MORDECAI-MARK MAC LOW

PLANET & STAR FORMATION

PLANET FORMATION

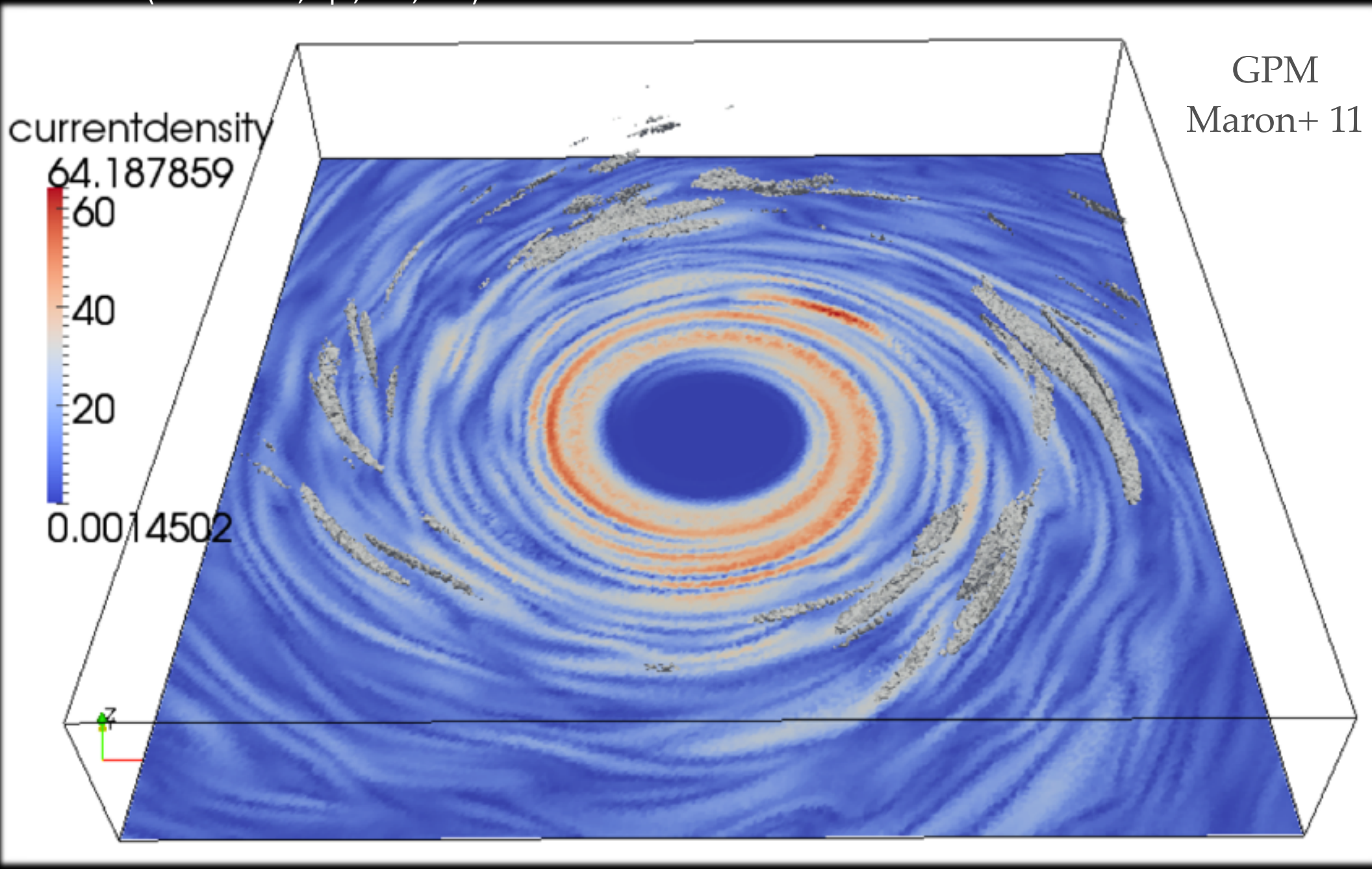
MINERAL FORMATION

Alexander Hubbard (AMNH)
Colin McNally (NBIA, Copenhagen)
Denton Ebel (AMNH)

O. Richard Norton, http://www.geokem.com/meteorites.html,

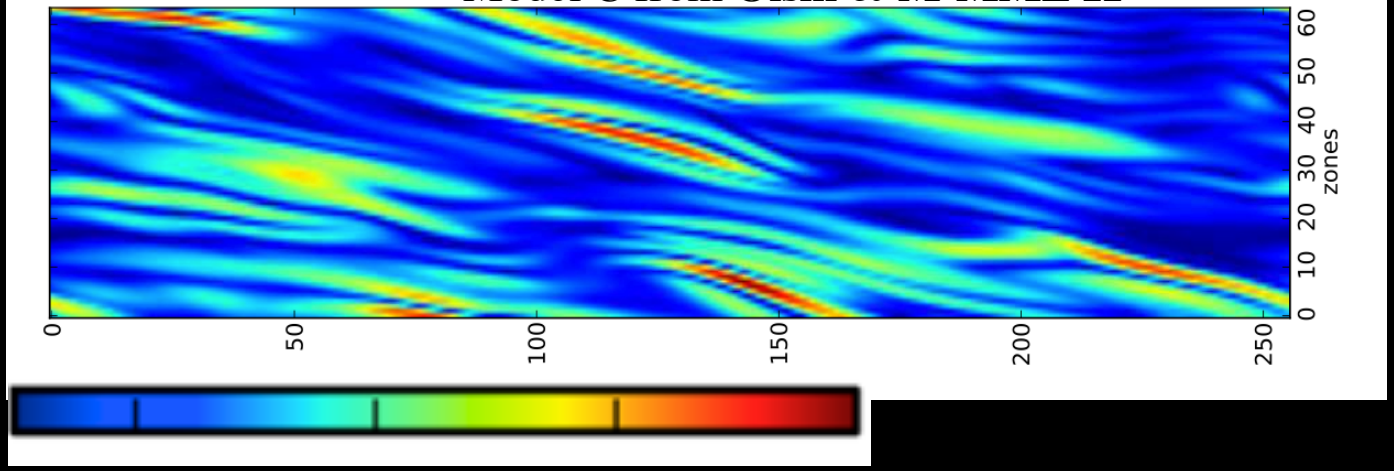
Magnetized turbulence forms ubiquitous current sheets

(Parker 1972, ApJ, 174, 499)



McNally 12 PhD Thesis, **McNally, Hubbard, M-MML, Ebel, D'Alessio 13**

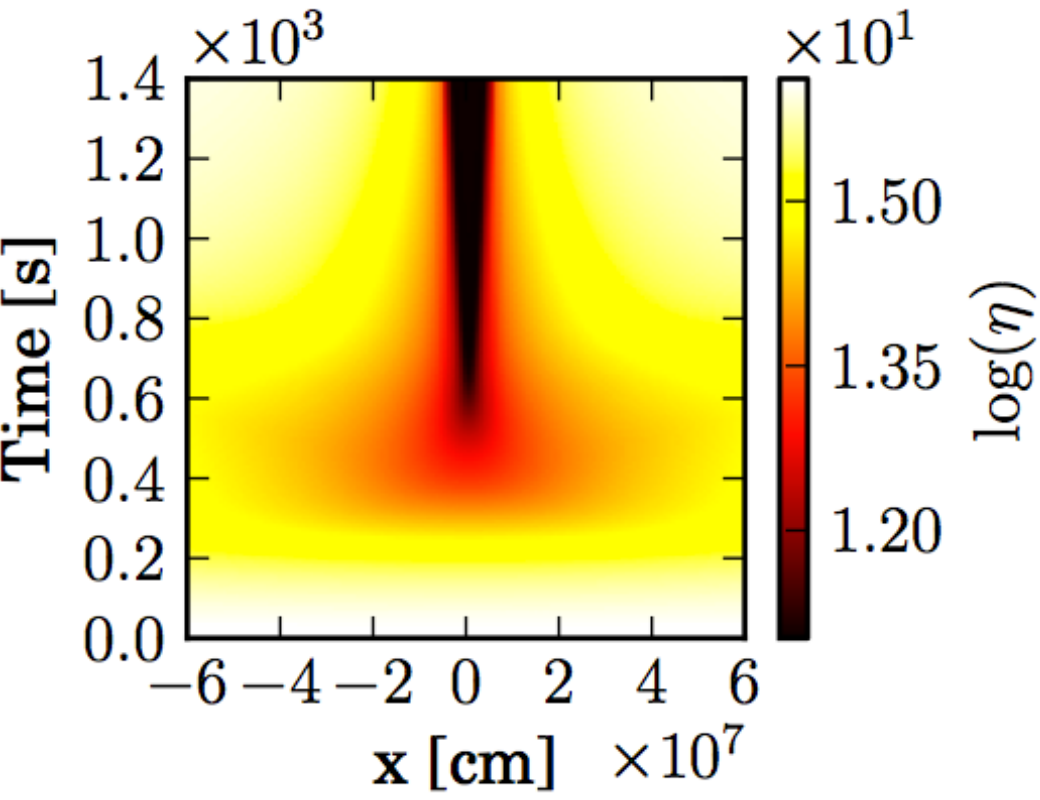
Model C from **Oishi & M-MML 11**

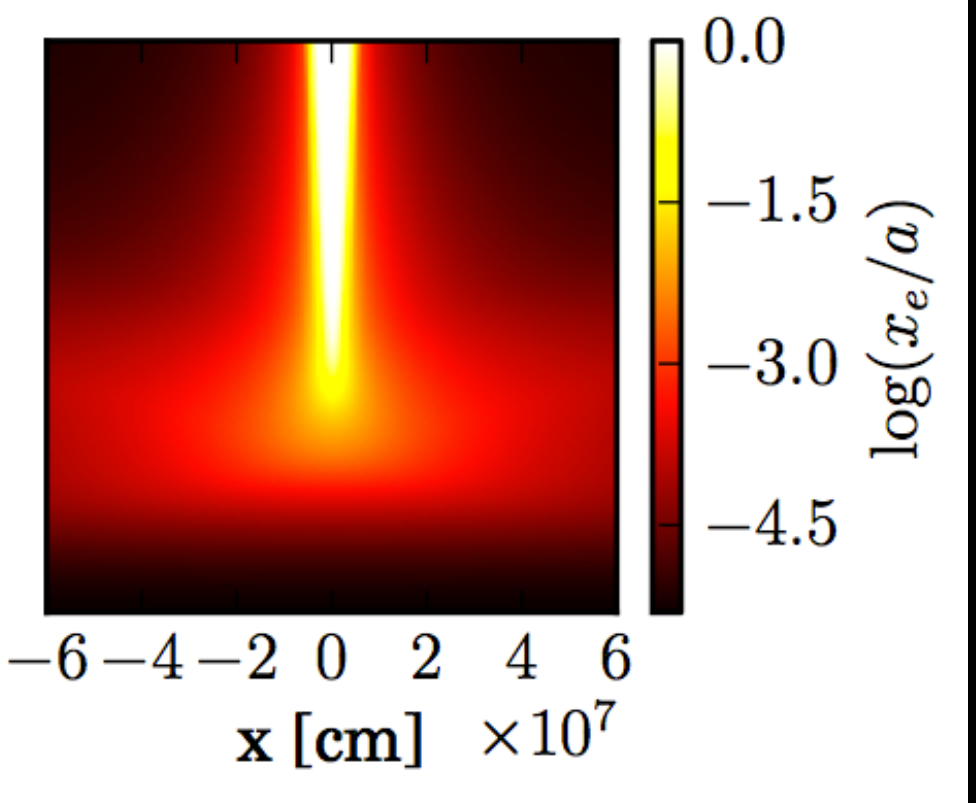


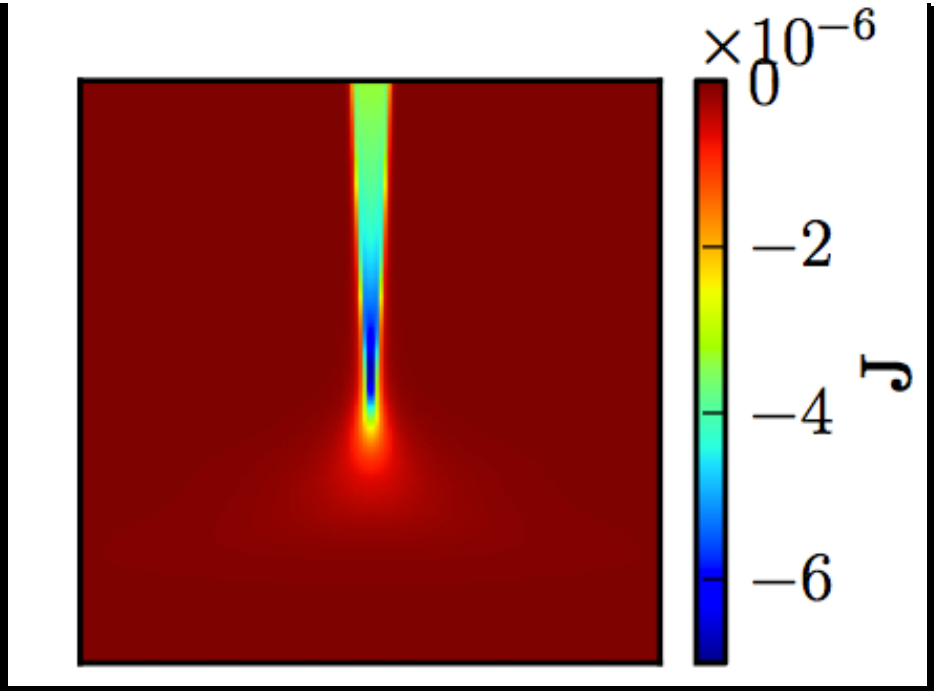
$$\frac{\partial \boldsymbol{B}}{\partial t} = \boldsymbol{\nabla} \times (\boldsymbol{U} \times \boldsymbol{B} - \eta \boldsymbol{J})$$

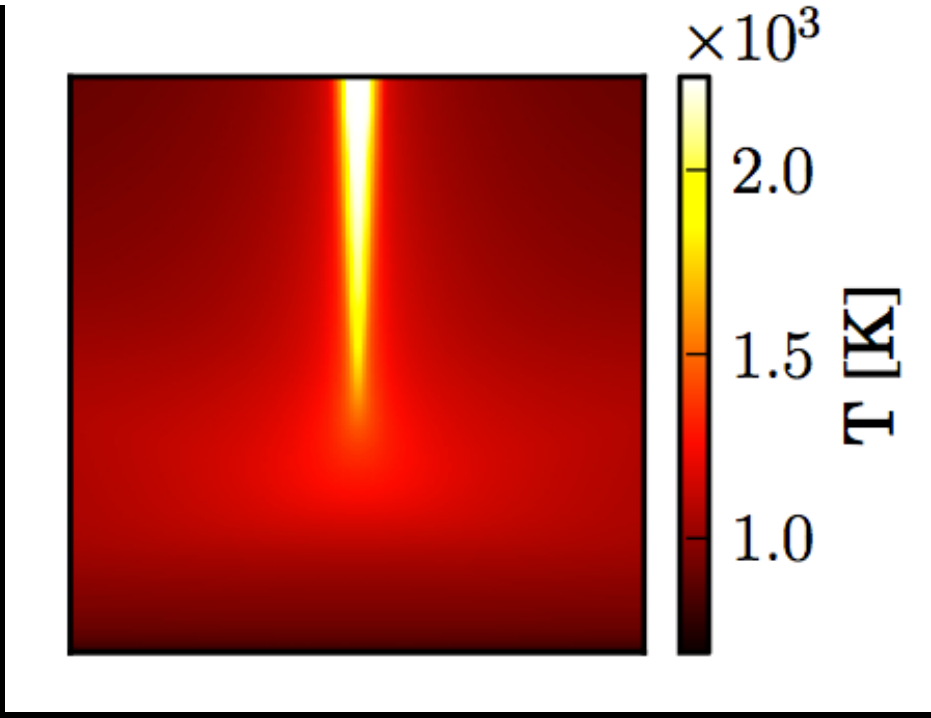
$$\frac{\partial \boldsymbol{B}}{\partial t} = \boldsymbol{\nabla} \times (\boldsymbol{U} \times \boldsymbol{B}) + \eta \boldsymbol{\nabla}^2 \boldsymbol{B} - (\boldsymbol{\nabla}\eta) \times \boldsymbol{J}$$

If temperatures rise high enough to ionize alkali metals, resistivity starts to drop exponentially (**Hubbard, McNally, M-MML 12**).





