

Rise of Normal, Dust-Obscured Galaxies During Cosmic Reionization

Yoshinobu Fudamoto

Waseda University

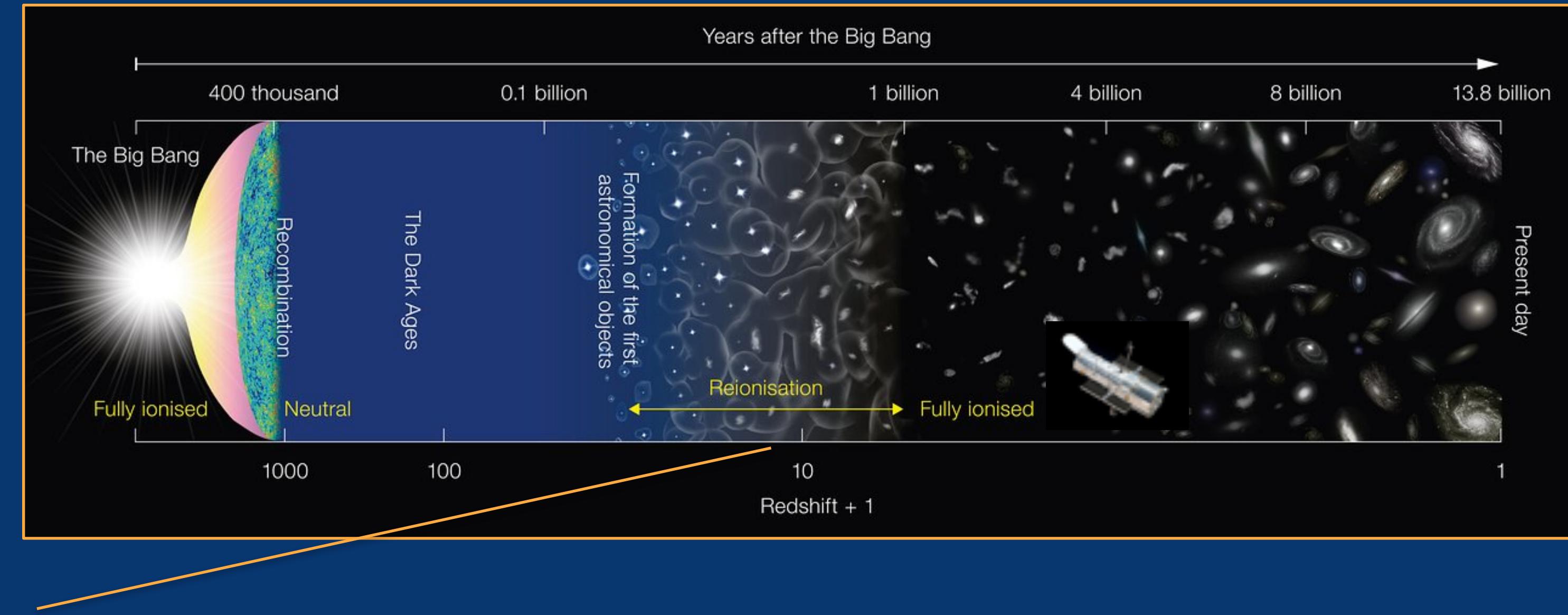
NAOJ-ALMA project

REBELS team

P. A. Oesch, S. Schouws, M. Stefanon, R. Smit, R. J. Bouwens, R. A. A. Bowler, R. Endsley, V. Gonzalez, **H. Inami**, I. Labbe, D. Stark, M. Aravena, L. Barrufet, E. da Cunha, P. Dayal, A. Ferrara, L. Graziani, J. Hodge, A. Hutter, Y. Li, I. De Looze, T. Nanayakkara, A. Pallottini, D. Riechers, R. Schneider, G. Ucci, P. van der Werf, C. White



Galaxies in the Cosmic Reionization Era

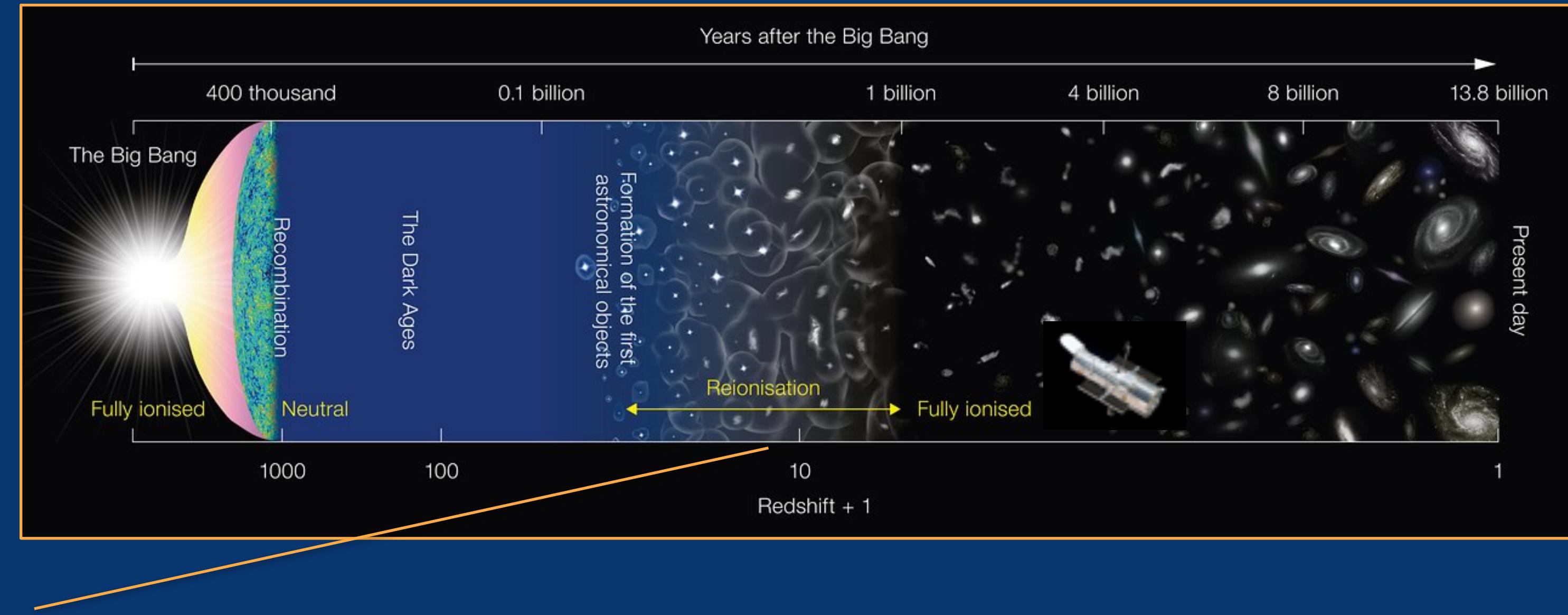


Complete census of galaxy formation is a pre-requisite
to understand cosmic reionization

So far, deep NIR observations (e.g., HST, Subaru)
obtained a large sample of galaxies at $z > 6$
based on galaxies' rest-UV emission (i.e., Lyman break galaxies).

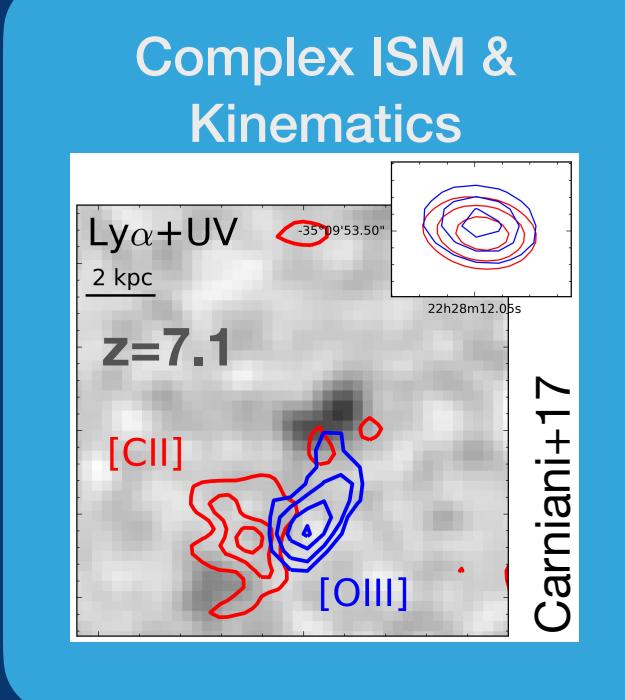
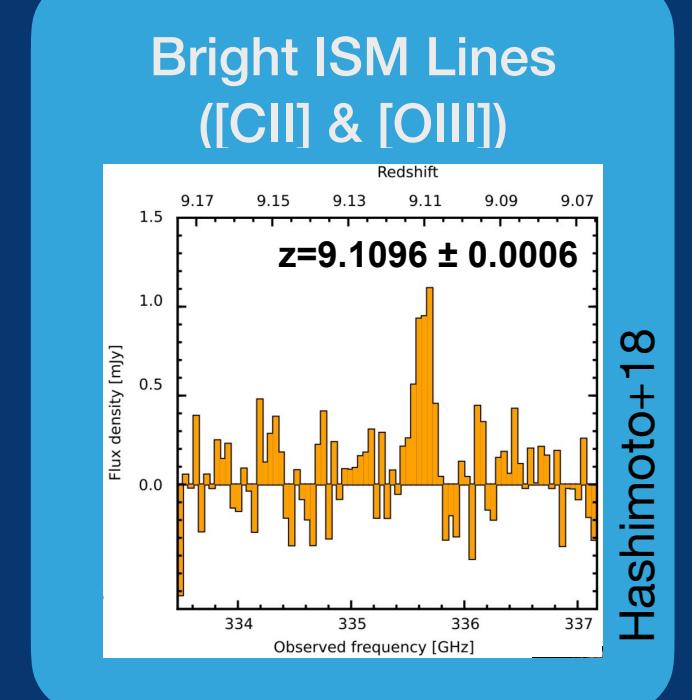
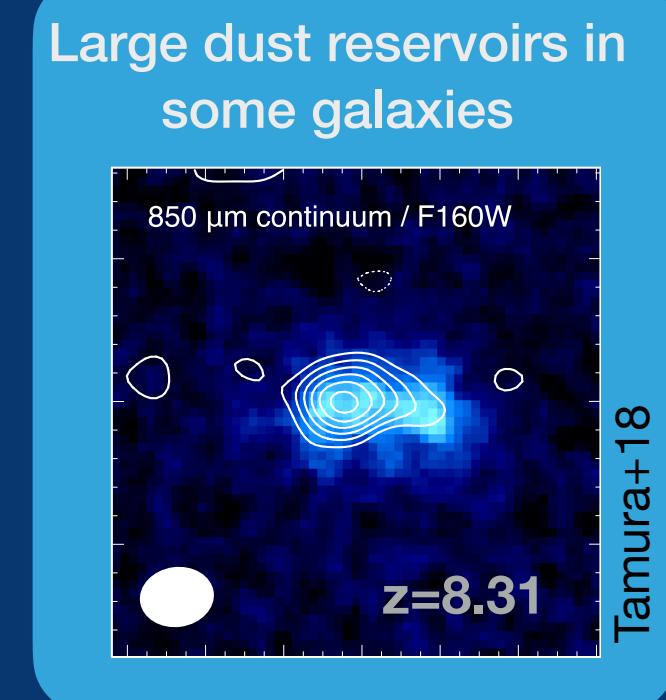
see also, e.g. Ginolfi+20, Schaefer+20, Miroslava-Dessauges+20, Loiacono+20 Inoue+16, Fujimoto+19/20, Harikane+20, Laporte+17/21, Smit+18, Knudsen+17, Pavesi+16, Watson+15

Galaxies in the Cosmic Reionization Era

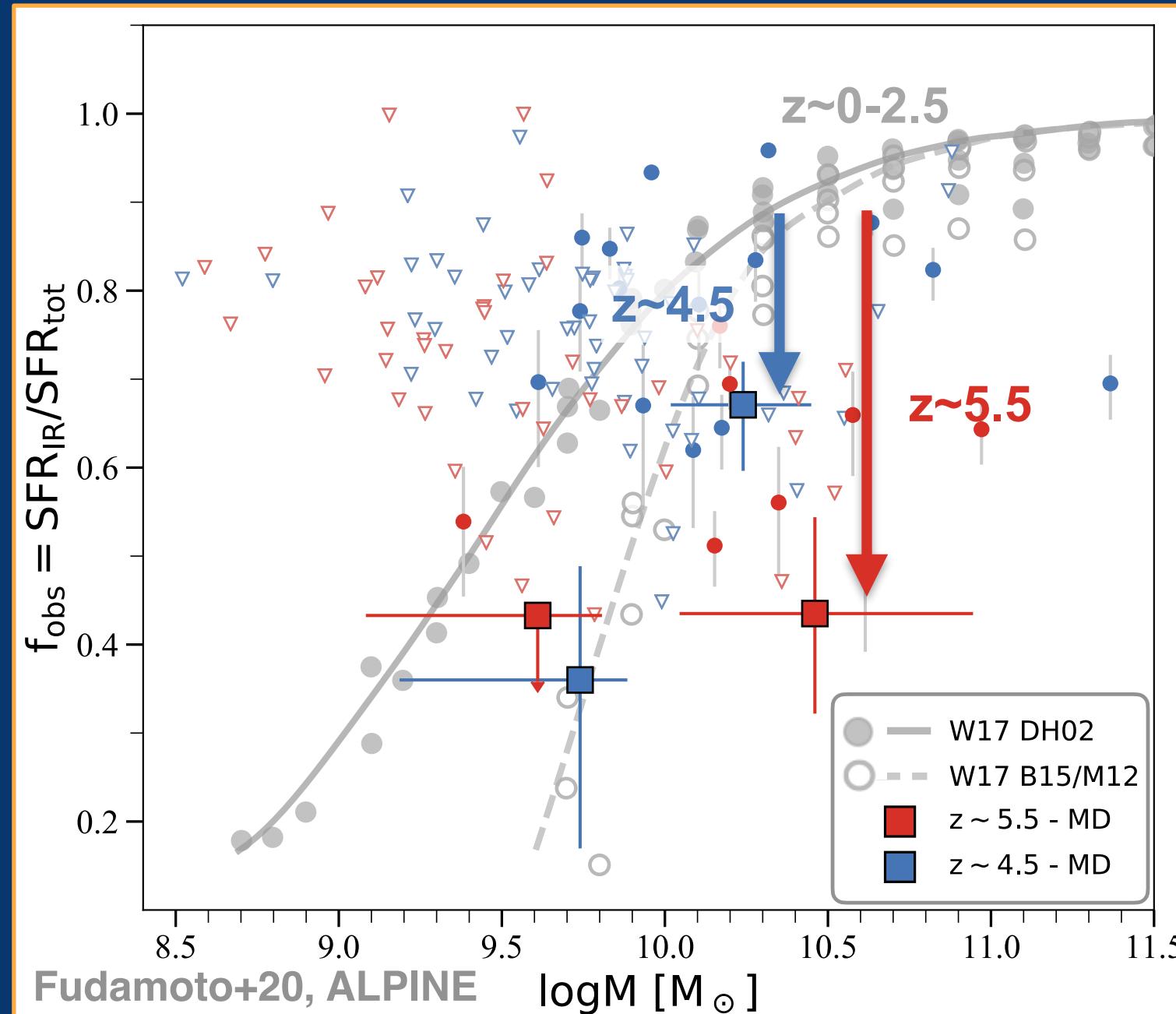


Complete census of galaxy formation is a pre-requisite to understand cosmic reionization

