Department of Earth and Space Science

The Department of Earth and Space Science was established in 1995 with a purpose of conducting physics-based research and education concerning (1) the evolution of the earth and the space and (2) the origin and properties of matters. Most graduate students have been majoring in physics in the School of Science. The quota of students for the course is 28 annually. The entrance examination is held in common with that for the Department of Physics. The Department of Earth and Space Science consists of three major research areas: (1) Astrophysics and Planetary Science, (2) Earth and Planetary Material Sciences and (3) Extreme Material Science. The related disciplines are basic astrophysics, X-ray and infrared astrophysics, planetary and geophysics and condensed matter physics involving biophysics.

The following is a list of the staff, including collaborating research member in the Institute of Laser Engineering.

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A photograph of the entrance lobby symbolizing evolution of lives and the birth of new Earth and Space Science from physics on microscopic world. The floor is covered with Precambrian granite (2.2 billion years old). The wall picture employs “stromatlite” formed by cyanobacteria 1.8 billion years ago and “wave-rippled sandstone” 1.2 billion years ago. Let us listen to the Precambrian wave sounds.

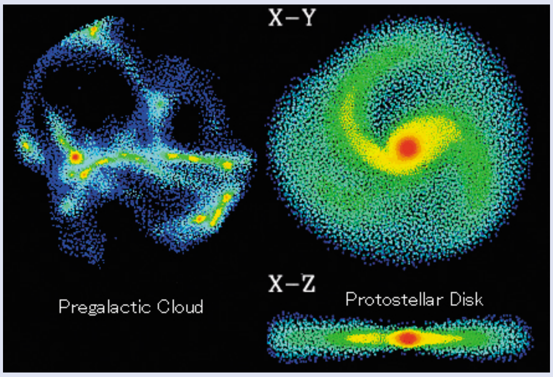
Department of Earth and Space Science

Theoretical Astrophysics Group

Members Kentaro NAGAMINE (Professor), Yutaka FUJITA (Associate Professor), Hideyuki TAGOSHI (Assistant Professor)

[Research Area]

1) High Energy Astrophysics (active galactic nuclei, gamma-ray bursts, cosmic jets, origin of cosmic rays).
2) Cosmology (early universe, large scale structure, clusters of galaxies).
3) Gravitational Waves (black holes, neutron star binaries).
4) Formation of Astronomical Bodies (star and planet formation, formation and evolution of galaxies).



It is widely believed that our universe was born about 13.8 billion years ago with temperature infinitely hot and density infinitely dense, known as the Big Bang. As the universe expanded, stars, galaxies and the large-scale structure of the universe have been formed. Various astrophysical phenomena in the extreme physical conditions take place, such as supernova explosion, evolution of chemical elements, black hole formation, gravitational wave emission, gamma-ray bursts and acceleration of high energy cosmic rays. The research of astrophysics and cosmology has recently much progressed both in theories and observations and a new picture of the universe is now opening up. Two complimentary approaches are needed to understand the universe; one is to study the universe from the fundamental physics point of view and the other is to study the astrophysical phenomena based on physics principles.

Our group pursues both approaches in the research and educational activities. Our group studies a wide range of topics cited at the top using various methods ranging from pure fundamental physics, astrophysical model building and computer simulations to data analysis.

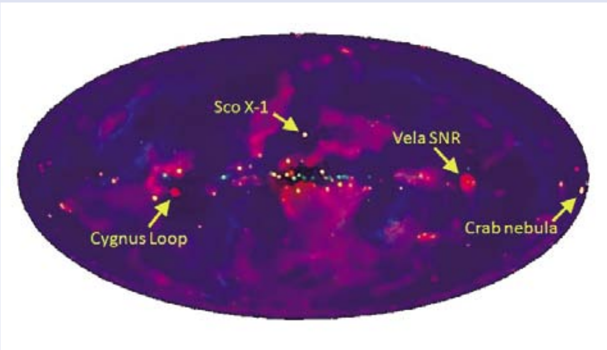
Department of Earth and Space Science

X-ray Astronomy Group

Members Hiroshi TSUNEMI (Professor), Kiyoshi HAYASHIDA (Associate Professor), Hiroshi NAKAJIMA (Assistant Professor)

[Research Area]

1) Observational study of the optically thin hot plasma.
2) Study of the Active Galactic Nucleus in X-ray wavelength.
3) R/D of the CCD for X-ray use onboard satellite.
4) Development of the technique on X-ray spectroscopy and X-ray polarimetry.



Our universe is prevailed by an optically thin hot plasma. For example, X-ray emitting hot gas occupies a substantial fraction of the luminous matter that is still much less than that of the dark matter. Therefore, the distribution of the hot gas in our universe is practically the key clue to investigate the universe. In our galaxy, the hot gas generated in the supernova explosion collides with the interstellar matter producing a high energy cosmic ray. In the vicinity of the blackhole, a high temperature gas is also generated, forming jet phenomena.

