4th grade, 2024
Themes of
Graduation Research-Experiments and
Graduation Research-Theoretical Studies

●On the 4th grade assignment to laboratories

Note that the maximum number of G30 students who are accepted to each laboratory is 2.

【Graduation Research-Experiments】

A student who selects the experimental course is assigned to an experimental laboratory and performs experiments for a year about one of the themes that the laboratory provides.

The number of students that each laboratory accepts in 2024 is as follows.

Particle Physics		Astrophysics		Condensed Matter Physics		Biophysics	
F	4	A	6	I	6	D	4
N	6	Uir	4	J	4	G	6
Φ	6	Uxg	4	V	2	K	4
μ	2			Y	4		
				O	2		

Heliospheric and Geospace Physics*	
AM	7
CR	
SS_E	
(SS_T†)	
SW	

†SS_T laboratory is a theoretical laboratory.

*The laboratories (AM, CR, SS_E, SS_T, and SW) on the Heliospheric and Geospace Physics accept a total of 7 students. The wish of students for the assignment of laboratories in this field is reflected as much as possible. However, if there is a bias in the number of applicants, it may be adjusted. Within the above limit on the total number of students, CR and SS_T can accept 5 students at maximum, and the other laboratories can accept 3 students.

AM, CR, SS_E, and SW laboratories are experimental laboratories, and SS_T laboratory is a theoretical laboratory.

【Graduation Research-Theoretical Studies】

A student who selects the theoretical course is assigned to a theoretical laboratory and studies for a year about a theme related to the researches of the laboratory.

The number of students that each laboratory accepts in 2024 is as follows.

B	6	QG	4	Ω	2
C	4	R	4	SS_T	Accept as Heliospheric and Geospace Physics
E	9	Sc	6		
H	4	St	4		
P	4	Ta	4		

Themes of
Graduation Research-Experiments in 2024

Particle Physics

●F laboratory (Fundamental Particle Physics Laboratory)

Since 1980's, we have been carrying out researches for elementary particles physics with nuclear emulsion,which can individually record tracks of elementary particles in sub-micron accuracy. In 2000, for example, we succeeded to find tau neutrino for the first time in the world and established the existence of muon neutrino to tau neutrino oscillation in 2015.

The following are the themes of our current studies. We are also making efforts to develop and improve detectors related to particle physics and astrophysics to promote these themes.

F-1 Study of neutrino physics

The existence of neutrino mass was confirmed by the observation of neutrino oscillation. However, many characteristics are still unknown such as absolute value and hierarchy of mass. Does right-handed neutrino exist? Is the neutrino Majorana particle? Is the CP-violating phase in the lepton sector non-zero? Tackle these challenging issues.

F-2 Directional dark matter detection

NEWSdm is the experiment for dark matter (WIMPS) search with ultra-fine grain nuclear emulsion, which is possible to detect the very short trajectory of the recoil atom caused by collision of with nucleus and dark matter. The goal is to demonstrate its existence and incoming direction of dark matter. This experiment is being started at Gran Sasso Laboratory in Italy. We also promote experimental research to explore the possibilities of dark matter candidates other than WIMPS.

F-3 Balloon borne gamma-ray telescope

Unknown gamma-ray sources exist in Universe such as galactic center gamma-ray excess. To investigate these objects, we promote the GRAINE project, which is balloon-borne gamma-ray telescope with the world's largest diameter ultra-high resolution nuclear emulsion telescope.

We are currently analyzing the Australian flight data in May 2023 and are aiming to observe at the world's highest resolution of gamma-rays imaging. We are also developing emulsion telescopes with the aim of achieving even higher sensitivity and resolution.

F-4 Development of particle detectors based on technologies including nuclear emulsion's

We will progress with development of detectors based on nuclear emulsion technology.
Example 1) Detection of unknown short-range force: detection and measurement of wavefunctions of neutrons using ultra-fine grained nuclear emulsion.
Example 2) Development of automatic readout system for nuclear emulsion (speeding up, improvement of image detection)
Example 3) Production of nuclear emulsion from chemical substances and its development.

●N laboratory (High Energy Physics Laboratory)

N-1, N-2, N-3, N-4 Experimental Particle Physics

The goal of particle physics is the understanding of fundamental principles of elementary particles and their interactions. According to the Standard Model (SM), six quarks and six leptons are the fundamental constituents of the matter, and their interactions are mediated by the gauge bosons such as the photon and the W bosons. The SM explains the origin of particle masses by the Higgs mechanism. The N laboratory contributed to the verification of the SM; we confirmed the Kobayashi-Maskawa theory that explains the asymmetry between particles and antiparticles, and more recently discovered the Higgs boson. Now, the researches at the N laboratory focus on the searches for physics beyond the SM. We promote "Super B-Factory Experiment", "LHC-ATLAS Experiment", and "Muon g-2/EDM Experiment". Our research would answer some of the fundamental questions in the Universe, e.g. "What is the Dark Matter?" and "How is the present matter-dominated Universe produced?".

The courses prepared for the fourth-grade students are shown in the following.

N-1 Super B-Factory Experiment

The B-factory experiment uses the KEKB collider located at the High Energy Accelerator Organization in Japan. The N laboratory played a leading role in the observation of CP violation in B meson decays, which verified the Kobayashi-Maskawa mechanism. Now, we are searching for physics beyond the SM via precision measurements of the B-meson and tau-lepton decays at the Super-KEKB collider, which provides 30 times higher luminosity than the KEKB. Research topics for students include analyses of data obtained at KEKB and Super-KEKB colliders and their simulation studies. The researches utilize high-quality computers owned by the N laboratory.

N-2 LHC-ATLAS Experiment

The LHC-ATLAS experiment is held at CERN located at Geneva, Switzerland. Proton-proton collisions are provided with the highest energy in the world. The N laboratory played a leading role in the development and the operation of the muon detectors, which were essential for the observation of the Higgs boson. We measured the top quark properties, studied the origin of muon mass, and searched for supersymmetric particles. Further searches for physics beyond the SM are ongoing. The students are expected to learn the basics of the LHC-ATLAS experiment through the development and the operation of the muon detectors as well as the analyses of the data.

N-3 Muon g-2/EDM Experiment

The g-2 is the anomalous magnetic dipole moment, a fundamental parameter of particle physics. The current measurement of muon g-2 is deviated from the SM prediction, which would be a hint of the physics beyond the SM. Aiming for more precise measurement with different sources of the systematic uncertainties, the N laboratory is preparing for a new experiment using the muon beam of the J-PARC accelerator at the High Energy Accelerator Organization in Japan. The students are expected to contribute to the development of a new system of the transportation and the diagnostics of the muon beam, a key element of the experiment.