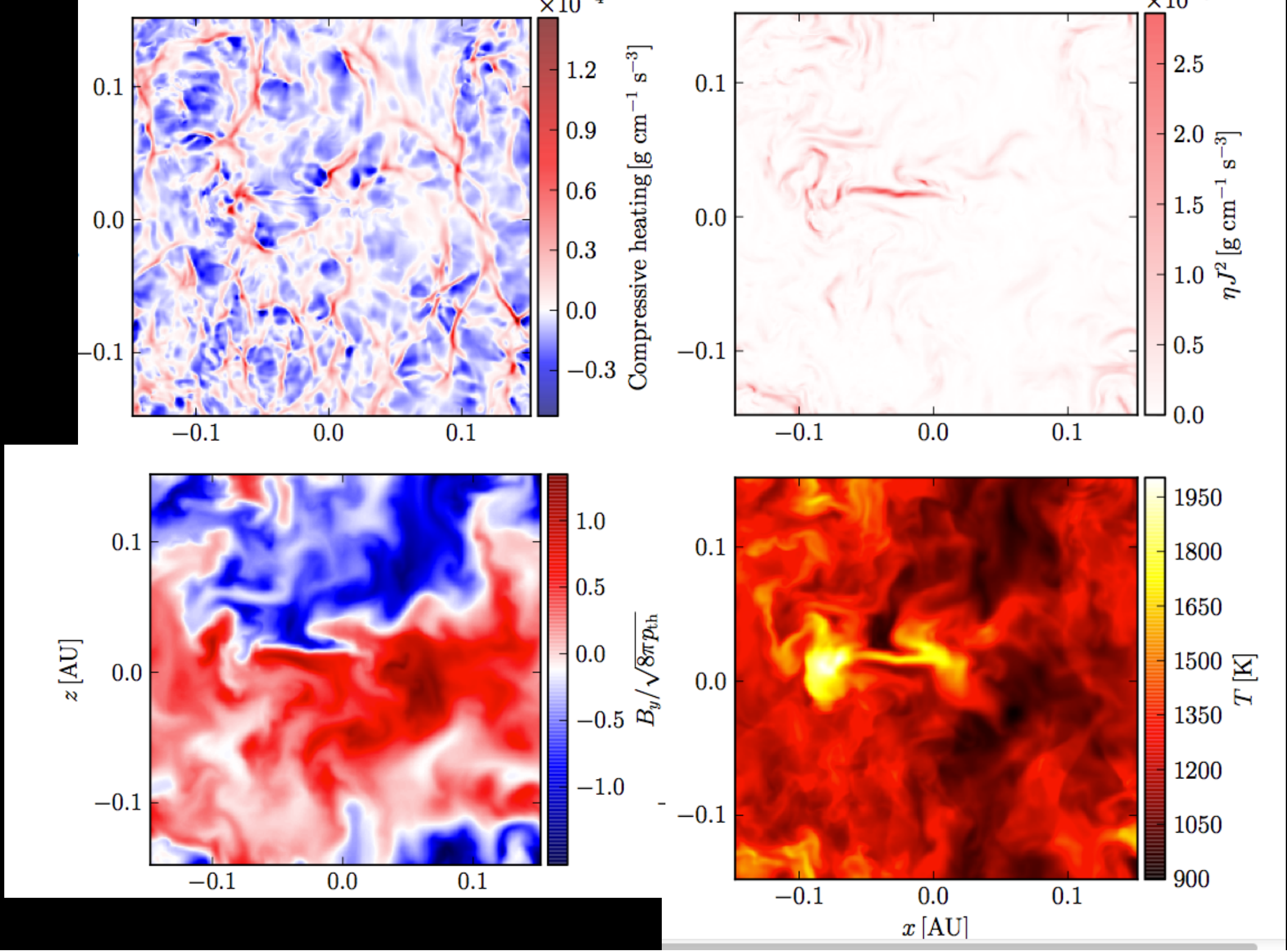


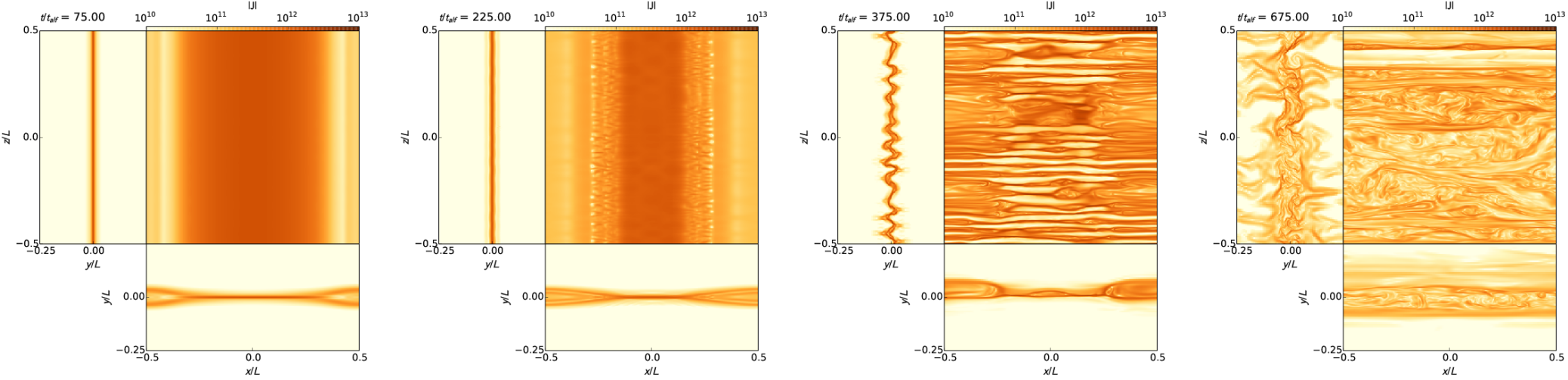


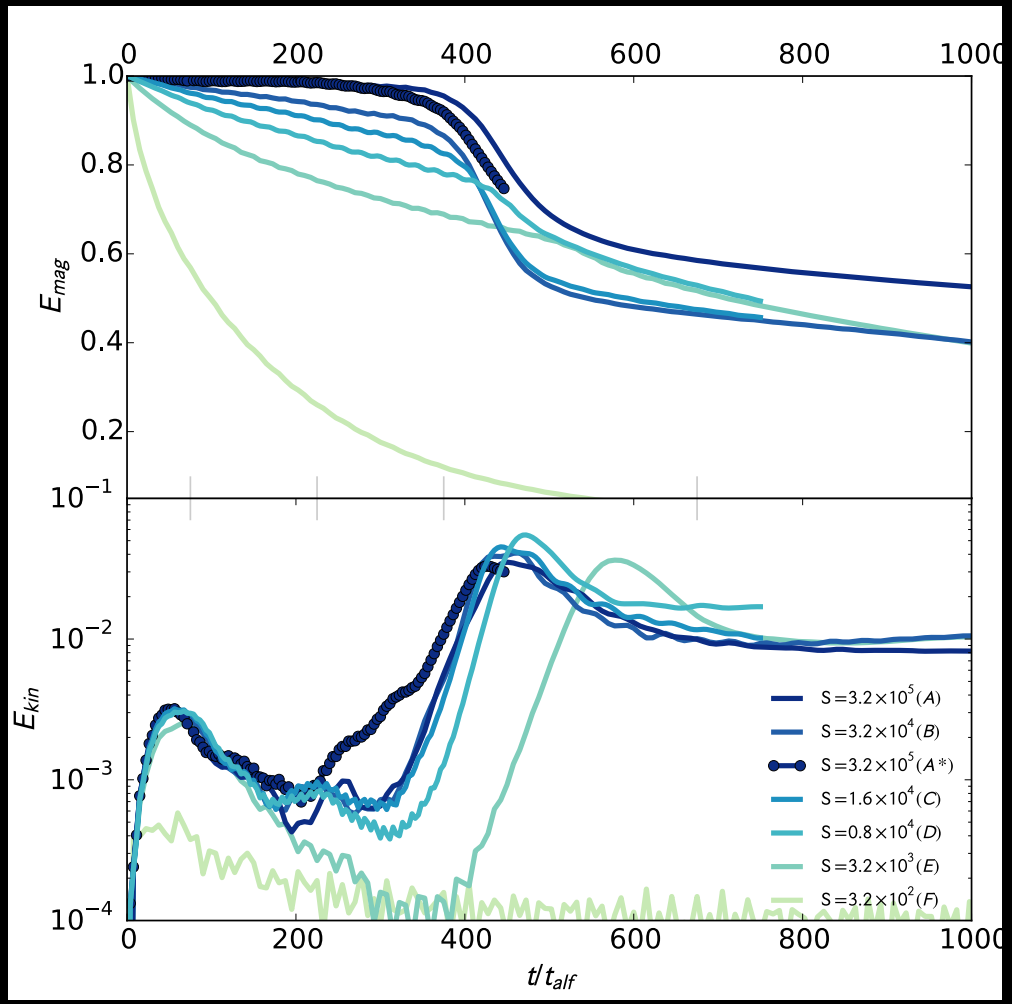
McNally, Hubbard, M-MML, Ebel, D'Alessio 12

SHEARING BOX MODEL

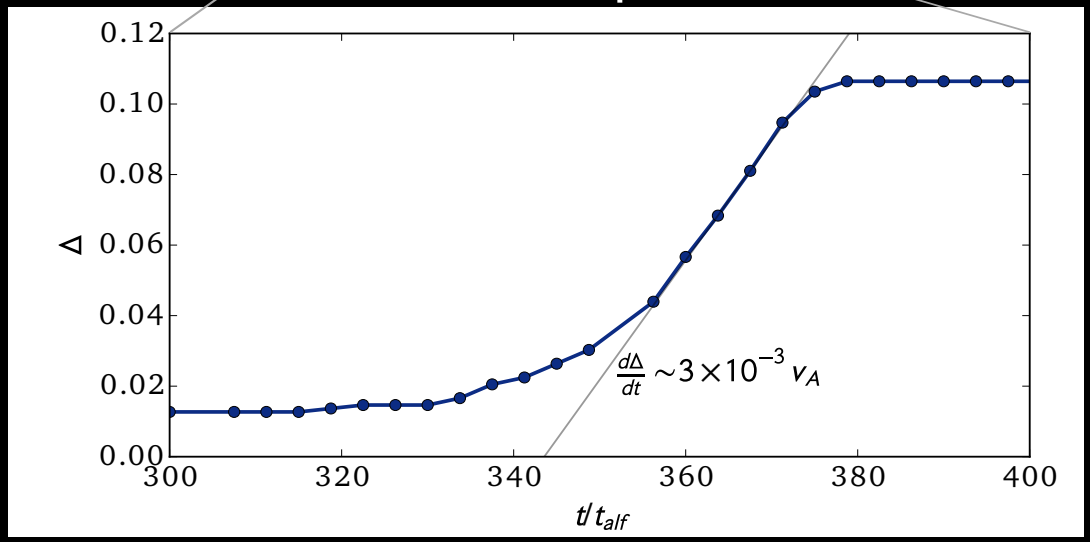
- Pencil Code (Brandenburg & Dobler 2002)
  - www.nordita.org/software/pencil-code/
- Finite-difference MHD code
- **Explicit resistivity to resolve current sheets**
- Sixth-order spatial, third-order time
- Hyperdiffusion for time-centered scheme
- Div B = 0 maintained using vector potential


×10
0.1
0.0
−0.1
−0.1
0.0
0.1
1.2
0.9
0.6
0.3
0.0
−0.3
Compressive heating [g cm^{-1} s^{-3}]
×10
2.5
2.0
1.5
1.0
0.5
0.0
ηJ^2 [g cm^{-1} s^{-3}]
z [AU]
1.0
0.5
0.0
−0.5
−1.0
$B_y/\sqrt{8\pi p_{\rm th}}$
1950
1800
1650
1500
1350
1200
1050
900
T [K]
x [AU]





Enzo Nested Grid
explicit resistivity
Lundquist-number indpt. reconnection speed



Oishi + 15

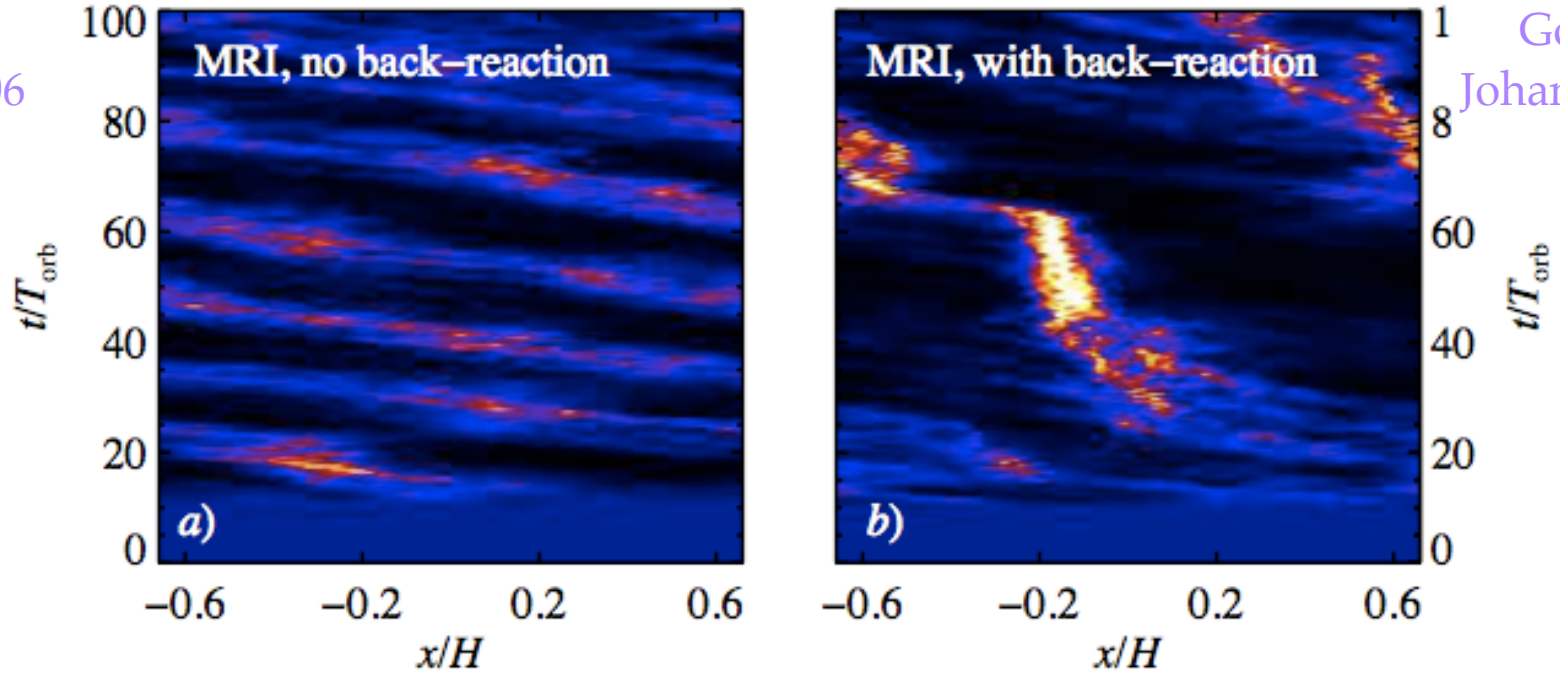
PLANETESIMALS

Anders Johansen (U. Lund)

