Clumps With Bounded Magnetic Fields And Their Interaction With Shocks

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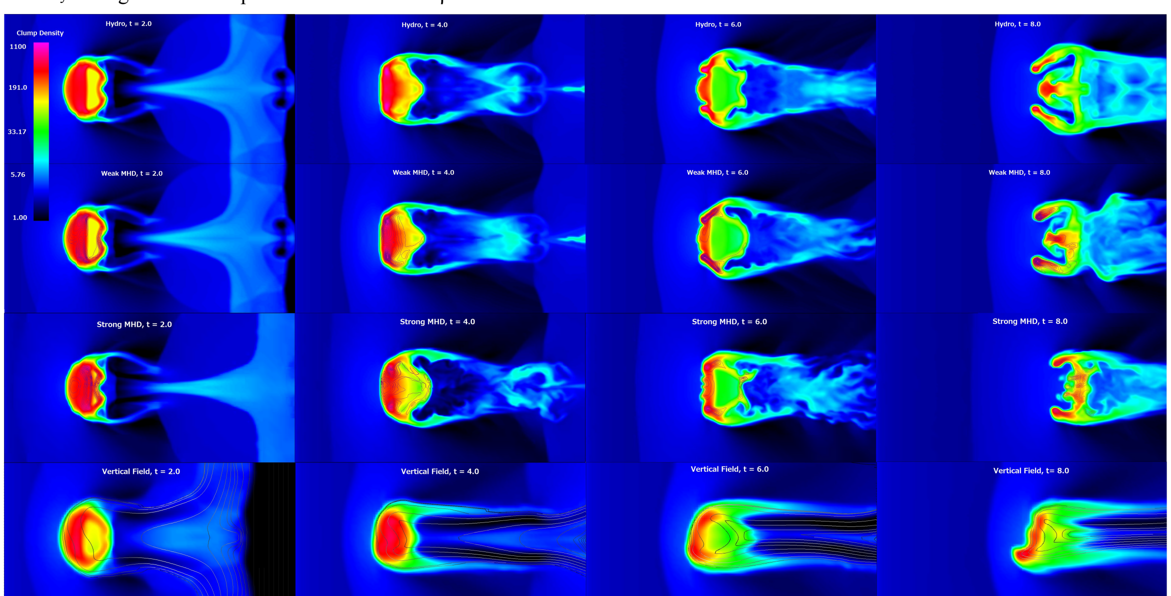
Introduction

The evolution of shocked heterogeneous flows is a fundamental problem in astrophysics relating to environments as diverse as AGN and Star Formation. Magnetic fields are expected to play a fundamental role in the evolution of such flows however to date most studies of shocked magnetized clumps have used highly simplistic "linear" fields which extend through both ambient medium and clump (*Jones, et al, 1996*). In reality clumps will likely carry complicated internal fields reflecting the clump formation process. Here we present first results of an ongoing campaign of simulations exploring how more realistic fields in shocked clumps will effect their evolution. The simulations are done using AstroBEAR.

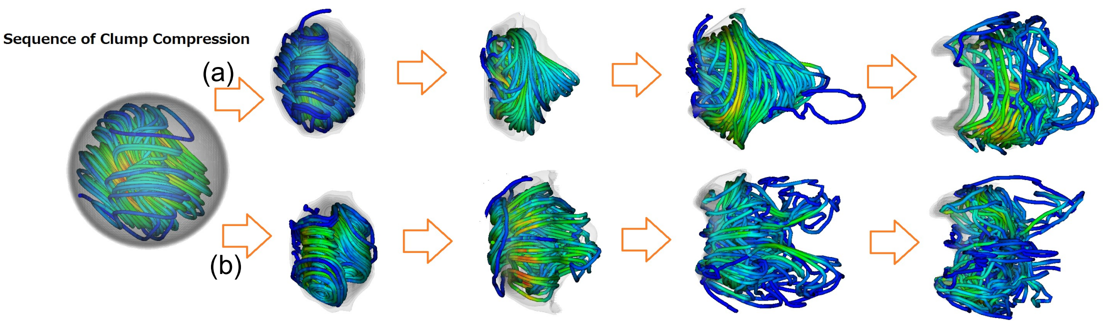
AstroBEAR is an Adaptive Mesh Refinement (AMR) distributed-memory parallel Eulerian code written in FORTRAN 90 which supports hydro- or magnetohydrodynamics in two or three dimensions. The code includes various multi-physics solvers for cooling, resistivity, thermal conduction, self gravity and sink particles. **AstroBEAR is available to other research groups.**

Ambient Density	Ambient Temperature	Density Contrast	Magnetic β	Shock Mach	Field Spectrum
$2m_H\ cc^{-1}$	2000 K	100	0.2 ~ 2	10	$B(k) \sim k^{-2}$

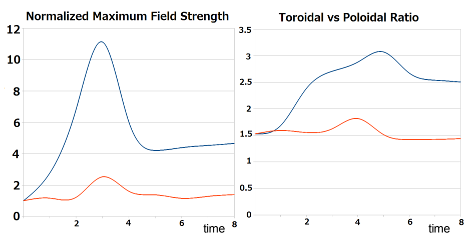
Simulation parameters are listed in the above table. Initially thermal pressure is locally balanced with magnetic pressure within clump. Note that fields are not force free and may still drive motions within clump though field strength is chosen so that even in the "Strong Filed" case, Alfvén speed are slower than the shock speed. Thus field relaxation is much slower than shock driven evolution. For this initial study we have run 5 models: "Hydro" case, with no contained field; "Weak Field" case with average β of 2; "Strong Field" case with average β of 0.2; "Vertical Field" case with $B = B_y$ throughout the computational domain and β = 2.



Shocked Field Evolution



3-D evolution of bounded field case for both weak and strong field simulations: in the weak bounded field (sequence **a**), field lines compressed and then unfold. The toroidal component becomes more distorted with the evolving flow. In the strong contained field case (sequence **b**), field are harder to compress. The fields retain more of original configuration and provide some restriction of clump deformation. Line plots shows maximum field strength evolution and toroidal vs poloidal ratio evolution. The weak MHD case is coded **blue**, the strong MHD case is coded **red**.



Comparative Clump Evolution

To the left we show a sequence of images for four clumps simulations (in descending order: Hydro; Weak Field; Strong Field; Vertical Field). In the vertical field case, field lines wrap around the clump as shock flow passes over the clump. The fields' cushioning effect reduces clump compression and deformation. In the contained field cases both the weak field, strong field runs are similar to the hydro model in compression phase. The evolution of field lines is different however and during expansion phase, the field lines unfold and become mostly toroidal within the clump for the weak field model. This field behavior limits the jet like flows at the final frame. In the strong field case magnetic lines of force resist deformation more strongly. In the final frame, the strong field clump has evolved into a cylindrical plug with less fragmentation than other models.

Conclusion and Future Works

We have presented simulations of shocked "internally" magnetized clumps comparing them with both hydrodynamic and linear global field cases. For the internal field configurations chosen we find that internal fields do not significantly alter clump evolution though we do see differences in the evolution of field topology. Future work will explore the effect of different initial internal field configurations and will also examine the influence of resistivity and anisotropic heat conduction on the evolution of shocked magnetic clumps (*Orlando, et al, 2008*).

References

Jones, T.W., Ryu, Dongsu, Tregillis, I.L. 1996 ApJ, 473, 365
Orlando, S., Bochino, F., Reale, F,. Peres, G., Pagano, P. 2008 ApJ, 678, 274