Interplanetary Coronal Mass Ejections from MESSENGER Orbital Observations at Mercury

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Reka M. Winslow[1], Noé Lugaz[1], Lydia C. Philpott[2], Nathan A. Schwadron[1], Charles J. Farrugia[1], Brian J. Anderson[3], and Charles W. Smith[1]

(1) Institute for the Study of Earth, Oceans, and Space, University of New Hampshire (reka.winslow@unh.edu), (2) Earth, Ocean and Atmospheric Sciences, University of British Columbia, (3) John Hopkins University Applied Physics Laboratory.

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1. Summary

- **Used observations from MESSENGER in orbit around Mercury to study interplanetary coronal mass ejections (ICMEs) near 0.3 AU.**
- **Cataloged over 60 ICMEs at Mercury between 2011 - 2014.**
- **Investigated key ICME property changes from Mercury to 1 AU.**

Find:

- **Good agreement with previous studies for magnetic field strength dependence on distance, and evidence that ICME deceleration continues past the orbit of Mercury.**
- **This ICME database useful for multipoint spacecraft studies of recent ICMEs, as well as for model validation of ICME properties.**

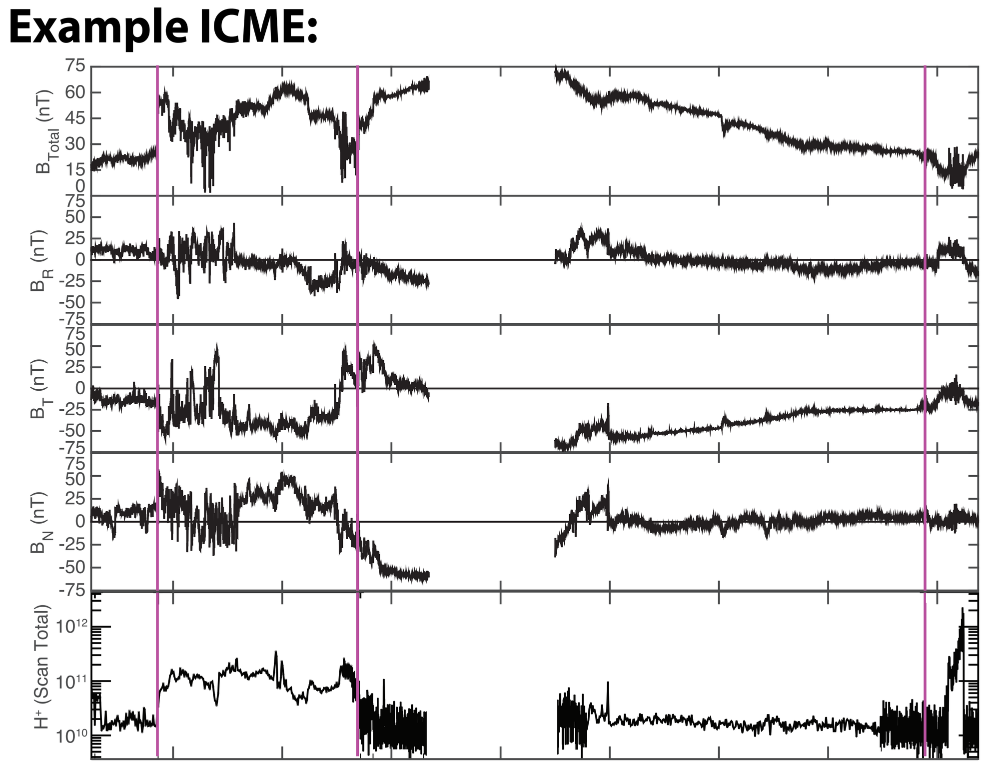
2. ICME Identification

- ICMEs identified using magnetic field measurements only, due to lack of solar wind data with MESSENGER.
- Strict selection criteria:

a) interplanetary shock observed
b) shock followed by sheath and magnetic ejecta
c) event lasted for the duration of at least 1 MESSENGER orbit through Mercury's magnetosphere
d) event caused a visible distortion of the magnetosphere