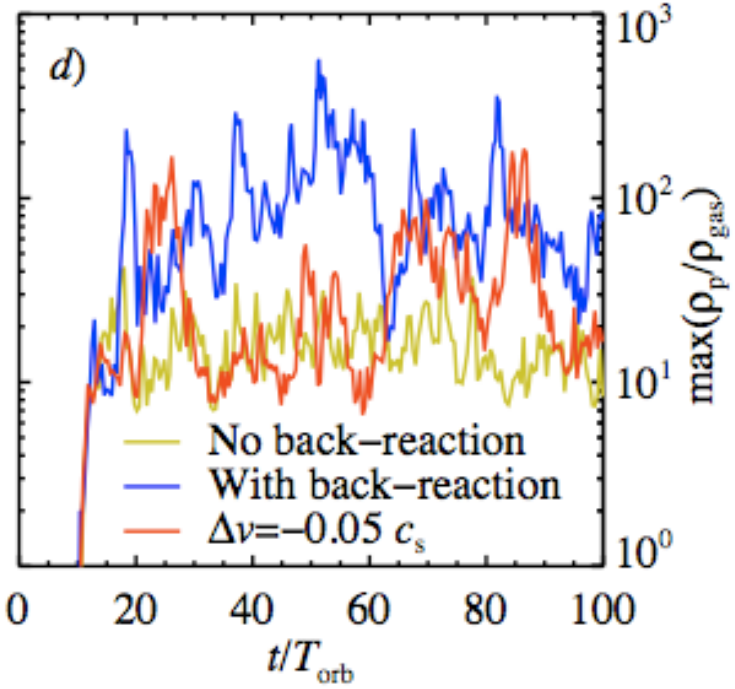
O. Richard Norton, http://www.geokem.com/meteorites.html,

See Johansen, Klahr & Henning 06

See Youdin & Goodman 05, Johansen & Youdin 07

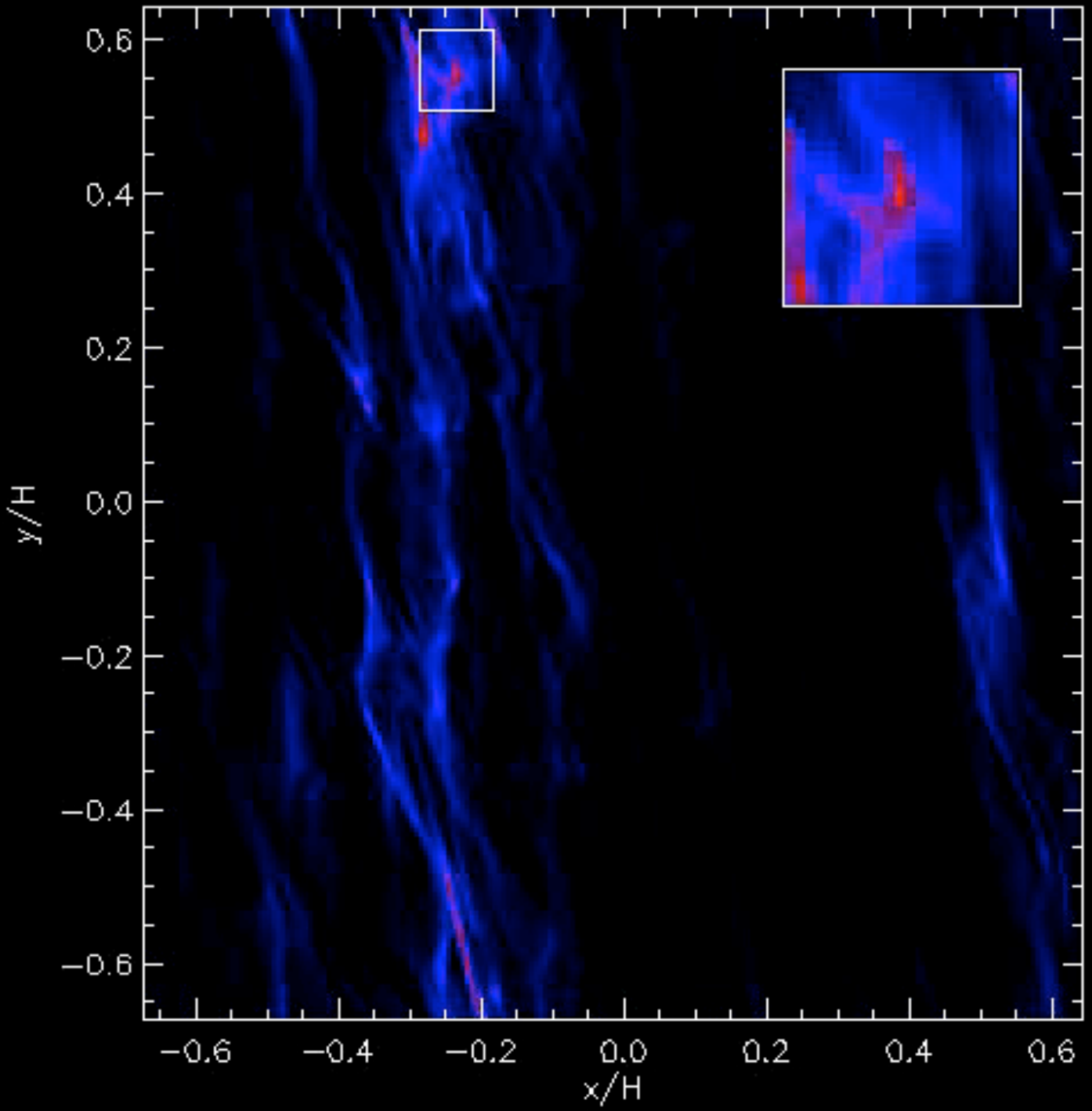


Turbulence and streaming instability interfere constructively!



Johansen, Oishi, Mac Low, Klahr, Henning, & Youdin, 07

including self-gravity of boulders allows tracking of non-linear gravitational instability



Johansen, Oishi, Mac Low, Klahr, Henning, & Youdin 07

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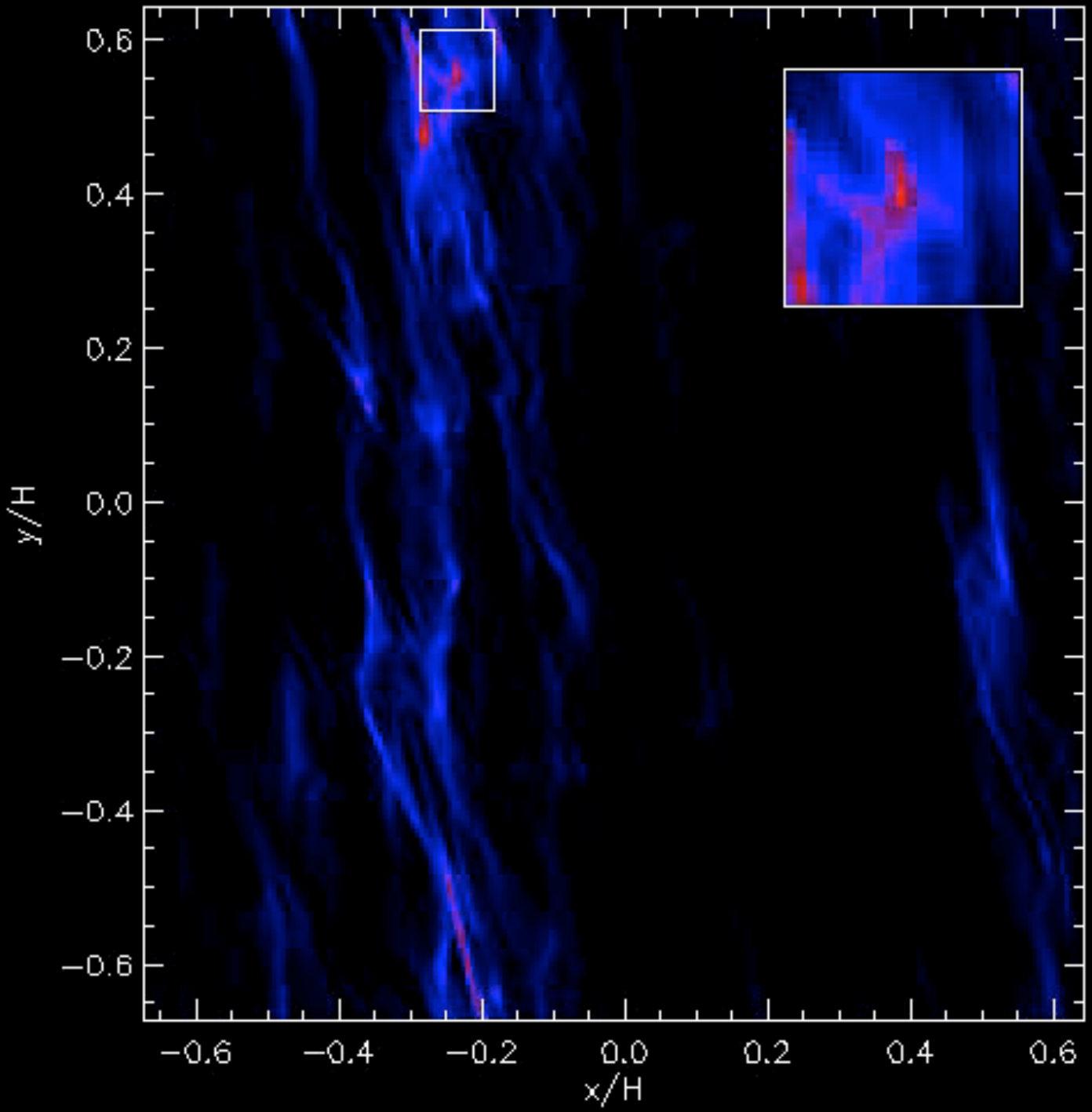

