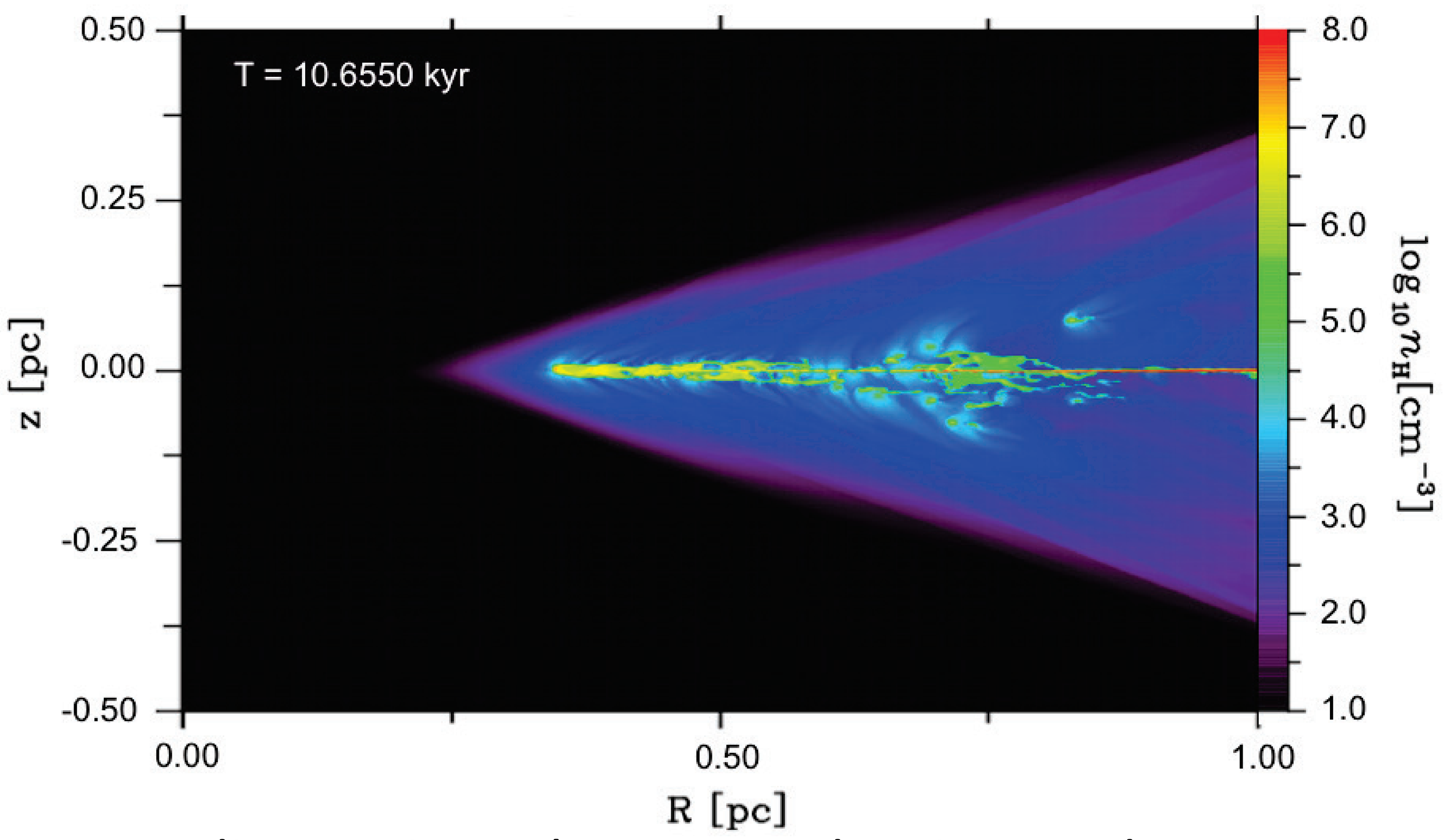
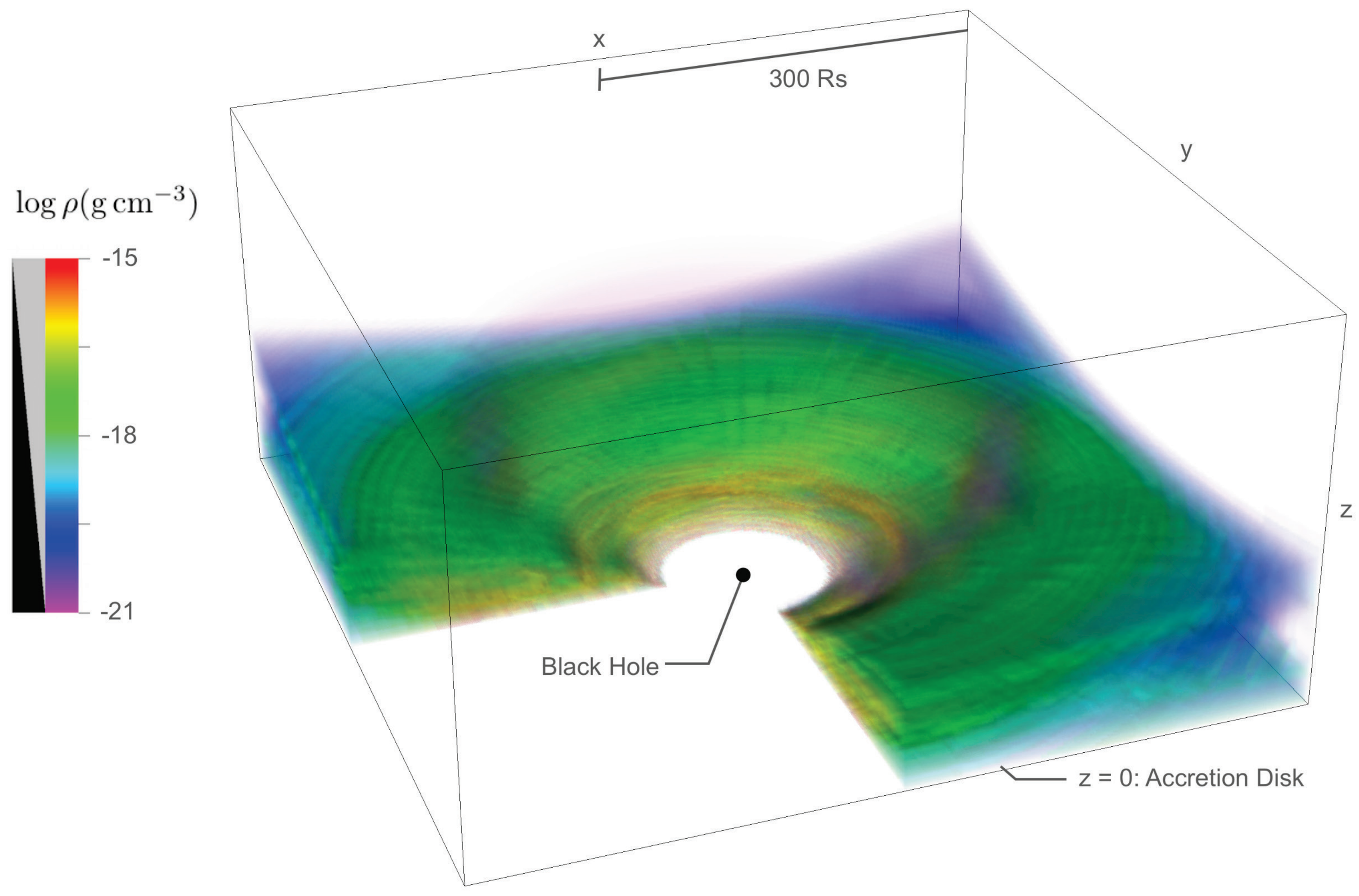
Uncovering the Mysteries of the Universe through Computational Astrophysics