N-4 Advanced Experimental Techniques

Frontiers of particle physics have been explored by advanced experimental techniques. In the N laboratory, a new particle detector called “TOP counter” was developed and installed for the super B-factory experiment. The TOP counter identifies the particle types by precise measurements (10 pico-second order) of Cherenkov photons generated in the quartz radiator. New photon detector for the TOP counter upgrade is under study. For the LHC-ATLAS experiment, a new attempt is ongoing for detecting the signatures of the physics beyond the SM by combinations of FPGA and machine learning. We also work on the techniques of muon acceleration, big data analysis, and applications of machine learning to data analyses and particle identifications. The students can contribute to these researches, which will possibly play essential roles in future discoveries.

●Φ laboratory (Laboratory of Particle Properties)

Experimental approaches to elementary particle physics can be categorized into two criteria: (1) direct observation of high energy particle reactions using high-energy accelerators (2) indirect observation of high energy phenomena in precision measurement of the contribution of higher-order quantum-loops of high-energy phenomena in low-energy processes. In the Phi-lab., slow neutrons from the most luminous pulsed neutron source at J-PARC (Japan Proton Accelerator Research Complex) will be mainly used to probe the properties of elementary particles. We also use muon beam. The following is out list of on-going research items. We encourage students to consider to invent new approaches and welcome motivated students.

Φ-1 Neutron Decay Rate (Lifetime)

Neutron decay rate is a key parameter to define the weak interaction for quarks and also the primordial nucleosynthesis. Its experimental accuracy is still insufficient for precise verification of theoretical models. We are going to improve our understanding by improving accuracy and to search for non-standard interactions.

Φ-2 Study of the breaking of the symmetry under spatial-inversion and time-reversal in neutron-induced compound nuclei

Large violation of the symmetry between matter and antimatter is required in order to explain our universe. We are now studying the enhancement of the symmetry breaking in neutron-nuclei reactions. The search for the symmetry breaking in some reactions is independent of and competitively sensitive to that of neutron EDM. We are also developing some techniques for neutron spin control, polarization of target nuclei, and high-speed neutron detection to improve the sensitivity beyond standard model of particle physics.

Φ-3 Breaking of Time Reversal Symmetry (Neutron Electric Dipole Moment)

Neutron does not have the electric dipole moment (EDM) as long as the time-reversal symmetry is a valid symmetry. In reality, any non-zero value of neutron EDM has been measured so far. However, the asymmetry between matter and antimatter in the universe implies a finite value of EDM. The determination of neutron EDM is one of the most important observables to find a clue to the origin of the asymmetry. Extremely slow neutrons, that are sufficiently slow to be confined in bottles, are commonly applied for improving experimental sensitivity to the neutron EDM. We will study to apply precision neutron optics for measurements of neutron EDM. We are also trying to search the neutron EDM by measuring the effects of neutron wave through the non-centrosymmetric crystal.

Φ-4 Exotic Medium-range Forces (including extra-dimensions)

Gravitational interaction has been known to us before the physics was established, but least known in elementary particle physics due to its extraordinary weakness. However, the motion of slow neutrons apparently affected by geo-gravity since the neutral first order electromagnetism is missing for neutrons, that is electrically neutral. The advantage will be applied in the search for exotic medium-range forces including the search for possible effects of extra-dimensions and dark energy.

Φ-5 Muonium Hyperfine Structure

Muonium is an atom that consists of a positive muon and an electron. Its hyperfine structure can be analyzed theoretically due to the simple system only with two leptons. Ultra-precise spectroscopy of the hyperfine structure can be used to verify the standard theory of particles physics. Muonic helium, which is a helium atom with one negative muon instead of a electron, can be also used to study the fundamental symmetry of physics through its hyperfine structure.

In addition to above research items, we study “search for the violation of baryon number conservation law (also B-L violation) in neutron anti-neutron oscillation”.

●μ laboratory (Laboratory of Cosmic-Ray Imaging)

In this laboratory, we are developing a technology for non-destructive imaging of the interior of huge man-made structures and natural objects such as pyramids and volcanoes by visualizing cosmic-ray muons (cosmic ray imaging) with a track detector such as a nuclear emulsions. We are developing a nuclear emulsion, which is a technology for detecting cosmic rays, as well as application research specific to the visualization target of cosmic ray imaging, and furthermore, social implementation of the technology. We welcome students with a broad range of interests and motivation that are not bound by the existing framework of physics.

μ-1 Development of basic technology for cosmic ray imaging

We will develop fundamental technologies for cosmic ray imaging: 1. development of new nuclear emulsions with long term stability required for cosmic ray imaging by introducing technologies such as organic chemistry, 2. development of simulation technologies for cosmic ray imaging, 3. Development of technology to reconstruct three-dimensional density distribution of observed objects.

μ-2 Development of survey techniques for archaeological sites such as pyramids

Since 2015, we have been promoting the ScanPyramids project to explore the unknown internal structure of the pyramids in Egypt. We have discovered two unknown cavities inside the pyramid of Khufu, and we will continue to study the pyramid of Khafra and other pyramids as new research targets. We are developing new survey methods that do not damage archaeological sites all over the world, such as the temple pyramids of the Mayan civilization in Central and South America, including Honduras and Guatemala, and the Greek underground ruins in downtown Naples, Italy.

μ-3 Development of technologies for underground structure exploration and inspection of social infrastructure, including civil engineering structures

In recent years, cave-ins caused by underground cavities, river bank breaches caused by torrential rains, and aging social infrastructures have become social problems, and we are developing technologies to prevent such accidents by visualizing the interior of underground structures and civil engineering structures using cosmic ray imaging. These researches need to be carried out in cooperation with research institutes specializing in the visualization target, local governments and companies that have problems, and the development will be carried out with a view to social implementation.

μ-4 Development of new targets for cosmic ray imaging

We will develop new investigation targets, such as diagnosis of trees and deterioration of bridges, internal visualization of the giant volcano Mt. Fuji and so on.

Astrophysics

●A laboratory (Radio Astronomy Laboratory)

Understanding how stars and galaxies formed and have been evolved across the Hubble time is one of the biggest challenges in modern astrophysics. We are trying to address those big questions by millimeter / submillimeter observations of interstellar gas and dust in the Milky Way and external galaxies far away.

A-1 Submillimeter-wave observations of distant galaxies in the early universe

Distant star-forming galaxies which are rich in interstellar medium, such as gas and dust, give off a vast amount of energy in the far-infrared, which is cosmologically-redshifted and can be observed in the submillimeter wave in the present-day Universe. Students will exploit a series of multi-wavelength data, especially those taken with the ALMA submillimeter telescope, to investigate how star-formation and supermassive black hole growths are going in galaxies from the epoch of reionization (~100 million years after the Big Bang) to the present day. The students will learn data analysis techniques and radiative processes of interstellar media and study the physical properties of gas and stars in galaxies.

