# The Herschel Space Observatory View of the 70-500 μm Emission from M81

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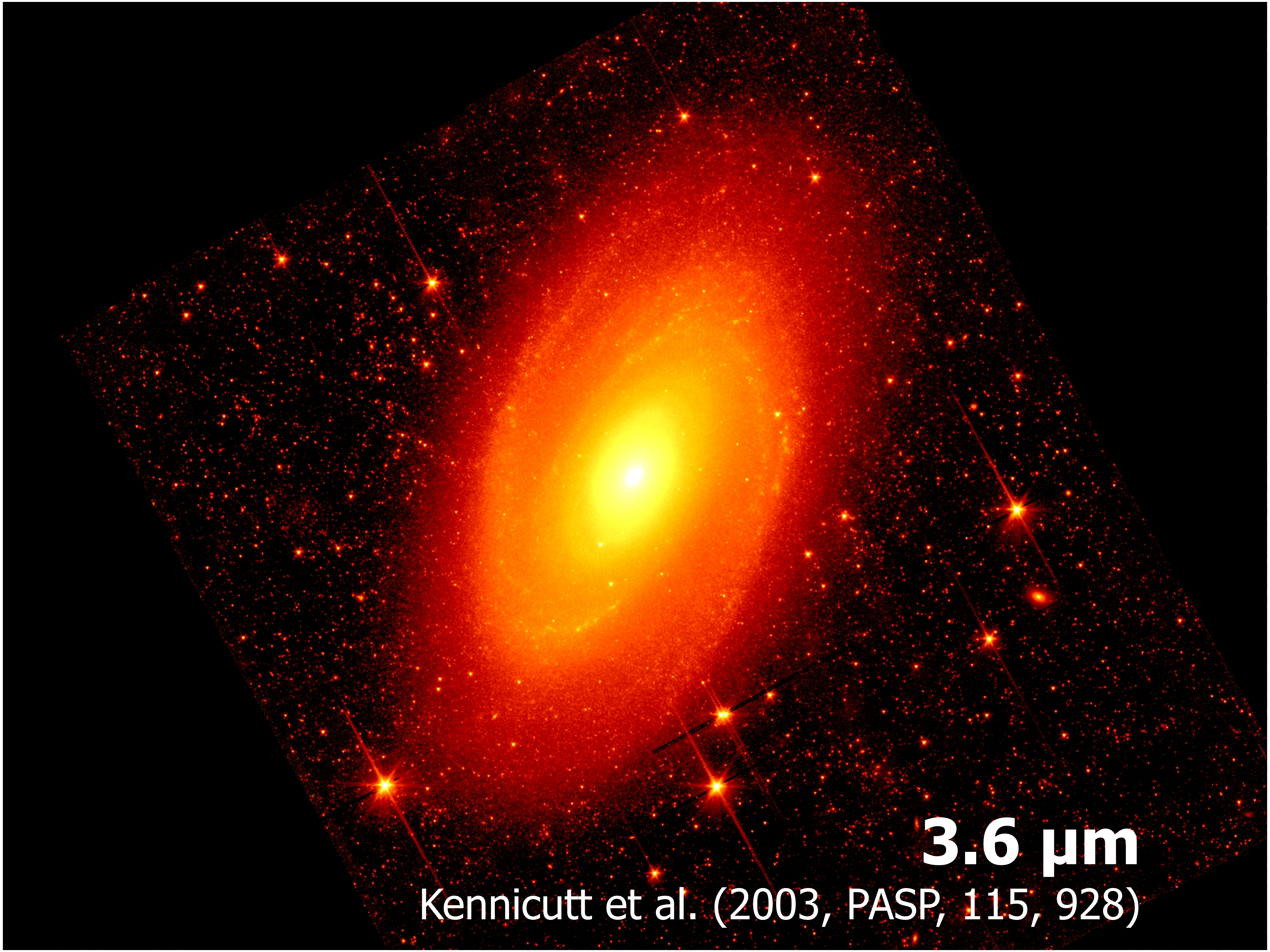
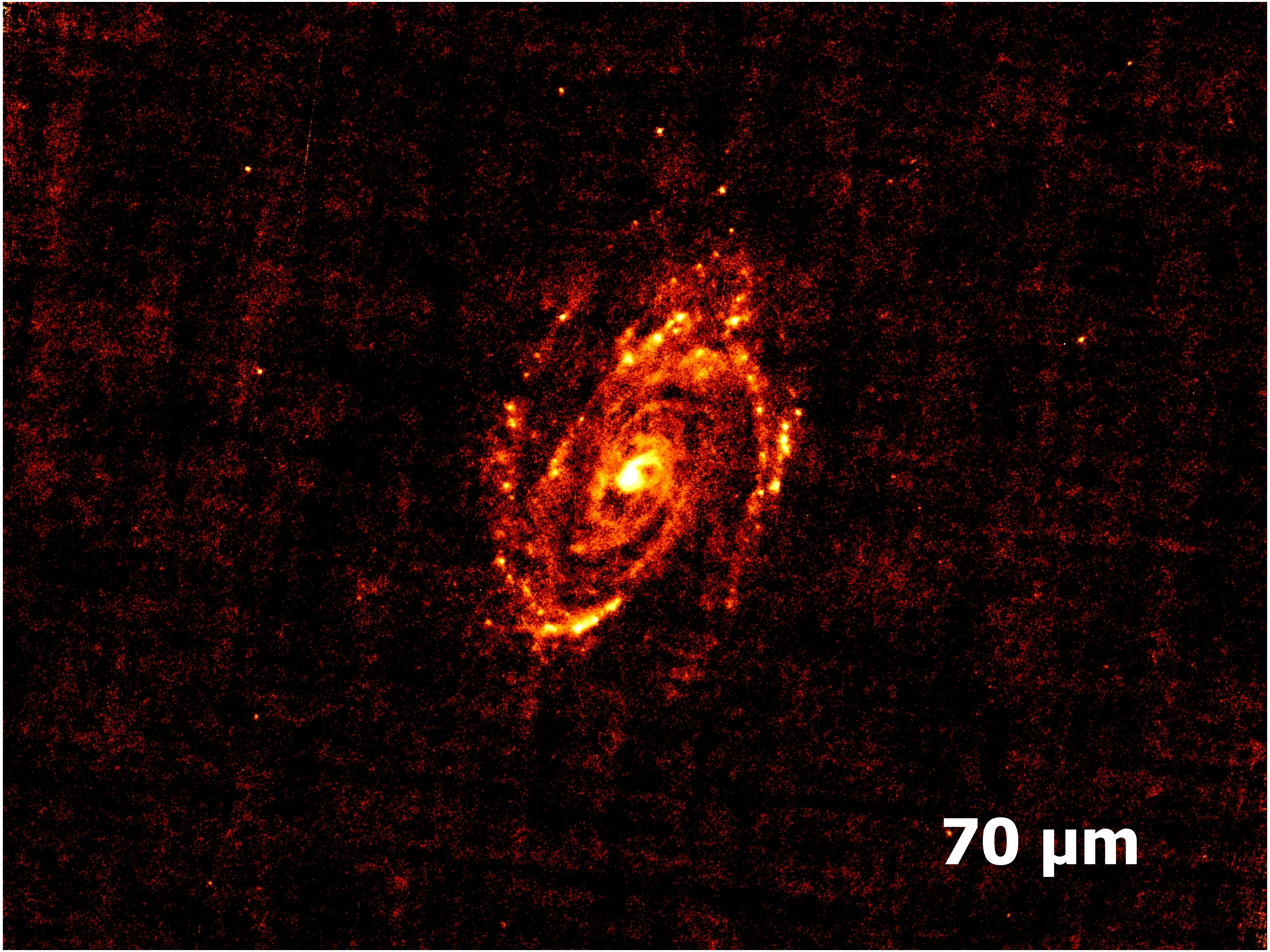
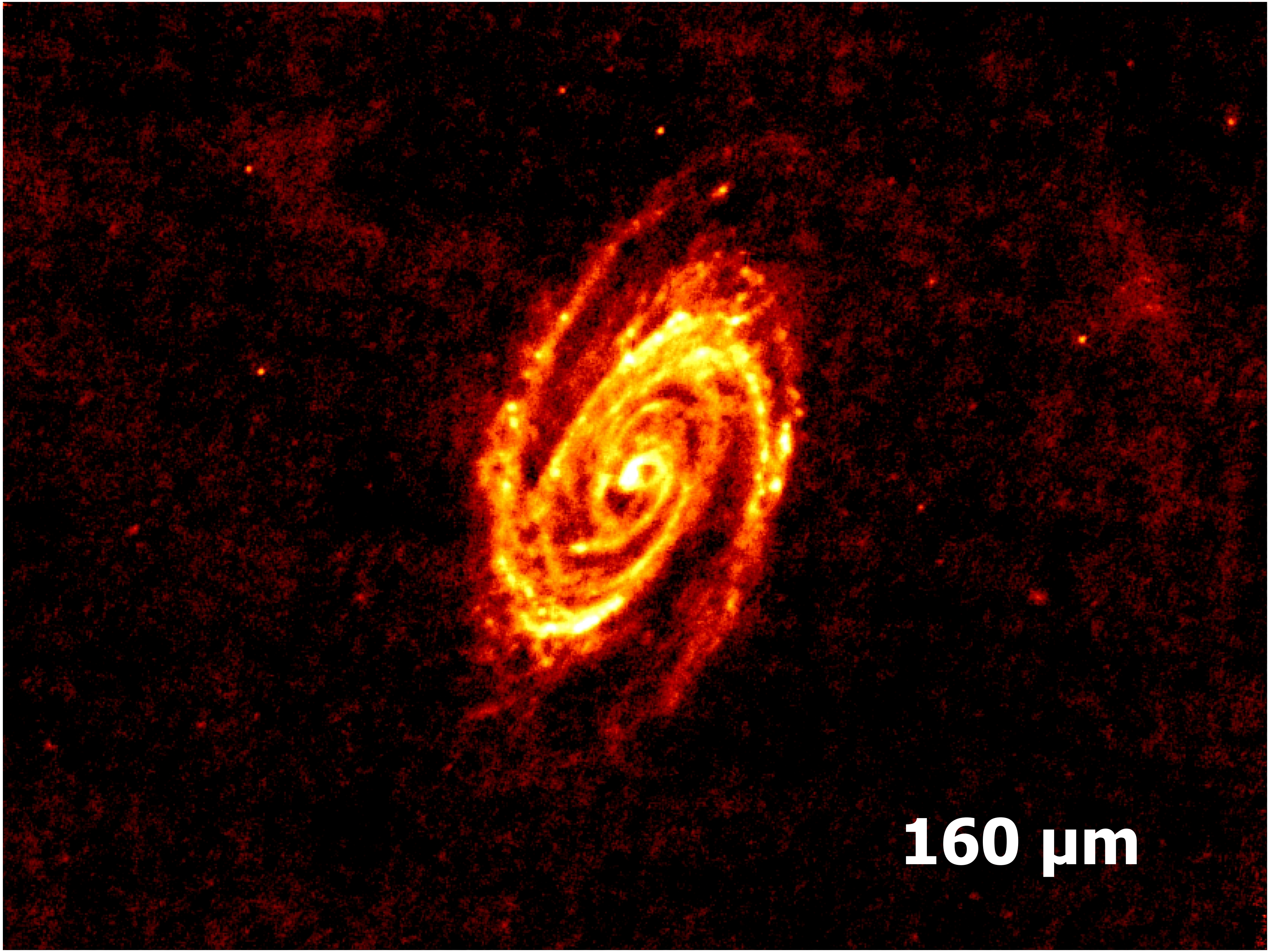
**Very Nearby Galaxies Survey (SAG2)**