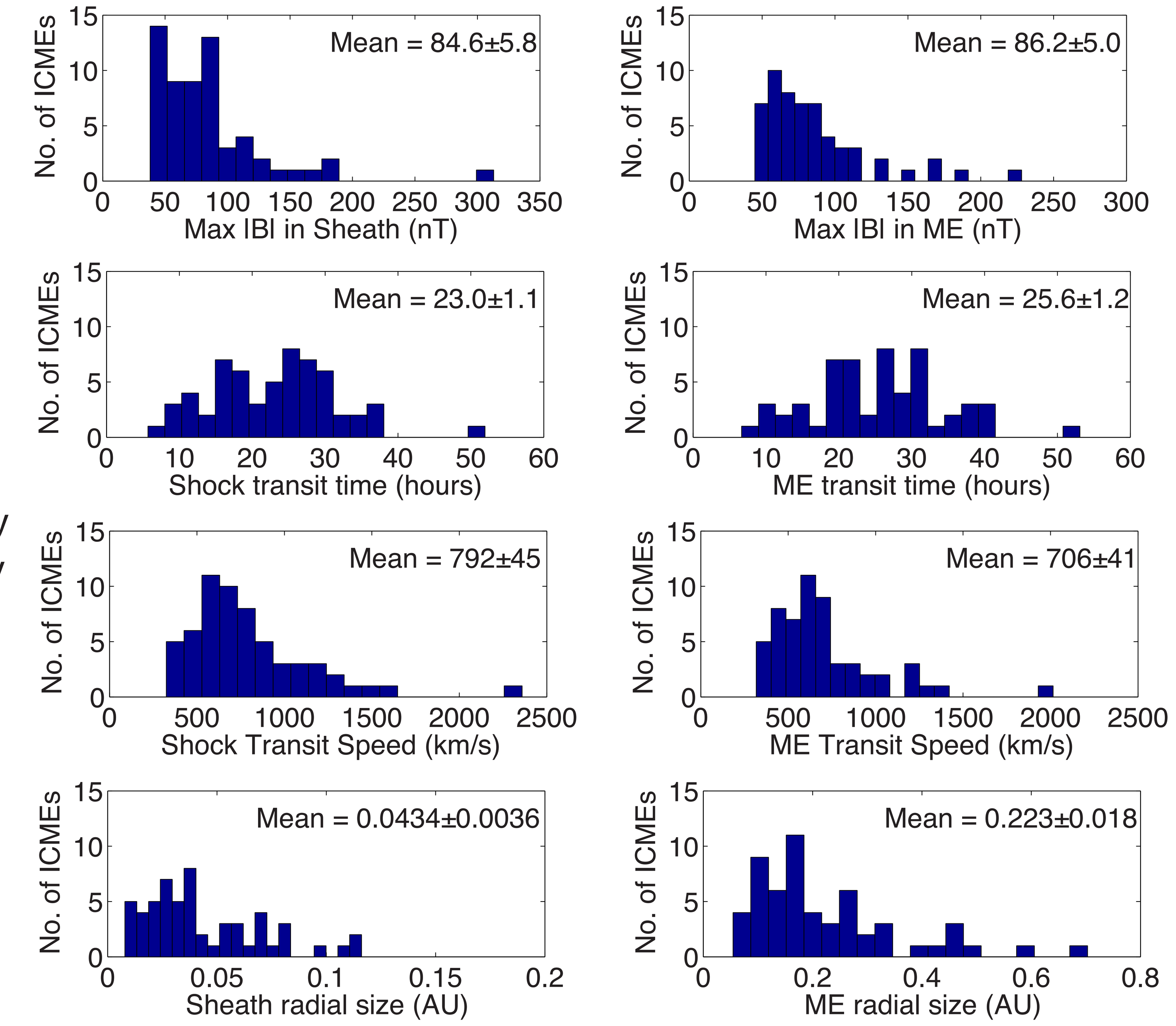
- Selection criteria biases towards fast ICMEs that are shock-driving and ICMEs with magnetic cloud-like characteristics.
- Also determined corresponding CME counterpart at the Sun for each event.

