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GROUNDBASED INFRARED MEASUREMENTS

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This report describes the results of a groundbased sky survey at 10 microns, an attempt to verify and study previously unknown sources detected by the AFCRL HI STAR rocket survey and the results of an absolute calibration of stellar fluxes.

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Groundbased Infrared Measurements

by

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ABSTRACT

This report describes the results of a groundbased sky survey at 10 microns, an attempt to verify and study previously unknown sources detected by the AFCRL Hi-star rocket survey and the results of an absolute calibration of stellar fluxes.

FINAL REPORT
Contract No. F 19628-70-C-0046

I. Introduction:

This program was begun in the fall of 1969 as an effort to answer a fundamental question raised by earlier infrared astronomical observations. It had been found that in the 5-, 10- and 20-micron windows there are many very bright infrared sources which could not be predicted on the basis of conventional astronomical data. It was considered important, both from a scientific and a practical point of view, to determine the density and distribution of bright sources. The ultimate scientific interest, of course, lies in understanding the physical nature of the different types of objects which produce intense infrared emission. Our work in this area can be divided as follows: A. The ground-based survey work, chiefly at 10 microns; B. The verification and study of the sources found by the AFCRL rocket program (Hi-Star); C. An absolute radiometric calibration of ground-based photometry at 11 microns.

In this report we will summarize the results achieved in these three areas.

II. Ground-based Survey:

A. The 5-micron Survey

Because of the relatively low background in the 5-micron atmospheric window and because many infrared stars are known to peak near 5 microns, we initiated a preliminary survey effort at this wavelength in the fall of 1969, after the start of the contract. A single detector was used on the 28-inch telescope with an instantaneous field of view of 5 x 5 arc-minutes. The telescope was scanned in declination at the fastest rate consistent with the object being in the beam for two times the RC time constant of the phase-sensitive demodulator. The right ascension drive of the telescope was not used, thus producing a 15^{o}/hour scan rate along that axis. 700 square degrees were surveyed at a flux limit of about 5×10^{-15} watts/cm^2/μ. No unidentified sources were detected unambiguously. Efforts were made to confirm one unidentified source of high signal-to-noise ratio, but were unsuccessful.

B. The 10-micron Survey

The 10-micron survey observations were started in the spring of 1970. Many variations have been tried in an effort to optimize the various parameters of the filter-bolometer-modulator system. These results are not perfectly homogeneous with respect to wavelength, flux limit or field of view. Basically, we have operated in four different modes, utilizing three different detector systems and three different telescopes. The methods for scanning the sky are basically the same as used in the 5-micron survey, and have been described earlier in the September, 1970 Annual Technical Reports.

Table I shows the four different systems, how they have been used, and the minimum detectable signal levels. System I was used only for a short time and served as a prototype for System II. System II has also been described in the September, 1970 Annual Technical Reports, and was used on the 28-inch telescope and also as System III on the 60-inch metal mirror telescope. System IV was an effort to extend the sensitivity to lower flux levels in order to obtain information at a flux level not covered previously. It utilized the techniques developed for single-channel, high-sensitivity photometers used for multiband photometry on discrete sources.

TABLE I

System	I	II	III	IV
Telescope	28"	28"	5'C	61"
Number of Channels	1	4	4	4
Minimum Detectable Signal (Typ)				
Flux (x 10^{-16} watts/cm^2/μ)	~10	~3.5	1.2	0.5-0.15
Magnitude	2.3	1.2	0.0	+1.0-+2.2
Scan Rate (Sq deg/hr)	0.85	3.8	.65	.09
Hours of Useful Data		~350	~170	~105
Total Observed Area (Sq. deg.)	470	1350	115	9.2
Number of Possible Sources	3	15	14	15
Number of Confirmed Sources	0	0	0	1

System IV utilizes the high resolution of the 61-inch telescope and the f-45 modulating secondary; a four-detector, four-channel array, was constructed with a field of view of about 10 arc-seconds for each detector. It was found that this system was largely background limited rather than sky noise limited, and a sensitivity on the order of 1 x 10^{-17} W/cm^2/μ was achieved. Unfortunately, only a limited amount of observing time was available. However, rewarding results were achieved with this system, with the discovery of a new source in Cameloparadalis. The 1950 coordinates are α = 03h 24m $45^{s}.8$ (±2) and δ = 58^{o} 45:5 (±0.1). The N magnitude is minus 0.8 or 2 x 10^{-16} W/cm^2/μ. Photometry has been carried out from 2.2 to 25 microns, and shows this source has a spectral distribution quite similar to NML Cyg, and VY CMa. It should be noted that this object is listed in the AFCRL Infrared Sky Survey as No. 508-3363.

As it is much less susceptible to sky noise than the wider field Systems II and III, System IV appears to be the most efficient way to use ground-based telescopes in this application, though it requires a large collecting area and small field of view. The 28-inch telescope was extensively modified to give it sensitivity comparable to the 61-inch at f-45, and so that it could be used with the most sensitive system. These modifications are extensively described in an earlier report (August, 1971, Semi-Annual Technical Report).

C. Observational Results of the 10-micron Ground-based Survey

The data produced by System I, which was a single-channel system, was recorded on stripchart paper and then reduced by hand. However, this was not practical for the multi-channel Systems II, III and IV. The data produced by the multi-channel systems was recorded digitally on magnetic tape and later processed by computer. The computer selects points that have the proper signature at 2.2 sigma above the RMS noise. Positions are calculated from timing pluses multiplexed onto the magnetic tape. The results of the reductions are summarized in Table I. Due to the expense of computer reductions, observations with high noise or many clouds have not been done. Of the approximately 1200 to 1500 hours that observing was attempted in Systems II, III and IV, about 625 hours provided useful data.

