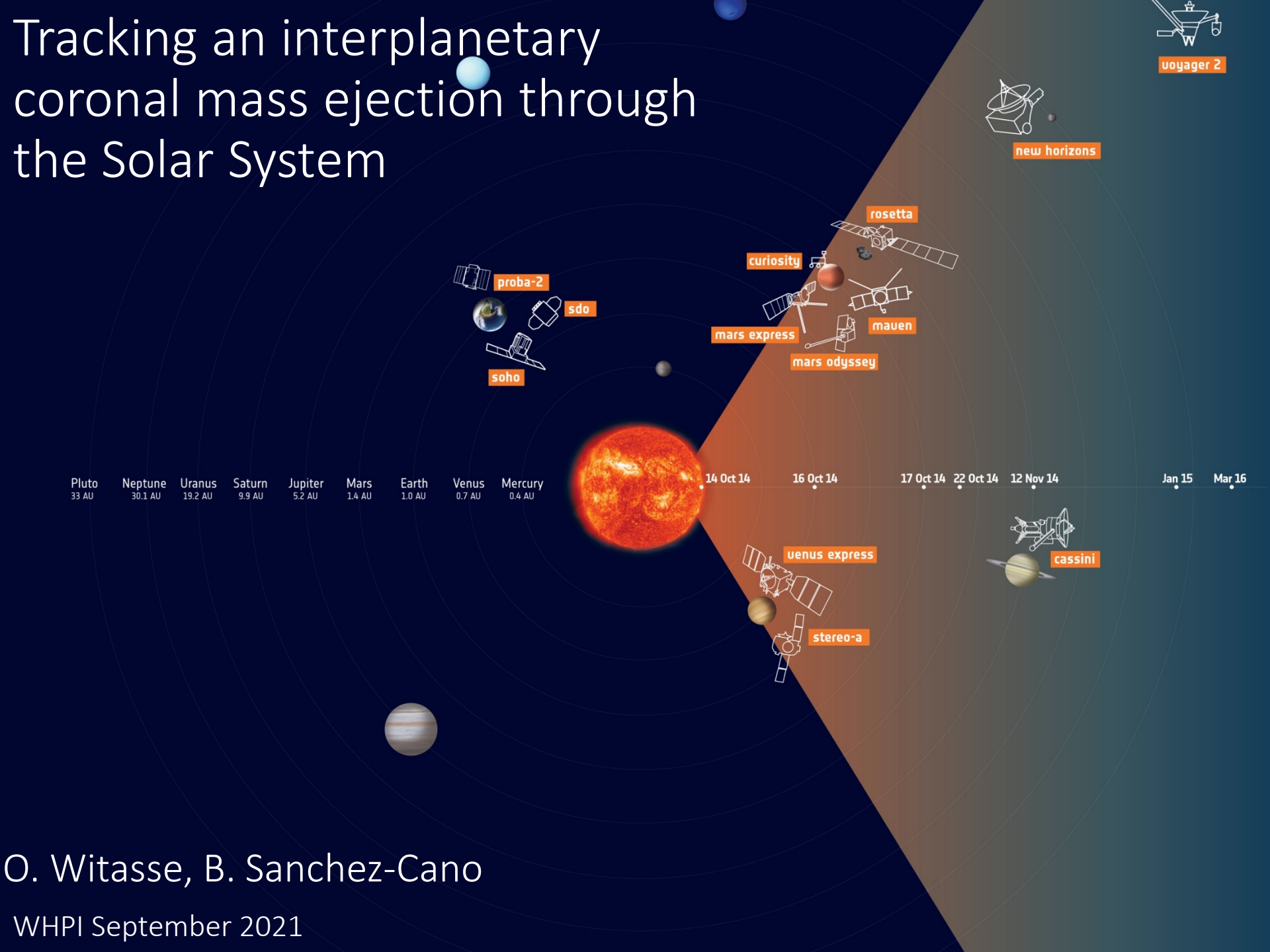
Tracking an interplanetary coronal mass ejection through the Solar System



