Hydro Simulations: How We Can Model Fluids to Understand Astronomy.

UMD Observatory Open House

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Experimental Science?

Science is usually based on experiments.

- Start with a hypothesis.
- Test it.
- Revise.
- Repeat.

Astronomy is not (exactly) an experimental science.

But that doesn't work for Astronomy. What we study is usually too big and too far away to do experiments.

But there are some exceptions...

Including recent ones.

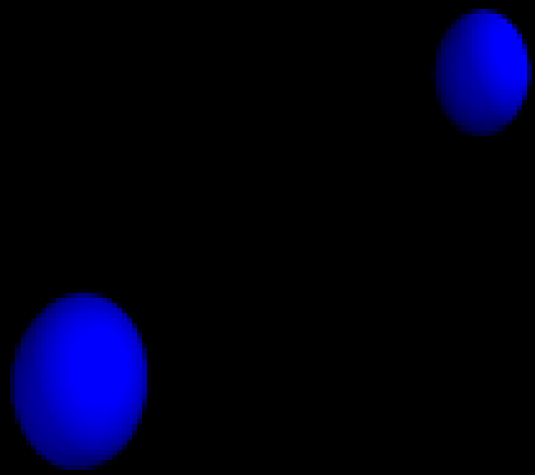
Types of Astronomers:

- Observers
- Theorists

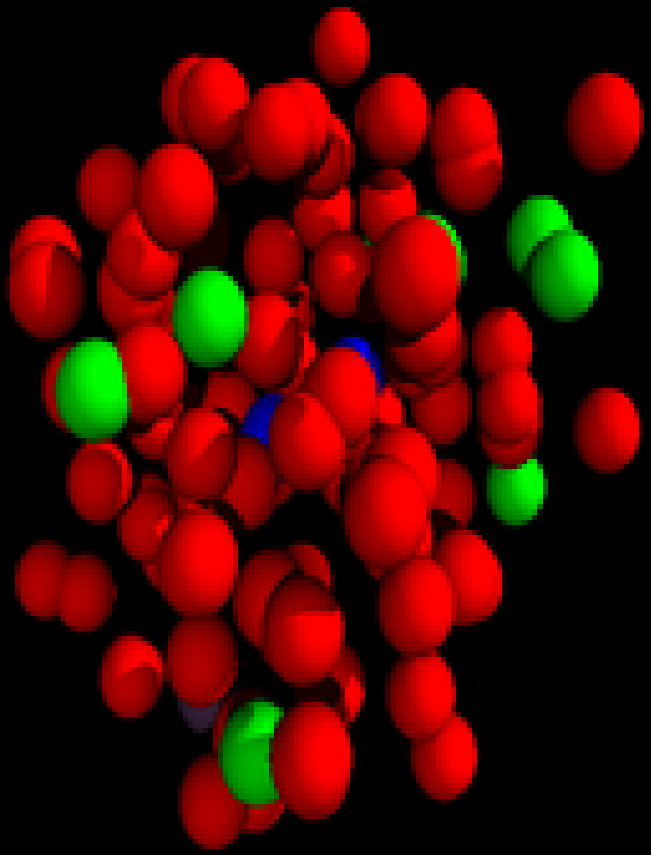
Numerical Experiments:

- NBody
- Hydrodynamics

Two bodies in orbit.



Many (N) Bodies.

