DustPedia & MeerKAT: Focus on the HI gas in the star formation process

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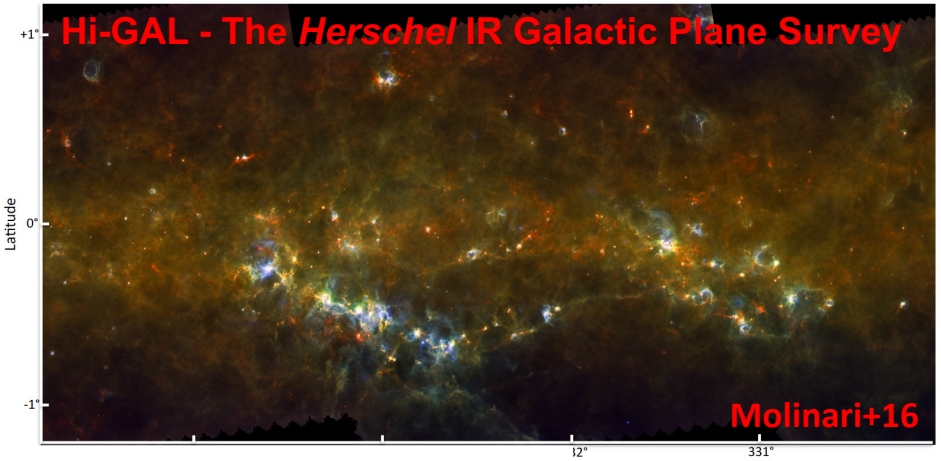
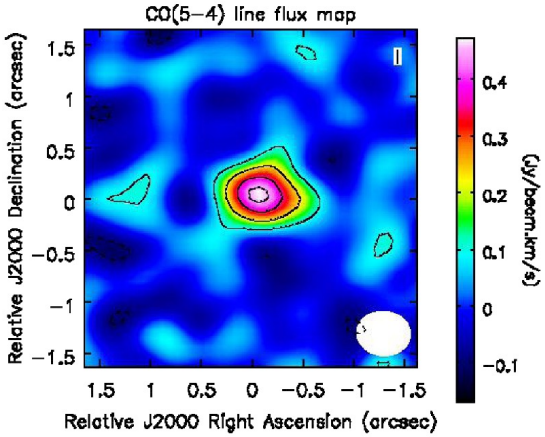
Third National Workshop on the SKA project - The Italian Route to the SKAO Revolution, 4-8 October 2021

Outline of my talk

- The role of the **Local Universe**
- **DustPedia** project
- ISM **Scaling Relations**: Global and Spatially Resolved
- **NGC 1365**: DustPedia & **MeerKAT**
- Conclusions & **Future**

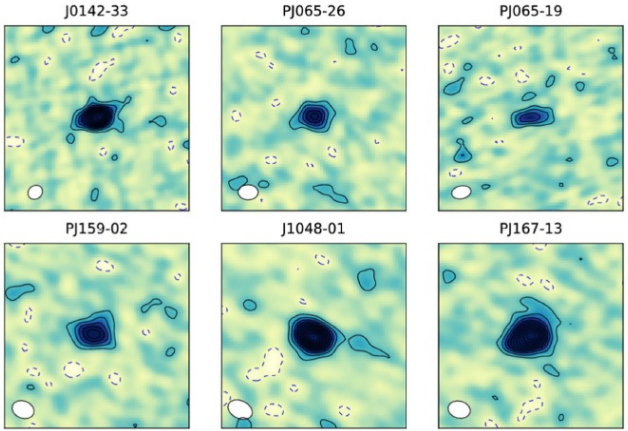
The ISM in the Local Universe:
Link between the Milky Way and high-redshift galaxies





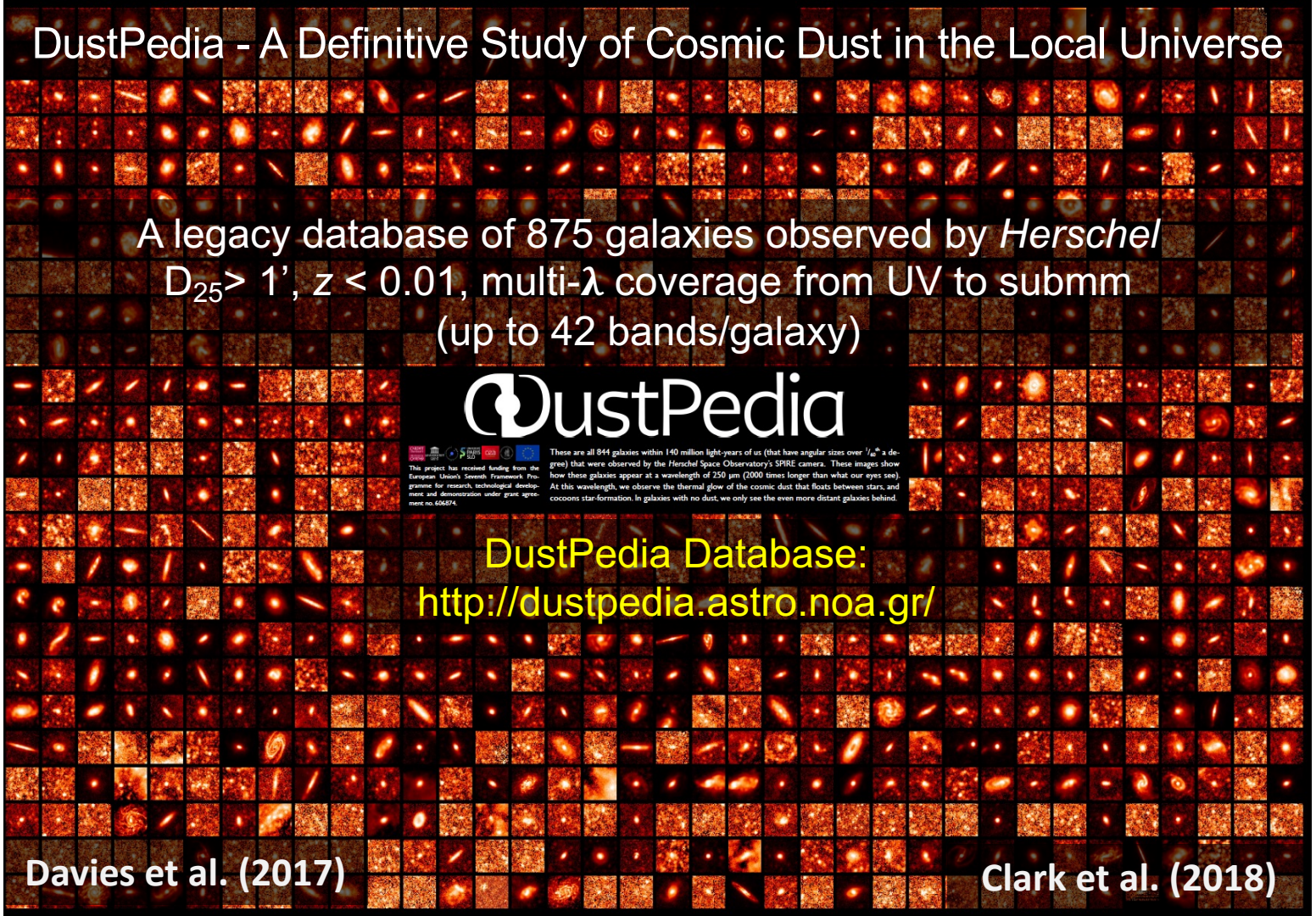
CO(5-4), XID2028
Quasar z = 1.6
Brusa+18
ALMA

[C II] line, Quasars z > 6
Decarli+18, ALMA



See also e.g., Carniani+17, Tacconi+10 & PHIBSS and many others …

DustPedia - A Definitive Study of Cosmic Dust in the Local Universe



A legacy database of 875 galaxies observed by *Herschel*

D_{25}> 1', z < 0.01, multi-λ coverage from UV to submm

(up to 42 bands/galaxy)

DustPedia

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 606874.

