FINAL REPORT

Contract NASw-2414

Observation of Soft X-Rays From Extended Sources

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INTRODUCTION

The purpose of this program was to continue the investigation of spectra and angular structure of extended sources of soft x-ray emission which was begun under Contract NASw-1388. The rocket payload flown on NASA-17.08 was refurbished, modified somewhat, and flown on 17.012 under this contract.

Initially, efforts were directed toward surveying several supernova remnants for the emission of soft x-rays. Data from the X-ray Astronomy Group at Lawrence Livermore Laboratory, however, indicated that the supernova remnants intended for survey emit x-rays very faintly, if at all. Rather than attempt to detect such faint x-ray emission, the program was redirected to observe the spectrum and angular structure of the extended x-ray source in the Perseus cluster of galaxies and the supernova remnant Puppis A. Also, an attempt was made to detect x-ray line emission from Puppis A with a Bragg crystal spectrometer. Observations by Burginyon et al. (1973) provide evidence for the presence of x-ray line emission in the spectrum of Puppis A near .65 keV. The energy of this feature is consistent with identification as the Lyman α line of O VIII. Such an identification is also consistent with the temperature obtained on the basis of assuming the plasma is isothermal.

Objectives of this research, in the case of the Perseus source, were to investigate the nature of the x-ray emission and its relationship to a nearby active galaxy NGC 1275. The attempt to observe an x-ray line from Puppis A was carried out with the objective of establishing the extent which thermal bremsstrahlung contributes to the x-ray emission.

EXPERIMENT PAYLOAD

A major part of the instrumentation used for observations under this contract has been flown previously on NASA-Aerobee 17.08. A schematic view of the payload for 17.012 is shown in Figure 1. The primary instrumentation consists of a pair of gas flow proportional counters which view space through a set of x-ray reflectors. These reflectors are parabolic in shape along the lengths shown and are linear in a dimension normal to the plane of the figure. The surface of these mirrors is made from polished Kanigen, a form of chemically deposited nickel. In this view, a plane wave of x-rays entering from the left undergoes a single reflection by the mirrors and is focussed on the window of a gas-flow proportional counter. Two counters are used in this system, one whose window lies on the reflector axis and another which is slightly off axis. The fields of view of these windows, when projected through the reflector system onto the sky, are 0.1° by 8° for the on-axis detector, and 0.3° by 8° for the one off-axis. The primary mode of acquiring data with this system is by slowly scanning these fields of view in a direction normal to their long dimension. By utilizing rate-integrating gyros, the rocket attitude control system (ACS) was able to provide a stable scan rate of $.03^{\circ}$ sec^{-1} during data acquisition. The star tracker allows the ACS to position the start of a scan on the sky to within a few tenths of a degree. A 35 mm camera photographs the star field every 1.5 sec to provide aspect data which is good to ± 3 arcmin.

During the flight of 17.012, the payload axis was scanned very slowly across Pup A through an angular range of 1.5°. By employing a fixed Bragg crystal and gas-flow proportional counter, this vehicle motion was converted into a high resolution scan in x-ray wavelength extending from 18.7 to 19.2A. The crystal spectrometer, indicated schematically in Figure 1, utilizes the fact that the Bragg angle for a KAP crystal at 18.97A is nearly 45°. X-rays are diffracted by the crystal across the payload diameter where they are detected by a multi-anode proportional counter designed to have a very low background counting rate. A schematic drawing of this counter design is shown in Figure 2. A principal of this design is to surround the x-ray detecting anodes as completely as possible with gas anticoincidence counters. The righthand part of Figure 2 is a view along the anodes of the x-ray detectors and shows the anticoincidence counters and the associated wires used to define ground planes between the anodes. These wires and anodes are actually $\sim$ .002" in diameter, and their size is greatly exaggerated in the drawing. This design has been in use for several years and is very effective except near the ends of the x-ray anodes. In these regions, cosmic rays, traveling at small inclination to the anodes, may produce a pulse in the x-ray detectors without entering an anticoincidence counter. In order to prevent this, the bottom anticoincidence counters were extended well past the termination of the x-ray anodes and another anticoincidence anode was added at each end of the x-ray detectors. The anodes of these additional anticoincidence counters run transverse to those of the other detectors as shown in the lefthand part of Figure 2. This design proved to be very effective in reducing the background counting rate. During laboratory tests, background