O. Witasse, B. Sanchez-Cano

WHPI September 2021

SidingSpring-To-Mars Range
Time (UTCG): 19 Oct 2014 17:42:20
Range (km): 204746

SidingSpring

Odyssey

Curiosity

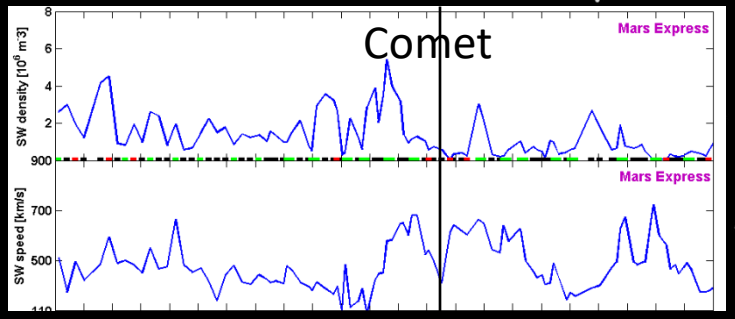
MarsExpress

MOM

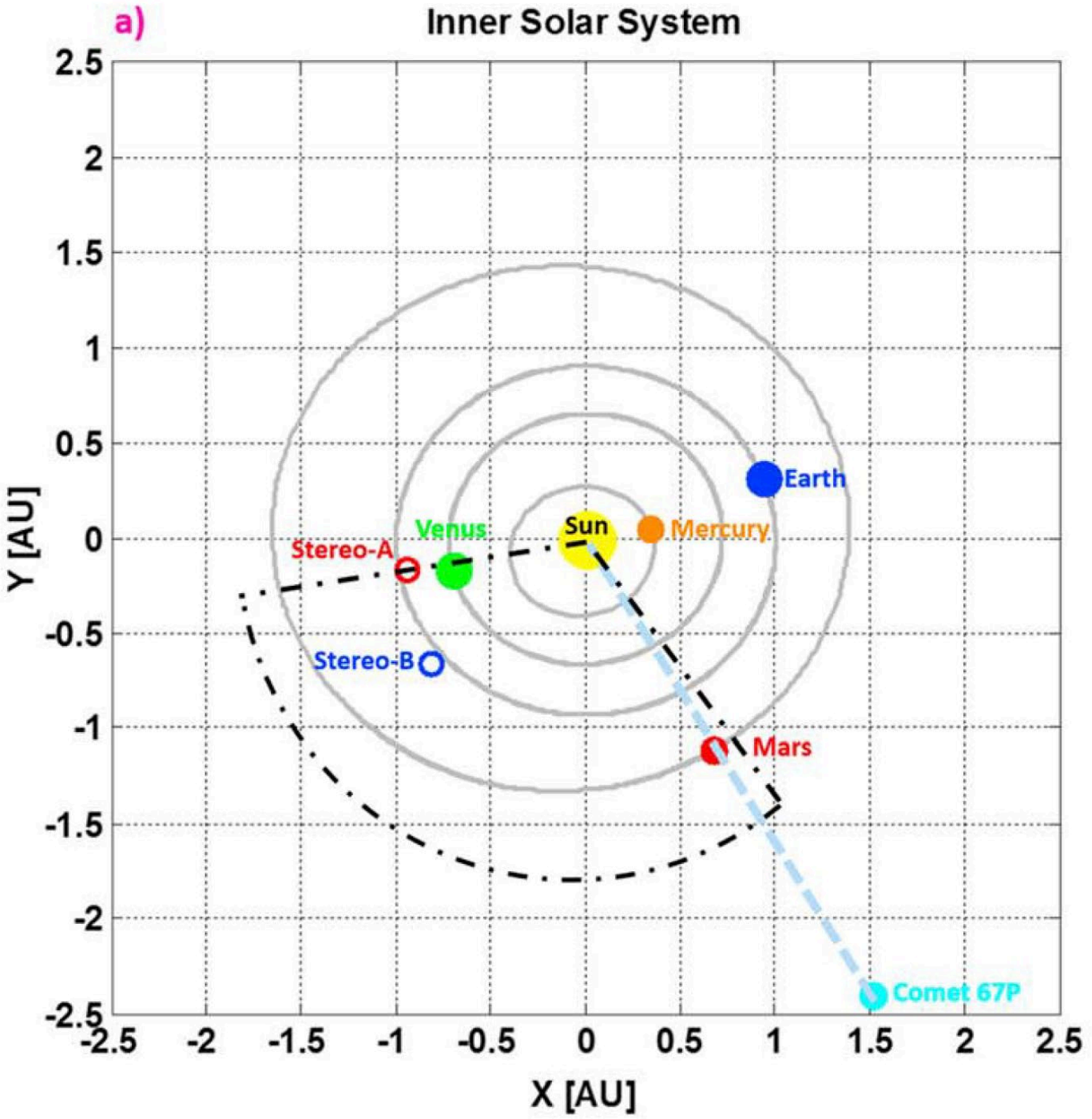
ortunity

MRO

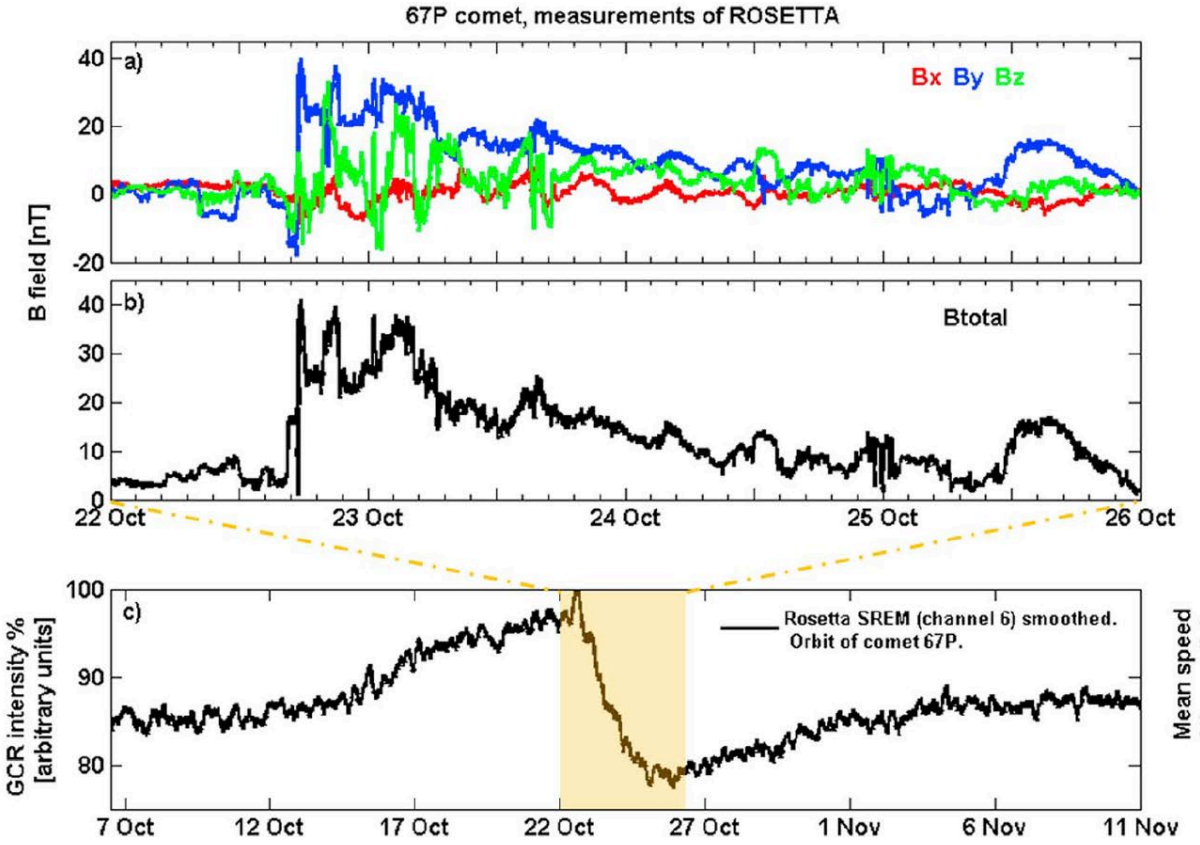
MAVEN

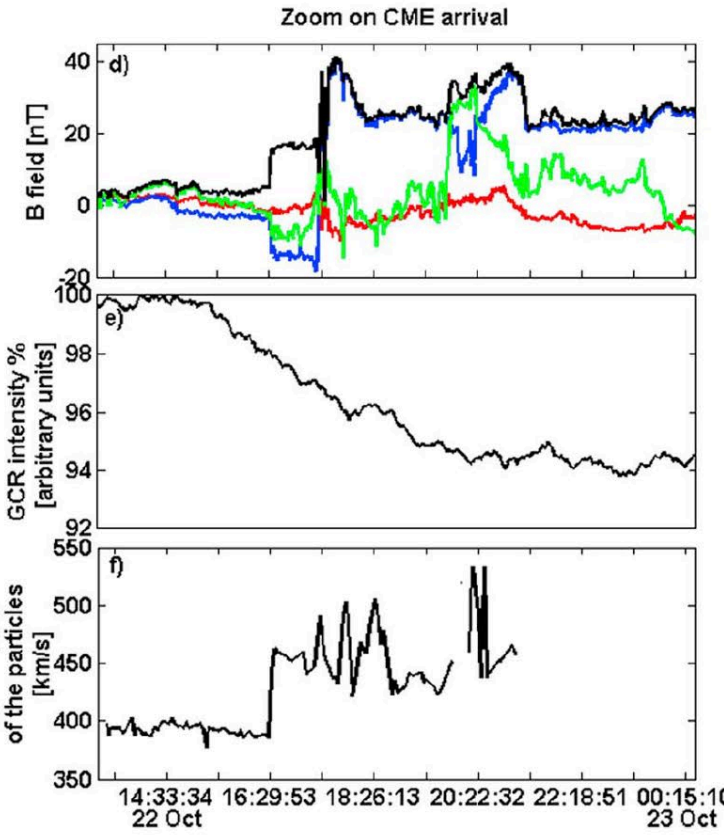


Cometary signature or space weather effect?


a)
Inner Solar System
Earth
Sun
Venus
Mercury
Stereo-A
Stereo-B
Mars
Comet 67P
Y [AU]
X [AU]
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5

