The UV-brightest starbursts in the distant Universe:

extreme modes of galaxy formation and Lyman continuum escape

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Introduction

- **JWST is now discovering a stunning population of UV-bright sources (even up to z~14)**
  (Bunker+23, Castellano+24, Carniani+24, etc.)

- **Far more numerous than previously thought:**
  Based on pre-JWST extrapolations and models

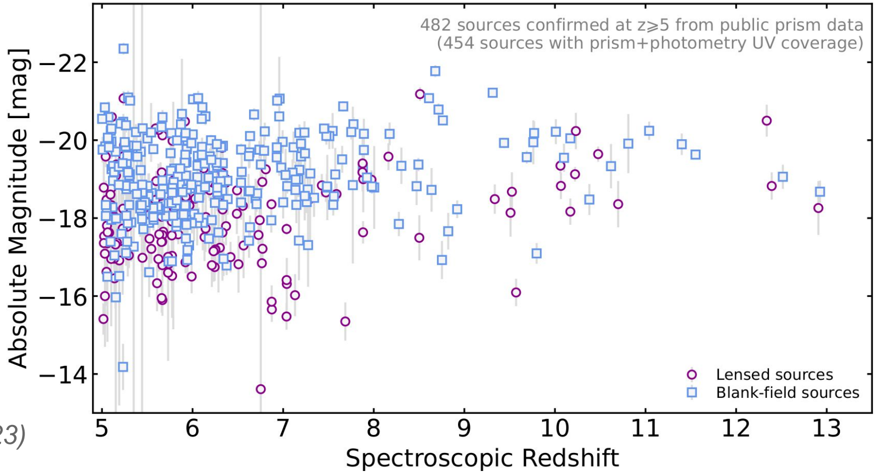
- **Why? Possible explanations:**

  Higher SF efficiency? *(Dekel+23, Li+24, Ceverino+24, etc.)*

  Dust removal? (*Ferrara+23, 24, Fiore+23, Ziparo+2)*

  Top-heavy IMF? (*eg, Trinca+23, Rasmussen Cueto+24)*

  Stochastic SFHs? *(eg, Mason+24, Mirocha & Furlanetto 2023, Shen+23)*

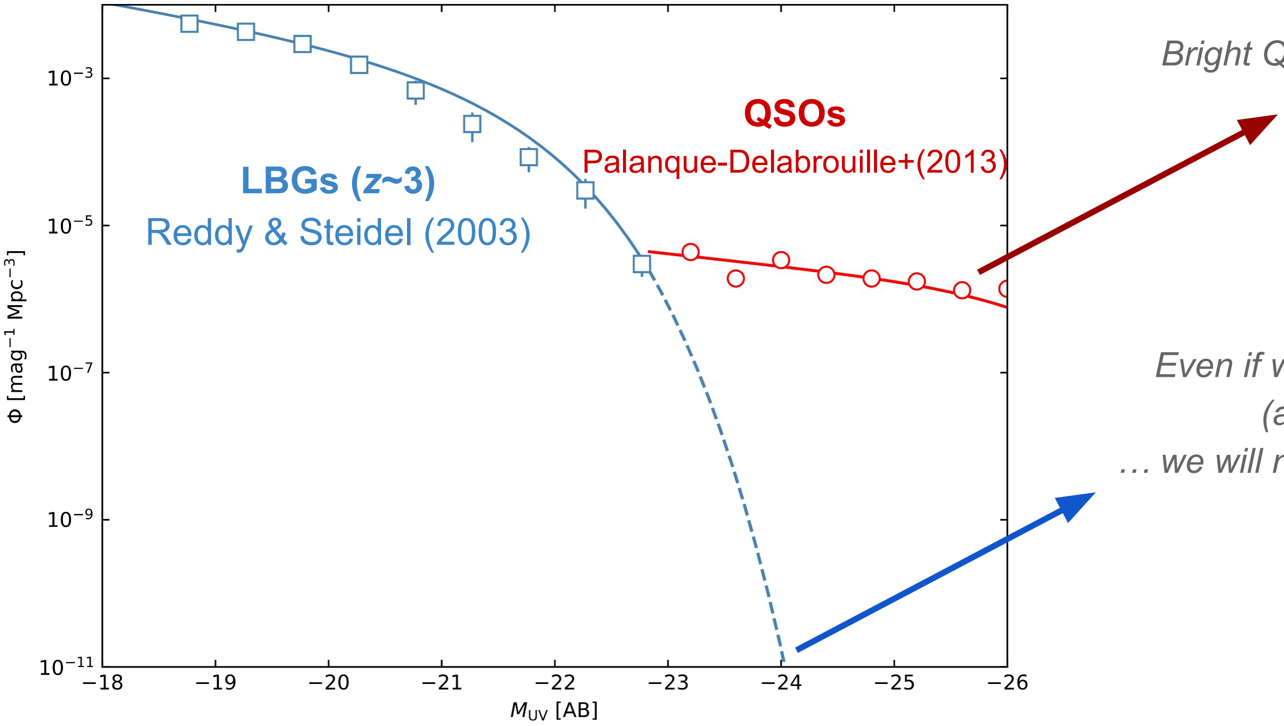


(Roberts-Borsani+2024)

Do they represent a specific phase in galaxy formation/evolution ?
Why are these sources so bright? Formation/properties/nature ?

