DRA

FINAL REPORT

Contract NASw-2672

ANALYSIS OF AEROBEE 17.012 DATA

25 July 1975

Richard C. Catura

Loren W. Acton

(NASA-CR-145875) ANALYSIS OF AEROBEE 17.012 DATA Final Report (Lockheed Missiles and Space Co.) 30 p HC $4.00 CSCL 22C

N76-13157

Unclas

G3/15 17996

Lockheed Palo Alto Research Laboratory
3251 Hanover Street
Palo Alto, California 94304

INTRODUCTION

This final report summarizes the results of reduction and analysis of data acquired during the flight of NASA-Aerobee 17.012CG. This rocket was launched from White Sands Missile Range on 6 April 1974 at 0410 U.T. The primary instrument in the experiment payload was a singly focussing x-ray reflector system sensitive in the range from 0.18 to 3 keV. X-ray detectors for this system consisted of two gas flow proportional counters with fields of view defined by apertures of 0.1° and 0.3° at the reflector focus. A Bragg spectrometer utilizing KAP crystals was included in the payload with the objective of detecting the Lyman α line of O VIII at 18.97Å in the Puppis supernova remnant. A 35 mm camera photographed the star field every 1.6 sec throughout the flight to provide aspect information.

During the flight of 17.012 the spectrum and angular structure of two extended x-ray sources were observed. Two nearly orthogonal scans were made over the extragalactic x-ray source in the Perseus cluster of galaxies. Later in the flight two scans were also made over the Puppis supernova remnant. In order to calibrate the attitude control system, a star sensor briefly pointed the payload axis at Capella (α Aur). During the period of stable pointing, x-rays were detected significantly above background in a detector co-aligned with the star sensor. These data have been interpreted as evidence for x-ray emission from Capella. Sufficient data were obtained to allow the spectrum and angular distribution of x-rays from these three objects to be determined.

The text of this report only summarizes results of the analysis of the cosmic x-ray data. Details are included as appendices in the form of published papers, abstracts, and pre-prints of papers now being submitted for publication. Since they do not appear in any of the appendices, results of the rocket aspect solution are presented in this report.

SUMMARY OF SCIENTIFIC RESULTS

X-ray emission in the range from 0.2 to 1.6 keV has been detected from an area of the sky which contains the binary star system, Capella. This system is a spectroscopic binary consisting of an F8-G0 giant of $2.9M_\odot$ and a G5 giant of $3.0\ M_\odot$. Capella is at a distance of 14 pc, has a binary period of 104 days and a separation between the stars of about 1 a.u. No known x-ray source lies in this region and the most prominent object within the error box for the source location is Capella. The lack of x-ray absorption by interstellar matter at 0.25 keV is consistent with such a nearby source and the observed upper limit on its angular extent of a few arc minutes is consistent with a starlike object. If this identification is correct, it indicates a galactic x-ray source with a luminosity of $\sim 10^{31}$ ergs s^{-1}. This is approximately a factor of 10^{4} below the luminosity of other known x-ray sources and the first observation of x-ray emission from such an apparently ordinary star system. The x-ray emission from this object is variable since previous rocket observations have failed to detect it and a subsequent observation of our own, on 3 Feb. 1975, has not observed it.

Observations of Capella by the ultraviolet experiment on Copernicus (Dupree, 1975) have detected a line of O VI. Results of analysis of the observations conclude there is appreciable plasma at a temperature of $\sim 5 \times 10^5$ K in this object. The ANS satellite (Mewe et al., 1975) has detected x-ray emission from Capella during observations on 1975 March. The evidence is therefore very strong that Capella is a variable x-ray source, however, the mechanism for this emission is not clear as yet.

The most prominent feature of the Perseus source detected in our observation is a point-like x-ray source at the position of NGC 1275. We find little evidence for an extended component to the x-ray emission unless its extent is comparable to the size of our 1.8° scan over the source. Analysis of our spectral data from this source indicates much less flux below 1 keV than has been reported by Fritz et al. (1971), Hayakawa et al. (1972) and

Agrawal, Long and Garmire (1974). Our observations, therefore, agree with the more recent results of Davidsen et al. (1975).

In a scan over the Puppis supernova remnant, proceeding along position angle 313°, the angular extent of the x-ray emitting region is observed to be 42 ± 4 arc minutes. This correlates very well with the angular size of the Puppis A radio shell along the scan direction. In the angular distribution of x-ray emission we find a point-like feature visible at over 4σ in the energy range 0.4 to 0.8 keV, which is not observed between 0.8 and 1.2 keV. This feature was detected as the reflector field of view crossed a region from which Zarnecki et al. (1973) also observed strongly peaked x-ray emission in data from x-ray telescopes on the Copernicus satellite. Their observations, however, did not detect a spectral difference in this feature compared to emission from the remnant as a whole (Charles et al., 1975). Our data, however, indicate the point-like feature to have a softer spectrum than the rest of the remnant. The angular structure of the source, as determined from our observations, is consistent with a strongly localized feature superimposed on a shell of x-ray emission. A shock wave model (treated by many authors and summarized recently by Gorenstein, Harnden, and Tucker, 1974) predicts development of such a structure for the x-ray emission as an expanding shock wave from the supernova sweeps up and heats material from the interstellar medium. Expansion of the shock depends on density of the interstellar medium. Non-uniformities in this density product asymmetries in the resulting shell of x-ray emission and variations in the spectrum. In denser regions the shock expands more slowly and temperature of the heated plasma is lower than in more tenuous regions. Since intensity of the x-ray emission depends on the plasma density squared, the regions of lower temperature (high density) will be of higher x-ray surface brightness. These features of the model are consistent with our observations which indicate presence of a small region in the remnant where the emission is sharply peaked in angle and of softer spectrum. This suggests the existence of a local density enhancement in the interstellar medium which an expanding shock from the Puppis supernova has encountered.

The Bragg crystal spectrometer was unable to detect the Lyman-α line of O VIII at 18.97Å significantly above background in emission from the Puppis supernova remnant. A one standard deviation increase in counting rate was observed in the spectrometer detector during the period when the remnant was within its field of view. This places a one sigma upper limit of 2 photons $cm^{-2}s^{-1}$ for the O VIII line emission from the entire remnant.

ROCKET ASPECT

During the flight of 17.012 the payload was maneuvered by an attitude control system (ACS) which utilized a star tracker and rate-integrating gyros. The tracker pointed the rocket axis at selected stars twice during the flight to reduce errors in the gyros accumulated during launch and from uncertainties in preceeding maneuvers. Rate-integrating gyros provided slow stable scans at a rate of 0.03^{o} s^{-1} during data taking portions of the flight.

Film was advanced every 1.6 sec in a pulse operated 35 mm camera which used a 100 mm f/1.9 lens and TRI-X film. Fourth magnitude stars were detectable in the photographs during ACS maneuvers at up to approximately 4 deg s^{-1}, while at a scan rate of 0.1 deg s^{-1}, sixth magnitude stars were visible.

Orientation of the reflector system fields of view relative to fiducial marks exposed with each photograph was calibrated before launch and verified in flight by observing a UV signal from Sirius during a period when the rocket axis was pointed at this star. The plate scale was determined by measuring the distance between known stars on each photograph and calculating the corresponding angular separation from their celestial coordinates. From the plate scale, coordinates of stars, and orientation of the fields of view in the photographs, the aspect of the reflector system was determined during data taking portions of the flight. These data are shown in Figures 1 and 2. Dashed lines in these figures indicate the maneuvers pre-programmed into the ACS while the points show the measured positions during flight. Uncertainties in the points are ± 0.05 degrees. These data refer to the reflector axis; the fields of view of the detector apertures extend for 9 degrees FWHM normal to the lines (or the best fit line through the points). Figure 1 refers to the two 1.8° scans over the Perseus x-ray source. NGC 1275 is indicated on the graph by an asterisk. Figure 2 shows the first scan over the Puppis supernova remnant. Extent of the radio shell along the scan path is indicated by the two solid lines normal to the scan direction. The second scan over this object was the reverse of that shown in Figure 2. Data from this scan have not been included since appreciable x-ray absorption occurred during this period, as the rocket re-entered the atmosphere, making the observations very difficult to interpret.

Data in Figures 1 and 2 indicate the ACS system performed well throughout the flight. The only difficulty was that the scan shown in Figure 2 began too close to the Puppis supernova remnant. This resulted in the field of view of one of the proportional counters behind the reflector system being positioned well onto the remnant at the beginning of the scan. Since the primary purpose of this detector was to observe the energy spectrum of the source, this did not seriously impact objectives of the experiment.

