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 Earth and space, and (2) the origin and properties of matter. Most graduate students major in physics in the School of Science. The student capacity of the department is 28 per year. The entrance examination is held in conjunction with the Department of Physics. The Department of Earth and Space Science conducts forefront research in the following three major areas: (1) Astrophysics and Planetary Science, (2) Earth and Planetary Material Science and (3) Extreme Material Science. The related disciplines are basic astrophysics, X-ray and infrared astrophysics, planetary and geophysics, and condensed matter physics, as well as biophysics.

The following is a list of faculty members.

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Photograph of the entrance lobby. The wall design symbolizes the evolution of life and the birth of new Earth and Space Science from physics in the microscopic world. The floor is covered with Precambrian granite (2.2 billion years old). The wall design employs "stromatlite" formed by cyanobacteria (1.8 billion years old) and "wave-rippled sandstone" (1.2 billion years old). Let us listen to the sound of Precambrian waves.

Department of Earth and Space Science

Theoretical Astrophysics Group

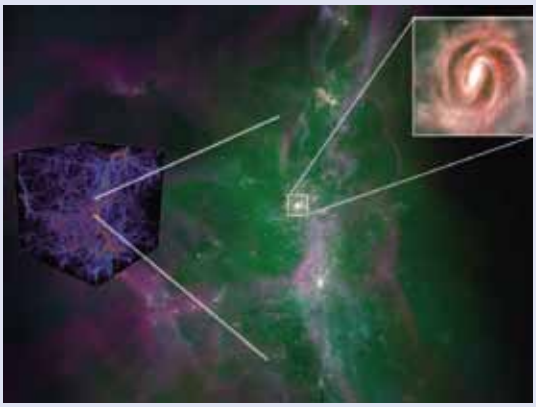
Members Kentaro NAGAMINE (Professor), Yutaka FUJITA (Associate Professor), Kengo TOMIDA (Assistant Professor), Isaac SHLOSMAN (Visiting Guest Professor), Luca BAIOTTI (Adjoint specially-appointed Associate Professor), Kazunari IWASAKI (Specially-appointed Assistant Professor)

Home Page http://vega.ess.sci.osaka-u.ac.jp/indexE.html

[Research Area]

1) Structure Formation and Cosmology (large scale structure in the Universe, intergalactic medium, galaxy formation, clusters of galaxies, cosmic magnetic fields)
2) High Energy Astrophysics (gamma-ray bursts, active galactic nuclei, cosmic jets, origin of cosmic rays, particle acceleration)
3) Formation of Astrophysical Bodies (planets, stars, galaxies, supermassive black holes)
4) Gravitational Wave Astronomy

It is widely believed that our Universe was born about 14 billion years ago in an event with infinitely high temperature and density, the so-called "Big Bang." As the Universe expanded and cooled, various forms of matter were created, and the structures such as stars and galaxies emerged. Various astrophysical phenomena in extreme conditions take place, such as supernova explosions, black hole formation, gravitational wave emission, gamma-ray bursts and cosmic ray acceleration. Our research group studies a wide range of topics using various methods ranging from pure fundamental physics, astrophysical models, computer simulations, and data analyses. The main objective of our research is to understand various astrophysical processes that took place during the course of cosmic evolution.



Department of Earth and Space Science

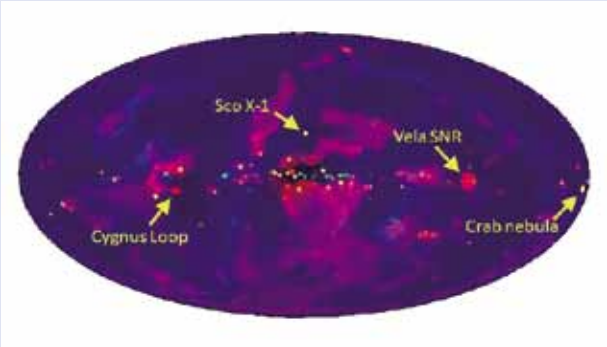
X-ray Astronomy Group

Members Hironori MATSUMOTO (Professor), Kiyoshi HAYASHIDA (Associate Professor), Hiroshi NAKAJIMA (Assistant Professor)

Home Page http://www.ess.sci.osaka-u.ac.jp/english/english/3_research/

[Research Area]

