Separating emission from hot and cold dust in nearby galaxies with Millimetron

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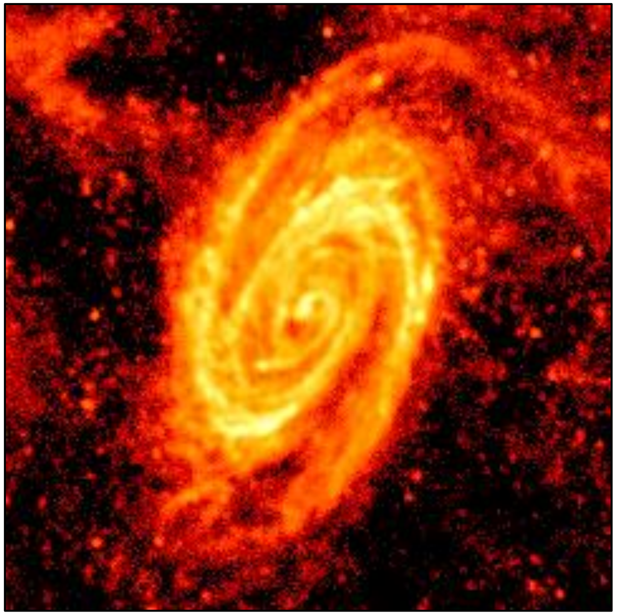
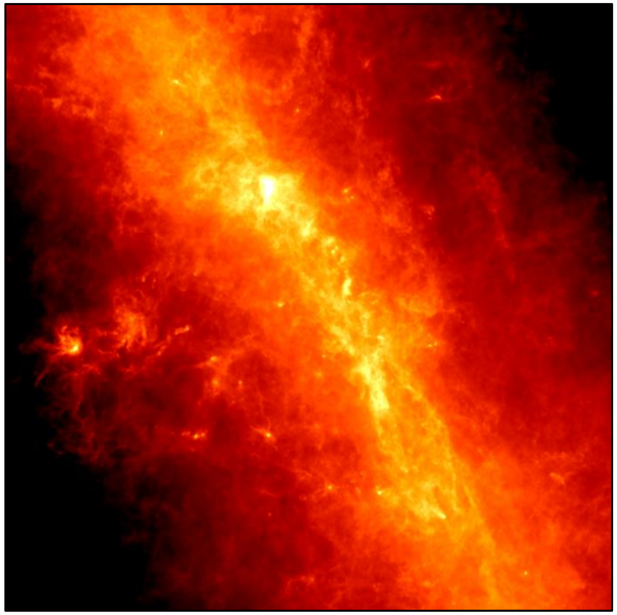
Reasons to Study Dust in Nearby Galaxies

In comparison to dust in the Milky Way:

- Global distribution of dust is readily apparent
- No complications from projection effects
- Associated stellar populations are more straightforward to identify
- Options to see dust in environments other than the typical spiral galaxy

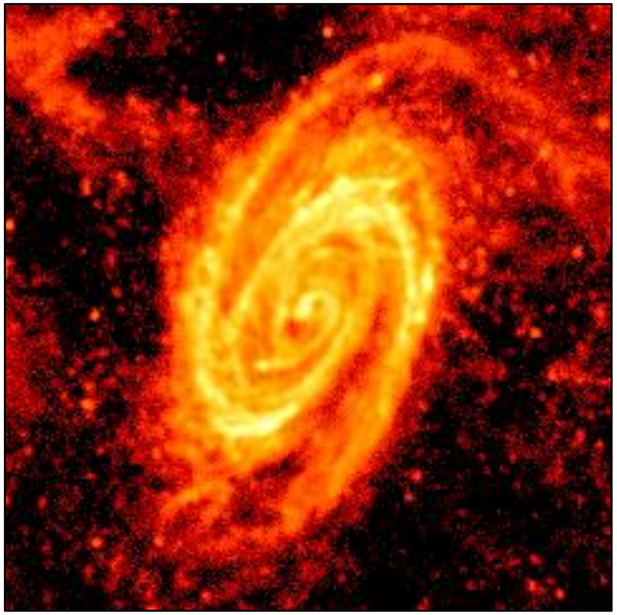


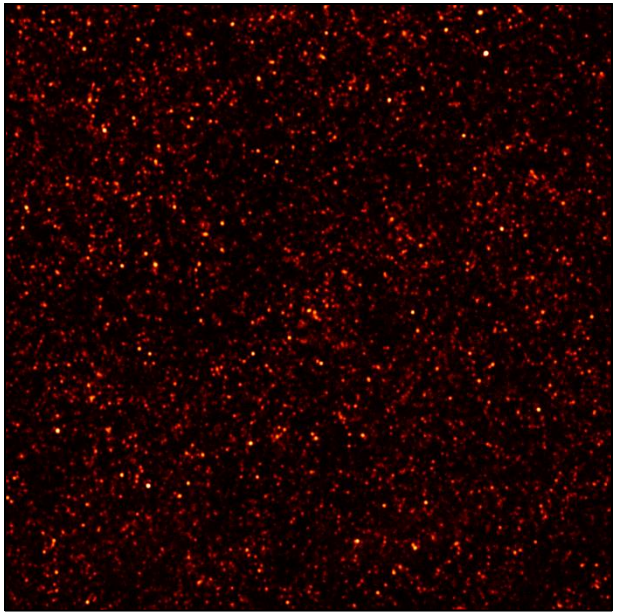


Reasons to Study Dust in Nearby Galaxies

In comparison to high-redshift galaxies:

- Dust structures are clearly visible
- Dust emission can be associated with star formation more exactly
- Resolved images of stars and dust allow for constructing dust emission/radiative transfer models
- Provide a baseline of what z=0 objects should look like
- Can study fainter/smaller objects not easily seen at high redshift





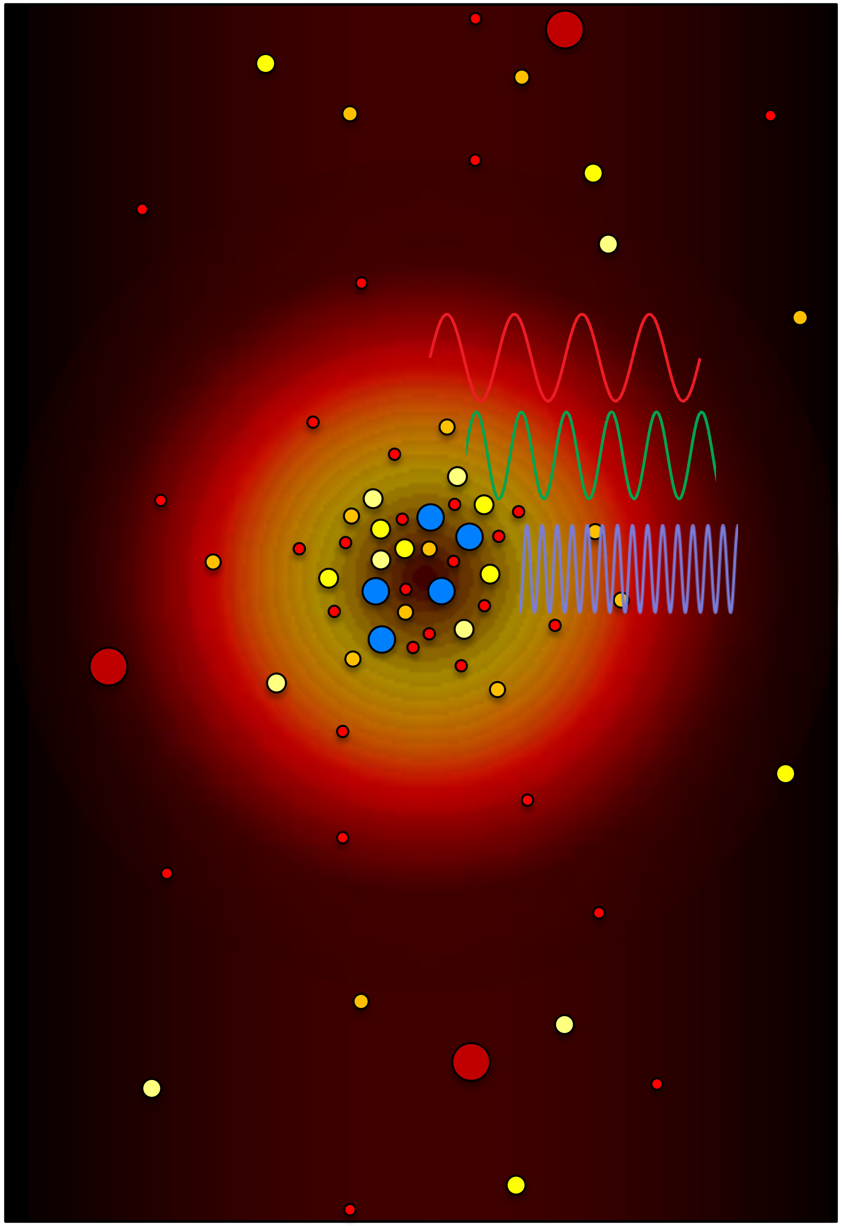
Simplified Model of Dust Emission

Dust emission could be characterized as originating from a shell structure around star forming regions.

