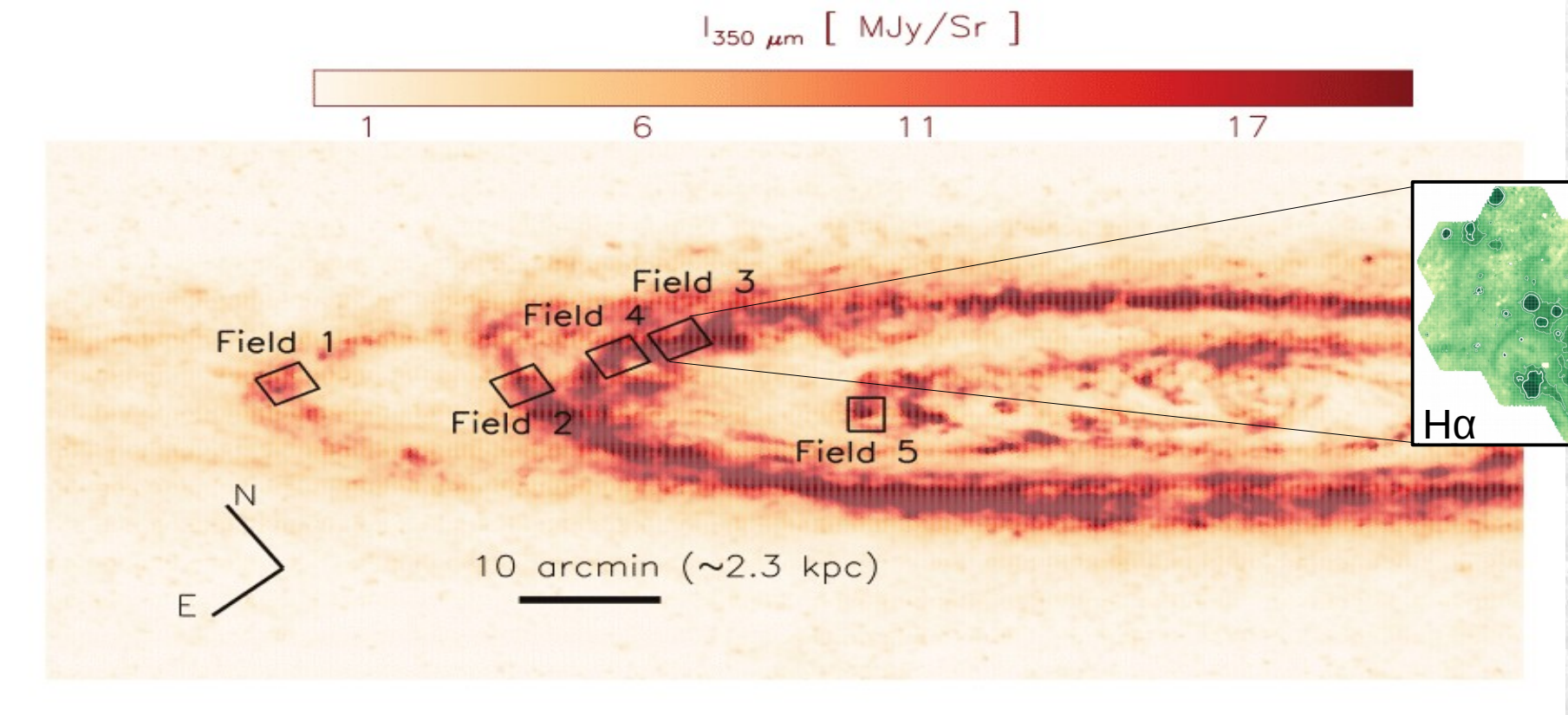
Dust/gas distribution and Star Formation tracers in M31

Neven Tomičić (MPIA, Germany), Kathryn Kreckel, Eva Schinnerer, Brent Groves, Karin Sandstrom, Tom Jarret, David Thilker, I-Ting Ho, Guillermo A. Blanc, Maria Kapala, Adam Leroy



MPIA

SFDE16
ICISE, Quy Nhon,
Vietnam, 8.8.2017.

tomicic@mpia.de
Tomičić et al. 2017, *ApJ 844:155*
Tomičić et al. 2017b, *in progress*

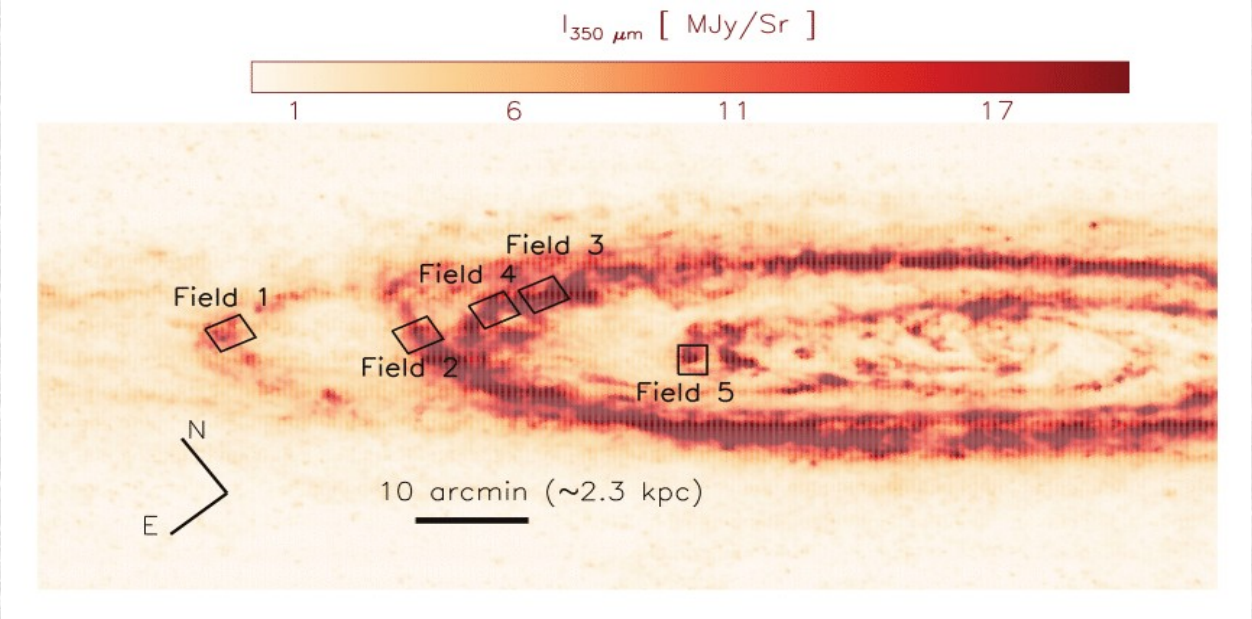
Outline:

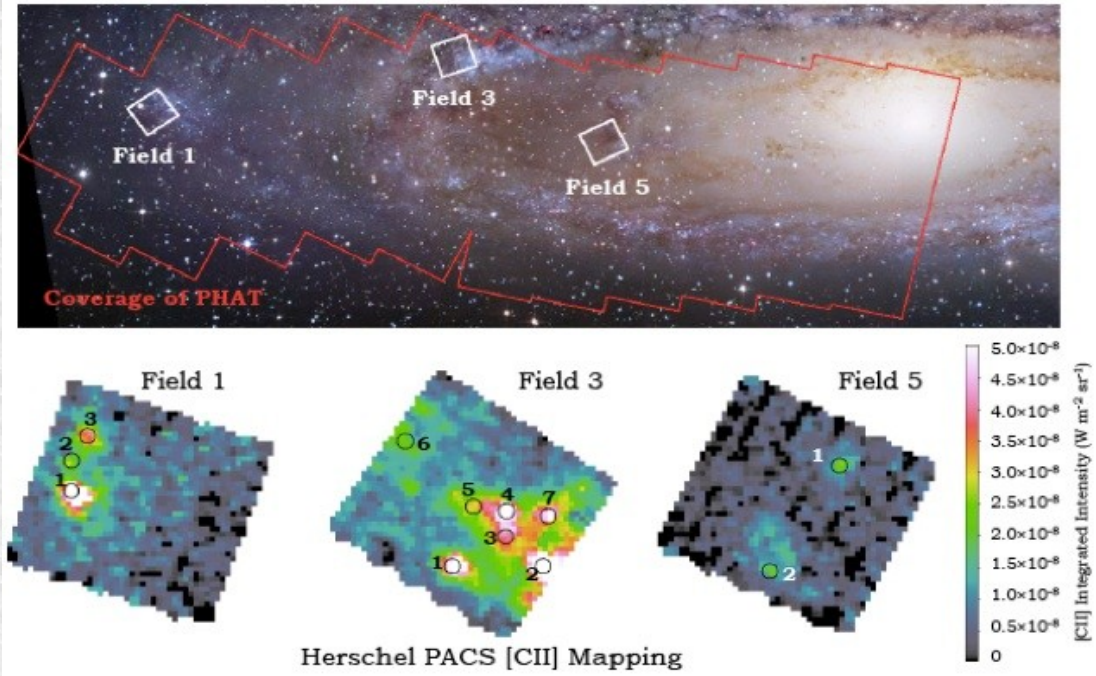
Target: 5 Fields in M31
Method: **IFU**
Small & large scales: 10 pc – 1 kpc

DUST/GAS distribution

Results

Conclusion





PHAT colaboration: K. Sandstrom led Herschel PACS + Optical IFU line imaging survey **SLIM**

Outline:

Target: 5 Fields in M31
Method: **IFU**
Small & large scales: 10 pc – 1 kpc

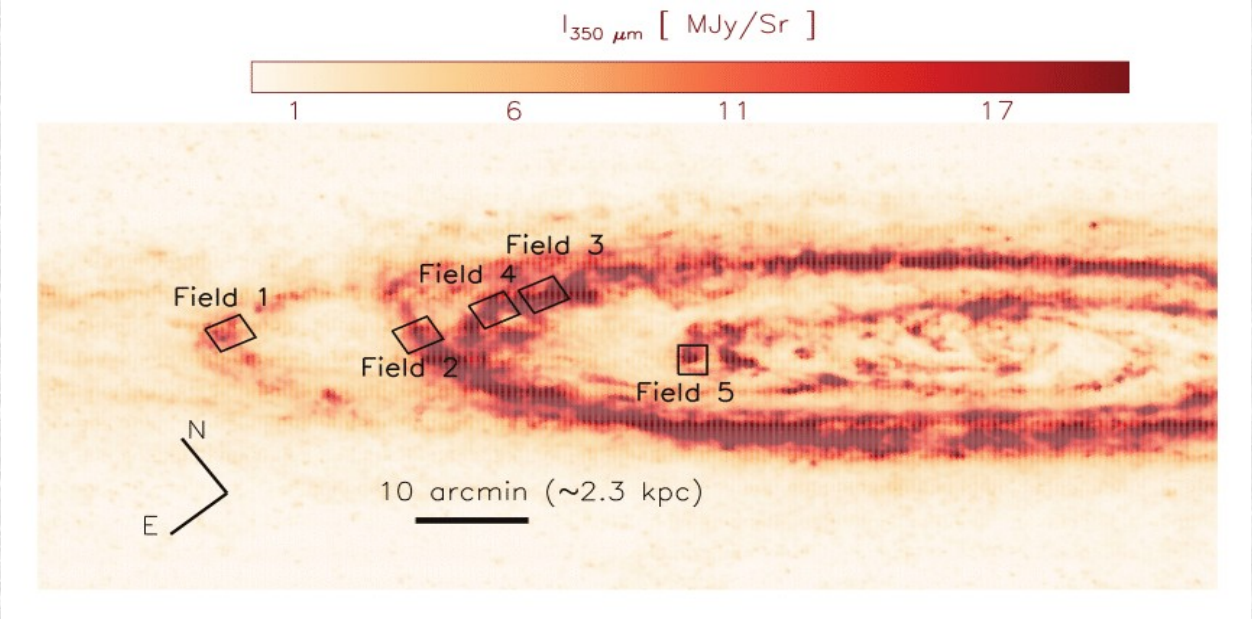
DUST/GAS distribution

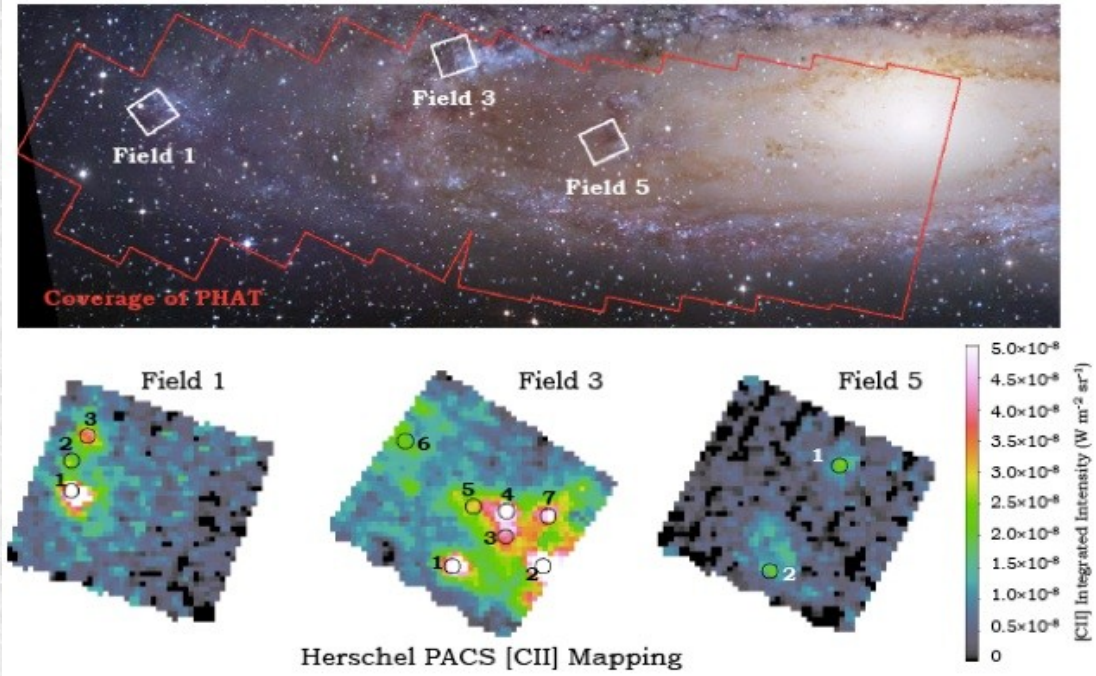
Results

Conclusion

STAR FORMATION TRACERS

First results





PHAT colaboration: K. Sandstrom led Herschel PACS + Optical IFU line imaging survey **SLIM**

Spatial distribution of dust and ionised gas

↓

Attenuation (A_V, Balmer) vs. Σ_{dust}

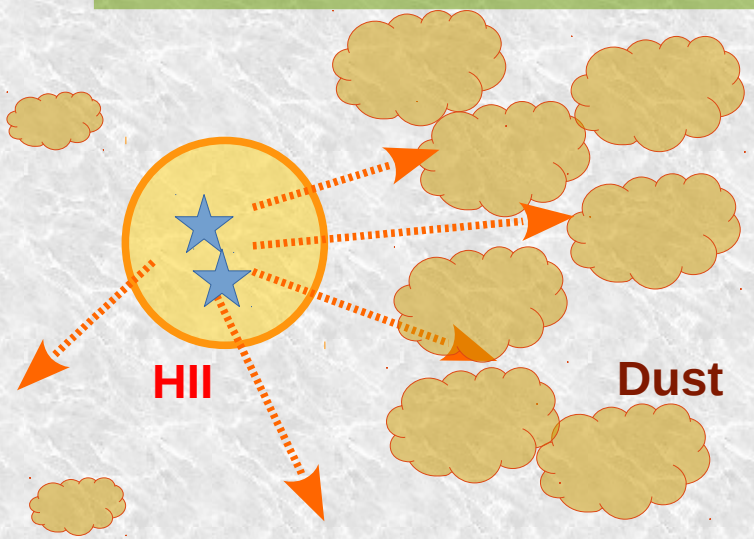
Spatial distribution of dust and ionised gas

↓

Attenuation (A_V, Balmer) vs. Σ_{dust}

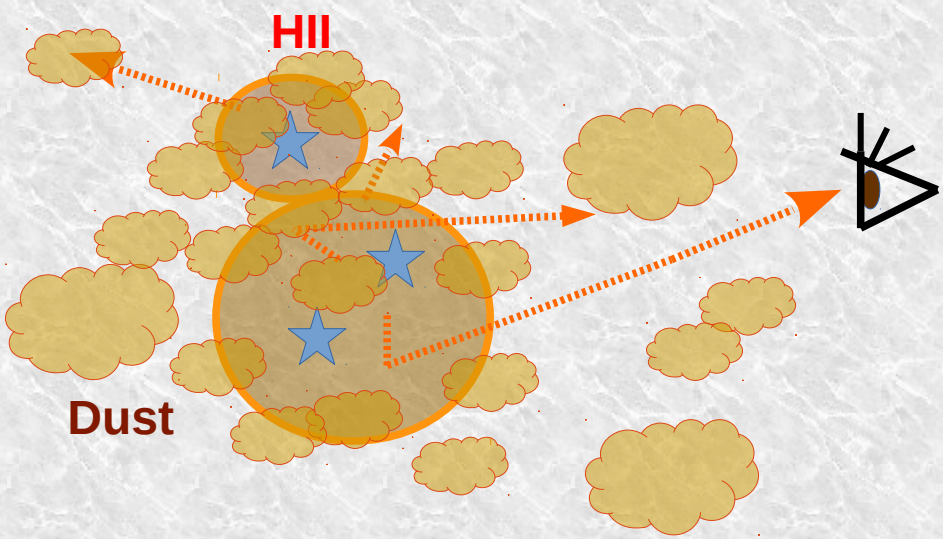
Calzetti et al. 1994

FOREGROUND SCREEN MEDIUM



$A_{V,screen}$ ~ Dust

MIXED MEDIUM

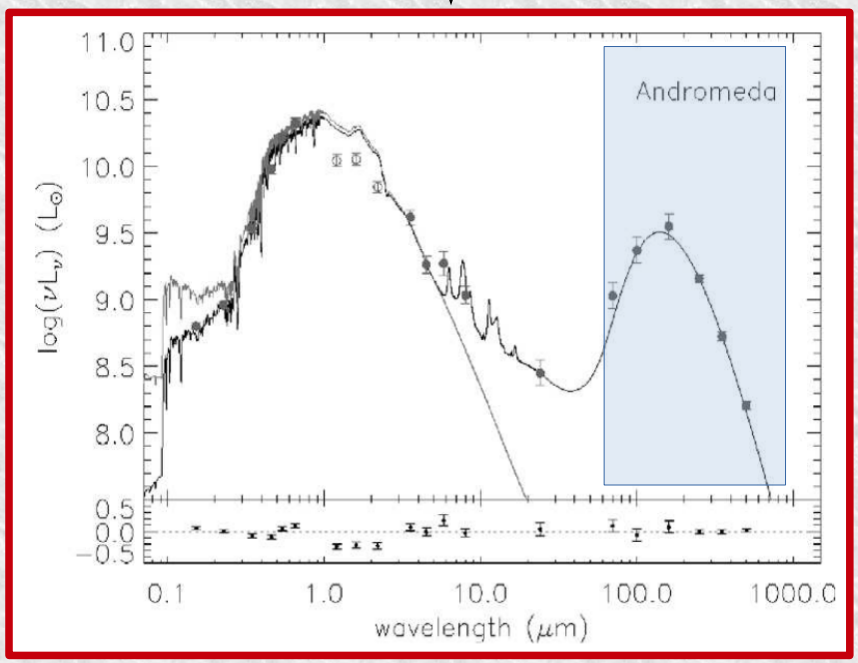


$A_{V,mixed} < A_{V,screen}$

DUST vs. **ATTENUATION**

Infra-Red (70-500 µm),
SED fitting,
Draine & Li model (2007) of grains

HERSCHEL TELESCOPE
(SPIRE, PACS,...)



c. Groves et al. 2012

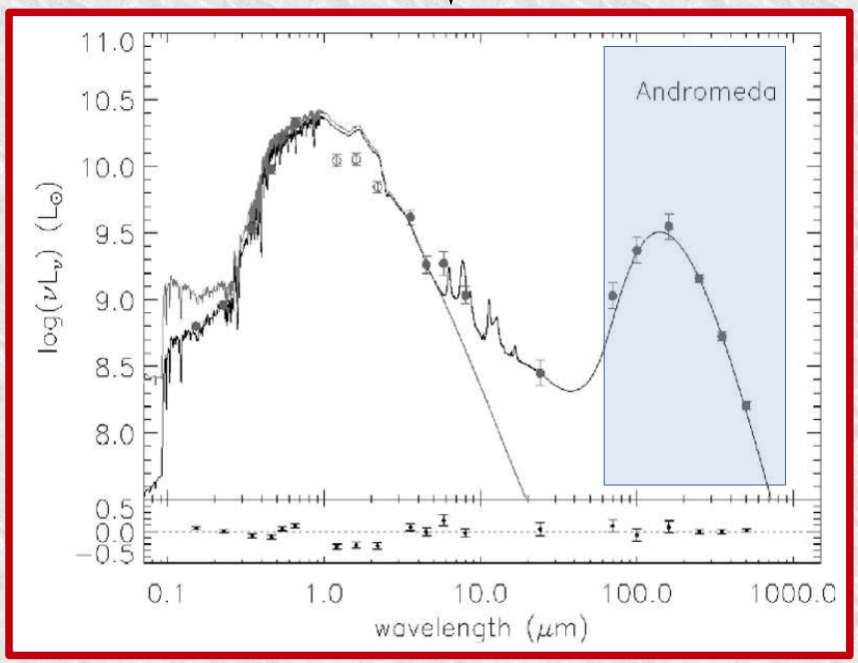
DUST

vs.

