Cold Dust Heating Mechanisms in Nearby Galaxies

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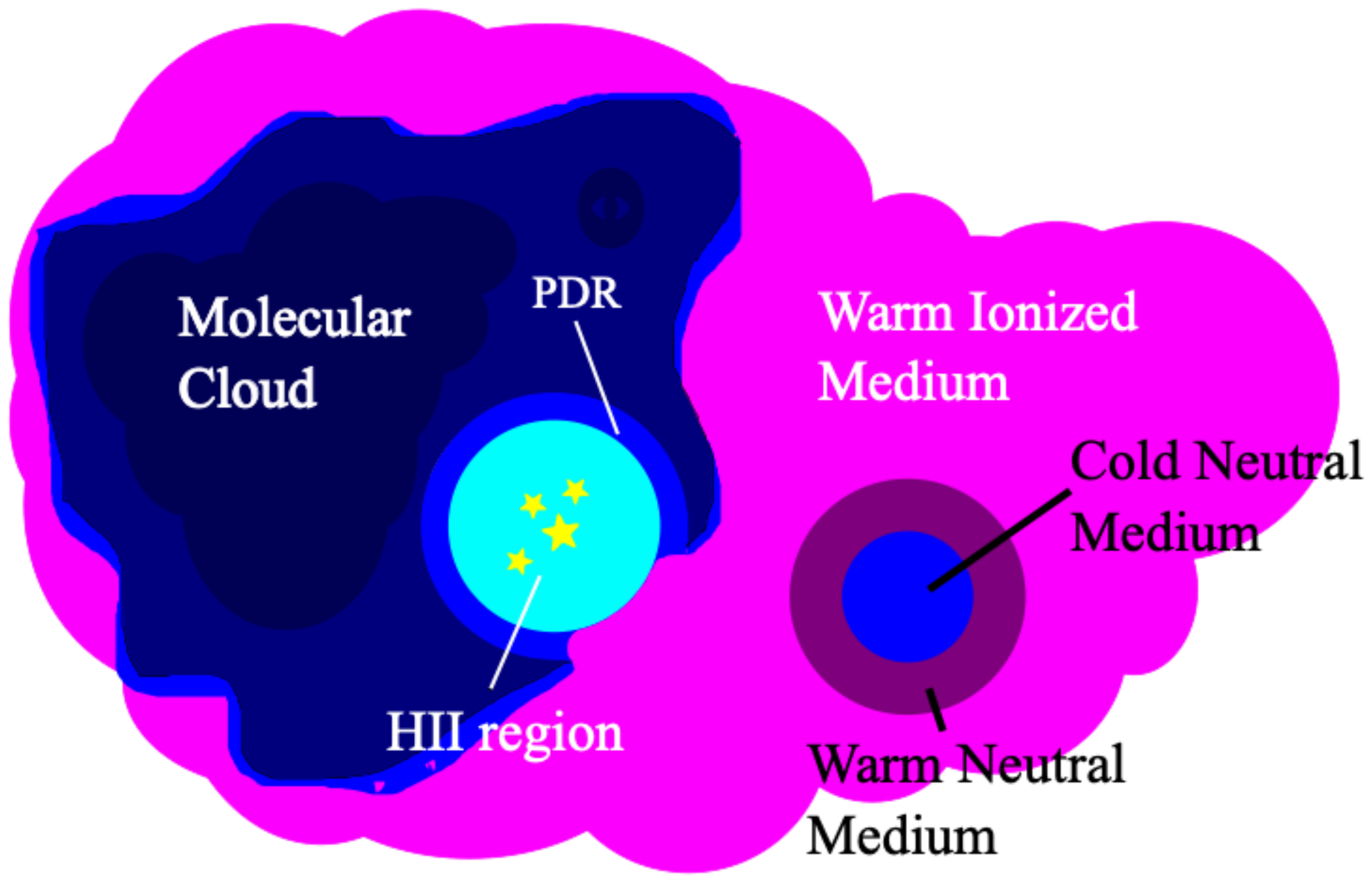
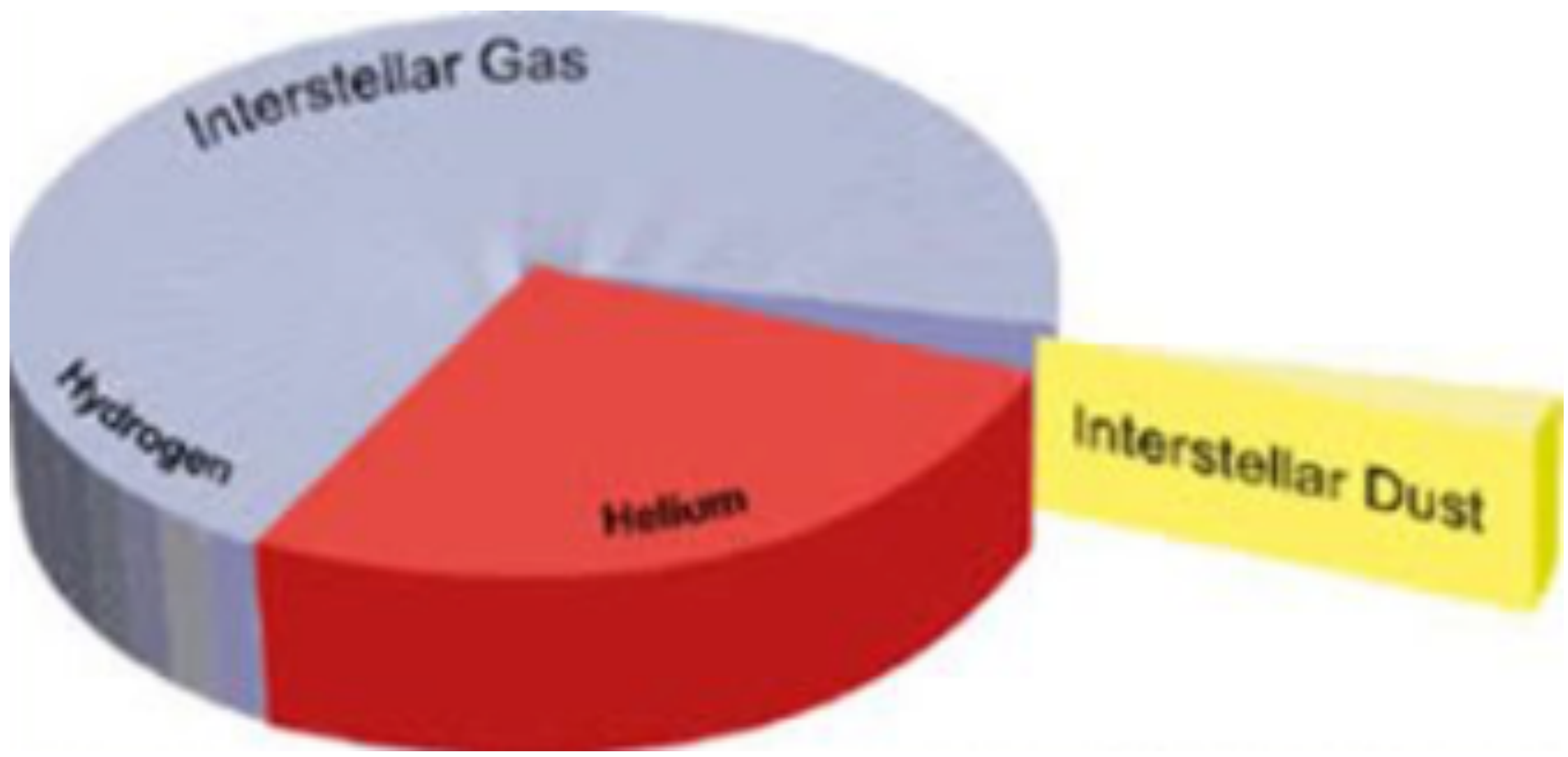
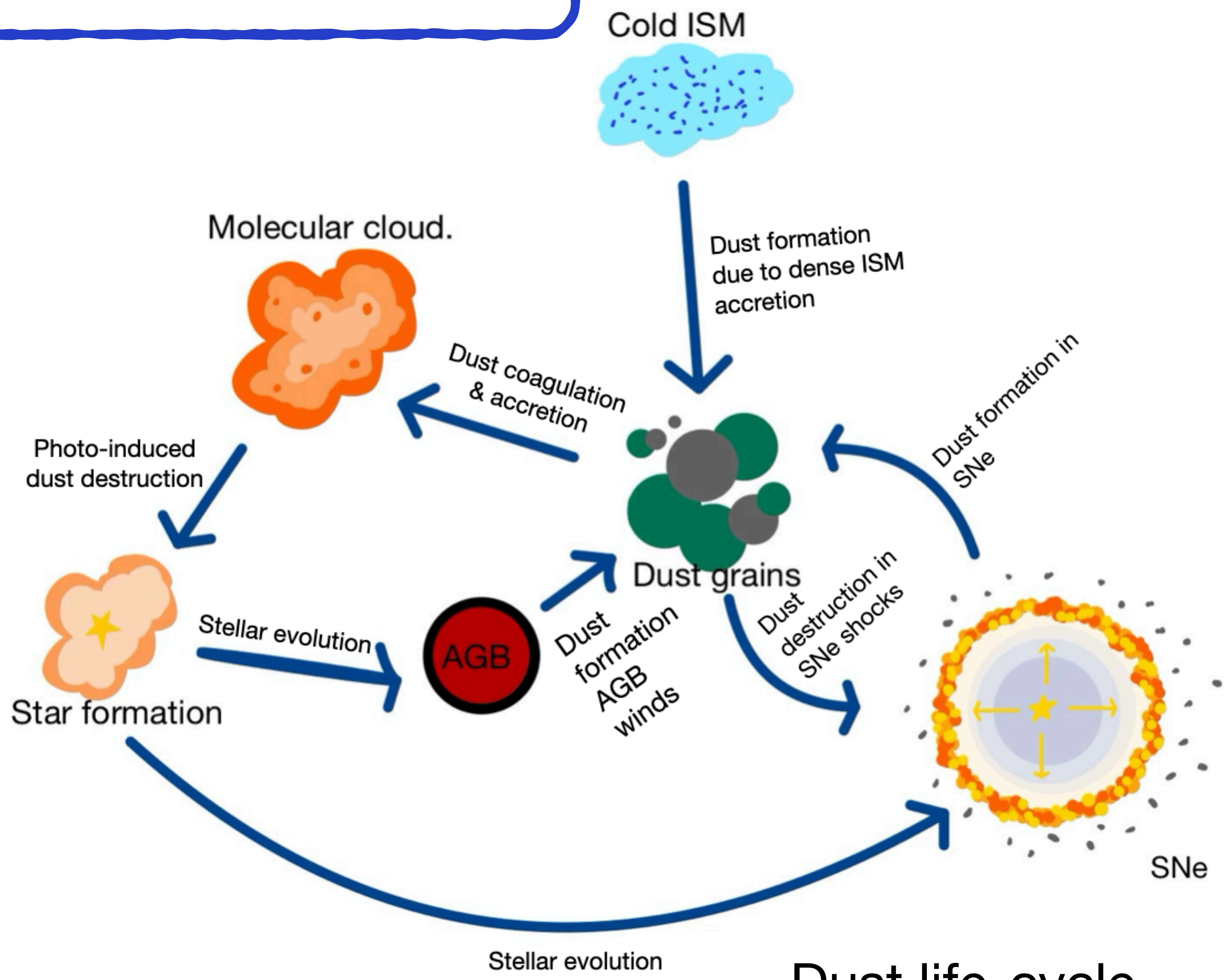
INAF IRA

