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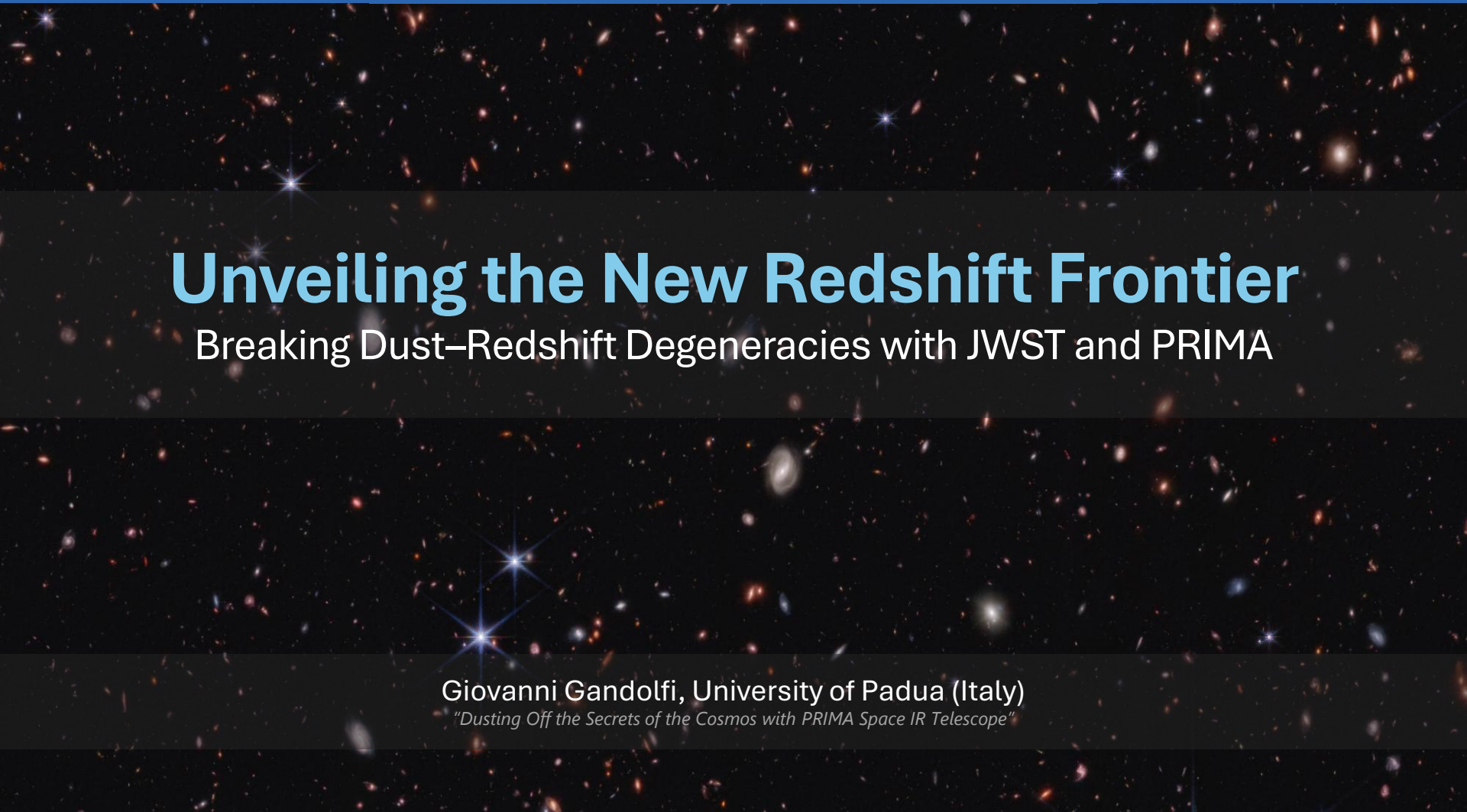

Unveiling the New Redshift Frontier

Breaking Dust–Redshift Degeneracies with JWST and PRIMA

Giovanni Gandolfi, University of Padua (Italy)

"Dusting Off the Secrets of the Cosmos with PRIMA Space IR Telescope"

