Searching

Wave

D. Constantinescu[1,2]

Sources

K.-H. Glassmeier[1]

Locations

K.-H. Fornaçon[1]

Using

R. Treumann[3]

Cluster Data

Abstract

We present a method which can be used for finding the position of wave sources under the assumption of spherical waves using multi-spacecraft measurements of the magnetic field.
The approach is closely related to the wave telescope technique used for determining the k-vector for plane waves. The method consists in computing the array gain (power) at different points in space. The array gain is constructed as a combination between the measurements and weights representing a test wave. The power maximizes when the test wave is close to the wave which is actually measured.
We apply the method to an interval when Cluster was in the fore-shock and find a well defined stable source at a distance from configuration center of several mean spacecraft separation.

Pattern analysis

- Assume the measured field $\boldsymbol{B}$ is a sum of patterns $\boldsymbol{w}$ depending on the parameters $\boldsymbol{q}$

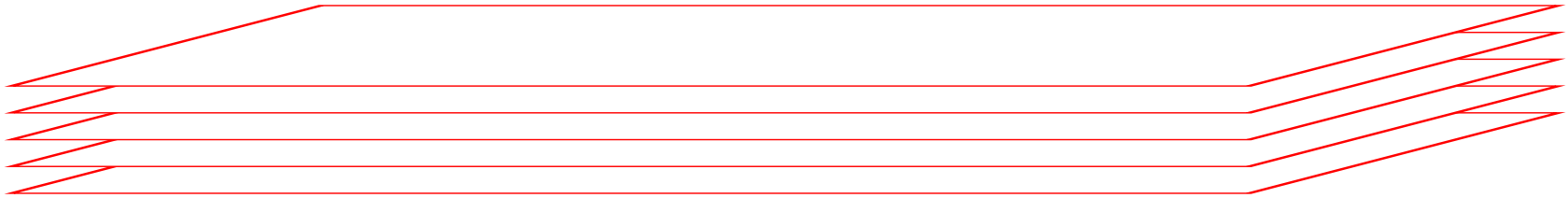
- The power associated with the measured field is:

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

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

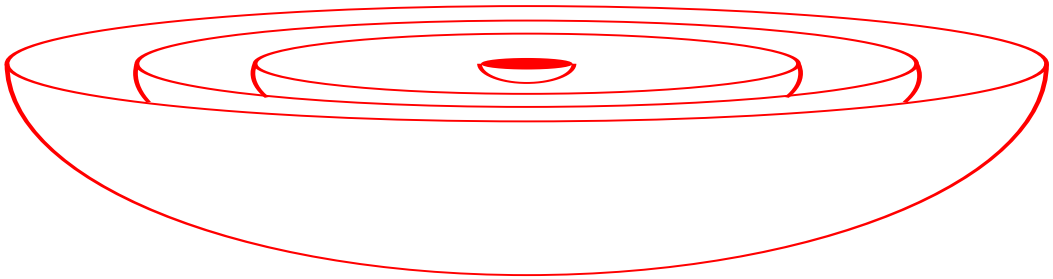
$$P(\boldsymbol{q})\Big|_{\boldsymbol{q}=\boldsymbol{q}_0} = \text{maximum}$$

