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SOFT X-RAYS FROM THE VICINITY OF THE NORTH POLAR SPUR

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ABSTRACT

Soft X-rays in the region $E < 284$ eV and $500 < E < 1000$ eV have been detected from the vicinity of the North Polar Spur.

In an early paper, Hanbury Brown, Davies and Hazard (1960) suggested that the North Polar Spur was a spherical shell viewed edge-on and that the shell was possibly a supernova remnant similar to the Cygnus Loop, but of course nearer. Recently Shklovskii and Sheffer (1971), from an examination of the soft X-ray observations of Bowyer, Field, and Mack (1968), suggested that the apparent regions of enhanced emission coincided with certain high-galactic-latitude Spur features. These regions, however, appear to have been the result of atmospheric scattering of solar X-rays (Ilovaisky and Bowyer 1971; Hayakawa *et al.* 1971). The prominent radio feature and most of the region of enhanced X-ray emission reported here were below the horizon at the time of the Bowyer *et al.* observation.

Our observations were made from an Aerobee 150 rocket launched 1970 May 29 from Woomera, Australia. Two proportional counters each of 290 cm^2 effective area viewed in opposite directions perpendicular to the rocket spin axis. At X-ray energies above 1 keV the circular collimation was 6° FWHM, but at lower energies collimator reflections resulted in a gradually increasing opening angle, reaching 10° FWHM at 180 eV. Counter windows were 300 μg cm^{-2} Kimfol (polycarbonate) coated with 10 μg cm^{-2} of colloidal carbon. Counting-rate data were telemetered in pulse-height channels corresponding to X-ray energies 160–280, 280–550, 550–1100, 1100–1800, 1800–6000, and 6000–10,000 eV. The two lowest channels each carried approximately half the carbon K-edge transmission-band data, and the ratio of the rates in these two channels was about one, as expected, throughout the flight.

The rocket spin period was about 60 seconds, and as the rocket axis precessed each counter alternately viewed the Earth and the sky for 30-s periods. The non-X-ray background rates, as determined during the Earth scans, were small and constant throughout the flight. The directions viewed at 1-s intervals are shown in Figure 1*a*.

The counting-rate data for channels 1 and 2 ($E < 284$ eV) and channel 3 ($1 \geq E \geq 0.5$ KeV) are shown in Figure 2. Several known X-ray sources were crossed during the flight. Those observable in channel 1, 2, or 3 are Sco X-1 at 293 s, the unresolved composite of Vela X and Puppis A at 249, 279, and 309 s, and an unresolved complex of sources near the galactic center at 320–325 s. The relatively small signal from Sco X-1 in the $E < 284$ eV data is entirely, to within the accuracy of the measurement, a counter-transfer phenomenon. No measured $E < 284$ eV flux is claimed. The implication of these data will be discussed in a separate publication.

We have combined the aspect data of Figure 1*a* with the counting-rate measurements and have prepared the isophote displays of the data shown in Figures 1*b* and 1*c*. Both the $E < 284$ eV and $500 < E < 1000$ eV data show a ridge of high intensity near the North Polar Spur. There are no features or holes in the columnar hydrogen distribution (Tolbert 1972) that would suggest an extragalactic origin for the detected radiation. The bars on the time axes of Figure 2 near 202, 229, 259, 289, and 319 are 10° wide and