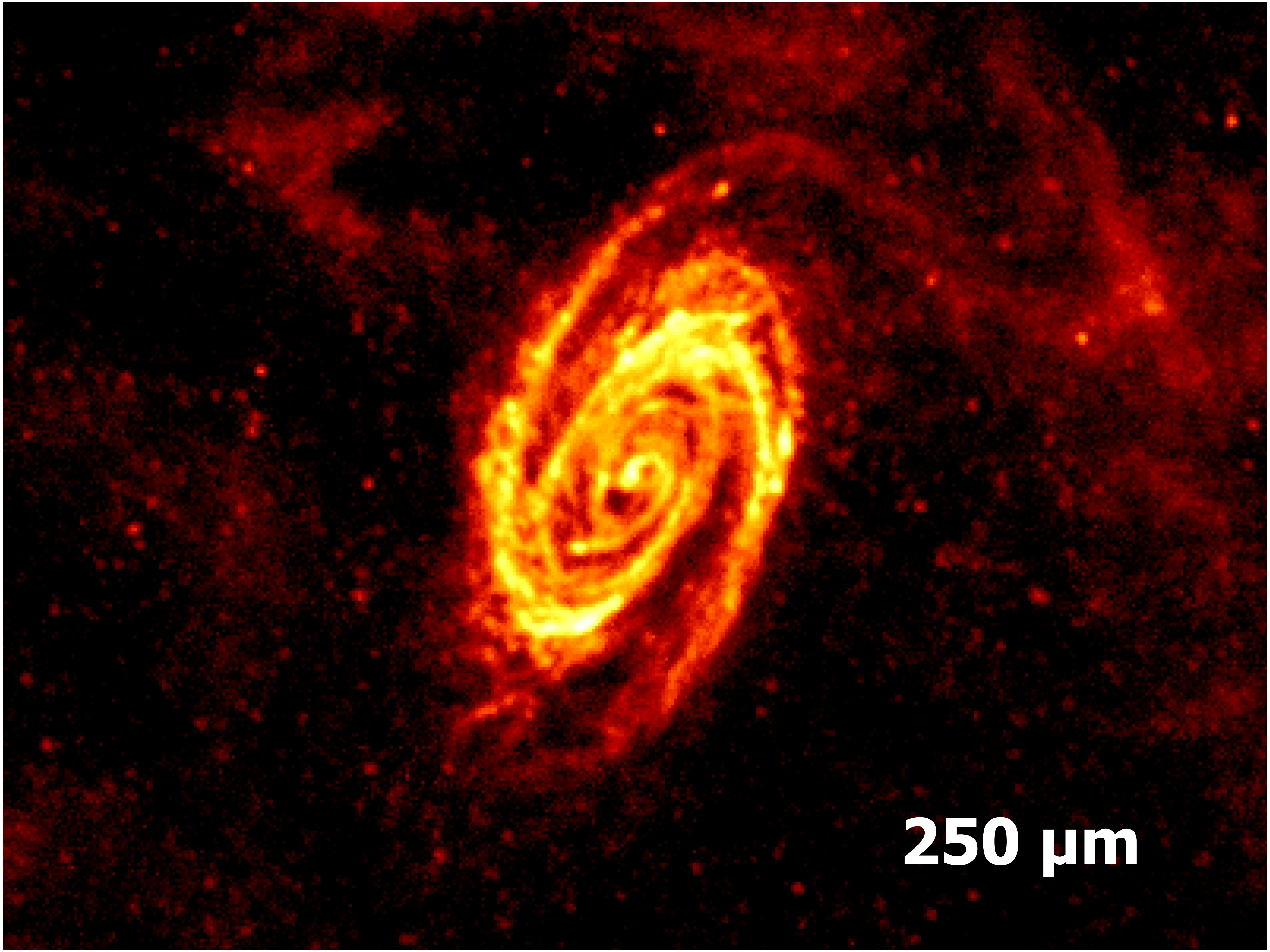
# Motivations for research:

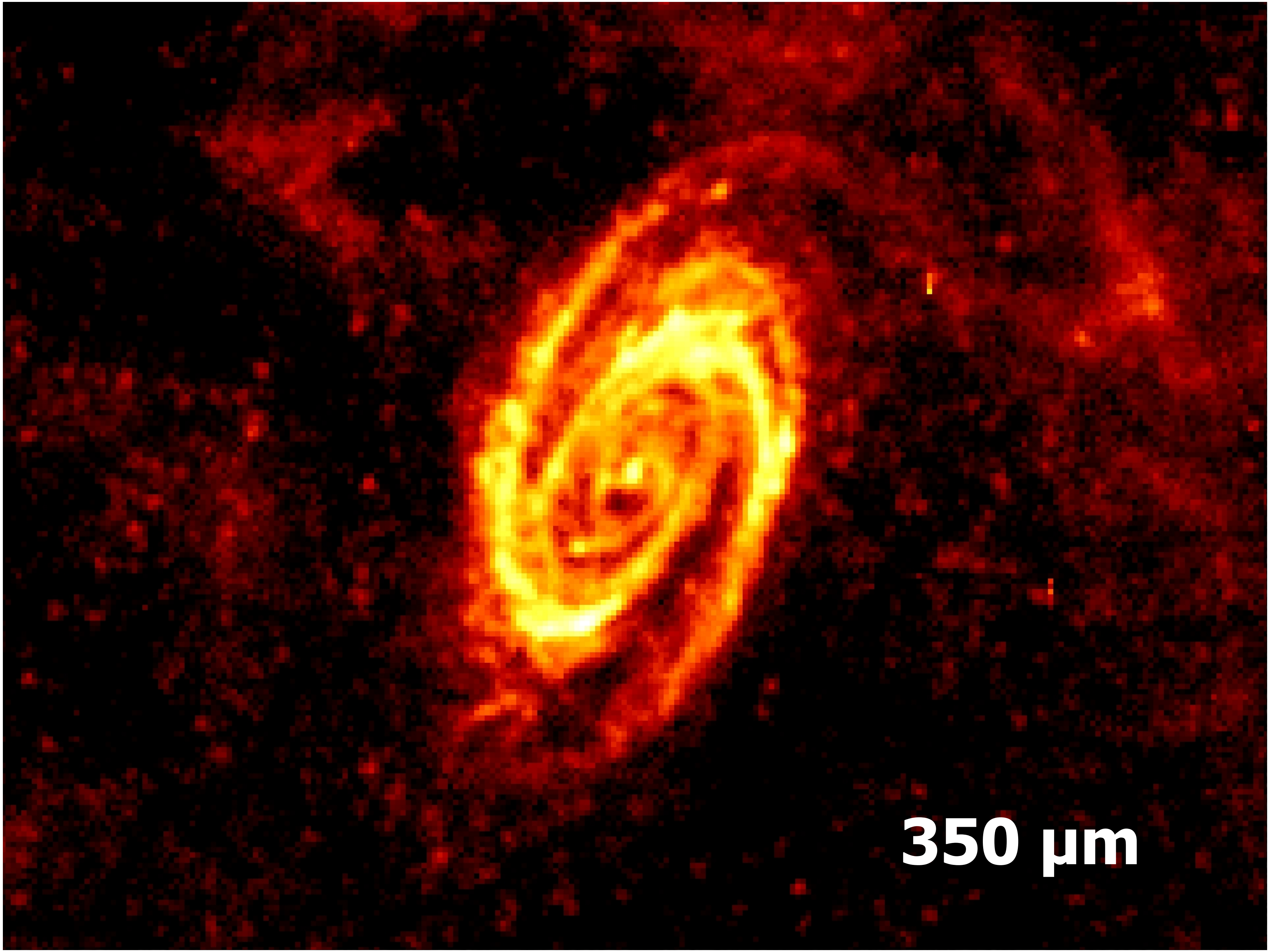
- Except for M82, some dwarf galaxies, and other odd objects, we were unable to examine the SED of dust emission between 200 and 850 µm in nearby galaxies before the launch of Herschel.
- Dust masses are poorly constrained without these data; large masses of ~15 K dust (or even colder dust) could be present, but only part of the emission would have been observed by IRAS/ISO/Spitzer.

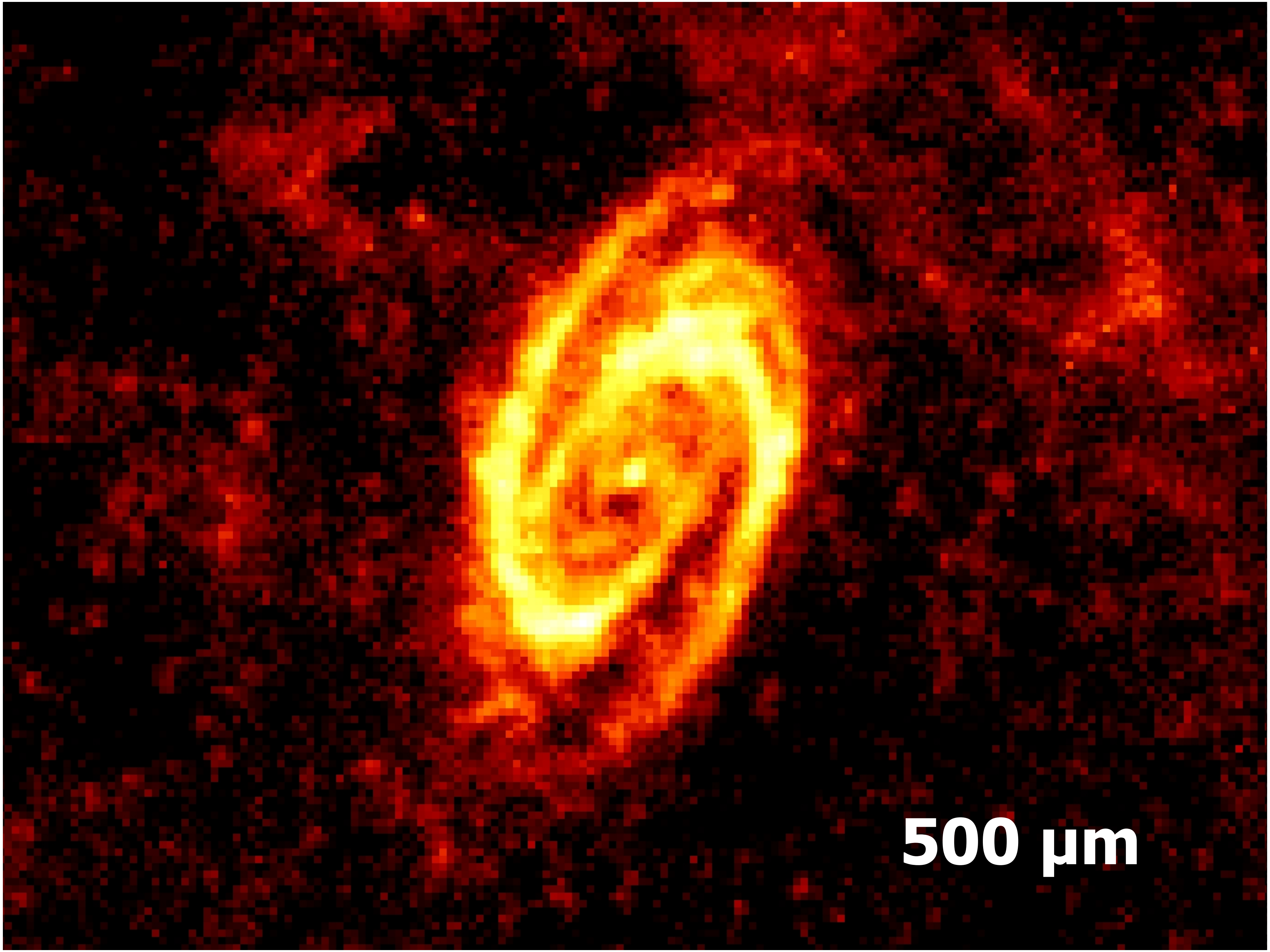

3.6 μm
Kennicutt et al. (2003, PASP, 115, 928)


