Generating Synthetic Turbulence in Astrophysical Plasmas

Introductory Talk

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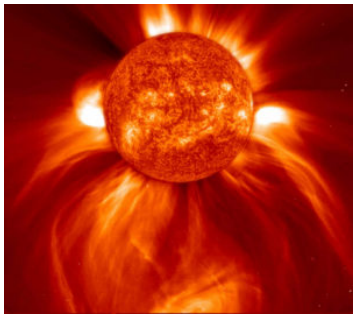
Background

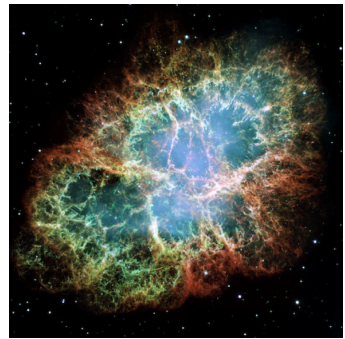
What is a Plasma?

- 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

- Studies of turbulence, e.g: Cosmic Ray Diffusion by turbulence or Turbulent Star Formation, are typically done using MHD simulations (Eyink et. al, 2013)
- Takes 0.1-1 million CPU hours
- Want to generate turbulence data cheaply

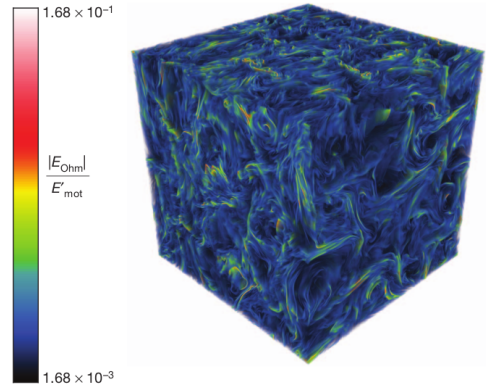


Figure: A 1024^3 point cube of the Electric Field. Colours display turbulent flow.

Theory

Most widely accepted theory of astrophysical turbulence is the Goldreich-Sridhar theory (1995). It predicts a spectrum for the turbulence:

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

where $E^{1/2}$ is the amplitude of the waves in 2D, $k_{\perp}$ and $k_{\parallel}$ are the perpendicular and parallel components of the wavevector respectively w.r.t the local mean magnetic field. The scalar field, Ψ, in k-space is generated using:

$$\Psi = E^{1/2}(cos\phi + isin\phi) \tag{2}$$

Squares Method

- Two methods to create turbulence data according to the GS-95 Spectrum:
  - First method is the Squares Method

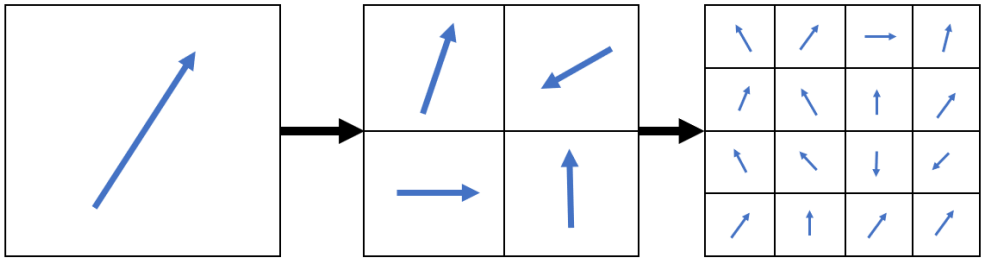


Figure: Domain split up into smaller areas, scalar field set according to local mean magnetic field. Keep splitting until Nyquist Frequency reached.

Displacement Method

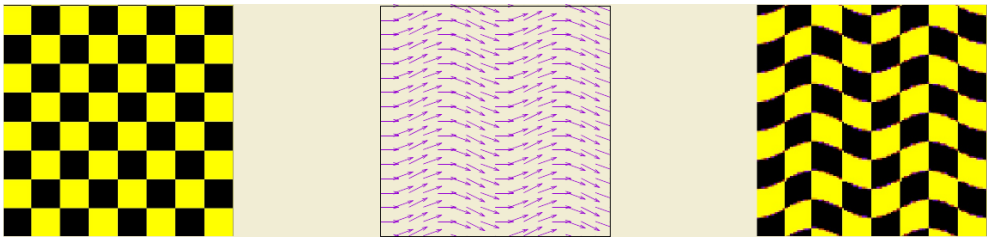
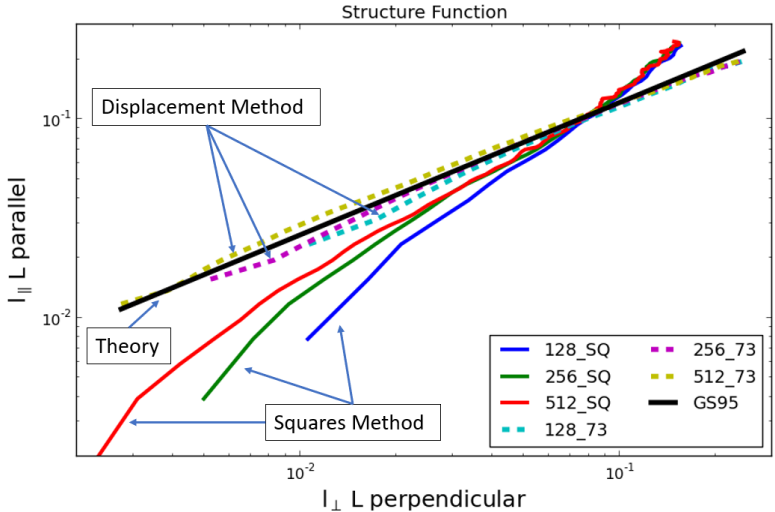


Figure: Given an initial scalar field (left) and a magnetic field (centre), the scalar field should be deformed to follow the magnetic field (right).

Project Goals

- To make both these 2D methods work
- To compare and find the best method either by combining or improving
- Implement both in 3D and parallelise

Results


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

Thank you!

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