Wave Telescope



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

Source Locator

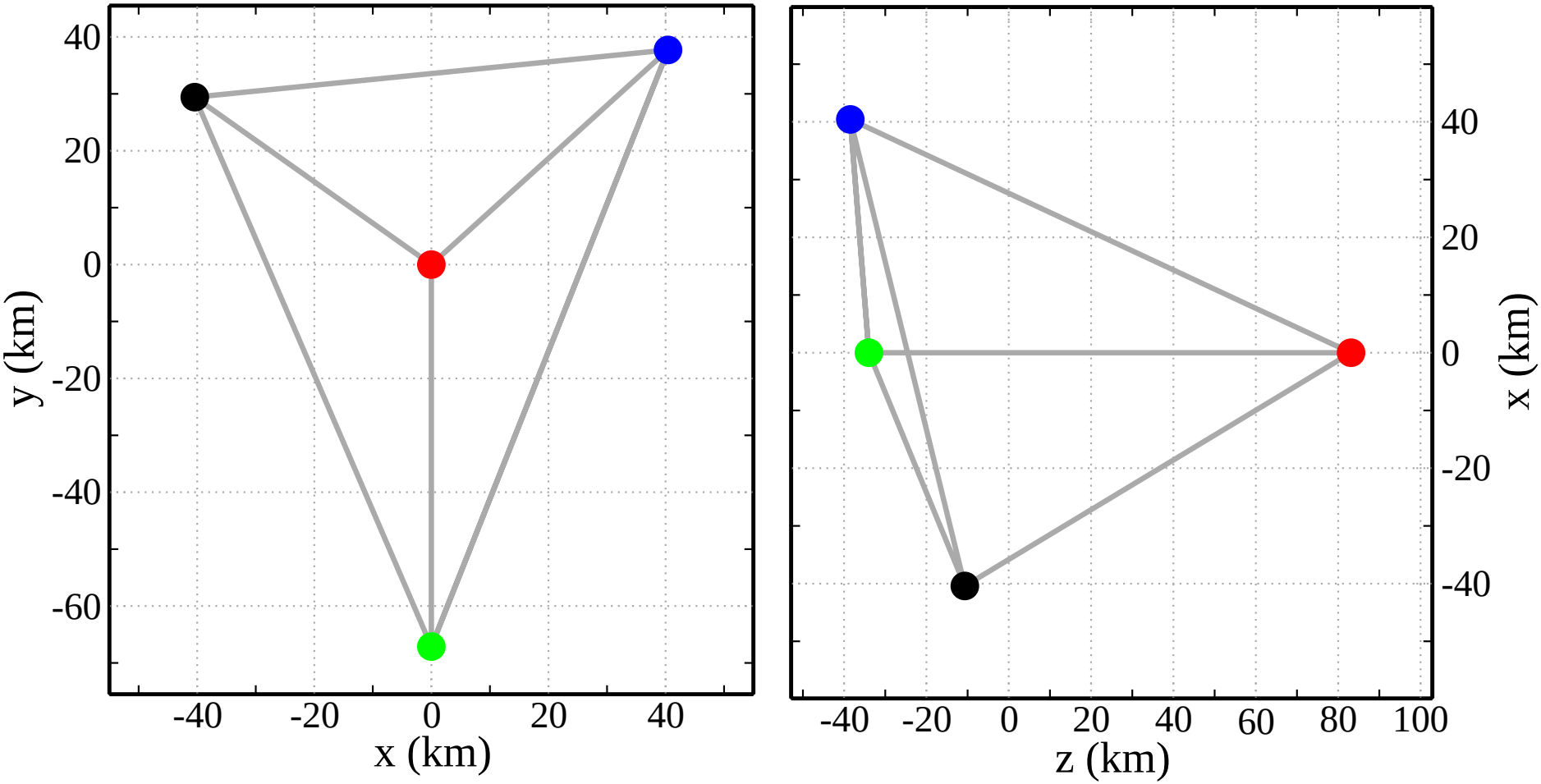


- pattern: $\boldsymbol{w}(k, \omega, \boldsymbol{r}_{\text{source}}) = C\frac{1}{\rho_s}e^{i(k\rho - \omega t)}$
- provided information:
  - wave number k
  - source position $\boldsymbol{r}_{\text{source}}$
  - frequency ω

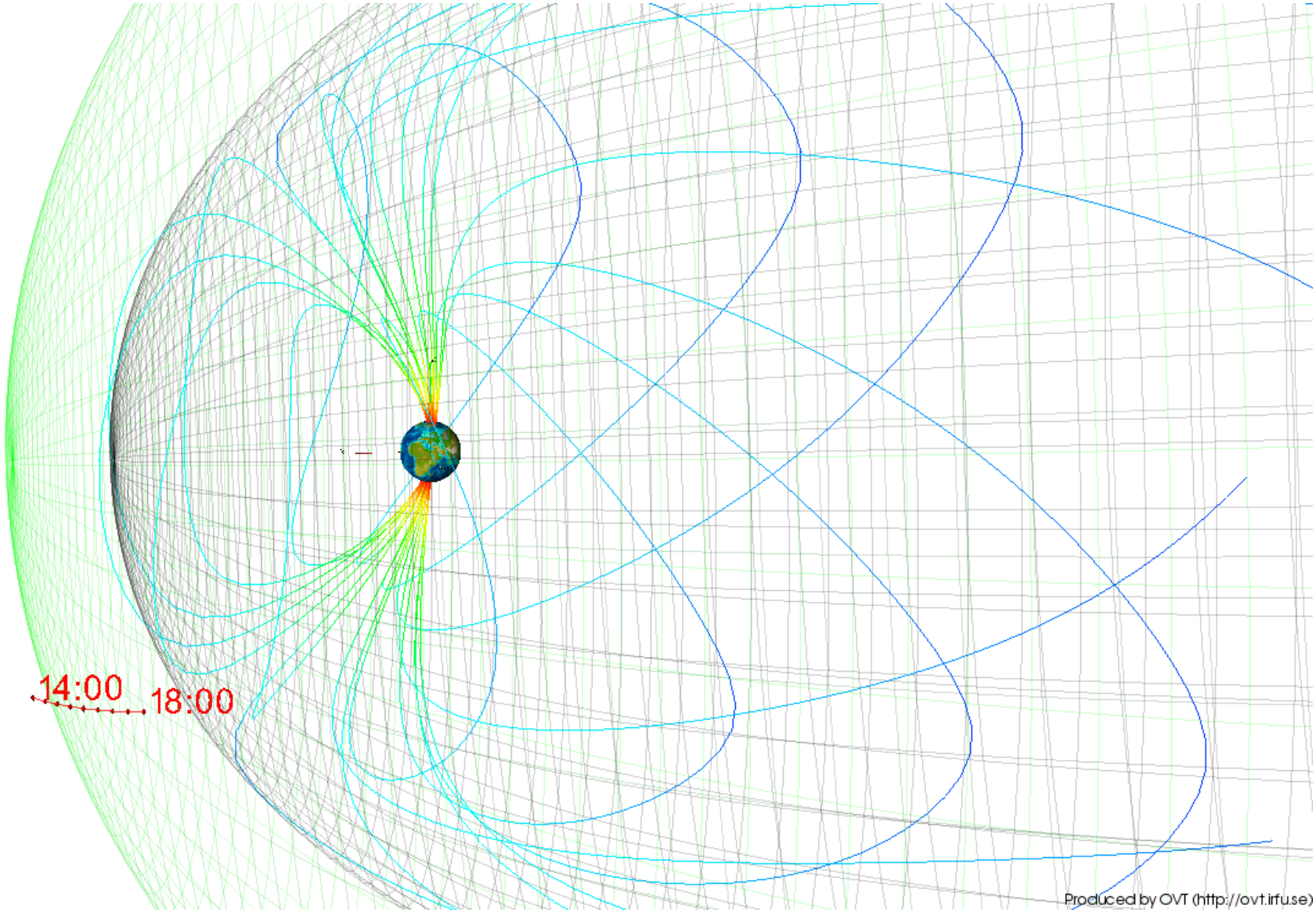
Case study

- Time interval: February 12, 2002, 15:48 – 15:56
- Location: Fore-shock
- SW speed: [-367, -28, -91] km/s
- Fluctuations: Compressional
- Tetrahedron: Close to regular
- Shock regime: Quasi-Parallel

