Division of Astrophysics

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We aim to use fundamental physics to understand a wide variety of questions, such as the birth and evolution of the first stars and galaxies in the universe; the characteristics of the light they emit; the formation and evolution of galaxies, galaxy clusters, and other large-scale structures; the formation and evolution of black holes and their activity; the formation of planets; and the birth of life in the universe. We are also researching how technologies developed in this field may find applications in medicine.

Black hole physics

In the accretion disk where matter accumulates owing to the strong gravity of a black hole, strong radiation and jets are generated by the release of gravitational energy. We are investigating such high-energy astrophysical phenomena around black holes and the radiation characteristics of black hole objects through general relativistic radiation magnetohydrodynamic simulations.

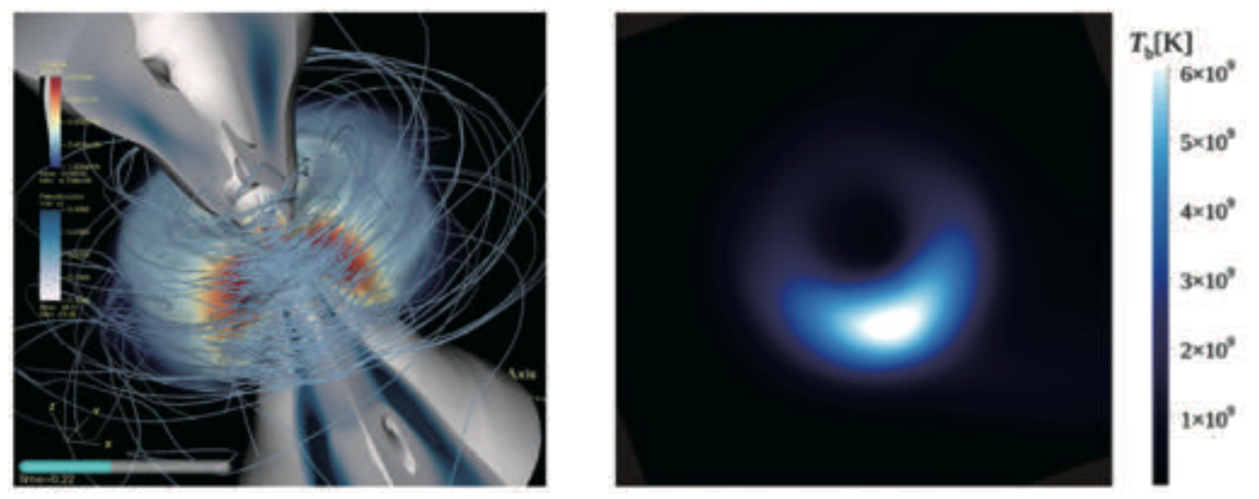

Fig.1
Left: Black hole accretion disks and jets in general relativistic radiative magnetohydrodynamic simulations
Right: Black hole shadow reproduced by general relativistic radiative transfer calculations

Supermassive black holes and galactic evolution

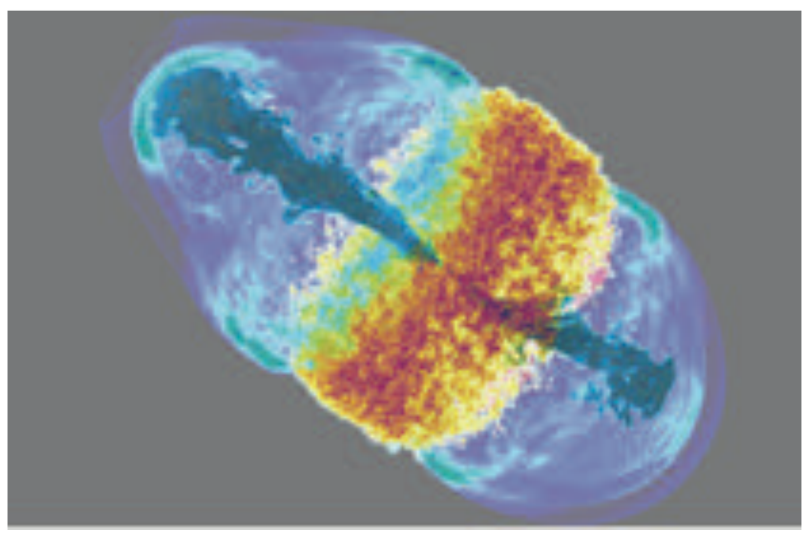

Fig. 2 Interaction between interstellar gas and jets

A supermassive black hole exists universally at the galaxy center and grows while swallowing the surrounding stars and interstellar medium. Simultaneously, its jets blow away the interstellar medium, strongly influencing the evolution of the galaxy. We are investigating this complex interdependence using relativistic magnetohydrodynamic simulations in an attempt to grapple with the mystery of galactic evolution.

