Magnetic Mirror Geometry Using Cluster data: Model and Correlation Technique

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Summary:

Magnetic mirror structures: Basic properties

Data used: Cluster location and tetrahedron configuration

Correlations: method and results

Model: method and results

Conclusions

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Magnetic mirror structures

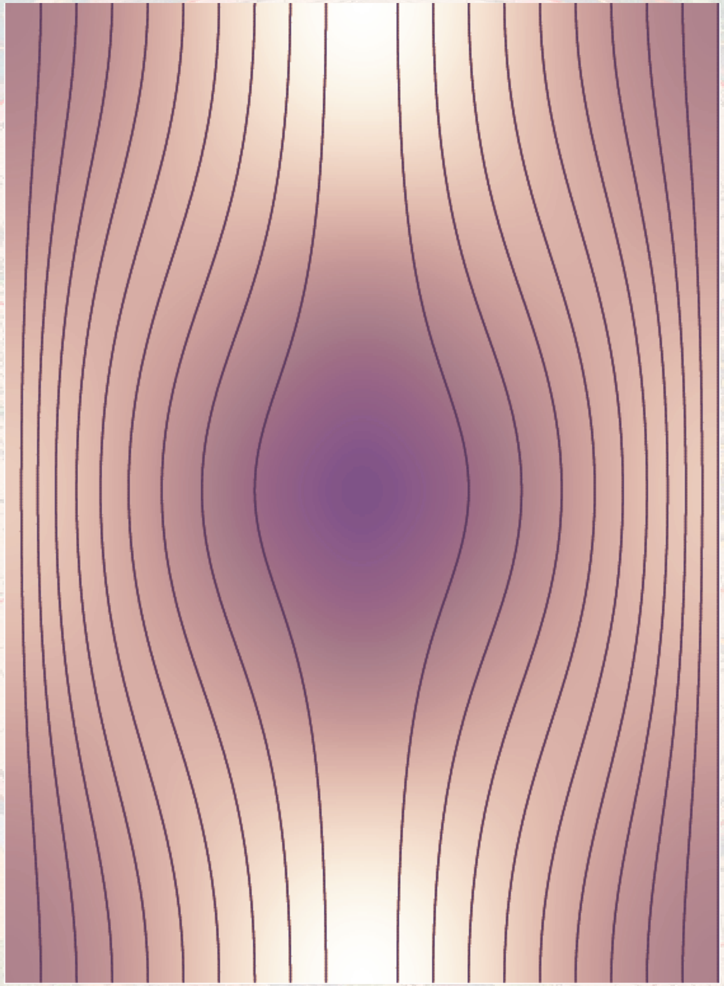
Fundamental plasma instability

Needs temperature anisotropy $(T_\perp > T_\parallel)$ in order to develop

Non propagating (purely imaginary frequency), strongly compressive mode

Magnetic field is anticorrelated with plasma density

Common in Earth magnetosheath but also in other space plasmas



Methods for deriving the geometry

Correlations

- applicable for any "well defined" magnetic structures
- assume linear correlation
- essentially statistical
- works when the correlations between measurements from different spacecraft are large

Model

- less general then correlations method
- assume certain geometry of magnetic mirror structures
- allow the study of each structure separately
- can work even if the measurements from different spacecraft are dissimilar

Magnetic field data

- Date: Nov. 10 2000,
  08:20:00 - 80:25:00 UT

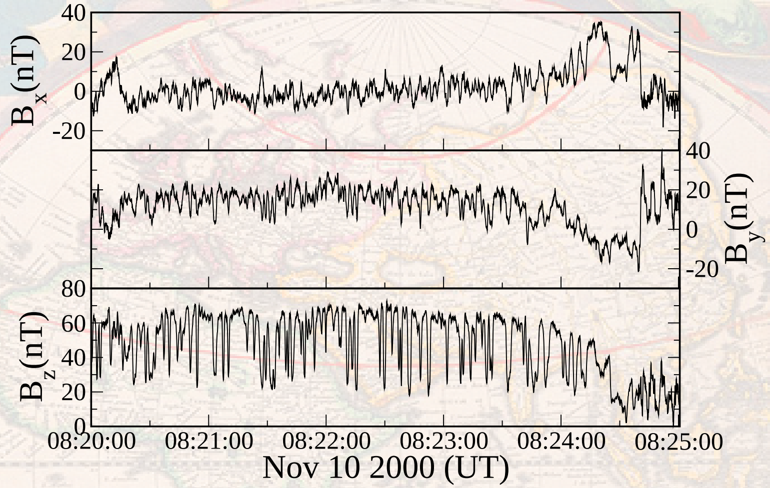
- Data resolution: High (22 vec/sec)

