Joint Institute for Computational Fundamental Science

JICFuS

Science is the branch of study engaged in uncovering laws hidden in nature and in understanding, predicting, and reproducing phenomena. Over time, humankind has learned to express these laws in the form of equations through the use of two basic scientific methods - theory and experiment (observation). But the nature of elementary particles and the phenomena involved in the evolution of the universe involve complexities that cannot be resolved through an analytical approach starting from the basic equations. The supercomputers have emerged as essential tools for their investigation and resolution, and computational science using the supercomputers has now joined theory and experiment as the third scientific method.

JICFuS

The Joint Institute for Computational Fundamental Science (JICFuS) is a collaborative effort of the Center for Computational Sciences (CCS) of the University of Tsukuba, the High Energy Accelerator Research Organization (KEK), and the National Astronomical Observatory of Japan (NAOJ). Through maximum utilization of the high-speed “K Computer” and in collaboration with other research organizations, JICFuS is engaged in advancement of MEXT SPIRE Field 5 - The origin of matter and the universe, and dedicated to enhancement of the computational science research and development through (1) strong, fine-grained support of fundamental computational scientists, (2) provision of a venue for cooperation between fundamental computational scientists and computer scientists, and (3) creation of new fields of research.

Elucidation of the fundamental laws and evolution of the universe

Realize precise calculations of the phenomena over wide range of scales from elementary particles to the universe. Combining with the data from large-scale experiments and observations, they play crucial roles to address the remaining problems in the history of the universe that extend across particle, nuclear and astro physics.

The science of the Joint Institute for Computational Fundamental Science

The origin and structure of matter and the universe

The history of the universe is believed to have began in the ultrahigh-temperature, ultrahigh-density state of the Big Bang, some 13.7 billion years ago. As the temperature declined, it led to the formation of baryons, better known as protons and neutrons, from the ubiquitous quarks, and then to interlinking of these protons and neutrons to form light atomic nuclei.

“Dark matter” is believed to exist throughout the universe in a far greater quantity than baryons. Structure emerged in the early universe when the dark matter formed aggregates under the force of gravity, and ordinary baryon matter was gravitationally drawn toward these aggregates, gradually leading to the formation of galaxies and stars, and ultimately to the present structure of the universe. Galaxies are the sites of the birth of new stars and the destruction of old ones by gravitational collapse leading to supernova explosions and other outcomes. Heavy atomic nuclei are formed in these processes. The origin and structure of matter are thus closely related to the origin and structure of the universe.

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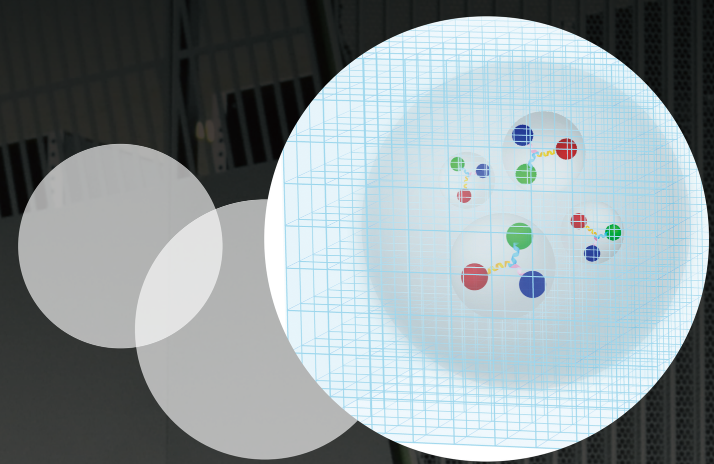
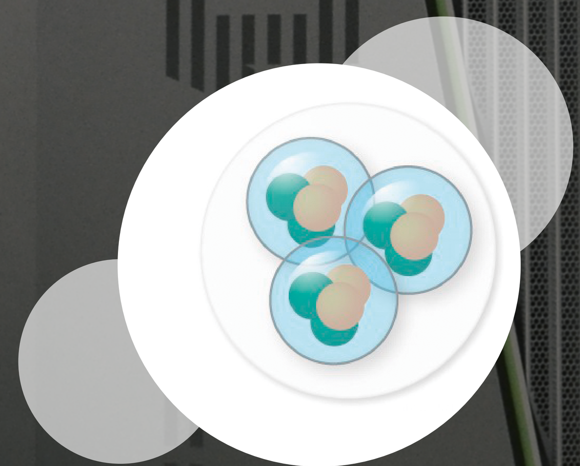
Lattice QCD
- For understanding quark dynamics

