Synthetic Turbulence in Astrophysical Plasmas

Introductory Talk

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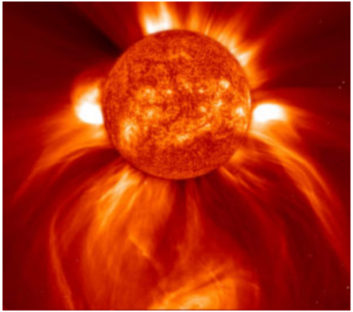
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Background

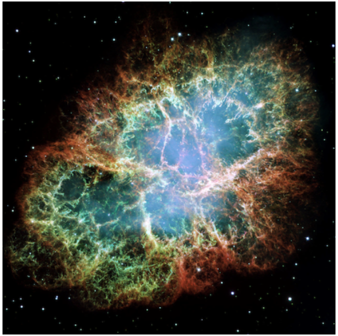
What is a Plasma?

- Ionised volume of gas where EM forces dominate
- Over 99.9% of observable matter is plasma (Pablo 1998)



Turbulence in Plasmas?

- Supernovae, solar wind, turbulent accretion flows etc.
- Cosmic Ray Scattering and Influences Solar Particles (Yan, Lazarian 2004)



Standard Method

- Turbulence simulated by solving the incompressible MHD equations (Eyink et. al, 2013)
- Takes 0.1-1 million CPU hours
- Want to generate turbulence data cheaply

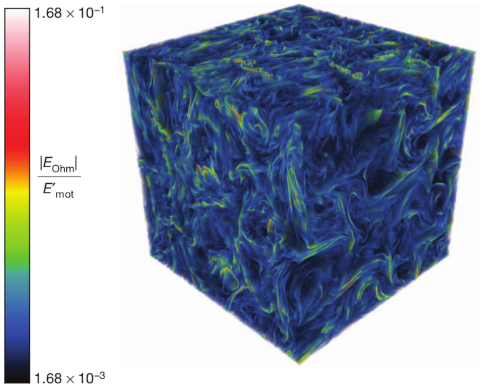


Figure: A 1024^3 point cube of the Electric Field. Colours display turbulent flow.

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Theory

Two important pieces of theory describing turbulence in plasmas:

- Kolmogorov (1941)
- Goldreich-Sridhar (1995)

GS-95 describes a spectrum for the turbulence:

$$E = k_{\perp}^{-7/3} \exp\left(-\frac{k_{\|}}{k_{\perp}^{2/3}}\right), \tag{1}$$

where $E^{1/2}$ is the amplitude of the waves in the plasma in 2D implementation

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Synthetic Data Methods

> Two methods to create turbulence data according to the GS-95 Spectrum:
  - Squares
  - Displacement

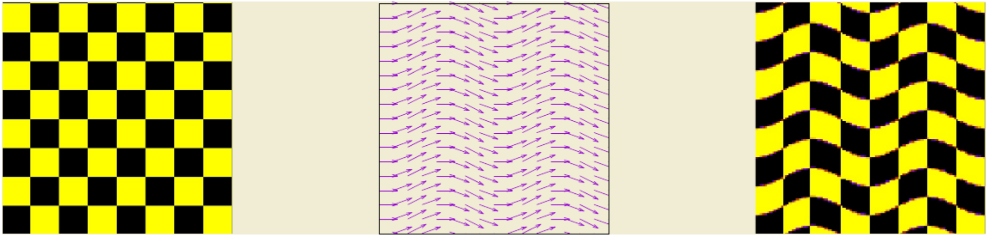
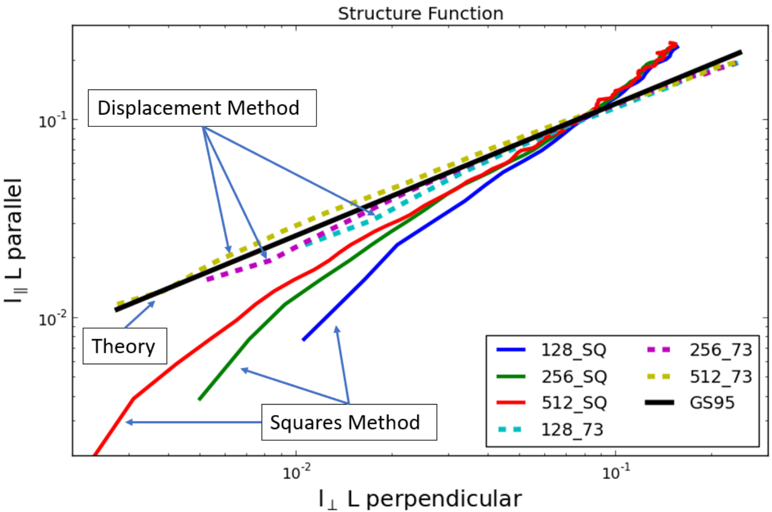


Figure: Displacement Method: Given an initial scalar field (left) and a magnetic field (centre), the scalar field should be deformed to follow the magnetic field (right)

Project Outline

- Squares initially thought to work well for small scales
- Displacement thought to work well for large scales
- To make these methods work, compare and contrast
- Try to find best method either by combining/improving
- Implement both in 3D and parallelise

Results



Structure Function
Displacement Method
Theory
Squares Method
10^{-1}
10^{-2}
10^{-2}
10^{-1}
$l_{\parallel}$ L parallel
$l_{\perp}$ L perpendicular
128_SQ
256_SQ
512_SQ
128_73
256_73
512_73
GS95

Thank you!

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