COLD DUST IN GALAXIES

S. A. EALES and C. G. WYNN-WILLIAMS
Institute for Astronomy, University of Hawaii

W. D. DUNCAN
United Kingdom Infrared Telescope

Models for dust heated by the interstellar radiation field of a normal galaxy show that most of the thermal emission from the dust should be occurring in the submillimeter waveband ($100 \mu m < \lambda < 1000 \mu m$) (Spitzer 1978; Draine and Lee 1984; Draine and Anderson 1985). The IRAS survey confirmed that because most galaxies are emitting more strongly at 100 $\mu m$ than at 60 $\mu m$, much of a galaxy's emission should be in this wavelength region. We have used the UKT14 bolometer on the United Kingdom Infrared Telescope to observe the submillimeter emission from a sample of 11 spiral galaxies that are bright at 100 $\mu m$. The instrumental beam of the bolometer system has an approximately Gaussian shape with size (FWHM) of $\approx 80$ arcsec. We used a beam separation of 136 arcsec E-W. The flux calibration and the extinction coefficients were obtained from observations of Saturn, Uranus, OMC-1, and IRC+10216. More details are given in Eales, Wynn-Williams, and Duncan (1989).

We detected 5 out of 11 galaxies at both 350 and 450 $\mu m$. Figure 1 shows the mean continuum energy distribution for the 5 galaxies. The error bars at each wavelength show the variance about the mean at that wavelength and hence the range of continuum energy distributions exhibited by this subsample of 5 galaxies.

The 12–1100 $\mu m$ flux densities cannot all be fitted by thermal emission from dust at a single temperature. We decided not to fit a multicomponent model to the IRAS and submillimeter data, but instead to see whether the 60–1100 $\mu m$ flux densities alone could be fitted by thermal emission from dust at a single temperature, because (1) the emission at 12 and 25 $\mu m$ may be dominated by nonequilibrium emission (Boulanger et al. 1989) and (2) this procedure should show whether the submillimeter data provide any evidence for a dust component in addition to those radiating in the IRAS bands. To do this, we fitted thermal spectra to the IRAS 60 and 100 $\mu m$ flux densities and to our submillimeter flux density (excluding upper limits) using a range of dust emissivity functions. We found that the 60–1100 $\mu m$ flux densities could always be fitted by emission from dust at a single temperature but that the data were too poor to distinguish between the different emissivity laws. The temperatures we obtained are typically between 30 and 50 K, considerably higher than the temperature ($\approx 10$–20 K) predicted for dust in the interstellar medium of a normal galaxy (Spitzer 1978; Draine and Lee 1984; Draine and Anderson 1985). A possible explanation is that although the submillimeter and far-infrared fluxes for a galaxy
Fig. 1.—The mean fluxes of the five galaxies that were detected at both 350 and 450 μm. Before calculating the mean, the energy distributions of the individual galaxies were normalized to 100 Jy at 100 μm. The IRAS measurements are shown by filled squares, our submillimeter measurements by filled circles, and the 1300 μm measurements of Chini et al. (1986) by an open circle. Beam corrections have been made so that all measurements are for the same region of each galaxy. The solid line shows the result of fitting a two-component dust model to the 60-450 μm measurements: dust at 35 K and at 10 K, in the proportions by mass of 1:5. The dashed line shows the emission from the 10 K dust, and the dotted dashed line shows the emission from the 35 K dust.

are best fitted by a warm thermal spectrum, this does not rule out the existence of colder dust in substantially larger quantities than the warm dust we have detected. The flux densities in Figure 1 are best fitted by a thermal spectrum with a temperature of 35 K, but they are also adequately fitted by a two-component model: dust at 35 K and a second component consisting of 5 times as much dust at 10 K. The gas masses that we estimated from our submillimeter flux densities (Hildebrand 1983) are as much as 8 times lower than the gas masses estimated from the brightness of the CO 1-0 line. In view of the problems with both methods, in particular the ease with which one can underestimate the amount of cold dust when using the submillimeter method, the discrepancy is not too surprising.

This work was partly supported by NSF grant AST 86-15684.