Moffat, John W.
Reinventing gravity. A physicist goes beyond Einstein. (English) Zbl 1233.83001
New York, NY: Smithsonian Books/Collins (ISBN 978-0-06-117088-1). xiv, 272 p. (2008).

It was Newton who theorized gravity for the first time. His theory was revolutionized by Einstein about 250 years later. This is well known as general relativity. Now it is the author's turn. Since 1979 the author has pursued a new theory of gravitation by reinterpreting Einstein's nonsymmetric unified field theory as a generalization of his purely gravitational theory [Phys. Rev. D (3) 19, No. 12, 3554–3558 (1979; Zbl 1222.83146); Can. J. Phys. 58, No. 11, 1595–1598 (1980; Zbl 1043.83513); Can. J. Phys. 58, No. 6, 729–736 (1980; Zbl 1043.83554); Can. J. Phys. 59, No. 2, 283–288; erratum ibid. 59, No. 9, 1289 (1981; Zbl 1043.83506); J. Math. Phys. 24, 886–889 (1983; Zbl 0508.53037); J. Math. Phys. 29, No. 7, 1655–1660 (1988; Zbl 0648.53045); General relativity and relativistic astrophysics, Proc. 2nd Can. Conf., Toronto/Can. 1987, 209–216 (1988; Zbl 0727.53071); Gen. Relativ. Gravitation 27, No. 9, 933–946 (1995; Zbl 0830.53070); J. Math. Phys. 36, No. 7, 3722–3732 (1995; Zbl 0841.53071); J. Math. Phys. 36, No. 10, 5897–5915 (1995; Zbl 0842.53073); Phys. Lett., B 355, No. 3–4, 447–452 (1995; Zbl 0997.83518)].

Towards the end of his life, Einstein attempted to construct a nonsymmetric unified field theory of gravitation and classical electromagnetism. It is well known that the theory does not correctly describe Maxwell's theory. The author argues that, though the theory is a blunder as a unified theory, it could be reinterpreted as a generalization of general relativity. In the nonsymmetric extension of general relativity, the symmetric metric tensor is replaced by the sum of symmetric and antisymmetric tensors. The antisymmetric part of the metric tensor gives rise to a torsion, twisting the geometry of spacetime. The theory is subject to general covariance and the weak principle of equivalence, in which the field equations are derivable from a Lagrangian action principle. The field equations for the nonsymmetric Hermitian $g_{\mu\nu}$ lead to a rigorous static spherically symmetric solution for the gravitational field in empty space excluding the essential singularity at $r = 0$. The predictions of the theory differ significantly from Einstein's general relativity for compact sources or supermassive stars, while the theory is concordant with all the classical tests of general relativity concerning weak gravitational fields. The theory is called the nonsymmetric gravity (NSG).

In 2003, the author ["Gravitational theory, galaxy rotation curves and cosmology without dark matter", J. Cosmol. Astropart. Phys. 2005, No. 5, Paper No. 003, 28 p. (2005; Zbl 1236.83045)] found out a simpler alternative to the above nonsymmetric extension of Einstein's general relativity, where the purely symmetric spacetime is used while the antisymmetric part occurs as an additional field (a new fifth force) in the equations of the theory. It is called Metric-Skew-Tensor Gravity (MSTG). Einstein's general relativity coupled to a massive skew symmetric field $F_{\nu\mu\lambda}$ leads to an acceleration law, modifying the Newtonian law of attraction between particles. The author uses a framework of nonperturbative renormalization group equations to characterize special renormalization group trajectories allowing for the running of the effective gravitational coupling G and the coupling of the skew field to matter. The equations of motion for test particles yield predictions for the solar system and the binary pulsar PSR 1913+16 that are concordant with the observations. The gravitational lensing of clusters of galaxies can be explained without exotic dark matter. A Friedmann-Lemaitre-Robertson-Walker cosmological model with an effective $G = G(t)$ running with time leads to consistent fits to cosmological data without any assumption of exotic cold dark matter.

In 2004, the author ["Scalar-tensor-vector gravity theory", J. Cosmol. Astropart. Phys. 2006, No. 3, Paper No. 004, 18 p. (2006; Zbl 1236.83047)] found out a yet simpler alternative, which is based upon Einstein's symmetric metric, a vector field called the phion field, and three scalar fields. The phion particle is the carrier of the fifth force, while the scalar fields describe the variation of the gravitational constant, the coupling of the phion field to the matter, and the effective mass of the phion field. The author has established that the theory, called Scalar-Tensor-Vector Gravity (STVG), is stable, has no negative energy modes and is free of any pathological singularities.

An important feature of the NSG, MSTG and STVG theories is that the modified acceleration law for weak gravitational fields has a repulsive Yukawa force added to the Newtonian acceleration law. This corresponds to the exchange of a massive spin 1 boson, whose effective mass and coupling to matter can vary with distance scale. A scalar component added to the Newtonian force law would correspond to an attractive Yukawa force and the exchange of a spin 0 particle. All the current applications of the author's three gravity theories that can be directly confronted with experiment are based upon weak gravitational fields. To really distinguish the three theories, it is necessary to obtain experimental data for strong gravitational fields, by way of example, black holes.

The book is intended to explain the author's modified gravity theories to the general audience. It is well written and highly readable.

Reviewer: Hirokazu Nishimura (Tsukuba)

MSC:

83-01 Textbooks (relativity)
83-03 Historical (relativity)
01A60 Mathematics in the 20th century
83C50 Electromagnetic fields in general relativity
83C05 Einstein's equations (general structure, canonical formalism, Cauchy problems)
85A05 Galactic and stellar dynamics
81T17 Renormalization group methods (quantum theory)
81V22 Unified theories of elementary particles
83C75 Space-time singularities, cosmic censorship, etc.
83C15 Closed form solutions of equations in general relativity
83F05 Relativistic cosmology
83C57 Black holes

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general relativity; modified gravity theory; scalar-tensor-vector gravity; metric-skew-tensor gravity; non-symmetric unified field theory of Albert Einstein