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X-RAY SOURCES IN THE AQUILA–SERPENS–SCUTUM REGION

F. D. Seward, C. G. Page, M. J. L. Turner and K. A. Pounds

X-ray Astronomy Group, Department of Physics, University of Leicester

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SUMMARY

The *Ariel-5* sky survey detectors have been used to study X-ray sources within 10° of the galactic plane between longitudes $l'' = 20°$ and $l'' = 55°$. Seventeen sources have been found and locations and strengths derived. These are compared with results of previous surveys. Seven of these sources were already known and this observation yields an improved position for four of them. Ten of the sources are new. One is possibly associated with the globular cluster NGC 6712, and one with the supernova remnant, W50.

1. HISTORY

Early surveys of this region all detected the strong source Ser X-1 (Seward 1970) and a second strong source, Aql X-1, was seen occasionally. In 1970 September a more sensitive survey in the energy range 2–30 keV was performed with a rocket-borne detector (Schwartz *et al.* 1972) and additional sources were detected. The observed emission was interpreted as coming from a total of five sources (including Ser X-1) which were roughly positioned as shown in Fig. 1.

The UHURU satellite surveyed most of the sky from 1970 December to 1971 April and the resultant data were used to compile the 3U catalogue. In the 3U classification, this region would be called ‘ complex ’; the sources are too closely spaced for them all to be resolved and identified clearly. The catalogue lists positions for nine sources in this region including Ser X-1 and Aql X-1 and intensities in the energy range 2–6 keV (Giacconi *et al.* 1974).

In 1973 June another sensitive rocket survey covered energies from 0·2 to 15 keV (Hill *et al.* 1974, 1975). No soft sources were found. From 2 to 15 keV Ser X-1, 3U 1822−00, and two other sources (not in the 3U catalogue) were seen with strength $\gtrsim$20 UHURU counts. Groups of unresolved weaker sources were also detected which were consistent with source positions and strengths listed in the catalogue.

2. THE ARIEL-5 SKY SURVEY INSTRUMENT

Details are given by Villa *et al.* (1976, in preparation). The satellite was launched on 1974 October 15 into an equatorial, 520–550 km, orbit. The spacecraft spins about its axis once in 6 s and the sky survey detectors look out perpendicular to this axis. The SSI has two sets of argon-filled proportional counters: the high energy (HE) system with 0·13 mm Be windows, effective area 290 cm², covering the energy range 2·5–20 keV; and the low energy (LE) system with 0·08 mm Be windows, effective area 145 cm², covering the range 1·2–6 keV. The field of view of these counters is restricted by slat collimators to a strip of sky 0·7° by 10·6° FWHM. The HE and LE fields of view are tilted in opposite directions, making angles of ±25° with the normal to the path-of-the-scan and forming an X-shaped field of view. Problems developed after launch in the LE detectors and they were turned off in 1975 December. Data taken after that date are with the HE system only.

Data are integrated and stored over each 110-min orbit. Since the detectors are turned on only when the spacecraft is in sunlight, and not in the south Atlantic anomaly when charged particle fluxes are high, the average data taking time for one orbit is ≈60 min. This is equivalent to ≈6-s exposure time for a given source, though in practice this is reduced by Earth-occultation and by sources not being centred in the collimator. Note also that these several-sec exposures are spread over the whole integration time of each orbit.

3. ARIEL OBSERVATIONS AND DATA REDUCTION

We used sums of data from many orbits during which the position of the satellite spin axis was nominally unchanged, any minor changes being removed in the analysis. The quoted source intensities are thus averaged over the several-day duration of an observation. We started with a 16-day scan of the galactic plane performed on 1974 November 10–25, when both HE and LE detectors were operating. Data were then included from scans which crossed the plane at angles of 60° and 90°. These cross-scans occurred at irregular intervals from 1975 January to July, were of duration 1–2 days, and only the HE detectors were operating. Exposure times ranged from 20 to 100 s.

