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Near-Infrared Observations of IRAS Minisurvey Galaxies

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ABSTRACT

Near-infrared photometry at J, H, and K has been obtained for 82 galaxies from the IRAS minisurvey. The near-infrared colors of these galaxies cover a larger range in J-H and H-K than do normal field spiral galaxies, and evidence is presented of a tighter correlation between the near- and far-infrared emission in far-infrared-bright galaxies than exists between the far-infrared and the visible emission. These results suggest the presence of dust in far-infrared-bright galaxies, with hot dust emission contributing to the 2.2 μm emission, and extinction by dust affecting both the near-infrared colors and the visible luminosities. In addition, there is some indication that the infrared emission in many of the minisurvey galaxies is coming from a strong nuclear component.

I. INTRODUCTION

The IRAS minisurvey contained a total of 86 galaxies that were detected at 60 μm with galactic latitude $|b| > 20°$, and that have visible counterparts on the Palomar Observatory Sky Survey (POSS) (see Soifer *et al.*, 1984, as well as Rowan-Robinson *et al.*, 1984 for an explanation of the IRAS minisurvey). As such, the galaxies in that survey represent a complete sample of infrared selected galaxies. Near-infrared observations of the IRAS minisurvey galaxies and the corresponding results are discussed in detail by Carico *et al.* (1986), and are summarized in what follows.

II. OBSERVATIONS AND DATA REDUCTION

The 86 galaxies analyzed by Soifer *et al.* (1984) which comprise the minisurvey sample are listed in *IRAS Circular No. 6* (1984). Of these, 82 were observed at 1.27 μm (J), 1.65 μm (H) and 2.2 μm (K) using the 5 m Hale telescope at Palomar Observatory. A solid nitrogen cooled InSb detector was used for the observations, and for most of the galaxies, a 10" diameter beam was used. Corrections were applied to the observed magnitudes and colors, ranging from 0 to 0.03 mag in J-H and H-K, to account for wavelength dependent distortions in the beam profiles. Statistical uncertainties in the observed colors are believed to be <0.04 mag.

K-corrections (from Neugebauer *et al.*, 1985) and galactic reddening corrections were also applied to the observed magnitudes of 80 galaxies for which redshifts were obtained or were available in the literature. For the galactic reddening corrections, the values of the color excess E_{B-V} were obtained for each galaxy individually by determining the reddening at that location on the reddening maps of Burstein and Heiles (1982), and the values of E_{B-V}/A_V, E_{J-H}/A_V, E_{H-K}/A_V, and A_K/A_V were taken from Cohen *et al.* (1981).

The near-infrared data, as well as the redshifts and the values of E_{B-V} for each galaxy, are tabulated in Carico *et al.* (1986).

III. RESULTS

a) Near-Infrared Colors

The near-infrared colors for the minisurvey galaxies, corrected for redshift and galactic reddening, are plotted in Figure 1. There is one galaxy, 04210+0400 (0421+040P06), which is distinct from the rest of the minisurvey sample with a value of 0.87 mag for H-K. This galaxy, which has near-infrared colors appropriate for a Seyfert nucleus, is discussed extensively by Beichman *et al.* (1985). The region in Figure 1 enclosed by a dashed line is the region occupied by the normal spiral galaxies of Aaronson (1977, converted to the CIT photometric system of Frogel *et al.*, 1978). Also included in Figure 1, indicated by the solid lines labeled A through D, are the changes in the near-infrared colors due to the effects of dust within the galaxies.

The near-infrared colors of the minisurvey galaxies differ from the normal galaxies of Aaronson primarily in that they represent a larger range in J-H and H-K than that spanned by the normal galaxy region, resulting in somewhat redder average colors. As is indicated in Figure 1, this can be understood by invoking

