An Empirical Analysis of Radiative Transfer in the Sombrero Galaxy

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The Sombrero Galaxy has multiple characteristics that make it an easy galaxy to work with in radiative transfer:

- The galaxy is axisymmetric.
- Most of the gas and dust is in a ring.
- Most of the extinction is seen in one half of the galaxy.

By relying on these characteristics, we can study how energy is emitted by stars, absorbed by dust, and re-emitted in infrared light.

- We do not need to model the stellar populations.
- We do not need to make any assumptions about the dust properties.
- We do not need to model the dust emission.

Using the Sombrero Galaxy, I have been working with other people in the audience on two separate project:

- Studying attenuation by the dust ring.
- Analysing dust heating.

Dust Attenuation

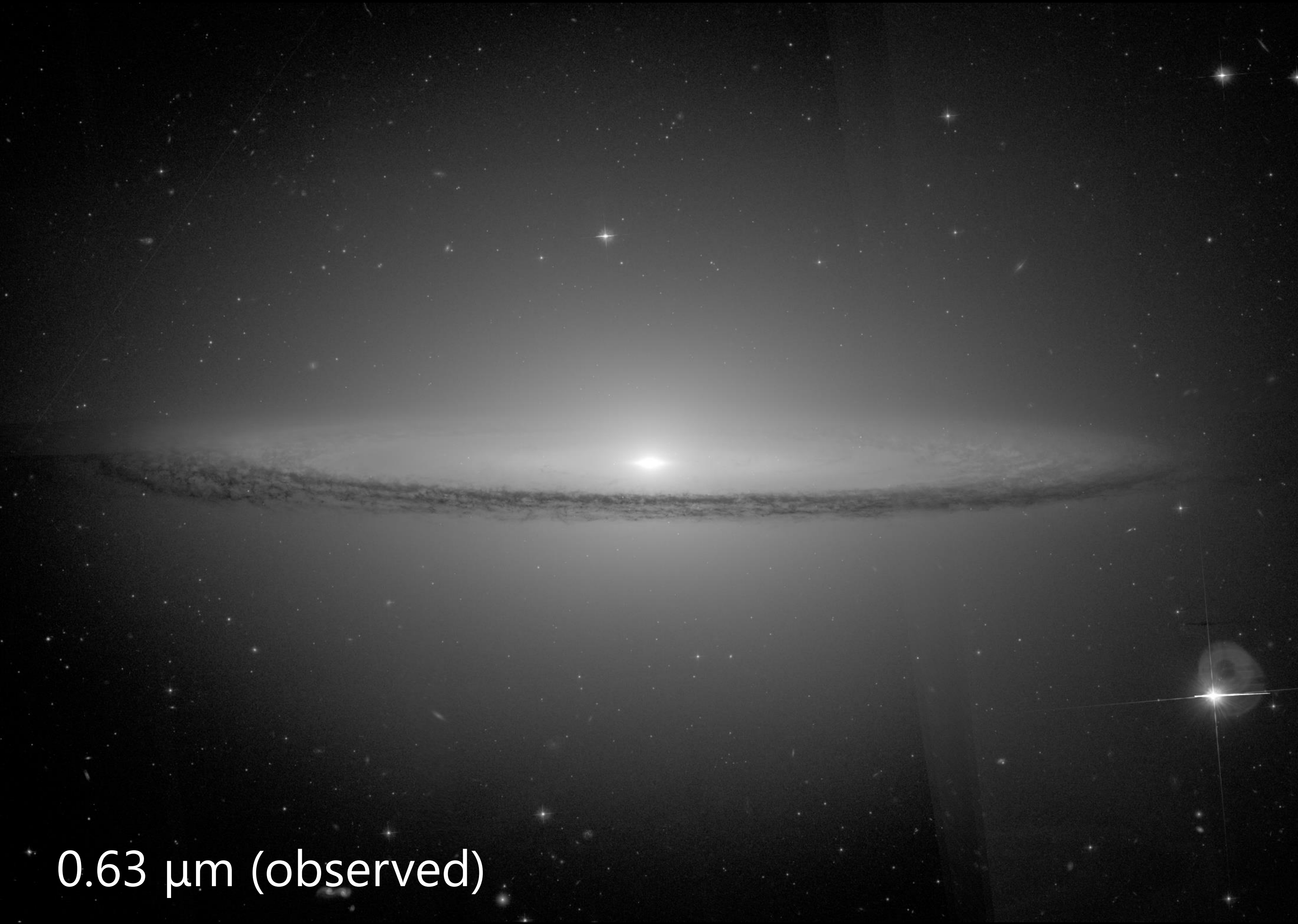
The overall goal of this work is to measure a dust attenuation curve from 0.15 μm to 5.7 μm in an extragalactic object:

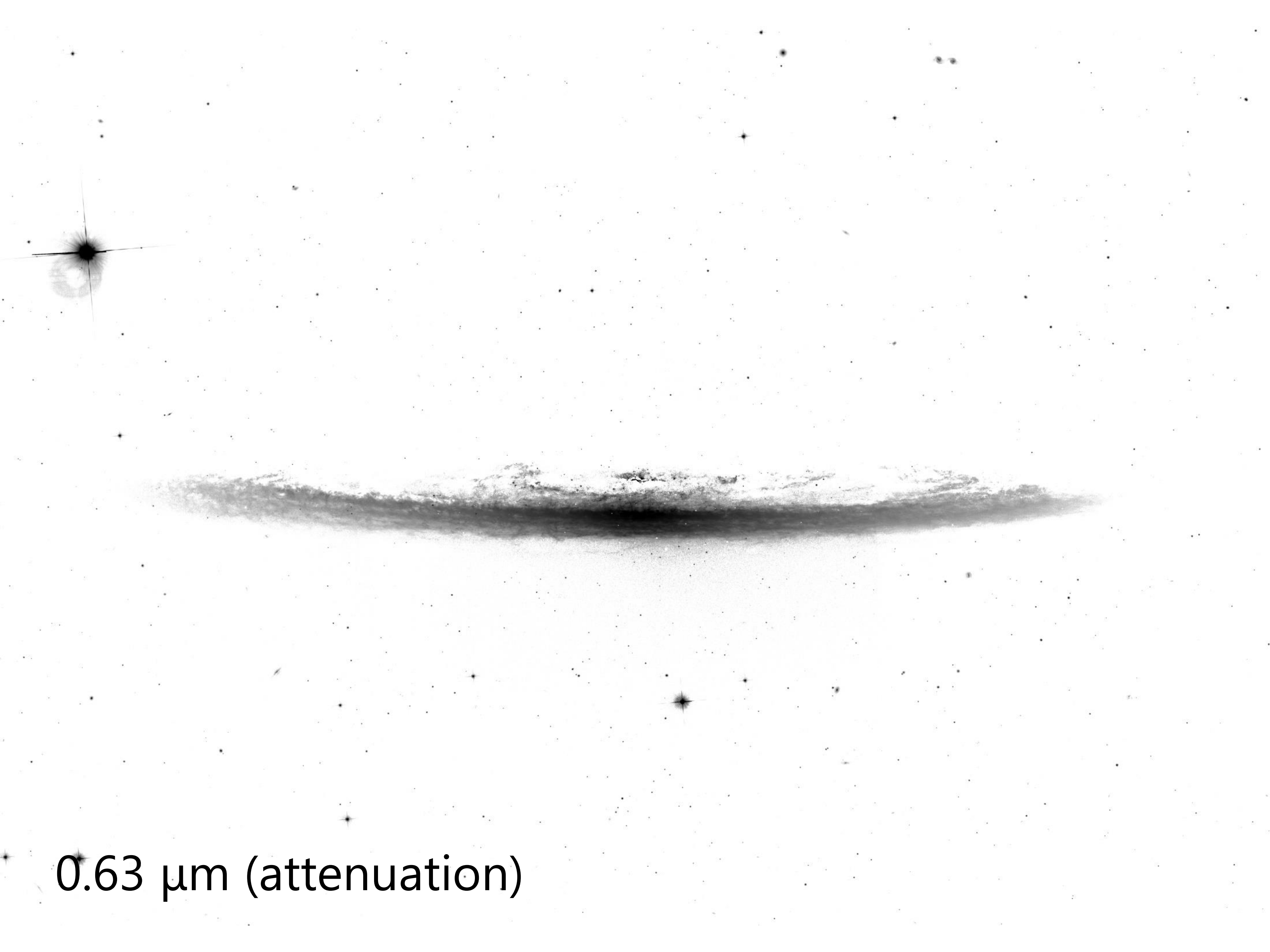
- This works as a check on measurements of attenuation curves within the Milky Way Galaxy.
- This also tests whether attenuation curves vary among galaxies.
- It also helps with the radiative transfer analysis.

