

GEAR-RT

Towards Exa-Scale Moment Based Radiative Transfer For Cosmological Simulations Using Task-Based Parallelism And Dynamic Sub-Cycling with SWIFT

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*Building Galaxies From Scratch
Vienna, 20. February 2024*



GEAR-RT

- **GEAR-RT: Novel Radiation Hydrodynamics Solver**
 - Radiative Transfer using a **Moment method** and the “M1 Closure”
 - Using **photon frequency groups** as multi-frequency approach
 - Using **GRACKLE** (Smith et al. 2017) for thermochemistry
- **Implemented in SWIFT**
 - Using **task-based parallelism**
 - Radiation Hydrodynamics using Finite Volume **Particle Method**
 - Able to dynamically **sub-cycle RT** w.r.t. hydrodynamics

GEAR-RT: Some Results

Cosmological Radiative Transfer Codes Comparison Project I: The Static Density Field Tests

Ilian T. Iliev^{1*}, Benedetta Ciardi², Marcelo A. Alvarez³, Antonella Maselli², Andrea Ferrara⁴, Nickolay Y. Gnedin^{5,6}, Garrelt Mellema^{7,8}, Taishi Nakamoto⁹, Michael L. Norman¹⁰, Alexei O. Razoumov¹¹, Erik-Jan Rijkhorst⁸, Jelle Ritzerveld⁸, Paul R. Shapiro³, Hajime Susa¹², Masayuki Umemura⁹, Daniel J. Whalen^{10,13}

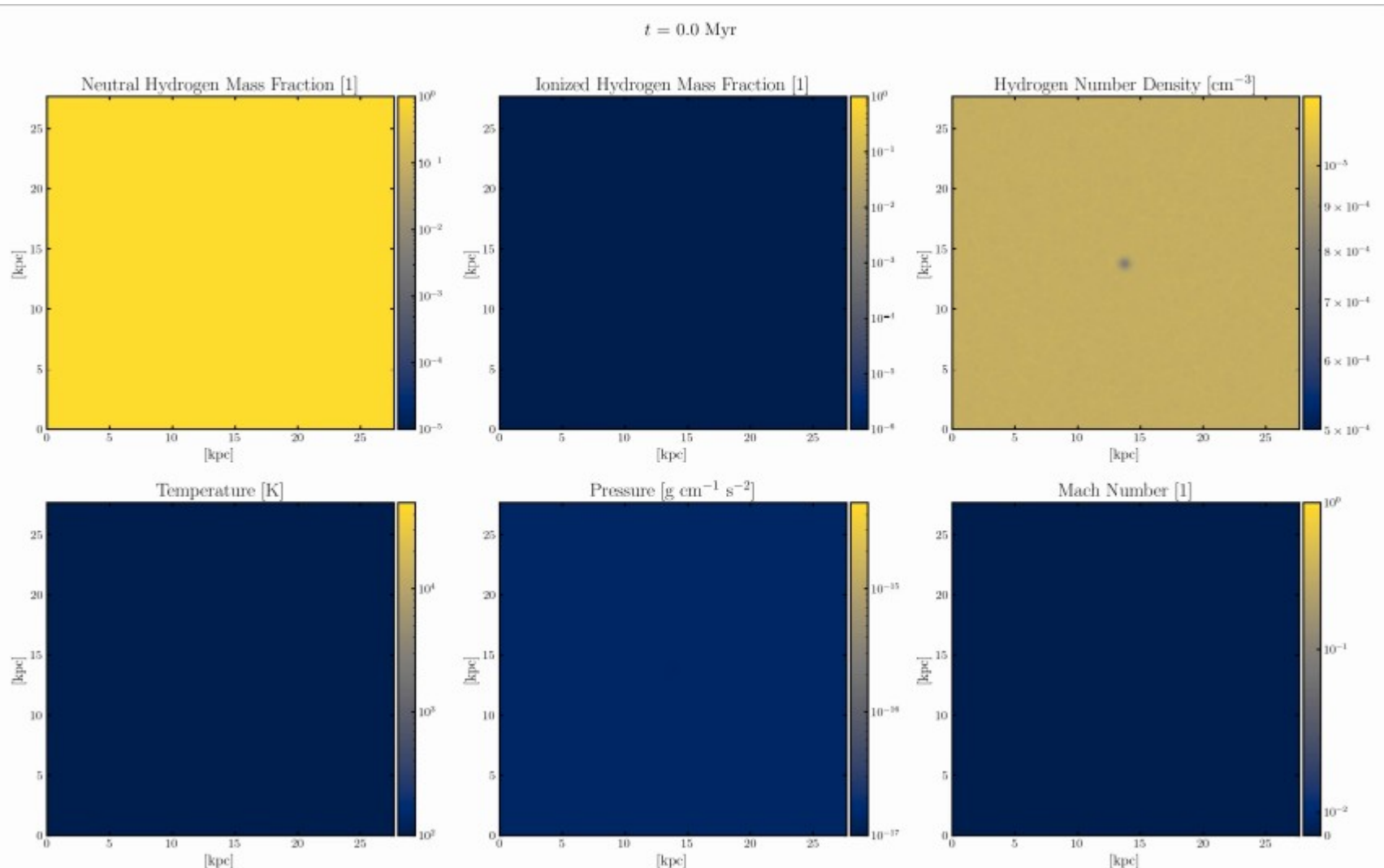
Iliev et al. 2006

Cosmological Radiative Transfer Comparison Project II: The Radiation-Hydrodynamic Tests

Ilian T. Iliev^{1,2,3*}, Daniel Whalen⁴, Garrelt Mellema⁵, Kyungjin Ahn^{6,7}, Sunghye Baek⁸, Nickolay Y. Gnedin⁹, Andrey V. Kravtsov¹⁰, Michael Norman¹¹, Milan Raicevic¹², Daniel R. Reynolds¹³, Daisuke Sato¹⁴, Paul R. Shapiro⁶, Benoit Semelin⁷, Joseph Smidt¹⁵, Hajime Susa¹⁶, Tom Theuns^{12,17}, Masayuki Umemura¹⁴

