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Source location of low frequency waves in the outer magnetosphere, magnetosheath, and near Earth solar wind: a Cluster case study

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Outline

1 Source localization: The method

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2 Application to Cluster data

Data overview

Typical samples

Statistical results

3 Conclusions



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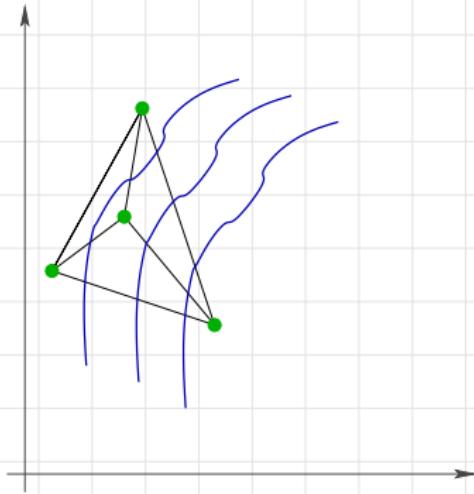
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Wave telescope: plane waves



- measurements: \mathcal{B}

$$\bullet \quad \mathcal{B}_{ij} = B_i B_j$$

- representation: $w(\mathbf{k}')$

$$w_s \propto \exp[i\mathbf{k}' \cdot \mathbf{r}_s]$$

Power

$$P(\mathbf{k}') = [w^\dagger(\mathbf{k}') \mathcal{B}^{-1}(\omega) w(\mathbf{k}')]^{-1}$$



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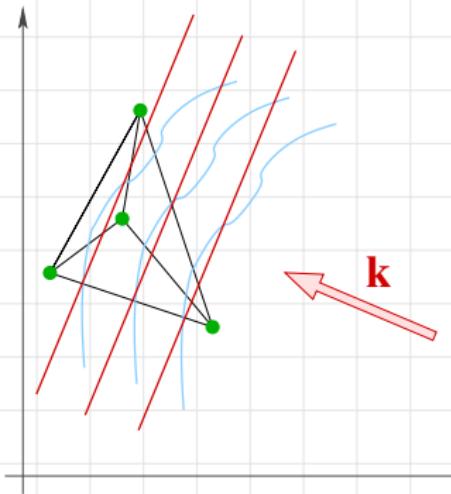
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Wave telescope: plane waves



- measurements: \mathcal{B}

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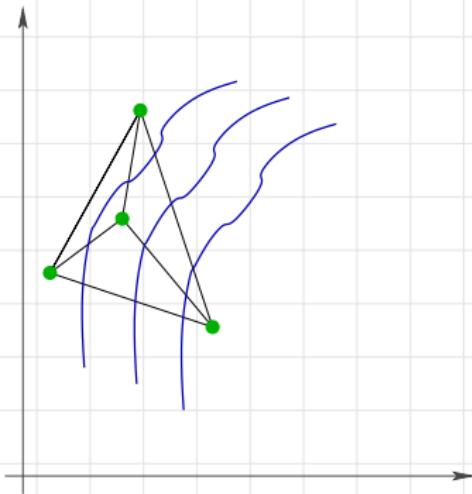
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Source locator: spherical waves



- measurements: \mathcal{B}

$$\bullet \quad \mathcal{B}_{ij} = B_i B_j$$

- representation: $w(k', r')$

$$w_s \propto p_s^{-1} \exp[i k' d_s]$$

Power

$$P(k', r') = [w^\dagger(k', r') \mathcal{B}^{-1}(\omega) w(k', r')]^{-1}$$



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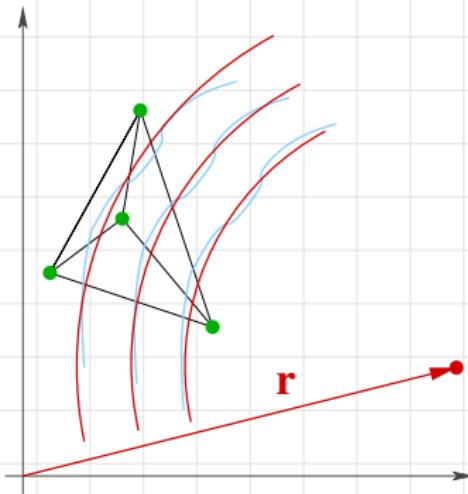
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Source locator: spherical waves



- measurements: \mathcal{B}

$$\bullet \quad \mathcal{B}_{ij} = B_i B_j$$

- representation: $\mathbf{w}(k', r')$

$$\bullet \quad w_s \propto \rho_s'^{-1} \exp\{ik'\rho_s'\}$$

Power

$$P(k', r') = [\mathbf{w}^\dagger(k', r') \mathcal{B}^{-1}(\omega) \mathbf{w}(k', r')]^{-1}$$



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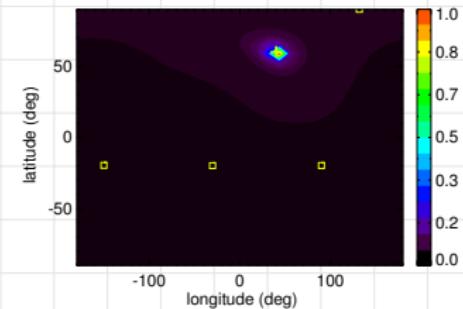
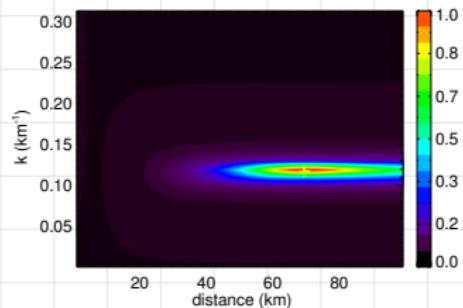
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Source location example

