SUBMILLIMETER OBSERVATIONS OF NGC 4151: EVIDENCE FOR THERMAL DUST EMISSION

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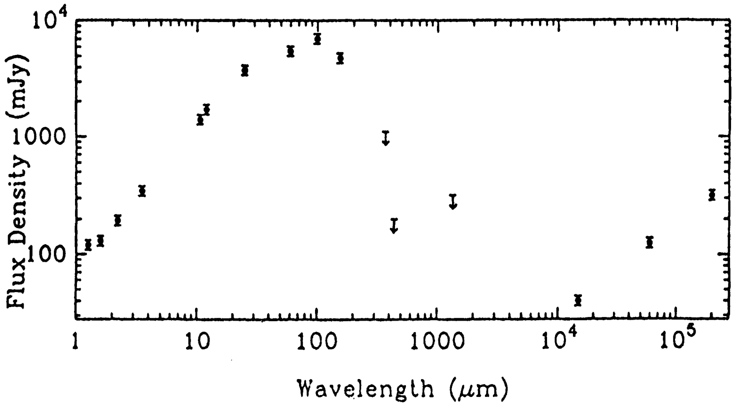
Observations of NGC 4151 were made with the JCMT on UT 20 April 1988. The detector was the UKT14 system, a dual-beam, ^{3}He cooled, composite doped Germanium bolometer. A bandpass filter was used to define a central wavelength of 438 μm (685 GHz) with a bandwidth of 84 GHz. The beam was approximately Gaussian, with a FWHM of 11″, and the pointing was good to $\lesssim 3''.7$. A very significant 5σ upper limit of 200 mJy was obtained. The Figure shows the continuum energy distribution for NGC 4151, made without correcting for beam size. When combined with the measured 155 μm flux density[1] of 4.8 Jy, a lower limit on the spectral index of $\alpha_{155-438\mu m} \geq +3.06$ is derived. Since the steepest cut off allowed by synchrotron self-absorption is $\alpha = +2.5$, these observations can place an upper limit on the flux at 155 μm arising from a synchrotron self-absorbed source, with the rest arising from a thermal dust source.



It is unlikely that the submillimeter-far-infrared fluxes are strongly variable or absorbed by free-free opacity. Repeated 10 μm observations showed that the flux was constant[2] to

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within $\lesssim 8\%$ over 1.25 yr, and it did not vary between 12 μm and 100 μm, at the $\lesssim 20\%$ level, when observed with IRAS over a one month period[3]. (In fact, that study found no evidence of any far-infrared variations in any Seyfert galaxy or normal quasar for time scales up to six months and more.) NGC 4151 was also constant to better than 10% at radio wavelengths[4] over $\sim$5 years. For free-free absorption to explain the observed steep submillimeter spectrum, the source would have to be fully covered by an intervening plasma with an emission measure of $EM \approx 2 \times 10^{14}$ pc cm^{-6} for $T \approx 1.5 \times 10^4$ K . Standard broad-line clouds[5] would have too low an emission measure ($EM \approx 6 \times 10^{12}$ pc cm^{-6}), which would not produce a cut off until $\sim$500 μm. Therefore we believe we have set a lower limit on the intrinsic slope of the continuum emission at these wavelengths.

Since the 155 μm measurement refers to a 45″ pixel (4 Kpc), while the 438 μm observations were made with an 11″ beam (1 Kpc), we considered a variety of possibilities for the spatial distribution and emissivity for the dust in NGC 4151. They all give similar results: No more than about half of the the 155 μm emission can be due to synchrotron self-absorbed emission. If, as we have previously argued[6], then a synchrotron source produces much of the mid-infrared continuum, it must become self-absorbed around $\lambda \lesssim 80$ μm.

The parameters derived for the thermally emitting dust are similar to those determined for other low-luminosity active galaxies and starburst galaxies. The derived dust temperature is $T_D \approx 33$ K, the dust mass is $m_D \approx 10^3$ $M_\odot$, and the minimum size of the emitting region is $r_D \approx 70$ pc. These are consistent with an origin in the narrow-emission-line region or star-forming regions in the underlying galactic disk.

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