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THE DIFFUSE COMPONENT OF COSMIC X-RAYS AND THE 8.3°K GALACTIC BLACKBODY RADIATION*

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Assuming that the far infared radiation, recently measured by Shivanandan, Houck, and Harwit, is galactic, we show that inverse Compton scattering of this radiation on cosmic ray electrons is sufficient to produce the observed flux of diffuse X-rays. Some recent experiments seem to support the predicted anisotropy of this flux. An analysis of the production of helium in the "big bang" expansion of the universe suggests that this radiation is not universal.

Origin of diffuse X-rays

The results of most of the measurements [1] of cosmic X-rays in the 0.25 keV to 1000 keV energy interval are plotted in Fig. 1. This radiation was generally believed to be isotropic, but the recent measurements of Cooke, Griffiths and Pounds [2] now present evidence to the contrary. They observed excess X-rays from the region of the galactic equator in the 1.4 to 18 keV region with an intensity of 0.3 photons $(\text{cm}^2 \text{ sec rad})^{-1}$ near $l = 260°$, increasing to 0.5 near $l = 300°$ in Centaurus region and about 1.0 near $l = 350°$. Perhaps the answer is that the diffuse X-rays result from two separate mechanisms, one producing an isotropic component and the other an anisotropic component.

In an earlier paper [3] we showed that if one assumed that the far infrared radiation [4] is galactic, then inverse Compton scattering of these photons with cosmic ray electrons would explain the flux and the energy spectrum of diffuse X-rays with some anisotropy. Recent measurements [2] provide evidence for this anisotropy.

Various production mechanism are summarized in Table 1. It seems clear that the inverse Compton scattering of photons with relativistic electrons would explain the nature of all the following components:

1. Anisotropic diffuse X-rays in the galactic plane (8.3°K photons + electrons) [3].
2. Anisotropic diffuse γ-rays in the galactic plane (8.3°K photons + electrons) [5].
3. Isotropic diffuse X-rays (3°K photons + metagalactic electrons) [6].

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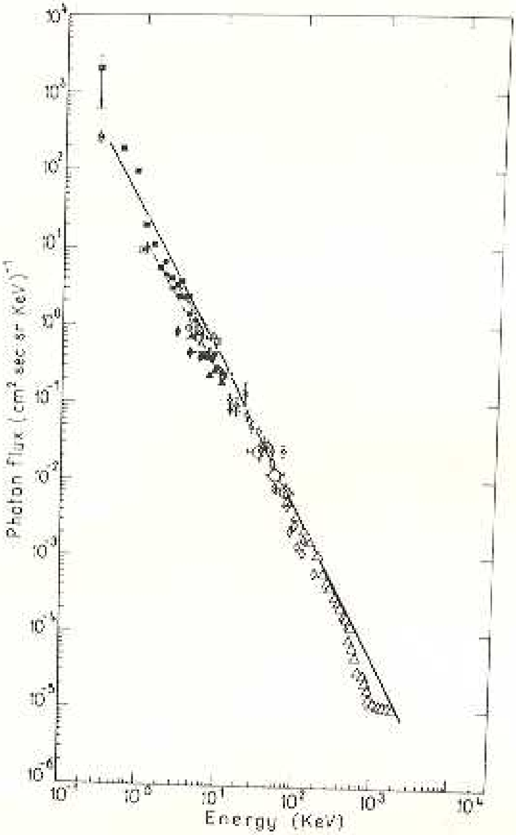

Fig. 1.' The flux and energy spectrum of diffuse X-rays. Solid and open symbols represent measurements [1] of diffuse X-rays. Open triangles: METZGER et al.; open circles: BLEEKER et al.; crosses: HAYAKAWA, et al.; open squares: FISHER et al.; X's: ROTHENFLUG et al.; solid squares: BAXTER et al.; solid circles: GREEN et al.; solid triangles and open half circles: proportional counter and scintillation counter data respectively (SEWARD et al.: Fig. 3); solid diamonds: MATSUOKA et al. (1968); circles with dots: MATSUOKA et al. (1969); open diamonds: BLEEKER and DEERENBERG (1969); open diamond with dot: BOWYER et al.; open square with dot: MANDEL'STAM and TINDO; dash-dot-dash line: GORENSTEIN et al.; dash lines: HENRY et al.; arrow: HENRY et al. The solid line represents the theoretical results for galactic blackbody radiation distribution corresponding to 8.3°K

