Overview of STEREO ICMEs during solar cycle 23 minimum

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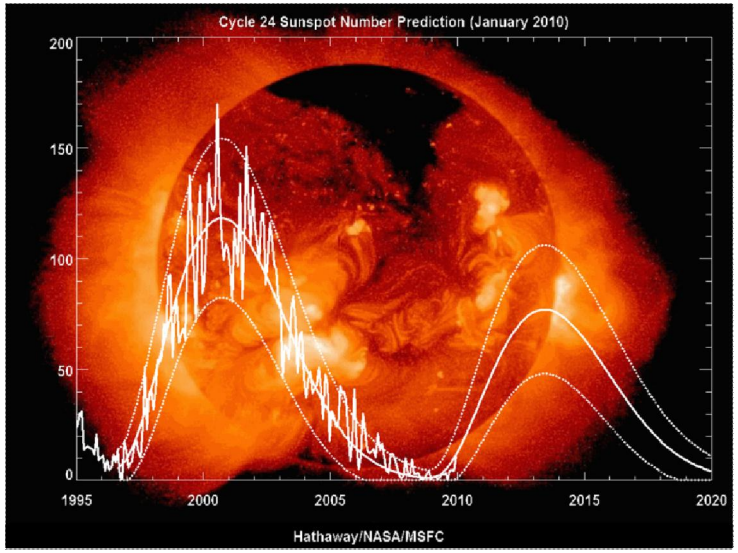
1. General properties of STEREO ICMEs

