

Selfgravity in AMR Simulations (of Turbulence)

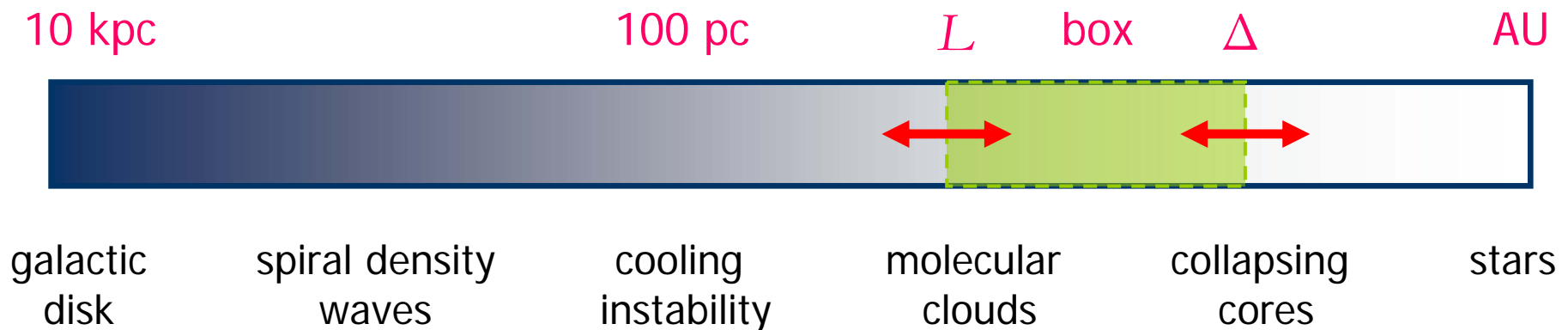
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Andreas Maier and Markus Hupp
University of Würzburg

Astrophysical Scenario: The ISM

- Multiscale turbulent flow
- Maintained by gravity, magnetic fields, thermal processes, supernovae,...
- Transient (no permanent equilibrium state)
- Highly intermittent (stars happen to be formed just in some regions at a certain time)
- Multiphase medium with complex chemistry

Simulation Scenario (1st Step)

- Periodic box
- Isothermal self-gravitating gas
- Supersonic turbulence
- Excitation of compressive/solenoidal modes
- Statistically stationary & homogeneous



