Why does dust distribution matter to galaxies?

1. Dust distribution inside high-redshift galaxies remains to be an open question.

   (→ better theoretical model of galaxy formation)

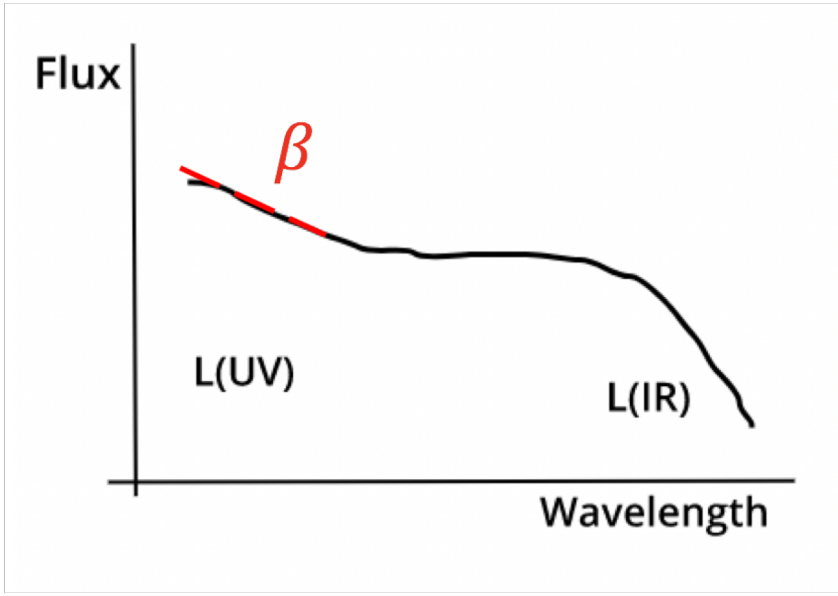
2. Dust influences measurement of galaxy star-formation rate.

   (→ more precise Madau relation)

