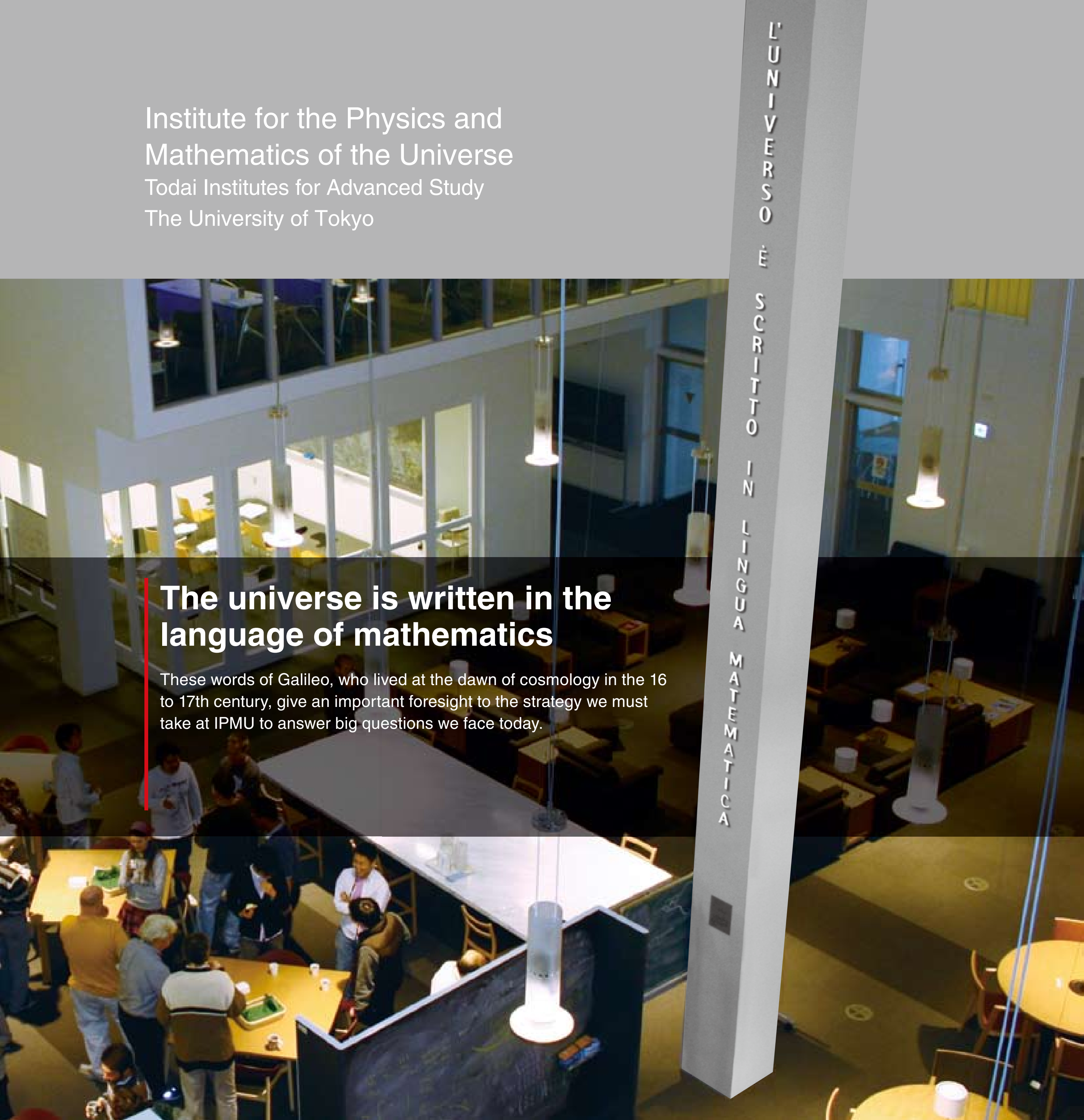
Institute for the Physics and
Mathematics of the Universe

Todai Institutes for Advanced Study

The University of Tokyo



The universe is written in the language of mathematics

These words of Galileo, who lived at the dawn of cosmology in the 16 to 17th century, give an important foresight to the strategy we must take at IPMU to answer big questions we face today.

