N87-24271

IRAS Colors of VLA Identified Objects in the Galaxy

Michel Fich
Astronomy Department
University of Washington, Seattle, WA 98195

Susan Terebey
High Altitude Observatory
NCAR, Boulder, CO 80307

ABSTRACT

IRAS sources found within 4 degrees of $l = 125°$, $b = 2°$ on the 3rd HCON 60μ Sky Brightness Images have been observed at the VLA. The intent of this project was to identify regions where massive stars are forming by looking for small areas of radio continuum emission. The IRAS sources could be divided into three groups by their IRAS $12\mu/25\mu$ and $60\mu/100\mu$ colors. The group identified with star forming regions contained essentially all of the objects with extended radio emission. In all of these cases the extended radio emission showed a morphology consistent with the identification of these objects as HII regions. The conclusion that may be drawn from this project is that star formation regions can be distinguished from other objects by their infrared colors.

INTRODUCTION

Our long term goal is to study star formation on a large scale in the Galaxy. To use IRAS observations for studying star formation in our Galaxy it is important to first learn how to distinguish star formation regions from other possible sources of infrared emission. This paper presents a first step in that direction. It might be expected that many of the pre-main sequence O stars will be shielded from view optically because of the high extinction of their progenitor cloud. However these objects should produce both infrared and radio continuum emission. The infrared emission for these objects will come from two separate regimes, hot dust near the star (possibly in a small HII region) and much cooler dust at large distances from the star. The radio continuum emission will come from the very young HII regions formed by such stars.

The method used here is to locate all of the infrared emitting objects within some field in the galactic plane and identify them. The field chosen was centered on $l = 125°$, $b = 2°$ and the IRAS 3rd HCON 60μ Sky Brightness Image for this area (plate number 13) was used to locate emission sources. One of these objects (Sharpless 187) was almost 30 arcminutes in diameter but the rest were smaller than 14 arcminutes, including 9 that were not resolved (ie. smaller than 4 arcminutes). A total of 35 were found with peak flux densities above our threshold of 2.3×10^7 Jy/sr within 4 degrees of the central position.

This particular field was not chosen strictly randomly. It is in the outer Galaxy where confusion is less and kinematic distances are not ambiguous. This field is not contaminated with any extremely large (several degrees or larger) objects and is in the area where kinematic distances are most accurately determined, although we are not con-

PRECEDING PAGE BLANK NOT FILMED

cerned with the distances in this paper. It is slightly above $b = 0°$ because HI images show that the galactic plane warps up by a few degrees here. For these reasons we have been studying this field at a variety of wavelengths, this project being the most recent in our study.

OBSERVATIONS

All 35 of the objects were observed at the VLA in the C array configuration at a wavelength of 6 cm in a snapshot mode of 3 minute observations. This provides a resolution of 4 arcsec and a field of view of approximately 10 arcmin, however it is not sensitive to structures larger than 1 arcmin and there is some loss of sensitivity (a factor of 2 for point sources) at the edge of the field. The snapshots were converted to images that covered the entire field of view at slightly lower resolution in order to search for radio emission anywhere in the field. Then the data were re-imaged at the maximum resolution, but with smaller areas, around each possible source of emission. These images were then CLEAN'd to a flux density of 0.5 mJy/beam using the standard AIPS (NRAO data reduction package) routine MX. The final images had an rms noise level of 0.4 mJy/beam.

In addition to the above observations, the single-dish radio continuum surveys by Kallas and Reich (1980), Taylor and Gregory (1983), and Condon and Broderick (1986) were examined at the position of each of the 60μ sources.

RESULTS

Radio continuum emission characteristic of HII regions was found in 19 out of the 35 objects from the IRAS 60μ image. Although the identification of these all of these objects as HII regions is not firm, this is highly suggestive. An even more suggestive result comes from comparing the radio emission to the infrared colors of the objects.

Most (25 out of 35) of the 60μ sources were found in all four bands of the IRAS images. Their peak brightnesses at 12μ, 25μ, 60μ and 100μ were measured. Figure 1 shows a color-color plot of these objects using all four bands. These objects can be split into three groups: (I) those with low $60\mu/100\mu$ flux density ratios (0.1 to 1.0, T = 20°K to 50°K) but high $12\mu/25\mu$ flux density ratios (0.3 to 1.2, T = 160°K to 300°K), (II) those with moderate $60\mu/100\mu$ flux density ratios (0.8 to 2.0, T = 50°K to 80°K) and low $12\mu/25\mu$ flux density ratios (0.1 to 0.3, T = 120°K to 160°K), and (III) those with high $60\mu/100\mu$ flux density ratios (greater than 4, T > 180°K). The group I objects all lie in the bottom right of Figure 1, group II objects all lie to the left of the center, and the group III objects are in the top right side of the figure.

All but one (ie. 15 out of 16) objects with radio emission in this plot (as indicated by open squares) lie in group I. (There are three objects with radio emission that are not shown in this plot since they were not detected at 12μ.) There are only 3 (of 18) objects in group I that show no radio emission. In contrast, only 1 of the 5 objects in group II shows any radio emission, and neither of the two objects in group III show radio emission.

Of those 10 objects with no emission at 12μ and therefore not shown in Figure 1 only 3 had detectable radio continuum emission. This is no surprise since these 10 objects are also the weakest infrared sources in this sample.