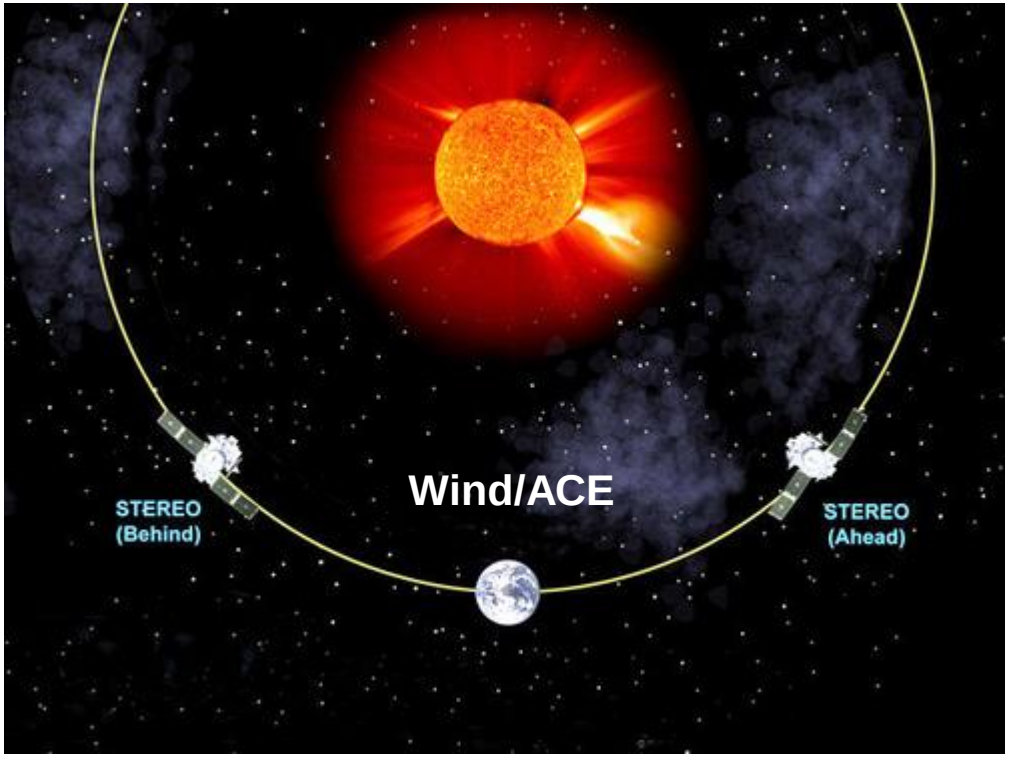
2. Multi-spacecraft ICME encounters

Data analysis

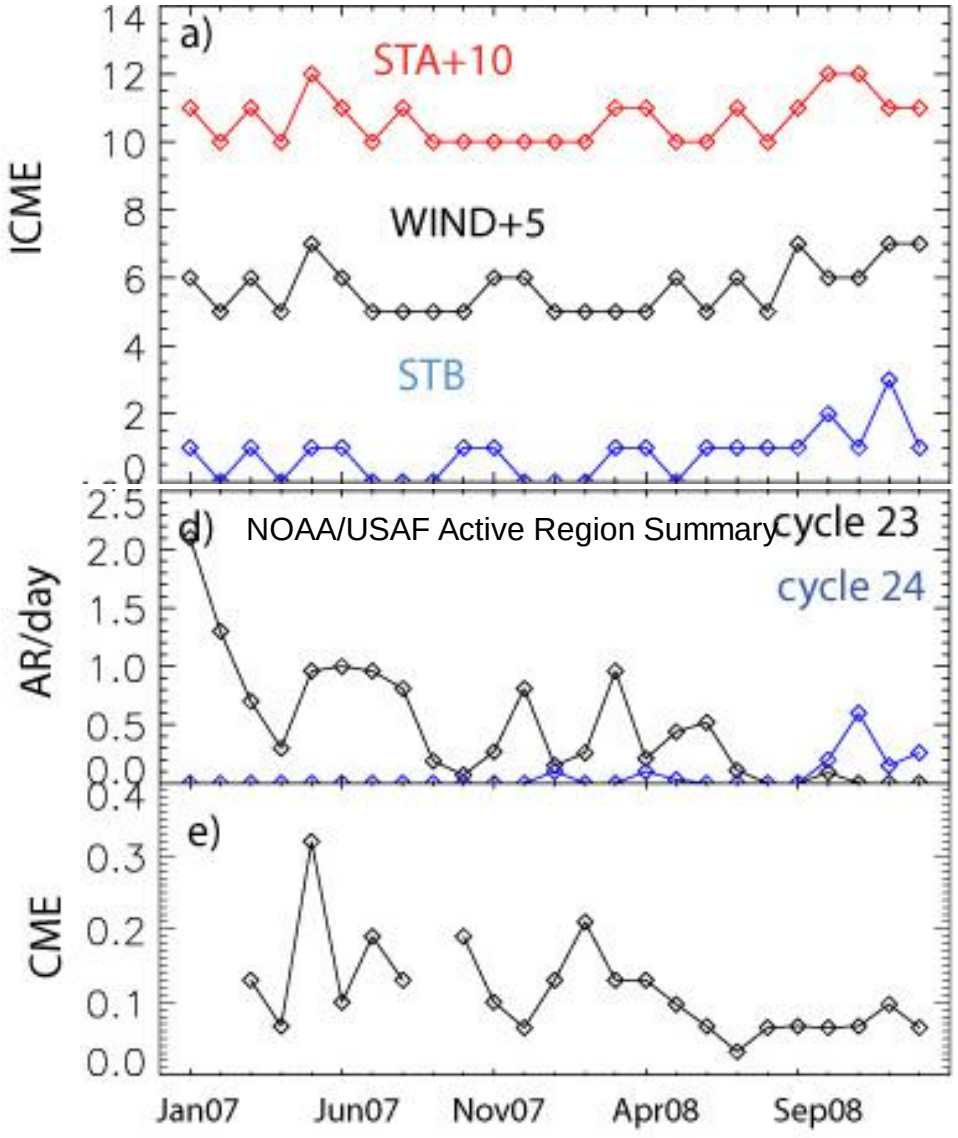
- ICMEs from January 2007 through October 2009

- Identified based on
  - magnetic field signatures (enhanced magnetic field magnitude, low variance, organized behavior of magnetic field direction)
  - counterstreaming suprathermal electrons
  - low plasma temperature, plasma beta





- ICMEs: Jan 2007 – Jan 2009
- required: B_{max} > 5 nT, duration > 3 hours
- total 41 ICMEs



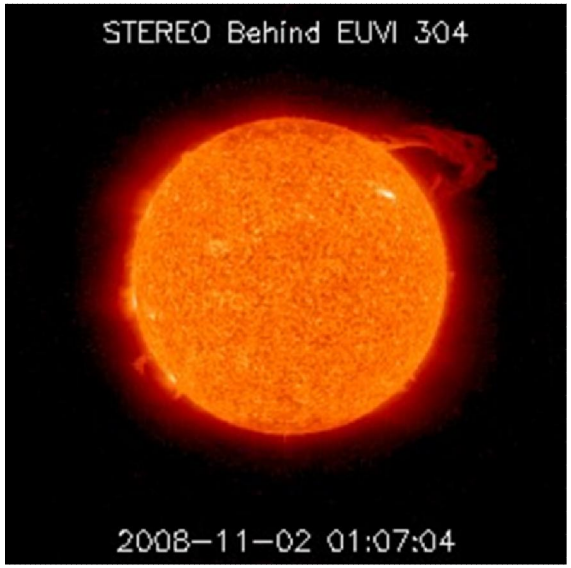
Jul 07 to Jun 08: 0.35 events/month
Aug 08 to Jan 09: 1.28 events/month

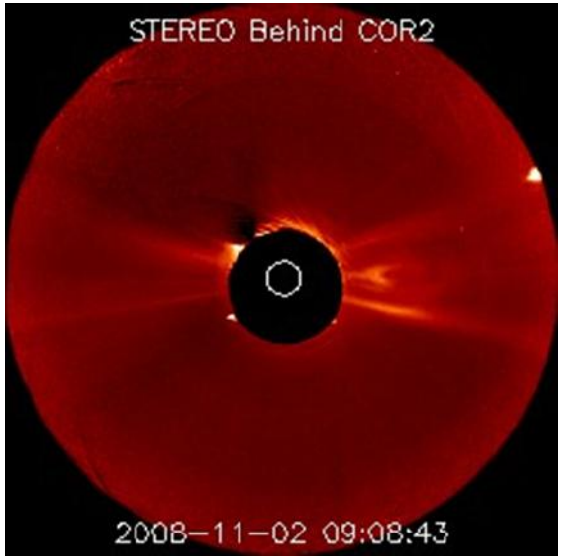
Averages:
- B_{max}: 10.1 nT
- width: 0.14 AU

