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P. 2

Evidence against a simple two-component model for the far-infrared emission from galaxies

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Two of the first *IRAS* results were that galaxies have a wide range of values for the ratio of 60 μm to 100 μm flux density ($0.2 \precsim S_{60}/S_{100} \precsim 1.0$) and that this ratio is correlated with L_{fir}/L_b, L_{fir} being the total far-infrared luminosity and L_b being the luminosity at visible wavelengths (de Jong et al. 1984; Soifer et al. 1984). From these results arose the following simple model for the far-infrared emission from galaxies (de Jong et al. 1984), which has remained the standard model ever since. In this model, the far-infrared emission comes from two dust components: warm dust ($T \approx 50$ K) intermingled with, and heated by, young massive OB stars in molecular clouds and HII regions, and colder dust ($T \approx 20$ K) associated with the diffuse atomic hydrogen in the interstellar medium and heated by the general interstellar radiation field. As the number of young stars in a galaxy increases, S_{60}/S_{100} increases, because there is a greater proportion of warm dust, and so does L_{fir}/L_b, because most of the radiation from the young stars is absorbed by the dust, leading to a swifter increase in far-infrared emission than in visible light. Although this model explains the basic *IRAS* results, it is inelegant—it uses two free parameters to fit two data (the 60 and 100 μm flux densities)—and there are now several observations that contradict it:

(1) Since the end of the *IRAS* mission, several groups have measured the submillimetre emission from galaxies, so there are now sufficient data to test a two-parameter model. Eales, Wynn-Williams & Duncan (1989), rather than needing two dust components, found that the 60-1100 μm flux densities of the 11 galaxies in their sample could be well-fitted by thermal emission from dust at a single temperature ($T \approx$ 30-50 K). Devereux and Young (this conference), using the submillimetre data of Stark et al. (1989), have demonstrated the same thing for a different sample.

(2) If the two-component model is correct, one expects galaxies with few molecular clouds and most of their gas in atomic form to have low values for S_{60}/S_{100}. On the contrary, there appears to be no correlation between S_{60}/S_{100} and the relative proportions of molecular and atomic gas (Young et al. 1989).

(3) A less direct but still highly suggestive argument comes from a study of the correlation between far-infrared and radio emission. Cox et al. (1988) and Devereux & Eales (1989) have shown that the slope of this relation is significantly different from unity, in the sense that L_{radio}/L_{fir} increases with luminosity. At first glance, this is what one might expect from the two-component model. The radio emission from galaxies probably arises, directly or indirectly, from the supernova explosions of massive stars. Therefore, as the number of young massive stars in a galaxy increases, the radio

emission will increase in proportion to the number of young stars, but the far-infrared emission will increase at a slower rate because of the underlying contribution to the far-infrared emission from the cold dust component. Nevertheless, at second glance this scheme dosn't work, because it predicts a correlation between S_{60}/S_{100} and L_{radio}/L_{fir} that isn't observed (Devereux & Eales 1989).

Despite these major problems with the two-component model, it is not clear what should be put in its place. The basic *IRAS* results can be explained by other models. As an example of one possible model, imagine that *all* the far-infrared emission from galaxies is from dust heated by young stars in molecular clouds and HII regions. If the number-density of young stars in a galaxy is increased, the radiation field will be more intense and so S_{60}/S_{100} will be higher; both the far-infrared emission and the visible light from the galaxy will increase, but the far-infrared emission will increase more swiftly because of the contribution to the visible light from old stars and because most of the visible light from the young stars is absorbed by dust: and so L_{fir}/L_b will be correlated with S_{60}/S_{100}. A model like this would also be more in accord with the studies of galaxies that have been made in the CO 1-0 line by Young and collaborators (Young 1986). When considering possible models for the far-infrared emission from galaxies, the observational evidence for our own galaxy must be considered. We suspect that the study by Boulanger & Pérault (1988) of the far-infrared properties of the local interstellar medium may be particularly relevant. They showed that molecular clouds are leaky—that most of the light from OB stars in molecular clouds does not heat the dust in the clouds, but instead leaks out—and also the consequence of this: that while most of the far-infrared emission from the solar neighbourhood is from dust associated with diffuse HI, this dust is nostly heated by young stars.

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