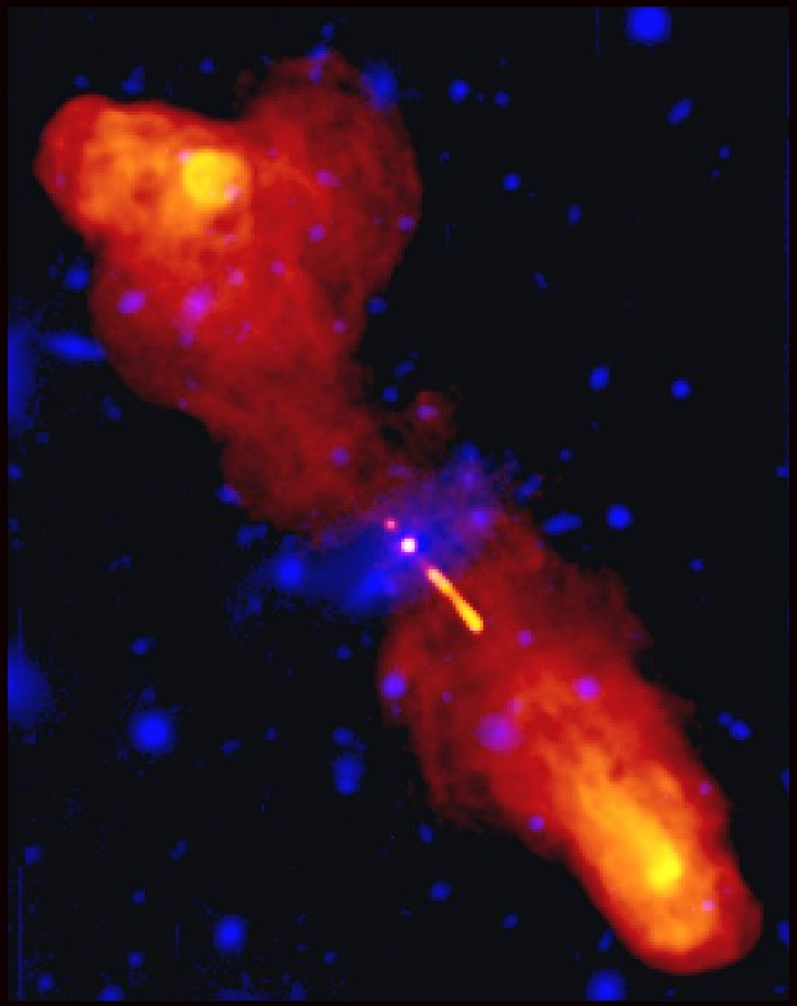


Hydrodynamics

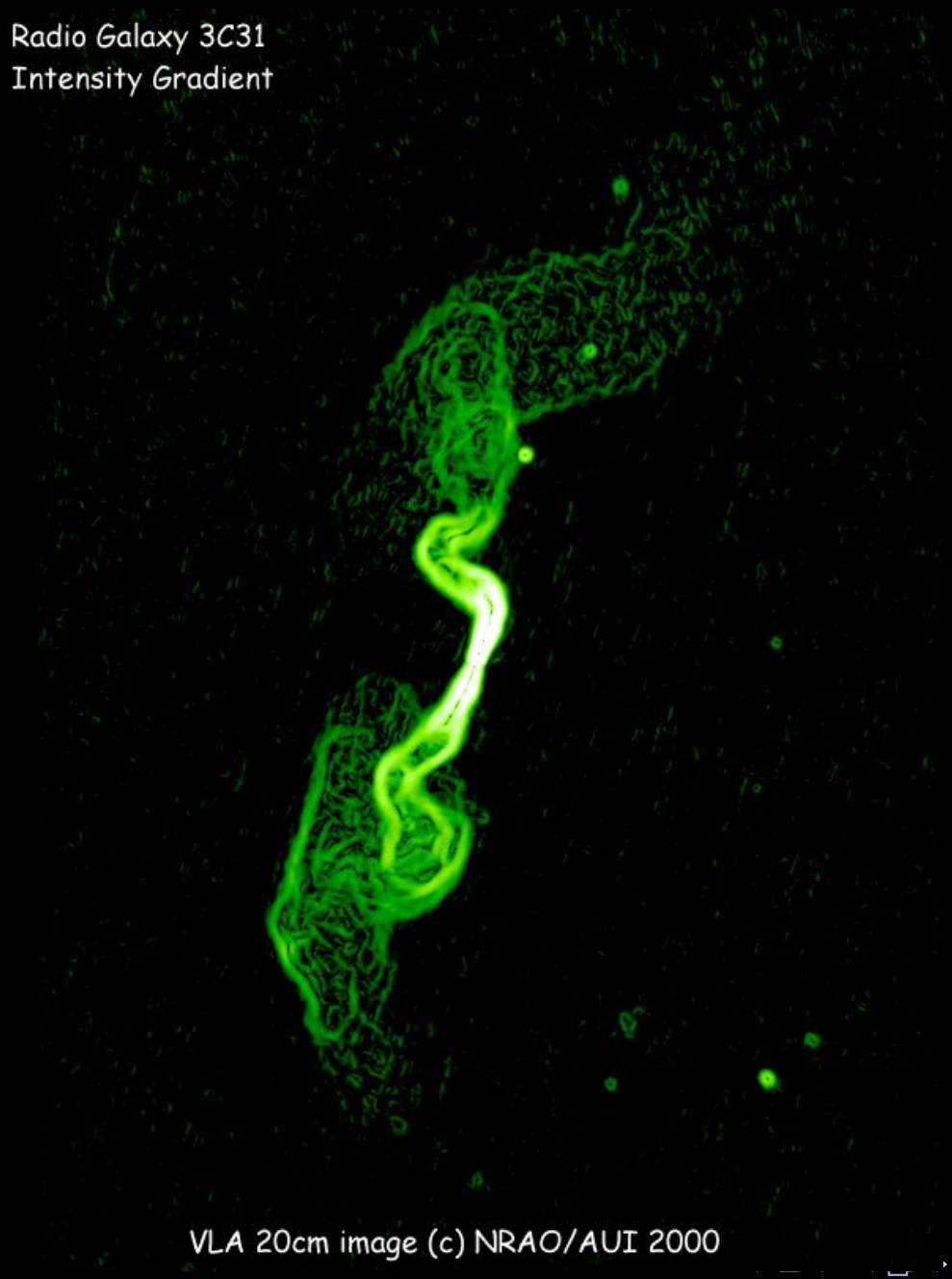
- How can the motion of fluids be useful for Astronomy?
- Most of the universe is actually either in the gas or plasma phase.
- Solids like us are a bit of a minority.
- Conveniently, gas and plasma behave a whole lot like fluids.

