



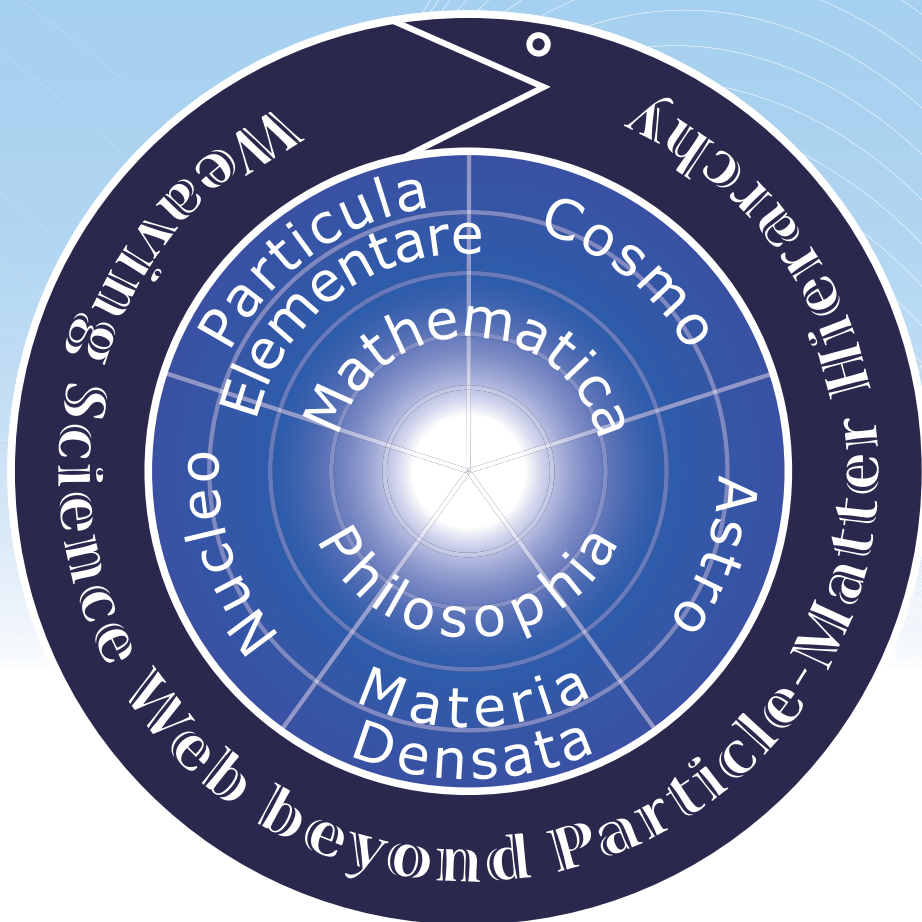
TOHOKU
UNIVERSITY

Tohoku University Global COE program

“Weaving Science Web beyond Particle-Matter Hierarchy”

東北大学GCOE「物質階層を紡ぐ科学フロンティアの新展開」

Annual Report 2011



May 2012

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Message from Prof. Kunio Inoue, GCOE Leader;

First of all, I would like to offer my deepest condolence to those who were in the disaster affected East-Japan due to the big earthquake on March 11, 2011 and the subsequent reactor breakdown. I also like to express my deepest application to those who have supported and are supporting the recovery of Japan in various ways. Tohoku University and our GCOE program have resumed our activities quickly and strongly. I believe our efforts and contributions in scientific and educational activities will propel the recovery and even the improvement of Japan.

