Supplementary Material

1 SUPPLEMENTARY TABLE

We use the minimum variance analysis to determine the local normal vector to the bow shock surface by each spacecraft crossing the bow shock. It should be noted that the MVA results are sensitive to the period of analysis. The normal directions reported in Table S1 are only estimates and are selected when high ratios of maximum to intermediate (λ_1/λ_2) and intermediate to minimum (λ_2/λ_3) eigenvalues are obtained. For bow shock crossings that showed strong wave activities, we also low-pass filter the magnetic field data. The last column shows the normal vectors determined from the mixed coplanarity method.

Table S1. Bow shock normal vectors and properties of the MVA and coplanarity analyses.

Satellite	Position (R_E)	Time	MVA (GSE)	$\lambda_1, \lambda_2, \lambda_3$	MC (GSE)
			Contraction		
MMS1	13.7, -15.9, -9.3	03:50:12.5	(0.92 -0.37 0.14)	146.4, 1.2, 0.35	(0.92 0.12 -0.37)
CL2	11.8, -9.7, 2.4	03:52:13.5	(0.89 -0.35 0.3)	380.6, 2.4, 0.3	
CL4	10.8, -8.2, -1.9	03:52:20.0	(0.97 -0.06 0.21)	635.4, 19.9, 3.0	
THD	8.7, -0.1, -0.8	03:53:34.7	(0.99 0.1 0.03)	742.8, 33.7, 17.4	(0.98 0.15 0.08)
THA	8.0, 0.0, -0.2	03:54:13.0	(0.83 -0.31 0.46)	751.9, 8.0, 6.8	(0.99 -0.02 -0.11)
THE	7.4, 0.9, -0.8				
			Expansion		
MMS1	-	04:02:03.2	(0.80 -0.59 0.05)	320.2, 4.8, 0.1	(0.87 -0.50 0.02)
CL2	-	03:59:09.0	(0.78 -0.53 0.32)	653.7, 1.6, 0.5	
CL4	-	03:57:42.7	(0.96 -0.15 -0.21)	764.3, 5.4, 1.9	
THD	-	03:55:10.1	(0.77 -0.41 0.45)	770.8 1.2, 0.2	(0.88 -0.31 0.36)
THA	-	03:54:47.6	(0.87 -0.35 0.34)	1026.6 10.7, 1.5	(0.94 -0.19 0.29)