Location of Wave Sources Using Cluster as a Sensor Array

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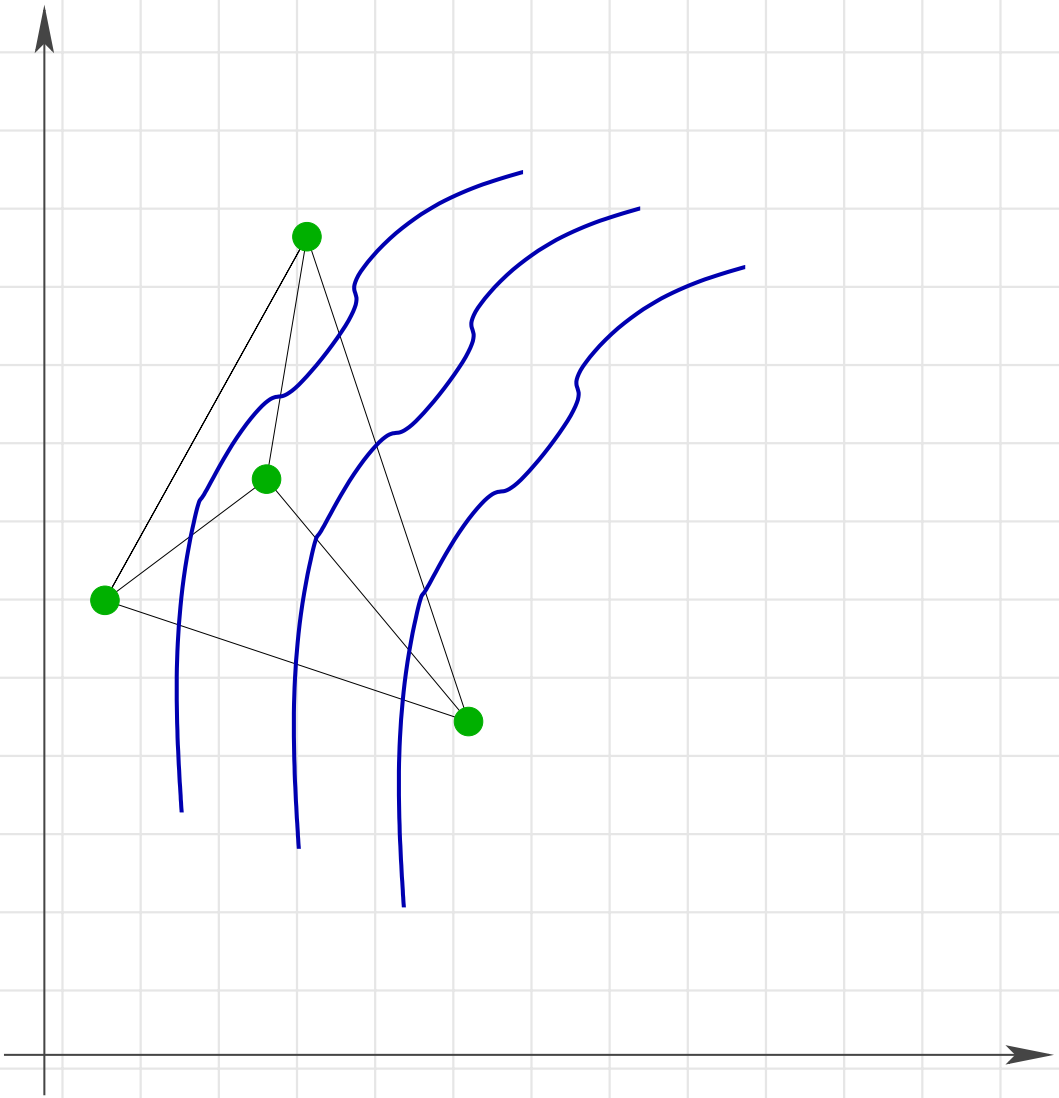
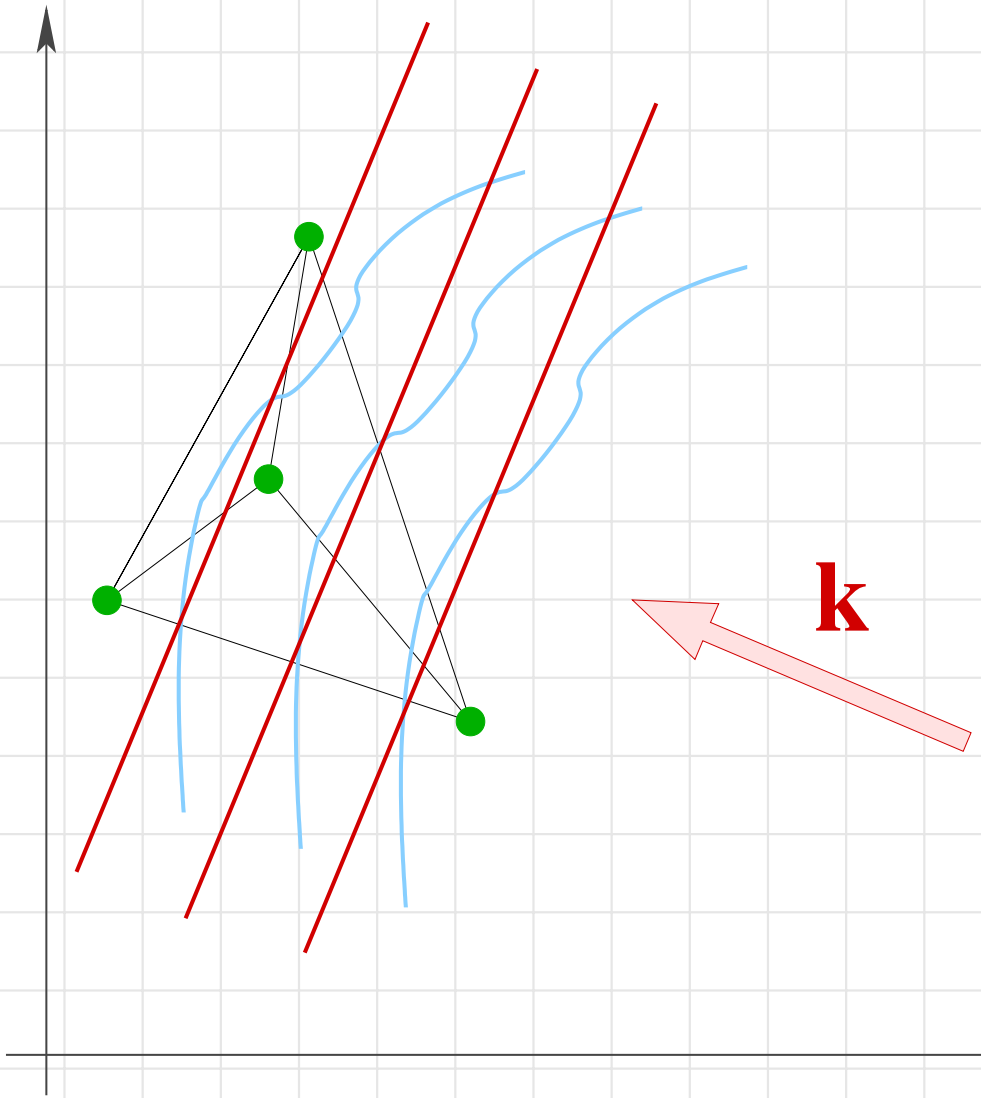
Outline

Plane Waves Representation



- sensor array
- measurements
- representation:
  - direction
  - wave length

Plane Waves Representation



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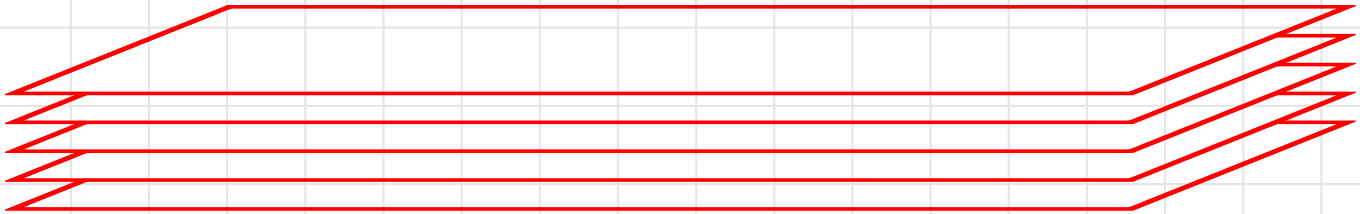
Wave Telescope / k-Filtering

