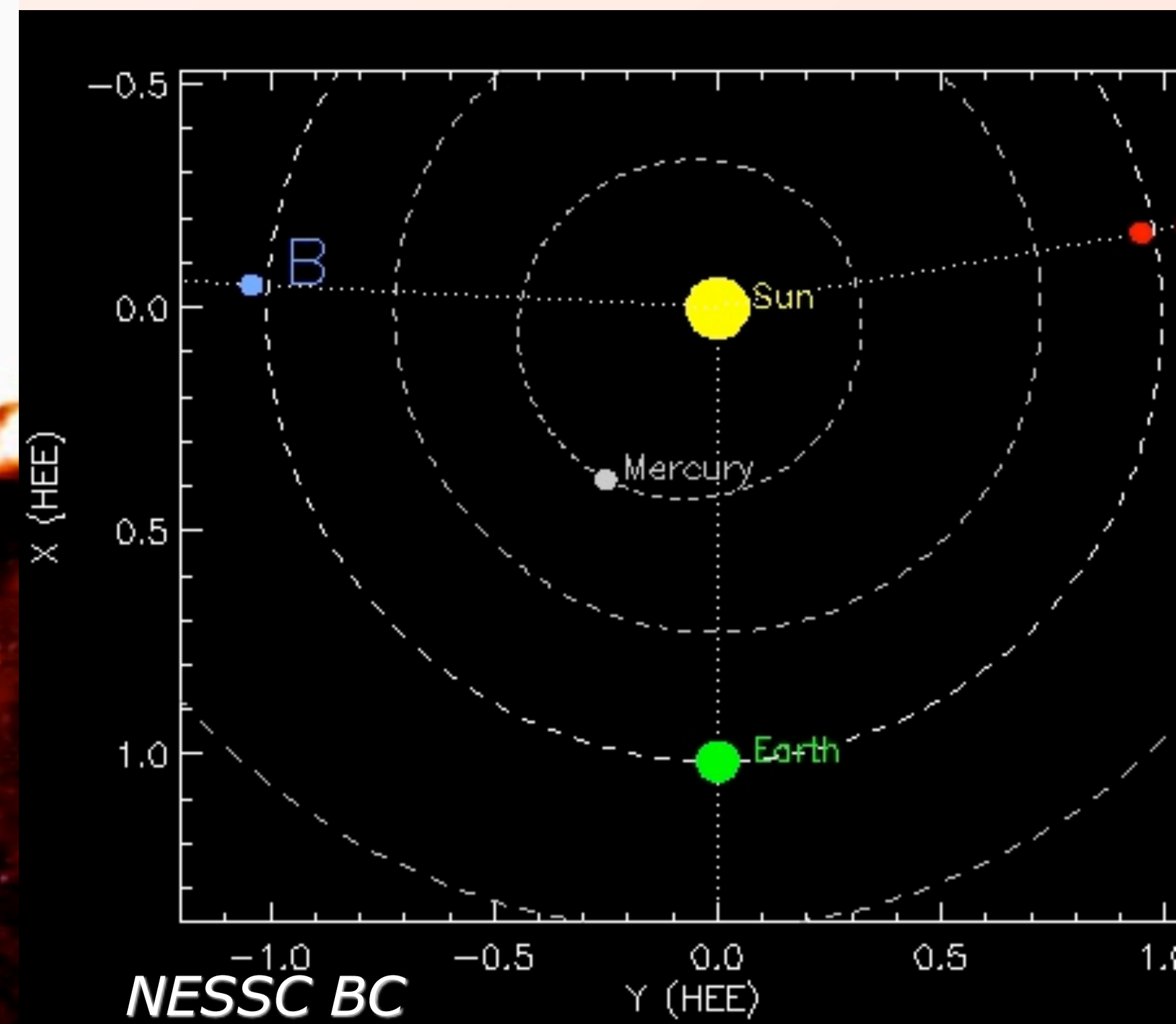




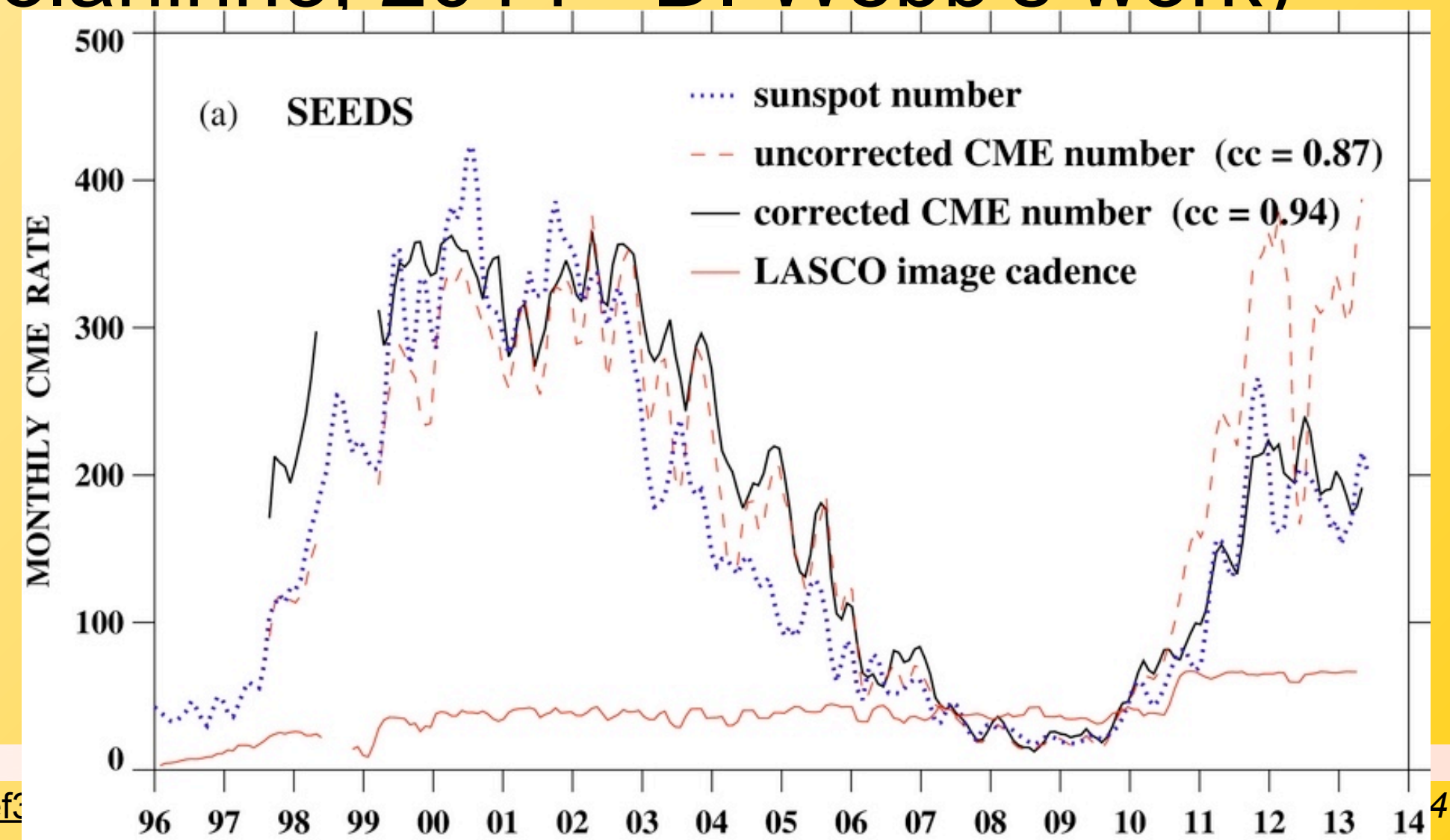
Complex Events in SC23 & 24

Noé Lugaz (University of New Hampshire)

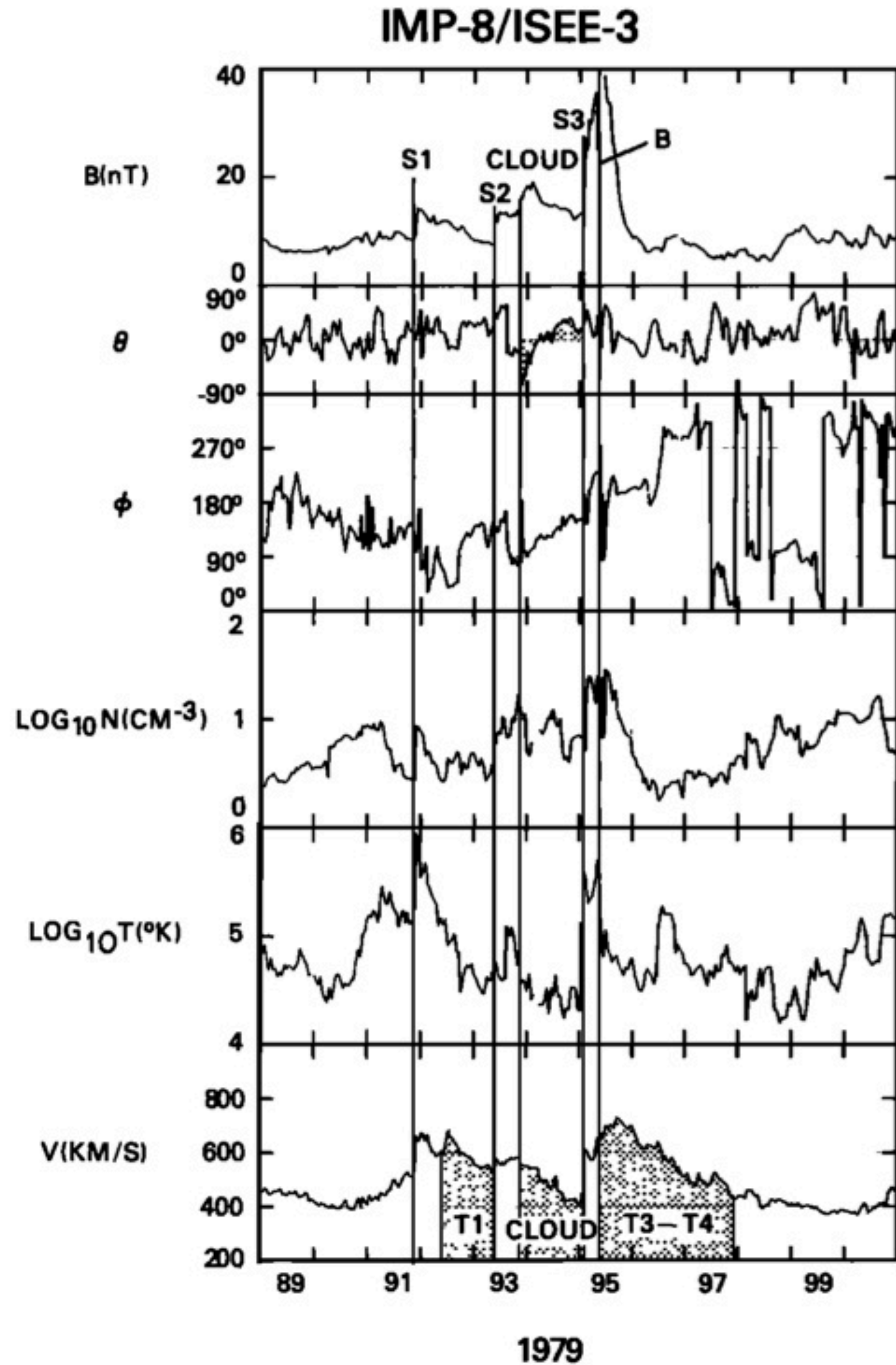


Complex events as source of geo-effectiveness

- ☀ CME causes ~85% of intense geo-magnetic storms (Zhang et al., JGR, 2007) and 40% of moderate storms (Echer et al., JGR, 2013).
- ☀ Superstorms are often caused by successive (ex: Halloween storm) or interacting CMEs: 6 out of the 16 largest input of the magnetosphere from SC 23 were due to interacting CMEs (ex: March-April 2001) (Farrugia et al., 2006). Large Dst drop due to CME-CME interaction (Cerrato et al., 2012).
- ☀ CME-CME interaction “got into the light” thanks to LASCO/C3 larger field-of-view in the solar max of SC23.
- ☀ Solar activity is down during SC (Wang & Colaninno, 2014 - D. Webb’s work)
- ☀ Larger field-of-view of HI1-2 should bring similar new detection of interacting CMEs.