Accretion and outflows in Active Galactic Nuclei *with radiation hydrodynamic simulations*

Every galaxy contains a supermassive black hole (SMBH) at its center, vigorously accreting gas through a dusty torus and an accretion disc. Under certain conditions the accreting system becomes active (active galactic nuclei, AGN), triggering a radiation-driven wind or jet from the near the SMBH. These outflows are extremely powerful and affect the evolution of the host galaxy.



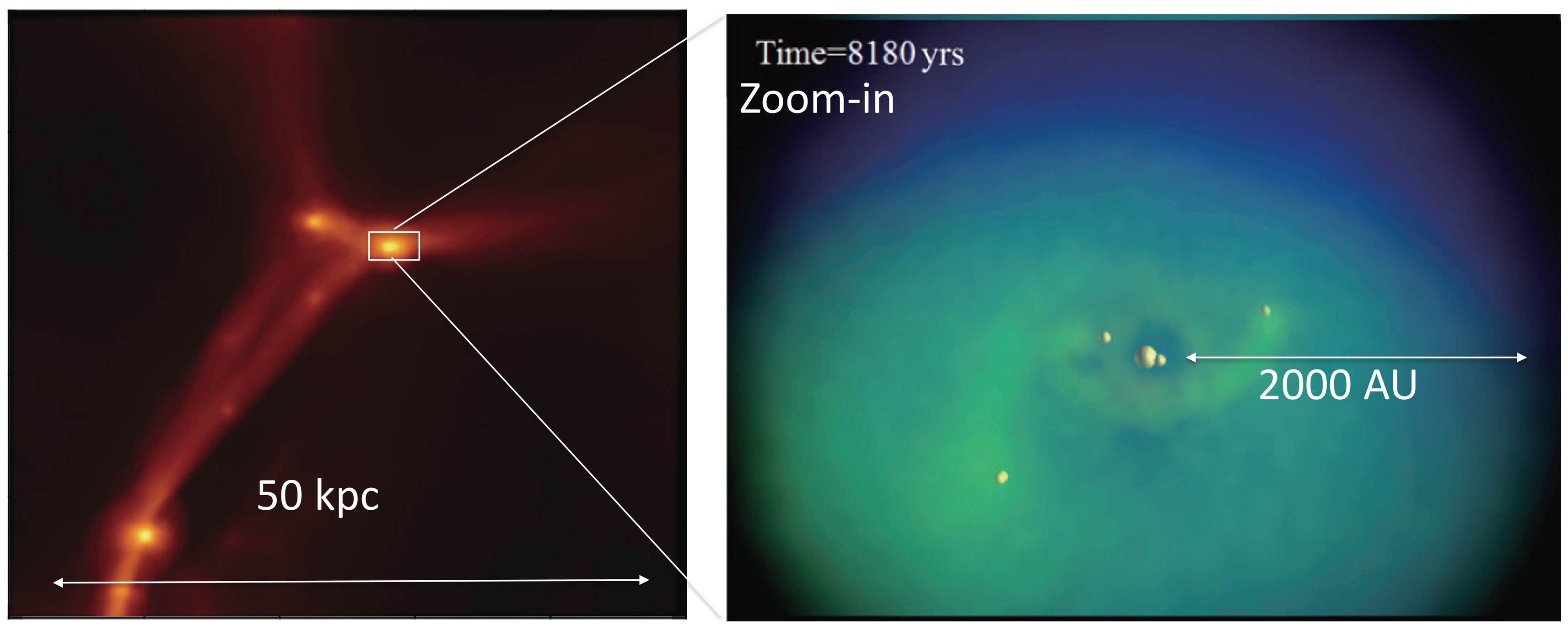


We are discovering the true density and temperature structures and the properties of outflows realized near the dust sublimation radius of AGN tori by performing radiation hydrodynamic simulations taking into account important physics such as photoionization, transfer of infrared photons reemitted by heated dust grains, and radiation pressure on gas and dust.

