Taylor's hypothesis and anisotropy in space plasma turbulence

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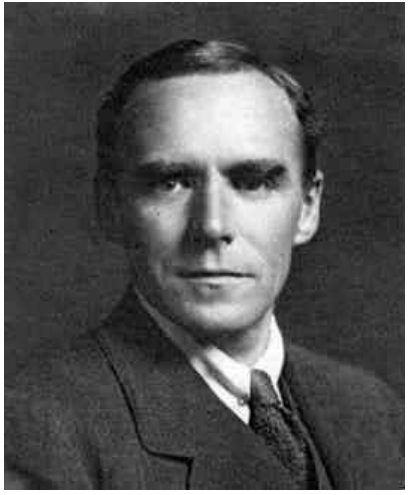
R. Bruno, N. Dwivedi, M. Echim, E. Teodorescu, Z. Vörös, E. Yordanova, and the STORM team

G. I. Taylor (1886-1975)



Proceeding of the Royal Society of London, Series A, 1938

The spectrum of turbulence

By G. I. Taylor, F.R.S.

(*Received* 1 *December* 1937)

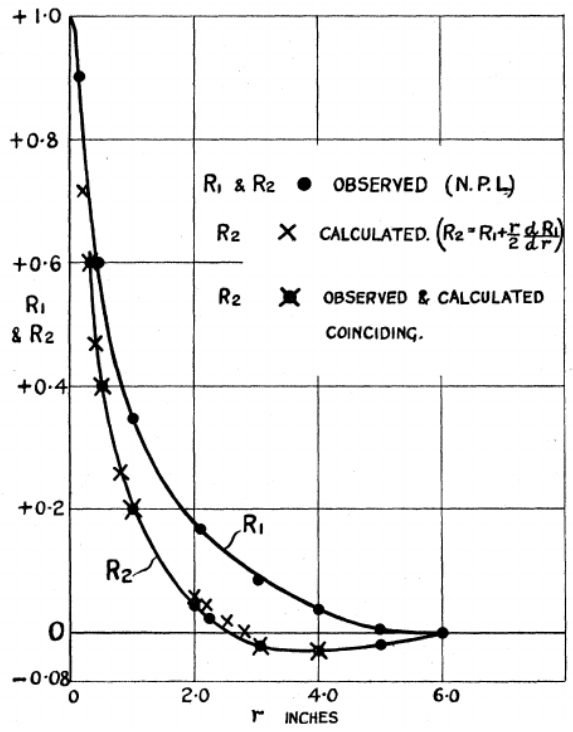
When a prism is set up in the path of a beam of white light it analyses the time variation of electric intensity at a point into its harmonic components and separates them into a spectrum. Since the velocity of light for all wave-lengths is the same, the time variation analysis is exactly equivalent to a harmonic analysis of the space variation of electric intensity along the beam. In a recent paper Mr Simmons (Simmons and Salter 1938) has shown how the time variation in velocity at a field point in a turbulent air stream can be analysed into a spectrum. In the present paper it is proposed to discuss the connexion between the spectrum of turbulence, measured at a fixed point, and the correlation between *simultaneous* values of velocity measured at two points.

If the velocity of the air stream which carries the eddies is very much greater than the turbulent velocity, one may assume that the sequence of changes in u at the fixed point are simply due to the passage of an unchanging pattern of turbulent motion over the point, i.e. one may assume that

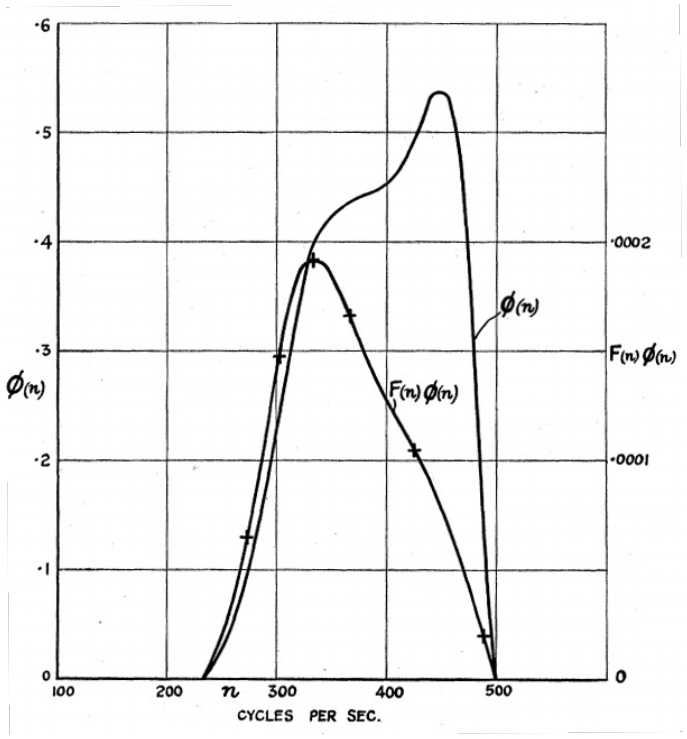
$$u = \phi(t) = \phi\left(\frac{x}{U}\right), \qquad (7)$$

