ICME propagation: testing the CDPP propagation tool

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Outline

Objective: test and validate the tools for prediction of the impact of solar events in the vicinity of inner solar system planets using in-situ spacecraft data.

propagation of ICMEs, based on a radial propagation tool developed at IRAP.

- CME propagation from the sun Sun to the Earth (ICME) is a widely studied subject.
- focus on ICME propagation between two satellites of the Sun.

Accuracy of the CDPP propagation tool

Events: ICME observed by MESSENGER (Winslow et al. 2015)

Number of Records : 143

Number of Pairs : 45

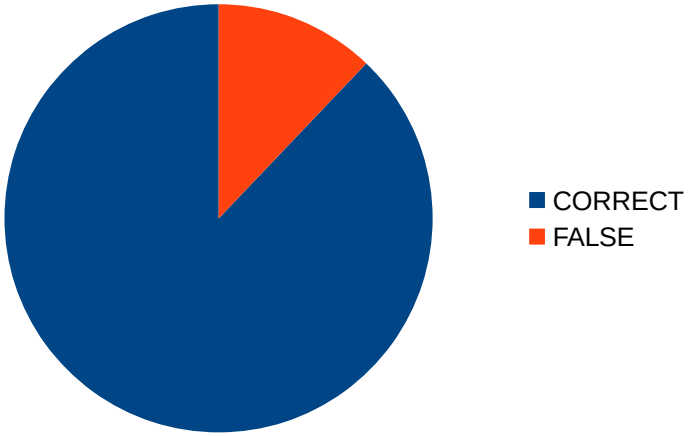
Time coverage : from 2011-05-19 to 2014-09-02

Prop tool default parameters: 500km/s and 45° angular wideness

Match: An ICME is observed close to the predicted arrival time (*is it the same ICME?*). Observations are based on the AMDA available datasets.

Spacecraft	Impacts predicted	FALSE	CORRECT	ERROR	HELCATS
STEREO-A	11	1	10	0	2
STEREO-B	6	1	5	0	0
ACE	4	0	4	0	1
VEX	16	2	10	4	0
MEX/MAVEN	8	0	0	8	0
Total	**45**	**4**	**29**	**12**	**3**

Accuracy of the CDPP propagation tool



- **Accuracy of the prop tool is good**: when an impact is predicted at a body, based on MESSENGER observations, an ICME is observed around the predicted time
- Role of the **CME angular wideness** (45deg)
- Default values are OK.
- False positive (no impact predicted but an ICME is observed): not taken into considerations

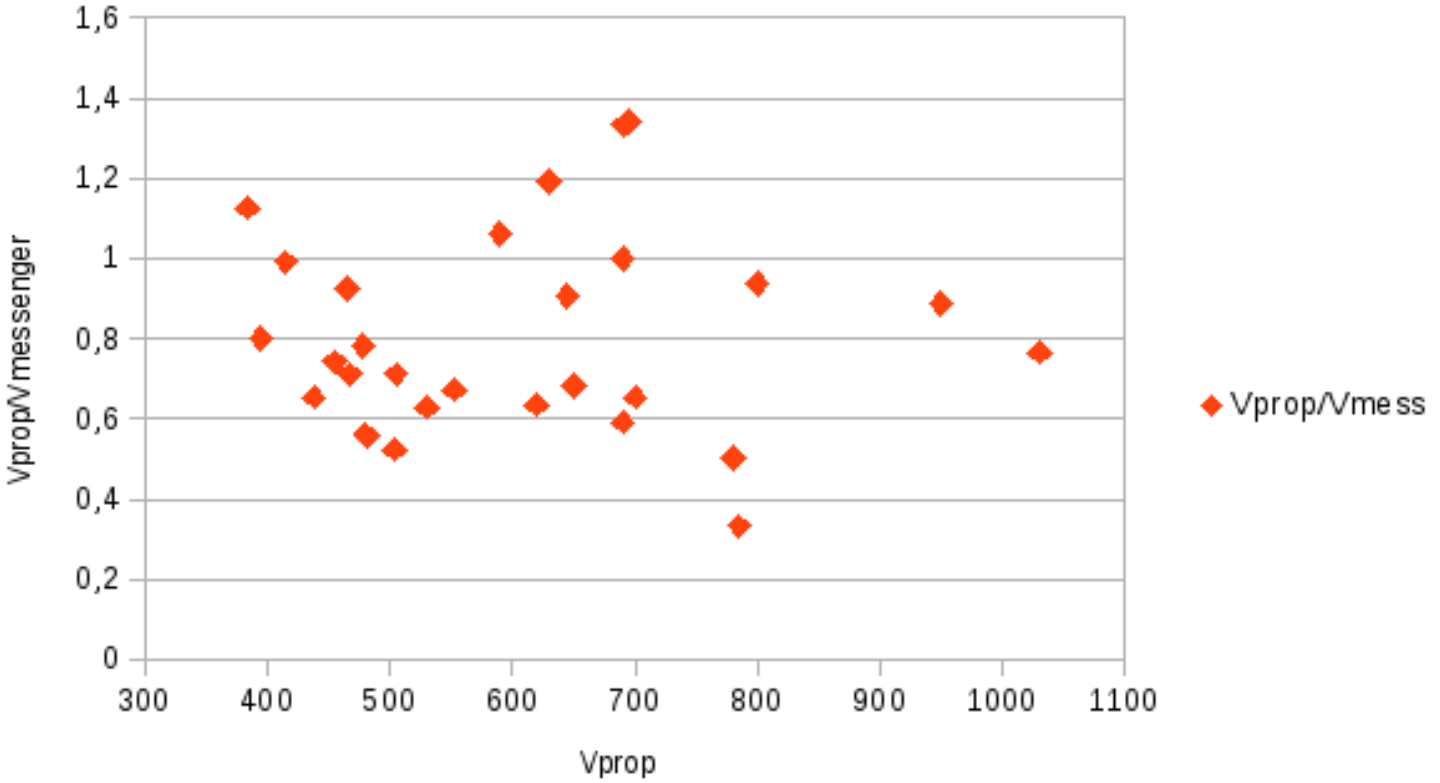
THE PROPAGATION VELOCITY

	Average [km/s]	Standard deviation [km/s]
ALL	603	162
1 AU	584	160
VENUS	639	169

Propagation velocity Vprop (starting from Mercury/MESSENGER)

- **Vprop**: velocity obtained from the prop tool that match both observed start time (at Messenger) and observed end time.
- High standard deviation values
- Decrease of Vprop with increased distance (*Is it significant statistically?*)
- To compare to the 500 km/s default velocity

Is the velocity at MESSENGER a good proxy to predict arrival time?