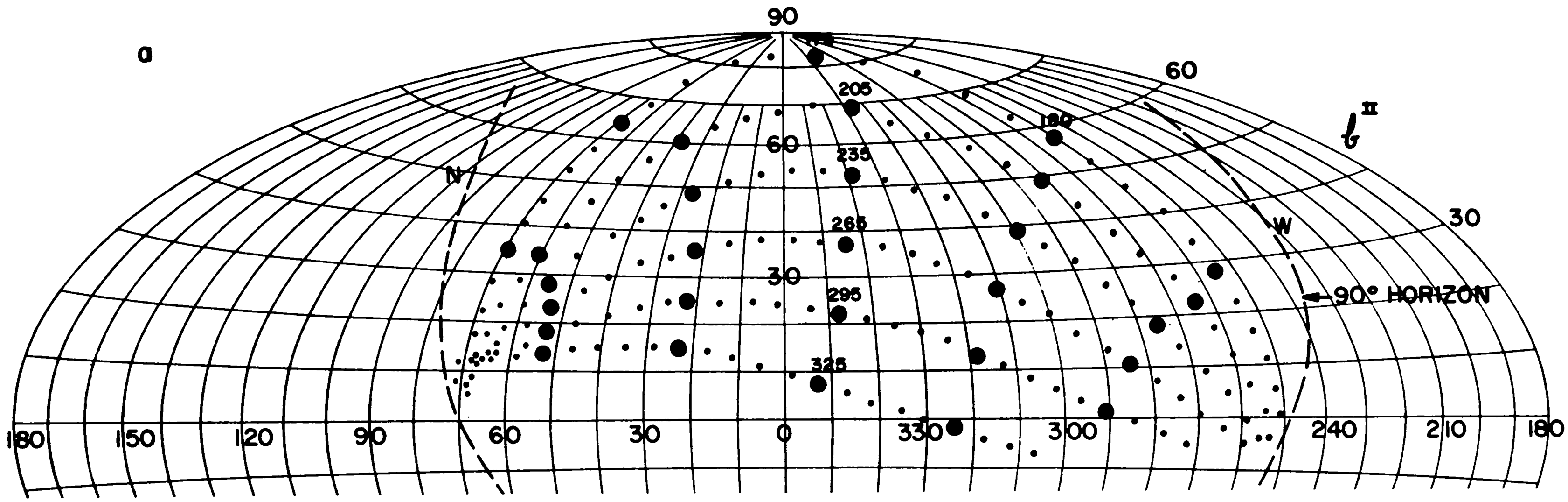

FIG. 1.—(*a*) The scan path with directions indicated at 1-s intervals. (*b*) Isophotes of counting rate for the $E < 284$ eV data. (*c*) Isophotes of counting rate for the $500 < E < 1000$ eV data. We see no observational reason to associate the bulge centered at $l^{II} = 340°$, $b^{II} = 20°$, with the North Polar Spur.

