

The Establishment of an Early Metropolis

Discovery of an Extreme Protocluster at $z > 7$

Thomas Herard-Demanche

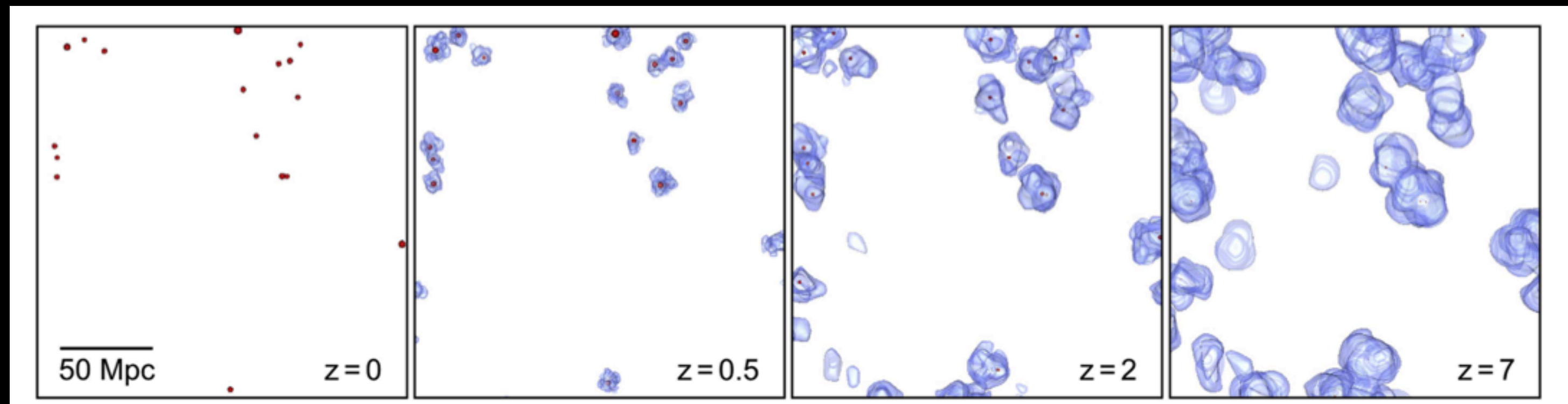
Supervisors: Rychard Bouwens & Jackie Hodge

Collaborators for this project: Sander Schouws & Lucie Rowland

Protoclusters: accelerators of early galaxy build-up

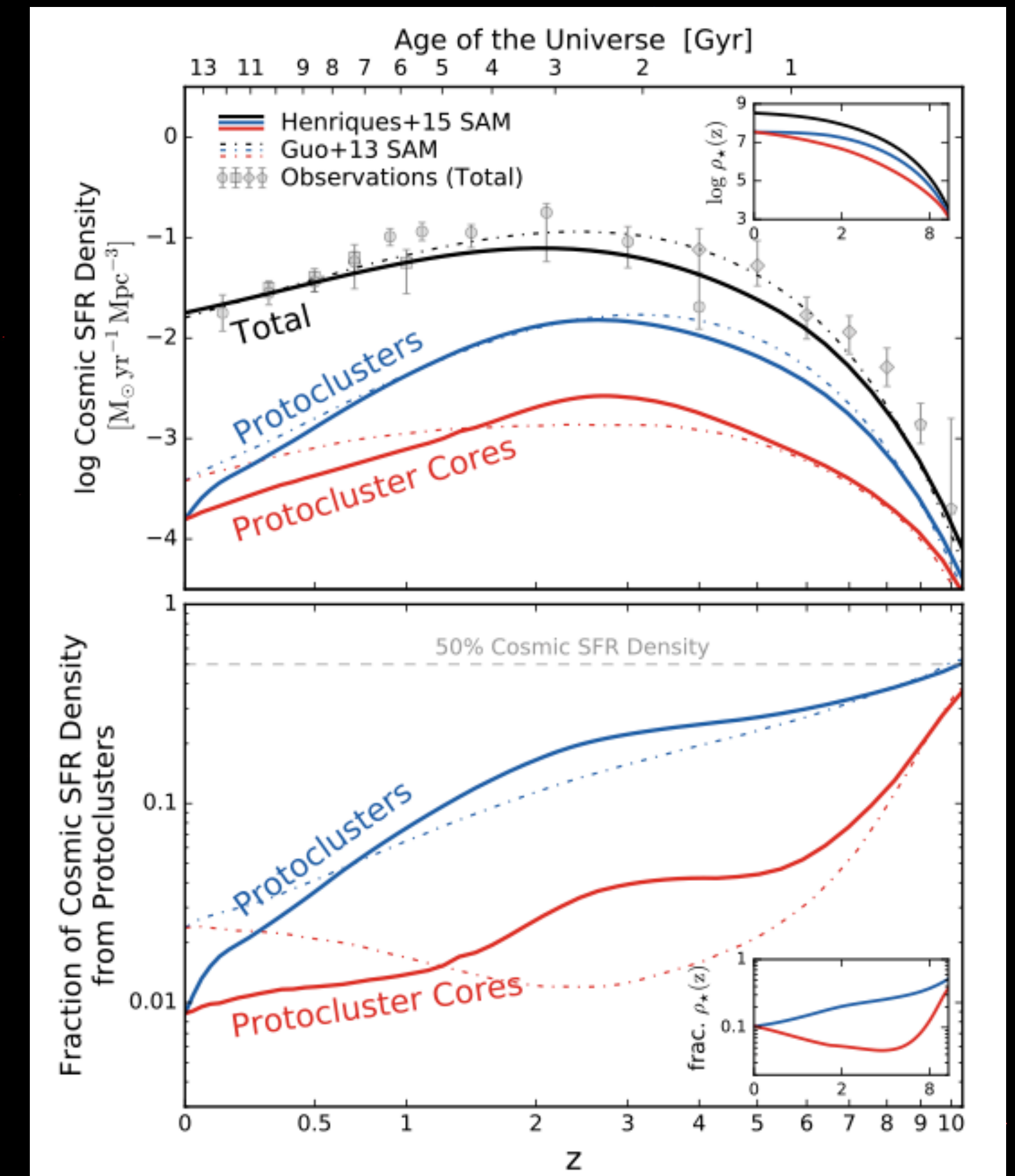
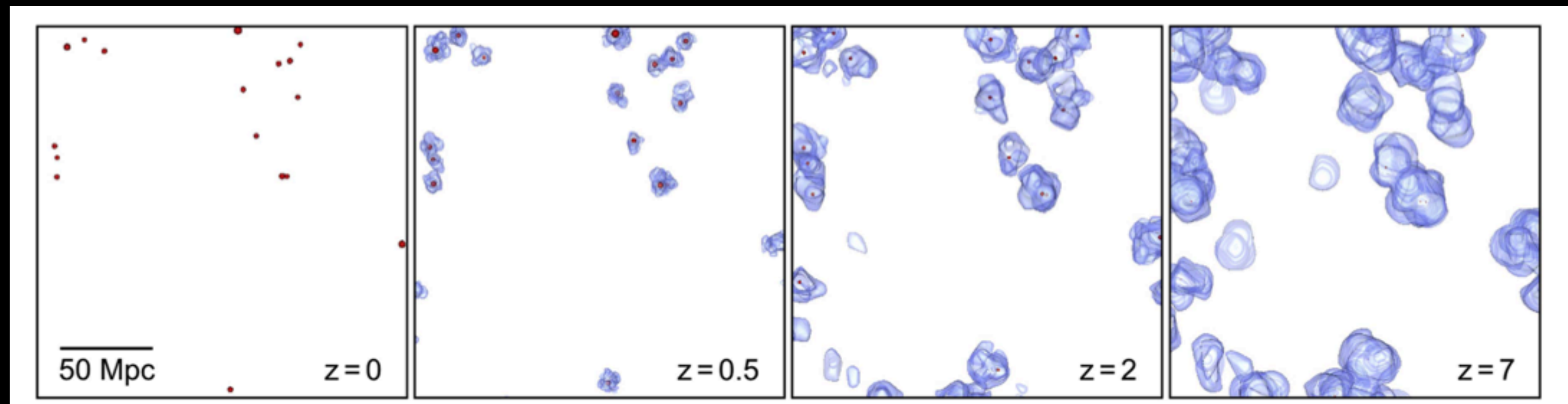
- Cosmic volume occupied by PCs grows $\sim 3\times$ from $z=0$ to $z=7$
- PCs contribute $30\text{--}50\%$ of cosmic SF at $z\geq 7$ (Chiang+17)
- More massive, star-forming and dusty than field galaxies

-> Unique laboratories to study how massive galaxies grow

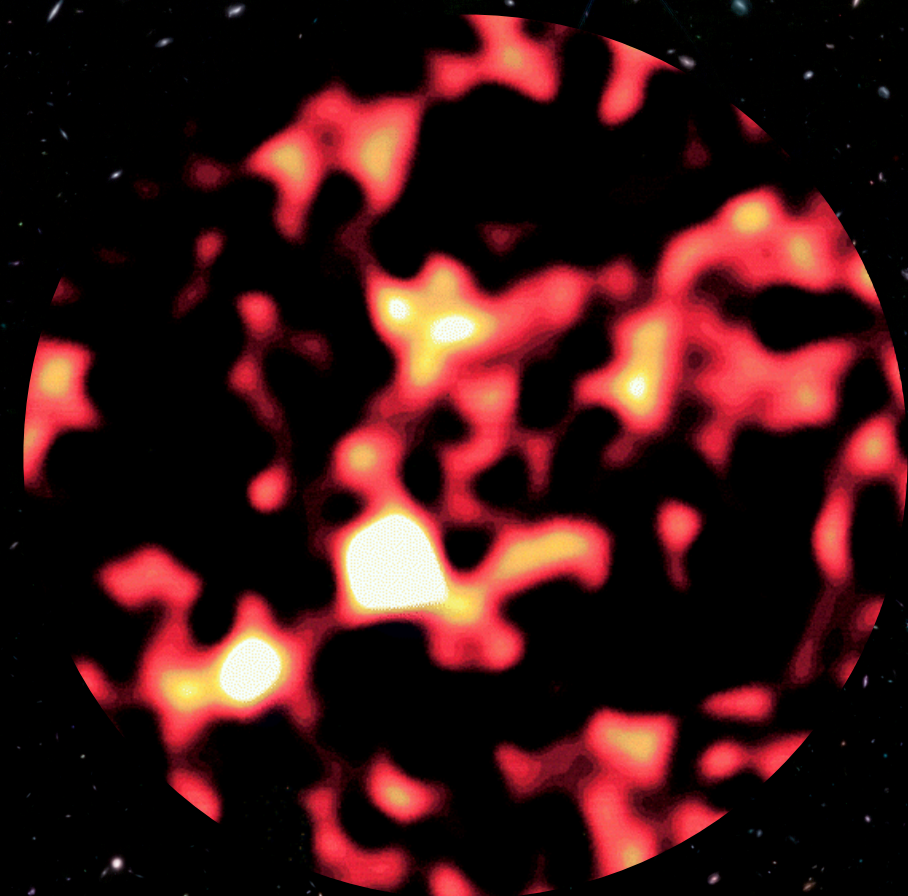


Protoclusters: accelerators of early galaxy build-up

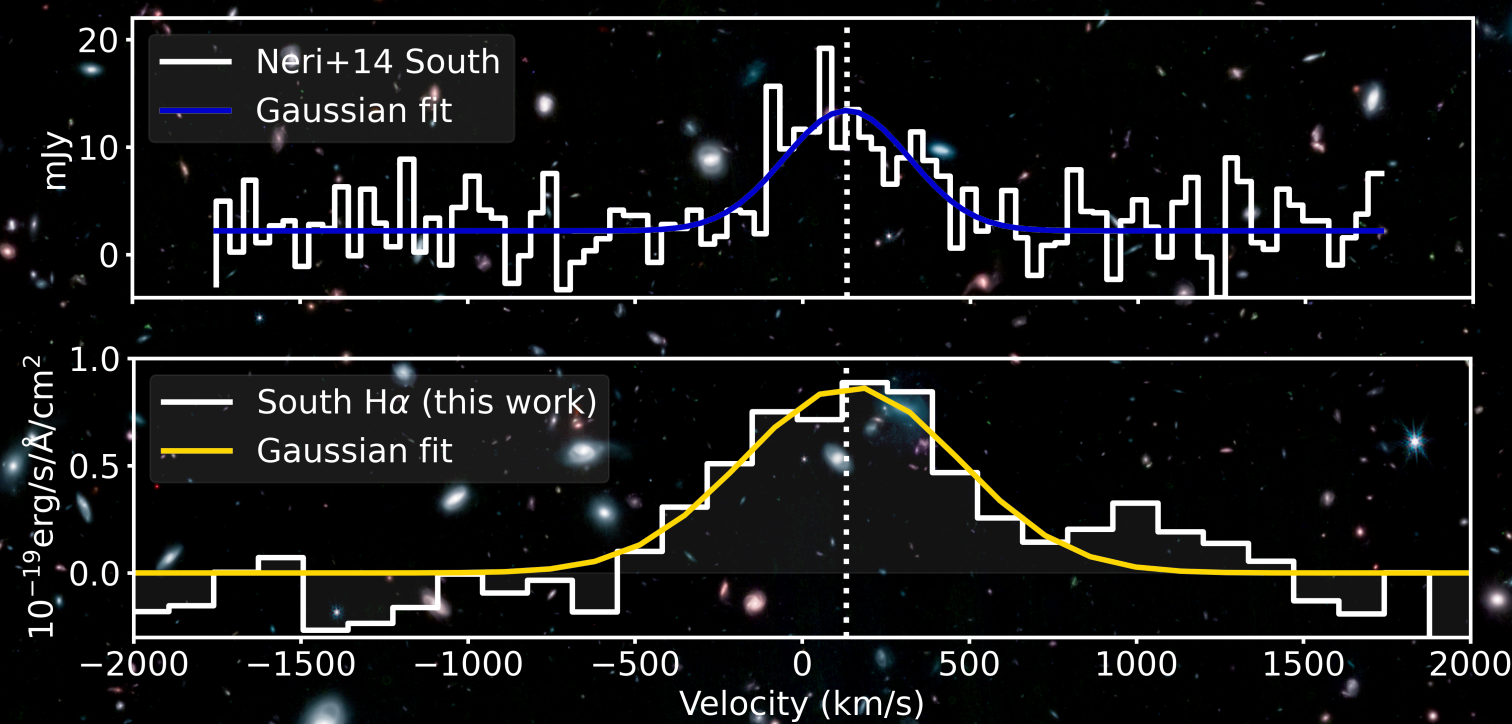
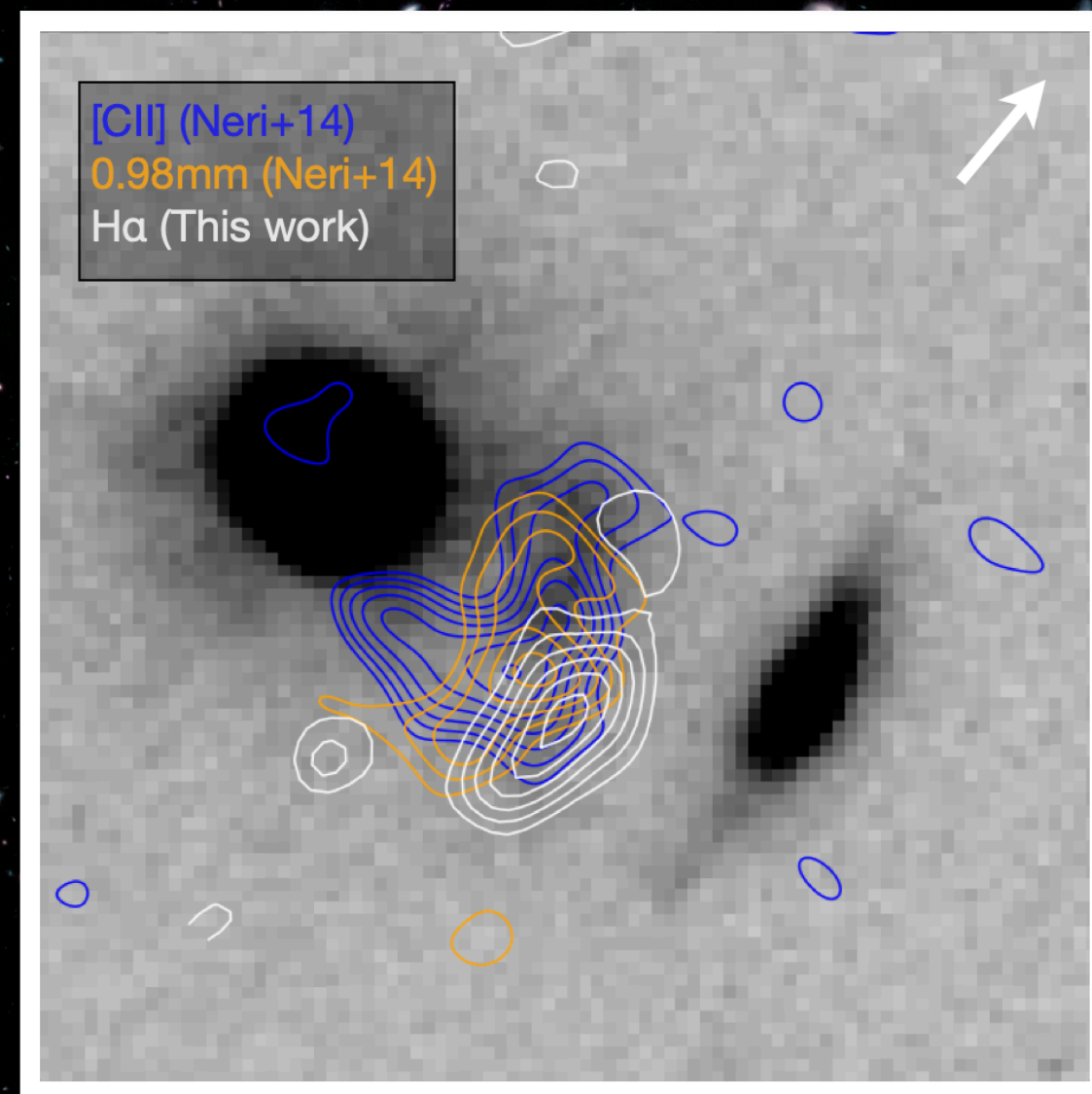
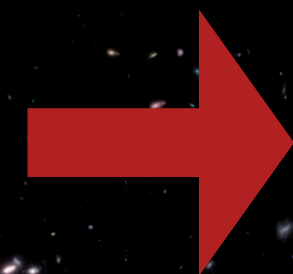
- Cosmic volume occupied by PCs grows $\sim 3\times$ from $z=0$ to $z=7$
 - PCs contribute 30–50% of cosmic SF at $z \geq 7$ (Chiang+17)
 - More massive, star-forming and dusty than field galaxies
- > Unique laboratories to study how massive galaxies grow



