in summary...

dust temp decreases with increasing atomic gas

Total dust mass 3×10^{7} Msolar

Dust mass correlated with molecular gas & SFR

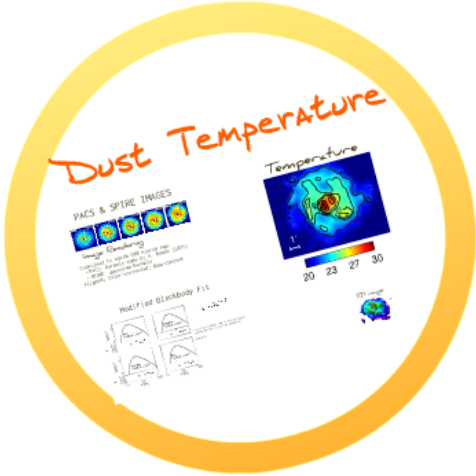
GDR ~100

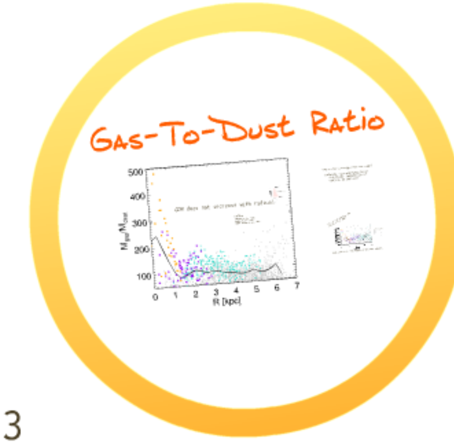
Dust mass peaks offset from temp

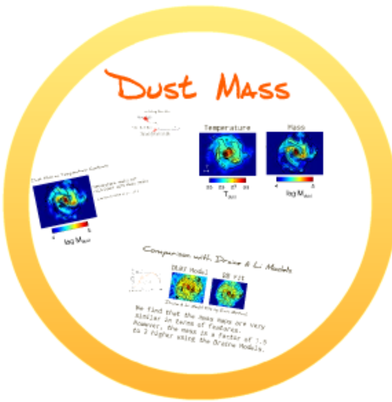
Two temperature peaks in nucleus

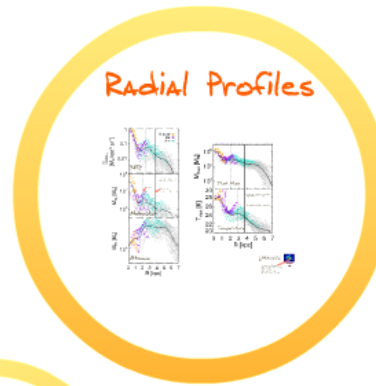
Resolving the Dust in M83

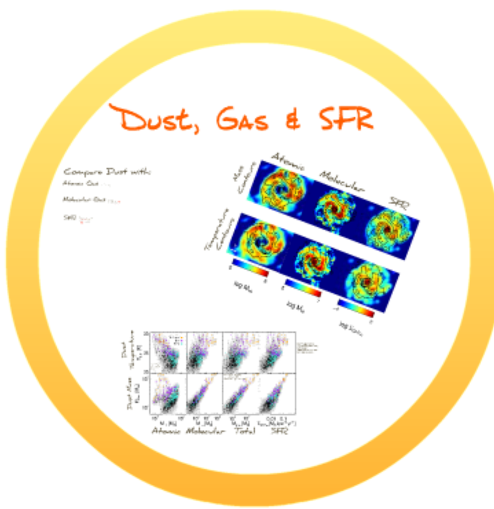
Kelly Foyle
McMaster University
C. Wilson, G. Bendo & E. Mentuch

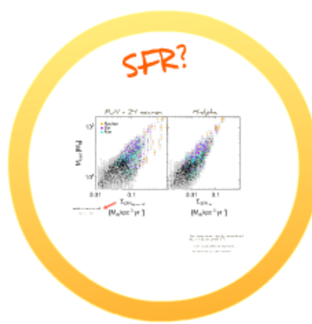


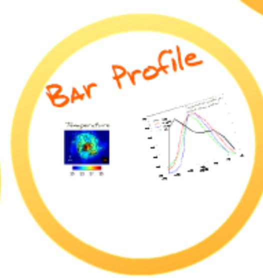












Resolving the Dust in M83

Kelly Foyle
McMaster University
C. Wilson, G. Bendo & E. Mentuch

Resolving the Dust in M83

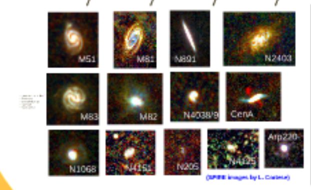
Kelly Foyle

McMaster University

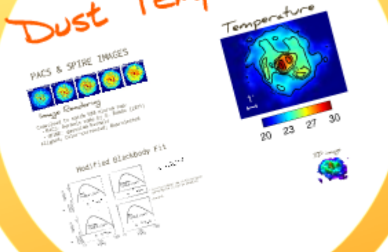
C. Wilson, G. Bendo & E. Mentuch

VNGS

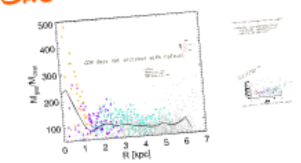
Very Nearby Galaxy Survey



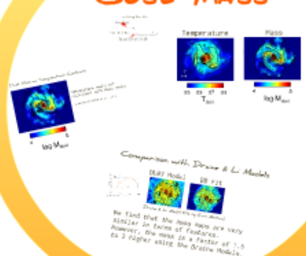
Dust Temperature



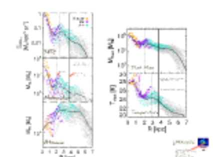
Gas-To-Dust Ratio



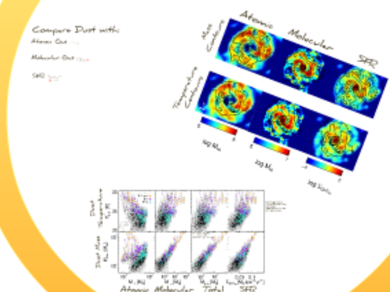
Dust Mass



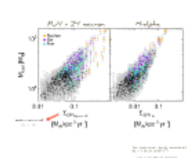
Radial Profiles



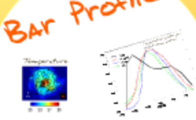
Dust, Gas & SFR



SFR?



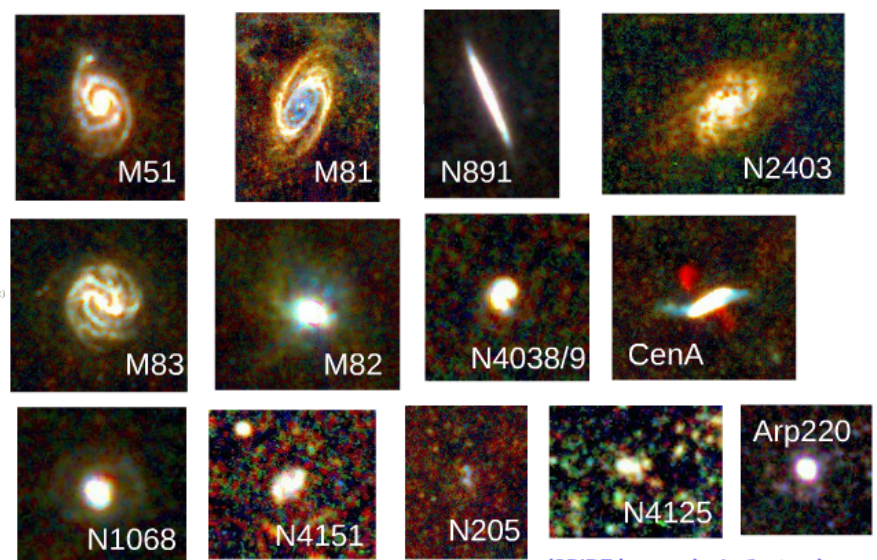
Bar Profile



VNGS

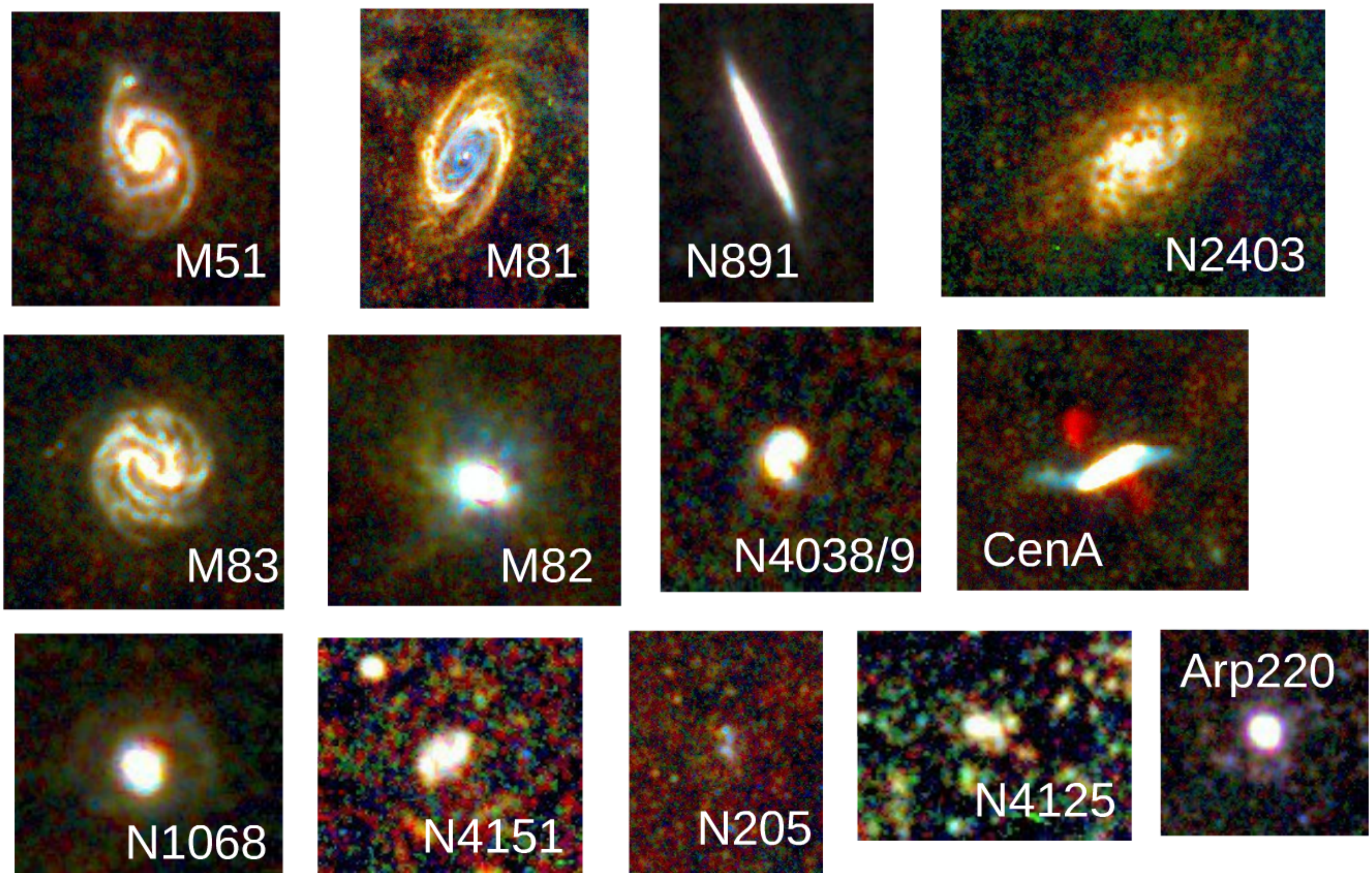
Very Nearby Galaxy Survey

- nearby (4.5 Mpc)
- face-on
- grand-design
- barred
- starburst



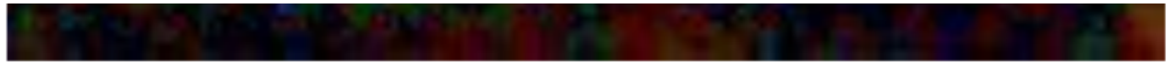
(SPIRE images by L. Cortese)

Very Nearby Galaxy Survey

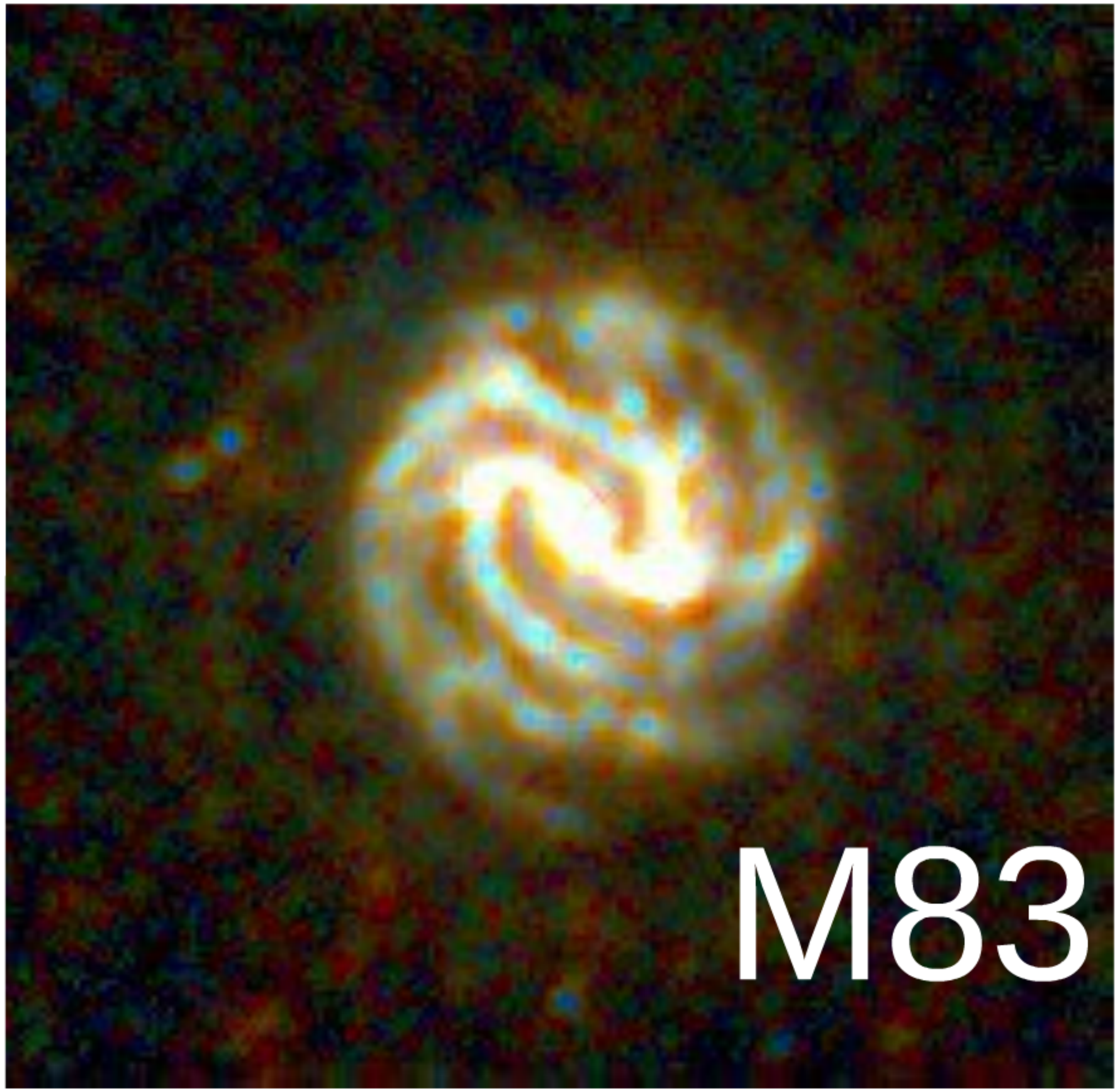


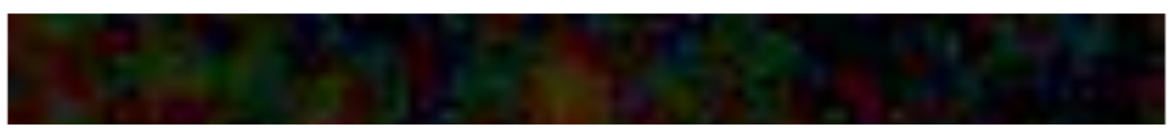
arby (4.5 Mpc)
ce-on
and-design
rred
arburst

(SPIRE images by L. Cortese)



- nearby (4.5 Mpc)
- face-on
- grand-design
- barred
- starburst

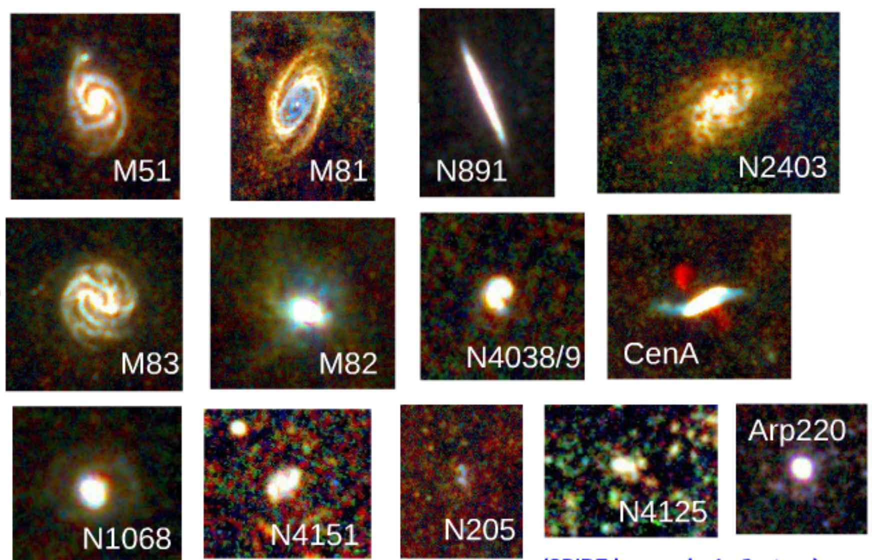




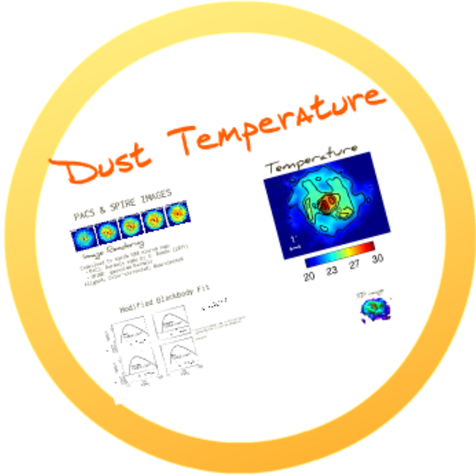
VNGS

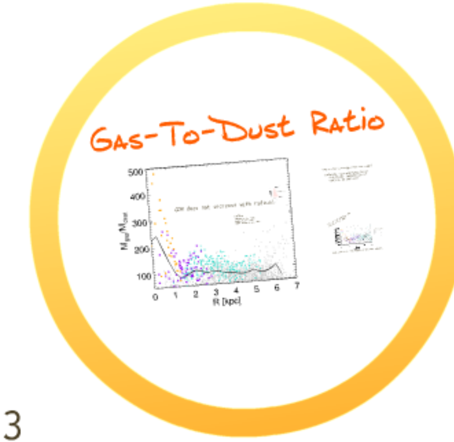
Very Nearby Galaxy Survey

- nearby (4.5 Mpc)
- face-on
- grand-design
- barred
- starburst



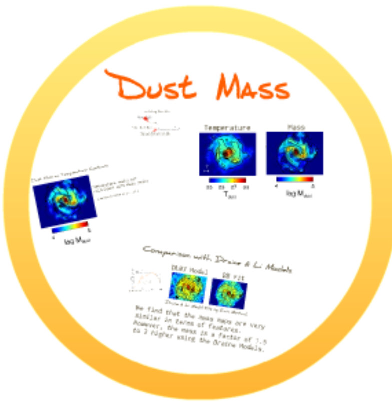
(SPIRE images by L. Cortese)

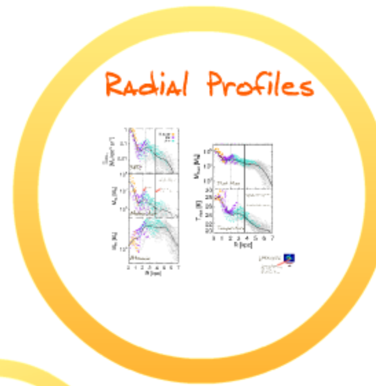


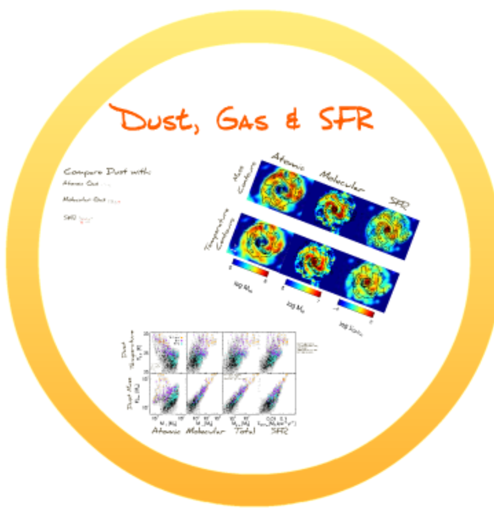


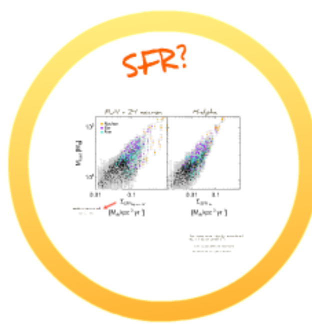
Resolving the Dust in M83

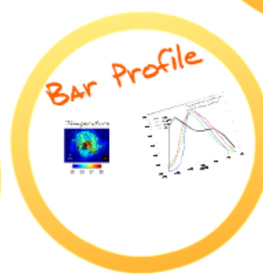
Kelly Foyle
McMaster University
C. Wilson, G. Bendo & E. Mentuch











Dust Temperature

PACS & SPIRE IMAGES

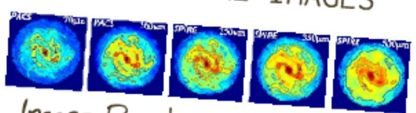
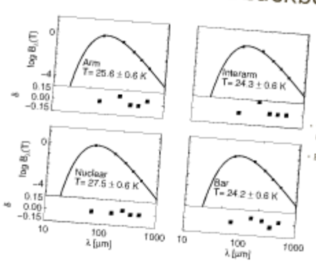


Image Rendering

Convolved to match 500 micron map:
- PACS: kernels made by G. Bendo (2011)
- SPIRE: gaussian kernels

Aligned; Color-corrected; Deprojected

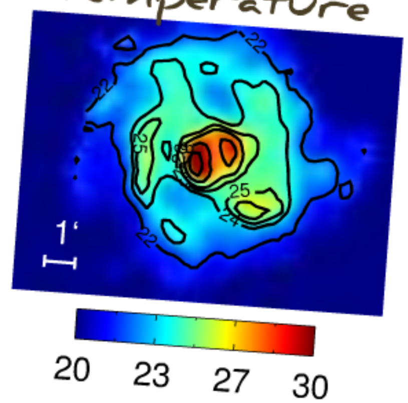
Modified Blackbody Fit



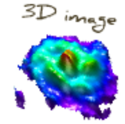
$$I_\lambda = B_\lambda \lambda^{-\beta}$$

