# General Disclaimer

## One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

# NASA

## Technical Memorandum 78087

# Observations of Low Luminosity
# X-Ray Sources in Vela-Puppis

## S. H. Pravdo, R. H. Becker, E. A. Boldt,
## S. S. Holt, P. J. Serlemitsos, and J. H. Swank

## February 1978

OBSERVATIONS OF LOW LUMINOSITY X-RAY SOURCES

IN VELA-PUPPIS

S.H. Pravdo[*], R.H. Becker[*], E.A. Boldt, S.S. Holt

P.J. Serlemitsos, and J.H. Swank

Laboratory for High Energy Astrophysics
NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

ABSTRACT

We present results of a study of the X-ray emission from a small portion of the galactic plane near galactic longitude $260^{\circ}$. This region contains at least six low luminosity X-ray sources within $\sim 10^{\circ}$ of PSR0833-45, which is near the center of the Gum Nebula. 4U0833-45, the X-ray source associated with the Vela pulsar, is observed at twice its 4U catalogue intensity. The lack of X-ray pulsations at the pulsar period (> 99% non-pulsed), the non-thermal power law spectrum, and models of the X-ray source distribution in this region suggest that a large fraction of the X-rays come from an extended source $\sim 1^{\circ}$ in radius. The observation of a high temperature ($T_{eff} \geq 10^{8}$ K) spectrum in a field of view containing only Puppis A among known sources has led to the discovery of a new OSO-8 source, OS0752-39. Other spectra from this region are discussed.

Subject headings: pulsars - X-rays: sources - X-rays: spectra

_____ _____

[*]Also, Department of Physics and Astronomy, University of Maryland

## I. INTRODUCTION

This is a report on an observational study of the X-ray emission

from the Vela-Puppis region. The previously identified sources, all

of which have low apparent luminosities, are 4U0833-45 (Vela pulsar)

and 4U0821-42 (Puppis A) (Giacconi et al. 1974), MX0836-42 (Markert et al.

1977), A0835-48 and A0854-46 (Seward et al. 1976), and 4U0813-38 (Forman

et al. 1977). Distance estimates exist only for 4U0833-45 ($\sim$ 500 pc, Milne

1968) and 4U0821-42 ($\sim$ 1000 pc, Milne 1971, Zarnecki et al. 1977).

Both, therefore, are on the low end of the galactic X-ray source luminosity

distribution. If the apparent clustering of all the known sources (and

a new source discussed in this work) is a true distance indicator rather

than a projection effect, then these sources belong to a class of intrinsically

weak X-ray sources ($10^{33-34}$ erg sec$^{-1}$) which are resolved only because

they are nearby. If so, this region could be a prototype for other more

distant and presently unresolved source regions.

## II. EXPERIMENT AND ANALYSIS

This observation utilized two gas proportional counters of the OSO-

8 Cosmic X-ray Spectroscopy Experiment. Table 1 summarizes the properties

of the detectors and the dates of their use. More complete detector descriptions

are given in Becker et al. (1976) and Pravdo et al. (1976a). The 5$^{o}$ FWHM

circular field of view of the primary forward detector complicates the process

of source separation in this confused region. However since the spin axis

executed slow scans through the area, it is possible to check the consistency

of the count rates with models of the X-ray source distribution. The smaller

3$^{o}$ field of view of the aft detector results in a lesser source confusion

problem, but a smaller fraction of the region was scanned with this detector. Figure 1 illustrates the three scans which were performed.

The positions of known sources were held fixed in the models. For simplicity and for a homogeneous sample, 4U Catalogue (Forman et al. 1977) positions were used. Model parameters were the intensities of these sources, and the positions and intensities of any new sources. In addition, the angular extent of 4U0833-45 was left as a free parameter in a simple face-on disk model. The background rate was deduced from adjacent source-free regions. Pravdo et al. (1977b) describe further this method of modeling.

Source spectra were deduced by folding model spectra through the detector response matrix and fitting the result to the pulse-height data (cf. Serlemitsos et al. 1975). Although a given source was seldom isolated in the field of view, we could estimate the possible contamination of its spectrum from other sources on the basis of the intensities derived from the models discussed above. Spectral models included thermal spectra, power law spectra, and linear combinations of these. Photoelectric absorption (Brown and Gould 1970, Fireman 1974) and line features were possible parameters, as well.

The experiment was commanded into the "real time" mode for two days (329-331 see Table 1) when PSR 0833-45 was in the field of view with sub-stantial effective area ($\sim 200$ cm$^2$). This modes yields 20 msec temporal resolution for pulse-height-analyzed (PHA) events. The data were folded over the 89 msec period of PSR0833-45 (Manchester et al. 1976) after making time-of-flight corrections for the satellite and Earth motion. The coarse temporal binning would not allow us to distinguish pulse durations from 0.04 to 0.20 of the period, which are the observed duty cycles of the radio pulse (Downs et al. 1973) and the gamma ray pulse (Thompson et al. 1975) respectively.

## III.  RESULTS

A.    Sources

The two forward detector scans revealed the presence of an additional source in this region.  The source, OS (OSO-8 source) 0752-39, has a best fit position at right ascension $7^h51^m36^s$ and declination $-38.7^o$.  Figure 1 shows the best fit positions and 90 per cent confidence areas for the two scans.  The second scan was considerably slower than the first, so that the source position was better defined, and the significance of its existence was at the ten sigma level.

Table 2 summarizes the fluxes and one sigma errors derived for each source.  There are indications of variability in 4U0813-38 and MX0836-42.  The scan 1 fluxes for A0835-48 and A0854-46 were held fixed at their Scan 2 values because the speed of Scan 1 made their determination extremely uncertain.  Based on a comparison of their Ariel 5, 4U, and OSO-8 values, A0854-46 has roughly constant intensity, while A0835-48 appears to be variable.

The flux of 4U0821-42 (Puppis A) is about 0.6 of its 4U Catalogue value.  This discrepency could be due in part to the soft Puppis spectrum (Zarnecki et al. 1977) and the enhanced efficiency of the UHURU detectors (Giacconi et al. 1971) below 2 keV relative  to this detector.  The intensity of 4U0833-45, conversely, is about twice the 4U value, although it is consistent with the Ariel 5 intensity (Seward et al. 1976).  We also find that the best-fit model for 4U0833-45 has non-zero angular extent.  On the basis of an increase in the minimum value of $\chi^2$ for 99% confidence (cf. Lampton et al. 1976, Avni 1976) the angular extent is $1. \pm 0.2^o$ in radius.  An equally acceptable fit is obtained with a combination of a point source at the

PSR0833-45 position and the 4U catalogue level and an extended source which is equally luminous. We see no evidence for variability of this source during the two scans (an upper limit of $\sim$ 10 per cent) or for a flare event such as the one observed by Smith and Pounds (1977).

