PWA90

A LIFETIME OF EMERGENCE

Editors
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A LIFETIME OF EMERGENCE

Preface

"Curiosity is, in great and generous minds, the first passion..."

— Samuel Johnson

In December 2013 a community of physicists gathered in Princeton on the occasion of Phil Anderson's 90th birthday to celebrate his curiosity and achievement across a remarkable career spanning more than six decades. As codified in his oft-quoted phrase "More is Different", Phil has been the most forceful and persuasive proponent of the radical (in the 1970s), but now ubiquitous, viewpoint of emergent phenomena: truly fundamental concepts can and do emerge from investigations of Nature at each level of complexity or energy scale. The workshop's title, "PWA90: Emergent Frontiers of Condensed Matter", was thus inspired by Phil's ideas of emergence that have deeply influenced developments in their original realm of condensed matter physics as well as in high energy physics, astrophysics, economics, computational optimization and computer science. Phil's insights have had a profound impact on such a broad number of topics that a two-day symposium could only touch on some of them. The meeting had six scientific sessions and two panel discussions; the program is included here as an Appendix. Each talk had a significant amount of time allocated for discussion that often was quite lively. Phil sat in the front row of the auditorium for the entire meeting, and asked questions after almost all the lectures. True to form, he enjoyed some healthy differences of opinion with some of the speakers. The meeting was well attended by current students, mainly from the tri-state area, who were inspired by the presentations and the animated discussions.

This workshop brought together many of Phil's students, postdocs, collaborators and colleagues from throughout his career, and some personal reminiscences from the celebration dinner are included in this volume. The scientific talks at the meeting covered several representatative topics that

Phil has deeply influenced. Let us now make Phil blush: the seminal work associated with his name includes Anderson localization, the Anderson local moment model of magnetism, the Anderson–Higgs mechanism, the Edwards–Anderson order parameter in spin glasses, the Anderson–Brinkman–Morel (ABM) phase of superfluid ^{3}He, Anderson's dirty superconductor theorem, the Anderson–Kim model of flux creep in superconductors, and the Anderson–Holstein impurity model and we are still not done! Furthermore many of the profound concepts that Phil has introduced and/or developed include broken symmetry and rigidity, superexchange, spin liquids, scaling in interacting systems, frustration and local moments, all of which are now part of the standard lexicon of the field. The challenges of celebrating Phil's deep and broad influences within the span of a two-day meeting should now be clear to all. The scientific talks at this workshop reviewed Phil's crucial contributions to representative areas and emphasized subsequent developments; the topics covered were Anderson localization, the Anderson–Higgs effect, frustrated magnetism and heavy fermions, high-temperature superconductivity, superfluids and entanglement, biological physics and neutron stars.

On the first day, the session on Anderson localization combined a historical introduction by Elihu Abrahams (UCLA) with a forward-looking discussion of modern challenges of many-body localization by Boris Altshuler (Columbia). The session on the Anderson–Higgs effect included presentations by Edward Witten (IAS) and Frank Wilczek (MIT) on Anderson's contributions from the perspective of high-energy physics. In the session on frustration and heavy fermions, Patrick Lee (MIT) discussed Anderson's theory of resonating valence bonds, and Ali Yazdani (Princeton) described scanning tunnelling microscopy as a probe of heavy fermion materials. The first day ended with a very animated panel discussion involving Bill Brinkman (Former Director, Office of Science, Department of Energy) and Anderson's students Pierre Morel, Ted Hsu, Joe Wheatley and Joe Zhou, who described how physics helped them in non-academic careers that included science policy, politics and investment banking.

The second day began with a session on strongly correlated superconductors where Maurice Rice (ETH, Zurich), Gabi Kotliar (Rutgers), J. C. Campuzano (UIC) and Mohit Randeria (Ohio State) discussed current progress towards a collective understanding of high-temperature superconductivity. The second session on superfluids, entanglement and biology involved talks by Albert Libchaber (Rockefeller) on the problem of self-reproduction, by Anthony Leggett (UIUC) on the concept of superconducting liquids and Duncan Haldane (Princeton) on topologically entangled matter. In the final session, Mal Ruderman (Columbia) spoke about neutron

stars. Then there was a lively description by Walter Kohn (UCSB) of Phil when both he and Walter were graduate students at Harvard. The symposium ended with a panel discussion on historical and grand challenges of condensed matter physics with participants Erio Tosatti (Sissa, Italy), David Thouless (Washington) and T. V. Ramakrishnan (Indian Institute of Science, Bangalore).

