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Compiling a list of SolO IP shocks and its application to studying the dynamics of ion reflection

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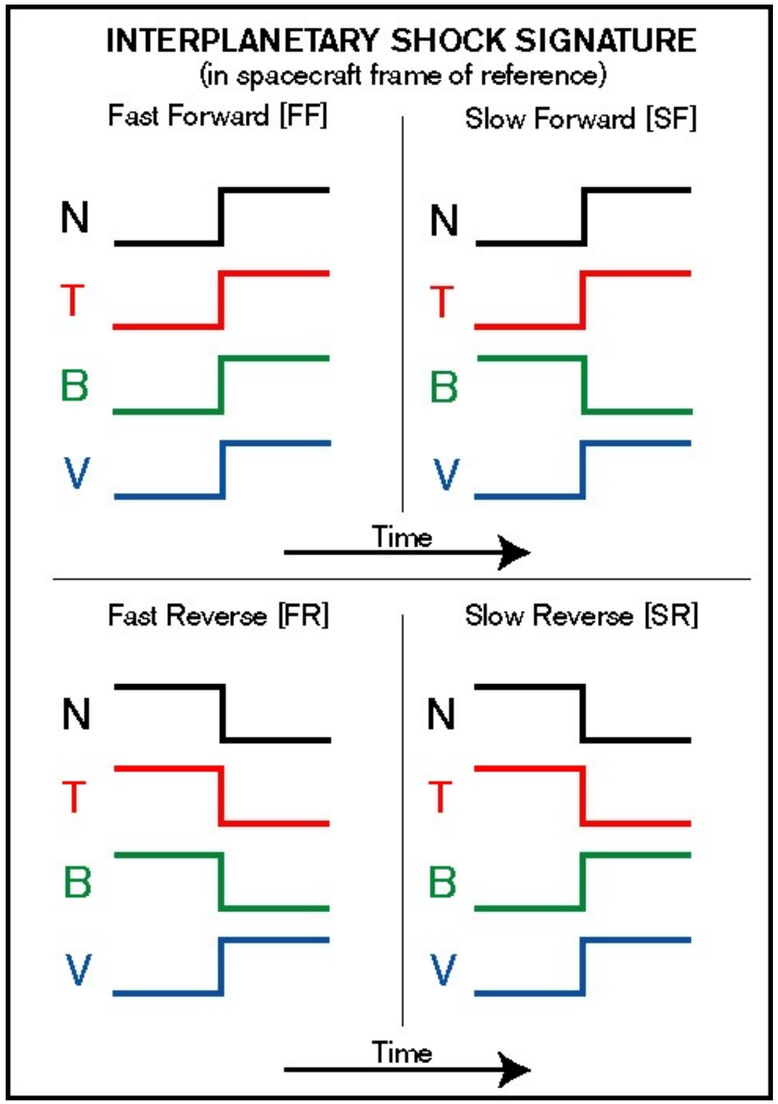
RPW consortium meeting #27 (online)
2-4 October 2023

Rymdstyrelsen
Swedish National Space Agency

Interplanetary Shock Signatures (s/c frame)



Database of Heliospheric Shock Waves

Method documentation

E. Lumme, E. K. J. Kilpua, A. Isavnin, K. Andreeova

October 31, 2019

In order to be included in the database the following upstream to downstream jump conditions had to be fulfilled:

$$\frac{B_{down}}{B_{up}} \geq 1.2 \quad (1)$$

$$\frac{N_p^{down}}{N_p^{up}} \geq 1.2 \quad (2)$$

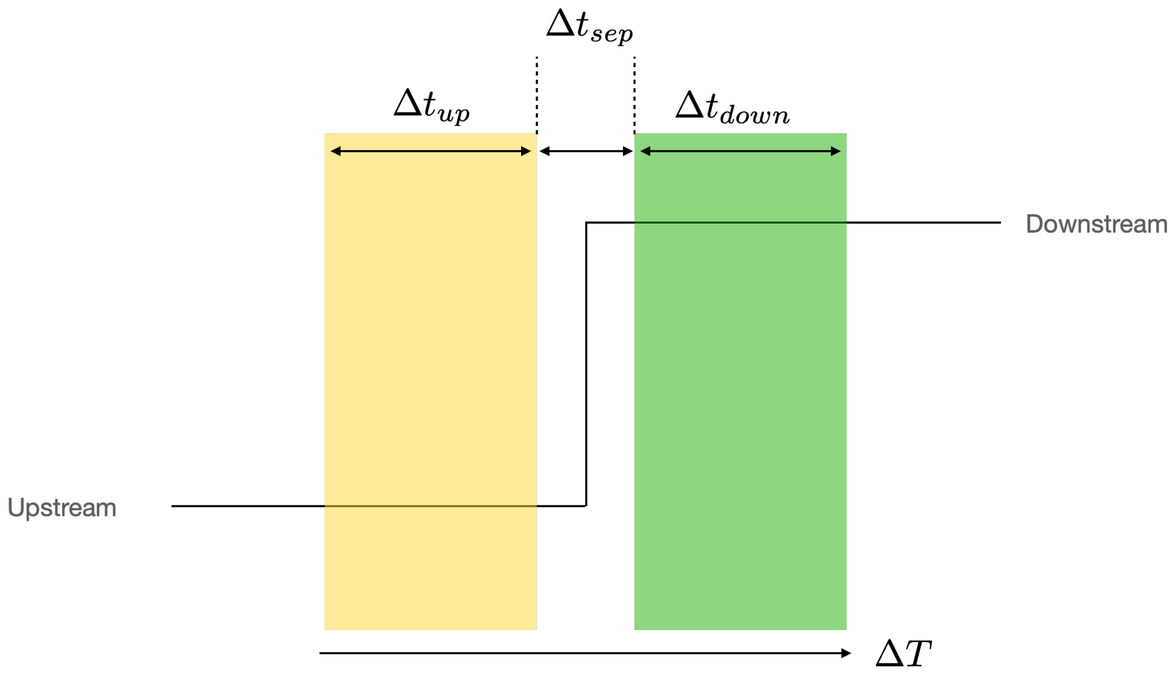
$$\frac{T_p^{down}}{T_p^{up}} \geq \frac{1}{1.2} \quad (3)$$

