

AMR Simulations of Clumped 3D Radiatively-Cooling Jets

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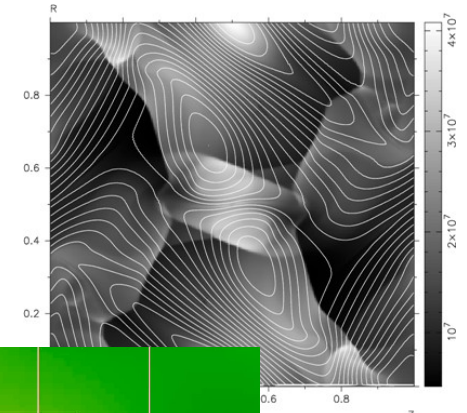
JETSET 5th School
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(Background:
somewhere in NGC3372)

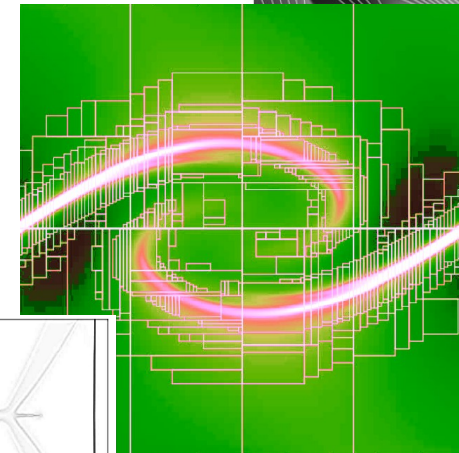


Astrophysics with AstroBEAR: a modular (M)HD+AMR code

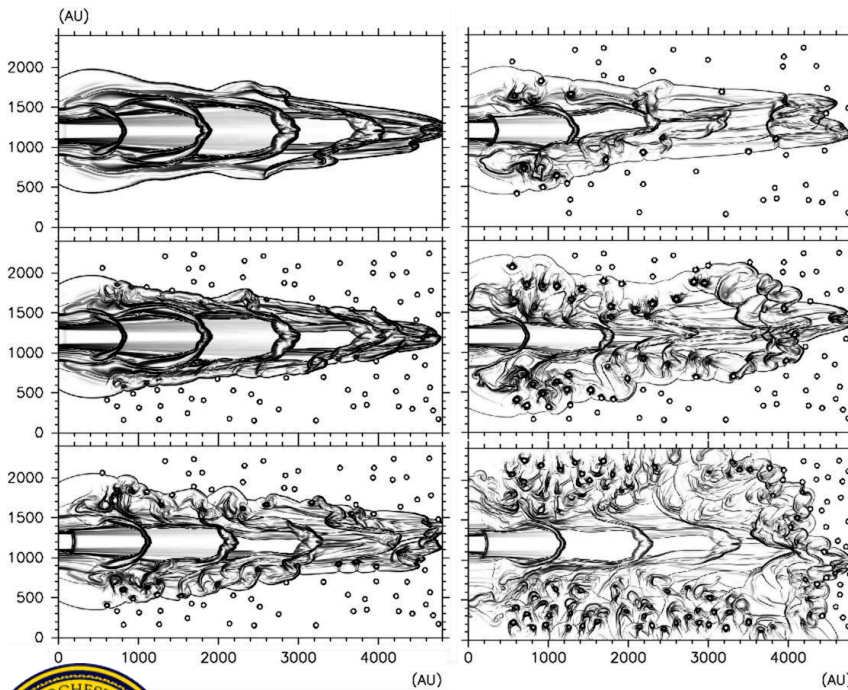
- MPI+OpenMP parallel implementation
- Advances a system of hyperbolic equations via explicit timestepping
- Vetted against a variety of test problems
- Applied to a variety of actual problems



