The SEDs of two nearby galaxies observed with Spitzer and JCMT

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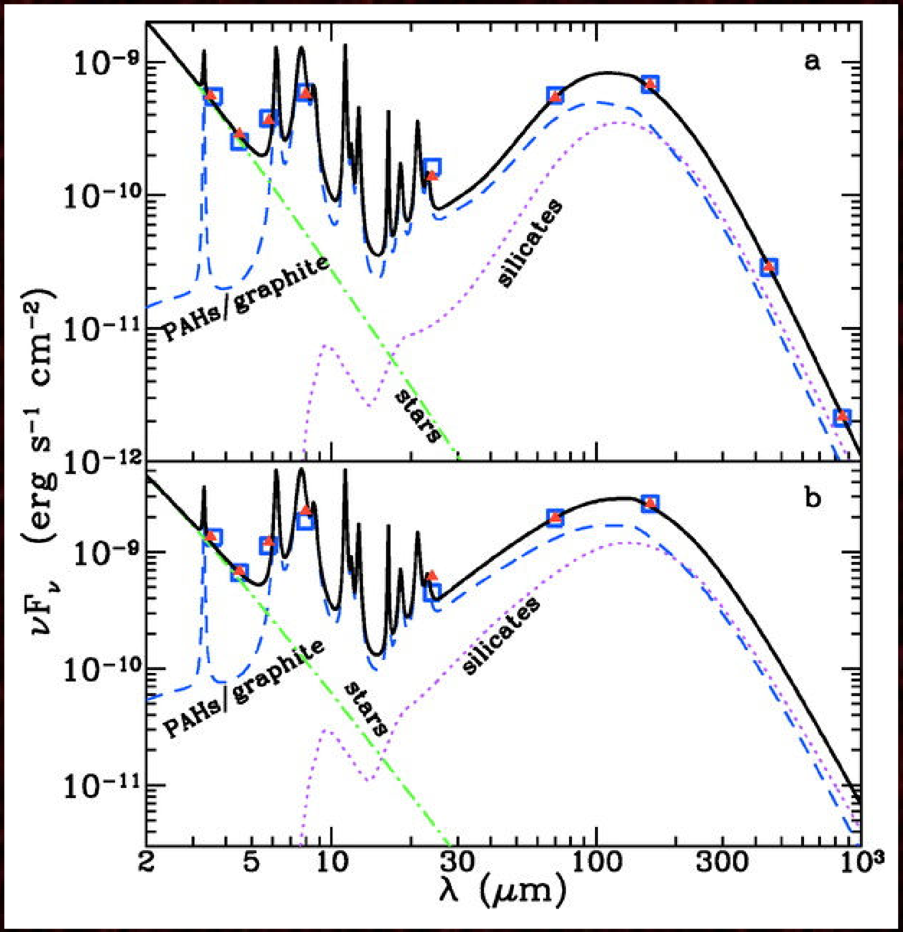
Background

Several groups found that emission in the 850–1300 μm regime superseded what was expected from 60-200 μm dust emission, although this excess was not always consistently found.

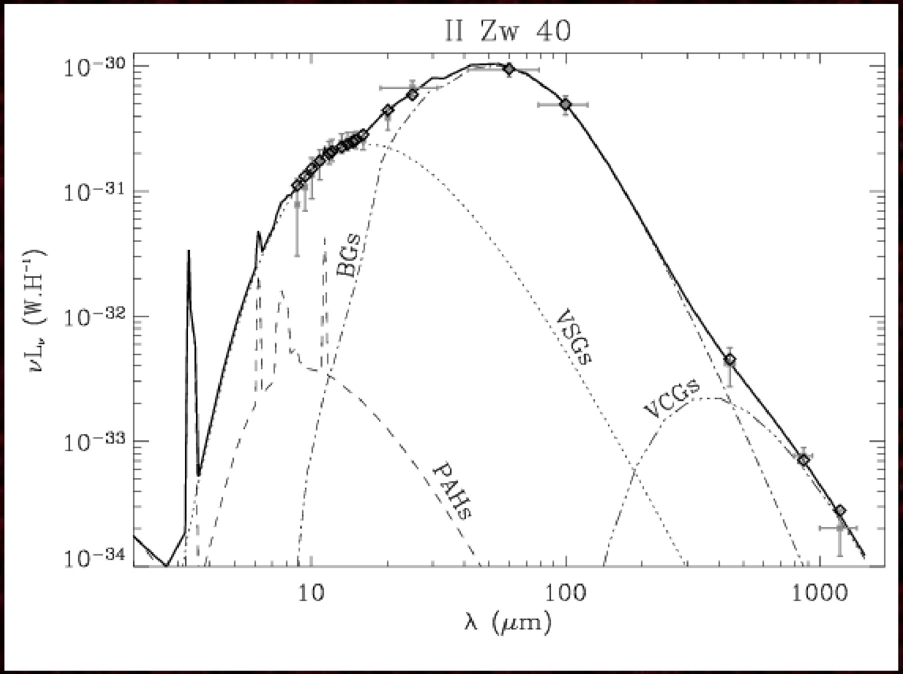
A number of explanations were put forth for this "excess", including the possible presence of very cold (5-10 K) dust or the possibility that dust emissivity deviated from a λ^{-2} law.

Spitzer and JCMT observations together allow for the study of dust SEDs for 1-2 kpc regions within individual galaxies.

Background



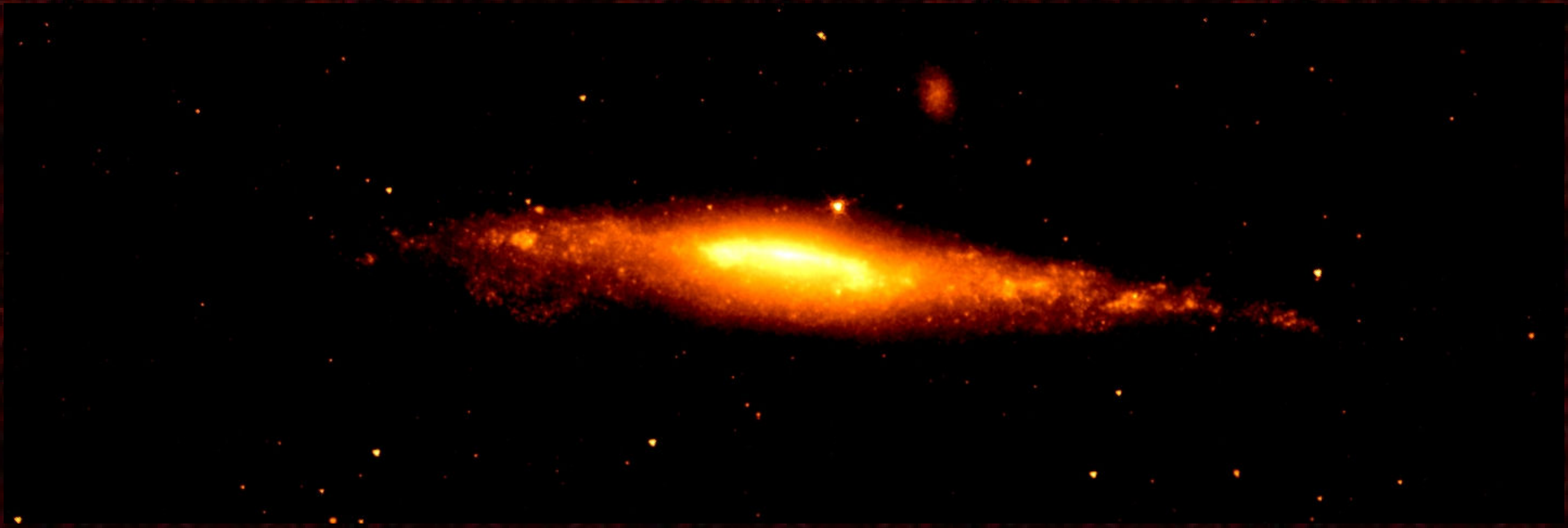
SED fits to NGC 7331 from Regan et al. (2004)



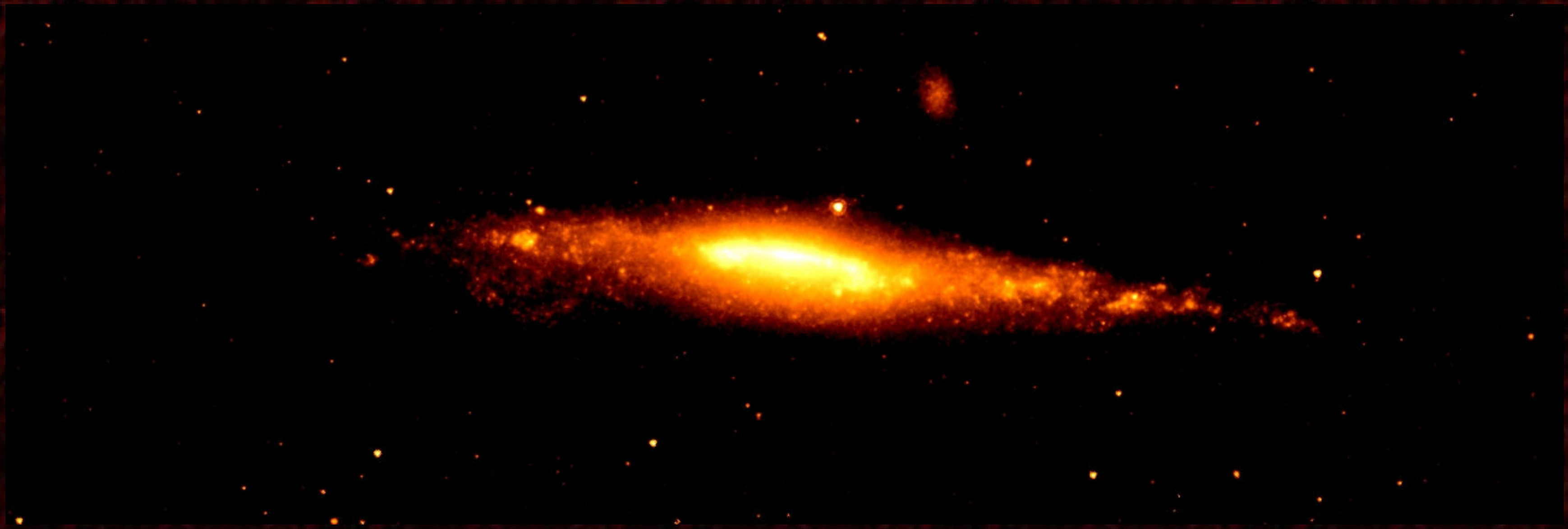
Sample SED fits from Galliano et al. (2005)