70 µm


160 µm


250 µm

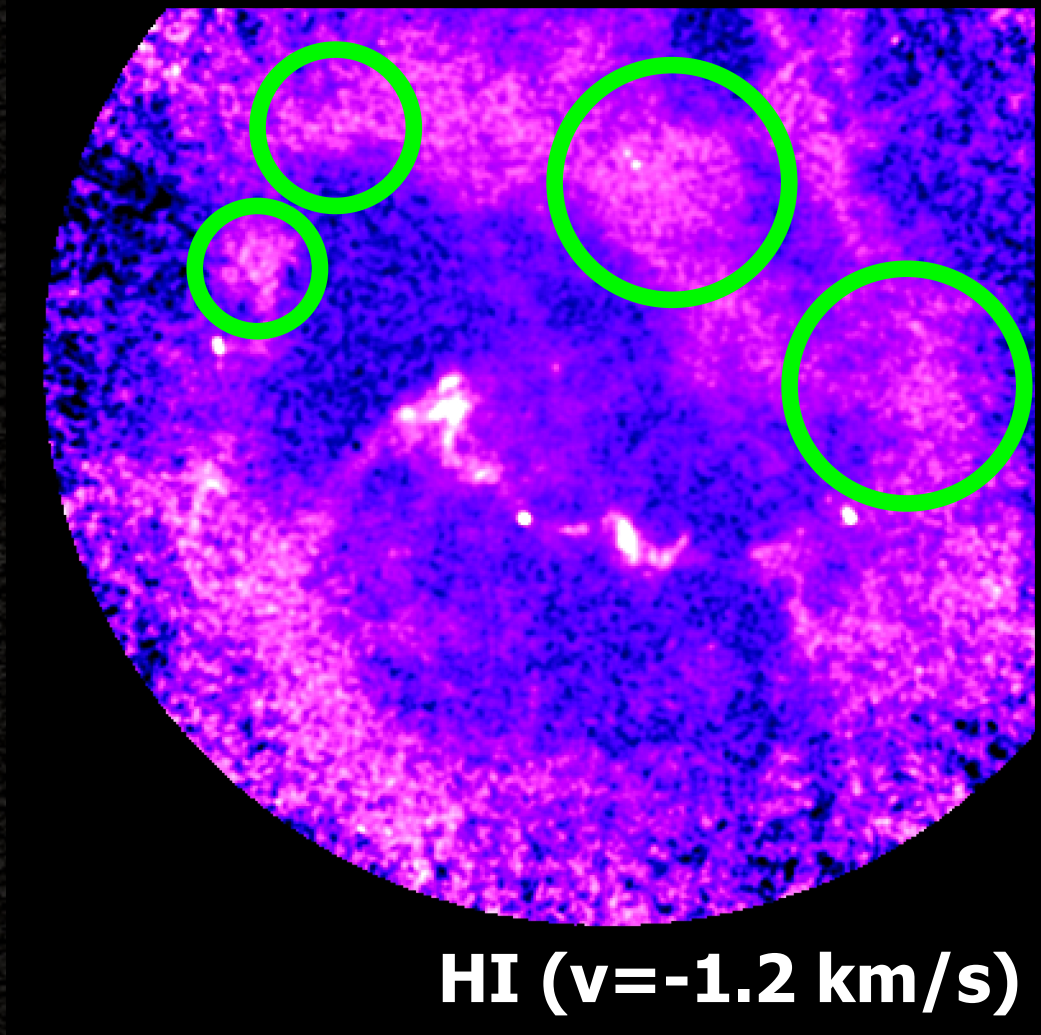

350 µm


500 μm

Much of the infrared emission seen outside the optical disk of M81 has HI counterparts.

However, the velocity width of the HI is ~3 km/s. This would be difficult to achieve in a large extragalactic structure but easy to achieve in foreground cirrus.

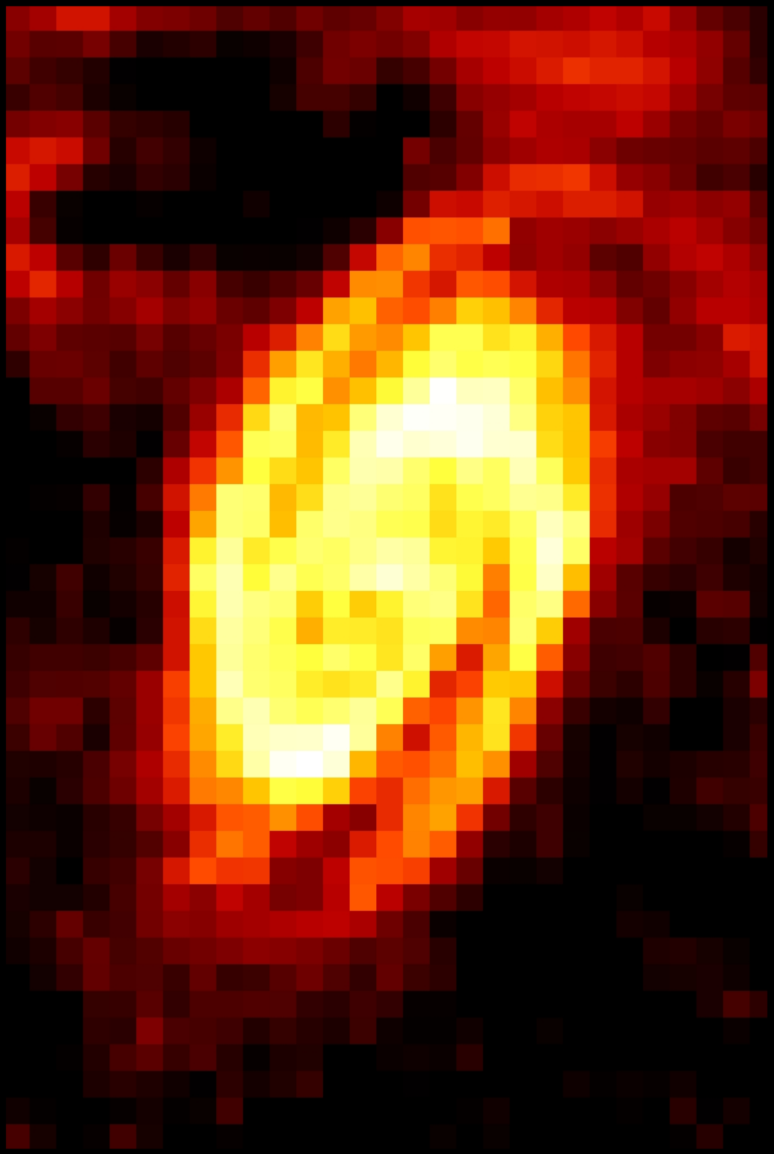
Other analyses also suggest that the infrared emission originates from foreground cirrus. See Davies et al. (2010, in preparation) for additional information.

