Dissecting the roles of feedback and interaction for LyC escape

A case study using NIRSpec Integral Field Spectroscopy

Escape of Lyman radiation from galactic labyrinths

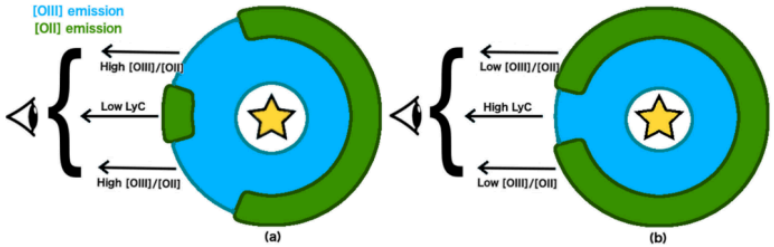
OAC, Kolymbari, Crete.

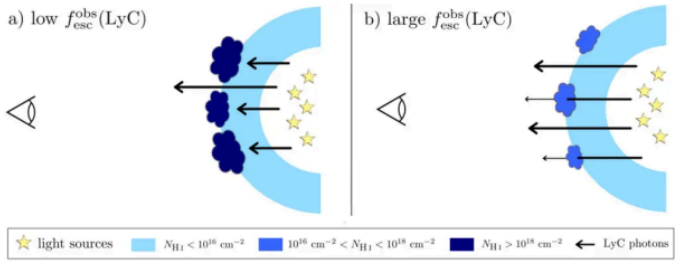
T. Emil Rivera-Thorsen 2025-04-09

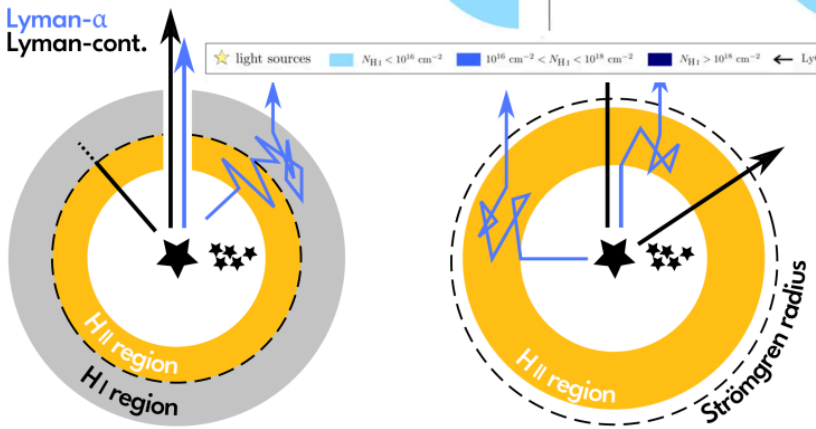
Motivation

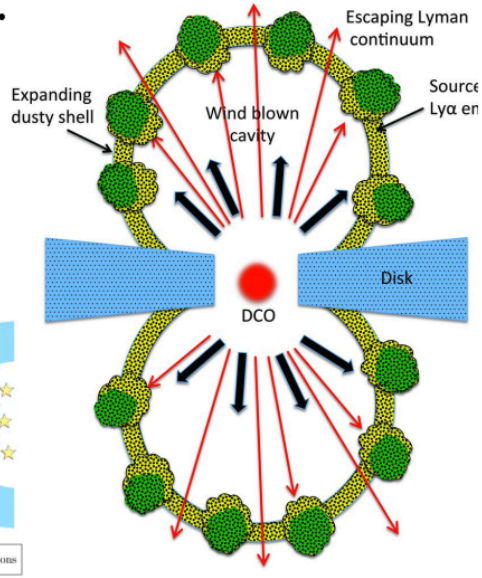
Ionizing escape is regulated to scales of single HII regions

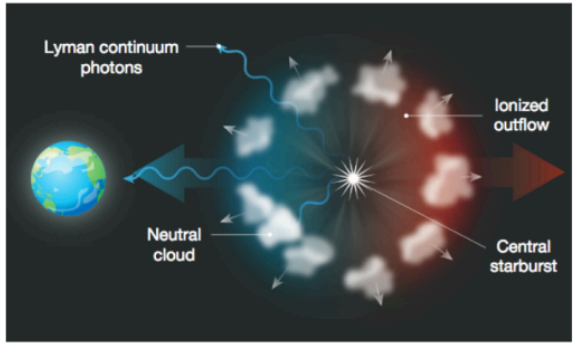
There is no shortage of explanatory models...