Rosetta

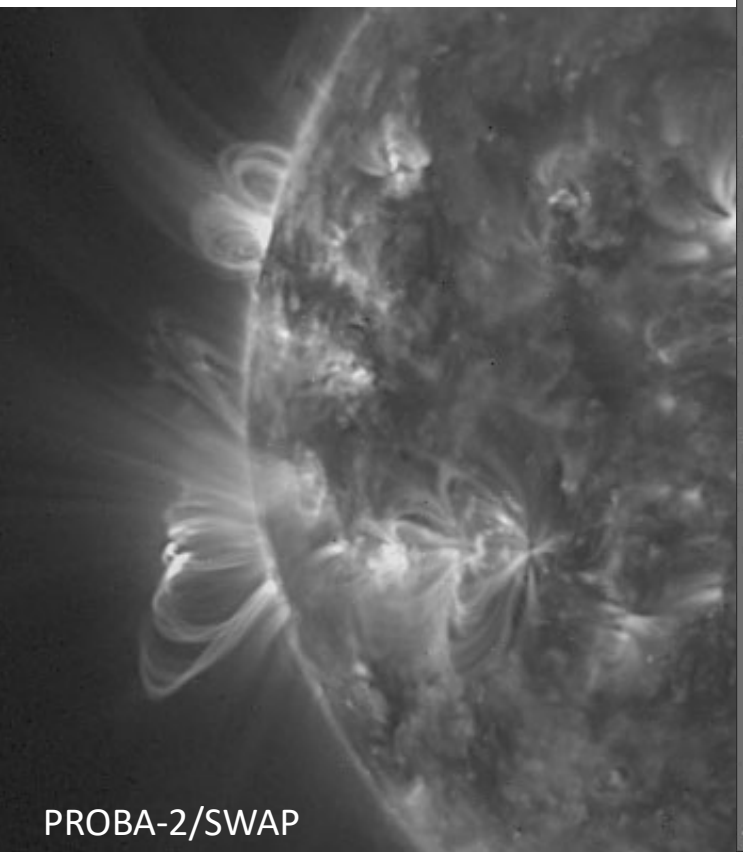


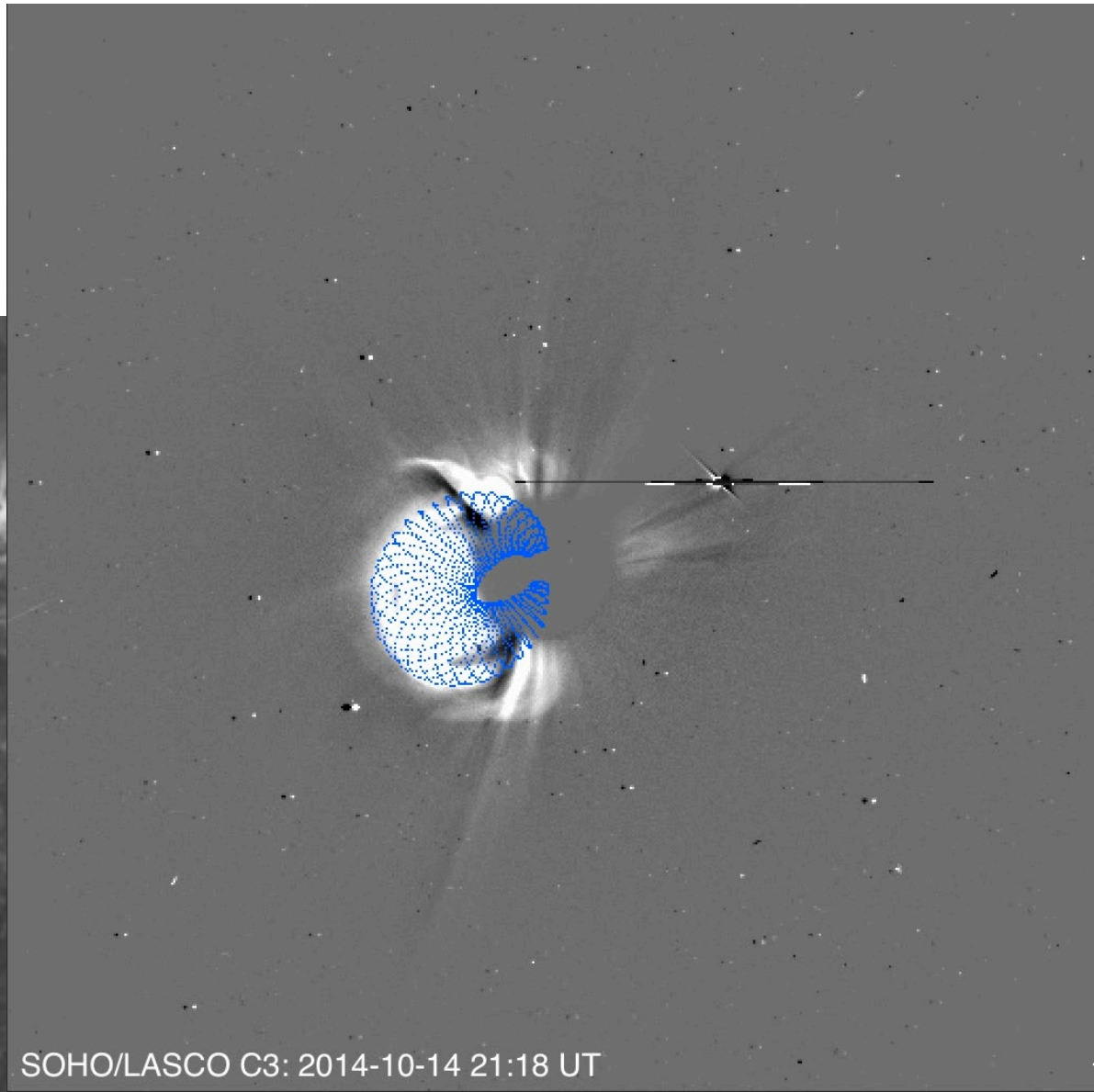


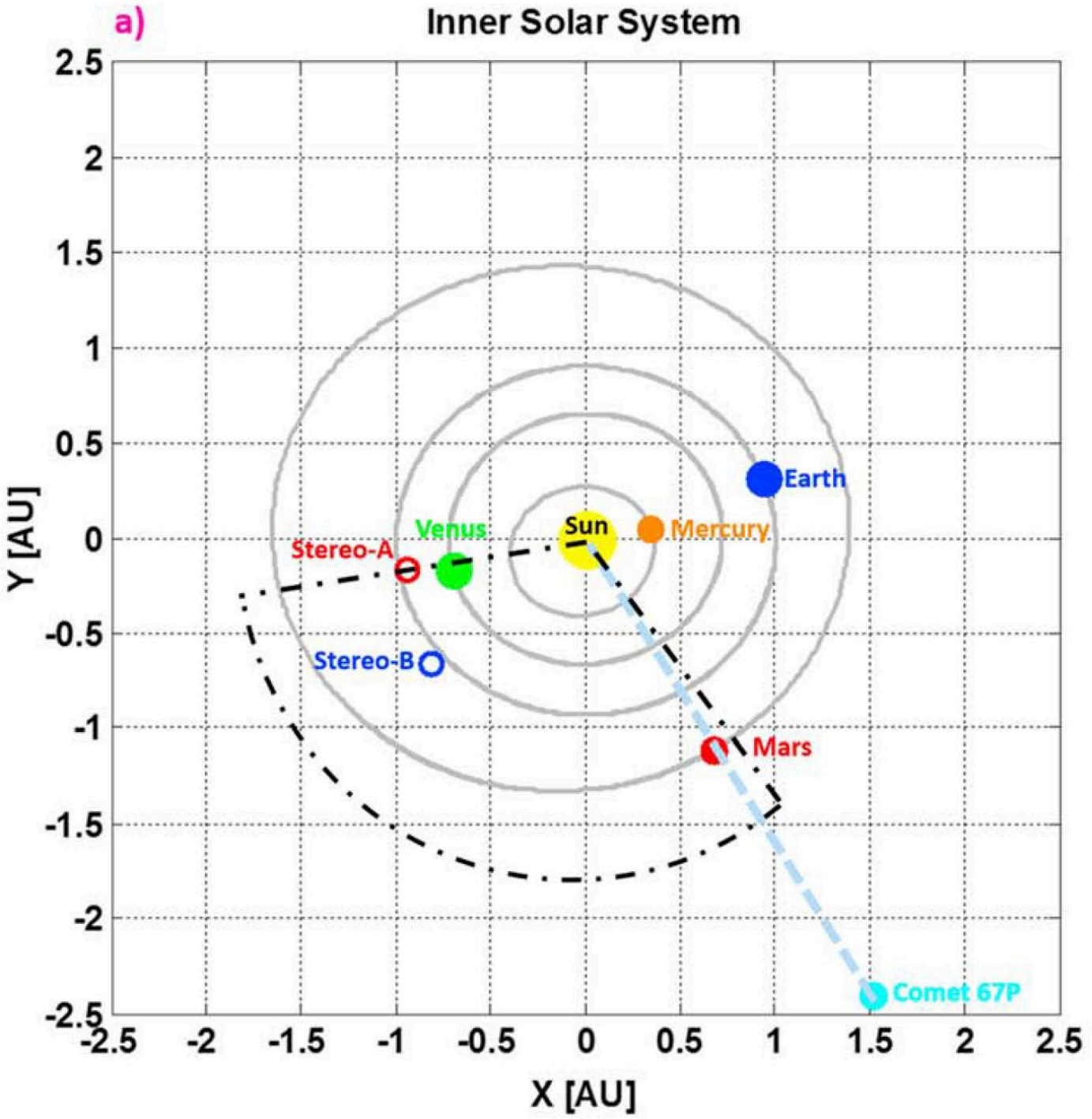
Comet 67P	CME detection with Rosetta magnetometer data	22 Oct 2014 T16:30	3.13
	CME detection with Rosetta ion data (solar wind proton energy)	22 Oct 2014 T17:24	
	FD onset with Rosetta SREM data (Channel 6)	22 Oct 2014 T14:24	
	CME associated shock/compression from WSA-ENLIL + Cone	22 Oct 2014 T09:30	
	CDPP propagation tool prediction	22 Oct 2014 T17:00	

14 October 2014 18:30 UT CME

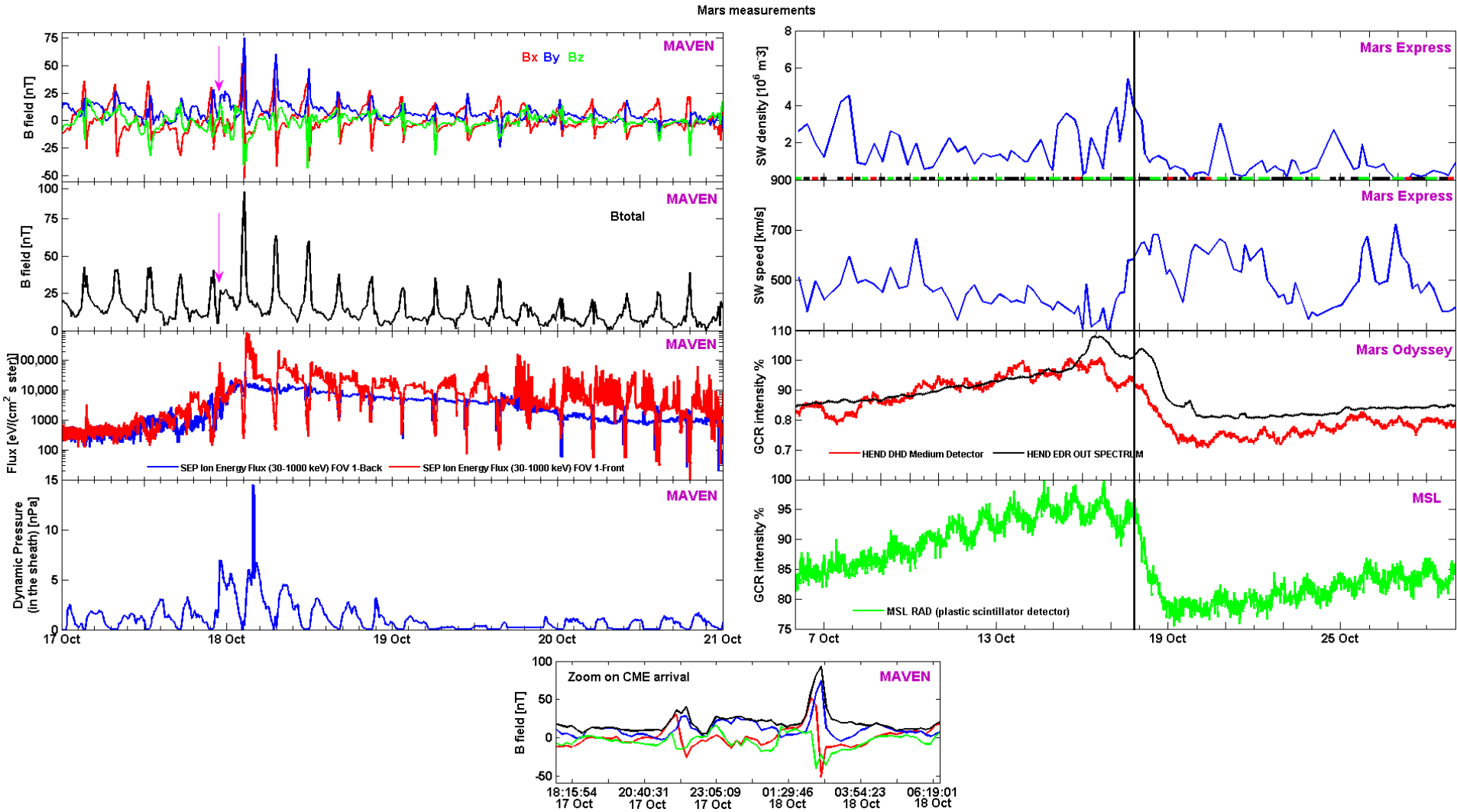
v = 850 ± 200 km/s
lon = -120° ± 30°
lat= -11° ± 5°
full width = 106° ± 10°






a)
Inner Solar System
Earth
Sun
Venus
Mercury
Stereo-A
Stereo-B
Mars
Comet 67P
Y [AU]
X [AU]
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5

