Spitzer Observations of Two Early-Type Spiral Galaxies with Dust Rings

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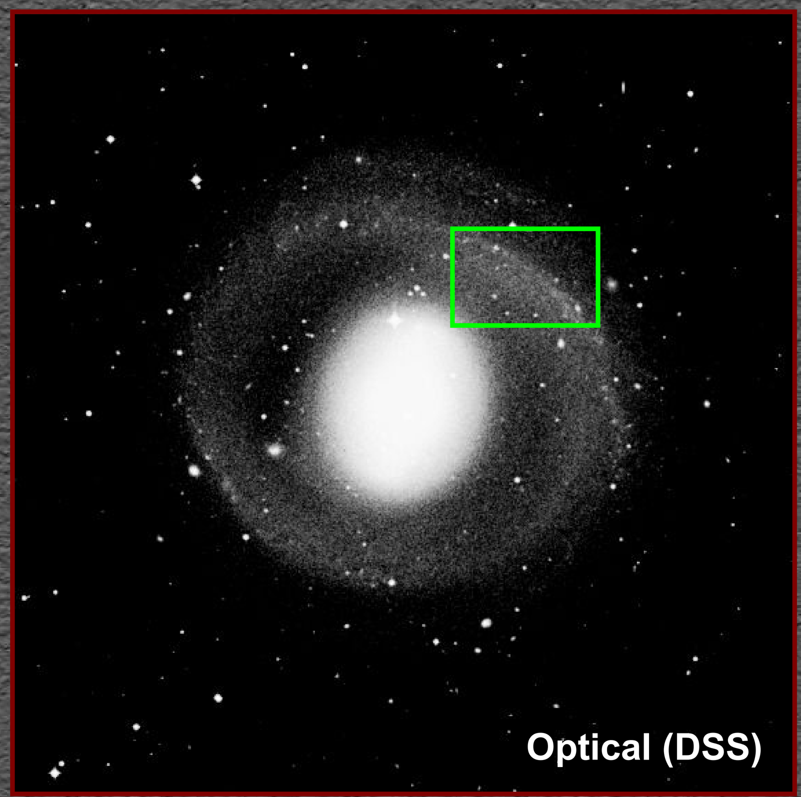
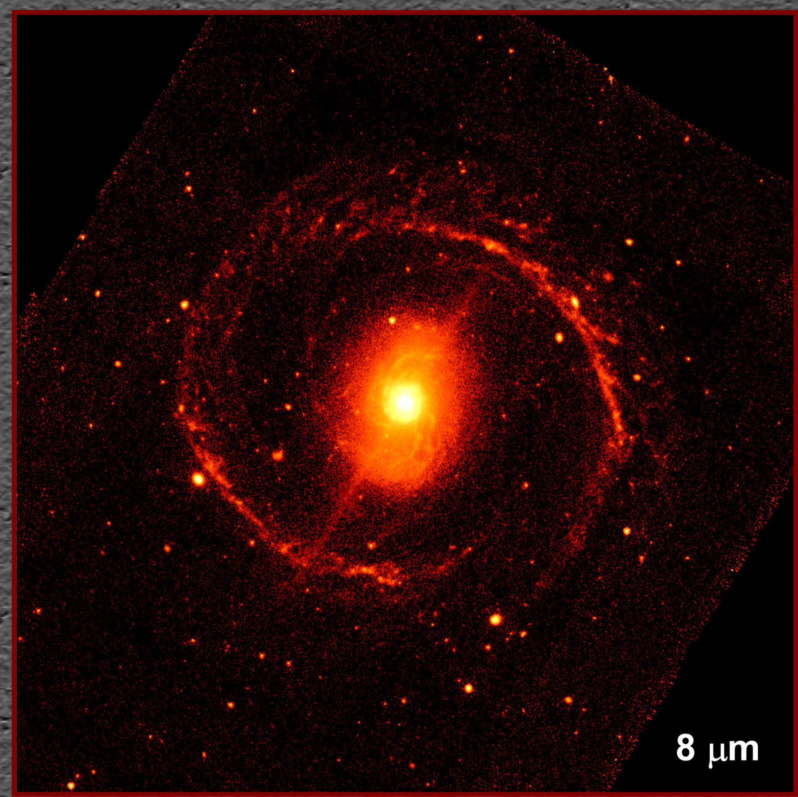
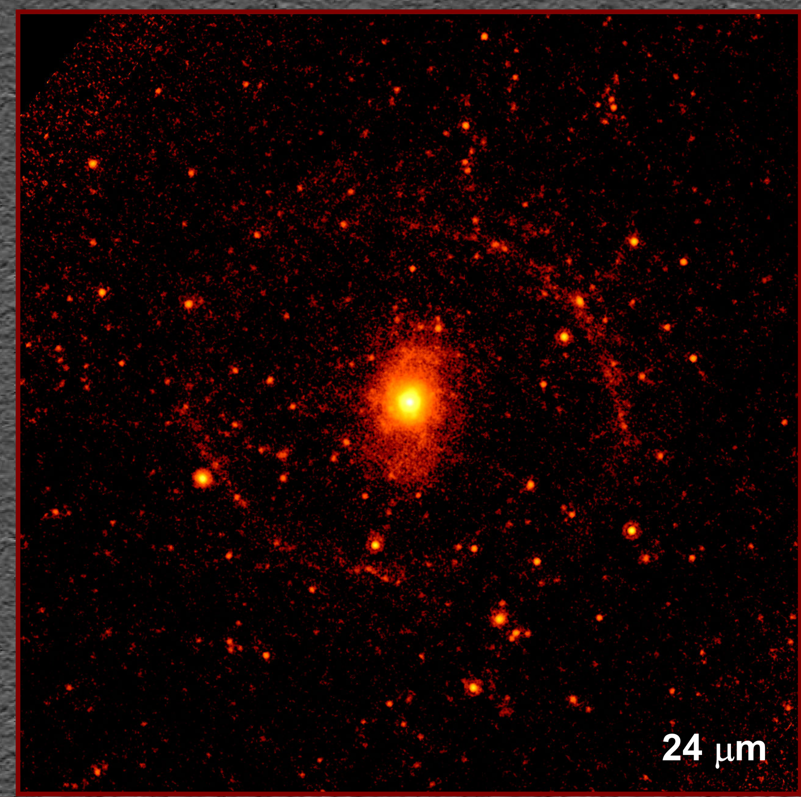
Abstract