Jets

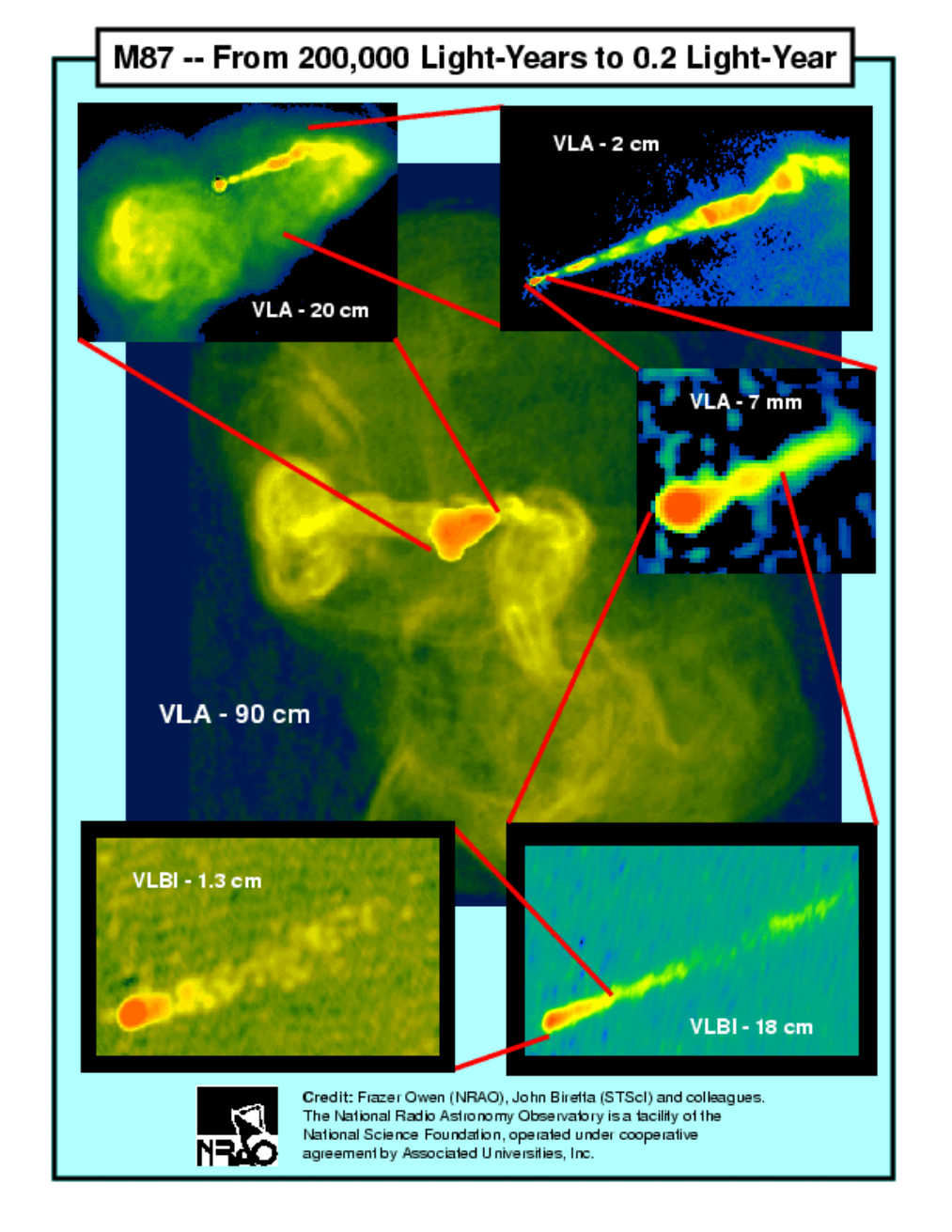
Radio Galaxy 3C219
Radio/optical Superposition



More Jets


Radio Galaxy 3C31
Intensity Gradient
VLA 20cm image (c) NRAO/AUI 2000

Even More Jets...



About Jets:

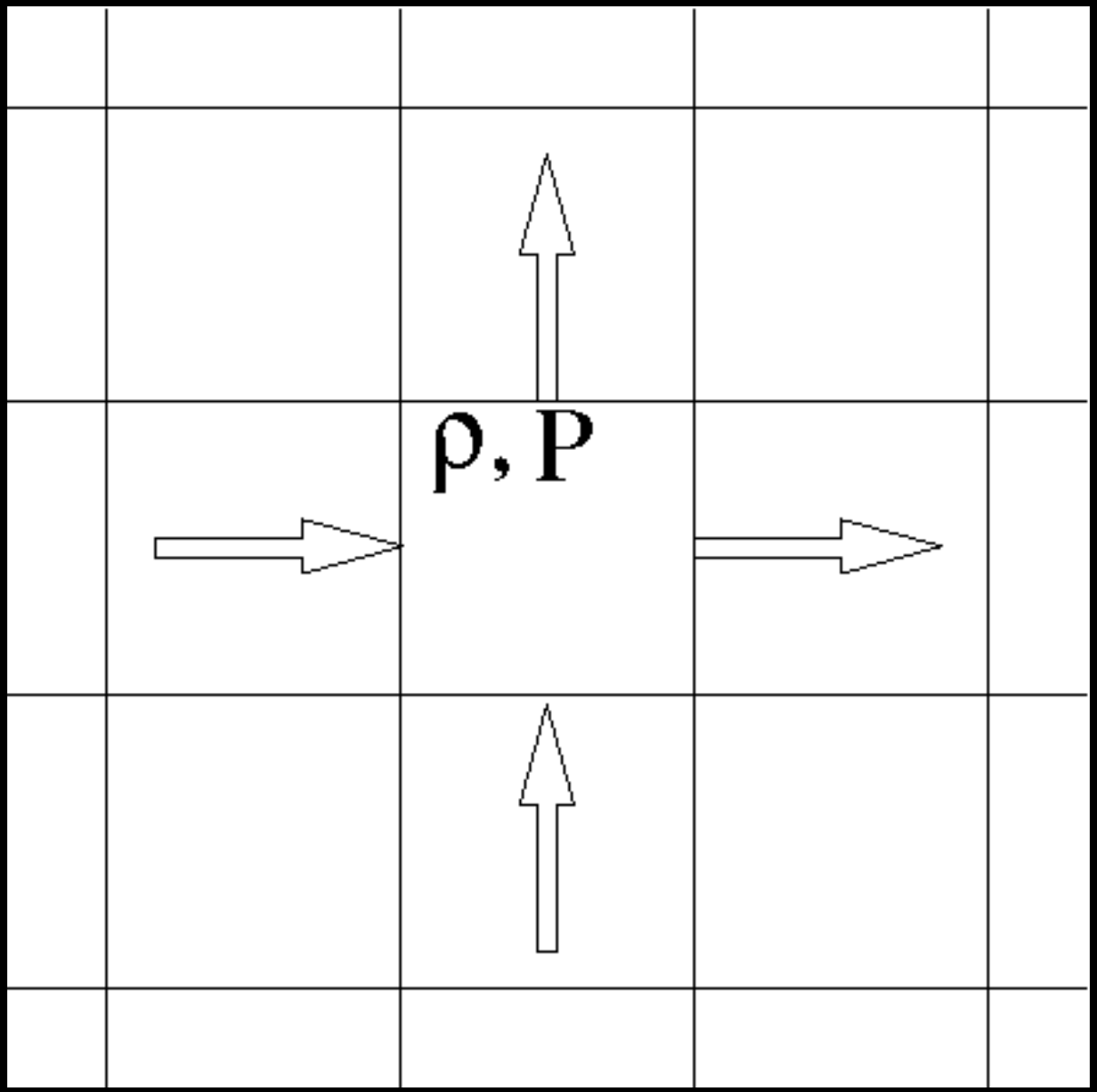
- Can travel near the speed of light.
- Powered by accretion onto supermassive black holes at the center of galaxies.
- Exact method of launching not totally understood.
- Probably made of very hot plasma and well modeled as a fluid (hitting a fluid background).
- Some more on jets later.