Johansen, Oishi, Mac Low, Klahr, Henning, & Youdin 07

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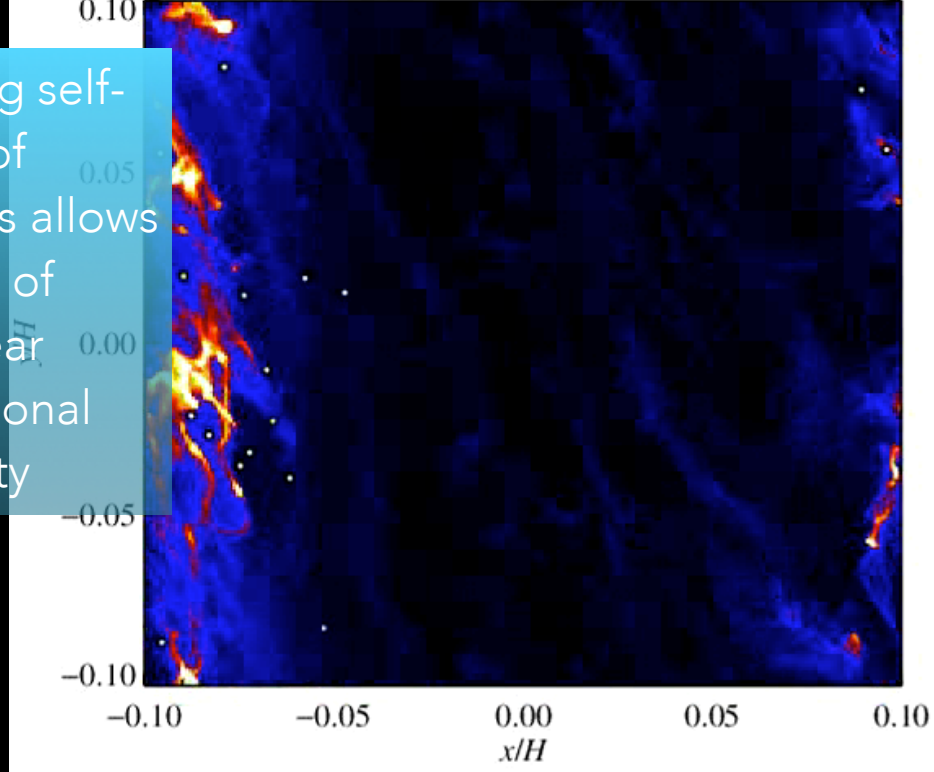
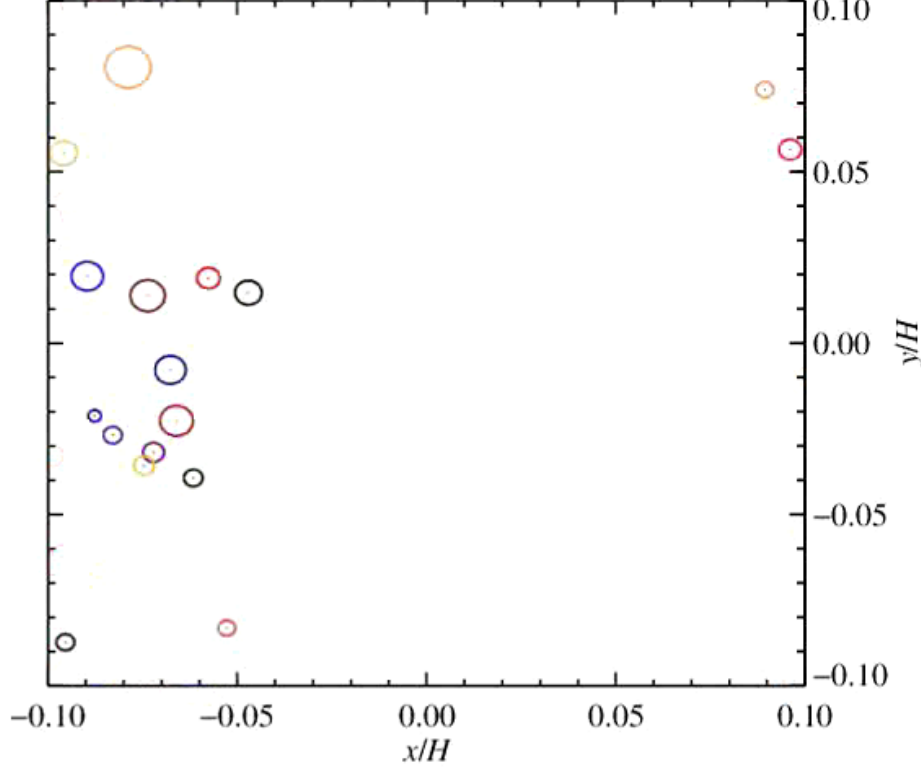
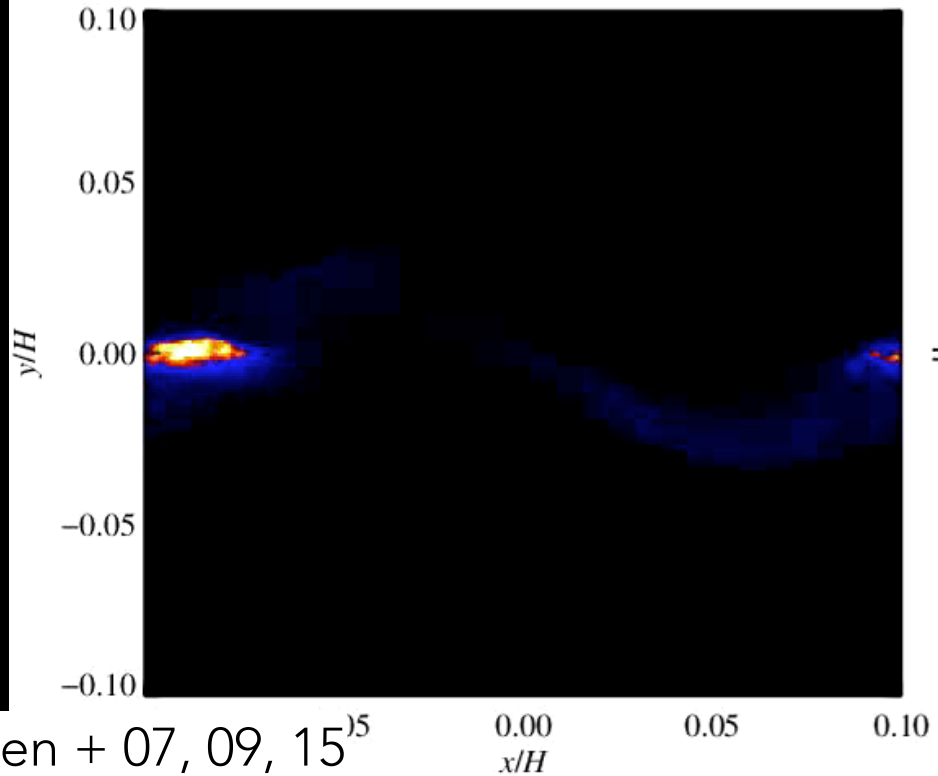
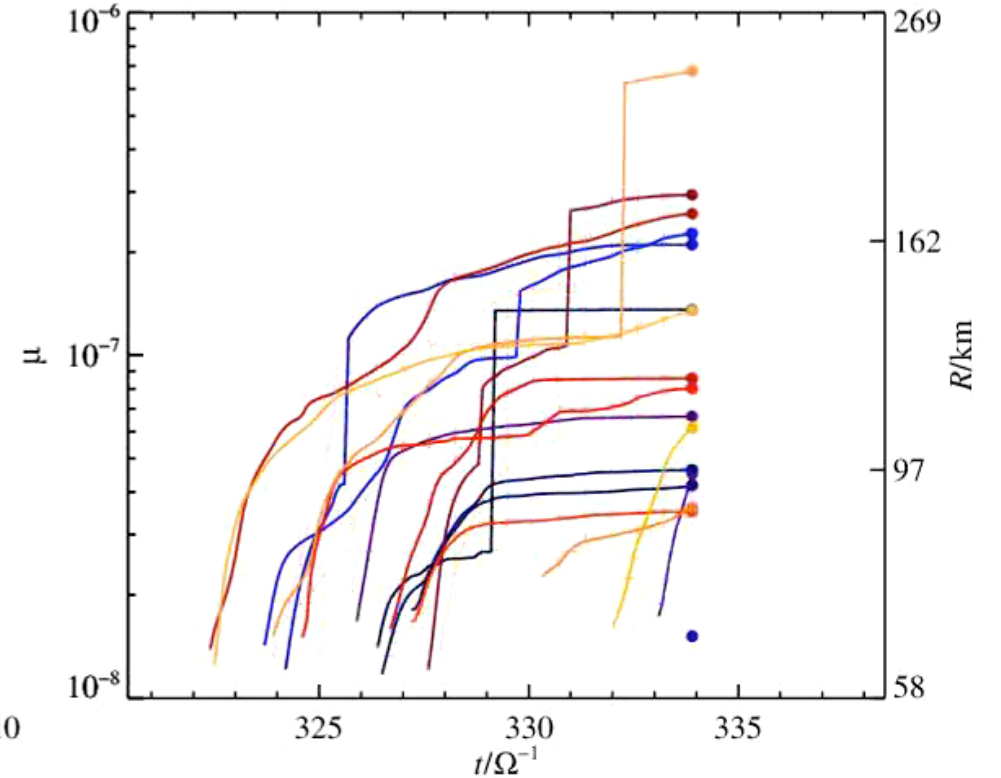


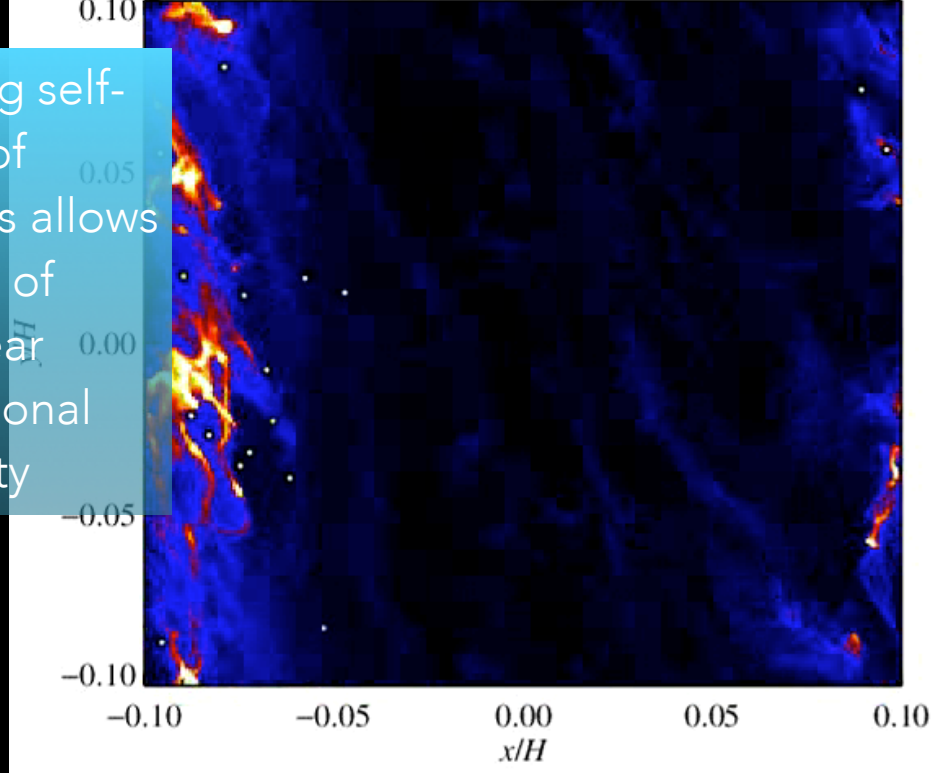


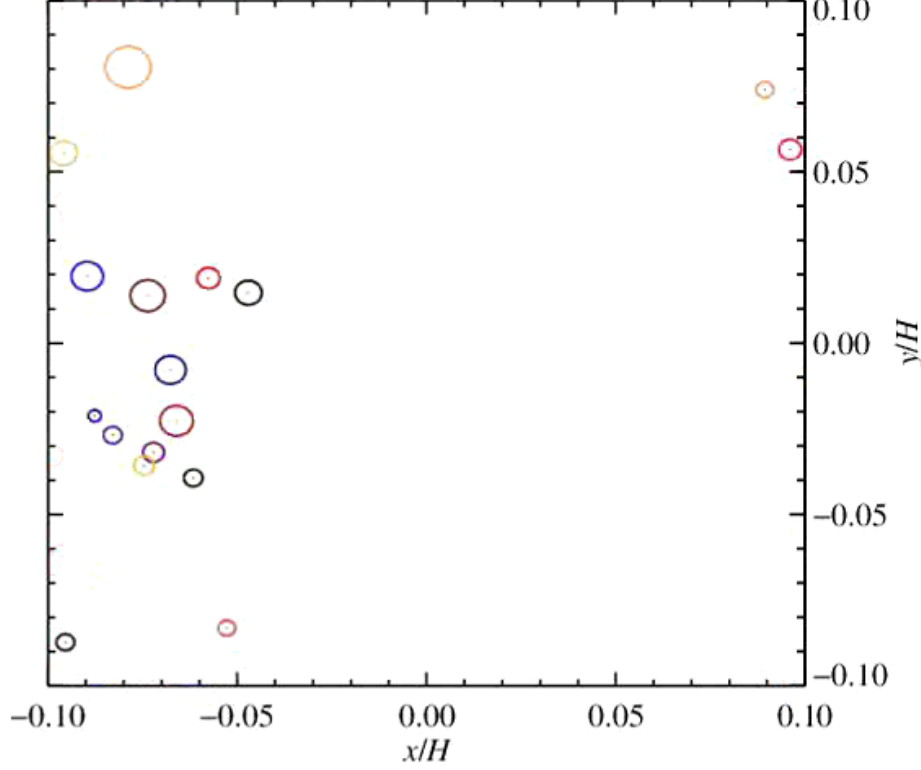


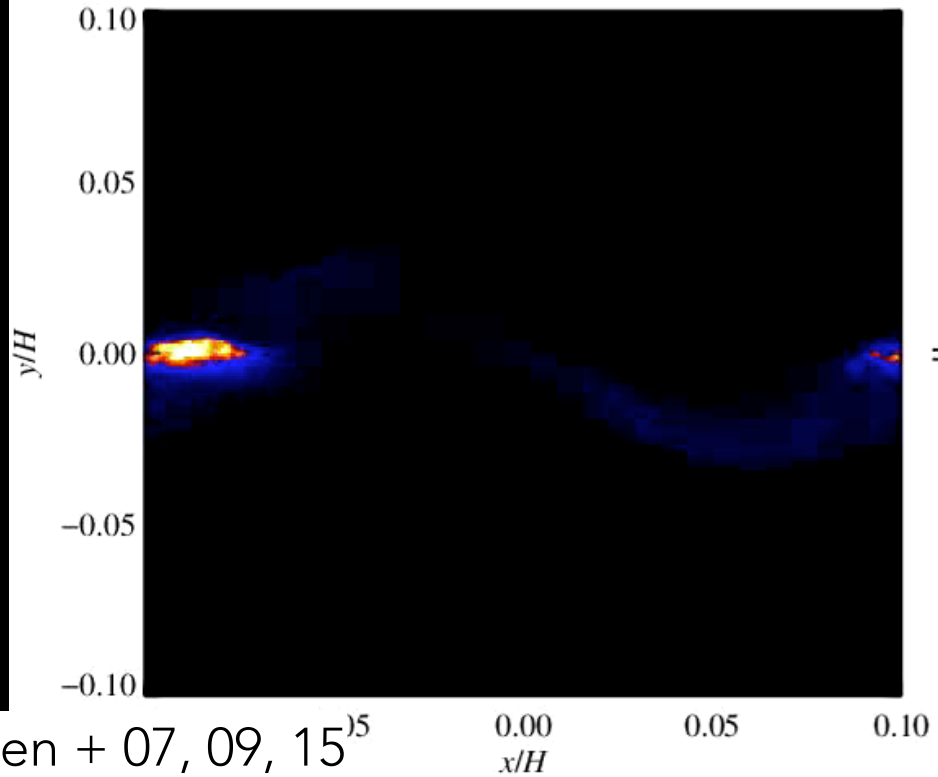


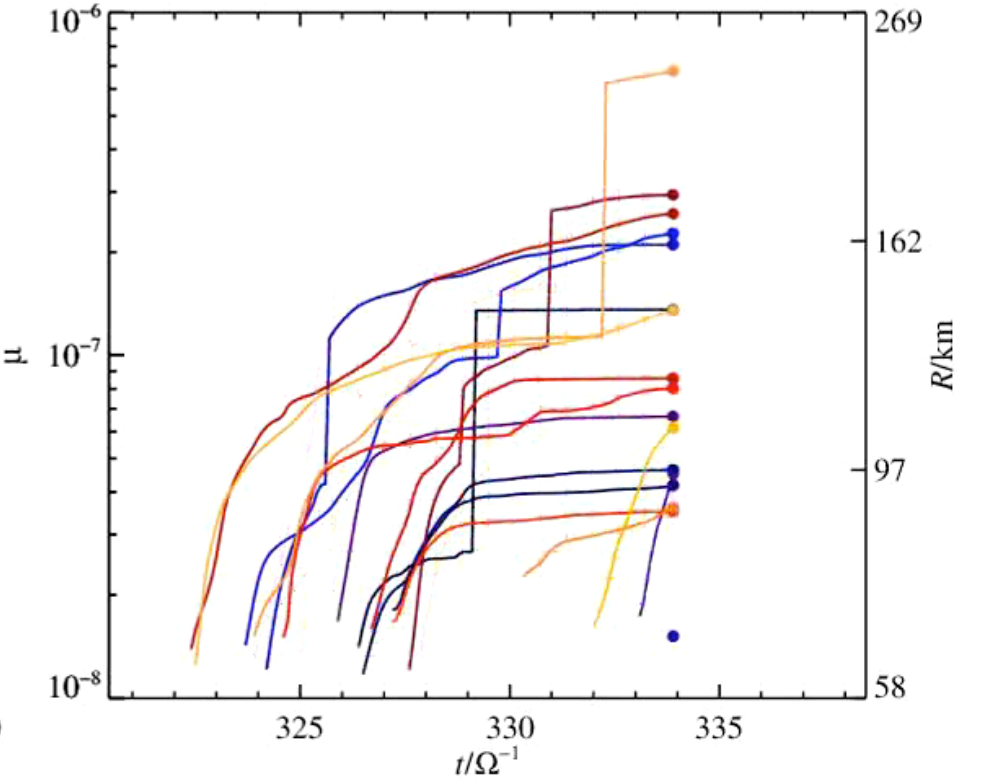
Johansen + 07, 09, 15

including self-gravity of boulders allows tracking of non-linear gravitational instability



