THE ASTROPHYSICAL JOURNAL, 166:L9–L12, 1971 May 15

LINE EMISSION IN THE X-RAY BACKGROUND

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Received 1971 February 1; revised 1971 March 20

ABSTRACT

Evidence is presented for a line feature in the 6–7-keV region of the diffuse X-ray background spectrum.

In recent years a great deal of effort has gone into the search for line emission from discrete X-ray sources, notably Sco XR-1 (Fritz *et al.* 1969; Holt, Boldt, and Serlemitsos 1969; Acton *et al.* 1970; Griffiths, Cooke, and Pounds 1971). Although claims have been made for a positive indication of such line emission, no confirming experiments have as yet been performed. In this Letter, we would like to examine another possible observation of X-ray line emission. The results, which are fraught with all the uncertainties and inconsistencies in other similar work, indicate the possibility of line emission in the diffuse X-ray background.

Two recent papers (Ducros *et al.* 1970; Henry *et al.* 1971) have indicated possible "bumps" in the diffuse background spectrum in the 4–8-keV region. A more recent NRL flight on 1970 February 28 has also been analyzed in this energy region. Approximately 30 sec of data were obtained between $\pm 30°$ galactic latitude and 120°–290° galactic longitude, and another 30 sec of data were obtained outside this region. The two groups of data will be referred to as "galaxy" and "pole" data, respectively.

A flat background spectrum was subtracted from the data; this background level was obtained from the accumulated observations of the Earth as the rocket spun. The data were also corrected for detector efficiency which is a smooth function of energy above 3.5 keV. The corrected galaxy and pole data are shown in Figure 1 (*top*) along with a power-law spectrum of $E^{-1.4}$. A similar plot of data obtained in the 1969 March 13 (Henry *et al.* 1971) flight is shown in Figure 1 (*bottom*). In the latter flight, approximately 40 sec of "galaxy" data were obtained between galactic latitudes 2° and 12° and galactic longitudes 190° and 230°; approximately 80 sec of "pole" data were obtained in a scan through the North Galactic Pole above galactic latitude 65°. In both cases there is a statistically significant enhancement in the 6–7-keV region above that expected from the $E^{-1.4}$ power-law spectrum previously obtained for the diffuse background (Henry *et al.* 1971).

There are several deficiencies in the data which we should point out to emphasize the tentative nature of the observations and the discussion which follows. Obviously data with better statistics are highly desirable, and more data above 8 keV are needed to test the $E^{-1.4}$ spectrum chosen to fit the continuum. Also, in the 1970 data, the galaxy peak appears to lie at least 0.5 keV lower than that in the 1969 data, and the shape of the feature in the pole data differs somewhat in the two flights. A gain shift during either of the two flights might explain these effects.

Ignoring these problems for the present, we find that the features correspond to a line

