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SYSTEMATIC IDENTIFICATION OF IRAS POINT SOURCES

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INTRODUCTION

A year ago we initiated a large scale programme to identify IRAS point sources. At ROE we have the ideal facilities to undertake such a large programme, viz. the rapid scanning capabilities of the COSMOS measuring machine to exploit the depth and resolution of the United Kingdom Schmidt Telescope (UKST) J survey plates. This automated procedure is more rapid than visual identification procedures and thus we have now covered about 1100 square degrees of sky containing about 1300 IRAS point sources. Figure 1 indicates the plates and areas that we have already processed together with those areas we hope to cover in the near future.

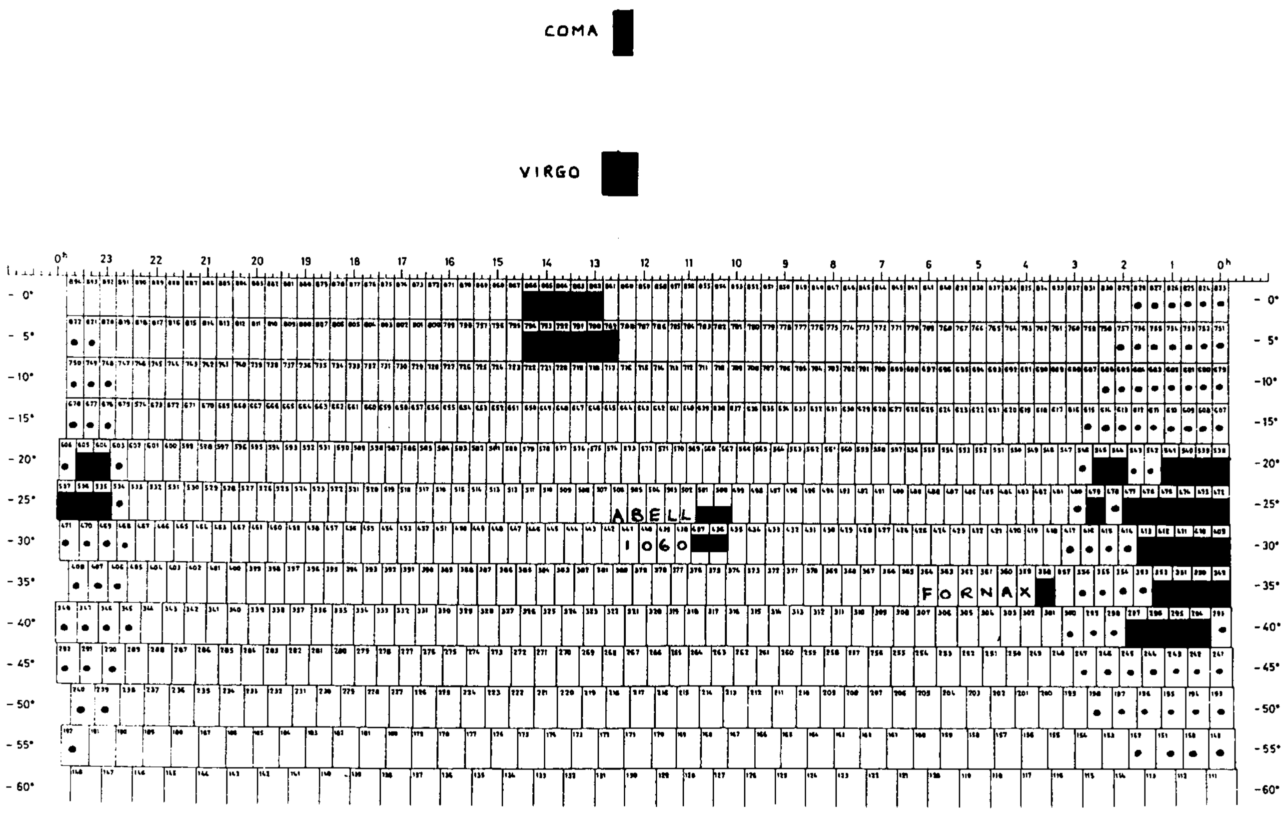

Figure 1. Distribution of UKST/SERC J survey fields showing those plates scanned by COSMOS (■) and to be scanned by COSMOS (•) as part of this project to systematically identify IRAS point sources.

