18. EXTRAGALACTIC X-RAY SOURCES AND THEIR CONTRIBUTION TO THE DIFFUSE BACKGROUND

Invited Paper

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Abstract. We present estimates of the integrated contribution of extragalactic sources to the diffuse X-ray background in the 2–10 keV energy interval. It appears that classes of objects already detected as X-ray sources easily account for at least 10% of the background. Quasistellar objects, and possibly Seyfert and radio galaxies might contribute a larger fraction of the background intensity.

We also suggest that several of the unidentified X-ray sources in the UHURU catalogue at high galactic latitudes may be bright QSO's as yet unknown. The detection of a larger number of QSO's in the X-ray band may allow a decisive test for the cosmological interpretation of the redshifts of QSO's.

1. Introduction

Since the basic mechanisms which might be responsible for the X-ray emission from extragalactic sources have already been reviewed by Burbidge (paper in this volume, p. 199), we shall here mainly concentrate on estimating the possible contribution of various classes of objects to the isotropic component of the diffuse X-ray background in the 2–10 keV energy range, whose measured intensity is ~ 30 keV cm^{-2} s^{-1} ster^{-1} (Gorenstein *et al.*, 1969). Also we shall not discuss the diffuse processes which might take place in intergalactic space. These processes and their possible role in explaining the diffuse X-ray background for energies $\gtrsim 1$ keV have been extensively reviewed by Setti and Rees (1970), and since then the situation has not basically changed either theoretically or experimentally. Because we shall find that the extragalactic sources are likely to make a substantial contribution to the background, if not explaining all of it, a rediscussion of the importance of the diffuse processes must necessarily await further observations on a larger number of such sources.

An earlier paper on this topic was published about two years ago (Setti and Woltjer, 1970a) and the present report is intended to update the estimates given there in the light of new observational evidence, in particular that from UHURU catalogue (Giacconi *et al.*, 1972).

2. Normal Galaxies

Assuming that the optical and X-ray luminosities of normal galaxies are proportional and deriving the constant of proportionality from the observed X-ray emission from M 31, the integrated background from all normal galaxies is ~ 0.6 keV cm^{-2} s^{-1} ster^{-1}

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in the energy interval 2–10 keV. Therefore, unless cosmological evolutionary effects of the type discussed by Silk (1968, 1969) are present, normal galaxies may account for about 2% of the diffuse background.

On the present assumption, the predicted flux from the Large Magellanic Cloud would be 0.7 keV cm^{-2} s^{-1}, compared to the observed 0.6 keV cm^{-2} s^{-1}. For the Small Magellanic Cloud, in which most of the emission is due to one very strong X-ray source, the predicted flux is about half of that, following from the above assumption. The next bright galaxy is NGC 598 (M 33) for which we predict a flux of $\sim 6 \times 10^{-3}$ keV cm^{-2} s^{-1}, about 8 times weaker than the flux from M 31.

For our own galaxy, assuming that it has the same mass to luminosity ratio as M 31, the X-ray luminosity would be $\sim 1 \times 10^{39}$ erg $^{-1}$ consistent with the observed emission from the galactic disk.

3. Seyfert Galaxies

To account for the whole X-ray background by Seyfert galaxies, assumed to be 1% of all bright galaxies, representative objects like NGC 1068, or NGC 4151, would have to have an X-ray emission of about 6×10^{51} keV s^{-1} in the energy interval 2–10 keV. In the case of NGC 4151 this would correspond to an X-ray flux of ~ 0.5 keV cm^{-2} s^{-1}, while the observed flux is only 0.04 keV cm^{-2} s^{-1}. Moreover the upper limits to the X-ray fluxes from two other Seyfert galaxies, NGC 1068 and NGC 4051, indicate X-ray emission $\lesssim \frac{1}{3}$ the emission for NGC 4151 (Kellogg, paper in this volume, p. 171). As a result Seyfert galaxies may perhaps account for about 5% of the background flux, but probably not for all of it unless evolutionary effects of a cosmological nature are present (Setti and Woltjer, 1970b). It can be easily shown that luminosity and/or density evolutions proportional to $(1+z)^4$ out to a redshift $z \approx 2.5$ would increase the resulting background by a factor of ten.

In the previous estimate we have not included an object like NGC 1275 both because it probably cannot be classified as a typical Seyfert and because its X-ray luminosity, about two order of magnitude greater than that of NGC 4151 (Gursky *et al.*, 1971), appears to be extended over a large volume with angular size $\sim 35'$. Therefore at the moment it is not clear if the X-ray emission is mainly associated with the Perseus cluster of galaxies or with the galaxy itself.