Introduction

But how well established is the bright-end of the UV-LFs at lower-z?



Bright QSOs are more numerous at M_{UV} < -23

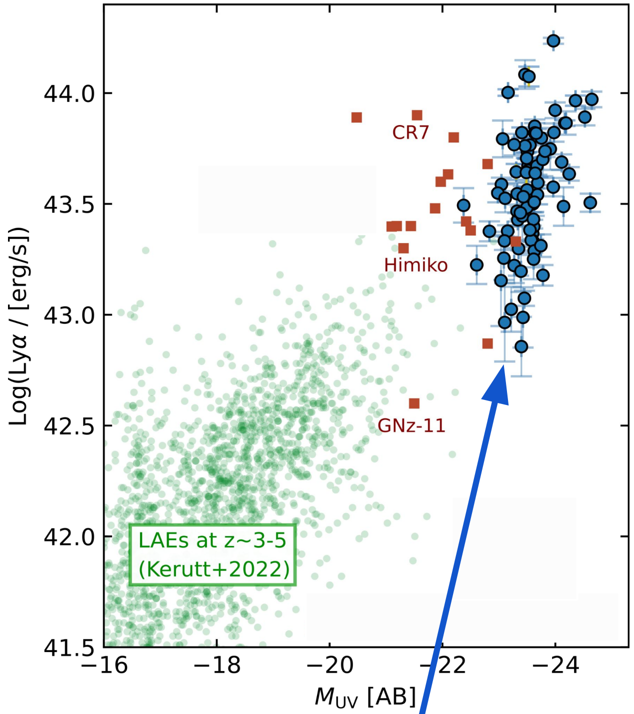
*Even if we could observe the **whole sky** (area ~40k deg^2, Δz = 0.1) … we will not expect any galaxy brighter than M_{UV} = -24 !*

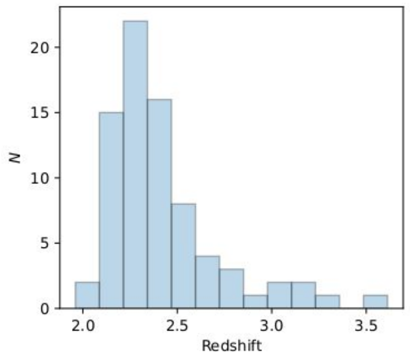
Is that true?

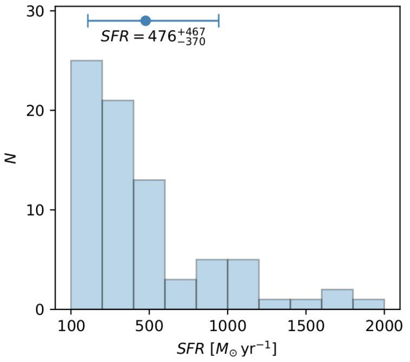
This talk: the most UV and Lyα luminous star-forming galaxies known so far

Selected from BOSS/SDSS (9000 deg2)