Galactic evolution and dark matter

Dark matter is known to play an important role in the evolution of galaxies, but its nature remains shrouded in mystery, and many contradictions within existing theories have been pointed out. We are investigating the nature of dark matter haloes by studying galaxy collisions.

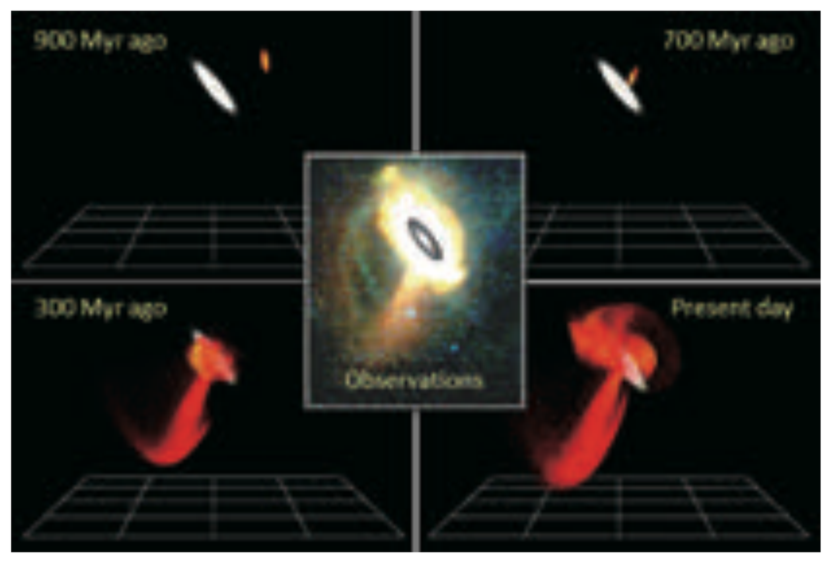

Fig. 3 A galaxy collision that occurred in the Andromeda Galaxy approximately 1 billion years ago

Neutrinos and formation of large-scale structures in the universe

We are conducting theoretical research to investigate the mass of neutrinos, which is yet to be elucidated, in preparation for future observational projects of large-scale galaxy survey. To this end, for the first time, Vlasov simulations have been accomplished as a high-precision numerical simulation method instead of the conventional n-body simulation.