Parameters

■ Length scales

- Integral length L

- Jeans length

$$\lambda_J \gg c_0 / (G\rho_0)^{1/2}$$

■ Time scales

- Dynamic time scale

$$T = L/V$$

- Free-fall time

$$T_{\text{ff}} \gg \lambda_J / c_0$$

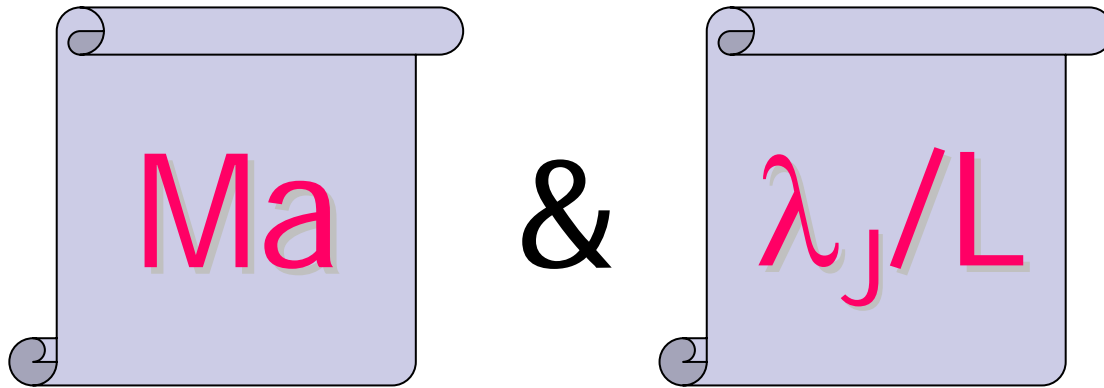