Compare with previous minima (Jian et al., 2006)
- B_{max}: 13.9 nT
- width: 0.27 AU

Monthly average of the daily Cactus CME rate, AW > 50°

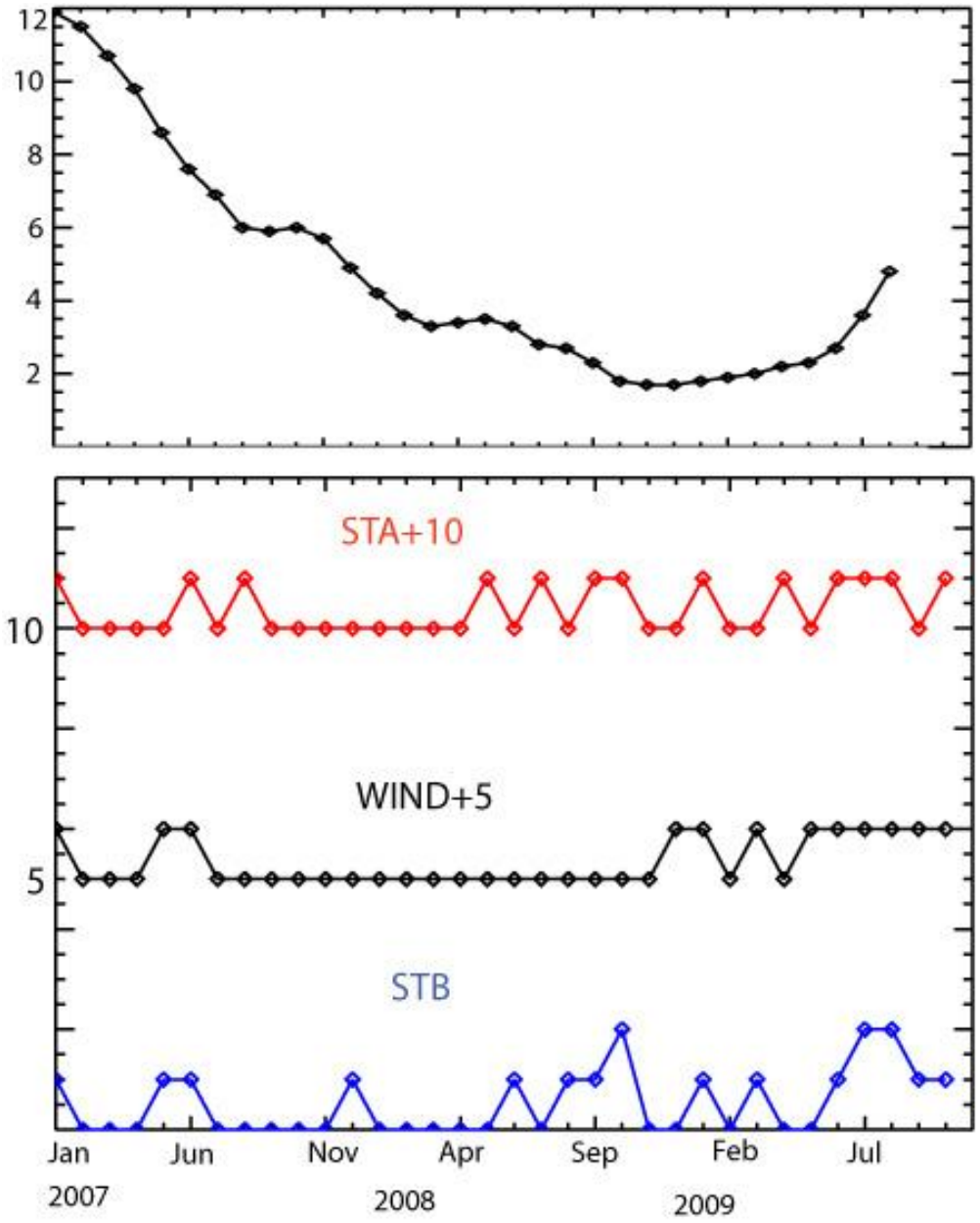
Kilpua et al., 2009, Annales Geophysicae





Kilpua et al., 2009, Annales Geophysicae

- CMEs deflecting from high latitude source regions add to the near ecliptic ICME rate?
- slow CMEs channeled to low latitudes?
- faint CMEs?
- decreased tilt of the heliospheric current sheet?



