Outflow Driven Turbulence in Molecular Clouds: MHD Simulation Studies

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Abstract

Protostellar outflows are ubiquitous in regions of star formation and inject sufficient momentum into their parent cloud to sustain supersonic turbulence. Here we present the results of 3-D MHD numerical simulations that demonstrate the capacity of multiple interacting outflows to both create and sustain supersonic turbulence. We discuss the differences between outflow driven turbulence and externally driven turbulence and the observational signatures of each. We also discuss the growth of magnetic fields from turbulent interactions with outflows.

Magnetic Fields and Outflows

Given spherical outflows with momentum \( \mathcal{P} \) in an environment with density \( \rho_0 \) occurring at a rate per volume \( S \):

- A given outflow will sweep up a shell of mass \( m = \rho_0 \mathcal{P} t^2 \) travelling at a velocity \( v = \frac{\mathcal{P} t}{m} \) over a period of time \( t = (S \rho_0)^{1/3} \) before encountering another outflow. Setting \( vt = \mathcal{P} \) gives:

\[
\mathcal{P} = \frac{\rho_0 S^{1/3} v^{1/3}}{\rho_0^{1/3}}
\]

Parameters

<table>
<thead>
<tr>
<th>Simulation Parameters</th>
<th>Run</th>
<th>( \beta )</th>
<th>Stirring</th>
<th>Outflows</th>
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<tbody>
<tr>
<td>( \rho_0 )</td>
<td>2.5e-2 g/cm³</td>
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<td>Y</td>
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<td>( \mathcal{P} )</td>
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<td>( S )</td>
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<td>( t )</td>
<td>37 pc</td>
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<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>( \mathcal{T} )</td>
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<td>Y</td>
<td>Y</td>
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<tr>
<td>( m )</td>
<td>19 M⊙</td>
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</table>

Conclusions

- Outflows drive and sustain supersonic turbulence.
- Outflows produce a knee in the turbulent spectrum.
- Outflow driven turbulence has a steeper velocity spectrum than cascade models.
- Outflows are able to enhance magnetic fields initially present, though not to equipartition with kinetic energy.
- Further comparisons between simulation and observation are needed to understand the role of feedback and star formation.

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