THE NATURE OF THE SOFT X-RAY EMITTING REGION IN THE DIRECTION OF THE NORTH POLAR SPUR

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The spatial structure of the X-ray sky in the direction of the North Polar Spur was examined in two energy bands, the B band (0.10 - 0.18 keV) and the C band (0.15 - 0.28 keV). A model with two emitting regions, one local with unabsorbed emission, and the other more distant with emission partially absorbed by spatially varying amounts was investigated.

Using the distribution of atomic hydrogen as a measure of absorbing material, this model was used to predict the flux in the direction of the North Polar Spur. The predicted flux was compared to the data obtained from several sounding rocket flights. The derived flux was found to correlate well with the observed data.

If the model is valid, several conclusion can be drawn from this analysis. The B band flux is almost entirely local in origin. While the local emitting region provides a substantial portion of the observed C band diffuse background, the majority of the C band X-ray originate in a more distant region. The contribution of the local region is relatively constant while the emission from the more distant region, partially absorbed by varying amounts of material, dominates the spatial structure of the X-ray sky in this direction.

This paper discusses one possible cause for the spatial structure observed in the soft X-ray sky as observed in the direction of the North Polar Spur. The data are from a series of sounding rocket flights. The detectors are two gas-filled proportional counters whose seven degree field of view is determined with honeycomb collimators.

Figure 1 shows the relative efficiency of the counters at various energies. Energy resolution is provided at lower energies by carbon and boron filters and at higher energies by pulse height discrimination. The minima which follow the K-edges very effectively define a boron band (B band) from 130 to 188 eV and a carbon band (C band) from 160 to 284 eV. Pulse height discrimination allows a third band (M band) to be defined from 0.45 to 1.0 keV.

The North Polar Spur refers to a region of enhanced radio emission along a longitude of 30°. That this region is also associated with enhanced soft X-ray emission was shown by Bunner et al. (1972) and is apparent in the M and C band maps and to a lesser extent in the B band map (Figure 2).

For the purposes of this discussion we will assume that the source of the X-rays is thermal in nature and consists of a mixture of bremsstrahlung and lines from recombination and collisionally excited ions. By convolving the emission spectrum of such a hot gas with the detector response functions, one can predict the count rates as seen by the detectors within the various bands. The relevant parameters are temperature, relative elemental aboundances, the extent of the emitting region, and absorption. In this discussion, absorption is an important effect.

Figure 3 shows the relative intensity for each band for a one million degree emitting region with varying amounts of absorption. The absorber is described in terms of the column density of neutral hydrogen with the relative amounts of heavier elements given by a specific set of relative abundances. For B and C band X-rays, helium and hydrogen are the dominant absorbers with oxygen becoming effective in the M band. It is important to note that, while the count rates depend on the extent of the emitting region, the ratios of the count rates do not. Figures 4 and 5 illustrate the C/B and M/C ratios as a function of temperture for various amounts of absorbing material.

The M/C and C/B ratios for a series of points along the spur were determined. Figure 6 indicates the temperatures implied by the two sets of ratios. It is immediately apparent that the C/B ratio implies increasing temperature with latitude while the M/C ratio implies decreasing temperature. This behavior persists for increasing amounts of absorption. Clearly, the data cannot be made consistant with emission from a single temperature region for any varying amounts of absorption. In an analysis of data from a single point of the spur, John Nousek (1978) demonstrated that, for the observations to be fit by a model of thermal emission, the data required two emitting regions, one local and unabsorbed at about one million degrees and another at a temperature of about 3 million degrees behind an absorbing layer.

Savage et al. (1977) have determined the column densities of molecular and atomic hydrogen towards a number of nearby stars which include the general direction of the galactic center and the NPS (Figure 7). Although the data here tend to be for stars at less than twenty degrees latitude, the distribution of the data suggests several important points. (1) There appears to be little neutral material in the direction of the NPS out to about 135 pc. (2) There is a dramatic increase in material at 135 pc. (3) The fact that the column densities do not continue to increase beyond 135 pc suggests that much of the neutral gas may be concentrated at about 135 pc.

This suggests a model in which the soft X-ray flux from the direction of the North Polar Spur originates in two regions, one local and unabsorbed and the other, more distant and partially absorbed by varying amounts of material. The model is illustrated in Figure 8. The two equations state that the observed C and B band fluxes originate in a local unabsorbed region, the first terms, and a more distant partially absorbed region, the second terms. The respective C and B ratios are determined by the assumed temperatures. Since B band X-rays are strongly absorbed by even small amounts of material, the observed B band flux in this model acts primarily as a measure of the local region. By using the observed B band flux and the neutral hydrogen column density as obtained from 21-cm measurements (Heiles et al. 1976) we can make the model predict a C band flux and then compare it to observations.

