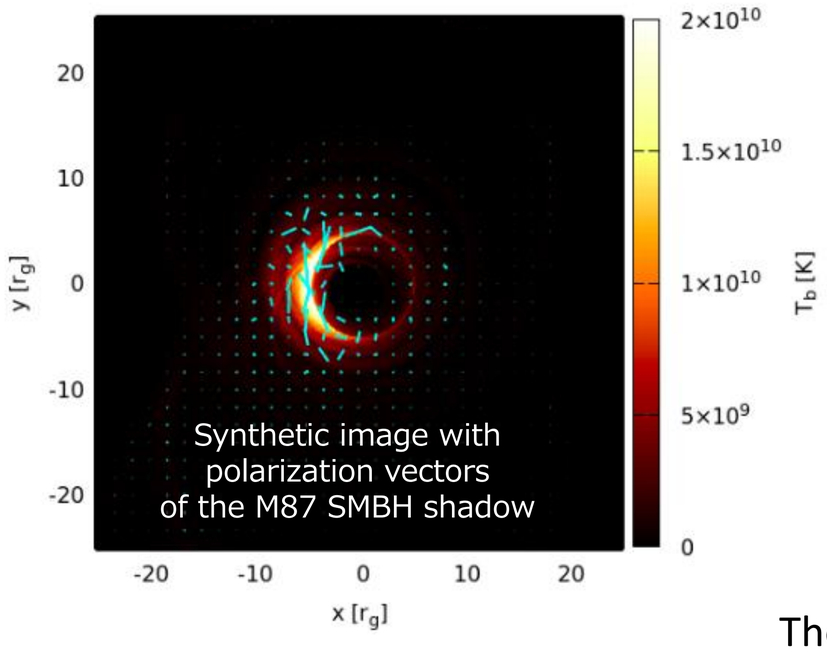
Solving the Mysteries of the Universe with Computational Astrophysics

Supermassive black holes and jets

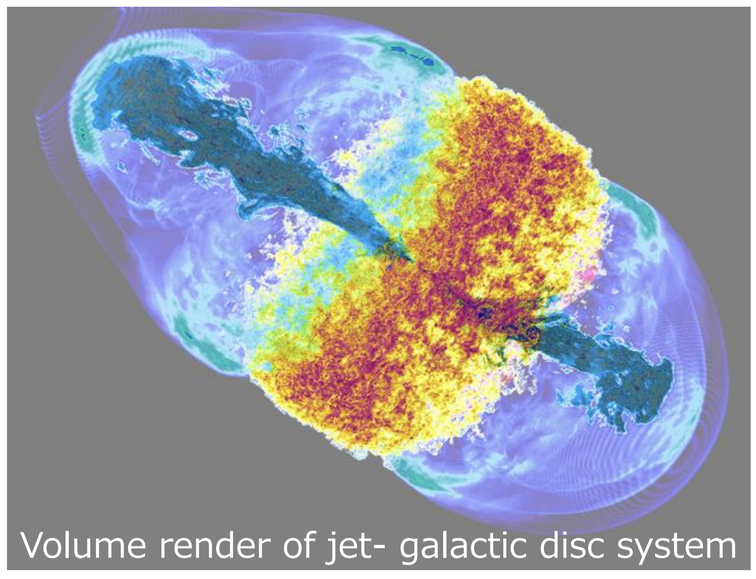
Every galaxy is thought to contain a supermassive black hole (SMBH) at its center. Their existence is deduced indirectly through their gravitational interactions with surrounding stars and gas. SMBH have also been predicted to cast shadows outlined by a ring of confined light. Sometimes, SMBH launch magnetized powerful jets.

Recently, the Event Horizon Telescope (EHT) captured the first image of a black hole shadow confirming the existence of a supermassive black hole at the center of M87.



We succeeded in producing a synthetic image (above) of the black hole shadow through a combination of general relativistic magnetohydrodynamic simulations and radiative transfer of polarized light, predicting regions of linearly polarized light. New EHT observations of polarized light can reveal the topology of the magnetic fields around the SMBH.

Tsunetoe, Mineshige, Ohsuga, Kawashima, Akiyama, submitted PASJ

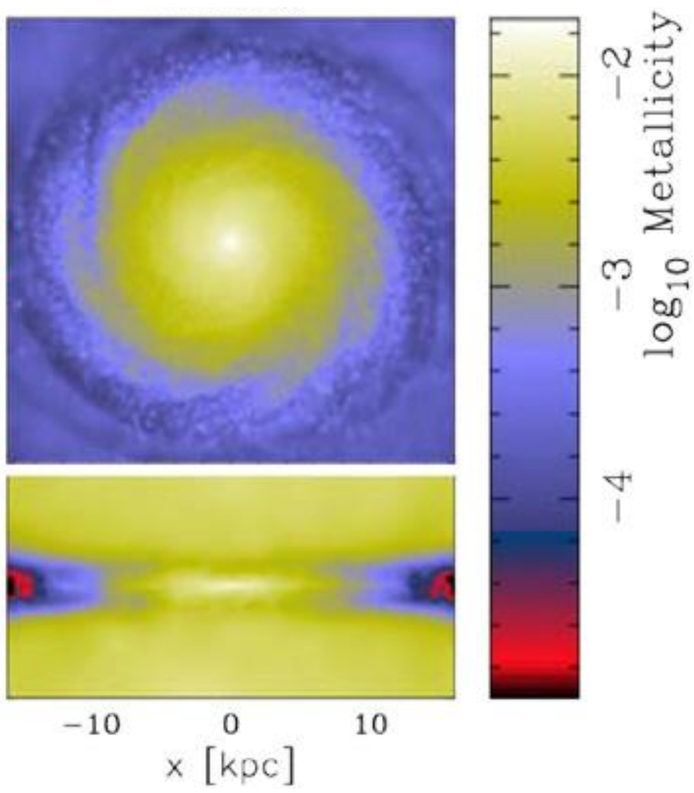


The powerful jets from SMBH at the centers of galaxies interact strongly with the interstellar medium of the galaxy. We captured these complicated effects with relativistic hydrodynamic simulations showing how the turbulence and outflows generated through the interactions affect the star formation history of a galaxy.

Mukherjee, Wagner, Bicknell, Silk, Sutherland, MNRAS 2018

Galaxy formation in the early, distant universe – simulations meet observations

Observing galaxies in the distant, early universe is challenging as they become rarer and fainter, but recent observations at infrared and ultraviolet wavelengths of massive, gas- and dust-rich galaxies with extreme star-formation rates are challenging our theoretical understanding of the formation of some of the earliest galaxies.



We implemented a new recipe for the energy and momentum injection due to supernovae in our cosmological smooth-particle hydrodynamics code, with which we modelled with unprecedented detail galactic winds driven by supernovae. The simulations successfully reproduced complex observations, e.g., the distribution of metals (all elements other than hydrodgen and helium) in isolated galaxies.

Shimizu, Todoroki, Yajima, Nagamine, 2019, MNRAS, 484, 2632

We performed multi-waveband radiative transfer calculations through high-resolution cosmological hydrodynamical simulations that follow the formation and evolution of the first galaxies. We produced synthetic observational images of what the galaxies would look like in the infrared and UV. The infrared and UV brightness can vary tremendously in response to the energetic feedback by supernovae.

Arata, Yajima, Nagamine, Khochfar, Li, 2019, MNRAS, 488, 2629