Galactic Component of the Diffuse X-ray Background

WICKRAMASINGHE's model for the galactic component of the diffuse X-ray background[1], which involves scattering of the isotropic component by dust grains, unfortunately contains a fundamental error which completely invalidates it. Particles along a line of sight may indeed scatter isotropic background radiation into the line of sight, but by the same process they will also scatter out of the line of sight the background radiation originally travelling in this direction (ref. 2, for example). If there is no absorption (that is, the albedo is unity) the two scattering effects are equal; this situation now satisfies the first and second laws of thermodynamics and ensures that the galactic disk is quite indistinguishable from the rest of the background. If the albedo is less than one, then the disk should show up in absorption, in contradiction with the observations. In no conditions can the model increase the flux from the disk relative to that of the isotropic background.

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[1] Wickramasinghe, N. C., *Nature*, **227**, 265 (1970).
[2] Lord Rayleigh, *Phil. Mag.*, **41**, 107 (1871).

Reply to Mack and Webster

As pointed out in my article[1] dust grains distributed throughout the disk of the galaxy will scatter X-ray photons from the isotropic cosmic background as well as from discrete sources. While I agree with the comments of Mack and Webster concerning the scattering of the isotropic background by dust I would like to point out that a diffuse galactic X-ray component similar to that observed[2] could arise from the scattering of X-rays from discrete sources. In discussing the contribution from discrete sources Mack neglects scattering by dust. It is likely that this effect is important for distances exceeding a few kiloparsecs. The analysis presented earlier is evidently valid for this case with two provisos: (*a*) discrete X-ray sources are distributed more or less uniformly (with respect to mean volume emissivity) throughout the hydrogen–dust layer of the galaxy, and (*b*) the intensity I (equations (6) and (7) of ref. 1) is defined as the ratio of the mean X-ray emissivity (due to sources) per unit volume to the X-ray extinction per unit distance, and this quantity is assumed comparable with the intensity of the isotropic background.

The data at present available on X-ray sources do not conflict with these requirements. A scattering model of the type considered could produce a fairly smooth galactic X-ray background with the observed concentration towards the galactic plane without requiring an excessive concentration of weak unresolved sources very near the galactic plane.

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[1] Wickramasinghe, N. C., *Nature*, **227**, 265 (1970).
[2] Cooke, B. A., Griffiths, R. E., and Pounds, K. A., *Nature*, **224**, 134 (1969).

Effect of Quantum Conditions in a Friedmann Cosmology

THE observed isotropy of the microwave background and its primordial interpretation has led many to investigate the nature of particle horizons in cosmological models near the initial singularity. The standard Friedmann radiation universe

$$ds^2 = dt^2 - \lambda t[dr^2 + r^2(d\theta^2 + \sin^2\theta \, d\varphi^2)], \quad \lambda = \text{constant} \quad (1)$$

has a particle horizon at

$$r = 2\left(\frac{t}{\lambda}\right)^{1/2} \quad (2)$$

at epoch t. Thus near the singularity $t=0$, very limited causal communication is possible between different parts of the universe. The observed isotropy of the microwave background cannot be understood in such a model except as arising from artificially imposed initial conditions. Misner[1] has sought to remedy the situation by looking for solutions of the classical Einstein equations very different from the Robertson-Walker form (to which that given by equation 1 above belongs). These solutions permit unlimited communication near $t=0$.

The purpose of this note is to point out that near the singularity quantum effects are important and may permit unlimited communication near $t=0$, even in the Robertson-Walker form.

There have been many different approaches to a quantum theory of gravitation. Here we adopt Feynman's path integral approach[2], for it best illustrates the difference between the classical and quantum theories. The basic concepts in relation to gravitation have been discussed by Wheeler[3] and are briefly described below. Suppose the system is specified by an action S. Classically, the transition of the system from a state I to a state II is described by a unique path Γ_c given by the principle of stationary action:

$$\delta S = 0 \quad (3)$$

In quantum theory, there is no unique path Γ_c; all paths from I to II are possible. The probability amplitude for the system to adopt a given path Γ is proportional to

$$\exp\{iS/\hbar\} \quad (4)$$

where S is computed along Γ. The classical limit (3) follows when $\hbar \to 0$ or alternatively when $S \gg \hbar$. In this case only paths close to Γ_c contribute any significant amplitude.

In Einstein's theory of gravitation, the action is

$$S = \frac{1}{16\pi G}\int R\sqrt{-g}\, d^4x - \sum_a \int m_a \, da \quad (5)$$

where radiation is temporarily omitted. R is the scalar curvature, g the determinant of the metric tensor, m_a the mass of a typical particle a. The volume integral is over the entire space time and the line integral is over the world line of a. Einstein's equations follow in the classical limit (3); but in the quantum theory this is not the case. We wish to consider equation 5 in relation to a Friedmann cosmology satisfying Einstein's equations

$$R_{ik} - \tfrac{1}{2} g_{ik} R = -8\pi G \, T_{ik} \quad (6)$$

Using the Robertson-Walker form of the metric