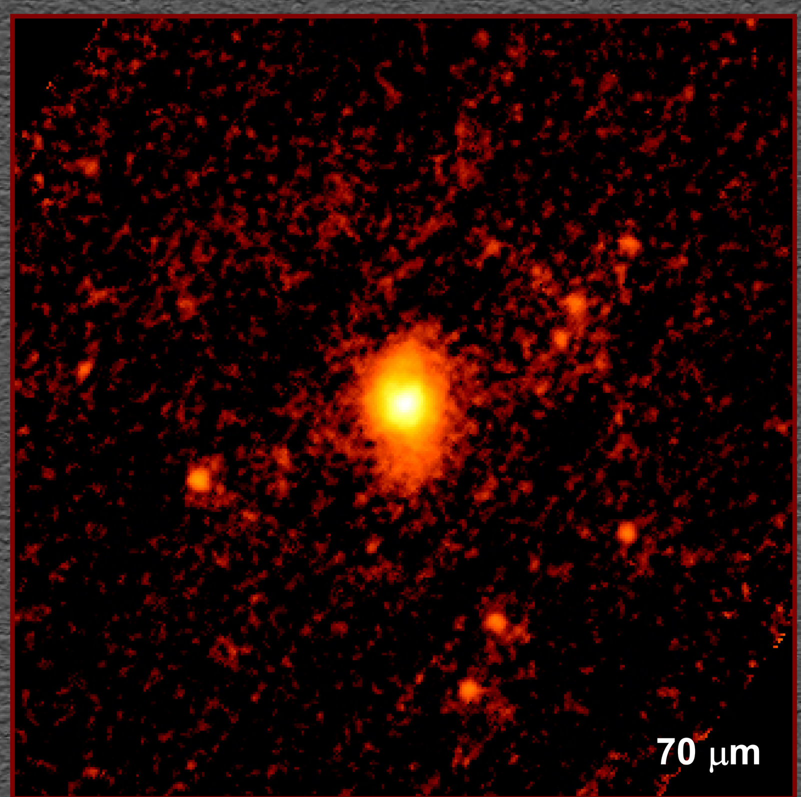
We present Spitzer images of the SB0/a galaxy NGC 1291 and the SAa galaxy NGC 4594. Both galaxies contain dust rings that can be used for studying the relation between dust emission and star formation activity. At 24 µm, the nuclei of both galaxies are the brightest sources in the galaxies, and dust emission from the rings is relatively weak. At 160 µm, however, the dust rings are more prominent sources; in NGC 4594, the dust ring is the source of virtually all of the 160 µm emission. We discuss whether the 160 µm emission from the rings is related to star formation activity or to heating by older stellar populations, and we examine the relation between dust and PAH emission. For NGC 4594, we also present submillimeter data that show that the nucleus dominates the 850 µm emission. These results demonstate that the 850 µm emission cannot come from the same dust that dominates the 160 µm emission. We examine the possible mechanisms that could be generating the 850 µm emission as well as the implications for dust models and galaxy spectral energy distribution templates.

