

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 the list of our faculty members.



Professor:

Hikaru KAWAMURA	(kawamura@ess.sci.osaka-u.ac.jp)
Tadashi KONDO	(tdskondo@ess.sci.osaka-u.ac.jp)
Sho SASAKI	(sasakisho@ess.sci.osaka-u.ac.jp)
Hiroshi SHIBAI	(shibai@ess.sci.osaka-u.ac.jp)
Takahiro SUMI	(sumi@ess.sci.osaka-u.ac.jp)
Kentaro TERADA	(terada@ess.sci.osaka-u.ac.jp)
Satoru NAKASHIMA	(satoru@ess.sci.osaka-u.ac.jp)
Kentaro NAGAMINE	(kn@astro-osaka.jp)
Takahiro HATANO	(hatano@ess.sci.osaka-u.ac.jp)
Hironori MATSUMOTO	(matumoto@ess.sci.osaka-u.ac.jp)
Mitsuo NAKAI	(mitsuo@ile.osaka-u.ac.jp)
(Collaborating Institute)	
Isaac SHLOSMAN	(shlosman@astro-osaka.jp)
(Visiting Guest Professor)	

Associate Professor:

Chiaki UYEDA	(uyeda@ess.sci.osaka-u.ac.jp)
Osamu OHTAKA	(ohtaka@ess.sci.osaka-u.ac.jp)
Kazuto SAIKI	(ksaiki@ess.sci.osaka-u.ac.jp)
Toshifumi TANIGUCHI	(ttani@ess.sci.osaka-u.ac.jp)
Hidenori TERASAKI	(terasaki@ess.sci.osaka-u.ac.jp)
Kiyoshi HAYASHIDA	(hayasida@ess.sci.osaka-u.ac.jp)
Osamu HISATOMI	(hisatomi@ess.sci.osaka-u.ac.jp)
Tetsuro HIRONO	(hirono@ess.sci.osaka-u.ac.jp)
Yutaka FUJITA	(fujita@astro-osaka.jp)
Chihiro YAMANAKA	(yamanaka@ess.sci.osaka-u.ac.jp)
Satoshi YUKAWA	(yukawa@ess.sci.osaka-u.ac.jp)
Shoichiro YOKOTA	(yokota@ess.sci.osaka-u.ac.jp)
Youichi SAKAWA	(sakawa-y@ile.osaka-u.ac.jp)
(Collaborating Institute)	

Assistant Professor:

Kazushi AOYAMA	(aoyama@ess.sci.osaka-u.ac.jp)
Makoto KATSURA	(mhirai@ess.sci.osaka-u.ac.jp)
Yosuke KAWAI	(ykawai@ess.sci.osaka-u.ac.jp)
Jun KIMURA	(junkin@ess.sci.osaka-u.ac.jp)
Tatsuhiko SAKAIYA	(tsakaiya@ess.sci.osaka-u.ac.jp)
Kengo TOMIDA	(tomida@astro-osaka.jp)
Noriko NAKAYAMA	(nnakayama@ess.sci.osaka-u.ac.jp)
Hirofumi NODA	(noda@ess.sci.osaka-u.ac.jp)
Taro MATSUO	(matsuo@ess.sci.osaka-u.ac.jp)

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<http://www.ess.sci.osaka-u.ac.jp/english/index-e.html>

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 "stromatolite" 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.

Theoretical Astrophysics Group

Members Kentaro NAGAMINE (Professor), Yutaka FUJITA (Associate Professor), Kengo TOMIDA (Assistant Professor), Isaac SHLOSMAN (Visiting Guest Professor)

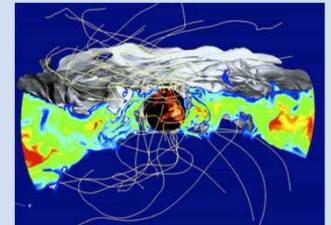
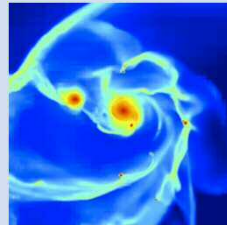
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[Research Area]

- 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, cosmic rays, particle acceleration)
- 3) Formation of Astrophysical Bodies (planets, stars, galaxies, black holes)
- 4) Gravitational Wave Astronomy

It is widely believed that our Universe was born about 14 billion years ago in 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 galaxy formation, supernova explosions, black hole formation, gravitational wave emission, and gamma-ray bursts. Various methods are adopted, ranging from fundamental theory, 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.



