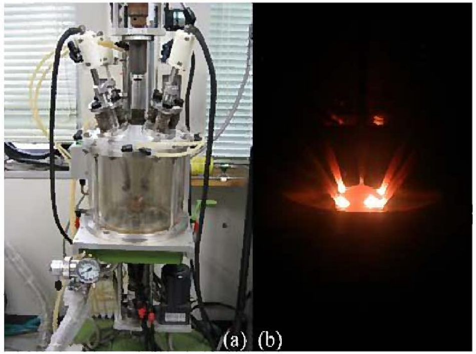
Physical Properties of Rare-earth and Transition-metal Intermetallic Compounds

Rare-earth and transition-metal intermetallic compounds show magnetically ordered states such as ferromagnetism and antiferromagnetism at low temperatures due to strong magnetic interactions between electrons. Among them, there exist materials in which electrons contribute to magnetic-ordering movements in solids and interact strongly with ligands and other electrons. These materials are known as 'strongly correlated electron systems'. Such materials show various interesting physical phenomena, for example, valence transitions, heavy fermions and superconductivity. To elucidate the origin of such interesting novel physical phenomena, we grow single crystals of various rare-earth and transition-metal intermetallic compounds and investigate their physical properties.



(a) Czochralski tetra-arc equipment. (b) A single crystal of $HoRh_2Si_2$ being grown by a Czochralski-pulling method (in the middle of necking processing).

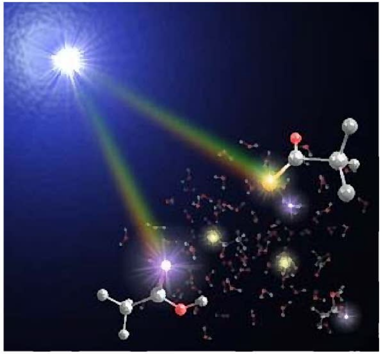
About Researcher

FUJIWARA Tetsuya, Ph.D.

Ph.D., 2003, Hiroshima University

The Electronic States of Liquid Molecules Probed by Soft-X-ray Spectroscopy

Our research interest is in understanding how the electronic structure of solute molecules changes due to hydrogen-bonding formation in solutions because interactions between solute and solvent molecules are important for everything from in-vitro chemical reactions to biomolecular structure in our body. For example, most organic-synthesis reactions occur in solutions and the reaction speed or efficiency depends upon the solution environment. Most biomolecules exist in aqueous solutions and solution-pH change leads to structural change of those molecules. We are working on developing a technique to observe the valence-electronic structures of molecules in solutions by means of soft-X-ray spectroscopy and focusing on the following three fields: 1) organic molecules in an aqueous solution; 2) hydrogen-bonding states of water in various environments and 3) the electronic states of ionic liquid under ambient conditions. In addition to the measurement study, we are also working on a quantum-chemical calculation to explain the observed results.



A conceptual drawing of the site-selective excitation of solute molecules in an aqueous solution

About Researcher

HORIKAWA Yuka, Ph.D.

Ph.D., 2010, Hiroshima University

WEB ≫ http://mms.sci.yamaguchi-u.ac.jp/~horikawa/index.html

Study of Structural Phase Transitions and Hydrogen Bonding in Organic Ferroelectrics and Related Materials

Ferroelectric materials are used for a variety of electric elements including, for example, capacitors, piezoelectric elements and pyroelectric infrared sensors. However most of these materials include toxic Pb or rare-metal atoms. Recently, organic ferroelectric materials composed of nontoxic, abundant and inexpensive elements have been developed. They also possess characteristic features in terms of flexibility and ease of processing.

In our laboratory, for the purpose of obtaining single crystals of new organic ferroelectric materials, experiments on pairing various organic bases having heterocyclic groups containing N atoms with organic acids have been performed. Hydrogen bonding is considered to play an important role in the appearance of ferroelectricity in organic ferroelectric materials. Therefore, structural changes in hydrogen bonds before and after paraelectric-ferroelectric phase transitions have been investigated by the use of X-ray diffraction, thermal analysis and the measurement of dielectric constants.

A four-circle X-ray diffractometer equipped with a CCD detector and sample-temperature controller.