CONCLUSIONS AND RECOMMENDATIONS

Observations made on the flight of 17.012 gave the first evidence that the binary star system, Capella, is a variable x-ray source. This result has been verified by subsequent observations made by the ANS satellite. It is the first observation of a low luminosity (10^{31} ergs s^{-1}) extra-solar x-ray source and the first evidence for x-ray emission from an apparently ordinary star system.

A very prominent feature in the angular structure of the Perseus x-ray source is a point-like x-ray emitting region at the position of NGC 1275.

The angular distribution of x-ray emission we have observed from the Puppis supernova remnant correlates very well with the extent of the Puppis A

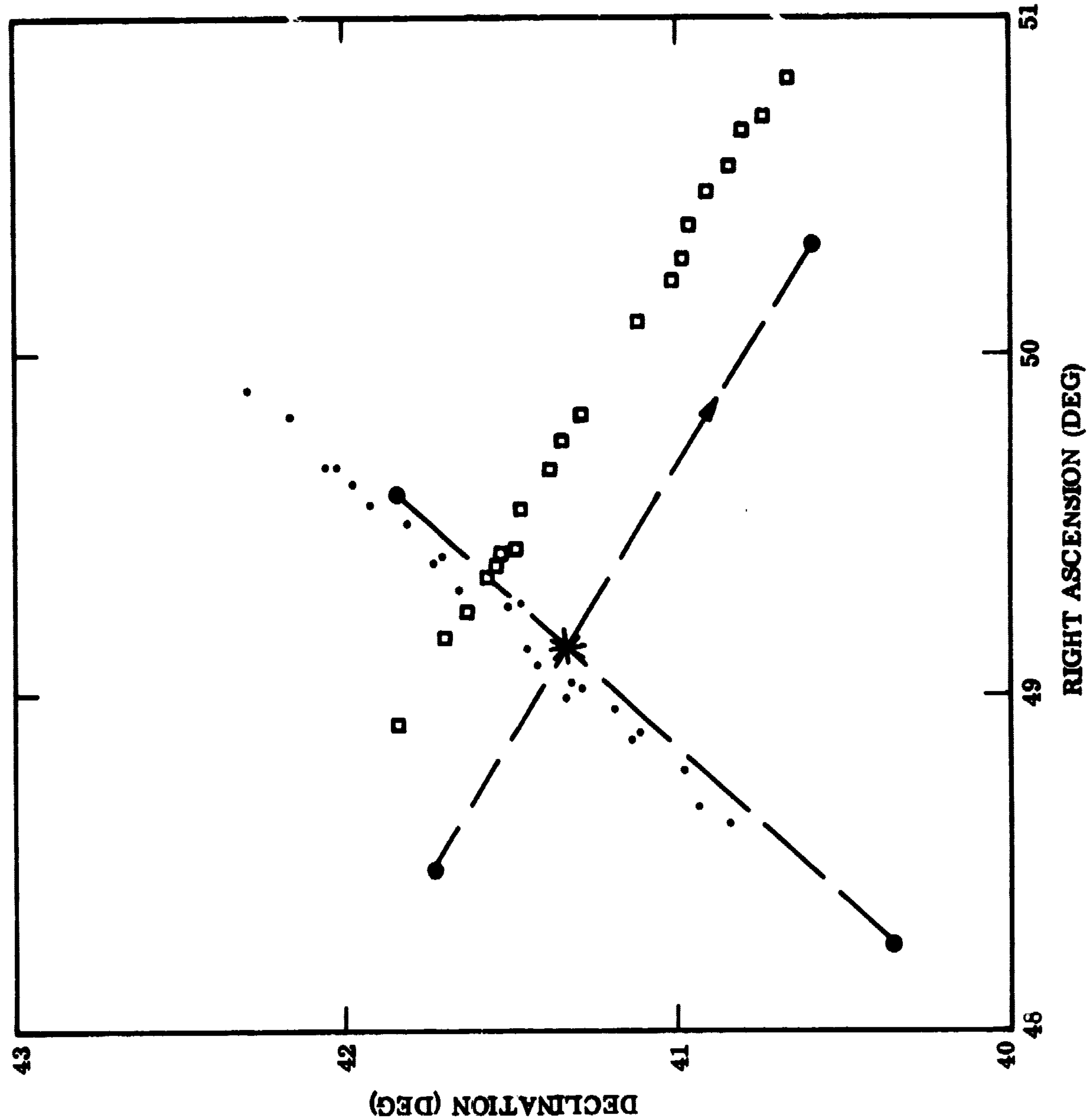


Figure 1

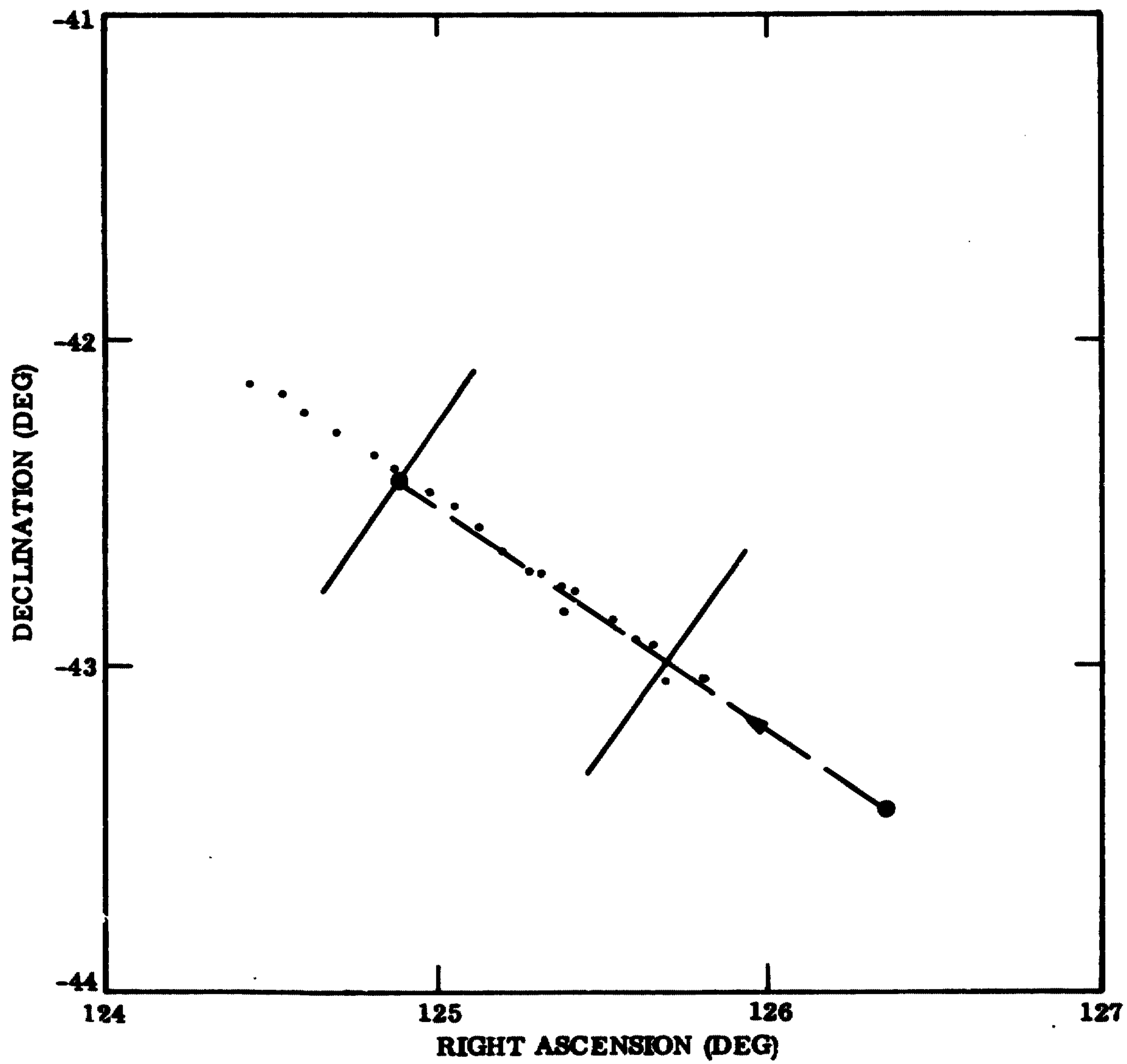

-41
-42
-43
-44
124
125
126
127
DECLINATION (DEG)
RIGHT ASCENSION (DEG)

Figure 2

radio shell along the direction of our scan. We confirm the existence of a feature within the remnant whose x-ray emission is strongly localized and observe the spectrum of this feature to be softer than the rest of the remnant.