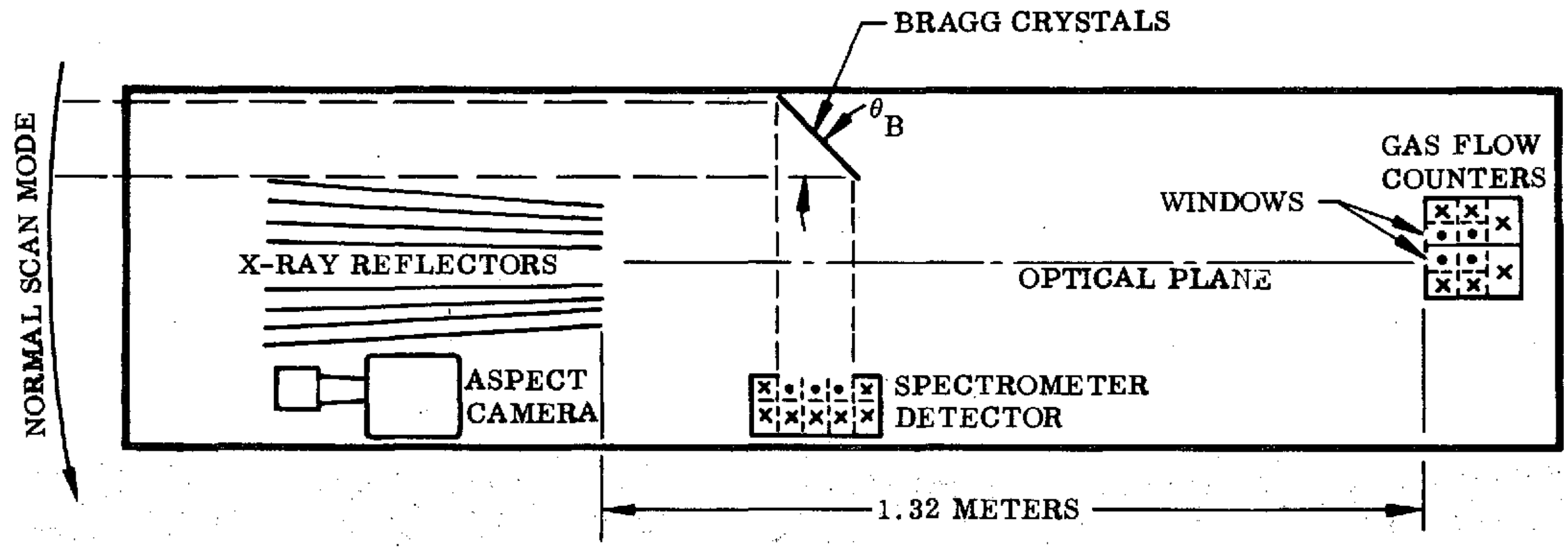


Fig. 1 A schematic view of the payload flown on Aerobee 17.012 CG.