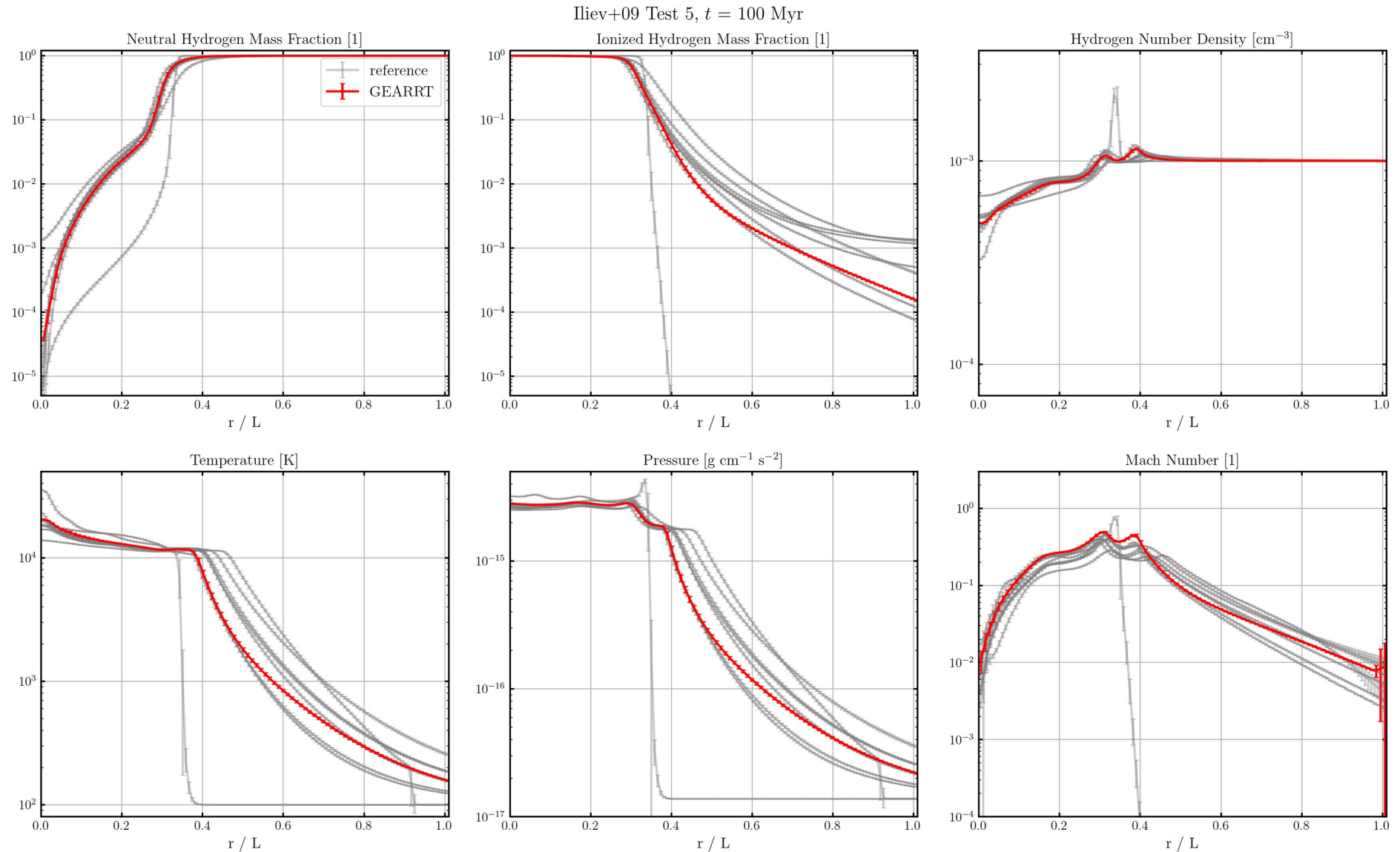
Iliev et al. 2009

GEAR-RT Validation: Iliev et al. 2009 Test 5

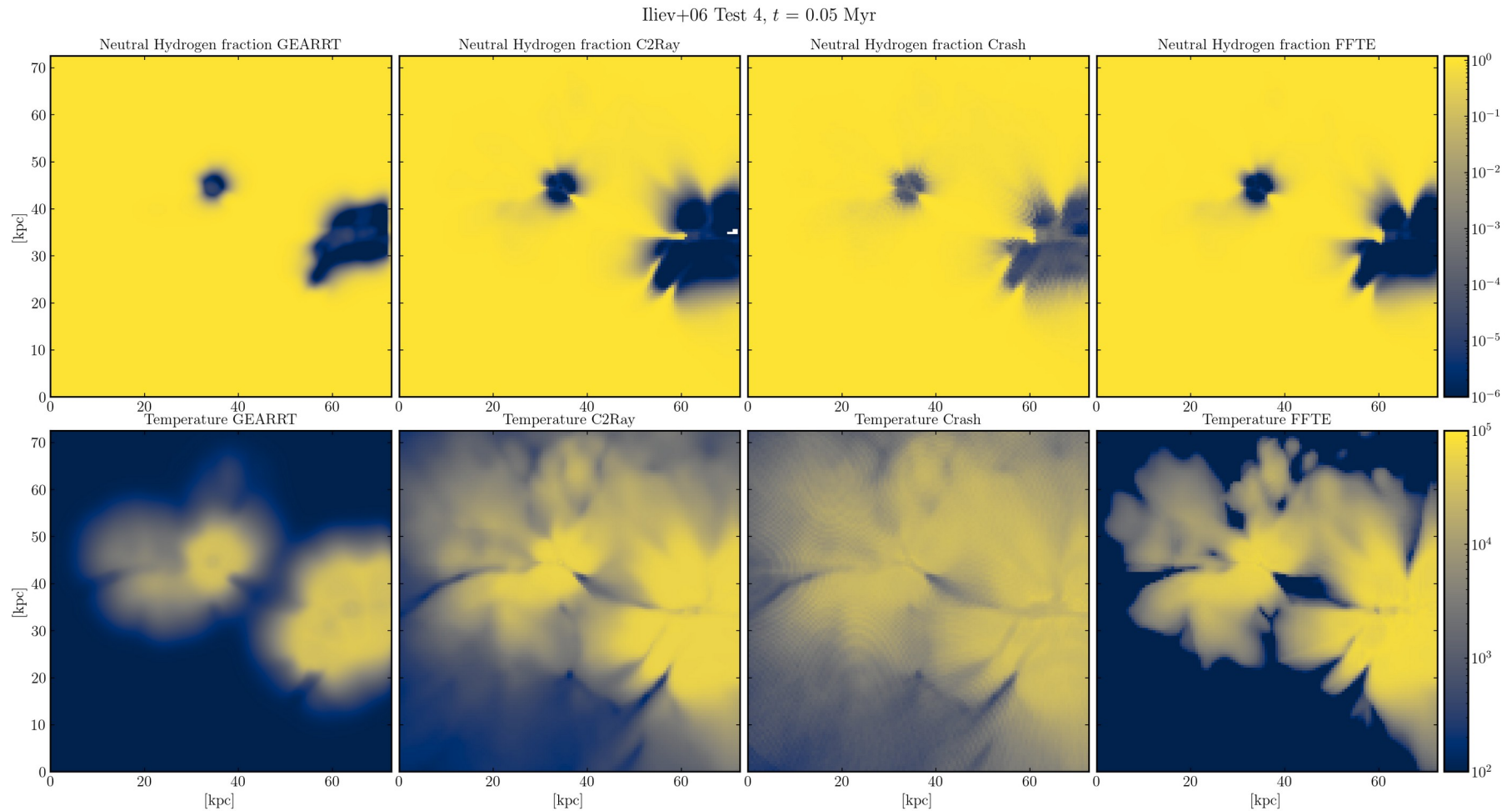


<https://www.youtube.com/watch?v=cucE5Esf5yw>