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Introduction

Very early galaxies are important to…

- Understand how galaxies **form** and **evolve** in their earliest phases
- Characterize the **first population of stars** in the Universe
- Characterize the **growth** and **coevolution** of **supermassive black holes**
- **Constrain** the properties of **dark matter** and **dark energy** (e.g., *Gandolfi+22*)

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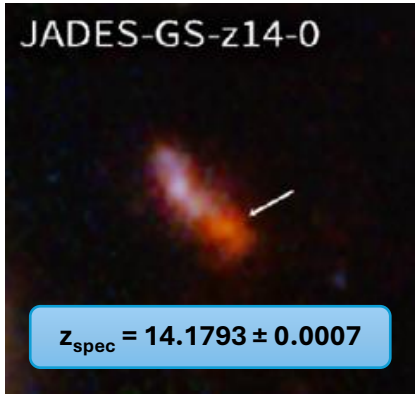
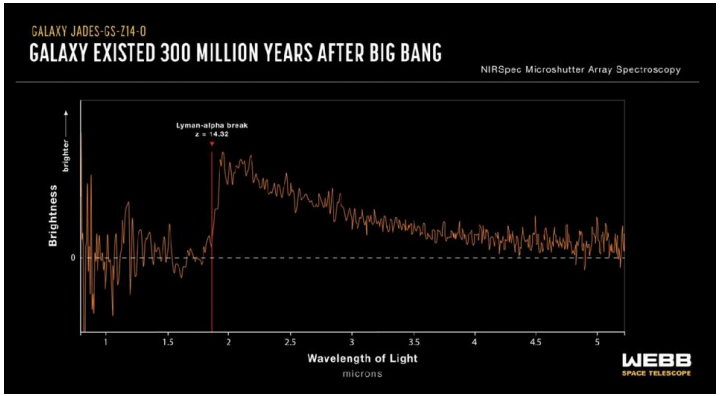


(see *Carniani+24, Schouws+25*)



Credits: NASA, ESA, CSA, STScI, Brant Robertson (UC Santa Cruz), Ben Johnson (CfA), Sandro Tacchella (Cambridge), Phill Cargile (CfA), Joseph Olmsted (STScI), S. Carniani (Scuola Normale Superiore), JADES Collaboration.

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The New Redshift Frontier

No spectroscopically confirmed galaxies beyond z = 15!

Photometric z > 15 galaxies searches: *Yan+23, Austin+2023, Harikane+23, Donnan+23; Pérez-González+23a, Kokorev+24, Pérez-González+25, Lovell+25* 🐟

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- Color-mag NIRCam wide-band selections from mock sources (e.g., *Kokorev+24, Castellano+25 in prep.*)
- Dropout-based selections (F200W-dropout, e.g. *Rodighiero+23, Bisigello+23, 24, 25b in prep.*)

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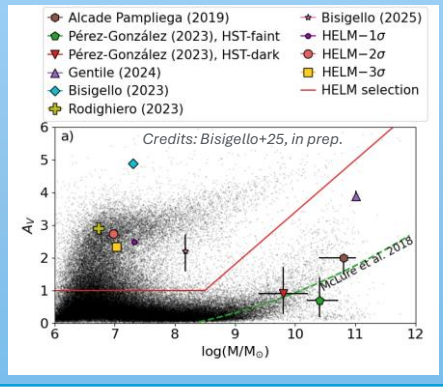
- Dusty dwarf galaxies (see **Laura Bisigello's talk**)



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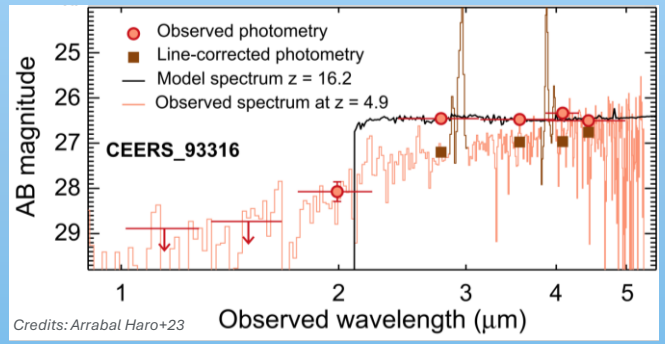
- Strong line emitters (e.g., CEERS-93316; *Donnan+22*)



