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UNIDENTIFIED POINT SOURCES IN THE *IRAS*[1] MINISURVEY

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ABSTRACT

Nine bright pointlike 60 μm sources have been selected from the sample of 8709 sources in the *IRAS* minisurvey. These sources have no counterparts in a variety of catalogs of nonstellar objects. Four objects have no visible counterparts, while five have faint stellar objects visible in the error ellipse. These sources do not resemble objects previously known to be bright infrared sources.

Subject heading: infrared: sources

I. INTRODUCTION

The discovery of fundamentally new types of objects is one of the potentials of every new instrument having unique capabilities. This is certainly the situation for *IRAS*. In this *Letter* we describe a group of unresolved point sources selected from the *IRAS* minisurvey data base (Rowan-Robinson *et al.* 1984) which we have not been able to correlate with any previously cataloged objects. In some cases, there are no objects visible on the Palomar Observatory Sky Survey (POSS) prints. In the others, one or more faint stellar-like images are within the 3 σ error ellipse about the *IRAS* position. In the next section, we describe the search criteria used in this study and the attempts to correlate these objects with previously cataloged objects.

II. OBSERVATIONS

The *IRAS* telescope and data reduction system are described in Neugebauer *et al.* (1984, hereafter Paper I). From the 8709 well-confirmed sources in the *IRAS* minisurvey data base, 133 objects were selected for being bright at 60 or 100 μm, or at both, but faint at the shorter wavelengths. In addition, these sources satisfied the following criteria.

1. To ensure confidence in their reality, the objects had to be detected on two or more independent scan pairs (hours-confirmations, see Paper I). The scans in a pair are separated by one or two orbital periods, while subsequent pairs are separated by one to several days. The reliability of such an object exceeds 99.8% (Rowan-Robinson et al. 1984).
2. To avoid confusion effects from the galactic plane, sources were required to have a galactic latitude $|b| > 20°$.
3. To ensure reasonably uniform and complete coverage by other catalogs, the declination had to exceed $-2\overset{\circ}{.}5$.
4. On both scans of at least one scan pair, the source had to be detected at both 60 and 100 μm.

A comparison of these 133 sources with the Ohio State University catalog of nonstellar objects (Dixon and Sonneborn 1980) revealed 42 matches, of which one was a known quasar, 38 were cataloged as galaxies, two were H II regions, and one was a reflection nebula. A visual inspection of the POSS prints revealed that 32 additional sources were associated with faint uncataloged galaxies within 1′ of the *IRAS* position (see Soifer *et al.* 1984). Eleven objects had faint galaxies near but outside the *IRAS* error ellipses. These may or may not be correlated with the *IRAS* sources. The remaining 48 objects were either in blank fields or in fields containing stellar-like images near the plate limit.

Of these 48 objects, 30 appear to arise in regions that are confused by the complex extended structure present in many parts of the sky. They all show weak correlations with the point-source profile at both 60 and 100 μm. These may be "hotspots" in the "infrared cirrus" discussed by Low *et al.* (1984) and are not considered further here.

A group of nine sources near R.A. = 4^h10^m, decl. = $+10°$ lie near the reflection nebula/H II region LBN 0828 (Lynds 1965) and may be associated with a nearby galactic cloud. The infrared characteristics of these sources are similar to those of infrared sources associated with Barnard 5 and other embedded objects found by *IRAS* (Beichman *et al.* 1984; Rowan-Robinson *et al.* 1984). These sources also are not considered further here.

Having eliminated a large number of potentially very interesting unidentified field objects, we are left with nine objects which are scattered throughout the minisurvey area and do not appear to cluster around either the galactic or ecliptic planes. Figures 1*a*–1*i* (Plates L7–L15) present finding charts for these sources. Table 1 lists the observed characteristics for each source, the expected interstellar reddening based on the work of Burstein and Heiles (1982), and the effective blackbody temperature based on the 60 μm to 100 μm flux ratio. The error rectangles listed for each source are derived from the uncertainty in the source's position as it passes across the focal plane and the uncertainty in the pointing of the telescope. There may be subtle systematic errors in the latter. We have, therefore, restricted the minimum error to be 15″. Two of the sources, 0404+101 and 0413+122, lie near the cluster mentioned above and may or may not be members. They are included here because of their questionable membership and

[1]The *Infrared Astronomical Satellite* was developed and is operated by the Netherlands Agency for Aerospace Programs (NIVR), the US National Aeronautics and Space Administration (NASA), and the UK Science and Engineering Research Council (SERC).