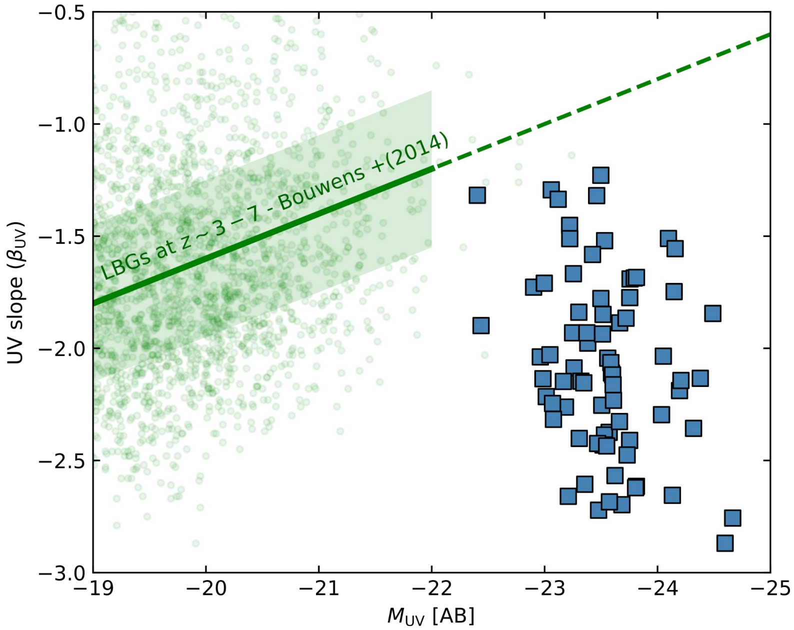
Fillers: there should be many more …







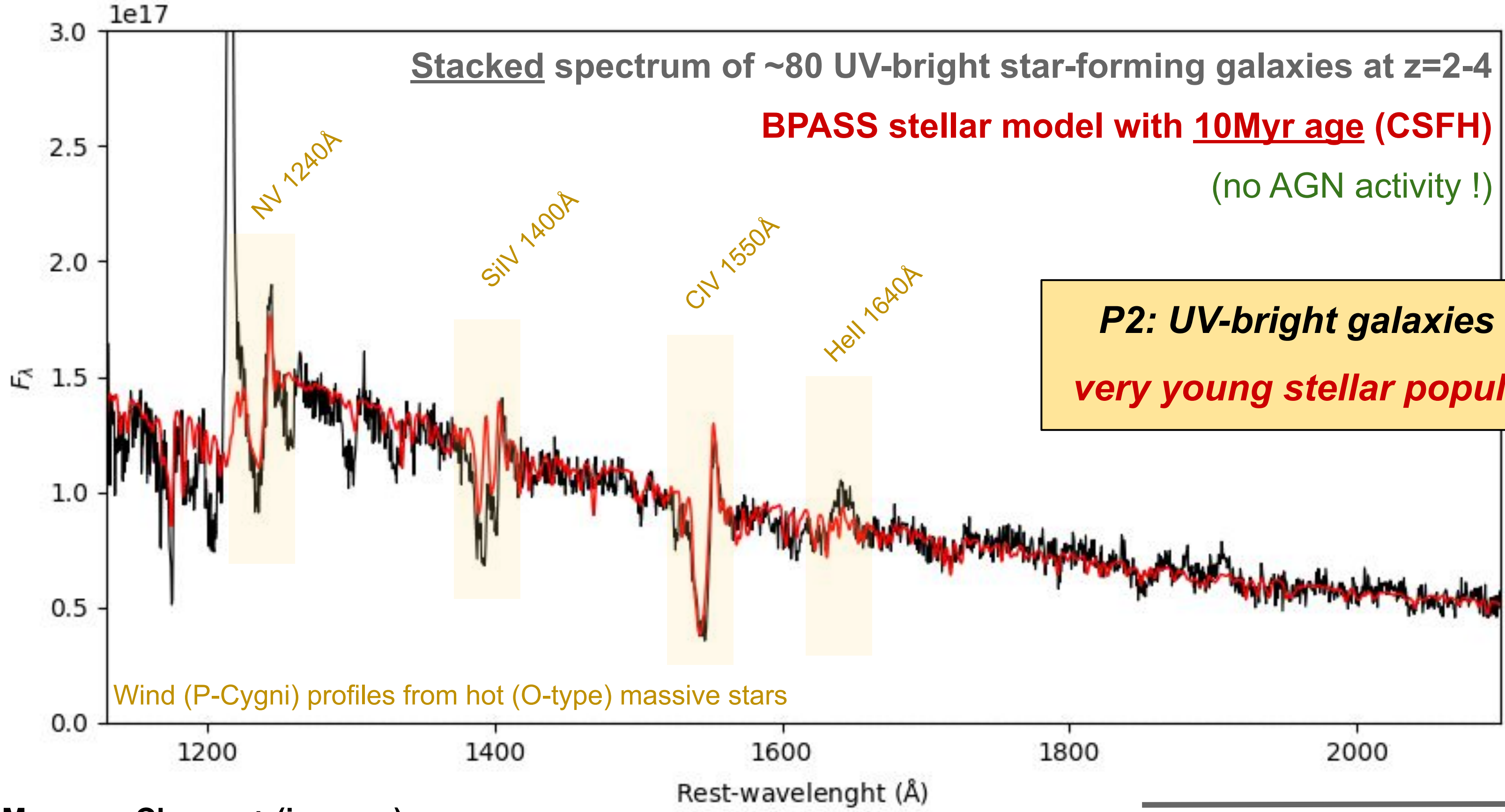
Marques-Chaves + (in prep.)



P1: UV-bright galaxies are BLUE

… as expected

The most UV and Lyα luminous star-forming galaxies known so far

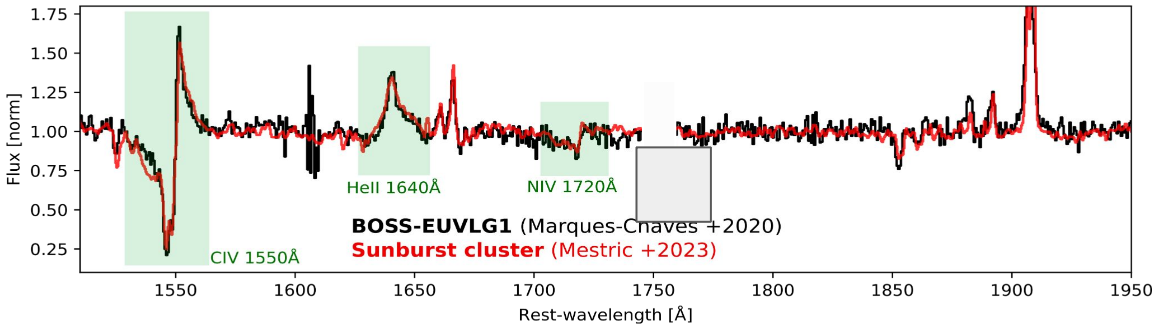


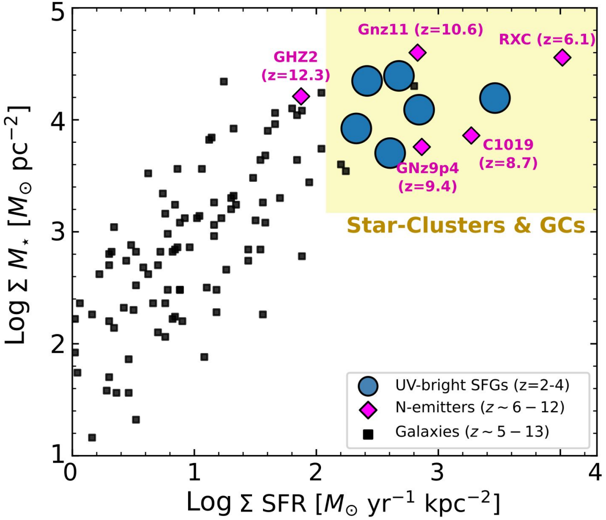
P2: UV-bright galaxies have very young stellar populations

