The Dynamics of Protostellar Outflow Interactions

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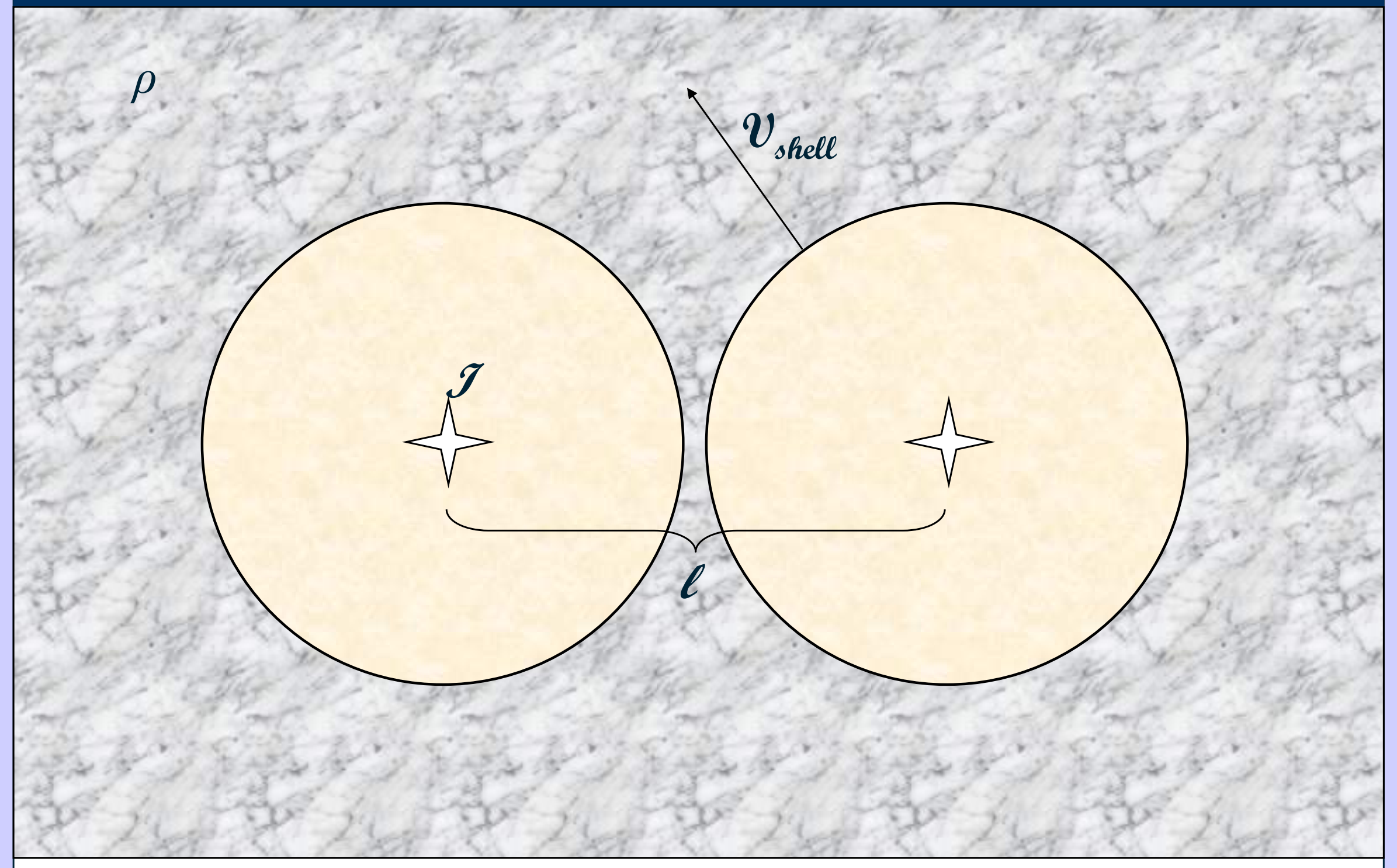
Outflow Properties



Given spherical outflows with momentum $\mathcal{I}$ in an environment with density ρ occuring at a rate per volume S:

A given outflow will sweep up a shell of mass $m \approx \rho \ell^3$ travelling at a velocity $v \approx \frac{\mathcal{I}}{m}$ over a period of time $t \approx \left(S\ell^3\right)^{-1}$ before encountering another outflow. Setting $vt = \ell$ gives:

$$\ell = \left(\frac{\mathcal{I}}{\rho S}\right)^{1/7}, \quad m = \frac{\rho^{4/7}\mathcal{I}^{3/7}}{S^{3/7}}, \quad t = \frac{\rho^{3/7}}{\mathcal{I}^{3/7}S^{4/7}}, \text{ and } v = \frac{\mathcal{I}^{4/7}S^{3/7}}{\rho^{4/7}}$$

For the choice of $\mathcal{I}$, S, and ρ in the numerical simulations, $v = .97 km/s = \text{Mach } 4.9$

Conclusions

- Collimated protostellar outflows are able to drive supersonic turbulent motions in molecular cloud cores at velocities consistent with theoretical predictions… and necessary to provide turbulent support against core collapse.

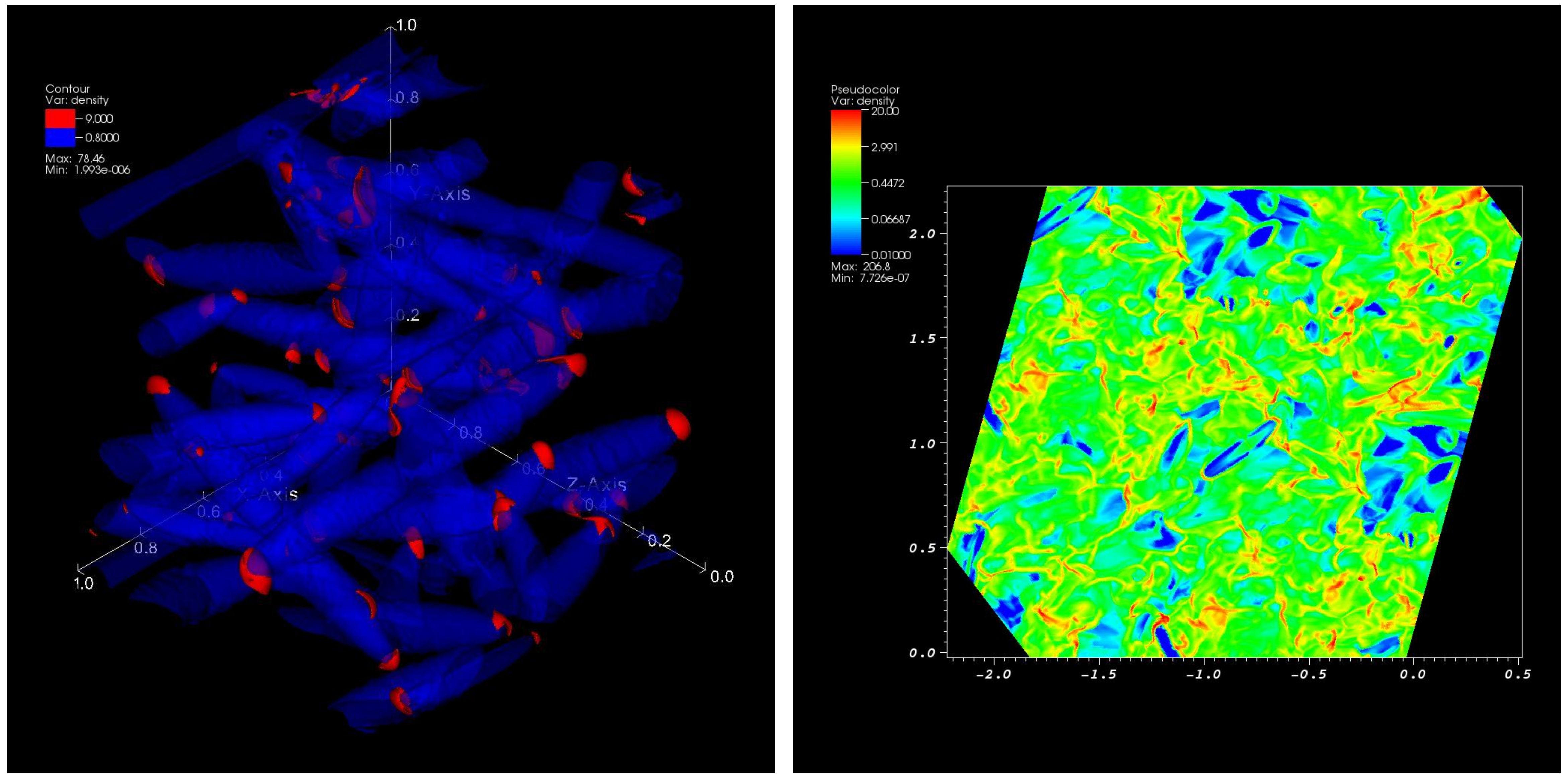
- The energy spectra associated with outflow driven turbulence indicates an outflow driving scale consistent with theoretical predictions…