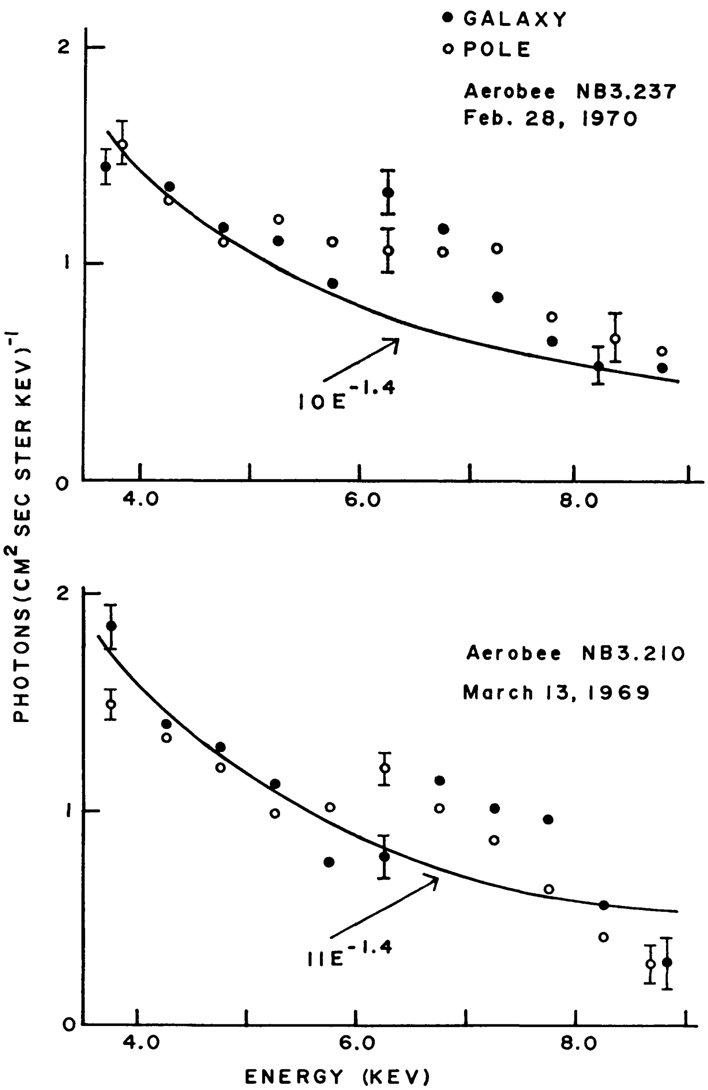

FIG. 1.—Spectrum of the X-ray background in the galactic plane (*filled circles*) and at the galactic pole (*open circles*). Smooth curve indicates a power-law spectrum, $E^{-1.4}$. The data from two flights are shown.

intensity of approximately 0.6 photons (cm^2 sec sterad)$^{-1}$. The line width in the galaxy data is about 1 keV, which is consistent with the detector response to a monochromatic feature near 6 keV. There is some indication that the feature is shifted or possibly broadened at the pole. We can rule out such possible spurious sources as an improperly shielded calibration source or cosmic rays by noting that when the detectors are looking at the Earth, only 0.15 counts (cm^2 sec sterad)$^{-1}$ are recorded in the 6–7-keV region, and there is no indication of a line. Similarly, there is no indication of a line in the spectrum of the Crab Nebula which was observed during both flights. This gives us added confidence that the line is not a fluorescence effect induced by continuum X-rays, even though we do not expect such an effect to be observable. The absence of the line in the Crab spectrum also implies that the effect is not caused by a malfunction in the pulse amplification and analysis electronics.

Steigman and Silk (1970) suggested that line emission might contribute to the diffuse galactic background in the 1–10-keV region. Their mechanism involves electron capture by low-energy cosmic rays in collisions with neutral hydrogen. They predict a line intensity in the region 6.4–8.0 keV from iron-group cosmic rays of 0.7 photons (cm^2 sec sterad)$^{-1}$ which is remarkably close to what we measure. However, they also predict that this line emission should be strongest in the line of sight lying within the galactic plane whereas we observe no significant difference between the pole and galaxy data. The presence of the line in the pole data suggests an extragalactic origin. The emission in the galactic plane should then include the extragalactic component since the absorption of X-rays is negligible at energies above 4 keV. The galactic component would be larger if there were an additional galactic mechanism also producing line emission, but the inadequate statistics of these experiments make it impossible to tell if such an excess is present.

In considering the possibility of an extragalactic origin for the line emission, we can estimate the flux that might be produced throughout the Universe by the mechanism proposed by Steigman and Silk. If we assume that all the iron in galaxies was produced in supernovae, then all of it must have gone through a stage where it was part of a low-energy flux of cosmic rays. The extragalactic photon flux that we would observe at the pole of our Galaxy is then

$$I = (4\pi)^{-1} c g_X n(\mathrm{Fe}) ,$$

where n(Fe) is the average density of iron in the Universe and g_X is the average number of X-ray quanta emitted by an iron atom as it slows down and comes into thermal equilibrium with the interstellar medium. If we take the average density of matter from galaxies in the Universe to be 3×10^{-31} g cm^{-3} (Oort 1958), assume that 70 percent is hydrogen by mass, and take 3.1×10^{-5} as the abundance of iron relative to hydrogen (Cameron 1968), then $n(\mathrm{Fe}) = 4 \times 10^{-12}$ atoms cm^{-3}. The factor g_X is probably equal to 2, since once a low-energy iron nucleus has captured two K-electrons there is no efficient mechanism that would reionize it and permit the electron-capture process to repeat itself. These values then lead to a line intensity $I = 0.02$ photons (cm^2 sec sterad)$^{-1}$, which is 30 times lower than that observed. A further problem associated with any universal production mechanism of line emission is that the cosmological redshift tends to broaden the line and make its detection more difficult. The redshift has been discussed by Clayton and Silk (1969) in connection with a universal background of γ-ray line emission from ^{56}Ni and ^{56}Co.

The mechanisms for producing lines in the diffuse background are of great interest in studies of the interstellar medium and possibly in extragalactic studies as well. At the moment, the most important task is to improve the observational evidence for or against this line feature in the 6–7-keV region. In this regard, we hope that other experimenters will examine all the relevant data they may possess for any sign of this feature.

We would like to thank J. Silk for helpful discussions of this work and A. Davidsen for pointing out the error in an earlier version of this Letter.

The E. O. Hulburt Center for Space Research is partially supported by the National Aeronautics and Space Administration.

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