Dust in ISM





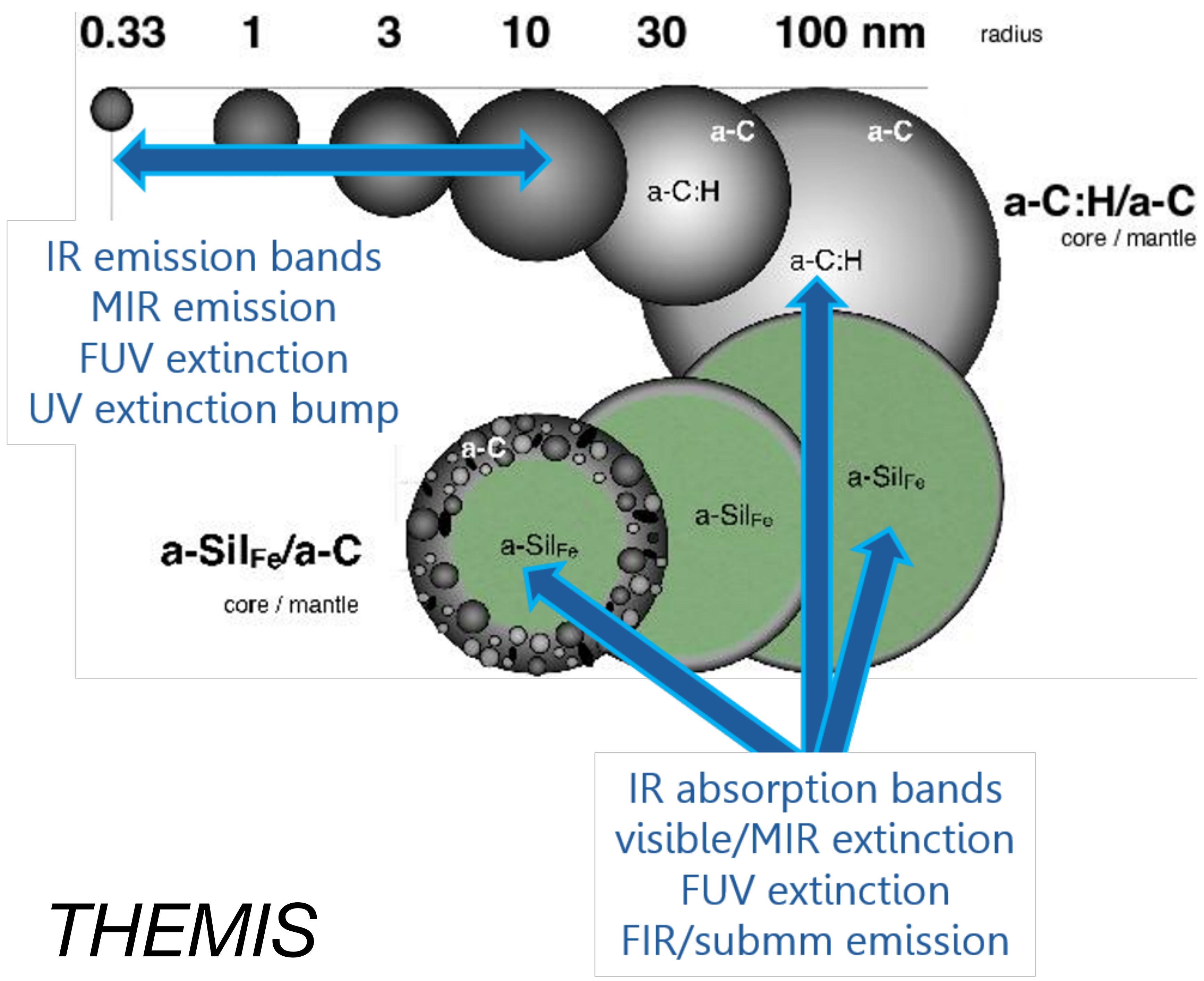


Dust life-cycle

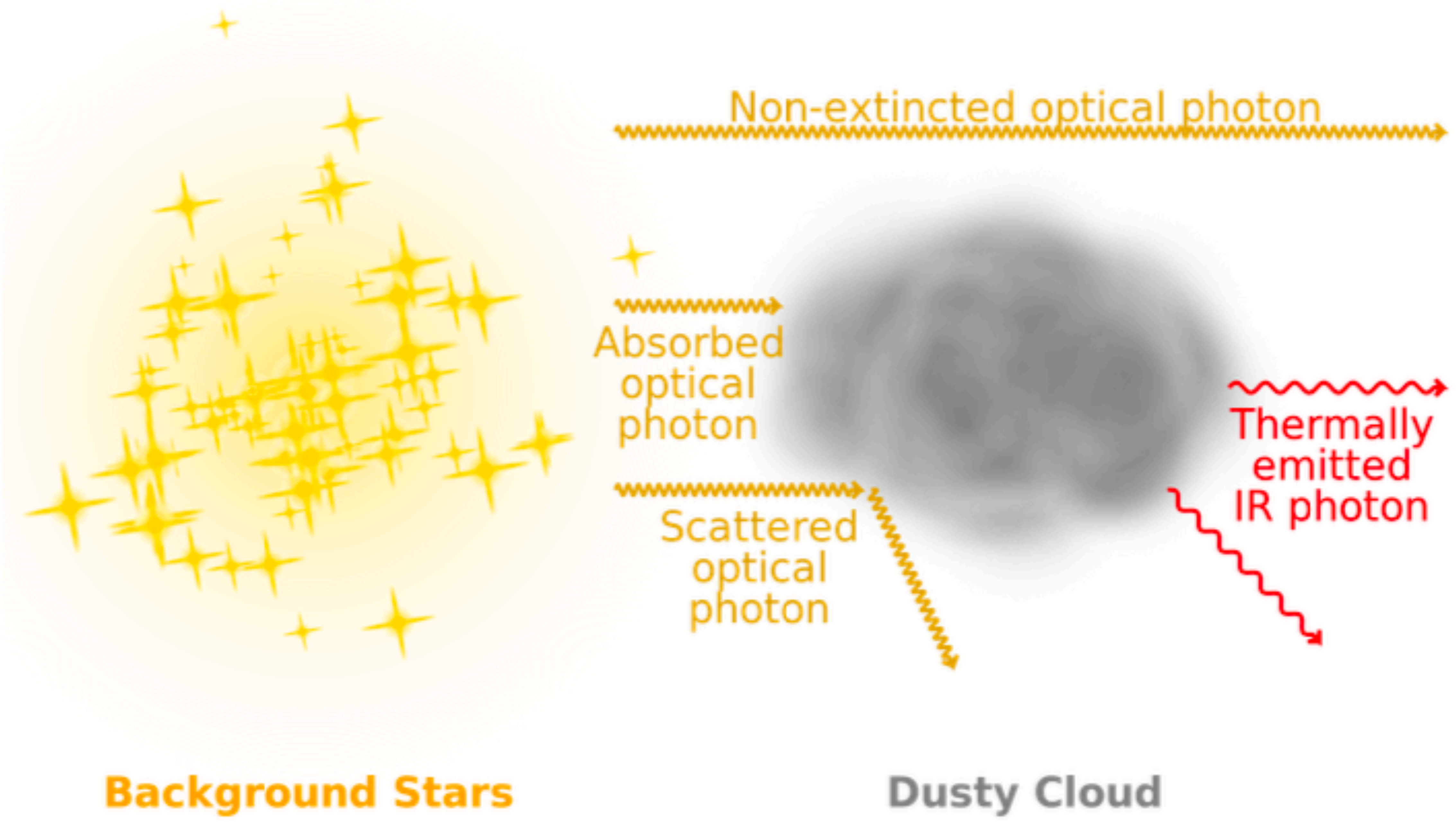
Role of dust

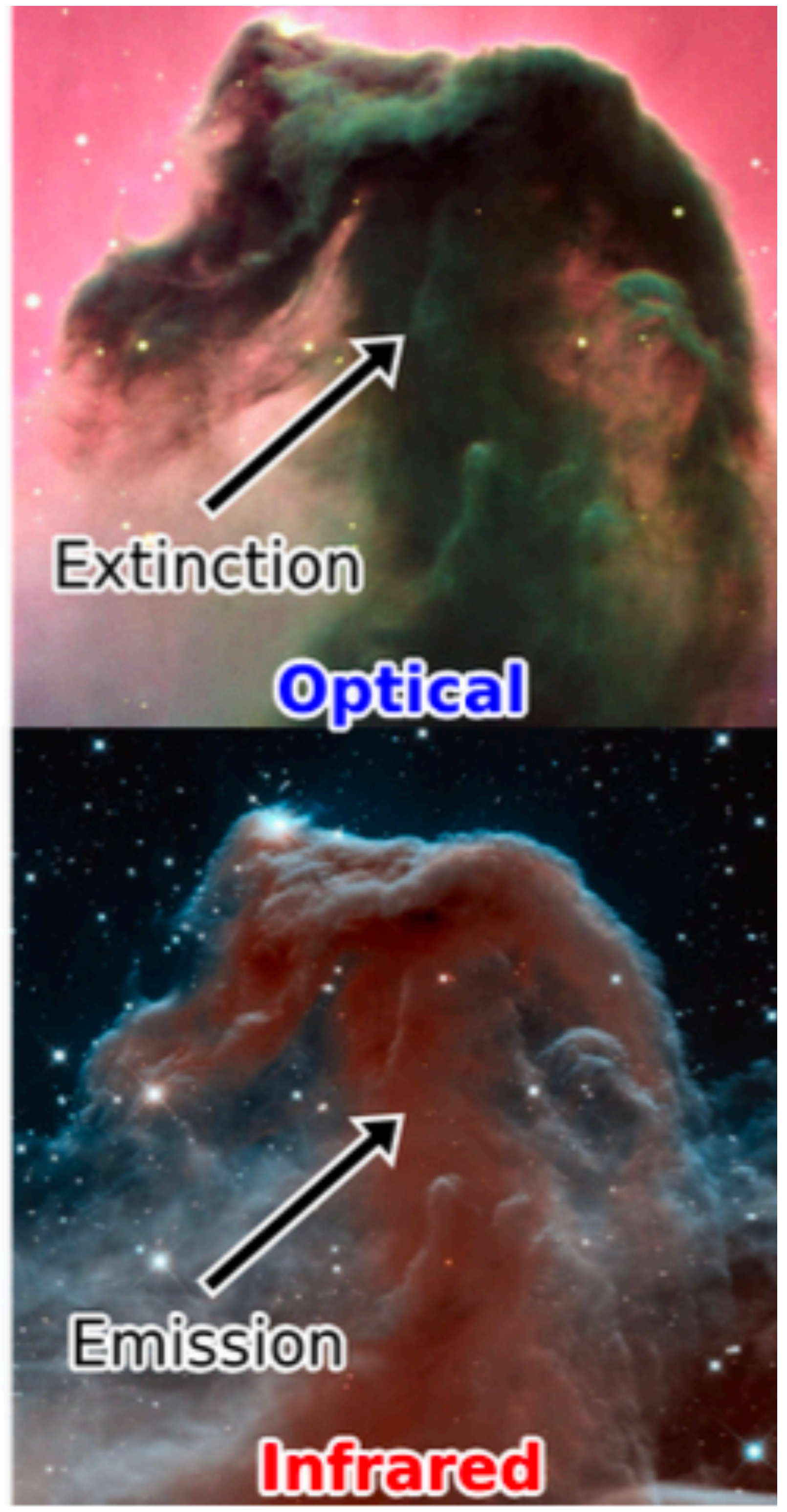
✴ Important catalyst for formation of H_2 molecule

✴ Affects observation: abs UV/Optical & re-emits at IR/sub-mm



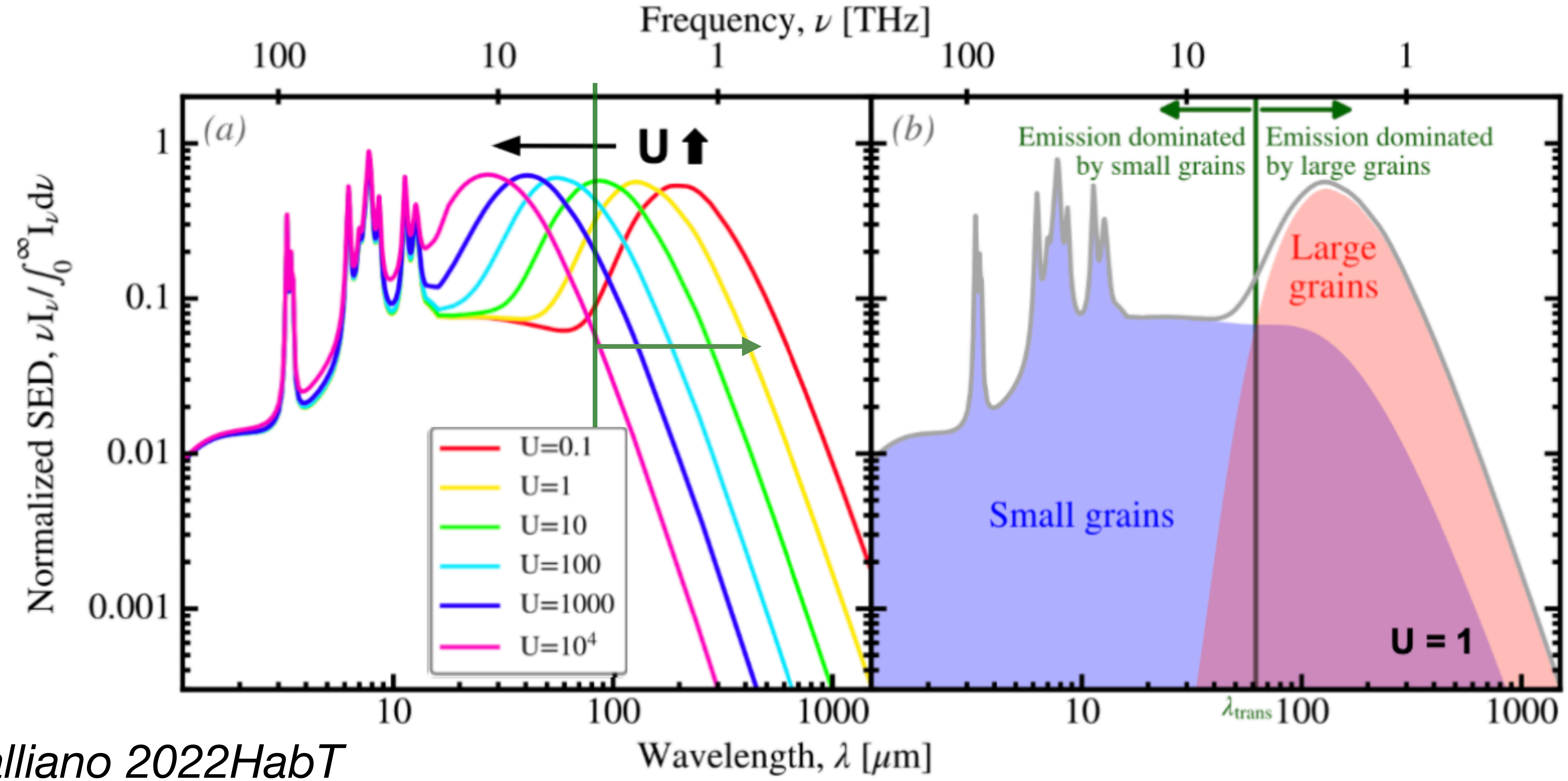
THEMIS





Galliano 2022HabT

Why study dust heating?



Galliano 2022HabT

<u>Dust heating regimes:</u>

1. Thermal equilibrium - Large grains ⟶ 15 - 30 K
2. Stochastic heating - Small grains ⟶ up to few 1000K

Aim of the Study

✳Dust heating in galaxies due to:
i. Diffuse interstellar radiation field (ISRF) from evolved stars
ii. Massive Young Stars
iii. AGN

✳Previous studies have often focused on two approaches: **correlating dust properties with tracers** of the ISRF and SF *(Boquien et al. 2011; Bendo et al. 2012, 2015)*, or using **integrated galaxy properties** to estimate dust parameters (*Nersesian et al. 2019)*

→ My study uses spatially resolved properties (T_d, M_d, Σ_{SFR}), providing more detailed and accurate insights into **local dust heating variations**.

