# ICME propagation: testing the CDPP propagation tool

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Europlanet PSWS workshop, IRAP, 09-11/10/2017

### Outline

<u>Objective</u>: 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.
- $\cdot$  focus on ICME propagation between two satellites of the Sun.

#### Accuracy of the CDPP propagation tool

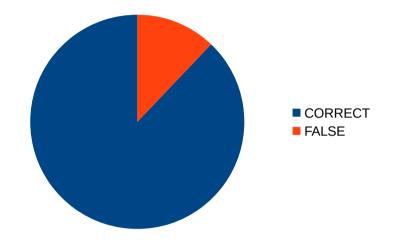
Events: ICME observed by MESSENGER (Winslow et al. 2015) Number of Records : 143 Number of Pairs : 45 Time coverage : from 2011-05-19 to 2014-09-02

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

<u>Match</u>: 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

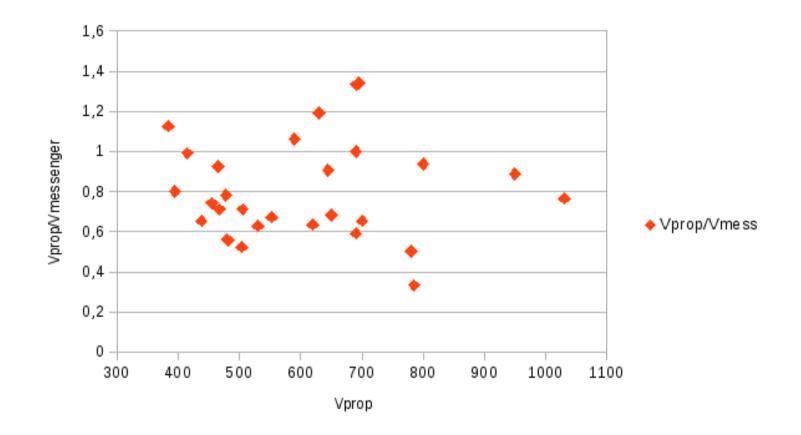
#### THE PROPAGATION VELOCITY

	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?



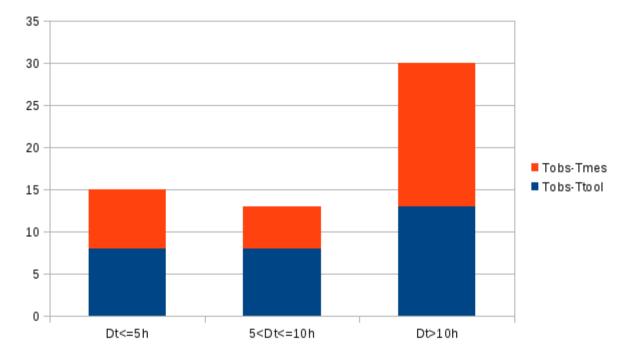
• No, but this is not surprising

### **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).

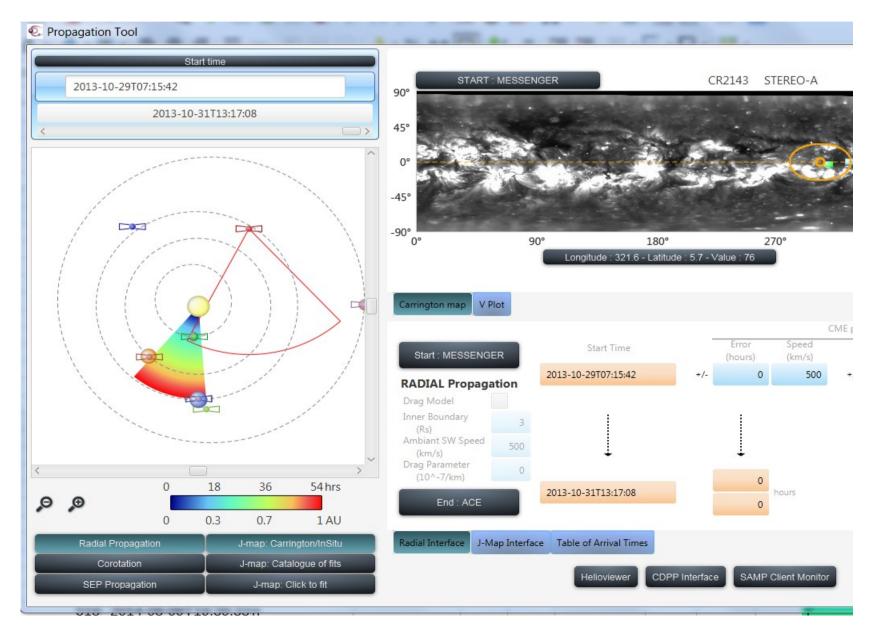
	Mean time difference [hours]	Standard deviation [hours]		
Tobs - Tdef	-4.6	10.0		
Tobs - Tmess	7.2	9.7		

