



Universiteit  
Leiden  
The Netherlands

## Local Universe as a benchmark to stellar populations in the epoch of reionisation

Nanayakkara, T.

### Citation

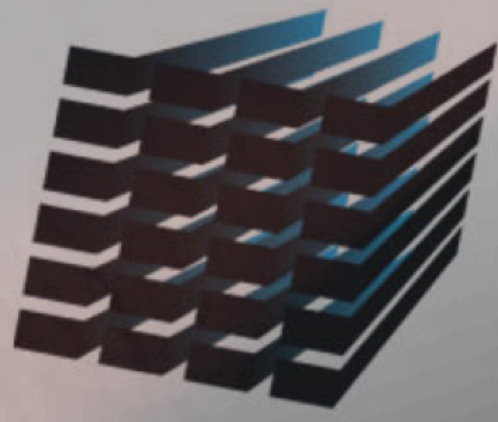
Nanayakkara, T. (2020). Local Universe as a benchmark to stellar populations in the epoch of reionisation. *The Build-Up Of Galaxies Through Multiple Tracers And Facilities*. doi:10.5281/zenodo.3756524

Version: Publisher's Version

License: [Creative Commons CC BY 4.0 license](#)

Downloaded from: <https://hdl.handle.net/1887/3142004>

**Note:** To cite this publication please use the final published version (if applicable).



**MUSE**  
multi unit spectroscopic explorer

**Sterrewacht  
Leiden**

LOCAL UNIVERSE AS A BENCHMARK TO STELLAR POPULATIONS IN THE  
EPOCH OF REIONISATION

THEMIYA NANAYAKKARA

@themiyan

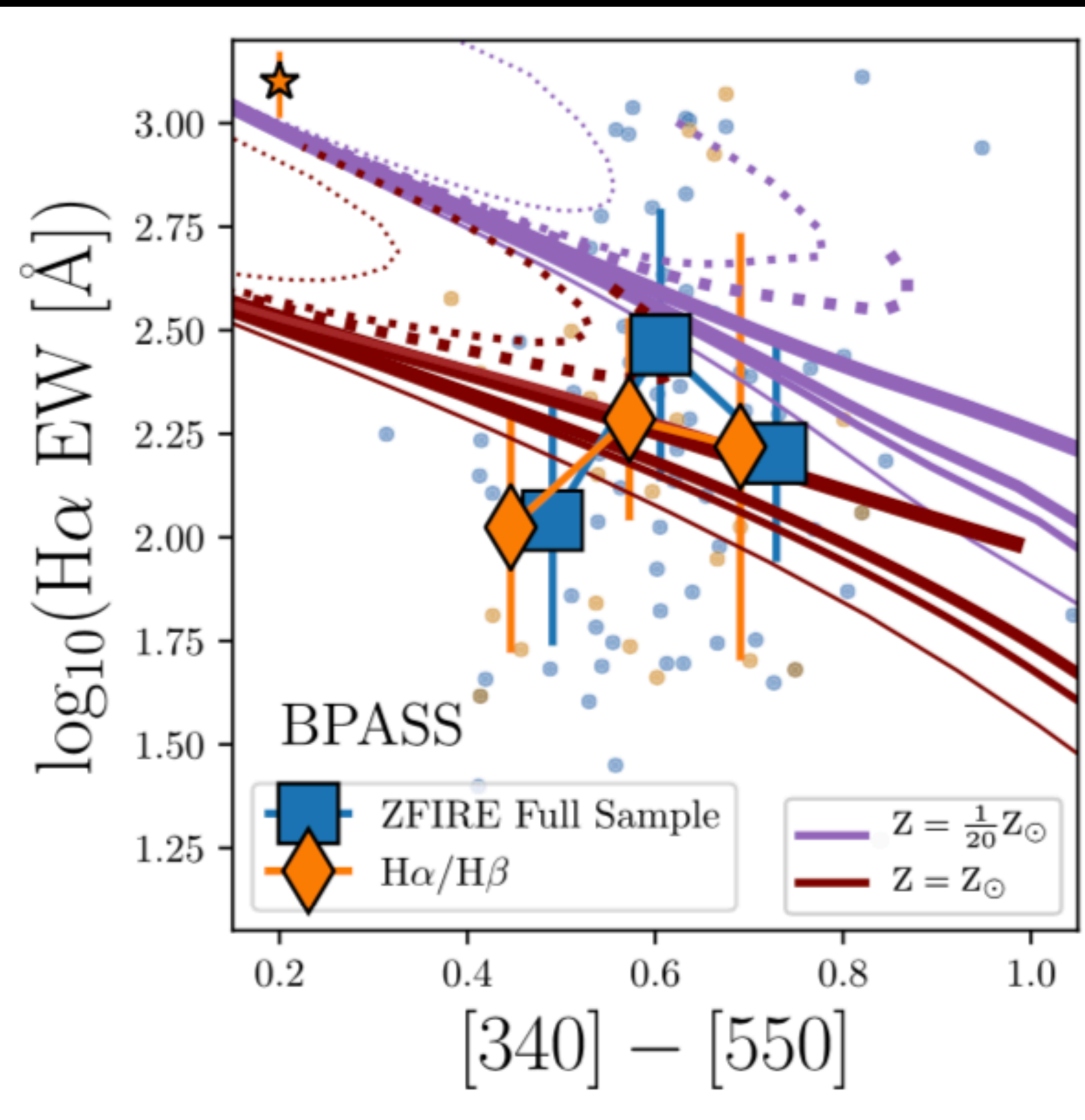


**SWIN  
BUR  
NE**

CENTRE FOR  
ASTROPHYSICS AND  
SUPERCOMPUTING

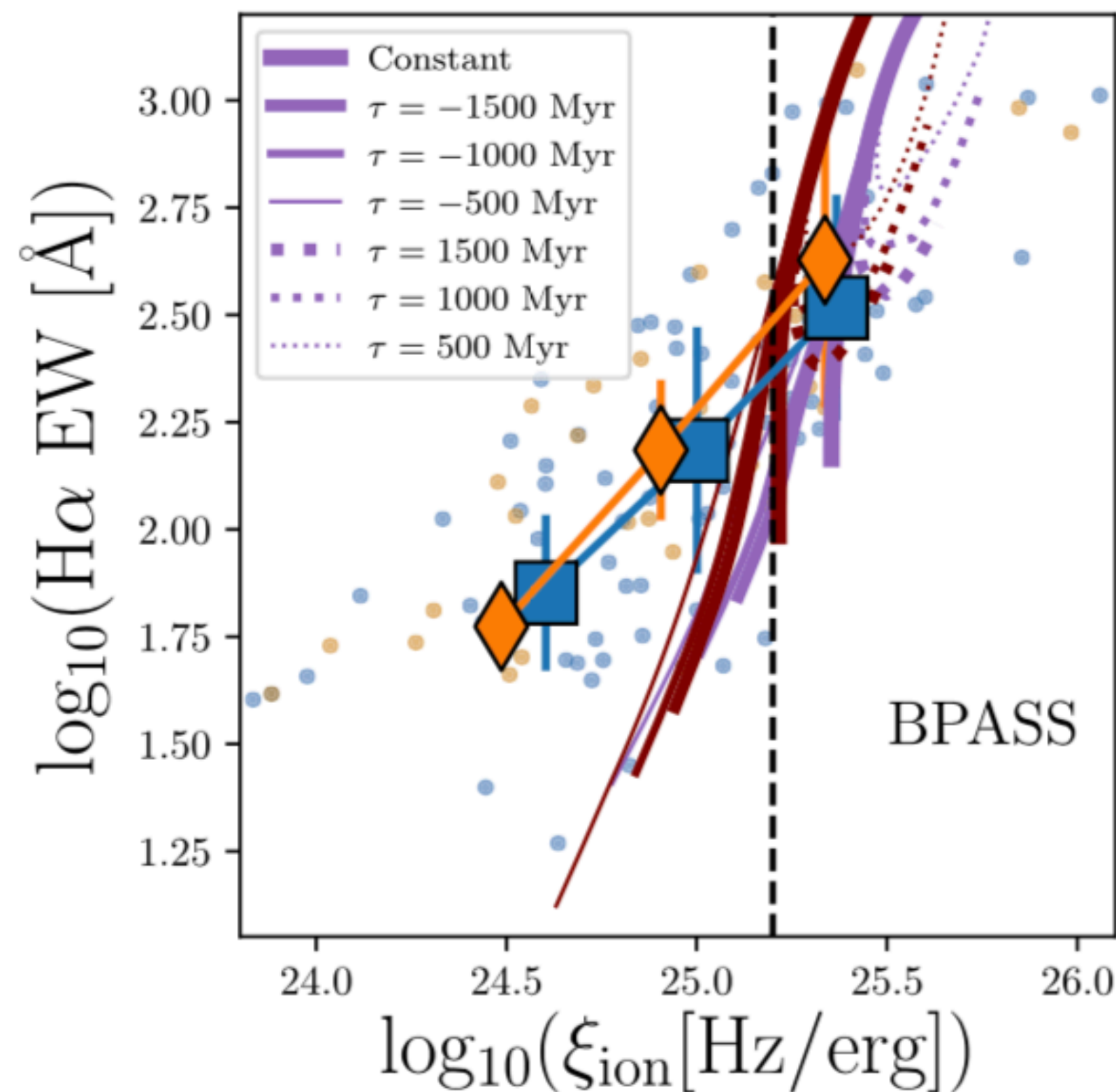
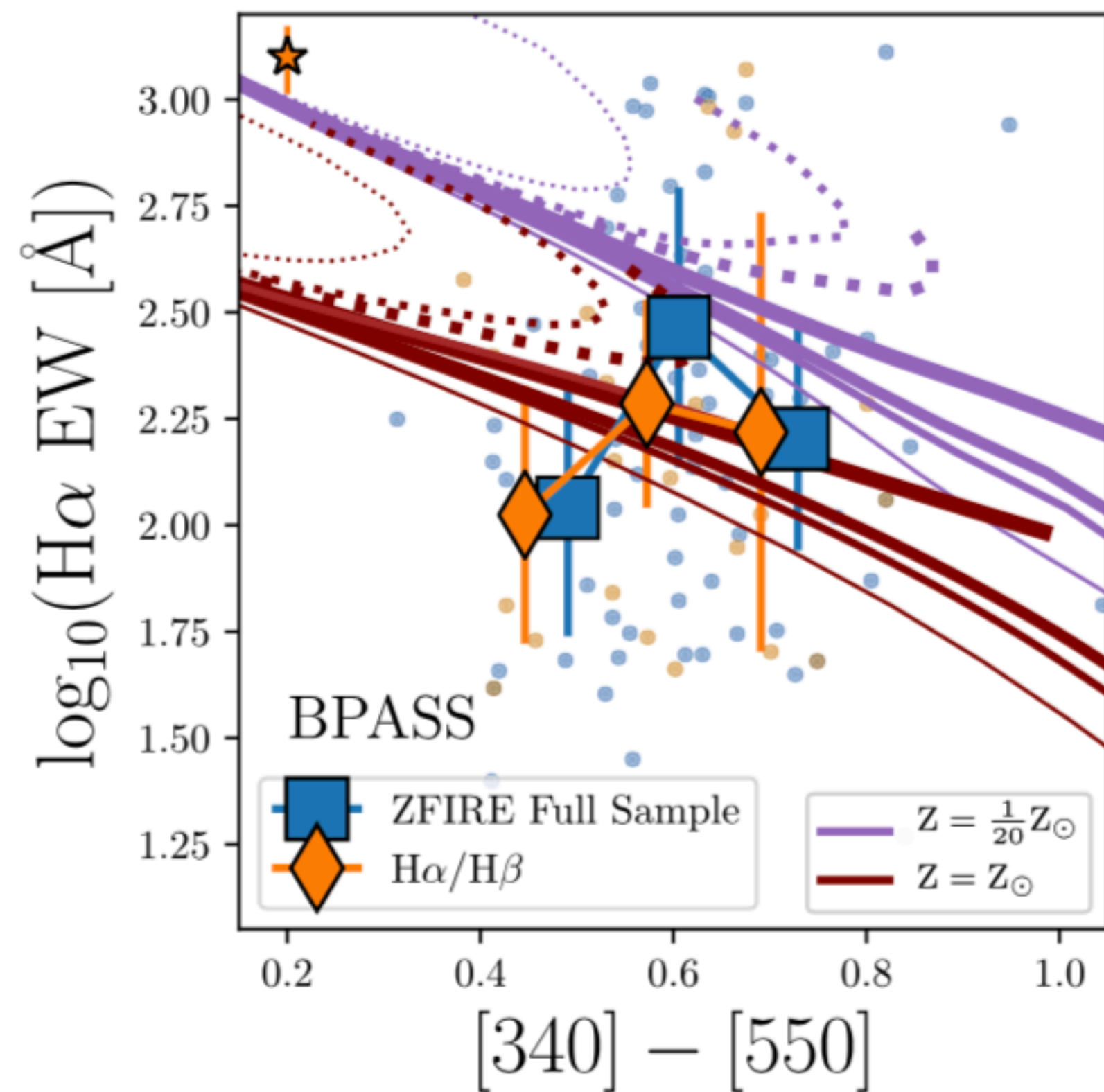
# Stellar populations in the early Universe