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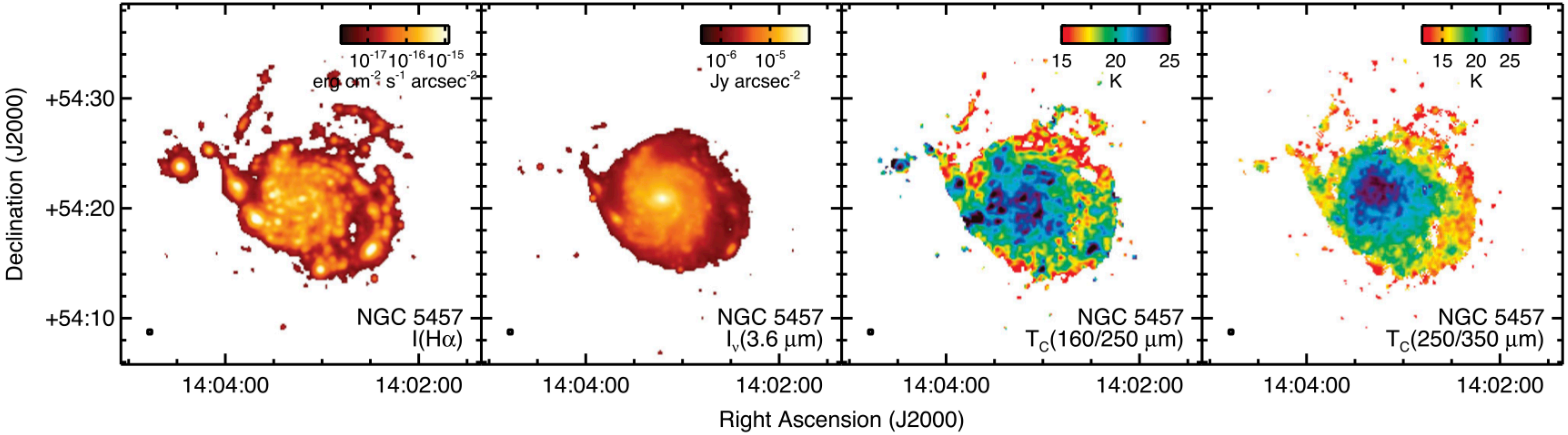

Bendo et al. 2015

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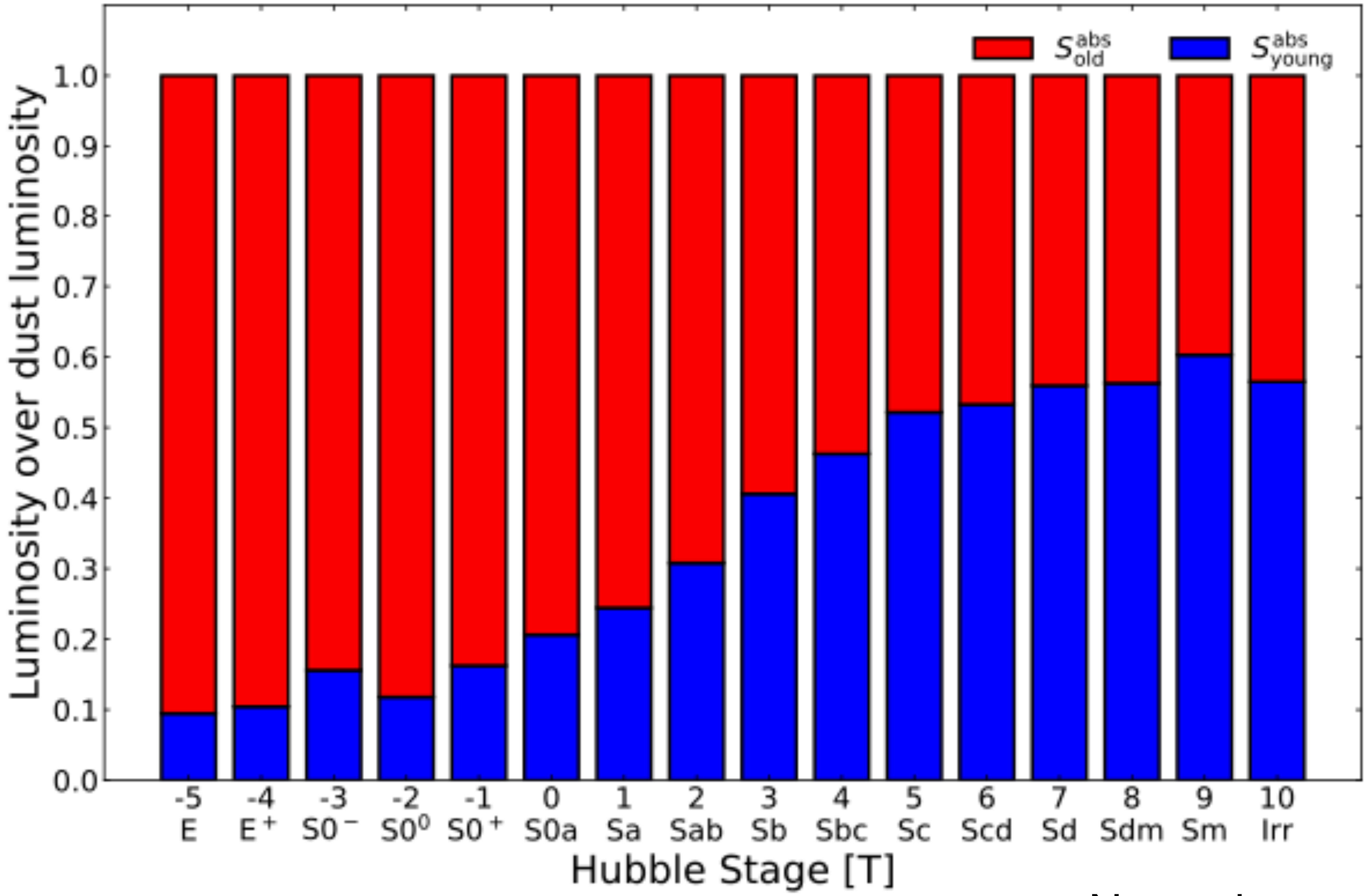

Nersesian *et al. 2019*

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DustPedia

[Davies et al. (2017), Clark et al. (2018)]

It contains 875 nearby galaxies (< 40 Mpc) from the Herschel Science Archive.

Galaxy Sample

Sample from *Casasola et al. (2017)* → **Subset of DustPedia sample**

18 large spiral face-on galaxies

Selection criteria:

$\ast\ (d/D)_{\rm submm} \geq 0.4$

$\ast\ D_{\rm submm} \geq 9'$ → **15 resolution elements** in *SPIRE* - 500 μm maps ($\theta = \mathbf{36''}$)

↓

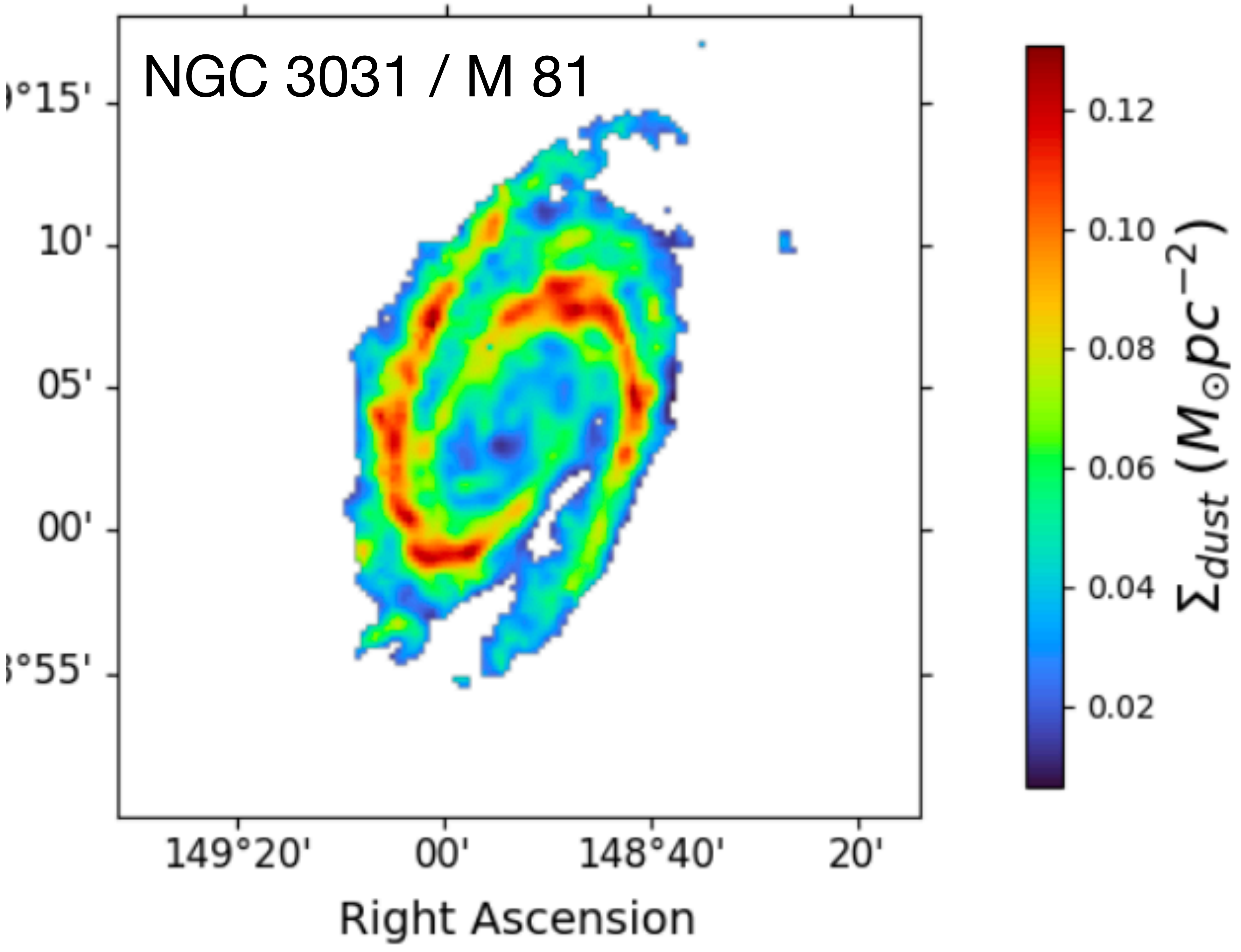
0.3 - 3.4 kpc

Galaxy Sample		
IC 342	NGC 2403	NGC 5055
NGC 300	NGC 3031	NGC 5194
NGC 628	NGC 3521	NGC 5236
NGC 925	NGC 3621	NGC 5457
NGC 1097	NGC 4725	NGC 6946
NGC 1365	NGC 4736	NGC 7793
$SFR\ range\ [M_{\odot} yr^{-1}]: 0.2 - 12.97$		
$\log M_{*}\ range\ [M_{\odot}]: 9.29 - 10.99$		