- one spherical wave
- random noise (10%)
- regular tetrahedron
- 10 km separation



	given	found
dist.	70 km	69 km
long.	40°	43°
lat.	60°	59°
k	0.11 km $^{-1}$	0.10 km $^{-1}$



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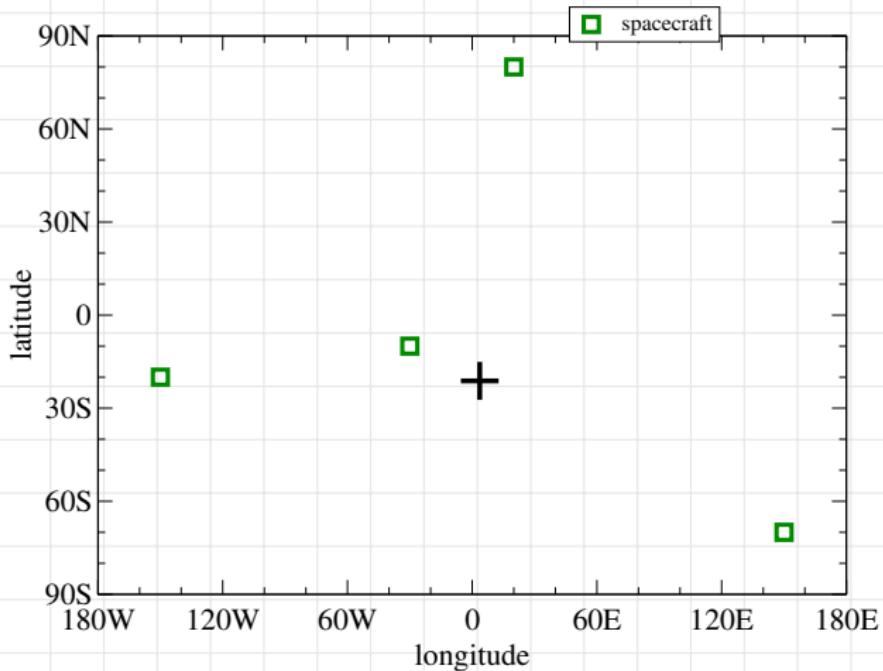
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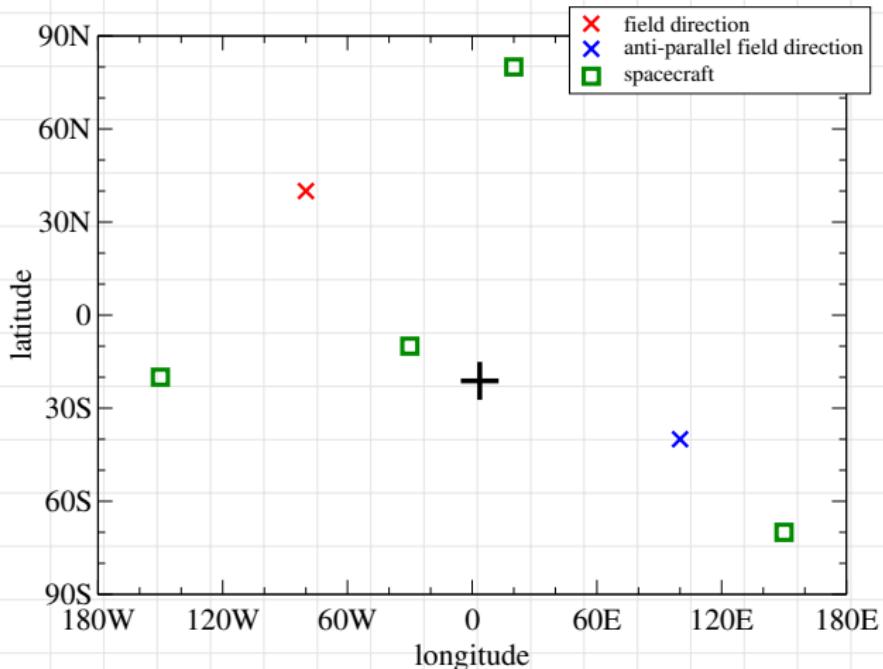
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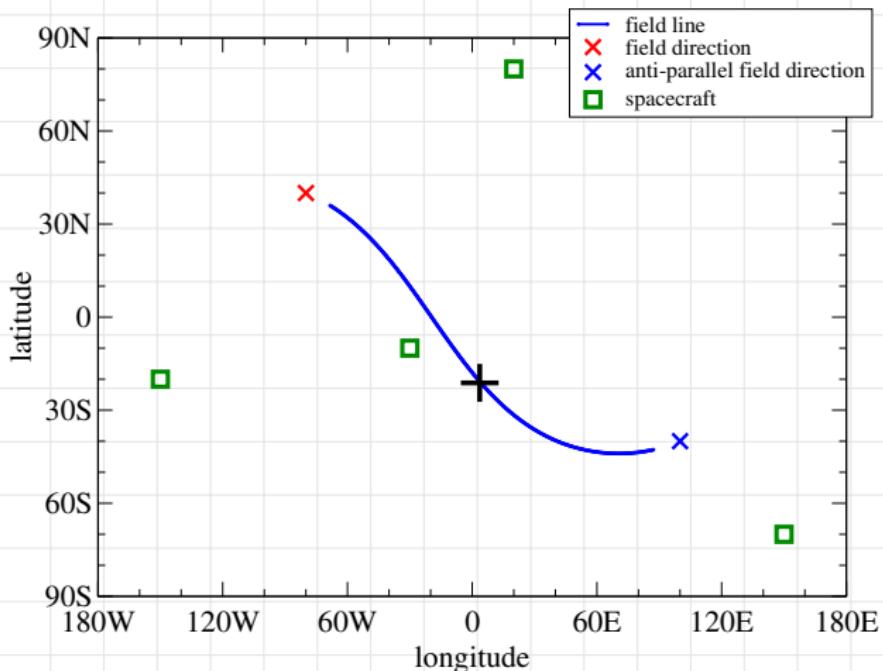
