

The surprising lives of Population III stars: whens, wheres and hows



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+

Alessandra Venditti

alessandra.venditti@utexas.edu



SAPIENZA
UNIVERSITÀ DI ROMA

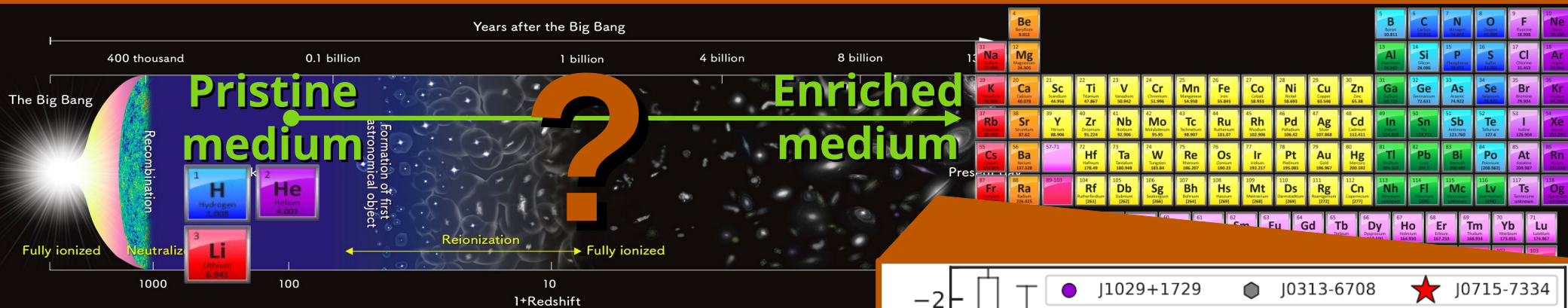


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NextGenerationEU

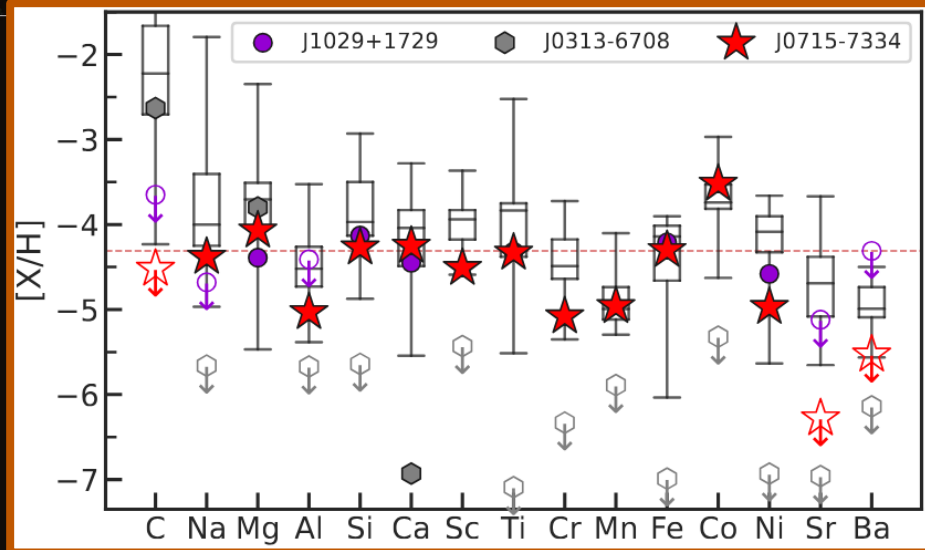


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MELBOURNE

Pop III stars: the missing cosmic puzzle piece



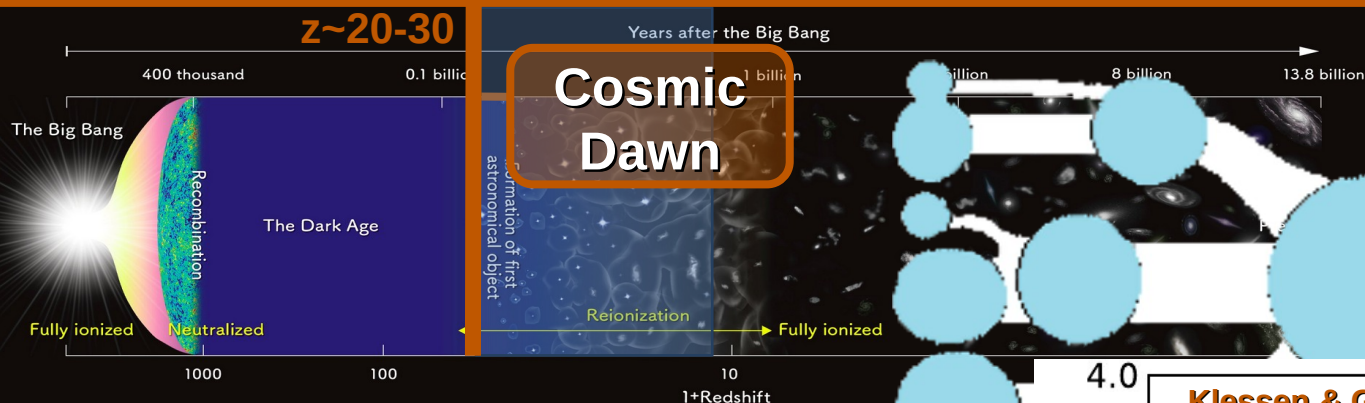
A nearly pristine star in the LMC:
 $< 10^{-4.3} Z_{\odot}$!



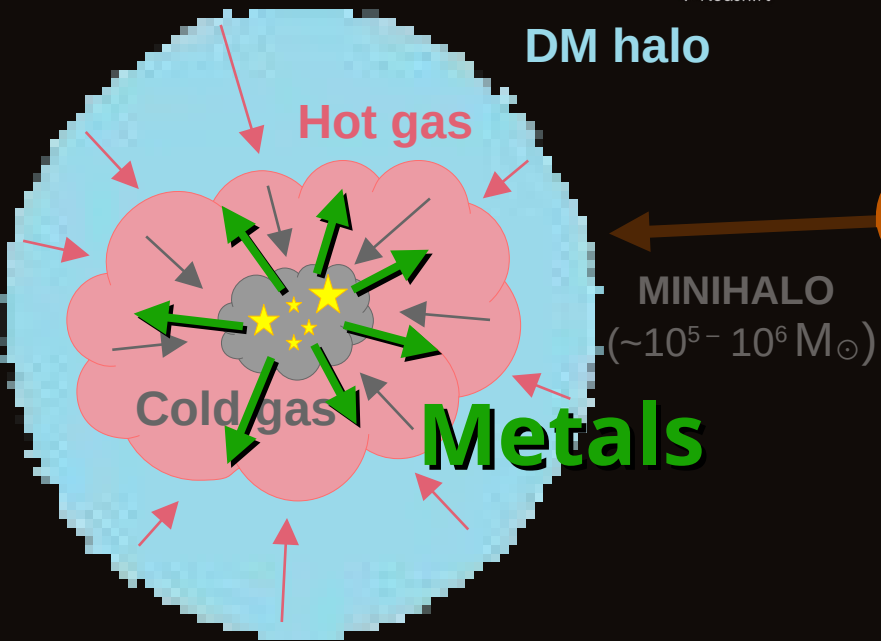
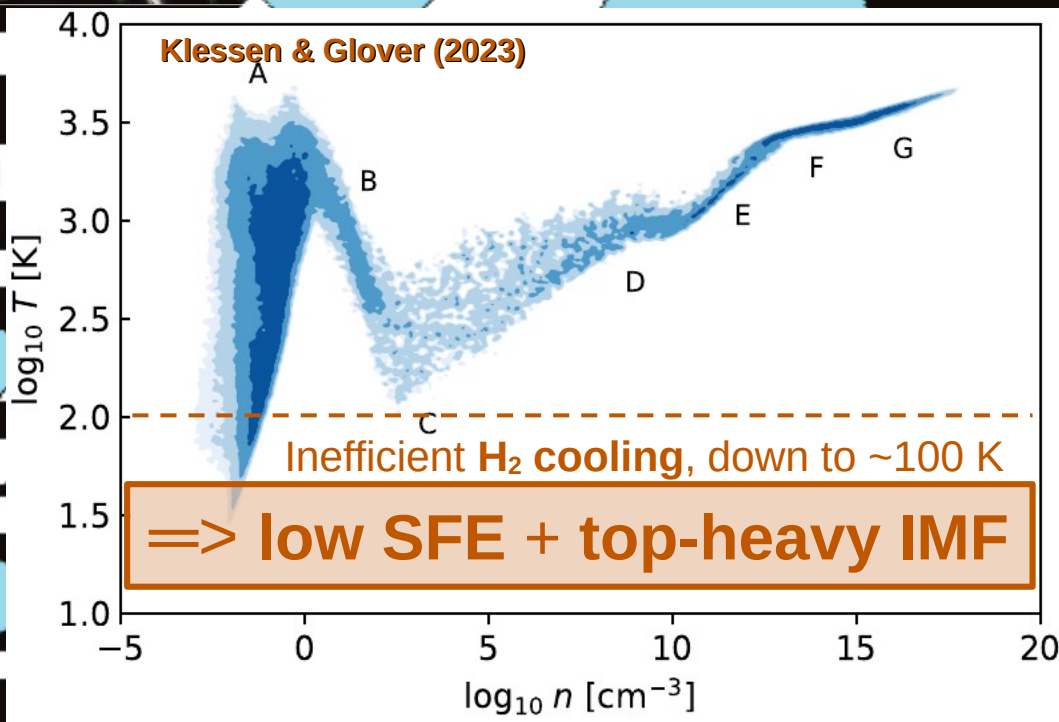
But no actually pristine stars so far!