- Location: Dusk side magnetosheath

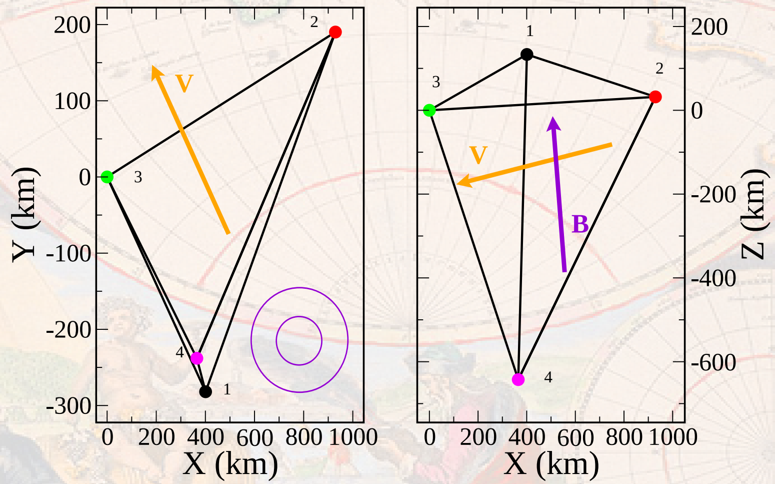
- Plasma flow: 815 km/s , C1 -> C3

- Magnetic field almost:
  - ▷ *aligned with Z_{GSE} axis*
  - ▷ *orthogonal to plasma flow*

Cluster 1 measured magnetic field



Cluster Tetrahedron Configuration



Correlations: Method and results

(Elisabeth Lucek et al: Cluster magnetic field observations in the magnetosheath: four-point measurements of mirror structures, *Annales Geophysicae*, 19, 1421-1428, 2001)

The autocorrelation function provides information about the extent of the structures in the flow direction

The cross correlations between data from different spacecraft provide information about the scale of the structures in other directions

Estimated dimensions for the interval [08:22:00, 08:24:00]:

- flow direction: 1500 - 3000 km
- magnetic field direction: >> 750 km
- magnetopause normal: < 600 km