Marques-Chaves + (in prep.)

UV-bright starbursts resembling young and massive star-clusters

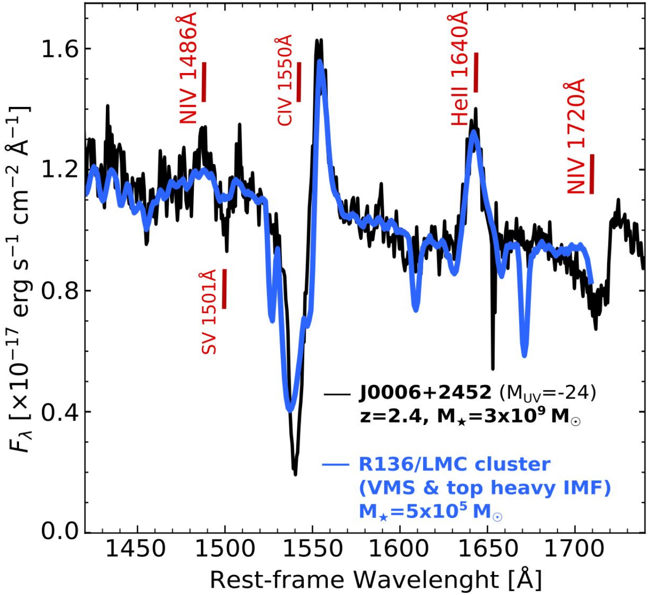
- $SFRs \sim 200\text{-}1000\ M_\odot/yr$
- $M_* \sim 10^9 - 10^{10}\ M_\odot$
- $r_{eff} \sim 220 - 600\ pc$





Marques-Chaves +24, and in prep.

P3: Spectra and densities of UV-bright galaxies resembling those of young and massive star-clusters … but x10⁴ more massive

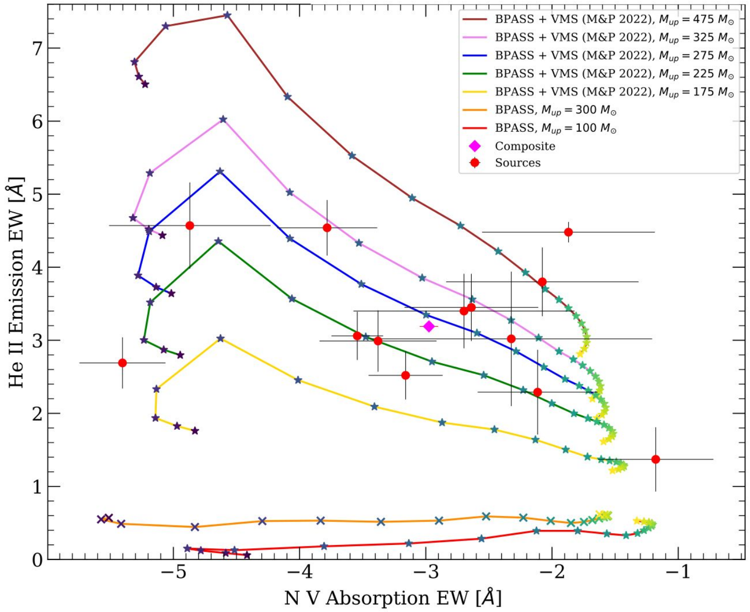


Upadhyaya +24

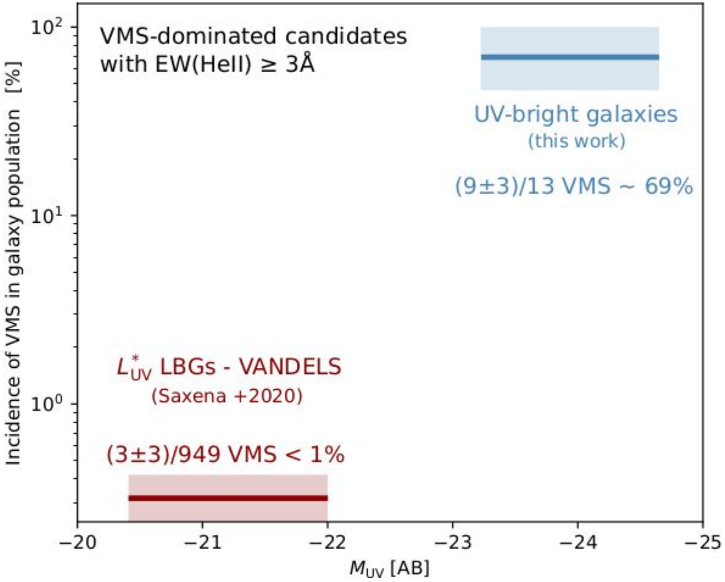
Signatures of Very Massive Stars (VMS) in their UV spectra