1) Observational study of hot plasma such as supernova remnants and clusters of galaxies
2) X-ray study of compact objects such as black holes
3) Developments of instruments for X-ray imaging spectroscopy and X-ray polarimetry



Our universe is prevailed by an optically thin hot plasma. For example, X-ray emitting hot gas in clusters of galaxies occupies a substantial fraction of the luminous matter in the system. 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 X-ray observations of the hot universe using various satellites: Chandra, XMM-Newton, and MAXI. Analyses of the data obtained in with Suzaku and Hitomi satellites are also important subjects of our activity. We have developed X-ray CCD cameras for Suzaku, MAXI and Hitomi. We are now developing a new type X-ray spectral imagers for future applications. Development of X-ray polarimeters and a new concept X-ray interferometry is also included in our activity.

Department of Earth and Space Science

Planetary Science Group

Members Kentaro TERADA (Professor), Chiaki UYEDA (Associate Professor), Chihiro YAMANAKA (Associate Professor), Yosuke KAWAI (Assistant Professor)

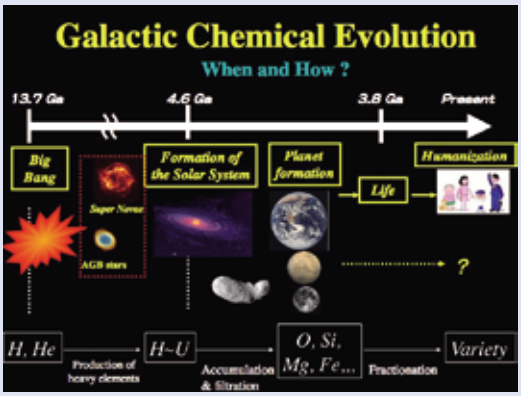
Home Page http://www.ess.sci.osaka-u.ac.jp/english/english/3_research/groups/g04terada.html

[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

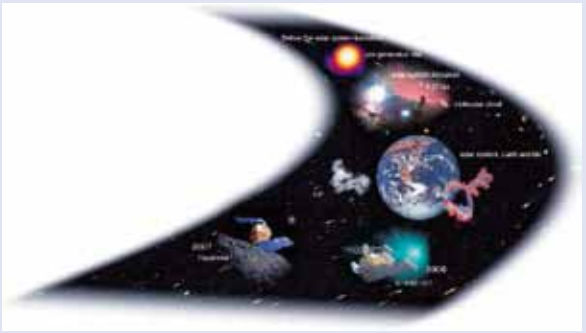
Members Sho SASAKI (Professor), Osamu OHTAKA (Associate Professor), Kazuto SAIKI (Associate Professor), Jun KIMURA (Assistant Professor)

Home Page http://www.ess.sci.osaka-u.ac.jp/english/english/3_research/groups/g07sasaki.html

[Research Area]

1) Formation and evolution processes of solid planets, satellites, and solar system small bodies.
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) Developments of apparatus and techniques (e.g., microtomography using synchrotron radiation, three-dimensional image analysis, hyperspectoral telescope, etc.).
4) Dynamic process for geologic activity on planetary bodies.
5) 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

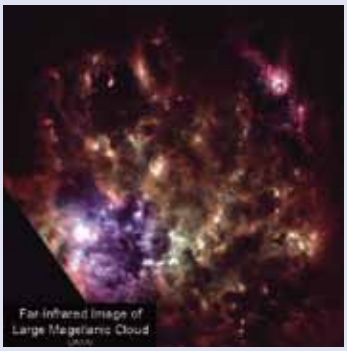
Members Hiroshi SHIBAI (Professor), Takahiro SUMI (Associate Professor), Taro MATSUO (Assistant Professor)

Home Page http://www-ir.ess.sci.osaka-u.ac.jp/index_e.html

[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 detectied Jovian and Neptune-mass extrasolar planets and are exploring Earth -mass planets.