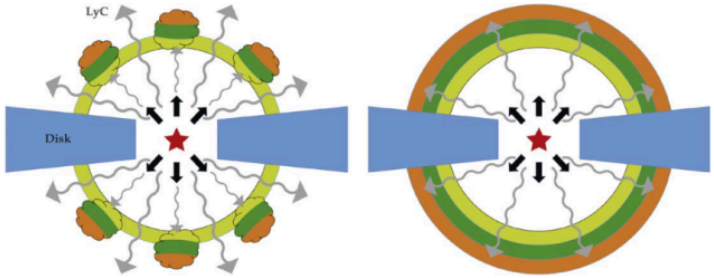


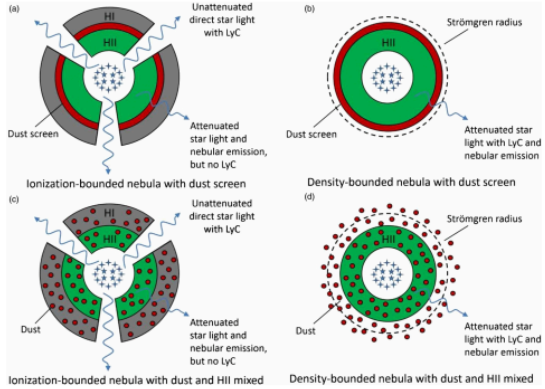


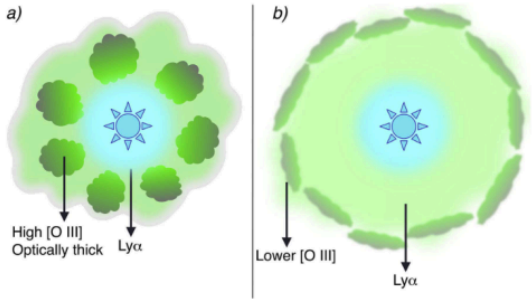






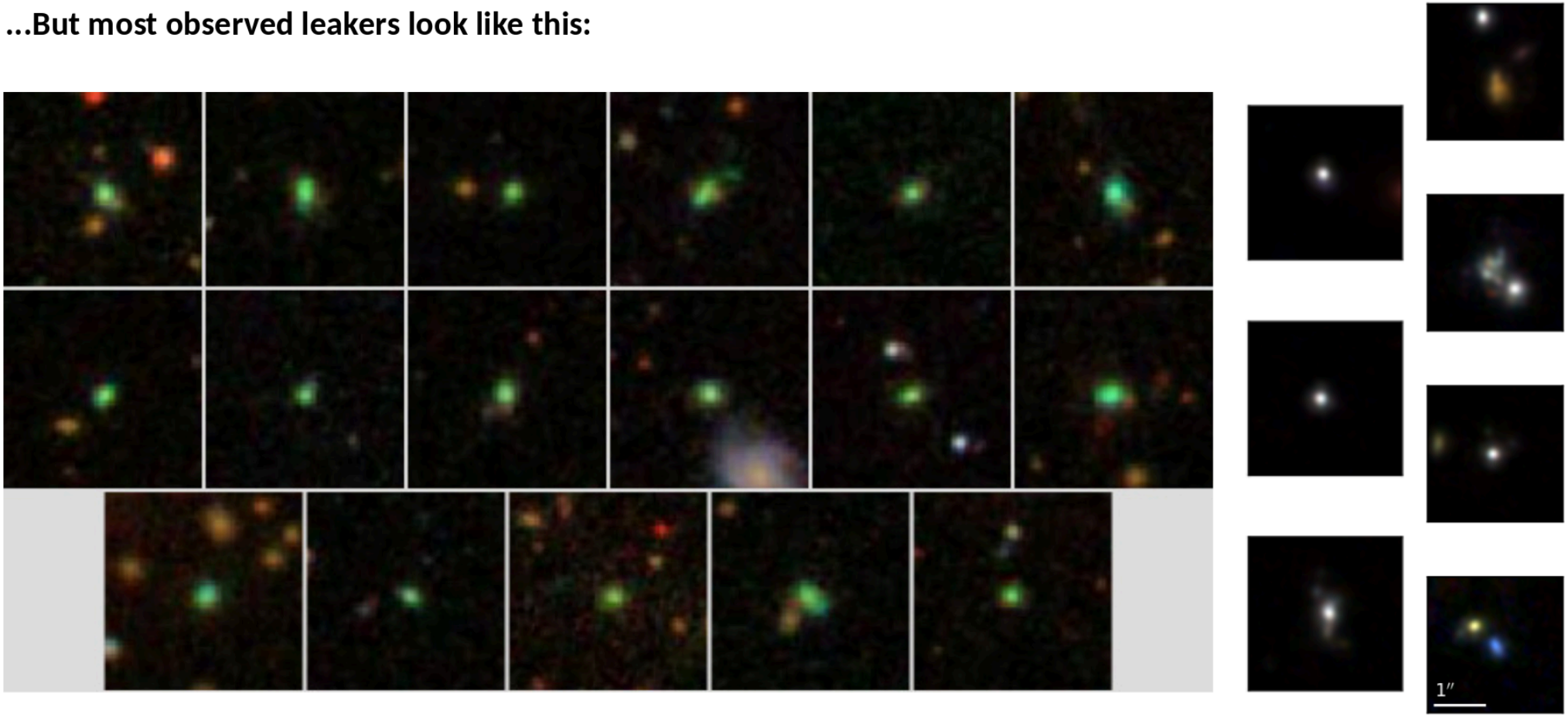






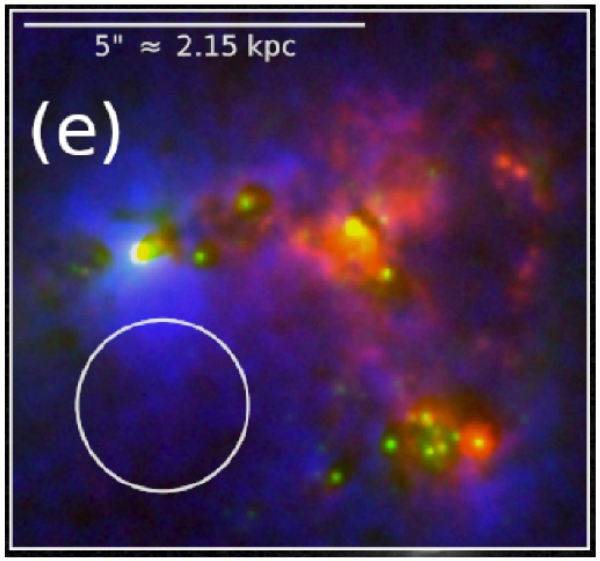
Ionizing escape is regulated to scales of single HII regions

...But most observed leakers look like this:



Up close, LyC is difficult to observe

Haro 11: Nearest known leaker at $z = 0.02$. LyC location is uncertain due to COS aperture size.



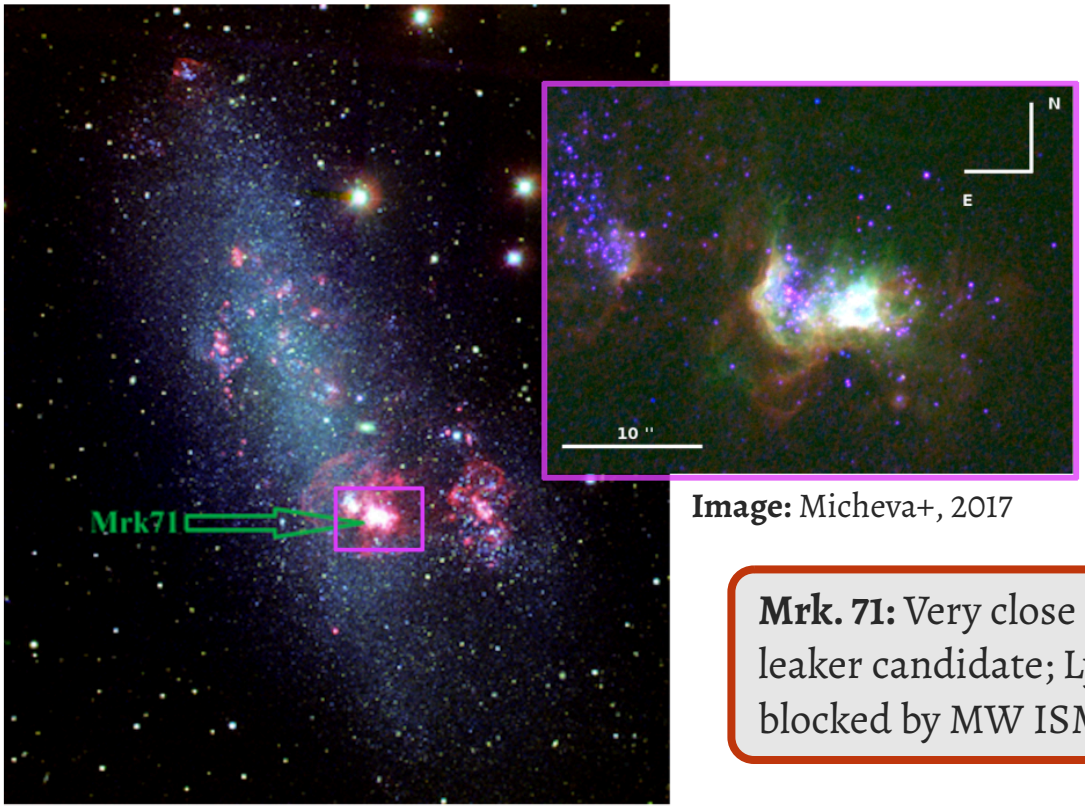


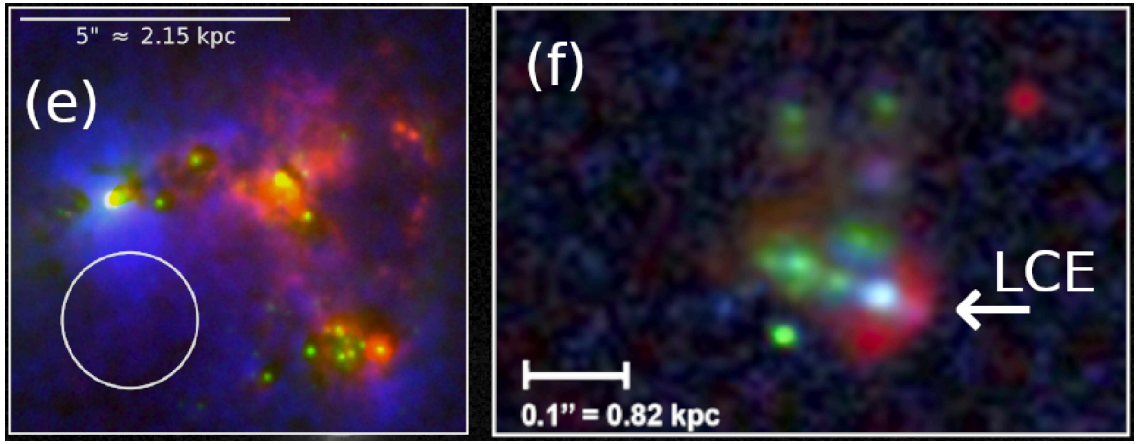
Image: Micheva+, 2017

Image: van Eymeren & López- Sánchez (ATNF)

Mrk. 71: Very close LyC leaker candidate; LyC is blocked by MW ISM.

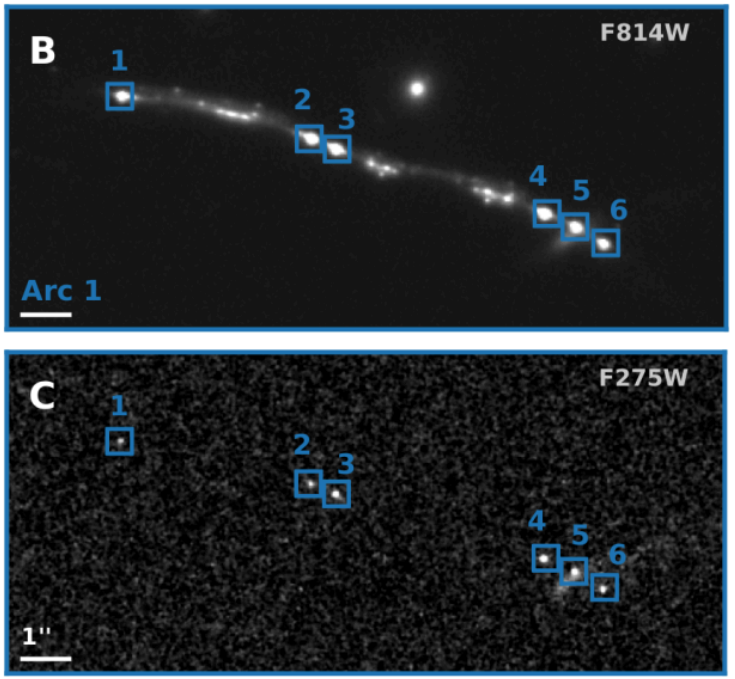
Gravitational Lensing to the rescue!

Lensed galaxies at Cosmic Noon let us see *both* precise LyC *and* detailed ISM



Haro 11 again.

The **Sunburst Arc** @ $z \sim 2.4$: Most precise localization of LyC escape (model of de-lensed galaxy courtesy of Keren Sharon).