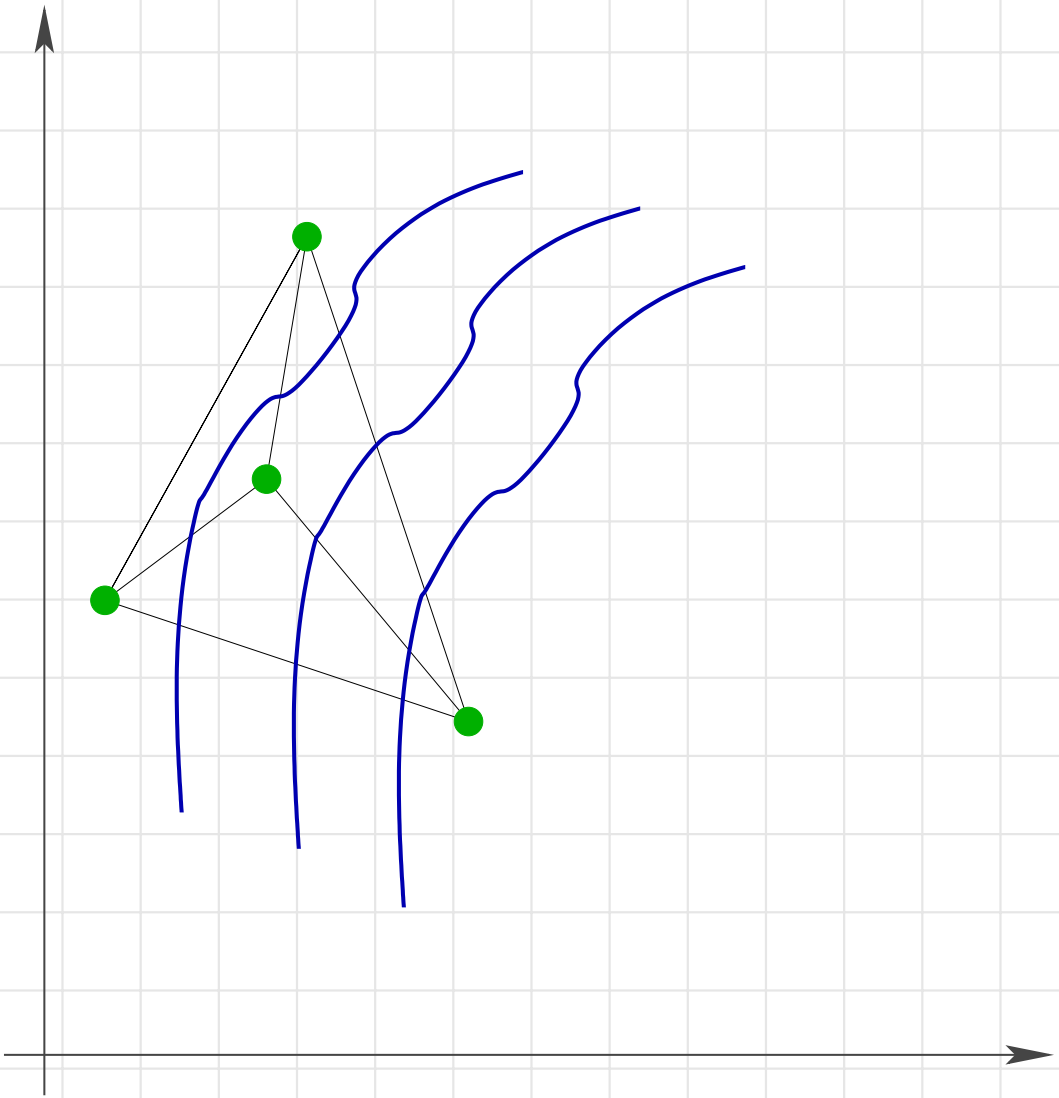


elementary wave $w_{\text{sensor}}(\boldsymbol{k'}) = Ce^{i\boldsymbol{k'}\cdot\boldsymbol{r}_{\text{sensor}}}$

array output matrix $\mathcal{B}_{ij} = B_i B_j$

output power $P(\boldsymbol{k'}) = [\boldsymbol{w}^{\dagger}(\boldsymbol{k'})\mathcal{B}^{-1}\boldsymbol{w}(\boldsymbol{k'})]^{-1}$

Spherical Waves Representation



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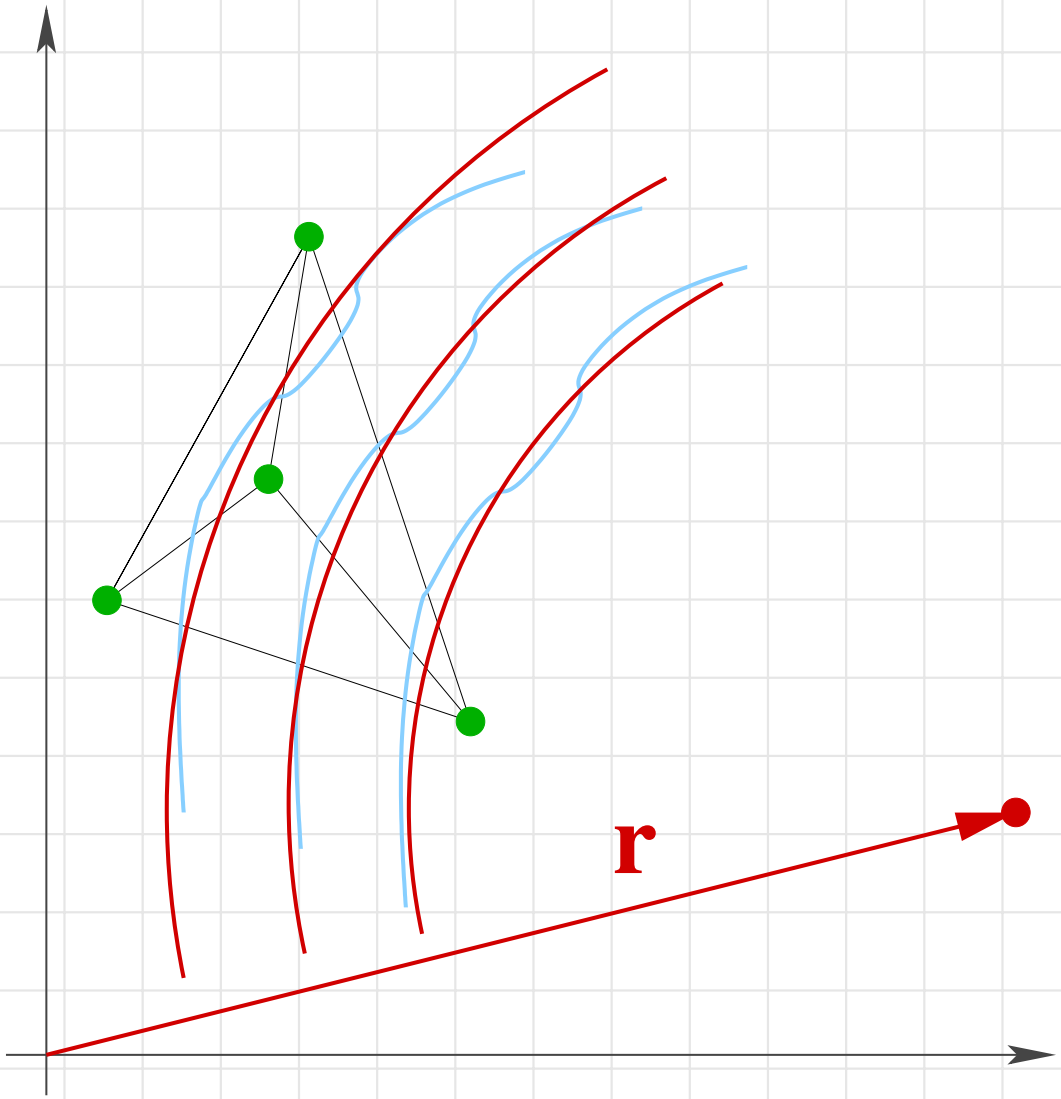
Spherical Waves Representation



- sensor array
- measurements
- representation:
  - position
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Source Locator

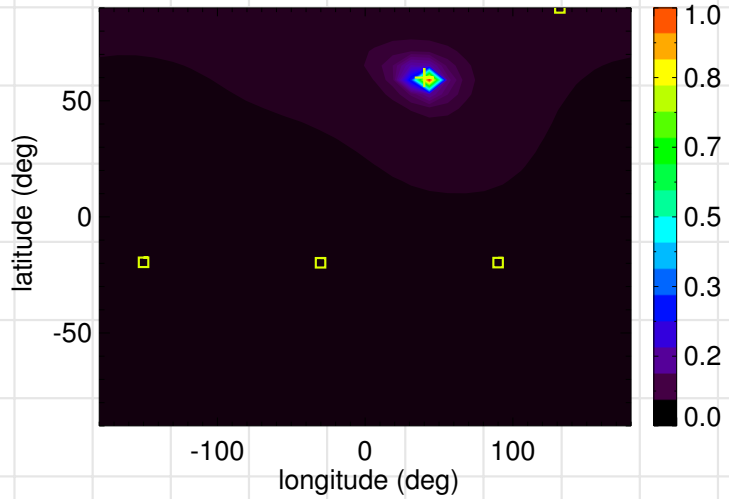
elementary wave $$w_{\text{sensor}}(k', \boldsymbol{r'}) = C \frac{1}{\rho'_{\text{sensor}}} e^{ik'\rho'_{\text{sensor}}}$$

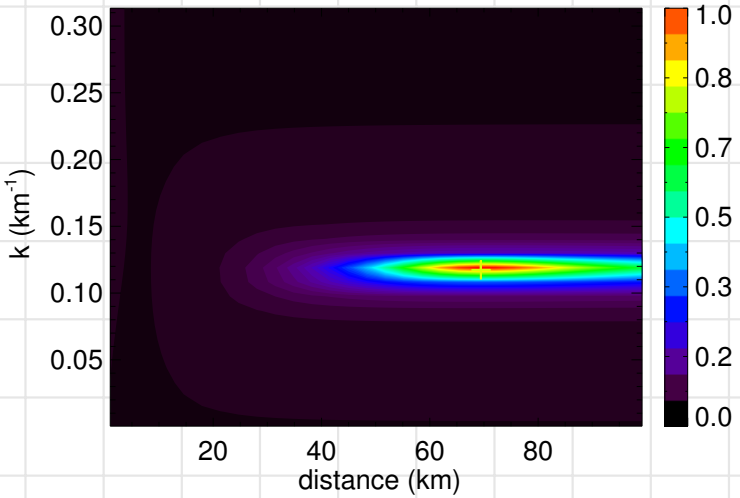
array output matrix $$\mathcal{B}_{ij} = B_i B_j$$

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

Artificial Data: Stationary Source

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

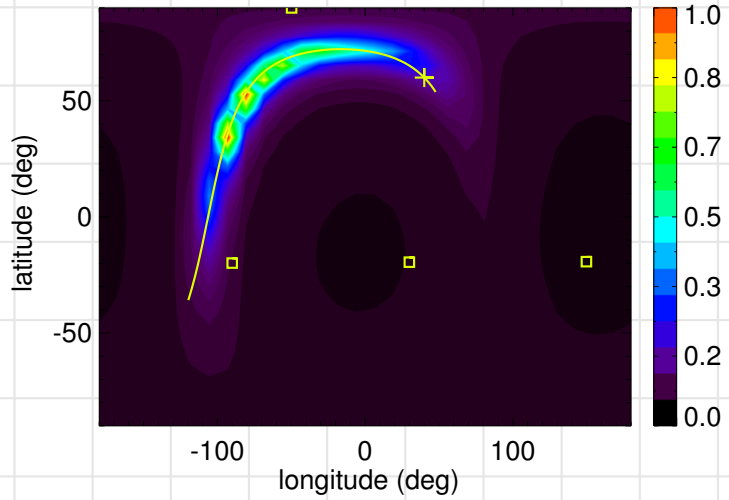




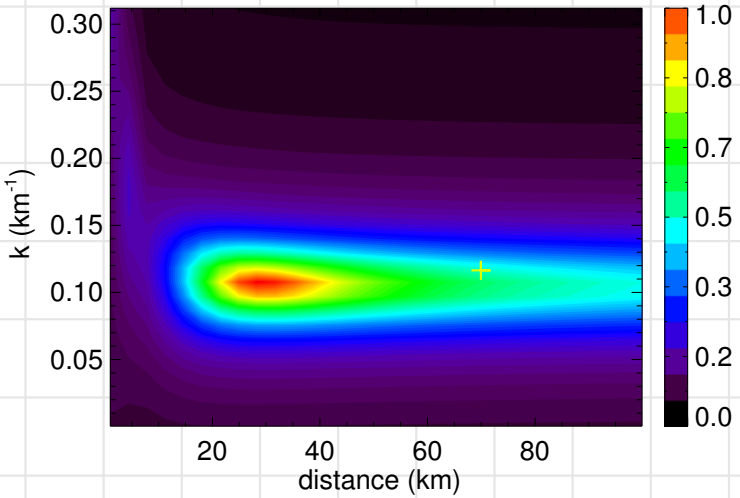
	given	found
dist.	70 km	69 km
long.	40°	43°
lat.	60°	59°
k	0.11 km^{-1}	0.10 km^{-1}