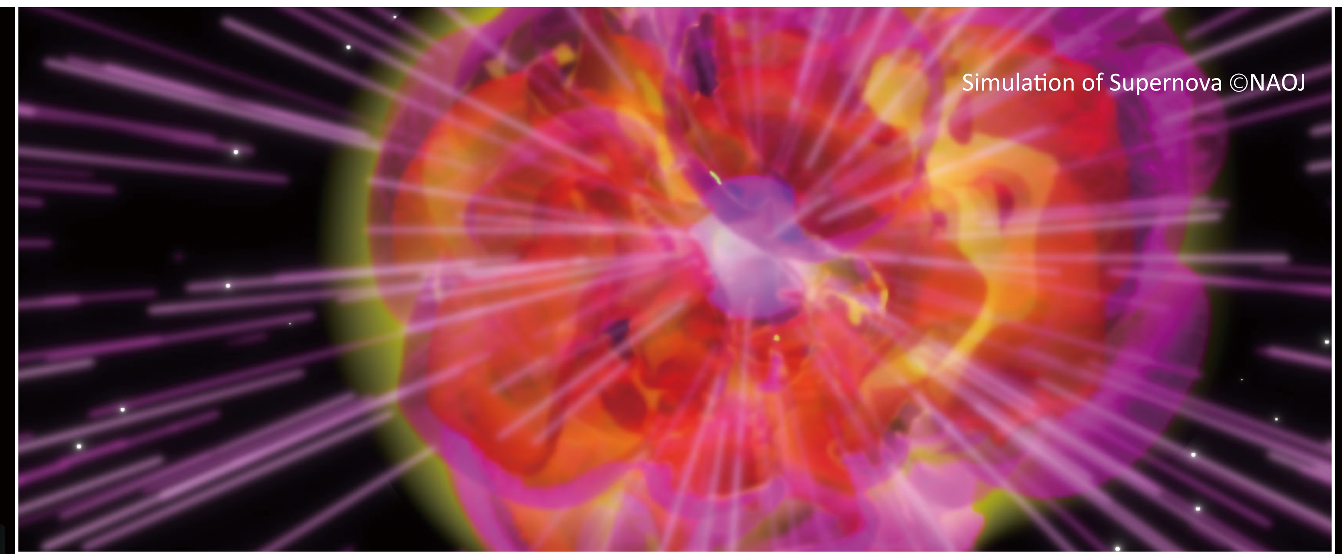
The protons and neutrons that form an atomic nucleus are each composed of three quarks. The quarks themselves cannot be seen, and individual quarks cannot be extracted. But through the use of supercomputers in the computational technique called lattice QCD (Quantum Chromodynamics), it is possible to gain a comprehensive understanding of physics extending from quarks to hadrons such as protons and neutrons, and ultimately to atomic nuclei.



Nuclear physics and the emerging paradigm shift

An atomic nucleus is a quantum many-body system composed of protons and neutrons, elementary particles bound together by the “nuclear force”. This force is rich in complexity, and the nature of quantum many-body systems bound by this force is not yet fully understood. Our work is to return to the starting point and elucidate the structure of the atomic nucleus by many-body theoretical computations based on the nuclear force derived from QCD.

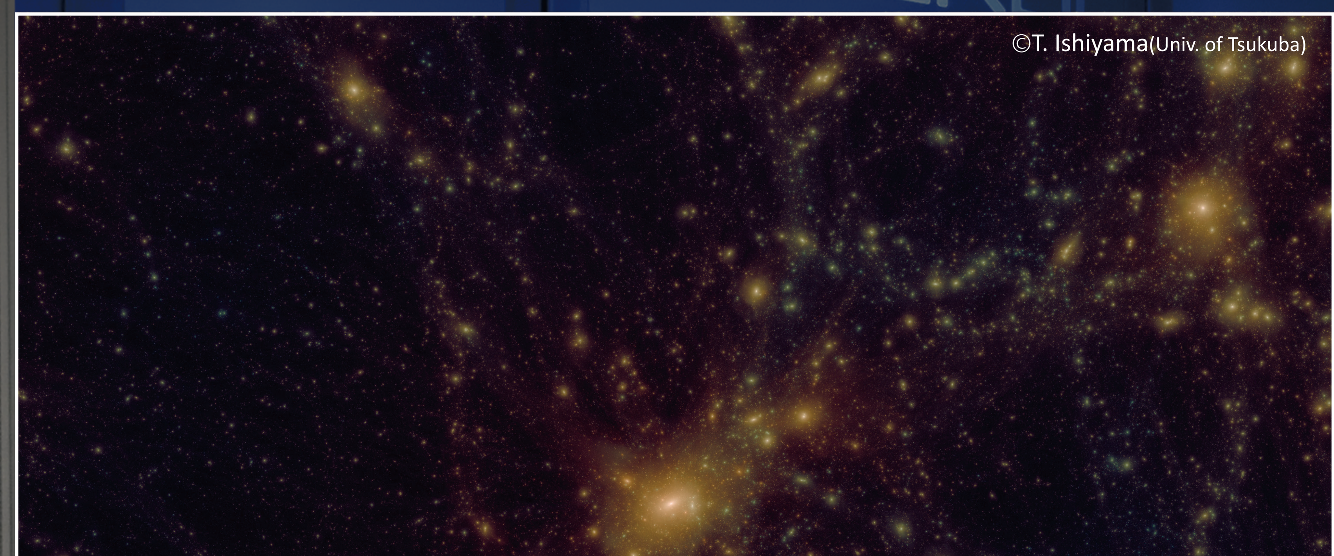




Simulation of Supernova ©NAOJ

Supernova explosions and black holes

In the last stage of their evolution, immense stars with over eight times the mass of our sun are believed to undergo gravitational collapse resulting in supernova explosions and the formation of neutron stars or black holes. All four of the forces existing in nature - gravity, electromagnetic interaction, strong interaction, and weak interaction - play key roles in this phenomenon, and a comprehensive understanding of physical laws is essential for their elucidation.



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The first astronomical bodies

One of the main tasks of modern astrophysics is to gain a better understanding of the processes of star and galaxy formation during the early stages of the universe. According to the present standard model, the astronomical bodies of the galaxies formed and grew in the early universe under gravitational instability induced by density fluctuations of dark matter.

Promotion of Computational Fundamental Science

In order to accelerate the research and development of computational fundamental science, we promote user support, exploratory research support, and human network construction.

To learn fundamental physics, we have developed ”Quark Card Dealer” the Quantum Chromodynamics collectible card game.