■ Dimensionless parameters

- Mach number $Ma = V/c_0$

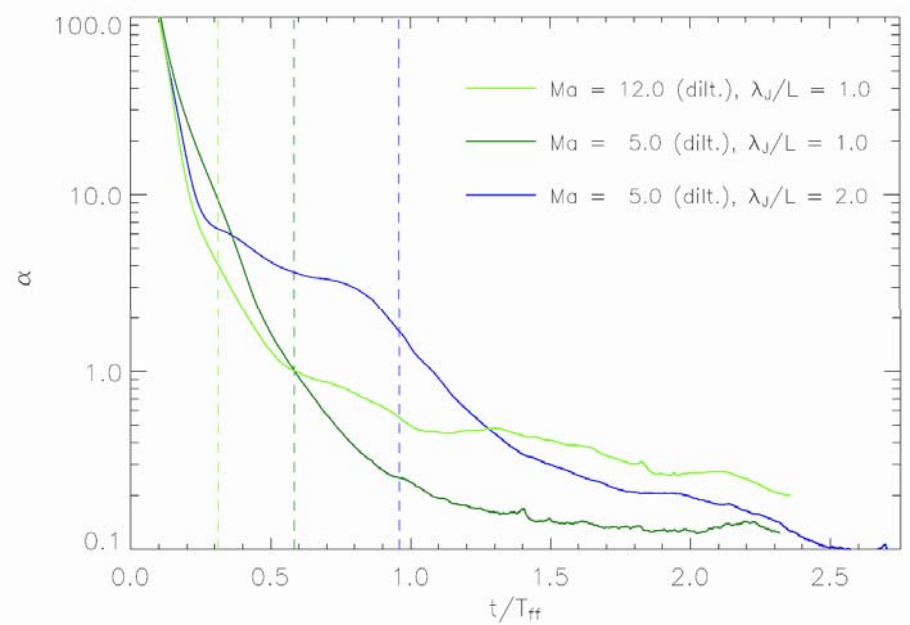
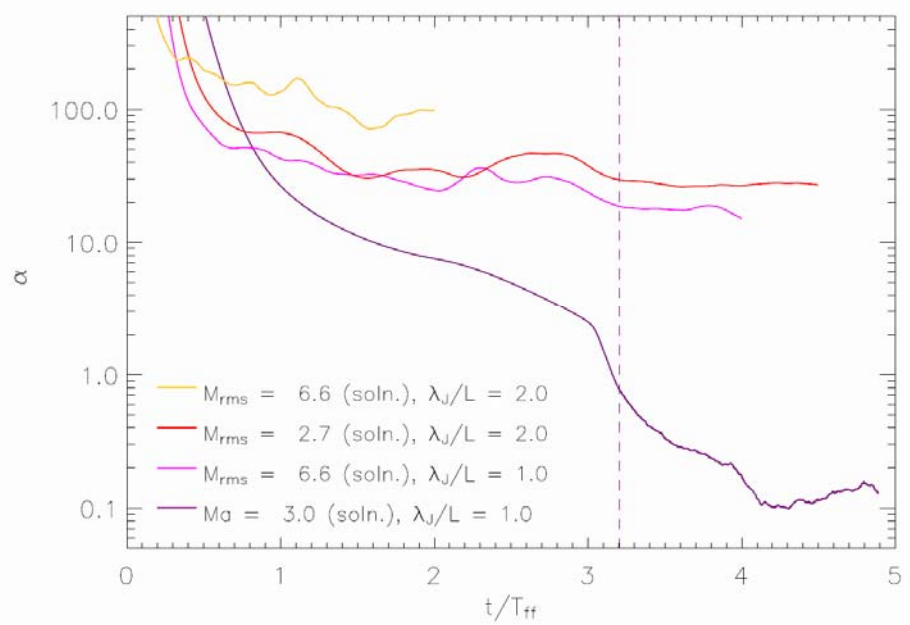
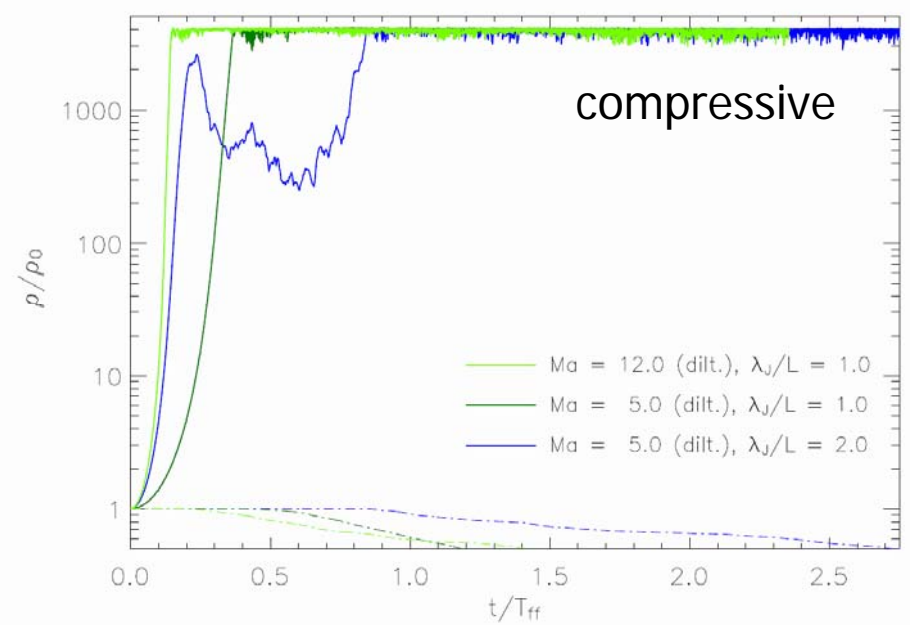
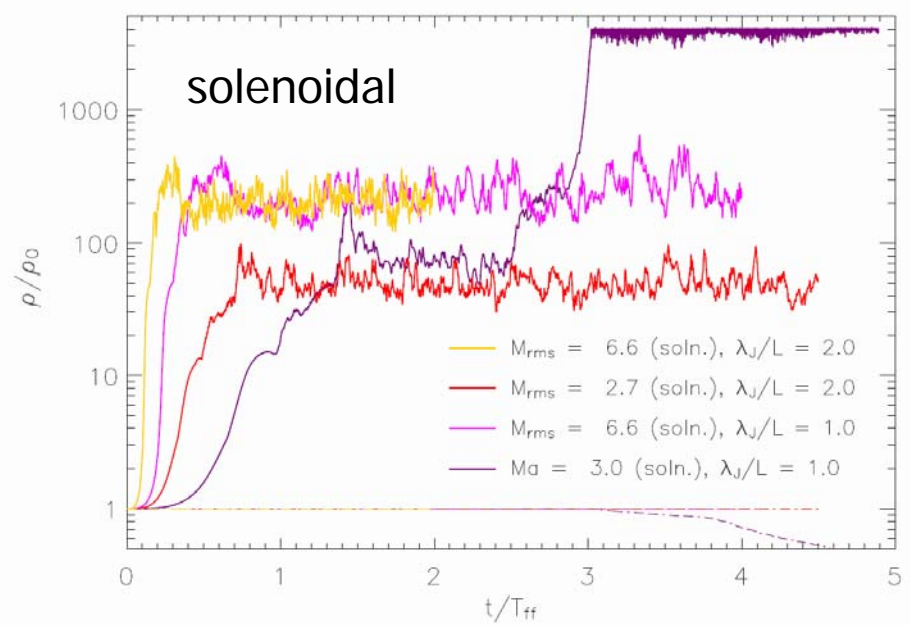
- Jeans length to integral length λ_J / L