A-2 Development of instruments for the next-generation radio telescopes

Our research includes development of technologies for the next-generation submillimeter telescopes; (1) development of millimetric adaptive optics for instantaneously correcting radio wavefront disturbed by atmosphere and deformation of telescope optics, (2) development of data-scientific method to design the structure of a telescope, and (3) development of ultra-wideband spectrometers for high-redshift galaxy surveys, especially in terms of signal processing and data analysis software. We also plan to install those instruments on existing radio telescopes, such as the Nobeyama 45 m telescope, the ASTE 10 m telescope in Chile, and the 50 m Large Millimeter Telescope in Mexico. The students will join one of the projects and learn instrumentation basics.

A-3 Submillimeter-wave and microwave observations and data analyses of molecular and atomic clouds in the Galaxy and nearby galaxies.

Revealing the distribution and nature of the molecular and atomic gas clouds in the Galaxy and nearby galaxies is important for understanding formation of stars, planets and their birth clouds. For this sake, students join observations of spectral lines of molecules (e.g., CO, OH) and atoms (e.g., hydrogen and carbon), by using the NANTEN2 4 m submillimeter telescope we are operating in Atacama, Chile (remotely) and/or JAXA's Usuda 64 m microwave antenna in Nagano (on site) to learn how the telescope system works. The students will also learn how to analyze the data taken for the Galactic Center, high-latitude diffuse gas clouds, low/high mass star forming regions, supernova remnants, a Galactic micro-quasar, and nearby galaxies, etc.

A-4 Developments of the multi-beam heterodyne receiver system and software

In order to enhance NANTEN2's capability exploiting the good sky transparency in Atacama, we develop a new multi-beam receiver system and related software for telescope control and data analysis. We also develop cryogenic microwave receivers and data analysis software for the Usuda 64m antenna. Students will join development of those instruments, such as receivers, spectrometers, and software for instrument control and data analysis.

●U laboratory (Space Astronomy Laboratory)

U-1, 2, 3, 4 Infrared Astrophysics (Uir)

The main purpose of our research is to understand the properties of dust grains and gas under various environments in galaxies through near- to far-infrared observations using space-borne and ground-based telescopes. We have developed a far-infrared imaging spectrometer for AKARI, a Japan-led infrared astronomical satellite. (U-1) We are analyzing AKARI data, in addition to other space and ground-based infrared observational data extensively, to pursue the above scientific researches. We are responsible for producing AKARI all-sky diffuse maps in the mid-infrared, which are uniquely designed to trace the distribution of organic matter in the interstellar space. (U-2) We are developing cryogenic optics and mid-/far-infrared detectors for future infrared astronomy satellite projects. (U-3) We are developing a near-infrared spectrometer as a new focal-plane instrument for the IRSF 1.4 m telescope in South Africa. We are also developing a far-infrared spectrometer to be carried aboard the balloon-borne 1 m telescope in India.

(U-4) Search for life in the universe toward understanding of the life.

More than 5000 planets have been discovered since 1995. Some of them may harbor life. To search for life in the universe, we will perform spectroscopy of the atmospheres of the planets orbiting nearby stars. This study aims to identify the life we search for by investigating how life co-evolved with Earth for 3.8 billion years. To establish the path to the search for life, we also develop a balloon-borne infrared interferometer with NASA Goddard Space Flight Center. A formation-flying interferometer using multiple small satellites will be realized with the space engineers of the Univ. of Tokyo.

U-5 Development of new instruments for X-ray and MeV gamma-ray astronomy (Uxg)

Universe is filled with hot and energetic phenomena, emitting strong X-rays. As these photons cannot penetrate earth's atmosphere, X-ray observation requires observatories in orbit. We are developing new devices to improve cosmic X-ray and MeV gamma-ray observations, such as; new X-ray telescope technology, innovative thermal control membrane technology, new hard X-ray imaging spectrometer and future sub-MeV Compton camera. Research on MeV gamma-ray emission from thundercloud is also on-going.

U-6 Observational X-ray astronomy (Uxg)

Using existing X-ray observatories and those to be launched soon, we are analyzing the X-ray observational data of high energy celestial objects, such as: stellar flares, Galaxy X-ray emission, Clusters of galaxies, black holes, neutron stars and others..

Condensed Matter Physics

●I laboratory (Solid State Magnetic Resonance Laboratory)

The Solid State Magnetic Resonance Laboratory aims to elucidate the universal physical laws governing the physical properties of materials using nuclear magnetic resonance (NMR), a microscopic measurement method.

As NMR can detect with high sensitivity small changes in the electron's orbit, spin, charge state, and local structure, using NMR, we can observe from the nuclear site closest to the electrons the properties of matter.

From the obtained results, we can know the origin of the ground state and the excited state of the matter.

In this laboratory, fourth-year students learn how to proceed with experimental research through research on the following research themes and study how to understand the physical properties of various kinds of matter based on quantum mechanics, statistical physics, and electromagnetism.

I-1 Magnetism of strongly correlated electron systems

Many-body effects in electronic systems are one of the problems to solve in solid-state physics. The novel physical phenomena found so far emerge in which the internal degrees of freedom of electrons, such as charge, spin, and orbit, are intertwined due to strong electron-electron interactions. Examples include quantum spin liquids, the quantum Hall effect, superconductivity, and exciton insulators. We synthesize and evaluate samples of transition metal compounds in which 3*d*, 4*d*, and 5*d* orbital electrons play a role, measure macroscopic physical properties, and measure microscopic physical properties mainly using NMR.

I-2 Physical properties of various superconductors such as iron-based superconductors

The iron-based superconductor discovered in 2008 has attracted attention as a new superconducting material with a superconducting mechanism different from metal-based superconducting materials and the high-Tc cuprate superconductors, and its superconducting mechanism and orbital state have been studied. Many researchers are interested in the physical properties of broken rotational symmetry. In addition, we will conduct everything from synthesis to macroscopic and microscopic physical property measurements of various transition metal chalcogenides/pnictides, and investigate the relationship between spin fluctuations/orbital fluctuations, which are thought to be the origin of the superconductivity.

I-3 Superfluid

Helium-3 and helium-4 are liquid that does not freeze no matter how cold it is and behave as quantum liquids at low temperatures. This ordered state is superfluid, and much research has been carried out to date. It is expected that by confining this helium in nanopores with a size of 10 to the power of -9 meters and controlling the motion of helium in low dimensions, a new helium quantum fluid will emerge. We will measure the thermal properties and magnetism in this state and investigate the ground state of this new quantum fluid.

