Distant matter in Physics

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ABSTRACT. The recent elucidation of electrodynamic induction points out the irrelevance of distant matter when dealing with *electromagnetic* phenomena at the most general level. Nevertheless, a main role of distant matter in Physics cannot be discounted when dealing with the origin of inertia.

1 Relativistic electrodynamics updated

In his masterful treatise on Classical electromagnetism Panofsky said [1]: “Practical devices for producing unipolar induction ordinarily involve rotation, and consequently some remarks should be added here concerning rotatory motion or accelerated motion in general”.

“Contrary to what is true of frames differing in motion only by relative velocity (Lorentz frames), experiments *can* be performed that distinguish rotating (accelerated) frames”.

“ Which frame is an **inertial frame** is presumably defined by **gravitational forces**, and therefore ‘a **preferred frame** as to totation’ is defined by the location of the **bulk** of the **masses** in the **universe**”.

More recently, Panofsky wrote [2]: “ It is quite straightforward to design arrangements using electromagnetic devices which demonstrate a preferred rotational frame, but this is not a contradiction with special relativity or to general relativity (which describes special properties to frames rotating with respect to a frame in which the preponderance of masses of the universe are at rest)”.

“ There is not relativity for rotations”, said Feynman in his famous Lectures [3]. ” For nearly a century after its discovery by Faraday in 1832 the unipolar generator was a conundrum for the theory of electromagnetism", said Bartlett [4].

Despite the above statements, recent undisputable experimental work [5,6,7,8,9,10] rescues the relational (i.e. absolutely relativistic) nature of electrodynamic phenomena, including rotational motion. By spun a conducting disk on a uniform permanent magnet, the disk becomes an electromotive force generator able to drive a direct current through a *closing-circuit* wire whose ends contact on the disk at diferent radii. By attaching the disk to the magnet the same output as above is observed from which follows, at first sight, that the whole phenomenom is insensitive to magnet´s rotation.

" Kennard makes no consideration about induction on the galvanometer. This means that he does not consider the galvanometer as a part of the seat of induction", said Assis and Thober [11]. Our experiments show that the closing-circuit wire (at relative motion with the magnet) is the seat of induction when disk and magnet comoves with null relative velocity.

The clue of the success of the above experiments lies on the *short-range* singularity introduced in a uniform permanent magnet by removing a small sector of the magnetized bulk [5,6]. ***B**-field* reverses *only* in the singularity leaving unaltered the field pattern *at large* (i.e., where the *closing-circuit* wire is located). The reciprocal actions between magnet, rotational probe, and closing-circuit wire were independently measured for the first time for both generator (Faraday disk) and motor (Maxwell motor [12]) configurations.

At the beginning of the 21st century we can ensure that the case of a conducting disk, rotating clockwise above a stationary uniform magnet, is equivalent to the magnet rotating counterclockwise beneath the stationary disk. This equivalence is observed despite the fact that $\partial \mathbf{B}/\partial t$ *is zero* at every point in the space. Recently G. R. Dixon was able to provide an elegant explanation of the observed facts consistent with the theory of Lorentz' field-transformations [10].

2 Mach's Principle and distants matter

The strict proportionality between inertial and gravitational masses (verified with a relative uncertainty below 10^{-11}) intrigued Mach all his life. It led him to suggest that distant matter might inertially regulate local interactions [13]. As is well known, the above proportionality appears only fortuitously in Classical Mechanics. Moreover, it is a well known empirical fact that the best inertial frames employed today are those anchored to distant galaxies. Once, Classical Mechanics is unable to answer the question since distant matter doesn't enter into its formulation. But Panofsky statements concerning the role of distant matter become actual when applied to inertial reactions, instead to electrodynamic forces.

In 1925 E. Schrödinger sought the origin of inertia by modifying Newtonian mutual gravitational energy (potential energy) in a suitable manner [14,15]. Guided by heuristic considerations he wrote, for two interacting point gravitational masses M_g and m_g :

$$U = - (M_g m_g /r)[1 - \varepsilon \dot{r}^2 /c^2]. \qquad (1)$$

In Eq. 1 $\dot{r} \equiv dr/dt$, c is the velocity of light in vacuum, and ε is a dimensionless parameter that becomes 3 in order to fit the observed planetary precessions.

