

So What's the Problem?

➤ Gravity

Good!

➤ Hydro + Ideal MHD

Yes!

➤ Chemistry / cooling physics

Not bad

➤ “Feedback”

Huh?

➤ Standard (in Galaxy Formation):
Couple SNe ($\sim 10^{51}$ erg/SN)
as “heating”/thermal energy

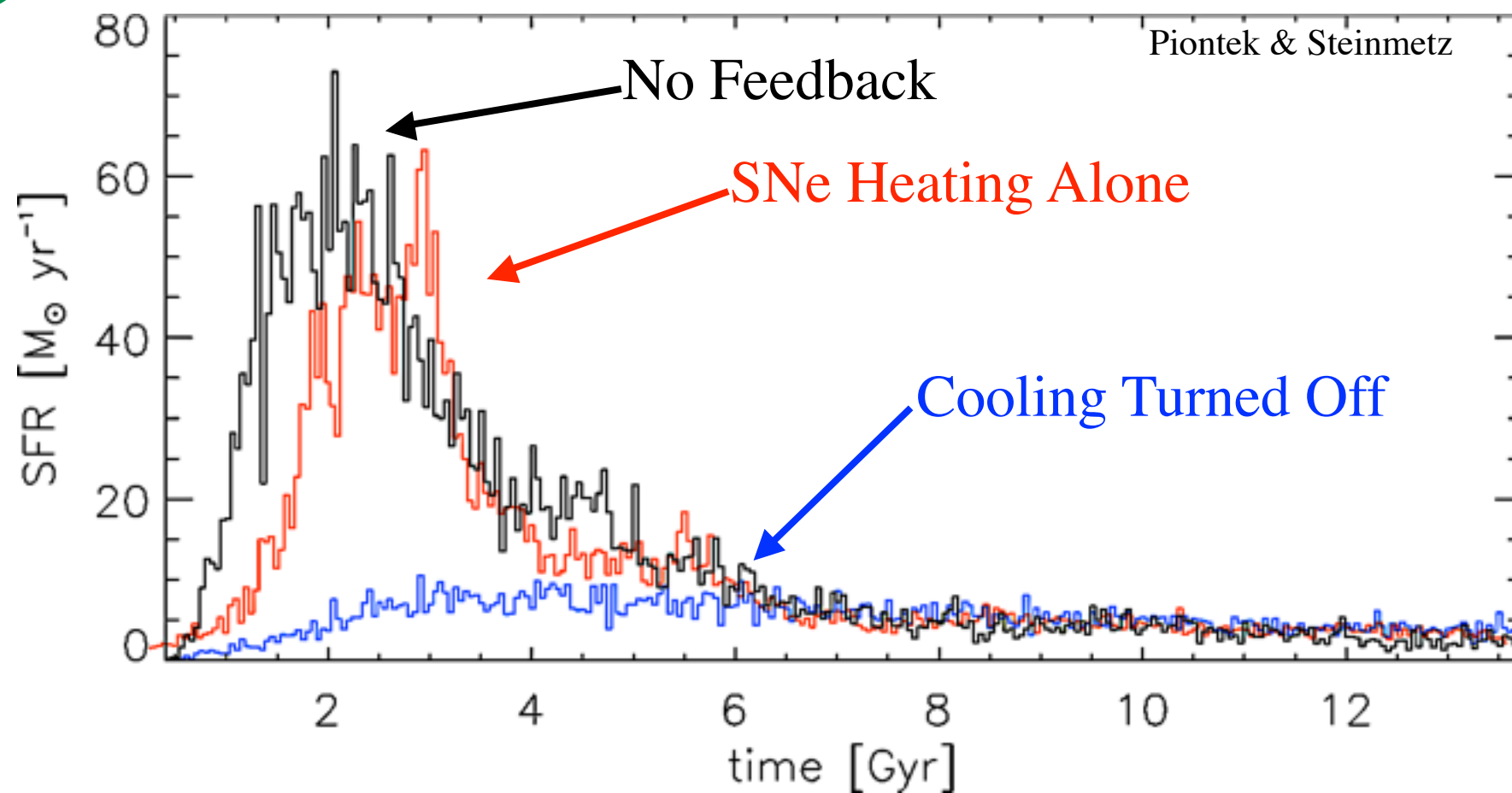
...

...

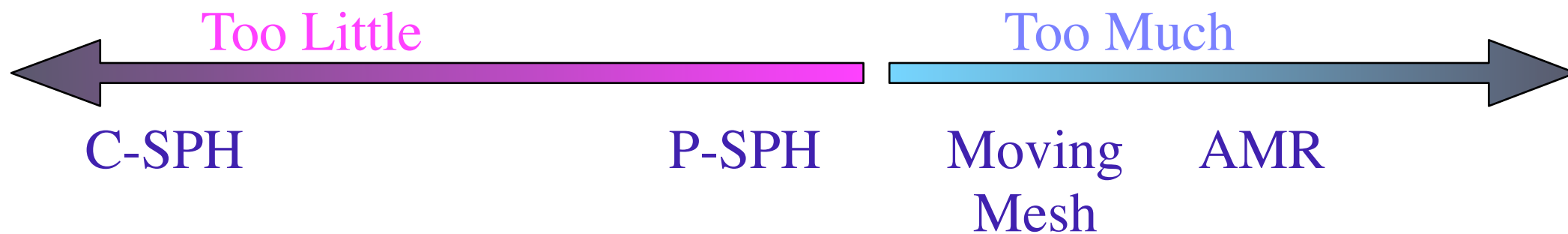
and then “cheat”:

