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# NEGATIVE MASS AND REPULSIVE GRAVITY IN NEWTONIAN THEORY, AND CONSEQUENCES

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**Abstract.** In the context of the Newtonian theory of gravity, the dynamical equivalence of hydrodynamic flows with geodesic lines, in the interior of a bounded, gravitating perfect-fluid source, results in the possibility of negative mass and, hence, of repulsive gravity. The consequences are outlined for the overall picture of the Solar System and the large-scale cosmological, structures, and some predictions are attempted based on some current and mostly unexplained so far observational data.

## 1. INTRODUCTION

According to many current observational data, the realistic picture and morphology of an astrophysical-cosmological structure differs greatly from its corresponding optical picture. This is true for the Solar System, whose linear dimensions are of the order of $10^5$ AU, namely, approximately half the distance to the nearest star to the Sun, and also for the Milky Way, whose linear dimensions are at least 200 kpc, almost ten times larger than its optical linear dimensions ($\sim 30$ kpc). Similar arguments hold for other types of galaxies and for even larger cosmological structures, namely, clusters of galaxies and super-clusters of galaxies.Therefore, it appears appropriate that the large-scale cosmological structures be treated as almost spherically symmetric, very complex, practically continuous, and of much larger linear dimensions cosmological structures than previously assumed. Consequently, the *constituent elements of the Universe and the Universe as a whole, can quite satisfactorily be treated as continuous gravitational systems and, more specifically, bounded, gravitating perfect-fluid sources, the physical-dynamical description of which is very well established at both the Newtonian and the general-relativistic levels.* So, we arrive at the very crucial result, that the motions of and in these constituents should be considered as as hydrodynamical flows rather than geodesic motions. Now, in view of the wealth of such observational data and strong indications, it has been suggested [1,14] that, in both the Newtonian and the general-relativistic theories of gravity, and at all levels, namely, cosmological [1,7,8,9,10,13], galactic [1,2,3,5,6,7,8,10,11], and stellar [1,2,4,6], it is possible to give to the equations of hydrodynamical (and hydromagnetic) flow motions in the interior of a bounded gravitating perfect-fluid source the form of the equations of the equations of geodesic motion in it. This approach is usually referred to as the *dynamical-equivalence approach.*

It is exactly this *dynamical-equivalence approach*, that enables us to recast the geodesic motions, mostly applied in the observational determination of masses, now taking into account, as sources of geodesic motions, not simply the mass density but all of the source's internal physical characteristics (like e.g. mass density, pressure, internal thermodynamic energy, velocities of both ordered and statistical thermodynamic motions). Similarly, this approach enables us to determine the contribution to the observationally determined mass of the fluid source of all of the source's internal physical characteristics.

In the context of the dynamical-equivalence approach, especially it has been proved [1,11,12,14] that, in the Newtonian theory of gravity, the flows take on the functional form of the geodesic motions in an explicitly known generalized potential containing, beyond the usual gravitational potential, also a part depending on the internal physical characteristics of the source. Quite interestingly, the generalized density producing the generalized potential can be positive, vanishing, or negative, defining, respectively, positive, vanishing, or negative mass, and so causing, respectively, decelerated geodesic motion (attractive gravity), unchanged acceleration, and accelerated geodesic motion (repulsive gravity).

Finally we recall, that according to the observations of the cosmic microwave background by the *Wilkinson Microwave Anisotropy Probe* (WMAP), the Cosmos is composed of heavy elements (0.03 %), ghostly neutrinos (0.3 %), stars (0.5 %), free hydrogen and helium (4%), dark matter (22 %), and dark energy (73 %).

In the following we shall briefly expose some the consequences of this equivalence on problems like dark-matter problem, the flat-rotation curves problem, the problem of the true linear dimensions of the cosmological structures, and, finally, the problem related to the so-called *Pioneer Anomaly Effect* in the Solar System.

## 2. APPLICATIONS

In this section we shall give only a brief account of the planetary, stellar, astrophysical, and cosmological consequences, explicit results on which can be found in the literature at the end.

According the dynamical equivalence of the hydrodynamic flows and geodesic motions, the observationally determined mass is not the baryonic mass, $m$, but the *generalized mass*, $m_v = m + m_i$ where the internal mass *internal mass*, $m_i$, is the contribution to the observationally determined mass of the internal physical characteristics of the source considered. I most of the cases of isentropic and isothermal flows, $m_i$(and the corresponding *internal mass density)* is a negative quantity. Therefore, the baryonic mass is larger than the observationally determined mass, and there is a plentitude not luck of baryonic matter, a conclusion of particular interest to the dark-matter problem.

Furthermore, it has been proved that in the case of a spherically-symmetric, gravitating, isentropic perfect-fluid source, the total velocity of an equatorial, circular geodesic orbit at a distance from the center depends, through an isothermal equation of state, also on the temperature and chemical composition of the source. It is straightforward to verify that, for an overall temperature of the order of $10^4$K, the (circular) velocity curve in the Milky Way remains flat for practically the whole optical part of the galaxy, and continues so up to a radial distance of at least 200 kpc retaining a constant value in the range $\sim 100 - 200$ km/s, in agreement with standard observational data.

Moreover, in the case of a super cluster of galaxies, additionally, the requirement for a vanishing total acceleration (or, independently, the requirement that the thermal velocities are not larger than the escape velocity at the free surface of the super cluster) specifies the true linear dimensions of the super cluster, which are of the order of those of the observable Universe. This prediction is in complete agreement with the fact that no third-order clusters of galaxies have been observed so far (simply because there existence is not necessary!!!).

Furthermore, in the stellar and galactic levels, the notion of the repulsive gravity, predicted in the dynamical-equivalence approach, can be used to tackle problems like the formation of the (stellar and galactic) winds, and, in the case of magnetohydrodynamical flows, of the (stellar and galactic) jets.

Finally, in the case of the (spherical) Solar System, from the functional form of the generalized potential, on the one hand, one can determine the true linear dimensions of the Solar System (approximately, $10^5$ AU, in agreement with observational data), and on the other hand, the anomalous behaviour of the acceleration of various space probes can be explained, like the famous "Pioneer-Anomaly Effect", and other similar anomalies for other space probes.

It sill remains to be examined whether the dynamical-equivalence approach could, in principle, be of some importance to the celebrated dark-energy problem, beyond the one to the dark-matter problem.

## 3. CONCLUDING REMARKS

From all the above we conclude that, if we insist in using the notion of the geodesic motions (inside and outside) of the cosmological structures for the description of their physical motions and for the observational determination of masses, in conjunction with the results of the dynamical equivalence, then *the internal mass $m_i$, due to the internal physical characteristics of the source, is revealed to be there*, it is negative and, in many cases, absolutely it can largely exceed the rest (baryonic) mass of the gas of the (corresponding region of the) large-scale cosmological structure under consideration. It is interesting that this negative extra mass "shows up", in planetary, stellar, astrophysical and cosmological levels, when, in the context of the dynamical-equivalence approach, the geodesic motion in the generalized potential is used, and *not* when the standard geodesic motion of a test particle in the original gravitational potential is used. Moreover, since the internal mass $m_i$ is negative, the observationally determined mass of the cosmological structure is smaller than its baryonic mass. These two general results can give a very simple, classical solution to the dark-matter and the flat-velocity-curves problems. Finally, it is stressed that the derivation of the these results is valid also in the exact general-relativistic theory of gravity, and that in this derivation nor any modifications of Newton's law of gravitational attraction or of the Einstein equations are required, neither any other theories, beyond classical

Newtonian and relativity theory, are introduced and used. Detailed results can be found in the literature cited below.

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