So far, deep NIR observations (e.g., HST, VLT) obtained a large sample of galaxies at $z > 6$ based on galaxies' rest-UV emission (i.e., Lyman break galaxies).

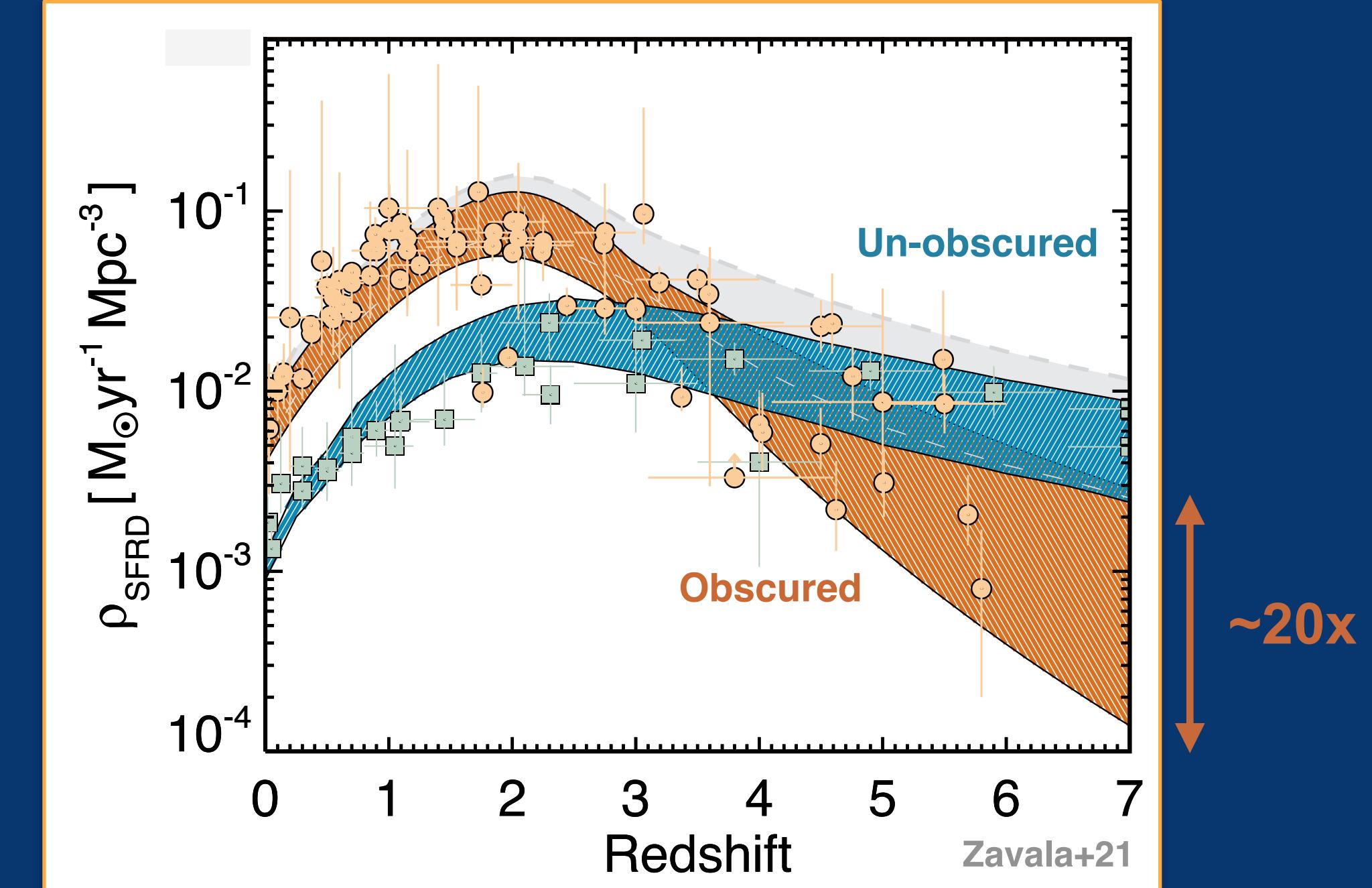
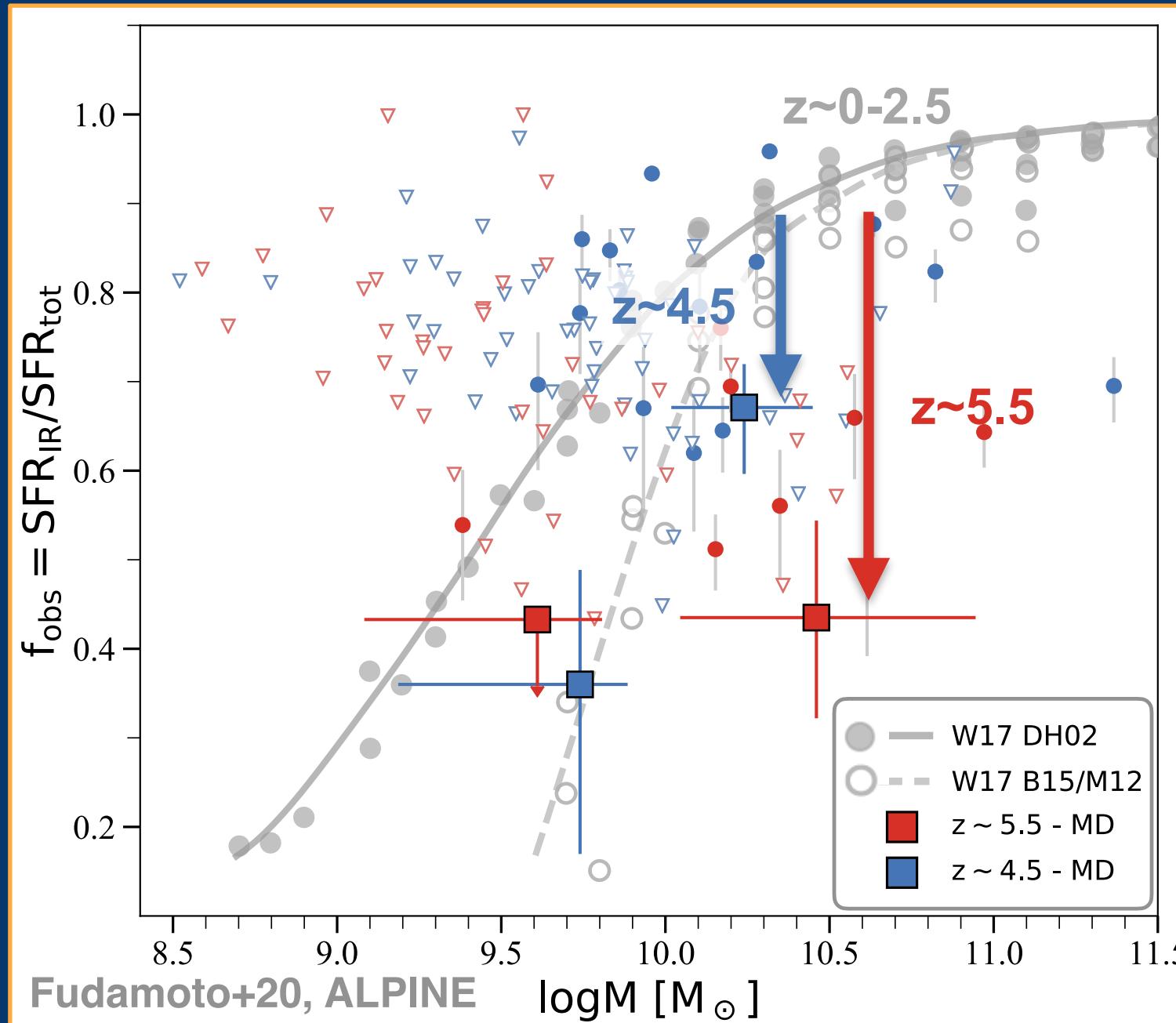


Galaxies in the Cosmic Reionization Era



Less and less dust-obscured star-formation activities at higher redshift?

Galaxies in the Cosmic Reionization Era

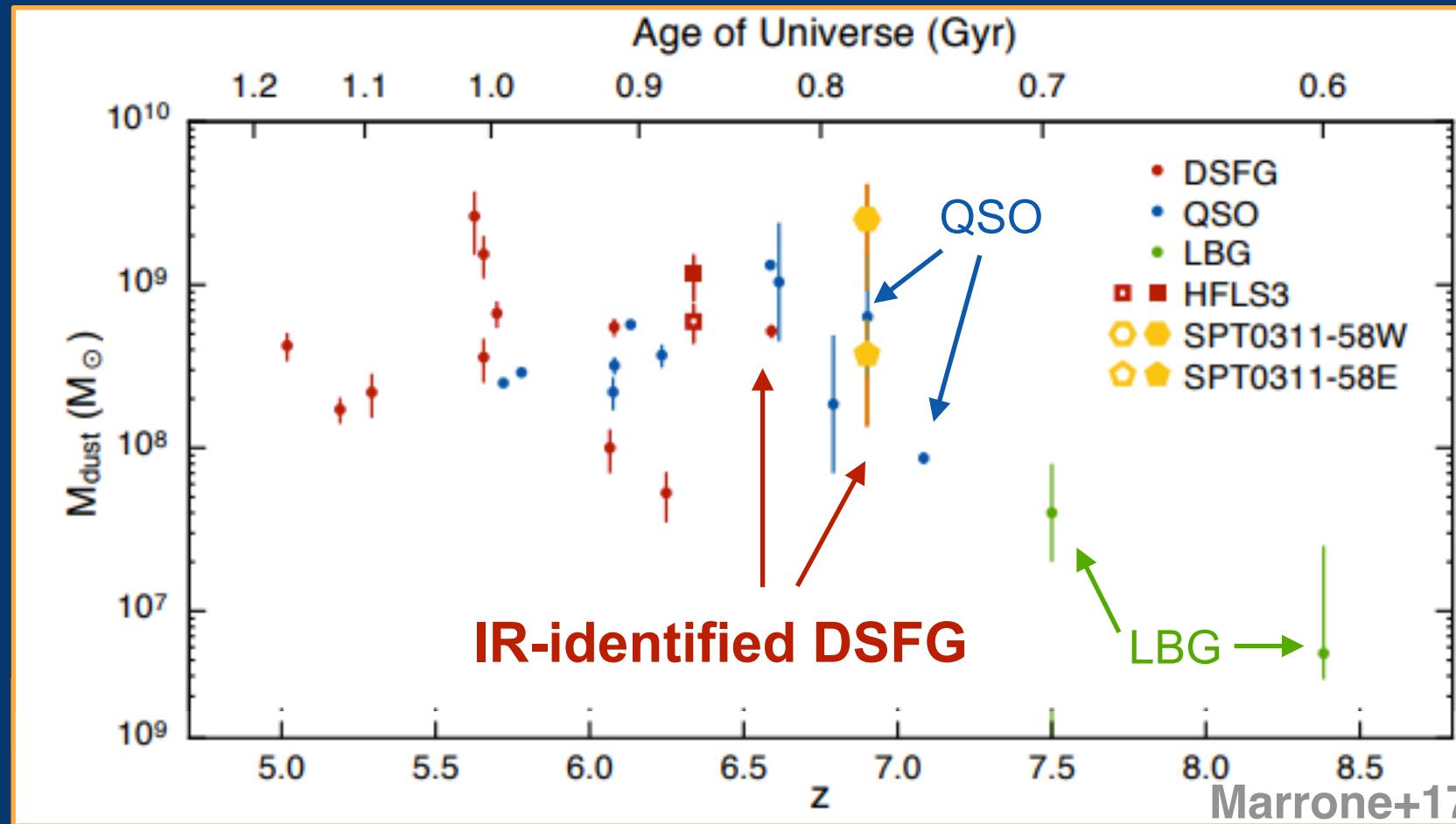


Less and less dust-obscured star-formation activities at higher redshift?

