Unconventional Superconductivity Workshop Summary

The discovery in the mid 1980s of superconductivity in the cuprates at unprecedentedly high transition temperatures ($T_c$) revolutionized experimental techniques, to the great benefit of today's studies of novel materials. It also provided many new theoretical concepts and approaches to the description of strongly correlated phases of matter. However, after a quarter century of extensive research, we still do not know the answers to a number of fundamental questions regarding these high-$T_c$ materials. This is in part the reason why the discovery of a completely new family of iron-based superconductors (the "pnictides") in 2008 generated such an excitement. In the short amount time since then, it has become clear that these new materials share a lot of similarities with the cuprates. Most notably, the quasi-two-dimensional crystal structures and transport properties, as well as the basic topology of the phase diagram. There also exist a number of fundamental differences, such as the symmetry of the superconducting order parameter, which is d-wave for the cuprates and most probably s-wave for most of the novel iron-based superconductors. This has opened the exciting possibility that the novel materials may prove to be an intermediate and much needed "link'' between the cuprates and conventional superconductors, such as elemental mercury, discovered exactly one century ago. Consequently, besides being of fundamental and potential applied significance, the study of the iron-based superconductors may provide valuable clues for the eventual understanding of the still mysterious cuprates.

This new development has also rekindled the belief that broad practical application of high-temperature superconductivity is a viable goal. Some of the newly discovered pnictides are rather three-dimensional, while others are quasi-two-dimensional but still much less anisotropic than the cuprates, which makes them potentially better suited for power applications. The discovery also demonstrated that the cuprates are not a unique family of unconventional, high-$T_c$ superconductors, and suggests that more fascinating discoveries can be expected.

The Unconventional Superconductivity Workshop brought together a wide spectrum of experts on the physics of the cuprates and pnictides. The goal of the meeting was to facilitate interactions and the exchange of ideas among the participants, and to advance our understanding of both classes of the materials. The first day was mostly devoted to the latest advances in the understanding of the cuprates. The talks were about evenly divided between experimental and theoretical topics. On the experimental side, the participants reviewed a number of most insightful, state-of-the-art techniques. **Marc-Henri Julien (***Grenoble, France*) spoke about possible spin-stripe order in underdoped YBCO, revealed by his NMR studies in high magnetic fileds. **Juan Carlos Campuzano** (*University of Illinois, Chicago)* reviewed recent advances in photoemission spectrometry, which provides an insight into the energy and momentum dependent properties of the electronic excitations, and discussed insights into the behavior of electrons in the pseudogap phase. **Philippe Bourges (***Laboratoire Léon Brillouin, France)* and **Yuan Li (***Max-Planck-Institute, Stuttgart, Germany*) spoke about the observation of highly unconventional magnetic order and excitations in the pseudogap phase, as detected by neutron scattering. **Joe Orenstein** *(Berkeley)* explained the power of non-linear optical techniques in revealing certain broken symmetries in the pseudogap phase. **Seamus Davis (***Cornell)* and **Jenny Hoffman (***Harvard)* both talked about their latest low-temperature scanning tunneling microscopy studies, presenting an intriguing and sometimes conflicting picture of the electronic inhomogeneities in the cuprates.

On the theoretical side, **Jan Zaanen (***Leiden, The Netherlands)* discussed the exciting possibility that elusive properties of the strongly correlated matter may be described in the framework of AdS/CFT

correspondence, recently discovered in some string theory models. **Michael Norman (***Argonne National Laboratory)* gave an exhaustive unbiased review of recent discussions regarding Fermi surface reconstruction in the cuprates, motivated by experiments on quantum magnetic oscillations. **Oskar Vafek (***Florida),* **Sudip Chakravarty** *(UCLA)* and **Chandra Varma, (***UC Riverside)* talked about their latest theoretical ideas regarding the nature and properties of the pseudogap phase of the cuprates.

On Saturday morning, **Jürgen Haase** (*Leipzig, Germany*) and **André-Marie Tremblay** (*Sherbrooke, Canada*) presented their latest experimental and theoretical results for the cuprates: NMR work at ambient and high pressure and calculations for the Hubbard model. **Senthil Todadri** (*MIT*) then discussed the theoretical possibility for high-temperature superconductivity in a new class of materials, the iridium oxides. The main part of the Saturday session was devoted to the latest advances in the research of the novel iron-based superconductors. Once again, we tried to balance experimental reports with discussions of relevant theoretical ideas. The experimental efforts were represented by speakers from leading crystal growth and characterization laboratories from around the globe, such as **Paul Canfield** and **Ruslan Prozorov (***Ames Laboratory),* **Takasada Shibuchi (***Kyoto, Japan),* **Hai-Hu Wen** (*Nanjing, China)* and **Neven Barisic (***Minnesota).* Together, they presented a most comprehensive review of the latest achievements in material growth, the emerging classification of novel compounds, and their characterization. Theoretical overviews were presented by **Peter Hirschfeld (***University of Florida),* **Jörg Schmalian (***Ames Laboratory)* and **Andrei Bernevig (***Princeton).*

The Sunday session was devoted to recent developments on superconductivity.
**Subir Sachdev** (*Harvard)* talked about his recent work on superconductivity and optical conductivity near an antiferromagnetic quantum critical point in a metal. **Tomo Uemura** (*Columbia)* talked about the application of his "Uemura plot" to both cuprates and pnictides. **Gabi Kotliar** (*Rutgers)* talked about recent advances of dynamical mean-field theory approach, and **Dirk van der Marel** (*Geneva, Switzerland)* talked about his recent work on superconductivity in the anti-adiabatic limit in doped strontium titanate.

By all accounts the workshop was very successful in its main goals of facilitating conversation between theorists and experimentalists and "cross fertilization" of research on cuprates and pnictides. It also featured a rather large number of poster presentations from junior participants, which conveyed the breadth and excitement of the exciting field of unconventional superconductivity. The participants used discussion time as well as meal times to exchange of ideas. It was suggested that a similar gathering in 2-3 years time would be highly desirable in order to gauge the progress in this rich and very active field.

For further information about the workshop please visit the workshop webpage at:
http://www.ftpi.umn.edu/workshops/2010-2011/supercon/index.html