But first a little bit about how hydrodynamics works.

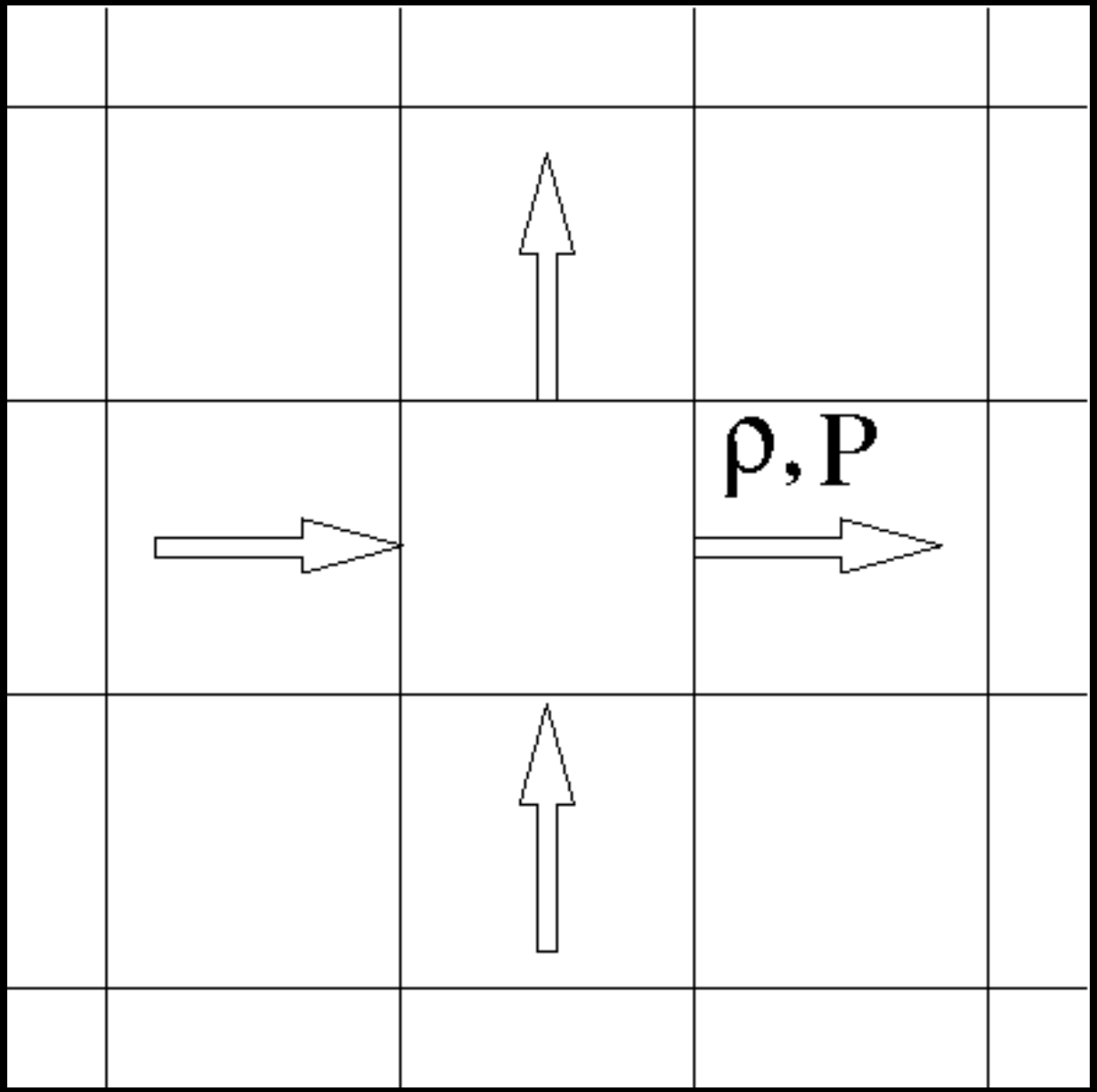
Different ways to do hydro.

In the most common method, we solve equations on a grid to see what a fluid behaves.