ATTENUATION

Infra-Red (70-500 μm),
SED fitting,
Draine & Li model (2007) of grains

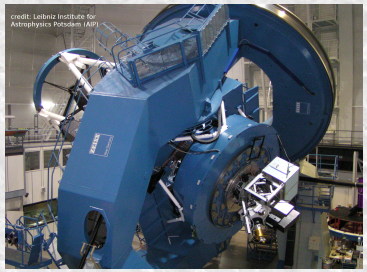
HERSCHEL TELESCOPE
(SPIRE, PACS,...)



c. Groves et al. 2012

OPTICAL SPECTRUM

Integral Field
Spectroscopy **(IFU)**
[Calar Alto 3.5 Telescope]
+
Simple Stellar Population
fitting (Sarzi et al. 2006)



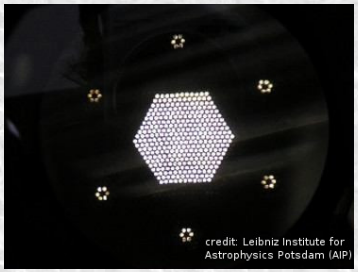
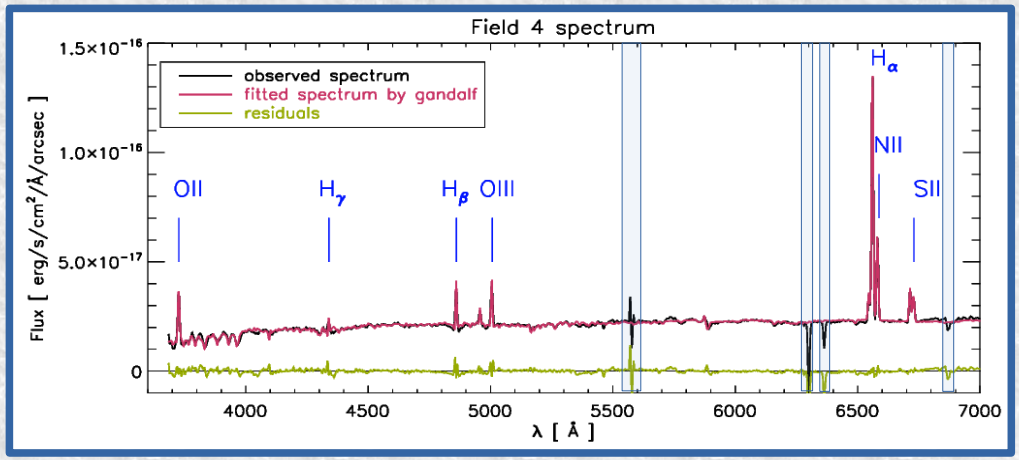


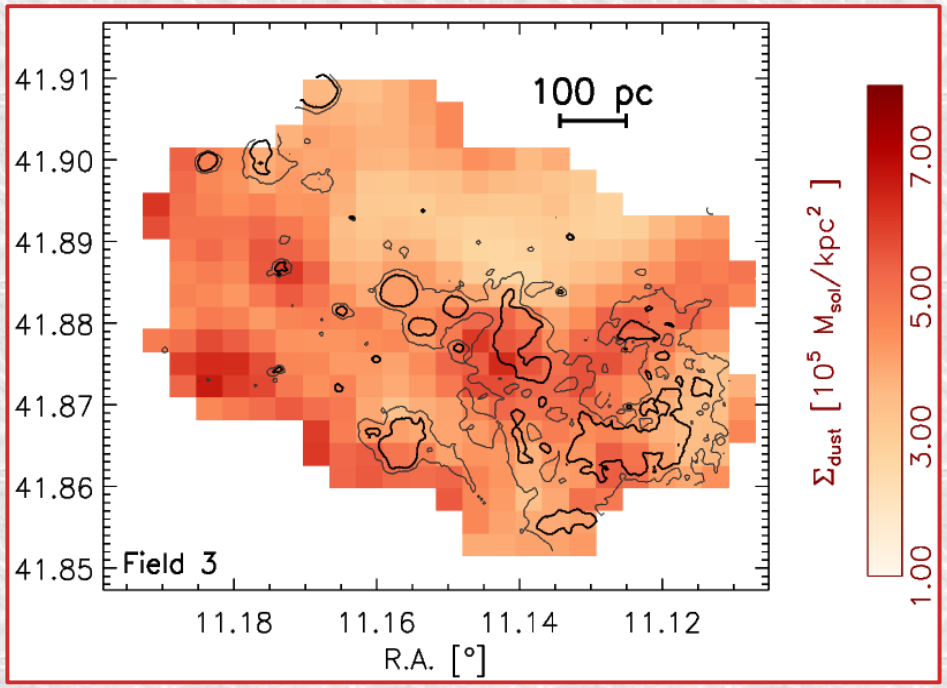
Fig: Calar Alto & IFU; c. AIP



c. Tomičić et al. 2017

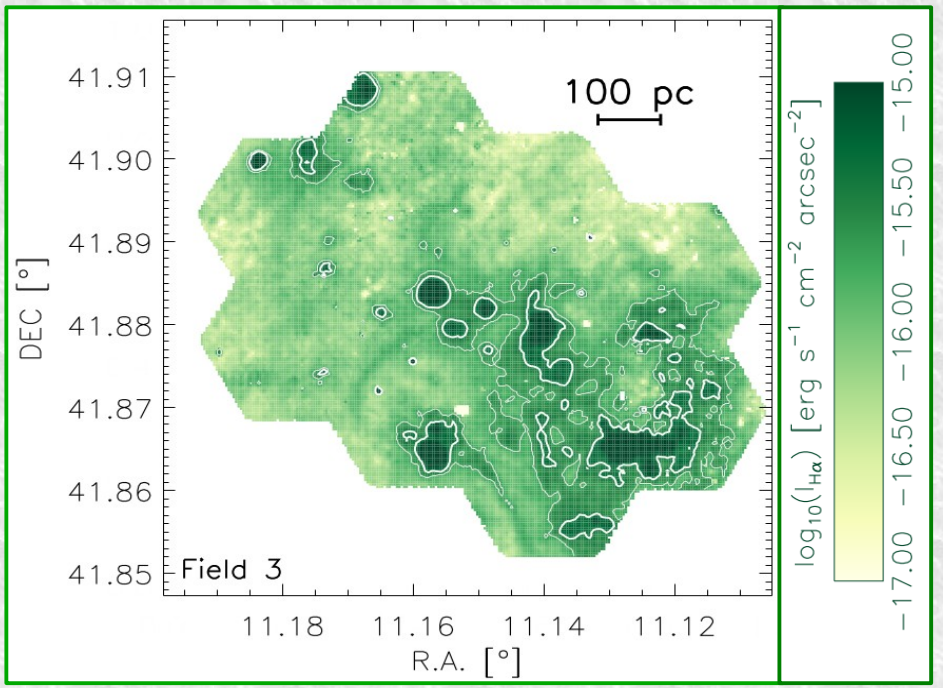
25" (100 pc)

Σ_{dust}



2.7" (10 pc)

Hα

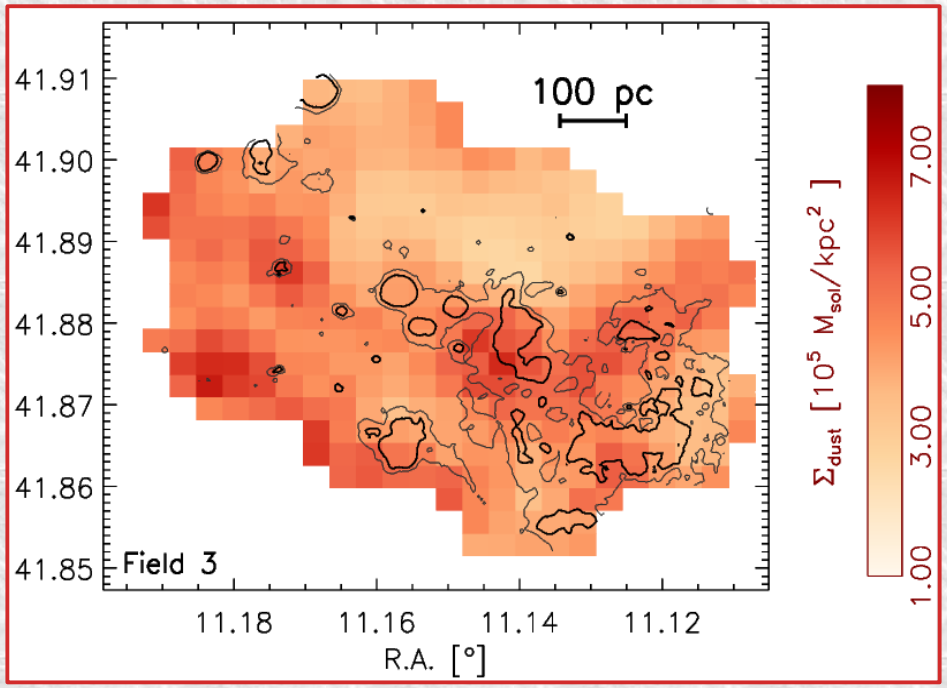


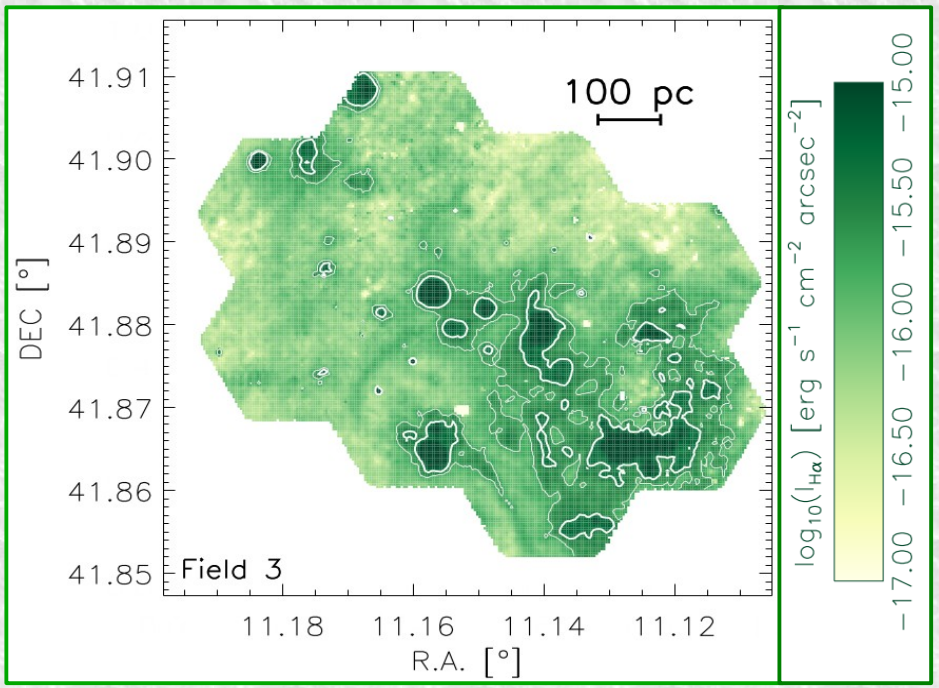
c. Tomičić+17

CONVOLUTION

25" (100 pc) → Σ_{dust}

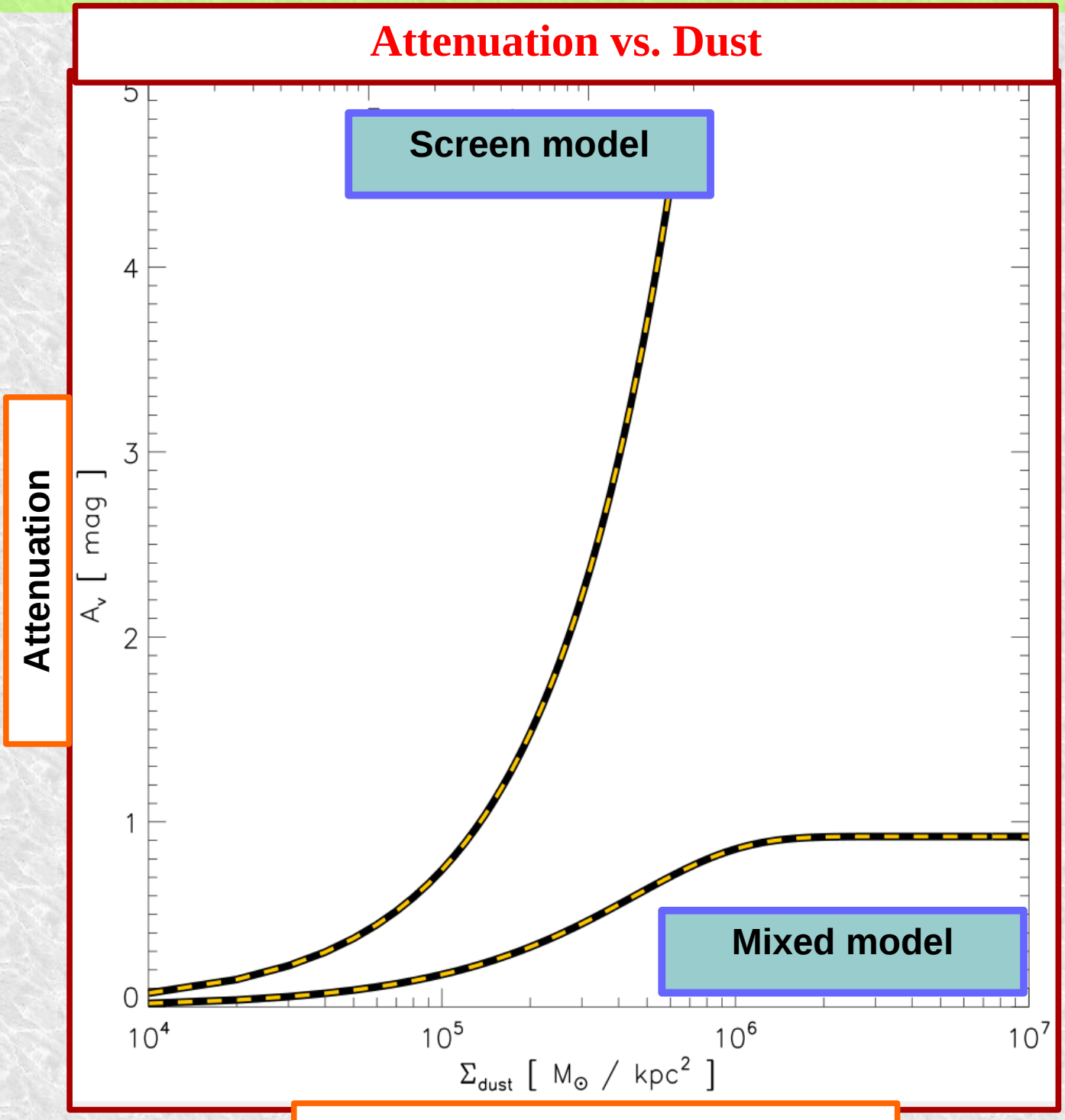
2.7" (10 pc) → **Hα**





c. Tomičić+17

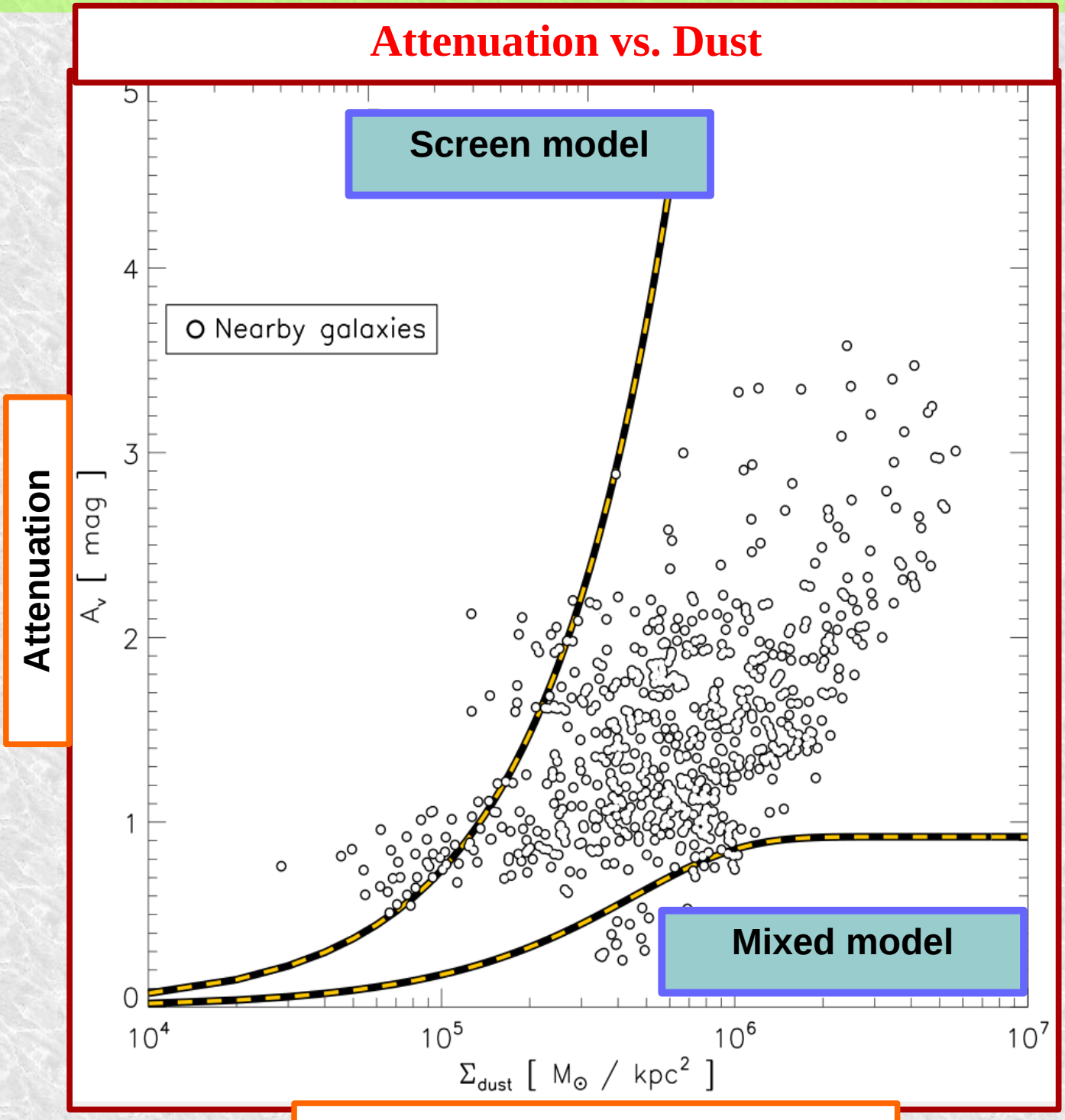
Main result :



c. Tomičić+17

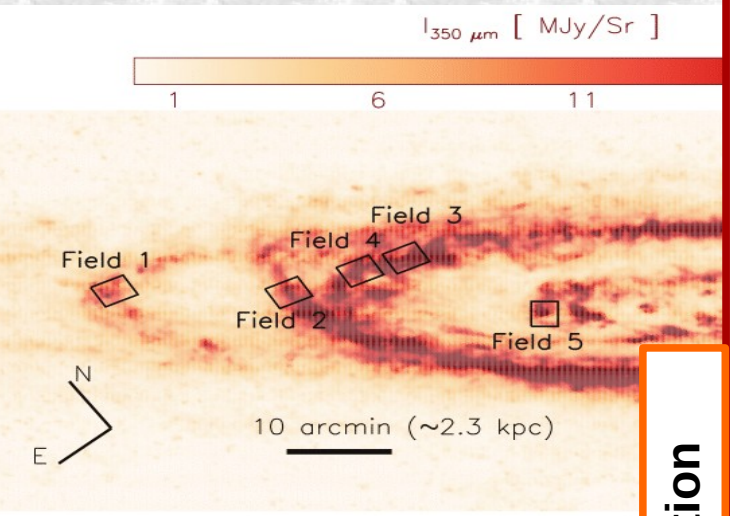
Main result :