Derivation of $\Sigma_{\rm dust}$ and $T_{\rm dust}$

$\Sigma_d [M_\odot pc^{-2}]$

$$L_{TIR} = \epsilon \times M_d \times U_{min}$$

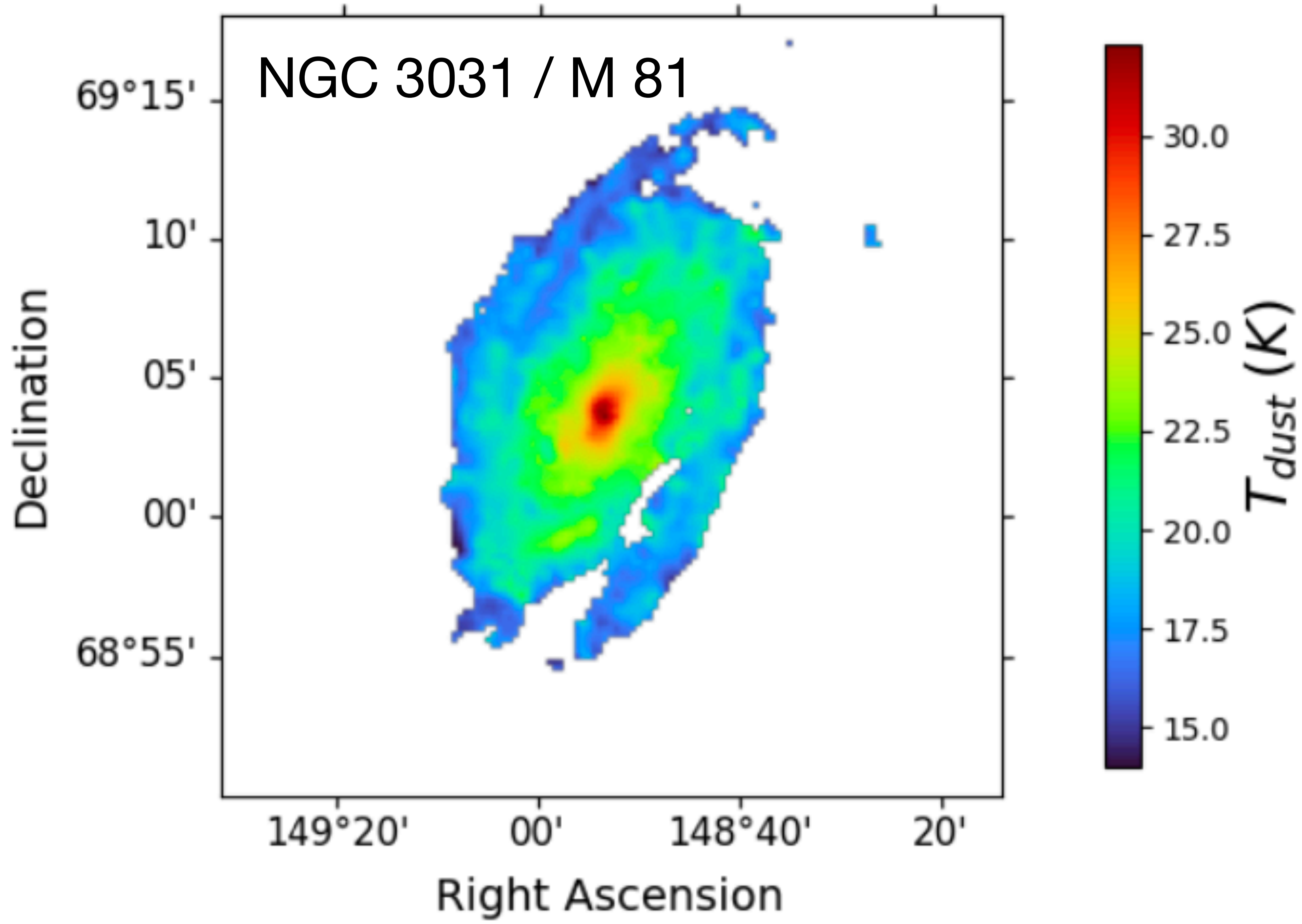


Tailor et al., in prep

$T_d \; [K]$

$$T_d = T_o U_{min}^{(1/4+\beta)}$$

(Aniano et al. 2012)



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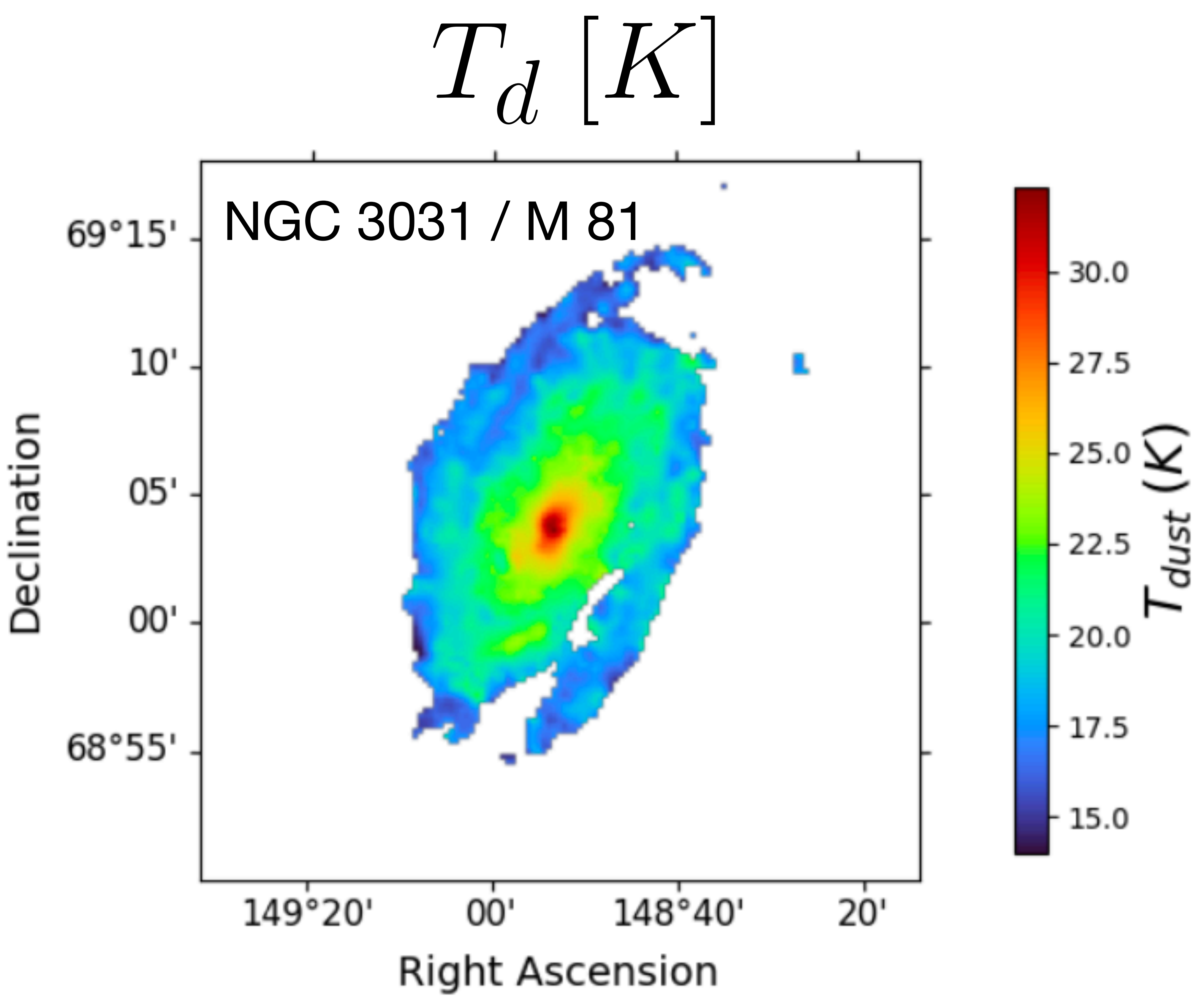
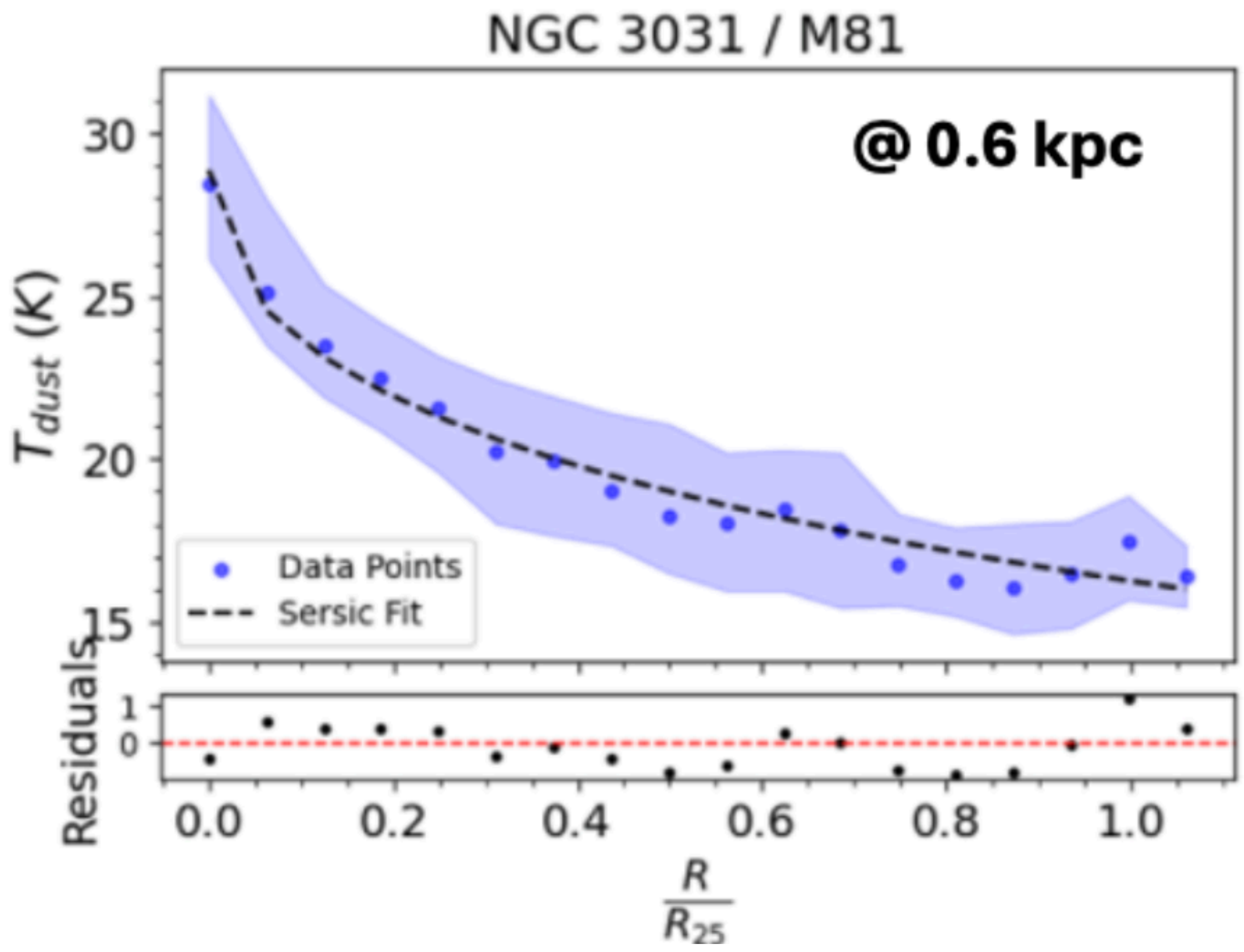
Dust Temperature Radial Profiles





