Decay of Anisotropic Turbulence

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From Star to Galaxies  
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Motivation

• Turbulence is always observed in molecular clouds
• Simulations say turbulence decays in one crossing time (e.g. Stone et al 1998, MacLow 1999, ...)
• Clouds are observed to live for multiple crossing times (e.g. Blitz et al 2007)
• Turbulence must be regenerated or the decay must be slowed
Hydrodynamic Anisotropic Turbulence

- Turbulent velocity field contains an isotropic component and an anisotropic component

- Anisotropy due to initial conditions

- Different from magnetically induced anisotropy
Isotropic Decay

One Velocity Model:

\[
\frac{1}{\sigma} \frac{\sigma}{dt} = -\epsilon \frac{\sigma}{L}
\]

\[
\sigma = \text{Velocity Dispersion}
\]

\[
L = \text{Inertial Scale}
\]

\[
\epsilon \sim 0.6 - 0.8
\]
Anisotropic Decay

Two Velocity Model:

\[
\frac{1}{\sigma_{iso}} \frac{\sigma_{iso}}{dt} = -C_1 \frac{\sigma_{iso}}{L} - C_3 \frac{\sigma_{ani}}{L}
\]

\[
\frac{1}{\sigma_{ani}} \frac{\sigma_{ani}}{dt} = -C_2 \frac{\sigma_{iso}}{L} - C_4 \frac{\sigma_{ani}}{L}
\]

\(\sigma_{iso}\) = RMS Isotropic Velocity Component

\(\sigma_{ani}\) = RMS Anisotropic Velocity Component
Simulations

• Drive turbulence to steady state using grid-based code Orion

• Allow to decay, measure anisotropy and decay rates

• Repeat, varying anisotropy
Measuring Anisotropy

• ‘Moment of Inertia’ Tensor

\[ 2T_{ij} = \langle \rho u_i' u_j' \rangle \]

• Eigenvalues give principle kinetic energy components
• Eigenvectors give ‘principle axes’
• Anisotropy present even if \( \sigma_x = \sigma_y = \sigma_z \)
Turbulent decay time is set by isotropic component only

(Hansen et al 2010 in prep)

\[ \sigma \frac{d\sigma}{dt} = 0.9 \frac{\sigma_{iso}^3}{L} + 0.7 \frac{\sigma_{ani}^2 \sigma_{iso}}{L} \]
Observables

- Perpendicular structure functions differ

Similar to Heyer et al 2008
Summary

• Anisotropic turbulence decays slower than isotropic turbulence
• Decay time is crossing time of the isotropic component
• High degrees of anisotropy should be observable in structure functions
• Related Work: Regenerating turbulence with compression