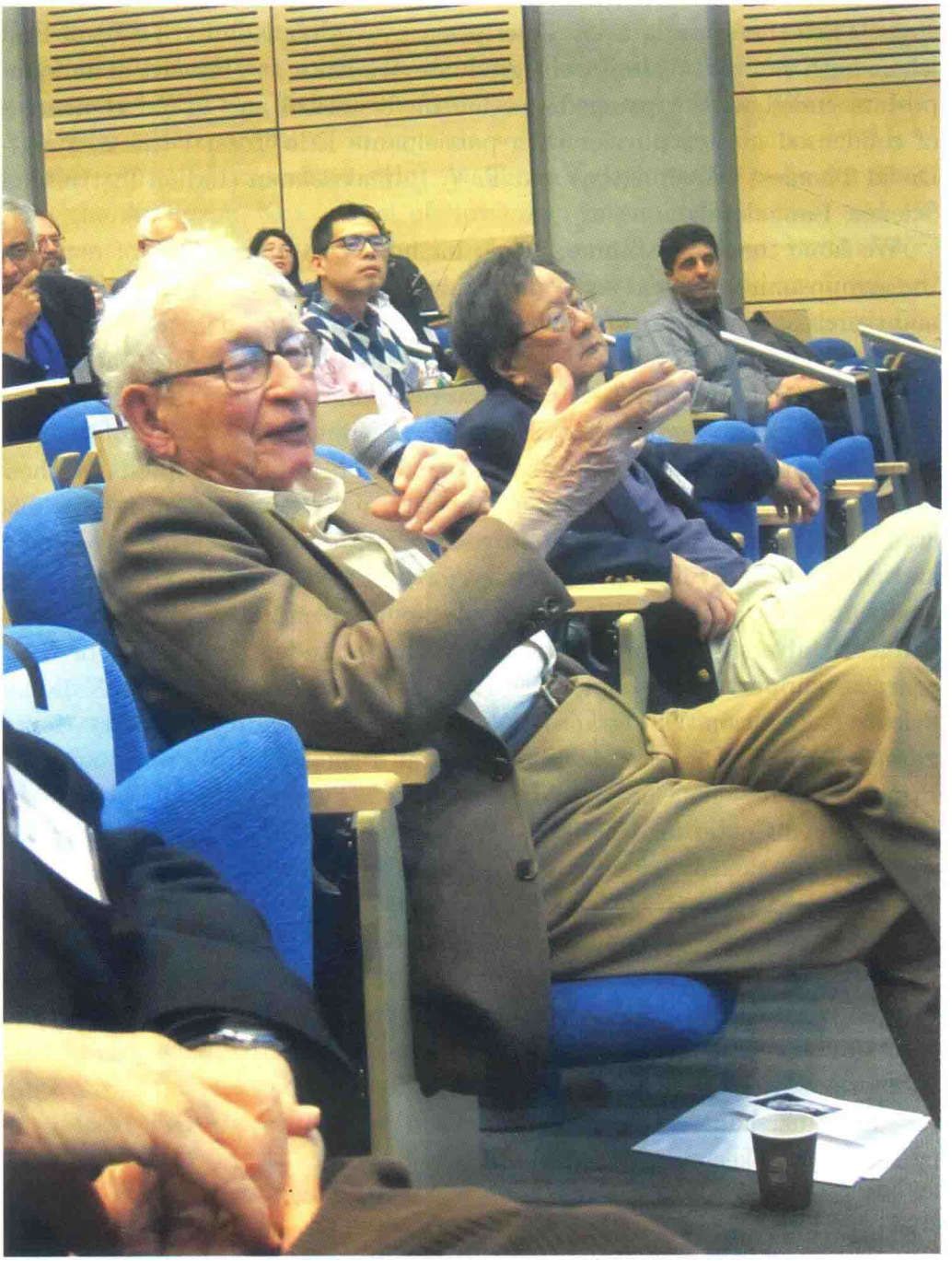
We hope that this volume, which includes written versions of many of the symposium talks and some personal reminiscences, will serve to inspire many present and future students and practitioners in the area of Emergent Condensed Matter Physics. We note that Ted Geballe (Stanford), and Scott Kirpatrick (Hebrew Univ. Jerusalem) were unable to attend the meeting but generously contributed articles to these Proceedings.