Since the counter area was larger, sources were best resolved and located with the HE detectors. The LE data were most useful in the reduction of confusion using the observed source variability. Most sources we observed varied in intensity over hours and days, with changes of a factor of 3 in strength common. When a particular source was bright in the HE data, sometimes the corresponding LE peak could be identified and the source located.

The source finding proceeded as follows: Data from the various scans were used to derive lines of position (lop) for individual sources. A statistically significant peak in counting rate with the appropriate triangular shape determined a lop. The width of a lop is $\pm 2\,\sigma$ so the probability of the source being inside is ≈0·95. This lop was a definite indication that there was at least one source somewhere along the line and could not be ignored. The lop's were placed on a map and, for this region, the number of accidental intersections was very large. It was impossible to determine the real source locations right away. The locations of the strongest sources, however, were obvious and the lop's corresponding to these were removed from the map. Positions of the next strongest sources were then clearer and these lop's were also removed leaving only lop's for the weak sources and only moderate confusion. Source variability and the LE data were then used to decide the ambiguous cases.

Some scans covered regions where sources, although clearly present, were not resolved and no lop's could be determined. We required that our array of sources account for most of the emission from these regions.

Thus the set of sources given here provides a consistent fit to our data. There are weak sources still unidentified in this region and not all observed counts are

Source	3U source	*Ariel* counts	Uhuru counts	Position RA, Dec.	Position l'', b''	Error box corners				Size of error box deg²	Comments
A1822+00	3U 1822−00	10–20	37	275·72	30·02	275·70	275·67	275·73	275·76	0·003	Improved location
				0·04	5·81	0·07	0·04	0·01	0·04		
A1829−10	—	1–3	—	277·3	21·4	277·8	276·4	276·7	278·1	0·6^c	New source
				−10·5	−0·5	−10·5	−9·9	−10·5	−11·1		
A1829−06	—	2–5	—	277·4	24·8	277·3	276·7	277·5	278·1	0·4^c	New source
				−6·7	1·2	−6·3	−6·0	−7·1	−7·4		
—	3U 1832−05	<2	6	—	—	—	—	—	—	—	Not seen
Ser X-1	3U 1837+04	55–70	130–270	279·38**	36·12	—	—	—	—	—	—
				4·99	4·84	—	—	—	—	—	
A1840+01	—	1–5	—	280·2	33·2	280·1	279·8	280·3	280·6	0·3^c	New source
				1·3	2·4	1·8	1·5	0·9	1·2		
A1845−02	—	5–9	—	281·3	30·25	281·35	281·05	281·45	281·75	0·13	New source
				−2·6	−0·35	−2·50	−2·50	−3·00	−3·00		
A1847−05	—	3–5	—	281·9	28·1	282·4	281·9	281·7	281·8	0·2^c	New source
				−5·3	−2·1	−5·0	−4·9	−5·5	−5·5		
A1850−08	—	3–9	—	282·5	25·5	282·9	282·4	282·2	282·7	0·2^c	New source
				−8·6	−4·2	−8·2	−8·5	−9·0	−8·7		
A1850+00	—	3–6	—	282·7	33·8	283·5	282·7	282·0	282·8	0·3^c	New source
				0·7	−0·1	1·1	0·9	0·3	0·5		
—	3U 1901+03	<0·5	20–90	—	—	—	—	—	—	—	Not seen
A1905+00	—	3–5	—	286·3	34·9	286·20	285·95	286·35	286·60	0·2^c	New source
				0·0	−3·6	0·35	0·20	−0·30	−0·15		
A1907+09	3U 1906+09	3–6	8	286·95	43·61	286·93	286·83	287·00	287·10	0·03	Improved location
				9·53	0·25	9·67	9·63	9·40	9·43		
A1908+07	3U 1912+07	2–5	20	287·00	41·62	287·03	286·76	286·93	287·23	0·11	Improved location
				7·25	−0·85	7·50	7·30	7·03	7·23		
Aql X-1	3U 1908+00	<0·5–80	70–200	287·18**	35·73	—	—	—	—	—	—
				0·51	−4·14						
A1909+04	—	2–5	—	287·35	39·57	287·43	287·13	287·33	287·57	0·06	New source
				4·75	−2·32	4·90	4·83	4·53	4·70		
A1916−05	3U 1915−05	9–12	23	289·07	31·46	289·15	289·03	288·99	289·03	0·006	Improved location
				−5·24	−8·45	−5·19	−5·22	−5·29	−5·29		
A1918+14	—	0·5–3	—	289·5	49·3	289·8	289·0	289·2	290·0	0·4^c	New source, weak
				14·6	0·4	15·0	14·5	14·2	14·7		
1956+11	3U 1956+11	13–23	17	299·20*	51·30						
				11·60	−9·26						