I-4 Development of NMR measurement technology

The unique physical properties of strongly correlated electron systems often appear under extreme conditions, and it is necessary to perform NMR measurements at high pressures, high temperatures, high magnetic fields, and extremely low temperatures. Therefore, we will develop NMR probes that can be used under these conditions, increase the sensitivity of NMR equipment, and develop NMR data analysis. Furthermore, we are developing cutting-edge technologies such as "Optically Detected Magnetic Resonance," which uses light to control and detect the states of nuclear spin and electron spin. These technologies have the potential to lead to the material design of new superconductors with higher transition temperatures, and to the core technology of quantum computers and MRI (magnetic resonance imaging) that surpass conventional performance.

●J laboratory (Laboratory of Nanomagnetism and Spintronics)

The group's research focus is on nanoscale magnetism and spin related effects, aiming at discovering novel concepts in condensed matter physics. Research study in nanostructures allows us to address the challenging questions in the field of spin-related phenomena by artificially designing and fabricating nanostructures. A number of remarkable new physical effects have been already discovered by designing artificial interfaces, where strong electron-phonon-spin coupling emerges at nanoscale. Quite the opposite, revealing the physics underlying provides a fundamental basis and means for manipulating the physical phenomena. In this course, you will be trained in state of the art techniques such as growth of nanoscale materials, fabrication, and magnetic and transport measurements, and will enjoy the superb flavor of condensed matter physics. The group's current research programs are divided into the following key themes.

J-1 Cross-correlations in multiferroic heterostructures

J-2 Spin dynamics in heterostructures with topological textures

J-3 Magnon propagation in exchange-biased heterostructures

J-4 Static and dynamic spin phenomena in artificial antiferromagnets

J-5 Electron correlations at magnetic/superconducting interfaces

●O laboratory (Optical physics laboratory)

O laboratory is a new group which starts from fiscal year 2024. Our research theme is the understanding of the physical properties and functions of condensed matters by developing state-of-the-art experimental apparatus based on the laser technology. We will construct new angle-resolved photoemission spectroscopy with focused monochromatic laser, in order to observe the fine electronic structures. By employing this system, we will obtain the information of the energy, momentum, spin and orbital of the electrons in the strongly-correlated electron systems and high-transition-temperature superconductors. Furthermore, it will be also available to detect the electronic states in a small region less than 1 μm, such as the self-organization of the strongly-correlated electrons and strange metallic behavior at the magnetic domain wall. At this time, we don't have our own experimental apparatus at Nagoya university, but we are going to keep constructing new photoemission spectroscopy system with undergraduate students. Please join our laboratory if you are interested in optical physics and apparatus development. During the apparatus development at Nagoya university, you will have experimental themes below by using shared photoemission spectroscopy at University of Tokyo and synchrotron radiation facilities. In this research program, you will obtain the skills of laser, vacuum and low-temperature measurements. We hope you enjoy the optical physics with originality and ingenuity.

O-1 Development of the photoemission spectroscopy with focused monochromatic laser

O-2 Electron pairing in the unconventional superconductors

O-3 Normal-state electronic structure of the high-transition-temperature superconductors

●V laboratory (Laboratory of Condensed-Matter Physics of Functional Materials)

We are interested in the sample syntheses and precise measurements for useful and interesting materials. Our research field covers a wide variety of functional properties in correlated electron systems; a large thermoelectric power in transition-metal oxides, nonlinear conduction phenomena in organic conductors, and magneto-dielectric behavior in novel low-dimensional materials. Basic understanding of electromagnetism, thermal/statistical physics, and quantum mechanics is prerequisite for graduate research. Typical subjects are listed below:

V-1 New physical phenomena from competing orders

V-2 Search for colossal responses in new semimetals

●Y laboratory (Materials Response Laboratory)

Our group focuses on various response properties of materials, including the dielectric response, the optical response, the magnetic response, the thermal response, and the mechanical response. Based on their fundamental mechanisms clarified from a viewpoint of the structure-property relationship, we address designing of functional materials, which lead innovation in science and technology. Current themes in our lab are listed below:

Y-1 Environmentally-friendly functional dielectric materials

Y-2 Novel ferroelectric materials

Y-3 Novel properties in quasicrystals

Y-4 Search for new quasicrystals and approximants

Biophysics

●D laboratory (Laboratory of Biomolecular Dynamics and Function)

Proteins are inherently dynamic molecules that undergo structural changes and interactions with other molecules over a wide timescale range, from nanoseconds to milliseconds or longer. Furthermore, protein motions play various important biological roles on assembly into protein complexes, ligand binding and enzymatic reactions. Therefore, understanding the dynamic behavior of a protein is a requisite for gaining insight into their function mechanisms. We develop novel methods for directly observing proteins' dynamics based on high-speed atomic force microscopy (HS-AFM), which is one of scanning probe microscopy, and exploit new paradigm of dynamic structural biology. Also we analyze structural dynamics of rhodopsin at atomic resolution using X-ray crystallographic technics for understanding the molecular mechanism and creating new functional GPCRs.

D-1 Direct observation of dynamic behavior of biological molecules and elucidating theirs function mechanisms

Unique functions of proteins are often elicited by global conformational changes after local ones due to environmental change, ligand bind and molecular interactions. We observe the conformational dynamics of molecules such as motor and membrane proteins with HS-AFM and elucidate molecular mechanisms of the protein's functions.

D-2 Developments of novel microscopy techniques for single-molecule biophysics

In biological molecules, not only structures but also local electric and mechanical properties play crucial roles for physiological functions. We develop novel functions of HS-AFM enabling local mapping of various properties in addition to topography of biological molecules. Further we develop combined systems of HS-AFM with state-of-art single-molecule imaging techniques such as single-molecule fluorescence microscopy towards analysis of more complex biological systems.

D-3 Development and Application of Novel Methods for Dynamic Mechanical Properties of Artificial Polymer Materials

HS-AFM has recently attracted attention as a technique for investigating the nanoscale structure and mechanical properties of artificial supramolecules, polymer gels, and polymer films. We study the mechanical stability of polymer particles and their water dispersions (synthetic latex) with sizes ranging from several tens of nanometers to several micrometers, and the control factors of particle degradation in response to multiple stimuli by nanoscale measurement using high-speed AFM.

D-4 X-ray structural biology of rhodopsin

We perform structural analysis on conformational dynamics of rhodopsin during the photocycle using advanced synchrotron radiation and newly developed X-ray free-electron laser to understand the molecular mechanism of activation rhodopsin. We also challenge to create novel functional rhodopsins on the basis of these accurate structures.