These are all 844 galaxies within 140 million light-years of us (that have angular sizes over $1/6^{th}$ a degree) that were observed by the *Herschel* Space Observatory's SPIRE camera. These images show how these galaxies appear at a wavelength of 250 μm (2000 times longer than what our eyes see). At this wavelength, we observe the thermal glow of the cosmic dust that floats between stars, and cocoons star-formation. In galaxies with no dust, we only see the even more distant galaxies behind.

DustPedia Database:

http://dustpedia.astro.noa.gr/

Davies et al. (2017)

Clark et al. (2018)

DustPedia

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M. Baes (co-PI)
S. Bianchi (co-PI)
A. Jones (co-PI)
S. Madden (co-PI)
E. Xilouris (co-PI)

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UK
Belgium
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Greece

ISM scaling relations in the Local Universe (DustPedia)

- **Nearby galaxies**: Intricate system of correlations between global properties, **scaling relations**
- **Scaling relations**: internal physics of galaxies, formation and evolutionary histories, different galaxy populations
- The number of works on the **ISM scaling relations** has grown (e.g., Boselli+14; Cortese+16; Catinella+18; Saintonge+18; Lisenfeld+19; De Looze+20; Ginolfi+20; Hunt+20)
- These works provide **constraints** for **models** of **galaxy evolution** (e.g., Lagos+11a,b; Crain+17; Marinacci+17; Diemer+19; Steven+19, De Lucia+20) and new references for **high-*z* galaxies**

ISM scaling relations in the Local Universe (DustPedia)

The Global ISM scaling relations

ISM scaling relations in the Local Universe (DustPedia)

Sample and data:

- **436** late-type (T = 1 – 10, Sa – Irregular) **DustPedia** galaxies (Davies+17)
- **Dust mass** (THEMIS dust mass model, Jones+17) [IR data from **Herschel**]
- **CO** and **HI** (gas mass) data (Casasola+20) [mm/ cm data from **IRAM, JVLA, …**]
- **Gas-phase metallicity** data (De Vis+19) through multiple strong-line calibrations, 12+log(O/H) = 8.0 – 9.5 (N2 calibration, Pettini & Pagel 04)

DustPedia sample + DustPedia data + DustPedia ancillary data: "ideal" project to characterize the global ISM scaling relations in the Local Universe

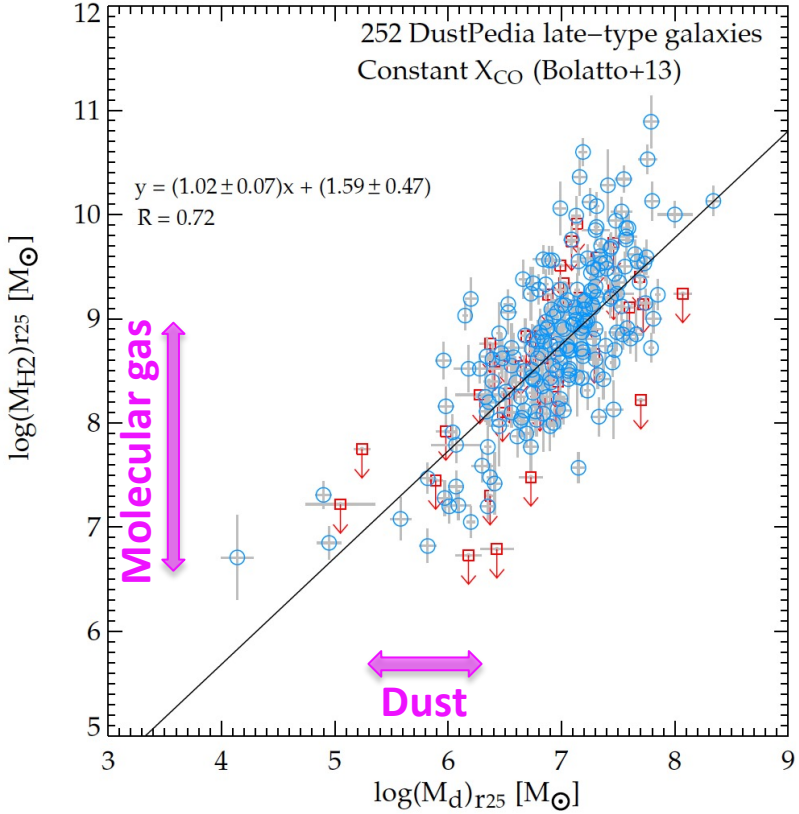
ISM scaling relations in the Local Universe (DustPedia)

Dust and gas components (CO→H_2, HI, HI+H_2)

ISM scaling relations in the Local Universe (DustPedia)

Dust and gas components (CO→H_2, HI, HI+H_2)

Both dust and gas masses are referred to the optical disk (r_{25})



Casasola et al. (2020)

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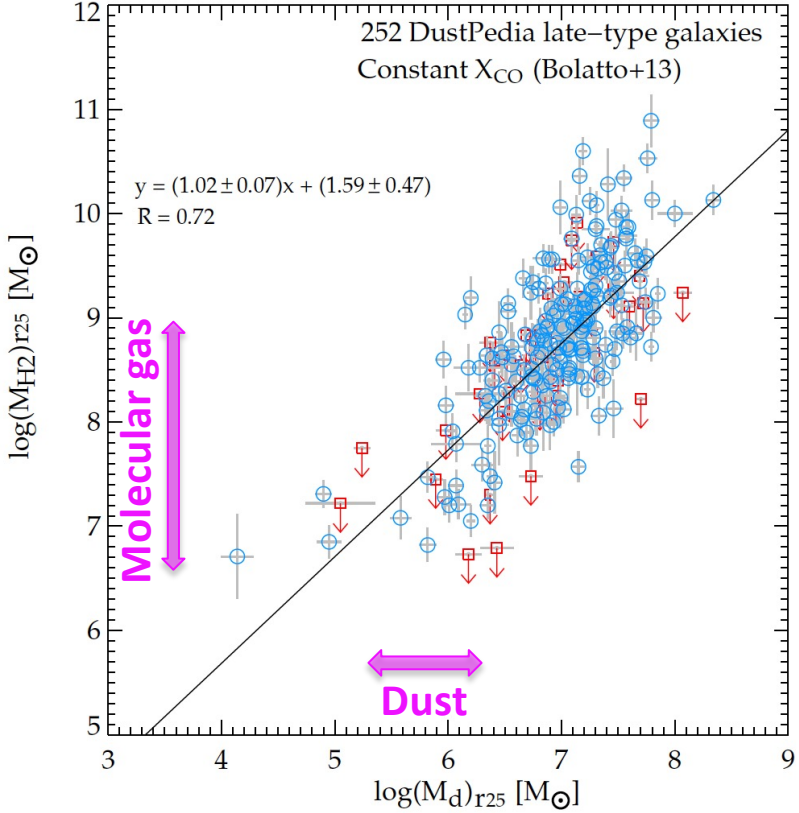

Dust and molecular gas are correlated

Consistent with star formation process

The correlation does not improve with a X_{CO} depending on metallicity (e.g., Sandstrom+13; Hunt+15; Amorin+16)

Casasola et al. (2020)