APPENDIX

Papers, pre-prints, and abstracts of papers presented at scientific meetings which have resulted from efforts under this contract are included as appendices to this report. Also included is the reproduction of a summary of our work on Capella which has appeared in Sky and Telescope.

REFERENCES

Agrawal, P.C., Long, K. and Garmire, G.P. 1974, Ap. and Space Sci. 28, 185.

Charles, P.A., Culhane, J.L., Fabian, A.C., Mitchell, R.J. and Zarnecki, J.C. 1975, M.N.R.A.S. 170, 61P.

Davidsen, A., Bowyer, S., Lampton, M. and Cruddace, R. 1975, Ap. J. 198, 1.

Dupree, A.K. 1975, Preprint.

Fritz, G., Davidsen, A., Meekins, J.F. and Friedman, H. 1971, Ap. J. (Letters), 164, L81.

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

Hayakawa, S., Kato, T., Kohno, T., Nishimura, K., Tanaka, Y. and Yamashita, K. 1972, Ap. and Space Sci. 17, 30.

Mewe, R., Heise, J., Gronenschild, E.H.B.M., Brinkman, A.C., Schrijver, J. and den Boggende, A.J.F. 1975, Preprint.

Zarnecki, J.C., Culhane, J.L., Fabian, A.C., Rapley, C.G., Silk, R., Parkinson, J.H. and Pounds, K.A. 1973, Nature Phys. Sci. 243, 4.

THE ASTROPHYSICAL JOURNAL, 196:L47–L49, 1975 March 1

EVIDENCE FOR X-RAY EMISSION FROM CAPELLA

R. C. CATURA, L. W. ACTON, AND H. M. JOHNSON
Lockheed Palo Alto Research Laboratory
Received 1974 November 7; revised 1974 December 5

ABSTRACT

X-ray emission in the range from 0.2 to 1.6 keV has been detected from an area of the sky which contains the binary star system Capella. The X-ray source is at most a few arc minutes in extent and shows no spectral turnover at low energy, consistent with a nearby source. We suggest Capella as the source of this emission and that this object belongs to a new class of galactic X-ray sources with a luminosity of 10^{31}–10^{34} ergs s^{-1}. Emission from this class of objects is variable, predominantly below 2 keV, and originates from nearby stellar objects.

Subject headings: spectra, X-ray — stars, individual — X-ray sources

I. OBSERVATIONS

In a rocket flight on 1974 April 5 a star sensor pointed the payload axis at Capella (α Aur) briefly to calibrate the attitude control system. During this period, X-rays in the range 0.2–1.6 keV were detected significantly above background by an X-ray reflector system which was co-aligned with the star sensor (instrument described by Catura *et al.* 1972).

Capella is a spectroscopic binary consisting of an F8–G0 giant of 2.9 $M_\odot$ and a G5 giant of 3.0 $M_\odot$ (Wright 1954). The system rotates in a nearly circular orbit with a period of 104.023 days and a separation between the stars of about 1 a.u. (Struve and Kilby 1953). The spectrum lines of the F component are broadened by an amount corresponding to a turbulent or rotational velocity of 10–12 km s^{-1} (Franklin 1959). No radio detection of the Capella system has been reported. There are no characteristics of this system which would *a priori* indicate it to be a strong X-ray emitter. The X-ray observations reported here were obtained nearly at conjunction, with the so-called F star toward the Earth.

The counting rate in a proportional counter at the focus of the X-ray reflector is shown in figure 1 for a time interval early in the flight bounded by the end of calibration with a radioactive source and the beginning of a scan over the extended X-ray source in Perseus. Analysis of aspect photographs indicate that the payload was pointed at Capella for a short period at 133 s after launch. As shown in figure 1, the X-ray detector experienced a large increase in counting rate for the 1°2 interval of stable pointing. The average counting rate in figure 1, excluding this interval, is 3.3 counts s^{-1}. The number of counts obtained when Capella was within the field of view of the reflector system was 22, while on the average only four counts would be expected. Thus, it is very improbable that this signal is a random fluctuation in the background counting rate.

The signal obtained while pointing at Capella is definitely not from an ultraviolet flux. Later in the same flight, the payload axis was pointed at Sirius and an ultraviolet signal was clearly observed. The difference in pulse amplitude distributions obtained when the reflector system was pointed at Sirius and at Capella is shown in figure 2. In the spectrum of Sirius, note the large predominance of pulses of the lowest amplitude, a result characteristic of the detector response to ultraviolet radiation. While pointing at Capella, however, the observed spectrum below 0.4 keV is consistent with an incident flux of X-rays passed by the carbon transmission band of the 1-μ polypropylene detector window. This spectrum also contains appreciable flux

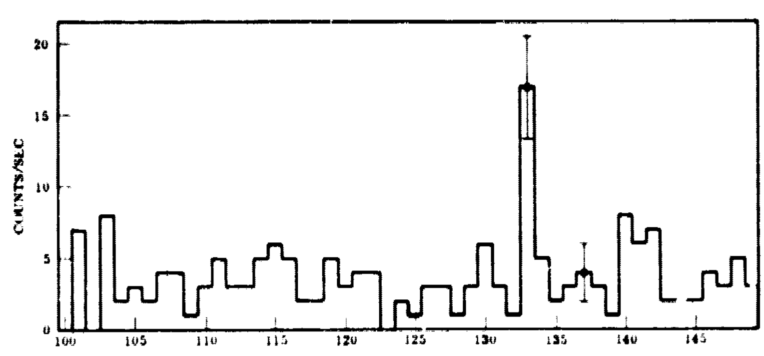


FIG. 1.—Counting rate of a detector at the reflector focus in the range 0.2–1.6 keV. The field of view of this detector was pointed at Capella for a 1°2 period 133 s after launch.

PRECEDING PAGE BLANK NOT FILMED

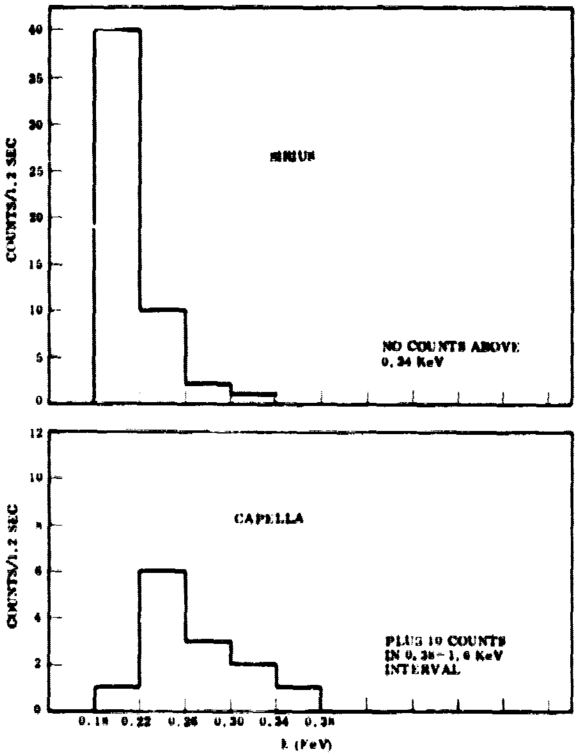


FIG. 2.—Energy spectra of pulses observed when the rocket was pointed at Sirius and Capella.

at higher energies which is not present in that from Sirius.

The data of figure 2 for Capella have been fitted to a function describing thermal bremsstrahlung of the form

$$\frac{dN}{dE} = AE^{-1}T^{-0.5}\left(\frac{E}{kT}\right)^{-0.3}e^{-E/kT}$$

$$\text{photons cm}^{-2}\,\text{s}^{-1}\,\text{keV}^{-1}\,,$$

where E is in keV and T is in degrees K. The parameters resulting from the least-squares fit are $T = 8 \times 10^6$ and $A = 1200$. Statistical uncertainties in the data allow temperatures ranging from 5 to 15×10^6 ° K. The spectrum shows no indication of a turnover at 0.25 keV from X-ray absorption by interstellar matter.

The X-ray emission originates within an area 0°.1 by 18° centered on Capella. The long dimension of this rectangle extends along a line through Capella defined by position angles of 147° and 327°. Angular extent of the emission perpendicular to this line is at most a few arc minutes. No known X-ray sources lie in this region, and the most prominent object within the error box is Capella. The lack of X-ray absorption at low energies is consistent with such a nearby source (14 pc), and the upper limit to its angular extent is consistent with a starlike object. On the basis of these results, we suggest that Capella is the source of the observed X-ray emission. If this identification is correct, it indicates a galactic X-ray source with a luminosity of $\sim 10^{31}$ ergs s^{-1}.