NGC 4631

NGC 4631 (3.6 μm)



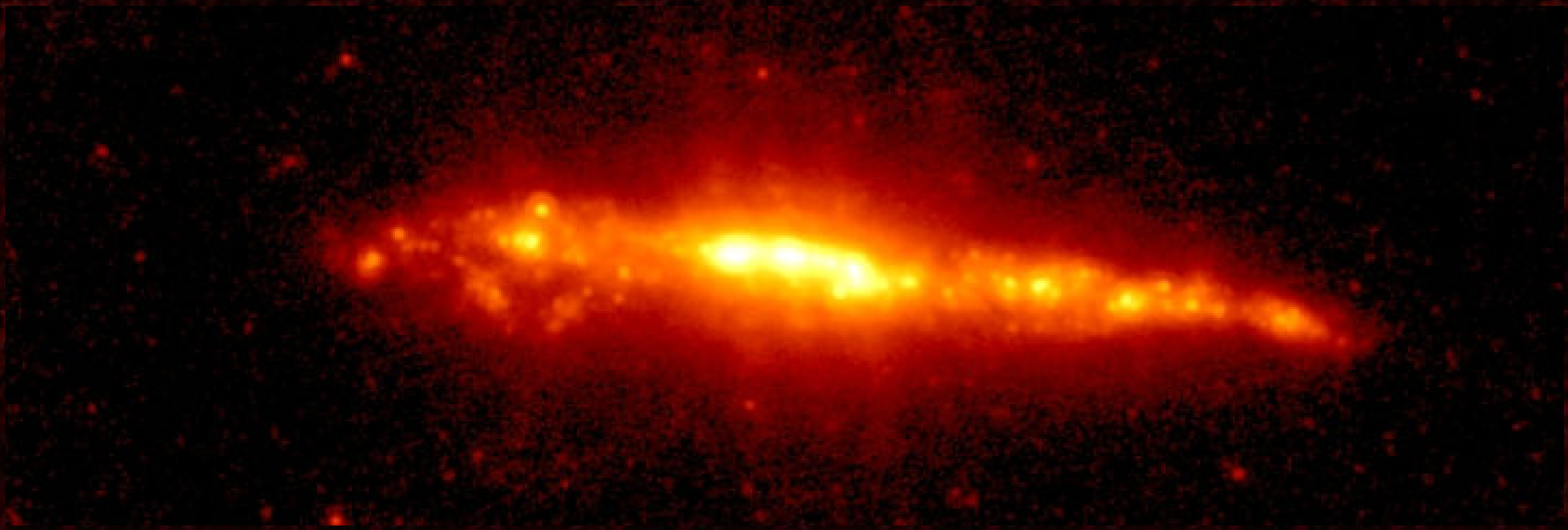
NGC 4631 (4.5 μm)



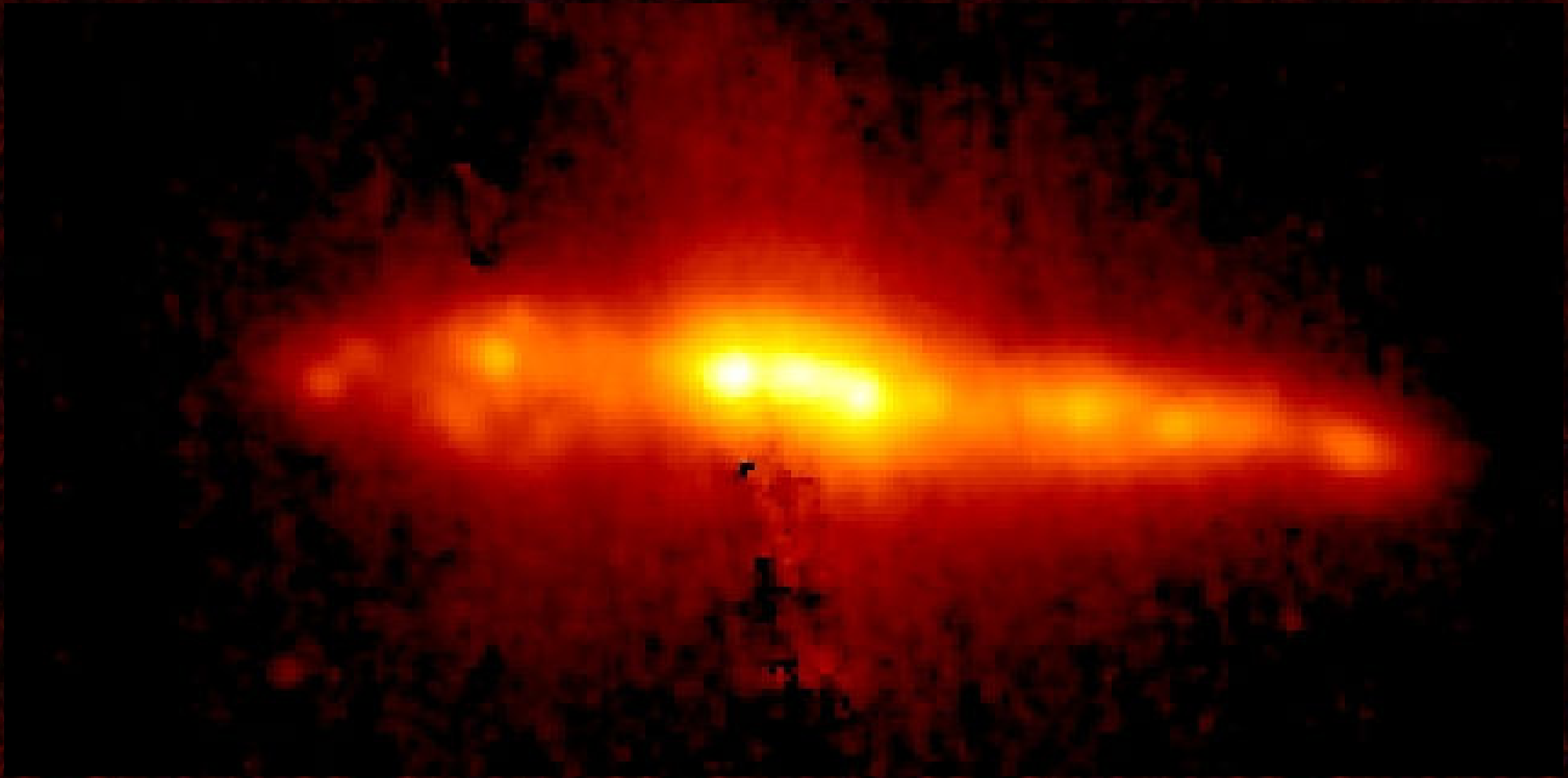
NGC 4631 (5.7 μm)

NGC 4631 (8 μm)