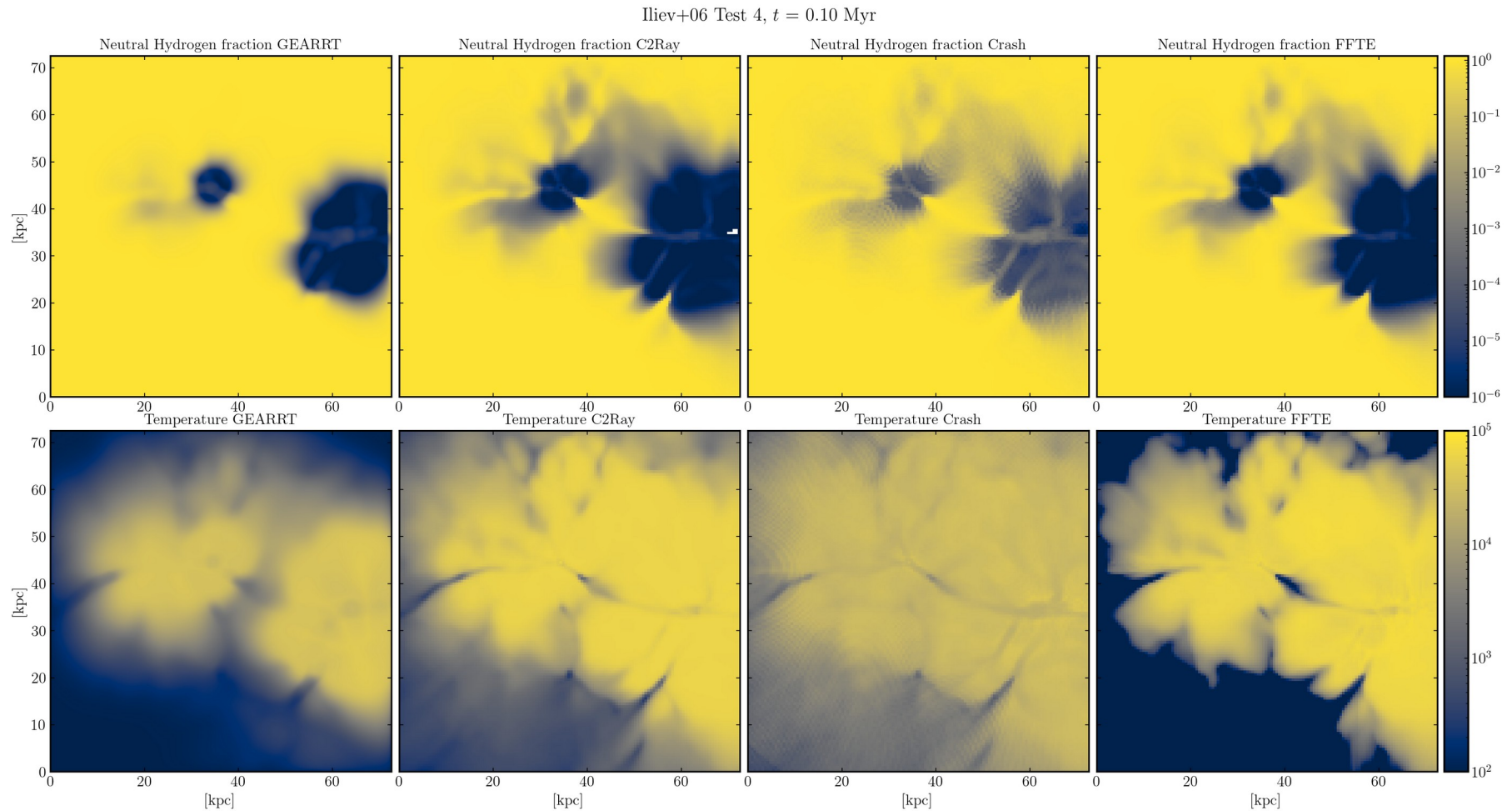
GEAR-RT Validation: Iliev et al. 2009 Test 5



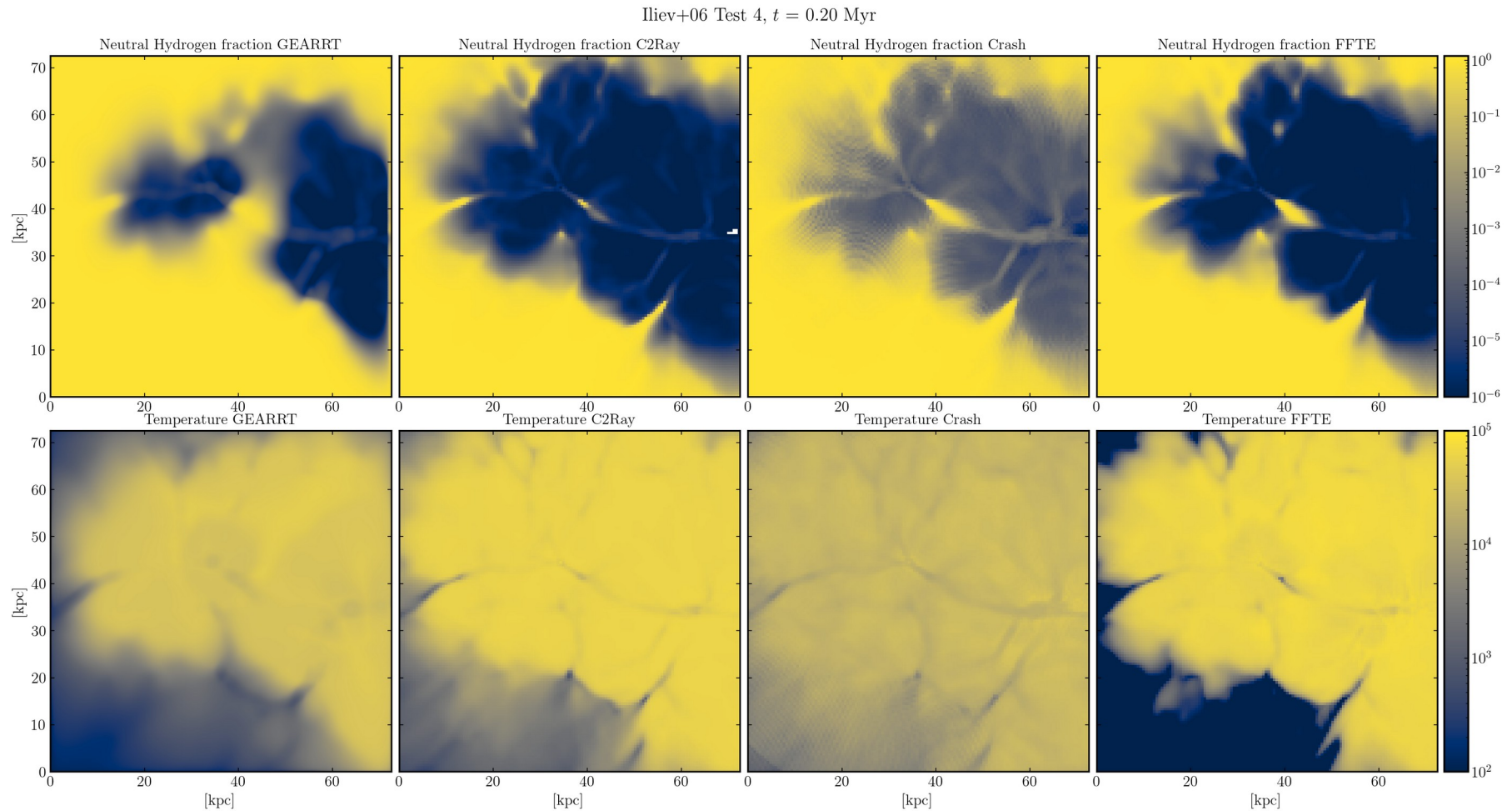
GEAR-RT Validation: Iliev et al. 2006 Test 4



