ON THE ORIGIN OF COSMIC MAGNETIC FIELDS

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ABSTRACT. In the past investigations of cosmological magnetic fields, Harrison (1970) assumed primordial turbulence with nonzero vorticity. More recently this idea lost favor with most cosmologists, primarily because vortices decay during the cosmic expansion (Rees, 1987). In contrast to these works we resort to no assumption as for the primordial condition but for the thermal equilibrium in the following. A plasma with temperature T in the early universe sustains fluctuations of electromagnetic fields and density even if it is in a thermal equilibrium. The level of fluctuations in the plasma for a given wavelength of electromagnetic fields, for example, can be rigorously computed by the fluctuation-dissipation theorem (Geary et al. 1986; Kubo 1957; Sitenko 1967). In particular, without assuming any turbulence we show that very low (or ~ zero) frequency magnetic fluctuations can also be excited and the level of these is computed

$$\frac{\langle B^2\rangle}{8\pi} = \sum_{\mathbf{k}} \frac{\langle B_{\mathbf{k}}^2\rangle}{8\pi V} = \frac{T}{2}\sum_{\mathbf{k}} \frac{1}{V}\frac{1}{1+k^2c^2/\omega_p^2},$$

$$B_\lambda = 9.4\times 10^{-7}\left(\frac{a}{a_0}\right)^{-1/2}\left(\frac{\lambda}{1\,\mathrm{cm}}\right)^{-3/2}\ \mathrm{Gauss},$$

where summation on $\mathbf{k}$ is over all the available wavenumbers V the volume of the Universe, and ω_p the plasma frequency $(4\pi e^2 n/m)^{1/2}$. The level of fluctuation $\langle B_{\mathbf{k}}^2\rangle/8\pi V$ is given approximately by the equipartition value of T/2 for $k<\omega_p/c$ and much less than that for $k>\omega_p/c$. These fields at the early radiation epoch $t=10^0$ sec (we call the radiation epoch in which the radiation effects dominate that of gravity in the universe as the plasma epoch: $t\epsilon 10^{-2} - 10^{13}$ sec) can act as seed fields and can evolve during the plasma epoch. The result is shown in Fig. 1. We show that magnetic fields with the size of $\lambda \lesssim 10^8$cm can be amplified by the dynamo effect and that the field strength corresponding to this size is greater than 10^{-19} Gauss.

R. Beck et al. (eds.), Galactic and Intergalactic Magnetic Fields, 531–532.

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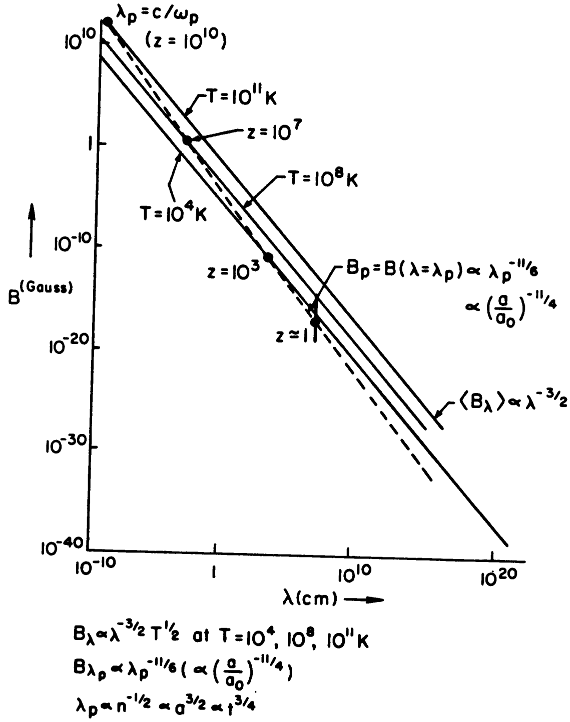

Figure 1. Magnetic fluctuations B_λ as a function of the wavelength λ. The upper right side of the broken line is the domain of meaningful magnetic field pressure.

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