#### **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

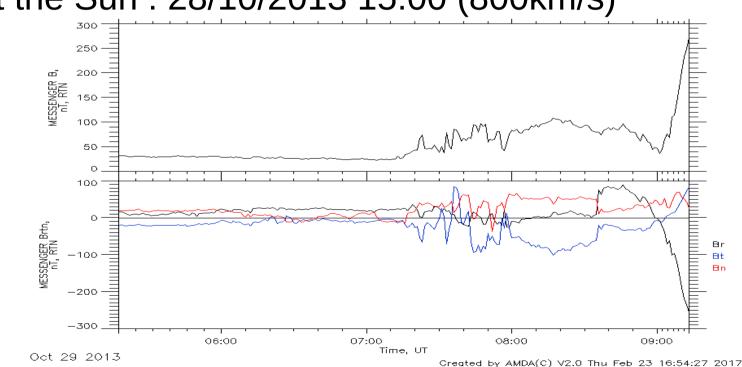
# Case study: Events involving multiple solar system bodies



#### Case study

- Event #49 in Winslows' list
- MESSENGER start time 29/10/2013 07:15:28

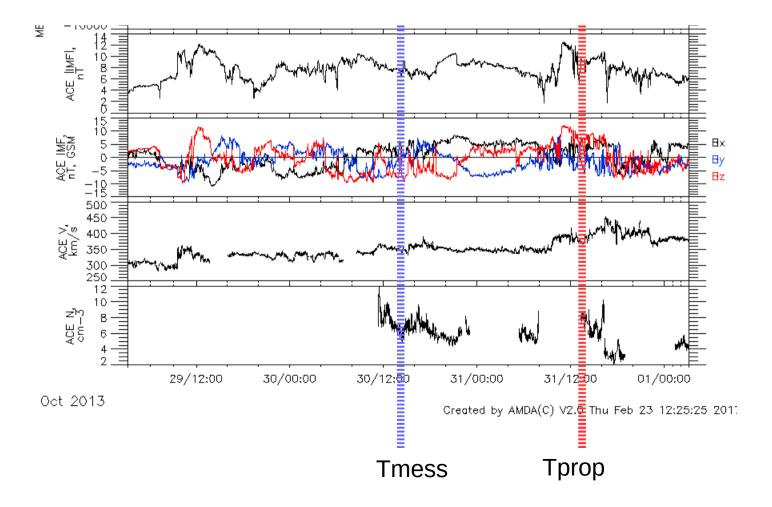
854 km/s



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

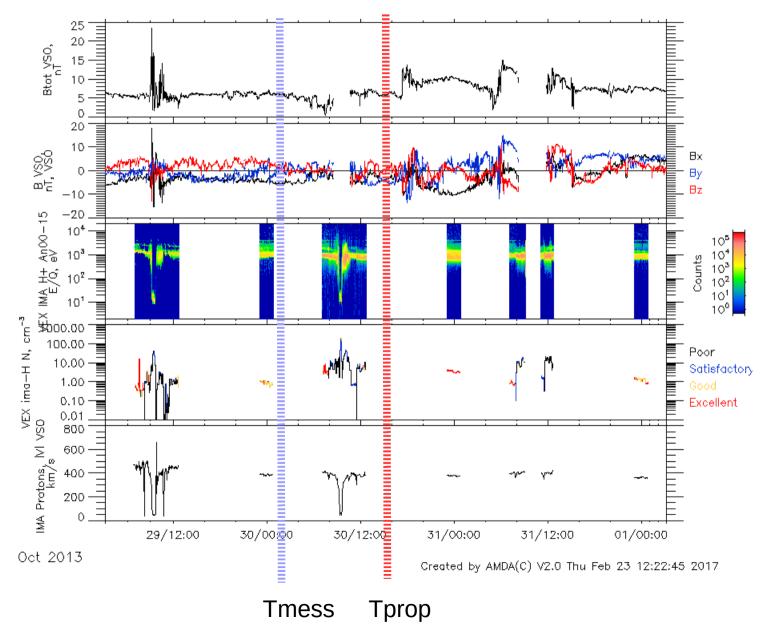
#### Case study

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



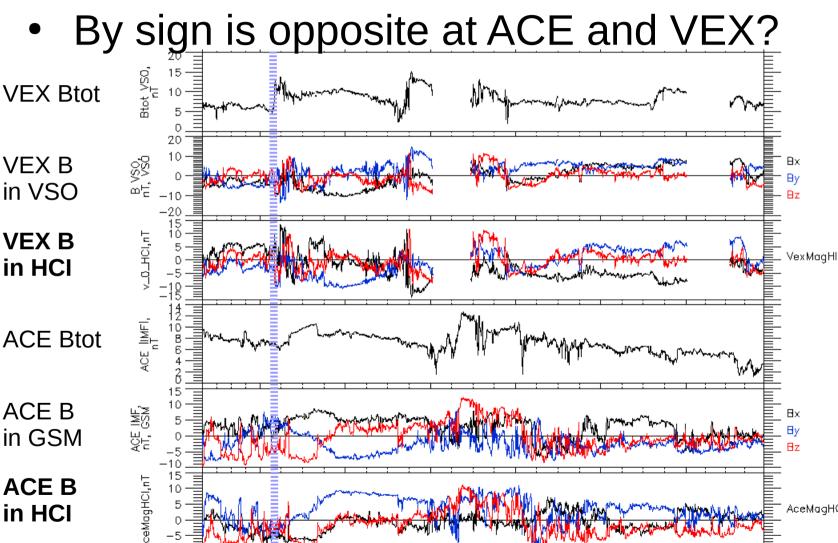