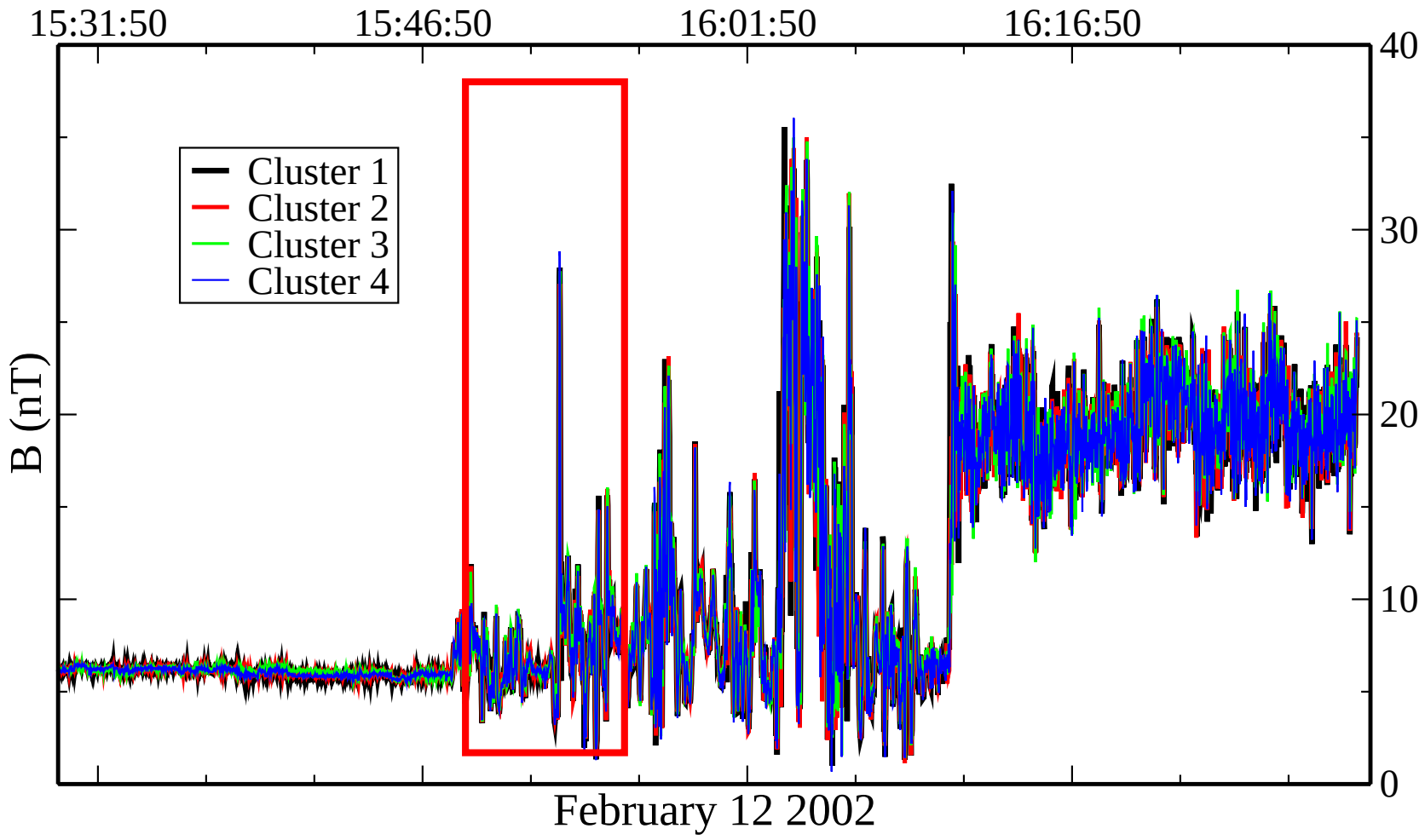
Configuration



