Wave Sources Location Using CLUSTER Data

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Abstract

Using a wave telescope method based on spherical waves representation we are able to determine the location of the plasma wave sources from Cluster magnetic field data. In the virtue of Huygens principle, our method also allows to determine the shape of the source region.
We apply the method to a typical Cluster crossing of the bowshock and we are able to locate wave sources both in the foreshock and in the magnetosheath.
The foreshock wave source is close to the Cluster tetrahedron indicating that waves are locally generated in the foreshock.
The magnetosheath wave originates from an elongated source region aligned with the average magnetic field.

1. Method

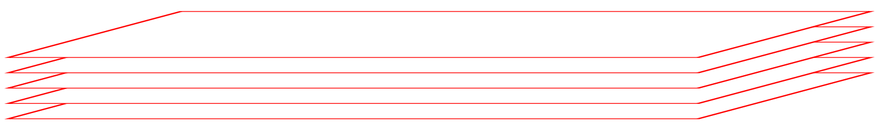
- Assume the measured field $\boldsymbol{B}$ is a sum of elementary waves $\boldsymbol{w}$ depending on the parameters $\boldsymbol{q}$
- The power associated with the measured field is:

$$P = \left(\boldsymbol{w}^{+}\underline{\boldsymbol{B}\boldsymbol{B}}^{-1}\boldsymbol{w}\right)^{-1}$$

- The power maximizes for the values $\boldsymbol{q}_0$ which are present in the measured field:

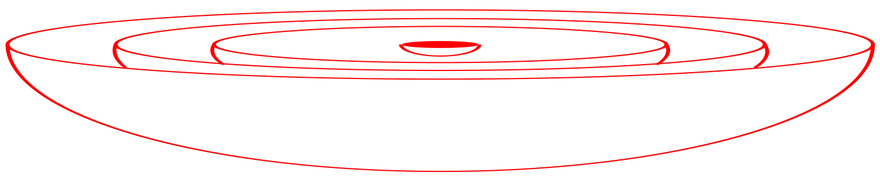
$$P(\boldsymbol{q})\big|_{\boldsymbol{q}=\boldsymbol{q}_0} = \text{maximum}$$

1.1 Wave Telescope



- elementary wave: $\boldsymbol{w}(\boldsymbol{k},\omega) = Ce^{i(\boldsymbol{k}\cdot\boldsymbol{r}-\omega t)}$
- provided information:
  - wave vector $\boldsymbol{k}$
  - frequency ω

1.2 Source Locator



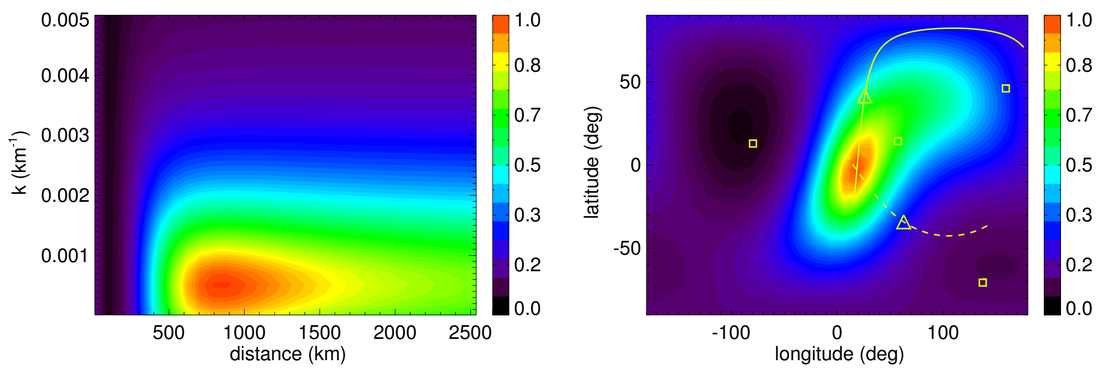
- elementary wave: $\boldsymbol{w}(k,\omega,\boldsymbol{r}_{\text{source}}) = C\frac{1}{\rho}e^{i(k\rho-\omega t)}$
- provided information:
  - wave number k
  - source position $\boldsymbol{r}_{\text{source}}$
  - frequency ω

2. Conditions

- Date: February 26, 2002
- Location: Bowshock inbound crossing
- Plasma Flow:
  - Foreshock: [-253, 52, -107] km/s
  - Magnetosheath: [-97, -14, -101] km/s
- Tetrahedron: Close to regular
- Shock regime: Quasi-Parallel

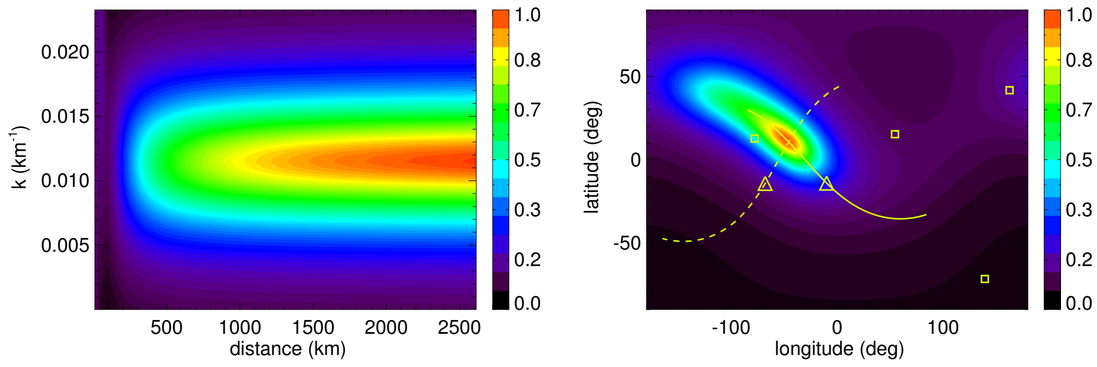
3. Results

3.1 Foreshock



- Frequency: 31 mHz
- Wave length: 12500 km
- Source shape: elongated
- Source location:
  - distance: 823 km
  - longitude: 15°
  - latitude: -4°

3.2 Magnetosheath



- Frequency: 181 mHz
- Wave length: 550 km
- Source shape: elongated, aligned with the magnetic field
- Source location:
  - distance: $>$ 2600 km
  - longitude: -46°
  - latitude: 10°

4. Conclusions

- SOURCE LOCATOR: Is the generalization of the wave telescope technique to spherical waves. It provides the position of the wave sources and the wave length.
- HUYGENS PRINCIPLE: If the wave source has a spatial extent, the source locator can give information about the shape of the source region.
- FORESHOCK: We have identified a close wave source in the foreshock. This proves that waves are locally generated there.
- MAGNETOSHEATH: We have identified a distant source region in the magnetosheath. It appears to be strongly elongated in the magnetic field direction.