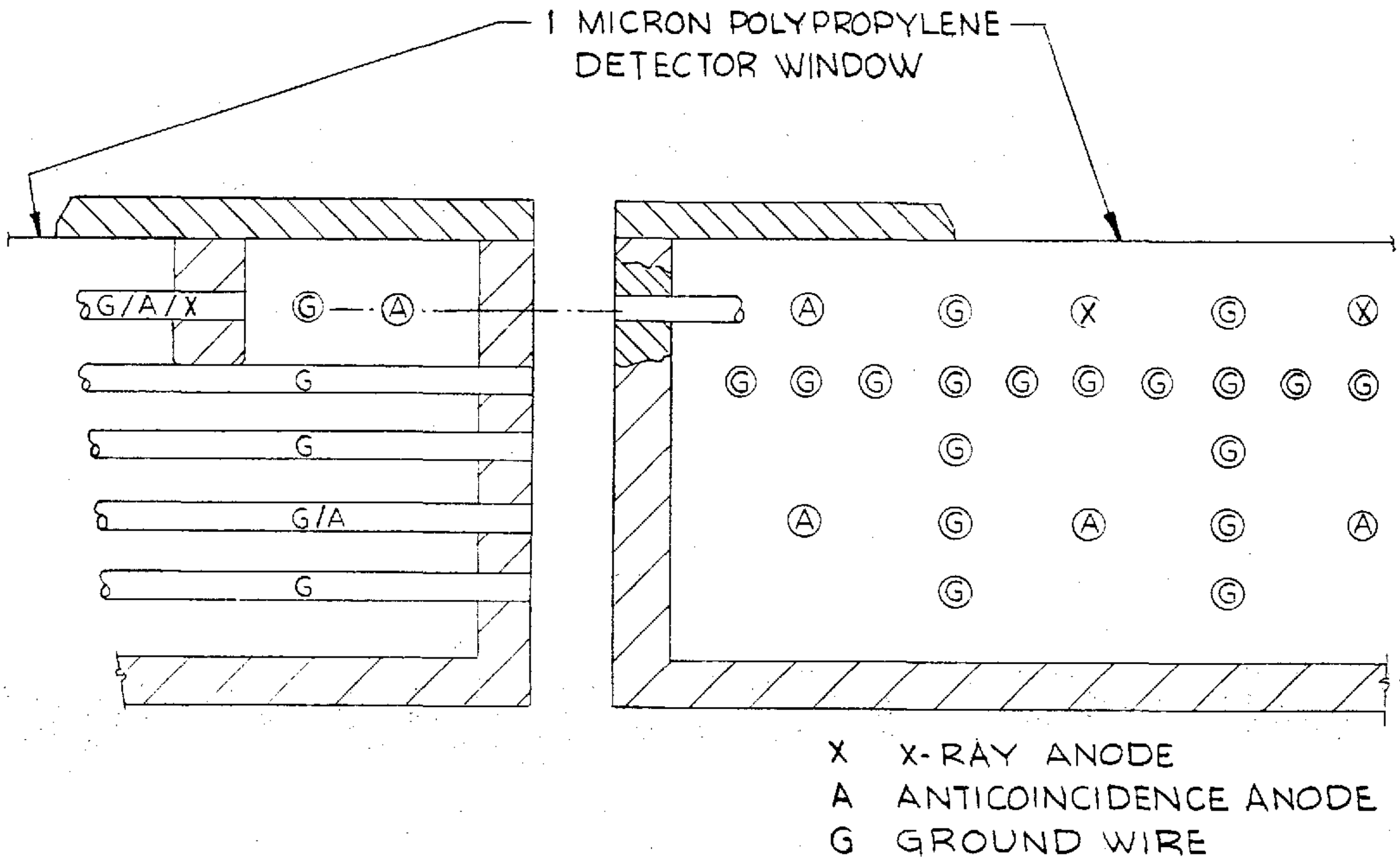


FIGURE 2 SCHEMATIC OF DETECTOR FOR BRAGG SPECTROMETER

rates of 0.2 counts sec^{-1} were achieved in the energy range from 0.2 to 1.2 keV with this detector. The detector was operated as a gas-flow proportional counter using P-10 at ~ one atmosphere pressure.

The spectrometer has three crystals which present a total projected area of 190 cm^2 to incident x-rays. Using the data of Burginyon et al. (1973), the expected intensity of line emission from Puppis A between .56 and .92 keV is ~ 2.7 photons $cm^{-2}sec^{-1}$. The calculations of Mewe (1972), modified to cosmic elemental abundances, indicate that 75 percent of the x-ray line intensity between .56 and .92 keV is from a hydrogen-like ion, OVIII, at 18.97A if the temperature of the emitting plasma is 4×10^6K, the value Burginyon et al. obtain from their analysis. Using a line intensity of 2 photons $cm^{-2}sec^{-1}$, a crystal reflectivity of 5×10^{-5} radians, a detector efficiency of 0.42 and a rocket scan rate of .03° sec^{-1} the spectrometer was estimated to detect ~ 10 counts per scan from the OVIII line with an expected background of ~ 2 counts.

In addition to the crystal spectrometer, the payload from 17.08 was modified in the following ways for the flight of 17.012.

a) Gas anticoincidence counters are located along two sides of each detector at the reflector focus. Previously, pulses in a primary detector were rejected when a count occurred simultaneously in one of its adjacent anticoincidence counters. This was done to make the counters operate independently, thereby providing a measure of redundancy. Since both detectors have always operated reliably, this system was changed on

17.012 so a detector pulse was rejected when a simultaneous pulse occurred in any of the anticoincidence counters.

b) The electronics of the primary detector system were modified so that amplitudes of individual x-ray pulses in the energy range from 0.1 and 0.8 keV were telemetered directly. Previously, the range from 0.1 to 0.5 keV was covered only by three window discriminators.