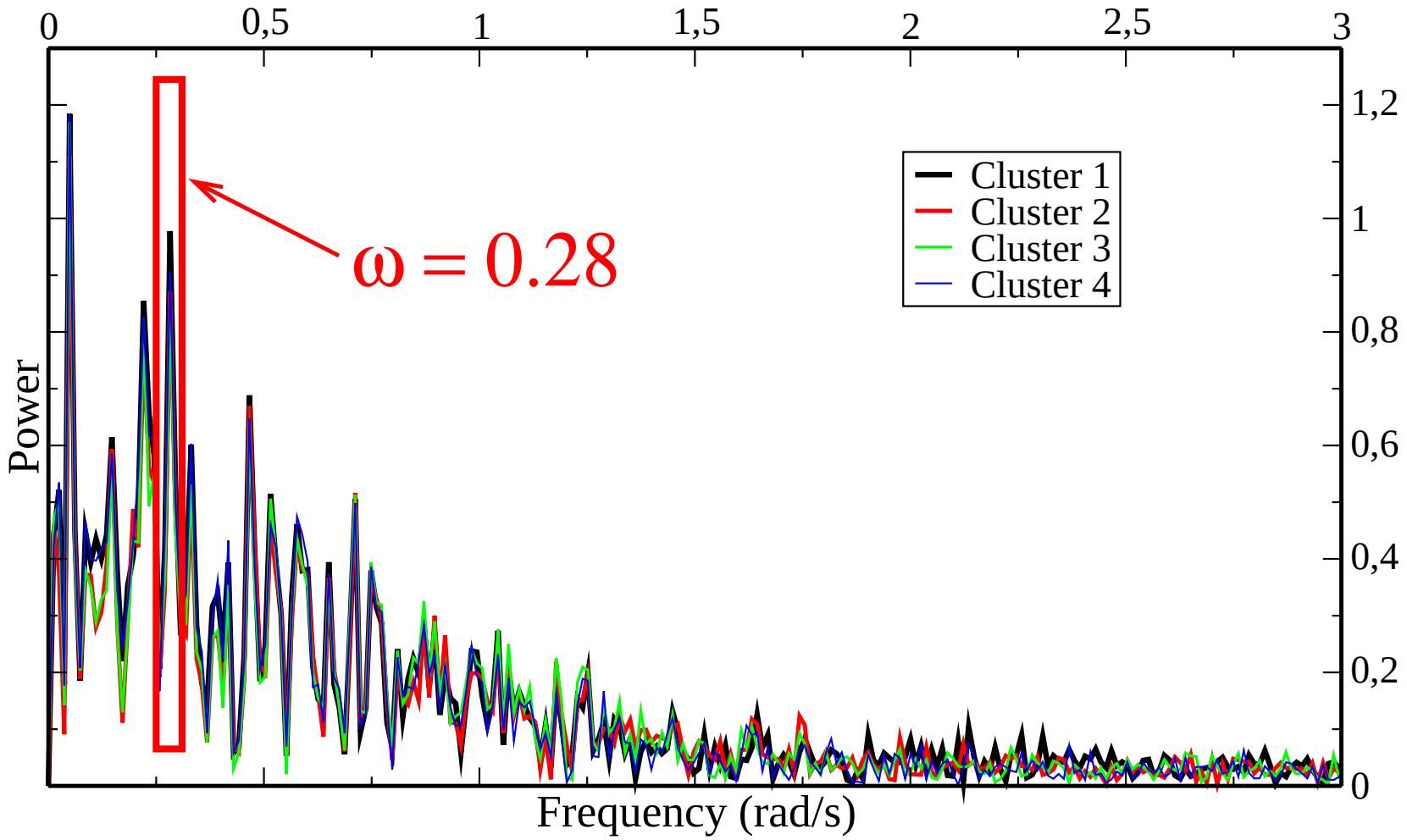
Orbit



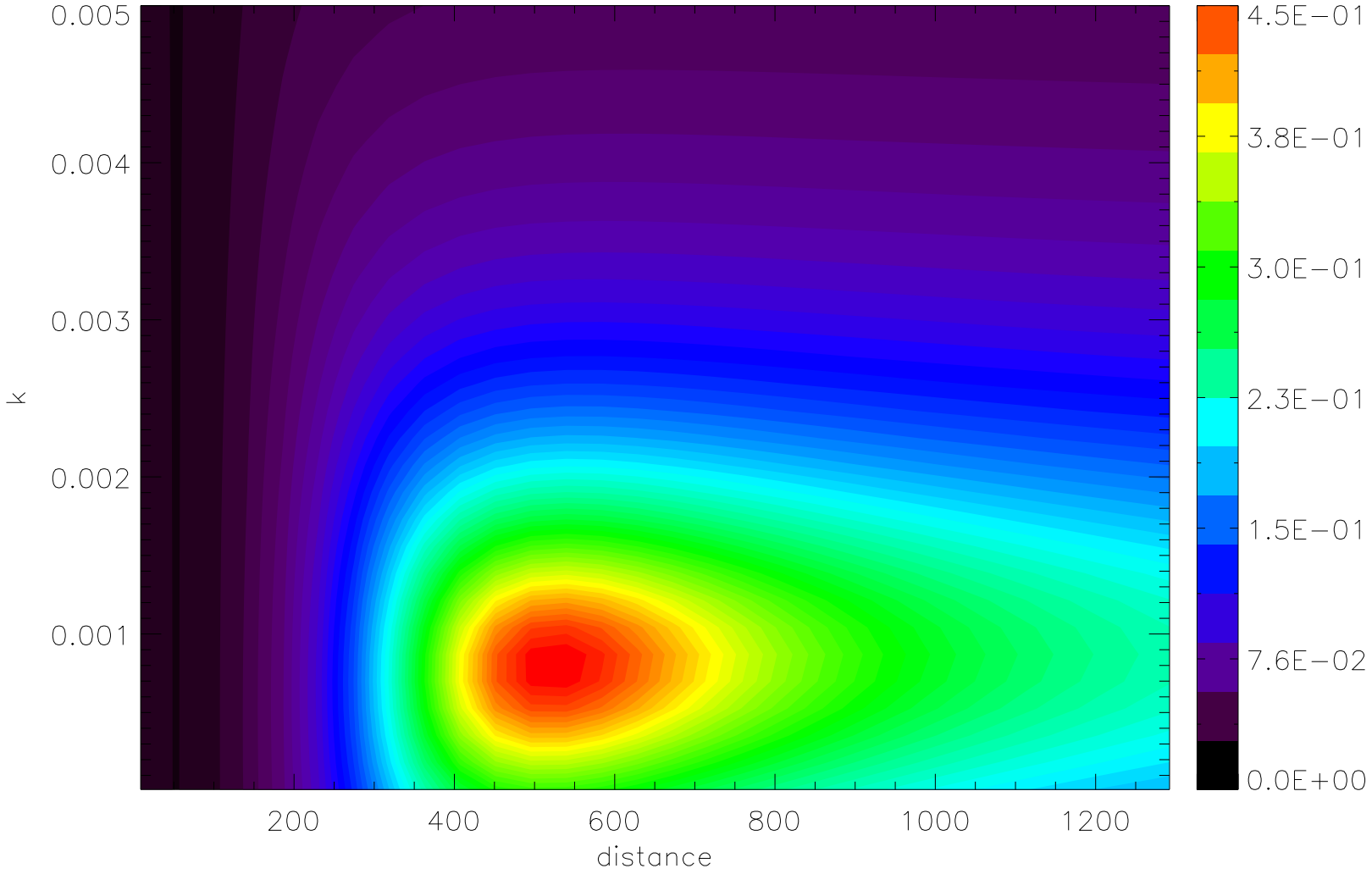