Mars: MAVEN, Mars Express, Mars Odyssey, MSL

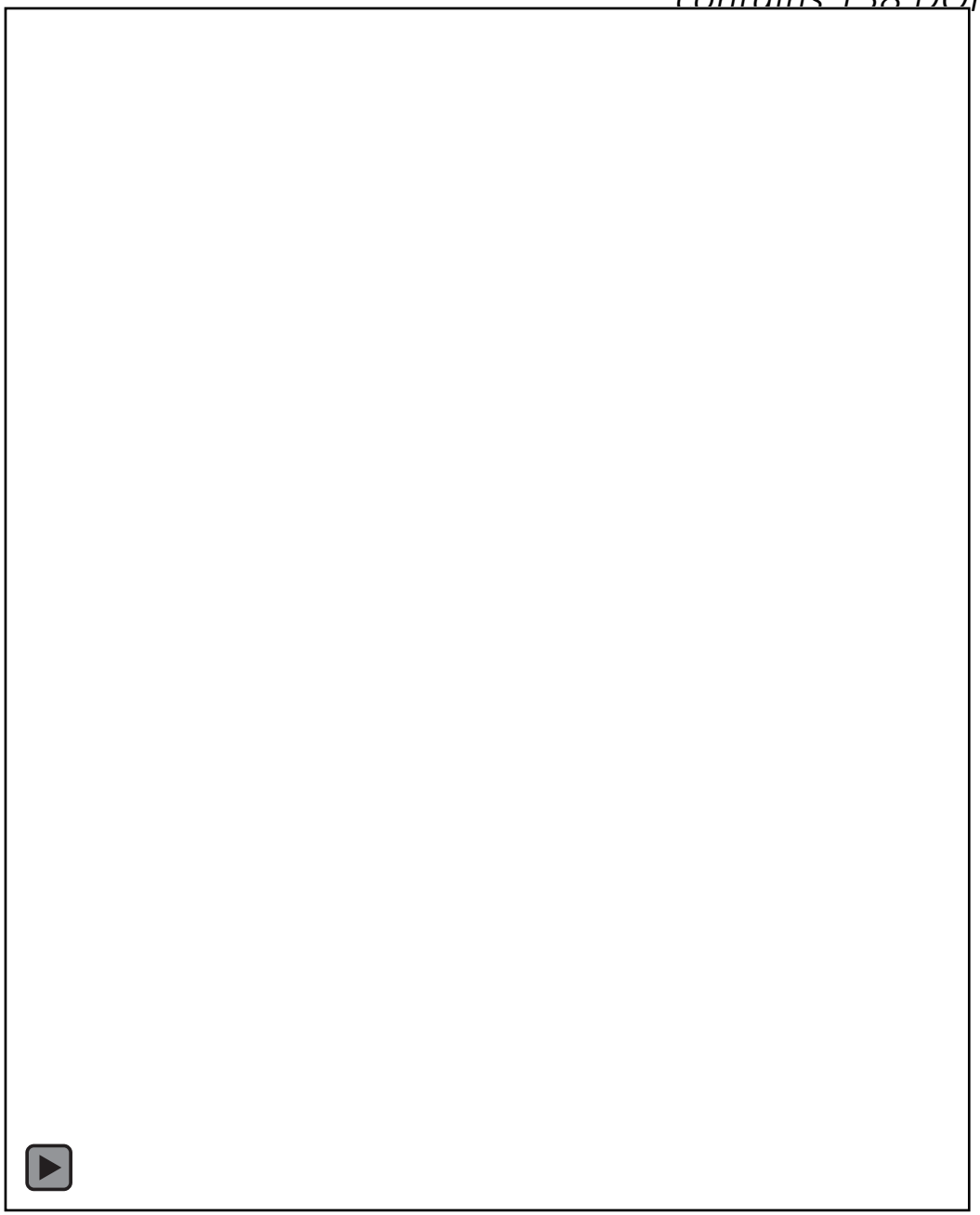


Mars	CME detection with Mars Express ASPERA data	17 Oct 2014 T15:45–22:50	1.41
	CME detection with MAVEN magnetometer data	17 Oct 2014 T22:53	
	FD onset with MSL RAD data (Plastic detector)	17 Oct 2014 T20:09	
	FD onset with HEND Mars Odyssey (DHD medium detector)	17 Oct 2014 T18:15	
	CME associated shock/compression from WSA-ENLIL + Cone	18 Oct 2014 T00:00	
	CDPP propagation tool prediction	17 Oct 2014 T22:51	

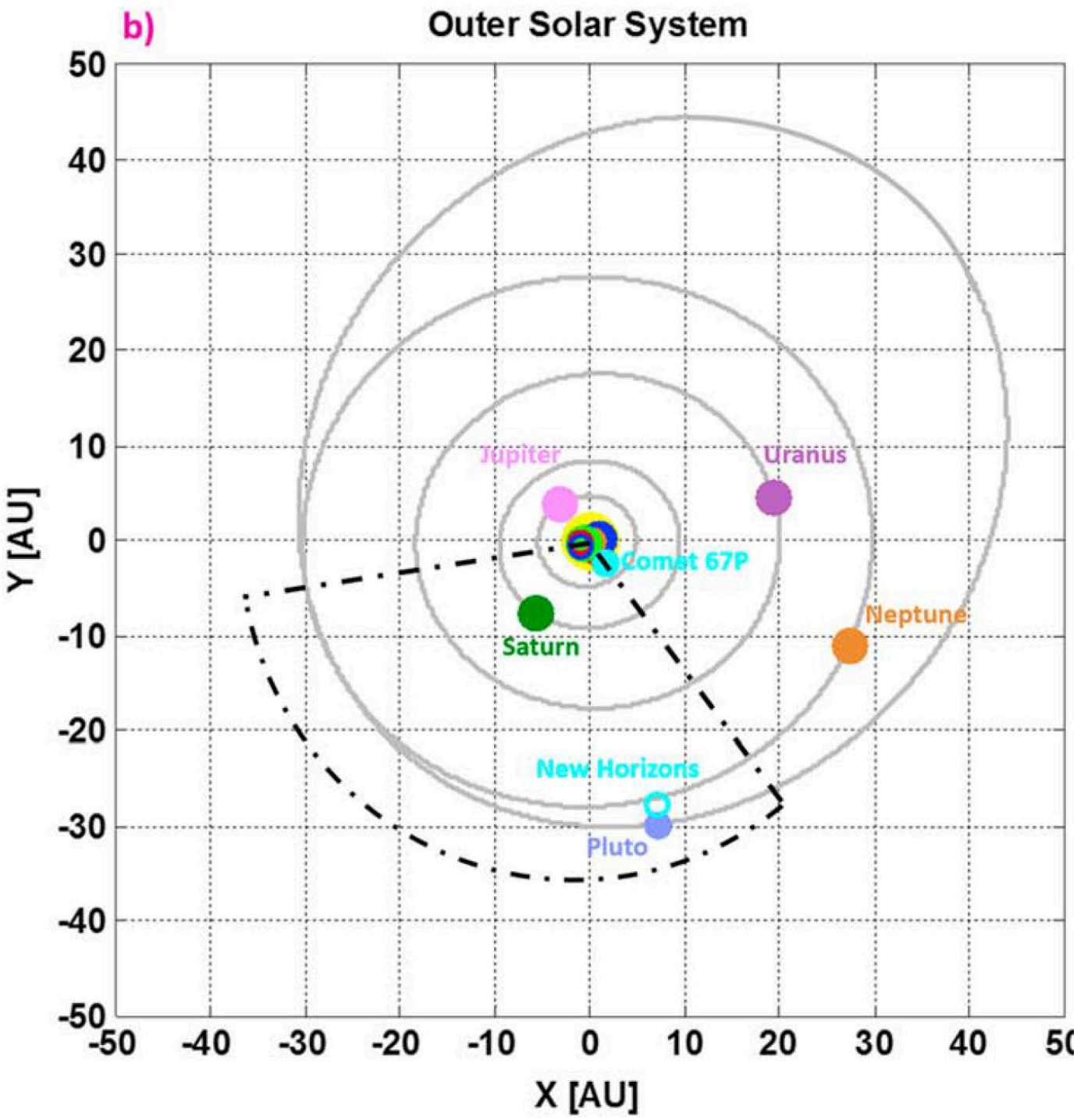
14 October 2014 18:30 UT CME WSA-ENLIL+Cone simulation