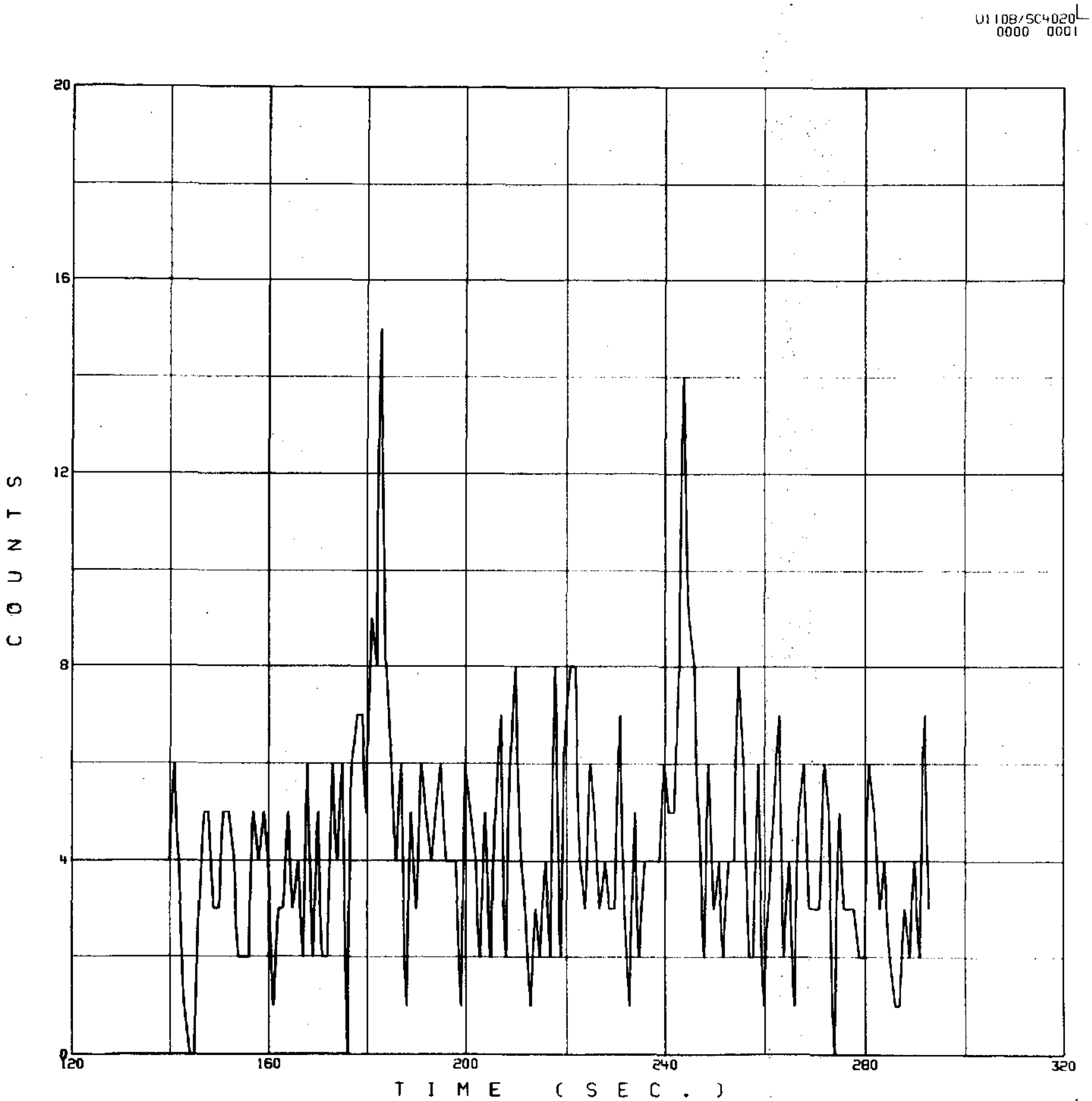
c) Squib actuated valves used in the gas-flow system on 17.08 were designed only for a single operation and it was therefore impossible to test them non-destructively. These valves were replaced with valves which could be recycled indefinitely for the flight of 17.012.