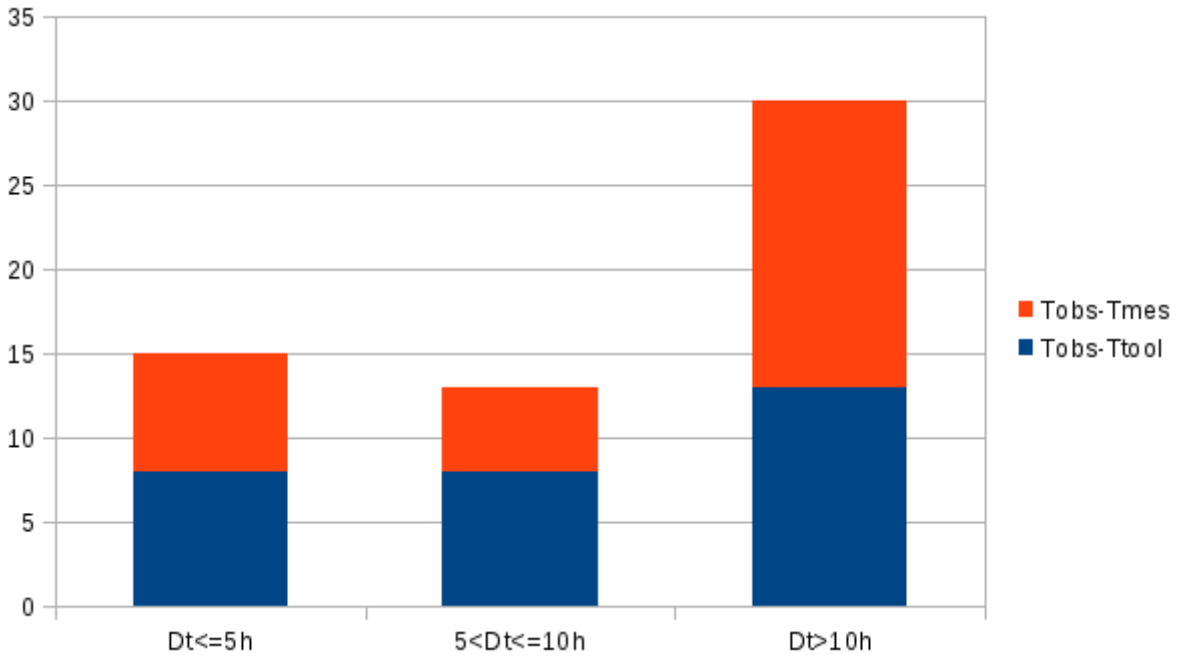
- No, but this is not surprising

Time Differences

- Average travel time: 39h (min 13h, max 76h)
- Absolute time difference is lower with the Default velocity value than with the observed velocity value (at Messenger).

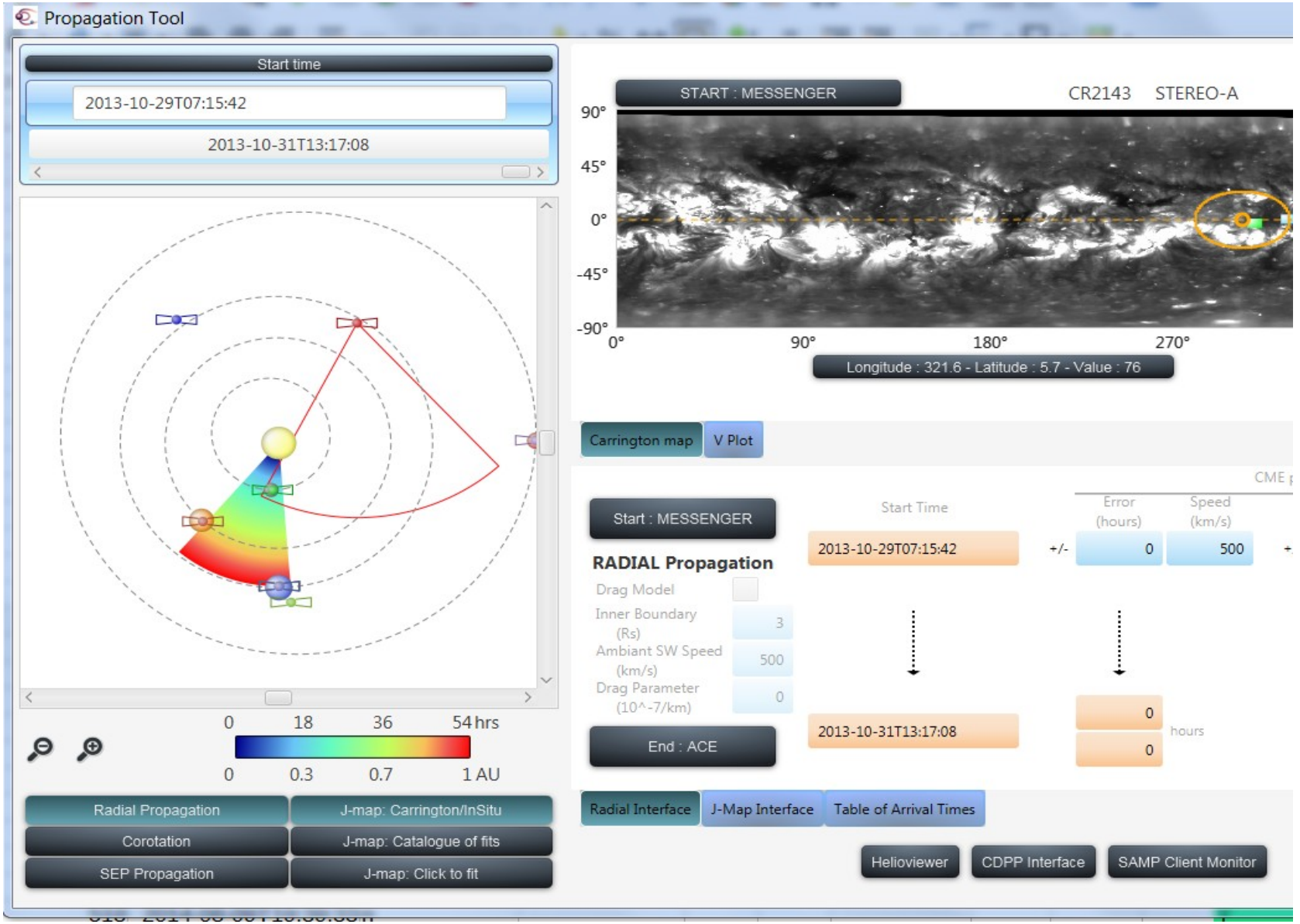
	Mean time difference [hours]	**Standard deviation [hours]**
Tobs - Tdef	-4.6	10.0
Tobs - Tmess	7.2	9.7

