COSMOLOGY, COSMOMICROPHYSICS AND GRAVITATION

DIFFERENT APPROACHES FOR DARK MATTER HALOS OF CLUSTERS OF GALAXIES

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ABSTRACT. To describe the density profile of dark matter halos of clusters of galaxies, we compare the approach based on the Schwarzschild-de Sitter metric with a recently developed mechanical one (discrete cosmology inside the cell of uniformity). In the first approach, the cosmological effects are completely incorporated into the cosmological constant, while in the second one the scale factor enters directly the corresponding equations. Hence, in the latter case we can take into account the effect on the density profiles not only the cosmological constant, but also other material components. Thus, we can evaluate how this dynamic impact is considerable and testable.

Key words: Dark matter; galaxy cluster.

1. Introduction

It is known, that our expanding Universe is well described by the isotropic and homogeneous Friedmann model on scales larger than the cell of uniformity which is of the order of 190 Mpc. The modern realization of this scenario is the ΛCDM model. However, according to astronomical obsevations, there is no clear evidence of spatial homogeneity inside the cell of uniformity. Here, the Universe consists of a set of discrete inhomogeneities (galaxies, groups and clusters of galaxies) which disturb the background Friedmann model. Hence, on such scales, classical mechanics of discrete objects provides more adequate approach than hydrodynamics.

2. Halo density profiles

According to the mechanical approach developed in the recent series of papers [1-3], the radius R_H of the zero acceleration sphere around a cluster of galaxies of the mass m is:

$$R_H{}^3 = \frac{G_N m}{\ddot{a}/a}, \frac{\ddot{a}}{a} = H_0^2\left(-\frac{1}{2}\Omega_M \frac{a_0^3}{a^3} + \Omega_\Lambda\right) > 0,$$

where the second formula represents the well-known second Friedmann equation for the scale factor a(t); dots denote the derivatives with respect to synchronous time t. We consider the late-time accelerated expansion of the Universe. Therefore, $\ddot{a}/a > 0$. In accordance with the standard ΛCDM model, the Universe is filled with the nonrelativistic dark matter (DM) characterized by the average rest mass density $\bar{\rho}$ (being constant in the comoving reference frame) and the dark energy represented by the cosmological constant Λ. We focus our attention on the isothermal profile which is spherically symmetric density profile of dark matter in halo of the form

$$\rho(R) = \rho_1\left(\frac{R_1}{R}\right)^2, \rho_1 = const, R_1 = const, \rho_1 = \rho(R_1)$$

For this distribution, the gravitational potential is

$$\Phi_{\Lambda CDM}(R) = -\frac{\ddot{a}}{a}\left(\frac{R^2}{2} - R_H^2 + \frac{R_H^3}{R}\right) + 4\pi G_N \rho_1 R_1^2 \ln\frac{R}{R_H} - 4\pi G_N \rho_1 R_1^2\left(1 - \frac{R_H}{R}\right) - \frac{G_N m}{R_H}$$

Here, we use the discrete cosmology approach where the background metrics is the Friedmann one. On the other hand, if the background metric is the Schwarzschild-de Sitter one, we obtain:

$$\Phi_\Lambda(R) = \frac{8\pi G_N}{3}\rho_\Lambda\left(\frac{R_\Lambda}{R}\right)^2 \ln\frac{R}{R_\Lambda} - \frac{4\pi G_N}{3}\rho_\Lambda - \frac{G_N m}{R_\Lambda}$$

Obviously, this expression is quite different from the previous one.

3. Conclusions

We found gravitational potentials for the isothermal halo density profiles in the case of two different approaches. This gives us an opportunity to consider motion of test massive bodies taking into account both gravitational attraction to inhomogeneities and cosmological expansion of the Universe. The comparison with observations should allow us to determine which approach best fits the experimental data.

References

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