- fitting without the 70 micron point overpredicts 70 micron emission
- Beta=2

Temperature



3D image



PACS & SPIRE IMAGES

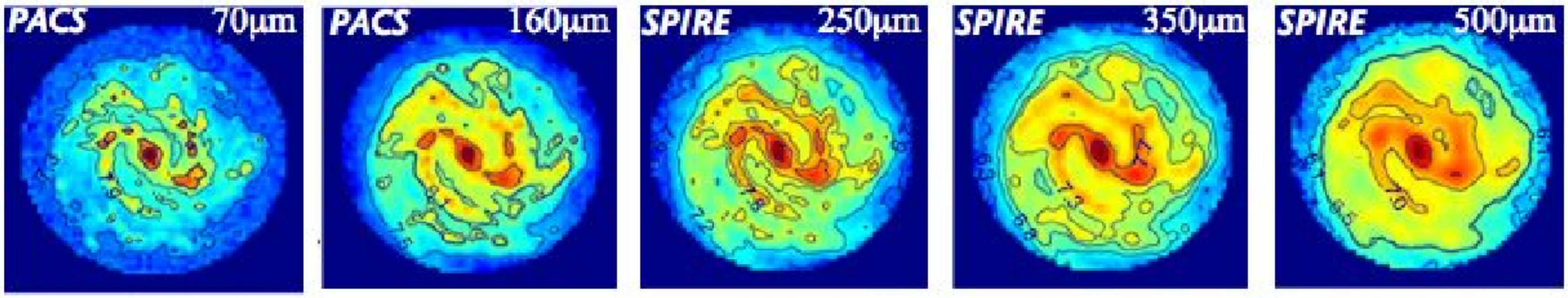


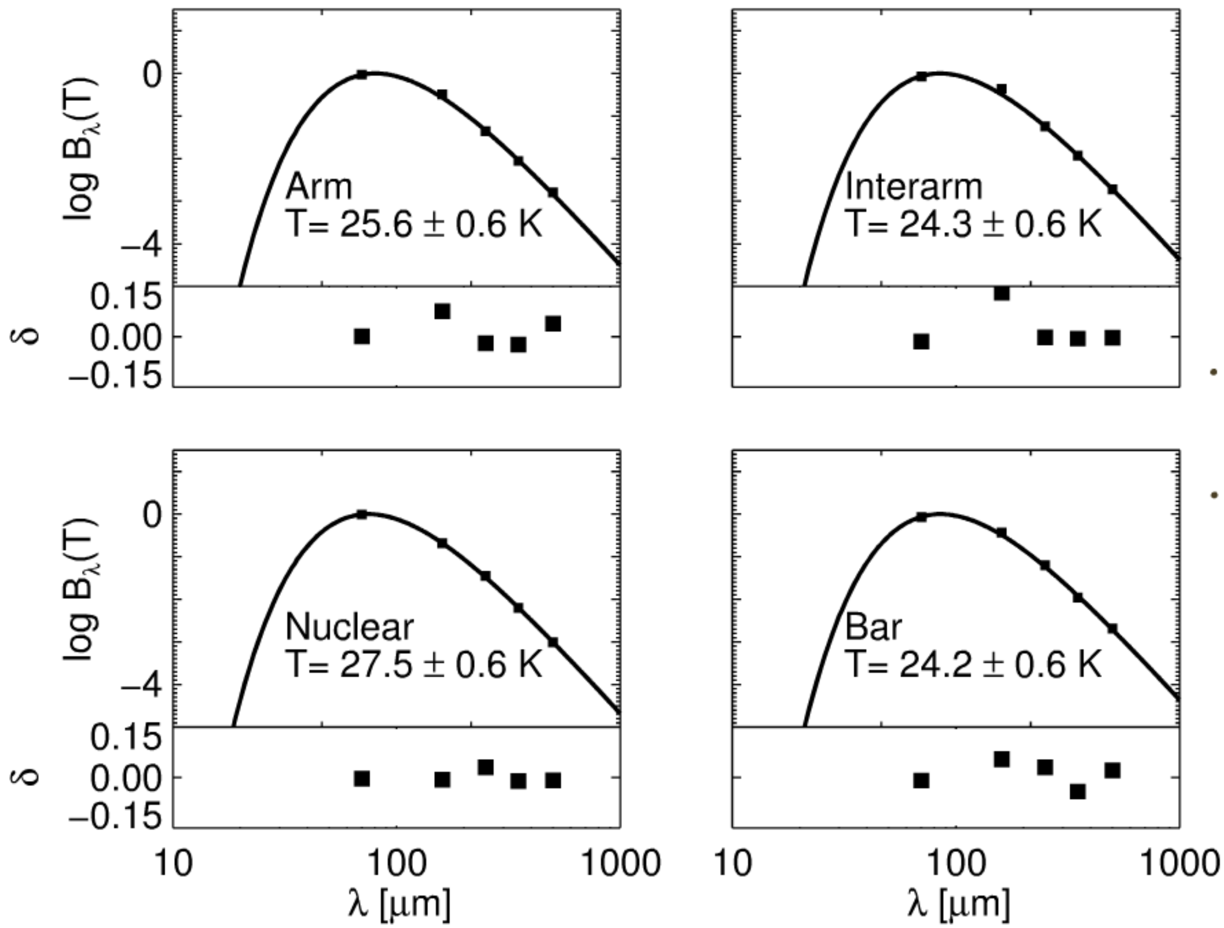
Image Rendering

Convolved to match 500 micron map:

- PACS: kernels made by G. Bendo (2011)
- SPIRE: gaussian kernels

Aligned; Color-corrected; Deprojected

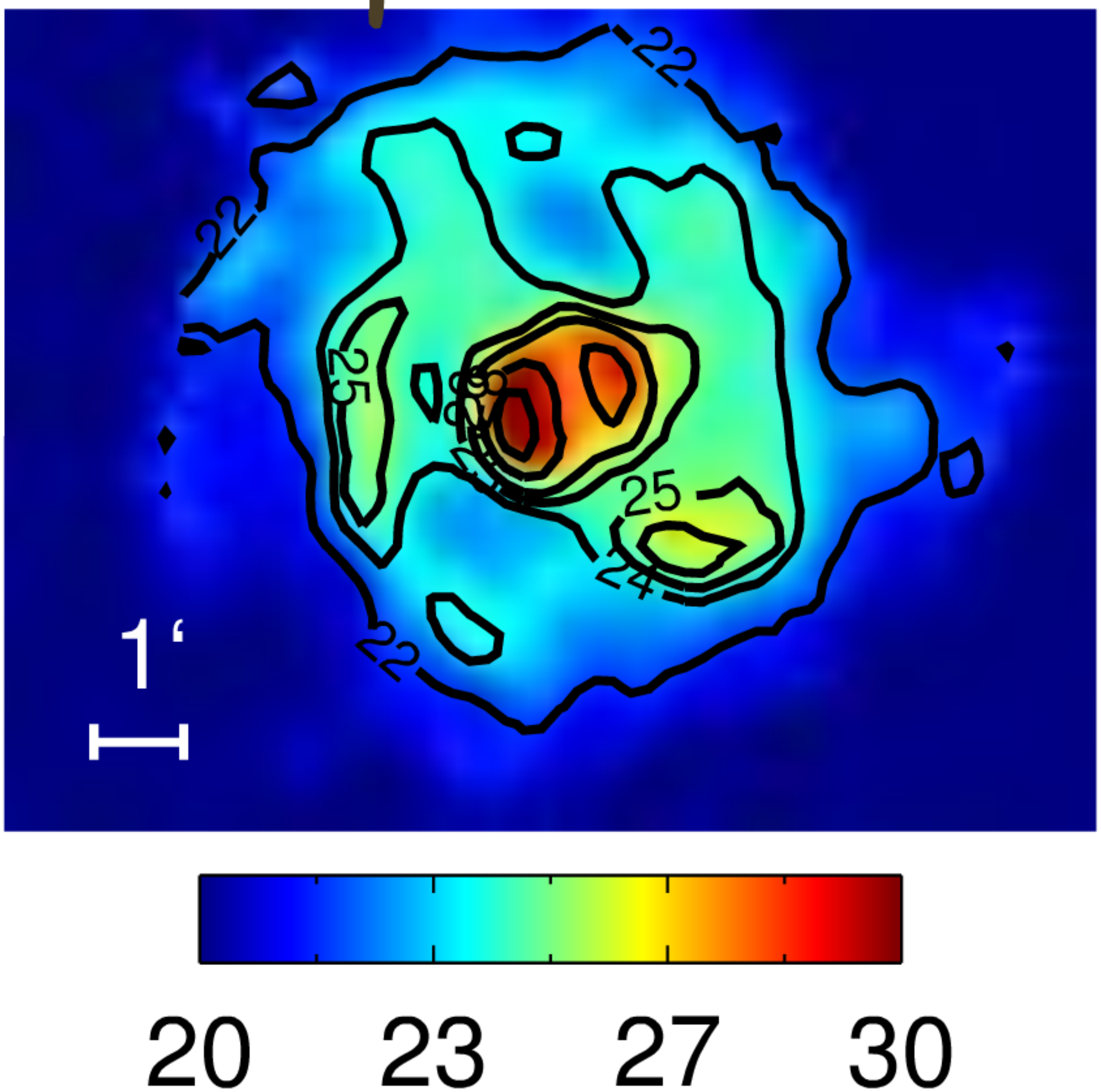
Modified Blackbody Fit



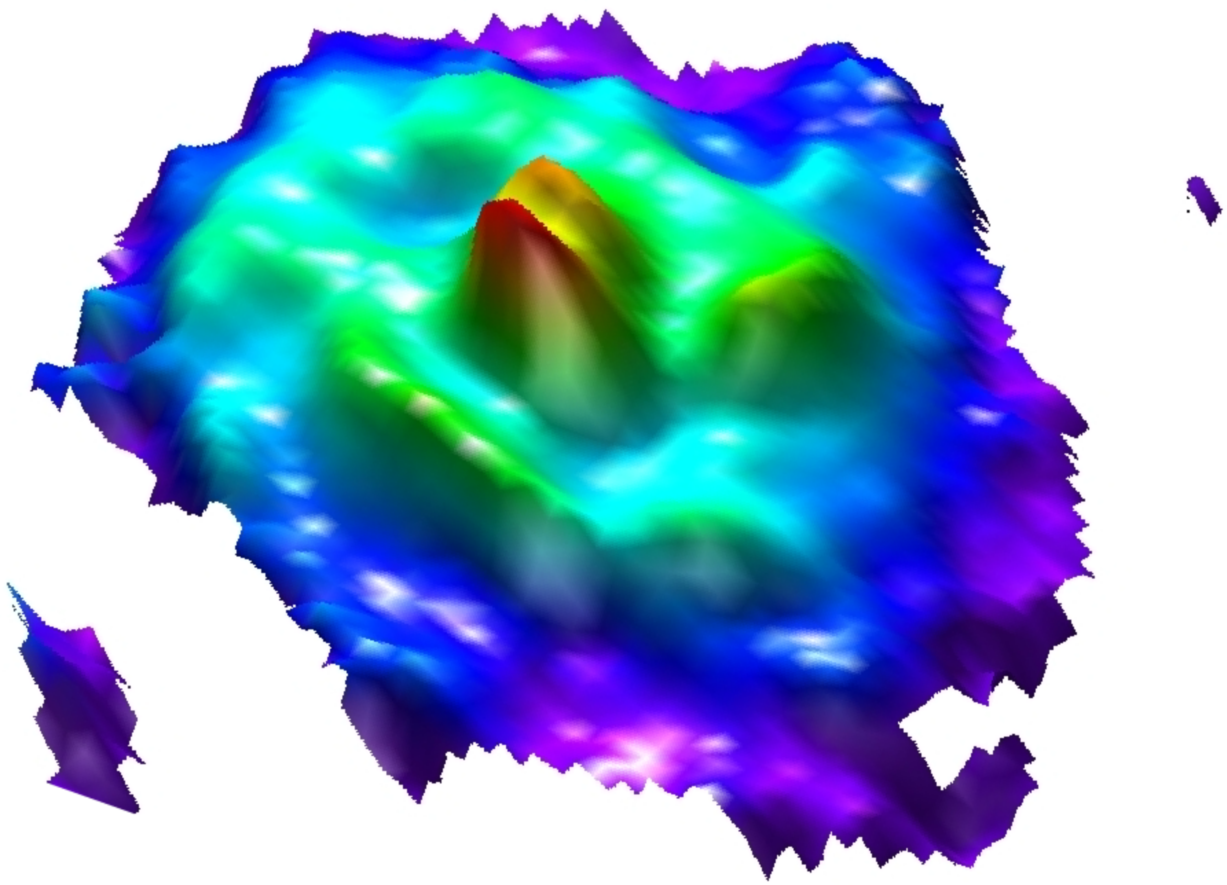
$$I_\lambda = B_\lambda \lambda^{-\beta}$$

- fitting without the 70 micron point overpredicts 70 micron emission
- Beta=2

Temperature



3D image



Dust Temperature

PACS & SPIRE IMAGES

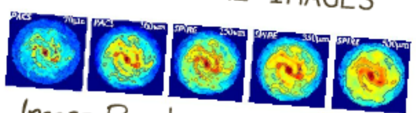
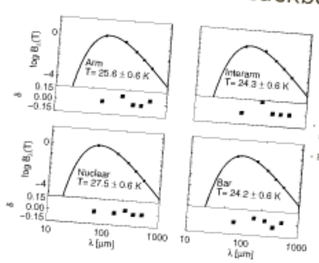


Image Rendering

Convolved to match 500 micron map:
- PACS: kernels made by G. Bendo (2011)
- SPIRE: gaussian kernels

Aligned; Color-corrected; Deprojected

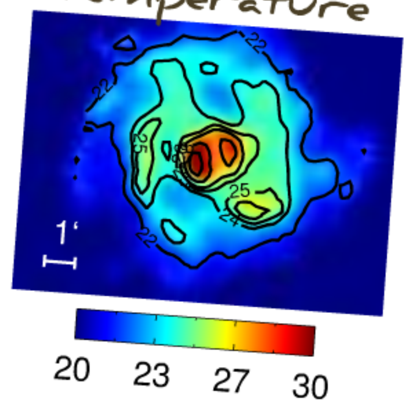
Modified Blackbody Fit



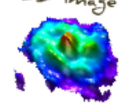
$$I_\lambda = B_\lambda \lambda^{-\beta}$$

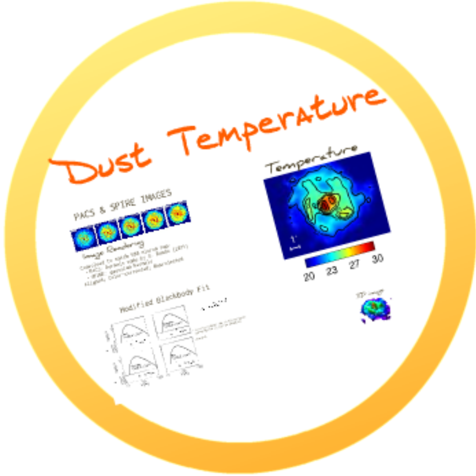
- Fitting without the 70 micron point overpredicts 70 micron emission
- Beta=2

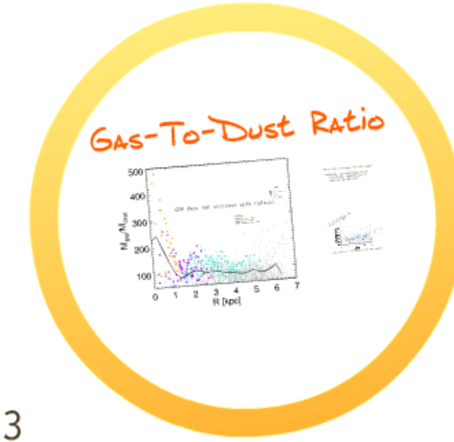
Temperature



3D image

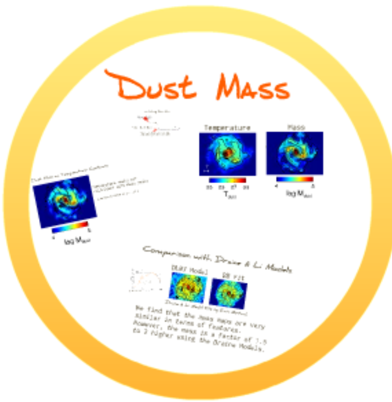


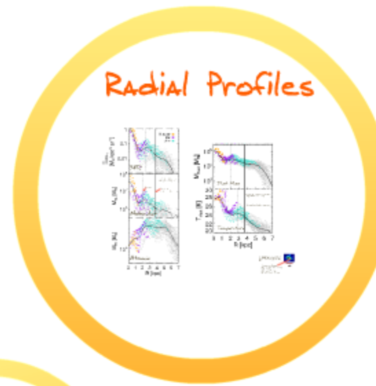


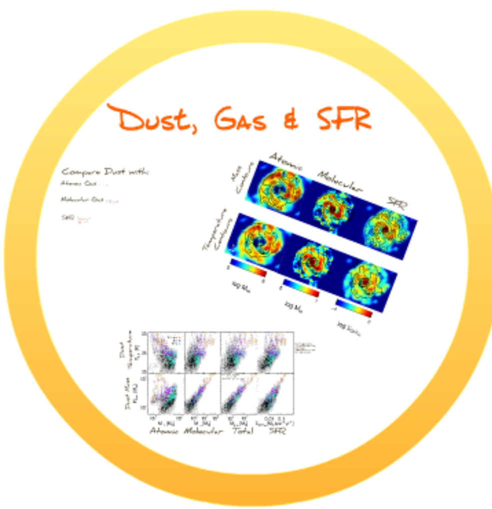


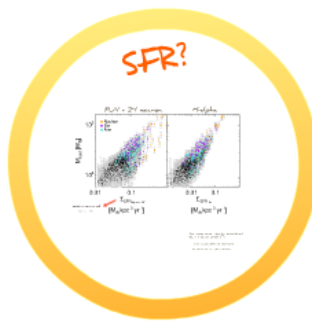
Resolving the Dust in M83

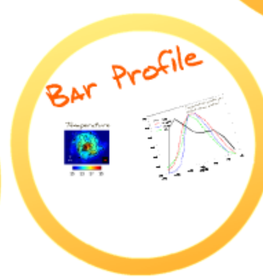
Kelly Foyle
McMaster University
C. Wilson, G. Bendo & E. Mentuch









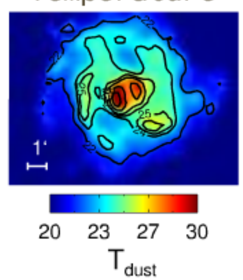


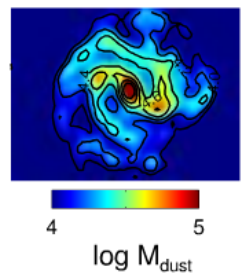
Dust Mass

Calculating Dust Mass

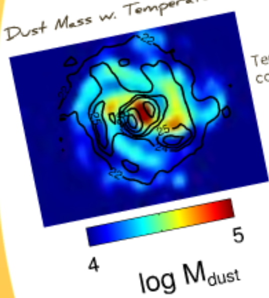
$$M_d = \frac{D^2 S_\nu}{\kappa_\nu B(\nu,T)}$$

Total Dust Mass: $M_d = 3.0 \pm 0.8 \times 10^7\ M_\odot$





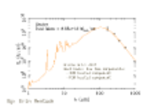
Dust Mass w. Temperature Contours

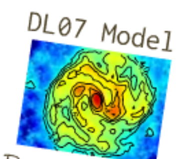


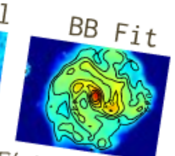
Temperature peaks not coincident with mass peaks

also seen by Smith et al. (2010)

Comparison with Draine & Li Models







Draine & Li Model Fits by Erin Mentuch

We find that the mass maps are very similar in terms of features. However, the mass is a factor of 1.5 to 2 higher using the Draine Models.

Calculating Dust Mass

$$M_d = \frac{D^2 S_\nu}{\kappa_\nu B(\nu,T)}$$

dust emissivity $\kappa = 2.92 \times 10^5 \left(\frac{\lambda}{\mu m}\right)^{-2} cm^2 g^{-1}$
(Li & Draine 2001)

Total Dust Mass: $M_d = 3.0 \pm 0.8 \times 10^7 \ M_\odot$

This is twice what previous estimates have found which relied on shorter wavelengths.
(Devereux & Young 1990)

$$\kappa = 2.92 \times 10^5 \, (\frac{\lambda}{\mu m})^{-2} \mathrm{cm}^2 \mathrm{g}^{-1}$$

y

01)

Calculating Dust Mass

$$M_d = \frac{D^2 S_\nu}{\kappa_\nu B(\nu, T)}$$

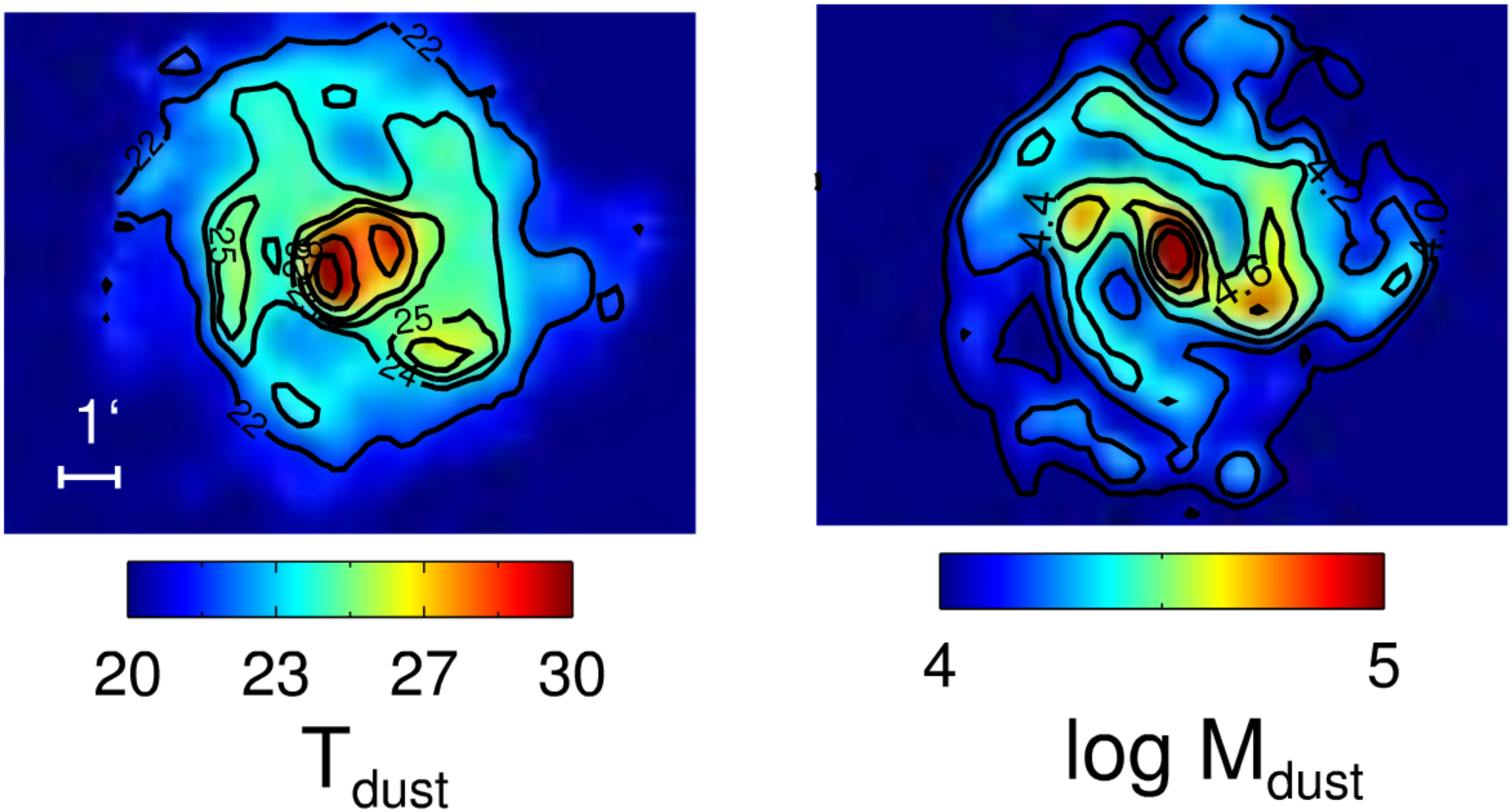
dust emissivity $\kappa = 2.92 \times 10^5 \, (\frac{\lambda}{\mu m})^{-2} \mathrm{cm^2 g^{-1}}$
(Li & Draine 2001)