Mid-infrared (~25 μm) emission originates mainly from ≳100 K dust near the photoionizing stars.

Submillimetre (≳200 μm) emission originates from the bulk of the dust mass (at 15-25 K) in outer shell regions or the diffuse ISM.

Far-infrared (50-200 μm) emission originates from 30-50 K dust in between these regions.

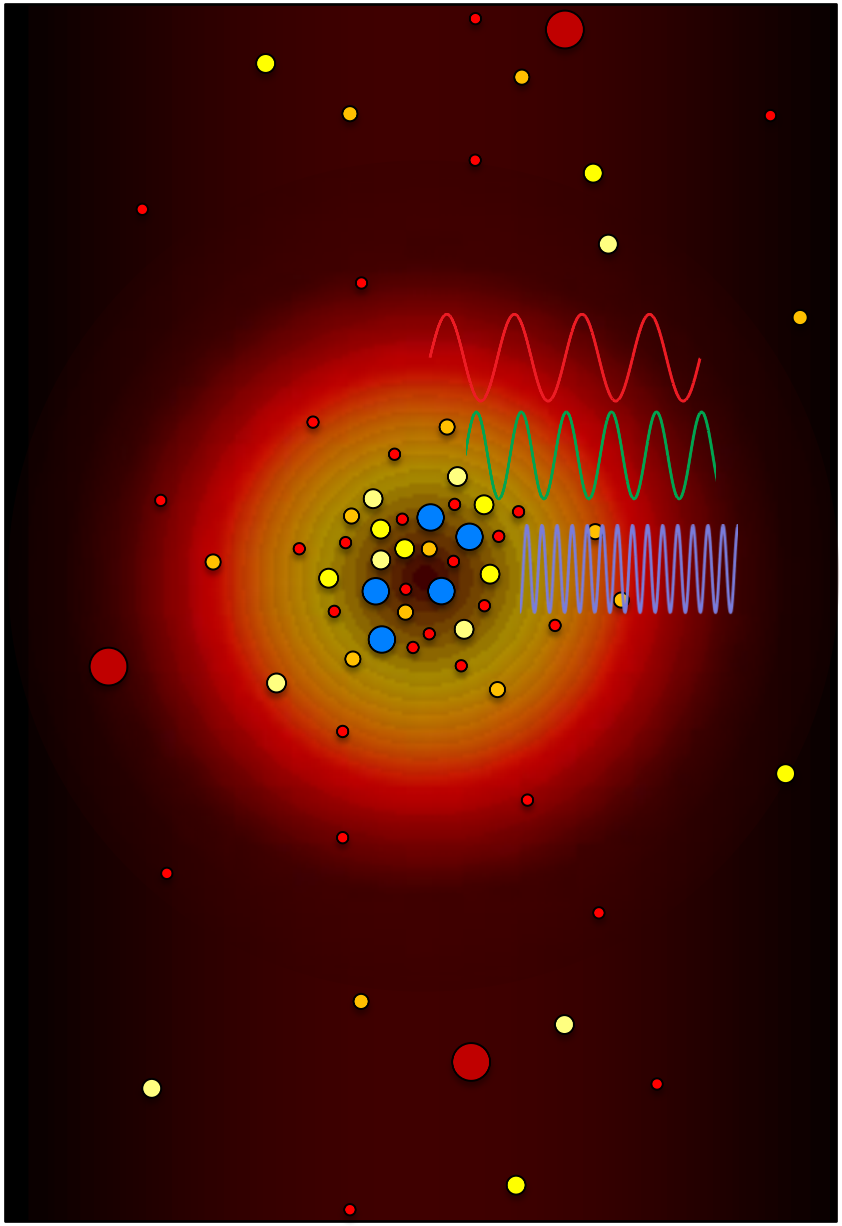


Dust directly heated by star formation can be used to measure star formation rates.

Colder dust can be used to measure dust masses (and ISM masses).

Separating the hot and cold dust allows for making better measurements of star formation rates and dust masses.

This also allows for improving dust emission and radiative transfer models.



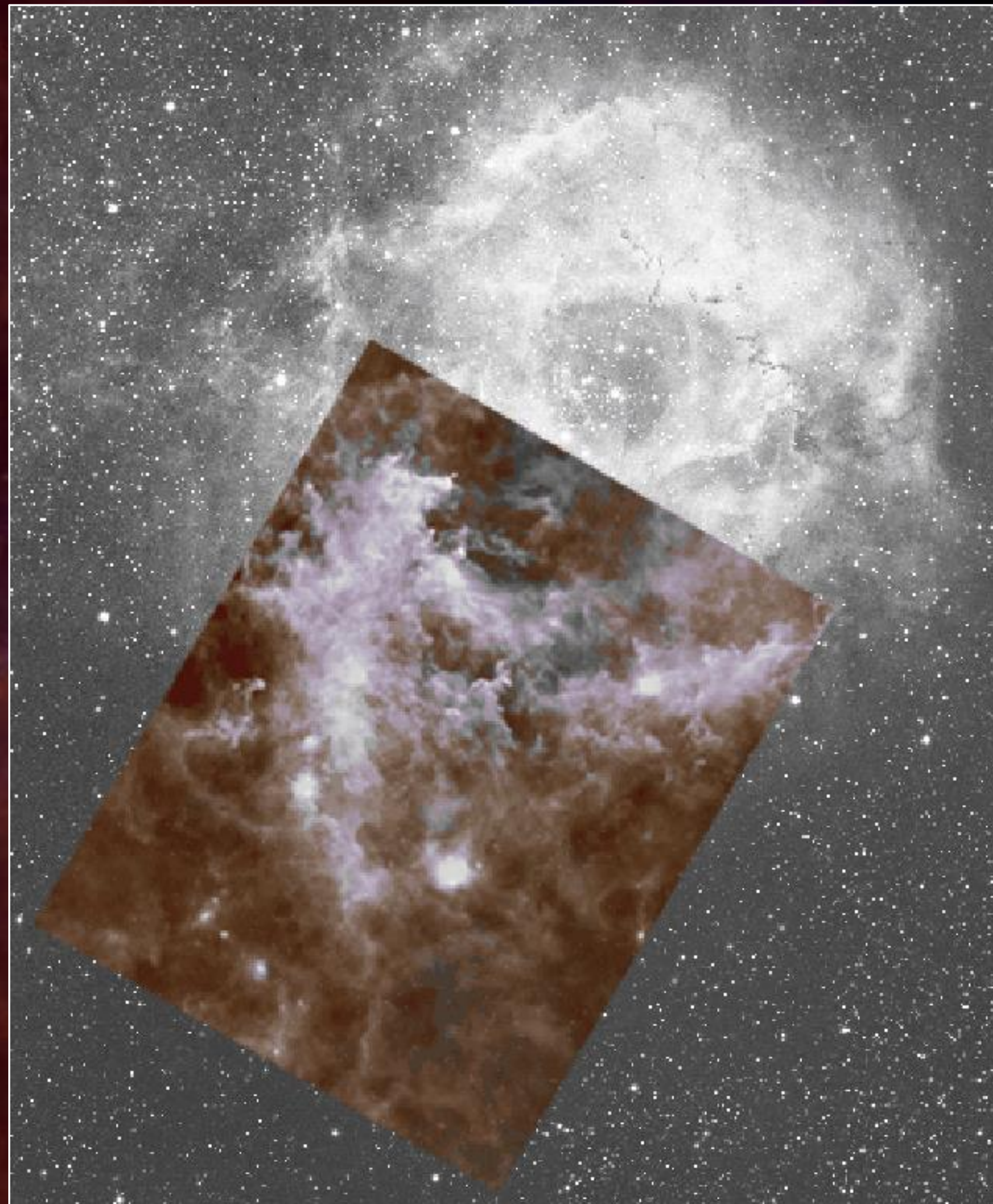
Observations of Dust

Within the Milky Way, it is possible to actually measure colour temperature gradients in the dust around star forming regions (although identifying the "background" can be difficult).