All Galaxies
T_{dust} (K)
Unbarred Galaxies
Barred galaxies
AGN
$L_X < 10^{42}$ erg s^{-1}
No AGN
$\frac{R}{R_{25}}$

Searching for dominant heating mechanism

Searching for dominant heating mechanism

Method 1 : Correlating $T_{\rm dust}$ with $\Sigma_{\rm SFR}$ and $\Sigma_{\rm M*}$

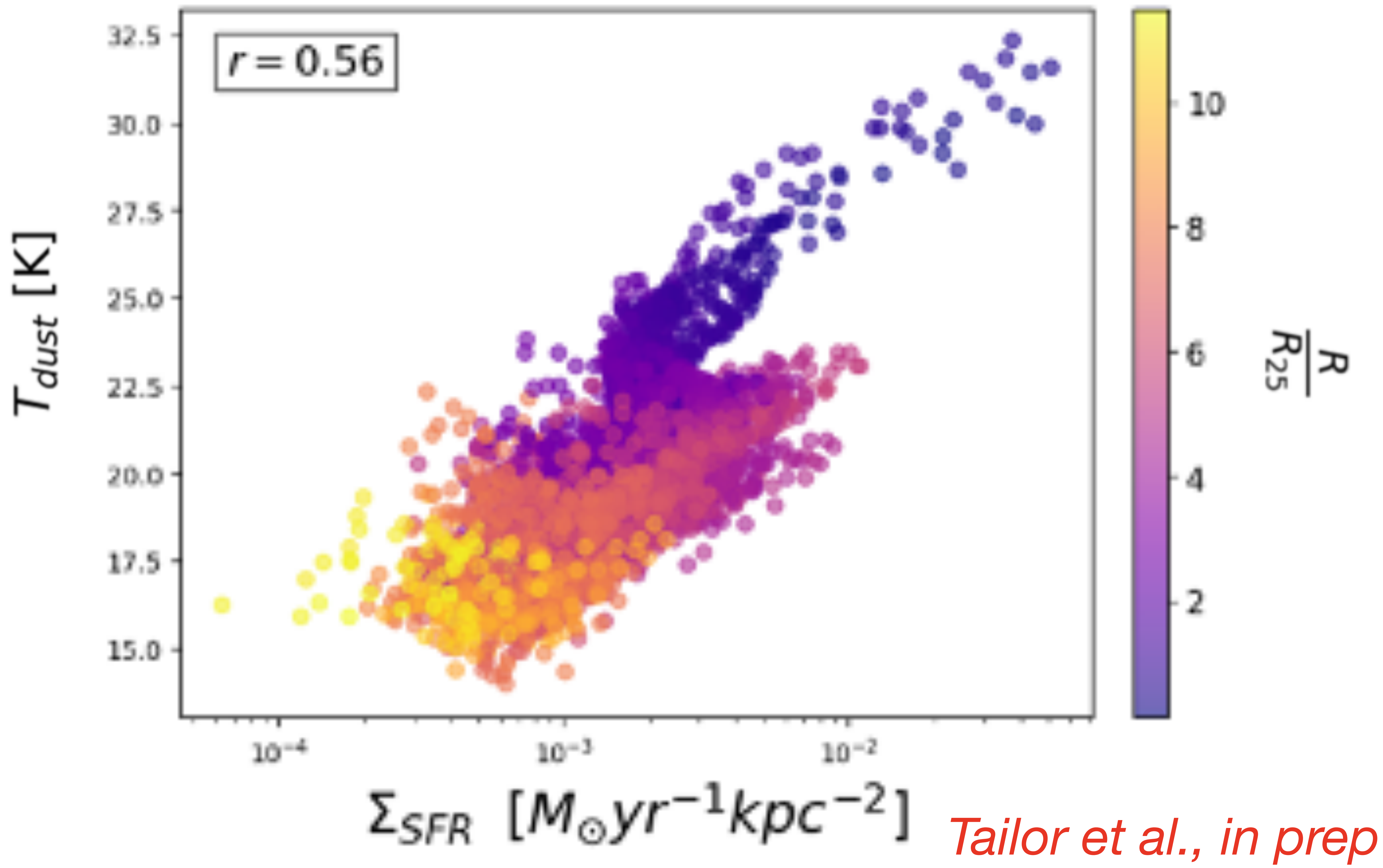
$r_{T_{\rm dust}-\Sigma_{\rm SFR}}$

$$\Sigma_{SFR} = 3.2 \times 10^{-3} \times I_{22} + 8.1 \times 10^{-2} \times I_{FUV}$$

(Bigiel et al. 2008)

WISE (I_{22}) GALEX (I_{FUV})

NGC 3031 / M 81



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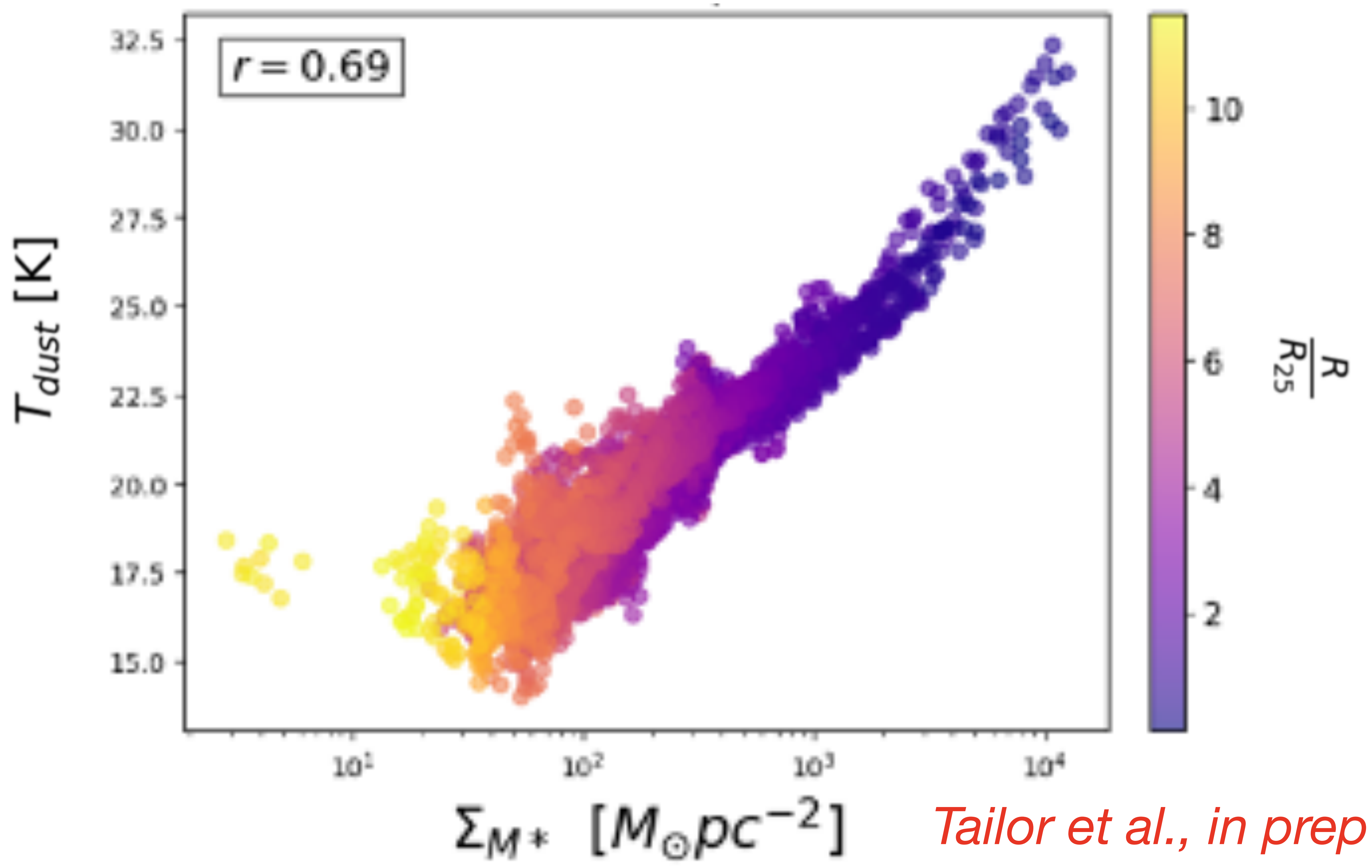
$r_{T_{\rm dust}-\Sigma_{\rm M*}}$