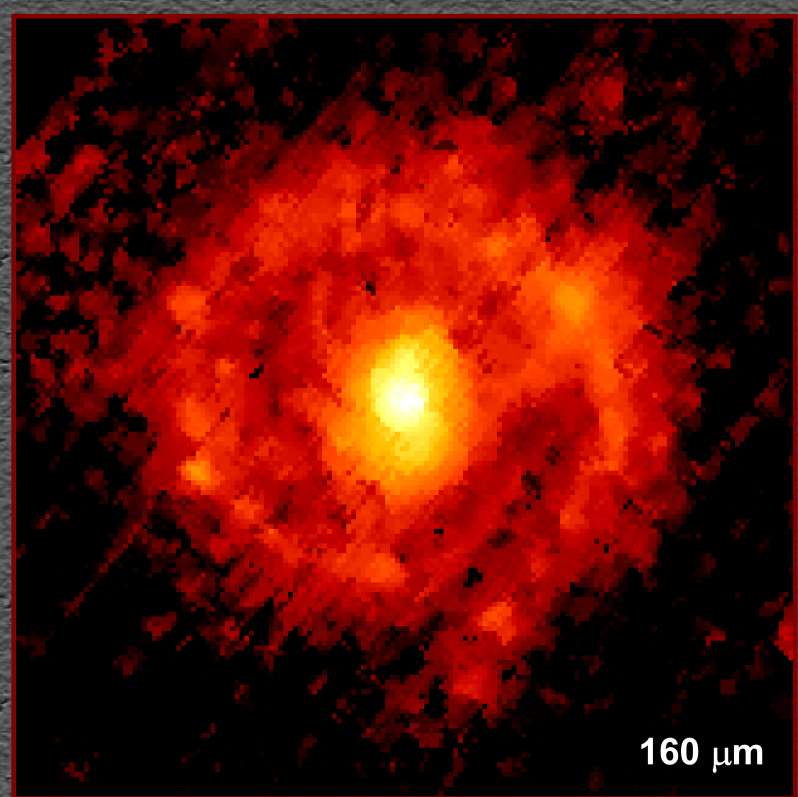
NGC 1291







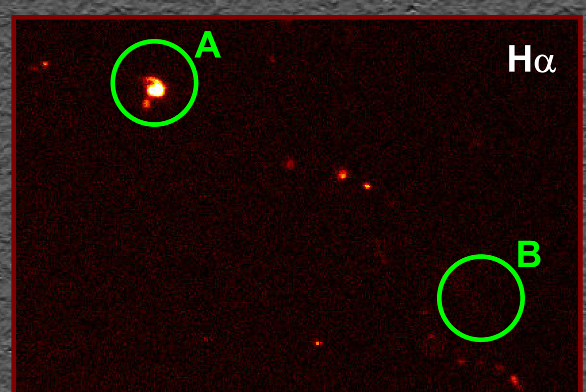


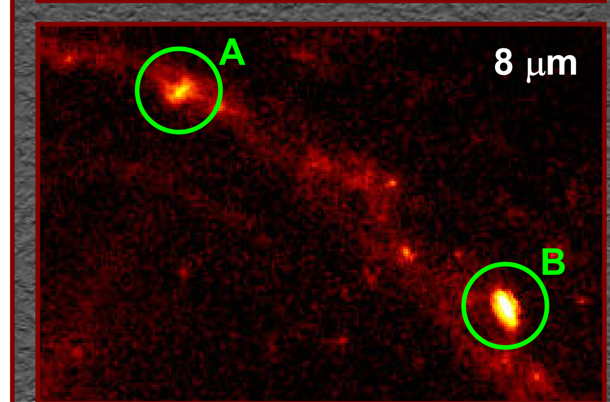


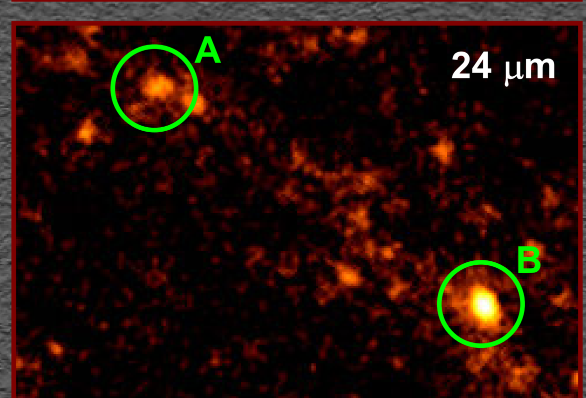
NGC 1291 (RSB0/a) in the optical, 8 µm, 24 µm, 70 µm, and 160 µm bands. Each image is 16′ × 16′, with north up and east to the left. The green box in the optical image shows the region in the magnified images below. The nucleus dominates the 8 µm waveband, which traces PAH emission, but some 8 µm emission can be seen from the outer ring. The 24 and 70 µm images, which trace warm dust grain emission, appear similar to the PAH emission, and the 8 and 24 µm wavebands do correlate quantitatively with each other. While the nuclear region is still the most prominent source of the cool dust emission at 160 µm, the dust ring is relatively stronger than at other wavebands.