MX0836-42 was the only known source scanned with substantial efficiency by the aft detector. The upper limit at that time to the flux of this source was $9.5 \times 10^{-12}$ erg cm$^2$ sec$^{-1}$. There is evidence at the two sigma level for an additional source near right ascension $8^h55^m36^s$ and declination $-41.1^o$. It is marked as "S" in Figure 1.

B.    Spectra

Figure 2a shows the derived incident spectrum from a position which includes Puppis A but excludes all other known sources. This spectrum is complex and can not be fit by a single simple model, although it is fit acceptably by a two-component model. The high temperature component is inconsistent with previous observations of the X-ray spectrum of Puppis A (Seward et al. 1971, Zarnechi et al. 1977), and was the first indication of the presence of 0S0752-39 in our analysis of these data. The temperature of the soft component can not be accurately determined because the detector window is opaque to X-rays with energy less than 2 keV. It is, however, consistent with a temperature of $\lesssim 10^7$ K. The hard component has a temperature $> 10^8$ K and also is fit with a power law spectrum of number index 1.44 $\pm$ 0.20. Figure 2b shows the spectrum of 0S0752-39 when it alone is in the field of view. This power law spectrum is consistent with the hard component of the previous spectrum, and its parameters are listed in Table 3.

The spectrum shown in Figure 3 was obtained from a pointing position closer to Puppis A and farther from 0S0752-39. In this two-component spectrum

- 6 -

the ratio of low to high temperature component flux is at least twice as
high as in the spectrum shown in Figure 2a. This is, of course, consistent
with the low temperature component originating from Puppis A and the high
temperature component from OSO752-39. Figure 3a demonstrates a 3.6 sigma
excess near 7 keV which can be attributed to a line with one sigma limits
of $6.9 \pm 0.3$ keV in energy and $0.57 \pm 0.06$ keV in equivalent width. A
thermal iron line with this equivalent width is not expected in the low temper-
ature continuum from Puppis A (cf. Raymond and Smith 1977). The increased
statistical significance of this line relative to that in Figure 2a (a two
sigma excess) may be due simply to the factor of two increase in net
high energy counts.

The spectrum from 4U0833-45 is shown in Figure 4. The continuum
is fit well by a power law (Table 3) and can not be fit by a thermal model.
There is also an emission feature with 3.6 sigma statistical significance
at $6.4 \pm 0.3$ keV with equivalent width $0.11 \pm 0.01$ keV. We estimate the
contamination of this spectrum by nearby sources to be less than 0.12
of the photons.

ORIGINAL PAGE
OF POOR QUALITY

C.   89 msec Pulsations

We continued the search for X-ray pulsations from 4U0833-45 at the
89 msec PSR0833-45 period. None were observed with a $3\sigma$ upper limit of
$2.9 \times 10^{-5}$ photons cm$^{-2}$ sec$^{-1}$ keV$^{-1}$ at 5 keV. This upper limit is a factor
of 10 below the previous upper limit at this energy (Pravdo et al. 1976b).
It falls close to an interpolation of the pulsed flux observations of
the optical emission (Wallace et al. 1977) and the integrated gamma ray

emission (Bennett et al. 1977). However, an extrapolation of the 0.1 –

1.0 GeV pulsed spectrum from the previous reference is at least a factor

of ten above the present pulsed flux upper limit. This indicates a turnover

in the pulsed spectrum between the X-ray and gamma ray regimes.

## IV.  DISCUSSION

A.    OSO752-39 and Puppis A

An additional weak source of high energy X-rays has been discovered

in this region.  Its hard spectrum would indicate an X-ray binary (Ulmer

1975, Rappaport et al. 1977), if indeed the source is galactic.  Although we

could not isolate Puppis A in our field of view, we conclude that the soft

component of the two-component spectra is associated with it.  We can not

obtain meaningful confidence limits on this low temperature but our estimate

is consistent with the $\lesssim 10^7$ K temperature observed by others (Seward et al.

1971, Zarnecki et al. 1977), and with the predicted temperature based on the

age of the supernova remnant and the shock wave model (cf. Gorenstein et

al. 1974, Culhane 1977).

B.    Vela Pulsar

The X-ray intensity of 4U0833-45 determined by OSO-8 is about twice

that reported by Kellogg et al. (1973), who used a detector with a smaller field

of view. This is perhaps consistent with our determination that at least half of this flux originates in an extended source $1^o$ in radius around the pulsar. The angular extent, the non-thermal spectrum, and the > 99% non-pulsed fraction suggest that an extended sychrotron source exists around the Vela pulsar (see also Silk 1976).

Vela and the Crab are the only known pulsars with both optical and gamma ray pulsations. The pulsed spectrum of the Crab has been shown to extend from X-rays to gamma rays over almost nine decades in energy with a single power law spectrum (Bennett et al. 1977). However, the Vela pulsed spectrum apparently turns over between 10 keV and 100 MeV. A spectral break in this energy range would be expected if the pulses originate from magnetic bremsstrahlung of relativistic electrons near the pulsar speed of light radius (Shen 1972, Thompson 1975), although the prediction of pulsed X-rays in the preceeding model is a factor of 5 above the observed upper limit. A model of Massaro and Salvati (1977) proposes that the pulse duty cycle will increase with decreasing energy from the gamma rays. This effect, if large, would decrease our sensitivity to observe pulsations. For example, a pulse duty cycle of 0.95, would increase our intensity upper limit by a factor of 20.

C.   MX0836-42

MX0836-42 has been reported to be a variable X-ray source which at one time was the brightest source in this region (Markert et al. 1977). Cominsky et al. (1977) observed this high state at an intensity of $9 \times 10^{-10}$ erg $cm^{-2}$ $sec^{-1}$ for about 50 days in 1972. Our intensity upper limit from May 1976 demonstrates a factor of at least 100 in variability.

During the remainder of times covered by OSO-7 (Markert et al 1977), UHURU
(Cominsky et al. 1977), and the times sampled by OSO-8, the source intensity
was $\lesssim 3 \times 10^{-11}$ erg cm$^{-2}$ sec$^{-1}$.  The soft spectrum observed by the experi-
menters above, as well as the prolonged high state, are typical of X-ray
transients similar to A0620-00 (Kaluzienski 1977).  An additional charact-
eristic of this proposed class is an intrinsic X-ray luminosity of $\geq 10^{37}$
erg sec$^{-1}$ during high states.  This would imply that the distance to
MX0836-42 is $\geq 10$ Kpc, or $\geq 10$ times the distances to the other sources
discussed here.