Total Dust Mass: $M_d = 3.0 \pm 0.8 \times 10^7 \, M_\odot$

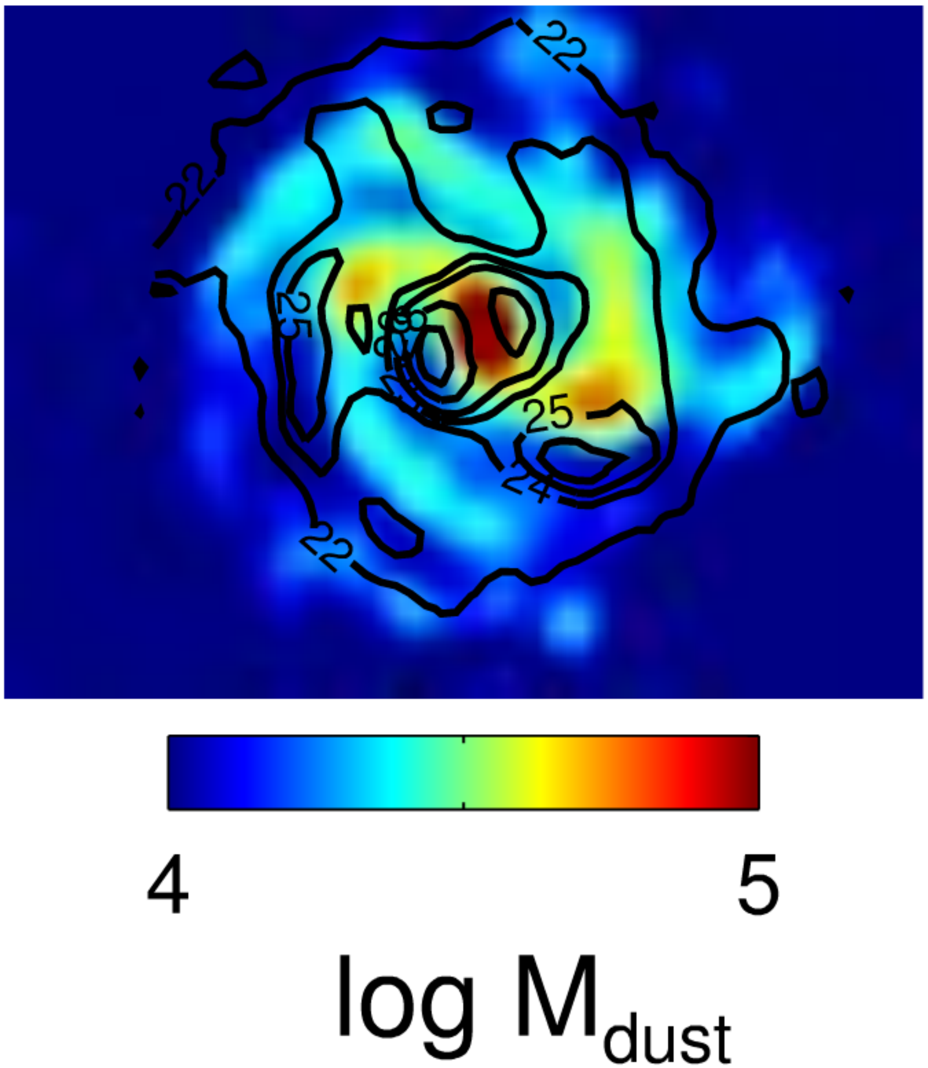
This is twice what previous estimates have found which relied on shorter wavelengths.
(Devereux & Young 1990)

Temperature

Mass



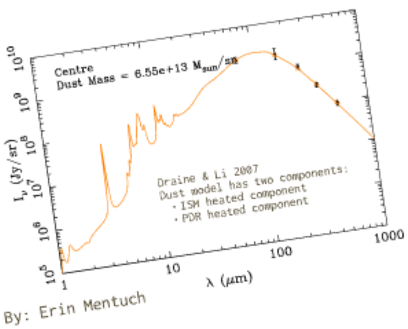
Dust Mass w. Temperature Contours



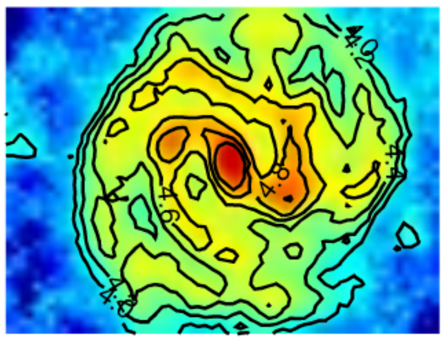
Temperature peaks not coincident with mass peaks

also seen by Smith et al. (2010)

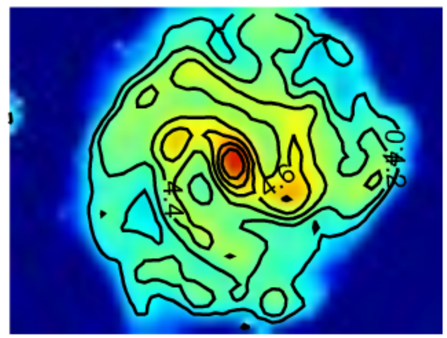
Comparison with Draine & Li Models



DL07 Model

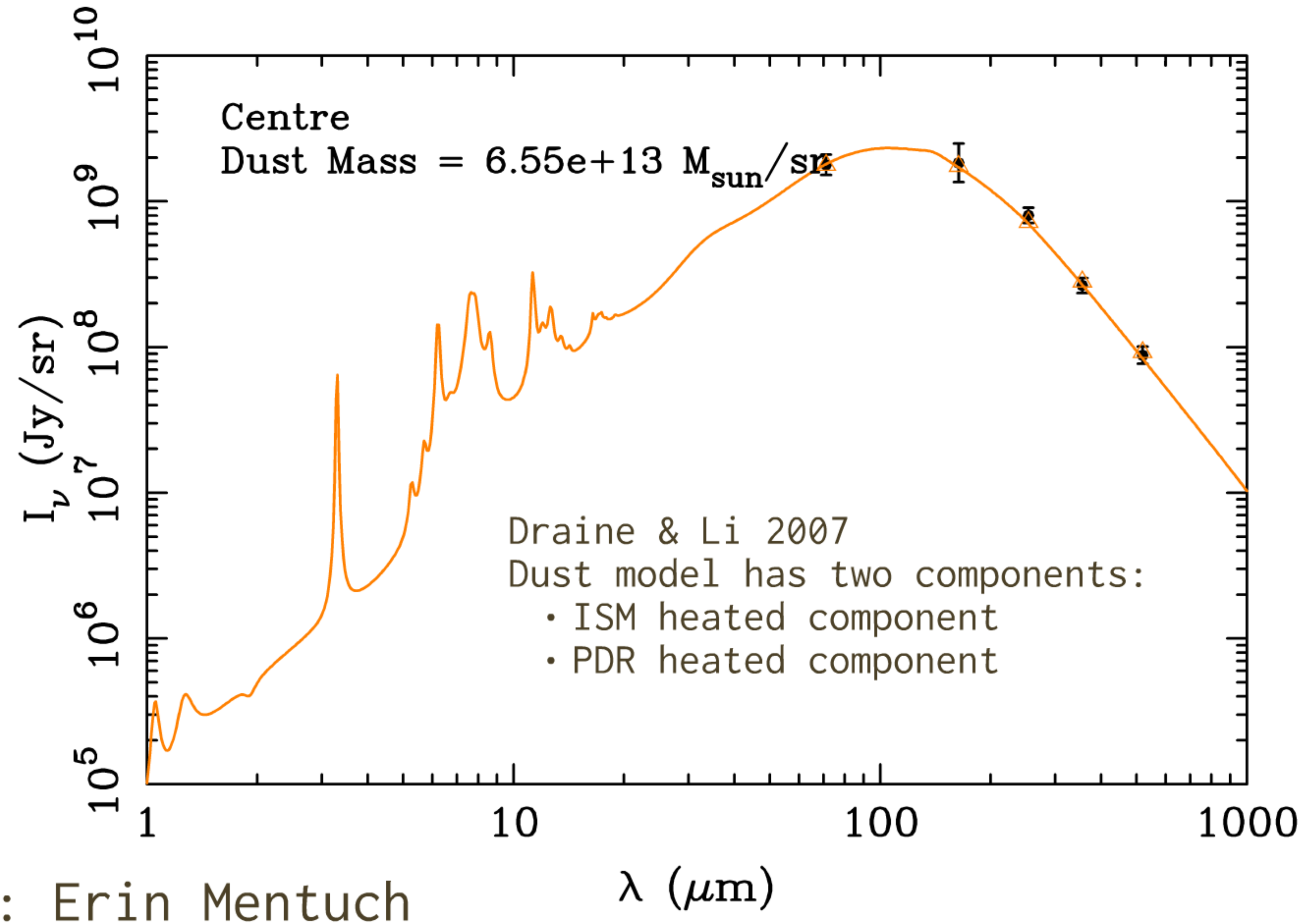


BB Fit



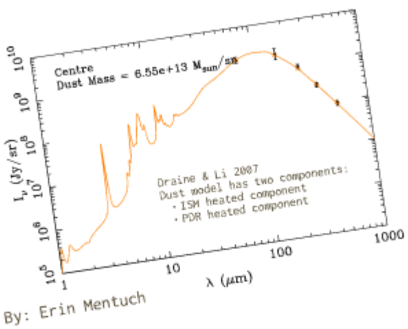
Draine & Li Model Fits by Erin Mentuch

We find that the mass maps are very similar in terms of features. However, the mass is a factor of 1.5 to 2 higher using the Draine Models.

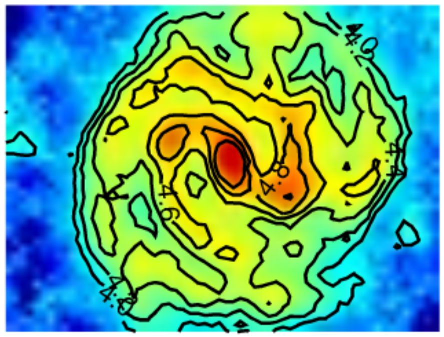


By: Erin Mentuch

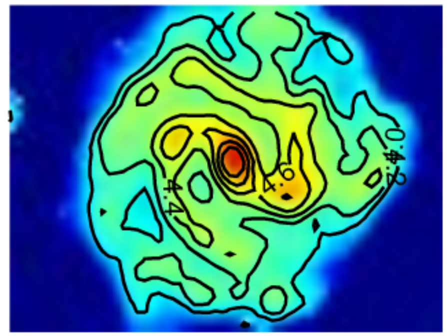
Comparison with Draine & Li Models



DL07 Model



BB Fit



Draine & Li Model Fits by Erin Mentuch

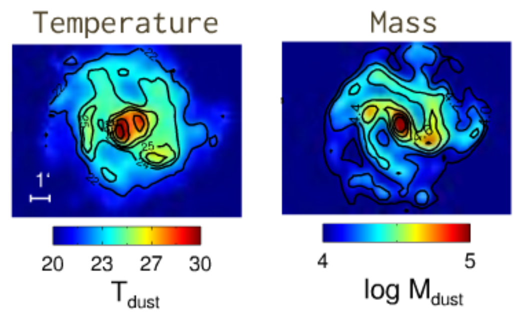
We find that the mass maps are very similar in terms of features. However, the mass is a factor of 1.5 to 2 higher using the Draine Models.

Dust Mass

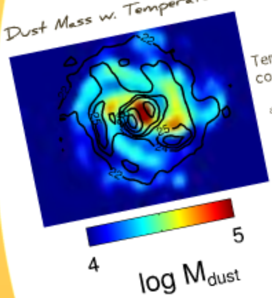
Calculating Dust Mass

Total Dust Mass: $M_d = 3.0 \pm 0.8 \times 10^7\ M_\odot$

This is twice what previous estimates have found which relied on shorter wavelengths.



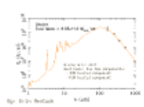
Dust Mass w. Temperature Contours

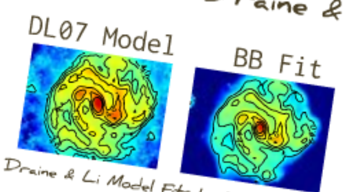


Temperature peaks not coincident with mass peaks

also seen by Smith et al. (2010)

Comparison with Draine & Li Models





Draine & Li Model Fits by Erin Mentuch

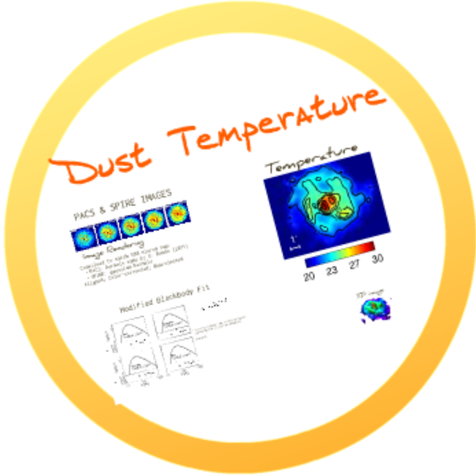
We find that the mass maps are very similar in terms of features. However, the mass is a factor of 1.5 to 2 higher using the Draine Models.

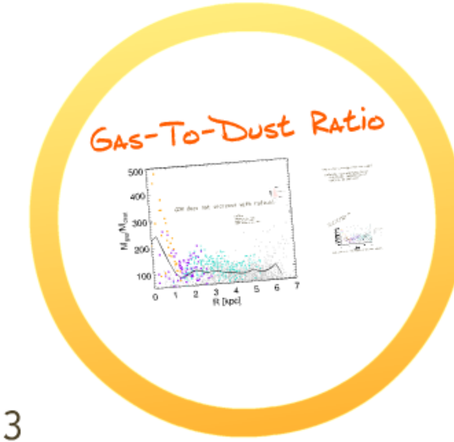
Resolving the Dust in M83

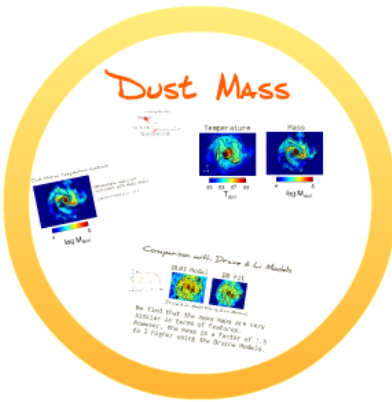
Kelly Foyle

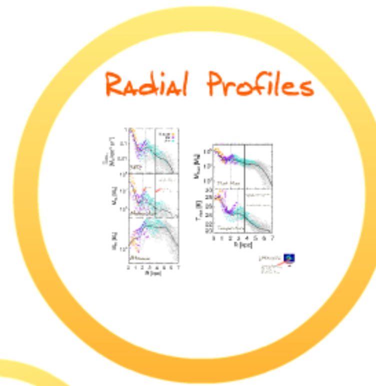
McMaster University

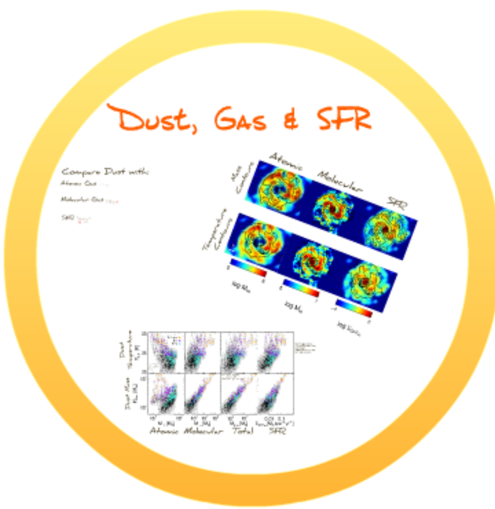
C. Wilson, G. Bendo & E. Mentuch

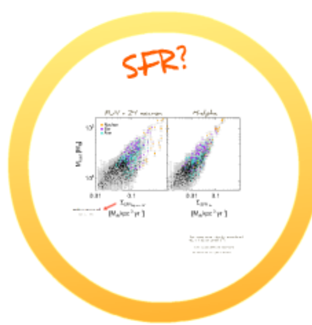


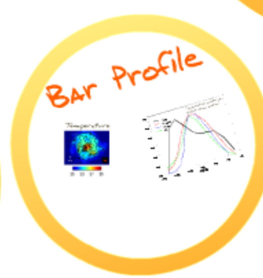












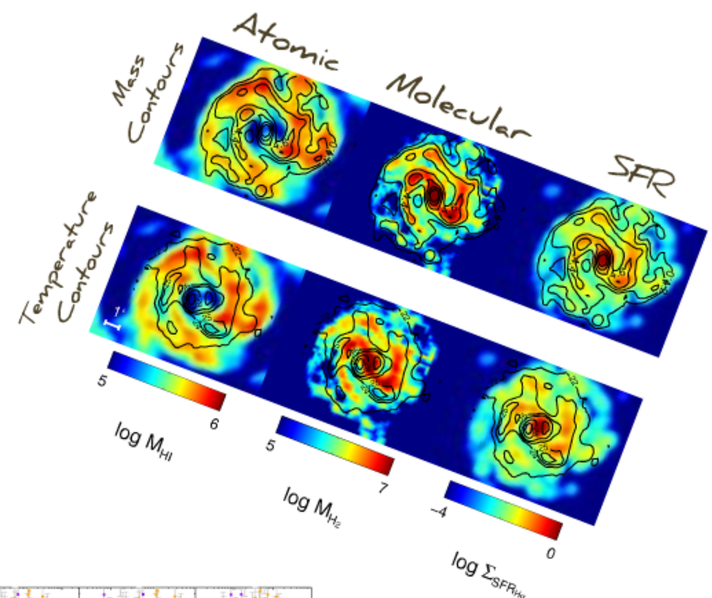
Dust, Gas & SFR

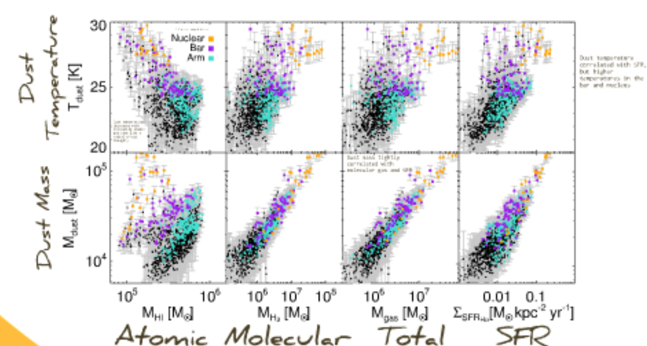
Compare Dust with:

Atomic Gas

Molecular Gas

SFR





Compare Dust with:

Atomic Gas

Atomic Gas:
- HI map (THINGS)

Molecular Gas

Molecular Gas:
- CO(3-2) map (JCMT)
- converted to CO(1-0) ~ 0.3
- converted to molecular hydrogen

$$X_{CO} = 2.0 \times 10^{20} \text{ mol cm}^{-2} (\text{K km s}^{-1})^{-1}$$

SFR

SFR:
- Extinction corrected H-alpha map (SINGG)
- corrected using 24 micron map

$$f_{H\alpha\ corrected} = f_{H\alpha\ observed} + (0.031 \pm 0.006) f_{24\mu m}$$

(Calzetti et al. 2007)

- credit: George Bendo & Ali Dariush

→ we will see other SFRs as well

Atomic Gas:

- HI map (THINGS)

Compare Dust with:

Atomic Gas

Atomic Gas:
- HI map (THINGS)

Molecular Gas

Molecular Gas:
- CO(3-2) map (JCMT)
- converted to CO(1-0) ~ 0.3
- converted to molecular hydrogen

$$X_{CO} = 2.0 \times 10^{20}\ \mathrm{mol\ cm^{-2}\ (K\ km\ s^{-1})^{-1}}$$

SFR

SFR:
- Extinction corrected H-alpha map (SINGG)
- corrected using 24 micron map

$$f_{H\alpha\ corrected} = f_{H\alpha\ observed} + (0.031 \pm 0.006) f_{24\mu m}$$

(Calzetti et al. 2007)

- credit: George Bendo & Ali Dariush

→ we will see other SFRs as well

Molecular Gas:

- CO(3-2) map (JCMT)
- converted to CO(1-0) ~ 0.3
- converted to molecular hydrogen

we'll come back to this

$$X_{CO} = 2.0 \times 10^{20} \text{ mol cm}^{-2} \text{ (K km s}^{-1})^{-1}$$

Compare Dust with:

Atomic Gas

Atomic Gas:
- HI map (THINGS)

Molecular Gas

Molecular Gas:
- CO(3-2) map (JCMT)
- converted to CO(1-0) ~ 0.3
- converted to molecular hydrogen

$$X_{CO} = 2.0 \times 10^{20} \text{ mol cm}^{-2} \text{ (K km s}^{-1})^{-1}$$

SFR

SFR:
- Extinction corrected H-alpha map (SINGG)
- corrected using 24 micron map

$$f_{H\alpha \text{ corrected}} = f_{H\alpha \text{ observed}} + (0.031 \pm 0.006) f_{24\mu m}$$

(Calzetti et al. 2007)

- credit: George Bendo & Ali Dariush

→ we will see other SFRs as well

SFR:

- Extinction corrected H-alpha map (SINGG)
- corrected using 24 micron map

$$f_{H\alpha\ corrected} = f_{H\alpha\ observed} + (0.031 \pm 0.006) f_{24\mu m}$$

(Calzetti et al. 2007)

- credit: George Bendo & Ali Dariush

→ we will see other SFRs as well

Compare Dust with:

Atomic Gas

Atomic Gas:
- HI map (THINGS)

Molecular Gas

Molecular Gas:
- CO(3-2) map (JCMT)
- converted to CO(1-0) ~ 0.3
- converted to molecular hydrogen

$$X_{CO} = 2.0 \times 10^{20} \text{ mol cm}^{-2} \text{ (K km s}^{-1})^{-1}$$

SFR

SFR:
- Extinction corrected H-alpha map (SINGG)
- corrected using 24 micron map

$$f_{H\alpha\ corrected} = f_{H\alpha\ observed} + (0.031 \pm 0.006) f_{24\mu m}$$

(Calzetti et al. 2007)

- credit: George Bendo & Ali Dariush

→ we will see other SFRs as well

All maps:

- deprojected
- aligned
- convolved (500 micron)

Compare Dust with:

Atomic Gas

Atomic Gas:
- HI map (THINGS)

Molecular Gas

Molecular Gas:
- CO(3-2) map (JCMT)
- converted to CO(1-0) ~ 0.3
- converted to molecular hydrogen

$$X_{CO} = 2.0 \times 10^{20} \text{ mol cm}^{-2} (\text{K km s}^{-1})^{-1}$$

SFR

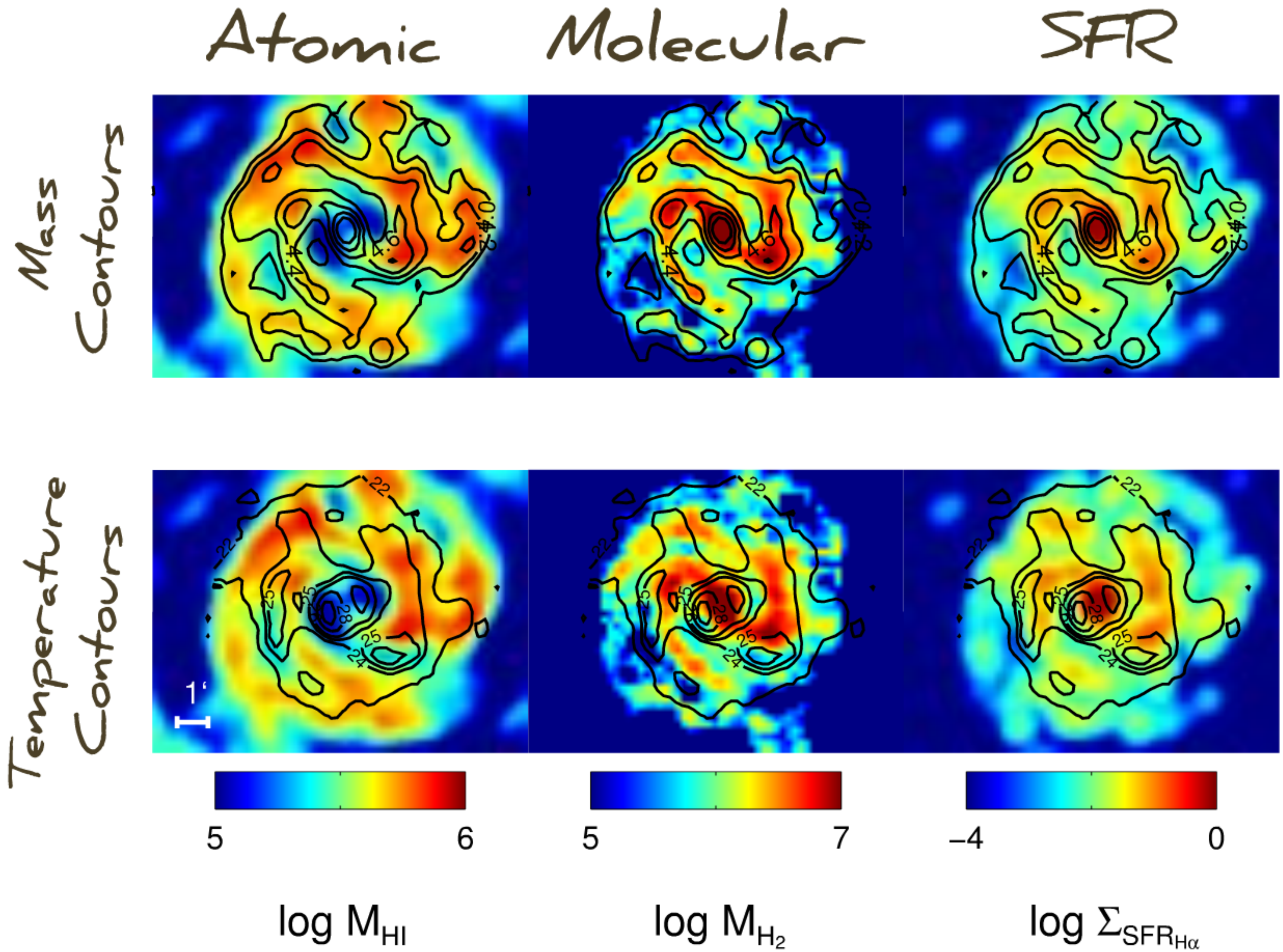
SFR:
- Extinction corrected H-alpha map (SINGG)
- corrected using 24 micron map

$$f_{H\alpha\ corrected} = f_{H\alpha\ observed} + (0.031 \pm 0.006) f_{24\mu m}$$