Grids



Grids



Public Hydro Code

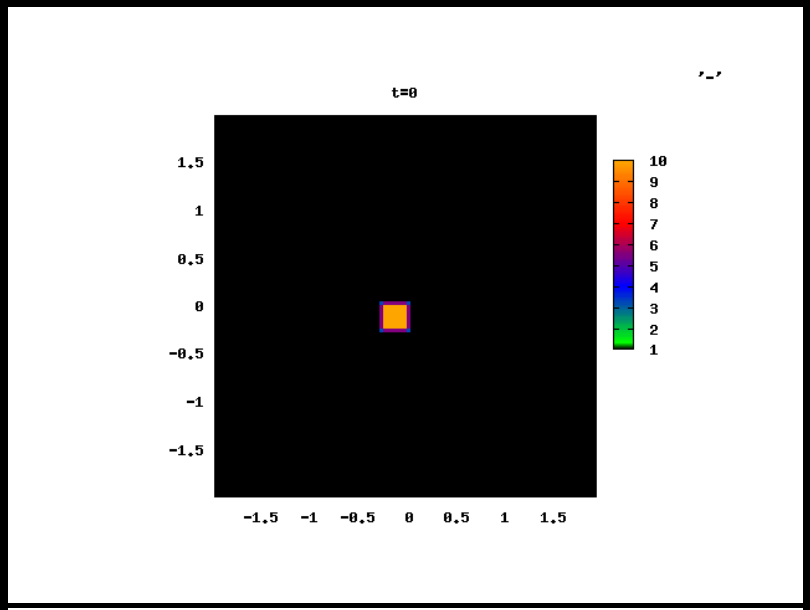
- Modified and updated version of FORTRAN 77 NCSA release.
- ZEUS-MP v1.5.13
- `http://www.astro.umd.edu/~vernaleo/zeusmp.html`

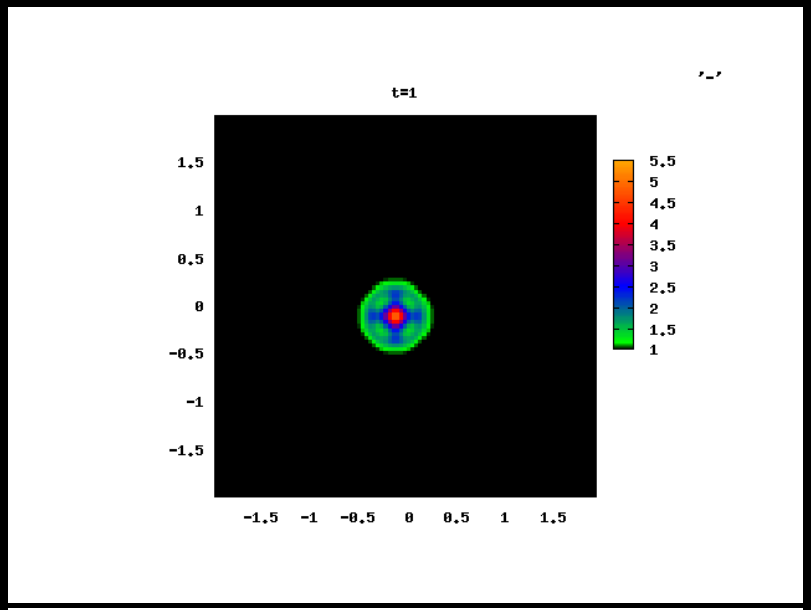
What can we learn with simulations?

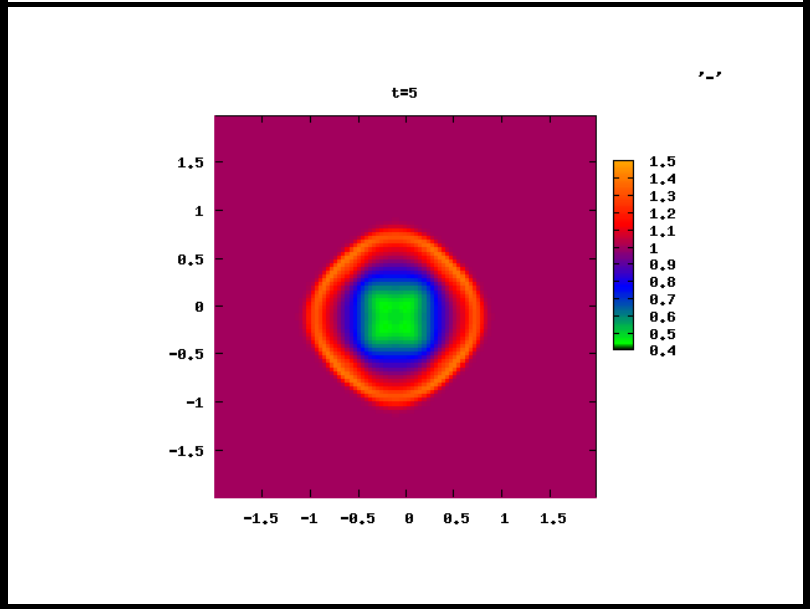
- We can try to understand real objects in the sky.
- We can study some specific physical process.
- Or some combination of the two.

