The nature of mass in logical perspective

György Darvas

Symmetrion
symmetry@symmetry.hu

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Latest discoveries in physics prioritise mass and issues concerning gravitation. Mass is a central notion in the general theory of relativity (GTR). My paper will concentrate on the nature of mass and discuss two related logical (pseudo- or real) problems. The easier one is the question on the difference between equivalence and identity – having treated by me in more details in earlier publications. Referring to the solution of this first problem prepares a more relevant logical problem, namely, that of the conservation of mass.

The equivalence principle is one of the main pillars of GTR. The equivalence principle states the equivalence of the gravitational and inertial masses. At the same time it does not mean that gravitational and inertial masses were identical. The equivalence principle states that the inertial mass and the gravitational mass of a test body are proportional, and (as we fixed the factor of proportion to "1") are measured on the same scale. Nevertheless, they should be considered not identical properties. Identical things cannot be equivalent: equivalence is a quantitative relation between qualitatively different (non-identical) entities. Only different things can be compared and proven to be equivalent. One needs to have two different qualities to claim they are of equivalent quantities. Therefore, gravitational mass and the inertial mass are qualitatively different entities that proved to be equivalent (at least at rest) in the measure of their effects. The paper will list a few consequences of the non-identity of the equivalent masses. We note that the isotopic field-charge (IFC) theory assumes the two kinds of masses to be different physical properties (that behave in different ways during a velocity boost), and considers them as isotopic IFC-s of the gravitational field.

Next, we investigate the conservation of mass. It has been assumed an apparently unproblematic question, without any open problem in connection with it. The picture is not so simple in the light of the difference between the two isotopic twin siblings of masses.

How did we conclude the mass conservation? In classical mechanics, we had empirical evidences for the conservation of energy. We had also empirical evidences for the conservation of mass (in general). Then three new issues entered the scene. (*i*) A proportionality between the quantity of energy and the measured quantity of mass was established. We have got also (*ii*) a proportionality between the measured quantities of the gravitational mass and the inertial mass. Finally we have got (*iii*) a principle of equivalence. Thus, we concluded from the conservation of energy the conservation of mass, and through the proportionality between the two kinds of masses, applying the equivalence principle, we extended the conservation to all kinds of masses.

Let us reconsider this logic. We must mention in advance the problem that in (*i*), originally, the energy was not the potential or the kinetic energy, rather the internal energy of a system, and the mass in the equation $E=mc^2$ was identical with the gravitational mass. (We will refer to quotations from Einstein.) The conservation of the energy (like other mechanical quantities) was concluded from the integration of the equations of motion. In modern treatment we can obtain it by the variation of the Lagrangian $L(x,\dot{x},t)$ for the geometric invariances. The conserved energy that we got, is proportional to the *mass* of the investigated system or the whole universe. To *which* mass? To the *gravitational mass*. (Here we will refer again to a few classical papers.) Where do we deduce from, that the full mass is conserved? We conclude it from the principle of equivalence. What does the principle of equivalence say us? It says, that (*a*) the effects of the two types of mass are indistinguishable. Moreover, we knew earlier that (*b*) the measured mass of a given object can behave both like gravitational mass and inertial mass, and (*c*) the measured quantities of these two masses are equal (at least in rest). These statements together are logically inadequate to conclude the conservation of the full mass.

If we assume, that the inertial and gravitational masses are two qualitatively different properties of matter, (at least, on the basis of the above clue), we have no reason to make any statement on the conservation of the inertial mass. The quantities of the two masses are equal, but they are supposed to be not identical. (Here we refer again to some classical papers.) This means, that we concluded the conservation of the gravitational mass (from the conservation of the energy), and we have good reason to state that this conserved amount gravitational mass is in its quantity equivalent to a certain amount of inertial mass. No more. It does not follow from this conclusion, that there are no other quantities of inertial mass in our universe, what are not without doubt conserved. I do not state, that there are certainly such non-conserved (inertial) masses. I state only, that all the above conclusions did not provide evidence for it. It has not been proven. (E.g., let's imagine a dance school. Boys and girls attend this school. The music starts and all the boys invite to dance a girl. The observer registers that all boys have found a partner. Then we read the record. Can we state that there were no more girls in the school?)

If we want to find evidence for the conservation of the full mass (both the gravitational and inertial), similar to the electromagnetics and the conservation of the electric charge, we should turn to the four-potential of the gravitational field and the energy-momentum tensor introduced in general relativity. In this course, there is irrespective that the mass is a quite different-property ‘charge’ of the field equations, quite different bosons mediate their interactions, and quite different Lagrangians govern their states and interactions, than the electric charges in the electromagnetic field. The common feature between them is the role of a central ($\sim 1/r$) scalar potential plus a kinetic part, and that we should expect some gauge invariance as a result of the four-potential. This latter did not follow from classical mechanics. The phenomenon is subject of field theory and GTR.

More precisely, in other words: when we concluded the conservation of the mass solely from the gravitational potential, we ignored any possible contribution by the kinetic part of the Hamiltonian (while the full Hamiltonian was generated by the full energy-momentum tensor in the GTR). The case is similar to that, when we derived the conservation of the electric charge – in classical electrodynamics – from the Maxwell equations alone, we derived an invariance solely from a transformation in the Coulomb field, so we concluded the conservation of the Coulomb charge (and not all electric charges). Thus – in classical electrodynamics – we did not couple it with a transformation in the gauge field.

This latter „imperfection” has been corrected by the coupled gauge transformation in QED. (In a proper gauge theory, symmetry transformations leave the total Hamiltonian invariant, and do not the kinetic and the potential components of the energy separately.) That gauge transformation was generated by the rest of the electromagnetic field tensor, and it led to the conservation of the full electric charge (Coulomb plus Lorentz types). Similar „correction” is to be done in case of the conservation of mass, by extending the derivation of the conservation to the full energy-momentum tensor in order to get conservation of the full mass.

This extension demands the consideration of the two kinds of masses, what is subject of the IFC theory. The IFC theory discusses, how the distinction between gravitational and inertial masses modifies physical equations. Their difference has not been reflected in the traditional physical equations. It makes itself apparent at high velocities relative to the observer, where the two kinds of masses differ also in their quantities. There was shown that they are subject to a hypersymmetry (conservation of a property called the isotopic field-charge spin, IFCS) that can transform them into each other (i.e., to rotate the IFCS in an abstract gauge field, where they can occupy two positions). That symmetry guarantees to keep the covariance of our physical equations. The hypersymmetry is broken at lower velocities (lower kinetic energies). Therefore, at least near to rest, one can observe the two IFC of the gravitational field equivalent. This indistinguishability was formulated as an equivalence principle. However, as we saw, equivalence – observed among limited conditions – did not mean identity. We put masses in physical equations marking the gravitational and inertial masses by different notations. Thus, we modify the equations (incl. the gravitational) that leads to novel conclusions at high velocities, while it does not result changes near to rest.