We are performing observation of high temperature gas using various satellites: Chandra, Newton, Suzaku and MAXI. We are now preparing the X-ray CCD camera for the coming satellite, ASTRO-H, that is planned to be launched in FY2015. FFAST, the following satellite project, is also planned in near future. It will scan a wide sky area using a focusing X-ray telescope covering the energy up to 80keV. New methods of spectroscopy and polarimetry are being developed in our laboratory for future application.

Department of Earth and Space Science

Planetary Science Group

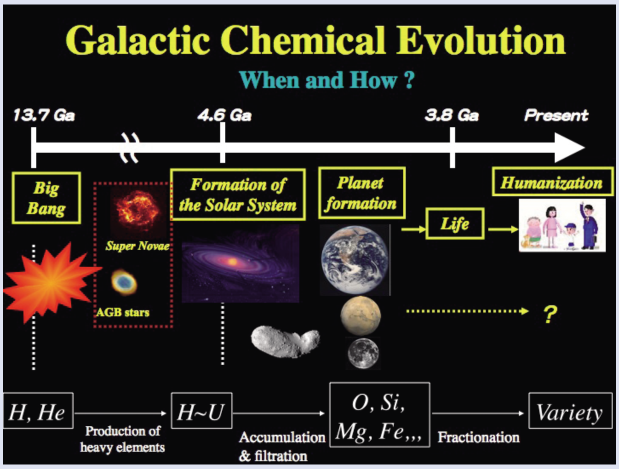
Members Kentaro TERADA (Professor), Chiaki UYEDA (Associate Professor), Chihiro YAMANAKA (Associate Professor), Ko HASHIZUME (Assistant Professor), Hikaru YABUTA (Assistant Professor), Yosuke KAWAI (Assistant Professor)

[Research Area]

1) The origin and the formation of our solar system.
2) The evolution of the Earth and planets.
3) The magnetic properties of magnetic & weak magnetic planetary materials.
4) The studies on the laboratory/environmental electromagnetic phenomena.
5) Development of the technique/instrument for a new frontier of planetary science

As far as we know, the planet Earth is a unique environment (especially for life). When and how were the Earth and other planets formed in the entire universe?

To decipher the history of the Earth, we focus on the origin, evolution and current environment of our solar system based on various experimental approaches. Mainly, we carry out precise isotopic analyses from hydrogen to uranium in Apollo samples, Martian meteorites, other various meteorites and circum-stellar dusts. We also conduct the studies on the organic matter in planetary materials. For better understanding of the magnetic structure of the primordial solar nebula, the magnetic properties of magnetic & weak magnetic planetary materials are examined. We are also investigating electron spin resonance and the relation between environmental electromagnetic field and natural phenomena.



Department of Earth and Space Science

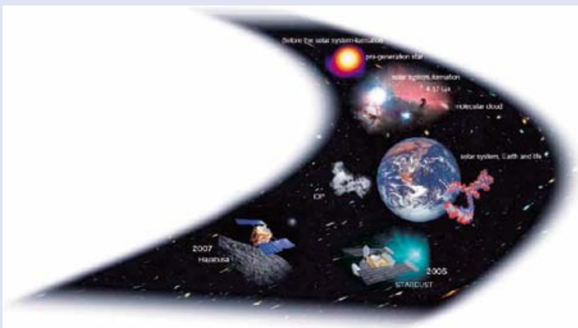
Earth and Planetary Materials Science Group

Members Sho SASAKI (Professor), Osamu OHTAKA (Associate Professor), Kazuto SAIKI (Associate Professor), Atsushi TANI (Assistant Professor)

[Research Area]

1) Formation and evolution processes of solid planets, satellites, and solar system small bodies, and their igneous processes.
2) Phase transitions and physical properties of the Earth's deep interior (Ultra-high pressure experiments using synchrotron radiation on the Earth's interior materials and their simulants).
3) Formation processes of the Earth's surface materials and topography (sediments, gas hydrates, etc.).
4) Developments of apparatus and techniques (e.g., microtomography using synchrotron radiation, three-dimensional image analysis, hyperspectoral telescope, etc.).
5) In situ detection of interplanetary and interstellar dust (e.g. BepiColombo mission) and development of dust accelerator.
6) Material sciences and instrument developments in space missions (e.g., HAYABUSA, KAGUYA, HAYABUSA-2, SELENE-2, JUICE).

The Earth, planets, the moon and satellites have wide varieties in surface environments and interior structures. Differentiation of materials along with planetary thermal evolution played a crucial role in the present state of these solar system bodies. Using spacecraft and ground observations, simulations, and experimental methods, we investigate the origin and evolution of various solar system bodies from dust particle to gas giant planets.