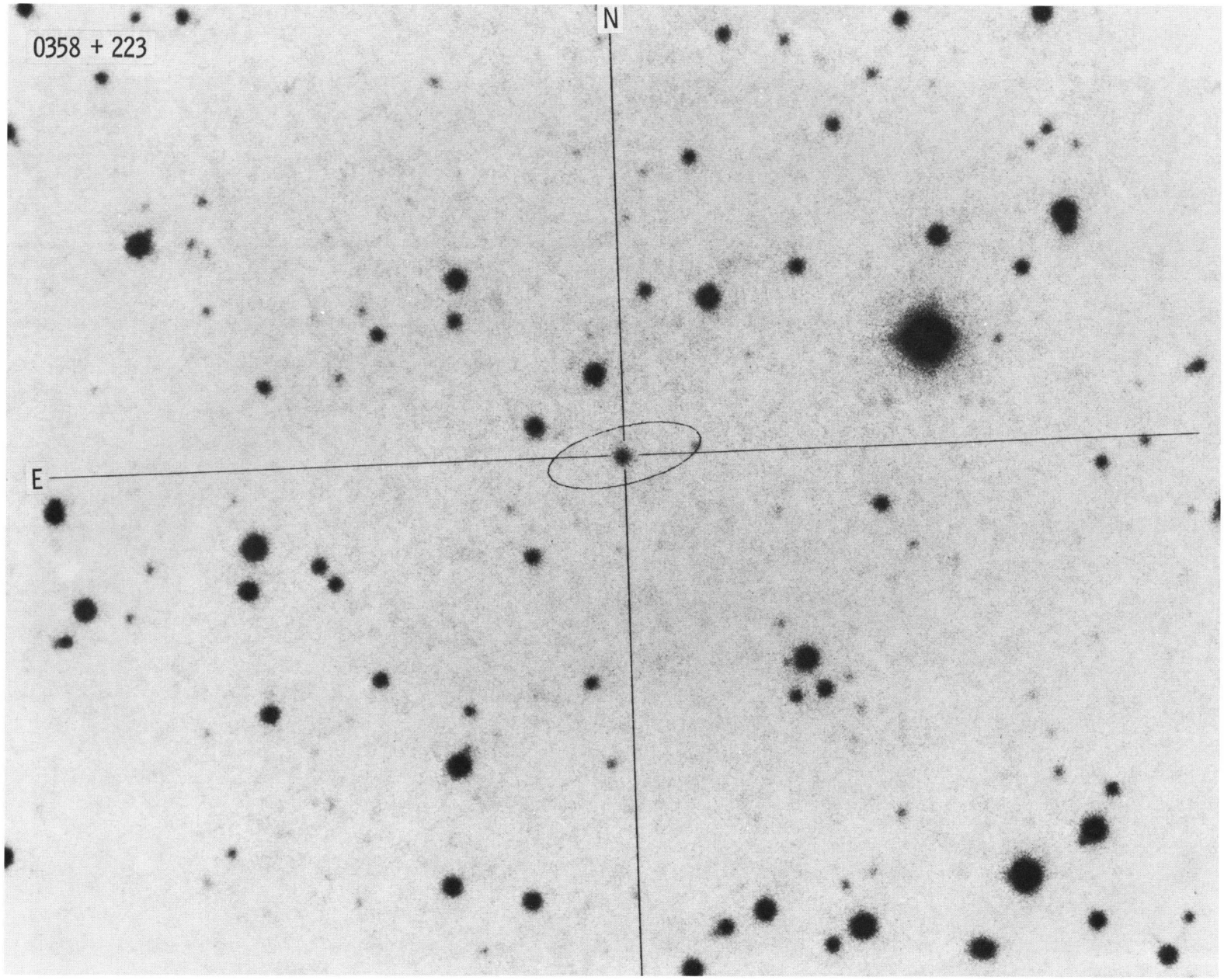

FIG. 1*a*

FIG. 1.—(*a*)–(*i*) POSS prints for the sources listed in Table 1 are shown. The error rectangles/ellipses correspond to the expected 3 σ errors for the 60 μm detections.

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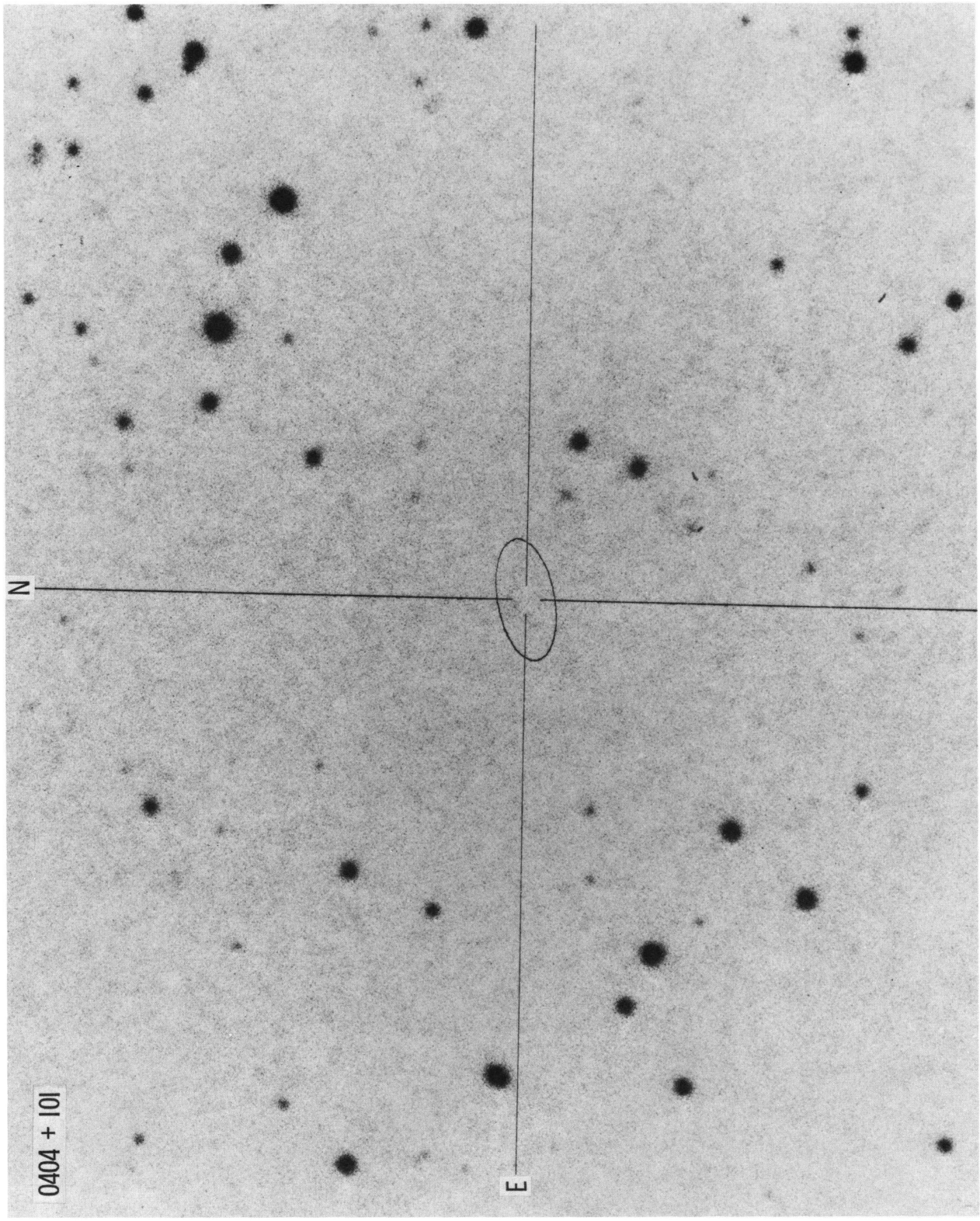

Fig. 1*b*

HOUCK *et al.* (*see* page L63)