Artificial Data: Moving Source

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

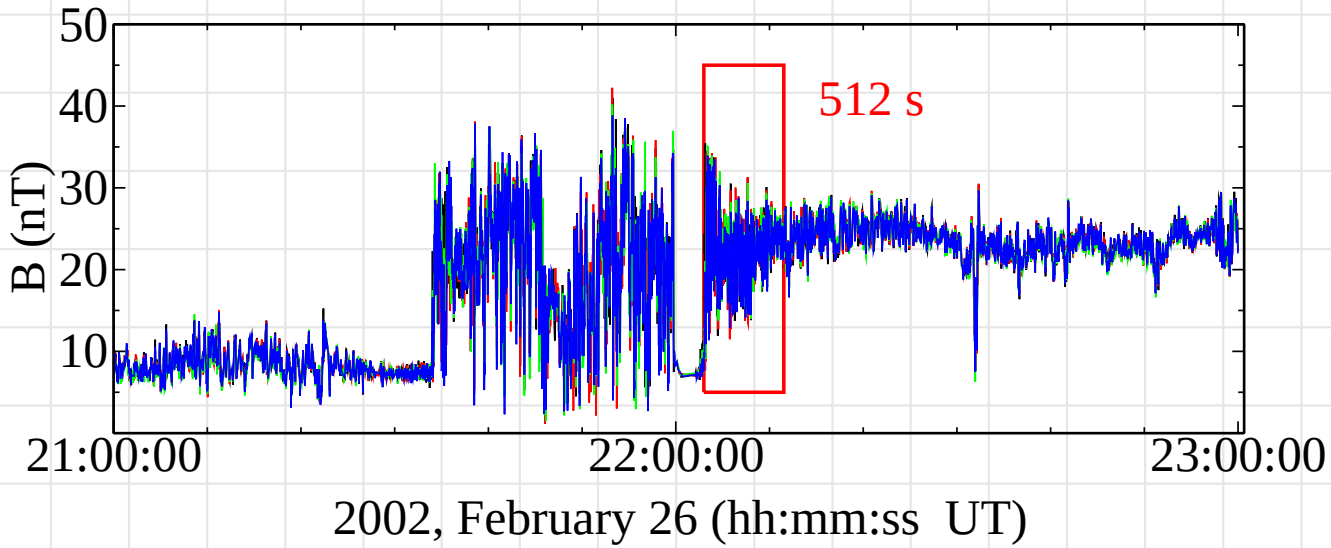


	closest	found
dist.	21 km	28 km
long.	$-91°$	$-93°$
lat.	39°	34°
k	0.11 km^{-1}	0.10 km^{-1}



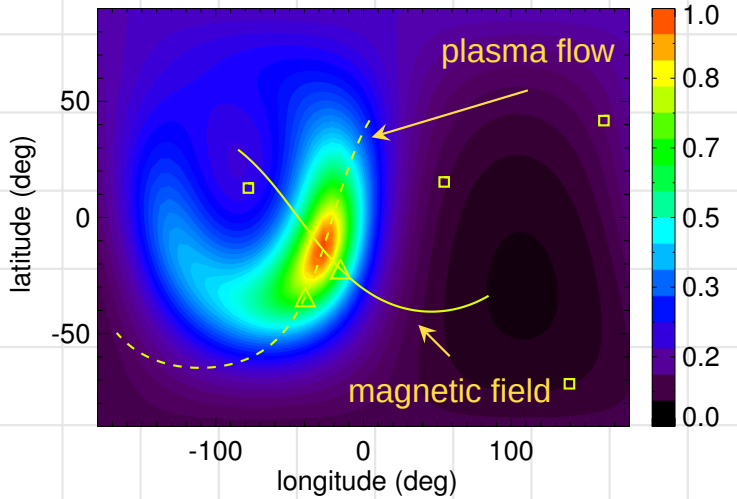
Cluster Data

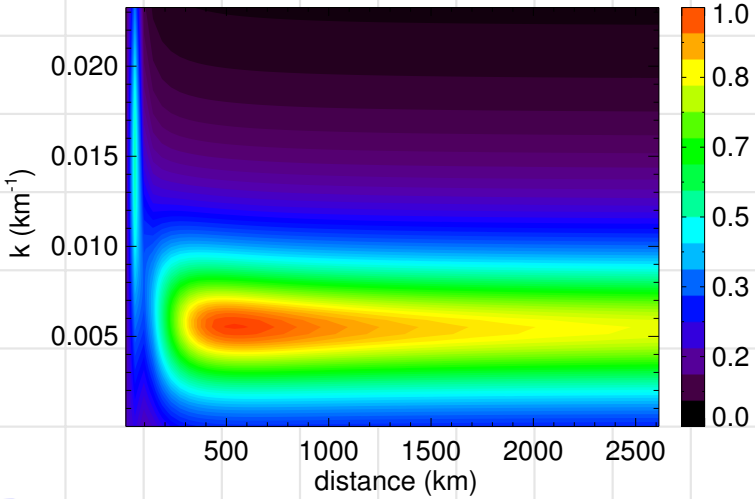
Time interval:	2002 February 26, 22:03 – 22:11 UT
Location:	magnetosheath
Plasma flow velocity:	140 km/s [-97, -14, -101] km/s
Spacecraft separation:	between 87 and 135 km
Maximum variance:	parallel with mean magnetic field

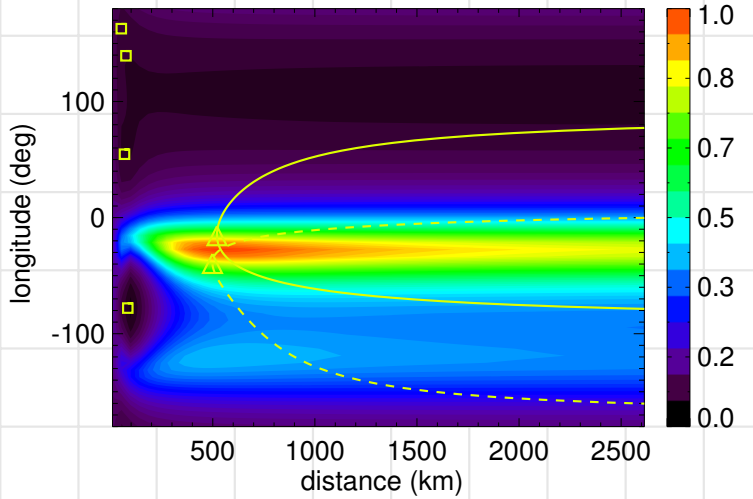


Cluster Data: Close Moving Source

frequency:	66 mHz
wave length:	1142 km
distance:	538 km
longitude:	-27°
latitude:	-13°

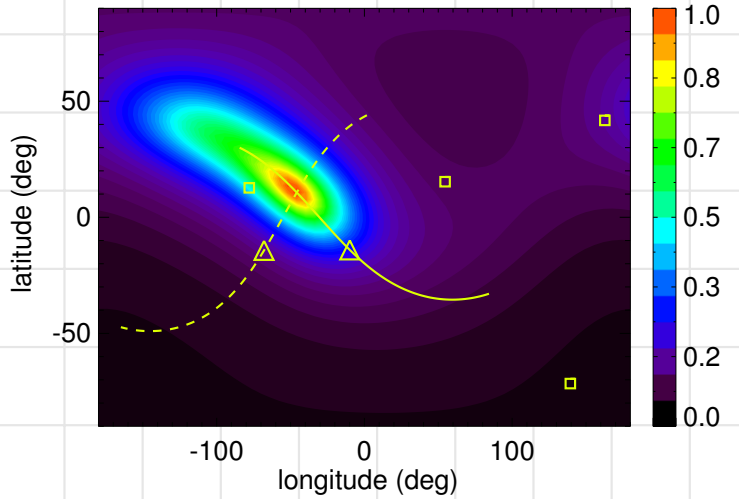


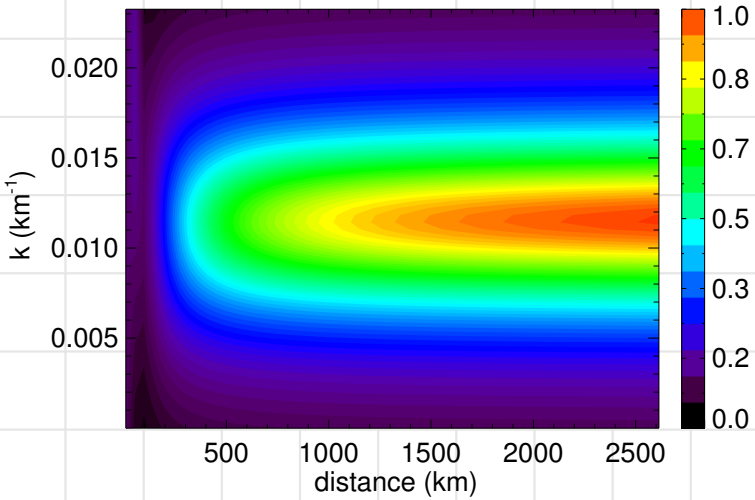


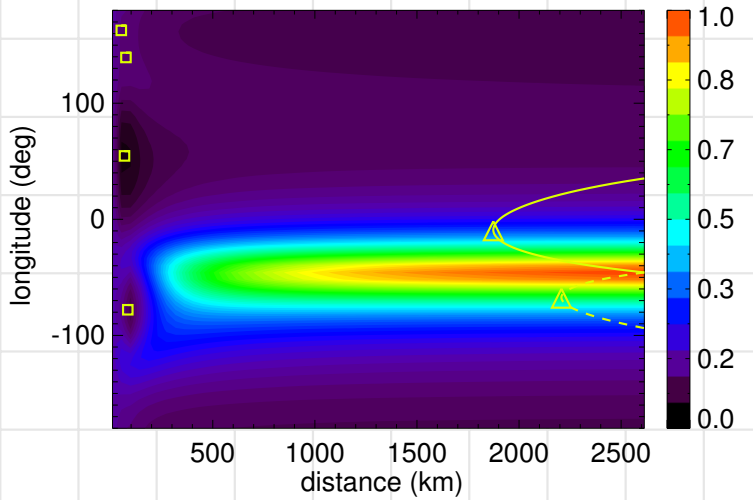


Cluster Data: Distant Elongated Source

frequency:	181 mHz
wave length:	551 km
distance:	$>$ 2500 km
longitude:	-45°
latitude:	-10°







Conclusions

1. Source locator is the generalization of the wave telescope technique to spherical waves.
2. Source locator determines a virtual source: Local curvature center of the detected wave fronts.
3. A virtual source is a representation of a real wave source.
4. Source locator provides information about the motion and shape of the wave sources.
5. We have identified a wave source in the magnetosheath, close to the shock.
6. Future work needs to take into account wave mode information.