Nearby galaxies:
c. Kreckel+13
(0.3 – 2 kpc)

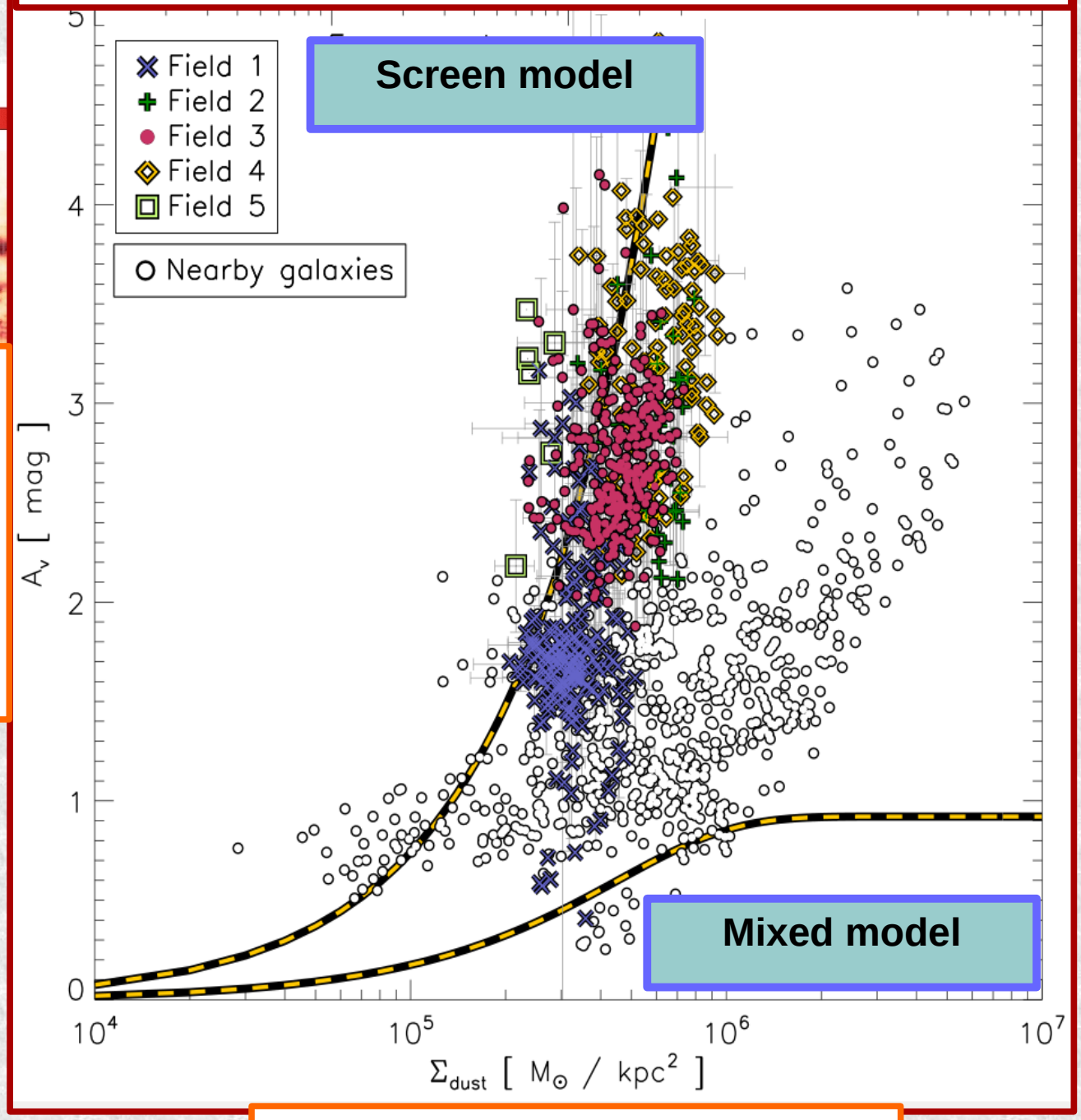


c. Tomičić+17

Main result :



Attenuation vs. Dust

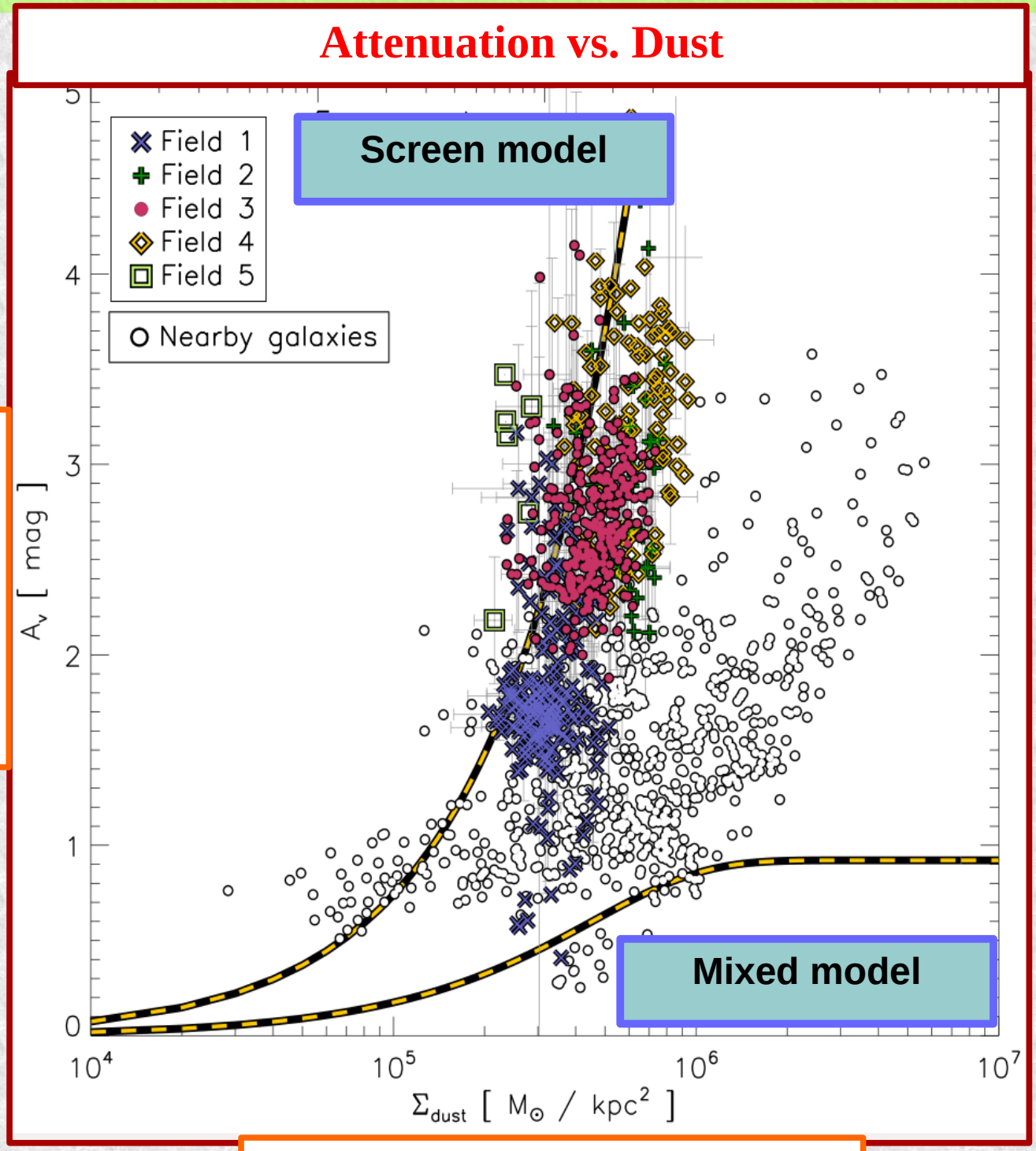


c. Tomičić+17

Main result :

Difference:

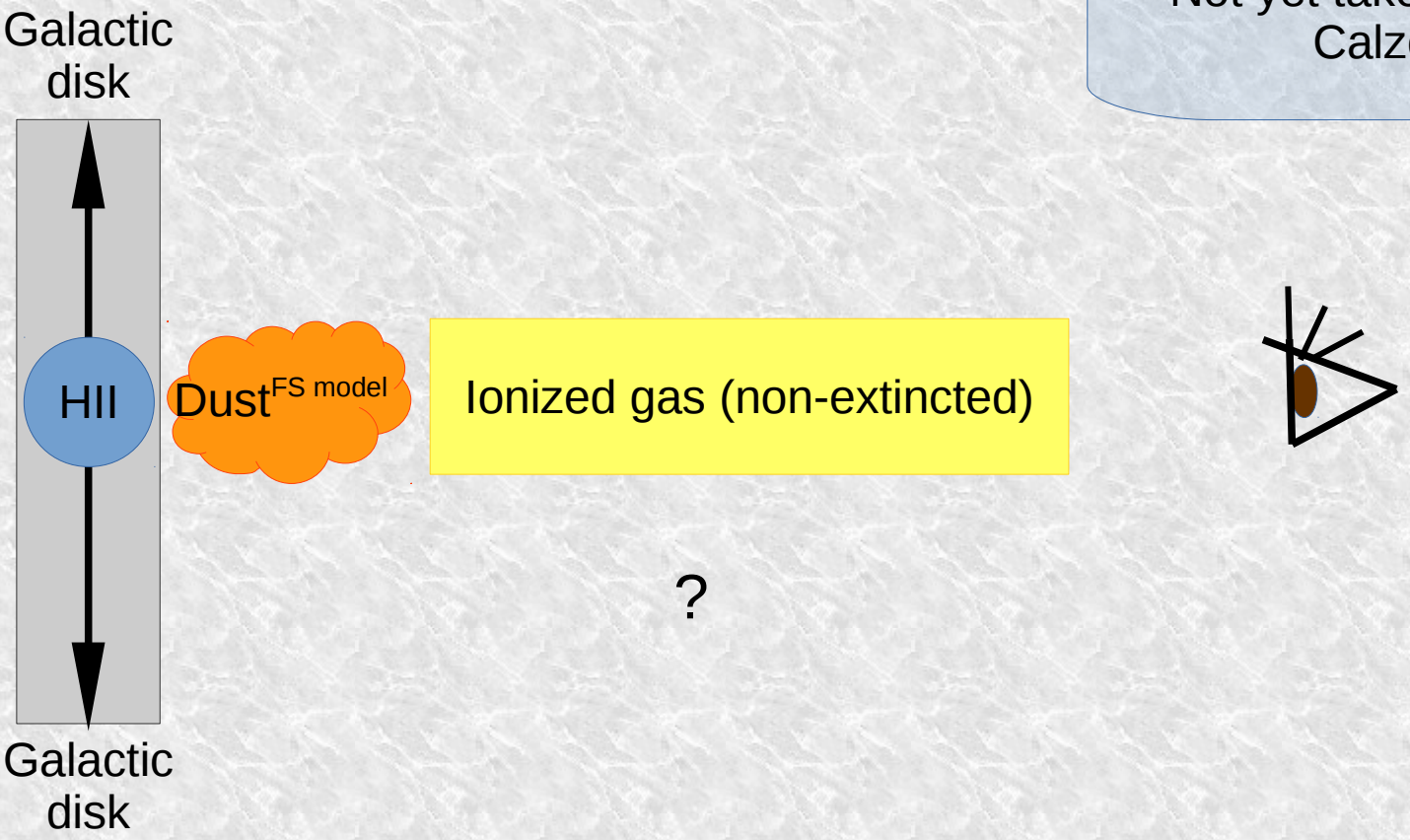
- M31 different galaxy?
- Extinction curve?
- inclination?
- Scales?
- <u>contribution from non-attenuated gas?</u>



c. Tomičić+17

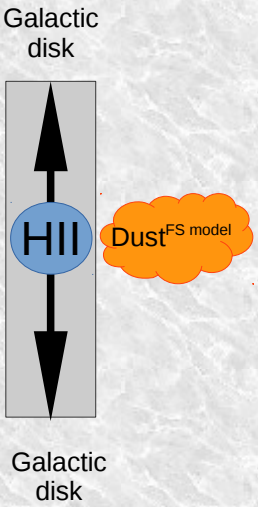
Does non-attenuated ionized gas affect results?

Not yet taken into account in Calzetti models



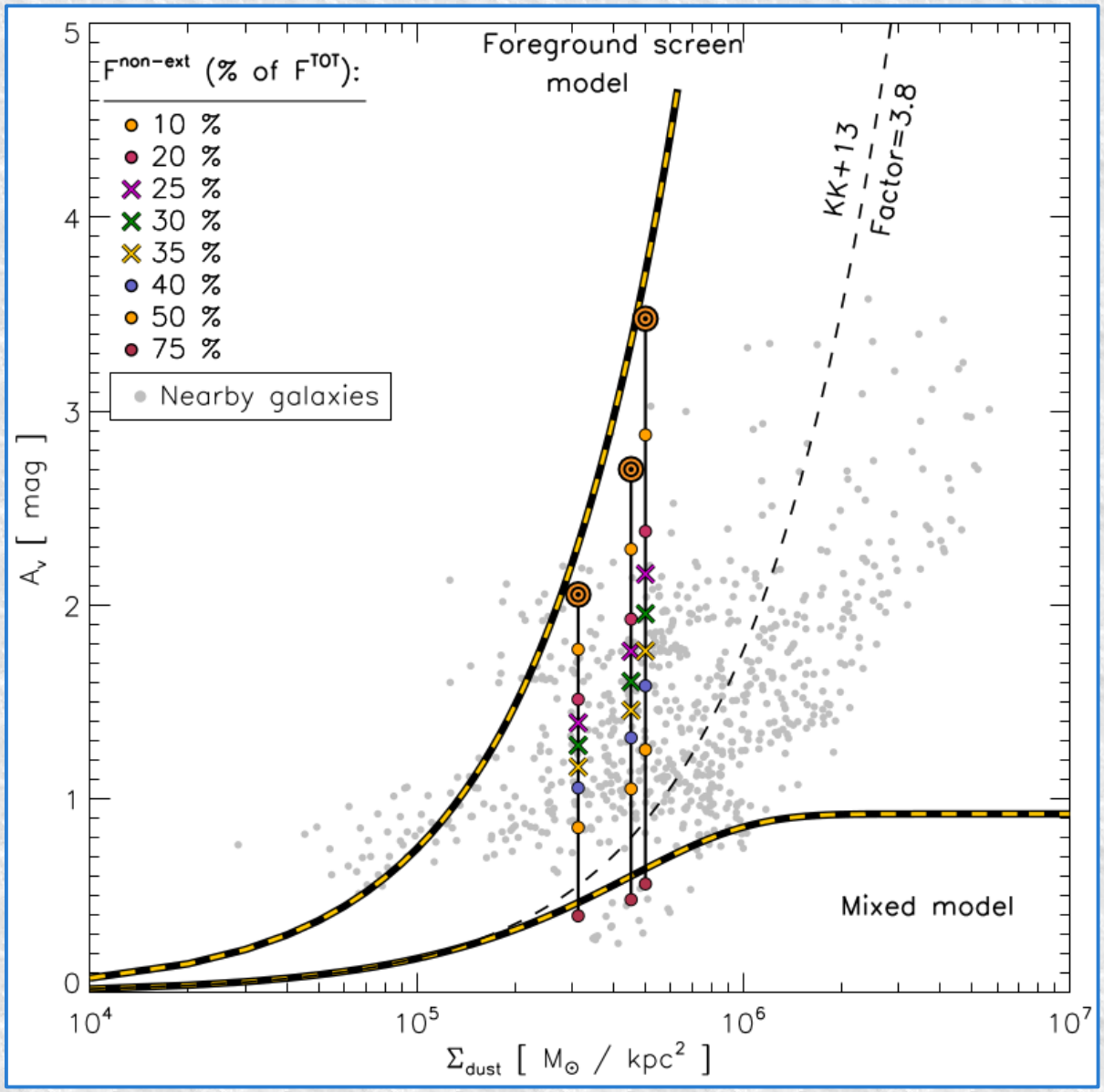
Varying HII/Dust/DIG distribution

Adding different amounts of unattenuated gas flux



Ionized gas (non-extincted)

?



c. Tomičić+17

Diffuse ionized gas (DIG)

Warm **I**onised **M**edium (**WIM**)
=
Diffuse **I**onised **M**edium (**DIG**)

Not yet taken into account in Calzetti models

- Warm (10^4 K)
- low density (10^{-1} cm^{-3})
- kilo-parsecs scales
- **SII/Hα > 0.2**
- **Sources**:
  OB stars
  SN remnants
  stellar winds
  clumpy (fractal) ISM

