matters arising

Dynamic measurement of matter creation and Earth expansion

RITTER *et al.*[1] have attributed to me the argument that continuous creation of matter where matter is already most dense at a rate of 7×10^{-18} g g^{-1} s^{-1} can account for the growth of the mass of the Earth (6×10^{27} g) in a time of 4.5×10^{9} yr. This is certainly numerically the case (ignoring the fact that the mass of the proto-Earth in the early stages would have been small and the creation rate correspondingly low). However, in the paper of mine which they quote[2], I pointed out (on page 54) that the observed upper limit on continuous creation (of Cohen and King[3]) of 4×10^{-23} g g^{-1} s^{-1} seems to rule out such a process. In order to remove doubt, it should be pointed out that the continuous creation hypothesis for the origin of the Earth will only be plausible if the experiment described by Ritter *et al.*[1] disproves the results of that of Cohen and King[3].

The continuous creation rate of 7×10^{-18} g g^{-1} s^{-1} is that given by the condition that the Universe be in a steady state[4,5]. It is indeed a remarkable coincidence that this creation rate can account for the Earth's mass with its known geological age (T_E); but it should be appreciated that what this coincidence means is that the timescale T_E is

$$T_E \approx 1/(7\times10^{-18}) \approx T_U \approx H^{-1} \quad (1)$$

where T_U is the 'age' of the Universe, which is believed to be of the order of the reciprocal of Hubble's parameter H. But the rate of expansion of the Earth at about 0.5 mm yr^{-1}, which is apparently observed[2] and which is remarked on by Ritter *et al.*[1] (in connection with continuous creation) also has another possible explanation: as pointed out some time ago[6], if one puts the radius of the Earth R_E into the Hubble formula one finds

$$\dot{R}_E \approx HR_E \approx 0.5 \text{ mm yr}^{-1} \quad (2)$$

with $R_E \approx 6{,}370$ km and H equal to the cosmological value of 75 km s^{-1} Mpc^{-1} ($=2.5\times10^{-18}$ s^{-1}). The coincidence, equation (2), seems to be at least equally as impressive as equation (1), and suggests that the expansion of the Universe may in some way be coupled to smaller systems[7]. If a system expands in this manner, whether as a response to continuous creation or some other process, the resultant change in the angular velocity of the system should be open to test using the experiment described by Ritter *et al.*[1].

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Do compact radio sources contain non-relativistic plasma?

THERE has been considerable discussion[1–3] of multifrequency polarisation measurements of compact variable radio sources. These measurements[4,5] indicate that the synchrotron radiation emitted by compact sources has undergone no significant amount of Faraday depolarisation. It has been argued[1–3] that these data imply that such radio sources contain no non-relativistic plasma. It is, therefore, concluded that radio source models[6–8] which rely on plasma turbulence in a non-relativistic background plasma for particle acceleration are inapplicable.

We wish to point out first, that these limitations actually apply only to the presence of non-relativistic electrons, and that Faraday depolarisation observations are insensitive to the presence of protons or other massive particles whether they are relativistic or not. (Faraday rotation due to 'cold' protons is a factor $m_p^2/m_e^2 \sim 3\times10^6$ less than that due to non-relativistic electrons.) In fact, the observations are consistent with the non-relativistic proton density which is more than 10^4 times greater than the density of observed, relativistic electrons, and statements[3] that the compact sources contain 'no non-relativistic matter' are, therefore, completely unjustified. Furthermore, the data of Wardle[2] seem to indicate source temperatures of the order of 10^{12} K. At this temperature the thermal electrons would be expected to be relativistic, as observed, but the thermal protons would be non-relativistic ($\gamma_p = E_p/m_pc^2 \sim 1.2$). Theoretical considerations also indicate[9], in agreement with Wardle's observations, that 10^{12} K is a natural upper limit to the proton temperature as pion production cooling acts as a natural thermostat mechanism and precludes higher temperatures.

It, therefore, seems likely that the internal energy state and dynamics of compact sources are dominated by a non-relativistic proton plasma. Thus, we also disagree with the previous contentions[1–3] that those source models are inapplicable which invoke non-relativistic plasma turbulence as a particle acceleration mechanism. Some models[6] rely on electron-supported electrostatic plasma turbulence, and the lack of non-relativistic electrons in compact sources does seem to rule out such theories (see ref. 3). However, models dealing with non-relativistic hydrodynamic turbulent acceleration[8] (such as statistical Fermi acceleration), Alfvénic turbulent[7] acceleration, or combinations thereof[10] are consistent with observations, as these types of turbulence are all supported by the background non-relativistic proton plasma.

The absence of Faraday depolarisation of the radiation from compact radio sources cannot, therefore, be used to determine the internal energy state of such sources, and models of compact sources including non-relativistic plasma turbulent particle acceleration agree with observations.

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WARDLE REPLIES—I do not disagree with the above comments. The physical picture described by Christiansen *et al.*[1] seems to be very similar to that suggested by us[2,3], that

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