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449 **Light hadron masses from lattice QCD**

Zoltan Fodor
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One of the most basic tests of quantum chromodynamics in the strong coupling regime is whether it can successfully predict the spectrum of light hadron masses in terms of a small number of inputs. This article surveys the status of lattice calculations of the spectrum, including the formalism, theoretical uncertainties, and current results. The calculations successfully reproduce relevant parts of the observed spectrum at the percent level.

497 ***Colloquium*: Disclination loops, point defects, and all that in nematic liquid crystals**

Gareth P. Alexander
Bryan Gin-ge Chen
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Topological defects play a strong role in the physics of a large class of systems with interacting components such as in the case of nematic liquid crystals. Recent experimental progress in this area has attracted a lot of attention. In this Colloquium the experimental situation is reviewed and the theoretical approaches that can describe the rich phase diagram of these systems are discussed.

515 **Leptonic *CP* violation**

G. C. Branco
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This article surveys the theoretical origins and experimental implications of possible CP violation in the lepton sector. The formalism for CP violation and its possible relation to neutrino masses are described. Experimental and observational constraints and possibilities involving neutrino oscillations, neutrinoless double beta decay, rare decays of charged leptons, nonunitary effects induced by heavy decoupled particles, and the possible collider signatures of the doubly charged scalars found in some theories are discussed. Finally, the possible explanation of the cosmological baryon asymmetry by the leptogenesis mechanism is reviewed. This article surveys the theoretical origins and experimental implications of possible CP violation in the lepton sector. The formalism for CP violation and its possible relation to neutrino masses are described. Experimental and observational constraints and possibilities involving neutrino oscillations, neutrinoless double beta decay, rare decays of charged leptons, nonunitary effects induced by heavy decoupled particles, and the possible collider signatures of the doubly charged scalars found in some theories are discussed. Finally, the possible explanation of the cosmological baryon asymmetry by the leptogenesis mechanism is reviewed.

567 **Radioactive decays at limits of nuclear stability**

M. Pfützner
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L. V. Grigorenko
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Nuclear physics began with the discovery of radioactivity. Several different forms of nuclear disintegration have been identified very early, starting with the familiar alpha, beta, and gamma decays. In 1938, nuclear fission joined the elite club of nuclear decays. The exotic, short lived nuclei, accessible experimentally during the last decades, have demonstrated quite a bit of skill and ingenuity in releasing its binding energy by spitting various particles out. This review is devoted to the traditional and unusual forms of nuclear radioactivity observed at the limits of nuclear stability.

621 **Gaussian quantum information**

Christian Weedbrook
Stefano Pirandola
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Nicolas J. Cerf
Timothy C. Ralph
Jeffrey H. Shapiro
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Quantum information processing and communication protocols are typically expressed in terms of discrete units of information, the quantum bits (or qubits). However, certain experimental setups involving, for instance, light or atomic ensembles, are based on continuous quantum system and, in particular, on Gaussian states and operations. This review adapts the main ideas and protocols in the field of quantum information to such systems, and explains their advantages and limitations.

671 **Theoretical aspects of massive gravity**

Kurt Hinterbichler

The discovery that the expansion rate of the Universe is accelerating, perhaps due to a nonzero and very small cosmological constant, has led to many speculations regarding modifications to the long distance structure of general relativity. This review discusses modifications which generate a mass for the graviton from a theoretical point of view and includes a treatment of diffeomorphism invariance, interactions, and the low-energy effective field theory treatment of such theories.

711 **Dual pairing of symmetry and dynamical groups in physics**

D. J. Rowe
M. J. Carvalho
J. Repka

Symmetries, group theory, and the related theory of Lie algebras underlie quantum mechanics and provide the essential language for the interpretation of physical phenomena. This review discusses foundations and applications of dual representations of pairs of symmetry and dynamical groups primarily in atomic and nuclear physics, especially in the context of bosonic and fermionic many-body systems such as superconductors, molecules, and nuclei. By studying such dual subgroup chains, associations of phenomenological many-body models with microscopic approaches are revealed.

759 ***Colloquium*: Supersolids: What and where are they?**

Massimo Boninsegni
Nikolay V. Prokof'ev

Supersolid is the name of an exotic quantum phase of matter, combining the seemingly antithetical properties of crystal and superfluid phases. This phase is expected to exist in rather extreme circumstances, for example, in solid helium near absolute zero. Indeed, claims of its experimental observation have been made. This Colloquium reviews the bulk of the existing phenomenology and offers an interpretation of it, based on theoretical results of first principle computer simulations. Other physical systems in which the supersolid phase might be observed in the laboratory are also described.

777 **Multiphoton entanglement and interferometry**

Jian-Wei Pan
Zeng-Bing Chen
Chao-Yang Lu
Harald Weinfurter
Anton Zeilinger
Marek Żukowski

Light is made out of photons, which now can be efficiently created, manipulated, and detected. This provides us with the possibility of testing several fundamental aspects of quantum mechanics, ranging from the quantization of energy to the superposition principle, or the violation of Bell inequalities. Also, the degree of control that has been achieved over the properties of the photons has opened up a broad spectrum of applications in the context of quantum information science. This review provides an introduction to multiphoton systems, with an emphasis on their entanglement properties. It also contains an exposition of the fundamental tests that have been carried so far with such systems, as well as the key experiments on quantum communication and computation.

839 **Statistical physics of fracture, friction, and earthquakes**

Hikaru Kawamura
Takahiro Hatano
Naoyuki Kato
Soumyajyoti Biswas
Bikas K. Chakrabarti

An explanation of the often disastrous nature of earthquakes, large scale mechanical failure phenomena, and in particular their forecasting remain to be a most important issue in physics and Earth science. Since earthquakes might be regarded as a large scale dynamical failure process involving friction and fracture of a preexisting fault, their understanding can be based on statistical approaches known, for example, from material science. The present article reviews the status of interpreting the properties of earthquakes from a statistical physics point of view.

885 **Ice structures, patterns, and processes: A view across the icefields**

Thorsten Bartels-Rausch
Vance Bergeron
Julyan H. Cartwright
Rafael Escribano
John L. Finney
Hinrich Grothe
Pedro J. Gutiérrez
Jari Haapala
Werner F. Kuhs
Jan B. Pettersson
Stephen D. Price
C. Ignacio Sainz-Díaz
Debbie J. Stokes
Giovanni Strazzulla
Erik S. Thomson
Hauke Trinks
Nevin Uras-Aytemiz

Ice is indeed all around us. This review looks ahead from the frontiers of research on ice dynamics in its broadest sense; on the structures of ice, the patterns or morphologies, and the physical and chemical processes involved. Open questions in the various fields of ice research in nature are highlighted; ranging from terrestrial and oceanic ice on Earth, to ice in the atmosphere, to ice on other Solar System bodies and in interstellar space.

945 **Lattice instabilities in metallic elements**

Göran Grimvall
Blanka Magyari-Köpe
Vidvuds Ozoliņš
Kristin A. Persson

Whether metallic elements possess metastable crystal structures in addition to the thermodynamically stable one is a question that is of both principal and practical importance. Modern *ab initio* methods have shown that many structures that were thought to be metastable are in fact dynamically unstable. This review gives a thorough introduction to stability criteria, theoretical concepts, and numerical methods for exploring these important questions.