We wish to thank all the speakers, contributors, and participants for their roles in making the workshop such an inspiring, enjoyable and memorable affair. In particular, we express our deep gratitude to Catherine Brosowsky and the staff at Princeton University for making all the detailed arrangements towards running the workshop smoothly, and to Fran de Lucia at Rutgers University for processing the graduate student expenses. For their generous support of the conference PWA90, we wish to thank the National Science Foundation (NSF grant PHY-1401789), the Gordon and Betty Moore Foundation, the Department of Physics at Princeton University, and the Princeton Center for Complex Materials. We are grateful for the hospitality of the Aspen Center for Physics (supported by National Science Foundation grant PHY-1066293) where some of us (CCY, PC, PC, and GK) put the finishing touches on these proceedings.

Finally, a toast. On behalf of the physics community past, present and future, we raise a glass to Phil and express our heartfelt thanks for a cornucopia of discoveries and insights that have provided the foundation for the work of generations to come. Isaac Newton once said, "If I have seen further than others, it is by standing on the shoulders of giants". Thank you, Phil, for giving us shoulders to stand on ... and we will do our very best to be curious and to keep exploring!

Premi Chandra
Piers Coleman
Gabi Kotliar
Phuan Ong
Dan Stein
Clare Yu

September 2015



Phil Anderson offers a comment to one of the speakers. Background: Phuan Ong.

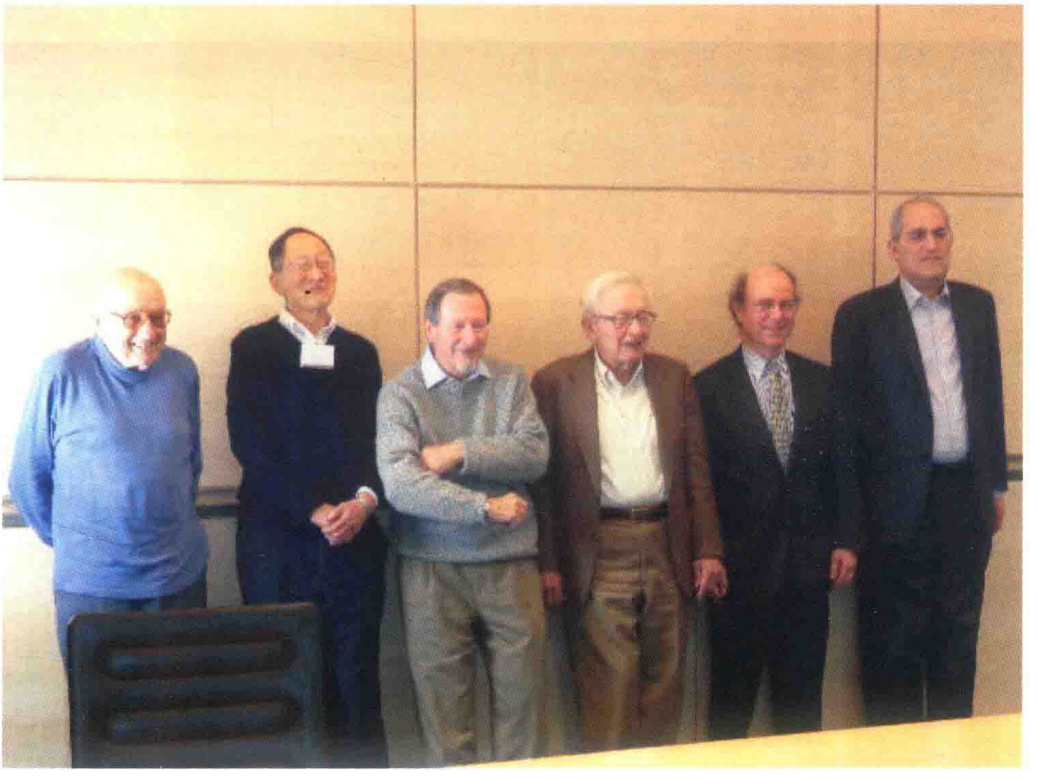
Phil Anderson poses a question to one of the speakers. Foreground: Elihu Abrahams. Background: Susan Anderson.