Complex events as source of geo-effectiveness

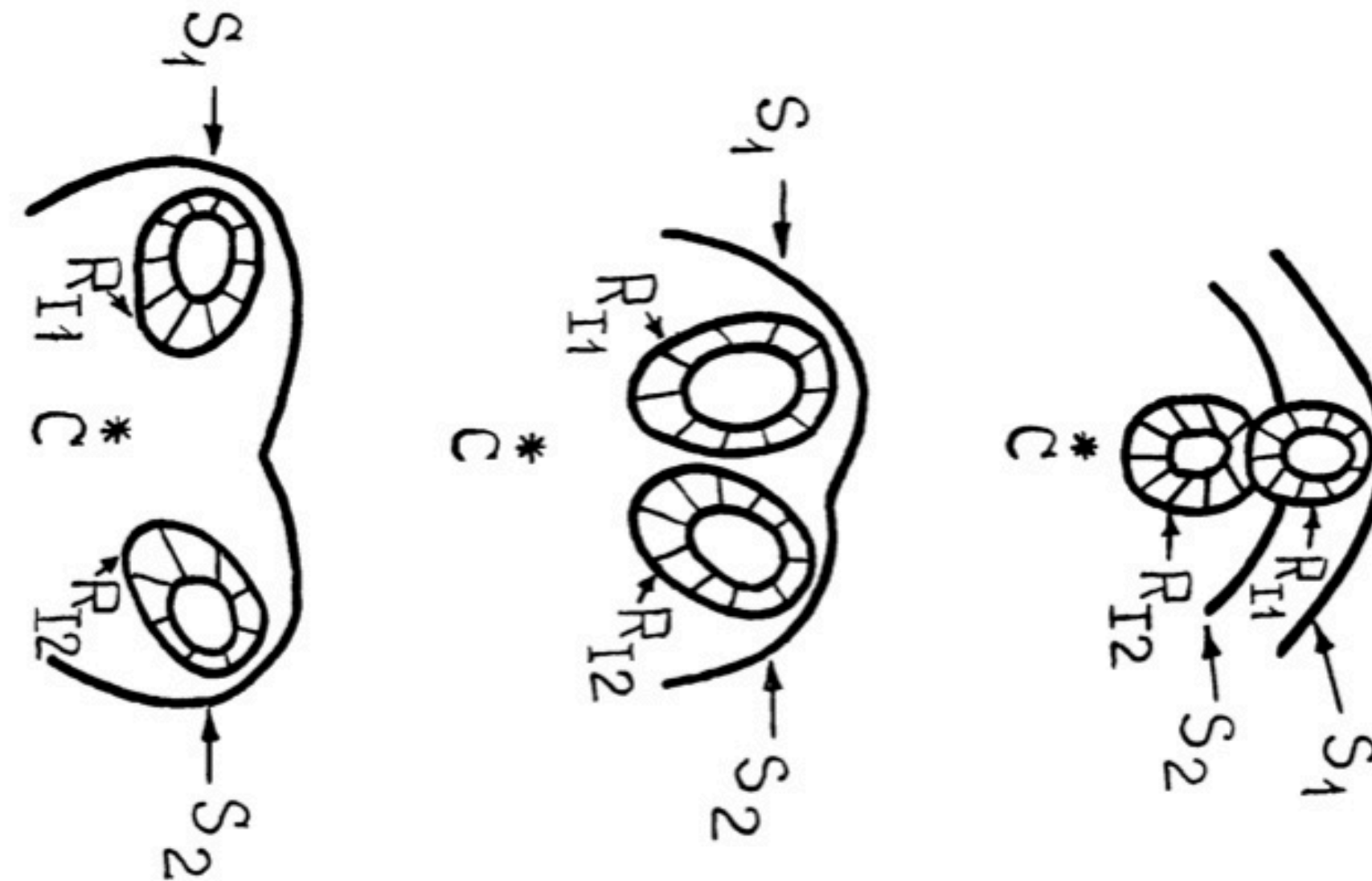


geo-magnetic storms (Zhang et al., JGR, 2007) and
 et al., JGR, 2013).

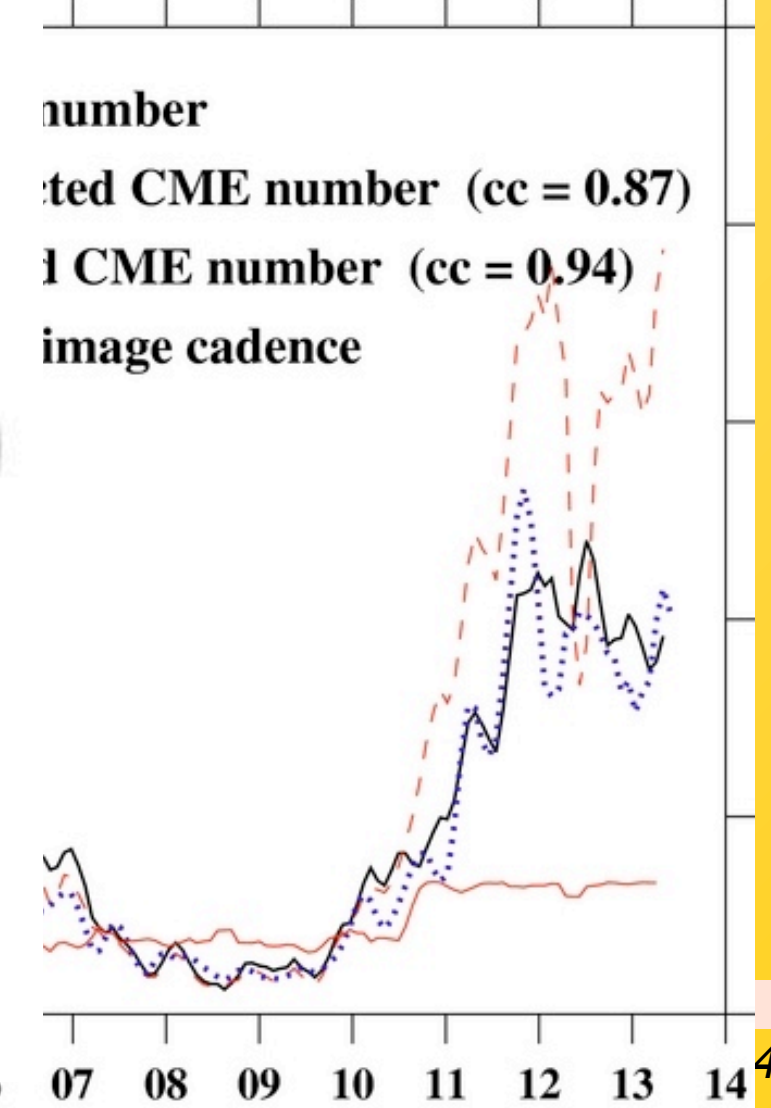
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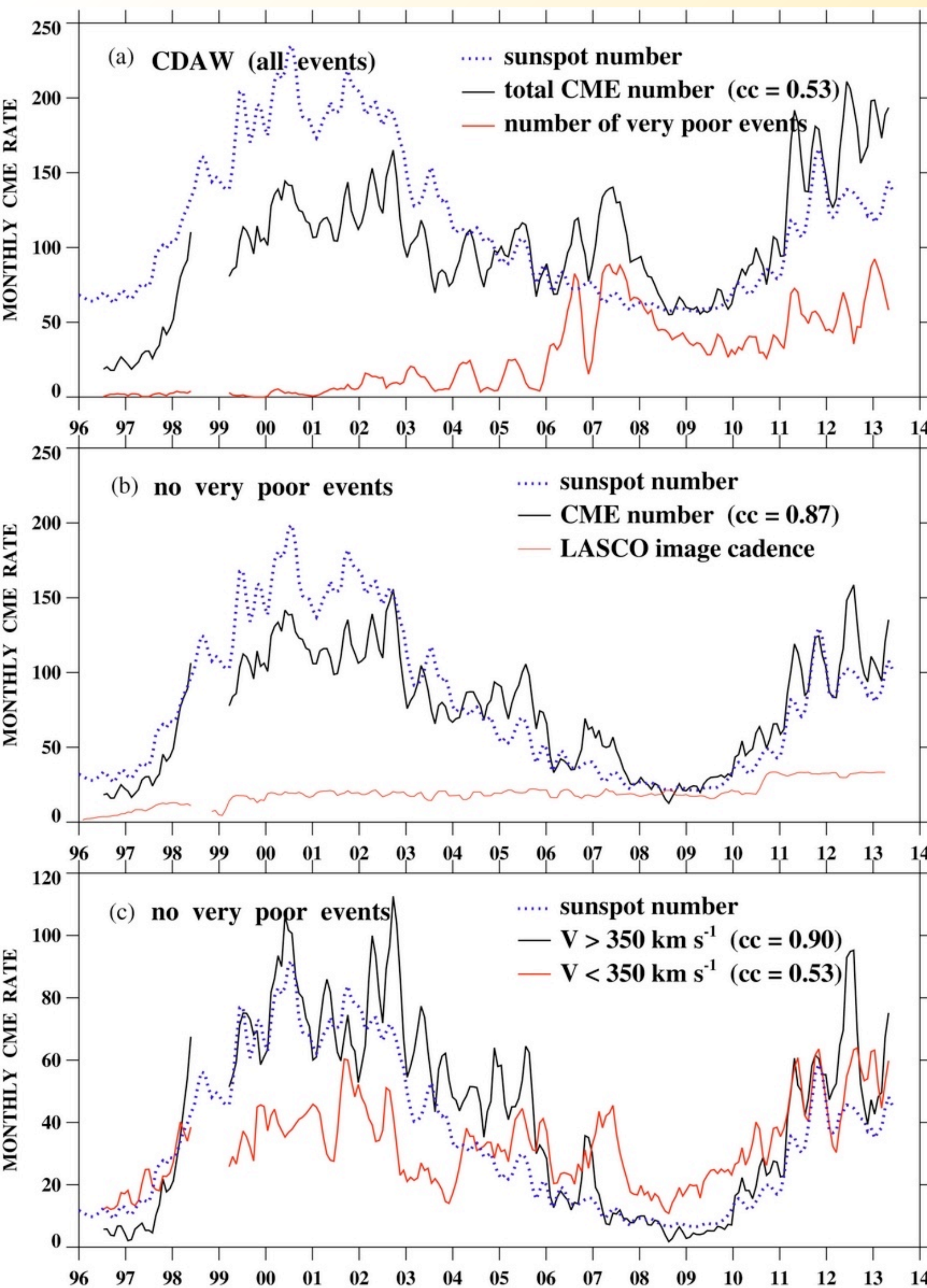


bb's work)