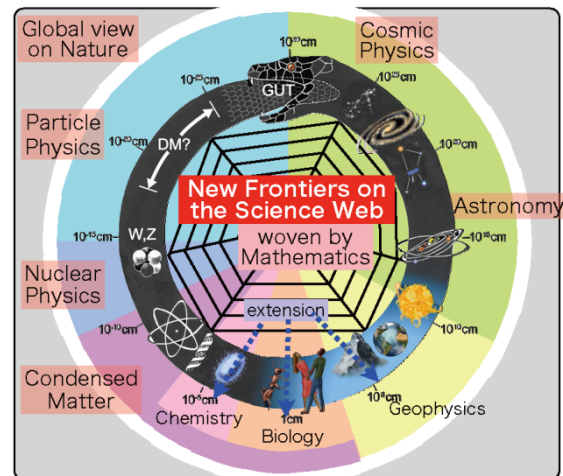
1. The GCOE program “Weaving Science Web beyond Particle-Matter Hierarchy”**Leader****Kunio Inoue**

Director and Professor of Research Center for Neutrino Science,
Tohoku University

To establish a new uniting science from Global COE.

Natural science has developed mainly with researches on the phenomena within each “Particle-Matter Hierarchy” formed along the universe creation and evolution, such as elementary particle physics, nuclear physics, condensed matter physics, astronomy and cosmic physics. Needless to say about the importance of the deeper research within the hierarchy, exploration of inter-hierarchical research frontier yet overlooked even by advanced intelligent majorities is indispensable for further development of physical science. Young scientists carrying such development have to lead a research in an international environment and have to possess wide view over natural science and science ethics for practical applications. On the other hand, separation between basic science and social interest under people’s unfamiliarity to science and deterioration of mathematical skill is argued in Japan. Thus, important things are research development concerning social relation and the nurturing of young talent who will continue the research development and will act as an opinion leader to bring up importance and outcomes of science researches to public.

Based on the experiences of propelling international cutting-edge researches in wide range of hierarchies under the previous COE program "exploring new science by bridging particle-matter hierarchy," this program attaches great importance to international collaboration and challenging new fields. International research collaborations and foreign institutes with an agreement on cooperative education program are synchronously organized as a Global Education Hub. We strongly promote characteristic studies in every hierarchy and also explore new science frontiers



through extensive increase of interconnections among hierarchies just like weaving a web. This Science Web provides an environment to pursue deep studies and to explore new science frontiers and thus new challenging fields.

And, it is full of zeal in making the best use of the given environment for nurturing students. In addition, it cooperates with the philosophy course and it challenges a new activity that removes the fence between Science and Liberal arts, too. It is convinced that a lot of unexplored science frontiers can be developed by promoting the cooperation among diverse fields, and many appear one after another top-class personnel having rich internationalism and a broad outlook. Thus, students grown with the education will create a new academic culture and contribute to a social innovation.

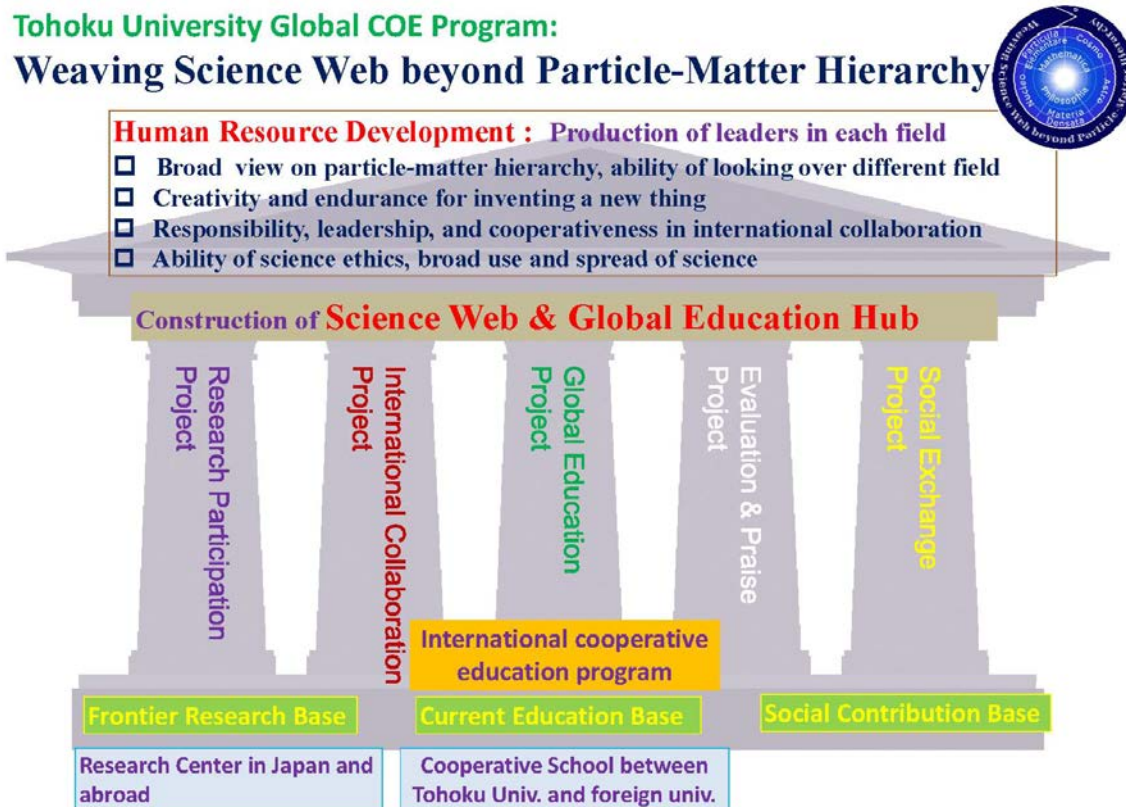
The research and educational environment achieved by weaving science web and by establishing global education hub will continue after this program as a world premier science research/education center. This program will widely distribute cutting-edge researches and will provide many young talents with science literacy and adaptability to the society. These young talents will connect basic science and social interest, and will contribute to raise the intellectual level of humankind. At the same time, talents experienced international cooperation in this global education hub will take active part in various countries and will become foundations of cordial relations to those countries.