Contents of Taylor's paper

1-D correlation functions



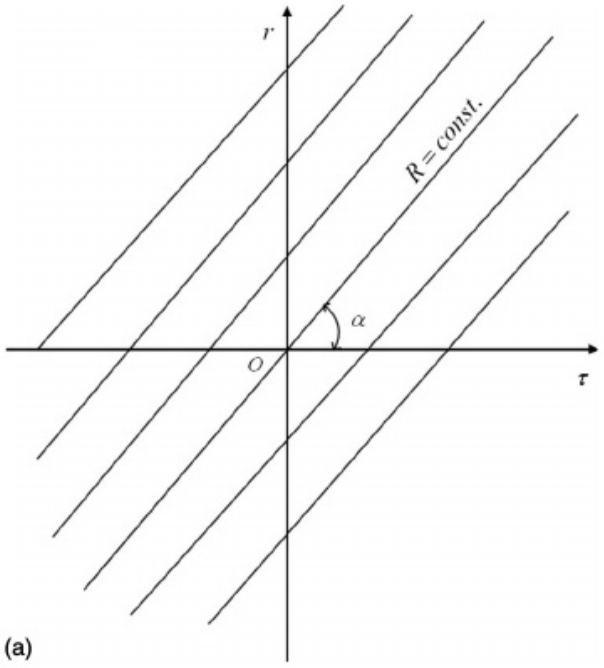
Frequency spectrum



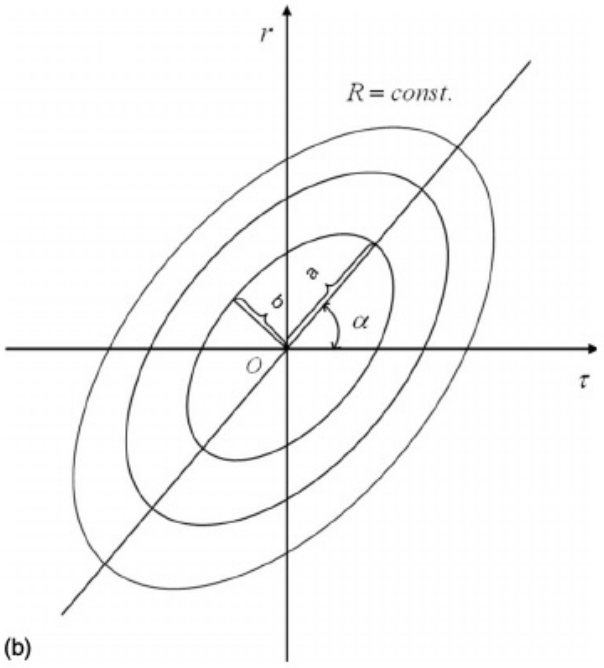
Taylor, Proc. Roy. Soc. London A (1938)

Contemporary picture

Turbulence is a spatio-temporal phenomenon, and only the 2-D correlation function R(tau, ell) can characterize the fluctuations unambiguously.



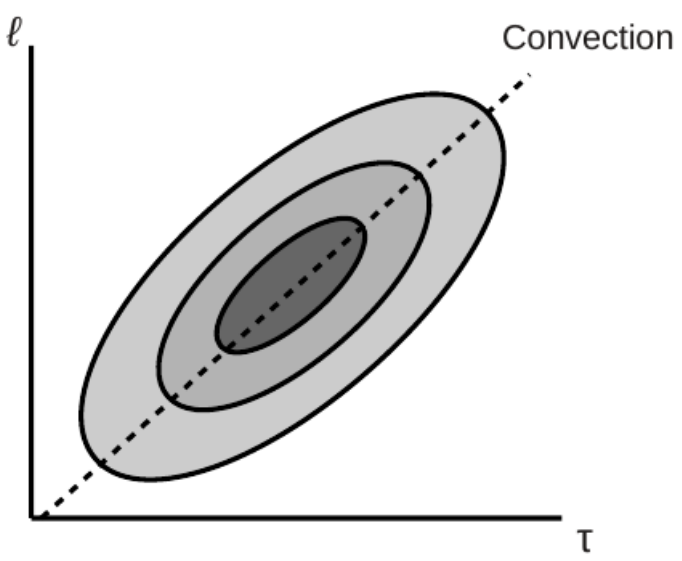
Frozen-in flow valid

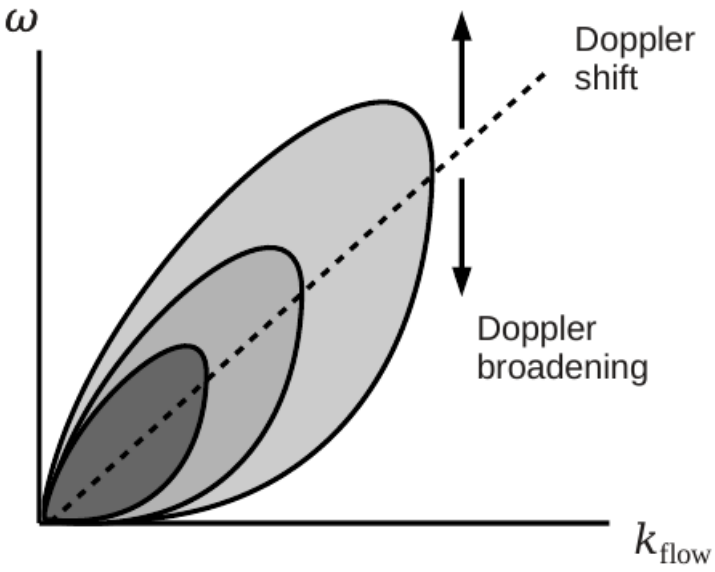


Frozen-in flow invalid

Zhao and He, Phys. Rev. E (2009)