➤ Turn off cooling

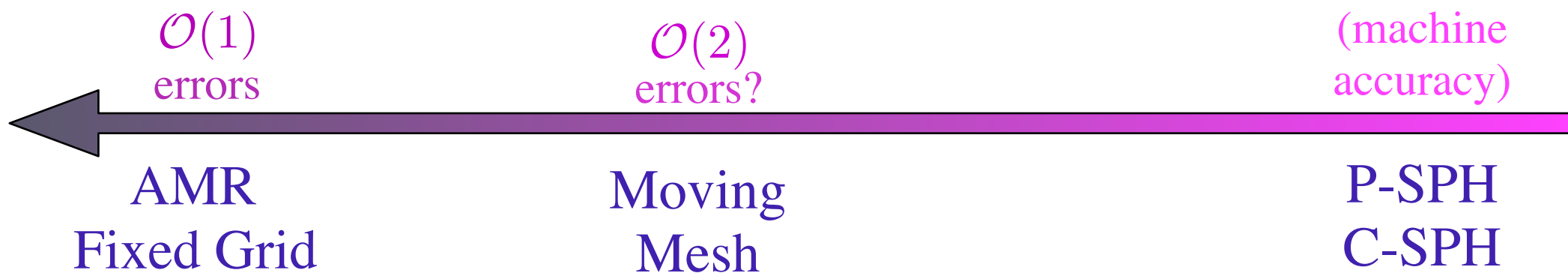
➤ Force wind by hand
(‘kick’ out of galaxy)



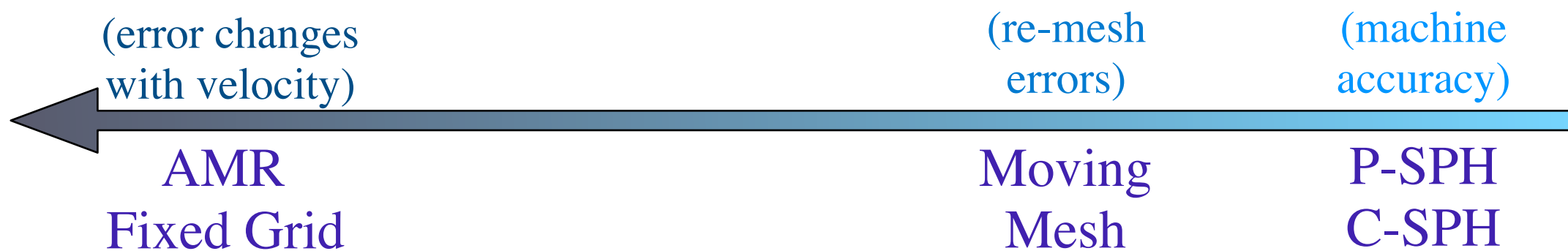
Mixing:
“Blobs”
K-H
Cooling:



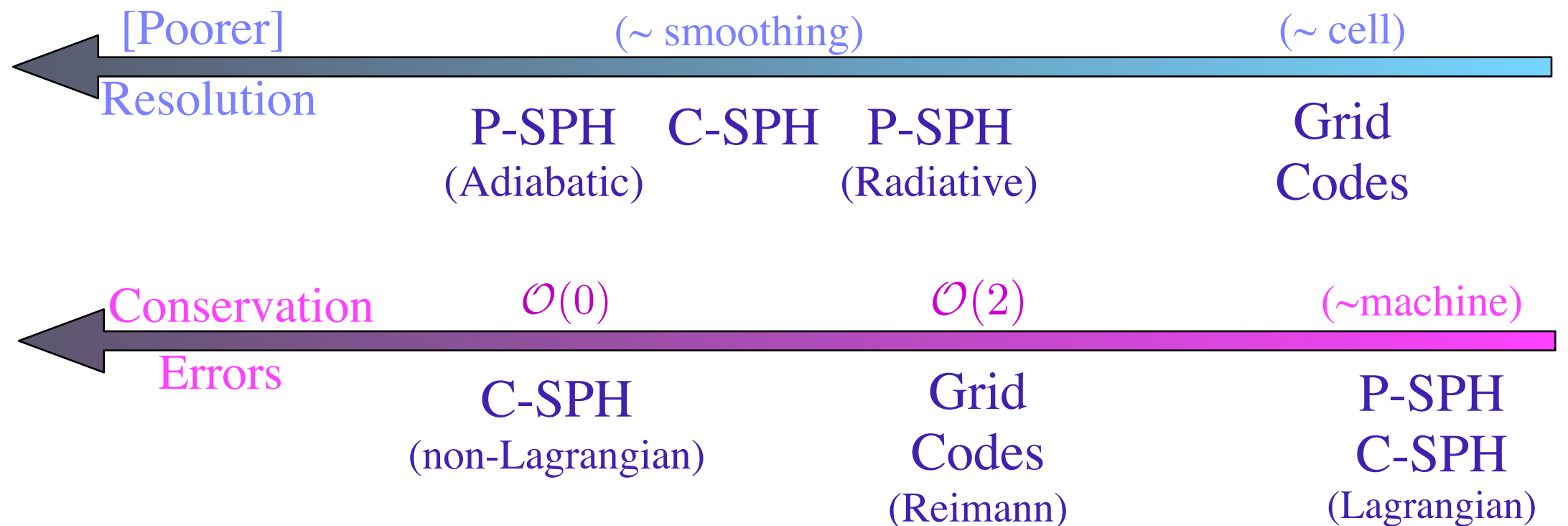
Angular
Momentum:



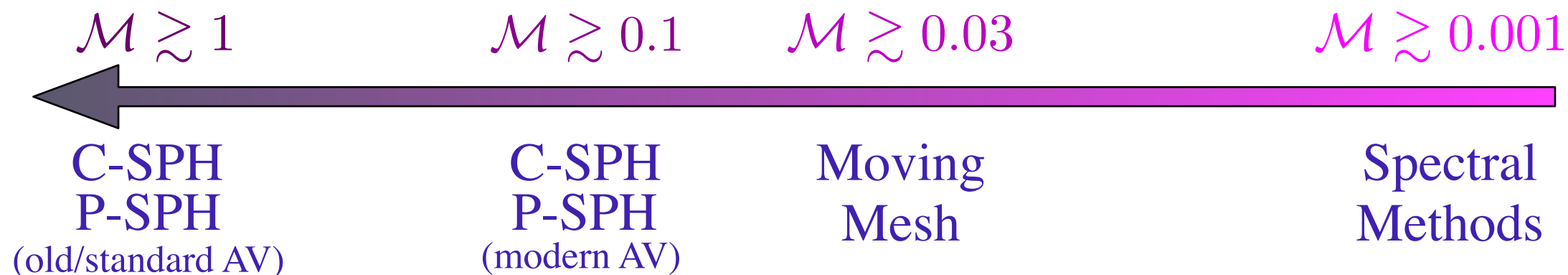
Galilean
Invariance:



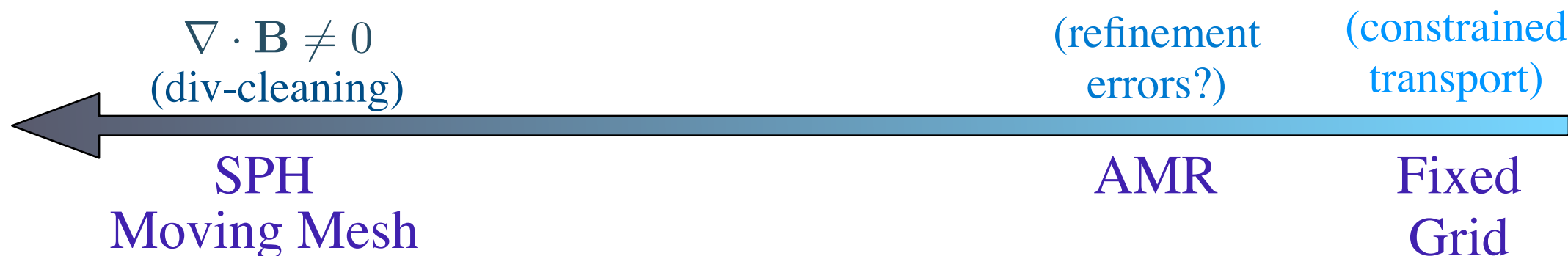
Strong
Shocks:



Subsonic
Turbulence:



MHD:
(Errors)



“Theory Facilities”

WHAT DO WE NEED TO MAKE BETTER MODELS (OTHER THAN BETTER DATA)

➤ **Challenges:**

- Dynamic Range: inherently resists parallelization
- *Loooooooooong* integrations: need an exceptionally stable method
- Feedback = strong coupling between small & large scales (mass, time, space)
- Radiation: *no* good method for all regimes we care about
(optically thin & thick, line & continuum, point sources & diffuse emission)
- Unknown physics!
AGN feedback? Cosmic Rays?

“Theory Facilities”

WHAT DO WE NEED TO MAKE BETTER MODELS (OTHER THAN BETTER DATA)

Hydro+Gravity+Cooling+Star Formation+Adaptive Resolution:

ART Flash ENZO Ramses

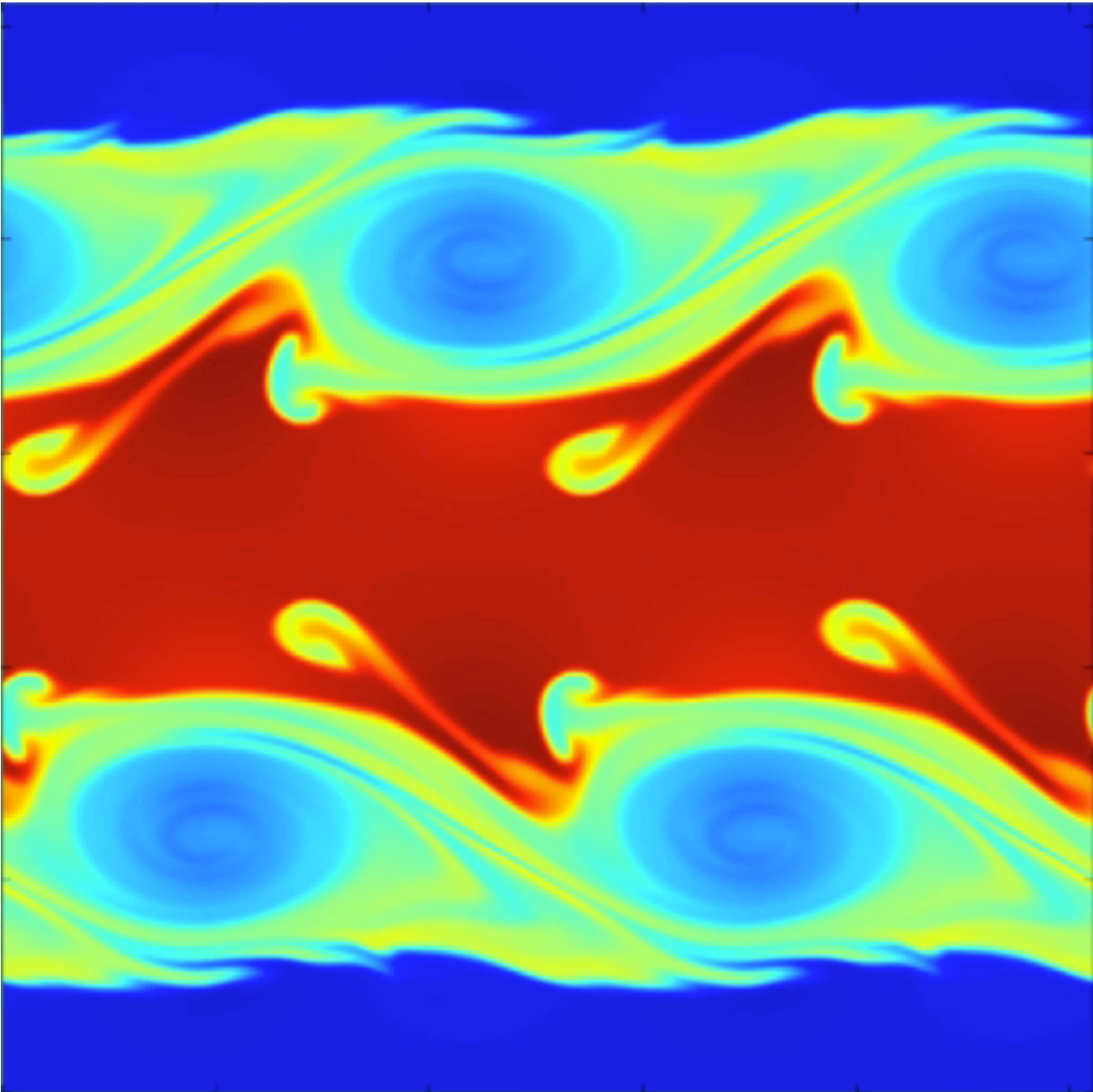
GIZMO AREPO

GADGET Gasoline

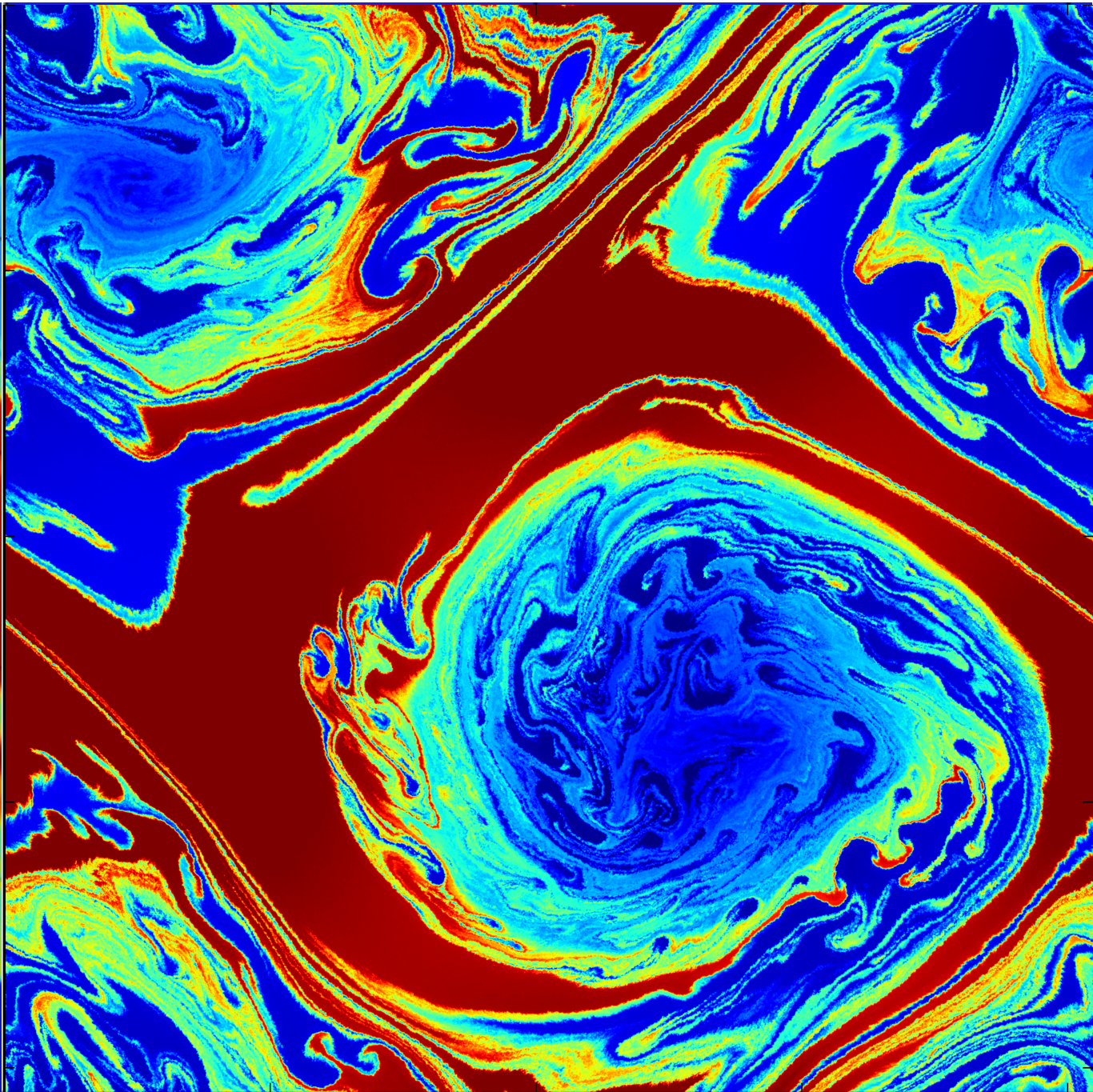
Issues remain between methods, but not dominant