II. DISCUSSION

The source we report here and suggest is associated with Capella was not observed by Hill *et al.* (1974) during a survey of this region in 1972. The sensitivity (Burginyon *et al.* 1971) of their observation was such as to detect Capella at a level $\sim 5\,\sigma$ above background if it then emitted the same flux we have observed. During the past several years a number of other soft X-ray sources have been reported, many of which have also been identified with nearby stellar objects, and which other observations of comparable or better sensitivity have failed to detect. In 1969, Coleman *et al.* (1971) reported a source, Cyg X-6, whose flux was concentrated between 0.5 and 1.3 keV. Succeeding observations in 1971 (Burginyon *et al.* 1973) and 1972 (Borken, Doxsey, and Rappaport 1972) did not detect this source. Similarly, a source tentatively identified with λ Sco by Bleeker *et al.* (1973) was not observed by Hill *et al.* (1972). Recent observation with *Copernicus* failed to detect X-ray emission from λ Sco (Strong, Coller, and Culhane 1974), or from η Car (Griffiths, Peacock, and Pagel 1974), a soft source whose identification was suggested by Hill *et al.* (1972). Other sources of soft X-ray emission which have not been confirmed have been reported by Hayakawa *et al.* (1972), who suggest the Pleiades cluster as the source, and Rappaport *et al.* (1974), who identify a very soft source with SS Cyg.

One must conclude from this evidence that either many spurious observations have been reported or these sources of soft X-ray emission are strongly variable in time. Since most of the observations are of high statistical significance, we suggest that the lack of confirming observations is due to source variability. Because interstellar matter absorbs soft X-rays strongly, the emission is likely to come from nearby objects. All of the candidate objects for the emission which have been suggested are of order 100 pc or less away, except η Car which is at a distance of ~ 1.6 kpc; and if these identifications are correct, they indicate a source luminosity ranging from 10^{31} to 10^{34} ergs s^{-1}.

We suggest, therefore, the existence of a new class of low-luminosity galactic X-ray sources whose emission is largely below 2 keV, is variable in time, and is possibly transient. The emission appears to be associated with nearby stellar objects whose X-ray luminosities are $\sim 10^{31}$–10^{34} ergs s^{-1}. If the unconfirmed observations indeed indicate real variable sources, then the rather large number which have been reported on rocket flights suggests they occur frequently and may contribute substantially to the diffuse X-ray background.

This research has been supported by NASA Contracts NASw-2414 and NASw-2672 and the Lockheed Independent Research Program. We acknowledge useful discussions with Dr. J. L. Culhane of University College London, and thank personnel of White Sands Missile Range and Mr. Rick Erdman and his co-workers of the NASA Sounding Rocket Division for valuable technical support.

REFERENCES

Bleeker, J. A. M., Deerenberg, A. J. M., Heise, J., Yamashita, K., and Tanaka, Y. 1973, *Nature Phys. Sci.*, **241**, 55.
Borken, R., Doxsey, R., and Rappaport, S. 1972, *Ap. J.* (*Letters*), **178**, L115.
Burginyon, G. A., Cornell, C. M., Hill, R. W., and Iantuono, A. 1971, *Nucl. Instr. and Meth.*, **96**, 461.
Burginyon, G. A., Hill, R., Palmieri, T., Scudder, J., Seward, F., Stoering, J., and Toor, A. 1973, *Ap. J.*, **179**, 615.
Catura, R. C., Fisher, P. C., Johnson, H. M., and Meyerott, A. J. 1972, *Ap. J.* (*Letters*), **177**, L1.
Coleman, P. L., Bunner, A. N., Kraushaar, W. L., and McCammon, D. 1971, *Ap. J.* (*Letters*), **170**, L47.
Franklin, K. L. 1959, *Ap. J.*, **130**, 139.
Griffiths, R. E., Peacock, A., and Pagel, B. E. J. 1974, *Nature*, **250**, 714.
Hayakawa, S., Kato, T., Kohno, T., Nishimura, K., Tanaka, Y., and Yamashita, K. 1972, *Ap. and Space Sci.*, **17**, 30.
Hill, R. W., Burginyon, G., Grader, R. J., Palmieri, T. M., Seward, F. D., and Stoering, J. P. 1972, *Ap. J.*, **171**, 519.
Hill, R. W., Burginyon, G. A., Seward, F. D., Stoering, J. P., and Toor, A. 1974, *Ap. J.*, **187**, 505.
Rappaport, S., Cash, W., Doxsey, R., McClintock, J., and Moore, G. 1974, *Ap. J.* (*Letters*), **187**, L5.
Strong, K. T., Colley, M. W., and Culhane, J. L. 1974, *Nature*, **248**, 34.
Struve, O., and Kilby, R. F. 1953, *Ap. J.*, **117**, 272.
Wright, K. O. 1954, *Pub. Dom. Ap. Obs.*, **10**, 1.

R. C. Catura, L. W. Acton, and H. M. Johnson: Lockheed Palo Alto Research Laboratory, Dept. 52-14, Bldg. 202, 3251 Hanover Street, Palo Alto, CA 94304

NEWS NOTES

FIRST HELIOS SUCCESSFUL

The German Helios spacecraft, launched last December 10th from Cape Canaveral, passed 0.301 astronomical unit (28 million miles) from the sun on March 15th. Reaching its perihelion at 11:12 Universal time, the 815-pound probe came closer to the sun than any previous spacecraft, including Mariner 10. (See November, 1974, issue, page 297.)

At that time, sensors recorded a temperature on board Helios of 155° centigrade, and observed a flux of solar radiation 10.4 times stronger than that at the earth's distance from the sun. Because the temperature was somewhat lower than expected, the second Helios, which is to be launched this December, will be sent even closer to the sun.

The German space operations center near Munich, in command of the probe, announced that all onboard experiments were operating normally at the time of perihelion. Helios carries instruments to measure the solar wind, electromagnetic radiation, cosmic rays, micrometeoroids, and the zodiacal light. With an orbital period of 192 days, it will again come to perihelion on September 23rd.

RADIATION DOSAGE NEAR JUPITER

The word "lethal" has often been loosely used to describe the roughly doughnut-shaped belt of trapped high-energy particles that surrounds Jupiter. But now three biophysicists at the University of Rochester's school of medicine have calculated the radiation dose that would have been encountered by any organisms on board Pioneer 10 when it flew by Jupiter in December, 1973.

The basic data used by M. W. Miller, G. E. Kaufman, and H. D. Maillie consisted of fluxes measured by seven electron detectors and eight proton detectors on Pioneer 10 while the craft was within about 100 radii of Jupiter. The flux in any one energy range was then summed to give the cumulative exposure over that time. The effect can be expressed in *rads*, one rad being the absorption of 100 ergs of energy per gram of irradiated biological material.

The Rochester scientists found that the radiation dose on the outer skin of the spacecraft was at least 4.9×10^5 rads from electrons and 2.9×10^6 rads from protons. This would have been enough to kill more than 99.9 percent of the spore-forming bacteria on the surface and practically all of the nonspore-formers. Thus, the outer surface of Pioneer 10 was significantly decontaminated by the radiation exposure.

Inside the spacecraft, the radiation dose was between 2.8×10^5 and 5×10^5 rads. This would have resulted in a spore survival rate of about 0.05 to 0.01. "For almost all 'higher' forms of life — such as seeds, plants, algae, worms, insects, and others — the radiation dose inside Pioneer 10 would have been supralethal. For man and other mammals the interior dose far exceeded the lethal level. Thus, Jupiter's radiation belts pose an extreme hazard to any manned mission passing through them," Dr. Miller and his colleagues note in *Science* for February 28, 1975.

NEW ESO DIRECTOR

L. Woltjer of Columbia University in New York City has been appointed director general of the European Southern Observatory, succeeding the Netherlands astronomer Adriaan Blaauw. As was mentioned on page 79 of the February issue, the observatory's 3.6-meter (142-inch) reflector at La Silla, Chile, is now approaching completion.

CAPELLA AN X-RAY SOURCE?

The possibility that Capella and a number of other nearby stars are sources of soft X-rays is pointed out in the March 1st issue of *Astrophysical Journal Letters*, by R. C. Catura, L. W. Acton, and H. M. Johnson, of the Lockheed Palo Alto Research Laboratory. They report that during a high-altitude rocket flight on April 5, 1974, an X-ray reflector system briefly recorded X-rays in the energy range 200-1,600 electron volts.