Department of Earth and Space Science

Theoretical Condensed-Matter Physics Group

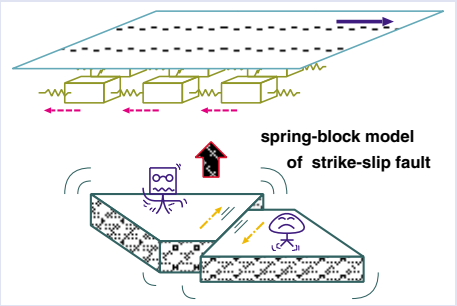
Members Hikaru KAWAMURA (Professor), Satoshi YUKAWA (Associate Professor), Kazushi AOYAMA (Assistant Professor)

Home Page http://www.ess.sci.osaka-u.ac.jp/english/english/3_research/groups/g03kawamura.html

[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

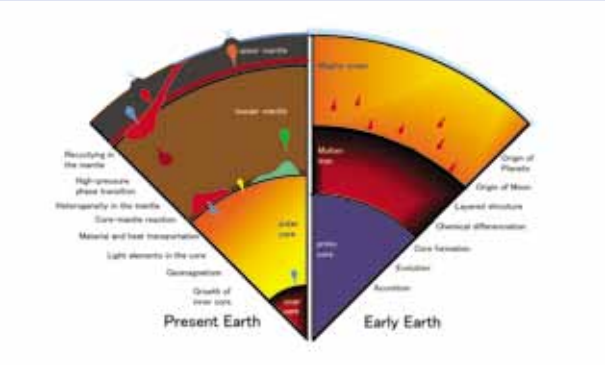
Members Tadashi KONDO (Professor), Toshifumi TANIGUCHI (Associate Professor), Hidenori TERASAKI (Associate Professor), Tatsuhiro SAKAIYA (Assistant Professor)

Home Page http://anvil.ess.sci.osaka-u.ac.jp/intro/English/index.html

[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

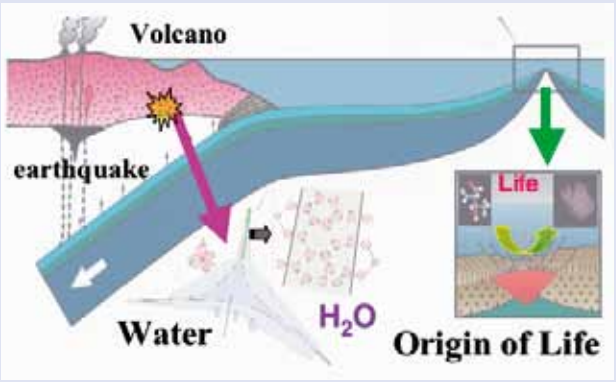
Members Satoru NAKASHIMA (Professor), Osamu HISATOMI (Associate Professor), Tetsuro HIRONO (Associate Professor), Makoto KATSURA (Assistant Professor),

Home Page http://life.ess.sci.osaka-u.ac.jp/HP/nakashimalab.e.html

[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

Laser astrophysics Group

(Institute of Laser Engineering)

Members Mitsuo NAKAI (Professor), Youichi SAKAWA(Associate Professor), Keisuke SHIGEMORI(Associate Professor)

Home Page http://www.ile.osaka-u.ac.jp/research/lap/

[Themes]

1) Astrophysical(colliionless) shock and particle acceleration (cosmic ray acceleration):
2) Experimental study on interior of Earth/Planets, and meteorite impacts with high-power laser
3) Nuclear science frontier cultivated byultrahigh-intensity laser
4) Relativistic plasma physics etc.

Astrophysics explains the variety of astrophysical phenomena with the physics verified on the earth. However, since mostof the astrophysical phenomena are those of non-equilibrium, multi-hierarchy, and complex systems which are realized under the extremely high-energy density environments, sophisticated computer simulations are carried out in order to understand the physics.Recent development of high-power lasers made it possible to simulate the astrophysical phenomena under the high-energy density condition, which has never been accessed in the laboratories before, and to verify the validity of those computer codes.

By realizing the extremely high temperatures, densities, and intense fields in the laboratory utilizing the various high-power lasers with international collaboration, we mimic the astrophysical phenomena like the explosion in the Universe, particle acceleration and magnetic filed generation/amplification at collisionless shock, meteor impact, ultra-high pressure relevant to interior of planets, relativistic plasmas, and astrophysical nuclear synthesis by bright gamma-ray flush.

High-energy GEKKOXII(right) and ultrahigh-intensityLFEX (left) laser system at ILE, Osaka University.