ICME Driven Shock of November 9th, 2004 and its Effect on Earth's Magnetosphere

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OVERVIEW

- Previously, ICME driven shocks from solar cycle 23 to more recent years were investigated by cross-referencing Richardson and Cane's list and the IPSHOCK database [Auriemma, 2021].
- 21 ICME driven shocks were found to have compressed the magnetopause to some degree [Samsonov, 2021], occasionally resulting in geosynchronous magnetopause crossings (GMCs).
- We investigate one more recent event as measured by Wind and ACE on November 9th, 2004 to study how ICME driven shocks effect Earth's magnetopause location.
- We compare observations via coordinated interplanetary magnetospheric spacecraft, and a magnetopause model [Shue, 1997].
- Model predicts the magnetopause compresses down close to geosynchronous equatorial orbit (GEO) six hours after November 9th, 2004 shock.

ACE/WIND AND OMNI

Date	UT	R_{SUB}, R_E	> 1 hour	ICME/SIR/CIR date (and time)	IP shock time
7 November 2004	12	6.5	+	7 November 2004 18:27	A 09:59
9 November 2004	13	6.6	+	9 November 2004 18:25(W)	A 09:13

Table from Samsonov 2021, showing GMC events. Date, time of GMC, standoff distance R_{SUB} at t = 0, the "+" sign indicates the GMC duration longer than 1 hour, ICME time, and shock time.

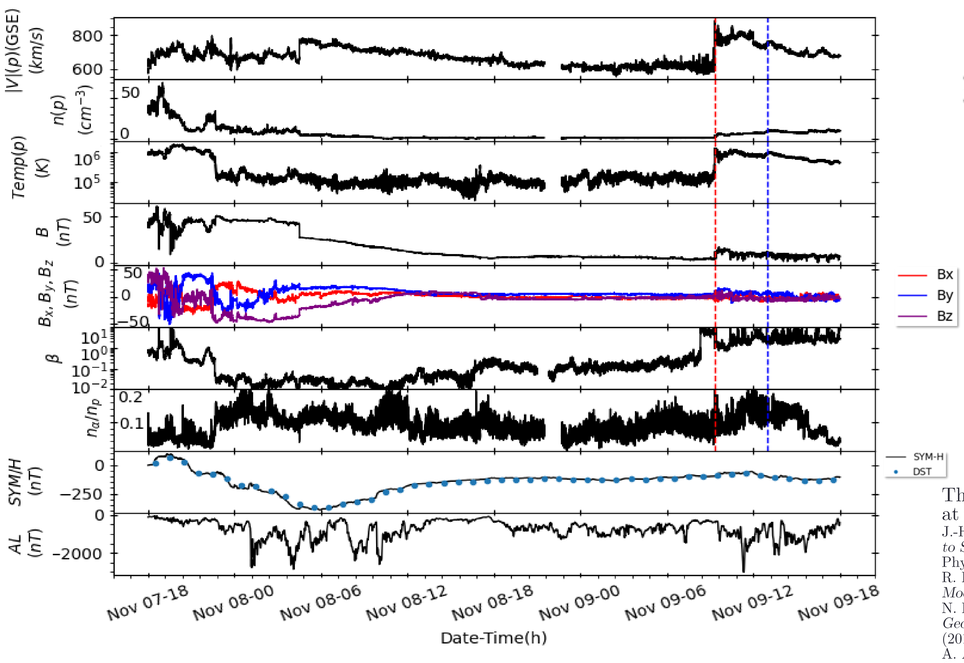


Figure 1: Magnetic field and plasma data (via WIND, panels 1-7; OMNI panels 8-9) on 7-9 November, 2004 event. Red dashed line marking observed shock time via ACE and blue dashed line being Samsonov's reported GMC time. Data via Coordinated Data Analysis Web (CDAWeb)

MAGNETOPAUSE COMPRESSION

We use the Shue 1997 model (eq. 1) and OMNI data to fit the size and shape of the magnetopause. The model has two parameters (eq. 2-3), r_0 and α, representing standoff distance and level of tail flaring.

