Spitzer Observations of Two Early-Type Galaxies with Dust Rings

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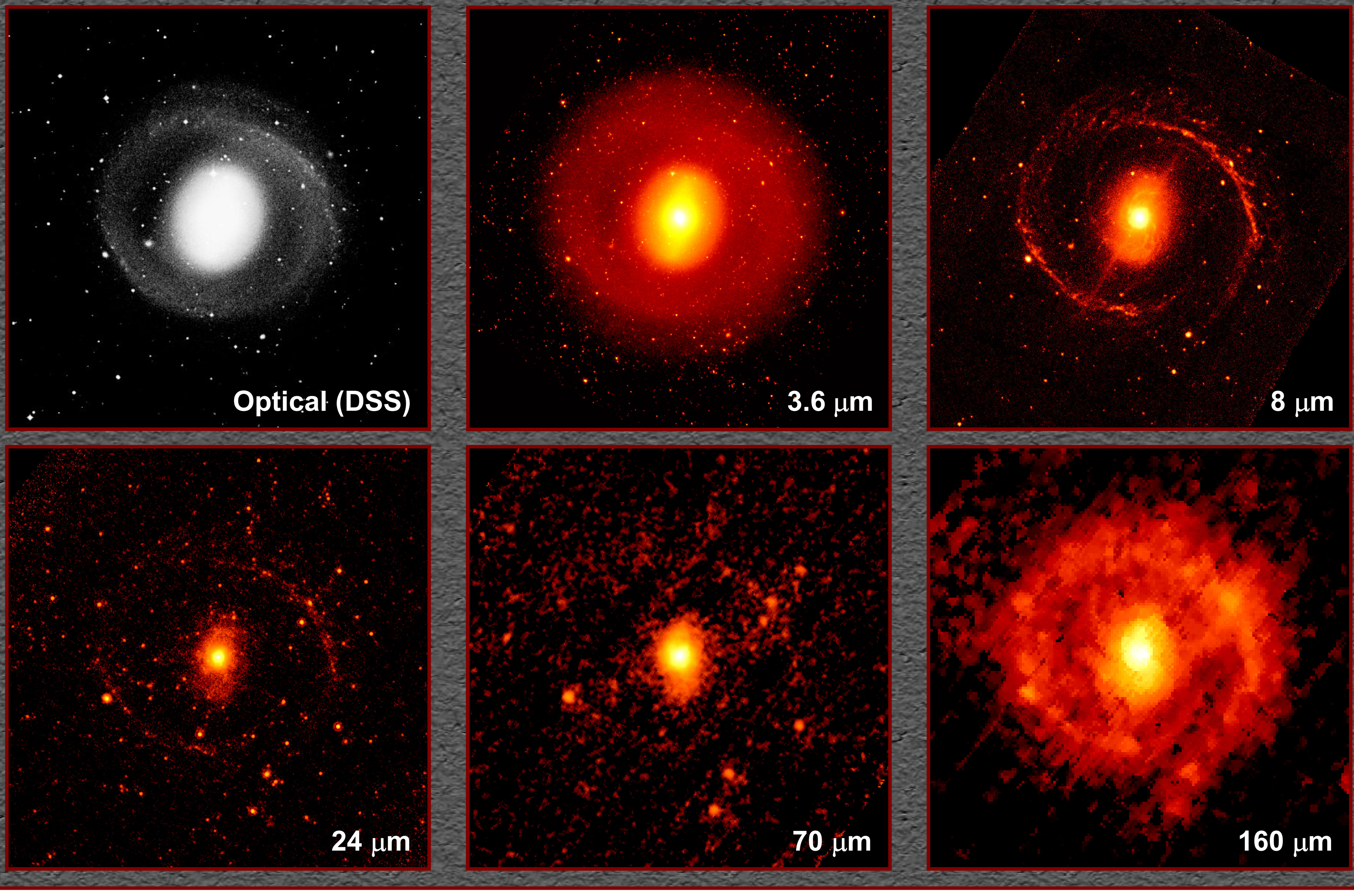
Abstract

We present Spitzer images of the SB0/a galaxy NGC 1291 and the SAa galaxy NGC 4594. Both galaxies contain dust rings. 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 examine whether the dust emission from the rings is related to star formation activity, and we study the relation between dust emission and PAH emission. For NGC 4594, we also present submillimeter data that show that the nucleus dominates the 850 μm emission. These results demonstrate that the 850 μm emission cannot come from the same cool dust that dominates the 160 μm emission. We examine the possible mechanisms that could be generating the 850 μm emission.