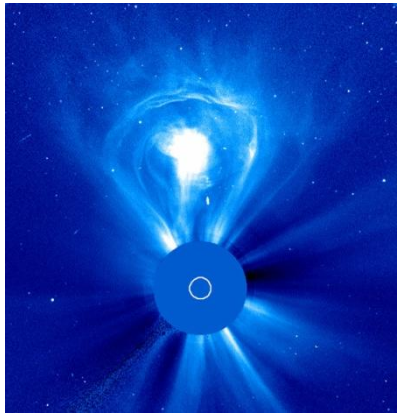
Smoothed sunspot number

January 2007 – October 2009

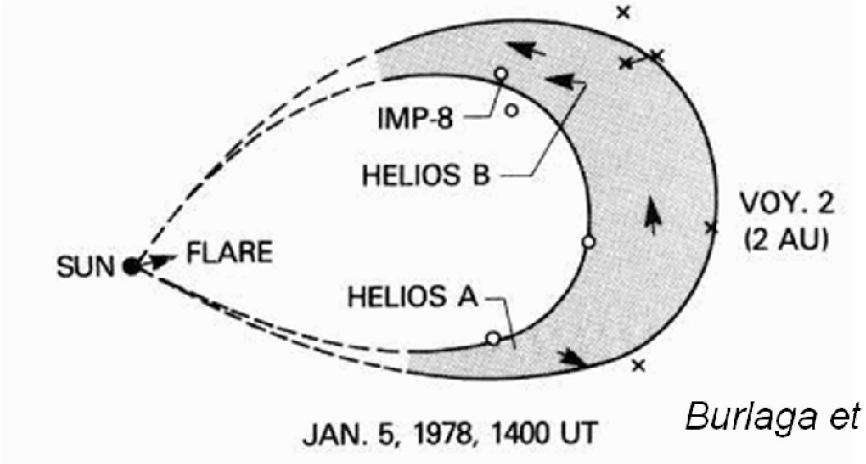
ICMEs with
maximum magnetic field > 8 nT
and
duration > 12 hours

Multi-spacecraft encounters

low inclination magnetic clouds

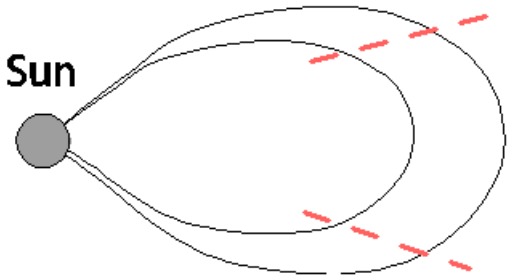


typical ICME extent ~50°
(e.g. Yashiro et al. 2004)



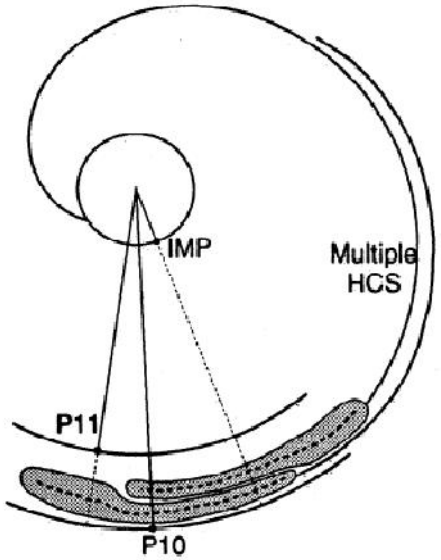
Burlaga et al., 1990

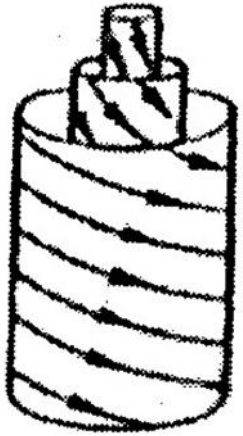
extent at least 30° in longitude

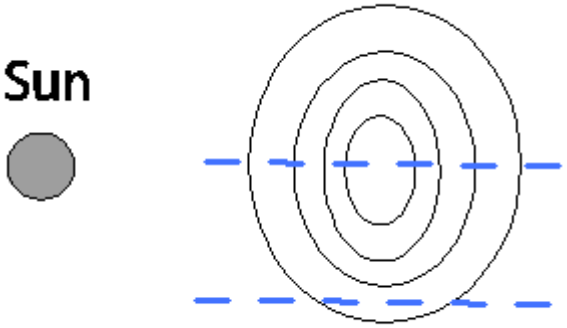


Multi-spacecraft encounters

high inclination magnetic clouds







Crooker and Intrilligator, 1996

significantly distended cross-sections
(aspect ratio 1:8).

Other multi-point studies before STEREO give cross-section aspect ratios 1:4-1:6.5 (*Mulligan et al*., 1999; *Mulligan and Russell*, 2001)