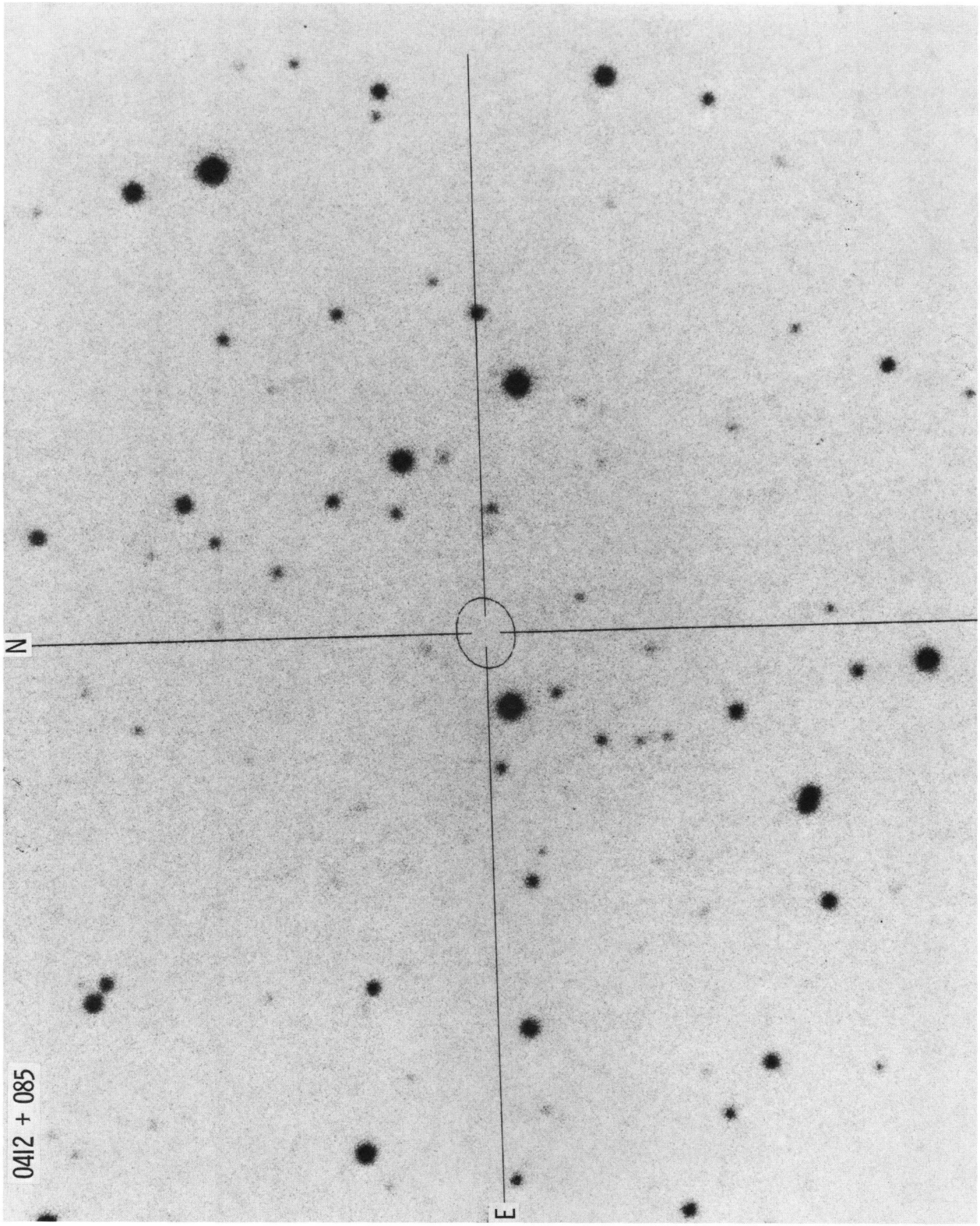

Fig. 1*c*

HOUCK *et al.* (*see* page L63)