Ji et al. (2025)

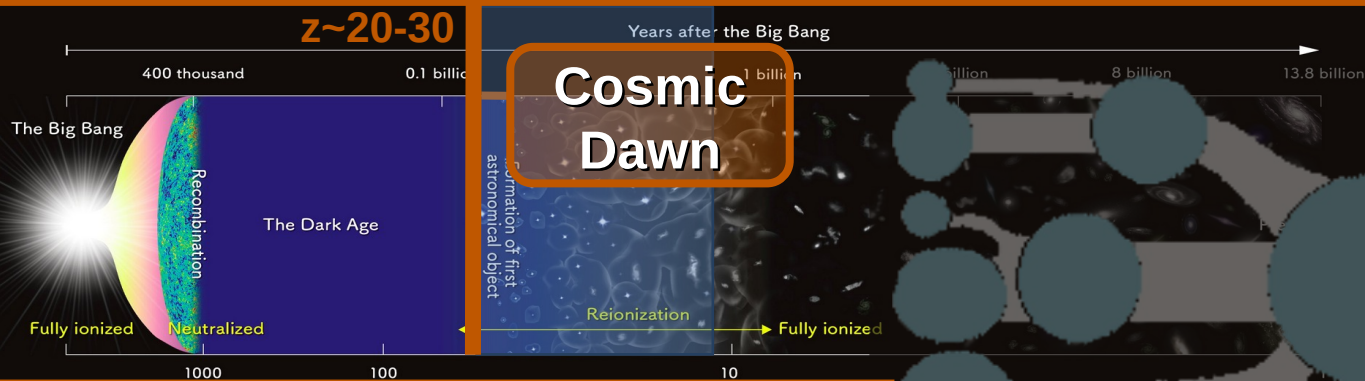
The standard framework on Pop III SF



Cosmic Dawn



The standard framework on Pop III SF



Direct search in first mini-halos

e.g. Schauer et al. (2020)

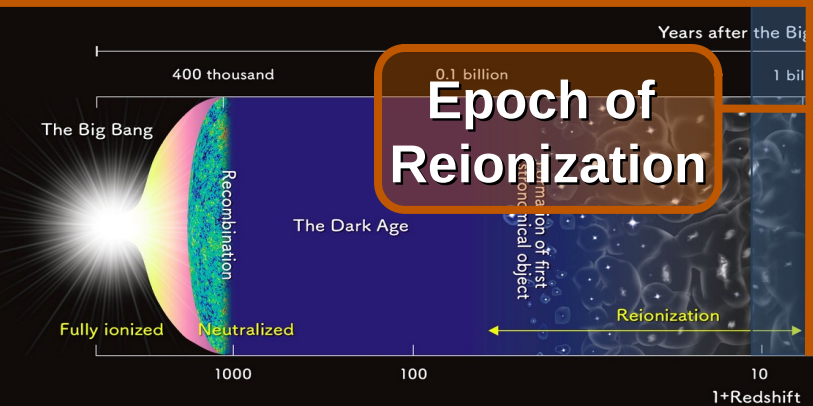
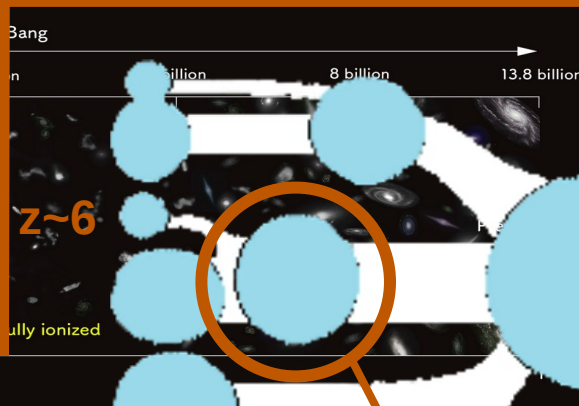
BUT Jeon et al. (2026) on
PISNe in overdense fields at $z \sim 30$



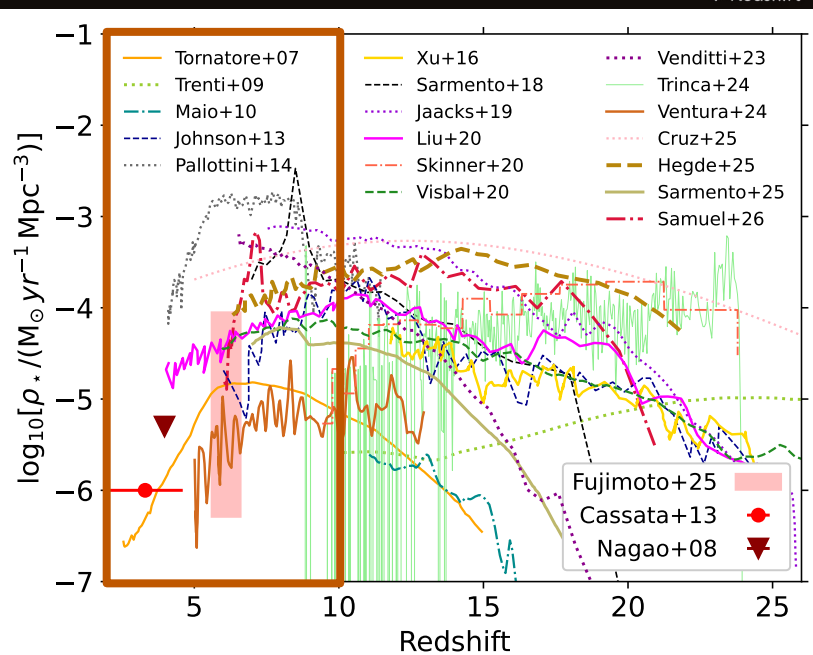
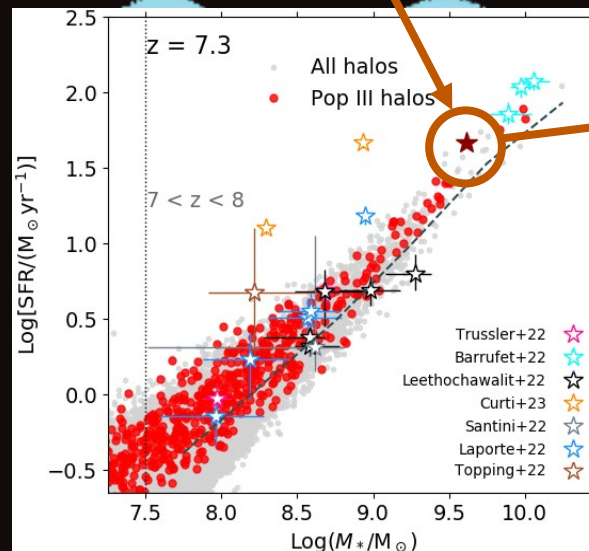
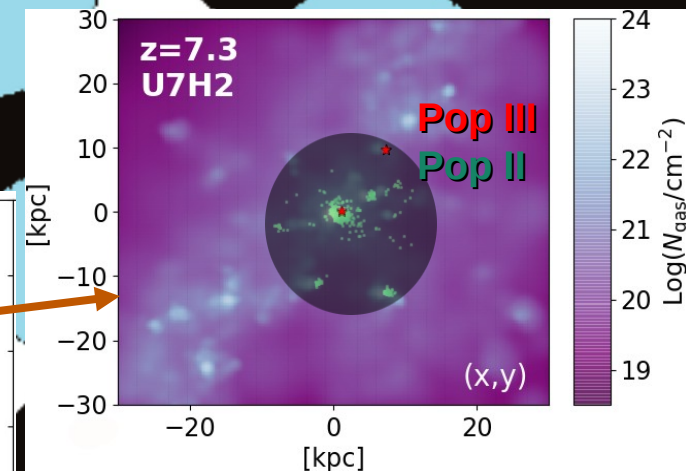
Junehyoung Jeon
UT Austin



...and in larger halos



Venditti et al. (2023),
MNRAS, 522, 3809



Venditti et al. (2026),
OJA, arXiv:2607.00167

A window on Pop III from JWST

Name	Redshift	$12 + \log(\text{O}/\text{H})$	Metallicity [$Z_{\odot}$]	M_{III} [$M_{\odot}$]	$M_{\star}$ [$M_{\odot}$]	SFR [$M_{\odot} \text{yr}^{-1}$]	Lensed	M_{UV}	β -slope	
GNHeII J1236+6215	2.9803 ± 0.0010	7.85 ± 0.22	0.003 ± 0.002	—	$(7.8 \pm 3.1) \times 10^8$	$12.2 \pm 2.0^{(a)}$	No	-22.09 ± 0.02	-2.18 ± 0.06	...
MPG-CR3	3.193 ± 0.016	< 6.52	$< 8 \times 10^{-3}$	$6.1e + 05$	—	—	No	—	—	
LAP2	4.189 ± 0.003	< 6.5	< 0.006	—	$\approx (1.2 - 5.0) \times 10^4$	—	Yes ^(d)	≈ -12.2	—	...
CAPERS-UDS-32520 ^(f)	5.1240 ± 0.0002	7.82 ± 0.07	< 0.15	—	$\sim 10^9$	—	No	-20.95 ± 0.05	-1.68 ± 0.05	
AMORE6	5.7253 ± 0.0001	< 5.78	< 0.0012	—	$(4.37^{+2.24}_{-0.73}) \times 10^5$	$0.35 \pm 0.06^{(i)}$	Yes ^(g)	$-14.52^{+0.07}_{-0.08}^{(h)}$	$-2.77^{+0.07}_{-0.09}$	...
LAP1	6.625 ± 0.001	$6.31^{+0.15}_{-0.23}$	$(4.2 \pm 1.8) \times 10^{-3}^{(k)}$	—	$\lesssim 2700$	—	Yes	> -10.4	—	
RX J2129-z8HeII	8.1623 ± 0.0007	$7.63^{+0.14}_{-0.09}$	~ 0.1	$(7.8 \pm 1.4) \times 10^5$	$(5.6^{+0.8}_{-0.7}) \times 10^7$	$9.56^{+4.51}_{-1.70}$	Yes	$-19.58^{+0.03}_{-0.02}$	$-2.53^{+0.06}_{-0.07}$	...
EXCELS-63107	8.271	$6.89^{+0.26}_{-0.21}^{(n)}$	0.016	—	$(3.72^{+4.05}_{-3.36}) \times 10^8^{(m)}$	7.8 ± 0.6	No	-19.9 ± 0.1	-3.3 ± 0.3	
Hebe (GN-z11)	10.5862 ± 0.0030	< 6.96	< 0.019	$\sim 2 \times 10^4 - 6 \times 10^5$	—	—	No ^(o)	—	—	

<https://utcfc.github.io/pages/popiiicandidates.html>

Only one candidate
at $z \gtrsim 10$!