About Researcher

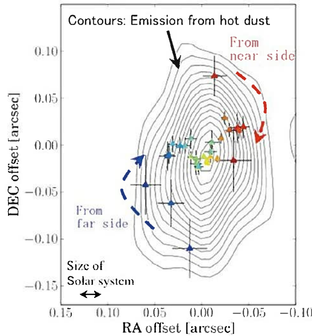
KASANO Hironobu, Dr.Sci.

Dr. Sci., 2005, Yamaguchi University

High spatial/time-resolution studies on high-mass star formation.

Our universe initially consisted of only three kinds of atoms (H, He, Li) just after the big bang. All the other atoms are considered to have been produced by high-mass stars, which are 8 (or more) times heavier than the sun, in two ways: (1) Thermonuclear reactions in the center of stars; (2) Supernova explosions at the end of the stellar life-time. Therefore, detailed studies on the high-mass star formation process are essential for understanding the chemical evolution of the universe.

We are studying how high-mass protostars evolve via mass accretion from the natal interstellar gas cloud using very high spatial/time–resolution radio observations. We use many radio interferometers all over the world, such as VLA, ATCA, VLBA and ALMA (see Figure 1), in order to obtain sensitive radio images. On the other hand, our own instruments, such as the Yamaguchi 32 m/34 m radio telescopes and Japanese VLBI network, are used for frequent monitoring observations in order to achieve very high time resolutions. The latter allows us to investigate dynamical activity around protostars we cannot resolve directly.



A radio image of G353.273+0.641 obtained using J-VLA and ATCA. The colored triangles indicate infalling gas clumps dragged in by stellar gravity (Motogi et al., 2017).

About Researcher

MOTOGI Kazuhito, Ph.D.

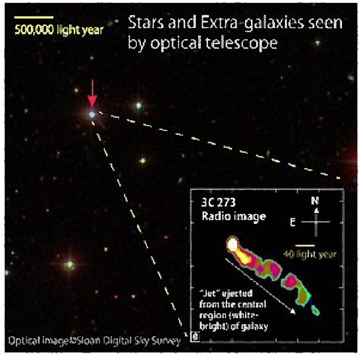
Ph.D., 2011, Hokkaido University

Study of High-energy Astrophysical Phenomena by Radio Observation

In the universe, many highly energetic and dynamic astrophysical phenomena have been discovered. ‘Astrophysical jets’, which are ejected from the vicinities of supermassive black holes located at the centres of galaxies, are one such exotic phenomenon. It is well known that 10^{12} times solar luminosity or more is radiated from the central few-light-year regions of active galaxies accompanied with astrophysical jets. However, some very important but very fundamental issues remain unclear. How are such astrophysical jets formed? Why is it possible to radiate extremely huge amounts of energy from a very compact region?

In order to deeply investigate astrophysical jets associated with active galaxies located at distances of more than a billion light years , we need enormous astronomical telescopes with very high angular resolutions (i.e. great eyesight).

To resolve the open issues in astrophysical jets, we are carrying out observational research in the radio band using the technique of very-long-baseline interferometry (VLBI), which allows us to observe it with angular resolutions of less than 1 milli arc seconds.



3C273 (red arrow) is located at a distance of approximately 2 Giga lightyears from the earth. Radio image shows the “jet” ejected from the central region in 3C273

About Researcher

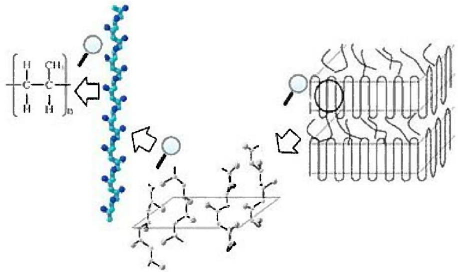
NIINUMA Kotaro,Ph.D.

Ph.D., 2007, Waseda University

Structural Evolution of Polymers and Long-chained Organic Molecules

Polymer materials are composed of long-chained molecules. The physical properties of polymers and long-chained organic-molecular materials are controlled by their structures. Structural evolution of such long-chained molecules often shows characteristic behaviours originating from their long-chained character and yielding interesting physical properties. Therefore, understanding the structural evolution of polymers and other long-chained organic molecules is an important field of research in condensed-matter physics. In particular, crystalline polymer shows characteristic hierarchical-structural evolution, which strikingly affects its physical properties.

We investigate the structural evolutions of crystalline polymers and long-chained organic molecules by means of X-ray diffraction, small-angle X-ray scattering, differential scanning calorimetry, optical microscopy and atomic-force microscopy.