This happened just when a star sensor pointed the payload axis at Capella to calibrate the rocket's attitude controls. Since interstellar matter strongly absorbs soft X-rays, this compact source must be relatively nearby, and may be identified with Capella itself, only 45 light-years distant.

However, previous observations of the same sky region have not shown such a source, which therefore is presumably variable. The authors point out that during the past several years a number of other soft X-ray sources have been reported and tentatively identified with nearby stars, yet observations of comparable or better sensitivity have failed to detect them. Since most of the positive observations have high statistical significance, the authors suggest that the lack of confirmation is due to source variability.

Hence the Lockheed scientists propose the existence of a new class of galactic X-ray sources that are nearby stellar objects with strongly variable emission. Their X-ray luminosities appear to be between 10^{31} and 10^{34} ergs per second. "If the unconfirmed observations indeed indicate real variable sources, then the rather large number which have been reported on rocket flights suggests they occur frequently and may contribute substantially to the diffuse X-ray background," the authors state.

IN THE CURRENT JOURNALS

ANASTIGMATIC CATADIOPTRIC TELESCOPES, by Robert J. Lurie, *Journal* of the Optical Society of America, March, 1975. "The amateur astronomer who would like to build his or her own camera for wide-field celestial photography might wish to consider a telescope that uses an ellipsoidal mirror, and a corrector that consists of a plano-convex lens ahead of, and in edge contact with, a plano-concave lens of the same glass type."

LET'S BE USELESS, by Neville Goodman, *Journal* of the British Astronomical Association, February, 1975. "The one enormously important practical study to which astronomers have contributed most is the study of spectroscopy . . . so much that many people . . . are quite likely to consider spectroscopy as an almost purely astronomical subject and to have little notion of its vital role in industry."

ARGON IN MARS' ATMOSPHERE

It has been widely accepted that the Martian atmosphere is nearly pure carbon dioxide, with spectroscopic traces of other gases, but there is growing evidence that about 30 percent may be argon.

The first observational indication was indirect, from the performance of an ion pump aboard the Soviet spacecraft Mars 6, which crash-landed on the planet in March, 1974. Expert opinion is divided, but Soviet scientists have inferred that one molecule in three of Martian air is of some inert gas, probably argon.

Other evidence comes from a preliminary study by Lewis Kaplan, University of Chicago, of high-dispersion Mars spectra taken with the 200-inch Hale telescope by P. Connes. Argon cannot be detected directly, as its resonance lines lie in the far ultraviolet, but its presence is inferred from a perceptible pressure broadening of the Martian carbon dioxide lines.

Writing in *Geophysical Research Letters*, J. S. Levine of NASA's Langley Research Center and G. R. Riegler of Bendix Corp. point out that radioactive decay of potassium in the Martian interior should release enough argon for it to comprise about 28 percent of the atmosphere. This outgassing, however, should have been accompanied by enormous quantities of water, Dr. Levine notes, some of which may still exist on the planet. The argon and water questions may be answered next year by Viking.

CORRECTION

The new double star described on page 199 of the March issue is not 27 Capricorni but 27 G. Capricorni (1950 coordinates 20h 28.3m, —15° 13').

PRECEDING PAGE BLANK NOT FILMED

AMERICAN ASTRONOMICAL SOCIETY

Abstract submitted for the 144th meeting

Category 9. Date submitted 10-8-74

Read by R. C. Catura

Evidence For X-Ray Emission From Capella. R.C. Catura, L.W. Acton and H.M. Johnson, Lockheed Palo Alto Research Laboratory.- In a recent rocket flight a star sensor guided the rocket axis onto Capella (α Aurigae) to reduce errors in the Attitude Control System. During the period when the rocket was pointed at this star x-rays in the range from 0.2 to 1 keV were detected significantly above background by an x-ray reflector system which was co-aligned with the star sensor. The x-ray emission originates within an area 0.1° by 18° and the angular extent of the source is less than a few arc minutes. No known x-ray sources lie in this region and the most prominent object within the error box is Capella. If this identification is correct, it indicates a new type of galactic x-ray source with luminosity $\sim 10^{30}$ ergs sec^{-1}. Details of the observation and its results will be presented. This work has been supported by Contracts NASw-2414 and NASw-2672 and the Lockheed Independent Research Program.

Special Instructions:

R. C. Catura

Signature of Author

Lockheed Palo Alto Research Lab.

Address

3251 Hanover St., Palo Alto, Cal.

Signature of Introducing Member if author is a non-member

We agree to pay $20 in partial support of the publication of this abstract in the B.A.A.S.

[illegible]

Signature of authorized agent

Same as authors address.

Address

ROCKET OBSERVATIONS OF THE PERSEUS X-RAY SOURCE

R.C. Catura and L.W. Acton
Lockheed Palo Alto Research Laboratory
Palo Alto, California

ABSTRACT

The spectrum and angular distribution of soft x-ray emission from the source in the Perseus Cluster has been observed. A prominent feature of this source is a point-like component at the position of NGC 1275. Preliminary analysis indicates the spectrum of this source does not rise as steeply at energies below 1 keV as has been reported previously.

OBSERVATIONS AND DISCUSSION

This paper presents some preliminary results of a recent rocket observation of soft x-rays from the extended source in the Perseus Cluster. The rocket payload consists of a singly focussing x-ray reflector system and has been described by Catura et al. (1972). The reflector illuminated two proportional counters having projected fields of view $0.1^{\circ} \times 9^{\circ}$ and $0.3^{\circ} \times 9^{\circ}$. Figure 1 shows the response of these detectors as the reflector is scanned over a point source of x-rays. Data points indicate the measured counting rate during a scan over Sco X-1 and the solid lines show the calculated response. Disagreement between amplitude of the observed and calculated response for the detector with a wide aperture is from uncertainty in dead time corrections applied to the data. The observed angular response agrees with calculations very well for both detectors.

During a rocket observation on 5 April 1974, the reflector was scanned over the Perseus x-ray source in two nearly orthogonal directions at a rate of 0.03° sec^{-1}. The first scan extended 1.8° along a line of constant Galactic longitude passing through NGC 1275. The second scan, also 1.8° in length and passing through NGC 1275, was along a line of constant Galactic latitude. Counting rates observed in the two detectors during these scans are shown in Figure 2. These data are in the 0.5 to 2.5 keV energy range and include detector background counting rates. Measurements from aspect photographs show that NGC 1275 crossed the narrow aperture field of view at 182 sec on the first scan and at 244 sec on the second scan. Peak counting rates were observed in both detectors on both scans at the line of position corresponding to these times. Data of Figure 2 have been averaged over time intervals such that a point source crosses each field of view in $\sim$ 3 intervals. It is clear from these data that this x-ray source has a very prominent point-like component at the position of NGC 1275. This is in agreement with Copernicus observations reported by Fabian et al. (1974). There is some indication in these data of an extended source as observed by Forman et al. (1972) but comment on this component must await further analysis.

Preliminary analysis of the spectrum from this source indicates much less x-ray flux below 1 keV than has been reported by Agrawal, Long and Garmire (1974), Hayakawa et al. (1972) and Fritz et al. (1971). Measurements by these observers were all made with broad collimation. Possible explanations for the disagreement are that the source may be very extended at soft x-ray energies or there may be contribution to their data from a nearby unidentified source of soft x-ray emission. The spectrum reported by Fabian et al. (1974) for the Perseus source is consistent with our observations.

This research has been supported by NASA Contracts NASw-2414 and NASw-2672 and the Lockheed Independent Research Program.

REFERENCES

Catura, R.C., Fisher, P.C., Johnson, H.M. and Meyerott, A.J. 1972, Ap. J. (Letters), 177, L1.

Fabian, A.C., Zarnecki, J.C., Culhane, J.L., Hawkins, F.J., Peacock, A., Pounds, K.A. and Parkinson, J.H. 1974, Ap. J. (Letters), 189, L59.

Forman, W., Kellogg, E., Gursky, H., Tananbaum, H. and Giacconi, R. 1972, Ap. J., 178, 309.

Fritz, G., Davidsen, A., Meekins, J.F. and Friedman, H. 1971, Ap. J. (Letters), 164, L81.