Image Credit: ESO

1. Using IRX and β to understand dust distribution

IRX: L(IR)/L(UV) β: slope of UV spectrum



1. Galaxies with no dust:

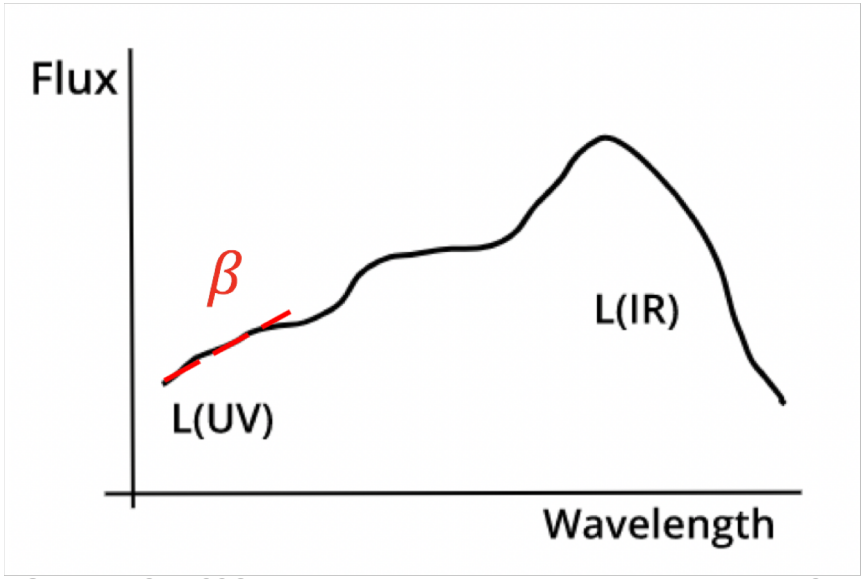
Low IRX value

Small (more negative) β value

2. Galaxies with much dust:

High IRX value

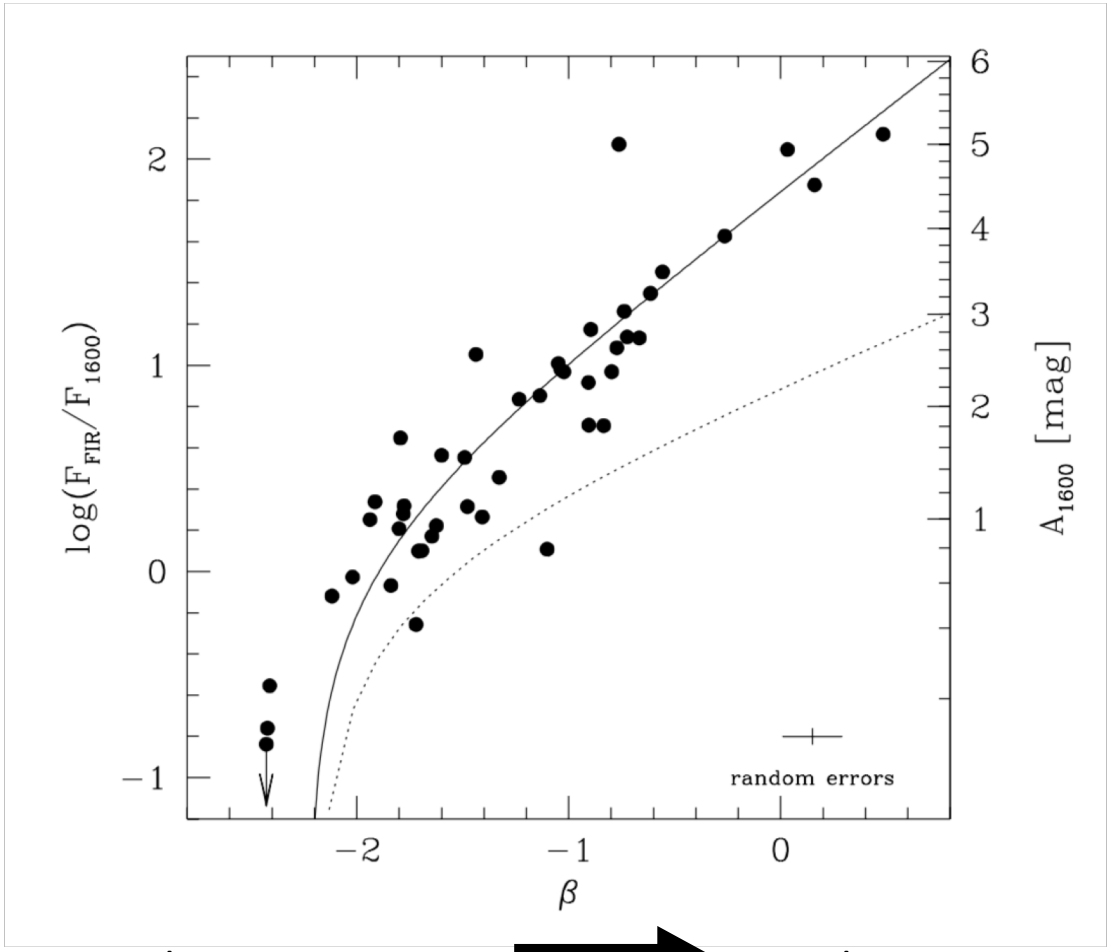
Large β value



1. Using IRX and β to understand dust distribution

High IRX

Low IRX



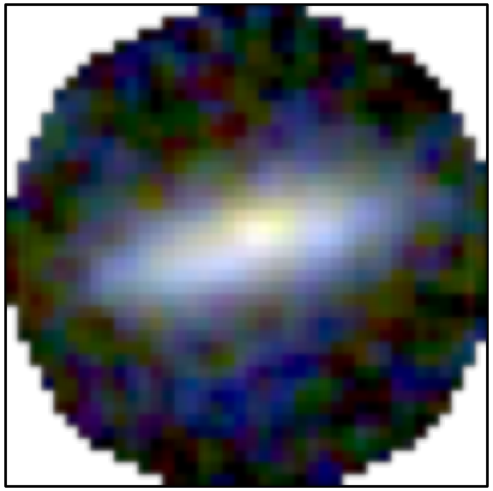
High A_{UV}

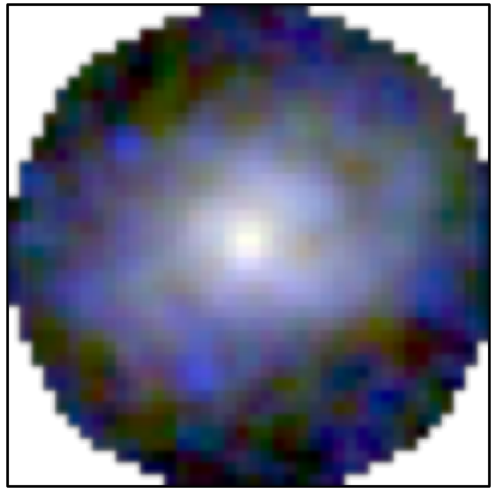
Low A_{UV}

Blue UV Spectrum → Red UV Spectrum

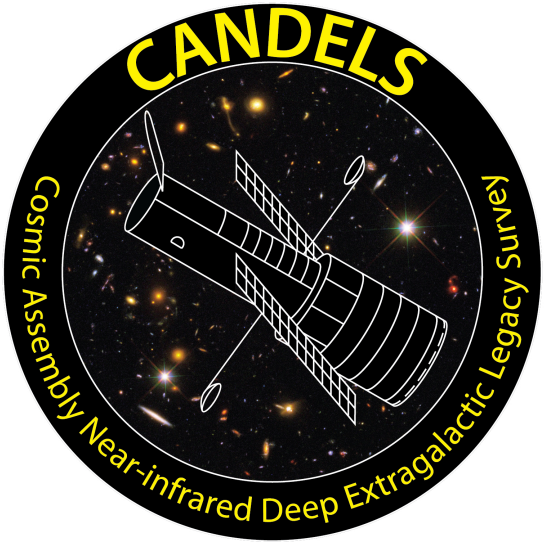
Local Starburst Galaxies, (Meurer, Heckman, and Calzetti 1999)