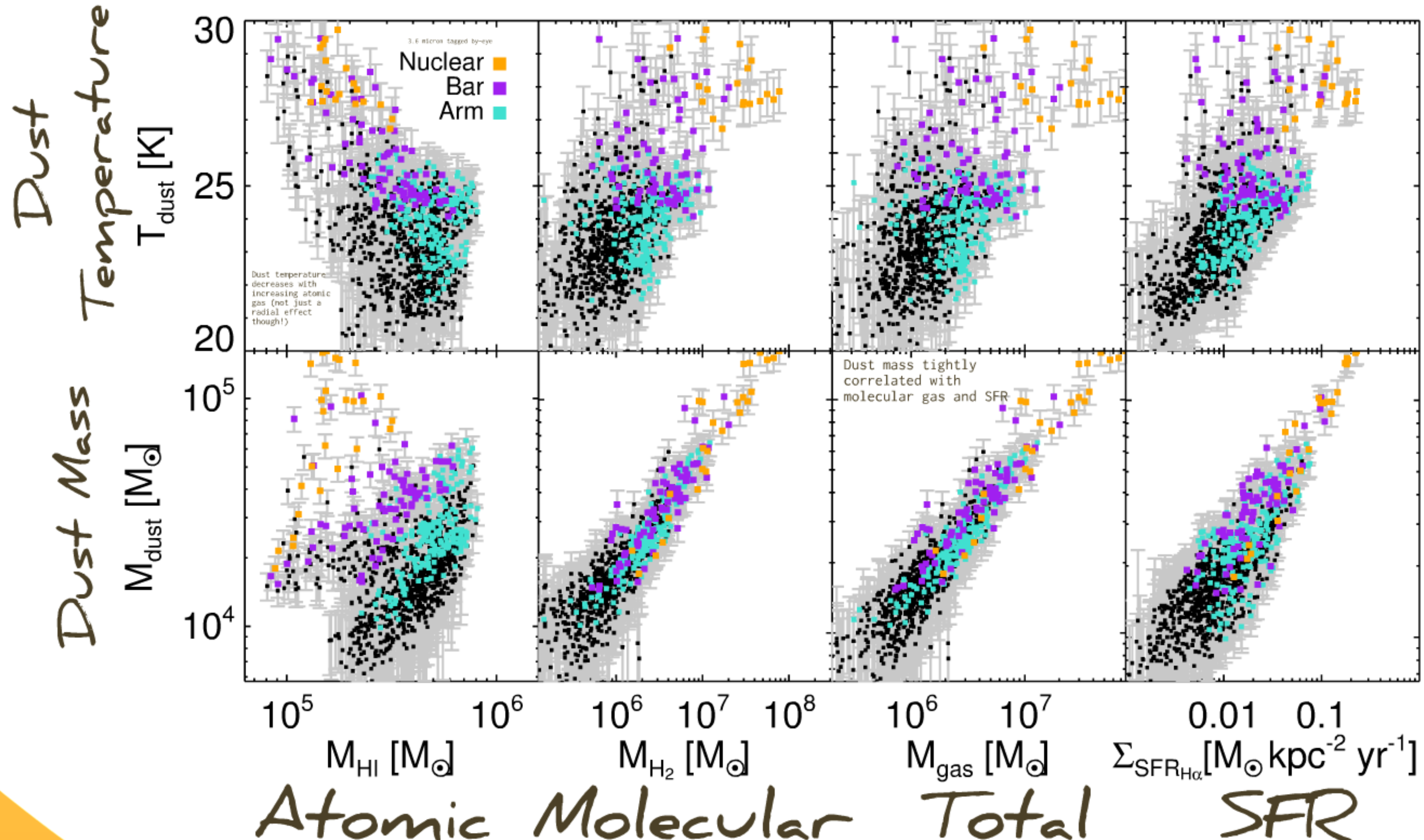
(Calzetti et al. 2007)

- credit: George Bendo & Ali Dariush

→ we will see other SFRs as well


Atomic
Molecular
SFR
Mass Contours
Temperature Contours
1'
5
6
5
7
–4
0
log M_{HI}
log M_{H_2}
log $\Sigma_{SFR_{H\alpha}}$

log M_{H_2}



Dust temperature correlated with SFR, but higher temperatures in the bar and nucleus

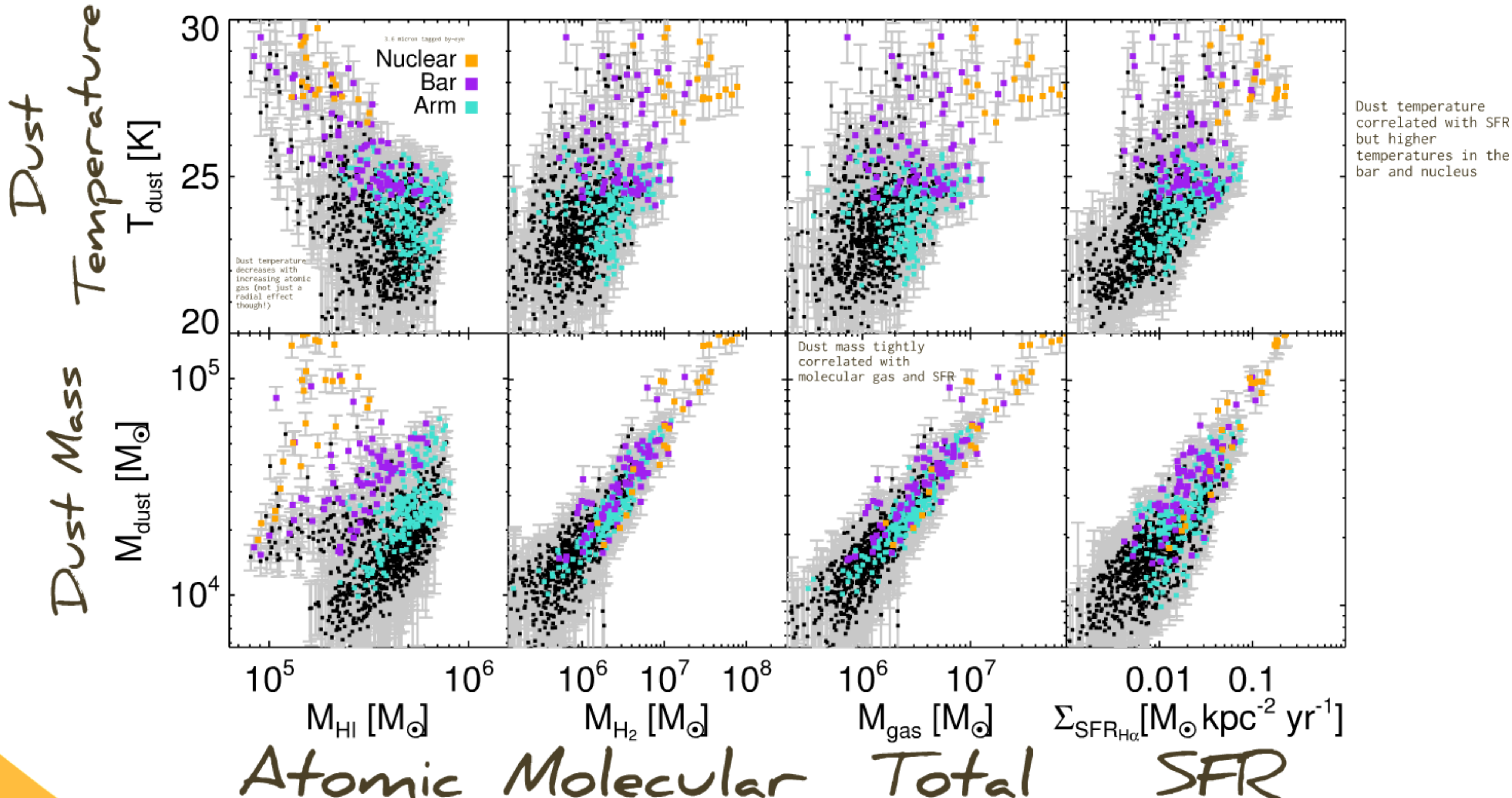
3.6 micron tagged by-eye

Nuclear

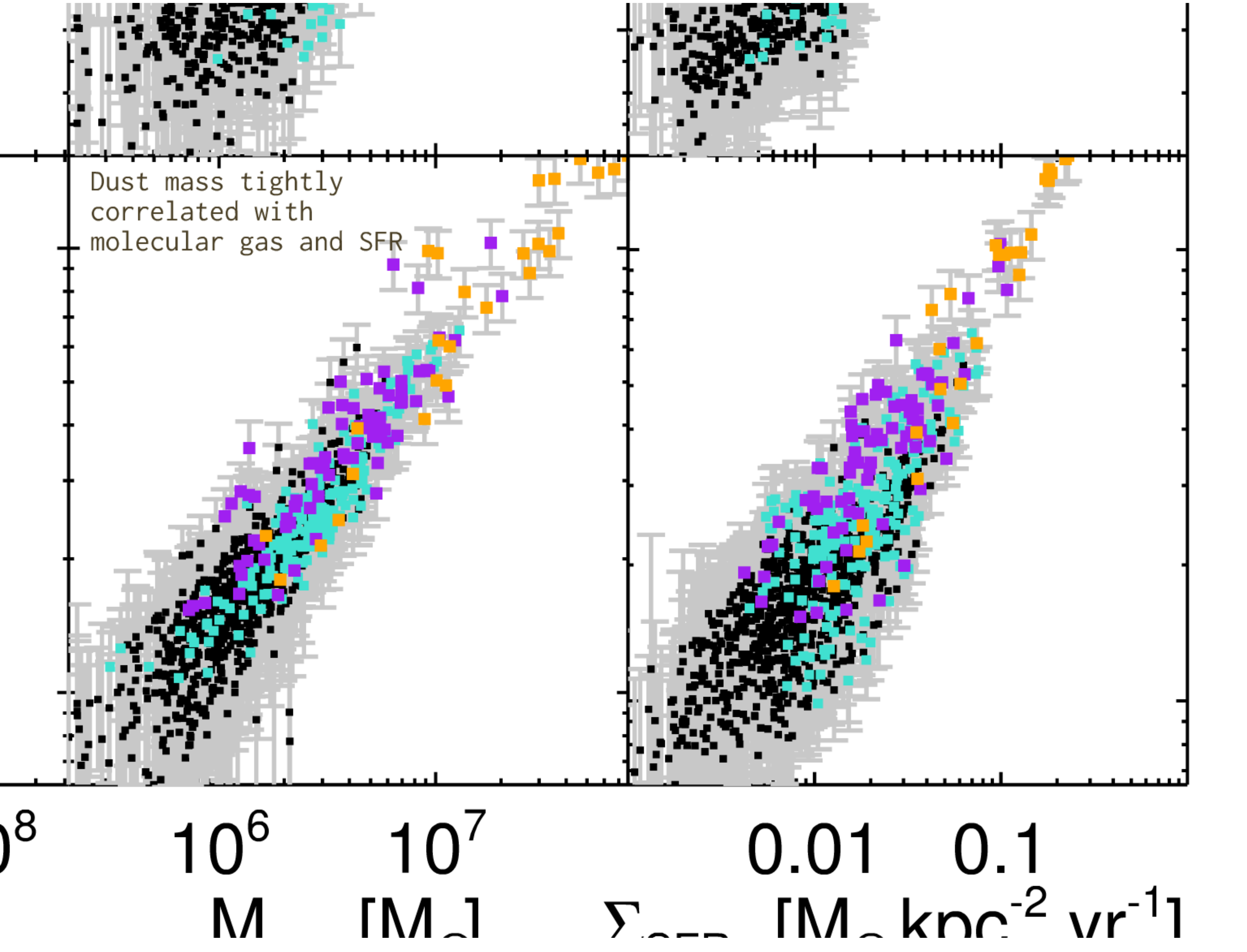
Bar

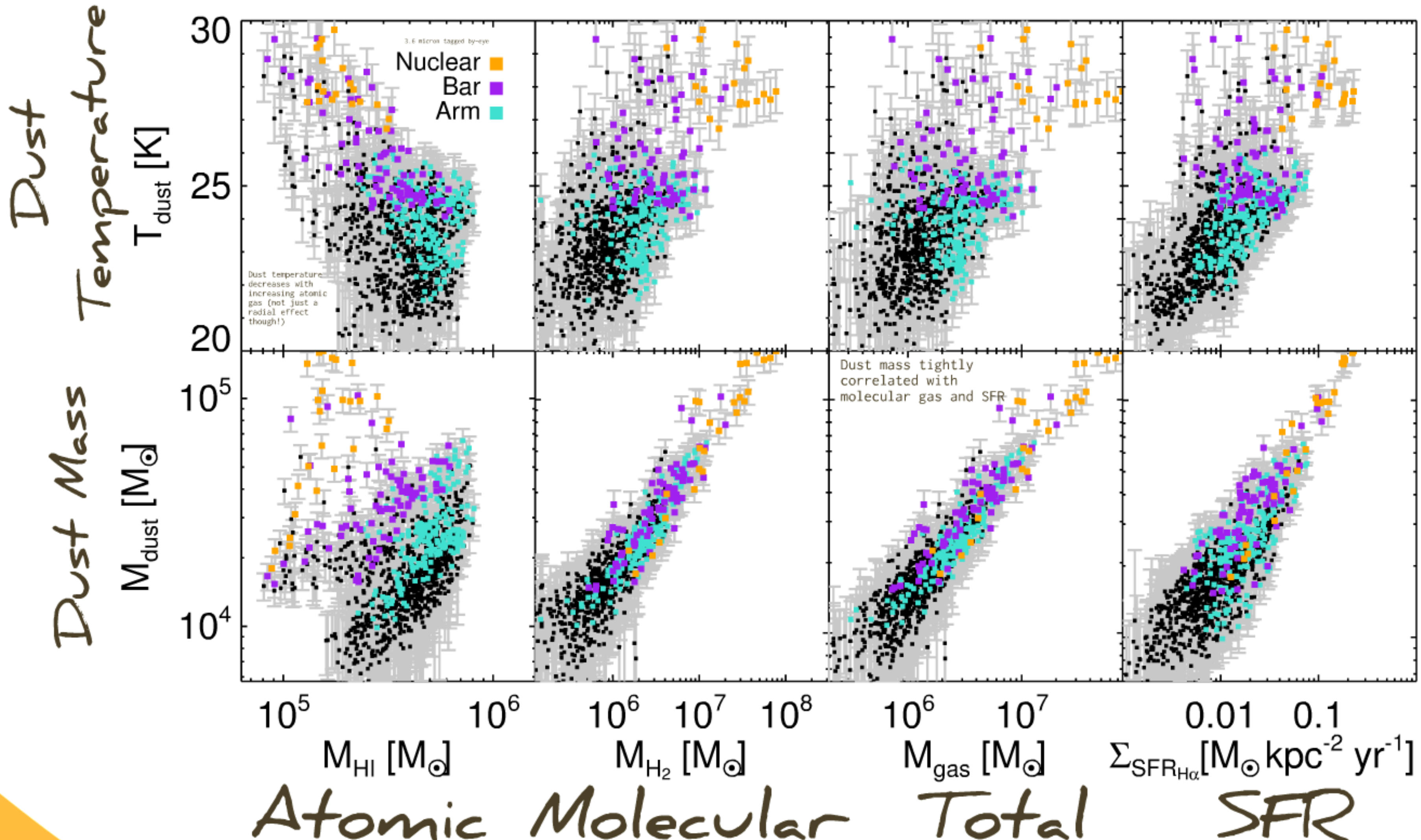
Arm

$\log M_{H_2}$

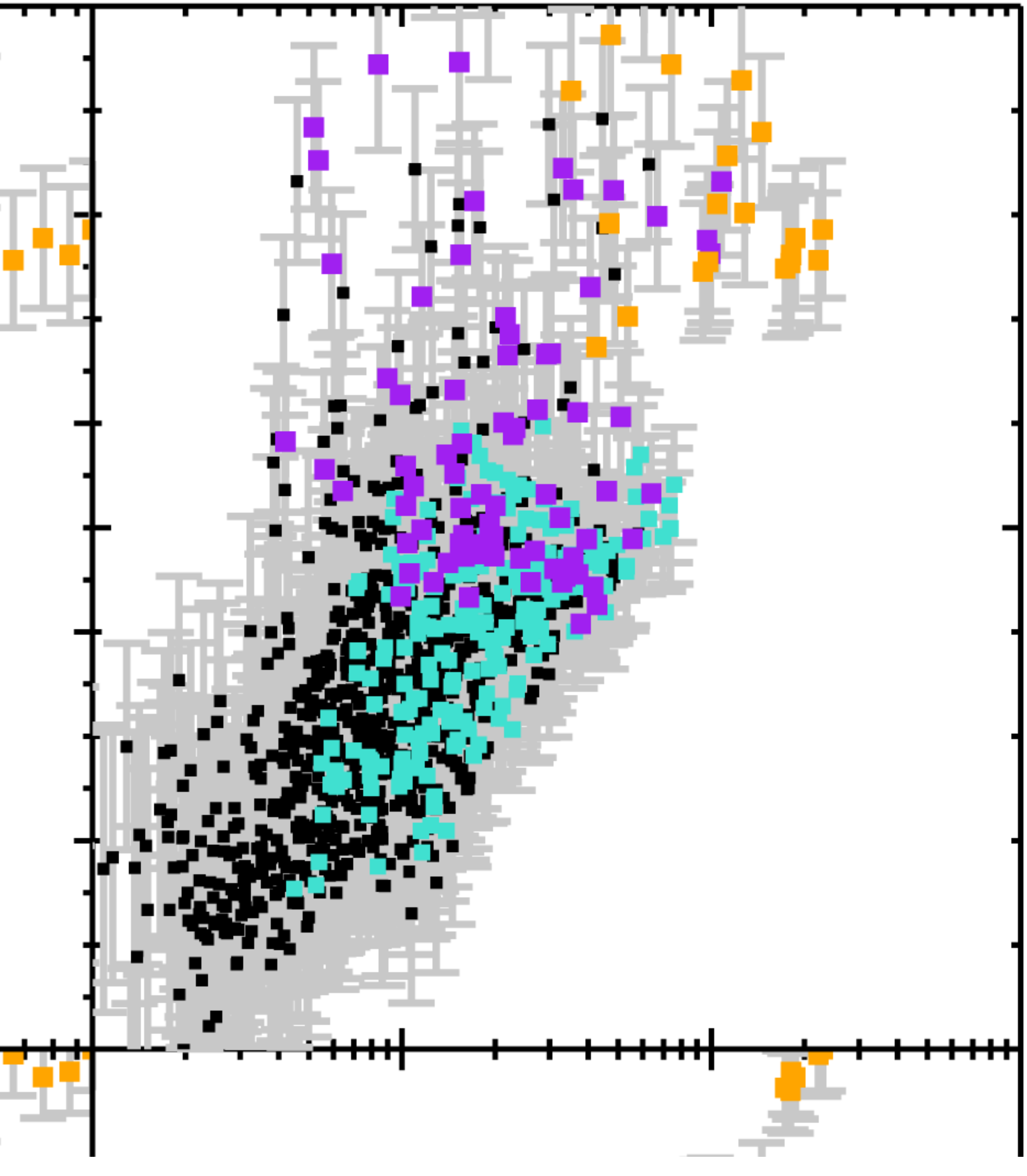


Dust Temperature
Dust Mass
T_dust [K]
M_dust [M⊙]
30
25
20
10^5
10^4
3.6 micron tagged by-eye
Nuclear
Bar
Arm
Dust temperature decreases with increasing atomic gas (not just a radial effect though!)
Dust mass tightly correlated with molecular gas and SFR
Dust temperature correlated with SFR, but higher temperatures in the bar and nucleus
10^5
10^6
M_HI [M⊙]
10^6
10^7
10^8
M_H2 [M⊙]
10^6
10^7
M_gas [M⊙]
0.01
0.1
Σ_SFR_Hα [M⊙ kpc^-2 yr^-1]
Atomic
Molecular
Total
SFR

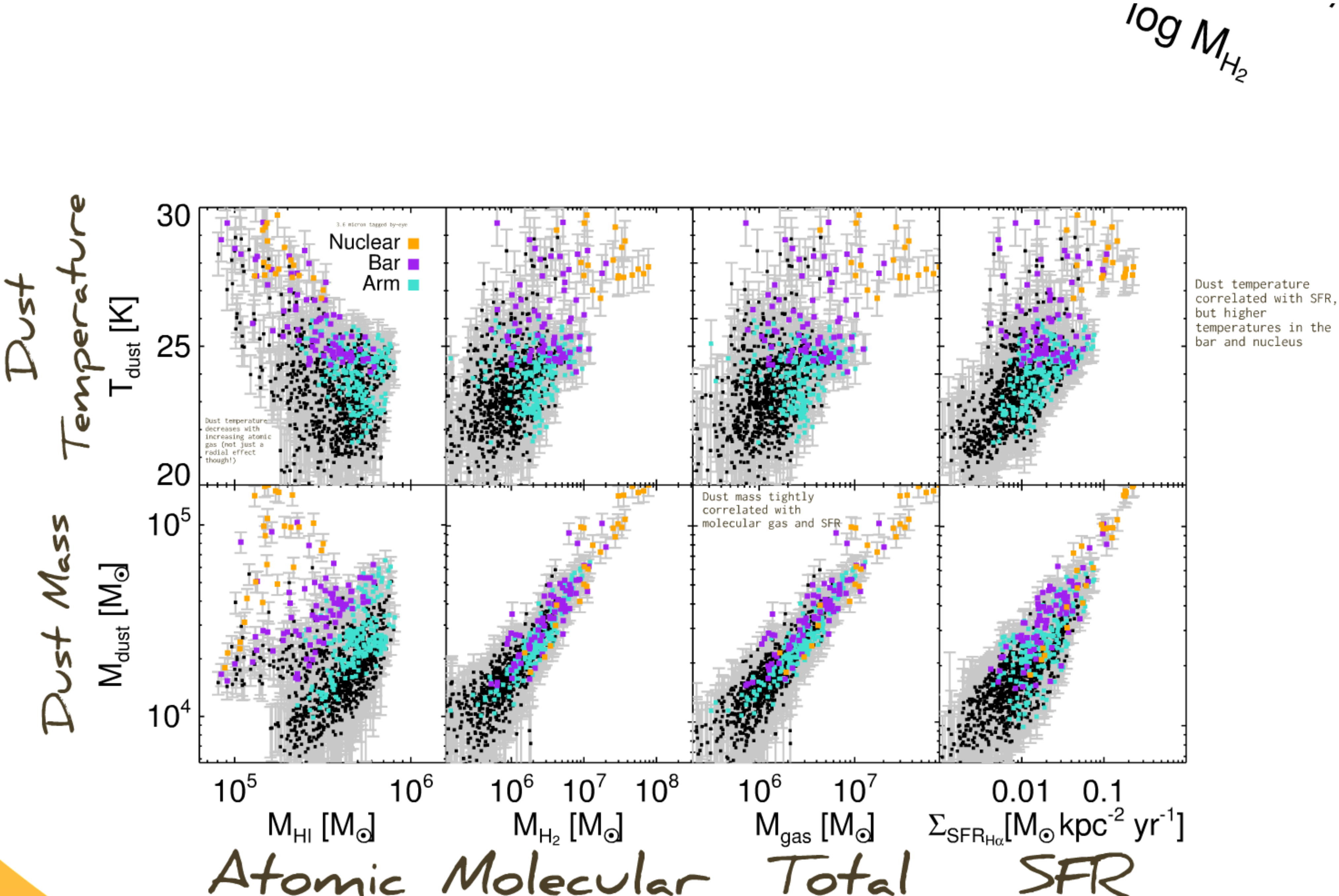

Dust mass tightly
correlated with
molecular gas and SFR
10^8
10^6
10^7
0.01
0.1

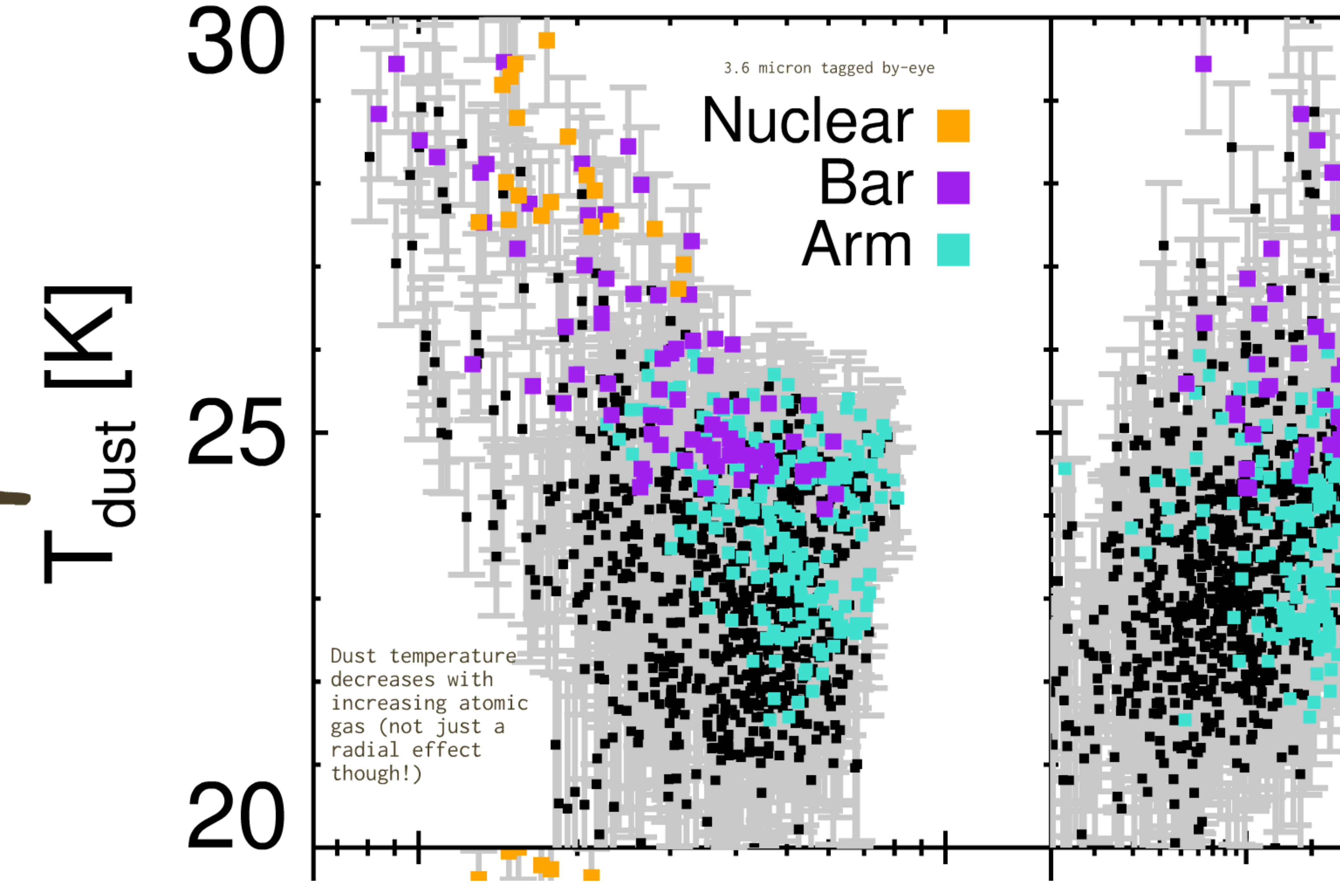


Dust temperature correlated with SFR, but higher temperatures in the bar and nucleus



