RAYMOND BISHOP AND HERMANN KÜMMEL: FEENBERG MEDALISTS 2005 THE COUPLED CLUSTER METHOD

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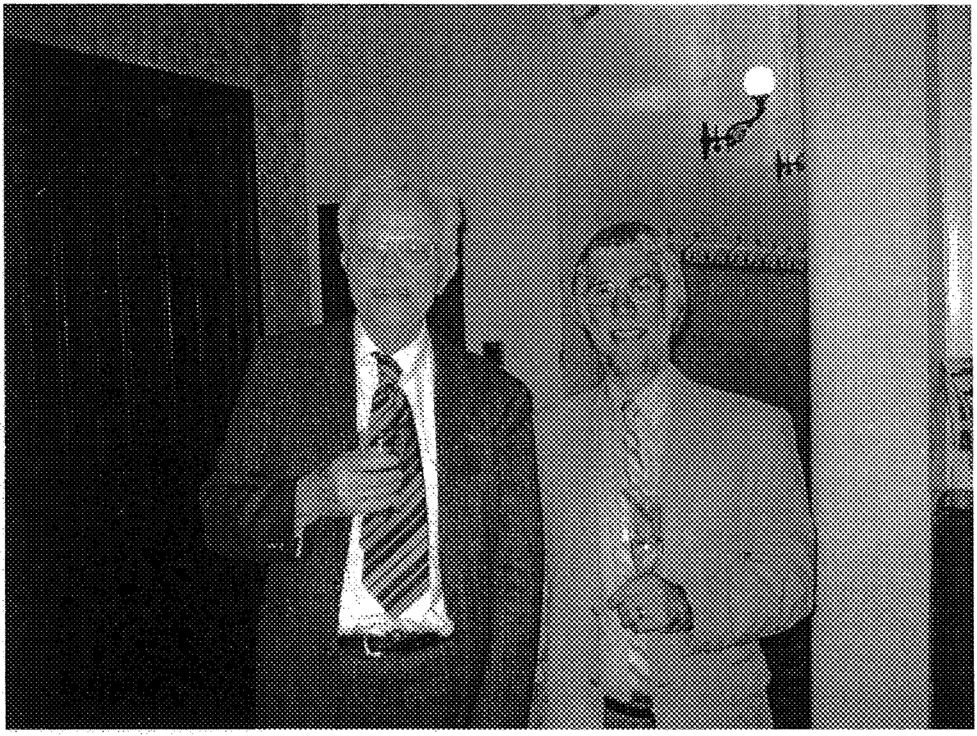
1. The Eugene Feenberg Memorial Medal

Raymond Bishop and Hermann Kümmel have been named as the recipients of the The Tenth Eugene Feenberg Award in Many-Body Physics, in recognition of their key roles in the development and application of the powerful coupled cluster method of quantum many-body theory. Feenberg Medals were presented to the awardees on December 5, 2005 at the Thirteenth International Conference on Recent Progress in Many-Body Theories, held in Buenos Aires, Argentina.

The Eugene Feenberg Memorial Medal was established in 1983 by the quantum many-body physics community to honor Eugene Feenberg, a pioneer in theoretical nuclear physics, for his unique and enduring contributions to the development of the microscopic quantum many-body theory of strongly interacting systems. The award commemorates and celebrates Feenberg's wise stewardship of a field that permeates all branches of physics, his deep physical insights and great formal achievements, his dedicated service as teacher and mentor, and his exemplary integrity in his professional and personal life.

The selection of Feenberg Medalists is conducted under the auspices of the International Advisory Committee for the Series of International Conferences on Recent Progress in Many-Body Theories. The previous recipients of the award are David Pines (1985), John W. Clark (1987), Malvin H. Kalos (1989), Walter Kohn (1991),



Hermann Kümmel and Raymond Bishop

David M. Ceperley (1994), Lev P. Pitaevskii (1997), Anthony J. Leggett (1999), Philippe Nozières (2001); and Spartak T. Belyaev and Lev P. Gor'kov (2004).