Detection of H α in HDF850.1

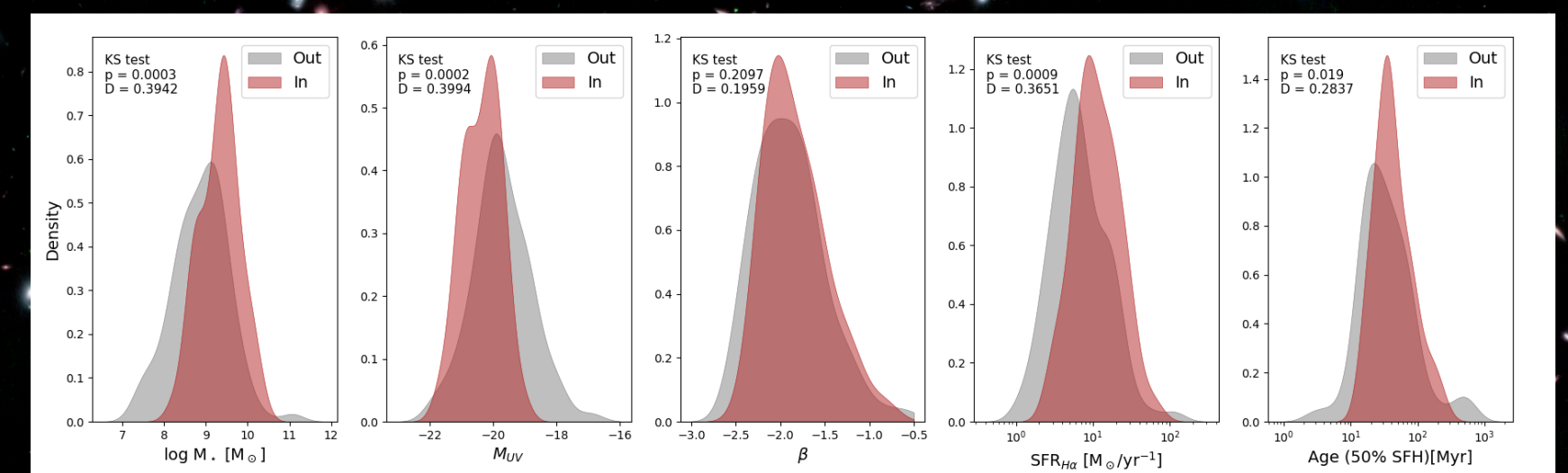
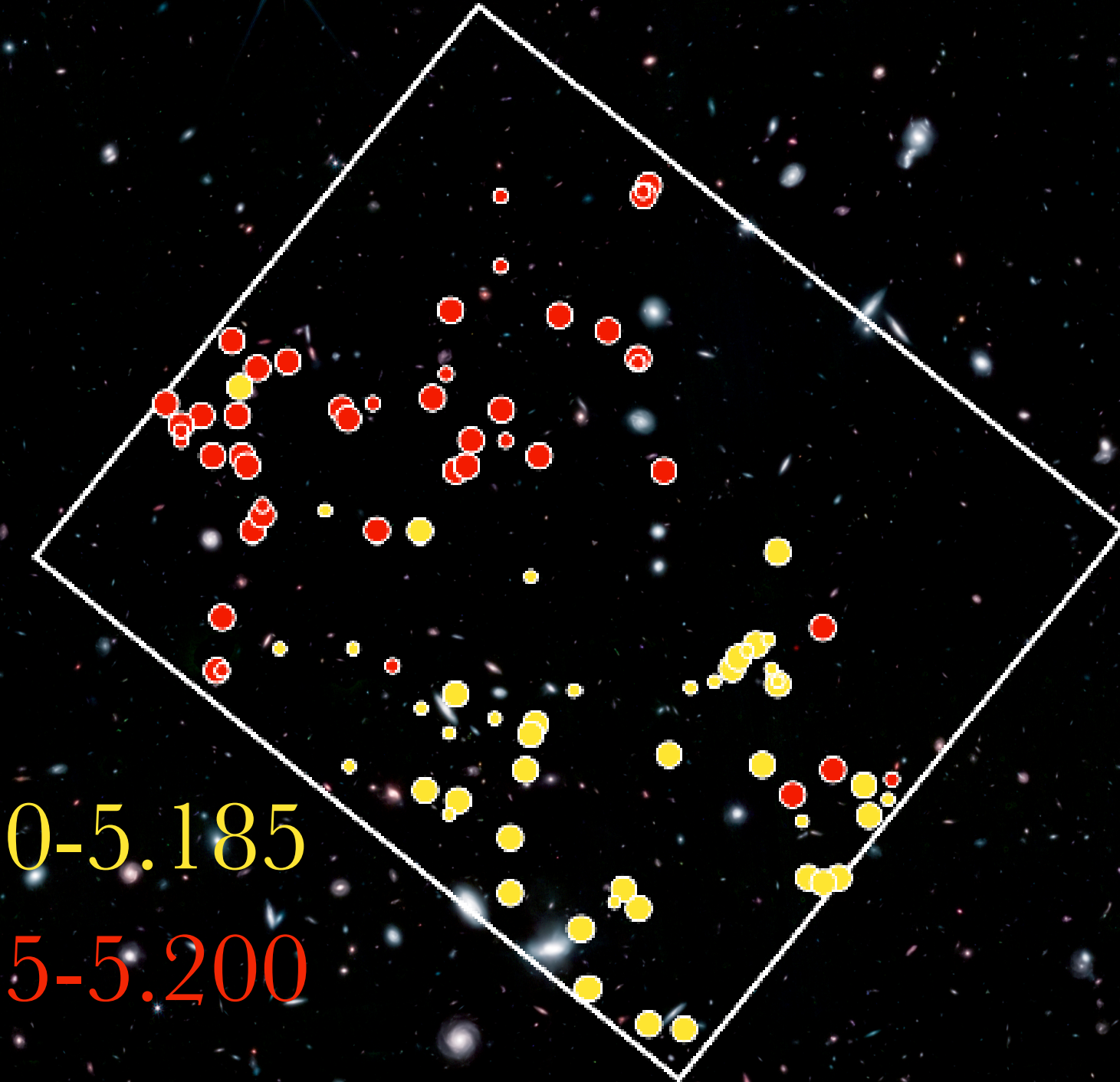


Hughes+98



☉ 5.170-5.185

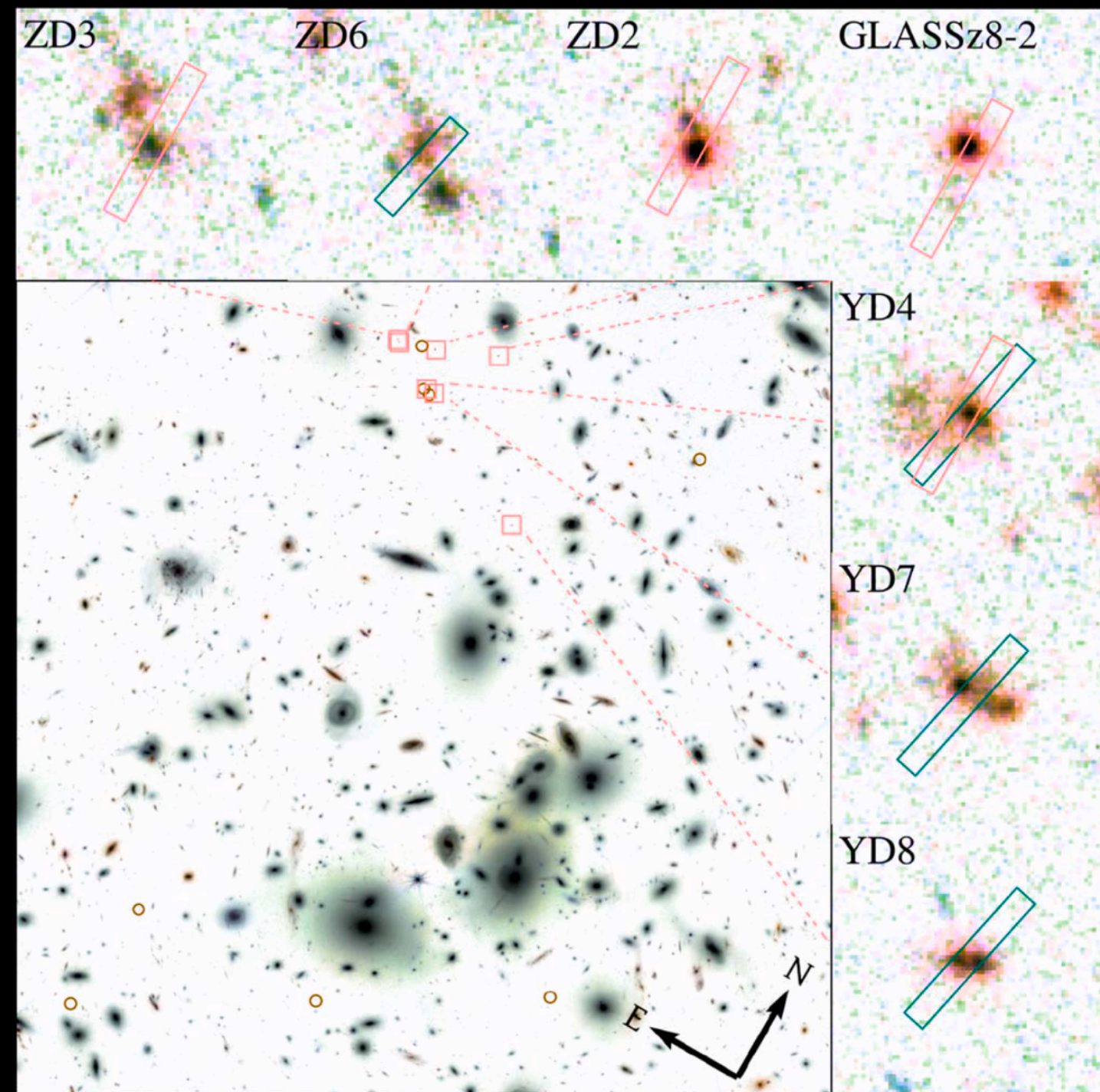
☉ 5.185-5.200



Herard-Demanche+25 (see also Sun+24)

PCs confirmed at higher and higher z

- A2744-z7p9OD
- 7 spectroscopically confirmed sources
- Grown to **23 confirmed members** (Witten+25)

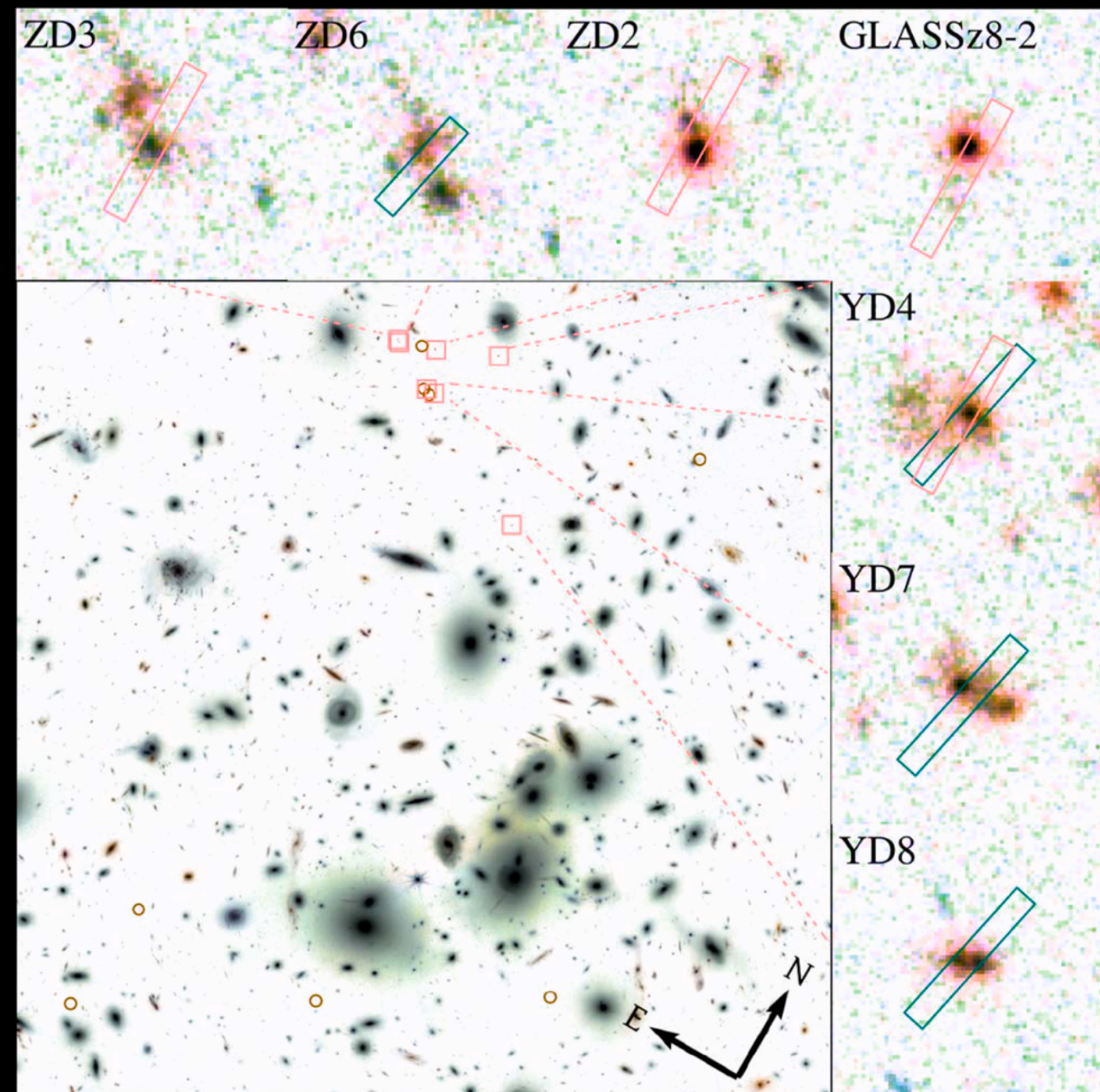


Morishita+23

Fudamoto+25

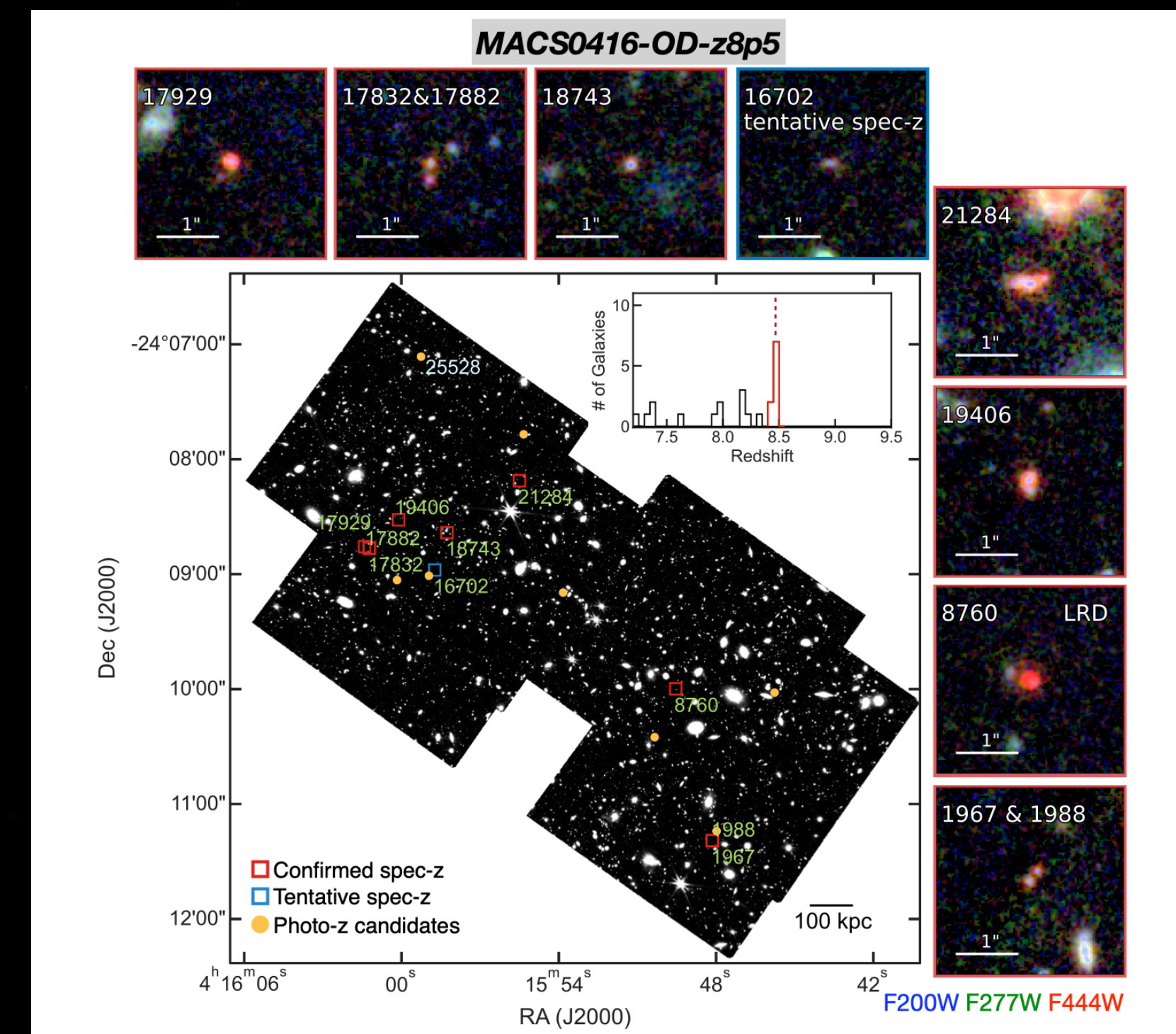
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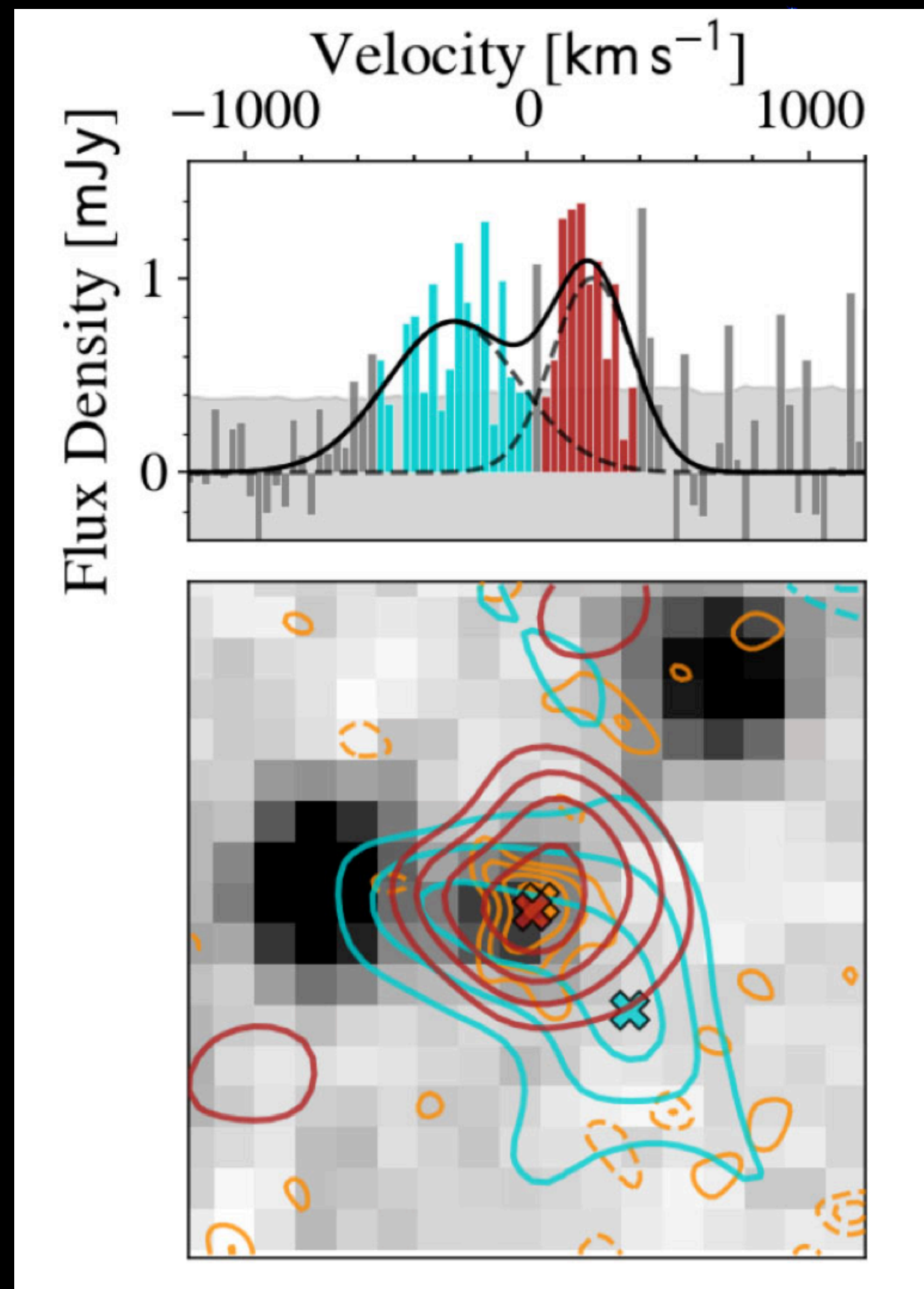
Morishita+23