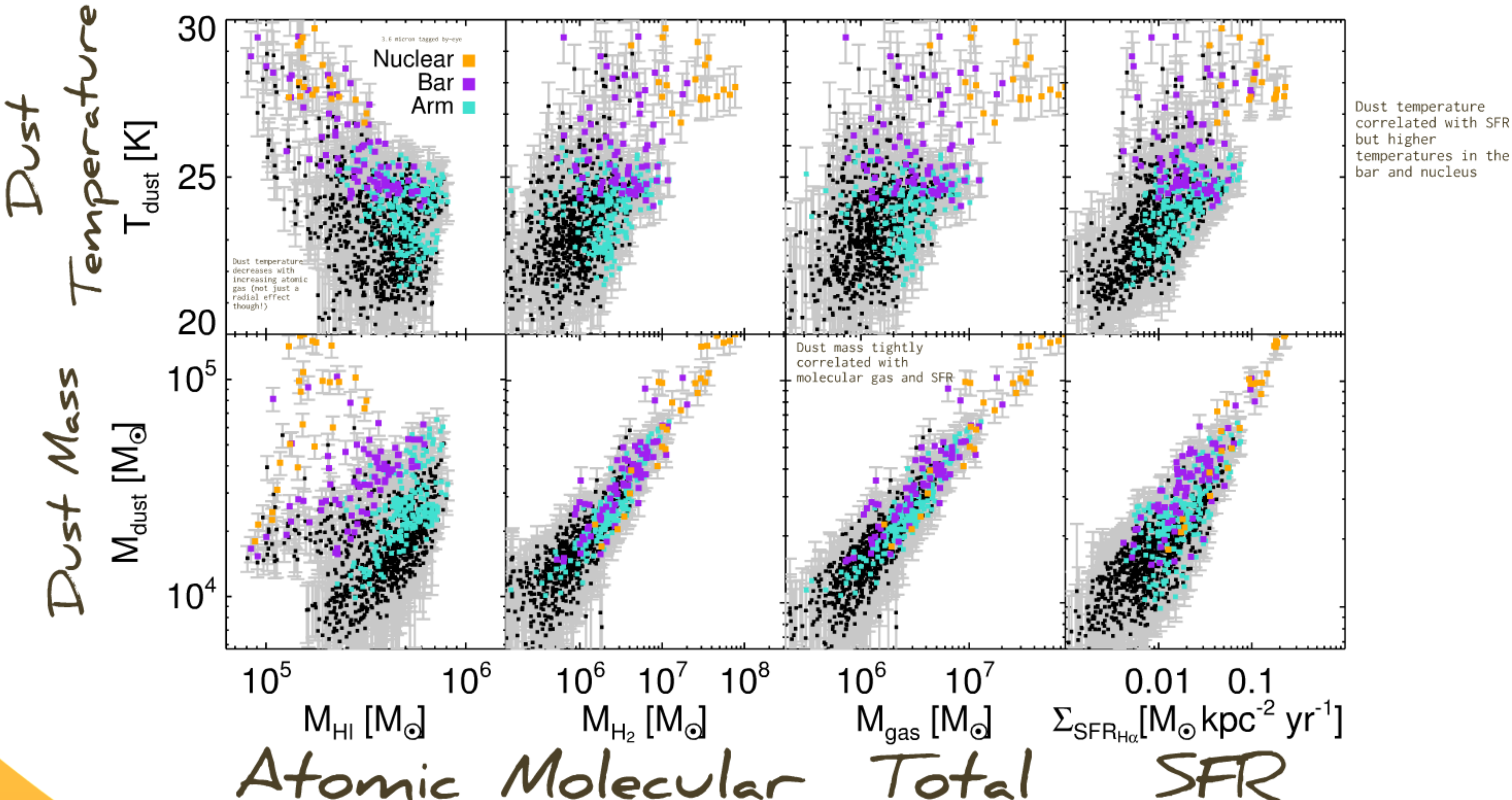
Dust temperature correlated with SFR, but higher temperatures in the bar and nucleus


log M_{H_2}
Dust Temperature
Dust Mass
T_{dust} [K]
M_{dust} [$M_\odot$]
30
25
20
10^5
10^4
3.6 micron tagged by-eye
Nuclear
Bar
Arm
Dust temperature decreases with increasing atomic gas (not just a radial effect though!)
Dust mass tightly correlated with molecular gas and SFR
Dust temperature correlated with SFR, but higher temperatures in the bar and nucleus
10^5 10^6
M_{HI} [$M_\odot$]
10^6 10^7 10^8
M_{H_2} [$M_\odot$]
10^6 10^7
M_{gas} [$M_\odot$]
0.01 0.1
$\Sigma_{SFR_{H\alpha}}$[$M_\odot$ kpc^{-2} yr^{-1}]
Atomic
Molecular
Total
SFR



30
25
20
T_dust [K]
3.6 micron tagged by-eye
Nuclear
Bar
Arm
Dust temperature
decreases with
increasing atomic
gas (not just a
radial effect
though!)

$\log M_{H_2}$


Dust Temperature
Dust Mass
T_{dust} [K]
M_{dust} [$M_\odot$]
3.6 micron tagged by-eye
Nuclear
Bar
Arm
Dust temperature decreases with increasing atomic gas (not just a radial effect though!)
Dust mass tightly correlated with molecular gas and SFR
Dust temperature correlated with SFR, but higher temperatures in the bar and nucleus
M_{HI} [$M_\odot$]
M_{H_2} [$M_\odot$]
M_{gas} [$M_\odot$]
$\Sigma_{SFR_{H\alpha}}$[$M_\odot$ kpc^{-2} yr^{-1}]
Atomic
Molecular
Total
SFR

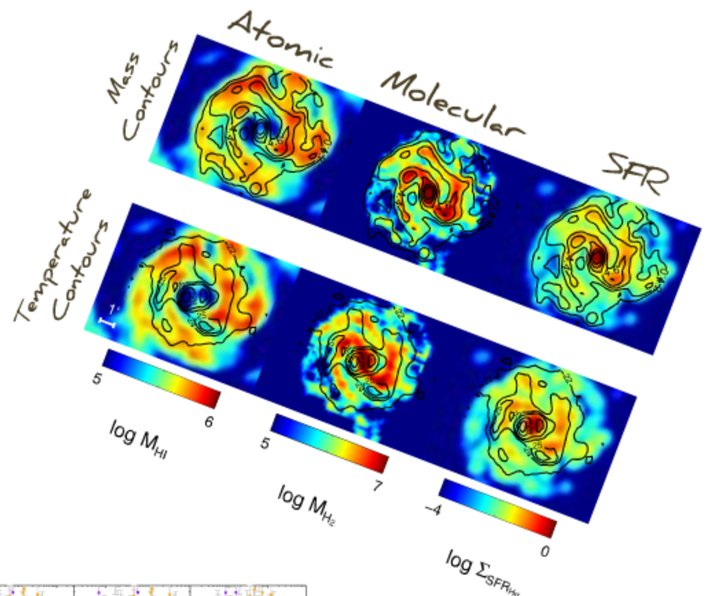
Dust, Gas & SFR

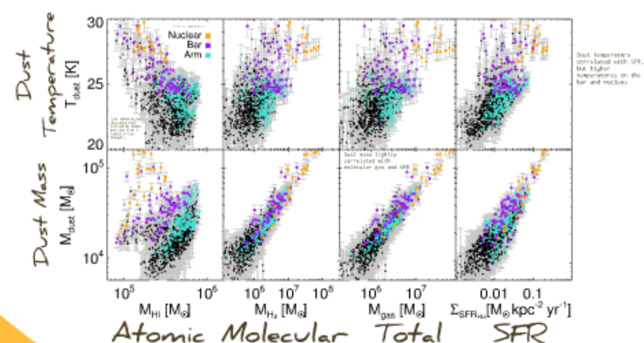
Compare Dust with:

Atomic Gas

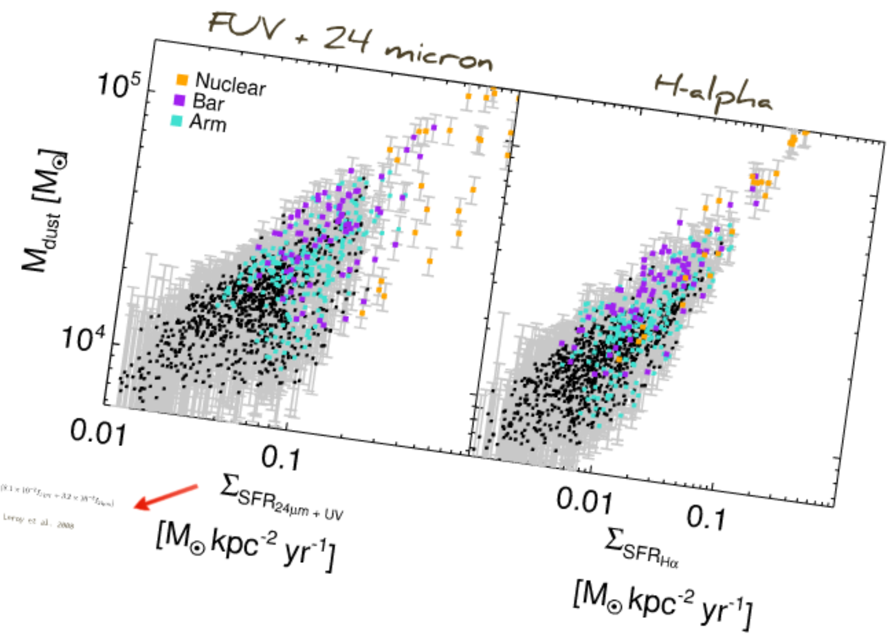
Molecular Gas

SFR





SFR?

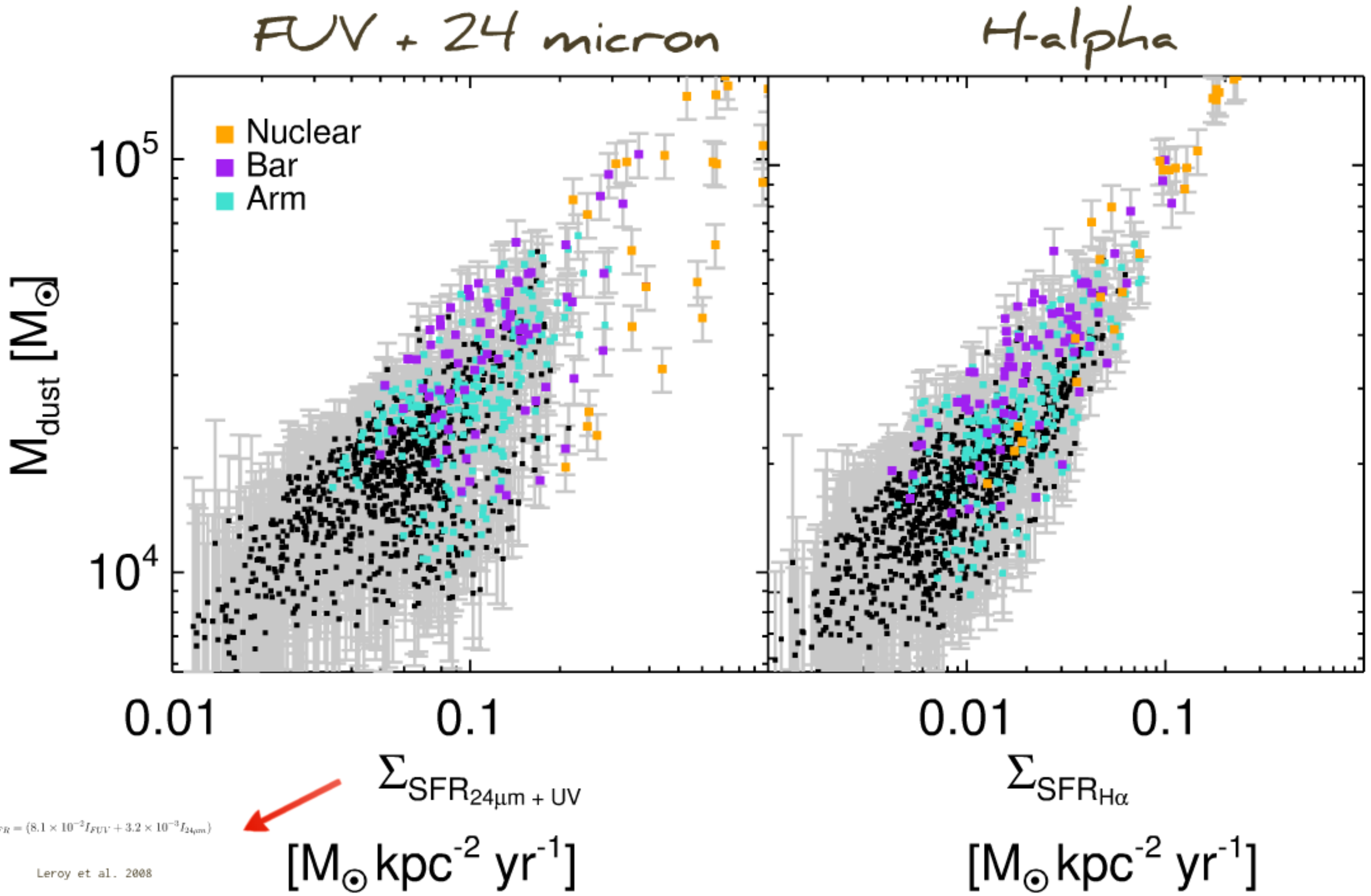


Leroy et al. 2008

Dust mass more tightly correlated with H-alpha based SFR

Tracers probe different timescales!

see Liu et al. 2011 (M51 & NGC3521)



$\Sigma_{SFR} = (8.1 \times 10^{-2} I_{FUV} + 3.2 \times 10^{-3} I_{24\mu m})$

Leroy et al. 2008

Dust mass more tightly correlated with H-alpha based SFR

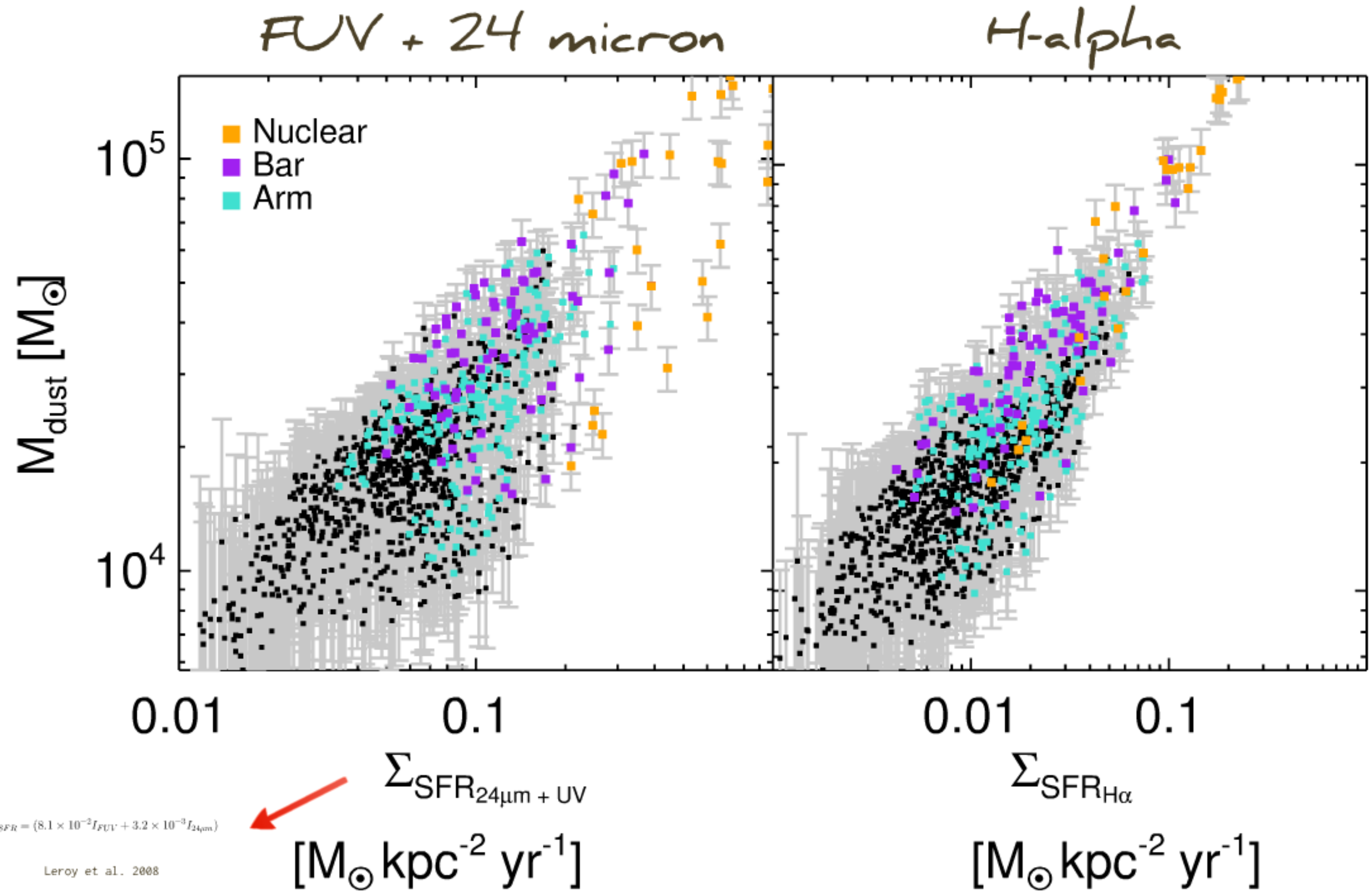
Tracers probe different timescales!

see Liu et al. 2011 (M51 & NGC3521)

0.01

$$\Sigma_{SFR} = (8.1 \times 10^{-2} I_{FUV} + 3.2 \times 10^{-3} I_{24\mu m})$$

Leroy et al. 2008



$\Sigma_{SFR} = (8.1 \times 10^{-2} I_{FUV} + 3.2 \times 10^{-3} I_{24\mu m})$

Leroy et al. 2008

Dust mass more tightly correlated
with H-alpha based SFR

Tracers probe different timescales!

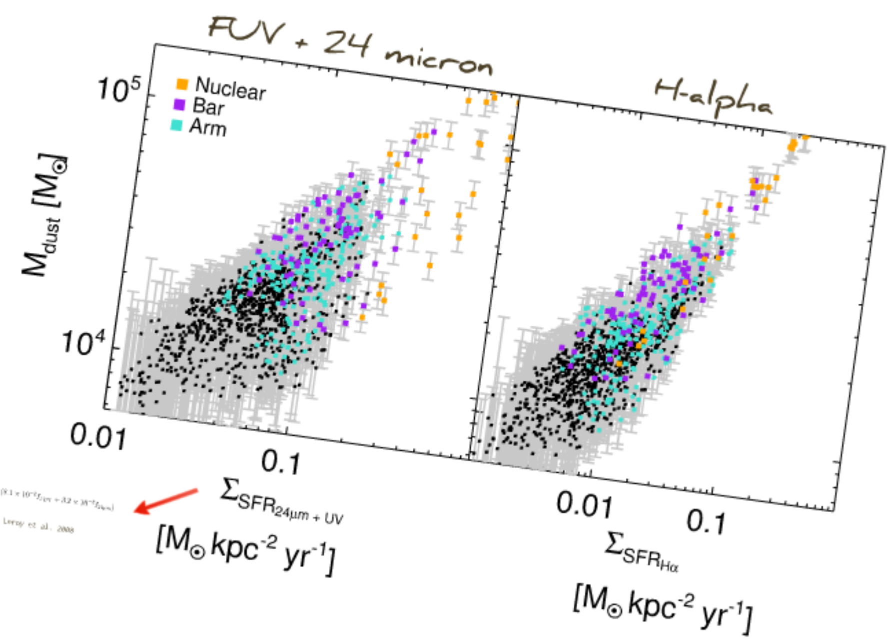
see Liu et al. 2011 (M51 & NGC3521)

Dust mass more tightly correlated with H-alpha based SFR

Tracers probe different timescales!

see Liu et al. 2011 (M51 & NGC3521)

SFR?



$\Sigma_{SFR} = (8.1 \times 10^{-2} f_{FUV} + 3.2 \times 10^{-3} f_{24\mu m})$

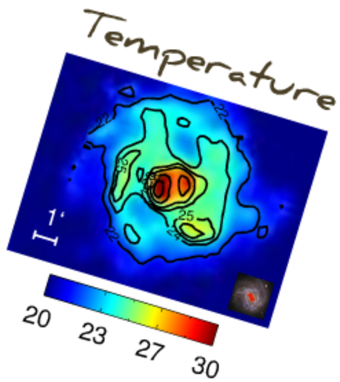
Leroy et al. 2008

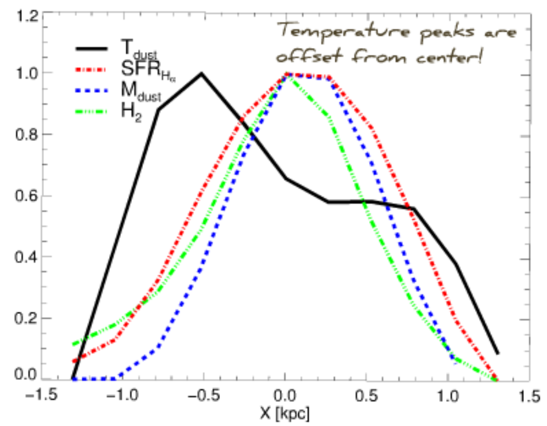
Dust mass more tightly correlated with H-alpha based SFR

Tracers probe different timescales!