# We have shown that current stellar population models find it challenging to reproduce observations



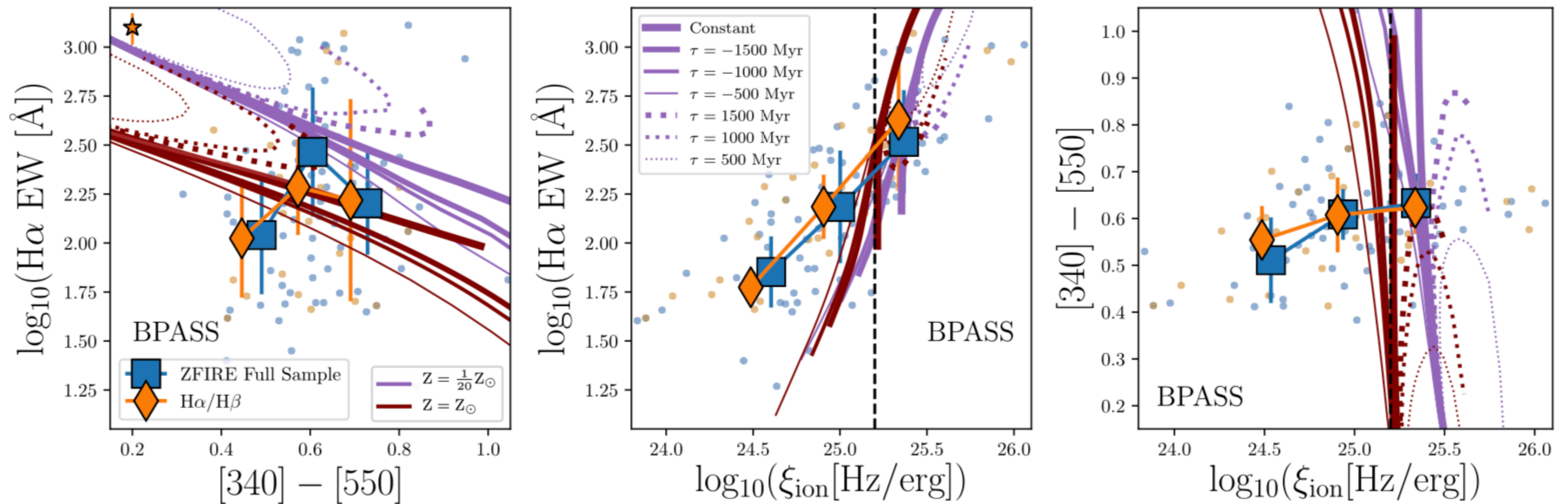
©Nanayakkara+(2020), also see Nanayakkara+(2018)

# We have shown that current stellar population models find it challenging to reproduce observations



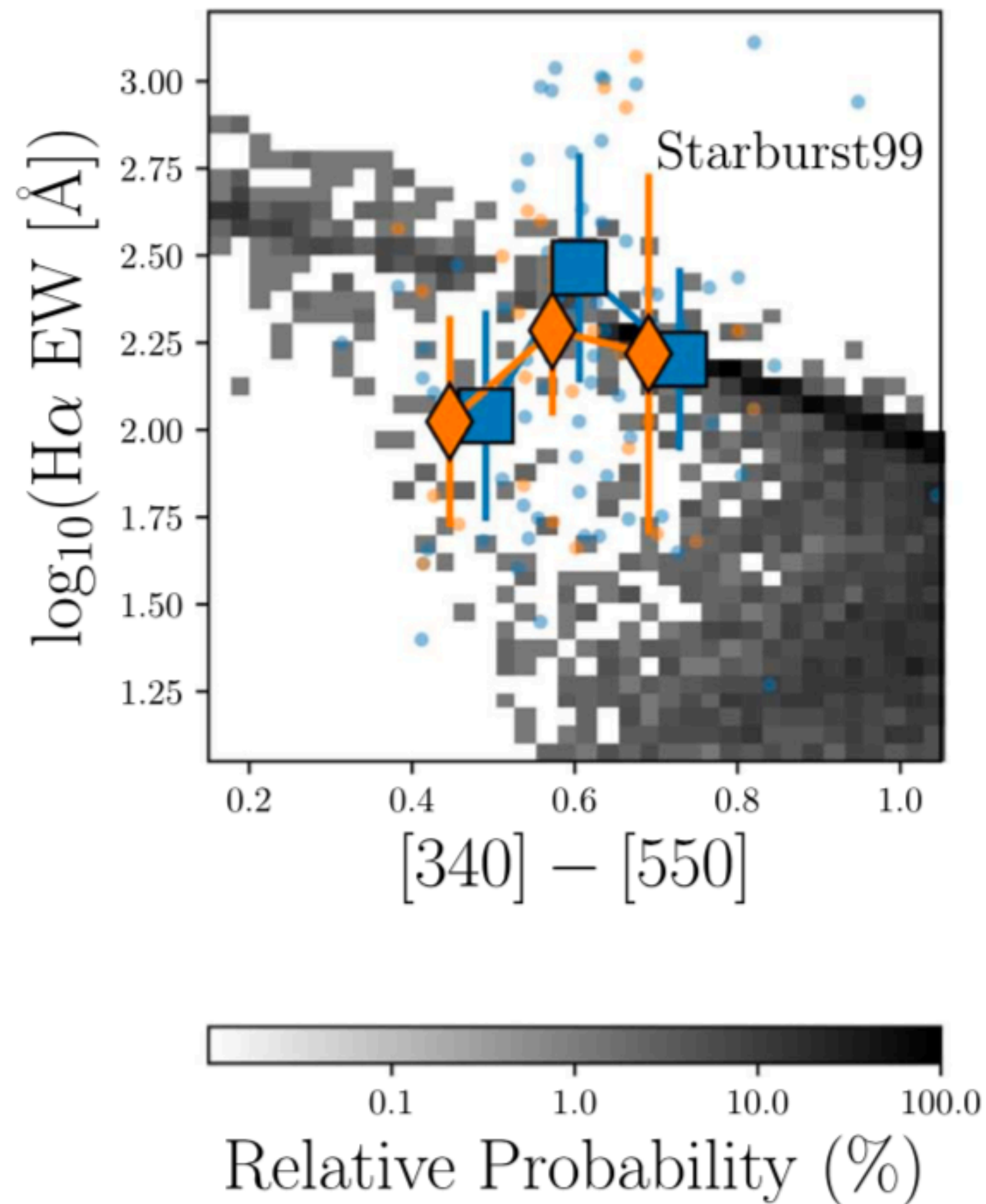
©Nanayakkara+(2020), also see Nanayakkara+(2018)