The Sunburst Arc

Quick (re-)introduction to the Sunburst Arc

- **Brightest known** lensed arc, with 12 (partial) images
- Central Lyα peak means **direct escape** with $N_{\mathrm{HI}} \lesssim 10^{13}$ — practically empty.
- Surrounding peaks mean **thicker HI cover** in other directions
- Strong, highly localized **LyC escape** — *but there is dust*
- LyC among multiple lines of sight $\Longrightarrow$ a rare chance for **IGM tomography** (see Michelle Berg's talk)

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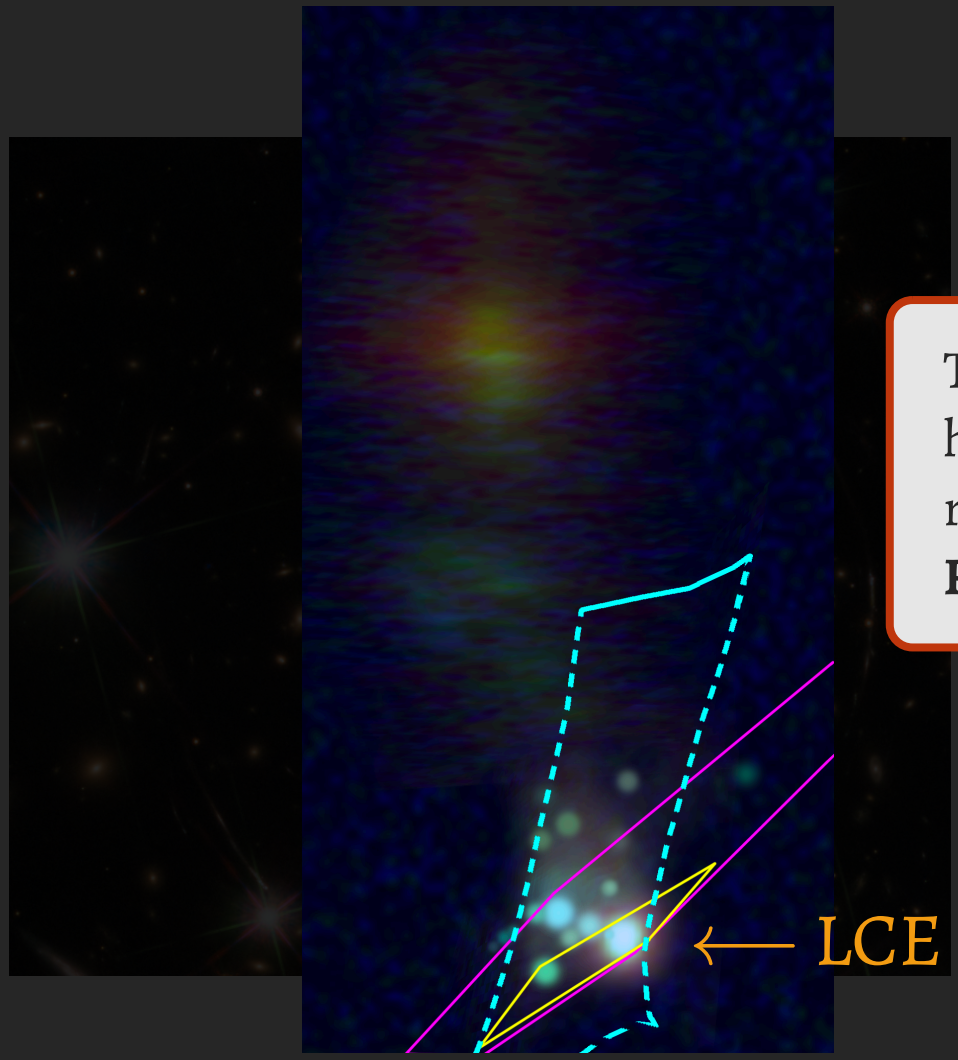

"Artist's impression" *by Keren Sharon*

- **Brightest known** lensed arc, with 12 (partial) images
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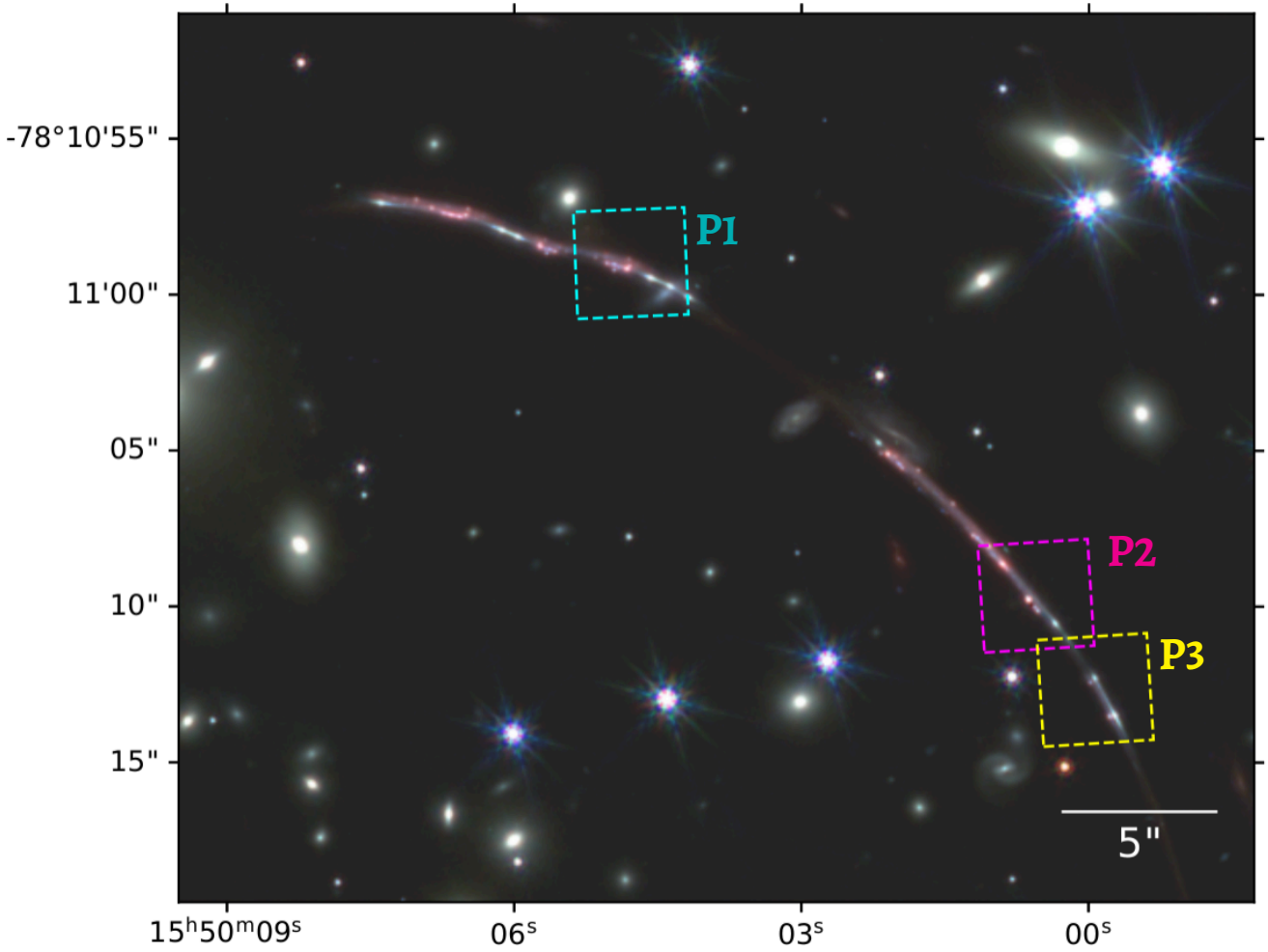
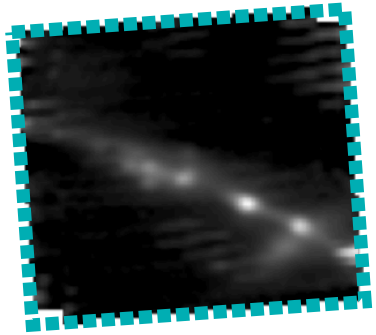
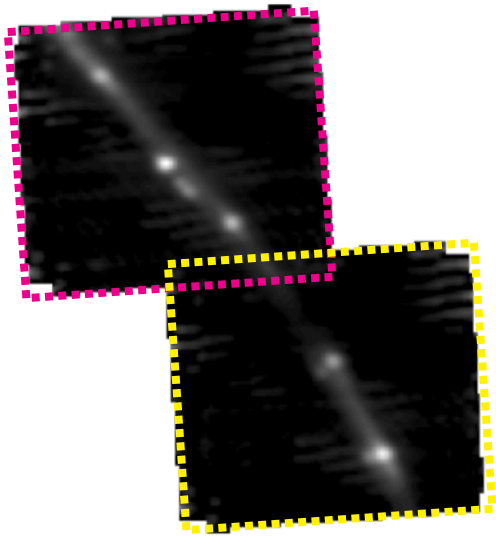
  y empty.
  ker HI cover
- **scape**
  — *but there is dust*
- LyC among multiple lines of sight ⟹ a rare chance for **IGM tomography** (see Michelle Berg's talk)

The galaxy is likely **interacting** or has been recently (Could well be relevant for LyC escape, see **Alex Le Reste**'s talk).