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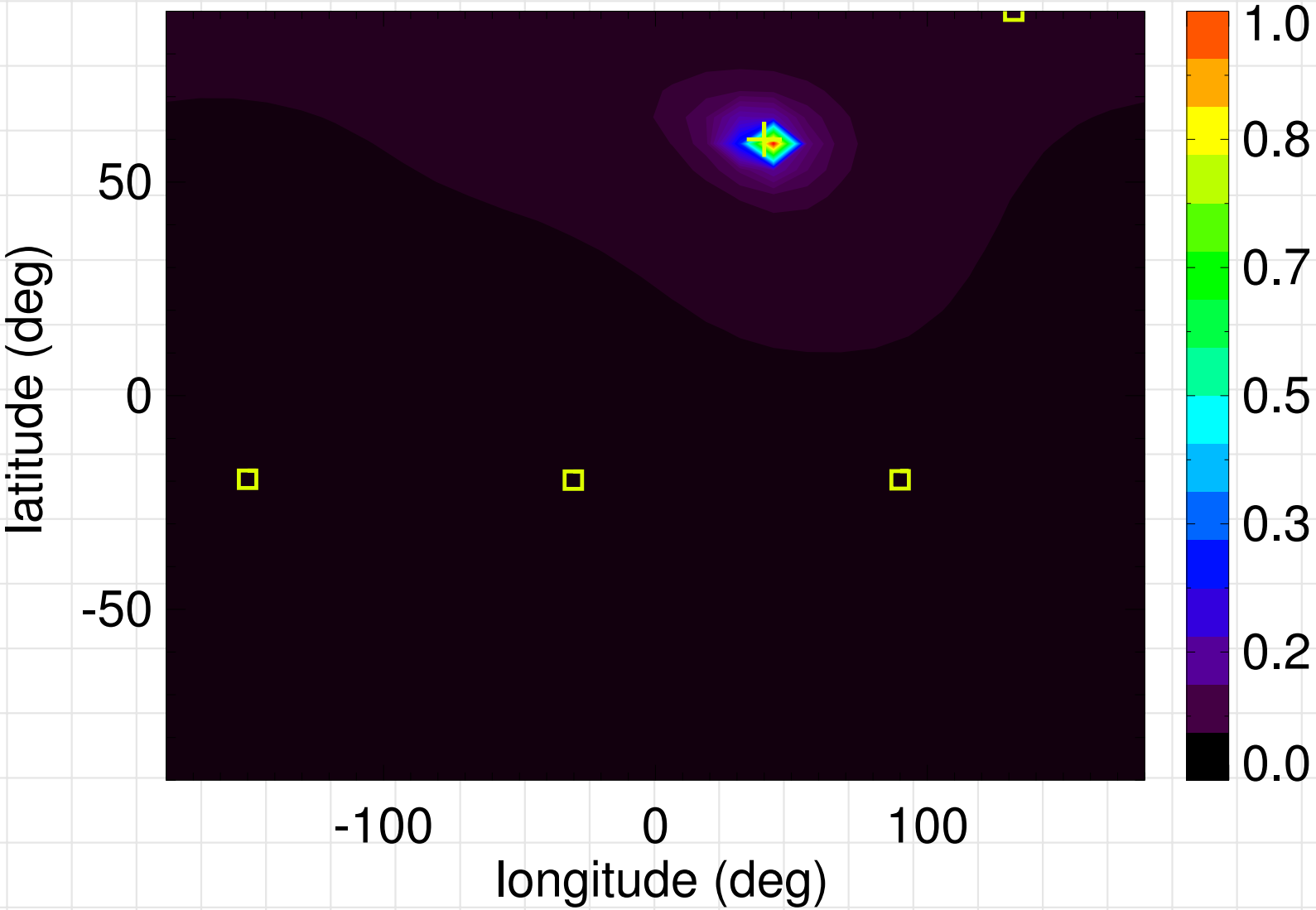

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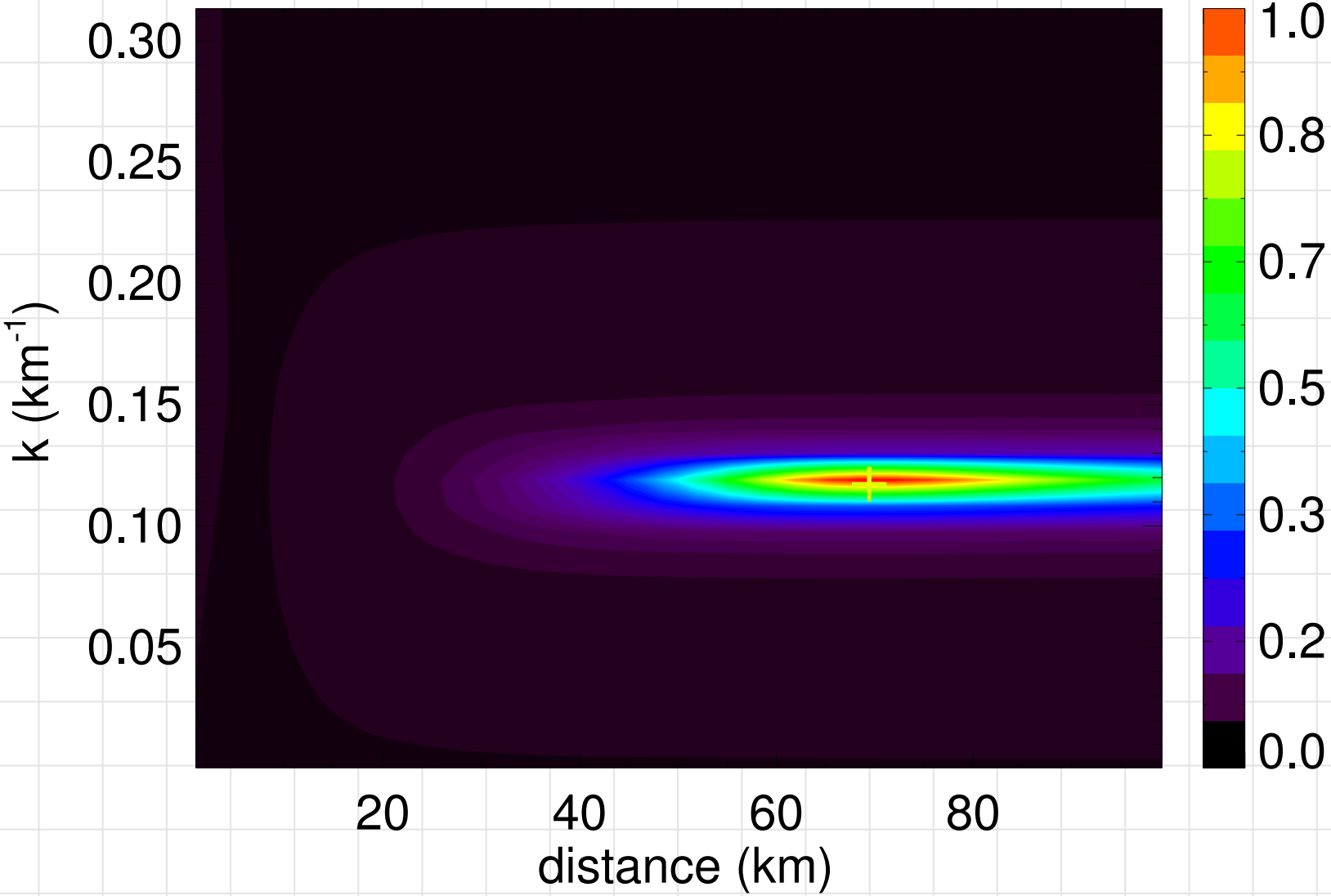

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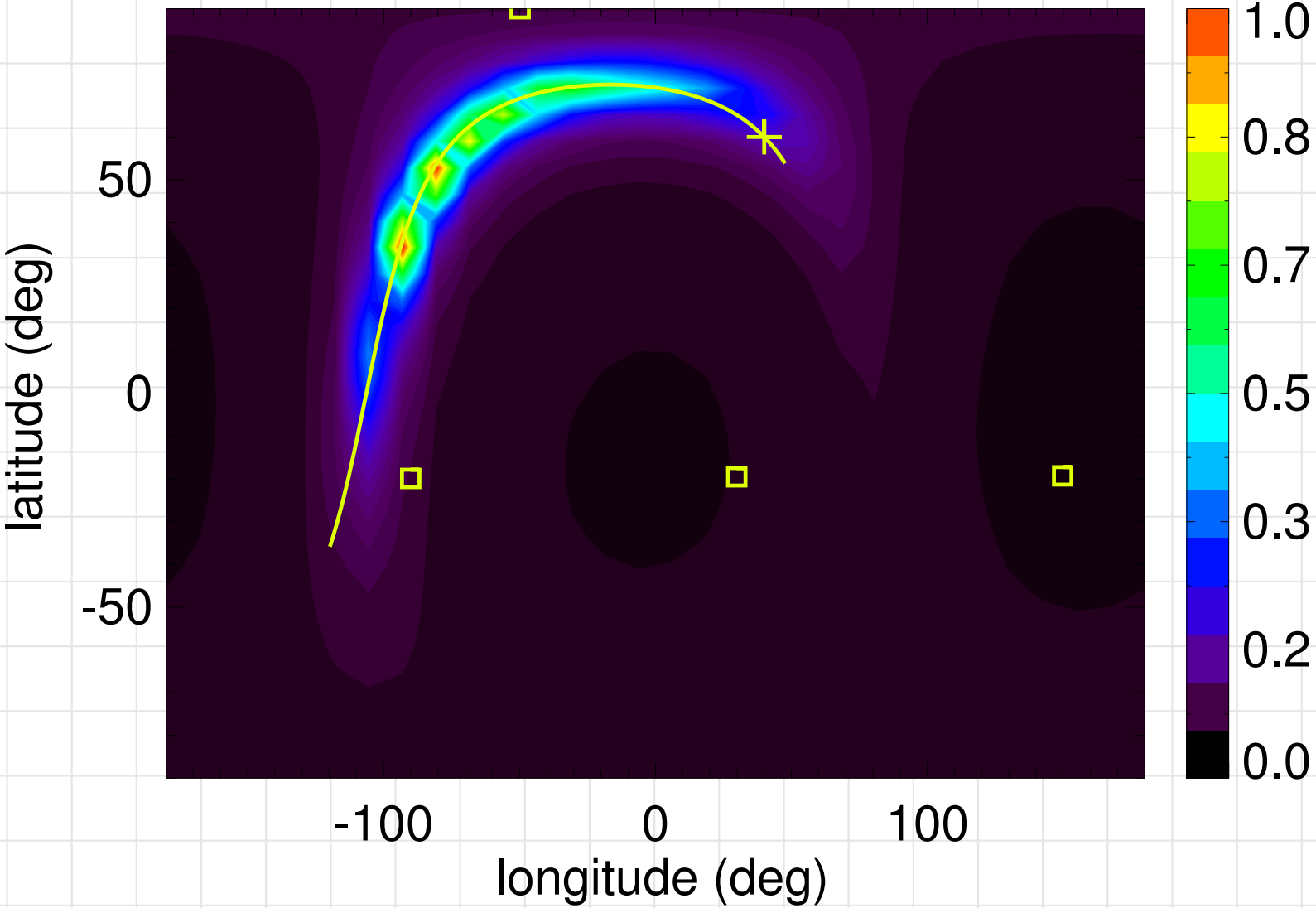