D.    Iron Line Emission

X-ray spectra of several galactic objects have revealed iron line
emission features which have been attributed to both thermal (cf. Pravdo
et al. 1976a, Becker et al 1976) and non-thermal (Pravdo et al. 1977a)
processes.    Iron line emission at the observed equivalent width would
arise naturally if the hard component
associated with        OSO752-39 is a thermal spectrum with temperature
$\lesssim 10^8$ K (cf. Raymond and Smith 1977).  This temperature, however, is only
marginally consistent with the OSO752-39 spectrum.  Line emission in
the power law spectrum of 4U0833-45 suggests other line formation mechanisms.
Iron line fluorescence is an efficient mechanism which requires a hard
X-ray source and a fluorescence target (cf. Hatchett and Weaver 1977).
Note that we can not effectively differentiate between these two on the basis
of the line energy, as our statistics do not allow us to formally exclude
either possibility in any of the spectra obtained.  For normal cosmic
abundance of iron (cf. Cameron 1973), hydrogen column densities in the

target $N_H \sim 10^{24}$ cm$^{-2}$ are required for significant fluorescence emission. Unless these high density regions are very patchy and not directly in the line of sight, this value for $N_H$ appears too high relative to the previous determinations for this region of $\sim 10^{20}$ cm$^{-2}$ (Gorenstein et al. 1974).

Alternatively, the possibility exists that this is a diffuse emission feature from the extended X-ray source around the pulsar. Charge exchange between low energy cosmic ray iron nuclei released in a supernova and the interstellar gas can account for the line luminosity in this region (Ramaty et al. 1971, Bussard et al. 1977). The product of hydrogen column density times cosmic ray energy density must equal $10^{19}$ H atoms cm$^{-2}$ x eV cm$^{-3}$ to produce the observed line strength (Bussard et al. 1977). With $N_H \sim 10^{20}$ cm$^2$, cosmic ray energy density in this model is 0.1 eV cm$^{-3}$. The intrinsic line width of 2 keV, which is characteristic of a charge exchange iron line, can not be identified in this measurement because of the low statistical level of the feature.

We add that the line emission region could extend beyond the immediate vicinity of Vela and into the Gum Nebula. The cosmic ray energy density estimated above is not in conflict with the observed ionization state (Ramaty et al 1971, Reynolds 1976b) or the (OIII) line emission (Reynolds 1976a) from this larger region. It is interesting to note that the observed iron line flux from both the Vela pulsar region and the OSO752-39 region is $\sim 4 \times 10^{-4}$ photons cm$^{-2}$ sec$^{-1}$.

E.    The Gum Nebula and the Galactic Ridge

If the low luminosity sources (excluding MX0836-42) observed from this region are at a distance of $\lesssim 1$ Kpc, there may be both local and

galactic implications. Locally, the sources would appear to form a cluster of X-ray sources. They would reside within the Gum Nebula, an extended low density ionized region of the local interstellar medium (cf. Brandt et al. 1971, Reynolds 1976b). One possible X-ray cluster production mechanism is a supernova cascade event (Opik 1953, Ogelman and Maran 1976) although the time scale for this process may be larger than the expected X-ray source lifetimes. More simply, a cluster could result from the evolution of a group of short-lived stars formed at the same time (e.g. an OB association).

These sources could be representative of a class of intrinsically weak X-ray sources which are now observed only in this nearby region of the galactic plane. An estimate for the space density of such sources in a disk distribution may be deduced from the result of Bleach et al. (1972), who observed excess X-ray emission associated with the galactic disk at longitude $\sim 60^{\circ}$—the so-called galactic ridge. They suggested that a distribution of weak, unresolved sources is responsible for the measured integral source function of $7 \times 10^{-30}$ erg cm$^{-3}$ sec$^{-1}$ (2-10 keV). This corresponds to a space density of $19/L_{34}$ Kpc$^{-3}$, where $L_{34}$ is the average source luminosity in units of $10^{34}$ erg sec$^{-1}$. There is no obvious contradiction between this value with $L_{34} \sim 1$, and the density of sources in the proposed Gum Nebula cluster, although the cluster volume is difficult to determine. In addition, if the source distribution is a disc with thickness D Kpc, then the number of such sources, $1 \times 10^{4}$ D/$L_{34}$, and their total luminosity, $1 \times 10^{38}$ D erg sec$^{-1}$, is not in conflict with observations or estimates of the total galactic X-ray luminosity. The longitudinal distribution of all low-latitude X-ray sources indicates that another cluster of low luminosity sources may be located near $\ell^{II} = 80^{\circ}$.

## V. CONCLUSIONS

Observations of the Vela-Puppis region have shown it to be densely populated with low luminosity sources. The existence of iron line emission and an extended source near the Vela pulsar are interesting possibilities which require further confirmation. Models for the pulsed emission from PSR0833-45 must address the question of a spectral break between 10 and $10^5$ keV. Finally, we add that HEAO-1 will increase the resolution horizon for low luminosity sources and continue the search for this class of objects.

## ACKNOWLEDGEMENT

We would like to thank Dr. L. Kaluzienski and R. Bussard for helpful discussions.

TABLE 1

| DATES OF OBSERVATIONS | DETECTOR | FIELD OF VIEW | TEMPORAL RESOLUTION |
|---|---|---|---|
| 315* – 331 (11/11/75–11/27/75) | Forward Xenon (237 $cm^2$) | Pointed 5° Circular FWHM | 160 msec/20 msec |
| 506 – 507 (5/20/76–5/21/76) | AFT Argon (36.7 $cm^2$) | Pointed 3° Circular FWHM | 160 msec |
| 678 – 697 (11/13/76–11/27/76) | Forward Xenon | Pointed 5° Circular FWHM | 160 msec |

*Day of 1975

## TABLE 2

### APPARENT SOURCE LUMINOSITIES

$$(\times\ 10^{11}\ erg\ cm^{-2}\ sec^{-1})$$

| SOURCE | DAYS 315-331 SCAN 1 | DAYS 678-697 SCAN 2 | 4U INTENSITY | ARIEL V INTENSITY |
|---|---|---|---|---|
| 4U0813-38 | 2.0 ± 0.6 | 0.2 ± 0.2 | 4.8 ± 0.9 | --- |
| 4U0821-42 | 8.2 ± 0.5 | 6.7 ± 0.3 | 12.8 ± 1.0 | 12.8 |
| 4U0833-45 | 33.7 ± 0.4 | 33.4 ± 0.2 | 15.5 ± 1.7 | 20.4 - 30.6 |
| MX0836-42 (4U0836-42) | 2.8 ± 0.5 | 0. ± 0.3 | 80. (variable) | <5.1 |
| A0835-48 (4U0842-47) | --- | 0. ± 0.5 | 5.0 ± 1.4 | 10.2 |
| A0854-46 (4U0854-44) | --- | 5.8 ± 0.8 | 6.7 ± 1.0 | 7.7 |
| OS0752-39 | 2.6 ± 0.5 | 3.7 ± 0.3 | --- | --- |

