

UDC 530.122

Gravitation, Cosmology and Nonsingular Universe

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Abstract. Isotropic cosmology built in the frame of the gauge gravitation theory in Riemann-Cartan space-time is investigated. It is shown that all cosmological models of flat, closed and open types are regular by certain restrictions on indefinite parameters of gravitational Lagrangian due to the conclusion about the possible existence of a limiting energy density in the nature. Physical processes at the beginning of cosmological expansion in dependence of limiting energy density and corresponding changes in the history of the early Universe compared to the Big Bang model are discussed. It is shown that gravitational interaction in astrophysics in dependence of space-time torsion is corrected in comparison with general relativity theory.

Keywords: cosmic singularity, gravity, modified gravity, space-time torsion, physics of the early universe

Introduction. Satisfying the correspondence principle with the general relativity theory (GR), the gauge gravitation theory in Riemann-Cartan space-time (GTRC) opens up possibilities for solving some fundamental problems of GR. Having as a gauge group the direct product of the 4-parametric group of space-time translations and the 6-parametric group of tetrad Lorentz transformations, GTRC is a theory of the gravitational field generated by Noether invariants corresponding to two subgroups of the gauge group, namely, by canonical energy-momentum tensor and tetrad spin moment tensor of gravitating matter [1, 2]. Unlike GR, in the frame of which the gravitational interaction in the case of ordinary gravitating matter with positive energy density and non-negative pressure always has the character of attraction, which increases with increasing energy density, the gravitational interaction in the frame of GTRC in certain situations can have the character of repulsion [1, 2]. This physical result was obtained on the basis of isotropic cosmology, constructed within the framework of GTRC using a general expression for the gravitational Lagrangian, which contains, in addition to scalar curvature, various quadratic in the curvature and the torsion invariants [3, 5]. Gravitational repulsion occurs in extreme conditions by extremely high energy density [3], as well as on a cosmological scale when the energy density is low and the vacuum effect of gravitational repulsion becomes significant [5].

Within the framework of the Big Bang cosmological model, gravitational singularity, which occurs at the beginning of the cosmological expansion, leads to cosmological problem related to the time limitation of the Universe's existence in the past. Solving this problem, in addition to obtaining regular cosmological solutions, means excluding singular solutions from the physical foundations. The GTRC opens up

ways to solve the cosmological problem due to the conclusion about the possible existence of a limiting (the maximum allowed) energy density in the nature.

Methods and materials; results. As a result of studies of the equations of isotropic cosmology of the GTRC [4], the following results have been obtained: 1. Numerical solutions of cosmological equations near the limiting energy density by transition from gravitational compression to expansion in dependence on energy density in the case of flat, closed and open models are obtained. 2. The physical processes at the beginning of cosmological expansion, described on the basis of the theory of elementary particles, depending on the magnitude of the limiting energy density (limiting temperature) and corresponding changes in the history of the early Universe are discussed. 3. The constraints for indefinite parameters of the theory under which solutions of isotropic cosmology describe a nonsingular accelerating Universe are given. Accelerating cosmological expansion as vacuum repulsion effect without using the dark energy notion is discussed.

According to the variational formalism for media with internal degrees of freedom in Riemann-Cartan space-time [6], the interaction of space-time torsion with the rotational moments of astrophysical objects (star systems, galaxies, clusters of galaxies) leads to the appearance of an additional force of gravitational interaction in addition to the Newtonian force of attraction (see e.g. [7]). A possible manifestation of space-time torsion in astrophysics is being considered.

Conclusion. The solution of cosmological problem and dark energy problem in the frame of GTRC testifies that this theory which is a direct development of GR by using methods of classical field theory opens up ways to solve fundamental problems of the gravitation theory.

References

- [1] Minkevich A.V. Gauge gravitation theory in Riemann — Cartan space-time and gravitational interaction. *Grav. Cosmol.*, 2016, vol. 22, no. 2, pp. 148–158.
<https://doi.org/10.1134/S0202289316020109>
- [2] Minkevich A.V. Towards the theory of regular accelerating Universe in Riemann — Cartan space-time. *Int. J. Mod. Phys.*, 2016, vol. A31, no. 2–3, art. no. 1641011.
<https://doi.org/10.1142/S0217751X16410116>
- [3] Minkevich A.V. Limiting Energy Density and a Regular Accelerating Universe in Riemann — Cartan Spacetime. *J. Exp. Theor. Phys. Lett.*, 2011, vol. 94, art. no. 831.
<https://doi.org/10.1134/S0021364011240052>
- [4] Minkevich A.V., Limiting energy density and gravity in Riemann — Cartan space-time. *JCAP*, 2022, vol. 03, no. 027, arXiv:2112.06739.
- [5] Minkevich A.V. De Sitter spacetime with torsion as physical spacetime in the vacuum and isotropic cosmology. *Mod. Phys. Lett. A*, 2011, vol. 26, pp. 259–266.
<https://doi.org/10.1142/S0217732311034797>
- [6] Minkevich A.V., Fyodorov F.I. The calibration approach in the theory of gravity and relativistic dynamics of classical systems. *Fundamental Interactions (Physics), Interuniversity Collection of Scientific Papers*, Moscow, MGPI Publ., 1984, pp. 141–159. (In Russ.).
- [7] Minkevich A.V. About gravitational interaction in astrophysics in Riemann — Cartan space-time. *Clas. Quant. Grav.*, 2019, vol. 36, art. no. 055003.