X-ray Astronomy Group

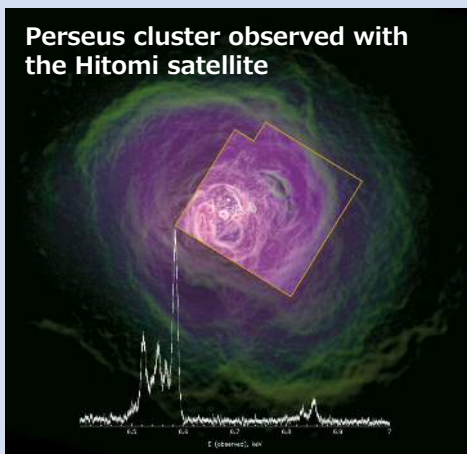
Members Hironori MATSUMOTO (Professor), Kiyoshi HAYASHIDA (Associate Professor), Hirofumi NODA (Assistant Professor)

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[Research Area]

- 1) Observational study of high-energy phenomena in the universe
- 2) Developments of instruments for X-ray astronomy

Perseus cluster observed with the Hitomi satellite



High-energy phenomena can be seen everywhere in the universe. For example, a star explodes as a supernova at the end of its life, and leaves hot gas of a temperature of a few tens of millions of Kelvins. The hot gas is called a supernova remnant, and it is luminous in X-rays. Black holes and neutron stars are thought to be born in supernovae. The gravity of these compact objects is extremely strong, and they can emit X-rays when they accrete gas. Almost all galaxies harbor a gigantic black hole at their centers. Some of them accrete interstellar gas and emit X-rays as active galactic nuclei. Clusters of galaxies, the largest gravitationally bounded system in the universe, are filled with hot gas, and they can be observed through X-rays.

We are performing X-ray observations of the hot universe using X-ray astronomical satellites in the world such as Suzaku, Hitomi, MAXI, Chandra, XMM-Newton, and so on. We have developed X-ray CCD cameras for Suzaku, MAXI and Hitomi. We are now developing new X-ray instruments for future applications.

Planetary Science Group

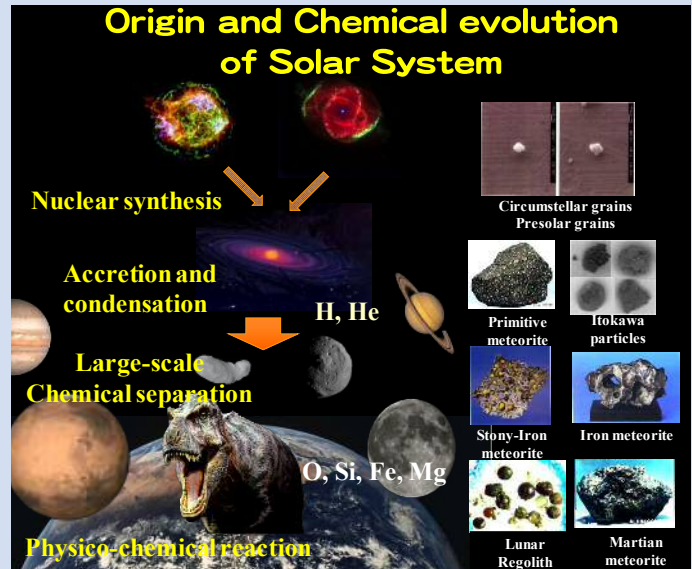
スタッフ Kentaro TERADA(Professor), Chiaki UYEDA(Associate Professor), Chihiro YAMANAKA (Associate Professor), Shoichiro YOKOTA(Associate Professor), Yosuke KAWAI(Assistant Professor)

ホームページ <http://planet.ess.sci.osaka-u.ac.jp>

[Research Area]

- 1) Origin and evolution of the Solar System.
- 2) The magnetic properties of magnetic & weak magnetic planetary materials.
- 3) Observation of the planetary environment by the laser spectrometry
- 4) Plasma measurements around planets and moons.
- 5) Development of the technique/instrument for a new frontier of planetary science.