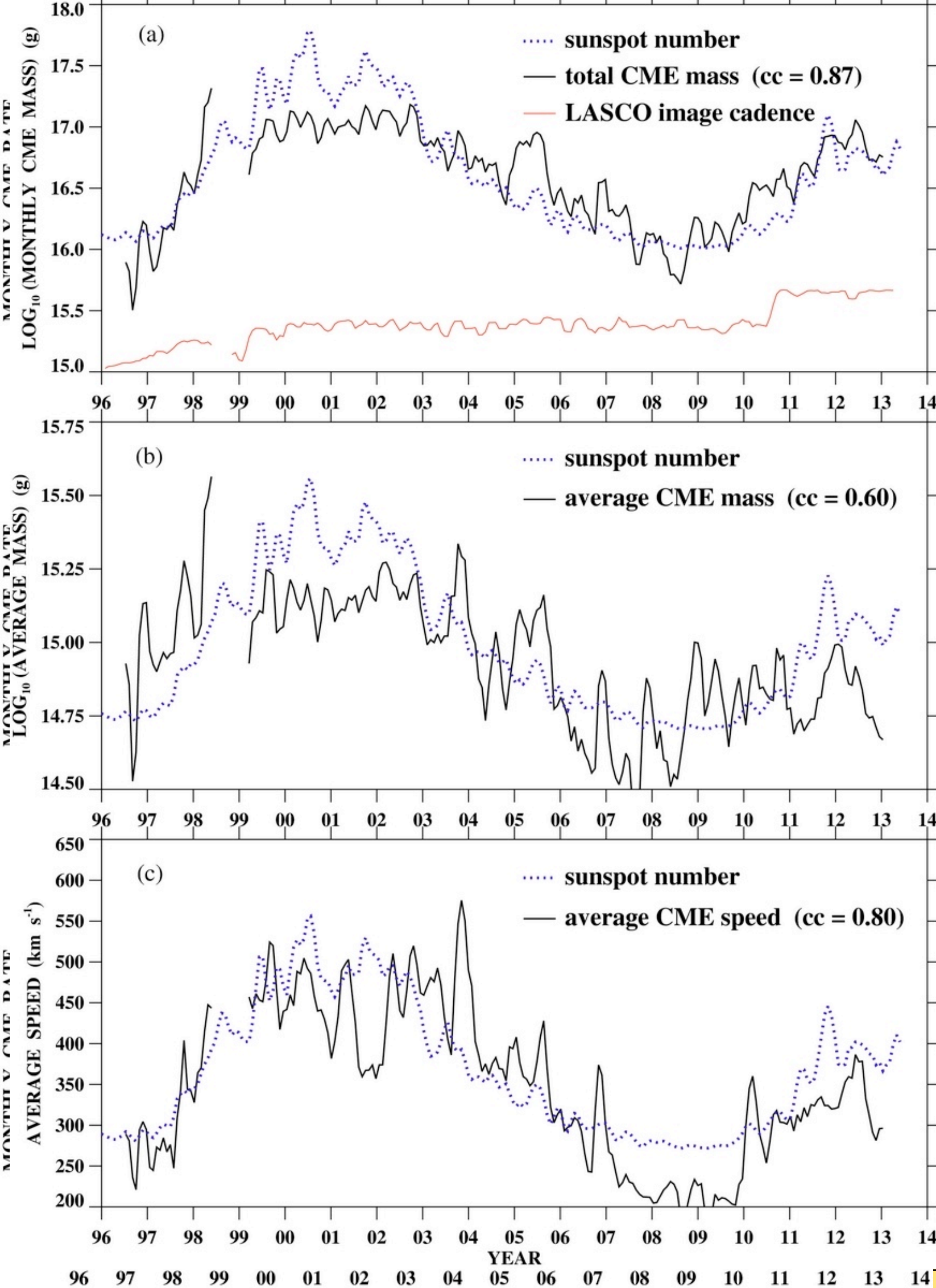
A bit more about CMEs

- ☀ Wang & Colaninno, 2014
 - ◆ Apparent increase or similar rate of CMEs from SC23 to SC24.
 - ◆ Part is more things are qualified as CMEs (small, weak, less dense), especially with automatic catalogs (SEEDS, CACTUS)
 - ◆ Major part is increase of LASCO observations rate.
 - ◆ Some studies have found that skipping every other frame has a major effect on detected rate.
 - ◆ Consistent with Webb & Howard (1994).
 - ◆ Slower and less massive CMEs.
 - ◆ Seems to imply little effect from the weakening field.



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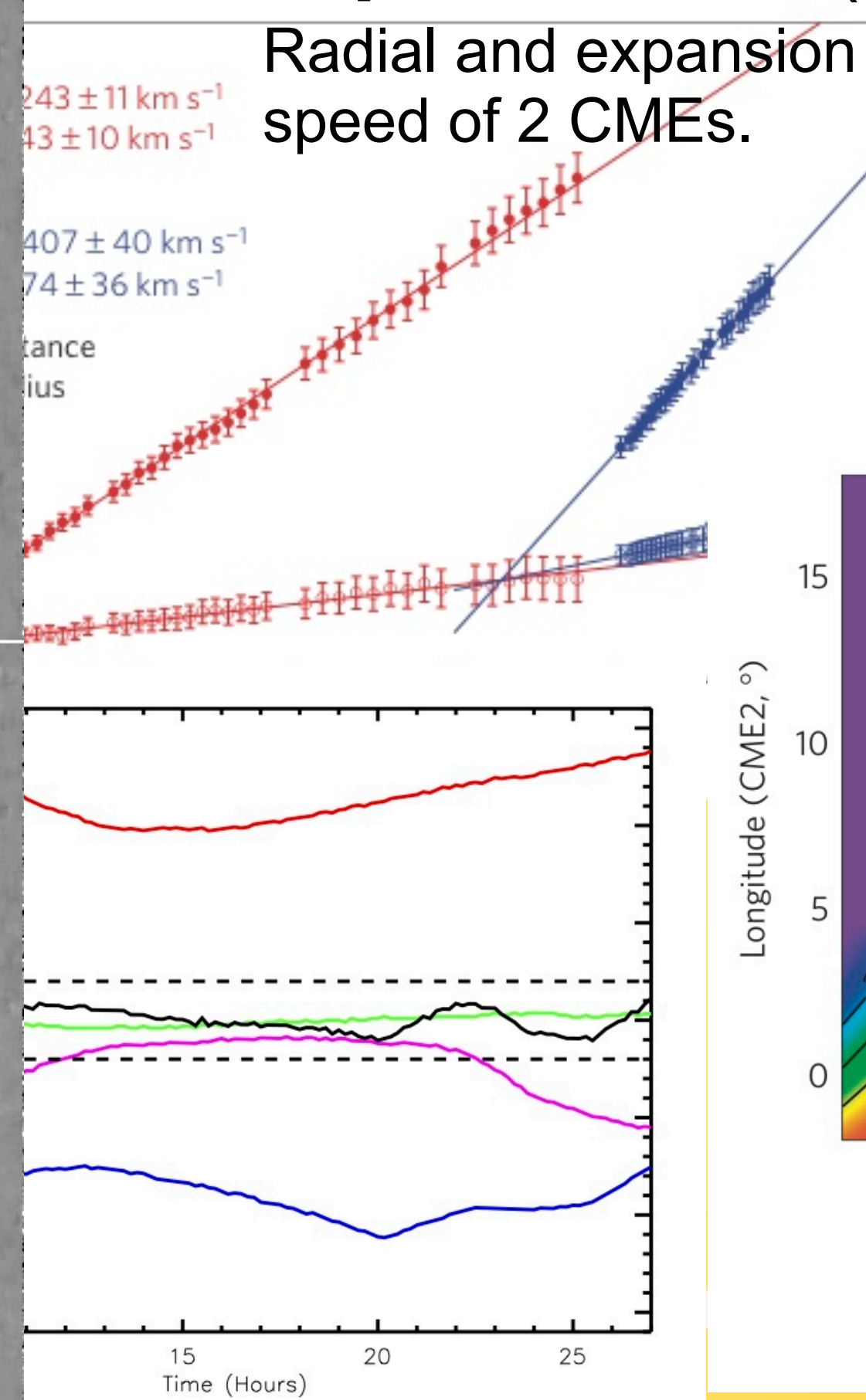
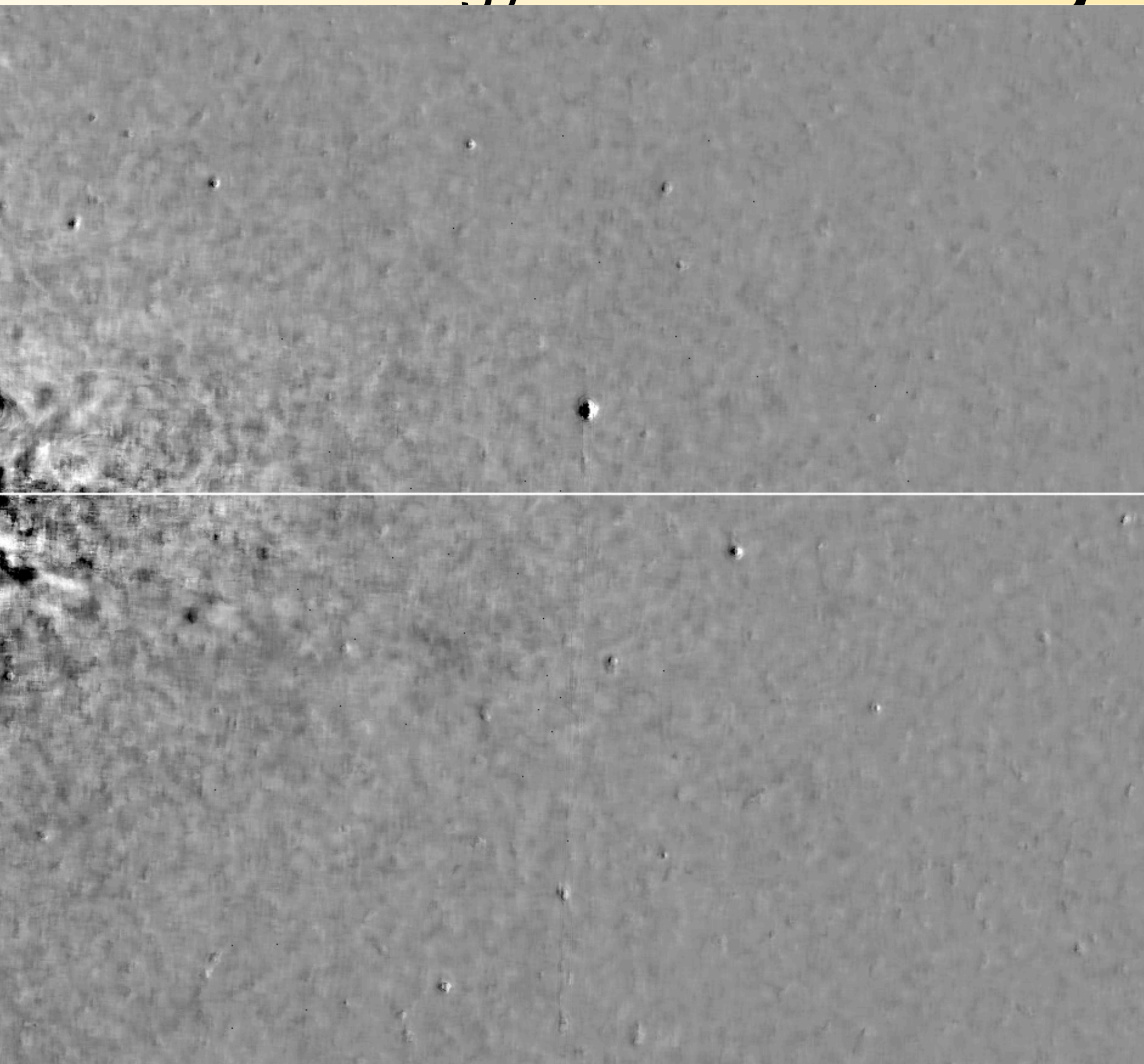