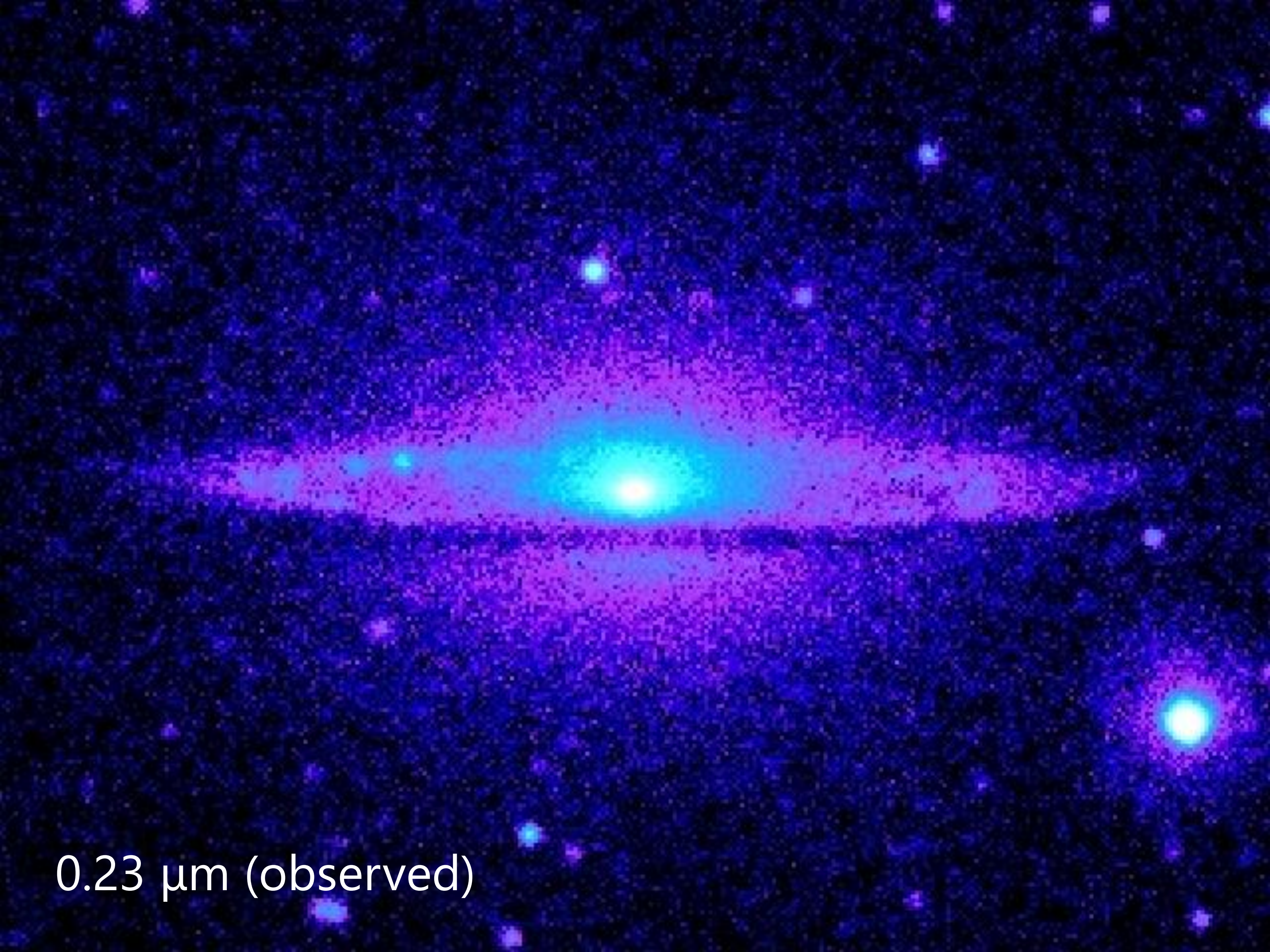
The analysis is relatively simple (but needs improvement):

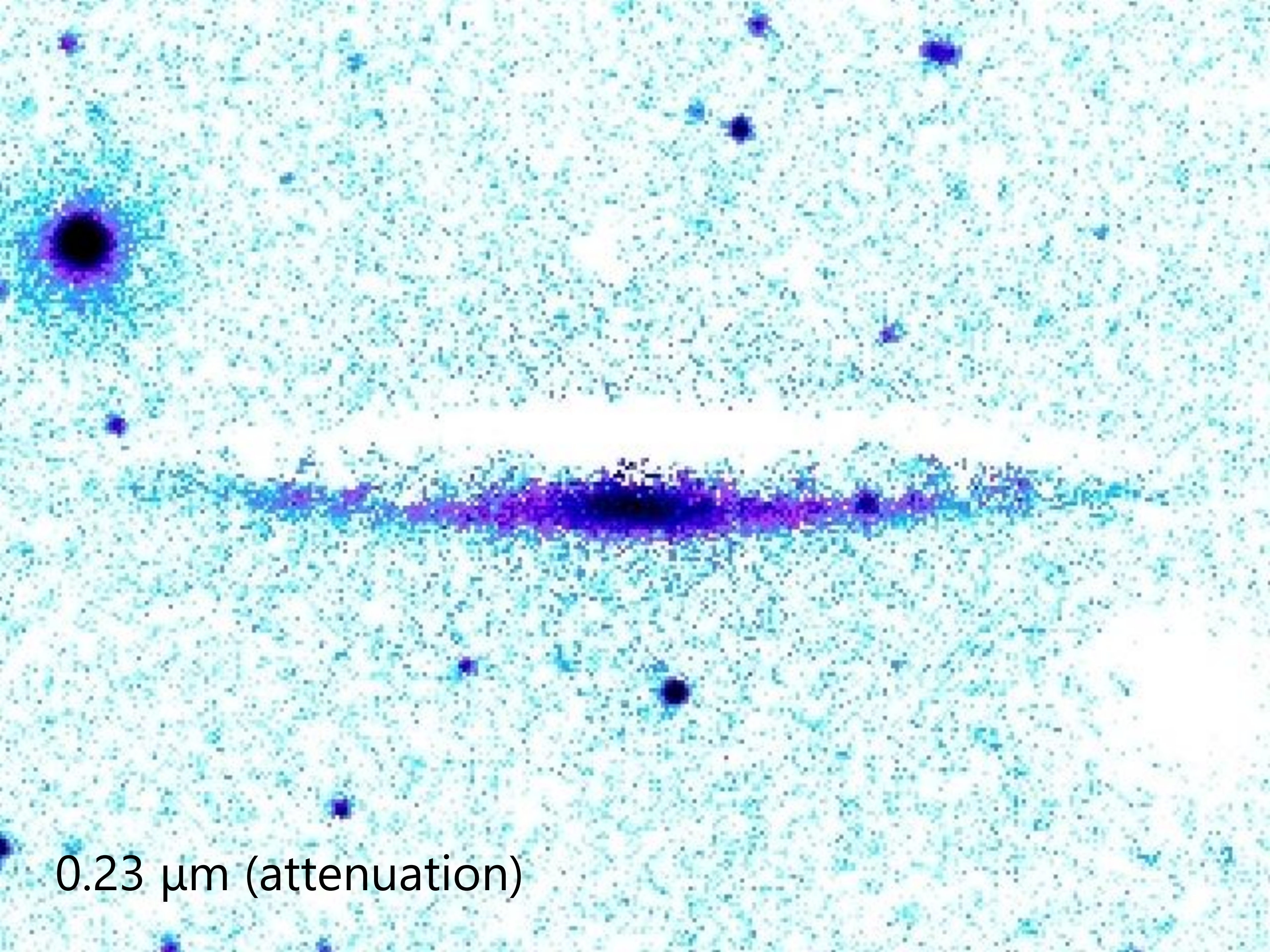
- Rotate each image 180°.
- Subtract the rotated image from the original image.
- Measure the total and relative amount of attenuated light.

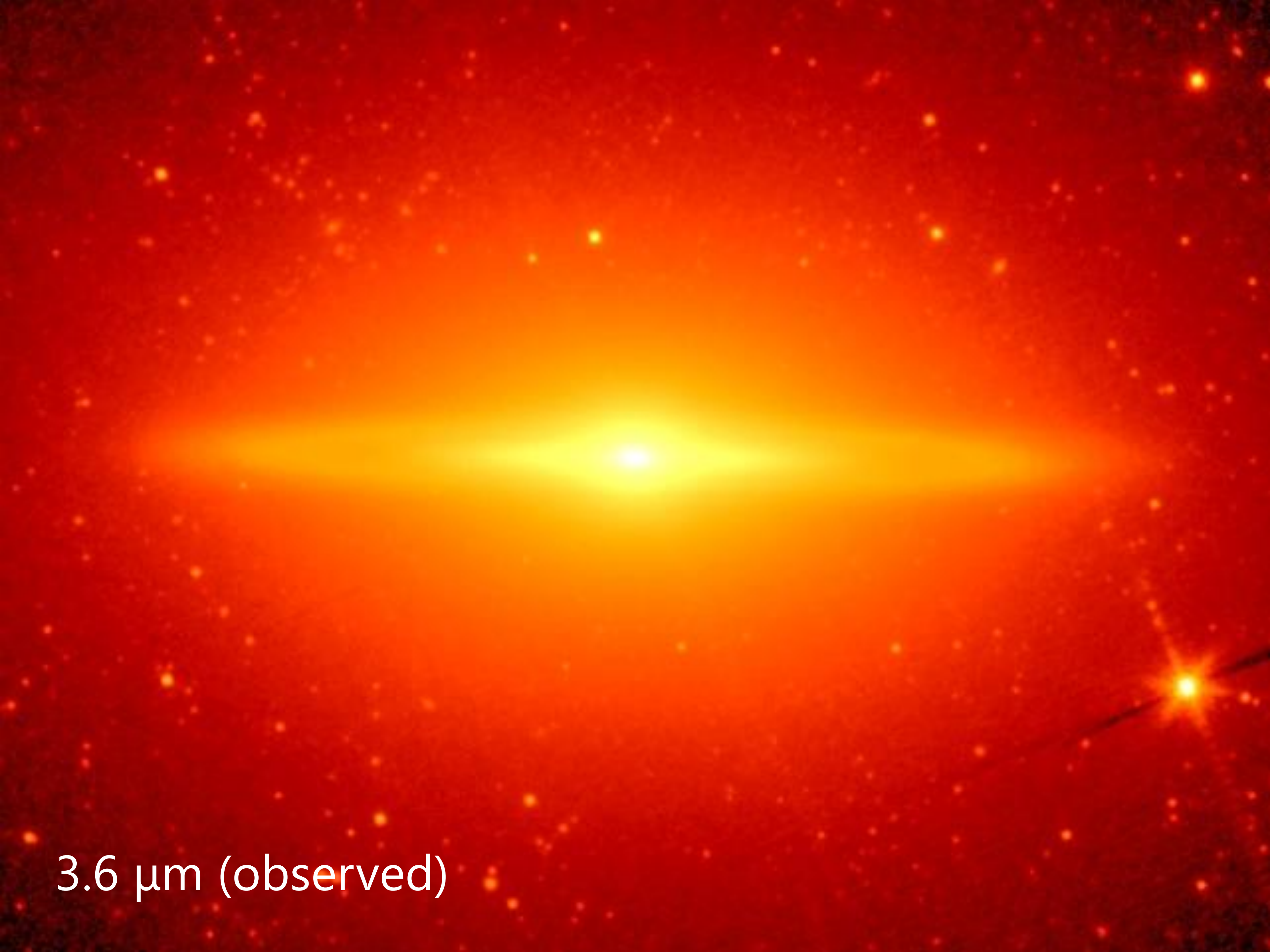
These early results ignore scattering effects, which we still need to incorporate.