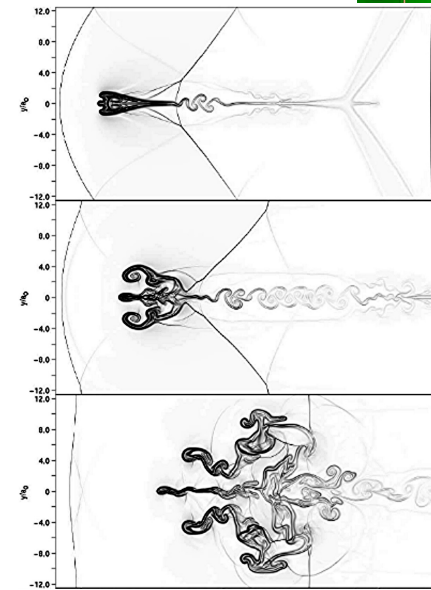
MHD OT



MHD KH



Astrophysical Jets
(Yirak, et al. 2007 ApJ, 672, 996)



Adiabatic Shocked Clumps
(Poludnenko, Frank, Blackman,
2002 ApJ, 576 832)



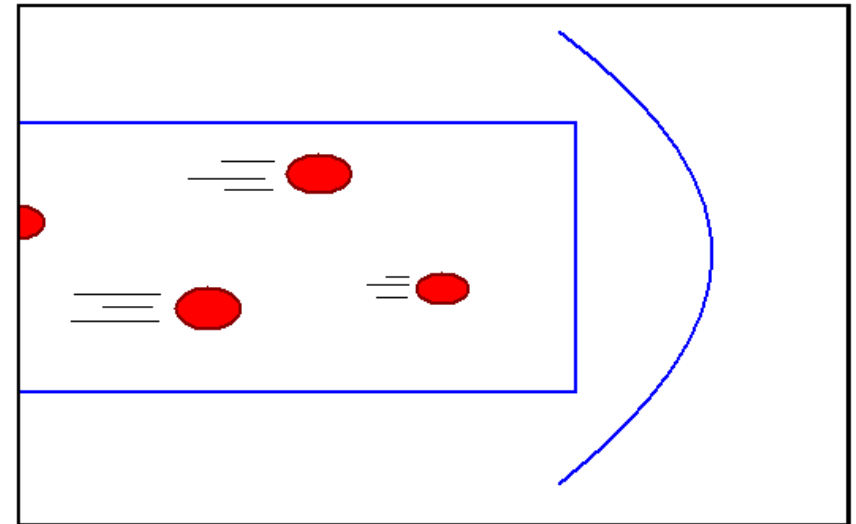
Astrophysical outflows are common, interesting, and important (still)

- Especially, the nature versus nurture debate (launching versus environment)



(HH 111)

?
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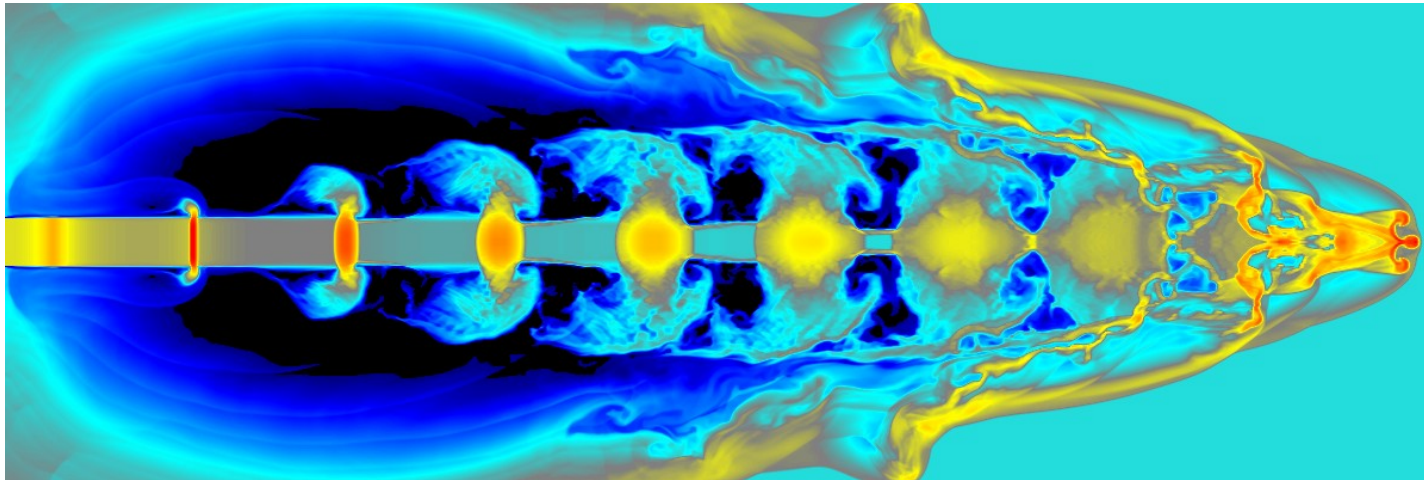