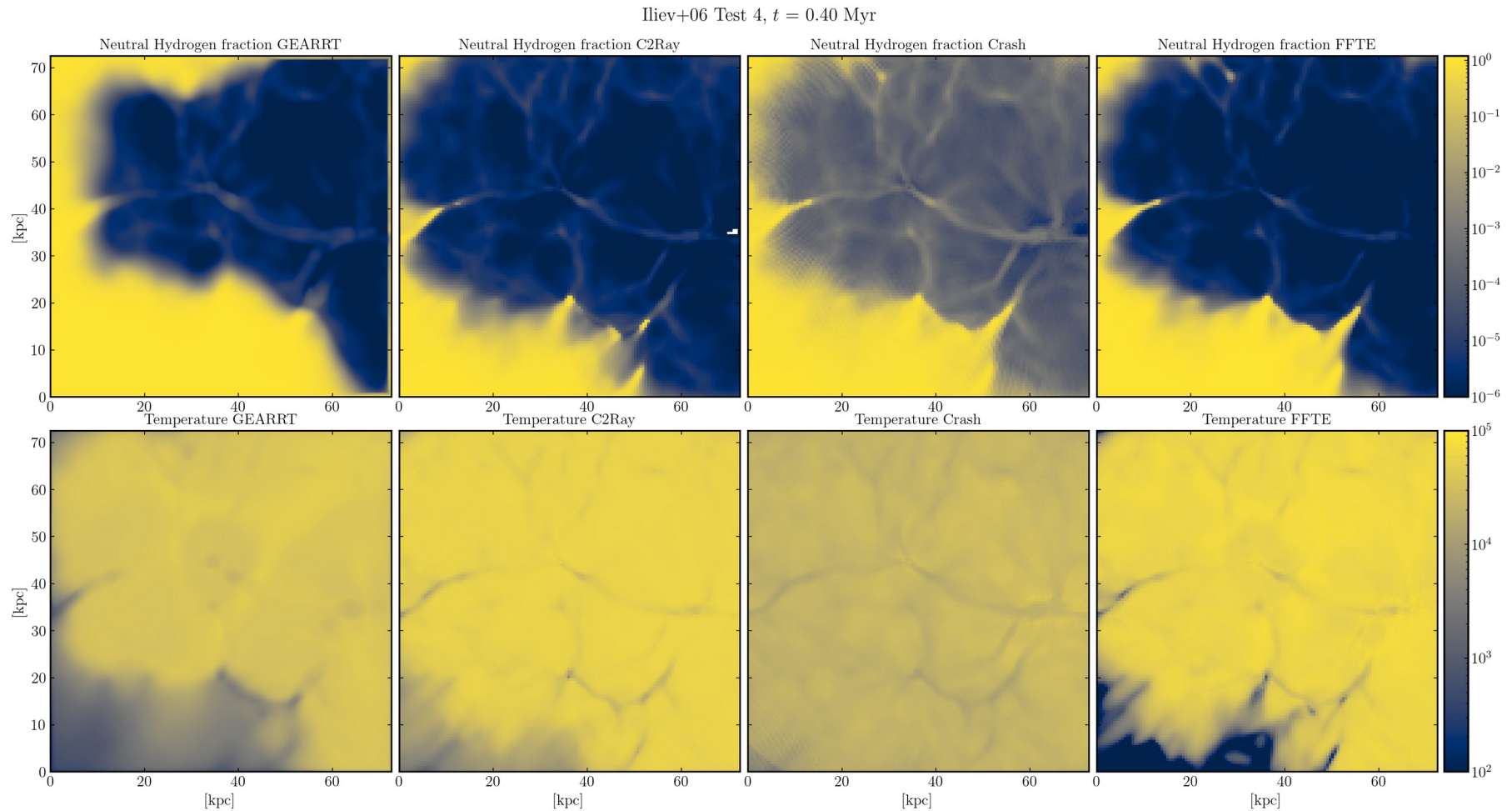
GEAR-RT Validation: Iliev et al. 2006 Test 4