Rest-UV spectra show intense HeII 1640 emission:

- EW(HeII) ≥ 3.0 Å (not reproduced by standard models/IMFs)
- VMS are required
- I.e., like R136 cluster and other (few) VMS-dominated clusters



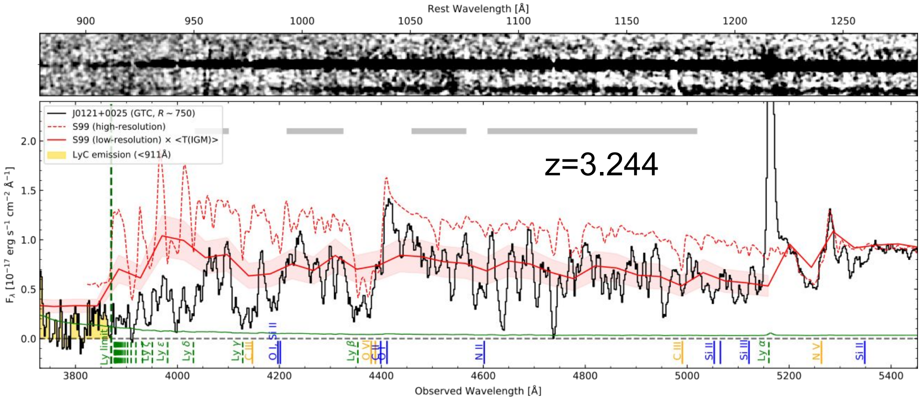
Upadhyaya +2024



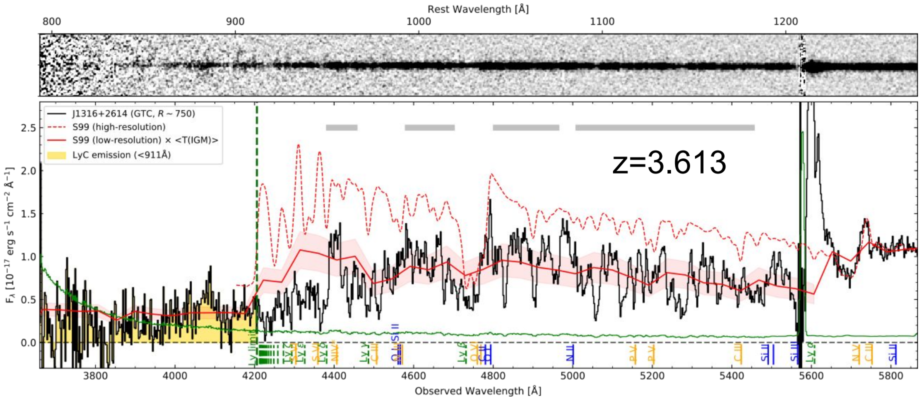
*P4: Signatures of **Very Massive Stars** are ubiquitous in the spectra of UV-bright galaxies: impling different IMF (Mup extended up to 475 $M_\odot$)*

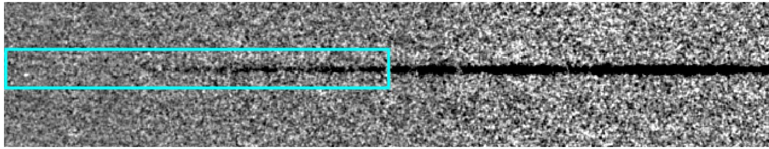
UV-bright galaxies are strong LyC emitters

Marques-Chaves +(2021)



Marques-Chaves +(2022b)