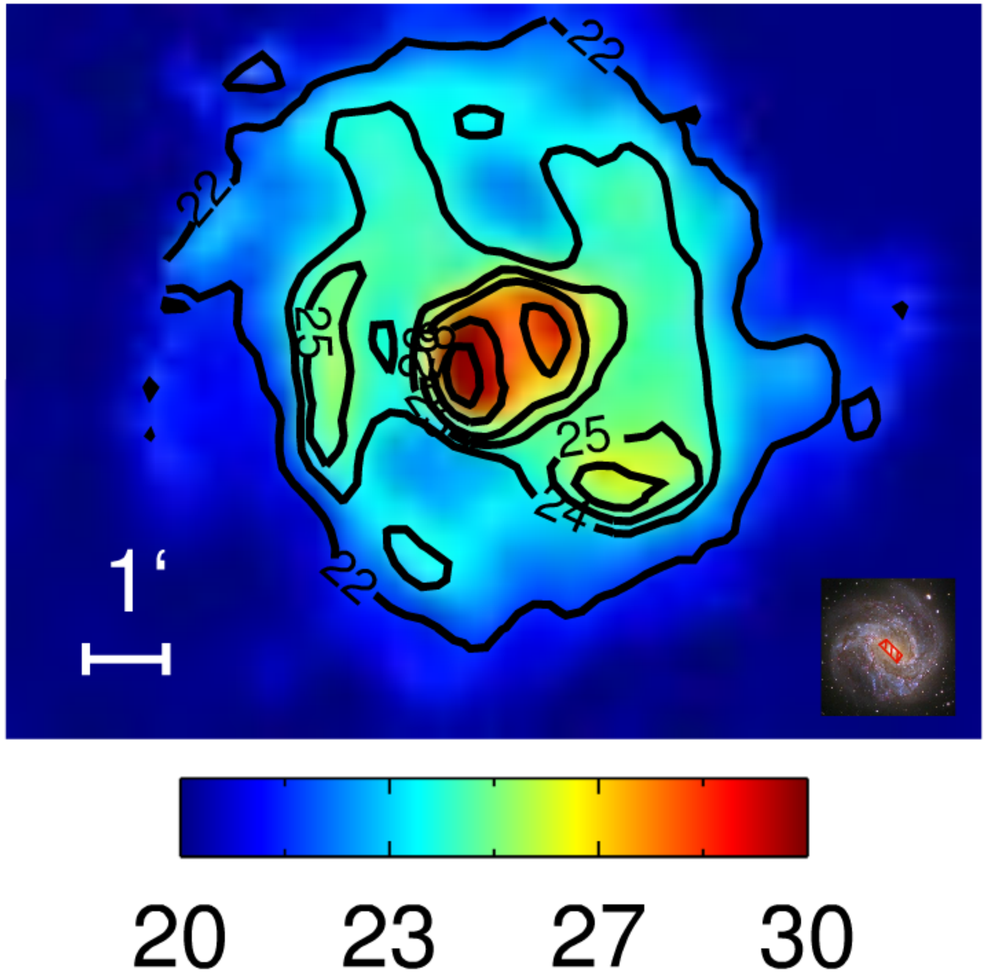
see Liu et al. 2011 (M51 & NGC3521)

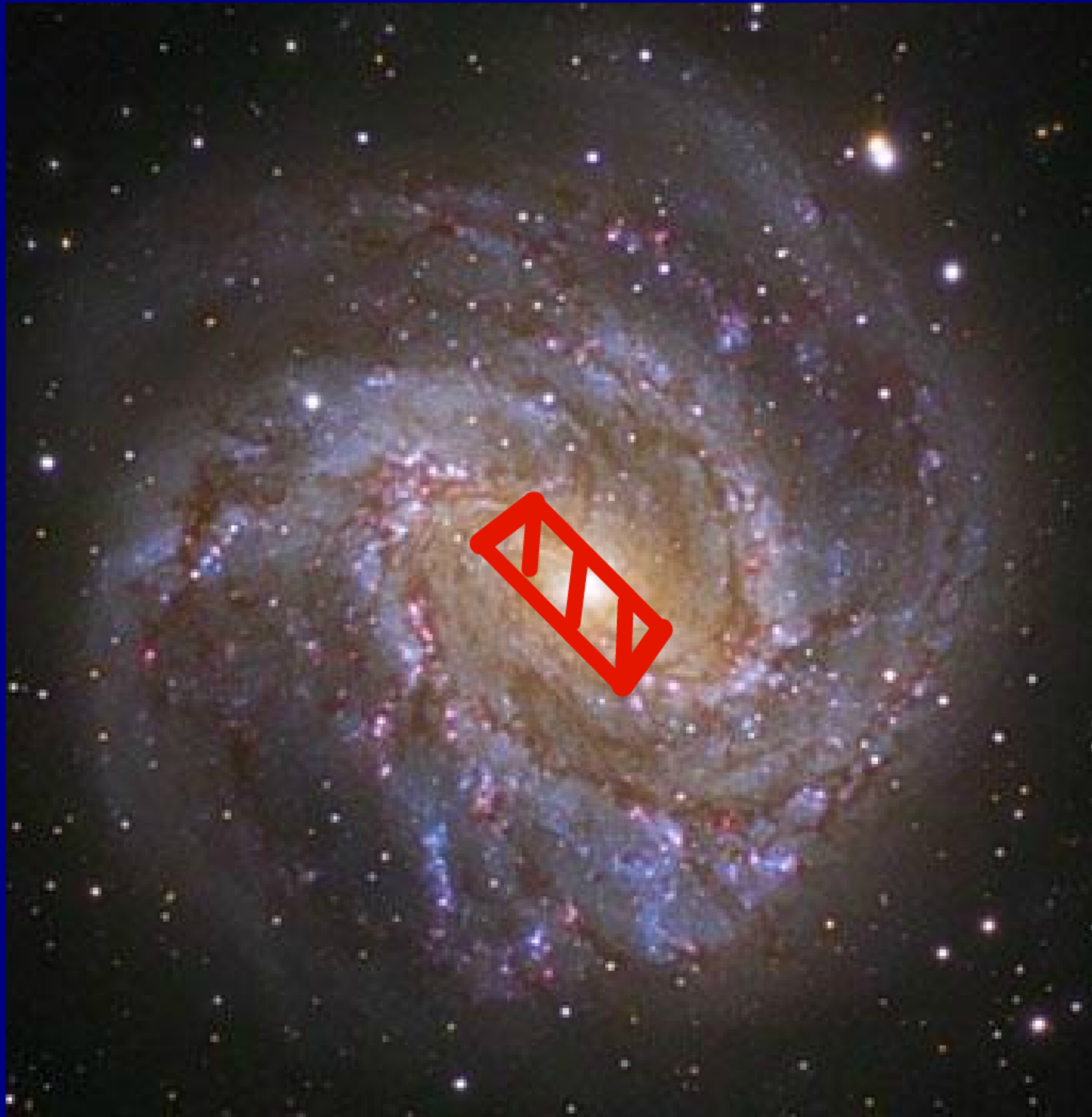
Bar Profile


Temperature
1'
20
23
27
30

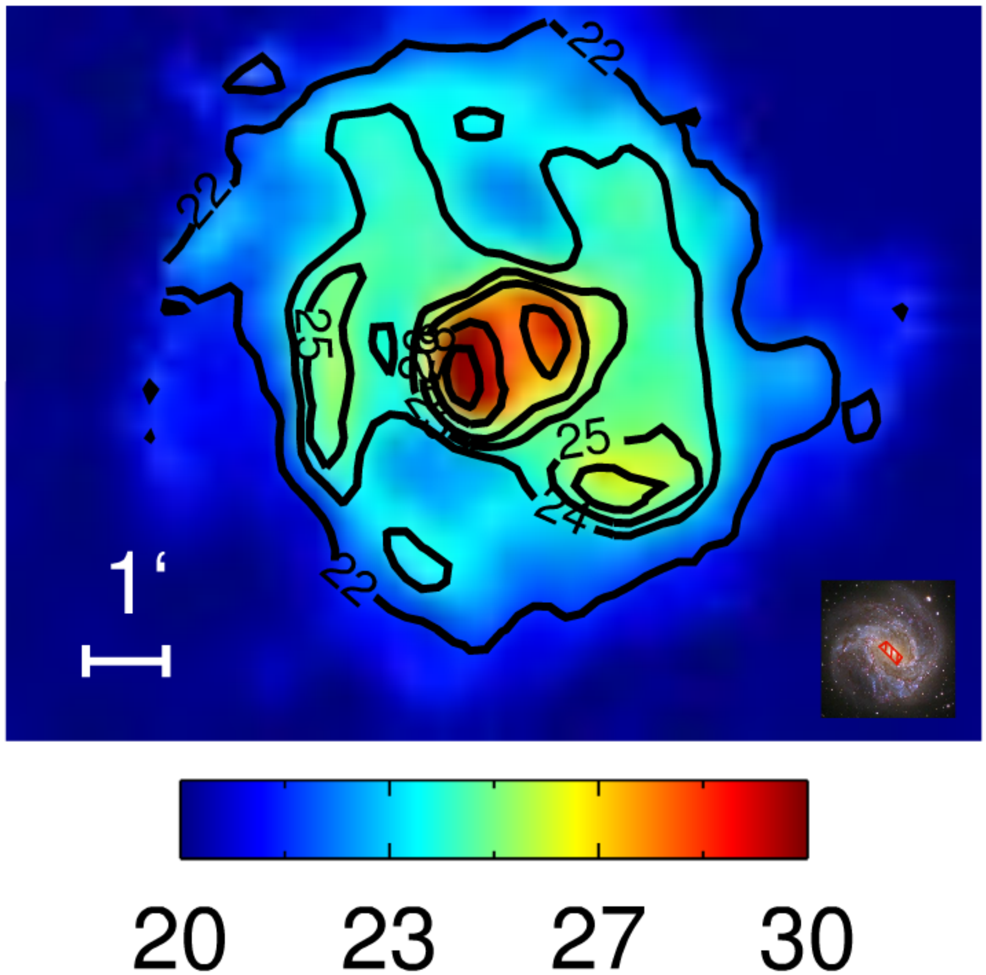

Temperature peaks are offset from center!
T_{dust}
$SFR_{H\alpha}$
M_{dust}
H_2
X [kpc]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5

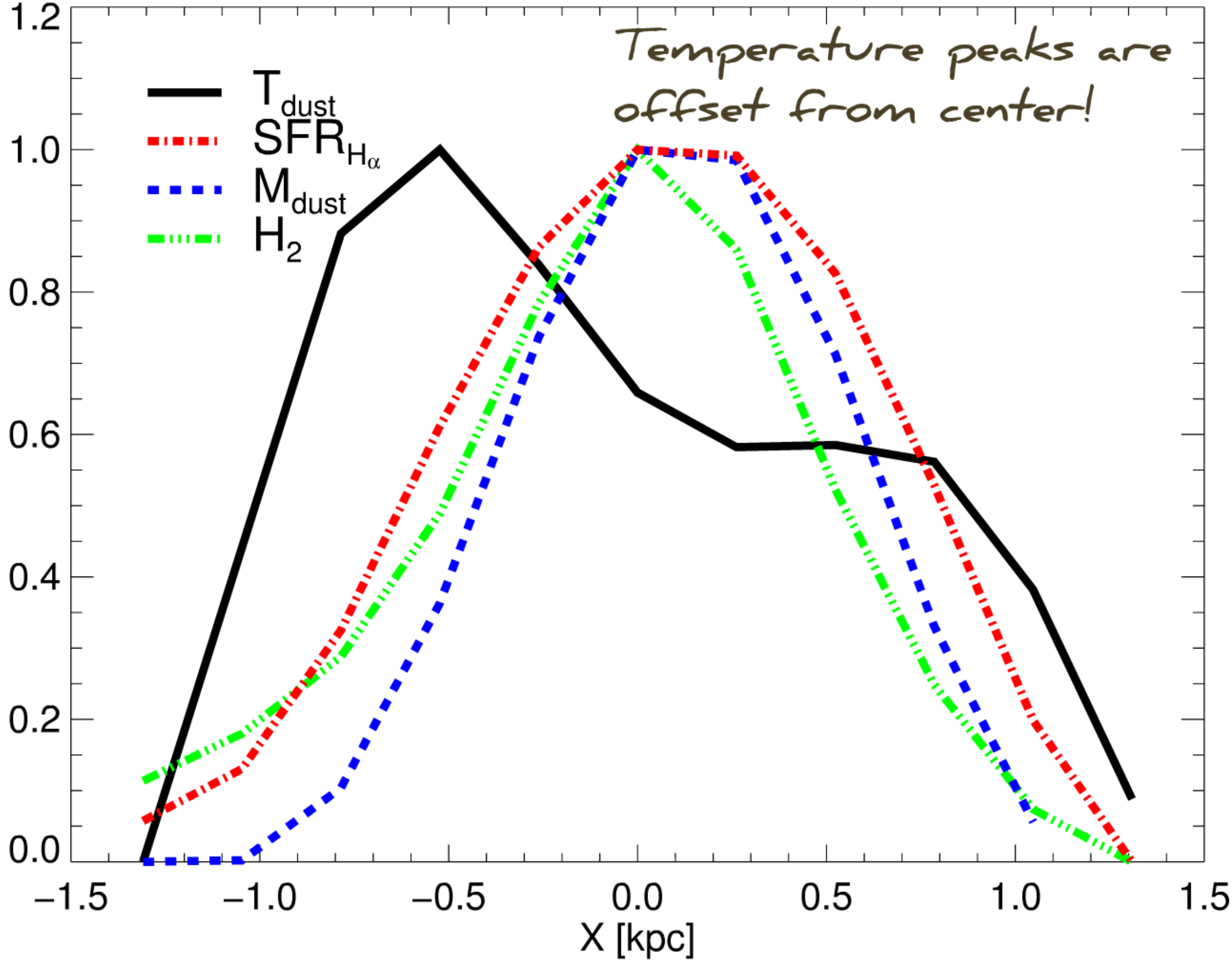
Temperature





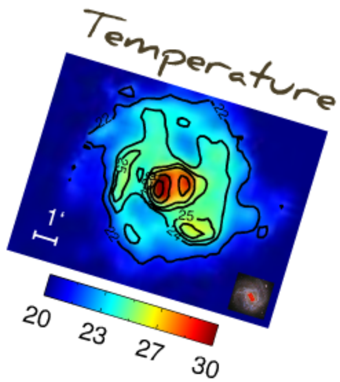
Temperature

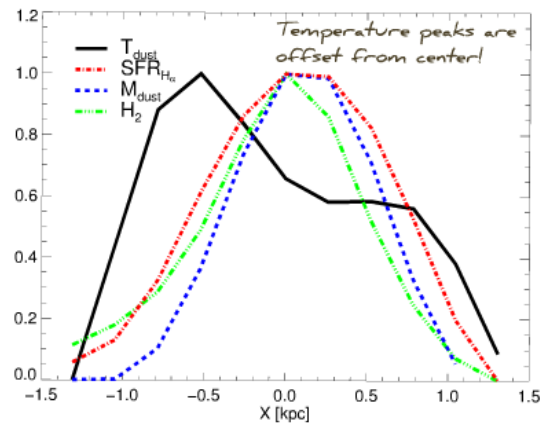




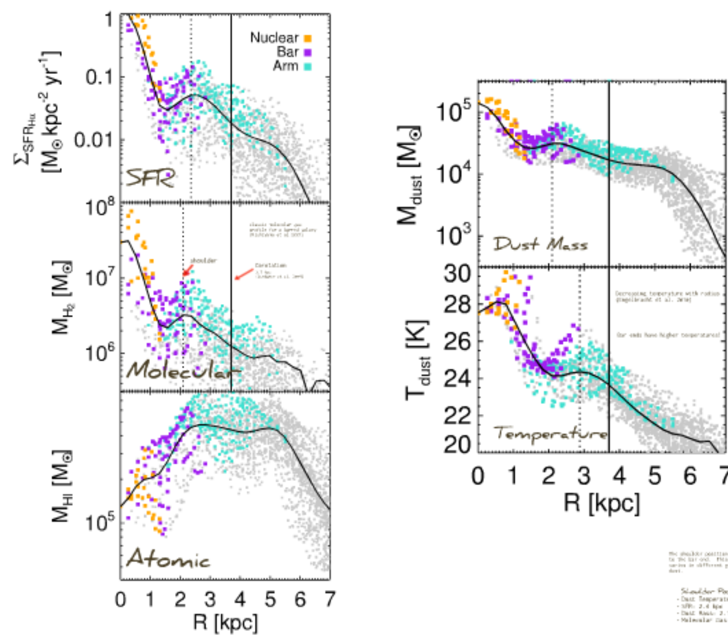
Temperature peaks are offset from center!
T_{dust}
$SFR_{H\alpha}$
M_{dust}
H_2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
X [kpc]

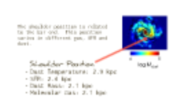
Bar Profile

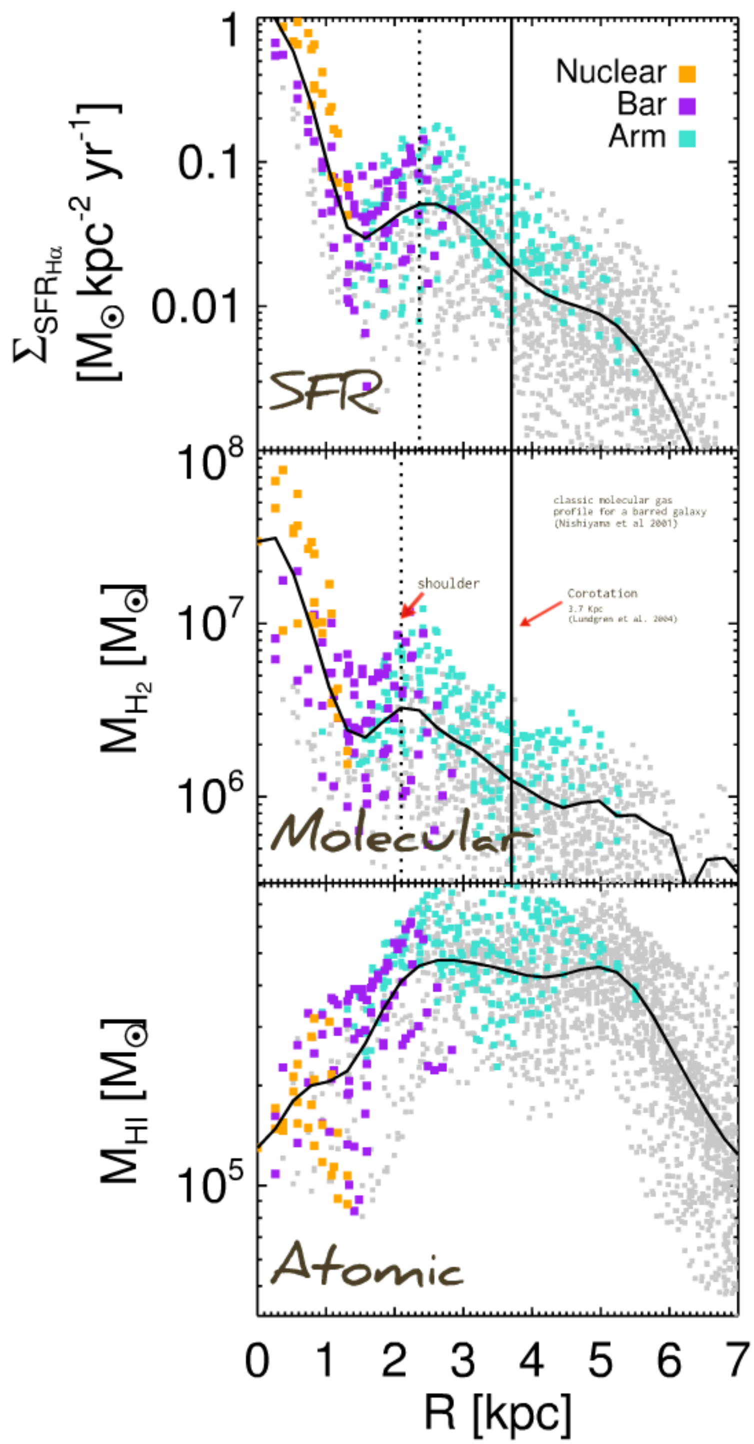

Temperature
1'
20
23
27
30

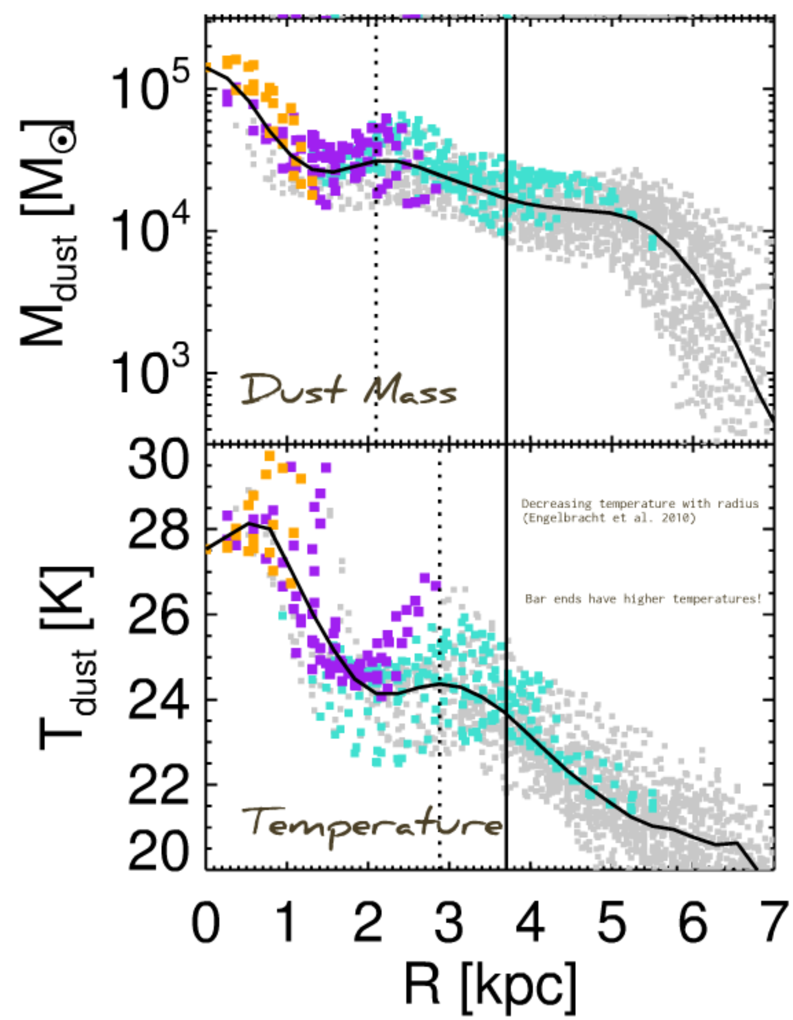

Temperature peaks are offset from center!
T_{dust}
$SFR_{H\alpha}$
M_{dust}
H_2
X [kpc]

Radial Profiles

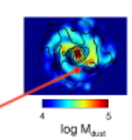






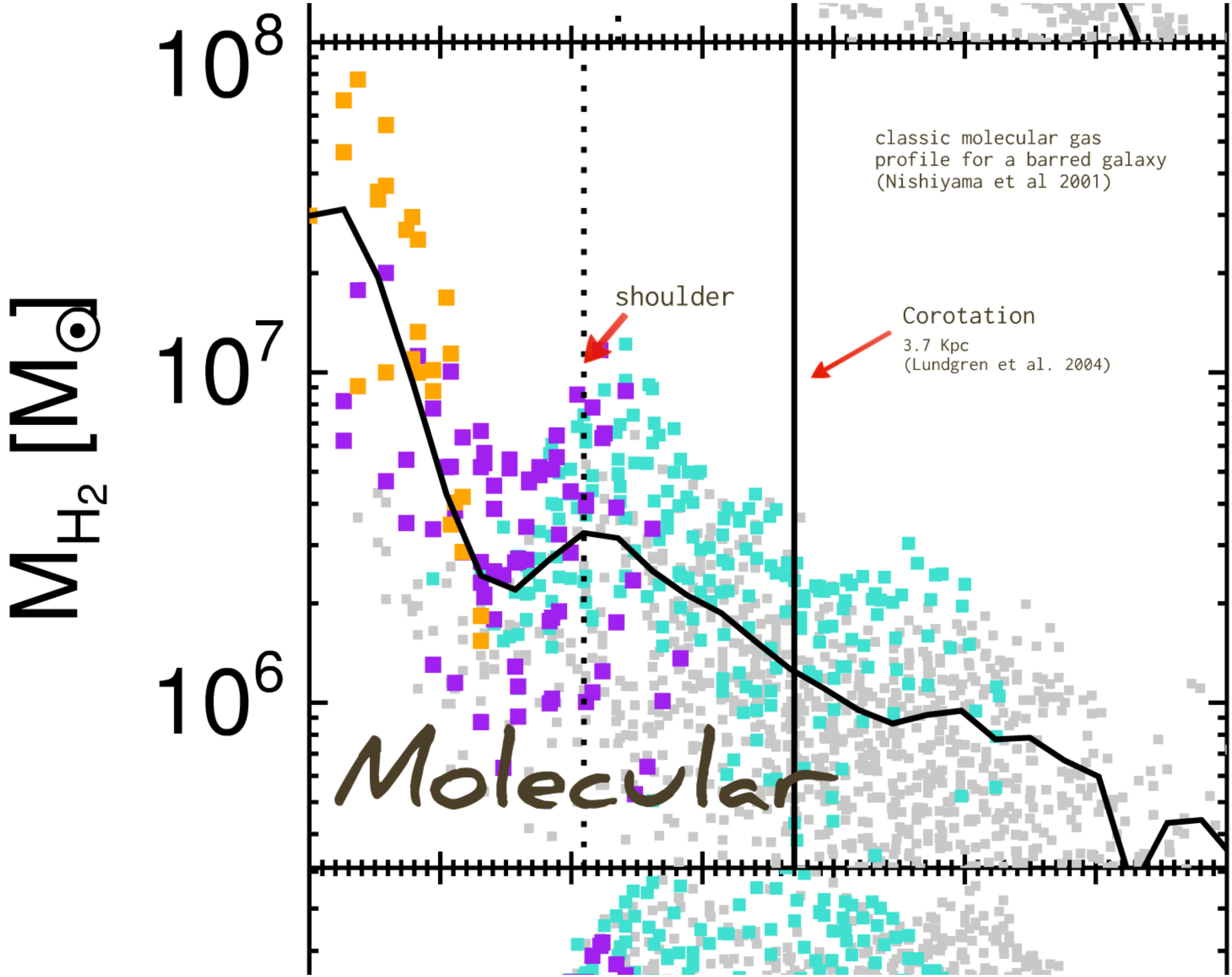


The shoulder position is related to the bar end. This position varies in different gas, SFR and dust.