TABLE 3

| SOURCE | NORMALIZATION COEFFICIENT | POWER LAW INDEX | $N_H$ $cm^{-2} \times 10^{-21}$ | REDUCED / DEGREE OF CHI SQUARED/FREEDOM |
|---|---|---|---|---|
| 0S0752-39 | $0.007 \pm 0.002$ | $1.19 \, (\pm \, 0.20)$ | $13. (+23., -13.)$ | $1.2 \, / \, 13$ |
| 4U0833-45 | $0.221 \pm 0.004$ | $2.17 \, (+ \, 0.08, \, -0.04)$ | $3.6(+7.2, \, -3.6)$ | $1.3 \, / \, 17$ |

# REFERENCES

Avni, Y. 1976, Ap. J. 209, 16.

Becker, R. H., Boldt, E. A., Holt, S. S., Pravdo, S. H., Rothschild, R. E., Serlemitsos, P. J., and Swank, J. H. 1976, Ap. J. (Letters) 209, L65.

Bennett, K., Bignami, G. F., Boella, G., Buccheri, R., Hermsen, W., Kanbach, G., Lichti, G. G., Masnov, J. L., Mayer-Hasselwander, H. A., Paul, J. A., Scarsi, L., Swanenburg, B. N., Taylor, B. G., and Wills, R. D. 1977, preprint.

Bleach, R. D., Boldt, E. A., Holt, S. S., Schwartz, D. A., and Serlemitsos, P. J. 1972, Ap. J. (Letters) 174, L101.

Brandt, J. C., Stecker, T. P., Crawford, D. L., and Maran, S. P. 1971, Ap. J. (Letters), 163, L99.

Brown, R. L. and Gould, R. J. 1970, Phys. Rev. D, 1, 2252.

Bussard, R. W., Omidvar, K., Ramaty, R. 1977, NASA/GSFC Document X-660-77-144.

Cameron, A.G.W. 1973, Space Sci. Rev. 15, 121.

Cominsky, L., Jones, C., Forman, W. and Tananbaum, H. 1977, preprint.

Culhane, J. L. 1977, Supernovae, David N. Schramm (ed.), D. Reidel Publishing Company, Dordrecht-Holland, p. 29-51.

Downs, G. S., Reichley, P. E., and Morris, G. A. 1973, Ap. J. (Letters) 181, L143.

Fireman, E. L. 1974, Ap. J. 187, 57.

Forman, W., Jones, C., Cominsky, L., Julien, P., Murray, S., Peters, G., Tananbaum, H., and Giacconi, R. 1977, submitted to Ap. J. (Supple).

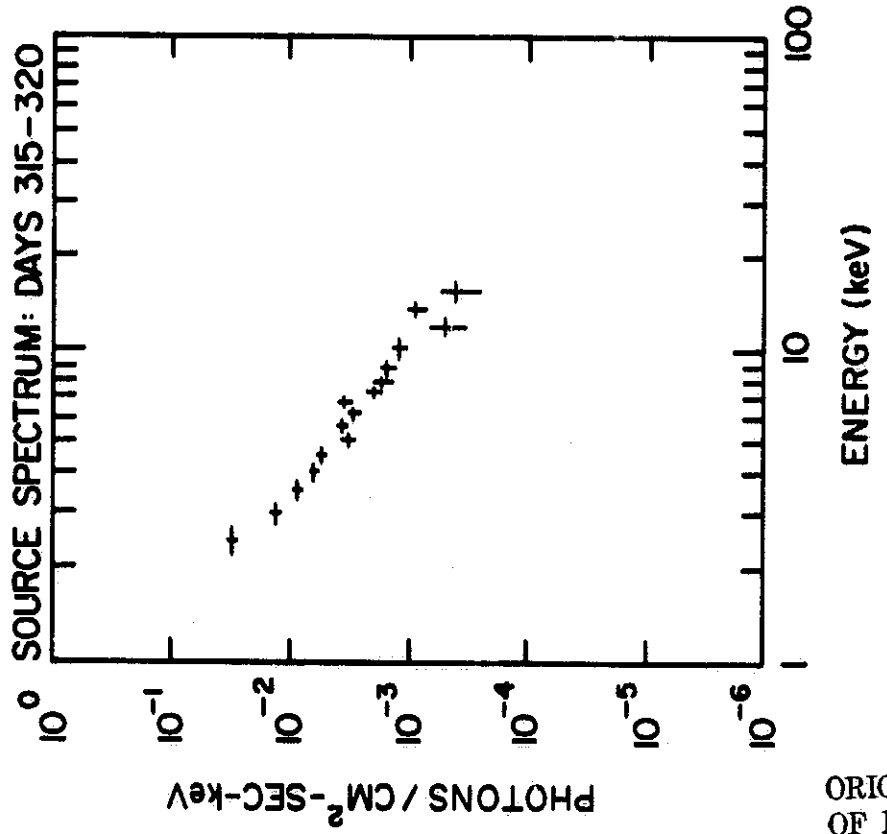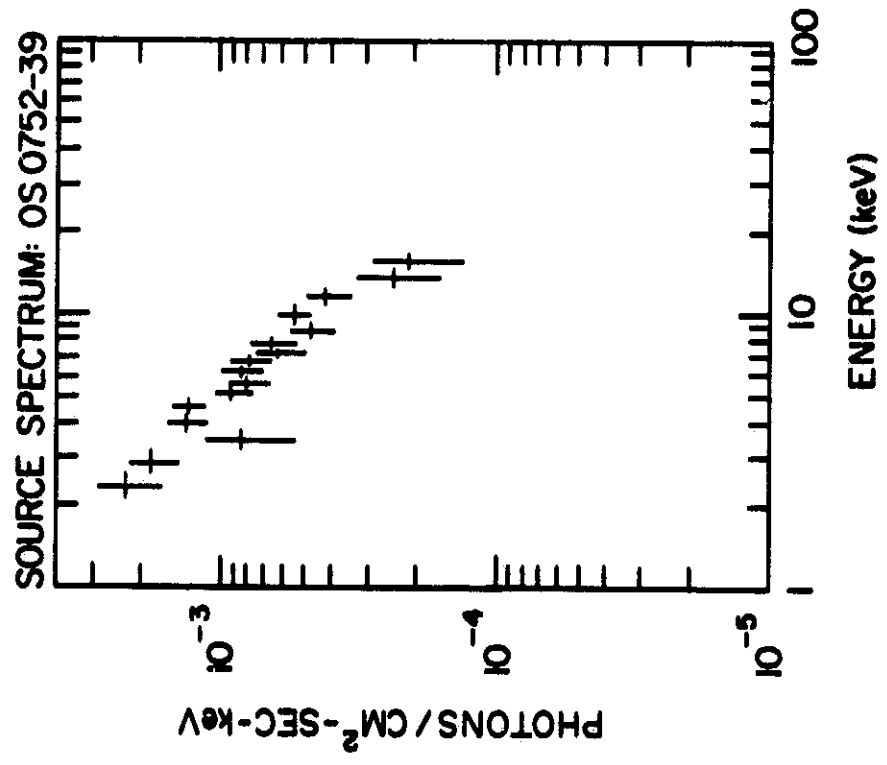Giacconi, R., Kellogg, E., Gorenstein, P., Gursky, H., and Tananbaum, H. 1971, Ap. J. (Letters), 165, L27.