Do we have complete galaxy sample in the EoR
or do we still miss some type of galaxies as they are difficult to find?

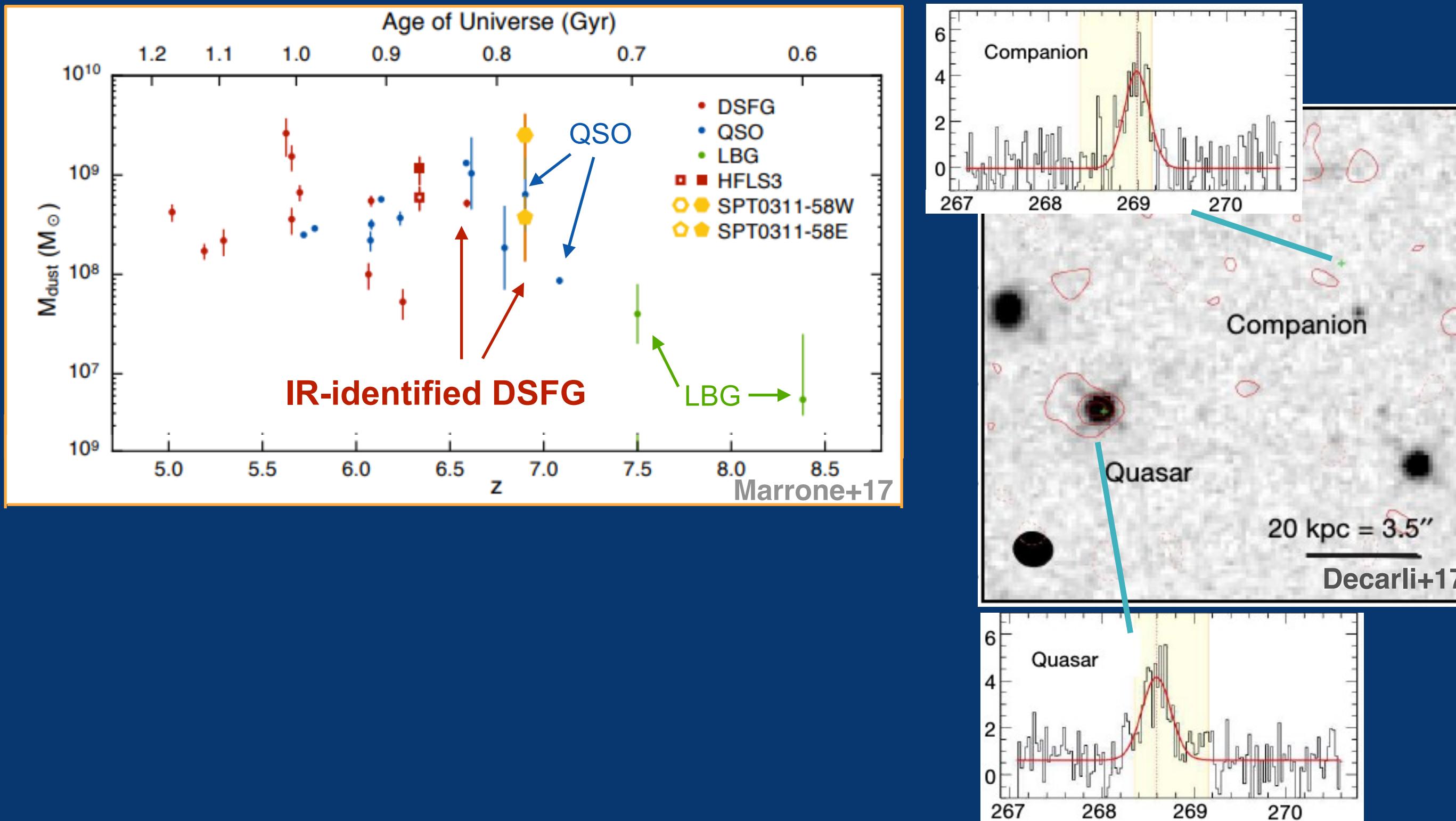
see also, e.g. Le Févre+20, Bethermin+20, Faisst+20, Whitaker+17, Bowler+18, Dunlop+16, Bouwens+16/20, Carniani+21, Capak+15, Alvarez-Marquez+19, Shvarei+20, Bax+20, Magnelli+20

Heavily Dust-obscured Galaxies in High-Redshift



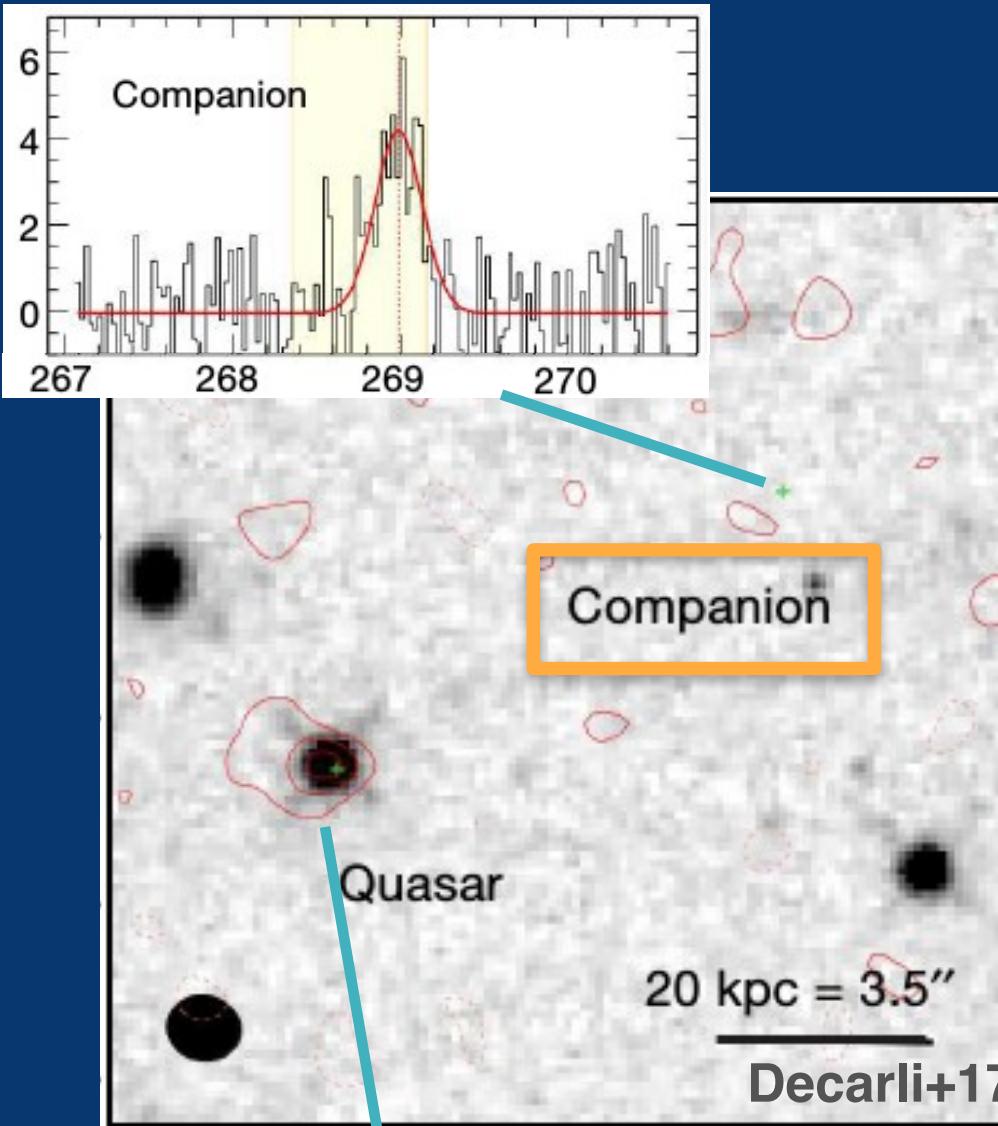
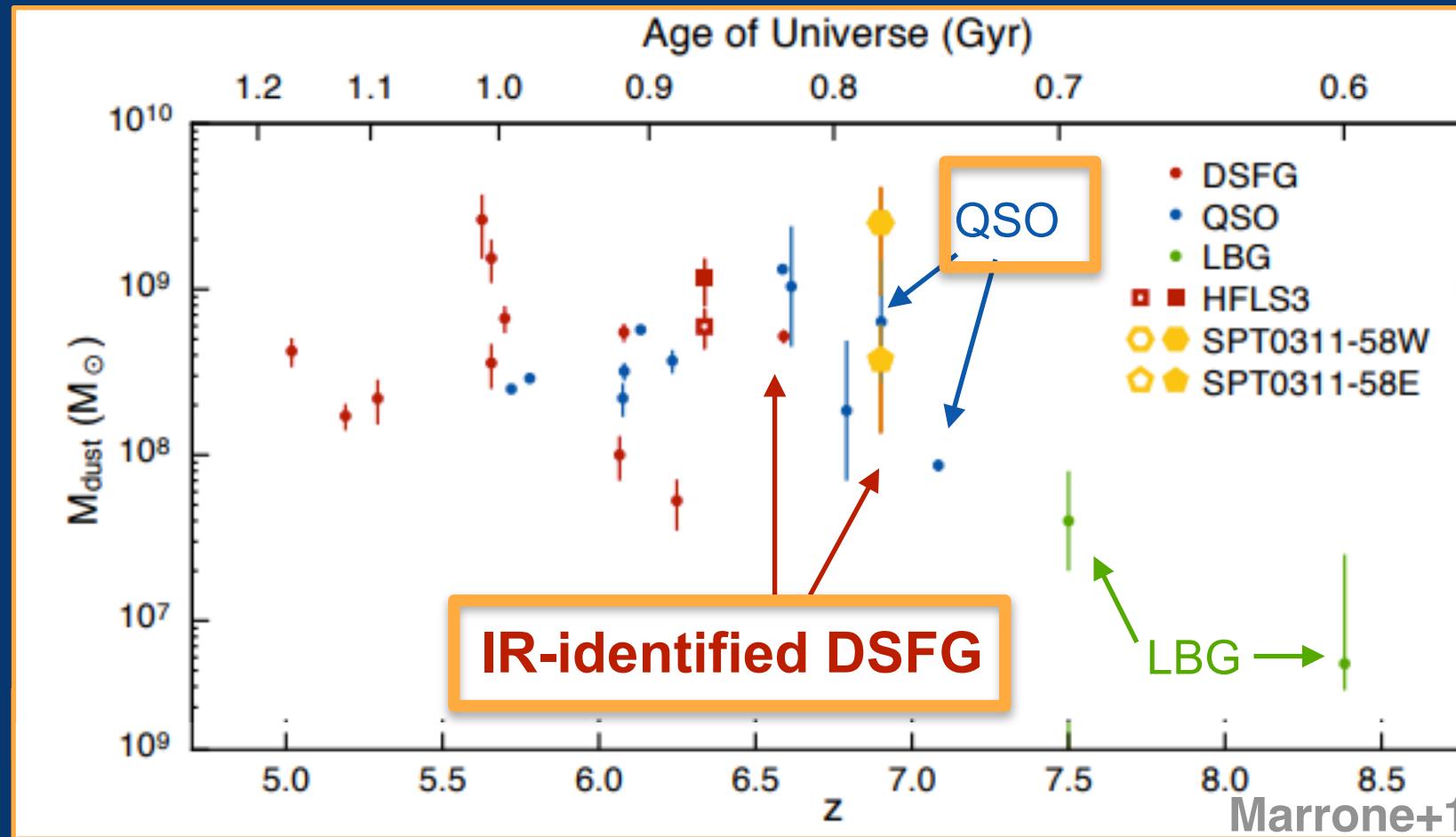
see also, e.g. Gómez-Guijaro+21, Pozzi+21, Romano+20, Riechers+20, Gruppioni+20, Wang+16, Mazzucchelli+19, Casey+19/18ab, Frabco+18, Zavala+18, Strandet+16, Caputi+15