2. High-mass star-forming galaxies (>10^{10} M_{sun})

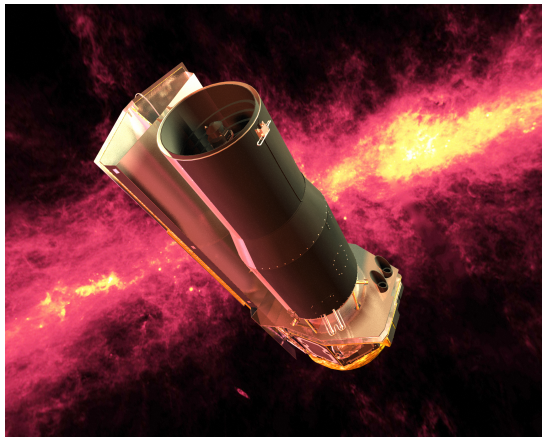




2. Data from the CANDELS survey (GOODS-S and GOODS-N)



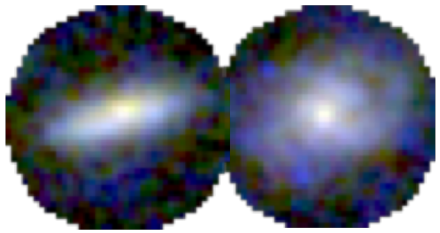
1. Star-forming galaxies ($10^{10} - 10^{11}$ $\mathrm{M_{sun}}$) at z=1.3-1.7
2. L(IR) is converted from Spitzer 24 μm flux
3. Measure β from ground-based U-band and HST ACS bands.



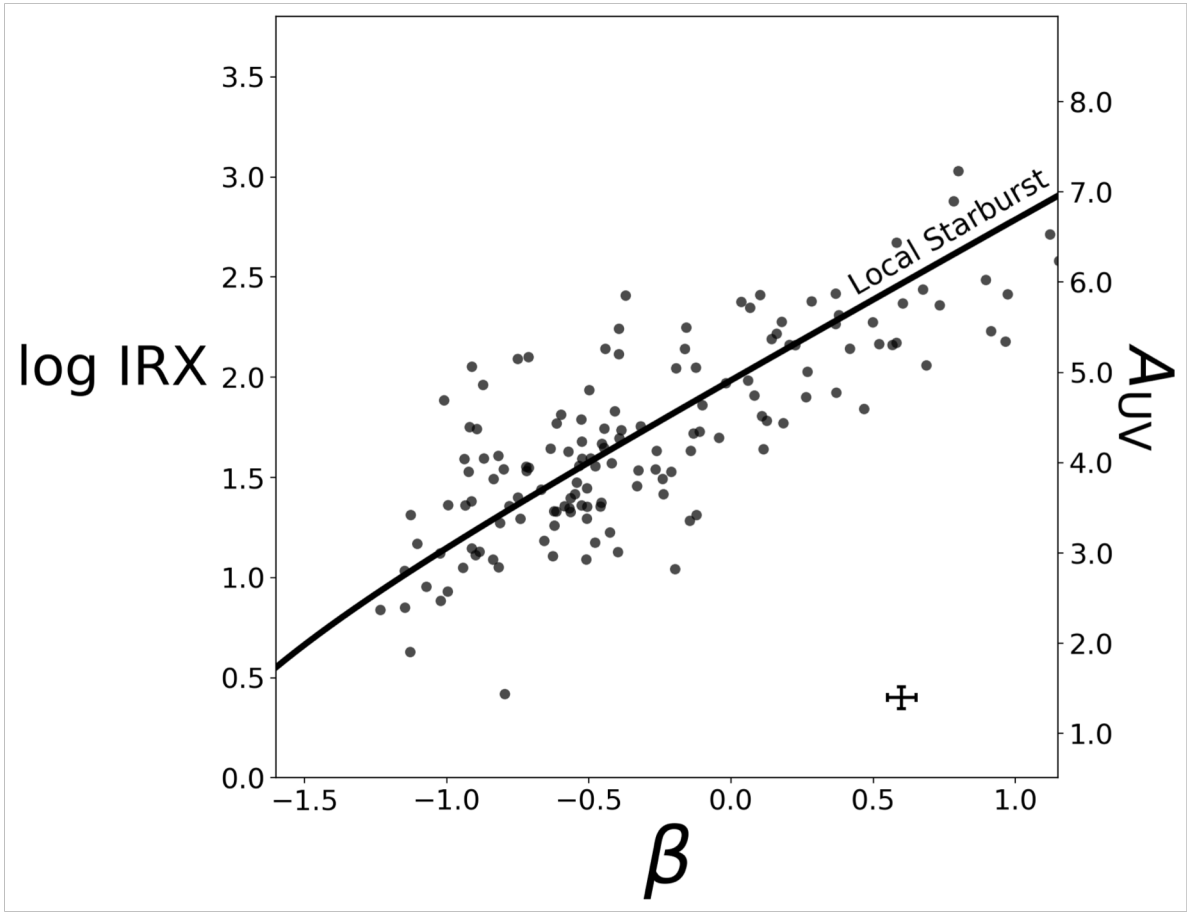
2. Observation Results:
average trend is consistent with local starbursts

$10^{10} - 10^{11}\ \mathrm{M_{sun}}$

$1.35 < z < 1.75$



Wang et al. 2018, ApJ



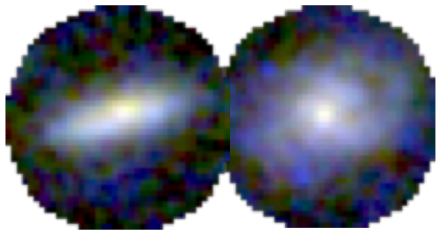
2. Observation Results:
edge-on galaxies stay above face-on galaxies.