Candidates proposed
down to $z \sim 3$!

Venditti et al. (2026),
OJA, arXiv:2607.00167

A window on Pop III from JWST

Name	Redshift	$12 + \log(\text{O}/\text{H})$	Metallicity [$Z_{\odot}$]	M_{III} [$M_{\odot}$]	$M_{\star}$ [$M_{\odot}$]	SFR [$M_{\odot}\text{yr}^{-1}$]	Lensed	M_{UV}	β -slope	
GNHeII J1236+6215	2.9803 ± 0.0010	7.85 ± 0.22	0.003 ± 0.002	—	$(7.8 \pm 3.1) \times 10^8$	$12.2 \pm 2.0^{(a)}$	No	-22.09 ± 0.02	-2.18 ± 0.06	...
MPG-CR3	3.193 ± 0.016	< 6.52	$< 8 \times 10^{-3}$	$6.1e + 05$	—	—	No	—	—	
LAP2	4.189 ± 0.003	< 6.5	< 0.006	—	$\approx (1.2 - 5.0) \times 10^4$	—	Yes ^(d)	≈ -12.2	—	...
CAPERS-UDS-32520 ^(f)	5.1240 ± 0.0002	7.82 ± 0.07	< 0.15	—	$\sim 10^9$	—	No	-20.95 ± 0.05	-1.68 ± 0.05	
AMORE6	5.7253 ± 0.0001	< 5.78	< 0.0012	—					$-2.77^{+0.07}_{-0.09}$	...
LAP1	6.625 ± 0.001	$6.31^{+0.15}_{-0.23}$	$(4.2 \pm 1.8) \times 10^{-3(k)}$	—					—	
RX J2129-z8HeII	8.1623 ± 0.0007	$7.63^{+0.14}_{-0.09}$	~ 0.1	$(7.8 \pm$					$-2.53^{+0.06}_{-0.07}$	...
EXCELS-63107	8.271	$6.89^{+0.26}_{-0.21}(n)$	0.016	—					-3.3 ± 0.3	
Hebe (GN-z11)	10.5862 ± 0.0030	< 6.96	< 0.019	$\sim 2 \times$					—	

+ Pop III candidates
at $z \sim 2$ from HETDEX
arXiv:2609.16134
Mahan Mirza Khanlari
UT Austin

[candidates.html](#)

Only one candidate
at $z \gtrsim 10$!

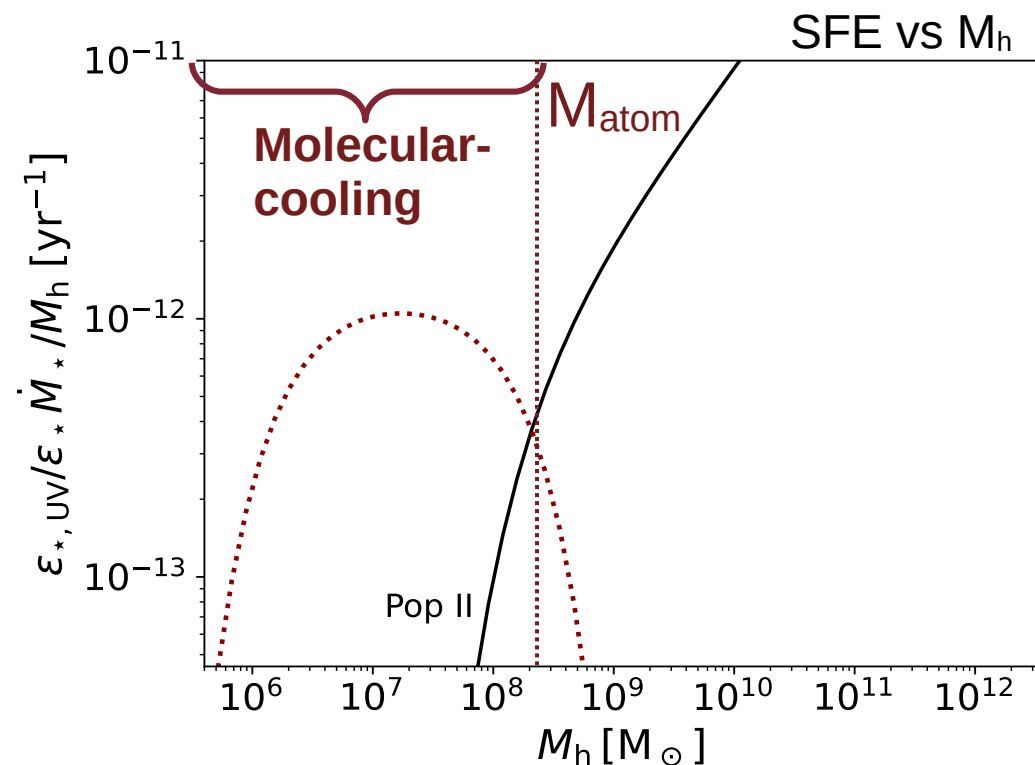
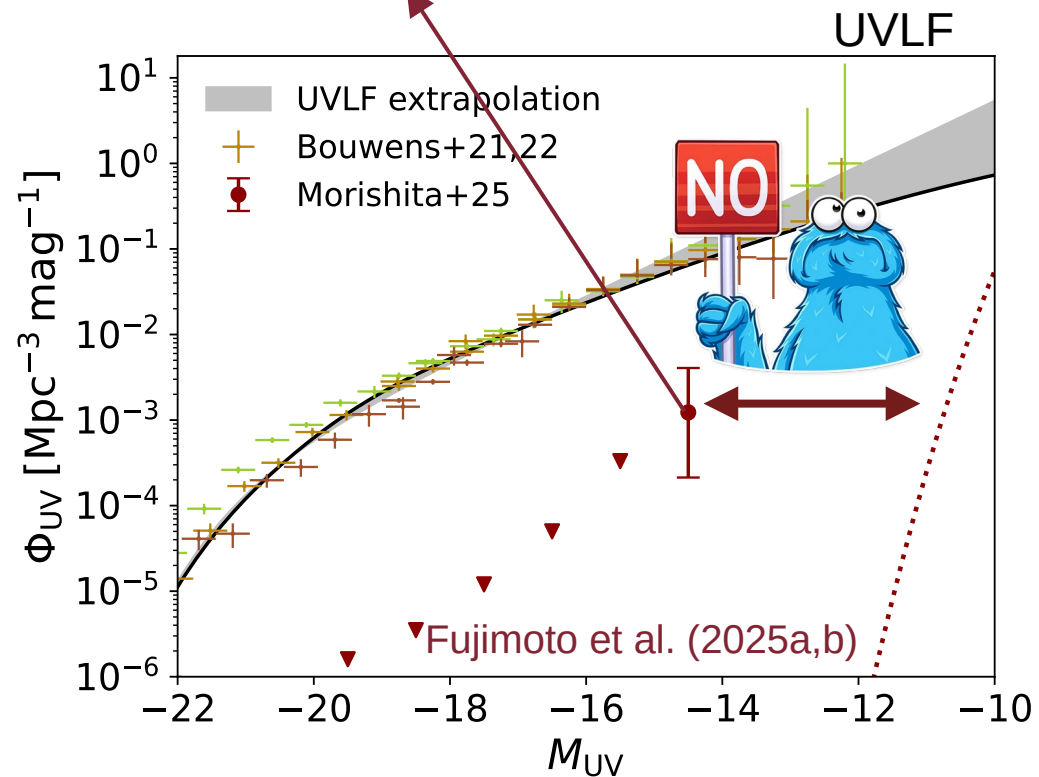
Candidates proposed
down to $z \sim 3$!