Heavily Dust-obscured Galaxies in High-Redshift



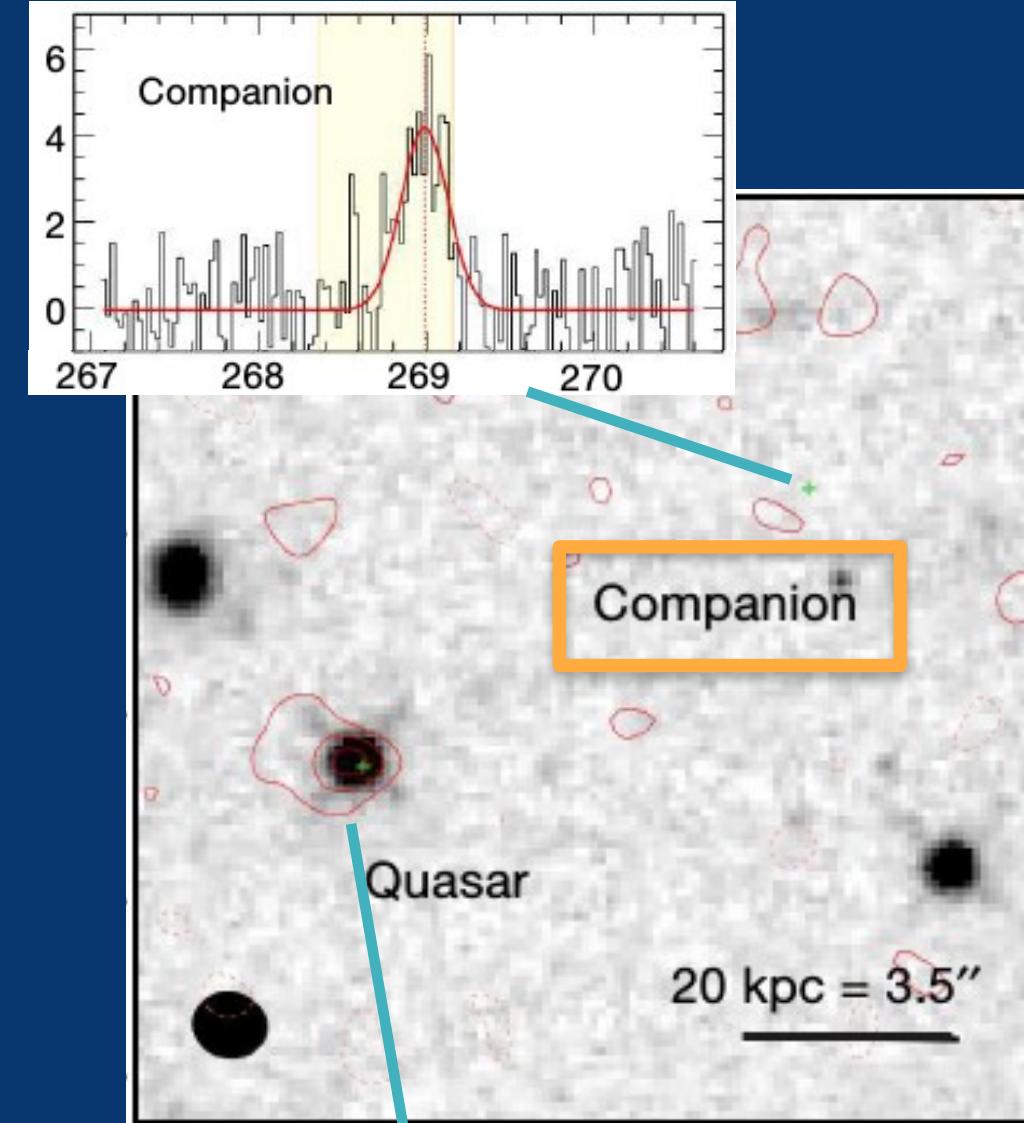
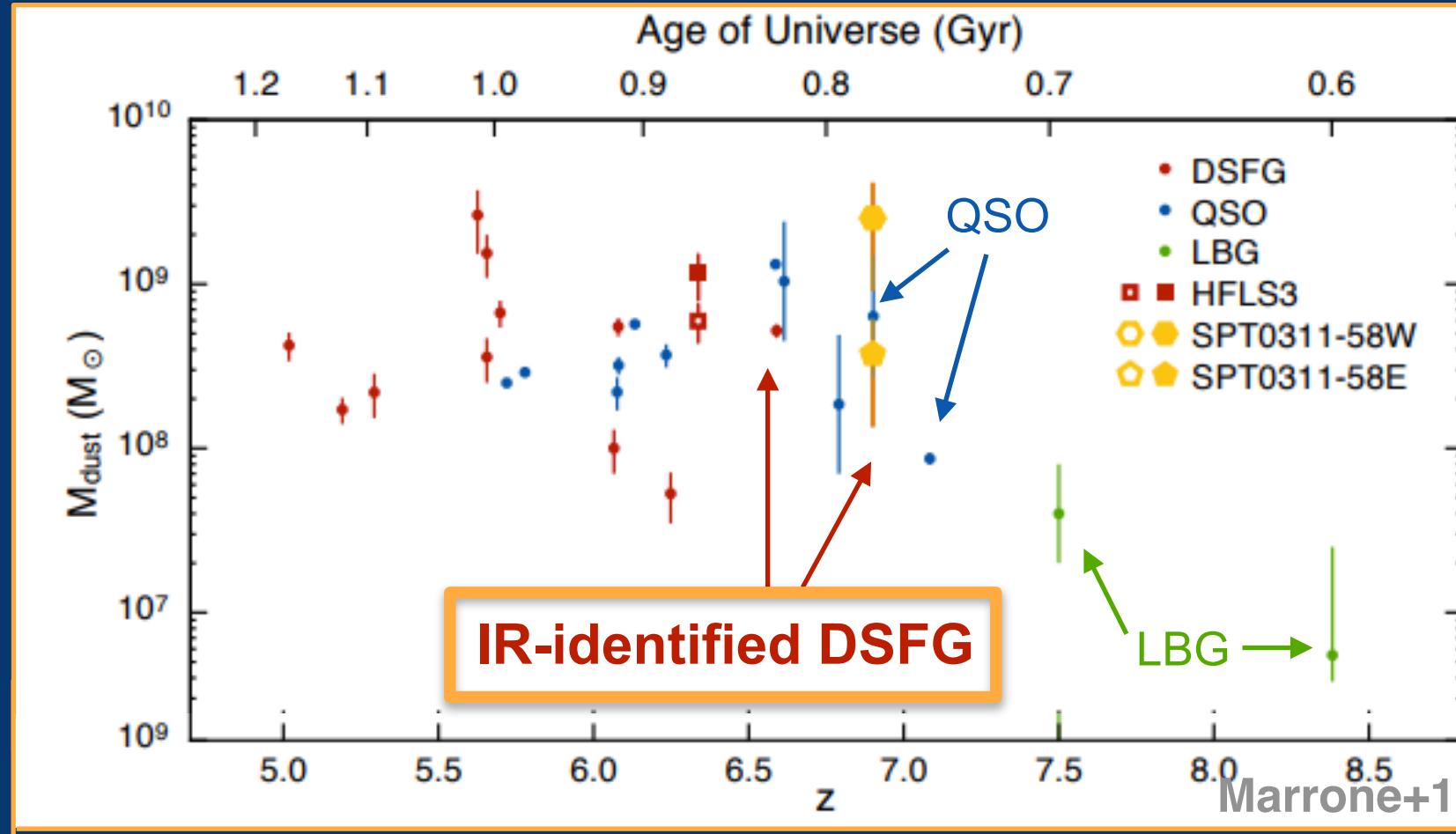
see also, e.g. Gómez-Guijaro+21, Pozzi+21, Romano+20, Riechers+20, Gruppioni+20, Wang+16, Mazzucchelli+19, Casey+19/18ab, Frabco+18, Zavala+18, Strandet+16, Caputi+15

Heavily Dust-obscured Galaxies in High-Redshift

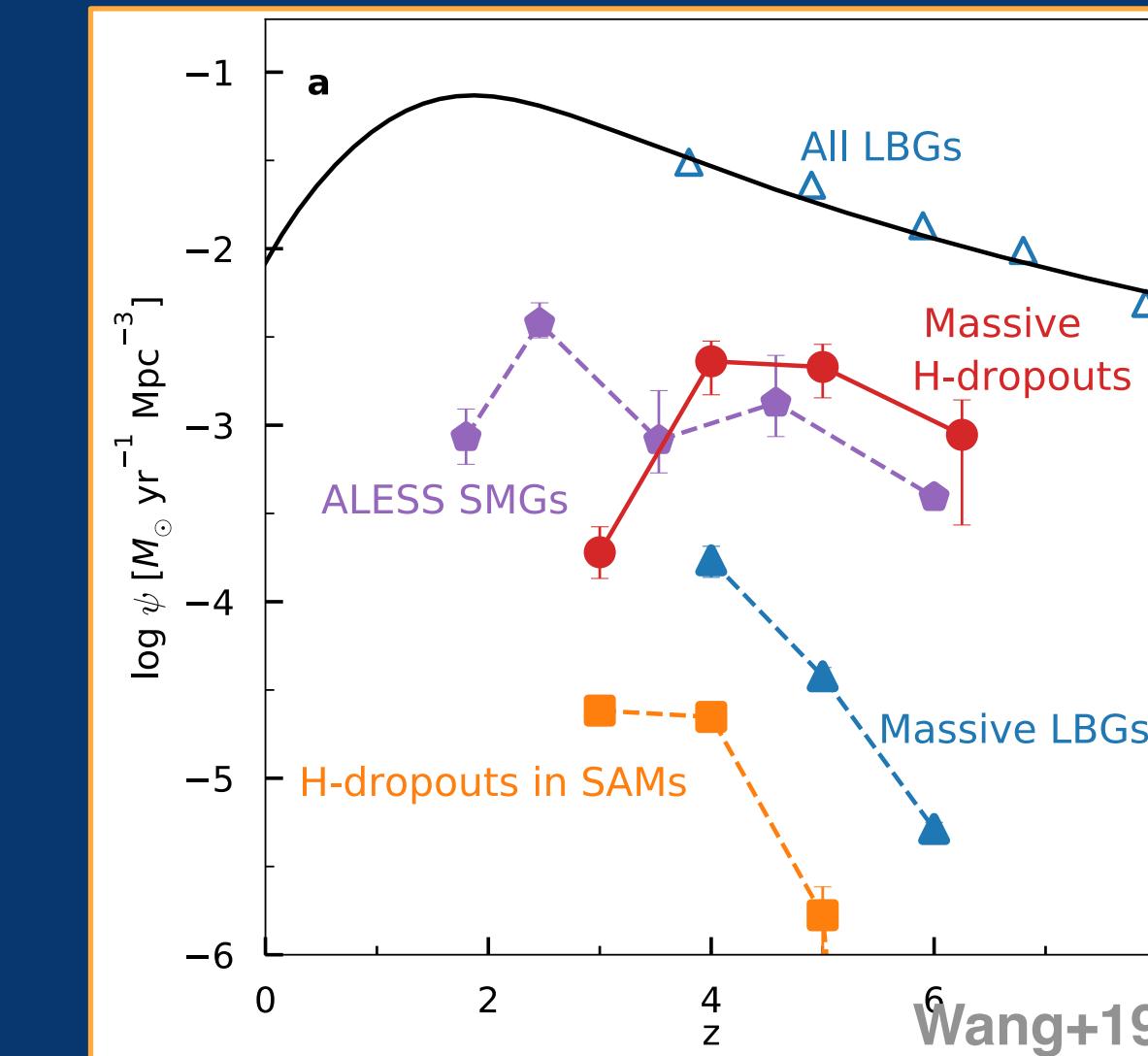


IR-identified galaxies are found only in rare and extreme environments
e.g. Dusty Starbursts, AGNs

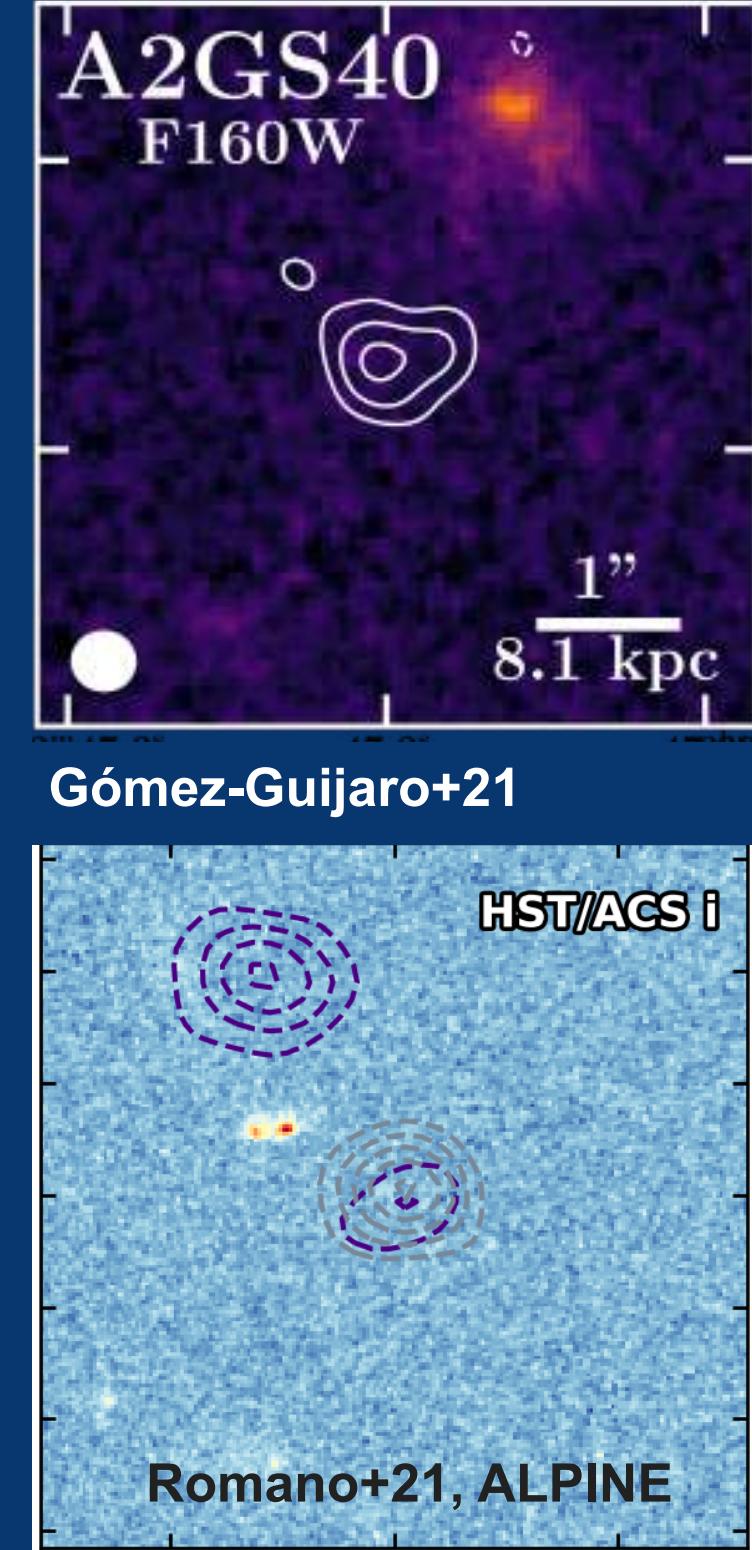
Heavily Dust-obscured Galaxies in High-Redshift