Gorenstein, P., Harnden, F. R., and Tucker, W. H. 1974, Ap. J. 192, 661.

Hatchett, S. and Weaver, R. 1977, Ap. J. 215, 285.

Kaluzienski, L. J. 1977, Ph. D. Thesis, University of Maryland, NASA/GSFC
    Document X-661-77-107

Kellogg, E., Tananbaum, H., Harnden, F. R. Jr., Gursky, H., and Giacconi,
    R. 1973, Ap. J. 183, 935.

Lampton, M., Margon, B. and Bowyer, S. 1976, Ap. J. 208, 177.

Manchester, R. N., Goss, W. M., and Hamilton, P. A. 1976, Nature 259, 291.

Markert, T. H., Canizares, C. R., Clark, G. W., Hearn, D. R., Li, F. K.,
    Sprott, G. F., and Winkler, P. F. 1977, preprint.

Massaro, E. and Salvati, M. 1977, Proceedings of the Frascati Conference,
    in press.

Milne, D. K. 1968, Australian J. Phys. 21, 206.

Milne, D. K. 1971, Australian J. Phys. 34, 429.

Ogelman, H. B. and Maran, S. P. 1976 Ap. J. 209, 124.

Opik, E., 1953, Irish Astr. J. 2, 219.

Pravdo, S. H., Becker, R. H., Boldt, E. A., Holt, S. S., Rothschild, R. E.,
    Serlemitsos, P. J., and Swank, J. H. 1976a, Ap. J. (Letters) 206, L41.

Pravdo, S. H., Becker, R. H., Boldt, E. A., Holt, S. S., Rothschild, R. E.,
    Serlemitsos, P. J., and Swank, J. H., 1976b, Ap. J. (Letters) 208, L67.

Pravdo, S. H., Becker, R. H., Boldt, E. A., Holt, S. S., Serlemitsos, P. J.
    and Swank, J. H. 1977a, Ap. J. (Letters) 215, L61.

Pravdo, S. H., Mushotzky, R. F., Becker, R. H., Boldt, E. A., Holt, S. S.,
    Serlemitsos, P. J., and Swank, J. H. 1977b, Nature, in press.

Ramaty, R., Boldt, E. A., Colgate, S. A., and Silk, J. 1971, Ap. J. 169, 87.

Rappaport, S., Markert, T., Li, F. K., Clark, G. W., Jernigan, J. G., and
McClintonk, J. E. 1977, Ap. J. (Letters) 217, L29.

Raymond, J. C. and Smith, B. W. 1977, Ap. J. Suppl., in press.

Reichley, P. E., Downs, G. S., and Morris, G. A. 1970, Ap. J. (Letters)
159, L35.

Reynolds, R. J. 1976a, Ap. J. 203, 151.

Reynolds, R. J. 1976, Ap. J. 206, 679.

Serlemitsos, P. J., Boldt, E. A., Holt, S. S., Rothschild, R. E., and
Saba, J.L.R. 1975, Ap. J. (Letters) 201, L9.

Seward, F. D., Burginyon, G. A., Grader, R. J., Hill, R. W., Palmieri,
T. M., and Stoering, J. D. 1971, Ap. J. 169, 515.

Seward, F. D., Page, C. G., Turner, M.J.L., and Pounds, K. A. 1976, M.N.R.A.S.
177, 13.

Shen, C. S. 1972, Phys. Rev. D 6, 2736.

Silk, R. 1976, Thesis, Leicester University.

Smith, A. and Pounds, K. A. 1977, Nature 265, 122.

Thompson, D. J. 1975, Ap. J. (Letters) 201, L117.

Thompson, D. J., Fichtel, C. E., Kniffen, D. A., and Ogelman, H. B. 1975,
Ap. J. (Letters) 200, L79.

Ulmer, M. P. 1975, Ap. J. 196, 827.

Wallace, P. T., Peterson, B. A., Murdin, P. G., Danziger, I. J., Manchester,
R. N., Lyne, A. G., Goss, W. M., Smith, F. G., Disney, M. J., Hartley,
K. F., Jones, D. H. P., and Wellgate, G. W. 1977, Nature 266, 692.

