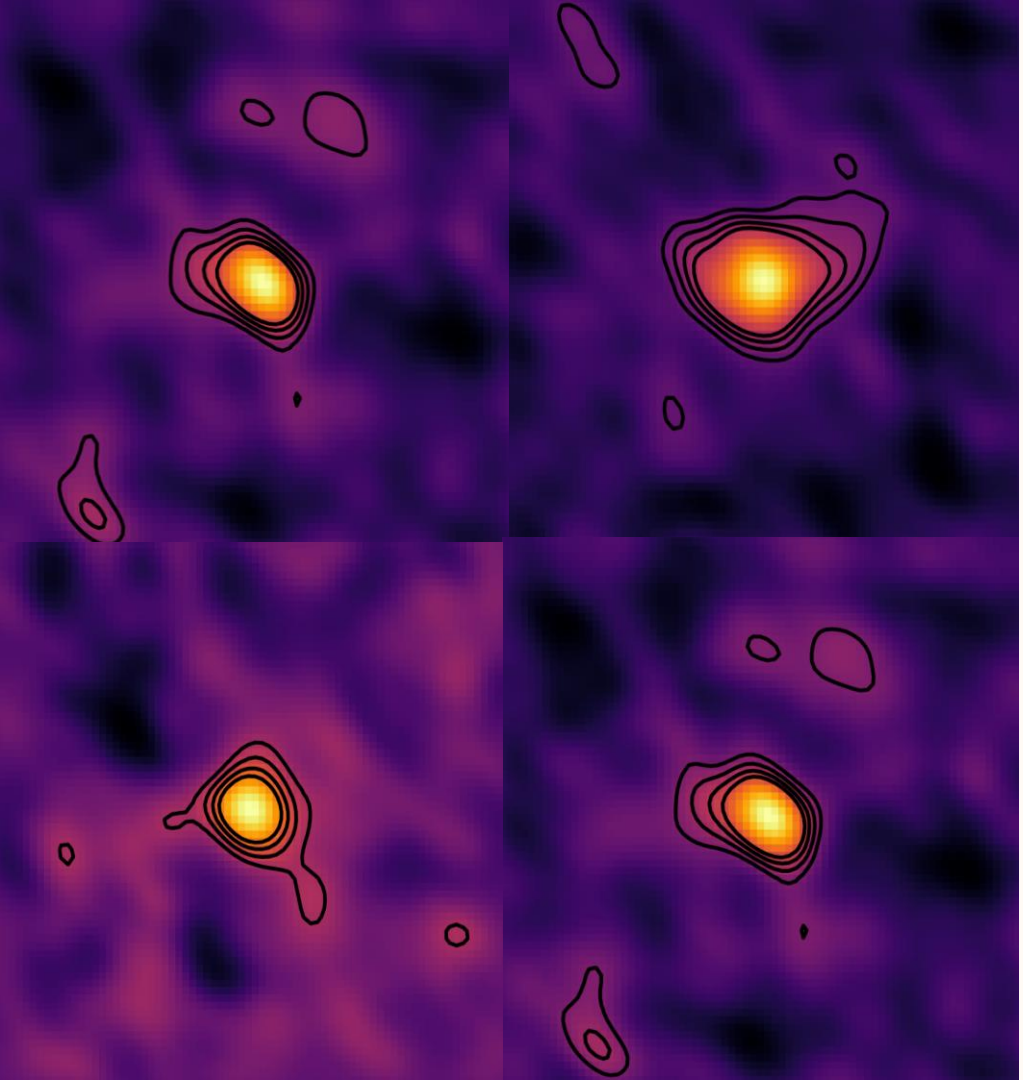

Radio-Selected NIRdark galaxies

The ALMA view behind the dust

mm Universe 2023,
Grenoble, 27 June 2023

Fabrizio Gentile
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fabrizio.gentile3@unibo.it

Margherita Talia,
M. Behiri, G. Zamorani, C. Vignali, F. Pozzi, M. Bethermin, A. Enia, A. L. Faisst, M.Giulietti, C. Gruppioni, A. Lapi, M. Massardi, V. Smolcic, M. Vaccari, A. Cimatti

Why are “dark galaxies” *so interesting*?

Why do we need a radio-selection of “dark galaxies”?

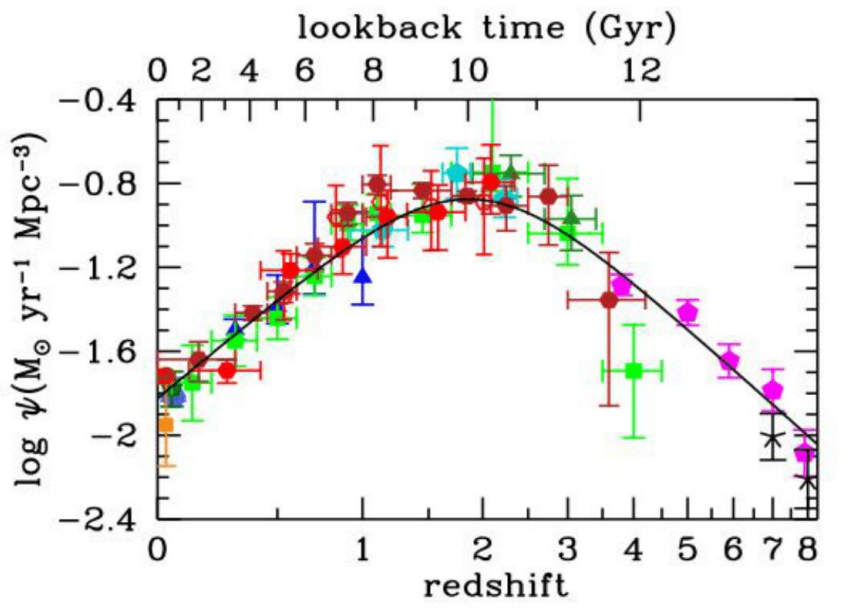
What can we learn from existing data?

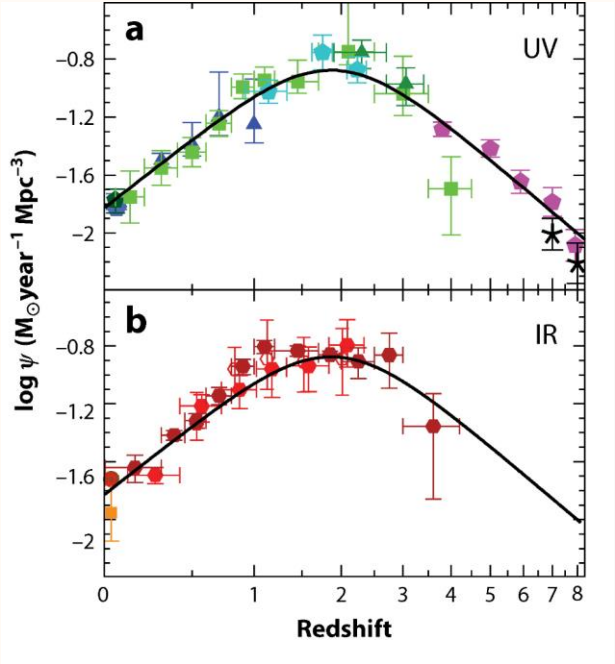
What can we learn from new data?

And why do I need nice reviews from ALMA/NOEMA referees?

