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DIFFUSE X-RAYS FROM THE GALACTIC DISK

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We wish to report on an anisotropic feature of the diffuse hard X-ray background that tracks the concentration of interstellar hydrogen in the plane of the galaxy. This feature supports a model of galactic X-ray emission by subrelativistic cosmic rays via a bremsstrahlung process. The measurement was carried out on August 9, 1971, using two multianode multilayer gas proportional counters onboard Aerobee 170 flight 13.08. A schematic diagram of the detectors used is shown in Figure 1. This type of construction and the appropriate utilization of the signals from the many anodes result in a low detector background, a prerequisite before undertaking a measurement of possible small variations in the brightness of the X-ray sky.

The measurement of possible galactic effects on the generally isotropic X-ray sky is a long-term objective of our group. As such, it has greatly influenced the inception and design of experiments proposed by us and approved for flight on board future satellites. The same objective but on a much limited scale underlied the planning of Aerobee flight 13.08. Consequently, the detectors and their collimators as well as the flight plan were carefully chosen for optimum utilization of the available time. The segment of the galactic plane near $l^{II} \sim 62^\circ$ was specifically chosen because during our previous Aerobee flight we found that region to be free of discrete X-ray sources down to a limiting strength of less than 1 percent of the Crab Nebula. Shown in Figure 1 is the orientation of the collimators relative to the galactic plane and the limits of the scan that took place. During the flight, the plane was crossed a total of four times.

Detectable galactic disk effects will be the net result of absorption and emission processes involving energetic charged particles and interstellar matter. Assuming extragalactic origin for the diffuse X-radiation, the galactic medium causes varying amount of absorption depending on the amount and composition of matter in the line of sight. The dominant absorption mechanism is the photoelectric effect which proceeds discontinuously as the incident photon energy exceeds the K-shell absorption edges of the abundant elements. If a given K-shell absorption edge could be resolved we would obtain a direct measure of the columnar density of the corresponding atomic species. At energies above 0.3 fJ (2 keV) it is the heavy elements beyond silicon that come into play.

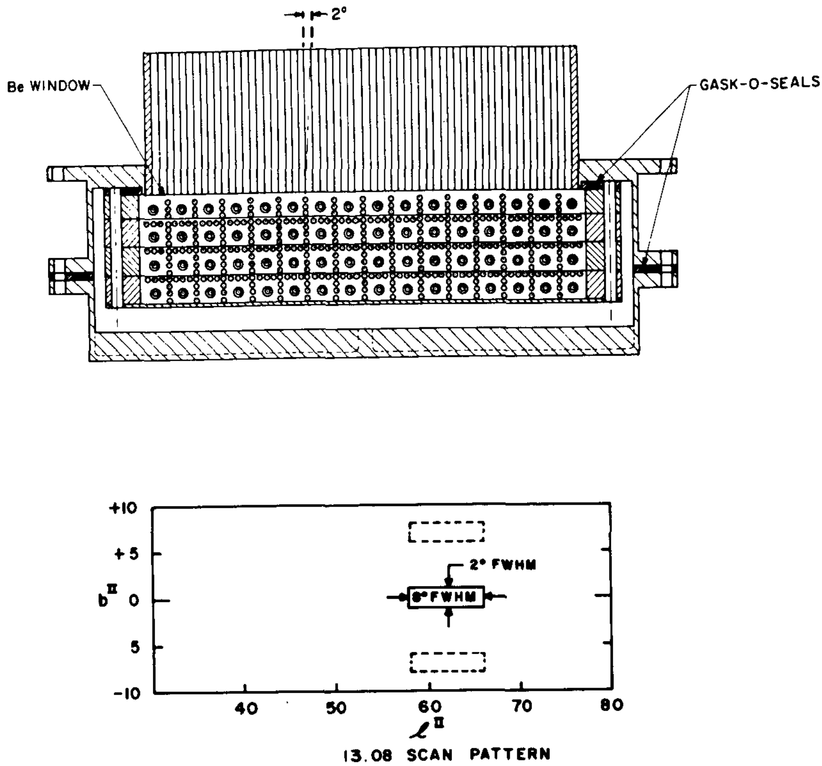

Figure 1–Schematic diagram of detectors.

An enhanced diffuse X-ray flux at low galactic latitudes likely signifies some interaction involving energetic charged particles, be it bremsstrahlung, inverse Compton, synchrotron, or recombination radiation. The profile of the radiation as it relates to the hydrogen concentration, as well as the spectrum, may be used as bases for identifying the particles involved and the nature of the process. In addition, because the same charged particles will necessarily ionize the interstellar gas, we have at our disposal an additional constraint; i.e., the ionization rate of this gas.

In Figure 2 we show the counting rate in selected energy channels from both detectors as a function of galactic latitude. The excess within 3.5° of the galactic plane is at least 6σ. A two-parameter least-squares fit rejects a single-point source contribution with 90 percent confidence. The best fit to a diffuse source is obtained with a 2° extended source centered near the galactic plane. This is in close accord with the hydrogen profile.