- Virial parameter $\alpha = E_{\text{kin}} / E_{\text{grav}}$

Everything Depends on...



... and the forcing



Conclusions

- Evolution very sensitive on parameters
- Onset of gravitational collapse if $\alpha \sim 1$
- Low star formation rate relies on minute balance between gravity and turbulence
 - hierarchical structure (multi-scale energy equipartition, intermittency)
 - cooling (supports collapse)
 - magnetic fields (resist collapse)

There is a Resolution Issue

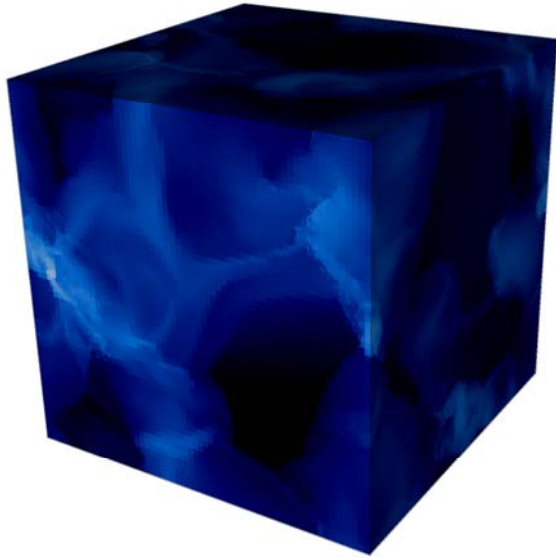
- True love criterion: $\Delta = \lambda_j/4$
 - 256^3 allows for $\rho_{\text{sink}} \sim 1000$
 - $\rho_{\text{max}} \sim 1000$ in supersonic turbulence
 - want $\rho_{\text{sink}}/\rho_{\text{sink}} \sim 10$
- Solutions:
 - Use SPH (presumably bad for turbulence)
 - Increase resolution to 1024^3 ($\rho_{\text{sink}} \sim 10^4$)

However, 1024^3 is costly

- #CPU-hrs (static grid)
 - ~ 500 for 256^3
 - ~ 100000 for 1024^3 (probably more due to SG)
- Solutions:
 - write a proposal to get more CPU-hrs
 - try AMR

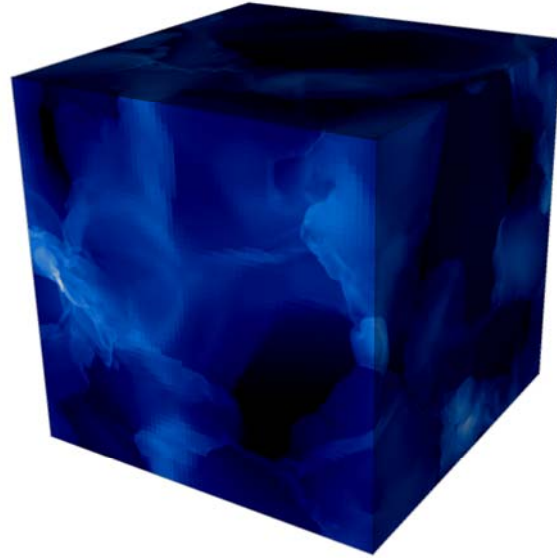
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Pseudocolor
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-1.000
-0.03162
-0.001000
Max: 4052.
Min: 0.0001412



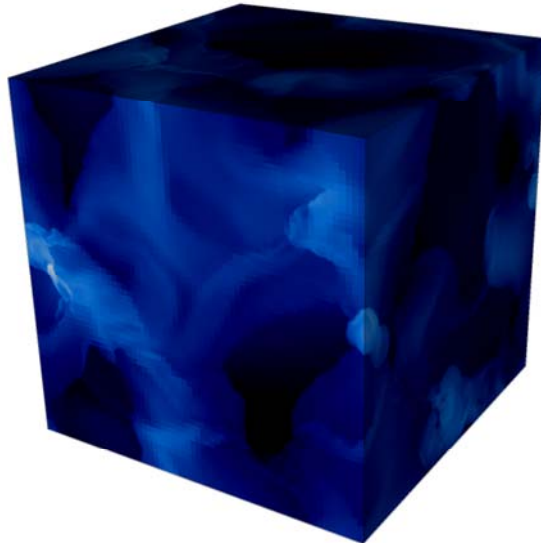
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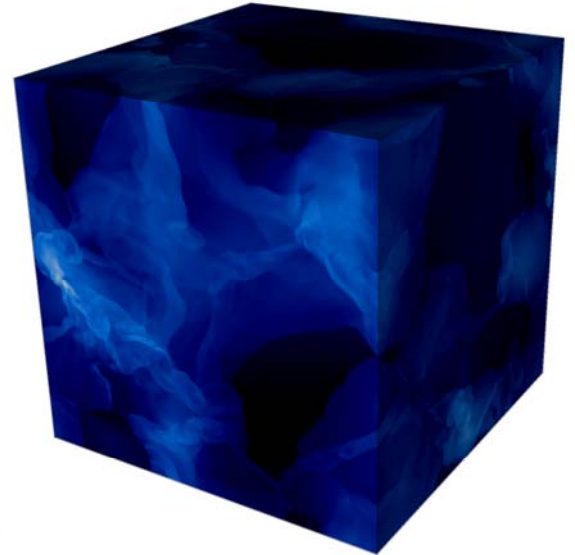
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Min: 0.0001878



