

Negative mass and repulsive gravity in Newtonian theory, and consequences

N. K. Spyrou

Astronomy Department, Aristoteleion University of Thessaloniki,
541.24 Thessaloniki, Macedonia, Hellas (Greece)

Email: spyrou@astro.auth.gr

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 (~ 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 hydrodynamic 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 hydrodynamic (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. In 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 plenitude not lack 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 centre 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 ~ 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 their 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 magnetohydrodynamic flows, of the (stellar and galactic) jets [15].

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 still remains to be examined whether the dynamical-equivalence approach could, in principle, be of some importance to the celebrated dark-energy problem [16], beyond the one to the dark-matter problem [17].

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 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.

Acknowledgements

It is a pleasure to express, from this position also, my sincere thanks to the LOC for their nice organizing and warm hospitality during the Conference.

Appendix (Address during the opening ceremony):

Dear Guests and Participants,

On behalf of the Scientific Committee of the 13th Conference “Recent Developments in Gravity”, I wish to welcome all of you, participants and guests, here in Thessaloniki, and to wish you a pleasant and fruitful stay in our city, the capital of Macedonia.

It is well-known that, in their initial form, these conferences intended to bring together, for a week or so every second year, all the relativists of Greece, for communicating their scientific results and for exchanging ideas, views and suggestions.

But now, after 24 whole years since the first conference in 1984, these conferences have developed into international reputable conferences on gravitational theories, both Newtonian and relativistic, and their applications, with, however, the responsibilities and demands of the eventual organizers continuously and naturally increasing.

So, we, at the Astronomy Department of our University, are really happy organizing and hosting the 13th Conference of the series, now in Greek, «Νεώτερες Εξελιξεις στη Βαρύτητα» .

In the name of its Chairman, our colleague Dr Nikos Stergioulas, I wish to congratulate all the members of the Local Organizing Committee for their continuous and successful efforts with this superb result.

As the National Delegate of Greece to the European Space Agency, I grasp this opportunity to point out, for the future, a new reality, of interest to these conferences. And I wish to do it, additionally, because of some recent, happy and interesting coincidences.

It is quite probable that some of you are not aware of three recent events, during the last few months, of importance to the space programme of Europe.

The first one is the launch of the European Space Laboratory “Columbus” of the European Space Agency, which is already docked to the International Space Station orbiting the Earth at a height of approximately 400 Km. This laboratory is Europe’s “house in space”.

The second is the launch of the European Automated Transfer Vehicle (ATV) “Jules Verne”, the European cargo ship, already docked to the International Space Station.

The third, as a consequence also of the above two events, is that this year, 2008, is the year for the recruitment of the new European astronauts. Recently, an informing press conference was co-organized at the University of Thessaloniki by the European Space Agency, the General Secretariat for Research and Technology of the Greek Ministry of Development and, of course, by the University of Thessaloniki.

To the above three important events one must add the new, and, this time, quite clear in its details, Announcement of Opportunity for the research programmes of the European Space Agency. This development is of particular interest on the one hand to Universities and Research Centers and on the other hand to the imperative involvement of the Greek Industry in the activities of Greece in the context of the European Space Agency, for the sake, of course, of the success of Greece joining the European Space Agency. This Announcement of Opportunity is expected to be released by the end of June 2008.

Also, to all these one must add the Announcement of Opportunity for a number of post-graduate scholarships for young Greek scientists to go to various Centers of the European Space Agency and be trained there on matters of Space Physics and technology of interest to the European Space Agency. These scholarships will be funded by the Greek Foundation of Scholarships (IKY, in Greek) and the Task Force for Greece and the European Space Agency, and the Announcement of Opportunity is expected to be released soon, perhaps, during June 2008.

All the above are of extreme importance to Greece and to us as scientists and researchers. Especially, General-Relativistic Effects in Space, Fundamental Interactions, and Quantum Physics in Space Time are of central importance to e.g. the so-called E.L.I.P.S. programme, namely, the European Life and Physical Sciences programme.

In relation to this, just recall that the International Space Station, at a height of approximately 400 km, moves as fast as about 7.5 km/sec.

So we all can understand that, for example, time measurement from space, using various types of clocks, like optical clocks in space and hydrogen maser clocks, is very important for a large number of problems, like e.g., just to mention a couple of them, the massive particle interferometers, and the Very Long-Baseline Interferometry of great importance to Cosmology and, more generally, to Astronomy.