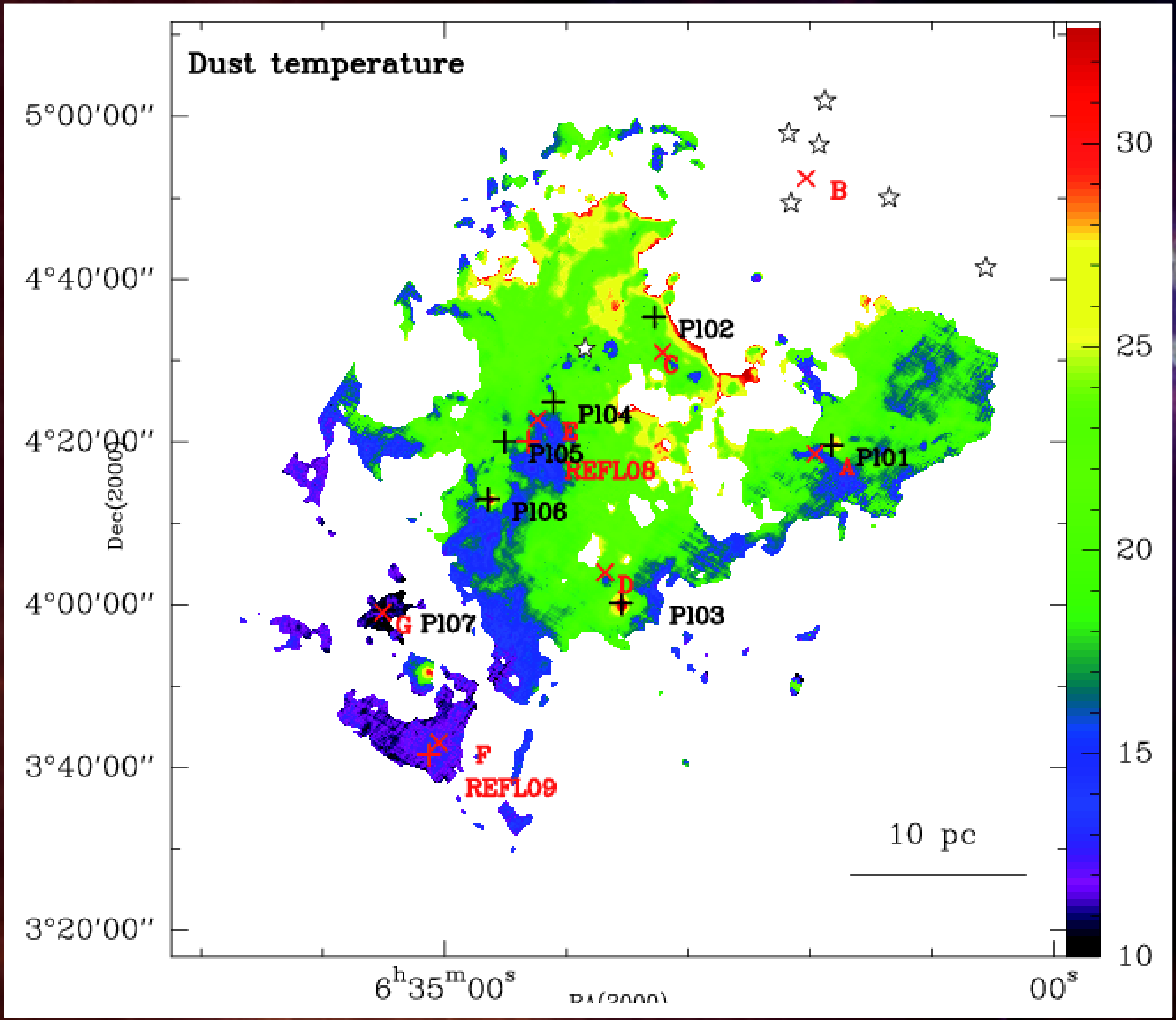
In the Magellanic Clouds, it is straightforward to spatially separate dust emission from star forming and diffuse regions.

In other galaxies in the Local Group, it is possible to resolve the largest star forming complexes.

In most other galaxies, star forming regions and diffuse dust tend to blend together. Disentangling the emission requires either clever empirical analyses or careful modelling.



NGC 2244 (Schneider et al., 2010, A&A, 518, L83)