# We have shown that current stellar population models find it challenging to reproduce observations



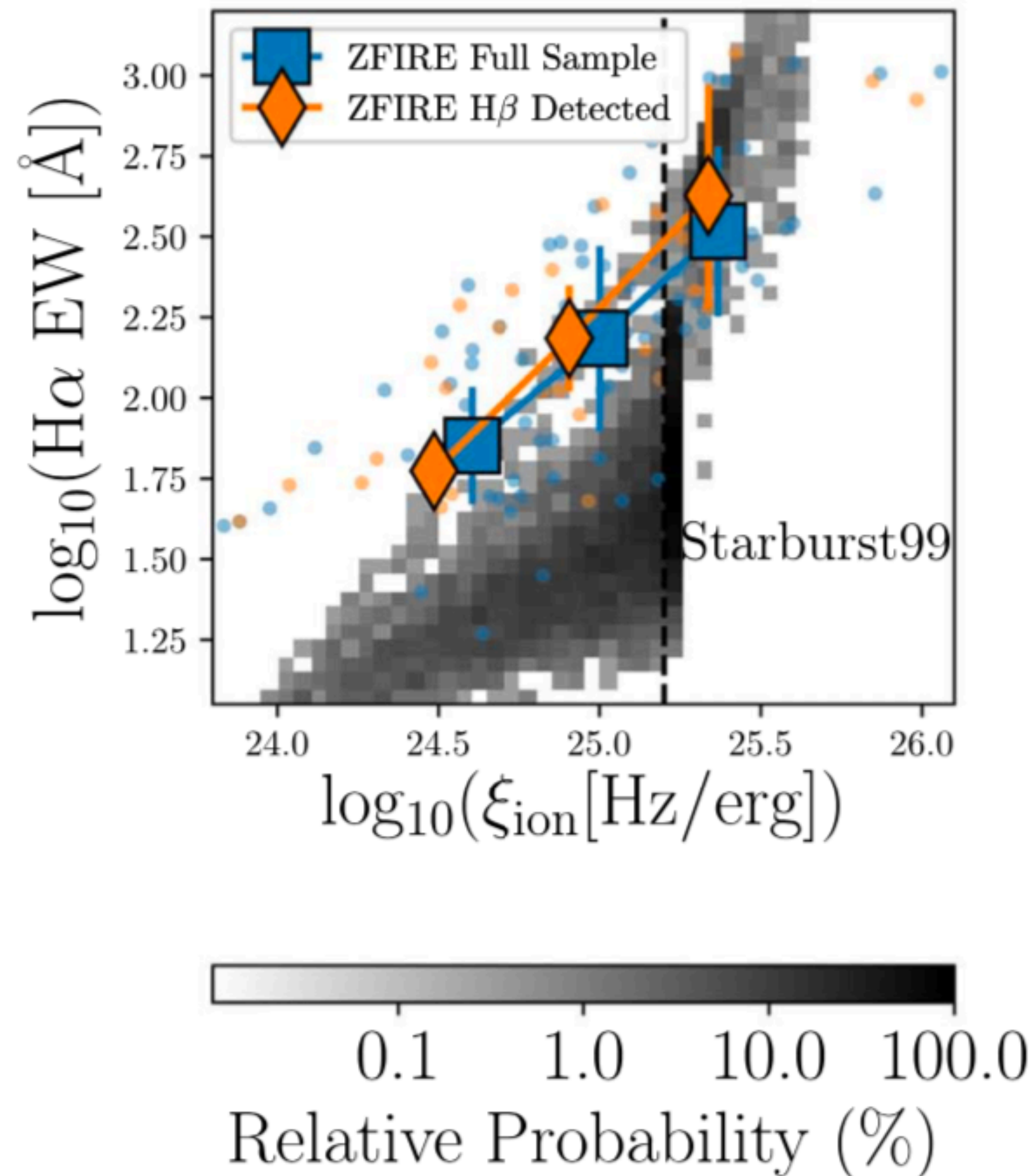
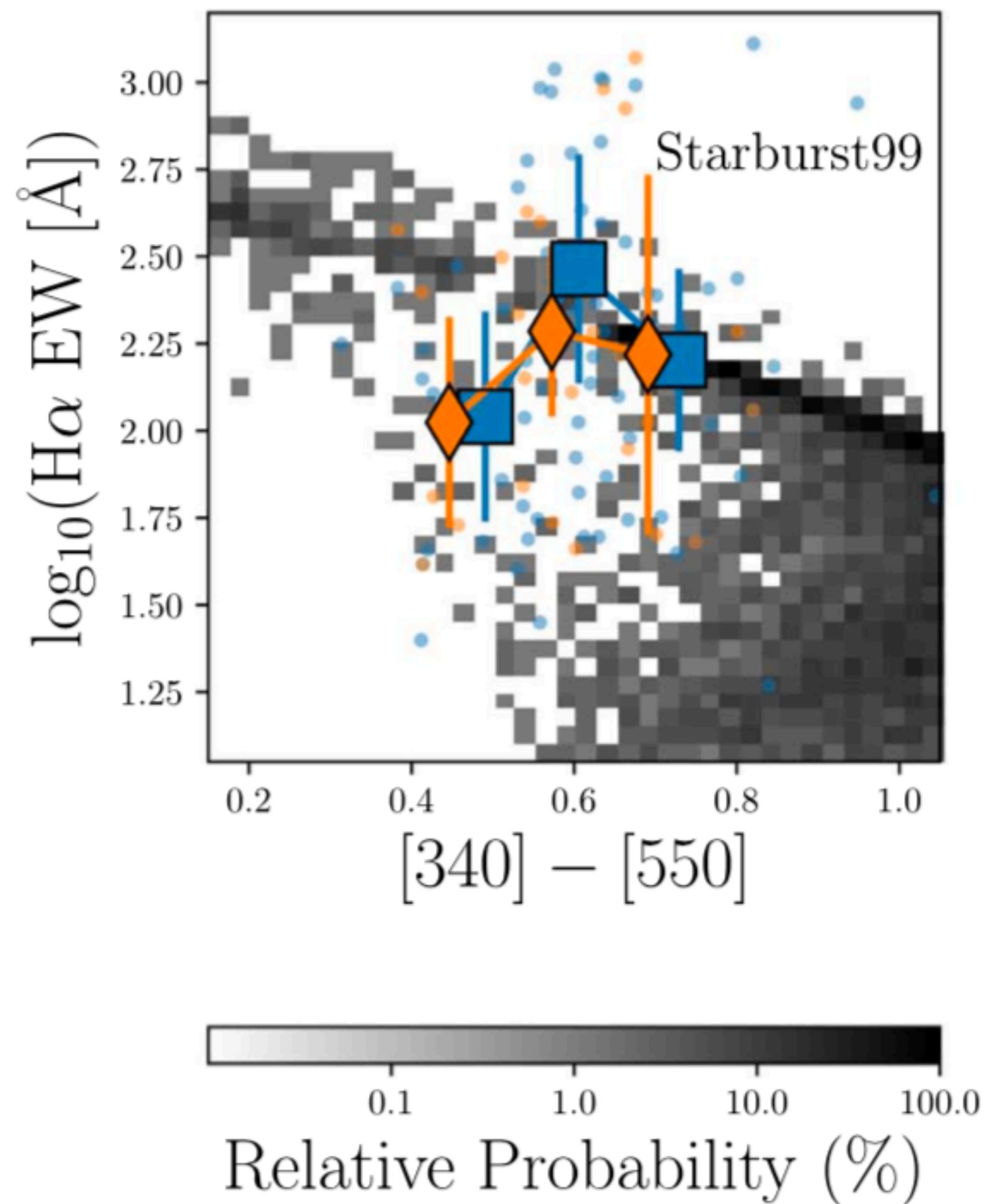
©Nanayakkara+(2020), also see Nanayakkara+(2018)

# We have shown that current stellar population models find it challenging to reproduce observations

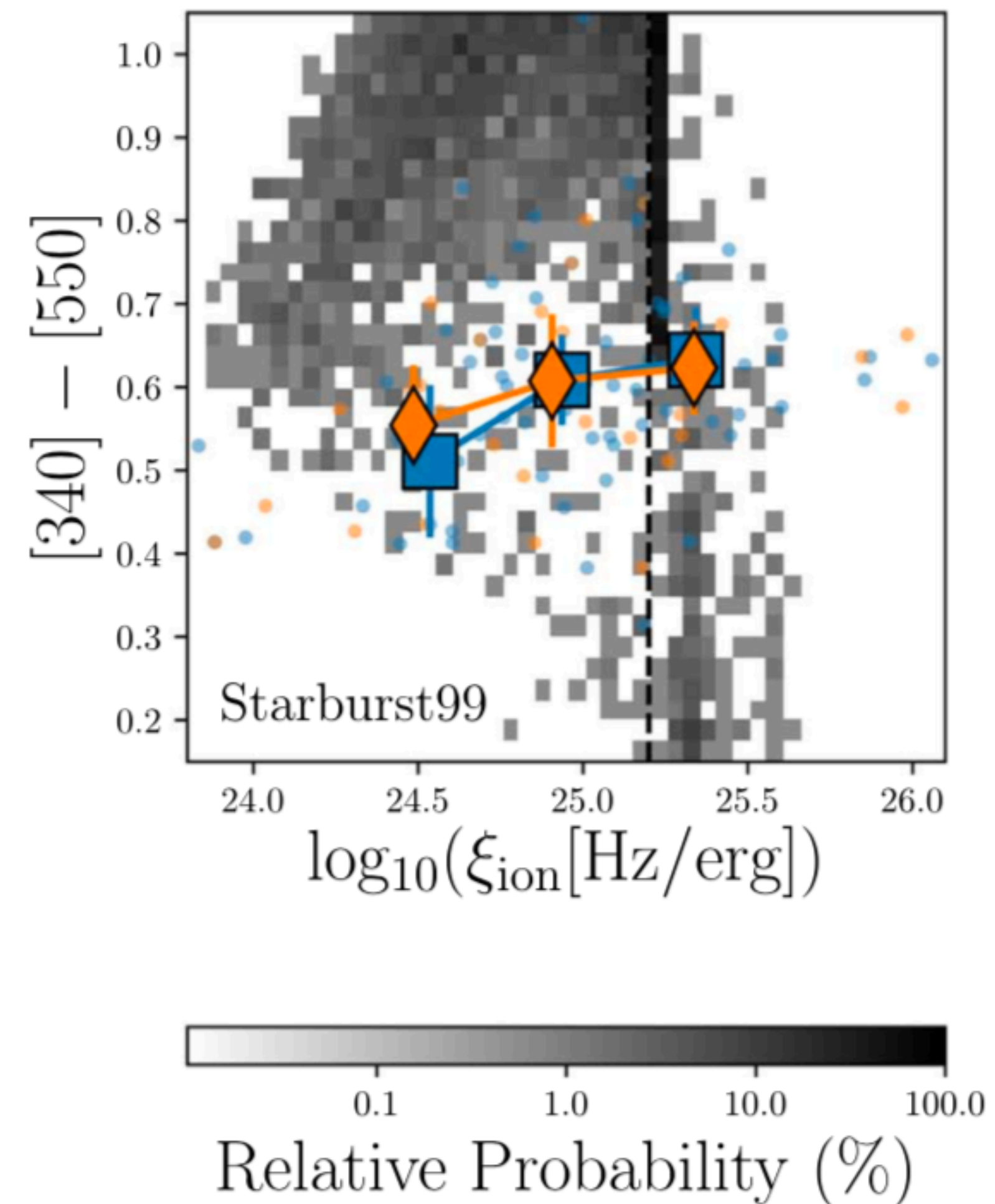
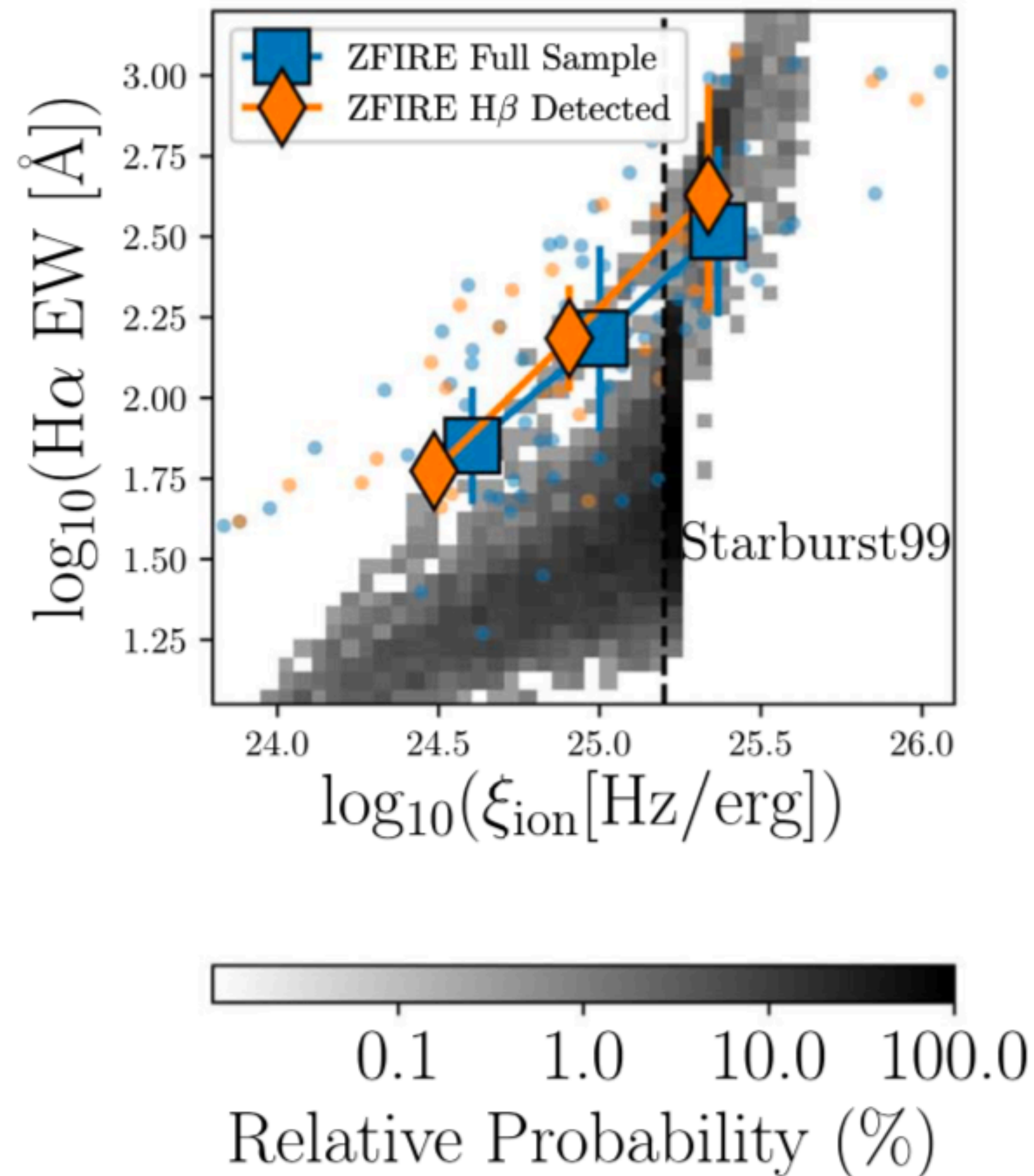
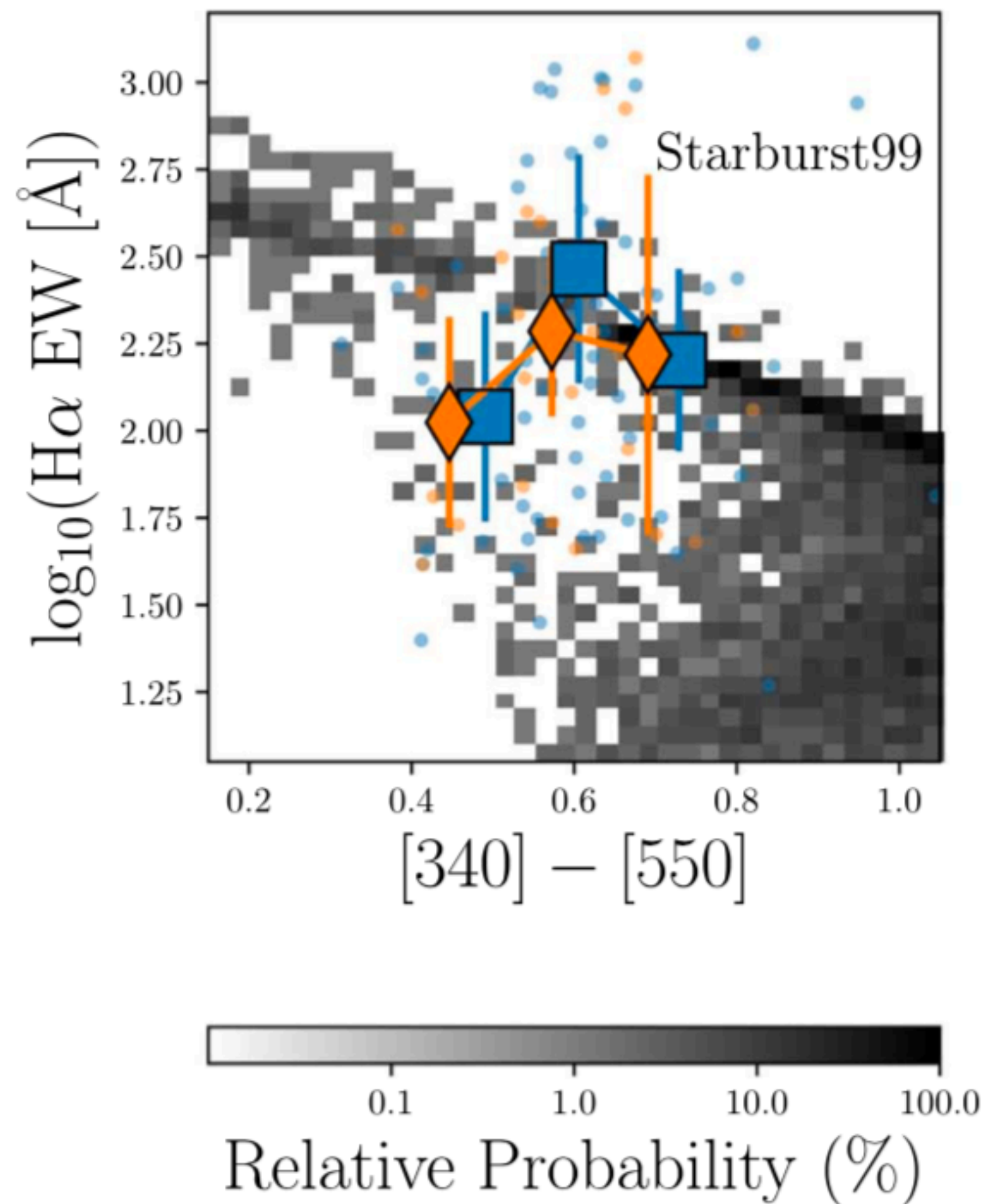