Answers

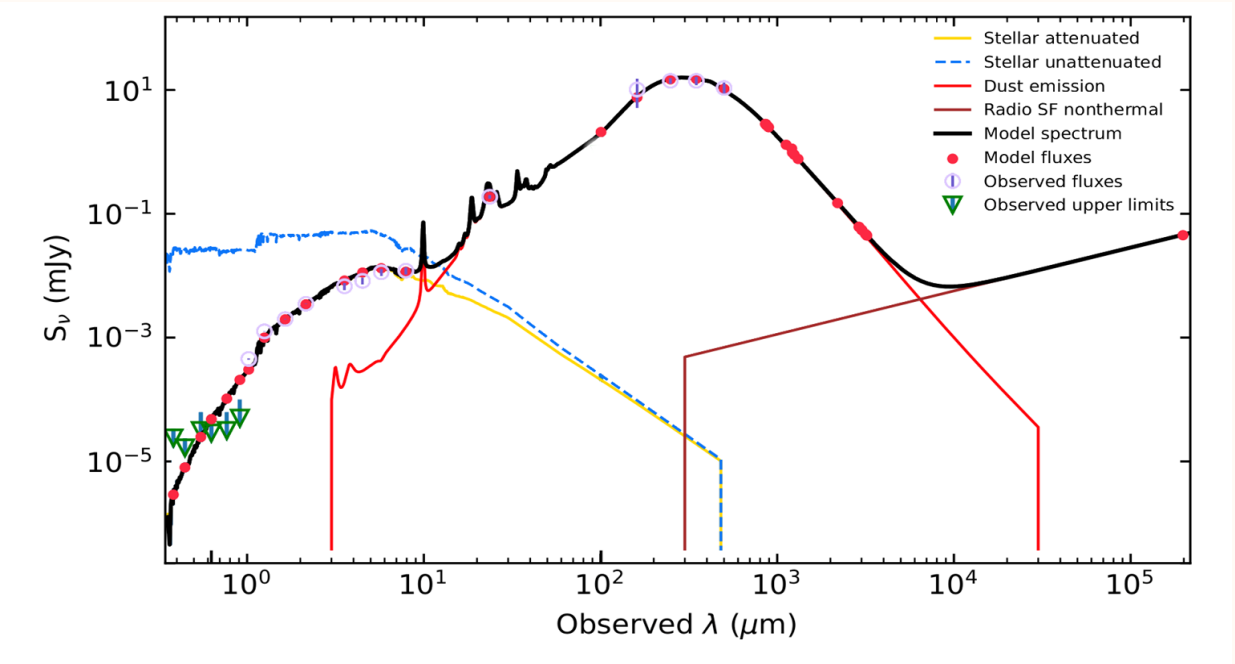
Background: Why are “dark galaxies” *so interesting*?

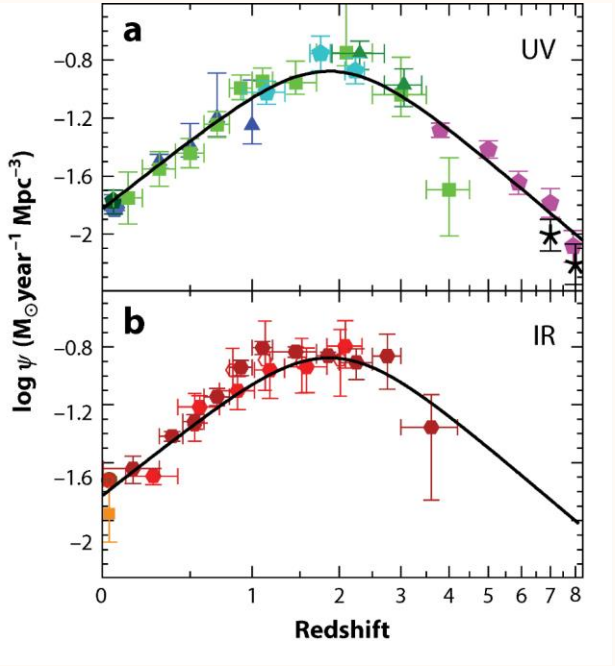




Madau & Dickinson (2014)

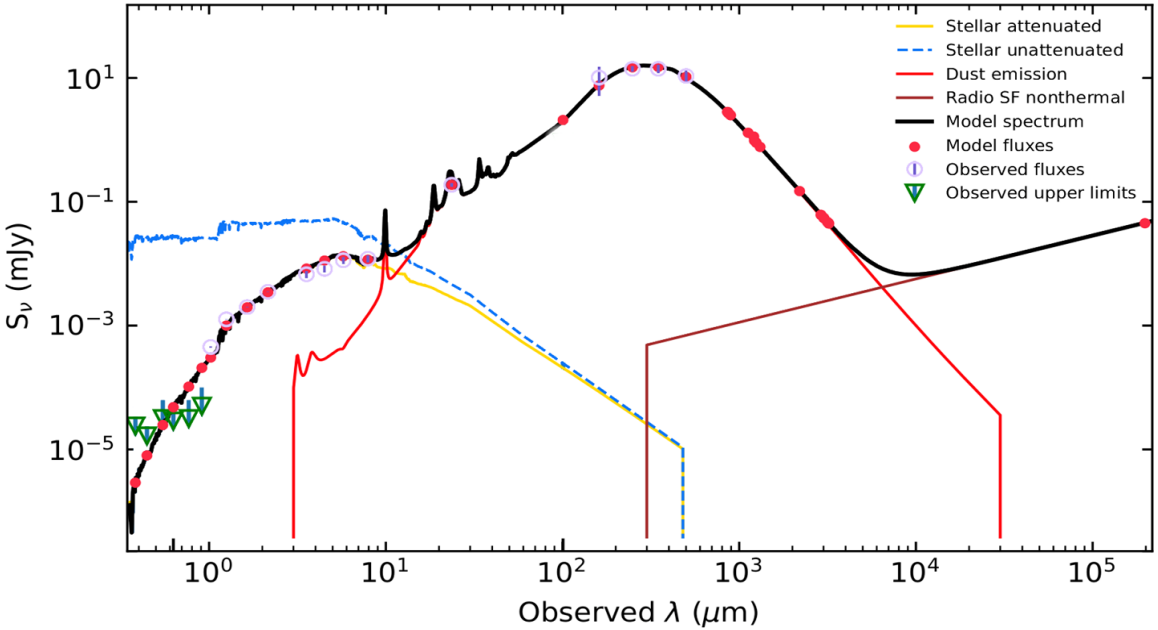
Background: Why are “dark galaxies” *so interesting*?

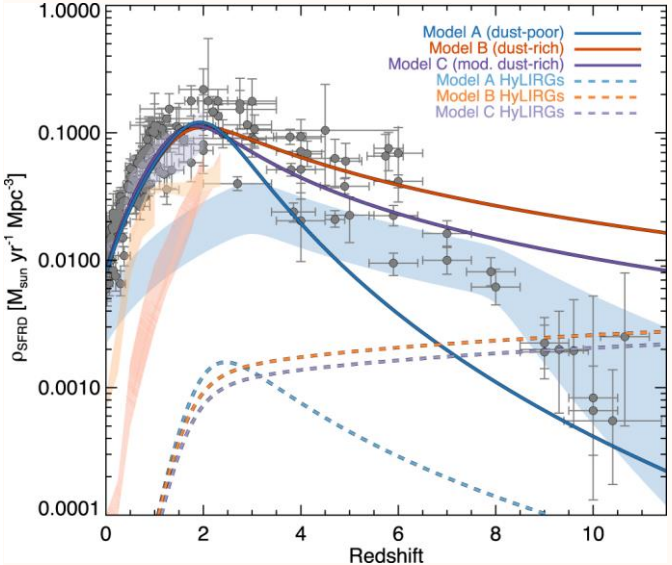




Madau & Dickinson (2014)

Background: Why are “dark galaxies” *so interesting*?