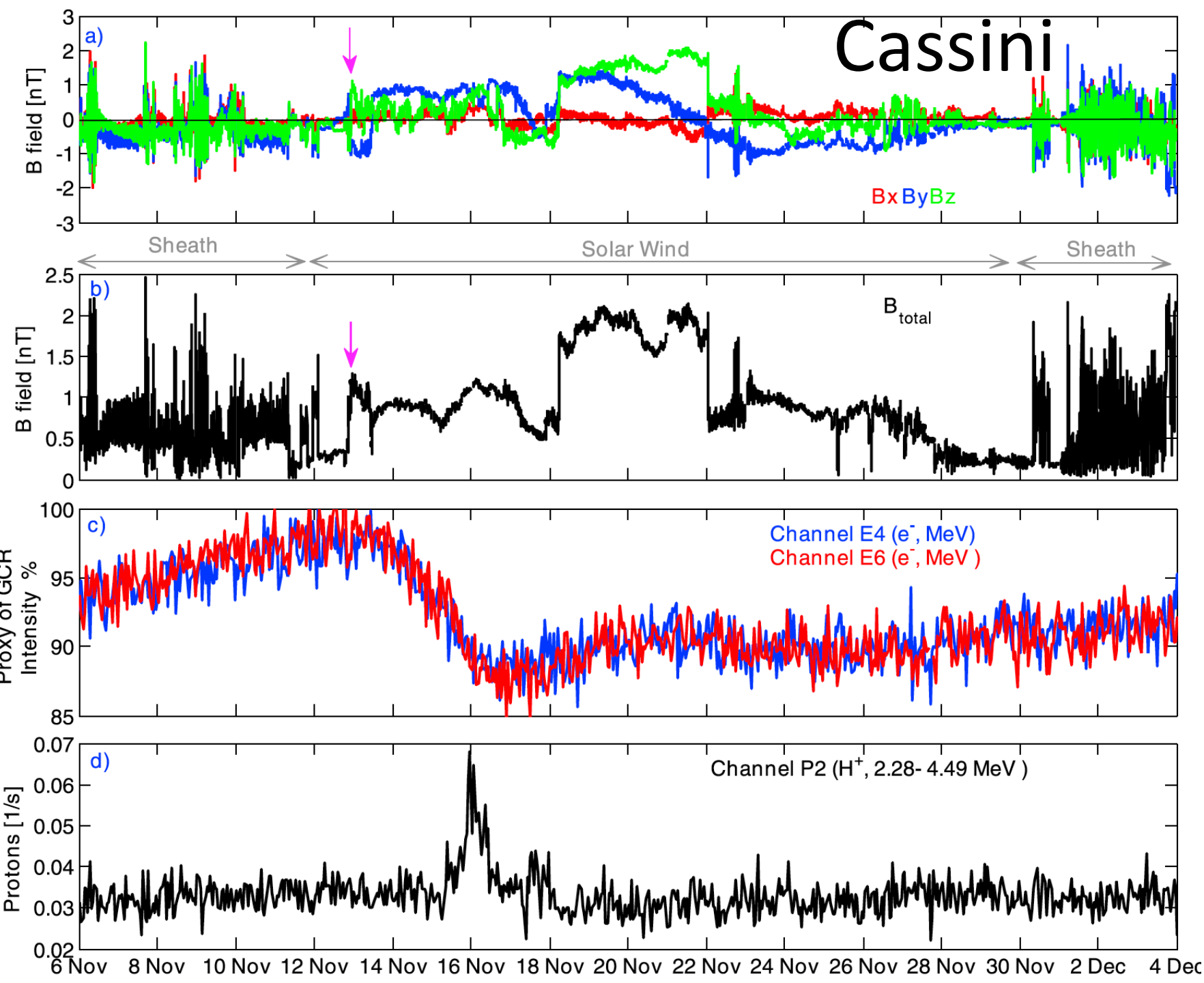
contains 138 DONKI CMEs with v>500 km/s

outer boundary: 10 AU

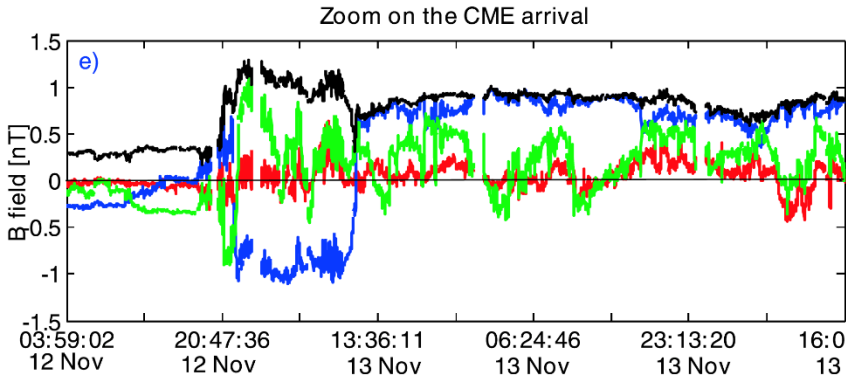


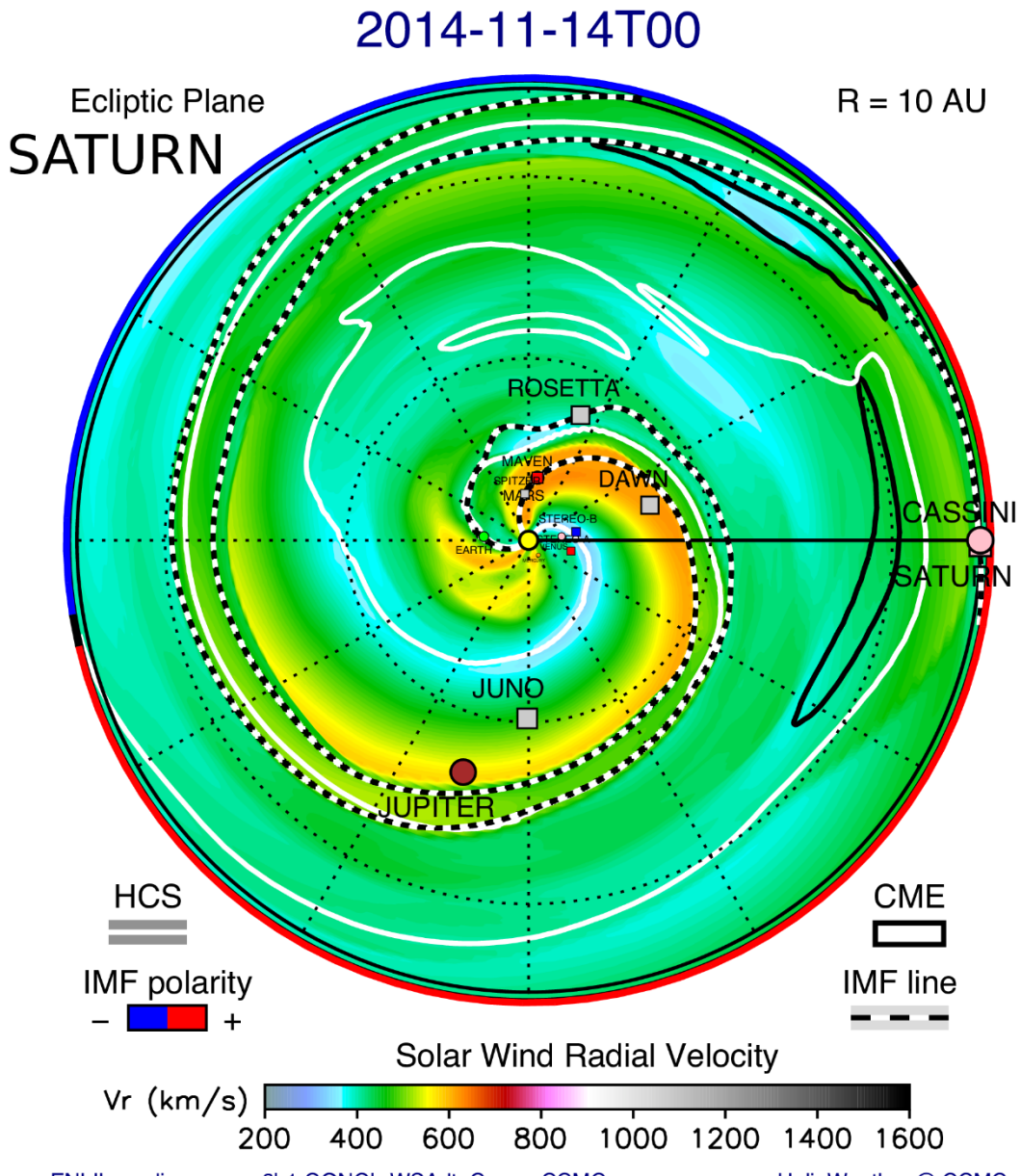
CME input parameters:
v = 1015 km/s
lon = -150°
lat= -12°
full width = 116°


b)
Outer Solar System
Jupiter
Uranus
Comet 67P
Saturn
Neptune
New Horizons
Pluto
Y [AU]
X [AU]
50
40
30
20
10
0
-10
-20
-30
-40
-50
-50
-40
-30
-20
-10
0
10
20
30
40
50

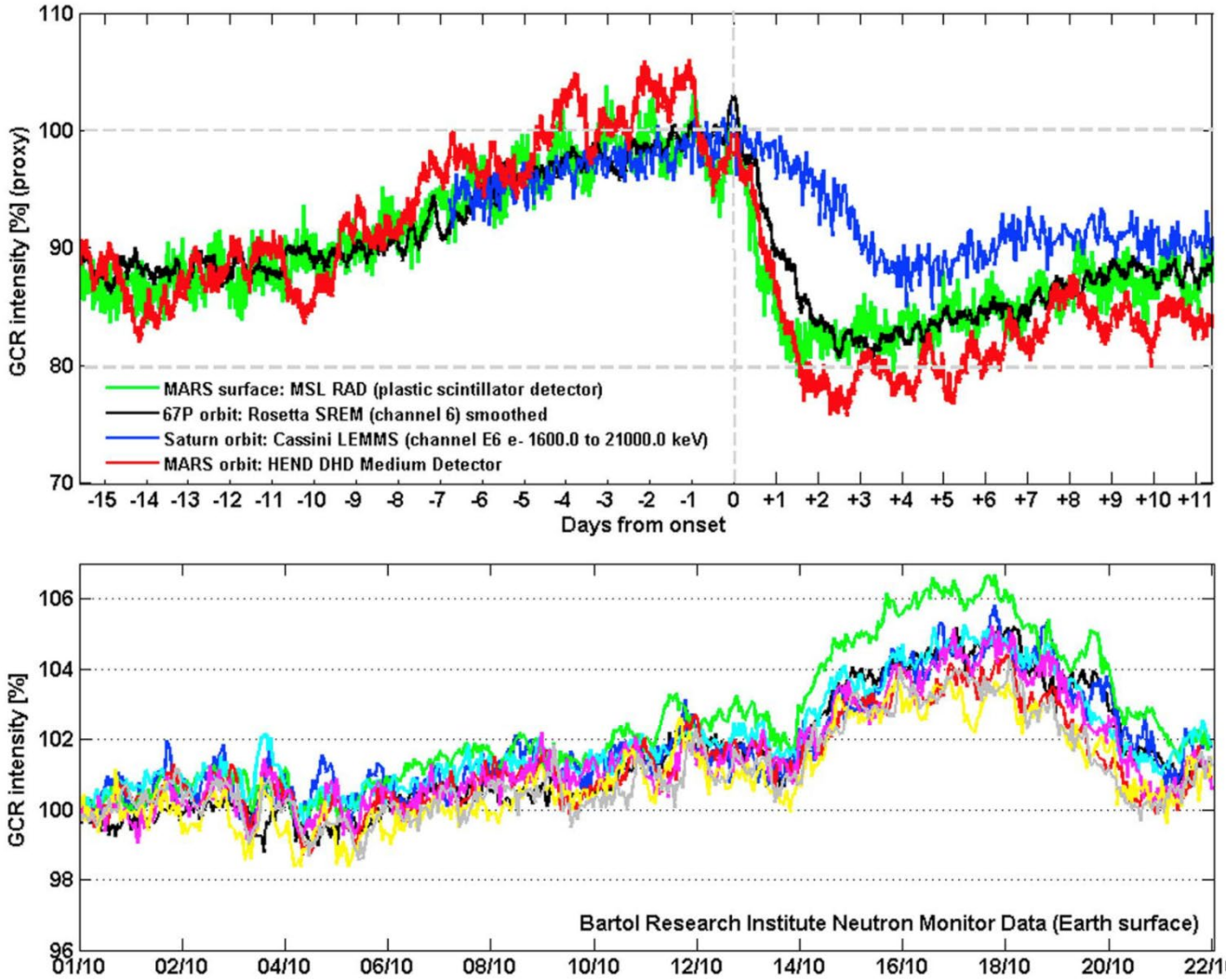

Cassini
a)
B field [nT]
Bx By Bz
Sheath
Solar Wind
Sheath
b)
B field [nT]
B total
c)
Proxy of GCR Intensity %
Channel E4 (e-, MeV)
Channel E6 (e-, MeV)
d)
Protons [1/s]
Channel P2 (H+, 2.28- 4.49 MeV)
6 Nov
8 Nov
10 Nov
12 Nov
14 Nov
16 Nov
18 Nov
20 Nov
22 Nov
24 Nov
26 Nov
28 Nov
30 Nov
2 Dec
4 Dec