GIZMO: New Meshless Methods & Fluid Mixing

(www.tapir.caltech.edu/~phopkins)

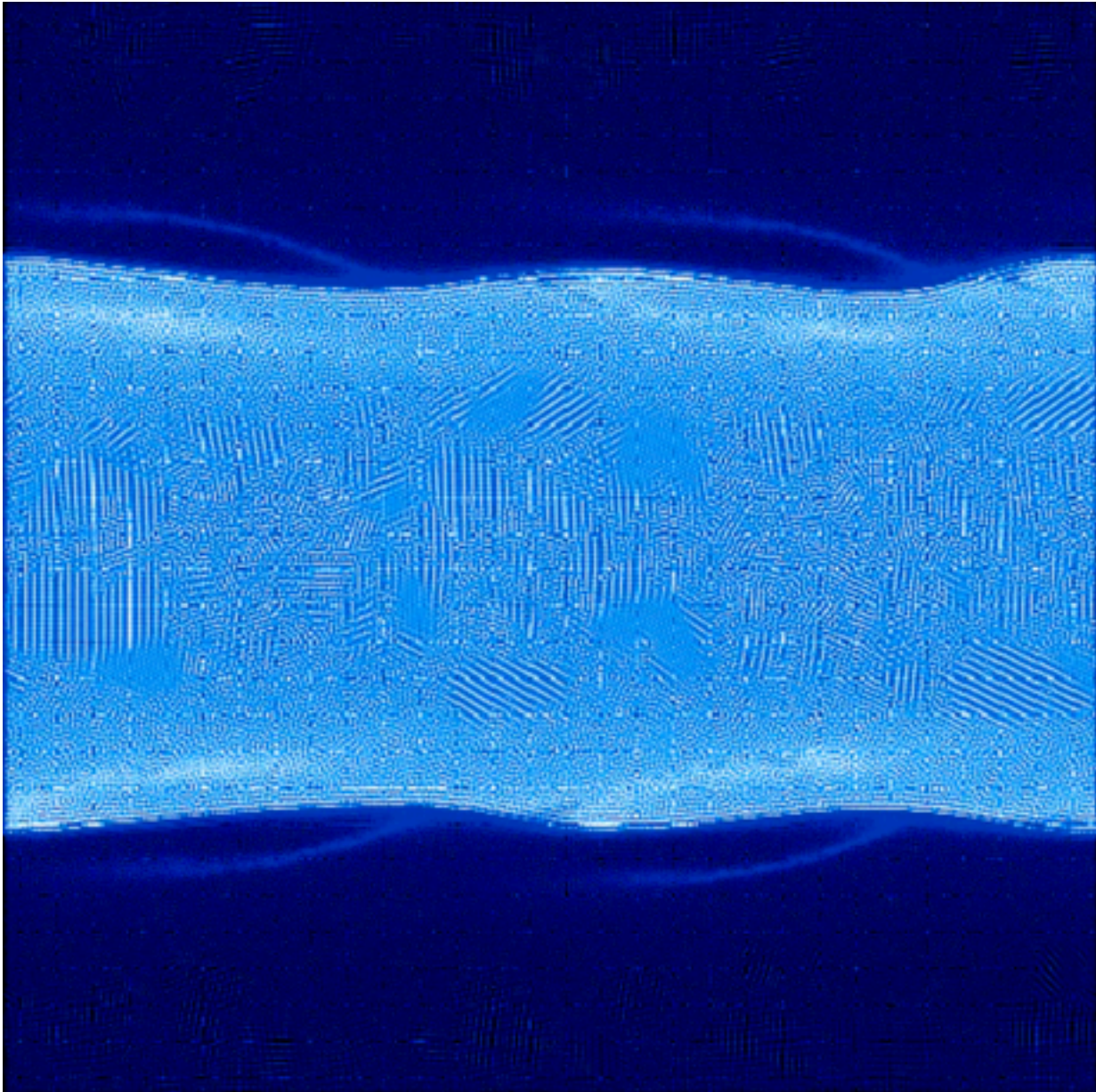


Cartesian Grid

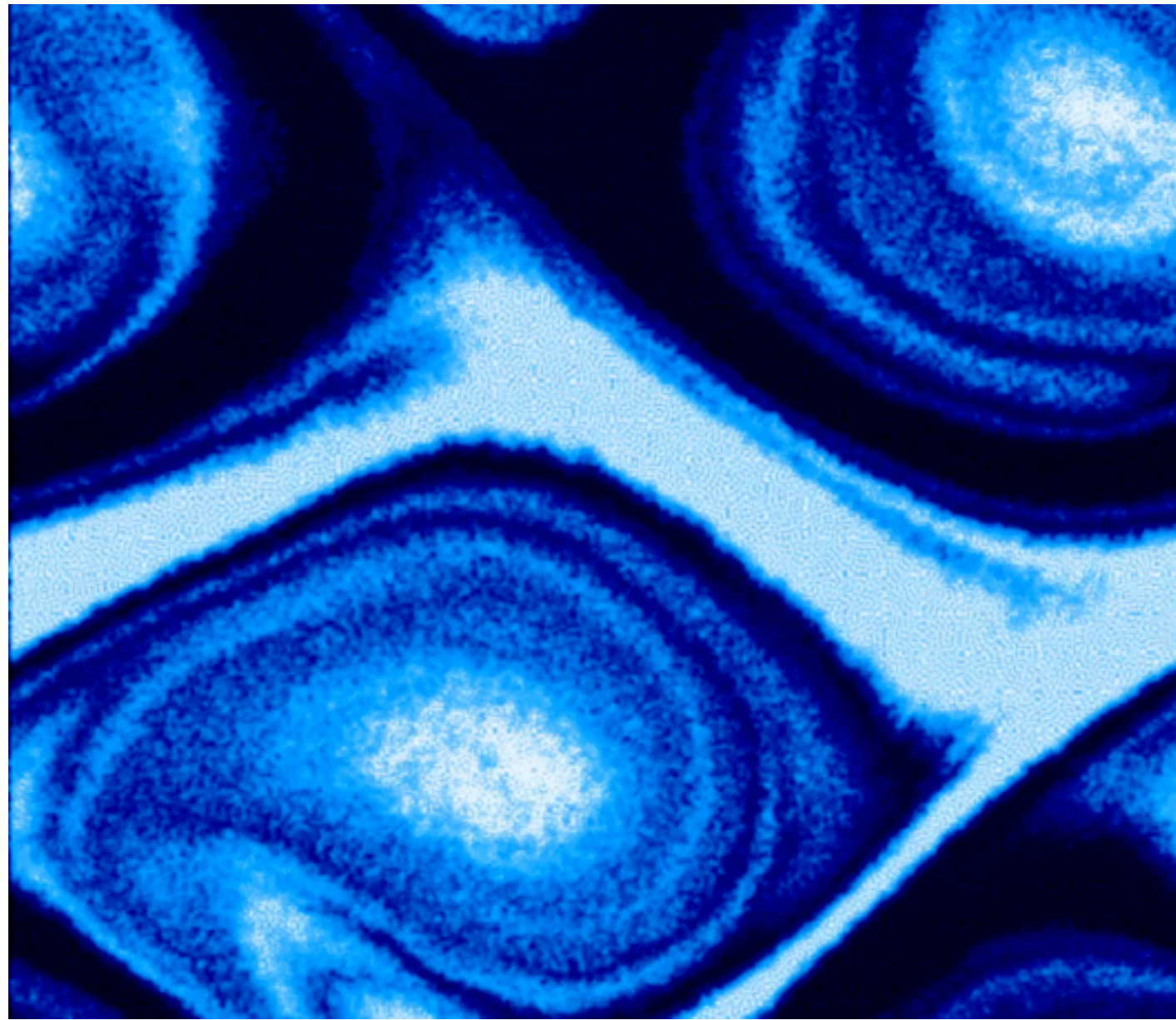


