Hands-on session using RAMSES:

MHD simulations of shocks and instabilities

Francisco Jara, Pierre Nürnberger, Jonathan Petersson,
Larissa Tevlin, Jack Berat, Ihaly Garcia, Jia Wei Teh

Supervisors: E. Ntormousi (& P. Lesaffre as the notoriously hopeless student)

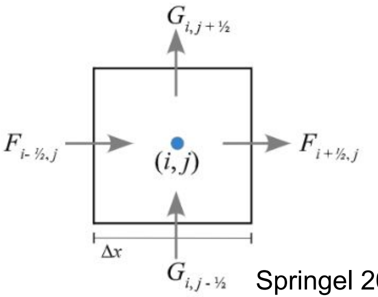
RAMSES (Teyssier 2002)

"Raffinement Adaptatif de Maillage Sans Effort Surhumain"

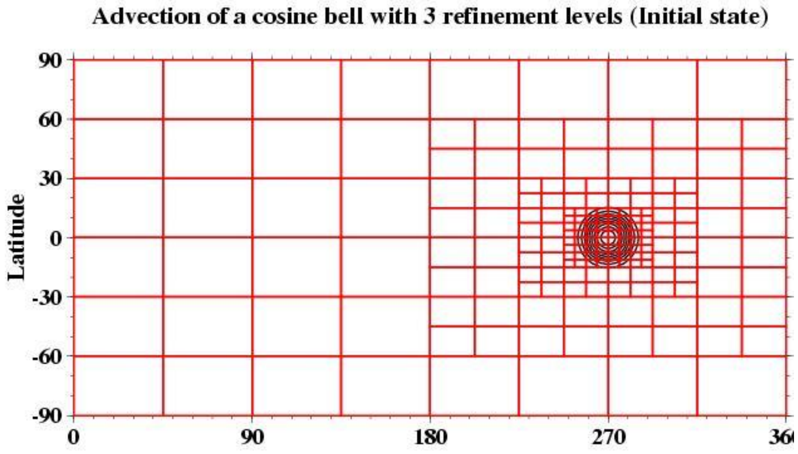
- Eulerian code for solving MHD + gravity
- Sub-grid models for baryonic physics, galaxy evolution, ISM cooling, …
- MHD equations are conservation equations:

$$\frac{\partial \mathbf{U}}{\partial t} + \boldsymbol{\nabla} \cdot \mathbf{F}(\mathbf{U}) = 0$$

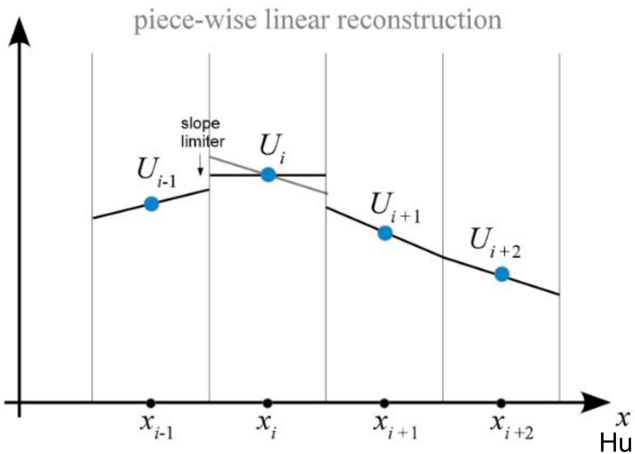
- Solve Riemann problem between cell interfaces:



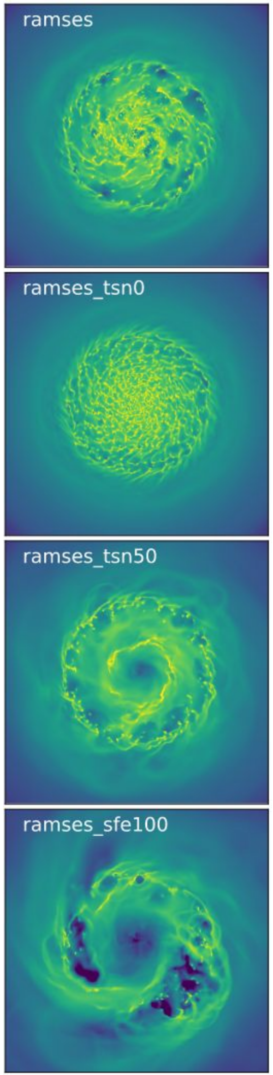
Springel 2021



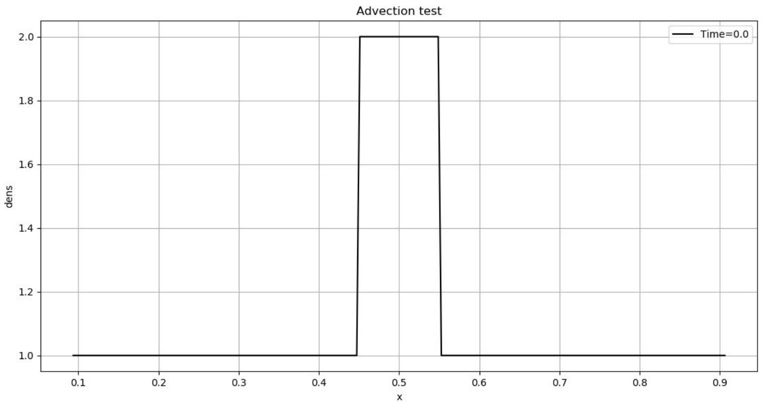
C. Jablonowski

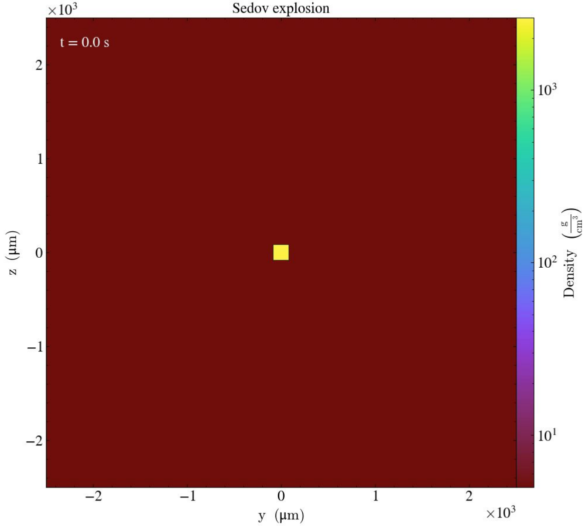


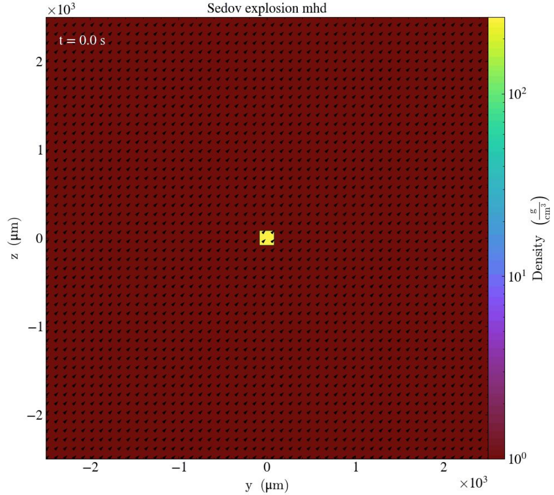
Hu et al. 2023

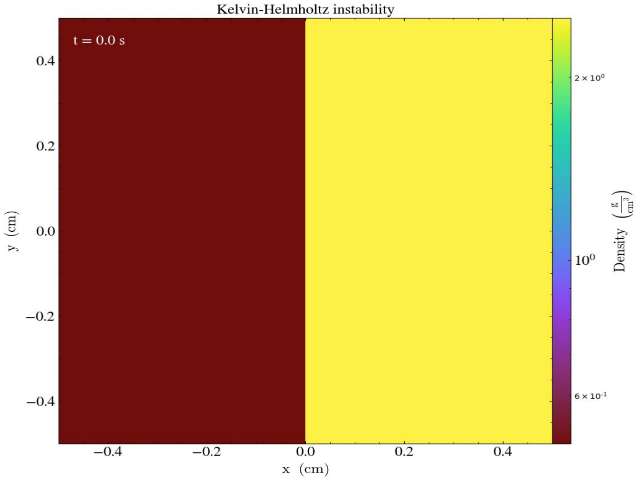


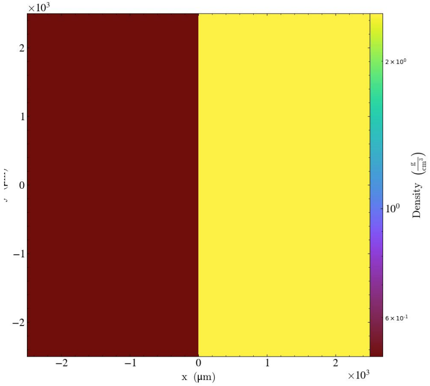
RAMSES EXERCISES









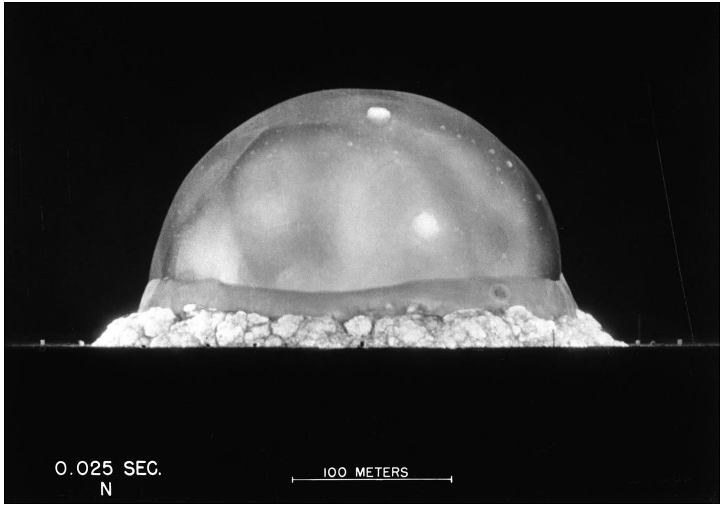


Zoom factor of 2

1D implementation using RAMSES:

The Taylor-von Neumann-Sedov blastwave