Additionally, the solar wind speed jump had to fulfil a condition which depends on the shock type:

$$\begin{array}{cc} \textbf{FF} & \textbf{FR} \\ V_{down} - V_{up} \geq 20 \text{ km/s} & V_{up} - V_{down} \geq 20 \text{ km/s} \end{array} \quad (4)$$

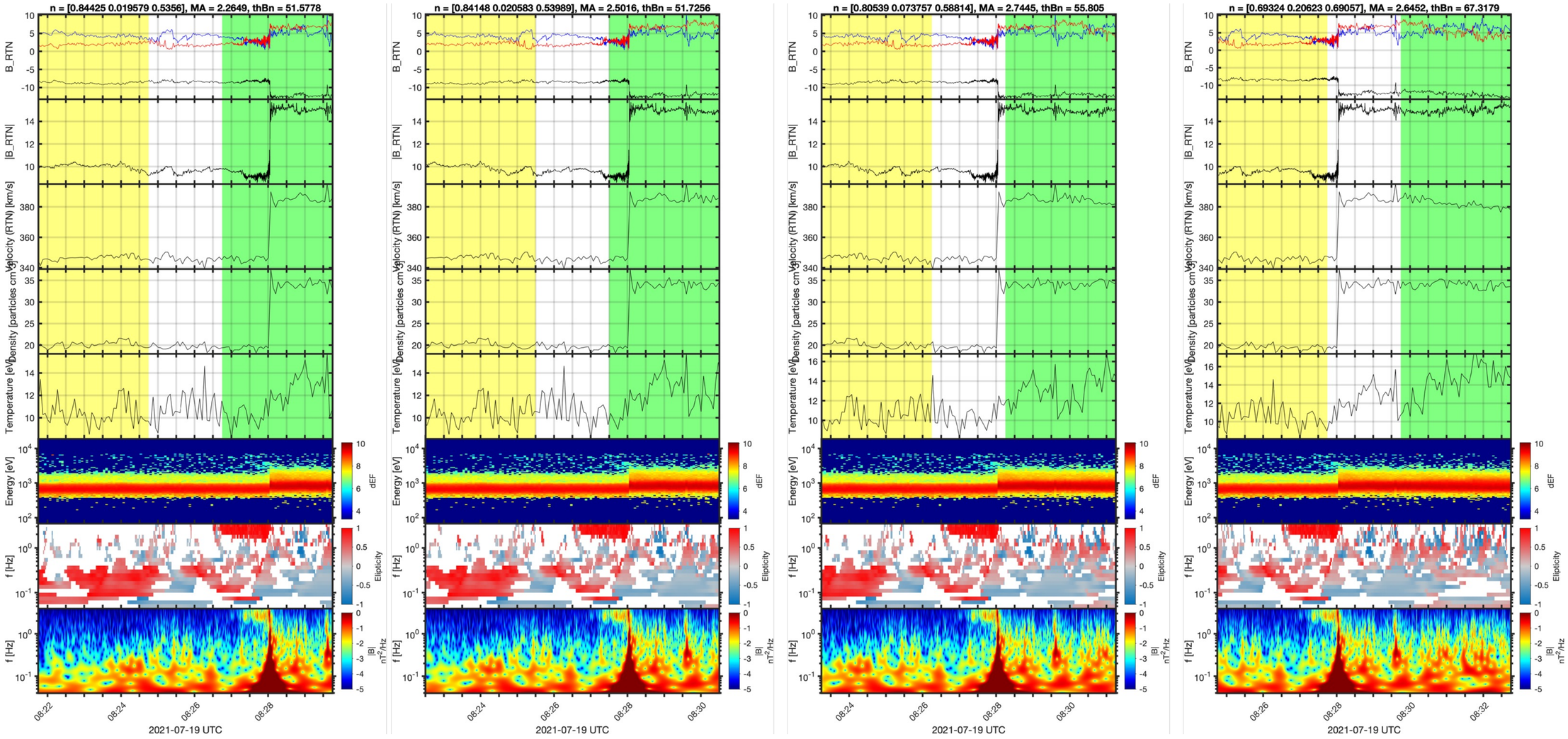
The condition differs for FF and FR type shocks due to opposite order of the upstream and downstream regions when the shock passes the observing spacecraft.