Notes: c—confused region, error box not precise; *—position from 3U Catalogue; **—position from Doxsey (1975).

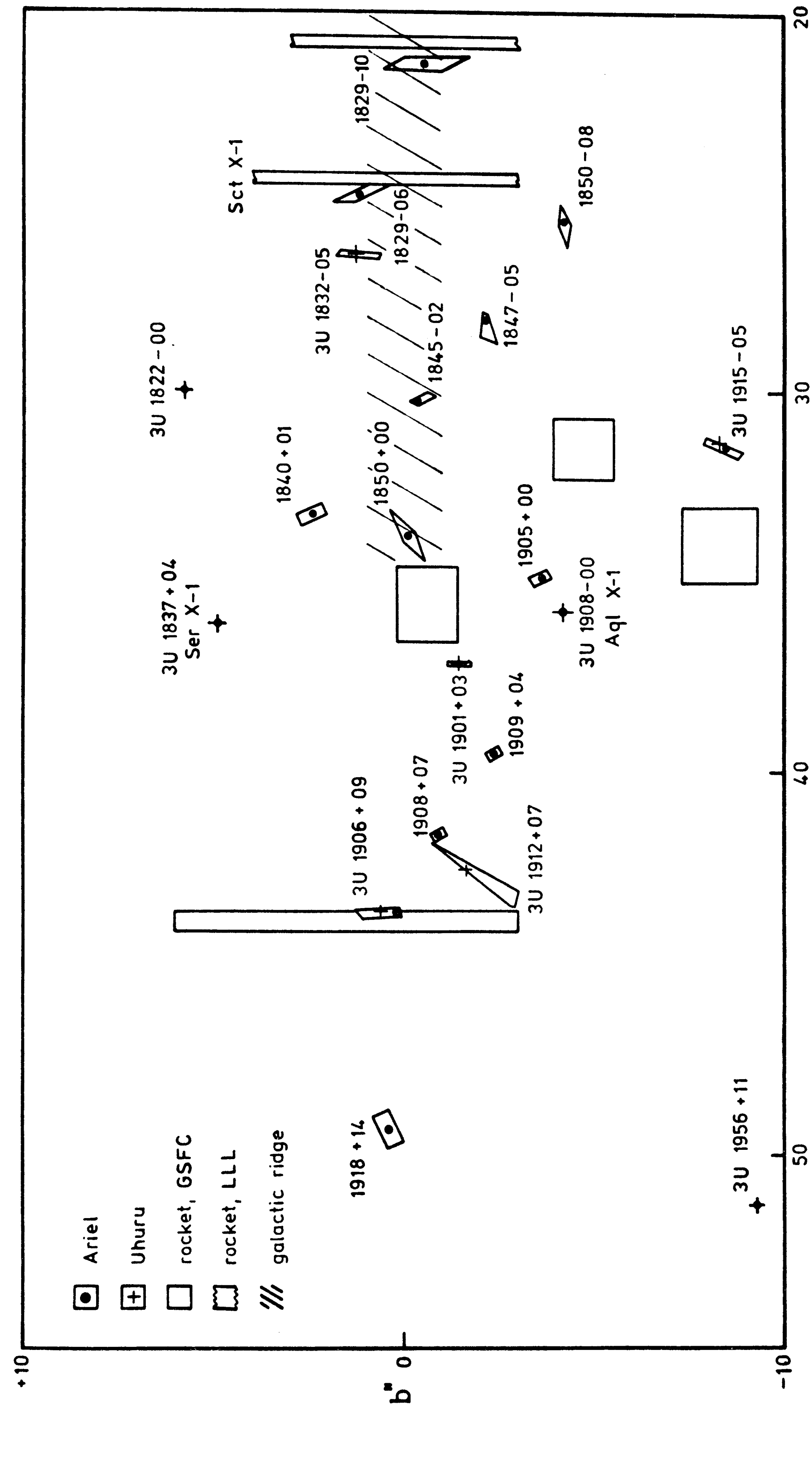

FIG. 1. *Source positions found in this survey and in previous surveys of this region. Error boxes are shown for all sources except when the box is smaller than the size of the point shown to mark the source location.*

explained. These are mostly concentrated in the 'galactic ridge' which is indicated in our map.

Weak sources were often obscured by nearby strong sources. Thus Ser X-1 hides a bit of the sky in every scan through the central part of this area. The strong sources in the direction of the galactic centre make it progressively more difficult to locate weak sources as we approach $l'' = 20°$. GX17+2 is the closest strong source and prevented this search from extending to $l'' < 20°$.

A strong source can also be clearly seen even when outside the nominal 10·6° collimator cut-off. The collimator material transmits a small fraction of high energy X-rays in this direction. This fraction is negligible for all but the strong sources. Sco X-1 is the worst offender and has been seen when the detector was pointed 35° away.

The variability of most sources makes it difficult to use source strength to distinguish different sources. Aql X-1 is particularly difficult since it varies from our threshold of detection to approximately the brightness of Ser X-1. There is