- MACS0416-OD-z8p5
- 9 spectroscopically confirmed sources $z \sim 8.47$



Fudamoto+25

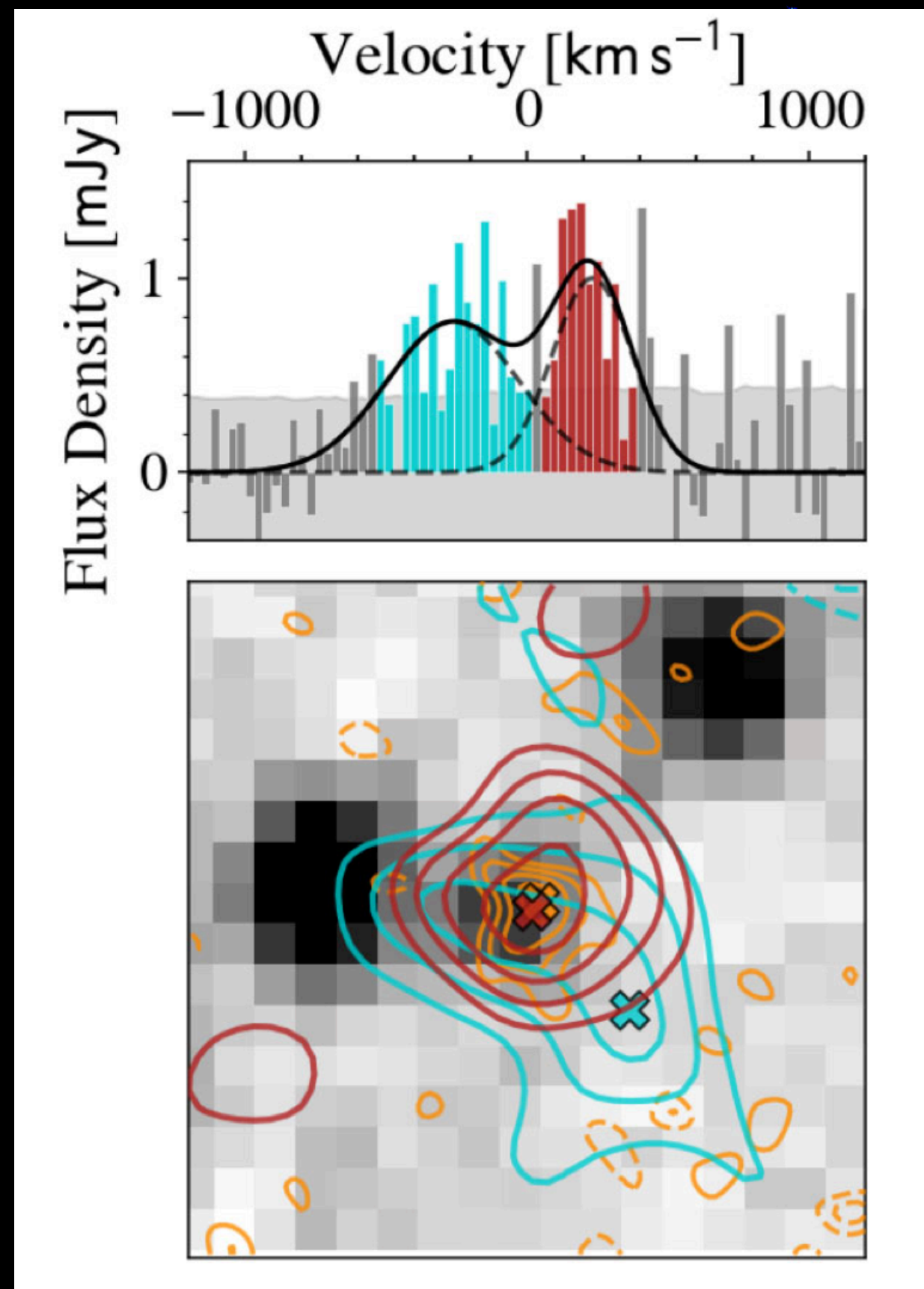
REBELS-12: An Extreme Galaxy at $z = 7.35$



Algera+24

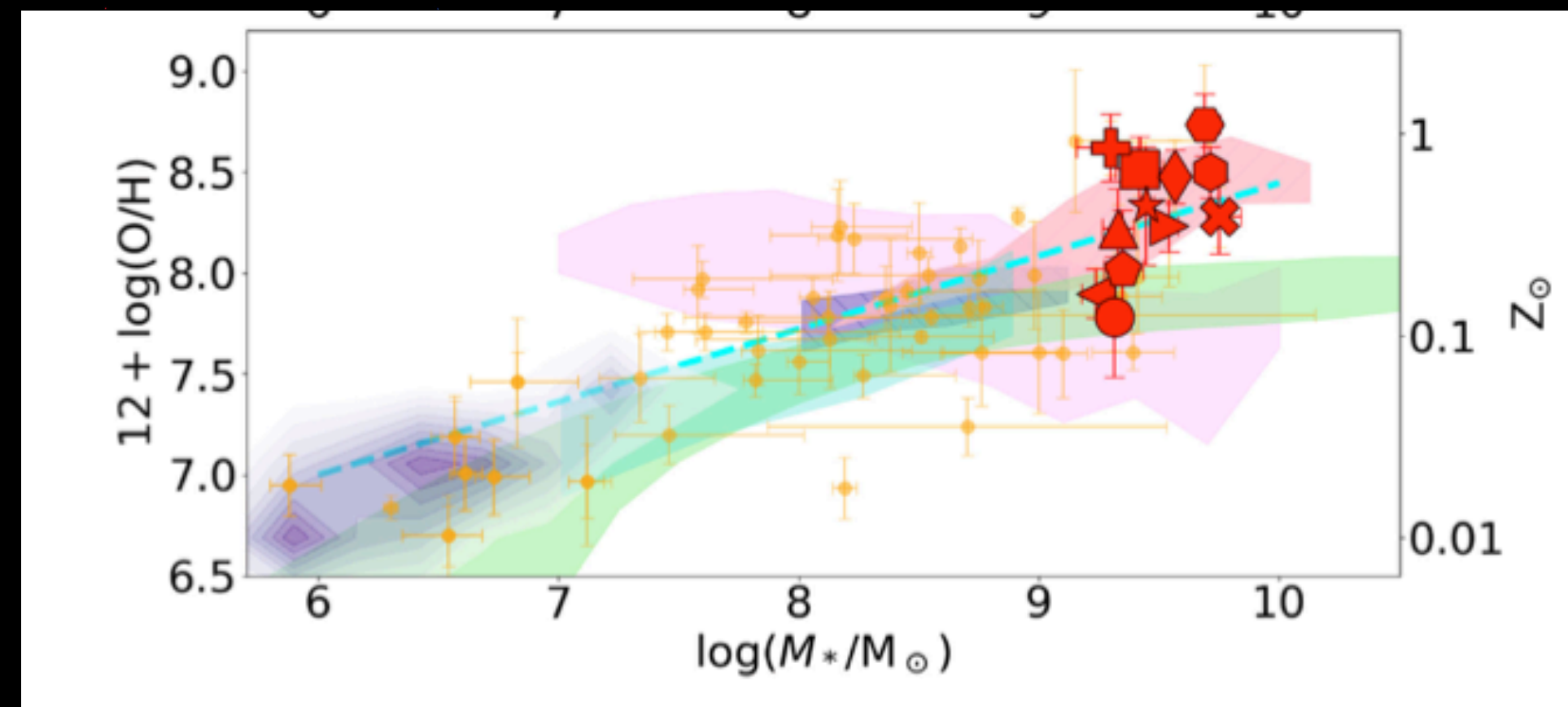
- Double peaked [CII] emission + dust detection
- **Merger?**
 - UV bright component emitting in [CII] and [OIII]88um
 - **UV dark** component only visible in [CII]

REBELS-12: An Extreme Galaxy at $z = 7.35$



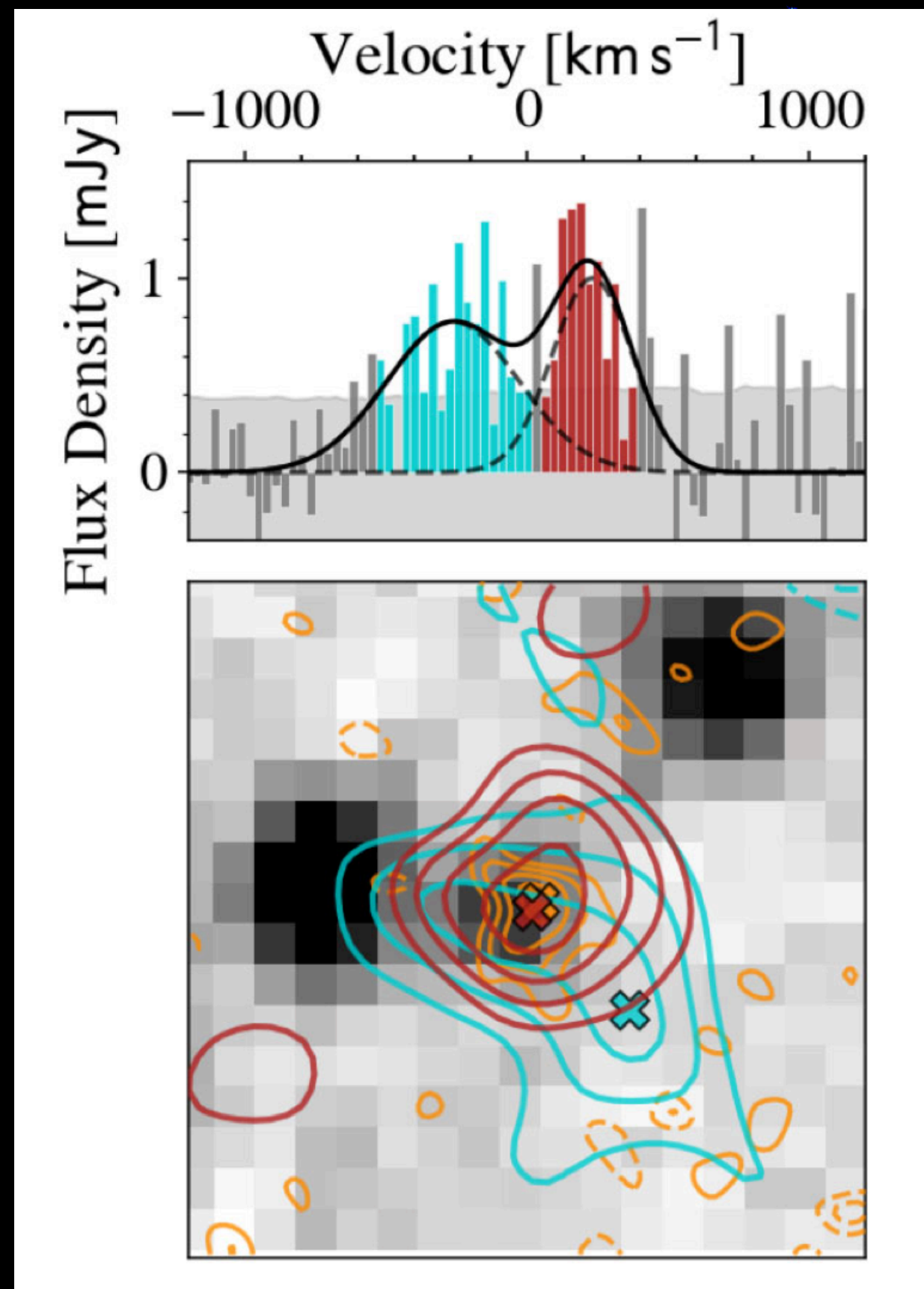
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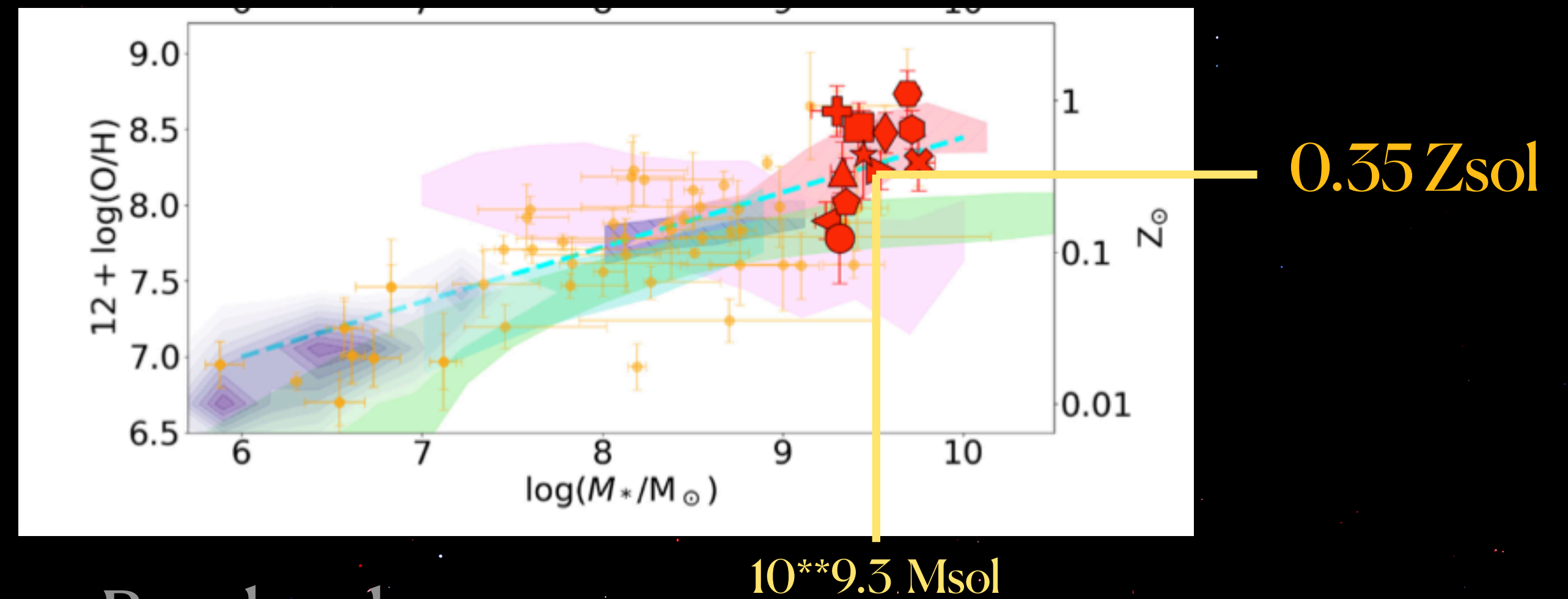
Rowland+25

REBELS-12: An Extreme Galaxy at $z = 7.35$



Algera+24

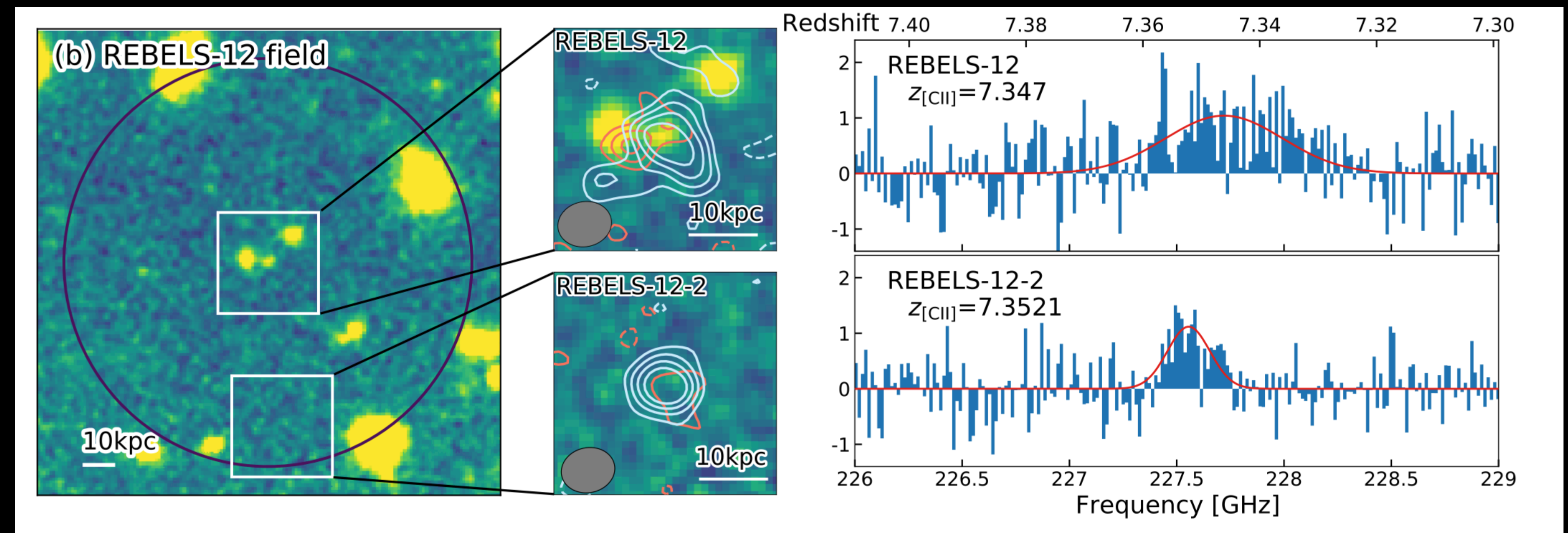
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Rowland+25

A Neighbour in Serendipity

- HST-dark companion to REBELS-12 at the same redshift
- [CII]-detected just ~ 50 pkpc away
- Also later revealed to be NIRCam dark



Fudamoto+21

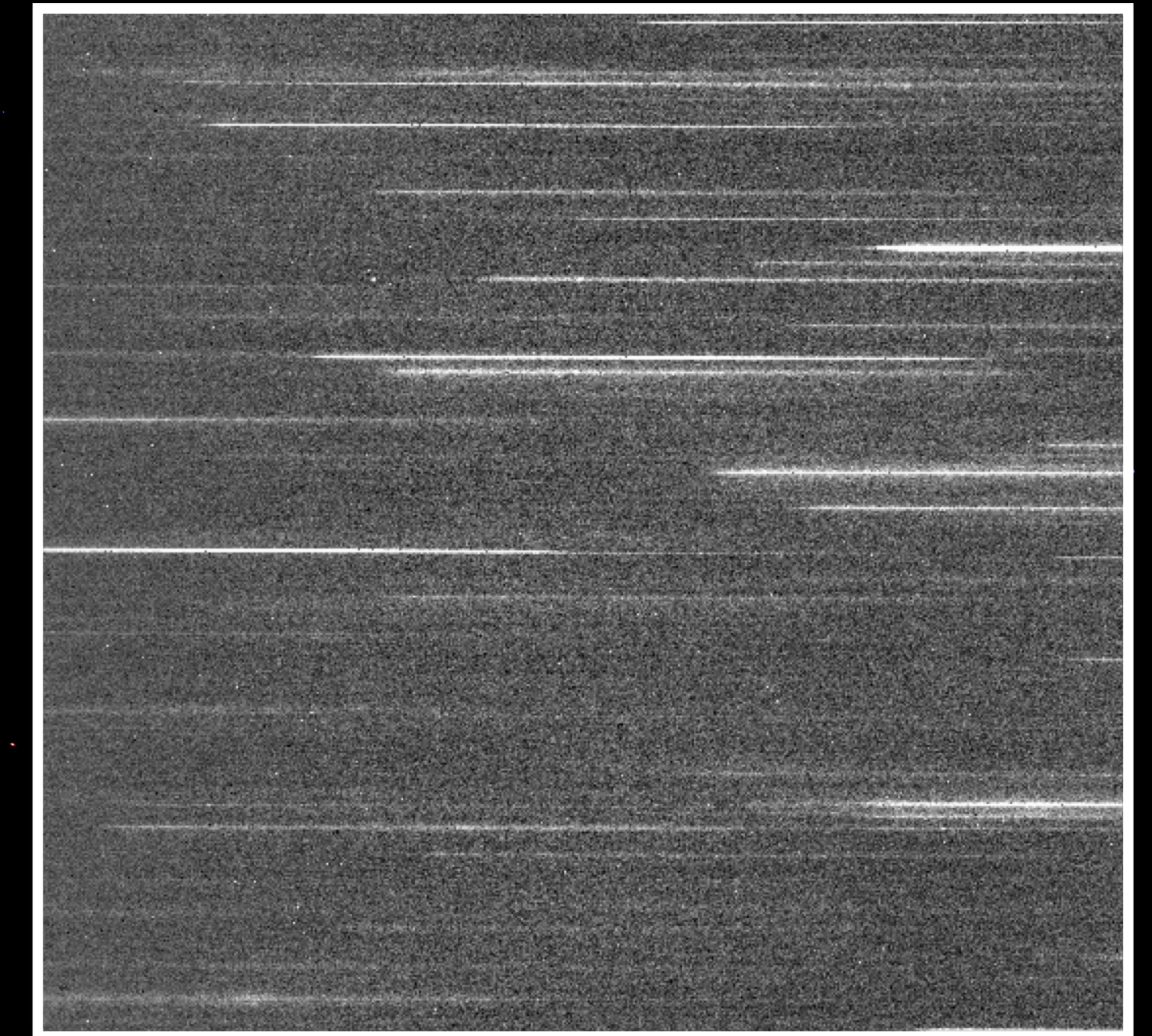
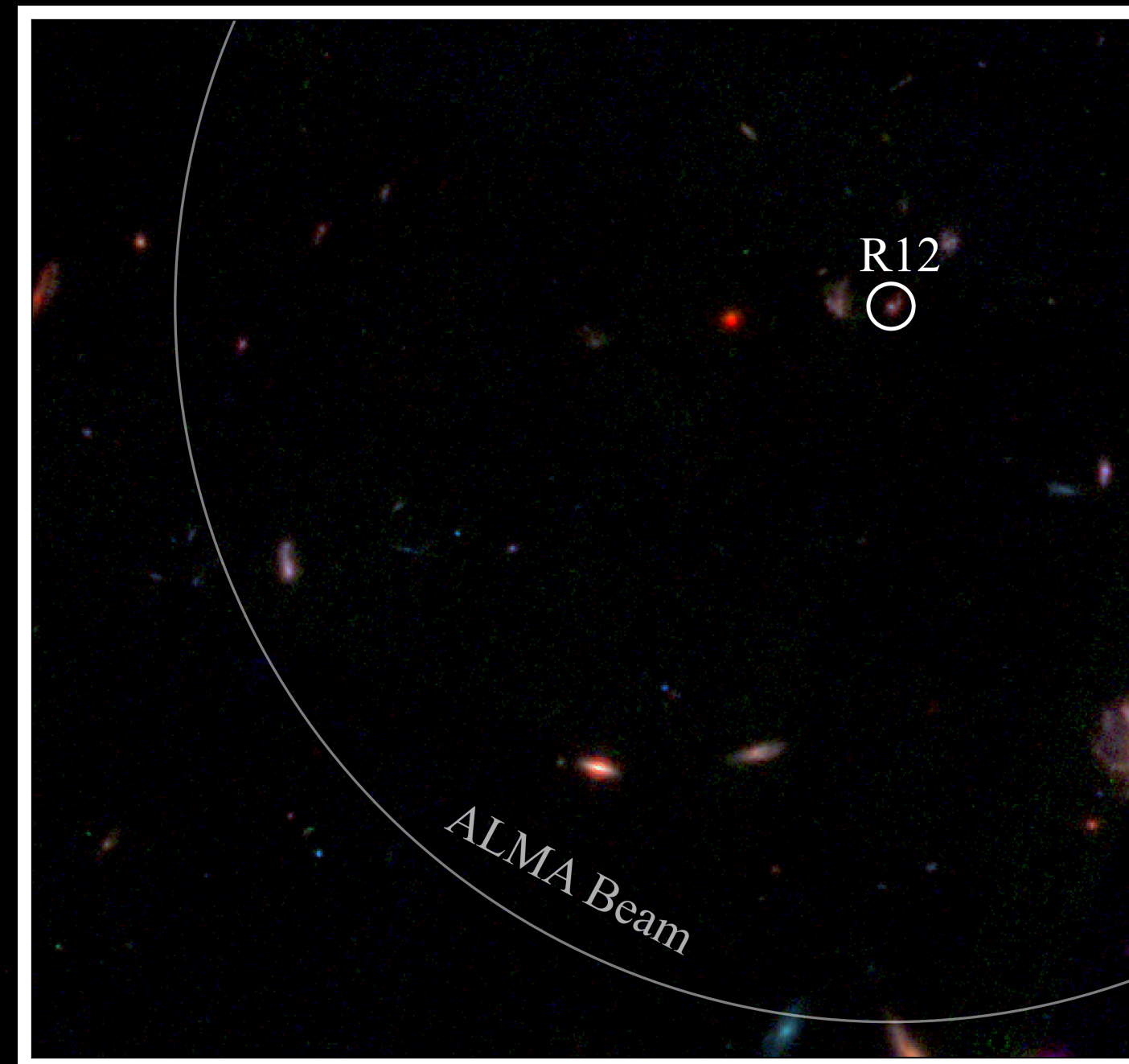
A Crowded Neighbourhood