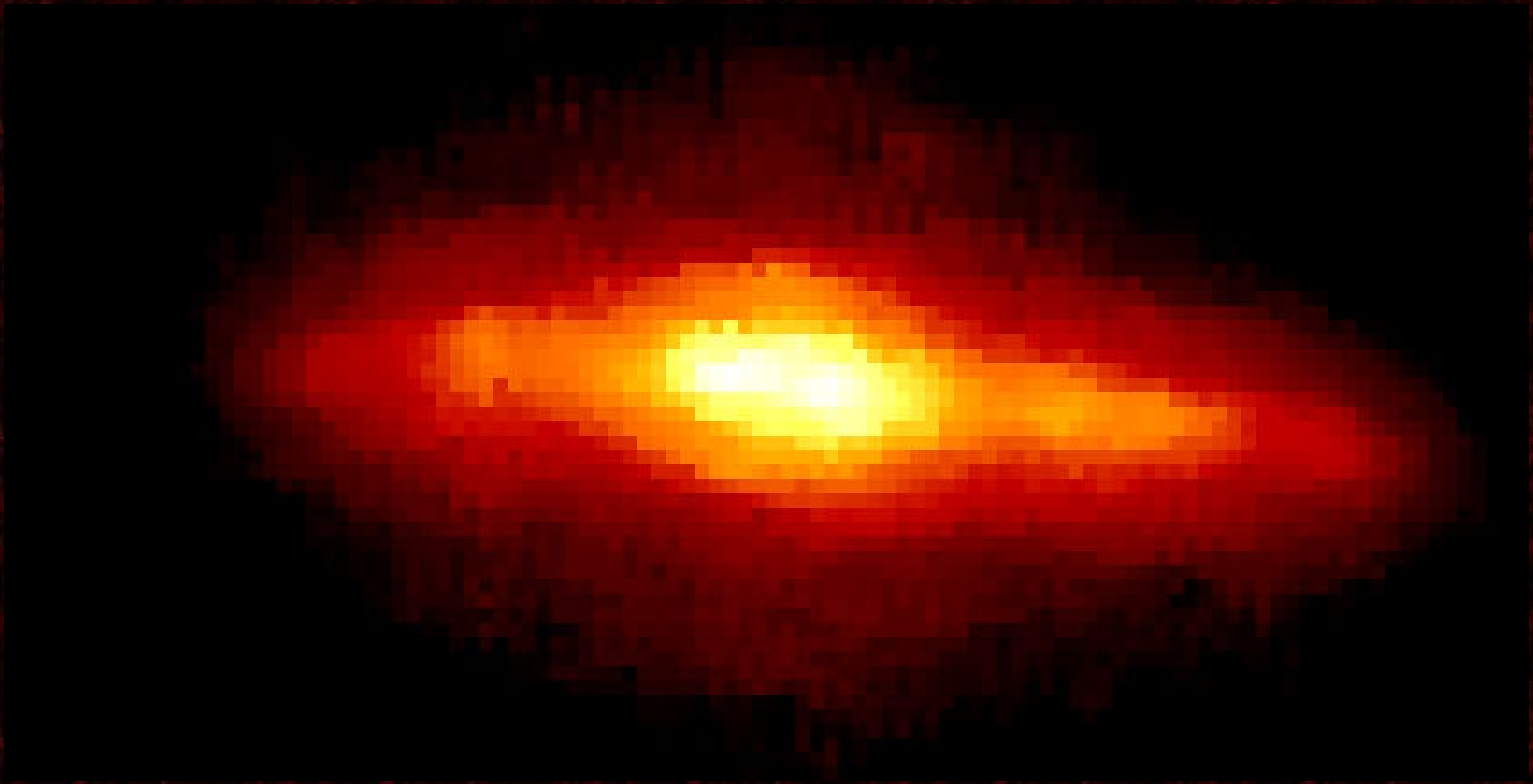
NGC 4631 (24 μm)



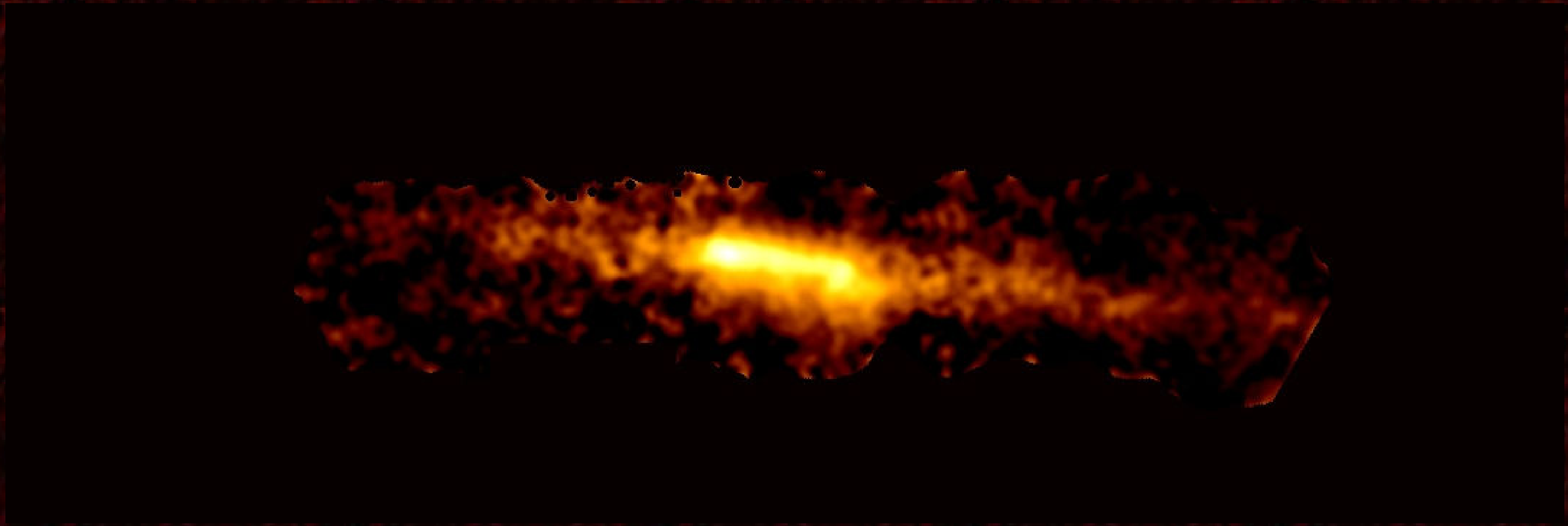
NGC 4631 (70 μm)



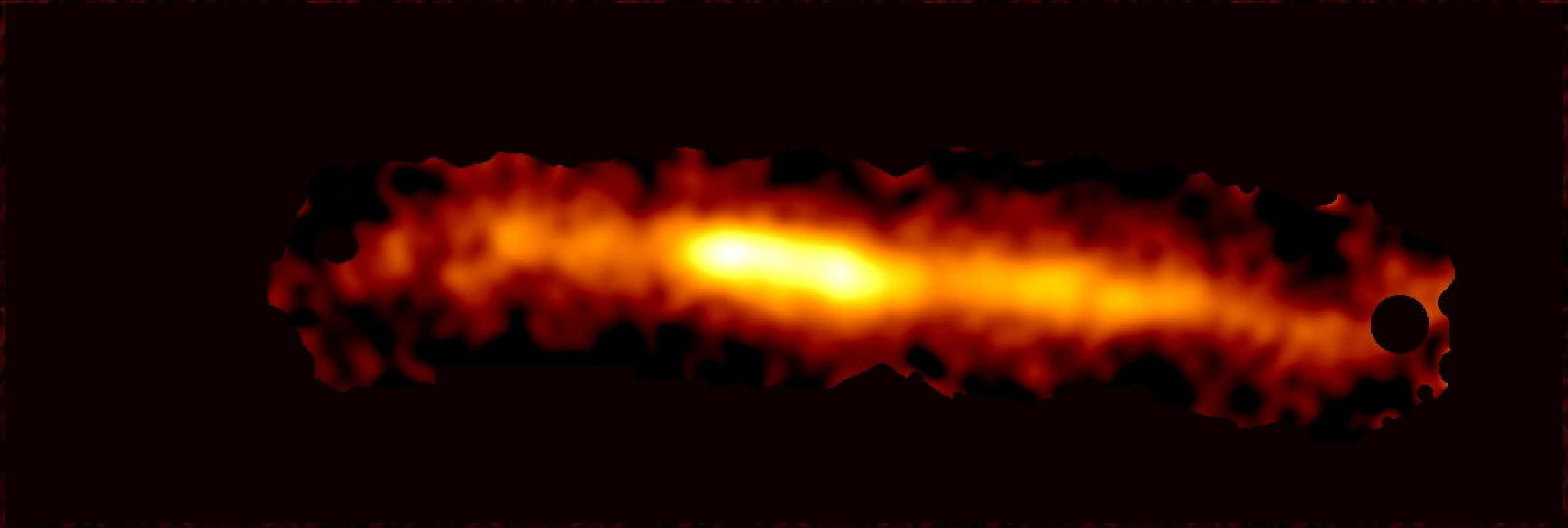
NGC 4631 (160 μm)



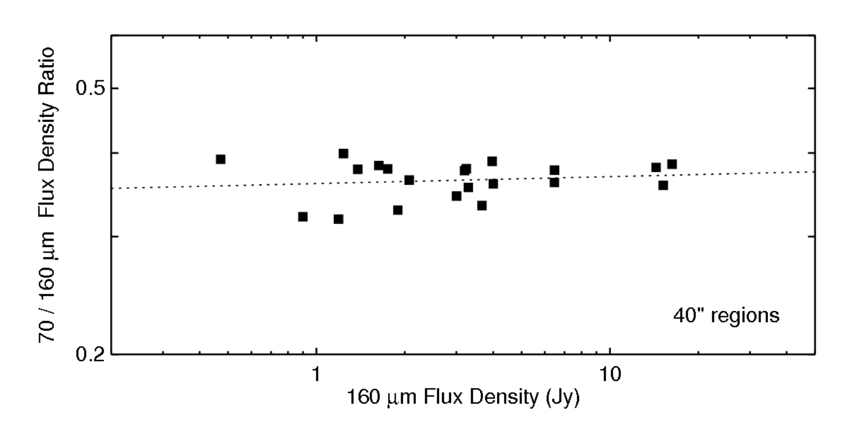
NGC 4631 (450 μm)