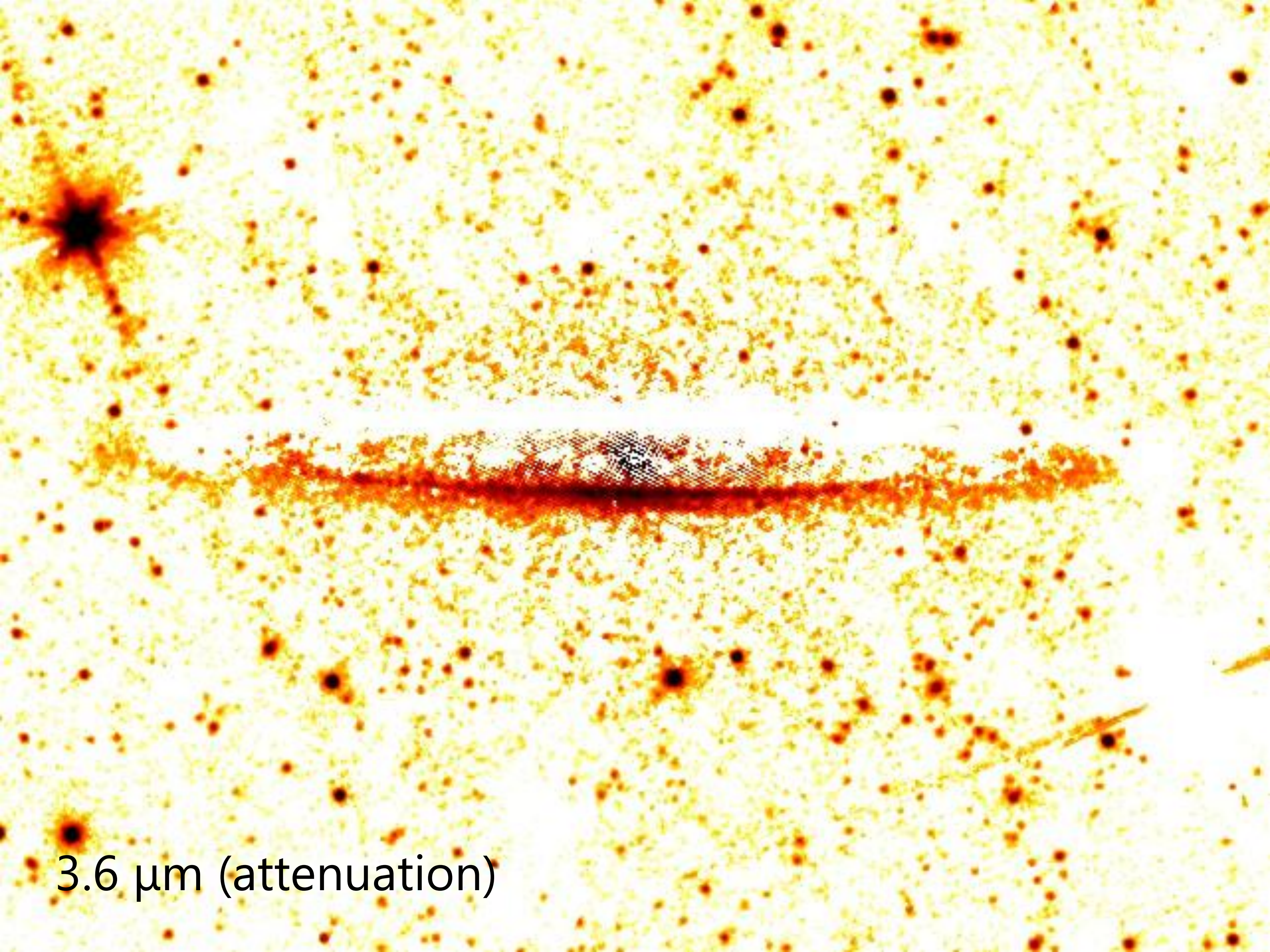

0.63 µm (observed)

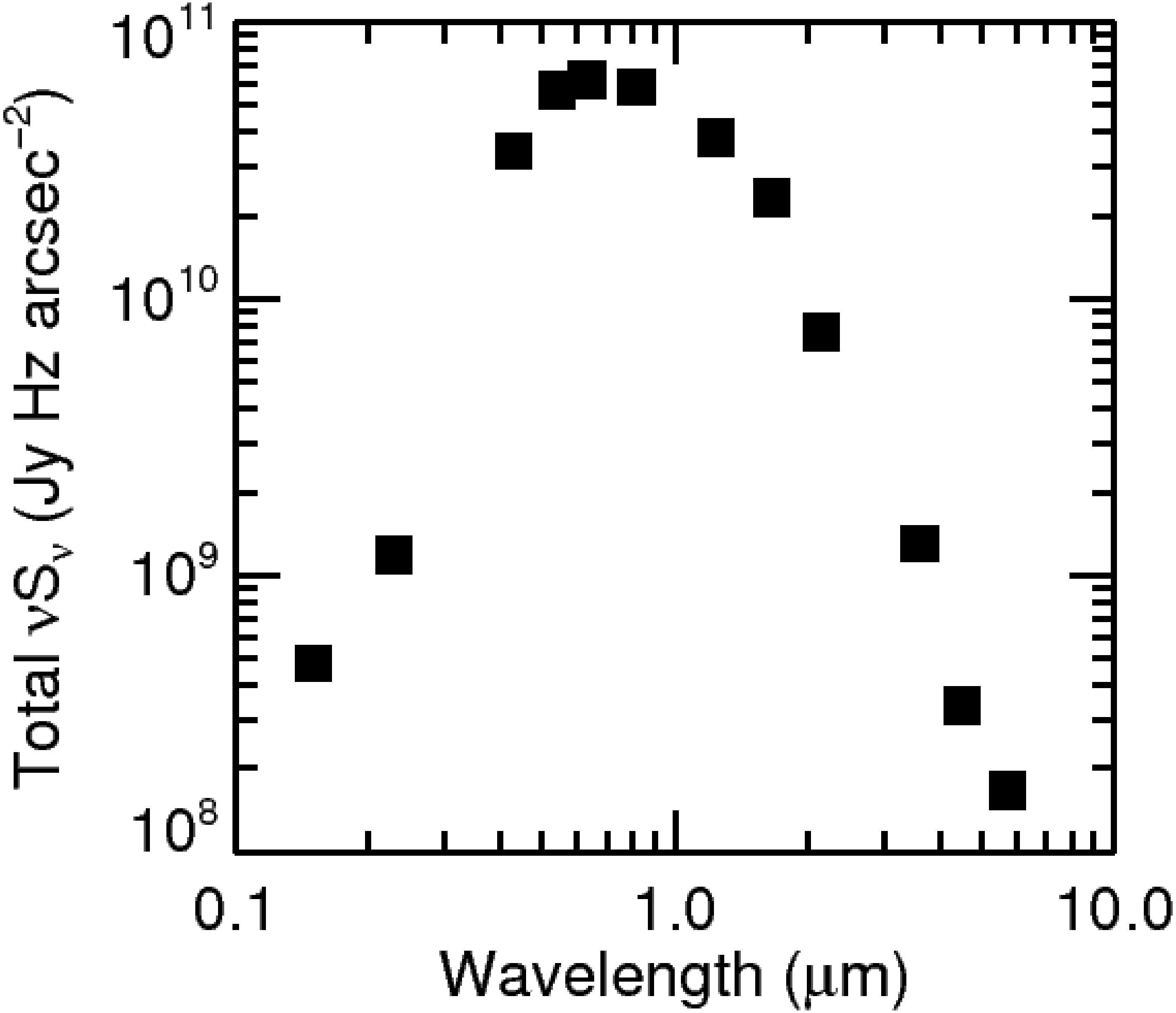

0.63 µm (attenuation)


0.23 µm (observed)

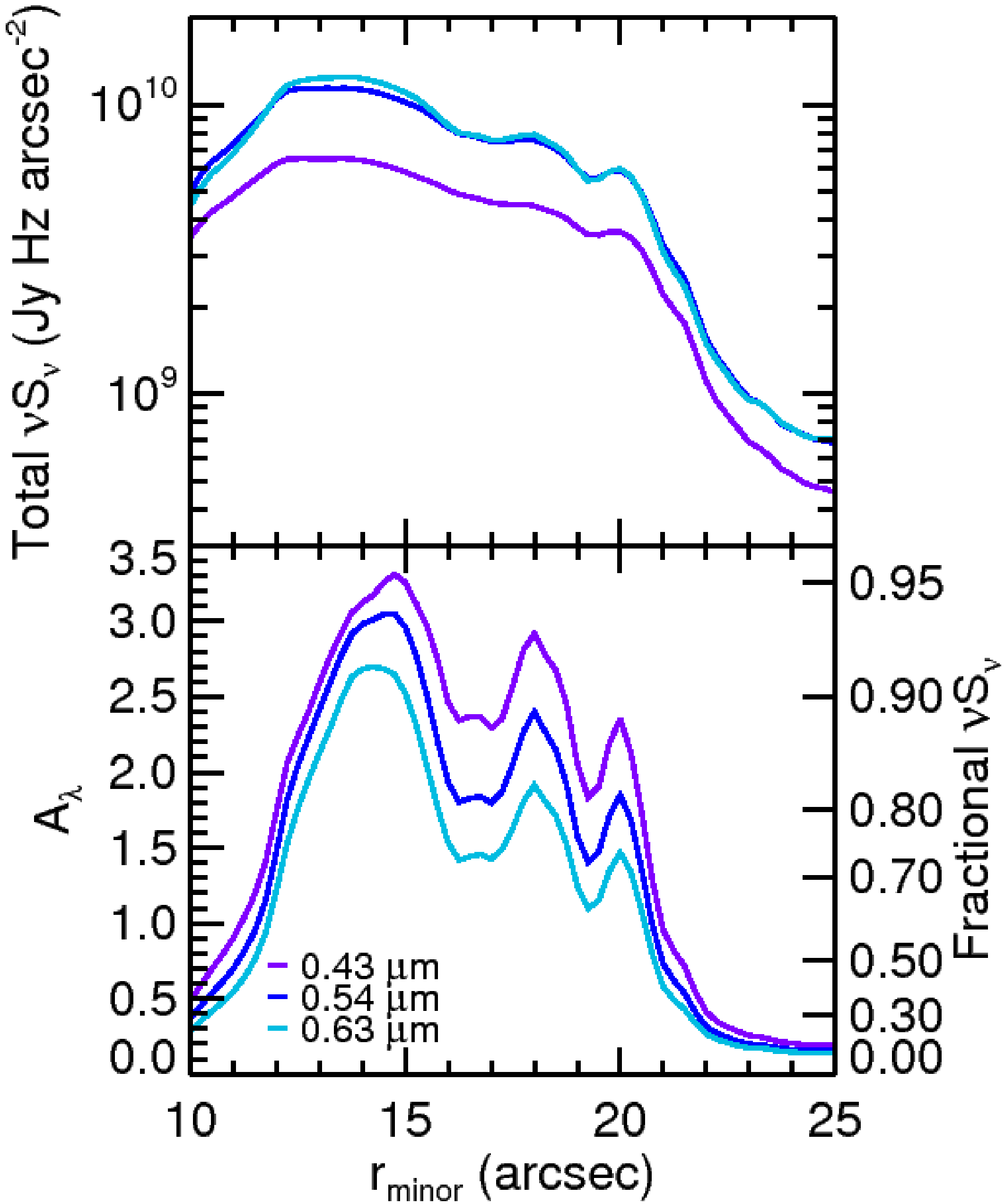

0.23 μm (attenuation)