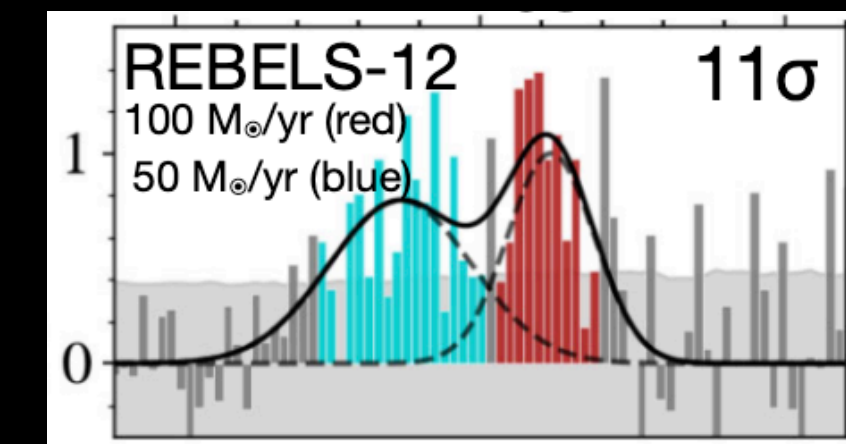
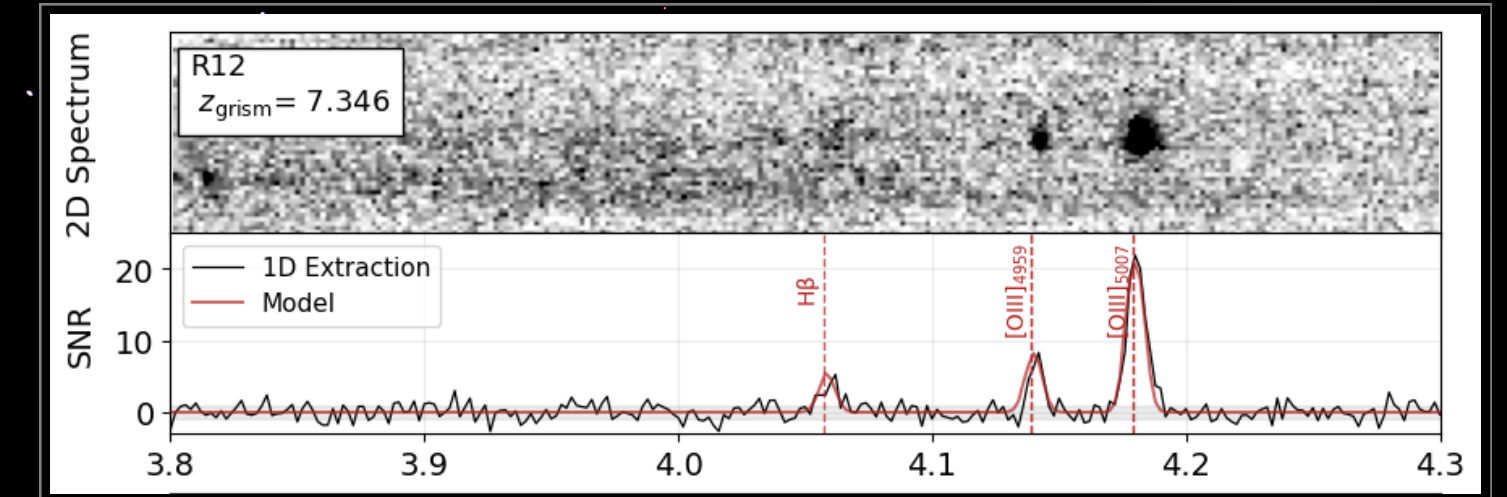
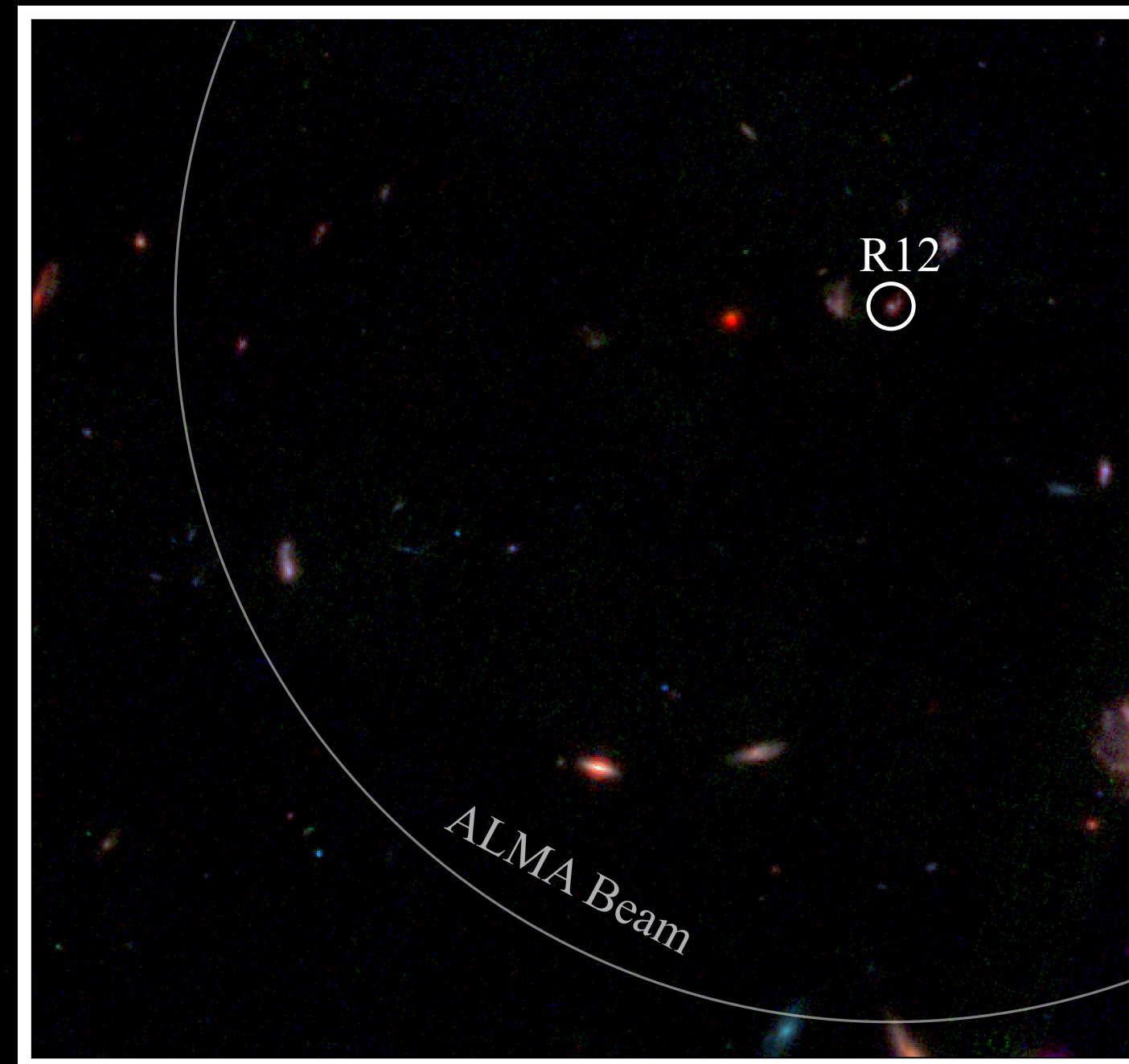
GO6480

(PI: Schouws, S)

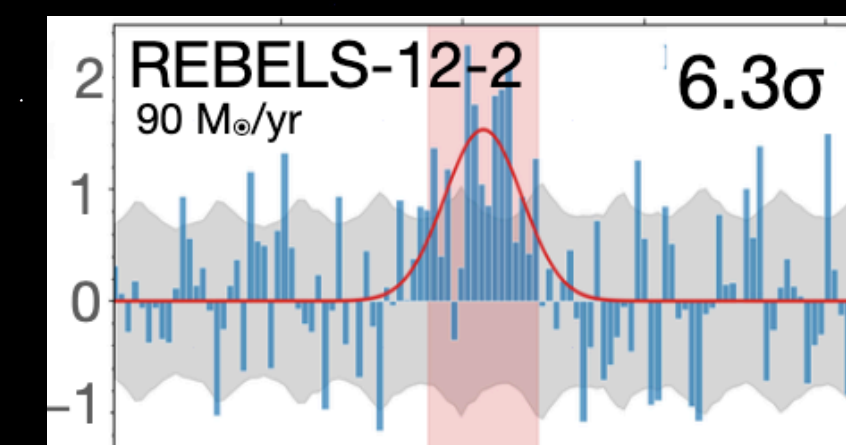
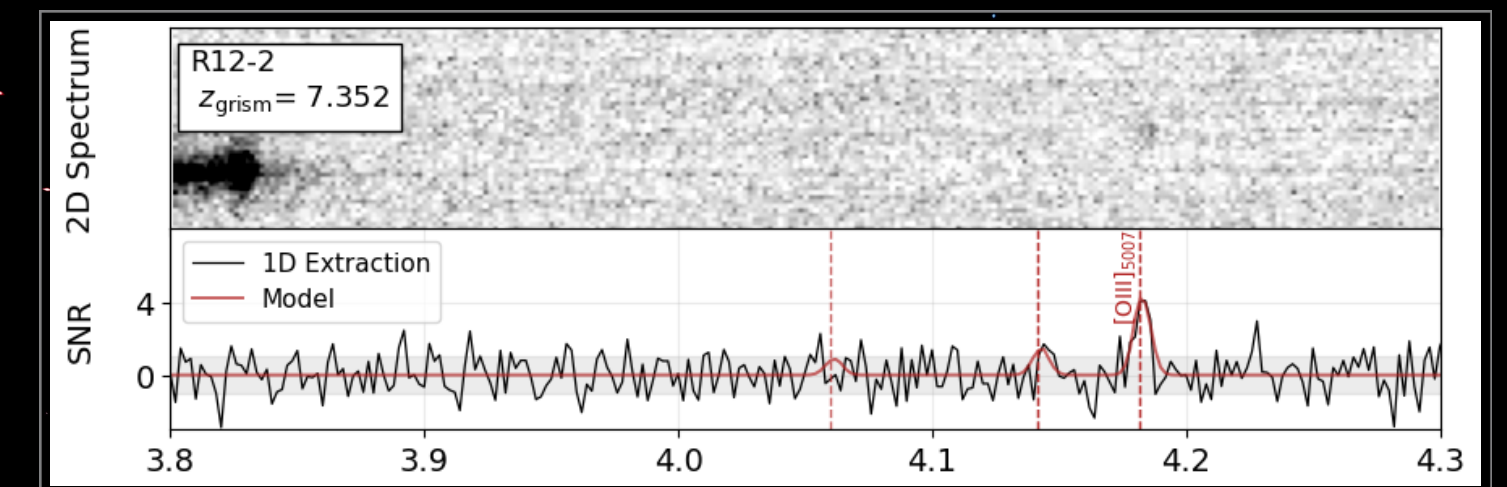
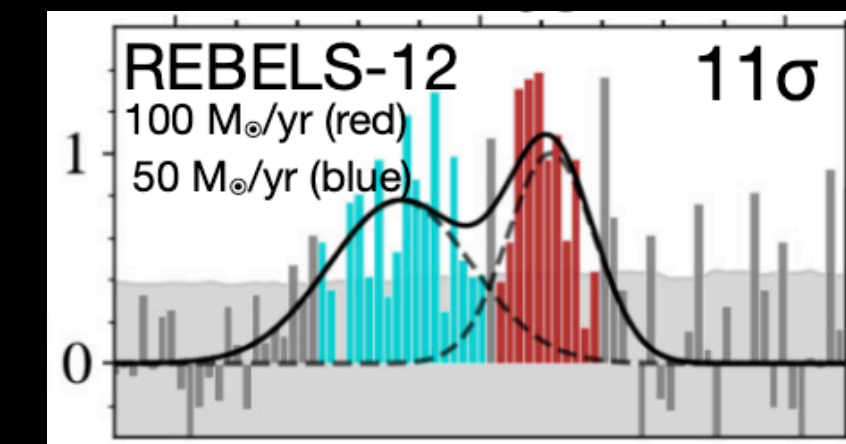
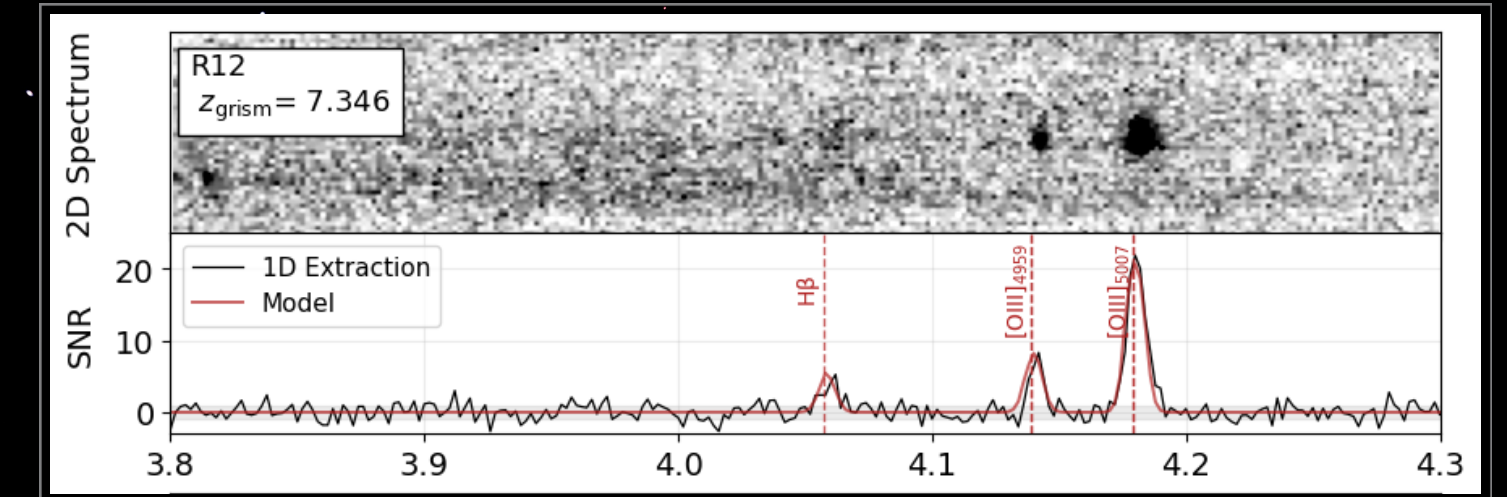
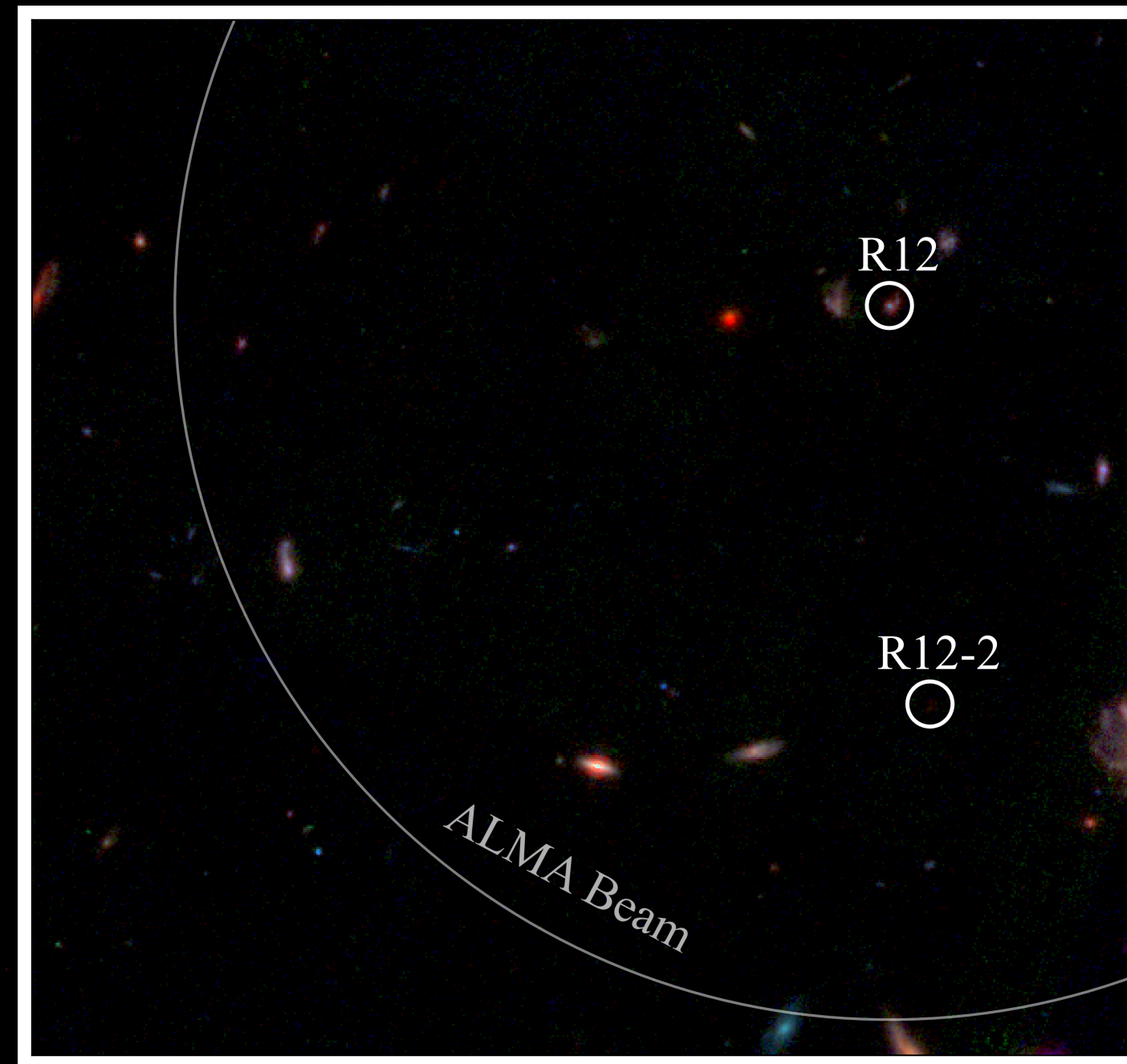
Revealing the Lifecycle and
Environment of Massive $z\sim 7$ Galaxies