GEAR-RT Validation: Iliev et al. 2006 Test 4

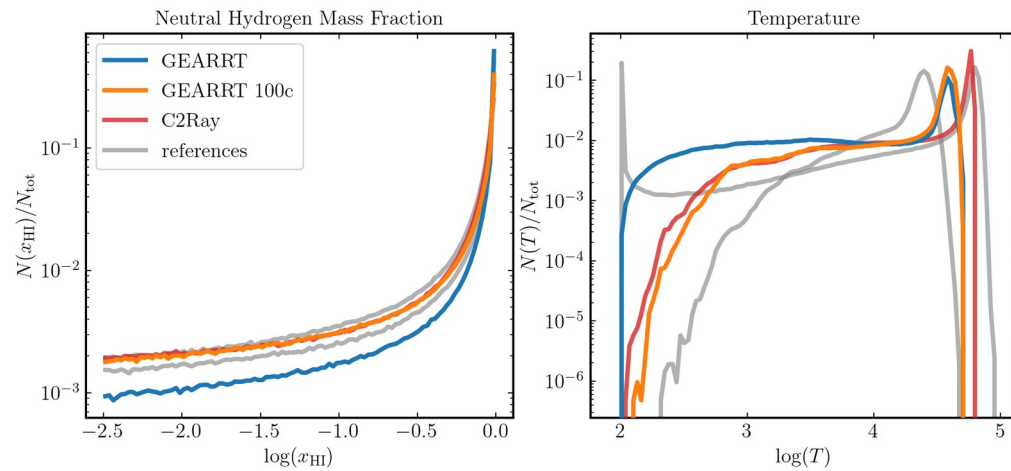


GEAR-RT Validation: Iliev et al. 2006 Test 4

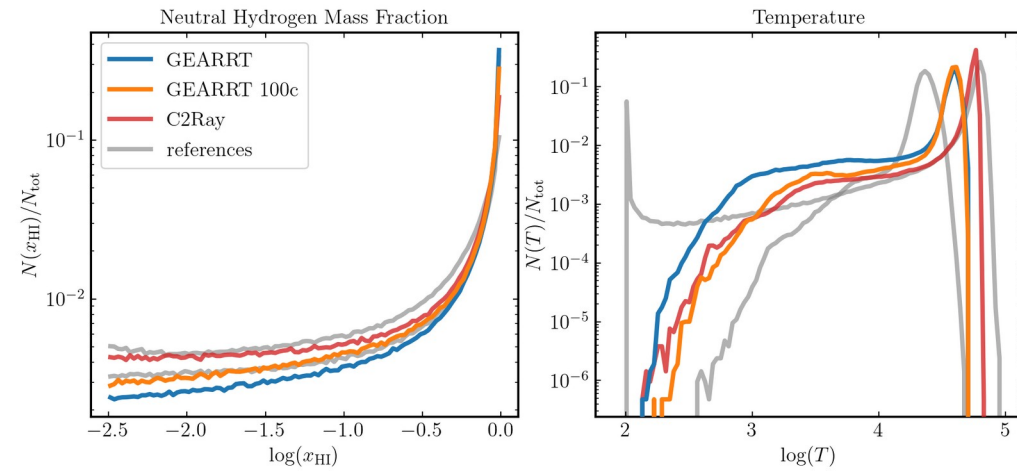


GEAR-RT Validation: Iliev et al. 2006 Test 4

Iliev+06 Test 4, $t = 0.20$ Myr



Iliev+06 Test 4, $t = 0.40$ Myr



Sub-Cycling

Idea: Instead of

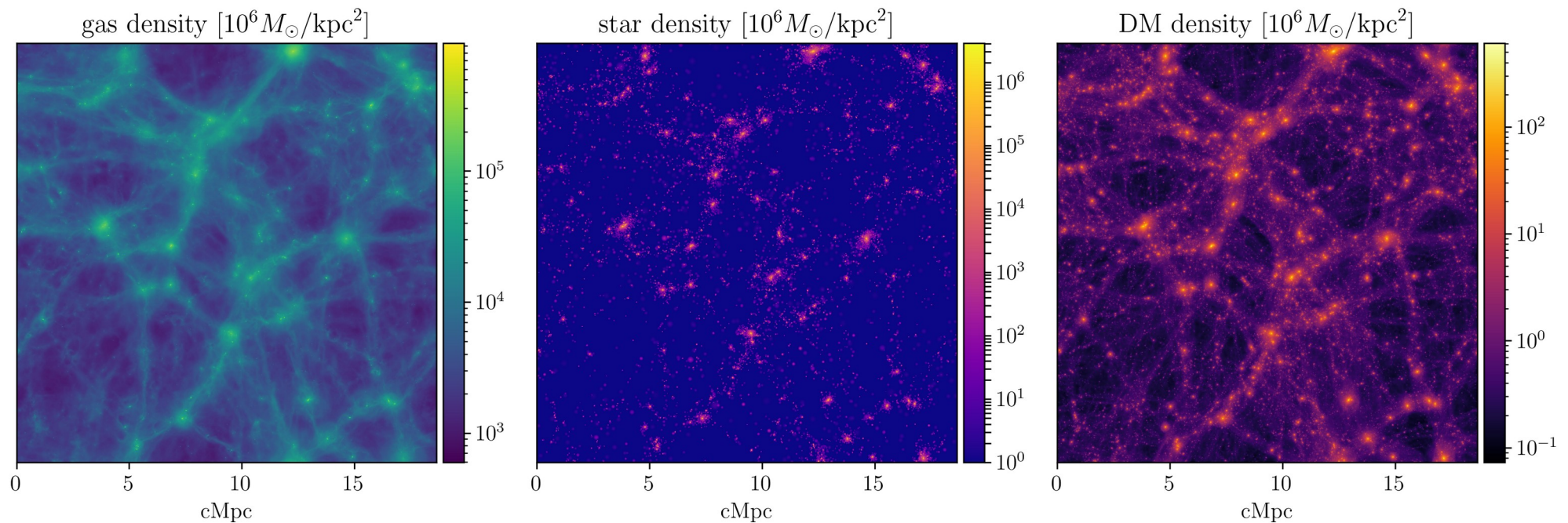
$$\mathcal{U}(t + \Delta t) = S(\Delta t) \circ H(\Delta t)[\mathcal{U}(t)]$$