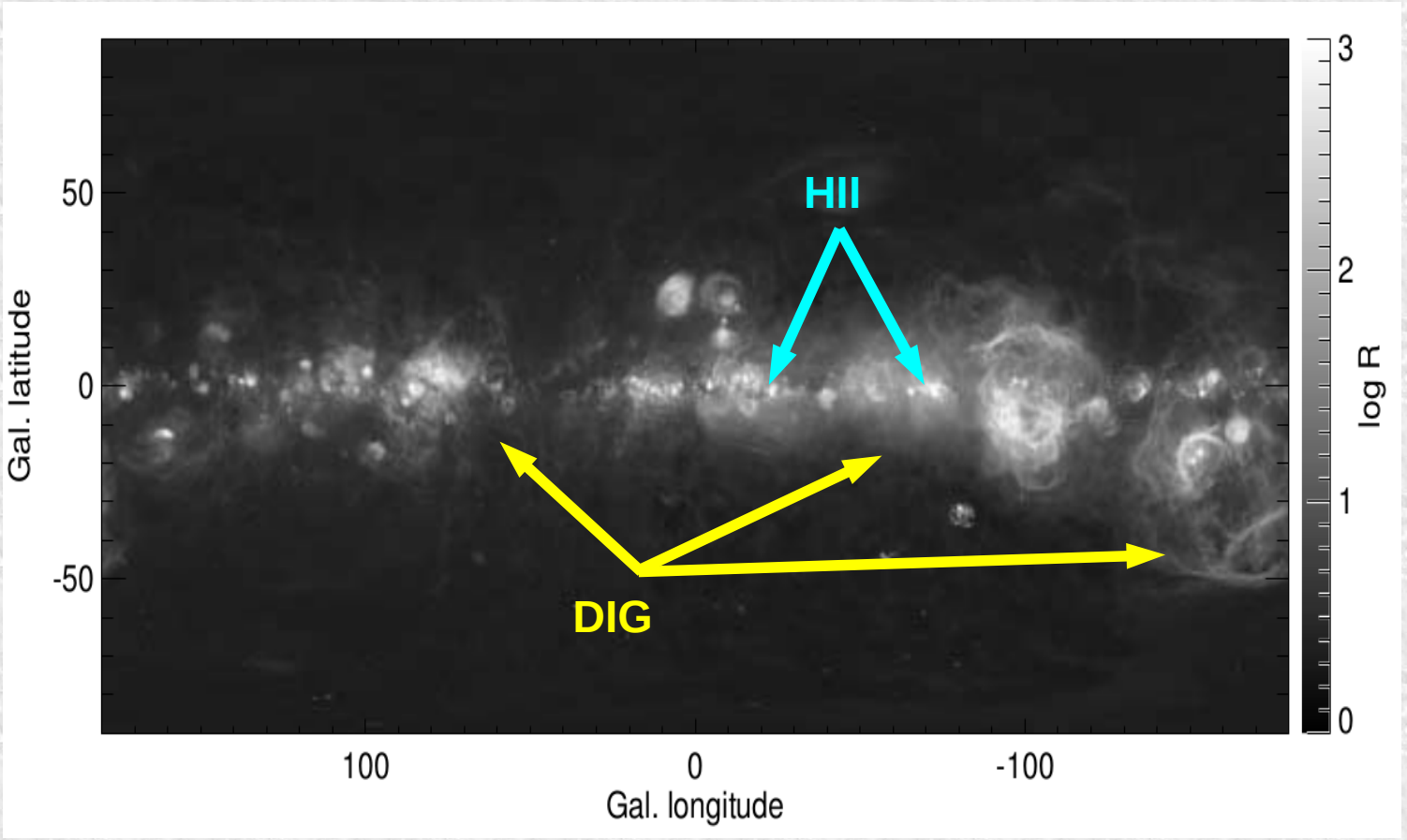
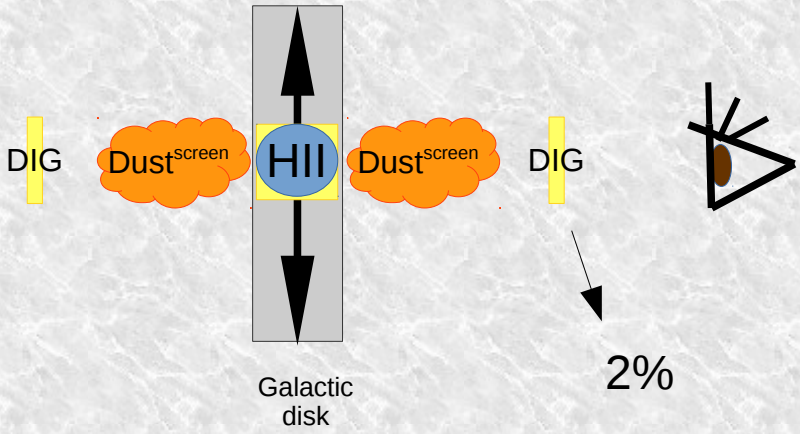
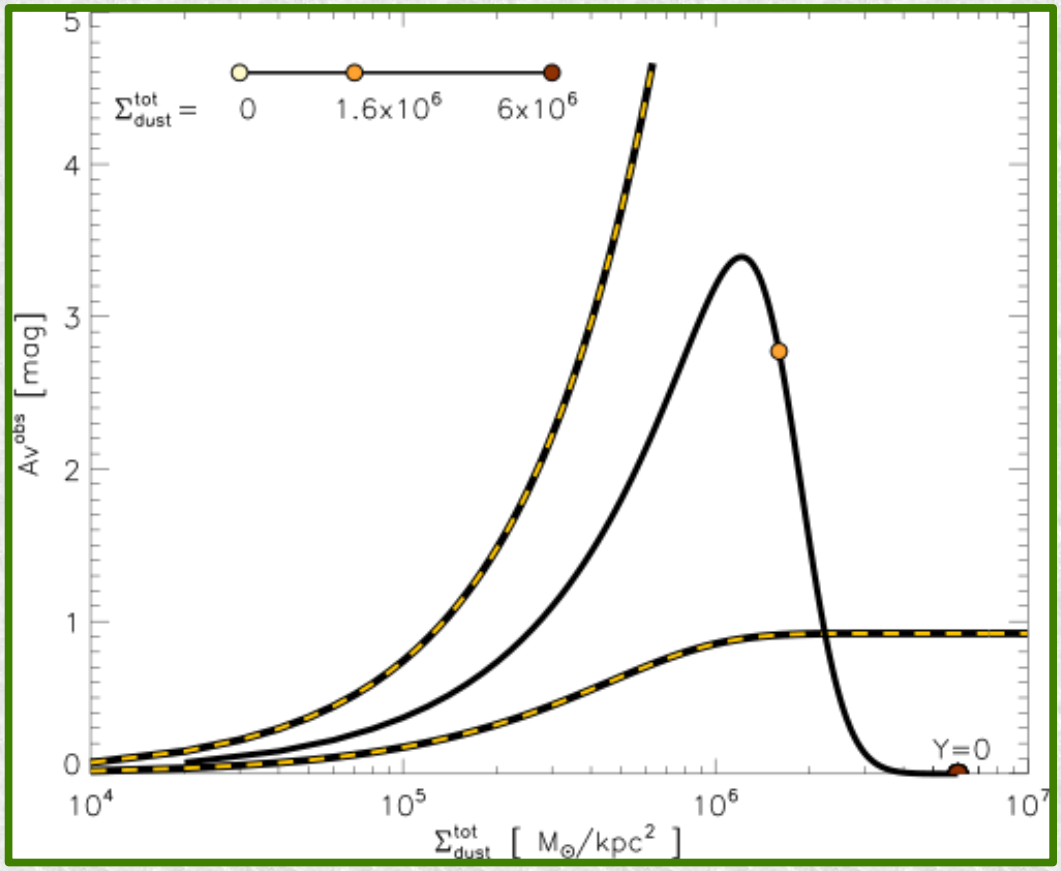
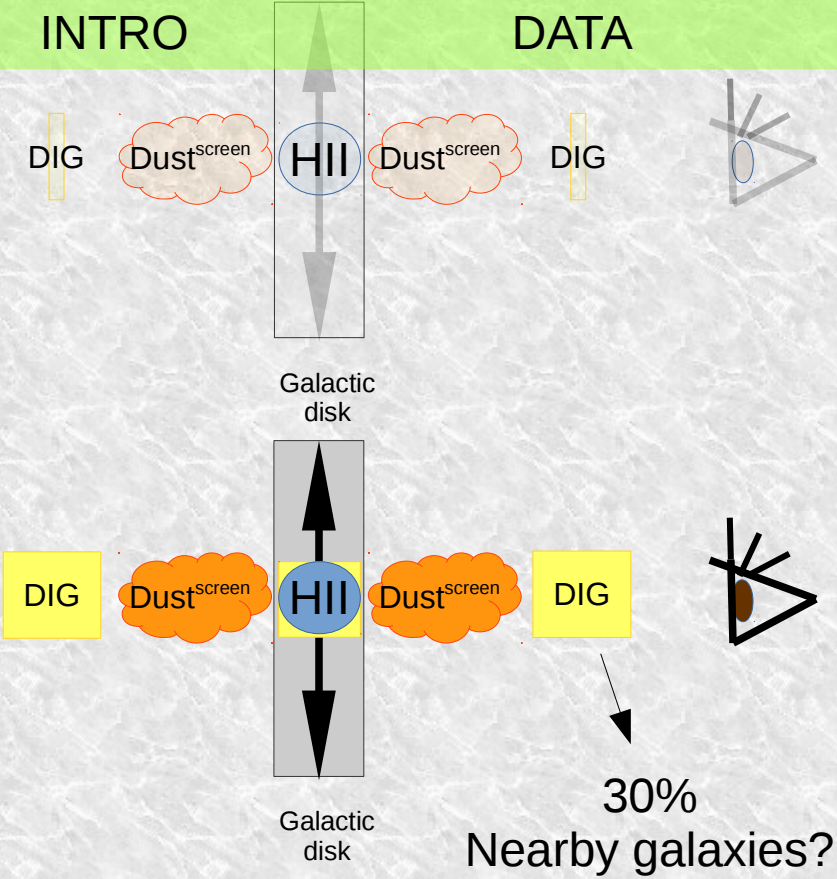


Fig: Composite Hα intensity map; c. Finkbeiner 2003

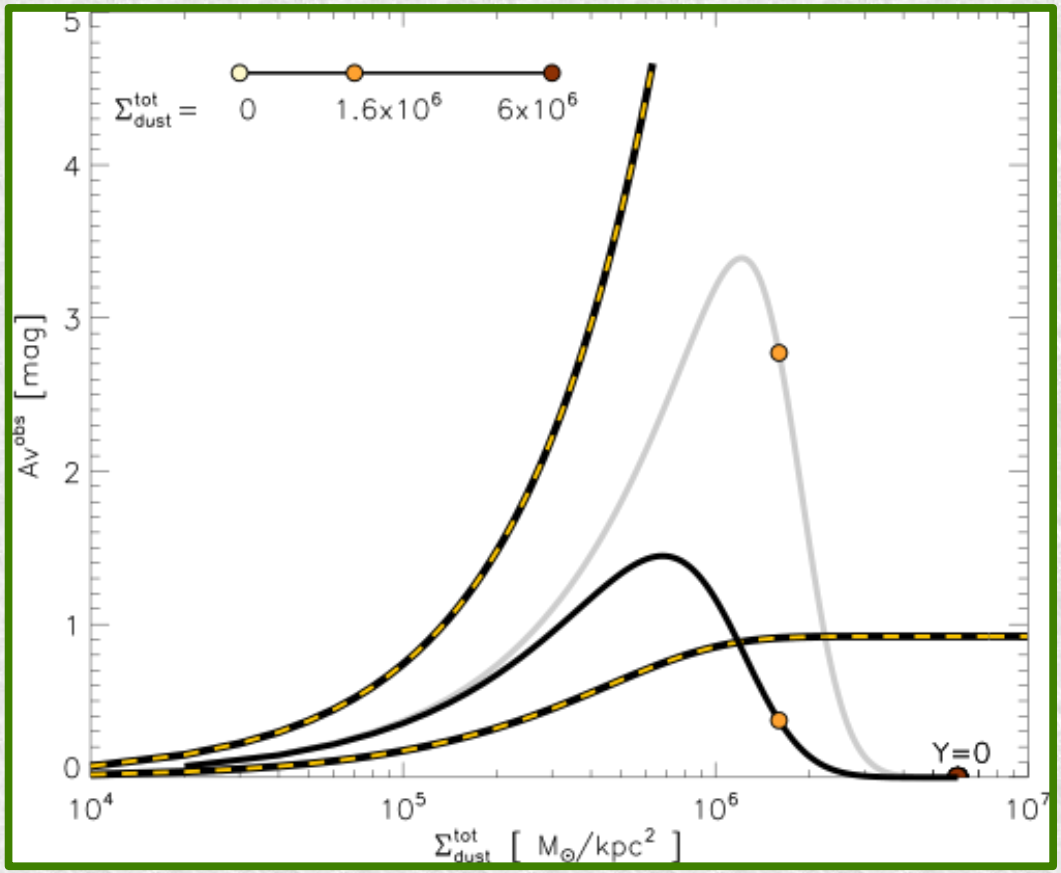

DIG
Dust screen
HII
Dust screen
DIG
Galactic disk
2%


Σ^{tot}_{dust} = 0 1.6x10^6 6x10^6
A_V^{obs} [mag]
Σ^{tot}_{dust} [M$_\odot$/kpc^2]
Y=0
0
1
2
3
4
5
10^4
10^5
10^6
10^7

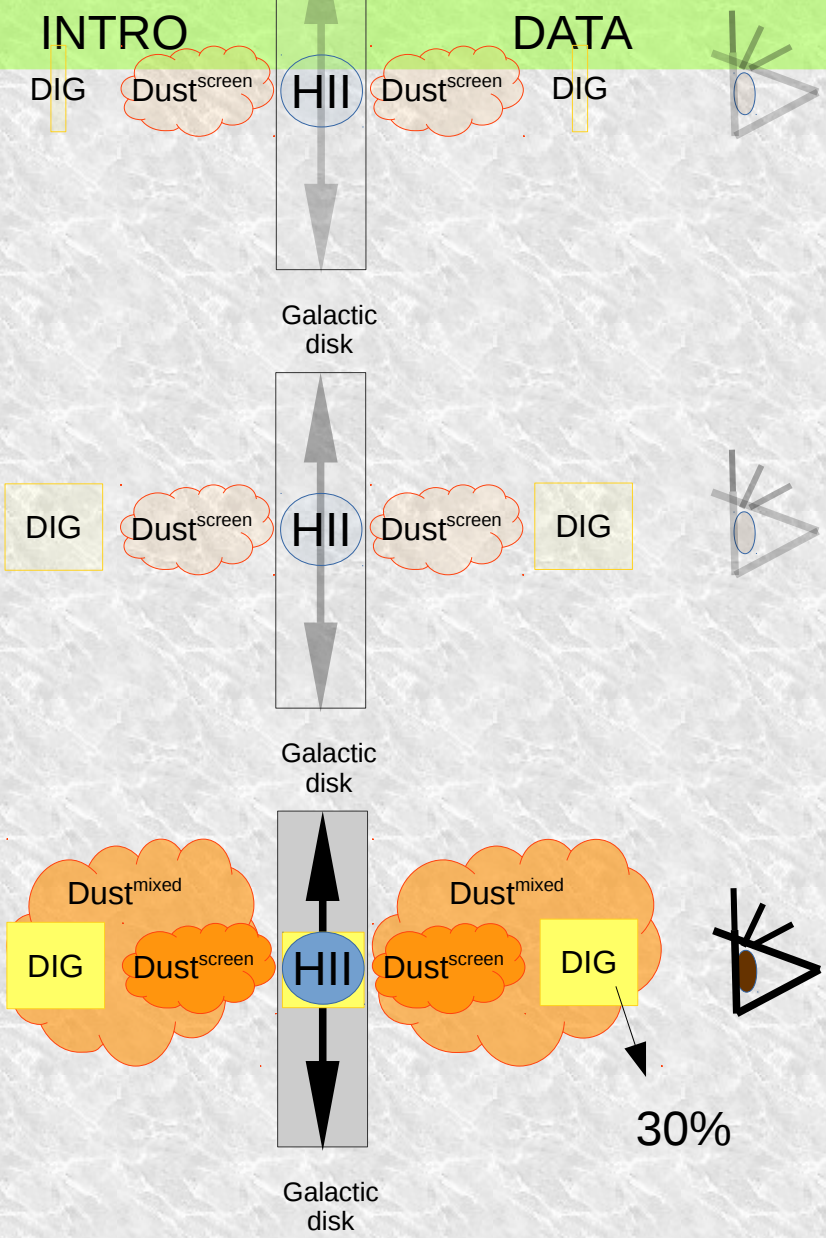
c. Tomičić+17

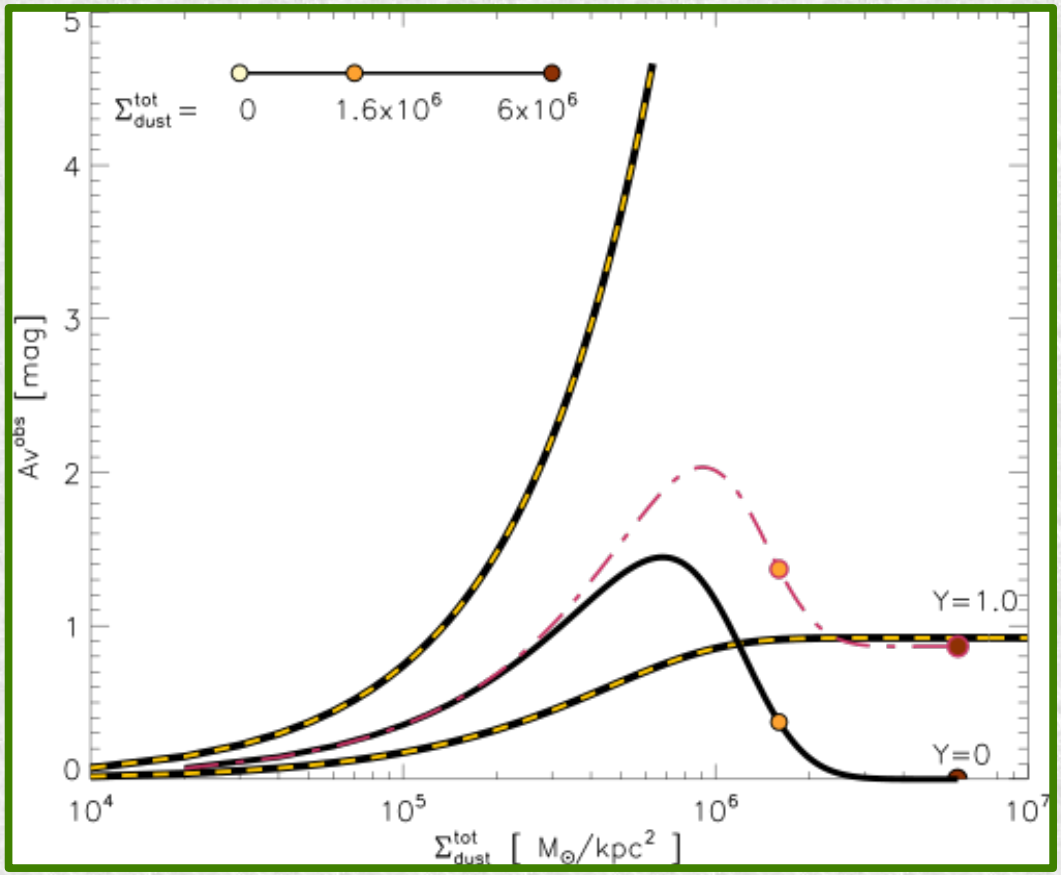


30%
Nearby galaxies?