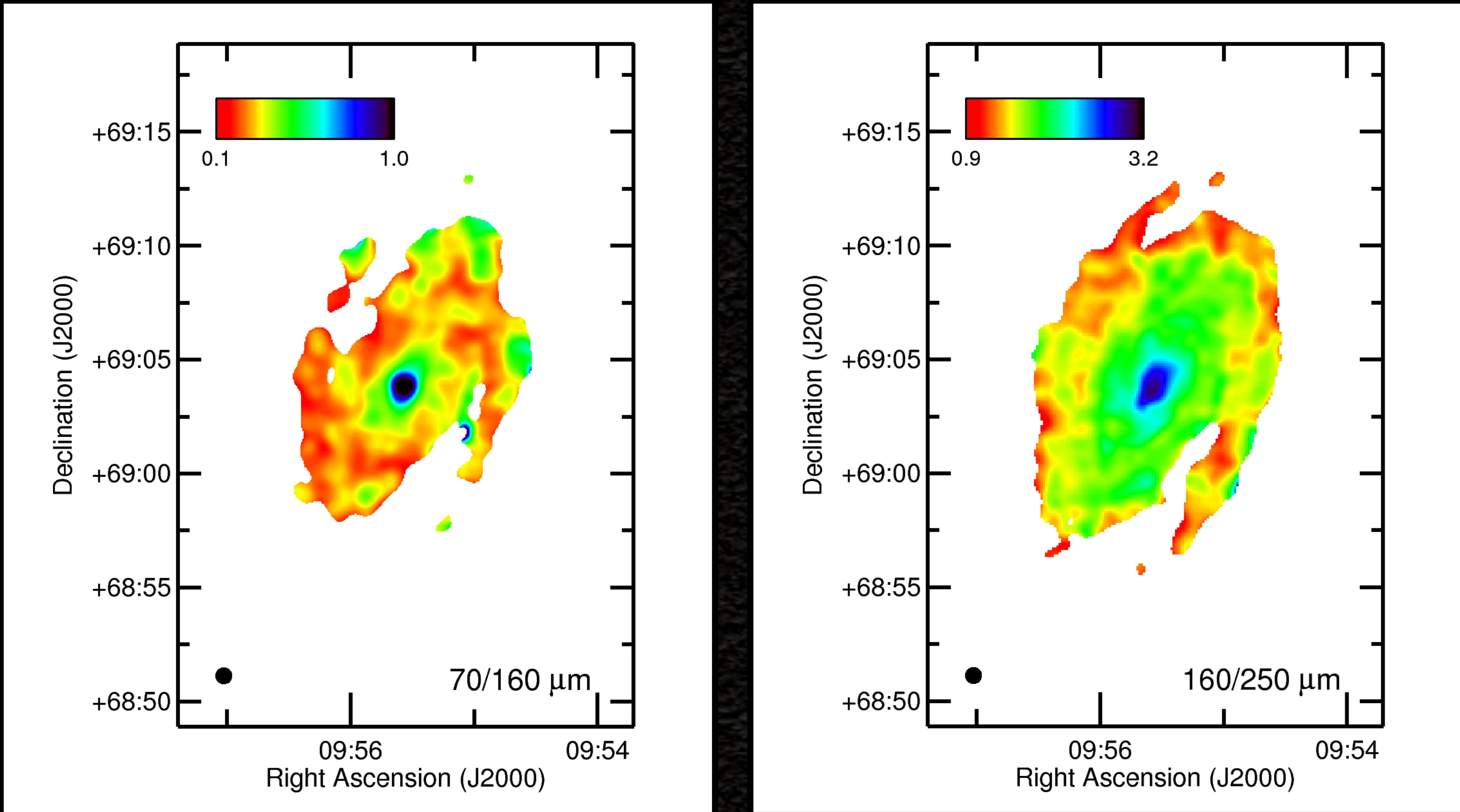



Walter et al. (2008, AJ, 136, 2563)

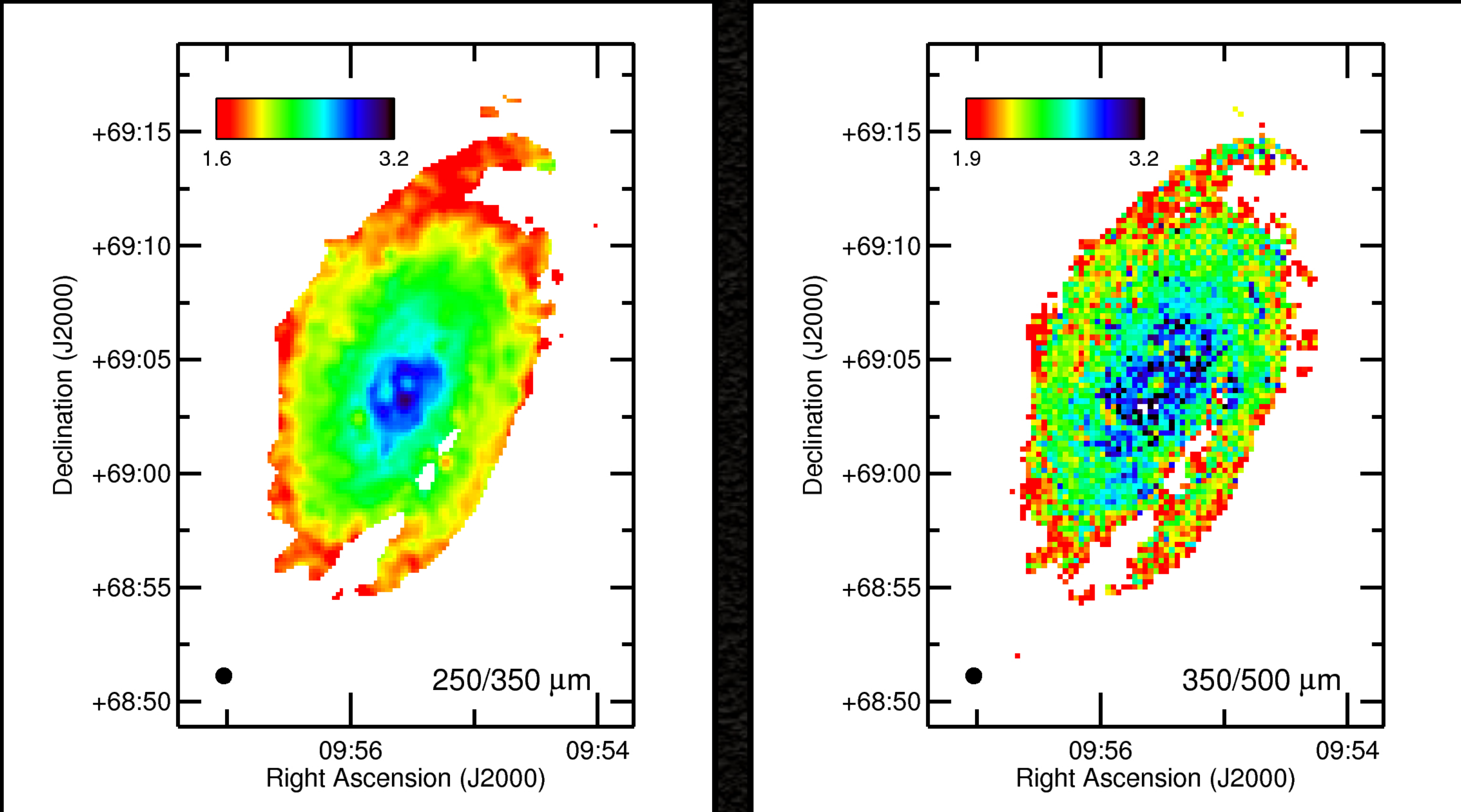
To compare data from different wave bands, we matched the PSFs of all data to that of the 500 μm data (FWHM: 37″).

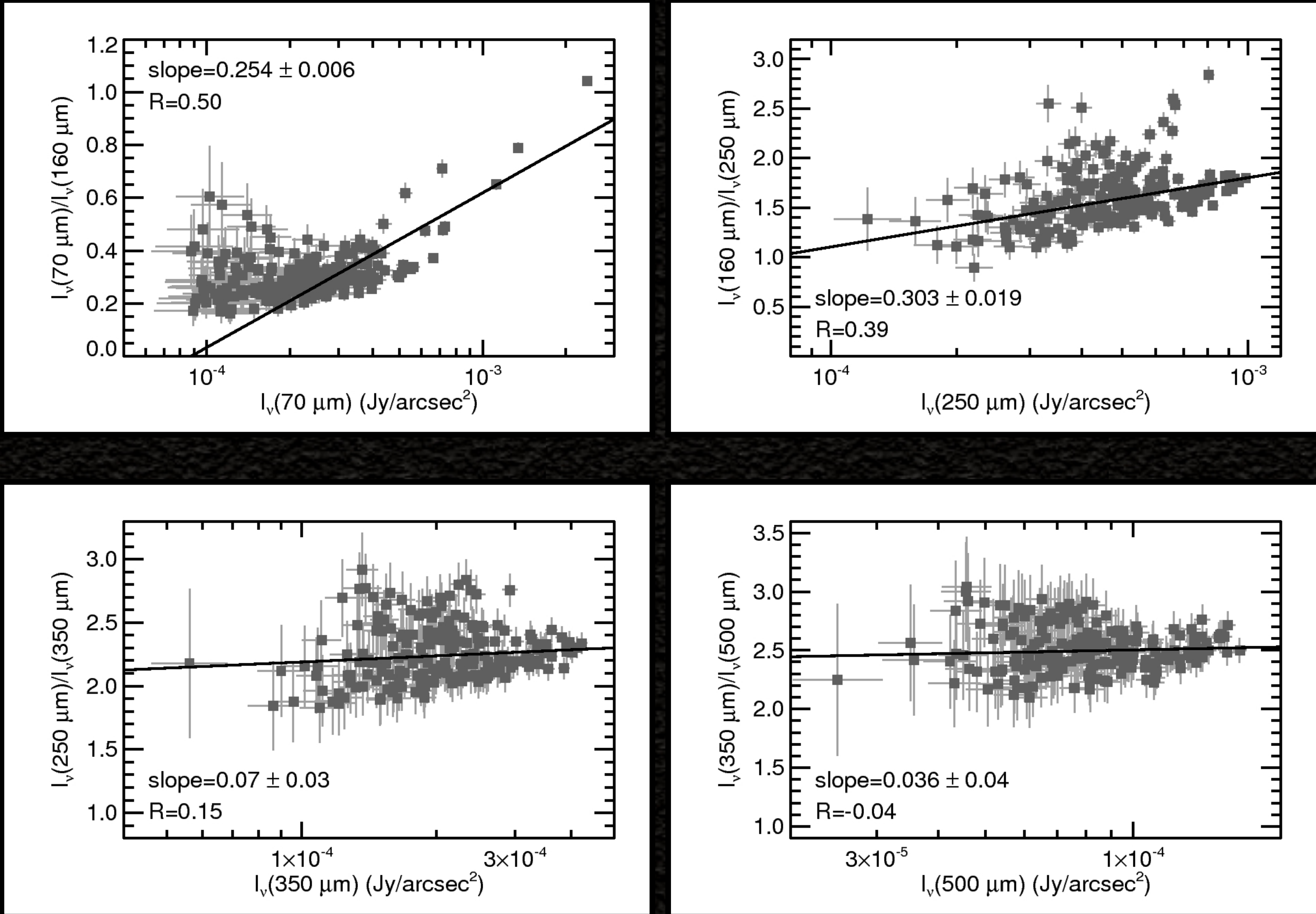
For quantitative analyses on subregions, we then rebinned the data into 42″ bins (3× the 500 μm pixels) that were treated as individual data points.