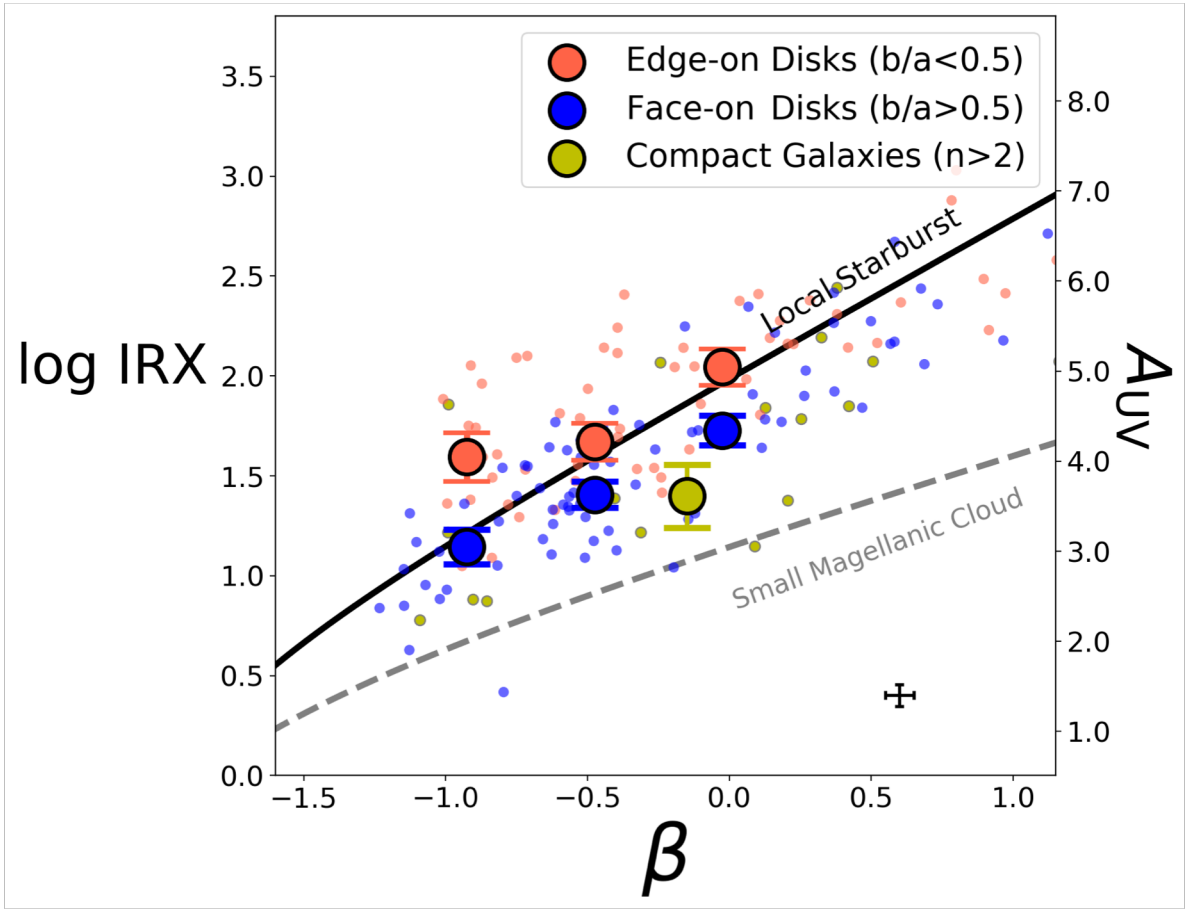
Red: Edge-on galaxies

Blue: Face-on galaxies

$10^{10} - 10^{11}\ \mathrm{M_{sun}}$

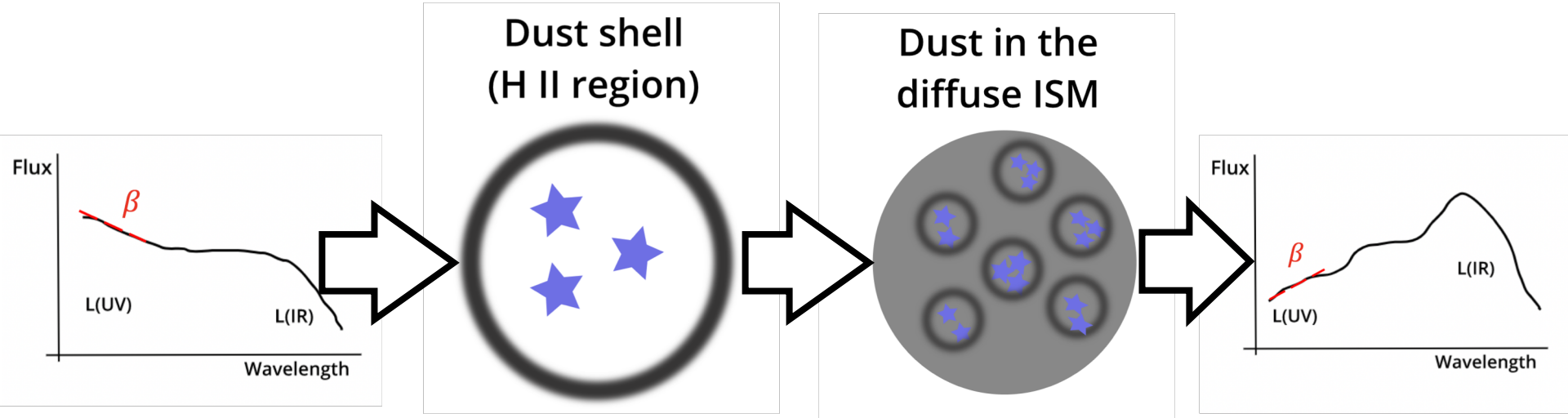
$1.35 < z < 1.75$





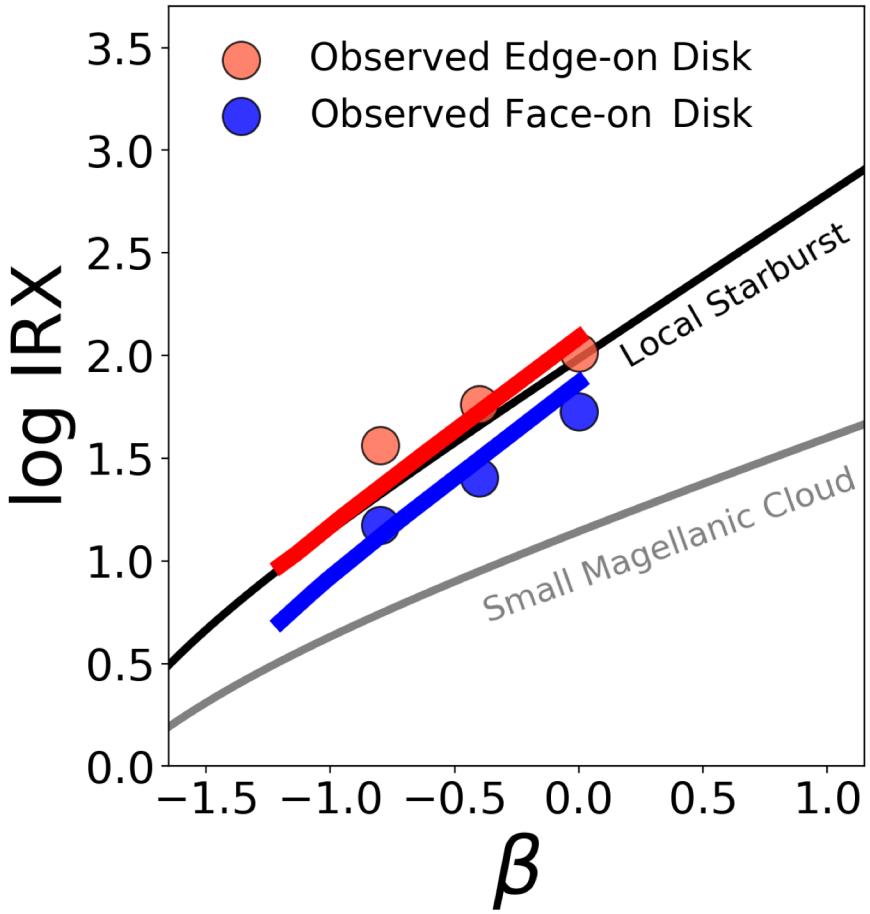
Wang et al. 2018, ApJ; See also
Salim et al. 2019 for local galaxies

2. Using IRX-β relation to understand dust distribution: radiative transfer modelling



Radiative transfer results from Seon & Draine (2016).