Derived using IRAC 3.6 and 4.5 μm

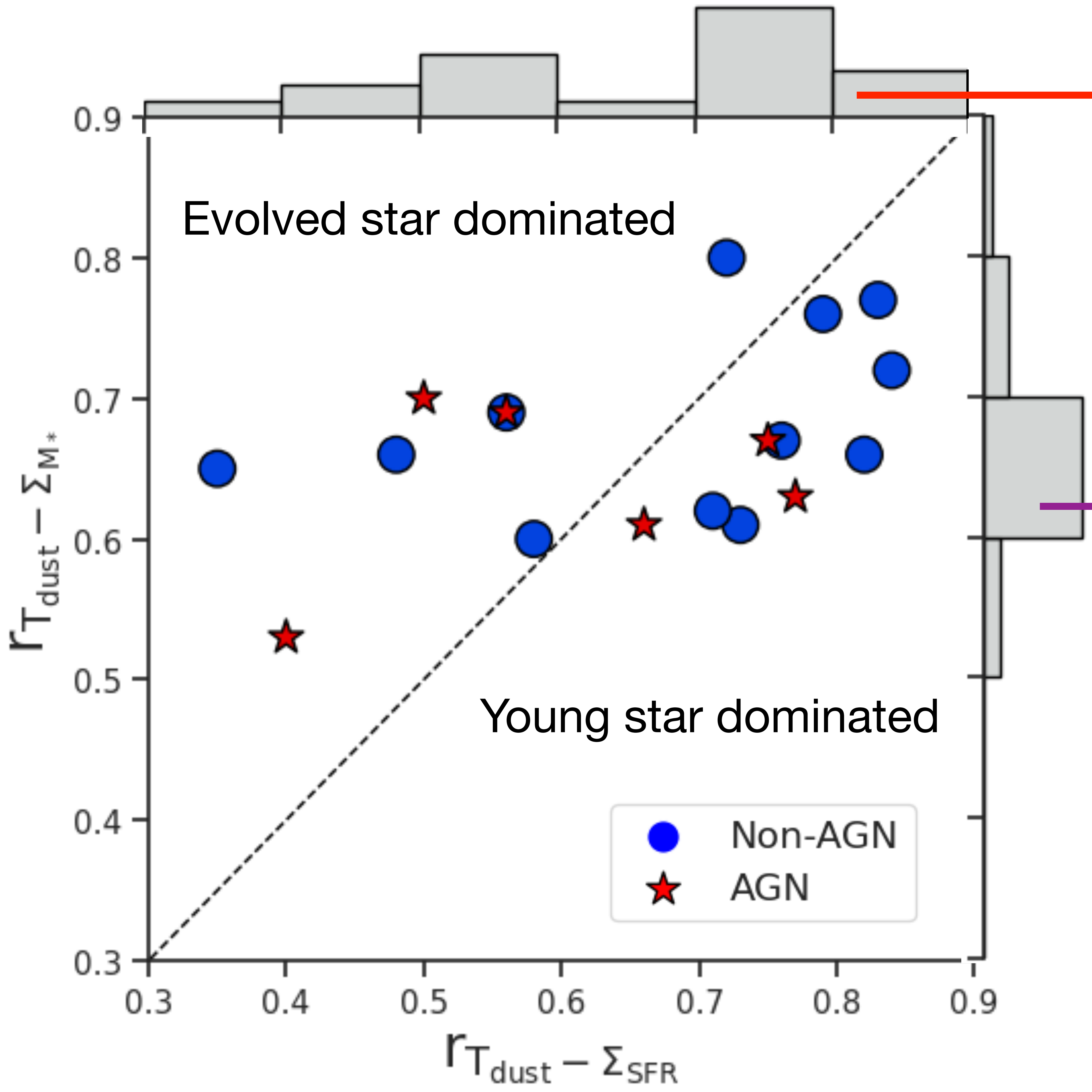
(Querejeta et al. 2015)

NGC 3031 / M 81



Tailor et al., in prep

Method 1 : Correlating T_{dust} with Σ_{SFR} and Σ_{M_*}



~50% young star-dominated

and

~50% evolved star-dominated

Evolved stars, due to their abundance and extended lifetimes, maintain a consistent level of energy input to dust over long timescales.

Searching for dominant heating mechanism

Method 2: Based on *Utomo et al. (2019)*

L(IR) due to young stars ← $\Sigma_{SFR} \propto L_{IR} \propto T^{4+\beta}\Sigma_d$ → Modified black-body

Kennicutt – Schmidt law ← $\Sigma_{SFR} \propto \Sigma_{gas}^{n}$

Dust to gas ratio ← $\Sigma_d \propto \Sigma_{gas}$

$$(\mathbf{n}-1)\,\mathbf{log}\Sigma_{\mathbf{d}} + \mathbf{A} = (4+\beta)\,\mathbf{log}\mathbf{T}_{\mathbf{d}}$$

β: 1.79 (THEMIS)

n = 2.19 (*Casasola et al. 2022*)

A: Normalising constant

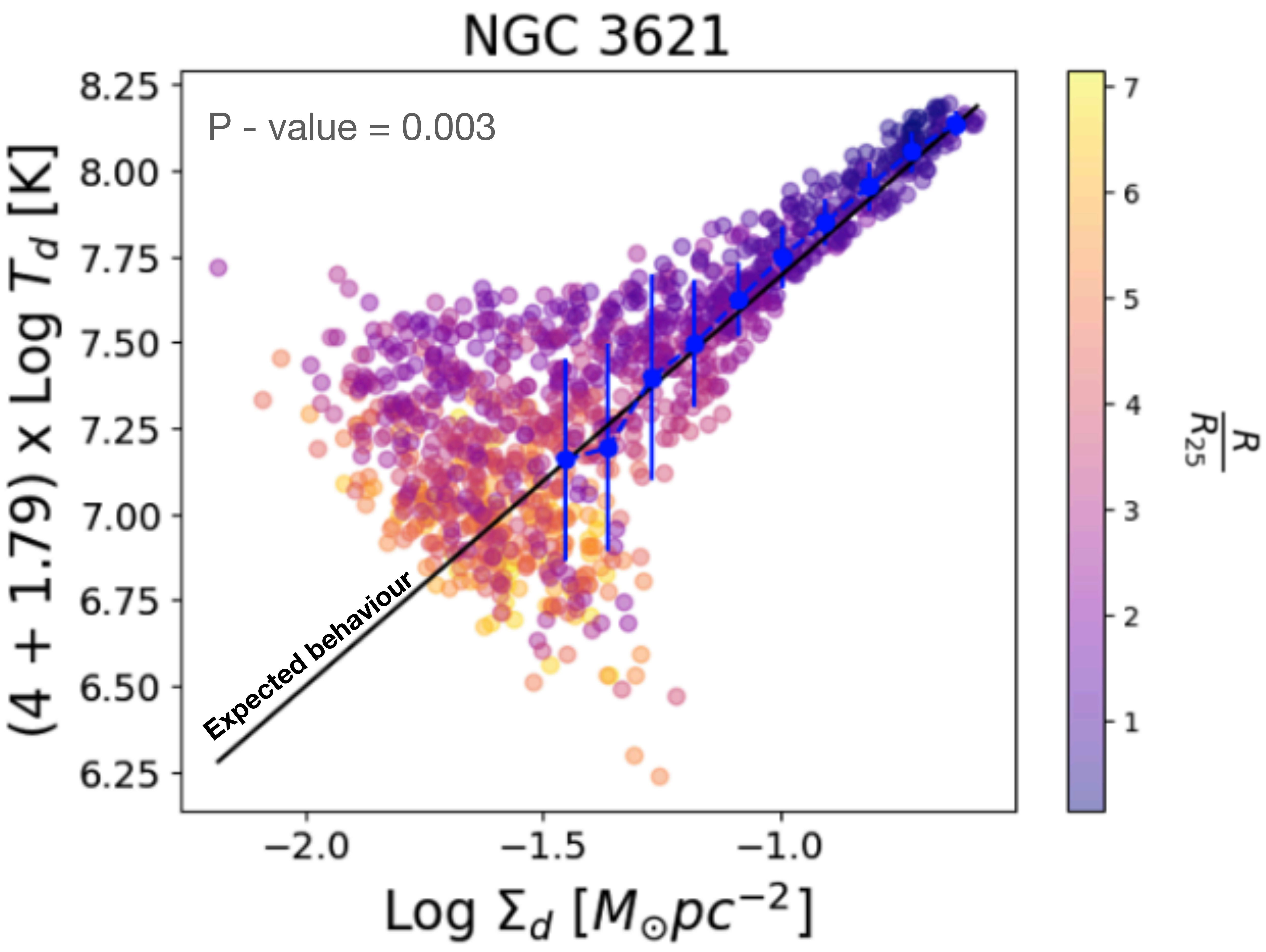
$$(2.19 - 1)\log \Sigma_{\mathrm{dust}} + \mathbf{A} = (4 + 1.79)\log \mathbf{T}_{\mathrm{dust}}$$