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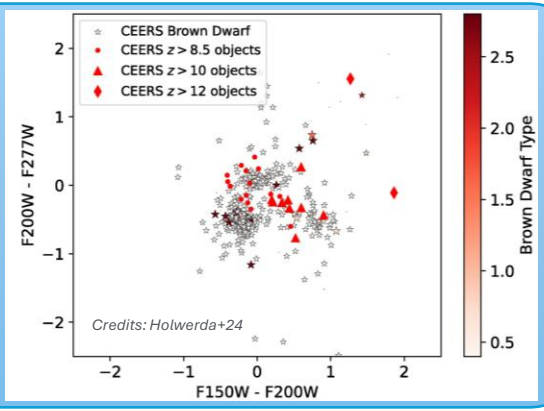

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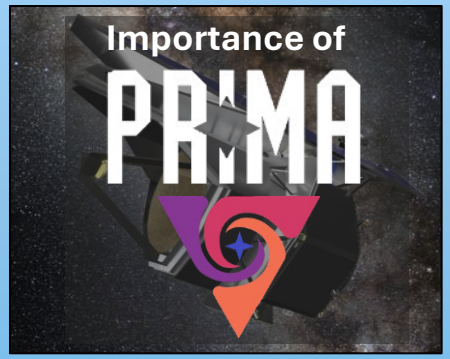

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F200W-dropouts selection

Catalogs using **CEERS latest DRs, optimized to detect faint & red sources**
(F444W detection image runs)

SELECTION CRITERION

- **S/N>3** in **F444W**
- **S/N < 2** at all wavelengths **≤ 2 μm** (NIRCam + HST)
- **S/N < 3** in the **co-added** short-wav NIRCam image (F090W+F115W+F150W+F200W)
- **Not present** in the **public CEERS catalog** (v.0.51)

+ not present in CEERS LRDs catalog (*Kocevski+24, Taylor+24*), no overlap with other high-z sources (*Yan+23*, *Finkelstein+24*) or HST-dark galaxies in CEERS (*Barrufet+23*). No NIRCam WFSS/NIRspec coverage, no CEERS MIRI coverage. NOEMA + SCUBA-2 upper limits for some sources.

→ **Total: 11 new** (and faint) **F200W-dropouts**

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A case study in CEERS

Cosmic Evolution Early Release Science (CEERS) survey, covering ~90 arcmin^2 of the Extended Groth Strip field

GOAL

Find and characterize previously missed **F200W-dropout objects** testing a setup capable of **addressing degeneracies** between different solutions

→ highlight promising candidate for follow-ups

Gandolfi et al., 2025

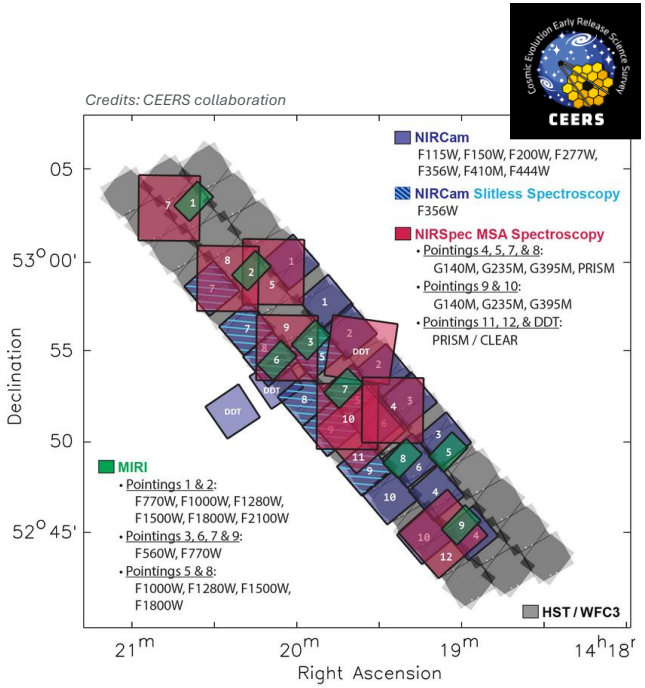
Ultra High-Redshift or Closer-by, Dust-Obscured Galaxies? Deciphering the Nature of Faint, Previously Missed F200W-Dropouts in CEERS