©Nanayakkara+(2020), also see Nanayakkara+(2018)

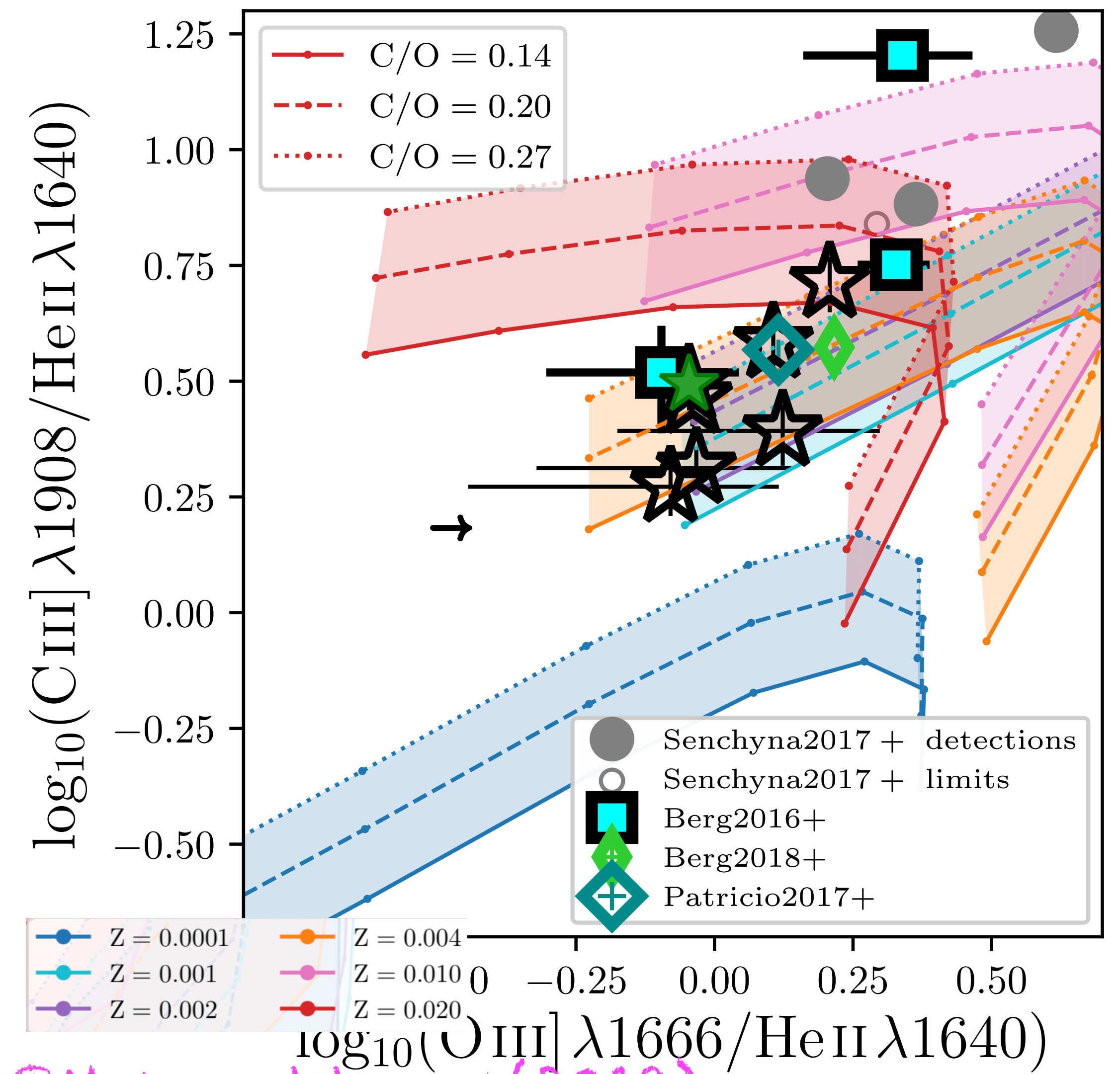
# We have shown that current stellar population models find it challenging to reproduce observations