Meshless Finite Volume

SURFACE TENSION IS FIX-ABLE, E0 ERRORS CAN BE REDUCED



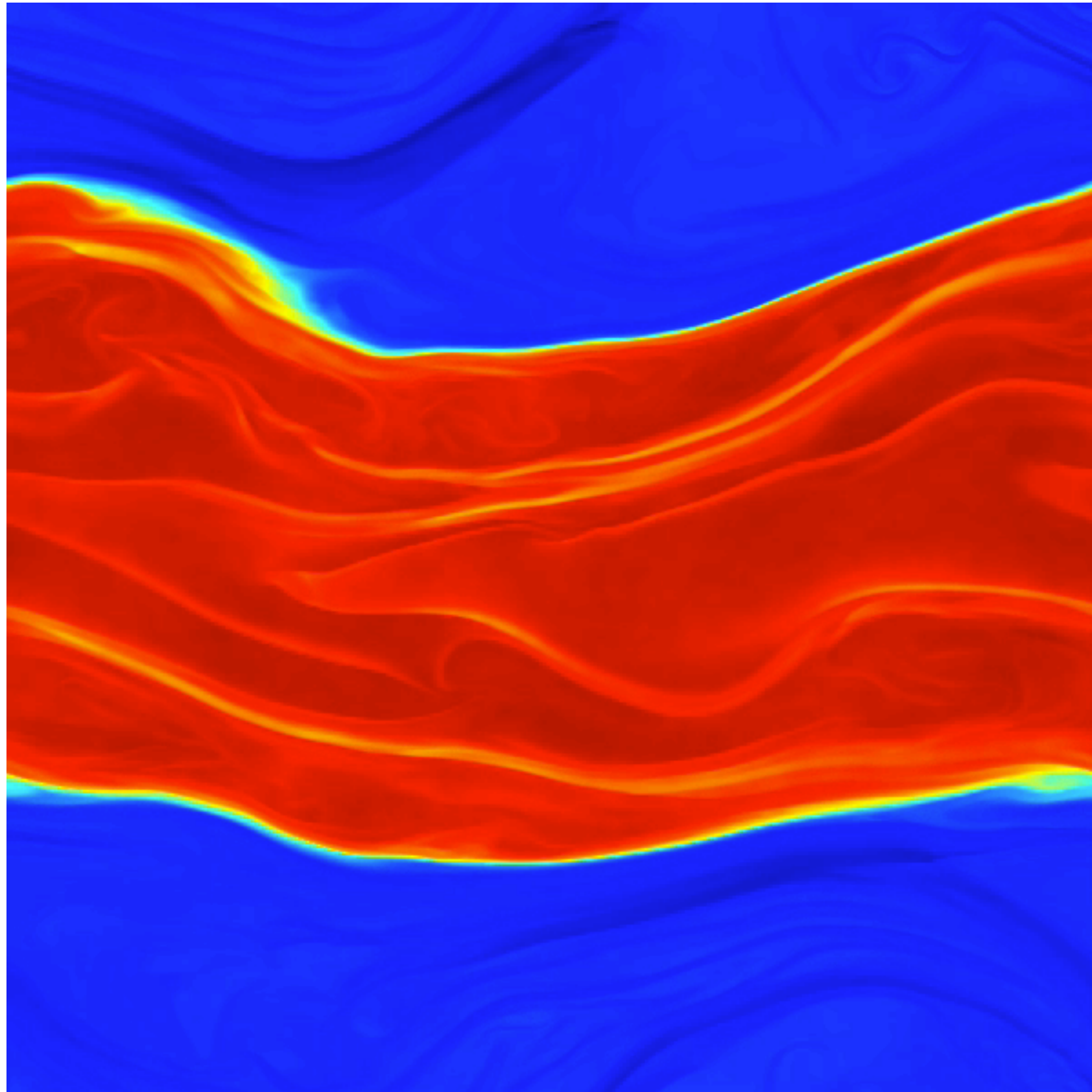
Density Formulation
("Old" GADGET / TSPH)



