Exact solutions of Einstein and Einstein-Maxwell equations

0.1 Topics

- Exact solutions of Einstein and Einstein-Maxwell equations
- Cosmology
- Quantum Fields
- Fundamental Relativity

0.2 Participants

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- V.A. Belinski
- H. Quevedo

0.3 Research activity

0.3.1 Exact solutions of Einstein and Einstein-Maxwell equations

• We define the physical conditions for stationary equilibrium of binary systems containing rotating black holes and naked singularities and prove that the system made up of a Kerr–Newman black hole and a Kerr–Newman naked singularity indeed can stay in equilibrium state. The similar question about the system of two charged rotating black holes or two rotating overextreme charged sources still remains open. Reference (1).

• It was shown that black hole inserted into Melvin magnetic universe can be interpreted as state of interaction of two solitons, one of which represents the Melvin geon corresponding to the pole at infinity in the complex plane of the spectral parameter and another is the standard black hole solitonic configuration having the pole in the finite region of this plane. The procedure how to construct such exact solution is described in details. Reference (2).

0.3.2 Cosmology

• We investigate the validity of a minimal cosmological model derived from the renormalizable Horava action at low redshift scales by using different cosmological and statistical tests. Assuming pure attractive gravity in the Horava action we compare the Union 2.1 supernova type Ia data with the kinematics following from a model-independent approach. The two approaches, although compatible, lead to explicit cosmographic constraints on the free parameters of the Horava action, which turn out to be in strong disagreement with the Lambda CDM, w-CDM and Chevallier-Polarski-Linder scenarios. To show this, we use standard diagnostic tools of regression models, namely the Akaike and the Bayesian Information Criteria. Using such model-independent statistical methods, we show that Horava-Lifshitz cosmology differs from the standard dark energy scenarios, independently of the number of free parameters involved in the model. Since this result is valid at small redshift domains, it indicates the presence of inconsistencies in the minimal version of Horava-Lifshitz cosmology even at the level of background cosmology. Reference (3).

0.3.3 Quantum fields

• For field theories in which no small parameter is available, we use Heisenberg quantization procedure to propose a definition of nonperturbative quantum states in terms of the complete set of Green functions. We present the corresponding quantization schemes in the case of Einstein gravity and gauge theories. To illustrate the procedure of quantization, we show that: (1) modified theories of gravity appear as an effective approximation of nonperturbative quantum gravity; (2) the Wheeler-DeWitt equation appear as a sort of approximation of the quantization procedure a la Heisenberg, and (3) it is possible to carry out explicit nonperturbative calculations in quantum chromodynamics, and we obtain the energy spectrum of a quantum monopole and some thermodynamic quantities for a gas of noninteracting quantum monopoles. Reference (7).

0.3.4 Fundamental Relativity

• The statistical mechanics of a cloud of particles interacting via their gravitational potentials encounters some issues when the Boltzmann-Gibbs statistics is applied. In this work, we consider the alternative statistical framework of Tsallis and analyze the statistical and thermodynamical implications for a self-gravitating gas, obtaining analytical and convergent expressions for the equation of state and specific heat in the ensembles of constant temperature and constant energy. Although our results are comparable in both ensembles, it turns out that only in the ensemble of constant temperature do the thermodynamic quantities depend explicitly on the Tsallis parameter, indicating that the question of ensemble equivalence for Tsallis statistics must be further reviewed. Reference (8).

• We propose a criterion for finding the minimum distance at which an interior solution of Einstein equations can be matched with an exterior asymptotically flat solution. The location of the matching hypersurface is thus constrained by a criterion defined in terms of the eigenvalues of the Riemann curvature tensor by using repulsive gravity effects. To determine the location of the matching hypersurface, we use the first derivatives of the curvature eigenvalues, implying C-3 differentiability conditions. The matching itself is performed by demanding continuity of the curvature eigenvalues across the matching surface. We apply the C-3 matching approach to spherically symmetric perfect fluid spacetimes and obtain the physically meaningful condition that density and pressure should vanish on the matching surface. Several perfect fluid solutions in Newton and Einstein gravity are tested. Reference (9).

• In this work, we investigate the correspondence between the Erez-Rosen and Hartle-Thorne solutions. We explicitly show how to establish the relationship and find the coordinate transformations between the two metrics. For this purpose the two metrics must have the same approximation and describe the gravitational field of static objects. Since both the Erez-Rosen and the Hartle-Thorne solutions are particular solutions of a more general solution, the Zipoy-Voorhees transformation is applied to the exact Erez-Rosen metric in order to obtain a generalized solution in terms of the Zipoy-Voorhees parameter $\delta = 1 + sq$. The Geroch-Hansen multipole moments of the generalized Erez-Rosen metric are calculated to find the definition of the total mass and quadrupole moment in terms of the mass, quadrupole and Zipoy-Voorhees delta parameter. The coordinate transformations between the metrics are found in the approximation of similar to q. It is shown that the Zipoy-Voorhees parameter is equal to $\delta = 1 - q$ with $s = -1$. This result is in agreement with previous results in the literature. Reference (10).

• We derive modified classes of Chaplygin gas by using the formalism of Geometrothermodynamics. In particular, our strategy gives us extended versions of Chaplygin gas, providing a novel thermodynamic explanation. Thus, we show that our models correspond to systems with internal thermodynamic interaction. Bearing this in mind, we find new free parameters which are derived from thermodynamics and we give them an interpretation. To this end, we predict the range of values that every term can take in the context of homogeneous and isotropic universe. We also show that our new versions of modified Chaplygin gas can be interpreted as unified dark energy models, independently from the introduction of our new additional terms. Finally, we compare our theoretical scenarios through a fit on a grid based on the Union 2.1 compilation and we evaluate the growth factor of small perturbations. In this respect, we show that our model better adapts to the theoretical Lambda CDM value than previous versions of modified Chaplygin gas. We show numerical constraints at late and early redshift domains, which turn out to be compatible with previous results on standard versions of Chaplygin gas models. Reference (4).

• Legendre invariant metrics have been introduced in Geometrothermodynamics to take into account the important fact that the thermodynamic properties of physical systems do not depend on the choice of thermodynamic potential from a geometric perspective. In this work, we show that these metrics also have a statistical origin which can be expressed in terms of the average and variance of the differential of the microscopic entropy. To show this, we use a particular reparametrization of the coordinates of the corresponding thermodynamic phase space. Reference (5).

• Recently, we have shown that non-selfdual self-gravitating dyonic fields with magnetic mass generalize the Dirac monopole. The unique topological index, which characterizes the field, is a four-dimensional analogue of the famous monopole configuration. An unexpected result of this analysis is that the electric parameter can only take certain discrete values as a consequence of applying the path integral approach to quantize the magnetic flux. Here, we show how this result can be generalized to higher dimensions, considering a special type of inhomogeneous geometries. Our results apply to a vast range of theories and situations in which topological charges are present. For concreteness, we focus here on Lovelock-Maxwell solutions and show that the magnetic flux corresponds to a topological excitation and the electric flux becomes discrete. Reference (6).

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