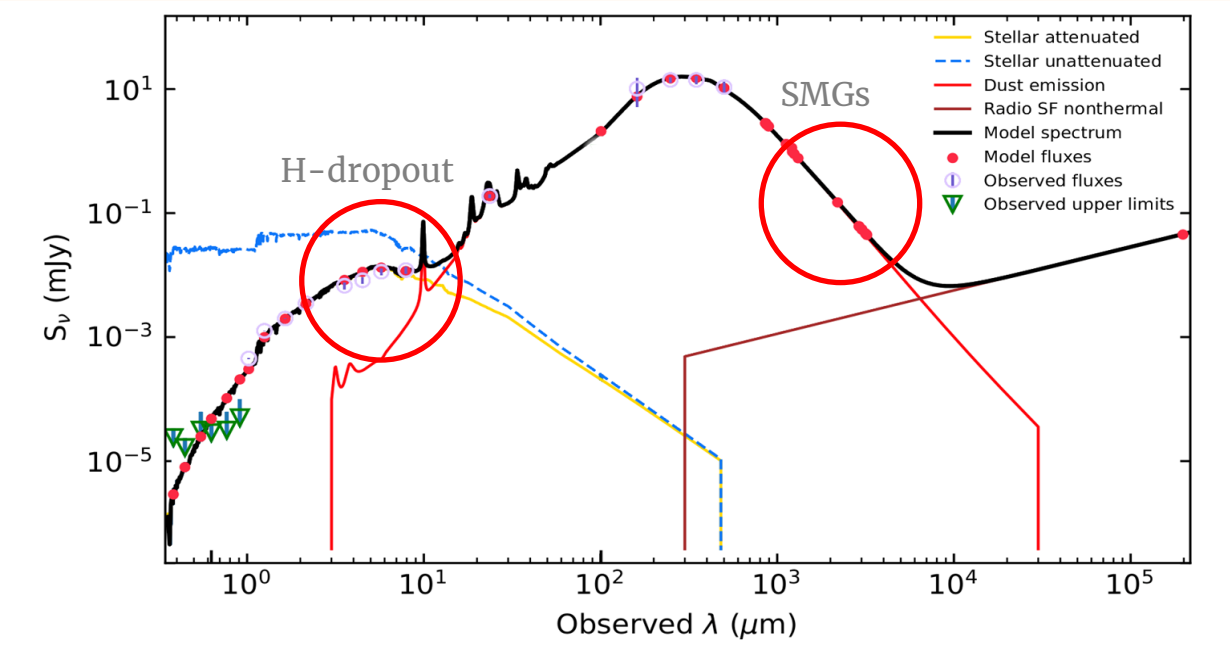




Casey+(2018)

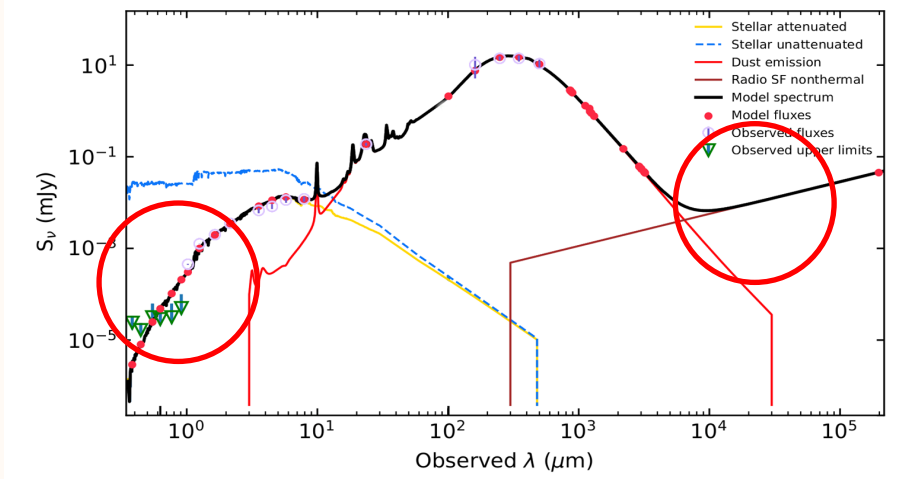
See also Novak+17; Gruppioni+20; Traina+(subm)

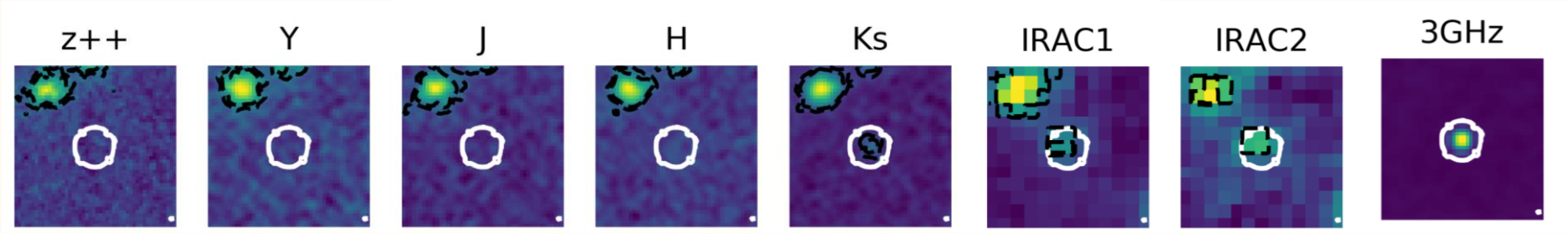
Background: How can we find “dark galaxies”?



See e.g. Casey+14; Wang+19; Gruppioni+20 etc

Our answer: Radio-Selected NIRdark galaxies





Talia+(2021), Enia+(2022), Behiri+(subm), Gentile+(subm)

Radio-Selected NIRdark galaxies

FIR / (sub)mm-Selection

Pros:

- Strongly negative *k*-correction in the (sub)mm regime

Cons:

- Large beam size and limited sensitivity (single-dish instruments)
- Small FOV (ALMA/NOEMA)
- Possible biases due to still-debated high-z properties of dust

Radio-Selection

Pros:

- High resolution, sensitivity and FOV of modern interferometers
- Radio = dust-unbiased tracer of star-formation

Cons:

- Positive k-correction in the radio regime
- Possible contamination by AGN

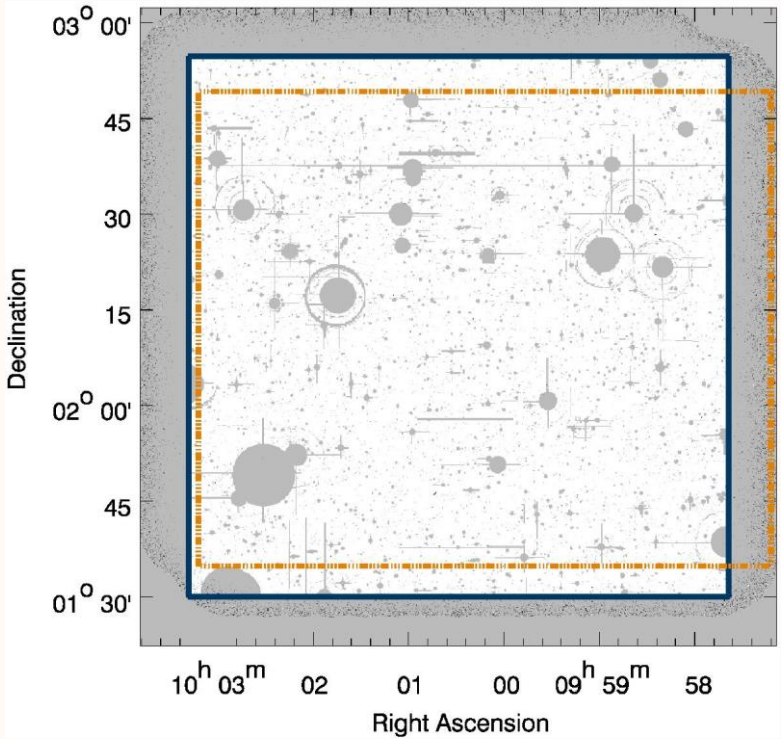
What can we learn from existing data?

We focus on the COSMOS field:

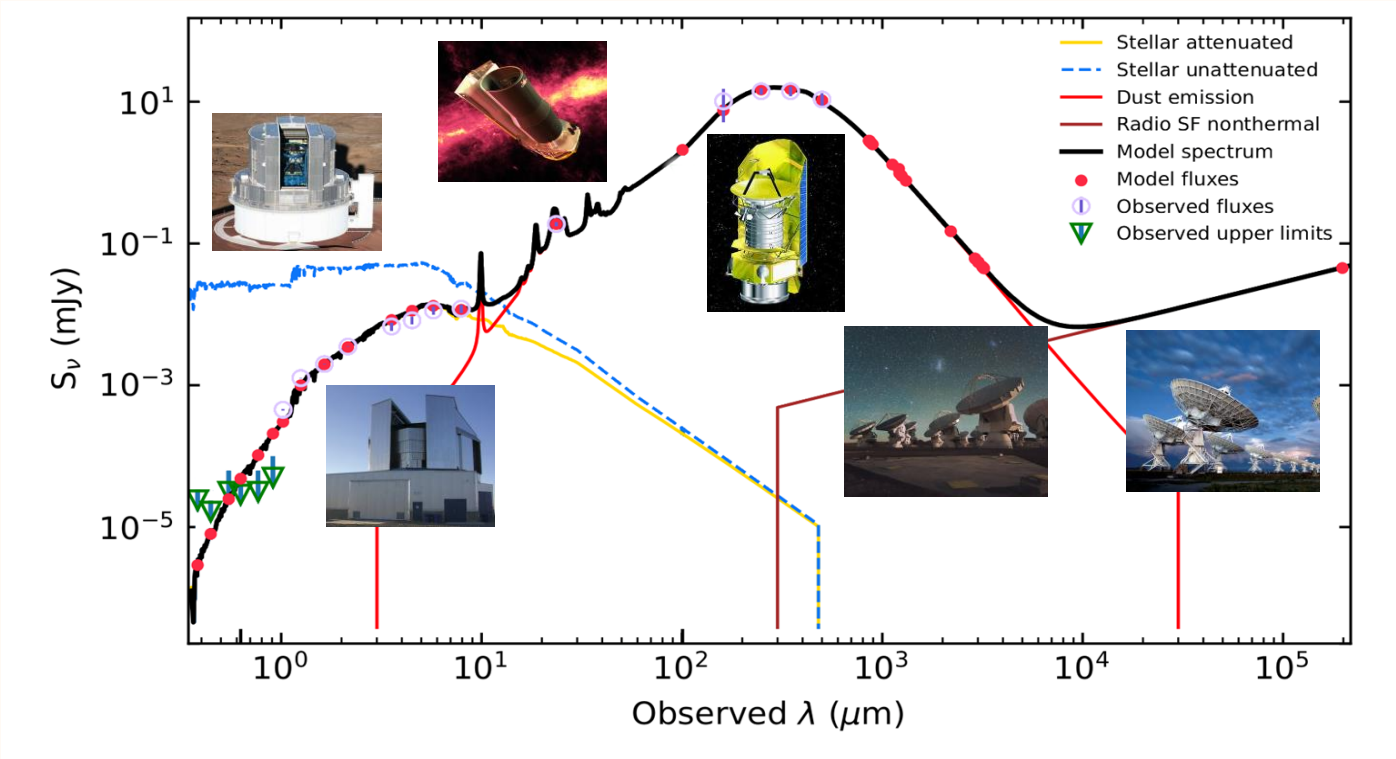
- $\sim 2.0\,\mathrm{deg}^2$ of extra-galactic sky
- Deep coverage in all the spectrum
- COSMOS-VLA 3GHz Large Project: Deep enough to identify SFGs up to $z \sim 5$

323 Radio-Selected NIRdark Galaxies

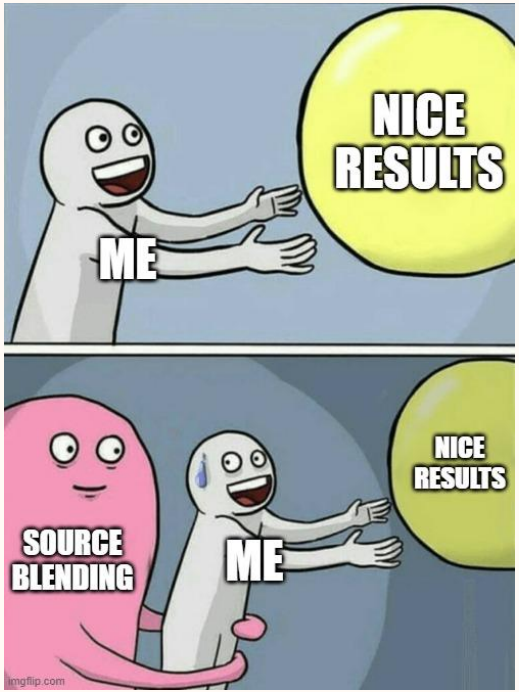
i.e. No opt/nir counterpart in the COSMOS2020 catalogue (Weaver+22)

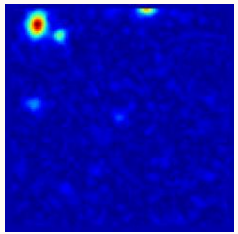


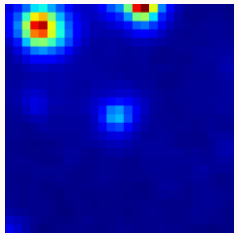
What can we learn from existing data?



What can we learn from existing data?