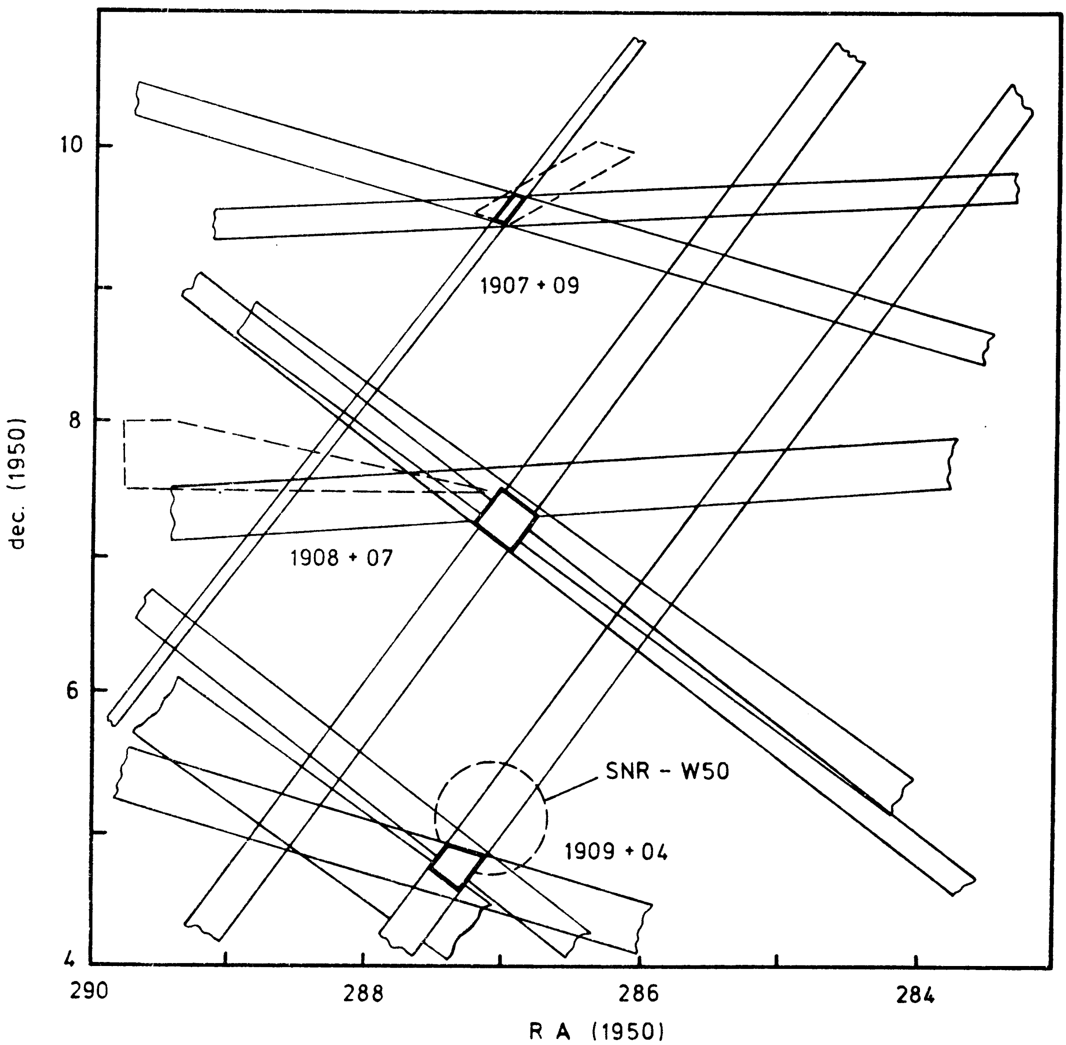

FIG. 2. *The location of three sources in Aquila. Lines of position from four Ariel scans have been used. If the source was too near a stronger source in any scan the corresponding lop was not used. Thus only one scan yielded lop for all three sources. The approximate shell of the SNR, W50, has been indicated. Dashed boxes are UHURU error boxes.*

also the concern that some sources may be transient and have lifetimes of < 2 months, less than the interval during which data were taken.

4. RESULTS

Table I and Fig. 1 summarize the locations of the sources we have detected. The positions of Ser X-1 and Aql X-1 are known (Doxsey 1975) to an accuracy of 1 arcmin, a precision greater than that of our observation. Ser X-1 was seen consistently and these sightings have been used to normalize data and to obtain better positions for 3U 1822−00 and 3U 1915−05. More accurate locations were also derived for 3U 1906+09 and 3U 1912+07. Aql X-1 was detected occasionally and 3U 1956+11 was also detected. No improvements in these locations were achieved. 3U 1832−05 and 3U 1901+03 were not detected. 3U 1901+03 was reported by UHURU to be rather strong. We have never seen a source in that location with any appreciable intensity. 3U 1832−05 is in a more crowded region and was reported weak. Our analysis does not require a source in this position but we cannot exclude it. Considering the low upper limit we can set for 3U 1901+03, this source must be highly variable or a transient which was bright in early 1971.

The locations shown in Fig. 1 derived from rocket experiments do not have the precision of the satellite observations. They are included not only for historical interest but because they represent a different type of observation. The *Ariel*

