Comments and Addenda

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Comment on Malin's theory of gravity*

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We find that the theory of gravity proposed by Malin, $R_{\mu\nu} = -4\pi T_{\mu\nu}$, is incompatible with experimental results.

In a recent paper Malin[1] suggests a theory of gravity governed by the field equations[2]

$$R_{\mu\nu} = -4\pi T_{\mu\nu} . \tag{1}$$

In this theory the left-hand side of Eq. (1) is the Ricci tensor computed in terms of the standard Christoffel connection; $T_{\mu\nu}$ is to be interpreted as the standard stress-energy tensor. Given these interpretations we find that this theory does not correctly predict the results of laboratory experiments.

Let us consider the fluid mechanics predicted by Eq. (1). The stress-energy tensor for a perfect fluid of density ρ and pressure p is given by

$$T_{\mu\nu} = (\rho + p)u_\mu u_\nu + p g_{\mu\nu} . \tag{2}$$

Using Eqs. (1) and (2) we find the following equivalent equation:

$$R_{\mu\nu} - \tfrac{1}{2} g_{\mu\nu} R = -4\pi[(\rho + p)u_\mu u_\nu + \tfrac{1}{2}(\rho - p)g_{\mu\nu}] . \tag{3}$$

The left-hand side of Eq. (3) is the Einstein tensor, whose divergence vanishes because of the Bianchi identities. Taking the divergence of the right-hand side of Eq. (3) gives the equations of fluid motion,[3]

$$2(\rho + p)\nabla_\mu u^\mu + u^\mu \nabla_\mu (\rho + 3p) = 0 , \tag{4}$$

$$(\rho + p)u^\mu \nabla_\mu u^\nu + \tfrac{1}{2}(g^{\nu\mu} + u^\nu u^\mu)\nabla_\mu (\rho - p) = 0 . \tag{5}$$

Equation (4) is the analog of the equation of "conservation of mass," and Eq. (5) is the analog of Euler's equation for fluid motion. We find that these equations are unacceptable.

Let us consider the Newtonian limit in which $p \ll \rho$ and $u^\mu \sim (1, v^i)$; then Eq. (4) reduces to

$$\frac{d\rho}{dt} + 2\rho \nabla_i v^i = 0 . \tag{6}$$

Consider a small volume V of fluid, chosen so that the boundary of V moves with the fluid. Let m be the mass of fluid contained within V. Equation (6) then reduces to

$$\frac{d}{dt}(\ln m) = -\frac{d}{dt}(\ln V) . \tag{7}$$

Equation (7) implies that mass will be nonconserved at a rate proportional to the expansion rate of the fluid. This result is catastrophic for laboratory experiments, for if the volume of a fluid element doubles, then Eq. (7) predicts that its mass will reduce to half of its original value. Thus in addition to the nonconservation of mass on a cosmological scale proposed by Malin, there is a nonconservation of mass on laboratory scales. [We note that for the case of a homogeneous cosmological model, Eq. (7) reduces to Malin's Eq. (1.3).]

We also point out that Eq. (5) does not reduce to the classical Euler equation in the Newtonian limit. The force on a fluid element is produced primarily by the density gradient rather than the pressure gradient. One consequence of this is that small-amplitude density perturbations propagate at the speed of light. It will also have significant effects on the structures of stars and planets. For these reasons we find that this theory is unacceptable.

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[1]S. Malin, Phys. Rev. D 11, 707 (1975).

[2]Note that this theory is a special case of a class of theories suggested by Peter Rastall, Phys. Rev. D 6, 3357 (1972).

[3]For a discussion of the standard treatment of relativistic hydrodynamics see C. W. Misner, K. S. Thorne, and J. A. Wheeler, *Gravitation* (Freeman, San Francisco, 1973), Chap. 22.