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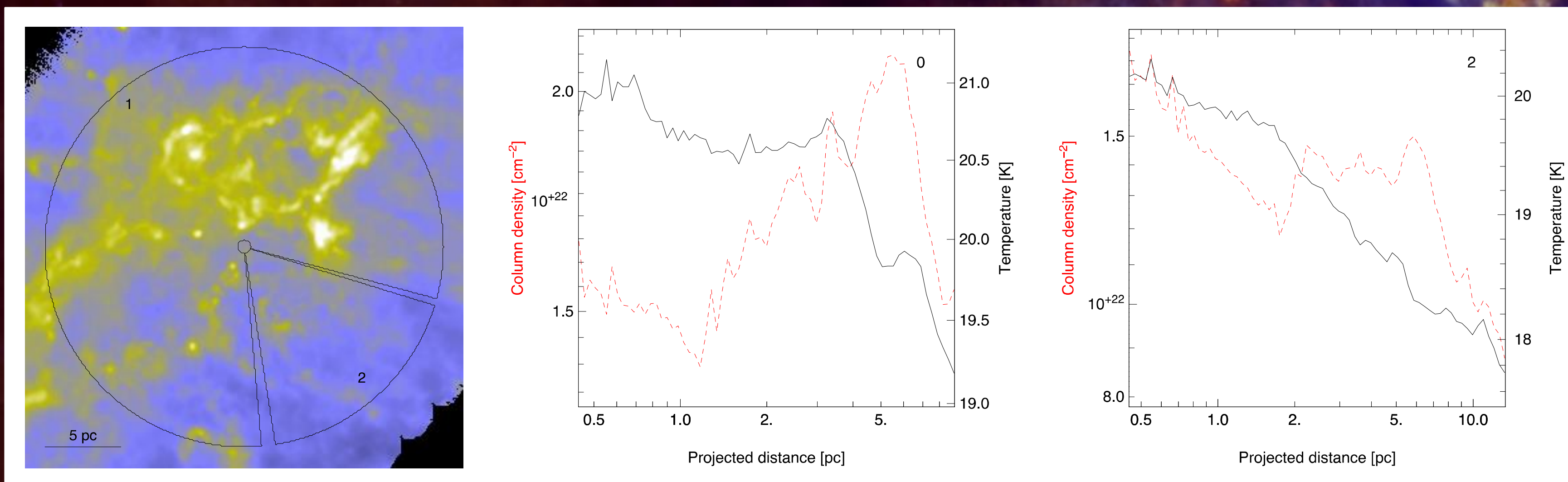
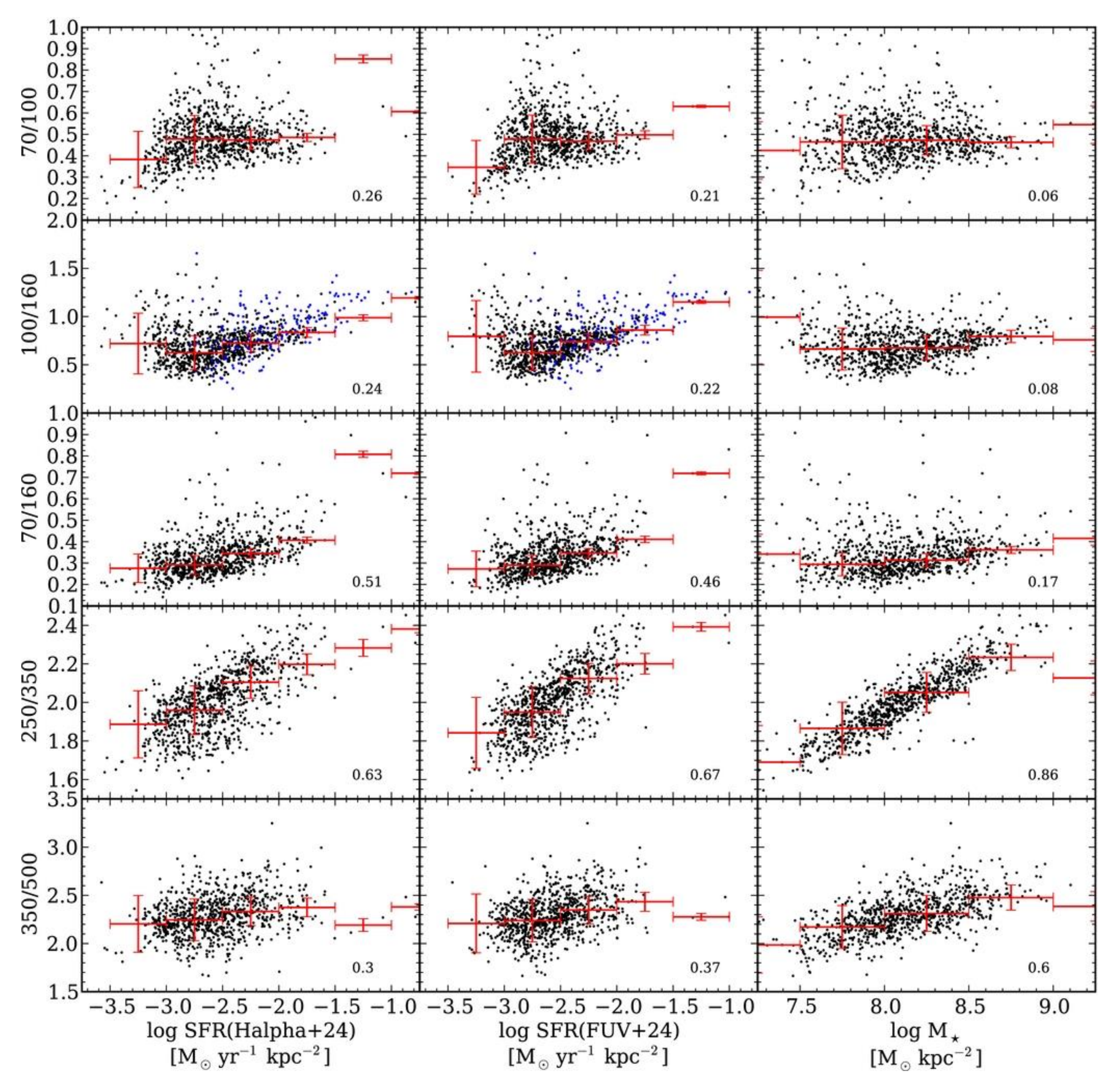
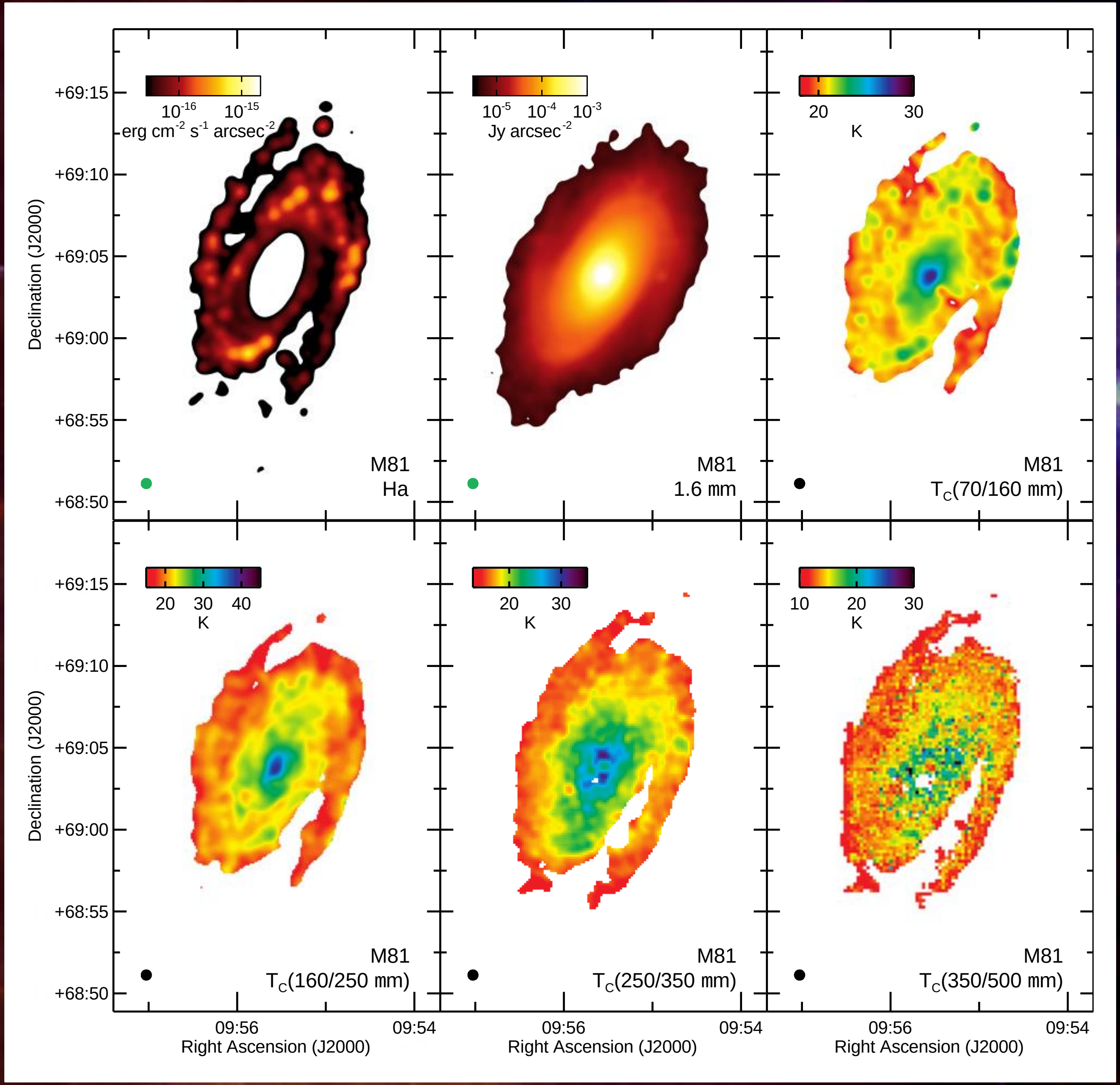


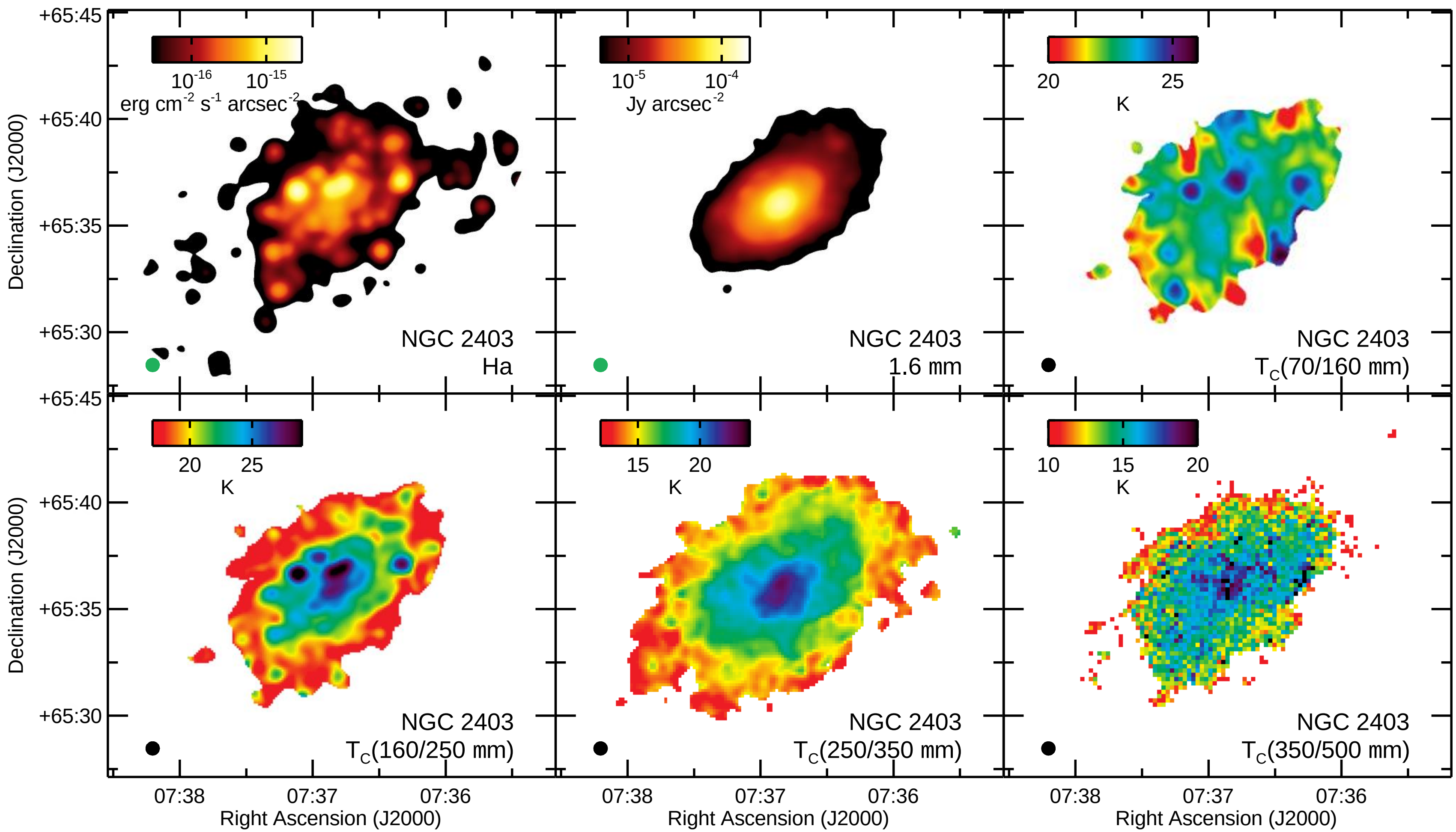
M16 (Hill et al., 2012, A&A, 542, A114)