3.6 µm (observed)

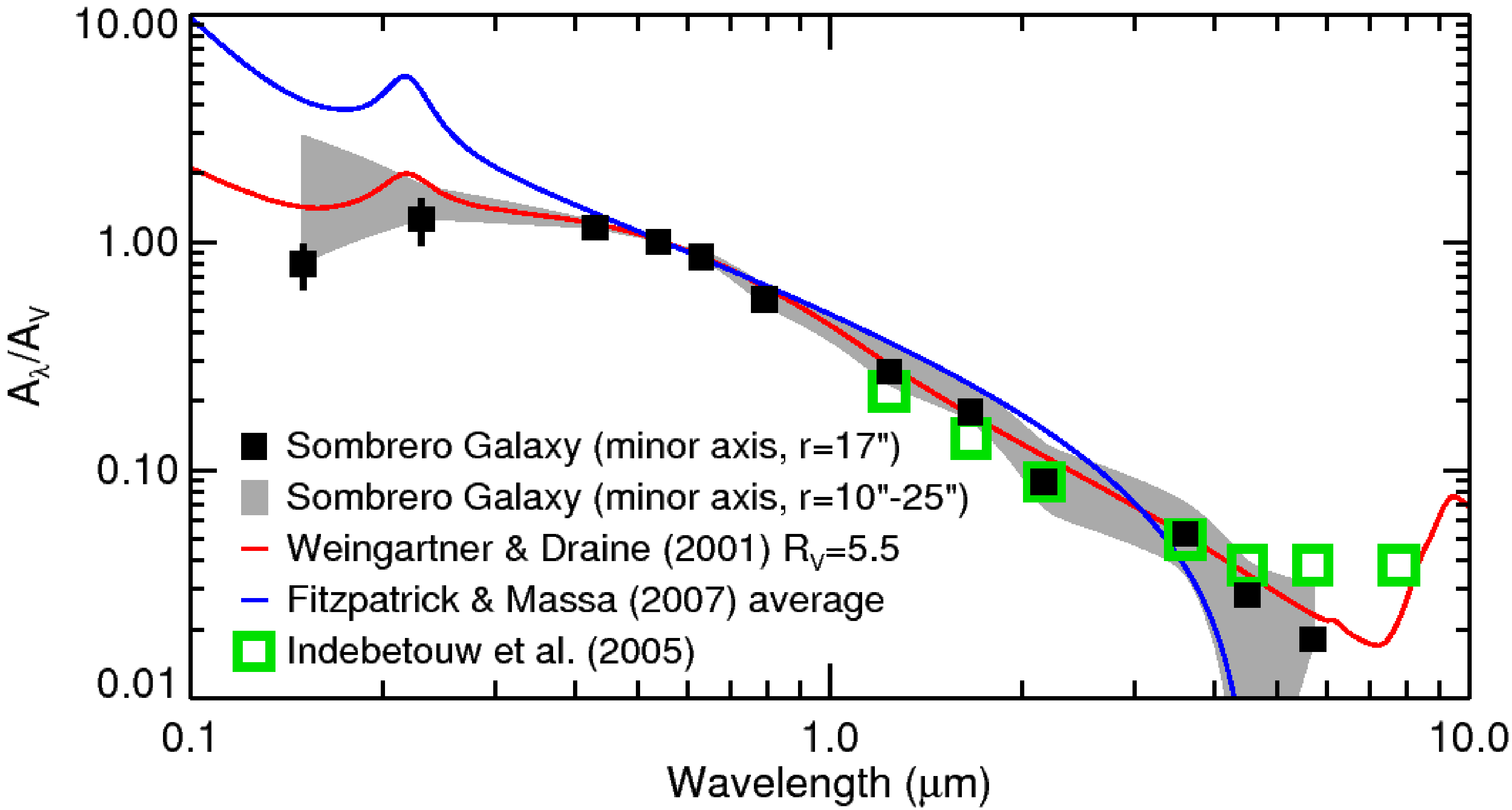

3.6 µm (attenuation)



Total νSν (Jy Hz arcsec⁻²)
10^11
10^10
10^9
10^8
0.1
1.0
10.0
Wavelength (μm)



Total νSν (Jy Hz arcsec⁻²)
10¹⁰
10⁹
Aλ
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.95
0.90
0.80
0.70
0.50
0.30
0.00
Fractional νSν
0.43 μm
0.54 μm
0.63 μm
10
15
20
25
r_minor (arcsec)



10.00
1.00
0.10
0.01
0.1
1.0
10.0
Wavelength (μm)
A_λ/A_V
Sombrero Galaxy (minor axis, r=17")
Sombrero Galaxy (minor axis, r=10"-25")
Weingartner & Draine (2001) R_V=5.5
Fitzpatrick & Massa (2007) average
Indebetouw et al. (2005)

Future plans to include scattering:

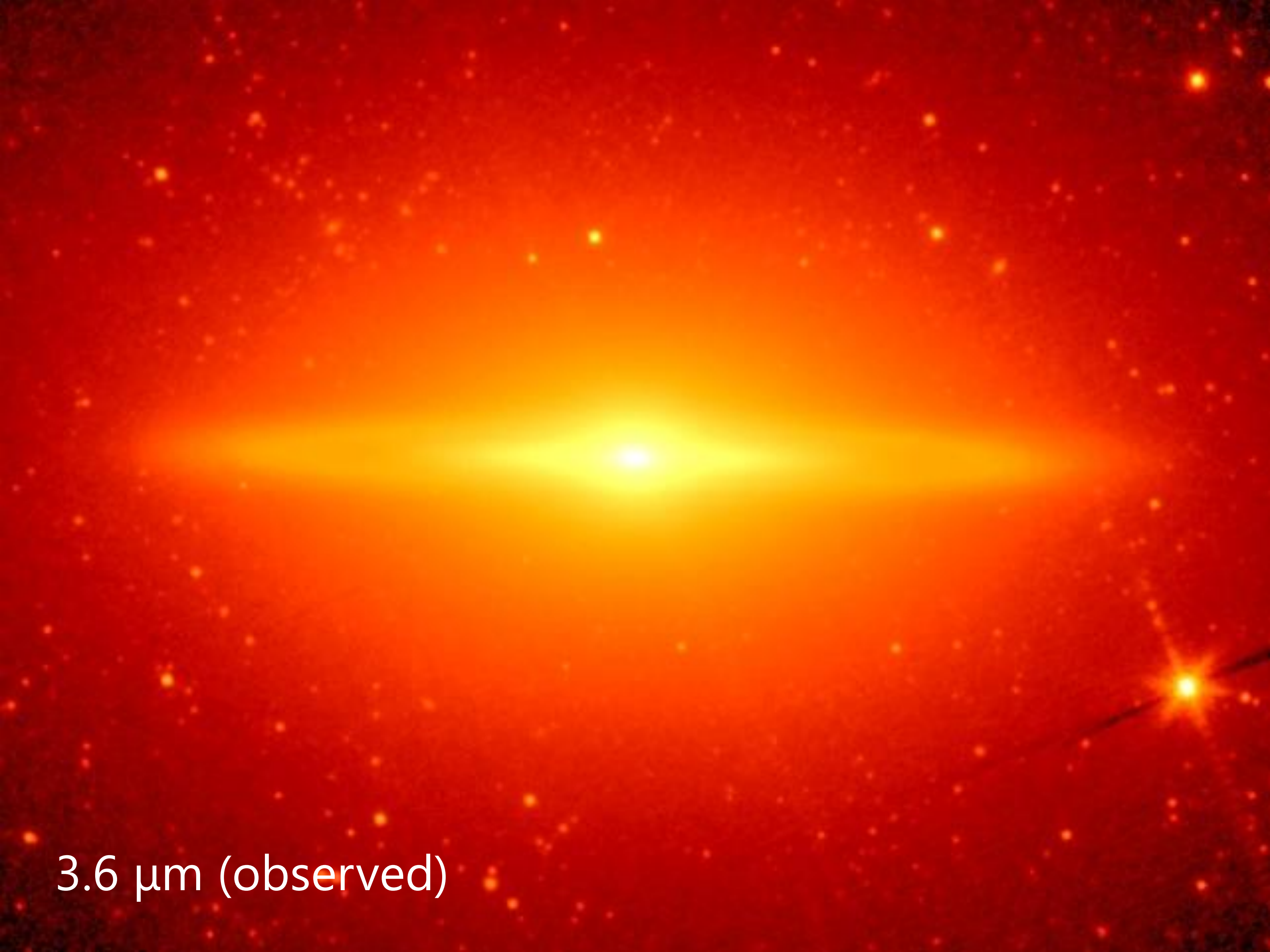
- Use HST curves to model the attenuation profile as two parts:
  - An inner section with scattering into the line of sight
  - A purely-obscuring outer section.
- Fit smoothed versions of these curves to other data to measure the attenuation.
- Adjust colours of inner section to match colours of outer section.