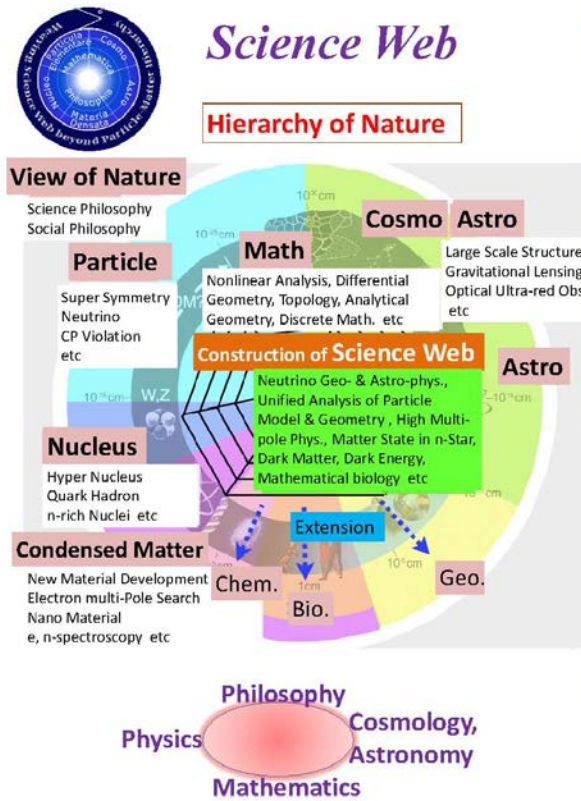
1.1. Purpose of the GCOE Program

In this GCOE, it has aimed to foster the following human resources.

- One has a bird's-eye nature-view for the material hierarchy and an ability of looking over a different field.
- One has creativity and endurance for inventing a new thing.
- One has a sense of responsibility, leadership, and cooperativeness under the international research.
- One is educated to have the ability of the science ethics, and to encourage broad use of science, and bears the creation of a new science culture society and contributes to the social innovation.