RAL Oxford meeting

- ☀ Meeting in 2014 March 17-21 with ~25 scientists to focus only on CME-CME interaction and associated particle acceleration.
 - ❖ Mario Bisi; Sergio Dasso ; Jackie A. Davies; Pascal Démoulin; Charles J. Farrugia; Adriana Gulisano; Mike Hapgood; Richard Harrison ; Tim Howard ; Benoit Lavraud; Gang Li; Noé Lugaz ; Olga Malandraki; Huw Morgan; Matt Owens; Athanasios Papaioannou; Fang Shen; Manuela Temmer; Rami Vainio; Bojan Vrsnak; Yuming Wang ; Francesco Zuccarello; Nathalia Alzate; Rahul Sharma; Wageesh Mishra; Simon Good
- ☀ SC24 focus on multiple/interacting CMEs (SDO + HIs)
 - ❖ August 2010 event (Liu et al., 2012; Temmer et al., Harrison et al., Moestl et al., Webb et al., 2013)
 - ❖ May 2010 CMEs (Lugaz et al., 2012)
 - ❖ February 2011 (Maricic et al., Temmer et al., 2014)
 - ❖ January 2012 (X. Cheng et al., 2013; Liu et al., 2013)
 - ❖ March 2012 (Liu et al., 2013)
 - ❖ November 2008 (C. Shen et al., 2012)
 - ❖ Initiation simulations (Török et al., 2011; Lynch et al., 2013; Chatterjee et al., 2013)
 - ❖ Propagation simulations (Lugaz et al, 2013; F. Shen et al., 2013)
 - ❖ Radio observations (Martinez-Oliveros et al., 2012)
 - ❖ SEP (G. Li et al., 2012; Kahler & Vourlidas, 2014)

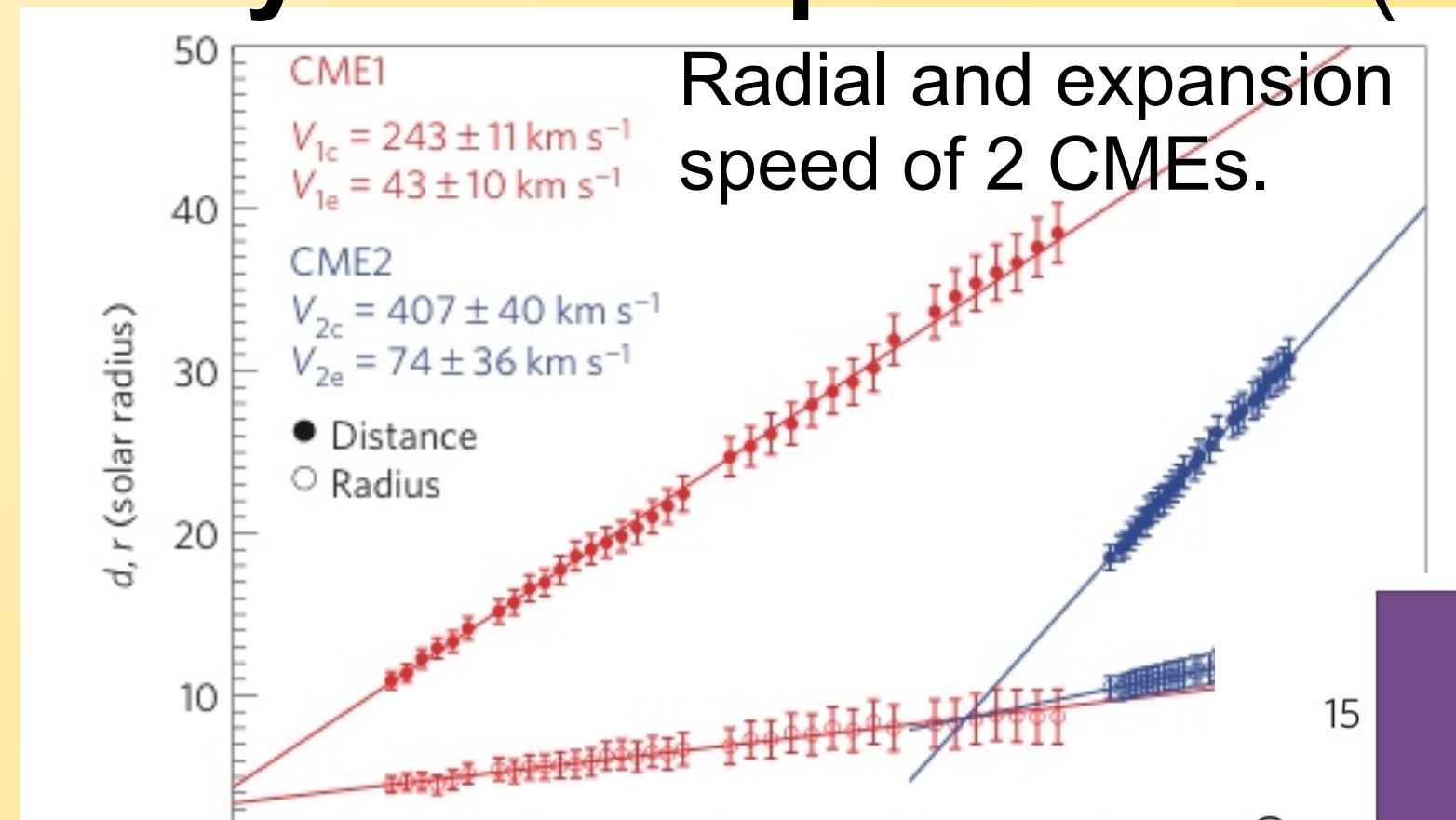
2008 November 2-3 CMEs: super elastic?

- ☀ 2 CMEs within about 22 hours and 20° from each other.
- ☀ Interaction lasted for ~ 16 hours, also resulted in small deflection.
- ☀ Speeds before and after the interaction consistent with a 6% increase in the kinetic energy. **Interaction likely to be super-elastic** (73% probable).

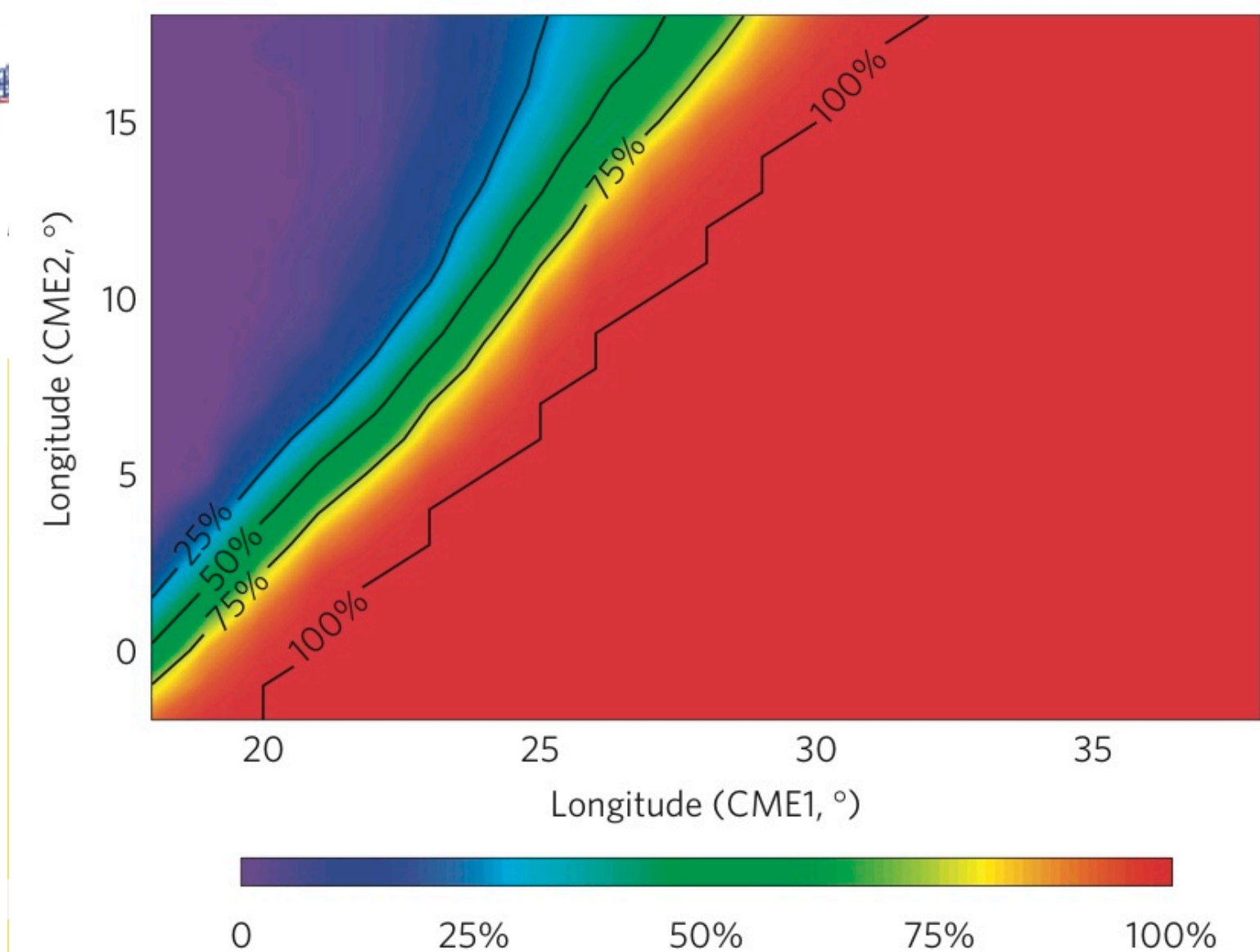
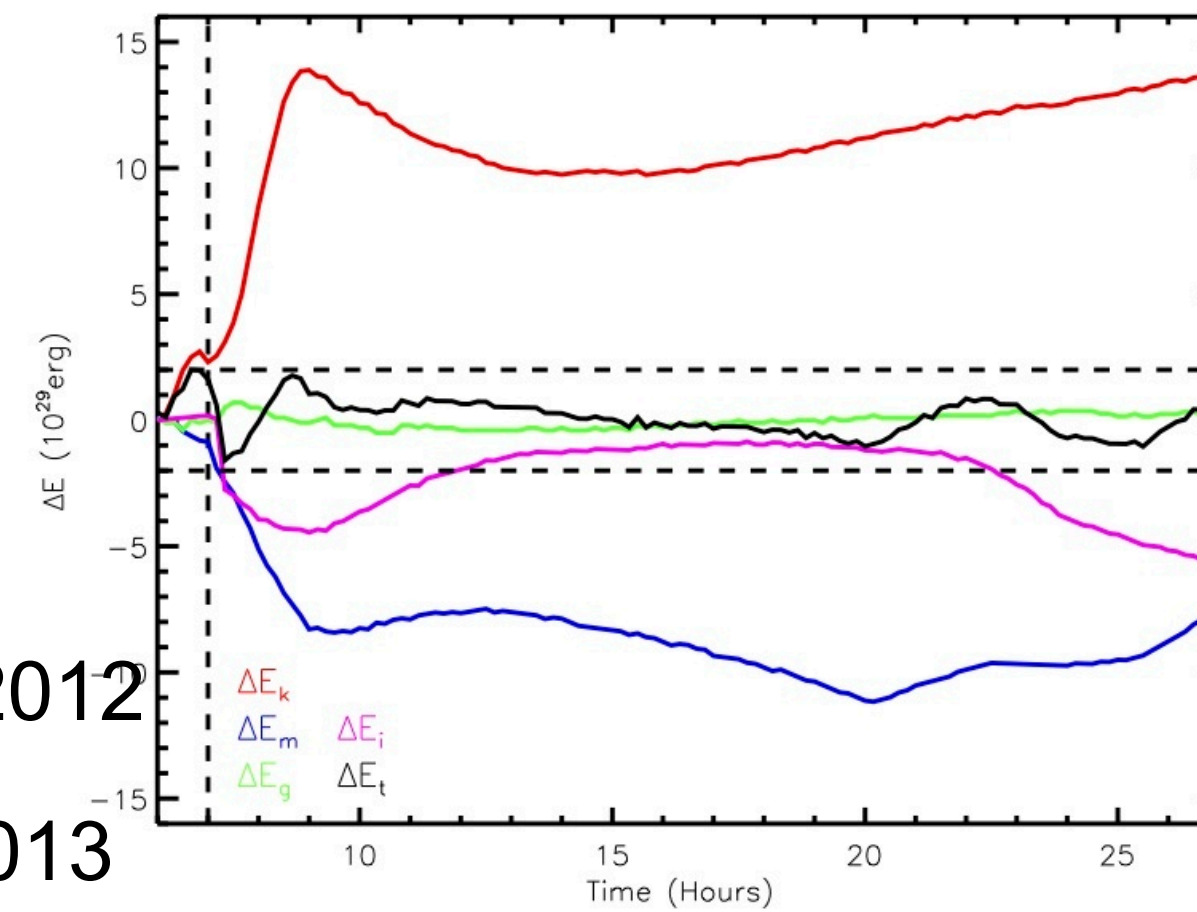