Observations for this work: NIRCam and NIRSpec IFU







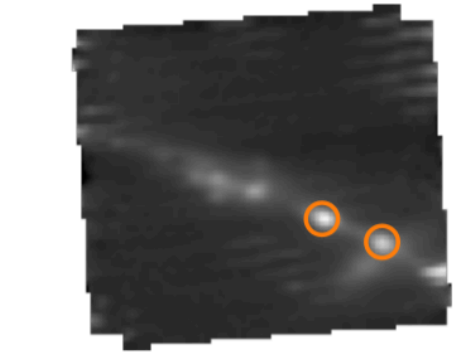
The LCE cluster

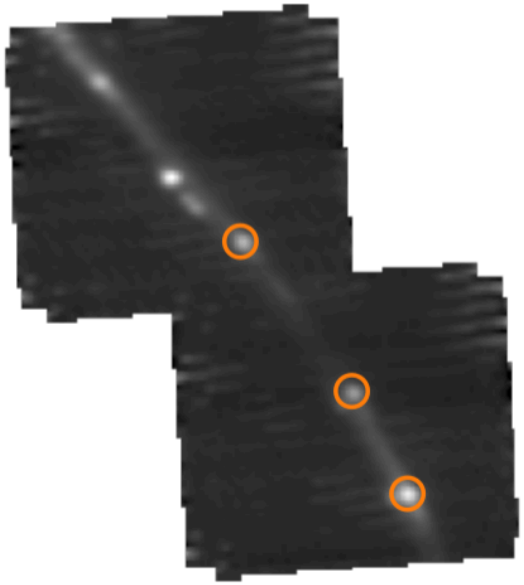
Cluster properties from previous works

- **Young** and very **blue** with very massive stars
  - Stellar pop. age $\sim 3 - 4$ Myr (Chisholm+ 2019, Meštrić+ 2023, R-T+ 2024)
  - Extreme blue slope $\beta \approx -3$ (Kim+, 2023)
  - Signs of presence of VMS (Meštrić+, 2023)
- **Masssive** and **dense**
  - $M_\star \approx 10^7 M_\odot$ (Pascale+, 2023)
  - $M_{\rm dyn} \approx 10^7 M_\odot$ (Vanzella+, 2022)
- **Nitrogen loud**
  - $\log(N/O)_{\rm N\ III]} \approx -0.23$ (Pascale+, 2023)

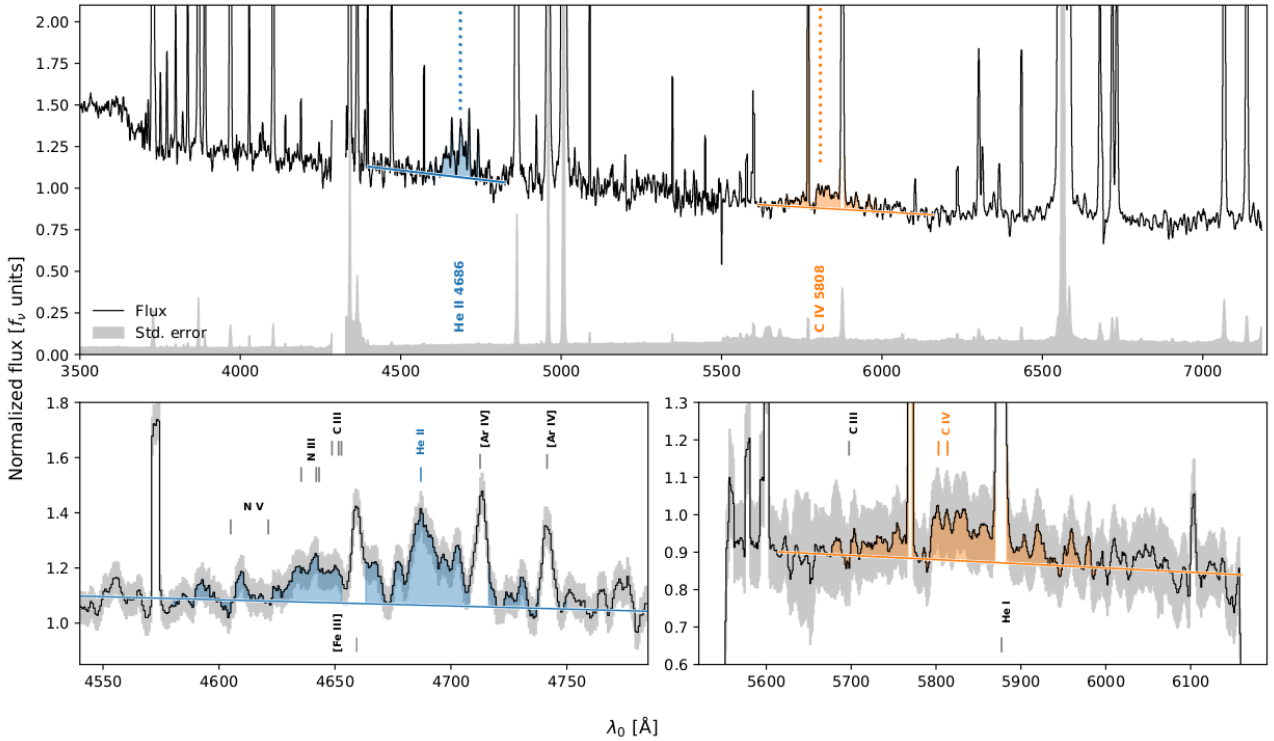
Model photo, not the real Sunburst LCE cluster.

Cluster properties from stacked NIRSpec IFU apertures





The LCE is a **massive** ($M \sim 10^7\,M_\odot$) proto-GC with a surprisingly large population of **WR-stars** (including VMS).



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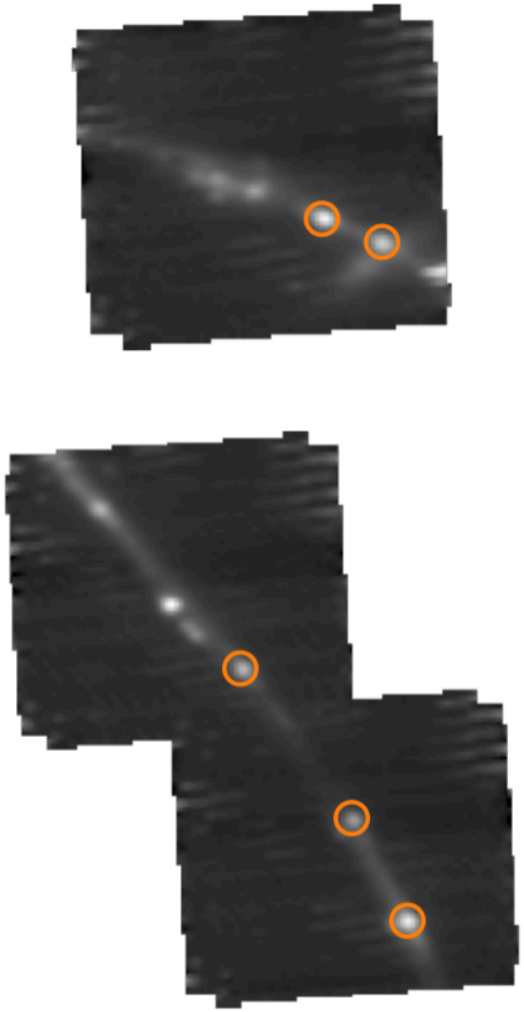