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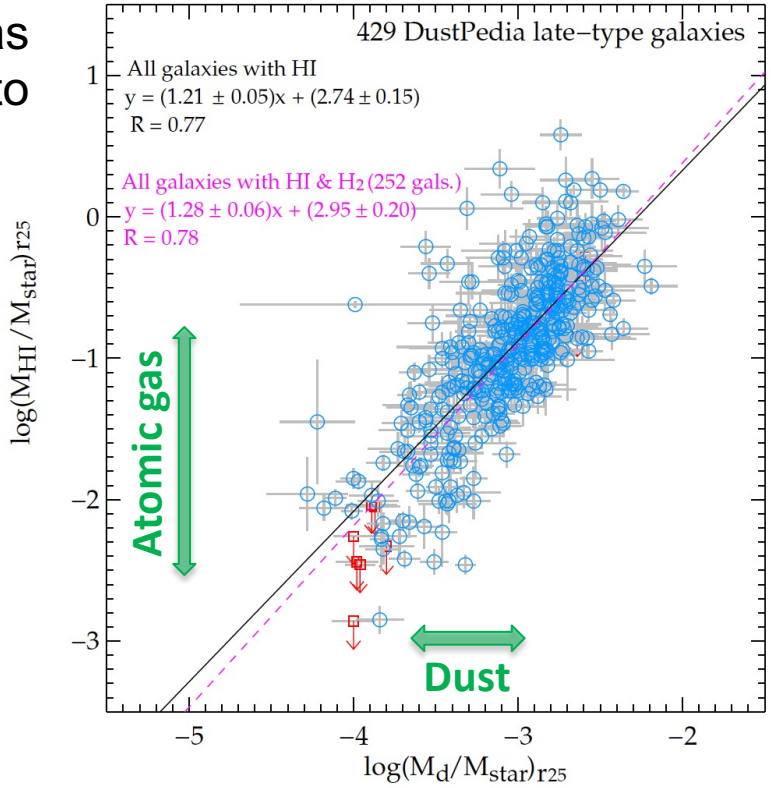

Dust and atomic gas (21cm-HI) are better correlated than dust and molecular gas

Casasola et al. (2020)

ISM scaling relations in the Local Universe (DustPedia)

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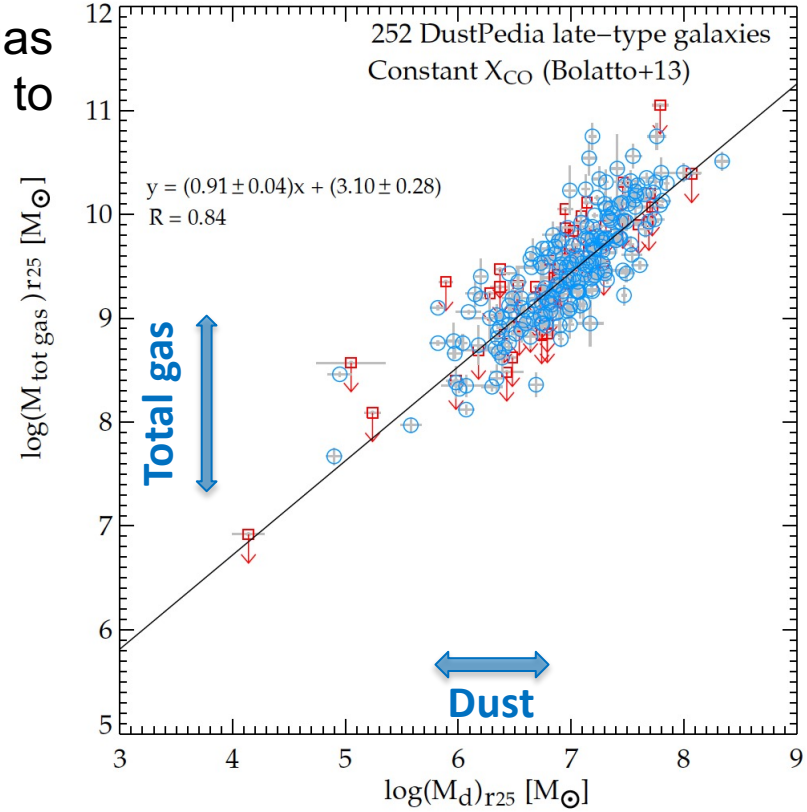


Dust and total gas is the best correlation

Scaling relations tested with a large and homogenous sample and under different physical assumptions.

Casasola et al. (2020)

What happens at small scales?

What happens at small scales?

What happens at small scales galaxy-by-galaxy?

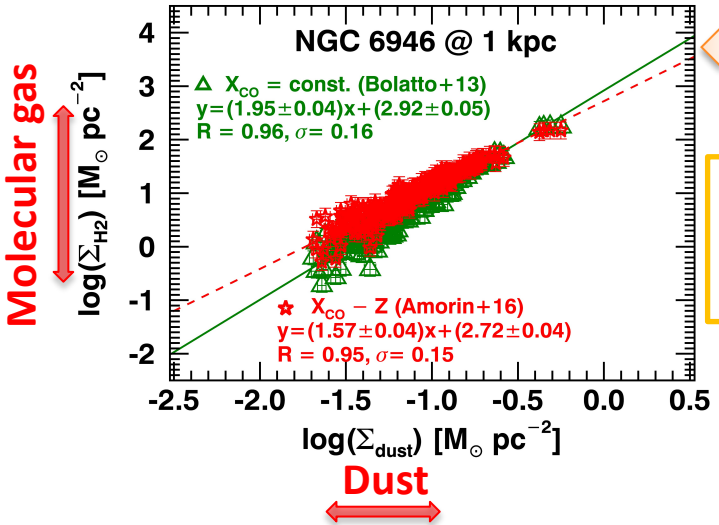
We are studying spatially-resolved scaling relations for different late-type DustPedia galaxies

We are using:

- 18 large, late-type, face-on DustPedia galaxies (Casasola+17), resolved in Herschel/dust
- CO & HI maps (IRAM, ALMA, JVLA, …)
- Stellar and SFR maps (DustPedia)
- Scaling relations @ resolutions of 0.3 – 3.4 kpc

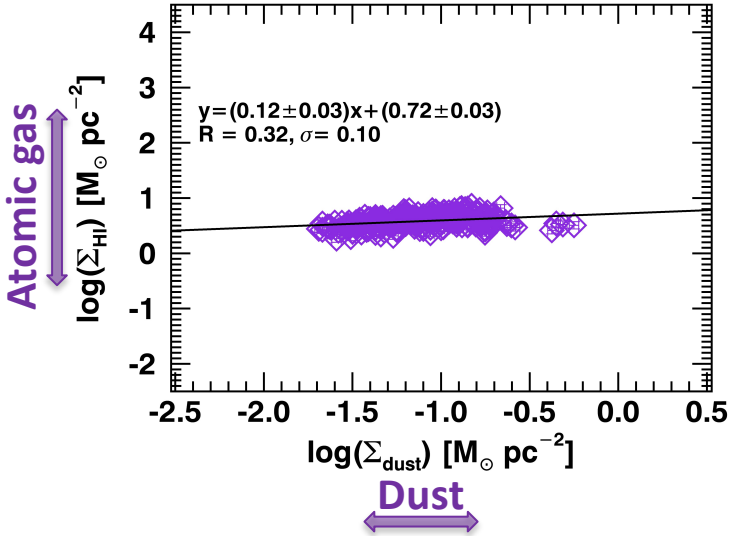
NGC 6946, SAB(rs)cd (T = 6) @ 1 kpc

Resolution imposed by dust map (36” @ the galaxy distance)



Consistent with SF

Opposite to what happens globally (Casasola+20)



Casasola, Bianchi+ in prep.

