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A CLASS OF ROTATING AND EXPANDING UNIVERSES

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It has long been a challenge for relativists to construct a model of a rotating Universe, if not for any other reason then just to see how it should look, and why our observed Universe seems not to rotate at all. Unfortunately, it appeared to be very difficult to construct a model exhibiting both rotation and expansion: all the existing rotating models are stationary, while all the expanding ones do not rotate.

A few years ago much interest was concentrated around irregular cosmological models which were anisotropic, but homogeneous in the sense of Bianchi. It is possible to consider models with rotation in this class, but then the physical meaning of homogeneity is slightly changed. In nonrotating models the Bianchi vector field defining homogeneous subspaces is colinear with the velocity field of matter, so it is just the rest-spaces of matter that are homogeneous. Now, in the case of nonzero rotation these two fields must not be colinear, and so the homogeneous 3-spaces become an additional, God-given structure attached to some preferred observers which are quite independent of matter. This is an unsatisfactory feature.

However, because of such great success that the homogeneous and isotropic models of Robertson and Walker had in explaining the properties of the observed Universe, it is reasonable to stay close to them when trying to construct some irregular models. Let us try to construct such a metric which could describe a rotating and expanding Universe, free of the aforementioned drawback of the Bianchi models, and remaining at the same time as close to the Robertson-Walker models as possible.

With rotation present, the isotropy must be lost, but it may leave a remainder in the Universe being axially symmetric about the local axis of rotation. Now, the natural remainder of 3-dimensional homogeneity of the R-W models will be the homogeneity along the axis of rotation, as no clear reason can be seen to disturb it when a R-W model is set into rotation. Consequently, such model should have two Killing vector fields describing cylindrical symmetry. It may be shown that with these symmetries, and with the two additional assumptions:

a) The Killing vectors are orthogonal and commuting,
b) The matter in the spacetime is a rotating isentropic perfect fluid or dust,

the metric form should look as follows:

$$ds^2 = H^{-2}(dx^0 + x^2 dx^1)^2 - h\,(dx^1)^2 - 2(hk)^{1/2} dx^1 dx^2 - (k + l)(dx^2)^2 - w(dx^3)^2 \qquad (1)$$

where h, k, l and w are unknown functions of x^0 and x^2, H is defined by:

$$H = H_{\bullet} + \frac{1}{c^2}\int_0^p \frac{d\tilde{p}}{\varrho(\tilde{p})} \qquad (2)$$

p being the pressure and ϱ the density of the rest-mass of the fluid ($\varrho = \varrho(p)$ because of the assumed isentropic type of motion), ϱ and p also being unknown, and the determinant of the metric tensor of (1) is equal to $-\varrho^{-2}H^{-2}$. This is the starting point for considering a new class of irregular cosmological models.