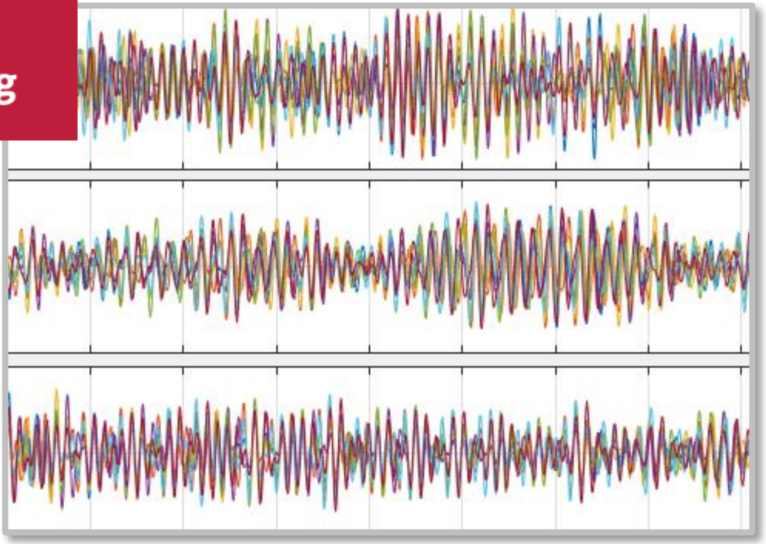

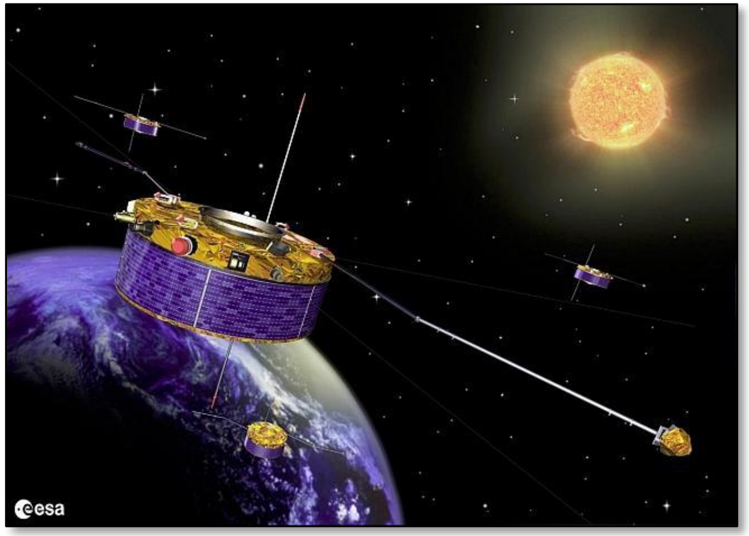

Revisiting the wave telescope for larger numbers of spacecraft

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Right image: ESA, available at: https://earth.esa.int/documents/163813/469993/Cluster_Auto1A [05.03.2020]

Motivation/Problem

Wave telescope (e.g. Motschmann et al. 1996, JGR) uses few spatial points (**spacecraft**) to **estimate spatial fourier transform**

→Able to find **wave vectors** in magnetic field data

Currently 4 S/C (MMS, Cluster)

→ But can be used with larger numbers of S/C! (e.g. HelioSwarm)

Some arising questions:

- What are the advantages of more satellites? → Better resolution, **increased number of waves resolved**
- **What is the Nyquist limit** for larger numbers of S/C?
- **What happens to the spatial blindness** for more than 4 S/C?