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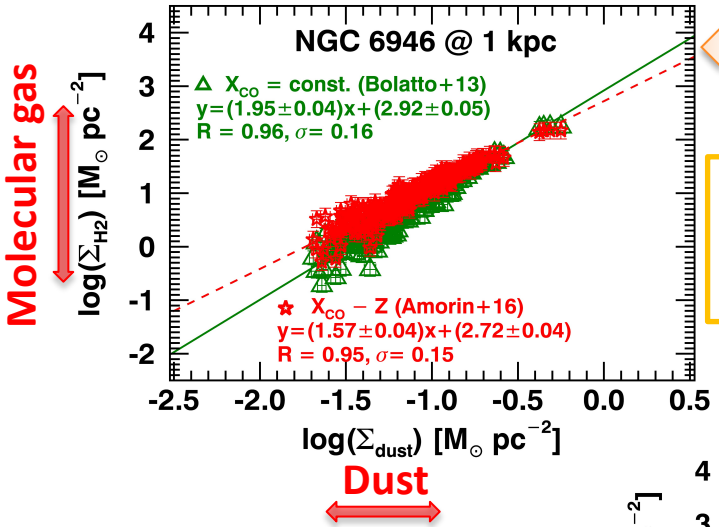

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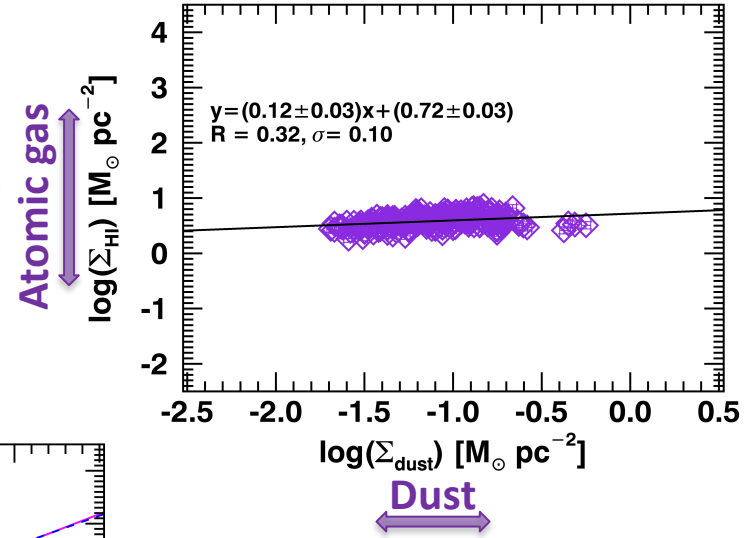
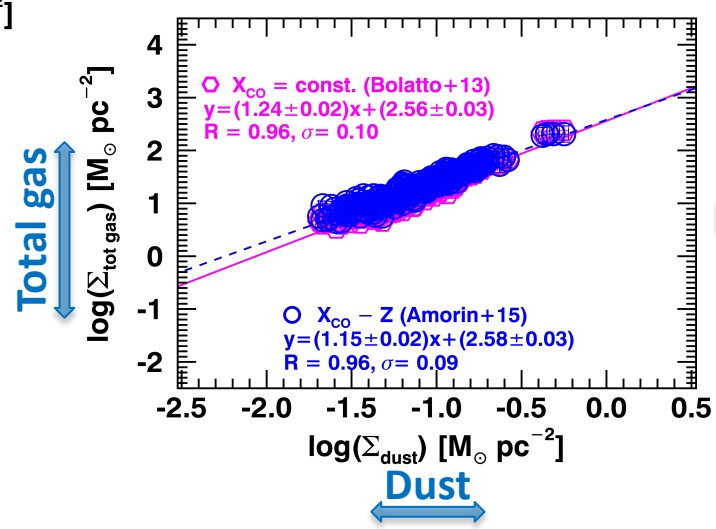


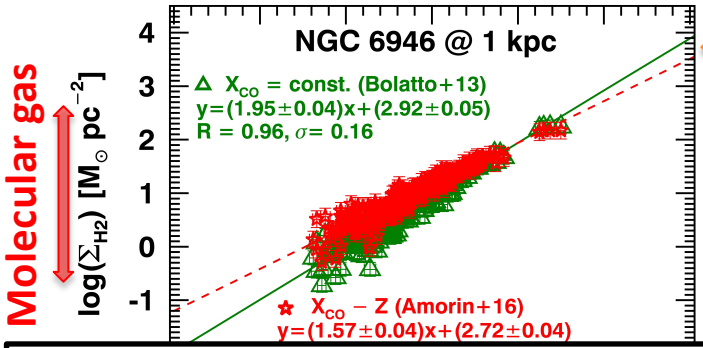


Dust–total gas: the best correlation at SMALL and GLOBAL scales

Casasola, Bianchi+ in prep.

NGC 6946, SAB(rs)cd (T = 6) @ 1 kpc

Resolution imposed by dust map (36” @ the galaxy distance)



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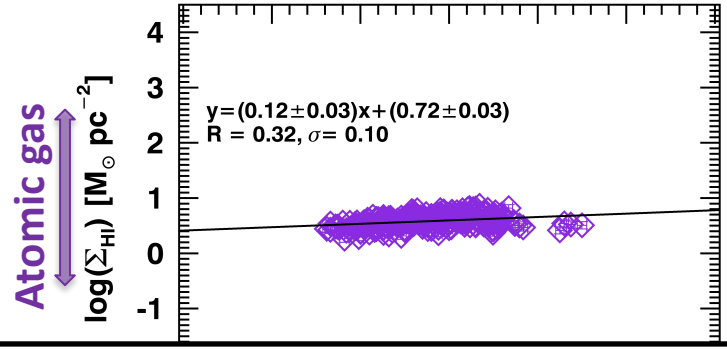
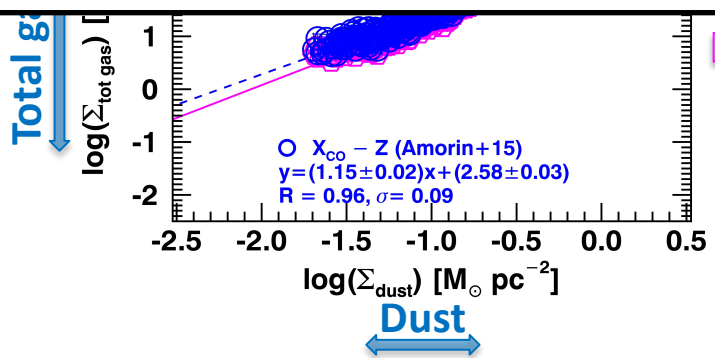


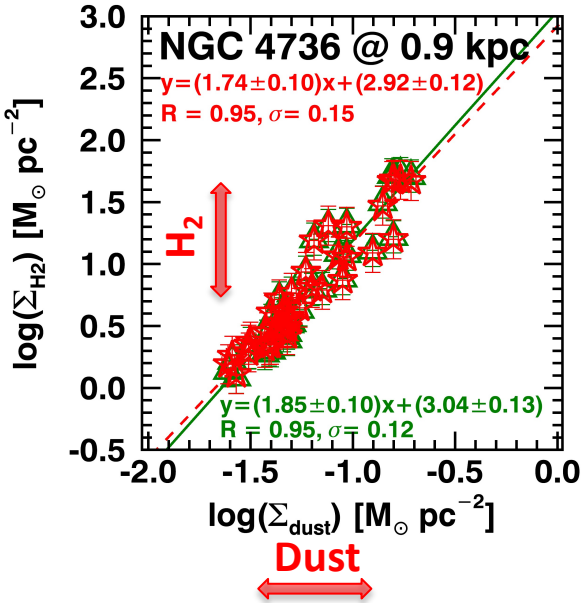
Common trends but each galaxy has distinct ISM scaling relations @ sub-kpc/kpc scales:
Not universal correlations