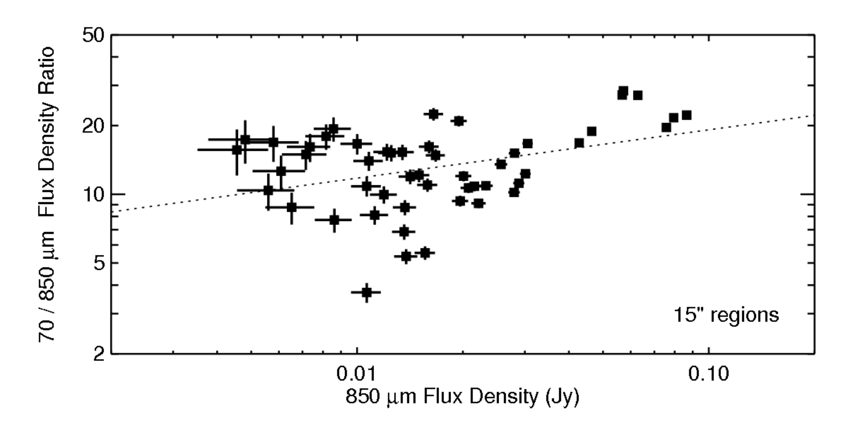


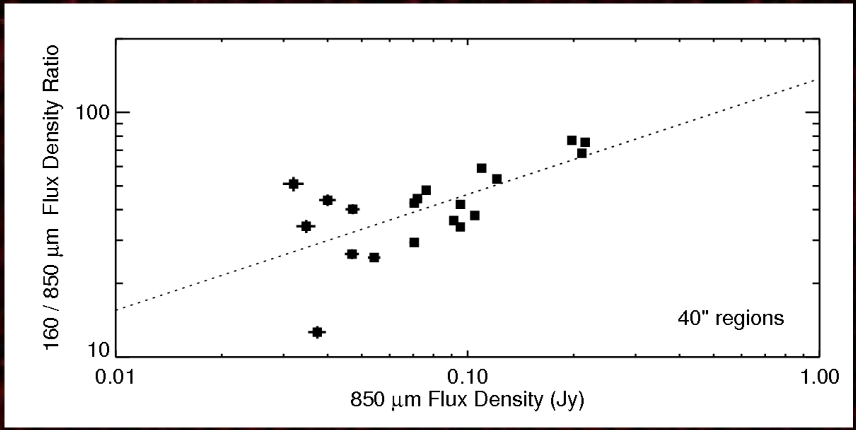
NGC 4631 (850 μm)

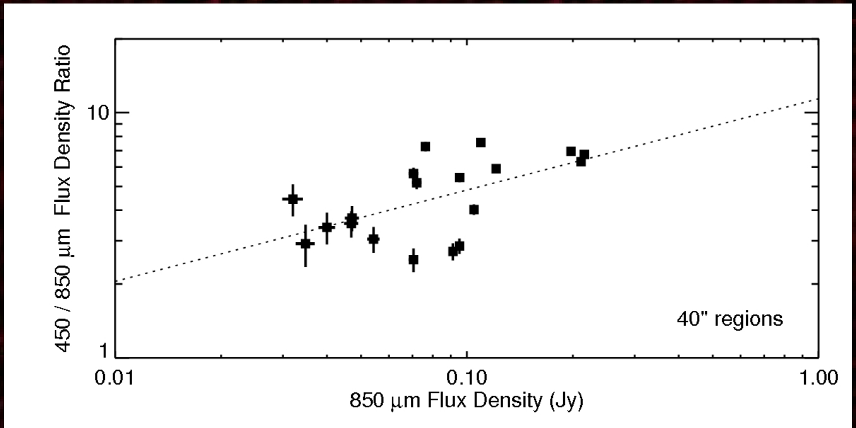


Relation between 70-850 μm Wave Bands







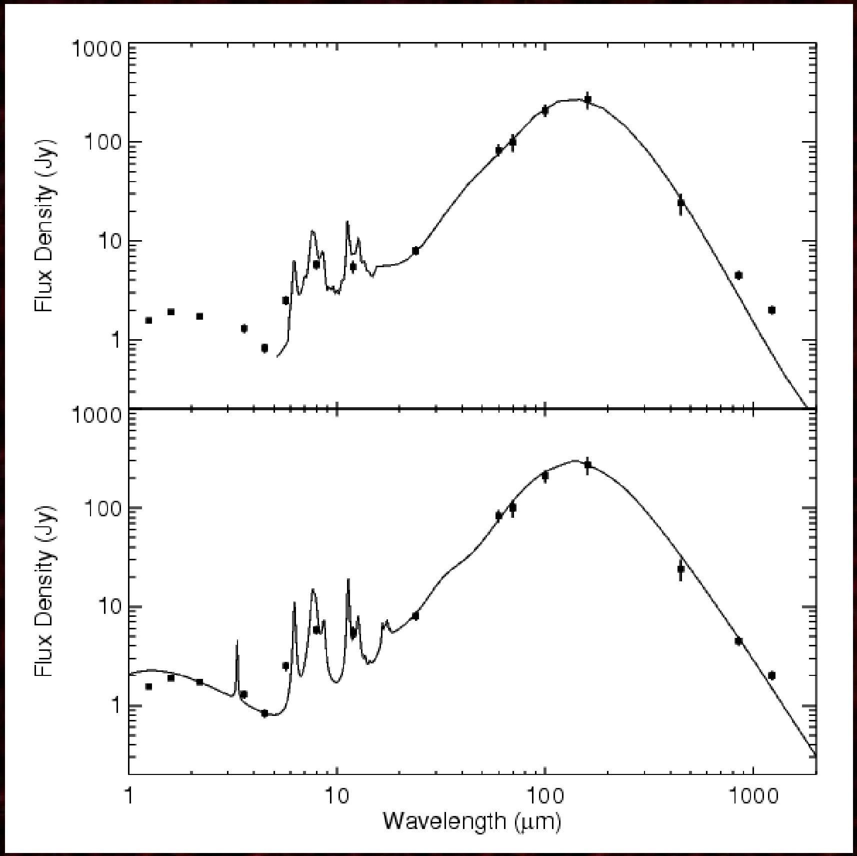


Global SED fits

The global SED fits generally show that excess 850-1230 μm emission is present (although Draine's models marginally fit the 850-1230 μm data).

The dust masses implied by the <450 μm emission are consistent with what is expected based on the gas mass.

If the 850-1230 μm emission originates from dust, it would be unrealistically cold (3.5 K) and unrealistically massive. Very cold dust cannot explain the excess emission.



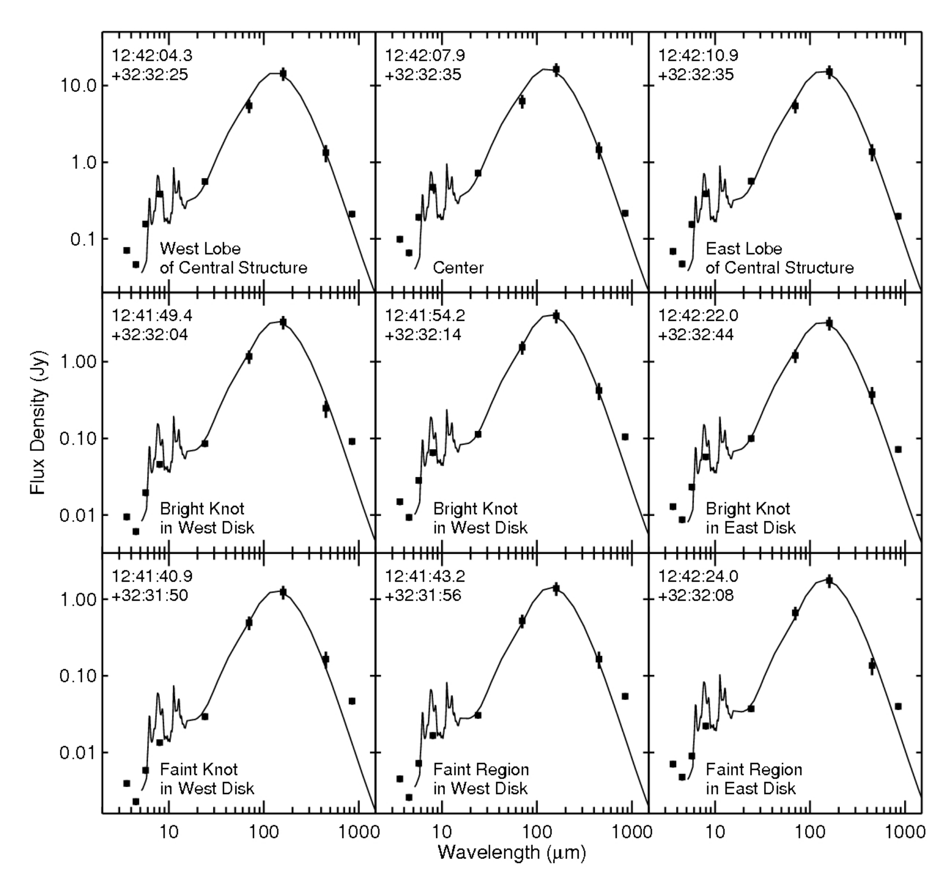
SED fits in individual regions

SED fits within individual regions show that the relative fraction of 850 μm emission originating from the excess varies throughout the galaxy.