Magnetic field



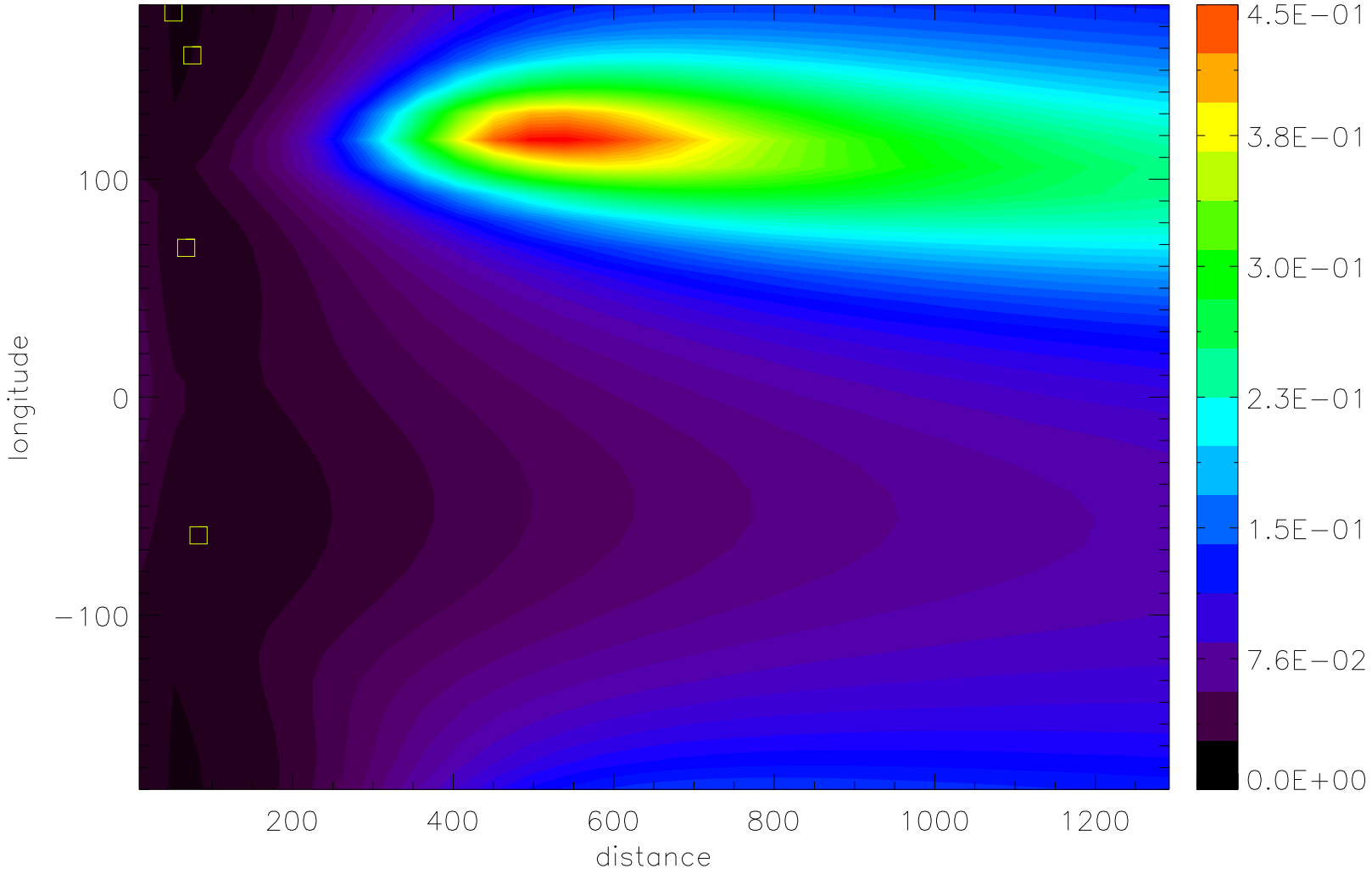
Fourier spectrum