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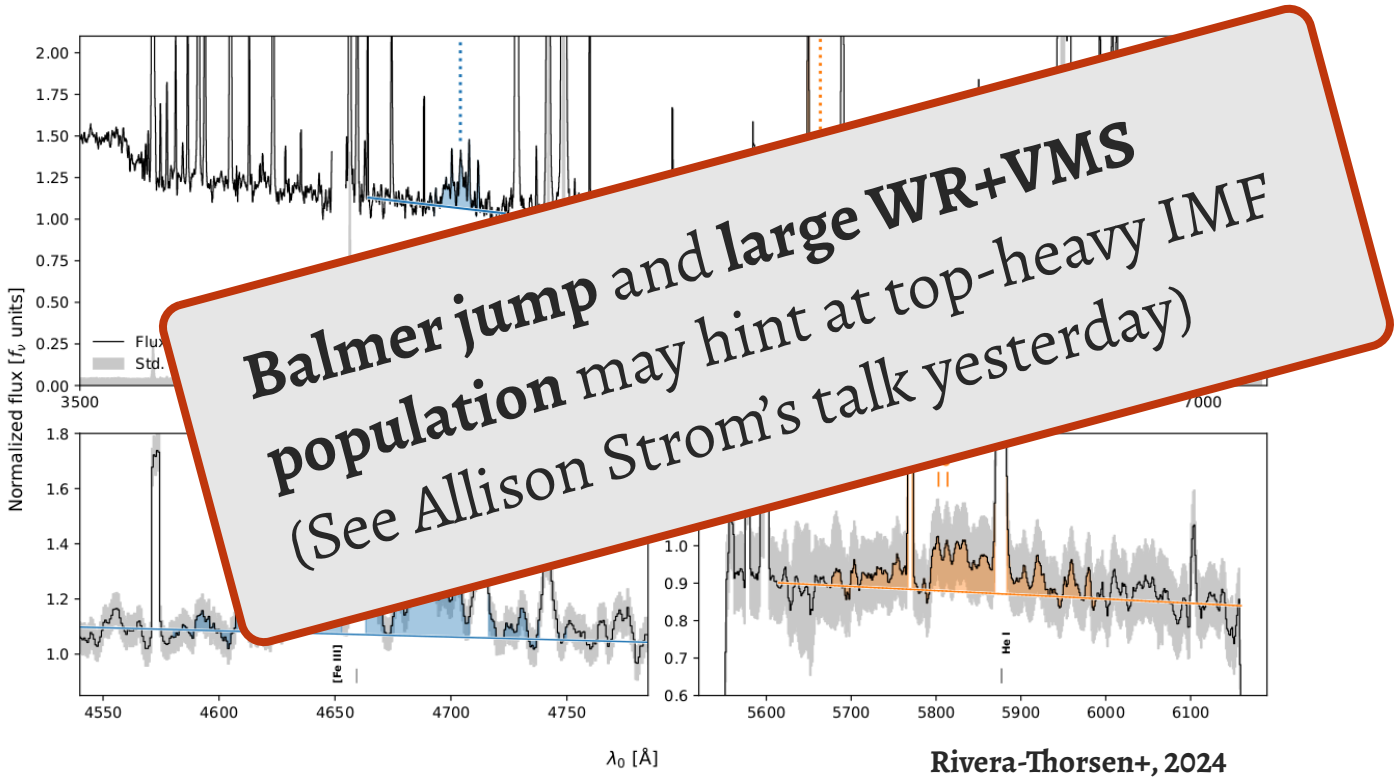
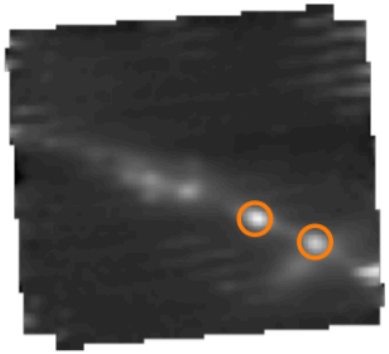
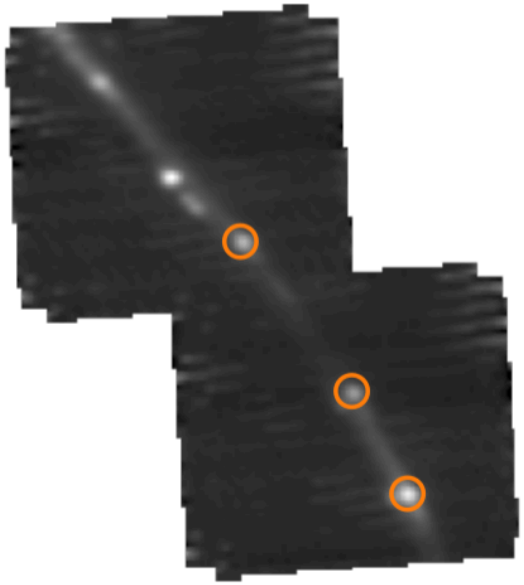


Balmer jump and **large WR+VMS population** may hint at top-heavy IMF (See Allison Strom's talk yesterday)

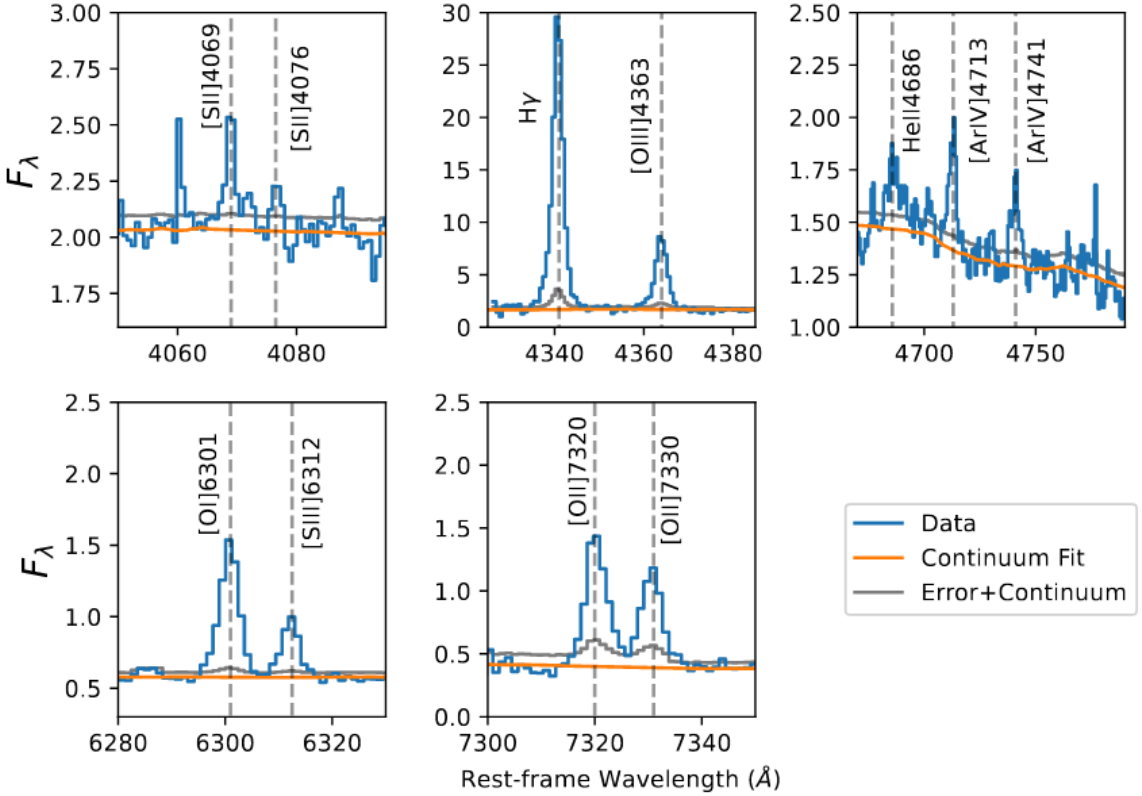
Rivera-Thorsen+, 2024

Abundances from direct T_e-method





The stacked spectrum contains **auroral lines** from multiplee ionization zones



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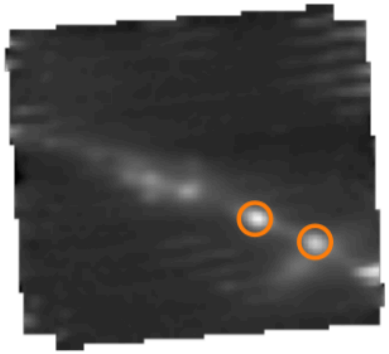
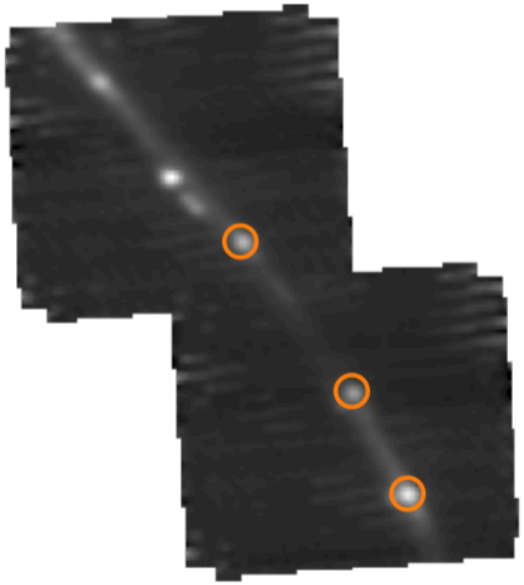
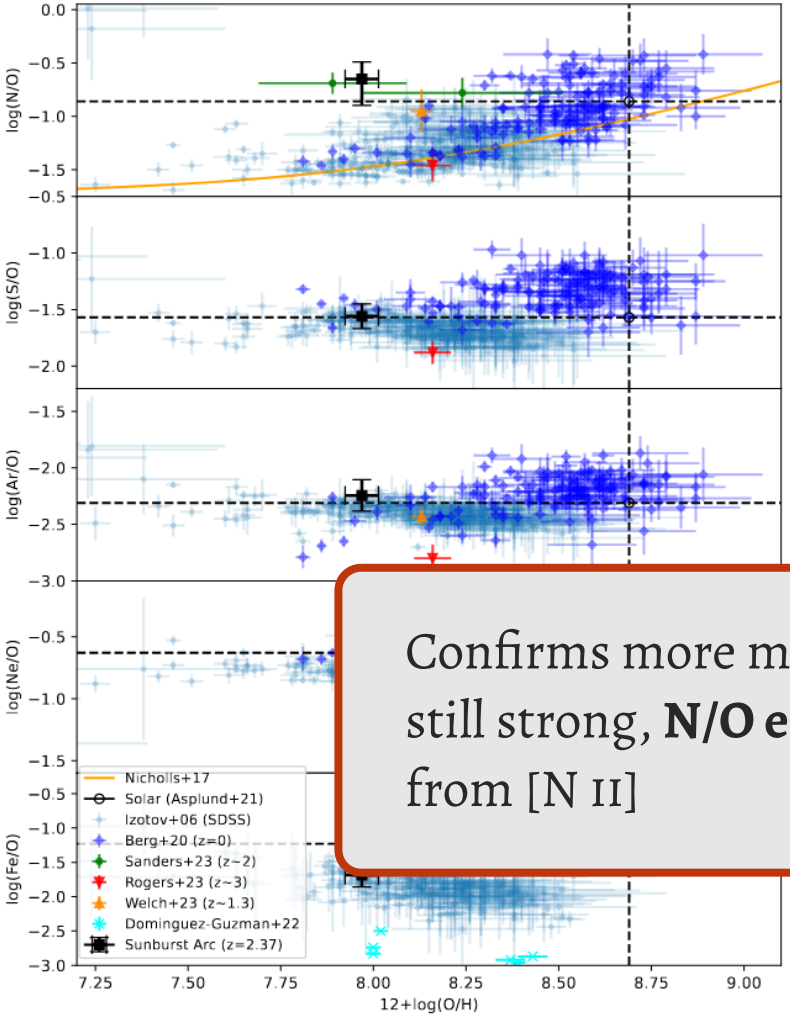