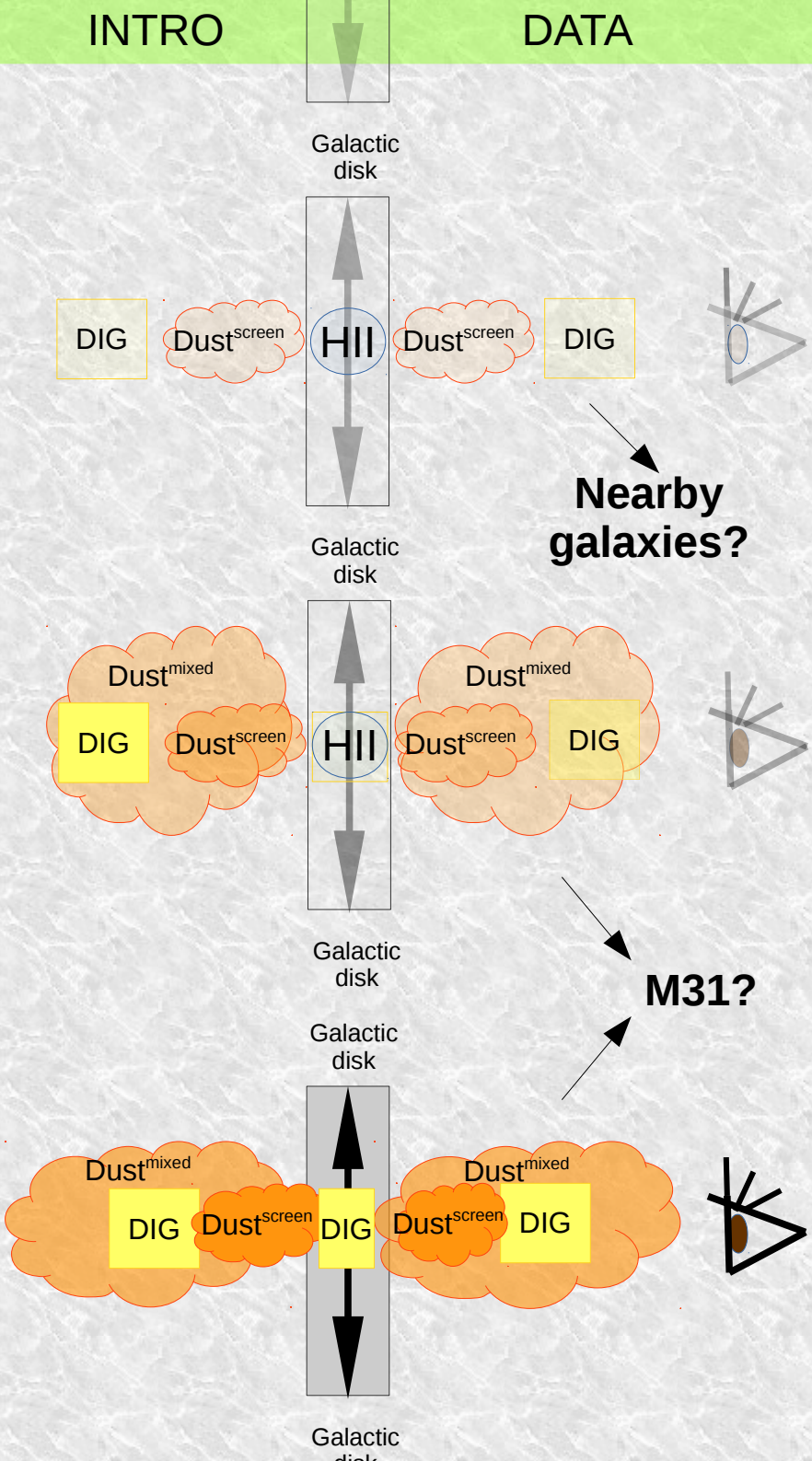


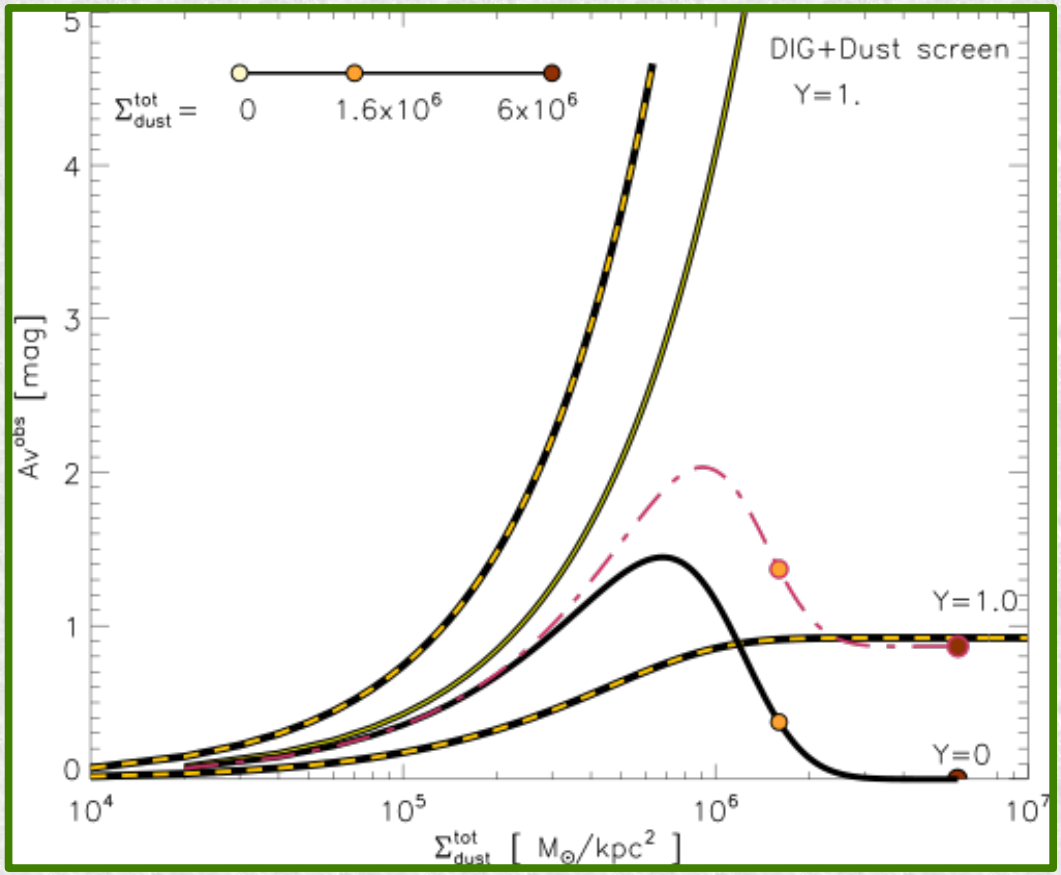
c. Tomičić+17


DIG
Dust screen
HII
Dust screen
DIG
Galactic disk
DIG
Dust screen
HII
Dust screen
DIG
Galactic disk
Dust mixed
DIG
Dust screen
HII
Dust screen
Dust mixed
DIG
30%
Galactic disk


Σ^{tot}_{dust} = 0 1.6x10^6 6x10^6
Y=1.0
Y=0
A_V^{obs} [mag]
Σ^{tot}_{dust} [$M_\odot$/kpc^2]
0
1
2
3
4
5
10^4
10^5
10^6
10^7

c. Tomičić+17

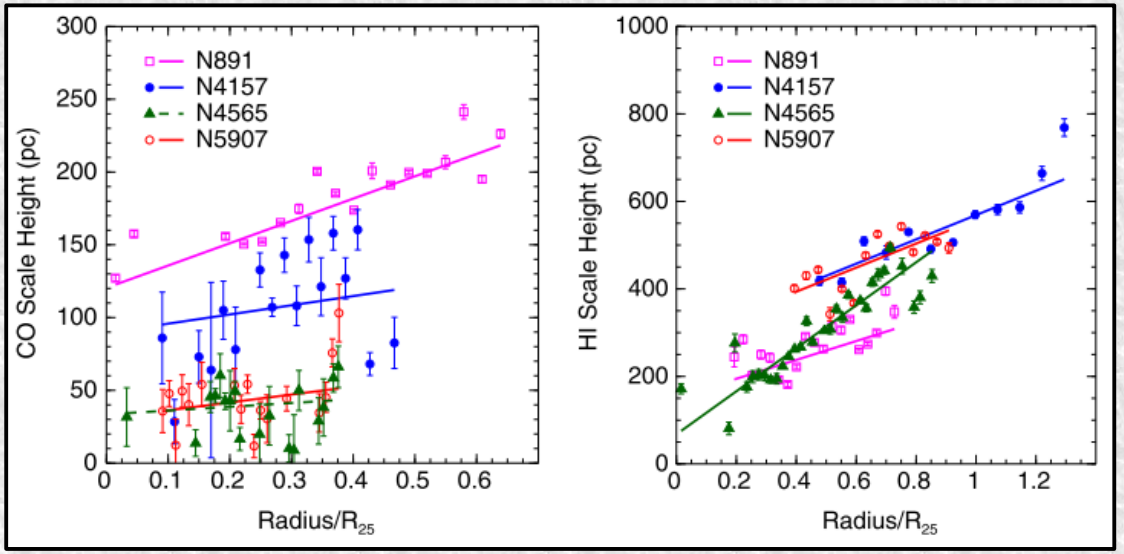

Galactic disk
DIG
Dust screen
HII
Dust screen
DIG
Nearby galaxies?
Galactic disk
Dust mixed
DIG
Dust screen
HII
Dust screen
Dust mixed
DIG
M31?
Galactic disk
Dust mixed
DIG
Dust screen
DIG
Dust screen
Dust mixed
DIG
Galactic disk


DIG+Dust screen
Y=1.
Σ tot dust = 0 1.6x10^6 6x10^6
Y=1.0
Y=0
Av obs [mag]
Σ tot dust [M⊙/kpc^2]
0
1
2
3
4
5
10^4
10^5
10^6
10^7

c. Tomičić+17

Nearby galaxies:

- <u>central regions</u>
- higher SFR
- more extended DIG?

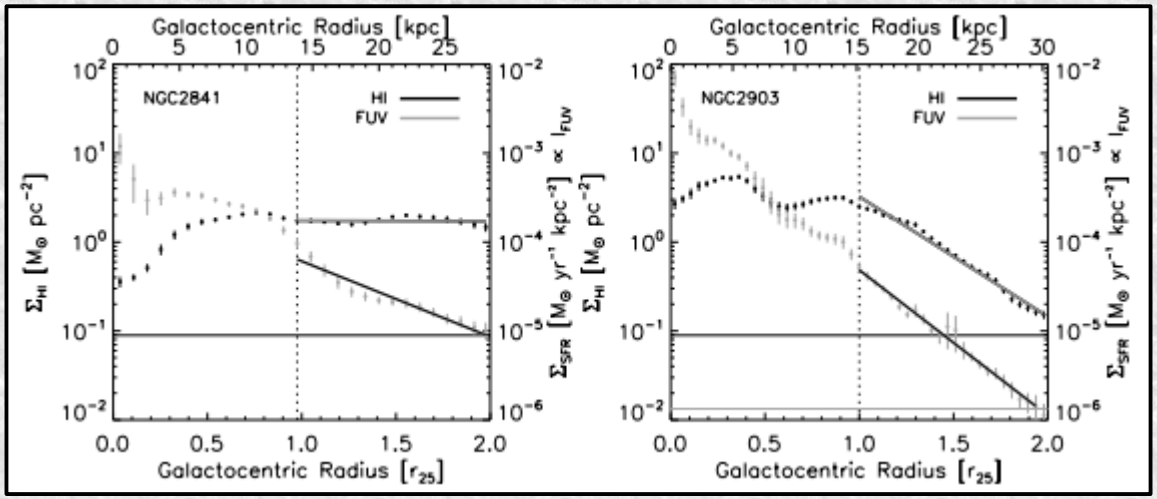


c. Yim et al. 2014

Fig: Scale height of gas with galactocentric R

M31:

- <u>spiral arms</u>
- lower SFR
- DIG embeded in dust?

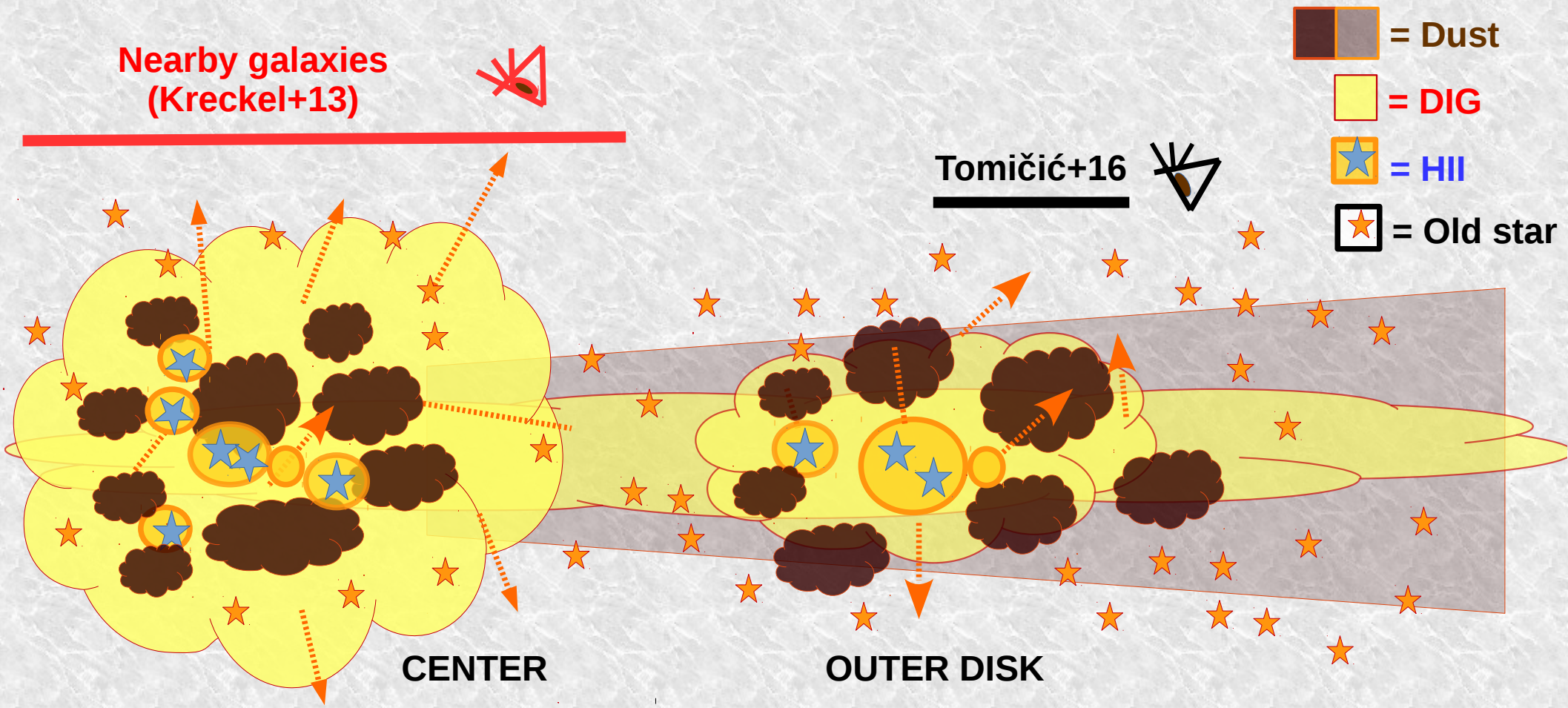


c. Bigiel et al. 2010

Fig: SFR with galactocentric R

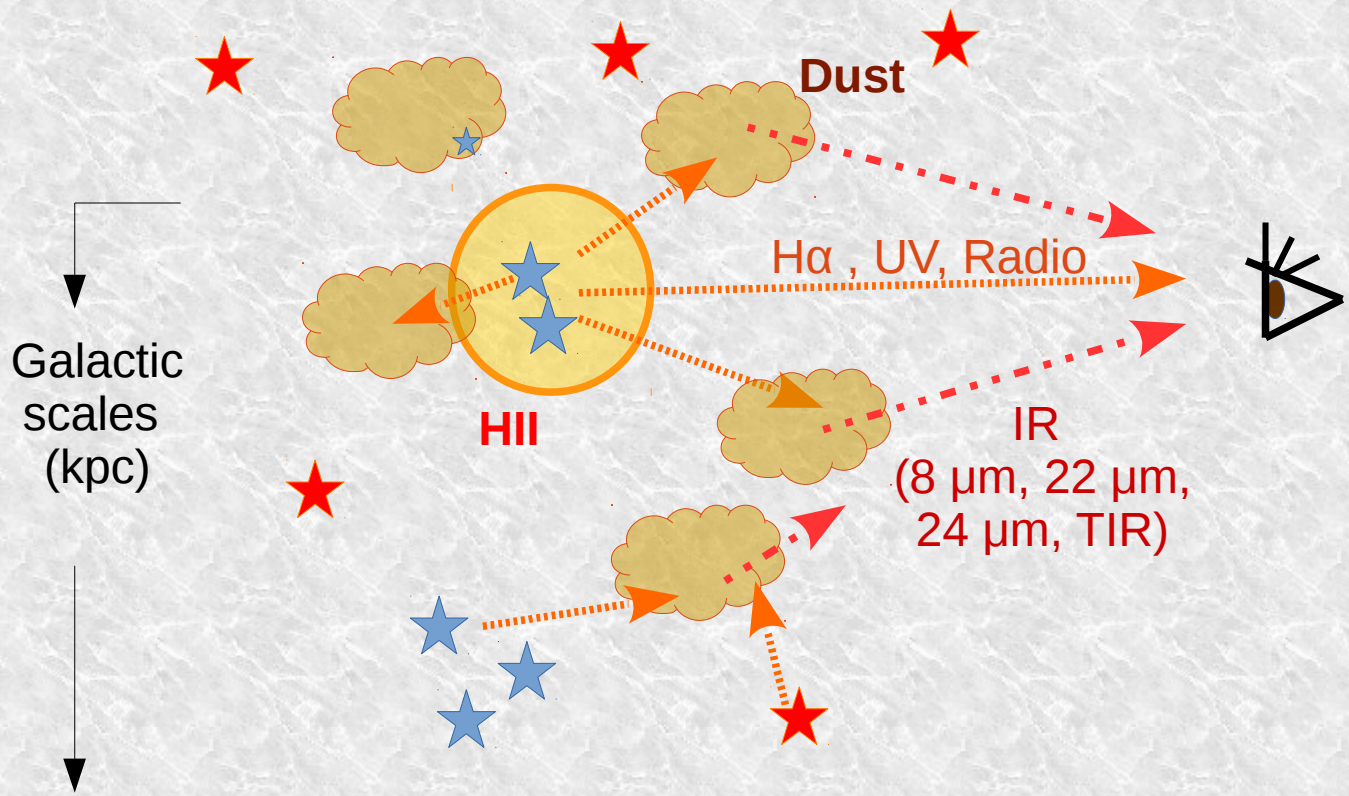
Summary

<u>Dust distribution:</u> Foreground screen + Contribution from DIG



Star Formation tracers at ~50 pc scales

Star Formation tracers at ~50 pc scales

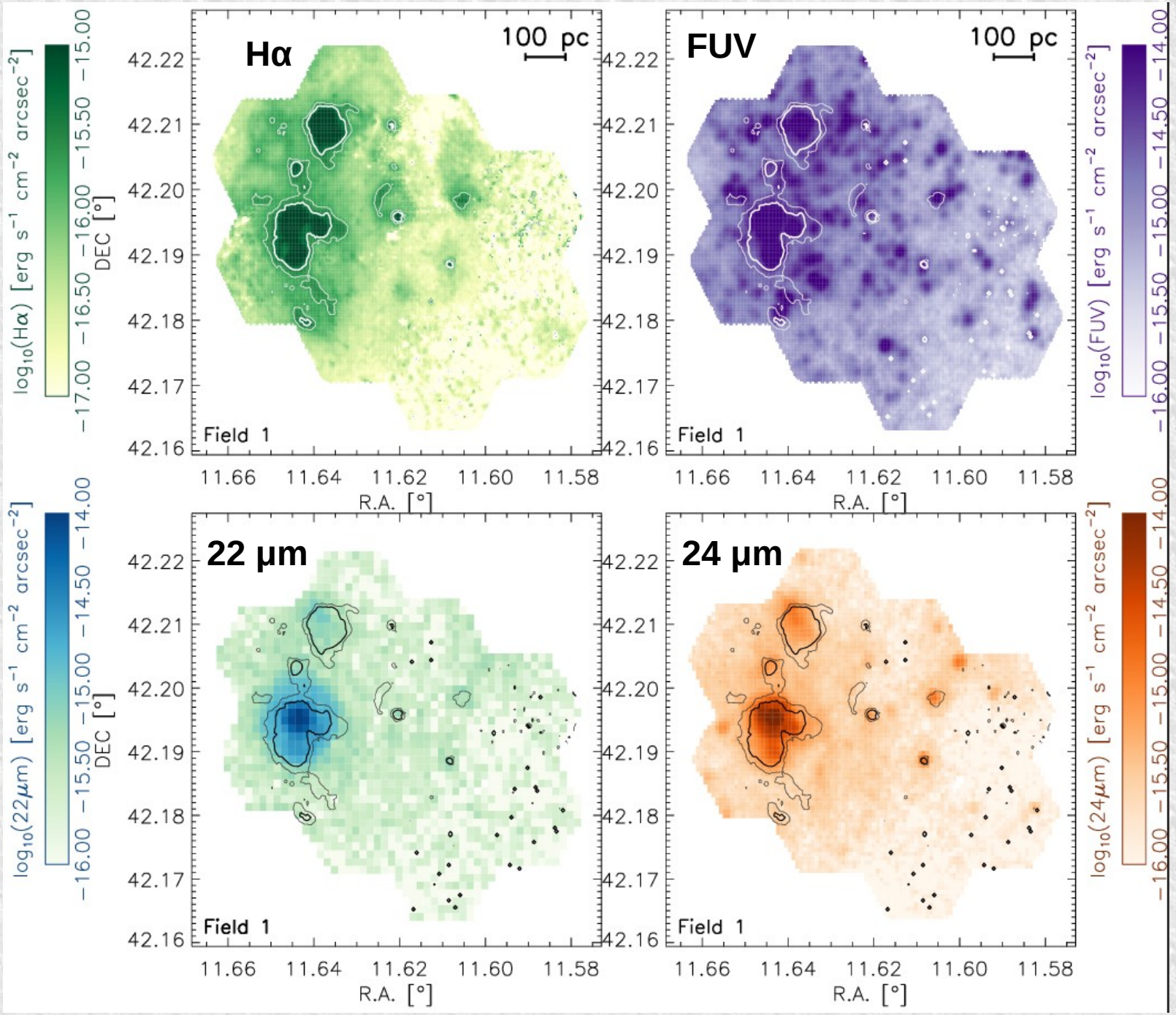


Is it correct? Does <u>small scales</u> calibration agree with those recipes?