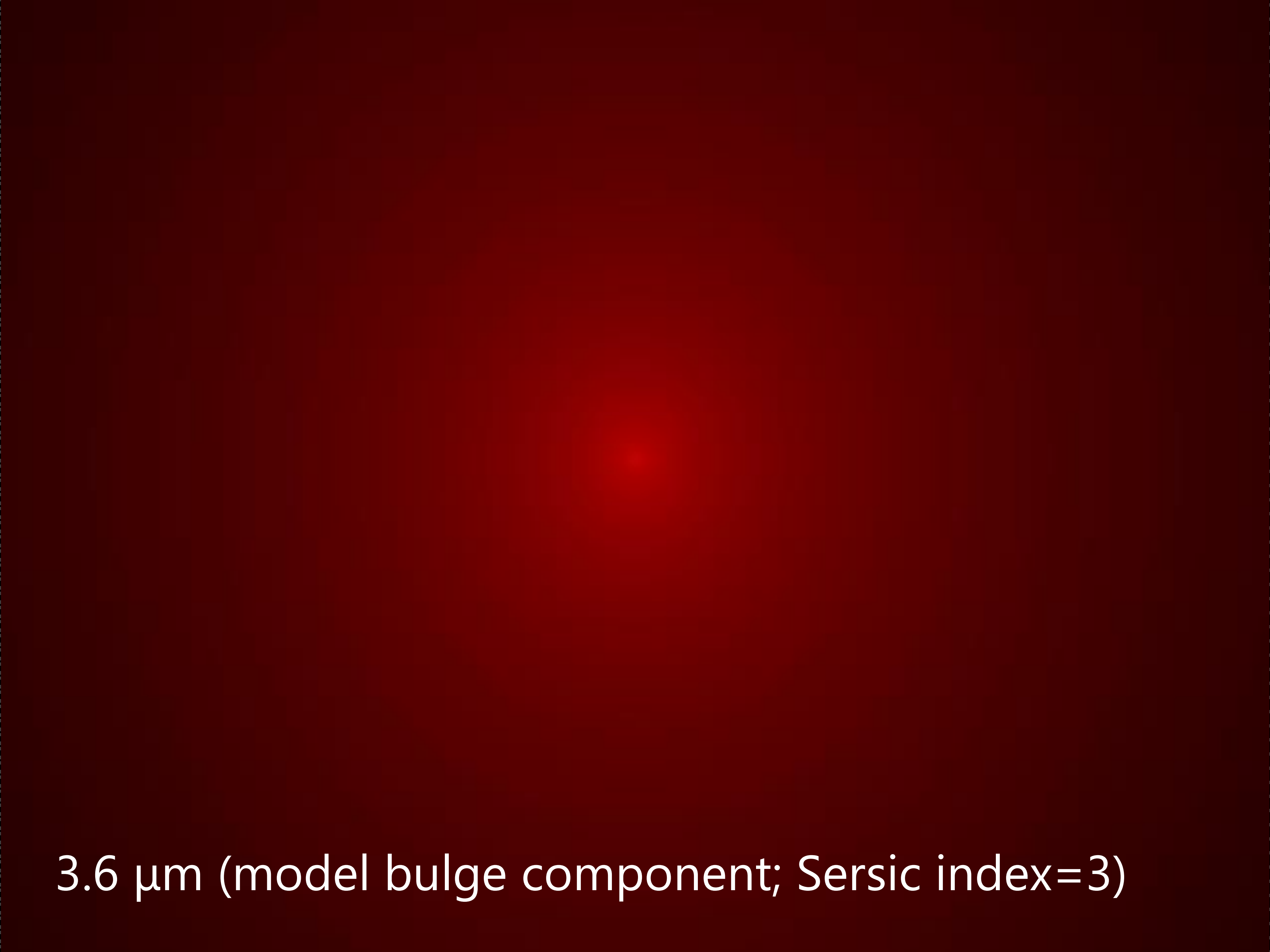
Dust Heating

This analysis is still ongoing, but consists of doing the following:

- Model each image from 0.15-1300 μm as a set of simple components.
- Measure the SED of stellar emission from all locations travelling to a given point in the disc.
- Measure the SED of dust emission from that point in the disc.

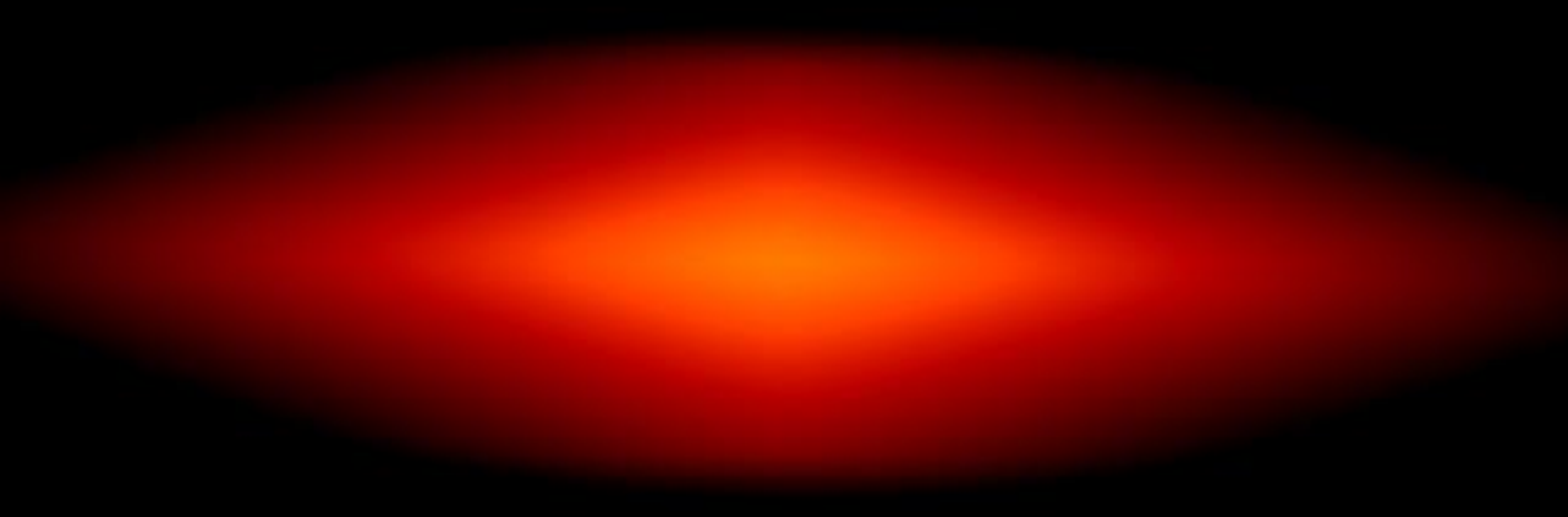
The ultimate goal is to identify how the Sombrero Galaxy dust ring is heated.


3.6 μm (observed)


3.6 µm (model bulge component; Sersic index=3)

3.6 μm (model bulge component; Sersic index=1)

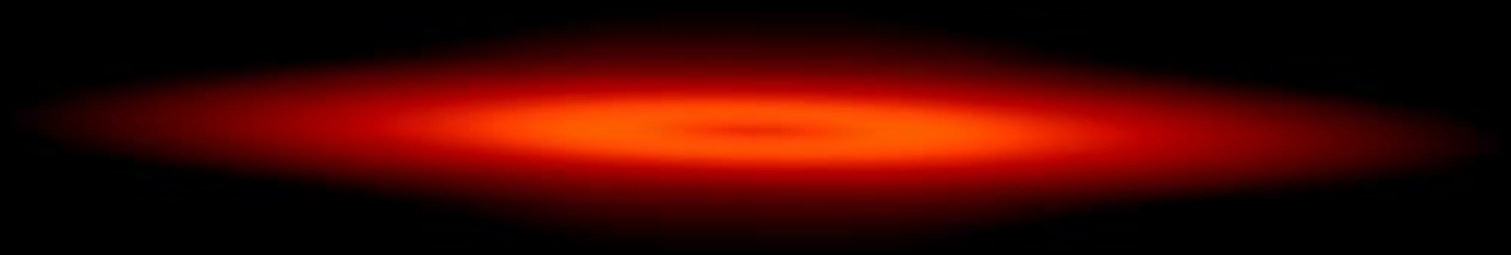
3.6 µm (model bulge component; Sersic index=4)



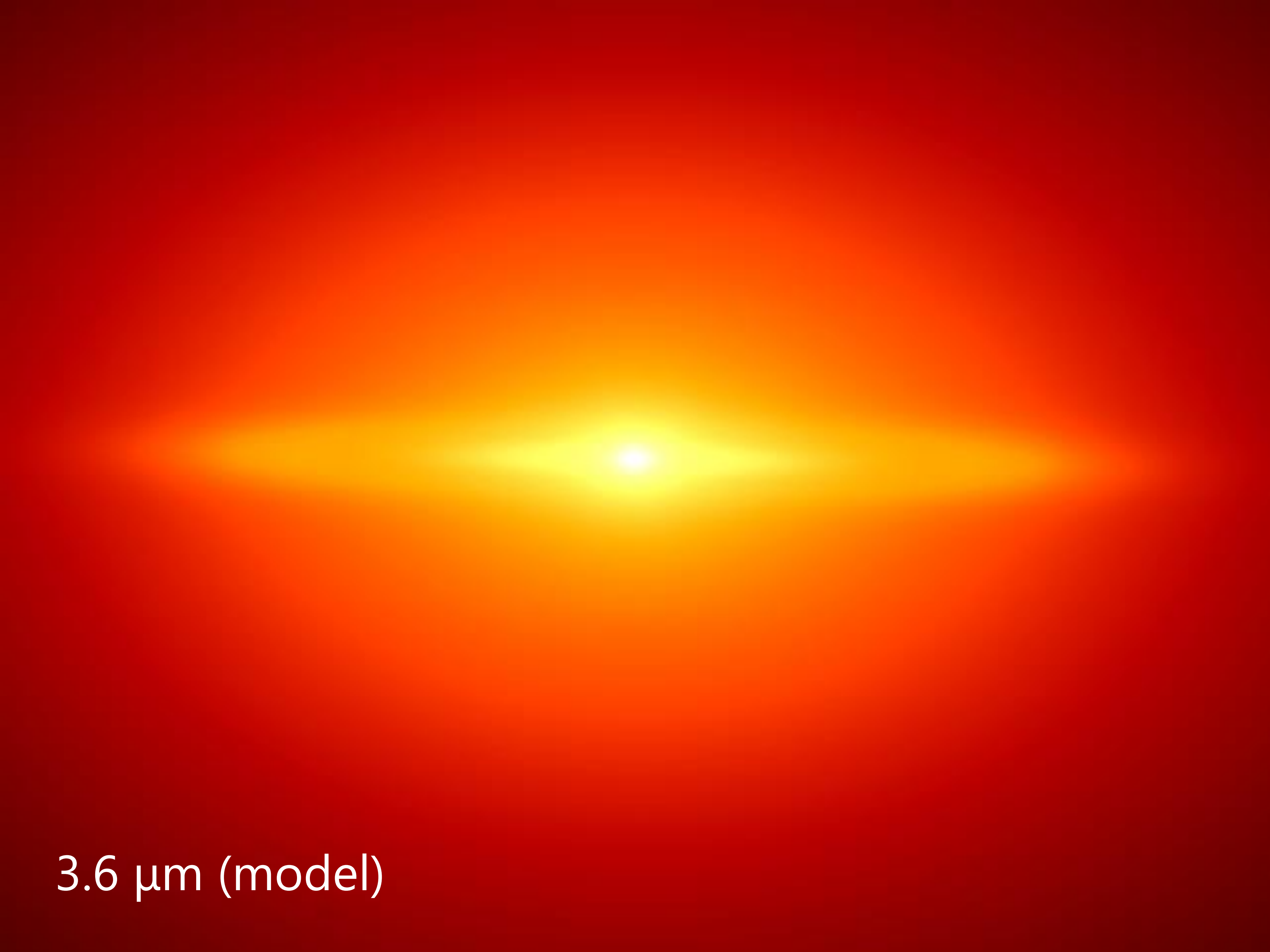
3.6 µm (model thick disc component)