Department of Earth and Space Science

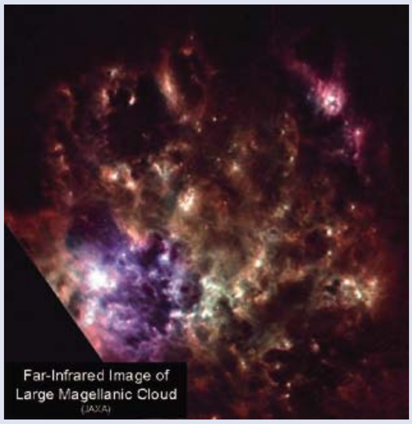
Infrared Astronomy Group

Members Hiroshi SHIBAI (Professor), Takahiro SUMI (Associate Professor), Misato FUKAGAWA (Assistant Professor)

[Research Area]

1) Infrared observations of extrasolar planets and protoplanetary/debris disks
2) Study on interstellar dust grains in galaxy formation/starburst phenomena
3) Development of far-infrared interferometer for astronomy

The infrared astronomy group conducts observational research to investigate formation process of extrasolar planets as well as galaxy formation and starburst phenomena. In these astronomical phenomena, small solid particles (interstellar dust grains) play important roles in energy conversion and various chemical reactions in space. As the dust grains reradiate absorbed energy mainly in the infrared domain, precise infrared observations provide us valuable information to elucidate important physical processes in space. The longer wavelength part of infrared (far-infrared) cannot be observed from the ground because the earth's atmosphere is completely opaque. Therefore, we mount the far-infrared telescopes on artificial satellites or scientific balloons, and execute precise observations in space. In particular, we are developing a far-infrared astronomical interferometer for the first time in the world so as to achieve a spatial resolution more than ten times higher than previously obtained. We also perform near-infrared high-contrast observations of protoplanetary disks and young, gaseous giant extrasolar planets using the Subaru telescope in Hawaii. We search for exoplanets via gravitational microlensing technique by using the MOA-Ⅱ telescope in New Zealand. We have detected Jovian and Neptune-mass extrasolar planets and are exploring Earth -mass planets.


Far-Infrared Image of Large Magellanic Cloud (JAXA)

Department of Earth and Space Science

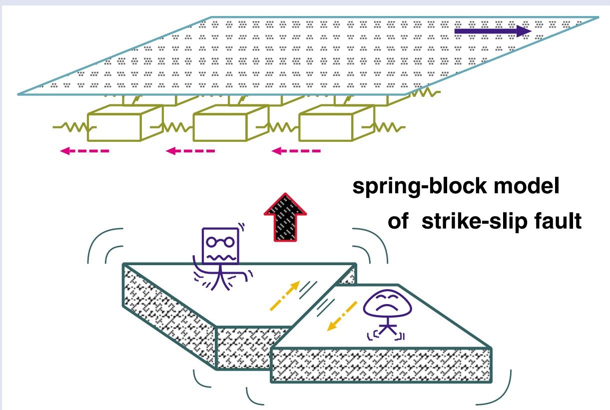
Theoretical Condensed-Matter Physics Group

Members Hikaru KAWAMURA (Professor), Satoshi YUKAWA (Associate Professor), Kazushi AOYAMA (Assistant Professor)

[Research Area]

1) Numerical simulations of the statistical model of earthquakes. Study of physics of earthquakes as a stick-slip frictional instability, based on the law of rock friction.
2) Study of the ordering process and slow dynamics of random and/or glassy systems. Phase transitions and slow dynamics of spin glasses, in particular.
3) Statistical physics of frustration. Study of the ordering of frustrated magnets with strong geometrical frustration such as pyrochlore magnets.
4) Study of the vortex order and the phase diagram of superconductors, especially, high-Tc superconductors with enhanced effects of fluctuations.
5) Study of out-of-equilibrium phenomena by means of molecular dynamics simulations.

There are a variety of materials in nature, which interact and cooperate forming more complex systems. We are theoretically attacking the problems of these interacting many-body systems, from atoms and molecules on microscopic scale to the earth and space on macroscopic scale. Two of our main current subjects are phase transition phenomena of various materials and earthquake phenomena as a stick-slip frictional instability of faults. We regard these phenomena as cooperative ones exhibited by many-body interacting systems, and investigate the problems from the statistical-mechanical standpoint, mainly by using computer simulations.