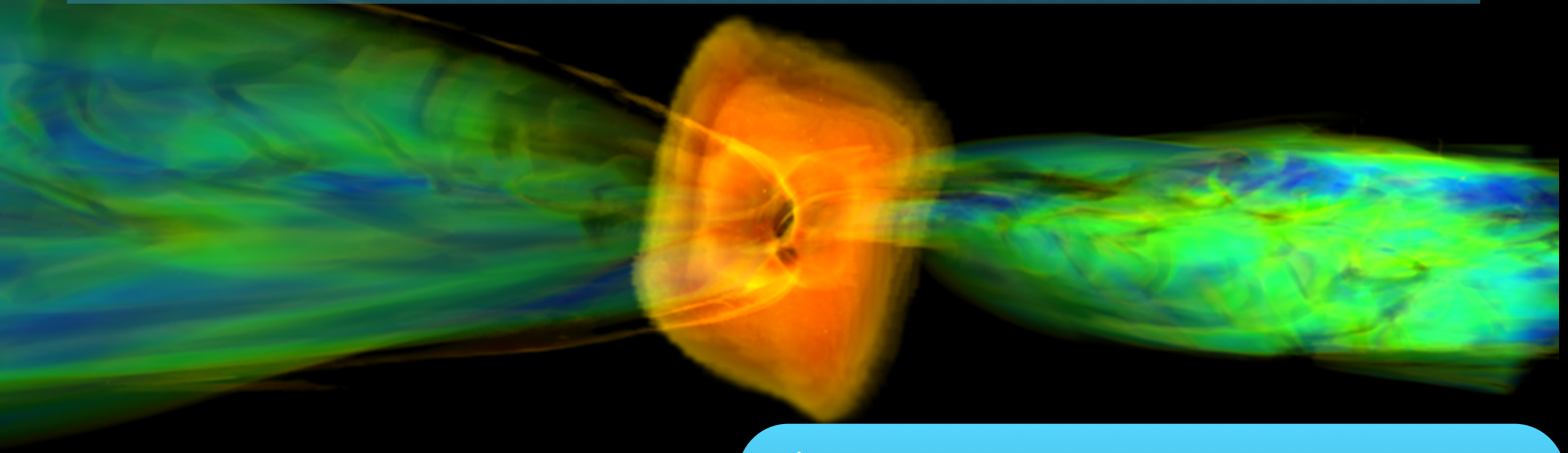






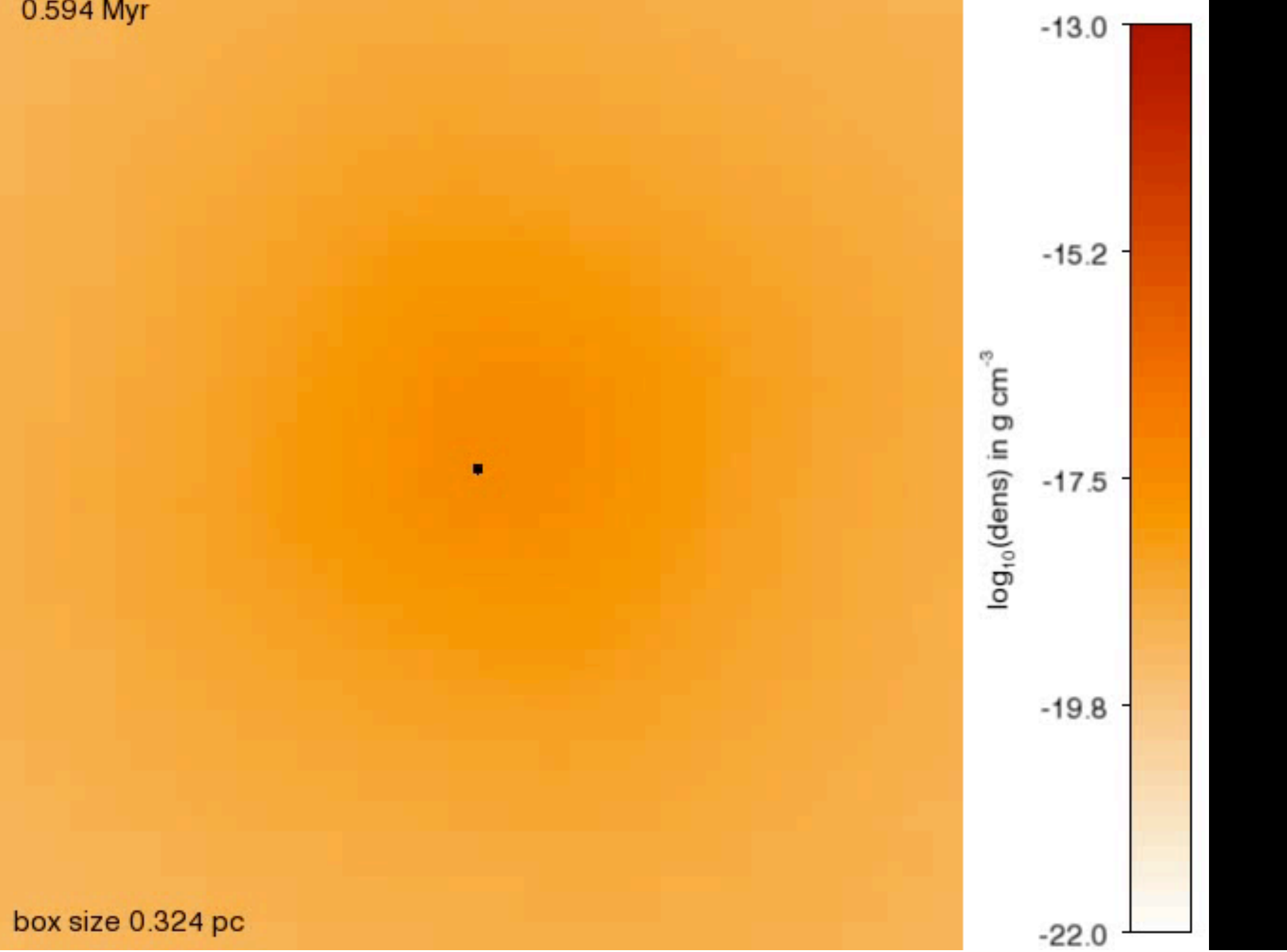
Johansen + 07, 09, 15

CLUSTER FORMATION



Peters + 14, Viz: Zilken, Jülich

Thomas Peters (MPA)
Joshua Wall (Drexel)
Steven McMillan (Drexel)
Simon Portegies-Zwart (Leiden)
Juan Ibañez-Mejia (AMNH/ITA-ZAH)
Kevin Olson (Drexel)
Ralf Klessen (ITA-ZAH)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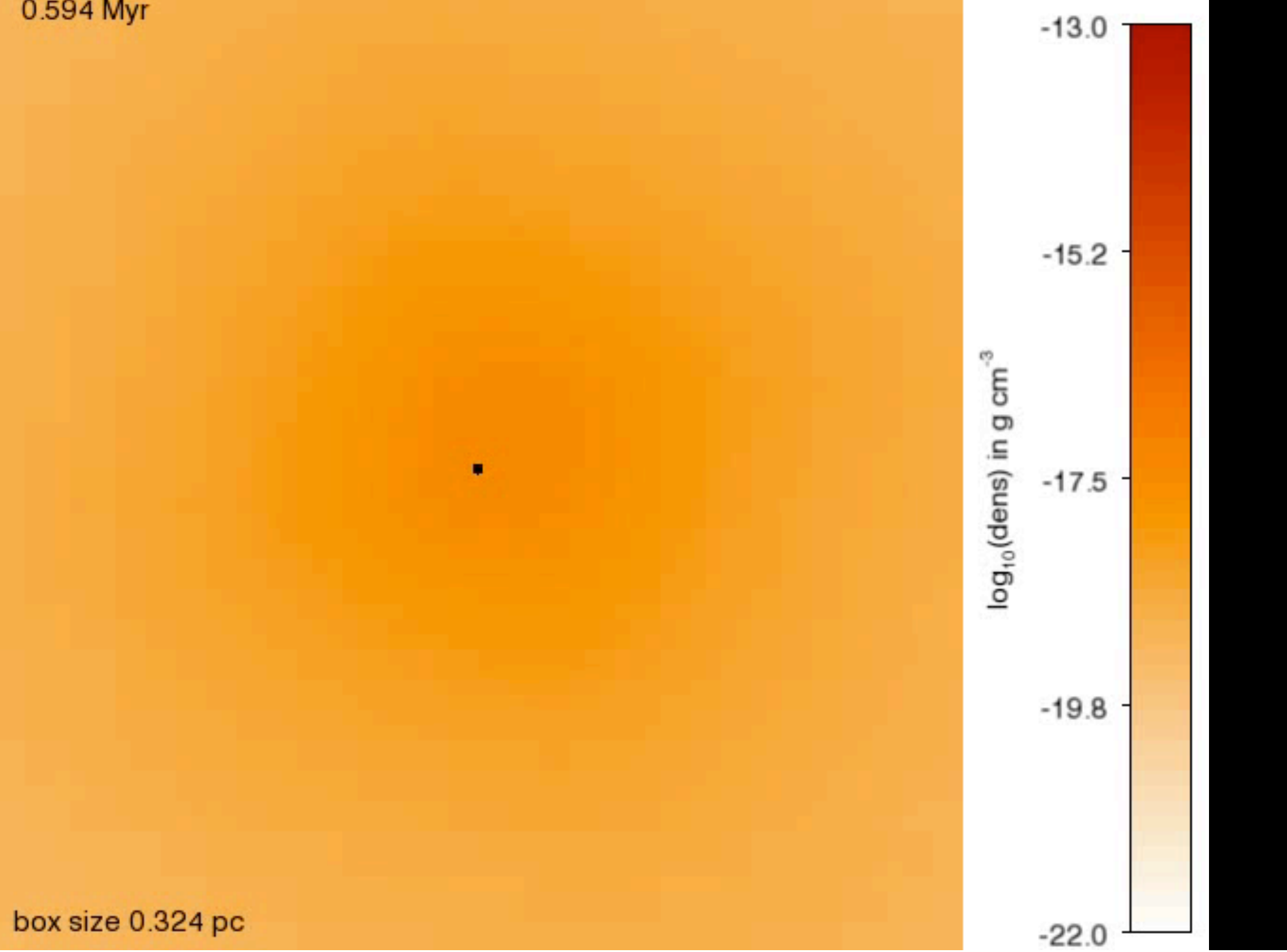
-13.0
-15.2
-17.5
-19.8
-22.0
log10(dens) in g cm-3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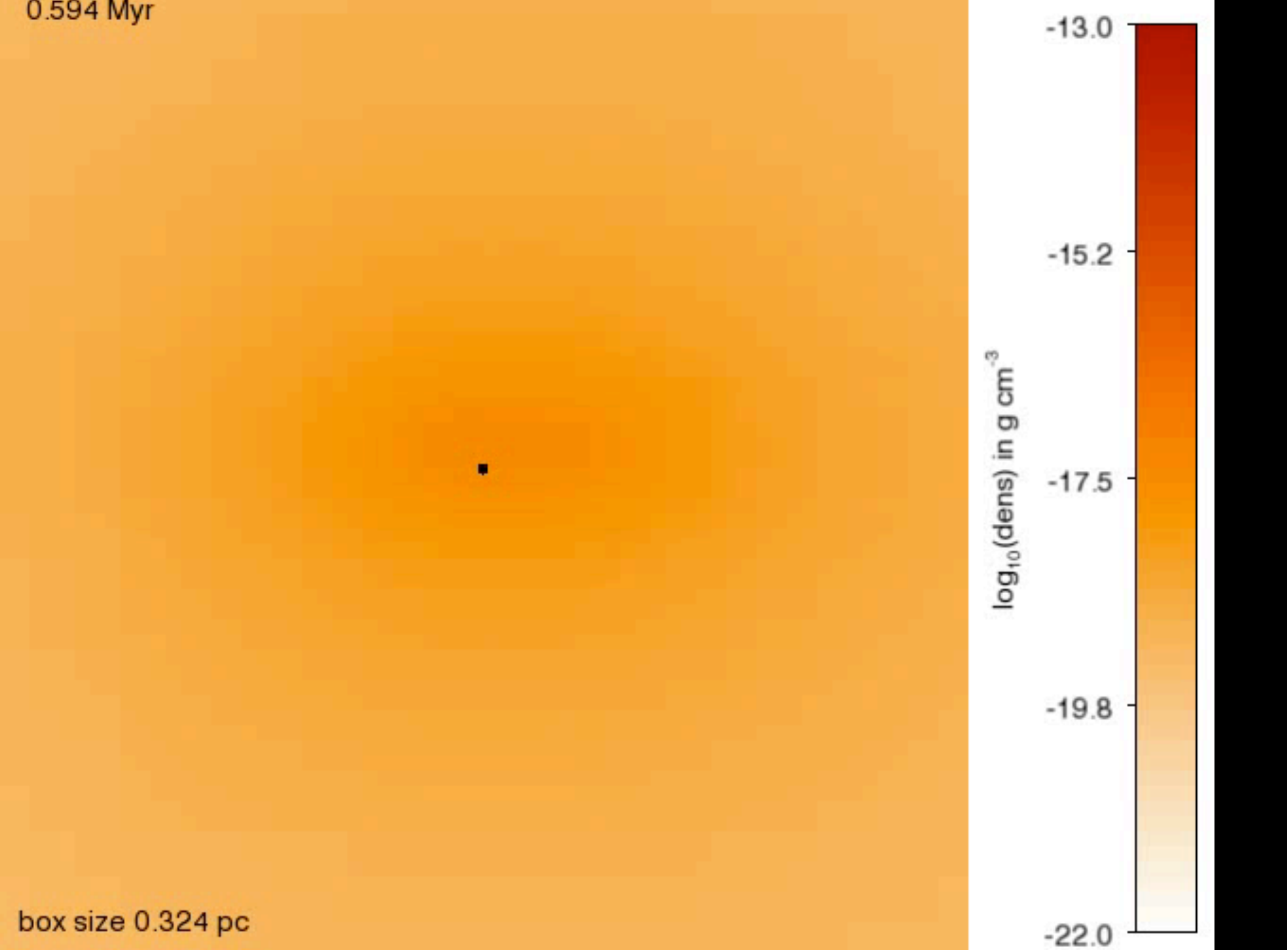
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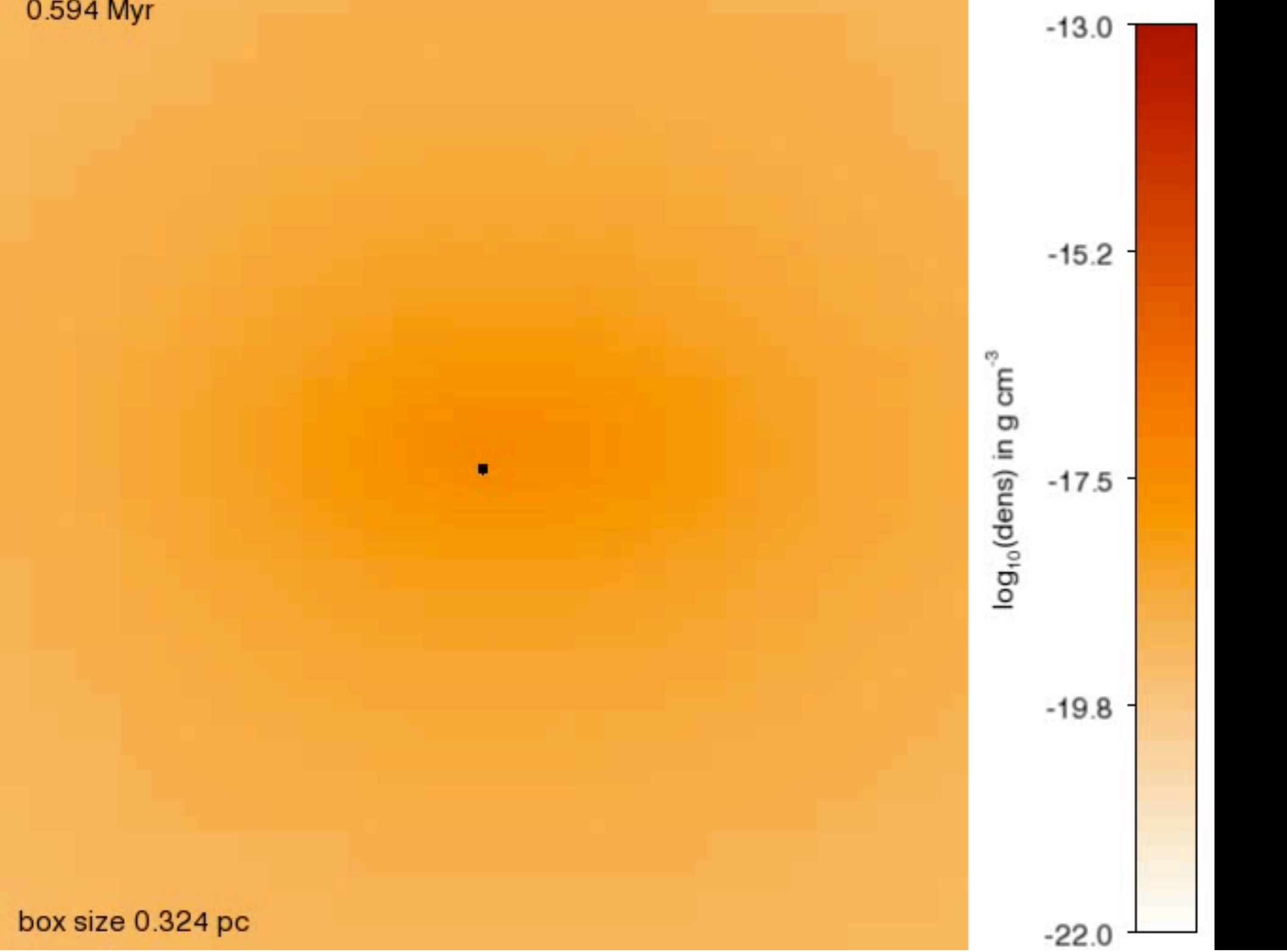
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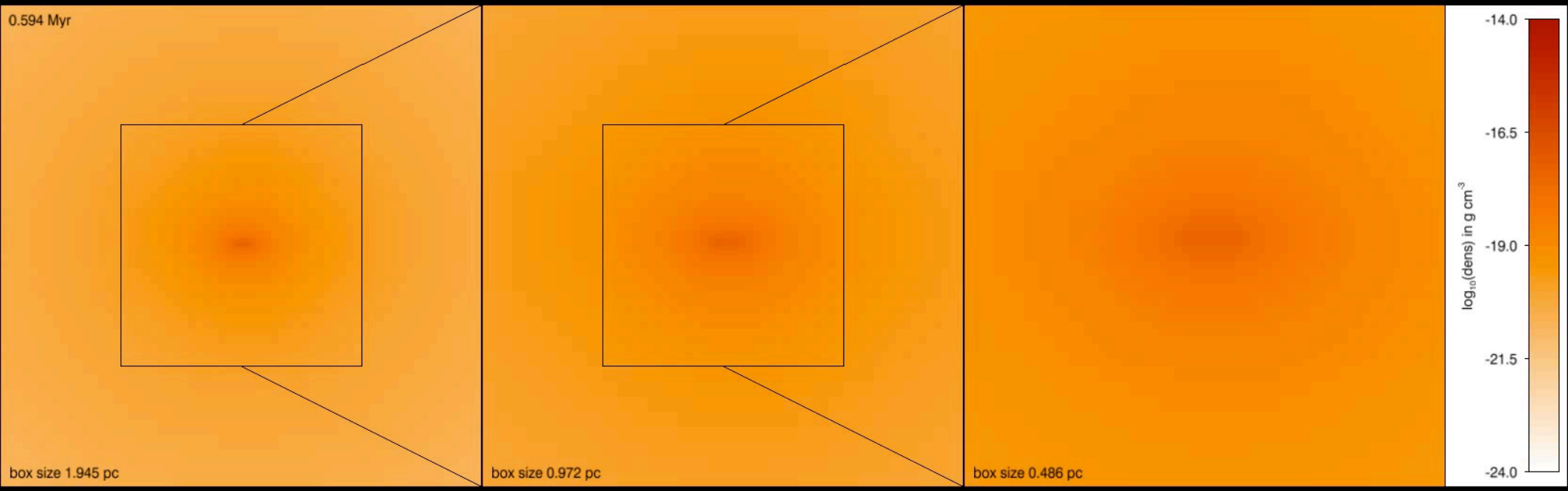
0.594 Myr
box size 1.945 pc
box size 0.972 pc
box size 0.486 pc
-14.0
-16.5
-19.0
-21.5
-24.0
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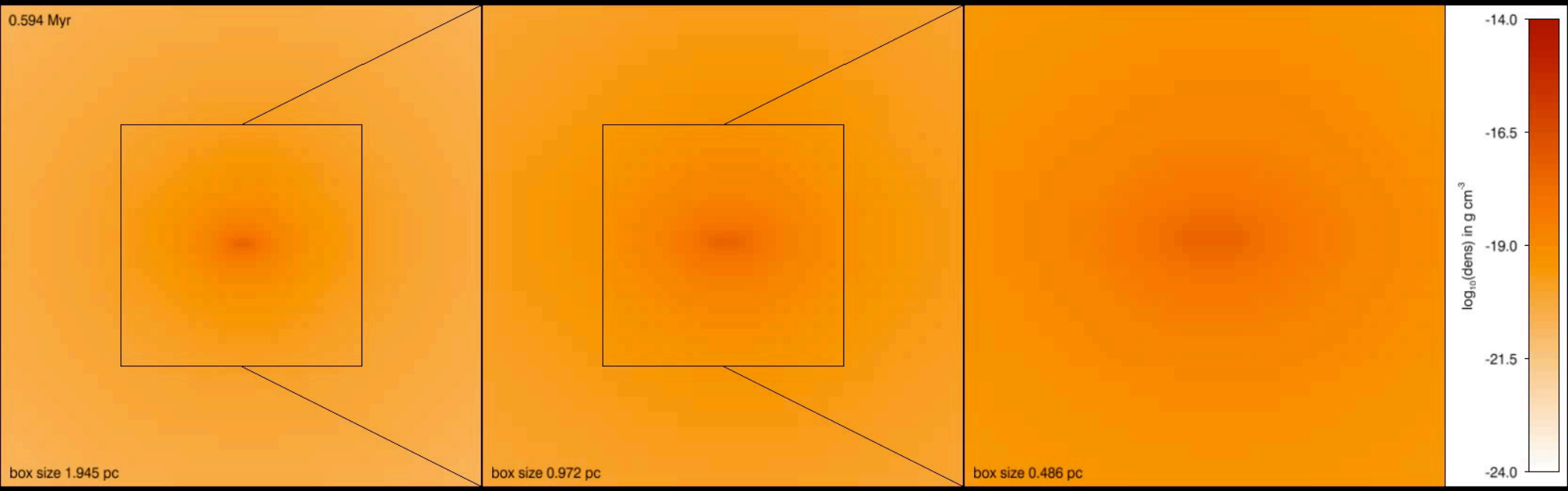
Peters + 14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log10(dens) in g cm-3