#### Case study

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



#### Case study: ACE-VEX comparisons

Shock is first detected by VEX, ICME by ACE



31/08:00

31/16:00

31/00:00

30/1630

Oct 2013

ACE B in HCI

01/08:00

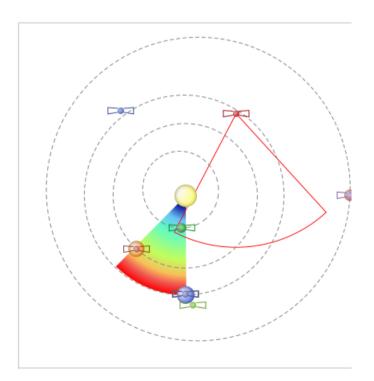
01/00:00

AceMagHCI

Created by AMDA(C) V2.0 Thu Feb 23 09:20:54 2017

#### 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 ?

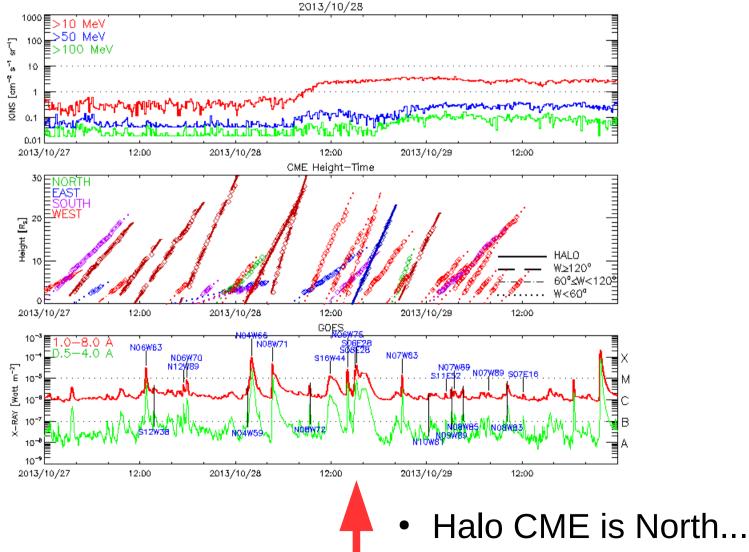
- A quite active period (15 CMEs that day)
- Halo CME is detected: so yes it might be the same.
- (SOHO LASCO CME CATALOG)