Model: Assumptions

Pressure equilibrium

▷ $P_{plasma} = P_{magneticfield}$

Small perturbations

▷ $\delta B << B$

Time-independent magnetic field

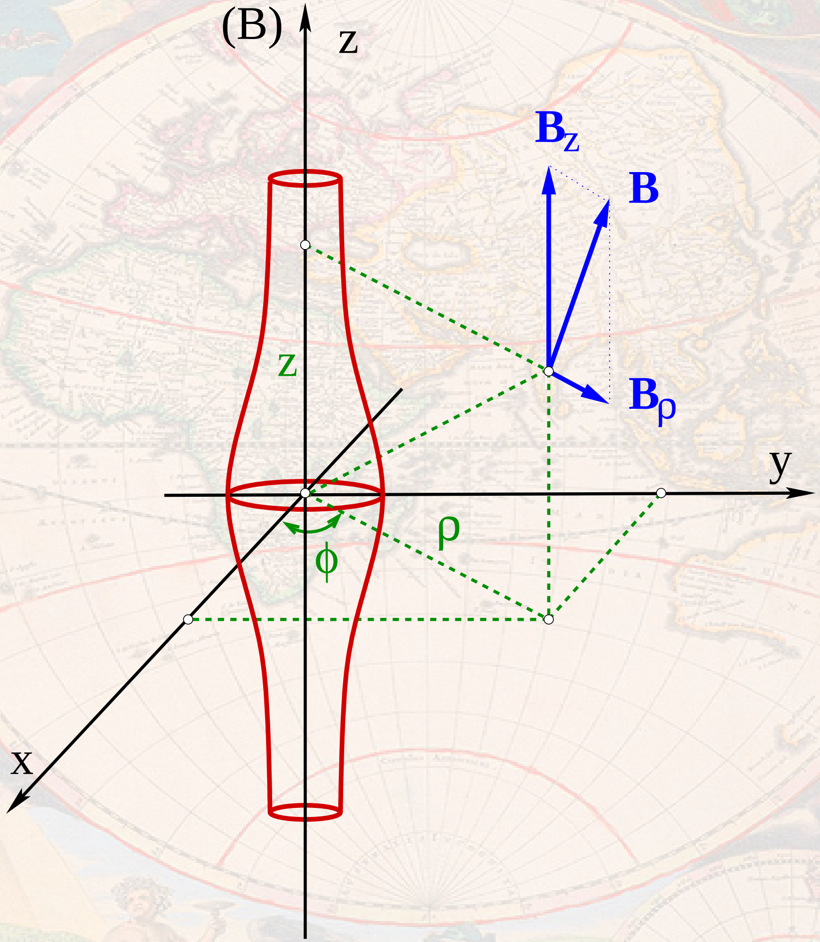
▷ $B \neq B(t)$

Symmetry around z-axis

▷ $B \neq B(\varphi)$

Periodicity along z-axis

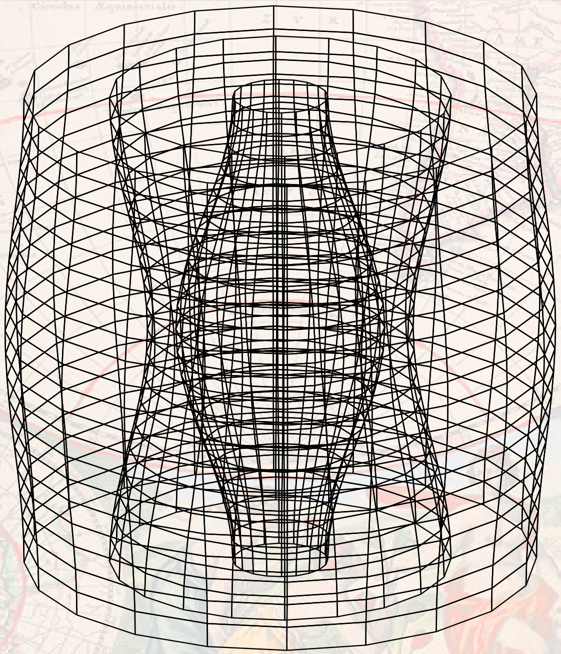
▷ $B(\rho, z + 2L) = B(\rho, z)$



Model: Magnetic field

Magnetic field perturbation:

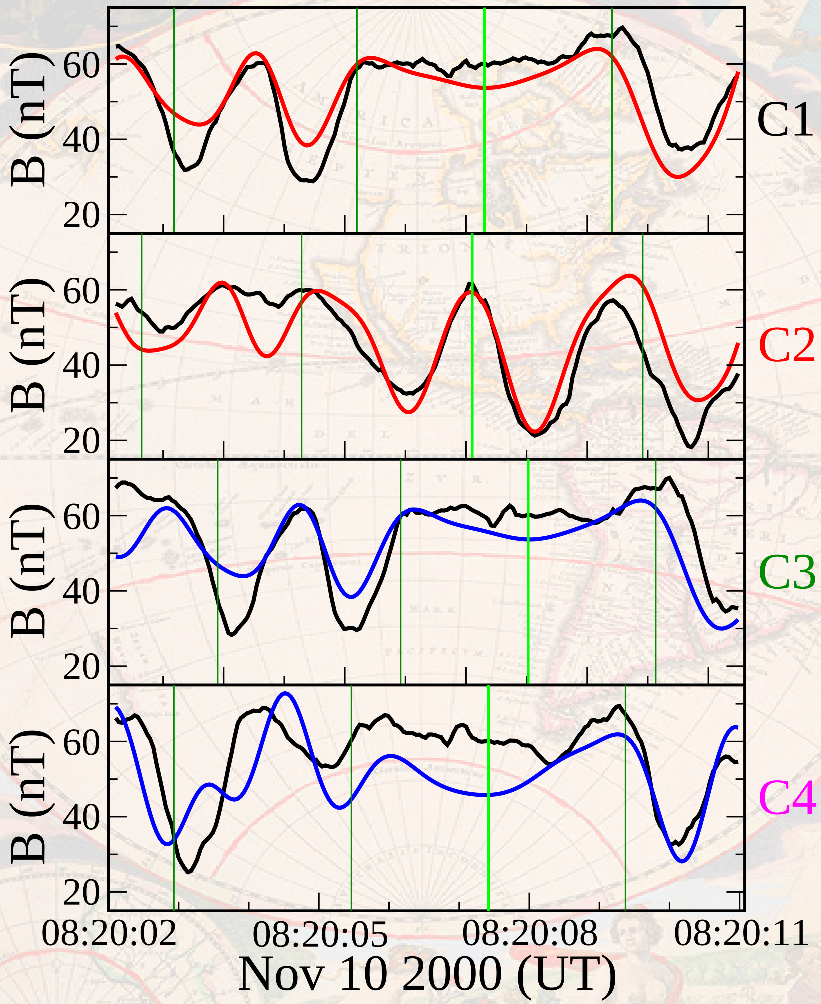
- $$\delta B_\rho(\rho, z) = \frac{2\pi}{\alpha} \sum_{n=1}^{\infty} J_1\left(\frac{n\alpha\rho}{L}\right)\left[a_n \sin\left(\frac{n\pi z}{L}\right) - b_n \cos\left(\frac{n\pi z}{L}\right)\right]$$
- $$\delta B_z(\rho, z) = 2 \sum_{n=1}^{\infty} J_0\left(\frac{n\alpha\rho}{L}\right)\left[a_n \cos\left(\frac{n\pi z}{L}\right) + b_n \sin\left(\frac{n\pi z}{L}\right)\right]$$