Acknowledgements

Abstract

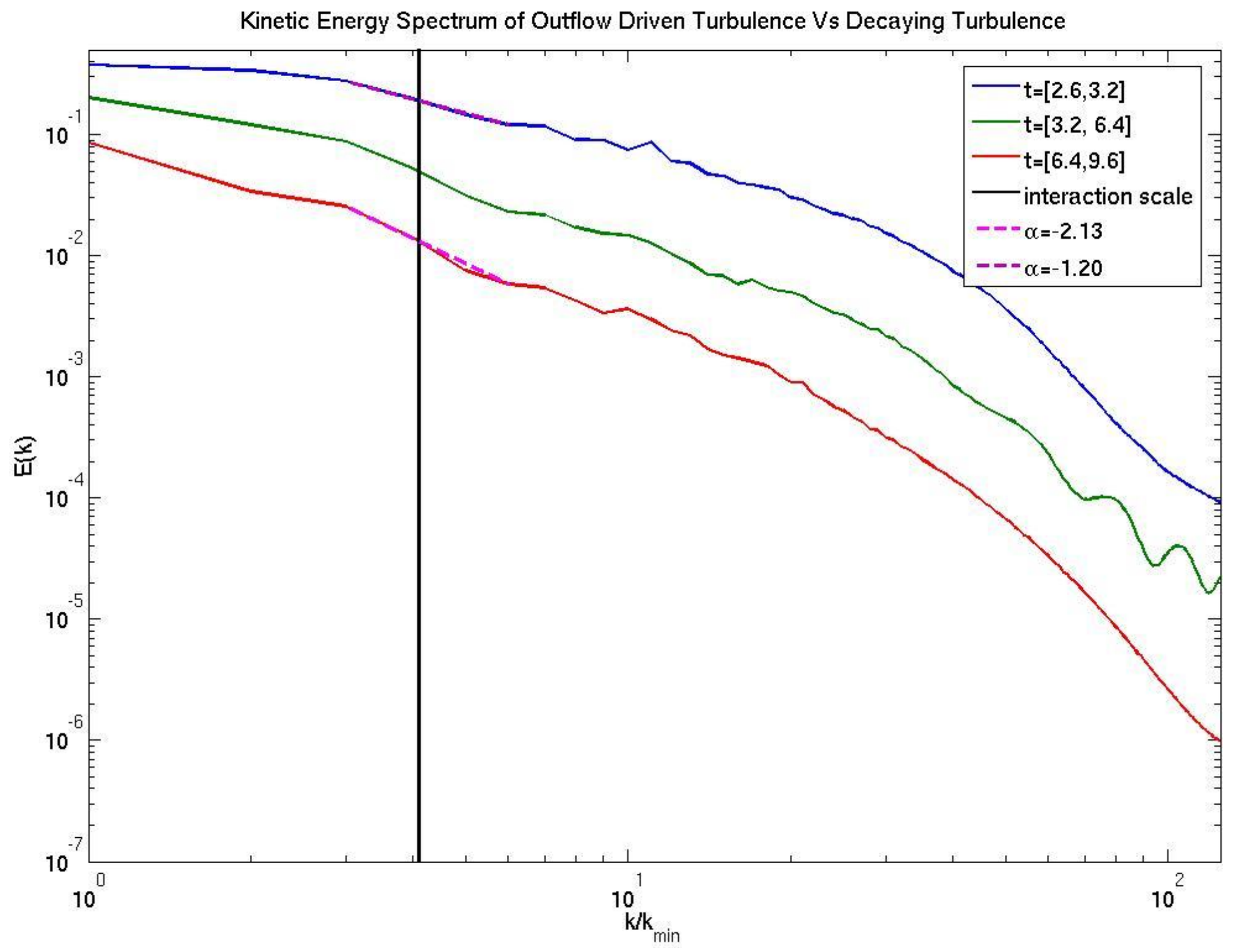
Protostellar outflows and their cavities are commonly observed within turbulent molecular cloud cores. However, the interplay between cloud turbulence and protostellar outflows remains poorly understood. Recent simulations of star forming cloud cores demonstrate that outflows can be important in regulating the SFR. Here we investigate the ability of many outflow interactions to seed turbulence and attempt to characterize the length scale at which outflows become subsumed into the overall turbulence.