# We have shown that current stellar population models find it challenging to reproduce observations

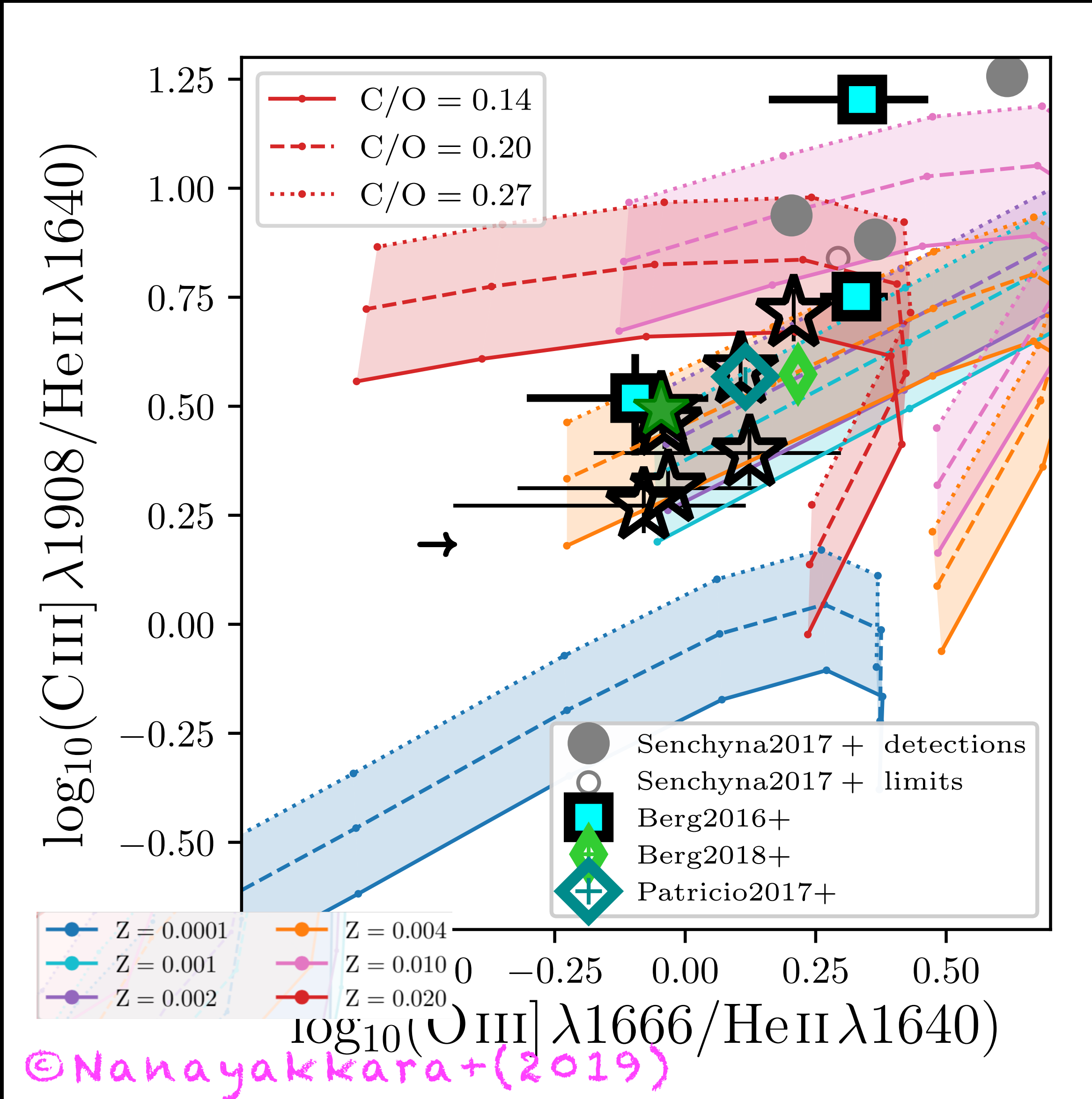
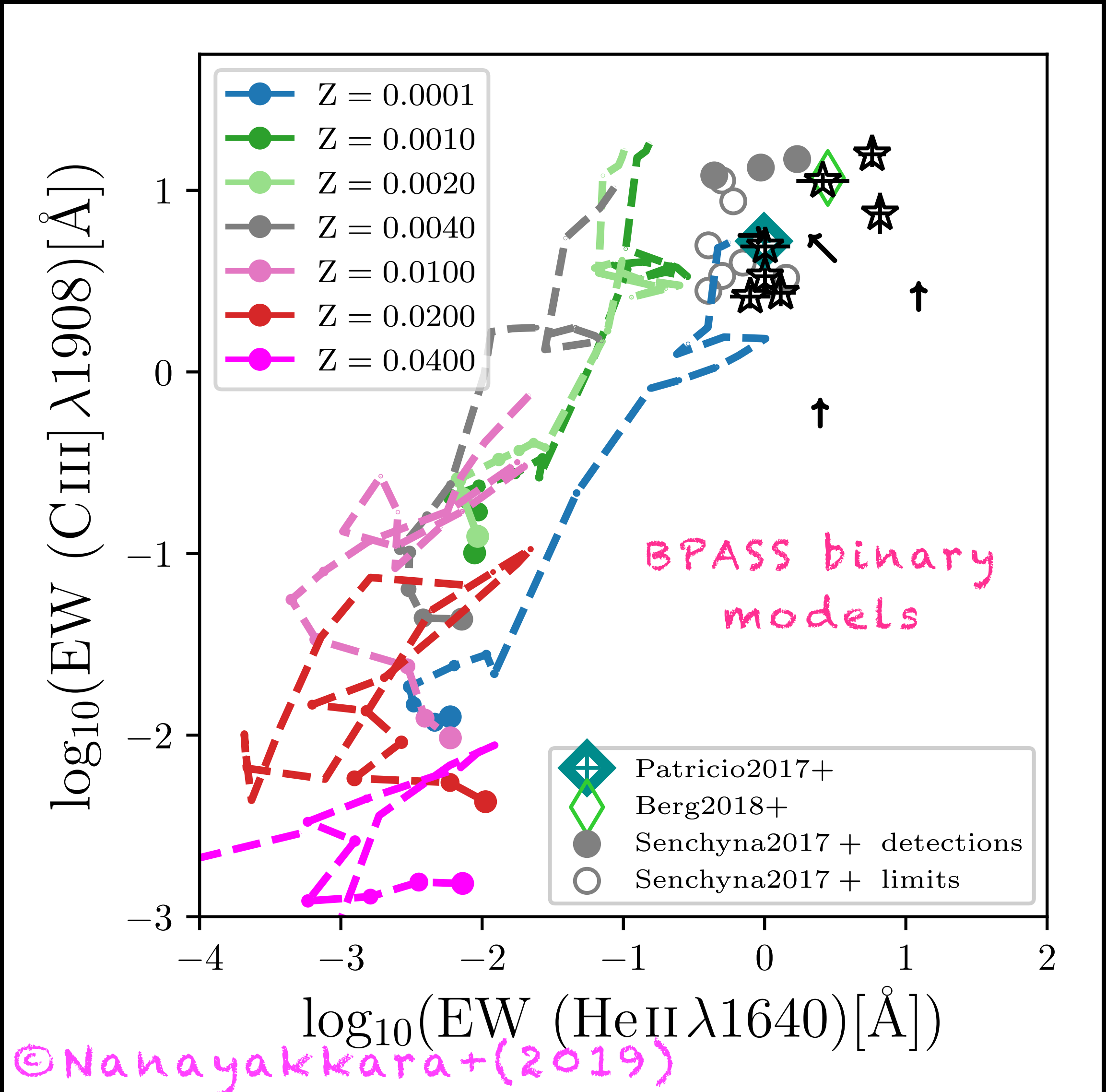


# We have shown that current stellar population models find it challenging to reproduce observations

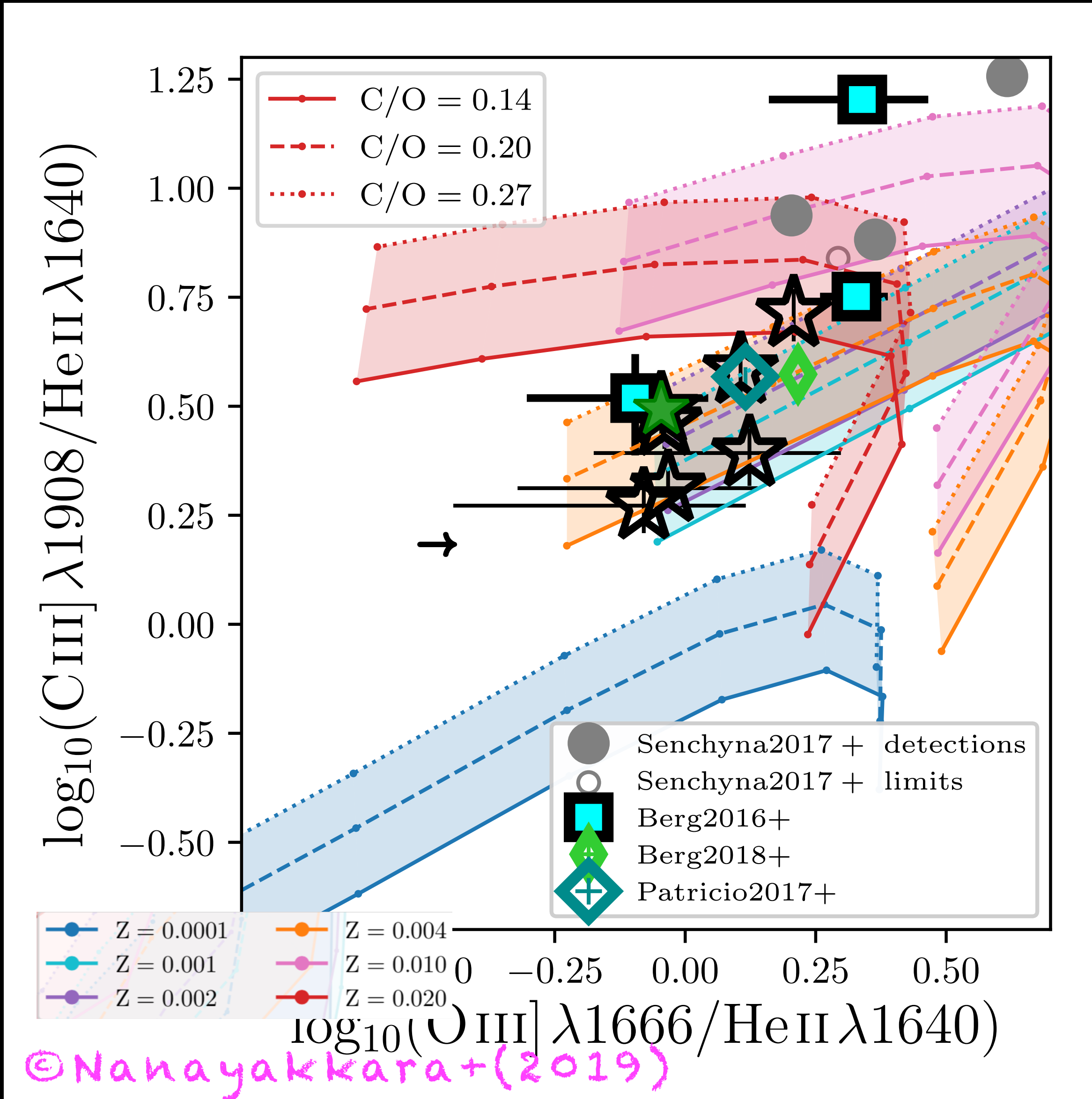
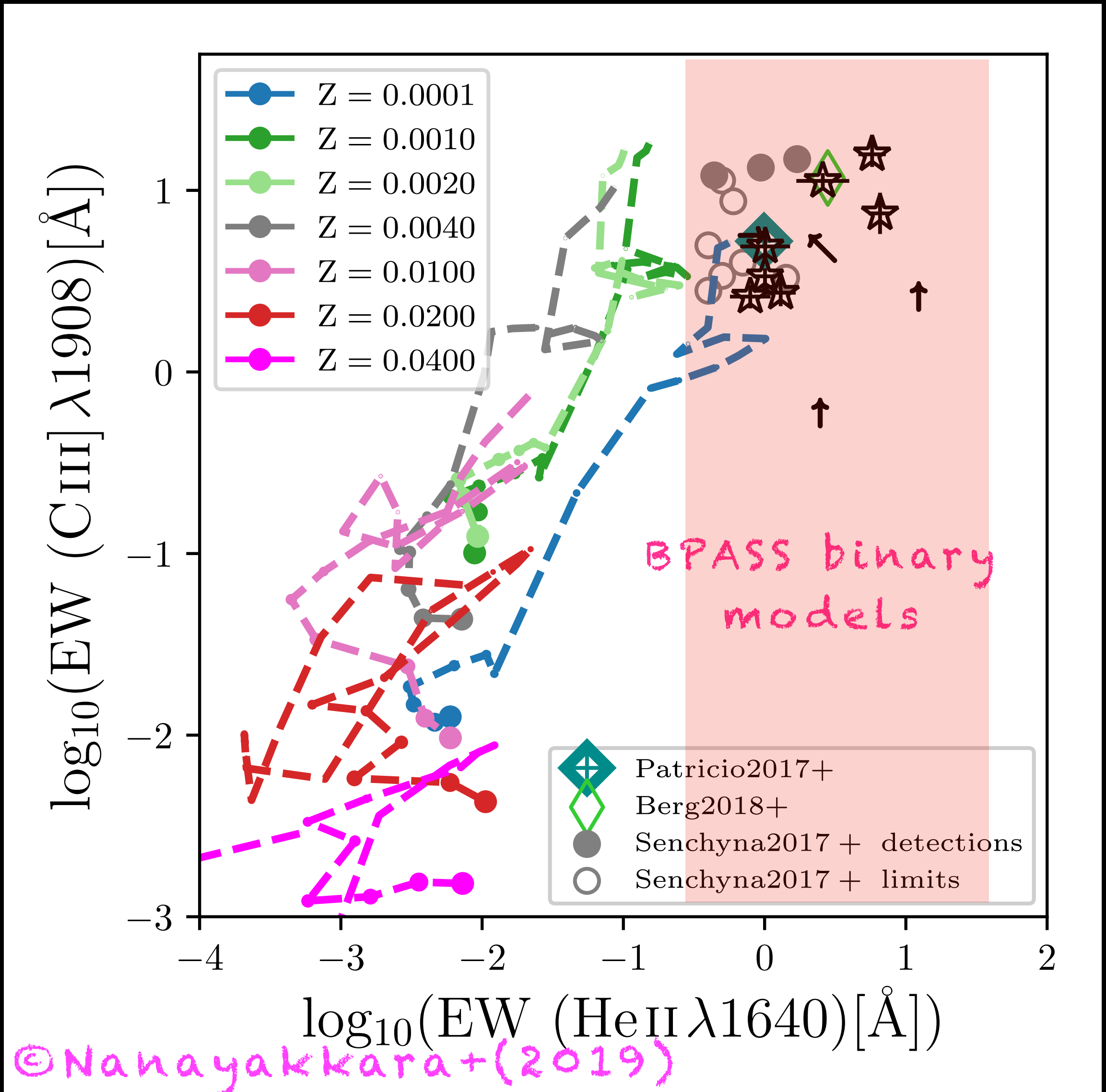