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Probability of super-elastic collision



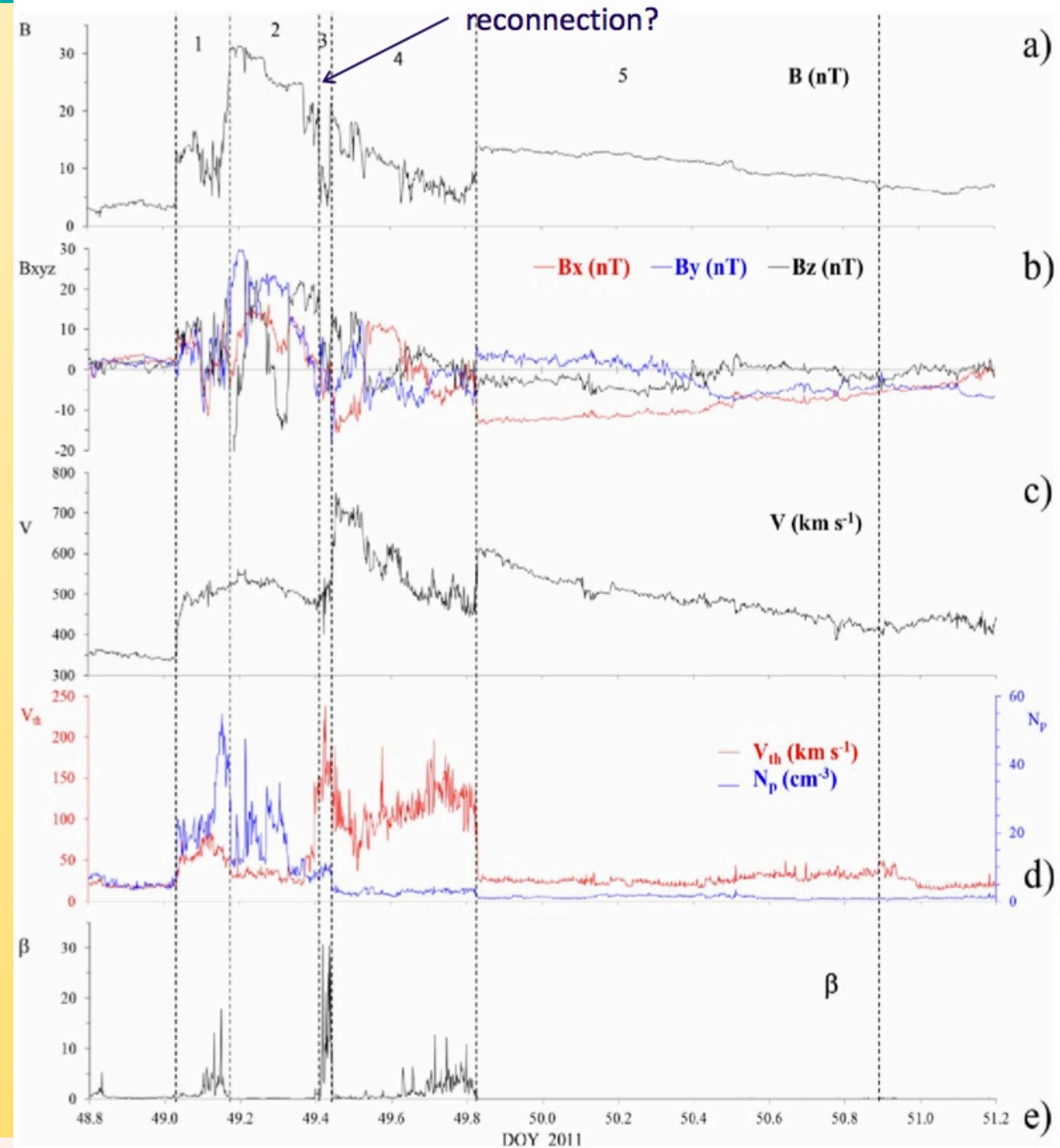
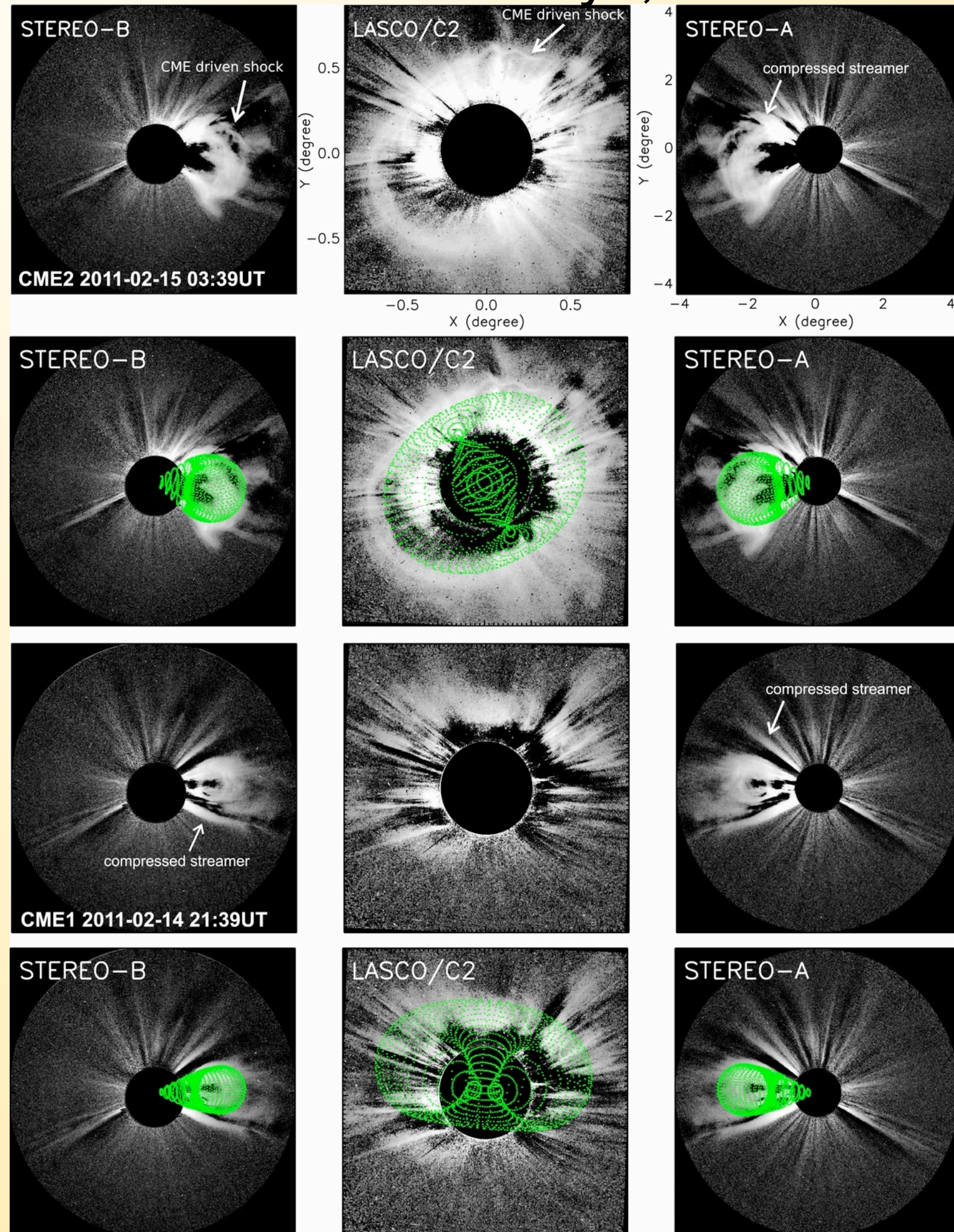
C. Shen, Y. Wang *et al.*, **Nature Physics**, 2012

