This Week's Citation Classic

Brans C & Dicke R H. Mach's principle and a relativistic theory of gravitation. *Phys. Rev.* **124**:925-35, 1961.
[Palmer Physical Laboratory, Princeton University, NJ]

This paper presents an alternative to standard Einstein theory, a scalar-tensor theory. In addition to the metric tensor, the reciprocal gravitational constant appears as a scalar field coupled to matter. It was originally motivated by Mach's principle. [The *SCI*® indicates that this paper has been cited in over 565 publications since 1961.]

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"This paper was based on my Princeton University PhD thesis, for which Bob Dicke supplied the seminal ideas. Charles Misner, as thesis adviser, helped with the development and presentation of the formalism. Dicke was strongly motivated by the ideas of Berkeley[1,2] and Mach[3,4] to find a physical basis for inertial reaction forces. In fact, he once remarked to me, a young theoretical graduate student, that some theorists might profit from a swift kick in an appropriate anatomical area to appreciate the reality of such forces. Sciama[5] had already proposed a model of such a theory, but it didn't seem likely to lead to a fully viable theory. Instead, Dicke suggested that we consider G, the ratio of gravitational to inertial mass. Any influence of the universe structure on inertial forces would then show up in terms of G, expressed in 'standard' units for which inertial mass is defined to be constant. This was also consistent with Dirac's conjecture $1/G \sim M/R$.

"I started from this point, looking for field equations which would contain 1/G as a field quantity, ϕ, and having mass as a source. A simple division of the Einstein Lagrangian by G, to isolate it from the matter Lagrangian, so that matter will be conserved as usual, came to mind quickly as a starting point. An extra term, involving ϕ and its derivatives, must then be added with its form determined by dimensional arguments. However, its numerical coefficient could not be determined and was left as a free dimensionless constant. Standard Einstein theory is recovered in the limit as this constant, ω, approaches ∞. Thus, in principle, with no independent guide to the value of ω, no experiment with finite error can rule out the scalar-tensor theory in favor of Einstein's.

"After getting well into the development of this theory, I discovered the work of Jordan[6] and devoted a good bit of space in my thesis to a comparison of the two. Years later, Peter Bergmann pointed out to me that he and Einstein had considered, but rejected, such a theory in the 1930s, well before Jordan.

"The widespread interest in this work is undoubtedly due to the enthusiastic programs initiated by Dicke[7] and his group. Until that time, experimental relativity had languished, both for technical reasons and for lack of motivation by competitive theories. The existence of a viable alternative to Einstein's theory and the technology of the space program combined to provide a much needed impetus for experimental work in this field. Thus the theory has proved useful, even though the experimental status of its original form is not good at present. Finally, I should also mention that the theory is related to the important topic of conformally invariant theories and has also been reconsidered, in a generalized Kaluza-Klein form,[8] with compactified extra dimensions, in quantum theories of internal symmetries and gauges."

1. **Berkeley G.** *A treatise concerning the principles of human knowledge.* Dublin: J. Pepyat, 1710. p. 111-17.
2. --------------. *De motu; sive de motus principio & natura et de causa communicationis motuum.* London: Jacobi Tonson, 1721. 27 p.
3. **Mach E.** *History and root of the principle of the conservation of energy.* Chicago, IL: Open Court, 1911. 116 p.
4. ----------. *The science of mechanics.* Chicago, IL: Open Court, 1893. Chapter II, Section VI.
5. **Sciama D W.** On the origin of inertia. *Mon. Notic. Roy. Astron. Soc.* **113**:34-42, 1953.
6. **Jordan P.** *Schwerkraft und Weltall.* Braunschweig: Freidrich Vieweg und Sohn, 1955. 277 p.
7. **Dicke R H.** *The theoretical significance of experimental relativity.* New York: Gordon and Breach, 1964. 153 p.
8. **Witten E.** Search for a realistic Kaluza-Klein theory. *Nucl. Phys. B* **186**:412-28, 1981.