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Phase correlation of large amplitude MHD waves in the earth's foreshock

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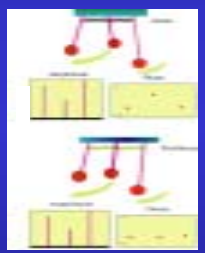
Abstract

Large amplitude MHD turbulence is common in space plasma. They can be written as a superposition of Fourier modes with characteristic frequency, amplitude, and phase. Nonlinear interactions between the Fourier modes are likely to produce finite correlation among the wave phases.

We analyze Geotail magnetic field data in the solar wind in order to identify whether the nonlinear interactions between the waves is in progress. Starting from a piece of observed field data (OBS), we make the phase-randomized surrogate (PRS), and the phase-correlated surrogate (PCS). Then we characterize statistics of three sets of data by a fractal analysis. We will report initial results for various turbulence levels and spectrum types.

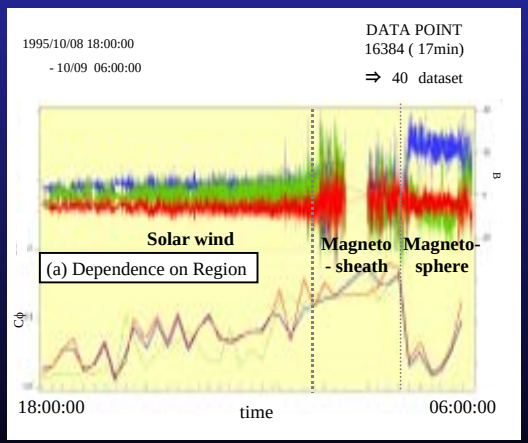


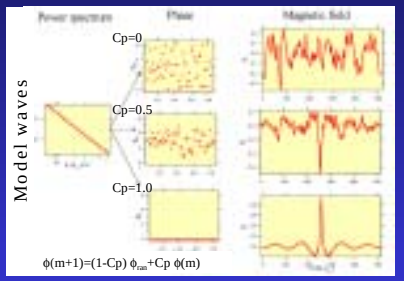
If oscillations are independent to each other, their phases will be totally random.

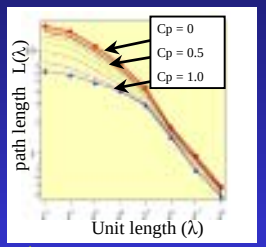
When nonlinear interaction is present, phase correlation is expected to be generated.

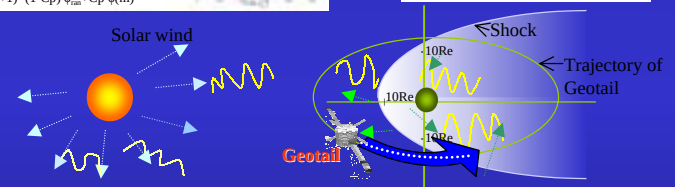
In the solar wind, Phase correlation is generated as the eigenmodes nonlinearly interact with each other.

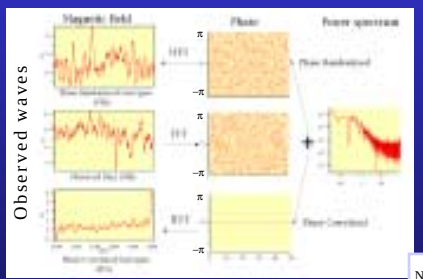
Geotail Data

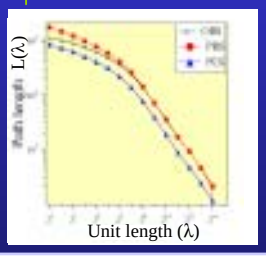




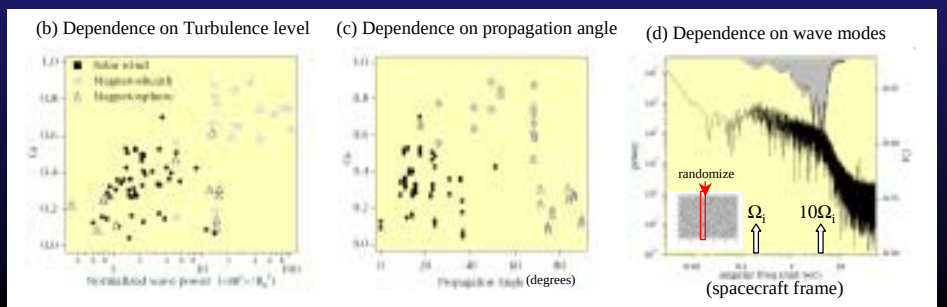






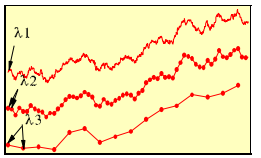


Normalized phase coherence factor Cϕ is defined as an index of the phase correlation $C\phi = \frac{L_{PRS} - L_{OBS}}{L_{PRS} - L_{PCS}}$



Fractal Analysis

When there is high (low) correlation among the phases, the waveform appears to be smooth (jaggy), i.e., the phase correlation can be characterized by a fractal property of the curves. (e.g. Higuchi 1990)



Path length (L) vs. Unit length (λ)

$$L(\lambda) \equiv \sum_x |B(x+\lambda) - B(x)|$$

$$L : L(\lambda_1) > L(\lambda_2) > L(\lambda_3)$$

$$\lambda : \lambda_1 < \lambda_2 < \lambda_3$$

$L(\lambda)$ is essentially identical to the first order structure function $S_1(\lambda)$

Summary

- **Using the Geotail magnetic field data, we analyzed the phase correlation among MHD waves in the solar wind.**
- **In order to characterize the phase correlation quantitatively, fractal analysis was performed.**
- **Normalized phase coherence factor $C\phi = \frac{L_{PRS} - L_{OBS}}{L_{PRS} - L_{PCS}}$ was defined and evaluated.**
- **Dependence on Cϕ to items below were discussed.**

(a) Region	**As approaching toward the shock from far upstream, Cϕ gradually increases.**
(b) Turbulence level	**Positively correlated.**
(c) Propagation angle	**Positively correlated within $0<\theta<70^\circ$.**
(d) Characteristic wave frequency	**Waves responsible for the generation of finite phase coherence have their wave angular frequency around $\omega=4$ (1/sec).**