Department of Earth and Space Science

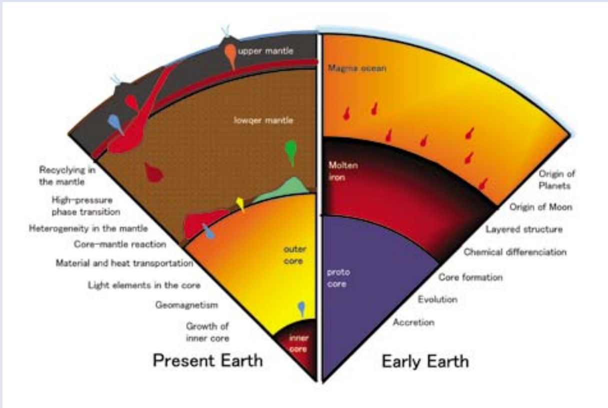
High Pressure Material Physics Group

Members Tadashi KONDO (Professor), Toshifumi TANIGUCHI (Associate Professor), Hidenori TERASAKI (Associate Professor), Tatsuhiro SAKAIYA (Assistant Professor)

[Research Area]

1) Phase transition and physical properties of minerals under pressure and temperature.
2) Origin and evolution of planetary interior.
3) Developments of extreme conditions and measurements in-situ.

Our research interests are in the change of materials under extreme conditions of high pressure, high/low temperature and occasionally strong magnetic field. Such conditions are generally realized in the planetary interiors in nature. Most materials change their physical and chemical properties drastically in the planets. For example, phase transition, crystal structure, density, elastic constants, electrical and magnetic properties, bonding nature and chemical reaction with coexisting phase are important clues for the geophysical modeling of the planets. These are affecting the global structure, evolution and dynamics from the core to the surface. We generate extreme conditions in the laboratory by using various techniques of high-pressure generation (multi-anvil apparatus, laser-heated diamond anvil cell, laser shock), then cook high-density materials and look with various in-situ observation techniques of X-ray diffraction (synchrotron), imaging, spectroscopy, electrical measurement and magnetic measurements. Through these laboratory-based experiments, we strive for the comprehensive understanding of the planetary system and materials in the world.



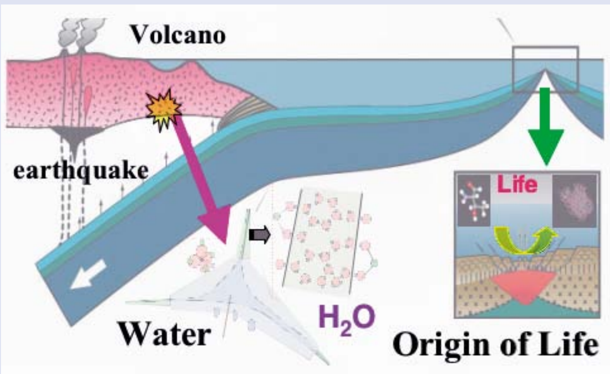
Department of Earth and Space Science

Physical Geochemistry Group

Members Satoru NAKASHIMA (Professor), Osamu HISATOMI (Associate Professor), Tetsuro HIRONO (Associate Professor), Makoto KATSURA (Assistant Professor), Tadashi YOKOYAMA (Assistant Professor)

[Research Area]

1) Water-rock-organic interactions.
2) Predictive sciences for the Earth's resources and environments.
3) Material sciences of earthquakes and faults.
4) Biophysics.



On the surface of the Earth, diverse dynamic processes are occurring such as tectonics, volcanisms, earthquakes, resource accumulation, and environmental pollution. These are results of complex interactions of water, inorganic (mineral), and organic substances. We are elucidating mechanisms, rates and time scales of these interactions. Also, we are investigating the molecular machinery of bio-molecules. By these interdisciplinary studies, we are trying to construct a new scientific framework for the complex real natural world.

Department of Earth and Space Science

Experimental Astro & Planetary Physics Group
(Institute of Laser Engineering)

Members Hideaki TAKABE (Professor), Youichi SAKAWA (Associate Professor)

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[Research Subject]

1) Strong Shock Wave Physics in Universe.
2) Mechanism of Cosmic-Ray Acceleration.
3) Non-LTE(local thermodynamic equilibrium) Plasma Physics.
4) Meteor-Impact Physics.

A very famous astrophysicist once said that Astrophysics is a discipline that aims to understand mysterious phenomena with the use of physics verified by experiments. It has become possible to realize the extremely high temperatures and pressures in the laboratory to study extreme phenomena like the explosion in the Universe, meteor impact, and so on. We try to study the physics of shock formation of SNR(super-nova remnant) and particle acceleration, and X-ray heating of accretion disk of Black Holes by modeling in the laboratory. This is a pioneering work and we are going to demonstrate how this method with large laser system is essential in Astrophysics. The group consists of theoreticians (Takabe, Kato, Wang) and experimentalists (Sakawa, Kuramitsu). We corporate and do joint experiments with scientists in the world, and more than 50 physicists in Japan.

Figures: Left is Gekko-XII laser system and right is the explosion in vacuum chamber in irradiating lasers