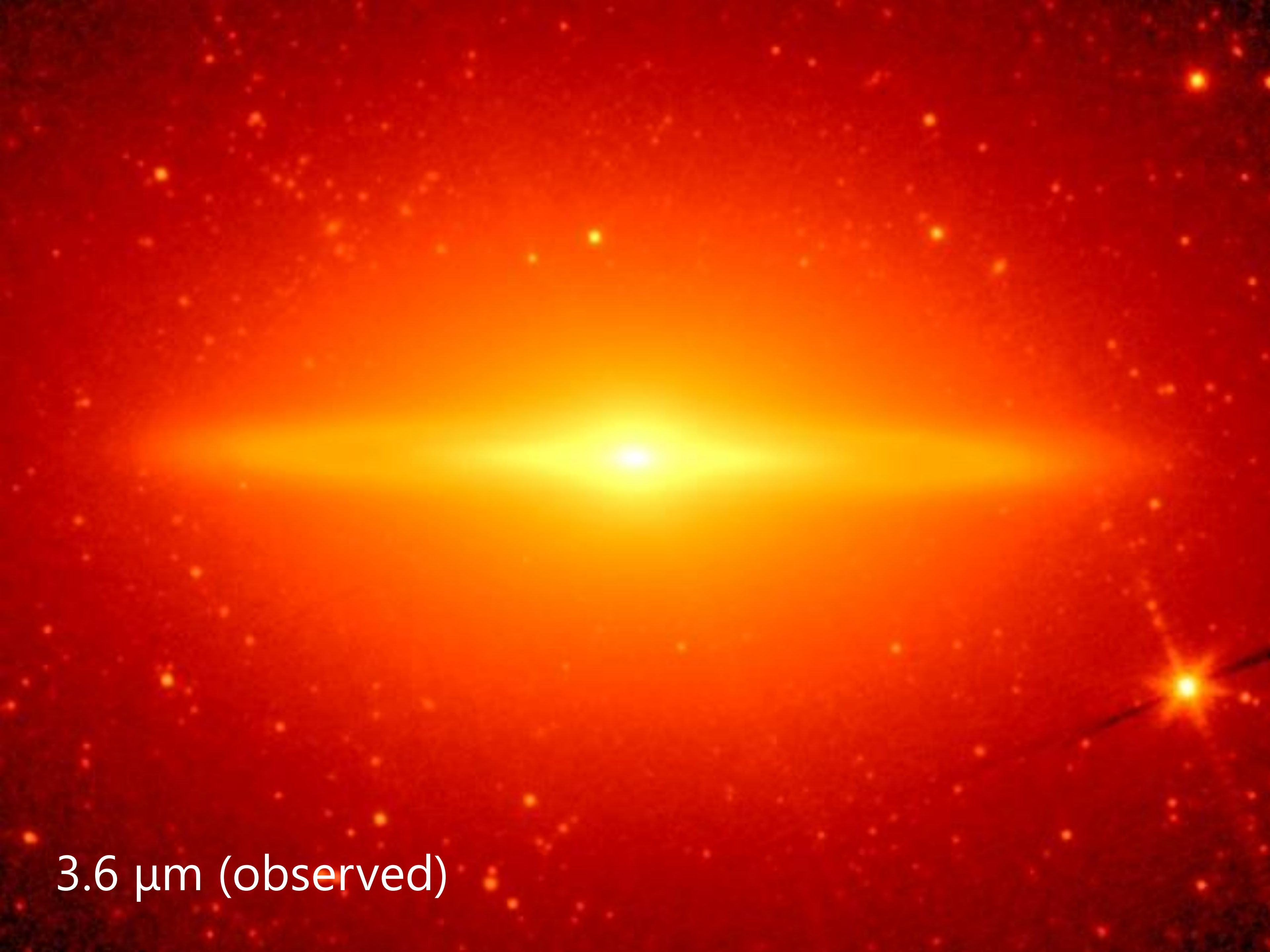
3.6 μm (model thin disc component)

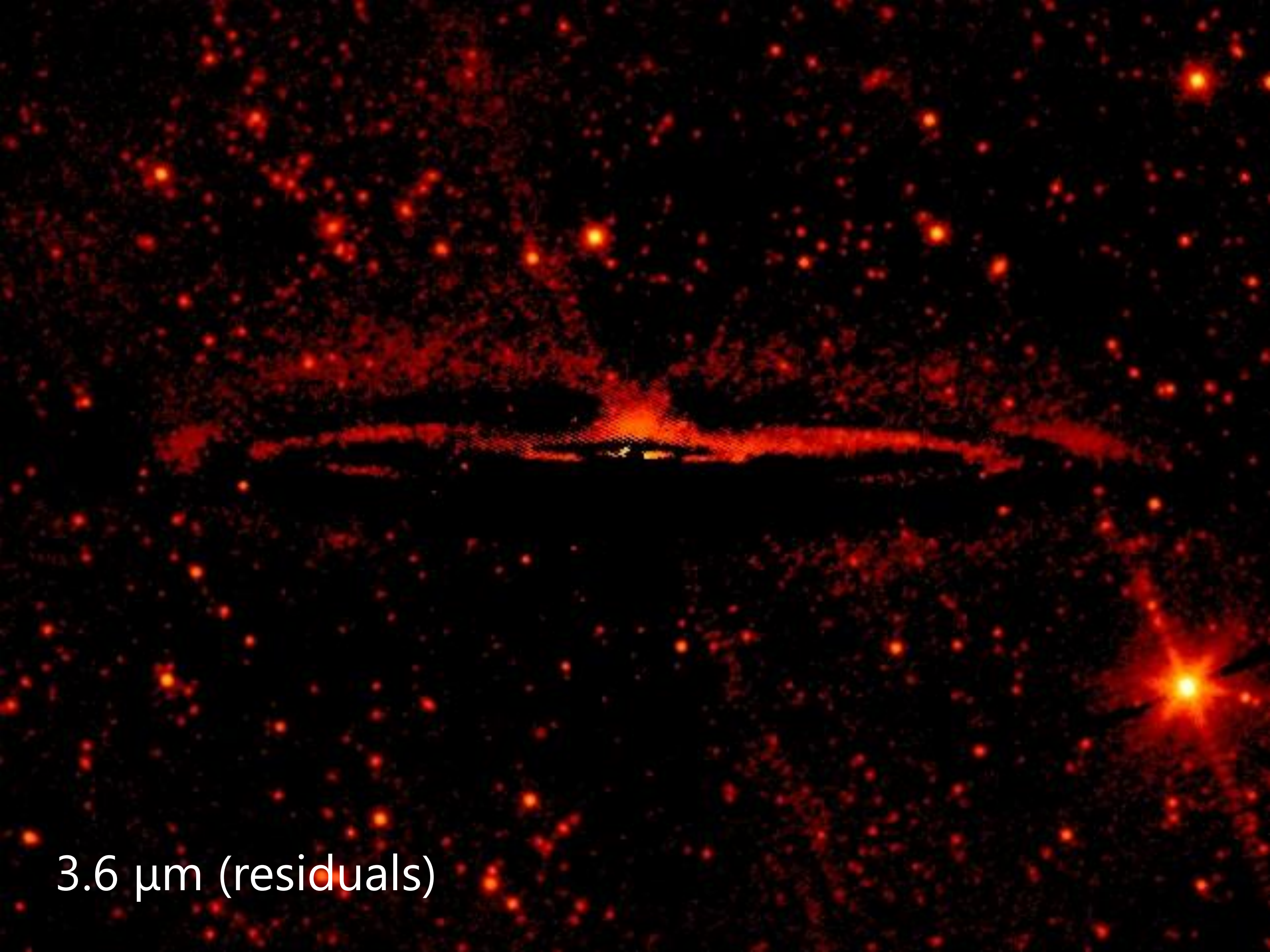
3.6 µm (model outer thick ring component)