2. Eugene Feenberg

As we near the centenary of his birth, it is especially appropriate to include memories of Eugene Feenberg on this occasion. Born on October 19, 1906 in Fort Smith, Arkansas, Feenberg received a B.A. in physics and M.A. in mathematics in 1929 from the University of Texas, Austin after three years of study. While a Harvard doctoral student he spent a year and a half in Europe as a Parker Traveling Fellow, visiting the institutes of Sommerfeld, Pauli, and Fermi. His time in Europe was cut short by the turmoil accompanying the Nazi ascent to power in Germany. Returning to Harvard, he completed his Ph.D. in 1933 under the direction of E. C. Kemble, founder of one of the earliest significant schools of theoretical physics in the United States. As a second mentor, John van Vleck also had a strong influence on Feenberg's early professional development. His Ph.D. thesis, on quantum scattering theory, contained the first statement and proof of the quantum optical theorem.

In the ensuing years, Feenberg held appointments as Instructor or Fellow at Harvard, Wisconsin, and the Institute for Advanced Studies, collaborating with Eugene Wigner, Gregory Breit, John Bardeen, and Melba Phillips, among others. In 1936, back-to-back papers in *The Physical Review* by Cassen and Condon and Breit and Feenberg presented evidence and arguments for the charge independence of nuclear forces and formally identified the first internal symmetry (isospin) of particle physics.[1,2] After eight years on the faculty of New York University, intermixed with four years in defense work at Sperry Gyroscopic during World War II, Feenberg joined the faculty of Washington University in St. Louis as an associate professor. In 1964 he succeeded Edward Condon as the Wayman Crow Professor of Physics, a chair previously held by Arthur H. Compton, and subsequently by Edwin T. Jaynes and currently by John Clark, continuing the very high standards and traditions of this important chair.

Much of Feenberg's research during the first phase of his career was concerned with nuclear theory, in work that culminated in publication of *Shell Theory of the Nucleus* by Princeton University Press 50 years ago.[3] In the mid-1950's, a career-long interest in perturbation theory stimulated his early entry into the new field of quantum many-body theory, coincident with pioneering developments in Russia and the West driven by advances in field theory. This engagement brought a shift of Feenberg's primary focus from nuclear problems to the theory of quantum fluids, most notably the helium liquids, a subject to which he would contribute very importantly for the next two decades until his death in 1977. Along with his students, he developed the method of correlated basis functions (CBF) in order to cope with the strong, short-range repulsion between helium atoms – a feature that defies mean-field approaches and makes the theory of the helium fluids virtually intractable using ordinary perturbation theory. The early part of this research is the subject of his now-classic monograph *Theory of Quantum Fluids.*[4]

Eugene Feenberg's courage in confronting the challenge of strong, short-range correlations by conceiving and developing a comprehensive *ab initio* framework to deal with them quantitatively from first principles, was characteristic of his research style. This body of work is the foundation of much of modern theoretical research on strongly correlated quantum fluids. His personal integrity and his high standards of professional achievement and behavior continue to inspire and guide his former students and colleagues.

The esteem in which Eugene Feenberg is held by those who knew and learned from him is eloquently captured in an excerpt from the commencement address "Giants Must Stand on Solid Ground" delivered in 1991 at the Massachusetts Institute of Technology by Walter Massey, President of Morehouse College and former Director of the U.S. National Science Foundation:[5]

> So, where do young researchers first learn the rules of the game that protect the integrity of their endeavors? For generations, the community has relied on the unique mentor-apprentice relationship that develops during the process of doctoral and postdoctoral research to teach these important lessons. When all goes well, a bond of trust develops between the professor and his or her students which is grounded in intellectual curiosity, a desire to discover new knowledge, and a common commitment to truth. What is conveyed and what is learned is more than simply a body of facts; it is an approach to understanding, an appreciation of standards, and a set of values – in effect, an ethic. I was very fortunate in my own graduate training to have had a research director from whom I learned a great deal of physics and much more besides. Professor Eugene Feenberg (now deceased) was a prominent physicist, well-respected among his peers, a man of integrity and unyielding honesty. All of us who were his students saw these traits in him and profited from working with him. To come to class ill-prepared or not take time to listen to his students and their problems; to publish a result prematurely simply to gain priority; or to put his name on a paper by one of his students when he had not shared in the work himself – all these things were anathema to Gene Feenberg. Those of us who were his students realize how lucky we are to have had an almost ideal mentor-apprentice relationship.

