WHAT POWERS ULTRA-LUMINOUS IRAS GALAXIES?

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I report here centimeter–wavelength observations carried out at the Very Large Array (VLA) to help resolve two questions. First, what is the source of the far infrared (FIR) emission in infrared–luminous IRAS galaxies, active nuclei or more widely distributed star formation? And what physics underlies the tight correlation (Helou *et al.*, 1985) between FIR and radio flux? To test potential answers to these questions, we believe it is important to study the most luminous IRAS galaxies. We selected 39 for study from the ultraluminous catalog of Strauss *et al.*(1990 and 1992). All sources had FIR luminosity $\geq 10^{11.4}$ $L_{\odot}$. Radio wavelength observations of these systems provide several advantages. First, in the radio there is no obscuration, so we can "see" the active galactic nuclei, if present. Radio spectral indices can distinguish between synchrotron and thermal emission. And finally, observations at the VLA provide sub–kpc resolution. We observed these sources with the VLA in its C configuration. At 1460 MHz, the effective resolution was $\sim 15''$; and $\sim 4''$ at 4860 MHz. We made follow-up observations on 24 sources in the A configuration with resolution at 4860 MHz of $\sim 0''.5$ (or $300 - 800$ h^{-1} pc for these sources).

All sources were detected in both configurations, with typical $20cm$ fluxes of $5 - 100$ mJy. The $6 - 20cm$ spectral indices had a mean value of -0.65 and a range -0.21 to -0.99, suggesting synchrotron emission as the primary mechanism. The one exception was source 0524+010, a remarkable gigahertz peak spectrum source, with $\alpha = +2.13$ at our frequencies of observation.

Eighteen of the 39 sources are multiple and/or marginally resolved at $4''$ resolution, implying extended radio emission on kpc scales. Sixteen of

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the 24 sources observed at higher resolution (0.5″) were multiple and/or resolved, on sub–kpc scales.

The 39 sources we observed have 20*cm* fluxes that correlate well with FIR flux; writing $S_{20} = 10^{-q} S_{FIR}$, we find $q = 2.36$, in excellent agreement with the value of 2.34 found for lower luminosity sources by Condon *et al.*(1991). We took from the literature radio fluxes for a further 24 ultraluminous sources also found in the Strauss *et al.* catalog. When these are combined with our measurements, we again obtain a good correlation with $q = 2.40$. These results are reported for the correlation between *total* radio flux and FIR flux. We separately compared both *nuclear* radio flux (within the central 0.5″, or $300 - 800\,h^{-1}pc$) and *extended* flux, defined as (total minus nuclear), with the FIR flux. Neither nuclear nor extended flux is as well correlated, so we conclude that the tight correlation we observe is dependent on activity in *both* the disks and the nuclei of these galaxies.

We thus find that these ultraluminous galaxies obey the same radio–FIR correlation as lower luminosity sources, where the FIR emission is very likely due to star formation (e.g., Helou and Bicay, 1993). Our observed correlation depends on both nuclear and extended radio flux. Further, there is no obvious segregation in the plots of this correlation between sources with optical AGN spectra and sources with HII region or other spectra (Crawford *et al.*, 1996). In addition, few sources at our resolution show convincing evidence of AGN features (jets, double–lobe sources, etc.). Finally, the radio spectral indices suggest synchrotron as the primary emission mechanism at radio wavelengths. The relativistic electrons are presumably generated by supernovae, produced in turn by starburst activity.

All these findings are consistent with the argument that star formation powers these IRAS galaxies, with their large FIR luminosity. Norris *et al.*(1990) report a similar conclusion from higher resolution studies of luminous starburst galaxies.

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