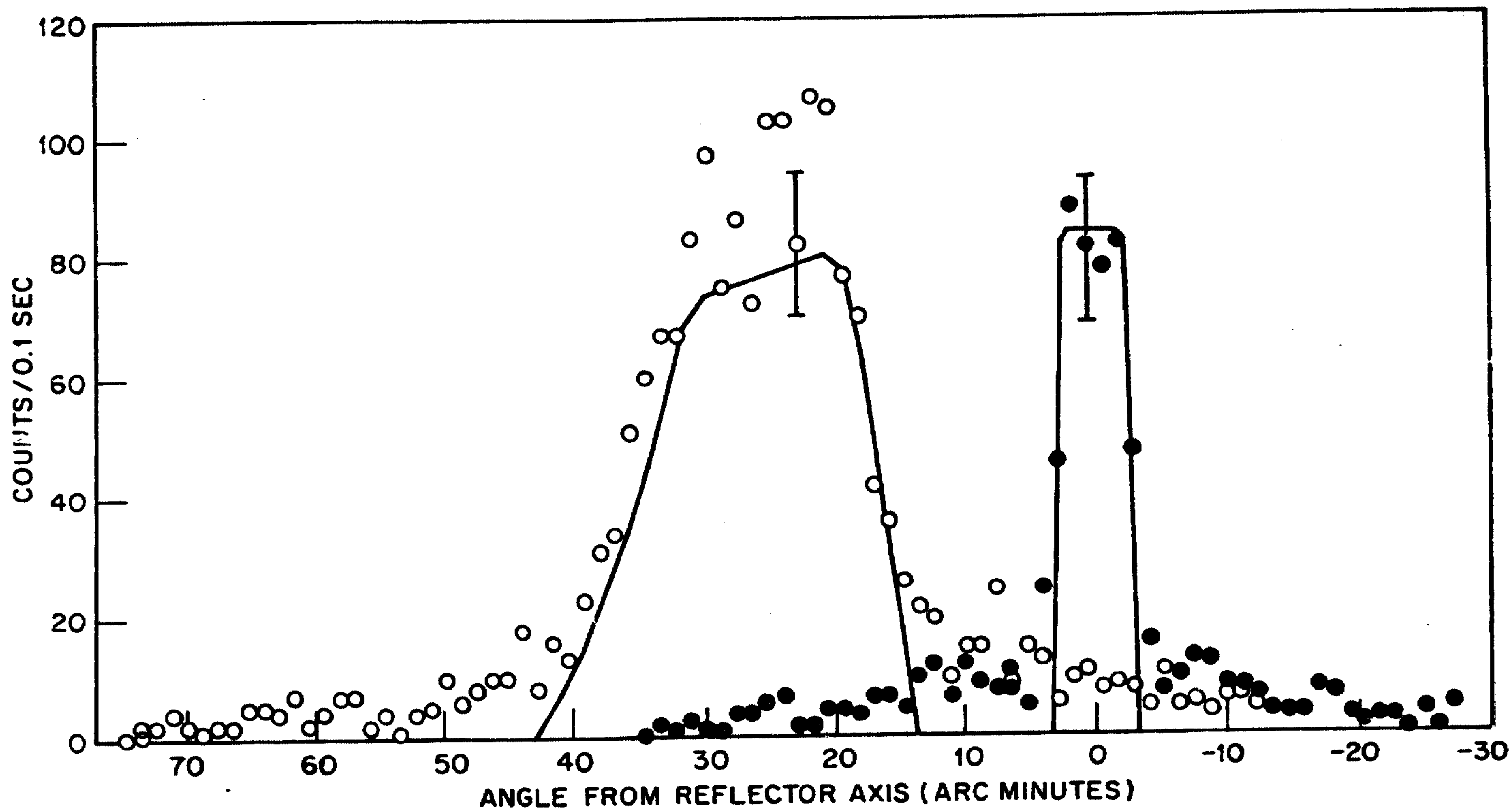
Hayakawa, S., Kato, T., Kohno, T., Nishimura, K., Tanaka, Y., and Yamashita, K. 1972, Ap. and Space Sci., 17, 30.

Agrawal, P.C., Long, K. and Garmire, G.P. 1974, Pre-print.

FIGURE CAPTIONS

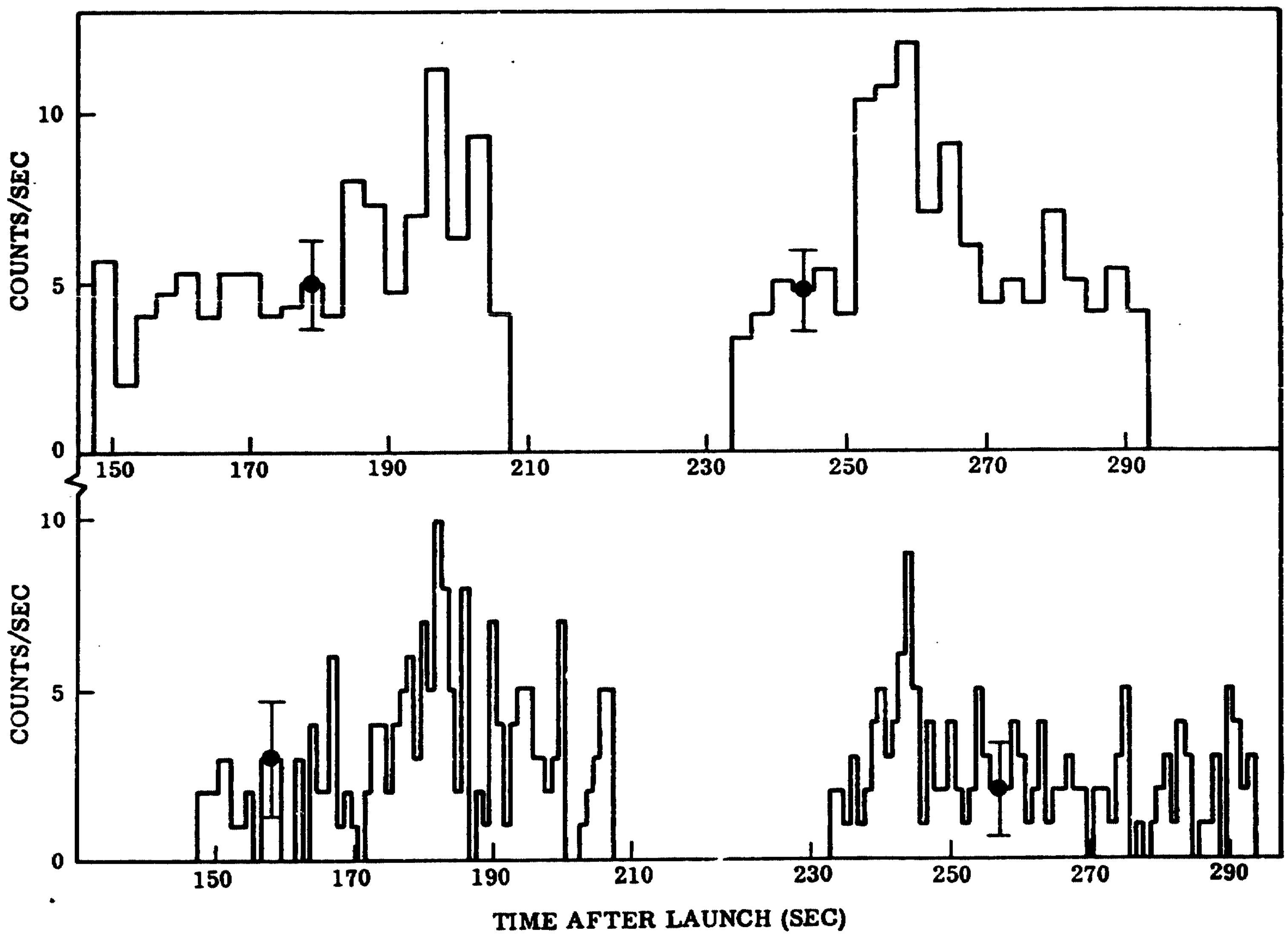
Figure 1. Calculated detector response at 1.5 keV (solid line) compared with counting rates observed in the one to two keV energy range during a scan over Sco X-1. Data from the detector with a narrow field of view (on the reflector axis) are indicated by disks and from the wide field of view detector by circles.

Figure 2. Counting rates observed during two nearly orthogonal scans over the extended x-ray source in the Perseus Cluster. Data from the detector with a wide field of view are plotted above while those from the narrow field of view detector are shown below. The time scales have been shifted so that data from the same line of position on the sky overlie. Data points indicate average counting rates outside the source region and the error flag shows its one sigma statistical uncertainty.