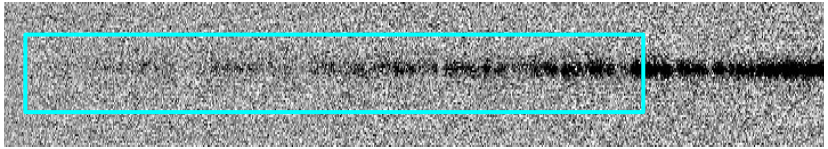


Detection of Lyman continuum (LyC) emission

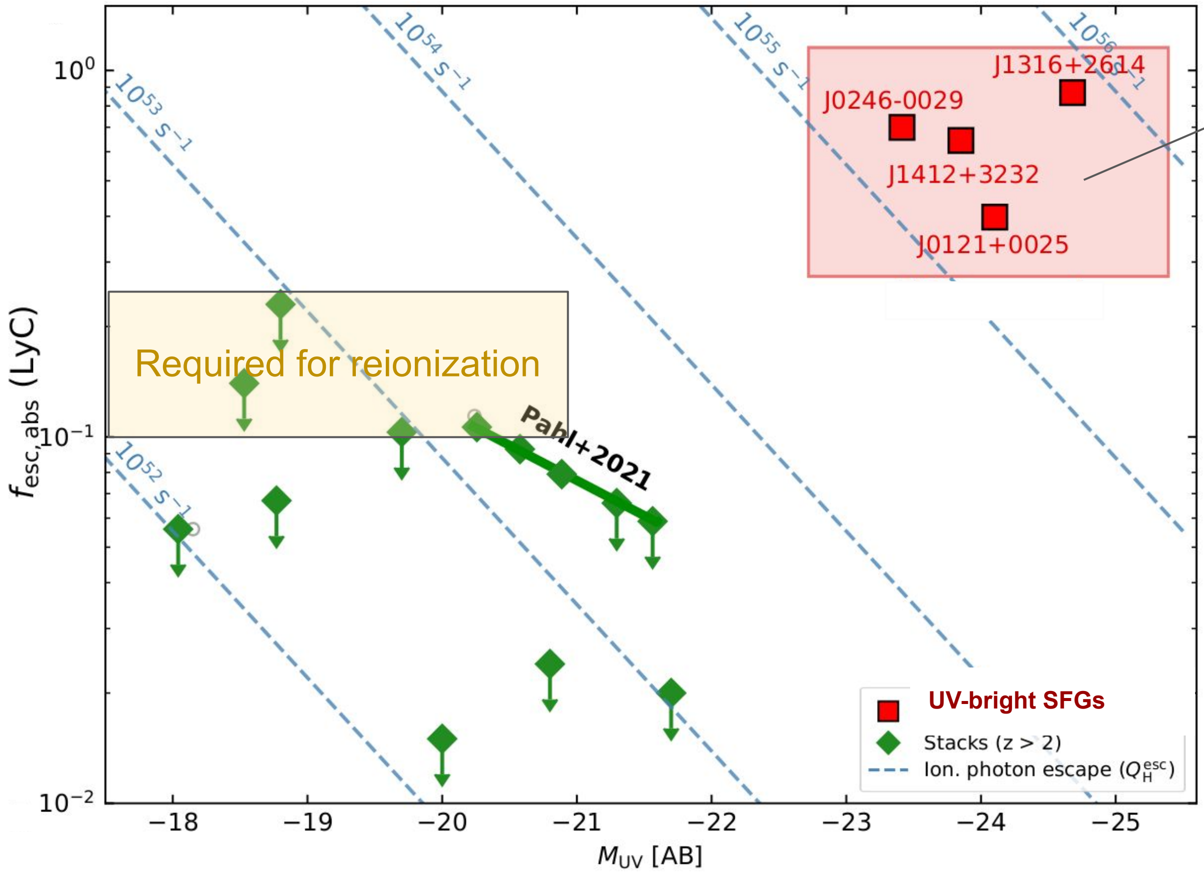
with high significance

LyC: λ_0 < 912 Å or > 13.6 eV

LyC escape fractions of ~ 40% to 90% !



UV-bright galaxies are strong LyC emitters



From Marques-Chaves+2021, 2022, in prep.

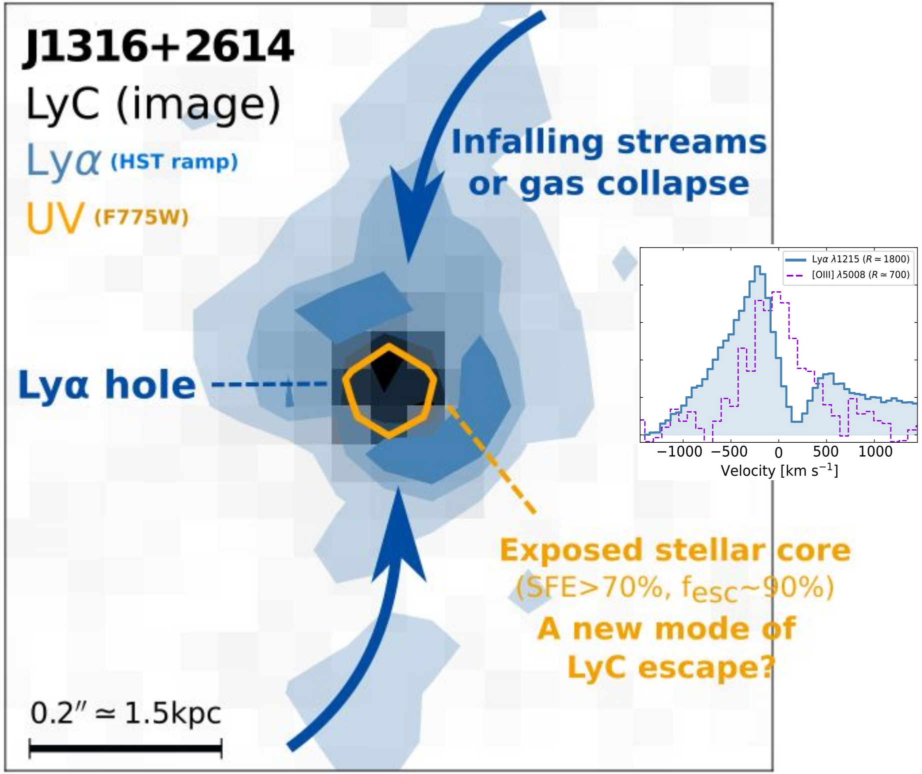
And more to come soon…

P5: UV-bright galaxies are strong ionizing sources

Literature sample:

Stacks (z~2-4): Grazian +2017; Marchi +2017; Rutkowski +2017; Steidel +2016: Fletcher +2019; Bian & Fan 2020; Pahl +2021

J1316+2416: the UV-brightest and strongest LyC emitter - HST view



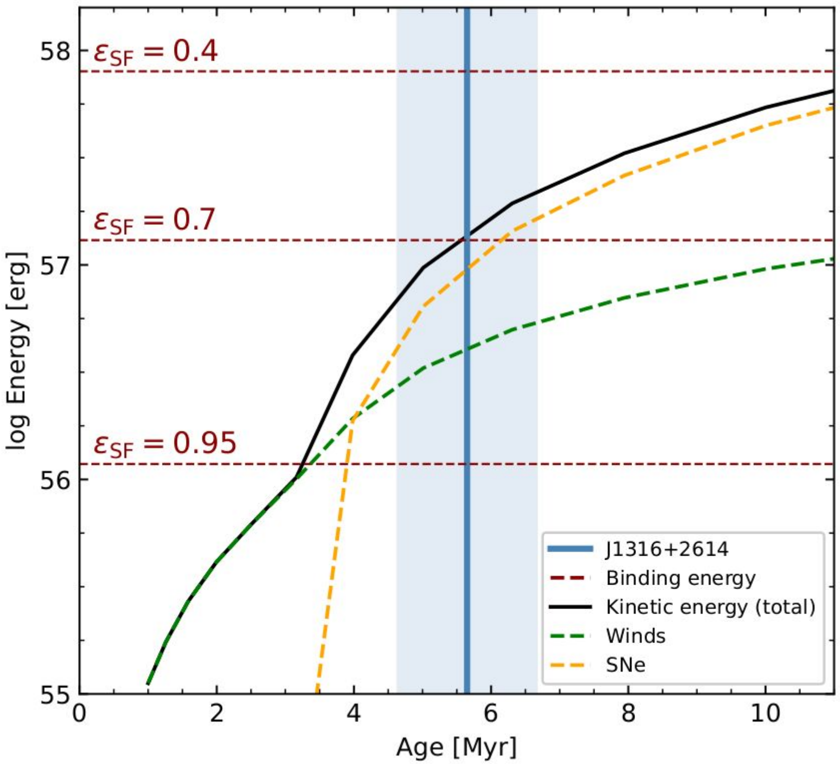
J1316+2614 at z = 3.613:

- *M_{UV} = -24.65, SFR = 900 $M_{\odot}$/yr , E(B-V) ~ 0*
- *M_* = 5x10^9 $M_{\odot}$; 6 Myr age (CSFH)*
- *f_{esc}(LyC) ~ 90%*
- ***Resolved LyC emission** and with similar size as the non-ionizing emission (r_{eff} = 220 pc)*
- ***Lyα emission is blueshifted > massive inflows** and shows an elongated morphology*
- *However, **Lyα is weak/absent within the stellar emission > exposed stellar core***

How is that possible?

Marques-Chaves+2024 (arXiv:2407.18804)

J1316+2416: Energetics and SF efficiency (ϵ_{SF})



Binding energy: $E_b \propto (1-\epsilon_{SF})\, M_{total}^2 / r_{eff}$

Kinetic energy: $E_k \propto$ SFR

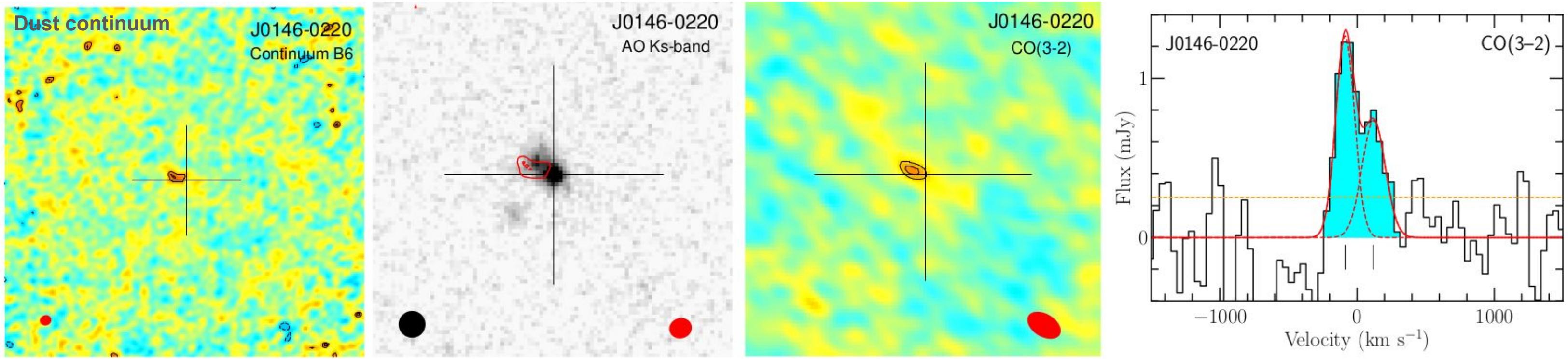
Gas clearance (i.e., $E_k > E_b$) only occurs when $\epsilon_{SF} > 70\%$

(similar for radiative driven outflows)

P6: high LyC leakage driven by high SF efficiency

Marques-Chaves+2024 (arXiv:2407.18804)