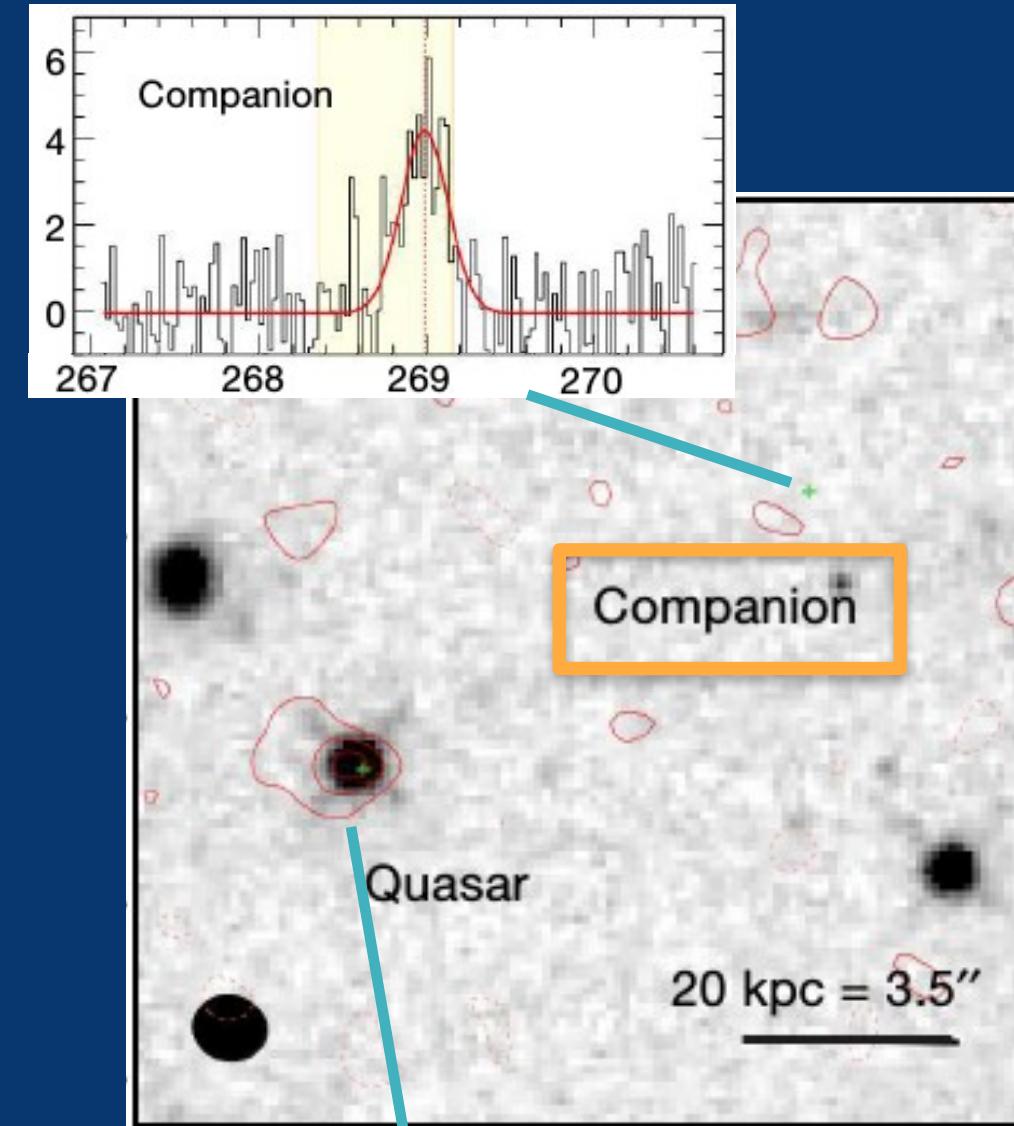
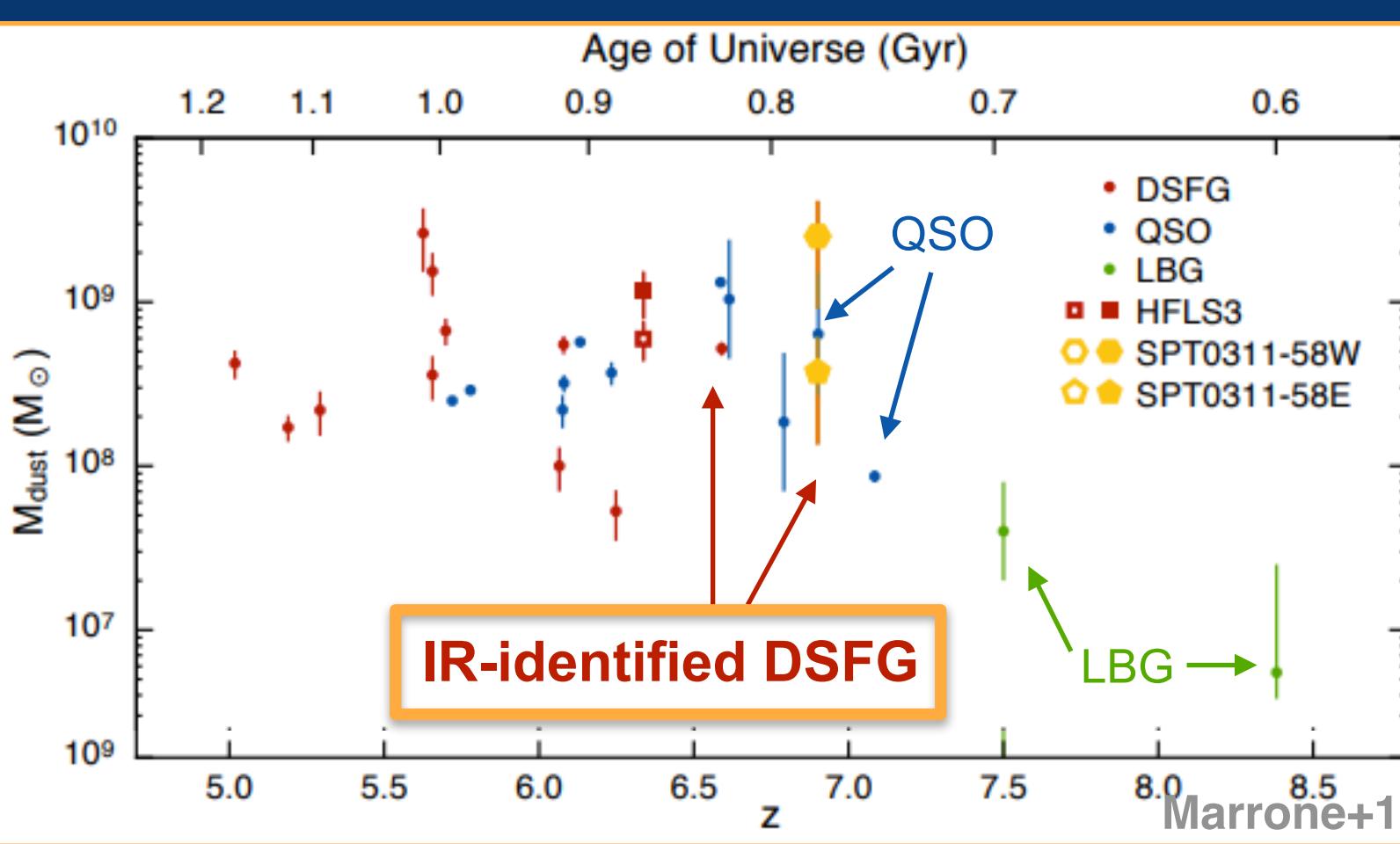
IR-identified galaxies are found only in rare and extreme environments
e.g. Dusty Starbursts, AGNs



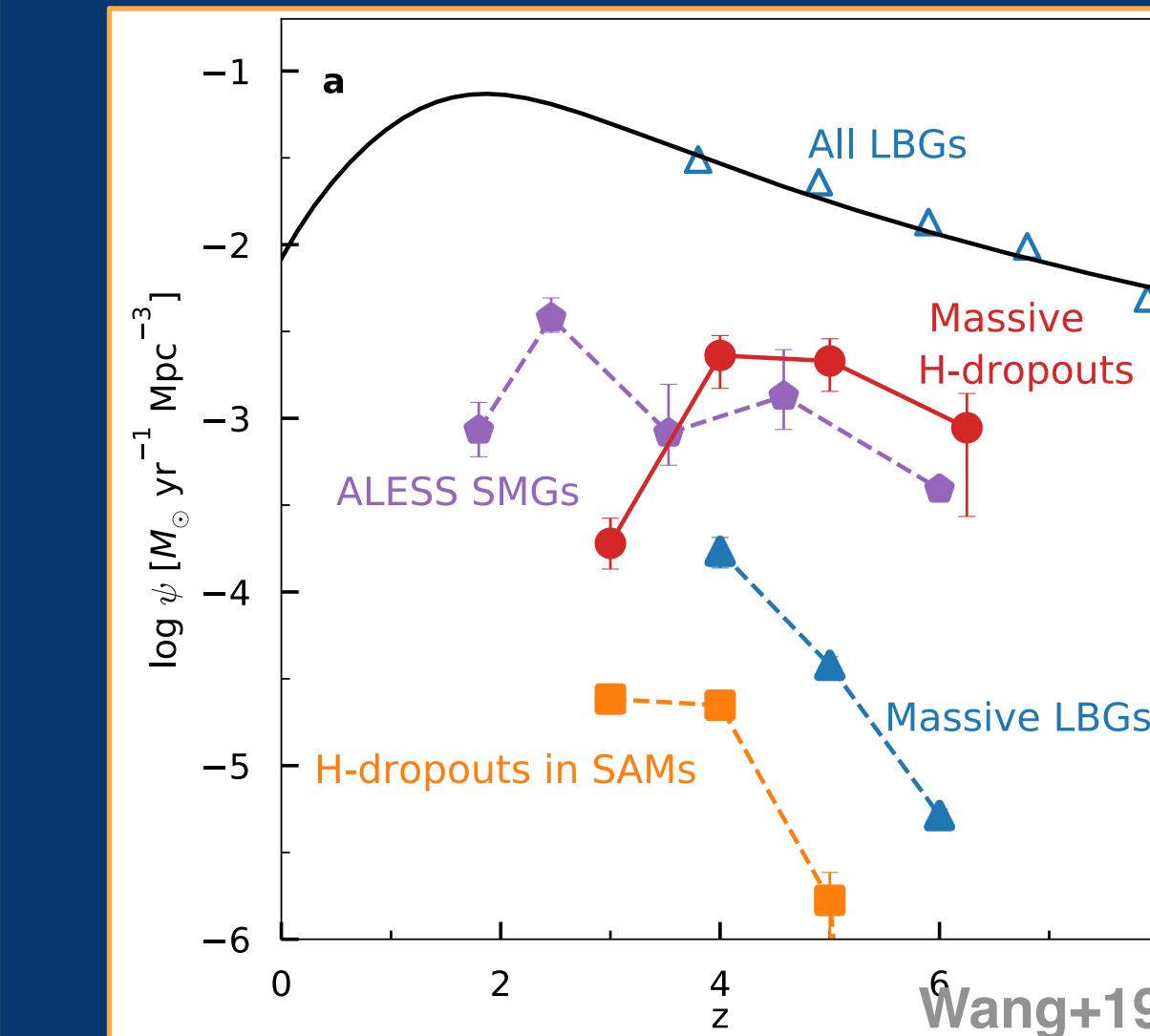
Optically-dark galaxies are less extreme cases,
Not yet identified in the EoR



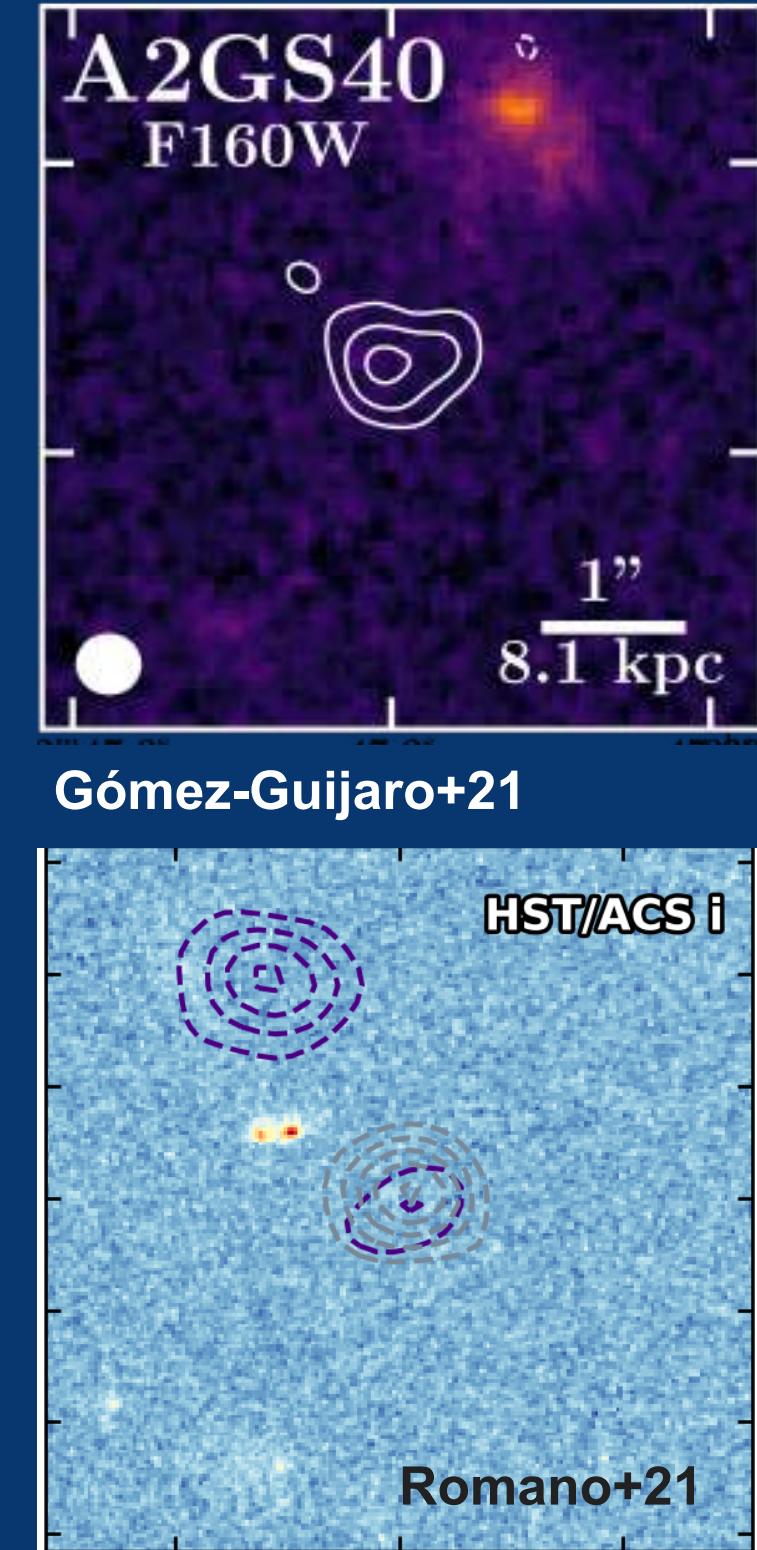
Heavily Dust-obscured Galaxies in High-Redshift