G. Gandolfi[1,2] *, G. Rodighiero[1,2], L. Bisigello[2], A. Grazian[2] S. L. Finkelstein[4], M. Dickinson[5], M. Castellano[6], E. Merlin[6], A. Calabrò[6], C. Papovich[12,13], A. Bianchetti[1,2], E. Bañados[19], P. Benotto[1,2], F. Buitrago[29,30], E. Daddi[25], G. Girardi[1,2], M. Giulietti[3], M. Hirschmann[32,33], B. W. Holwerda[28], P. Arrabal Haro[17]**, A. Lapi[20,3], R. A. Lucas[18], Y. Lyu[25], M. Massardi[21,20], F. Pacucci[23,24], P. G. Pérez-González[31], T. Ronconi[20], M. Tarrasse[25], S. Wilkins[27], B. Vulcani[2], L. Y. A. Yung[18], J. A. Zavala[7,26], B. Backhaus[16], M. Bagley[4], V. Buat[8], D. Burgarella[8], J. Kartaltepe[10], Y. Khusanova[19], A. Kirkpatrick[9], D. Kocevski[11], A. M. Koekemoer[18], E. Lambrides[17], N. Pirzkal[22], and G. Yang[14,15]

(Affiliations can be found after the references)

Camera	Filter	$\lambda_{pivot}(\mu m)$
JWST/NIRCam SW	F090W	0.9022
JWST/NIRCam SW	F115W	1.1543
JWST/NIRCam SW	F150W	1.6592
JWST/NIRCam SW	F200W	1.9886
JWST/NIRCam LW	F277W	2.7617
JWST/NIRCam LW	F356W	3.5684
JWST/NIRCam LW	F410M	4.0822
JWST/NIRCam LW	F444W	4.4043
HST/ACS	F435W	0.4329
HST/ACS	F606W	0.5922
HST/ACS	F814W	0.8046
HST/WFC3	F105W	1.0550
HST/WFC3	F125W	1.2486
HST/WFC3	F140W	1.3923
HST/WFC3	F160W	1.5370

Credits: CEERS collaboration



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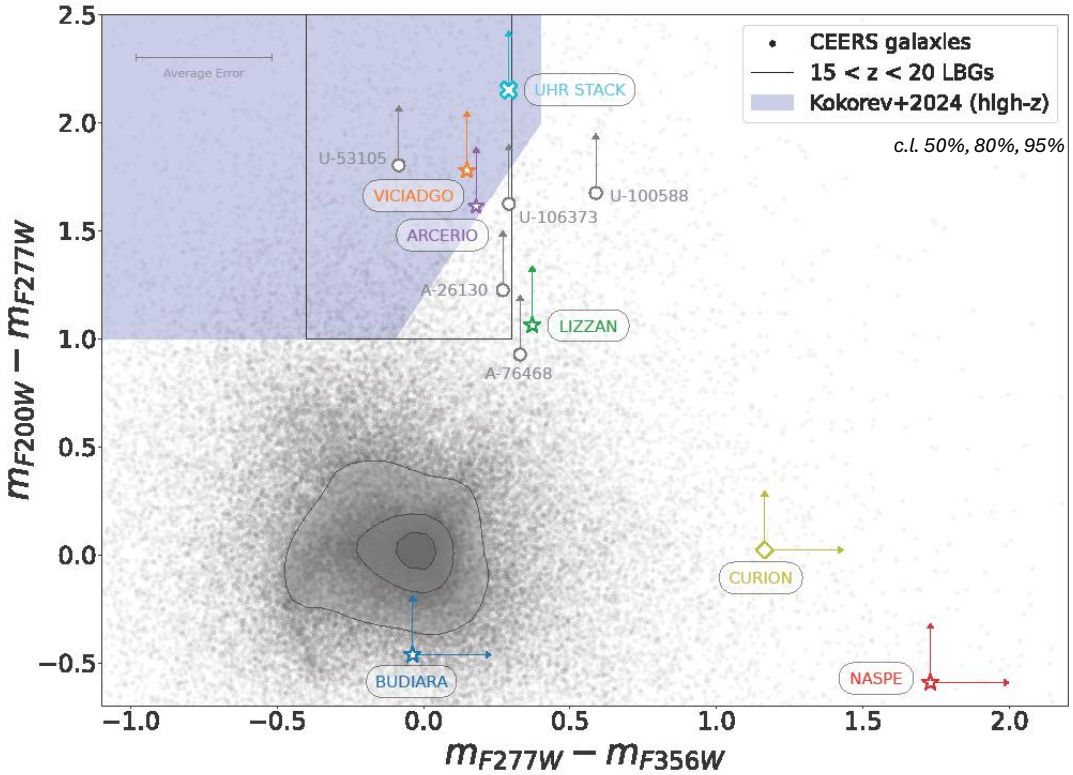
Sample properties