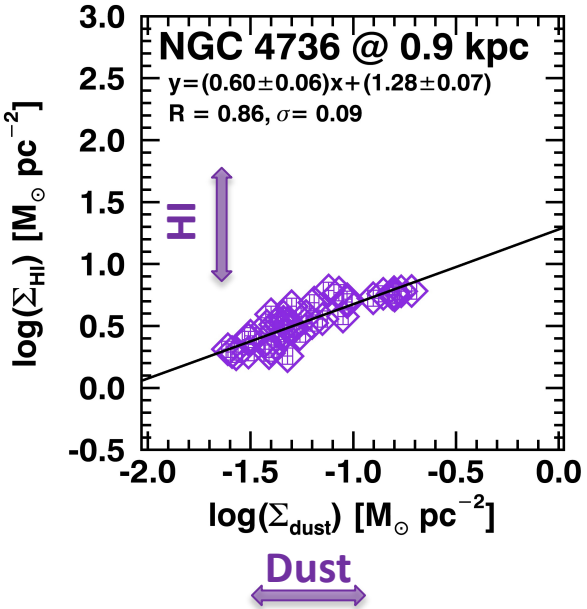


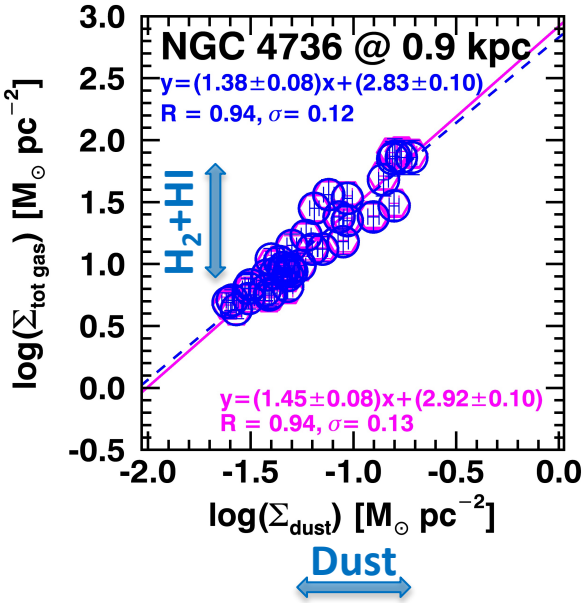
the best correlation at SMALL and GLOBAL scales

Casasola, Bianchi+ in prep.

NGC 4736, (R)SA(r)ab(T = 2) @ 0.9 kpc ➡ Resolution imposed by dust map (36” @ the galaxy distance)





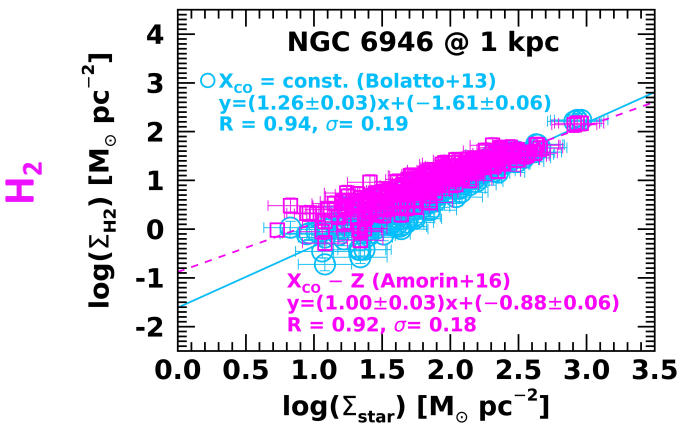


In some galaxies dust and HI are well correlated at small scales
In some galaxies HI can break down scaling relations

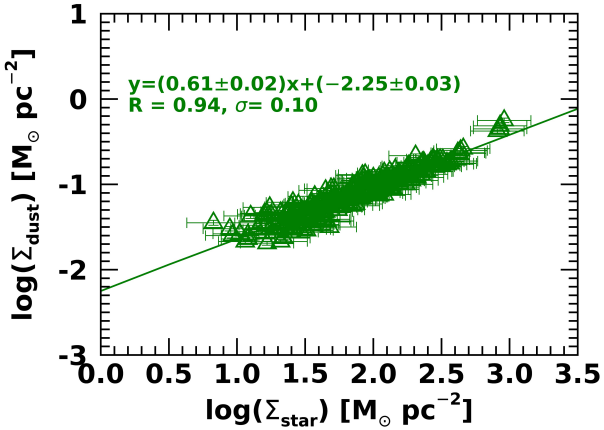
See also Saikia+20

Casasola, Bianchi+ in prep.

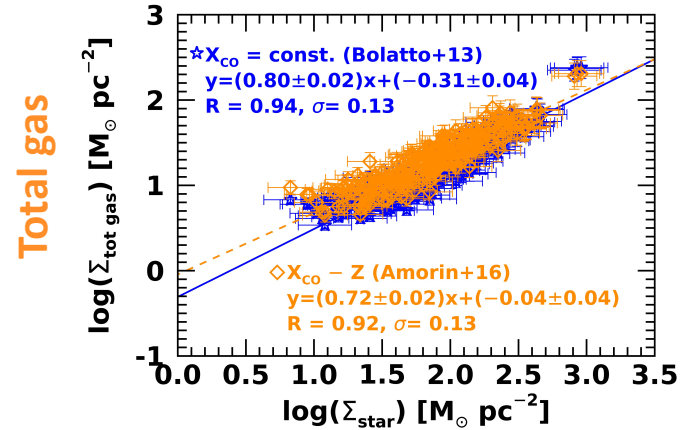
NGC 6946, SAB(rs)cd (T = 6) @ 1 kpc ⟹ Resolution imposed by dust map (36" @ the galaxy distance)