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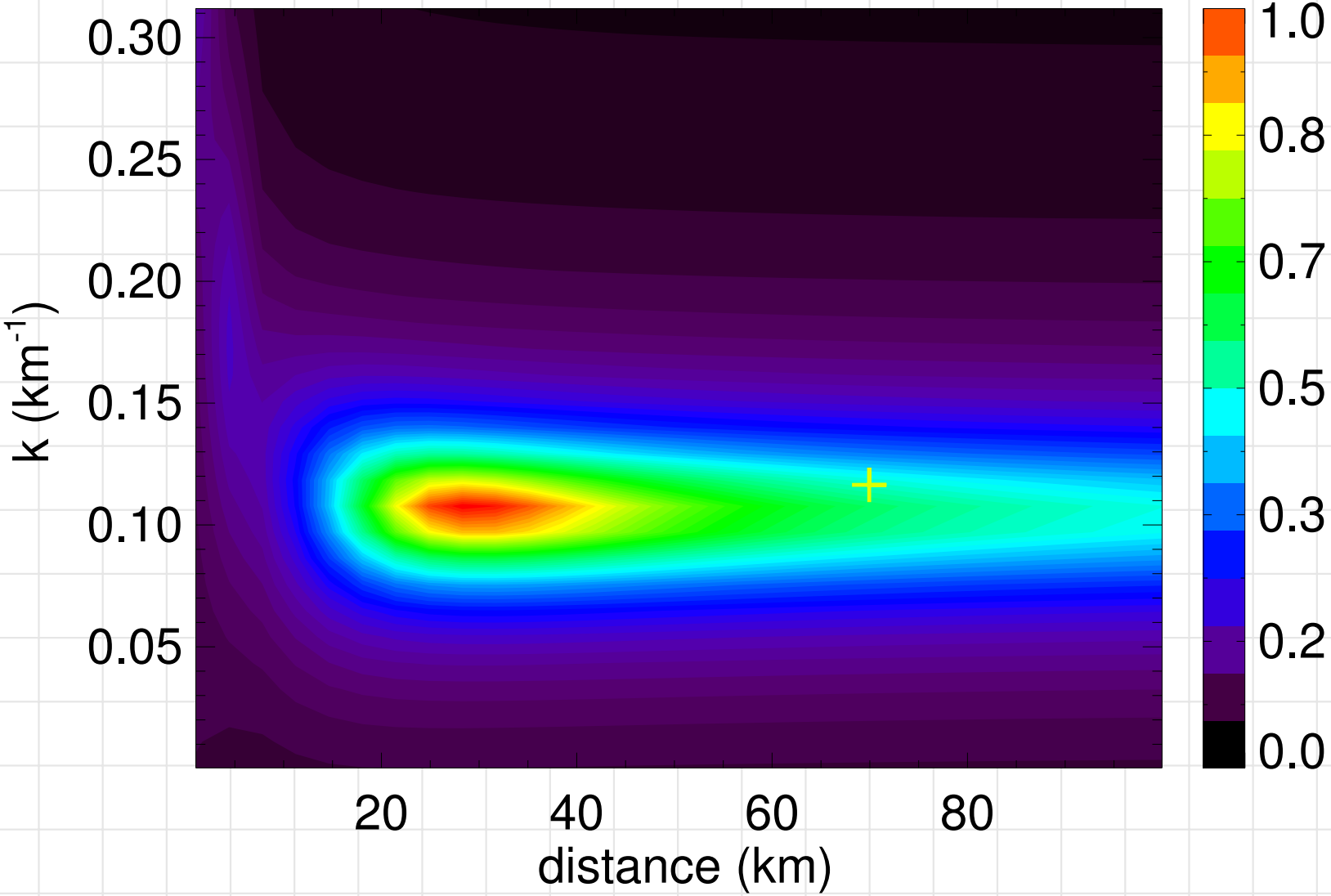
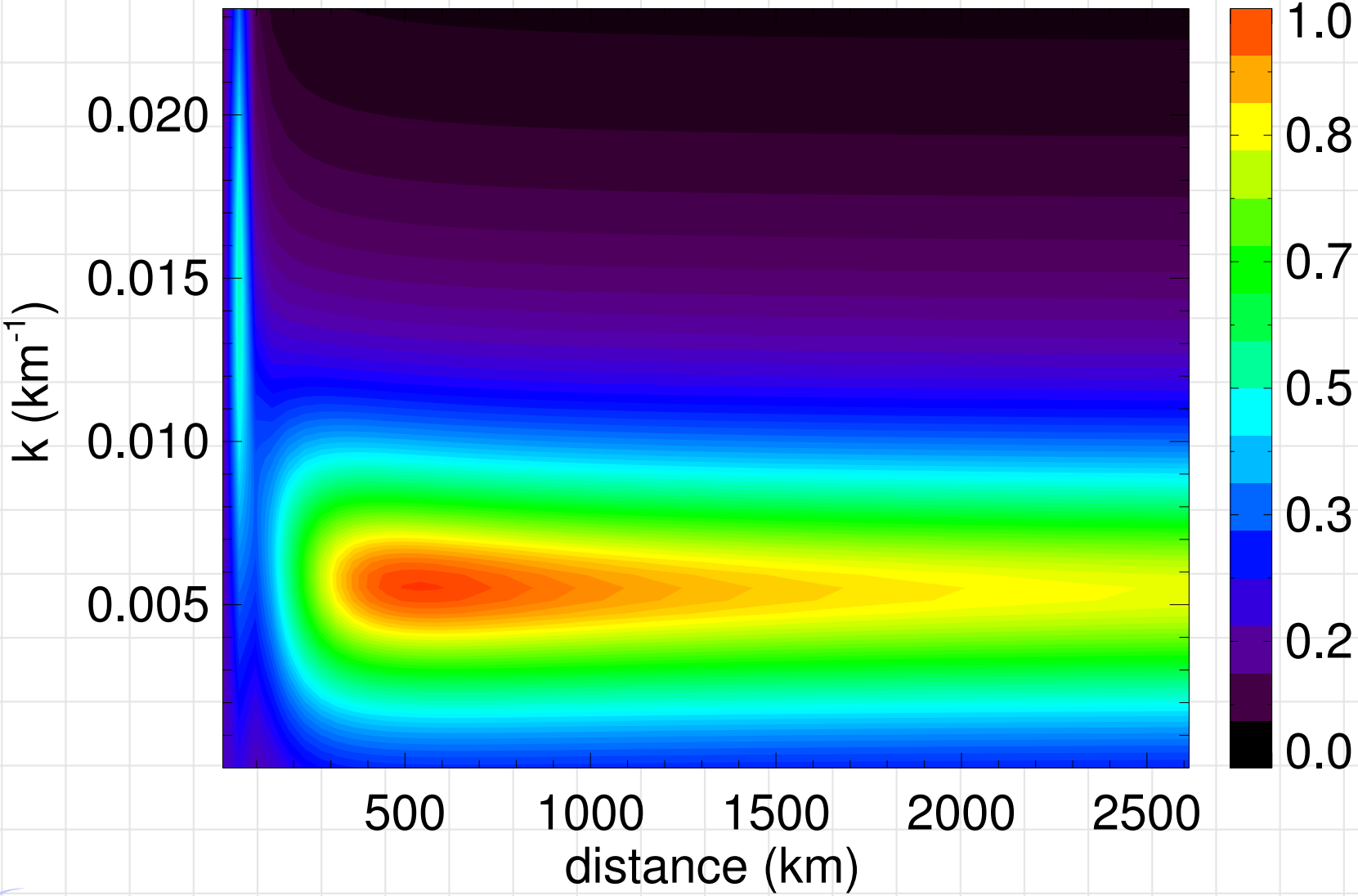