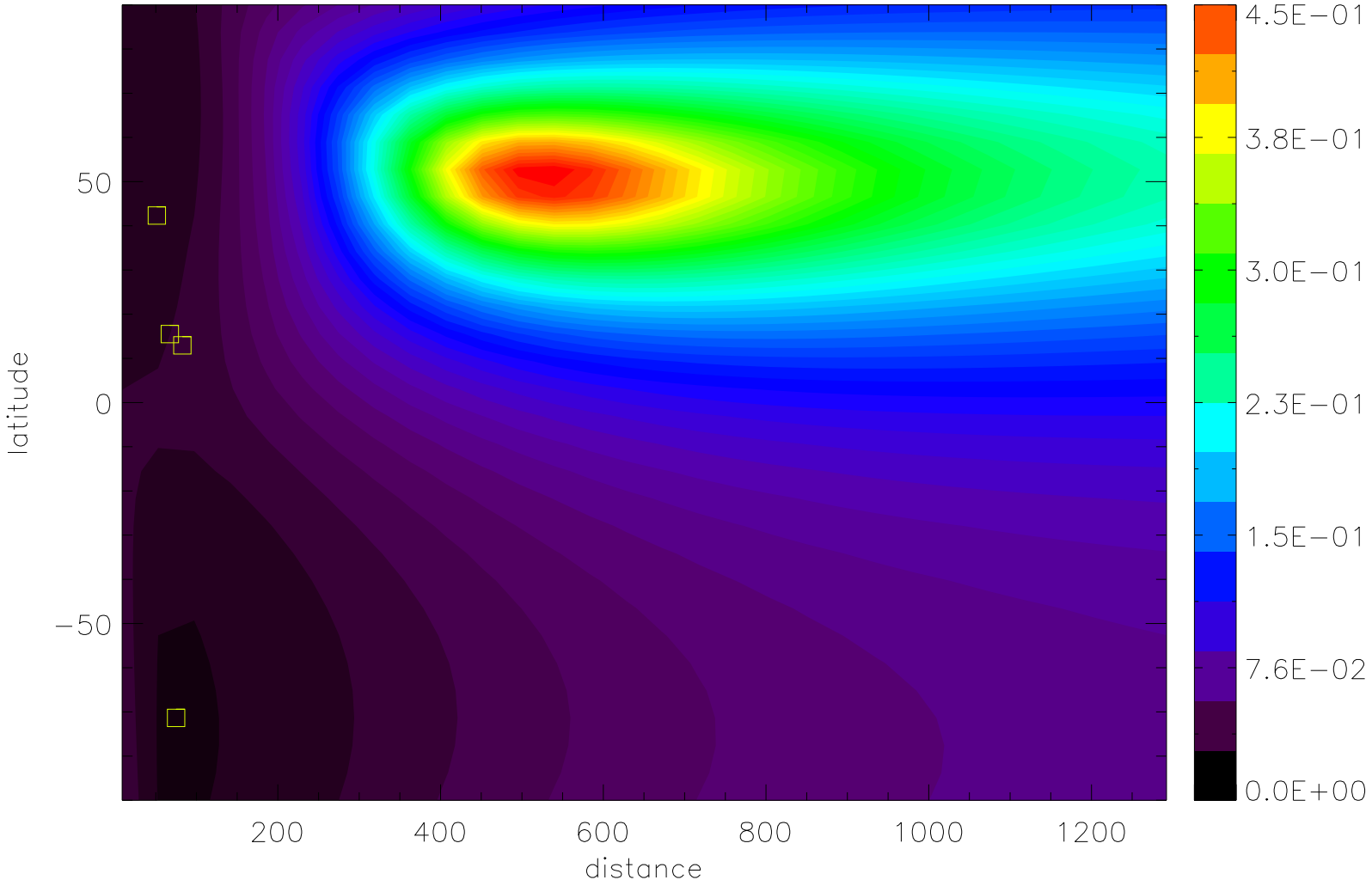
Power: Slice (ρ, k)