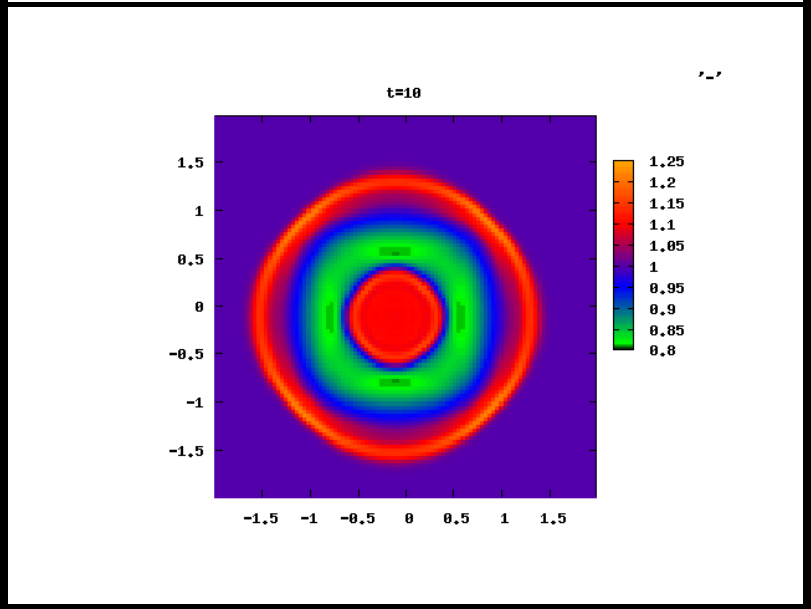
Hubble image of ring around SN 1987a.

Modeling a blast.

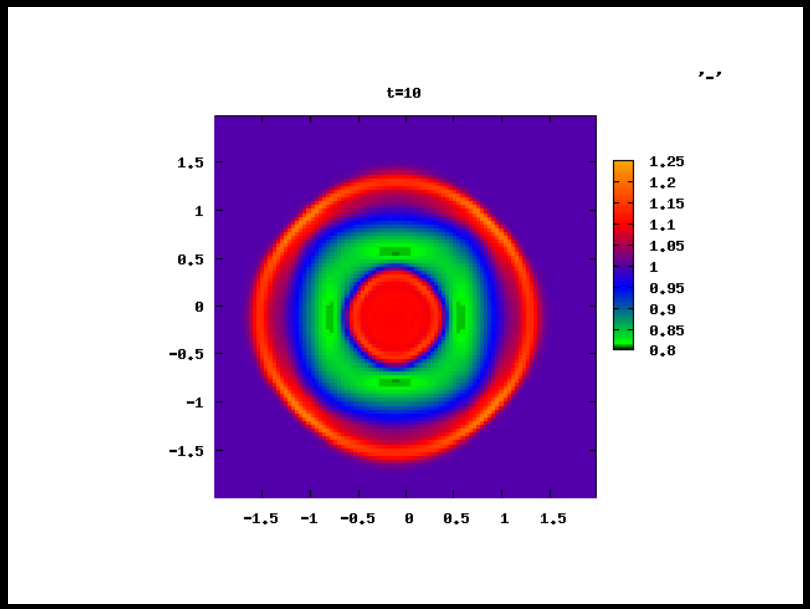








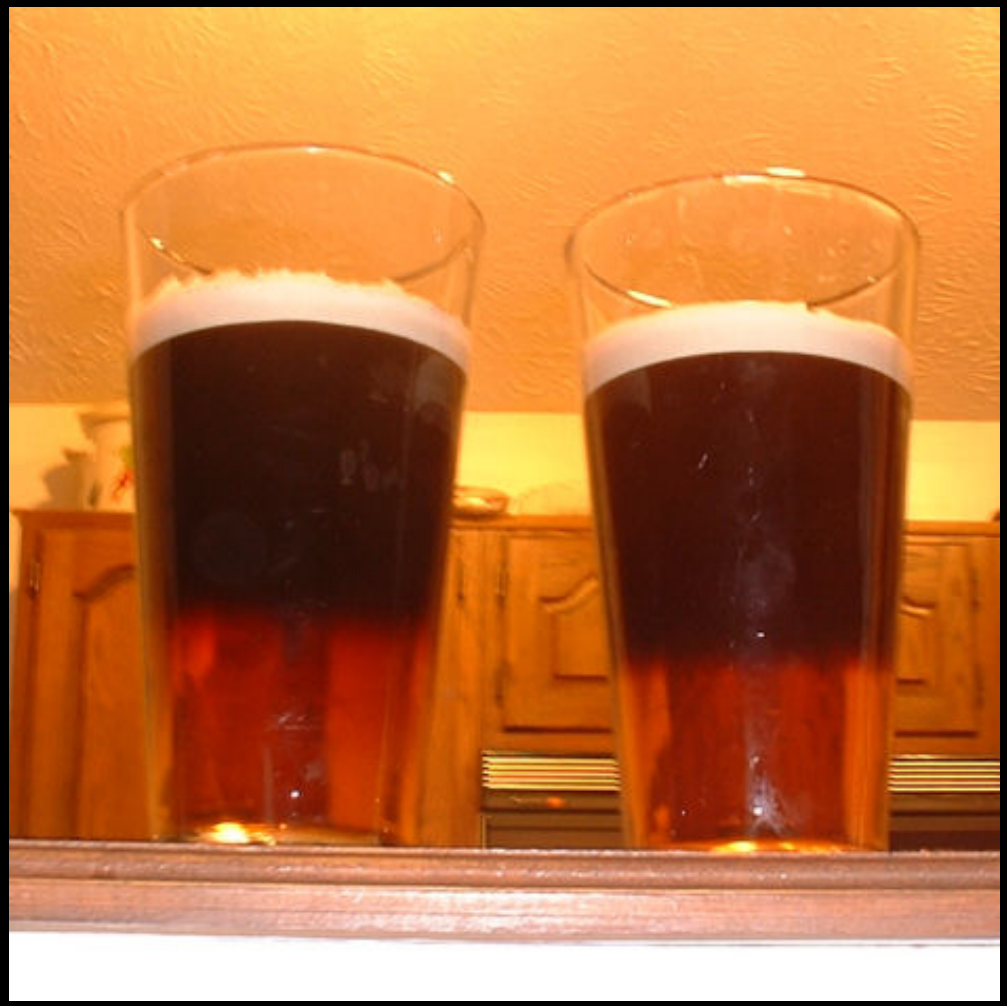
Can we compare?