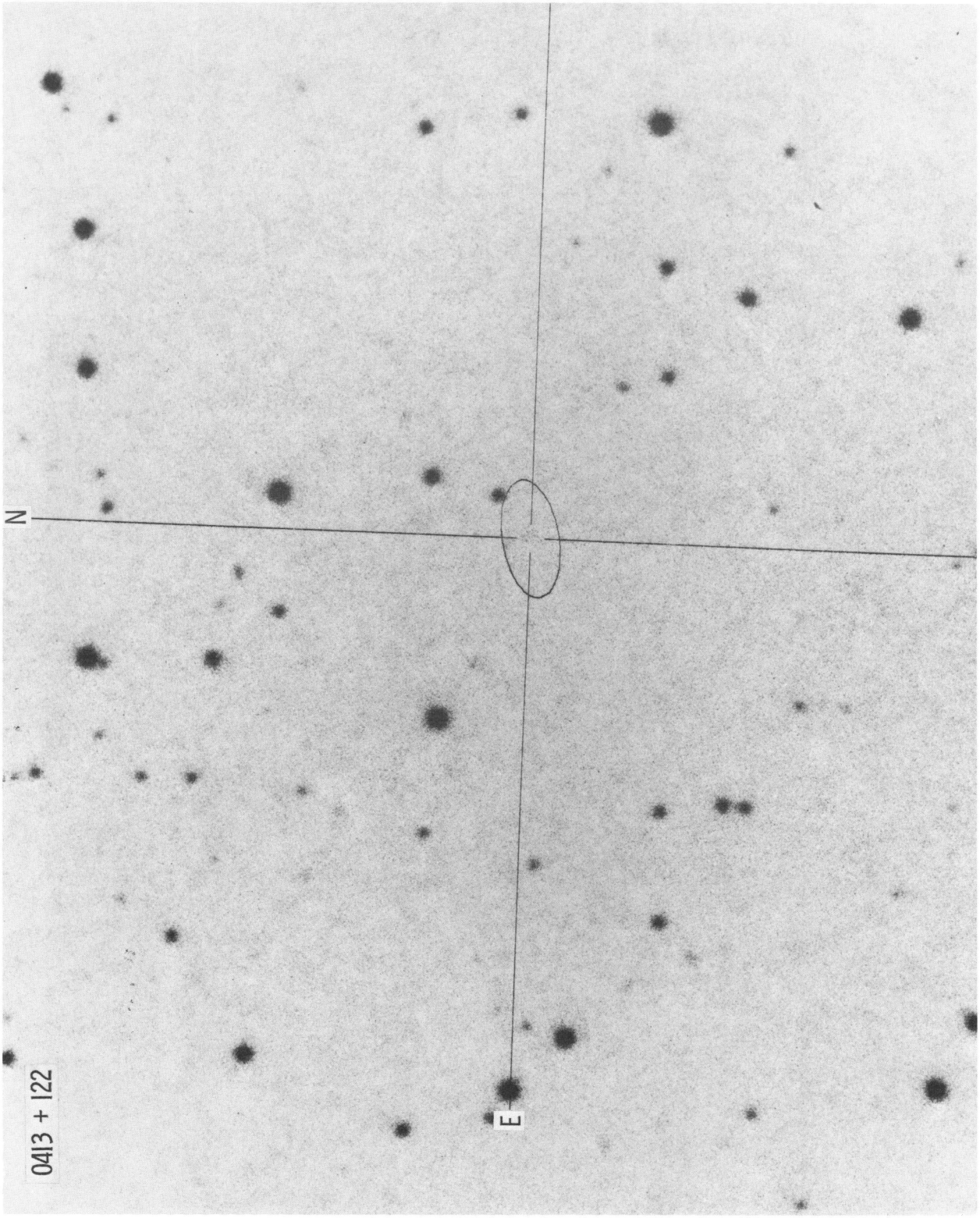

Fig. 1*d*

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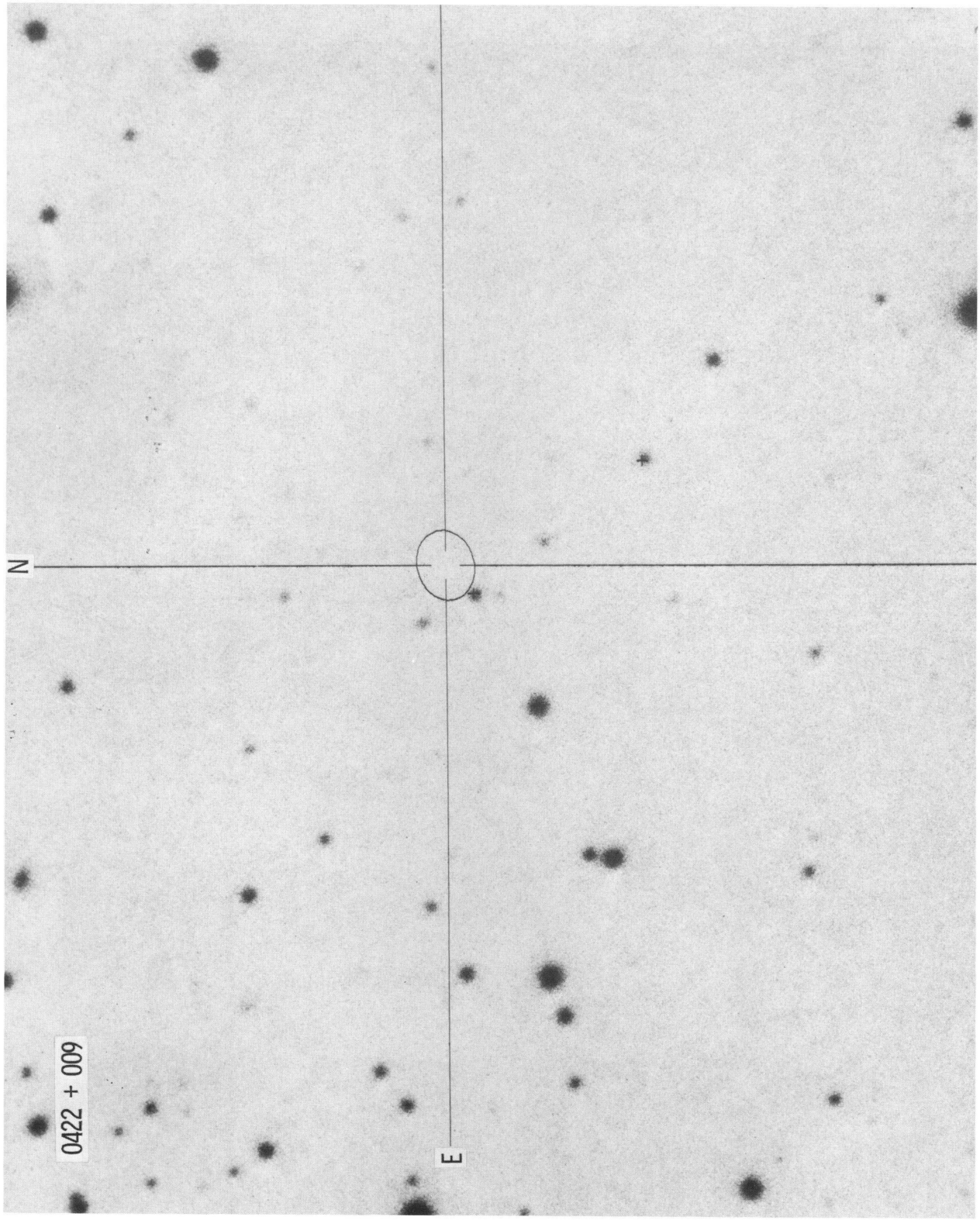