To decipher the history of the Solar System, 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, other various meteorites and circum-stellar dusts. We also conduct in-situ plasma observation including mass analyses by spacecraft to study the environments around planets and moons. The three-dimensional non-destructive analysis using “muon” is developed for the planetary science.



Earth and Planetary Materials Science Group

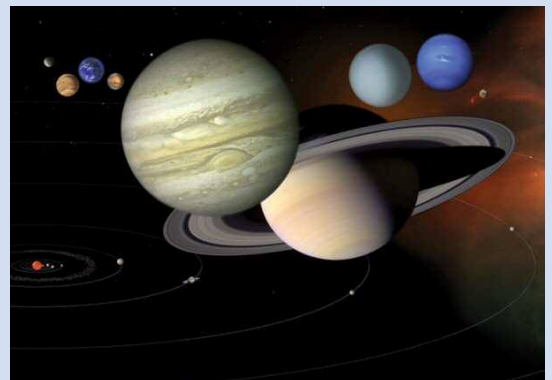
Members Sho SASAKI (Professor), Osamu OHTAKA (Associate Professor), Kazuto SAIKI (Associate Professor), Jun KIMURA (Assistant Professor)

Home Page <http://www.astroboy-jp.com/>

[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., in-situ observations under high pressure, hyperspectral imager, three-dimensional image analysis and space weathering apparatus, etc.).
- 4) Dynamic process for geologic activity on planetary bodies.
- 5) Material sciences and instrument developments in space missions (e.g., HAYABUSA-2, SLIM, MMX, JUICE).

The Earth, planets, satellites and other objects in the Solar System 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 spacecrafts and ground observations, theoretical simulations and experimental methods, we investigate the origin and evolution of various solar system bodies from dust particle to planets.



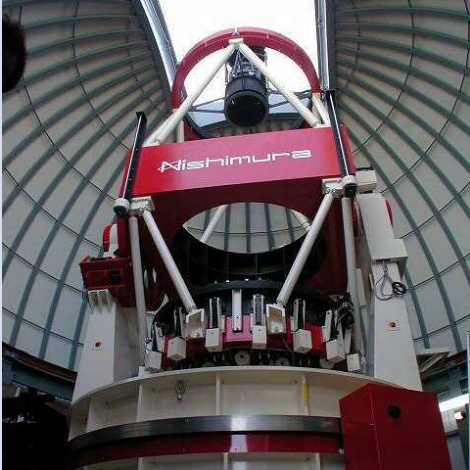
Infrared Astronomy Group

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

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

[Research Area]

- 1) Observational study of Exoplanets
- 2) Astrobiology
- 3) Observation of gravitational wave event
- 4) Galactic structure and dark matter



We study various astrophysical phenomena by using ground and space telescopes in infrared and develop related instruments. Especially, we focus on the formation of exoplanets and aim to find a bio-signature in exoplanets in future. We also conduct optical follow-up observations of gravitational wave events, studies of the Galactic structure and dark matter.

We search for exoplanets by using the 1.8m MOA-II telescope with the gravitational microlensing technic. We also construct the 1.8m telescope in South Africa to conduct the microlensing exoplanet search in infrared. We are exploring Earth-mass exoplanets. We are planning to join to NASA's WFIRST mission to carry out the space microlensing exoplanet search. We are also developing the ultra stable spectrograph to detect the biosignature in exoplanets for future space missions.

Theoretical Condensed-Matter Physics Group

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

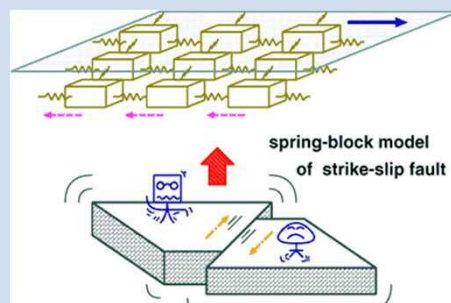
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[Research Area]

- 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. Unified understanding of a variety seismic slips including slow slips such as silent earthquakes, afterslips and nucleation process.
- 2) Statistical physics of frustration. Study of the ordering of frustrated magnets with strong geometrical frustration such as pyrochlore and kagome magnets.
- 3) Study of the ordering process and slow dynamics of random and/or glassy systems. Phase transitions and slow dynamics of spin glasses, with particular interest in the chirality.
- 4) 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, magnets in particular, 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.