Using its own energy, Schrödinger calculated the energy of interaction of a spherical shell (gravitational mass M_g , radius R) with an internal point mass m_g , moving in the vicinity of the shell's center with a velocity v relative to the shell. He obtains $U=-(M_g m_g/R)[1-v^2/c^2]$. He identified the velocity-dependent component of the potential energy with the particle's kinetic energy. That is, $M_g m_g v^2 /Rc^2 = m_i v^2/2$, where m_i signifies inertial mass. It then follows that $m_i=(2M_g/Rc^2)m_g=(8\pi \sigma R/c^2)m_g$, where σ is the (presumably constant) surface density of gravitational mass.

Subsequently, Schrödinger adapts this result for a spherical shell to a "world" of radius R_o, where he assumes a constant mass density. He concludes that if the radius and the mass density of our own galaxy are used, one obtains a value for G (the gravitational constant) some 10^{11} times smaller than what is actually measured. He concludes that the inertia of particles in the solar system must primarily be due to matter external to our galaxy.

3 Recent account

The pioneering work of Schrödinger was recently improved by Assis [16,17,18], who was able to implement Mach's ideas in a rigorous, entirely general way.

Departing from Schrödinger, Assis begins with the formulation of a Weber-like force law that reads, for point masses 1 and 2,

$$F = -H_g(m_{g1}m_{g2} / r^2)[1 - \xi \dot{r}^2/2c^2 + \xi r\ddot{r} /c^2]. \qquad (2)$$

In Eq. 2, $\ddot{r} \equiv d^2r/dt^2$ and H_g and ξ are constants. ξ is dimensionless and becomes 6 in order to fit the observed planetary precessions. H_g becomes 1 and is also dimensionless when working with any coherent system of standards such as the cgs or the MKS ones [19, 20, 21, 22]. The outstanding mathematical property of Eq.(2) is that it is *invariant* (frame independent), which means that each term in the Weber-Assis force has the same value for *all* observers, even for non-inertial ones.

With the aid of Eq.(2) and the Principle of Dynamical Equilibrium ("The sum of all forces of any nature acting on a body is always zero in all frames of reference") Assis was able to explain the origin of inertia and the reality of the so-called fictitious forces of inertia ($-m\boldsymbol{a}$, *centrifugal*, *Coriolis*, etc.). In short, Assis has developped a true relativistic mechanics which complies with Mach's requirements. He coined the name *Relational Mechanics* for his model.

The reactive force, exerted by the whole isotropic universe on an accelerated test particle *k* (gravitational mass m_{gk}), has a magnitude [22] $\boldsymbol{f_r} = -m_{gk}\Phi\,\boldsymbol{a}$. This reactive force opposes the active, local force $\boldsymbol{f_a}$ that accelerates the test particle. Here $\Phi = (2\pi\,\xi\,\rho_g/3H_o^2)$, where ρ_g signifies the mean density of gravitational mass in the universe and H_o signifies Hubble's constant. It follows from the Principle of Dynamical Equilibrium ($\boldsymbol{f_a}+\boldsymbol{f_r}=0$) that $\boldsymbol{f_a}=m_{gk}\Phi\,\boldsymbol{a} \equiv m_{ik}\boldsymbol{a}$, where the inertial mass of the test particle is defined by $m_{ik}=m_{gk}\Phi$ in order to recover Classical Mechanics.

Assuming the (mean) density of inertial mass in the universe scales like inertial mass ($\rho_i=\Phi\,\rho_g$ and $m_g=\sqrt{G}\,m_i$,) we derive GH_o^2/ρ_i, a result first advanced by Dirac, based on numerological considerations [23].

4 Concluding remarks

At present the role of a preferred frame of reference, in which **"preponderance of the mass of the universe is at rest"** [1,2, 24], cannot be discounted when considering the inertial reaction of the whole universe, in opposition to locally applied active forces on a test body. However, the above preferred frame appears to be superfluous when dealing with electrodynamic actions. In recent Rohrlich's words [2]: "Your experiments should remove the last shadow of doubt even of the most skeptical minds, that the electromagnetic phenomena are of a relativistic nature".

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