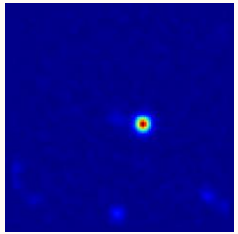


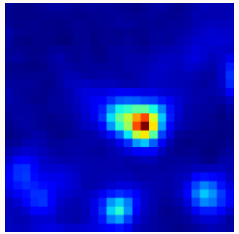




UltraVISTA

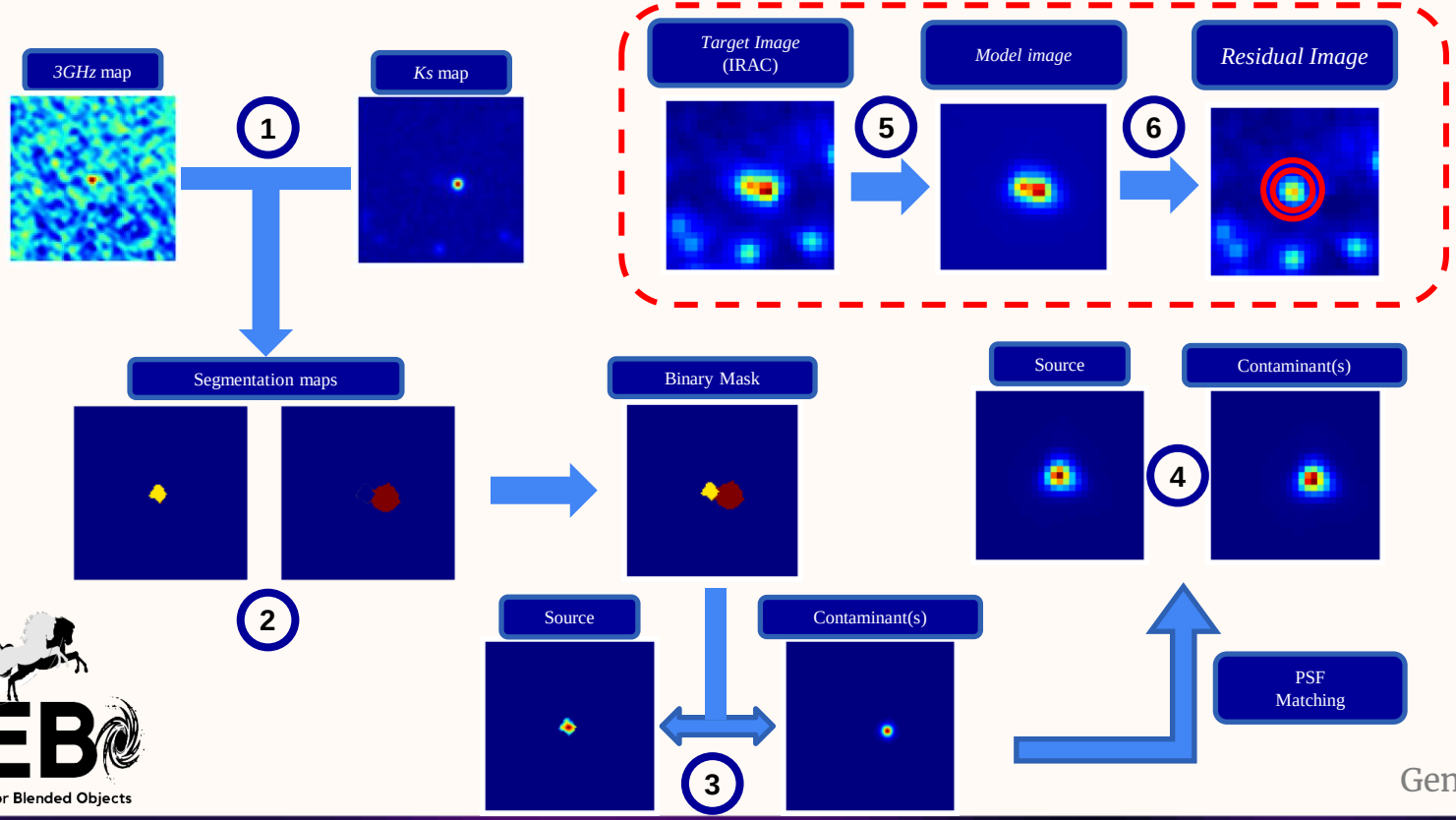
IRAC





How to deal with source-blending?

PhoEBO: the Photometry Extractor for Blended Objects

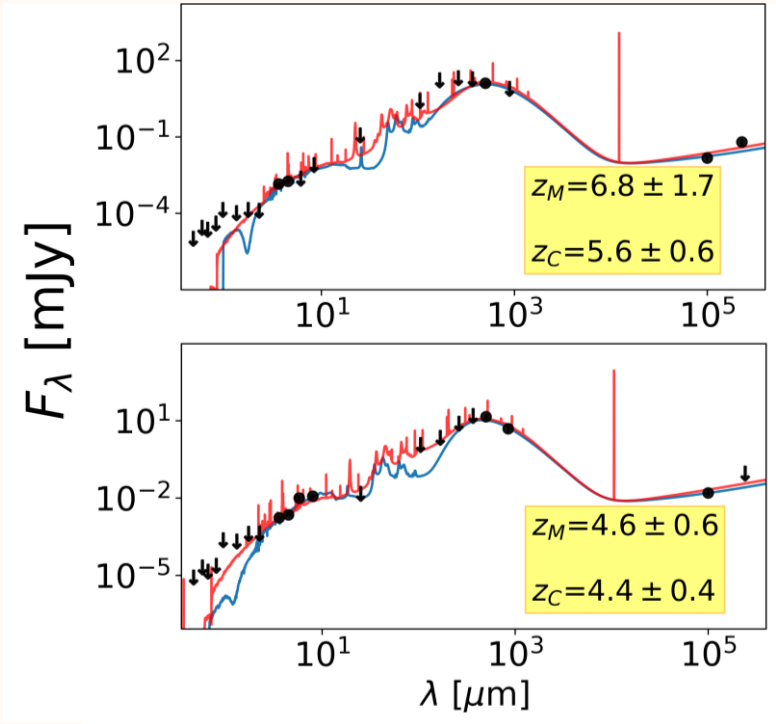


PhoEBO
Photometry Extractor for Blended Objects

Gentile+(subm)

What can we learn from existing data?

- Optical/NIR/MIR: PhoEBO
  (Gentile+subm)
- FIR: SuperDeblended
  (Jin+18)
- (sub)mm: A3COSMOS
  (Liu+19)
- Radio: VLA-COSMOS (1.4/3 GHz)
  (Schinnerer+10;Smolcic+17)



Gentile+(subm)

What can we learn from existing data?