The identification procedure has been thoroughly described in Wolstencroft et al. (1986) and will not be repeated here. These new results are preliminary, and mainly relate to the gross properties of the sample as a whole.

EMPTY FIELDS

Paper 1 (Wolstencroft et al. 1986) analyses the 10 empty field sources with no identification ($B_J \leqslant 21$) out of 312 IRAS sources in this SGP area. Likelihood criteria were used to estimate the reliability of individual identifications which should be a more conservative estimator than that from gaussian errors alone.

Table I compares the chance coincidence rates with the likelihood ratios LR for both low and high Galaxy densities.

TABLE 1

	All galaxies $B_J < 21^m$		All galaxies $B_J < 17^m$	
r	LR	N	LR	N
1.0	15.5	0.08	1197	0.001
2.0	3.5	0.33	267	0.004
3.0	0.28	0.74	22	0.009

N is the number of galaxies at the SGP expected by chance within a defined dimensionless angular distance, r, between the infrared and optical positions, it and all other parameters are defined in Paper 1. Our adopted limit of LR $\geqslant 3$ corresponds in the limiting case, for an individual object, to a reliability of 75%: however the reliability of our identified sample as a whole is well over 90%. Also for some of the fainter galaxy identifications, if we are to have a fairly high reliability, the search radius has to be small to meet the LR constraint and thus some potential identifications may be excluded.

However for our 10 original empty fields 5 do have possible or probable identifications ($B_J \leqslant 21$) just outside the 2σ error ellipse derived from the known galaxy and stellar identifications, 1 is a confused source and 1 is a probable cirrus detection. The remaining 3 sources are either due to faint cirrus or may be true empty field sources. In reality the genuine empty field sources may be extremely rare. We have subsequently noticed whilst working through the new areas that all of the new 13 "empty field" sources have a cirrus 1 flag > 1 and tend to be associated with small localized clumps of cirrus. Examples are shown in Figure 2. In Figure 2(b) there is evidence of some very faint optical nebulosity on the original plate. Reappraisal of the original SGP and Virgo cluster areas confirms that some of the empty field sources in those samples also appear in such clouds. There probably remain very few, if any, distant galaxies to be identified which are not fairly easily visible in optical wavebands.

STELLAR IDENTIFICATIONS

Although it is possible in the great majority of cases to tell from the IRAS flux density ratios whether the source is a galaxy or a star we prefer to keep this information in reserve to be as objective as possible. Thus we are identifying all IRAS sources. This in retrospect has been a wise decision. Figure 3 shows a selection of unusual stellar objects which we have identified with IRAS sources. 3(c) IRAS 10299-2803 has a blue point-like image but a diffuse extended red image. It