PRELIMINARY RESULTS FROM 17.012

NASA-Aerobee 17.012 was successfully launched on 5 April 1974 at 2210 MDT. Two previously scheduled launch attempts on 15 and 22 March were cancelled because of problems not associated with the experiment payload. On April 4, the day before launch, high voltage breakdown occurred in the anticoincidence counter of the detector for the Bragg crystal spectrometer. This appears to have resulted from insufficient flushing of the detector with counter gas prior to turn-on. After thoroughly flushing the system, the breakdown ceased but the anticoincidence efficiency had been degraded by a factor of ~ 5 due to damage of a pre-amplifier. Because the window for 17.012 was nearly at an end and repair of the preamp would require scrubbing the 5 April attempt, it was decided to launch with the preamp in its existing condition. This decision was also influenced by the fact the crystal spectrometer was not a part of the primary experiment on 17.012.

Both of the primary x-ray detectors at the reflector focus operated properly throughout the flight. X-rays were detected from the Perseus x-ray source in each detector on both scans over this object. These data are shown in Figures 3 and 4. Angular resolution of the detector and the energy range of the data are shown in the lower right of each figure. In Figure 3 the Perseus source was observed at $\sim$ 183 sec on the first scan and at $\sim$ 243 sec on the second scan. Since the vehicle was rolled $\sim 90^{\circ}$ at 208 sec, these data represent two nearly orthogonal scans over the source. These data indicate the Perseus source to have a very localized component since the observed distributions are approximately those expected from the instrument responding to a point source. This is consistent with the results of Copernicus x-ray observations reported by Fabian et al. (1974). Figure 4 contains data from the detector with a 0.3° field of view. At a scan rate of 0.3° sec^{-1} the source should appear in these data 15 sec later than in the data of Figure 3. As expected, there are signals centered at 198 sec and 258 sec.

Data acquired by these detectors during the scans over Puppis A are shown in Figures 5 and 6. The starting point for the first scan was reached by a long maneuver during which the fields of view passed over Puppis A. A slow scan was then made across the source, the direction of motion reversed and a second scan was made retracing the same path in an opposite sense. The initial rapid crossing of Puppis A is shown in the data