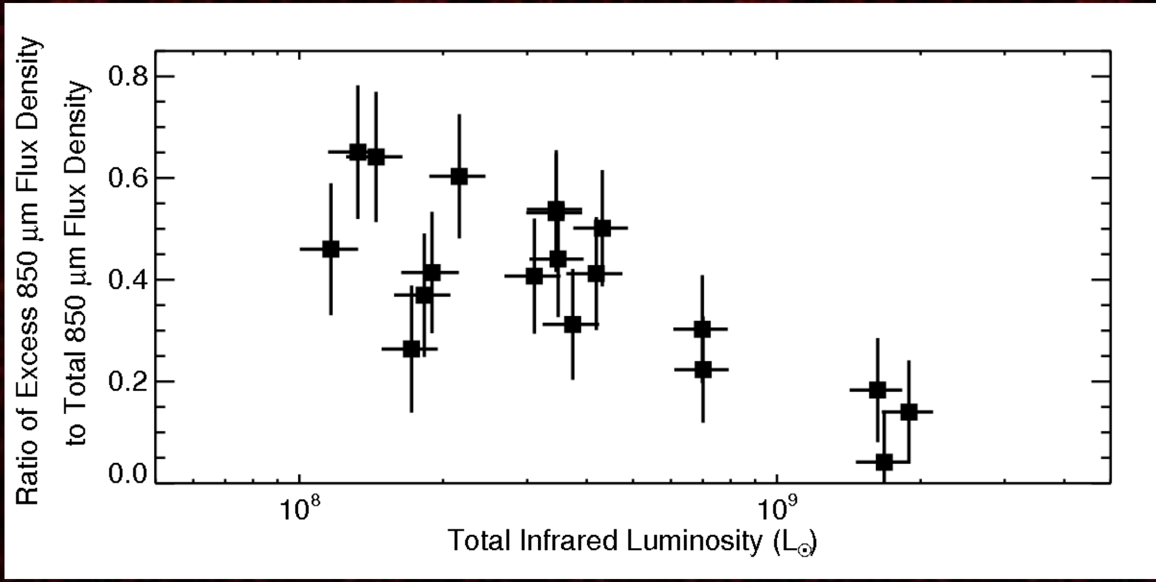
The excess is brightest in the center, but it comprises only a small fraction of the 850 μm emission.

The excess comprises the greatest fraction of the 850 μm emission in infrared faint regions.

The nature of this color variations suggests that the dust emissivity does not vary from a λ^{-2} law shortward of 450 μm but may deviate from it at 850 μm and longer wavelengths.



SED fits



Ratio of Excess 850 μm Flux Density
to Total 850 μm Flux Density
0.8
0.6
0.4
0.2
0.0
10^8
10^9
Total Infrared Luminosity (L☉)

Conclusions from NGC 4631

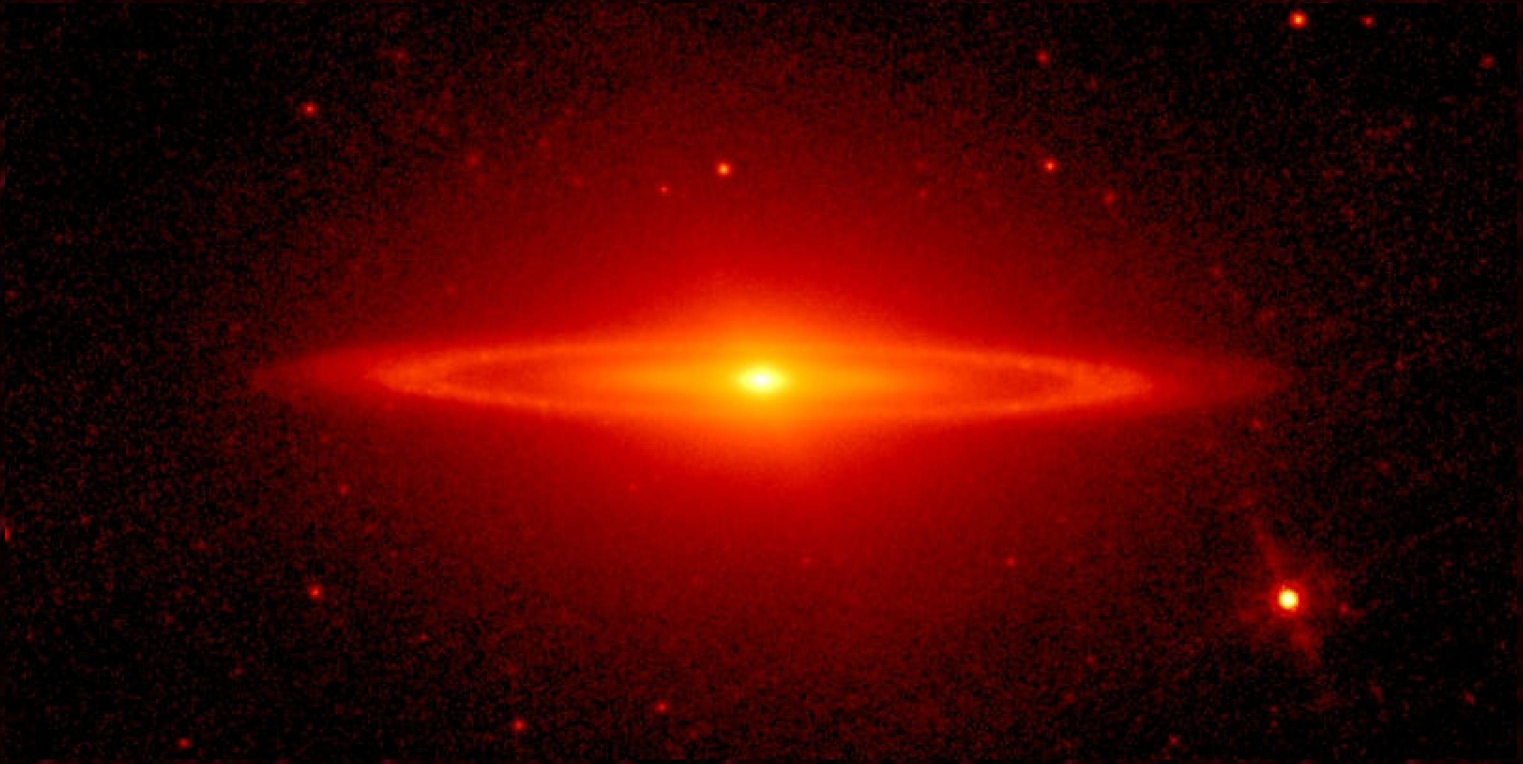
- Excess 850 μm emission is found within this galaxy.
- The relative amount of excess 850 μm emission varies within the galaxy.
- The excess probably originates from a change in the dust emissivity between 450 and 850 μm.

NGC 4594
(Sombrero Galaxy)

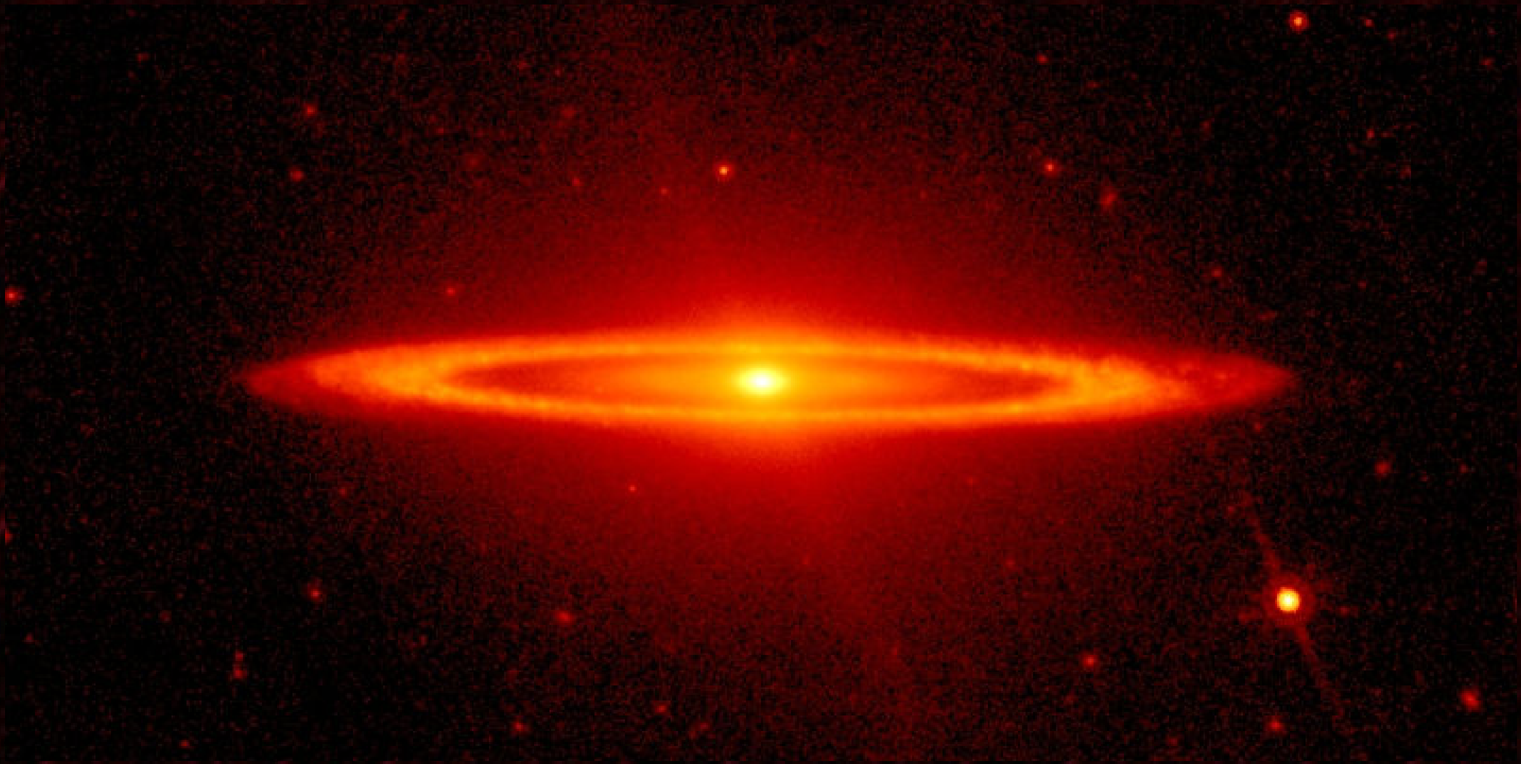
NGC 4594 (3.6 μm)