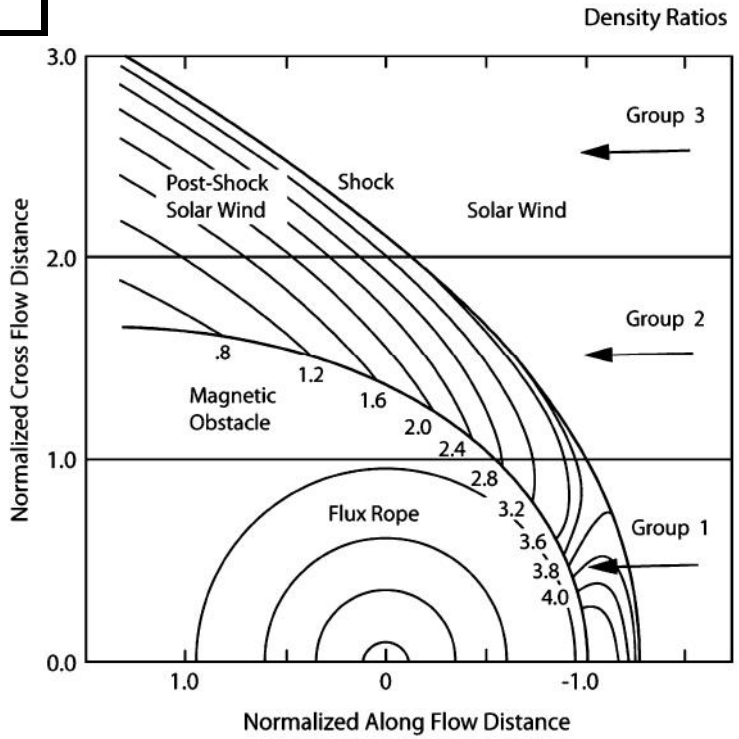
STEREO multi-spacecraft encounters

date	**S/C**	**sep**	**inclination**
May 22, 2007	B&L1&A?	9°	High
May 23, 2007	A&L1	9°	High
Nov 19, 2007	B&L1&A?	41°	Low
Nov 25, 2007	B&L1	44°	Low
Dec 30, 2007	B&L1	44°	Low
Mar 8, 2008?	A&L1	48°	Low

Kilpua et al., 2010, submitted to JASTP

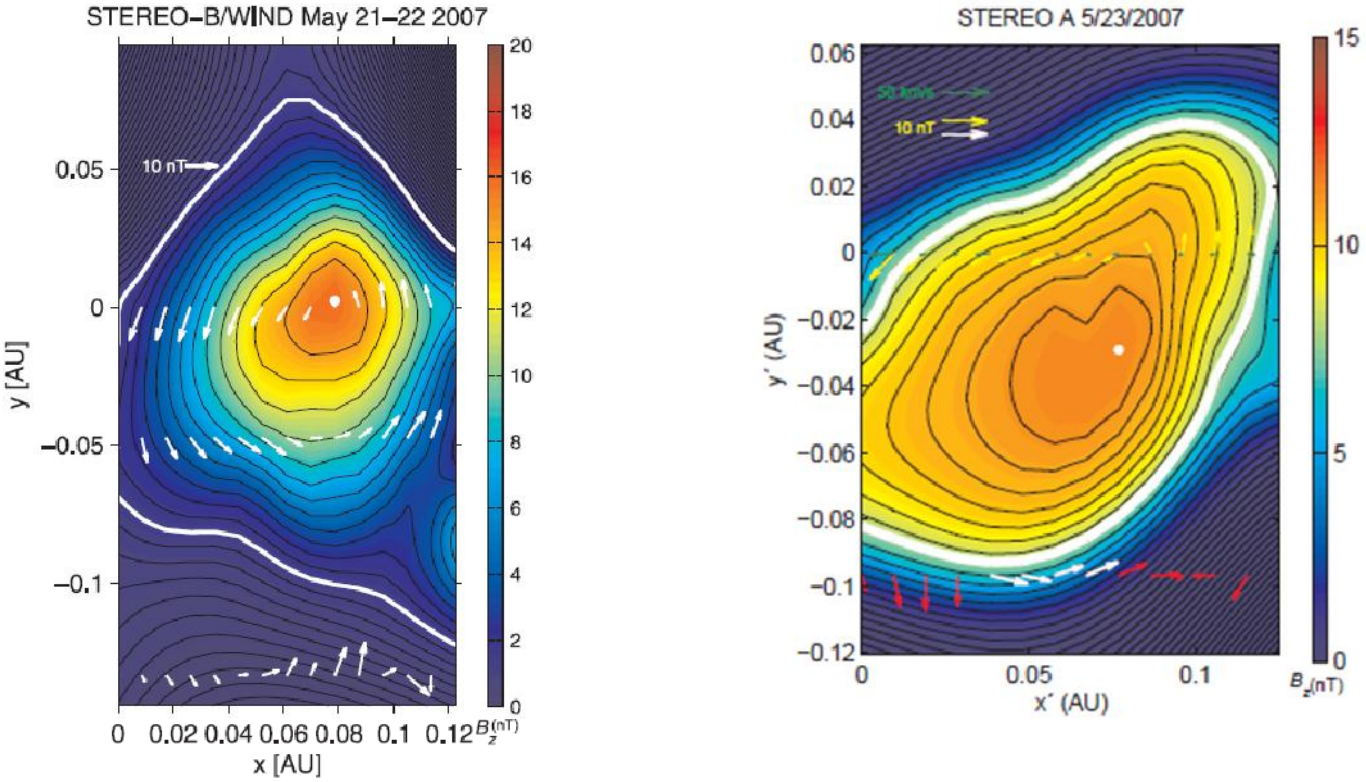
total perpendicular pressure profile

(*Russell, Shinde and Jian,* 2005; *Jian et al*. 2006)



May 2007, magnetic clouds

(Kilpua et al. 2009. Liu et al. 2008, Möstl et al. 2009, Li et al. 2009)

