

CHARLES CAMPBELL AT SIXTY-FIVE: A TRIBUTE TO INNOVATION AND ENDURING DEDICATION

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Received 31 July 2008

A retrospective of the career of Charles E. Campbell in condensed matter physics is presented as a tribute to his pathbreaking contributions to quantum many-body theory and his selfless dedication to the advancement of the research community associated with the Condensed Matter Workshop series.

1. Career History

A native of Ohio, Charles E. Campbell attended Ohio State University and received his B.S. in 1964, having been elected to Phi Beta Kappa. I first came to know him in the fall of the same year, when he entered our graduate program at Washington University in St. Louis. He was a student in several of my courses, developed rapidly as one of the top theory students of an outstanding class, and joined our many-body theory group, working under the direction of Eugene Feenberg. His promise for exceptional achievement was already visible at the time, and indeed was exemplified in a brilliant thesis on the correlation structure of quantum fluids, completed in 1969. Chuck (as he is known to most of us) then spent two years as a postdoc with Michael Schick at the University of Washington in Seattle, followed by two more postdoctoral years with Alexander Fetter at Stanford. During this period his research led to significant advances in the theory of helium monolayers.

In 1973, Campbell joined the physics faculty of the University of Minnesota (Twin Cities) and rose through the ranks to become full professor in 1981. He has served as Head of the School of Physics and Astronomy and played an important role in the establishment of the Theoretical Physics Institute. His distinguished service to the University of Minnesota has been interrupted only by research leaves spent at the University of Cologne (as a Humboldt Fellow), Los Alamos National Laboratory (Associated Western Universities Sabbatical Fellow), Hong Kong Institute of Science & Technology (Visiting Professor), and the University of Linz (Fulbright Senior Lecturer and Guest Professor).

2. Benchmarks of Innovation in Many-Body Theory

In 1996, Charles Campbell's outstanding research achievements and leadership within condensed matter physics received amply deserved recognition in his election to Fellow of the American Physical Society. Chuck's knowledge and expertise extend over many areas of condensed matter physics and theoretical physics. He is a master at the synthesis of ideas and techniques drawn from diverse sources, and an articulate spokesman for the unity of physics. Blessed with extraordinarily acute physical intuition, he has developed into one of the intellectual leaders of the subdiscipline of microscopic many-body theory. Complementing the breadth of his knowledge, there is a clarity, depth, and solidity about his thinking that is rare to find. Running against the current trend, he is not one who simply grinds out results using some fashionable theoretical recipe. Rather, he is a true pioneer and innovator. The impact of his work on the present shape of *ab initio* many-body theory has been substantial; in fact it abundantly clear that his contributions to correlated wave-function theories have been critical for the success that this approach has enjoyed since the 1970's.

Over the years, Chuck Campbell's primary research efforts have been focused on the theory of quantum fluids. He has played a pioneering role in bringing correlated-basis (or CBF) approaches to a high level of quantitative accuracy, through the introduction of procedures for optimal determination of the essential correlation functions. Early in his career, he developed the *paired-phonon analysis* into a practical method for microscopic description of the ground states and elementary excitations of strongly-interacting Bose systems. Paired-phonon analysis (PPA), which he formulated together with Eugene Feenberg,¹ is an approach within CBF theory in which the many-particle Hamiltonian is diagonalized in a subspace spanned by paired-phonon states. Importantly, the two of them recognized that the paired-phonon subspace contains the *optimal* Jastrow trial ground state for the system. They went on to show how to find this state consistently within the hypernetted-chain (HNC) approximation, in a paper that preceded any similar work by nearly a decade. At Minnesota, Campbell extended the optimization of ground-state structure beyond the Jastrow trial function to include triplet (or intrinsic three-body) correlations² and (with C. C. Chang, one of his first doctoral students) applied this extension³ to study the density dependence of the roton spectrum in liquid ⁴He. An important calculational breakthrough within PPA came in 1977, when Campbell and Chang⁴ transformed the approach into an efficient and powerful iterative scheme for optimal determination of the static structure function and the two-body pseudopotential.

This body of work has been of fundamental importance for the development of modern many-body theory,⁵ allowing us to move beyond model problems and asymptotic behaviors to quantitative prediction of structure, excitations, and dynamics from first principles. Applications of PPA optimization theory have expanded far outside the original context of bulk liquid ⁴He, with successes in such

diverse problems as helium films and surfaces, helium clusters, ^3He - ^4He mixtures, the electron gas, metal surfaces, atoms, nuclei, spin systems, and even lattice gauge models. One of the most valuable properties of variational-CBF/HNC theory, as formulated by Campbell and collaborators, is that it fails when it should fail – e.g. if one is seeking the optimal translationally invariant Jastrow ground state, the equations have no solutions at densities below the spinodal point, or in the high-density region corresponding to a solid phase. Such behavior stands in strong contrast with that of more traditional (and sometimes more famous) approaches rooted in perturbation theory – which continue to yield predictions (and sometimes continue to be taken seriously) in regions where they are known to be incorrect on qualitative physical grounds.