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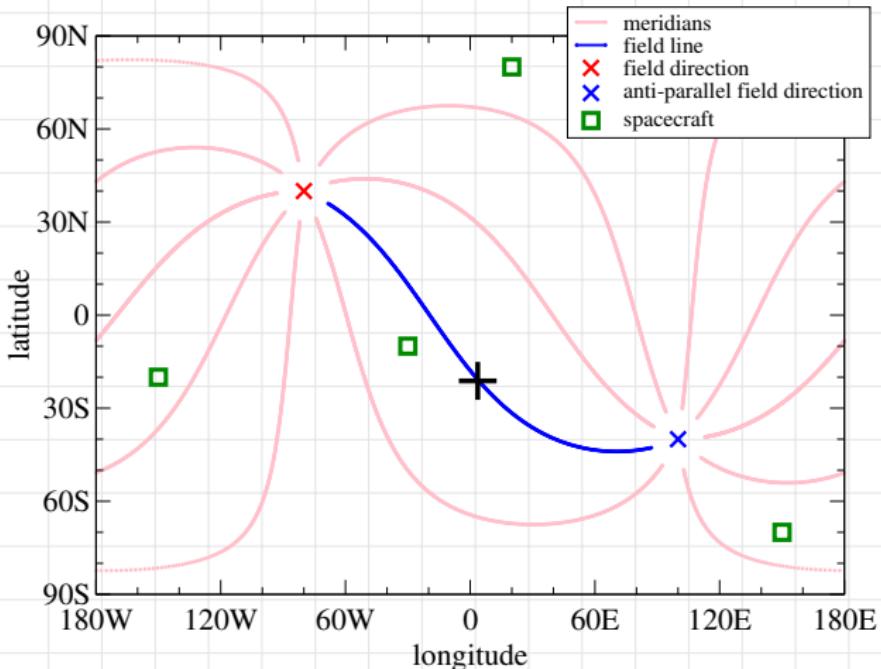
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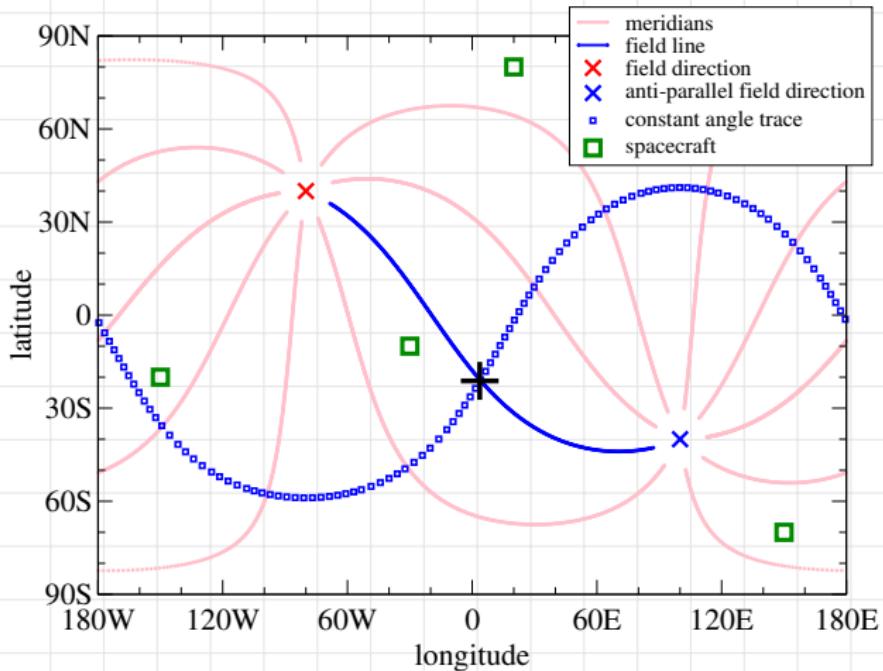
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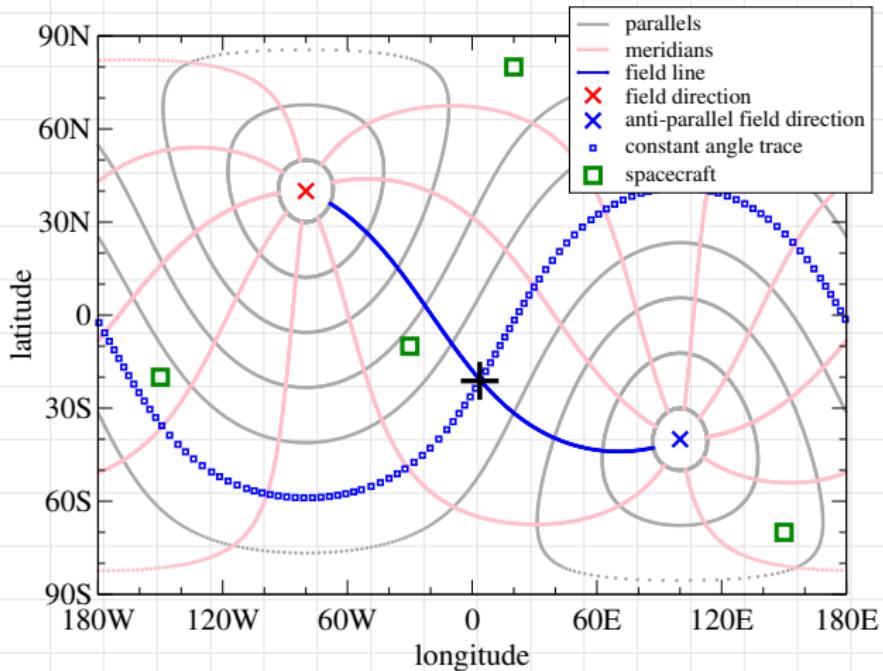
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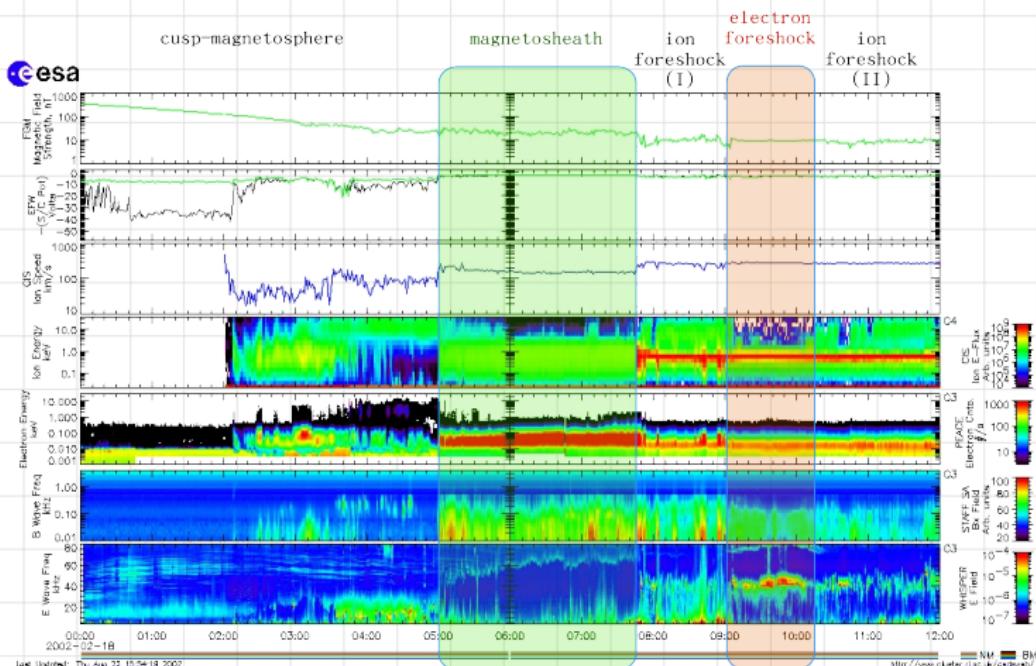
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February 18 2002: overview





