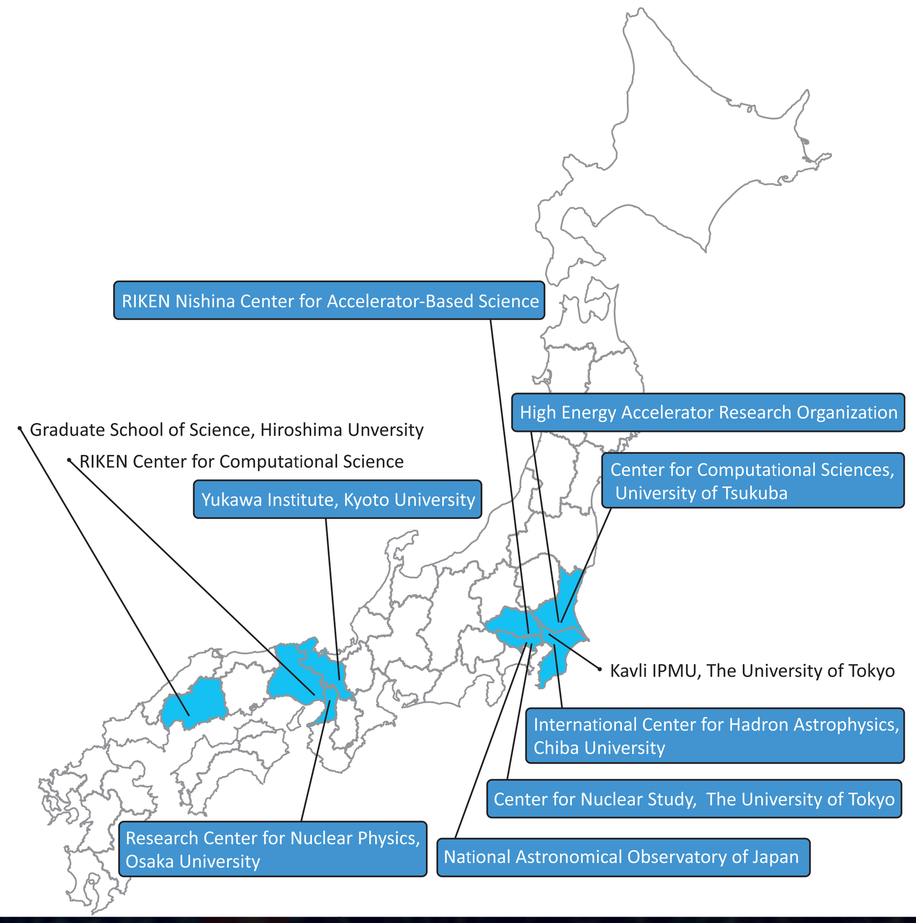
計算基礎科学連携拠点

JICFuS Joint Institute for Computational Fundamental Science

Joint Institute for Computational Fundamental Science (JIC-FuS) is a collaborative effort eight institutions. We had con-ducted nuclear calculations using quantum chromodynamics, simulations of neutron star mergers, and research on the gener-ation of density fluctuations in dark matter, under MEXT SPIRE Field 5 “The origin of matter and the universe” imple-mented in fiscal 2015. JICFuS had gained some noteworthy research results, winning the ACM Gordon Bell Prize.MEXT as “Priority Issue on Post-K computer” (Elucidation of the Fundamental Laws and Evolution of the Universe) starts from fiscal 2016, we aim to create further research results. JICFuS dedicated to enhancement of the computational science research and development through (1) strong, fine-grained sup-port of fundamental computational scientists, (2) provision of a venue for cooperation between fundamental computational sci-entists and computer scientists, and (3) creation of new fields of research.



Elucidation of the Fundamental Laws and Evolution of the Universe

The ultimate purpose of computational science in the fields of particle physics, nuclear physics, and astrophysics is to elucidate the history of the creation of matter, in a manner that bridges the three fields. Our aim is to conduct precise lar ge-scale calculations using a supercomputer in order to investigate phenomena on scales ranging from that of elementary particles to the universe itself. We will com-bine the results obtained with those of large-scale experi - ments and observational data, in an ef fort to elucidate the history of the creation of matter.