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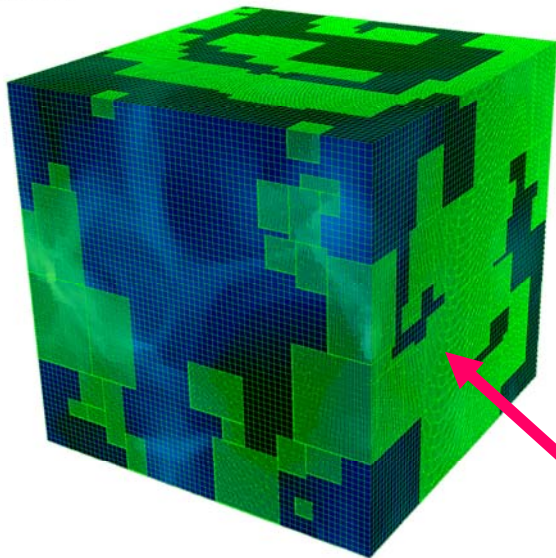
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DB: ISMTurb_0025.hierarchy
Cycle: 399 Time:0.678375
Mesh
Var: mesh

Pseudocolor
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Max: 4052
Min: 0.0001412

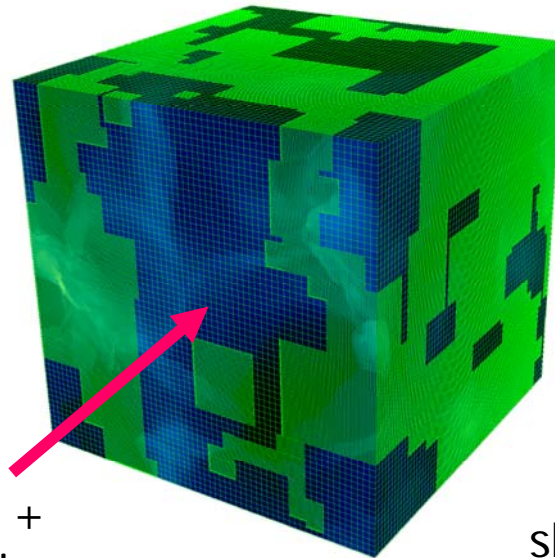
48 %



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63 %



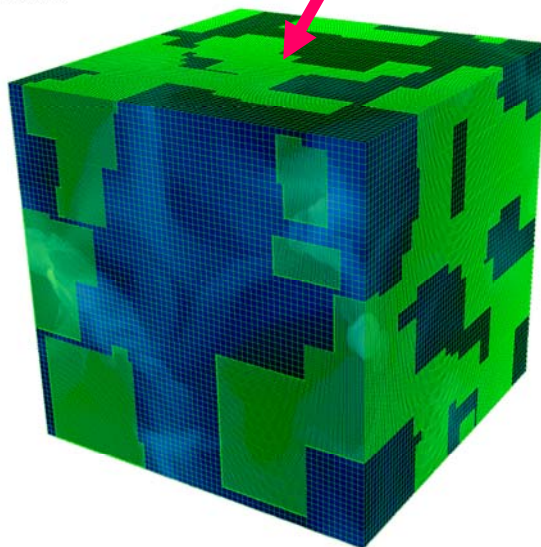
enstrohy +
compression

Jeans +
shocks + strain

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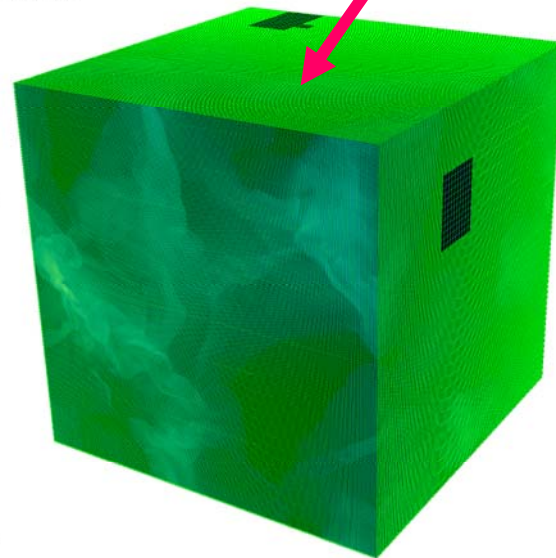
50 %



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Mesh
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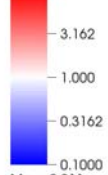
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-0.03162
-0.001000
Max: 3992
Min: 0.0002040