F. Shen *et al.*, **GRL**, 2013

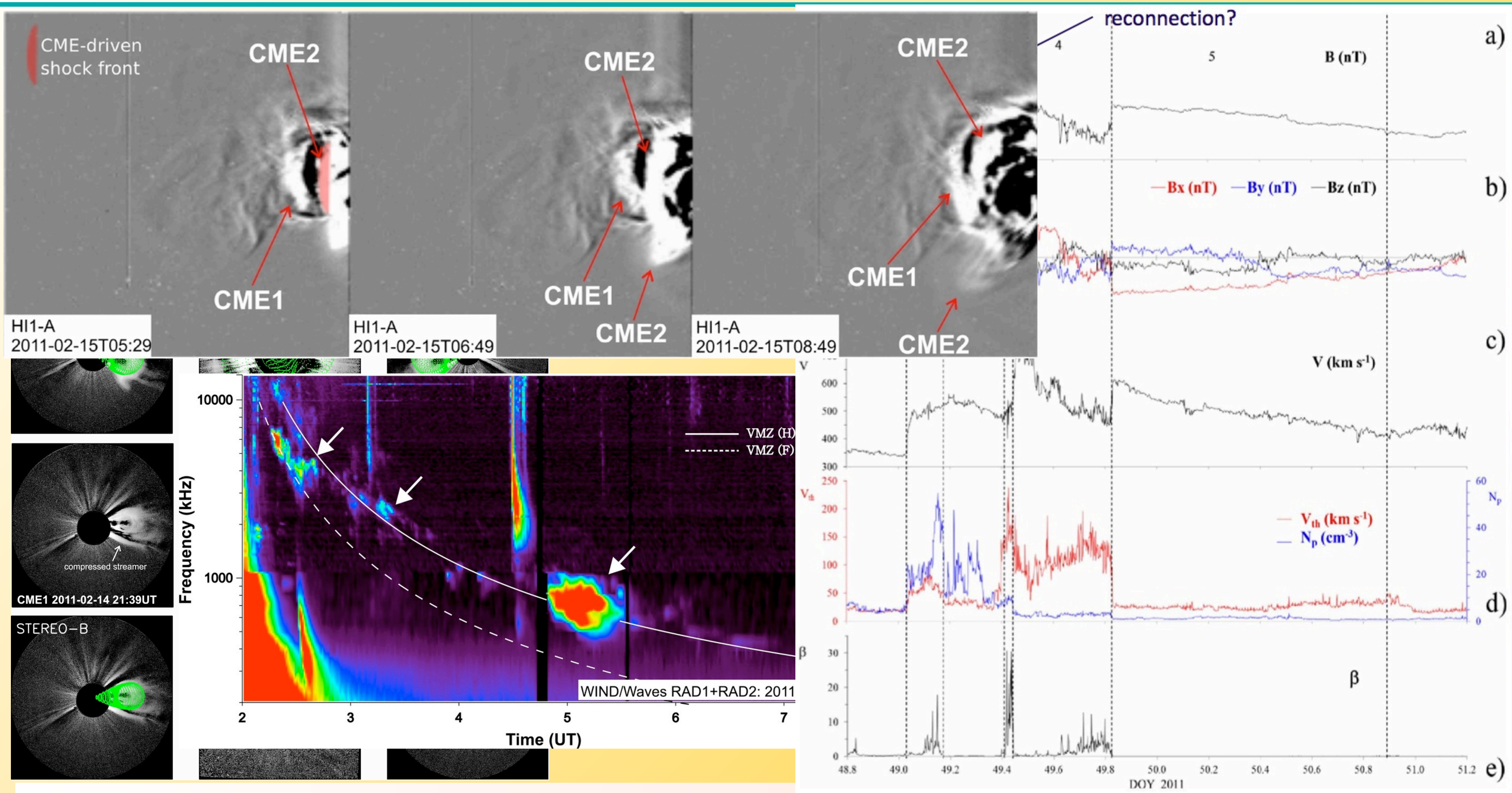
February 2011 event

Temmer et al, ApJ, 2014

Maricic et al. SolPhys, 2014

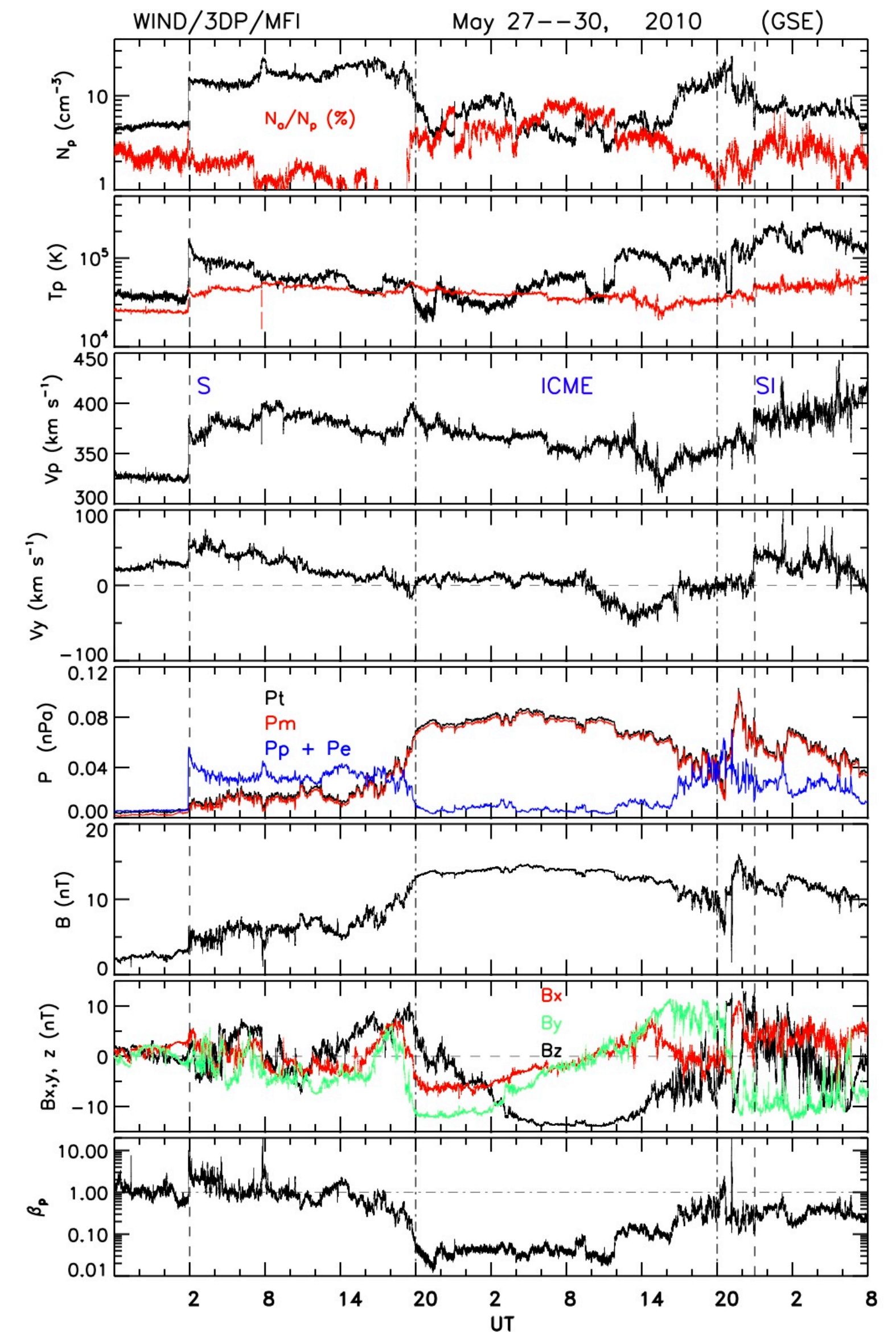
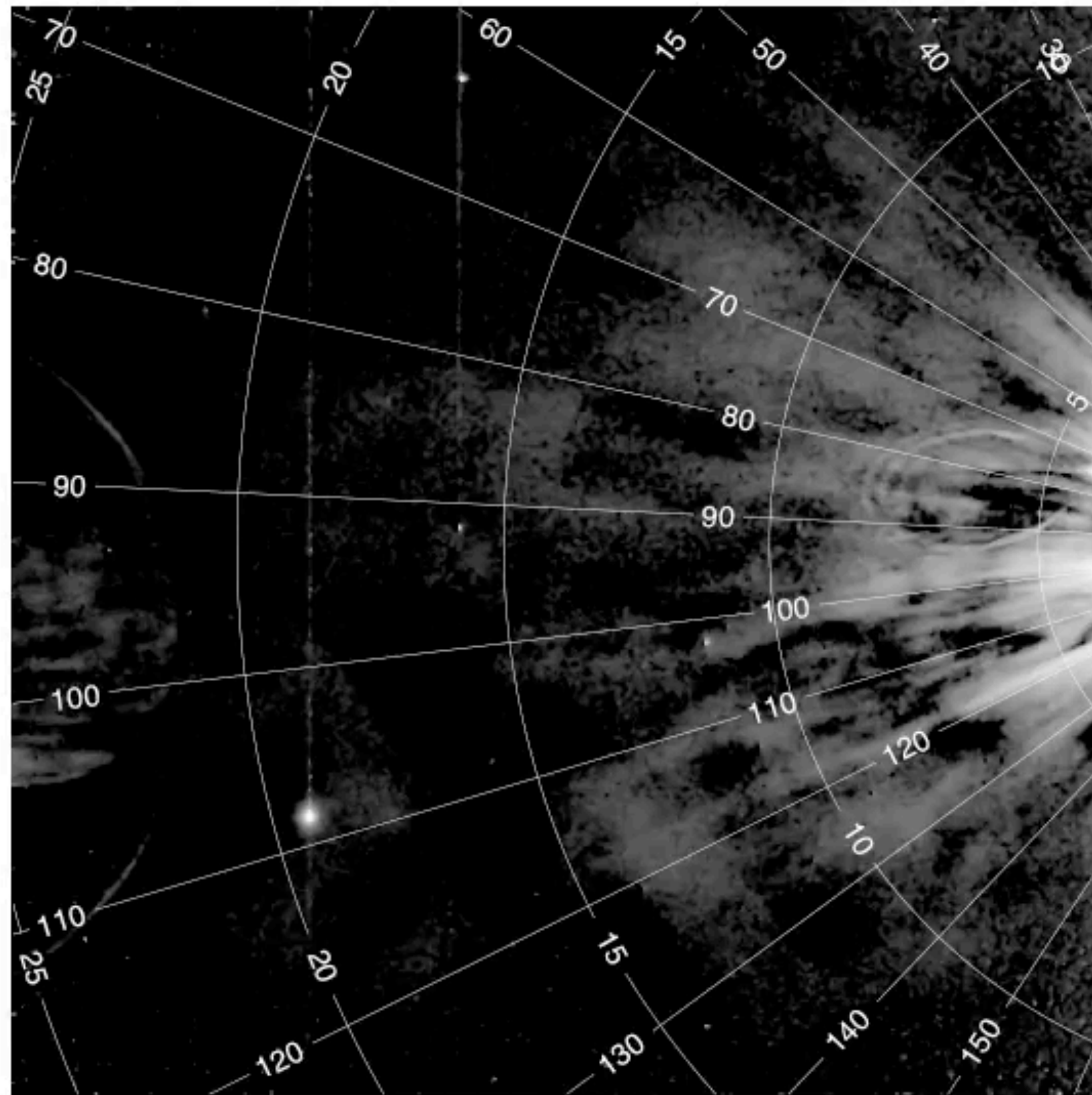


February 2011 event



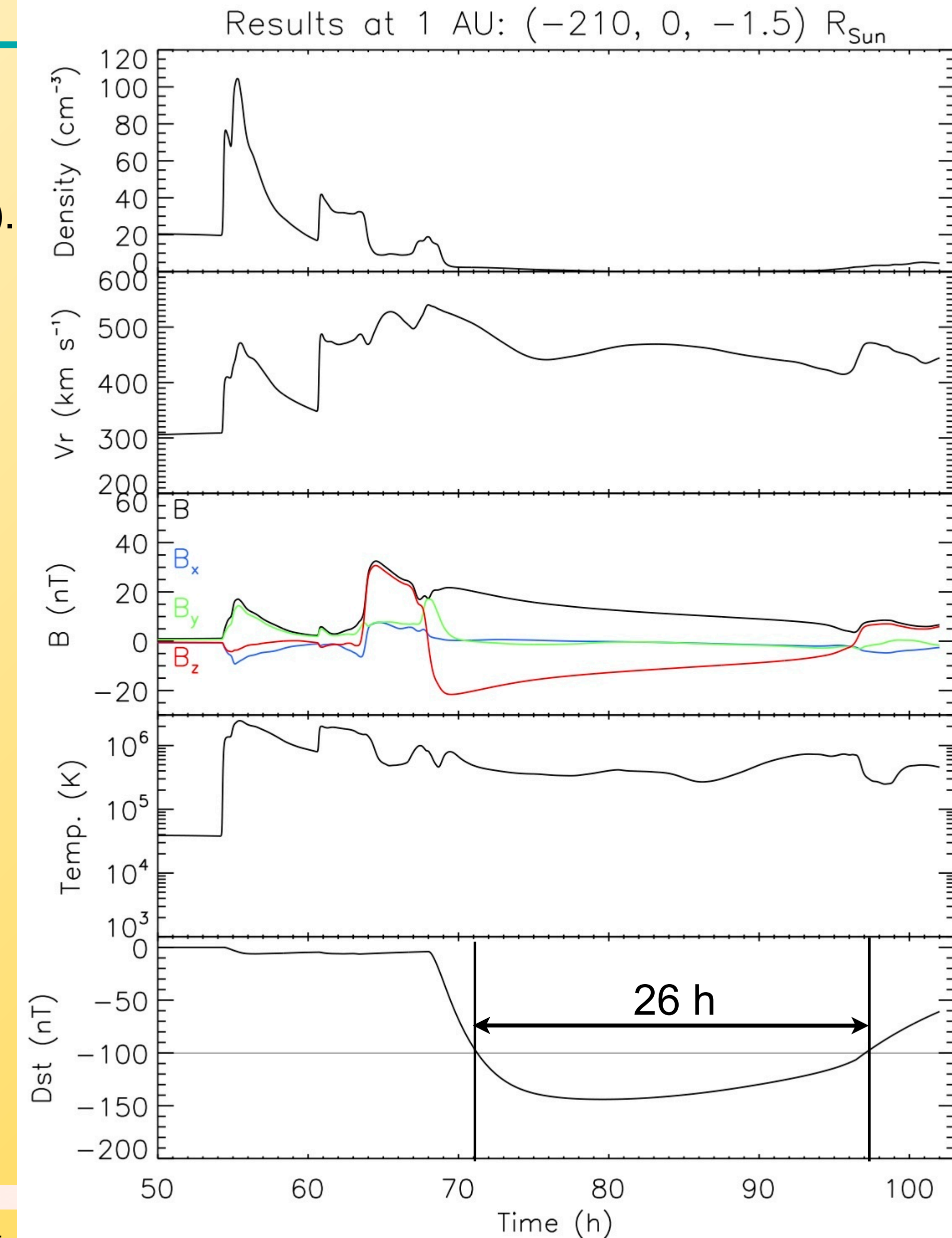
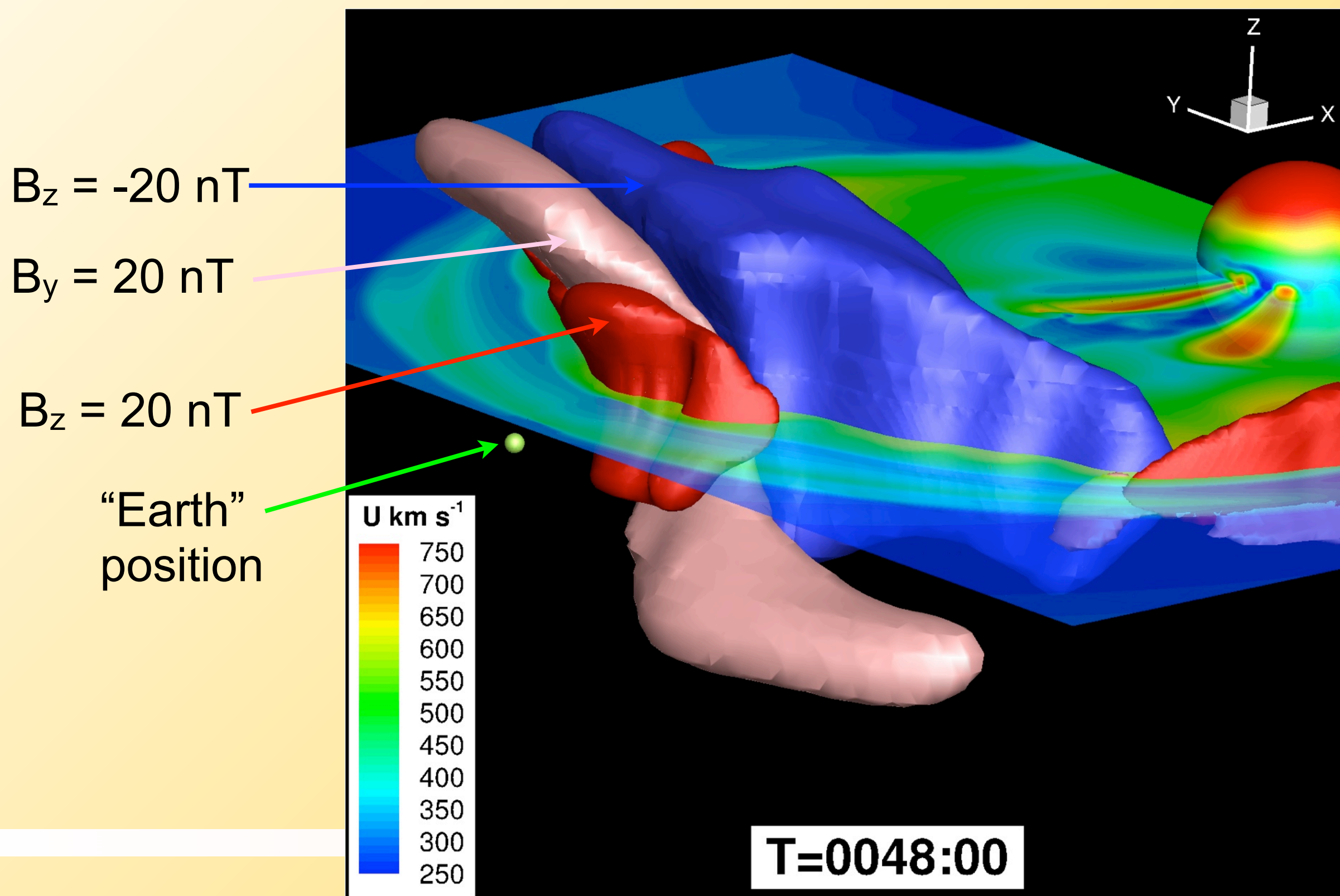
Seeing CME-CME interaction everywhere