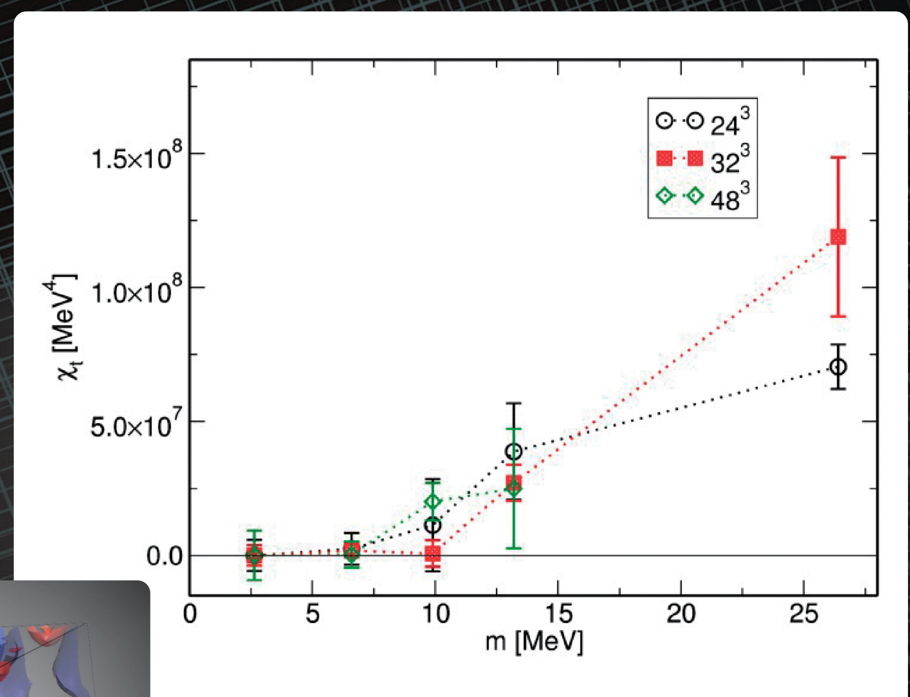
To realize these aims, MEXT as “Priority Issue on Post-K computer” (Elucidation of the Fundamental Laws and Evolution of the Universe), which will begin operation in fiscal about 2020, will develop simulation code to verify the Standard Model of particle physics, and investigate superstring theory , particle interactions, the structure of heavy nuclei, and stellar explosions, and so unlock the mysteries of the evolution of the universe.

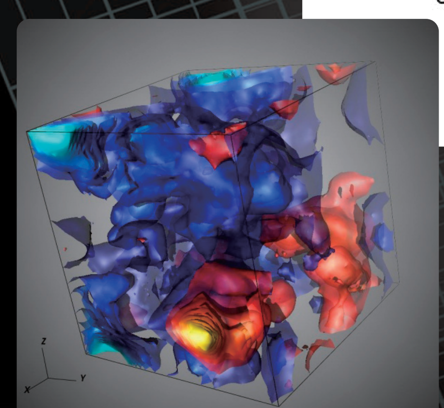
Quest for the Ultimate Laws and the Birth of the Universe

We plan to perform large-scale simulations of lattice quan-tum chromodynamics (QCD) in order to calculate the physi-cal quantities needed to interpret the experimental results obtained at la rge particle accelerators such as SuperKEKB and J-PARC.

Primary accomplishment

In the cooling process immediately following the birth of our hot universe, there may have been a dramatic phase transition similar to the transformation of water into ice. Now, we have used large-scale simulations involving lattice QCD—a model closely related to the actual world in which we live—to shed light onto this possibility. This figure plots the results of simulations conducted at a temperature of 20 billion Kelvin, with the masses of the u and d quarks on the horizontal axis and topological fluctuations of the gluon field shown on the vertical axis. There is no question that these simulations reveal new features that were previously unknown, and we are working to push the techniques even further.