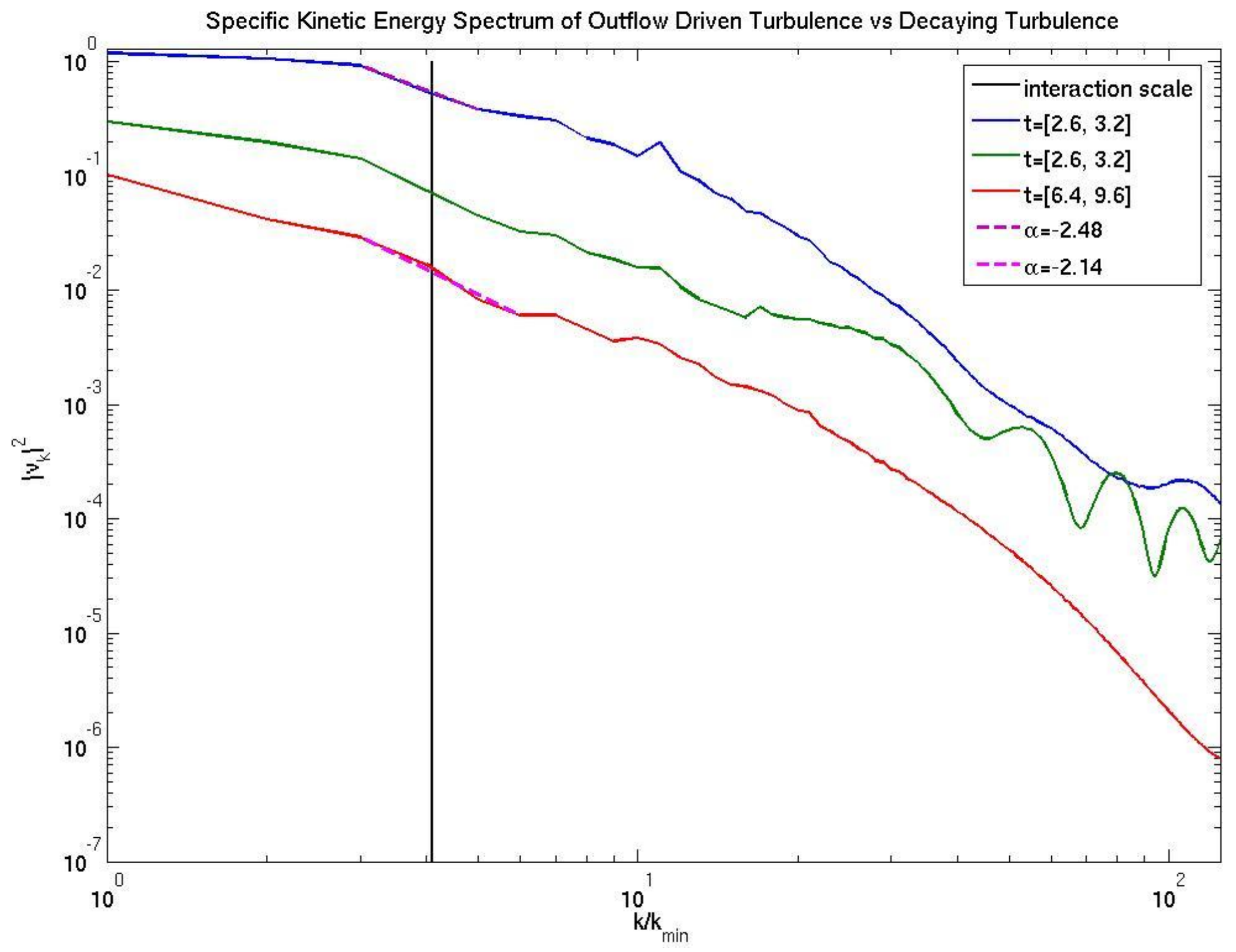
Numerical Simulations



Hydrodynamic simulations were performed on a periodic cube of length 1.5 pc for 1 Myr at a resolution of 256^3 using a polytropic equation of state (γ=1.0001) to approximate an isothermal gas at 10°K