©Nanayakkara+(2019)

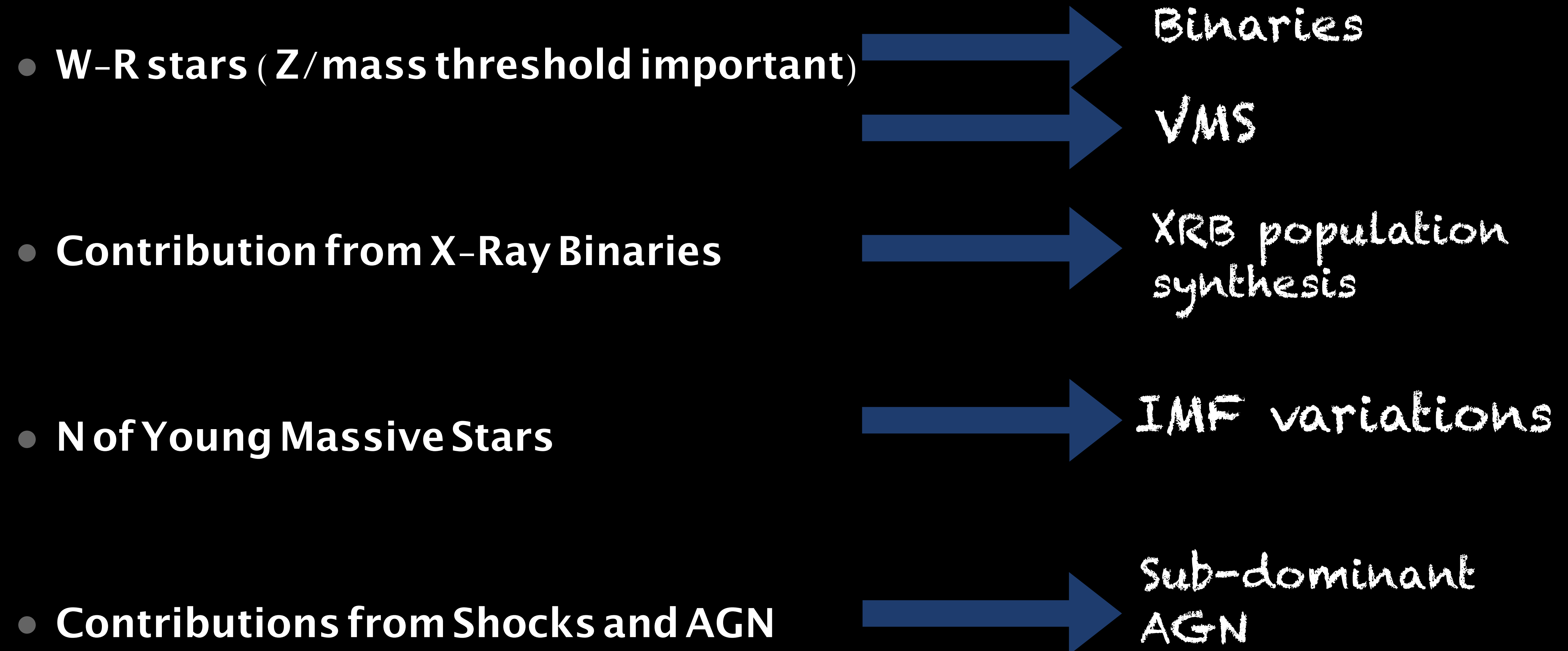
# We have shown that current stellar population models find it challenging to reproduce observations



# We have shown that current stellar population models find it challenging to reproduce observations



# Multiple theories currently exist to explain the difference



# Multiple theories currently exist to explain the difference

- W-R stars (Z/mass threshold important)

varies

- Contribution

Complicated to constrain at higher-z

population synthesis

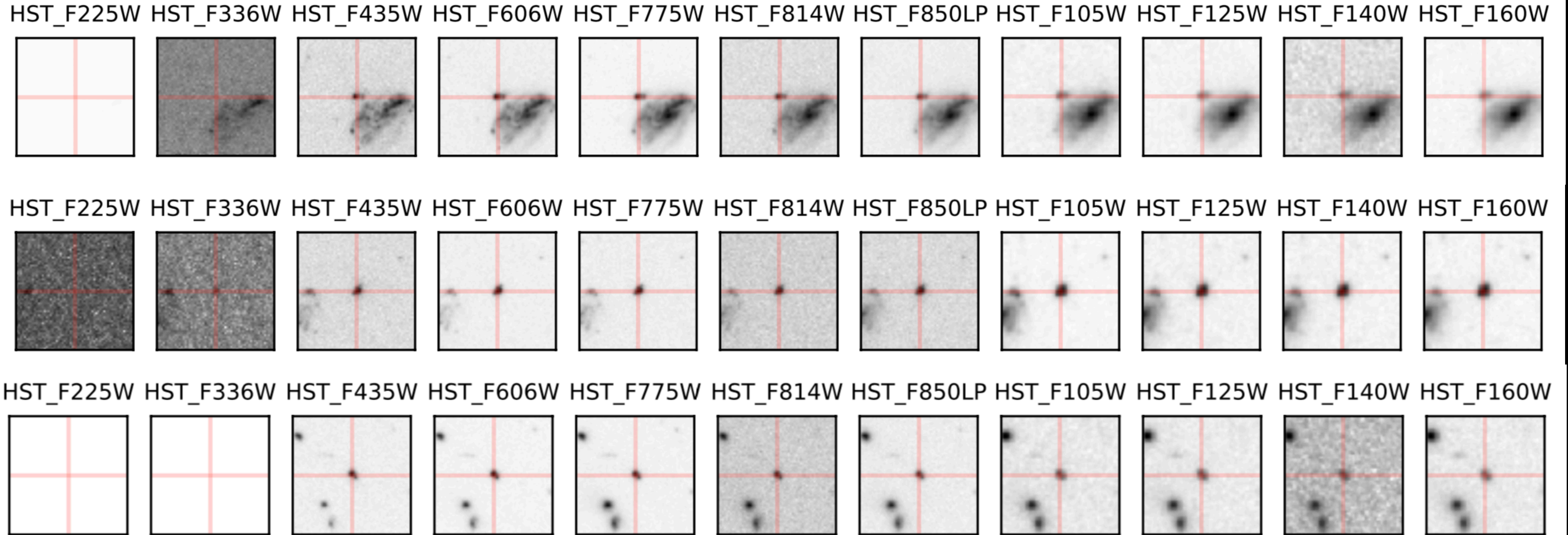
- N of Young Mass

IMF variations

- Contributions from Shocks and AGN

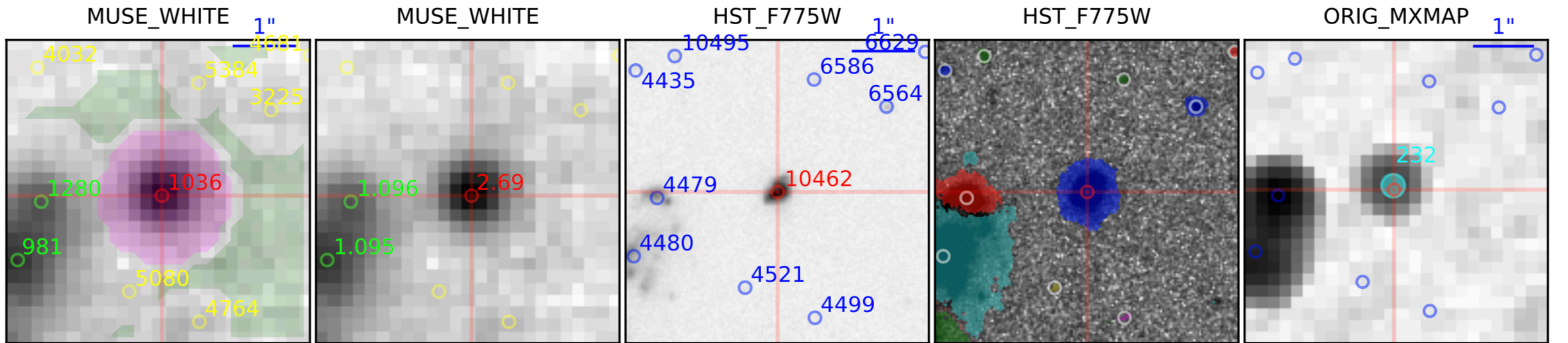
Sub-dominant AGN

# With current instrumentation, spatially resolving capabilities are lower



# With current instrumentation, spatially resolving capabilities are lower

HST\_F225W HST\_F336W HST\_F435W HST\_F606W HST\_F775W HST\_F814W HST\_F850LP HST\_F105W HST\_F125W HST\_F140W HST\_F160W