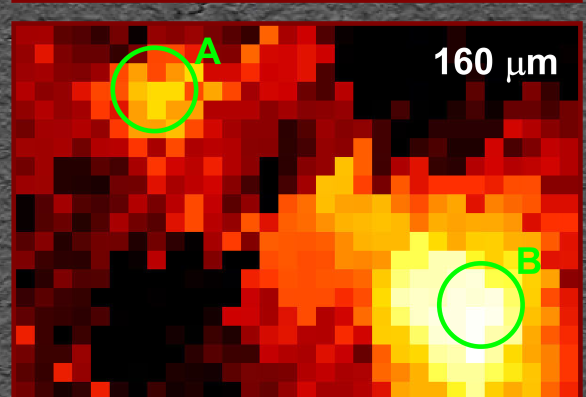
Correspondence between Hα, PAH, and dust emission: qualitative analysis

The images to the right show the northwest (upper right) side of the dust ring in the Hα, 8 µm, 24 µm, and 160 µm bands. All four bands represent potential tracers of star formation. The best correspondence is between the 8 and 24 µm bands; this correspondence demonstrates that PAH emission is linked with very small grain emission. However, neither the 8 µm PAH emission, the 24 µm very small grain emission, nor the 160 µm large cool grain emission correlate well with the Hα emission. Consider, for example, regions A and B. Region A is the brightest Hα source in the dust ring, yet it produces only modest PAH and dust emission. In contrast, region B is relatively bright in all infrared wavebands, yet the source is absent in the Hα image.





