University of Tsukuba | Center for Computational Sciences

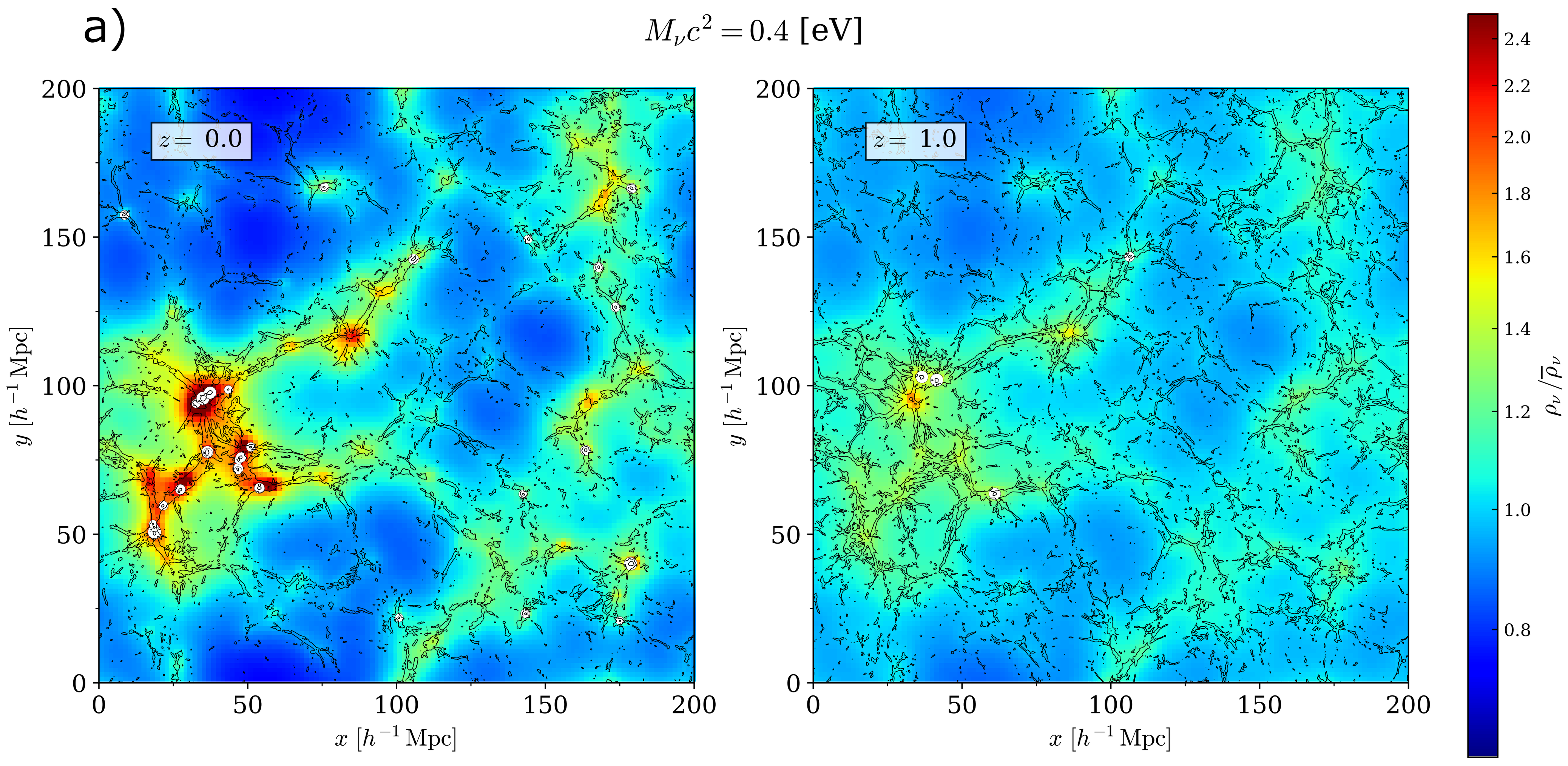
Solving the Mysteries of the Universe with Computational Astrophysics

Vlasov-Poisson simulation of cosmic neutrinos in the large-scale structure of the universe

Neutrinos are elementary particles ubiquitous in the universe. The Super-Kamiokande experiment revealed that neutrinos have mass, which implies that neutrinos can dynamically affect the formation of large-scale structure (LSS) in the universe. We perform numerical simulations of LSS formation incorporating the effect of massive neutrinos by directly solving the collisionless Boltzmann equation in 6D phase-space on two supercomputers, FUGAKU and Oakforest-PACS. Our highly optimized simulation code achieves almost ideal weak and strong scaling on FUGAKU.

