Appendix

Table A1 is an event list of Io FPT crossings when Juno/JEDI observed signatures of energetic protons. Predict times are based off the analysis of Juno's trajectory and requires the modeled s/c footprint to intersect the moon's footprint to within 500 km (https://lasp.colorado.edu/home/mop/files/2022/04/Fluxtube_Crossing_Xing_readme.pdf). Observed times are based off the analysis of Juno/JEDI energetic proton signatures.

Table A1: List of Io FPT crossings with signatures of accelerated energetic protons and associated observations from Juno/JEDI

PJ	N/S	Predict Time [MM/DD/YYYY-HH:MM:SS]	Observed Time [MM/DD/YYYY-HH:MM:SS]	X_{IAU}[km]	Y_{IAU}[km]	Z_{IAU}[km]	$\Delta\lambda_{Alfvén}$ [°]	Altitude [km]	JEDI EF [mW/m^2]	JEDI NF [cm^{-2} s^{-1}]
1	S	08/27/2016-13:20:45	08/27/2016-13:20:35	-2.98E-01	-6.82E-01	-1.24E+00	256.651	35436.2	0.70942	2.98E+06
3	N	12/11/2016-16:32:41	12/11/2016-16:32:35	4.87E-01	1.20E-01	1.38E+00	263.47	37618.6	0.31368	8.86E+05
3	S	12/11/2016-17:31:17	12/11/2016-17:30:43	7.71E-01	-3.14E-01	-1.11E+00	272.708	31438.3	0.21721	6.06E+05
4	S	02/02/2017-13:29:51	02/02/2017-13:29:17	3.27E-01	6.91E-01	-1.28E+00	330.352	39663.4	0.53221	1.04E+06
5	N	03/27/2017-08:34:43	03/27/2017-08:34:37	-7.73E-01	-8.90E-02	9.10E-01	13.359	16740.9	0.3329	4.16E+05
6	N	05/19/2017-05:39:57	05/19/2017-05:39:35	-3.83E-01	-5.53E-01	1.07E+00	91.381	21883.5	0.3427	2.41E+06
6	S	05/19/2017-06:39:50	05/19/2017-06:40:04	-6.44E-01	-1.43E-01	-1.51E+00	28.066	50044.6	1.0553	2.45E+06
7	N	07/11/2017-01:24:58	07/11/2017-01:24:52	3.92E-01	-1.79E-01	1.37E+00	115.089	35490.4	0.28883	4.76E+05
7	S	07/11/2017-02:22:27	07/11/2017-02:22:33	3.09E-01	-8.21E-01	-1.09E+00	89.65	31015.2	0.65544	4.61E+06
8	N	09/01/2017-21:23:55	09/01/2017-21:23:09	2.38E-01	4.65E-01	1.25E+00	130.847	28028.9	0.10137	5.78E+05
9	N	10/24/2017-17:22:57	2017-10-24 17:22:55	-5.77E-01	3.60E-01	1.03E+00	184.494	20602.6	0.18905	6.56E+05
10	S	12/16/2017-18:30:48	12/16/2017-18:30:50	6.91E-01	5.17E-01	-1.26E+00	212.34	41060.9	0.4027	1.34E+06
12	N	04/01/2018-09:20:56	04/01/2018-09:20:42	4.52E-02	-4.73E-01	1.25E+00	1.801	27897.2	12.481	7.05E+07
12	S	04/01/2018-10:28:26	04/01/2018-10:28:04	-6.89E-01	-3.32E-01	-1.54E+00	277.683	56000.4	0.64124	2.29E+06
13	N	05/24/2018-05:13:39	05/24/2018-05:13:33	4.19E-01	8.75E-02	1.30E+00	15.315	30056.7	0.099312	1.75E+05
13	S	05/24/2018-06:11:25	05/24/2018-06:10:59	5.66E-01	-7.54E-01	-1.12E+00	349.912	36746	0.64915	1.66E+06
14	N	07/16/2018-04:50:19	07/16/2018-04:50:01	3.48E-01	-1.74E-01	1.33E+00	56.45	31378.7	0.53532	1.77E+06