H2

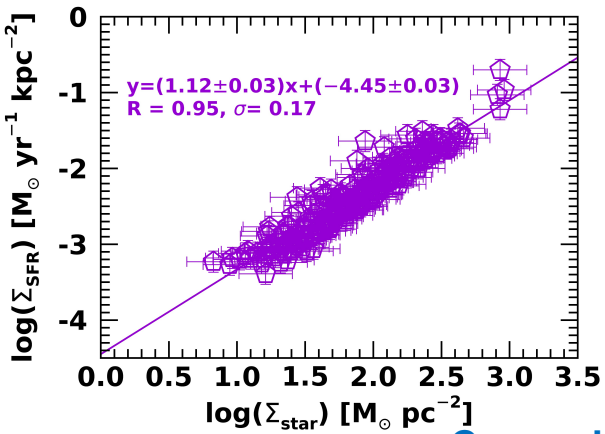


Dust



Total gas

Star

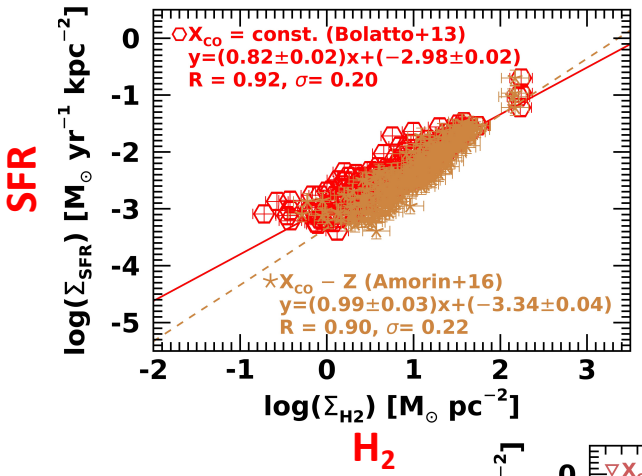


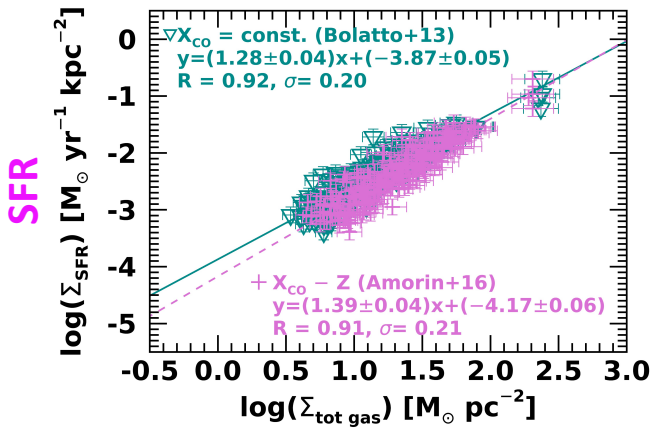
SFR

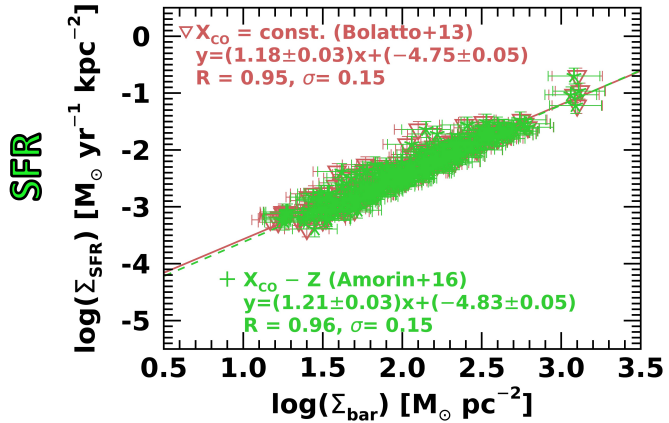
Star

Casasola, Bianchi+ in prep.

NGC 6946, SAB(rs)cd (T = 6) @ 1 kpc ⟹ Resolution imposed by dust map (36" @ the galaxy distance)





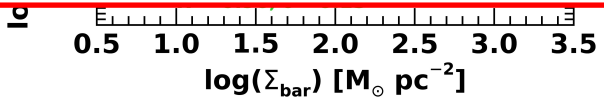


H_2 + HI + stars + dust = Baryons

Casasola, Bianchi+ in prep.

NGC 6946, SAB(rs)cd (T = 6) @ 1 kpc ⟹ Resolution imposed by dust map (36" @ the galaxy distance)

- Often scaling relations hold from 0.3 kpc: they are not universal
- Galaxy-by-galaxy variations are due mainly to local (sub-kpc) processes (e.g., turbulence, stellar feedback, protostellar outflows) driving the SF (multi-scale and multi-physics process)
- Global processes/properties (e.g., strong bars, interactions/mergers, gas inflows/outflows, AGN) can influence galaxies in an indirect way, via the physical processes affecting SF
- **At sub-kpc/kpc scales also HI can play a role! … also at high-redshift (see, e.g., Morselli+21): HI is crucial at all redshifts and all scales!!!!**



H_2 + HI + stars + dust = Baryons

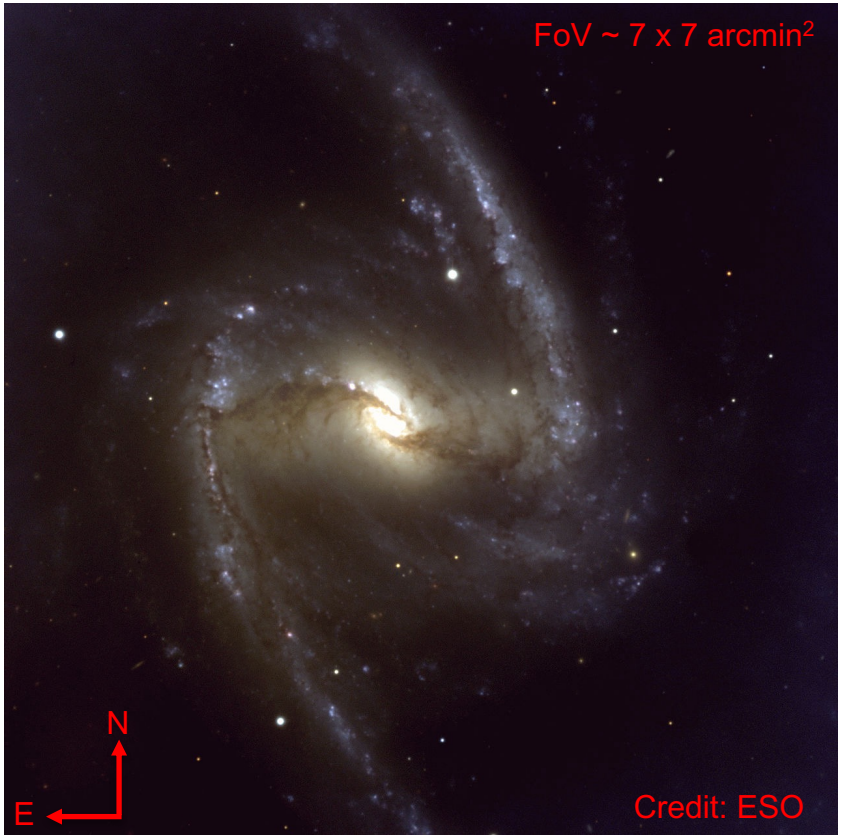
Casasola, Bianchi+ in prep.

Focus on NGC 1365

NGC 1365

VLT: B (blue), V (green), R (red)