We will look:
Hα (IFU) + 24 μm (Spitzer)
Hα + 22 μm (WISE)
UV (GALEX) + 24 μm
UV + 22 μm

c. Sandstrom K.

c. Thilker D.



c. Jarett T.

c. Gordon, K. D

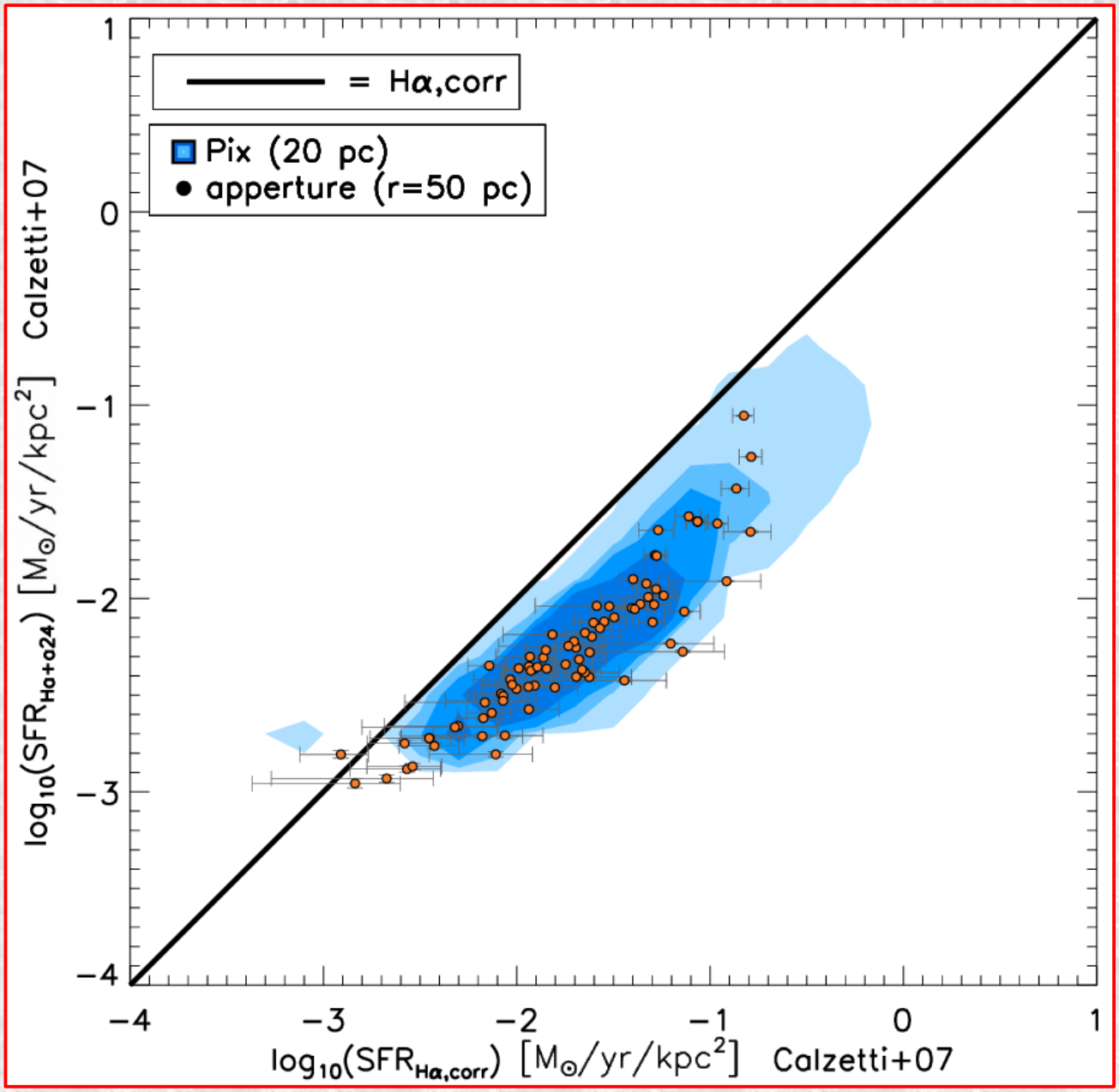


Fig: SFR ($H\alpha_{obs}$ + a * 24 μm) vs SFR ($H\alpha_{corr}$) using Calzetti et al. 2007 proscription

c. Tomičić+17b

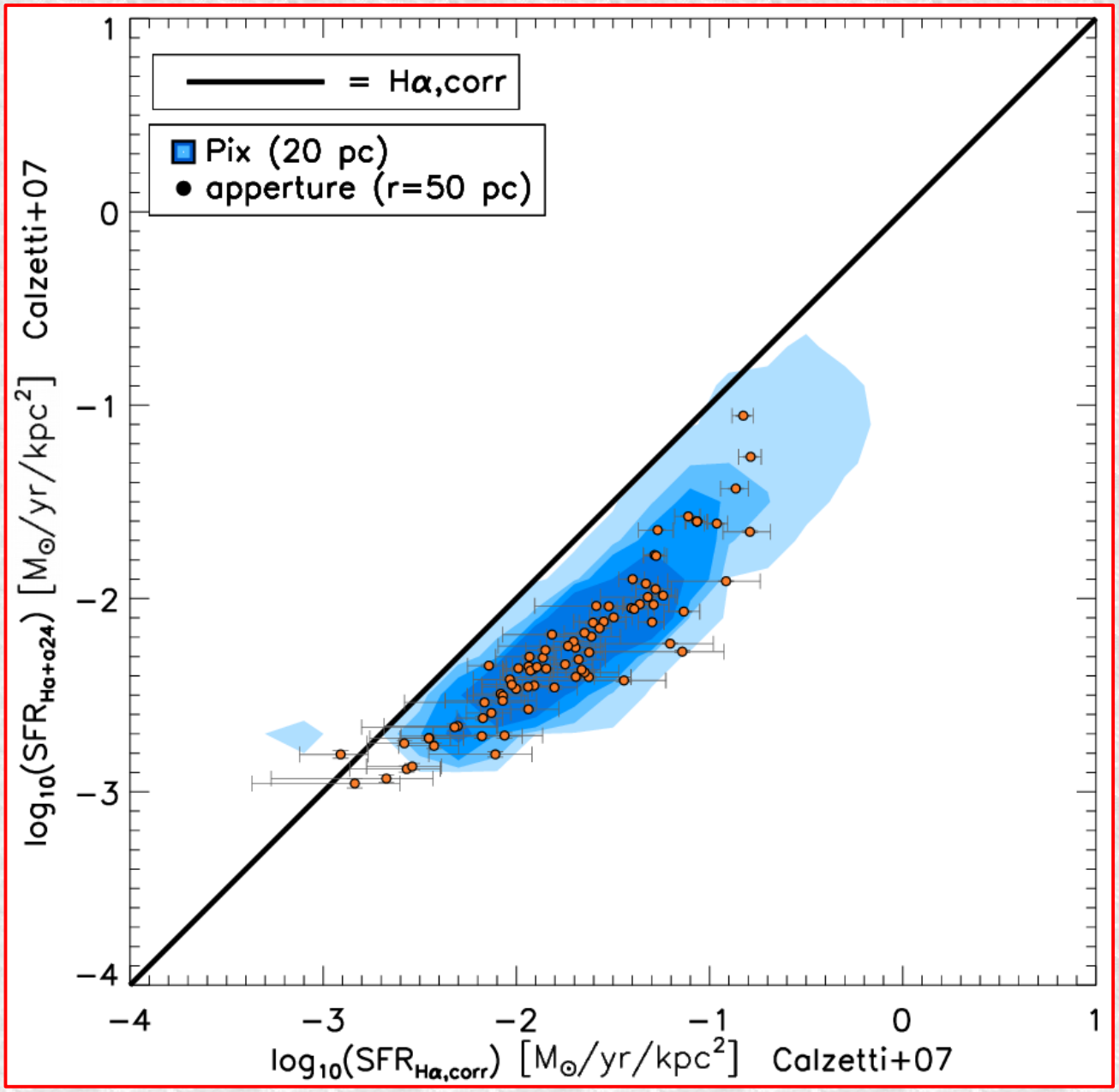


Fig: SFR ($H\alpha_{obs}$ + a * 24 μm) vs SFR ($H\alpha_{corr}$) using Calzetti et al. 2007 proscription

Proscription changed by:

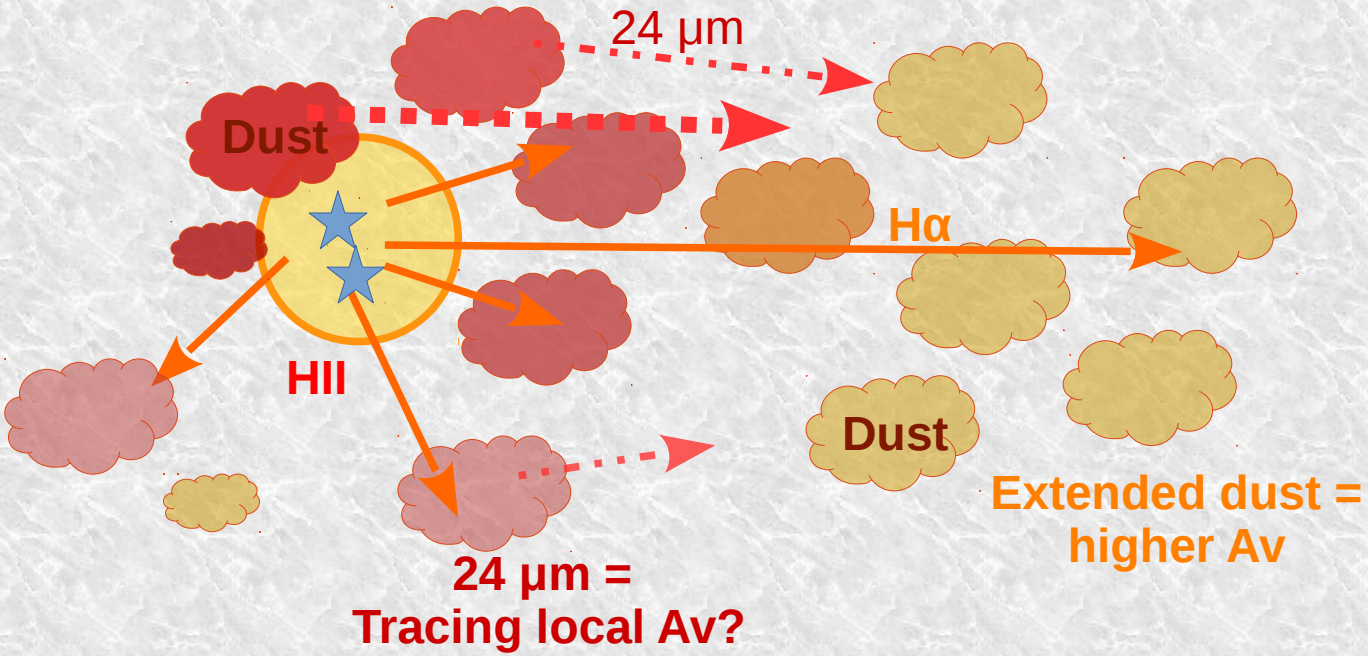
1) Scales (50 pc to 200 pc radius)

2) Diffuse component removal

c. Tomičić+17b

Proscription changed by:

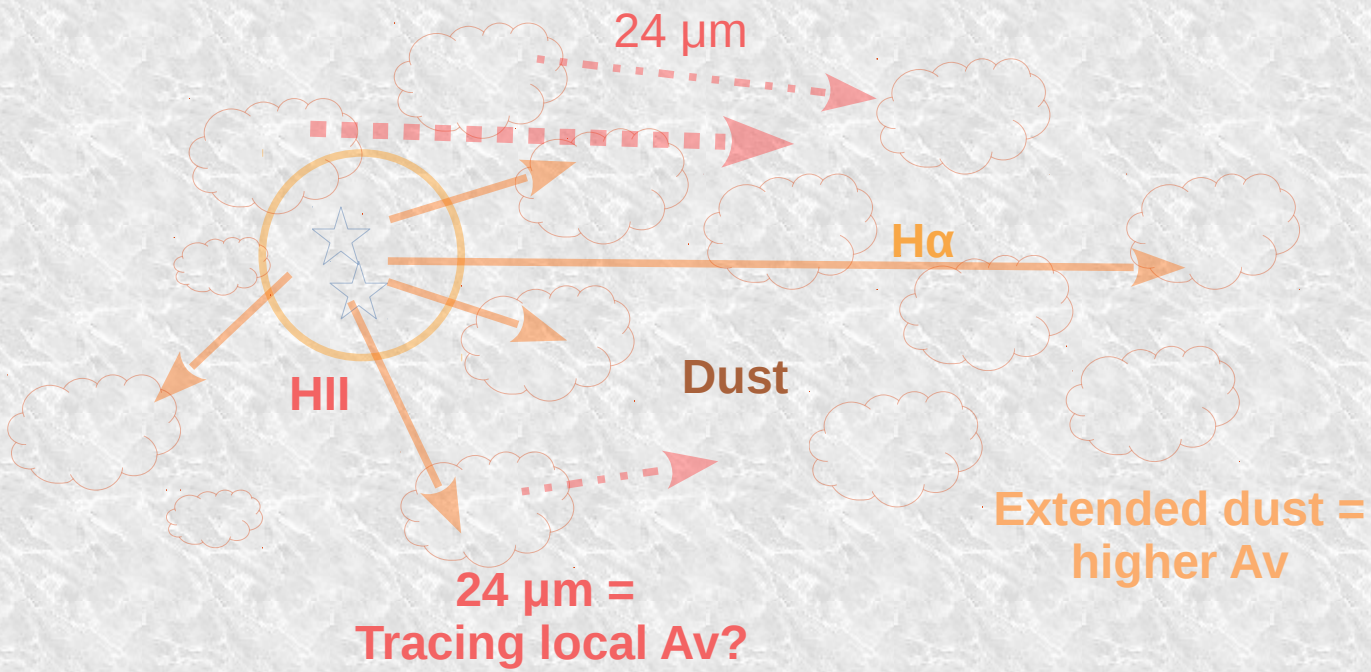
3) Dust scale height?



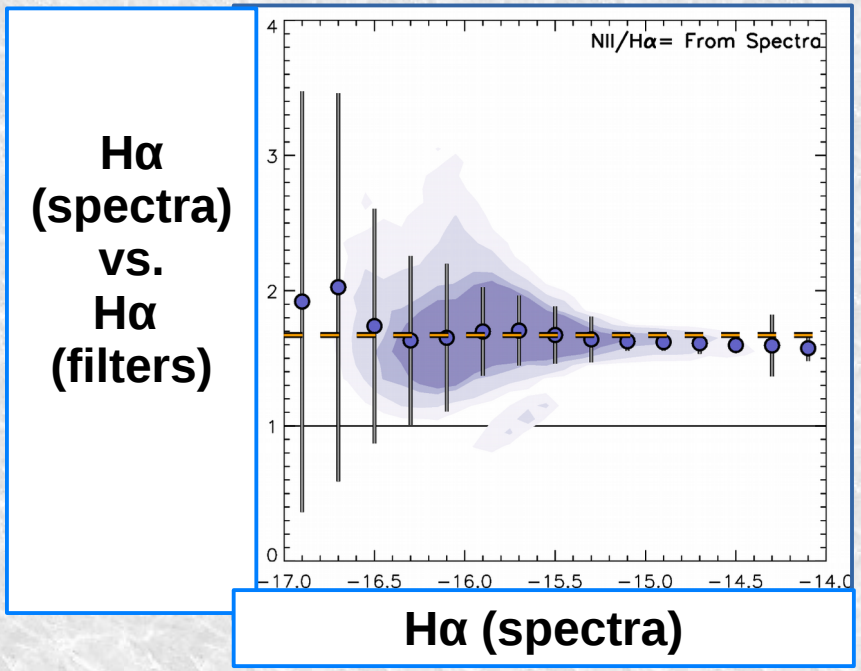
2) Hα photometry (R filters)?

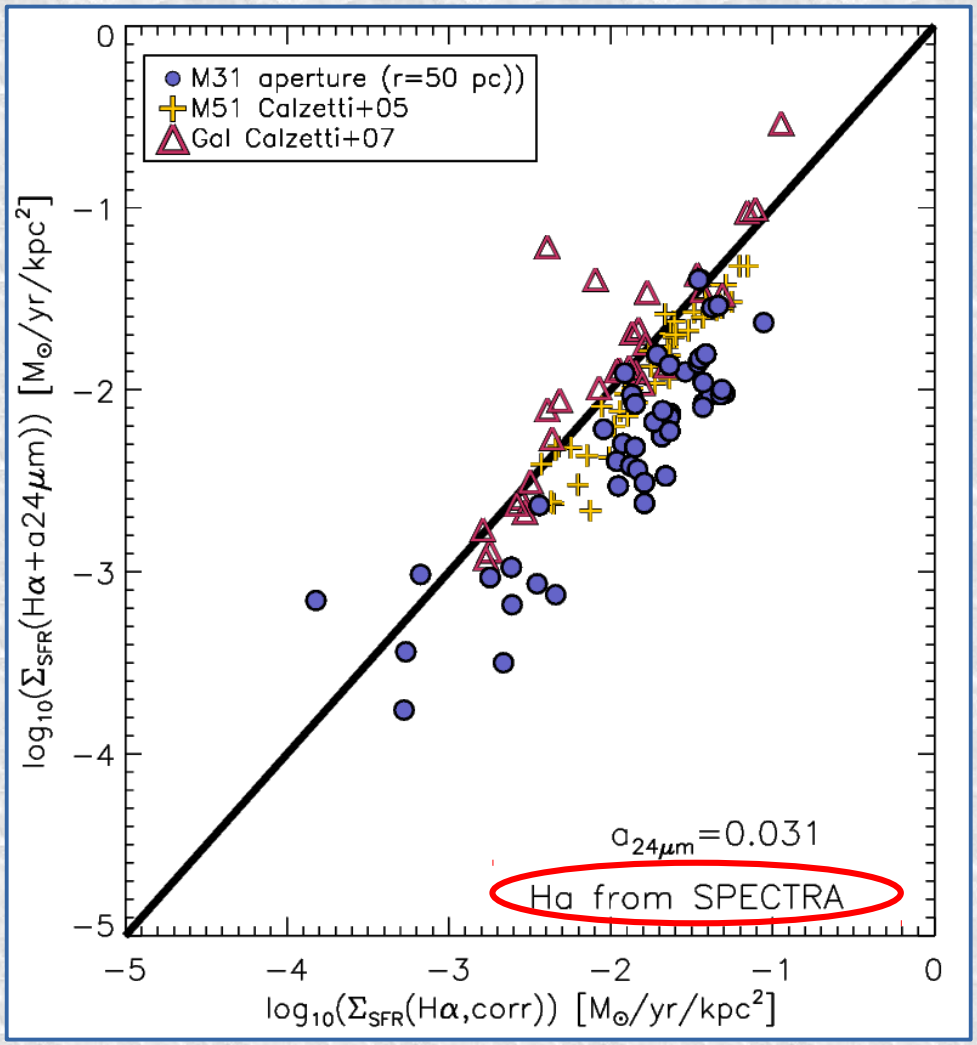
Proscription changed by:

3) Dust scale height?



2) Hα photometry (R filters)?