F200W-dropout sample

ID	Name[4]	RA	DEC
U-31863	BUDIARA	215.064009	52.882608
U-34120	VICIADGO	214.962236	52.827796
U-53105	-	214.958983	52.867184
U-75985	LIZZAN	214.851223	52.886427
U-80918	NASPE	214.929089	52.928587
U-100588	-	214.887376	52.797809
U-106373	-	215.005197	53.008687
U-112842	CURION	214.940860	52.907705
A-22691	ARCERIO	215.006121	52.890428
A-26130	-	215.040845	52.920593
A-76468	-	214.893779	52.936404



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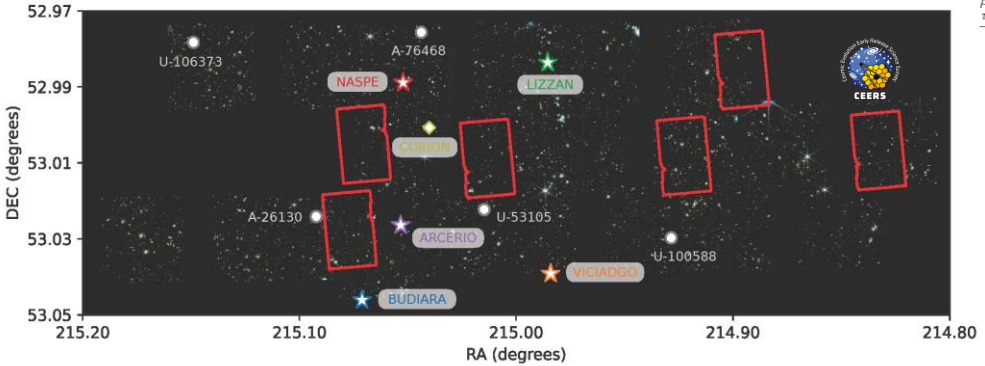
SED-Fitting Setup

AIM: discriminate between **contaminants**, test the impact of different SFHs and dust extinction laws

- ⭐ **BAGPIPES** (*Carnall+18*) – continuous uniform priors (logU up to -1), all SFHs, Calzetti + SMC dust exctinction, 2000 live points
- **CIGALE** *(Boquien+19)* to reveal potential AGN presence (*Fritz+06* model)
- **EAZY** (*Brammer+08*) – legacy templates + EAZY-Py templates + *Steinhardt+23* high-z templates
- **BDs** check w/ size estimation and template fit



Bagpipes fit parameters	Prior range	Description
General		
$\log M_*/M_\odot$	[1, 15]	Logarithmic stellar mass in solar mass units
z	[0, 25]	Redshift
A_V	[0, 6]	Dust attenuation index (SMC attenuation law)
logU	[-4, -1]	Logarithmic ionization parameter
Z	[0, 2.5]	Metallicity in solar units
Delayed SFH		
Age_{del}	[0.1, 14]	Time since the beginning of star formation in Gyr
τ_{del}	[0.1, 14]	Time since the end of star formation in Gyr
Exponential SFH		
Age_{exp}	[0.1, 14]	Time since the beginning of star formation in Gyr
τ_{exp}	[0.1, 14]	Timescale of star formation decrease in Gyr
Log-normal SFH		
t_{max}	[0.1, 15]	Age of the Universe at the star formation peak in Gyr
FWHM	[0.1, 20]	Full width at half maximum star formation in Gyr
Double powerlaw SFH		
α	[0.1, 1000]	Falling slope index
β	[0.1, 1000]	Rising slope index
τ_{dbl}	[0.1, 14]	Age of the Universe at turnover in Gyr