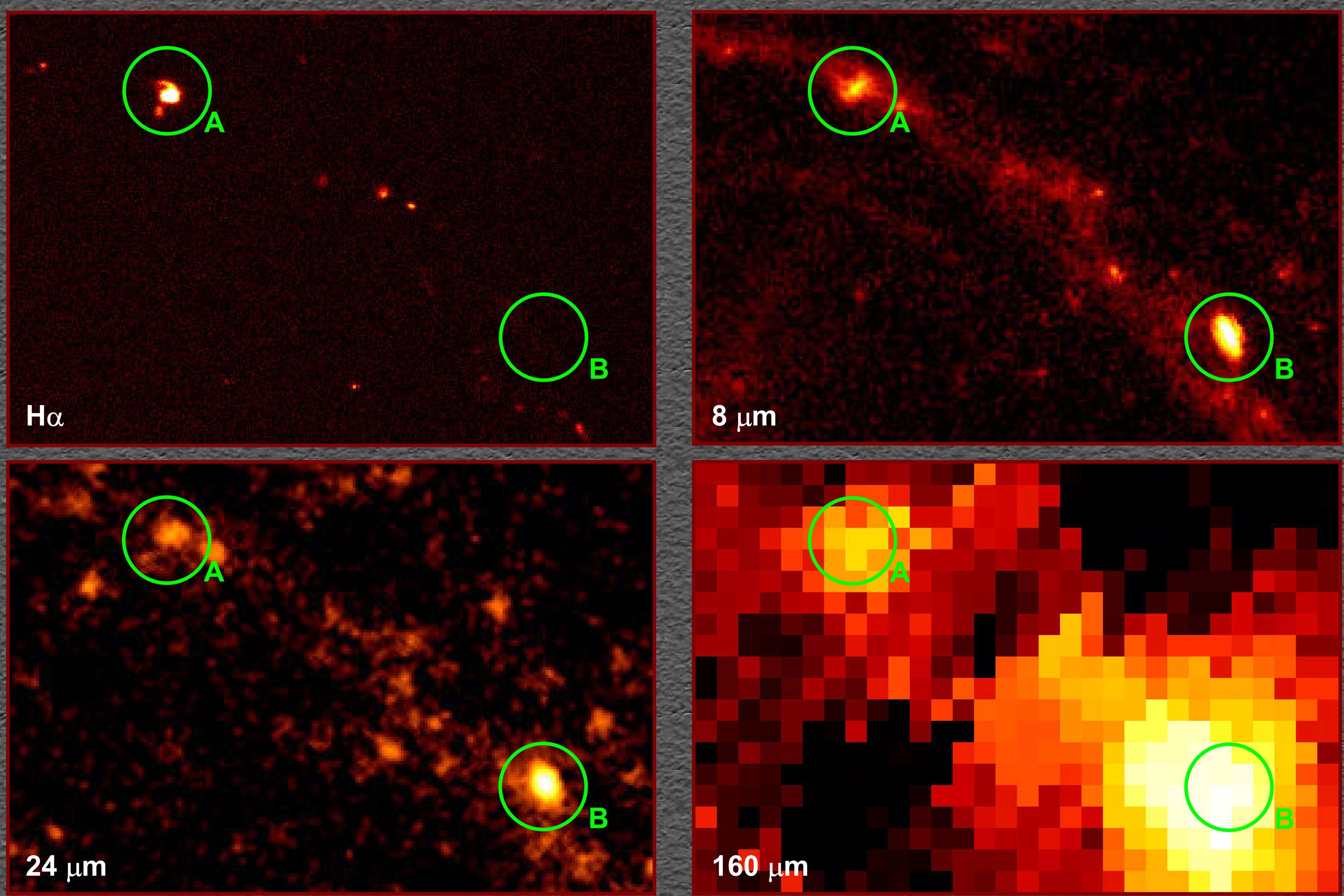
NGC 1291



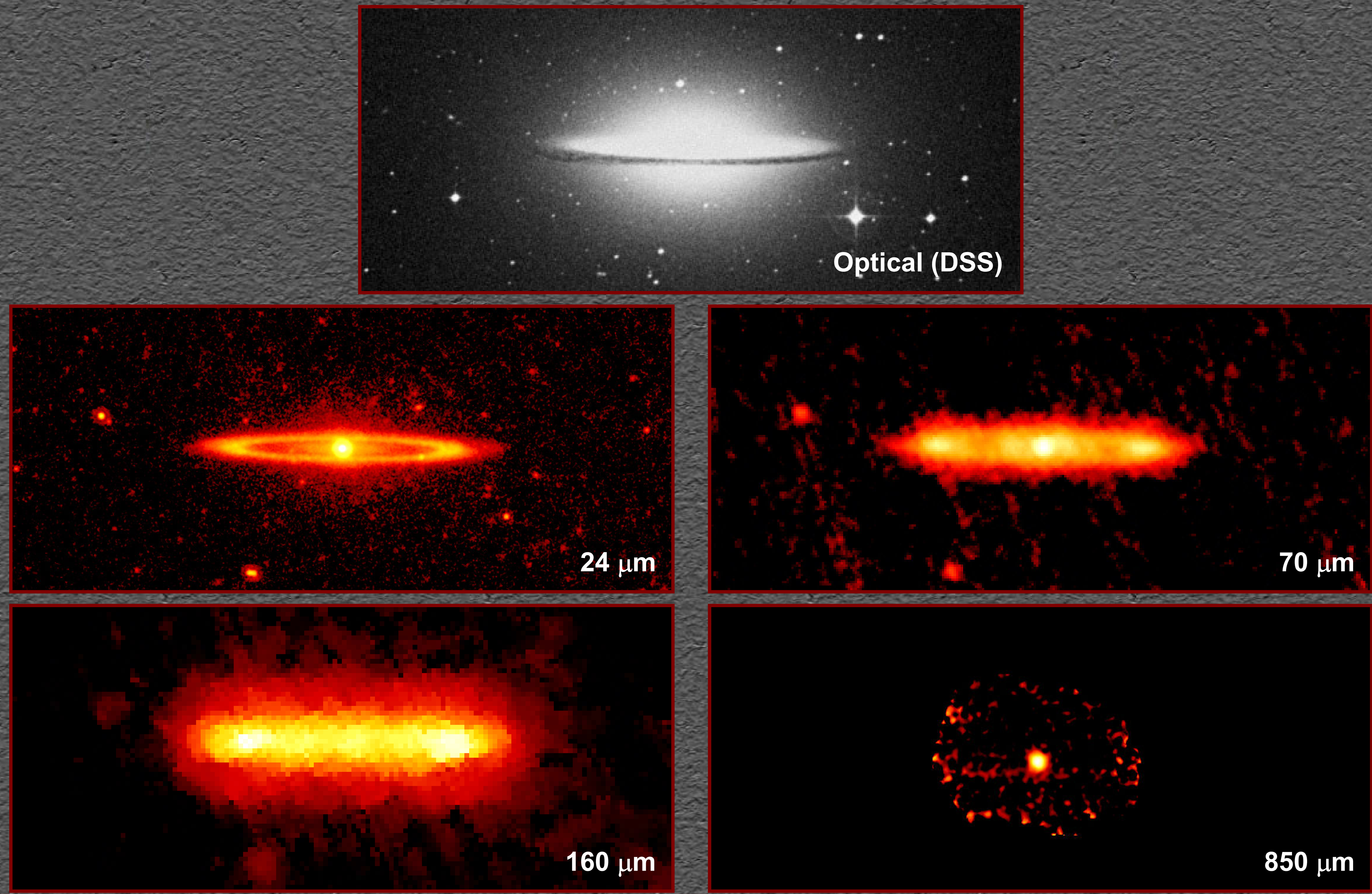
NGC 1291 (RSB0/a) in the optical, 3.6 μm, 8 μm, 24 μm, 70 μm, and 160 μm bands. The 3.6 μm image traces the stars. The nucleus dominates the 8 μm waveband, which traces PAH emission, but some 8 μm emission can be seen from the outer ring. The 24 and 70 μm images, which trace warm dust grain emission, appear similar to the PAH emission, and the 8 and 24 μm wavebands do correlate very well 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

The images below show the 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.