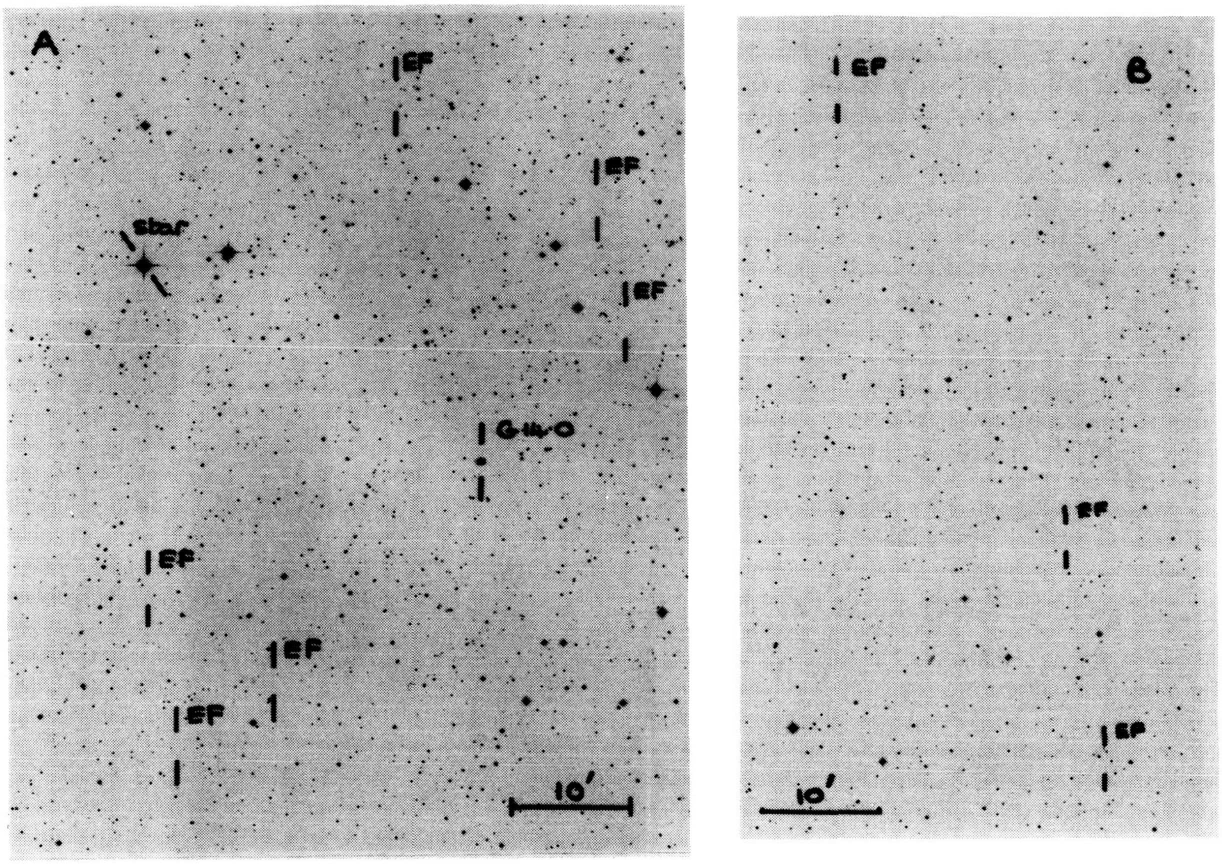

Figure 2. Reproductions from UKST/SERC J survey glass atlas showing the positions of definite IRAS cirrus sources, identifications and possible empty field identifications. All sources have a cirrus 1 flag > 1. Since these are closely associated in the sky and since optical nebulosity can be seen on the original plate at (B) these proposed empty field sources are probably low level cirrus detections.

has IRAS fluxes which do indicate a galaxy identification and its morphological appearance suggests an "N" galaxy or a low redshift quasar. An optical spectrum taken on the Anglo-Australian Telescope confirms the extragalactic nature of this object. Another advantage of this kind of objective systematic approach starting in areas of the lowest IRAS source densities is that we are able to distinguish new populations of stellar identifications. Figure 4 illustrates this.

Figure 4 shows the increasing numbers of fainter stellar identifications, Mira variables, extreme M and carbon stars which begin to appear at lower galactic latitudes. Optical spectra have been obtained on the Anglo-Australian Telescope of a representative sample of these stars having magnitude ~ 15. These spectra confirm that the stars are of late M spectral type. The availability of a wide variety of UKST/SERC/ESO plate material covering a range of epochs suggests that these stars may also be variable. Both the above are suggestive of Mira variables. A variety of Schmidt plate material is also required to identify such sources. Neither IRAS 00193-4033 nor IRAS 10299-2803 are visible on the J survey material but both are easily visible on R (5900-6900Å) or I (7150-9000Å) plate material (see Figure 3).