Yoshikawa, K., Tanaka, S., Yoshida, N. & Saito, S. (2020) accepted for publication in ApJ.

a)



b)

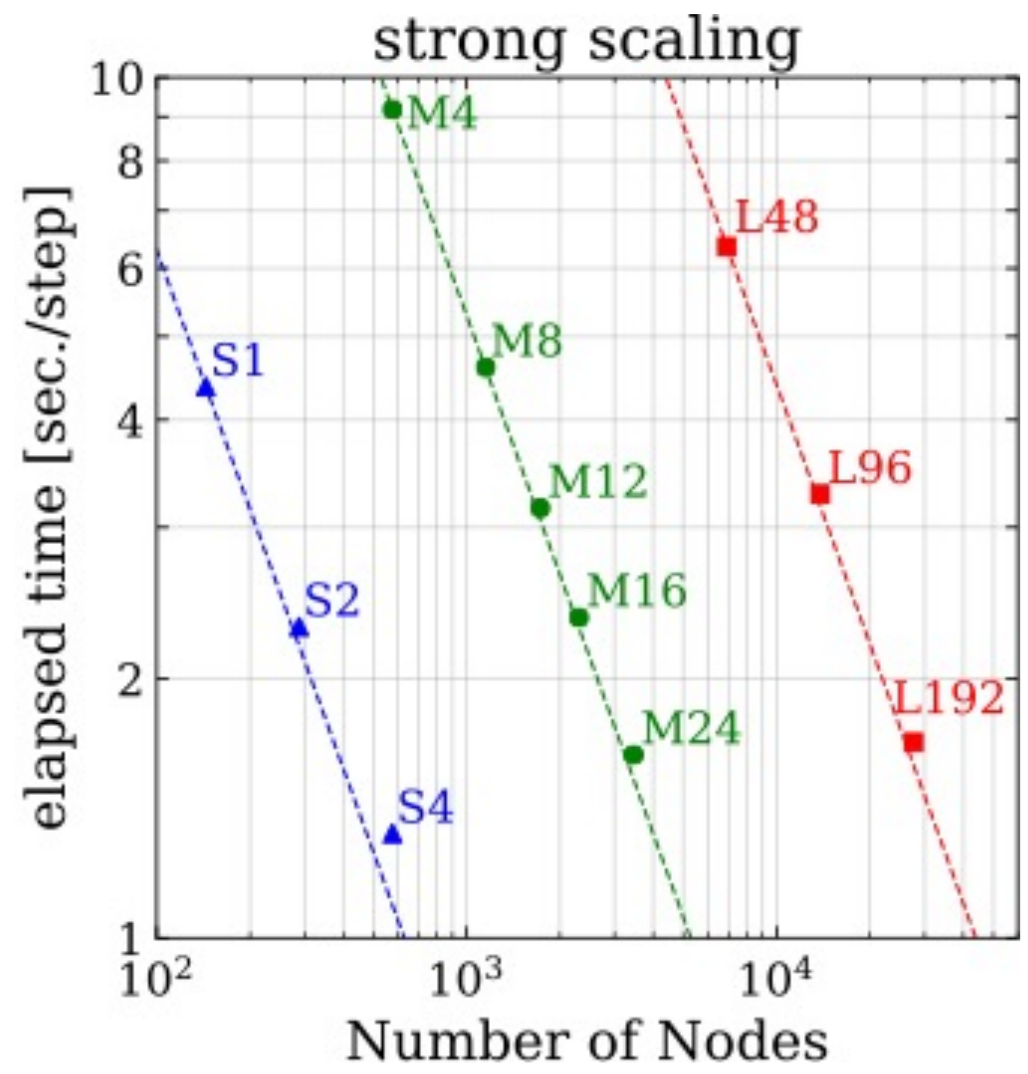


Fig. 1a: Simulated distributions of massive neutrinos (color scale) and dark matter (contours) as well as dark matter halos (white circle) at a) redshift $z = 0$ (the present), and b) redshift of 1 (about 7.9 Gyr ago).