Table II is a listing of 44 possible sources from Systems II, III and IV, of which only one has been confirmed. The other sources are mainly of low signal-to-noise ratios, and attempts have been made to confirm only those considered most promising. The lack of confirmed sources is not inconsistent with the limiting flux levels of these observing systems, and the chances of coincident noise fluctuations. The flux levels of these sources will be about the same as the limiting flux of the telescope they were observed with.

TABLE II

DATE	TELESCOPE	α 1971	δ 1971
3-18-71	61"	$00^h05^m46^s$	$+59^o$ 00'
5-16-71	5'C	00 51 40	-28^o 08.5
3-20-71	61"	00 58 29	$+58^o$ 42'
3-20-71	61"	01 08 53	+58 42
3-20-71	61"	01 20 12	+58 42
1-9-71	28"	02 17 35	+38 53'
5-24-71	61"	02 25 08	+57 06

TABLE II (CONT'D.)

DATE	TELESCOPE	α 1971	δ 1971	
3-21-71	61"	00 26 56	+56° 00'	
4-17-71	61"	02 37 34	+58° 50'	
4-16-70	28"	02 55 21	+16° 41'	
3-20-71	61"	03 25 40	+58° 42'	confirmed
4-17-71	61"	03 45 09	+58° 09'	
11-20-70	28"	03 46 30	-01° 53'	
4-4-71	28"	04 45 29	-25° 56'	
11-14-70	28"	05 26 39	-14° 23'	
11-12-70	28"	05 33 50	-05° 24'	
5-24-71	61"	05 51 04	+57° 06'	
1-6-71	28"	06 37 38	+39° 49'	
4-27-71	5'C	06 51 33	-28° 51'	
11-19-70	28"	07 13 37	-02° 02'	
11-16-70	5'C	$07^h52^m45^s$	+16° 36'	
5-9-71	5'C	07^h55 35	-28° 19'	
5-24-71	5'C	$08^h31^m39^s$	-28° 15'	
5-24-71	5'C	10^h05 37	-28° 15'	
1-6-71	28"	10 27 53	+39° 48'	
5-9-71	5'C	10 28 59	-28° 19'	
11-3-70	28"	11 42 03	-28° 19'	
5-9-71	5'C	11 42 24	-28° 19'	
5-9-71	5'C	11 53 46	-28° 19'	
5-9-71	5'C	12 37 37	-28° 19'	
5-9-71	5'C	$13^h22^m53^s$	-28° 19'	

TABLE II (CONT'D.)

DATE	TELESCOPE	α 1971	δ 1971
5-17-71	5'C	18^h 03 10	-28^o 04'
11-15-70	5'C	18^h 40 10	16 56
4-17-71	61"	19^h 17 56	+58 50'
12-7-70	28"	20 07 08	+40 58'
3-19-71	61"	20 14 49	$+58^o$ 40'
3-18-71	61"	21 13 52	59^o 00'
1-5-71	28"	21 18 29	39 48
3-21-71	61"	21 35 26	$+56^o$ 00
5-20-71	61"	23 03 45	$+58^o$ 39'
11-15-70	5'C	23^h 06 03	$+17^o$ 00'
1-6-71	28"	23^h 24 45	+39 55'
11-14-70	28"	23^h57 52	+09 00'
11-15-70	28"	23^h 58 18	$+16^o$ 59'

D. Conclusions from Ground-based Survey

The conclusions drawn now are essentially the same as those drawn in the February 1971 Semi-Annual Technical Report, which are:

1. The mean density of stars brighter than 3×10^{-16} W/cm^2/μ is at least 0.005 per square degree, and that these stars are almost randomly distributed across the sky.
2. The results of the survey with System II, as given in Table I, are compatible with a mean star density given in Part 1 above.
3. The results of the survey at high sensitivity with System IV, as given in Table I, suggest that the density of stars increases as brightness decreases faster than a factor of 4 per magnitude, at least in the galactic plane. The results of the AFCRL Survey show the same trends.
4. At flux levels below 1×10^{-18} W/cm^2/μ, extragalactic sources which are randomly distributed may become significant.

III. The AFCRL Rocket Sources:

In the spring of 1972, a program was undertaken to verify objects listed in the AFCRL infrared sky survey (Walker and Price 1972). Two lists of sources were provided, the second list representing a revision of the first. Both were to be considered as preliminary results. Since there were many apparently bright 10-micron sources which could not be identified with optical, radio or other infrared sources, we chose to concentrate all of our effort in this area. When sources were verified, we attempted to improve the positional accuracy to determine whether the source was a star or some other type of body. We also obtained multi-band infrared photometry for most of the new sources.

An area of the sky equal to plus and minus two times the listed AFCRL error in right ascension and declination was scanned in search of each object. The 28-inch telescope was modified for this program, to obtain a 30-arcsecond setting capability in right ascension and declination. A four-channel detector system with a field of view of about 20 arcseconds for each detector was used. The sensitivity of this system was approximately 5×10^{-17} W/cm^2/μ at a wavelength of 10.2 microns.

Table III lists, in order of right ascension, all 27 sources that were verified. It is clear that from the photometry that this body of sources represents more than one class of object. Some are stars. Others may be colder, more extended objects associated with radio or molecular line emission. Figure 1 shows the distribution on the sky of the 135 objects which were searched for but could not be detected. The dashed curve represents the galactic plane. Note that, with only one exception, all of the verified sources are extremely close to or in the galactic plane. The unverified sources appear randomly distributed over the sky.