2013/10/28	<u>00:12:05</u>	158	22	<u>103</u>	<u>109</u>	<u>202</u>	1.3*1	7.6e+13	4.0e+27	156	<u>C2 C3 195 PHTX DST</u> Java Movie	Very Poor Event; Only C2
2013/10/28	01:36:06	268	46	<u>480</u>	<u>712</u>	<u>1791</u>	128.5 <sup>*1</sup>	2.7e+15	3.1e+30	273	<u>C2 C3 195 PHTX DST</u> Java Movie	Poor Event; Only C2
2013/10/28	02:24:05	Halo	360	<u>695</u>	<u>575</u>	<u>616</u>	-12.1	8.6e+15*2	2.1e+31*2	296	<u>C2 C3 195 PHTX DST</u> Java Movie	
2013/10/28	04:48:05	315	156	<u>1201</u>	<u>881</u>	<u>1116</u>	-45.2	6.3e+15*2	4.5e+31*2	313	<u>C2 C3 195 PHTX DST</u> Java Movie	Partial Halo
2013/10/28	<u>08:36:06</u>	90	32	<u>266</u>	<u>329</u>	<u>414</u>	5.4 <sup>*1</sup>	1.3e+14	4.6e+28	97	<u>C2 C3 195 PHTX DST</u> Java Movie	Poor Event
2013/10/28	<u>09:36:05</u>	277	27	<u>814</u>	<u>550</u>	<u>606</u>	-32.1	1.9e+14	6.2e+29	286	<u>C2 C3 195 PHTX DST</u> Java Movie	
2013/10/28	12:12:05	272	27	<u>681</u>	<u>628</u>	<u>596</u>	-7.7	1.7e+14	4.0e+29	282	<u>C2 C3 195 PHTX DST</u> Java Movie	
2013/10/28	12:48:07	195	71	<u>354</u>	<u>425</u>	<u>550</u>	9.4 <sup>*1</sup>	7.1e+14	4.5e+29	186	<u>C2 C3 195 PHTX DST</u> Java Movie	Width was revised on 2014/0'
2013/10/28	<u>13:36:05</u>	274	40	<u>495</u>	<u>555</u>	<u>1092</u>	42.6 <sup>*1</sup>	3.7e+14	4.5e+29	275	<u>C2 C3 195 PHTX DST</u> Java Movie	Only C2
2013/10/28	<u>14:12:05</u>	283	93	<u>1073</u>	<u>805</u>	<u>859</u>	-42.2	9.0e+14	5.2e+30	303	<u>C2 C3 195 PHTX DST</u> Java Movie	
2013/10/28	<u>15:36:05</u>	Halo	360	<u>812</u>	<u>685</u>	<u>674</u>	-17.7	9.3e+15*2	3.1e+31*2	86	<u>C2 C3 195 PHTX DST</u> Java Movie	
2013/10/28	16:24:05	273	41	<u>482</u>	<u>535</u>	<u>578</u>	6.1	1.5e+15	1.8e+30	267	<u>C2 C3 195 PHTX DST</u> Java Movie	
2013/10/28	20:12:05	313	50	<u>886</u>	<u>864</u>	<u>809</u>	-7.0 <sup>*1</sup>	5.3e+14	2.1e+30	318	<u>C2 C3 195 PHTX DST</u> Java Movie	Poor Event
2013/10/28	20:12:05	271	64	<u>469</u>	<u>401</u>	<u>0</u>	-30.6*1	1.5e+15	1.6e+30	284	<u>C2 C3 195 PHTX DST</u> Java Movie	
2013/10/28	21:25:11	284	142	<u>771</u>	<u>669</u>	<u>630</u>	-16.1 <sup>*1</sup>	3.0e+15*2	8.9e+30*2	301	<u>C2 C3 195 PHTX DST</u> Java Movie	Partial Halo
	2013/10/28 2013/10/28 2013/10/28 2013/10/28 2013/10/28 2013/10/28 2013/10/28 2013/10/28 2013/10/28 2013/10/28 2013/10/28 2013/10/28	2013/10/28   00:12:05     2013/10/28   01:36:06     2013/10/28   02:24:05     2013/10/28   04:48:05     2013/10/28   04:48:05     2013/10/28   09:36:06     2013/10/28   09:36:05     2013/10/28   12:12:05     2013/10/28   12:48:07     2013/10/28   13:36:05     2013/10/28   14:12:05     2013/10/28   15:36:05     2013/10/28   16:24:05     2013/10/28   20:12:05     2013/10/28   20:12:05     2013/10/28   20:12:05     2013/10/28   20:12:05     2013/10/28   20:12:05     2013/10/28   20:12:05	2013/10/28   01:36:06   268     2013/10/28   02:24:05   Halo     2013/10/28   02:24:05   Halo     2013/10/28   04:48:05   315     2013/10/28   04:48:05   315     2013/10/28   08:36:06   90     2013/10/28   09:36:05   277     2013/10/28   12:12:05   272     2013/10/28   12:48:07   195     2013/10/28   13:36:05   274     2013/10/28   14:12:05   283     