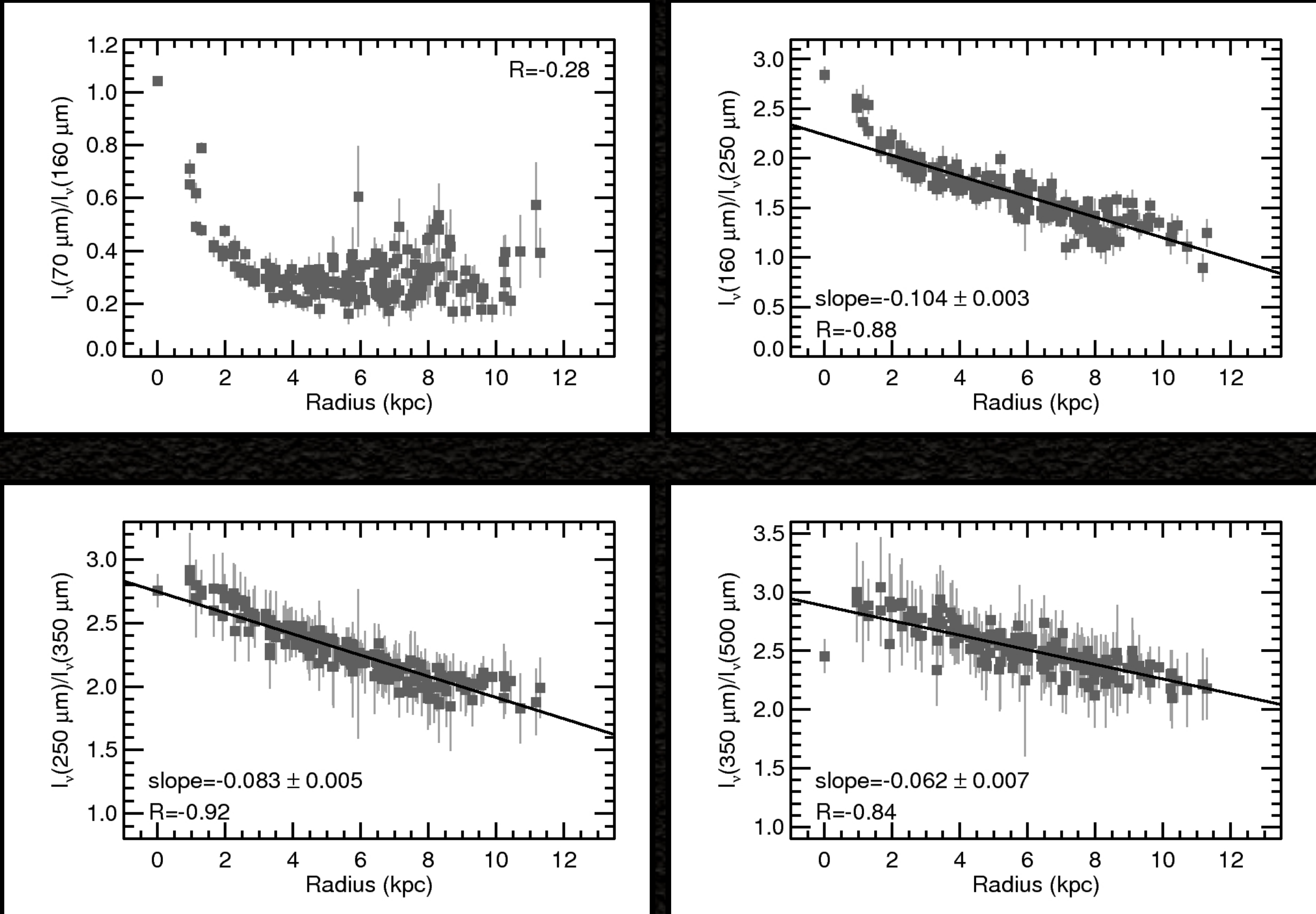




0.1
1.0
+69:15
+69:10
+69:05
+69:00
+68:55
+68:50
Declination (J2000)
70/160 µm
09:56
09:54
Right Ascension (J2000)
0.9
3.2
+69:15
+69:10
+69:05
+69:00
+68:55
+68:50
Declination (J2000)
160/250 µm
09:56
09:54
Right Ascension (J2000)