At this time, it is difficult to determine why we failed to detect so many sources in the AFCRL listing. Clearly, it is not a matter of sensitivity. Figures 2 and 3 show the difference between our positions and AFCRL positions compared to the listed AFCRL error for those 27 objects that we were able to find. The right ascension graph indicates a systematic position error to the west upon application of the "F" test for equality of variances. These figures also clearly show that a positional error alone cannot account for the fact that we were able to detect only 20 percent of the sources. The other factor which must be taken into account is the very large difference between the ground-based and rocket fields of view, 20 arcseconds and 3 x 10 arcminutes respectively. It should be noted that, in many cases amongst the 27 verified sources, our measured flux is considerably less than the flux observed with the large field of view rocket system. Tables IV and V are right ascension lists of the unverified sources from the first and second AFCRL listings.

TABLE IIIa

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES

U of A No.	AFCRL No.	α (1972)	±ε^m	δ (1972)	±ε'	(4)	(11)	(20)
1	508-3363	$03^h25.7^m$	.3	58° 40'	2		-1.08	-3.36
2	603-1218	$06^h02.4^m$	.1	+07° 26'	2		-1.97	-2.78
3	618-1343	$06^h18.5^m$	.1	-10° 35'	2	+0.82	-2.77	-4.33
4	517-1208	$08^h36.9^m$	.2	-10° 23'	3	+1.16	-1.79	
5	712-1551	$14^h09.9^m$	.1	-07° 40'	2		-1.37	
6	219-1544	$17^h06.2^m$	.1	-24° 38'	2	+0.36	-3.31	-3.98
7	425-1912	$17^h48.7^m$	.1	-27° 54'	2		-2.18	
8	423-1907	$17^h52.6^m$	.1	-25° 47'	2		-2.38	
9	423-1864	$18^h09.7^m$	.1	-26° 31'	1	+1.02	-2.23	
10	416-1858	$18^h14.9^m$	.1	-19° 00'	2	+1.18	-1.38	-3.20
11	411-1850	$18^h19.7^m$	.1	-13° 05'	2		-2.20	-4.59
12	423-1836	$18^h20.9^m$	.1	-27° 04'	2	-0.38	-2.59	
13	713-753	$18^h25.0^m$	.2	+23° 27'	2	+0.94	-2.71	-3.68
14	217-1228	$18^h25.0^m$	.1	-06° 56'	2	+0.64	-2.17	
15	218-1233	$18^h29.9^m$	.1	-08° 37'	3	+0.34	-2.19	
16	408-1819	$18^h30.2^m$	.1	-10° 01'	2	+0.66	-1.31	
17	409-1810	$18^h32.7^m$	.1	-11° 31'	2	+0.65	-1 55	
18	212-1080	$18^h34.3^m$	.1	+05° 35'	2		-1.55	-3.32
19	218-1192	$18^h36.0^m$	.1	-05° 26'	2		-2.09	-3.92
20	213-1011	$18^h48.4^m$	.2	+09° 30'	2		-1.92	
21	217-693	$19^h12.4^m$	.2	+10° 55'	2		-2.38	-5.15
22	218-973	$19^h14.3^m$	.2	+09° 36'	2	+0.82	-2.25	-3.24
23	423-1693	$19^h19.1^m$	.1	-26° 15'	2		-2.07	
24	216-646	$19^h42.2^m$	.1	+35° 10'	1		-1.99	
25	219-571	$20^h00.5^m$	.2	+40° 51'	1	+1.24	-2.62	-3.33
26	222-687	$20^h08.2^m$	.2	+31° 22'	2	+0.30	-2.38	-3.18
27	224-569	$20^h28.5^m$	.2	+40° 05'	2	+0.63	-2.70	-4.99

TABLE IIIb

UNIVERSITY OF ARIZONA

U of A No.	α (1972)	±ε^s	δ (1972)	±ε"	K	L	M	N	Q	Remarks
1	$03^h25^m23.5^s$	.75	+58° 41' 10"	10	+4.1		+1.9	-0.9	-2.3	a
2	$06^h02^m29.3^s$	1	+07° 26' 07"	15	+6.8	+2.6	+0.2	-2.4		b
3	$06^h18^m36.6^s$	1	-10° 36' 50"	15	+3.4	+1.4	+0.1	-2.0		c
4	$08^h36^m48.0^s$	1	-10° 18' 19"	15	+5.3	+2.9	+1.4	-0.8		d
5	$14^h09^m45.5^s$	2	-07° 36' 33"	30				-0.6		e
6	$17^h06^m16.9^s$	1	-24° 42' 19"	15	+5.4	+2.0	-0.5	-3.2		
7	$17^h48^m54.5^s$	2	-27° 51.5'	30		+2.9	+1.8	-1.4		f
8	$17^h52^m40^s$	2	-25° 49.5'	30		+2.6	+0.8	-0.8		
9	$18^h09^m47^s$	2	-26° 30'	30		+3.0	+1.7	-0.8		
10	$18^h14^m59^s$	3	-18° 59.5'	45				-1.6		
11	$18^h19^m47.5^s$	2	-13° 02'	30		+2.9	+1.0	-2.2		g
12	$18^h20^m49.5^s$	2	-27° 07.25'	30		+0.1	-1.9	-3.8		
13	$18^h25^m01^s$	2	+23° 27.75'	30		+3.0	+0.7	-2.2		
14	$18^h25^m15^s$	2	-06° 55'	30		+0.7	-1.0	-2.7		
15	$18^h30^m06^s$	2	-08° 37'	30		+2.6	+0.7	-1.8		h
16	$18^h30^m12^s$	3	-09° 59.5'	45				-0.8		i
17	$18^h32^m45^s$	3	-11° 31'	45				-1.9		
18	$18^h34^m23.8^s$	3	+05° 34'	45				-1.5		
19	$18^h36^m09^s$	2	-05° 25.75'	30		+1.7	-0.8	-2.8		
20	$18^h48^m32^s$	2	+09° 28.5'	30		+1.6	+0.1	-2.1		
21	$19^h12^m00^s$	2	+10° 50.5'	30		+4.3	+2.8	-1.7		j
22	$19^h14^m28.5^s$	2	+09° 34'	30		+1.3	+0.1	-2.2		
23	$19^h19^m12^s$	2	-26° 18'	30		+1.2	-0.2	-1.8		
24	$19^h43^m06.5^s$	1	+35° 10' 30"	15	+6.1	+3.9	+1.5	-0.4		
25	$20^h00^m17^s$	2	+40° 51'	30	+4.6	+1.4	-0.6	-2.5		k
26	$20^h08^m17.5^s$	2	+31° 21.5'	30	+3.7	+1.3	-0.3	-1.8		
27	$20^h28^m22^s$	1	+40° 06' 20"	15	+6.1	+1.7	-0.5	-2.1		l