Fig. 1*e*

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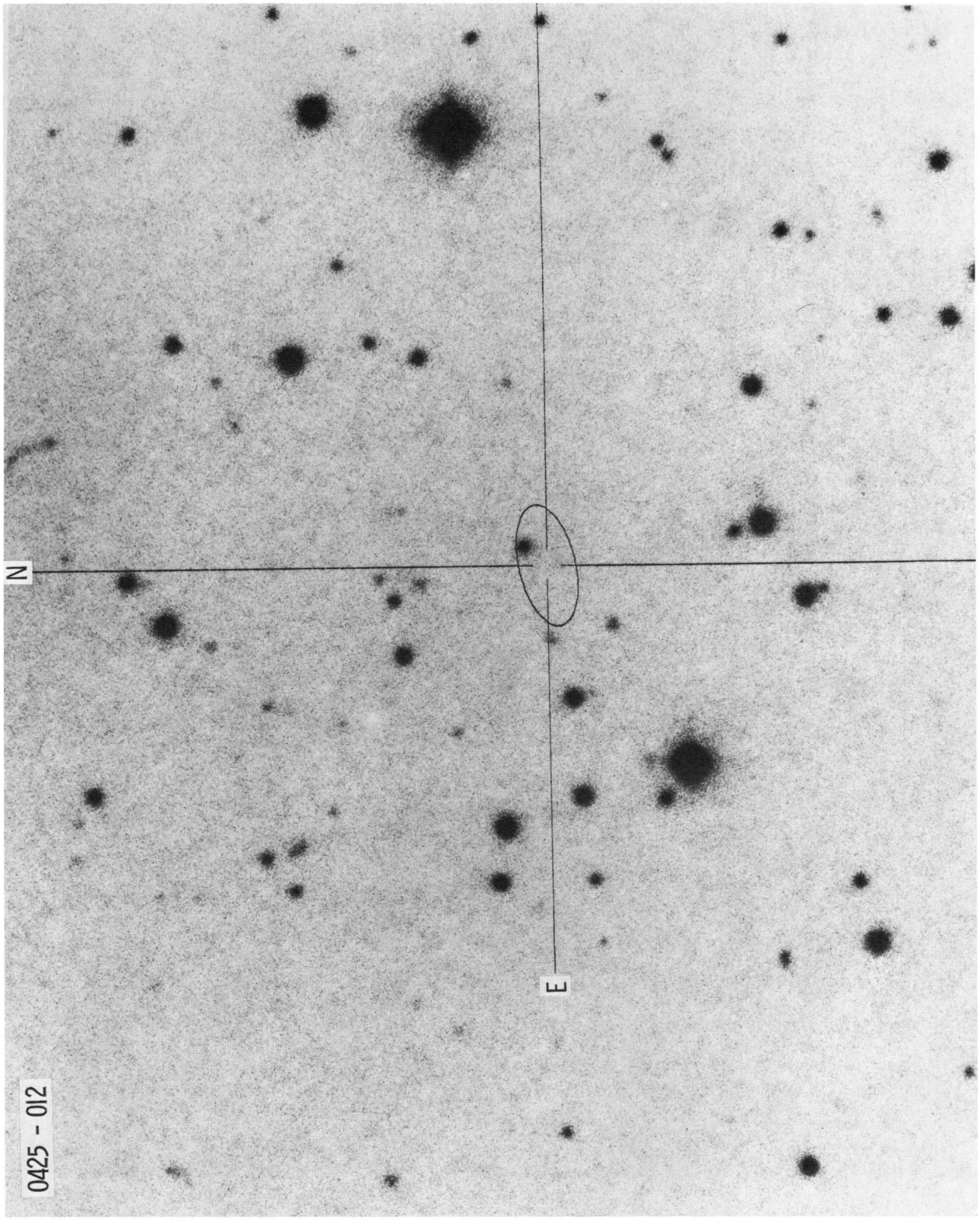

Fig. 1*f*

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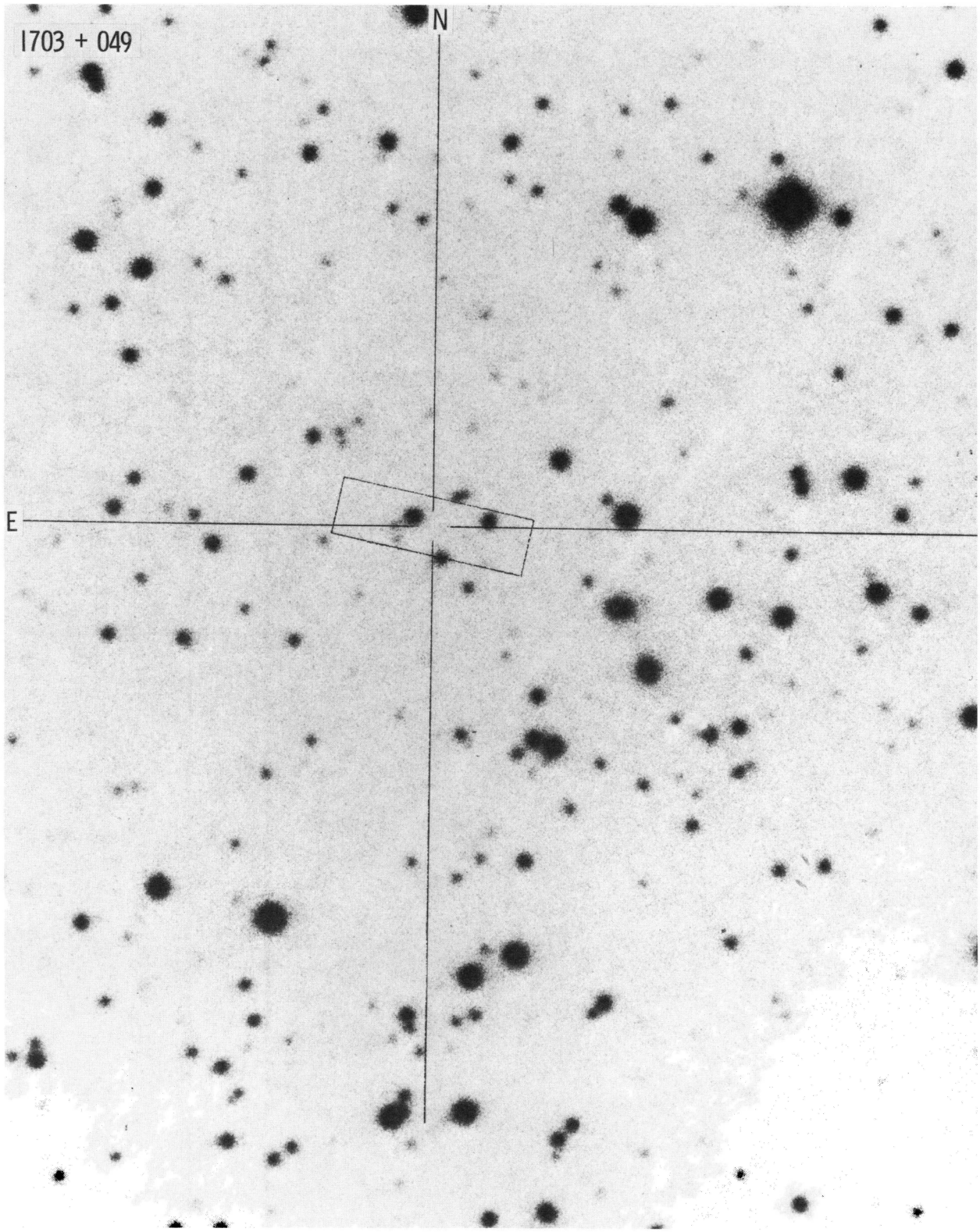