**Venditti et al. (2026),
OJA, arXiv:2607.00167**

Pop III UVLF constraints at $z \sim 6$

Venditti et al. (2025), APJ, 994, 32

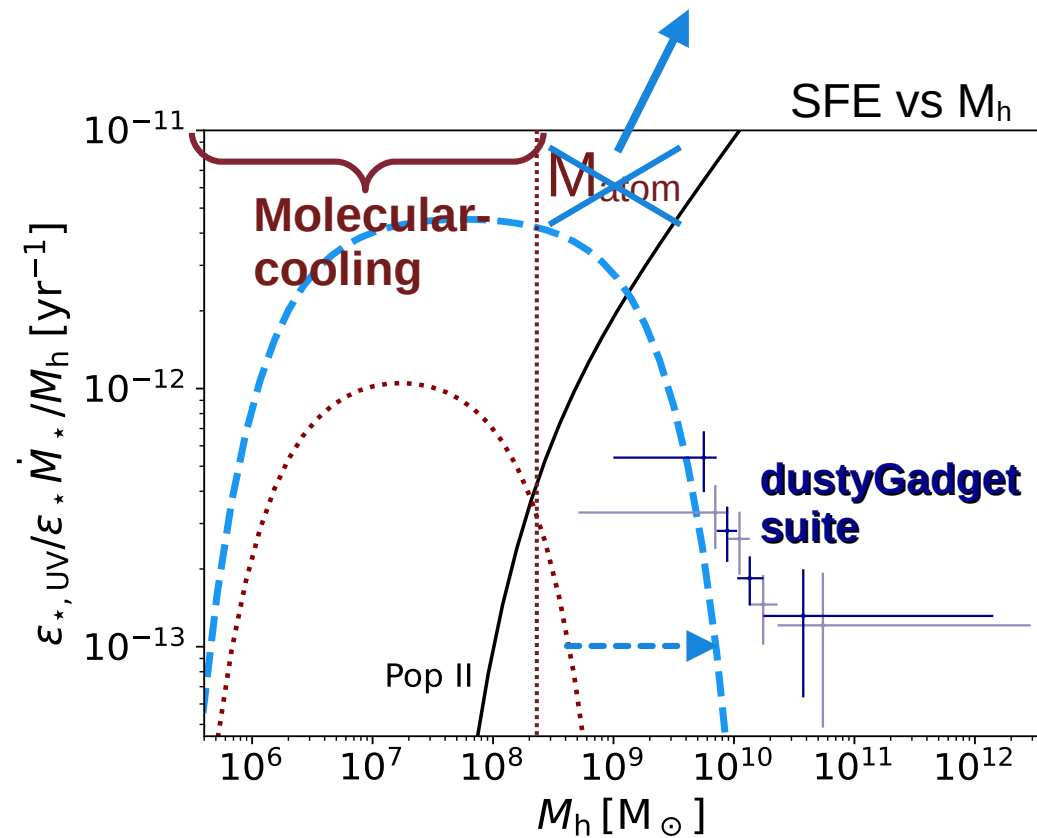
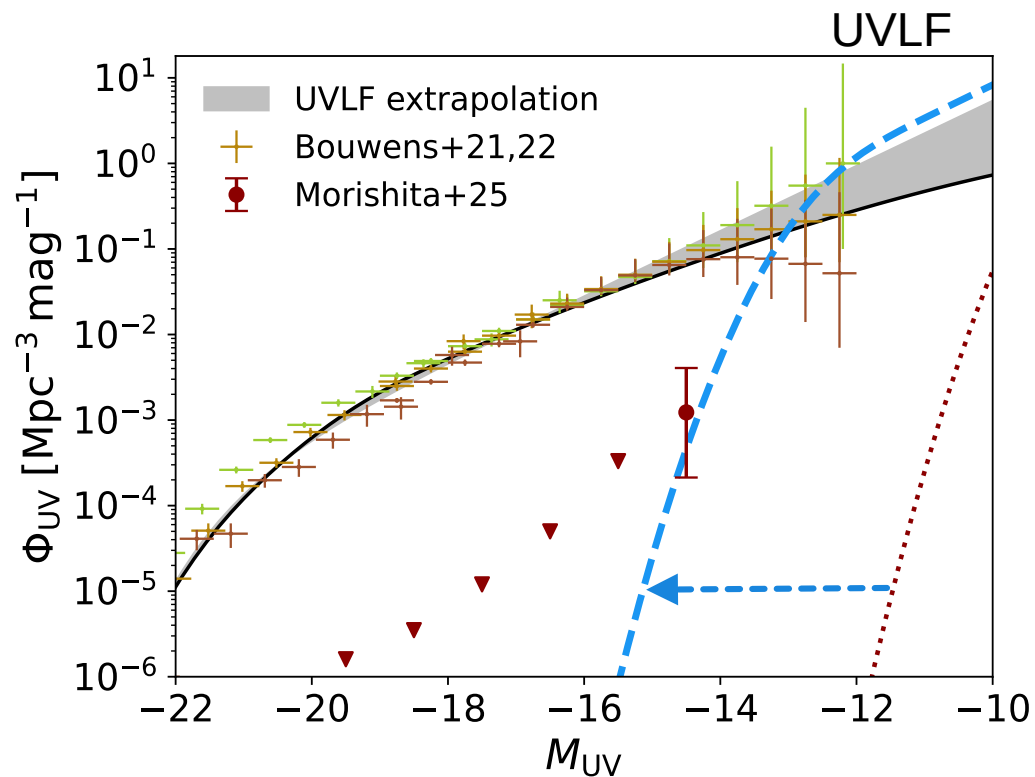
Name	Redshift	$12 + \log(\text{O}/\text{H})$	Metallicity [$Z_{\odot}$]	$M_{\star}$ [$M_{\odot}$]	SFR [$M_{\odot} \text{yr}^{-1}$]	Lensed M_{UV}	β -slope
AMORE6	5.7253 ± 0.0001	< 5.78	< 0.0012	$(4.37^{+2.24}_{-0.73}) \times 10^5$	$0.35 \pm 0.06^{(i)}$	Yes ^(g) $-14.52^{+0.07}_{-0.08}^{(h)}$	$-2.77^{+0.07}_{-0.09}$



A “HEAVY” solution

Venditti et al. (2025), APJ, 994, 32

exponential cut-off at $\gtrsim 10^{9.5} M_{\odot}$

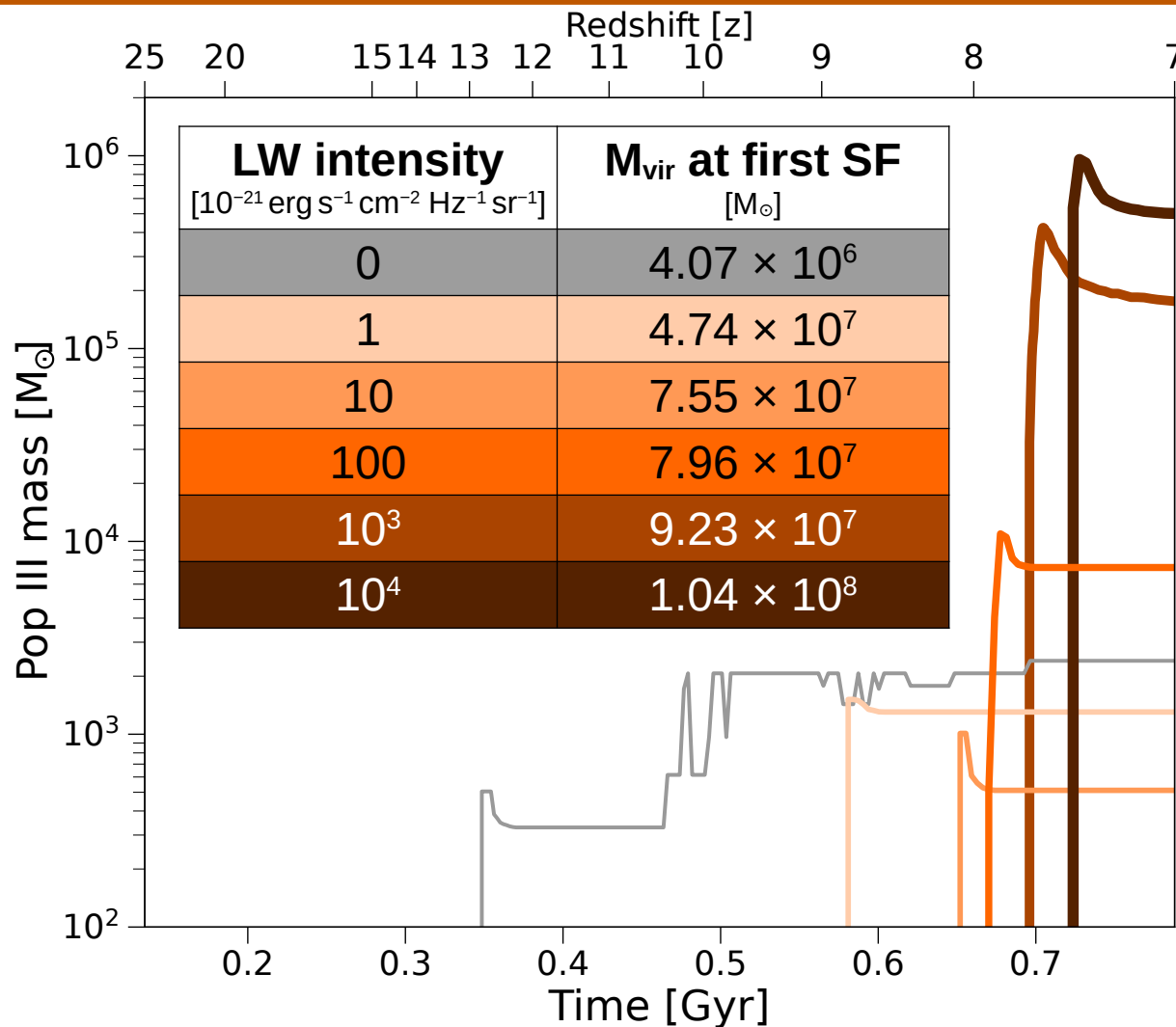


How to make Pop III
stars in a massive halo



Delayed Pop III starbursts in massive halos

(+ Bromm 2006, Greif et al. 2008, Sugimura et al. 2024, ...)