- The model for this talk: the effect of entrained heterogeneity (clumpyness)



The main idea: inducing pronounced asymmetry

The usual pulsed jet setup yields near-axisymmetry in the jet beam.



(from Jim Stone's webpage)

Do non-axially-aligned features in HH objects necessarily imply variable-angle jet launching?

Or, is it possible to recreate important non symmetric features with a “clumped” jet beam?



The present model “magically” seeds dense clumps into a smooth jet beam

The clumps have random radii and speeds within a range of $0.25-0.75r_{\text{jet}}$ and 5% of v_{jet} .
 Given below is a description of an example simulation:

Physical Properties

<u>Ambient Medium</u>		<u>The Jet</u>		<u>The Clumps</u>	
Density	10 cm^{-3}	Density	100 cm^{-3}	Density	1000 cm^{-3}
Temperature	2,000 K	Temperature	2,000 K	Temperature	200 K
Size of Domain	$3200 \times 1200^2 \text{ AU}$	Radius	100 AU	Radius	20-40 AU
Sound Speed	$<1 \text{ km/s}$	Velocity	150 km/s	Relative Velocity	$\pm 4 \text{ km/s}$

Computational Properties

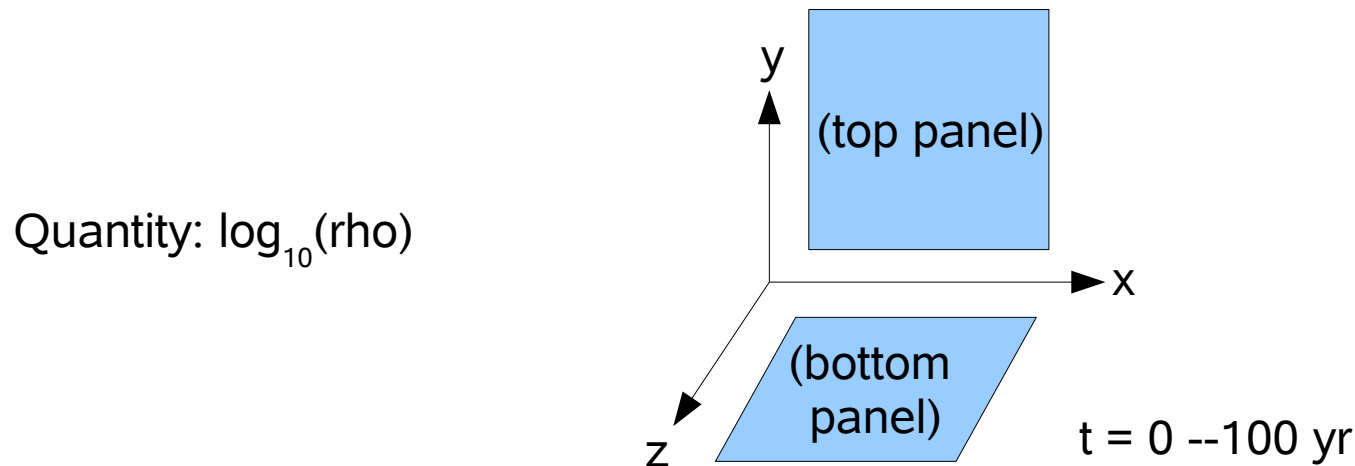
AMR Levels	0 +3	Cells/Jet Radius	6 (24)	Cells/Clump Radius	(6-14)
Resolution (Max. Effective)	$96 \times 36 \times 36$ ($768 \times 288 \times 288$)			Clump Frequency	$\sim 4 \text{ yr}$
Hydro; Simple Radiative Cooling; O(2) Temporal/Spatial		$t_{\text{end}} = 100 \text{ yr}$		Number of Clumps	~ 25

