Understanding Energy Transfer In Plasma Turbulence

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Introduction:

- **Plasma turbulence** plays a key role in many astrophysical phenomena, but this process is **not well understood**
- We are interested in understanding how **energy transfer** takes place in compressible magnetized turbulence
- It is unknown in how far the calculated energy **power spectra will differ** based on one's definition of kinetic energy density

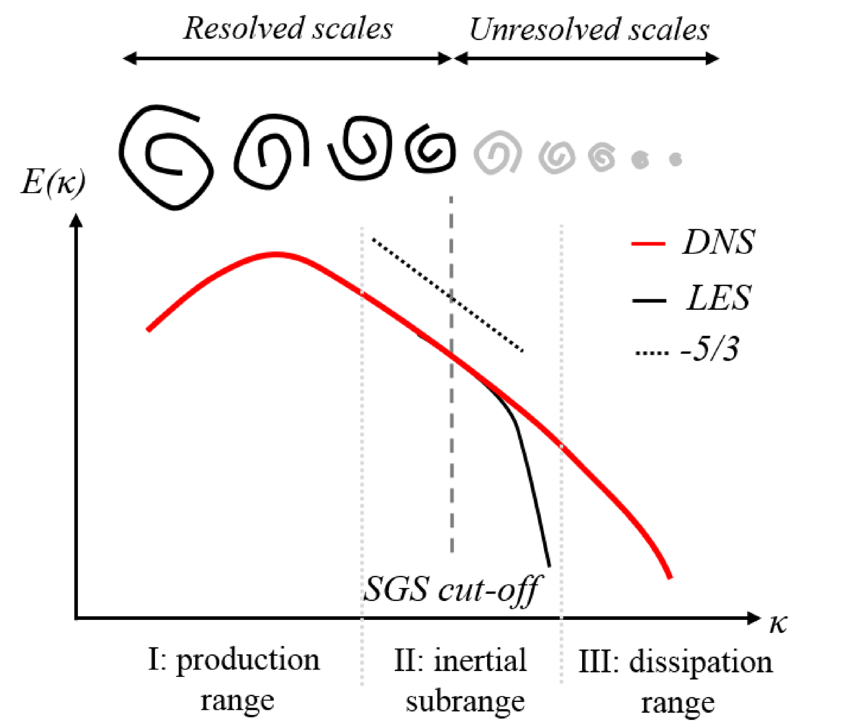

Fig. 1: Energy spectrum representation illustrating eddy sizes and resolution of scales. Dotted line denotes the Kolmogorov slope.

Methods:

- We use Athena[1] to conduct **large scale computer simulations** which virtually produce turbulent systems by numerically solving the equations of ideal magnetohydrodynamics (MHD)
- We test simulations with **different compressibility** levels by varying the strength at which the plasma is stirred
- We analyze these simulations using two **different mathematical formalisms.** The first takes a Fourier transform to calculate the power spectrum ($E_{FT}(k) = |\widehat{\sqrt{\rho}u}(k)|^2$)[2], while the second produces a filtered power spectrum from a Favre decomposition of kinetic energy density ($E_{flt}(k) = \overline{|\rho u(k)|}^2 / 2\overline{\rho(k)}$)[3]

Visualizing Turbulence:

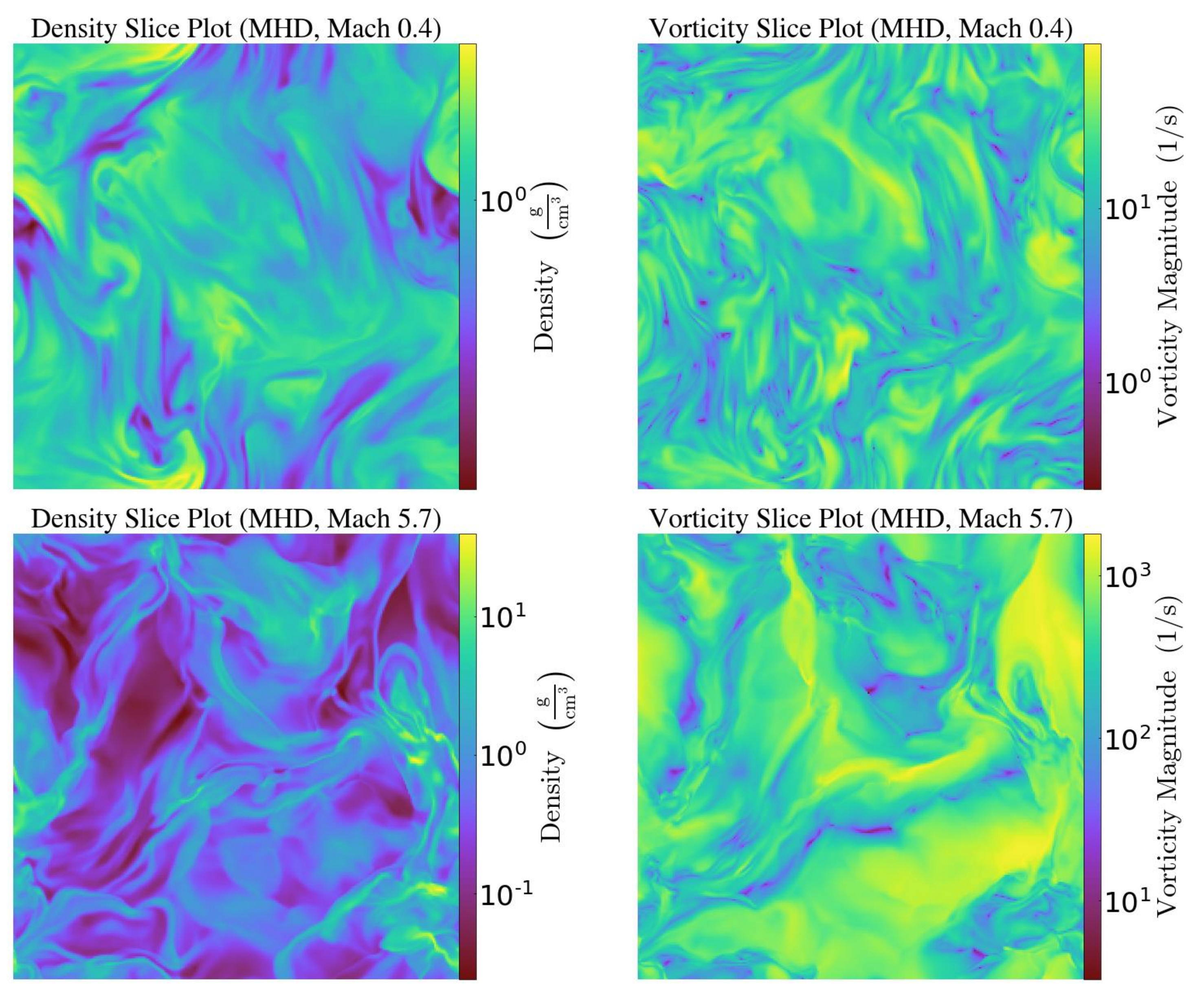

Fig. 2: Slice plots along the y axis illustrating density (left column) and vorticity (right column) for Mach 0.4 (top) and Mach 5.7 (bottom) of a magnetohydrodynamic simulation.

Results:

- We calculate **two power spectra**—one for each mathematical formalism—for each of 5 different hydrodynamic simulations with Mach numbers ranging from Ms = 0.4 to Ms = 5.7.
- We see that the two **power spectra largely agree** in the inertial range up to Mach number 5.7. At the highest Mach number (5.7) we see the **methods begin to diverge slightly** in the intermediate scales, beginning around wavenumber k = 10.

The calculated **energy power spectrum** of simulated **plasma turbulence** is minimally affected by our chosen definition of kinetic energy density.