Time Differences



Histogram of the number of 29 pair events in function of the absolute time delay (Dt) between observations and predictions. Predicted times are obtained with Vmes (red) and Vdef (blue, 500km/s). There are more events with a time delay lower than 10h with the default velocity of the propagation tool than with the velocity observed at MESSENGER

Case study: Events involving multiple solar system bodies



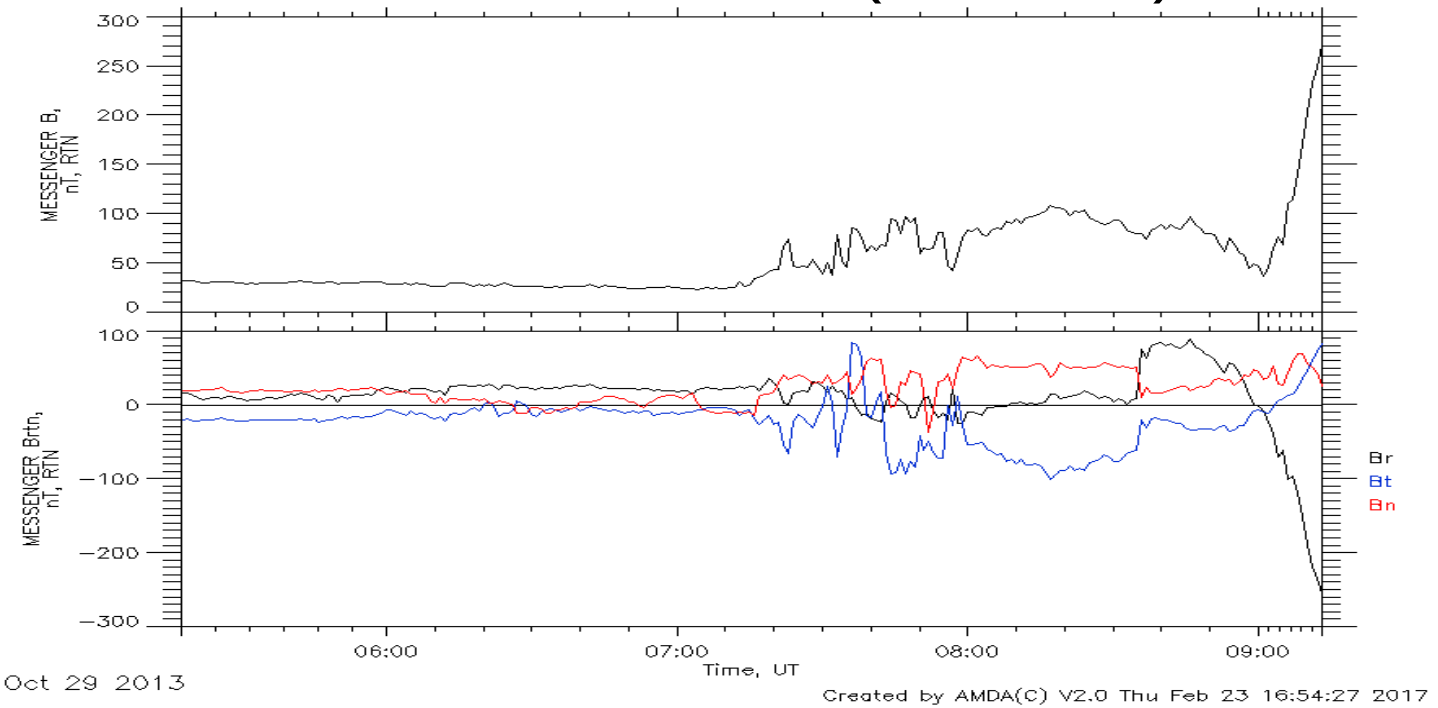