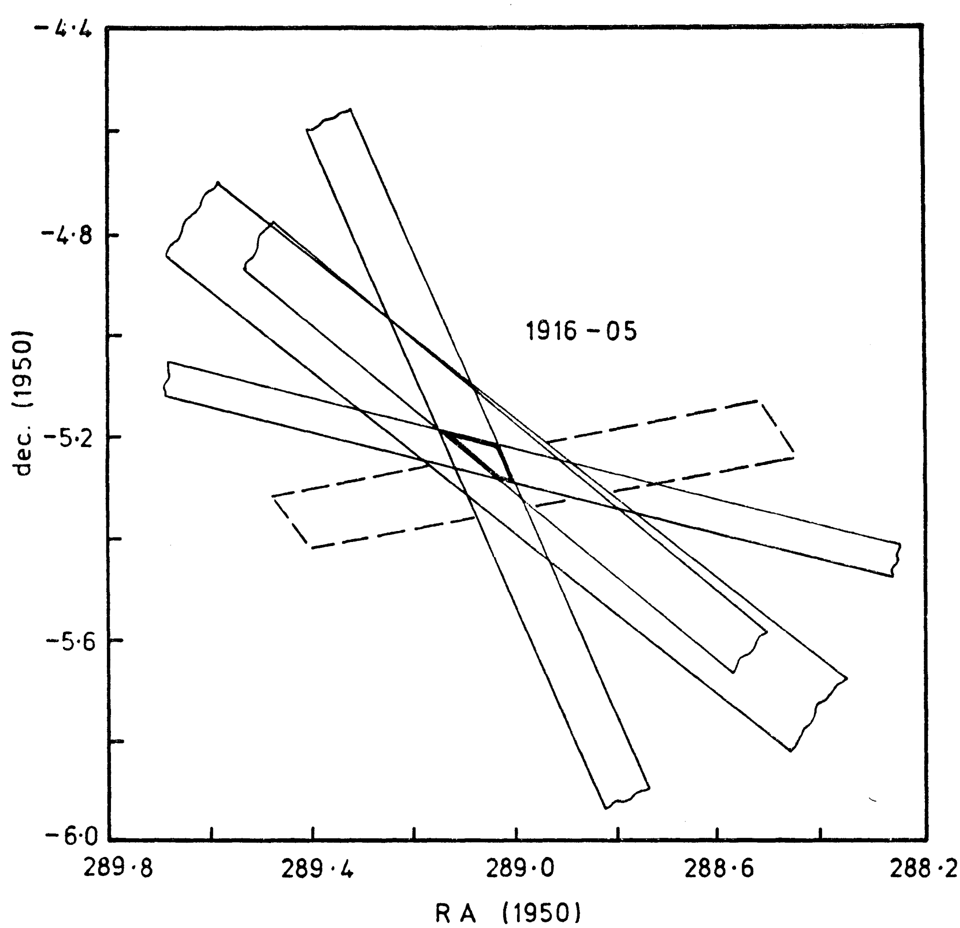

FIG. 3. *A new position for 3U 1915−05 with lop from four scans intersecting to give the odd-shaped error box. The dashed line is the UHURU error box. The source is in Aquila.*

data are averaged over many hours or days. The rockets observed given sources for only a few seconds. Thus normally weak sources which brighten or flare only briefly may be observable above background in the rocket data but not by *Ariel*.

The GSFC rocket seems to have observed 3U 1906+09. The LLL rocket-sources GX21 and Sct X-1 may correspond to A1829−10 and A1829−06 although the error boxes do not quite overlap. There is a *Copernicus* result which places Sct X-1 at $l'' = 24{\cdot}1$, $b'' = 0{\cdot}5$ by combining hour-long satellite observations