Saturn	CME detection with Cassini-Huygens magnetometer data	12 Nov 2014 T18:55	9.94
	FD onset with Cassini-Huygens MIMI data	12 Nov 2014 T17:30	
	CME associated shock/compression from WSA-ENLIL + Cone	15 Nov 2014 T12:00	
	CDPP propagation tool prediction	12 Nov 2014 T16:09	

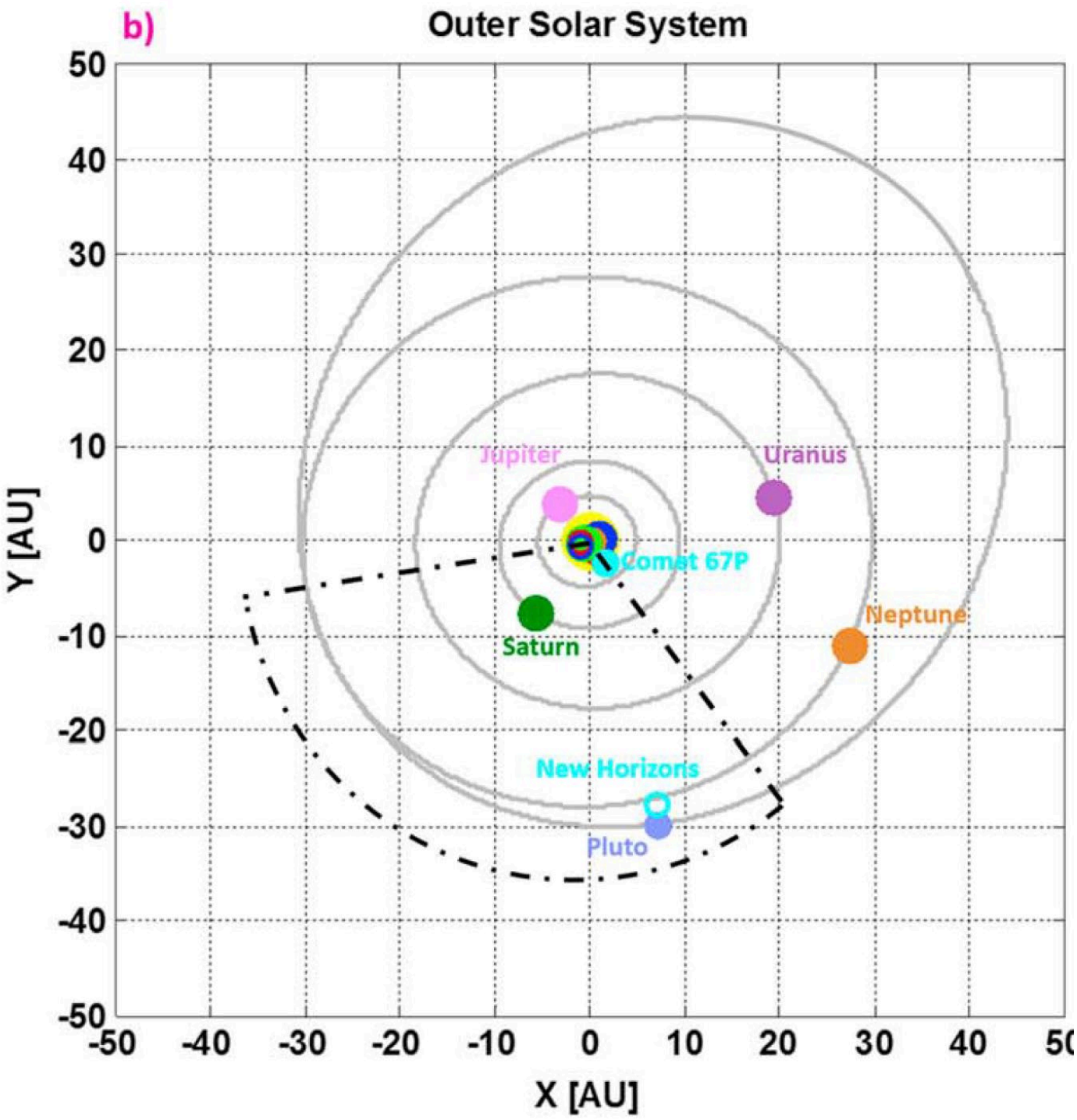




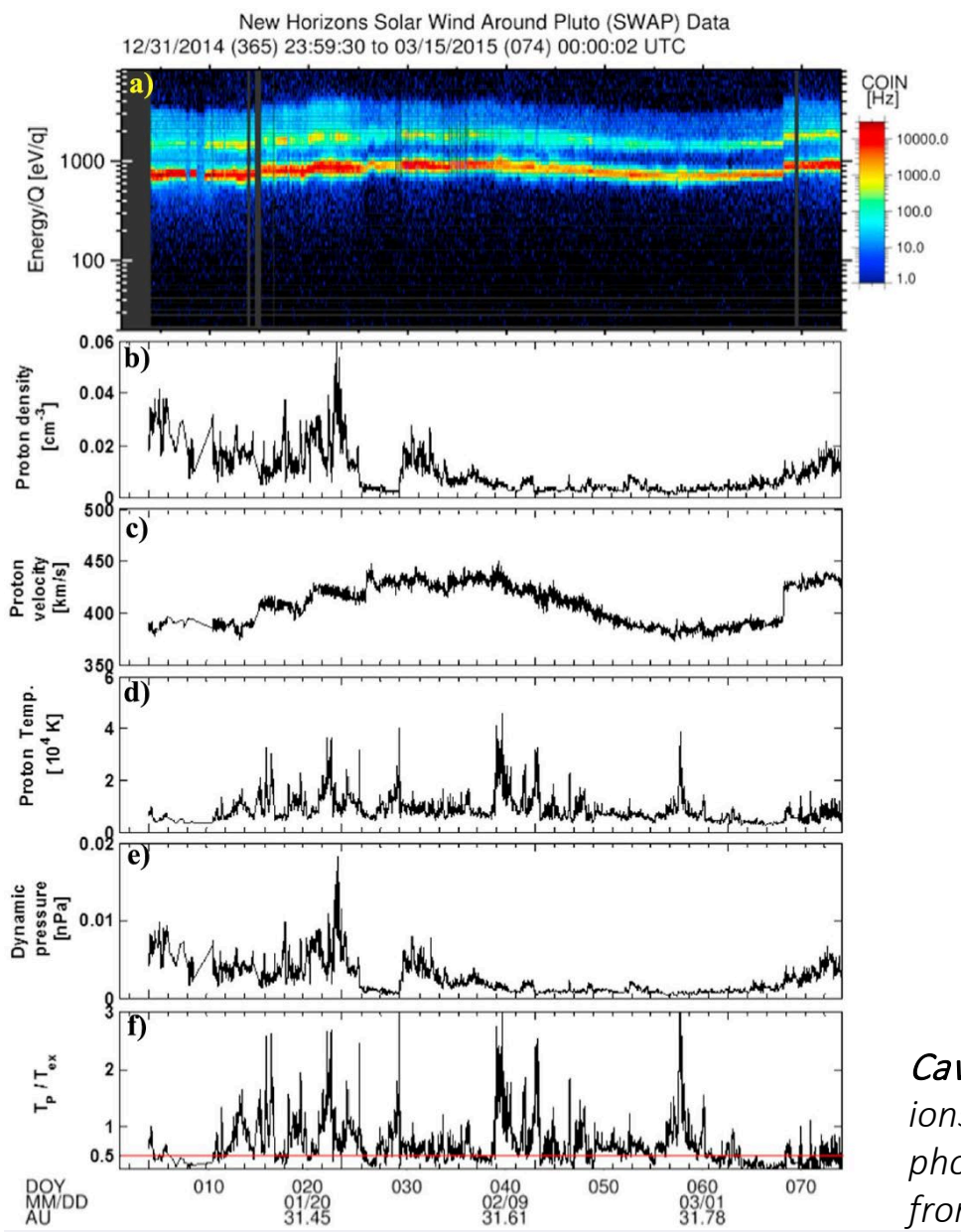
Comparison of Forbush decreases at Mars, Rosetta, and Saturn