Case study

- Event #49 in Winslows' list

MESSENGER start time 29/10/2013 07:15:28

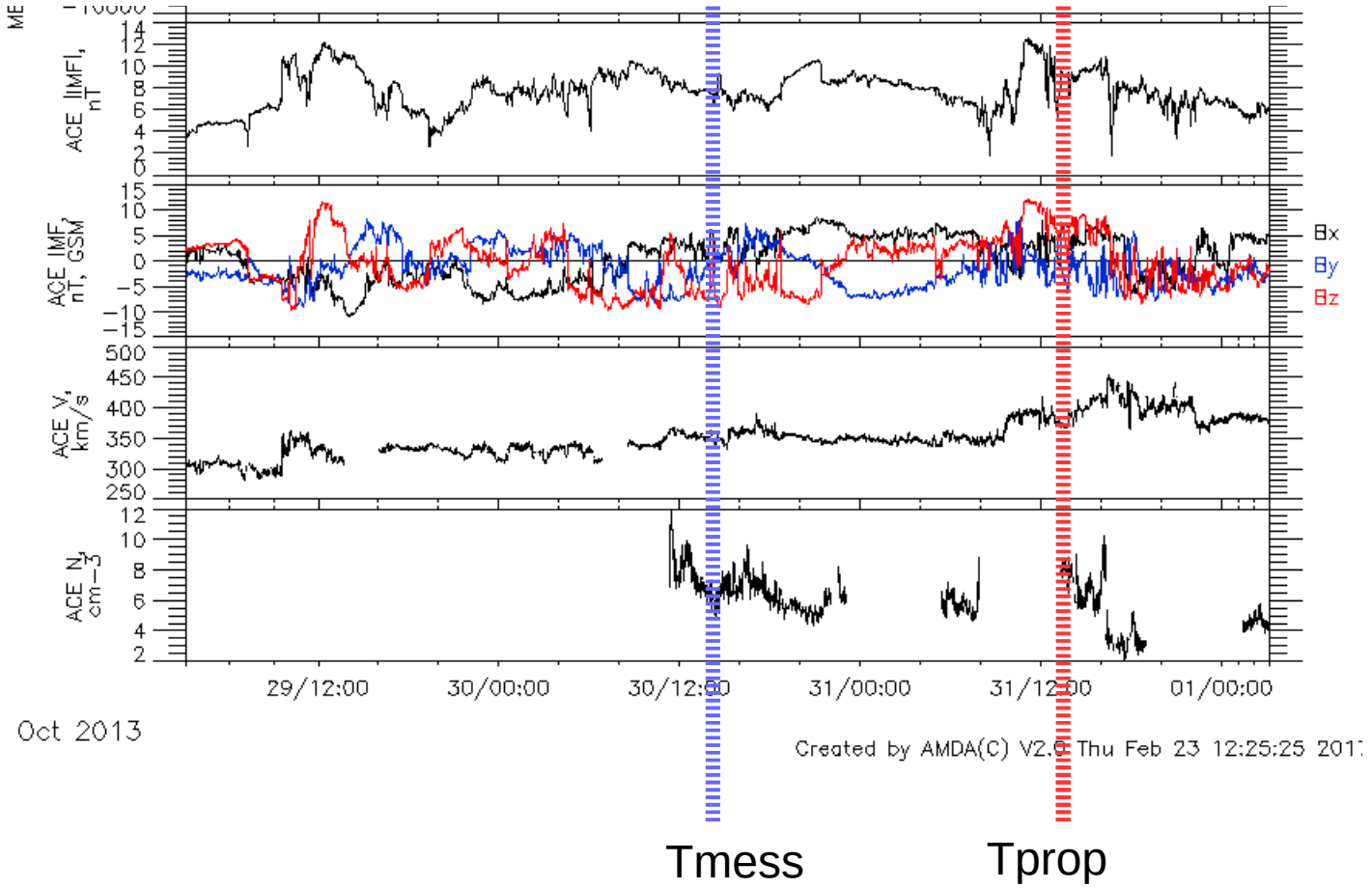
854 km/s

CME At the Sun : 28/10/2013 15:00 (800km/s)



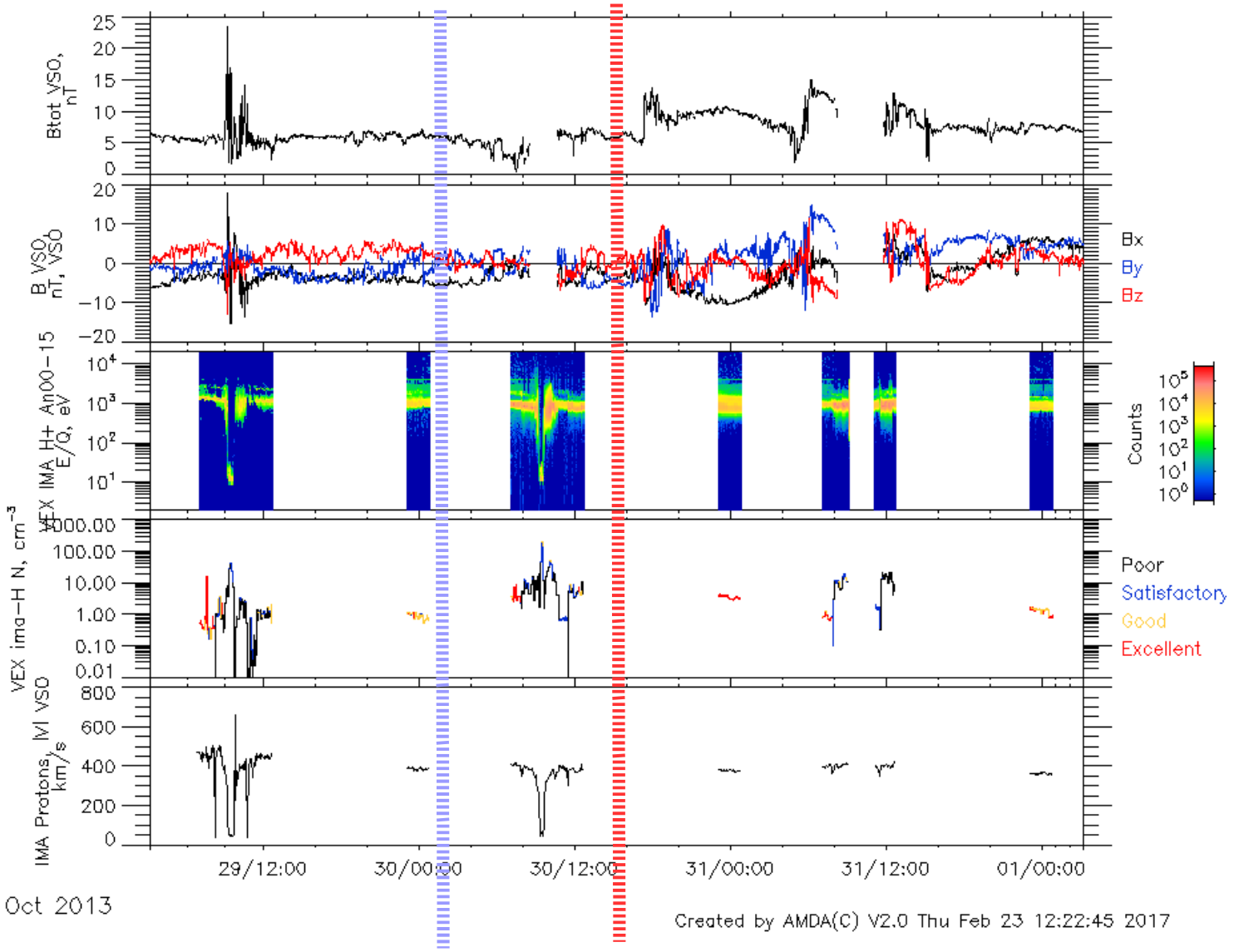
Case study

- Ace Observations : 30/10/2013 17:05:15



Case study

- VEX observations : 30/10/2013 17:30:47



Tmess Tprop

Case study: ACE-VEX comparisons

- Shock is first detected by VEX, ICME by ACE
- By sign is opposite at ACE and VEX?