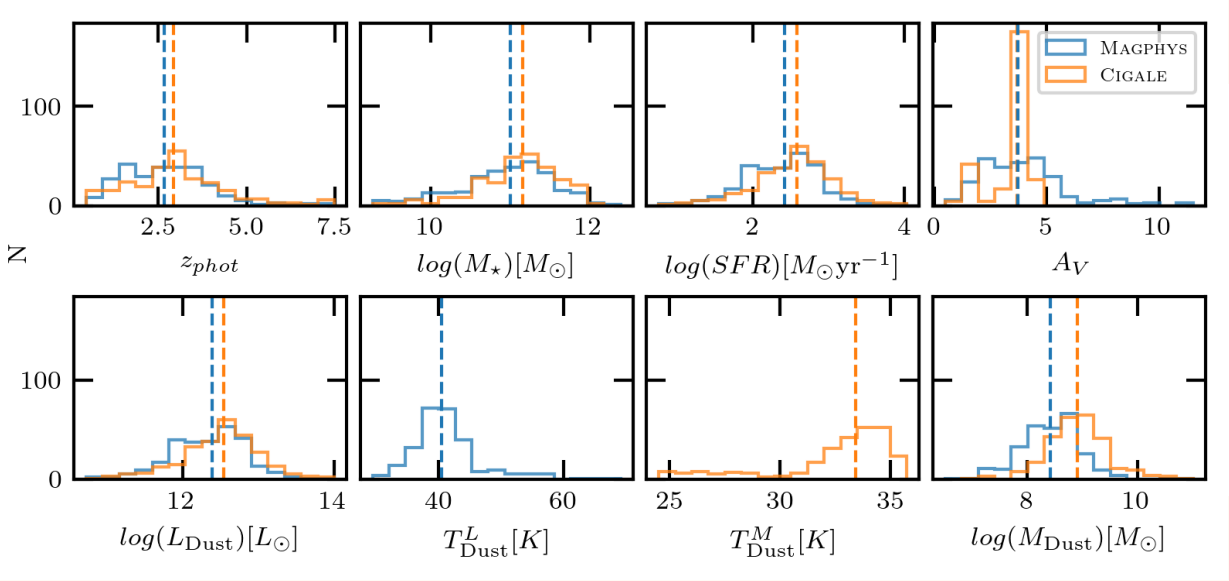


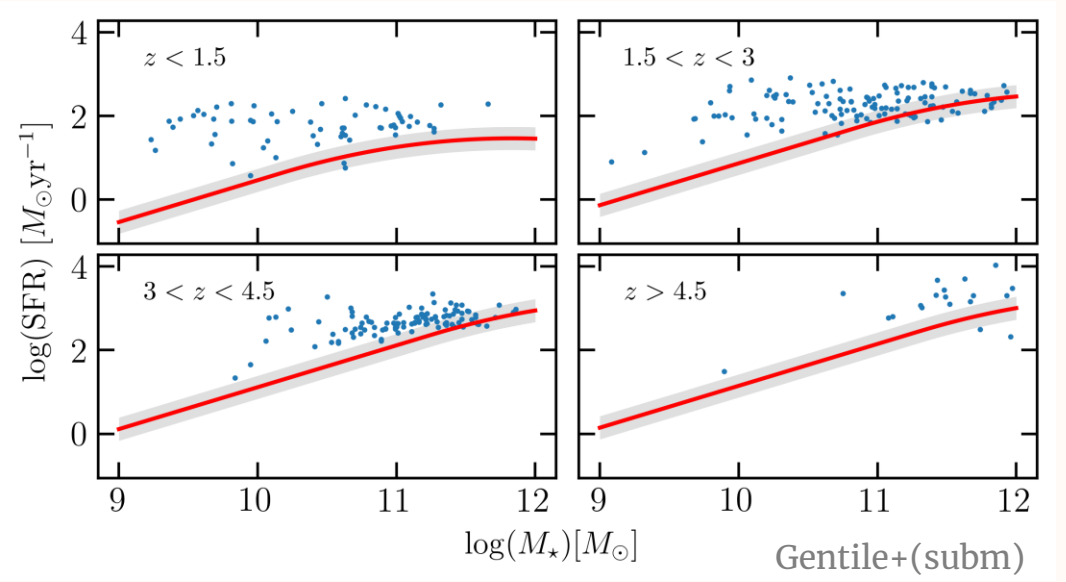
Table 2. Comparison between the median properties estimated by MAGPHYS and CIGALE

Property	MAGPHYS median	CIGALE median	Unit
z_{phot}	2.68 ± 0.04	2.93 ± 0.04	
$\log(M_\star)$	11.00 ± 0.02	11.15 ± 0.02	$M_\odot$
$\log(SFR)$	2.42 ± 0.02	2.58 ± 0.04	$M_\odot \mathrm{yr}^{-1}$
A_v	3.74 ± 0.04	3.70 ± 0.05	mag
$\log(L_{\mathrm{Dust}})$	12.39 ± 0.02	12.54 ± 0.02	$L_\odot$
T^L_{Dust}	40.5 ± 0.2	–	K
T^M_{Dust}	–	33.4 ± 0.2	K
$\log(M_{\mathrm{Dust}})$	8.43 ± 0.02	8.91 ± 0.02	$M_\odot$

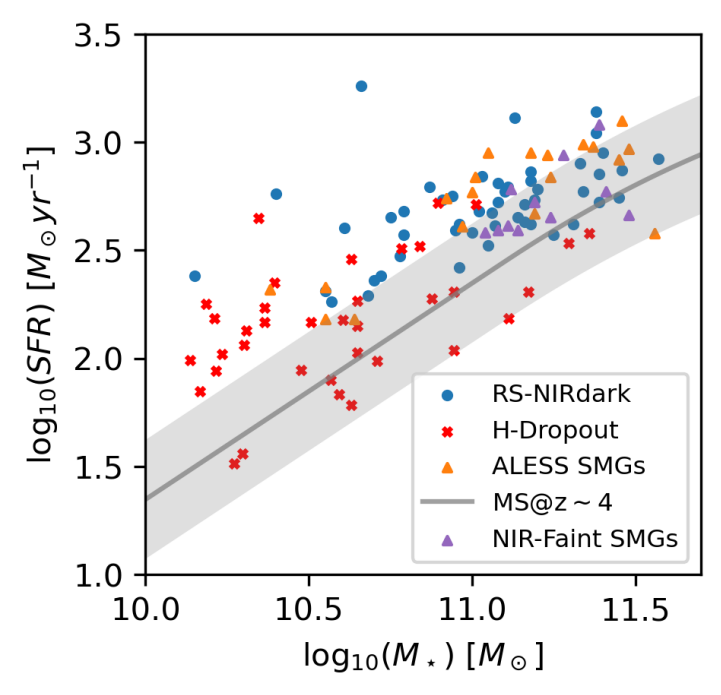
Gentile+(subm)

What can we learn from existing data?

- ~ 40% of the RS-NIRdark galaxies lie on the main sequence
- ~ 55% galaxies are classified as «starburst»



What can we learn from existing data?



Gentile+(subm)

What can we learn from new data?