NGC 4594 (4.5 μm)

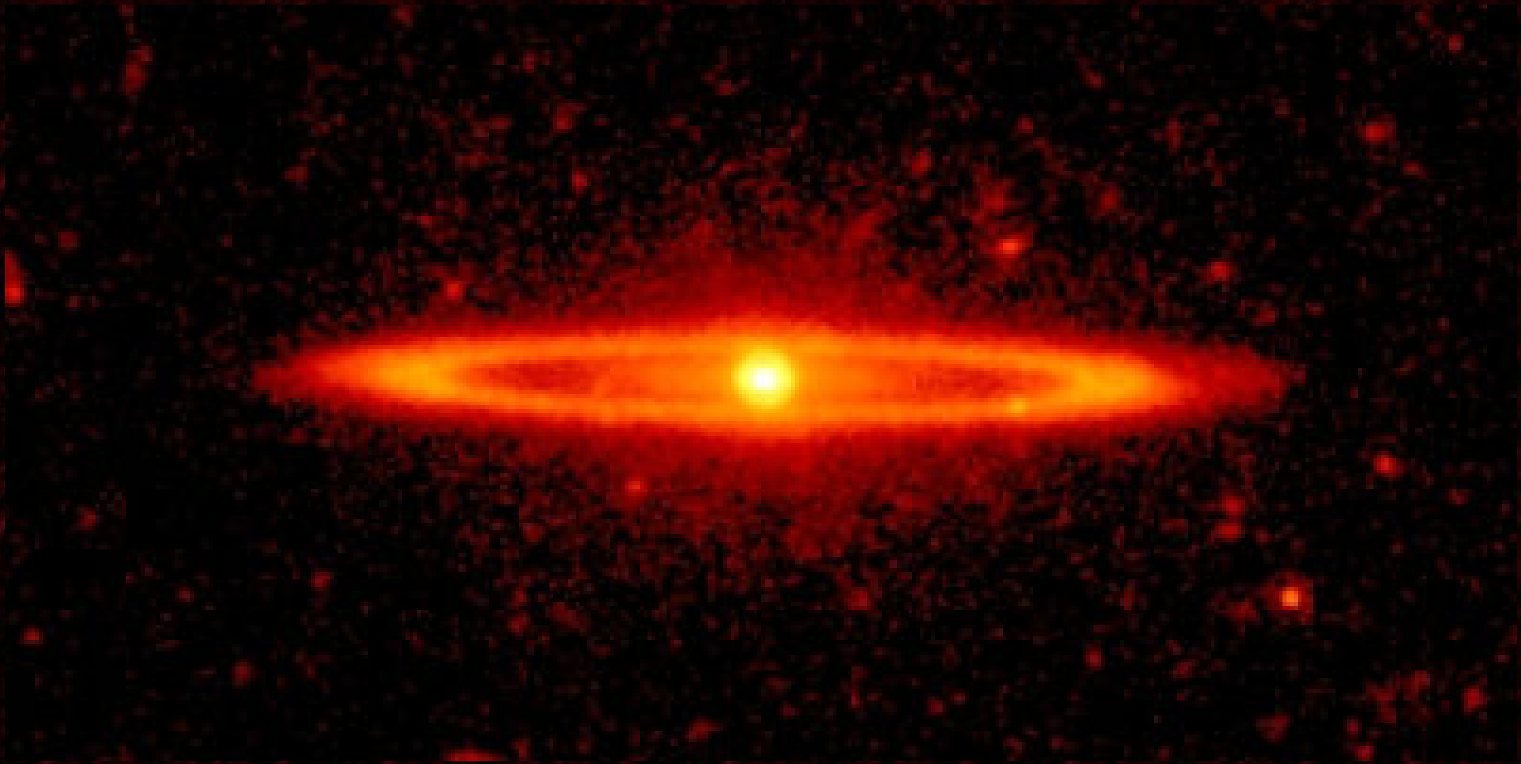
NGC 4594 (5.7 μm)



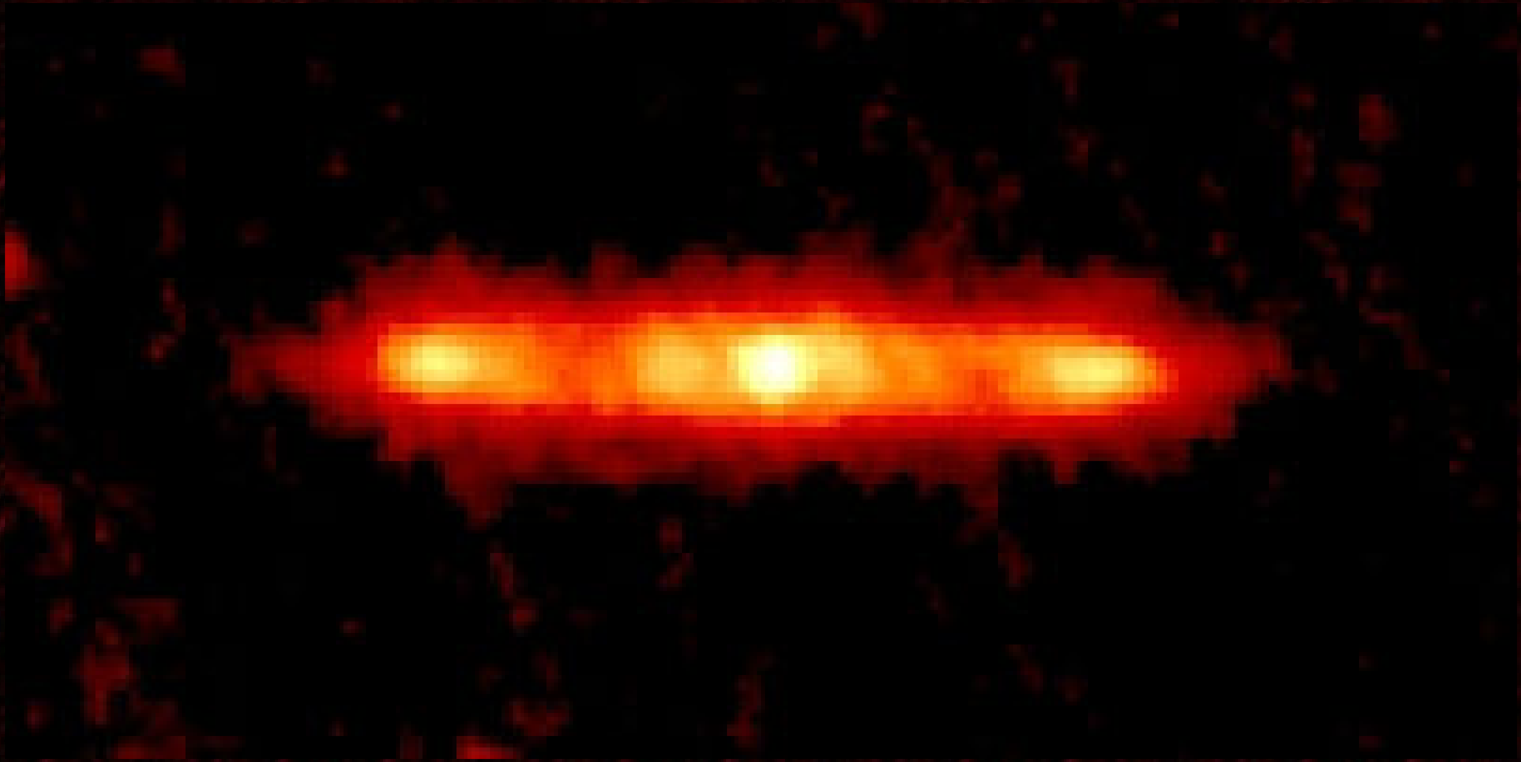
NGC 4594 (8 μm)