120
100
80
60
40
20
0
COUNTS/0.1 SEC
70
60
50
40
30
20
10
0
-10
-20
-30
ANGLE FROM REFLECTOR AXIS (ARC MINUTES)

Figure 10



COUNTS/SEC
10
5
0
150
170
190
210
230
250
270
290
COUNTS/SEC
10
5
0
150
170
190
210
230
250
270
290
TIME AFTER LAUNCH (SEC)

X-RAY STRUCTURE OF THE PUPPIS SUPERNOVA REMNANT

R. C. Catura and L. W Acton

July 20, 1975

ABSTRACT

During a rocket flight on 5 April 1974 the angular distribution of x-ray emission from the Puppis supernova remnant was investigated with a focussing x-ray collector during a single scan over this object. The angular extent of the x-ray emitting region is observed to be 42 ± 4 arc minutes and is found to be well correlated with the size of the Puppis A radio-shell. We confirm the existence of a feature within the remnant whose x-ray emission is strongly localized and observe its spectrum to be softer than the rest of the remnant.

Lockheed Palo Alto Research Laboratory
3251 Hanover Street
Palo Alto, California 94304

The Puppis A supernova remnant is a non-thermal radio source with a shell structure approximately 1° in diameter (Kundu, 1970; Milne, 1971; and Green, 1971). Baade and Minkowski (1954) identified the radio source with a loose collection of optical filaments, visible mainly in the red. X-ray emission from the Puppis supernova remnant was discovered by Palmieri et al. (1971). Subsequent observations by Seward et al. (1971) could not distinguish the emitting region from a point source with the 1.3° angular collimation of their instrument but indicated the source could be as much as 0.5° in diameter. More recently Zarnecki et al. (1973) have investigated the structure of the Puppis remnant using x-ray telescopes on the Copernicus satellite. The instruments used for these observations have circular fields of view 6 and 10 arc minutes in diameter. They conclude that the angular distribution of x-ray emission from this object is contained entirely within the radio-shell, is strongly peaked, and does not correlate well with obvious radio or optical features of the remnant. Gorenstein, Harnden and Tucker (1974) have scanned over this remnant in two directions with a focussing x-ray collector having a one dimensional angular resolution of 0.3°. They report the x-ray emission to be extended by 0.3° and 0.5° in the two scan directions and that their data are better fitted by including a small region of high x-ray surface brightness at the location given by Zarnecki et al. (1973). The results reported here were acquired to further investigate the angular structure of x-ray emission from the Puppis supernova remnant using an instrument with a resolution of 0.1°.

Instrumentation used for these observations was sensitive between 0.2 and 2.2 keV and has been described in detail by Catura and Roethig (1975). The data presented here were obtained during a 1.5° scan over Puppis A at a rate of $0.03^{\circ}\ s^{-1}$. Figure 1 shows x-ray data from our rocket observation adjacent to a 408 MHz radio contour map of Puppis A which has been adapted from the work of Green (1971). The histogram at upper left indicates the counting rate between 0.4 and 1.2 keV observed in the x-ray detector during the scan over the remnant. X-ray data have been summed over one second time intervals corresponding to approximately 2 minutes of arc along the scan path. The angular scale of the histogram has been normalized to that of the radio map. The dashed line at the base of the x-ray plot shows the average background counting rate of 3 counts s^{-1} and its orientation indicates the scan direction. The x-ray signal rises and falls very abruptly during the scan, indicating sharply defined boundaries for the emission. The dashed lines extending across the radio map show angular extent of the x-ray emission after allowance for the 0.1^{o} detector resolution. Boundaries of the x-ray emitting region correlate very well with the radio shell. The observed angular extent of the x-ray emission is 42 ± 4 arc minutes, where the principal source of error is uncertainty in determination of the rocket attitude.

Figure 2 shows the distribution of x-ray emission observed during the scan over Puppis A divided into two energy intervals. Each bin is 3 secs wide, approximately the time required for a point source to cross the detector's field of view. The histograms appear to have rather flat tops except for data in the 0.4 to 0.8 keV interval where an increase in counting rate of over 4 standard deviations occurs in the bin at 343 sec. The width of this feature is consistent with the presence of a sharply defined (angular size $\leq 0.1^{o}$) source of x-ray emission within the Puppis supernova remnant. Since this feature does not appear significantly in the .8 - 1.2 keV range its spectrum must be somewhat softer than the rest of the remnant. The line of position determined for this soft source is shown in Figure 1 by the solid line extending across the radio map. Location of the region of strongly peaked x-ray emission observed by Zarnecki et al. (1973) is indicated by an asterisk in Figure 1. Within the experimental uncertainties of our observation, the line of position for this sharply defined feature agrees with the Copernicus location. Analysis of the Copernicus observations (Charles et al., 1975) did not detect a spectral difference for this strongly peaked emission. Their analysis averaged data over a rather large region of the source and, since the soft emission appears to be very localized in our data, the effect may have been sufficiently diluted to remain undetected.

A shock wave model describing evolution of a supernova remnant has been treated by many authors and summarized recently by Gorenstein, Harnden and Tucker (1974). This model predicts development of a shell-like structure for the x-ray emission as an expanding shock wave from the supernova sweeps up and heats material from the interstellar medium. The sharply defined boundaries of the x-ray emission shown in Figure 1 and the rather flat topped angular distributions of Figure 2 are consistent with the response of our instrument as it scans over a spherical shell of x-ray emission. Other evidence, however, indicates the x-ray structure of this source is not so simple. The sharply peaked region of soft x-ray emission shown in Figure 2 and that observed by Zarnecki et al. (1973) are inconsistent with a uniform shell of emission. Also, the x-ray map of Zarnecki et al. (1973) and the data of Gorenstein, Harnden and Tucker indicate asymmetries in the overall x-ray structure of this source. The shock wave model allows such asymmetries to develop while preserving a basically shell-like structure since expansion of the shock depends on density of the interstellar medium. Non-uniformities in this density produce asymmetries in the resulting shell of x-ray emission and variations in its spectrum. In denser regions the shock expands more slowly and temperature of the heated plasma is lower than in more tenuous regions. Since intensity of the x-ray emission depends on the square of the plasma density regions of lower temperature (higher density) will be of higher x-ray surface brightness. These features of the model are consistent with observations shown in Figure 2 which indicate presence of a small region in the remnant where the emission is strongly localized and of lower temperature. This suggests the existence of a local density enhancement in the interstellar medium which an expanding shock from the Puppis supernova has encountered.

This research has been supported by NASA contracts NASw-2414 and NASw-2672 and the Lockheed Independent Research Program. We wish to thank personnel of White Sands Missile Range and Mr. Rick Erdman and his co-workers of the NASA Sounding Rocket Division for valuable technical support. We are indebted to R. Caravalho, E. Laveen and D.T. Roethig of Lockheed Research Laboratories for their invaluable support.

FIGURE CAPTIONS

Figure 1 X-ray data compared to a 408 MHz radio map from Green (1971). The dashed base line of the histogram indicates the direction of the rocket scan path and is at the level of average detector background rate. Dashed lines across the map indicate extent of the x-ray emission while the solid line shows the line of position for a strongly localized source of soft x-ray emission within the remnant.

Figure 2 Counting rates in two energy intervals observed during the scan over the Puppis supernova remnant.

REFERENCES

Baade, W. and Minkowski, R. 1954, Ap. J. 119, 206.

Catura, R.C. and Roethig, D.T. 1975, Space Sci. Inst. (in press).

Charles, P.A., Culhane, J.L., Fabian, A.C., Mitchell, R.J. and Zarnecki, J.C. 1975, M.N.R.A.S. 170, 61P.

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

Green, A.J. 1971, Aust. J. Phys. 24, 773.

Kundu, M.R. 1970, Ap. J. 162, 17.

Milne, D.K. 1971, Aust. J. Phys. 24, 429.

Palmieri, T.M., Burginyon, G., Grader, R.J., Hill, R.W., Seward, F.D. and Stoering, J.P. 1971, Ap. J. 164, 61.

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

Zarnecki, J.C., Culhane, J.L., Fabian, A.C., Rapley, C.G., Silk, [illegible]., Parkinson, J.H. and Pounds, K.A. 1973, Nature Phys. Sci. 243, 4.