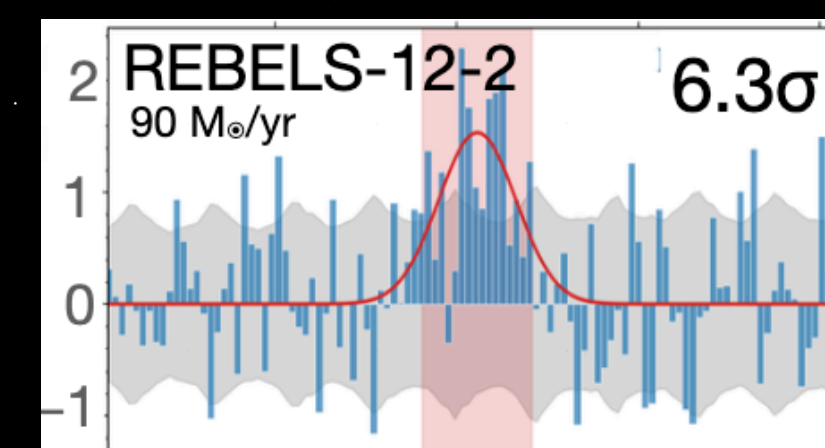
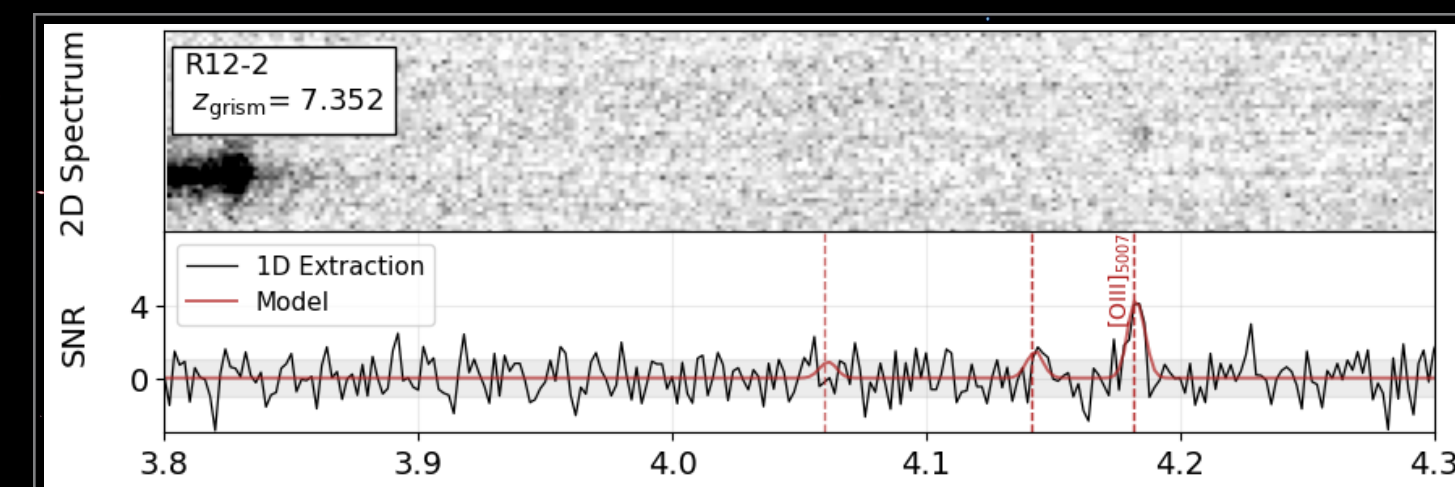
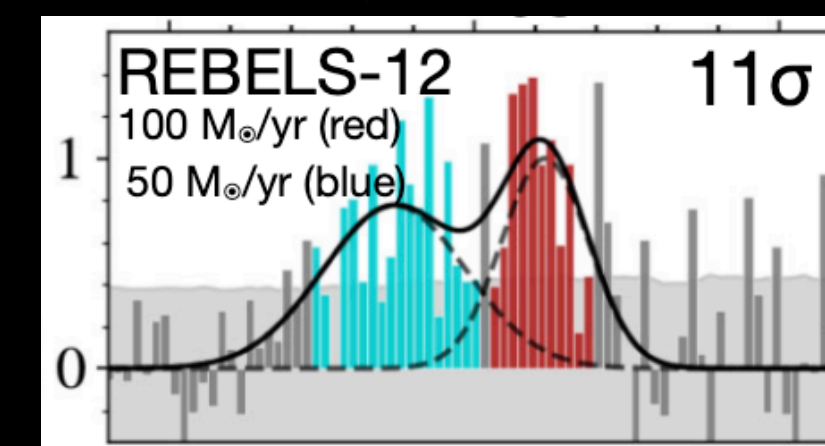
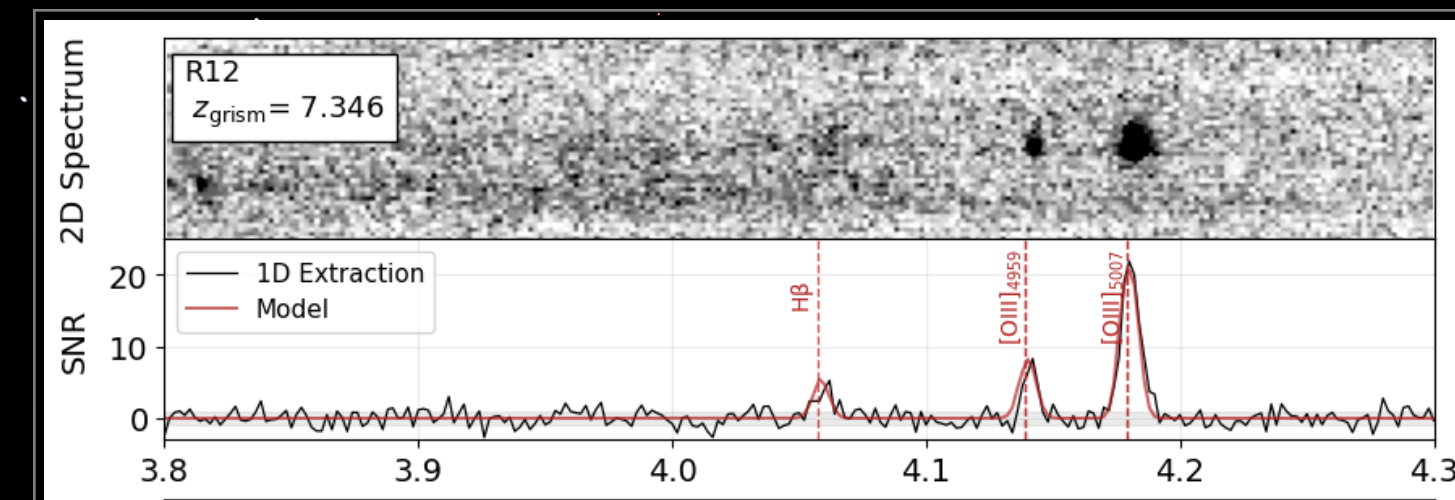
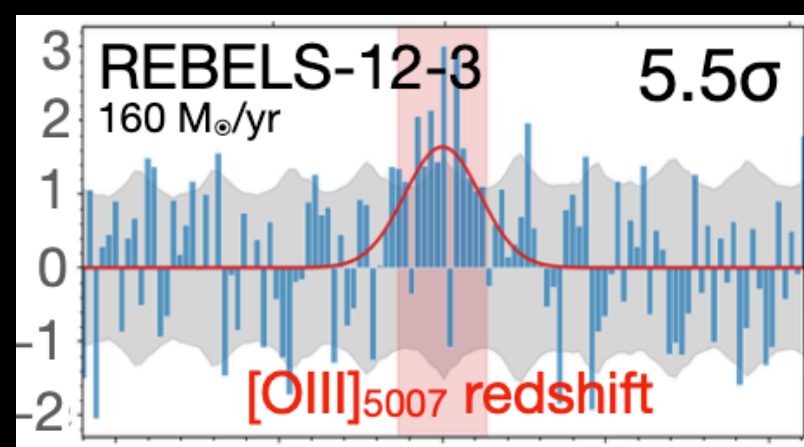
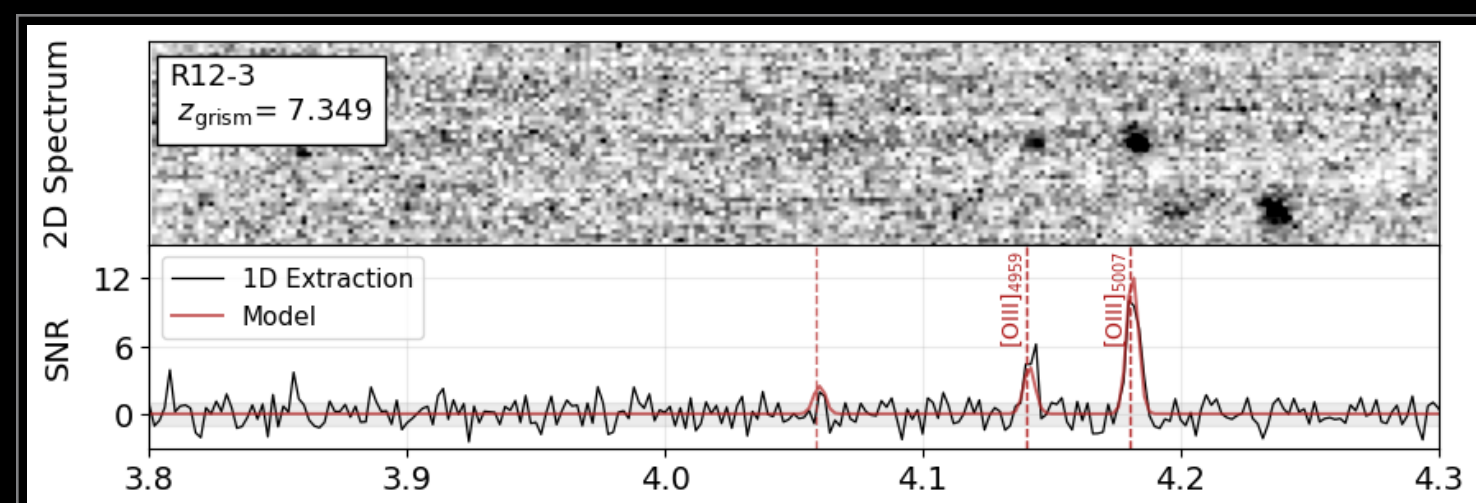
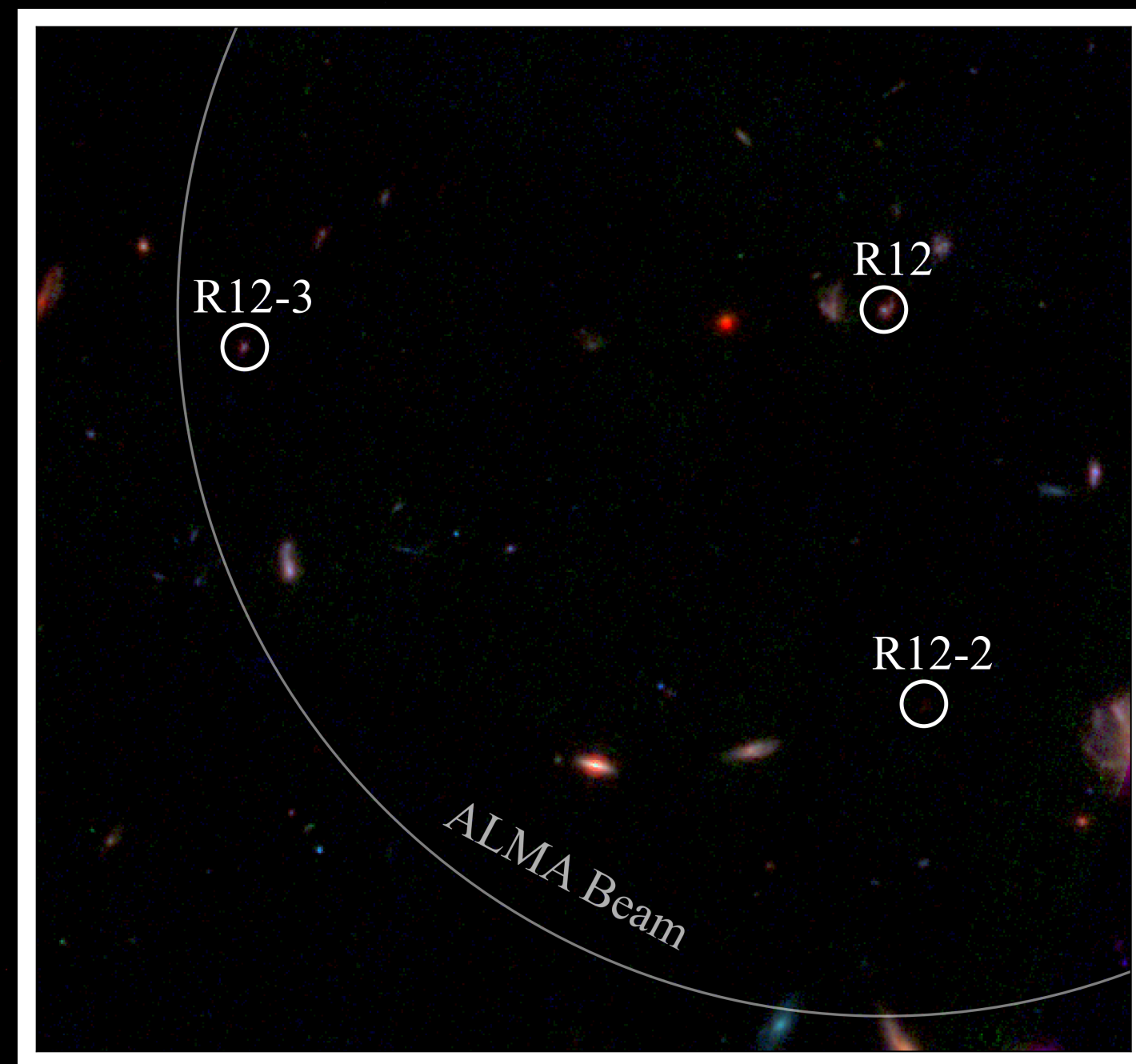
A Crowded Neighbourhood