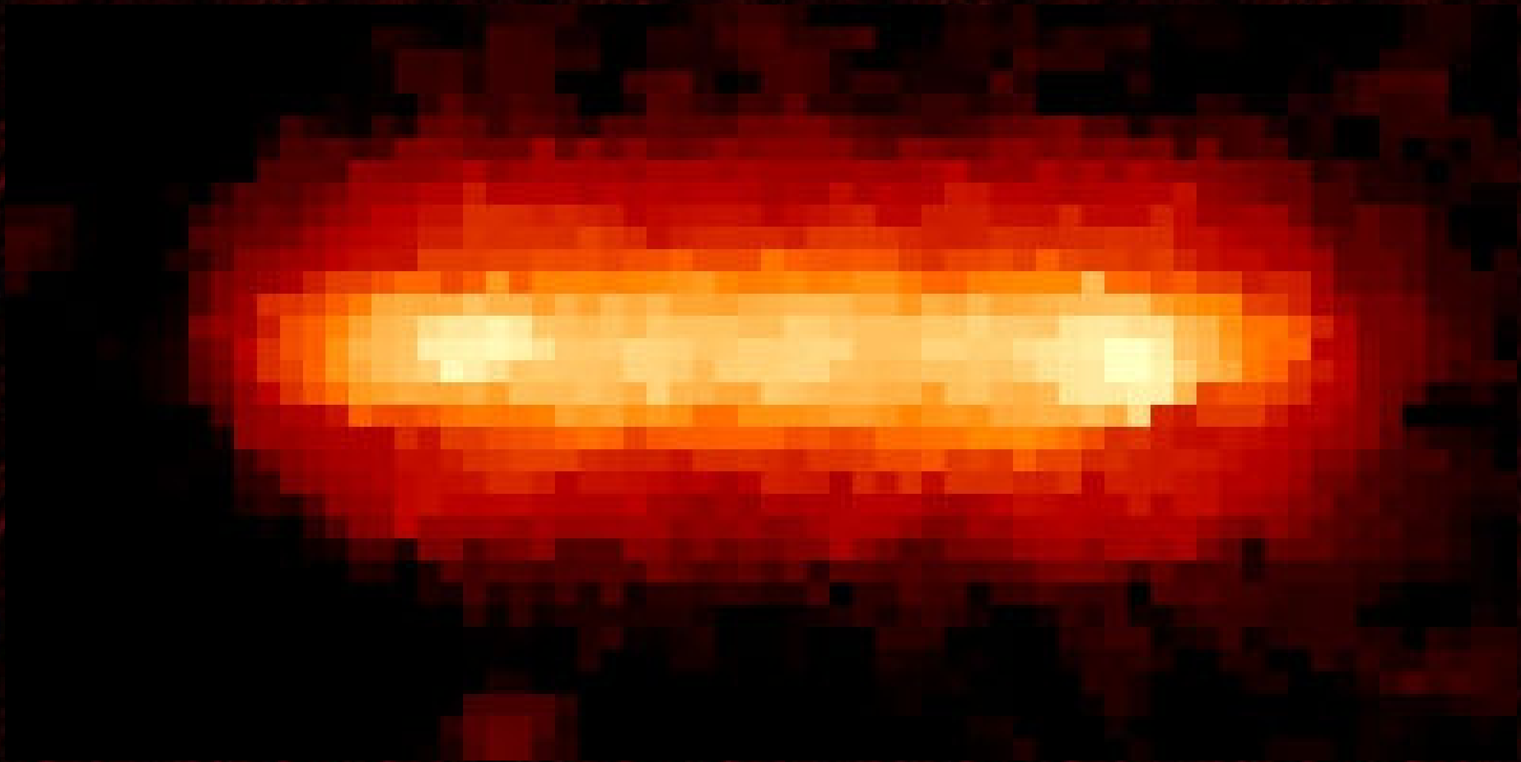
NGC 4594 (24 μm)



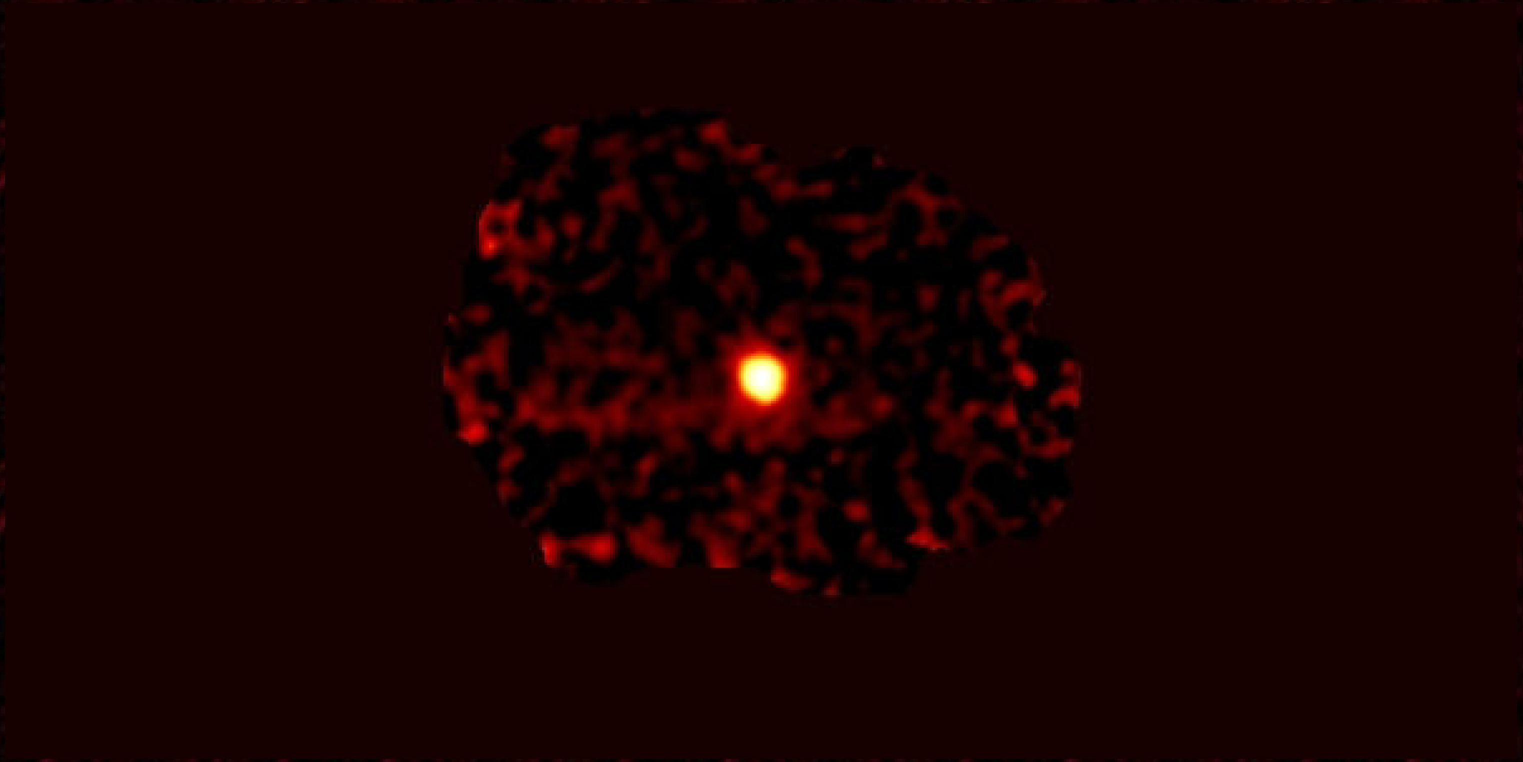
NGC 4594 (70 μm)



NGC 4594 (160 μm)



NGC 4594 (850 μm)

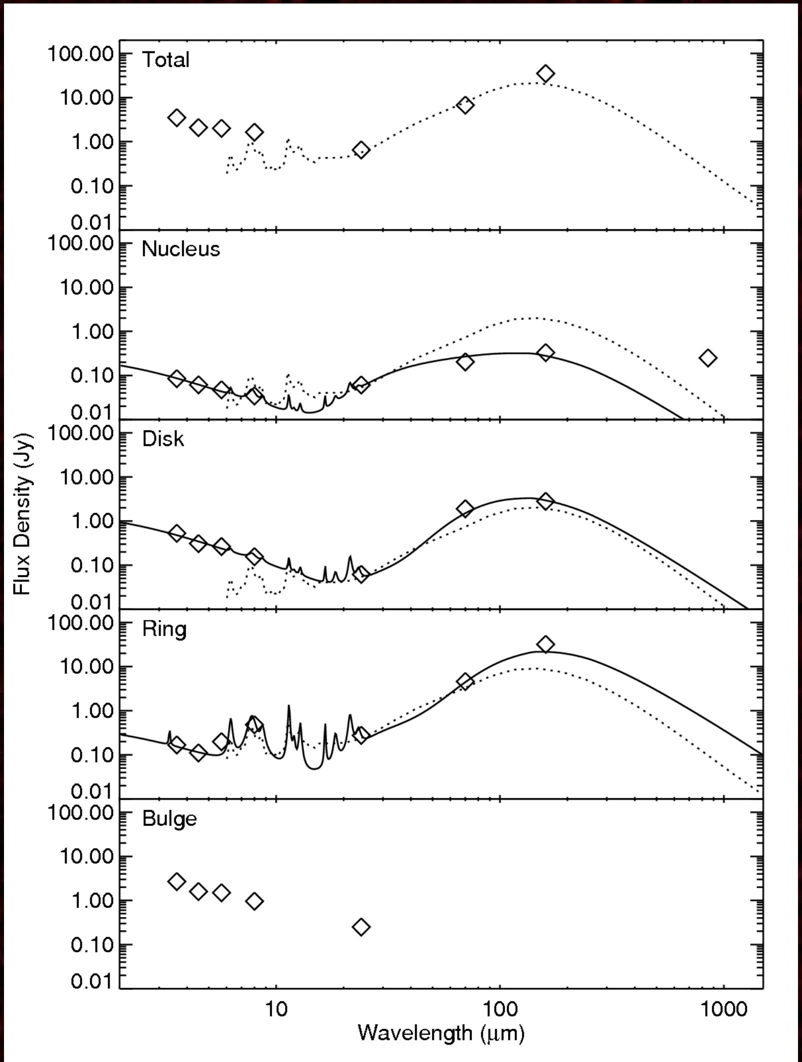


Immediate Impressions

- The nucleus virtually disappears at 160 μm!
- The nucleus is the only thing in the image at 850 μm!
- Whatever is producing the 850 μm emission probably is not ~20 K dust.