TABLE IIIb

UNIVERSITY OF ARIZONA

U of A No.	α (1972)	±ε^s	δ (1972)	±ε"	K	L	M	N	Q	Remarks
1	$03^h25^m23.5^s$	.75	+58° 41' 10"	10	+4.1		+1.9	-0.9	-2.3	a
2	$06^h02^m29.3^s$	1	+07° 26' 07"	15	+6.8	+2.6	+0.2	-2.4		b
3	$06^h18^m36.6^s$	1	-10° 36' 50"	15	+3.4	+1.4	+0.1	-2.0		c
4	$08^h36^m48.0^s$	1	-10° 18' 19"	15	+5.3	+2.9	+1.4	-0.8		d
5	$14^h09^m45.5^s$	2	-07° 36' 33"	30				-0.6		e
6	$17^h06^m16.9^s$	1	-24° 42' 19"	15	+5.4	+2.0	-0.5	-3.2		
7	$17^h48^m54.5^s$	2	-27° 51.5'	30		+2.9	+1.8	-1.4		f
8	$17^h52^m40^s$	2	-25° 49.5'	30		+2.6	+0.8	-0.8		
9	$18^h09^m47^s$	2	-26° 30'	30		+3.0	-1.7	-0.8		
10	$18^h14^m59^s$	3	-18° 59.5'	45				-1.6		
11	$18^h19^m47.5^s$	2	-13° 02'	30		+2.9	+1.0	-2.2		g
12	$18^h20^m49.5^s$	2	-27° 07.25'	30		+0.1	-1.9	-3.8		
13	$18^h25^m01^s$	2	+23° 27.75'	30		+3.0	+0.7	-2.2		
14	$18^h25^m15^s$	2	-06° 55'	30		+0.7	-1.0	-2.7		
15	$18^h30^m06^s$	2	-08° 37'	30		+2.6	+0.7	-1.8		h
16	$18^h30^m12^s$	3	-09° 59.5'	45				-0.8		i
17	$18^h32^m45^s$	3	-11° 31'	45				-1.9		
18	$18^h34^m23.8^s$	3	+05° 34'	45				-1.5		
19	$18^h36^m09^s$	2	-05° 25.75'	30		+1.7	-0.8	-2.8		
20	$18^h48^m32^s$	2	+09° 28.5'	30		+1.6	+0.1	-2.1		
21	$19^h12^m00^s$	2	+10° 50.5'	30		+4.3	+2.8	-1.7		j
22	$19^h14^m28.5^s$	2	+09° 34'	30		+1.3	+0.1	-2.2		
23	$19^h19^m12^s$	2	-26° 18'	30		+1.2	-0.2	-1.8		
24	$19^h43^m06.5^s$	1	+35° 10' 30"	15	+6.1	+3.9	+1.5	-0.4		
25	$20^h00^m17^s$	2	+40° 51'	30	+4.6	+1.4	-0.6	-2.5		k
26	$20^h08^m17.5^s$	2	+31° 21.5'	30	+3.7	+1.3	-0.3	-1.8		
27	$20^h28^m22^s$	1	+40° 06' 20"	15	+6.1	+1.7	-0.5	-2.1		l

TABLE IIIb (CONT'D)

Remarks:

a - Found by U of A survey
~ 20 mag. red star

b - Visual limit ~ 15 mag.

c - DM-10 1476 V +8.8 mag.
Spectral Type B8

d - Visual limit ~ 15 mag.

e - Star on Palomar photograph
~ 20 mag.

f - 10th mag. star

g - Possible ~ 10 mag. star

h - Near RCW 171

i - Area of SG 021.9-0.4

j - Near OH Region G45.1 +0.1
Verified from AFCRL 217-963 - 1st list
Deleted from 2nd list