Conference photograph

Phil Anderson cuts the birthday cake.

Bill Brinkman and Maurice Rice

Jim Langer and David Thouless



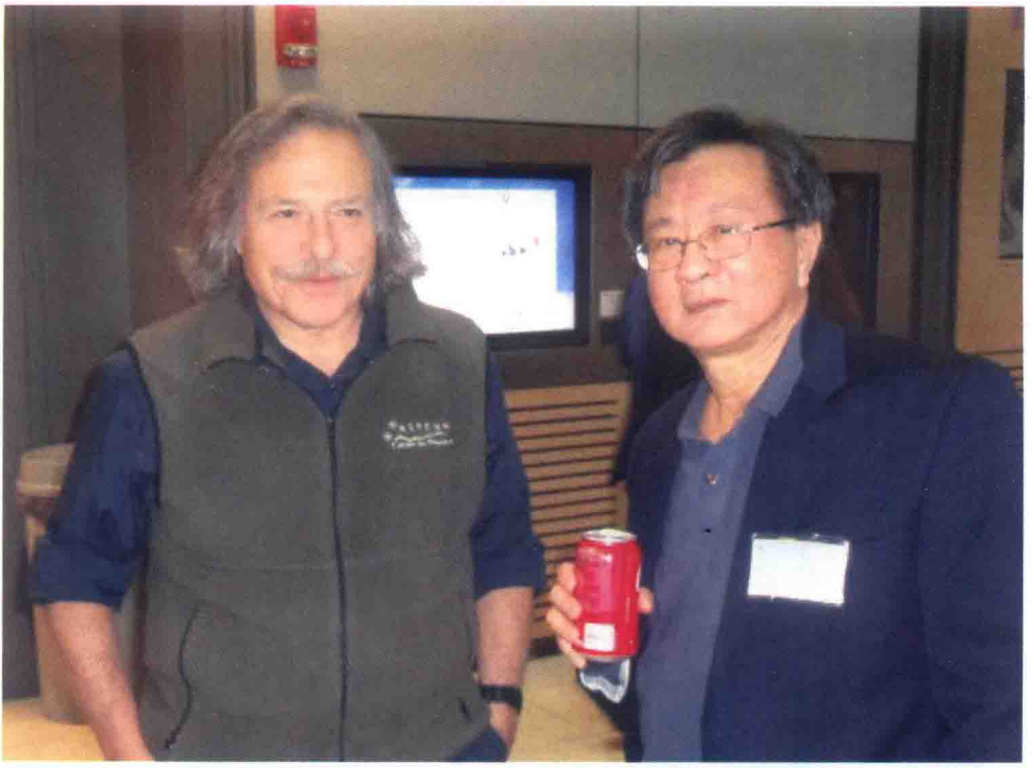
Walter Kohn, Daniel Tsui, Douglas Osheroff, Phil Anderson, Frank Wilczek and Edward Witten

Gabriel Kotliar, Phil Anderson, Clare Yu and Piers Coleman

Premi Chandra and Frank Wilczek

Ali Alpar and Jim Sauls

Bert Halperin and Walter Kohn



Paul Chaikin and Phuan Ong

Walter Kohn and Phil Anderson

Frank Wilczek, Phil Anderson and Erio Tosatti

Don Hamann, Patrick Lee and Phil Anderson