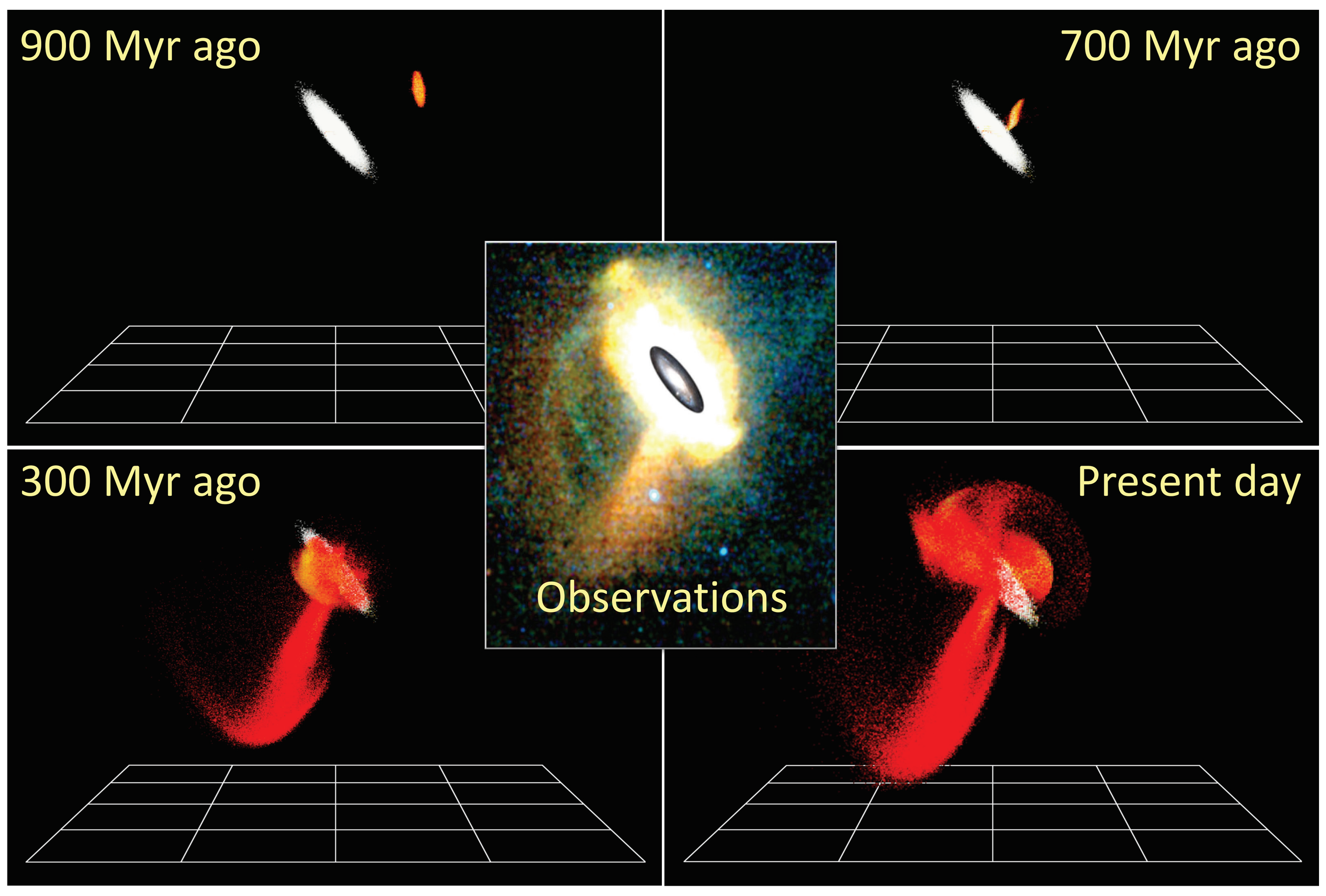
Using the three-dimensional radiation hydrodynamic simulations including the radiation force due to spectral lines, we simulated the dynamics of line-driven disc winds around SMBH. The simulations reveal how the line force effectively accelerates a wind (see Nomura et al. 2013). We are also investigating newly-discovered non-axisymmetric structures in the outflow.

Cosmological star- and galaxy formation *with radiation SPH and N-body simulations*

In the current theory of cosmological structure formation, dark matter, through its self-gravitational interactions, forms the scaffolding of the universe, along which everything from the first stars to clusters of galaxies coalesce. The complicated physics involved in capturing the birth of the first generation of stars and the evolution of galaxies can only be handled with large-scale numerical simulations.



Very little is known about the properties of the first generation of stars in the universe, not even what their masses were, let alone how many were formed. Yet the first stars are thought to have had a big influence on the subsequent evolution of the universe, especially in its re-ionization through strong ultraviolet radiation. We have, for the first time, succeeded in predicting the mass spectrum, binary fraction, and abundance patterns of the first generation of stars in the universe by conducting cosmological hydrodynamic simulations with non-equilibrium primordial chemistry followed by zoom-in radiation hydrodynamic simulations. (Susa, Hasegawa, & Tominaga 2014).



Our nearest neighbor, the Andromeda Galaxy features great streams of stars in its outer halo – relics of a galaxy collision that occurred 700 million years ago. We have narrowed down the impact parameters of the event through a vast parametric study of large N-body simulations, matching the distribution of stars in our simulations (surrounding panels) to that observed (center) (Kirihara et al 2015, submitted, Proc. IAU).