- Multi-layer structure
- Central structure is the classical image of magnetic mirror
- Multiple magnetic field minima belong to one structure
- In real world only inner layers will survive

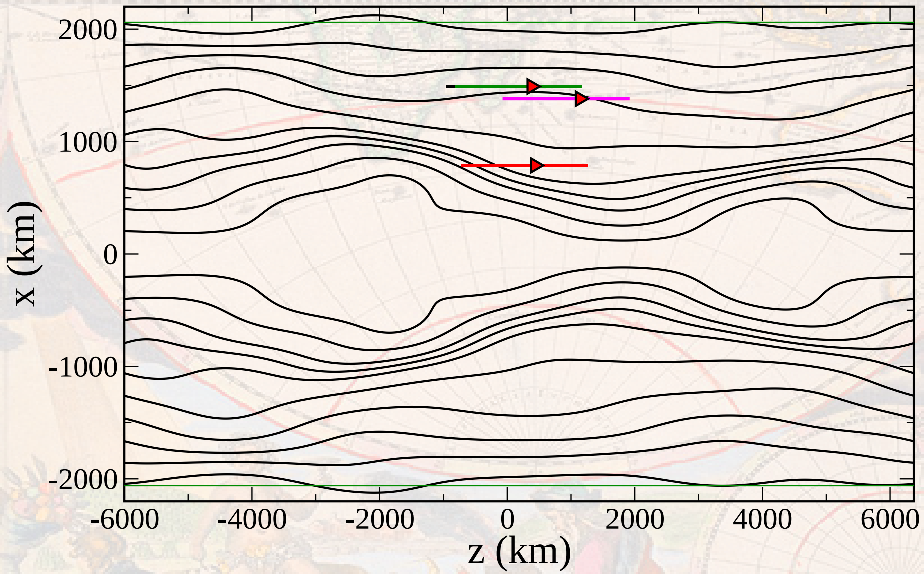
Model: Results

Fit Results



- fit on data from C1 and C2
- C3 and C4 are witness spacecraft
- Resulting dimensions:
  - ▷ $L = 6186$ *km*
  - ▷ $R = 2051$ *km*

Magnetic field lines



Conclusions

Both methods allow one to estimate the geometry of magnetic mirror structures making full use of multi-spacecraft measurements

While in some directions the results are consistent between the two approaches, in others they are not.

- **flow direction:** Both methods indicate about the same dimension
- **magnetic field direction:** The results are consistent but the model approach allows more precise estimation
- **magnetopause normal:** Correlations method indicate a very compressed structure while the model method implies a symmetric structure

The two methods are complementary

- correlation method gives a statistical view of the dimensions.
- model method provides further details of the geometry for selected events

The question of compressed structures needs to be elucidated