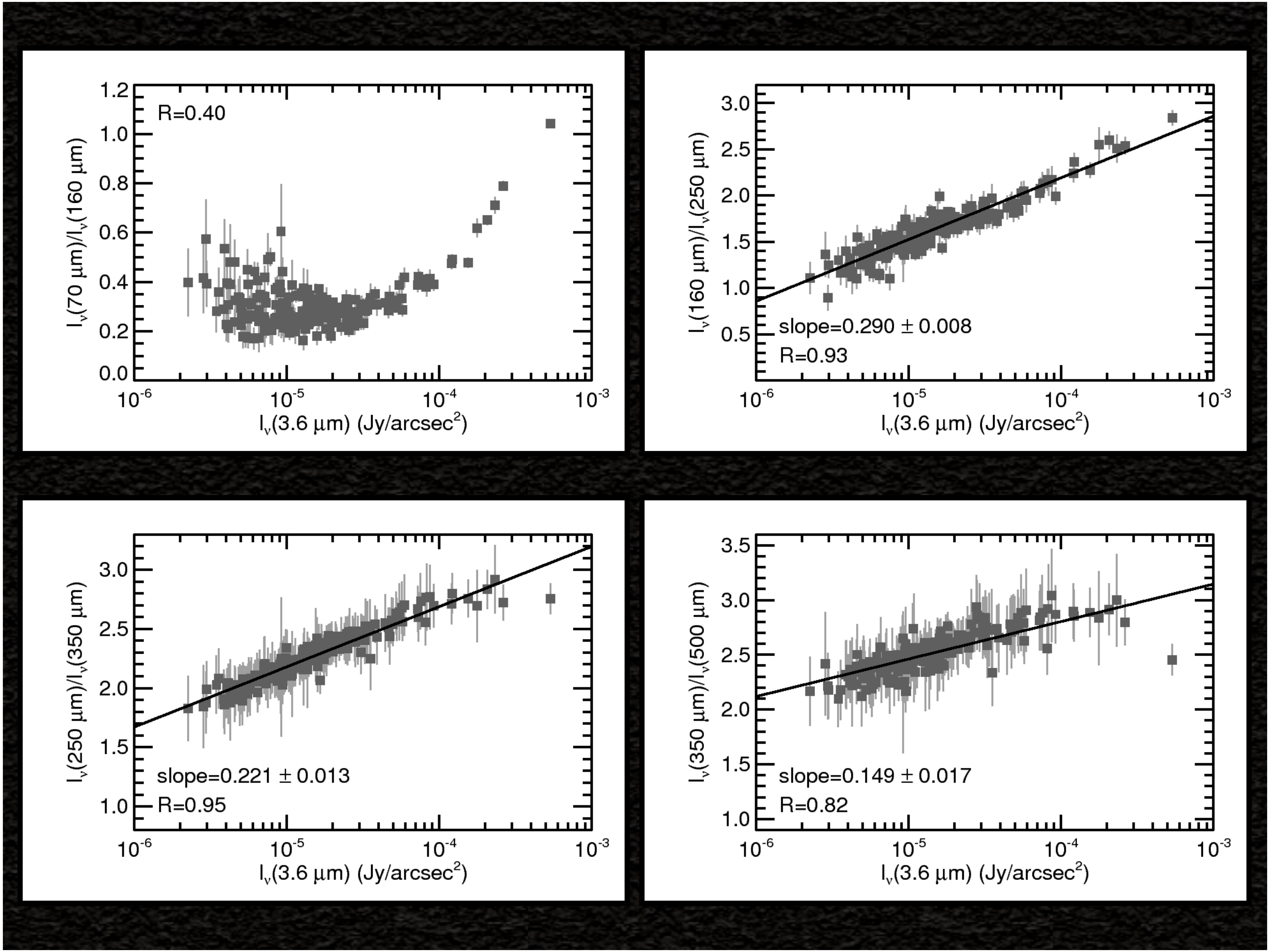

1.6
3.2
+69:15
+69:10
+69:05
+69:00
+68:55
+68:50
Declination (J2000)
250/350 µm
09:56
09:54
Right Ascension (J2000)
1.9
3.2
+69:15
+69:10
+69:05
+69:00
+68:55
+68:50
Declination (J2000)
350/500 µm
09:56
09:54
Right Ascension (J2000)


slope=0.254 ± 0.006
R=0.50
$I_\nu$(70 μm)/$I_\nu$(160 μm)
$I_\nu$(70 μm) (Jy/arcsec$^2$)
slope=0.303 ± 0.019
R=0.39
$I_\nu$(160 μm)/$I_\nu$(250 μm)
$I_\nu$(250 μm) (Jy/arcsec$^2$)
slope=0.07 ± 0.03
R=0.15
$I_\nu$(250 μm)/$I_\nu$(350 μm)
$I_\nu$(350 μm) (Jy/arcsec$^2$)
slope=0.036 ± 0.04
R=-0.04
$I_\nu$(350 μm)/$I_\nu$(500 μm)
$I_\nu$(500 μm) (Jy/arcsec$^2$)



R=-0.28
$I_\nu(70\ \mu m)/I_\nu(160\ \mu m)$
Radius (kpc)
slope=-0.104 ± 0.003
R=-0.88
$I_\nu(160\ \mu m)/I_\nu(250\ \mu m)$
Radius (kpc)
slope=-0.083 ± 0.005
R=-0.92
$I_\nu(250\ \mu m)/I_\nu(350\ \mu m)$
Radius (kpc)
slope=-0.062 ± 0.007
R=-0.84
$I_\nu(350\ \mu m)/I_\nu(500\ \mu m)$
Radius (kpc)

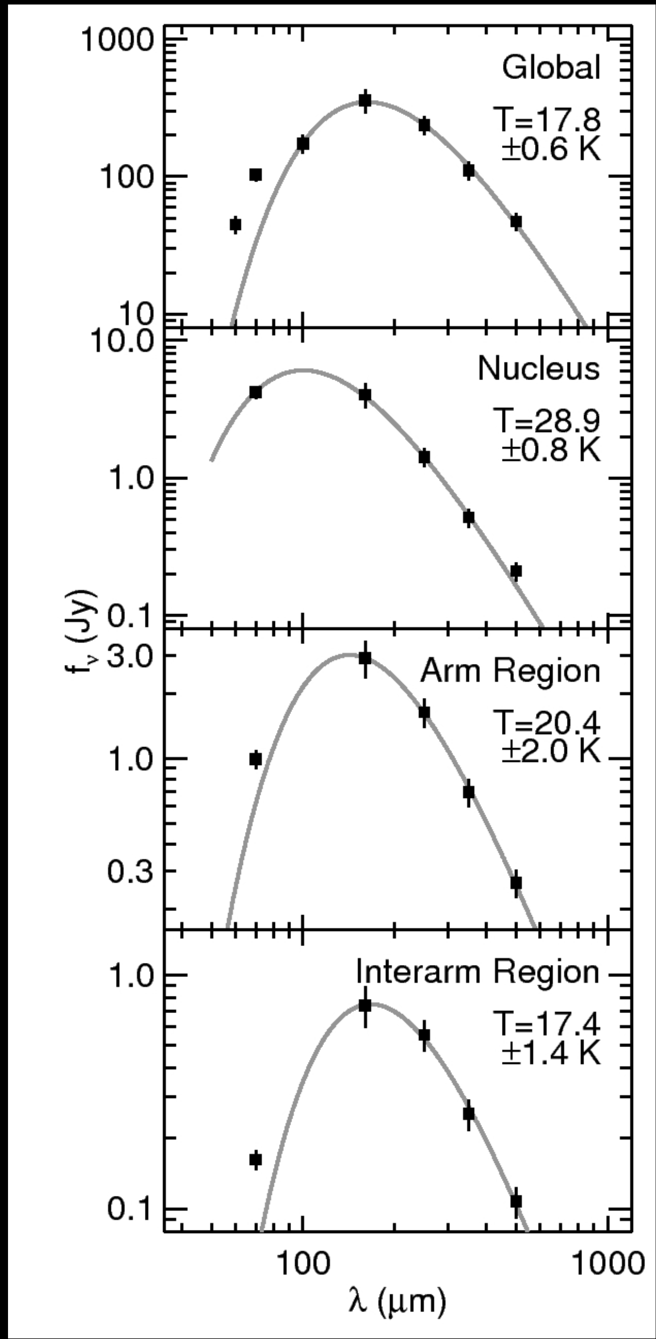
- 70 µm emission appears boosted in infrared-bright regions, although no strong correlation with surface brightness is present.
- 160/250, 250/350, and 350/500 µm ratios all depend much more strongly on radius than on surface brightness.
- These results show that the 70 µm emission is affected by local dust heating (star formation) while the 160-500 µm bands are not.
- Instead, the 160-500 µm bands primarily trace dust heated by the evolved stellar population in the disk and bulge.