Peters + 14

NEXT STEPS

- Update ionization to FERVENT (Baczynski +15), based on Wise & Abel MORAY algorithm (HEALPIX ray-tracing)
- Integrate N-body dynamics (ph4, McMillan) using the AMUSE framework (http://amusecode.org/doc/, Portegies-Zwart)
- Incorporate Glover chemistry module following lead of SILCC collaboration (Walch)

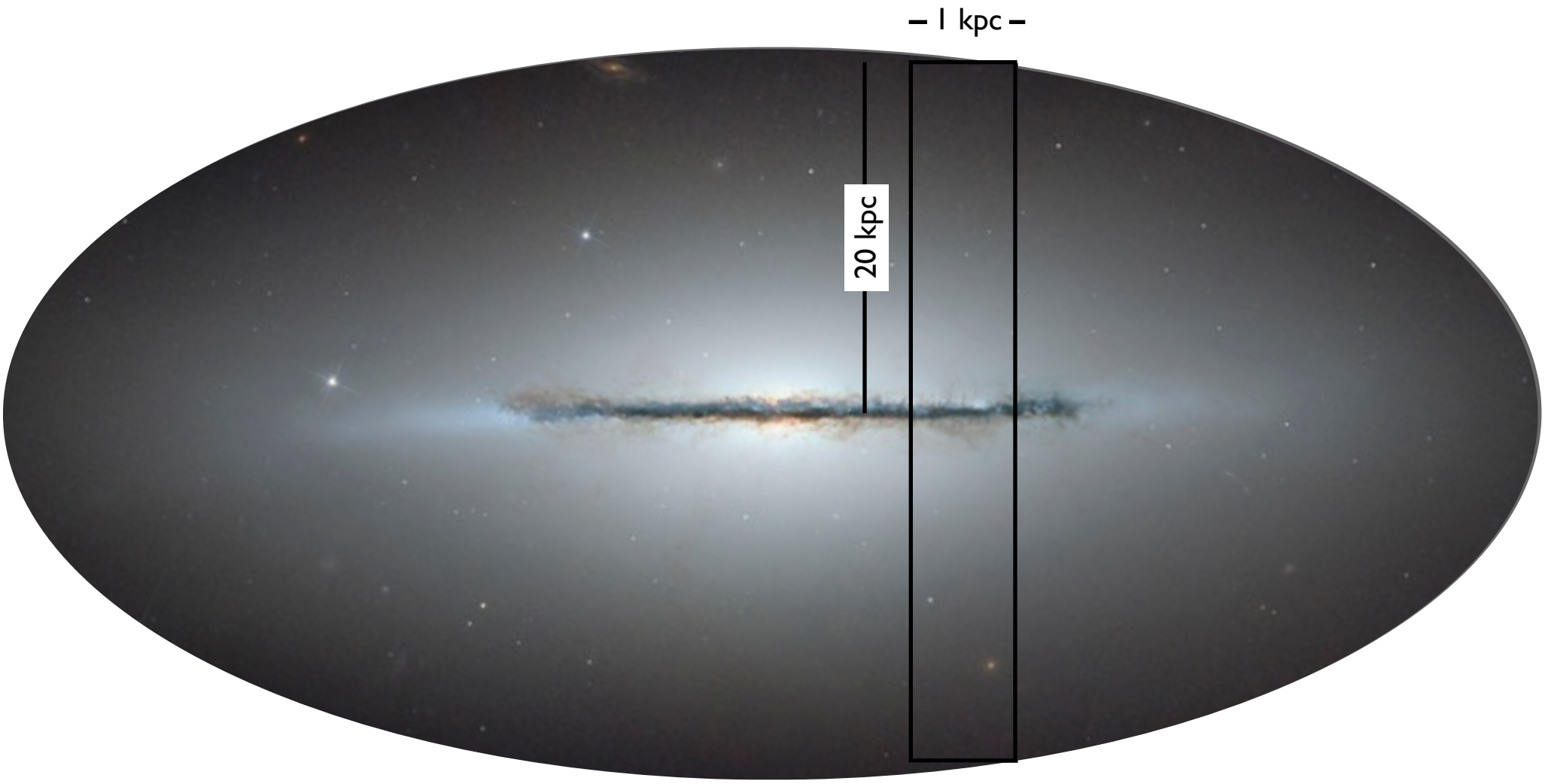
STAR FORMATION

GALACTIC STAR FORMATION

Juan Ibañez-Mejia (AMNH/ITA-ZAH)
Ralf Klessen (ITA-ZAH)
Andrea Gatto (MPA)
Stefanie Walch (U. Köln)
Christian Baczynski (ITA-ZAH)
Simon Glover (ITA-ZAH)
Alex Hill (Haverford)

Our Model

Our Model



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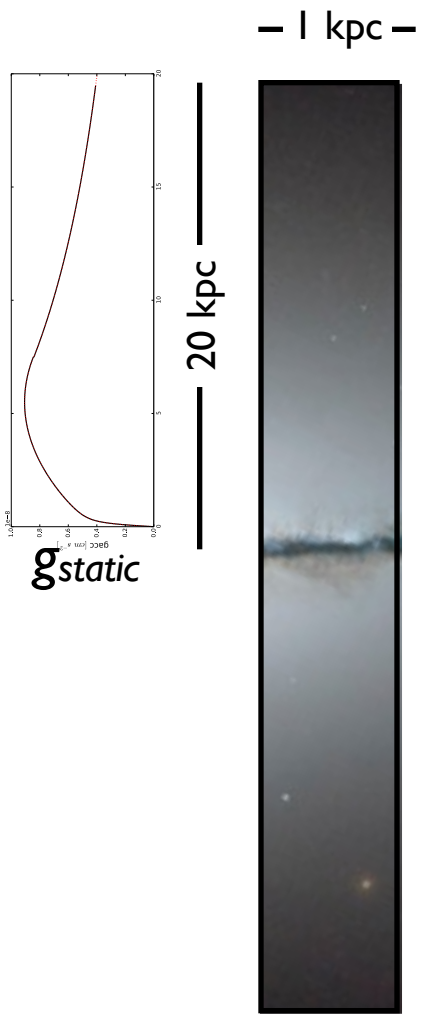
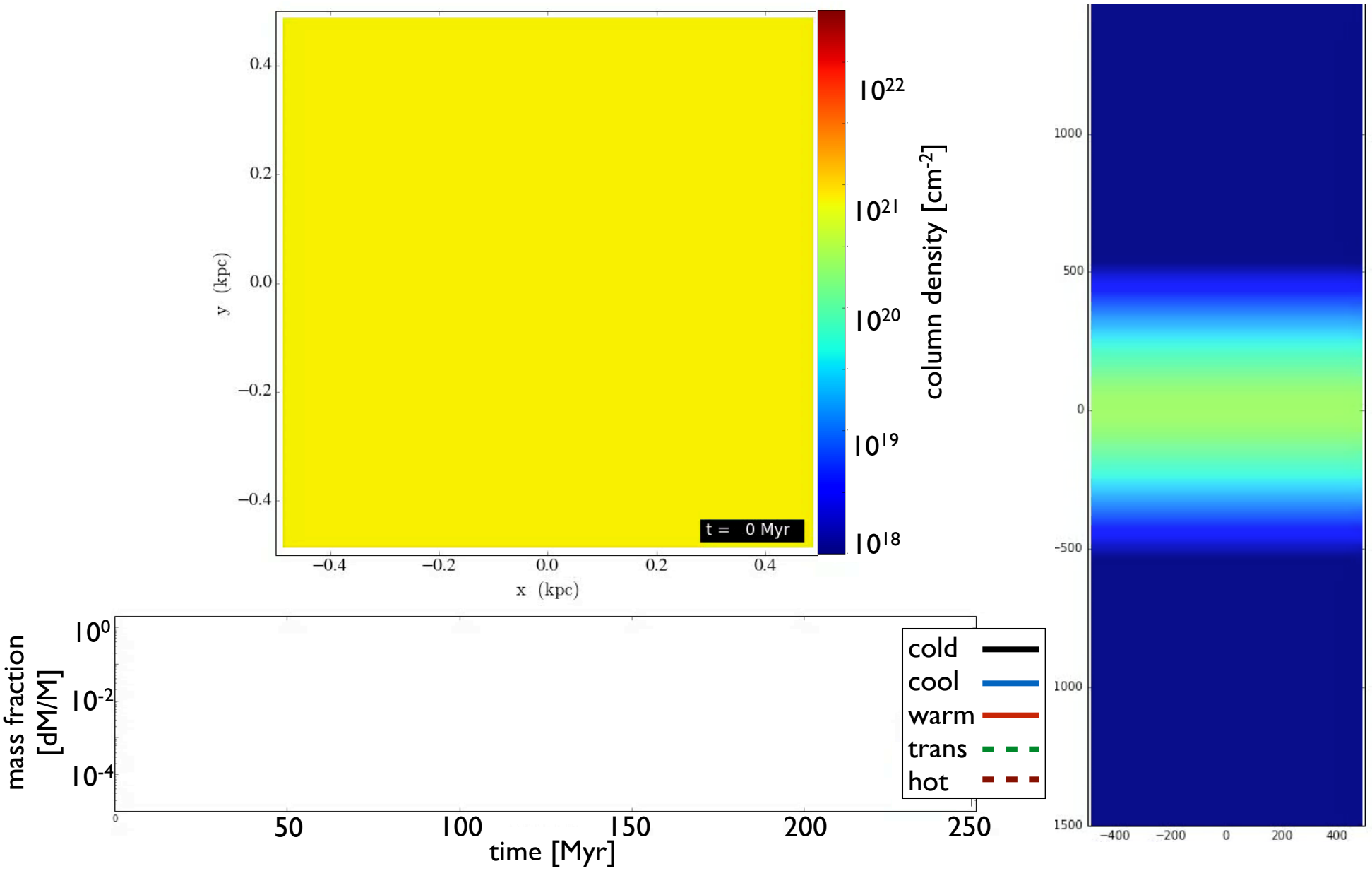
Our Model