Method



- Upstream window (3 min) Δt_{up}
- Downstream window Δt_{down} (3min)
- Window separation (2) Δt_{sep}
- Window advancement = ΔT 0.25 Δt_{up}

Example


n = [0.84425 0.019579 0.5356], MA = 2.2649, thBn = 51.5778
n = [0.84148 0.020583 0.53989], MA = 2.5016, thBn = 51.7256
n = [0.80539 0.073757 0.58814], MA = 2.7445, thBn = 55.805
n = [0.69324 0.20623 0.69057], MA = 2.6452, thBn = 67.3179
B_RTN
|B_RTN|
Velocity (RTN) [km/s]
Density [particles cm^3]
Temperature [eV]
Energy [eV]
f [Hz]
dEF
Ellipticity
|B| nT^2/Hz
2021-07-19 UTC

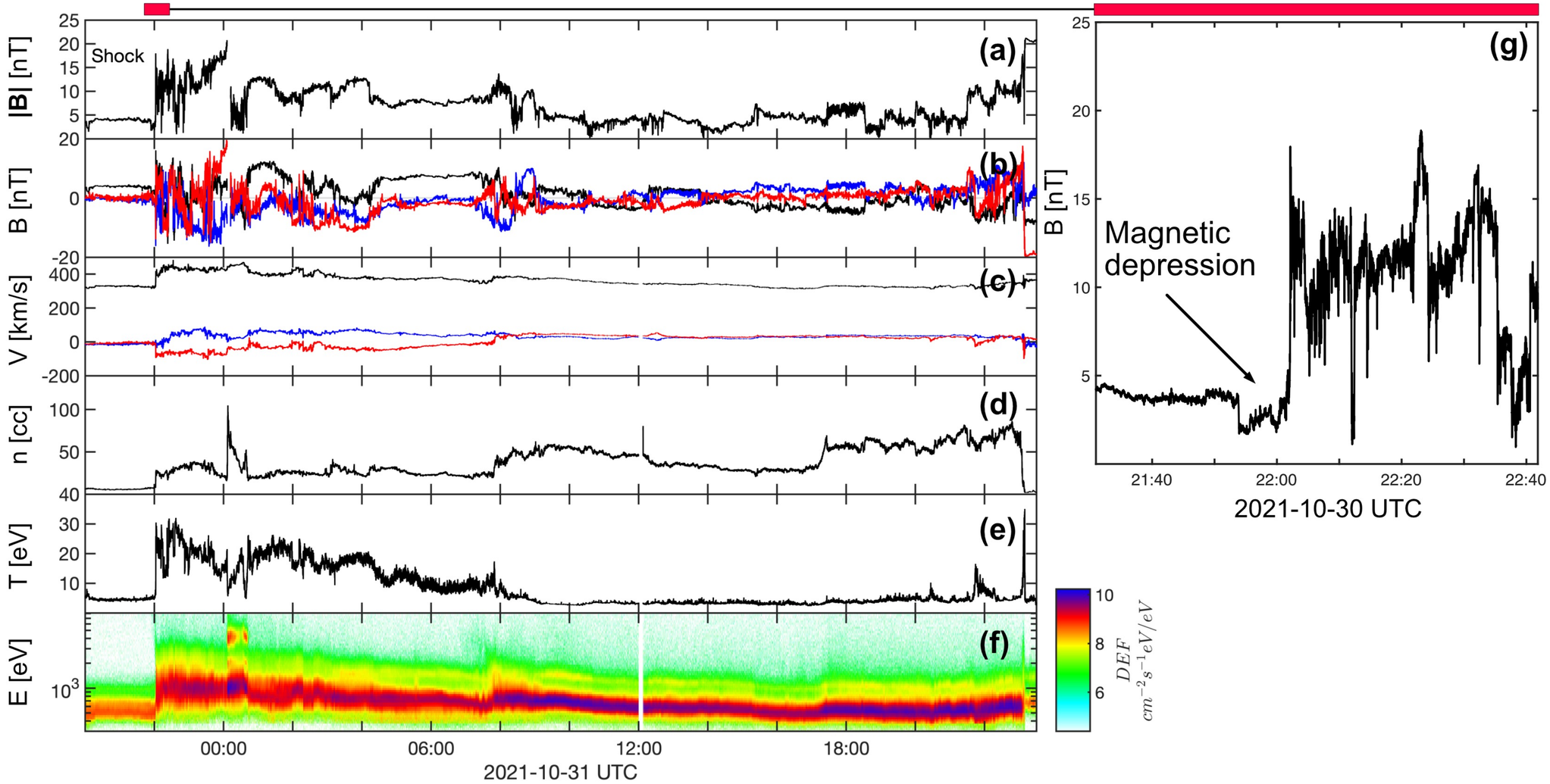
Shock list

#	Date	Time (UTC)	$\|R\|$ [AU]	θ_{bn} [°]	M_A	#	Date	Time (UTC)	$\|R\|$ [AU]	θ_{bn} [°]	M_A
1[a]	2020-04-19	05:06:18	0.8	47	NaN						
2[a]	2020-08-21	19:17:06	0.9	72	NaN						
3	2020-09-17	11:44:17	1.0	NaN	NaN						
4[a]	2020-11-12	23:26:57	0.9	72	NaN						
5[a]	2020-11-14	19:16:14	0.9	80	NaN						
6[a]	2020-12-06	15:14:25	0.8	58	NaN						
7[a]	2020-12-14	02:49:49	0.8	78	NaN						
8[a]	2021-04-15	20:22:46	0.8	12	NaN						
9[a]	2021-06-07	20:02:24	1.0	29	NaN	37	2022-06-10	22:55:40	1.0	22	2.6
10	2021-06-13	10:08:41	0.9	74	1.5	38	2022-06-17	00:40:07	1.0	16	9.6
11[a]	2021-06-23	22:15:31	0.9	73	NaN	39	2022-06-28	08:09:09	1.0	46	5.3
12[a]	2021-06-27	05:54:53	0.9	17	NaN	40	2022-07-03	06:00:04	1.0	50	4.2
13	2021-07-18	17:57:54	0.8	83	2.8	41	2022-07-21	09:29:52	1.0	78	2.6
14	2021-07-19	08:28:02	0.8	67	2.8	42	2022-07-25	06:22:48	1.0	65	9.7
15	2021-07-31	00:39:37	0.8	63	1.7	43	2022-08-01	14:17:52	1.0	87	1.4
16	2021-09-25	18:26:07	0.6	NaN	NaN	44	2022-08-18	02:56:45	0.9	80	2.5
17	2021-10-11	07:32:24	0.7	66	2.6	45[a]	2022-08-28	23:51:53	0.8	51	NaN