Energy spectrum of turbulence





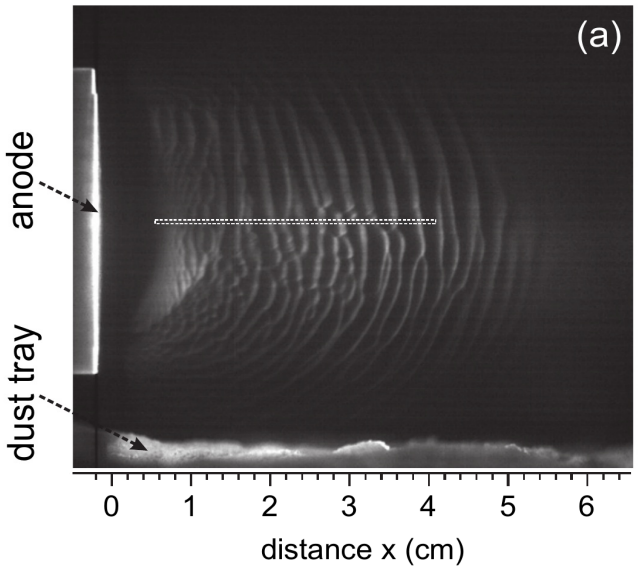
Mean flow
Large-scale fluctuation (eddies)

→ Advection and Doppler shift
→ Doppler broadening

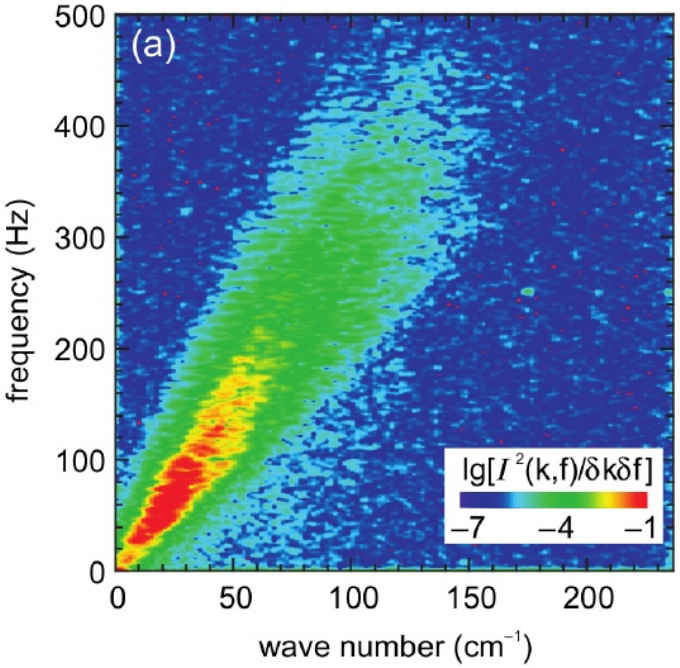
Kraichnan, Phys. Fluids (1964)
Wilczek and Narita, Phys. Rev. E (2012)

Laboratory studies

Dust acoustic turbulence experiment



k-omega spectrum

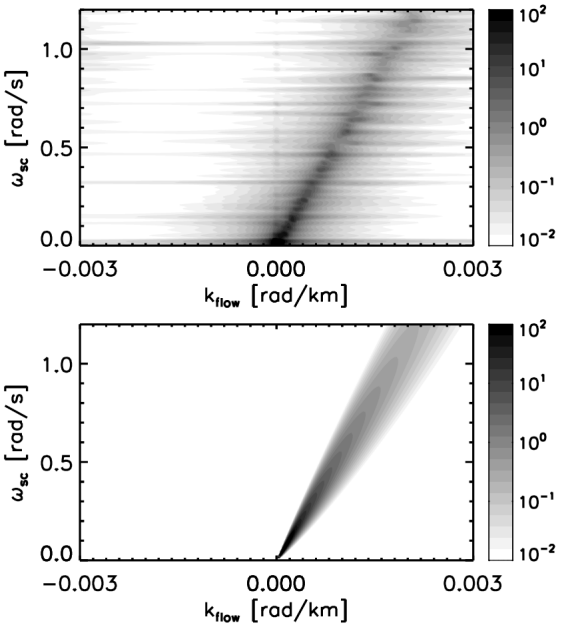


Nosenko et al., Europhys. Lett. (2009)

