and scattering at about 3,350 cm^{-1}. The coupling constants range from the order of magnitude of solid *n*-decanol for methanol and ethanol to about 50% larger for the higher members of the series.

These observations provide a direct spectroscopic argument for the "polymeric" structure of liquid alcohols and suggest grounds for reconsidering earlier studies which failed to account for the possibility of multiple −OH stretching modes. The unexplained secondary splittings and the effect of increasing molecular weight on the spectra suggest areas of further investigation and raise the possibility that Raman spectroscopy may soon become a more powerful and widely applied tool for the study of hydrogen-bonded liquids than infrared spectroscopy was two decades ago.

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Can Spin Avert Singularities?

TRAUTMAN has suggested[1] that the introduction of intrinsic spin effects into general relativity through the Einstein–Cartan torsion theory may avert a gravitational singularity. In this note we suggest that the singularity is avoided only because of the high symmetry of the model used.

We shall not describe the Einstein–Cartan theory here (see ref. 1 for a bibliography), except to point out that for a classical description of spin, with spin density tensor

$$s^a{}_{bc} = \eta_{bcde}\, u^a u^d s^e \qquad (1)$$

the usual relativistic description of the fluid flow[2] is valid. (In equation 1, u^a is the 4-velocity of the spinning matter, and s^a is the spacelike spin vector of the fluid satisfying $s^a u_a = 0$.) But one modification has to be made. The usual vorticity vector $\omega^a = \frac{1}{2}\eta^{abcd} u_{c,a} u_b$ which gives the angular velocity of the fluid with respect to a Fermi-propagated frame becomes $\omega^a + s^a$. Hence the Raychaudhuri equation[2] takes the form

$$\theta + \tfrac{1}{3}\theta^2 + 2[\sigma^2 - (\omega_a + s_a)(\omega^a + s^a)] + \rho = 0 \qquad (2)$$

for dust of density ρ, where $\theta = u^a{}_{;a}$ is the expansion of the fluid, and σ is the shear scalar. In Trautman's quasi-Friedmann model, $\sigma = \omega^a = 0$, and conservation of matter and spin implies $\rho = \rho_0 R^{-3}$, $s = s_0 R^{-3}$, where $R(t)$ is the usual Robertson–Walker scale length, and $s = (s^a s_a)^{1/2}$. It follows that for small R, the repulsive spin term $-2s^2 \sim R^{-6}$ in equation 2 dominates the attractive $\rho \sim R^{-3}$ term, and the singularity is avoided. If a perfect radiation fluid is considered, $\rho \sim R^{-4}$, which does not alter the conclusion.

But Trautman[1] invokes a primordial magnetic field to produce global spin alignment, and so his universe must be anisotropic. We have solved the Einstein–Cartan field equations for an axisymmetric homogeneous Bianchi I model with metric

$$ds^2 = -dt^2 + X^2(t)dx^2 + Y^2(t)(dy^2 + dz^2) \qquad (3)$$

We find $\sigma = \sigma_0 R^{-3}$ (just as in the usual relativistic models), $\rho \sim R^{-3}$, $s \sim R^{-3}$, $\omega^a = 0$, where for this model $R = (XY^2)^{1/3}$. It can now be seen from equation 2 that the attractive shear term $2\sigma^2$ is of the same order of magnitude as the repulsive spin term, and indeed if $\sigma_0 > s_0$ a singularity cannot be prevented.

In these simple models $\sigma^2 = \lambda s^2$, where λ is a constant. In Trautman's model $H^2 \sim \rho \sim R^{-3}$ except near $t = 0$, where $H = \frac{1}{3}\theta$ is the usual Hubble constant. Thus $(\sigma^2/H^2) \approx \lambda s^2/\rho = \lambda(s^2/\rho)_{t=0}(\rho/\rho_{t=0})$. At $t = 0$ $s^2 = \rho/2$, in Trautman's model, and $\rho_{now}/\rho_{t=0} = 10^{-84}$ if $\rho_{now} = 10^{-29}$ g cm^{-3}. Thus Trautman's suggestion for avoiding the singularity is only applicable if $(\sigma^2/H^2)_{now} \lesssim 10^{-84}$. But the best observational evidence is $(\sigma^2/H^2)_{now} \lesssim 10^{-6}$ and so, unless the Universe is very isotropic indeed, a singularity cannot be avoided in this way.

We thank Bernd Schmidt and Martin Walker for a helpful discussion. Since this communication was submitted Copzýnski[3] has independently constructed the same Bianchi I model.

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Reference Abbreviations

FROM September 1 it is *Nature's* intention that all abbreviations of references should conform to the style of the *World List of Scientific Periodicals*, fourth ed. (Butterworth, 1963–65). The changeover will be gradual and authors submitting manuscripts from now on are asked to ensure that the references are written appropriately.

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