Zarnecki, J. C., Culhane, J. L., Toor, A., Seward, F. D., and Charles, P. A.
1977, submitted to Ap. J. (Letters).
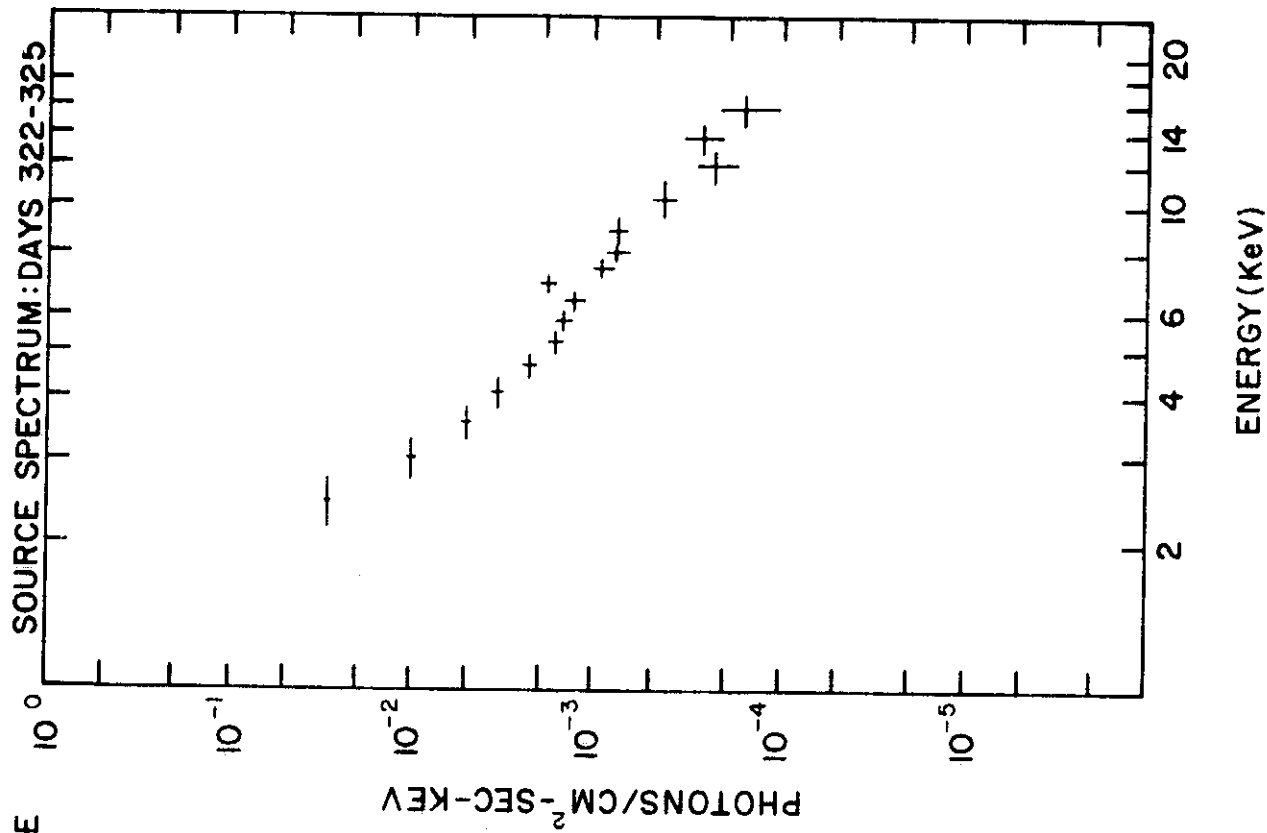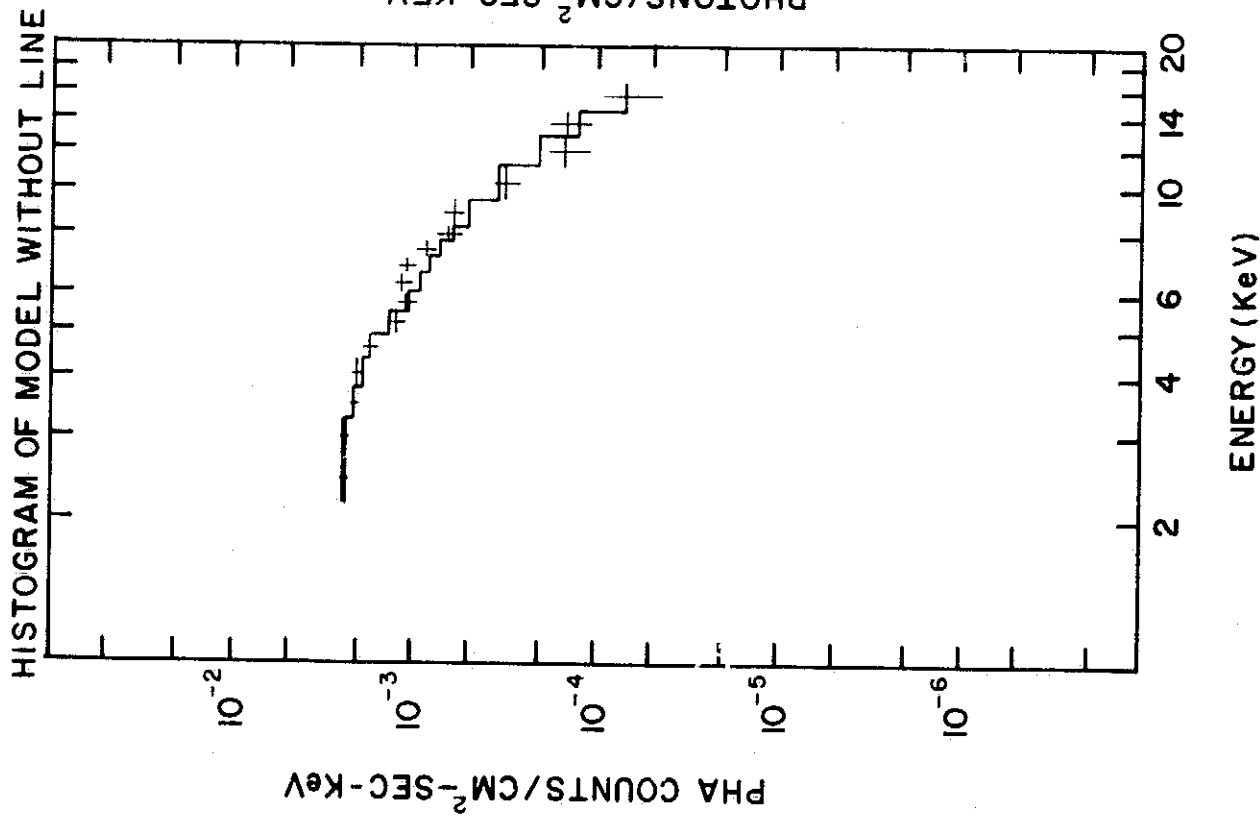
FIGURE CAPTIONS

Figure 1.        The Vela-Puppis region.  The three scans (marked with

                 day number of 1975) performed by the OSO-8 pointed

                 detectors are shown with arrows.  Previously known

                 sources and their error boxes are shown.  The hatched

                 region is the error box for OSO752-39 which intersects

                 with the larger error box derived from another scan.  A

                 possible source is marked "S".

Figure 2a.       Composite spectrum including both Puppis A and OSO752-39

                 in the field of view.

Figure 2b.       Derived incident spectrum for OSO752-39.

Figure 3.        PHA histogram and derived incident spectrum from position

                 near Puppis A which shows a $3.6\sigma$ excess near 7 keV.