●G laboratory (Photo-Bioenergetics Laboratory)

Proteins are extremely elaborate 'nano-devices' that have been formed during evolution for 4 billion years. Photosynthesis performed by plants and cyanobacteria realizes light-energy conversion with an extremely high quantum yield using a number of pigments and metal ions embedded in proteins. To understand this most basic and significant biological process, it is necessary to clarify the mechanisms of light-energy conversion in the photosynthetic 'nano-devices'. In our laboratory, we investigate the molecular mechanisms of the reactions in photosynthetic proteins using various physical methods such as vibrational spectroscopy, electron spin resonance, and quantum chemical calculations. Students in the 4th grade challenge their own research themes mastering basic experimental and analytical techniques, like preparations of biological samples, spectroscopic measurements, and analyses using computer calculations.

G-1 Mechanism of light-energy conversion in photosynthetic proteins

In photosynthesis, successive processes of light absorption, excitation transfer, charge separation, electron transfer, and proton transfer take place upon light illumination in the time scale from femtoseconds to milliseconds. It is also possible to trap the intermediate states after charge separation at cryogenic temperatures. The molecular mechanism of light-energy conversion in photosynthesis is investigated by detecting reactions and intermediates in photosynthetic proteins using various spectroscopic methods.

G-2 Molecular mechanism of photosynthetic oxygen evolution

The mechanism of photosynthetic oxygen evolution remains to be the biggest mystery in photosynthesis researches. Although oxygen evolution is known to be performed by water oxidation at the Mn_4CaO_5 cluster in photosystem II protein complexes, the detailed reaction mechanism has not been well understood. We challenge the clarification of water oxidation mechanism utilizing spectroscopic methods such as infrared spectroscopy and electron spin resonance.

●K laboratory (Laboratory of Cellular Signaling Biophysics)

Our laboratory aims at understanding the mechanisms of the information conversion and communication occurring in biological systems at the molecular and cellular levels. We focus on the mechanisms of protein folding / complex formation as the research at the molecular level (K-1). We also focus on the mechanisms of communication between nerve cells at the synapse as the research at the cellular level (K-2). The specific aims and the details of the research are described below.

K-1 Protein folding mechanisms

Proteins are biological macromolecules consisting of a series of amino acids, and indispensable in almost all aspects of biological phenomena. Proteins play their roles in biological systems only after they form their own specific three-dimensional structures and often multimeric complex. The conversion from an ensemble of the unstructured conformations without biological functions to the specific native structures is referred to as protein folding. There are many questions to be addressed in their physicochemical mechanisms although the protein folding / assembly is important in that these phenomena are associated with biology as well as molecular science. For the purpose of addressing the questions, our laboratory studies the mechanisms of proteins folding / assembly by means of our own ultrarapid mixing devices and spectroscopy. The details of the course are molecular biology to construct variant proteins, expression and purification of proteins, spectroscopic measurements of proteins and kinetic measurements of protein folding / assembly.

K-2 Research on the mechanism of synaptic transmission

In the nervous system, communications between nerve cells are executed through chemical synapses. In the presynaptic process, inflow of Ca^{2+} through Ca^{2+} channels opened by an action potential triggers the exocytosis of neurotransmitter through the fusion of synaptic vesicles with presynaptic membrane. When nerve is repeatedly stimulated, the amount of transmitter released gradually increases. This phenomenon, synaptic plasticity, is essential for higher function of brain as memory and learning. You study about the presynaptic mechanism and its regulation, especially modulation of transmitter release and dynamics of divalent cations, with the preparation of frog neuromuscular junction synapses using electrophysiological methods and ion-imaging techniques.

Heliospheric and Geospace Physics

●AM laboratory (Atmospheric and Environmental Science Laboratory)

The atmospheric environment on the Earth has been affected by various anthropogenic causes of human activities since the industrial revolution, including the recent increase of greenhouse gases and the depletion of the ozone layer. On the other hand, the atmosphere is also affected by a variety of natural causes, such as changes in UV radiation and solar wind associated with the solar activities, galactic cosmic rays from space, and volcanic activities on the Earth. In order to predict the future atmospheric environment more accurately, it is necessary to clarify the mechanisms and effects of the atmospheric changes by the natural and anthropogenic factors. In AM Laboratory, we use state-of-the-art millimeter-wave (radio) and infrared remote sensing techniques to study the mechanism of atmospheric changes through ground-based observations and laboratory experiments. We welcome motivated students to face the environmental issue and to study the atmospheric science, based on their knowledge and skills of physics.

AM-1 Study the influence of solar activity on the Earth's atmosphere by using the observed data of trace gas in the polar regions

Atmospheric molecules having electric dipole moments emit spectral lines in the millimeter wavelength through the rotational transitions. We have been conducting long-term observations of trace gas molecules at Syowa Station in Antarctica and Tromsø (Norway) in the Arctic region. In the 4th-grade experiment, students will develop data analysis programs for these observations and analyze the data to clarify the actual situation of variability of the trace gases in the polar region. In addition, students will work together with the research group on the magnetosphere and ionosphere to reveal the impact of energetic particles on the composition in the polar middle atmosphere.

AM-2 Study on variations of trace molecules such as greenhouse gases by infrared spectroscopic observation

The atmospheric minor constituents such as greenhouse gases, a primary cause of climate change, have many absorption lines in the infrared region. Our group, in collaboration with the National Institute for Environmental Studies, has been operating large high-resolution Fourier transform infrared spectrometers (FTIRs) in Nagoya and Hokkaido, and has obtained the altitude distribution of various minor constituents from solar absorption spectral data. In the 4th-grade experiment, students will study changes in the atmospheric environment and their causes by analyzing the altitude distribution and temporal variation of greenhouse gases and air pollutants. In addition, we will develop analysis software and perform actual observations using infrared spectroscopic instruments such as FTIR.

AM-3 Development of the next generation instruments for the millimeter-wave atmospheric observation

The atmospheric emission lines in mm-wave are often very faint, and the use of superconducting receiver with ultra-low noise is essential to obtain the data with a sufficient signal-to-noise ratio. We have developed a multi-frequency observation system in collaboration with a research group at National Astronomical Observatory of Japan (NAOJ) and succeeded in simultaneous ground-based multi-molecular-line observations at 230 GHz and 250 GHz bands for the first time in the world at Syowa Station. We are also about to start development of a planar integrated superconducting receiver for multi-beam observations. We hope that motivated students will participate in these developments and get a part of creating the world's first observation instruments.

AM-4 Study of global composition change of trace gases by using satellite observation dataset and model simulations

By using the ground-based instruments, we can continuously observe the temporal change of the trace gases, but spatially, observable only above a fixed point on the Earth. On the other hand, by using satellite sensors in orbit around the Earth, we can acquire data above various locations on the Earth, but the observing time over a certain point on the Earth is a very short period while the satellite passes over that point. Thus, ground-based and satellite-based observations are complementary, and in order to capture global-scale phenomena more accurately, it is effective to utilize various satellite data and model simulations to combine and/or to compare with the ground-based data. This 4th-grade experiment aims to develop tools to read and visualize the satellite and simulation datasets, and to promote the combined use with ground-based observation data, as well as to develop new analysis methods for atmospheric composition change using so-called AI such as machine learning and deep learning.