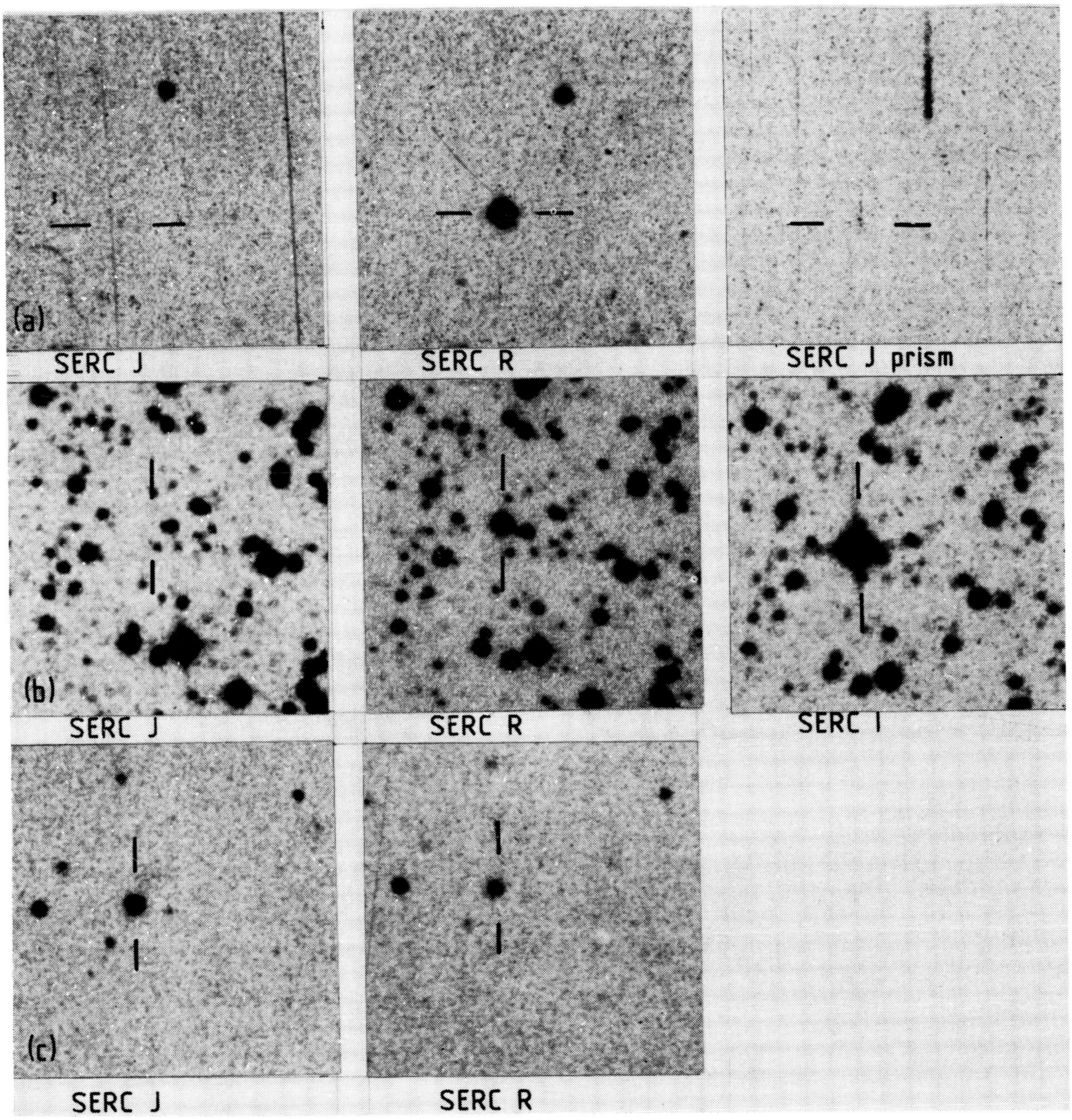

Figure 3. A selection of the more extreme types of stellar identifications.

(a) IRAS 00193-4033. Probably a dusty Mira star. The IRAS spectrum shows a strong 10μm silicate emission feature indicating an oxygen rich dust envelope. It is just visible with a very red spectrum on UKST objective prism plate material.

(b) IRAS 15194-5115. A similar type of stellar identification to (a) above.

(c) IRAS 10299-2803. A very blue star which appears slightly fuzzy on the red sensitive emulsion. It has IRAS fluxes which indicate a galaxy type identification. It is probably an "N"-galaxy or low redshift quasar with a redshift of about 0.3.