- Code: Flash 4.0
  - Eulerian grid based code
  - 3 dimensional MHD solver.
  - Adaptive mesh refinement
- Physics
  - Static gravitational potential (Gas + Stars + DM)
  - Random & correlated supernova (SN & SB)
  - Parameterized heating & cooling
  - Ideal magnetic fields
  - Self-gravity

The Stratified, Magnetized, Turbulent ISM



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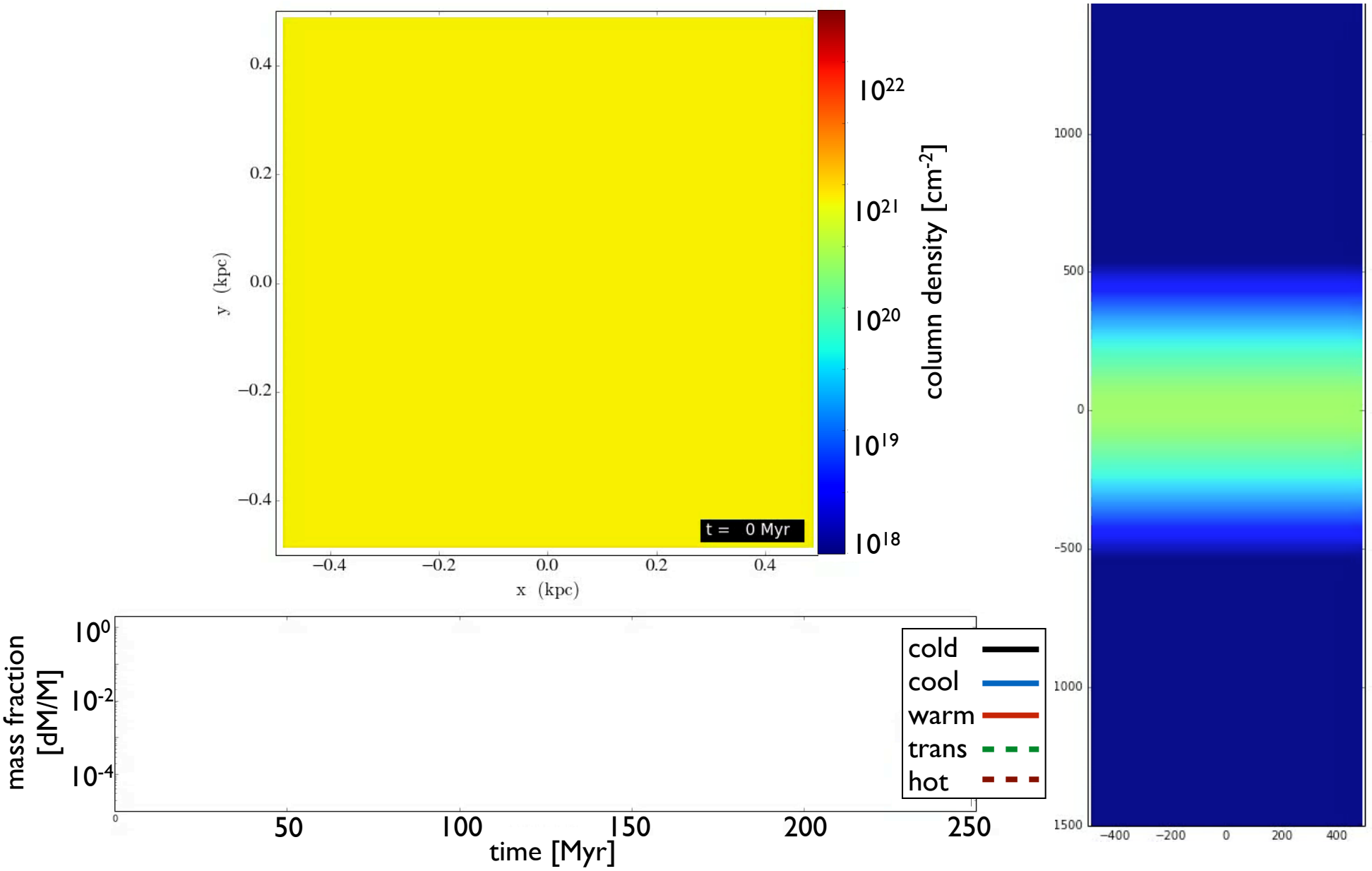
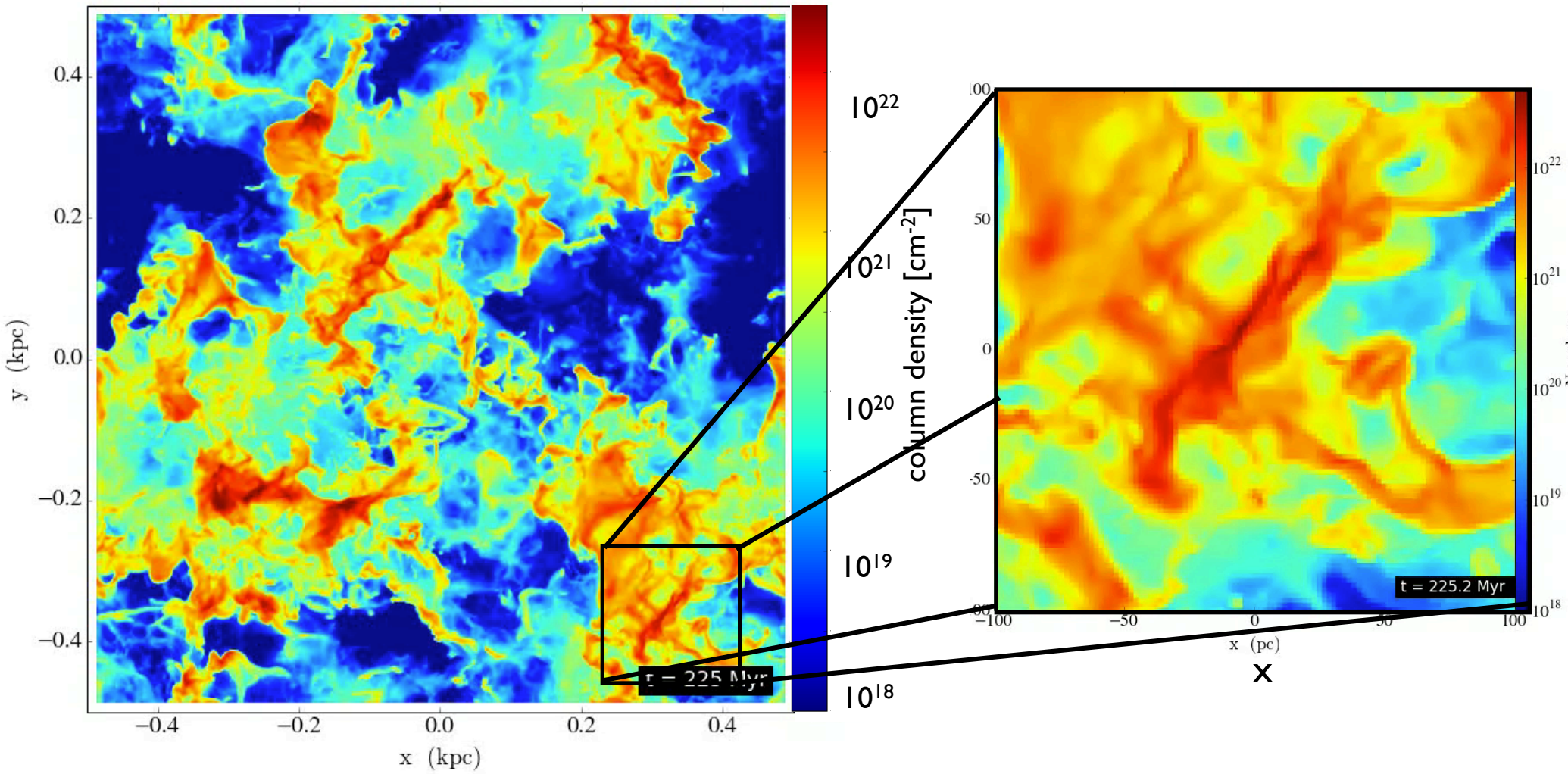
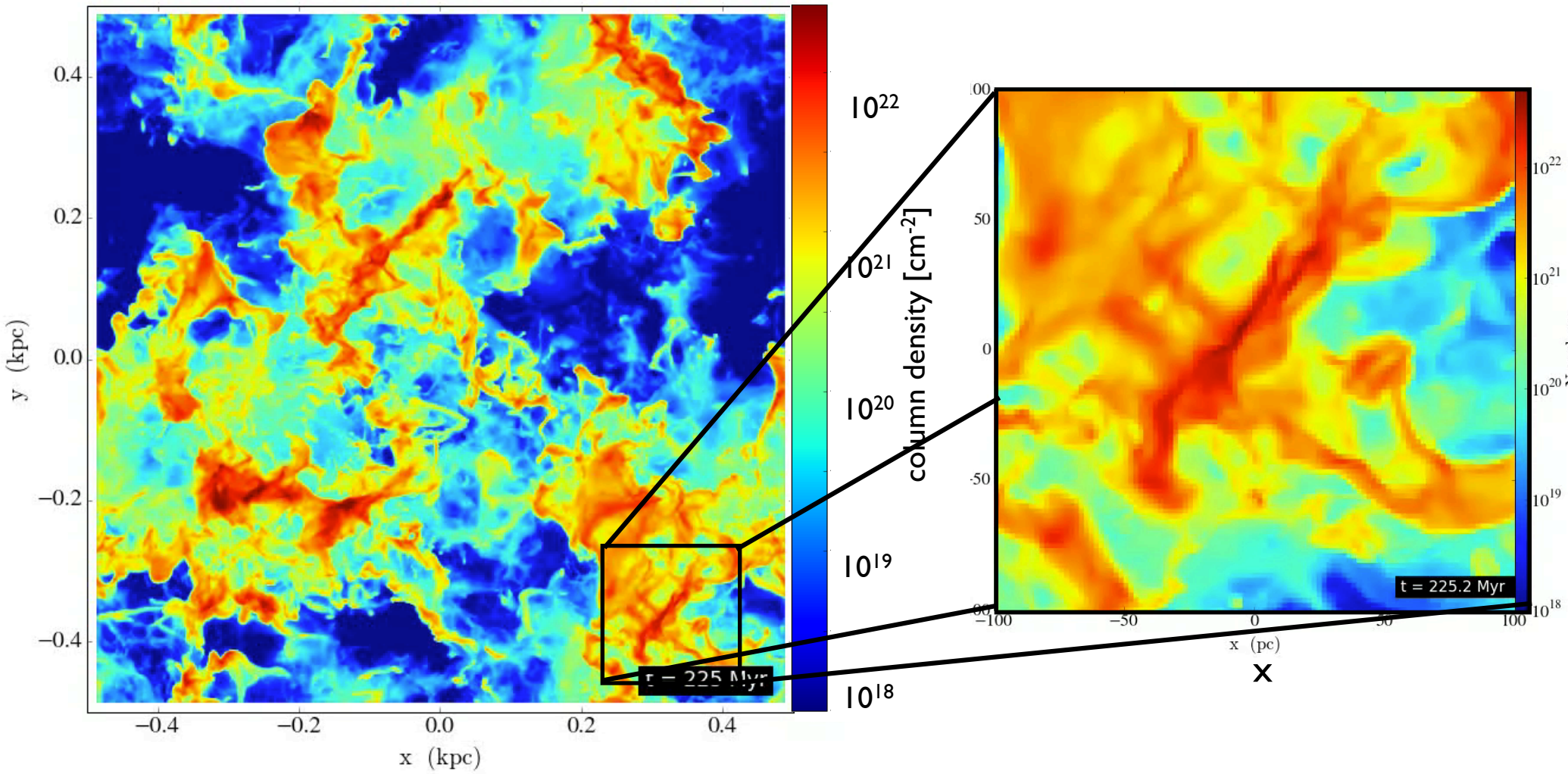