Only free parameter

(Utomo et al. 2019)

Young stars are dominant

Young stars are **NOT** dominant



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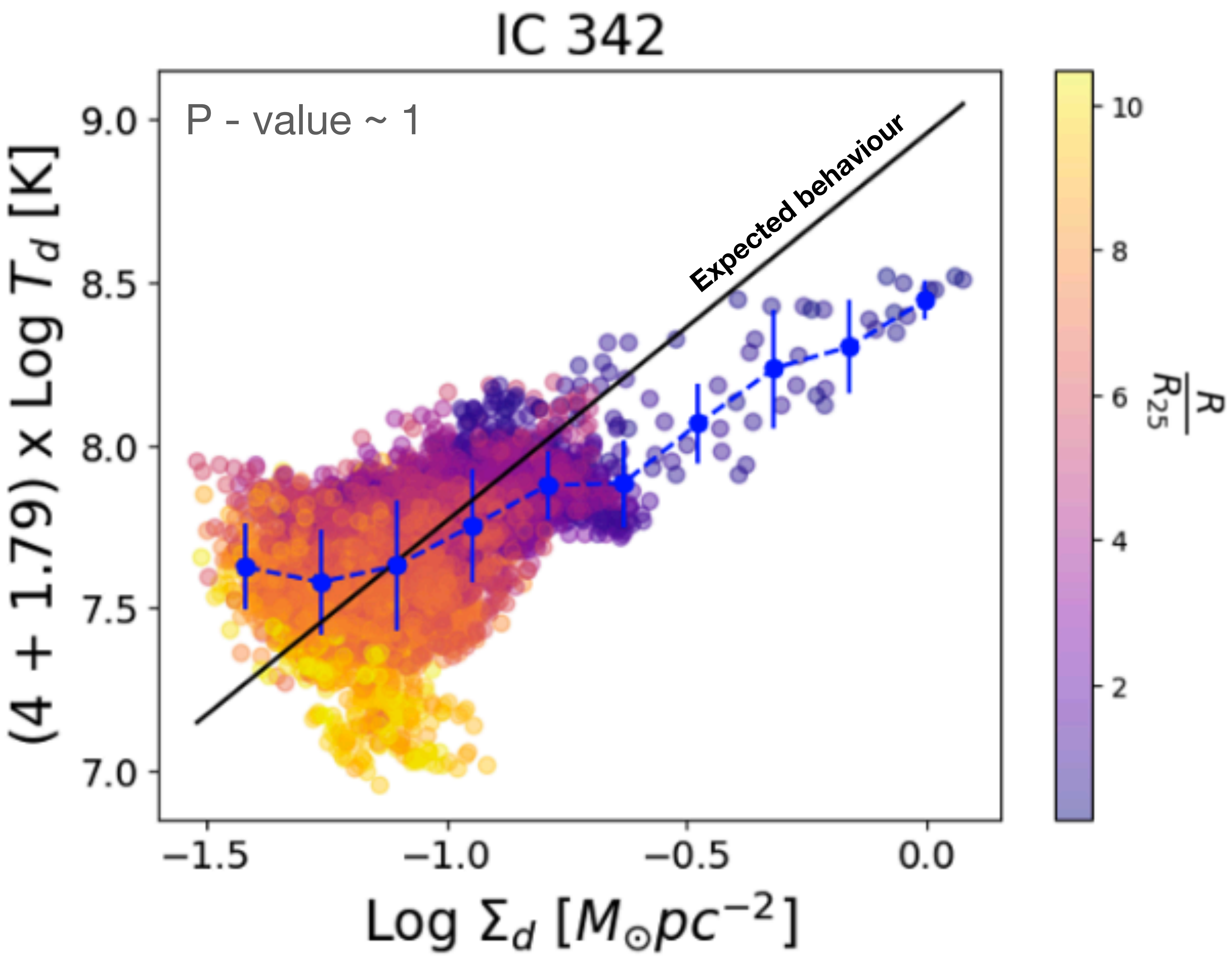
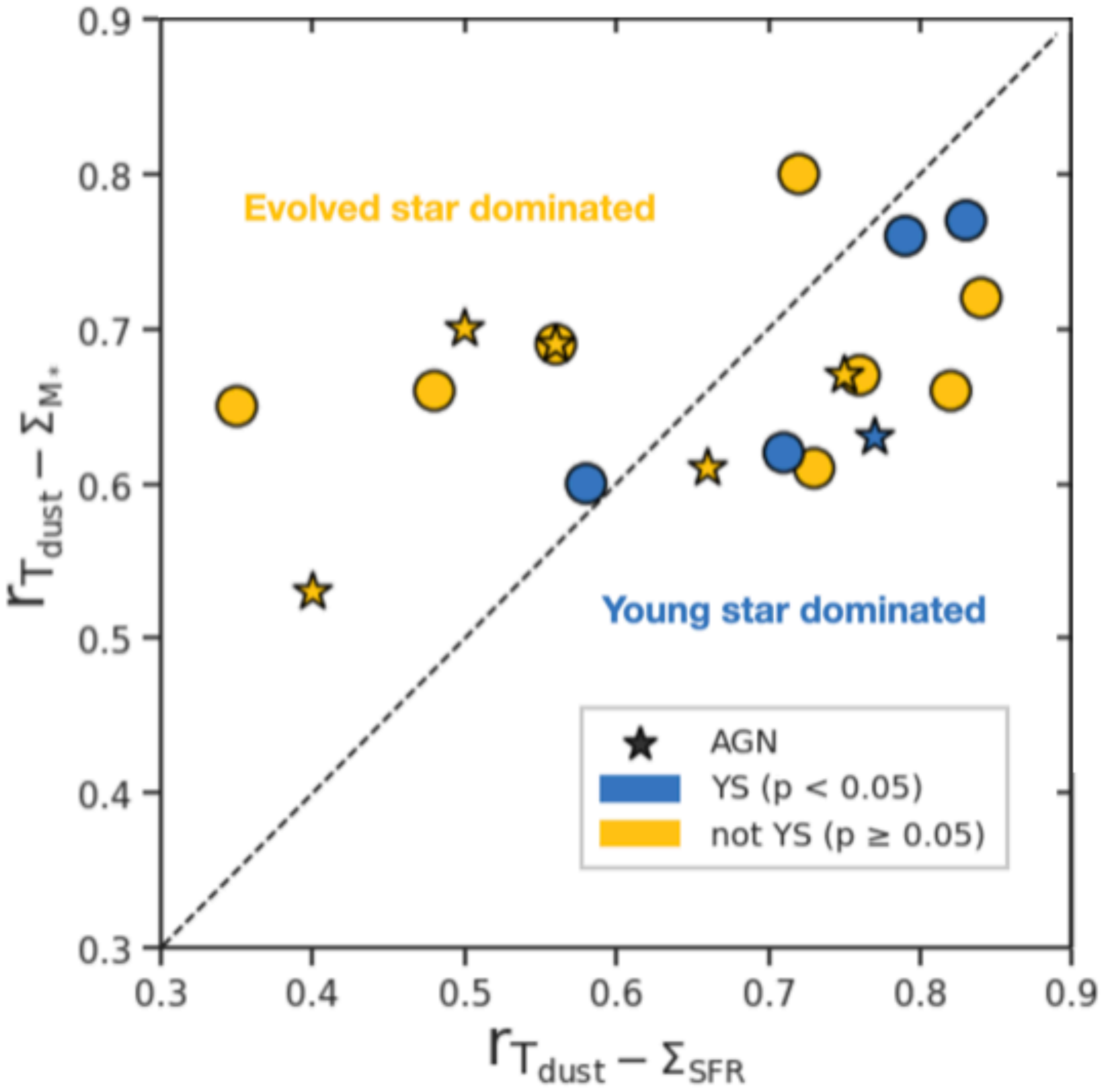


Tailor et al., in prep

Comparison between 2 methods



- The two methods agree for 11 out of 18 galaxies.
- The discrepancies arise from:

  1. resolution effects

  2. assumption of a constant slope for the KS law across galaxies

  3. Assumption of a linear relation between Σ_{dust}, Σ_{gas} .

  4. Assumption of constant CO-to-H_2 conversion factor.

Towards the Future —

How PRIMA will help?

Future applications of PRIMA

➡ 24 - 235 μm range ⟶ Warm dust observations ⟶ Expected to be linked to recent SF

➡ Improved sensitivity in the shorter wavelengths than Herschel

➡ Warm and cold dust radial profiles ⟶ constraining dependency of local conditions on heating mechanisms

➡ Detect the presence of AGN and provide better constraints on their impact on dust

Conclusions

- AGN presence doesn't significantly affect temperature profiles at our sampled spatial scales

- Both $\Sigma_{\rm SFR}$ and $\Sigma_{\rm M_*}$ correlated roughly equally with $T_{\rm dust}$

- Analysis of $T_{\rm dust}$ - $\Sigma_{\rm dust}$ relation ⟶ in ~78% of sample young stars are not dominant heating mechanisms.

- Out of the 18 galaxies analyzed, the two methods are consistent in 11 cases.

Looking forward to PRIMA !!

Thank You!