Do

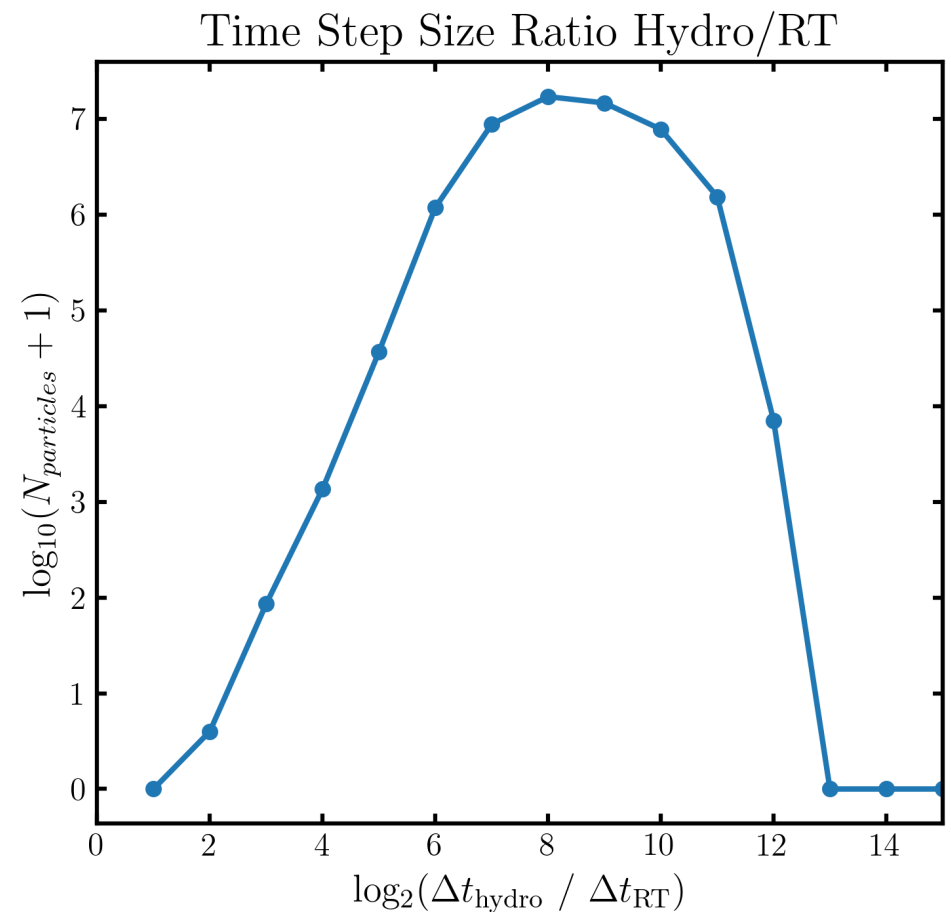
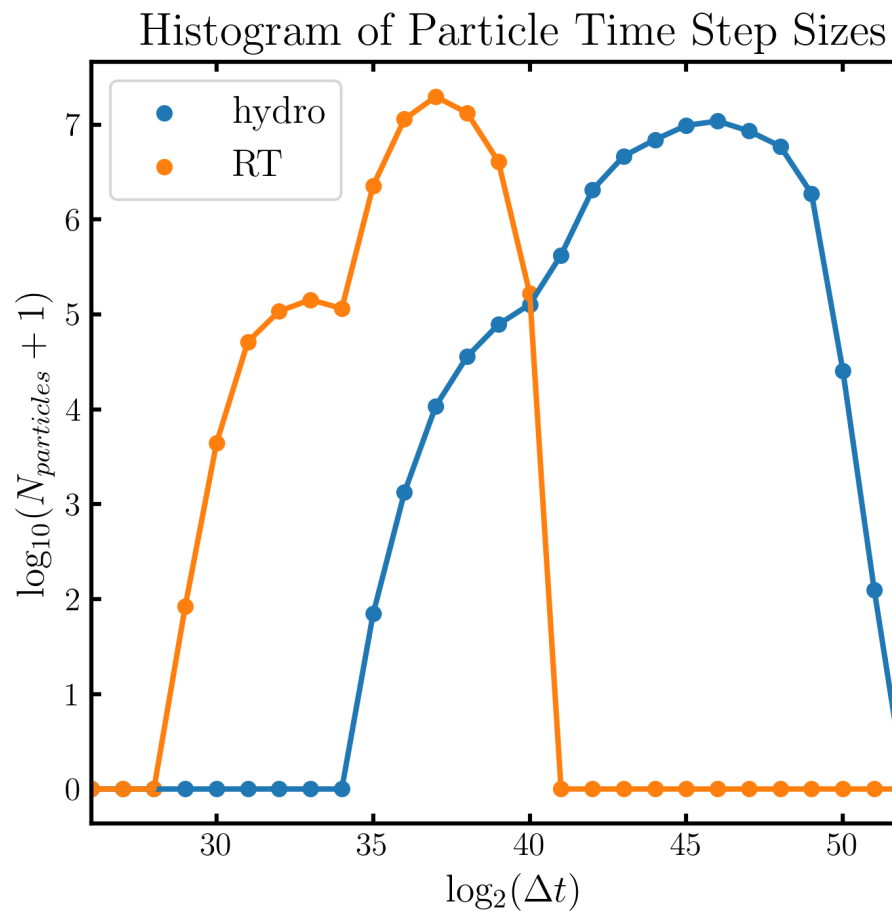
$$\mathcal{U}(t + \Delta t) = S(\Delta t/n) \circ S(\Delta t/n) \circ \dots \circ S(\Delta t/n) \circ H(\Delta t)[\mathcal{U}(t)]$$

Dynamic Sub-Cycling

Let each particle decide for itself how many sub-cycles it requires (up to some maximum)