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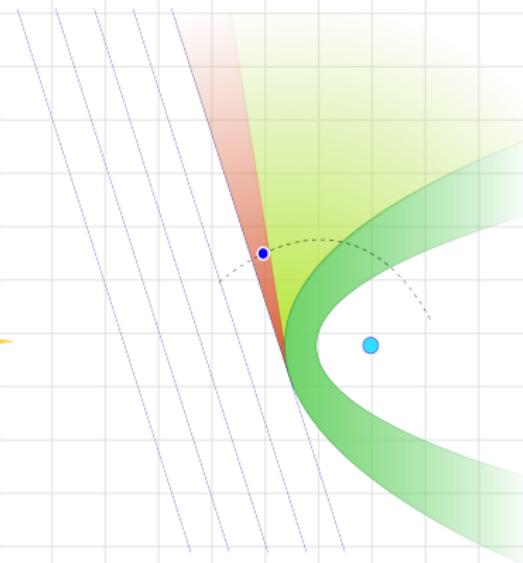
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Foreshock configuration



Ion foreshock (I),

Electron foreshock,

$$(\mathbf{B}, \hat{\mathbf{x}}_{\text{GSE}}) = 60^\circ$$



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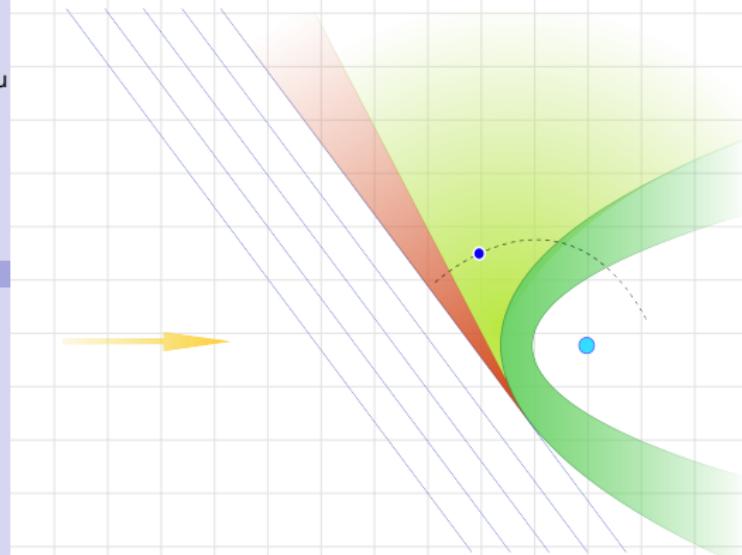
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Foreshock configuration