2. Using IRX-β relation to understand dust distribution: radiative transfer modelling

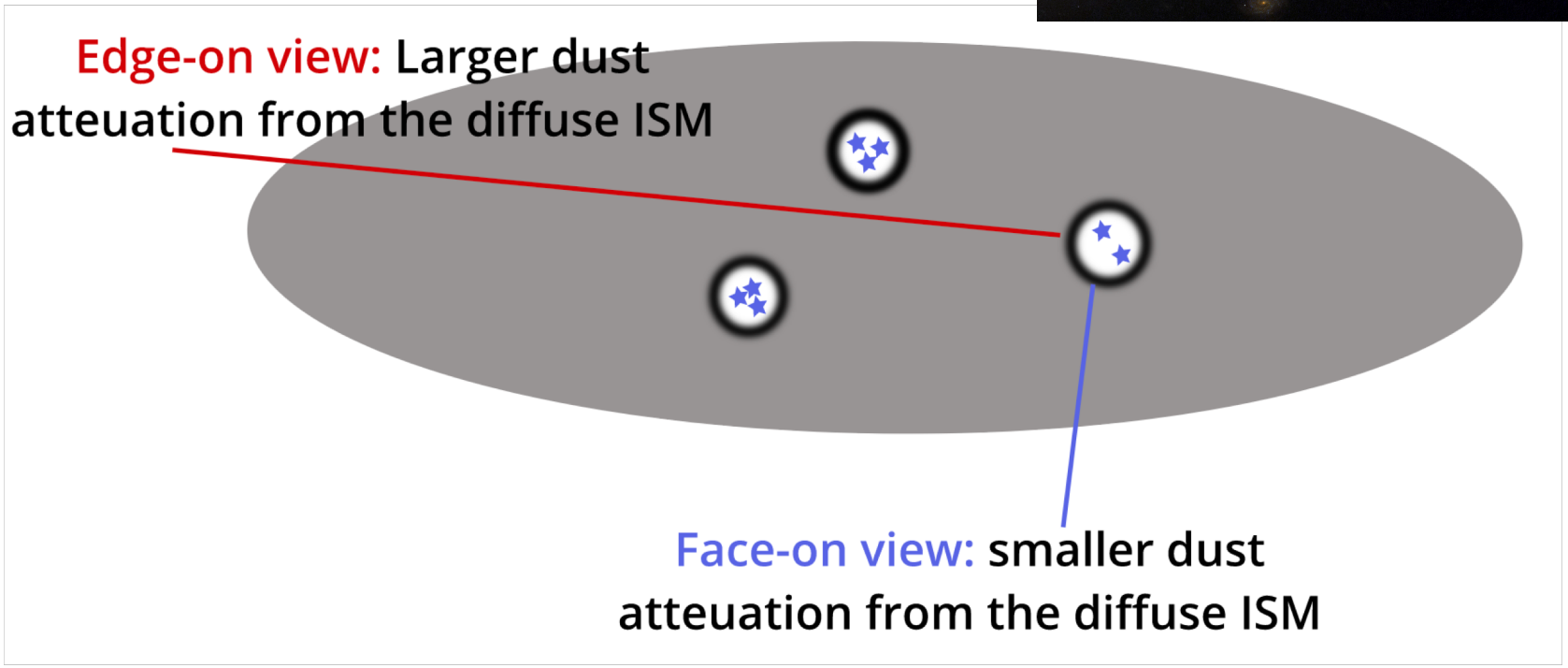


Shell+Diffuse ISM, $\tau_{V,\,\mathrm{diffuse\ ISM}} = 1.2$

Shell+Diffuse ISM, $\tau_{V,\,\mathrm{diffuse\ ISM}} = 0.6$

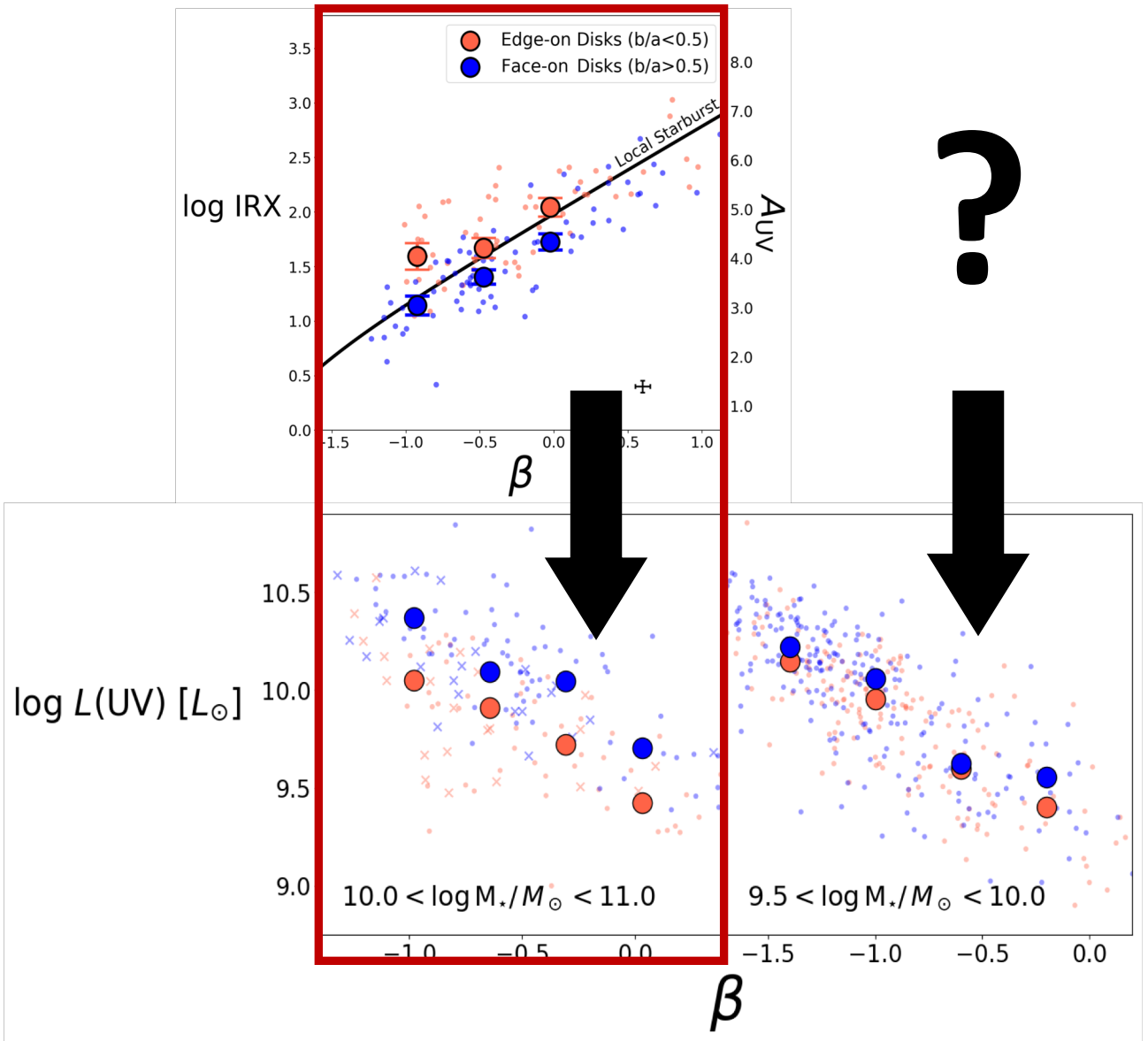
Edge-on galaxies have a higher dust optical depth from the diffuse interstellar medium.