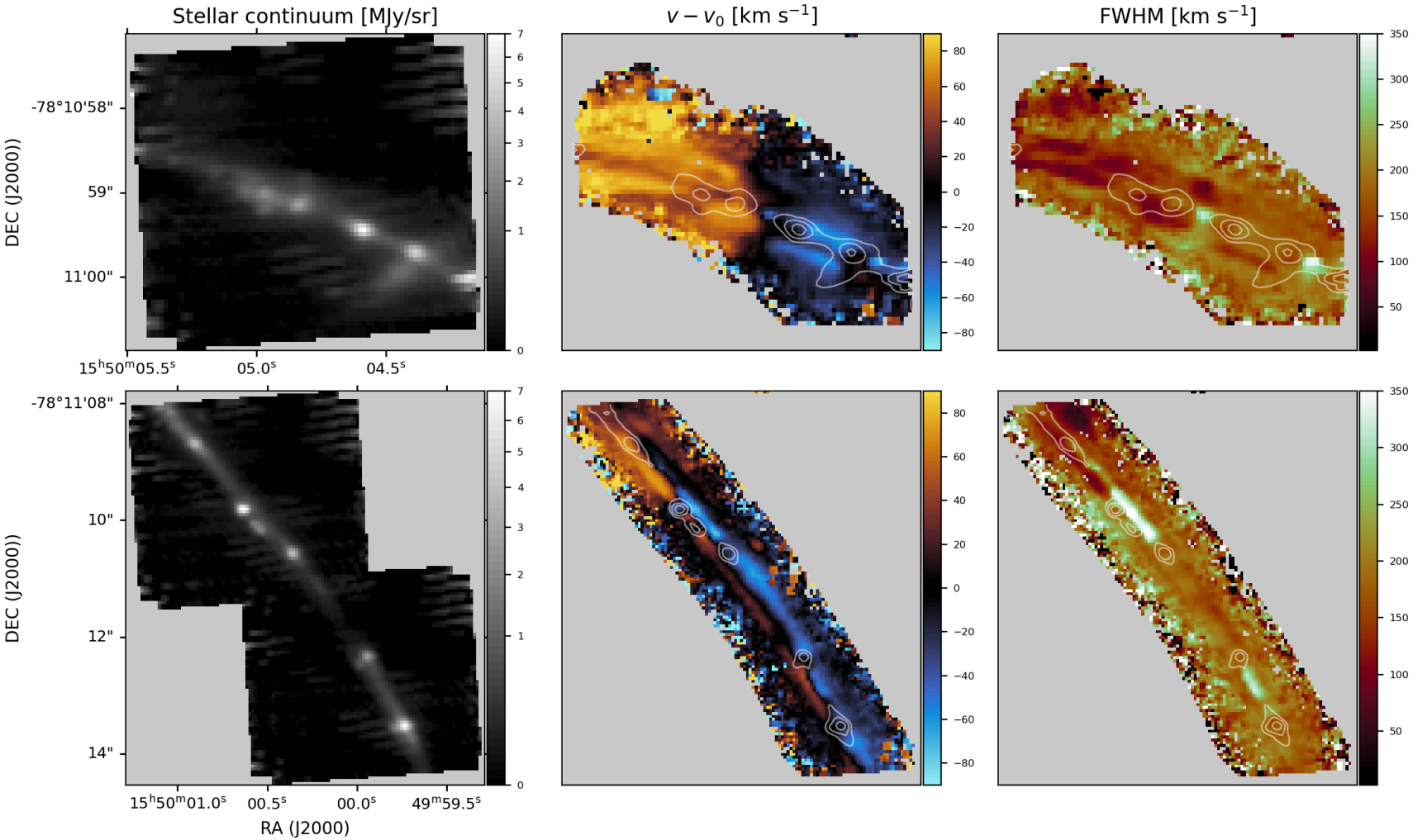




Confirms more moderate, but still strong, **N/O enhancment** from [N II]