2013/10/28   15:36:05   Halo     2013/10/28   15:36:05   313     2013/10/28   16:24:05   273     2013/10/28   20:12:05   313     2013/10/28   20:12:05   271	2013/10/28   01:36:06   268   46     2013/10/28   02:24:05   Halo   360     2013/10/28   02:24:05   Halo   360     2013/10/28   04:48:05   315   156     2013/10/28   04:48:05   315   156     2013/10/28   09:36:05   277   27     2013/10/28   12:12:05   272   27     2013/10/28   12:48:07   195   71     2013/10/28   13:36:05   274   40     2013/10/28   14:12:05   283   93     2013/10/28   15:36:05   Halo   360     2013/10/28   15:36:05   313   50     2013/10/28   20:12:05   313   50     2013/10/28   20:12:05   271   64	2013/10/28 01:36:06 268 46 480   2013/10/28 02:24:05 Halo 360 695   2013/10/28 04:48:05 315 156 1201   2013/10/28 04:48:05 315 156 1201   2013/10/28 04:48:05 315 156 1201   2013/10/28 04:48:05 277 27 814   2013/10/28 09:36:05 277 27 681   2013/10/28 12:12:05 272 27 681   2013/10/28 12:48:07 195 71 354   2013/10/28 13:36:05 274 40 495   2013/10/28 14:12:05 283 93 1073   2013/10/28 15:36:05 Halo 360 812   2013/10/28 16:24:05 273 41 482   2013/10/28 20:12:05 313 50 886   2013/10/28 20:12:05 271 64 469	2013/10/28 01:36:06 268 46 480 712   2013/10/28 02:24:05 Halo 360 695 575   2013/10/28 02:24:05 Halo 360 695 575   2013/10/28 04:48:05 315 156 1201 881   2013/10/28 04:48:05 315 156 1201 881   2013/10/28 08:36:06 90 32 266 329   2013/10/28 09:36:05 277 27 814 550   2013/10/28 12:12:05 272 27 681 628   2013/10/28 12:48:07 195 71 354 425   2013/10/28 13:36:05 274 40 495 555   2013/10/28 14:12:05 283 93 1073 805   2013/10/28 15:36:05 Halo 360 812 685   2013/10/28 16:24:05 273 41 482 535   2013/10/28 20:12:05 313 50 886 864	CO13/10/28   O1:36:06   268   46   480   712   1791     2013/10/28   02:24:05   Halo   360   695   575   616     2013/10/28   02:24:05   Halo   360   695   575   616     2013/10/28   04:48:05   315   156   1201   881   1116     2013/10/28   08:36:06   90   32   266   329   414     2013/10/28   08:36:05   277   27   814   550   606     2013/10/28   12:12:05   272   27   681   628   596     2013/10/28   12:48:07   195   71   354   425   550     2013/10/28   13:36:05   274   40   495   555   1092     2013/10/28   14:12:05   283   93   1073   805   859     2013/10/28   15:36:05   Halo   360   812   685   674     2013/10/28   16:24:05   273	$2013/10/28$ $01:36:06$ $268$ $46$ $480$ $712$ $1791$ $128.5^{*1}$ $2013/10/28$ $02:24:05$ Halo $360$ $695$ $575$ $616$ $-12.1$ $2013/10/28$ $02:24:05$ Halo $360$ $695$ $575$ $616$ $-12.1$ $2013/10/28$ $02:24:05$ $315$ $156$ $1201$ $881$ $1116$ $-45.2$ $2013/10/28$ $02:36:05$ $277$ $27$ $814$ $550$ $606$ $-32.1$ $2013/10/28$ $09:36:05$ $277$ $27$ $681$ $628$ $596$ $-7.7$ $2013/10/28$ $12:12:05$ $272$ $27$ $681$ $628$ $596$ $-7.7$ $2013/10/28$ $12:48:07$ $195$ $71$ $354$ $425$ $550$ $9.4^{*1}$ $2013/10/28$ $13:36:05$ $274$ $40$ $495$ $555$ $1092$ $42.6^{*1}$ $2013/10/28$ $14:12:05$ $283$ $93$ $1073$ $805$ $859$ $-42.2$ $2013/10/28$ $15:36:05$ Halo $360$ 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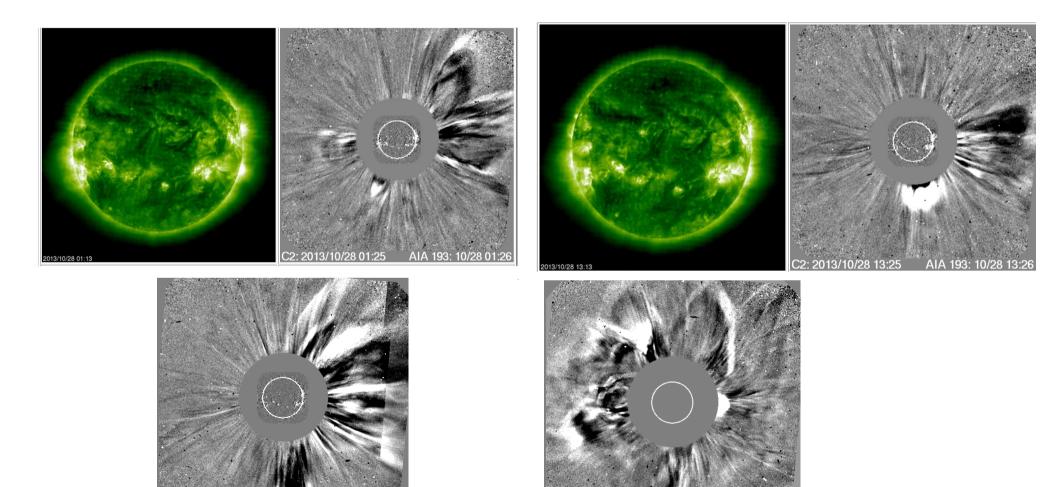