Jeong et al. (2026),
APJ, 1006, 89

Tae Bong Jeong
UT Austin



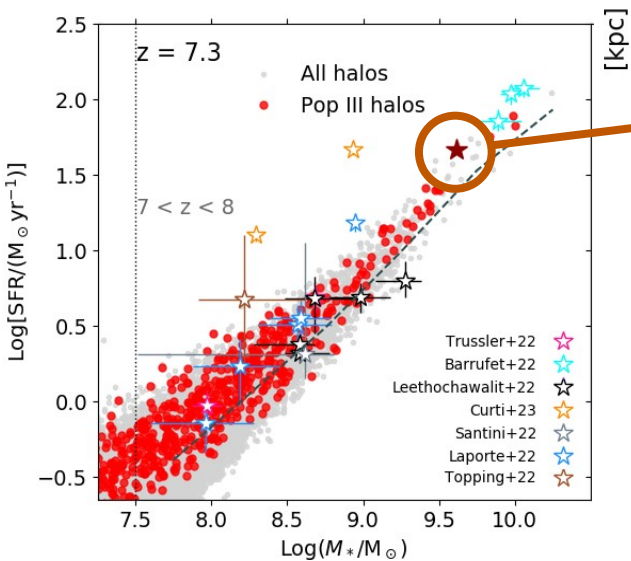
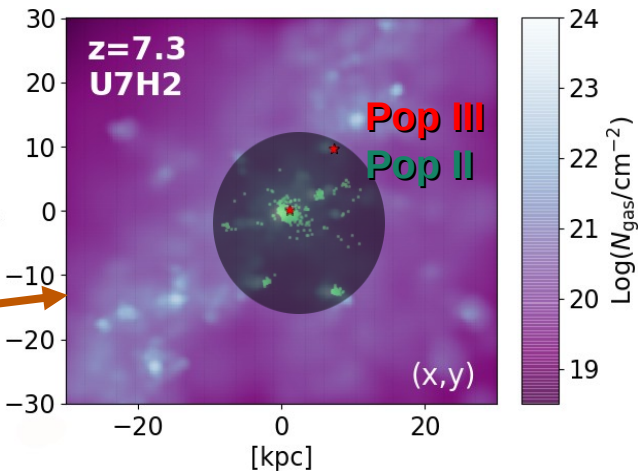
Pop III SF in peripheral regions of enriched halos

Graziani et al. (2020)
Di Cesare et al. (2023)

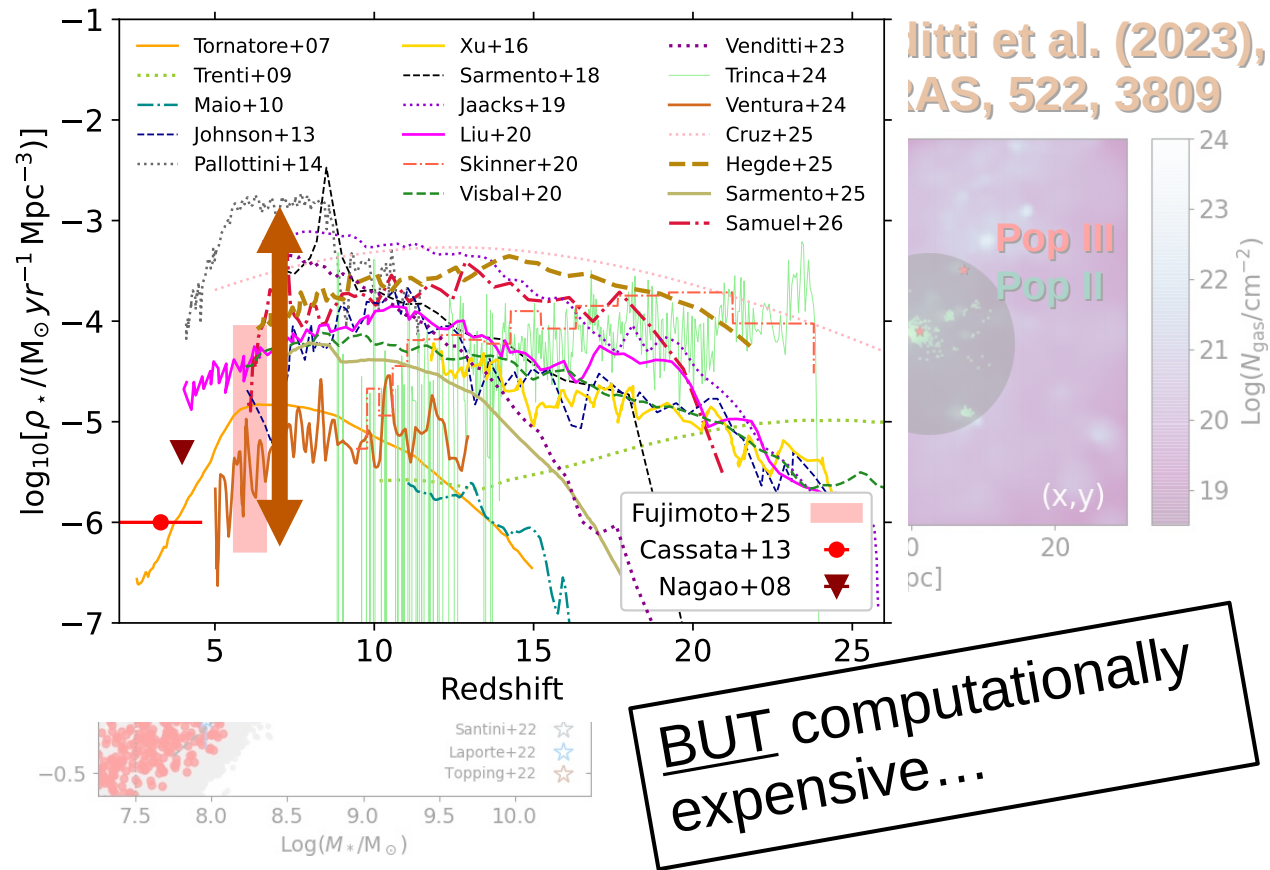
dustyGadget

cosmological simulations

Venditti et al. (2023),
MNRAS, 522, 3809



Pop III SF in peripheral regions of enriched halos

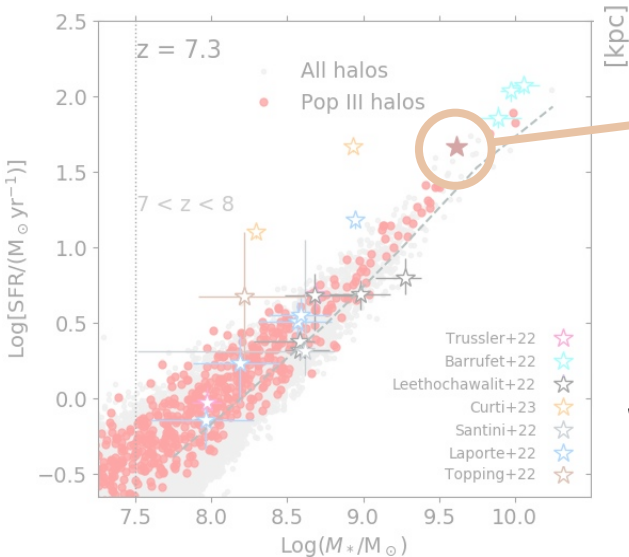


Pop III SF in peripheral regions of enriched halos

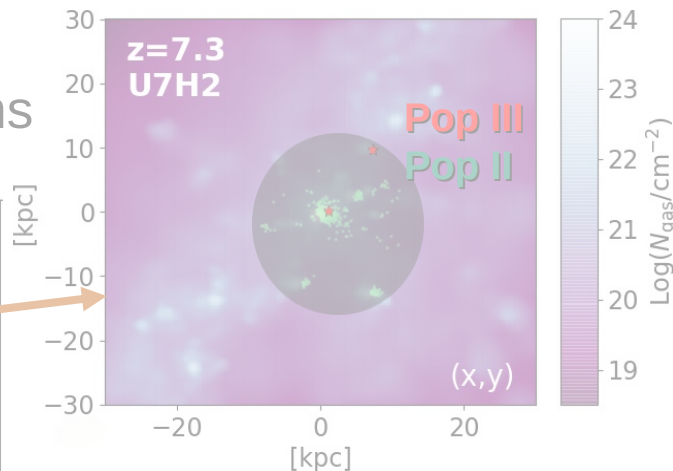
Graziani et al. (2020)
Di Cesare et al. (2023)

dustyGadget

cosmological simulations



Venditti et al. (2023),
MNRAS, 522, 3809

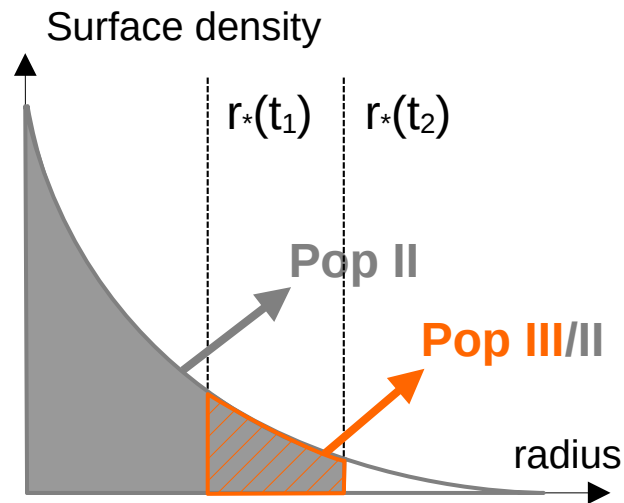


BUT computationally
expensive...

Emanuele Ventura
University of Melbourne



(+ abcd model from
Hegde & Furlanetto 2025)

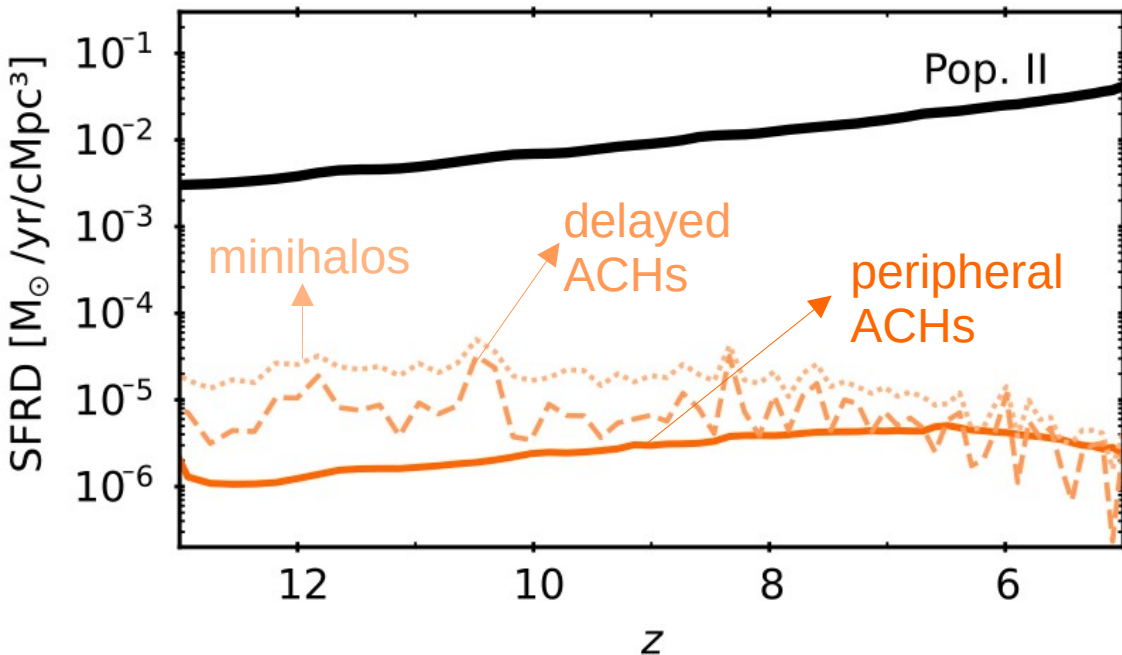


Mutch et al. (2016)
Ventura et al. (2024)