Ion foreshock (II),

$$(\mathbf{B}, \hat{\mathbf{x}}_{\text{GSE}}) = 20^\circ$$



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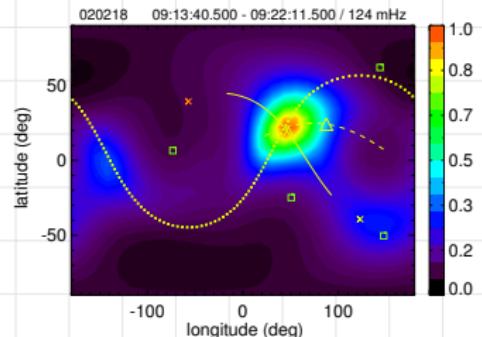
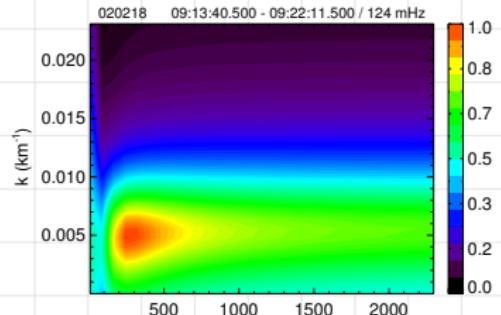
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Electron foreshock sample

distance (km)	244
wave length (km)	1300
longitude (deg)	43
latitude (deg)	21





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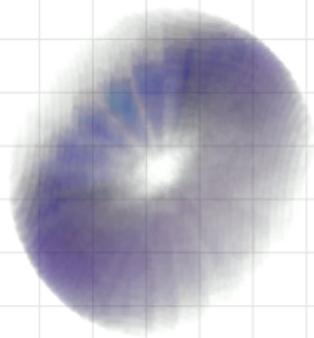
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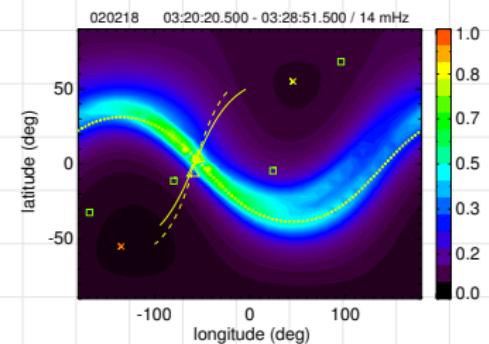
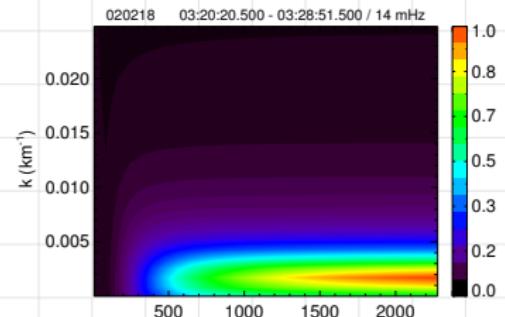
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distance (km)	> 2000
wave length (km)	3600
longitude (deg)	-55
latitude (deg)	3

Magnetosphere sample





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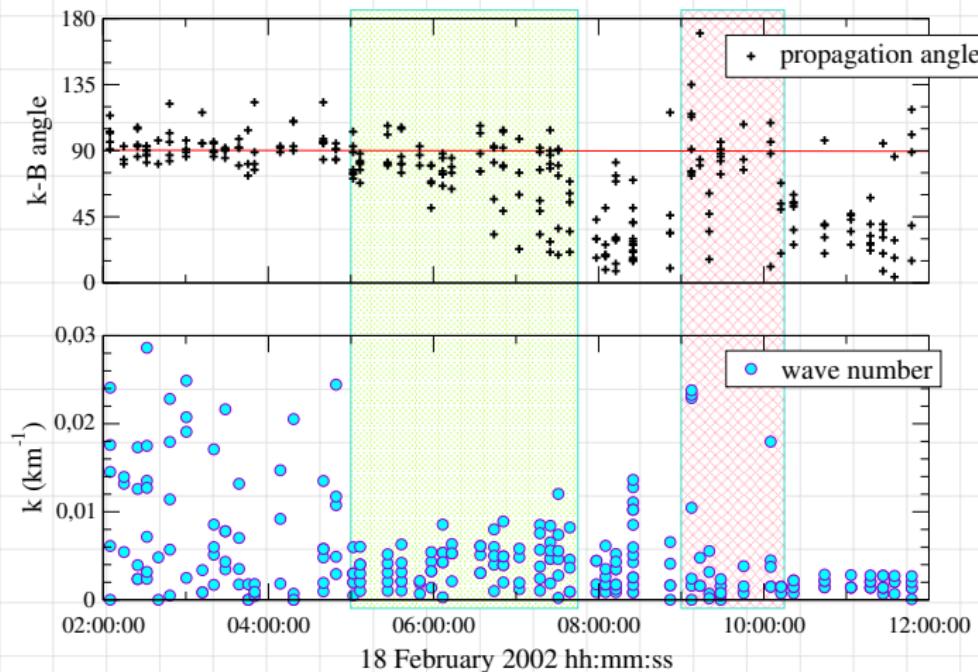
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Angle and wave number





