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ON NEWTONIAN UNIVERSES

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Recently Zeldovich (1) has criticized a result obtained by me in an earlier paper on Newtonian universes (2). This criticism is based on a misunderstanding of the basic assumptions in my paper. For the sake of clarity I shall restate those assumptions and point out the difference between the approaches of (1) and (2).

In (2) the universe is assumed to be *infinite*, *homogeneous* and *anisotropic*, with a set of fundamental observers whose motion satisfies the velocity distance relation

$$v_\mu = H_{\mu\nu} x_\nu. \tag{1}$$

Further, it is assumed that each observer follows Newton's law of gravitation, *stated as an inverse square law*. This immediately leads to the equation

$$\ddot{\mathbf{x}} = -\frac{4\pi G\rho}{3}\mathbf{x}. \tag{2}$$

This procedure extends the postulates of the standard Newtonian theory to the case of an infinite mass distribution. (Strict Newtonian theory cannot be applied to an infinite mass distribution, without some such extension.)

In (1), Zeldovich follows a different method. As his example of the homogeneous ellipsoid shows, he is considering a *finite* but arbitrarily large mass. Such a mass distribution in an otherwise empty space could either be looked upon as an *infinite inhomogeneous* distribution or as a finite homogeneous one. Either way it is different from the mass distribution considered in (2).

This difference is revealed further by the calculations. In solving the problem of a finite mass distribution Zeldovich has to consider the Poisson equation

$$\nabla^2\phi = 4\pi G\rho, \tag{3}$$

together with the boundary conditions imposed by the shape of the distribution (e.g. an ellipsoid). In (2), on the other hand the assumption of the inverse square law selects a particular solution of (3), and the boundary value problem does not arise. Zeldovich is therefore solving an altogether different problem and it is not surprising that he gets a different answer.

Finally, it is interesting to note that if in (2) the assumption of inverse square law were dropped, and any other solution of (3) were chosen, additional force terms would appear in the right hand side of (2). These terms arise from the potential which satisfies the Laplace equation

$$\nabla^2\phi = 0. \tag{4}$$

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These forces can be transformed away locally by a choice of suitably accelerated reference frame. Physically this would mean modifying Newton's law of motion. Only the assumptions of (**2**) retain both Newton's laws of motion and gravitation.

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References

(**1**) Zeldovich, Y., 1965. *Mon. Not. R. astr. Soc.*, **129**, 19.
(**2**) Narlikar, J. V., 1962. *Mon. Not. R. astr. Soc.*, **126**, 203.

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