$N_{\text{proc}} = 16$

$T = 10 \text{ days}$



The clumps have pronounced effect on the jet beam and jet shock (movie 1)

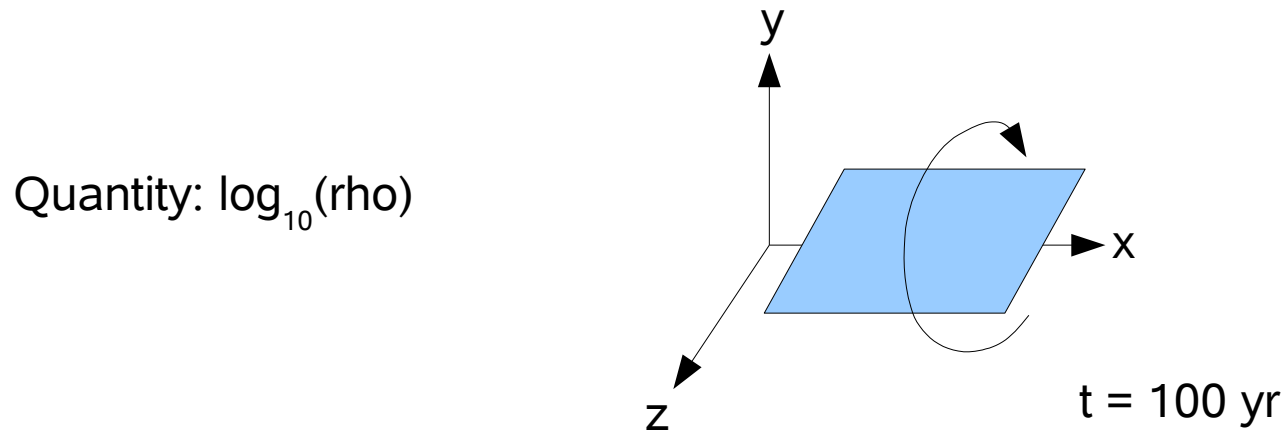


(This movie shows the y- and z-planes through the center of the jet beam, over time.)

slices.AVI



The clumps have pronounced effect on the jet beam and jet shock (movie 2)



(This movie shows the rotation of a plane about the jet axis, at a fixed point in time.)

slicerotate.AVI



This work is in very early stages – steps to quantitative evaluation of this model are in progress

The morphologies are intriguing, but effective evaluation requires characterization via

- Emission line diagnostics
- Observational characteristics (P-V diagrams, etc.)
- Multifluid advection results
- Additional morphological features (“bending”?)

The next stage: MHD clumps



BEGIN EXTRA SLIDES



3D contour plot movie

Red through blue: $\log_{10}(\text{jet density tracer})$
Green: $\log_{10}(\text{clump tracer})$

contours.AVI



Clumps vs. velocity movie

(Complicated.)

v-vs-clump-density.AVI



More of NGC3372 (because it's pretty)