18	2021-10-14	23:13:06	0.7	51	1.1	46	2022-08-29	11:06:39	0.8	47	3.7
19	2021-10-30	22:02:09	0.8	44	6.7	47	2022-08-30	13:02:05	0.8	81	3.2
20	2021-11-03	12:28:04	0.8	34	2.8	48	2022-08-31	21:44:28	0.7	36	6.0
21	2021-11-03	14:04:26	0.8	37	5.1	49	2022-09-05	00:23:48	0.7	69	1.8
22	2021-11-16	04:01:35	0.9	66	3.4	50	2022-09-06	10:00:51	0.7	58	2.7
23	2021-11-27	22:59:45	1.0	72	2.8	51	2022-09-08	04:10:27	0.7	68	0.9
24	2021-12-27	10:16:33	1.0	79	1.8	52	2022-09-08	21:00:45	0.7	15	2.5
25	2022-01-08	01:51:08	1.0	82	3.8	53	2022-09-13	17:10:35	0.6	69	2.0
26	2022-02-16	21:44:55	0.7	45	1.8	54	2022-12-07	05:22:07	0.8	55	2.1
27	2022-02-21	14:32:20	0.7	65	2.8	55	2022-12-26	05:21:27	0.9	50	3.2
28	2022-03-08	14:45:59	0.5	58	1.1	56	2023-01-05	09:44:06	1.0	90	2.4
29	2022-03-08	21:32:56	0.5	69	3.7	57	2023-01-13	01:37:54	1.0	53	1.2
30	2022-03-11	19:52:14	0.4	21	3.1	58	2023-01-17	09:56:35	1.0	NaN	NaN
31	2022-04-03	04:51:33	0.4	47	2.7	59	2023-02-17	14:03:26	0.8	38	2.4
32	2022-04-08	13:48:53	0.4	44	7.6	60	2023-02-19	09:58:49	0.8	37	4.3
33	2022-04-14	08:51:56	0.5	21	0.8	61	2023-02-20	22:48:49	0.8	52	1.1
34	2022-05-08	08:15:14	0.8	49	2.9	62	2023-02-21	03:35:58	0.8	86	2.4
35	2022-05-21	14:51:12	0.9	59	4.1	63	2023-02-21	16:59:14	0.8	85	12.1
36[a]	2022-06-08	12:04:27	1.0	42	NaN	64	2023-03-14	01:08:29	0.6	80	4.9

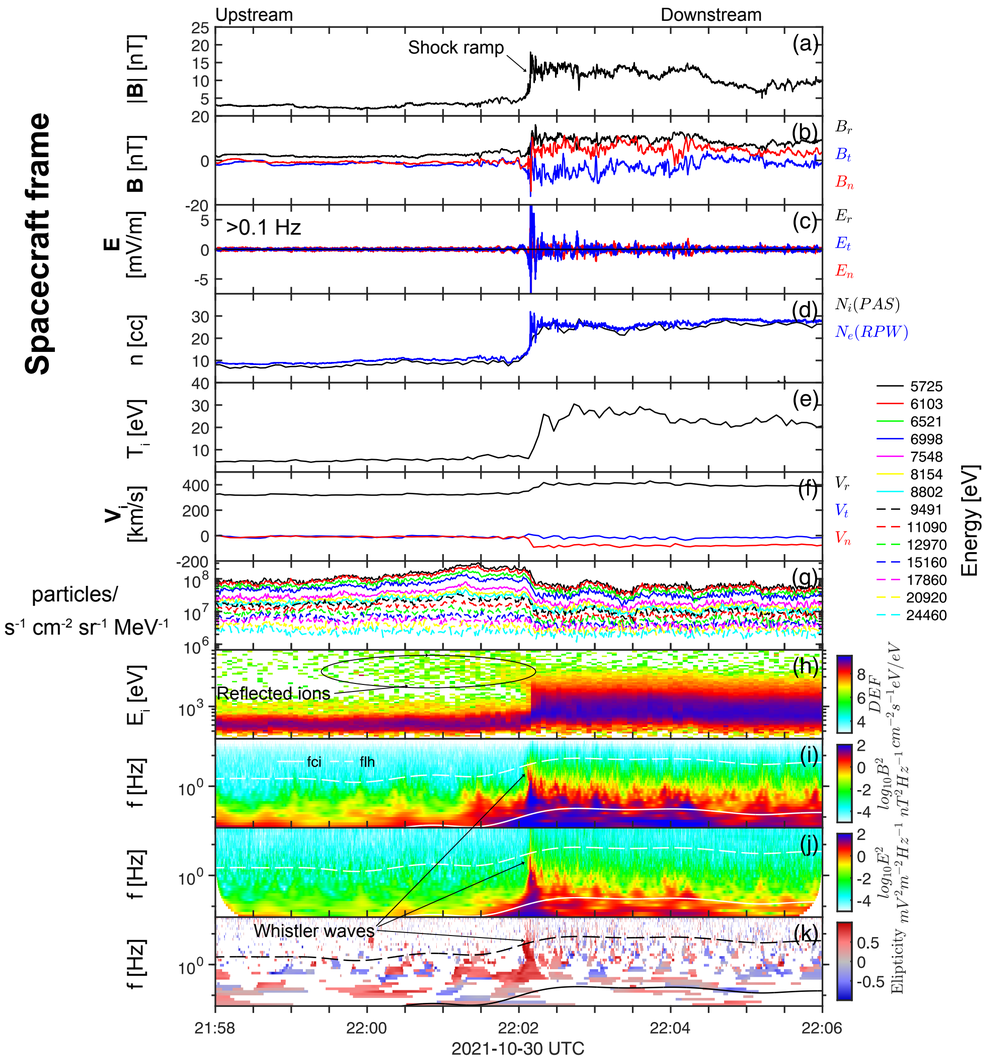
Applications

- Refining/testing RPW shock trigger mode.
- Identification of interesting case studies (e.g., ion reflection, waves, quasi-parallel, perihelion).
- Shock (and surrounding regions) statistical studies (see presentation by Jordi).
- Comparison with other shock types (bow shocks, astrophysical shocks)

