Notes on Diss. and Heating in Supersonic HD and MHD turbulence

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1 Introduction

- Molecular clouds are observed to contain supersonic turbulence, the details of which can have an effect on the SF ($\vec{B}$ and $\mathcal{M}$)
- Turbulent driving mechanism is unknown: periodic, pulse, driving scales?
- Study details of energy dissipation in HD and MHD supersonic turbulence
- Study effects of numerical dissipation by comparing to ZEUS
- Compare solenoidal and compressional driving
- Convergence test for HD and MHD cases

2 Numerical Methods

- 64^3 to 1024^3 resolution simulations made with ATHENA
- Ideal, isothermal MHD equations with periodic BC's
- Exact / approximate Riemann solver for HD / MHD

2.1 Set up

- Uniform stationary medium with $\bar{\rho}$=1
- Magnetic field is uniform in x-axis, set by the β parameter
- For decaying turbulence, start with single pulse (adiabatic)
- β ranges from 0.02 to infinity in the strong field and HD case
- Assuming L = 2 pc, $n_{H_2} = 10^3$, and T = 10 K (a typical MC), $\dot{E} = 0.4$ $L_\odot$ and B = 44 μG when $\beta = 0.02$

3 Convergence Results

For HD:

- HD convergence by 64^3 or 128^3 depending on driving scale and energy injection
- solenoidal / compressive fraction converges to 0.78 / 0.22 in HD
- energy dissipation timescale is independent of driving scale and < 1
- $\mathcal{M}$ converges to 7.2 to 5.8 for large / small driving scales

For MHD:

- Higher mach number for larger driving scales, though smaller than HD in all cases
- Convergence is around 512^3, with sol / comp frac at 0.9 / 0.1
- dissiption timescale is around unity

There is a good agreement between overall diagnostics for ATHENA and ZEUS. Rapid decay of supersonic turbulence is not due to high numerical dissipation

4 $\mathcal{M}$

Mach number has a strong effect on the turbulence state. Though E_C is small in all cases, it increases slightly from 0.05 to 0.1 with higher mach number. Dissipation timescale decreases with mach number, from 1.7 at low numbers to less than one at high mach numbers.

5 Power Spectra

Much higher resolution is required to appropriately resolve the intertial range of the simulation. For the HD case, supersonic turbulence has a roughly power law slope in the intertial range (between -2 and -1.7) but that higher resolution runs are needed to appropriately resolve this. Bottleneck effect is present in the supersonic turbulence PS.

Power law in the MHD case is roughly -4/3. **u** should scale to the -5/3, but is observed here at -4/3. This is expected if the helicity timesacle is non-negligible

For the MHD system, anisotropy in the PS is present, with more perpendicular to the mean field (-4/3 perp, -2 parallel). Compressive comp. is isotropic. Results suggest that turbulent cascade in the compressive comp. of velocity is not present here.

6 Sonic Scale

Sonic scale is point at which velocity dipserions become subsonic. For the HD case, it scales as l to the 0.58. There is no nice power law relationship for the MHD case, as physics change drastically on many scales due to different wave families of the MHD equations

7 Questions

- Why did they start with a uniform B field? What motivates that the magnetic field has to be uniform and coherent on scales of the MC? This should likely have a large effect on the dissipation rate and development of the subsequent system.

8 Conclusions

- Supersonic turbulence decays rapidly (often far less than flow time)
- High res is needed to appropriately model the intertial range
- Less than high res is needed for convergence in overall diagnostics
- Should not rely on PS to characterize these states until higher res is readily achievable
- MHD turbulence is very anisotropic (roughly HD parallel, shallow perp)
- Need structure functions to determine origin of power laws
- Larger driving scales lead to greater time variability in temperature