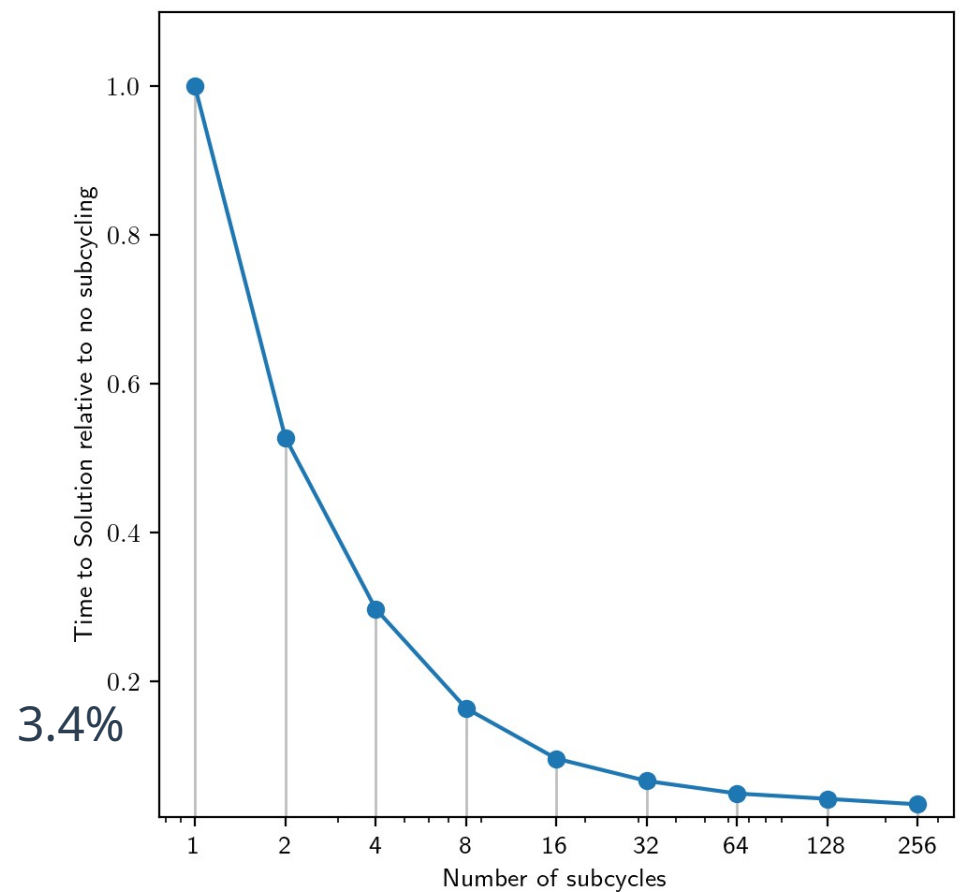
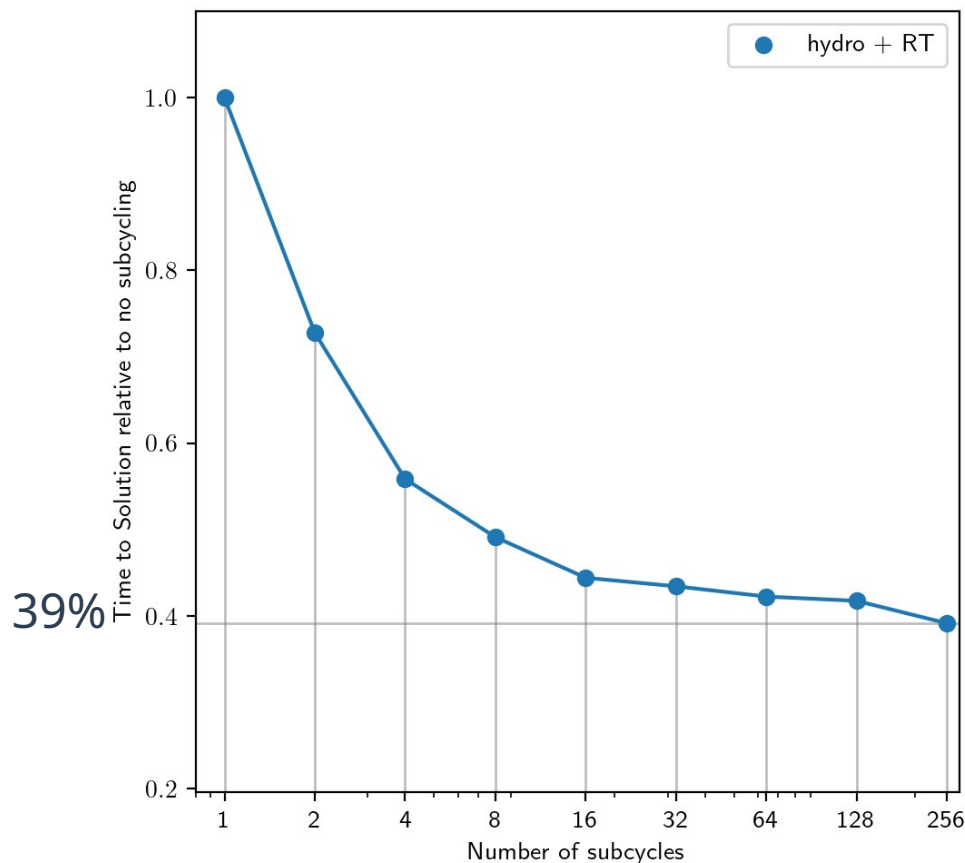


Dynamic Sub-Cycling



Sub-Cycling: Performance

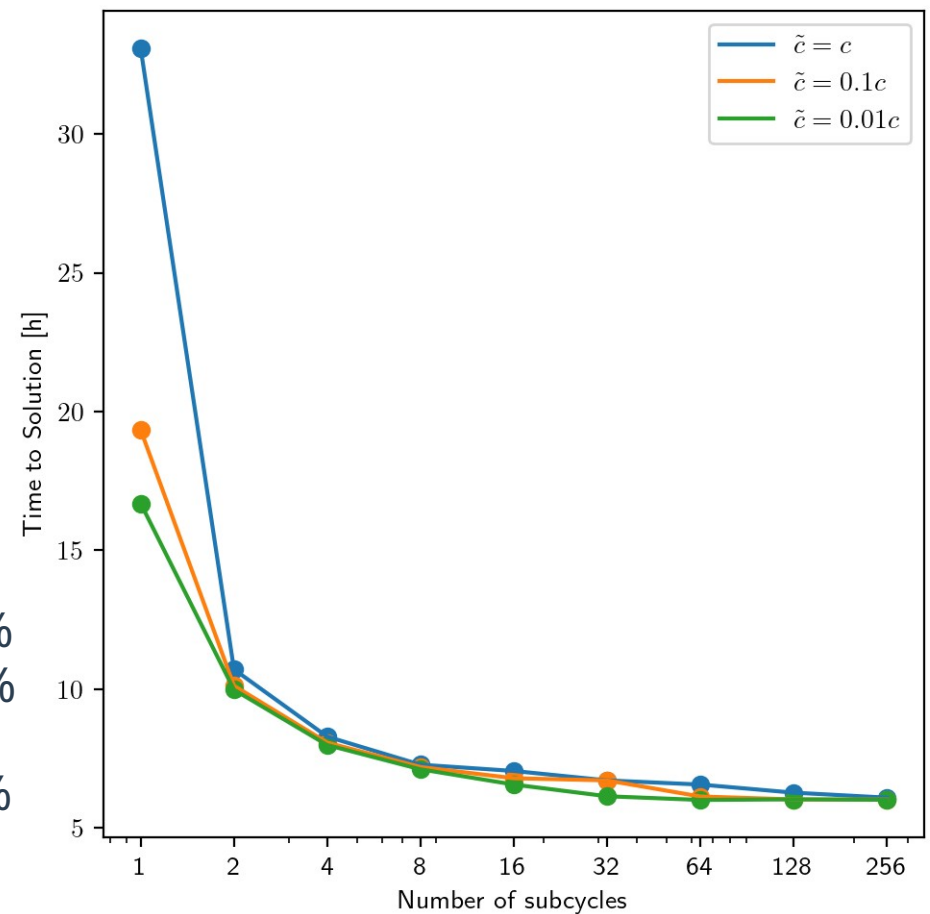
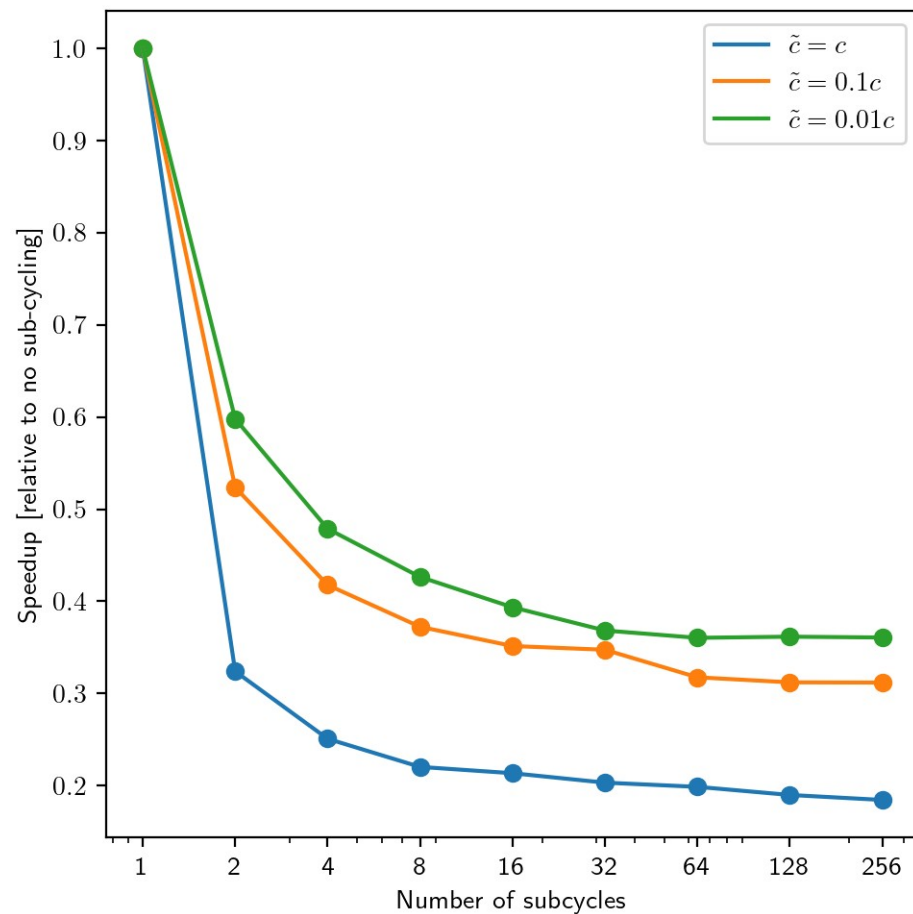
- **Ideal Case:**
 - Uniform box of gas, all particles have equal time steps



