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IPMU

The University of Tokyo
Institute for the Physics and Mathematic of the Universe

Ooguri Wins Inaugural Prize from the American Mathematical Society for Research on Black Holes

Hirosi Ooguri, a principal investigator of the Institute for the Physics and Mathematics of the Universe (IPMU) of the University of Tokyo, is the first winner of the Leonard Eisenbud Prize for Physics and Mathematics of the American Mathematical Society (AMS). The award ceremony took place on January 7, 2008 at the Annual Meeting of AMS in San Diego, California, where more than five thousand mathematicians gathered. The Eisenbud prize was established in 2006 to honor a work that brings mathematics and physics together, and it is awarded only once every three year. Ooguri was chosen by the prize committee that includes Edward Witten, a Fields Medalist.

IPMU was launched on October 1, 2007 as one of the World Premier International Research Centers funded by Ministry of Education, Culture, Sports, Science and Technology. Its objective is to solve deepest mysteries of the universe by gathering world leading researchers in mathematics and physics.

1. Title: Ooguri Wins Inaugural Prize from the American Mathematical Society for Research on Black Holes.

2. Release date: January 4, 2008

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4. Press Release Summary:

IPMU's Ooguri wins the inaugural Eisenbud Prize of the American Mathematical Society for research on black holes. IPMU is one of the World Premier International Research Centers funded by Ministry of Education, Culture, Sports, Science, and Technology of Japan.

The American Mathematical Society (AMS) announced on January 7 that Hirosi Ooguri, principal investigator of the Institute for the Physics and Mathematics of the Universe (IPMU), is a co-recipient of the first ever Leonard Eisenbud Prize for Mathematics and Physics.

The AMS Eisenbud prize was established to honor a work that strengthened the connection between mathematics and physics, and is awarded only once every three years. After two years since the solicitation for nomination and rigorous selection by the prize committee that includes Edward Witten, a Fields Medalist, the inaugural prize was awarded to Ooguri, together with Andrew Strominger and Cumrun Vafa of Harvard University. The award ceremony on January 7 was held during the Annual Meeting of the AMS in San Diego, California. With more than five thousands participants, it is the largest annual gathering of mathematicians in the world. The AMS was established in 1888, and has more than thirty thousand members.

In 1974, Stephen Hawking of Cambridge University shocked the physics community worldwide by predicting that mysterious black holes are not entirely black but emit their heat in the form of light or particles and may even completely evaporate. However, the origin of their heat remained a big puzzle.

String theory, which is expected to be the ultimate unified theory of physics, postulates that our universe is actually not three-dimensional as we know it but rather nine-dimensional. In this theory, the properties of black holes in our three-dimensional universe depend on the size and shape of the unseen six dimensions, whose study requires the latest mathematics. Ooguri, Stominger, and Vafa used string theory and the forefront of higher-dimensional geometry to study properties of small black holes that were beyond the reach of Hawking's theory. In what the AMS calls a "beautiful and highly unexpected proposal," they showed that the unseen six dimensions of space explain the origin of the mysterious heat of black holes. Their achievement demonstrated the close connection between the frontiers of mathematics and fundamental questions in physics.

IPMU at the University of Tokyo was launched on October 1, 2007 as one of the "World Premier

International Research Centers" (WPI) and aims at solving the deepest mysteries of the universe by combining the cutting-edge knowledge in mathematics and physics. Ooguri is a principal investigator (PI) of IPMU and a professor of theoretical physics at California Institute of Technology (Caltech). "This prize is exciting since it reaffirms my belief that we need both mathematics and physics to understand our universe and encourages our effort to jump start research activities at IPMU," says Ooguri. Hitoshi Murayama, who just arrived at IPMU as its director from University of California, Berkeley, rejoices and says, "This award is very happy news that symbolizes the synergy of mathematics and physics at IPMU as an international research institute." Both Ooguri and Murayama left Japan in early stages of their careers, but returned to Japan to build IPMU as a world leading research institute.

The WPI program instituted five research centers in 2007 including this one at the University of Tokyo. The Institute for Integrated Cell-Material Sciences of Kyoto University, which includes Prof. Shin'ya Yamanaka, who pioneered induced pluripotent stem (iPS) cells, is another. Sadanori Okamura, Executive Vice President and Managing Director of Research, commented, "This is yet more great news that continues to come out from WPI researchers. I believe it is critically important that WPI centers stimulate each other and thrive to become world-leading institutions in their respective areas."

5. Brief biographical data of PI Hirosi Ooguri

After receiving B.A. in 1984 and M.S. in 1986 from Kyoto University, Ooguri became an Assistant Professor at University of Tokyo. He was awarded Sc.D. from the University of Tokyo in 1989.

Ooguri have done research at the Institute for Advanced Study, the University of Chicago, Kyoto University, University of Paris VI, and Harvard University. In 1994, he became a Professor at the University of California at Berkeley and was appointed a Faculty Senior Scientist at the Lawrence Berkeley National Laboratory in 1996. Since 2000 he has been at Caltech, where he is now Fred Kavli Professor of Theoretical Physics. He became a PI of IPMU in 2007.