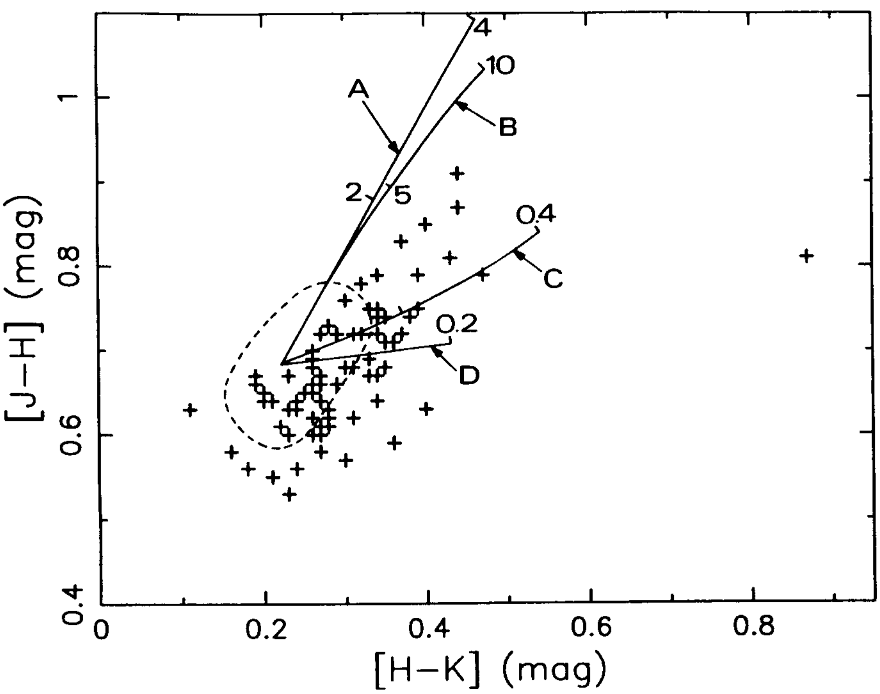

Figure 1 : Near-infrared colors for the IRAS minisurvey galaxies. The region enclosed by a dashed line is that occupied by the normal spiral galaxies of Aaronson (1977). The solid lines **A** through **D** are from Aaronson (1977) and represent the effect of dust on the near-infrared colors. Specifically, they are as follows: **A** corresponds to a reddening screen of purely absorbing dust, drawn as a function of the optical depth at V, τ_V; **B** to reddening from dust that is uniformly mixed with the emitting source, also drawn as a function of τ_V; **C, D** to 600 K and 1000 K dust, respectively, with emissivity, ϵ, given by $\epsilon \propto \nu^2$, where ν is the frequency. Lines **C** and **D** are labeled according to the fractional contribution to the 2.2 μm emission, assuming zero contribution from dust emission for a normal stellar population. All of the lines **A** through **D** are taken from Aaronson (1977).

the presence of dust in the minisurvey galaxies, affecting the near-infrared colors through absorption with visual optical depths up to about 5, for the case of dust uniformly mixed throughout the galaxy, coupled with hot dust emission. It can also be seen from Figure 1 that a large fraction of the minisurvey galaxies would be well fitted by the normal galaxy region were it not for a slight shift, amounting to barely 0.02 mag in both J-H and H-K. Considering the potential sources of systematic uncertainties inherent in the comparison between the two samples, we consider such a small systematic effect with some skcpticism.

b) Near and Far-Infrared Luminosity Correlation

The near- and far-infrared luminosities (L_{NIR} and L_{FIR}, respectively) have been calculated using the flux densities given in the *IRAS Point Source Catalog* (1985). The corresponding distributions are plotted in Carico *et al.* (1986), where it is found that the distribution of near-infrared luminosities has a mean of $\log(L_{NIR}/L_{\odot}) = 9.6$ with a dispersion of $\log(L_{NIR}/L_{\odot})$ of $\sigma_{NIR} = 0.5$, and the far-infrared luminosity distribution has a mean of $\log(L_{FIR}/L_{\odot}) = 10.4$ with a dispersion of $\log(L_{FIR}/L_{\odot})$ of $\sigma_{FIR} = 0.5$.

Galaxies detected by IRAS show little correlation between their far-infrared and blue luminosites (Soifer, 1986a). One would like to see whether the far-infrared luminosity is better correlated with the near-infrared luminosity, which is more representative of the total stellar luminosity, and less affected by internal reddening, than is the blue luminosity. Investigation of the ratio of far- to near-infrared luminosities for the minisurvey galaxies indicates that the corresponding distribution has a mean of $\log(L_{FIR}/L_{NIR}) = 0.8$ with a dispersion of $\log(L_{FIR}/L_{NIR})$ of $\sigma_o = 0.2$.

It would be useful to compare the distributions of L_{FIR}/L_{NIR} and L_{FIR}/L_B, where L_B is the blue luminosity, for the minisurvey galaxies. However, these galaxies have not yet been systematically measured at visible wavelengths. Another sample of far-infrared-bright IRAS galaxies does exist for which blue luminosities are available. This sample, the IRAS bright galaxy sample (Soifer *et al.*, 1986b), is similar to that obtained in the minisurvey in that it represents a complete, flux-limited sample of infrared selected galaxies; we assume that these galaxies will have similar properties to those in the minisurvey. The distribution of the ratio of the far-infrared to blue luminosity for the bright galaxy sample has a mean of $\log(L_{FIR}/L_B) = 0.6$ with a dispersion of $\log(L_{FIR}/L_B)$ of $\sigma_{bg} = 0.6$. Taking account of the possible differences between the two samples, the larger dispersion in L_{FIR}/L_B as compared to L_{FIR}/L_{NIR} appears to be statistically significant, indicating that far-infrared- bright galaxies have a tighter correlation between their far- and near-infrared emission than between their far-infrared and blue light. Such a tighter correlation in the far-infrared to 2.2 μm luminosity suggests that extinction by dust is indeed significantly affecting the visible luminosity of far-infrared- bright galaxies.

It has also been found that the dispersion of the distribution of $\log(L_{FIR}/L_{NIR})$ for the minisurvey galaxies increases when an attempt is made to apply beam-size corrections to the near-infrared luminosities. Such an increase in scatter indicates that the beam-size corrections are inappropriate, suggesting that the far-infrared emission in the majority of the minisurvey galaxies may have a strong nuclear component.

CONCLUSIONS

Near-infrared observations of 80 galaxies from the IRAS minisurvey have produced the following results:

1) The near-infrared colors of far-infrared-bright galaxies are similar to those of normal field spiral galaxies, but show a larger range in J-H and H-K, possibly indicating the presence of dust in far-infrared-bright galaxies. For the minisurvey sample, there is evidence for dust absorption of visual optical depths ranging up to about 5, coupled with hot dust emission.

2) The far-infrared emission of far-infrared-bright galaxies appears to be more tightly correlated with the near-infrared emission than with the visible emission. This suggests the possibility of a significant effect from dust absorption on the visible luminosity of these galaxies.

3) There is some indication that a substantial percentage of far-infrared-bright galaxies emit their infrared luminosity primarily from a strong nuclear component.

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