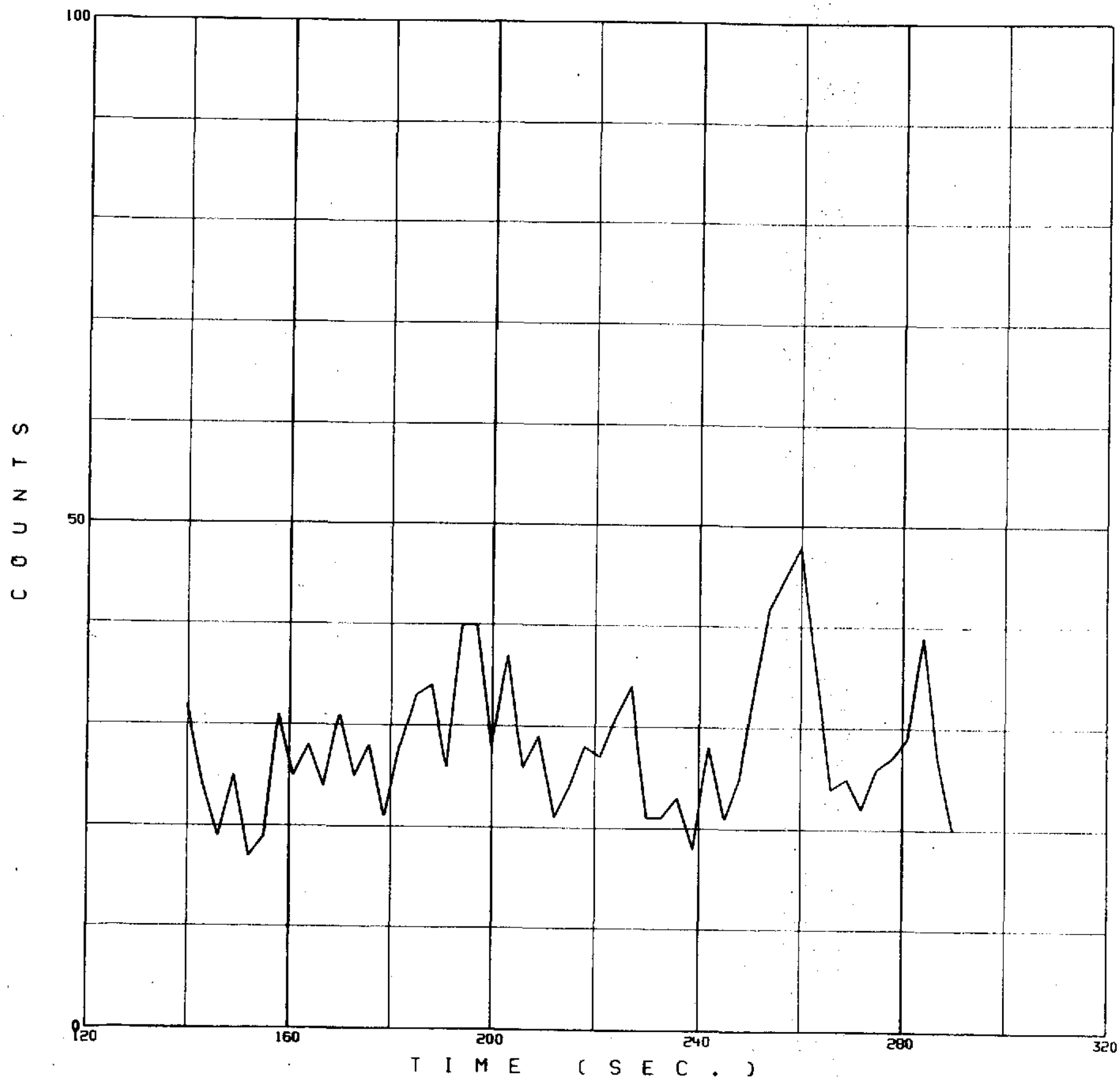


$\Delta\theta \sim 0.1°$

$\Delta E \sim 0.5 - 3$ keV

PERSEUS SCANS

FIGURE 3



$\Delta\theta \sim 0.3°$

$\Delta E \sim 0.5 - 3$ keV