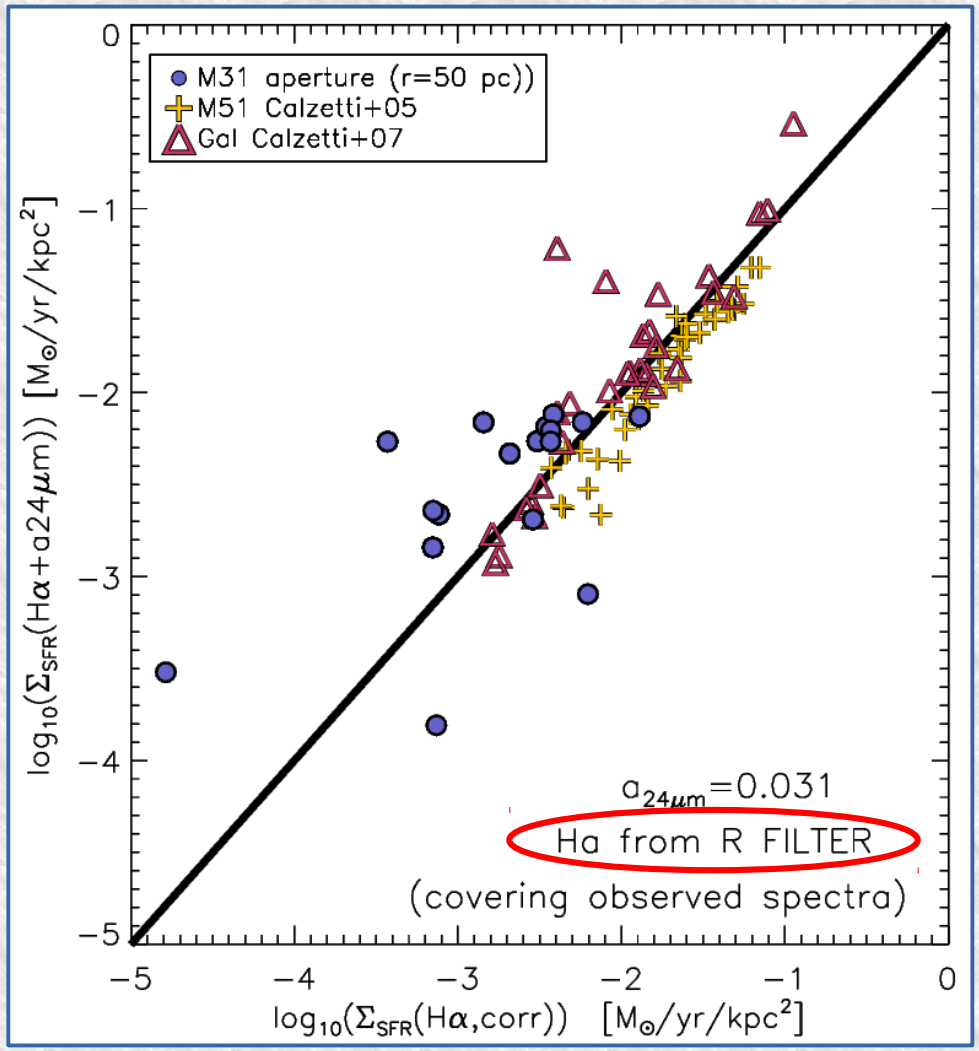
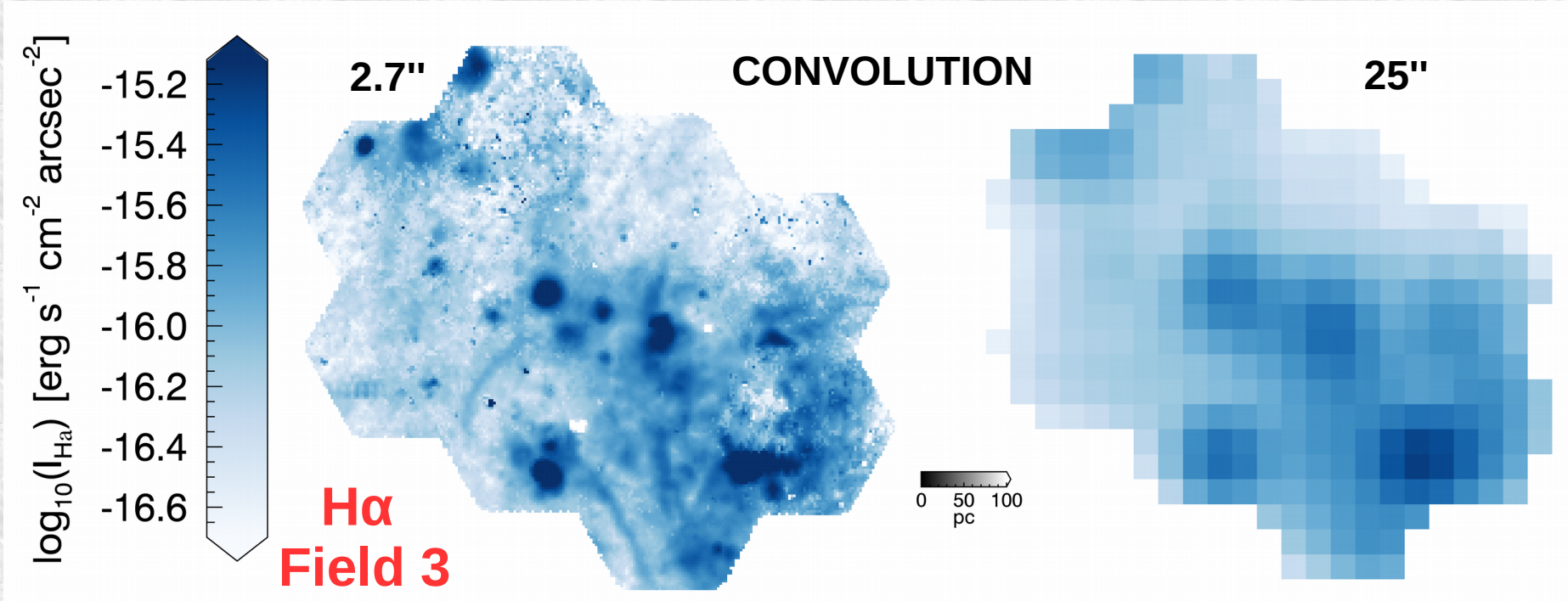
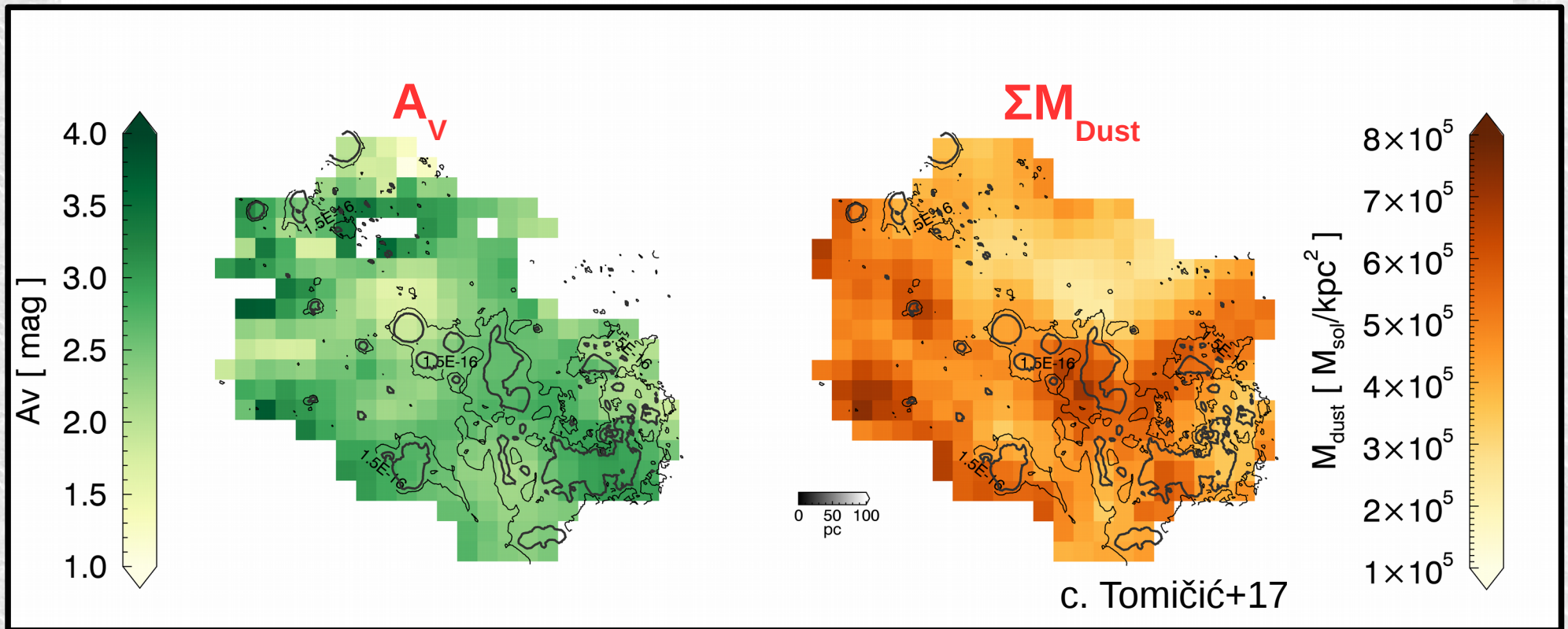


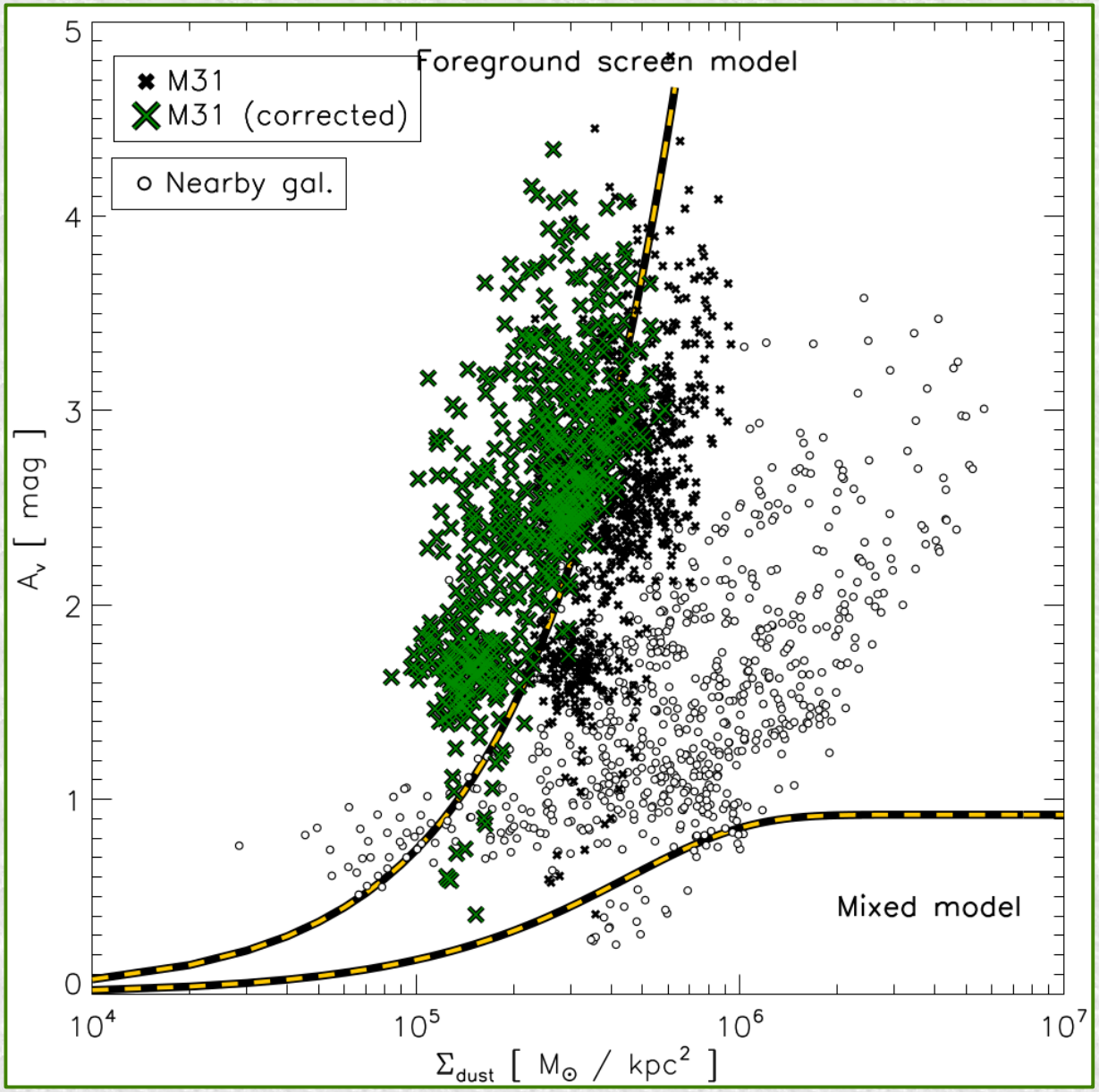
Fig. Using map analysis as in Calzetti papers!

Thank you!


log10(IHa) [erg s-1 cm-2 arcsec-2]
-15.2
-15.4
-15.6
-15.8
-16.0
-16.2
-16.4
-16.6
2.7"
CONVOLUTION
25"
0 50 100
pc
Hα
Field 3


Av [mag]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
AV
ΣMDust
1.5E-16
0 50 100
pc
Mdust [Msol/kpc2]
8×10^5
7×10^5
6×10^5
5×10^5
4×10^5
3×10^5
2×10^5
1×10^5
c. Tomičić+17

Delcanton/Planck correction?



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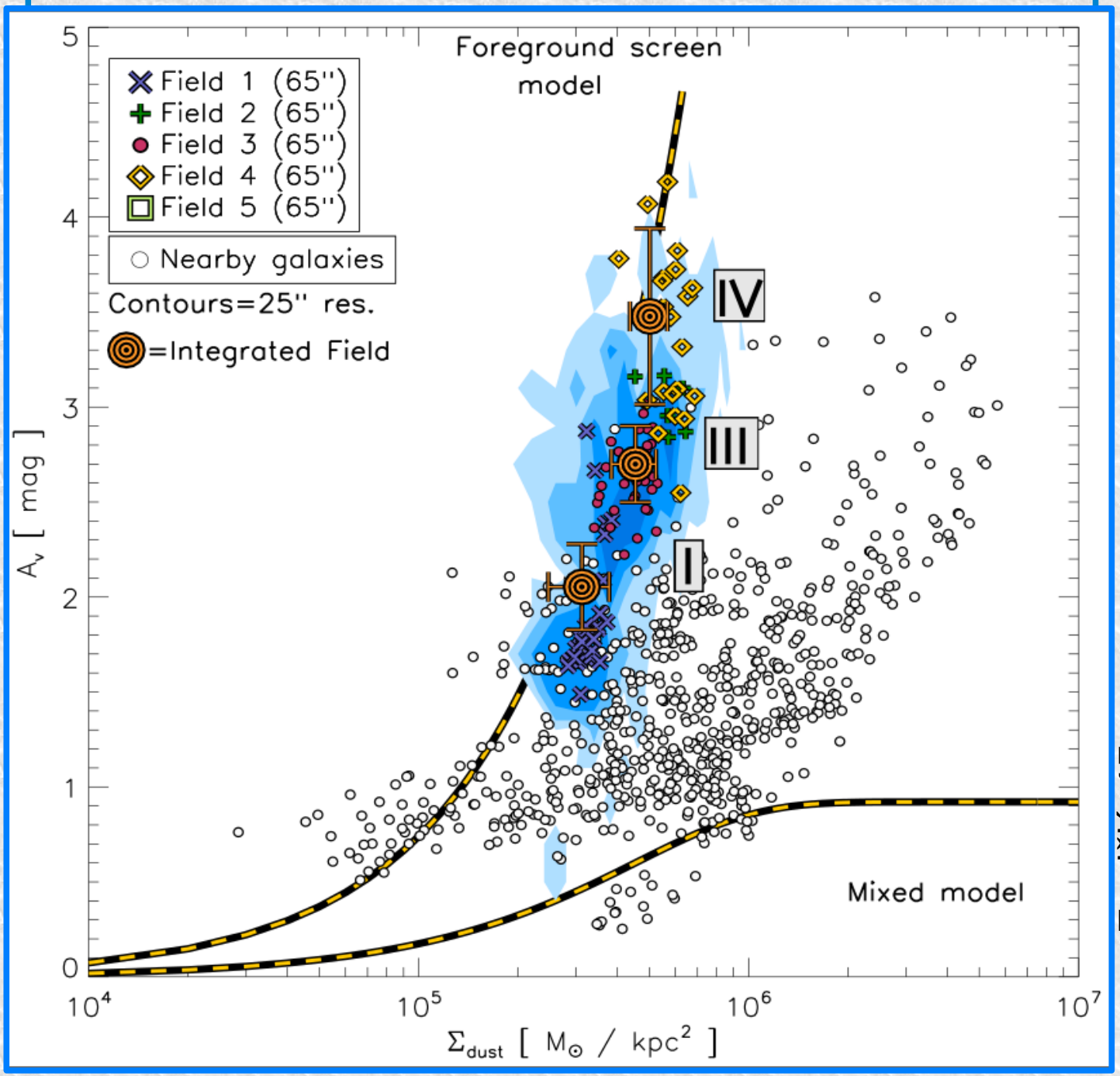
CHANGING SPATIAL SCALES?

Scales:
-100 pc
-250 pc
-0.6-0.9 kpc
(Integrated)

Attenuation at different scales



c. Tomičić+17

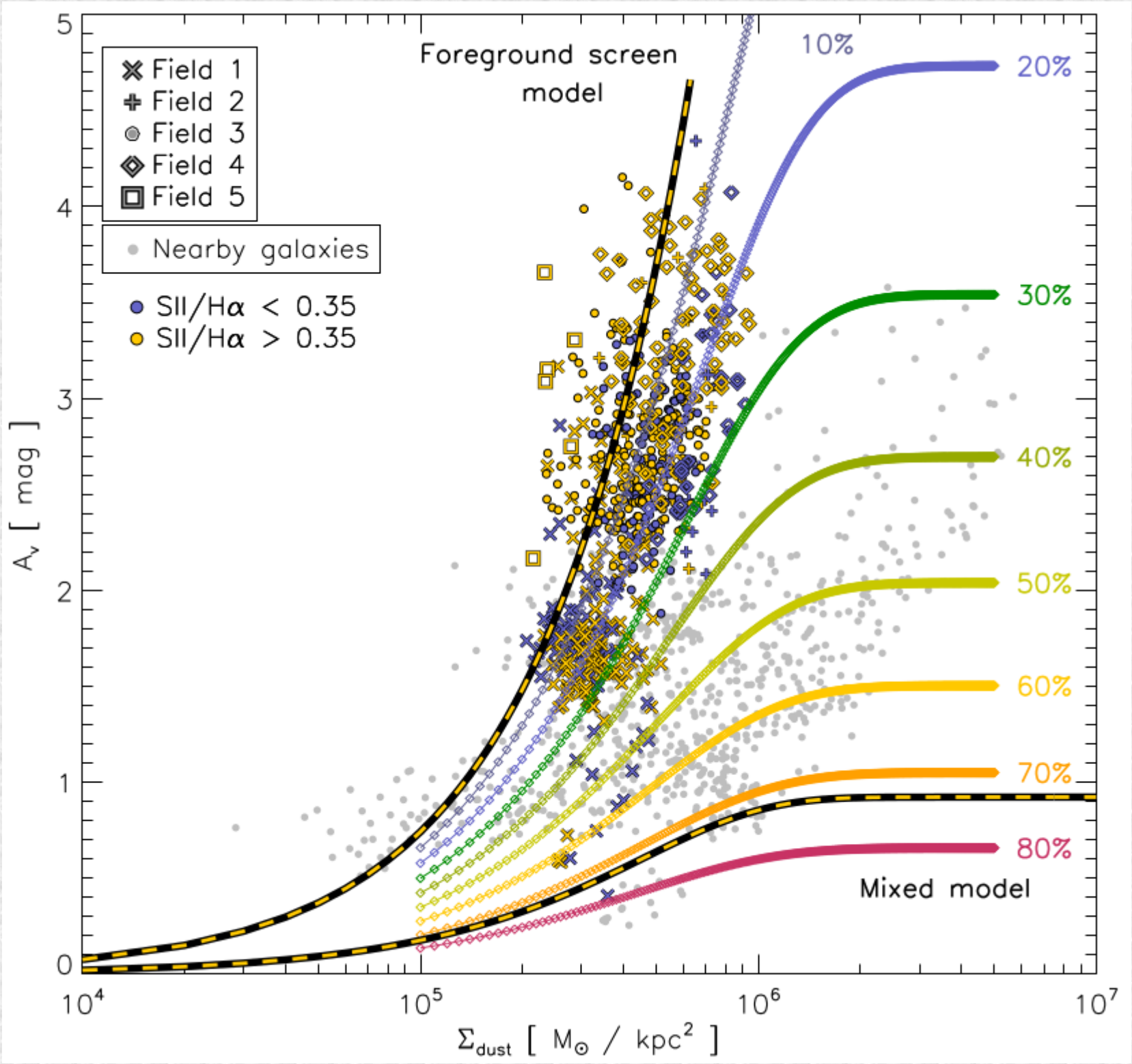
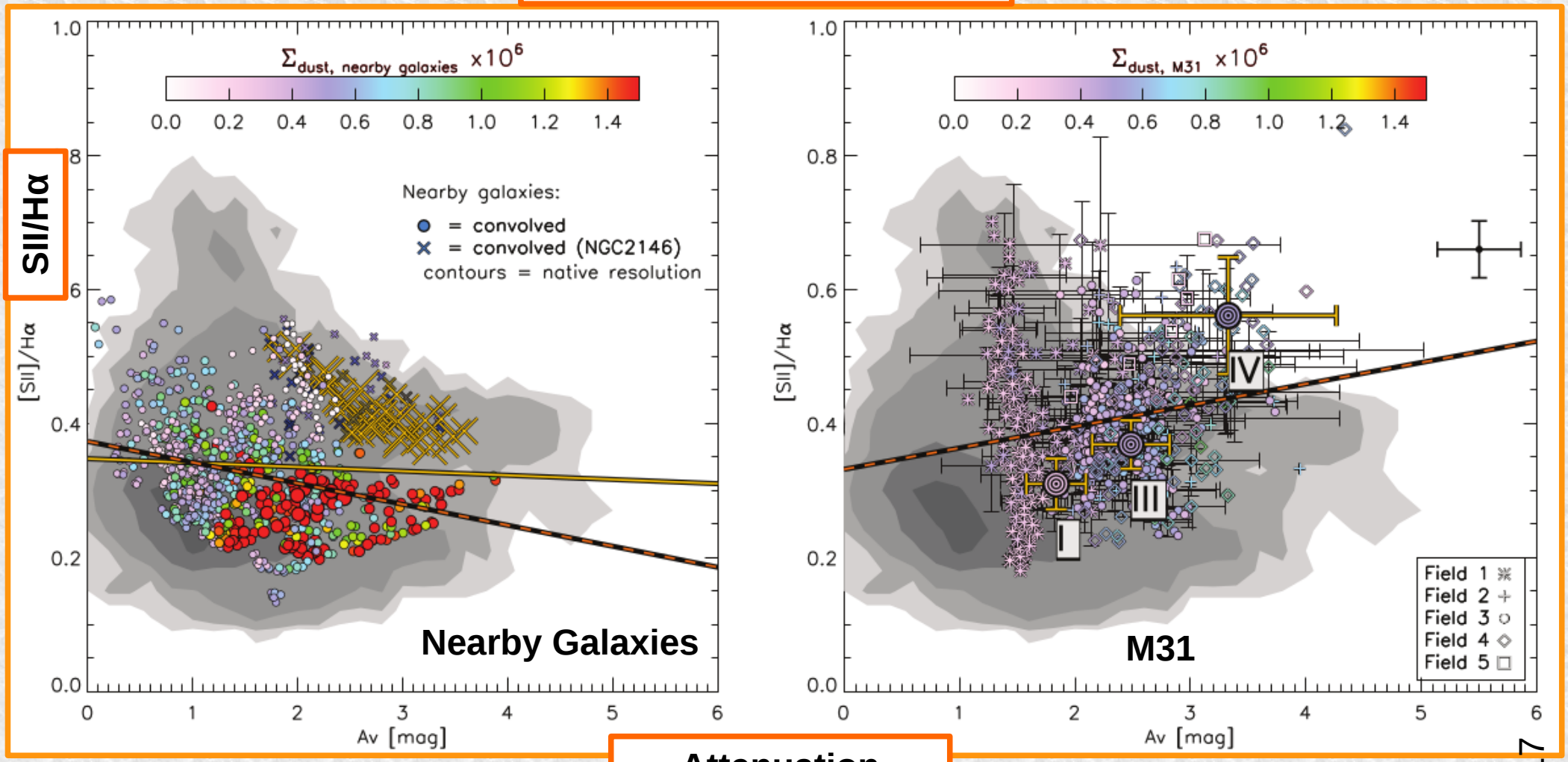