Fig. 1*g*

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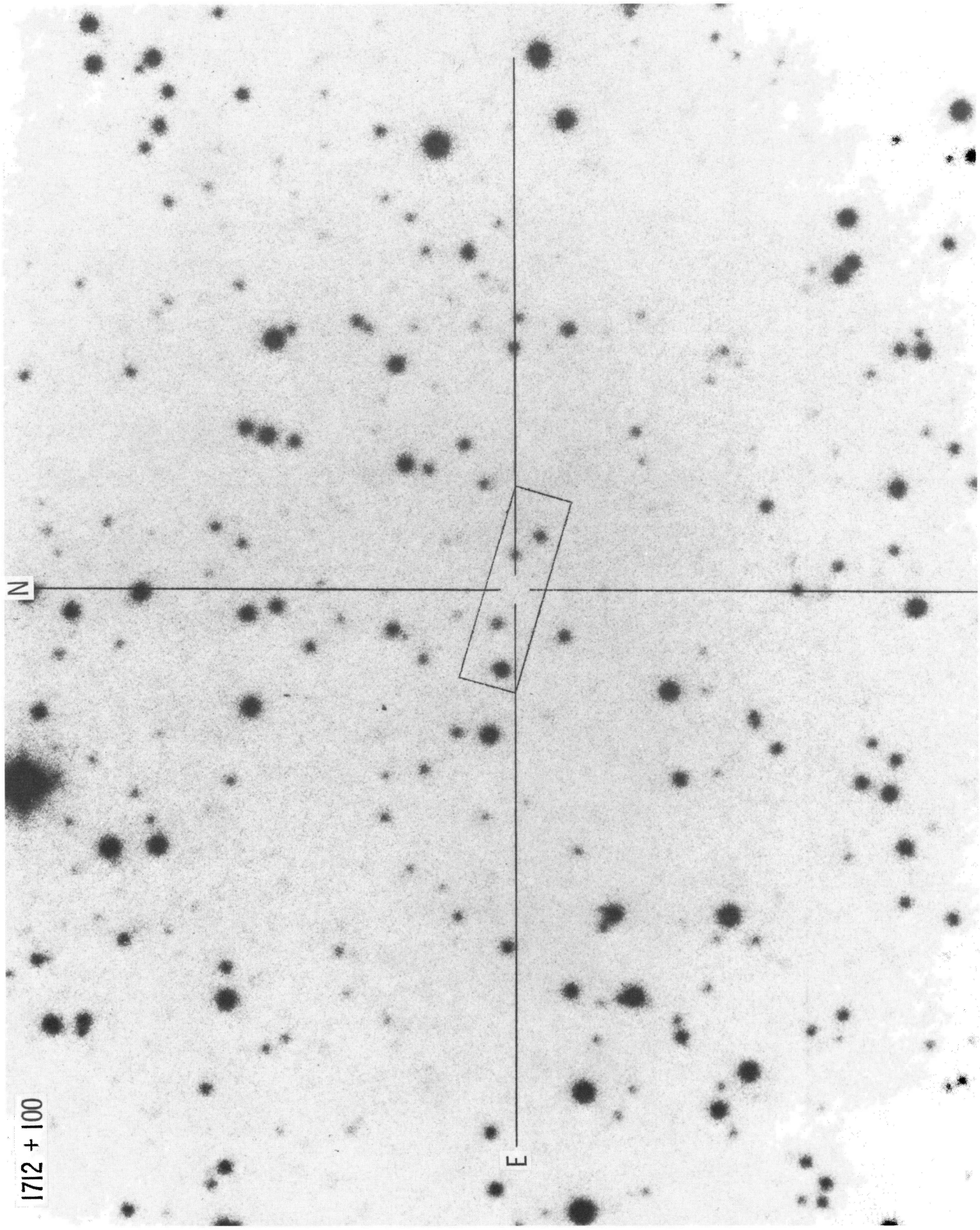