Cluster Data: Close Moving Source



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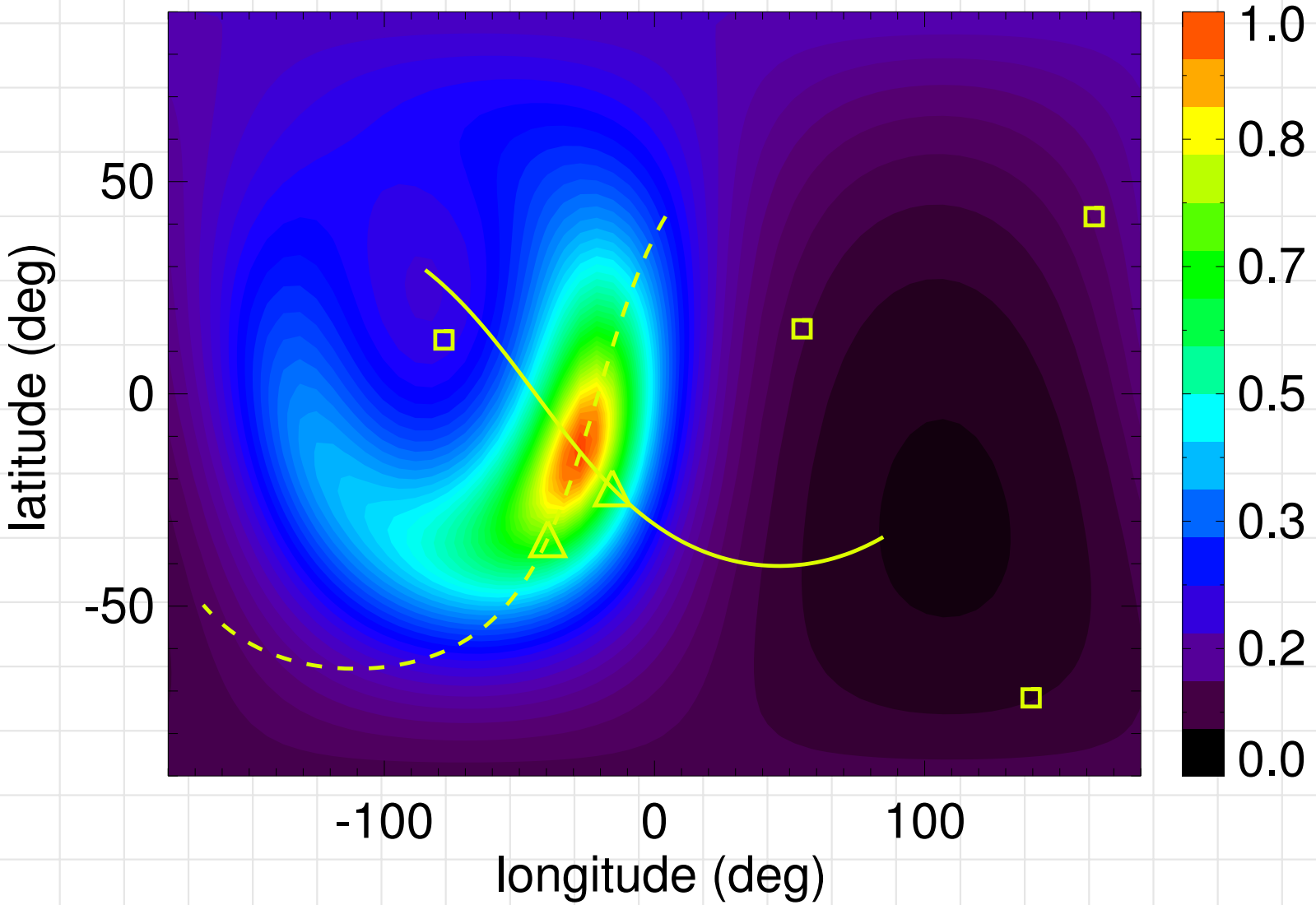

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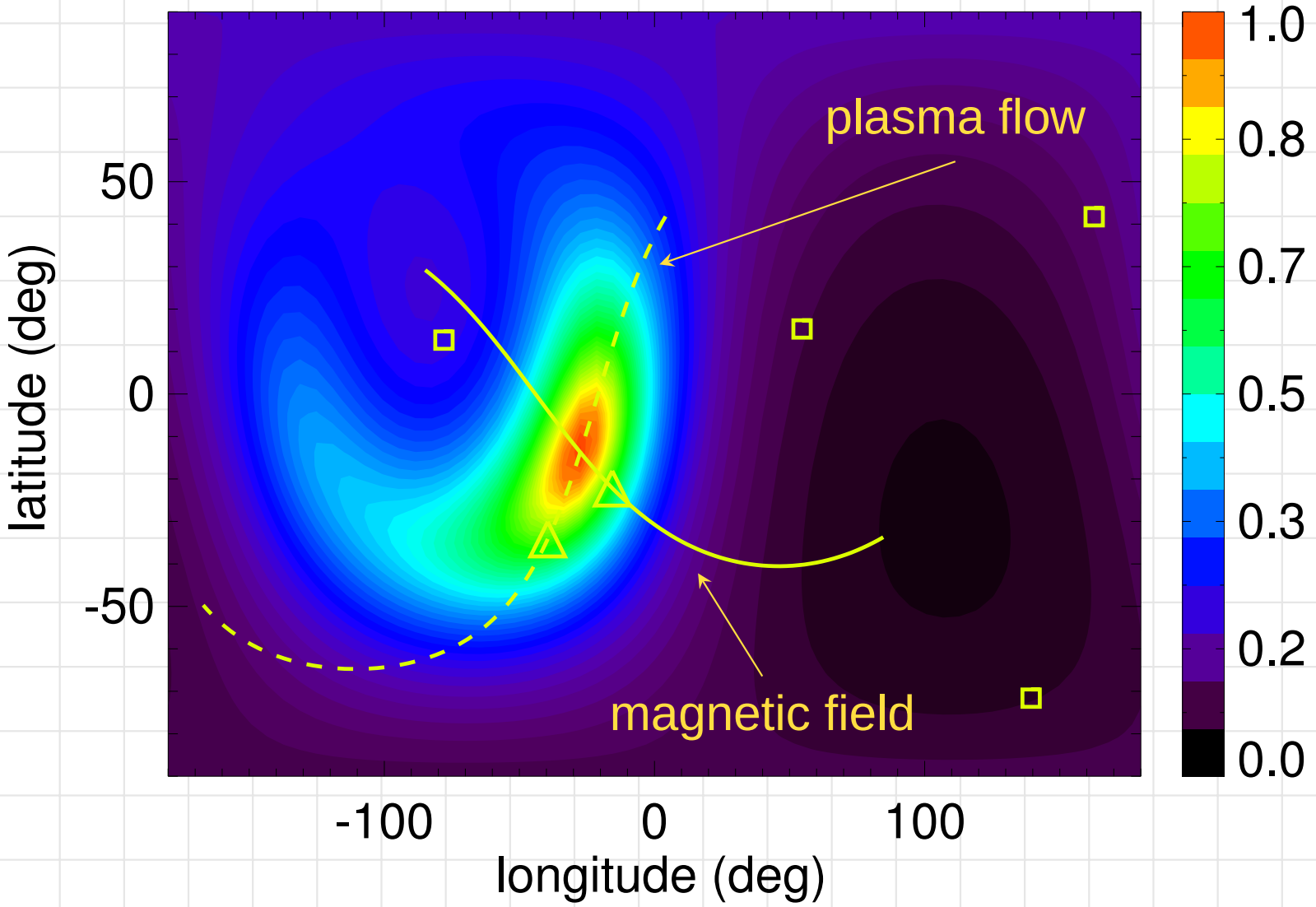

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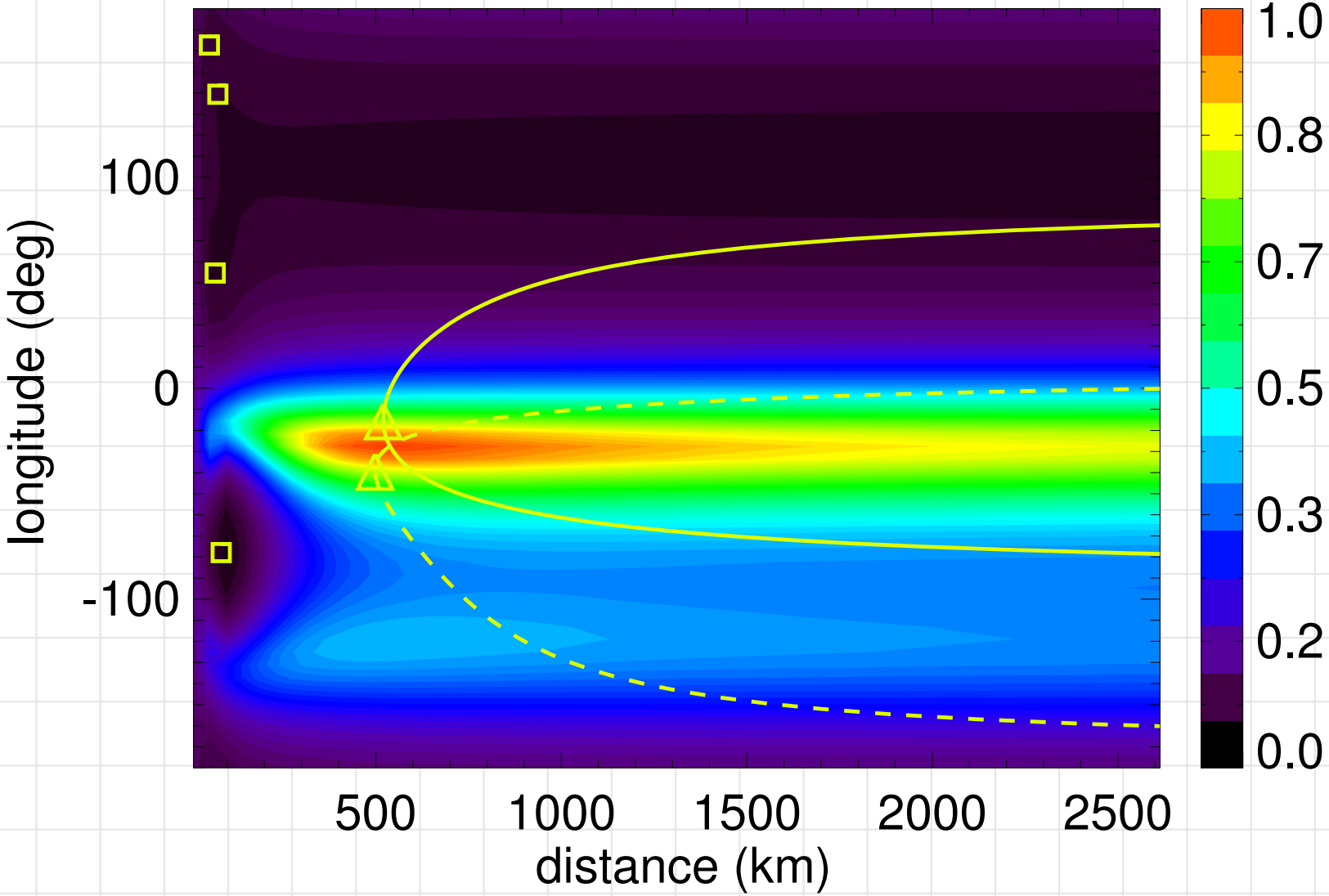