- Blast wave induced by strong energy injection
- Self-similar solution - dimensions scalable!



1D implementation using RAMSES:

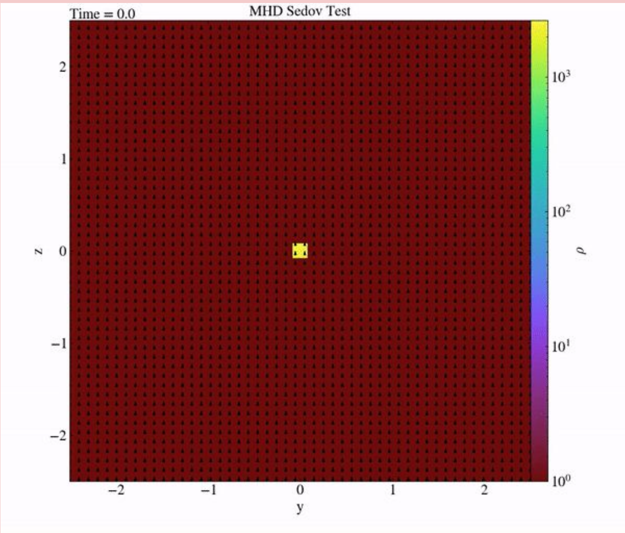
The Taylor-von Neumann-Sedov blastwave $P_{explosion} = 10^5 \, P_{ambient}$

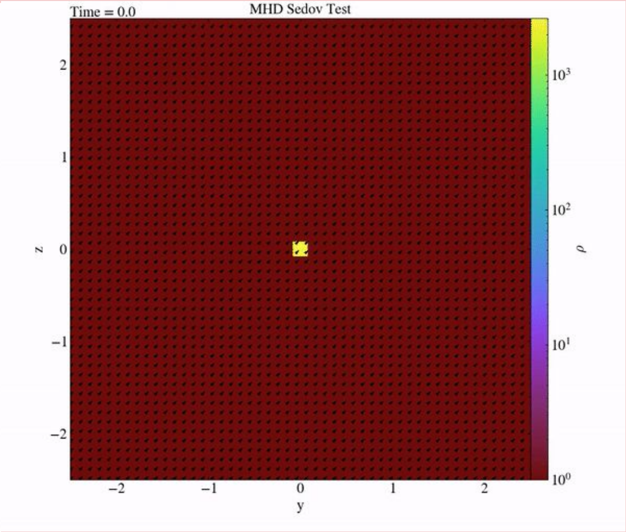
3D Sedov Blast Wave interacting with Magnetic Field (MF)

Post processing using yt (Turk et al. 2011)

Propagation of the blast wave as a function of time, colored by density + MF lines.