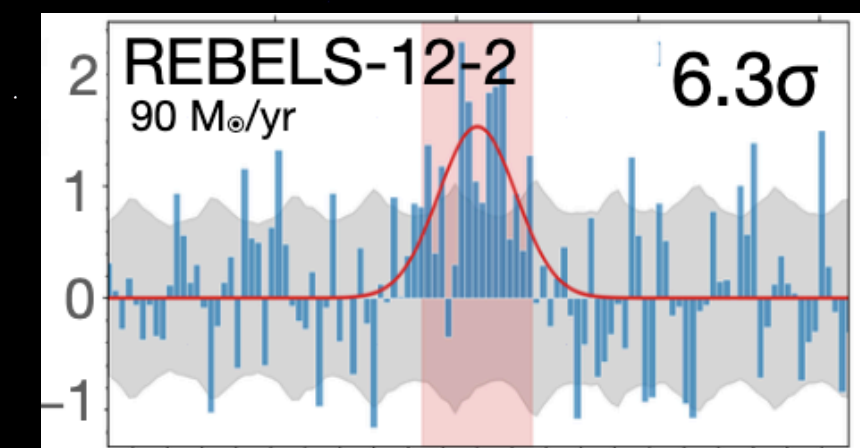
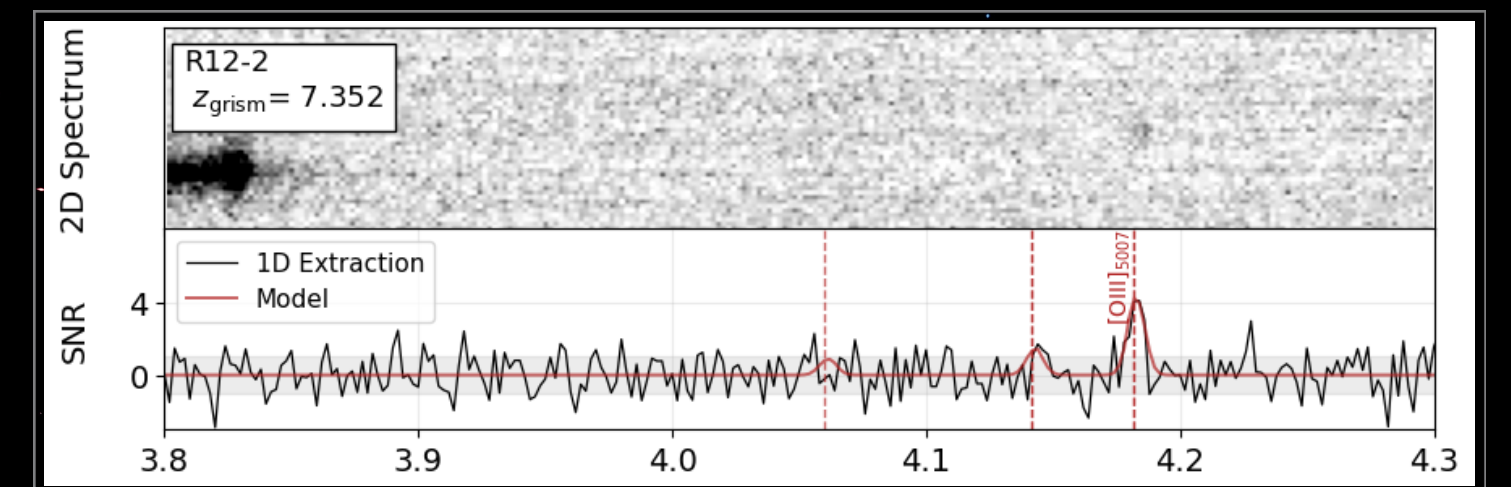
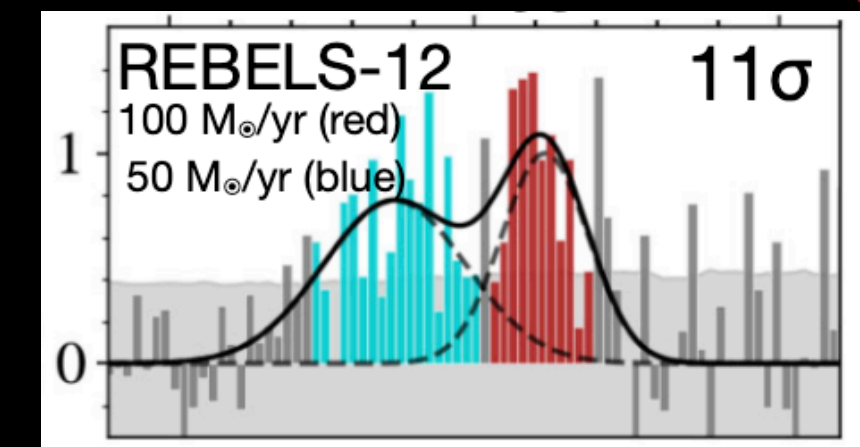
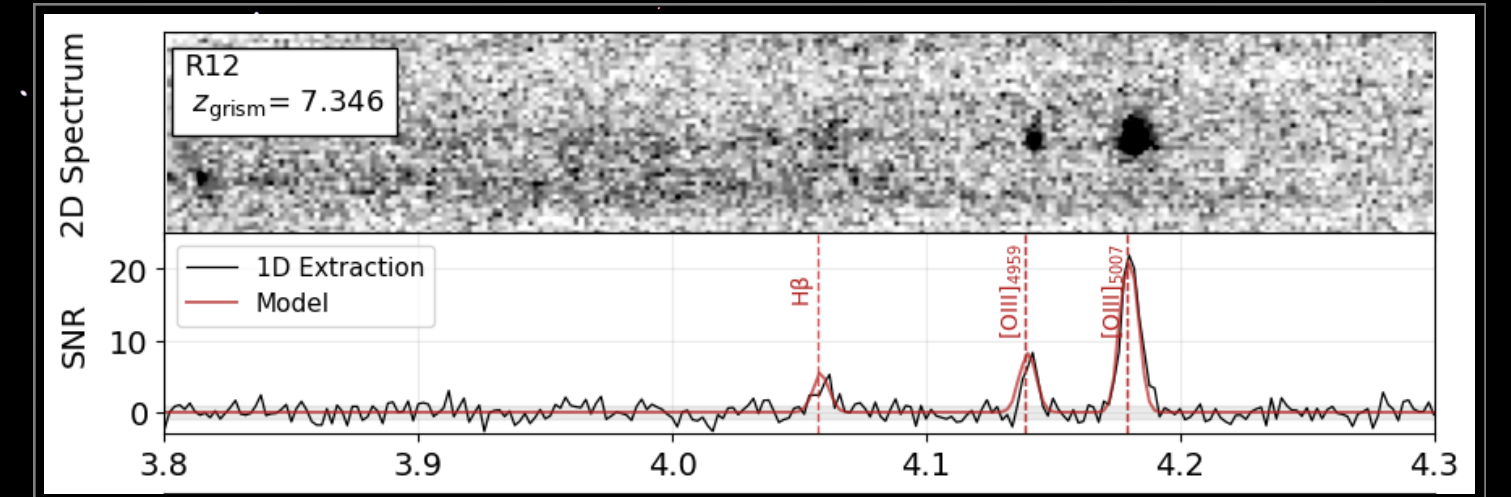
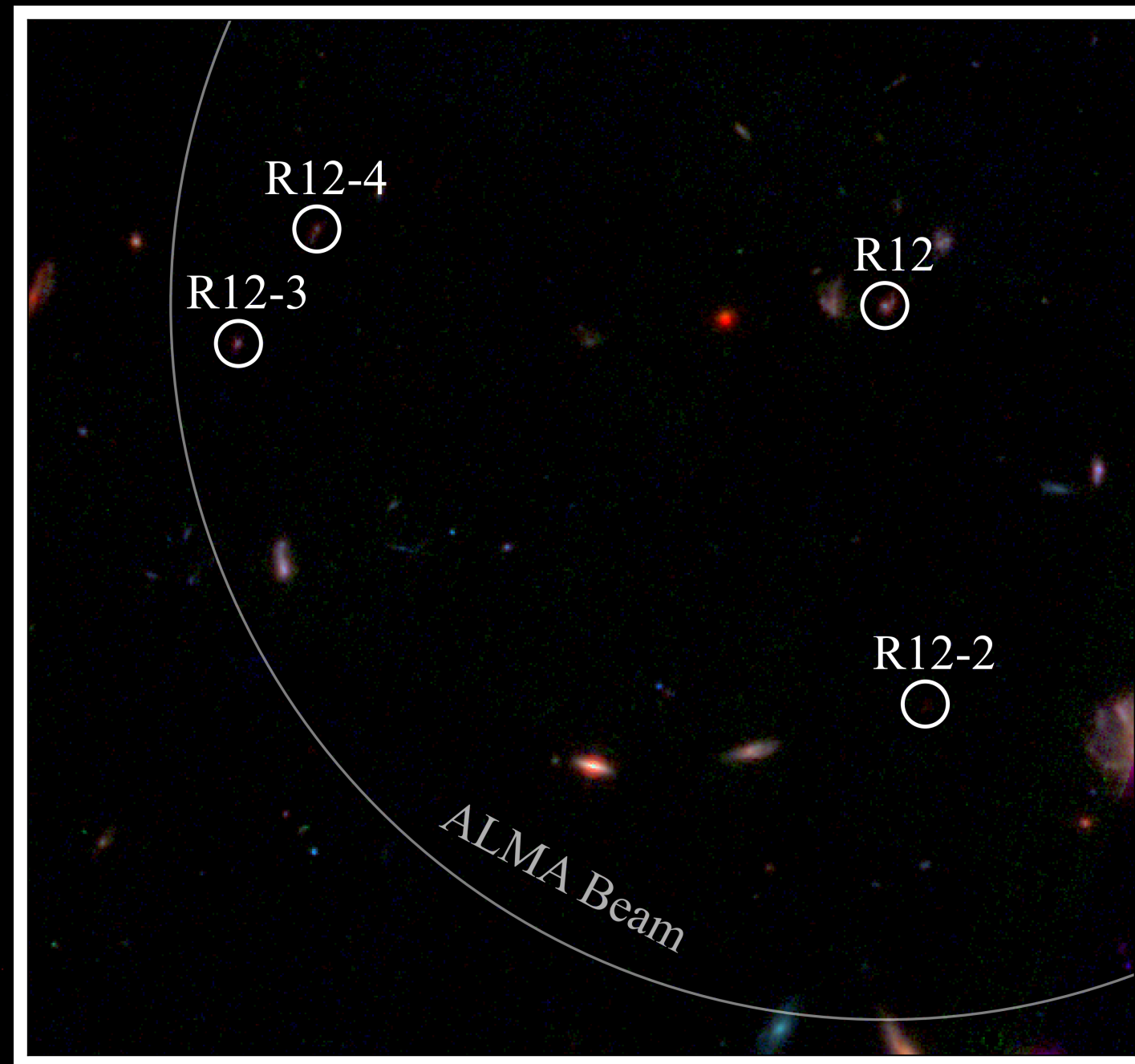
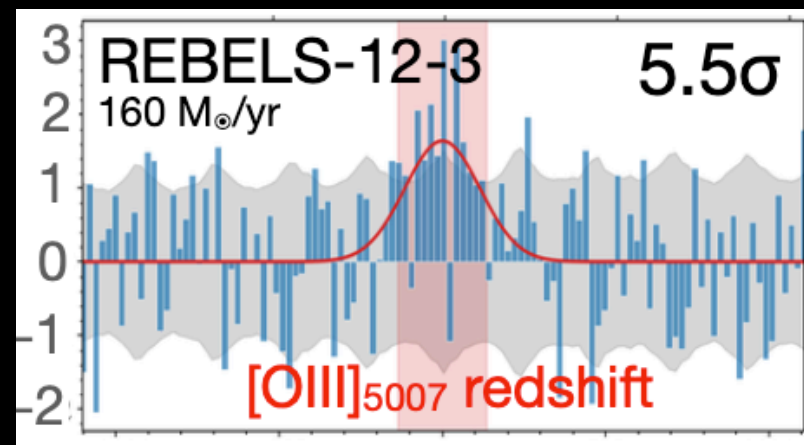
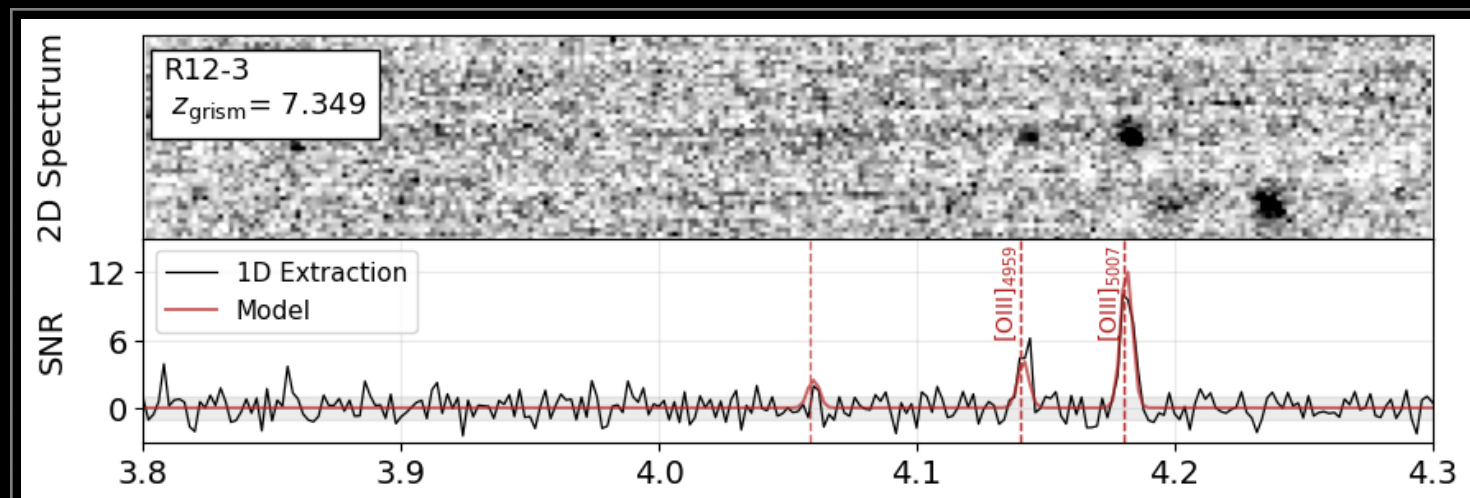
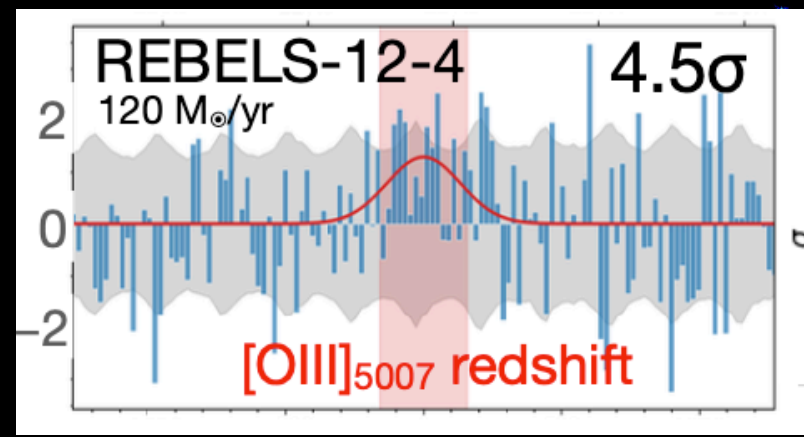
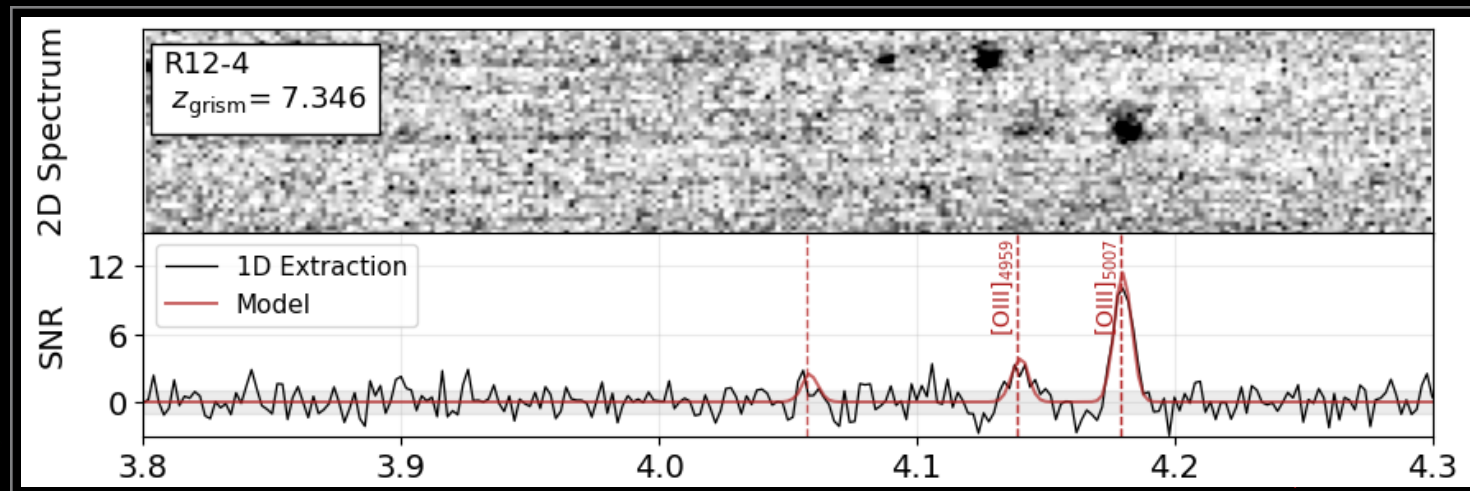


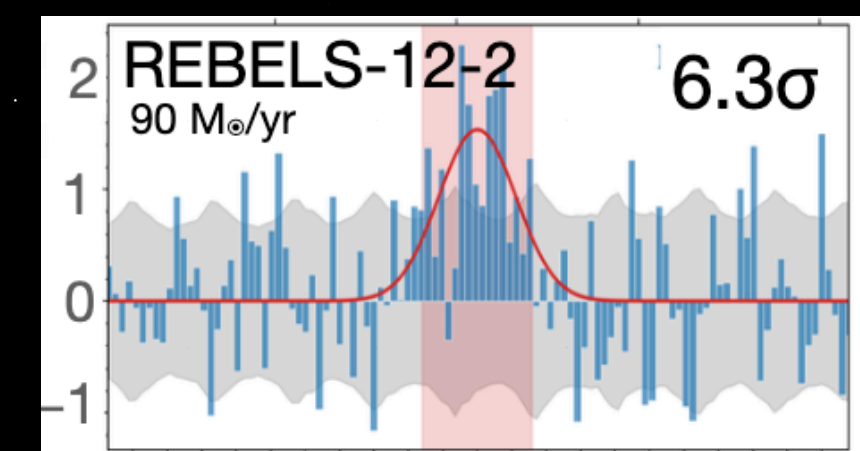
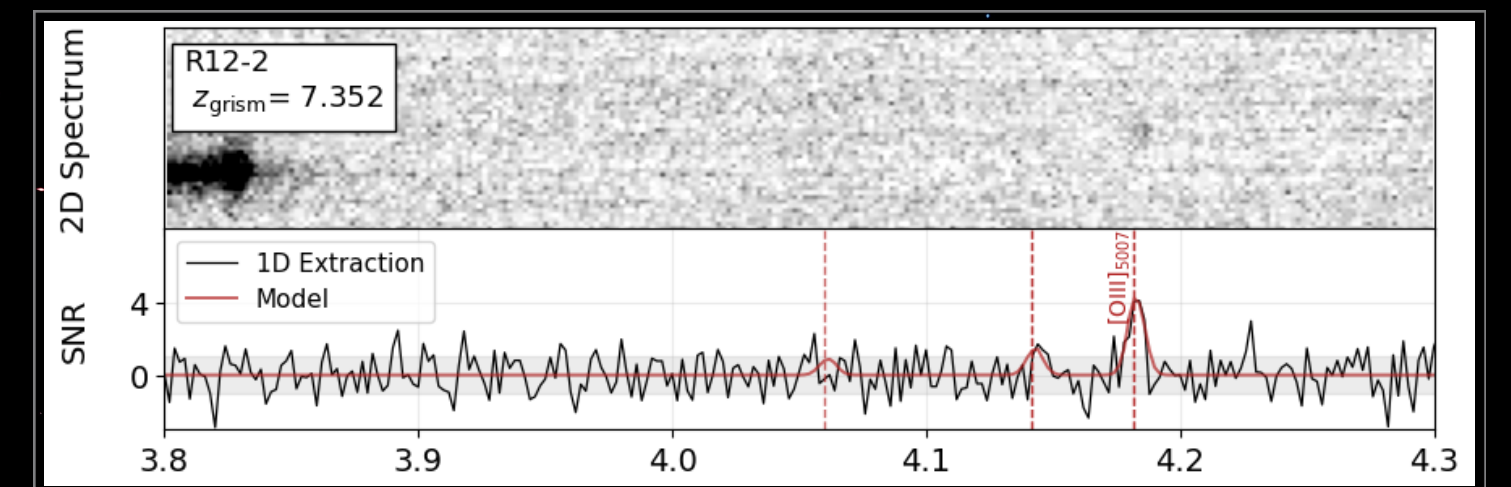
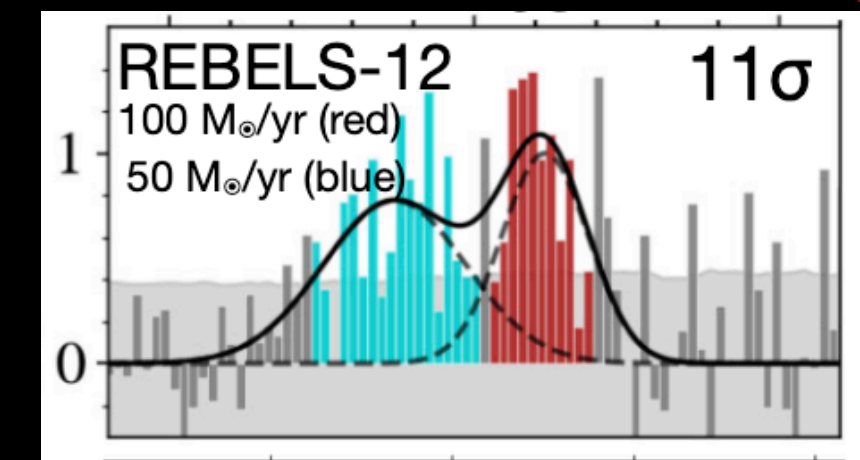
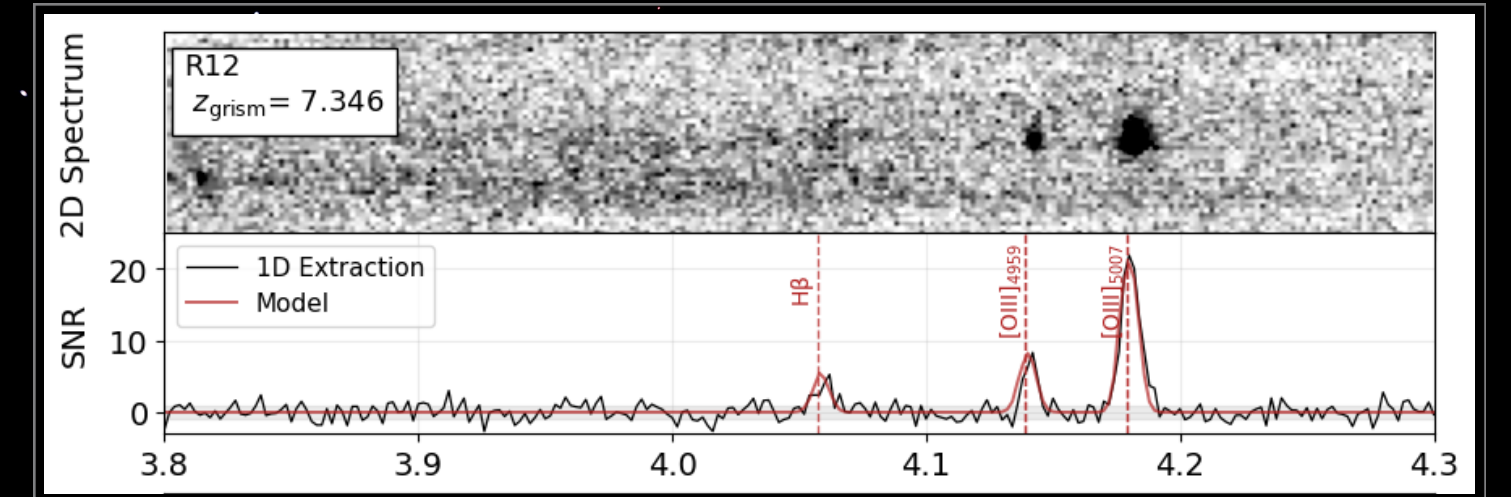
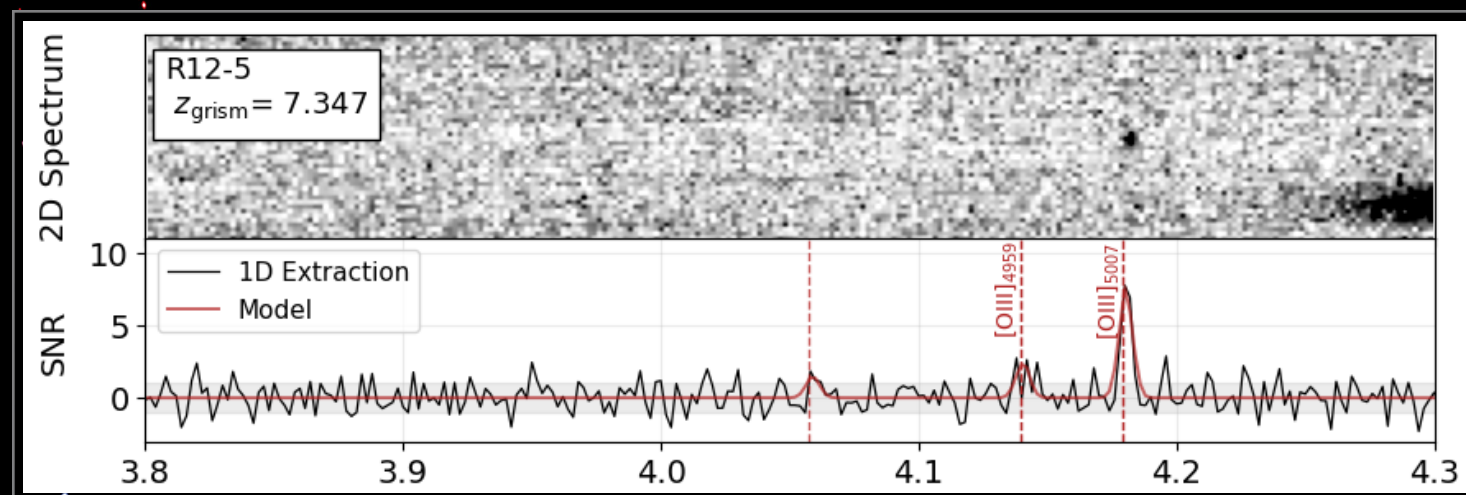
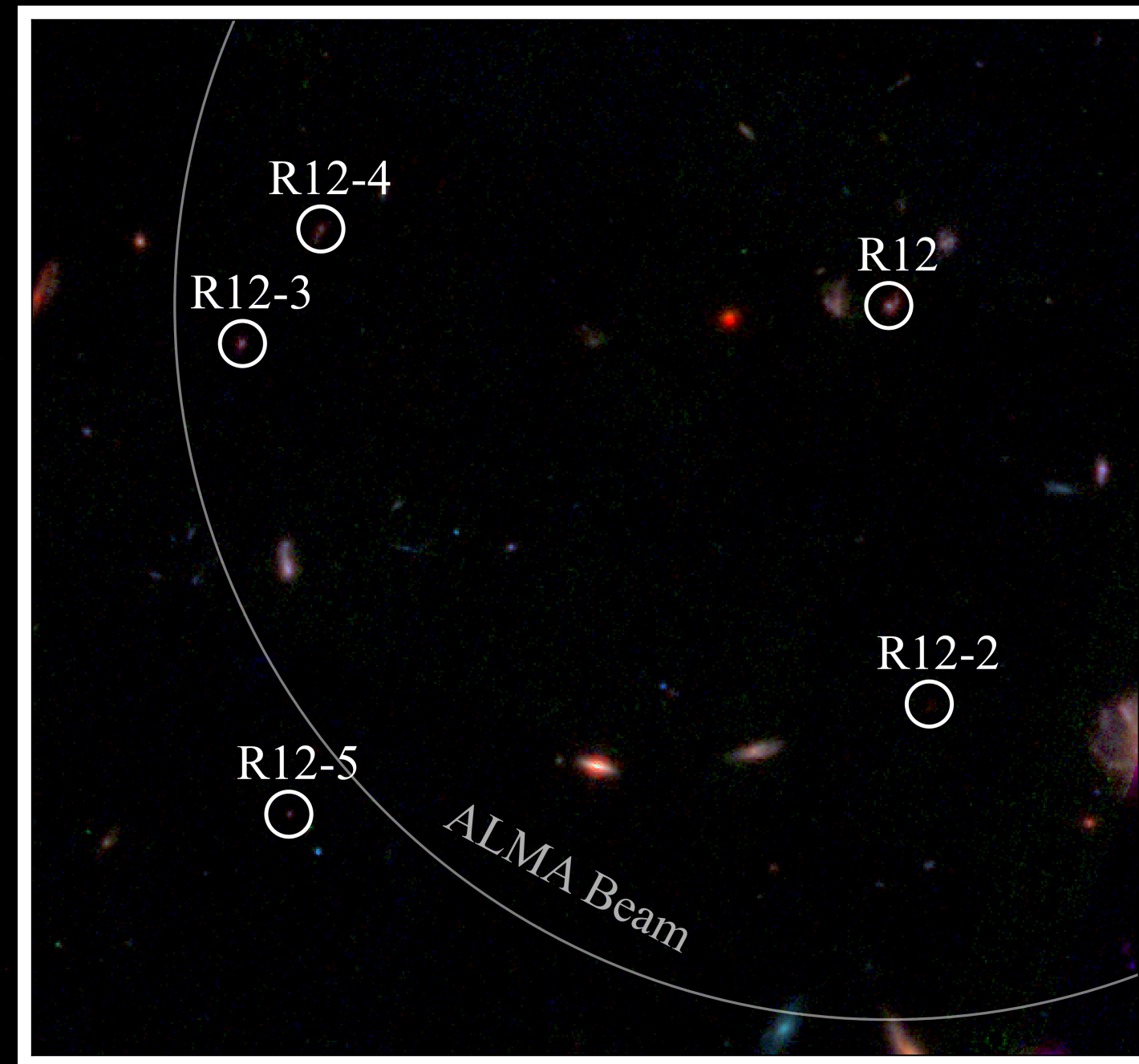
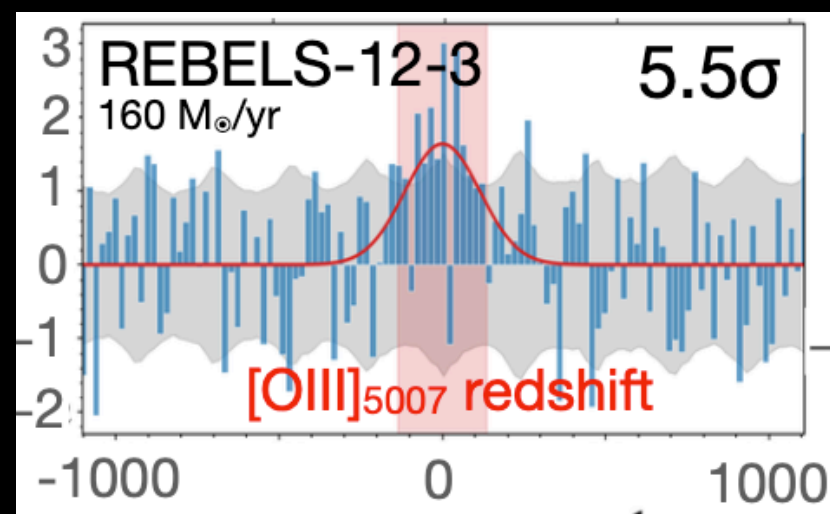
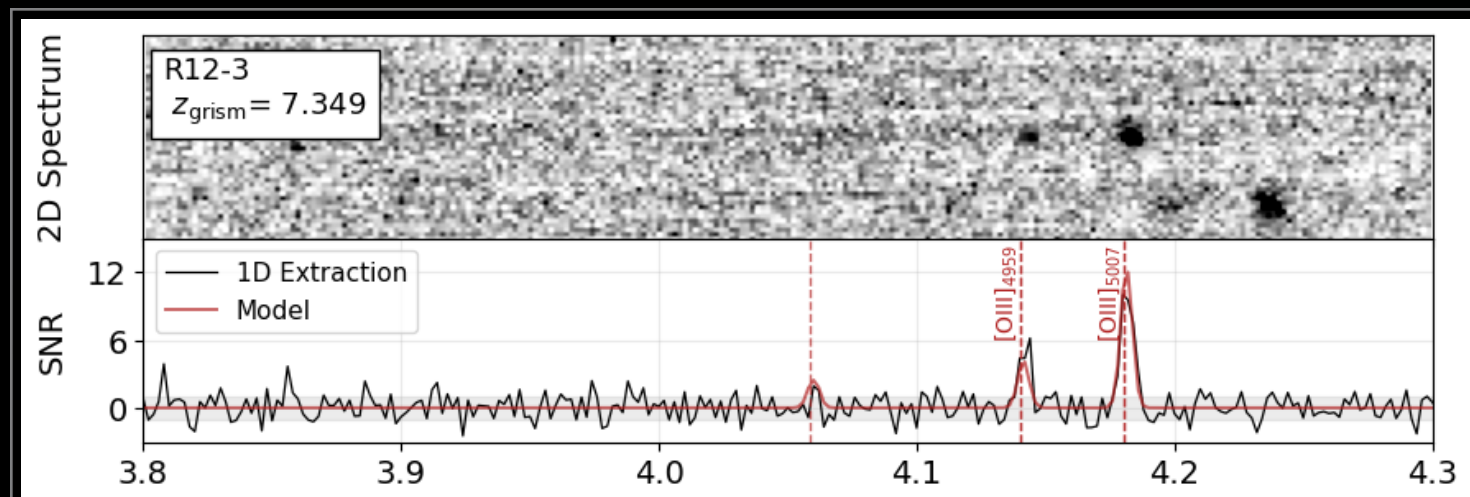
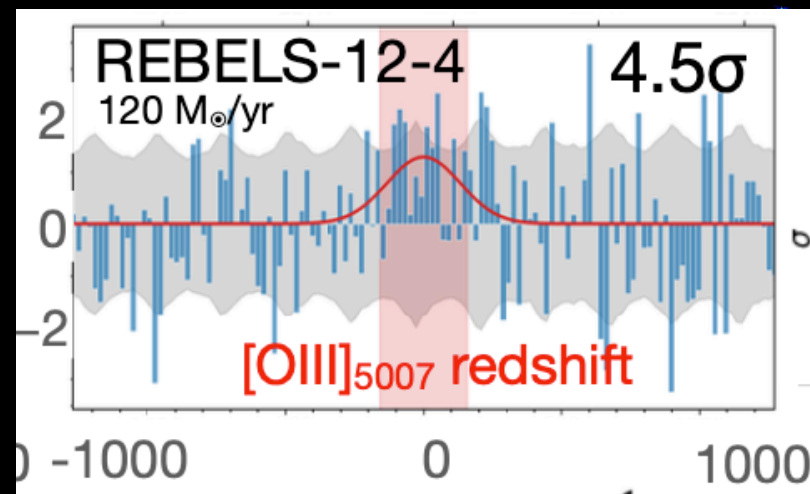
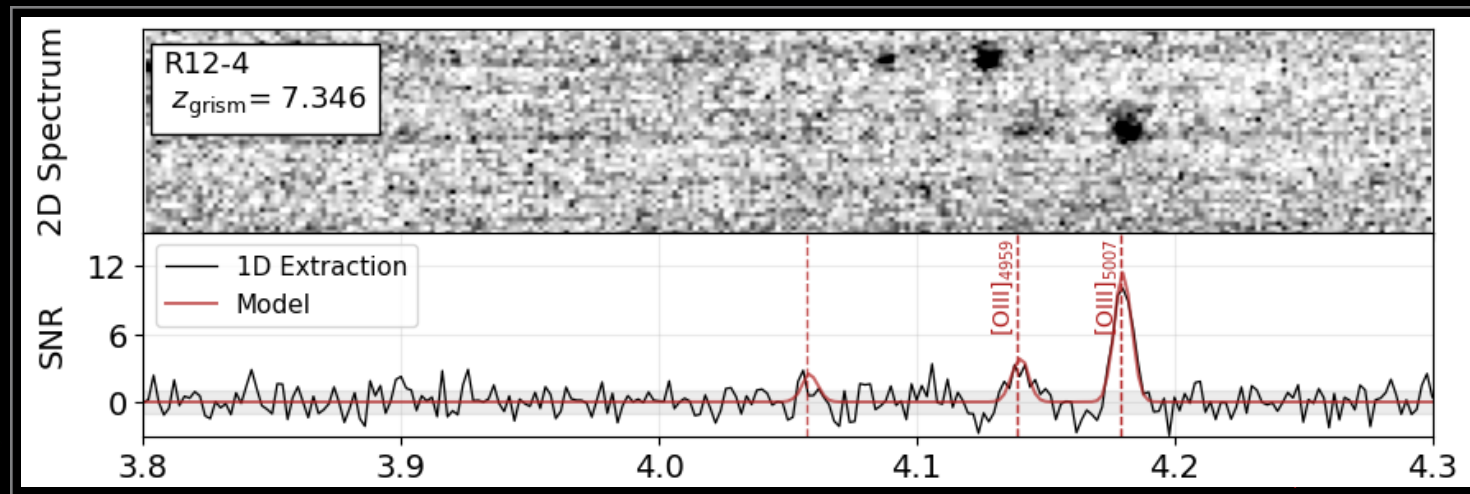
A Crowded Neighbourhood