VEX Btot

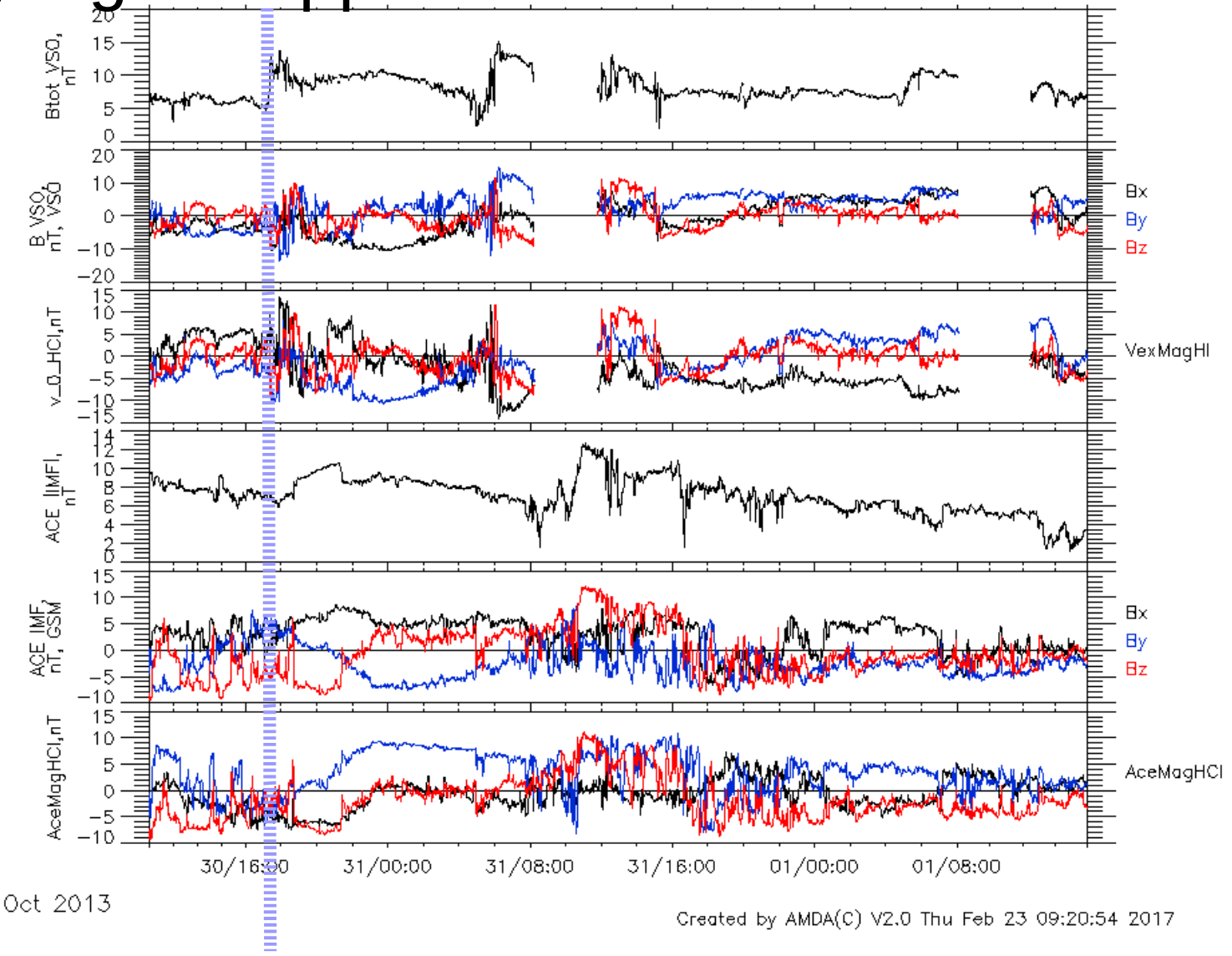
VEX B in VSO

VEX B in HCI

ACE Btot

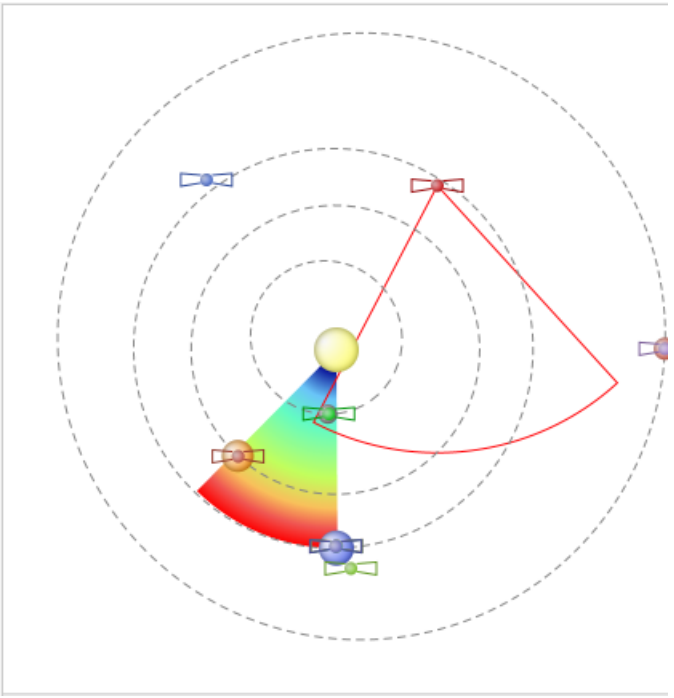
ACE B in GSM

ACE B in HCI



Case study: ACE-VEX comparisons

- Shock is first detected by VEX, ICME by ACE
- By sign is opposite at ACE and VEX?
- It might be explained with a CME starting from the west side of the Sun.