→ `yt.SlicePlot(dat, projection ="x", field = ("gas", "density"))`

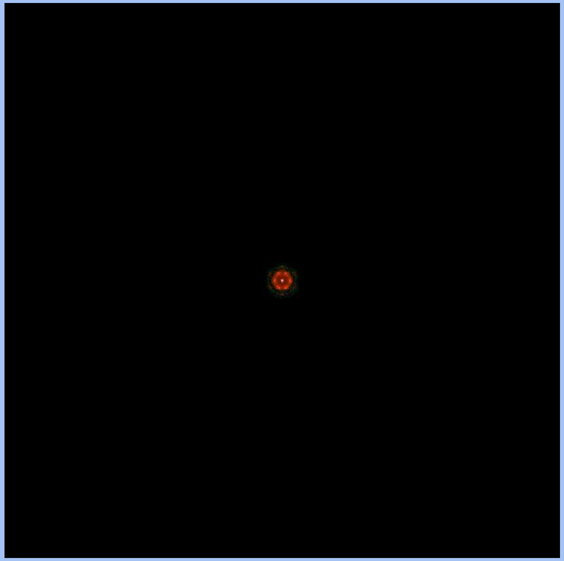




Only Bz

Bx, By, Bz ≠ 0

3D Representation
Colored by density, under the effect of uniform MF.



```
yt.create_scene(dat, field=("gas", "density"), lens_type="perspective")
```

Impact of different injection parameters
(Collision of shock fronts)

all values in code units

quicker expansion / larger momentum

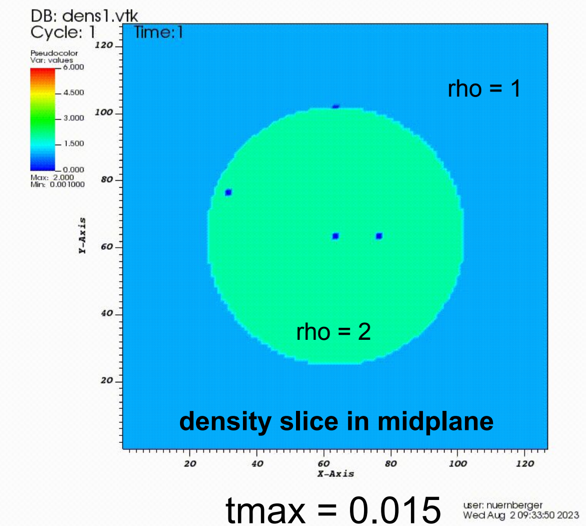
Injection parameters:

density = 0.1
pressure = 1e4

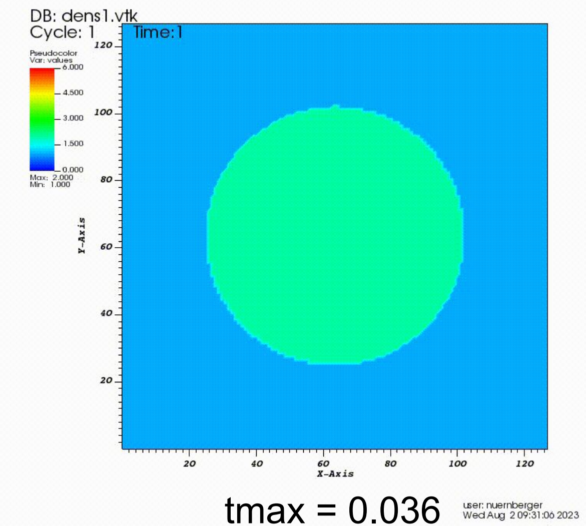
even faster expansion

density = 2.0 (amb)
pressure = 1e5

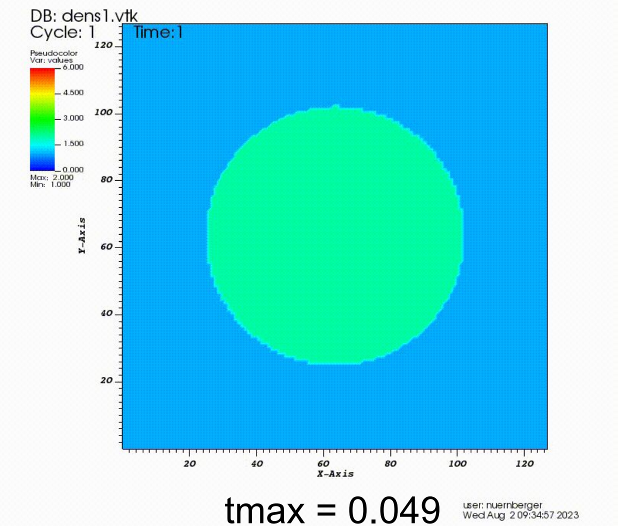
density = 2.0 (amb)
pressure = 1e4



tmax = 0.015



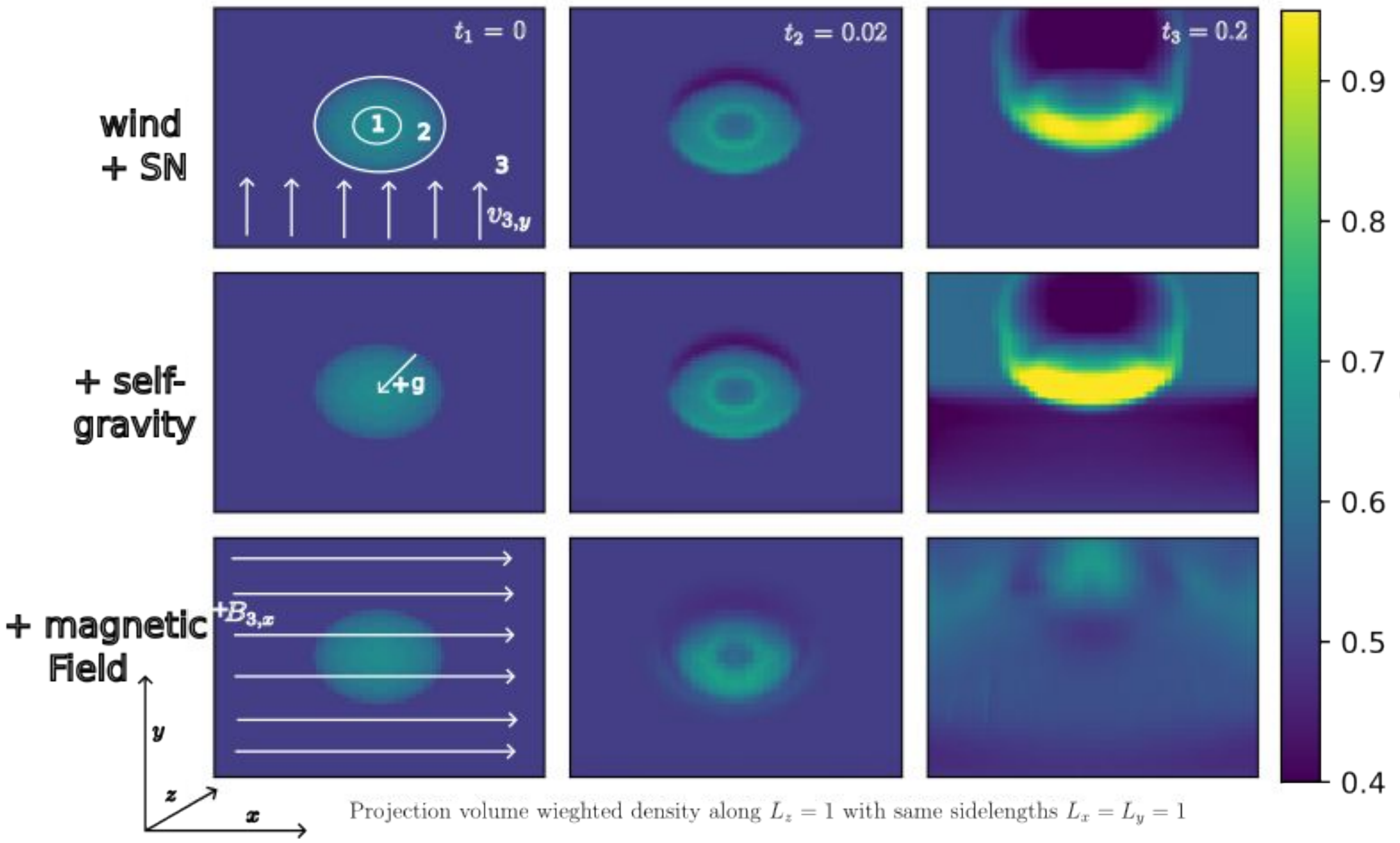
tmax = 0.036



tmax = 0.049

Pierre Nürnberger

Molecular Cloud in a Dense Wind



$R_2 = 0.2$
$R_1 = 0.04$

$\rho_2 = 0.9$
$\rho_1 = 0.9$
$\rho_3 = 0.2$

$P_2 = 10^{-5}$
$P_1 = 20$
$P_3 = 10^{-5}$

$v_2 = 0$
$v_1 = 0$