●CR laboratory (Cosmic-Ray Physics Laboratory)

Cosmic rays are high-energy elementary particles, such as protons, gamma-rays, neutrinos and so on, coming to the earth from the space. Cosmic-ray protons also can probe interstellar magnetic fields and solar activity. We carry out experimental cosmic ray physics where two cutting-edge fundamental research fields, particle physics and astrophysics, cross over. Students with wide-scope of interests those who are fascinated by both of particle physics and astrophysics are encouraged to be enrolled in our CR-lab.

In graduated course of CR-lab, we conduct various projects of experimental cosmic ray physics such as gamma ray astronomy by Fermi and CTA, neutrino physics in Super-Kamiokande and WIMP dark matter search by liquid xenon in XENONnT, LHCf ; study of high energy cosmic ray interactions at LHC, study past solar energetic events by measuring cosmogenic nuclides such as radio carbon-14 in ancient tree rings, and so on. Related to these activities, 4th degree of students in our under-graduated course participate one of following independent topics to learn basic knowledge and techniques for experimental particle physics. In addition to these experimental efforts, we perform a seminar to read following text books in "journal club" style; "Cosmic Rays" by Minoru Oda, Shoka-bou (in Japanese), "Astroparticle Physics" by D.Perkins, (Oxford Univ. Press). We are also making an effort to promote data science education to give lectures on data analysis or to develop machine learning based data analysis.

CR-1 Direct dark matter searches by using liquid xenon detector at XENON and DARWIN

Dark matter, accounting for most of gravitational potential of the universe, is considered as WIMP, a yet undiscovered elementary particle. A liquid xenon TPC detector is the most promising technique to discover dark matter WIMP. Students will participate in activities of newly started XENONnt dark matter experiment and various detector development for a future 40-ton liquid xenon detector DARWIN by developing a homemade liquid xenon detector to learn/study cryogenic system or new ultra-violet photo-sensors, and basic of direct dark matter experiments.

CR-2 High-energy astrophysics and dark matter search with gamma-rays at CTA and Fermi

Origins of cosmic rays can be studied with a neutral messenger particle such as gamma rays or neutrons since those particles are not bent by cosmic magnetic field. Students participate in development of a new Silicon photosensors to be used for the Cherenkov Telescope Array project or future gamma-ray satellites, and also participate in searches for dark matter or studies of acceleration mechanism of cosmic rays in cosmic-ray accelerator candidates such as supernova remnants or supermassive blackholes using Fermi satellite data.

CR-3 Neutrino physics/astronomy using a large water Cherenkov detector.

Neutrino is a neutral particle with tiny mass and left-handed-only, which may connect to mysterious history of the early universe and baryogenesis. Students will participate to data analysis of Super-Kamiokande, a gigantic water Cherenkov detector, to study neutrino physics and neutrino astronomy. Students also may work on a new photo-sensors or develop analysis tools based on machine learning for future Hyper-Kamiokande currently being built.

CR-4 Hadronic interactions of ultra high energy cosmic rays.

The very high energy interactions by highest energy cosmic rays having 10**20 eV can be studied at LHC or at RHIC with a very forward angle detector LHCf/RHICf. Students can join the data analysis of such a very high energy intractions taken by LHCf/RHICf experimetns or develop a detectors used for future measurements, and also participate to Monte Carlo simulation study of high-energy cosmic ray air-showers in the atmosphere.

CR-5 Past cosmic rays activity probed by cosmogenic radiocarbon-14 and belilium-10.

Cosmogenic nuclide; radioisotopes produced by cosmic rays in the atmosphere, is an unique tool to understand past activity of cosmic rays and solar cycles at even >1000 years ago. Radiocarbon-14 in tree rings or belilium-10 in the ice-core of Antarctica can be used to search for past extreme solar events or nearby supernova or past solar cycles. Variation of cosmic ray intensity a few 1000 years ago. Students participate data analysis of radiocarbon-14 to study ancient cosmic ray burst events, or variability of past solar activity.

●SS$_E$ laboratory (Space Science Experiment Laboratory)

The outer space near the Earth and planets are consists of multi-type regions, as represented by the ionosphere/plasmasphere/magnetosphere, where numerous physical mechanisms are emerging. For instance, the solar wind/intrinsic magnetic field/atmospheric plasma/neutral atmosphere/lower atmosphere are interacting in complex ways, producing the auroras in the polar regions and the substorms/storms widely in the magnetosphere. Since these physical processes are fundamental and universal not only in our solar system but also in the distant universe, it brings us with comprehensive understandings on the space/Earth/planets to demonstratively elucidate the phenomena and their variations occurring in the near-Earth space that we could explore directly and precisely and the other various regions, e.g., the upper atmospheres and their space environment surrounding the planets in the solar system. In our SS_E laboratory, we have been conducting experimental studies based both on the intensive/worldwide ground-based observations and the space explorations through innovative developments of state-of-the-art science instruments.

For more details, please visit "https://www.isee.nagoya-u.ac.jp/en/research/study03.html".

SS_E-1 Measurement technique innovation/data analyses on space plasma explorations

Our group has been leading several space exploration missions for the research of the fundamental processes and physical mechanisms in the space coupling with the terrestrial/planetary environment by applying in-situ (direct) observation techniques to spacecraft/satellites. In this subject, some experimental studies will be conducted in order to innovatively develop new types of plasma particle analyzers for the future space missions in our particle beamline facilities. The construction and renewal of the facilities/equipment in a clean room are also required in our research and development. As another subject, the physical mechanisms in the terrestrial/planetary boundary regions adjacent to the space could be studied by the plasma data analyses in the space missions.

SS_E-2 Study of upper mesosphere and lower thermosphere

The upper mesosphere and lower thermosphere (70-120 km in altitude) is influenced significantly by atmospheric waves (tides, gravity, and planetary waves), and then the temperature and wind vary with time/altitude. Furthermore, solar wind energy comes into and disturb the atmosphere there. We study such variations using EISCAT, MF, meter radars and a sodium lidar operated in northern Scandinavia. Fourth-grade students will learn the observational tools and basic atmospheric dynamics, and study scientific topics using data obtained with the radars and lidar.