Those who would like to know more about Eugene Feenberg and his work are invited to read George Pake's biographical memoir for the National Academy of Sciences.[6]

Presentation of Feenberg Medals at successive conferences in the series on Recent Progress in Many-Body Theories serves both to remind us of and to perpetuate this man's extraordinary influence on physics and physicists. Our two laureates, Hermann Kümmel and Raymond Bishop, exemplify the steadfast integrity and uncommon commitment to the highest of standards that were so visible in the professional career and personal life of Eugene Feenberg.

3. Hermann Kümmel

The Tenth Feenberg Memorial award cites Hermann Kümmel for his role in the creation and early development of the coupled cluster method, and pioneering high-accuracy applications of it to problems in nuclear and subnuclear physics.

The volume of the World Scientific Series on Advances in Quantum Many-Body Theory devoted to the proceedings of MB11 contains an excellent biography of Hermann Kümmel, in a tribute written by Raymond Bishop in celebration of Kümmel's 80th birthday.[7] From that source we learn that Kümmel was born in 1922 in Berlin, and that all of his formal education took place in that city. He received the Diplom in 1950 from Humboldt University in the East Zone, and his Ph.D. in theoretical physics in 1952 from the Free University in West Berlin, where he continued with his research until moving to the U.S. to work at the University of Iowa. It was during his two years as a research associate in Iowa City that, in consultation with Fritz Coester, the foundations were laid for the coupled cluster method (CCM) (more commonly known in the early days as the Exponential-S Theory). Kümmel and Coester presented the seminal ideas of CCM in a 1960 paper published in *Nuclear Physics*.[8]

After a brief period at the University of Tübingen, Kümmel spent several years in Mainz with joint appointments at the Max Planck Institute for Nuclear Chemistry and the University of Mainz. Then came two years back in the U.S. as Professor of Physics at Oklahoma State University. Returning to Mainz as a senior scientist at the Max Planck Institute and adjunct professor at the University, he built a strong research group in nuclear theory.

In 1969 Kümmel moved with his entire research group to take a Chair in Physics at the newly founded Ruhr University in Bochum (RUB), Germany. His efforts soon established Bochum as one of the world's leading centers in quantum many-body theory. Significantly, it was at this time that he turned his attention in earnest to the theoretical and computational development of CCM. Although nuclear systems remained the primary focus of applications, important results were also obtained for the electron gas, a basic problem in solid-state physics and a testbed for many-body theories. The level of sophistication achieved in Bochum under his leadership, in both formal and computational strength, has rarely been matched. He retired in 1988 at the mandatory age, but has remained active in research at RUB as Professor Emeritus.

An authoritative and insightful account of Hermann Kümmel's pioneering contributions to the formal development of CCM and its subsequent application in a host of problem settings may be found in his paper entitled "A Biography of the Coupled Cluster Method".[9] Kümmel was both a co-founder of the CCM and the first to appreciate and exploit its power in the context of nuclear physics. Arguably, the earliest applications of coupled cluster theory by his group to medium-mass atomic nuclei stand to this day as never having been surpassed. Considering the computing power that was available at the time, the results obtained for both closed-shell nuclei and open-shell nuclei comprising one or two valence particles or holes outside closed shells, are breathtaking in their sophistication and accuracy. They were undoubtedly the first fully microscopic calculations for nuclei to be demonstrably converged for a selection of the best available, realistic, two- and three-nucleon interaction potentials, for both ground- and excited-state energies and properties.