Example ICME:



3. ICME Properties at Mercury

- ICME speed estimated from CME ejection time at the Sun, arrival time at Mercury, and Mercury's heliocentric distance. -> This average speed is likely a maximum speed of the ICME at MESSENGER.
- Maximum ICME |**B**| observed is 310 nT.
- Fastest transit time from Sun to Mercury was 6 hr, longest transit time 52 hr.
- Fastest transit speed 2350 km/s, slowest transit speed 325 km/s.
- Large spread in transit times and speeds indicates that due to proximity to Sun, MESSENGER observed a wide range of ICMEs, even ones that may be too slow or small to be detected at 1 AU.

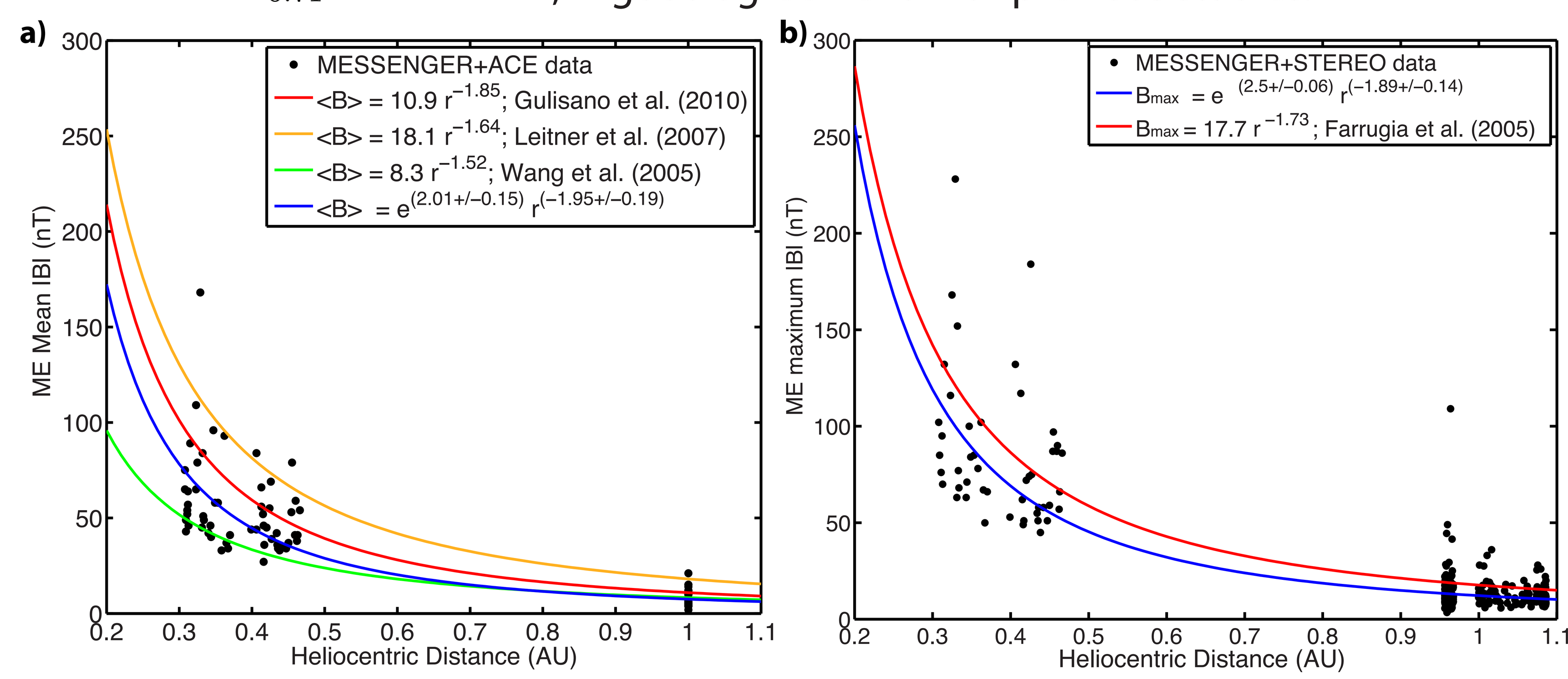


4. Differences in ICME Properties Between Mercury and 1 AU

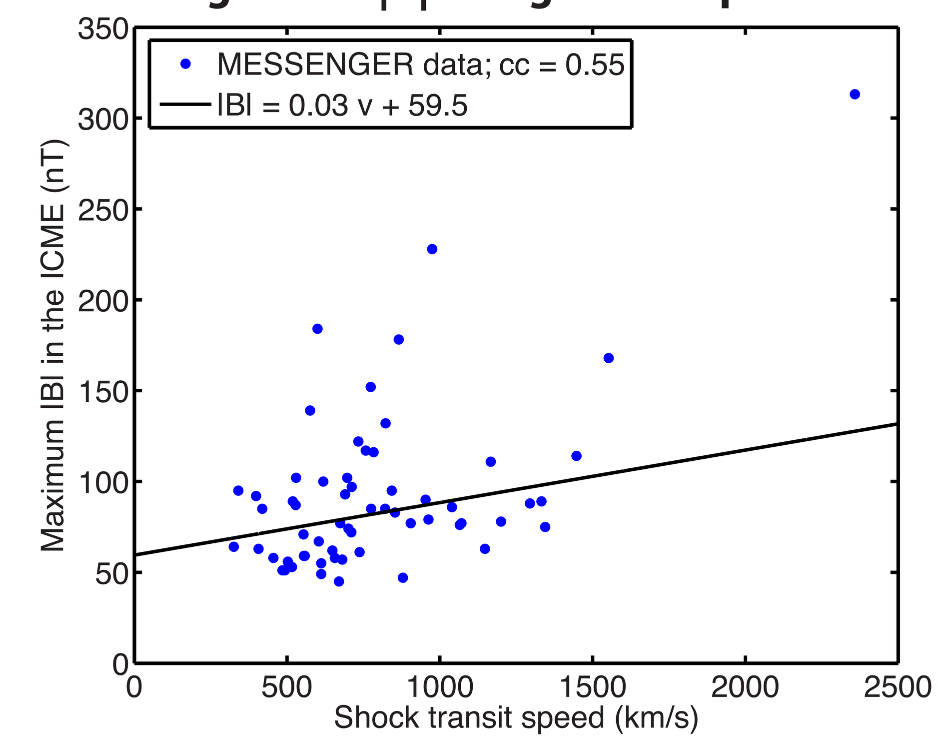
- Used existing databases of ICMEs at 1 AU for the same time period.

Main Results:

$B_{max} = 12.18^{+0.75}_{-0.71}\, r^{(-1.89 \pm 0.14)}$, in good agreement with previous studies.