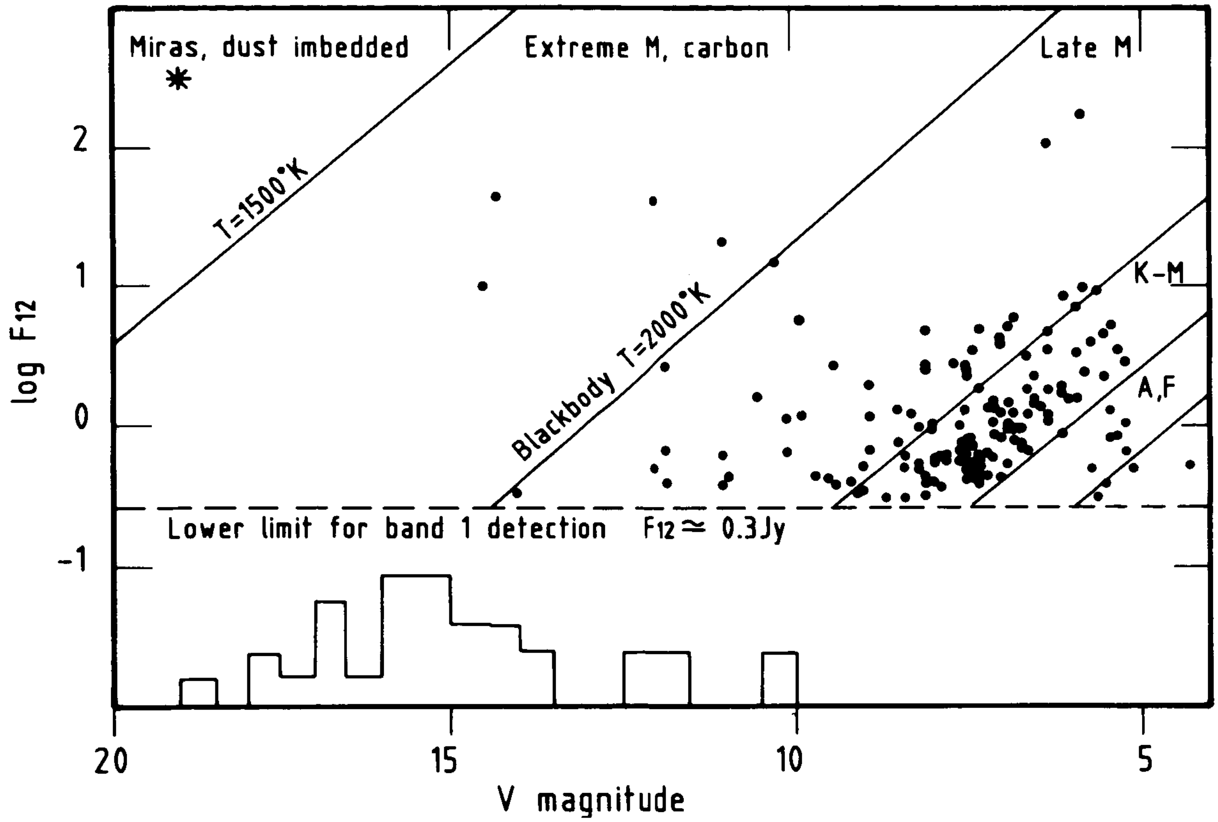

Figure 4. The relation between V magnitudes and $\log F_{12}$ for the 148 stars in Paper 1 (see text). Also indicated is an extremely red star, probably a Mira (*), found in the more recent identifications. The histogram indicates the increasing numbers of stars fainter than 10 magnitude being identified as we move to lower latitudes and found in the regions either side of the SGP area of Paper I.

GALAXY IDENTIFICATIONS

Our major aim with the galaxy identifications is to provide a database from which sound statistical analyses can be made. We are producing accurate blue magnitudes and morphological classifications for each identification. In addition other workers at ROE (MacGillivray et al.) are producing magnitude limited samples of field galaxies in each of the areas in which we are working. We should eventually be able to make firm statements about the proportions of all galaxies at a given magnitude which are IRAS sources and see if there are any strong correlations with morphological type. Clarification of the variation of L_{IR}/L_B with morphological type will also be possible with this large database; our present work indicates that many optically similar galaxies show a range in excess of 10^3 in L_{IR}/L_B, although our first paper (Wolstencroft et al. 1986) did find a trend with morphology.