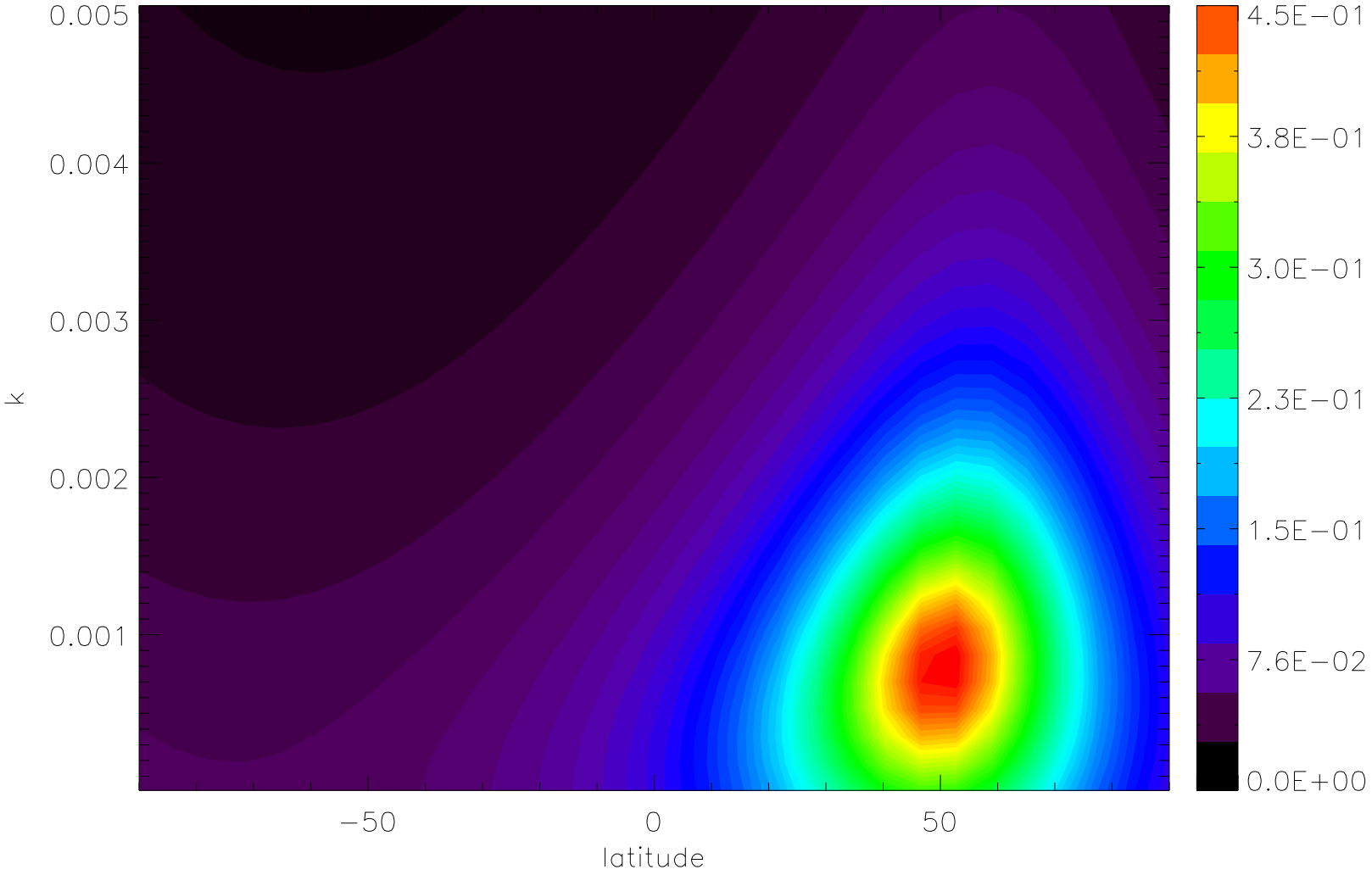
Power: Slice (ρ, φ)



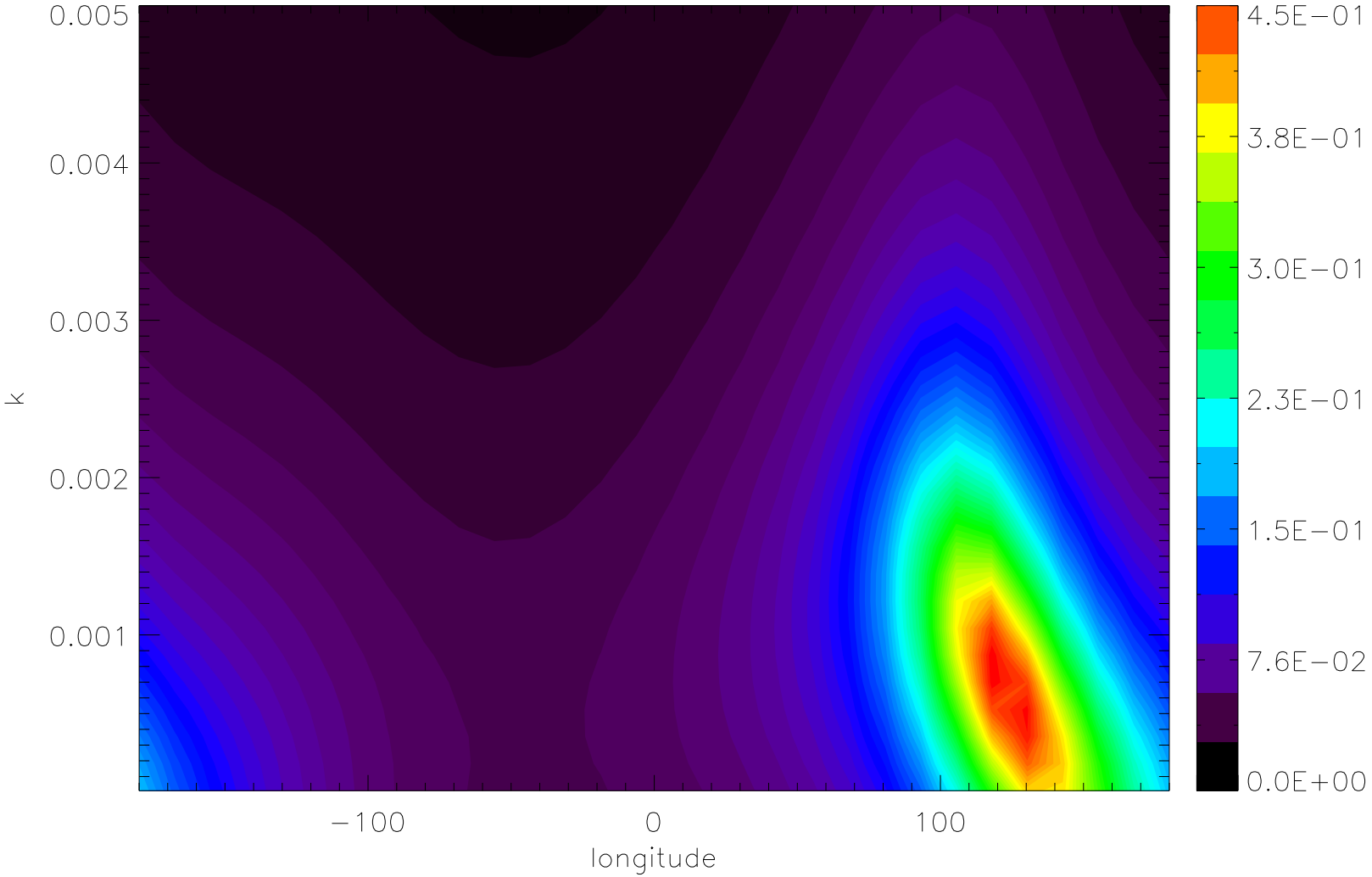
Power: Slice (ρ, θ)