Figure 4.        PHA histogram and derived incident spectrum for 4U0833-45.
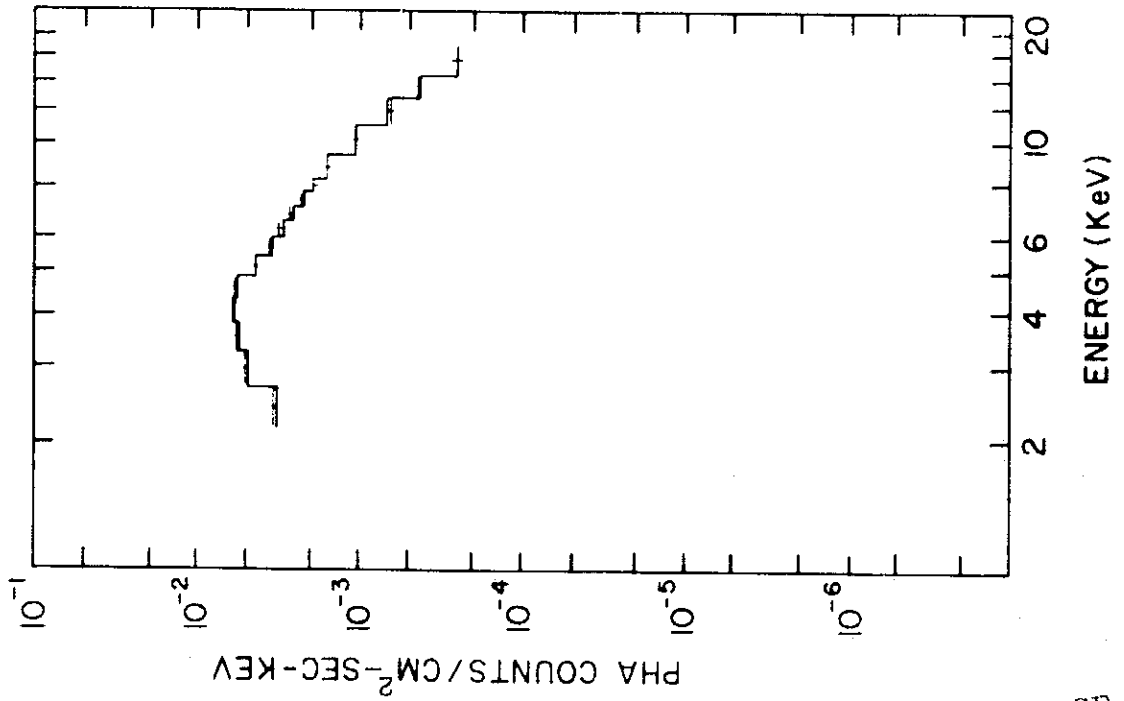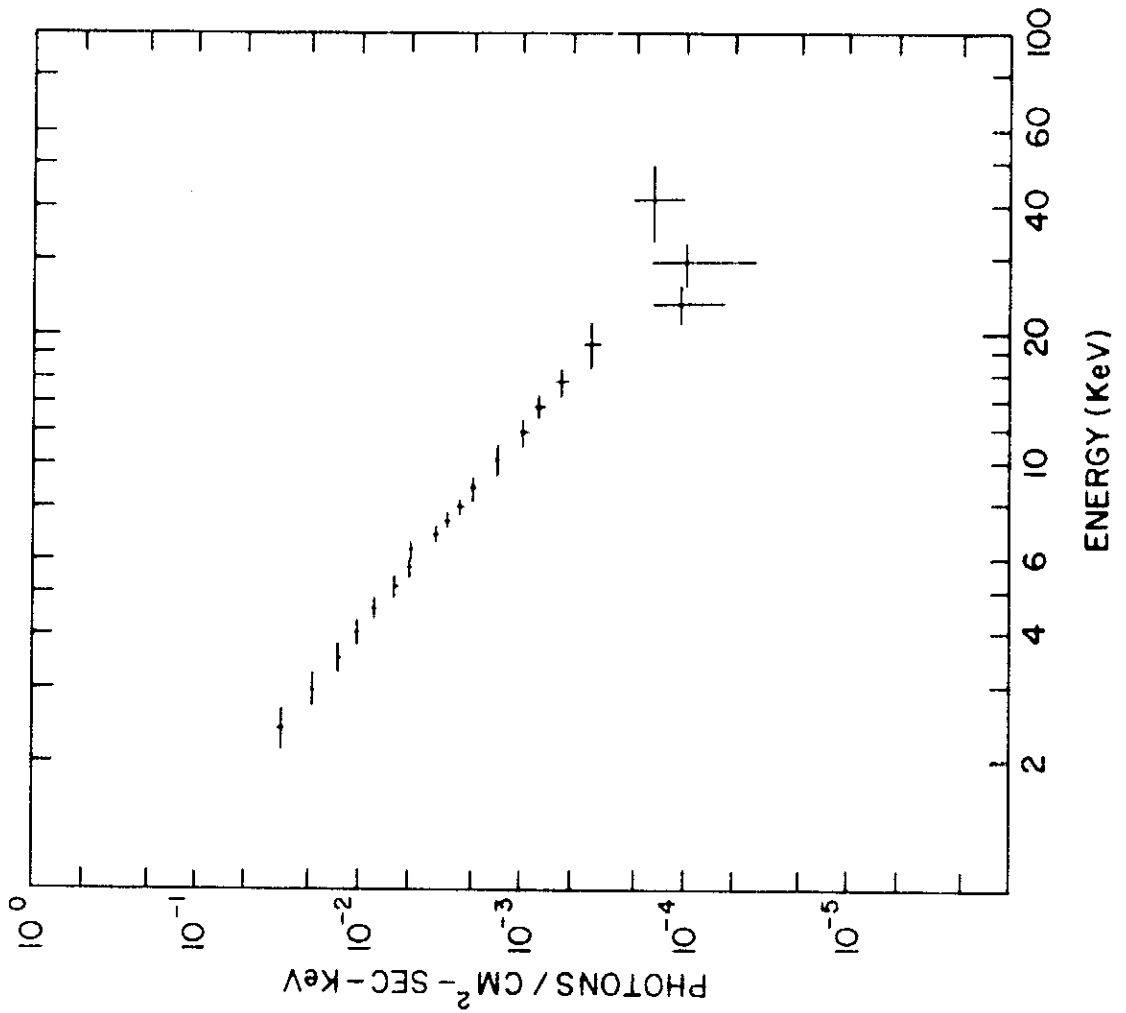
SOURCE SPECTRUM: OS 0752-39

SOURCE SPECTRUM: DAYS 315–320

PHOTONS / CM$^2$-SEC-keV

PHOTONS / CM$^2$-SEC-keV

ENERGY (keV)

ENERGY (keV)

SOURCE SPECTRUM: DAYS 322-325

PHOTONS/CM²-SEC-KEV

ENERGY (KeV)