k - W-57 area

l - W-67 area

TABLE IV

Objects from 1st List Searched for But Not Verified

AFCRL#	α	δ	AFCRL#	α	δ
509-1548	6 52.3	-20 57	208-1534	16 48.5	-13 40
513-784	9 12.5	21 59	401-2140	17 9.3	2 38
518-700	9 42.0	2746	404-2101	17 12.7	- 1 55
524-914	9 51.7	8 18	401-2017	17 39.9	- 0 3
222-2948	10 53.4	33 25	220-128[illegible]	18 23.4	-13 14
425-3189	11 46.0	51 40	215-1196	18 26.1	- 3 51
420-3154	12 27.4	51 40	203-587	18 28.4	39 53
422-3096	12 29.1	46 02	218-1204	18 36.7	- 6 50
216-2388	12 40.1	- 5 32	215-1030	18 57.2	16 40
206-2474	13 2.1	6 27	217-963	19 12.4	10 47
423-2808	13 28.2	22 52	217-959	19 13.0	11 5
424-2745	13 38.4	17 25	215-665	19 37.1	33 53
423-2713	13 52.8	16 18	219-764	19 45.8	25 7
423-2687	13 58.0	14 19	224-601	20 26.4	37 17
408-2958	14 11.4	41 42	224-566	20 31.7	40 11
425-2548	14 21.3	2 32	402-1243	20 54.7	9 6
424-2548	14 26.0	3 39	402-1213	21 11.0	10 30
412-2633	14 49.7	17 34	402-1022	21 34.3	20 35
405-2641	15 13.1	22 07	402-994	21 40.6	21 55
407-2541	15 26.3	15 22	404-1020	21 42.0	19 29
407-2517	15 29.1	13 38	404-914	21 59.0	25 46
407-2493	15 33.9	12 17	403-767	22 19.0	35 4
409-2307	16 9.0	0 56	406-701	22 42.9	38 12

TABLE V

Objects from 2nd List Searched for But Not Verified

AFCRL#	α	δ	AFCRL#	α	δ
518-2620	1 52.6	5 19	423-3000	12 47.2	37 56
526-2068	3 32.4	-37 2	703-1792	12 56.7	- 0 54
628-1641	5 2.3	-33 4	425-2819	13 19.9	22 47
726-2995	7 9.4	37 40	425-2820	13 21.3	23 6
511-1491	7 10.8	-20 15	732-1705	13 36.9	-31 52
519-1449	7 45.2	-26 12	210-2196	13 40.4	-11 03
527-1383	8 30.5	-28 58	203-2264	13 45.4	- 1 57
512-1064	8 40.1	2 18	732-1684	13 46.0	-31 33
710-2960	8 43.3	42 34	732-1681	13 47.2	-31 30
513-397	9 .8	51 18	732-1676	13 49.8	-31 41
718-2579	9 29.5	15 49	408-2957	14 11.6	41 42
523-880	9 49.7	11 37	217-1993	14 24.6	-24 40
226-3242	10 .1	58 2	401-3246	14 44.3	62 58
521-486	10 4.9	45 34	403-2847	14 51.2	35 60
720-2308	10 9.6	- 5 4	226-1872	15 .9	-36 47
524-652	10 14.2	30 52	409-2401	15 47.8	5 57
421-3393	10 39.9	68 49	407-2425	15 49.3	8 57
527-447	10 41.4	48 47	401-2440	16 4.1	13 57
723-2071	10 57.9	-27 29	221-1721	16 4.3	-30 45
219-2825	11 21.6	24 16	411-2289	16 9.0	- 1 28
732-1887	12 15.8	-32 3	204-1617	16 20.8	-11 22
414-3265	12 43.9	63 1	215-1551	16 57.1	-21 24
226-2228	12 46.9	-23 2	225-1603	16 57.6	-32 49

TABLE V (CONT'D.)

AFCRL#	α		δ	
402-2170	17	.6	2	41
401-2171	17	1.0	3	2
202-186	17	10.9	61	18
733-1088	17	14.1	- 3	12
710-514	17	23.8	51	15
403-2033	17	32.8	- 2	2
718-722	17	35.3	33	15
425-1911	17	49.3	-28	24
724-771	17	54.1	26	5
204-1105	18	2.4	8	27
424-1868	18	7.6	-27	31
418-1873	18	9.1	-20	25
213-1236	18	10.5	- 4	35
419-1852	18	16.0	-22	8
409-1826	18	27.7	-10	59
216-1201	18	28.3	- 4	52

IV. Absolute Calibration of Ground-Based Astronomy:

The original Arizona photometric system extends in wavelength from the visible to 10.2μ and was calibrated by Johnson (1965). His calibration was based on absolute flux measurements of the sun made by Saiedy (1960) and others, and on the assumption that solar type stars observed on the photometric system have flux distributions identical to that of the sun. Low and Smith (1966) extrapolated this procedure to 22μ. It was realized that this type of calibration, though probably reliable within the stated uncertainty of ±15 to ±20 percent, should be improved by means of an absolute radiometric measurement of bright stars and planets. Here we report the results of such an experiment. It should be noted that in the intervening years since Johnson's original work the accuracy and sensitivity of infrared observations has improved greatly. Therefore Low and Rieke (1973) recently reobserved a set of solar type stars at 2.2, 3.5, 5.0 and 10.6μ and updated the original Johnson calibration. Thus we will be able to compare the new radiometric determinations with a modern revision of the classical stellar calibration. It will be seen that rather good agreement exists between these two totally independent procedures.

Any absolute calibration of groundbased photometry must take into account the uncertainties introduced by the atmosphere. To minimize this problem we chose a narrow band filter centered at 11.34 ± .15μ with a band width of only .79μ. A 12-inch infrared telescope was utilized with a germanium bolometer as the detector. The 1.0 arcmin diameter beam was switched rapidly between sky and star using the secondary mirror. A temperature regulated black-body cavity manufactured by Barnes, Inc. was located on a horizontal path at a distance of 515m. The black-body cavity was positioned behind a uniform black screen large enough to subtend the full diameter of both beams. The black-body cavity was heated to a temperature of 600°C and could be manually blanked by means of an ambient temperature shutter. Measurements of the black-body source were made during the winter of 1971-72 when the planet Mars was conveniently located in the southern sky. Thus it was possible to rotate the telescope from the horizontal position to make repeated measurements of Mars and the black-body source. Signals of comparable strength were measured in both cases. The results for Mars are given in Table VI below.

