Shocked Heterogeneous Flows with Heat Conduction

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Introduction

•**In shock-clump interactions, thermal conduction and radiative cooling at the bow and transmitted shocks can be different given an incident Mach number and clump density contrast.**
This difference has not been recognized before and can lead to different global behavior when multiple clumps are present.

•**The study of shocked, heterogeneous flows with various physics processes such as cooling and thermal conduction operating can help us understand the structure and characteristics of inter and circumstellar media.**

Basic Parameters

Clump Radius = 1 PC
Ambient Density = 1 part/cm^2
Clump Density = 10 parts/cm^2
Ambient Temperature = 10000 K

Results

•Clump crushing time scales, radiative cooling time scales and thermal conduction time scales divide the parameter space of Mach number and density contrast into different regimes with different physics (Figs 9 and 10). In the multi-clump case, the clump interaction behaviour will be affected by this difference.

• When bow shock conduction dominates, post bow shock material around the clump will develop into a thick corona leading to clump evaporation. In this case two-clump interactions will be characterized by strong mass mixing and merging between the two clumps (Figs 3 and 4).

• In the case of transmitted shock cooling domination, jet-like flows develop after some time between clumps and the two-clump evolution will be characterized by the interaction of these jets (Figs 7 and 8). The interaction also depends on clump distance, the figures show the situation when clumps are densely packed.

Future Works

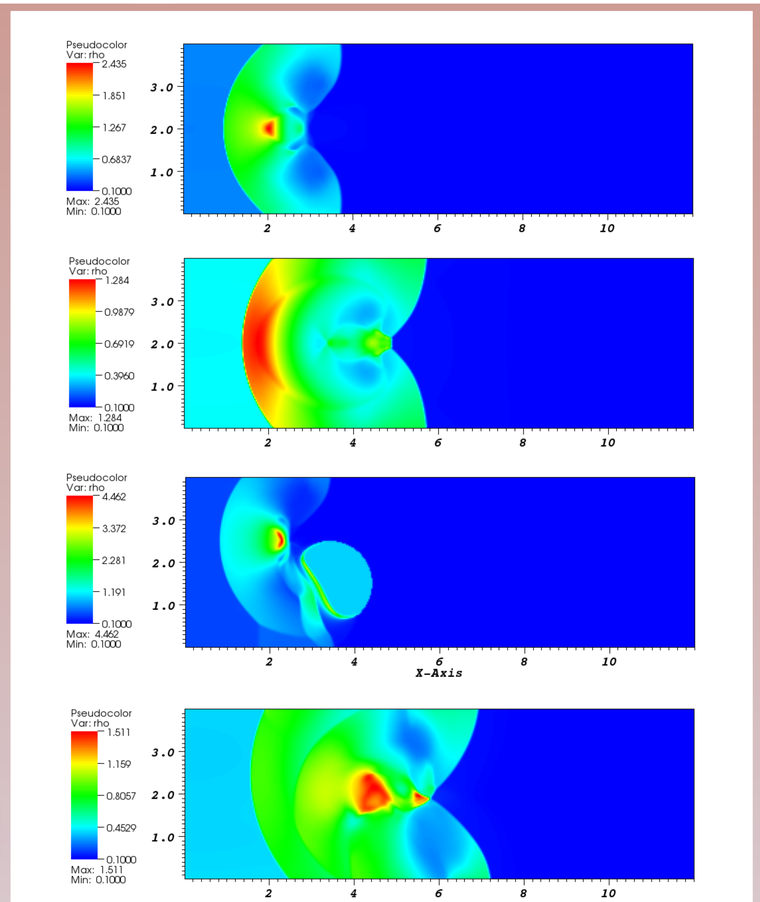
•By including magnetic fields, a field dependent thermal conduction, a more realistic cooling curve and randomly placed arrays of clumps, we can further study the behaviour of shock multi-clump interactions in different regimes of the Mach number vs density contrast parameter space.