The summary of this program:





Research Project **Math promotes weaving of matter hierarchy;**

- Neutrino Astro- & Geo-phys (Particle • Math • Astro • Geo)
- Solar problem & Earth dynamics by **Mathematical analysis of fluid dynamics**
- Dark Matter & Dark Energy by Gravitational Lensing (Astro • Particle)
- Birth & Formation of Universe by **Geometry & Topology** (Math • Particle)
- Unified Analysis of Particle Model & Geometry (Particle • Math)
- Math. Physics by **Nonlinear Wave & Dispersion Equation** (Math • Phys)
- State Eq. of Nucleosynthesis, n-Star, Gravitational wave emitting in Supernova (Astro • Nucleus • Matter)
- **Math. Analysis of Rotating Black-Hole** (Astro • Math)
- High Multipole by connecting Nucleus & Matter Phys. (Matter • Nucleus)
- Polymer • Impact Fragmentation • Soft matter • Large-scale struc. of Univ. by **Renormalization group & Path integral of Functional Differential Eq.** (Math • Matter • Astro)
- **Galaxy structure formation, Bio-ecosystem formation and dynamics,** Superconductor by **Reaction-diffusion Eq.** (Math • Astro • Bio. • Matter)
- Graphene & Quantum Hall by Particle & Matter Phys. (Matter • Particle)
- Surface & Crystal growth Phys. by **Mean curvature Eq.** (Matter • Math)
- Nuclear Spin Electronics & **Non-commutative Geometry** (Matter • Math)
- New Functional Material & classifying of Excitation spectrum profile (Matter • Math)
- Applied Neutrino Science

Example of Cooperative Study with nonlinear Eq. & Geometry

Neutrino Obs. ↔ Fluid analysis of solar/earth-interior ↔ New function, nano-material ↔ Geometrical form, excitation spectrum

Statistics of correlation between geo-neutrino and matter structure / matter core convection, death of convection layer and CNO cycle neutrinos

Accelerating of theoretical / experimental matter phys. from modeling and systematizing by geometrical classification

Nuclear spin electronics ↔ Non-commutative geometry, spectrum analysis ↔ Surface-phys., Crystal growth ↔ Mean curvature (Geometry)

Low dimensional structure

Anderson localization, Fractional quantum Hall effect, Non-Abelian Statistics

Measured resistance

Nano-scale NMR

Path integral

Many-body effect, Spin Correlation, Spin current, Quantum Information process

Surface phys., Crystal growth

In 1975, H. Gross-Braunmann draws the picture with hyperbolic and bi-joint points. Gyroid is used a study of surface phys. / block copolymer.

Global Education Hub



Exchange Program of Human Resource, Education and Research

Joining Universities / Institutions

- China:**
- Tsinghua U. (Science) ○
 - Peking U. (Math)
 - Fudan U. (Math)
 - Lanzhou U. (Science)
 - Jilin U. (Matter)
 - Xi'an Jiaotong U. (Math)
 - IHEP (Particle)
 - Chinese Acad. Scie. (Matter)
 - Hong Kong U. S. Tech (Science)
- Korea:**
- Seoul Nati. U. (Science)
 - Sungkyunkwan U. (Matter)
 - Pusan National U. (Math)
 - Pohang U. Scie. Tech (Science)
 - KIAS (Math)
 - KIST (Math)
- Taiwan:**
- Nati. Taiwan U. (Science)
 - Nati. Chiao Tung U. (Matter)
- India:**
- India Inst. Science (Matter)
 - Raman Inst. (Science)
- Thailand:**
- Suranaree U. Tech (Science)
- USA:**
- Princeton (Astro)
 - Stanford (Particle)
 - Alabama (Particle)
 - Jefferson Lab (Nucleus)
 - LBL (Particle)
 - LLNL (Particle)
 - Hawaii (Astro)
 - California(6-schools) (Science)
 - Cal Tech (Particle)
- France:**
- Ecole Normale (Science) ○
 - IN2P3 (Particle)
- Sweden:**
- Stockholm (Matter)
- Germany:**
- Mainz (Nucleus)
- Etc.

○ Double Degree System

1.2. Outline of the GCOE Program

1) Construction of science web

- (1) This GCOE program covers widely a material hierarchy over space from the elementary particle. The science web environment is constructed with the tie of each hierarchy by mathematics that is a common language of the science, and also with weaving the hierarchy by the diversification of cooperation.
- (2) The philosophy of science is taken to promote the bird's-eye nature-views of the material hierarchy, and the overall understanding of the feature of space and material is aimed at.
- (3) This GCOE has basic research facilities, and is playing a leading role in the worldwide highly accurate measurement devices and the technology, and then will strongly promote the international cutting-edge researches by using them.