Mars is, of course, highly variable though extremely bright in the infrared. In order to relate the absolute calibration of Mars to standard stars whose magnitudes were both well determined and known to be constant we carried out an additional concurrent set of observations at a nearby site. We made observations of Mars and several bright standard stars using an identical filter. Although the telescope was 28 inches in diameter the angular size of the beam was still 1 arcminute. The results for the standard stars are quoted in Table VI below.

TABLE VI. Absolute Fluxes at 11.34μ

Source	Flux Density ($w/cm^2/\mu$)	Percent Error
Mars (1-4-72)	3.38×10^{-13}	6
β And	5.27×10^{-16}	10
α Tau	1.22×10^{-15}	10
α Aur	4.38×10^{-16}	10

The procedure utilized here appears to be fully capable of yielding results with a precision better than 5 percent. It should be noted that a major source of error, namely atmosperic losses, is largely conpensated by the equivalence of the horizontal path to the black-body source and the slant path to the star or planet. In making the transfer from Mars to the standard stars it is only necessary to apply differential extinction corrections which are essentially negligible at 11.0μ. Error analysis of the absolute measurement of Mars with the 12-inch telescope yields a conservative estimate of total error equal to ±6 percent. Unfortunately, the 28-inch observations of Mars and standard stars introduces additional uncertainties which raise the final error to ±10 percent. It should be noted that this new absolute calibration agrees with the stellar results based on stars like the Sun to within only 4 percent. We therefore have adopted an average of the two results and fix the maximum error at ±7 percent.

In Table VII we list the absolute fluxes for zero magnitude stars observed on the revised Arizona photometric system. No errors are given since these values are adopted as part of the defining criteria. Table VIII lists magnitudes of the principle standard stars based on the Low and Rieke (1973) results from solar type stars and Saiedy's (1960) solar fluxes and on our new absolute radiometry experiment. The interpolation from 11.34μ to 10.6 and 21μ was made assuming the stars emit like 4000°K blackbodies over this interval. In using these results note that β And, α Tau and α Aur should be accurate to ±7 percent but that the stars in other parts of the sky are less well determined. At 10.6μ the largest error should be smaller that ±10 percent. At M and Q the data are not as reliable as at K, L and N where ±10 percent or better seems conservative. M and Q results may be uncertain by ±15 percent.

TABLE VII. Flux Level for 0.0 Magnitude

Filter	$\lambda_o(\mu)$	$F(\lambda)$ ($W/cm^2\mu$)	$F(\nu)$ W/m^2Hz
K	2.22	4.14×10^{-14}	6.80×10^{-24}
L	3.6	6.38×10^{-15}	2.76×10^{-24}
M	5.0	1.82×10^{-15}	1.52×10^{-24}
N	10.6	9.7×10^{-17}	3.63×10^{-25}
Q	21	6.5×10^{-18}	9.56×10^{-26}

TABLE VIII. Magnitudes of Standard Stars

Name	B.S.	K	L	M	N	Q
β And	337	-1.85	-2.10	-1.97	-2.06	-2.23
α Ari	617	- .65	- .75	- .80	- .78	- .85
α Tau	1457	-2.89	-3.00	-2.89	-2.99	[illegible]
α Aur	1708	-1.78	-1.86	-1.92	-1.90	-1.93
α CMi	2943	- .64	- .67		- .48	- .57
α Hya	3748	-1.16	-1.36	-1.25	-1.30	
α Boo	5340	-2.99	-3.14	-2.98	-3.05	-3.30
γ Dra	6705	-1.29	-1.50		-1.36	-1.52
γ Aql	7525	- .59	- .80			