Fig. 1*h*

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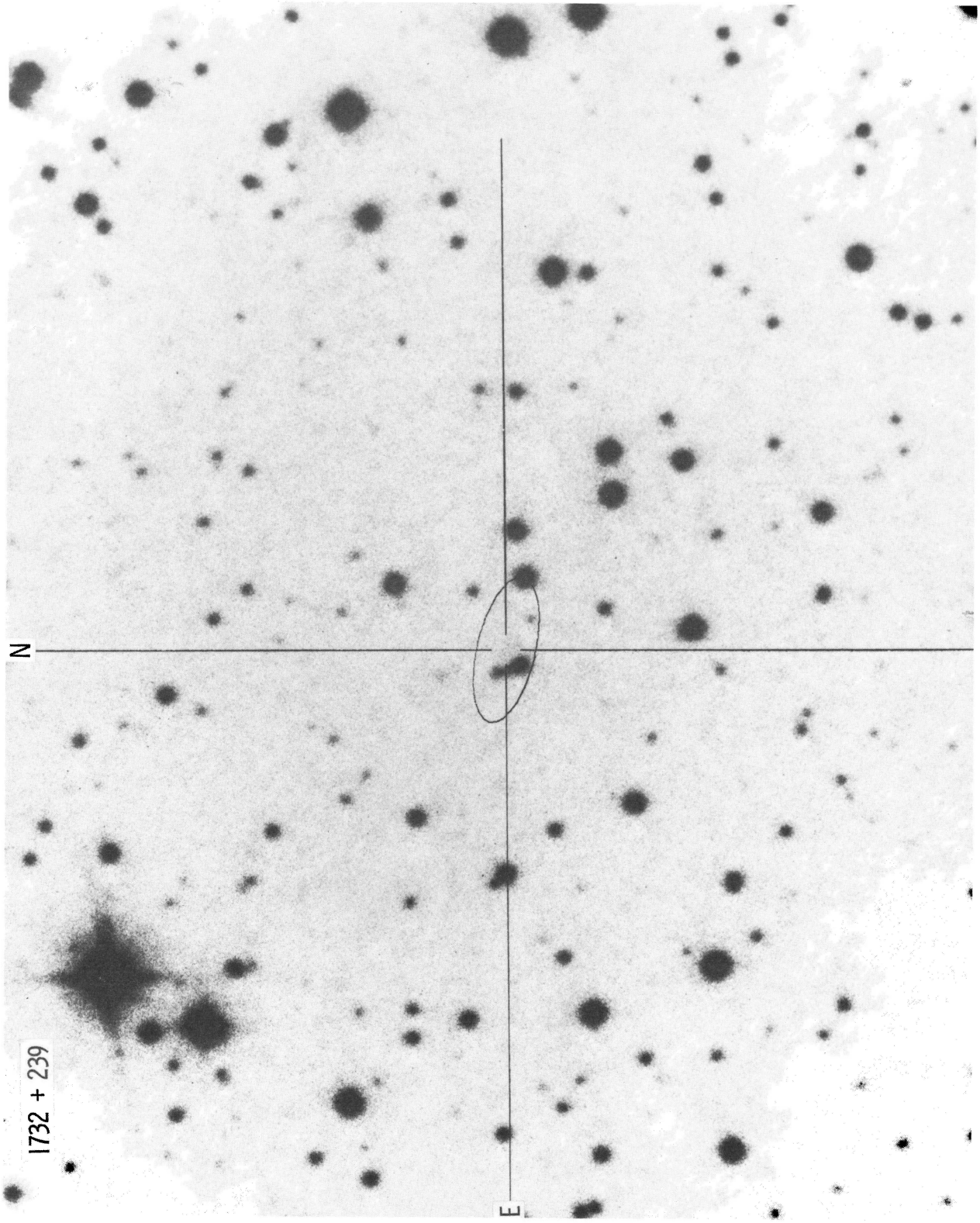

Fig. 1*i*

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TABLE 1

IRAS UNIDENTIFIED SOURCES

Name	1950 Position R.A.	1950 Position Decl.	Uncertainty[a] Rectangle Size (arcsec)	Uncertainty[a] Rectangle P.A.	b[b]	β[c]	Flux Densities[d] 60 μm (Jy)	Flux Densities[d] 100 μm (Jy)	N_{sp}[e]	$E(B-V)$[f] (mag)	T_{BB}[g] (K)
0358+223	$03^h58^m02^s.8$	+22°18′00″	84 × 30	101°	−22°.5	1°.8	0.68 ± 0.04	1.5 ± 0.15	5	0.15	44
0404+101	04 04 44.7	+10 11 52	66 × 30	101	−29.5	−10.4	0.56 ± 0.03	4.2 ± 0.3	5	0.24	26
0412+085	04 12 32.3	+08 31 13	38 × 30	102	−29.1	−12.4	1.50 ± 0.16	7.0 ± 1.2	2	0.18	31
0413+122	04 13 47.3	+12 17 36	64 × 30	101	−26.5	−8.8	2.20 ± 0.18	3.4 ± 0.24	4	0.24	55
0422+009	04 22 54.0	+00 56 06	38 × 30	103	−31.4	−20.3	0.68 ± 0.05	3.0 ± 0.6	4	0.09	31
0425−012	04 25 12.1	−01 14 50	66 × 30	102	−32.1	−22.6	0.75 ± 0.06	2.0 ± 0.12	4	0.06	39
1703+049	17 03 01.4	+04 57 50	100 × 30	78	25.7	27.6	0.72 ± 0.04	1.7 ± 0.14	6	0.09	41
1712+100	17 12 57.8	+10 04 08	104 × 30	74	25.9	33.0	0.65 ± 0.05	1.9 ± 0.16	4	0.09	37
1732+239	17 32 51.4	+23 56 36	78 × 30	77	26.8	47.2	0.54 ± 0.04	1.8 ± 0.27	4	0.09	29

[a] Full sized 99% error boxes. P.A., the position angle, refers to the major axis of the box, east of north.
[b] Galactic latitude.
[c] Ecliptic latitude.
[d] The 12 and 25 μm flux densities are less than 0.2 Jy (3 σ) for all objects.
[e] Number of independent scan pairs. The scans in a pair are separated by one or two orbital periods. Pairs of scans are separated by one to several days.
[f] Expected interstellar reddening (Burstein and Heiles 1982).
[g] Blackbody temperature based on the 60 μm to 100 μm flux ratio.

because they are strong pointlike infrared sources. As an illustrative example of the nine unidentified sources, Figures 2*a* and 2*b* show contour plots of the region surrounding source 0422+009. These maps were generated by combining the data from eight scans of the area. Strong 60 μm signals were detected on every scan. A pointlike 100 μm source was detected on only two scans. While a compact source is evident on the 60 μm map, there is little or no indication of it on the 100 μm map. The 100 μm map does, however, show the presence of extended emission throughout the area, probably arising from the low-temperature dust associated with galactic H I clouds along the line of sight (Low *et al.* 1984). All of the unidentified objects presented here consistently show good correlations with the point-source profile at 60 μm. A brief inspection of the data base of sources found only at 60 μm shows an even larger fraction of unidentified objects. One is, therefore, likely to make a significant underestimation of the number of low-temperature unidentified objects based on the current sample.

III. DISCUSSION

For those sources where no stellar objects are within the error ellipse, a limit on the visual to infrared colors can be made by comparing the upper limit on a possible visual object of +18.5 mag and the measured 60 μm flux. The infrared to visual flux ratio is defined by

$$R = (\nu F_\nu)_{60\,\mu\mathrm{m}}/(\nu F_\nu)_{\mathrm{pg}},$$

where $\log(\nu F_\nu)_{\mathrm{pg}} = -7.54 - m_{\mathrm{pg}}/2.5$ with F in W m^{-2} Hz^{-1}. For $m_{\mathrm{pg}} = 18.5$ mag and F_ν (60 μm) = 1.0 Jy, $R = 44$. Several of the objects listed in Table 1 are as faint as 0.5 Jy at 60 μm, and the blue extinction through the Galaxy is as large as 0.75 mag (Burstein and Heiles 1982). Thus the lower limits to the intrinsic infrared to blue luminosity ratios range from about 12 to 50.