The Action of Self Gravity

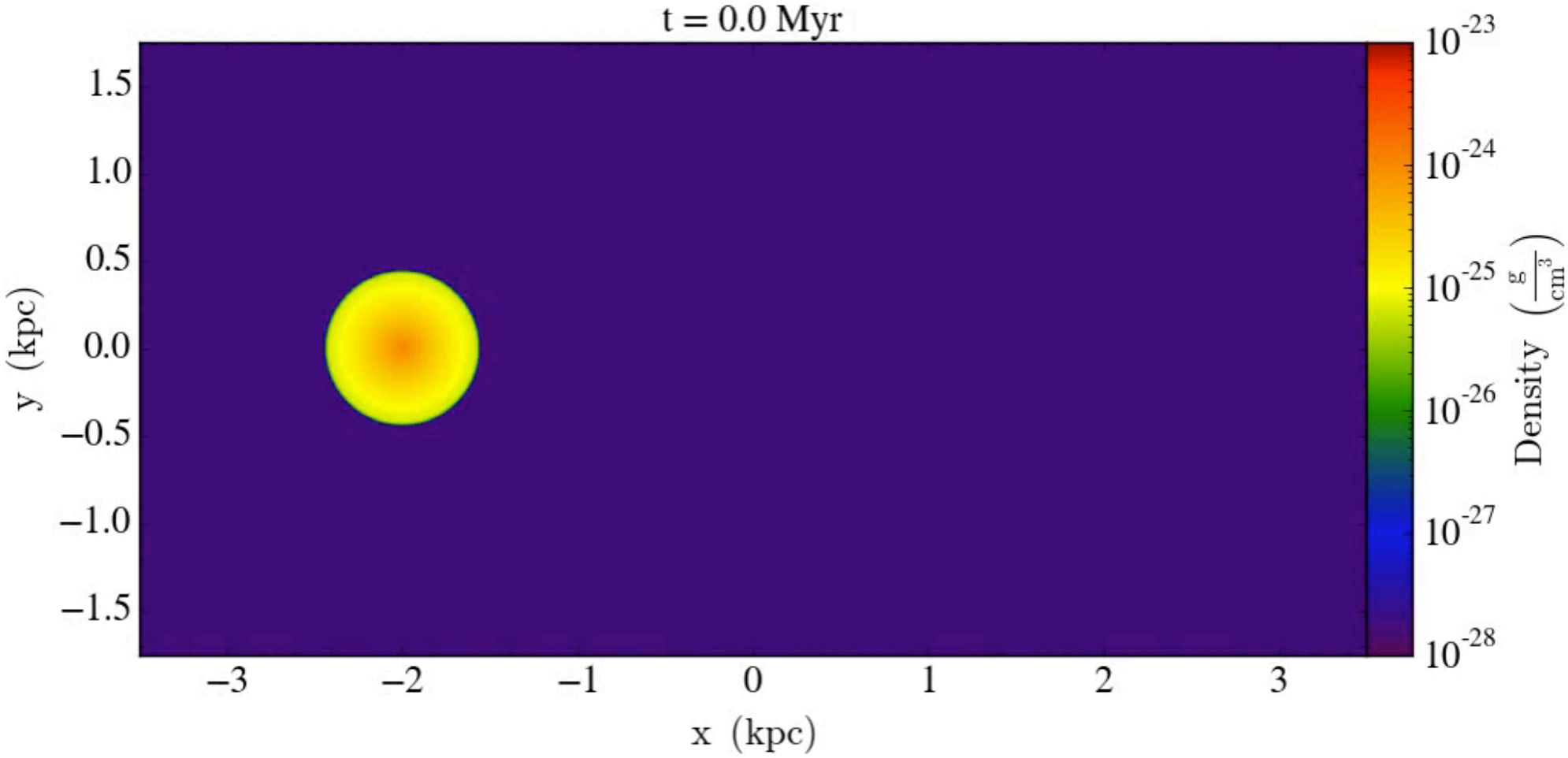


The Action of Self Gravity



STRIPPING OF DWARF GALAXIES

ANDREW EMERICK (COLUMBIA)
JANA GRCEVICH (AMNH)



Emerick, Grcevich, Mac Low, Gatto 15

STRIPPING OF DWARF GALAXIES

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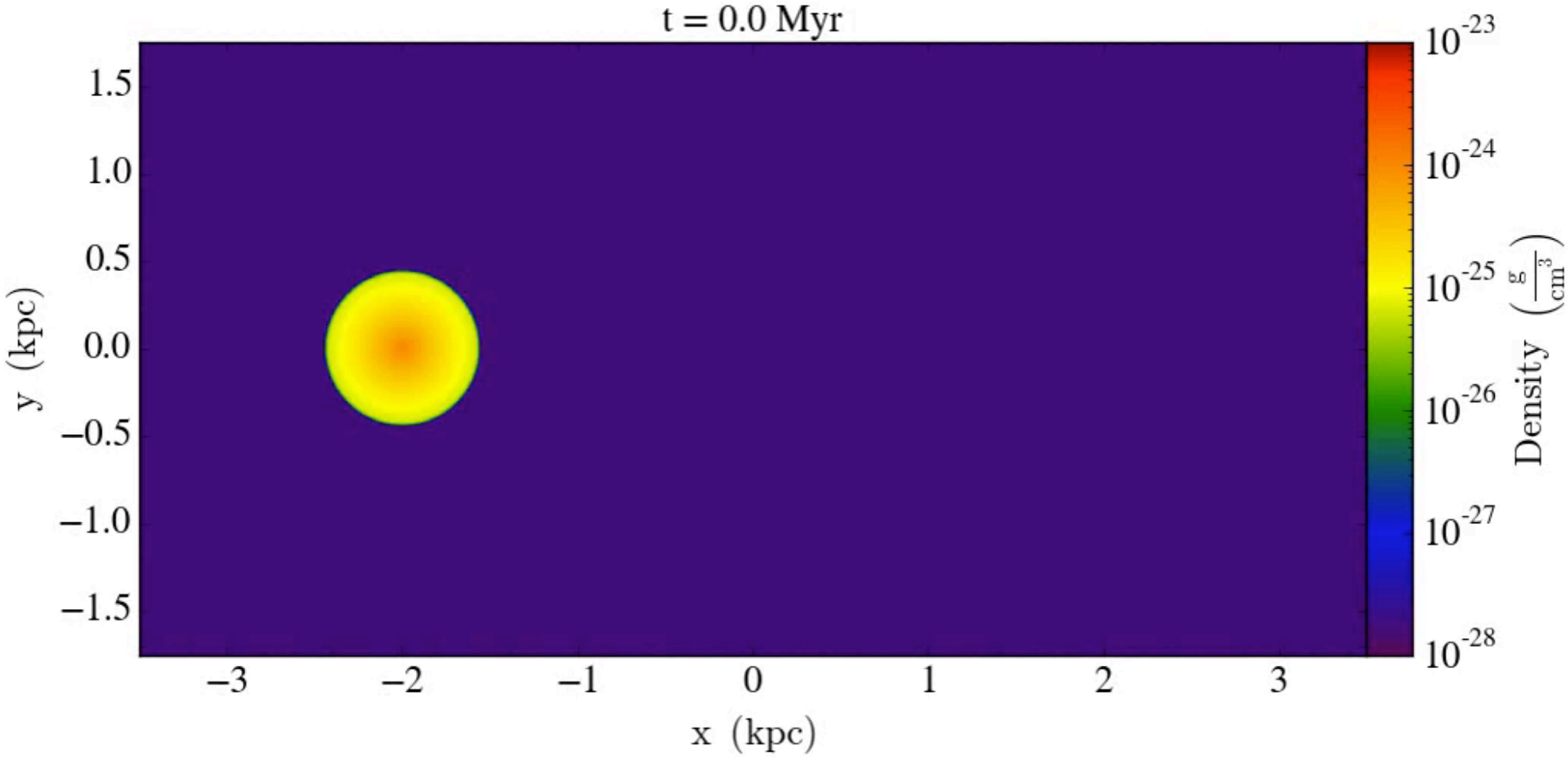
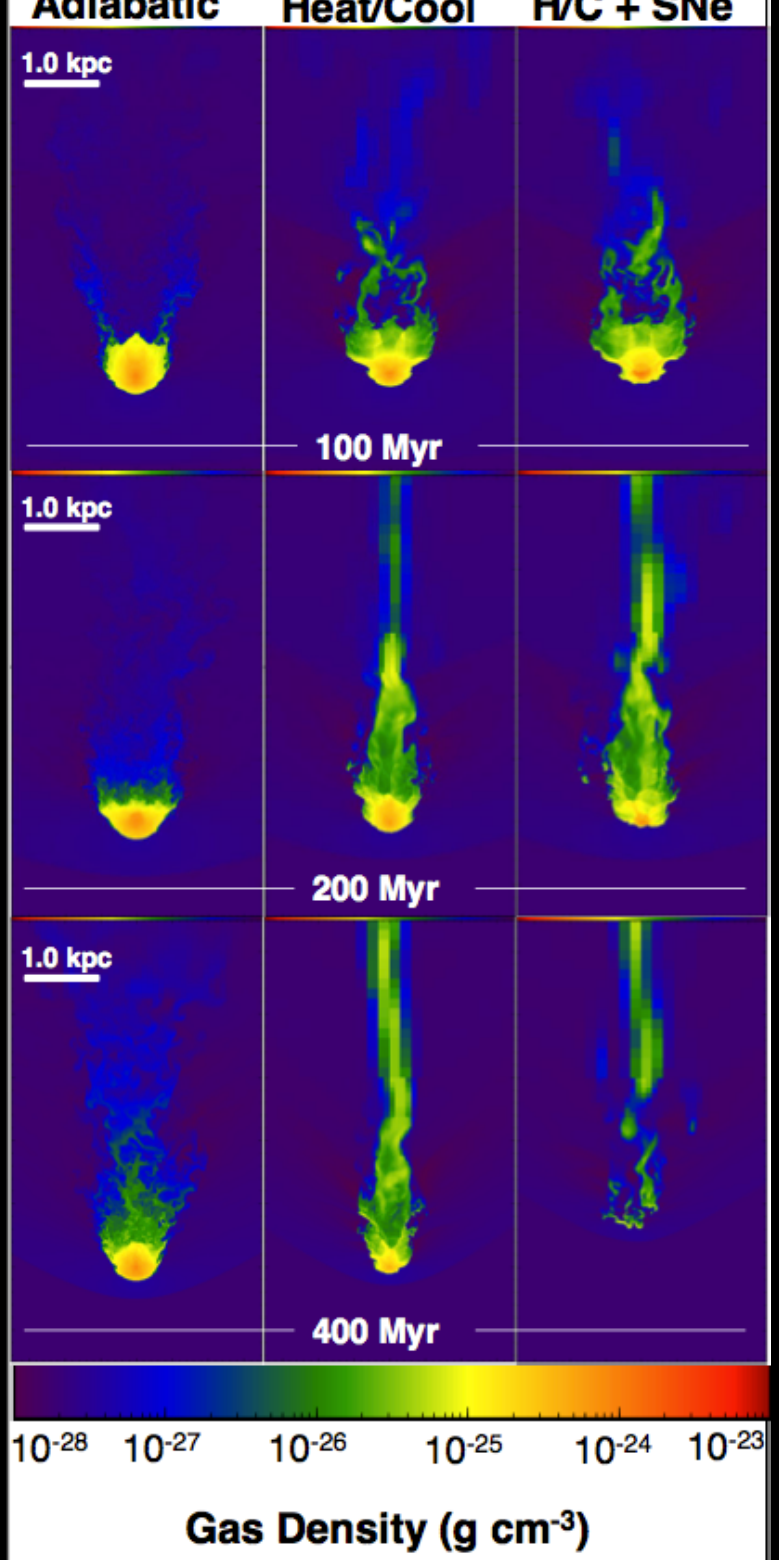
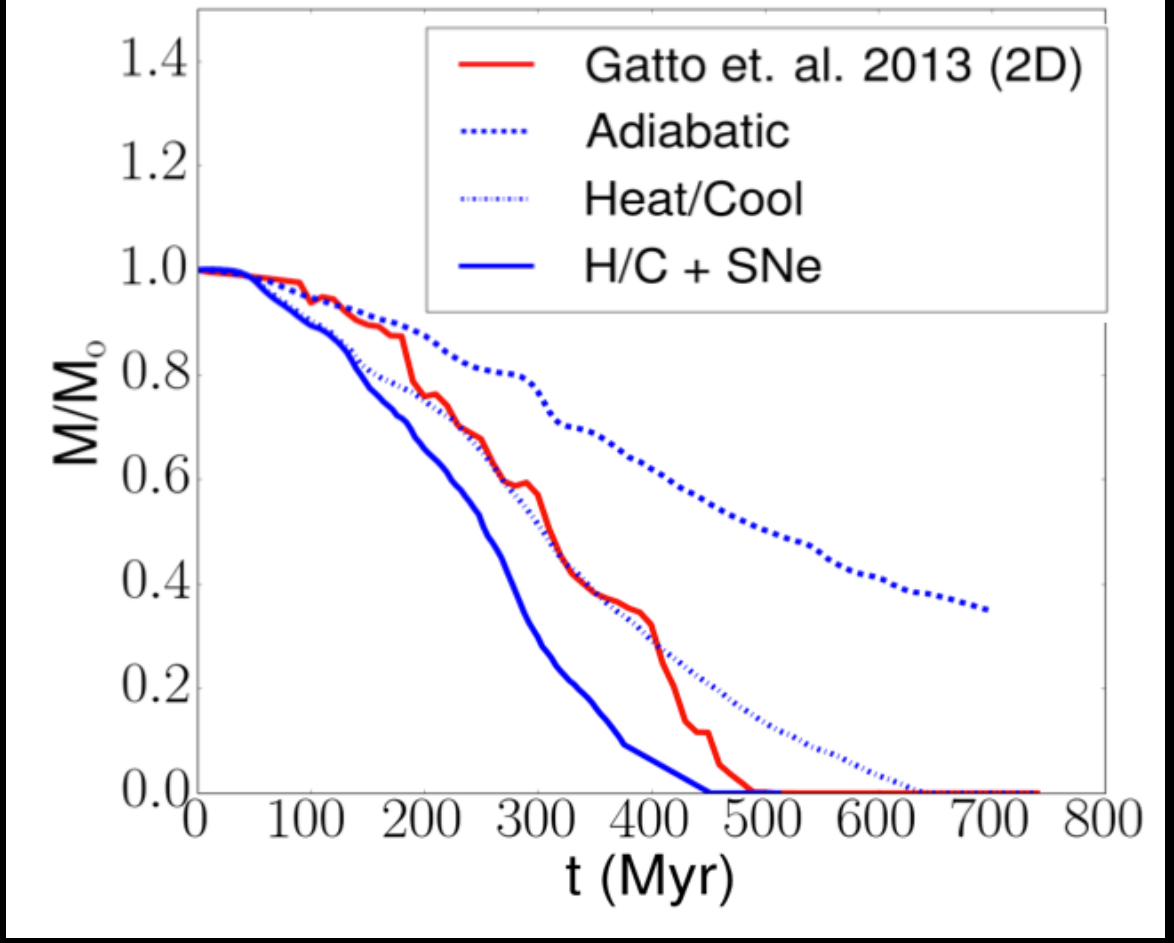


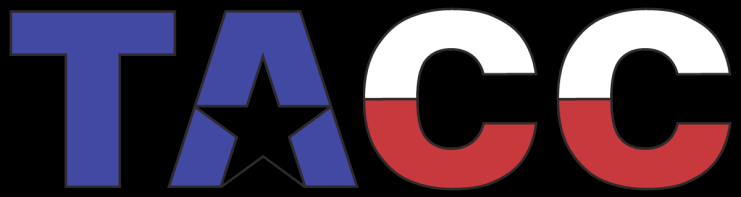
Emerick, Grcevich, Mac Low, Gatto 15





Emerick, Grcevich, Mac Low, Gatto 15

Computational Resources



Collaborators

People I have mentored in my group in orange

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