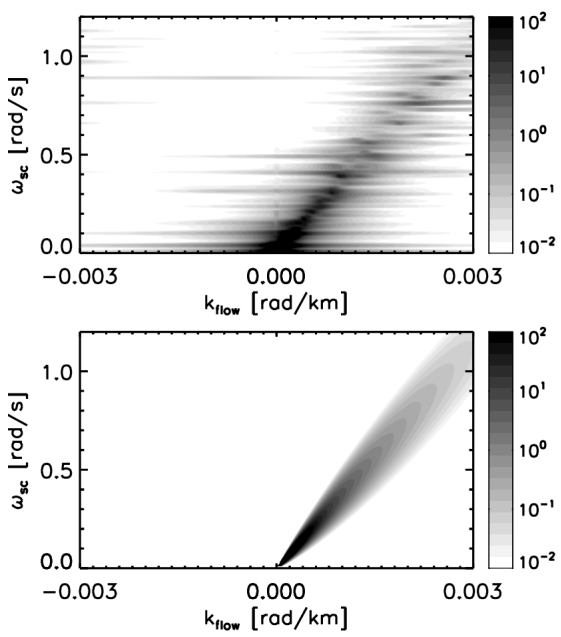
The STORM project

Cluster solar wind measurements in year 2005 on a 1000-km tetrahedral scale

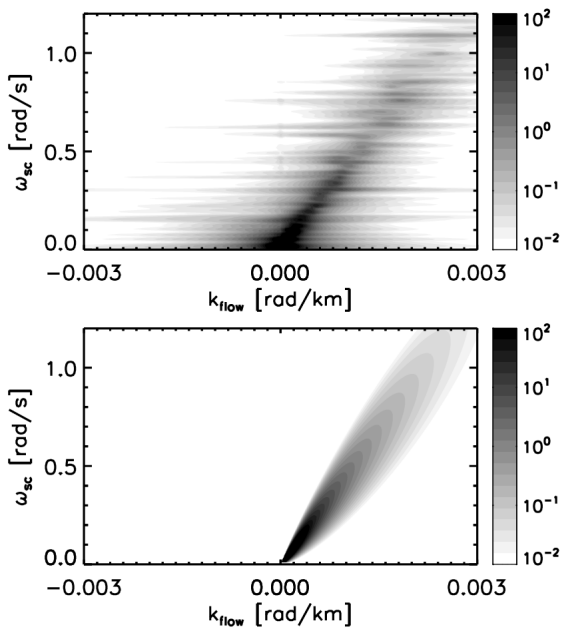
2005-02-12



2005-03-17



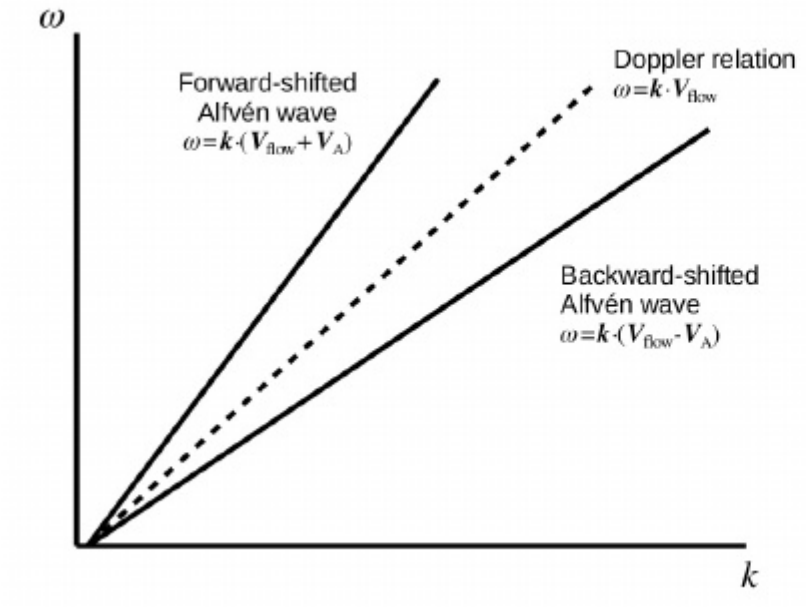
2005-03-19



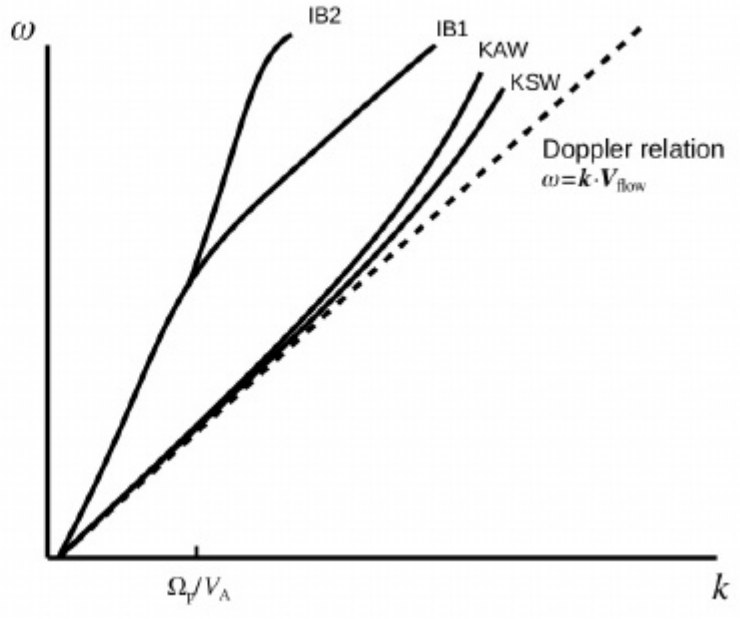
STORM project deliverable D6.1 (2015)