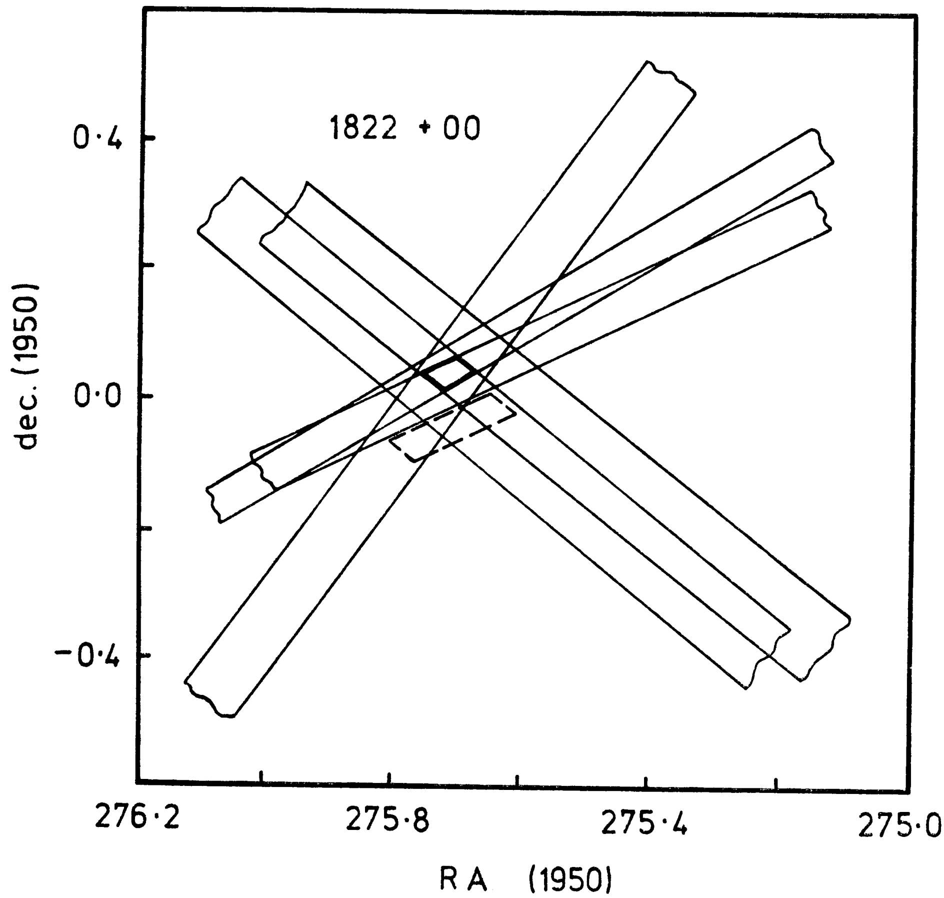

FIG. 4. *A new position for 3U 1822−00. Lop from five scans intersect to give the indicated error box. The dashed line is the UHURU error box. The source is in Serpens Cauda.*

scanning in b'' with the LLL rocket scan in l'' (Charles, Mason & Davidson 1975). In view of the source confusion in this region, this must be regarded as an uncertain result.

The location of the sources marked with a ' c ' in Table I is not as certain as that of the others. If a source is close to the location specified then the chance that it is within the error box given is $\approx 0{\cdot}9$. However, because the region is complex, a different arrangement of sources might also fit the data. We find the arrangement shown to be a good fit with a minimum number of sources but the possibility of error due to confusion should not be forgotten.

Figs 2, 3 and 4 show the lop and error boxes derived for sources which have been located accurately. The lop are $\pm 2\ \sigma$ wide. If the sources were not well resolved in all scans, the error boxes have been made somewhat larger.

Table II

Possible associations

Source	Object
A1829 − 06	SNR, G24·7 + 0·6
A1829 − 10	Galactic cluster NGC 6649
A1847 − 05	Galactic cluster NGC 6704
A1850 − 08	Globular cluster NGC 6712
A1850 − 00	SNR's 4C 00·70, W44
A1909 + 04	SNR, W50

5. POSSIBLE IDENTIFICATIONS

This is a crowded region. The density of X-ray sources is high as is the number of SNR and clusters. Since the chance of accidental coincidence is high, none of these identifications can be considered definite. Some, however, are worthy of more study.

The SNR were obtained from the recent catalogue of Clark & Caswell (1976). These are all extended objects and the above list contains objects in which the X-ray source error box overlaps part of the SNR. The source A1909 + 04, reasonably well located and not confused, is the most interesting. The associated remnant, W50, is shown schematically in Fig. 2. Since the X-ray source appears as a point source and is variable it is a candidate for the remnant of the original star (which does not necessarily remain at the centre of the radio source) rather than a source associated with the ejecta.

Several X-ray sources are associated with globular clusters and are all apparently variable (Clark, Markert & Li 1975). Thus the observed variability of A1850 − 08 is consistent with the association of this source with the globular cluster NGC 6712. If this is true and the cluster is at a distance of 5·7 kpc (Arp 1965), the 2–10 keV X-ray luminosity of the source is $\approx 2 \times 10^{36}$ erg s^{-1}.

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