So far the galaxy identifications still appear to be primarily a selection of field spirals. The combined galaxy error diagrams (Figure 5) for the total area that we have now covered are considerably worse than the similar diagram for the stellar identifications. In Figure 5 the error diagrams have been divided into two components (A) for galaxies brighter than $B_J \approx 15.5$ and (B) for galaxies fainter than $B_J \approx 15.5$.

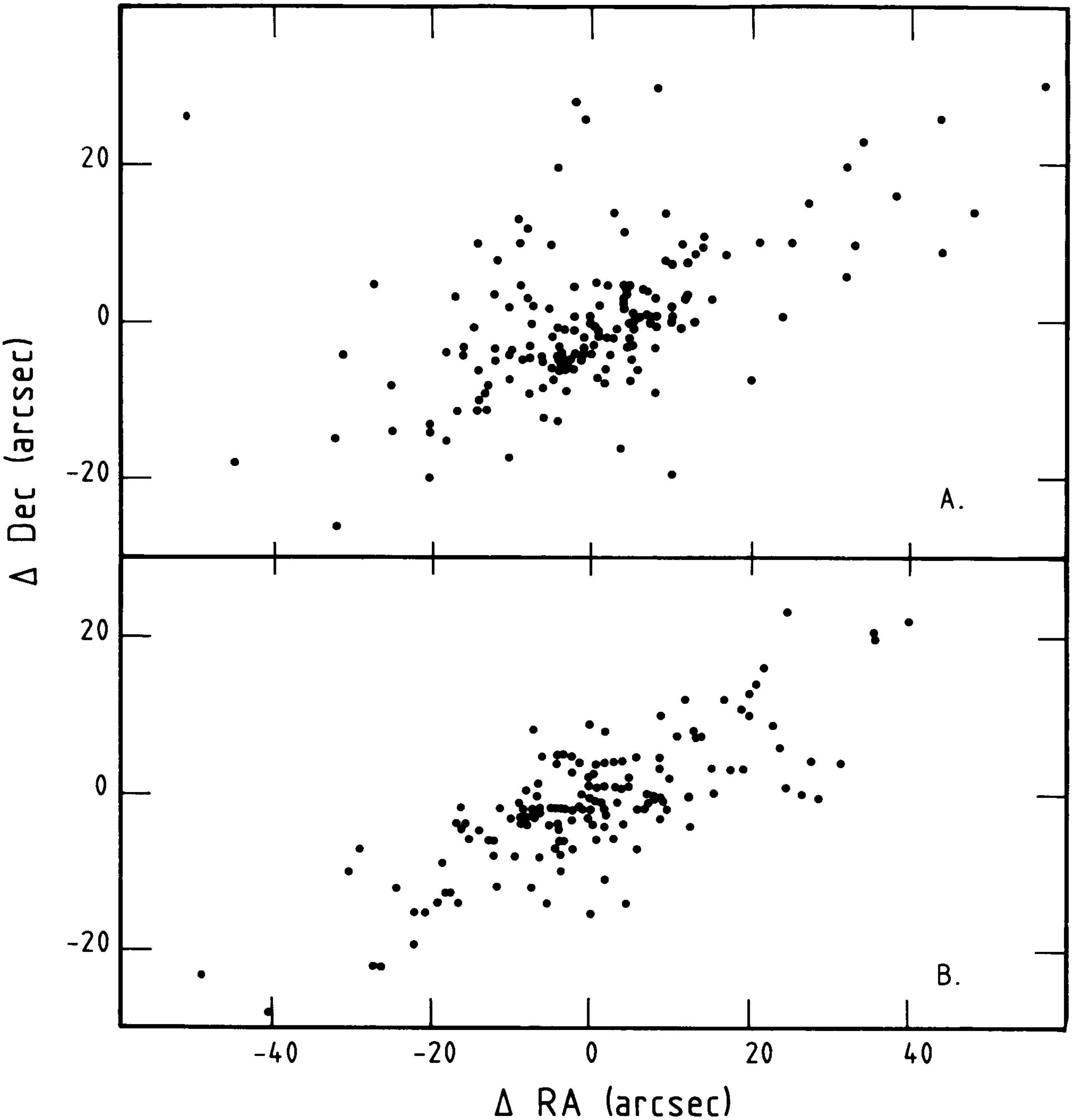

Figure 5. Position differences IRAS minus optical for (A) the IRAS galaxy identifications brighter than $B_J \approx 15.5$ and (B) $B_J \geqslant 15.5$ from the SGP area covered to date. It can be seen that the scatter is much larger for the brighter galaxies presumably because in some cases the IRAS source is not associated with the nucleus of the galaxy. The offsets for the fainter galaxies are similar to those for the stars and compatible with similar residuals quoted in the IRAS Explanatory Supplement, Beichman et al. 1985.

It appears to be the brighter galaxies that contribute most to this scatter. Figure 5 shows that for a significant number of the bright galaxies (which are unambiguous identifications) there is an offset between the optical and the IRAS point sources which is much larger than the IRAS position uncertainty. This indicates that regions of star formation are not confined solely to the nucleus but there may be a significant fraction of flux from the outer regions.

The UKST has a prism combination which acts as an intermediate dispersion objective prism with a reciprocal dispersion of 1200Å/mm at $H\gamma$. On plates taken with this prism many bright galaxies show prominent HII regions by virtue of their emission-line spectra. It is hoped to use such prism plate material to investigate the distribution of star formation regions in individual galaxies. As an interim measure some low dispersion UKST prism plate material, which already exists for some of our fields has been