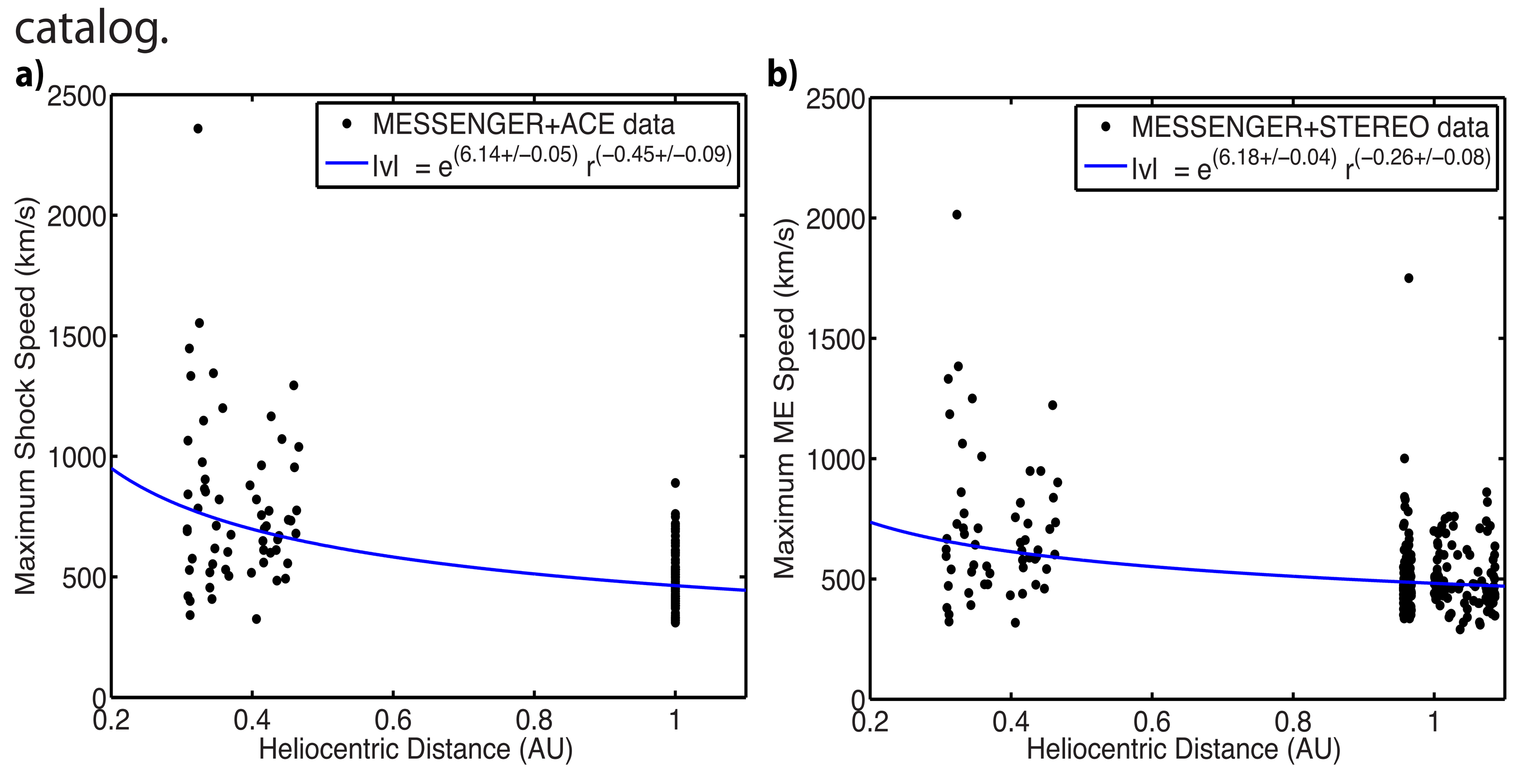


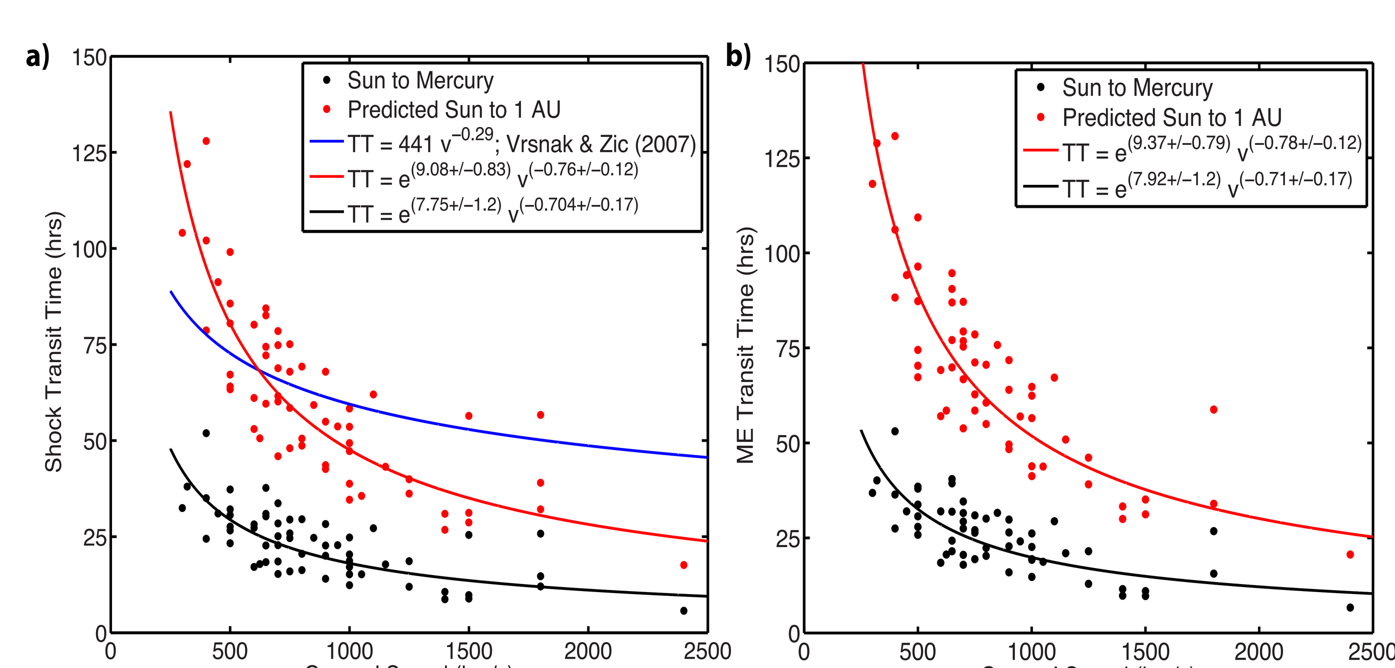
High ICME |B| -> high ICME speed?



- ICME deceleration continues beyond the orbit of Mercury:

(1) Shallow speed decrease with distance,
(2) Average transit time from Sun to Mercury 20% faster than expected based on average transit times to 1 AU,
(3) Significantly shallower ICME transit time dependence on initial CME speed observed at 1 AU compared to predictions based on MESSENGER ICME catalog.