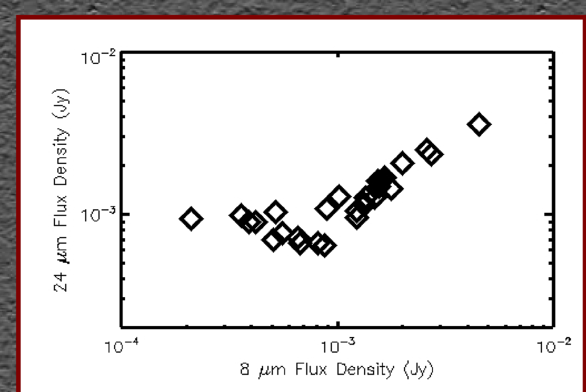


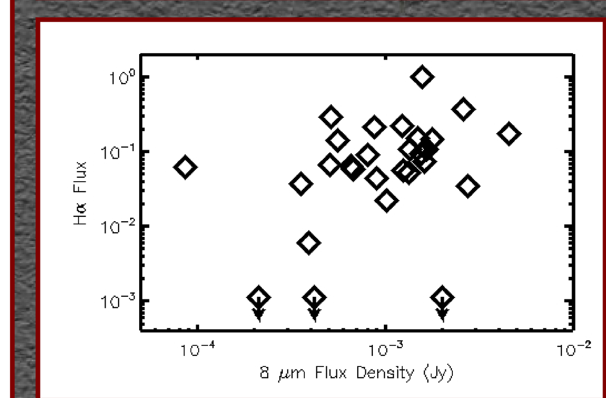


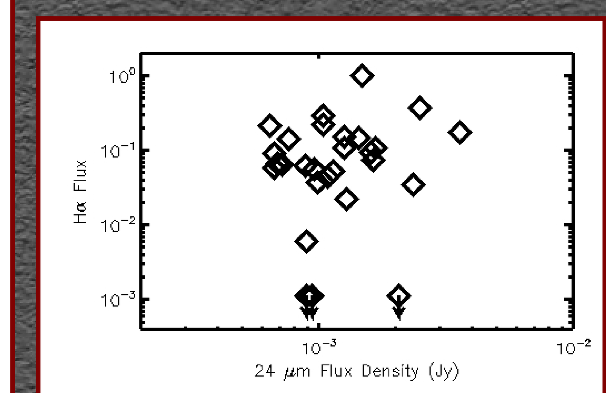
Correspondence between Hα, PAH, and dust emission: quantitative analysis

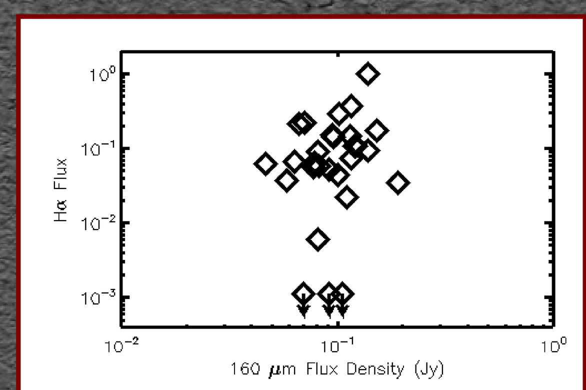
The figures to the right show comparisons of fluxes and flux densities measured from individual regions identified in the outer ring of NGC 1291. A scaled version of the 3.6 µm image was subtracted from the 8 µm image to remove the stellar continuum at 8 µm. The calibration for the Hα data is currently being readjusted, so the data shown here have been normalized to the highest flux measurement. The measurement errors are smaller than the symbols.

These data show quantitatively what is demonstrated by the images to the left. The PAH emission at 8 µm is correlated with the very small grain emission at 24 µm. However, the Hα flux is uncorrelated with the 8 µm PAH emission, the 24 µm very small grain emission, or the 160 µm large grain emission. These results clearly show how different star formation rates can easily be inferred from different star formation tracers.