95 %

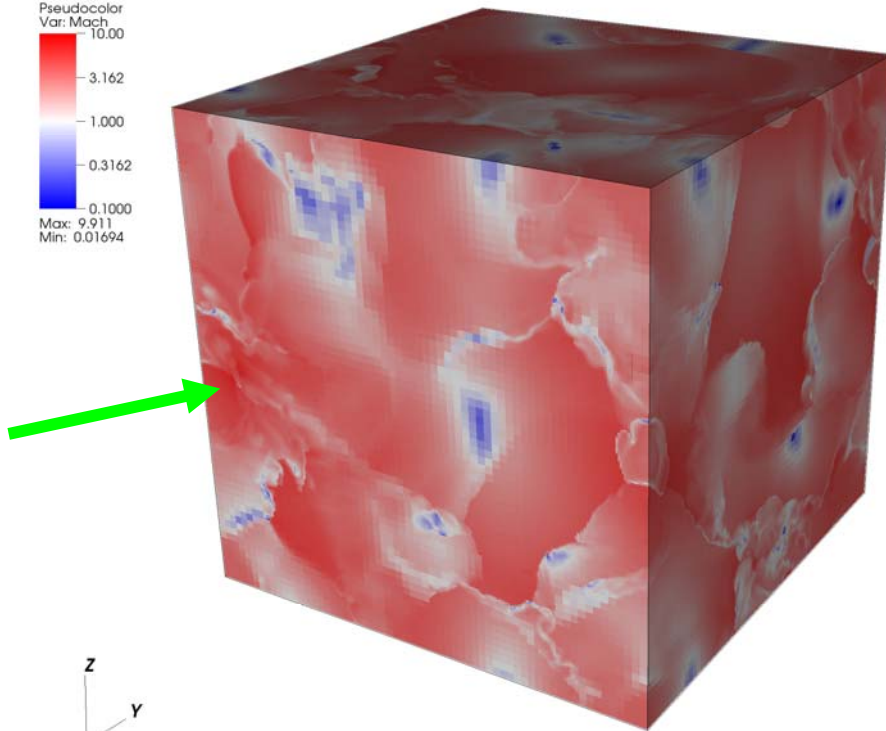


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Pseudocolor
Var: Mach
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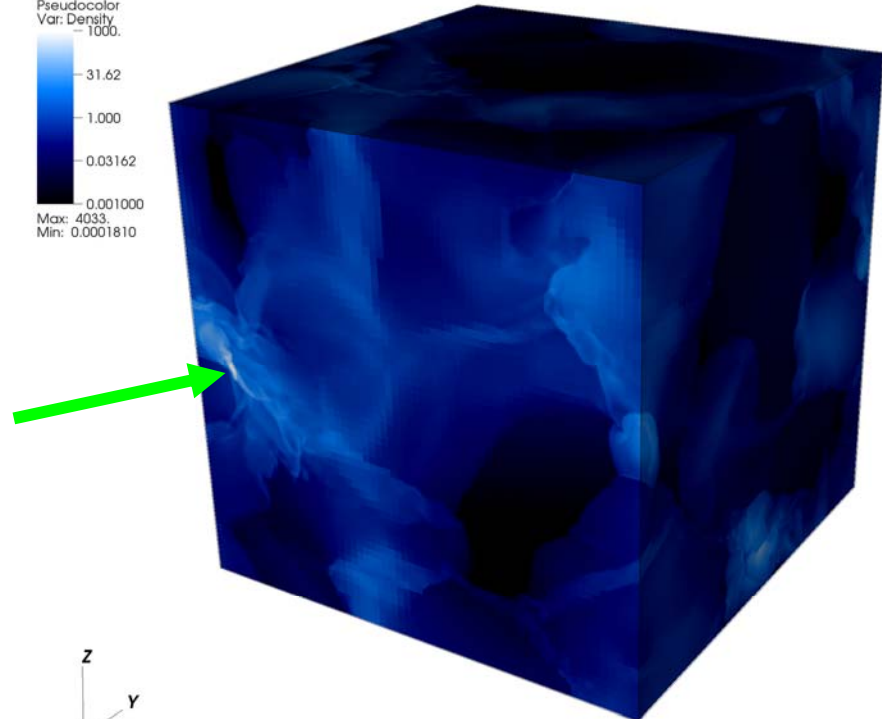