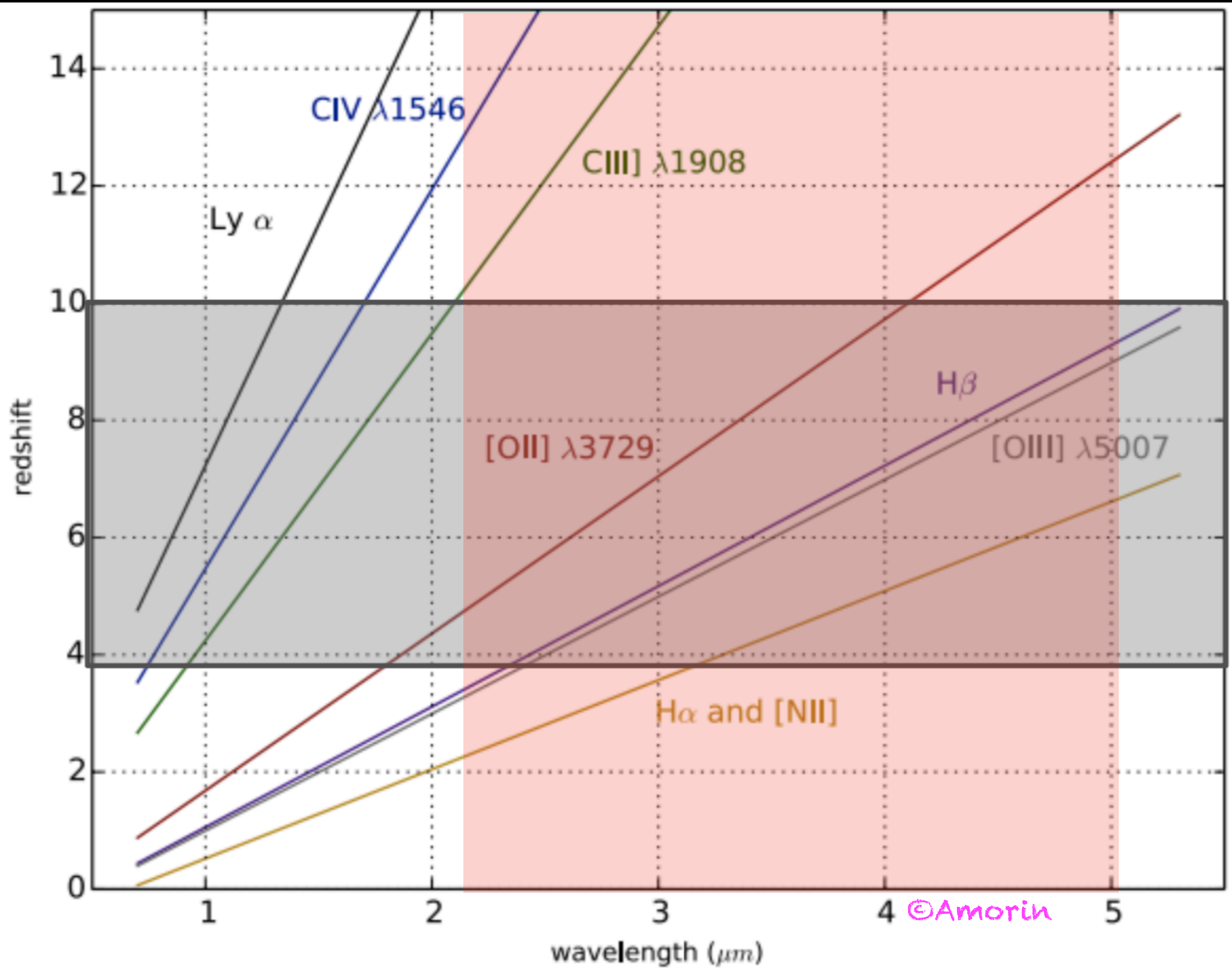
master\_idlist.vot

MUSE redshifts

Rafelski Catalog

Rafelski Catalog

Rafelski Catalog



**Observational limitations in the near-infrared**

# The local Universe

Also see Gunawardhana+2019  
(arXiv:1912.08151)

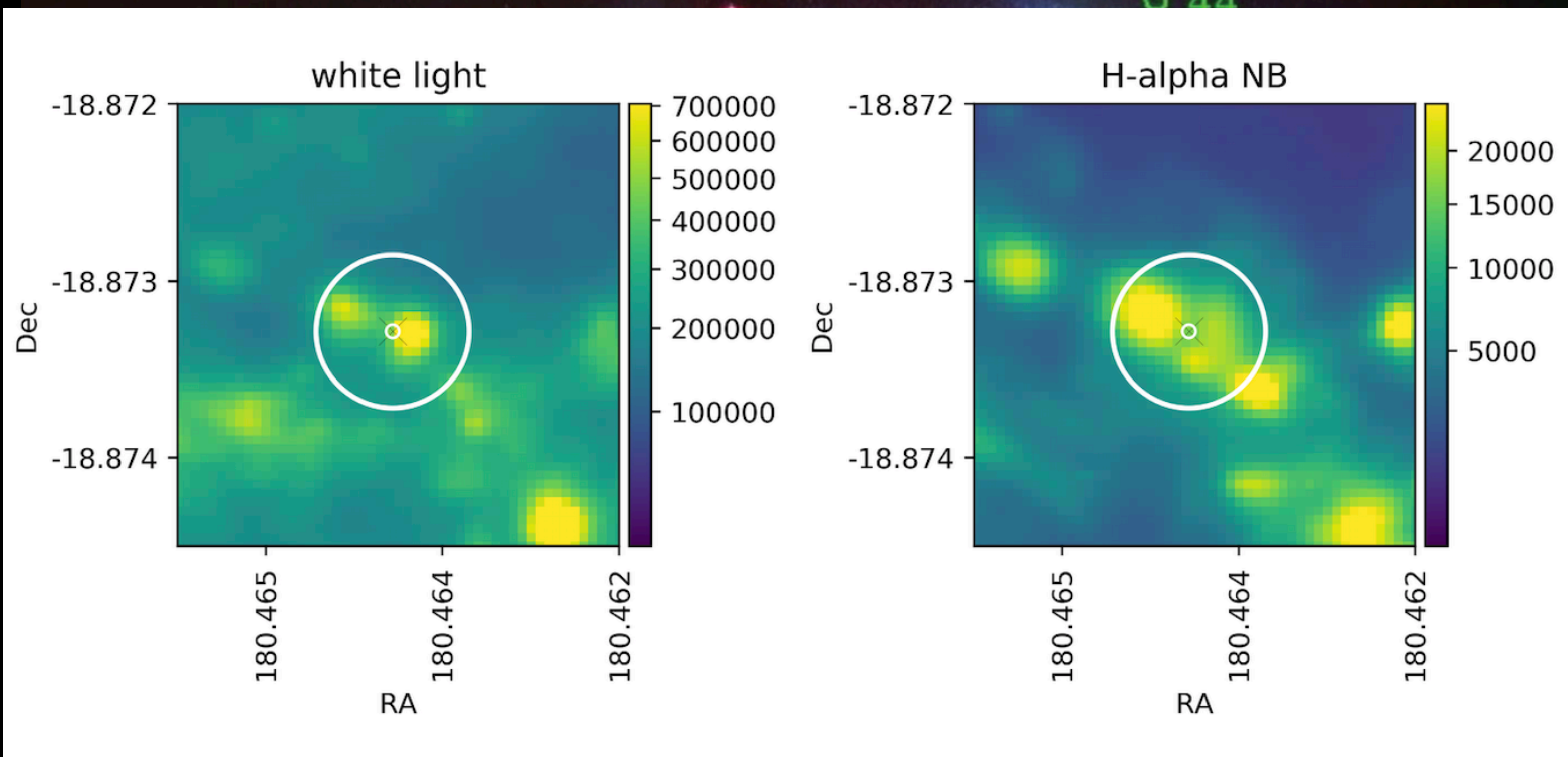
# Example 1

**Local star-burst systems  
with spatially resolved  
analysis of**

- **HII regions**
- **SNR**
- **X-ray binaries**

Also see Gunawardhana+2019  
(arXiv:1912.08151)