Sub-Cycling: Performance

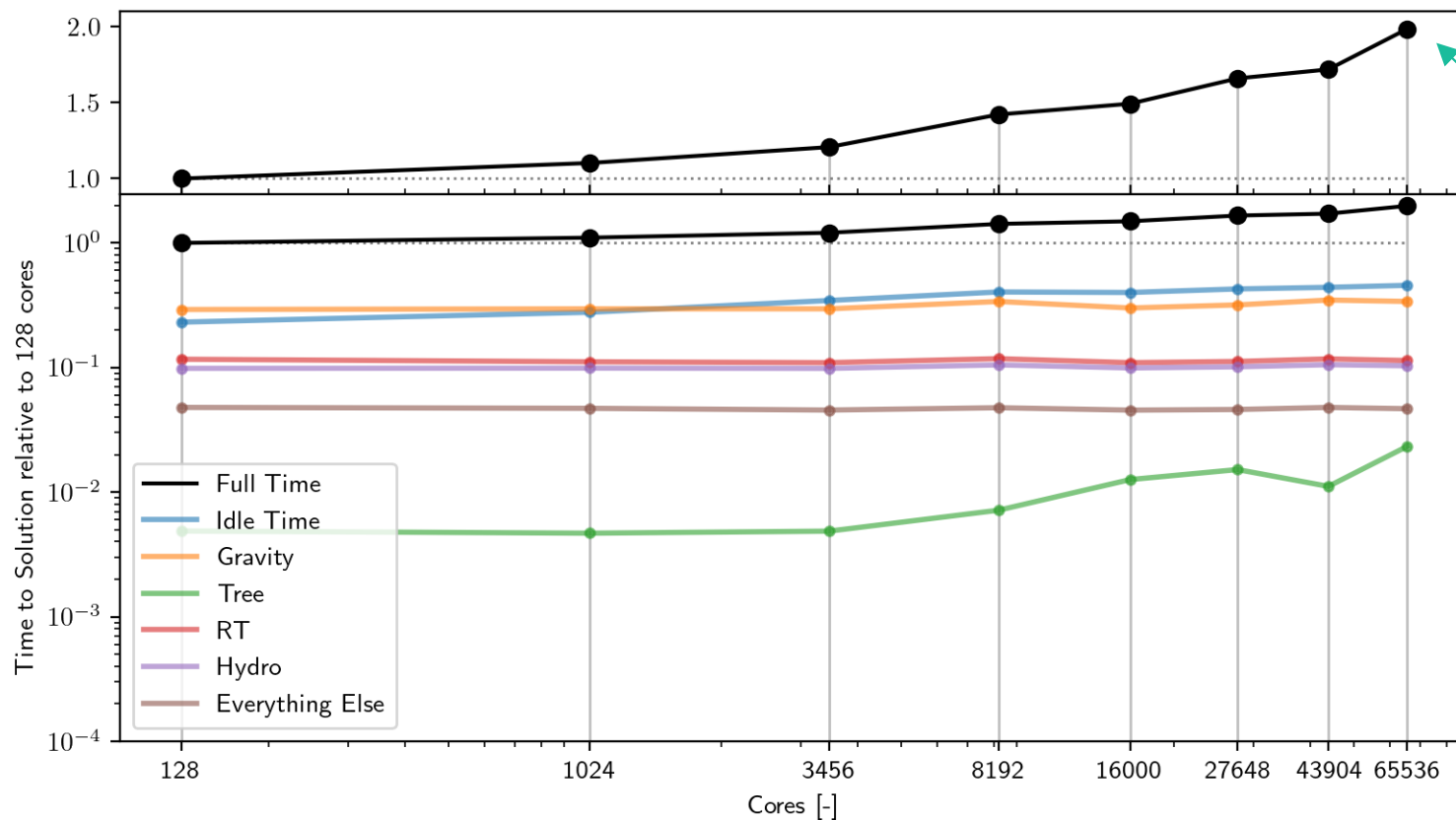
- Realistic Case

- Low-z full cosmological box with hydro, gravity & RT



36%
31%
19%

GEAR-RT: Weak Scaling



207 billion gas particles,
207 billion DM particles,
11 billion star particles