Fig. 1b: Strong scaling of VLASOV simulations on super computer FUGAKU. Run ID prefixes S, M, and L denote grid resolutions of 96^3, 192^3, and 384^3, respectively, and the number denotes the number of computational nodes in multiples of 144.

Theoretical galaxy formation – numerical simulations reveal the fate of stars and gas

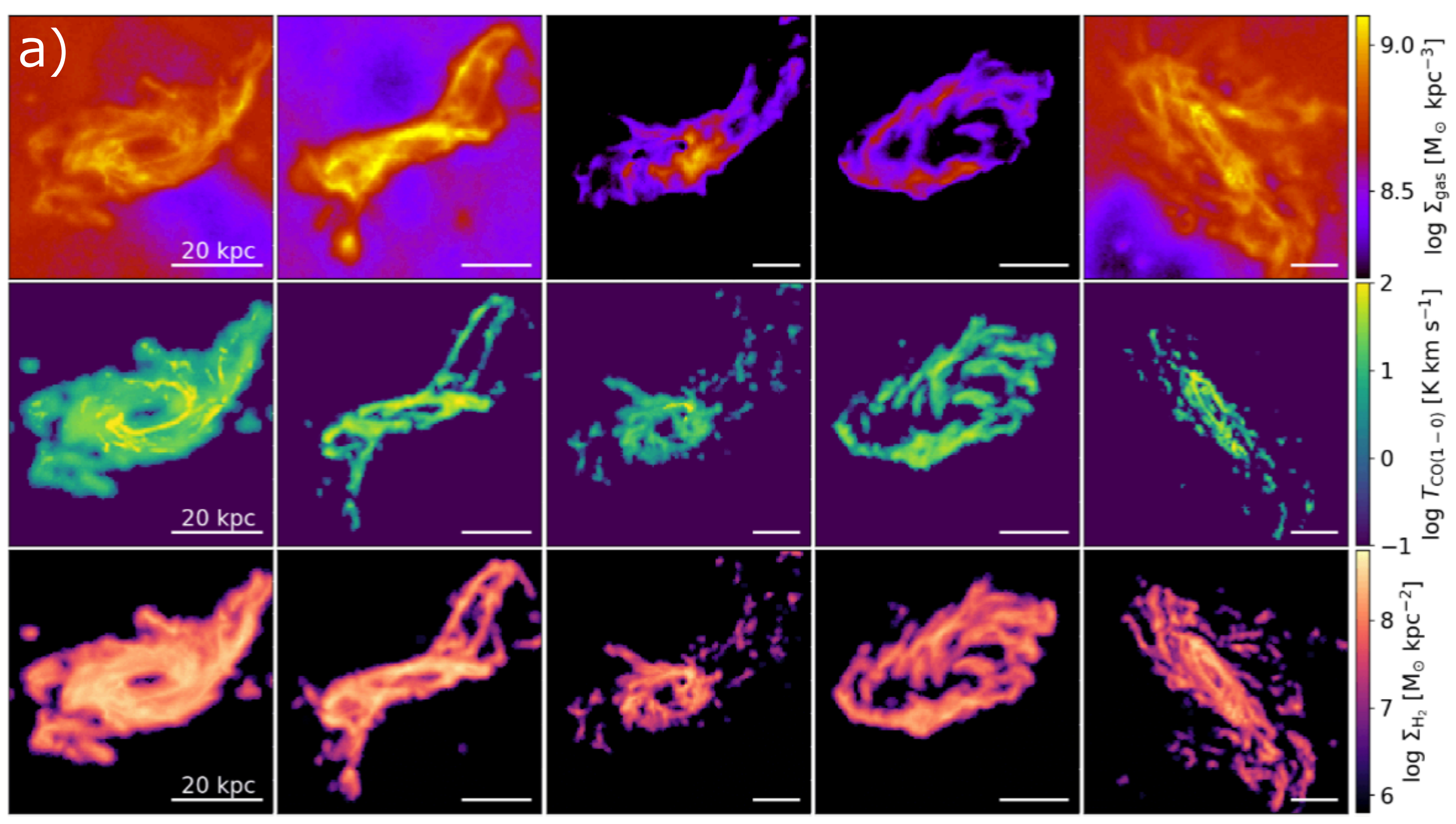
We devise a physical model to determine the formation, distribution, and kinematics of molecular gas clouds in galaxies, and predict the intensities of carbon monoxide (CO) lines and the molecular hydrogen (H_2) abundance, taking into account the interstellar radiation field and dust attenuation. We apply the model to data from the Illustris-TNG cosmological simulations and compare the CO luminosities and H_2 masses with recent observations of galaxies at low and high redshifts. The model successfully reproduces the observed CO-luminosity function and the total H_2 mass in the local universe.