High-pressure Material Physics Group

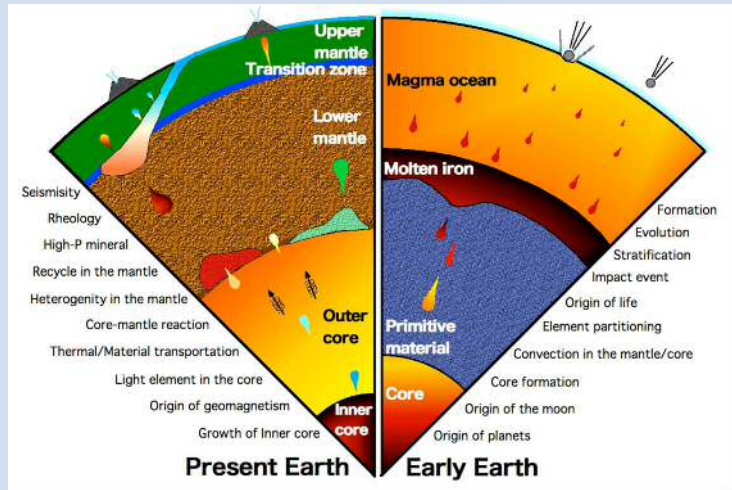
Members Tadashi KONDO (Professor), Toshifumi TANIGUCHI (Associate Professor),
Hidenori TERASAKI (Associate Professor), Tatsuhiro SAKAIYA (Assistant Professor)

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

[Research Area]

- 1) Phase transition and mineral physics in the mantle.
- 2) Formation, light elements, physical properties of the core.
- 3) Early Earth & planets, satellite and their evolution.
- 4) In-situ observation under High P-T condition.
- 5) Development of High P-T generation & measuring.

Our research interests are in the change of materials under ultra-high pressure and high/low temperature corresponding to the planetary interiors. Most materials change their physical and chemical properties drastically in such extreme conditions. For example, crystal structure, density, elastic properties, electrical and magnetic properties, bonding nature and chemical reaction with coexisting phase are important clues for the geophysical modeling and understanding the evolution of the planets. We generate various P-T fields in the laboratory by using various techniques of high-pressure generation (both static and dynamic), with various in-situ observations and recovery analysis. Through these laboratory-based experiments, we aim to understand comprehensively planetary system and components from the point of view of material science.



Interesting issues in the present Earth and early Earth

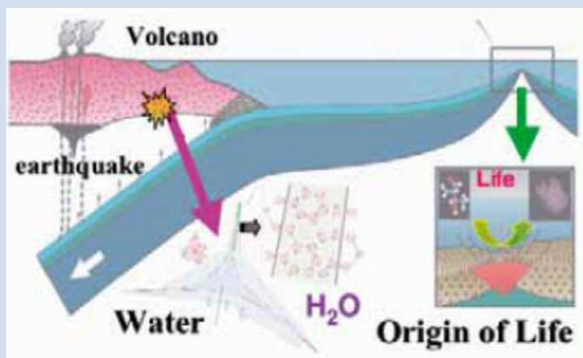
Physical Geochemistry Group

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

Home Page <http://life.ess.sci.osaka-u.ac.jp/>

[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.

Laser Astrophysics Group (Institute of Laser Engineering)

Members

Mitsuo NAKAI (Professor), Youichi SAKAWA (Associate Professor)

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<http://www.ile.osaka-u.ac.jp/research/lap/>
[Research Area]

- 1) Astrophysical (collisionless) shock and particle acceleration (cosmic ray acceleration)
- 2) Relativistic plasma physics
- 3) Explore the frontier of nuclear science with ultra-intense lasers

Astrophysics studies the variety of astrophysical phenomena using the physics knowledge experimentally obtained on Earth. Since most of the astrophysical phenomena are in the non-equilibrium / multi-hierarchy complex systems and occur under extremely high-energy-density environments, such phenomena have never been accessible in the laboratories before.

By realizing extremely high temperatures, densities, and intense fields in national and international laser facilities through international collaboration, we mimic the conditions of astrophysical phenomena to understand the underlying physics.



High-energy GEKKO XII (right) and ultrahigh-intensity LFEX (left) laser systems at ILE, Osaka University.