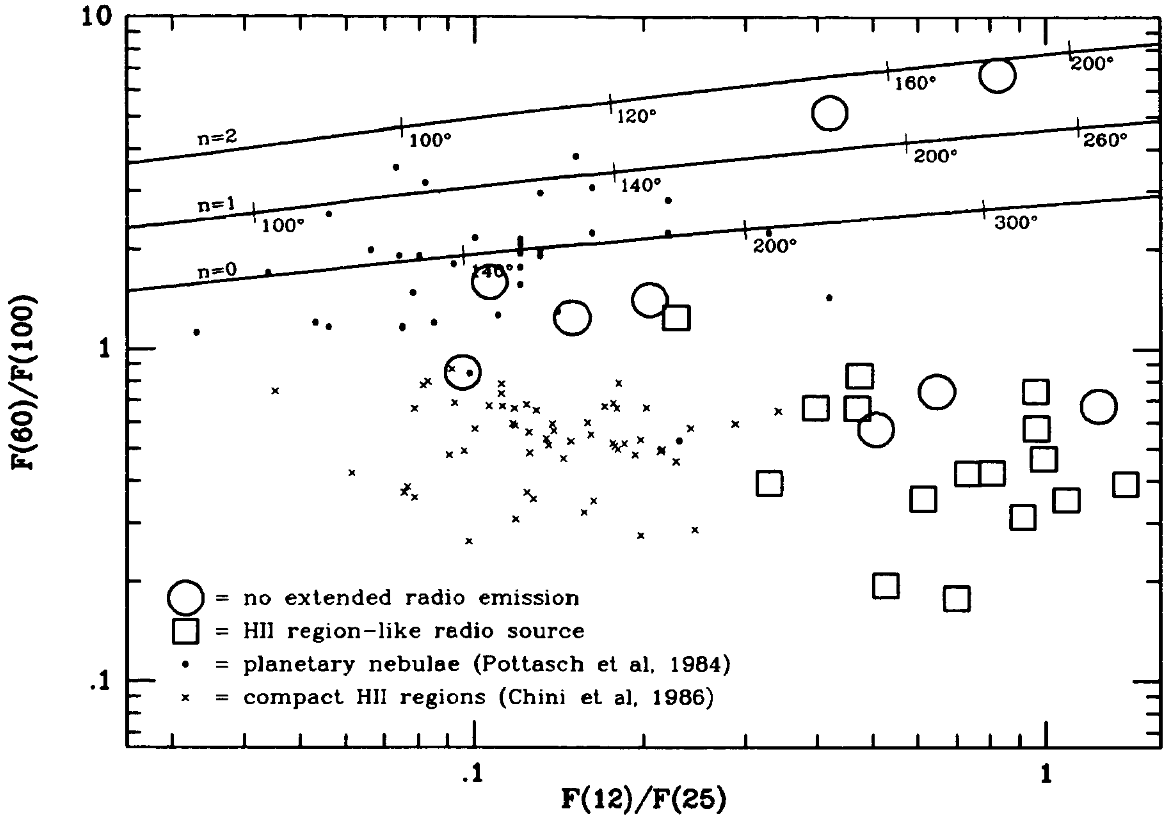

Figure 1: A color-color plot of all objects in VLA survey that were detected in all four IRAS bands. The solid lines show the Planck curves for emissivities of λ^{-n} for n = $0, 1, 2$. The objects in the lower right hand corner all appear to be star forming regions. Also plotted here, for color comparison, are the planetary nebulae measured by Pottasch et al (1984) and the compact HII regions detected by Chini et al (1986).

DISCUSSION

It is possible to tentatively identify the objects in group I as star formation regions. Essentially all of the objects with radio continuum emission are in this group and most of the members of this group have radio continuum emission. This also indicates that most of these new stars must be earlier than B2 in order to produce the ionizing photons seen in these HII regions. The physical explanation for these colors is probably the following: at the longer wavelengths emission from cool dust around the HII region is seen while at the shorter wavelengths the heated dust within the HII region dominates the emission.

The colors of objects in group II correspond with the colors of planetary nebulae (plotted in Figure 1 using data from Pottasch et al). Most of them do not have any detected radio continuum emission and planetary nebulae are normally quite weak in the radio. For these reasons group II is tentatively identified as planetary nebulae. The group III objects are probably cool giant stars.

There is a problem reconciling these results with those of Chini et al (1986) shown plotted in Figure 1. The compact HII regions in their sample are hotter in the 12 and 25 micron bands but are not as hot as those in our sample. This may be due to some physical difference between their objects and ours. Their sample contains very young HII regions excited predominantly by very early types of stars (earlier than O8) and ours may be excited by somewhat later stars or the HII regions may be older. Another possibility is that there may be a difference due to selection effects inherent in their use of the IRAS Point Source catalog and our use of the Sky Brightness Images. Despite this difference in the $12\mu/25\mu$ colors, the $60\mu/100\mu$ colors of the compact HII regions still match the colors of the objects in our survey and are different from those of the planetary nebulae.

In summary: this project indicates that it is possible to distinguish star forming regions from other objects on the basis of their infrared colors. Star forming clouds have Sky Brightness Image peak flux density ratios of $F(60\mu)/F(100\mu) < 1$ and (possibly depending on type of star forming object) $F(12\mu)/F(25\mu) > 0.3$.

REFERENCES

Chini, R., Kreysa, E., Mezger, P. G., and Gemund, H.-P. 1986, *Astr. Ap.*, **154**, L8.

Condon, J. J., and Broderick, J. J. 1986, *A. J.*, **91**, 1051.

Kallas, E., and Reich, W, 1980, *Astr. Ap., Suppl.*, **42**, 227.

Pottasch, S. R., Baud, B., Beintema, D., Emerson, J., Habing, H. J., Harris, S., Houck, J., Jennings, R., and Marsden, P. 1984, *Astr. Ap.*, **138**, 10.

Taylor, A. R., and Gregory, P. C. 1983, *A. J.*, **88**, 1784.