Based on his successes in applying coupled cluster theory to finite nuclei, Kümmel next turned his attention to various strongly correlated systems in subnuclear physics and quantum field theory. In particular, his treatment of the deuteron from the field-theoretic standpoint of pions and nucleons interacting via the standard pseudoscalar, isovector coupling, may be recognized as a landmark calculation. It provides a rare example of a fully converged calculation for a non-trivial, strongly interacting quantum field theory. Throughout his long and fruitful career, Hermann Kümmel has been a pioneer, a leader, an inspiration, and a mentor in the international community of many-body theorists.

4. Raymond Bishop

The Tenth Feenberg Memorial Medal award cites Raymond Bishop for his development of the coupled cluster method toward a comprehensive ab initio approach, and innovative applications across the full spectrum of subfields of quantum many-body physics.

Raymond Bishop was born in London in 1945. After earning his B.A. degree at the Queen's College, Oxford in 1966 and a Ph.D. in theoretical physics at Stanford University in 1971, he returned to England as Science Research Council Research Fellow. Subsequently, he was Senior Research Associate and Lecturer in the Department of Physics, Manchester University, simultaneously being associated with the Theory Group at the Science Research Council, Daresbury Laboratory.

Bishop returned to the U.S. and spent several years at the University of California, Berkeley as Staff Scientist at the Lawrence Berkeley Laboratory and Lecturer in the Department of Physics. In 1979 he joined the faculty of the Department of Mathematics at the University of Manchester Institute of Science and Technology (UMIST). He was appointed Professor of Theoretical Physics at UMIST in 1988 and Head of the Department of Mathematics in 1991. Theoretical Physics moved to the Department of Physics in 1995, where Bishop became Head in 1996. He is currently Professor of Theoretical Physics in the School of Physics and Astronomy of the combined University of Manchester formed in the merger of UMIST with Manchester University in 2004.

Bishop initiated his research program in the coupled cluster method during lengthy visits to Bochum in the mid-to-late-1970s. While at Bochum, he began a fruitful collaboration with Karl-Heinz Lührmann, in which they applied CCM theory exhaustively, and with great success, to that touchstone problem of many-body theory, the electron gas. From that point on, Bishop was responsible for a series of pivotal formal developments in coupled cluster theory, often with the close participation of the late Jouko Arponen. He has systematically and energetically developed the CCM into the elegant, consistent, flexible, and accurate tool for microscopic applications that we know today. Indeed, he has been the driving force behind the 25-year evolution of coupled cluster theory from a promising framework for *ab initio* treatment of quantum many-particle systems into its mature form as a powerful and universal method for quantitative investigation of ground states, excitations, and phase transitions. Applications abound in nuclei and nuclear matter, atoms and molecules, quantum fluids and electronic systems in condensed matter, lattice-spin and lattice-gauge models, quantum optics, and quantum field theory.

In more detail, his numerous significant achievements include: (a) incisive analysis of correlations in the electron gas at high, intermediate (metallic), and low densities; (b) extensive development of the extended coupled cluster formalism, its uses to map arbitrary quantum field or quantum many-body theories exactly onto classical Hamiltonian mechanics, and for its applications to the treatment of excited states and the zero-temperature hydrodynamics of strongly-interacting condensed Bose fluids; (c) formulation and implementation of a translationally-invariant coupled cluster theory for light nuclei; (d) pathbreaking studies of spin-lattice models yielding new insights into quantum antiferromagnets; (e) exploration of Hamiltonian lattice-gauge theories in the coupled cluster framework; and (f) publication of comprehensive and authoritative reviews on the important ramifications of coupled cluster theory within both chemistry and physics.

At Manchester, Bishop has established one of the world's foremost groups in quantum many-body physics and has directed an intensive computational effort exploiting automated symbolic manipulation. At the same time he has developed and leads what amounts to an informal international school of many-body physics research through his extensive collaborations throughout the world and his development and application of CCM to an enormously broad range of theoretical physics subdisciplines.

5. Selected significant publications

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