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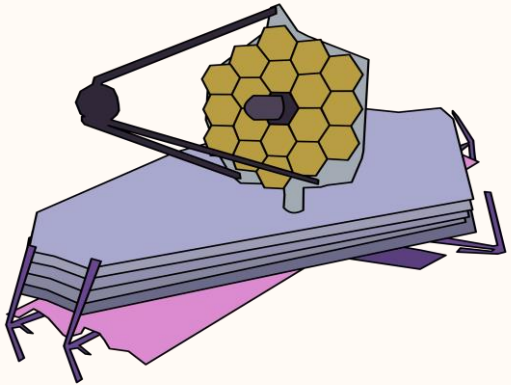
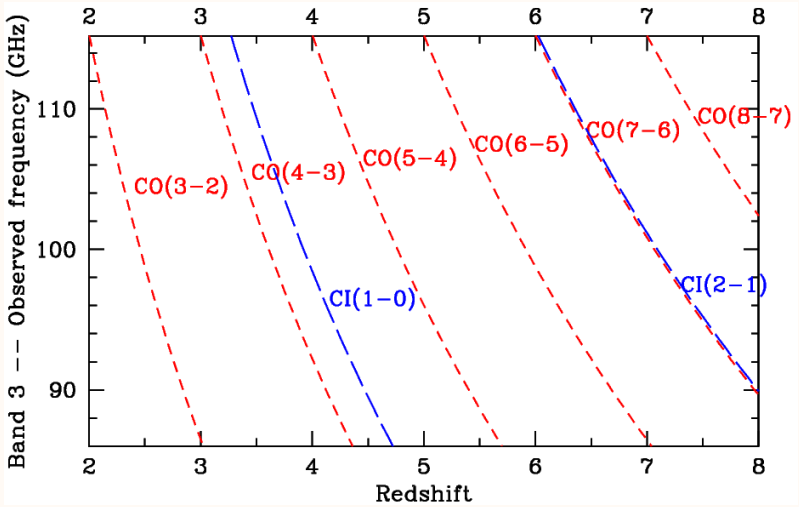


COSMOS WEB

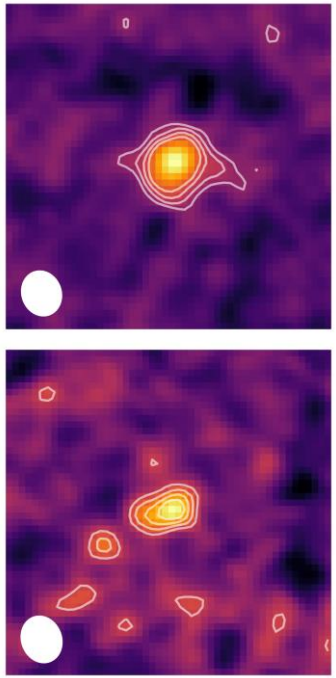
What can we learn from new data?

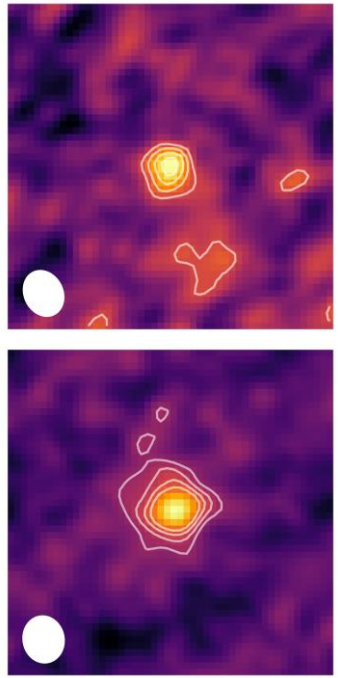
What can we learn from new data?

- Two proposals accepted:
  - ALMA spectral scan for 9 RS-NIRdark galaxies
  - NOEMA spectral scan for 2 RS-NIRdark galaxies



ALMA data – Continuum detections





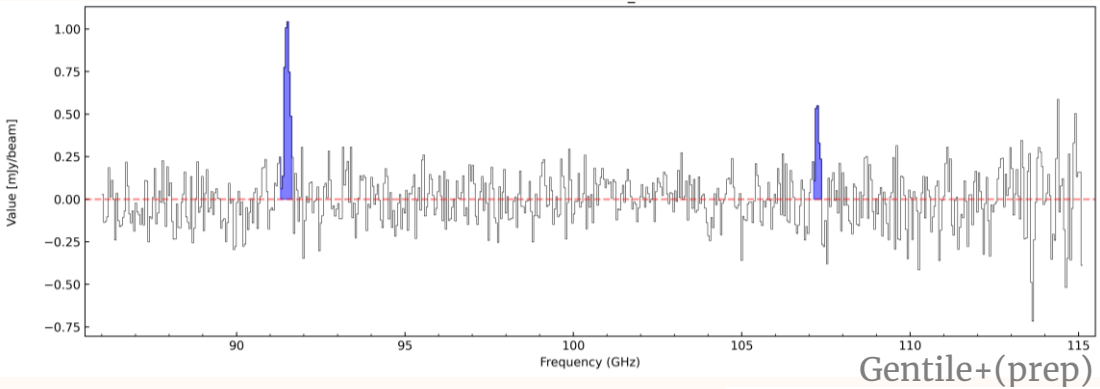
- Robust (S/N>5) continuum detection for 6/9 galaxies ->
  The two populations are not totally overlapping!

- $S_{3\mathrm{mm}} \sim 0.1 - 1\,\mathrm{mJy}$

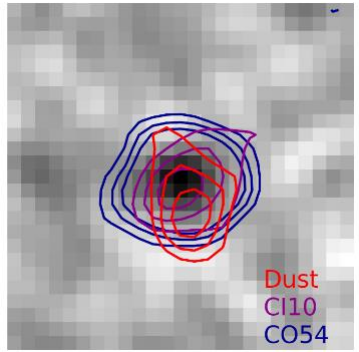
- Most of the sources are unresolved, some partially-resolved ->
  Future constraints on sizes!

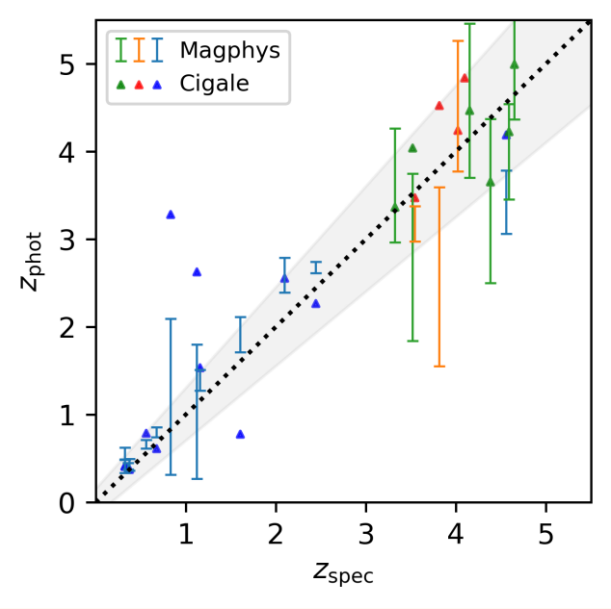
Gentile+(prep)

ALMA – Spectroscopic redshifts



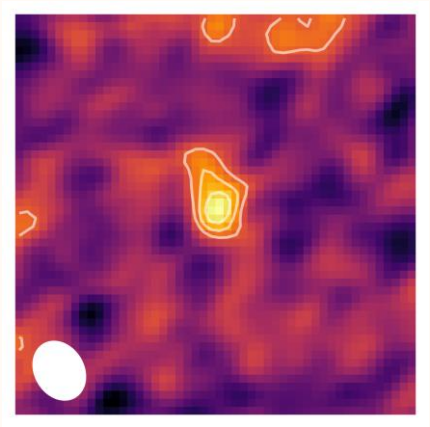
$$\text{median}\left(\frac{|\Delta z|}{1+z_{spec}}\right) \sim 0.07$$