CIGALE fit parameters	Grid values	Description
Double exponential SFH [sfh2exp module]		
τ_{main}	2, 6, 10	e-folding time of the main stellar population model in Gyr
Age	1000, 2000, 5000, 10000, 13000	Age of the main stellar population in the galaxy in Myr
SSP component [bc03 module]		
Z	0.0001, 0.004, 0.008, 0.02, 0.05	Metallicity
Nebular component [nebular module]		
log U	-4, -3, -2, -1	Logarithmic ionization parameter
Dust attenuation component [dustatt_modified_CF00 module]		
$A_{V,ISM}$	0.1, 0.5, 1, 1.5, 2.5, 4, 5, 6	V-band attenuation in the interstellar medium
AGN component [fritz2006 module]		
β	-1, -0.5, 0	Dust density distribution parameter
γ	0, 2, 4	Dust density distribution parameter
Ψ	0.001, 50.1, 80.1	Angle between the equatorial axis and line of sight
f_{AGN}	0., 0.1, 0.25, 0.5, 0.75	AGN fraction
Redshifting component [redshifting module]		
z	1, 2, 3, ..., 25	Redshift of the source

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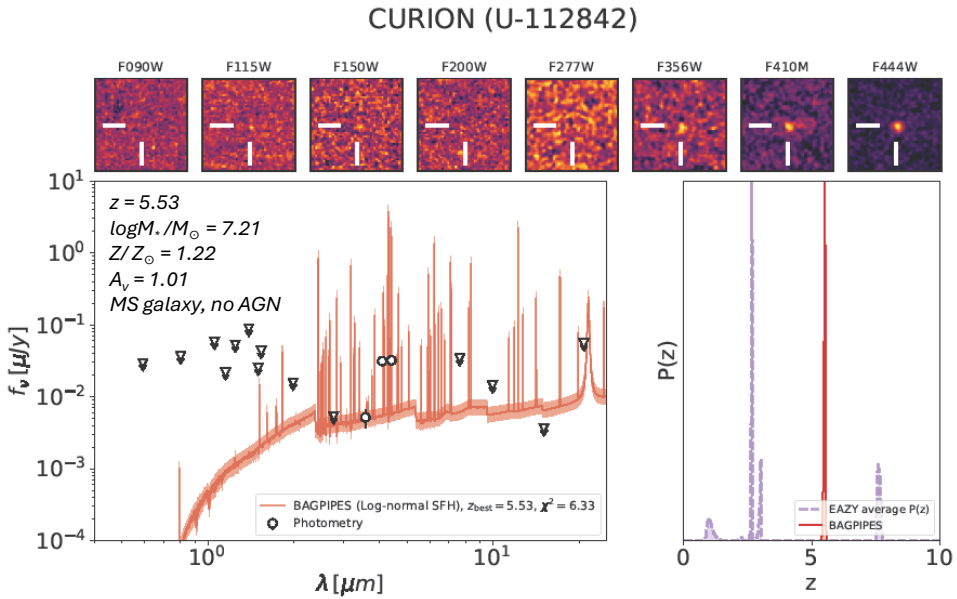
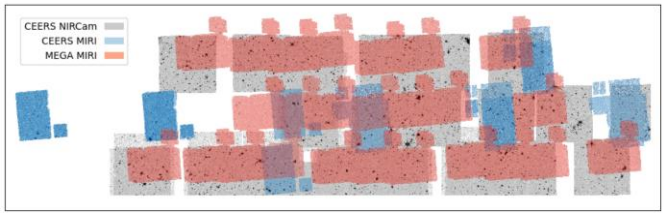
"Curion" – a Strong Line Emitter



Underscoring the need of data **beyond the NIR!**

- **z = 13** primary solution **w/ NIRCam-only photometry** (with lower-z secondary solutions)
- Inclusion of **MIRI photometry** (courtesy of *The MIRI EGS Galaxy and AGN Survey (MEGA; Backhaus+25)* → **z = 5.5 SLE**