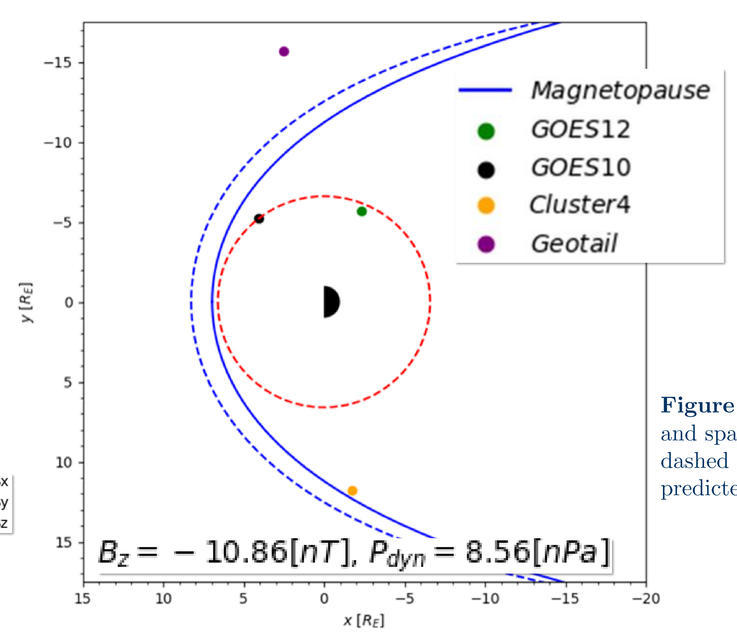
$$r = r_0\left(\frac{2}{1+\cos\theta}\right)^{\alpha} \quad (1)$$

$$r_0 = \begin{cases} (11.4 + 0.013B_z)(D_p)^{-\frac{1}{6.6}} & B_z \geq 0 \\ (11.4 + 0.14B_z)(D_p)^{-\frac{1}{6.6}} & B_z < 0 \end{cases} \quad (2)$$

$$\alpha = (0.58 - 0.010B_z)(1 + 0.010D_p) \quad (3)$$

The Shue model (figure 2) predicts the magnetopause to be pushed down to 6.95 R_E, six hours after the shock is observed by ACE/Wind. This predicted location leads to further studies into spacecraft that potentially crossed the magnetopause into the magnetosheath.

It is to be noted that without erosion ($B_z > 0$), the model predicts a different magnetopause location (figure 2, dashed blue curve). Both compression and erosion are needed for the magnetopause to be pushed down to lower distances.



GOES, CLUSTER, GEOTAIL

To confirm the model predictions, we analyze Geotail, Cluster-4, and GOES-12 observations.

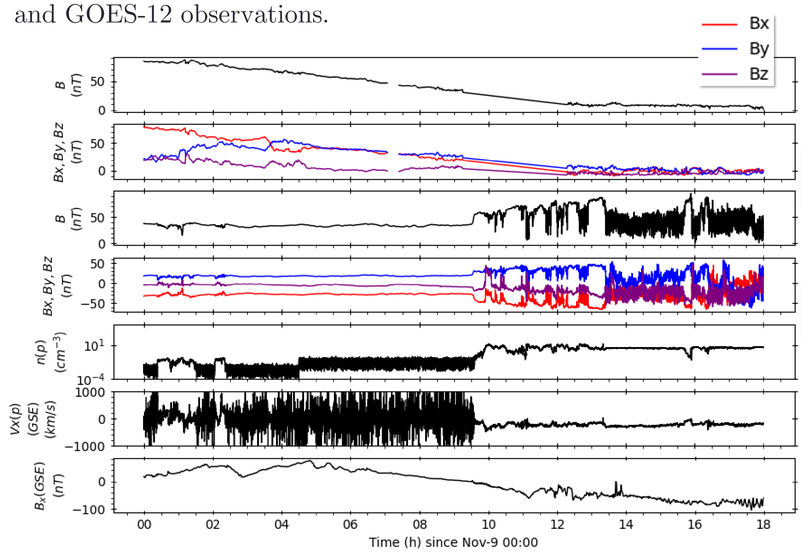


Figure 3 (above): Geotail (panels 1-2), Cluster 4 (panels 3-6), & GOES 12 (panel 7) observations for 7-9 November, 2004.

At the time of observed shock (9:19 UT), we begin to observe perturbations in data due to typical ICME and shock compression.

Specifically, Cluster 4 experiences a magnetic field orientation change around 13:15 UT, indicating this GEO spacecraft crossed from into the magnetosheath. This implies the Shue 1997 model is not entirely accurate, as in figure 2 we observe Cluster 4 still within the magnetosphere, or analysis must be made in higher dimensions, or different coordinate systems.

Figure 2 (left): Modelled location(s) of the magnetopause (blue solid curve) and spacecraft (colored dots) at time reported GMC (13:00UT, 11/09). Red dashed circle is geosynchronous orbit (6.6 R_E). Blue dashed curve is the predicted magnetopause location without erosion.

CONCLUSION & FUTURE WORK

- By utilizing the Shue 1997 model and data onboard interplanetary magnetospheric spacecraft, we observe the magnetospheric compression to 6.95 R_E due to the ICME driven shock of 9 November, 2004.
- This event, as well as other ICME driven shocks, provide a great opportunity to observe GMC due to the abundance of GEO spacecraft.
- Our future objectives are to compare different prediction models as well as analyze shock normal fronts. This will lead to a better understanding of dayside magnetospheric compression.

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