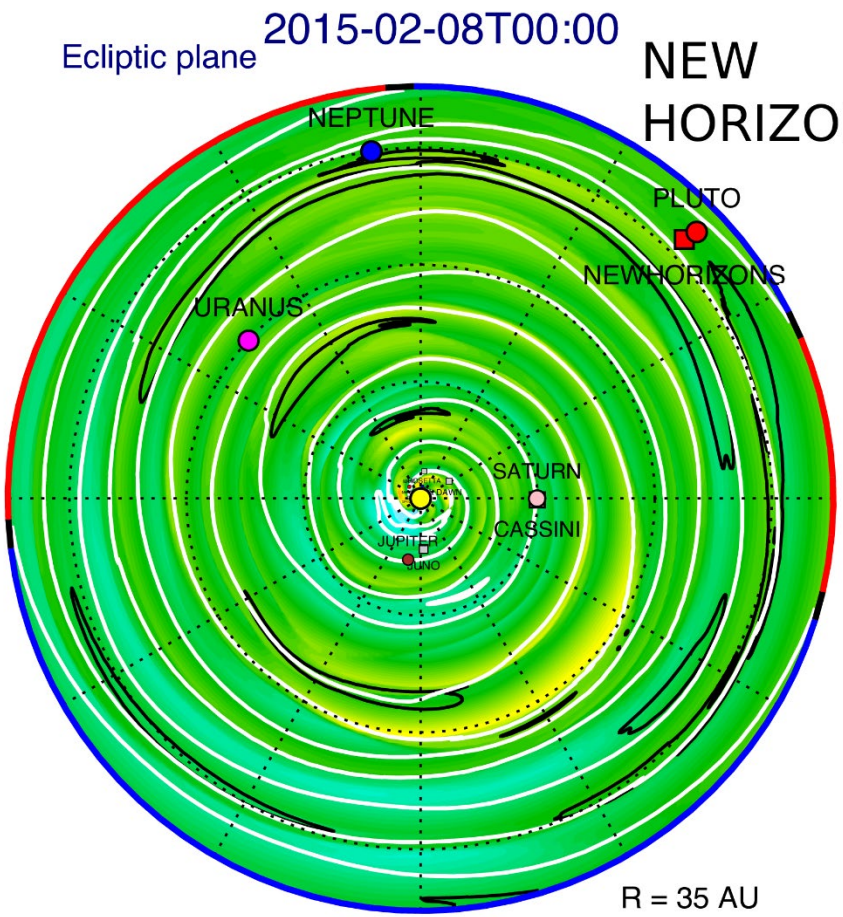


		Possible Shock (Start of the Sheath Passage) (UT)	Start of the ICME Ejecta Passage (CME Plasma Body) (UT)	End of the Forbush Decrease (UT)	Magnitude of Decrease (Related to the ICME Body) (%)	Duration of the Decrease (hour)	Slope of the Decreases (%/hour)
Mars	MSL	16 Oct 2014 T18:11	17 Oct 2014 T20:09	19 Oct 2014 T04:56	19	~33	0.57
	Mars Odyssey	16 Oct 2014 T18:05	17 Oct 2014 T18:15	19 Oct 2014 T08:35	23	~38.5	0.60
Comet 67P		22 Oct 2014 T09:50	22 Oct 2014 T14:24	25 Oct 2014 T02:40	17	~60	0.28
Saturn		12 Nov 2014 T18:30	15 Nov 2014 T10:30	16 Nov 2014 T21:20	15	~98.5	0.15


b)
Outer Solar System
Jupiter
Uranus
Comet 67P
Saturn
Neptune
New Horizons
Pluto
Y [AU]
X [AU]
50
40
30
20
10
0
-10
-20
-30
-40
-50
-50
-40
-30
-20
-10
0
10
20
30
40
50

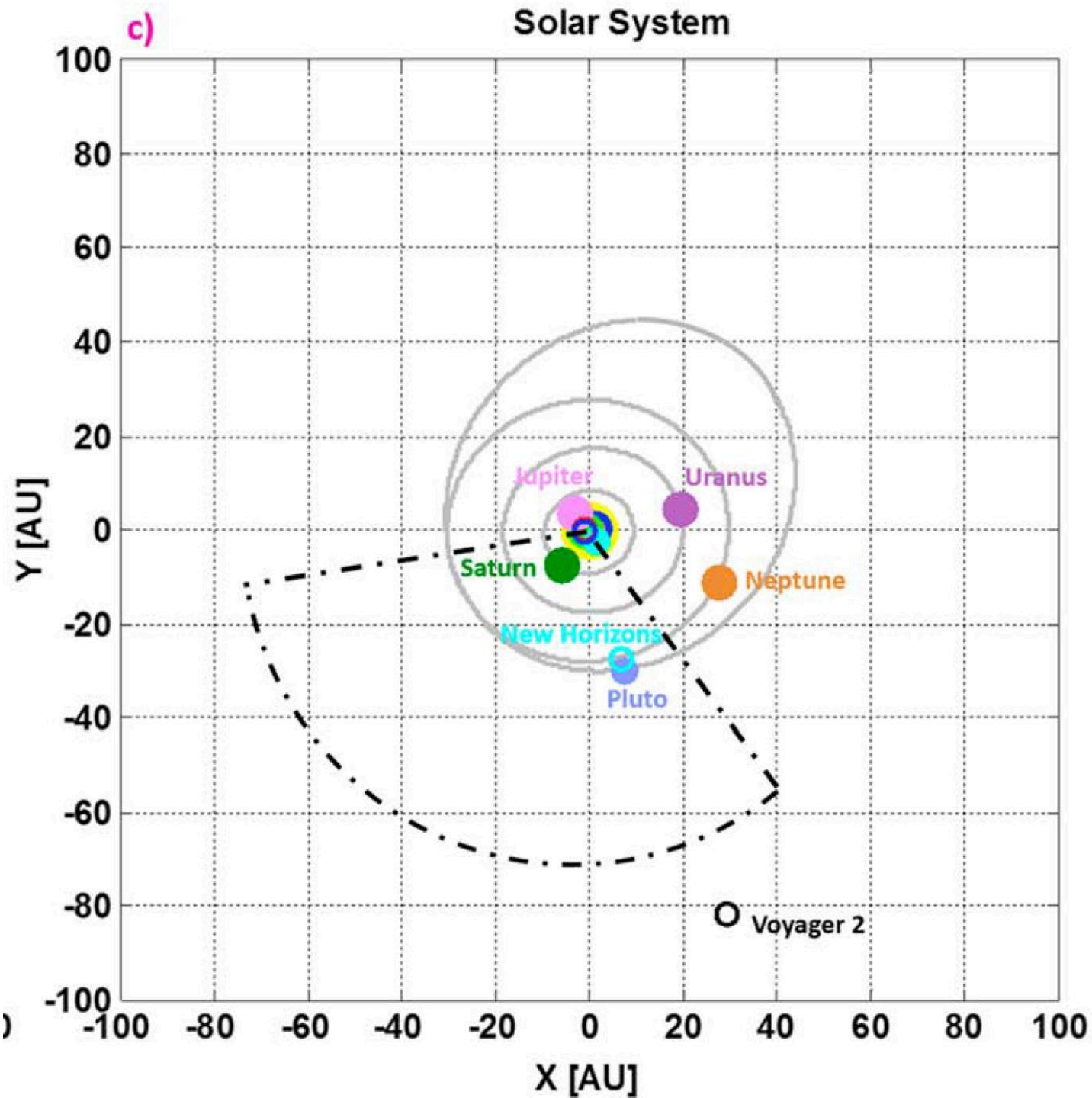
New Horizons



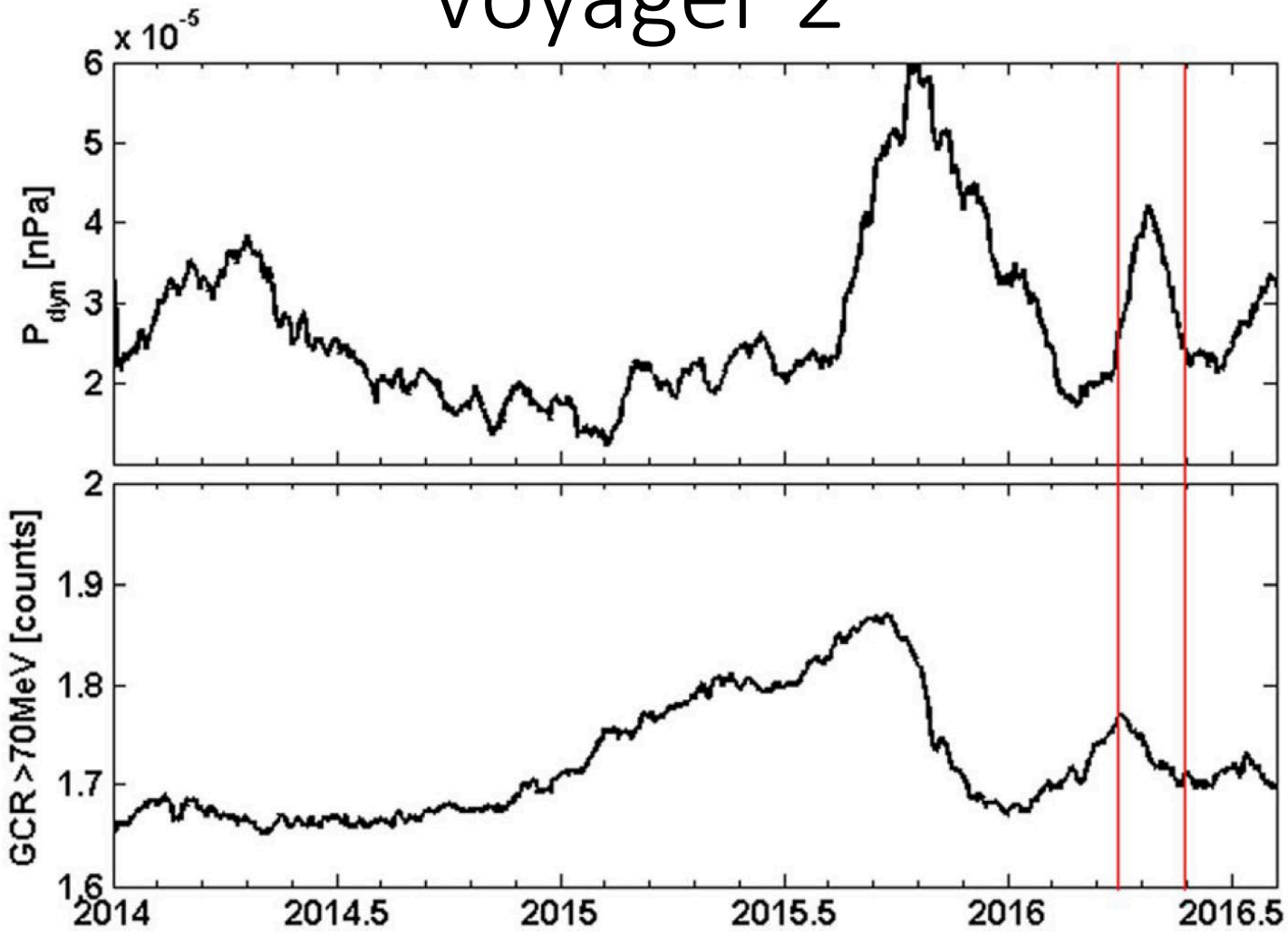


Caveat: *ENLIL does not include the drag effect from pickup ions or the enhancement of the wind mass density due to photoionization of neutral hydrogen entering the heliosphere from the interstellar medium*