Wave propagation effects

MHD waves with Doppler shift



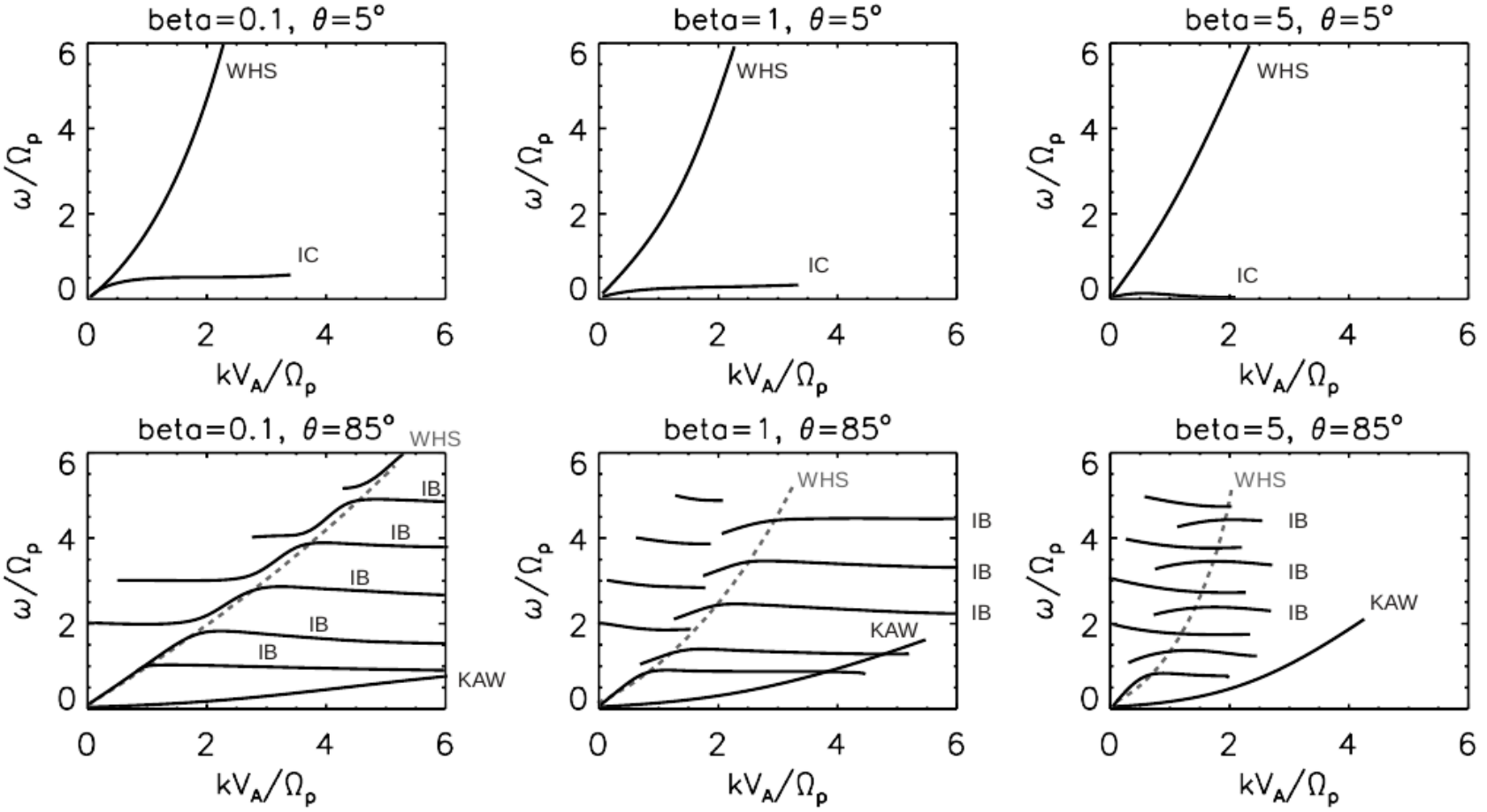
Kinetic waves with Doppler shift



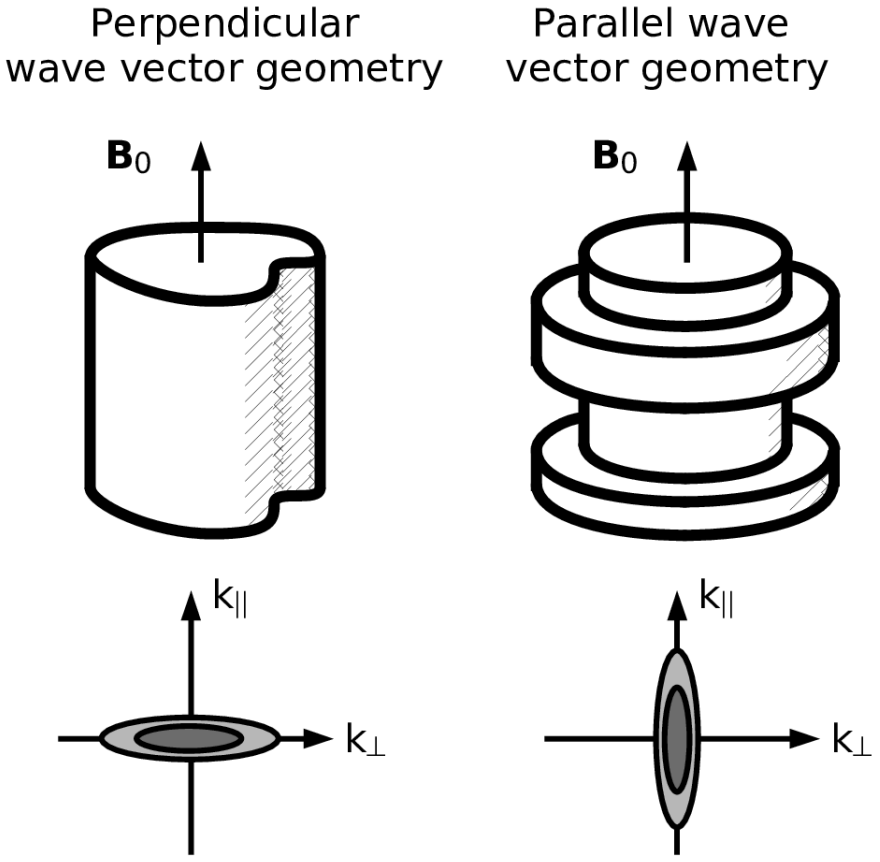
STORM project deliverable D6.1 (2015)