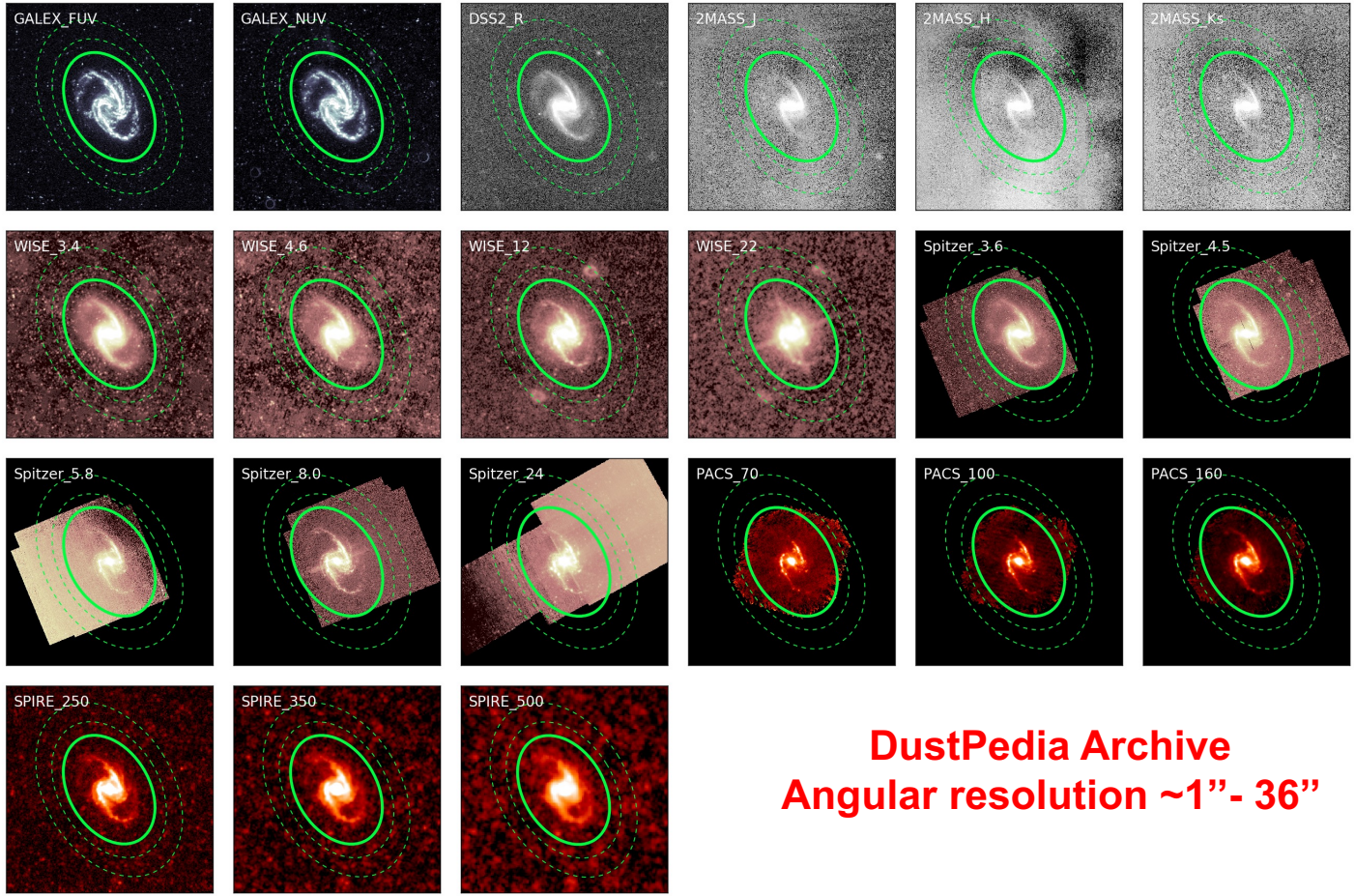
SB(s)b
Dist. = 17.7 Mpc
D_{25} = 12 arcmin
Seyfert 1.8



A DustPedia galaxy with 31 available band images: FUV-submm

NGC 1365

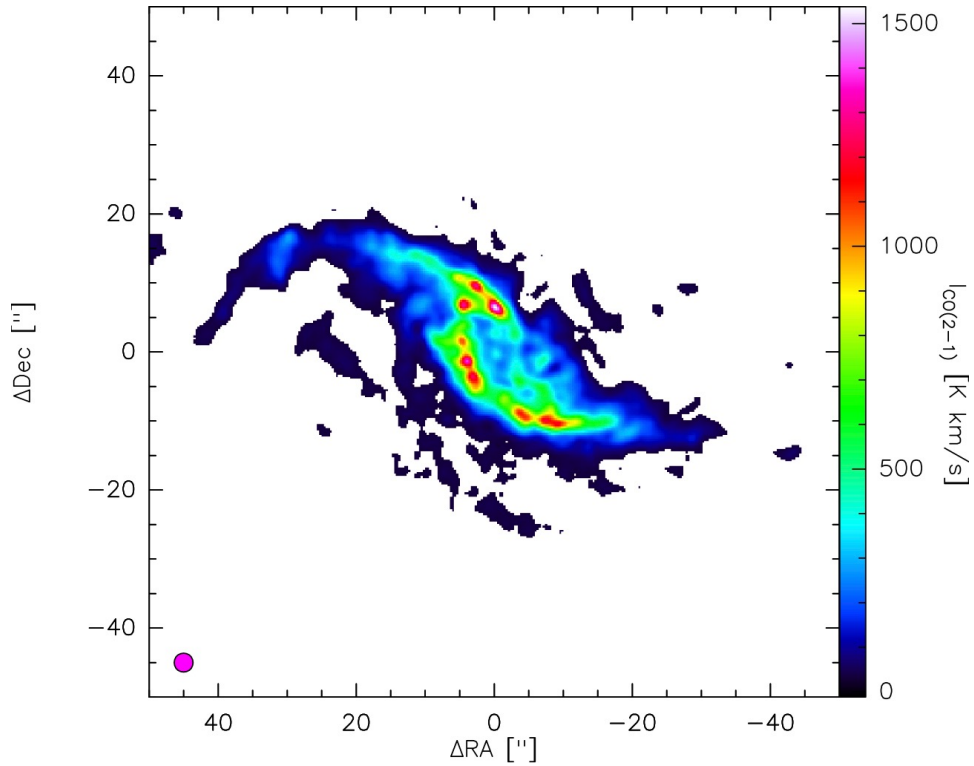
Old stars
Young stars
Cold dust
Hot dust
….



DustPedia Archive
Angular resolution ~1”- 36”

NGC 1365

CO(2-1) @ 1.4” (120 pc) - ALMA PHANGS



NGC 1365: HI emission with MeerKAT

MeerKAT commissioning obs:

1. **Dec. 2019, 60 antennas, 7 hrs (correlator 32k mode)**

2. **Sep. 2020, 60 antennas, 9 hrs (correlator 32k zoom mode)**

Combining 1 + 2:
6 km/s velocity resolution

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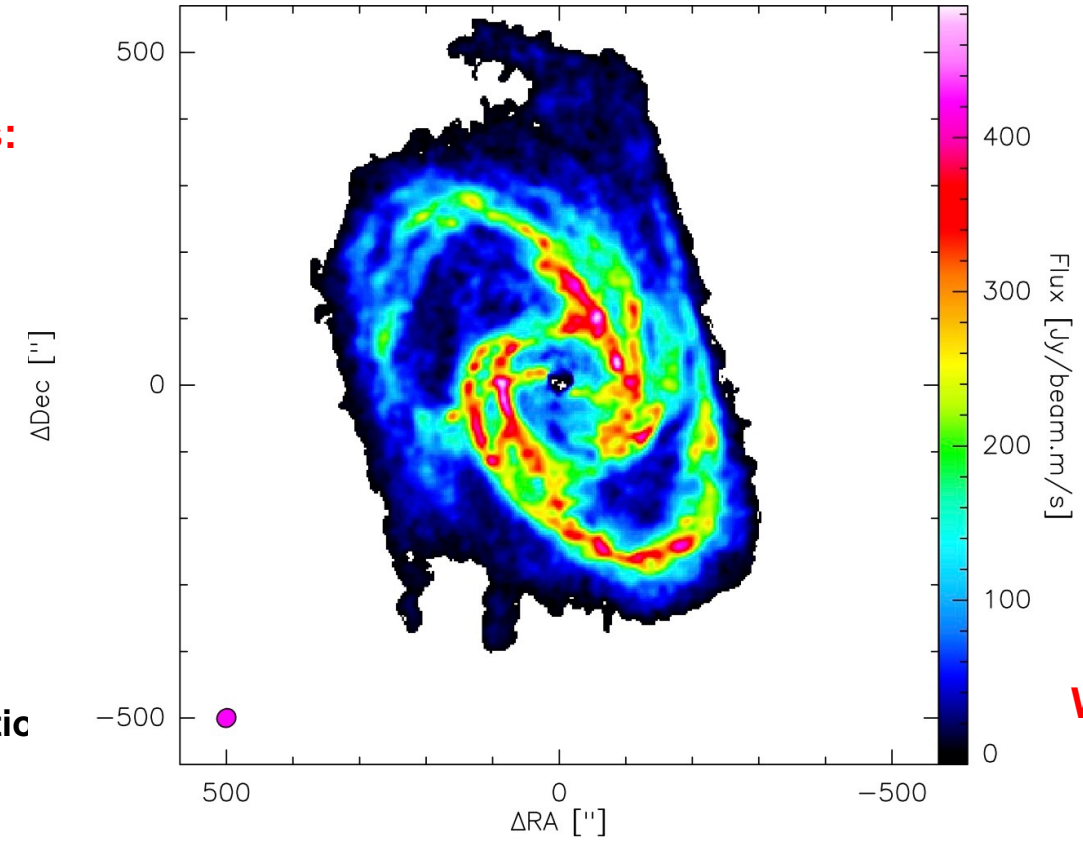