Codes

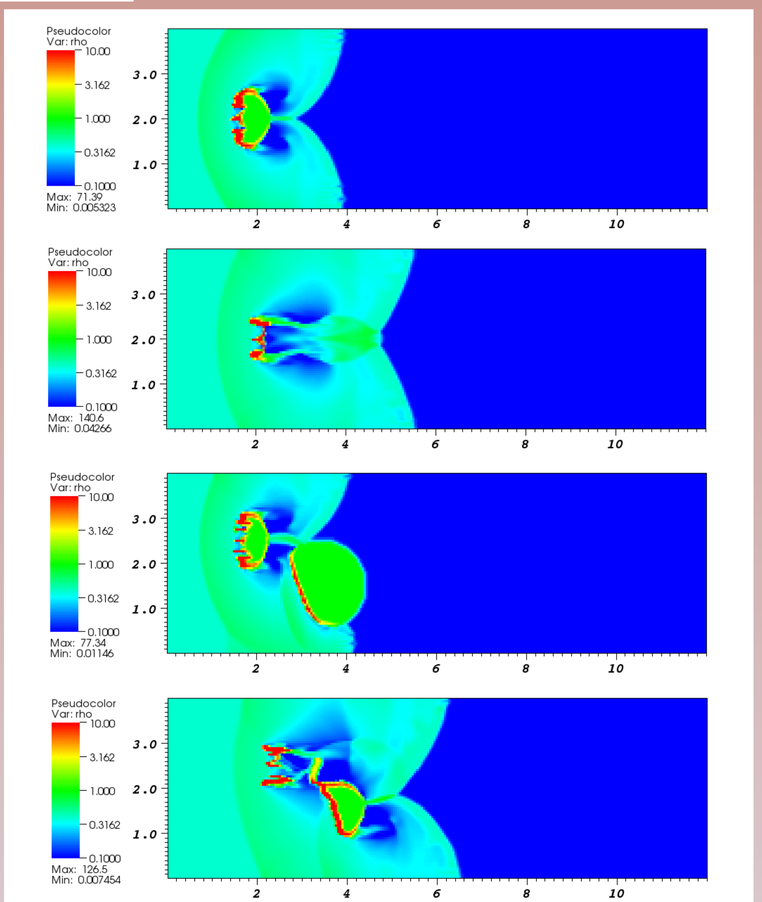
• The simulation is done with AstroBear, University of Rochester's AMR MHD code along with HYPRE, high performance preconditioners developed by Lawrence Livermore National Laboratory.

Supporting Institutions

•U.S. Department of Energy
•NSF, NASA, StSci, JPL
•Laboratory for Laser Energetics, University of Rochester
•Center for Research Computing, University of Rochester



Figs. 1 – 4: Density snapshots of a shock clump interaction when the thermal conduction in the bow shock dominates (M=50). 1) single clump at 0.6 clump crushing time; 2) single clump at clump crushing time; 3) two clump interaction at 0.6 clump crushing time; 4) two clump at clump crushing time.



Figs. 5 – 8 Density snapshots of a shock clump interaction when the cooling in the transmitted shock dominates (M=20). 1) single clump at 0.5 clump crushing time; 2) single clump at 1.0 clump crushing time; 3) two clump interaction at 0.7 clump crushing time; 4) two clump interaction 1.2 clump crushing time

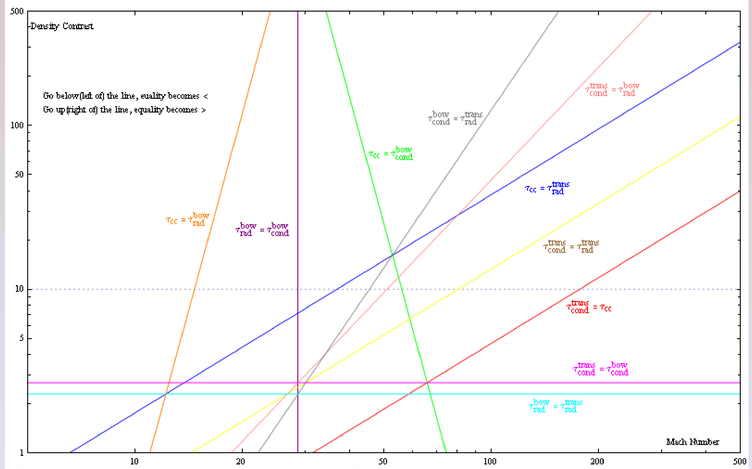


Fig. 9: Mach number vs density contrast for "large" clumps.
The clump radius is taken to be 1 pc. Ambient density is 1.0 part / cm^2, Ambient temperature is 10000 K.

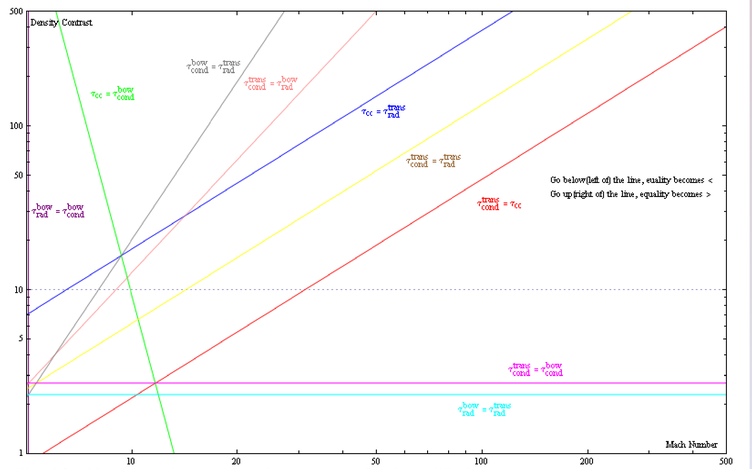


Fig. 10: Mach number vs density contrast for "small" clumps.
The clump radius is taken to be 200 au. Ambient density is 1.0 part / cm^2, Ambient temperature is 10000 K.