Fluid effects we can see:

- Waves
- Clouds
- Mushroom clouds
- Fire
- And more...

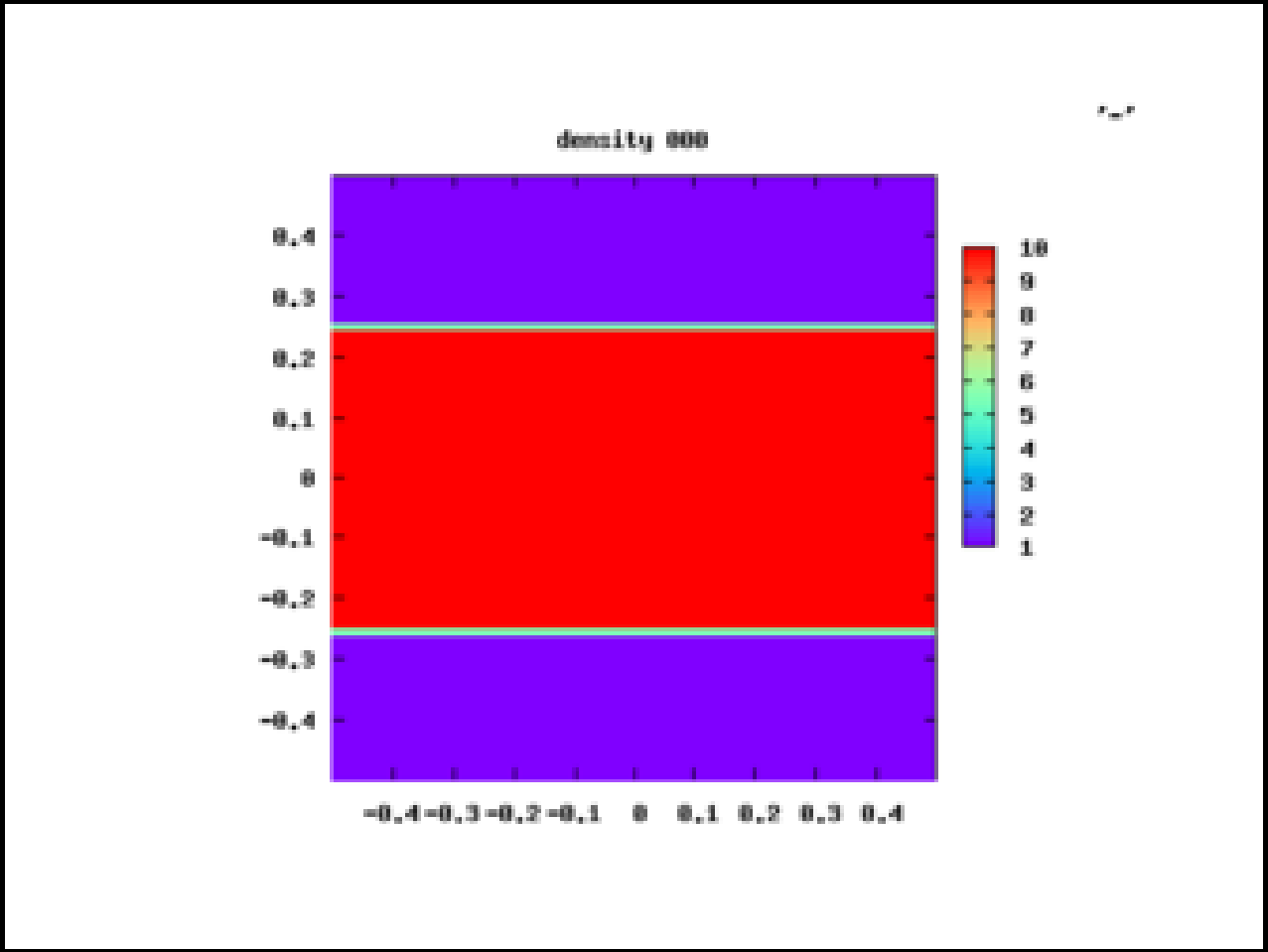
Heavy fluid on top of light one.