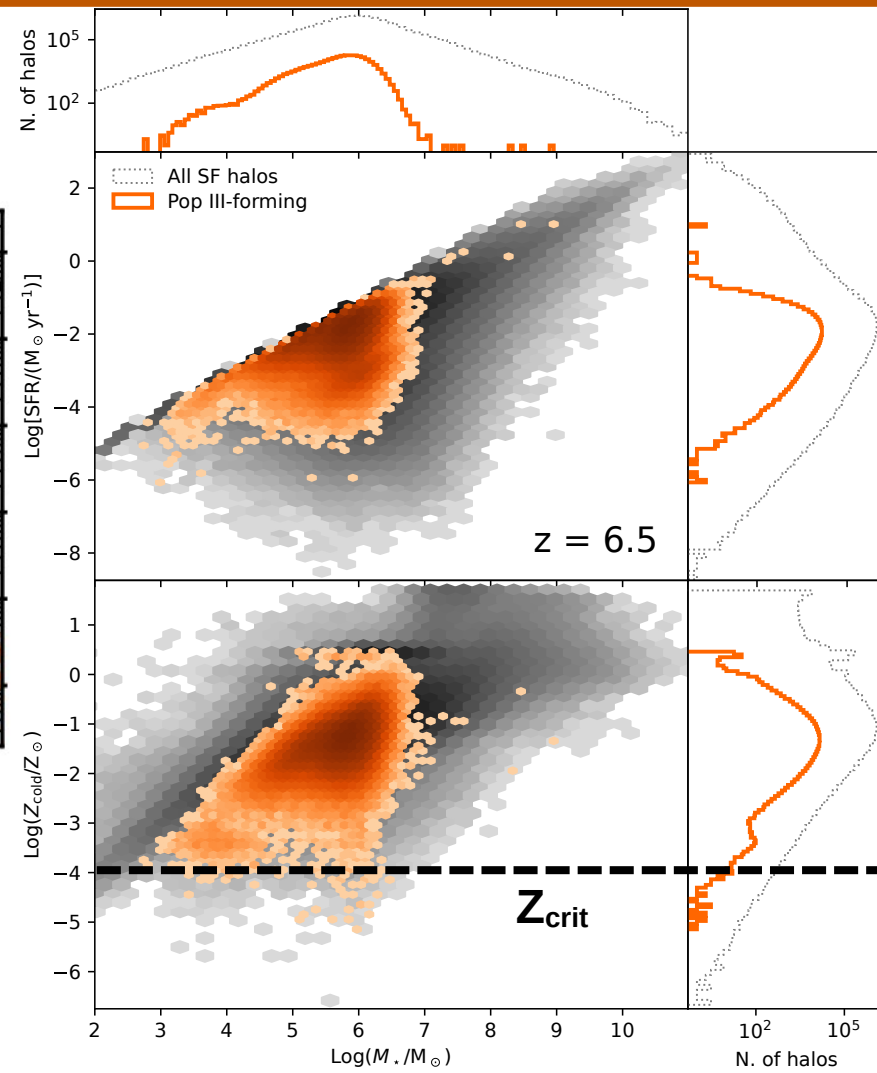
PRELIMINARY

Radially resolved metal transport in the SAM **Meraxes**,
=> fast, self-consistent exploration of Pop III parameters

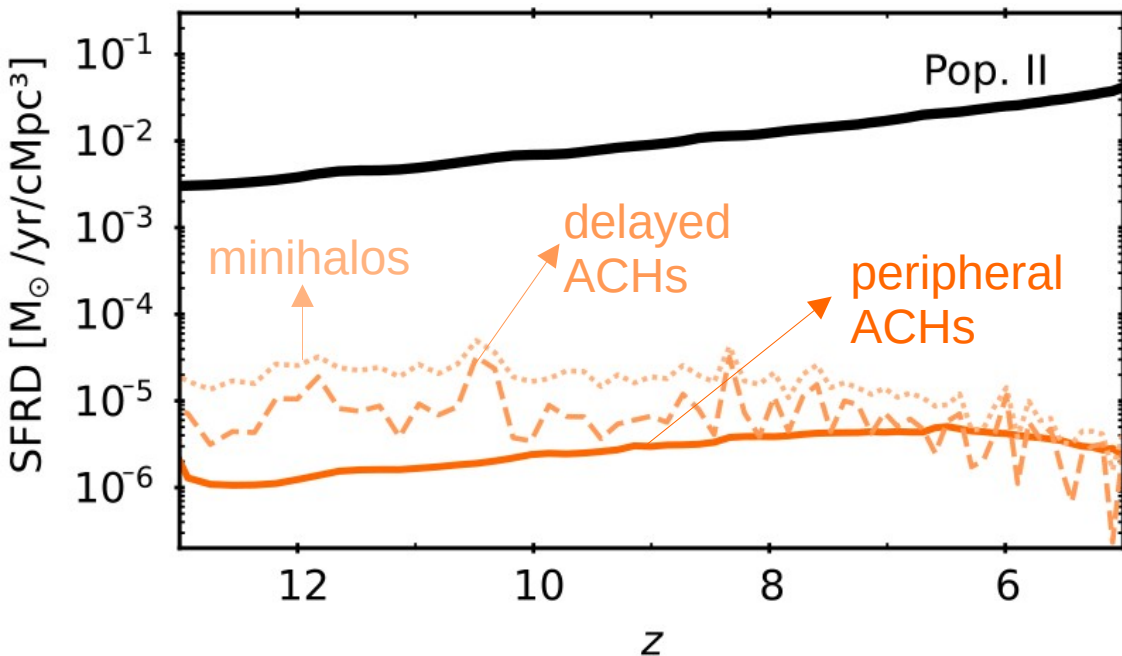
Pop III SF in peripheral regions of enriched halos



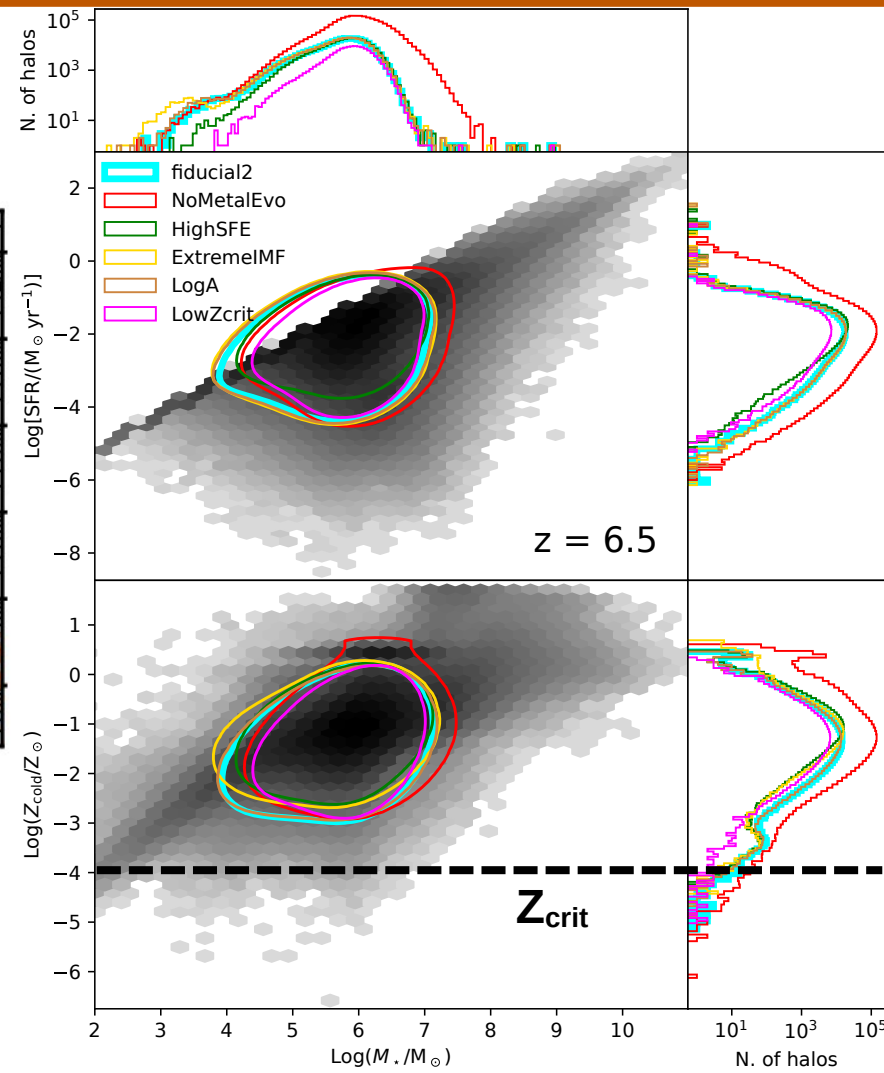
PRELIMINARY



Pop III SF in peripheral regions of enriched halos



PRELIMINARY

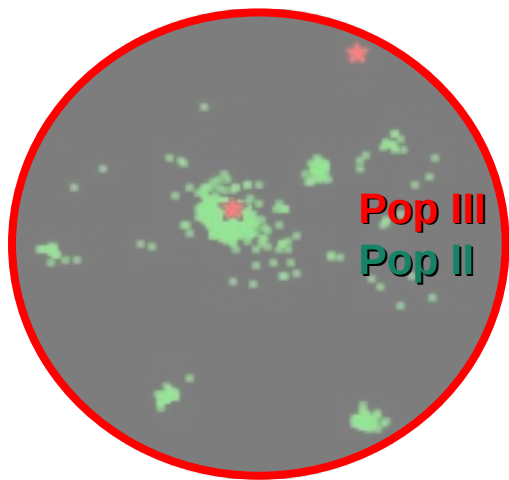


Cool...
but can we see them?