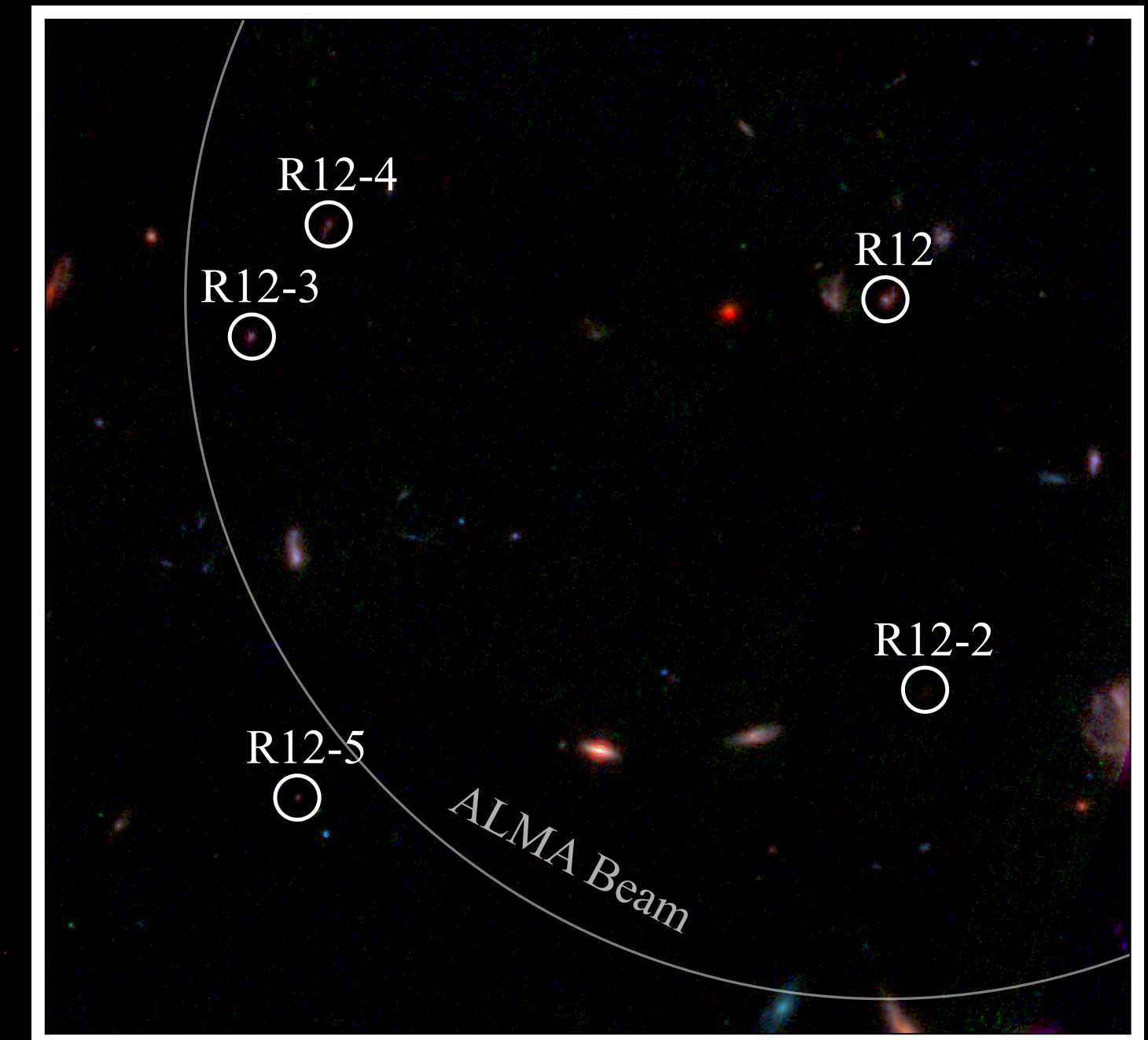
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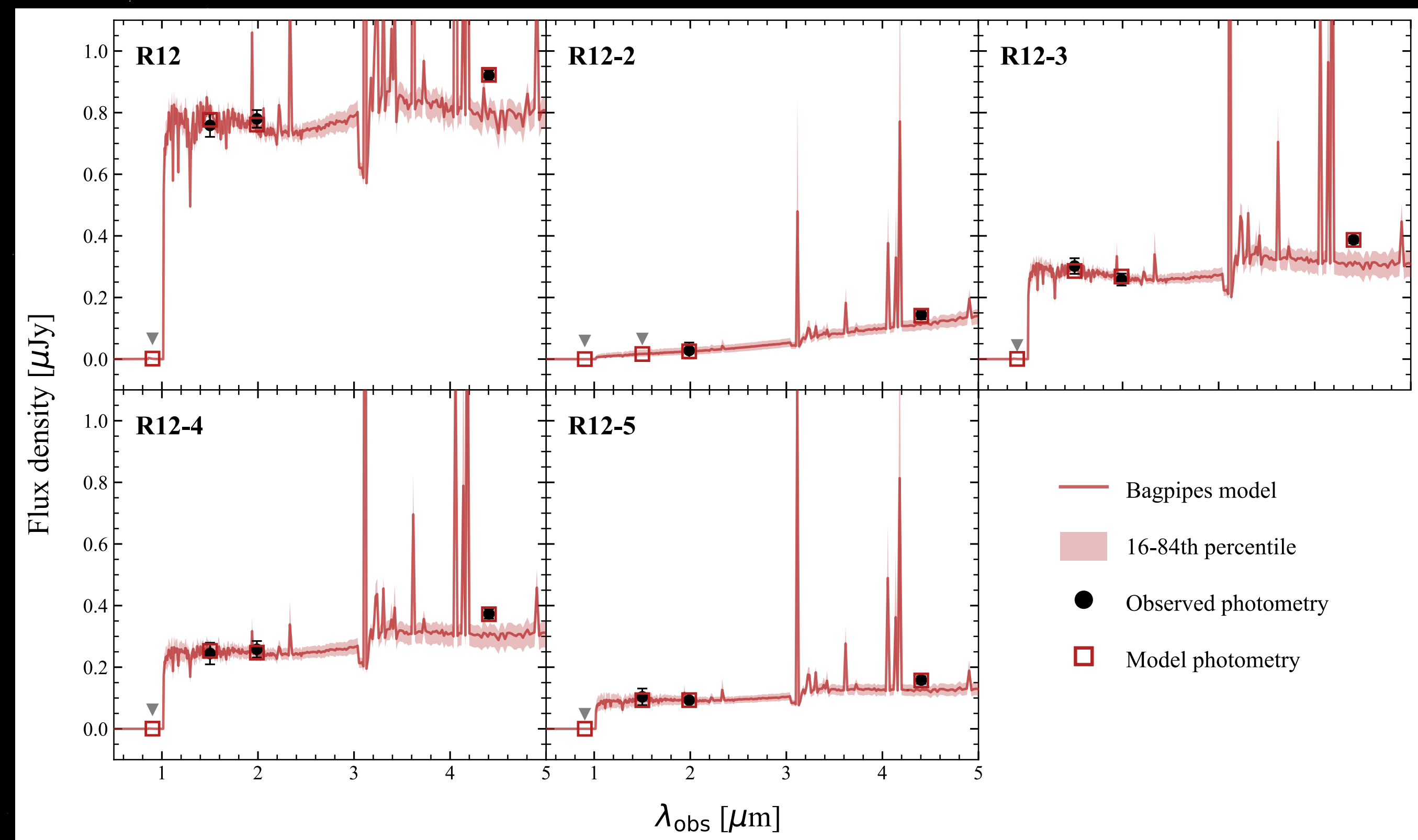


- 5 spectroscopically confirmed PC members
- $dz=0.005$
- $21'' \times 21'' \rightarrow 108 \text{ pkpc} < 1 \text{ cMpc}$ at $z=7.35$
- One merger (R12)
- One NIRC*am*-dark source (R12-2 in F150W)

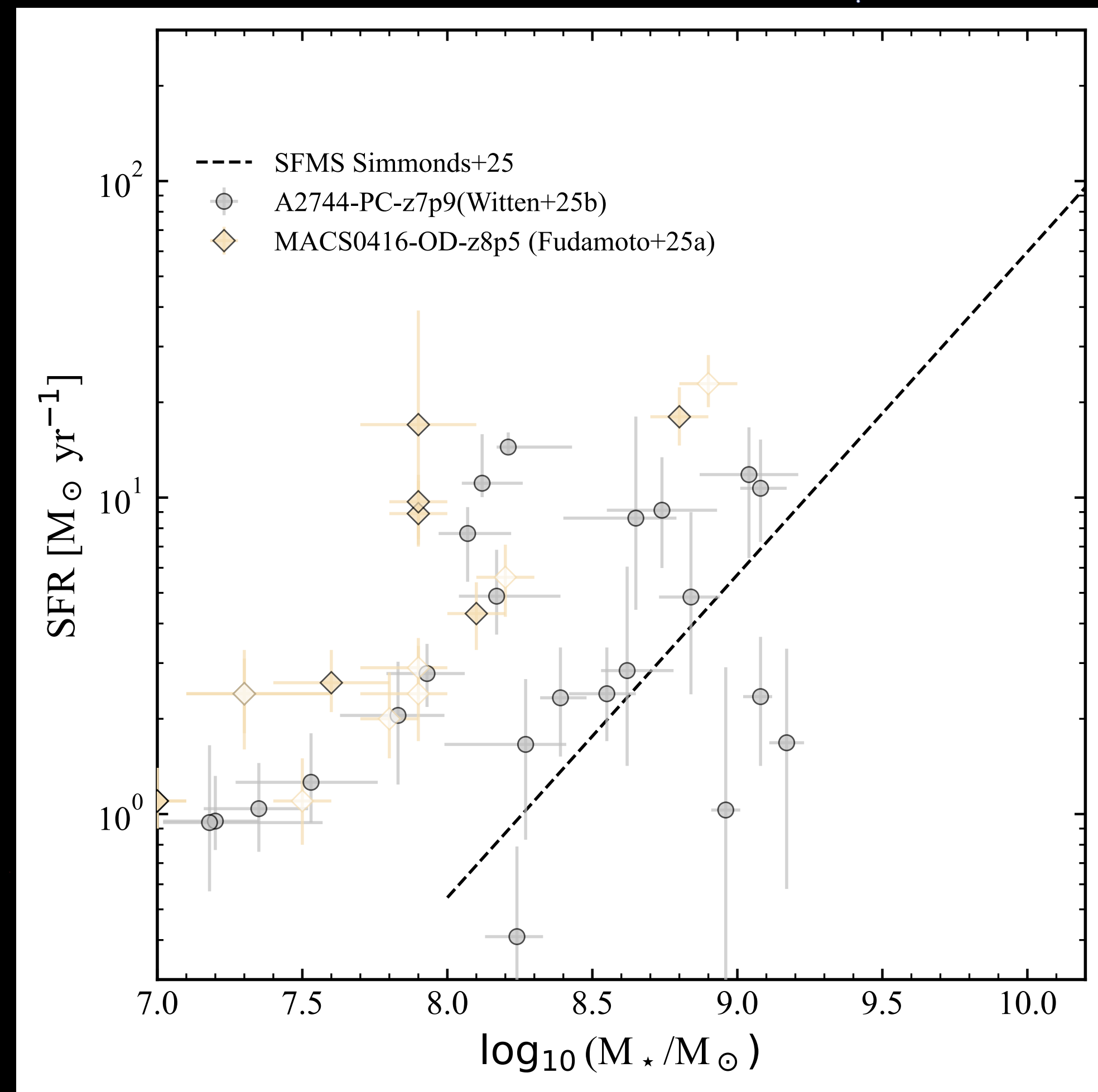


SED fits

- Photometry from **GO-6480** (PI:Schouws)
- F090W, F150W, F200W and F444W
- + dust detections for R12 and R12-2
- $\log M = 9.5 \pm 0.2$
- $\beta_{UV} = -2.06 \pm 0.2$
- $M_{UV} = -20.7 \pm 0.1$
- Particularly bright but **not** redder than field galaxies at $z \sim 7$ (except R-12-2)
- Unlike Witten et al+2025a ($\beta \sim -1.3$)