New Horizons	Time window based on solar wind speed (see text)	18 Jan to 14 Feb 2015	31.49
	Possible detection of the ICME in the SWAP data	21–29 Jan 2015	
	CME associated shock/compression from WSA-ENLIL + Cone, prediction for the distance of NH (see text)	8 Feb 2015	
	CDPP propagation tool prediction for 31.5 AU	24 Jan 2015	


c)
Solar System
Jupiter
Uranus
Saturn
Neptune
New Horizons
Pluto
Voyager 2
Y [AU]
X [AU]
100
80
60
40
20
0
-20
-40
-60
-80
-100
-100
-80
-60
-40
-20
0
20
40
60
80
100

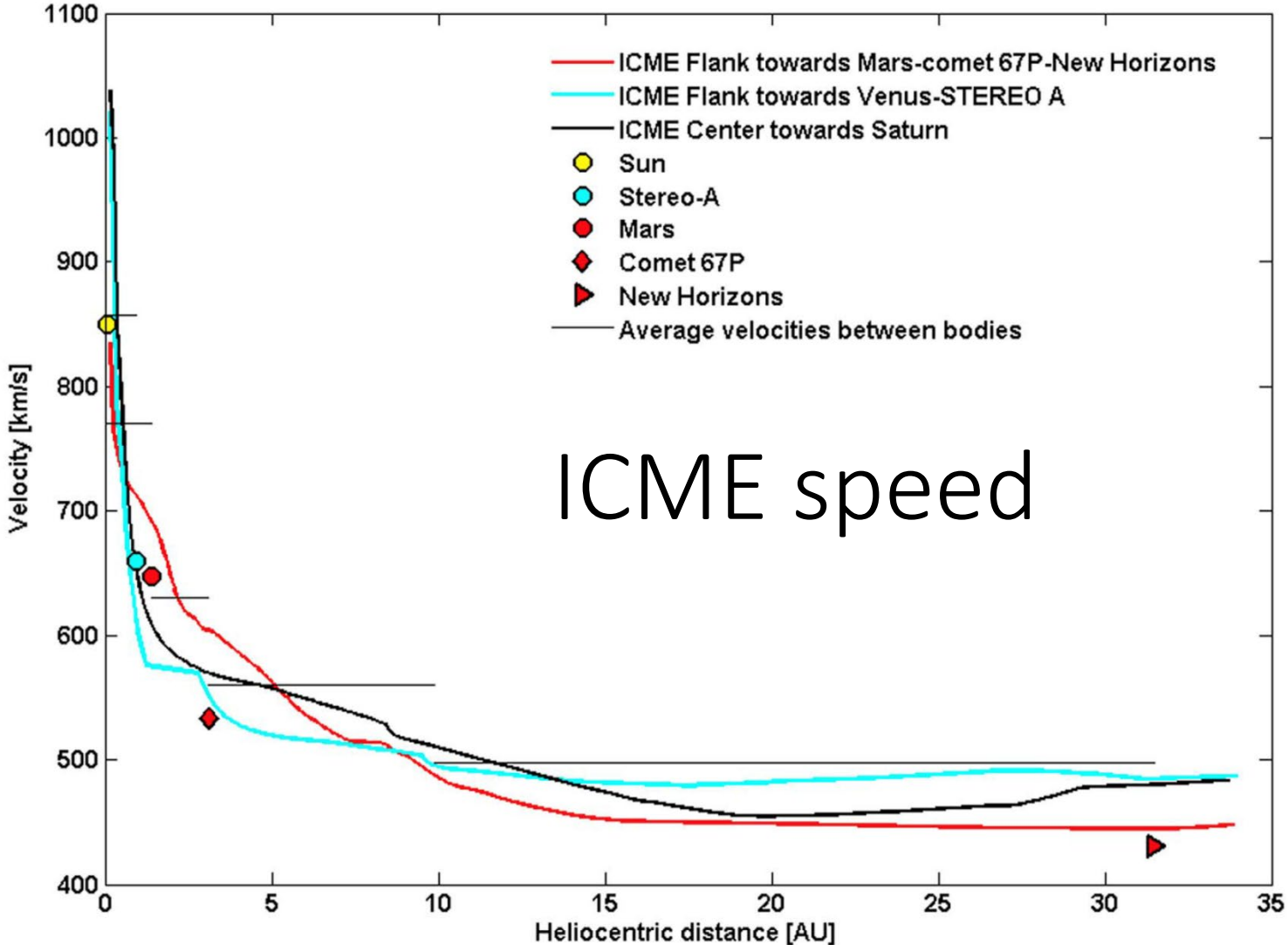
Voyager 2


x 10^-5
6
5
4
3
2
P_dyn [nPa]
2
1.9
1.8
1.7
1.6
GCR >70MeV [counts]
2014
2014.5
2015
2015.5
2016
2016.5

Timeline Summary

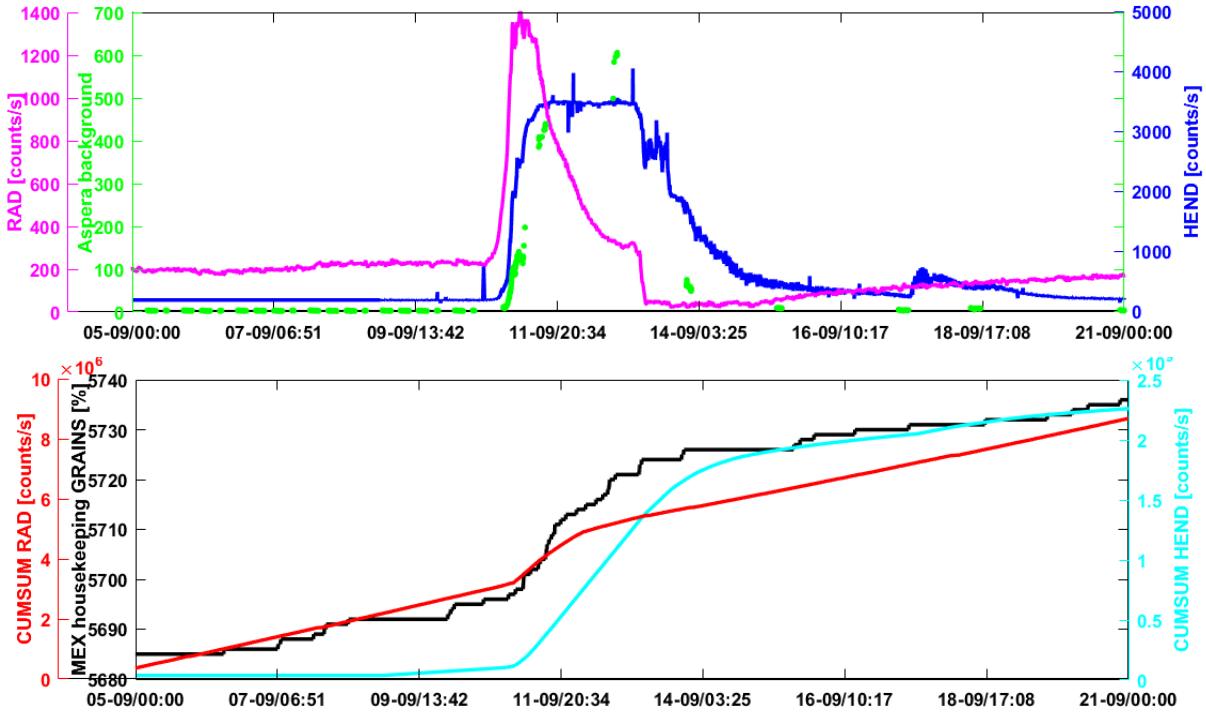
Date	Detected By	Location in Space	Distance from the Sun
Oct. 14, 2014	--	Sun – CME Launches	--
Oct. 16, 2014	Venus Express *(indirect data)*	Venus	0.72 AU
Oct. 16, 2014	STEREO-A	The Far Side of the Sun	0.96 AU
Oct. 17, 2014	Curiosity	Mars	1.41 AU
	MAVEN		
	Mars Express		
	Mars Odyssey		
Oct. 22, 2014	Rosetta	Comet 67P	3.13 AU
Nov. 12, 2014	Cassini	Saturn	9.94 AU
Jan. 18 – Feb. 14, 2015	New Horizons *(possible detection)*	En Route to Pluto	31.49 AU
Late March 2016	Voyager 2 *(possible detection)*	The Heliosheath	111.06 AU

Location	Heliocentric Distance (AU)	Measured Background Solar Wind Speed (km/s)	Measured ICME Speed (km/s)	Modeled ICME Speed With WSA-ENLIL + Cone Model (km/s)
Solar ejection	~0	Not available	850 ± 200 at 21.5 $R_{\odot}$	1015
Venus	0.72	Not available	Not available	625
STEREO-A	0.96	300	660	550
Mars	1.41	450–500	647	625
Comet 67P	3.13	400	550	500
Saturn	9.94	Not available	Not available	500
New Horizons	31.49	380–400	420–450	450



ICME speed

Use of housekeeping data to identify space weather event



Powerful space weather event which was detected at Mars in mid-September 2017.
This event consisted of:

- An X8.2-class solar flare at ~13.40 UT 10th September 2017 at Mars and peaking at 16:10 UT
- A fast coronal mass ejection that arrived at Mars 12th September 2017
- A long-lasting (10 days) associated solar energetic particle event – based on MAVEN SEP data

Concluding remarks

- Analysis of upper atmosphere data → Always check the space weather contest
- Multi-mission / multi-instrument / multi target analysis is a must
- Use expertise of: planetary scientists, instrument scientists, modellers, solar and solar wind experts
- Spacecraft housekeeping data are promising for space weather studies