Synthetic spectra of massive EoR galaxies

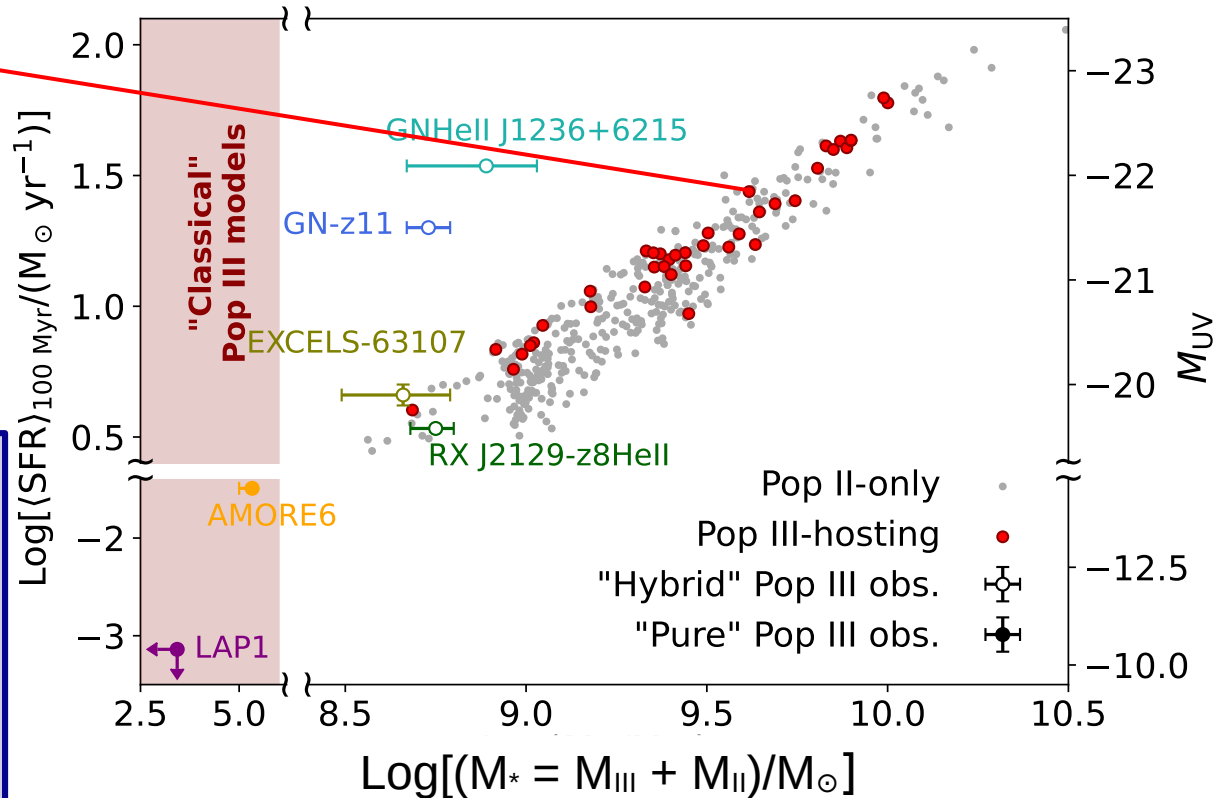
Venditti et al. 2026,
APJ, 1005, 226



SIMULATED GALAXY
 $M_* \gtrsim 10^9 M_\odot$
from **dustyGadget** suite

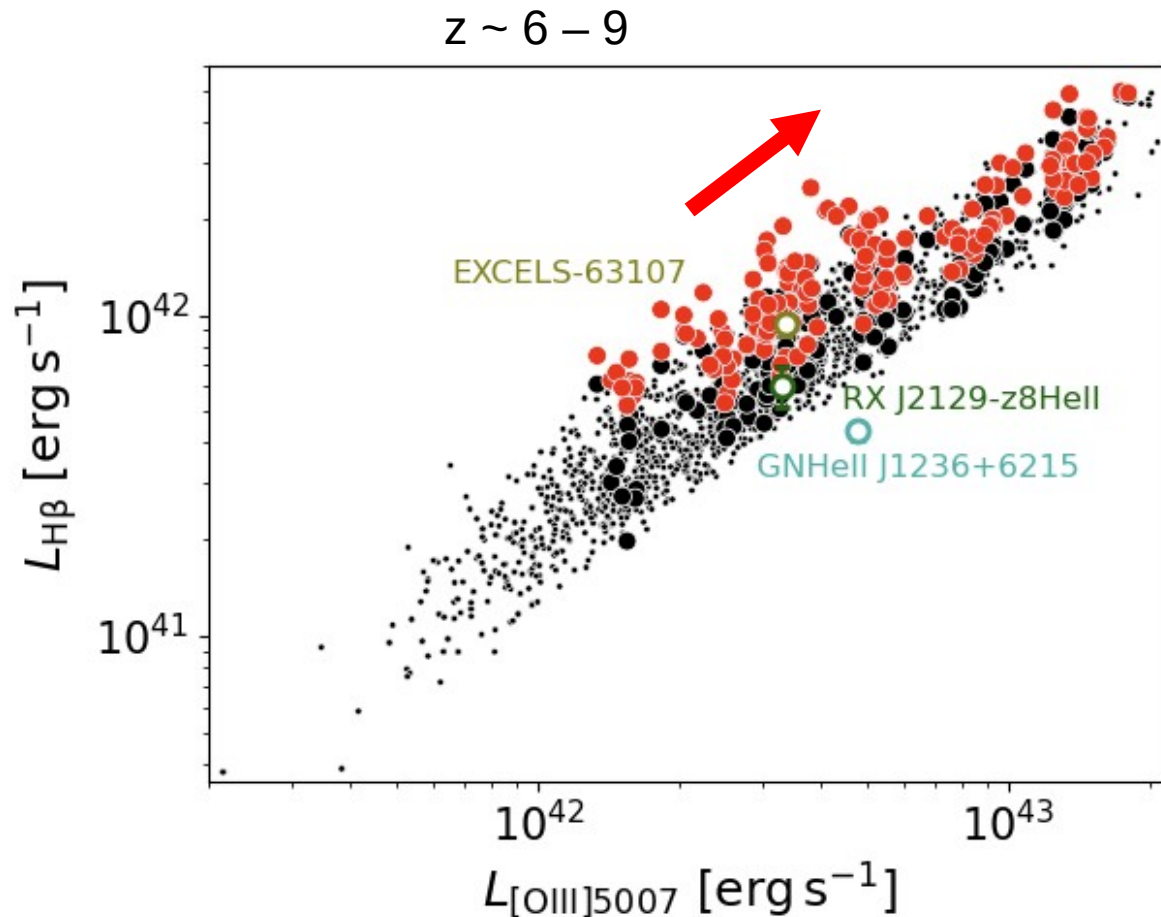
Largest cosmological
simulations including Pop III
SF and feedback

Model presentation: Graziani et al. (2020)
SF/dust formation: Di Cesare et al. (2023)
Pop III SF: Venditti et al. (2023), MNRAS, 522, 3809
+ Venditti et al. (2024a), MNRAS, 527, 5102
+ Venditti et al. (2024b), APJL, 973, L12



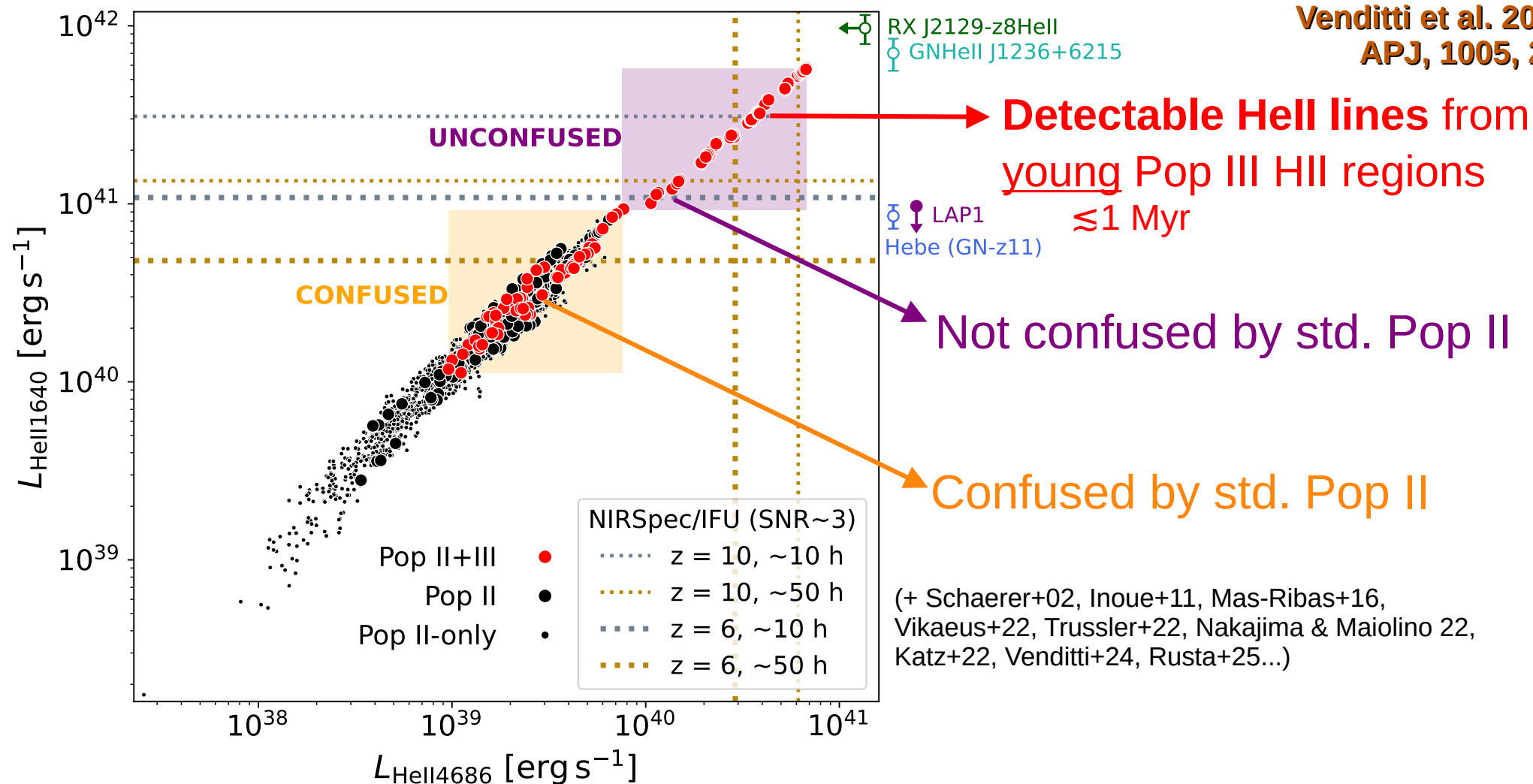
Massive Pop III hosts can emit strong metal lines!