To improve statistics, data were averaed over six by six degrees for a number of pixels which are indicated in Figure 9. The model was then used to predict C band rates which were then compared to observed rates. The NH used was the total NH from -20 to +20 km/sec.

Figure 10 compares the predicted C band flux with the observed rates. The predicted and observed fluxes appear to agree well. The error bars reflect the uncertainty in the measured B and C band count rates. The correlation coefficient for this plot is 0.89.

Figure 11 is a plot of the local and distant contributions to the C band flux as predicted by the model. If the model is valid, it implies that, at least in the direction of the NPS, much of the flux originates in the more distant region (in this case slightly more than half). Also, as evidenced by the large intensity variations in the upper part of the figure, the bulk of the spatial structure is caused by absorption effects. That almost all of the B band flux is local is implicit in the model.

Bunner, A. N. et al. 1972, Ap. J. (Letters), 172, L67.
Nousek, J. A. 1978, Ph.D. Thesis, University of Wisconsin.
Savage, B. D. et al. 1977, Ap. J., 216, 291.
Heiles, C. et al. 1976, Astr. Ap., 46, 333.

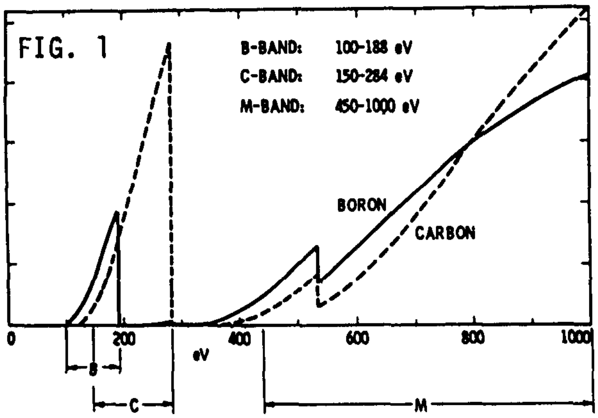


FIG. 1

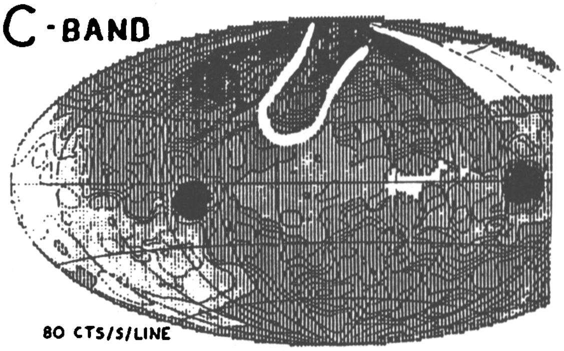


FIG. 2

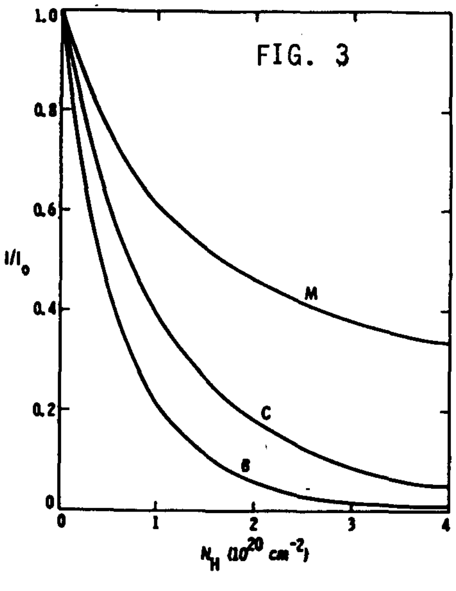


FIG. 3

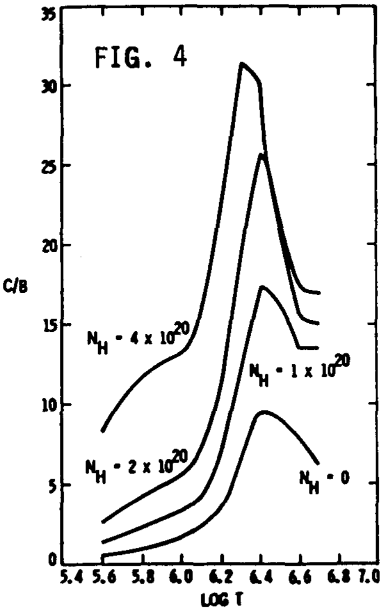


FIG. 4

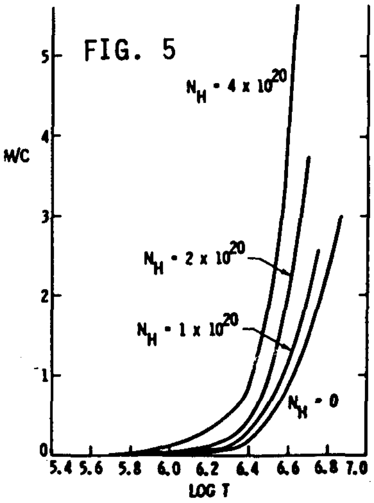


FIG. 5

FIG. 6

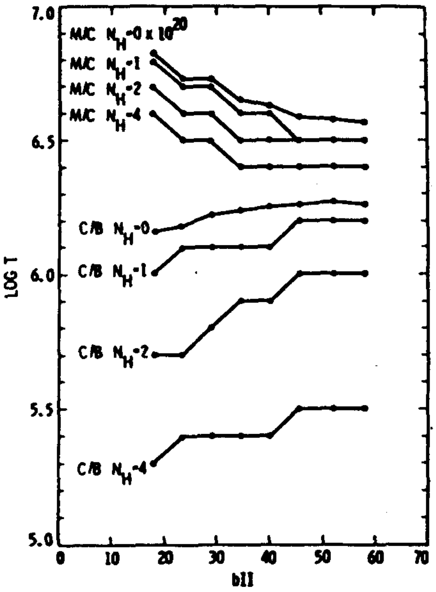


FIG. 7

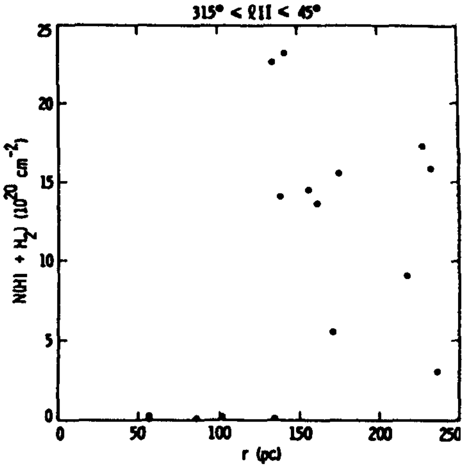
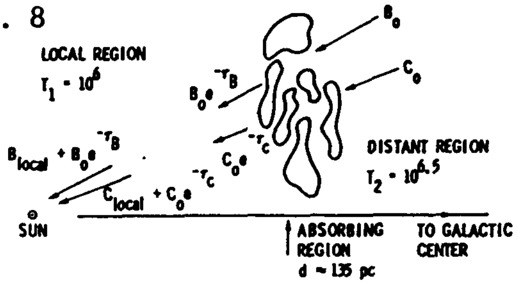


FIG. 8



$$\text{C-BAND FLUX OBSERVED} = C_{Local} + C_0 e^{-\sigma_C N_H}$$

$$\text{B-BAND FLUX OBSERVED} = B_{Local} + B_0 e^{-\sigma_B N_H}$$

$$\frac{C_{Local}}{B_{Local}}\ (T = 10^{6.0}\ K) = 2.1$$

$$\frac{C_0}{B_0}\ (T = 10^{6.5}\ K) = 10.4$$

$$\downarrow$$

N_H ($|V| < 20$ Km/sec, Heiles and Jenkins (1975))

← CALCULATE C-BAND FLUX

FIG. 9

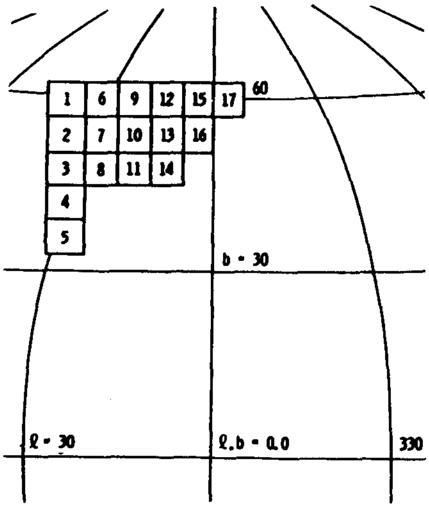


FIG. 10

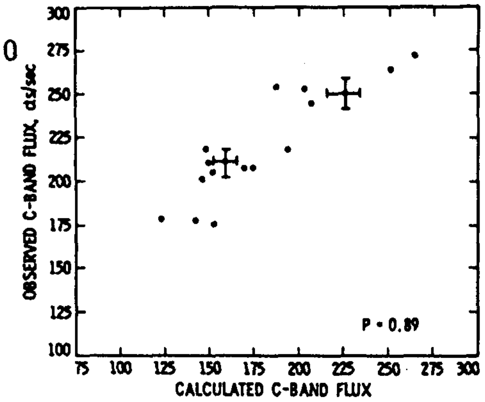


FIG. 11