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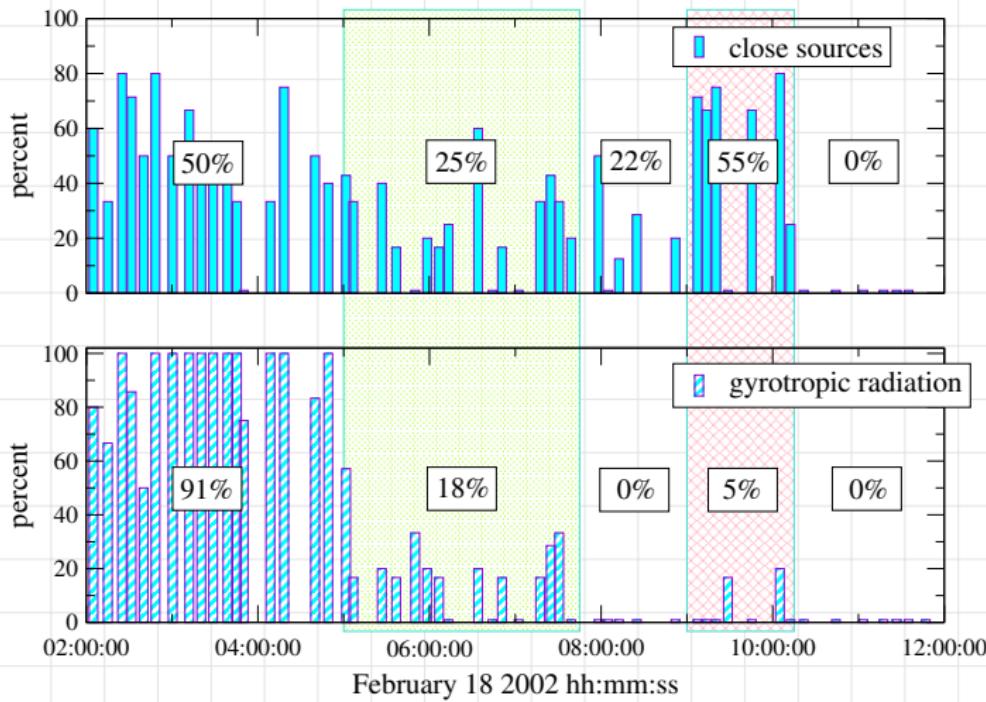
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Distance and gyrotropy





Conclusions

- ① The **source locator** determines both the **wave vector** and the **position** of wave sources.
- ② It can be used to identify active magnetospheric regions where waves are generated.
- ③ Most waves in the foreshock are generated in, or close to the electron foreshock.
- ④ Wave sources are almost uniformly distributed in the magnetosheath.
- ⑤ Waves are locally generated in the magnetosphere. Highly gyrotropic wave field indicates low damping.



Conclusions

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- ① The source locator determines both the wave vector and the position of wave sources.
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Conclusions

- 1 The source locator determines both the wave vector and the position of wave sources.
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- 3 Most waves in the foreshock are generated in, or close to the electron foreshock.
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- ⑤ Waves are **locally generated** in the **magnetosphere**. Highly **gyrotropic** wave field indicates **low damping**.



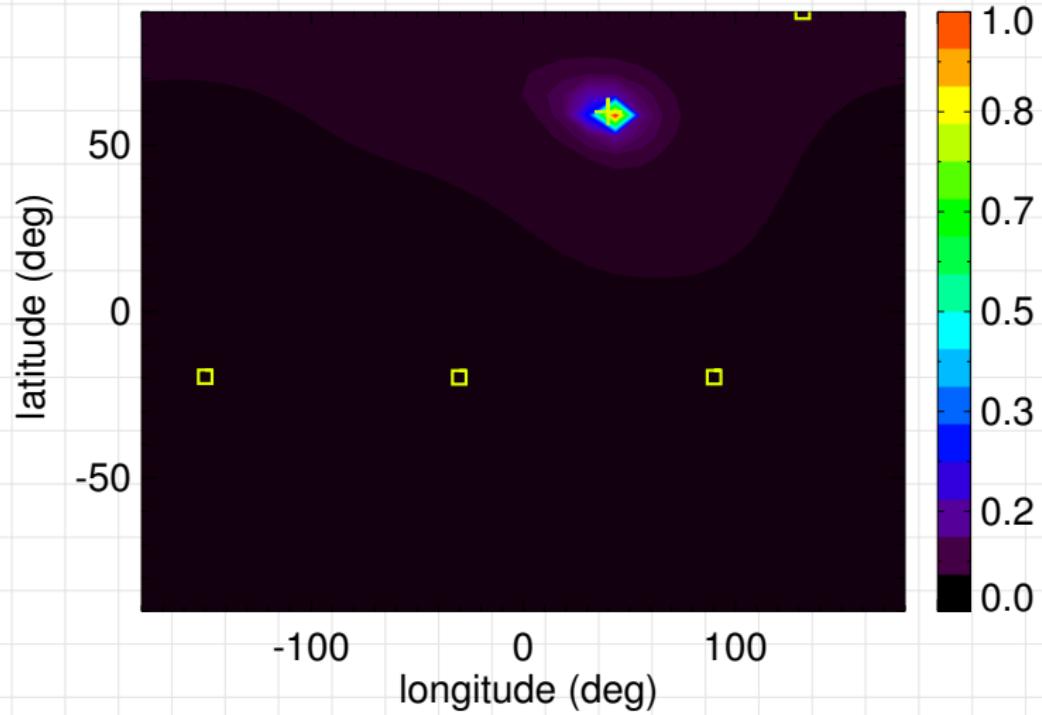
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Zoom