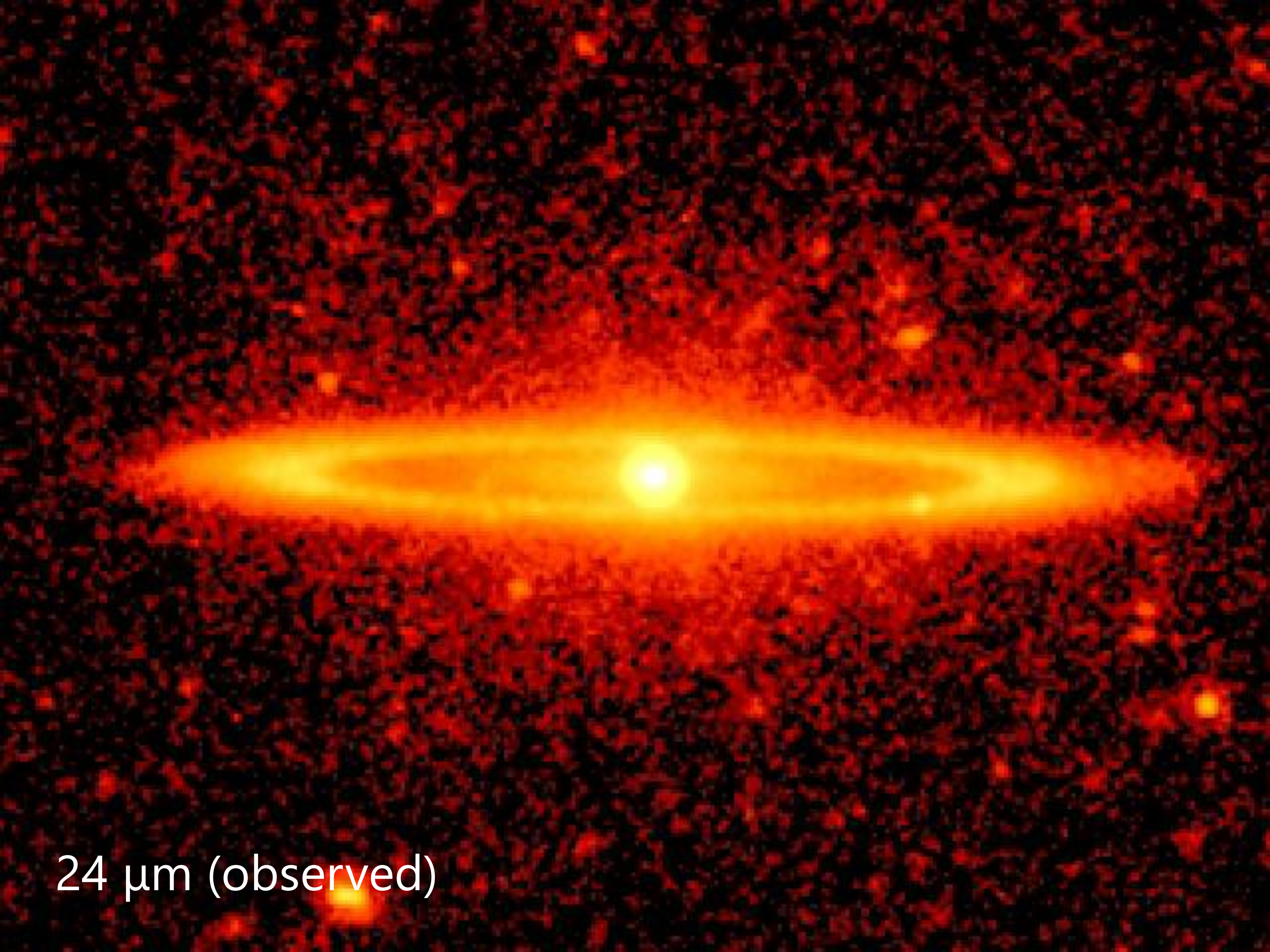


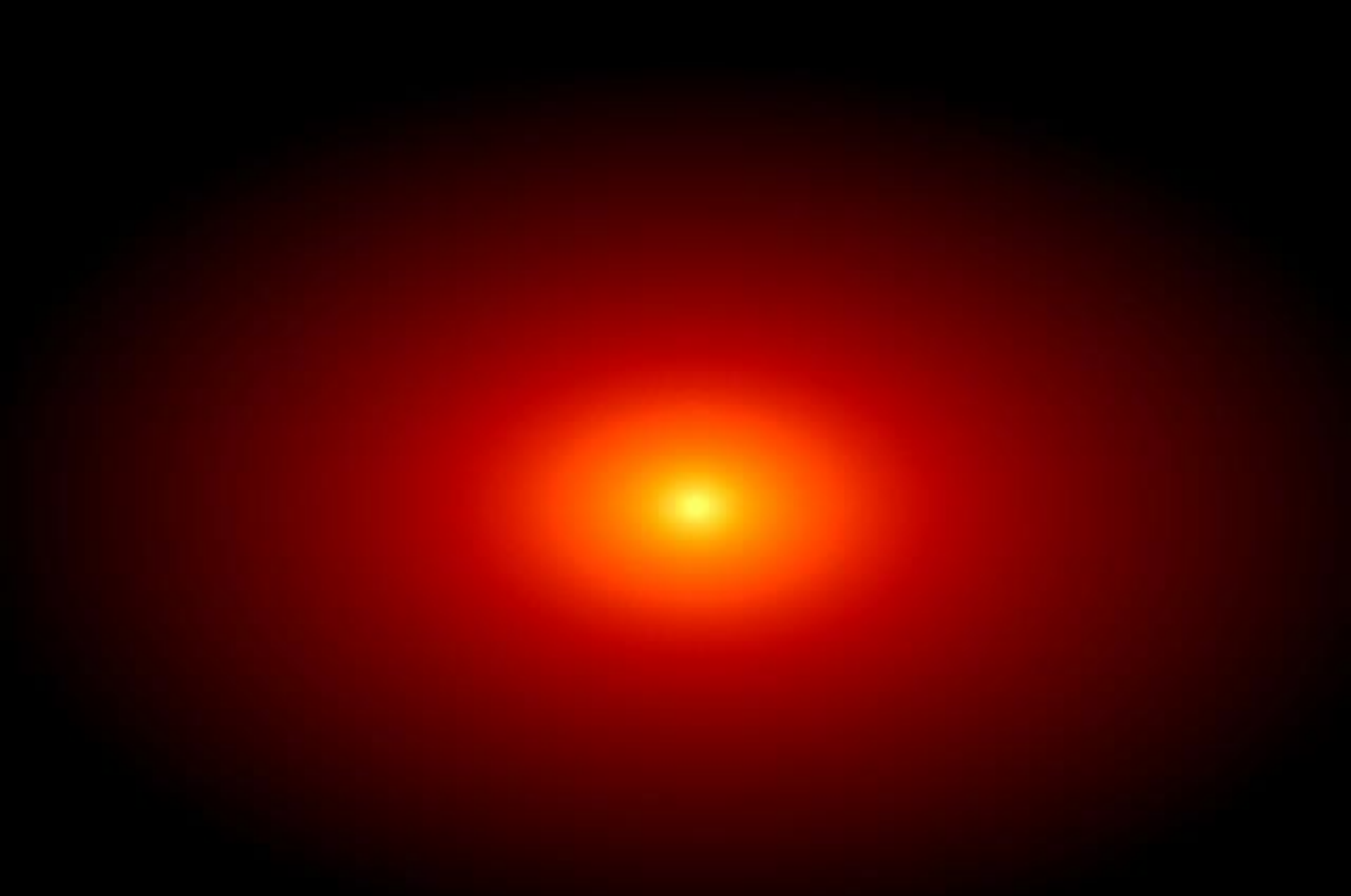
3.6 µm (model inner thin ring component)


3.6 µm (model)


3.6 µm (observed)


3.6 μm (residuals)

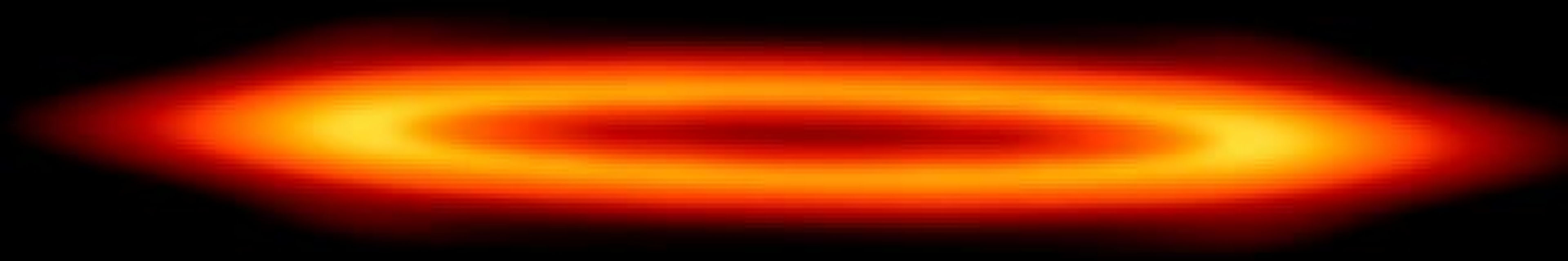

24 µm (observed)