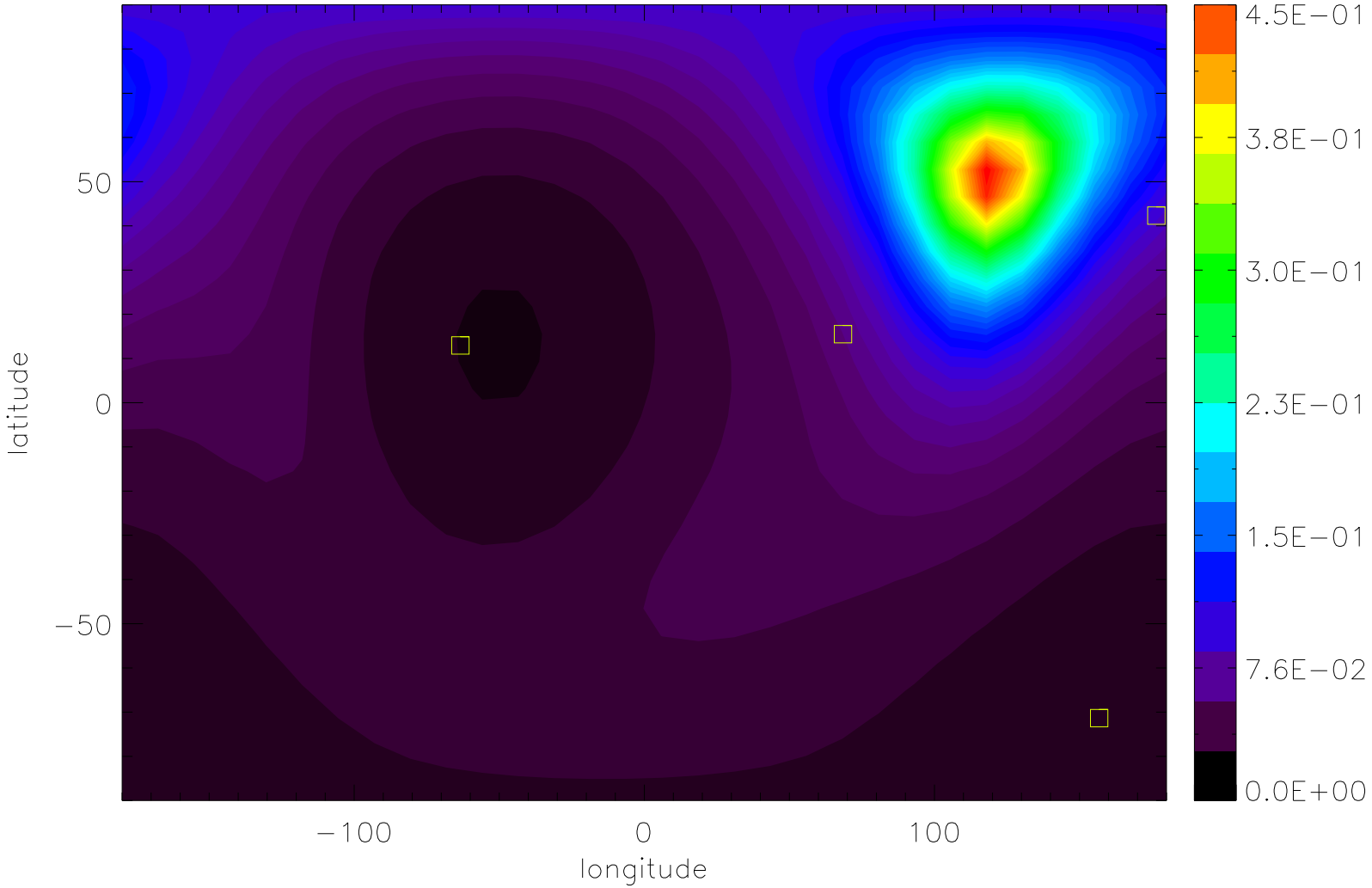
Power: Slice (θ, k)



Power: Slice (φ, k)



Power: Slice (φ, θ)



Results

- Source location:
  - distance: 540 km
  - longitude: 118°
  - latitude: 53°
- Wave length: 7200 km
- Frequency: 44.5 mHz

Conclusions

- We generalized the wave telescope technique to spherical waves
- In addition to the information provided by the wave telescope, the generalized method provides the distance to the source
- We have successfully located a wave source in the fore-shock
- Further work:
  - Consider Doppler effect
  - Determine source motion

Affiliation

1. Institute for Geophysics and Extraterrestrial Physics, Braunschweig, Germany

2. Institute for Space Sciences, Bucharest, Romania

3. Max-Planck Institute for Extraterrestrial Physics, Garching, Germany

Contact: d.constantinescu@tu-bs.de