2. The IRX-β relation can be explained by the two-component dust model



Dust attenuation from shells does not change with viewing angle.
(Charlot & Fall 2000; Calzetti 2001; Chevallard et al. 2013)

3. High-mass star-forming galaxies (>10^{10} M_{sun})



?

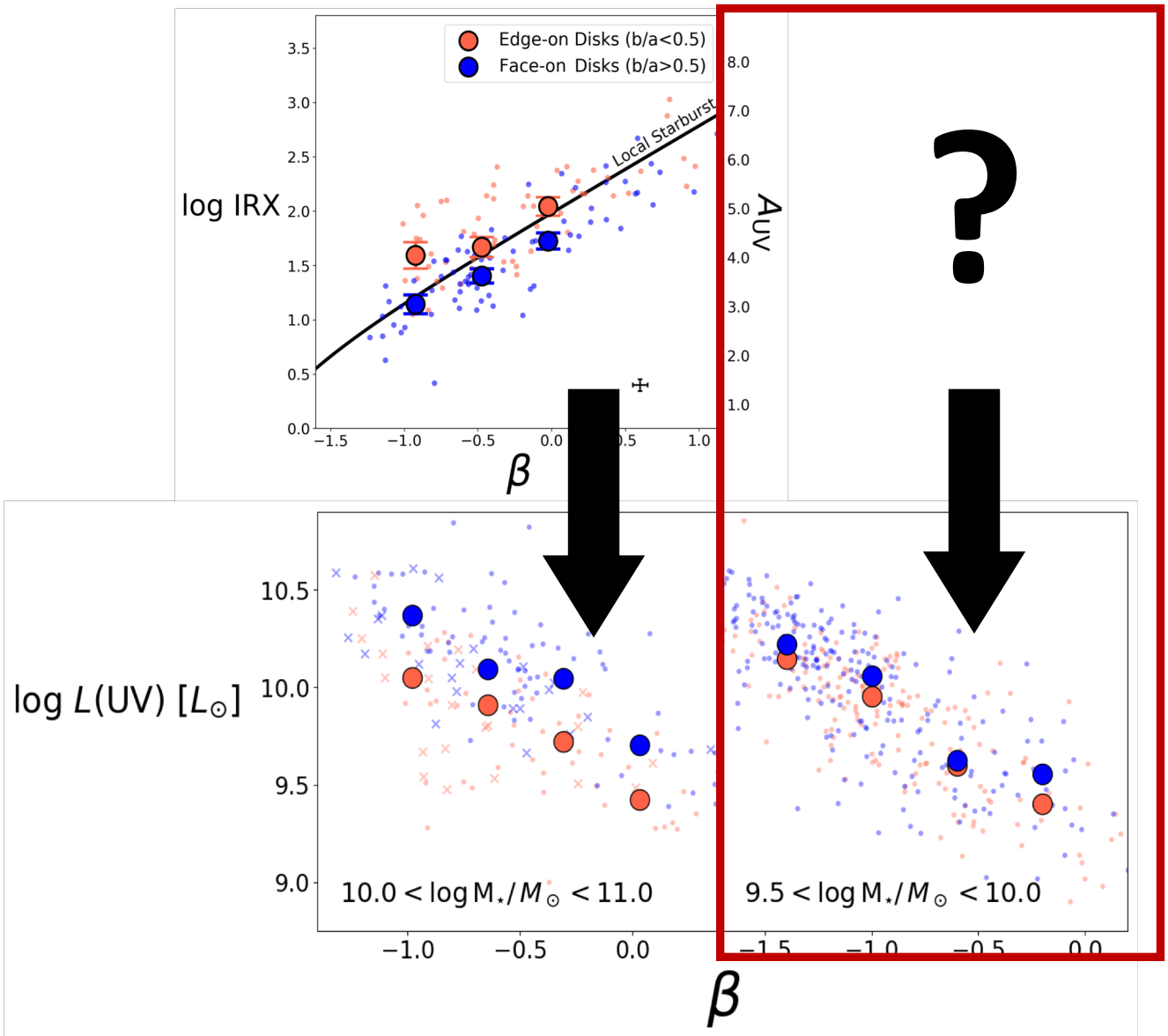
IRX-β relation

L_{UV}-β relation

Red: Low b/a galaxies

Blue: High b/a galaxies

3. Low-mass star-forming galaxies (<10^{10} M_{sun})



IRX-β relation

L_{UV}-β relation

Red: Low b/a galaxies

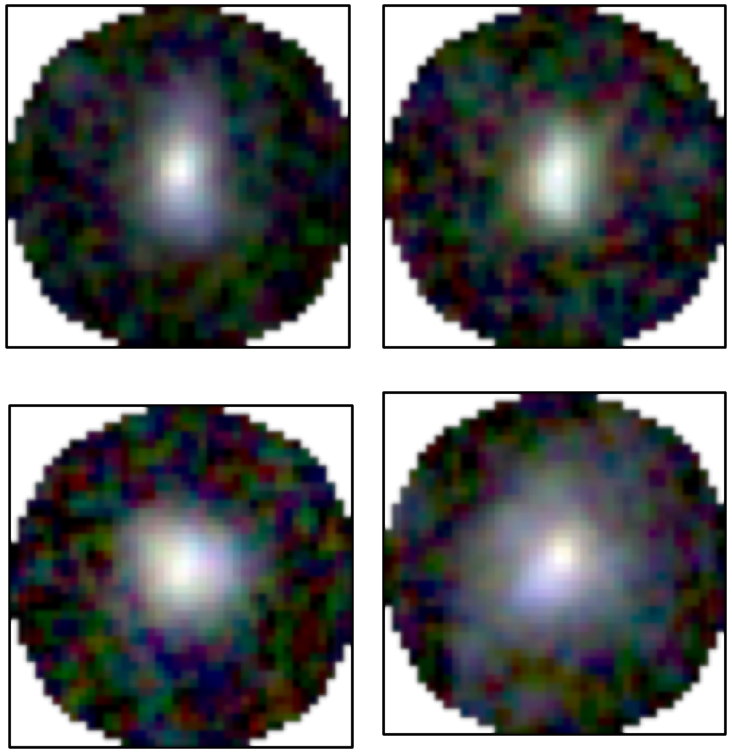
Blue: High b/a galaxies

3. Dust distribution of low-mass galaxies does not look like that of massive ones

Possible physical reason:

a. Dust may not distribute in a well shaped disk.
(evidence from gas kinematics by Simons et al. 2017)

b. Many low-mass galaxies at z∼1.5 may even have prolate shapes.
(evidence from morphology by van der Wel et al. 2014)



Conclusions

1. The IRX-β relation for massive star-forming galaxies varies with inclination at z~1.5.
2. For massive galaxies, a model which has two dust components inside a smooth disk matches observation.
3. For low-mass galaxies, their dust distribution is not consistent with the model for massive galaxies.

We need different dust distribution models for galaxies with different redshifts and masses.

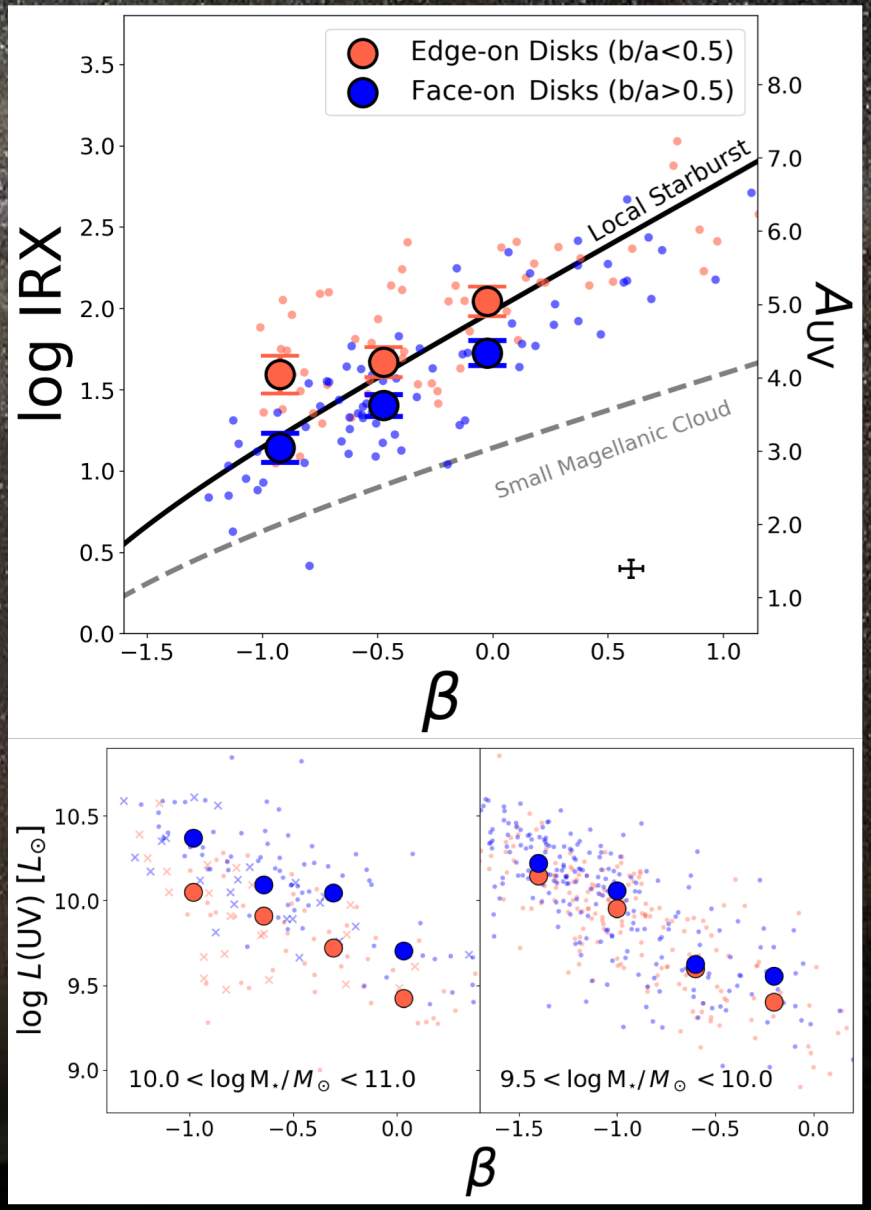


Image Credit: ESO