UV-bright galaxies: ALMA observations of dust and molecular gas

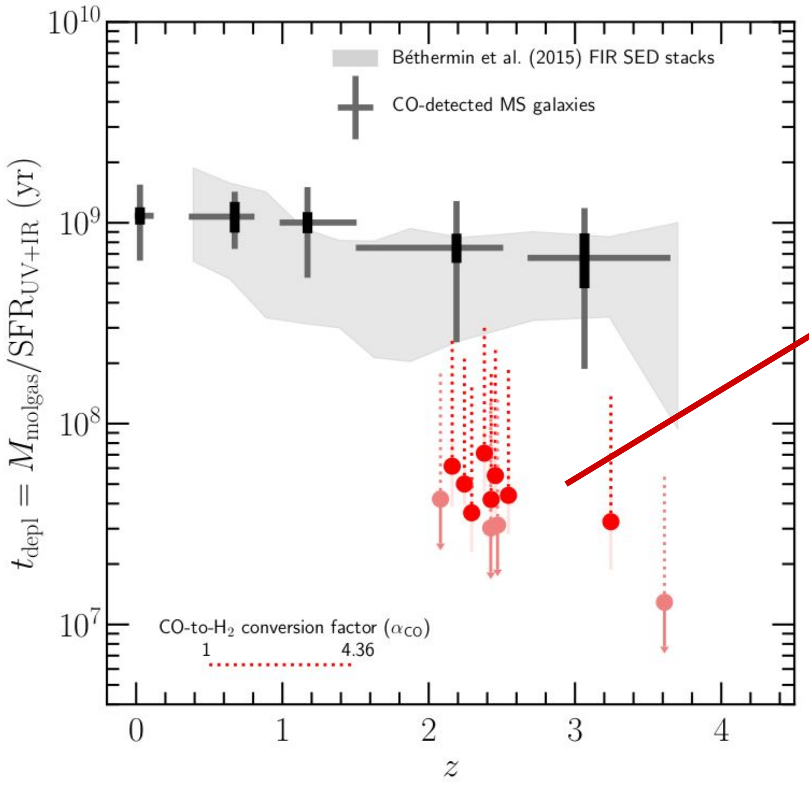


Target	$z_{\rm nebular}$[a]	$M_{\rm UV}$	$\beta_{\rm UV}$	$\epsilon_{\rm SF}$[h] (%)
J1322+0423	2.0800	−23.49	−2.06 ± 0.12	> 31
J0146–0220	2.1595	−23.68	−1.98 ± 0.12	21 ± 3
J1415+2036	2.2435	−23.53	−3.49 ± 0.11†	> 14 ± 3
J1249+1550	2.2928	−23.41	−1.84 ± 0.12	37 ± 5
J0006+2452	2.3796	−24.17	−2.30 ± 0.10	8 ± 0.9
J0850+1549	2.4235	−23.76	−2.62 ± 0.14	> 20
J1220–0051	2.4269	−23.50	−2.43 ± 0.11	13 ± 2
J0950+0523	2.4548	−23.69	−2.41 ± 0.15	9 ± 1
J1220+0842	2.4698	−24.36	−2.36 ± 0.09	> 24
J1157+0113	2.5450	−23.40	−2.15 ± 0.34	15 ± 6
J0121+0025	3.2445	−24.11	−2.19 ± 0.20	> 29 ± 10
J1316+2614	3.6122	−24.65	−2.59 ± 0.05	> 40

P6: on average, UV-bright galaxies show high SF efficiencies (8% to > 40%)

Dessauges-Zavadsky +2024 (2410.11121)

UV-bright galaxies: ALMA observations of dust and molecular gas



Dessauges-Zavadsky +2024 (2410.11121)

They also show very short gas depletion timescales (<10 Myr to 70 Myr)

P7: while observationally rare, these UV-bright phases may be common in the early Universe

Game changers in our understanding of early galaxy formation and reionization ?

Summary / Main Properties (Part I)

P1: UV-bright galaxies (M_{UV} ~ -23 to -25) are blue / almost unobscured

P2: Emission dominated by very young stellar populations (~ 10Myr)

P3: Spectra and M_* and SFR surface densities similar to young massive star clusters

P4: UV spectra dominated by Very Massive Stars > different IMF (top-heavy?)

P5: Among the strongest Lyman continuum emitting galaxies known

P6: Indications of high SF efficiencies > critical for high LyC escape

P7: Short gas depletion timescales > very short-lived phases / how many are we missing?

Can models of galaxy formation & evolution predict these properties?

Summary / Main Properties (Part II)

Are they related to UV-bright galaxies found at z>10 ?

- EoR UV-bright sources are fainter (does it matter?)
- New (extreme) modes of star-formation and LyC escape at high-z ?

Scenarios invoked to explain the overabundance of EoR UV-bright sources:

Higher SF efficiencies? ***-> Yes***

Dust removal? ***-> Outflows are common (but not shown here) - maybe yes***

Top-heavy IMF? ***-> Still ongoing, possibly yes (VMS)***

Stochastic SFHs? ***-> UV-bright galaxies are powerful starbursts*** *(sSFR > 100 Gyr^{-1})*, ***so why not***

Thank you!