Inoue, S., Yoshida, N. & Yajima, H., (2020) accepted for publication in MNRAS

When a cluster of stars forms, only a part of the natal cloud is converted into stars, and the rest is ionized and heated by the powerful stellar radiation and ejected outward. Using radiation-hydrodynamic simulations, we found that star formation is primarily controlled by the formation of ionized regions, as well as the surface density and dust content of the natal cloud. We developed a new semi-analytic model that captures this behaviour and can be incorporated in subgrid recipes for large-scale cosmological simulations.

Fukushima, Yajima, et al. (2020), MNRAS, 497, 3830

a)



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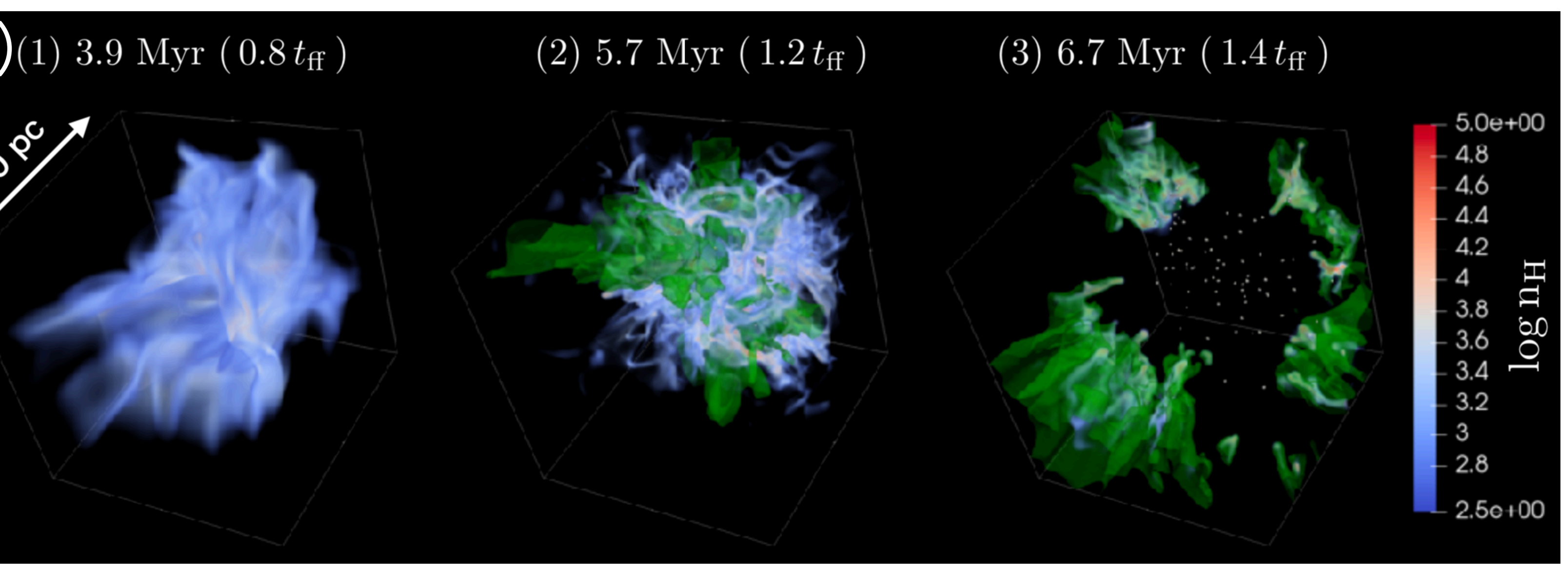

Fig. 2a: The structure of the five brightest galaxies in CO(1-0) in the simulation.
Fig. 2b: Density evolution in the formation of star clusters. White circles indicate stars and the green contours bound ionization regions.

contact address: ayw@ccs.tsukuba.ac.jp / pr@ccs.tsukuba.ac.jp