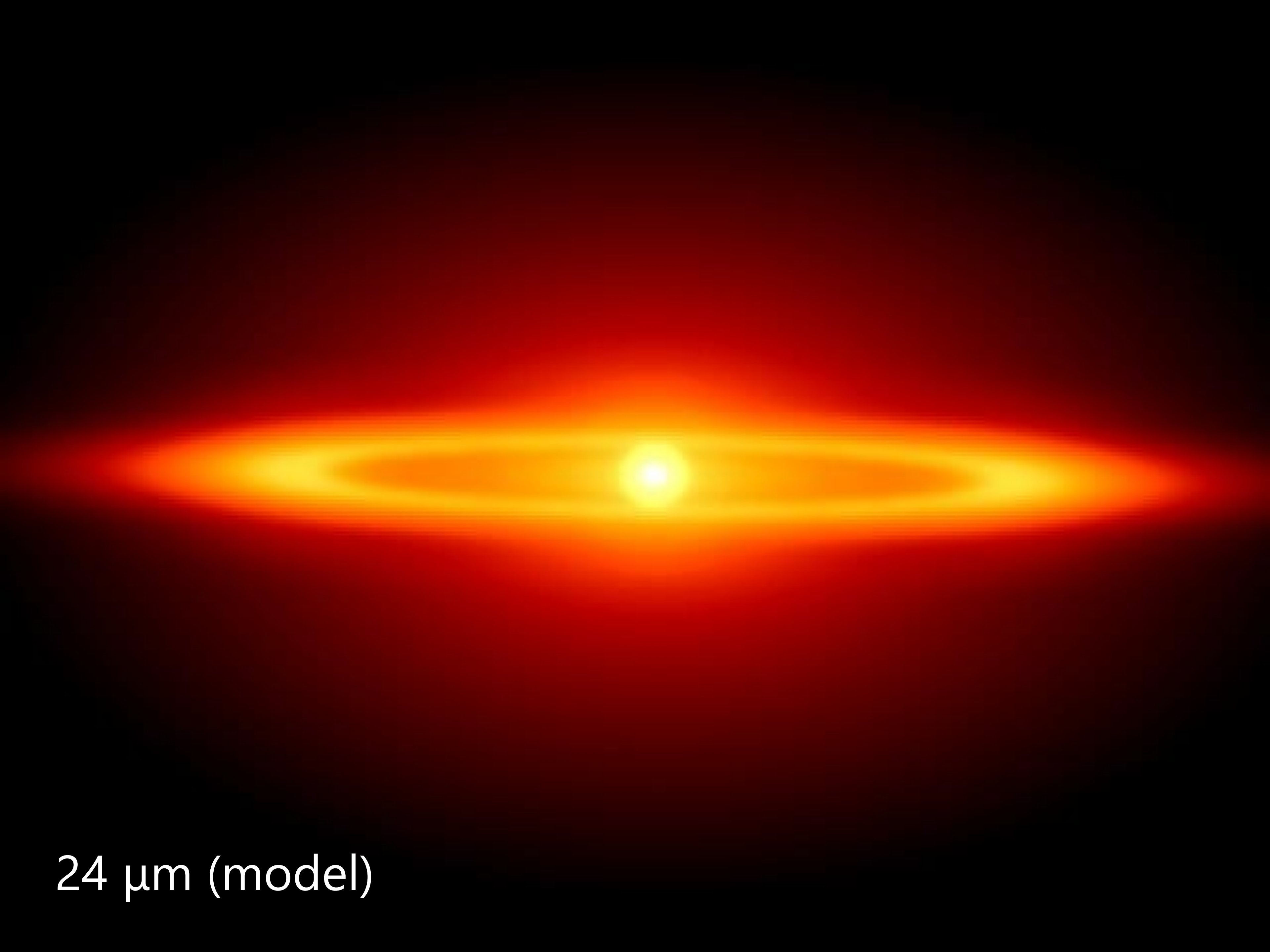
24 µm (model bulge component)

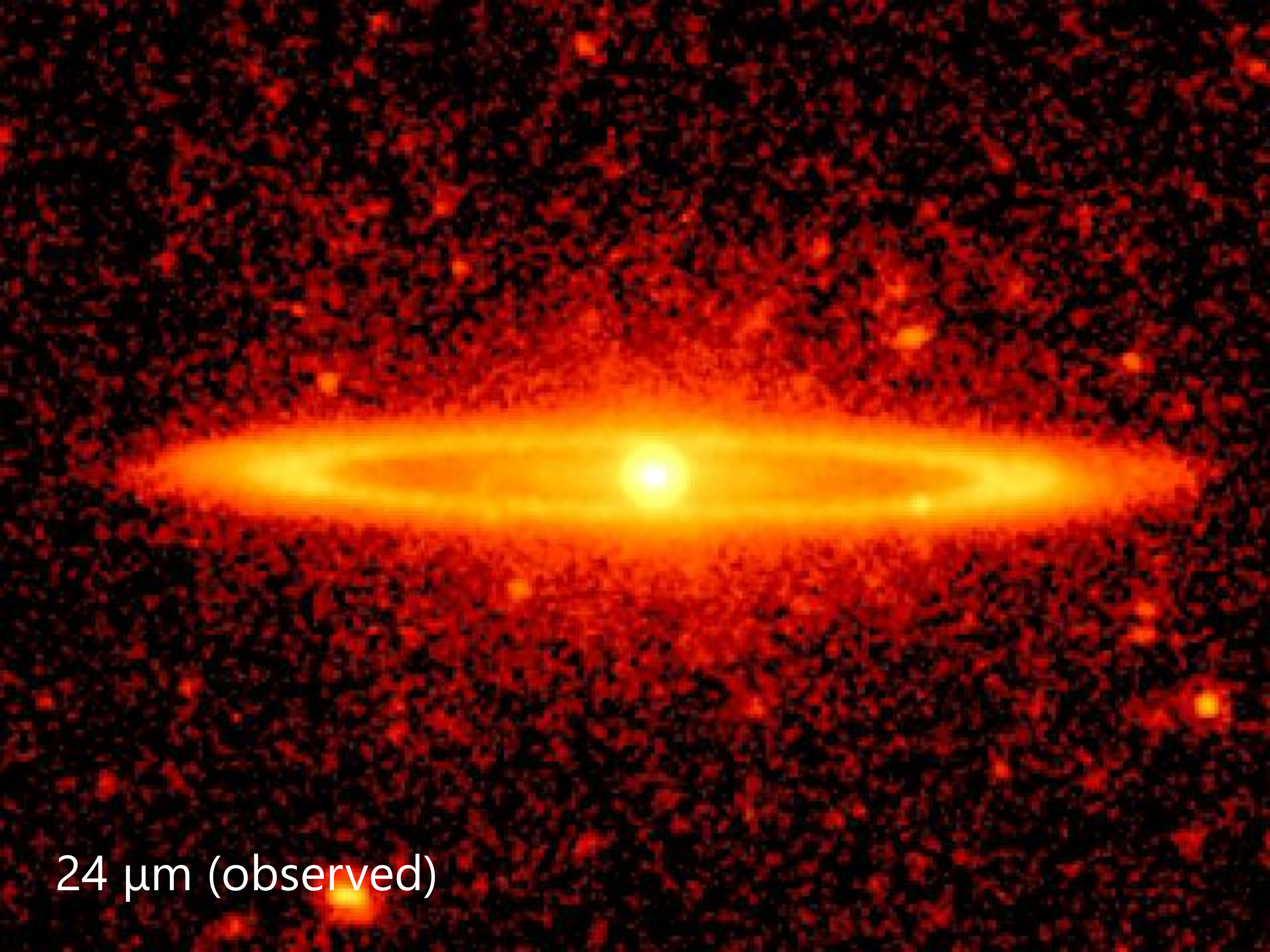
24 µm (model central source component)

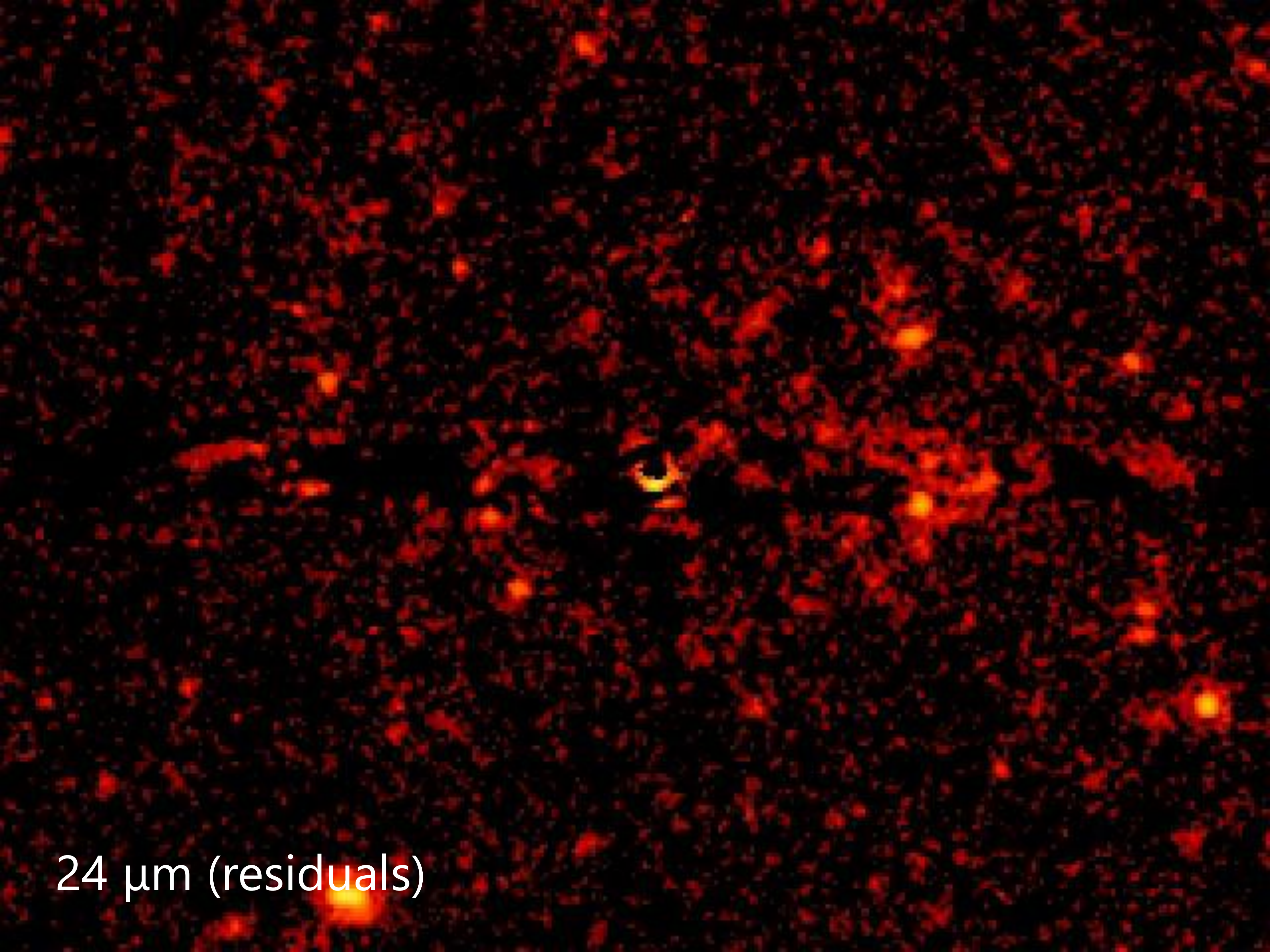
24 µm (model disc component)



24 µm (model ring component)


24 µm (model)


24 µm (observed)


24 µm (residuals)

Although this seems focused on a single object, it has broader implications:

- Many other S0 and early-type spiral galaxies have similar ring structures that may be heated in the same way.
- The implications for dust heating in the Sombrero Galaxy potentially relate to other early-type galaxies in general.
- If dust ring in the Sombrero Galaxy is not heated by star forming regions, this affects using infrared emission as a star formation tracer.