I am in the happy position to tell you that the national priorities of Greece for Human Spaceflight, Microgravity, and Exploration, to be finalized in the coming Ministerial Council of Europe next November, are

1. The full use and exploitation of the International Space Station and Columbus,
2. The promotion and use of the E.L.I.P.S. programme, and
3. The promotion and use of the really rich educational material of ESA.

Finally, let me point it out, of particular interest is the fact that, with all these developments occurring “over our heads”, on which every European citizen-taxpayer must be informed, the notion “environment” is changing, because, now, in a decisive way, the Near Earth Space Environment enters the environmental game, beyond the standard forms of environment, namely, the atmospheric and sub-atmospheric environments with all their serious problems.

Also, the notion “astronaut” has changed, because, now, it is possible for a young European scientist, under certain circumstances, of course, to fly to the International Space Station and Columbus and perform his/her research up there.

In conclusion, in view of all the above developments, new opportunities emerge for the Greek science, research, technology and industry, and new positions of work are created especially for our younger colleagues

This is something that we must soon realize and do our best for contributing to the success of the joining of Greece with the large family called Europe and, of course, the European Space Agency.

So, I look forward to the active, close, and intense collaboration, involvement and interaction of our scientific community as well, with the European Space Agency, and, of course, finally, I thank you very much for your patience and attention.

References

- [1] Kleidis K and Spyrou N K 2000 *Class. Quantum Grav.* **17** 2965-2982
- [2] Spyrou N K 1997 in The Physics of Ionized Gases, Proceedings of the 18th Summer School and International Symposium on the Physics of Ionized Gases (Kotor, Yugoslavia, 2-6 September 1996), eds. B.Vujicic, S. Djurovic and I. Puric, Institute of Physics, Novi Sad University, Yugoslavia, 417-446
- [3] Spyrou N K 1997 in The Earth and the Universe, Volume in Honorem L. Mavrides, eds. G. Asteriadis, A. Bandellas, M. Contadakis, K. Katsambalos, A. Papademetriou and I. Tziavos, Thessaloniki, Greece, 277-291
- [4] Spyrou N K 1997 *Facta Universitatis* **4** 7-14
- [5] Spyrou N K and Kleidis K 1999 On the Nature of Nuclear Galactic Masses, Proceedings of JENAM 1999, Samos
- [6] Spyrou N K 1999 in Current Issues of Astronomical and Planetary Environmental Concern, Proceedings of International Seminar (Thessaloniki, 6-7 April 1999) ed. N.K.Spyrou, Astronomy Department, Aristoteleion University of Thessaloniki, Thessaloniki, Greece, 23-35
- [7] Spyrou N K 2001 Conformal Invariance and the Nature of Cosmological Structures, Invited Talk, Proceedings of The Conference on Applied Differential Geometry-General Relativity, and The Workshop on Global Analysis, Differential Geometry, Lie Groups, (Thessaloniki, 27 June-1 July 2001) eds. G. Tsagas, C. Udriste, and D. Papadopoulos, 101-107
- [8] Spyrou N K 2002, in Modern Theoretical and Observational Cosmology, Proceedings of the 2nd Hellenic Cosmology Meeting (Athens, 19-20 April 2001), eds. M.Plionis and S.Cotsakis, Kluwer Academic Publishers, Dordrecht, **276** 35-43
- [9] Spyrou N K 2003 in Proceedings of the 10th Hellenic Relativity Conference Recent Developments in Gravity, eds. K. Kokkotas and N. Stergioulas, World Scientific, 90-96.
- [10] Spyrou N K 2004 in Laskarides P. G., ed., Proc. 6th Hellenic Astronomical Conference, Editing Office of the Univ. of Athens, Athens, 229
- [11] Spyrou N K, Tsagas C G 2004 *Class. Quantum Grav.* **21** 2435
- [12] Spyrou N K 2005 *J. Phys. Conf. Ser.* **8** 122
- [13] Spyrou N K 2006 in Proceedings of the International Scientific Workshop Cosmology and Gravitational Physics, eds. N.K. Spyrou, N. Stergioulas, and C.Tsagas, Publishing ZITI, Perea-Thessaloniki, 57-66
- [14] Spyrou N K and Tsagas C G 2008 *Mon. Not. R. Astron. Soc.* **388** 187-196
- [15] Spyrou N K and Tsagas C G 2009 in preparation
- [16] Kleidis K and Spyrou N K 2009 in preparation
- [17] Plionis M, Vasilakos S and Spyrou N K 2009 in preparation