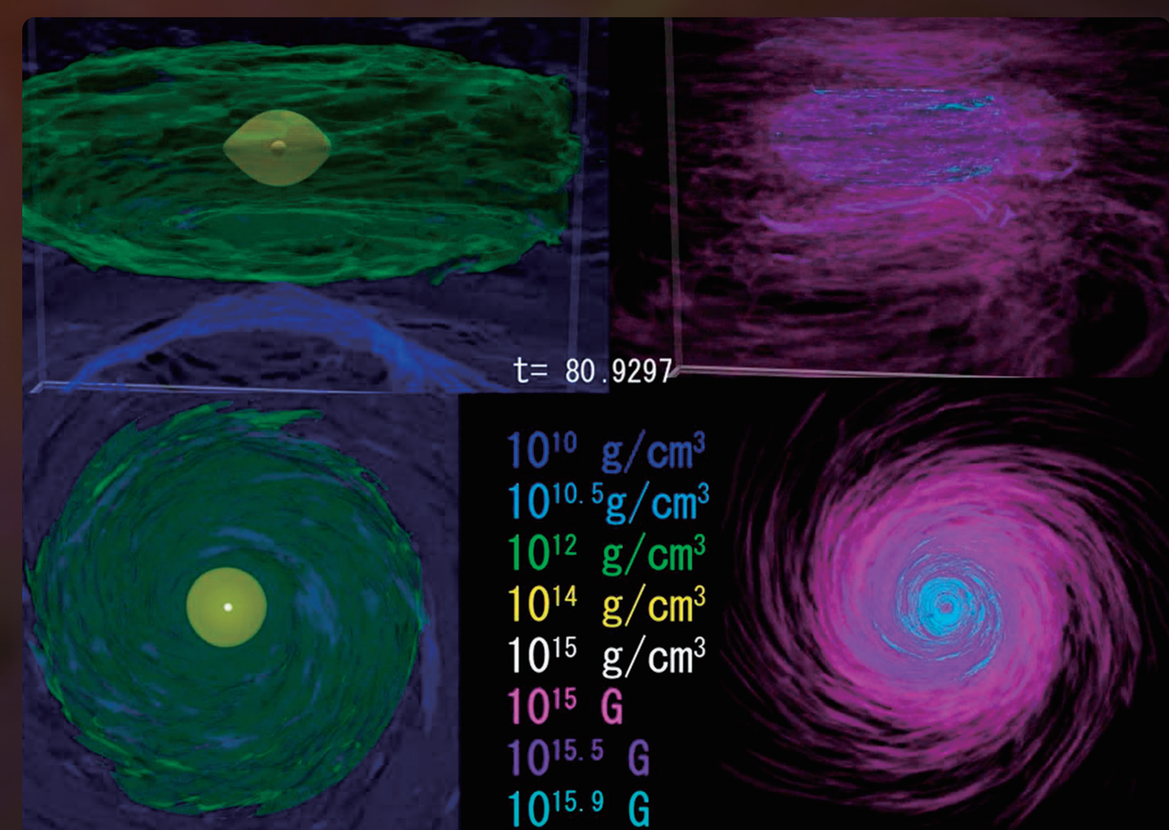
Depiction of a quark field in vacuum as obtained from a QCD simulation
(©Guido Cossu)

Exploring the Origin and Evolution of Matter

The purpose of this project is to explore the unsolved issues in microscopic physics by larger-scale numerical computation. Specifically, the issues are to accurately deter - mine the baryon-baryon interactions, nuclear structure and many-body reactions between nuclei, and the equation of state for high-density nuclear matter.

Primary accomplishment

This is a simulation of the internal state of a massive and rapidly rotating neutron star formed by the merger of a neutron-star binary. The figure one the left plots the density, while the figure on the right shows surfaces of constant magnetic-field strength. We see that the shape of the star is distorted due to centrifugal forces; we also see that ultra-strong magnetic fields are produced in the interior, inducing a state of turbulent flow. This turbulent flow gives rise to viscosity, which results in angular-momentum transport that determines the star’ s ultimate fate.



Large-Scale Simulations and Astronomical Big Data

In the next ten years, a variety of la rge observational programs will be conducted. We will push the frontier of big data cosmology that combines observational data and large-scale simulations to elucidate the evolution of the universe and the formation of galaxies.

Primary accomplishment

Using the K computer, we computed the gravitational evolution of approximately 550 billion dark-matter particles to reproduce the present dark-matter distribution of our universe confined within a box of side length 5.4 billion light years (background image). The inset at the lower right shows the most massive dark-matter halo formed in this simulation, which is the size of a galaxy cluster. We see that many such halos are formed, and it is predicted that galaxies are formed at their centers and black holes exist in the centers of the galaxies.