HI mostly concentrated in spiral arms and outside the bar

Work in progress

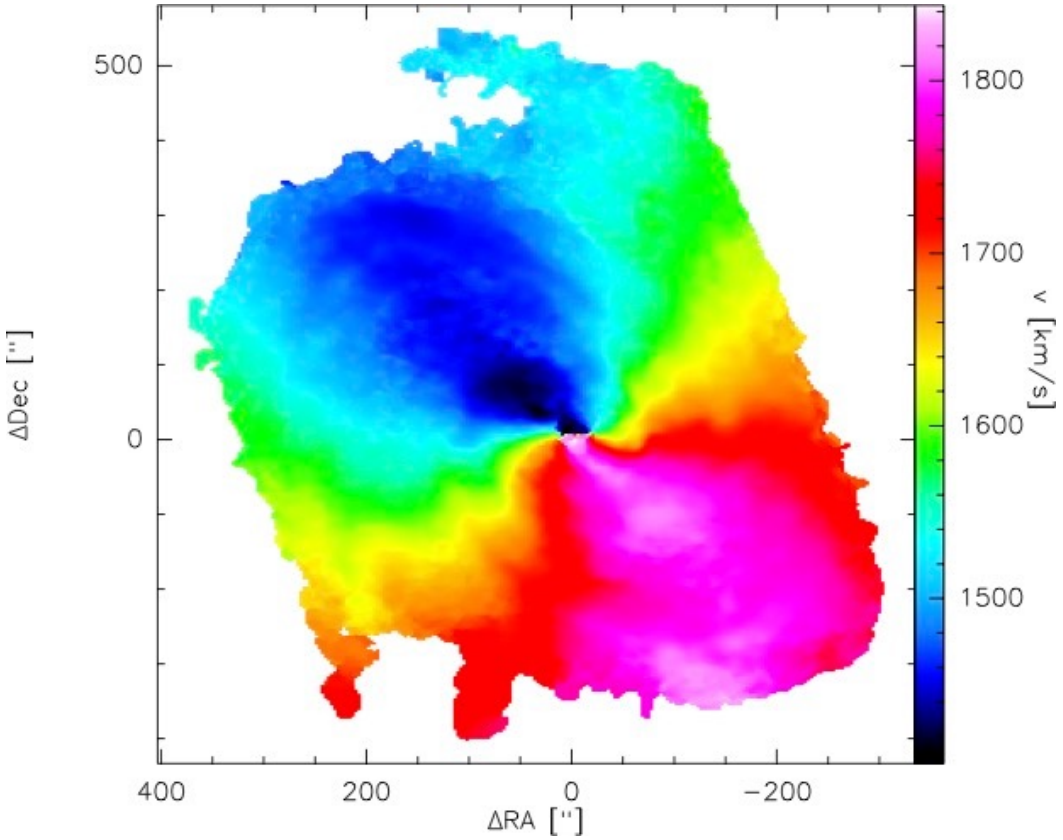
Beam = 14.8” x 13.6” ~1.2 kpc

Casasola+ II, in prep.

NGC 1365: HI velocity field with MeerKAT

Regular circular rotation

Deviations outside the bar, consistent with a strong bar potential

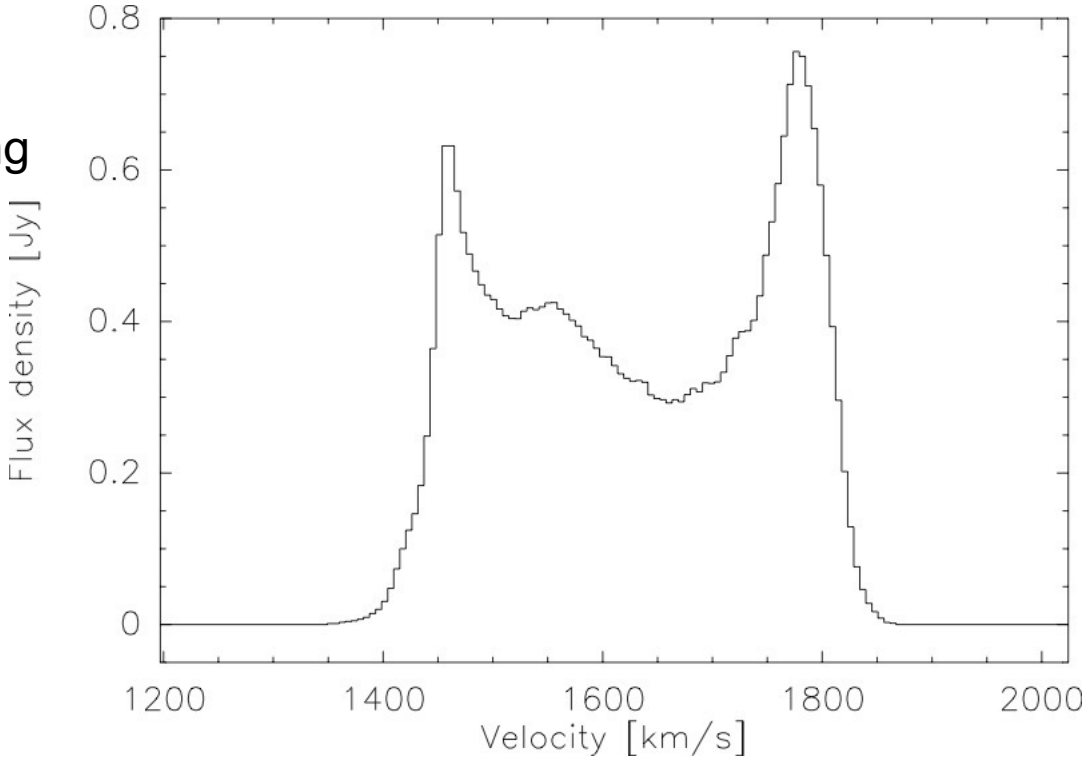


Work in progress

Casasola+ II, in prep.

NGC 1365: HI spectrum with MeerKAT

Double-horn profile: rather regularly rotating disc



Work in progress

Casasola+ II, in prep.

Conclusions

- **Nearby galaxies**: link between MW and high-*z* Universe: **Galaxy Evolution**
- **ISM Scaling Relations** in **DustPedia** (see also JINGLE, MAGMA, PHANGS, …, and next talk by Leslie)
- **HI** gas is **crucial** everywhere: at small/global scales, in local/high-*z* galaxies
- We need **new HI observations**: **new constraints** for models

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The re-emerged importance of HI
is timing with current/incoming facilities:
MeerKAT, **MeerKAT+**, …, in the route to **SKA**

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MeerKAT, **MeerKAT+**, …, in the route to **SKA**

Difficult challenge: Collaboration, synergy, community-building, …

Third National Workshop on the SKA Project: **the Italian Route to the SKAO Revolution**

SKA

Italian community

Thanks for your attention!