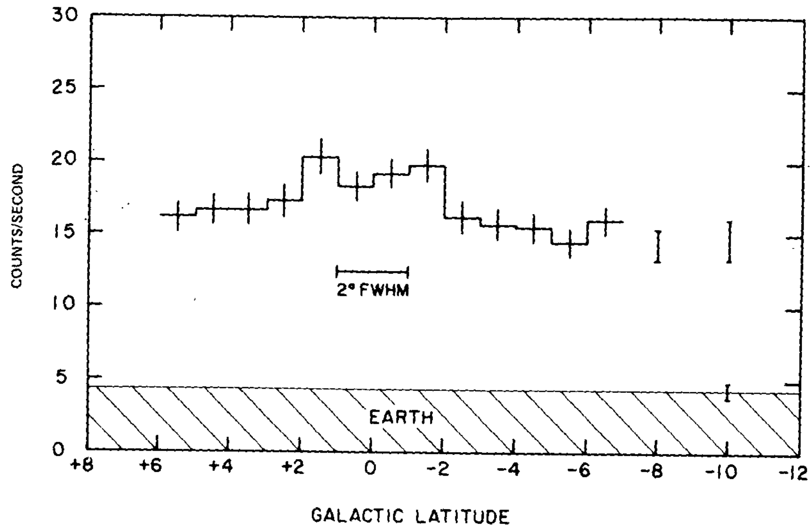

Figure 2–Counting rate as a function of galactic latitude.

To obtain a spectrum for the observed excess, we have broken the data into two groups separated by the latitudes $b^{II} = \pm 3.5^\circ$. The combined spectrum from both detectors is shown in Figure 3. The two most significant data points give a flux of about 9.6 aJ $(cm^2 \text{ s aJ rad})^{-1}$ (or about 0.06 keV $(cm^2$ s keV rad$)^{-1}$) which is about half as much as previous estimates of a galactic flux. Of special interest is the energy bin 0.94 to 1.5 fJ (5.9 to 9.1 keV) where the data point lies some 2.5σ below the average of the two neighboring points. This is where iron K edge effects would be expected. Observations of 21 cm at this longitude give a hydrogen columnar density through the plane of 2×10^{22} H atoms cm^{-2}. A universal abundance of iron relative to hydrogen would result in only a 2 percent absorption jump, whereas the effect in our data is at least five times that amount. Thus, if the low point is indeed caused by absorption, we would require at least a five-fold increase in the iron abundance relative to the hydrogen density as given by 21-cm measurements.

In general, however, this spectrum allows us to draw only limited conclusions about the mechanism of emission. Based on the profile of the radiation as well as existing upper limits at higher energies and radio data, we favor a bremsstrahlung process. If that is the case, we would expect about 2×10^4

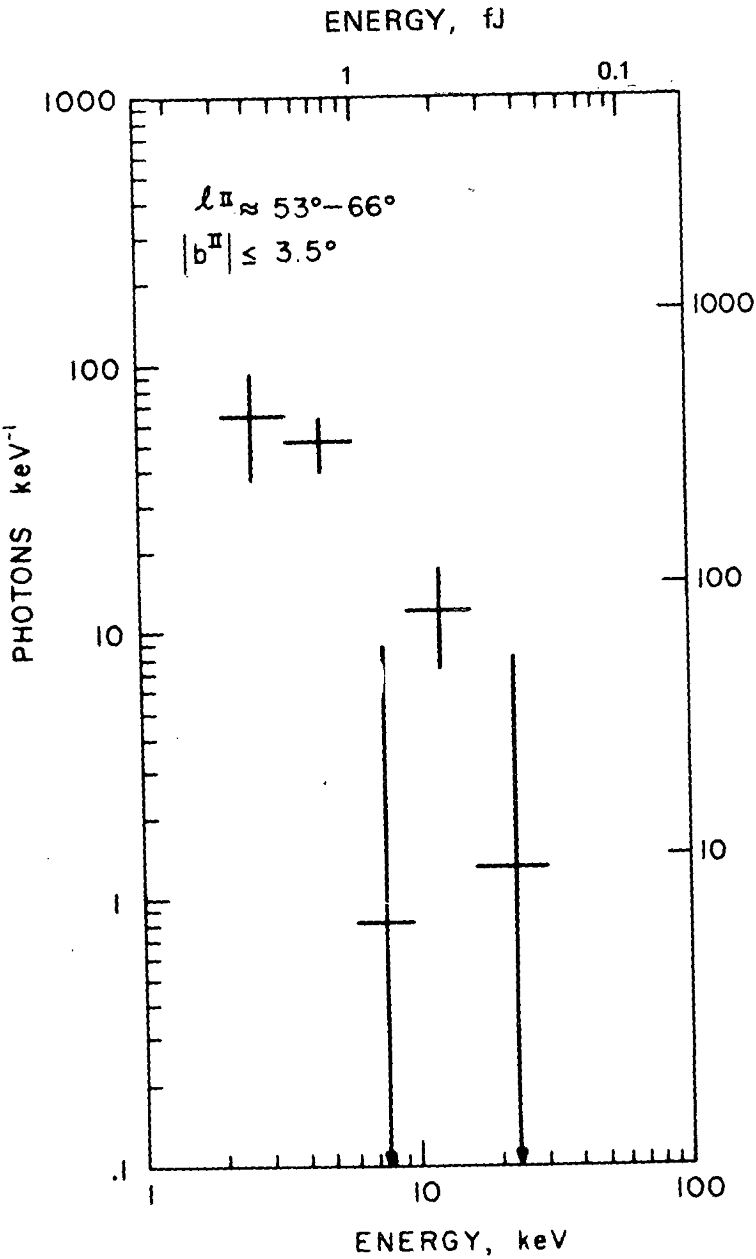

Figure 3–Galactic disk net X-ray flux.

as much energy to go into ionizing the interstellar medium as the amount that goes into producing the observed X-rays. Using this efficiency, we estimate a hydrogen ionization rate of 3×10^{-15} (s H atom)$^{-1}$. This value is well in agreement with estimates based on pulsar dispersion measures and current models of the interstellar gas.