Credits: Backhaus+25

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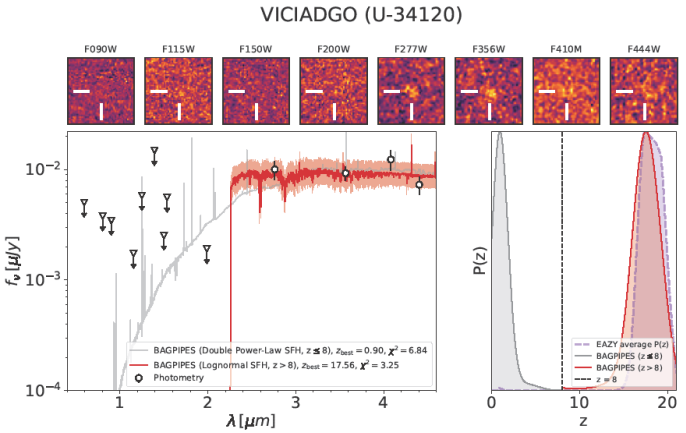
Ultra-high-z Candidates

5 objects showing **bi-modal** solutions:

- **Extreme** DDs (in the $M_\star$ - A_v plot), one could be a SLE?
- Or **15 < z < 20 galaxies!** (better likelihood)

Name[4]
BUDIARA
VICIADGO
-
LIZZAN
NASPE
-
-
CURION
ARCERIO
-
-

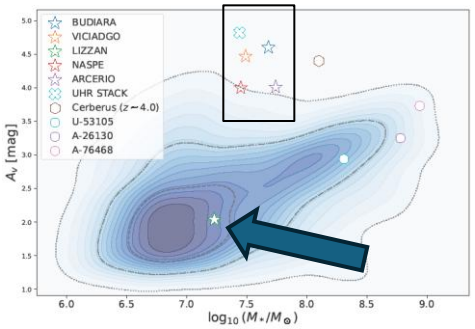


Inferred properties:

- Lower-z solutions are within 1sigma from the **MS** of SF galaxies
- Compatible with the **R_e VS z** relation by *Westcott+24*
- z > 15 solutions' bet-fit masses are **compatible with LCDM**

High-z solutions
17.32 < z < 17.8
7.63 < logM⋆/M⊙ < 8.19
1.07 < Z/Z⊙ < 1.27 (rather unconstrained)
0.07 < A_v < 0.27 (compatible w/ 0)
no AGN

Low-z solutions
0.91 < z < 4.31
7.23 < logM⋆/M⊙ < 7.68
0.77 < Z/Z⊙ < 1.4
2 < A_v < 4.6
MS galaxy, no AGN



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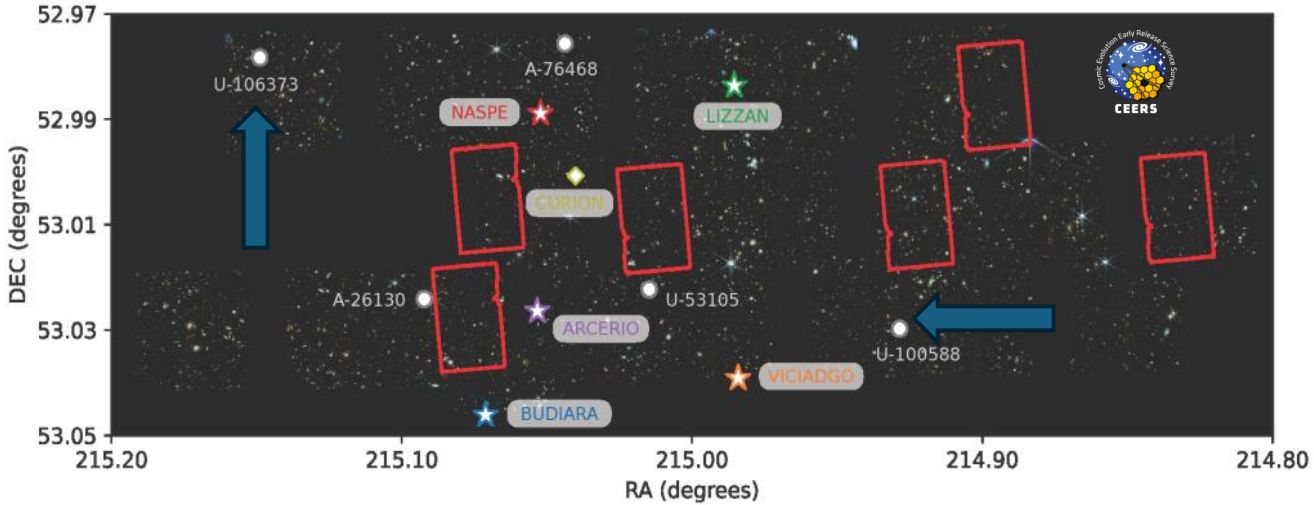
Two Extreme Objects

2 very extreme objects – respectively an F277W and an F356W dropouts!