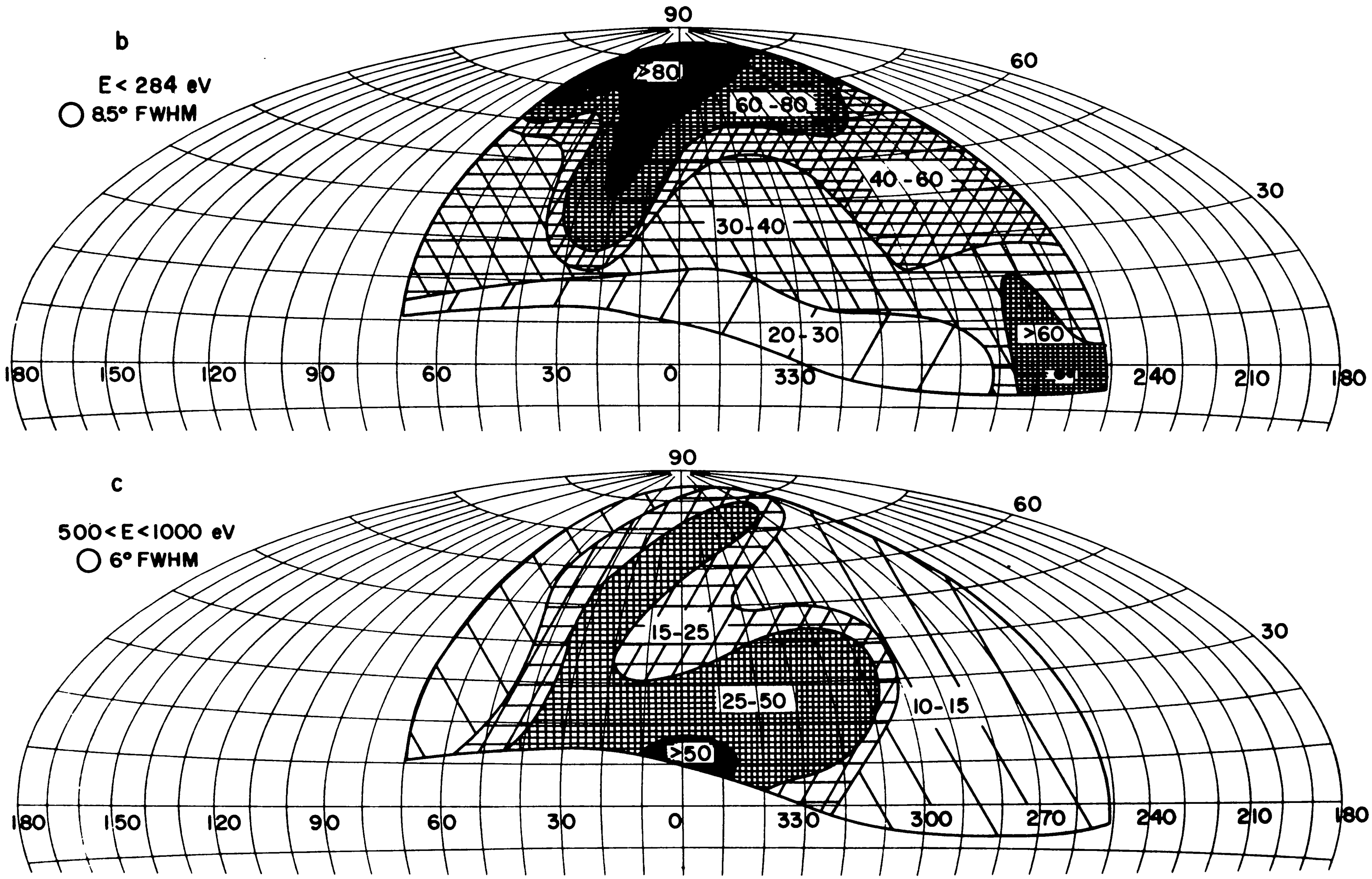

FIG. 1.—*Continued*

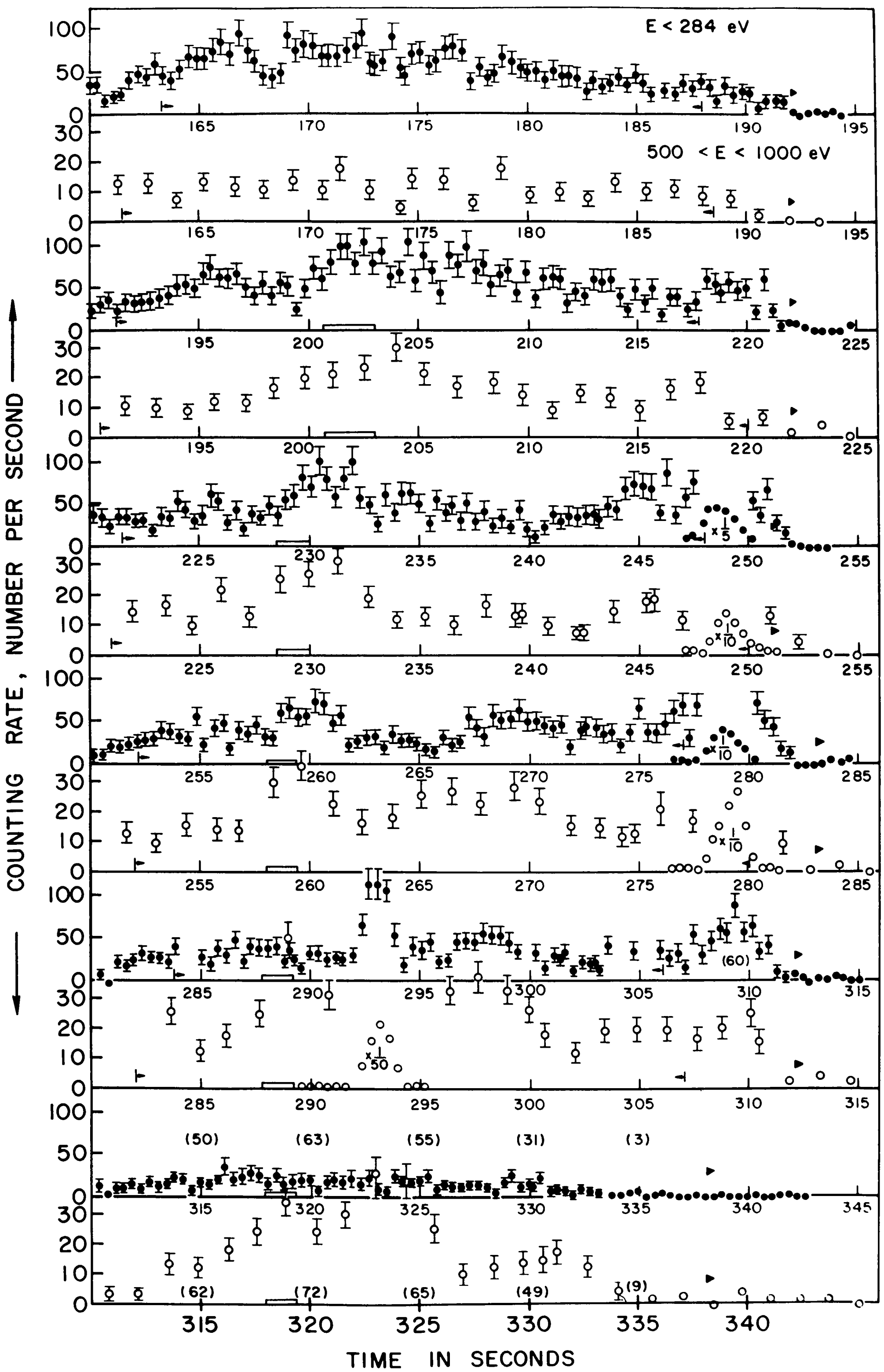

FIG. 2.—Counting rate for X-rays of $E < 284$ eV (*closed circles*) and for X-rays of $500 < E < 1000$ eV (*open circles*) as a function of time into the flight. Arrows indicate regions where atmospheric transmission was >80 percent, and triangles indicate where atmospheric transmission along the collimator axis was essentially zero. On the last scan, atmospheric transmission was always less than 80 percent, and some transmission values are shown in parentheses. Background rates, which averaged three and two counts per second for the $E < 284$ eV and $500 < E < 1000$ eV data, respectively, have not been subtracted.

centered on the maximum radio brightness of the North Polar Spur, as given by Haslam, Kahn, and Meaburn (1971). The regions of enhanced X-ray emission, while reasonably close to the bars, seem to be systematically shifted to the right as though the X-ray-emitting shell were of somewhat smaller diameter than the radio shell.

It is tempting to regard the gradual decrease of the $E < 284$ eV intensity with galactic latitude as an absorption effect, particularly since the $500 < E < 1000$ eV intensity remains approximately constant. Referred to the Spur crossing at 231 s ($b^{II} \approx 51°$), the *additional* gas paths implied at 259 s ($b^{II} \approx 35°$) and 289 s ($b^{II} \approx 24°$) are 1.4×10^{20} and greater than 2.5×10^{20} H cm^{-2}, respectively. If the observed X-rays emanate from an arc of tangents to a spherical shell, all points along the observed arc are equidistant from us. Barring significant local fluctuations in gas density, the absorption could then be a consequence of the diminishing gas density with height above the galactic plane. The distance to the emitting region would then be of the order of or greater than the gas scale height, ~100 pc. Given the angular extent of the arc, the radius of the supposed spherical shell would also be of the order of or greater than 100 pc, five or more times the radius of the Cygnus Loop. Mathewson, as reported in Berkhuijsen, Haslam, and Salter (1970), has suggested 50–200 pc as the distance to the dust associated with the Spur and evidently responsible for the observed starlight polarization. See Mathewson and Ford (1970).