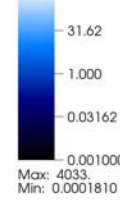


Max: 9.911
Min: 0.01694



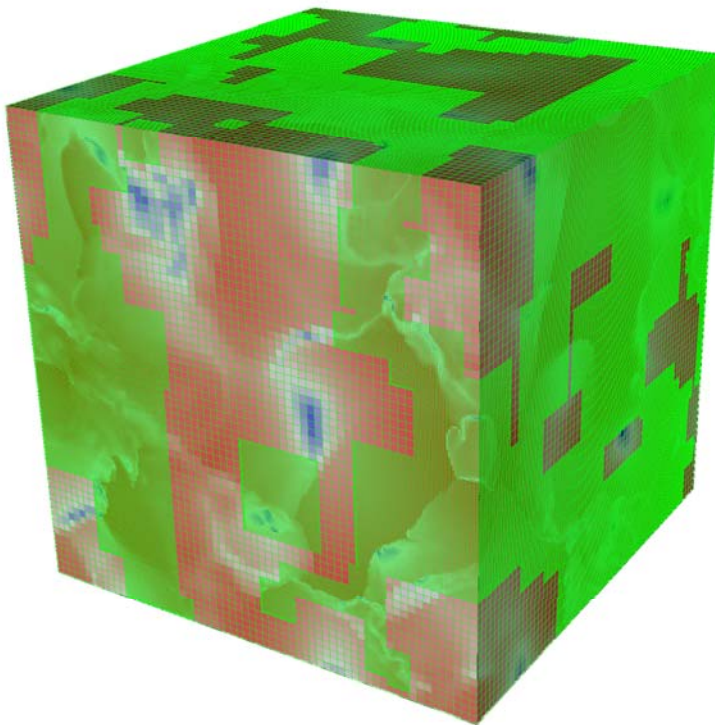
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Pseudocolor
Var: Density
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Mesh
Var: mesh