IPMU addresses deep mysteries of the universe by integrating the forefront knowledge of physics and mathematics.
New approaches under new strategies open new possibilities.

IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

THE UNIVERSITY OF TOKYO

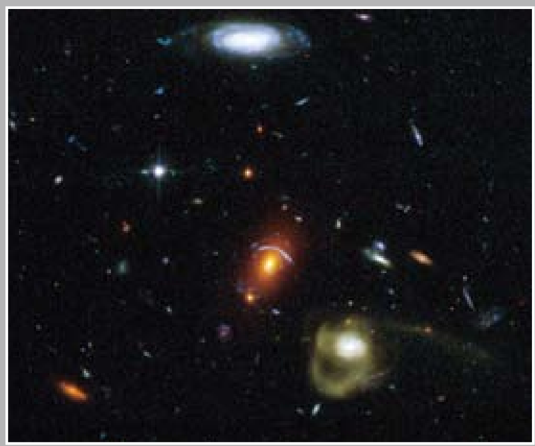
wpi World Premier International Research Center Initiative

Our universe is full of mystery.

"Everything is made of atoms" had been the basic concept that had dominated our view of the universe for the past two centuries. The universe was made of atoms that obeyed quantum mechanics, and all gravity phenomena on earth and in the solar system were well-described by Einstein's general relativity.

But the 1998 discovery that "the universe is expanding with an accelerated speed" has changed our entire understanding. Many researchers now believe that mysterious dark energy must be distributed across the universe and the cause of this acceleration.

Atoms, human, solar system

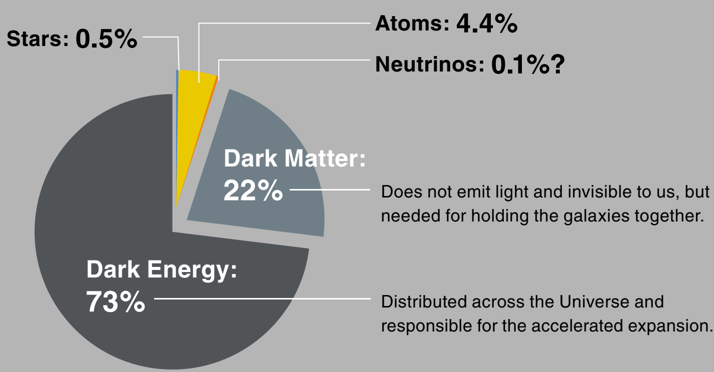


The universe is expanding with an accelerated speed.
©NASA, ESA, J. Blakeslee and H. Ford (JHU)

It has been known for some time that the galaxies must contain large amount of invisible dark matter in order to hold their spiral shapes. But we do not know what they are.

Galaxy ©2005 NAOJ

We knew only 5% of the universe!



Composition of the universe

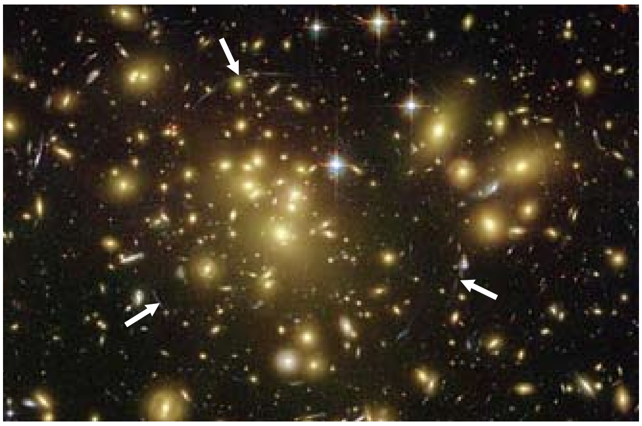
An attempt to describe the early and still tiny universe faces serious difficulty because quantum fluctuation becomes so enormous that theories of general relativity and quantum mechanics break down. A necessity to combine quantum mechanics and general relativity, which must be overcome for fundamental understanding of elementary particles, also appears as we try to understand the universe. Many researchers believe that string theory can solve this problem. But its whereabouts is still not known.