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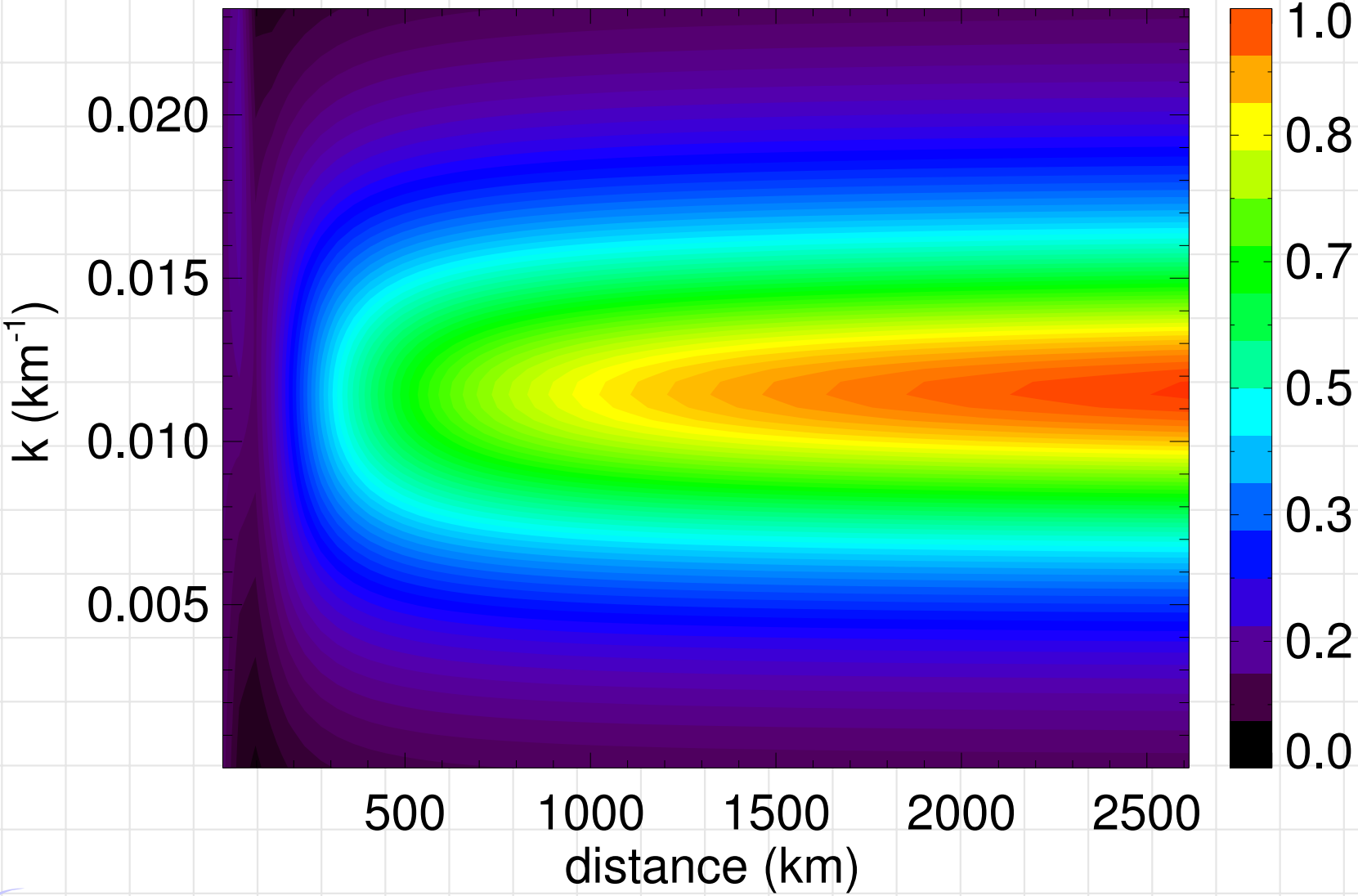

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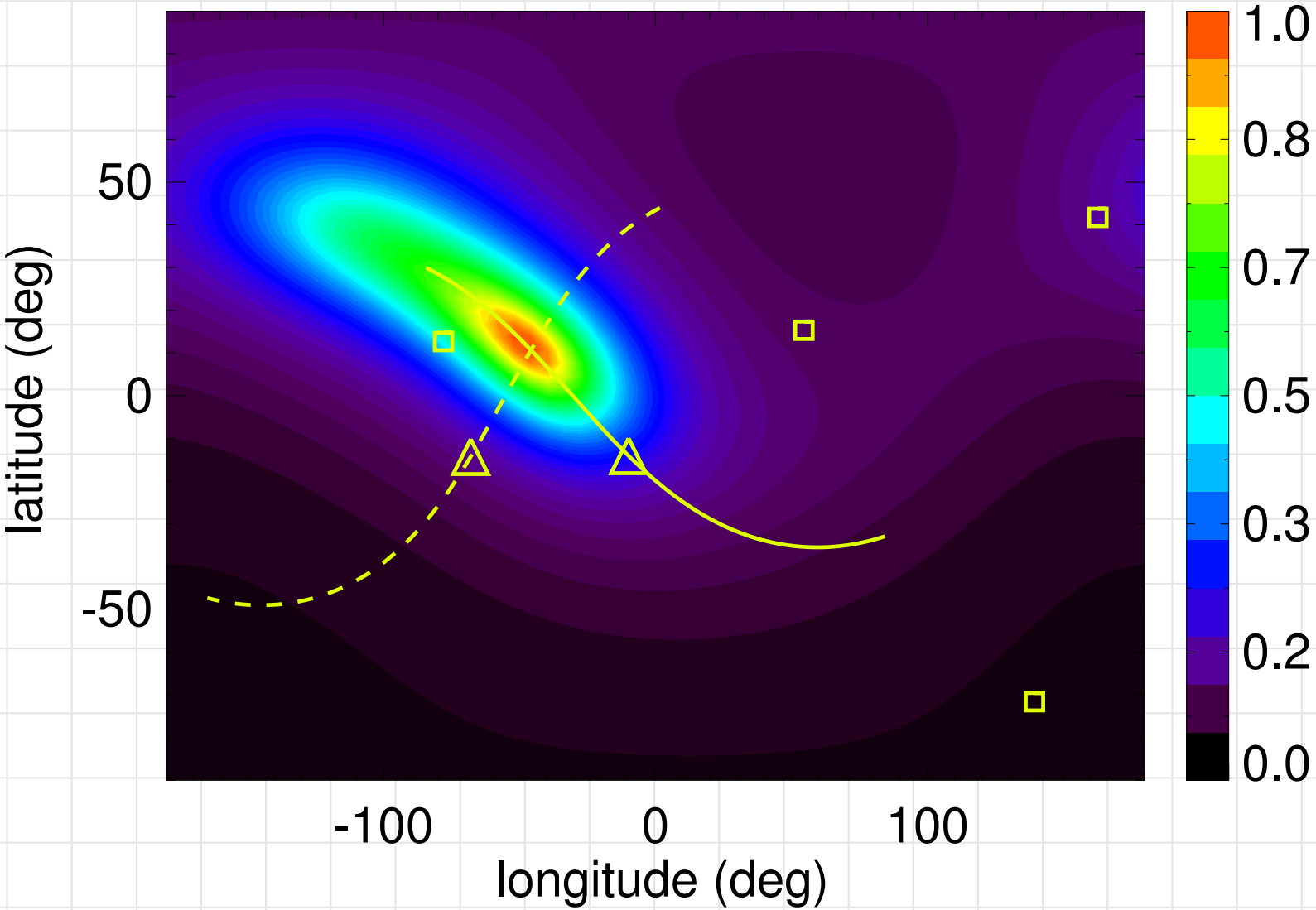

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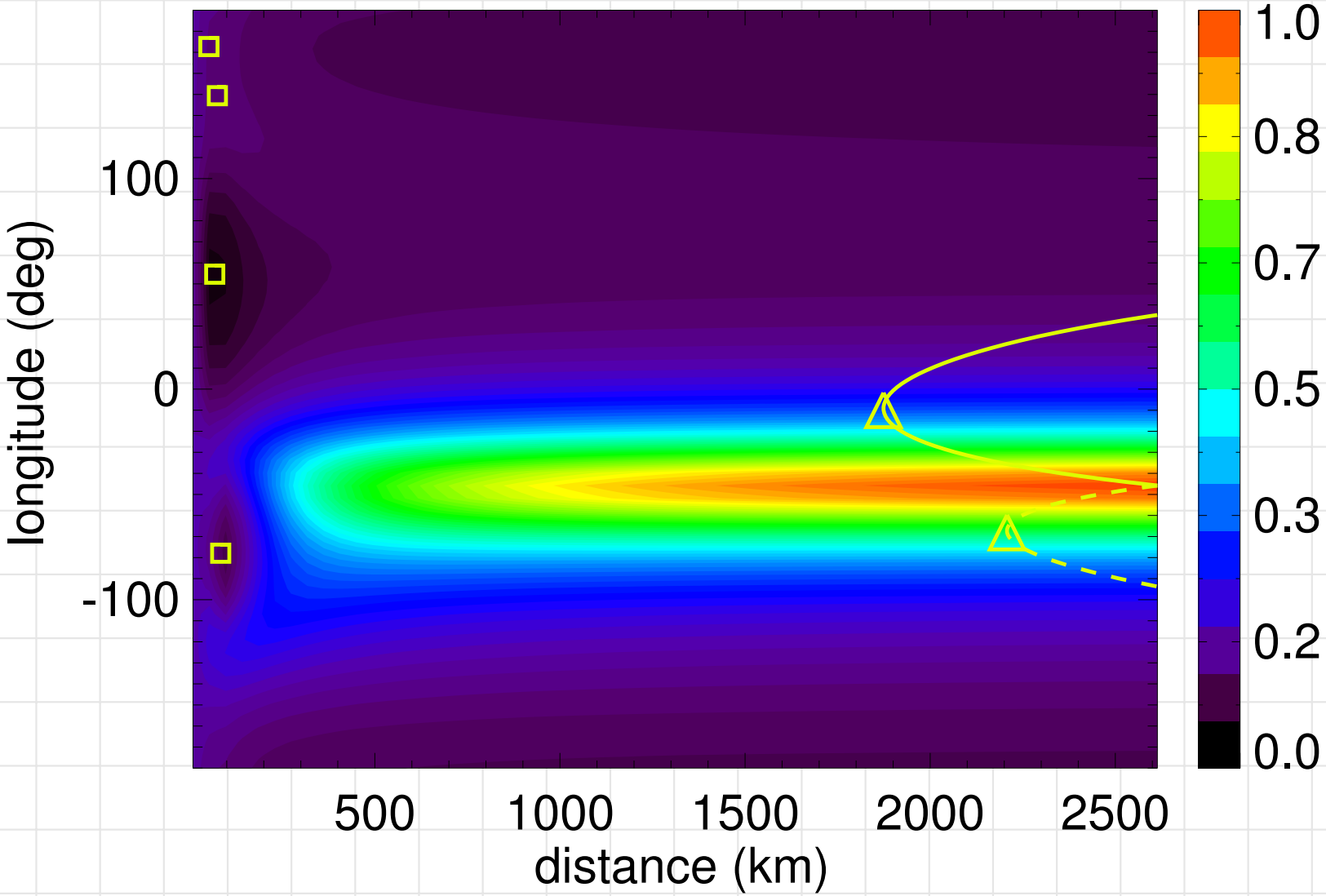