Our data on the Spur near 202 and 231 s correspond to the photon intensities given below for any reasonable continuum spectrum:

$$I\ (E = 260\ \text{eV}) = 300 \pm 150\ \text{photons (cm}^2\ \text{s sterad keV)}^{-1}\,,$$

$$I\ (E = 800\ \text{eV}) = 60 \pm 30\ \text{photons (cm}^2\ \text{s sterad keV)}^{-1}\,,$$

$$I\ (E = 1500\ \text{eV}) < 5\ \text{photons (cm}^2\ \text{s sterad keV)}^{-1}\,.$$

Since the column density of hydrogen in these directions is only 4×10^{20} H cm^{-2} (Tolbert 1972), the $E = 800$ eV and $E = 1500$ eV intensities are almost independent of the source distance while the $E = 260$ eV intensity could have been attenuated by a factor of as much as five. If the incident spectrum is a series of widely spaced lines on a weak continuum, then interpretation of the quoted intensities is complicated and clarification must await either better spectral measurements or more specific spectral assumptions.

At 298 s, our field of view passed close to the Lupus Loop, a 4°5 diameter radio source identified as a supernova remnant by Milne (1970). Particularly the $E < 284$ eV data suggest but do not demonstrate the existence of an extended soft X-ray source at this position. Brandt and Maran (1972) have pointed out that the North Polar Spur is nearly concentric with the Lupus Loop.

We (Bunner *et al.* 1971) have previously reported intensities in the galactic plane of about 120 photons (cm^2 s sterad KeV)$^{-1}$ at 260 eV. The calibration of the instrument used to obtain the present data is such that a counting rate of 20 s^{-1} ($E < 284$ eV) including the 3 s^{-1} background rate corresponds to the plane intensity mentioned above. While there is no plane observation clear of atmospheric absorption, we see that this predicted rate, based on measurements in other parts of the galactic plane, is in reasonable accord with the observations.

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