inspected. This plate material has a dispersion of 2440Å/mm at $H\gamma$ and the wavelength range covered is 3200Å to 5400Å. At this low dispersion only those galaxies with very prominent emission show detectable features of the blend [0III] 5007/$H\beta$ and of [0II] 3727 indicative of HII regions. Some galaxies with prominent features are shown in Figure 6. Unfortunately the dispersion is too low to investigate the distribution of HII regions in a reasonably large sample of galaxies nor is it possible to determine accurate redshifts. A programme to measure redshifts for the more luminous galaxies is under way and this is discussed in the poster paper by Wolstencroft et al. at this conference.

The average number of field galaxy identifications is 0.5 per square degree. Half of these are brighter than $B_J \approx 15.5$. The fainter galaxies appear to be uniformly distributed with no fields of 25 square degrees showing greater than a 2σ variation. However the brighter galaxies do seem to be clustered with some fields showing density variations in excess of three sigma. Similar variations are also seen in the field galaxy counts in two 25 square degree fields for galaxies brighter than $B_J \approx 15.5$ (Kalafi et al. 1986).

SUMMARY

We have now identified sources in 44 Schmidt plate areas including 1300 sources and covering 1100 square degrees. The identifications comprise 700 galaxy identifications (field and cluster members) and 600 stellar identifications. We hope to extend this area to cover some 3000 square degrees which should include some 1500 galaxy identifications. There are also about 40 sources with no obvious identification but which can be most easily explained by cirrus, confusion between two sources or sources just outside the 2 sigma error box. We feel confident that we can tackle the increased source densities, confusion and cirrus problems of lower galactic latitudes, and succeed in our aim of compiling a sound database for detailed statistical analyses.