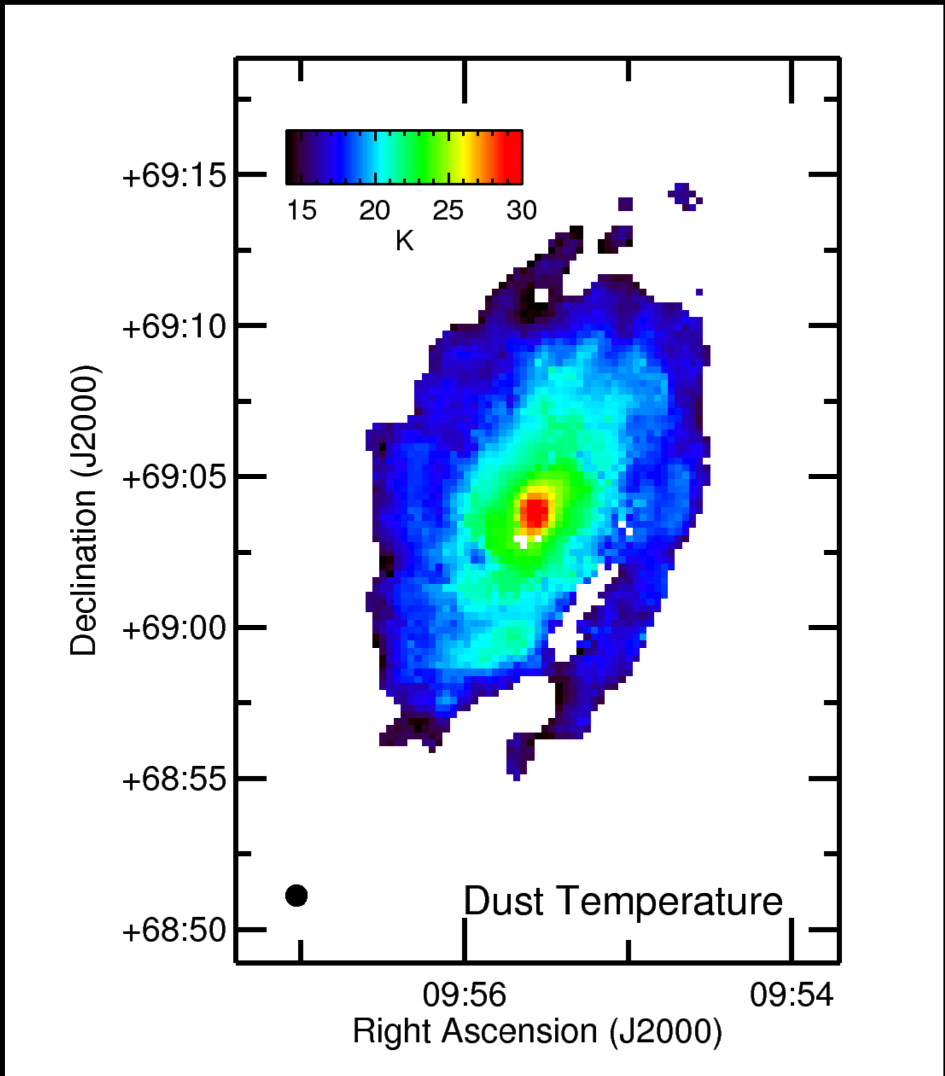

R=0.40
$I_\nu(70\ \mu m)/I_\nu(160\ \mu m)$
$I_\nu(3.6\ \mu m)$ (Jy/arcsec$^2$)
slope=0.290 ± 0.008
R=0.93
$I_\nu(160\ \mu m)/I_\nu(250\ \mu m)$
$I_\nu(3.6\ \mu m)$ (Jy/arcsec$^2$)
slope=0.221 ± 0.013
R=0.95
$I_\nu(250\ \mu m)/I_\nu(350\ \mu m)$
$I_\nu(3.6\ \mu m)$ (Jy/arcsec$^2$)
slope=0.149 ± 0.017
R=0.82
$I_\nu(350\ \mu m)/I_\nu(500\ \mu m)$
$I_\nu(3.6\ \mu m)$ (Jy/arcsec$^2$)

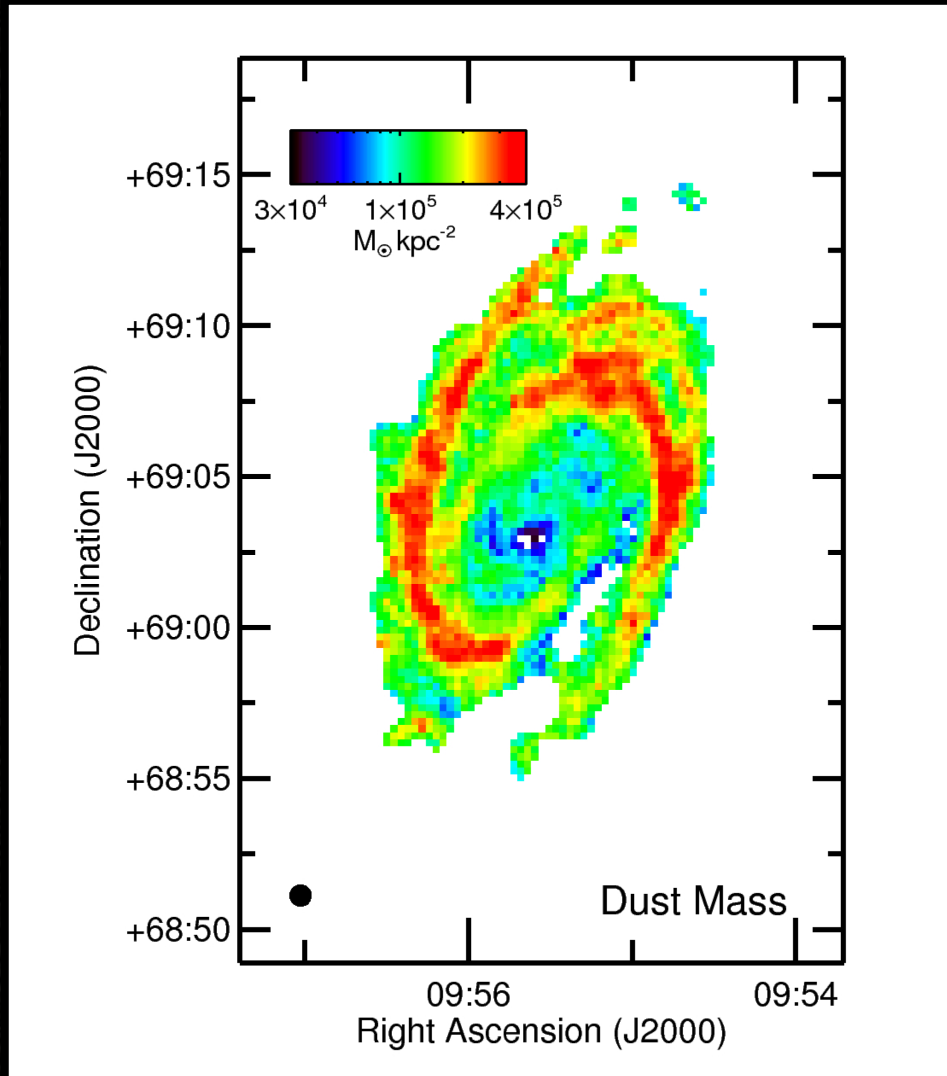
Global SED fits as well as SED fits for arm and interarm region show that it is possible that the 70 μm emission could originate from a warmer dust component than the 160-500 μm emission.

The integrated global gas/dust ratio based on this simplistic fit is 107 ± 17.

Also note that we do not see evidence for <15 K dust.




15 20 25 30
K
+69:15
+69:10
+69:05
+69:00
+68:55
+68:50
Declination (J2000)
Dust Temperature
09:56
09:54
Right Ascension (J2000)


3×10^4 1×10^5 4×10^5
M☉ kpc^-2
+69:15
+69:10
+69:05
+69:00
+68:55
+68:50
Declination (J2000)
Dust Mass
09:56
09:54
Right Ascension (J2000)

Some IRAS and Spitzer papers had suggested that the far-infrared emission could originate from dust heated by evolved stars, although this was difficult to study at <200 μm.

As Herschel covers longer wavelengths, it will be more effective at properly quantifying the amount of emission from dust heated by evolved stars.

We also anticipate that the relative fraction of dust heated by evolved stars could vary along the Hubble sequence.  In late-type galaxies, the 160-500 μm colors may generally be correlated more strongly with surface brightness (see, for example, the poster by Galametz et al. on NGC 6822).

# Implications:

- Dust emission models need to account for different heating sources in the far-infrared more effectively. At least in the case of M81, the heating source for the dust emitting at 160-500 μm should be treated as independent of the dust emitting at ≤70 μm.

- Far-infrared flux densities, especially at ≥160 μm, may be very ineffective as star formation tracers.

# Summary:

- Emission at 70 µm from M81 originates in part from dust heated by star formation regions.
- Emission at 160-500 µm from M81 originates mostly, if not entirely, from dust heated by the evolved stellar population in the bulge and disk.
- Future work with a larger sample of spiral galaxies is needed to determine whether far-infrared dust emission in other galaxies could be dominated by dust heated by evolved stars.