MANY-BODY OPEN QUANTUM SYSTEMS: FROM ATOMIC NUCLEI TO QUANTUM DOTS

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NUMBER OF PARTICIPANTS: 43

MAIN TOPICS:

- Shell model description of open quantum systems
- Resonances and correlations in halo/few-body continuum
- Ab initio description of unstable systems
- Threshold effects in multichannel coupling
- Non-hermitian Hamilton operators
- Spreading of wave packets
- Quantum transport in mesoscopic systems and microwave billiards
- Laser induced continuum structures in atoms and molecules
- Dephasing in mesoscopic structures

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SCIENTIFIC REPORT:

Aim and Purpose Today, much interest in various fields of physics is devoted to the study of small open quantum systems, whose properties are profoundly affected by environment, i.e., continuum of decay channels. Although every finite fermion system has its own characteristic features, resonance and threshold phenomena are generic; they are great interdisciplinary unifiers. It was therefore urgent to bring together scientists working on different many-body open quantum systems such as weakly bound/unbound atomic nuclei, atoms and molecules in strong external fields, quantum dots, microwave cavities , etc. to stimulate interdisciplinary contacts and contribute to exchange of ideas.

In the field of nuclear physics, the growing interest in theory of open quantum systems is associated with experimental efforts in producing weakly bound/unbound nuclei close to the particle drip-lines, and studying structures and reactions with those exotic systems. To this end, the major problem for nuclear theory is a unification of structure and reaction aspects of weakly-bound or unbound nuclei, based on the open quantum system many-body formalism. Solution of this challenging problem has been advanced recently through the new-generation continuum shell model approaches. These approaches can be used also for studies of other finite-size quantum many-body systems such as coupled quantum dots or atomic molecules which are easier to control experimentally than atomic nuclei.

Revival of the theory of open quantum systems is rooted in the work of Tore Berggren on the completeness of an ensemble consisting of resonant Gamow states and the complex-energy, non-resonant continuum of scattering states. One of the goals of the workshop was to celebrate the 40th anniversary of this seminal work which opened a window for the formulation of a comprehensive modern many-body theory of weakly bound/unbound states and henceforth put a foundation for the open quantum system community across the frontiers of various fields of physics.

Results and Highlights Description of the dynamics of weakly bound and unbound many-body systems such as the atomic nuclei, clusters of neutral atoms, few-electron quantum dots, etc. close to the particle-emission thresholds became possible in the open quantum system formalism. This is one of the main highlights of the workshop. Few-body open quantum systems can be treated by solving Fadeev equations or using the Complex Scaling ap-

proach. Ab initio description of these systems is now also available using the Gamow Shell Model or the Coupled Cluster approach in Berggren ensemble, which can be applied to light and medium-mass nuclei. The development of the Density-Matrix Renormalization Group algorithms for open quantum systems enables presently a fully converged shell model calculations resolving the many-body completeness relation in Berggren ensembles.

Heavy atomic nuclei or atomic clusters, both bound and decaying, can be described in the density functional approach and the self-consistent Continuum-Hartree-Fock(-Bogoliubov) method. Collective excitations in those systems can then be studied using the self-consistent continuum QRPA.

Over last few years, one could notice an impressive development of the many-body techniques appropriate for studies of the dynamics of strongly correlated quantum many-body systems in the transitional region around the (multi-)particle emission threshold(s). Realistic applications, following an experimental progress in the fields of loosely bound atomic nuclei, atomic clusters, or cold atoms will be the challenge for future studies.

Deeper understanding of loosely bound or unbound many-body systems will help to identify salient features of the continuum coupling induced transition in the particle-particle coupling and its consequences for binding energy systematics, spectroscopic amplitudes, response functions, effective symmetries, reaction cross-sections, etc. To bridge the gap between configuration-interaction approaches with realistic interactions and the approaches rooted in the density functional theory is the long-term objective of those studies.

Many aspects of open quantum systems are generic and independent of the system dimensionality. These include: properties of the exceptional points and related topological phases, crossings and avoided crossings of resonance energies, redistribution of widths, symmetry-breaking effects in different regimes of resonance densities, S-matrix fluctuations, width distributions, etc. Those phenomena have been originally studied in nuclear reactions but it is not possible to experimentally control the behavior of the nuclear system by varying external parameters as in, e.g., atoms and molecules, quantum dots, or microwave resonators. In those systems, the new quality of precision table-top experiments have been recently achieved to study and prove fundamental quantum-mechanical laws that govern open quantum systems. Exact mapping between observed quantities and eigenfunctions of the Schrődinger equation, which is possible for example in microwave experiments (as well as in certain experiments in quantum optics), allow to view the microwave resonator as an analog computer solving Schrődinger equation in different

regimes of level densities. This analogy can be further used, e.g., to test assumptions of the compound-nucleus reaction theory in the microwave resonator experiments.

Conclusions The multi-configurational models based on the Berggren ensemble are tools of choice for the description of structure and reaction aspects of many-body systems that require microscopic treatment of open channels. A number of developments are on the way, primarily pertaining to nuclear physics; however, future applications to other systems (hypernuclei, molecules, dots) are envisioned.

Many experiments in quantum optics or in coupled quantum dots interacting with the environment, can be modelled by replacing degrees of freedom of the environment by the fluctuating force. Here the theoretical challenge are experimental results on decoherence (dephasing) and relaxation processes in open quantum systems generated by the fluctuating environment. It has been stressed that the formulation of a consistent quantum stochastic theory of such processes should be attempted also within the Berggren approach.

The participants have felt that discussions related to generic features of open systems were most stimulating and have led to excellent cross-fertilization. The topics of general interests included, among others,

- Properties of metastable states, resonances, and many-body continuum
- Threshold phenomena and channel coupling
- Channel alignment and clustering
- Statistical features of spectra; overlapping resonances
- Bound states in the continuum
- Nature of exceptional points
- Time evolution of wave packets and tunneling
- Rigged quantum mechanics and imaginary potentials
- Advanced computational techniques

It has been concluded that the inter-disciplinary workshops of this kind should definitely continue; a manifesto of the open-systems community is being drafted.

The talks can be browsed from the website:

http://www.ect.it/Meetings/ConfsWksAndCollMeetings/ConfWksDocument/2007/Talks/1