Charles Campbell's productivity has been sustained over many years in a series of contributions of exceptional quality. In a not-quite-random sampling, these include his research on the stability of quantum fluid mixtures with Karl Kürten,⁶ on liquid metallic hydrogen with John Zabolitzky,⁷ on the quantized Hall effect with Tao Pang,⁸ and on the static pair-pair correlation function in classical fluids.⁹ One may point especially to the superb work on electron correlations in atomic systems carried out with Pang and Krotscheck¹⁰ within the optimal variational theory of inhomogeneous Fermi systems. In this last-cited effort there is the promise (yet to be fully exploited) of fundamental advances in the realistic calculation of electronic structure and correlations. These studies are indicative of the breadth of Campbell's command of central issues in condensed matter physics.

Another profoundly important development spearheaded by Campbell is the extension of variational-CBF theory to finite temperatures, an advance with impact comparable to that of PPA optimization theory. The essential steps were taken while Chuck was visiting and working with Fred Ristig in Cologne on a Humboldt Fellowship (1981–82), the first papers^{11,12} being coauthored with Fred, Karl Kürten, and Fred's student Gerd Singer. This effort epitomizes the path-breaking nature of much of Campbell's research. Trial density matrices are constructed that build in strong correlations along with thermal excitations; the Gibbs-Delbrück-Molière variational principle is applied to the corresponding free energy, to yield Euler-Lagrange equations for the temperature-dependent correlations and excitations. Implementation of this methodological breakthrough continues to spread across a broad range of strongly-correlated many-body problems, notably in studies of the thermodynamic properties of lattice gauge models and lattice-spin systems as well as helium surfaces and films. Further work along this line by Chuck includes (i) seminal conceptual papers^{13,14} with Clements, Krotscheck, and Smith, (ii) the landmark calculations on the thermodynamics of boson quantum films with Clements, Krotscheck, and Saarela,¹⁵ and (iii) steps toward a true microscopic understanding of the λ transition in liquid ^4He and its relation to Bose-Einstein condensation.¹⁶

For the last five years or so, Chuck has been active in a quite separate area of condensed matter physics, exploring new ideas and empirical findings^{17,18,19} on

micromagnetic domain evolution in magnetic thin films, stripes, and nanoscale dots, interacting strongly with experimental colleagues and students in the Magnetic Microscopy Center at Minnesota. However, he comes to CMT31 fresh from a lengthy stay at Johannes Kepler University in Linz, where he returned with new vigor to revisit the dynamical properties of boson quantum fluids with Eckhard Krotscheck's group.

3. A Life of Service and Dedication

Charles Campbell's service to the profession, to his university, and to his students has been prodigious in its generosity – inspiring admiration (and not a small glint of guilt) in all who know him. He is universally recognized as a leading figure and contributor to two sizable communities within physics, namely quantum many-body theory and quantum fluids and solids. He has played indispensable roles in the promotion, organization, and guidance of three prominent conference series in these subfields: the International Conferences on Recent Progress in Quantum Many-Body Theories (the main series of the field, the seventh meeting being held at the University of Minnesota in 1991 with Campbell as chief local organizer), the International Symposia on Quantum Fluids and Solids (QFS2000 having been held in Minneapolis, again with Chuck as a key organizer), and of course our annual International Workshops on Condensed Matter Theories, which is distinguished by strong involvement of scientists from developing countries. As a major voice in these communities, Campbell has gained respect from his colleagues for his integrity and wisdom, his dedication, and his clear-headed approach to problems. He has given freely of his time and energy, in spite of heavy obligations to teaching, service, and research at his home institution. We could not do without him.

Although less familiar to his professional colleagues at other institutions, Campbell's dedication to his own school and university has been phenomenal in its scope and impact. His appointments and committee assignments, far too numerous to list, some reaching to the highest levels of policy formation, reflect an intense commitment to the welfare of his university and its people. In 2001, this important aspect of Chuck's life and career was recognized in part by the University of Minnesota's Institute of Technology with the George W. Taylor Award for Distinguished Service.

The third dimension of Campbell's service, at least as important as the others, is expressed in his extraordinary dedication to teaching. He has a brilliant record as a master classroom teacher, admired for his excellent rapport with both undergraduate and graduate students. As a research mentor, he is a splendid example, a wise and thoughtful counselor to his doctoral students. He is not only a teacher to the young: although I was once his teacher, I continue to learn from him, year by year.

Chuck Campbell's not-so-secret secret is that in everything he does — research, service, teaching — *He cares, and cares deeply!*

4. A Personal Note: Campbell and Feenberg

Eugene Feenberg regarded Chuck Campbell as one of his very best students (probably the deepest among us). His great promise was apparent to Eugene at a very early stage. It was with great pride that he followed Chuck's development as a physicist of unusual breadth and originality — recognized today as among the true pioneers and scholars of microscopic many-body theory. I know of no one who has been more successful, in his life work, in re-expressing the Feenberg pattern of insight, clarity, and integrity.

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