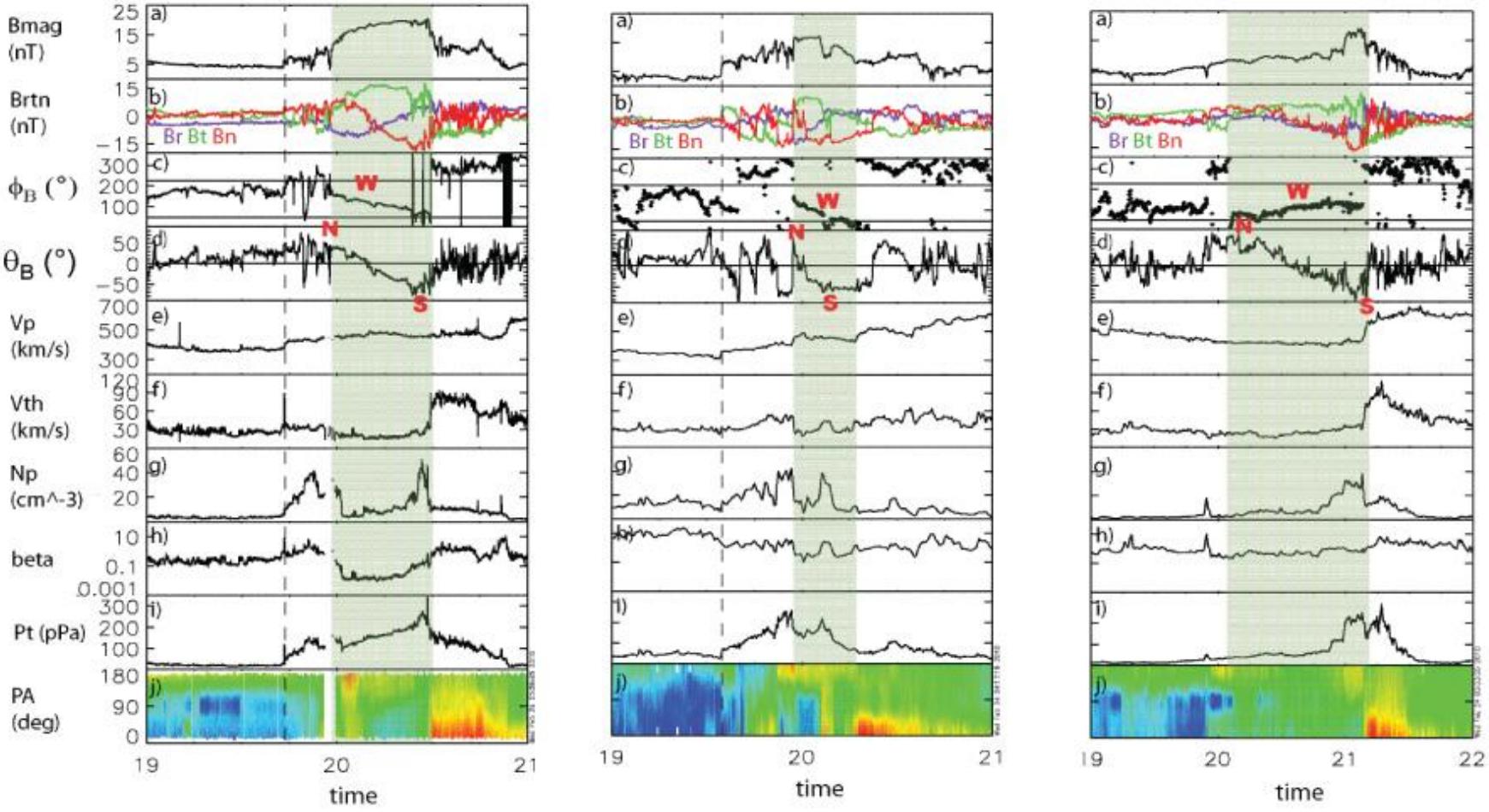


Grad-Shafranov reconstruction

Möstl et al. 2009, JGR& Solar Physics

almost circular cross-sections
(aspect ratio 1:1.5 – 1:2)