#### Is it the same ICME ?

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

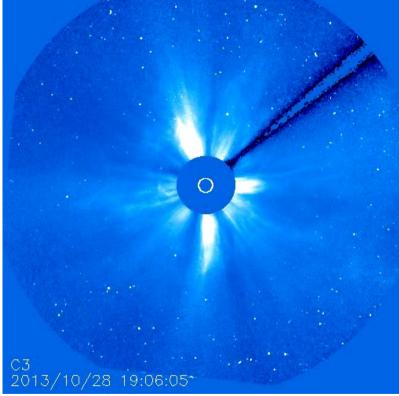


# Is it the same ICME ?A quite active period (15 CMEs that day)



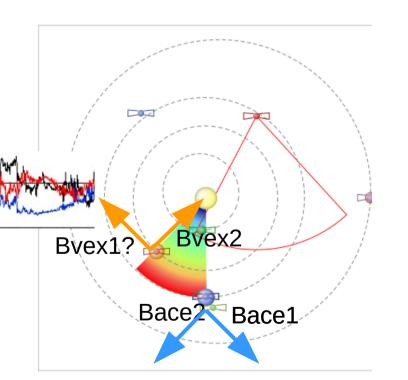
### Is it the same ICME ?

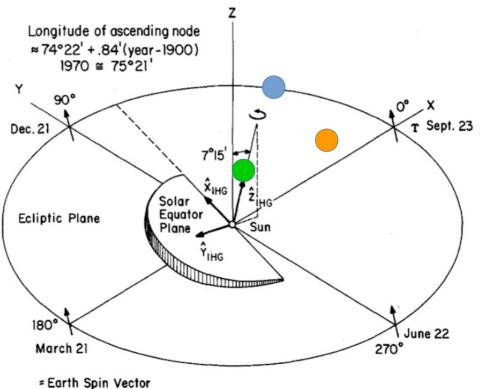
- A quite active period (15 CMEs that day)
- Halo CME is detected: so yes it should be the same.



#### 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...





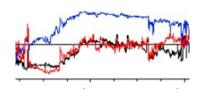


Figure 3 Inertial Heliographic (IHG) coordinates defined by Burlaga (1984); Heliocentric Inertial (HCI) coordinates are defined in the same way but based on an epoch of J2000. The plane of the Heliocentric Aries Ecliptic (HAE) system is shown; the first point in Aries in on/around March 21.

### **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