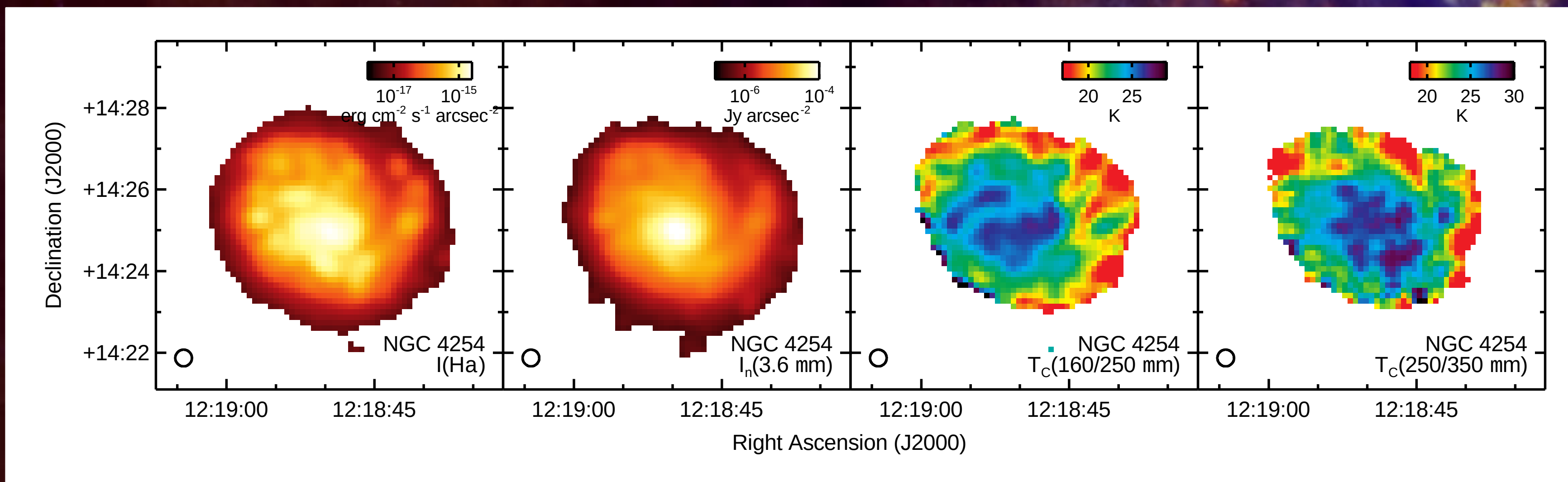
M33 (Boquien et al., 2011, A&A, 142, 4)



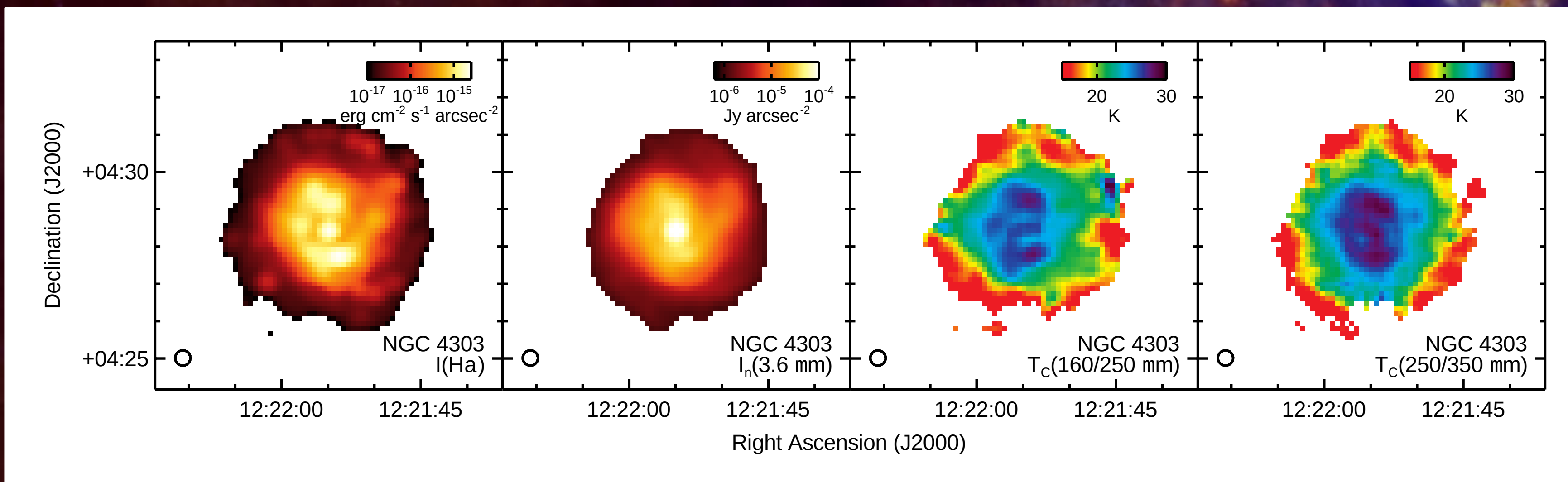
M81 (Bendo et al., 2012, MNRAS, 419, 1833)



NGC 2403 (Bendo et al., 2012, MNRAS, 419, 1833)



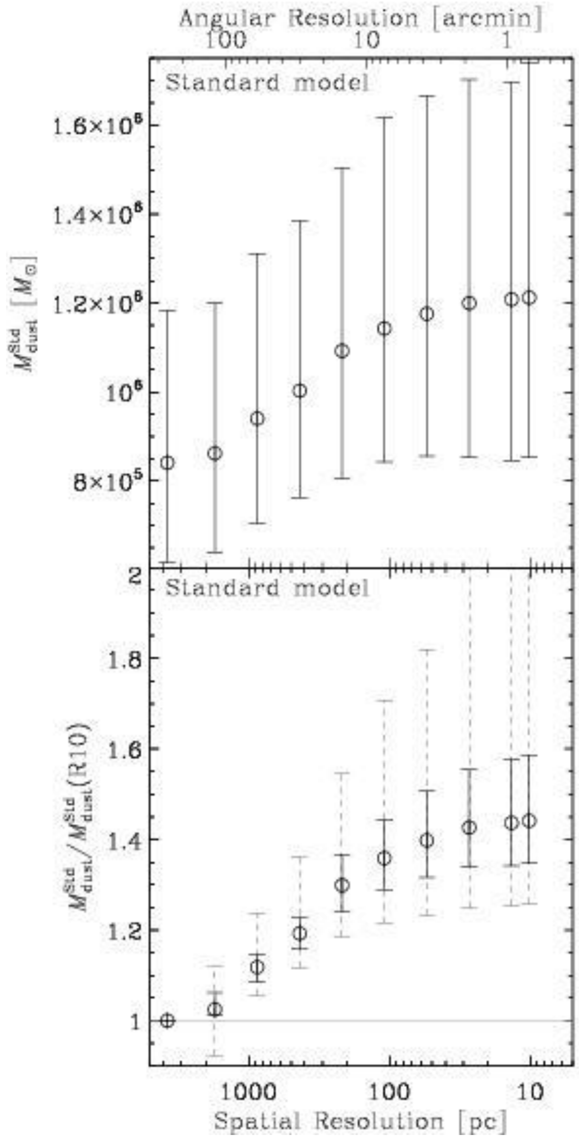
NGC 4254 (Bendo et al., 2015, MNRAS, 448, 135)