Field 1
Field 2
Field 3
Field 4
Field 5
Nearby galaxies
SII/Hα < 0.35
SII/Hα > 0.35
Foreground screen model
10%
20%
30%
40%
50%
60%
70%
80%
Mixed model
A_v [mag]
Σ_dust [M⊙ / kpc²]
0
1
2
3
4
5
10^4
10^5
10^6
10^7

Fig. : SII/Hα vs. Av



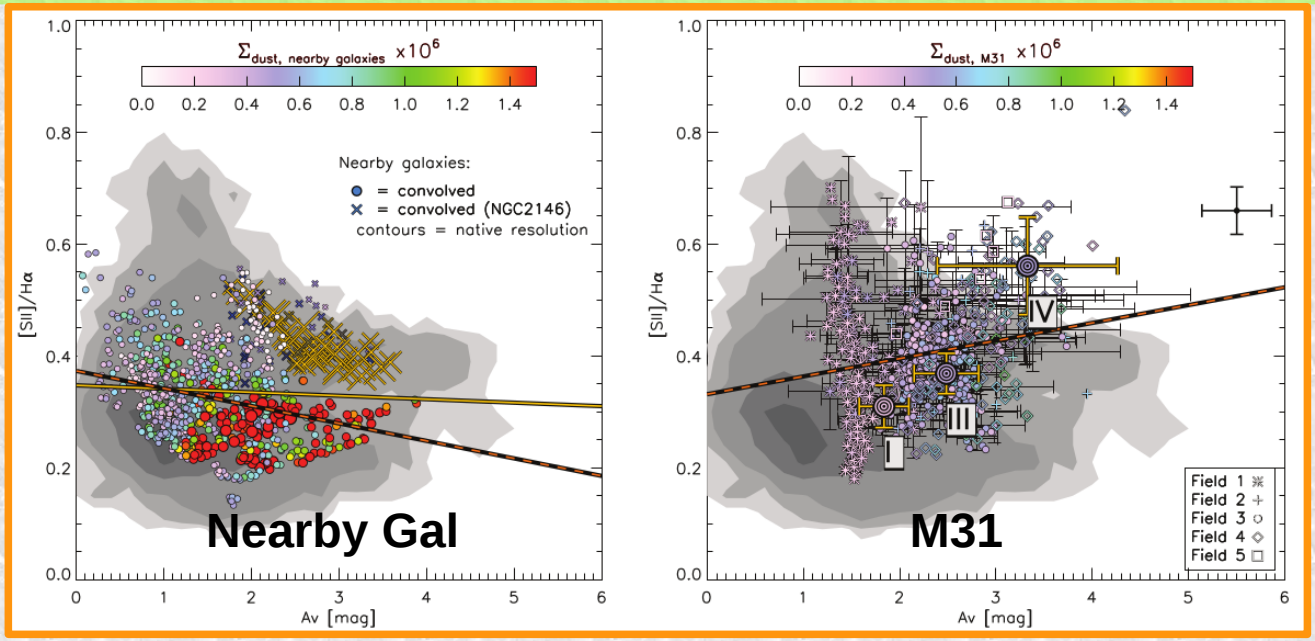
Attenuation

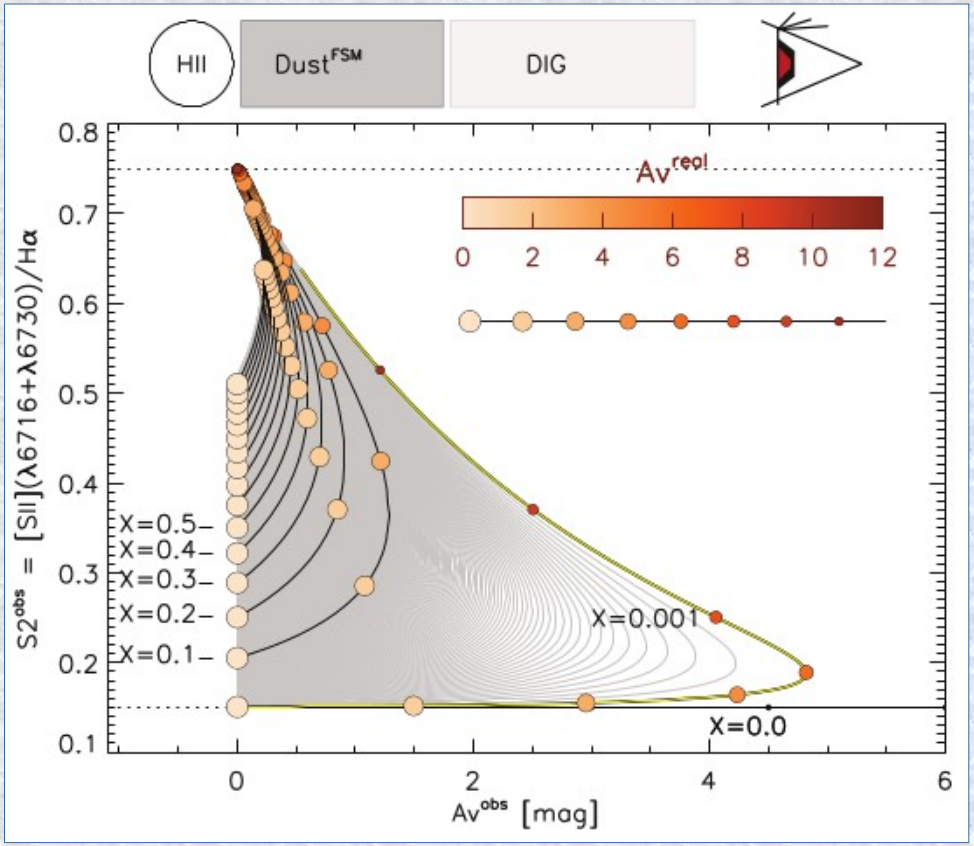
↓ Test

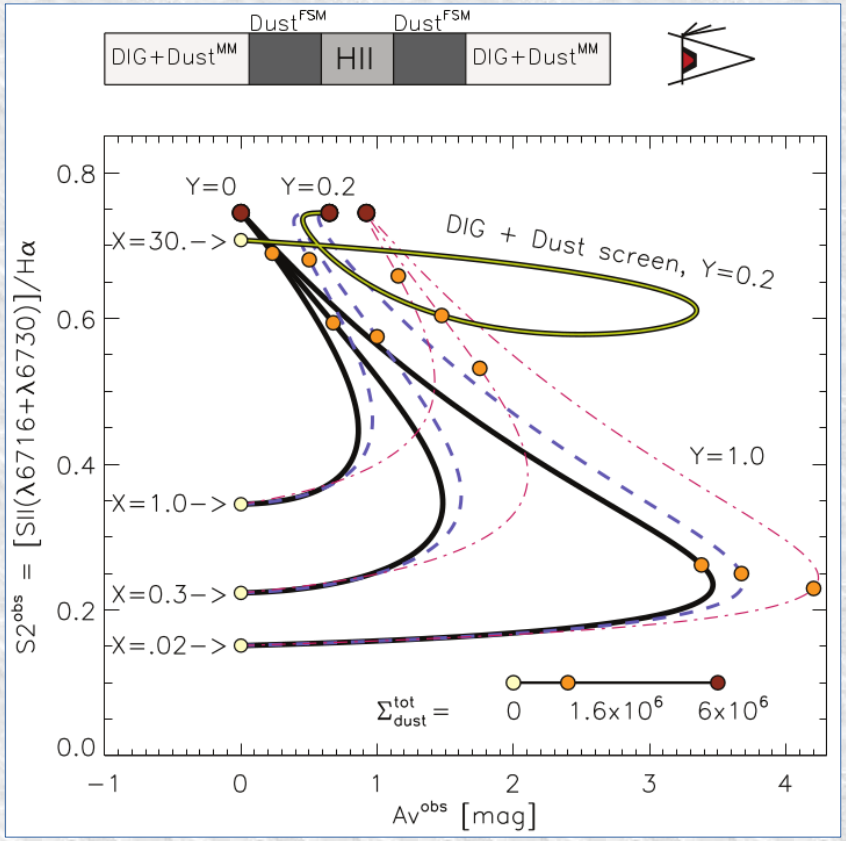
3) TOY MODEL

c. Tomičić+17

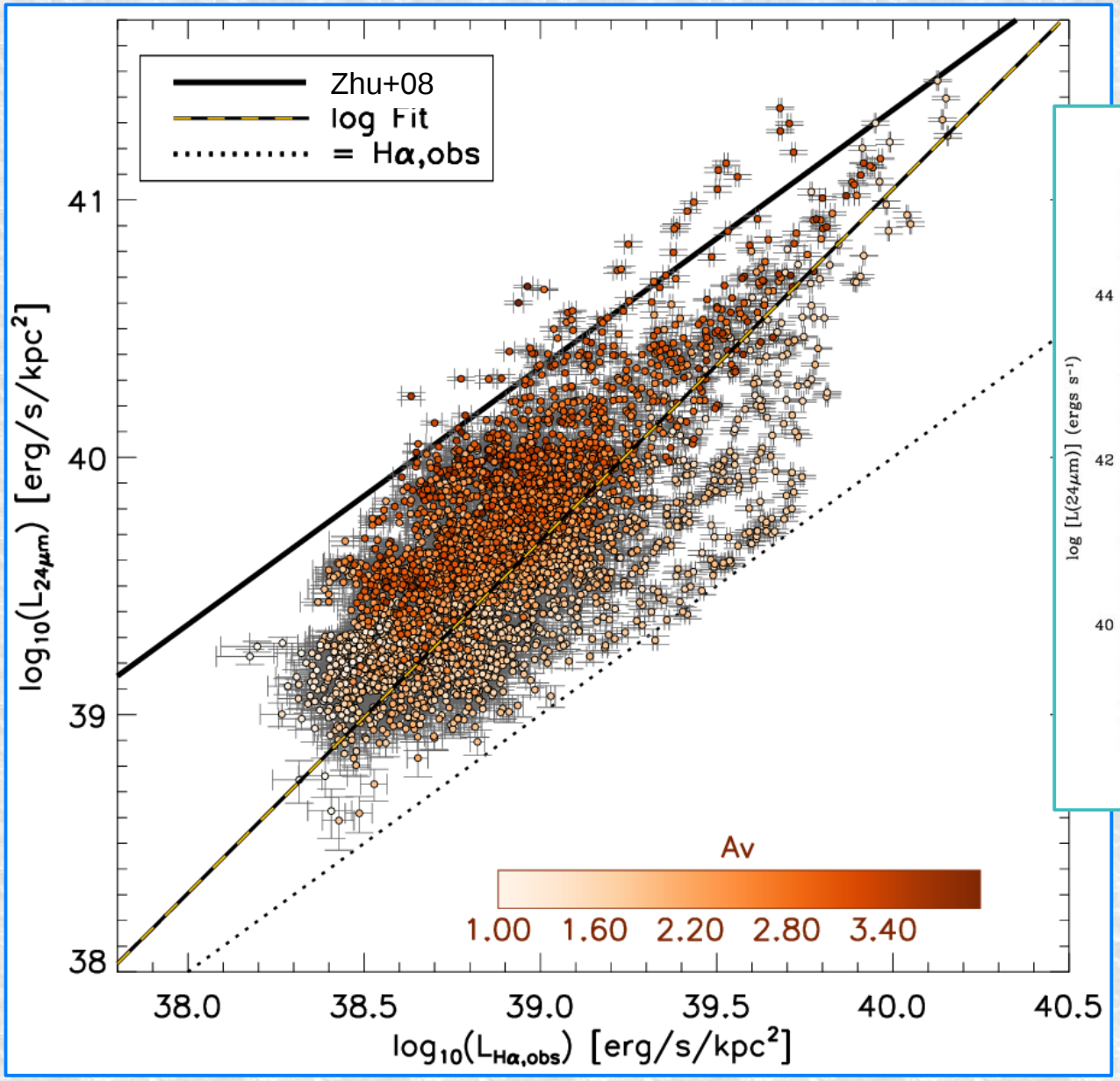
Fig:
SII/Hα vs Av

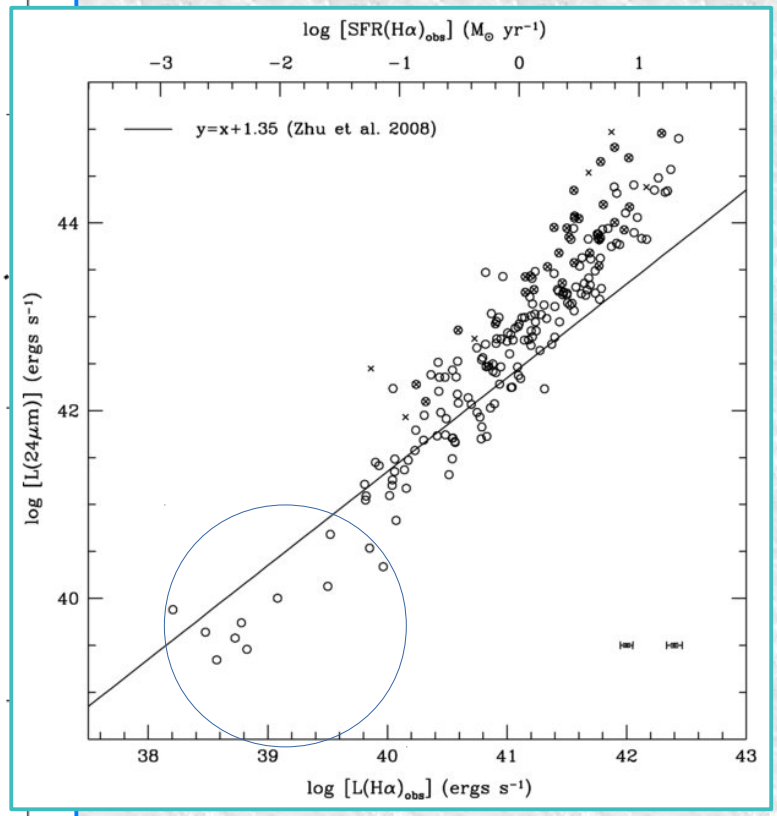






c. Tomičić+17





c. Kennicutt+09

Fig: L(24μm) vs L(Hα)

c. Tomičić+17b

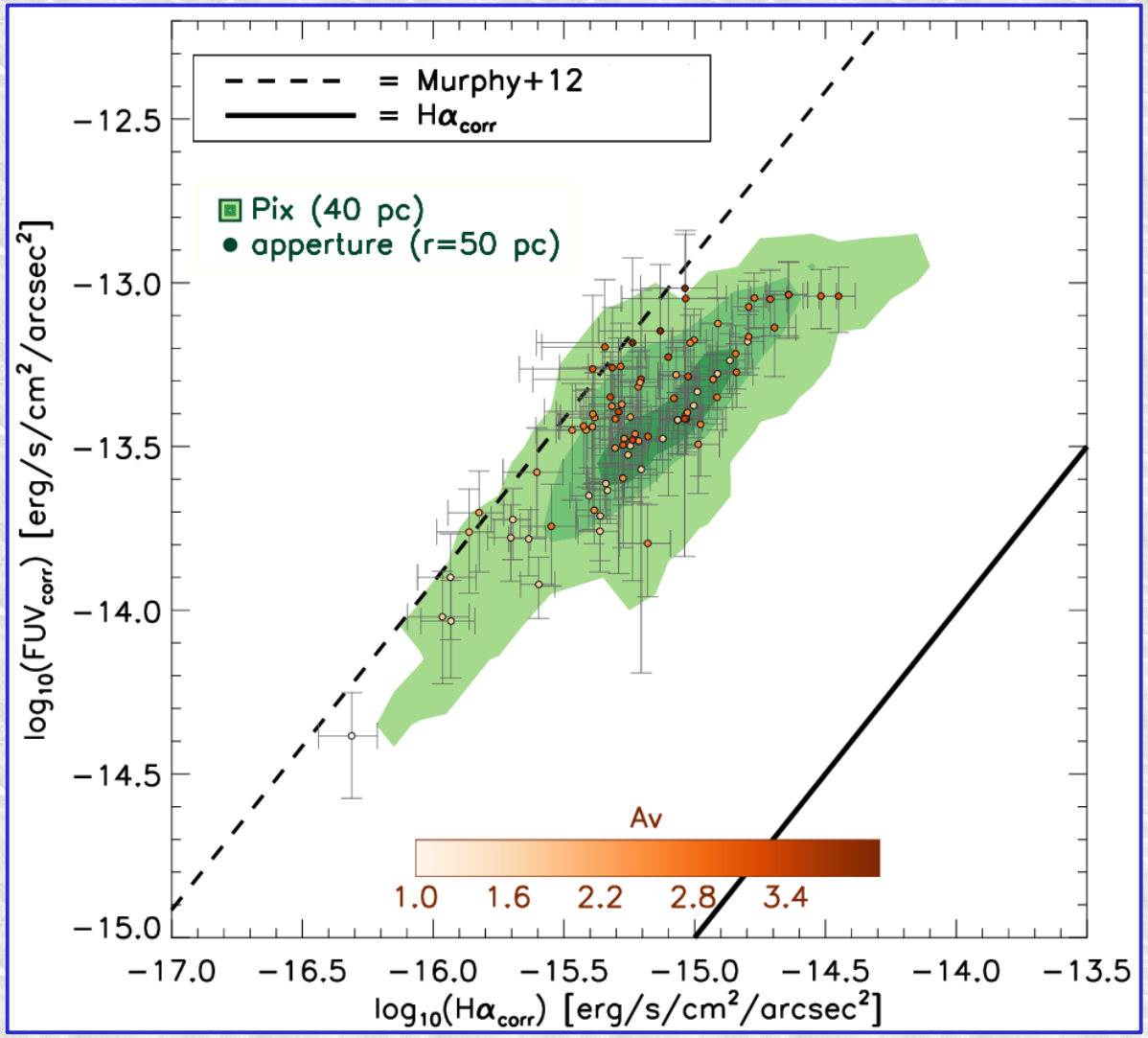


Fig: FUV vs Hα.
FUV (Hα) are corrected by stellar (Balmer) extinction, respectivelly.

c. Tomičić+17b