

021001 *Colloquium: Hadron production in open-charm meson pairs at e^+e^- colliders*

Xiongfei Wang
Xiang Liu
Yuanning Gao

Hadron spectroscopy is a frontier of particle physics; searching for new hadrons is crucial for validating the theory of strong interaction (QCD). Investigating how charmonium, a bound state of charm and anticharm quarks, decays and searching for new charmoniumlike states yield valuable insights into strong interaction mechanisms, including quark confinement and gluon binding. Hadrons produced at e^+e^- collisions decaying to open-charm meson pairs are a primary source of experimental information for these investigations. This Colloquium reviews current progress from *BABAR*, Belle, CLEO-c, and BESIII experiments. As BESIII accumulates high-precision data, it has emerged as the leading facility for measuring hadron production in charm-meson pair systems, and recent advances are highlighted.

021002 *Colloquium: Simulating non-Markovian dynamics in open quantum systems*

Meng Xu
Vasilii Vadimov
J. T. Stockburger
J. Ankerhold

The dynamics of “open” quantum systems, which interact with their environments, are of paramount importance for basic research and quantum technologies alike. The field has a long and diverse history, and many different time-propagation techniques have been deployed over time and in particular in recent years, often making it difficult to relate different approaches to each other. Based on a unified framework, this Colloquium provides an overview of methods used to describe and to simulate open quantum systems in various contexts, including quantum optics, quantum information, quantum thermodynamics, and solid-state and many-body physics, as well as chemical physics, highlighting the commonalities and differences between them.

025001 *Exactly solvable quantum many-body dynamics from space-time duality*

Bruno Bertini
Pieter W. Claeys
Tomaž Prosen

Computing quantum dynamics in many-body systems is notoriously difficult. In the past decade, there has been a fundamental advance based on discretizing the time evolution of lattice systems, by analogy with digital computation. Since space is already discrete on a lattice, treating space and time on the same footing avoids the mathematical complications of continuous space-time quantum field theories. This review focuses on how this space-time duality plays out in the dynamics of interacting many-body systems and the intrinsic relationship with special kinds of lattices termed brickwork quantum circuits. From this pedagogical review, readers will learn how this far-reaching analogy with quantum computation lies at the heart of a unified view of dynamical evolution of quantum many-body systems.

025002 Radiation forces and torques in optics and acoustics

This review presents a unified perspective of how local energy, momentum, and spin densities in optical and acoustic wave fields induce forces and torques on particles—a topic that has captivated researchers for centuries. Applications discussed include trapping and manipulation of atoms and nanoparticles by light, sorting of biological cells by the combination of acoustics and microfluidics, and pulling forces that draw particles against the direction of wave propagation.

Ivan Toftul
Sebastian Golat
Francisco J. Rodríguez-Fortuño
Franco Nori
Yuri Kivshar
Konstantin Y. Bliokh

025003 2D van der Waals magnets: From fundamental physics to applications

Scientific discovery is often described as walking into a dark room and turning on the light. The discovery of 2D magnetism in van der Waals materials in 2016 was one such leap forward, removing one spatial dimension from macroscopic materials. The study of 2D magnets has challenged established theories and uncovered new phenomena. This review summarizes the current state of knowledge of magnetic phenomena in 2D van der Waals materials. The field encompasses not just the traditional study of ferromagnets and antiferromagnets but also topology, quantum and nonequilibrium dynamics, Floquet effects, magnons and spintronics, and the interaction of magnetism with light, phonons, and electric fields (multiferroics). The field is actively evolving, expanding theoretical understanding, materials capabilities, and experimental phenomenology while opening new directions for application.

Je-Geun Park
Kai-Xuan Zhang
Hyeonsik Cheong
Jae Hoon Kim
Carina A. Belvin
David Hsieh
Honglie Ning
Nuh Gedik

025004 Fundamentals of vacuum breakdown in high-gradient accelerator structures

Vacuum breakdown or arcing happens when a very strong electric field causes a metal surface in a vacuum to suddenly form plasma, allowing large electrical currents to flow. Breakdown can damage particle accelerators, fusion reactors, satellites, and x-ray devices, though it is useful in technologies like plasma thrusters. Scientists have studied this unpredictable and fast phenomenon for over a century. Recent advances in experiments and computer simulations now provide a coherent mechanistic picture: tiny surface defects, electrical stress, heat, and emitted particles interact in complex ways to trigger breakdowns. These insights could improve high-power technologies and make advanced accelerators more reliable and efficient.

Walter Wuensch
Sergio Calatroni
Flyura Djurabekova
Andreas Kyritsakis
Yinon Ashkenazy

025005 Quantum linear system solvers: A survey of algorithms and applications

Given vector $\mathbf{b}$ and matrix A , solve for vector $\mathbf{x}$ such that $A\mathbf{x} = \mathbf{b}$: this problem of solving linear-algebraic equations is arguably the central task of machine computation. The quantum linear system problem (QLSP) asks whether, given efficient quantum access to A and a state encoding $\mathbf{b}$, a quantum computer can prepare a state encoding the solution. The QLSP has driven extensive algorithmic development since Harrow, Hassidim, and Lloyd (HHL)'s pioneering 2009 algorithm. This review explores quantum algorithmic techniques that have been devised for efficiently tackling the QLSP, with a thorough explanation of HHL and subsequent post-HHL developments.

Mauro E. S. Morales
Lirandë Pira
Philipp Schleich
Kelvin Koor
Pedro C. S. Costa
Dong An
Alán Aspuru-Guzik
Lin Lin
Patrick Rebentrost
Dominic W. Berry

025006 High-energy emission from the Galactic Center

Andrea Goldwurm
Maïca Clavel
Stefano Gabici
Régis Terrier

In this review, the authors provide a comprehensive multiwavelength view of high-energy emission from the center of our Galaxy. This region contains the closest supermassive black hole to us, which offers the best studied galactic nucleus in the Universe, with its quiescent emission and accretion contrasted by flaring activity. The Galactic Center also hosts diverse compact sources, plasma bubbles, and x-ray chimneys, altogether forming a dense interacting molecular zone—a gigantic powerhouse in the Milky Way.

025007 Tip-enhanced molecular fluorescence microscopy with atomic-scale resolution

Anna Rosławska
Katharina Kaiser
Sofia Canola
Song Jiang
Fabrice Scheurer
Javier Aizpurua
Tomáš Neuman
Guillaume Schull

Scanning probe techniques have transformed our ability to study materials at the atomic scale, providing atom-by-atom views of surfaces. Tip-enhanced molecular fluorescence microscopy combines scanning probes with optical fluorescence. Such optical techniques normally have spatial resolution limited by the wavelength of the light used. However, using the scanning tip itself as a nanoscale optical antenna confines the electromagnetic field to the tip apex, achieving superresolution down to the atomic scale. Fluorescence is a fundamental probe of materials that reveals electronic structure and vibronic properties by exciting electrons to higher levels and observing the photons emitted when they relax. These capabilities are of particular interest for studying and identifying molecules, submolecular structures, and their reactions. This review discusses the techniques of tip-enhanced molecular fluorescence microscopy and the new insights they have revealed.