NGC 4303 (Bendo et al., 2015, MNRAS, 448, 135)

When the SEDs for the warmer dust around star forming regions and the colder diffuse dust are not separated properly, models fit to the SED could yield inaccurate results, including:

- Higher temperatures
- Lower dust emissivity coefficients (β)
- Low dust masses
- High gas-to-dust mass ratios



Large Magellanic Cloud
(Galliano et al. 2010, A&A, 536, A88)

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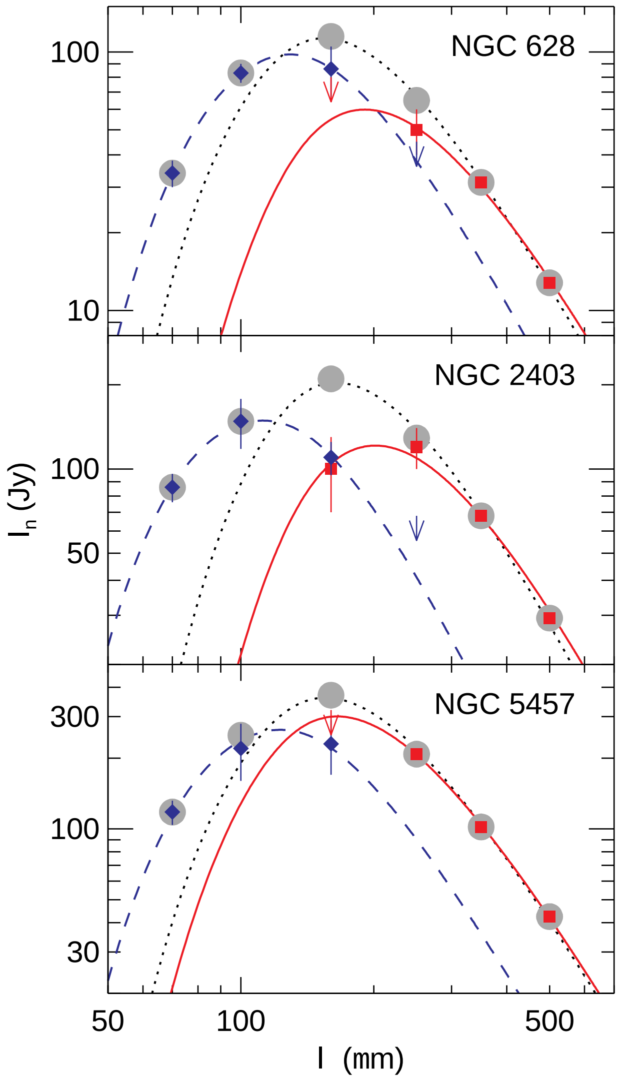
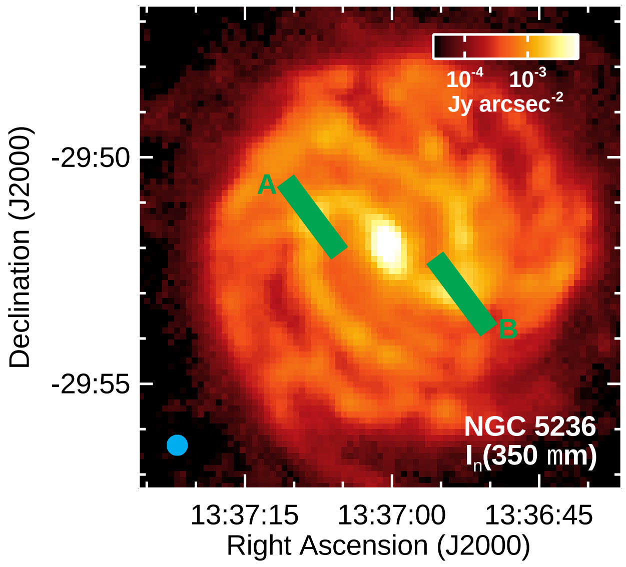


(Bendo et al., 2015, MNRAS, 448, 135)

Colour temperature analyses have also hinted at the possibilities of radiative transfer effects related to spiral density waves (but only in very nearby grand design spiral galaxies).

If similar effects related to shocks are present in cluster galaxies, they may be impossible to see with Spitzer and Herschel.



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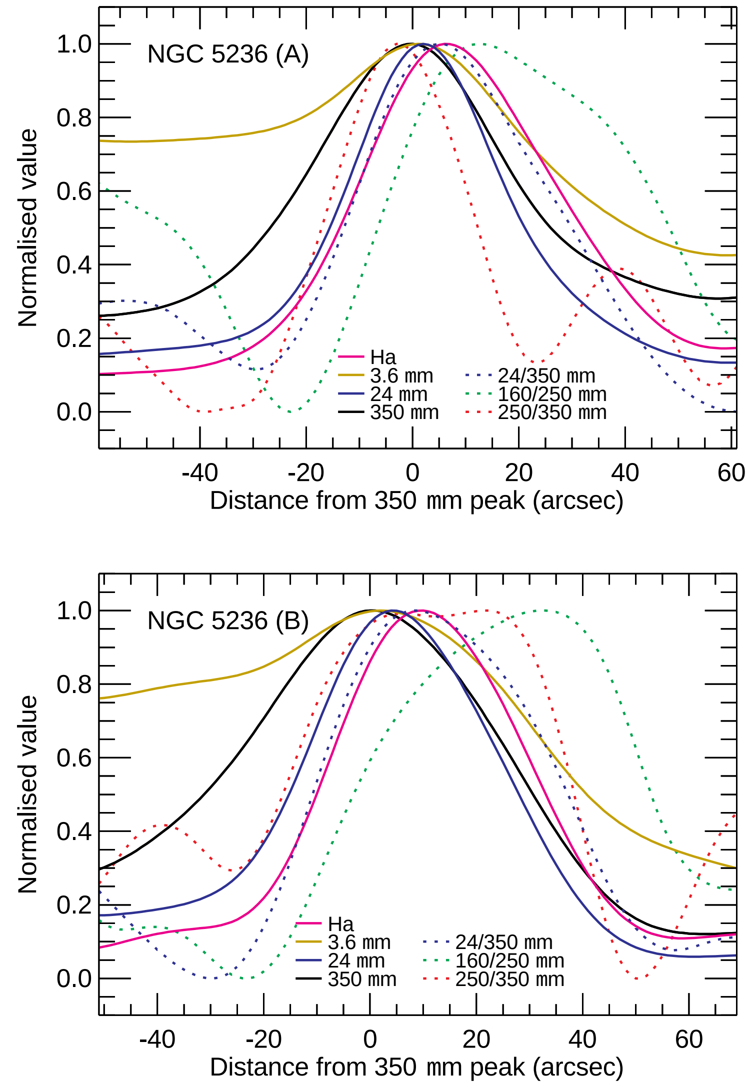


(Bendo et al., 2015, MNRAS, 448, 135)