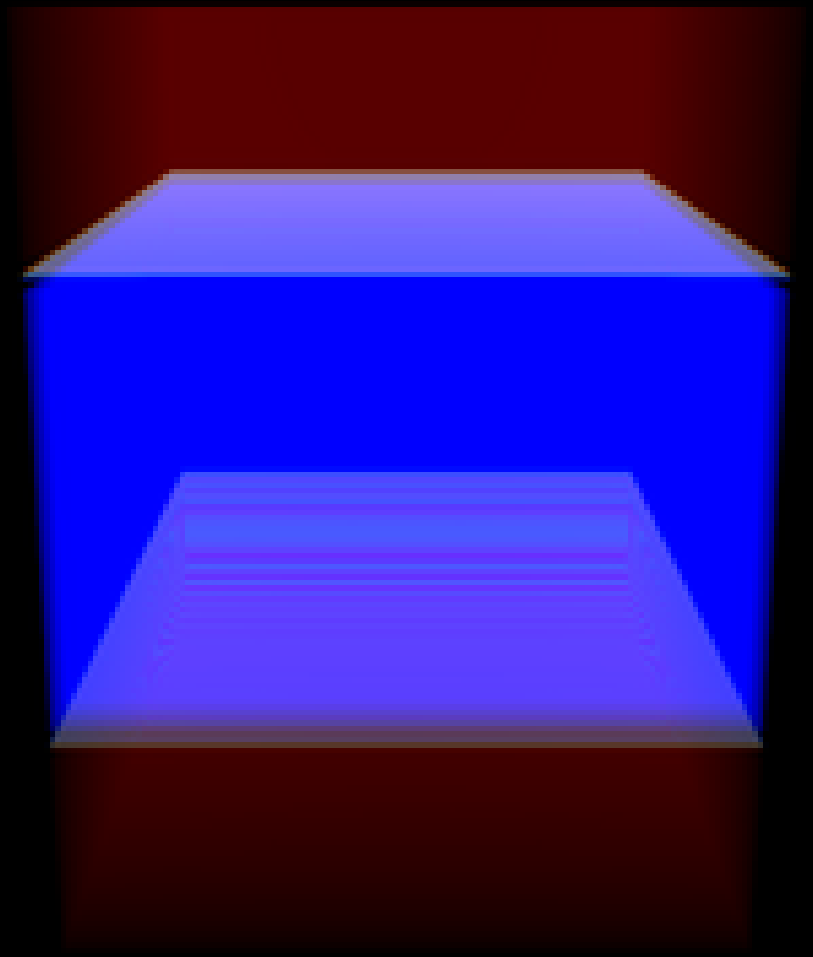
Black and Tan

Kelvin-Helmholtz Instability

Fluids with Shear



Now in 3D!

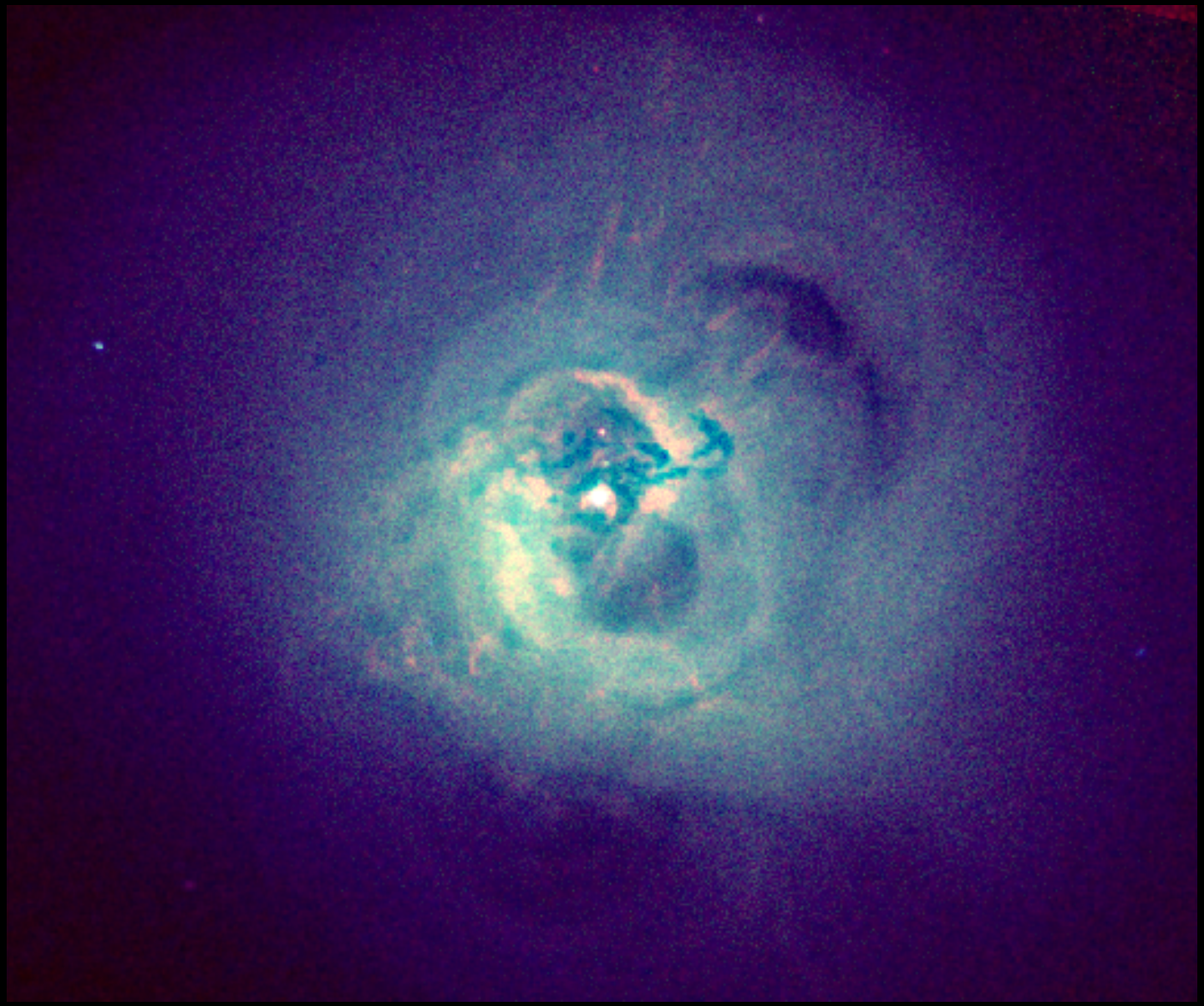


And finally an example from what I actually do.

I work on Galaxy Clusters with my advisor, Dr. Chris Reynolds.

- Largest bound structures in the Universe.
- Important for understanding structure formation, dark matter, and more.
- Mostly made up of hot, diffuse gas.
- Still some unanswered questions.
- The Cooling Flow Problem.

Perseus A



Fabian et al. 2005

Single Jet Burst in Galaxy Cluster (but it doesn't exactly balance the cooling).