Raymond F. BISHOP: Research Interests

My main field of research is microscopic quantum many-body theory and its applications to systems in nuclear physics, subnuclear physics and quantum field theory, condensed matter physics, quantum fluids and ultra-dense matter, statistical physics, and quantum information theory.

Examples of quantum many-body systems abound in Nature. Thus, it is clear that in fields like molecular, solid-state, and nuclear physics most of the fundamental objects of discourse are interacting many-body systems. But even in elementary particle physics one is usually dealing with more than one particle. For example, at some level of reality a nucleon comprises three quarks interacting via gluons and surrounded by a cloud of mesons, which are themselves made of quark-antiquark pairs. Even more fundamentally, even the "physical vacuum" of any quantum field theory is endowed with an enormously complex infinite many-body structure due to virtual excitations. A key central role in modern physics is thus occupied by quantum many-body theory, where we are especially interested in the possible existence of any universal techniques that are powerful enough to treat the full range of many-body and field-theoretic systems. One such method is the ***coupled cluster method***, which my collaborators and I have pioneered. This has become one of the most pervasive (possibly the most pervasive), most powerful, and most successful of all fully microscopic formulations of quantum many-body theory. It has been applied to more systems in quantum field theory, quantum chemistry, nuclear, subnuclear, condensed matter and other areas of physics than any other competing method. It has yielded numerical results which are among the most accurate available for an incredibly wide range of both finite and extended systems on either a spatial continuum or a regular discrete lattice. The further development and applications of the coupled cluster method remains one of my primary research interests.

Specific examples of problems and topics on which I have worked include:

- dense nuclear (and baryonic) matter, and
- neutron stars and beta-stable matter;
- finite atomic nuclei;
- hypernuclei and hypernuclear matter, and
- the general problem of impurities in Fermi systems;
- a two-fluid model of nuclear rotations and surface vibrations;
- translationally-invariant cluster methods in coordinate space, as an efficient alternative to shell-model expansions;
- the electron liquid and electron correlations (metals and plasmas), and
- other Coulombic liquids;
- the liquids ^{3}He and ^{4}He;
- condensation in interacting Bose systems, and
- the general theory of critical phenomena;
- pairing and higher-order clustering in Fermi systems;
- constrained variational theories of dense quantum liquids;
- general development of the coupled cluster method, and its applications to
- anharmonic oscillators and nonlinear systems in quantum field theory,
- quantum (antiferro)magnets and low-dimensional quantum spin arrays,
- strongly correlated lattice electrons, e.g., the Hubbard model,

- lattice gauge field theories, e.g., U(1), Z(2), SU(2) models,
- chiral lattice field theories, and
- the Rabi Hamiltonian and other models in quantum optics, quantum electronics, and solid-state optoelectronics;
- the development of the extended coupled cluster method, and its applications to
- a generalised bosonisation procedure as an exact mapping of quantum many-body/field theory into classical Hamiltonian mechanics,
- an exact hierarchical generalisation of the random-phase approximation for many-body mean fields,
- the holomorphic representations of simple model field theories,
- quantum fluid mechanics, and
- charged impurities in polarizable media, e.g., positron annihilation in metals;
- generalised coherent states,
- new classes of mixed coherent states, including thermal coherent states,
- generalised thermofield dynamics, and
- noisy bases in Hilbert space.

My current areas of interest include the following:

- further development of techniques of microscopic quantum many-body theory (especially the coupled cluster method), and their applications to
    - the structure of light and intermediate-mass atomic nuclei
    - lattice and continuum quantum field theories
    - spin-lattice systems in quantum magnetism, especially their quantum phase transitions
    - strongly correlated electronic systems
    - systems in quantum optics, quantum electronics and solid-state optoelectronics
- strongly correlated fermion/boson systems
- quantum coherence and quantum information theory, especially
    - generalised pure coherent states
    - new classes of mixed coherent states (including thermal coherent states)
    - noisy bases in Hilbert space
    - coherence/decoherence phenomena
- generalised thermofield dynamics
- extended quantum phase space methods and their applications to quantum many-body theory and quantum information theory