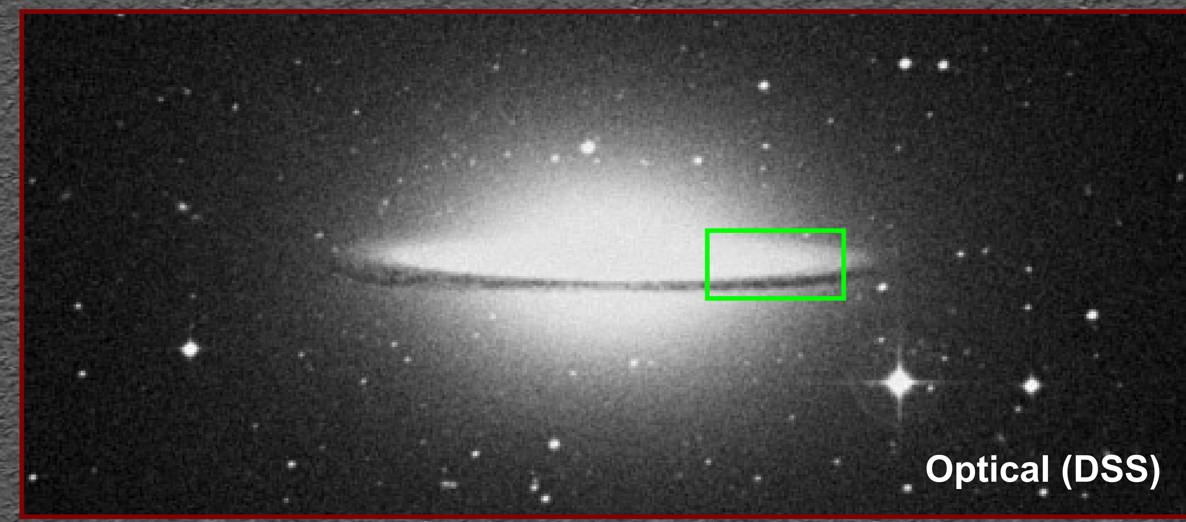


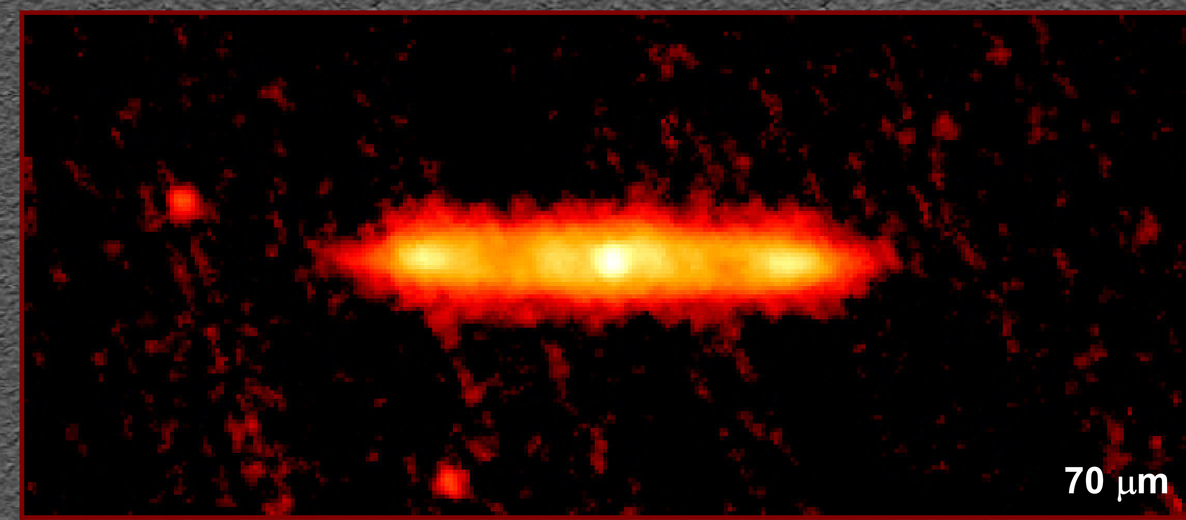


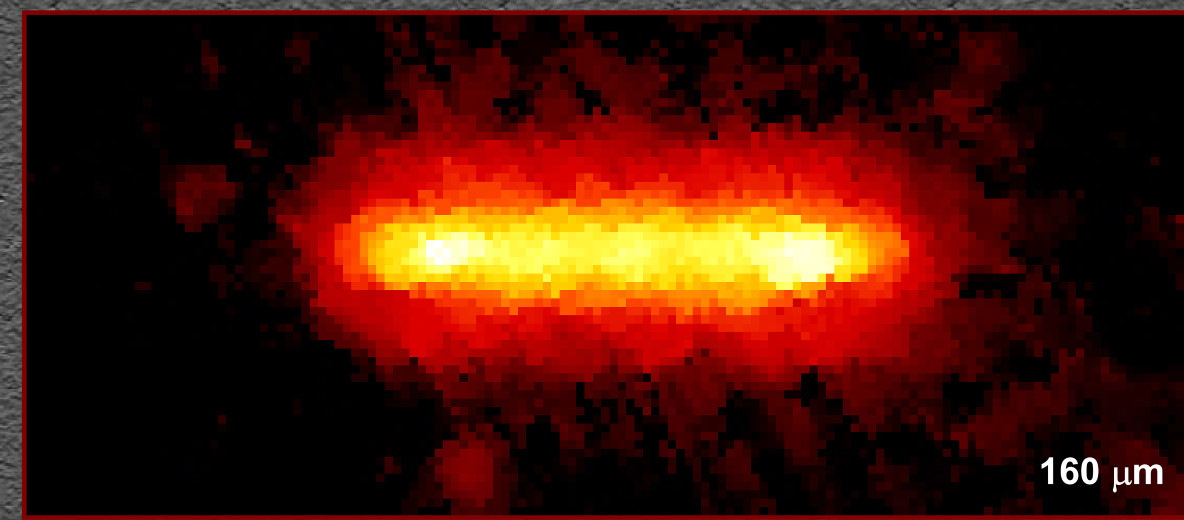


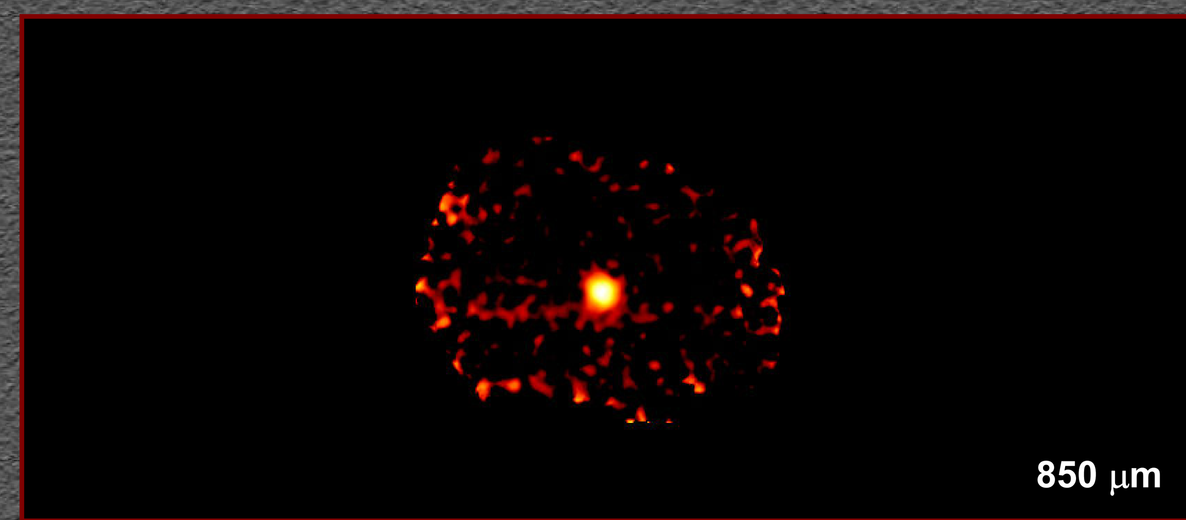


NGC 4594







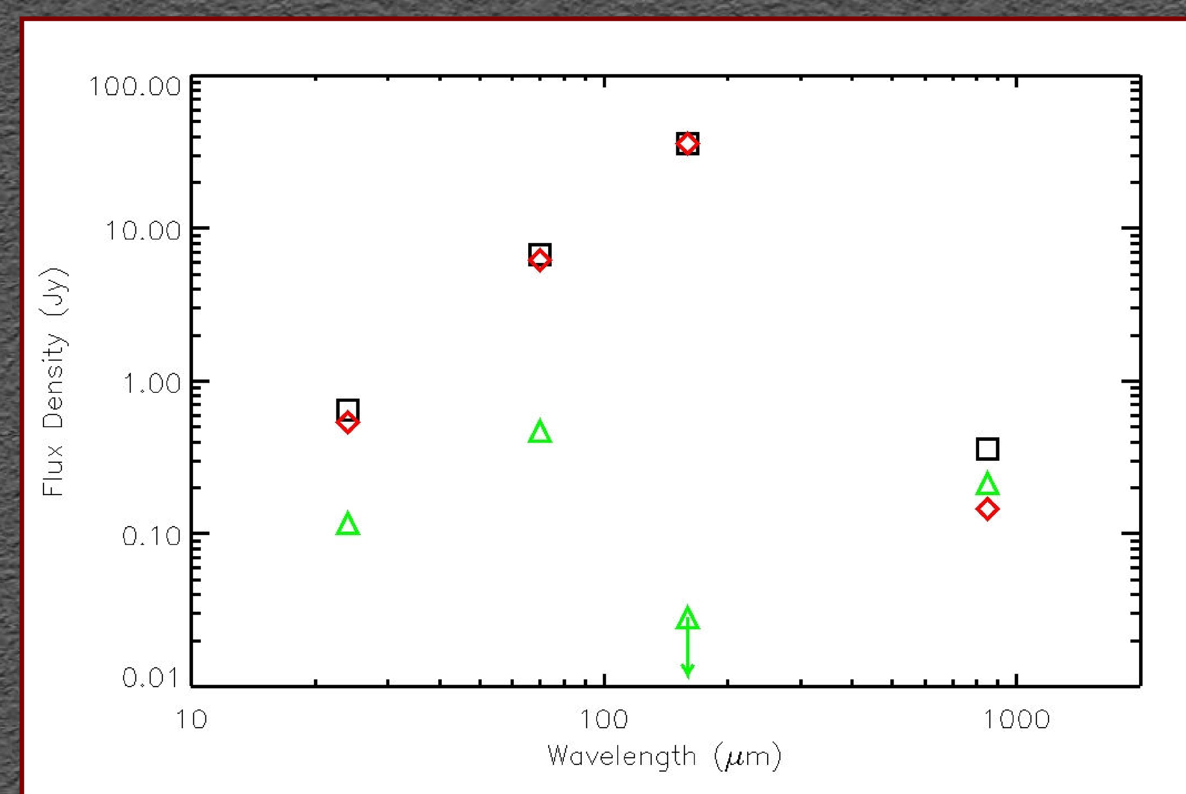


NGC 4594 (the Sombrero Galaxy; SAa) in the optical, 24 µm, 70 µm, 160 µm, and 850 µm bands. Each image is 14′ × 6′, with north up and east to the left. The green box in the optical image shows the region in the magnified images below. In the 24 and 70 µm images, which trace warm dust emission, the AGN nucleus is the most prominent source, but a ring structure is also visible. This dust ring dominates the cool dust emission in the 160 µm band; no nuclear emission can be measured. At 850 µm, the nucleus again dominates the emission, and the dust ring becomes only a minor