Short-wavelength waves in plasma

Numerical solutions for linear wave modes in the Vlasov theory



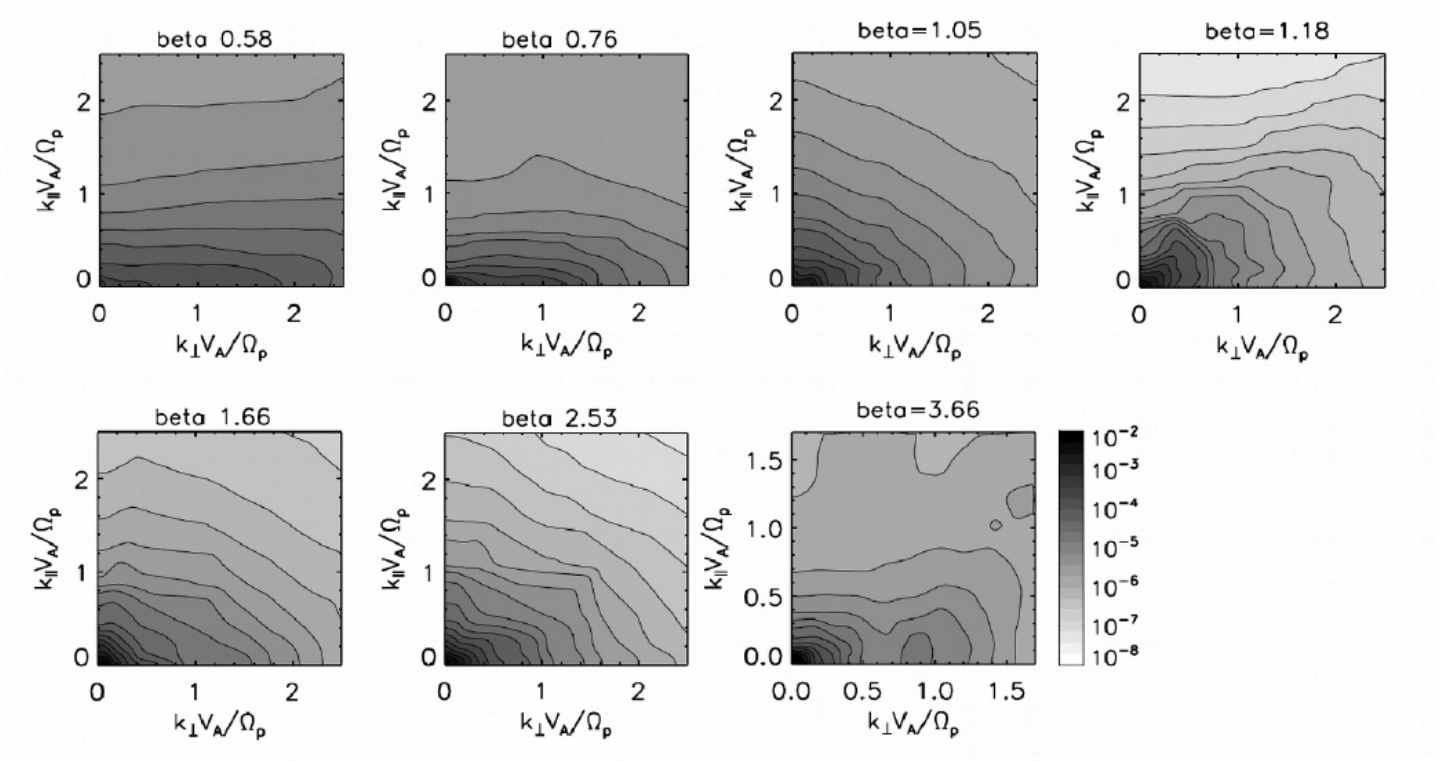
Anisotropy in plasma turbulence



Filament formation vs. Alfvén wave packets

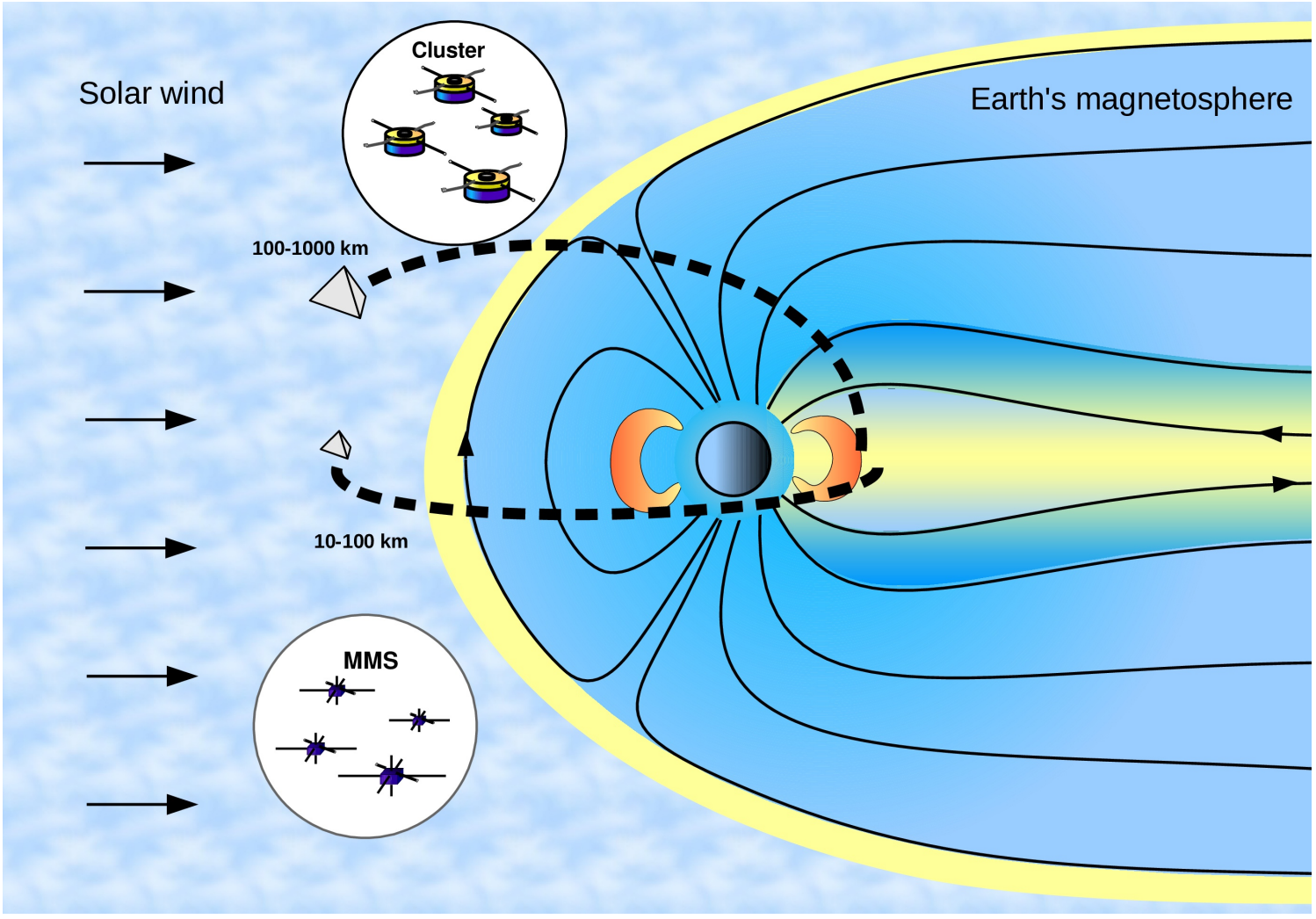
The STORM project