At this point, some of the members of the audience probably think that they know what produces the 850 μm emission. They are probably wrong.

SEDs of NGC 4594



Possible Conventional Sources for 850 μm Emission

- Very cold dust
- CO or other spectral line emission
- Bremsstrahlung
- Synchrotron emission

Very Cold Dust

- The highest dust temperature that is still consistent with the data is ~9 K.
- The implied gas mass is $3.2 \times 10^9\ M_{SUN}$.
- The central black hole has a mass of $1.0 \times 10^9\ M_{SUN}$.
- The measured gas mass of the galaxy is $<7.8 \times 10^8\ M_{SUN}$.
- The center of the galaxy contains an AGN with hard X-ray emission; finding <10 K dust in such an environment is unlikely.
- The very cold dust scenario clearly does not work.

CO or Other Spectral Line Emission

- Previous CO measurements imply that the CO is found primarily in the ring, but the data are not very good.
- The expected 850 μm flux density is a factor of ~10 too small.
- Follow-up observations with SMA measured a similar flux density at 1.3 mm, but no spectral lines were present.

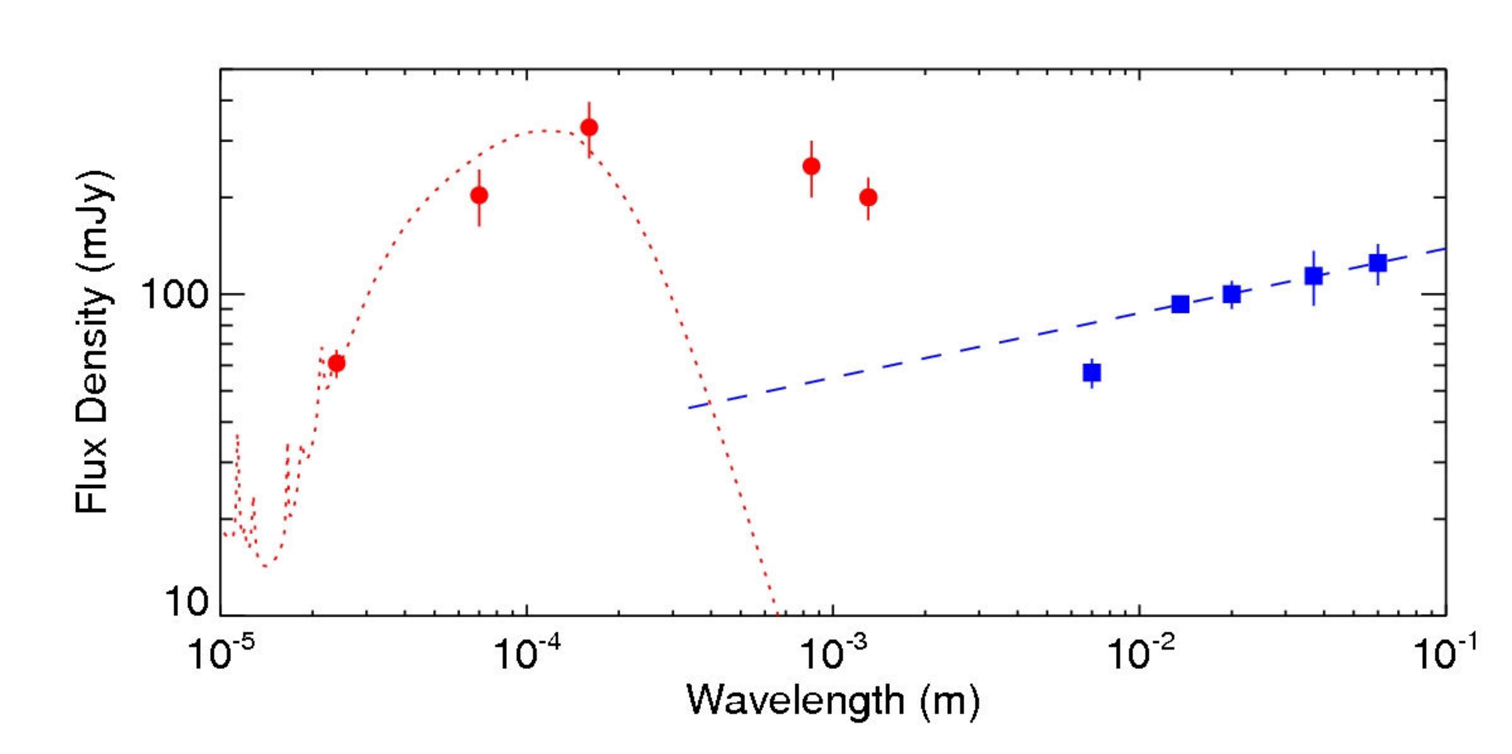
Bremsstrahlung

- Calculation based on optical hydrogen lines suggests that the bremsstrahlung is negligible.
- The extinction of the nucleus is low, so the bremsstrahlung estimate from the hydrogen lines should be accurate.

Synchrotron Emission (from jet)

- Extrapolations from radio or X-ray wavelengths show that synchrotron emission from jets may only account for ~25% of the 850 μm emission.
- The AGN's flux density has only been observed to vary by ~20%.

Infrared-Radio SED of the Nucleus



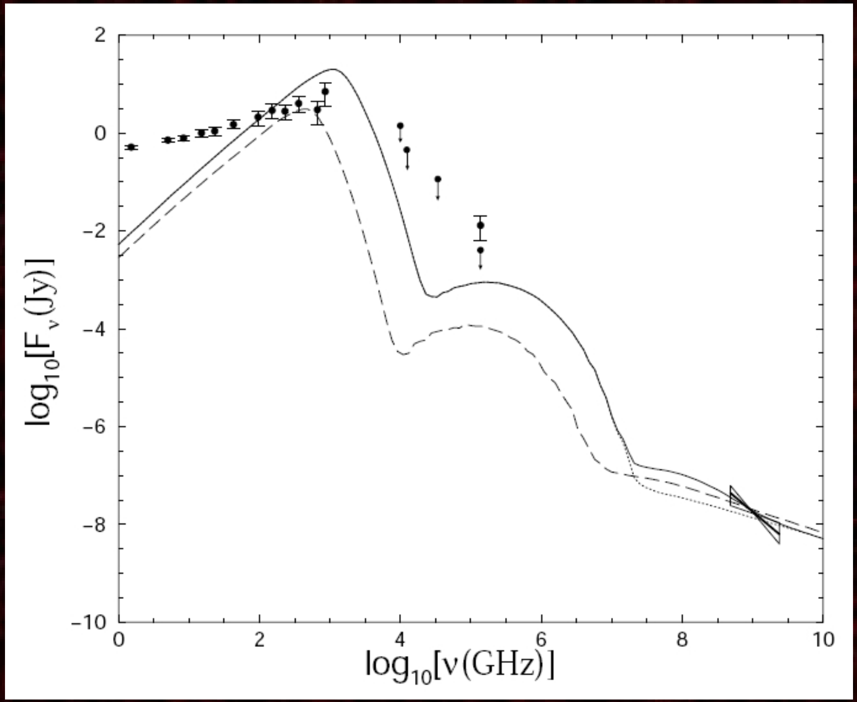
Emission from Inefficient Accretion Flows

While I was doing this, other people elsewhere were desperately searching for a “submillimeter bump” from other AGN.

The emission would originate from gas in an inefficient accretion flow near the AGN. The emission would be synchrotron emission that is affected by inverse Comptonization.

NGC 4594 is a candidate for being such a source. It may be only the second or third source ever identified with such emission and the first source where such emission is predominant at submillimeter wavelengths.

However, even this explanation has problems…



Models applied to data of Sag A*

Yuan et al. (2002)

Future Herschel Nearby Galaxy Surveys

- Photometry/spectroscopy at 70-520 μm
- Three guaranteed-time SPIRE surveys planned
  - Nearby (“famous”) galaxies
  - Dwarf galaxies
  - Unbiased sample (250-520 μm only)
- Could identify Sombrero-like submillimeter emission
- Probably miss 850 μm excess

Future JCMT Nearby Galaxy Surveys

- Photometry at 450, 850 μm
- Two relevant legacy surveys
  - Local Universe Survey (155 galaxies)
  - SASSy (large scale survey)
- If combined with Spitzer/Herschel data:
  - Probably identify Sombrero-like submillimeter emission
  - Identify 850 μm excess

General Conclusions

- Resolved infrared/submillimeter images of nearby galaxies are going to reveal new emission processes.
- Using resolved infrared or submillimeter data by itself is not useful.
- Spitzer/Herschel/JCMT data of nearby galaxies may reveal many submillimeter color variations like the ones seen in NGC 4631.
- Surveys of nearby galaxies using combined Spitzer/Herschel/JCMT data may reveal more objects like NGC 4594.