IR-identified galaxies are found only in rare and extreme environments
e.g. Dusty Starbursts, AGNs



Optically-dark galaxies are less extreme cases,
Not yet identified in the EoR



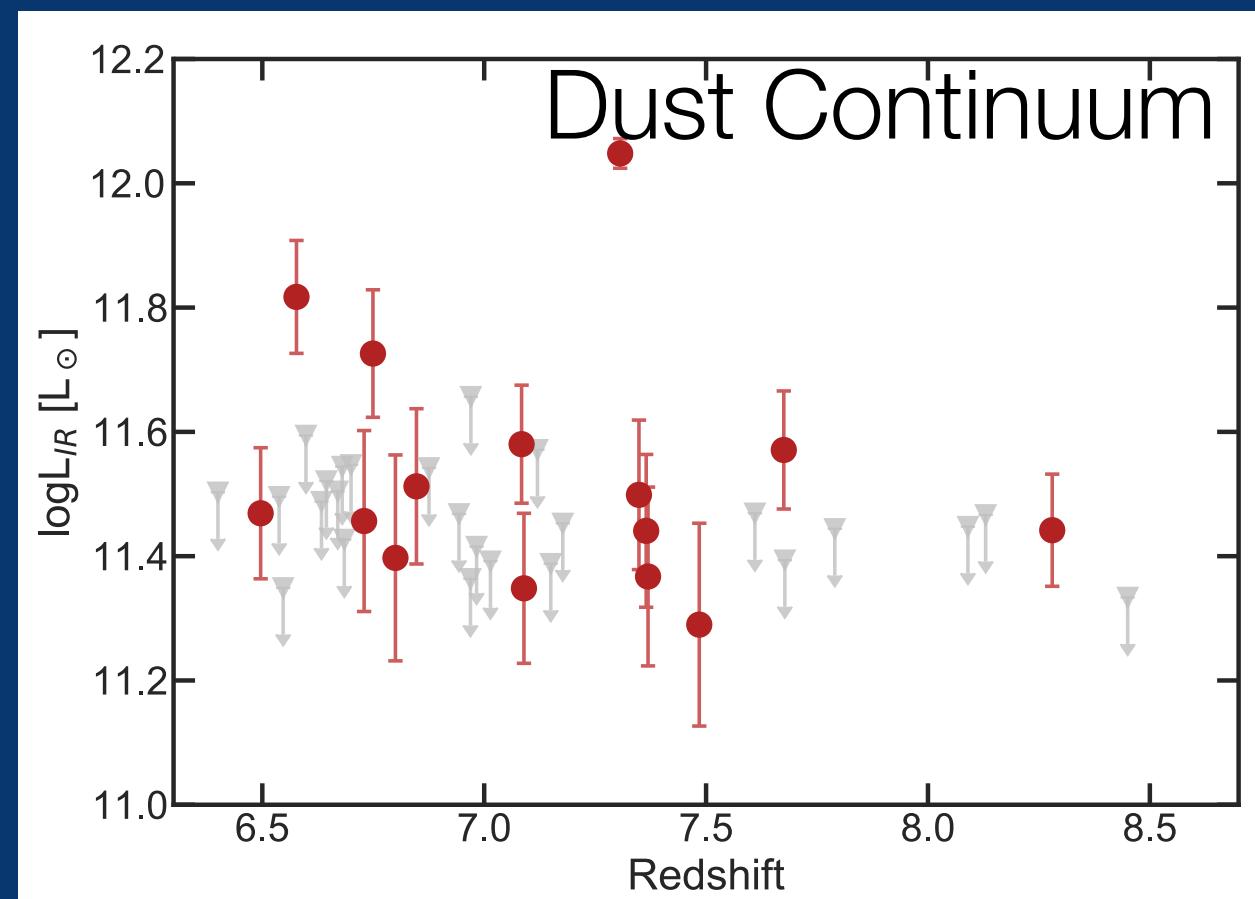
Do we already have all type of dust-obscured galaxies in the EoR?

see also, e.g. Gómez-Guijarro+21, Pozzi+21, Romano+20, Riechers+20, Gruppioni+20, Wang+16, Mazzucchelli+19, Casey+19/18ab, Frabco+18, Zavala+18, Strandet+16, Caputi+15



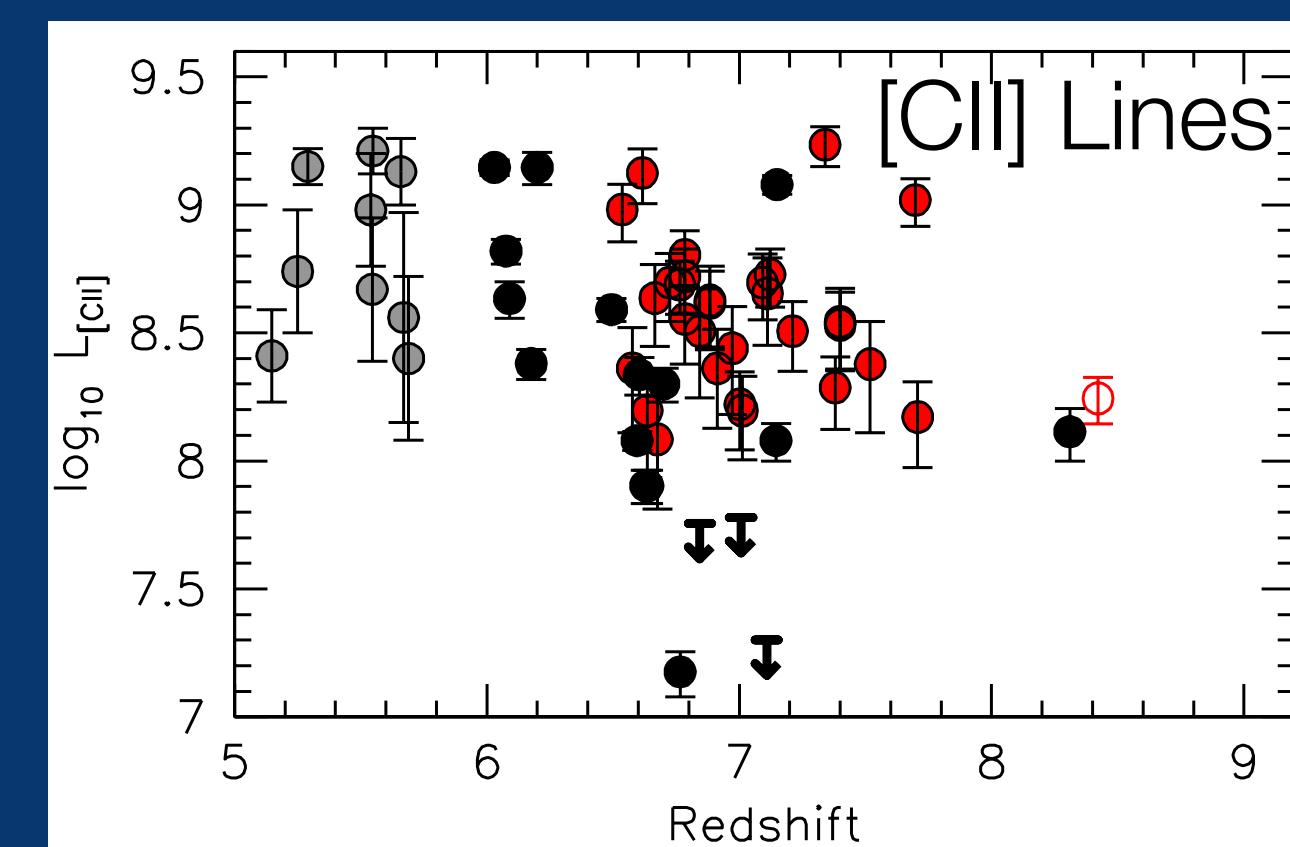
REBELS: Reionization Era Bright Emission Line Survey

Targets 40 UV luminous $z=6.5\text{-}9.5$ galaxies from 7 deg^2 search
and scanning for [CII] or [OIII] & looking for dust continuum

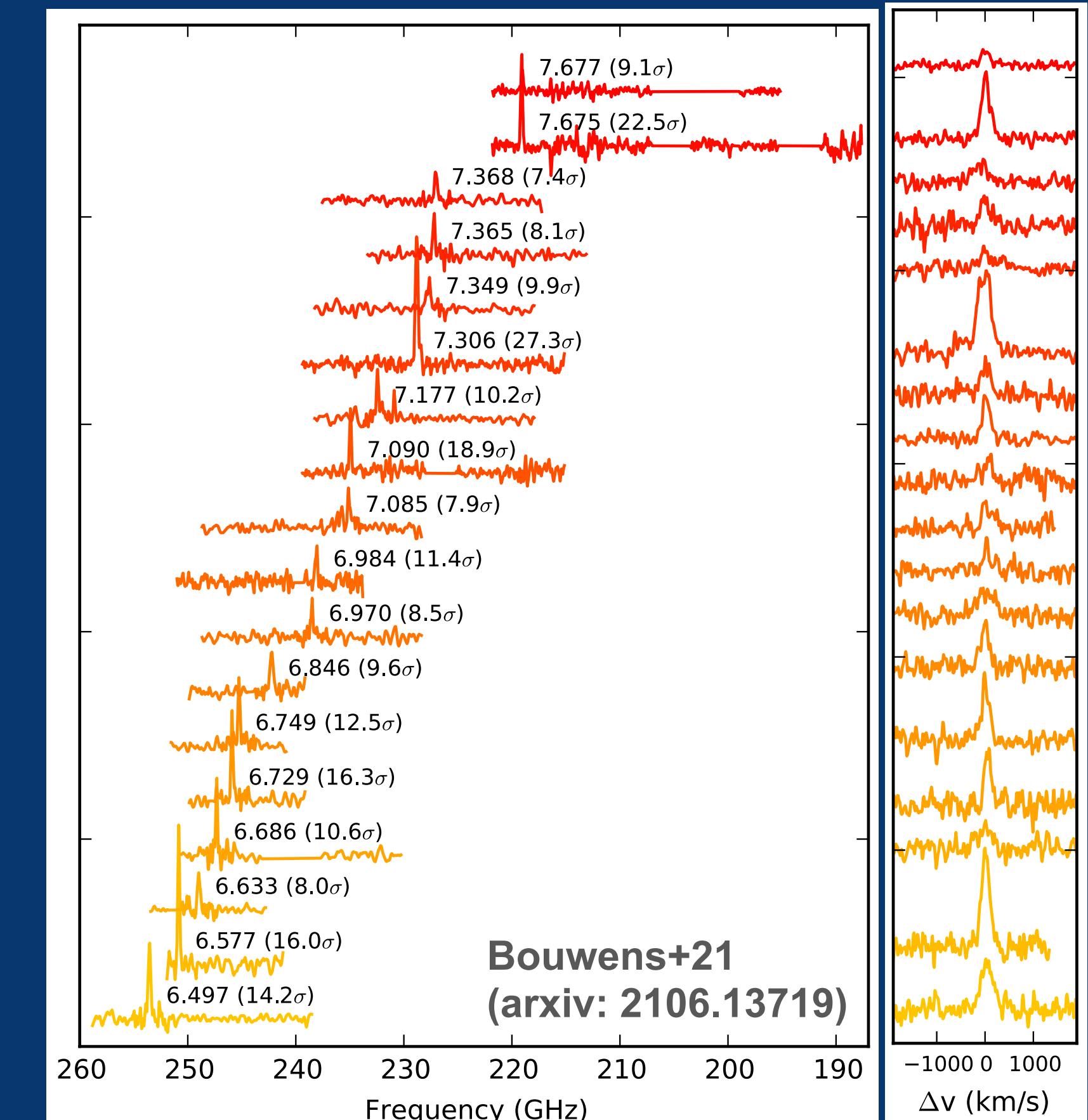


Redshift

(Schouws+ in prep)