14	S	07/16/2018-05:53:27	07/16/2018-05:53:41	-2.17E-01	-8.72E-01	-1.30E+00	350.667	44317.6	0.36498	1.19E+06
15	N	09/07/2018-00:49:01	09/07/2018-00:48:39	2.80E-01	3.98E-01	1.20E+00	64.348	24806.1	0.15116	2.01E+05
15	S	09/07/2018-01:46:21	09/07/2018-01:45:55	9.24E-01	-1.98E-01	-1.21E+00	61.459	41817.6	0.68126	1.22E+06
16	N	10/29/2018-20:47:34	10/29/2018-20:47:48	-4.38E-01	4.10E-01	1.05E+00	111.4	18916.6	0.2227	3.43E+05
18	N	02/12/2019-17:17:55	02/12/2019-17:18:09	-5.27E-01	3.35E-01	1.00E+00	174.026	16563.9	0.12013	2.62E+05
20	S	05/29/2019-08:46:05	05/29/2019-08:46:27	7.01E-01	-8.09E-01	-1.24E+00	274.427	47681.3	1.8996	1.89E+06
21	S	07/21/2019-04:45:43	07/21/2019-04:45:53	8.55E-01	6.22E-01	-1.40E+00	330.337	56573.2	0.40691	8.30E+05
22	N	09/12/2019-03:19:29	09/12/2019-03:18:55	1.51E-01	4.94E-01	1.21E+00	2.831	25667.4	2.4901	5.40E+06
23	S	11/03/2019-23:10:42	11/03/2019-23:10:48	-2.72E-01	9.42E-01	-1.70E+00	31.52	72310.3	0.63555	8.62E+05
24	N	12/26/2019-17:09:19	12/26/2019-17:09:33	4.21E-01	-2.16E-02	1.31E+00	167.215	31753.4	0.67487	1.19E+06
26	N	04/10/2020-13:23:18	04/10/2020-13:23:12	3.95E-01	1.04E-01	1.26E+00	223.237	27205.4	0.15067	5.17E+05
27	N	06/02/2020-10:00:13	06/02/2020-09:59:35	1.98E-01	4.15E-01	1.16E+00	233.65	20821.5	0.064622	1.35E+05
28	N	07/25/2020-05:59:51	07/25/2020-06:00:09	-4.12E-01	3.87E-01	1.01E+00	273.488	15402.8	0.11422	2.60E+05
28	S	07/25/2020-07:01:59	07/25/2020-07:02:13	6.71E-01	8.30E-01	-1.48E+00	257.616	61638.6	1.5241	3.63E+06
29	N	09/16/2020-02:00:29	09/16/2020-02:00:35	-5.63E-01	-3.88E-01	8.54E-01	7.161	9729.8	0.47383	1.27E+06
30	S	11/08/2020-02:42:18	11/08/2020-02:41:56	-3.86E-02	1.05E+00	-1.65E+00	324.609	72382.3	0.34786	8.67E+05
31	S	12/30/2020-22:45:25	12/30/2020-22:45:07	-9.98E-01	7.54E-02	-1.88E+00	354.163	84910.3	0.93583	1.65E+06
32	N	02/21/2021-17:19:53	02/21/2021-17:19:51	3.59E-01	1.19E-01	1.20E+00	109.731	22961.8	0.075939	3.46E+05
32	S	02/21/2021-18:22:26	02/21/2021-18:23:24	3.40E-01	-1.10E+00	-1.30E+00	60.659	53469	0.67615	1.12E+06
33	S	04/16/2021-00:17:58	04/16/2021-00:18:00	1.10E+00	3.16E-01	-1.39E+00	39.518	59902.8	0.19977	2.10E+05
34	N	06/08/2021-07:29:34	06/08/2021-07:29:32	-8.74E-02	4.63E-01	1.08E+00	2.199	16469	0.59978	8.21E+05

Figure A1 provide a distribution of time differences between the predicted time and the observed times associated with Io's FPT from Juno/JEDI's perspective. The median offset is ~14s (or ½ a Juno spin). The predicted timing analysis method uses 10 second resolution data and these offsets are on that order, therefore this confirms that the majority of the events match the location Io's FPT.

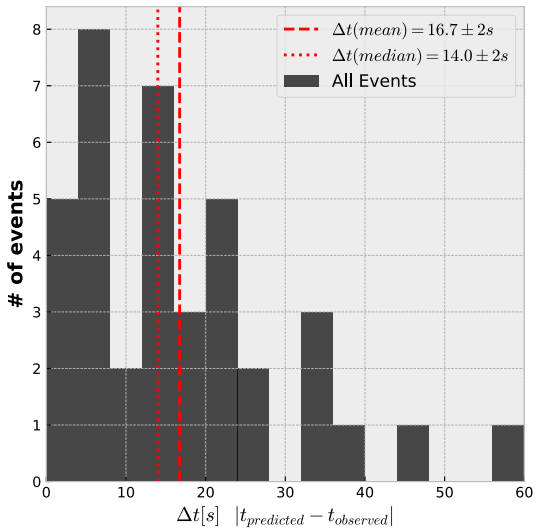

Figure A1: Distribution of timing differences between predicted and observed timing of the Io FPT. Red dashed lines correspond to the mean and median of the dataset.

Figures A2-A5 show magnetic and electric frequency-time and energetic proton energy-time spectrograms for several Io FPT events. It can be seen that the spectral densities increase both during the FPT crossing and near the f_{cH^+}. When the waves extend up to the f_{cH^+}, they become dispersive in frequency-time, which is consistent with the cone of ion-cyclotron waves.

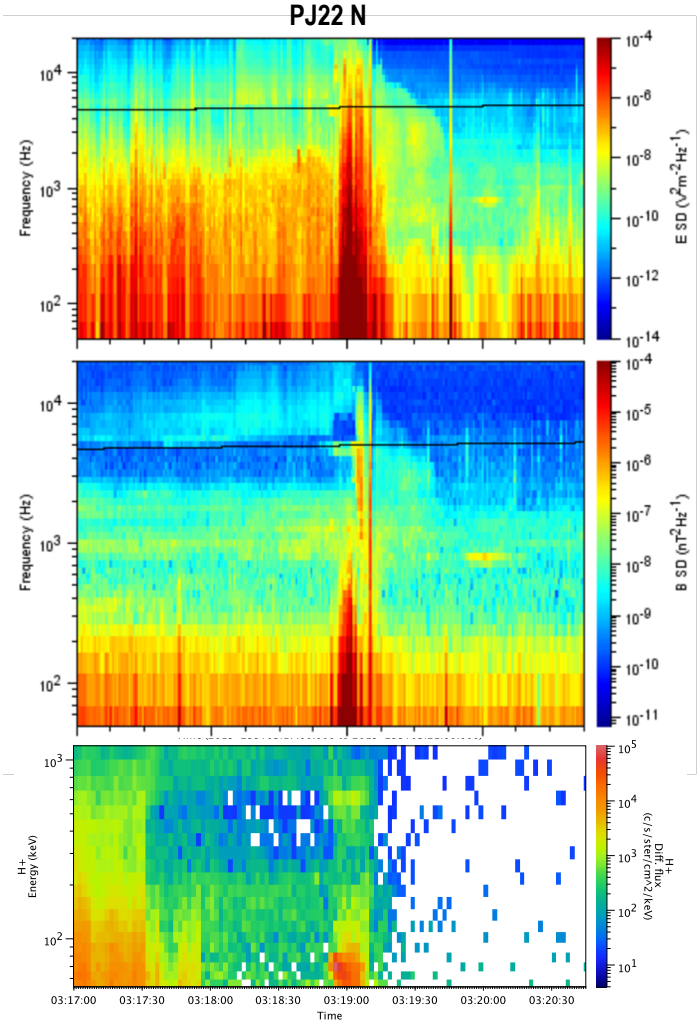

Figure A2: Frequency-time spectrograms of the electric (top panel) and magnetic (middle panel) spectral densities measured by Juno-Waves. The bottom panel are color-coded energetic proton intensities as a function of energy and time. The enhancement in the middle across all panels corresponds to the crossing of the Io FPT for PJ22 N.

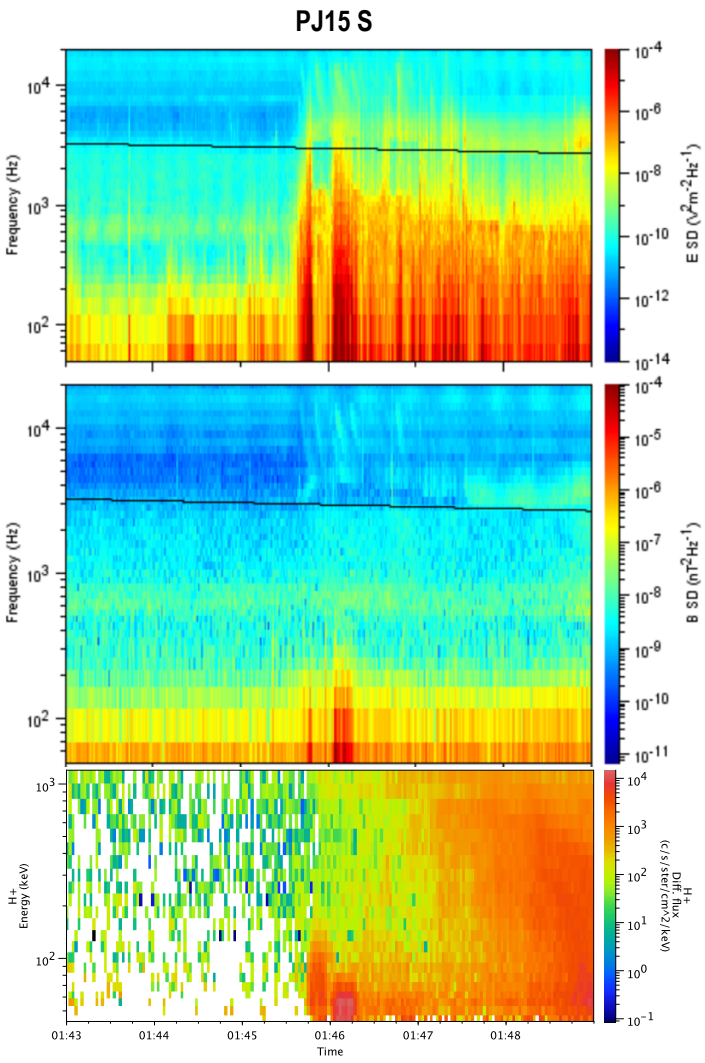

Figure A3: Same format as A2, but for PJ15 S.

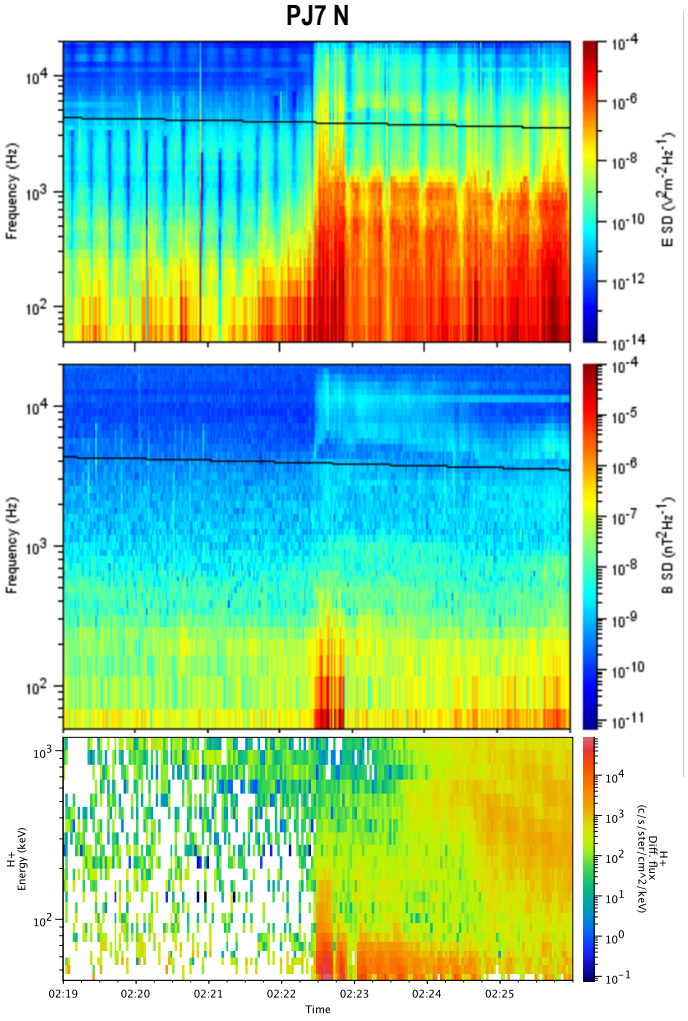

Figure A4: Same format as A2, but for PJ17 N.

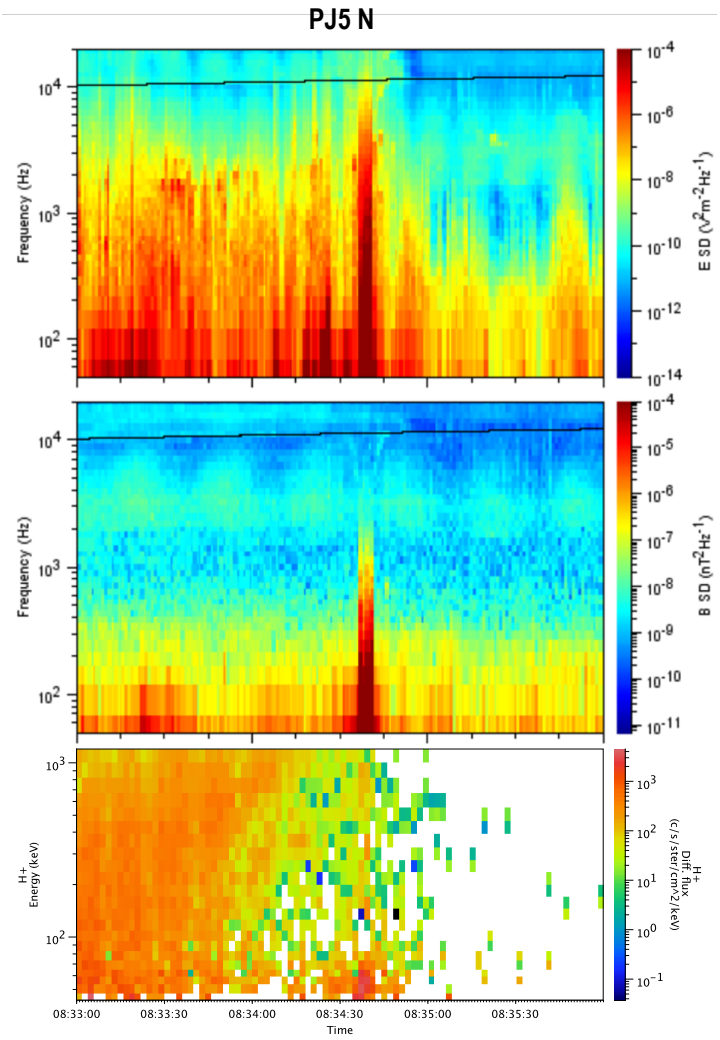

Figure A5: Same format as A2, but for PJ5 N.