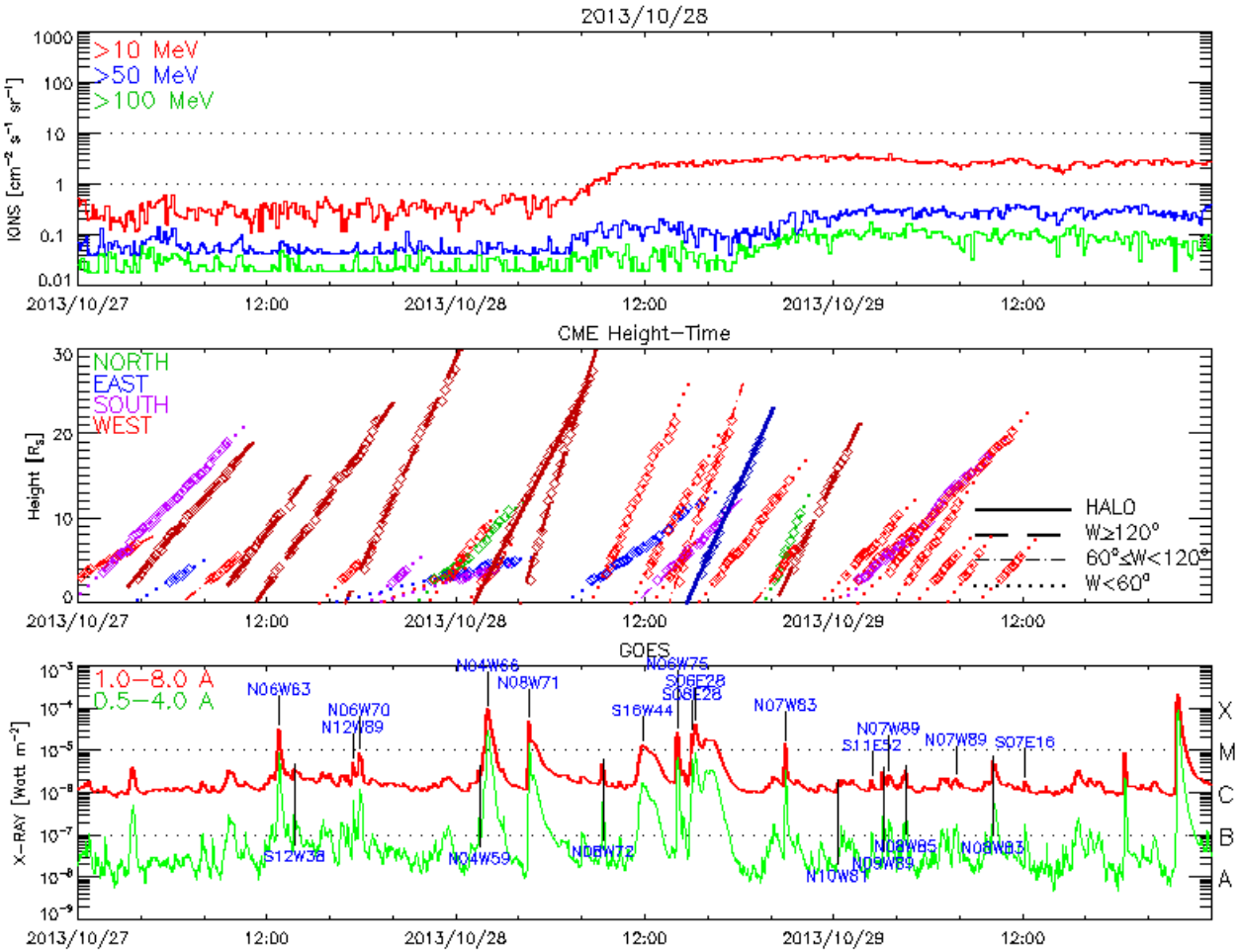
Is it the same CME ?

- A quite active period (15 CMEs that day)
- Halo CME is detected: so yes it might be the same.
- (SOHO LASCO CME CATALOG)

2013/10/28	00:12:05	158	22	103	109	202	1.3*1	7.6e+13	4.0e+27	156	C2 C3 195 PHTX DST Java Movie	Very Poor Event; Only C2
2013/10/28	01:36:06	268	46	480	712	1791	128.5*1	2.7e+15	3.1e+30	273	C2 C3 195 PHTX DST Java Movie	Poor Event; Only C2
2013/10/28	02:24:05	Halo	360	695	575	616	-12.1	8.6e+15*2	2.1e+31*2	296	C2 C3 195 PHTX DST Java Movie	
2013/10/28	04:48:05	315	156	1201	881	1116	-45.2	6.3e+15*2	4.5e+31*2	313	C2 C3 195 PHTX DST Java Movie	Partial Halo
2013/10/28	08:36:06	90	32	266	329	414	5.4*1	1.3e+14	4.6e+28	97	C2 C3 195 PHTX DST Java Movie	Poor Event
2013/10/28	09:36:05	277	27	814	550	606	-32.1	1.9e+14	6.2e+29	286	C2 C3 195 PHTX DST Java Movie	
2013/10/28	12:12:05	272	27	681	628	596	-7.7	1.7e+14	4.0e+29	282	C2 C3 195 PHTX DST Java Movie	
2013/10/28	12:48:07	195	71	354	425	550	9.4*1	7.1e+14	4.5e+29	186	C2 C3 195 PHTX DST Java Movie	Width was revised on 2014/0
2013/10/28	13:36:05	274	40	495	555	1092	42.6*1	3.7e+14	4.5e+29	275	C2 C3 195 PHTX DST Java Movie	Only C2
2013/10/28	14:12:05	283	93	1073	805	859	-42.2	9.0e+14	5.2e+30	303	C2 C3 195 PHTX DST Java Movie	
2013/10/28	15:36:05	Halo	360	812	685	674	-17.7	9.3e+15*2	3.1e+31*2	86	C2 C3 195 PHTX DST Java Movie	
2013/10/28	16:24:05	273	41	482	535	578	6.1	1.5e+15	1.8e+30	267	C2 C3 195 PHTX DST Java Movie	
2013/10/28	20:12:05	313	50	886	864	809	-7.0*1	5.3e+14	2.1e+30	318	C2 C3 195 PHTX DST Java Movie	Poor Event
2013/10/28	20:12:05	271	64	469	401	0	-30.6*1	1.5e+15	1.6e+30	284	C2 C3 195 PHTX DST Java Movie	
2013/10/28	21:25:11	284	142	771	669	630	-16.1*1	3.0e+15*2	8.9e+30*2	301	C2 C3 195 PHTX DST Java Movie	Partial Halo

Is it the same ICME ?