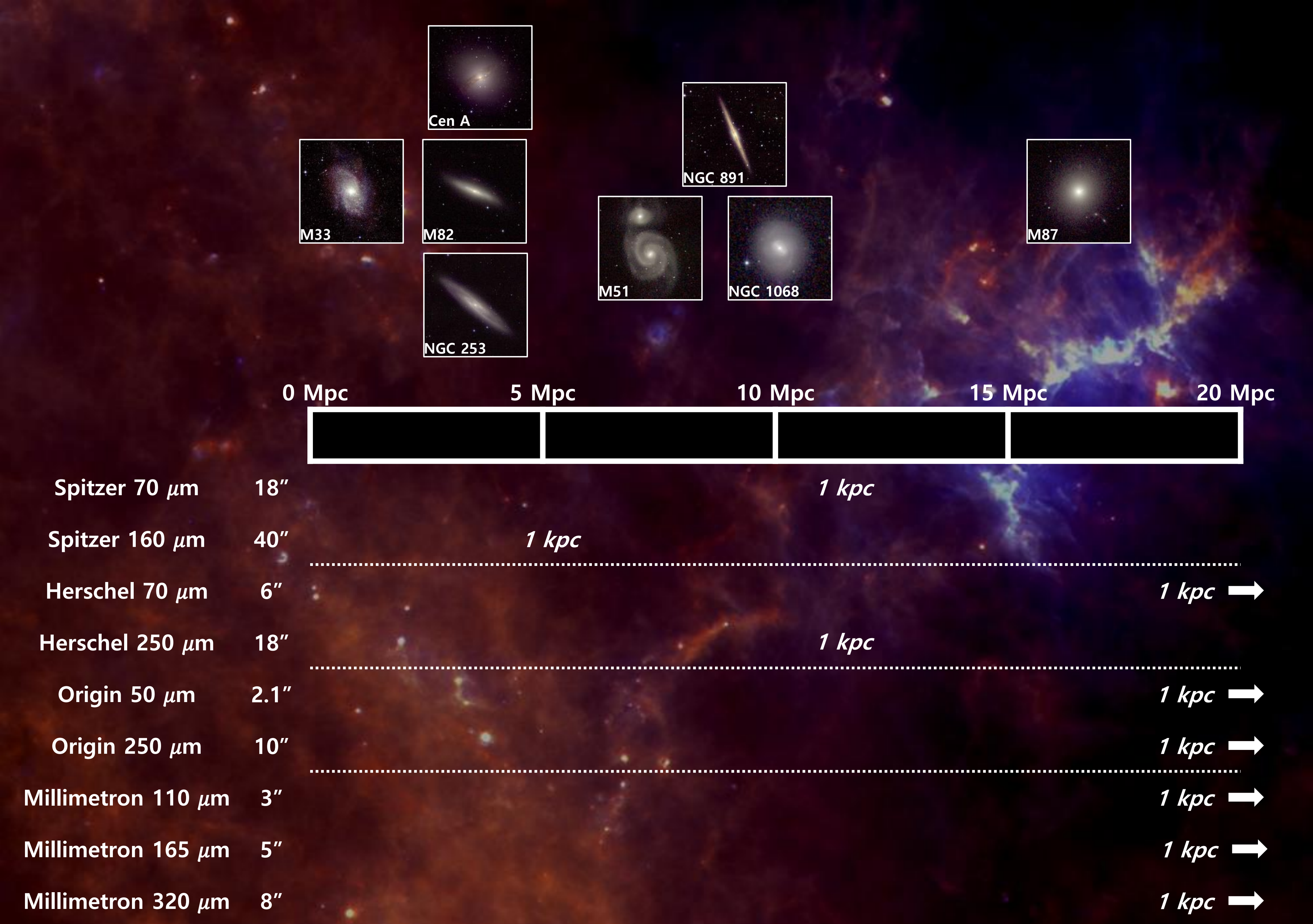
Advances with Millimetron

The improved resolution of Millimetron allows for studying dust in smaller structures than possible before. This will include:

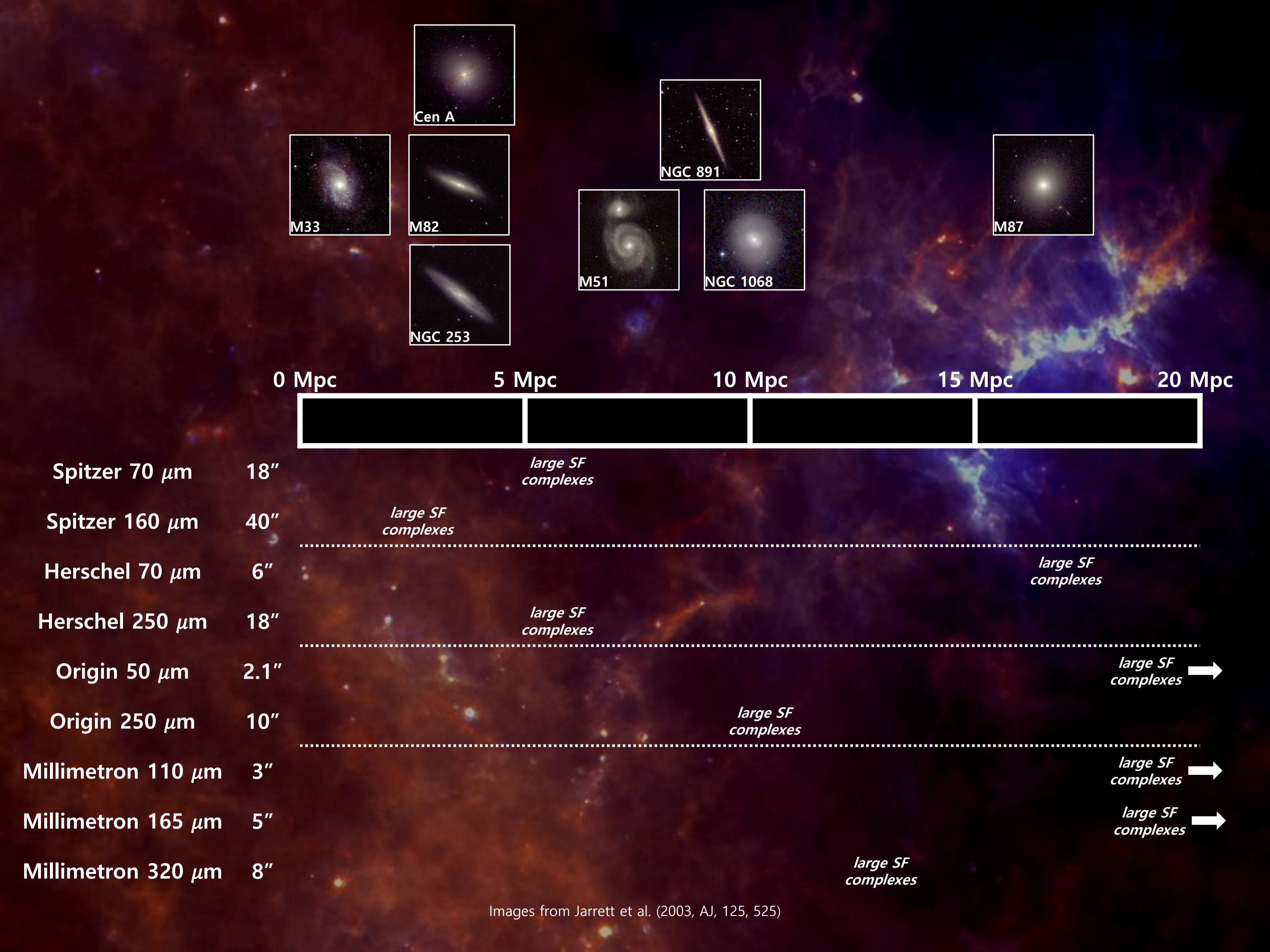
- Resolving 100 pc structures (the size of typical OB associations)
  - At 14 Mpc for wavelengths of 60 μm (Band 1 of SACS)
  - At 7 Mpc for wavelengths of 110 μm (Band 2 of SACS)
  - At 4 Mpc for wavelengths of 165 μm (Band 3 of SACS)

- Resolving 500 pc structures (the scale at which colour variations from spiral density waves are visible) up to 13 Mpc at 320 μm (Band 4 of SACS)