November 19-20, 2007



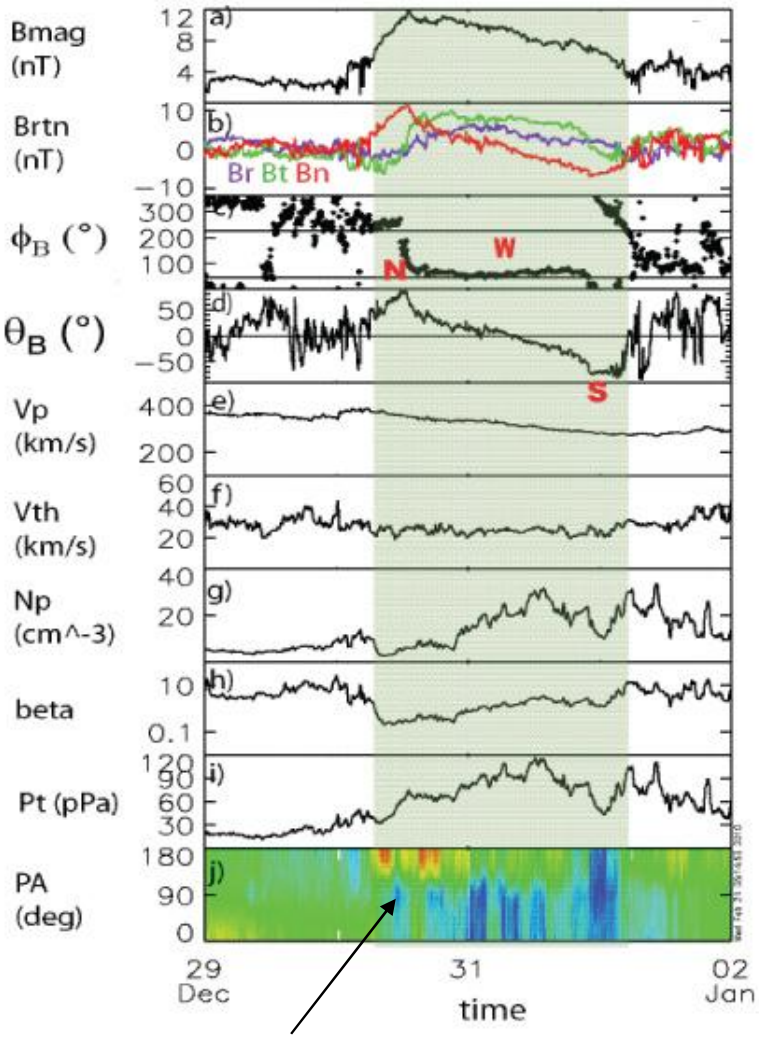
WIND STEREO B STEREO A

STEREO separation: 41°

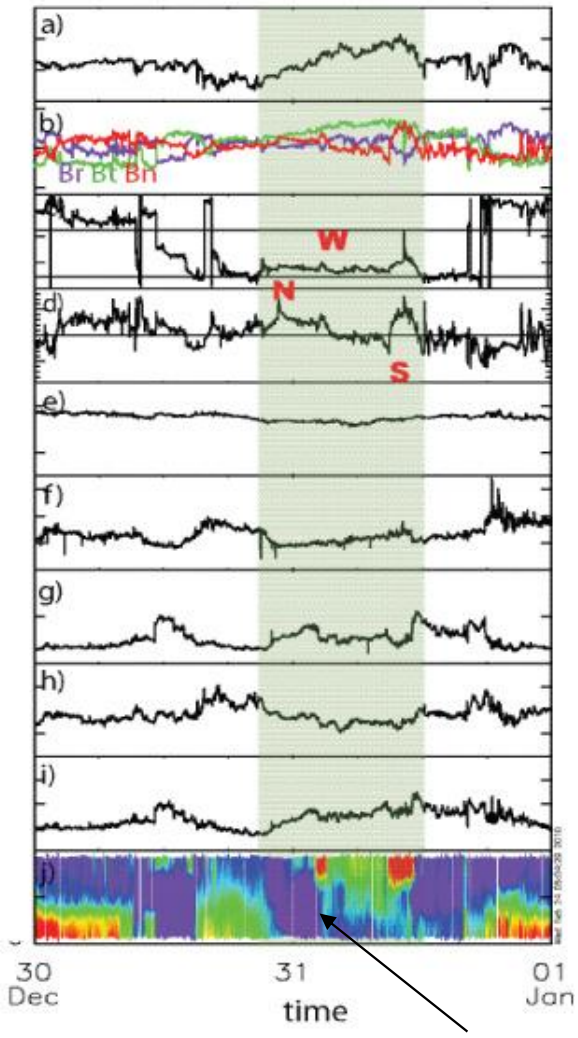
Kilpua et al., 2010, submitted to JASTP

Farrugia et al. 2010

December 30, 2007 - January 1, 2008



STB, central pass through the flux rope



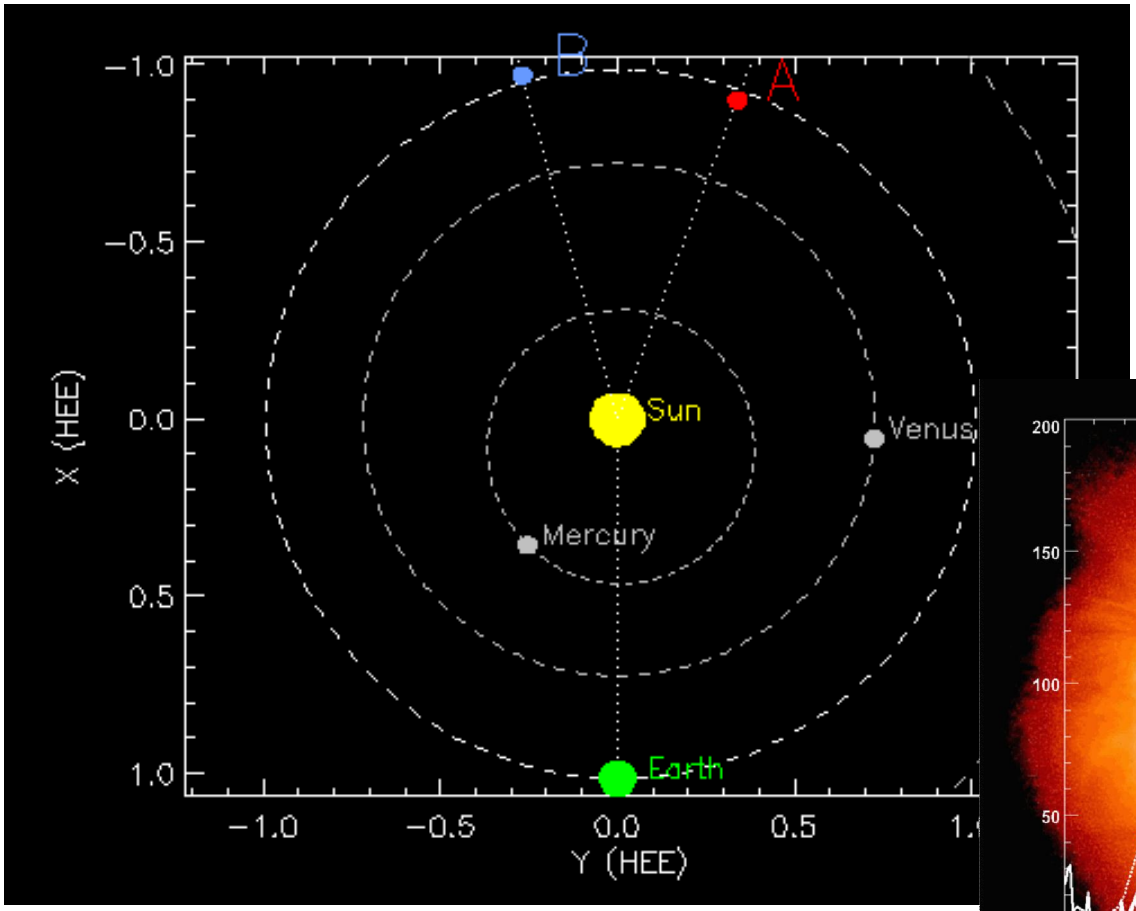
WIND, flanks of the same ICME

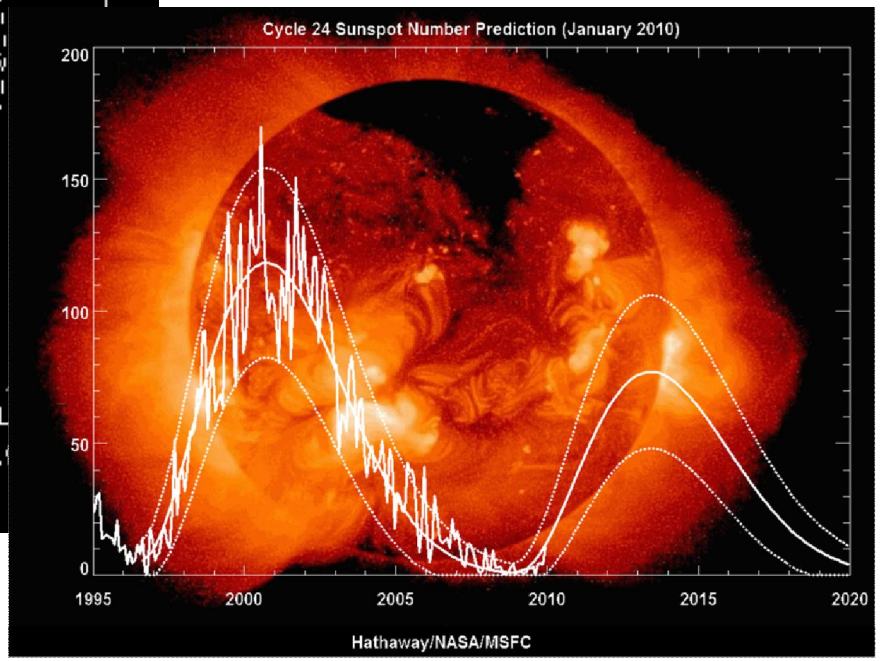
STB – WIND separation: 22°

Kilpua et al., 2010, submitted to JASTP

Summary

- despite the low solar activity several ICMEs have been identified in the solar wind
- connection between narrow CMEs and ‘weak’ ICMEs? (e.g *Rouillard et al*., 2009)
- increase in the ICME rate after mid 2008. Precedes the increases in the CME rate and in sunspot number
- cross-section shapes of perpendicular MCs vary from circular to highly distented. off-ecliptic observations: aspect ratio ~1:6 (*Liu et al*. 2006, *Riley et al*. 2006)
- ICMEs may extend several tens of degrees in longitude
- ICMEs cannot be forced in to a single, simple flux rope model
- refined methods needed to study the ICME structure + unique solar wind background
- flux rope signature disappears when a ICME is crossed far from the center





- STEREO spacecraft back together in 2014

- early declining phase of cycle 24? Increased ICME rate and stronger ICMEs (e.g. *Jian et al*. 2006)

- Hopefully more multipoint ICME observations!