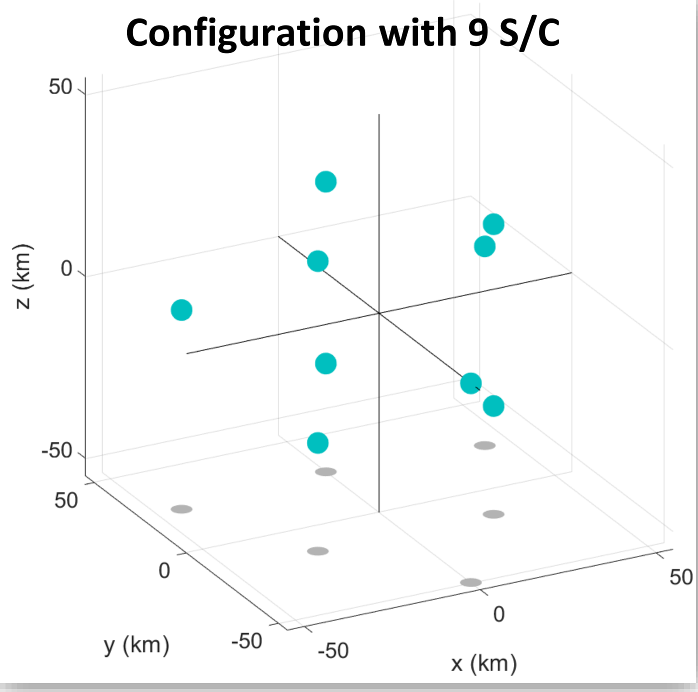
→ **Simulations**

Number of detectable waves

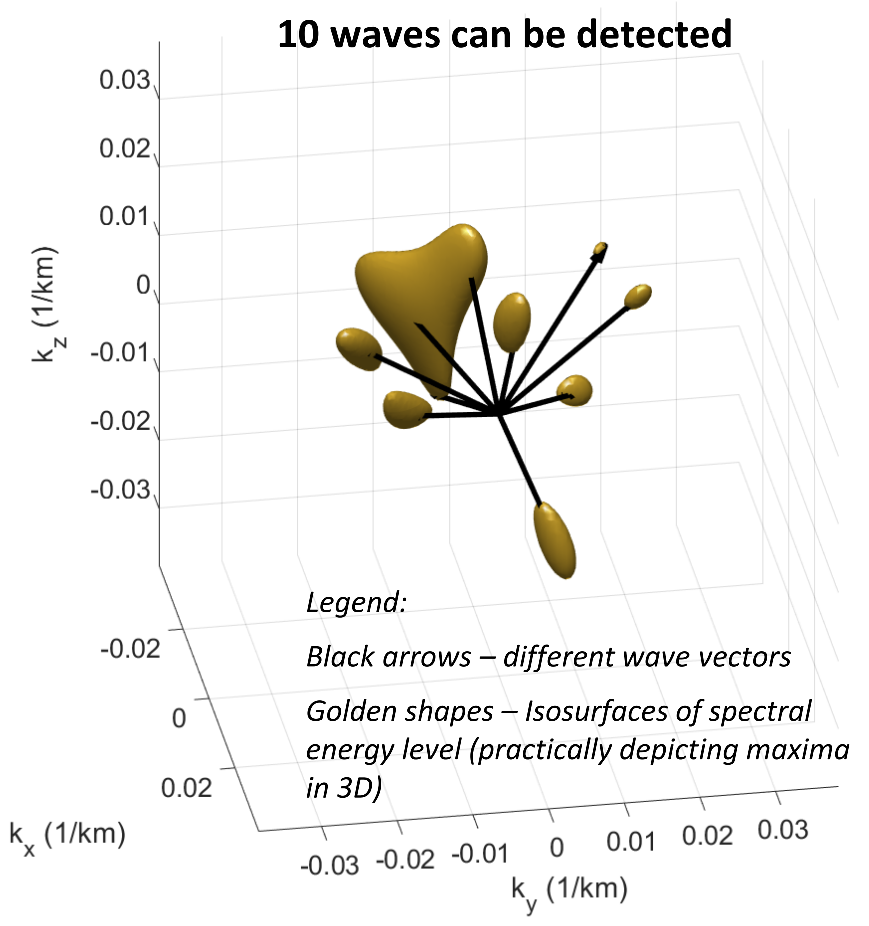
Theoretical limit of 3*n-1 waves (e.g. Tjulin et al. 2005) is never reached (e.g. Motschmann et al. 1996, JGR → 7 waves, 4 S/C; own simulations)

Higher number of S/C can increase the number of detected waves!

For example:



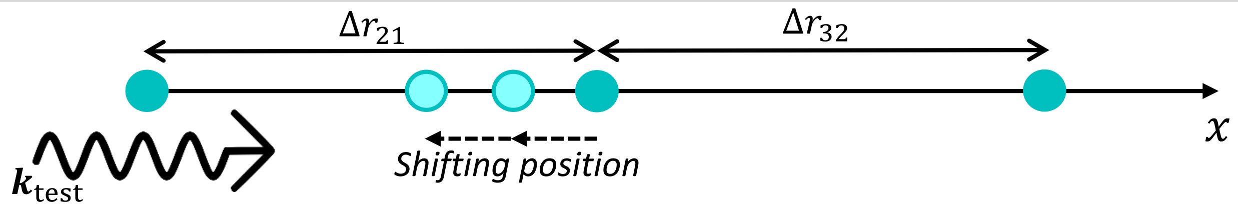
→



Nyquist limit in 1D

3 S/C configuration:

Center S/C position shifted in every simulation

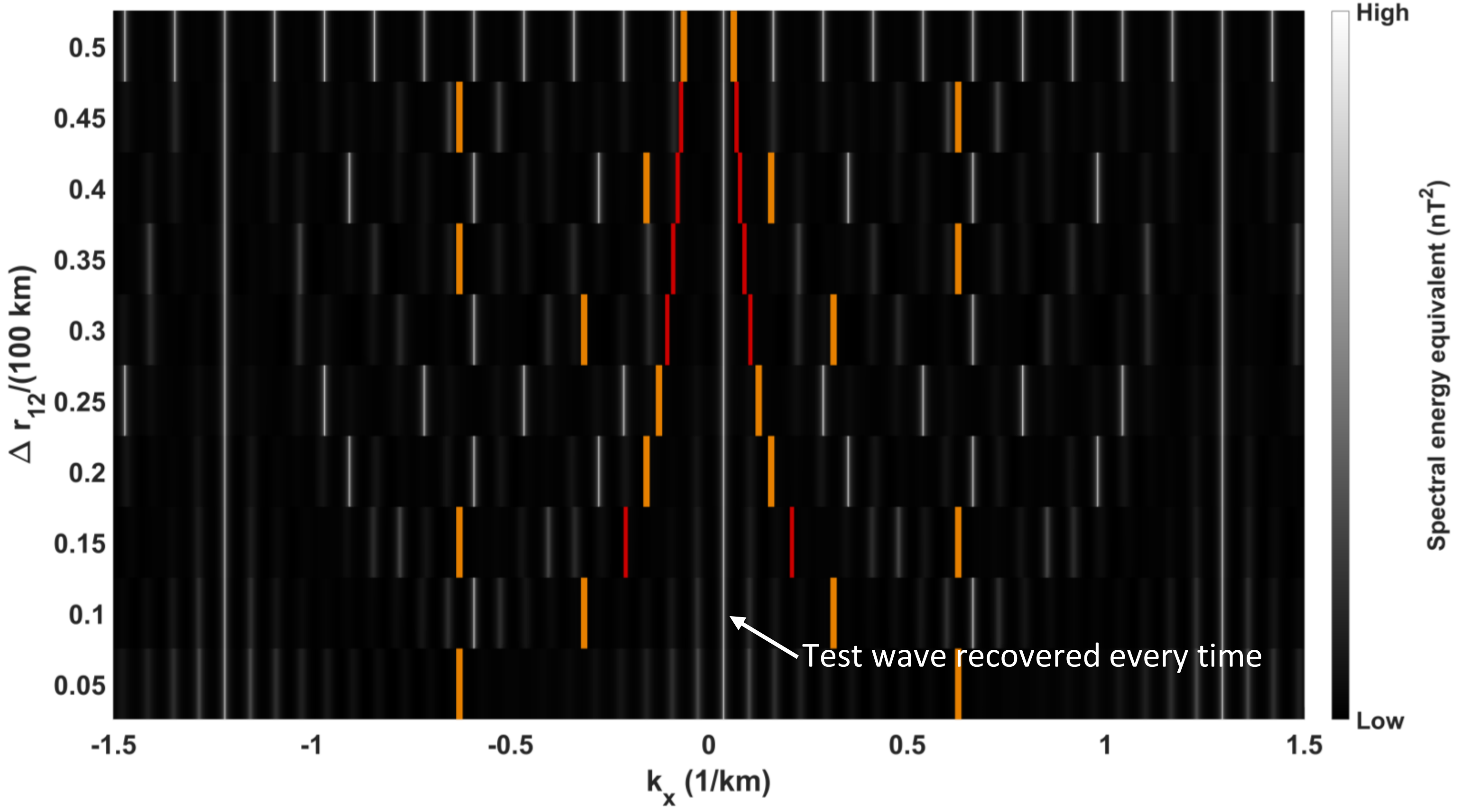


Nyquist wave vector defined by spacecraft distances:

2 S/C: $k_{\text{Ny}} = \frac{\pi}{\Delta r_{21}}$

3 S/C: $k_{\text{Ny}} = \frac{\pi}{\gcd(\Delta r_{21}, \Delta r_{32})}$

Implications for 2D and 3D case!