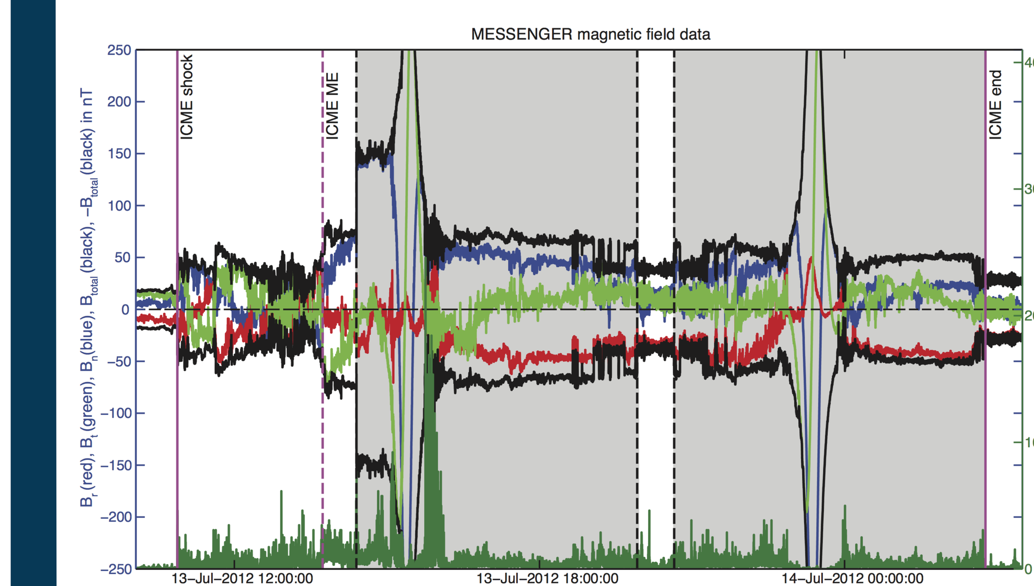


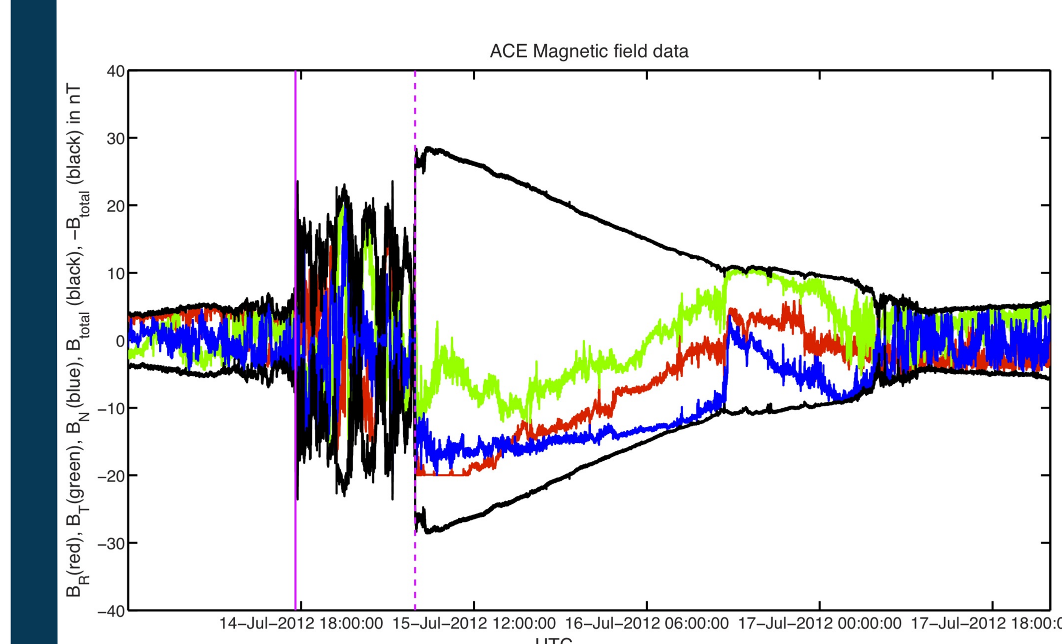


- ICME magnetic shock compression ratio higher at MESSENGER (1.97) than at STEREO (1.64). ICME deceleration may explain the lower mean shock compression at 1 AU compared to that at Mercury.

5. Example ICME: 12 July 2012 Event

- Observed by MESSENGER and ACE
- Illustrates that this ICME database can be used for both model validation and propagation studies of events observed in conjunction.
- Some of the large-scale structure is retained in propagation (B_R stongly negative at both distances)
- Non-dimensional expansion rate of the cloud confirmed by two separate methods at Mercury and ACE to be: $\zeta = \frac{\Delta V_x D}{\Delta t V_c^2} \sim 0.9$





- Compare to model predictions of Hess & Zhang [2014] for this event, which fit remote-sensing observation a posteriori to the semi-empirical drag model of Vrsnak et al. [2013].
- Model does quite well at estimating sheath size and arrival time at Mercury: