Supplemental to:
Revisting the structure of low Mach number, low beta, quasi-perpendicular shocks

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1 Shock Parameters

We use the following notations for any quantity, Q, thoughout this paper: Q_o, δQ, and $\langle Q \rangle_j$, where Q_o is any quasi-static quantity, δQ is any fluctuating or high pass filtered quantity, $\Delta Q = \langle Q \rangle_{dn}$ - $\langle Q \rangle_{up}$, and $\langle Q \rangle_j$ is the time average of any quantity over region j = upstream (up) or downstream (dn). Note that Q_o is not the same as $\langle Q \rangle_j$ in this context.

Herein we use the following parameter definitions: $\mathbf{B}_o$ is the quasi-static magnetic field vector [nT]; $\mathbf{V}_{bulk}$ is the bulk flow velocity vector [$km\ s^{-1}$]; n_s is the number density of species s [cm^{-3}]; m_s is the mass of species s [kg]; T_s is the scalar temperature of species s [eV]; $W_s = \sqrt{k_B\ T_s/m_s}$ is the rms thermal speed of species s; $V_A = B_o/\sqrt{\mu_o\ m_i\ n_i}$ is the Alfvén speed [$km\ s^{-1}$]; $\delta\mathbf{B}$ is the high pass filtered fluctuating magnetic field due to a whistler precursor [nT]; $\Delta|\mathbf{B}_o|$ is the change in the magnetic field magnitude across a shock ramp [nT]; SCF is the spacecraft rest frame; and SHF is the shock rest frame.

All shock parameters used herein were taken from the Harvard Smithsonian Center for Astrophysics' Wind shock database (WSDB), which can be found at:
https://www.cfa.harvard.edu/shocks/wi_data/.
The WSDB provides tables of numerical solutions to the Rankine-Hugoniot relations [e.g., *Koval and Szabo*, 2008; *Szabo*, 1994; *Vinas and Scudder*, 1986] for eight different methods (see Appendix A for definitions). The first table, titled *General Information*, on each event webpage lists the selected best method from which we take the values for all events examined herein (e.g., second column of Table S1).

In the tables that follow on each event webpage of WSDB, some parameters are listed by name while others use symbols or abbreviations. In the following we will state our definition followed by the WSDB equivalent label in parentheses and italicized text. Rather than repeated state that $\langle Q \rangle_j$ corresponds to the quantity Q averaged over the j^{th} region, we will simply imply it for brevity. These parameters we used are: $\langle W_s \rangle_j$(*Ws*) is the rms thermal speed of species s [$km\ s^{-1}$]; $\langle V_A \rangle_j$(*Alfven Speed*) is the Alfvén speed averaged [$km\ s^{-1}$]; $\langle C_s \rangle_j$(*Sound Speed*) is the sound or ion-acoustic sound speed, defined here as $\sqrt{\frac{5}{3}}\ \langle W_i \rangle_j$; $\langle \beta_{Tot} \rangle_j$(*Plasma Beta*) is the "total" plasma beta, define here as $(3/5){C_s}^2/{V_A}^2$; $\hat{\mathbf{n}}$(*Nx*, *Ny*, and *Nz*) is the shock normal unit vector [GSE]; $\mathcal{R}$(*Compression*) is the shock density compression ratio, defined as $\langle n_i \rangle_{down}/\langle n_i \rangle_{up}$; $\langle \theta_{Bn} \rangle_{up}$(*ThetaBn*) is the shock normal angle, defined as the acute reference angle between $\langle \mathbf{B}_o \rangle_{up}$ and $\hat{\mathbf{n}}$; $|V_{shn}|$(*Shock Speed*) is the upstream shock normal speed in the SCF (determined numerically from Equation A.2d); $\langle U_{shn} \rangle_j$($dV$) flow speed along shock normal in the SHF [$km\ s^{-1}$] (defined in Equation B.2); $\langle M_A \rangle_j$(not shown) is the Alfvénic Mach number, defined as $\langle |U_{shn}| \rangle_j/\langle V_A \rangle_j$; and $\langle M_f \rangle_j$(*Fast Mach*) is the fast mode Mach number, defined as $\langle |U_{shn}| \rangle_j/\langle V_f \rangle_j$ where V_f is the MHD fast mode phase speed given by:

$$2{V_f}^2 = \left({C_s}^2 + {V_A}^2\right) + \sqrt{\left({C_s}^2 - {V_A}^2\right)^2 + 4{C_s}^2{V_A}^2\sin^2\theta_{Bn}} \tag{1.1a}$$

$$= \left({C_s}^2 + {V_A}^2\right) + \sqrt{\left({C_s}^2 + {V_A}^2\right)^2 - 4{C_s}^2{V_A}^2\cos^2\theta_{Bn}} \tag{1.1b}$$

where C_s is the sound speed [e.g., see Equation 1.9.1 in *Krall and Trivelpiece*, 1973], which is formally defined as:

$${C_s}^2 \equiv \frac{\partial P}{\partial \rho_m} \tag{1.2a}$$

which is often approximated by assuming an adiabatic equation of state to give:

$$= \frac{\gamma P}{\rho_m} \tag{1.2b}$$

and in a plasma where the ions and electrons carry different polytrope indices, we have the ion-acoustic sound speed:

$${C_s}^2 = \frac{k_B\left(Z_i\gamma_e T_e + \gamma_i T_i\right)}{M_i + m_e} \tag{1.2c}$$

where k_B = Boltzmann constant, Z_i = ion charge state, and one generally assumes that either $\gamma_e = 1$ (isothermal) and γ_i = 2 or 3, or $T_e \gg T_i$ and $\gamma_e = 1$ such that ${C_s}^2 \sim \frac{k_B T_e}{M_i}$.

The sound speed reported on the WSDB is, as stated above, give by $\langle C_s \rangle_j = \sqrt{\frac{5}{3}}\ \langle W_i \rangle_j$, the total plasma beta relies only upon ion data.

2 Defining Good Shocks

At the time of writing this manuscript, there were 430 fast forward (i.e., anti-sunward propagating in plasma rest frame) shocks in the WSDB, of which 250 were low Mach number, low beta, quasi-perpendicular shocks. We define low Mach number as satisfying $\langle M_f \rangle_{up} \geq 1$ and $1 \leq \langle M_A \rangle_{up} \leq 3$. We define low beta as satisfying $\langle \beta_{Tot} \rangle_{up} \leq 1$. Finally, quasi-perpendicular is defined, as per usual, as satisfying $\langle \theta_{Bn} \rangle_{up} \geq 45°$. Of the 250 analyzed quasi-perpendicular fast mode shocks, 145 satisfied these criteria which we will call “good shocks.”

The center ramp time, shock normal numerical method, $|V_{shn}|$, $\langle n_i \rangle_{up}$, $\langle |\mathbf{B}_o| \rangle_{up}$, $\langle M_A \rangle_{up}$, and $\langle M_f \rangle_{up}$, and two-letter shock designation or “Shock Label” (see definition below) are shown in Table S1. All numerical values are shown with associated uncertainties.

We examined the ramp region and/or whistler precursor fluctuations to determine whether the data were well resolved (i.e., smooth, continuous transitions between points) or under-sampled (i.e., spiky, discontinuous transitions between points). To parameterize these properties, we categorized every shock with a two-letter code. The code is summarized as follows:

1. **First Letter**
   (a) Y = yes, a whistler precursor is clearly observed;
   (b) N = no, nothing is observed; and
   (c) M = maybe/unclear
2. **Second Letter**
   (a) S = data are resolved or sampled well enough (e.g., precursor appears as smooth modulated sine wave);
   (b) U = fluctuation(s) present but under-sampled (e.g., looks like triangle or sawtooth wave);
   (c) P = data are mostly resolved but still a little spiky (e.g., some of the precursor is smooth but some parts are triangle-wave-like);
   (d) G = data gap is present within the precursor time interval but data are still well resolved;
   (e) M = data gap is present within the precursor time interval and data are under-sampled (similar comments as above); and
   (f) N = nothing is observed

From the 145 events based upon the first letter only, then there are 113($\sim$78%) Y's, 15($\sim$10%) M's (i.e., maybe but not clear), and 17($\sim$12%) N's (i.e., no fluctuations immediately adjacent to the shock ramp). When looking at the second letter only, then there are 83($\sim$57%) U's or M's, 33($\sim$23%) P's, 13($\sim$9%) S's or G's, and 16($\sim$10%) were N's. These two-letter designations are shown in Tables S1 and S2 for every event.

Table S1: IP Shock Parameters and Whistler Observation Designation

Ramp Time [UTC]	**RH Meth.**	$\|\mathbf{V_{shn}}\|$ **[km/s]**	$\langle \mathbf{n_i} \rangle_{\mathbf{up}}$ $[\mathbf{cm^{-3}}]$	$\langle \|\mathbf{B_o}\| \rangle_{up}$ **[nT]**	$\langle \mathbf{M_A} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f} \rangle_{\mathbf{up}}$	**Shock Label**
1995-03-04/00:36:58.500	RH08	380.20±8.40	5.20±0.30	3.91±0.15	2.60±0.17	1.96±0.09	MU
1995-04-17/23:33:07.755	RH08	389.20±4.40	14.40±0.20	7.79±0.24	1.29±0.02	1.14±0.01	YU
1995-07-22/05:35:45.354	RH08	9.30±6.10	3.80±0.20	3.38±0.16	1.38±0.09	1.22±0.04	YP
1995-08-22/12:56:49.213	RH08	381.00±5.30	3.40±0.20	2.11±0.13	2.57±0.13	1.82±0.04	YG
1995-08-24/22:11:04.526	RH08	387.70±13.00	20.40±0.80	6.61±0.46	2.49±0.10	2.01±0.05	YU
1995-09-14/21:24:55.549	RH08	328.40±17.80	3.00±0.20	2.91±0.31	1.99±0.18	1.50±0.09	NN
1995-10-22/21:20:15.947	RH08	333.00±14.10	5.40±0.30	4.42±0.12	2.72±0.15	2.06±0.10	YU
1995-12-24/05:57:35.591	RH08	422.80±11.50	16.40±1.50	6.33±0.38	2.95±0.26	2.52±0.17	YU
1996-02-06/19:14:24.148	RH08	383.40±5.90	7.60±0.30	3.88±0.23	1.71±0.10	1.40±0.06	YU
1996-04-03/09:47:17.151	RH08	379.20±3.80	14.50±0.50	4.24±0.07	2.02±0.06	1.59±0.02	YP
1996-04-08/02:41:09.765	RH08	182.30±4.00	15.80±0.20	5.69±0.35	2.42±0.04	2.08±0.03	YP
1996-06-18/22:35:55.500	RH08	460.80±16.30	10.50±0.50	7.40±0.30	1.66±0.11	1.42±0.10	NN
1997-01-05/03:20:46.500	RH09	384.20±8.30	7.10±0.10	5.21±0.20	1.45±0.05	1.19±0.02	MU
1997-03-15/22:30:33.074	MX3	386.10±7.30	7.00±0.10	5.02±0.21	1.41±0.05	1.10±0.03	YS
1997-04-10/12:58:34.717	RH08	371.40±5.70	15.00±0.40	8.50±0.35	1.49±0.10	1.25±0.04	YU
1997-04-16/12:21:25.500	RH08	401.30±4.00	19.10±1.00	5.28±0.23	2.20±0.08	1.41±0.05	MU
1997-05-20/05:10:48.500	RH08	349.60±2.60	8.60±0.30	3.39±0.48	1.92±0.13	1.50±0.08	NN
1997-05-25/13:49:55.500	RH08	374.10±8.30	9.30±0.20	4.63±0.21	2.57±0.06	1.80±0.04	MU
1997-05-26/09:09:07.500	RH08	335.20±2.60	13.80±0.30	3.07±0.11	2.98±0.09	2.26±0.04	NN
1997-08-05/04:59:04.500	RH08	392.40±10.10	11.00±0.20	4.53±0.36	1.52±0.10	1.03±0.06	NN
1997-09-03/08:38:40.500	MX3	477.30±15.10	8.60±0.30	9.98±0.23	1.28±0.03	1.08±0.01	NN
1997-10-10/15:57:07.500	RH08	477.30±10.10	12.10±0.70	8.46±0.63	1.60±0.08	1.50±0.08	MU
1997-10-24/11:18:09.990	RH08	490.90±13.00	11.00±0.70	9.14±0.45	1.92±0.07	1.73±0.06	YP
1997-11-01/06:14:45.660	RH08	309.20±6.00	29.50±0.30	5.87±0.15	2.35±0.03	1.81±0.02	YP
1997-12-10/04:33:14.806	RH08	391.20±12.40	10.20±0.90	7.10±0.21	2.73±0.17	2.26±0.10	YU
1997-12-30/01:13:43.921	RH08	423.40±8.10	7.70±0.20	5.37±0.32	2.47±0.07	1.89±0.03	YU
1998-01-06/13:29:00.368	RH08	408.40±10.00	9.70±0.40	6.53±0.21	2.41±0.07	1.97±0.05	YU
1998-02-18/07:48:44.519	RH08	463.40±11.00	17.20±0.40	15.56±0.37	1.15±0.03	1.08±0.02	YS
1998-05-29/15:12:04.523	RH08	692.50±29.00	7.70±0.50	11.60±0.24	1.83±0.09	1.36±0.06	YU
1998-08-06/07:16:07.589	RH08	478.80±36.50	10.90±1.00	10.31±0.34	1.66±0.10	1.58±0.08	YU
1998-08-19/18:40:41.694	RH08	334.70±6.20	7.80±0.30	3.54±0.31	2.80±0.17	2.32±0.13	YU
1998-11-08/04:41:17.414	RH08	644.50±64.30	4.40±0.70	17.35±0.36	1.51±0.14	1.49±0.14	YU
1998-12-26/09:56:06.449	RH09	483.70±18.80	5.90±0.10	8.09±0.25	1.38±0.04	1.09±0.04	MU
1998-12-28/18:20:16.211	RH08	465.20±30.20	6.90±0.90	6.88±1.33	1.75±0.27	1.42±0.16	YP
1999-01-13/10:47:45.119	RH08	433.10±22.40	9.70±1.10	5.06±0.90	2.48±0.27	1.85±0.20	YP
1999-02-17/07:12:13.985	RH08	560.20±17.80	6.10±0.40	7.00±0.24	1.57±0.07	1.38±0.05	YU
1999-03-10/01:33:01.500	RH08	509.30±15.40	7.20±0.20	4.42±0.34	2.78±0.09	1.74±0.03	NN
1999-04-16/11:14:11.089	RH09	479.80±14.50	4.00±0.50	6.60±0.23	1.60±0.11	1.49±0.08	YP
1999-06-26/19:30:58.154	RH08	467.20±9.70	15.60±1.00	11.85±0.92	2.22±0.07	1.83±0.03	YM
1999-08-04/01:44:38.601	RH08	418.10±6.90	8.70±0.20	6.23±0.41	2.07±0.08	1.95±0.04	YP
1999-08-23/12:11:14.769	RH08	491.20±12.70	6.20±0.20	8.17±0.10	1.48±0.03	1.44±0.03	YP
1999-09-15/07:43:48.000	RH08	665.50±16.30	2.60±0.10	5.69±0.91	2.04±0.12	1.42±0.06	NN
1999-09-22/12:09:25.567	RH08	510.70±37.20	17.00±0.70	11.29±1.66	2.44±0.10	1.88±0.08	YU
1999-10-21/02:20:51.968	RH08	477.30±28.60	13.40±0.40	9.17±0.38	2.46±0.07	2.21±0.06	YM
1999-11-05/20:03:10.098	RH08	392.60±6.90	6.10±0.20	6.74±0.21	1.46±0.06	1.25±0.04	YP
1999-11-13/12:48:57.367	RH08	470.30±7.00	2.90±0.10	6.49±0.22	1.36±0.04	1.31±0.02	YU
2000-02-05/15:26:29.213	RH08	444.00±8.10	5.30±0.10	5.87±0.18	1.29±0.03	1.15±0.03	YU
2000-02-14/07:12:59.975	RH08	700.70±593.50	2.90±0.40	5.85±0.31	1.83±0.18	1.46±0.09	YP
2000-06-23/12:58:00.164	RH08	527.60±24.60	6.10±0.70	7.52±0.49	2.80±0.24	2.22±0.08	YP
2000-07-13/09:43:52.019	RH08	641.40±13.90	4.20±0.30	5.94±0.47	2.14±0.14	1.52±0.05	YU
2000-07-26/19:00:15.048	RH08	425.00±5.60	13.70±0.50	5.80±0.14	1.95±0.05	1.40±0.02	YU
Ramp Time [UTC]	**RH Meth.**	$\langle \|\mathbf{V_{shn}}\| \rangle_{\mathbf{up}}$ **[km/s]**	$\langle \mathbf{n_i} \rangle_{\mathbf{up}}$ $[\mathbf{cm^{-3}}]$	$\langle \|\mathbf{B_o}\| \rangle_{up}$ **[nT]**	$\langle \mathbf{M_A} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f} \rangle_{\mathbf{up}}$	**Shock Label**

Table S1: IP Shock Parameters and Whistler Observation Designation

Ramp Time [UTC]	**RH Meth.**	$\lvert\mathbf{V_{shn}}\rvert$ **[km/s]**	$\langle \mathbf{n_i} \rangle_{\mathbf{up}}$ **[cm^{-3}]**	$\langle \lvert\mathbf{B_o}\rvert \rangle_{up}$ **[nT]**	$\langle \mathbf{M_A} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f} \rangle_{\mathbf{up}}$	**Shock Label**
2000-07-28/06:38:46.187	RH08	491.40±19.20	5.60±0.90	8.57±0.35	1.88±0.18	1.84±0.14	YU
2000-08-10/05:13:21.711	RH08	379.90±7.00	6.10±0.40	6.61±0.39	1.33±0.08	1.14±0.06	YU
2000-08-11/18:49:34.684	RH08	605.10±163.10	1.60±0.50	9.39±0.33	1.27±0.21	1.27±0.23	YM
2000-10-03/01:02:20.500	RH08	457.20±7.90	7.00±0.30	5.72±0.42	2.20±0.17	1.66±0.05	NN
2000-10-28/06:38:31.899	RH08	413.60±11.70	3.80±0.40	4.40±0.27	1.99±0.17	1.71±0.09	MU
2000-10-28/09:30:41.475	RH08	441.10±7.00	9.70±1.00	6.73±0.43	2.12±0.18	1.53±0.06	YU
2000-10-31/17:09:59.376	RH08	475.30±24.90	5.40±0.40	7.40±0.56	1.79±0.10	1.60±0.06	YU
2000-11-04/02:25:46.500	RH08	450.10±9.10	16.30±0.30	8.36±0.78	2.33±0.06	1.91±0.04	NN
2000-11-06/09:30:15.569	RH08	626.00±21.60	2.00±0.30	4.91±0.61	1.96±0.23	1.66±0.15	YP
2000-11-11/04:10:49.500	RH08	975.60±85.00	1.10±0.10	4.39±1.17	1.78±0.28	1.50±0.20	MU
2000-11-26/11:43:31.355	RH08	509.70±29.10	7.60±1.00	9.19±0.67	2.52±0.14	1.77±0.09	YM
2000-11-28/05:27:42.233	RH08	603.80±21.00	5.30±0.40	6.61±0.58	1.62±0.09	1.40±0.06	YP
2001-01-17/04:07:53.254	RH08	379.20±5.60	9.40±0.50	5.05±0.17	1.68±0.07	1.33±0.02	YP
2001-03-03/11:29:19.410	RH08	553.60±14.40	3.10±0.30	3.92±0.46	2.37±0.13	1.92±0.09	YS
2001-03-22/13:59:06.530	RH08	382.00±7.10	19.80±1.60	9.95±0.88	1.44±0.08	1.28±0.06	YU
2001-03-27/18:07:48.865	RH08	552.10±19.40	6.40±0.50	10.48±0.51	2.14±0.16	1.76±0.08	YU
2001-04-21/15:29:14.585	RH08	395.40±2.10	7.10±0.20	3.49±0.11	2.47±0.10	1.82±0.10	YU
2001-05-06/09:06:08.766	RH08	365.60±5.30	8.70±0.20	4.92±0.23	1.58±0.04	1.31±0.04	YP
2001-05-12/10:03:14.540	RH08	574.70±16.40	5.20±0.10	12.43±0.40	1.21±0.04	1.10±0.03	YP
2001-08-12/16:12:46.500	RH08	340.20±13.20	13.60±0.60	9.65±0.18	2.19±0.11	1.88±0.10	MU
2001-08-31/01:25:04.500	RH08	475.30±16.80	3.20±0.10	5.08±0.10	1.52±0.04	1.25±0.03	NN
2001-09-13/02:31:28.009	RH08	454.50±33.40	6.70±0.80	8.40±0.39	1.31±0.10	1.08±0.05	YU
2001-10-28/03:13:48.680	RH08	591.80±53.00	2.60±0.70	7.58±0.66	2.34±0.39	2.32±0.29	YU
2001-11-30/18:15:45.600	RH08	417.90±21.50	3.80±0.20	3.65±0.28	2.01±0.11	1.61±0.07	YP
2001-12-21/14:10:18.049	RH08	565.80±141.90	4.20±0.70	8.96±0.74	2.15±0.29	1.99±0.17	YP
2001-12-30/20:05:07.154	RH08	669.00±24.00	7.00±0.40	11.44±1.59	2.47±0.16	1.79±0.06	YM
2002-01-17/05:26:58.160	RH09	404.30±9.90	6.50±0.40	6.35±0.80	1.26±0.10	1.13±0.04	YP
2002-01-31/21:38:10.686	RH08	363.90±8.30	4.80±0.20	5.86±0.12	2.36±0.08	2.14±0.05	YU
2002-03-23/11:24:09.197	RH08	520.10±9.00	3.60±0.30	3.41±0.58	2.82±0.17	2.12±0.10	YU
2002-03-29/22:15:13.397	RH08	398.70±14.40	23.20±2.10	5.45±1.12	2.93±0.38	2.05±0.12	YU
2002-05-21/21:14:16.399	RH09	257.30±4.50	8.50±0.40	4.30±0.27	1.93±0.09	1.55±0.05	YP
2002-06-29/21:10:26.075	RH08	385.40±15.10	5.50±0.20	6.02±0.50	1.38±0.06	1.17±0.05	YS
2002-08-01/23:09:07.514	RH08	497.40±5.30	12.10±0.10	8.12±0.30	1.51±0.03	1.42±0.03	YU
2002-09-30/07:54:24.470	RH08	326.50±6.80	19.30±0.90	13.41±0.63	1.40±0.04	1.24±0.04	YM
2002-10-02/22:41:04.500	RH08	527.20±19.80	3.10±0.30	3.48±0.55	1.98±0.13	1.59±0.06	MU
2002-11-09/18:27:49.389	RH08	425.00±7.40	13.10±0.90	6.71±0.18	1.85±0.10	1.70±0.08	YU
2003-05-29/18:31:08.012	RH08	907.80±51.60	7.70±1.20	14.14±1.27	1.97±0.22	1.88±0.19	YU
2003-06-18/04:42:06.396	RH08	618.70±38.40	6.60±0.30	10.53±0.27	1.76±0.06	1.53±0.03	YP
2004-04-12/18:29:46.590	RH08	558.60±30.50	3.20±0.20	4.19±0.88	2.71±0.13	2.05±0.08	YU
2005-05-06/12:08:39.840	RH08	416.80±0.30	9.30±0.10	4.45±0.14	2.35±0.15	1.93±0.07	YS
2005-05-07/18:26:16.447	RH08	437.90±1.20	17.90±0.90	13.27±0.76	1.15±0.03	1.04±0.03	YU
2005-06-16/08:09:10.578	RH08	620.60±10.60	4.10±0.80	11.83±0.08	1.29±0.16	1.29±0.13	YU
2005-07-10/02:42:30.953	RH08	540.50±14.70	7.30±0.80	10.79±0.38	2.25±0.19	2.06±0.16	YU
2005-07-16/01:40:58.500	RH08	421.80±1.70	8.60±0.50	5.30±0.43	2.03±0.19	1.47±0.07	NN
2005-08-01/06:00:52.500	RH08	479.60±4.50	3.30±0.20	7.64±0.21	1.79±0.09	1.61±0.09	MU
2005-08-24/05:35:24.651	RH08	579.10±1.30	11.60±0.80	10.36±1.38	1.97±0.25	1.65±0.11	YM
2005-09-02/13:50:16.303	RH08	587.00±3.80	4.90±0.60	6.05±0.77	2.63±0.19	2.04±0.06	YU
2005-09-15/08:36:30.500	RH08	683.70±3.00	1.50±0.10	3.33±0.69	2.54±0.47	2.13±0.28	MU
2005-12-30/23:45:23.000	RH08	619.00±1.00	2.00±0.00	3.10±0.10	1.59±0.09	1.19±0.05	NN
2006-08-19/09:38:49.144	RH08	373.30±1.50	14.90±0.60	7.67±0.51	1.21±0.08	1.02±0.07	YS
2006-11-03/09:37:16.500	RH08	397.50±1.80	10.80±0.50	4.98±0.12	2.05±0.05	1.58±0.02	NN
Ramp Time [UTC]	**RH Meth.**	$\langle\lvert\mathbf{V_{shn}}\rvert\rangle_{\mathbf{up}}$ **[km/s]**	$\langle \mathbf{n_i} \rangle_{\mathbf{up}}$ **[cm^{-3}]**	$\langle \lvert\mathbf{B_o}\rvert \rangle_{up}$ **[nT]**	$\langle \mathbf{M_A} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f} \rangle_{\mathbf{up}}$	**Shock Label**

Table S1: IP Shock Parameters and Whistler Observation Designation

Ramp Time [UTC]	**RH Meth.**	$\lvert \mathbf{V}_{shn} \rvert$ **[km/s]**	$\langle \mathbf{n}_{i} \rangle_{up}$ **[cm^{-3}]**	$\langle \lvert \mathbf{B}_{o} \rvert \rangle_{up}$ **[nT]**	$\langle \mathbf{M}_{A} \rangle_{up}$	$\langle \mathbf{M}_{f} \rangle_{up}$	**Shock Label**
2007-07-20/03:27:17.000	RH08	357.20±0.60	8.60±0.20	3.56±0.10	1.99±0.05	1.41±0.03	NU
2007-08-22/04:34:03.509	RH08	356.90±0.70	8.40±0.40	2.41±0.18	2.13±0.14	1.54±0.06	YU
2007-12-17/01:53:18.835	RH08	289.30±0.70	6.60±0.10	3.56±0.09	2.33±0.09	1.70±0.06	YP
2008-05-28/01:17:38.485	RH08	402.40±1.00	10.90±0.70	3.89±0.53	2.88±0.18	2.05±0.07	YU
2008-06-24/19:10:41.966	RH08	354.80±0.80	7.10±0.20	3.57±0.10	2.01±0.06	1.68±0.03	YP
2009-02-03/19:21:03.298	RH08	407.70±10.20	3.00±0.30	4.63±0.20	1.69±0.12	1.59±0.10	YU
2009-06-24/09:52:20.572	RH08	350.40±1.80	12.10±0.70	4.60±0.20	2.80±0.21	2.03±0.10	YP
2009-06-27/11:04:19.171	RH08	426.10±1.50	3.80±0.20	3.79±0.10	1.59±0.03	1.32±0.02	YU
2009-10-21/23:15:10.175	RH08	307.70±1.30	10.10±0.40	3.47±0.23	2.38±0.21	1.71±0.09	YU
2010-04-11/12:20:56.470	RH08	465.20±1.80	3.20±0.20	4.58±0.41	2.53±0.17	2.17±0.16	YP
2011-02-04/01:50:55.821	RH10	285.10±4.80	2.50±0.20	2.51±0.10	1.97±0.16	1.63±0.12	YS
2011-07-11/08:27:25.529	RH08	601.40±3.00	5.00±0.10	5.41±0.46	2.82±0.18	1.98±0.10	YU
2011-09-16/18:56:59.489	RH08	291.10±5.90	1.00±1.00	3.41±2.37	1.35±1.90	1.28±1.28	YP
2011-09-25/10:46:32.224	RH08	85.60±2.50	3.90±0.70	6.12±1.04	1.15±0.25	1.06±0.39	YU
2012-01-21/04:02:01.998	RH08	326.80±2.20	5.10±0.20	4.54±0.09	1.85±0.03	1.70±0.02	YU
2012-01-30/15:43:13.436	RH08	411.10±5.70	2.90±0.60	3.03±0.23	2.84±0.14	2.51±0.10	YU
2012-03-07/03:28:39.500	RH08	479.00±4.50	6.90±0.40	8.93±0.52	2.09±0.13	1.88±0.08	NN
2012-04-19/17:13:31.500	RH08	410.10±2.20	5.20±0.20	2.77±0.19	2.45±0.15	1.73±0.09	MU
2012-06-16/19:34:39.463	RH08	486.90±2.30	18.70±0.60	7.95±0.53	2.40±0.16	1.78±0.05	YU
2012-10-08/04:12:14.203	RH08	465.40±6.20	7.10±0.40	8.14±0.60	2.32±0.11	2.02±0.11	YU
2012-11-12/22:12:41.856	RH08	377.10±1.50	17.90±0.80	7.58±0.72	2.52±0.31	2.07±0.16	YU
2012-11-26/04:32:51.244	RH08	586.40±5.40	3.10±0.40	4.80±0.56	2.20±0.30	1.78±0.21	YP
2012-12-14/19:06:13.500	RH08	384.30±2.40	6.80±0.30	5.92±0.10	2.10±0.06	1.78±0.05	NN
2013-01-17/00:23:43.500	RH08	424.90±1.00	22.50±0.70	5.44±0.11	1.83±0.07	1.26±0.02	MU
2013-02-13/00:47:45.971	RH08	447.80±3.00	5.10±0.30	3.54±0.37	2.60±0.15	1.96±0.07	YP
2013-04-30/08:52:46.649	RH08	461.40±3.70	5.70±0.20	4.91±0.52	2.17±0.12	1.78±0.09	YU
2013-06-10/02:52:01.571	RH08	387.70±1.20	11.10±0.40	4.05±0.12	1.62±0.06	1.18±0.06	YP
2013-07-12/16:43:27.886	RH08	499.30±6.90	3.20±0.30	5.14±0.20	2.31±0.21	1.86±0.08	YP
2013-09-02/01:56:50.404	RH08	524.70±3.90	1.50±0.10	2.99±0.39	2.20±0.09	1.71±0.08	YG
2013-10-26/21:26:02.434	RH08	336.50±0.80	3.90±0.10	4.21±0.10	1.59±0.03	1.54±0.02	YS
2014-02-13/08:55:29.210	RH08	465.60±2.80	3.70±0.10	5.75±0.10	1.74±0.03	1.71±0.03	YU
2014-02-15/12:46:37.044	RH08	499.60±2.70	6.60±0.40	6.69±0.15	2.68±0.12	2.11±0.06	YU
2014-02-19/03:09:39.045	RH08	632.40±6.40	2.40±0.00	8.50±0.14	2.06±0.03	2.00±0.03	YU
2014-04-19/17:48:25.374	RH08	549.20±2.70	6.30±0.20	5.50±0.25	1.63±0.05	1.52±0.04	YP
2014-05-07/21:19:39.118	RH08	386.40±1.00	5.10±0.20	4.76±0.19	1.22±0.04	1.13±0.04	YS
2014-05-29/08:26:41.450	RH08	381.70±1.80	4.40±0.30	4.73±0.14	1.26±0.07	1.11±0.06	YS
2014-07-14/13:38:09.110	RH08	278.10±4.60	27.80±2.90	7.99±0.62	1.30±0.14	1.07±0.06	YU
2015-05-06/00:55:49.856	RH08	527.50±3.60	5.00±0.90	5.72±0.25	2.61±0.26	2.28±0.13	YU
2015-06-05/08:30:57.400	RH08	326.90±0.60	6.70±0.20	2.54±0.30	2.42±0.07	1.57±0.05	MU
2015-06-24/13:07:15.538	RH08	591.70±15.50	1.00±0.10	5.50±0.68	2.09±0.16	2.00±0.21	YS
2015-08-15/07:43:42.090	RH08	477.40±3.70	11.40±1.60	10.79±0.19	2.38±0.20	2.27±0.19	YM
2016-03-11/04:29:17.468	RH08	363.10±1.90	15.60±1.40	5.54±0.38	2.01±0.18	1.46±0.13	YU
2016-03-14/16:16:32.196	RH08	412.50±1.70	13.80±0.50	5.73±0.65	2.27±0.12	1.52±0.02	YU
Ramp Time [UTC]	**RH Meth.**	$\langle \lvert \mathbf{V}_{shn} \rvert \rangle_{up}$ **[km/s]**	$\langle \mathbf{n}_{i} \rangle_{up}$ **[cm^{-3}]**	$\langle \lvert \mathbf{B}_{o} \rvert \rangle_{up}$ **[nT]**	$\langle \mathbf{M}_{A} \rangle_{up}$	$\langle \mathbf{M}_{f} \rangle_{up}$	**Shock Label**

3 Critical Mach Numbers

For each crossing, we estimated four different critical Mach numbers. The first critical Mach number, M_{cr}, defines the maximum Mach number above which an ion sound wave could not phase stand within the shock ramp, thus for $\langle M_f/M_{cr} \rangle_{up} \geq 1$ the shock cannot rely upon resistive dissipation effects to maintain a stable discontinuity [e.g., *Edmiston and Kennel*, 1984; *Kennel et al.*, 1985]. We also estimated three whistler critical Mach numbers [*Krasnoselskikh et al.*, 2002], defined as: M_{ww} is the maximum Mach number for which a linear whistler can phase stand upstream of the shock ramp; M_{gr} is similar to M_{ww} but depends upon the whistler group velocity, thus determines the cutoff where a linear precursor can no longer carry energy into the upstream; and M_{nw} defines the separation between a stable/stationary and "breaking" shock front.

The ratios between the upstream fast mode Mach number and each critical Mach number is shown in Table S2 along with the upstream average beta and shock normal angle for the 145 good shocks. All values are reported with associated uncertainties. Notice that only 12(∼8%) satisfy $\langle M_f/M_{cr} \rangle_{up} \geq 1$, thus most of these shocks are subcritical.

As a side note, for all 250 quasi-perpendicular shocks in the WSDB, 104(∼42%) satisfy $\langle M_f/M_{cr} \rangle_{up} \geq 1$ thus slightly less than half are supercritical. Further, only 40(∼16%) satisfy $\langle M_f/M_{ww} \rangle_{up} \geq 1$, thus most quasi-perpendicular interplanetary shocks should exhibit upstream whistler precursor waves, assuming cold plasma and a dispersion-only dissipation mechanism [e.g., *Krasnoselskikh et al.*, 2002].

Table S2: IP Shock Critical Mach Number Ratios

Ramp Time [UTC]	$\langle \boldsymbol{\beta}_{\mathbf{Tot}} \rangle_{\mathbf{up}}$	$\langle \boldsymbol{\theta}_{\mathbf{Bn}} \rangle_{\mathbf{up}}$ [°]	$\langle \mathbf{M_f/M_{cr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{ww}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{gr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{nw}} \rangle_{\mathbf{up}}$	**Shock Label**
1995-03-04/00:36:58.500	0.47±0.47	86.10±4.80	0.89±0.19	1.17±1.02	0.90±0.79	0.83±0.72	MU
1995-04-17/23:33:07.755	0.16±0.16	80.00±0.70	0.46±0.04	0.31±0.02	0.24±0.02	0.22±0.02	YU
1995-07-22/05:35:45.354	0.23±0.23	52.10±2.80	0.55±0.06	0.09±0.01	0.07±0.01	0.07±0.00	YP
1995-08-22/12:56:49.213	0.65±0.67	66.10±7.40	0.91±0.24	0.21±0.06	0.16±0.05	0.15±0.04	YG
1995-08-24/22:11:04.526	0.34±0.34	73.70±1.80	0.88±0.14	0.33±0.04	0.26±0.03	0.24±0.03	YU
1995-09-14/21:24:55.549	0.48±0.49	81.30±8.90	0.69±0.15	0.46±0.45	0.35±0.35	0.32±0.32	NN
1995-10-22/21:20:15.947	0.50±0.50	65.70±5.80	0.99±0.22	0.23±0.05	0.18±0.04	0.17±0.04	YU
1995-12-24/05:57:35.591	0.29±0.26	58.40±3.30	1.14±0.16	0.22±0.03	0.17±0.02	0.16±0.02	YU
1996-02-06/19:14:24.148	0.42±0.43	48.40±4.60	0.70±0.13	0.10±0.01	0.08±0.01	0.07±0.01	YU
1996-04-03/09:47:17.151	0.39±0.38	75.70±1.40	0.71±0.12	0.30±0.03	0.23±0.02	0.21±0.02	YP
1996-04-08/02:41:09.765	0.23±0.23	73.30±1.10	0.87±0.10	0.34±0.02	0.26±0.02	0.24±0.02	YP
1996-06-18/22:35:55.500	0.32±0.32	49.90±3.00	0.68±0.11	0.10±0.01	0.08±0.01	0.07±0.01	NN
1997-01-05/03:20:46.500	0.34±0.36	64.30±2.40	0.54±0.09	0.13±0.01	0.10±0.01	0.09±0.01	MU
1997-03-15/22:30:33.074	0.51±0.51	49.90±3.00	0.57±0.12	0.08±0.01	0.06±0.00	0.06±0.00	YS
1997-04-10/12:58:34.717	0.32±0.33	58.50±1.50	0.57±0.09	0.11±0.01	0.09±0.00	0.08±0.00	YU
1997-04-16/12:21:25.500	0.93±0.95	67.70±4.00	0.75±0.24	0.17±0.03	0.13±0.02	0.12±0.02	MU
1997-05-20/05:10:48.500	0.54±0.54	46.00±11.30	0.80±0.18	0.10±0.02	0.08±0.02	0.07±0.02	NN
1997-05-25/13:49:55.500	0.63±0.62	85.50±4.00	0.86±0.22	1.07±0.95	0.83±0.73	0.76±0.67	MU
1997-05-26/09:09:07.500	0.58±0.58	50.30±1.30	1.19±0.27	0.17±0.01	0.13±0.00	0.12±0.00	NN
1997-08-05/04:59:04.500	0.82±0.83	56.50±7.40	0.56±0.17	0.09±0.02	0.07±0.01	0.06±0.01	NN
1997-09-03/08:38:40.500	0.26±0.26	78.20±2.20	0.46±0.06	0.25±0.05	0.19±0.03	0.17±0.03	NN
1997-10-10/15:57:07.500	0.09±0.09	87.70±6.60	0.57±0.04	0.78±0.51	0.60±0.39	0.55±0.36	MU
1997-10-24/11:18:09.990	0.16±0.16	68.30±4.50	0.71±0.06	0.22±0.04	0.17±0.03	0.15±0.03	YP
1997-11-01/06:14:45.660	0.42±0.42	77.30±1.80	0.82±0.16	0.38±0.05	0.30±0.04	0.27±0.04	YP
1997-12-10/04:33:14.806	0.30±0.28	70.90±1.60	0.99±0.14	0.32±0.03	0.25±0.02	0.23±0.02	YU
1997-12-30/01:13:43.921	0.42±0.41	87.40±8.10	0.85±0.16	0.81±0.53	0.62±0.41	0.57±0.37	YU
1998-01-06/13:29:00.368	0.30±0.30	82.30±6.20	0.84±0.12	0.69±0.55	0.53±0.43	0.49±0.39	YU
1998-02-18/07:48:44.519	0.13±0.13	48.70±2.00	0.48±0.03	0.08±0.00	0.06±0.00	0.05±0.00	YS
1998-05-29/15:12:04.523	0.55±0.55	64.50±2.40	0.66±0.15	0.15±0.01	0.11±0.01	0.10±0.01	YU
1998-08-06/07:16:07.589	0.06±0.07	80.80±3.90	0.60±0.04	0.46±0.20	0.36±0.15	0.33±0.14	YU
1998-08-19/18:40:41.694	0.42±0.41	45.50±8.10	1.19±0.22	0.16±0.02	0.12±0.02	0.11±0.02	YU
1998-11-08/04:41:17.414	0.03±0.03	54.60±1.40	0.61±0.06	0.12±0.01	0.09±0.01	0.08±0.01	YU
Ramp Time [UTC]	$\langle \boldsymbol{\beta}_{\mathbf{Tot}} \rangle_{\mathbf{up}}$	$\langle \boldsymbol{\theta}_{\mathbf{Bn}} \rangle_{\mathbf{up}}$ [°]	$\langle \mathbf{M_f/M_{cr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{ww}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{gr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{nw}} \rangle_{\mathbf{up}}$	**Shock Label**

Table S2: IP Shock Critical Mach Number Ratios

Ramp Time [UTC]	$\langle \boldsymbol{\beta}_{\mathbf{Tot}} \rangle_{\mathbf{up}}$	$\langle \boldsymbol{\theta}_{\mathbf{Bn}} \rangle_{\mathbf{up}}$ [°]	$\langle \mathbf{M_f/M_{cr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{ww}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{gr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{nw}} \rangle_{\mathbf{up}}$	**Shock Label**
1998-12-26/09:56:06.449	0.37±0.38	78.60±2.70	0.48±0.08	0.26±0.06	0.20±0.05	0.18±0.04	MU
1998-12-28/18:20:16.211	0.41±0.43	60.70±12.90	0.68±0.15	0.14±0.06	0.11±0.04	0.10±0.04	YP
1999-01-13/10:47:45.119	0.52±0.49	70.90±12.70	0.89±0.21	0.27±0.18	0.21±0.14	0.19±0.12	YP
1999-02-17/07:12:13.985	0.19±0.18	86.60±2.90	0.56±0.05	1.09±0.93	0.84±0.71	0.77±0.66	YU
1999-03-10/01:33:01.500	0.94±0.94	84.70±5.90	0.90±0.29	0.82±0.76	0.63±0.59	0.58±0.54	NN
1999-04-16/11:14:11.089	0.12±0.11	62.30±3.40	0.61±0.05	0.15±0.02	0.12±0.01	0.11±0.01	YP
1999-06-26/19:30:58.154	0.34±0.36	59.40±3.70	0.85±0.13	0.17±0.02	0.13±0.01	0.12±0.01	YM
1999-08-04/01:44:38.601	0.11±0.11	54.10±4.80	0.83±0.05	0.16±0.02	0.12±0.01	0.11±0.01	YP
1999-08-23/12:11:14.769	0.04±0.04	60.70±0.90	0.57±0.02	0.14±0.00	0.11±0.00	0.10±0.00	YP
1999-09-15/07:43:48.000	0.68±0.73	73.60±4.30	0.70±0.19	0.24±0.06	0.18±0.05	0.17±0.04	NN
1999-09-22/12:09:25.567	0.44±0.46	70.80±3.40	0.87±0.18	0.27±0.05	0.21±0.04	0.19±0.03	YU
1999-10-21/02:20:51.968	0.17±0.16	69.40±3.30	0.91±0.08	0.29±0.05	0.23±0.04	0.21±0.03	YM
1999-11-05/20:03:10.098	0.29±0.29	52.70±2.40	0.58±0.08	0.10±0.01	0.07±0.00	0.07±0.00	YP
1999-11-13/12:48:57.367	0.05±0.05	69.10±1.80	0.50±0.01	0.17±0.01	0.13±0.01	0.12±0.01	YU
2000-02-05/15:26:29.213	0.16±0.16	68.10±2.10	0.47±0.04	0.14±0.01	0.11±0.01	0.10±0.01	YU
2000-02-14/07:12:59.975	0.44±0.41	56.30±3.30	0.71±0.13	0.12±0.01	0.09±0.01	0.09±0.01	YP
2000-06-23/12:58:00.164	0.45±0.40	56.10±7.00	1.09±0.19	0.19±0.03	0.14±0.03	0.13±0.02	YP
2000-07-13/09:43:52.019	0.75±0.71	51.90±2.60	0.83±0.22	0.12±0.01	0.09±0.01	0.08±0.01	YU
2000-07-26/19:00:15.048	0.57±0.58	86.00±3.00	0.66±0.16	0.94±0.70	0.72±0.54	0.66±0.50	YU
2000-07-28/06:38:46.187	0.05±0.05	56.20±1.10	0.75±0.06	0.15±0.01	0.12±0.01	0.11±0.01	YU
2000-08-10/05:13:21.711	0.24±0.25	67.00±2.70	0.49±0.06	0.14±0.02	0.10±0.01	0.10±0.01	YU
2000-08-11/18:49:34.684	0.03±0.03	78.20±3.70	0.47±0.09	0.29±0.10	0.22±0.08	0.21±0.07	YM
2000-10-03/01:02:20.500	0.59±0.58	51.50±3.60	0.87±0.20	0.12±0.01	0.10±0.01	0.09±0.01	NN
2000-10-28/06:38:31.899	0.27±0.25	59.10±5.60	0.77±0.10	0.16±0.03	0.12±0.02	0.11±0.02	MU
2000-10-28/09:30:41.475	0.69±0.70	51.60±6.50	0.82±0.22	0.12±0.02	0.09±0.01	0.08±0.01	YU
2000-10-31/17:09:59.376	0.17±0.17	71.10±1.50	0.65±0.06	0.23±0.02	0.18±0.02	0.16±0.01	YU
2000-11-04/02:25:46.500	0.32±0.32	66.40±4.00	0.85±0.13	0.22±0.04	0.17±0.03	0.16±0.03	NN
2000-11-06/09:30:15.569	0.26±0.27	70.40±13.10	0.72±0.11	0.24±0.15	0.18±0.12	0.17±0.11	YP
2000-11-11/04:10:49.500	0.32±0.27	56.70±15.90	0.70±0.13	0.13±0.06	0.10±0.05	0.09±0.04	MU
2000-11-26/11:43:31.355	0.68±0.70	64.90±4.60	0.90±0.24	0.20±0.03	0.15±0.03	0.14±0.02	YM
2000-11-28/05:27:42.233	0.26±0.25	58.30±3.00	0.63±0.08	0.12±0.01	0.10±0.01	0.09±0.01	YP
2001-01-17/04:07:53.254	0.39±0.38	69.70±2.20	0.60±0.10	0.18±0.02	0.14±0.01	0.13±0.01	YP
2001-03-03/11:29:19.410	0.48±0.50	45.50±4.60	1.01±0.21	0.13±0.01	0.10±0.01	0.09±0.01	YS
2001-03-22/13:59:06.530	0.18±0.17	73.50±4.50	0.52±0.05	0.21±0.06	0.16±0.04	0.15±0.04	YU
2001-03-27/18:07:48.865	0.36±0.34	57.20±2.10	0.83±0.13	0.15±0.01	0.12±0.01	0.11±0.01	YU
2001-04-21/15:29:14.585	0.52±0.51	81.00±1.50	0.85±0.19	0.54±0.09	0.42±0.07	0.38±0.07	YU
2001-05-06/09:06:08.766	0.41±0.42	45.80±5.20	0.67±0.12	0.09±0.01	0.07±0.01	0.06±0.01	YP
2001-05-12/10:03:14.540	0.15±0.15	68.20±1.40	0.45±0.04	0.14±0.01	0.11±0.01	0.10±0.01	YP
2001-08-12/16:12:46.500	0.23±0.22	72.40±1.40	0.79±0.09	0.29±0.03	0.22±0.02	0.21±0.02	MU
2001-08-31/01:25:04.500	0.28±0.28	82.50±1.30	0.53±0.07	0.45±0.08	0.34±0.06	0.32±0.06	NN
2001-09-13/02:31:28.009	0.31±0.33	72.10±9.00	0.47±0.07	0.17±0.08	0.13±0.06	0.12±0.06	YU
2001-10-28/03:13:48.680	0.04±0.03	60.30±6.80	0.92±0.12	0.22±0.05	0.17±0.04	0.16±0.04	YU
2001-11-30/18:15:45.600	0.40±0.38	59.70±3.90	0.76±0.13	0.15±0.02	0.11±0.01	0.11±0.01	YP
2001-12-21/14:10:18.049	0.13±0.15	65.10±3.00	0.82±0.09	0.22±0.03	0.17±0.02	0.16±0.02	YP
2001-12-30/20:05:07.154	0.61±0.64	63.00±3.90	0.90±0.22	0.18±0.03	0.14±0.02	0.13±0.02	YM
2002-01-17/05:26:58.160	0.22±0.20	51.20±4.50	0.51±0.05	0.08±0.01	0.06±0.01	0.06±0.01	YP
2002-01-31/21:38:10.686	0.15±0.14	67.90±2.70	0.87±0.06	0.27±0.03	0.20±0.02	0.19±0.02	YU
2002-03-23/11:24:09.197	0.51±0.50	68.00±4.20	1.01±0.22	0.26±0.05	0.20±0.04	0.19±0.04	YU
2002-03-29/22:15:13.397	0.67±0.59	82.90±10.50	1.02±0.24	0.59±0.46	0.46±0.36	0.42±0.33	YU
2002-05-21/21:14:16.399	0.46±0.46	49.50±3.60	0.79±0.15	0.11±0.01	0.09±0.01	0.08±0.01	YP
2002-06-29/21:10:26.075	0.29±0.28	61.10±2.80	0.52±0.07	0.11±0.01	0.09±0.01	0.08±0.01	YS
Ramp Time [UTC]	$\langle \boldsymbol{\beta}_{\mathbf{Tot}} \rangle_{\mathbf{up}}$	$\langle \boldsymbol{\theta}_{\mathbf{Bn}} \rangle_{\mathbf{up}}$ [°]	$\langle \mathbf{M_f/M_{cr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{ww}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{gr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{nw}} \rangle_{\mathbf{up}}$	**Shock Label**

Table S2: IP Shock Critical Mach Number Ratios

Ramp Time [UTC]	$\langle \boldsymbol{\beta}_{\mathbf{Tot}} \rangle_{\mathbf{up}}$	$\langle \boldsymbol{\theta}_{\mathbf{Bn}} \rangle_{\mathbf{up}}$ [°]	$\langle \mathbf{M_f/M_{cr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{ww}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{gr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{nw}} \rangle_{\mathbf{up}}$	**Shock Label**
2002-08-01/23:09:07.514	0.09±0.09	70.10±2.80	0.56±0.03	0.19±0.03	0.15±0.02	0.14±0.02	YU
2002-09-30/07:54:24.470	0.16±0.17	78.80±2.10	0.50±0.04	0.30±0.06	0.23±0.04	0.21±0.04	YM
2002-10-02/22:41:04.500	0.35±0.34	78.40±7.90	0.70±0.11	0.37±0.25	0.29±0.19	0.26±0.18	MU
2002-11-09/18:27:49.389	0.12±0.13	70.00±1.40	0.68±0.05	0.23±0.02	0.18±0.01	0.16±0.01	YU
2003-05-29/18:31:08.012	0.08±0.08	73.00±10.60	0.73±0.08	0.30±0.19	0.23±0.14	0.21±0.13	YU
2003-06-18/04:42:06.396	0.19±0.20	86.80±2.00	0.62±0.06	1.28±0.80	0.99±0.62	0.90±0.57	YP
2004-04-12/18:29:46.590	0.52±0.54	60.20±9.70	1.01±0.23	0.19±0.06	0.15±0.04	0.14±0.04	YU
2005-05-06/12:08:39.840	0.41±0.39	48.60±2.30	0.97±0.17	0.14±0.01	0.10±0.01	0.10±0.01	YS
2005-05-07/18:26:16.447	0.16±0.16	61.60±4.00	0.44±0.04	0.10±0.01	0.08±0.01	0.07±0.01	YU
2005-06-16/08:09:10.578	0.02±0.02	66.00±0.60	0.49±0.05	0.15±0.02	0.11±0.01	0.10±0.01	YU
2005-07-10/02:42:30.953	0.12±0.12	80.70±3.20	0.81±0.08	0.60±0.21	0.46±0.16	0.42±0.15	YU
2005-07-16/01:40:58.500	0.57±0.56	84.00±5.20	0.69±0.17	0.66±0.57	0.51±0.44	0.47±0.40	NN
2005-08-01/06:00:52.500	0.15±0.17	84.20±2.60	0.64±0.06	0.74±0.34	0.57±0.26	0.53±0.24	MU
2005-08-24/05:35:24.651	0.27±0.26	86.90±7.00	0.69±0.10	0.78±0.52	0.60±0.40	0.55±0.37	YM
2005-09-02/13:50:16.303	0.52±0.52	53.00±3.60	1.04±0.22	0.16±0.01	0.12±0.01	0.11±0.01	YU
2005-09-15/08:36:30.500	0.37±0.34	54.80±11.90	1.03±0.21	0.17±0.06	0.13±0.04	0.12±0.04	MU
2005-12-30/23:45:23.000	0.50±0.47	71.70±2.00	0.56±0.12	0.18±0.02	0.14±0.02	0.13±0.01	NN
2006-08-19/09:38:49.144	0.37±0.36	46.90±2.90	0.51±0.09	0.07±0.01	0.05±0.00	0.05±0.00	YS
2006-11-03/09:37:16.500	0.41±0.40	87.80±1.00	0.70±0.13	1.92±0.87	1.48±0.67	1.36±0.62	NN
2007-07-20/03:27:17.000	0.64±0.66	66.30±1.90	0.70±0.18	0.16±0.01	0.13±0.01	0.12±0.01	NU
2007-08-22/04:34:03.509	0.63±0.60	62.00±2.40	0.78±0.19	0.15±0.01	0.12±0.01	0.11±0.01	YU
2007-12-17/01:53:18.835	0.65±0.64	53.80±1.90	0.90±0.22	0.13±0.01	0.10±0.01	0.10±0.01	YP
2008-05-28/01:17:38.485	0.61±0.58	75.10±12.00	1.00±0.24	0.38±0.30	0.29±0.23	0.27±0.21	YU
2008-06-24/19:10:41.966	0.37±0.37	49.70±2.40	0.82±0.13	0.12±0.01	0.09±0.00	0.09±0.00	YP
2009-02-03/19:21:03.298	0.08±0.09	85.20±1.90	0.61±0.05	0.89±0.35	0.68±0.27	0.63±0.25	YU
2009-06-24/09:52:20.572	0.55±0.55	88.10±1.30	0.95±0.23	2.86±1.96	2.20±1.51	2.02±1.39	YP
2009-06-27/11:04:19.171	0.28±0.27	87.50±1.20	0.56±0.07	1.41±0.68	1.09±0.52	1.00±0.48	YU
2009-10-21/23:15:10.175	0.64±0.53	66.00±2.50	0.87±0.19	0.20±0.02	0.15±0.02	0.14±0.02	YU
2010-04-11/12:20:56.470	0.27±0.26	60.30±4.10	0.97±0.14	0.20±0.03	0.16±0.02	0.14±0.02	YP
2011-02-04/01:50:55.821	0.29±0.30	73.20±3.70	0.70±0.11	0.26±0.06	0.20±0.05	0.19±0.04	YS
2011-07-11/08:27:25.529	0.64±0.66	78.40±9.40	0.96±0.25	0.46±0.37	0.36±0.29	0.33±0.26	YU
2011-09-16/18:56:59.489	0.07±0.07	71.20±0.00	0.50±0.50	0.19±0.19	0.14±0.14	0.13±0.13	YP
2011-09-25/10:46:32.224	0.26±0.09	83.80±4.40	0.45±0.17	0.46±0.37	0.35±0.28	0.32±0.26	YU
2012-01-21/04:02:01.998	0.11±0.10	83.20±1.20	0.66±0.04	0.67±0.12	0.52±0.09	0.47±0.08	YU
2012-01-30/15:43:13.436	0.23±0.19	53.20±4.40	1.14±0.11	0.20±0.02	0.15±0.02	0.14±0.02	YU
2012-03-07/03:28:39.500	0.15±0.16	82.40±1.90	0.75±0.07	0.66±0.17	0.51±0.13	0.47±0.12	NN
2012-04-19/17:13:31.500	0.61±0.63	84.20±0.70	0.83±0.21	0.80±0.10	0.62±0.08	0.57±0.07	MU
2012-06-16/19:34:39.463	0.53±0.47	70.20±2.70	0.86±0.17	0.25±0.03	0.19±0.03	0.17±0.02	YU
2012-10-08/04:12:14.203	0.21±0.20	74.40±4.40	0.84±0.09	0.35±0.10	0.27±0.08	0.25±0.07	YU
2012-11-12/22:12:41.856	0.35±0.38	65.40±4.60	0.94±0.17	0.23±0.04	0.18±0.03	0.16±0.03	YU
2012-11-26/04:32:51.244	0.36±0.41	71.00±7.10	0.80±0.17	0.26±0.10	0.20±0.07	0.18±0.07	YP
2012-12-14/19:06:13.500	0.28±0.28	61.60±1.50	0.79±0.10	0.17±0.01	0.13±0.01	0.12±0.01	NN
2013-01-17/00:23:43.500	0.68±0.67	78.70±2.70	0.62±0.16	0.30±0.07	0.23±0.05	0.21±0.05	MU
2013-02-13/00:47:45.971	0.47±0.45	75.70±2.20	0.91±0.18	0.37±0.06	0.29±0.04	0.26±0.04	YP
2013-04-30/08:52:46.649	0.34±0.35	64.90±2.50	0.80±0.13	0.20±0.02	0.15±0.02	0.14±0.01	YU
2013-06-10/02:52:01.571	0.56±0.55	72.60±2.60	0.56±0.13	0.18±0.03	0.14±0.02	0.13±0.02	YP
2013-07-12/16:43:27.886	0.41±0.45	56.80±1.50	0.90±0.17	0.16±0.01	0.12±0.01	0.11±0.01	YP
2013-09-02/01:56:50.404	0.47±0.48	60.10±4.20	0.83±0.17	0.16±0.02	0.12±0.02	0.11±0.02	YG
2013-10-26/21:26:02.434	0.07±0.06	46.90±1.00	0.67±0.02	0.11±0.00	0.08±0.00	0.07±0.00	YS
2014-02-13/08:55:29.210	0.03±0.03	68.30±0.90	0.65±0.01	0.22±0.01	0.17±0.01	0.15±0.01	YU
2014-02-15/12:46:37.044	0.38±0.42	78.30±3.60	0.94±0.17	0.49±0.15	0.37±0.11	0.34±0.10	YU
Ramp Time [UTC]	$\langle \boldsymbol{\beta}_{\mathbf{Tot}} \rangle_{\mathbf{up}}$	$\langle \boldsymbol{\theta}_{\mathbf{Bn}} \rangle_{\mathbf{up}}$ [°]	$\langle \mathbf{M_f/M_{cr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{ww}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{gr}} \rangle_{\mathbf{up}}$	$\langle \mathbf{M_f/M_{nw}} \rangle_{\mathbf{up}}$	**Shock Label**

Table S2: IP Shock Critical Mach Number Ratios

Ramp Time [UTC]	$\langle \beta_{Tot} \rangle_{up}$	$\langle \theta_{Bn} \rangle_{up}$ [°]	$\langle M_f/M_{cr} \rangle_{up}$	$\langle M_f/M_{ww} \rangle_{up}$	$\langle M_f/M_{gr} \rangle_{up}$	$\langle M_f/M_{nw} \rangle_{up}$	**Shock Label**
2014-02-19/03:09:39.045	0.04±0.04	72.00±0.70	0.76±0.02	0.30±0.01	0.23±0.01	0.21±0.01	YU
2014-04-19/17:48:25.374	0.14±0.14	50.50±1.60	0.67±0.05	0.11±0.00	0.09±0.00	0.08±0.00	YP
2014-05-07/21:19:39.118	0.11±0.12	69.40±0.70	0.45±0.03	0.15±0.01	0.12±0.01	0.11±0.01	YS
2014-05-29/08:26:41.450	0.19±0.20	64.20±4.30	0.47±0.05	0.12±0.02	0.09±0.02	0.08±0.01	YS
2014-07-14/13:38:09.110	0.33±0.37	70.20±5.00	0.48±0.08	0.15±0.04	0.11±0.03	0.10±0.03	YU
2015-05-06/00:55:49.856	0.20±0.20	87.50±9.50	0.93±0.11	0.85±0.57	0.66±0.44	0.60±0.40	YU
2015-06-05/08:30:57.400	0.83±0.86	84.50±7.70	0.79±0.24	0.61±0.49	0.47±0.38	0.43±0.35	MU
2015-06-24/13:07:15.538	0.06±0.06	85.50±3.30	0.75±0.08	1.19±0.88	0.92±0.68	0.84±0.62	YS
2015-08-15/07:43:42.090	0.09±0.09	56.80±0.80	0.94±0.09	0.19±0.02	0.15±0.01	0.14±0.01	YM
2016-03-11/04:29:17.468	0.68±0.67	53.10±4.20	0.78±0.21	0.11±0.02	0.09±0.01	0.08±0.01	YU
2016-03-14/16:16:32.196	0.82±0.75	61.40±8.10	0.82±0.22	0.15±0.04	0.11±0.03	0.11±0.03	YU
Ramp Time [UTC]	$\langle \beta_{Tot} \rangle_{up}$	$\langle \theta_{Bn} \rangle_{up}$ [°]	$\langle M_f/M_{cr} \rangle_{up}$	$\langle M_f/M_{ww} \rangle_{up}$	$\langle M_f/M_{gr} \rangle_{up}$	$\langle M_f/M_{nw} \rangle_{up}$	**Shock Label**

4 Statistics of Whistler Amplitudes

For every shock exhibiting a clear whistler precursor, we:

1. defined the time interval of the whistler precursor;
2. performed a standard Fourier high pass filter on the entire two hour interval of high time resolution magnetic field data;
3. detrended the high pass filtered data using a 10 point box car average to remove large offsets due to the shock ramp;
4. calculated the convex hull (i.e., outer envelope) of the filtered three component waveform (e.g., see Figure ???) using a four-point sliding window;
5. determined the peak-to-peak precursor amplitude, δB_{pk-pk}, for every pair of points from the convex hull (i.e., the peak-to-peak amplitude of the outer wave envelope); and
6. calculated the standard one-variable statistics (i.e., X_{min}, X_{max}, $\bar{X}$, $\tilde{X}$, σ_x, and $\sigma_x/\sqrt{N}$) on all the δB_{pk-pk}, $\delta B_{pk-pk}/\Delta|\mathbf{B}_o|$, and $\delta B_{pk-pk}/\langle|\mathbf{B}_o|\rangle_{up}$ values within every precursor interval.

The values for $\Delta|\mathbf{B}_o|$ and $\langle|\mathbf{B}_o|\rangle_{up}$ were taken from the WSDB for each event.

4.1 Normalized to Shock Ramp

Table S3 shows the normalized whistler amplitude ($\delta B_{pk-pk}/\Delta|\mathbf{B}_o|$) statistics for all 113 events examined herein. Notice that the maximum values for all events (i.e., X_{max} column) range from $Max\left(\delta B_{pk-pk}/\Delta|\mathbf{B}_o|\right) \sim 0.04$–$15.32$ with the average(median) of these values being ∼0.79(∼0.51). Thus, on average, the whistler precursor amplitudes for low Mach number, low beta, quasi-perpendicular collisionless shocks are ∼80% of the shock ramp amplitudes.

Table S3: Whistler Precursor Amplitude Statistics for $\delta B_{pk-pk}/\Delta|\mathbf{B}_o|$

Date	Start Time [UTC]	End Time [UTC]	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma}_\mathbf{x}$	$\boldsymbol{\sigma}_\mathbf{x}/\sqrt{\mathbf{N}}$
Statistics of $\boldsymbol{\delta}\mathbf{B_{pk-pk}}/\boldsymbol{\Delta}|\mathbf{B_o}|$ for each of the 113 shocks with precursors satisfying: $\langle M_f\rangle_{up} \geq 1$; $1 \leq \langle M_A\rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle\theta_{Bn}\rangle_{up} \geq 45°$								
1995-04-17	23:32:57.740	23:33:07.610	0.122	0.712	0.299	0.267	0.163	0.032
1995-07-22	05:34:15.740	05:35:45.049	0.017	0.939	0.113	0.059	0.160	0.010
1995-08-22	12:56:39.240	12:56:48.970	0.038	1.536	0.305	0.127	0.387	0.054
1995-08-24	22:10:53.360	22:11:04.379	0.026	0.391	0.109	0.086	0.074	0.010
1995-10-22	21:20:09.761	21:20:15.694	0.020	0.832	0.163	0.073	0.167	0.027
1995-12-24	05:57:33.368	05:57:35.006	0.012	0.495	0.097	0.070	0.102	0.014
1996-02-06	19:14:13.830	19:14:25.350	0.026	0.397	0.119	0.055	0.123	0.022
1996-04-03	09:46:57.259	09:47:17.037	0.021	1.015	0.086	0.054	0.124	0.012
1996-04-08	02:41:03.620	02:41:09.639	0.028	0.705	0.217	0.089	0.225	0.040
1997-03-15	22:29:44.490	22:30:32.279	0.032	1.105	0.258	0.176	0.234	0.021
1997-04-10	12:57:53.649	12:58:34.480	0.025	0.289	0.110	0.091	0.070	0.007
1997-10-24	11:17:03.750	11:18:09.830	0.009	1.394	0.074	0.035	0.136	0.007
1997-11-01	06:14:27.659	06:14:45.110	0.024	0.270	0.095	0.092	0.053	0.005
1997-12-10	04:33:03.539	04:33:14.666	0.008	0.574	0.127	0.051	0.164	0.031
1997-12-30	01:13:20.450	01:13:43.639	0.014	0.383	0.077	0.038	0.087	0.011
1998-01-06	13:28:11.509	13:29:00.182	0.153	15.320	2.148	1.085	2.666	0.233
1998-02-18	07:46:50.370	07:48:43.870	0.010	1.950	0.235	0.139	0.262	0.015
1998-05-29	15:11:58.159	15:12:04.299	0.039	0.229	0.105	0.082	0.055	0.014
1998-08-06	07:14:35.190	07:16:07.495	0.007	0.393	0.079	0.053	0.068	0.004
1998-08-19	18:40:34.169	18:40:41.519	0.030	0.963	0.319	0.305	0.269	0.062
1998-11-08	04:40:53.240	04:41:17.230	0.028	0.261	0.082	0.067	0.050	0.006
1998-12-28	18:19:57.519	18:20:16.065	0.009	0.155	0.024	0.015	0.027	0.004
1999-01-13	10:47:36.970	10:47:44.669	0.044	2.580	0.621	0.123	0.763	0.171
1999-02-17	07:11:31.720	07:12:13.843	0.015	0.602	0.098	0.068	0.091	0.009
1999-04-16	11:13:23.500	11:14:12.000	0.024	1.296	0.248	0.193	0.207	0.018
1999-06-26	19:30:24.860	19:30:55.759	0.013	0.913	0.130	0.088	0.143	0.016
1999-08-04	01:44:01.429	01:44:38.368	0.019	0.810	0.200	0.131	0.175	0.018
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma}_\mathbf{x}$	$\boldsymbol{\sigma}_\mathbf{x}/\sqrt{\mathbf{N}}$

Table S3: Whistler Precursor Amplitude Statistics for $\delta B_{pk-pk}/\Delta|\mathbf{B}_o|$

Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma}_\mathbf{x}$	$\boldsymbol{\sigma}_\mathbf{x}/\sqrt{\mathbf{N}}$
Statistics of $\delta\mathbf{B}_{\mathbf{pk-pk}}/\boldsymbol{\Delta}|\mathbf{B}_\mathbf{o}|$ for each of the 113 shocks with precursors satisfying: $\langle M_f \rangle_{up} \geq 1$; $1 \leq \langle M_A \rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle \theta_{Bn} \rangle_{up} \geq 45^\circ$								
1999-08-23	12:09:18.200	12:11:14.590	0.016	1.175	0.164	0.095	0.203	0.011
1999-09-22	12:09:24.743	12:09:25.473	0.065	2.699	0.683	0.553	0.746	0.156
1999-10-21	02:19:01.000	02:20:51.235	0.004	0.523	0.057	0.042	0.058	0.003
1999-11-05	20:01:36.899	20:03:09.659	0.017	1.024	0.193	0.132	0.189	0.012
1999-11-13	12:47:31.509	12:48:57.250	0.014	0.436	0.075	0.055	0.062	0.004
2000-02-05	15:25:06.629	15:26:29.031	0.013	0.925	0.161	0.100	0.176	0.012
2000-02-14	07:12:32.429	07:12:59.740	0.037	1.734	0.307	0.137	0.384	0.045
2000-06-23	12:57:16.379	12:57:59.327	0.008	0.387	0.098	0.068	0.086	0.008
2000-07-13	09:43:38.389	09:43:51.580	0.037	0.683	0.216	0.143	0.177	0.030
2000-07-26	18:59:52.940	19:00:14.860	0.012	0.214	0.068	0.046	0.053	0.007
2000-07-28	06:38:15.860	06:38:45.817	0.008	0.855	0.109	0.060	0.134	0.015
2000-08-10	05:12:21.080	05:13:21.370	0.009	0.236	0.061	0.042	0.050	0.004
2000-08-11	18:49:30.659	18:49:34.379	0.023	0.257	0.120	0.124	0.071	0.013
2000-10-28	09:30:28.309	09:30:41.879	0.027	3.621	0.657	0.183	1.072	0.179
2000-10-31	17:08:33.149	17:09:59.284	0.011	0.751	0.092	0.045	0.121	0.008
2000-11-06	09:29:09.789	09:30:20.669	0.016	0.992	0.224	0.150	0.205	0.015
2000-11-26	11:43:20.870	11:43:26.710	0.022	0.742	0.130	0.084	0.154	0.030
2000-11-28	05:25:33.700	05:27:41.985	0.010	0.262	0.044	0.033	0.034	0.002
2001-01-17	04:07:10.799	04:07:53.059	0.014	0.138	0.047	0.040	0.022	0.002
2001-03-03	11:28:22.080	11:29:20.899	0.019	0.902	0.134	0.079	0.154	0.012
2001-03-22	13:58:30.230	13:59:06.240	0.005	0.219	0.039	0.018	0.046	0.005
2001-03-27	18:07:15.600	18:07:48.210	0.007	0.129	0.033	0.025	0.027	0.003
2001-04-21	15:29:02.879	15:29:14.123	0.023	0.119	0.044	0.036	0.024	0.004
2001-05-06	09:05:27.789	09:06:08.332	0.017	0.507	0.111	0.073	0.100	0.010
2001-05-12	10:01:41.690	10:03:14.317	0.010	0.138	0.042	0.038	0.020	0.001
2001-09-13	02:30:10.129	02:31:26.029	0.014	0.329	0.068	0.054	0.051	0.004
2001-10-28	03:13:23.950	03:13:48.500	0.005	0.276	0.055	0.020	0.071	0.009
2001-11-30	18:15:10.889	18:15:45.440	0.017	0.326	0.075	0.050	0.065	0.007
2001-12-21	14:09:42.850	14:10:17.090	0.014	0.263	0.093	0.073	0.059	0.006
2001-12-30	20:04:29.870	20:05:05.830	0.019	0.338	0.075	0.051	0.061	0.006
2002-01-17	05:26:51.590	05:26:56.879	0.010	0.279	0.073	0.027	0.082	0.014
2002-01-31	21:37:31.419	21:38:10.404	0.010	0.138	0.056	0.045	0.031	0.004
2002-03-23	11:23:24.620	11:24:09.210	0.007	0.222	0.050	0.036	0.044	0.004
2002-03-29	22:15:09.809	22:15:13.250	0.011	0.343	0.074	0.041	0.076	0.014
2002-05-21	21:13:11.610	21:14:15.840	0.016	0.739	0.147	0.074	0.167	0.013
2002-06-29	21:09:57.429	21:10:26.399	0.024	0.465	0.115	0.076	0.089	0.010
2002-08-01	23:08:31.379	23:09:07.282	0.009	0.417	0.067	0.040	0.066	0.007
2002-09-30	07:53:38.919	07:54:24.149	0.020	0.661	0.112	0.089	0.082	0.007
2002-11-09	18:27:30.419	18:27:49.240	0.008	0.162	0.041	0.032	0.031	0.004
2003-05-29	18:30:49.730	18:31:07.827	0.020	0.257	0.077	0.063	0.048	0.007
2003-06-18	04:40:53.679	04:42:06.159	0.030	0.866	0.165	0.120	0.132	0.009
2004-04-12	18:28:23.210	18:29:46.279	0.015	0.584	0.090	0.065	0.081	0.005
2005-05-06	12:03:02.500	12:08:38.930	0.011	1.252	0.079	0.049	0.118	0.004
2005-05-07	18:26:09.069	18:26:16.081	0.020	0.120	0.043	0.030	0.031	0.007
2005-06-16	08:07:07.720	08:09:10.069	0.005	0.749	0.077	0.040	0.103	0.006
2005-07-10	02:41:17.430	02:42:30.726	0.006	0.229	0.046	0.025	0.042	0.003
2005-08-24	05:34:39.140	05:35:24.414	0.004	0.320	0.049	0.020	0.060	0.005
2005-09-02	13:48:38.779	13:50:16.069	0.011	0.611	0.066	0.040	0.083	0.005
2006-08-19	09:33:17.500	09:38:48.400	0.022	1.818	0.260	0.161	0.285	0.009
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma}_\mathbf{x}$	$\boldsymbol{\sigma}_\mathbf{x}/\sqrt{\mathbf{N}}$

Table S3: Whistler Precursor Amplitude Statistics for $\delta B_{pk-pk}/\Delta|\mathbf{B}_o|$

Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$
Statistics of $\delta \mathbf{B_{pk-pk}}/\boldsymbol{\Delta}|\mathbf{B_o}|$ for each of the 113 shocks with precursors satisfying: $\langle M_f \rangle_{up} \geq 1$; $1 \leq \langle M_A \rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle \theta_{Bn} \rangle_{up} \geq 45°$								
2007-08-22	04:31:24.700	04:34:03.000	0.049	0.783	0.135	0.118	0.078	0.004
2007-12-17	01:52:53.579	01:53:18.549	0.010	0.606	0.056	0.021	0.110	0.013
2008-05-28	01:14:59.750	01:17:38.161	0.010	0.433	0.050	0.032	0.049	0.002
2008-06-24	18:52:21.700	19:10:41.963	0.007	2.073	0.041	0.031	0.084	0.002
2009-02-03	19:21:01.865	19:21:03.157	0.012	0.851	0.129	0.055	0.195	0.040
2009-06-24	09:52:07.650	09:52:20.400	0.018	0.261	0.094	0.065	0.071	0.012
2009-06-27	11:03:13.559	11:04:18.898	0.015	0.414	0.082	0.072	0.059	0.004
2009-10-21	23:13:55.190	23:15:09.880	0.014	0.722	0.066	0.036	0.086	0.006
2010-04-11	12:19:16.900	12:20:56.220	0.006	0.816	0.086	0.054	0.102	0.006
2011-02-04	01:50:37.319	01:50:55.670	0.037	0.783	0.203	0.115	0.201	0.029
2011-07-11	08:26:30.220	08:27:25.471	0.013	0.633	0.100	0.069	0.099	0.008
2011-09-16	18:54:08.200	18:57:15.299	0.038	0.342	0.118	0.107	0.049	0.002
2011-09-25	10:43:56.410	10:46:32.085	0.006	0.742	0.054	0.030	0.073	0.004
2012-01-21	04:00:32.019	04:02:01.809	0.017	0.589	0.090	0.060	0.096	0.006
2012-01-30	15:43:03.640	15:43:13.309	0.008	0.116	0.029	0.019	0.023	0.005
2012-06-16	19:34:25.569	19:34:39.369	0.040	0.378	0.125	0.105	0.080	0.013
2012-10-08	04:11:45.970	04:12:14.022	0.006	0.276	0.060	0.038	0.060	0.007
2012-11-12	22:12:34.461	22:12:41.579	0.008	0.345	0.096	0.064	0.104	0.024
2012-11-26	04:32:36.150	04:32:50.960	0.026	0.286	0.086	0.050	0.072	0.012
2013-02-13	00:46:46.049	00:47:45.742	0.022	0.766	0.112	0.065	0.126	0.010
2013-04-30	08:52:30.789	08:52:46.417	0.020	0.170	0.064	0.054	0.033	0.005
2013-06-10	02:51:45.099	02:52:01.335	0.018	0.506	0.064	0.038	0.094	0.014
2013-07-12	16:42:29.809	16:43:28.516	0.009	1.292	0.146	0.060	0.216	0.017
2013-09-02	01:55:13.480	01:56:49.119	0.020	0.562	0.108	0.077	0.089	0.006
2013-10-26	21:18:46.200	21:26:02.099	0.011	1.024	0.068	0.043	0.100	0.003
2014-02-13	08:53:39.980	08:55:28.934	0.008	0.458	0.047	0.023	0.062	0.004
2014-02-15	12:46:04.039	12:46:36.901	0.008	0.316	0.056	0.047	0.052	0.006
2014-02-19	03:09:14.809	03:09:38.861	0.006	0.036	0.015	0.013	0.006	0.001
2014-04-19	17:46:30.859	17:48:25.604	0.010	1.832	0.186	0.078	0.302	0.017
2014-05-07	21:17:03.170	21:19:38.779	0.015	0.433	0.075	0.050	0.071	0.003
2014-05-29	08:25:13.950	08:26:40.940	0.012	0.457	0.067	0.049	0.066	0.004
2014-07-14	13:37:34.940	13:38:08.971	0.007	0.296	0.055	0.037	0.057	0.006
2015-05-06	00:55:30.509	00:55:49.854	0.004	0.509	0.053	0.012	0.110	0.015
2015-06-24	13:06:37.990	13:07:14.601	0.008	0.220	0.034	0.025	0.033	0.003
2015-08-15	07:43:17.430	07:43:40.250	0.009	0.874	0.104	0.055	0.148	0.019
2016-03-11	04:24:15.900	04:29:29.400	0.007	0.350	0.043	0.028	0.043	0.001
2016-03-14	16:16:06.680	16:16:31.880	0.011	0.106	0.042	0.037	0.024	0.003
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$

4.2 Normalized to Upstream Average Field

Table S4 shows the normalized whistler amplitude ($\delta B_{pk-pk}/\langle|\mathbf{B}_o|\rangle_{up}$) statistics for all 113 events examined herein. Notice that the maximum values for all events (i.e., X_{max} column) range from $Max\,(\delta B_{pk-pk}/\langle|\mathbf{B}_o|\rangle_{up}) \sim$ 0.03–1.59 with the average(median) of these values being ∼0.46(∼0.38). Thus, on average, the whistler precursor amplitudes for low Mach number, low beta, quasi-perpendicular collisionless shocks are ∼50% of the upstream average magnetic field magnitudes.

Table S4: Whistler Precursor Amplitude Statistics for $\delta B_{pk-pk}/\langle|\mathbf{B}_o|\rangle_{up}$

Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma}_\mathbf{x}$	$\boldsymbol{\sigma}_\mathbf{x}/\sqrt{\mathbf{N}}$
Statistics of $\boldsymbol{\delta}\mathbf{B_{pk-pk}}/\langle|\mathbf{B_o}|\rangle_\mathbf{up}$ for each of the 113 shocks with precursors satisfying: $\langle M_f\rangle_{up} \geq 1$; $1 \leq \langle M_A\rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle\theta_{Bn}\rangle_{up} \geq 45°$								
1995-04-17	23:32:57.740	23:33:07.610	0.036	0.209	0.088	0.078	0.048	0.009
1995-07-22	05:34:15.740	05:35:45.049	0.014	0.771	0.093	0.048	0.131	0.008
1995-08-22	12:56:39.240	12:56:48.970	0.036	1.468	0.291	0.121	0.370	0.052
1995-08-24	22:10:53.360	22:11:04.379	0.017	0.267	0.074	0.059	0.050	0.007
1995-10-22	21:20:09.761	21:20:15.694	0.012	0.485	0.095	0.043	0.097	0.016
1995-12-24	05:57:33.368	05:57:35.006	0.015	0.608	0.120	0.086	0.125	0.018
1996-02-06	19:14:13.830	19:14:25.350	0.012	0.192	0.057	0.026	0.059	0.011
1996-04-03	09:46:57.259	09:47:17.037	0.012	0.591	0.050	0.032	0.072	0.007
1996-04-08	02:41:03.620	02:41:09.639	0.016	0.412	0.127	0.052	0.132	0.023
1997-03-15	22:29:44.490	22:30:32.279	0.009	0.298	0.070	0.047	0.063	0.006
1997-04-10	12:57:53.649	12:58:34.480	0.009	0.102	0.039	0.032	0.025	0.002
1997-10-24	11:17:03.750	11:18:09.830	0.010	1.422	0.076	0.036	0.139	0.007
1997-11-01	06:14:27.659	06:14:45.110	0.015	0.166	0.059	0.057	0.032	0.003
1997-12-10	04:33:03.539	04:33:14.666	0.010	0.700	0.155	0.062	0.201	0.037
1997-12-30	01:13:20.450	01:13:43.639	0.013	0.353	0.071	0.035	0.080	0.010
1998-01-06	13:28:11.509	13:29:00.182	0.010	0.957	0.134	0.068	0.167	0.015
1998-02-18	07:46:50.370	07:48:43.870	0.004	0.764	0.092	0.054	0.103	0.006
1998-05-29	15:11:58.159	15:12:04.299	0.027	0.157	0.071	0.056	0.038	0.010
1998-08-06	07:14:35.190	07:16:07.495	0.005	0.287	0.058	0.039	0.049	0.003
1998-08-19	18:40:34.169	18:40:41.519	0.033	1.063	0.353	0.337	0.297	0.068
1998-11-08	04:40:53.240	04:41:17.230	0.025	0.238	0.074	0.061	0.046	0.006
1998-12-28	18:19:57.519	18:20:16.065	0.007	0.119	0.018	0.012	0.021	0.003
1999-01-13	10:47:36.970	10:47:44.669	0.027	1.592	0.383	0.076	0.471	0.105
1999-02-17	07:11:31.720	07:12:13.843	0.010	0.384	0.063	0.043	0.058	0.005
1999-04-16	11:13:23.500	11:14:12.000	0.013	0.711	0.136	0.106	0.114	0.010
1999-06-26	19:30:24.860	19:30:55.759	0.012	0.893	0.128	0.086	0.140	0.015
1999-08-04	01:44:01.429	01:44:38.368	0.019	0.822	0.204	0.133	0.178	0.018
1999-08-23	12:09:18.200	12:11:14.590	0.006	0.467	0.065	0.038	0.081	0.005
1999-09-22	12:09:24.743	12:09:25.473	0.011	0.475	0.120	0.097	0.131	0.027
1999-10-21	02:19:01.000	02:20:51.235	0.007	0.896	0.098	0.072	0.099	0.006
1999-11-05	20:01:36.899	20:03:09.659	0.008	0.462	0.087	0.059	0.085	0.005
1999-11-13	12:47:31.509	12:48:57.250	0.009	0.274	0.047	0.035	0.039	0.003
2000-02-05	15:25:06.629	15:26:29.031	0.007	0.471	0.082	0.051	0.090	0.006
2000-02-14	07:12:32.429	07:12:59.740	0.022	1.007	0.178	0.080	0.223	0.026
2000-06-23	12:57:16.379	12:57:59.327	0.012	0.539	0.137	0.095	0.120	0.011
2000-07-13	09:43:38.389	09:43:51.580	0.026	0.472	0.149	0.099	0.122	0.021
2000-07-26	18:59:52.940	19:00:14.860	0.007	0.128	0.041	0.028	0.032	0.004
2000-07-28	06:38:15.860	06:38:45.817	0.009	1.014	0.129	0.071	0.159	0.018
2000-08-10	05:12:21.080	05:13:21.370	0.006	0.155	0.040	0.027	0.033	0.003
2000-08-11	18:49:30.659	18:49:34.379	0.024	0.267	0.124	0.129	0.074	0.013
2000-10-28	09:30:28.309	09:30:41.879	0.009	1.228	0.223	0.062	0.364	0.061
2000-10-31	17:08:33.149	17:09:59.284	0.007	0.509	0.062	0.031	0.082	0.005
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma}_\mathbf{x}$	$\boldsymbol{\sigma}_\mathbf{x}/\sqrt{\mathbf{N}}$

Table S4: Whistler Precursor Amplitude Statistics for $\delta B_{pk-pk}/\langle|\mathbf{B}_o|\rangle_{up}$

Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma}_\mathbf{x}$	$\boldsymbol{\sigma}_\mathbf{x}/\sqrt{\mathbf{N}}$
Statistics of $\delta\mathbf{B_{pk-pk}}/\langle|\mathbf{B_o}|\rangle_\mathbf{up}$ for each of the 113 shocks with precursors satisfying: $\langle M_f\rangle_{up} \geq 1$; $1 \leq \langle M_A\rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle\theta_{Bn}\rangle_{up} \geq 45°$								
2000-11-06	09:29:09.789	09:30:20.669	0.015	0.935	0.211	0.141	0.193	0.014
2000-11-26	11:43:20.870	11:43:26.710	0.013	0.435	0.076	0.049	0.090	0.018
2000-11-28	05:25:33.700	05:27:41.985	0.007	0.184	0.031	0.023	0.024	0.001
2001-01-17	04:07:10.799	04:07:53.059	0.006	0.055	0.019	0.016	0.009	0.001
2001-03-03	11:28:22.080	11:29:20.899	0.018	0.843	0.125	0.074	0.144	0.011
2001-03-22	13:58:30.230	13:59:06.240	0.004	0.201	0.036	0.016	0.043	0.004
2001-03-27	18:07:15.600	18:07:48.210	0.007	0.137	0.035	0.026	0.029	0.003
2001-04-21	15:29:02.879	15:29:14.123	0.012	0.065	0.024	0.019	0.013	0.002
2001-05-06	09:05:27.789	09:06:08.332	0.010	0.300	0.066	0.043	0.059	0.006
2001-05-12	10:01:41.690	10:03:14.317	0.004	0.052	0.016	0.014	0.008	0.000
2001-09-13	02:30:10.129	02:31:26.029	0.006	0.144	0.030	0.023	0.022	0.002
2001-10-28	03:13:23.950	03:13:48.500	0.007	0.390	0.078	0.028	0.100	0.012
2001-11-30	18:15:10.889	18:15:45.440	0.008	0.157	0.036	0.024	0.031	0.003
2001-12-21	14:09:42.850	14:10:17.090	0.005	0.088	0.031	0.024	0.020	0.002
2001-12-30	20:04:29.870	20:05:05.830	0.015	0.269	0.060	0.041	0.048	0.005
2002-01-17	05:26:51.590	05:26:56.879	0.008	0.228	0.060	0.023	0.067	0.011
2002-01-31	21:37:31.419	21:38:10.404	0.013	0.179	0.072	0.058	0.040	0.006
2002-03-23	11:23:24.620	11:24:09.210	0.014	0.466	0.106	0.076	0.091	0.008
2002-03-29	22:15:09.809	22:15:13.250	0.014	0.446	0.096	0.054	0.098	0.018
2002-05-21	21:13:11.610	21:14:15.840	0.014	0.625	0.124	0.063	0.141	0.011
2002-06-29	21:09:57.429	21:10:26.399	0.009	0.180	0.044	0.029	0.035	0.004
2002-08-01	23:08:31.379	23:09:07.282	0.008	0.367	0.060	0.035	0.058	0.006
2002-09-30	07:53:38.919	07:54:24.149	0.012	0.391	0.066	0.052	0.049	0.004
2002-11-09	18:27:30.419	18:27:49.240	0.007	0.137	0.034	0.027	0.026	0.004
2003-05-29	18:30:49.730	18:31:07.827	0.031	0.389	0.116	0.095	0.072	0.010
2003-06-18	04:40:53.679	04:42:06.159	0.018	0.501	0.096	0.069	0.076	0.005
2004-04-12	18:28:23.210	18:29:46.279	0.018	0.724	0.111	0.080	0.101	0.007
2005-05-06	12:03:02.500	12:08:38.930	0.006	0.680	0.043	0.027	0.064	0.002
2005-05-07	18:26:09.069	18:26:16.081	0.007	0.040	0.014	0.010	0.010	0.002
2005-06-16	08:07:07.720	08:09:10.069	0.003	0.546	0.056	0.029	0.075	0.004
2005-07-10	02:41:17.430	02:42:30.726	0.005	0.177	0.035	0.019	0.032	0.002
2005-08-24	05:34:39.140	05:35:24.414	0.004	0.362	0.056	0.023	0.067	0.006
2005-09-02	13:48:38.779	13:50:16.069	0.013	0.681	0.073	0.044	0.092	0.006
2006-08-19	09:33:17.500	09:38:48.400	0.007	0.573	0.082	0.051	0.090	0.003
2007-08-22	04:31:24.700	04:34:03.000	0.011	0.183	0.032	0.028	0.018	0.001
2007-12-17	01:52:53.579	01:53:18.549	0.011	0.654	0.060	0.023	0.118	0.014
2008-05-28	01:14:59.750	01:17:38.161	0.010	0.409	0.047	0.030	0.046	0.002
2008-06-24	18:52:21.700	19:10:41.963	0.004	1.254	0.025	0.019	0.051	0.001
2009-02-03	19:21:01.865	19:21:03.157	0.008	0.614	0.093	0.040	0.141	0.029
2009-06-24	09:52:07.650	09:52:20.400	0.012	0.178	0.064	0.044	0.049	0.008
2009-06-27	11:03:13.559	11:04:18.898	0.008	0.209	0.041	0.036	0.030	0.002
2009-10-21	23:13:55.190	23:15:09.880	0.007	0.385	0.035	0.019	0.046	0.003
2010-04-11	12:19:16.900	12:20:56.220	0.007	0.874	0.093	0.057	0.109	0.007
2011-02-04	01:50:37.319	01:50:55.670	0.031	0.657	0.170	0.097	0.169	0.024
2011-07-11	08:26:30.220	08:27:25.471	0.012	0.588	0.093	0.064	0.092	0.008
2011-09-16	18:54:08.200	18:57:15.299	0.007	0.061	0.021	0.019	0.009	0.000
2011-09-25	10:43:56.410	10:46:32.085	0.005	0.610	0.045	0.025	0.060	0.003
2012-01-21	04:00:32.019	04:02:01.809	0.010	0.336	0.052	0.034	0.055	0.004
2012-01-30	15:43:03.640	15:43:13.309	0.013	0.186	0.047	0.031	0.038	0.008
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma}_\mathbf{x}$	$\boldsymbol{\sigma}_\mathbf{x}/\sqrt{\mathbf{N}}$

Table S4: Whistler Precursor Amplitude Statistics for $\delta B_{pk-pk}/\langle|\mathbf{B}_o|\rangle_{up}$

Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$
Statistics of $\delta\mathbf{B_{pk-pk}}/\langle|\mathbf{B_o}|\rangle_{up}$ for each of the 113 shocks with precursors satisfying: $\langle M_f\rangle_{up} \geq 1$; $1 \leq \langle M_A\rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle\theta_{Bn}\rangle_{up} \geq 45^\circ$								
2012-06-16	19:34:25.569	19:34:39.369	0.039	0.369	0.122	0.103	0.078	0.013
2012-10-08	04:11:45.970	04:12:14.022	0.005	0.257	0.056	0.036	0.056	0.006
2012-11-12	22:12:34.461	22:12:41.579	0.008	0.360	0.100	0.067	0.108	0.025
2012-11-26	04:32:36.150	04:32:50.960	0.024	0.273	0.082	0.048	0.069	0.011
2013-02-13	00:46:46.049	00:47:45.742	0.017	0.593	0.087	0.050	0.098	0.008
2013-04-30	08:52:30.789	08:52:46.417	0.011	0.093	0.035	0.030	0.018	0.003
2013-06-10	02:51:45.099	02:52:01.335	0.010	0.279	0.035	0.021	0.052	0.008
2013-07-12	16:42:29.809	16:43:28.516	0.008	1.153	0.131	0.054	0.193	0.015
2013-09-02	01:55:13.480	01:56:49.119	0.011	0.308	0.059	0.042	0.049	0.003
2013-10-26	21:18:46.200	21:26:02.099	0.006	0.520	0.034	0.022	0.051	0.001
2014-02-13	08:53:39.980	08:55:28.934	0.005	0.296	0.030	0.015	0.040	0.002
2014-02-15	12:46:04.039	12:46:36.901	0.009	0.348	0.061	0.052	0.057	0.006
2014-02-19	03:09:14.809	03:09:38.861	0.005	0.028	0.011	0.010	0.004	0.001
2014-04-19	17:46:30.859	17:48:25.604	0.006	1.130	0.115	0.048	0.187	0.011
2014-05-07	21:17:03.170	21:19:38.779	0.006	0.192	0.033	0.022	0.031	0.002
2014-05-29	08:25:13.950	08:26:40.940	0.006	0.246	0.036	0.026	0.036	0.002
2014-07-14	13:37:34.940	13:38:08.971	0.005	0.218	0.041	0.028	0.042	0.004
2015-05-06	00:55:30.509	00:55:49.854	0.006	0.642	0.066	0.015	0.139	0.019
2015-06-24	13:06:37.990	13:07:14.601	0.007	0.194	0.030	0.022	0.029	0.003
2015-08-15	07:43:17.430	07:43:40.250	0.010	1.031	0.123	0.065	0.175	0.022
2016-03-11	04:24:15.900	04:29:29.400	0.005	0.266	0.032	0.021	0.032	0.001
2016-03-14	16:16:06.680	16:16:31.880	0.009	0.084	0.033	0.030	0.019	0.002
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$

4.3 Precursor Amplitudes

Table S5 shows the whistler precursor peak-to-peak amplitude (δB_{pk-pk}) statistics for all 113 events examined herein. Notice that the maximum values for all events (i.e., X_{max} column) range from $Max\left(\delta B_{pk-pk}\right) \sim$ 0.21–13.0 nT with the average(median) of these values being ∼2.99(∼2.34) nT. Thus, on average, the whistler precursor amplitudes for low Mach number, low beta, quasi-perpendicular collisionless shocks are >2 nT and can be up to ∼13 nT in magnitude.

Table S5: Whistler Precursor Amplitude Statistics for δB_{pk-pk}

Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$
Statistics of $\delta\mathbf{B_{pk-pk}}$ [nT] for each of the 113 shocks with precursors satisfying: $\langle M_f \rangle_{up} \geq 1$; $1 \leq \langle M_A \rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle \theta_{Bn} \rangle_{up} \geq 45°$								
1995-04-17	23:32:57.740	23:33:07.610	0.280	1.629	0.685	0.610	0.373	0.073
1995-07-22	05:34:15.740	05:35:45.049	0.046	2.603	0.314	0.163	0.443	0.029
1995-08-22	12:56:39.240	12:56:48.970	0.076	3.099	0.615	0.256	0.781	0.109
1995-08-24	22:10:53.360	22:11:04.379	0.115	1.766	0.492	0.391	0.333	0.043
1995-10-22	21:20:09.761	21:20:15.694	0.051	2.143	0.419	0.188	0.430	0.071
1995-12-24	05:57:33.368	05:57:35.006	0.094	3.848	0.758	0.543	0.794	0.111
1996-02-06	19:14:13.830	19:14:25.350	0.048	0.742	0.222	0.102	0.229	0.042
1996-04-03	09:46:57.259	09:47:17.037	0.051	2.505	0.213	0.134	0.305	0.030
1996-04-08	02:41:03.620	02:41:09.639	0.093	2.344	0.722	0.297	0.750	0.133
1997-03-15	22:29:44.490	22:30:32.279	0.043	1.496	0.350	0.238	0.317	0.028
1997-04-10	12:57:53.649	12:58:34.480	0.076	0.870	0.329	0.275	0.211	0.020
1997-10-24	11:17:03.750	11:18:09.830	0.087	12.996	0.690	0.326	1.267	0.067
1997-11-01	06:14:27.659	06:14:45.110	0.086	0.977	0.345	0.334	0.190	0.020
1997-12-10	04:33:03.539	04:33:14.666	0.069	4.975	1.101	0.441	1.425	0.265
1997-12-30	01:13:20.450	01:13:43.639	0.068	1.897	0.380	0.188	0.431	0.055
1998-01-06	13:28:11.509	13:29:00.182	0.063	6.256	0.877	0.443	1.089	0.095
1998-02-18	07:46:50.370	07:48:43.870	0.059	11.886	1.433	0.845	1.597	0.091
1998-05-29	15:11:58.159	15:12:04.299	0.309	1.818	0.829	0.649	0.437	0.113
1998-08-06	07:14:35.190	07:16:07.495	0.055	2.958	0.595	0.400	0.509	0.032
1998-08-19	18:40:34.169	18:40:41.519	0.117	3.760	1.247	1.192	1.051	0.241
1998-11-08	04:40:53.240	04:41:17.230	0.440	4.137	1.290	1.066	0.796	0.100
1998-12-28	18:19:57.519	18:20:16.065	0.045	0.818	0.125	0.081	0.144	0.021
1999-01-13	10:47:36.970	10:47:44.669	0.136	8.058	1.940	0.385	2.382	0.533
1999-02-17	07:11:31.720	07:12:13.843	0.067	2.687	0.438	0.302	0.405	0.038
1999-04-16	11:13:23.500	11:14:12.000	0.089	4.689	0.898	0.699	0.749	0.065
1999-06-26	19:30:24.860	19:30:55.759	0.145	10.584	1.512	1.015	1.661	0.182
1999-08-04	01:44:01.429	01:44:38.368	0.118	5.121	1.268	0.831	1.109	0.111
1999-08-23	12:09:18.200	12:11:14.590	0.051	3.817	0.534	0.308	0.658	0.037
1999-09-22	12:09:24.743	12:09:25.473	0.129	5.357	1.356	1.098	1.481	0.309
1999-10-21	02:19:01.000	02:20:51.235	0.061	8.216	0.899	0.662	0.912	0.053
1999-11-05	20:01:36.899	20:03:09.659	0.053	3.110	0.586	0.401	0.574	0.036
1999-11-13	12:47:31.509	12:48:57.250	0.058	1.778	0.304	0.226	0.252	0.017
2000-02-05	15:25:06.629	15:26:29.031	0.039	2.765	0.482	0.299	0.528	0.035
2000-02-14	07:12:32.429	07:12:59.740	0.127	5.888	1.044	0.466	1.305	0.153
2000-06-23	12:57:16.379	12:57:59.327	0.087	4.056	1.033	0.716	0.905	0.084
2000-07-13	09:43:38.389	09:43:51.580	0.153	2.804	0.888	0.587	0.728	0.123
2000-07-26	18:59:52.940	19:00:14.860	0.043	0.742	0.235	0.161	0.184	0.024
2000-07-28	06:38:15.860	06:38:45.817	0.080	8.692	1.106	0.612	1.363	0.152
2000-08-10	05:12:21.080	05:13:21.370	0.041	1.026	0.263	0.181	0.218	0.017
2000-08-11	18:49:30.659	18:49:34.379	0.228	2.507	1.168	1.207	0.692	0.126
2000-10-28	09:30:28.309	09:30:41.879	0.062	8.263	1.499	0.418	2.446	0.408
2000-10-31	17:08:33.149	17:09:59.284	0.053	3.767	0.460	0.227	0.606	0.040
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$

Table S5: Whistler Precursor Amplitude Statistics for δB_{pk-pk}

Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$
Statistics of $\delta \mathbf{B_{pk-pk}}$ [nT] for each of the 113 shocks with precursors satisfying: $\langle M_f \rangle_{up} \geq 1$; $1 \leq \langle M_A \rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle \theta_{Bn} \rangle_{up} \geq 45^{\circ}$								
2000-11-06	09:29:09.789	09:30:20.669	0.072	4.585	1.036	0.694	0.945	0.068
2000-11-26	11:43:20.870	11:43:26.710	0.116	3.998	0.701	0.453	0.832	0.163
2000-11-28	05:25:33.700	05:27:41.985	0.044	1.214	0.205	0.155	0.156	0.008
2001-01-17	04:07:10.799	04:07:53.059	0.029	0.279	0.095	0.081	0.044	0.004
2001-03-03	11:28:22.080	11:29:20.899	0.071	3.307	0.492	0.291	0.565	0.045
2001-03-22	13:58:30.230	13:59:06.240	0.045	2.000	0.354	0.162	0.425	0.043
2001-03-27	18:07:15.600	18:07:48.210	0.076	1.438	0.369	0.275	0.305	0.033
2001-04-21	15:29:02.879	15:29:14.123	0.043	0.226	0.084	0.068	0.046	0.009
2001-05-06	09:05:27.789	09:06:08.332	0.049	1.478	0.325	0.212	0.292	0.028
2001-05-12	10:01:41.690	10:03:14.317	0.046	0.648	0.197	0.178	0.096	0.006
2001-09-13	02:30:10.129	02:31:26.029	0.051	1.206	0.250	0.196	0.187	0.013
2001-10-28	03:13:23.950	03:13:48.500	0.055	2.958	0.593	0.211	0.760	0.094
2001-11-30	18:15:10.889	18:15:45.440	0.031	0.572	0.131	0.088	0.113	0.012
2001-12-21	14:09:42.850	14:10:17.090	0.042	0.786	0.280	0.218	0.178	0.019
2001-12-30	20:04:29.870	20:05:05.830	0.170	3.072	0.682	0.467	0.551	0.056
2002-01-17	05:26:51.590	05:26:56.879	0.052	1.451	0.380	0.143	0.429	0.072
2002-01-31	21:37:31.419	21:38:10.404	0.075	1.050	0.425	0.341	0.234	0.032
2002-03-23	11:23:24.620	11:24:09.210	0.047	1.590	0.361	0.259	0.312	0.028
2002-03-29	22:15:09.809	22:15:13.250	0.076	2.430	0.521	0.293	0.537	0.098
2002-05-21	21:13:11.610	21:14:15.840	0.059	2.683	0.533	0.269	0.605	0.046
2002-06-29	21:09:57.429	21:10:26.399	0.056	1.083	0.267	0.177	0.208	0.024
2002-08-01	23:08:31.379	23:09:07.282	0.061	2.984	0.483	0.285	0.471	0.048
2002-09-30	07:53:38.919	07:54:24.149	0.161	5.239	0.889	0.702	0.653	0.059
2002-11-09	18:27:30.419	18:27:49.240	0.047	0.919	0.231	0.185	0.176	0.025
2003-05-29	18:30:49.730	18:31:07.827	0.438	5.502	1.647	1.344	1.022	0.147
2003-06-18	04:40:53.679	04:42:06.159	0.186	5.275	1.008	0.731	0.805	0.057
2004-04-12	18:28:23.210	18:29:46.279	0.077	3.030	0.464	0.337	0.421	0.028
2005-05-06	12:03:02.500	12:08:38.930	0.026	3.025	0.191	0.120	0.286	0.009
2005-05-07	18:26:09.069	18:26:16.081	0.086	0.528	0.189	0.130	0.135	0.032
2005-06-16	08:07:07.720	08:09:10.069	0.039	6.456	0.660	0.341	0.889	0.049
2005-07-10	02:41:17.430	02:42:30.726	0.051	1.909	0.381	0.208	0.350	0.025
2005-08-24	05:34:39.140	05:35:24.414	0.046	3.754	0.575	0.234	0.699	0.063
2005-09-02	13:48:38.779	13:50:16.069	0.077	4.123	0.444	0.268	0.559	0.034
2006-08-19	09:33:17.500	09:38:48.400	0.054	4.395	0.628	0.389	0.688	0.023
2007-08-22	04:31:24.700	04:34:03.000	0.028	0.441	0.076	0.067	0.044	0.002
2007-12-17	01:52:53.579	01:53:18.549	0.039	2.329	0.214	0.080	0.422	0.052
2008-05-28	01:14:59.750	01:17:38.161	0.037	1.591	0.183	0.119	0.179	0.009
2008-06-24	18:52:21.700	19:10:41.963	0.014	4.473	0.089	0.067	0.181	0.003
2009-02-03	19:21:01.865	19:21:03.157	0.039	2.844	0.430	0.184	0.651	0.133
2009-06-24	09:52:07.650	09:52:20.400	0.057	0.819	0.296	0.204	0.224	0.038
2009-06-27	11:03:13.559	11:04:18.898	0.029	0.790	0.156	0.137	0.113	0.009
2009-10-21	23:13:55.190	23:15:09.880	0.025	1.335	0.122	0.066	0.160	0.011
2010-04-11	12:19:16.900	12:20:56.220	0.032	4.005	0.424	0.263	0.499	0.030
2011-02-04	01:50:37.319	01:50:55.670	0.079	1.651	0.427	0.243	0.425	0.061
2011-07-11	08:26:30.220	08:27:25.471	0.066	3.179	0.504	0.347	0.499	0.041
2011-09-16	18:54:08.200	18:57:15.299	0.023	0.210	0.072	0.065	0.030	0.001
2011-09-25	10:43:56.410	10:46:32.085	0.031	3.731	0.273	0.153	0.368	0.018
2012-01-21	04:00:32.019	04:02:01.809	0.045	1.526	0.234	0.156	0.250	0.016
2012-01-30	15:43:03.640	15:43:13.309	0.039	0.563	0.142	0.093	0.114	0.023
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$

Table S5: Whistler Precursor Amplitude Statistics for δB_{pk-pk}

Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$
Statistics of $\delta \mathbf{B_{pk-pk}}$ [nT] for each of the 113 shocks with precursors satisfying: $\langle M_f \rangle_{up} \geq 1$; $1 \leq \langle M_A \rangle_{up} \leq 3$; $1 \leq \mathcal{R} \leq 3$; $\langle \theta_{Bn} \rangle_{up} \geq 45°$								
2012-06-16	19:34:25.569	19:34:39.369	0.313	2.931	0.967	0.817	0.620	0.103
2012-10-08	04:11:45.970	04:12:14.022	0.043	2.092	0.456	0.291	0.454	0.052
2012-11-12	22:12:34.461	22:12:41.579	0.061	2.726	0.758	0.506	0.818	0.193
2012-11-26	04:32:36.150	04:32:50.960	0.117	1.313	0.393	0.231	0.333	0.053
2013-02-13	00:46:46.049	00:47:45.742	0.059	2.099	0.306	0.178	0.346	0.027
2013-04-30	08:52:30.789	08:52:46.417	0.053	0.457	0.172	0.146	0.090	0.014
2013-06-10	02:51:45.099	02:52:01.335	0.041	1.131	0.144	0.086	0.210	0.032
2013-07-12	16:42:29.809	16:43:28.516	0.040	5.928	0.672	0.276	0.991	0.079
2013-09-02	01:55:13.480	01:56:49.119	0.032	0.921	0.177	0.126	0.146	0.009
2013-10-26	21:18:46.200	21:26:02.099	0.023	2.187	0.144	0.092	0.213	0.006
2014-02-13	08:53:39.980	08:55:28.934	0.028	1.699	0.174	0.085	0.229	0.013
2014-02-15	12:46:04.039	12:46:36.901	0.058	2.329	0.411	0.349	0.385	0.041
2014-02-19	03:09:14.809	03:09:38.861	0.042	0.234	0.095	0.087	0.038	0.005
2014-04-19	17:46:30.859	17:48:25.604	0.034	6.223	0.632	0.265	1.027	0.058
2014-05-07	21:17:03.170	21:19:38.779	0.031	0.914	0.159	0.106	0.149	0.007
2014-05-29	08:25:13.950	08:26:40.940	0.030	1.165	0.172	0.124	0.168	0.011
2014-07-14	13:37:34.940	13:38:08.971	0.044	1.740	0.324	0.220	0.336	0.035
2015-05-06	00:55:30.509	00:55:49.854	0.032	3.674	0.380	0.084	0.796	0.110
2015-06-24	13:06:37.990	13:07:14.601	0.039	1.066	0.165	0.121	0.161	0.016
2015-08-15	07:43:17.430	07:43:40.250	0.113	11.120	1.325	0.700	1.887	0.242
2016-03-11	04:24:15.900	04:29:29.400	0.028	1.476	0.179	0.119	0.180	0.006
2016-03-14	16:16:06.680	16:16:31.880	0.050	0.481	0.191	0.170	0.108	0.013
Date	**Start Time [UTC]**	**End Time [UTC]**	$\mathbf{X_{min}}$	$\mathbf{X_{max}}$	$\bar{\mathbf{X}}$	$\tilde{\mathbf{X}}$	$\boldsymbol{\sigma_x}$	$\boldsymbol{\sigma_x}/\sqrt{\mathbf{N}}$

5 Data Availability

All relevant Wind instrument data can be found on CDAWeb at:
http://cdaweb.gsfc.nasa.gov.
including quasi-static magnetic fields from Wind/MFI [*Lepping et al.*, 1995] and solar wind plasma parameters from the Wind/SWE Faraday Cups (FCs) [*Ogilvie et al.*, 1995].

The Harvard Smithsonian Center for Astrophysics' Wind interplanetary shock list can be found at:
https://www.cfa.harvard.edu/shocks/wi_data/.

The critical Mach number analysis software can be found at:
https://github.com/pulupa/Critical-Mach.

Any additional analysis software can be found at:
https://github.com/lynnbwilsoniii/wind_3dp_pros.

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A Conservation Relations

In the case of a planar shock, we can define the conservation relations called the Rankine-Hugoniot relations across the shock ramp. If we define $\Delta[X] = \langle X \rangle_{dn}$ - $\langle X \rangle_{up}$, where the subscript u(d) corresponds to upstream(downstream). Then we have the following Rankine-Hugoniot relations [*Koval and Szabo*, 2008; *Szabo*, 1994; *Vinas and Scudder*, 1986]:

$$\Delta\left[G_{n}\right] \equiv \Delta\left[\rho\left(V_{n}-V_{shn}\right)\right]=0 \tag{A.1a}$$

$$\Delta\left[B_{n}\right] \equiv \Delta\left[\hat{\mathbf{n}} \cdot \mathbf{B}\right]=0 \tag{A.1b}$$

$$\Delta\left[\mathbf{S}_{t}\right] \equiv \Delta\left[\rho\left(V_{n}-V_{shn}\right)\mathbf{V}_{t}-\frac{B_{n}}{\mu_{o}}\mathbf{B}_{t}\right]=0 \tag{A.1c}$$

$$\Delta\left[\mathbf{S}_{t}\right] \equiv \Delta\left[\left(\hat{\mathbf{n}} \times \mathbf{V}_{t}\right)B_{n}-\left(V_{n}-V_{shn}\right)\left(\hat{\mathbf{n}} \times \mathbf{B}_{t}\right)\right]=0 \tag{A.1d}$$

$$\Delta\left[S_{n}\right] \equiv \Delta\left[P+\frac{\mathbf{B}_{t} \cdot \mathbf{B}_{t}}{2\ \mu_{o}}+\rho\left(V_{n}-V_{shn}\right)^{2}\right]=0 \tag{A.1e}$$

$$\begin{aligned} \Delta[\varepsilon] \equiv \Delta\Bigg[& \rho\left(V_{n}-V_{shn}\right)\left\{\frac{1}{2}\left(\mathbf{V}_{sw}-V_{shn}\ \hat{\mathbf{n}}\right)^{2}+\frac{\gamma}{\gamma-1}\frac{P}{\rho}+\frac{\mathbf{B} \cdot \mathbf{B}}{\rho\ \mu_{o}}\right\} \\ & -\frac{B_{n}\left(\mathbf{V}_{sw}-V_{shn}\ \hat{\mathbf{n}}\right) \cdot \mathbf{B}}{\mu_{o}}\Bigg]=0 \end{aligned} \tag{A.1f}$$

where we have defined:

$$Q_{n}=\mathbf{Q} \cdot \hat{\mathbf{n}} \tag{A.2a}$$

$$\mathbf{Q}_{t}=(\hat{\mathbf{n}} \times \mathbf{Q}) \times \hat{\mathbf{n}} \tag{A.2b}$$

$$=\mathbf{Q} \cdot(\mathbb{I}-\hat{\mathbf{n}}\hat{\mathbf{n}}) \tag{A.2c}$$

$$V_{shn}=\frac{\Delta\left[\rho\ \mathbf{V}_{sw}\right]}{\Delta[\rho]} \cdot \hat{\mathbf{n}} \tag{A.2d}$$

and ρ is the mass density, P is scalar total (ion plus electron) thermal pressure, and γ is the ratio of specific heats or polytrope index. We note that P = $\hat{\mathbf{n}} \cdot \mathbb{P} \cdot \hat{\mathbf{n}}$ = 1/3 Tr[$\mathbb{P}$] $\sim n_o\ k_B\ (T_e + T_i)$ for an ideal gas.

The Harvard Smithsonian Center for Astrophysics' Wind shock database (WSDB), which can be found at: https://www.cfa.harvard.edu/shocks/wi_data/
provides tables of numerical solutions to the Rankine-Hugoniot relations [e.g., *Koval and Szabo*, 2008; *Szabo*, 1994; *Vinas and Scudder*, 1986] for eight different methods, where the labels are defined as:

1. **MC:** Magnetic Coplanarity [e.g., *Abraham-Shrauner and Yun*, 1976; *Russell et al.*, 1983; *Vinas and Scudder*, 1986];
2. **VC:** Velocity Coplanarity [e.g., *Abraham-Shrauner and Yun*, 1976; *Russell et al.*, 1983; *Vinas and Scudder*, 1986];
3. **MX1:** Mixed Mode Normal 1 [e.g., *Abraham-Shrauner and Yun*, 1976; *Russell et al.*, 1983];
4. **MX2:** Mixed Mode Normal 2 [e.g., *Abraham-Shrauner and Yun*, 1976; *Russell et al.*, 1983];
5. **MX3:** Mixed Mode Normal 3 [e.g., *Abraham-Shrauner and Yun*, 1976; *Russell et al.*, 1983];
6. **RH08:** Rankine-Hugoniot with 8 Equations [e.g., *Abraham-Shrauner and Yun*, 1976; *Koval and Szabo*, 2008; *Russell et al.*, 1983; *Szabo*, 1994; *Vinas and Scudder*, 1986];
7. **RH09:** Rankine-Hugoniot with 9 Equations [e.g., *Abraham-Shrauner and Yun*, 1976; *Koval and Szabo*, 2008; *Russell et al.*, 1983; *Szabo*, 1994; *Vinas and Scudder*, 1986]; and
8. **RH10:** Rankine-Hugoniot with 10 Equations [e.g., *Abraham-Shrauner and Yun*, 1976; *Koval and Szabo*, 2008; *Russell et al.*, 1983; *Szabo*, 1994; *Vinas and Scudder*, 1986].

The shock normals for the first five methods are given by:

Magnetic Coplanarity (MC)

$$\hat{\mathbf{n}}=\pm\frac{\left(\left\langle\mathbf{B}_{o}\right\rangle_{up} \times\left\langle\mathbf{B}_{o}\right\rangle_{dn}\right) \times\left(-\Delta \mathbf{B}_{o}\right)}{\left|\left(\left\langle\mathbf{B}_{o}\right\rangle_{up} \times\left\langle\mathbf{B}_{o}\right\rangle_{dn}\right) \times\left(-\Delta \mathbf{B}_{o}\right)\right|} \tag{A.3a}$$

Velocity Coplanarity (VC)

$$\hat{\mathbf{n}} = \pm \frac{\Delta \mathbf{V}_{bulk}}{|\Delta \mathbf{V}_{bulk}|} \tag{A.3b}$$

Mixed Mode Normal 1 (MX1)

$$\hat{\mathbf{n}} = \pm \frac{(\Delta \mathbf{V}_{bulk} \times \langle \mathbf{B}_o \rangle_{up}) \times \Delta \mathbf{B}_o}{|(\Delta \mathbf{V}_{bulk} \times \langle \mathbf{B}_o \rangle_{up}) \times \Delta \mathbf{B}_o|} \tag{A.3c}$$

Mixed Mode Normal 2 (MX2)

$$\hat{\mathbf{n}} = \pm \frac{(\Delta \mathbf{V}_{bulk} \times \langle \mathbf{B}_o \rangle_{dn}) \times \Delta \mathbf{B}_o}{|(\Delta \mathbf{V}_{bulk} \times \langle \mathbf{B}_o \rangle_{dn}) \times \Delta \mathbf{B}_o|} \tag{A.3d}$$

Mixed Mode Normal 3 (MX3)

$$\hat{\mathbf{n}} = \pm \frac{-\Delta \mathbf{B}_o \times (\Delta \mathbf{V}_{bulk} \times \Delta \mathbf{B}_o)}{|\Delta \mathbf{B}_o \times (\Delta \mathbf{V}_{bulk} \times \Delta \mathbf{B}_o)|} \tag{A.3e}$$

B Field Transformations

We can define the velocity transformation from any arbitrary frame of reference (*e.g.* spacecraft frame) to he shock frame of reference as:

$$\mathbf{V}_{sh}{}^{rest} = \mathbf{V}^{arb.} - \left(\mathbf{V}_{sh}{}^{arb.} \cdot \hat{\mathbf{n}}\right) \hat{\mathbf{n}} \tag{B.1}$$

where $\hat{\mathbf{n}}$ is the vector normal to the assumed planar shock front (see Appendix A). For an experimentalist's purposes, $\mathbf{V}^{arb.} \to \mathbf{V}_{sw}{}^{SCF}$, where $\mathbf{V}_{sw}{}^{SCF}$ is the bulk flow velocity (e.g., solar wind velocity) in the spacecraft frame (SCF) of reference. Therefore, let us define V_{shn} as the shock normal speed in the SCF and $\langle U_{shn} \rangle_j$ as the flow speed along shock normal in the shock rest frame (SHF) averaged over the j^{th} region. Therefore, Equation B.1 goes to:

$$\langle U_{shn} \rangle_j = \left[\langle \mathbf{V}_{sw}{}^{SCF} \rangle_j - \left(V_{shn} \ \hat{\mathbf{n}} \right) \right] \cdot \hat{\mathbf{n}} \ . \tag{B.2}$$

For many applications, one may want to know the upstream incident bulk flow speed in the shock frame, which is given by:

$$\mathbf{V}_{u}{}^{SHF} = \mathbf{V}_{sw} - \left(V_{shn} \ \hat{\mathbf{n}} \right) \ . \tag{B.3}$$

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