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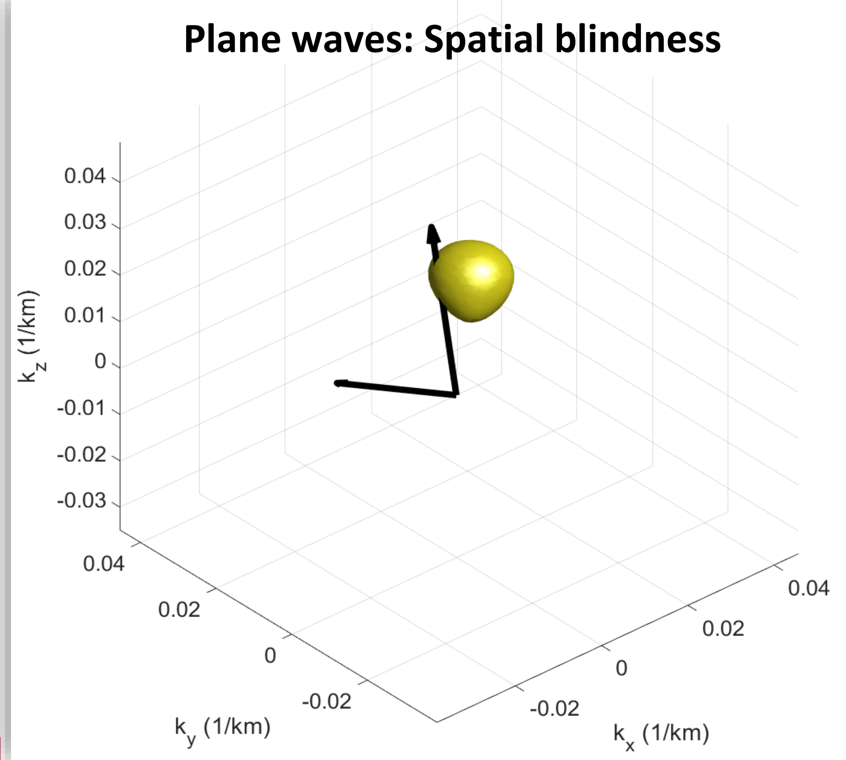
Spatial blindness

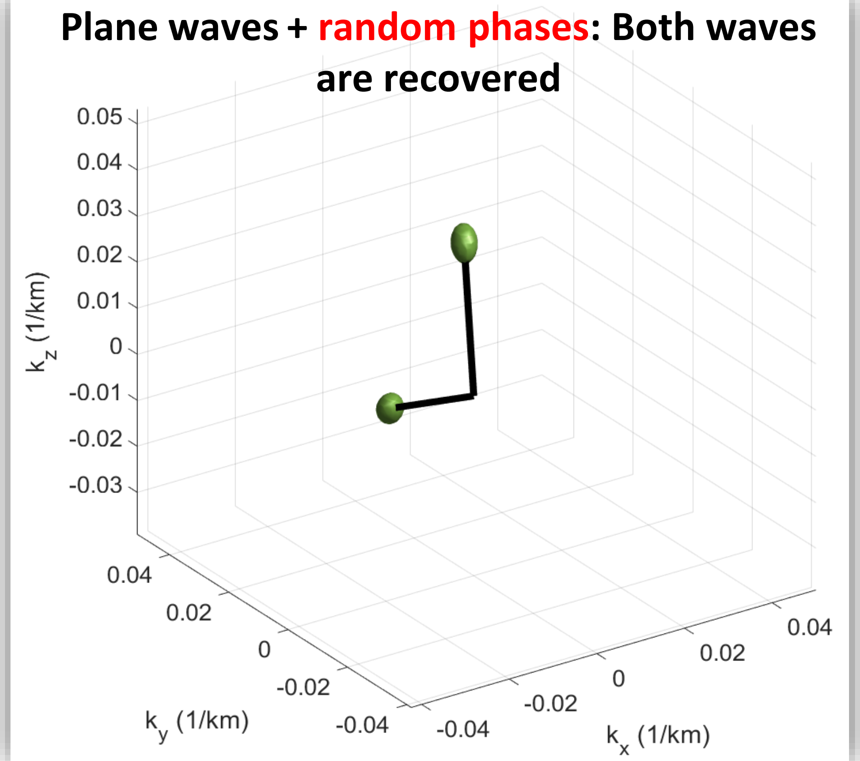
Using only plane waves: $\boldsymbol{B} = \boldsymbol{B_0}\exp(i(\omega_0 t - \boldsymbol{kx}))$ → wave telescope suffers from spatial blindness (can't resolve waves with same ω_0 but different wave vectors $\boldsymbol{k}$)

Introducing random phases ϕ_q: $\boldsymbol{B} = \boldsymbol{B_0}\exp(i(\omega_0 t - \boldsymbol{kx}))exp(i\phi_q)$ → wave telescope can separate and recover waves with different $\boldsymbol{k}$

→ Essentially introduction of phase jumps during the measurement, elimination of coherence

We found: spatial blindness is also present for more than 4 S/C!





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Summary

The wave telescope is able to work with more than 4 S/C

Larger numbers of detection points (spacecraft) lead to:

- **Increased resolution** in k-space
- **Larger numbers of waves** that can be separated
- The **Nyquist limit** in k-space (defining the analysis limit) **gets larger and more complex** in 1D, even more so in 2D and 3D
- **Spatial blindness** is **still present**

→ **Our research in all of those areas is ongoing.**