Pressure-Entropy Formulation
(P-SPH)

A Caution:

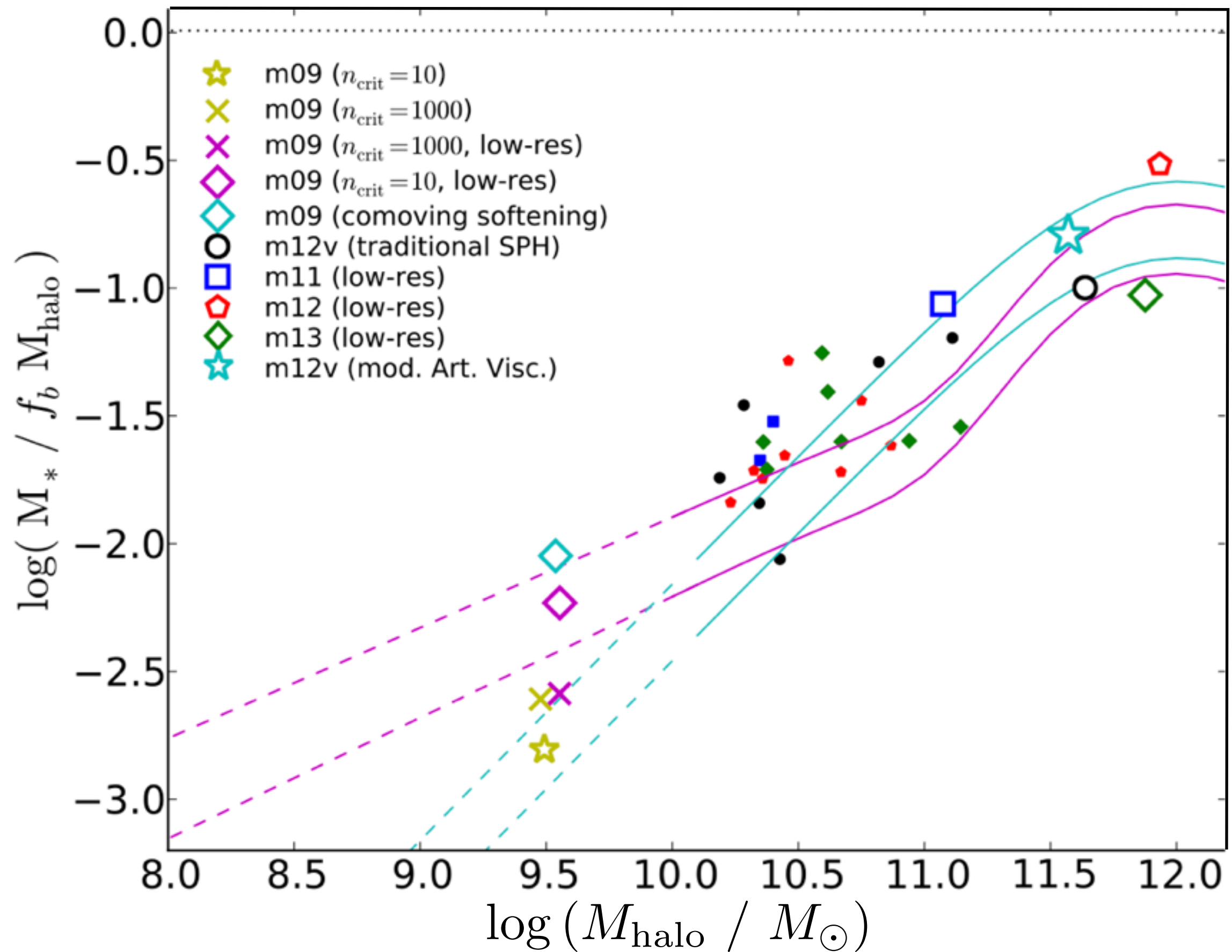
DON'T MISTAKE NUMERICAL "PRECISION" FOR PHYSICAL ACCURACY!