The exponent γ of the electron energy spectrum is ≈ 2.62 above 3 GeV resulting in the X-ray spectrum having an exponent $\alpha = (\gamma + 1)/2 = 1.81$. A solid line with exponent 1.81 is shown in Fig. 1. It passes through most of the data points in the 30 to 1000 GeV energy interval corresponding to electron energies from 1 to 10 GeV. Below 30 keV the X-ray spectrum flattens considerably ($\alpha = 1.3 - 1.5$). This is quite consistent with the exponent of the electron spectrum below 1 GeV ($\gamma = 1.6 - 2.0$).

The X-ray spectrum above 500 keV region seems to steepen. This may indicate that the electron energy spectrum may have an exponent $\gamma > 2.62$ at higher energies.

Table 1

Diffuse X-rays from the galactic disc
Observed intensity ≈ 1 photon $(\text{cm}^2 \text{ sec rad})^{-1}$

Some proposed mechanisms	Remarks	Predicted/Observed
Synchrotron emission by galactic electrons [7]		≈ 0.05
Inverse Compton scattering of 3°K photons on galactic electrons [6, 7, 10]		≈ 0.05
Bremsstrahlung emission by galactic electron with thermal gas [8]		≈ 0.03
π^0 production by C. R. protons [10] on galactic matter and N-$\bar{\text{N}}$ annihilation [11]		≈ 0.1
Extragalactic X-ray sources		
a) Sco-X1 type sources [12]	(Inadequate)*	≈ 1
b) Population II objects [13]	(Inadequate)*	?
Inverse Compton scattering of 3°K photons on metagalactic electrons [6]	Requires a high electron intensity	≈ 1
Bremsstrahlung emission by nonrelativistic protons interacting with the thermal electron component of the intergalactic medium [8, 9]	Requires a high electron density	≈ 1 (?)
Inverse Compton scattering of ~ 8.3°K photons on galactic electrons [3]	Explains flux, spectrum and possible anisotropy	≈ 1

* It explains the flux of the low energy (1 to 10 keV) X-rays, but it cannot explain adequately the source of the hard X-rays and the shape of the spectrum

Far infrared 8.3°K radiation

An interesting question now arises – is the equivalent 8.3°K radiation not only galactic, but universal? Actually strong evidence against the universality of the 8.3°K radiation already exists [14]. However, it is interesting to comment briefly on other phenomena which we feel also argue against such an assumption. First of all, the sharp cut-off in the cosmic ray proton spectrum [15, 16] is reduced by a factor of 2.8 from about 3×10^{19} eV, using the current estimates of BURBIDGE [16] to about 10^{19} eV. This accentuates the discrepancy with observations [17], if one takes the viewpoint that the cosmic ray protons are universal [18]. Second, theoretical calculations [19, 20] based on the "big bang" expansion model of the universe and assuming a present day temperature T of 3°K, predict that about 23 to 38 per cent by mass of helium is produced. This is in the vicinity of the amount of helium found in many astrophysical objects [20]. Now, if T is increased by a factor of 2.8 from 3°K to 8.3°K, then the baryon density at the time when helium production becomes possible is reduced [19] by a factor of 2.8^3. Assuming a present day density [21] of 7×10^{-31} g/cm^3 and taking $T = 8.3$°K leads to a helium mass ratio of about 17%, which is considerably less than the observed abundances. Taking a present day density of 2×10^{-29} g/cm^3 (the amount of matter needed to close the universe) increases this figure to only 22 and inclusion of other effects, as electron neutrino degeneracy [20], scalar fields [22], or a primordial magnetic field [23] reduces the mass ratio still more. Of course, such relatively low theoretical mass ratios are acceptable if one takes the viewpoint that not all observed helium is produced cosmologically, but that some of it is produced by stellar evolution.

In summary, the observed flux of diffuse X-rays can be explained by the assumption that the 8.3°K radiation is galactic but other considerations suggest that this radiation is not universal. In addition, the expected anisotropy of diffuse X-rays is consistent with the recent measurements [2].

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