PERSEUS SCANS

FIGURE 4

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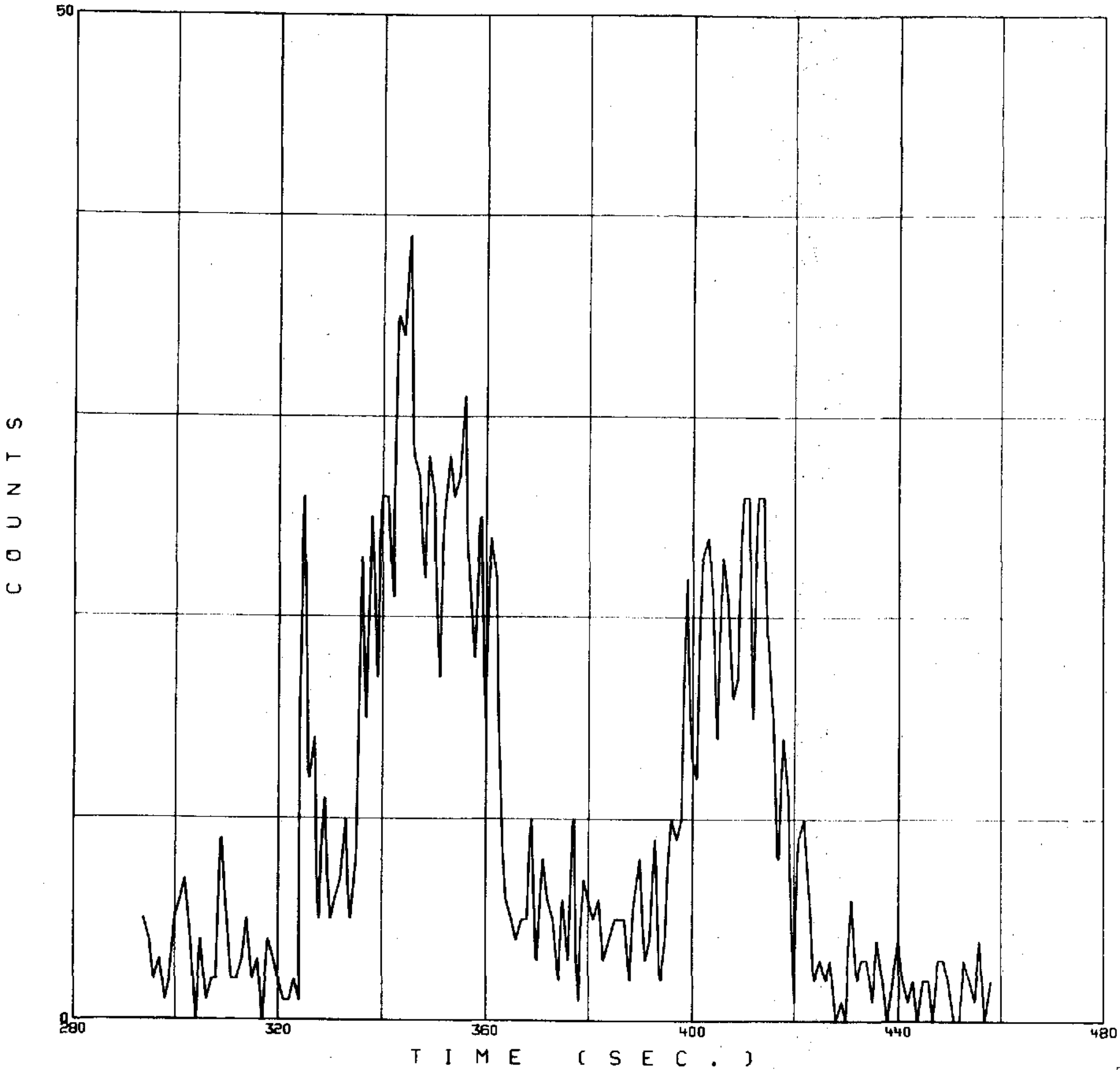
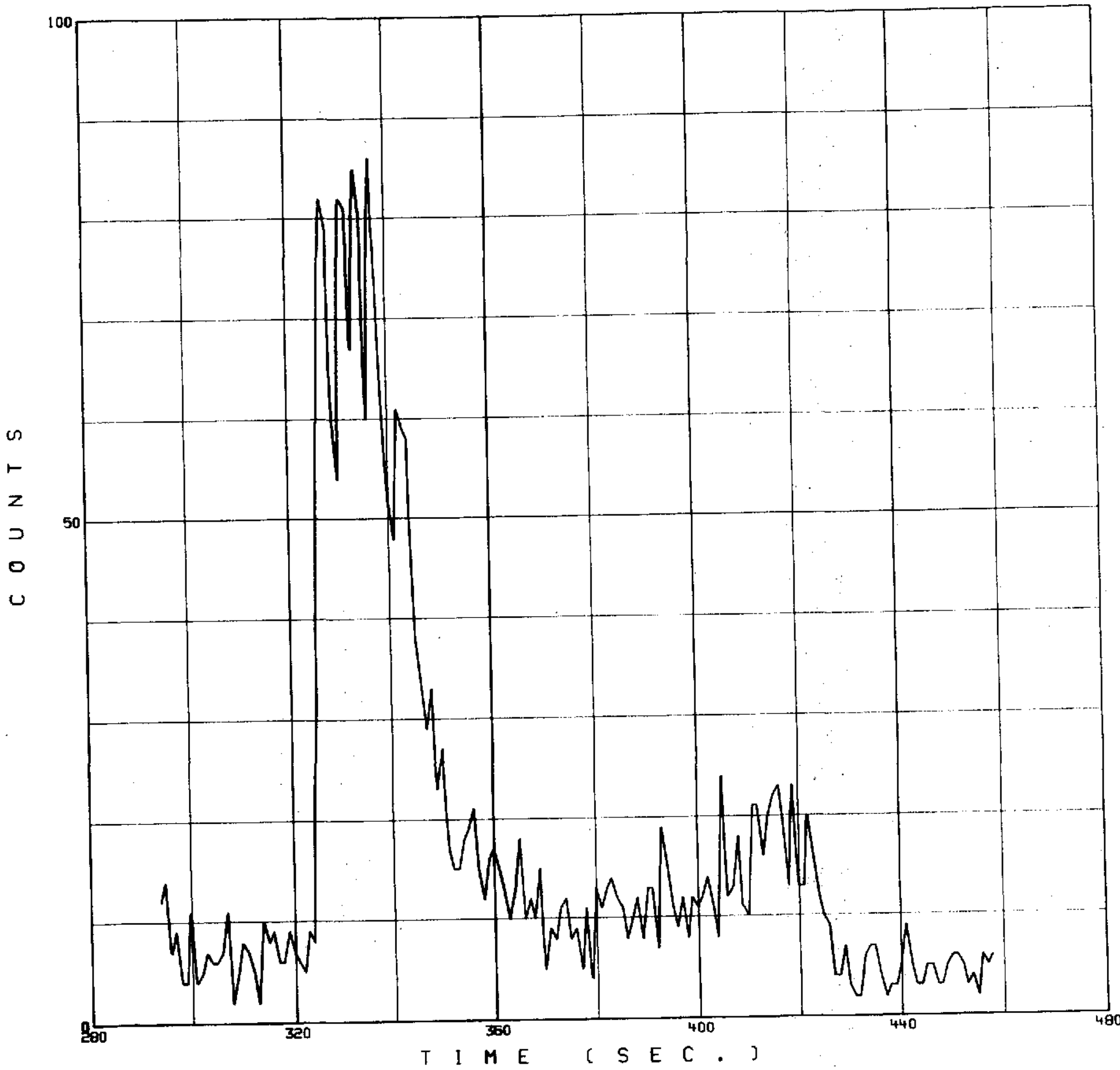