Will be shortly observed by the The CANDELS-Area Prism Epoch of Reionization Survey (**CAPERS**): Cycle 3 NIRSpec program (PI M. Dickinson) targeting UDS + EGS objects



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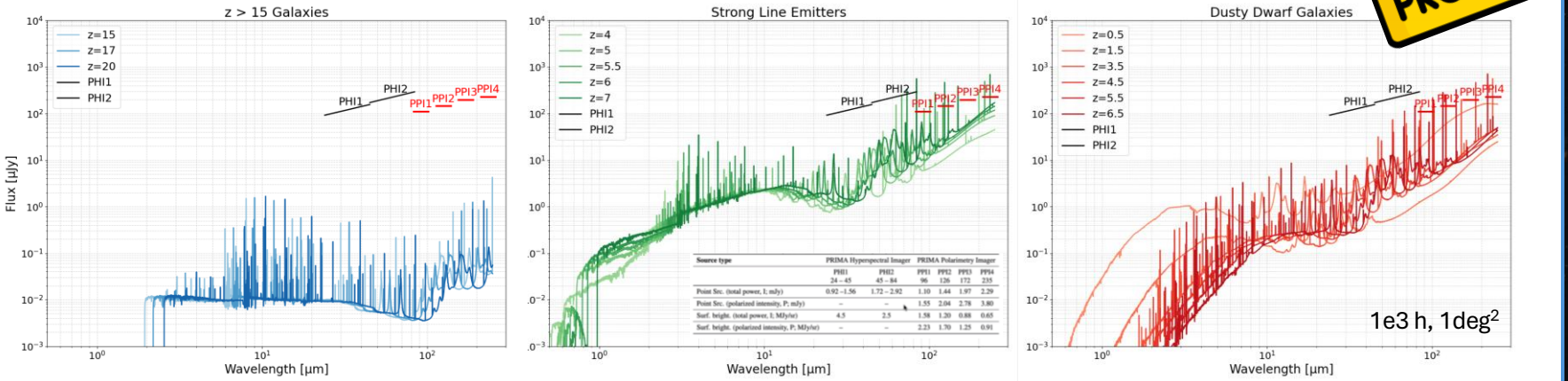
The importance of PRIMA

PRIMAger obs could help to **rule out** or **confirm** lower-z solutions for UHR galaxies with deep observations (Preliminary analysis with **mock SEDs** generated w/ Bagpipes)



- **UHR** (15 < z < 20) solutions should be **undetected** in all PRIMA bands
- **SLEs** could be **detectable** in **both** all **Polarimetry Imager** channels and the long-wavelength end of the **Hyperspectral Imager's** channels (or even **PHI1** for massive SLEs)
- **DDs** could be **detected** in **PPIs** and **undetected in PHIs** channels

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Conclusions

- **UHR** (z>15) **galaxy searches** NEED to account for **potential interlopers!**
- **PRIMA** could **discriminate** between high-redshift objects and potential contaminants
- **Expect news** on our **CEERS F200W-dropouts**!

📖 **Paper:**

Gandolfi et al., 2025

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📖 **Paper:**

Gandolfi et al., 2025

🎵 **A Song For PRIMA? –** The "Dance At The Event Horizon" Project

- **Disco dance music inspired by Astrophysics** w/ K. Wolz (Oxford U.) and M. Giulietti (INAF)
- Made **a song for Euclid** (ESA's "Cosmic Mystery" contest)
- Included in official ESA's playlists + **live performance** @ ESA's European Space Operations Centre for Euclid's launch

… what about **PRIMA?** 👀

🎵 **Listen to "Cosmic Mystery"!**