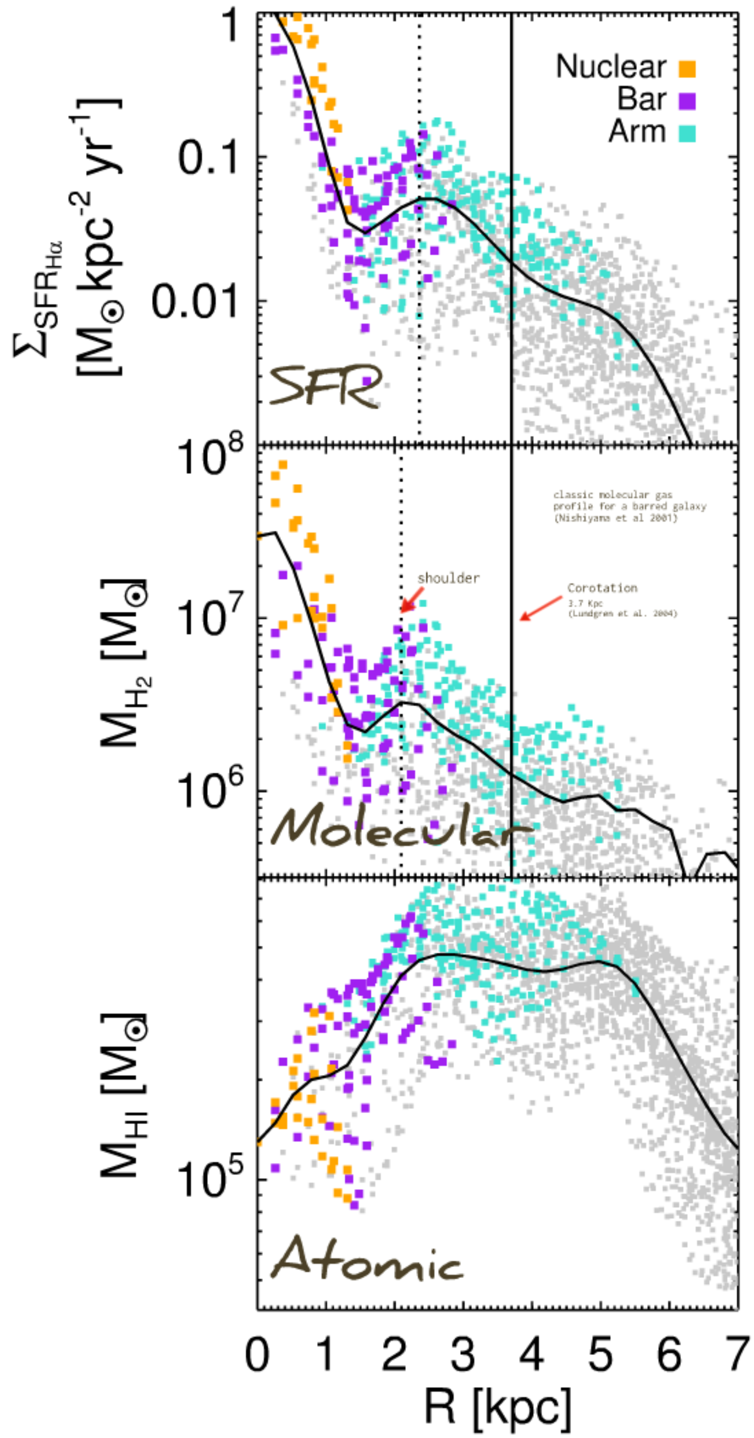


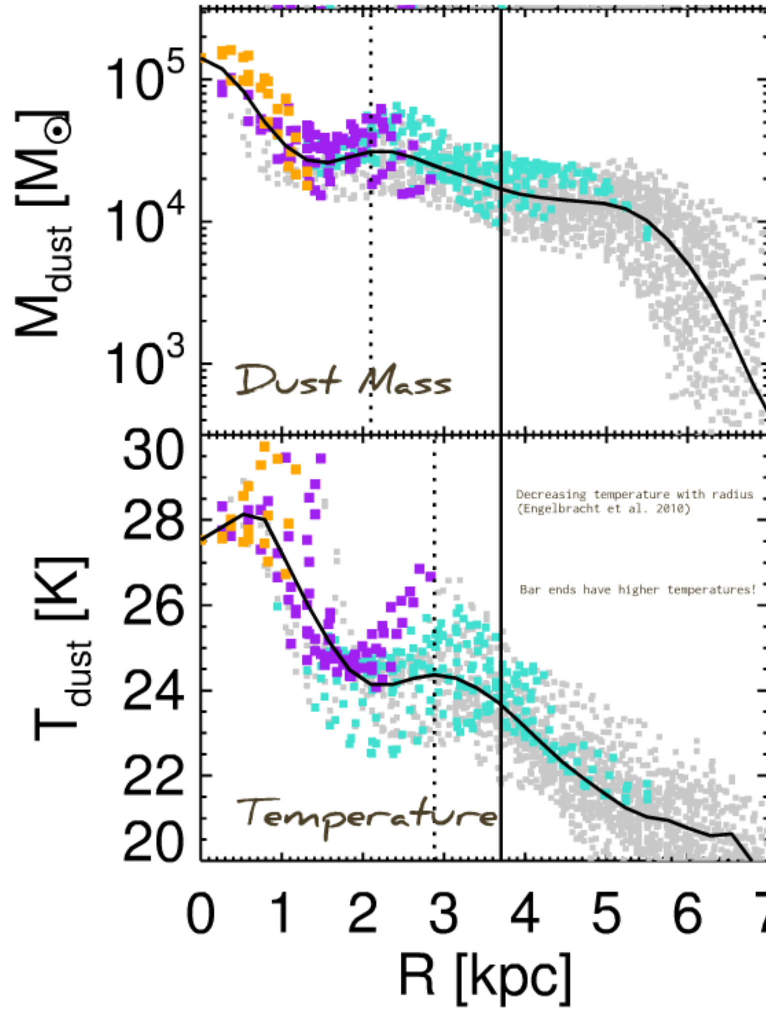
Shoulder Position

- Dust Temperature: 2.9 kpc
- SFR: 2.4 kpc
- Dust Mass: 2.1 kpc
- Molecular Gas: 2.1 kpc

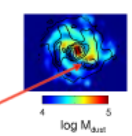


10^8
10^7
10^6
M_{H_2} [$M_\odot$]
classic molecular gas
profile for a barred galaxy
(Nishiyama et al 2001)
shoulder
Corotation
3.7 Kpc
(Lundgren et al. 2004)
Molecular



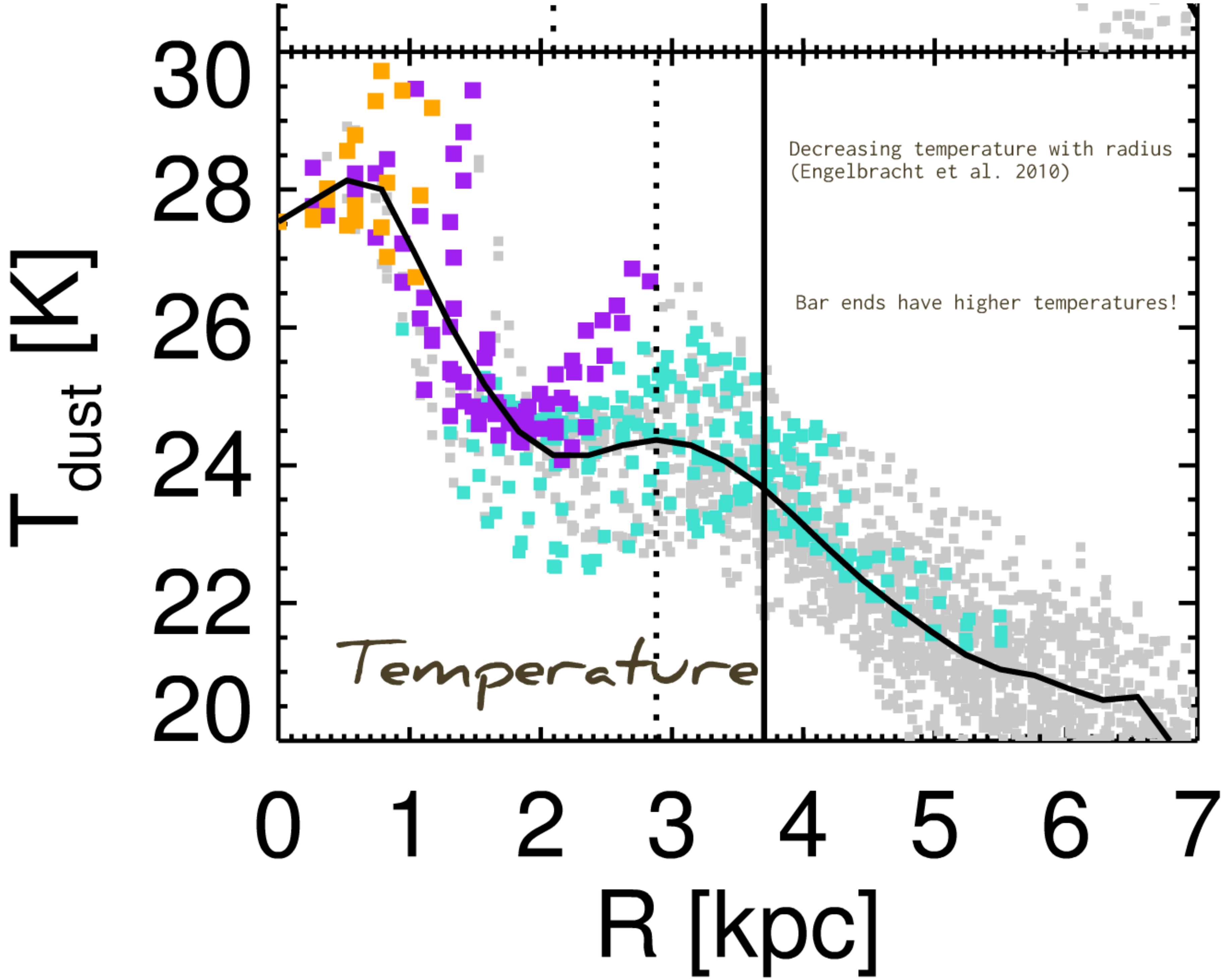


The shoulder position is related to the bar end. This position varies in different gas, SFR and dust.

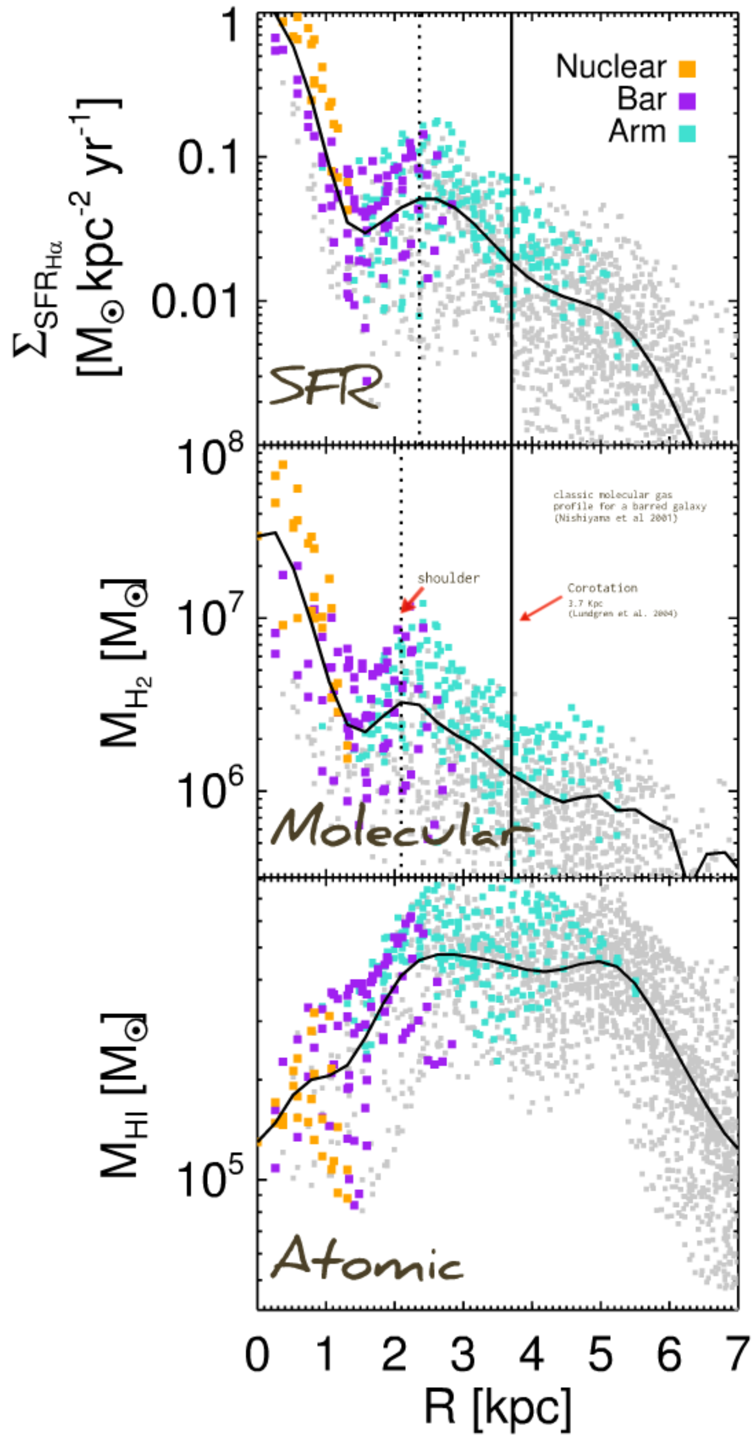


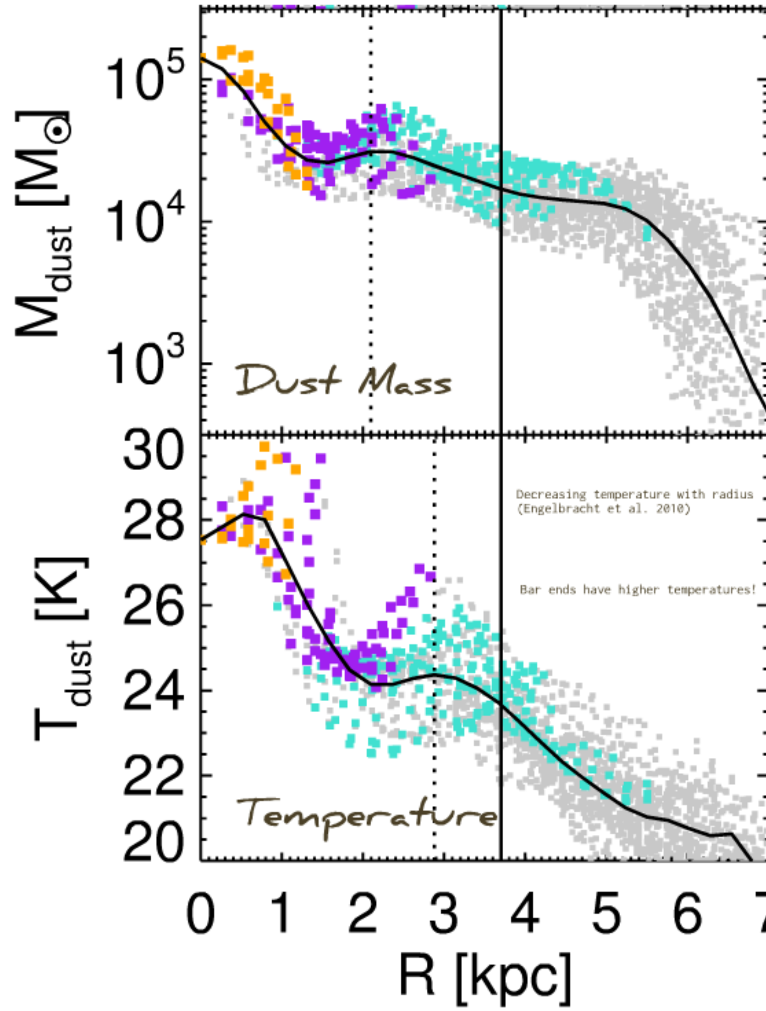
Shoulder Position

- Dust Temperature: 2.9 kpc
- SFR: 2.4 kpc
- Dust Mass: 2.1 kpc
- Molecular Gas: 2.1 kpc

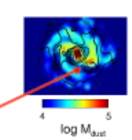


Decreasing temperature with radius
(Engelbracht et al. 2010)
Bar ends have higher temperatures!
Temperature
T_dust [K]
R [kpc]
30
28
26
24
22
20
0
1
2
3
4
5
6
7





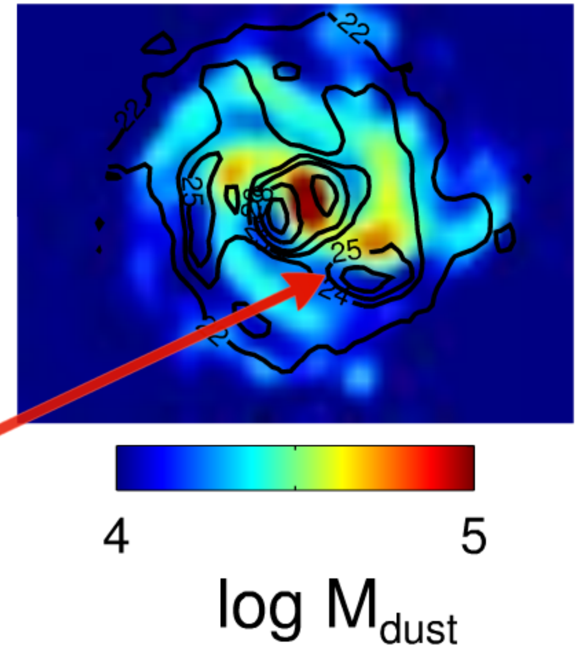
The shoulder position is related to the bar end. This position varies in different gas, SFR and dust.



Shoulder Position

- Dust Temperature: 2.9 kpc
- SFR: 2.4 kpc
- Dust Mass: 2.1 kpc
- Molecular Gas: 2.1 kpc

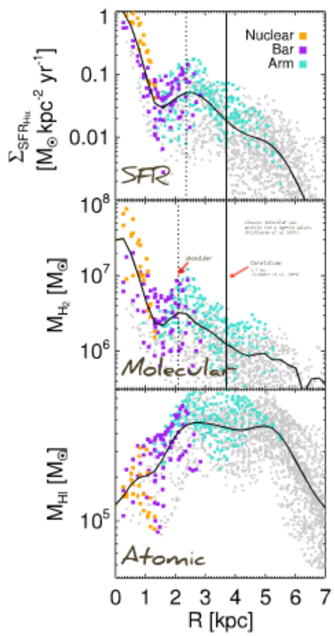
The shoulder position is related to the bar end. This position varies in different gas, SFR and dust.

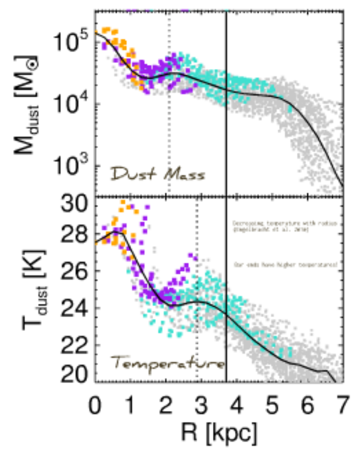


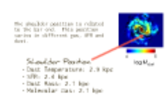
Shoulder Position

- Dust Temperature: 2.9 kpc
- SFR: 2.4 kpc
- Dust Mass: 2.1 kpc
- Molecular Gas: 2.1 kpc

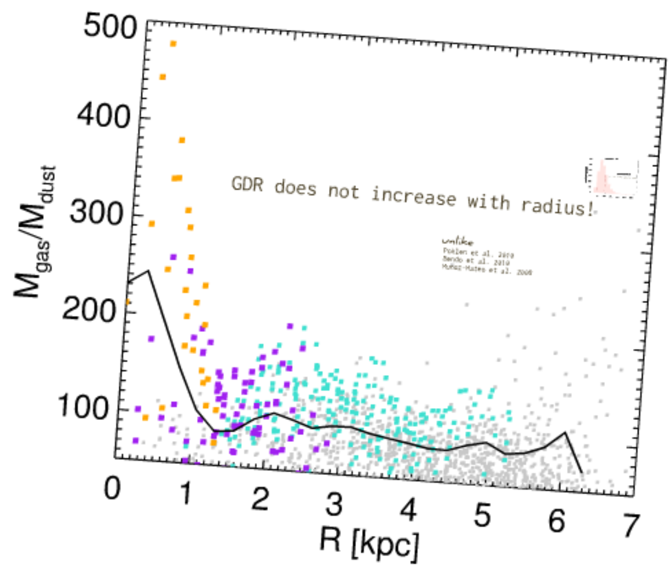
Radial Profiles







Gas-To-Dust Ratio

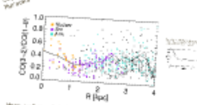


GDR does not increase with radius!

unlike
Pohlen et al. 2010
Bendo et al. 2010
Muñoz-Mateos et al. 2009

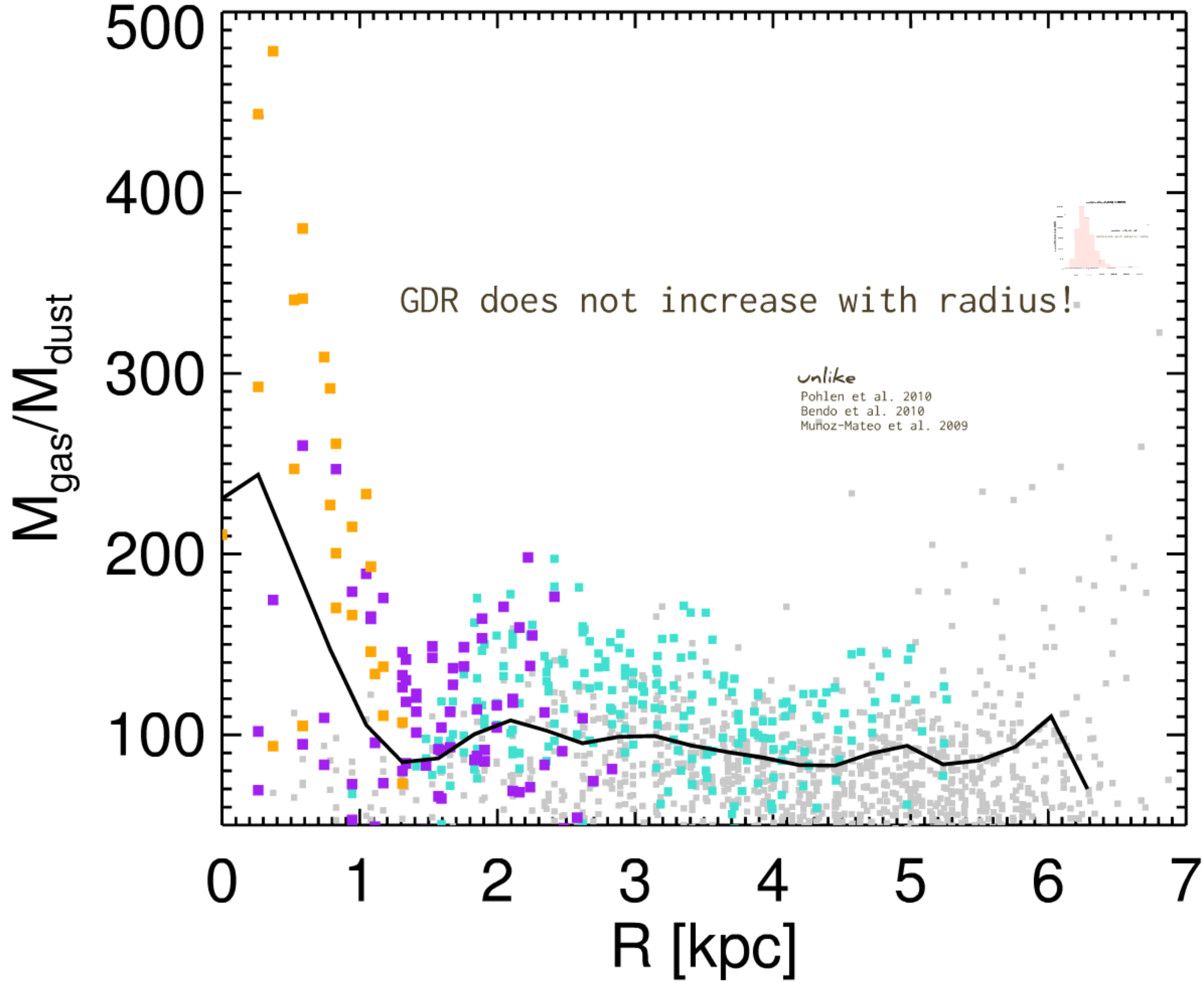
Why are the values high in the inner region?

