HYDRODYNAMIC FLOWS VERSUS GEODESIC MOTIONS IN CONTEMPORARY ASTROPHYSICS AND COSMOLOGY §

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Abstract

In the context of both the Newtonian theory and the theory of General Relativity, we have examined the exact conditions, under which, in the interior of a gravitating perfect-fluid source, the geodesic motions and the isentropic hydrodynamic flows are *dynamically equivalent* to each other. Dynamical equivalence rests on the functional similarity between the corresponding, covariantly expressed differential equations of motion. As we have found, such a similarity can be revealed by a *conformal transformation* between the metric tensor of the original fluid and the corresponding quantity of the (so-called) *virtual fluid*, in which the hydrodynamic flows are formally the same as the geodesic motions. In this case, the conformal factor involved, is, essentially, the *specific enthalpy* of the original fluid. The underlying idea, that led us to explore a possible equivalence between geodesic motions and hydrodynamic flows, is based on our belief that, in determining the equations of motion in the interior of an astrophysical- or/and cosmological-fluid source, all the *internal physical characteristics* (internal motions, pressure, etc.) of this fluid should be taken into account as sources of the gravitational field (hydrodynamic approach) and not just its mass-energy content (geodesic approach). As we shall demonstrate, almost every astrophysical or/and cosmological system, which, so far, was treated as a system of particles receding from each other, within the context of the hydrodynamic approach acquires a more appropriate (and physical) interpretation. The functional expressions, determining the evolution of the various physical quantities in the original and the virtual fluid (i.e., the components of their energy–momentum tensor), can be related to each other through the *functionally-invariant field equations*, thus guarantying that the transition from the one kind of treatment to the other is performed covariantly.

There is a wide variety of astrophysical or/and cosmological issues, that can be treated (and resolved) within the context of *conformal dynamical equivalence* (CDE), which extends from the solar system to the central regions of galaxies, the clusters of galaxies, and the Universe as a whole. In particular: In the *Newtonian limit*, the extra contribution to the original mass-energy density results in an extra inertial-energy density and hence in an extra mass, both of which are always non-vanishing. By virtue of Newton's law, this extra mass will give rise to an extra force and, hence, to an extra acceleration, as well. In this framework, the celebrated *Pioneer-Anomaly Effect*, i.e., an unexpected small acceleration of the homonymous space-probe towards the Sun, acquires a quite acceptable classical explanation. On larger scales, but still in the Newtonian approximation, the flat rotational curves of the disk galaxies can also be explained naturally, based on the (conformally implemented) functional similarity between the equations of the ballistic motions and the generalized Euler flows. Furthermore, it is shown that, in the determination of masses in the central regions of the active galactic nuclei (AGNs), the observationally-determined nuclear mass is being *underestimated* with respect to the real physical quantity. On evaluating the corresponding *mass deficit*, we have found that, in typical cases of AGNs, it is not always negligible as compared to the mass of the central dark object, and, in fact, it can be comparable to the total rest-mass of the circumnuclear gas involved.

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