IPMU addresses these questions by integrating the forefront knowledge of physics and mathematics.

Main Research Fields

Observing Dark Matter and Dark Energy with Gravitational Lensing

We cannot see dark matter by our eyes because they do not emit light. However, they can distort the space according to Einstein's general relativity since they carry weight, which then can distort the images of distant galaxies behind the cloud of dark matter. Using this "Gravitational Lensing Effect," we can map out the distribution of dark matter.



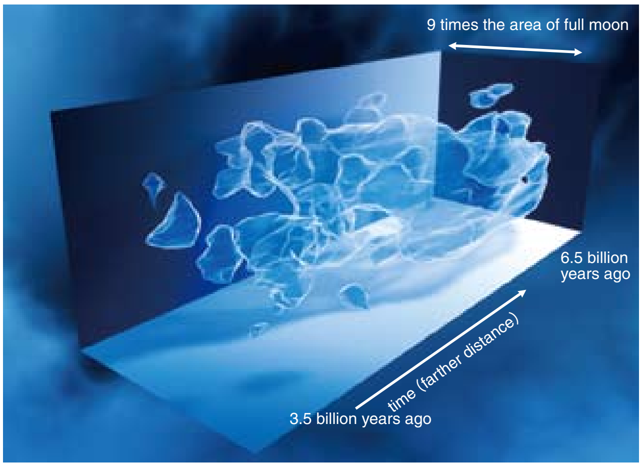
Galaxy images in the Abell 1689 group of galaxies, that are distorted by the Gravitational Lensing Effects

©NASA, N. Benitez (JHU), T. Broadhurst (Racah Institute of Physics/The Hebrew University), H. Ford (JHU), M. Clampin (STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA

Subaru telescope
(National Astronomical Observatory of Japan).

A new camera with 10 times wider coverage is under construction by a team lead by IPMU.

Dark energy can influence the matter distribution of the universe because it causes accelerated expansion of the universe. We can explore the properties of dark energy by examining how the matter distribution, which is obtained by the Gravitational Lensing Effect, varies with time (farther the distance, we see farther in the past).

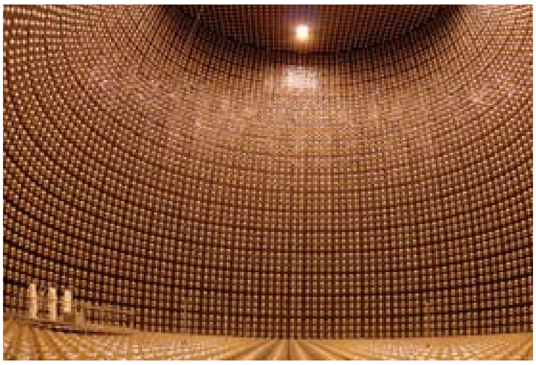


Three-dimensional distribution of dark matter.

This result is based on a combined data of four telescopes in the world including Subaru.

Exploring the Universe from Underground

Located deep underground in Kamioka Mine are three huge particle astrophysics detectors (Super-Kamiokande, XMASS and KamLAND). IPMU works closely with them and conducts searches for "supernova relic neutrinos" (neutrinos that are produced by ancient supernova explosions and wander through the present universe), dark matter that must be present in our Milky Way Galaxy, and an important but yet to be discovered neutrinoless double beta decay.