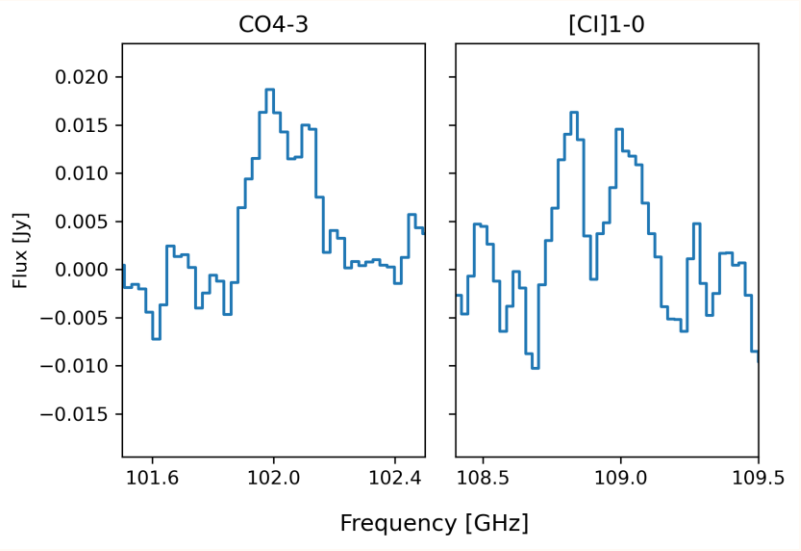


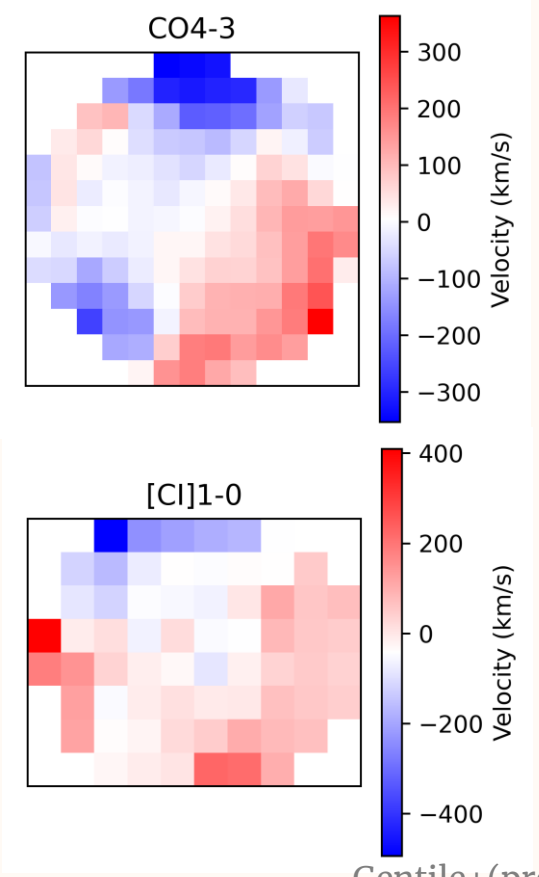


ALMA - Kinematics

- For one of the galaxies observed with ALMA ($z = 3.52$) the spectrum gave some interesting insights on the ISM kinematics







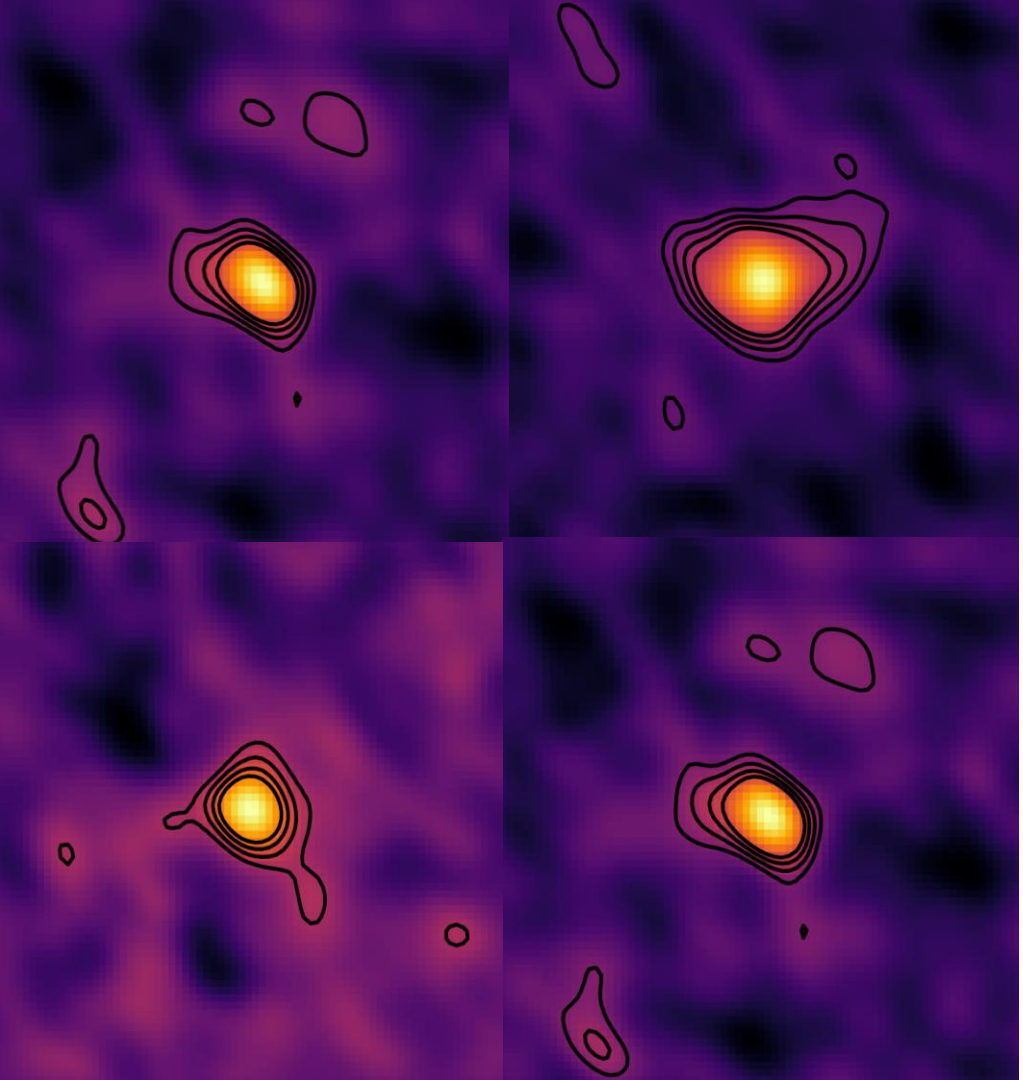
Gentile+(prep)

ALMA & NOEMA – Future steps

- Constraints on dust temperature (continuum detection + A3COSMOS)
- Direct measure of the gas mass (from [CI] line)
- Improvement in the SED-fitting (from spec-z and additional point)
- Constraints on the physical sizes

Conclusion

- The role of “dark” DSFGs in the cosmic SFRD and in the evolution of massive galaxies could be extremely significant
- We assembled a sample of 323 Radio-Selected NIRdark galaxies in the COSMOS field, extracting photometry from the optical to the radio with PhoEBO and cross-matching with pre-existing catalogues
- The physical properties estimated through SED-fitting confirm the DSFG nature of the RS-NIRdark galaxies
- Ongoing ALMA/NOEMA/JWST programmes will give new insights on these promising sources. So... stay tuned!



Thank you

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