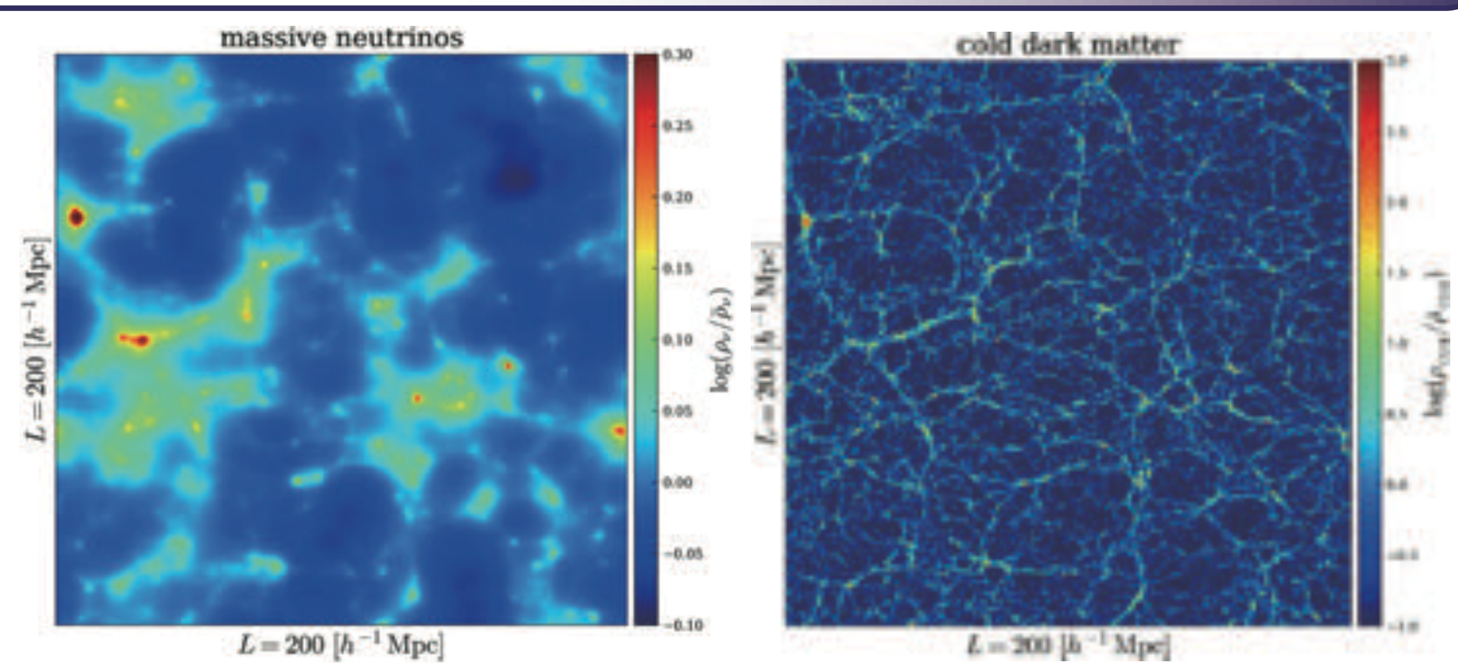

Fig. 4
Left: Result with neutrino effect
Right: Result without neutrino effect

Galaxy formation

In the early universe, massive galaxies and supermassive black holes may have been formed by the frequent merging of galaxies and accretion in dense regions of galaxies called primordial clusters. We are studying the physical phenomena occurring in primordial clusters of galaxies through cosmological radiation hydrodynamic simulations.

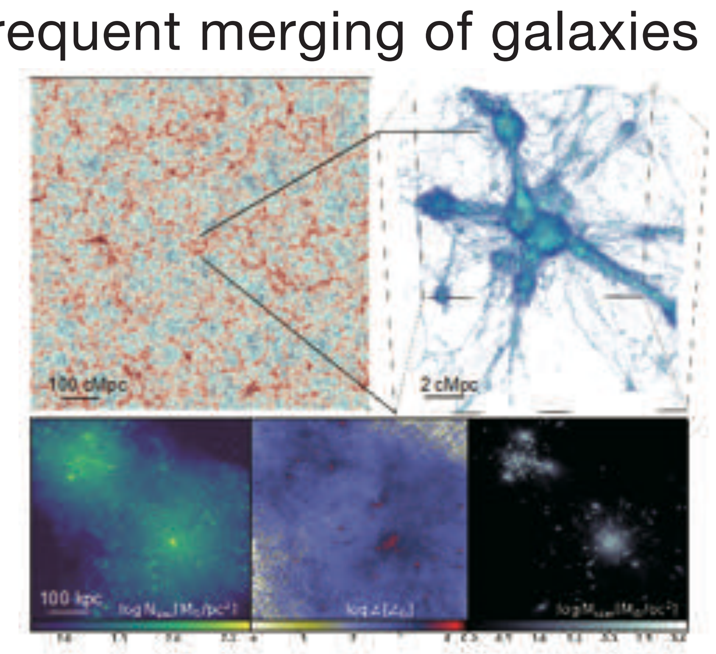

Fig.5
Upper left: Large-scale mater distribution in the universe
Upper right: Structure of gas near the central galaxy in a proto-galaxy cluster
Bottom:From left: galactic gas, heavy elements, and stellar surface density

Applications in medicine

Diffuse optical tomography (DOT) using near-infrared light in the wavelength range of 700–1000 nm has been attracting attention as a new medical diagnostic method because it is a non-invasive procedure that does not expose the patient to radiation. We are studying light propagation in living organisms by applying the high-precision technique for radiative transfer calculation developed in astrophysics to DOT.

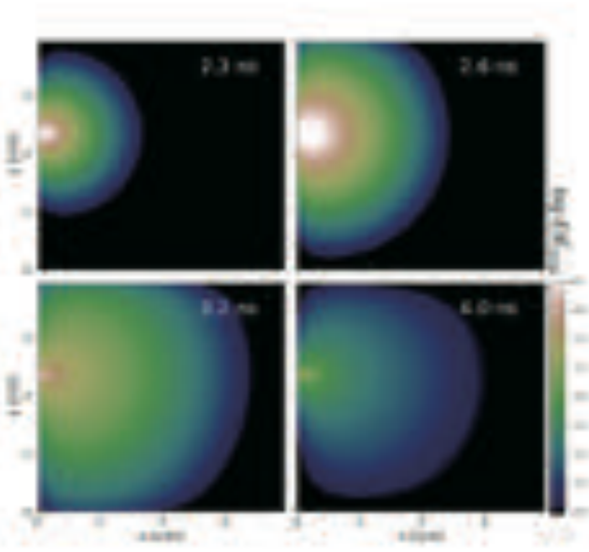

Fig. 6 Radiative transfer simulation assuming pulsed light irradiation of a living body