Inside the Super-Kamiokande detector tank ©ICRR

XMASS detector during construction ©ICRR

Studying Dark Matter in Elementary Particle Theory

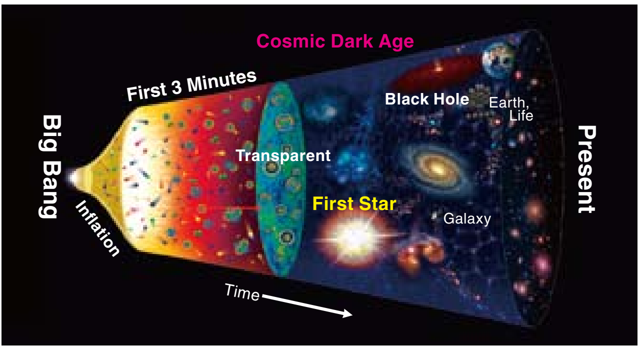
We face difficulties in the present theory of elementary particles, and look for more fundamental theories, such as supersymmetry, that might give solutions. We look for new particles that are predicted by these new theories in the data coming from accelerator experiments and astronomical observations, and study their connections to dark matter.

Untangling Strange Space-Time Structure Predicted by String Theory

In string theory, different oscillation modes of strings correspond to different particles. The most striking prediction of this theory is that "we live in a space-time that exceeds 4 dimensions." Strings can only live in a 10 dimensional space-time. Where are the extra dimensions beyond 4 dimensions that we are familiar with? "They are everywhere, but we cannot see because they are so tiny and curled up" is one possibility. Physicists and mathematicians are working jointly to untangle these strange, but fascinating extra dimensions.

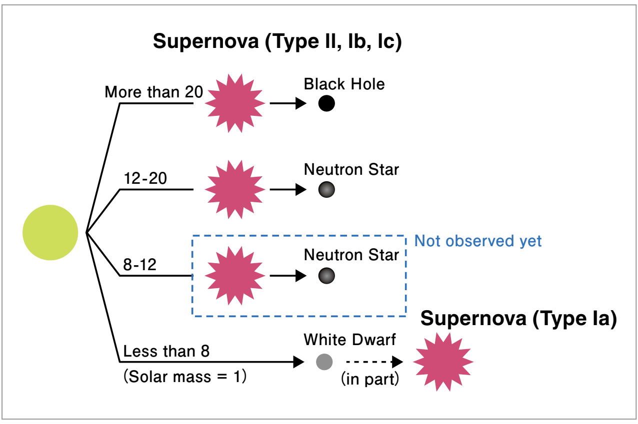
Birth and Death of Stars

The universe has evolved into its present form, with billions of stars and galaxies, by going through a continuous expansion after the birth via the Big Bang. When atoms were formed and the universe became transparent to radiation about 380,000 years after the Big Bang, the universe was still dark with no stars nor galaxies. Therefore we carry out computer simulation studies to find out how the first stars were born from such darkness. Recent results show that the first star was likely to be born when the universe was 300 million years old.



Evolution of the Universe
Adapted from “Physics of the histroy of the universe” by Yasuo Fukui *et al*.

A supernova is an explosion of a star when its life comes to an end. Among several types of explosions, the one called “Type Ia” has lead to the discovery of dark energy and contributed greatly to the development of cosmology since it has a constant brightness and serves as a standard light source in the cosmological distance determination. Both theoretical and observational investigations at IPMU have revealed many new findings about the supernovae.



Different types of supernova explosions

Newly found 2005cz supernova (arrow) within the NGC4589 Galaxy

Finally found “gravitational collapse” type supernova of a light star (about 10 times the solar mass)

Scientists gather from worldwide.

Tea time is held everyday at 3 PM, where lively discussion takes place among researchers of diffent disciplines.

Collaboration takes place with many institutions.