ACKNOWLEDGEMENTS

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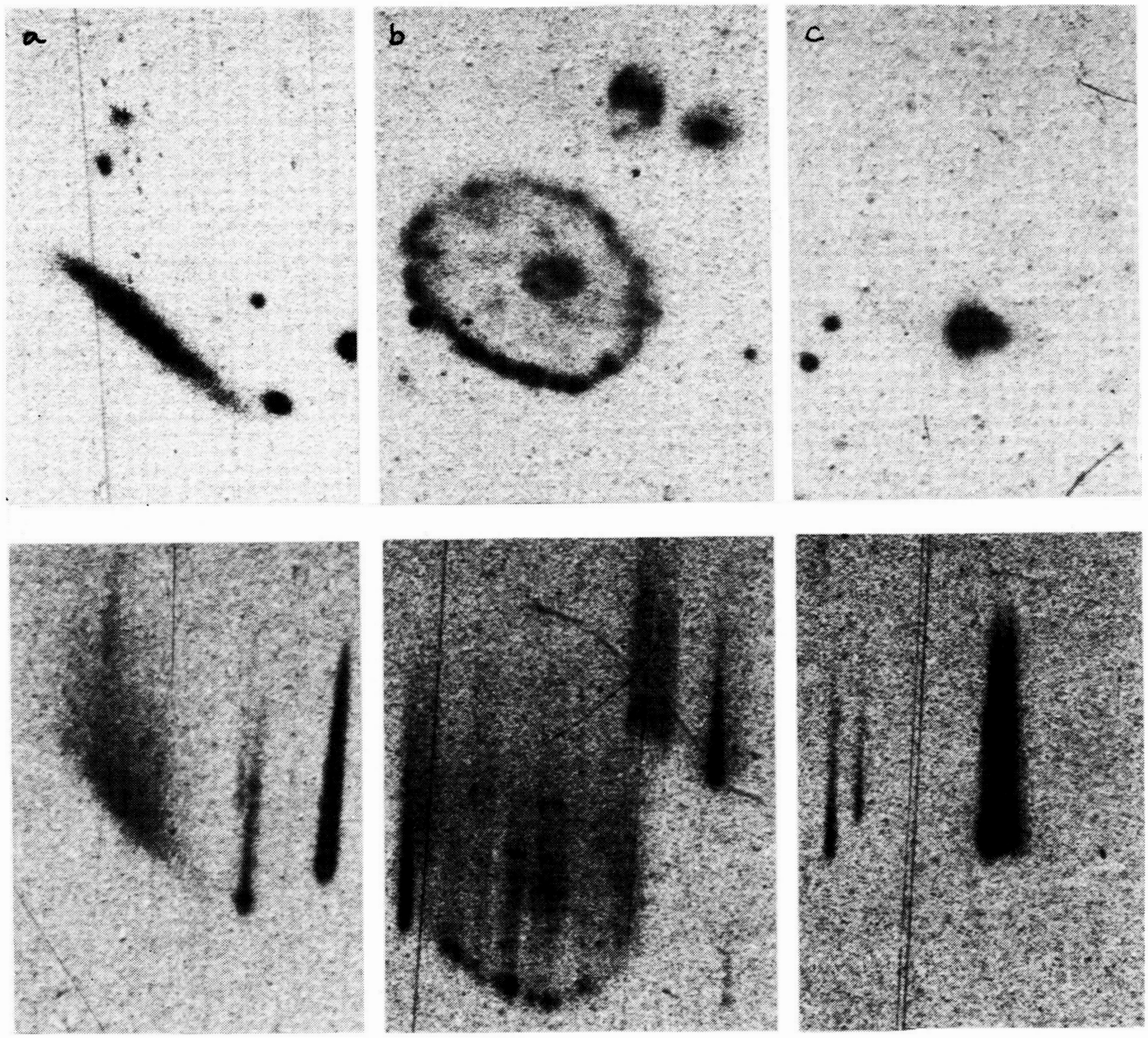

Figure 6. These are a selection of IRAS source counterparts for which UKST low dispersion objective prism plate material exists. This plate material has a dispersion of 2440Å/mm at Hγ and the wavelength range here is 3200Å to 5400Å. At this low dispersion only those galaxies with very prominent emission show detectable features of the blend [0III] 5007/Hβ and [0II] 3727. For the galaxy at (a) the IRAS source may be related to the strong extragalactic HII region rather than the bright Sbc galaxy; (b) is the well studied galaxy complex "The Cartwheel" A0035-34 and (c) is clearly resolved into two compact nuclei or galaxies.

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DISCUSSION

TELESCO:

Do you think there's a chance that the clustering of IRAS sources in the SGP is due to cirrus?

SAVAGE:

No.