Characteristic hierarchical-structural evolution of crystalline polymers

About Researcher

NOZAKi Koji, Ph.D.

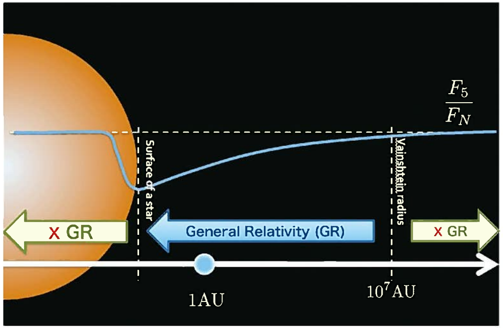
Ph.D., 1998, Hiroshima University

WEB ≫ http://mms.sci.yamaguchi-u.ac.jp/~nozaki/nozaki_e.html

What is the fundamental physics behind the universe?

My primary interest is to determine the physics that describes the universe. Recent measurements have revealed how the universe evolved into what we observe today with high precision. However, we have not achieved an understanding of the universe at a fundamental level. There are some mysterious phenomena that cannot be described by our current best theory based on general relativity and the standard model of particle physics. In my projects, I aim to obtain new information on the universe by introducing new observables or refining existing observational tools, and ultimately discover the fundamental physics that describes our universe.

Recently, I have mainly focused on projects to test our best theory of gravity, general relativity, on cosmological scales. In spite of its many successes, it is known that it cannot explain the current accelerating expansion of the universe, which was discovered in 1998 from supernovae observations. I am investigating the possibility that the gravitational law is different from general relativity on cosmological scales, and how to test this possibility.



A new long-range force, the fifth force, generally appears in modified theories of gravity, and shows rich and complex phenomenology.

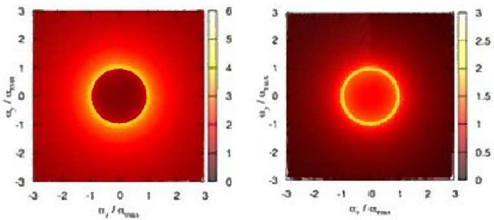
About Researcher

SAITO Ryo, Ph.D.

Ph.D, 2011, The University of Tokyo

Theoretical Astrophysics and Sports Physics

We work on a variety of topics in astrophysics on the basis of general relativity and particle physics. Our research areas include creation of universes, inflationary cosmology, solitons in field theories, black holes and other strongly gravitating objects. Our current interest is in making theoretical predictions about undiscovered objects in order to detect them by future observations.
In addition, we also make a theoretical research of physical movements in sports such as baseball and kendo.



Our theoretical predictions of a black hole shadow (left) and a wormhole shadow (right) when bright gas surround them. These results indicate that we can distinguish between them by future radio observations.

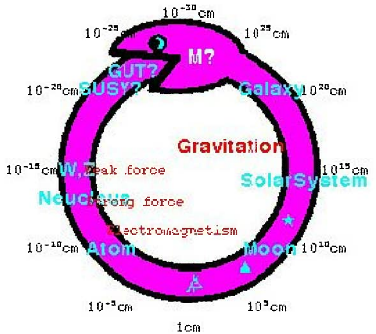
About Researcher

SAKAI Nobuyuki, Ph.D.

Ph.D., 1995, Waseda University

Seeking the Ultimate Theory of Everything

All luminous matter is formed by elementary particles, quarks and leptons. In addition, the four forces acting amongst elementary particles, the 'electromagnetic force', 'strong force,' 'weak force', and 'gravity', are known. Do we have a theory that describes everything in the universe? No, there are many remaining problems. Why do we have six quarks, six leptons and four forces? One may wonder if they came from the unknown fundamental existence, but the problem with a formulating a unified theory of forces is in the handling of gravity. Why is gravity so weak compared to the other three forces? On the other hand, why does spacetime have four dimensions? What are dark matter and dark energy made of? Can an 'ultimate theory' answer all of these at once? In our laboratory, we investigate higher-dimensional unified theories including gravity by studying a number of theoretical models.



Ouroboros. The four fundamental forces govern the universe. The physics on the minimal-length scale determines the present universe.

About Researcher

SHIRAISHI Kiyoshi, Ph.D.

Ph.D., 1987, Tokyo Metropolitan University