$\Delta\theta \sim 0.1°$

$\Delta E \sim 0.5 - 3$ keV

PUPPIS SCANS

FIGURE 5



$\Delta\theta \sim 0.3°$

$\Delta E \sim 0.5 - 3$ keV

PUPPIS SCANS

FIGURE 6

of Figure 5 at $\sim$ 325 sec. The first scan of the 0.1° field of view observed the source from 336 sec to 363 sec. At a scan rate of 1.8 arc-min sec^{-1}, this indicates the x-ray source to be $\sim$ 48 arc min in extent, in good agreement with the size observed in radio measurements. Note the rather sharp peak observed at 345 sec. The Copernicus x-ray observations of this object reported by Zarnecki et al. (1973) also indicated a portion of the emission to be localized. Substantial x-ray absorption in the earth's atmosphere was encountered on the second scan. This was a result of decreased observing time from a) peak altitude of the rocket being less than predicted, and b) the ACS system did not reach the first target at the anticipated time due to a high angular rate imparted to the payload at vehicle severance and the substantially longer maneuvers required because of delays in launch date.

The detector for the Bragg spectrometer operated stably during the flight with the expected increase in background counting rate. A slight increase in counting rate was observed in this detector on the first scan over Puppis A. Preliminary reduction of these data are inconclusive as to the detection of an x-ray line and a more thorough analysis is required.

Film from the 35 mm camera, which photographed the star field, has been developed and reduction of this data will provide the necessary aspect information.

CONCLUSIONS AND RECOMMENDATIONS

A. X-ray reflectors that are built in the future should focus in both dimensions to produce an image of an x-ray source. While singly focussing optics have some advantage over collimated proportional counters, they suffer from the fact that in acquiring data their field of view must be scanned over a source. This is very inefficient for measurements with good angular resolution since only a small fraction of the observation time is spent collecting data from a given part of the source. Imaging optics, however, can acquire data with high resolution from each part of an extended source region for the full observing time.

B. Background counting rates in proportional counters may be substantially reduced by adding anticoincidence detectors at the ends of the primary x-ray detecting anodes in the manner shown in Figure 2.

REFERENCES

Burginyon, G., Hill, R., Seward, F., Tarter, B. and Toor, A. 1973, Ap. J. (Letters) 180, L75.

Fabian, A.C., Zarnecki, J.C., Culhane, J.L. and Hawkins, F.J. 1973, Ap. J. (Letters) 189, L59.

Mewe, R. 1972, Solar Physics 22, 439.

Zarnecki, J.C., Culhane, J.L., Fabian, A.C., Rapley, C.G., Silk, R., Parkinson, J.H., and Pounds, K.A. 1973, Nature Physical Science 243, 5.