Interesting shock on 31 October 2021



Interesting shock on 31 October 2021

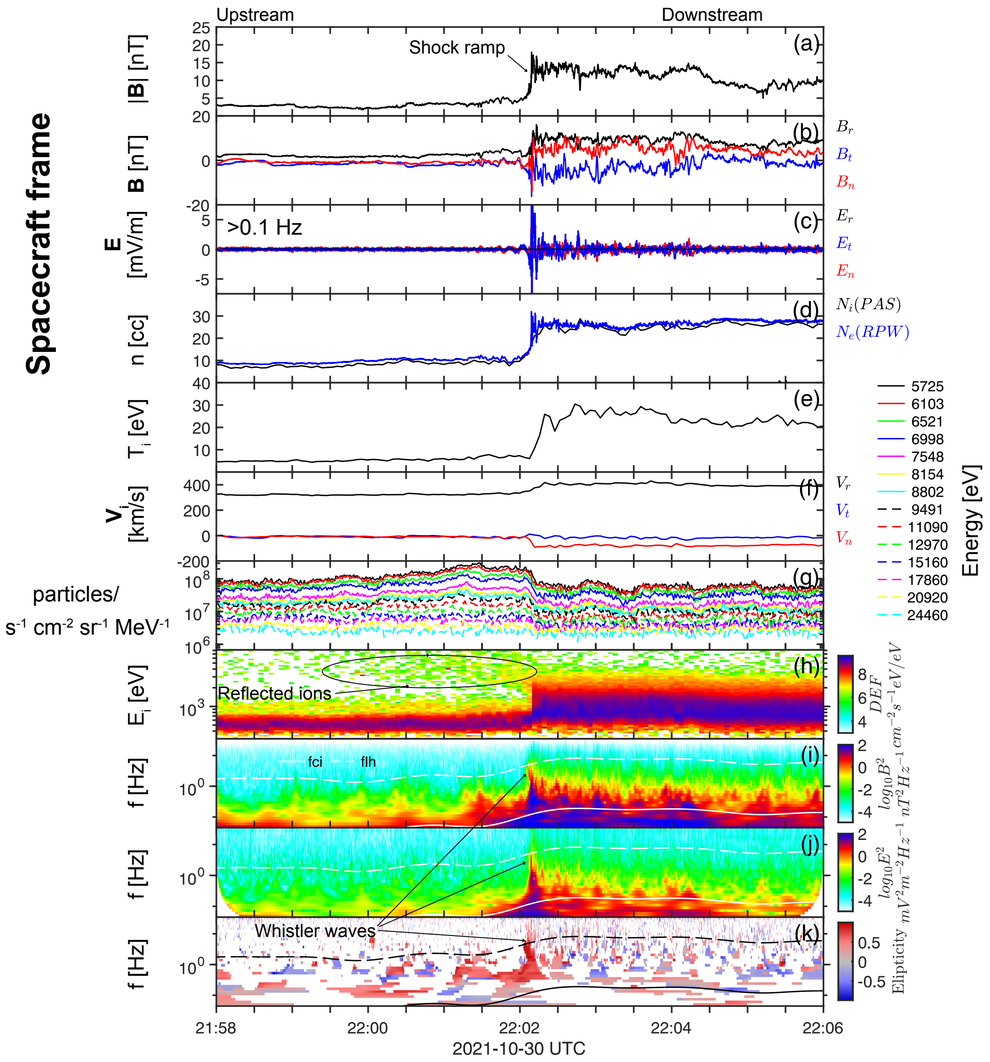


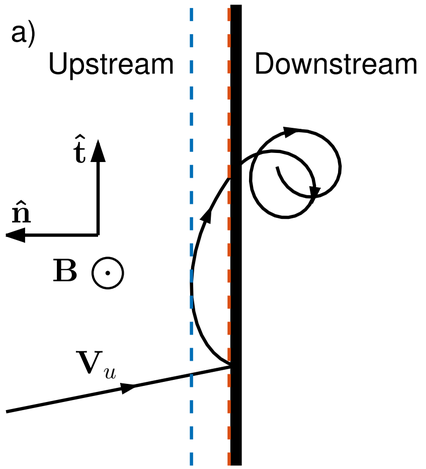
Spacecraft frame

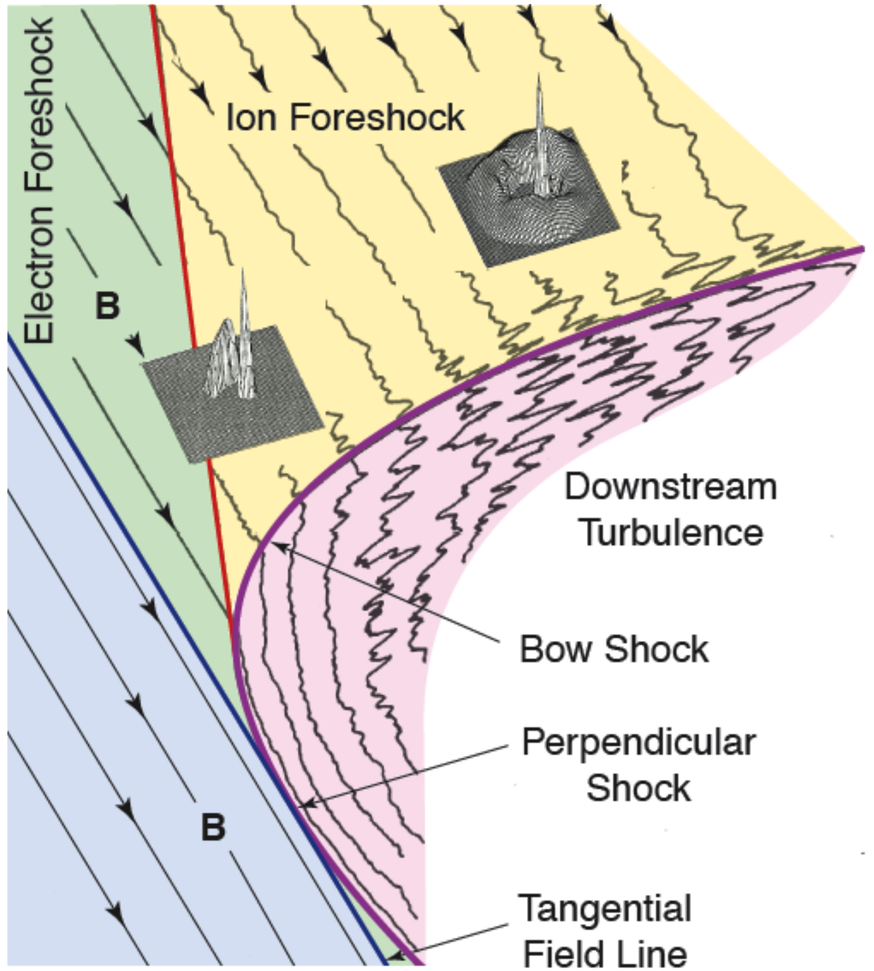
Parameter	Value
Date	2021-10-30
Time of shock ramp (UTC)	22:02:09
θ_{bn}[a] [°]	44
Alfvén Mach number[a] M_A	6.7
Fast Mode Mach number[a] M_f	2.5
Shock normal $\hat{\mathbf{n}}_{mx3}$ (mixed mode 3)	[0.64, -0.04, -0.77]
Shock normal $\hat{\mathbf{n}}_{mc}$ (magnetic coplanarity)	[0.47, -0.56, -0.68]
Shock normal $\hat{\mathbf{n}}_{mva}$ (minimum variance)	[0.80, -0.20, -0.57]
Shock speed[a] [km/s]	348
Solar wind speed V_u [km/s]	321
Magnetic field B_u [nT]	2.7
Magnetic compression ratio (B_u/B_d)	3.6
Ion Temperature T_{iu} [eV]	5.0
Density (ion, electron) n_u [cm^{-3}]	7.3, 8.9
Density compression ratio (n_u/n_d)	3.5
Ion plasma β_{iu}	2.3
Upstream window Δ_u	21:58:00 - 22:00:00
Downstream window Δ_d	22:05:09 - 22:08:06

[a]Based on mixed mode 3 shock normal $\hat{\mathbf{n}}_{mx3}$.
[b]Assuming T_e = 14 eV.