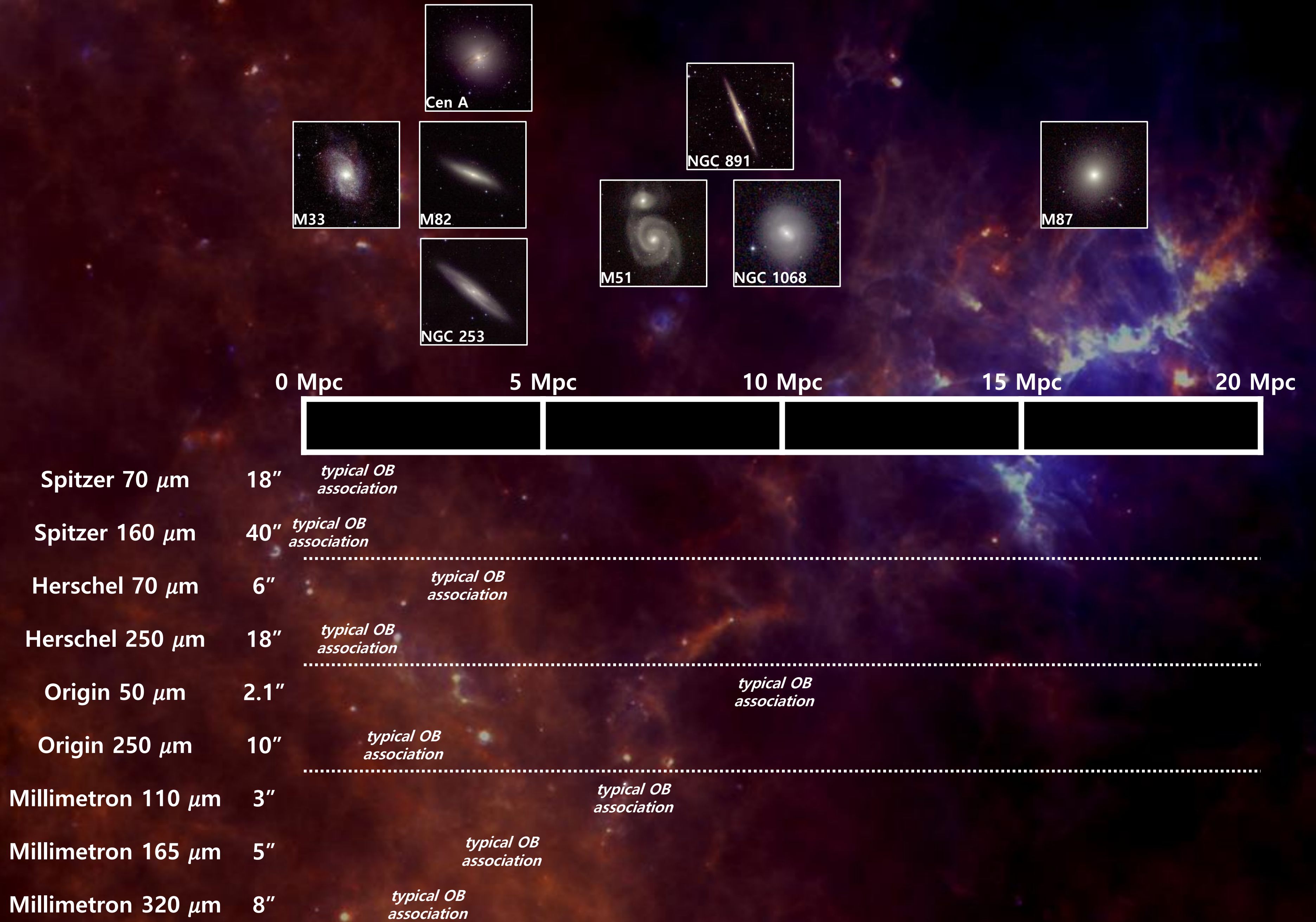
- Resolving 1 kpc structures out to ~25 Mpc at 320 μm (Band 4 of SACS)



Images from Jarrett et al. (2003, AJ, 125, 525)



Cen A
NGC 891
M33
M82
M87
M51
NGC 1068
NGC 253
0 Mpc
5 Mpc
10 Mpc
15 Mpc
20 Mpc
Spitzer 70 μm 18″
large SF complexes
Spitzer 160 μm 40″
large SF complexes
Herschel 70 μm 6″
large SF complexes
Herschel 250 μm 18″
large SF complexes
Origin 50 μm 2.1″
large SF complexes
Origin 250 μm 10″
large SF complexes
Millimetron 110 μm 3″
large SF complexes
Millimetron 165 μm 5″
large SF complexes
Millimetron 320 μm 8″
large SF complexes
Images from Jarrett et al. (2003, AJ, 125, 525)



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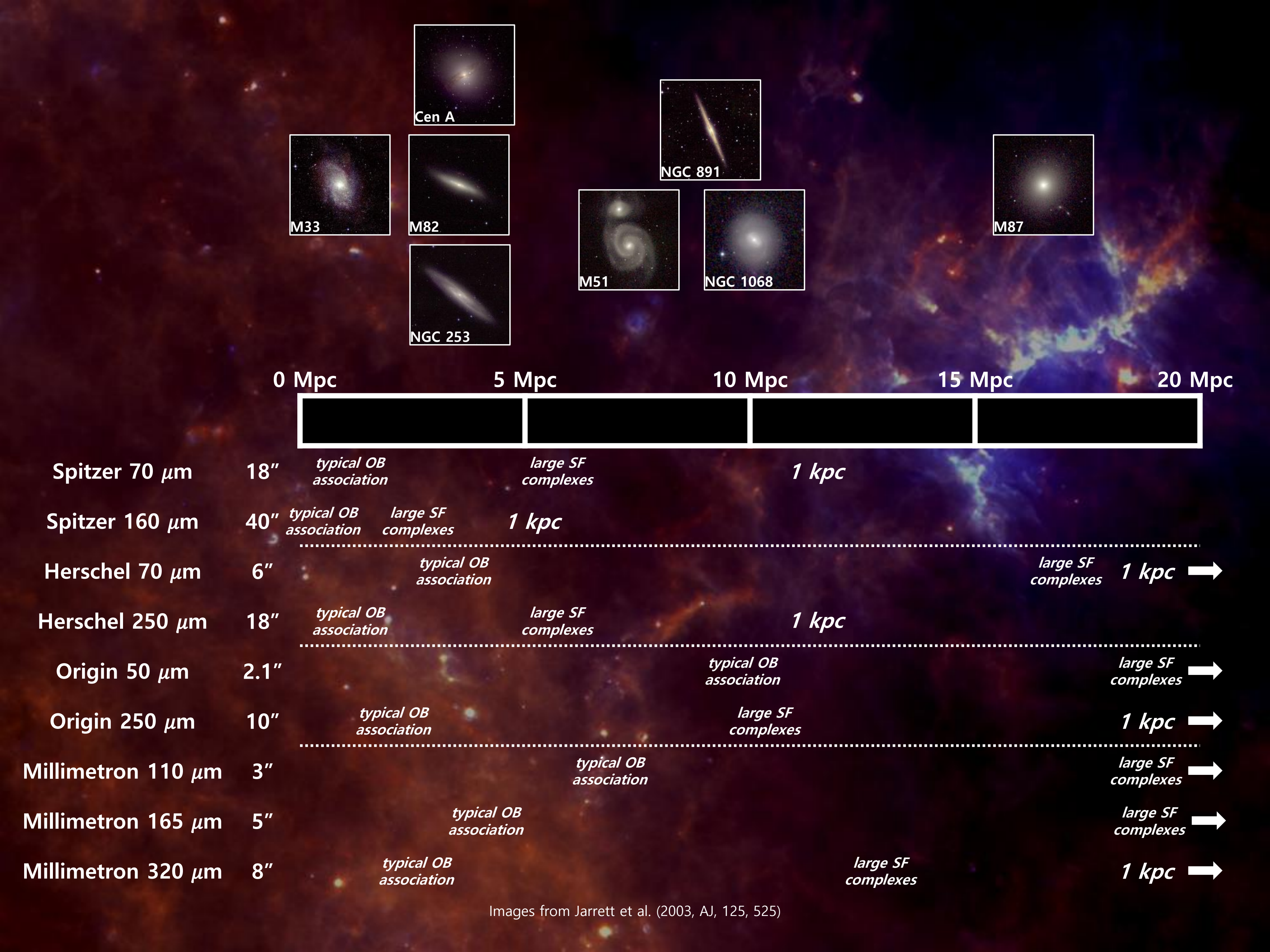

Cen A
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15 Mpc
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Spitzer 70 μm
18″
typical OB association
large SF complexes
1 kpc
Spitzer 160 μm
40″
typical OB association
large SF complexes
1 kpc
Herschel 70 μm
6″
typical OB association
large SF complexes
1 kpc
Herschel 250 μm
18″
typical OB association
large SF complexes
1 kpc
Origin 50 μm
2.1″
typical OB association
large SF complexes
Origin 250 μm
10″
typical OB association
large SF complexes
1 kpc
Millimetron 110 μm
3″
typical OB association
large SF complexes
Millimetron 165 μm
5″
typical OB association
large SF complexes
Millimetron 320 μm
8″
typical OB association
large SF complexes
1 kpc
Images from Jarrett et al. (2003, AJ, 125, 525)

Science Questions

- What is the structure of dust around star forming regions in other galaxies?
- What are the separate SEDs of star forming complexes and diffuse dust?
- How can radiative transfer models be improved by observing dust structures on smaller spatial scales?
- How exactly does far-infrared emission relate to star formation?
- How does radiative transfer work for spiral density waves?
- Does ram-pressure stripping affect the radiative transfer in spiral galaxies?