Source location example





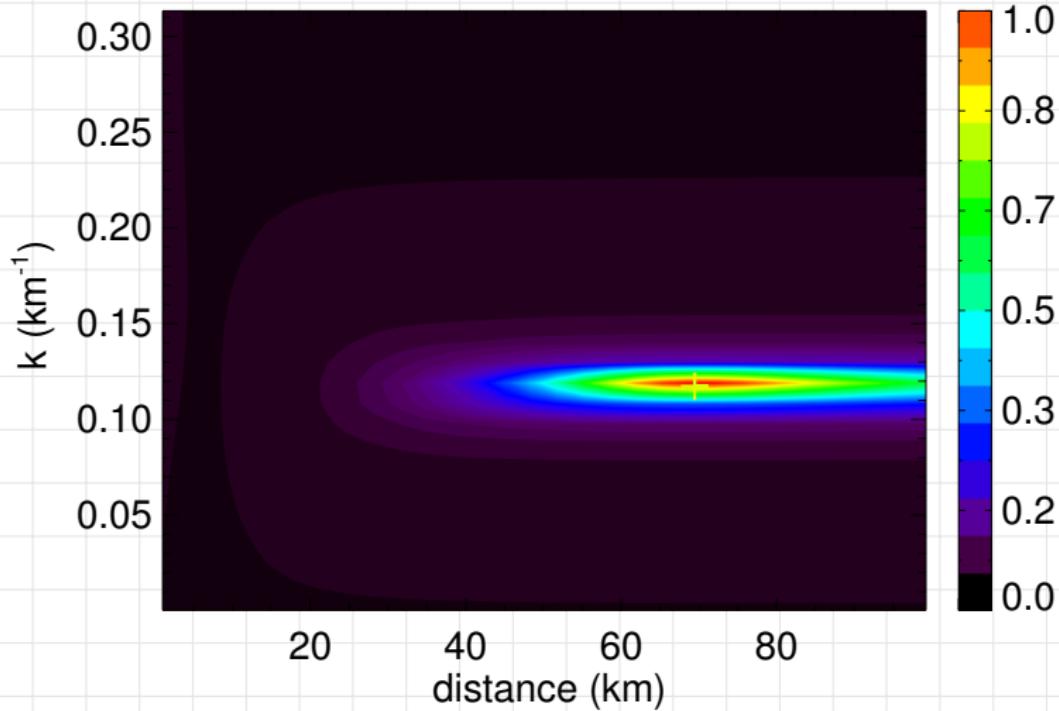
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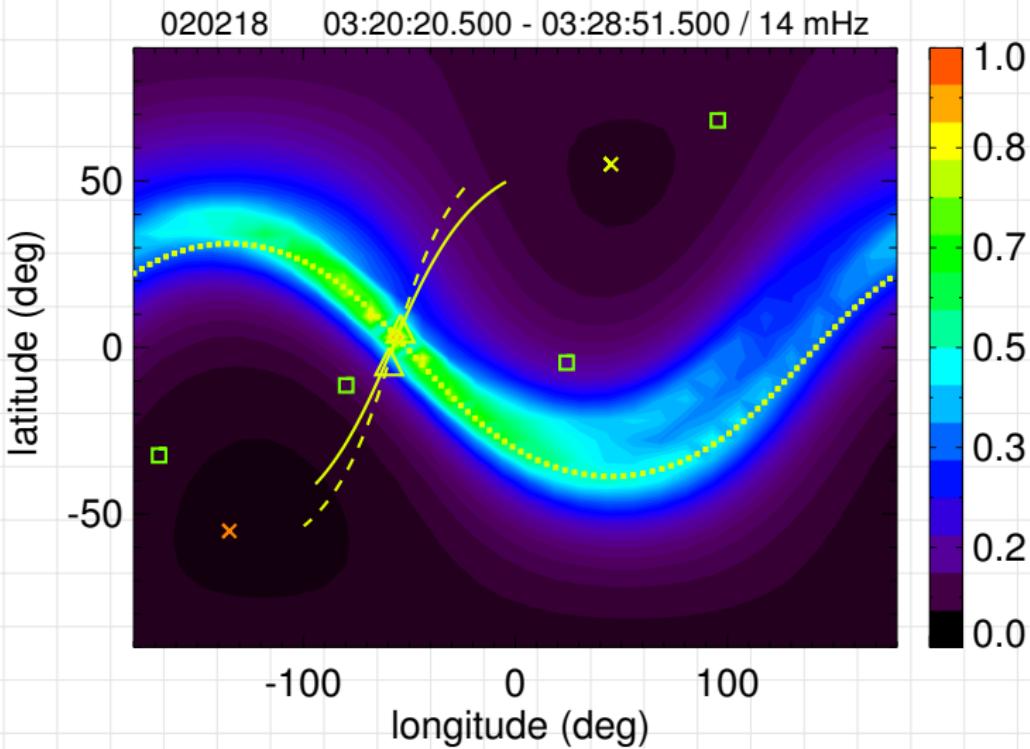
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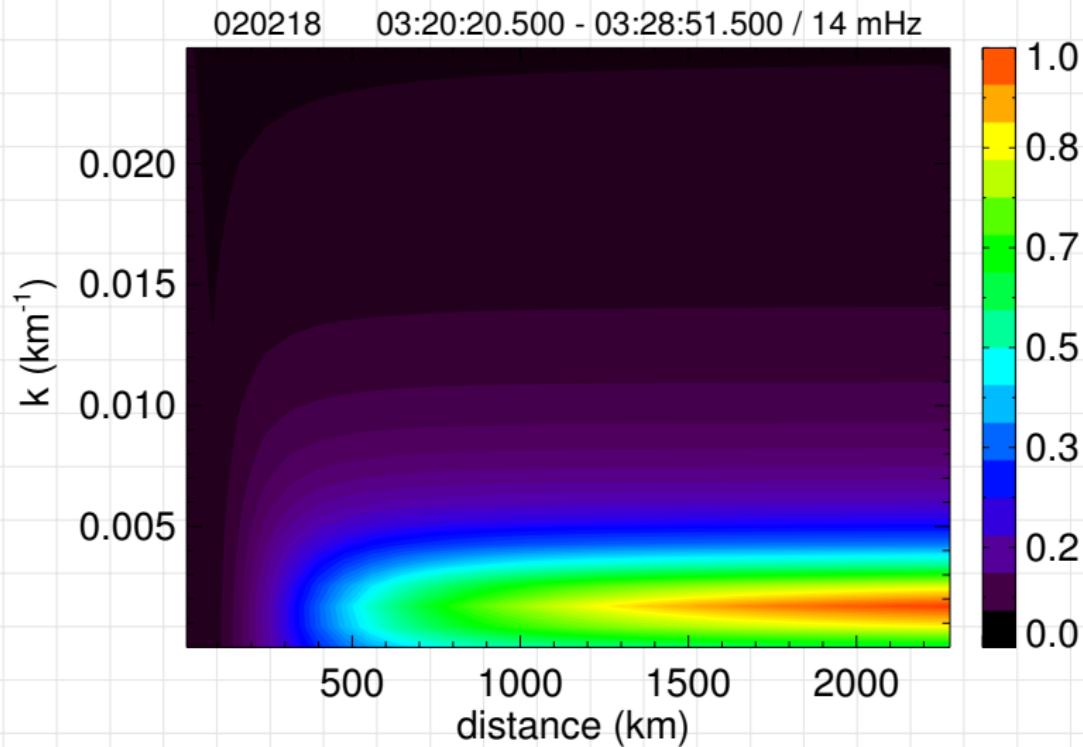