REFERENCES

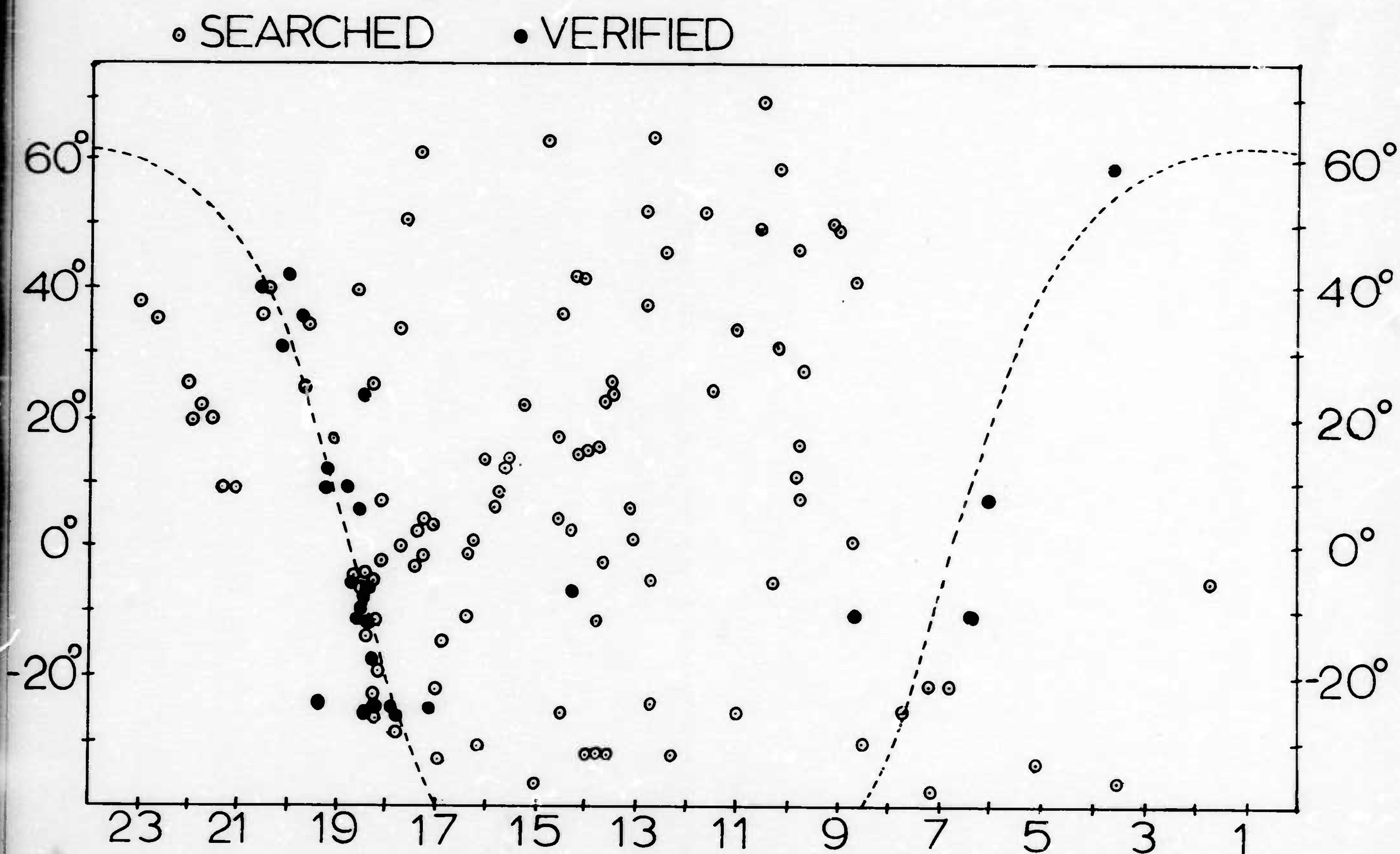
1. Johnson, H.L., Comm. Lunar and Planetary Lab. #53 (1965).
2. Low, F.J. and Smith, B.J., Nature 212, 675-76 (1966).
3. Low, F.J. and Rieke, G.H., In Press (1973).
4. Saiedy, F., M.N., 121, 483 (1960).
5. Walker, R, and Price, S.D., Private Communication (1972).

FIGURE CAPTIONS

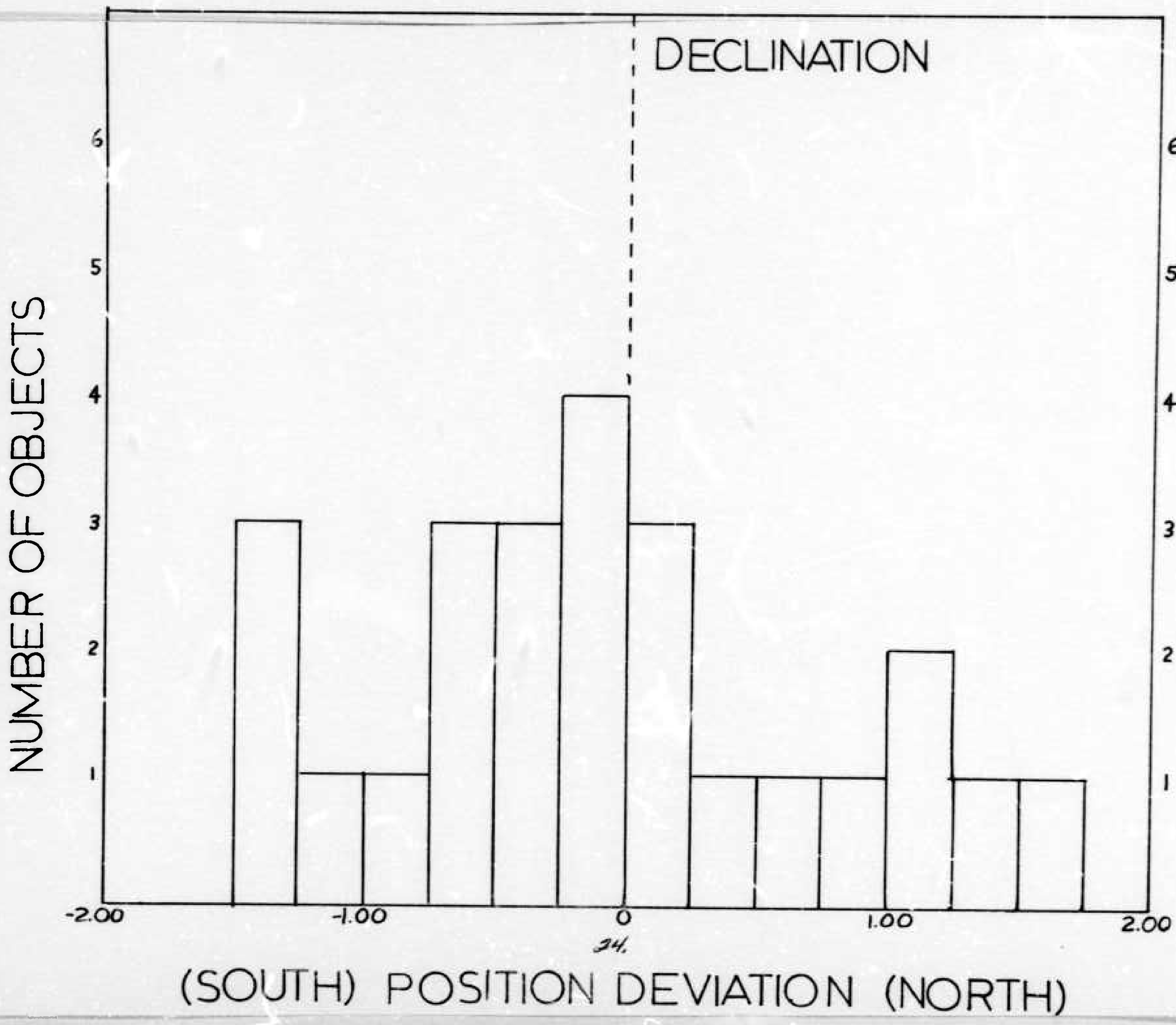
1. A map of the sky showing the sources from the AFCRL lists. The open circles represent sources that could not be verified. The filled circles represent sources that were verified. Further data is presented in Tables III, IV and V.