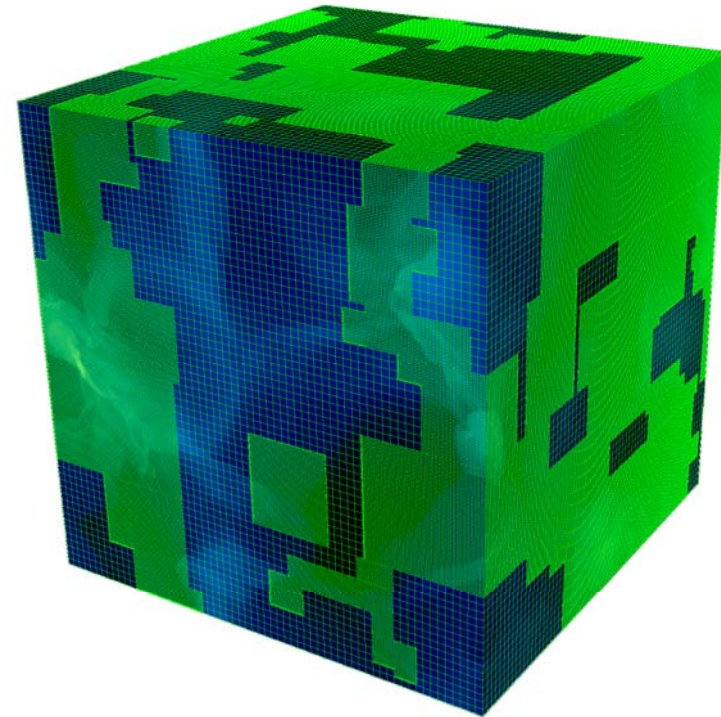
Pseudocolor
Var: Mach
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1.000
0.3162
0.1000
Max: 9.911
Min: 0.01694



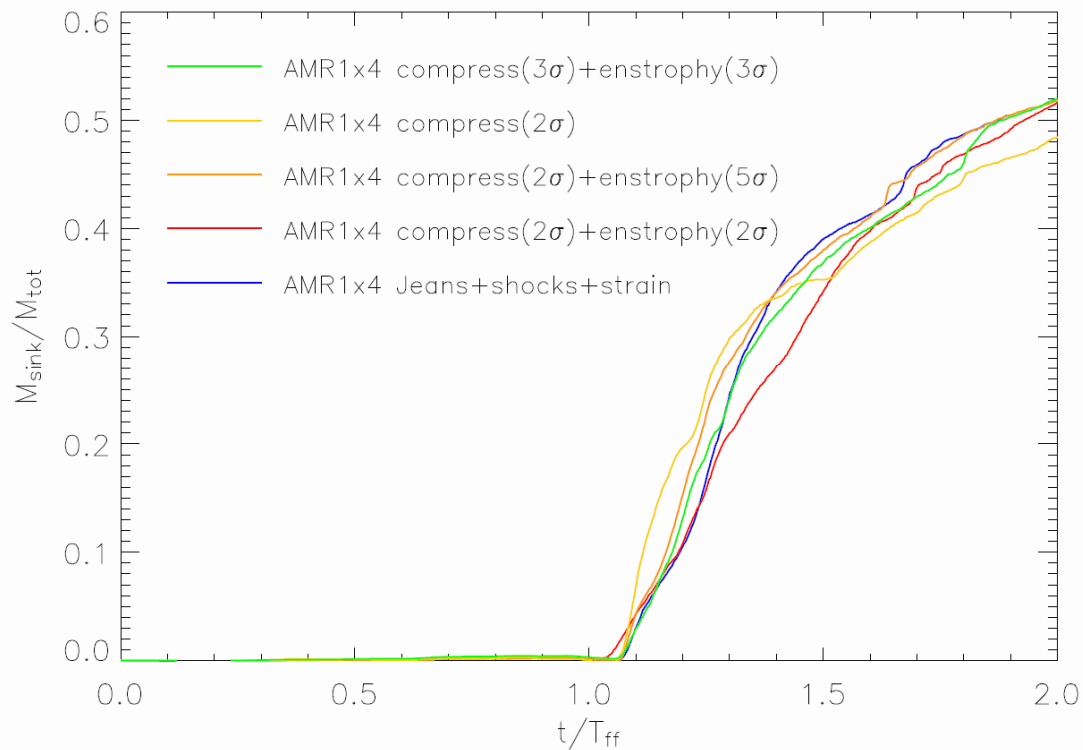
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Mesh
Var: mesh

Pseudocolor
Var: Density
1000.
31.62
1.000
0.03162
0.001000
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Min: 0.0001810



Robust: Sink Particle Creation



Unclear: Fragmentation

■ Need...

- smarter sink particles
- validation (clumpfind etc.)
- further study of refinement criteria
- code optimization