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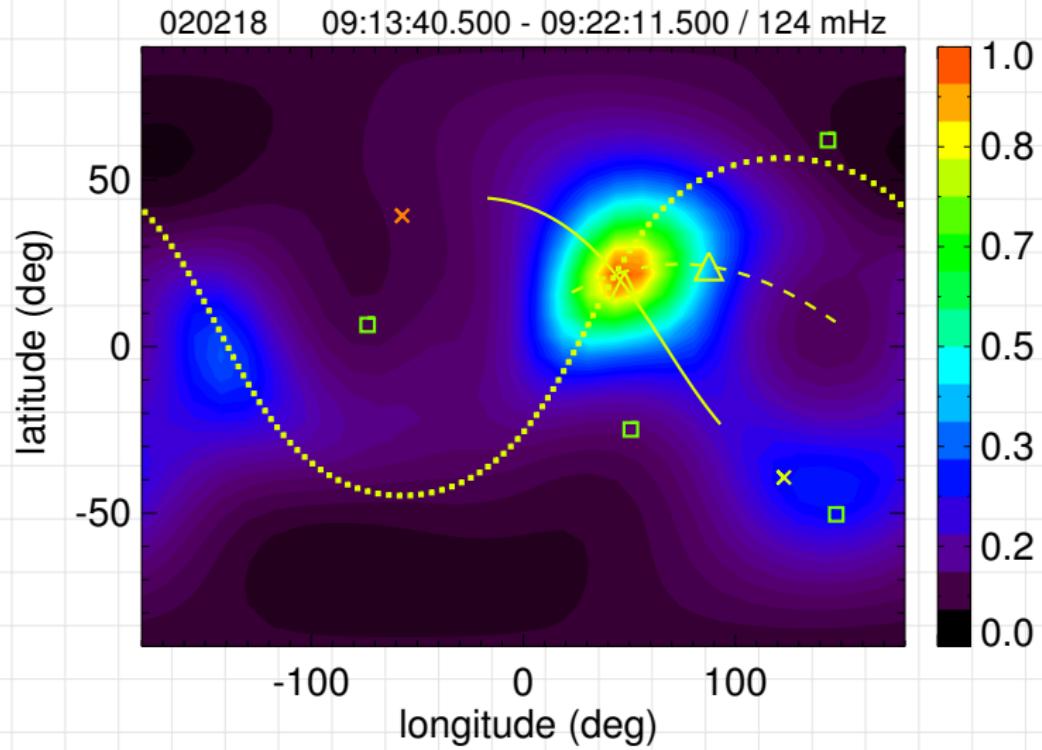
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Electron foreshock sample





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