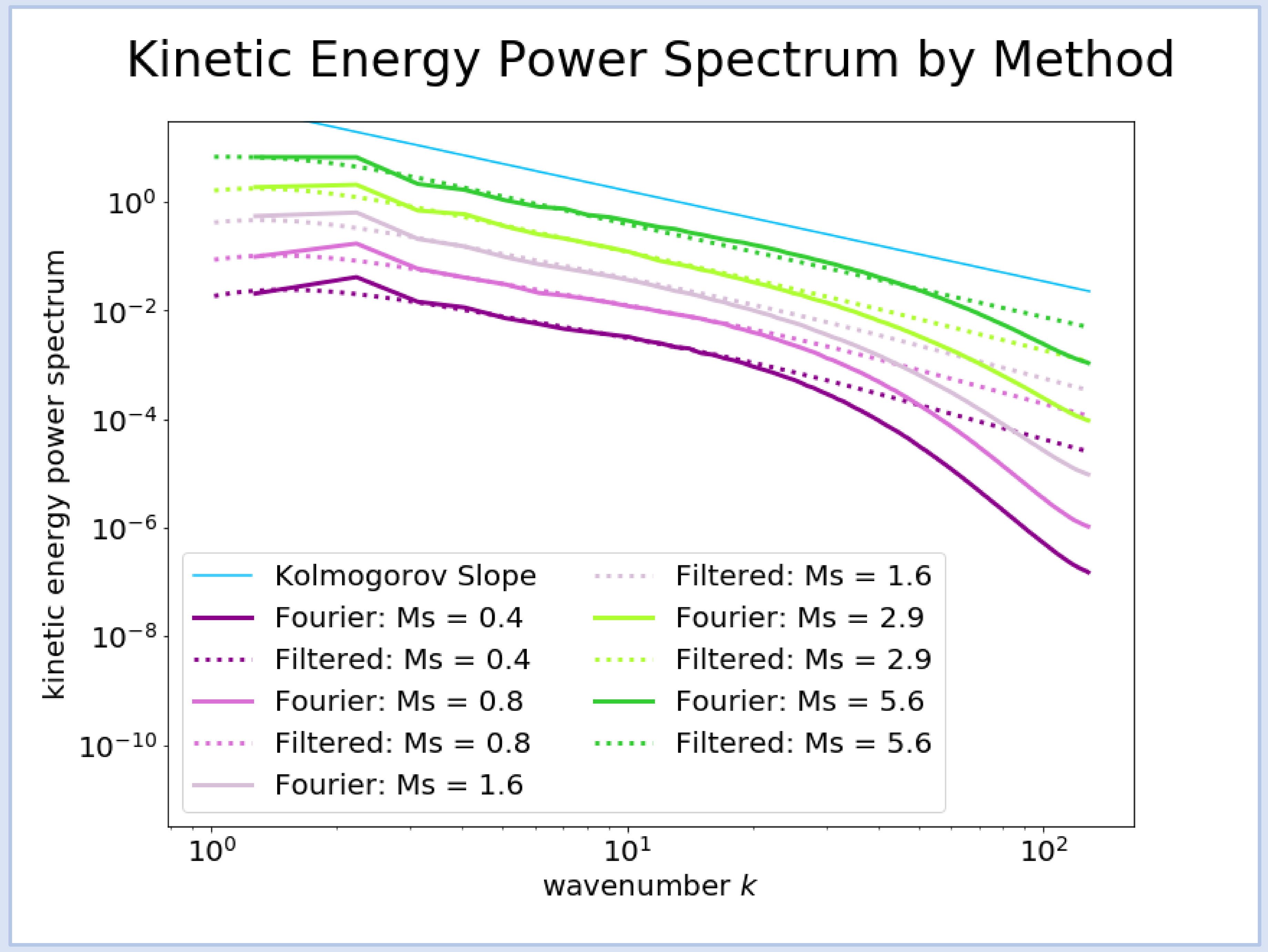

Fig. 3. Two power spectra were calculated for each of five simulations with varying forcing amplitudes. Solid lines were calculated using a Fourier transform[2] while dotted lines were calculated using a filtered Favre decomposition[3]. Light blue line denotes the Kolmogorov slope.

References:

[1] J. M. Stone, et. al. (2008). *Astrophys. J. Suppl. Ser. 178, 137*

[2] Grete, P., et. al. (2017). Energy transfer in compressible magnetohydrodynamic turbulence. *Physics of Plasmas*, *24*.

[3] Sadek, M., & Aluie, H. (2018). Extracting the spectrum of a flow by spatial filtering. *Physical Review Fluids*, *3*.

Fig. 1: Ouro, Pablo. (2017). Large-Eddy Simulation of Tidal Turbines.

Fig. 2: produced using yt-project-3.5.1

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