SS_E-3 Observations of diffuse aurora and energetic electron precipitation

Aurora is characterized by various temporal variations and spatial patterns. In the diverse morphology, recent studies have revealed that "diffuse aurora", which has obscure spatial structures, associates with several MeV (relativistic) electrons capable of penetrating deep into the atmosphere. These electrons reach approximately 60 km altitude, going through the auroral emission altitude (100-300 km), and generate anomaly ionization and ozone depression in the mesosphere. This study leads integrated observations with cameras, radars, radio wave receivers and satellites in Scandinavia and North America and proceeds resourceful analyses of measurements in order to disclose the physical mechanism behind the auroral morphology and the energetic electron precipitation.

SS_E-4 Global observations of upper atmosphere using radio and optical instruments

Atmospheric waves excited by disturbances in the polar upper atmosphere, such as auroras, propagate into middle and low latitudes and cause global-scale disturbances in the upper atmosphere. In this study, we use high-sensitive optical instruments to capture faint light, called "airglow", emitted from the upper atmosphere, and worldwide GPS data to clarify the mechanism of disturbances in the upper atmosphere. Disturbances in the ionospheric plasma in the upper atmosphere degrade satellite broadcasting, communications, and GPS positioning. We are conducting a research to mitigate such influences.

●SW laboratory (Heliospheric Plasma Physics Laboratory)

The solar wind is a supersonic (300-800 km/s) plasma flow emanating from the Sun, creating a huge region called the heliosphere. There are many unsettled questions on the solar wind; e.g. the mechanism for solar wind acceleration, global structures of the heliosphere, and responses to the solar activity. We intend to elucidate these questions from observations of interplanetary scintillation (IPS) with large radio-telescopes developed by our laboratory. The IPS observations of SW laboratory is able to derive 3D properties of the solar wind. Taking advantage of IPS observations, the following subjects are studied in our laboratory, and students are able to acquire skills for system development and programing through the graduation research.

SW-1 Solar wind acceleration

The magnetic field of the Sun is considered to play an important role in accelerating the solar wind. In our laboratory, we investigate relation between the solar wind acceleration and magnetic field properties of the corona by comparing between IPS and solar-magnetograph observations. We also tackle this issue by comparing with in situ observations obtained near the Sun.

SW-2 Origin of solar wind

The solar wind is composed of fast and slow streams. Whereas the fast solar wind is considered to originate from the coronal hole associated with rarefied and cool plasma, the origin of the slow wind remains an open question.

In our laboratory, we intend to elucidate the origin of the slow solar wind by combining between solar observation stellate "Hinode", IPS, and magnetograph observations.

SW-3 Propagation dynamics of solar wind disturbances and improvement of space weather

Disturbances of the solar wind impose significant influences on the space environment and the upper atmosphere around the Earth, and sometimes cause serious damages to infrastructure of our society. Therefore, social needs are growing for predictions of the arrival of solar wind disturbances at the Earth. In order to improve the accuracy of space weather predictions, we investigate propagation process of solar wind disturbances from assimilating with IPS data and simulations and comparing with in situ observations. In addition, practical applications of this system to the real-time space weather operations are under development with space weather forecasting centers.

SW-4 Development of the next generation radio telescope

The radio telescopes developed and operated by our laboratory is one of the largest radio astronomy telescopes in Japan, with a dimension of about 100 m. We are developing new radio telescopes to lead the next-generation heliosphere researches. Students can join developments of phased array antennas, digital signal processing systems, and control / data analysis software that enables us to acquire the latest observation data.

Themes of
Graduation Research-Theoretical Studies in 2024

●B laboratory seminar (Computational Biophysics Laboratory)

Structure, function and dynamics of biological molecules through simulations.

Biophysics is a field of study that aims to understand biological phenomena using the principles and tools of physics. Every living organisms must be following the laws of physics, however, due to their complexity, our understanding on biological systems is still limited.

B laboratory focuses on the studies of biological molecules such as proteins and nucleotides using computational techniques, often in collaboration with experimental groups. During the first part of the year, students will become familiar with computational techniques and biological systems through literature. In the second half, student will perform research on a specific project.

We use English in Tama group and English/Japanese in Yamato/Kimura group. For more information, please visit https://www.phys.nagoya-u.ac.jp/docs/pamphlet/B.pdf.

●C laboratory seminar (Cosmology Group)

Astrophysics Theory, especially Observational Cosmology

Recent observations reveal that the energy density in the Universe consists of 70% of dark energy, 25% of dark matter. The purpose of observational cosmology is to find effects of dark energy and dark matter on the evolution of the Universe and the formation of structures such as galaxies, clusters of galaxies, and large scale structure, and to understand the nature and beginning of the Universe through observable quantities. In the first term of this seminar, participants read a book written in English and learn the fundamentals of cosmology. In the second term, participants do numerical calculations and data analysis on cosmology and give presentations.

●E laboratory seminar (Theoretical Elementary Particle Physics Laboratory)

Relativistic quantum field theory

Purpose of this course is to study the relativistic quantum field theory, which is a basis of theoretical elementary particle physics. Text in this course will be chosen after the students attending this course discuss with tutors.

They have to learn following topics in quantum mechanics before the course starts: general theory of quantum mechanics, including the Schrodinger, Heisenberg, and interaction pictures, angular momentum, scattering theory, symmetry and conservation law, and perturbation theory.

The students in the course are also required to make a report about one of selected topics and present it at the end of this course.

● H laboratory seminar (Quark-Hadron Theory Group)

Fundamentals of quark-hadron physics

Aiming to learn the fundamentals of quark-hadron physics. In Fall semester, students will attend a seminar once or twice a week. In the seminar, students read a textbook and explain the main points of it in turn. The textbook will be decided based on the discussion among the students and instructors at the guidance. An example of the textbook is "An Introduction to Quantum Field Theory" written by Peskin & Schroeder. In Spring semester, students perform graduation studies. The topic of the study for each student is chosen from the discussion with faculties. Each student submits a report and gives a presentation for the graduation study. The credit is given by evaluating the attendance and the effort to the seminar and the graduation study including the final presentation and report. We expect that the students earned the credit of Quantum Mechanics I and II before the seminar starts. We can accept 4 students at most.

●P laboratory seminar (Theoretical Plasma Physics Laboratory)

Basic plasma physics

High temperature plasmas in space and fusion involve a variety of instabilities, turbulence, shocks, or relaxation processes which extend over a wide range of spatio-temporal scales. In the seminar it is aimed to master basic theories and methods for studying the plasma phenomena. In the first semester, an introductory text is used for learning fundamentals in plasma physics. The second semester is devoted to learning more advanced topics or numerical computations on plasma physics. It is also requested to submit a report on the product and to make a presentation.