Venditti et al. 2026,
APJ, 1005, 226



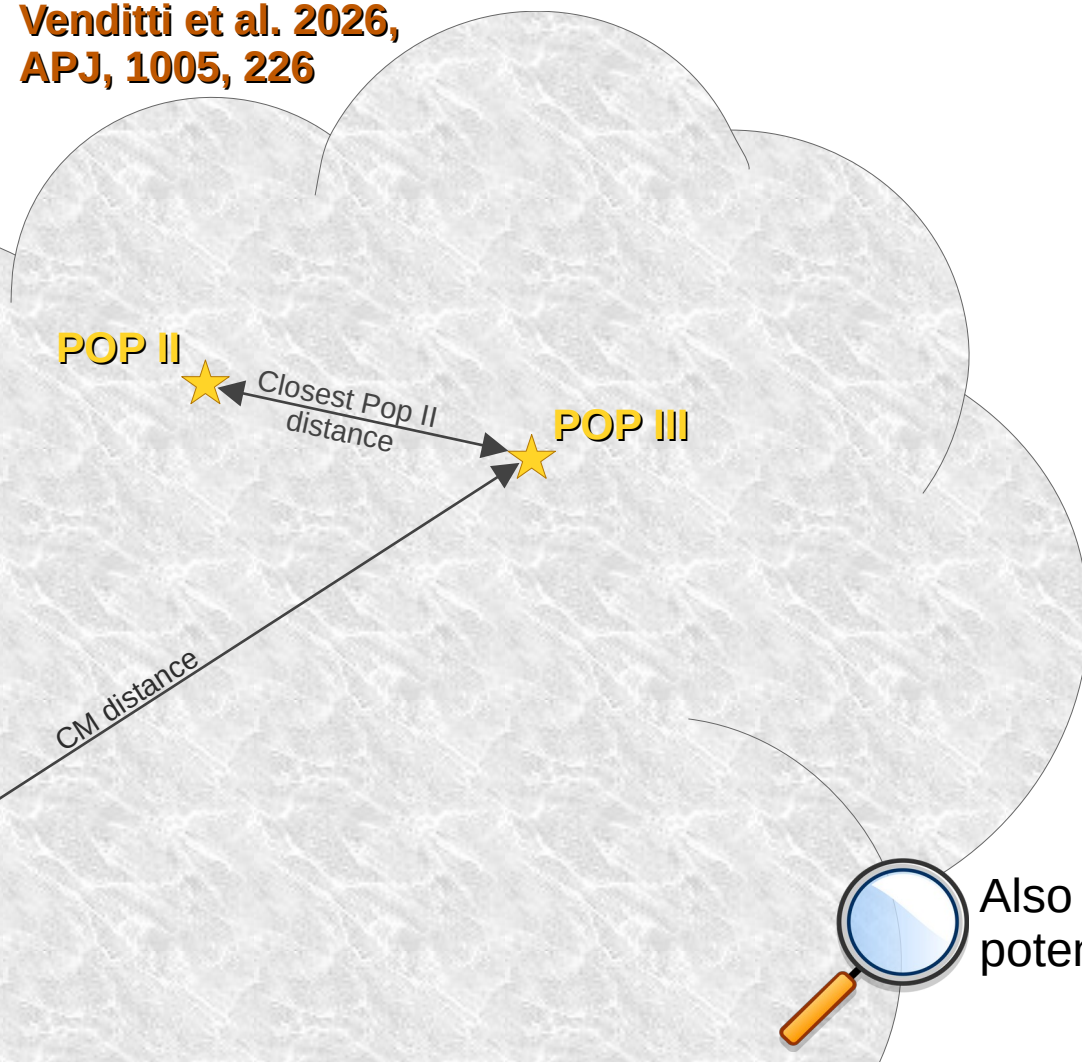
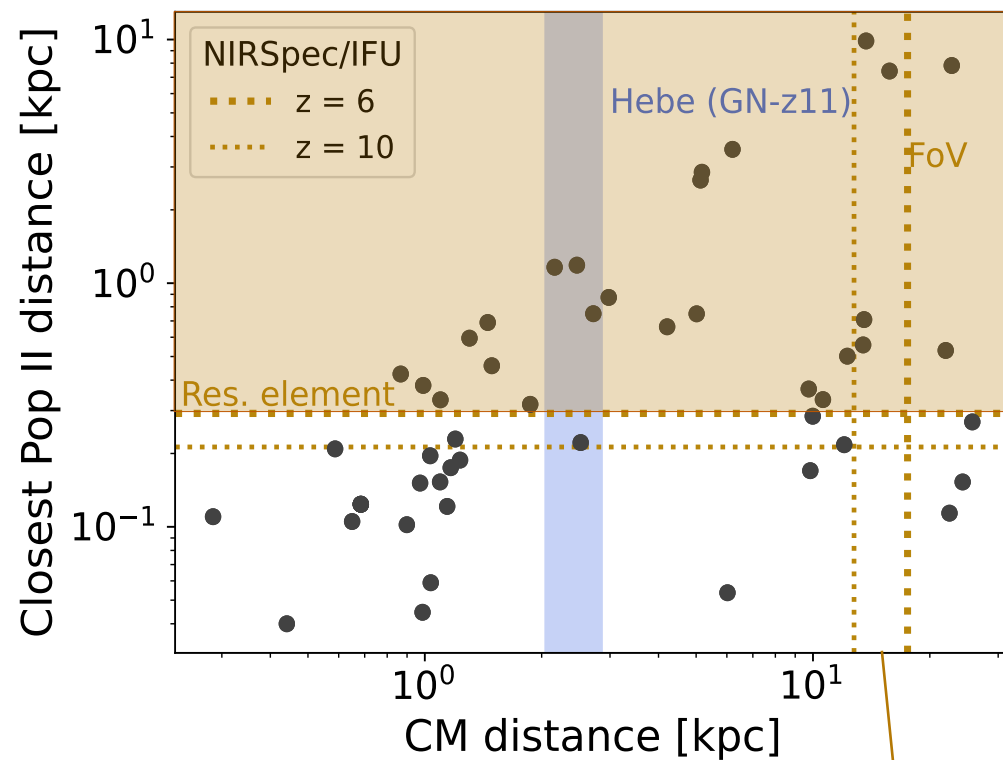
HeII emission from massive Pop III hosts

Venditti et al. 2026,
APJ, 1005, 226



Spatial resolution: a powerful ally

Venditti et al. 2026,
APJ, 1005, 226



Also Venditti et al. (2024b), APJL, 973, L12 on potential misses due to **insufficient Field-of-View**

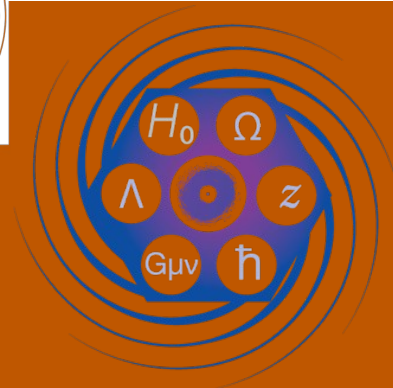
(1) **Early times / low masses** → Pop III SF **down to the EoR**, even in **massive (enriched) halos**
 Venditti et al. (2023), MNRAS, 522, 3809 Venditti et al. (2024a), MNRAS, 527, 5102 Venditti et al. (2024b), APJL, 973, L12
 Venditti et al. (2025), APJ, 994, 32 Jeong et al. (2026), APJ, 1006, 89 Venditti, Ventura et al., prep.

(2) **No metals** → **Metal-line emission** does not exclude the presence of a Pop III component in high-z galaxies
 Venditti et al. (2026), APJ, 1005, 226

(3) **Which way forward?** → - Other tracers, e.g. strong **Hell lines**, weakly confused by standard Pop II
 - **Spatial resolution** is our ally!

Check out our review!

Venditti et al. (2026),
 OJA, arXiv:2607.00167



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Thank you for
 your attention!

Theoretical Astroparticle and Cosmology
 Symposium in Texas (TACOS)

October 23, 2026



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Finanziato
 dall'Unione europea
 NextGenerationEU



Alessandra Venditti
 Cosmic Frontier Center
alessandra.venditti@utexas.edu