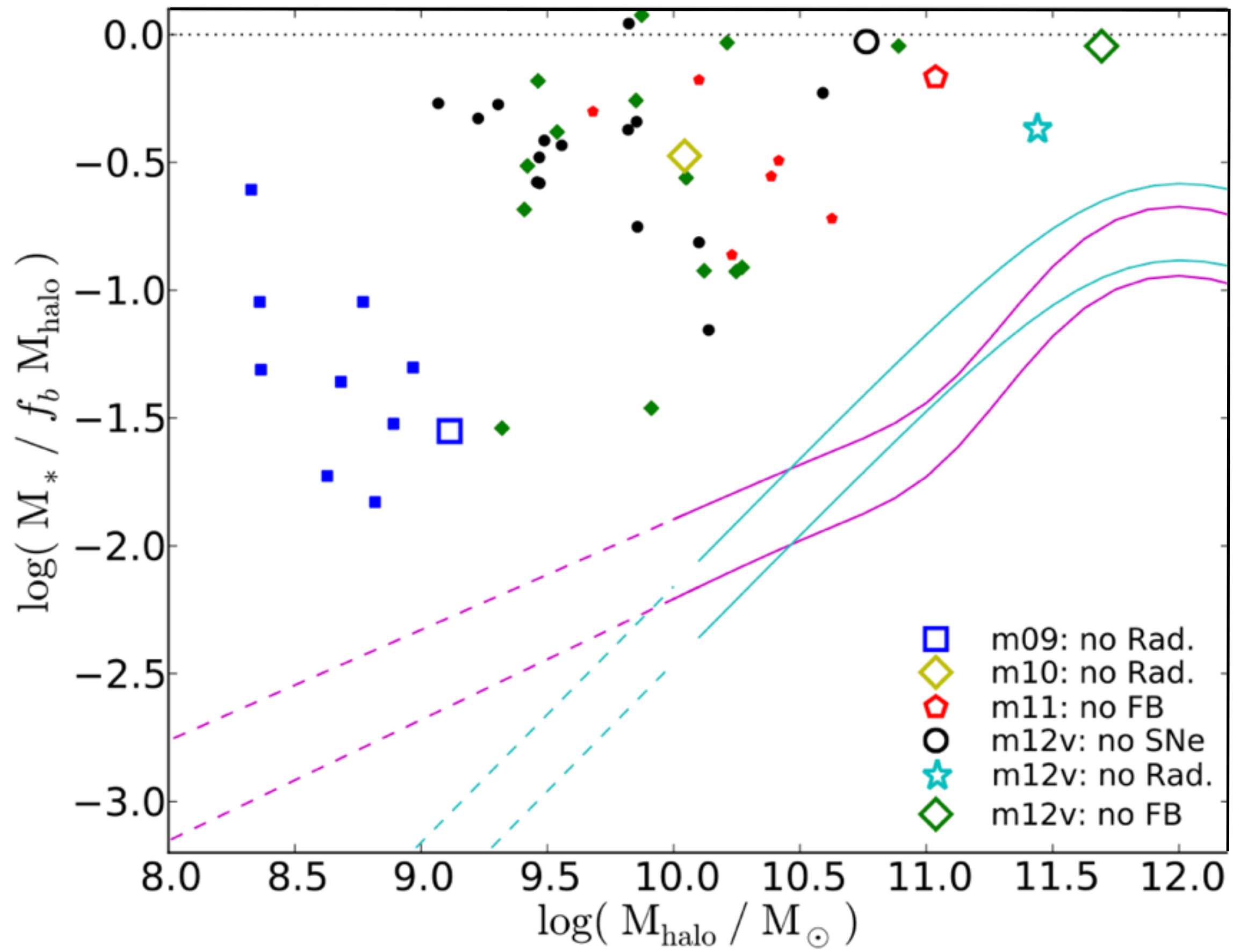


Magnetic KH (Athena)
(Equipartition field)

- **Important:**
 - non-ideal MHD
 - conduction
 - physical viscosity
 - radiation hydro
 - multi-phase structure (feedback, cooling)
 - dust-gas coupling
 - plasma effects
 - cosmic rays

“ALGORITHMIC” CHOICES NOT DOMINANT





“Theory Facilities”

WHAT DO WE NEED TO MAKE BETTER MODELS (OTHER THAN BETTER DATA)

Hydro+Gravity+Cooling+Star Formation+Adaptive Resolution:

ART Flash ENZO Ramses

GIZMO AREPO

GADGET Gasoline

“Theory Facilities”

WHAT DO WE NEED TO MAKE BETTER MODELS (OTHER THAN BETTER DATA)

**Hydro+Gravity+Cooling+Star Formation+Adaptive Resolution:
+Magnetic Fields**

~~ART~~ Flash ENZO ~~Ramses~~

GIZMO AREPO

~~GADGET~~ ~~Gasoline~~

“Theory Facilities”

WHAT DO WE NEED TO MAKE BETTER MODELS (OTHER THAN BETTER DATA)

Hydro+Gravity+Cooling+Star Formation+Adaptive Resolution:
+Magnetic Fields

~~ART~~ Flash ENZO ~~Ramses~~

GIZMO AREPO

~~GADGET~~ ~~Gasoline~~

Hydro+Gravity+Cooling+Star Formation+Adaptive Resolution:
+Run-able Radiation Hydro

~~ART~~ ~~Flash~~ ~~ENZO~~ ~~Ramses~~

~~GIZMO~~ ~~AREPO~~

~~GADGET~~ ~~Gasoline~~

“Theory Facilities”

WHAT DO WE NEED TO MAKE BETTER MODELS (OTHER THAN BETTER DATA)

- **The “Next Big Thing”**
- Adaptive, massively parallel MHD methods: in progress
- Efficiently parallelized RT (go between thick/thin)
 - GPU or MIC-based subcycling of RT
- Systems to run this:
 - High-memory! (*opposite* of current computing trend)
 - +Fast chips
- Task-based parallelization (some work now)
- “Better” sub-grid models (where the observations come in)
- Archival resources: astrophysics source code library (good start)
 - Need a place for simulations to live and be made public (Millenium?)