Spectra

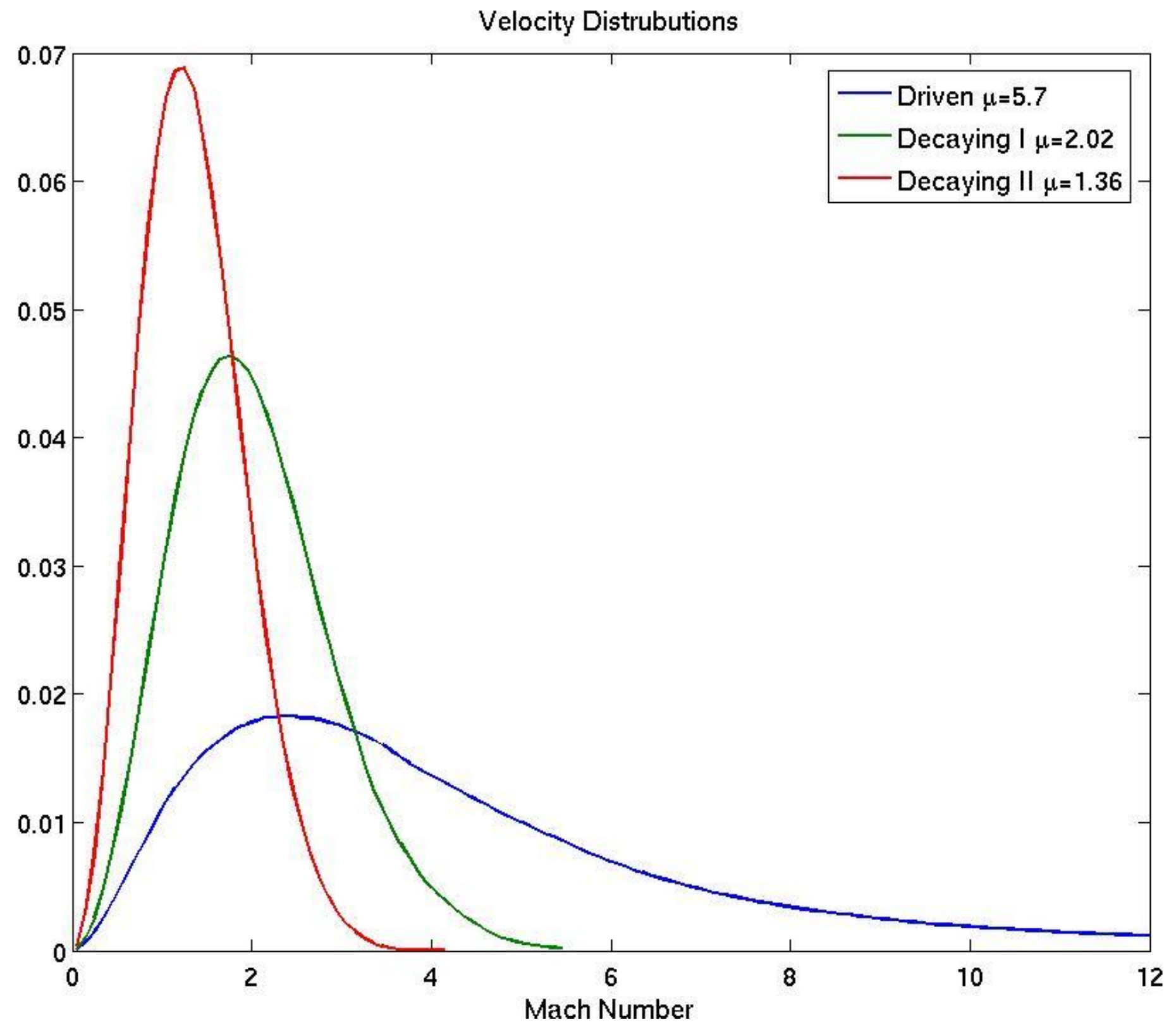




Simulations parameters

ρ	371 M☼ /pc³
$\mathcal{I}$	17 M☼ /Myr
S	59 pc⁻³Myr⁻¹
ℓ	.36 pc
t	.36 Myr
m	17 M☼
c_s	.2 km/s
$\rho_{outflow}$	92 M☼ /pc³
$v_{outflow}$	240 km/s
$t_{outflow}$	.8 kyr
θ_{half}	5°
$r_{outflow}$	.03 pc

Velocity Distribution



Density Distribution