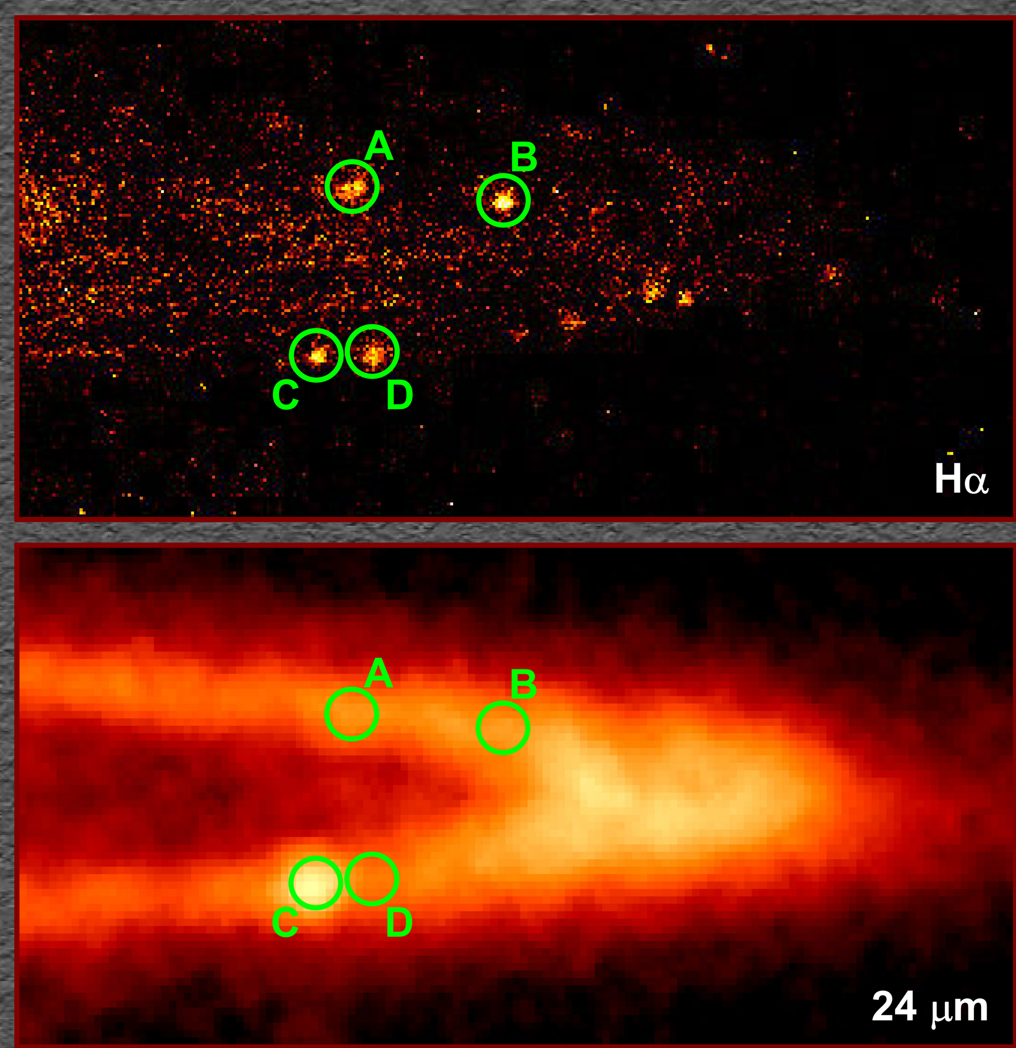
NGC 4594



NGC 4594 (the Sombrero Galaxy; SAa) in the optical, 24 μm, 70 μm, 160 μm, and 850 μm bands. 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.

Correspondence between Hα and 24 μm emission

The images below show the 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.



The source of the 850 μm emission

Clearly, the 850 μm emission in this galaxy does not originate from the ~20 K dust that dominates the 160 μm emission. An alternative mechanism must be the source.

850 μm emission mechanisms that were considered first in the analysis but then rejected include:

- *CO emission.* Data from Young et al. (1995 ApJS 98, 219) show no central peak in CO emission.
- *Synchrotron radiation.* An extrapolation from radio data (from Hummel et al. 1984 A&A 134, 207) to 850 μm can only account for 1/4 of the nuclear emission, although we caution that additional millimeter measurements are necessary to securely rule this out as a source.
- *Very cold (~9K) dust.* The strong dust heating evident in the enhanced 24μm/160μm colors make it appear unlikely that dust at 9K could exist in a sufficient mass in the nucleus to produce the flux seen at 850 μm.

Other possible 850 μm emission mechanisms include:

- *Bremsstrahlung radiation.* This is a known source of short-wavelength radio emission (e.g. Condon 1992 ARA&A 30, 575).
- *Dust with exotic emissivity properties.* This has been proposed to explain the millimeter excess seen some galaxies (e.g. NGC 4631; Dumke et al. 2004, A&A 414, 475).
- *Unidentified spectral line emission.*

Clearly, more data in other wavebands is needed to identify the source of the 850 μm emission.