There is no reason to assume that these sources are extragalactic or even extra-solar system. Insight into the nature of these objects could be gained if an estimate of the distance were available. Unfortunately, the only sources of information are the *IRAS* data themselves. The fact that multiple hours confirmations are possible only implies that each source lies beyond 30 AU (a 3 σ lower limit).

Soifer *et al.* (1984) and de Jong *et al.* (1984) find that the ratio of infrared to blue luminosity, R, for spiral galaxies ranges from $0.06 \leq R \leq 50$, so the unidentified objects are not inconsistent with more distant (or less luminous) examples of the most infrared-rich spiral galaxies found by these authors.

A circumstellar dust shell origin for these objects is another possibility. An object would be required with enough dust to make the stellar source invisible, while having a dust shell sufficiently far from the star or optically thick, or both, to produce the low color temperatures observed. A highly evolved star, perhaps like the Egg nebula, is a possibility. Perhaps some of the objects where stellar objects are in the error ellipse represent this kind of source.

The sources in the cluster near the H II region/reflection nebula, LBN 0828 and perhaps some of the other unidentified sources, are probably stars in an early stage of formation or very heavily obscured young stars.

An alternative explanation for a 1 Jy source of 60 μm emission is a nearby 40 K blackbody having the same diameter as Jupiter (1.4×10^5 km) at a distance of approximately 570 AU. Therefore, the *IRAS* objects must be very much smaller than Jupiter if they are at all near their 30 AU lower limits. At a distance of 570 AU a Jupiter-like object would have a visual brightness of +18.3 mag and would likely have remained undetected in the visible. By observing an object again about 6 months after the initial observations, the dis-

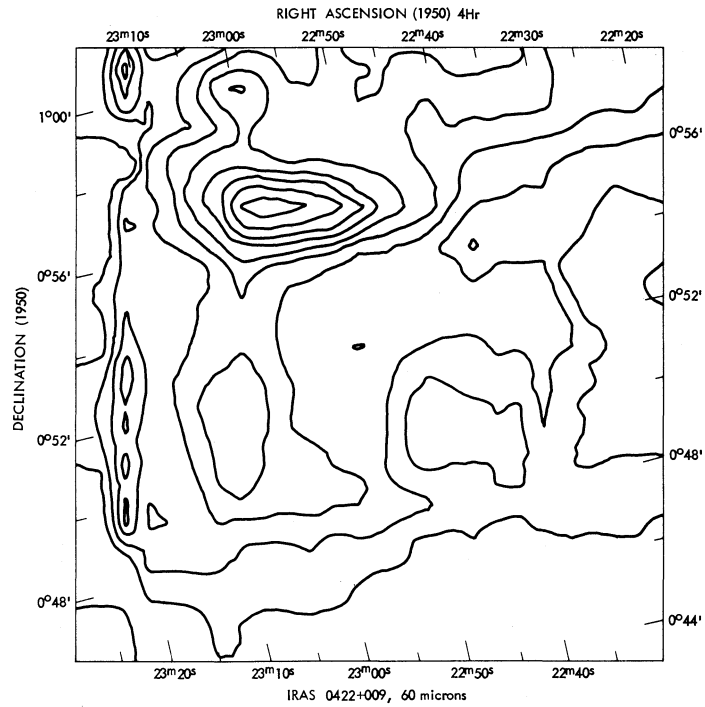

Fig. 2*a*

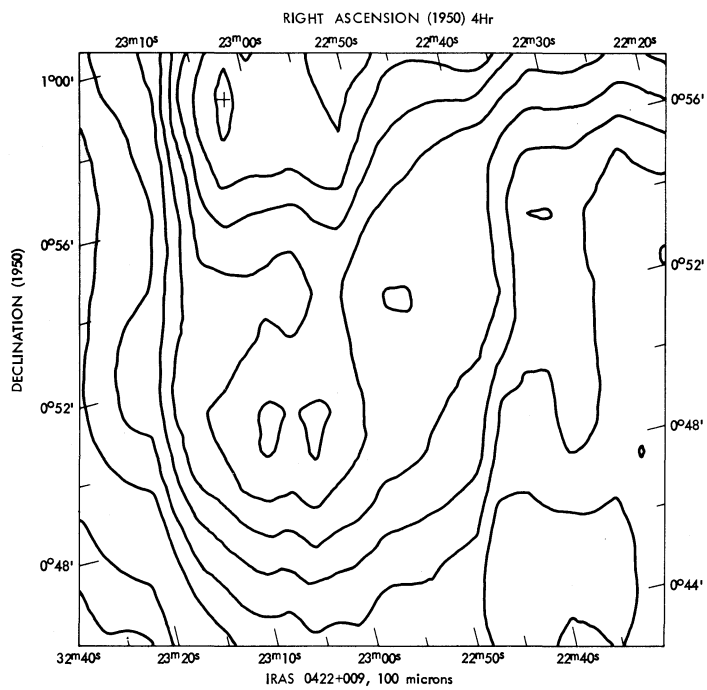

Fig. 2*b*

FIG. 2.—Contour plots for object 0422+009 (Table 1) at (*a*) 60 μm and (*b*) 100 μm. The zero-point calibrations of these maps are still uncertain; however, the steps between contour levels correspond to 2 times the local noise. The highest point on the 60 μm map corresponds to object 0422+009. The highest level on the 100 μm map is indicated by a plus sign. It is not located on the 60 μm peak, and the emission is too extended to be identified as a "point source." There is no indication of emission at 10 or 25 μm.

tance limit for a distant point source can be raised to $\geq$ 5000 AU.

Deeper visual photographs may be able to identify the underlying objects and establish their actual color ratios. High spatial resolution radio observations might also prove useful in classifying these sources. Additional observations are planned with *IRAS* to determine the position of these objects more accurately.

IV. CONCLUSIONS

Data have been presented on nine point sources found in the course of the *IRAS* minisurvey with no obvious identified optical counterparts brighter than 18.5 mag. A number of candidate identifications have been considered including near–solar system, galactic, and extragalactic objects. Further observations at infrared and other wavelengths may provide additional information in support of one of these conjectures, or perhaps these objects will require entirely different interpretations.

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