Concretely, the breakthrough research targets are the neutrino astronomy, the geophysics, the large-scale structure and the dark matter in the universe, the matter state under the extreme environment such as celestial object internal including the hyper nucleus, the electron state in the matter by using a synchrotron radiation, a neutron and a photoelectric spectrum, and the ultimate law of elementary particles.

- (4) The research application for society is aimed by developing with life sciences by the cooperation of mathematics and physics, the nuclear spin electronics, the new function materials, and a nuclear reactor nondestructive diagnosis by the neutrino.

In addition, it is developed into a large center of the science frontier that has a huge science web, and affected other sciences of the intermediate substance hierarchies of the chemistry, the biology, and the geoscience in the future.

2) Construction of global education hub

The above-mentioned science web is used for the construction of global education hub.

(1) Research participation project

The graduate students and the young researchers can really experience the challenge and the creation in a new field by independent participation in a frontier research on a huge and creative science web.

(2) International cooperation project

This GCOE is a international research center and has the cooperation program between schools in foreign countries, and then is able to develop globally the interactive cooperation education. The talent who plays a leading role in the international society is promoted.

(3) Global education project

One learns the idea and the technique of another hierarchy from the hierarchical uniting education, and acquires a broad outlook for the entire of mater hierarchy. In addition, the education of the

philosophy of science and the science ethics leads to train the ability of having the nature-views, turning to practical use of the science technology and prevailing that.

(4) Evaluation and praise project

The willingness of research and learning is improved with the evaluation and praise system including economic support.

(5) Social exchange project

An academic and social consideration for one's own research is recognized by participation in a social exchange, and various career paths are formed.

The environment constructed with the above-mentioned measure continues as a center of science research and education after the program ends. A frontier of research is widely sent to a general society. And it appears one after another the excellent science course talent who is adapted to the social community, and the liberal arts course talent of having the science literacy. It contributes to the level improvement of humankind's knowledge over the fence between the science and liberal arts. Moreover, talents who appear with the global education hub of this GCOE take an active part in various foreign countries, and become the foundation of friendly relationship with those countries.

1.3. Research Field

Our final goal is to establish a unified understanding on the time, space, matter and all together beyond that on the particle-matter hierarchy. Throughout such our advanced studies, we promote to enrich the research of mathematics and its application to the researches of the particle-matter hierarchy. With advanced mathematical methods and high precision measurement techniques, we aim:

- to establish the resolution of the solar problem and the study on the dynamics of the earth in connection with the neutrino astronomy and geophysics,
- to understand the large scale structure of the universe and the nature of dark matter from both observational and theoretical points of view,
- to pursue the study of hyper-nuclear matters and clarify the nature of matter states under the extreme circumstances with high temperature, high pressure and high density such as interior of neutron stars,
- to reveal the nature of strongly correlated electron systems by using the synchrotron X-ray/neutron-scattering measurements and photoemission spectroscopy,
- to build ultimate picture of elementary particles.
- to develop the application technologies to the society, such as to foster bio-scientific investigation with strong cooperation between mathematics and physics,
- to develop the nuclear spin-electronics for application to quantum computers,
- to develop multifunctional nanomaterials, and
- to nondestructive monitoring of nuclear reactors with neutrinos.

Furthermore, we will propagate our Science Web itself onto intermediate hierarchies covered by chemistry, biology and geo-science so strongly that it might have a great influence on all fields of the natural science in the near future. Science philosophy/ethics, educationally employed for a global view on nature and for an application of leading-edge science technology, will also provide new boundary field between sciences and humanities.

Physics	Mathematics	Astronomy	Philosophy
Particle / Nuclear Physics Condensed Matter Physics	Geometry / Mathematical Science	Astrophysics / Cosmology	Science Philosophy / Science Technology Ethics