Reviews of Modern Physics

Volume 84 **Number 3** **July–September 2012**

987 **How higher-spin gravity surpasses the spin-two barrier**

Xavier Bekaert
Nicolas Boulanger
Per A. Sundell

Gauge theories mediate forces through particle of spin one while the gravitational force is mediated through particles of spin two. It has long been thought that there are no consistent theories with fundamental particles of spin greater than 2, but recent constructions show that while this standard lore is probably true in flat spacetimes, spaces with constant curvature that occur in the presence of a cosmological constant provide a loophole that allows construction of consistent higher-spin generalizations of gravity. This review explains the original no-go results in flat space and then discusses the construction of higher-spin theories in backgrounds with a cosmological constant.

1011 **Theories of photoelectron correlation in laser-driven multiple atomic ionization**

Wilhelm Becker
XiaoJun Liu
Phay Jo Ho
Joseph H. Eberly

A century after Einstein's explanation of the photoelectric effect, ionization of atoms by light is still a debated subject. This review addresses the new class of phenomena that occurs when atoms are irradiated with picosecond or femtosecond laser pulses of intensity above 1 TW/cm2. Pairs of electrons are emitted with a rate that exceeds the prediction of standard optical ionization theory by several orders of magnitude. The theoretical interpretations that have been proposed for this new few-body effect are reviewed and their results are compared with recent experimental data.

1045 ***Colloquium*: Phononics: Manipulating heat flow with electronic analogs and beyond**

Nianbei Li
Jie Ren
Lei Wang
Gang Zhang
Peter Hänggi
Baowen Li

Just as electrons in electronics, lattice vibrations or phonons, i.e., the carriers of heat, can be manipulated to produce useful devices for controlling energy and processing information. This Colloquium reviews, from the experimental and theoretical perspectives, the main issues and challenges in the young field of phononics.

1067 **Electron-electron interactions in graphene: Current status and perspectives**

Valeri N. Kotov
Bruno Uchoa
Vitor M. Pereira
F. Guinea
A. H. Castro Neto

Graphene has a unique band structure that leads to a relativistic single-electron spectrum. This paper reviews the effects of electron-electron interactions, covering phenomena that range from the Dirac liquid that replaces the familiar Fermi liquid to the Kondo effect, the RKKY interaction, and superconductivity in graphene. In addition, remaining open issues are discussed.

1127 **Nobel Lecture: Measuring the acceleration of the cosmic expansion using supernovae**

Saul Perlmutter

1151 **Nobel Lecture: Accelerating expansion of the Universe through observations of distant supernovae** — Brian P. Schmidt

1165 **Nobel Lecture: My path to the accelerating Universe** — Adam G. Riess

The 2011 Nobel Prize for Physics was shared by Saul Perlmutter, Adam G. Riess, and Brian P. Schmidt. These papers are the text of the address given in conjunction with the award.

1177 **Extremely high-intensity laser interactions with fundamental quantum systems** — A. Di Piazza, C. Müller, K. Z. Hatsagortsyan, C. H. Keitel

With the steady increase in recent years of optical laser intensities up to extremely high values, completely new physical phenomena beyond the usual atomic-physics energy scales can be studied. The laser light-electron interaction is pushed to the extreme and allows one to investigate the radiation backaction on the electron dynamics, the structure of the quantum vacuum, the creation of massive particles such as electrons, muons, and pions, and their respective antiparticles. The present article discusses furthermore how novel high-intensity lasers and laser-accelerated particle beams might be used to trigger directly nuclear and high-energy processes as well as to test the physics beyond the standard model.

1229 **Publisher's Note: *Colloquium*: Disclination loops, point defects, and all that in nematic liquid crystals [Rev. Mod. Phys. 84, 497 (2012)]** — Gareth P. Alexander, Bryan Gin-ge Chen, Elisabetta A. Matsumoto, Randall D. Kamien

1231 ***Colloquium*: The shape of hadrons** — Constantia Alexandrou, Costas N. Papanicolas, Marc Vanderhaeghen

In this Colloquium, the concepts related to the shape of hadrons, the smallest extended particles in the Universe, and in particular the proton, are examined. It is shown how recent high-precision experimental results and theoretical understanding combine to provide a description of hadron shape, in the context of relativistic quantum field theory. Credence is given to the conjecture that hadrons, and in particular the proton, are not spherical.

1253 **One-dimensional quantum liquids: Beyond the Luttinger liquid paradigm** — Adilet Imambekov, Thomas L. Schmidt, Leonid I. Glazman

One-dimensional quantum fluids are usually described within the Luttinger liquid theory. It simplifies a real system by replacing the true spectrum of its particles with a linear one. Including the spectrum nonlinearity has proven to be difficult. This review describes a breakthrough in the theory of a nonlinearized fluid, which includes a set of universal singularities of the dynamic response functions and kinetic processes. The theory is a generalization of the original one and is applicable to a diverse group of systems.

1307 **From eV to EeV: Neutrino cross sections across energy scales**

J. A. Formaggio
G. P. Zeller

Neutrinos have been important probes and ingredients of nuclear physics, elementary particle physics, astrophysics, and cosmology. Their interaction cross sections are vital for their own sake and also for understanding the signals and backgrounds associated with neutrino sources, production processes, oscillations, and other processes such as the search for proton decay. This review summarizes our knowledge of neutrino cross sections over energy scales ranging from very low energies up to the ultrahigh energies associated with astrophysical sources.

1343 **Imaging physical phenomena with local probes: From electrons to photons**

Dawn A. Bonnell
D. N. Basov
Matthias Bode
Ulrike Diebold
Sergei V. Kalinin
Vidya Madhavan
Lukas Novotny
Miquel Salmeron
Udo D. Schwarz
Paul S. Weiss

The junction of a nanometer-sized probe tip and a surface contains much more information than is intrinsic to conventional tunneling and atomic force measurements. This review focuses on the numerous modifications of these conventional probes to further elucidate electrical, optical, magnetic, dielectric, and chemical phenomena at ultrahigh spatial resolution. These novel spatially localized probes are transforming our understanding of processes ranging from chemical reactions at surfaces to electron correlations in solids to dielectric polarization of atoms and molecules.