Field of Research: theoretical high energy physics, in particular quantum field theory and superstring theory

Homepage: http://www.theory.caltech.edu/~ooguri/

6. Description of the award-winning research

Black holes were predicted by Einstein's general theory of relativity as completely black astronomical objects. Because the gravitational force is so strong, even light cannot escape its gravity once it falls into one. Initially this was a purely theoretical prediction, but more recently it has become clear that there indeed are many black holes in the universe. For example, there is a supermassive black hole at the center of our galaxy, which is three million times as heavy as the Sun.

Using the quantum mechanics needed to study microscopic world, Stephen Hawking predicted that black holes are not completely black, but actually have slight heat and emit light or particles. Surprisingly, smaller black holes are hotter and may even totally evaporate. Hawking's prediction of black hole evaporation posed a serious question to one of the basic principles of physics called determinism. However, the origin of the heat of black holes remained a mystery within Hawking's theory.

The current mathematical framework of physics cannot deal with problems where both strong gravity and quantum mechanics are involved. String theory is expected to be capable of solving these kind of difficult problems. The work by Ooguri and collaborators used string theory to clarify the origin of the heat of small black holes, which Hawking's theory cannot deal with. To achieve this result, they used state-of-the-art mathematics to compute the heat of black holes. Their work demonstrated tight connections between modern mathematics and the fundamental question in physics.

According to string theory, our universe has a total of nine dimensions, in addition to the familiar three dimensions we can see (up and down, left and right, forward and backward). Six of them have to be curled up in tiny size so that we cannot experience them in our daily life. However, many phenomena we can observe in three dimensions, ranging from properties of elementary particles to the structure of the universe, are influenced by properties of the curled-up six dimensional space. This is why Ooguri and collaborators were able to understand the properties of black holes by studying geometry of six-dimensional spaces. Since this study requires very complicated shapes of six-dimensional spaces, understanding their geometry was beyond the reach of modern mathematics until recently, when research by physicists working on string theory led to breakthroughs that resulted in many important discoveries. The award-winning research demonstrated how the forefront geometry will help us understand properties of black holes and attracted a wide attention.

Einstein's general theory of relativity is one of the two pillars of modern physics and describes gravity in terms of "curved" space and time. The Global Positioning System (GPS) familiar to many of us would not work without using this theory. The second pillar is quantum mechanics that describes the microscopic world. Modern technologies such as electronics, DVD, and computers all operate on the principle of quantum mechanics. However, there is not yet a truly unified theory that combines both of these pillars. String theory is the best candidate for such a unified theory, and it is expected to be critical to study big questions, such as how the universe began, which physicists could not study so far. This award-winning work is one of very few examples of research so far that showed how string theory can be relevant to real-life questions.

Glossary

Quantum Mechanics

Quantum mechanics describes microscopic properties of matter and is one of the pillars of modern physics established in the first half of the twentieth century. It describes, among many things, how light can be both a particle (called photon) and wave, and how a particle such as an electron can exist at many positions at the same time. This way, it explains many counterintuitive phenomena observed in experiments. The atoms that make up everything around us cannot be understood without quantum mechanics.

General Theory of Relativity

A theory proposed by Albert Einstein to describe the law of gravity. As demonstrated in the famous experiment by Galileo from the leaning tower of Pisa, heavy and light objects fall at the same speed. In Newton's theory of gravity, we describe this fact by assuming the "mass," that shows how difficult it is to move the object, and the "weight," that shows how strong gravity is, are the same. This can be understood naturally if we describe the gravity as an intrinsic property of space and time, not as a force that acts on individual objects. This way, Einstein succeeded in connecting gravity and geometry.

Superstring Theory

Elementary particles, such as electrons and photons, have been regarded point-like without an intrinsic size. This has led to nonsensical results when gravitational effects are taking into account. Physicists have learned that this problem can be overcome if the particles are considered not point-like but rather a *string* with a finite size. The theory that considers elementary particles as vibrating strings is called superstring theory, or simply string theory. It has attracted very strong interest as the ultimate unified theory that combines quantum mechanics and general relativity, and is further developing with a strong synergy with the forefront mathematics research.

Nine dimensions, six dimensions

In our universe, there are three spatial directions in which to move: up and down, left and right, front and back. In mathematics, one can consider spaces with many more directions of motion. Such spaces are called higher dimensional. String theory predicts that our universe actually has nine dimensions. However, we can experience only three out of nine dimensions for some reason. It is a very difficult problem in the string theory how big the remaining six dimensional space is and what shape it has. Nonetheless this is a very important question because the properties of physics in “our” three-dimensional universe depend on the geometry of the other six dimensions.

Related web sites:

IPMU: http://www.ipmu.jp

AMS Eisenbud prize: http://www.ams.org/prizes/eisenbud-prize.html