contributor to the global flux. Since the 160 and 850 µm maps look so radically different, the 850 µm emission must come from a source other than ~20 K dust.

Spectral Energy Distributions

Plotted below are the spectral energy distributions of the total galaxy (as black squares), the dust toroid (as red diamonds), and the AGN (as green triangles). The errors are smaller than the symbol sizes. Note that the toroid dominates at far-infrared wavelengths but that the AGN dominates at submillimeter wavelengths. Also note that the AGN is not detected at 160 µm. These results convincingly demonstrate that this low-luminosity AGN produces insignificant far-infrared emission. Previously, only inferences based on ISO data had demonstrated that nearby AGN may produce little far-infrared emission.

The source of the 850 µm emission is still being investigated. Cool (~20K) dust emission, very cold (~6 K) dust emission, bremsstrahlung emission, synchrotron emission, and CO emission have all been eliminated as probable sources through either logic or quantitative analysis. Either submillimeter spectroscopy or millimeter photometry are needed to identify the source of the emission.



Correspondence between Hα and 24 µm emission

The images below show the west (right) side of the dust ring. A substantial part of the 24 µm emission in the dust ring does not originate from the HII regions that are detected in the Hα image. Furthermore, the 24 µm emission does not necessarily peak in the HII regions. Note regions A, B, C, and D. All four regions have similar Hα fluxes, yet the 24 µm flux only strongly peaks in region C.