Resolved ISM properties

Line maps and kinematics from single Gaussian fits



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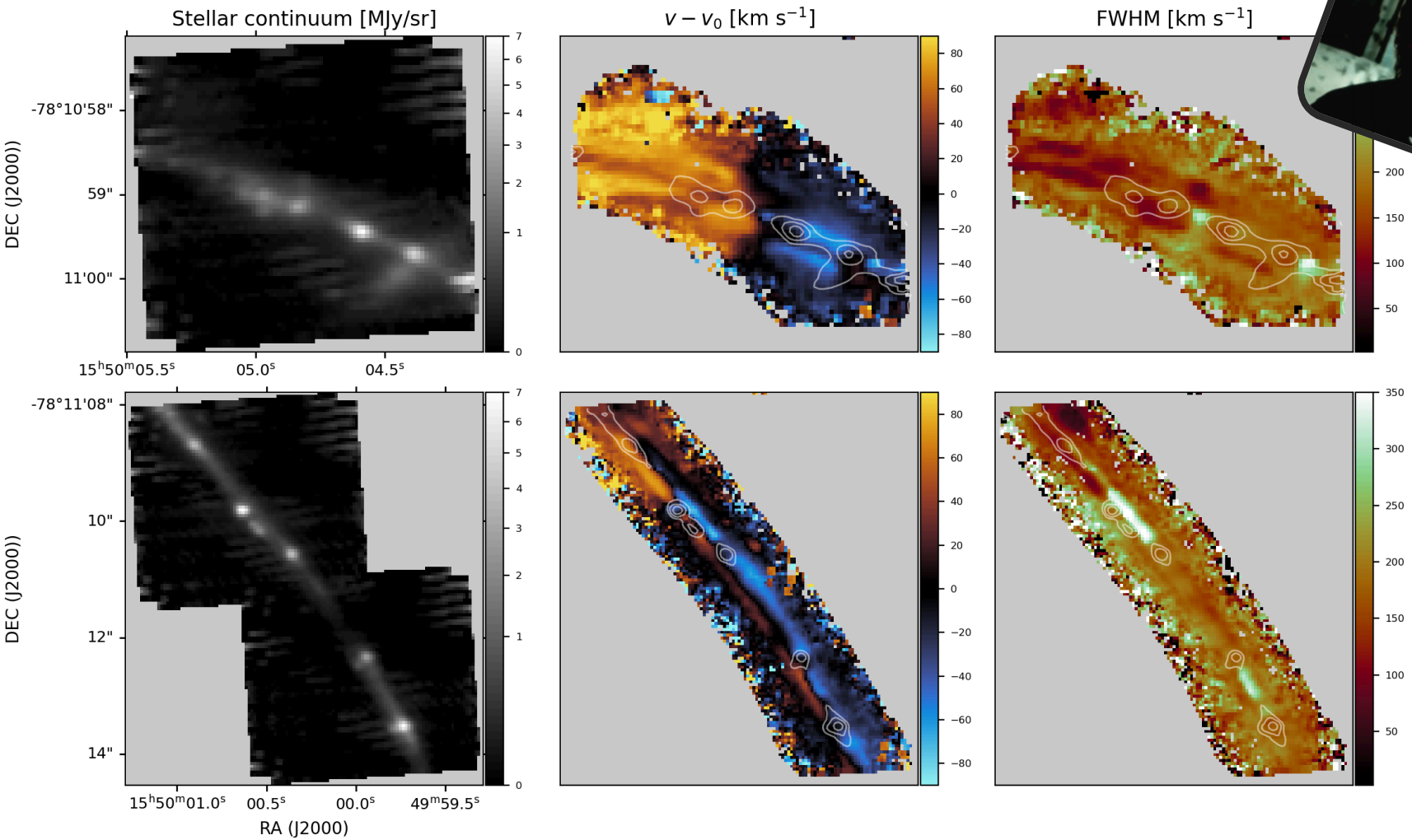
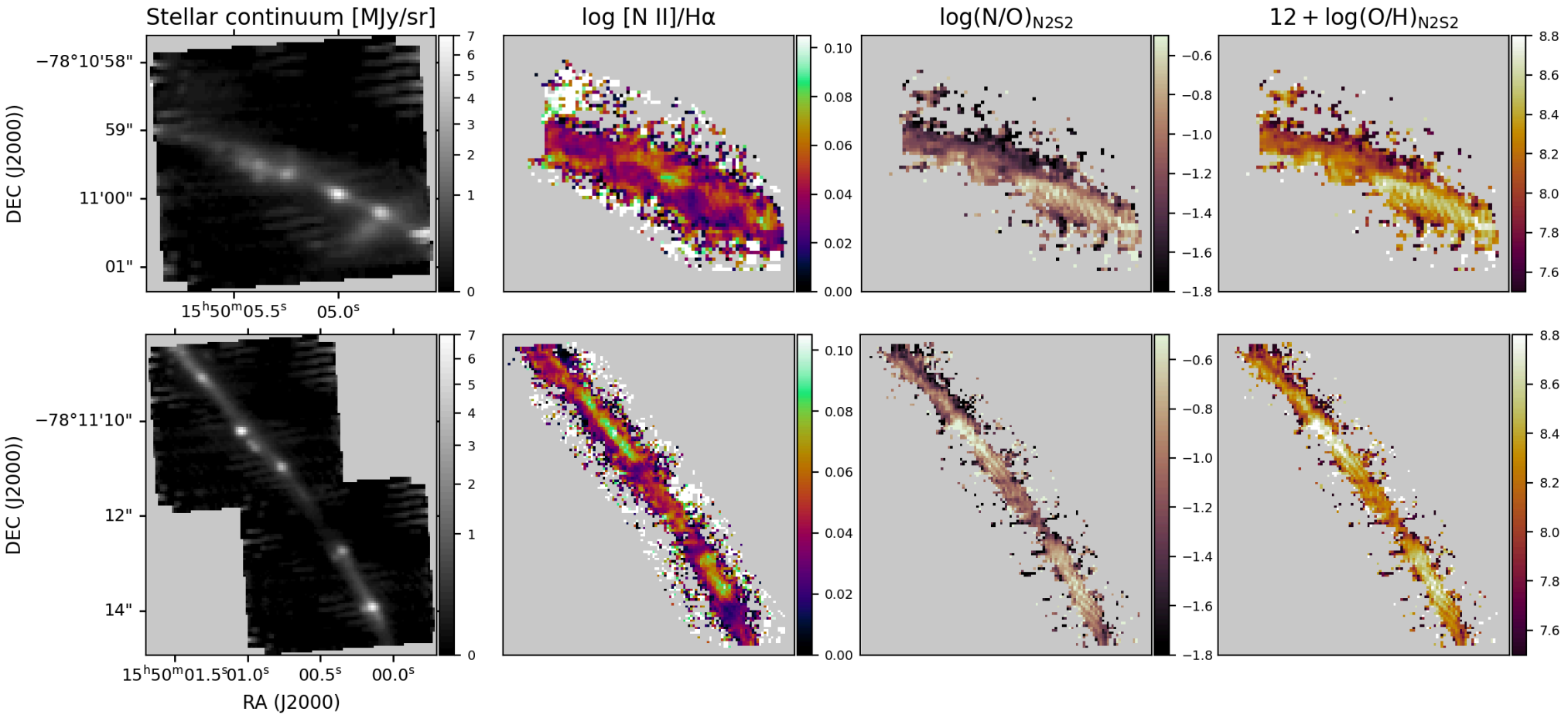
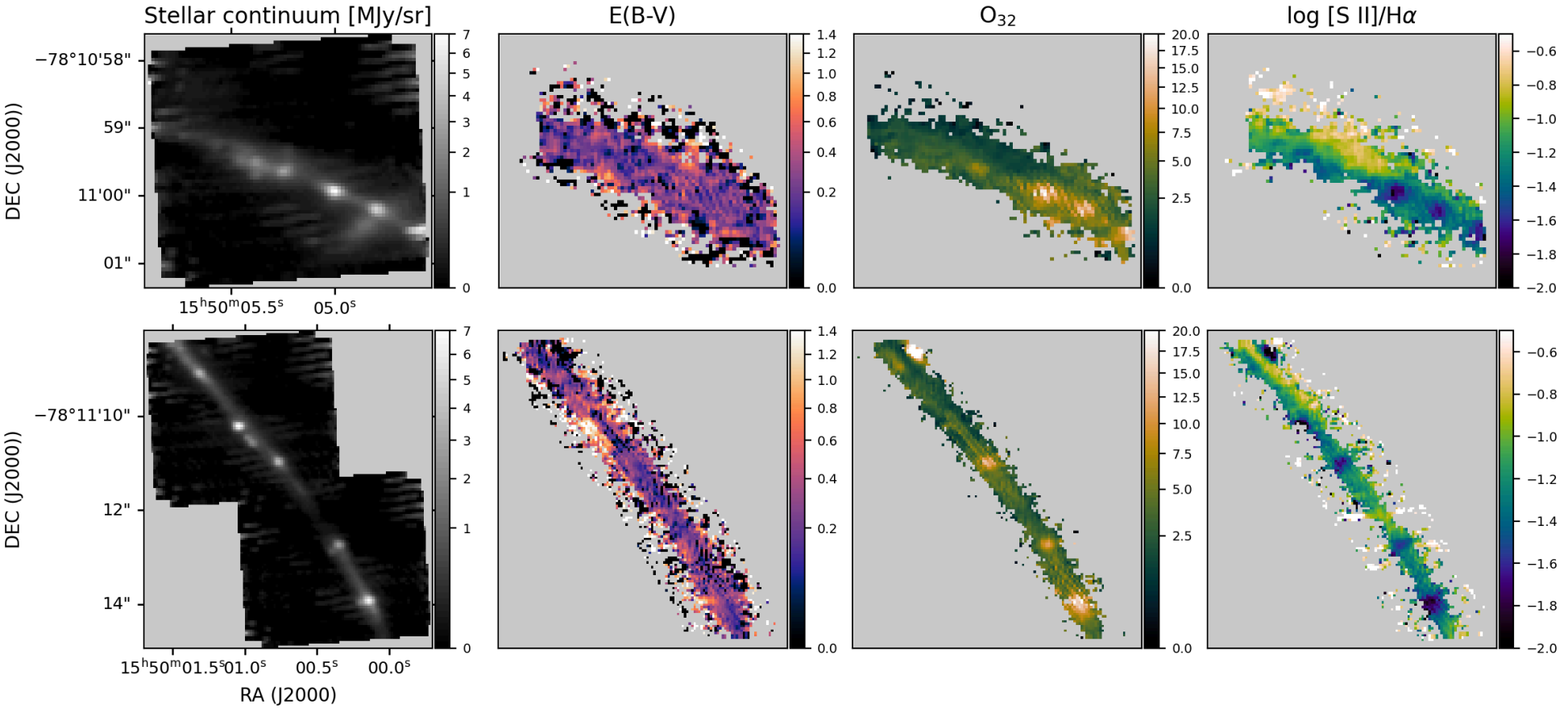


Chemical enrichment



Patterns in dust, ionization and sulphur deficiency



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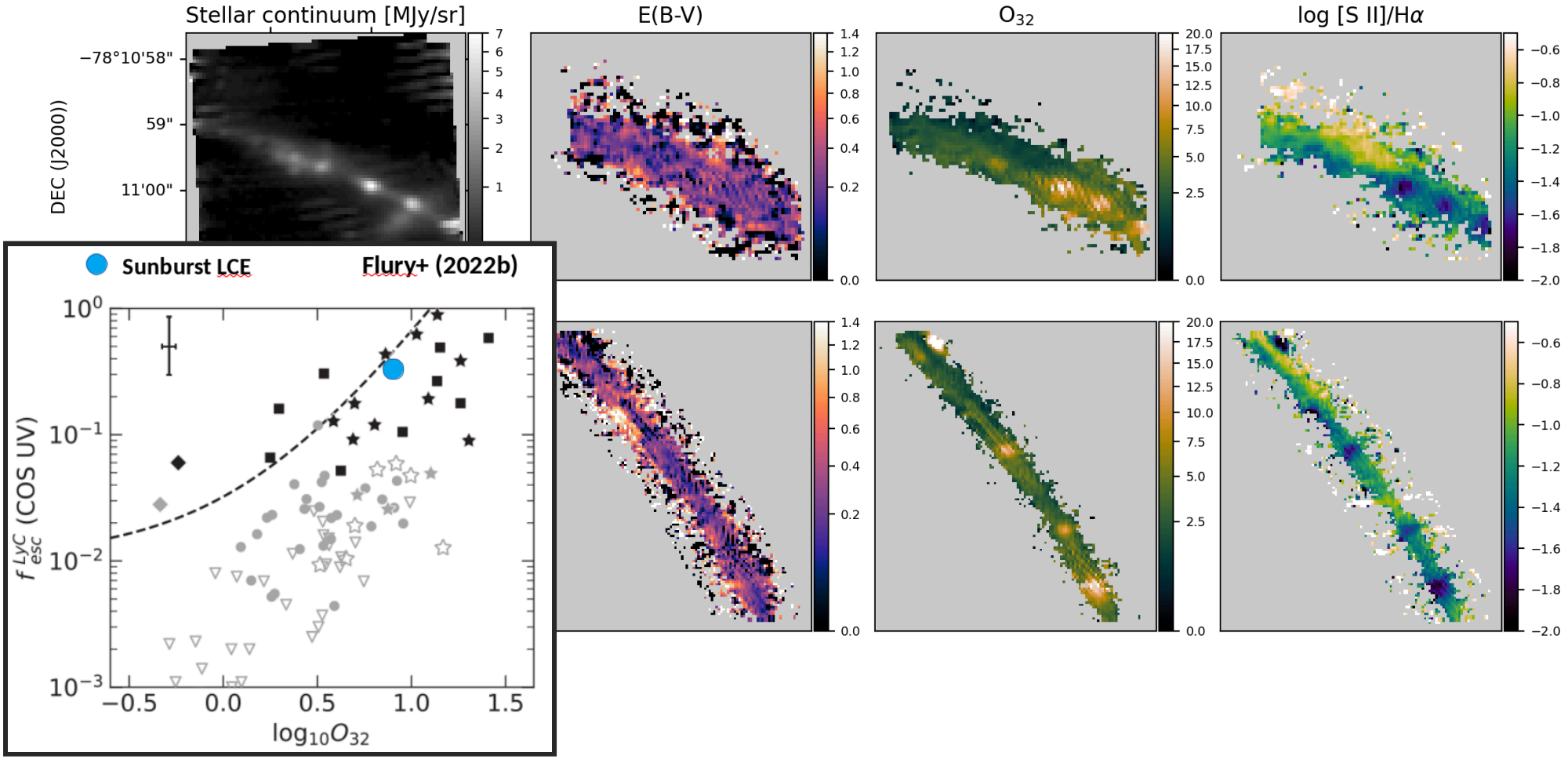
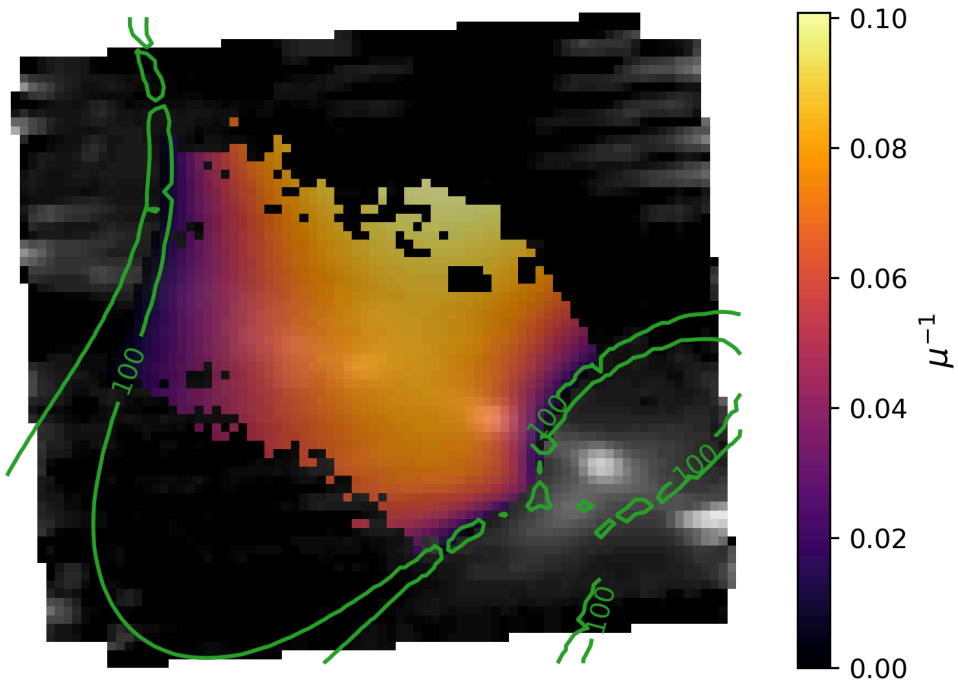