4. Quasistellar Objects

To date only 3C 273 has been observed with a flux of 0.04 keV cm^{-2} s^{-1} in the 2–10 keV interval. Its X-ray spectrum corresponds to an energy flux $\propto E^{-0.9 \pm 0.3}$ which appears to be compatible with the spectrum of the background. Adopting a constant ratio of optical to X-ray luminosity for all quasistellar objects *including the radioquiet* ones, the predicted background due to QSO's down to a blue magnitude 19.4 would be ~ 4 keV cm^{-2} s^{-1} $ster^{-1}$, or 13%.* However including the fainter

* This estimate is based on the detailed computations made in our previous paper (Setti and Woltjer, 1970a) where, however, a slightly different spectrum was adopted for the average QSO.

QSO's in Schmidt's (1971) extrapolation to the 23rd magnitude the contribution would become 20 keV cm^{-2} s^{-1} $ster^{-1}$. Consequently QSO's may well suffice to account for most of the observed background, but a definite conclusion has to await data on a larger sample of QSO's. It should be noted that 3C 273 appears as a relatively weak source in the UHURU catalogue, and therefore if our assumption is correct the next brightest known QSO would not have been detected.

We note that in Schmidt's table of numbers of QSO's as a function of magnitude there are estimated to be 5 QSO's of the 13th magnitude and 25 of the 14th. As a consequence the interesting possibility arises that several of the unidentified X-ray sources in the UHURU catalogue at higher galactic latitudes (21 sources $\geqslant 20°$ off the galactic plane) may well be bright QSO's. We also note that if the QSO's were 'local' objects, say nearer than 30 Mpc, the integrated background from all QSO's in the universe would become at least ten times the observed value, and therefore a 'local' theory is possible only if 3C 273 is an anomalously bright object in X-rays.

With regard to the uniformity of the background we note that with Schmidt's extrapolation to the 23rd magnitude there would be of the order of 10^4 QSO's per 25 deg^2 of the sky, and consequently the fluctuations observed with this type of resolution would be no more than 1–2%, in agreement with present observational evidence.

5. Radio Galaxies and Rich Clusters of Galaxies

X-ray emission has been observed from several radio galaxies, but in the majority of cases there is doubt whether the X-rays are due to the radio galaxy itself or to an associated cluster of galaxies. If we assume, following the suggestion of Gursky *et al.*, (1972), that all rich clusters of galaxies are strong X-ray sources, then on the basis of the UHURU data we find that their contribution to the diffuse background is only about 3% of the total. As there should be about one richness 2 cluster per square degree of the sky out to the Hubble distance, the fluctuations observed with a resolution of 25 sq deg would be about 1%, which in turn excludes the possibility that the same clusters can contribute a substantial fraction of the background (say 30% or more, as has been suggested by some) because the fluctuations then expected in the X-ray background would exceed existing upper limits.

Since about half of the radio galaxies occur in clusters, we conclude that neither the clusters nor the radio galaxies are likely to make a significant contribution to the background. Of course this does not exclude that radio galaxies at large z may be of importance if cosmological effects of the kind considered by Rees and Setti (1968) are present.

6. Concluding Remarks

The above estimates show that classes of extragalactic objects already detected as X-ray sources are likely to account altogether for at the very least 10% of the background intensity in the 2–10 keV energy interval. If all the background is due to sources the most likely candidates are QSO's, and perhaps Seyfert galaxies and radio galaxies at large z.

Various authors (Apparao, 1968; Tucker, 1970) have proposed that the X-ray emission produced during the early phases of a supernova outburst might be sufficient to account for the whole X-ray background in terms of the integrated flux from supernova explosions in normal galaxies. Up to now there is no direct evidence that supernovae are powerful X-ray sources during their early phases, and there are only rather large upper limits several days after the optical outbursts. However Cavallo and Messina (1972) have shown that broad beam observations in the direction of the Virgo Cluster already demonstrate that the average X-ray emission from such supernova is at least a factor of 20 below the required output, unless the emission took place in rather short time ($\lesssim 2$ days) after the explosion; however in this case the resulting fluctuations would be incompatible with the observed uniformity of the X-ray background.

In the present paper we have only analysed the contribution of sources to the intensity of the background in a limited energy interval. Of course when more data become available about the spectra of the various kinds of sources, a comparison between the source spectra and the background spectra should provide a much more conclusive test. Finally the graininess of the background may contain useful information with regaıd to the sources but here the effect of X-rays from our own galaxy may well prevent a unique interpretation, as is actually the case with regard to the 100 MHz radio background.

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