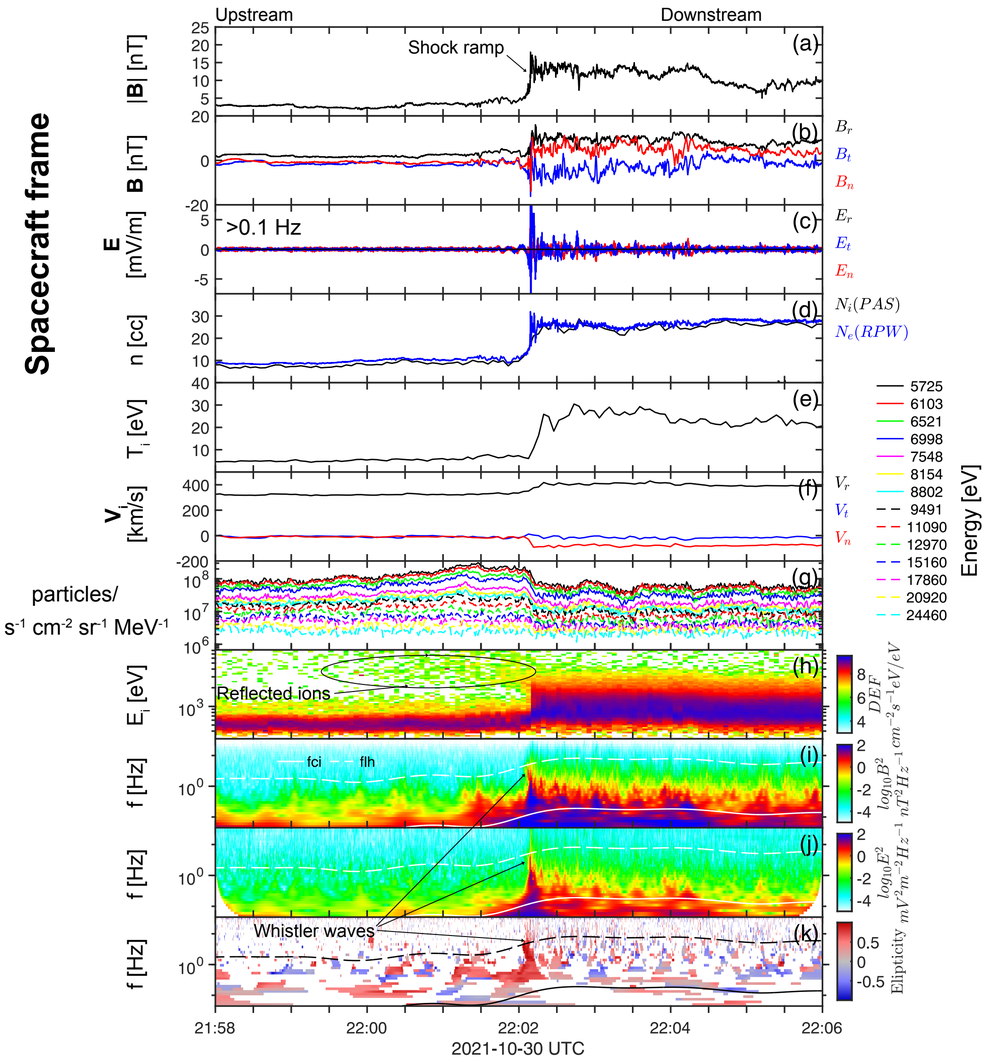
Interesting shock on 31 October 2021

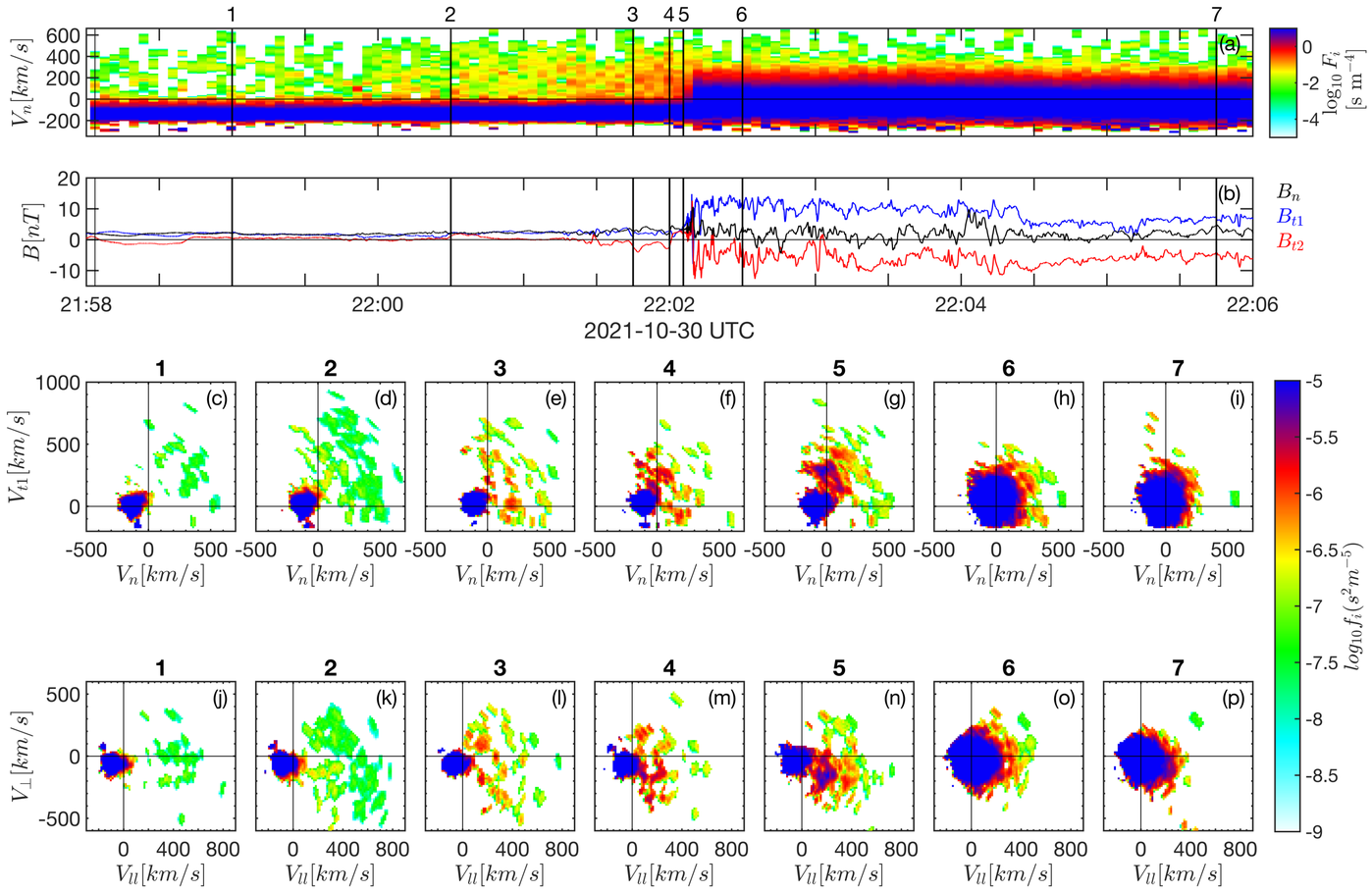




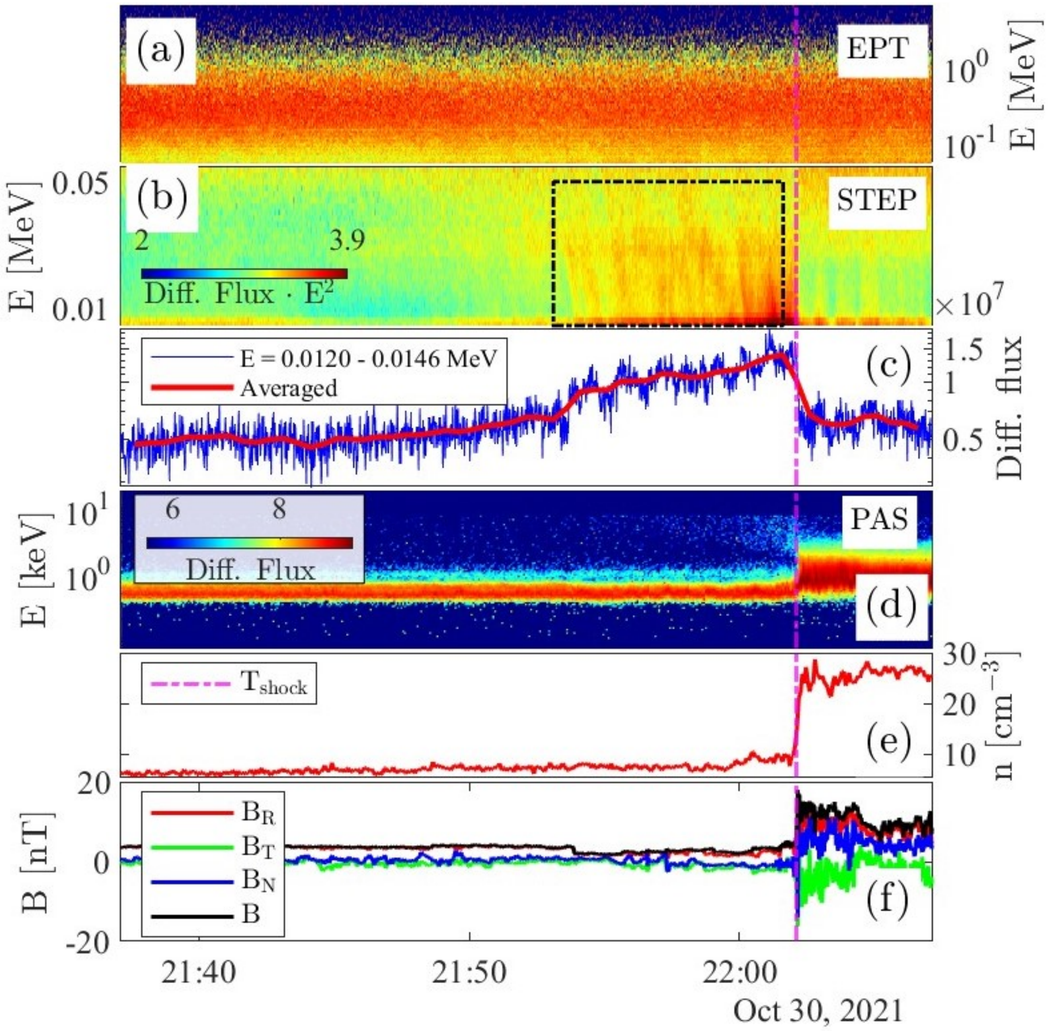


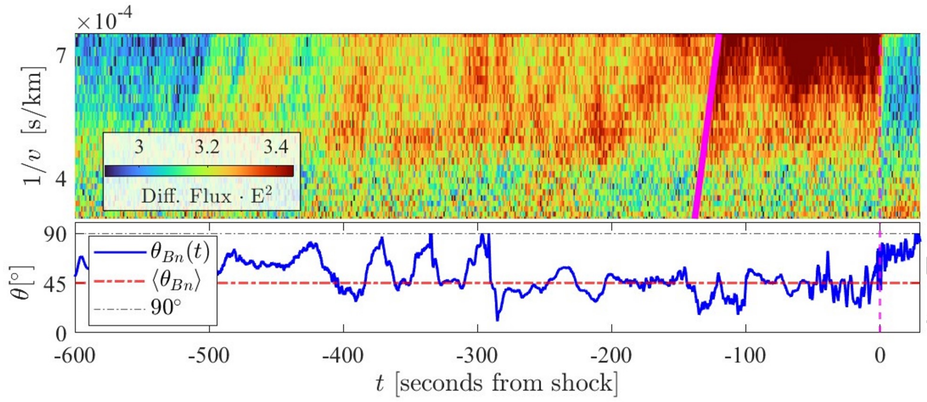
Interesting shock on 31 October 2021

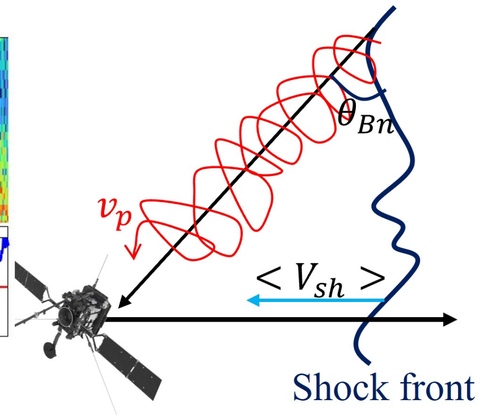




Interesting EPD observations







Conclusions

- Solar Orbiter shocks can be identified automatically using MAG and SWA-PAS data.
- Currently, we have 64 shocks (until the end of March 2023).
- Contact me if you are interested in using the list.
- We recently studied a high Mach number IP shock and were able to observe ion reflection
- Ions are observed several minutes upstream and are predominantly field-aligned.
- Evidence of local shock irregularities may be connected with the features of the backstreaming ions revealed in the ion VDF.