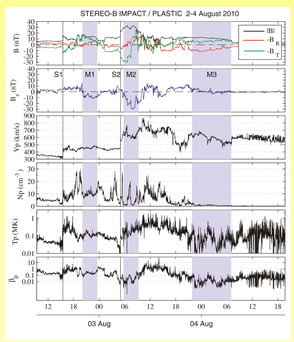


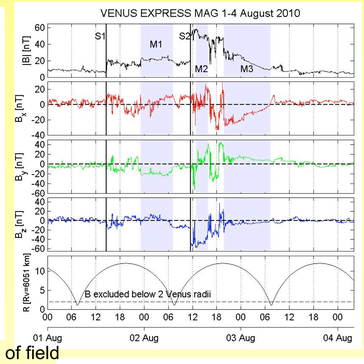


Source regions of the 5 CMEs

We call shocks *Si* (i=1,2) and magnetic clouds or magnetic flux ropes *Mi* (i=1,2,3)

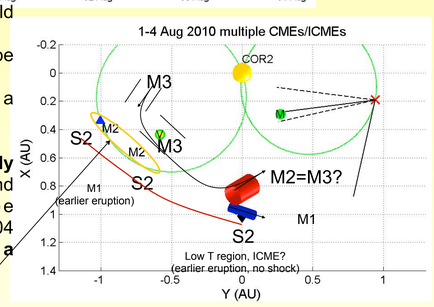






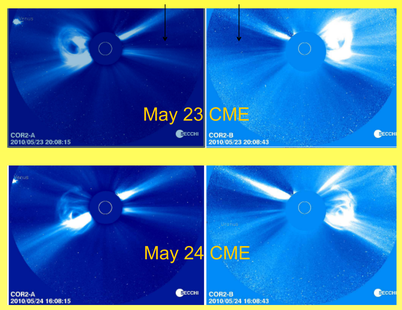
At **STB and VEX**, temporal profiles of field and plasma parameters are **~ similar**. Both saw min. 3 flux-rope type ICMEs and 2 moderately strong shocks (but S1/M1 shock-ICME pair was from a previous eruption on July 30).

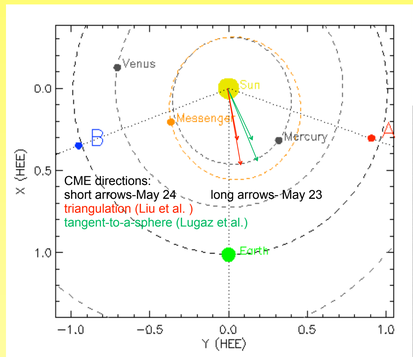
Flux rope M2 is of WSE type, thus **highly inclined** to the ecliptic, at both STB and VEX, and has similar flux rope parameters, but a radial size of only 0.04 AU. At 18° separation this leads to a ***pancake cross-section of ~ 1:7.***

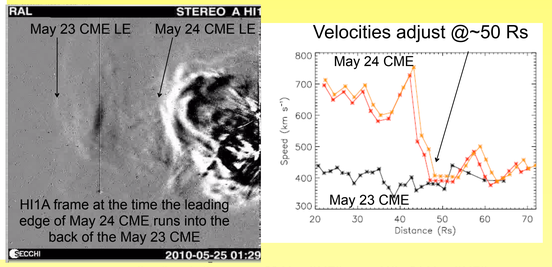


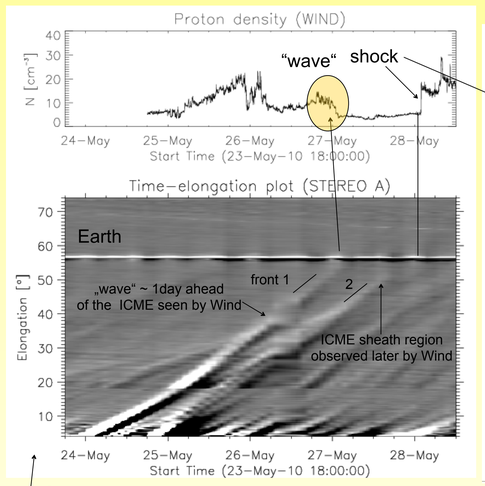
Dst index shows a double dip behaviour, with the **1st minimum due to the sheath region** and the **2nd caused by magnetic flux rope M2.** M1 shows signs of compression (D1), heating and does not expand – **M1 and M2 have likely interacted** before 1 AU. D2 is a strong density jump at the front of M2.

COR2A COR2B



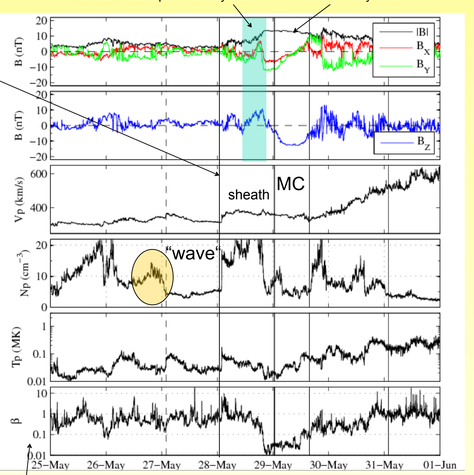






Combined HI2A Jplot and Wind proton density

Small scale flux rope = 23 May CME? MC= 24 May CME?



Wind magnetic field and proton bulk parameters

May 23 - 29 2010 event

- a CME on May 24 catches up with another CME from May 23 @50 Rs
- We find that both have similar directions, using triangulation methods for HI1A/B
- Two separating fronts in the HI2A Jplot, only the 2nd is associated with ICME signatures observed by Wind near Earth
- We speculate that the 1st front could be a freely propagating, decaying shock wave produced by the CME-CME interaction.

CONCLUSIONS

- **Aug 2010 events**: Well located and **widely separated spacecraft** observed the impacts of at least 3 ICMEs. STEREO-B and VEX observations at 18° longitudinal separation are similar, near Earth signatures are clearly different. These in situ observations will serve as **boundary conditions** for **benchmark tests of numerical models** for a sequence of CMEs erupting in close temporal proximity.
- **May 2010 events**: in our interpretation, a density "wave" results from the interaction between two approximately Earth-directed CMEs at 50 solar radii. This "wave" arrives *a day earlier* at Wind than the ICME (consisting of shock/sheath+ 1 or 2 MCs).

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