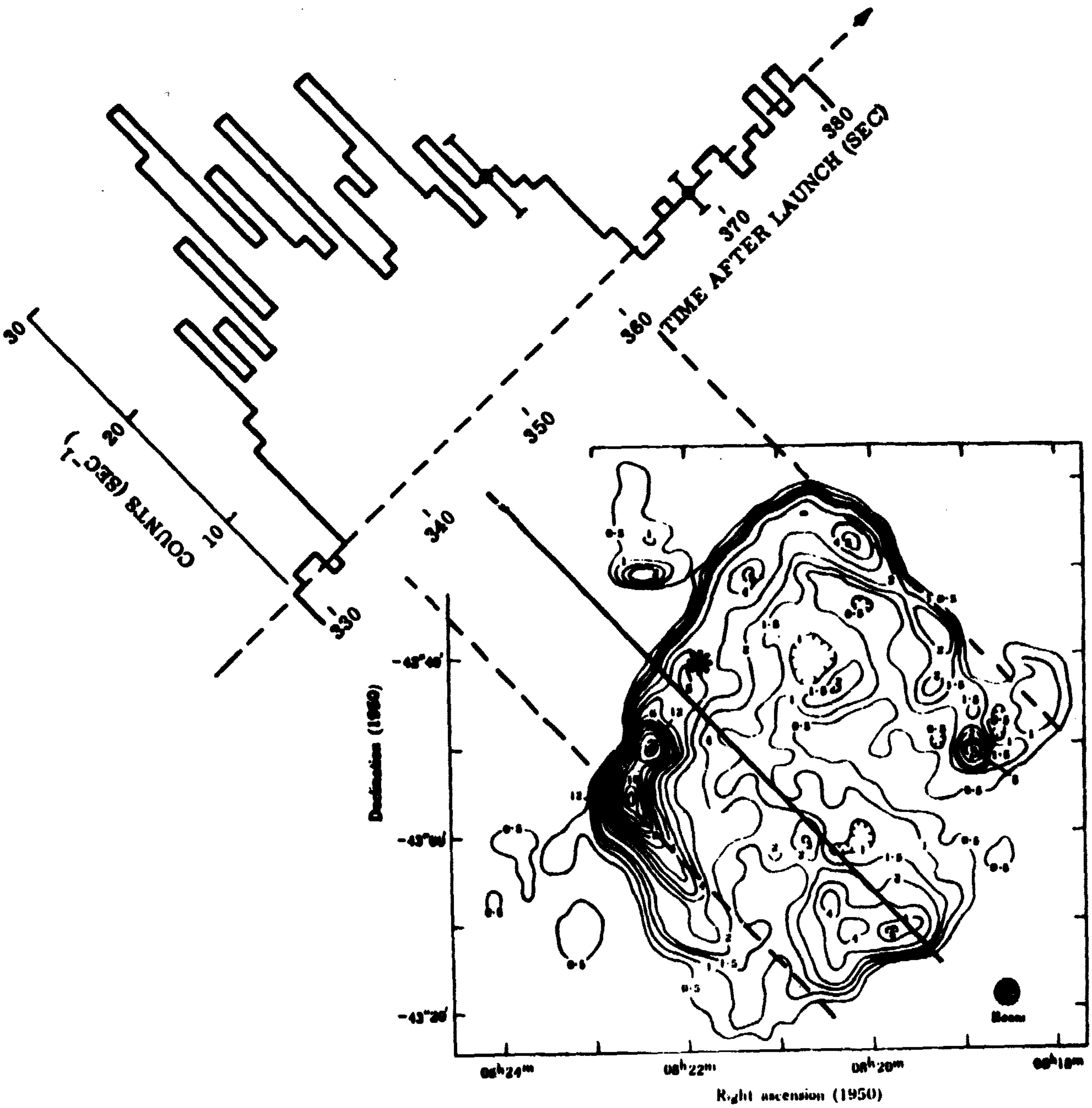


Figure 4

PRECEDING PAGE BLANK NOT FILMED

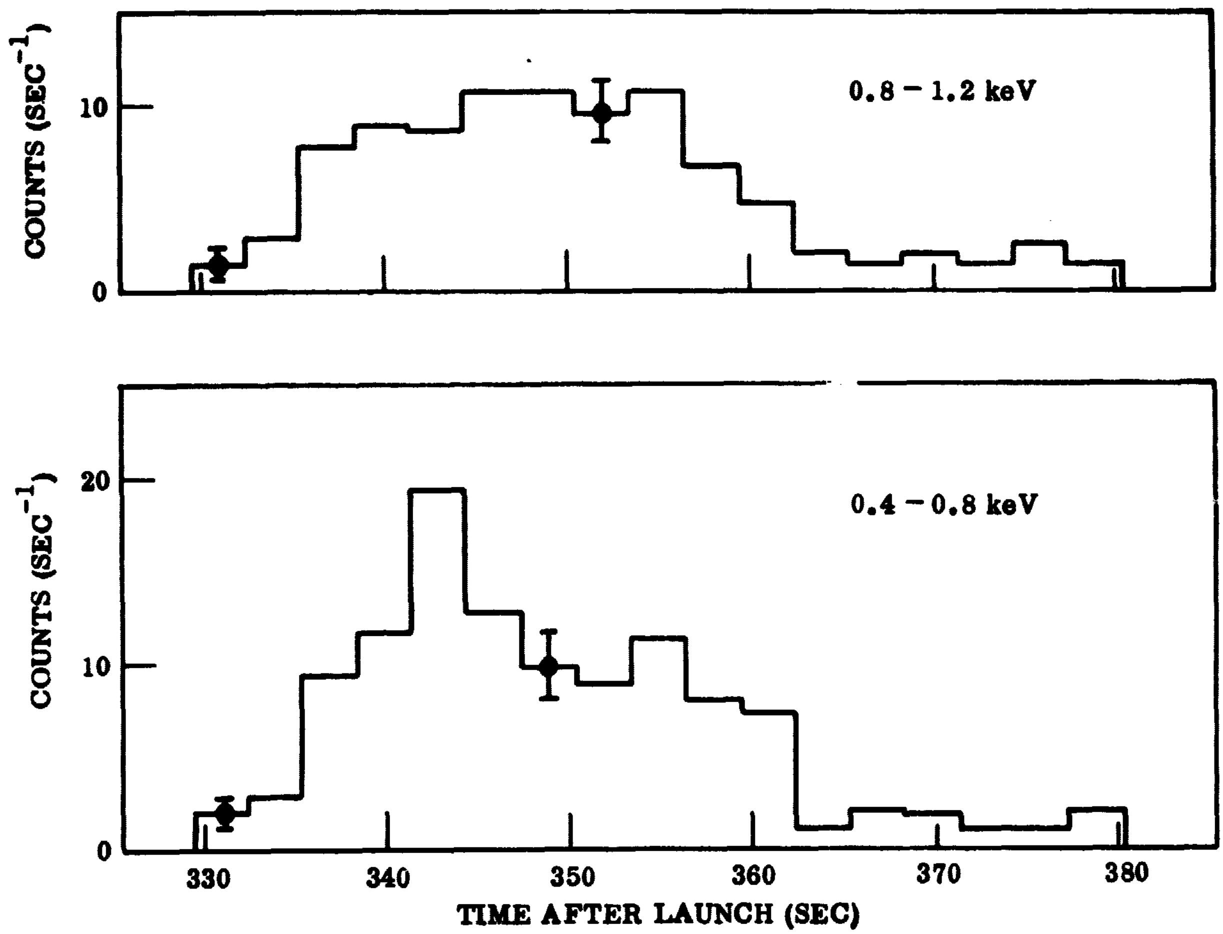

0.8 − 1.2 keV
COUNTS (SEC^{-1})
10
0
0.4 − 0.8 keV
COUNTS (SEC^{-1})
20
10
0
330
340
350
360
370
380
TIME AFTER LAUNCH (SEC)

Figure 2

AMERICAN ASTRONOMICAL SOCIETY

Abstract submitted for the 145th meeting

Category 9. Date submitted 1-7-75

Read by R.C. Catura

Spectrum and Structure of X-ray Emission From Puppis A. R.C. Catura and L.W. Acton, Lockheed Palo Alto Research Laboratory.- During a recent rocket flight the spectrum and angular distribution of x-rays from the Puppis A supernova remnant were observed with a focussing x-ray collector. This instrument had a one dimensional angular resolution of 6 arc min and was sensitive in the x-ray energy range from 0.2 to 3 keV. X-rays were detected from the remnant at energies between 0.4 and 2 keV and the data indicate presence of a very localized component of emission when the field of view passed near the center of the object. This localized component has an angular extent, in one dimension, less than a few arc minutes and a somewhat softer spectrum than the rest of the emission. Details of the observation and its results will be presented. This work has been supported by Contracts NASw-2414 and NASw-2672 and the Lockheed Independent Research Program.

Submitted for special session on Supernova Remnants

Richard C Catura

Signature of author

Lockheed Palo Alto Research Labs.

Address

3251 Hanover St., Palo Alto, Cal.

Signature of Introdu[illegible] Member if author is a non-member

We agree to pay $20 in partial support of the publication of this abstract in the B.A.A.S.

[illegible signature]

Signature of authorized agent

Same as author's address

Address