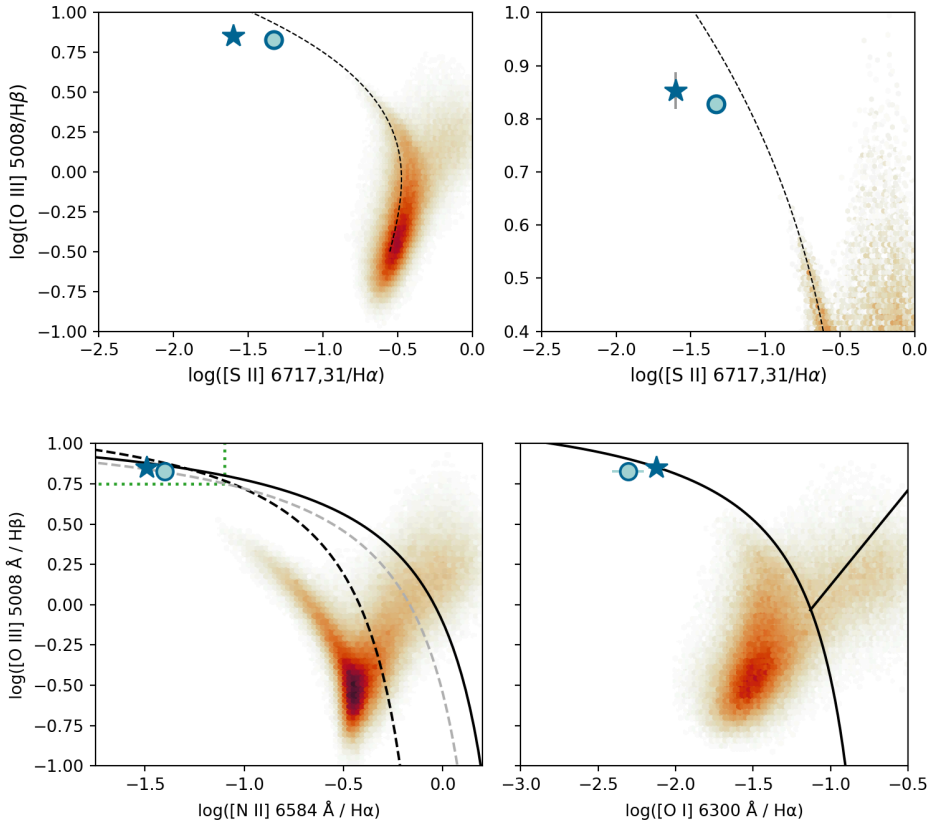
Integrated, weighted properties

We can “squint” to compare to un-lensed galaxies at similar redshifts:



Mask containing the most complete image of the galaxy, overlaid with inverse magnification

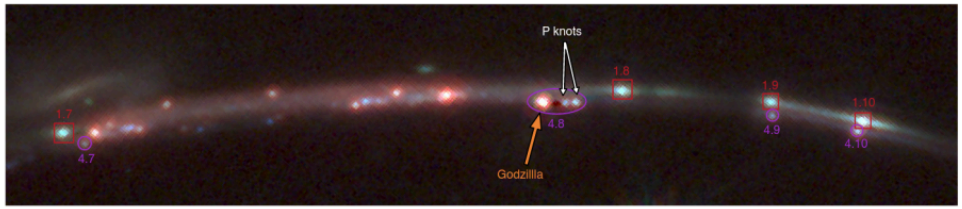
Example: BPT and [S II] diagram

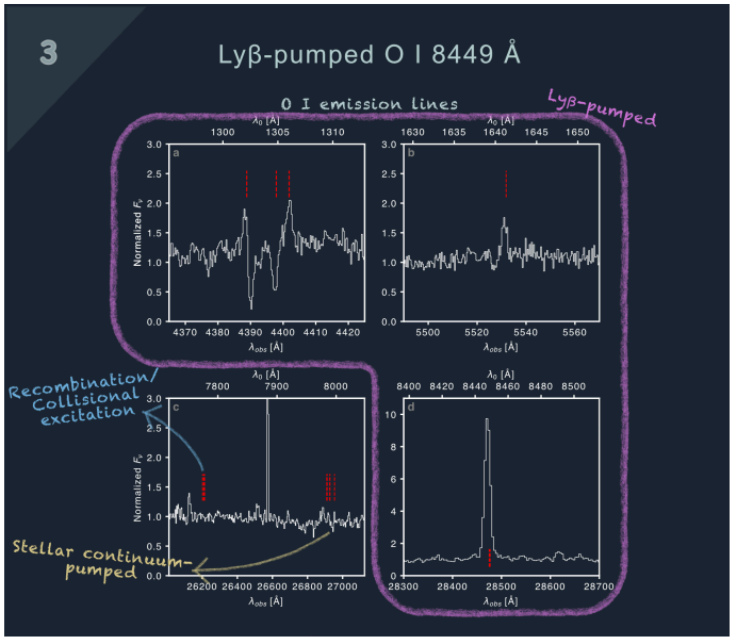


Shameless plug

The Sunburst Arc with JWST: II. Observations of an Eta Carinae Analog at $z = 2.37$

S. Choe[1⋆], T. Emil Rivera-Thorsen[1], H. Dahle[2], K. Sharon[3], M. Riley Owens[4], J. R. Rigby[5], M. B. Bayliss[4], M. J. Hayes[1], T. Hutchison[5], B. Welch[5,6,7], J. Chisholm[8], M. D. Gladders[9,10], and G. Khullar[11]





Pointing 2 contains an extremely magnified ($\mu \approx 10^4$) η Car-analog embedded in a bright cluster!

Summary

A coherent picture is beginning to form:

- The cluster is **young**, **hot** and **massive**
- It sits in the **outskirts** of the galaxy
- The galaxy is likely interacting → could help strip HI away from the cluster (*hat tip @ le Reste*)
- The moderately thick and uniform **dust layer** could hint at photoionization as most important ionization mechanism
- **Outflows** exist but… They are weird.
- This scenario seems consistent with the Lyα modeling by *Almada Monter+*
- LyC proxies such as O32, SII deficit, and Lyα seem to work fairly well in this case
  - Especially locally near the LCE, but also for the "squinted" spectra.
- Strange spatial coincidence in N^+ enrichment and gas outflows

Thank y’all for now!