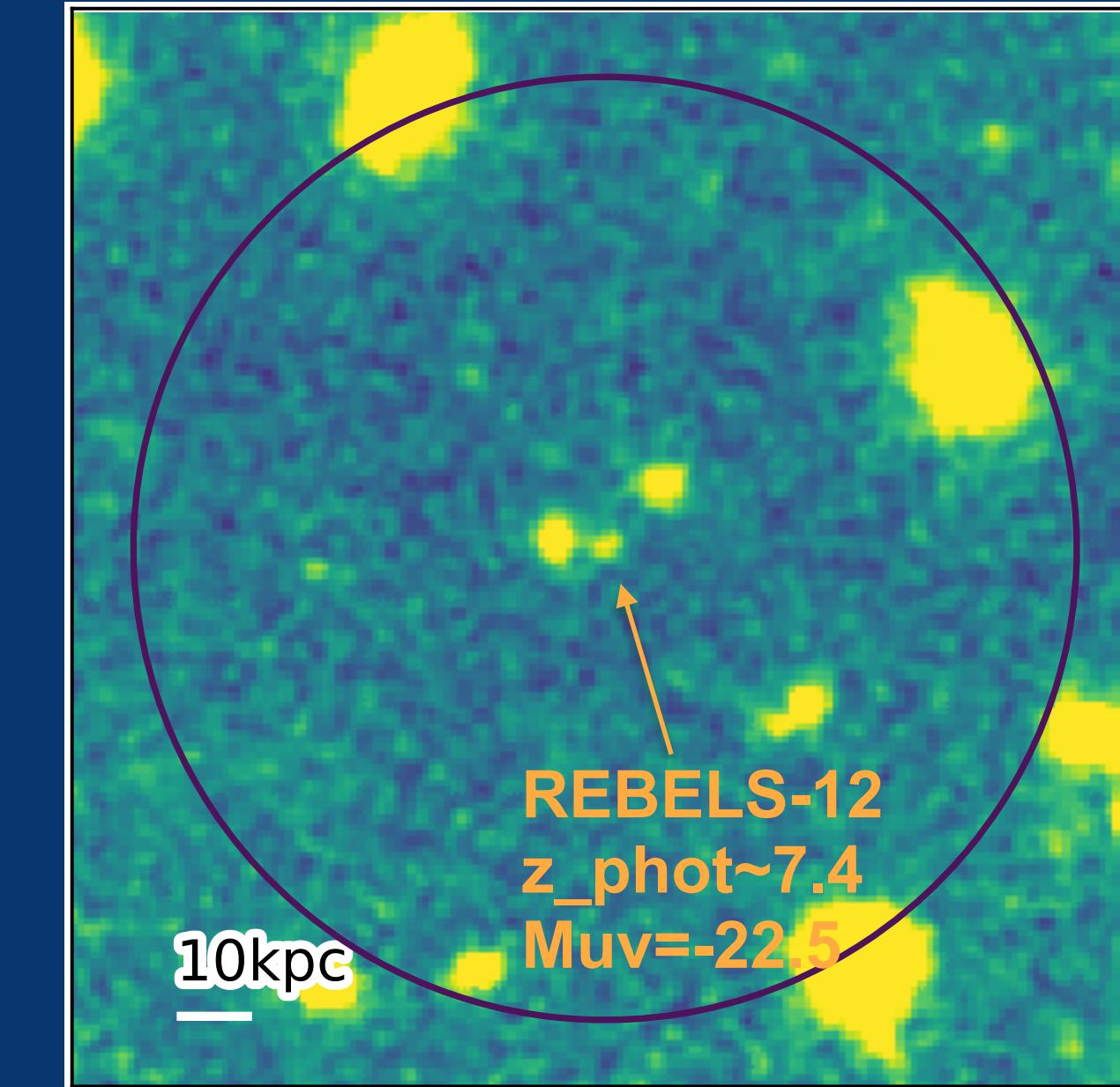
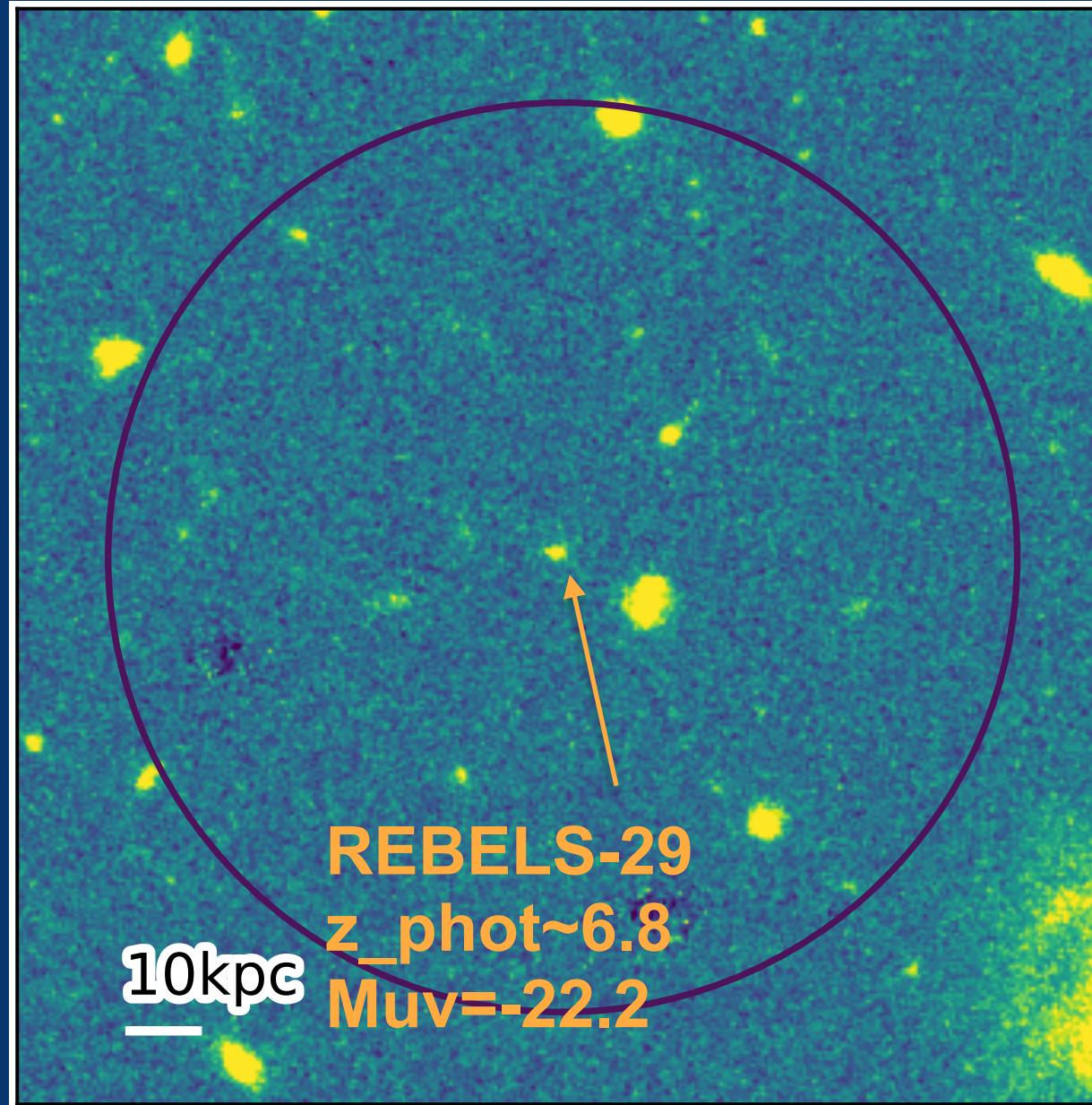
(Inami+ in prep)



Frequency (GHz)
 Δv (km/s)

