Workshop Report

Focus Week: Condensed Matter Physics Meets High Energy Physics

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Beautiful ideas developed by theorists in one area of physics often have unexpected applications in others. In 2008, Yoichiro Nambu was awarded the Nobel Prize in Physics for his theory of the origin of the mass of the proton. In this work, he applied the theory of superconductivity to elementary particle physics.

Superstring theory is the most promising candidate for the ultimate unified theory of elementary particle physics, and it is one of the major research areas at IPMU. In the September 2009 issue of IPMU News, we reviewed the holographic principle, which is one of the important recent developments in superstring theory.[1] In the past couple of years, this idea has started to attract attention in condensed matter physics because it may hold the key to solving the mystery of high temperature superconductivity.[2] Conformal field theory, a building block of superstring theory, has been used to understand the quantum Hall effect and carbon nanotubes, and it is also playing an important role in the theory of quantum computation.

IPMU is located right next to the Institute for Solid State Physics (ISSP), and scientific exchanges between the two institutes have begun with joint seminars and so on. Tadashi Takayanagi at IPMU is collaborating with Shinsei Ryu, who is a condensed matter theorist, to apply the holographic principle to understand topological insulators and superconductors. This Focus Week, hosted by IPMU in cooperation with ISSP, was organized by 2 high energy theorists and 3 condensed matter theorists to enhance such interdisciplinary collaborations between the two communities.

We invited 6 high energy theorists and 6 condensed matter theorists from all over the world as lecturers. Among them is Dam Son, who is one of the pioneers in applications of the holographic principle to quantum phase transitions and quantum fluid, and Sean Hartnoll, Shamit Kachru, Hong Liu, Shiraz Minwalla, who are major players in this area. World-leading experts in topological insulators and superconductors, including Satoshi Fujimoto, Alexei Kitaev, Nicholas Read, Xiao-Gang Wen, and Shoucheng Zhang, also gathered at IPMU. The talk by Volker Schomerus on his exact solutions to conformal field theory inspired many condensed matter theorists. The conference concluded with a

talk by Eduardo Fradkin.

In addition to regular talks, we asked 4 invited lecturers to give pedagogical lectures to enhance communications between high energy theorists and condensed matter theorists and to set a stage for technical talks in each area. We also solicited contributed talks, and 7 high energy theorists and 6 condensed matter theorists have been selected to give 30 minutes talks. Hallways surrounding the main lecture hall were covered by approximately 30 posters to present latest research results.

A panel session was organized to come up with a list of important unsolved questions that condensed matter theorists can pose to high energy theorists and vice versa. The process of clarifying the meanings of these questions led to lively discussions involving both the panelists and the audience. We are planning to publish a selected set of questions – "IPMU homework problems" – in the Bulletin of the Japanese Physical Society. Before the panel discussion, George Smoot, who received the Nobel Prize in Physics in 2006 for his discovery of fluctuations of the cosmic microwave background radiation, gave a short lecture reviewing a variety of condensed matter phenomena in astrophysics.

With approximately 200 participants, this was by far the largest international conference at IPMU. This is a reflection of the high level of research activities at the interface of high energy theory and condensed matter theory. Approximately 40 participants came from abroad, from 12 different countries. In order to encourage informal exchanges, we held 3 coffee breaks on each day, and discussions continued until late at night at *La Piazza Fujiwara* on the third floor of IPMU. The meeting offered exceptional opportunities for researchers in both fields to compare notes and share common problems. A number of possibilities of interdisciplinary collaborations have already emerged, and we look forward to further developments from them.

We are grateful to administrative staff members of IPMU for their dedicated service.

(written by Hirosi Ooguri)

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[1] Hirosi Ooguri: *Gravity's Holography*, IPMU News, Vol. 7, September 2009.
[2] Eric Hand: *String theory hints at explanation of superconductivity*, Nature, 19 July 2009.