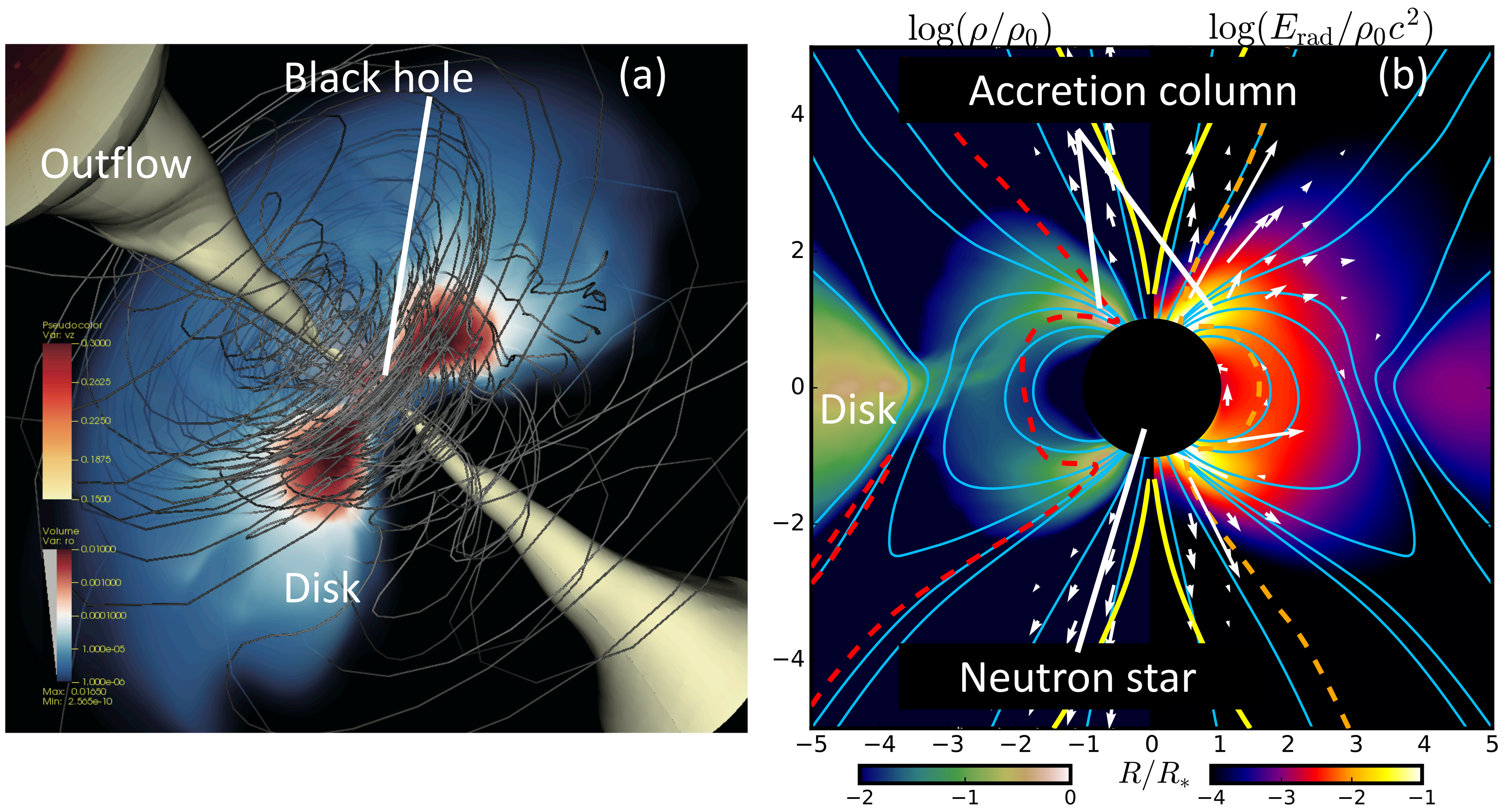
Solving the Mysteries of the Universe with Computational Astrophysics

General-relativistic radiation-magnetohydrodynamics simulations of accretion flows onto black holes and neutron stars

Accretion flows/disks onto compact objects, such as black holes (BHs) and neutron stars (NSs), are the most powerful energy sources in the Universe. However, neither the energy production mechanism nor the flow structure is known.

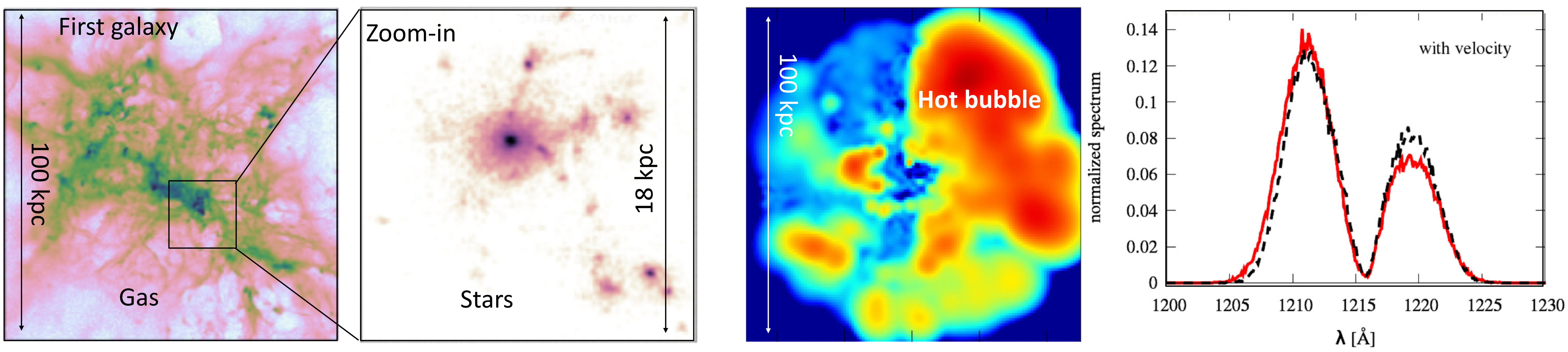
Our general-relativistic radiation-magnetohydrodynamics simulations revealed that the luminosity of the BH accretion disks can exceeds the Eddington luminosity, the upper limit for a spherical system. As a result, the strong radiation pressure force drives outflows above the disks (Fig 1a, Takahashi et al. 2016; 2018).

If the NSs have strong dipole magnetic fields, the accretion disks are truncated near the NSs and matter falls onto the magnetic poles through an accretion column because the strong magnetic fields prevent accretion through a disk (Fig 1b, Takahashi & Ohsuga 2017).



Cosmological galaxy formation with SPH and radiative transfer calculations

In the standard picture of structure formation, galaxies form through merging of smaller galaxies and continuous accretion of gas. Once stars form, galaxy evolution proceeds under the influence of stellar feedback. The complicated baryonic physics can be treated with state-of-the-art cosmological simulations.



We performed cosmological SPH simulations with zoom-in initial conditions which resolved the spatial scale from the large-scale structure to star-forming regions (Yajima et al. 2017). Our simulations showed that star formation occurs intermittently due to supernova feedback. The simulated galaxies agreed with the stellar mass of observed Lyman-alpha emitters at redshift 7.

Separately, using the three-dimensional radiation hydrodynamic simulations, we modeled the evolution of the first galaxies influenced by stellar UV radiation. The simulations revealed that stellar feedback creates hot bubbles and allows Lyman-alpha photons to escape (Abe et al. 2018). The multiple-scattering process of Lyman-alpha photons resulted in the formation of extended bright sources, which nicely reproduced recent galaxy observations.

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