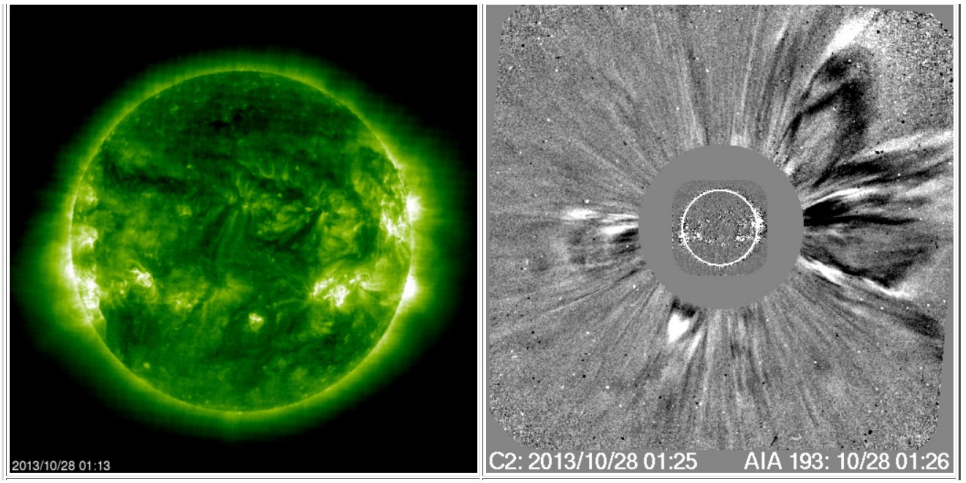
- A quite active period (at least 15 CMEs that day)

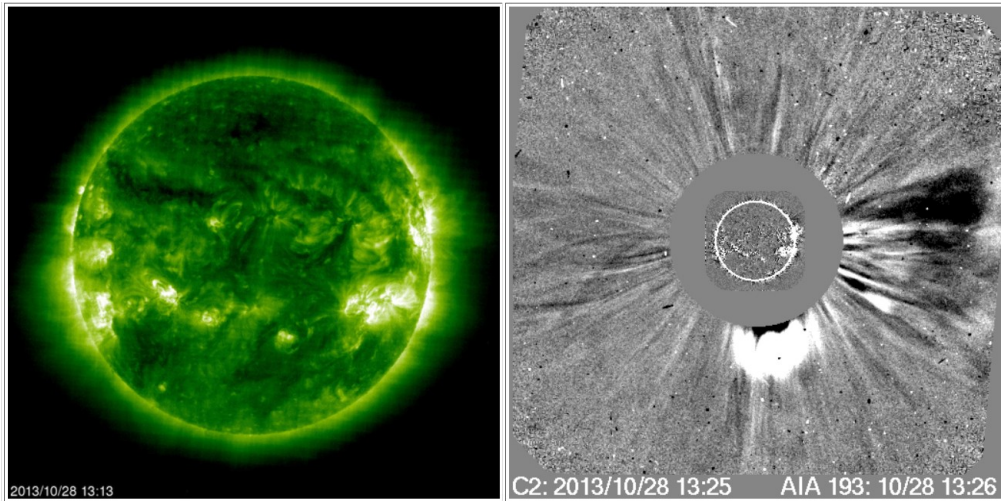


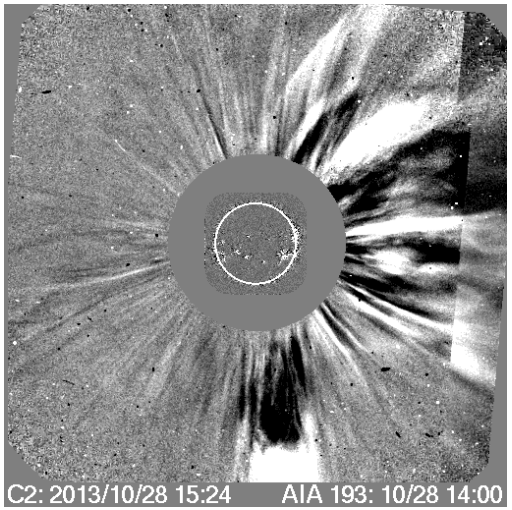
- Halo CME is North...

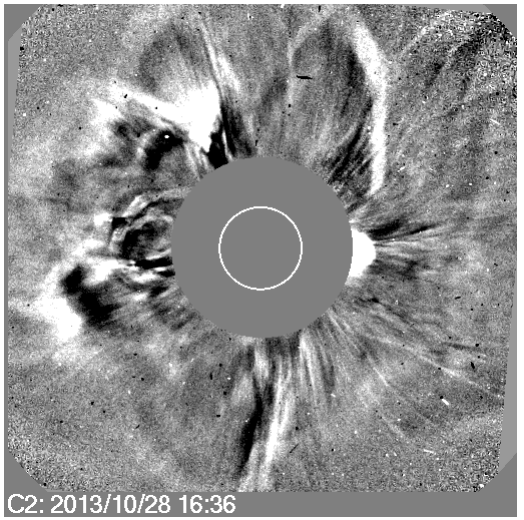
Is it the same ICME ?

- A quite active period (15 CMEs that day)



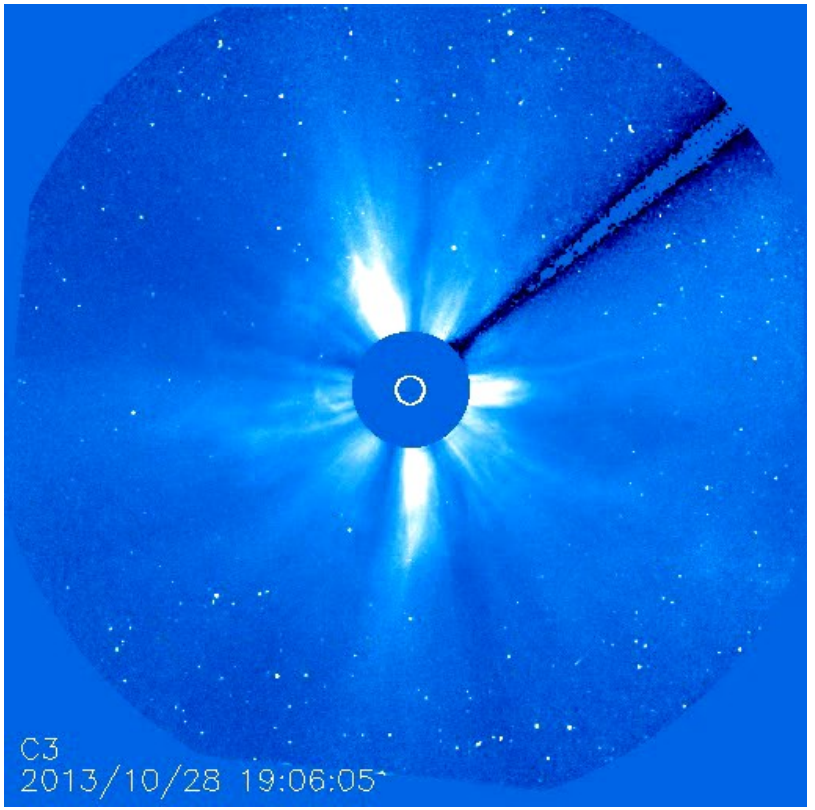






Is it the same ICME ?