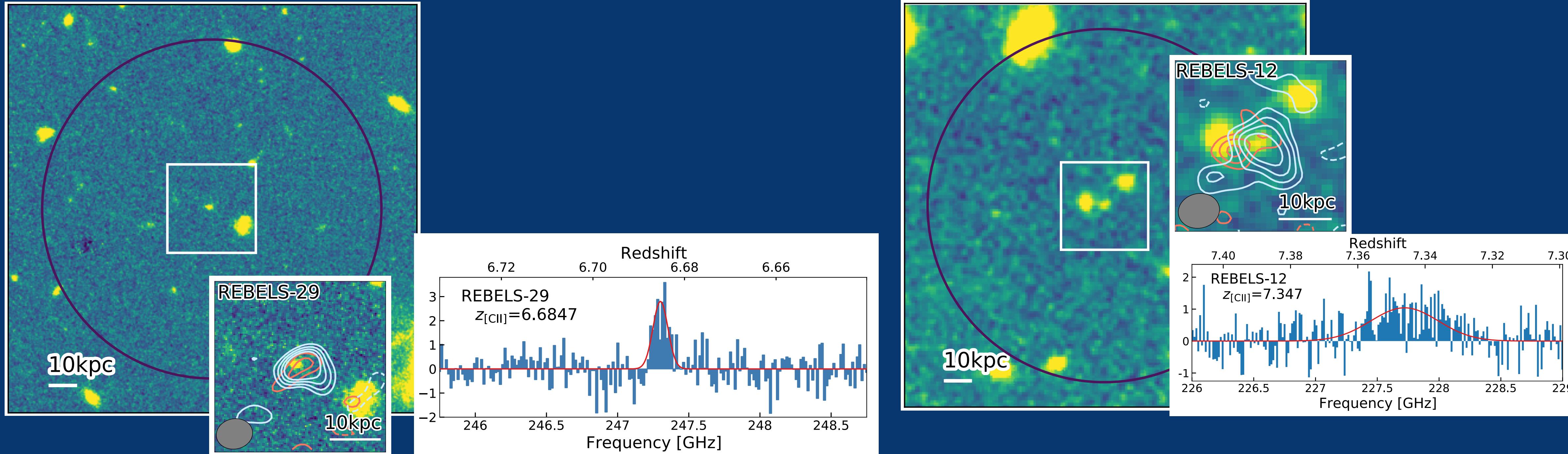
REBELS: REBELS-29 and REBELS-12

Fudamoto+21 submitted



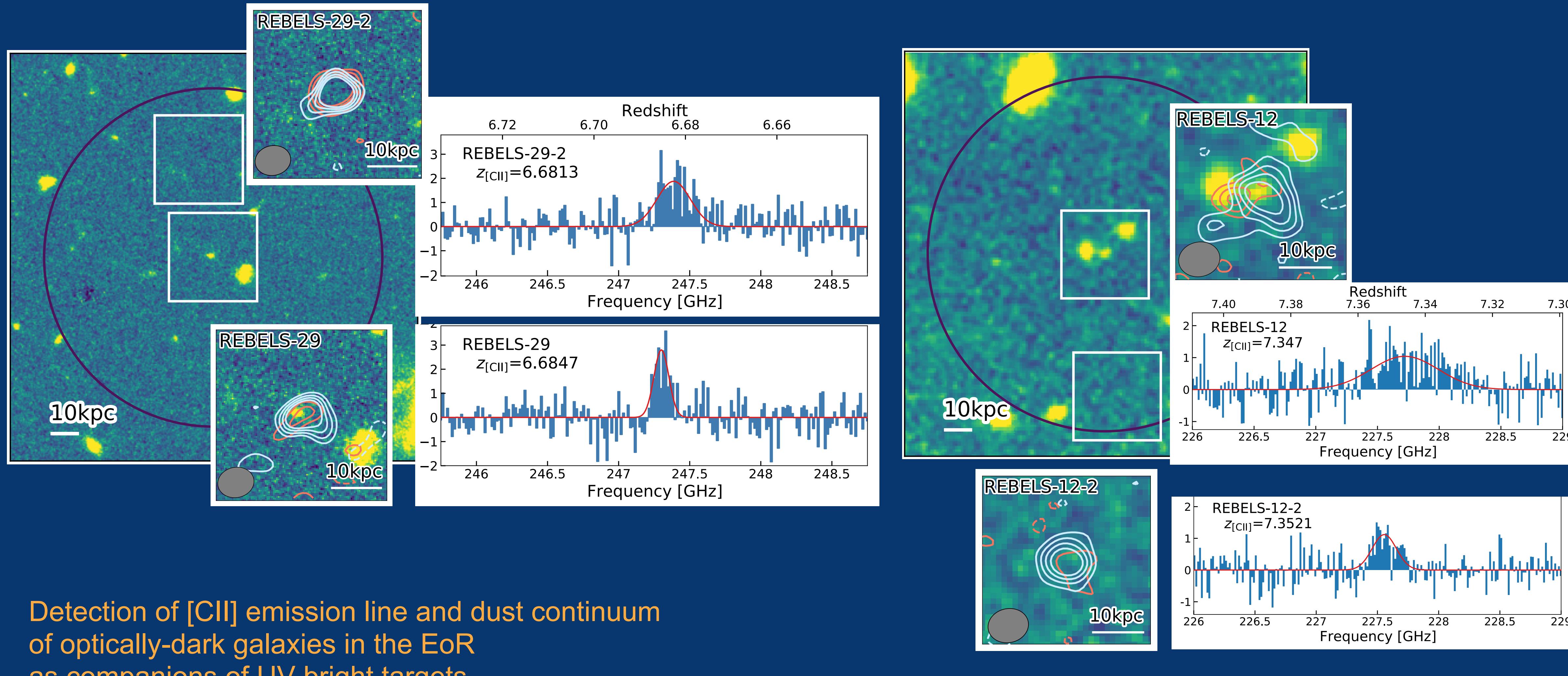
REBELS: REBELS-29-2 and REBELS-12-2

Fudamoto+21 submitted



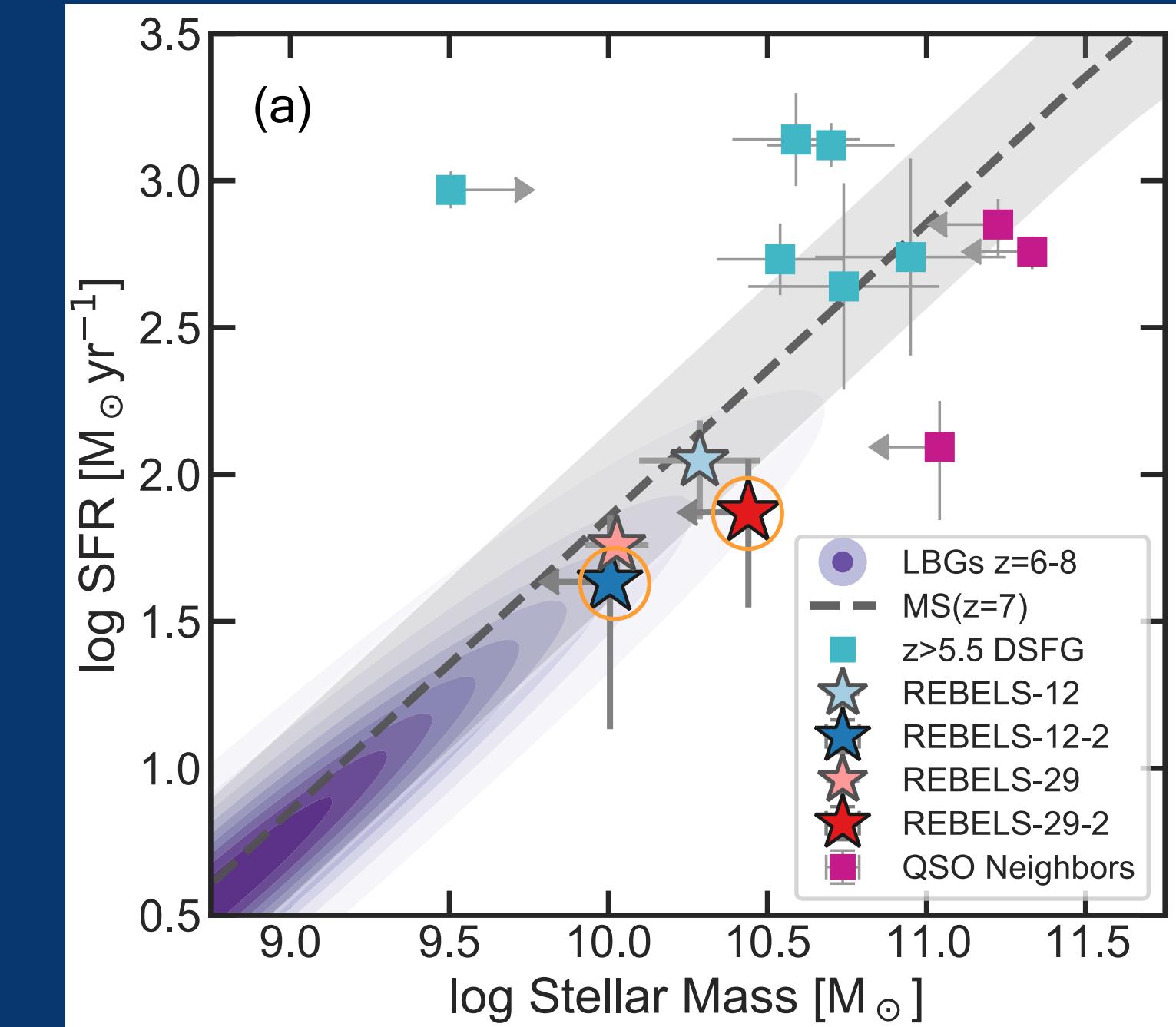
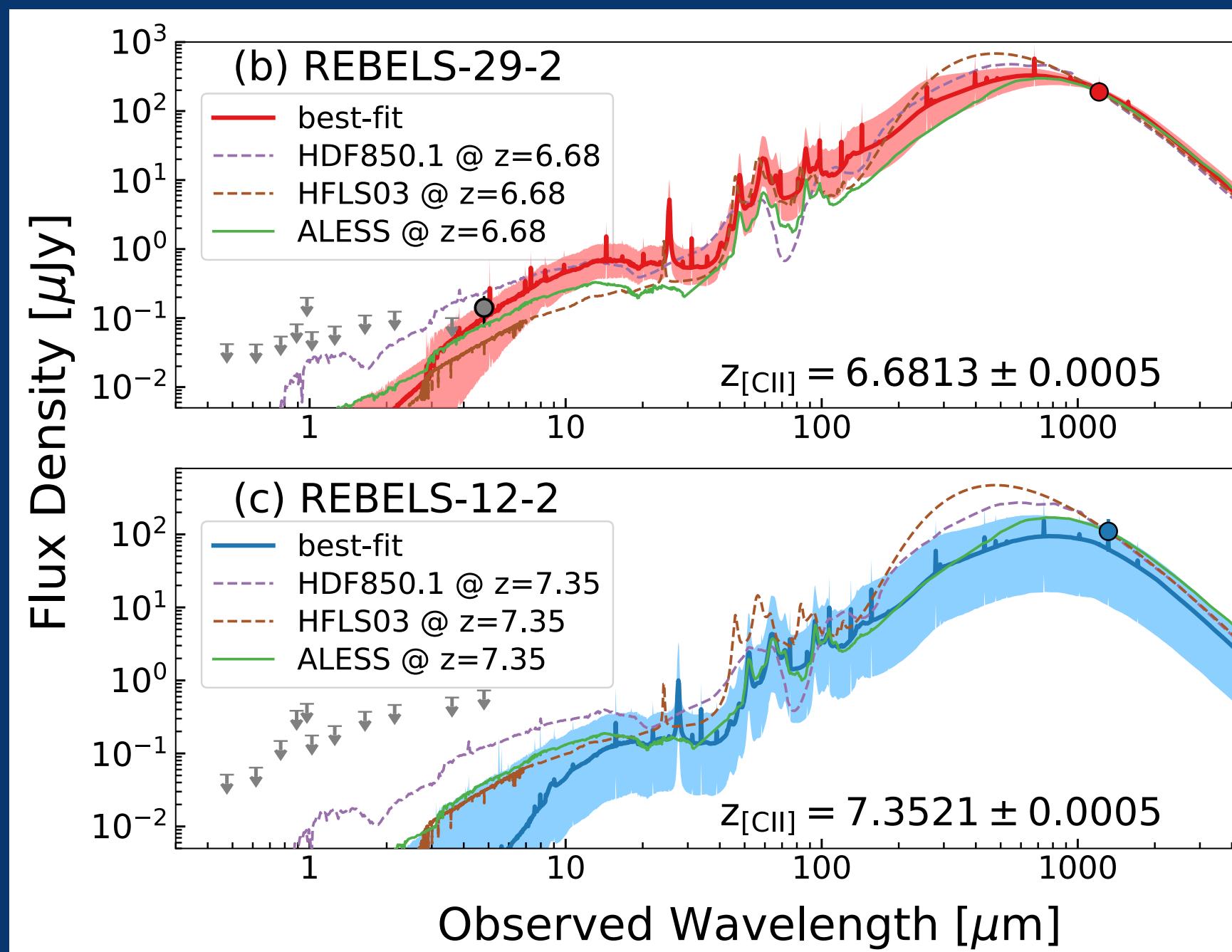
REBELS: REBELS-29-2 and REBELS-12-2

Fudamoto+21 submitted



REBELS: REBELS-29 and REBELS-12

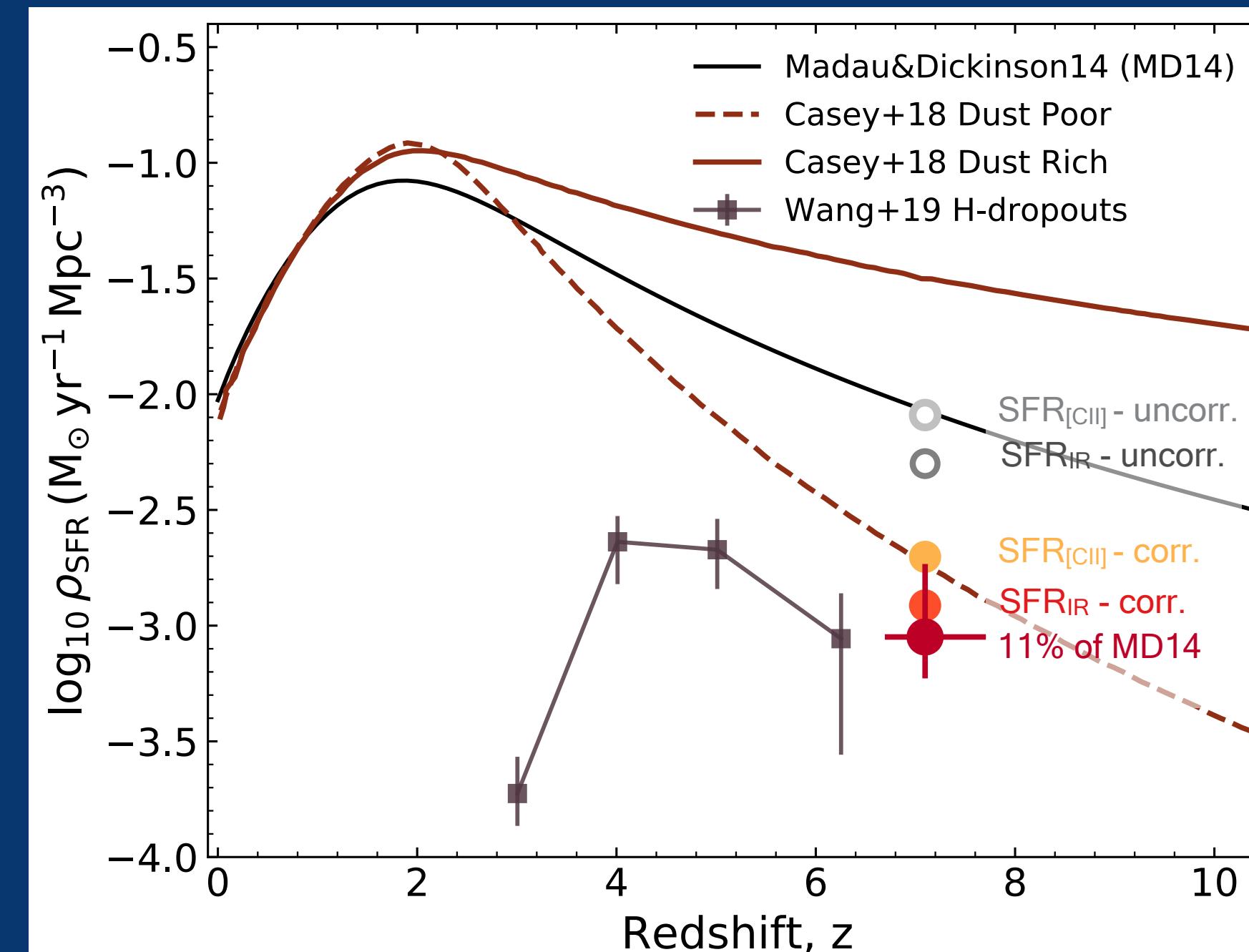
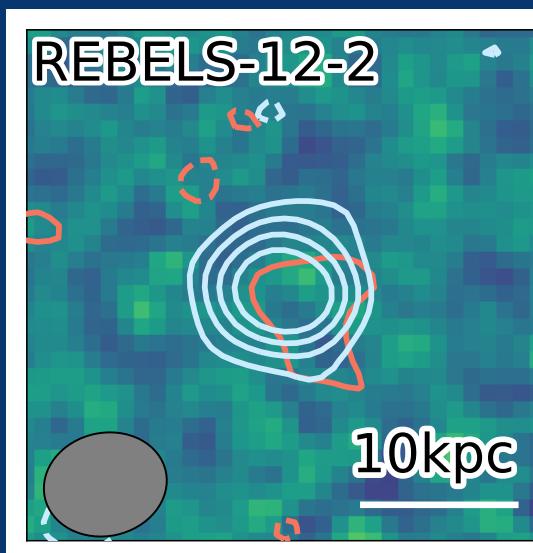
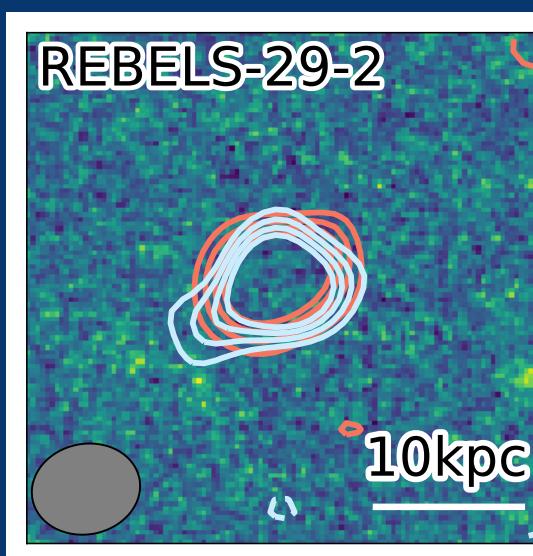
Fudamoto+21 submitted



Fudamoto+21 in press

New Contribution to SFRD from Dust-Obscured Galaxies

Surprising discovery of two dust-obscured galaxies at the same redshift as primary, UV-luminous targets



Proof that “normal” star-forming galaxies are still missing from our cosmic census in first Gyr

Fudamoto+21 in press



Summary

We detected two dust-obscured, normal galaxies
as companions of normal UV-bright galaxies.

Proof that normal galaxies are still missing from our census of galaxy formation in the EoR

Deep ALMA / JWST survey would be required to identify these normal, dust-obscured galaxies.