STEREO-A HI-1
2010-05-23 17:29UT



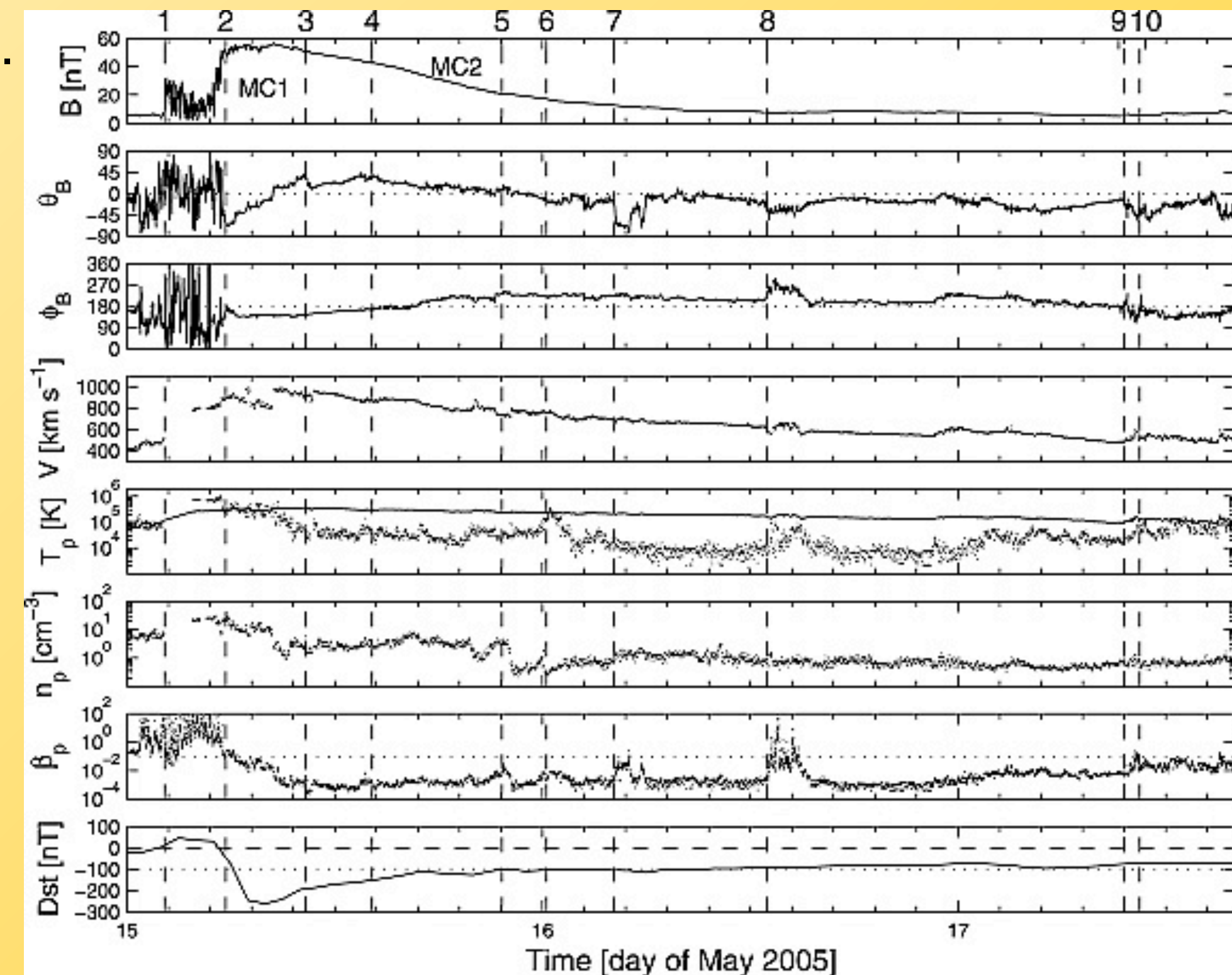
Synthetic satellite data at 1 AU

- ☀ We extended the NES-ESW simulation to 1 AU.
 - ❖ 14-hour dense sheath with multiple structures.
 - ❖ 30-hour long CME with 20+ hour of southward B_z tail (CME2).
 - ❖ CME2 is characterized by uni-directional B field (B_z south).
 - ❖ Dst calculated following O'Brien and McPherron (2000).
 - ❖ Dst < -100 nT for 26 hours; peak Dst = -144 nT.



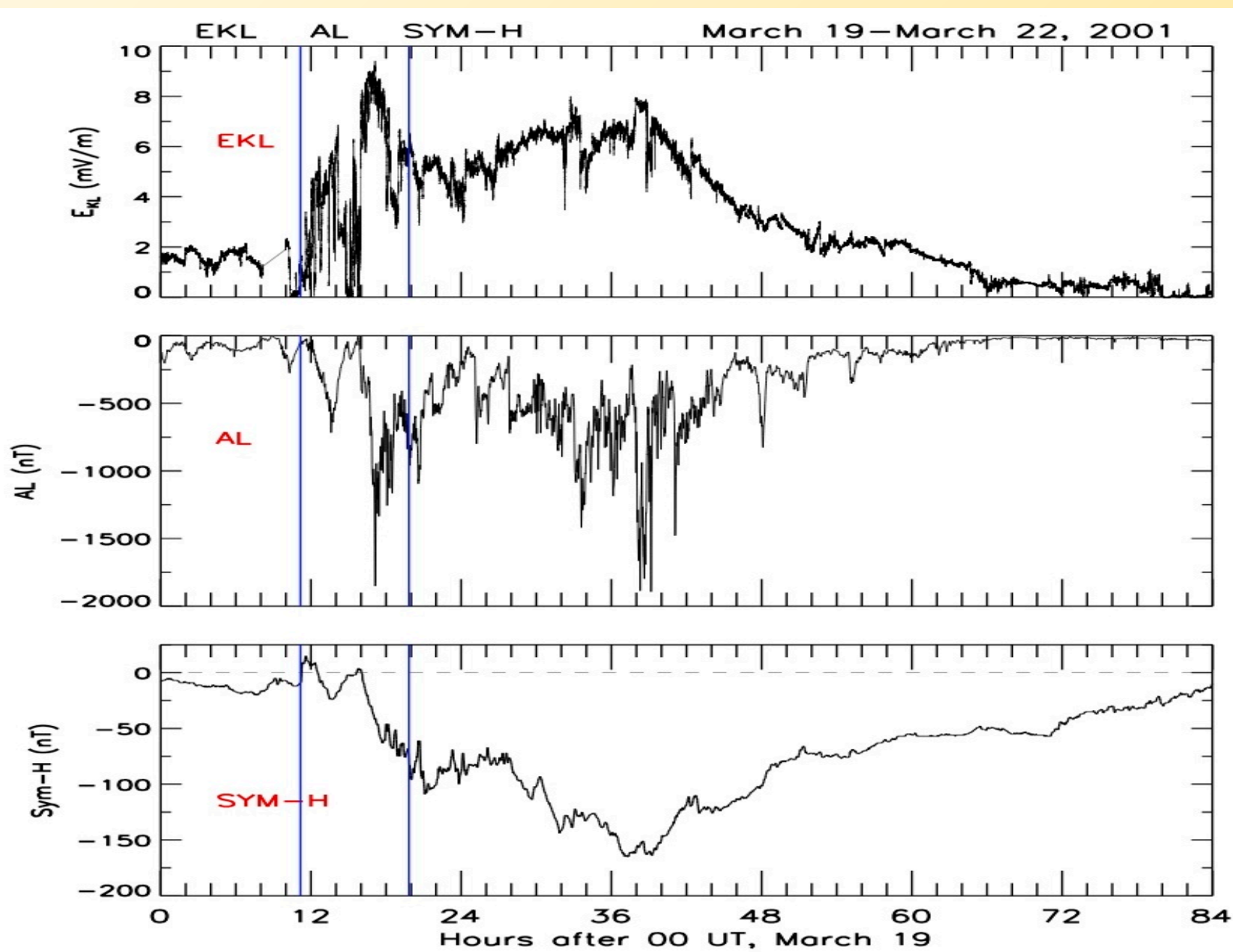
Does this exist in reality?

