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THE *AGORA* HIGH-RESOLUTION GALAXY SIMULATIONS COMPARISON PROJECT: PUBLIC DATA RELEASE

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ABSTRACT

As part of the *AGORA* High-resolution Galaxy Simulations Comparison Project (Kim et al. 2014, 2016) we have generated a suite of isolated Milky Way-mass galaxy simulations using 9 state-of-the-art gravito-hydrodynamics codes widely used in the numerical galaxy formation community. In these simulations we adopted identical galactic disk initial conditions, and common physics models (e.g., radiative cooling and ultraviolet background by a standardized package). Subgrid physics models such as Jeans pressure floor, star formation, supernova feedback energy, and metal production were carefully constrained. Here we release the simulation data to be freely used by the community. In this release we include the disk snapshots at 0 and 500 Myr of evolution per each code as used in Kim et al. (2016), from simulations with and without star formation and feedback. We encourage any member of the numerical galaxy formation community to make use of these resources for their research — for example, compare their own simulations with the *AGORA* galaxies, with the common analysis `yt` scripts used to obtain the plots shown in our papers, also available in this release.

Keywords: galaxies: formation – galaxies: evolution – methods: numerical – hydrodynamics

1. THE *AGORA* INITIATIVE: PAST, PRESENT, AND FUTURE

Since its launch in 2012, the *AGORA* High-resolution Galaxy Simulations Comparison Project (*Assembling Galaxies of Resolved Anatomy*) has taken aim at carefully comparing high-resolution galaxy simulations on multiple code platforms widely used in the contemporary galaxy formation research.[1] The main goal of this initiative has been to ensure

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[1] See the Project website at http://www.AGORAsimulations.org/ for more information about the *AGORA* Collaboration.

that physical assumptions are responsible for any success in galaxy formation simulations, rather than manifestations of particular numerical implementations, and by doing so, to collectively raise the predictive power of numerical galaxy formation studies. Over 160 individuals from over 60 different academic institutions worldwide are participating or participated in the collaborative effort of the Project.

The first result by the *AGORA* Collaboration (Kim et al. 2014, hereafter Paper I) was our flagship paper which explained the philosophy behind the initiative and detailed the publicly available Project infrastructure we have assembled. Also described was the proof-of-concept test, in which we field-tested our infrastructure with a dark matter-only cosmological zoom-in simulation using the common initial condition (generated with MUSIC; Hahn & Abel 2011), finding a robust convergence amongst participating codes. In the second paper of the Project (Kim et al. 2016, hereafter Paper II), we focused on the evolution of an isolated Milky Way-mass galaxy. All participating codes shared the common initial condition (generated with MAKEDISK; Springel 2005), common physics models (e.g., radiative cooling and extragalactic ultraviolet background provided by the standardized package GRACKLE; Smith et al. 2017), and common analysis platform (`yt` toolkit; Turk et al. 2011). Subgrid physics models such as Jeans pressure floor, star formation, supernova feedback energy, and metal production were carefully constrained across code platforms. With a spatial resolution of 80 pc that resolves the scale height of the disk, we find that any intrinsic inter-code difference is small compared to the variations in input physics such as supernovae feedback.

Through workshops and teleconferences, and with common infrastructures built together, the *AGORA* Collaboration has initiated a one-of-a-kind, open forum where users of different simulations codes can talk to and learn from one another. This platform allows the members (and non-members) to validate one another's work, promoting collaborative and reproducible research essential in any scientific community. Armed with the common infrastructures established, *AGORA* now serves as a launchpad to initiate ambitious, astrophysically-motivated comparisons using cosmological zoom-in simulations. Currently we are working on the gravito-hydrodynamical simulations of a $M_{\rm vir} \sim 10^{12}\,{\rm M}_\odot$ halo at redshift 0. This new suite of simulations will be fully described in an upcoming paper from the *AGORA* Collaboration in 2020 (Roca-Fàbrega et al. in prep). For these simulations we have adopted most of the subgrid physics and simulation strategies developed for Paper II, with improvements such as a recalibrated stellar feedback prescription and the most recent version of the GRACKLE library. The data from these new models will be utilized to undertake a number of sub-projects based on multi-platform comparison. The first of the sub-projects we launched focuses on the properties and evolution of the circumgalactic medium (CGM) and its dependence on the numerical scheme.

2. PUBLIC RELEASE OF THE ISOLATED DISK SIMULATION DATA

Here we provide the simulation snapshots used in the analysis of Paper II. The cohort of widely-used, state-of-the-art galaxy simulation codes who contributed to this release includes: the Lagrangian smoothed particle hydrodynamics codes CHANGA (e.g., Menon et al. 2015), GADGET-3 (e.g., Choi & Nagamine 2012; Aoyama et al. 2017)., GASOLINE (e.g., Wadsley et al. 2017) and GEAR (e.g., Revaz et al. 2016), and the Eulerian adaptive mesh refinement codes ART-I (e.g., Ceverino et al. 2014), ART-II (e.g., Agertz et al. 2013), ENZO (e.g., Bryan et al. 2014) and RAMSES (e.g., Teyssier 2002), and the mesh-free finite-volume Godunov code GIZMO (e.g., Hopkins 2015). The provided snapshots are at 0 Myr (right after each code processed the initial condition) and at 500 Myr, from two different runs, the first one in which star formation is not activated and the second one with star formation and feedback. This release will allow any interested party in the community to be able to, for example, compare their own simulation snapshots with the *AGORA* snapshots, using the publicly available analysis scripts on the `yt` platform. They may also study the properties of the *AGORA* galaxies in coordination with the Collaboration.

The simulation data and the common analysis scripts in `yt` used to obtain the figures and diagnostics presented in Paper II are available through the Project website.[2] Also available in the same link are isolated and cosmological initial conditions generated by the *AGORA* Collaboration for galaxy simulations, and the links to the key softwares. We encourage all members of the numerical galaxy formation community to freely make use of these resources for their research.

[2] http://www.AGORAsimulations.org/ or http://sites.google.com/site/santacruzcomparisonproject/blogs/quicklinks/

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