●QG laboratory seminar (Gravity and Particle Cosmology Group)

In QG lab., main research topics are physical phenomena in which gravity plays an important role. The students in QG lab. will study general relativity and quantum theory in the curved space-time as fundamental tools to study those subjects. In fall semester, the students will study general relativity by using textbooks. In spring semester, the students will study about some specific theme, which will be determined by the discussion between the teaching staffs and the students. We will approve the credits by a report and presentation on the theme. We assume that the students could have mastered classical mechanics including analytical mechanics and special relativity, electromagnetism.

●R laboratory seminar (Theoretical Nonequilibrium Physics Group)

In the spring semester, we read representative textbooks on the subject, such as R. Zwanzig "Nonequilibrium Statistical Mechanics" (Oxford) or R. Kubo et al. "Statistical Physics II" (Springer) to master the basics of nonequilibrium/nonlinear physics. Like a journal club, a section or two will be assigned to every student and she/he is to give a "lecture" on the section(s) at the weekly gatherings. In the fall semester, the students learn more advanced subjects and undertake a small project, under the supervision of one of faculties, (K. Miyazaki and T. Kawasaki). The final report should be presented at the group colloquium at the end of the course. We accept not more than 4 students per year.

●S laboratory seminar (Theoretical Solid State and Statistical Physics Laboratory)

Condensed Matter Theory Group (Sc)

In metals, interesting quantum phenomena occur thanks to the electron correlations, such as the superconductivity (=Cooper pair formation) and various types of symmetry breaking phenomena. Recent topics of condensed matter physics are the unconventional (high-Tc) superconductivity, the electronic nematic/smectic orders, and the permanent charge/spin current orders due to the topological phase transition. The aim of this seminar is to learn the basis of the strongly correlated electron systems. In the first semester, the students study statistical physics and many-body physics by reading a textbook, such as "Statistical Mechanics" written by Feynman. In the second semester, each student selects his/her theme of graduation work on condensed matter physics, and studies it under the guidance of the staffs, by reading textbooks and scientific papers. At the end of the second semester, we have a presentation of graduation theses. The maximum number of acceptable fourth year students is six. Each student is required to have gotten the credits of Statistical Physics I and II.

Quantum Transport Theory Group (St)

Our research interest is in material physics that focuses on spin current (flow of spins) and topology of electrons' wave functions in solids. The former field is called spintronics and the latter topological quantum physics. Students in St Lab learn basic quantum statistical physics in the first semester, and apply it to some specific problems (graduation project) in the second semester. Each student writes a report on the project and gives a presentation around the end of the semester. We accept up to four students who are familiar with Quantum Mechanics and Statistical Physics.

●Ta laboratory seminar (Laboratory for Theoretical Astronomy & Astrophysics)

Faculty Member:
Shu-ichiro Inutsuka and Hiroshi Kobayashi

The theme of this seminar is to learn spectacular astronomical phenomena in terms of basic physics. It focuses on some of very recent topics in astrophysics. Students choose their own favorite topics and try to start introductory research. In the spring semester students mainly study the textbook subjects in the form of a group seminar, but in the fall semester they learn the basics of numerical analysis and try to investigate some of frontier subjects. Finally each student is required to give a summary presentation of the research. Choices of the research subjects are made in discussion between students and supervisors.

●Ω laboratory seminar (Laboratory of Galaxy Evolution)

A galaxy is a huge agglomeration of stars, interstellar medium, and dark matter, and in a cosmological scale, a unit structure of the large-scale structure in the Universe at the same time. While the spatial distribution of matter in the beginning of the Universe was almost homogeneous, namely there was not astronomical object like a galaxy, we observe tremendous number of galaxies with rich cosmological structures in the present-day Universe. Also, it is known that the heavy elements consisting the earth and life like ourselves were not produced by the Big-Bang nucleosynthesis in the early Universe. These elements have been produced at the center of stars through nuclear fusion, and injected into the interstellar space at the final phase of stellar life. Thus, how galaxies formed and evolved in the cosmic history is one of the most important topics in the astrophysics today.

In our laboratory, we aim at understanding the physics of the formation and evolution of galaxies through the cosmic age, based on the multiwavelength data analysis, theoretical models, and data-scientific methods such as machine learning. We provide the latest observational data for the graduation study, like for master or PhD students. We try to choose a theme which may be published as a research article as much as possible. Then, we want students who are enthusiastic to the theme and responsible for taking part of the international project.

●SS_T laboratory seminar (Solar and Space Physics – Theory Laboratory)

SST laboratory conducts the research to understand the solar and space environment as a single holistic system which consists of the Sun, the Earth, and the interplanetary space by using numerical simulation/modeling and in-situ data analyses. Research targets of SST laboratory are wide-ranging, e.g., solar activity such as solar flares and sunspots, solar wind and interplanetary space dynamics, geomagnetic phenomena such as aurora and geomagnetic storms, fundamental space plasma phenomena such as magnetic reconnection, and the development of numerical simulation method.

The solar and space dynamics driven by solar flares and magnetic storms impact not only artificial satellites and astronauts, but also social infrastructures such as aviation, communications, and power networks, and may cause "space weather disasters." It can also influence the global climate. In SST laboratory, we study not only to elucidates the mechanisms of various solar and space dynamics but also to predict them to mitigate space weather disasters.

In this laboratory, graduation research themes will be set based on each student's interests from the following topics, and we will hold a seminar to learn the basics of solar/stellar physics and space physics by reading a textbook. We will also provide training on computer usage and programming necessary for research.

Elucidation of the mechanism of solar flare and coronal mass ejections (CMEs) and space weather prediction

We will conduct research using theory and numerical simulations to understand the mechanism of solar flares and coronal mass ejections (CMEs), which may cause a space weather disaster, and to predict their onset through combination with analysis of observational data.

Radiative magnetohydrodynamic simulations of solar/stellar interior, surface, and wind

We will perform numerical simulations for solar/stellar turbulence, large-scale flows and magnetic field generation in the interior, sunspot formation on stellar surfaces, and chromosphere, corona, and solar wind toward solving significant problems in solar and stellar physics, including the 11-year cycle of magnetic activity, chromosphere and corona heating, and solar wind acceleration.

Solar flare research through the analysis of multi-wavelength observational data

We will study the physical processes on high-energy phenomena in solar flares, such as particle acceleration and plasma heating, through the analysis of multi-wavelength data observed with spacecraft and ground-based telescopes.

Solar flare and solar wind effects on the geospace dynamics such as aurora and space storms

Various disturbances in the Earth caused by solar flare and solar wind will be studied with the satellite data analysis and simulations. Such disturbances include the ionization of the atmosphere in 8 min caused by the X-ray and ultraviolet radiation, the increase of radiation flux in a few hours caused by the high-energy particles, and the magnetic storms, aurora substorms and plasma dynamics in geospace caused by the fast solar wind.