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Abstract. A possible causal relationship between the four interactions is developed, based on Dicke's interpretation of Mach's principle. The dimensionless coupling constants which are predicted from this relationship are of the correct magnitude.

Dicke (1962) has shown that the requirements of Mach's principle may be most readily stated by expressing the gravitational constant G as a summation of the form

$$G^{-1} \sim \sum \frac{m}{rc^2} \tag{1}$$

where the exact method of summation over the observable Universe remains to be specified. Experimental evidence forbids any particular summations for which significant perturbations of G are predicted as a result of local variations in the distribution of matter.

For a homogeneous fluid region of the Universe, which is rotating and gravitationally stable, one has the precise result

$$G^{-1} = \frac{2\pi\rho k}{\omega^2} \tag{2}$$

where ω and ρ are the angular velocity and density of the region and k is a boundary shape constant ($\leqslant 1$).

In a universe consisting only of rotating and gravitationally stable regions there then exists an exact dynamical summation for equation (1), provided it is stipulated that the rotation of any particular region will not affect the value of the gravitational constant when it is measured outside the boundary surface of that particular region. Under these circumstances the value of G at a point in space, which is enclosed by the stable rotating boundary surface N, but which is not enclosed by the stable rotating boundary surface $N+1$, may be written

$$G_N{}^{-1} = \sum_{n=N}^{n=1} \frac{2\pi\rho_n k_n}{\omega_n{}^2} \tag{3}$$

where the boundary $n = 0$ is taken to correspond to the boundary of the observable, or causally related, universe. No dynamical interpretation of equation (1) has been previously suggested.

To test the validity of equation (3), it is necessary to substitute values of ω and ρ for various regions of the Universe which may approximate to the requirement of gravitational stability. It may then be seen whether the predicted gravitational force values correspond to established experimental force values. These force values are most conveniently expressed, for comparison purposes, as dimensionless coupling constants. When applying equation (3) to a point in the vicinity of the Earth's surface there are only four separate regions which can enclose the point and which, at the same time, may meet the requirement of being gravitationally stable. These regions are, in descending order of size, the Galaxy ($n = 1$), the Earth ($n = 2$), the atom ($n = 3$) and the atomic particle ($n = 4$). Substitutions of ω and ρ appropriate to these regions are shown summarized in table 1.

The first point to be noted in table 1 is that the agreement between the predicted magnitude of the component of G for $n = 1$, and the usual measured value for the terrestrial gravitational constant, is a trivial agreement once one has set $n = 0$ to correspond to the boundary of the observable Universe.

Table 1

Region within whose boundary G component is to be calculated	n	Values to be inserted in equation (3)	Predicted gravitational values from equation (3)		
			G component	Coupling constant $(e^2/m^2 = 1)$	Range
Galaxy	1	$\omega_{\mathrm{Galaxy}} = 10^{-15}\ \mathrm{s}^{-1}$ $\rho_{\mathrm{Galaxy}} = 5 \times 10^{-24}\ \mathrm{g\ cm}^{-3}$	$G_g = 5 \times 10^{-8}$	$\simeq 10^{-42}$	r_{Galaxy}
Earth	2	$\omega_{\mathrm{Earth}} = 7 \times 10^{-5}\ \mathrm{s}^{-1}$ $\rho_{\mathrm{Earth}} = 5{\cdot}0\ \mathrm{g\ cm}^{-3}$	$\Delta G = 10^{-10}$	$\simeq 10^{-45}$	r_{Earth}
atom	3	$\omega_0 = \dfrac{8\pi^3 me^4}{h^3} \quad \rho_e = \dfrac{3m}{4\pi r^3}$	$G_w = \dfrac{2\alpha^6 e^2}{3m^2}$	$\simeq 10^{-11}$	10^{-13} cm
electron	4	$\omega_e = \dfrac{h}{4\pi m r^2} \quad \rho_e = \dfrac{3m}{4\pi r^3}$	$G_s = \dfrac{e^2}{6\alpha^2 m^2}$	$\simeq 10^3$	10^{-13} cm

e, electron charge; m, electron mass; h, Planck's constant; c, velocity of light; $\alpha = 2\pi e^2/hc$; $r = e^2/mc^2$.

The predicted perturbation of G caused by the Earth's spin, associated with the term $n = 2$, is supported by experimental evidence to a limited extent (Stephenson 1967). Further experimental tests are being undertaken to check this result (Cooke 1968).

The most interesting result is for the term for which $n = 3$, where the substitution of a value of ω appropriate to the first Bohr orbit velocity predicts a coupling constant equal to 10^{-11}. The magnitude of this predicted coupling constant is in close agreement with the weak interaction coupling constant.

In the substitution to obtain the term for $n = 4$ a value of ω appropriate to the spin of the electron about its own axis is used, and this predicts a coupling constant which is close to that associated with strong interactions. This result also requires the effective radius of the electron to be less than the classical radius, which is in agreement with experimental measurements.

It should be emphasized that equations (1) and (3) can be looked upon, in the limit, as being merely dimensional relationships which may have no causal significance. If one could arbitrarily choose from a wide range of values of ω and ρ, in an attempt to achieve a small number of particular values for G components from equation (3), then the empirical nature of such a process would substantially invalidate any conclusions. But, in contrast with such a process, table 1 includes all regions of the Universe which might be gravitationally stable and which, at the same time, may enclose a point of measurement situated in the vicinity of the Earth's surface. Thus, on the atomic scale, only two primary spin constants are associated with atoms and atomic particles, the first Bohr orbit velocity and the angular momentum of the electron $h/4\pi$. In both cases substitution in equation (3) produces a predicted result which corresponds to an experimentally observed coupling constant. This correspondence can be interpreted as being either coincidence, or, alternatively, as indicating that equation (3) may possibly form a causal relationship between gravitational, electromagnetic, weak and strong interactions.

Department of Electrical
and Electronic Engineering,
University College London.

L. M. Stephenson

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