- ☉ One example from May 2005 event (Dasso *et al.*, **JGR**, 2009).
- ☉ We looked for long-duration MCs which may be 2 CMEs.
 - ❖ List of long-duration MCs by Marubashi & Lepping (2007).
 - ❖ March 19–22, 2001: 52 hours with low β , low T_p and high B.
 - ❖ Double-peaked intense storm with $Dst < -50$ nT for 55 hours.
 - ❖ Sawtooth event during 1st part; uni-directional B in 2nd part.



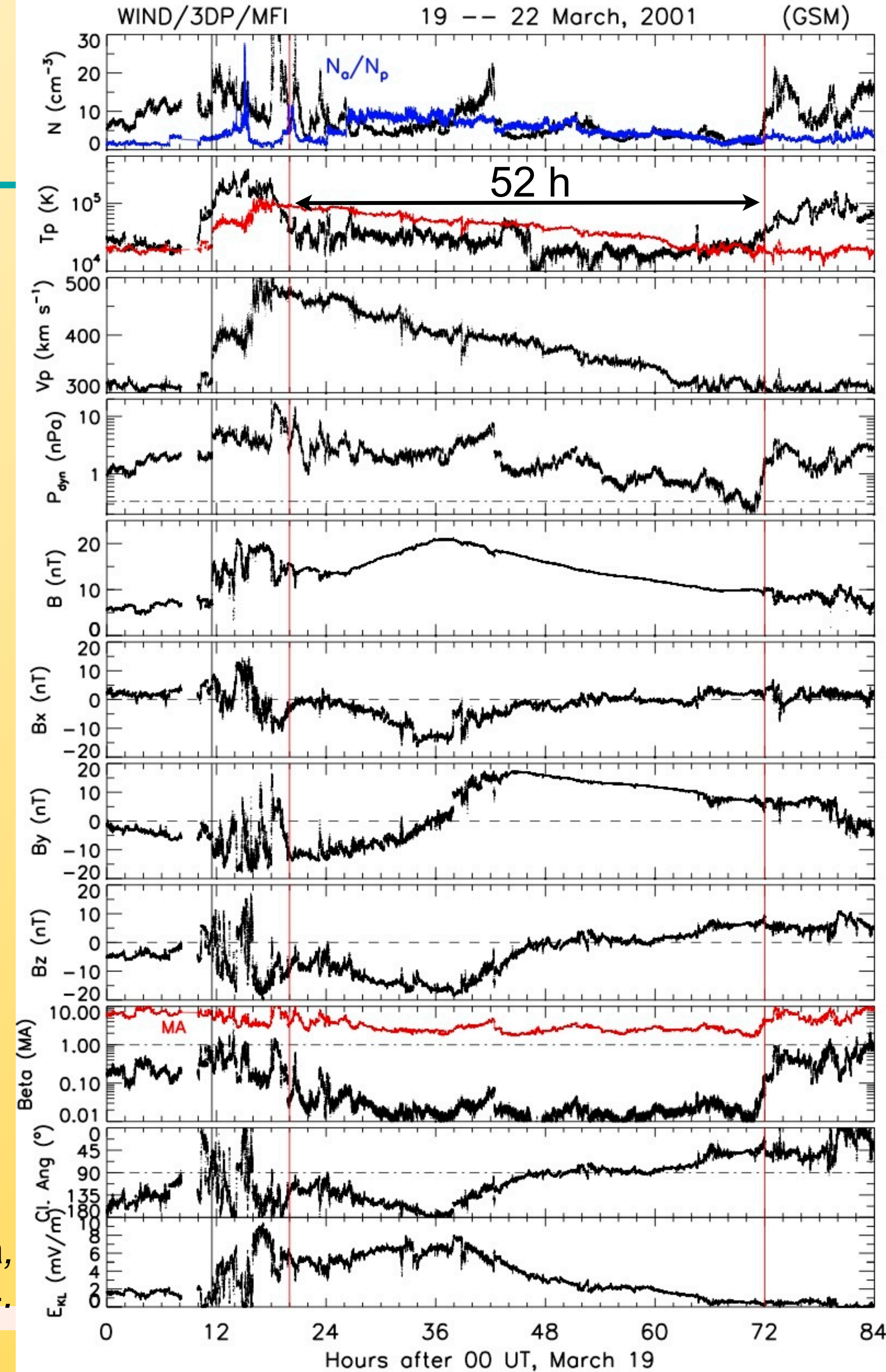
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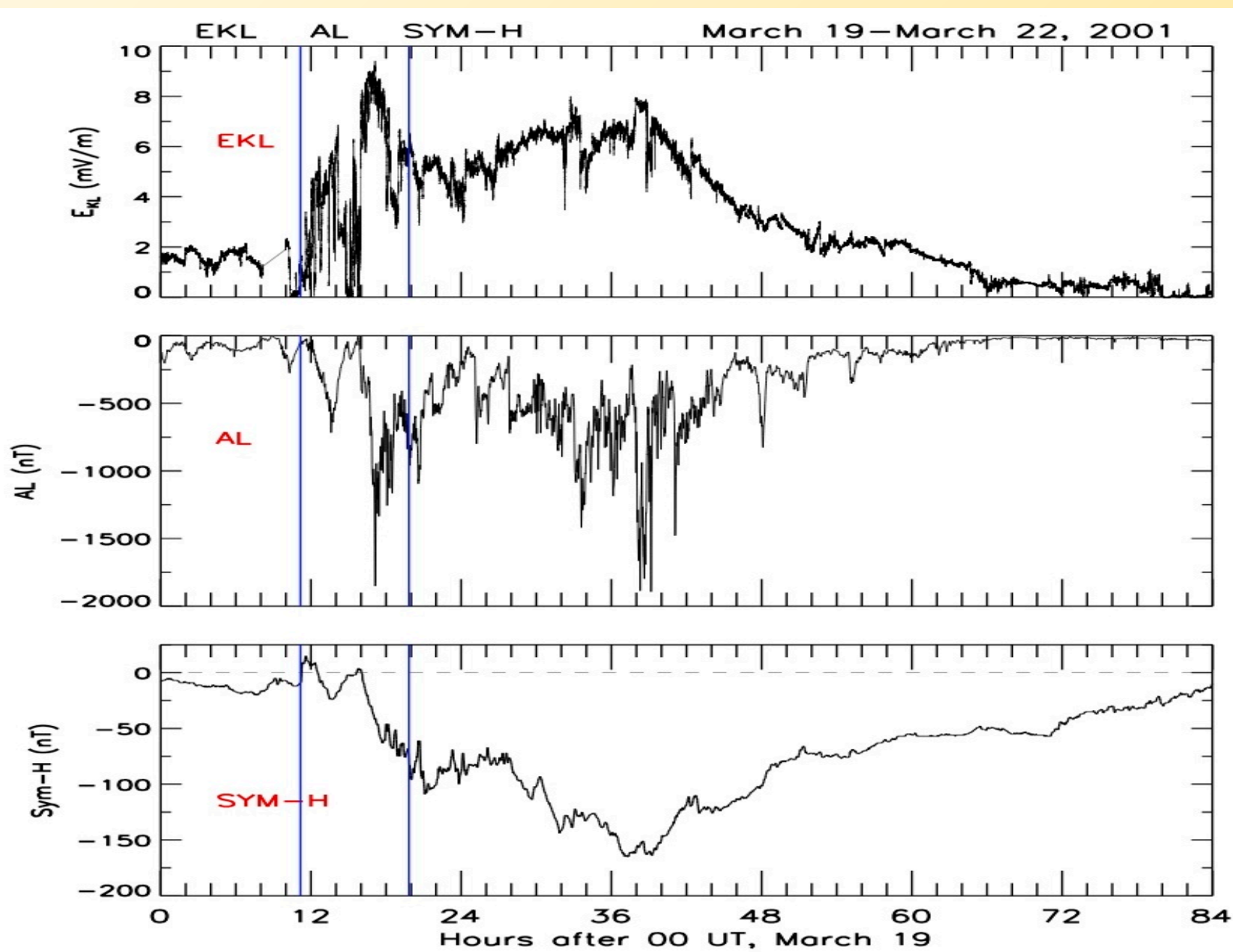
Lugaz & Farrugia,
GRL, 2014.

<http://pubpages.unh.edu/~nef32>



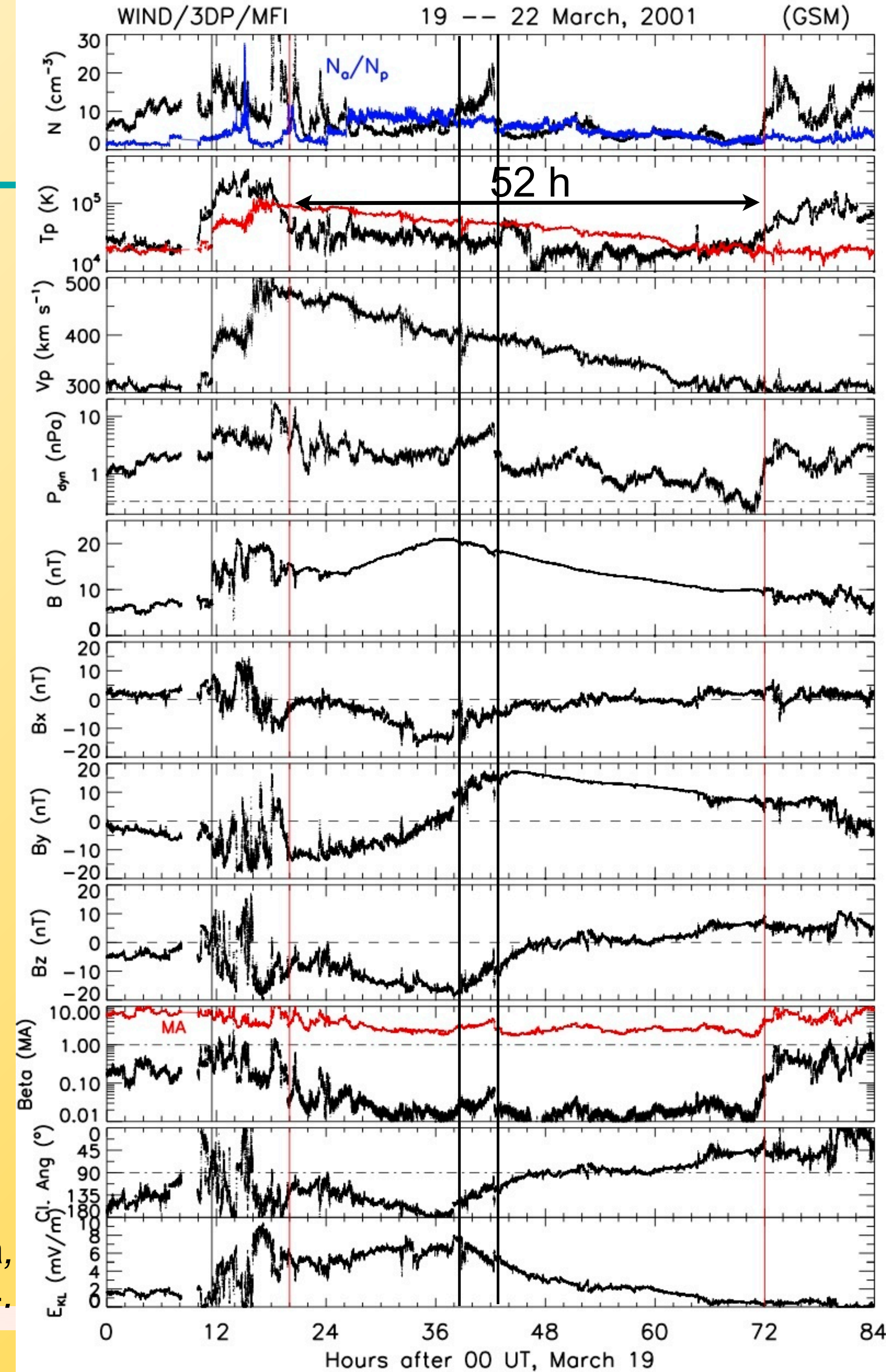
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