2. Histogram showing the differences between measured positions and AFCRL positions in declination for sources that were verified.

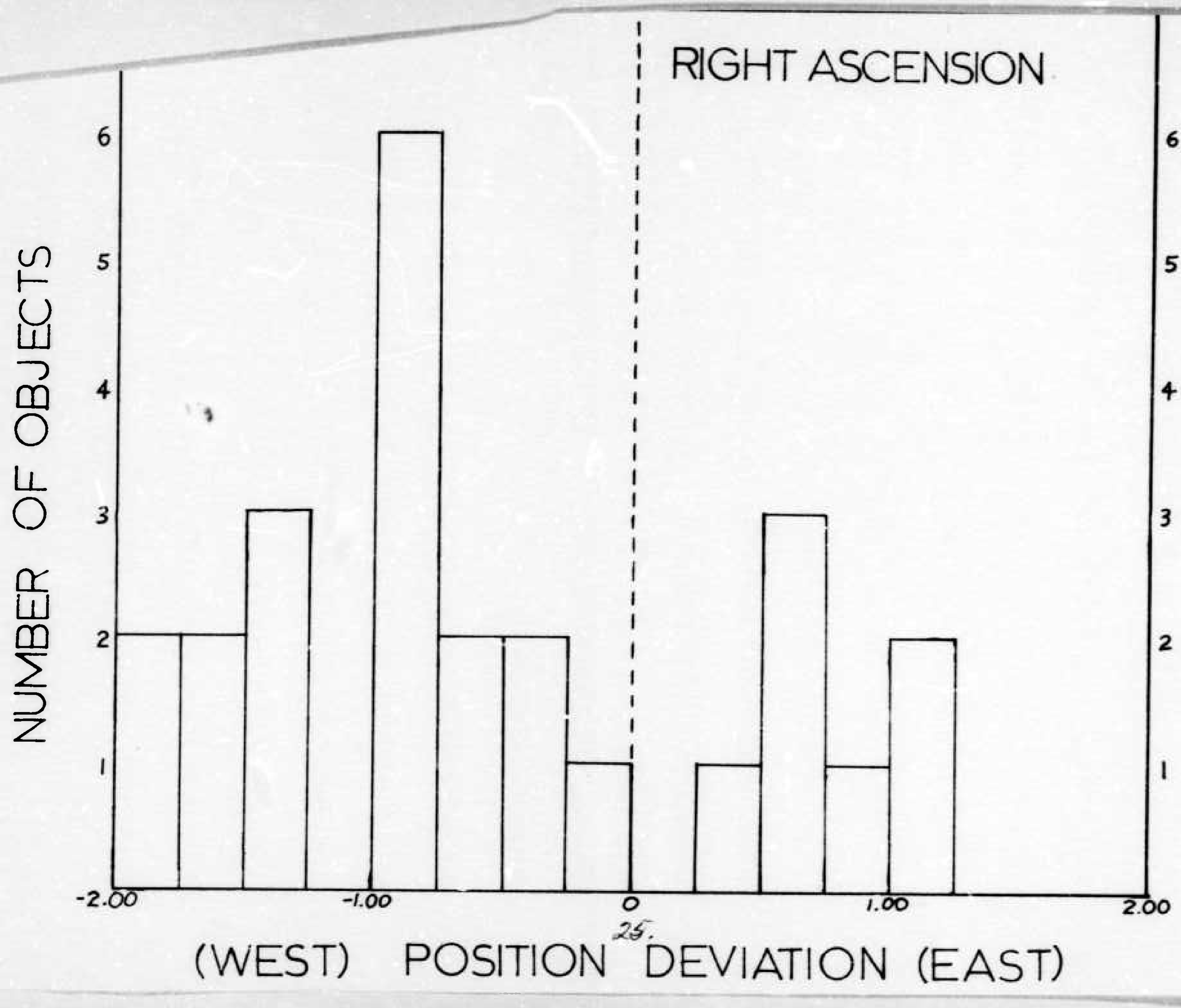
3. Histogram showing the differences between measured positions and AFCRL positions in ascension for sources that were verified.



SEARCHED
VERIFIED
60°
40°
20°
0°
-20°
23
21
19
17
15
13
11
9
7
5
3
1


DECLINATION
NUMBER OF OBJECTS
1
2
3
4
5
6
-2.00
-1.00
0
1.00
2.00
(SOUTH) POSITION DEVIATION (NORTH)

24.


RIGHT ASCENSION
NUMBER OF OBJECTS
6
5
4
3
2
1
-2.00
-1.00
0
1.00
2.00
(WEST) POSITION DEVIATION (EAST)

25.