Cluster's solar wind measurements in year 2002 on a 100-km tetrahedral scale

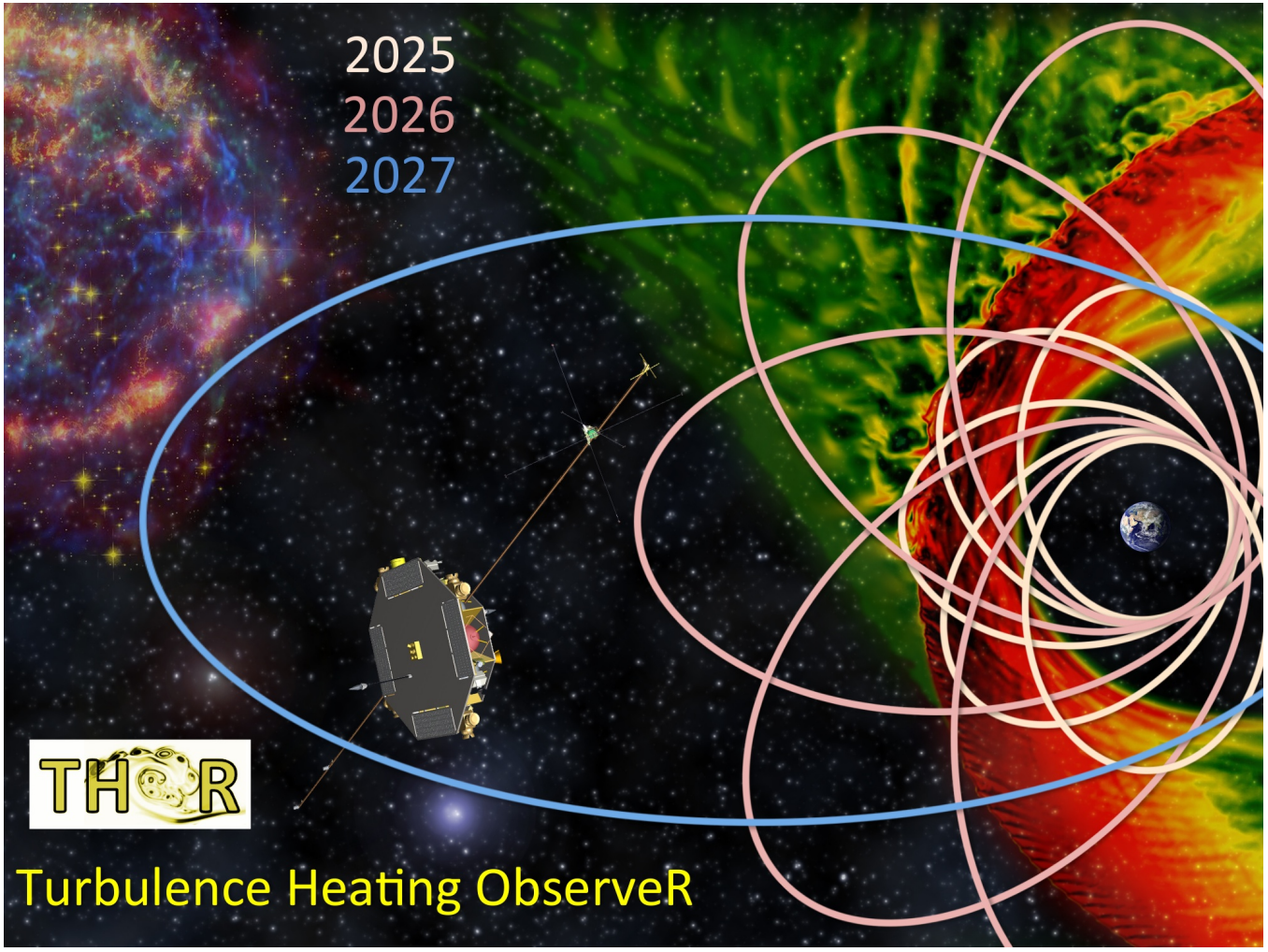


STORM project deliverable D6.2 (2015)
Narita et al., Front. Phys. (2014)
Comişel et al., Nonlin. Process Geophys (2014)

Outlook

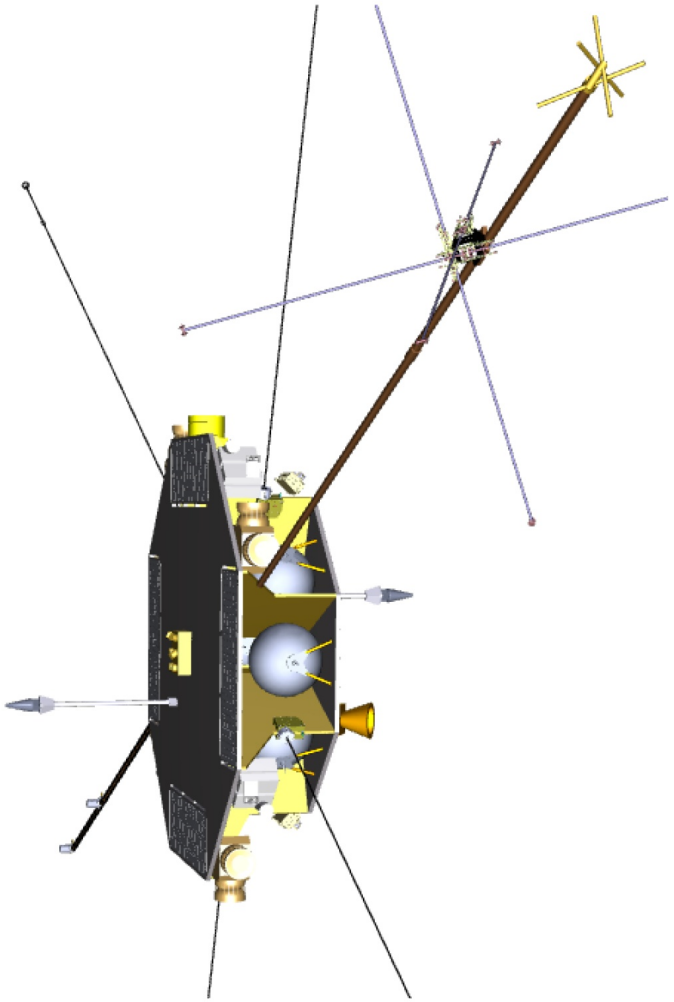

Solar wind
Cluster
100-1000 km
Earth's magnetosphere
10-100 km
MMS

THOR mission (2025-2027)



THOR mission (2025-2027)

- Sun-pointer
- Slow spinner (2rpm)
- Advantages for E fields and for particle instruments



OHB SWEDEN

Mission profile

Eric Clacey

OHB Sweden