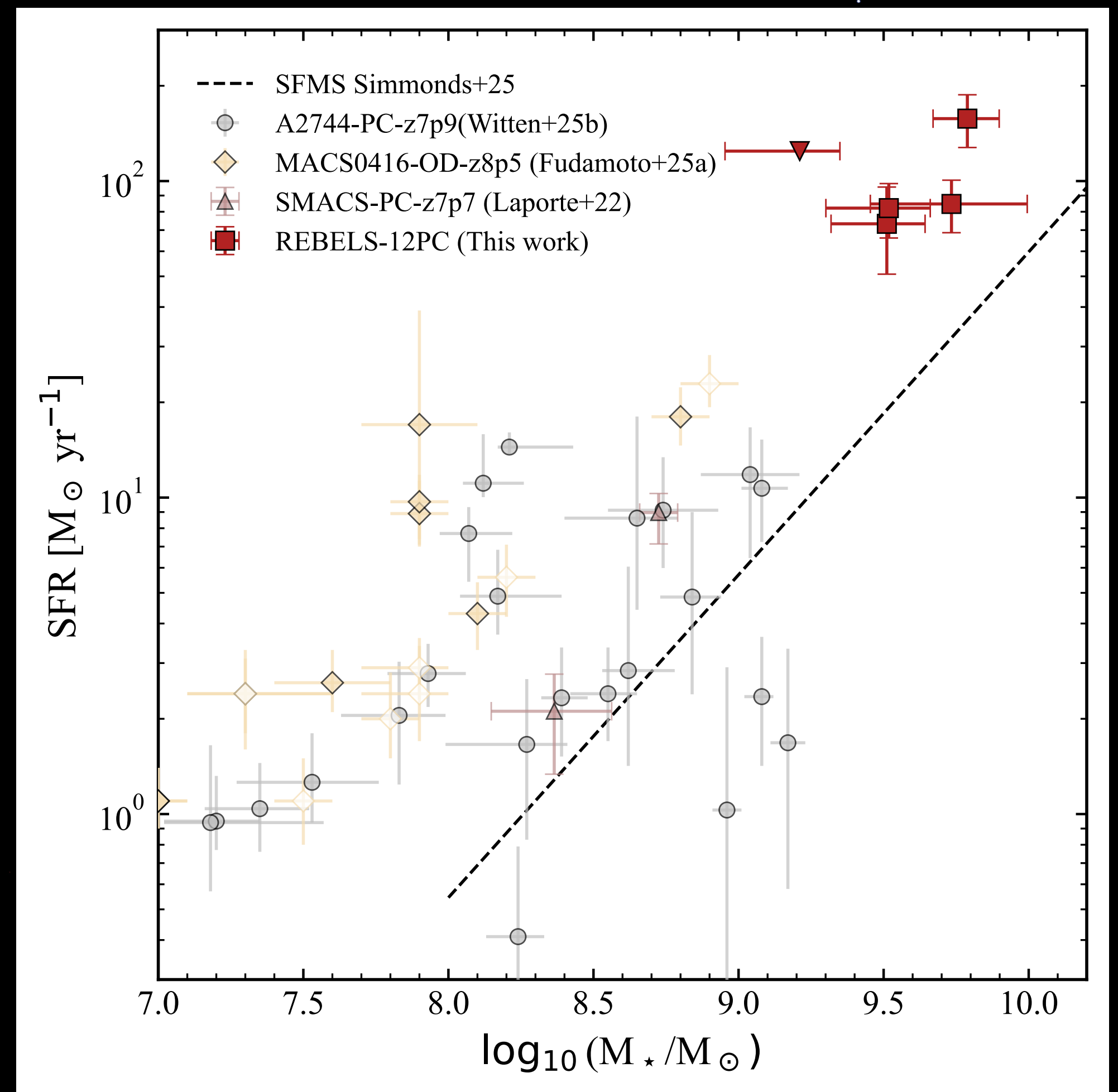


Extreme by Several Metrics



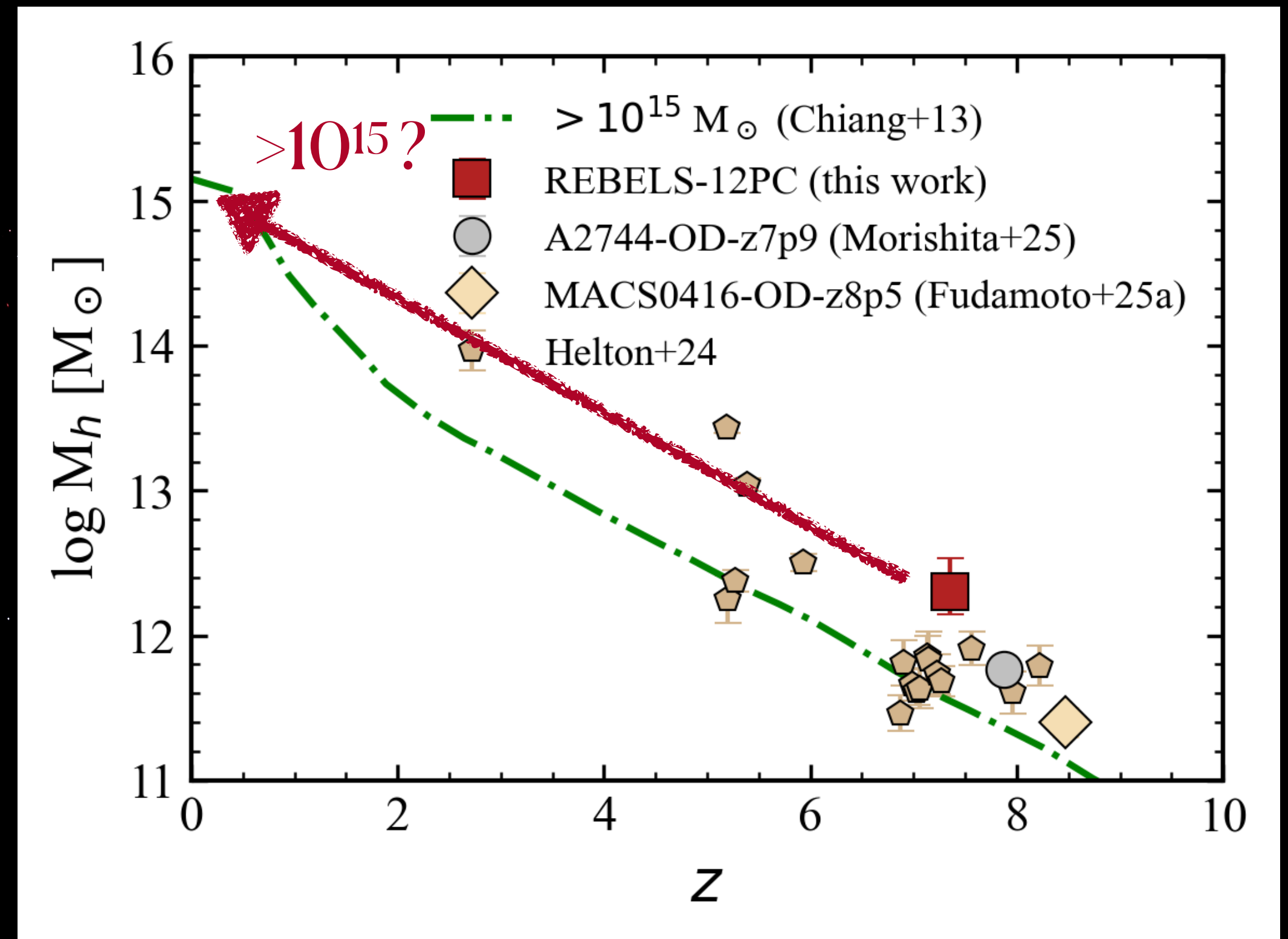
Extreme by Several Metrics

- $\log M \sim 9.5$
- $\text{SFR}[\text{CII}] \sim 100$
- Sits above MS at $z \sim 7$
- $10\times$ more massive than members of other $z > 7$ PCs



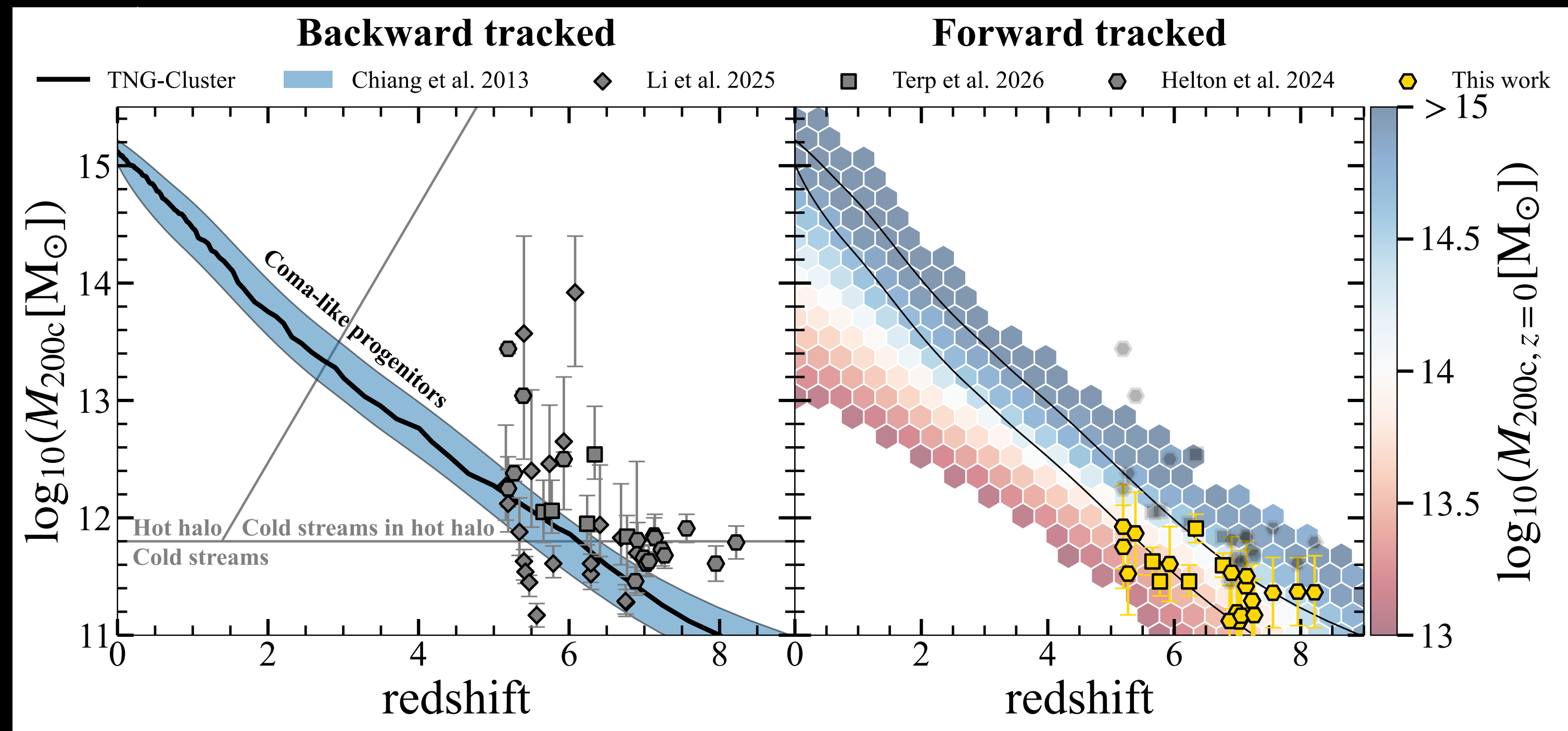
Urban Macrocephaly

- Sub-halo masses from Behroozi+19 SMHM
- $\log M_h / M_{\text{sol}} \sim 12.3$ (assuming PC dominated by 4 members)
- Sits above Chiang+13 Coma-like cluster track



A Coma-like Cluster?

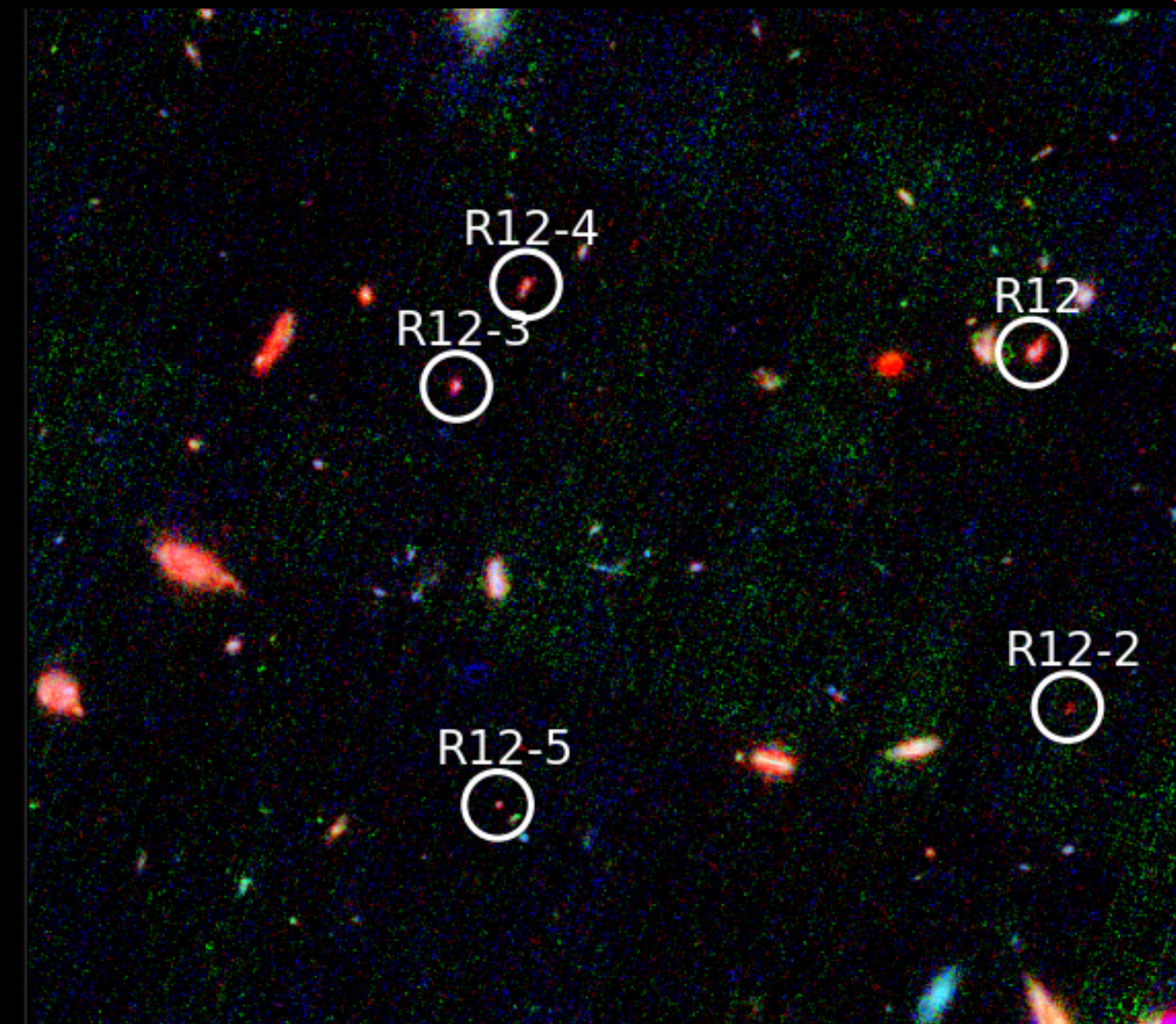
- Need to reconcile # density of PCs and Clusters
- Standard practice: backward-track from $z=0$ clusters PCs
- **Forward-track instead**, descendant fate is a *distribution* \rightarrow *probability*
- Many $z > 7$ PC candidates fall below the cluster threshold
- R12-PC has a **90%** chance of becoming a $\log M_{200}/M_{\text{sol}} = 14$ cluster by $z \sim 0$



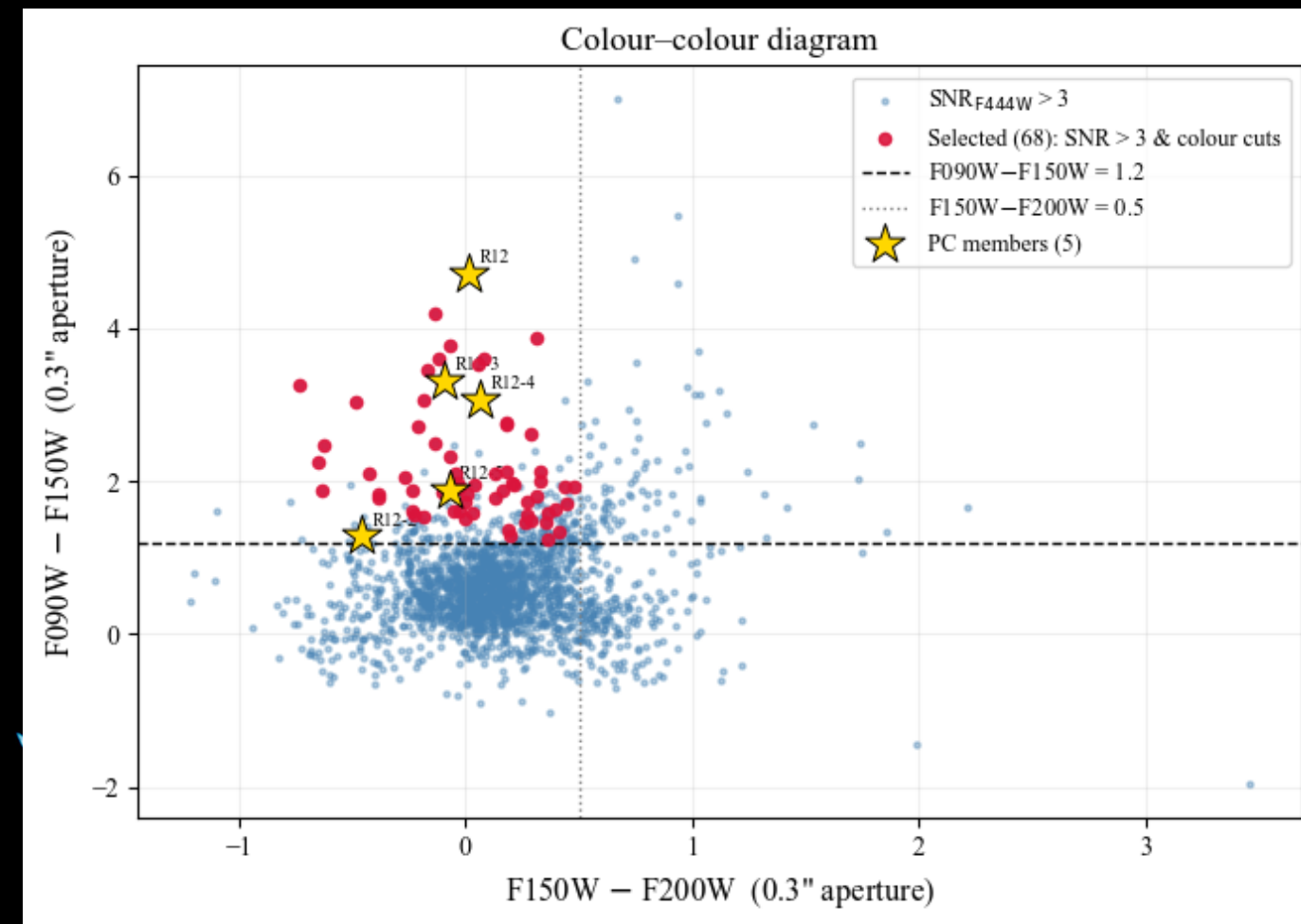
Witten+26 (ArXiv this week)

Summary

- 5 spec-confirmed members at $z = 7.35$ within 108 pkpc and $\Delta z = 0.005$
- Most compact spec-confirmed PC core at $z > 7$
- 4 [CII] (ALMA) + 5 [OIII] 5007 (NIRCam grism)
- Merger evidence, highly dust obscured source
- $10\times$ more massive and 1 dex above MS vs. other $z > 7$ PC members
- Extreme at high- z but likely to become a normal sized cluster at $z \sim 0$
- Need deeper ALMA and JWST to map extent of the structure with fainter members



Dropout Catalogue



- Colour-colour cut
 - Select F090W dropouts
 - F090W-F150W to limit contaminants
 - One potential other PC member in [OIII]