Host Institute (Univ. of Tokyo)

- Department of Mathematics
- Institute for Cosmic Ray Research (Kashiwa, Kamioka)
- Department of Physics
- Department of Astronomy

IPMU

Kashiwa Campus

Kamioka Satellite

Berkeley Satellite

Collaborating Institutions (international)

- Department of Physics, Univ. of California Berkeley, USA
- Department of Astrophysical Sciences, Princeton University, USA
- Institut des Hautes Etudes Scientifiques (IHES), France

Collaborating Institutions (domestic)

- National Astronomical Observatory in Japan
- Department of Physics, Kyoto University
- High Energy Accelerator Research Organization (KEK)
- Yukawa Institute for Theoretical Physics, Kyoto University
- Research Center of Neutrino Science, Tohoku University

Principal Investigators

Principal Investigators are the group leaders at IPMU. They gather from the University of Tokyo (host institution) as well as from other collaborating institutions both in Japan and abroad, and are world top-level scientists in their research fields.


Hitoshi Murayama
Director
Particle theory, Cosmology


Hiroaki Aihara
High energy physics


Yoichiro Suzuki
Neutrino physics, Particle astrophysics


Alexey Bondal
Mathematics


Masataka Fukugita
Astrophysics


Kunio Inoue
Neutrino physics


Takaaki Kajita
Neutrino physics, Particle astrophysics


Stavros Katsanevas
Neutrino physics, Particle astrophysics


Taketoshi Kohno
Mathematics


Masayuki Nakahata
Neutrino physics, Particle astrophysics


Mihoko Nojiri
Particle theory


Ken'ichi Nomoto
Astronomy


Hirosi Ooguri
String theory


Kyoji Saito
Mathematics


David Spergel
Cosmology


Henry Sobel
Neutrino physics, Particle astrophysics


Naoshi Sugiyama
Cosmology

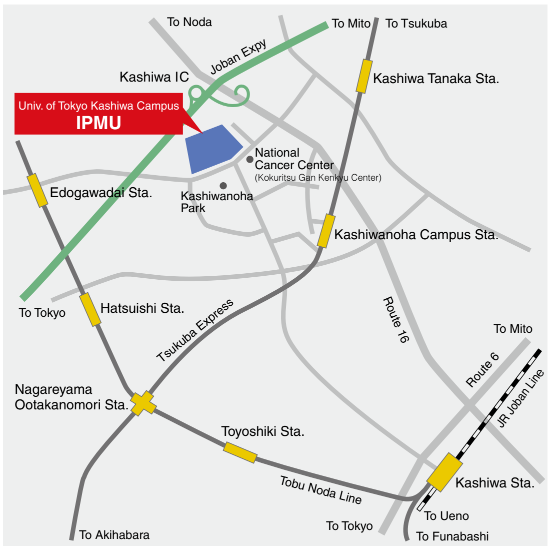

Tsutomu Yanagida
Particle theory

Strong emphasis is placed on supporting foreign researchers and outreach programs.


Japanese language class students playing a Japanese fairy tale


Director Murayama answers questions at a public lecture.

Kashiwa Campus




Aerial view of Kashiwa campus


IPMU building

Access to Kashiwa Campus

From Kashiwanoha Campus Station (Tsukuba Express): Take either #03 or #04 bus at the bus stop #1 of West Exit, get off at Todaimae (10 minutes), and walk for 3 minutes. Taxi ride takes 4 minutes. Walking takes 25 minutes.

From Kashiwa Station (JR Joban Line): Take either #44 or #01 bus at the bus stop #2 of West Exit, get off at Kokuritsu Gan Kenkyu Center (30 minutes). Taxi ride takes 20 minutes.

From Edogawadai Station (Tobu Noda Line): Take a bus for Kashiwanoha Campus station, get off at Todaimae. Taxi ride takes 7 minutes. Walking takes 30 minutes.

From Kashiwa IC of Joban Expressway: It takes 5 minutes.

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