$v_{3,y} = 2$

$B_{2,x} = 2$
$B_{1,x} = 2$
$B_{3,x} = 2$

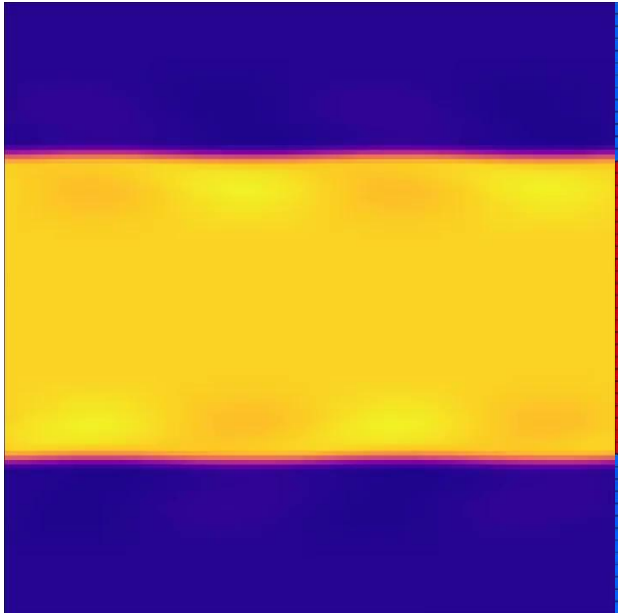
Kelvin-Helmholtz Instabilities: RAMSES vs AREPO

Velocity perturbation (Springel, 2010):

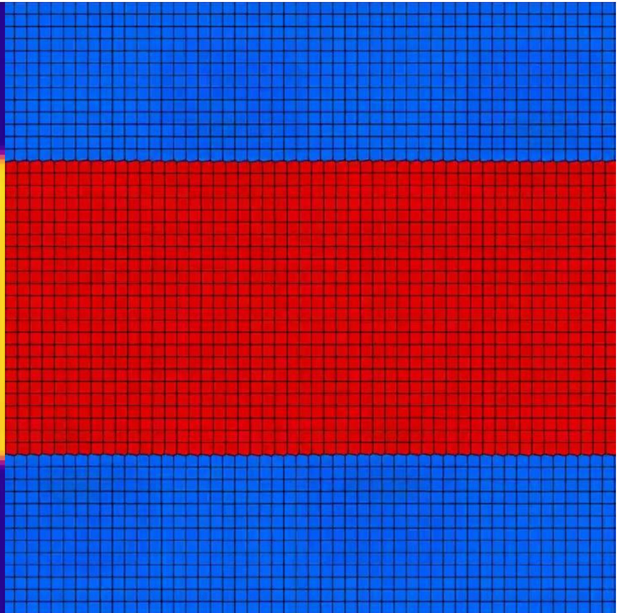
$$v_y(x, y) = w_0 \sin(4\pi x) \times \left\{ \exp\left[-\frac{(y-0.25)^2}{2\sigma^2} \right] + \exp\left[-\frac{(y-0.75)^2}{2\sigma^2} \right] \right\}$$

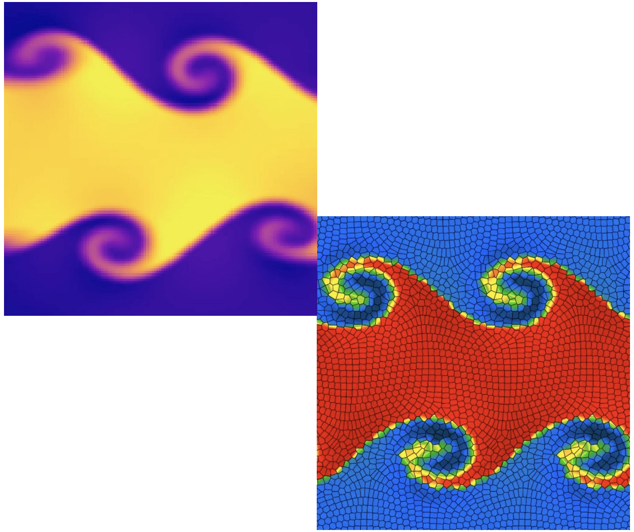
Gas density projection:

RAMSES



AREPO





(Springel, 2010)

Thank you!