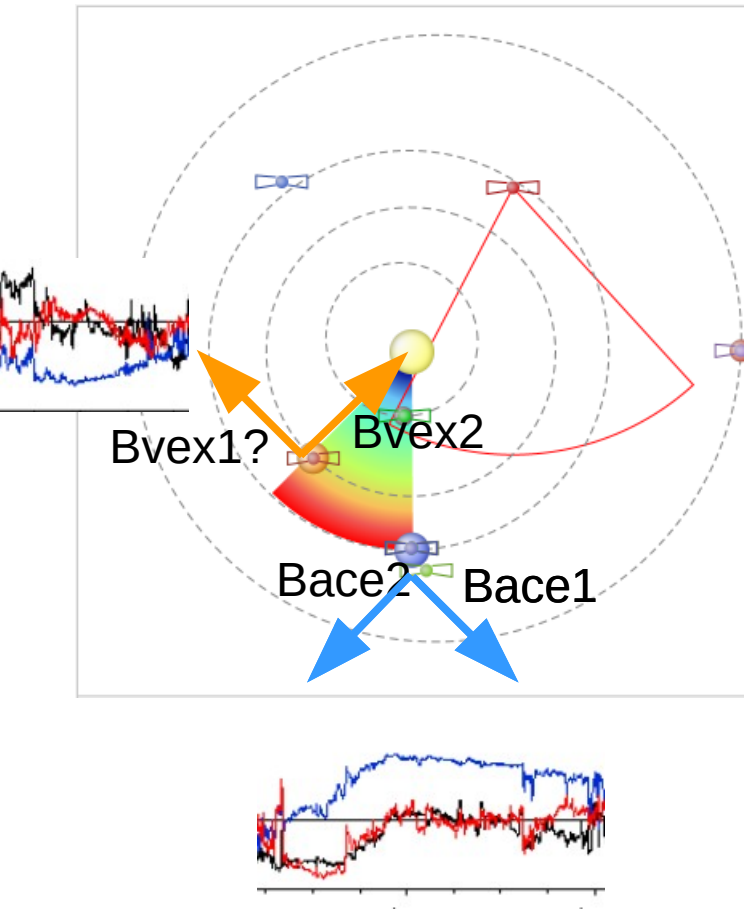
- A quite active period (15 CMEs that day)
- Halo CME is detected: so yes it should be the same.
-



Is it the same ICME ?

- HCI coordinate system
- Same sense of rotation
- Next: Refine the choice of the CME source

  and Draw a nice flux rope...



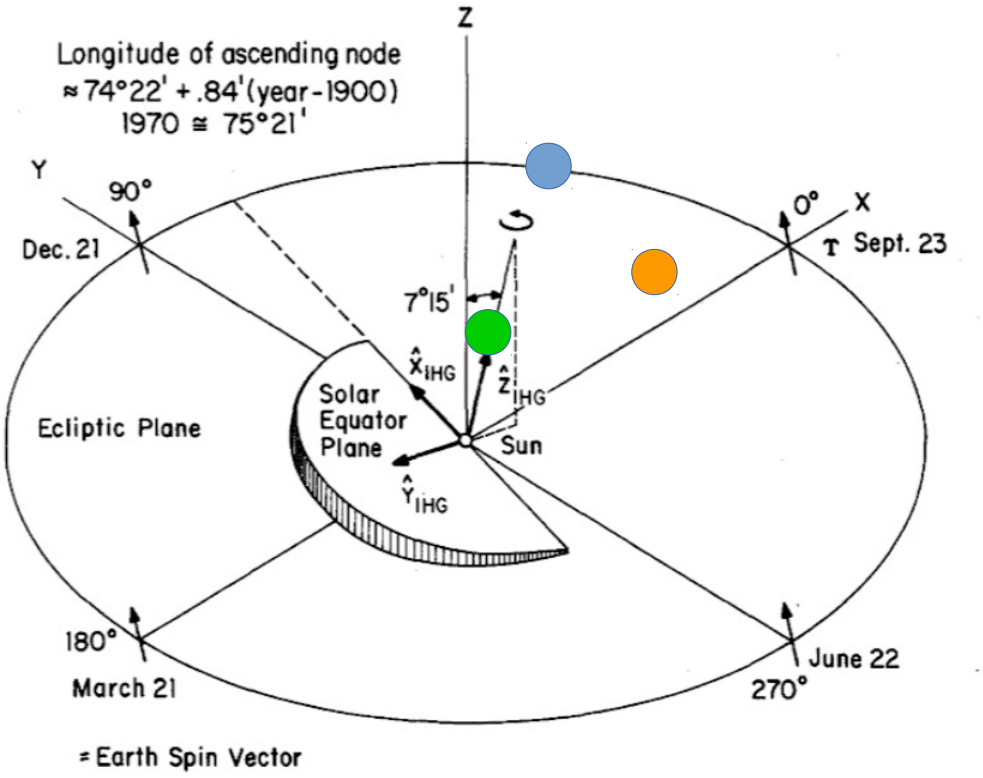


Figure 3 Inertial Heliographic (IHG) coordinates defined by Burlaga (1984); Heliocentric Inertial (HCI) coordinates are defined in the same way but based on an epoch of J2000. The plane of the Heliocentric Aries Ecliptic (HAE) system is shown; the first point in Aries in on/around March 21.

Propagation Tool

As a conclusion **the propagation tool is good at predicting the ICME encounter** with an object in the inner heliosphere.

The default parameters of the tool are good. **Increasing the default velocity might improve the time arrival prediction**. The default velocity could be adapted in function of the start and end points.

The propagation tool predicts an ICME arrival with a precision of -4.6h +/- 10h