HISTOGRAM OF MODEL WITHOUT LINE

PHA COUNTS/CM²-SEC-KeV

ENERGY (KeV)

SOURCE SPECTRUM: 4U0833-45

HISTOGRAM OF MODEL WITHOUT LINE

ENERGY (KeV)

ENERGY (KeV)

PHOTONS / CM$^2$-SEC-KeV

PHA COUNTS/CM$^2$-SEC-KEV
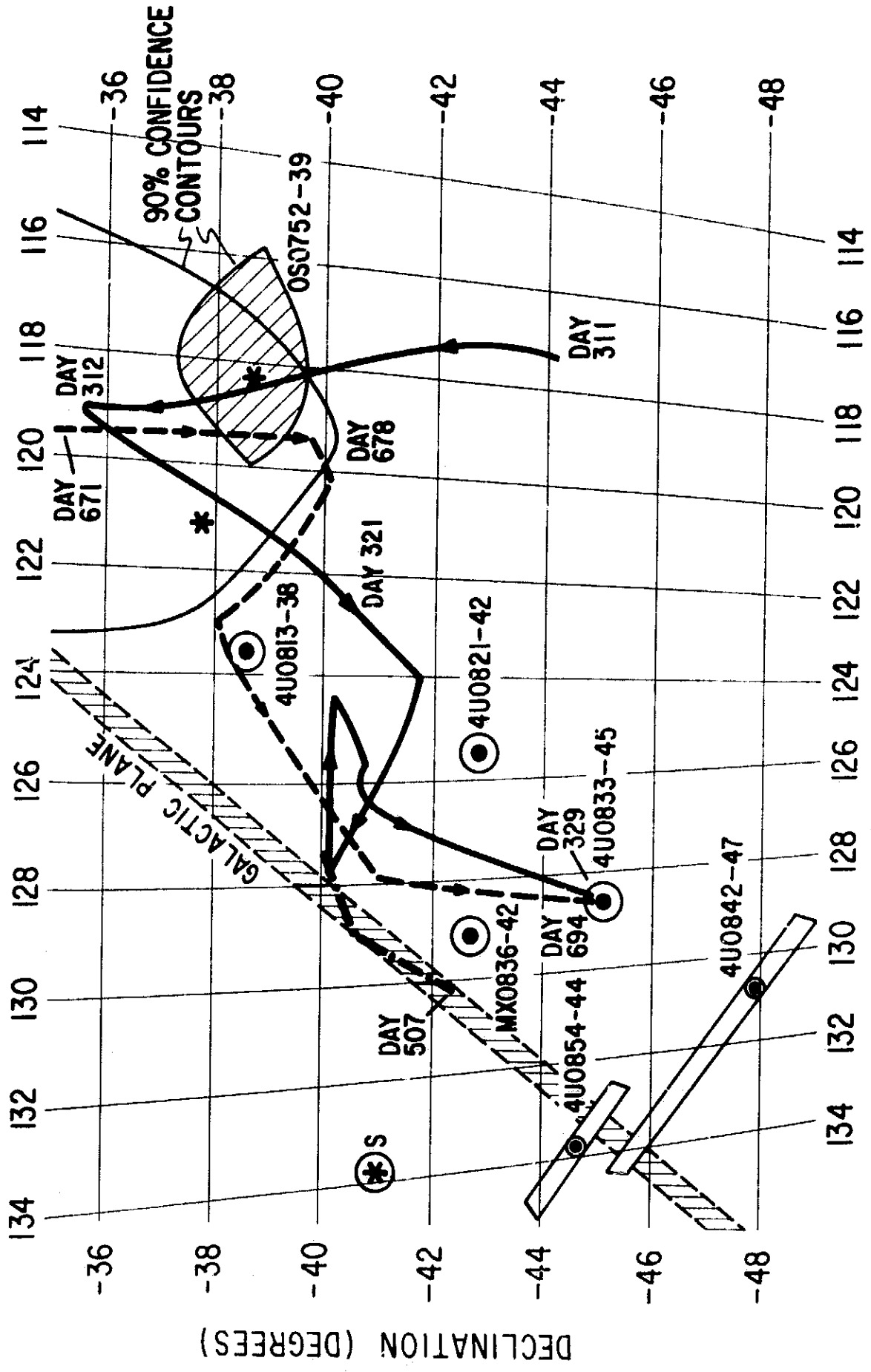
# BIBLIOGRAPHIC DATA SHEET

| 1. Report No.<br>TM 78087 | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|

| 4. Title and Subtitle<br>OBSERVATIONS OF LOW LUMINOSITY X-RAY SOURCES IN VELA-PUPPIS | 5. Report Date<br>February 1978 |
|---|---|
| | 6. Performing Organization Code<br>661 |

| 7. Author(s) S.H. Pravdo (U. MD.), R.H. Becker (U.MD)<br>E.A. BOLDT, S.S. HOLT, P.J. SERLEMITSOS, J.H. SWANK | 8. Performing Organization Report No. |
|---|---|

| 9. Performing Organization Name and Address<br>Cosmic Radiations Branch<br>Laboratory for High Energy Astrophysics<br>Code 661 | 10. Work Unit No. |
|---|---|
| | 11. Contract or Grant No. |
| | 13. Type of Report and Period Covered<br>TM |
| 12. Sponsoring Agency Name and Address | |
| | 14. Sponsoring Agency Code |

15. Supplementary Notes

To be published in The Astrophysical Journal

16. Abstract

We present results of a study of the X-ray emission from a small portion of the galactic plane near galactic longitude $260°$. This region contains at least six low luminosity X-ray sources within $\sim 10°$ of PSR0833-45, which is near the center of the Gum Nebula. 4U0833-45, the X-ray source associated with the Vela pulsar, is observed at twice its 4U catalogue intensity. The lack of X-ray pulsations at the pulsar period ($> 99\%$ non-pulsed), the non-thermal power law spectrum, and models of the X-ray source distribution in this region suggest that a large fraction of the X-rays come from an extended source $\sim 1°$ in radius. The observation of a high temperature ($T_{eff} \geq 10^8$ K) spectrum in a field of view containing only Puppis A among known sources has led to the discovery of a new OSO-8 source, OSO752-39. Other spectra from this region are discussed.

| 17. Key Words (Selected by Author(s))<br>X-rays--pulsars, sources, spectra | 18. Distribution Statement |
|---|---|

| 19. Security Classif. (of this report)<br>U | 20. Security Classif. (of this page)<br>U | 21. No. of Pages<br>23 | 22. Price* |
|---|---|---|---|

*For sale by the National Technical Information Service, Springfield, Virginia 22151.　　　GSFC 25-44 (10/77)