Molecular gas dominates here!
- Xco factor (metallicity)?
- CO(3-2) to CO(1-0)?



Mean value of 0.3 but higher in the inner regions!

83



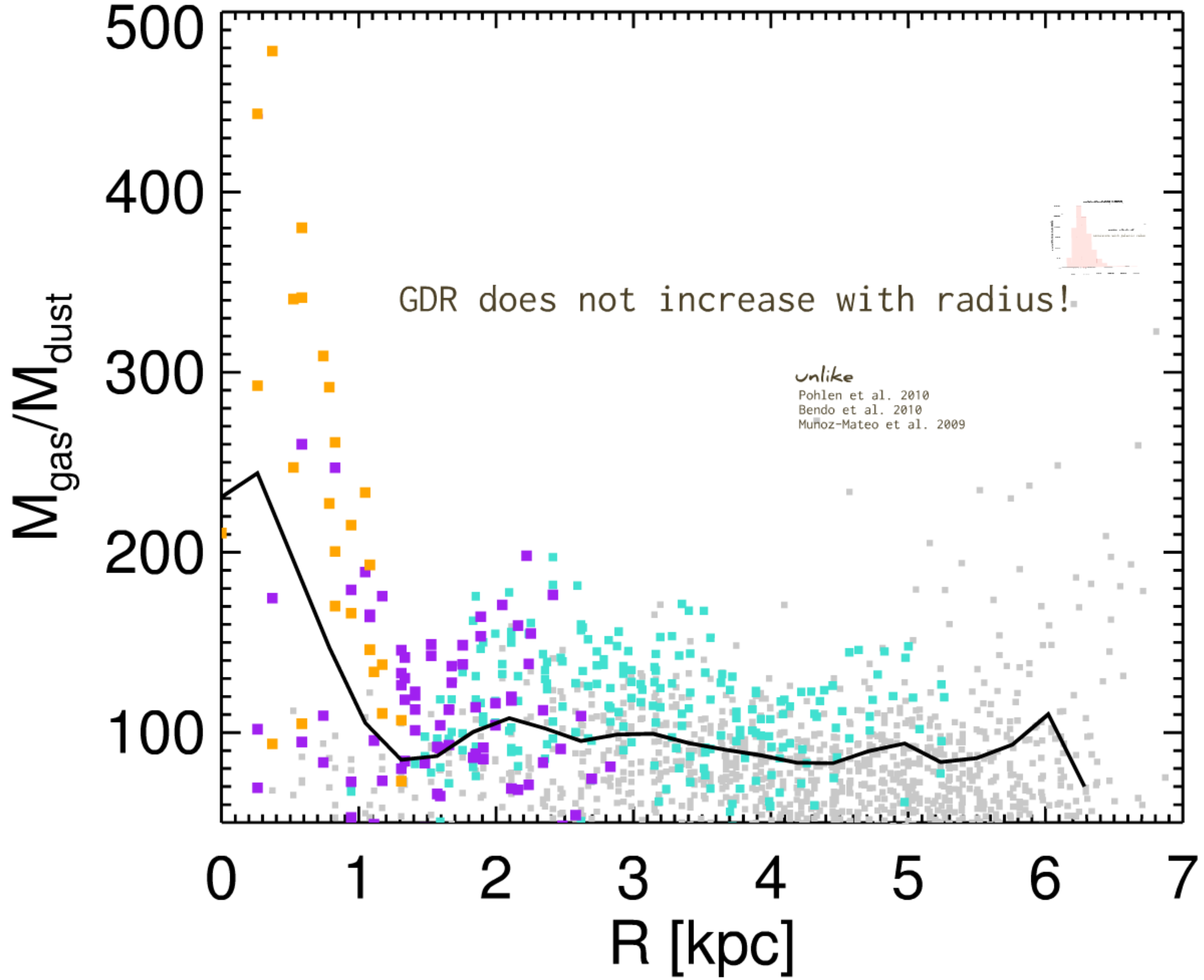
GDR does not increase with radius!
unlike
Pohlen et al. 2010
Bendo et al. 2010
Munoz-Mateo et al. 2009
M_{gas}/M_{dust}
500
400
300
200
100
0
1
2
3
4
5
6
7
R [kpc]

unlike

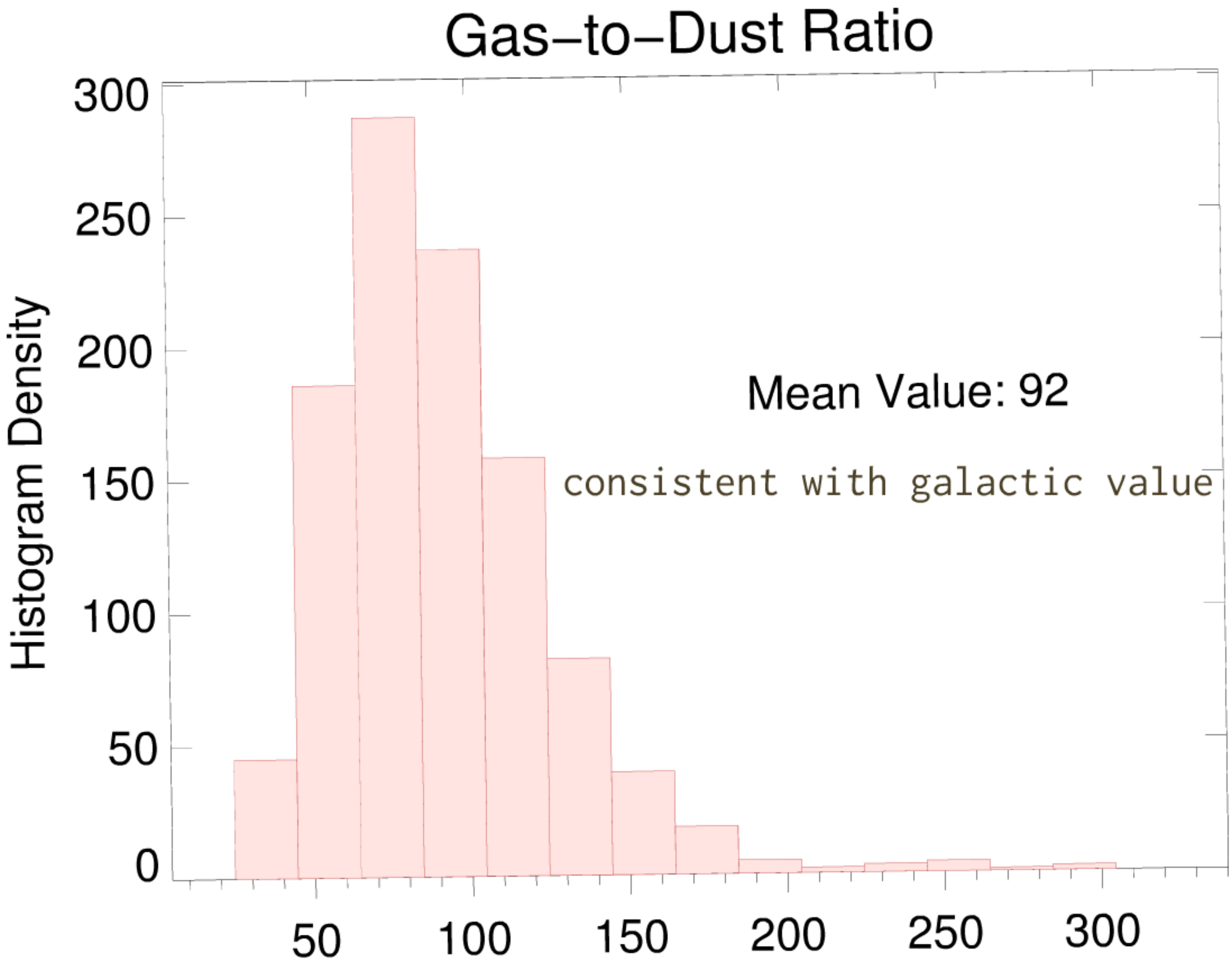
Pohlen et al. 2010

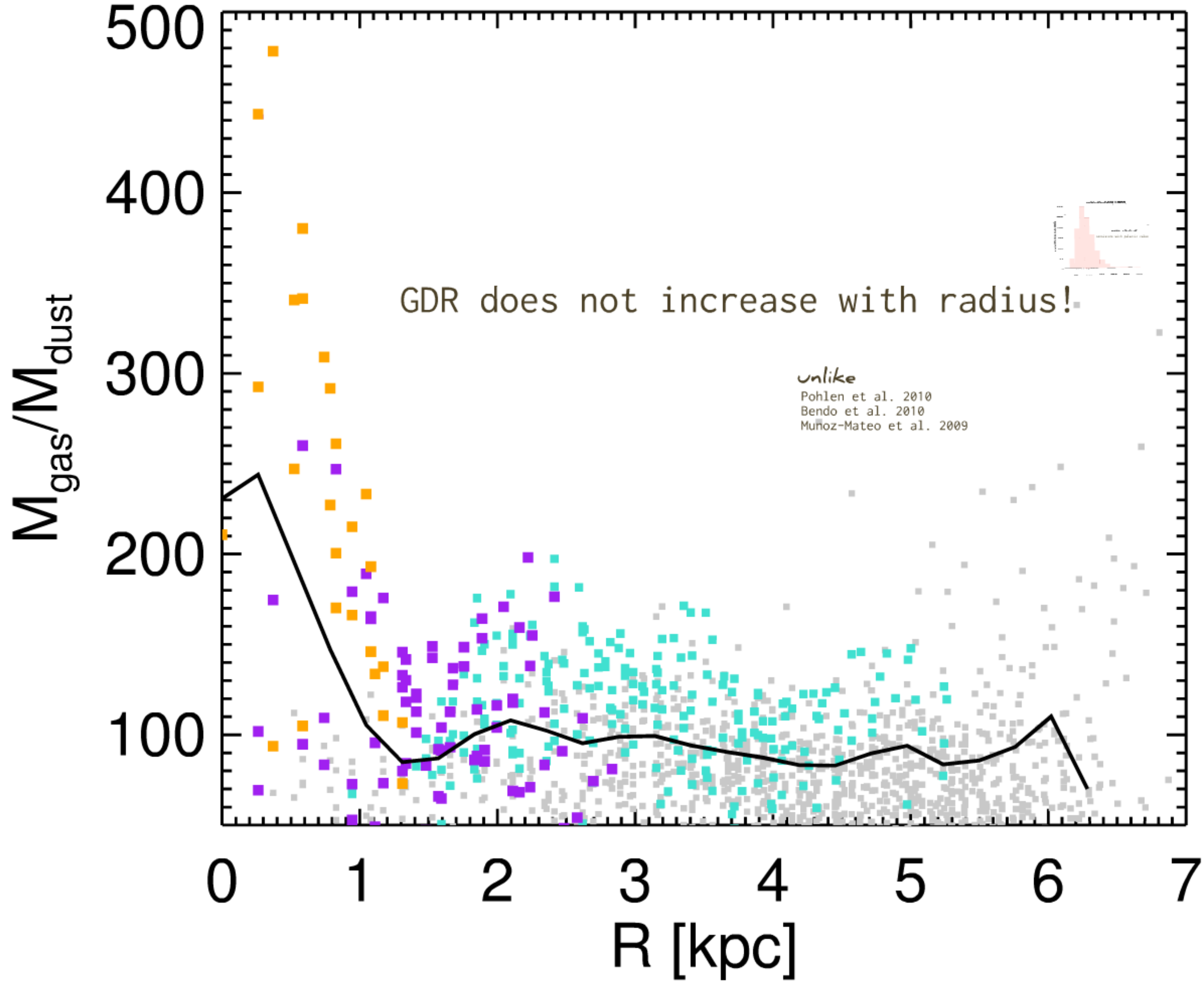
Bendo et al. 2010

Munoz-Mateo et al. 2009



GDR does not increase with radius!
unlike
Pohlen et al. 2010
Bendo et al. 2010
Muñoz-Mateo et al. 2009
M_{gas}/M_{dust}
500
400
300
200
100
0
1
2
3
4
5
6
7
R [kpc]


Gas–to–Dust Ratio
Histogram Density
Mean Value: 92
consistent with galactic value
0
50
100
150
200
250
300
50
100
150
200
250
300



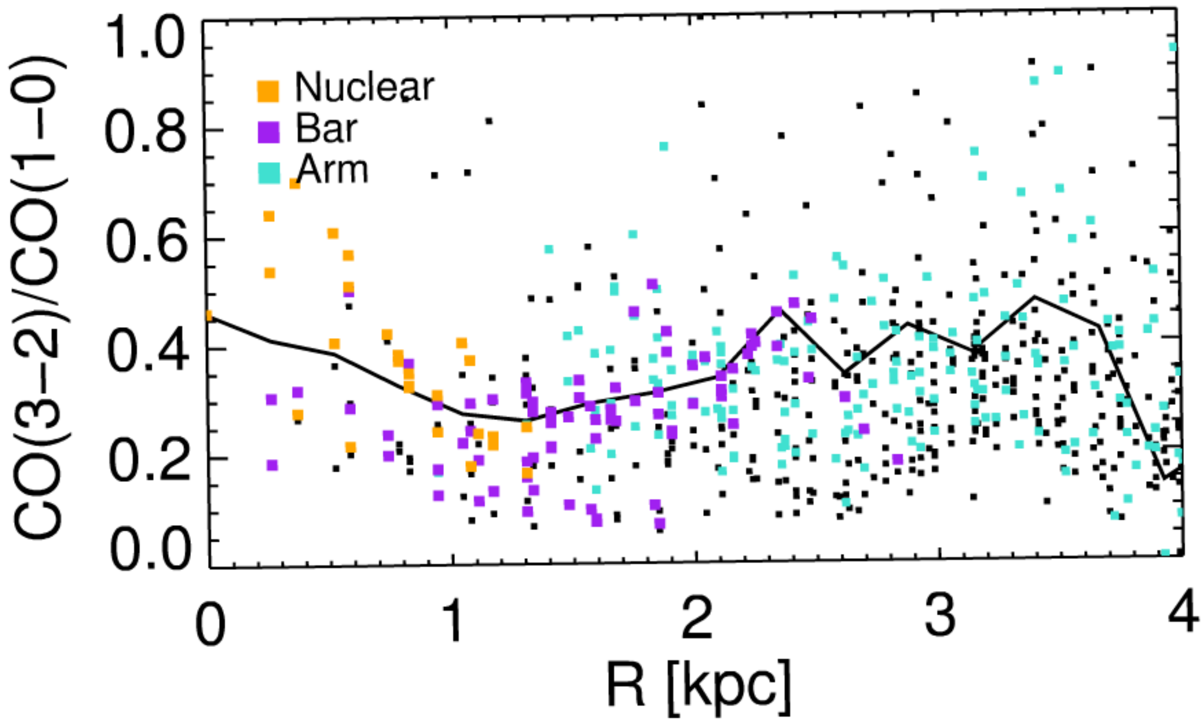
500
400
300
200
100
0
1
2
3
4
5
6
7
R [kpc]
M_{gas}/M_{dust}
GDR does not increase with radius!
unlike
Pohlen et al. 2010
Bendo et al. 2010
Munoz-Mateo et al. 2009

Why are the values high in the inner region?

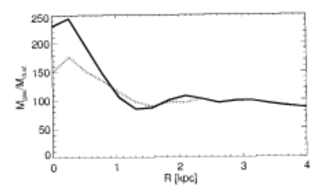
Molecular gas dominates here!

- Xco factor (metallicity)?
- CO(3-2) to CO(1-0)?

CO(1-0) from Nobeyama 45m
Muraoka et al. 2009

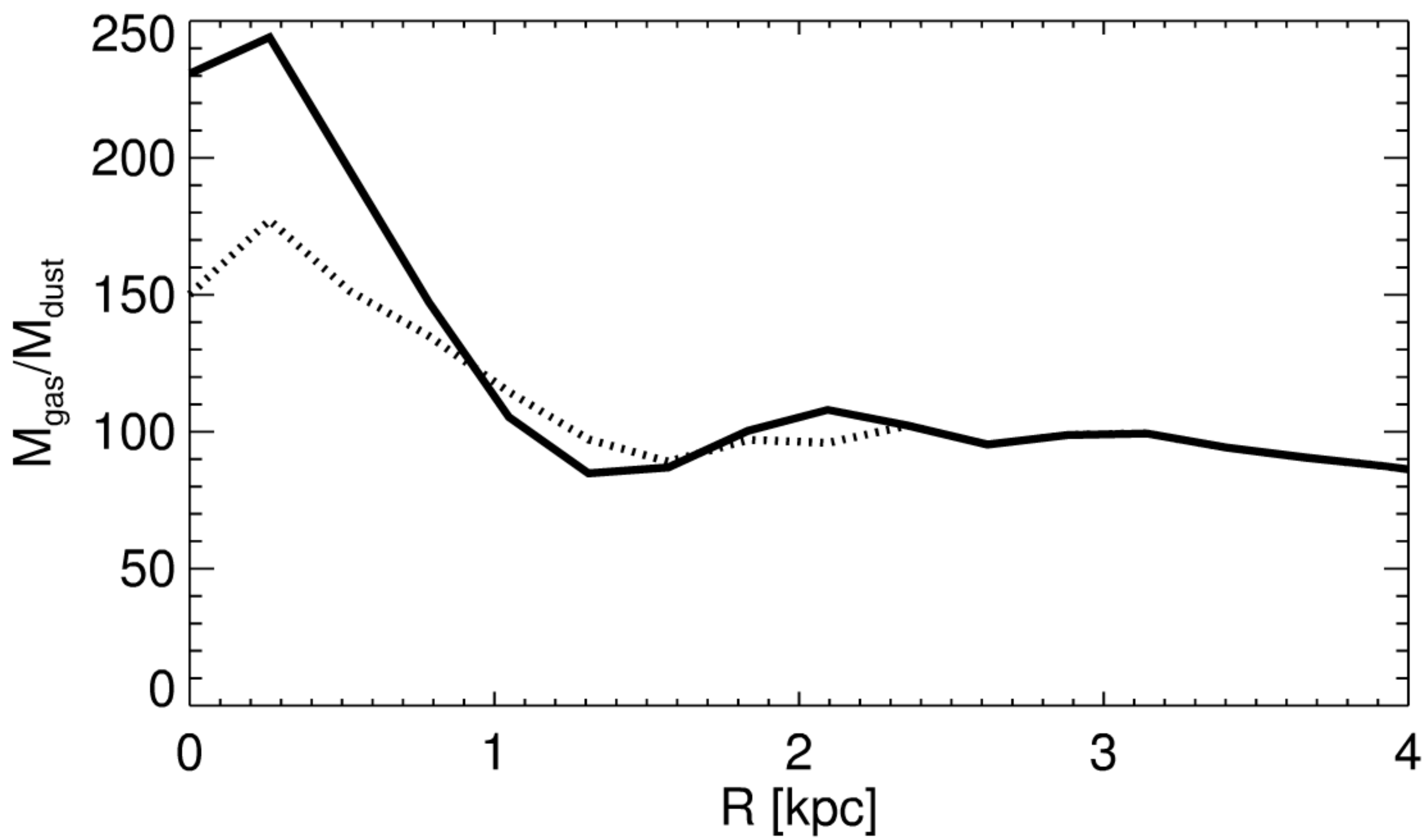


By using a radially varying CO(3-2) conversion to CO(1-0) the GDR is reduced in the inner region.

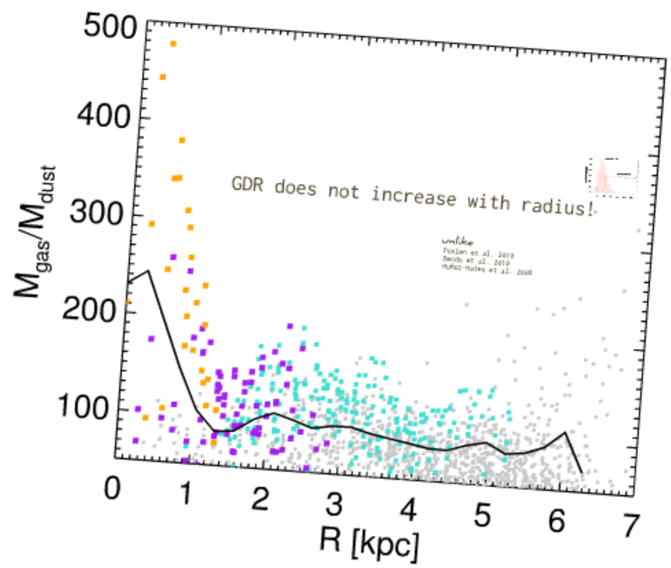


Mean value of 0.3 but higher in the inner regions!

By using a radially varying CO(3-2) conversion to CO(1-0) the GDR is reduced in the inner region.

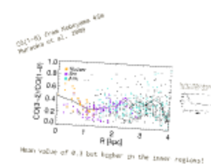


Gas-To-Dust Ratio



Why are the values high in the inner region?

Molecular gas dominates here!
- Xco factor (metallicity)?
- CO(3-2) to CO(1-0)?




Dust Temperature
VNGS
Very Nearby Galaxy Survey
Gas-To-Dust Ratio
Dust Mass
Resolving the Dust in M83
Kelly Foyle
McMaster University
C. Wilson, G. Bendo & E. Mentuch
Radial Profiles
Dust, Gas & SFR
SFR?
Bar Profile

in summary...

Total dust mass 3×10^{7} Msolar

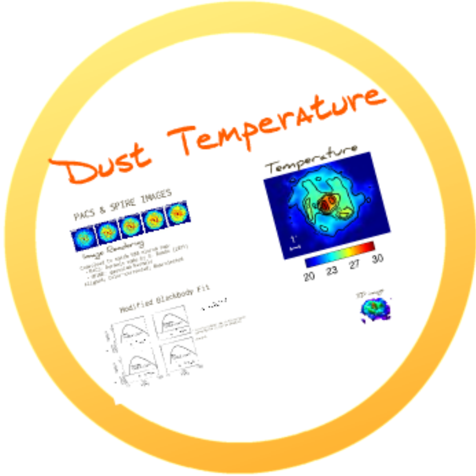
dust temp decreases with increasing atomic gas

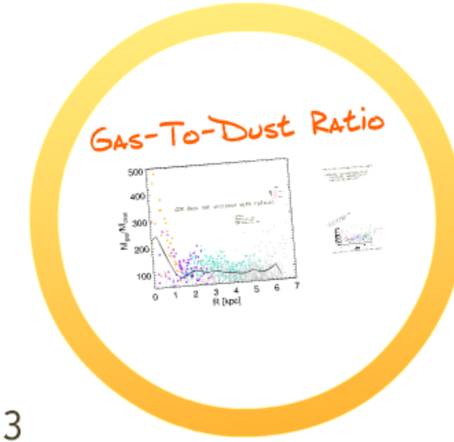
Dust mass correlated with molecular gas & SFR

GDR ~100

Dust mass peaks offset from temp

Two temperature peaks in nucleus





Resolving the Dust in M83

Kelly Foyle

McMaster University

C. Wilson, G. Bendo & E. Mentuch