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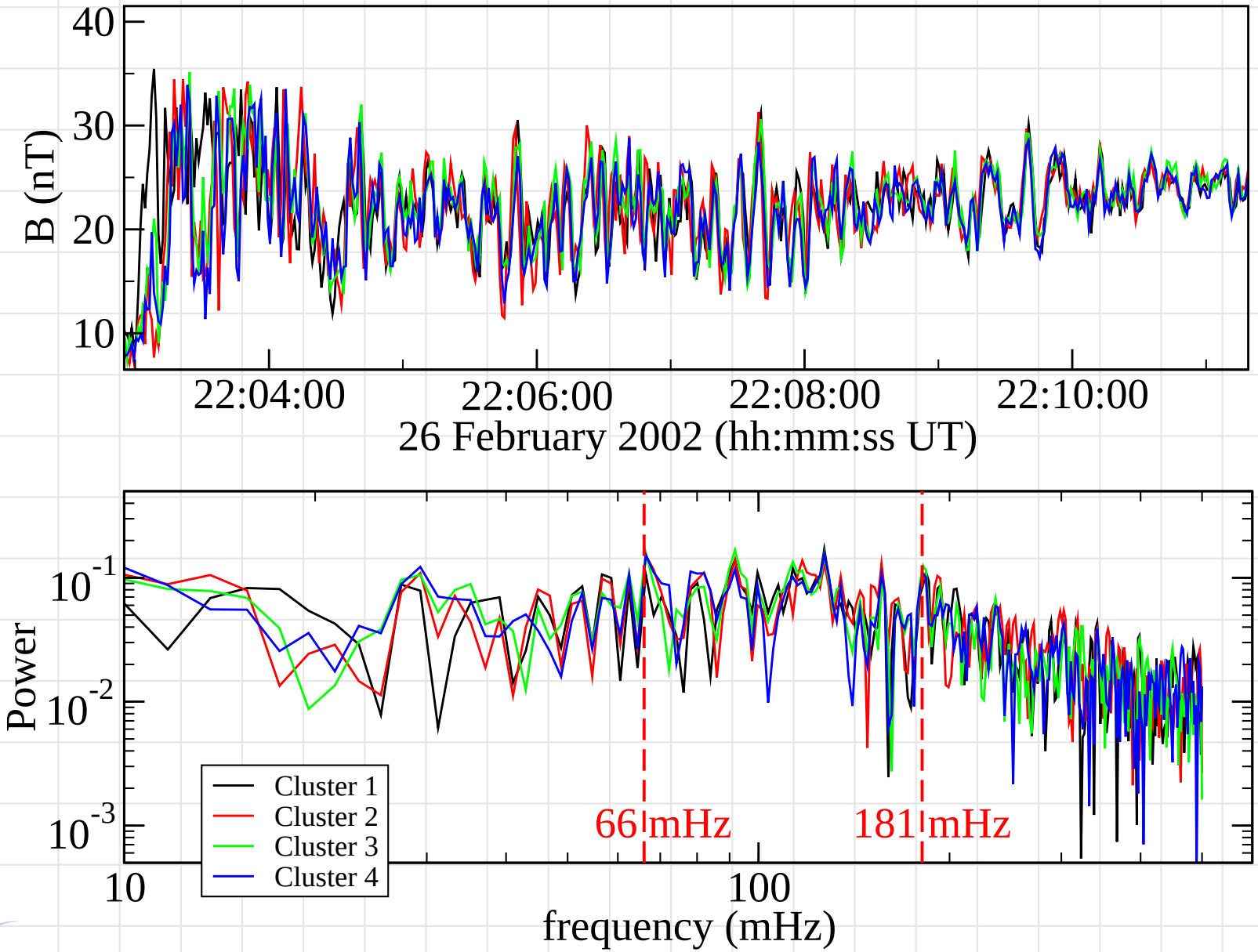
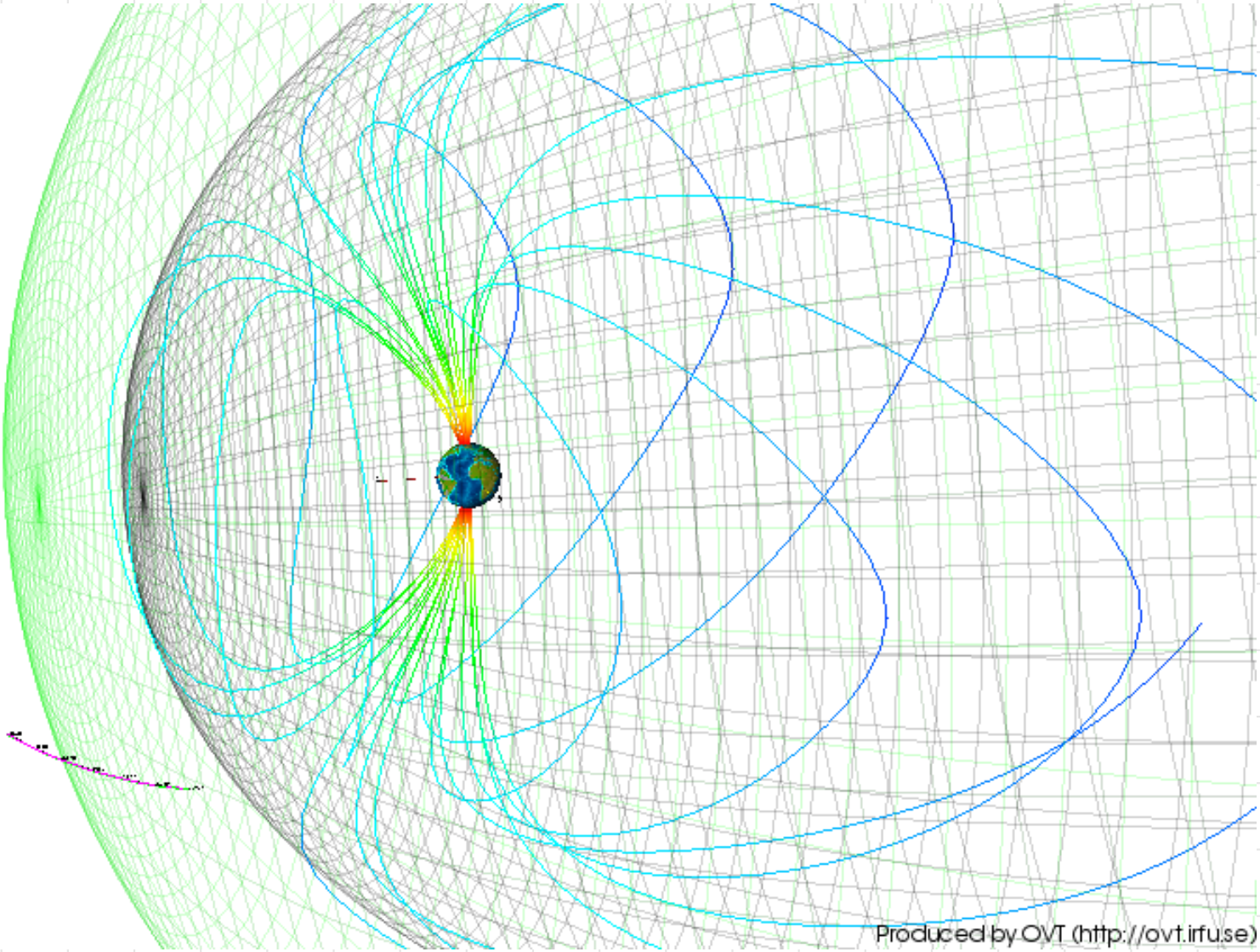
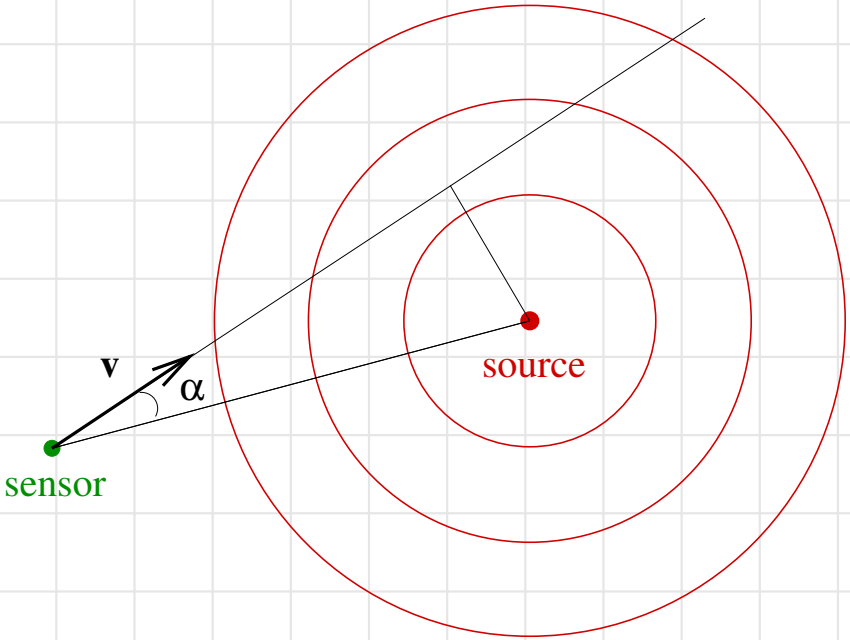


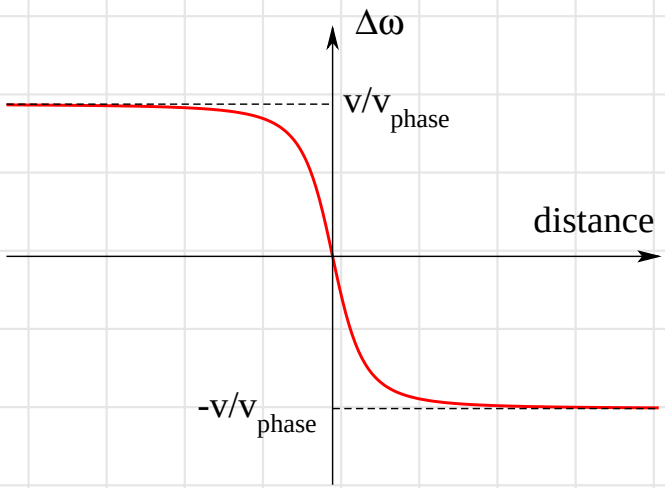
Orbit, 18:00 – 24:00



Doppler Effect

$$\omega(t) = \omega_0 \left[1 - \frac{v}{v_{phase}} \cos\alpha(t)\right]$$





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