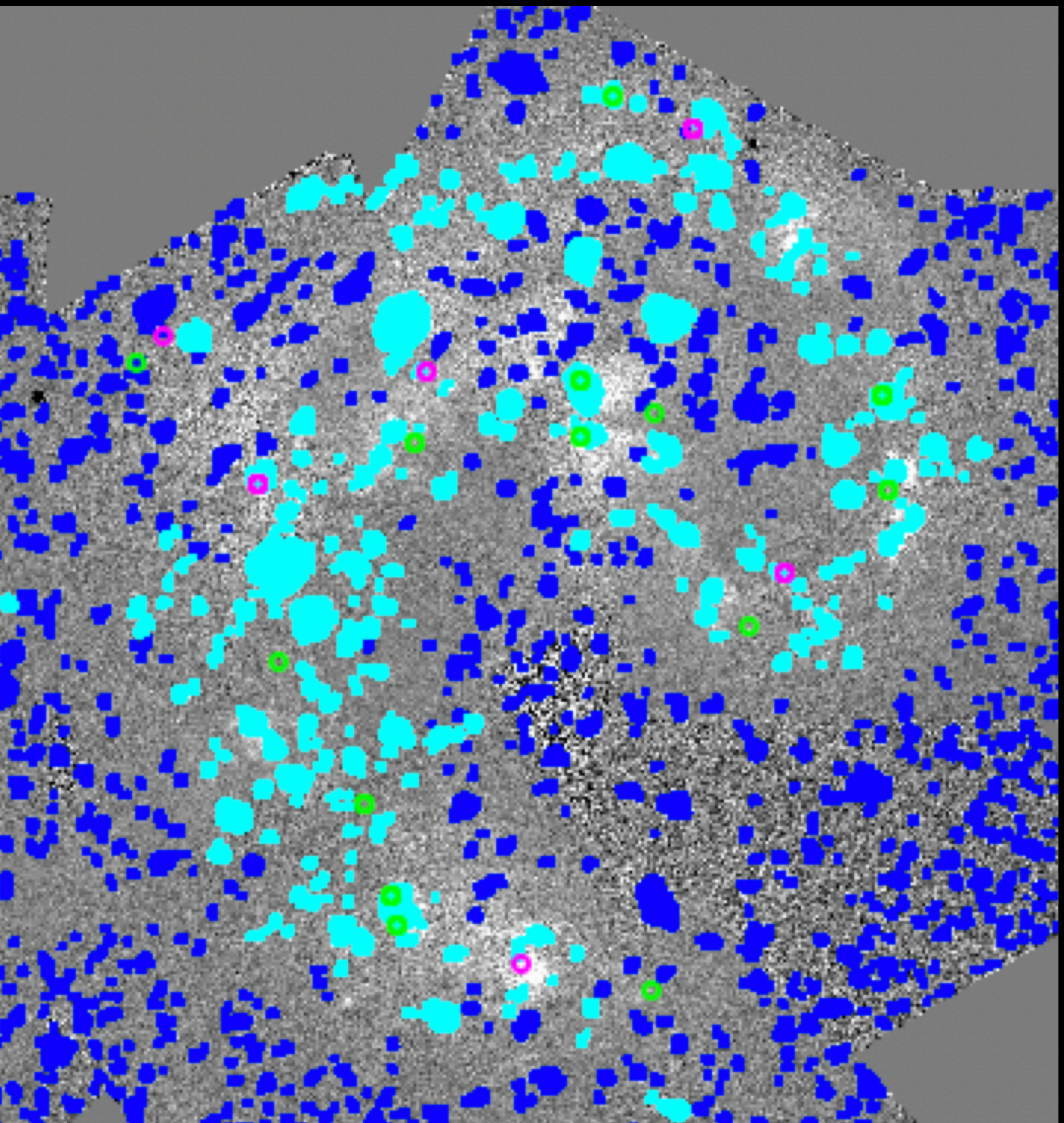
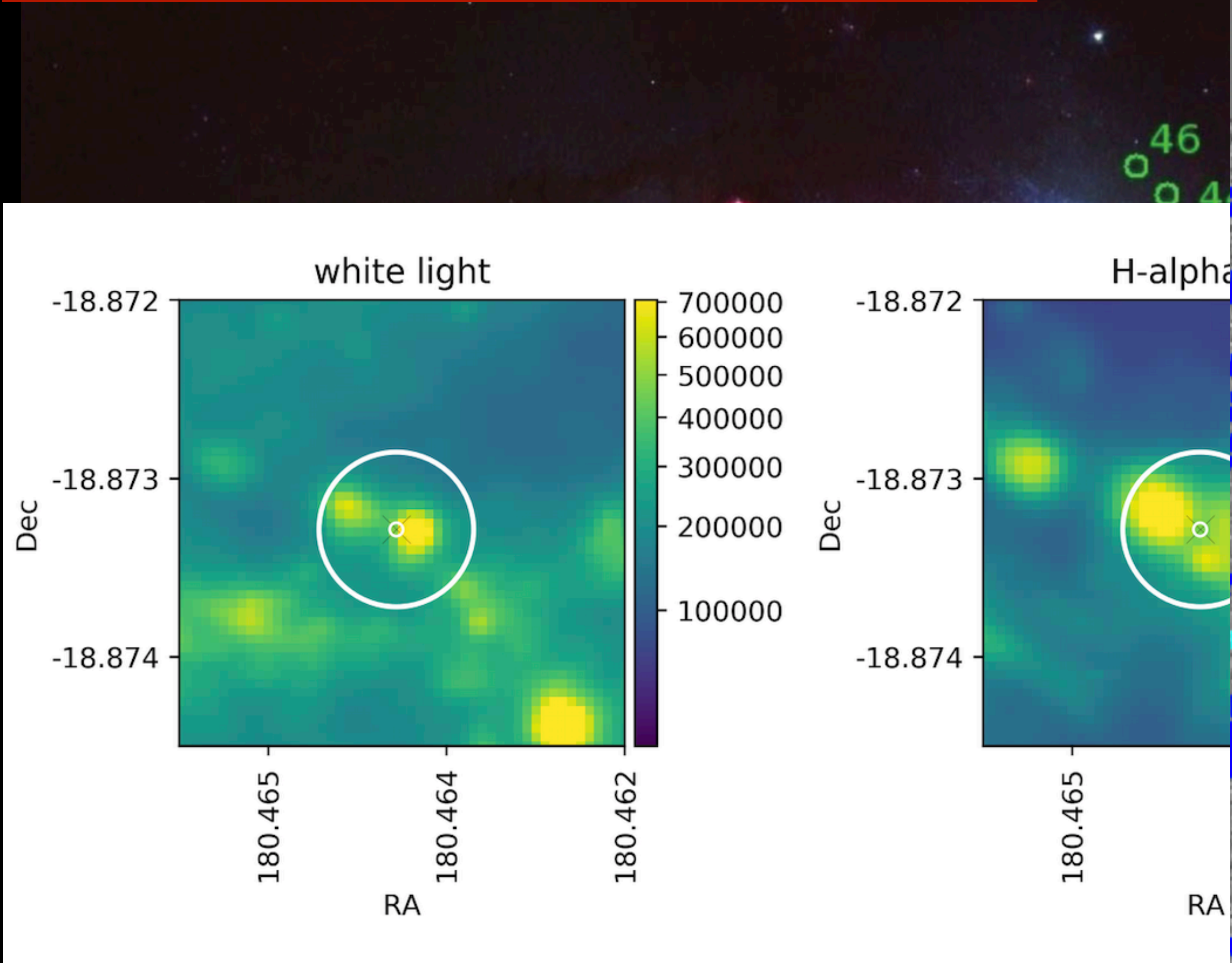
# Example 1



**Local star-burst systems  
with spatially resolved  
analysis of**

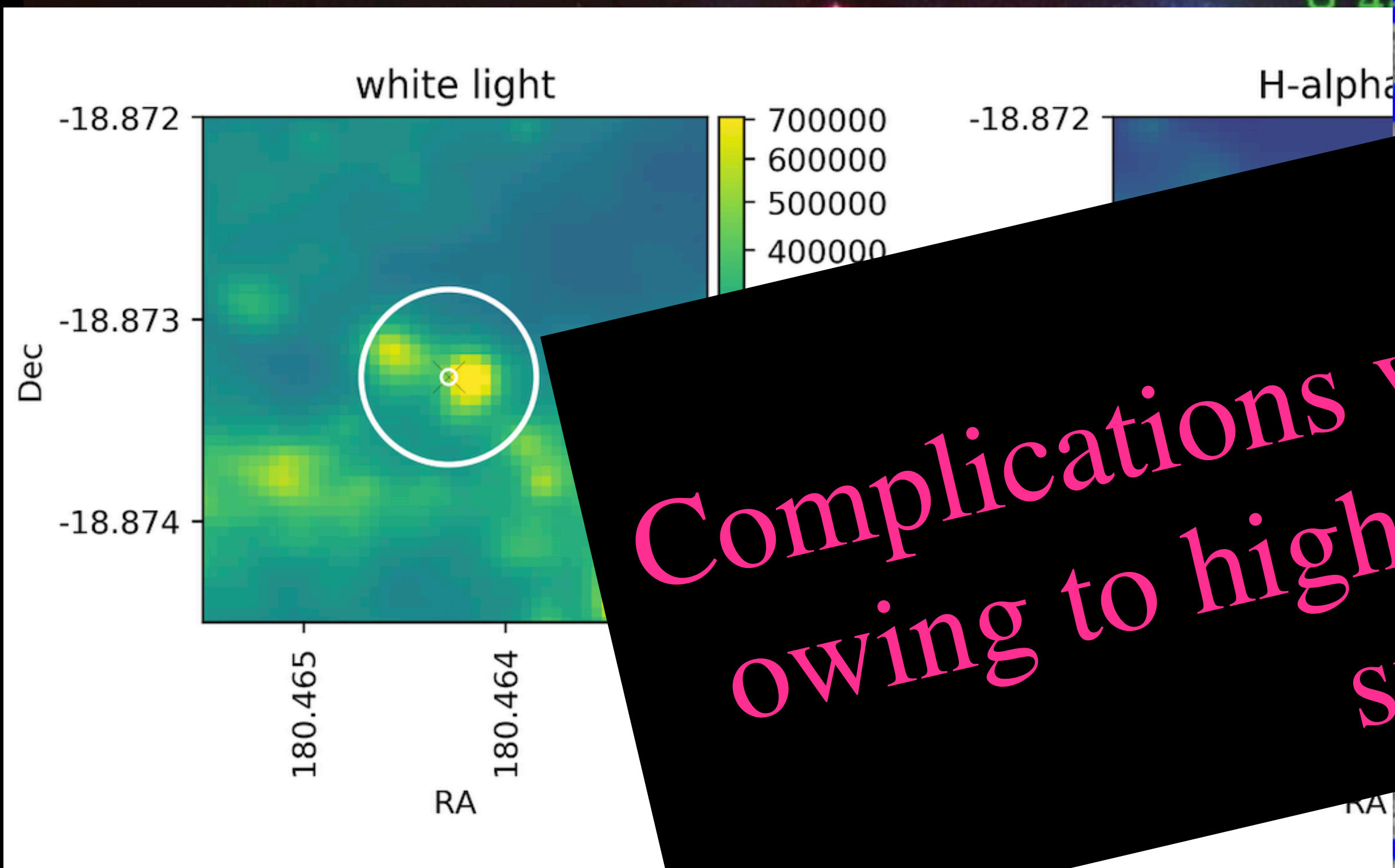
- **HII regions**
- **SNR**
- **X-ray binaries**

Also see Gunawardhana+2019  
(arXiv:1912.08151)

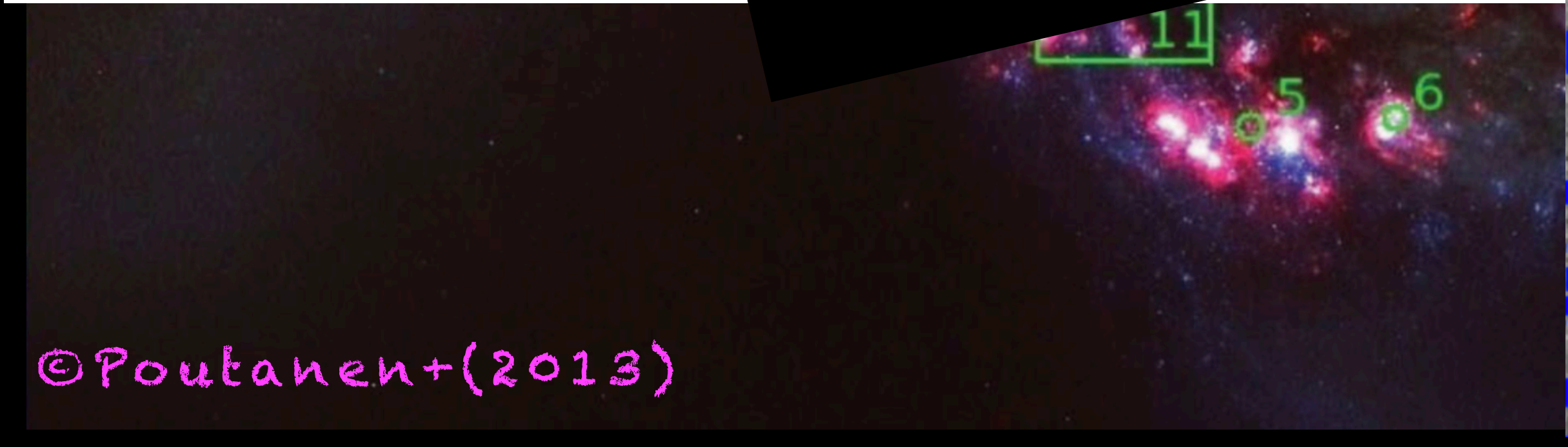
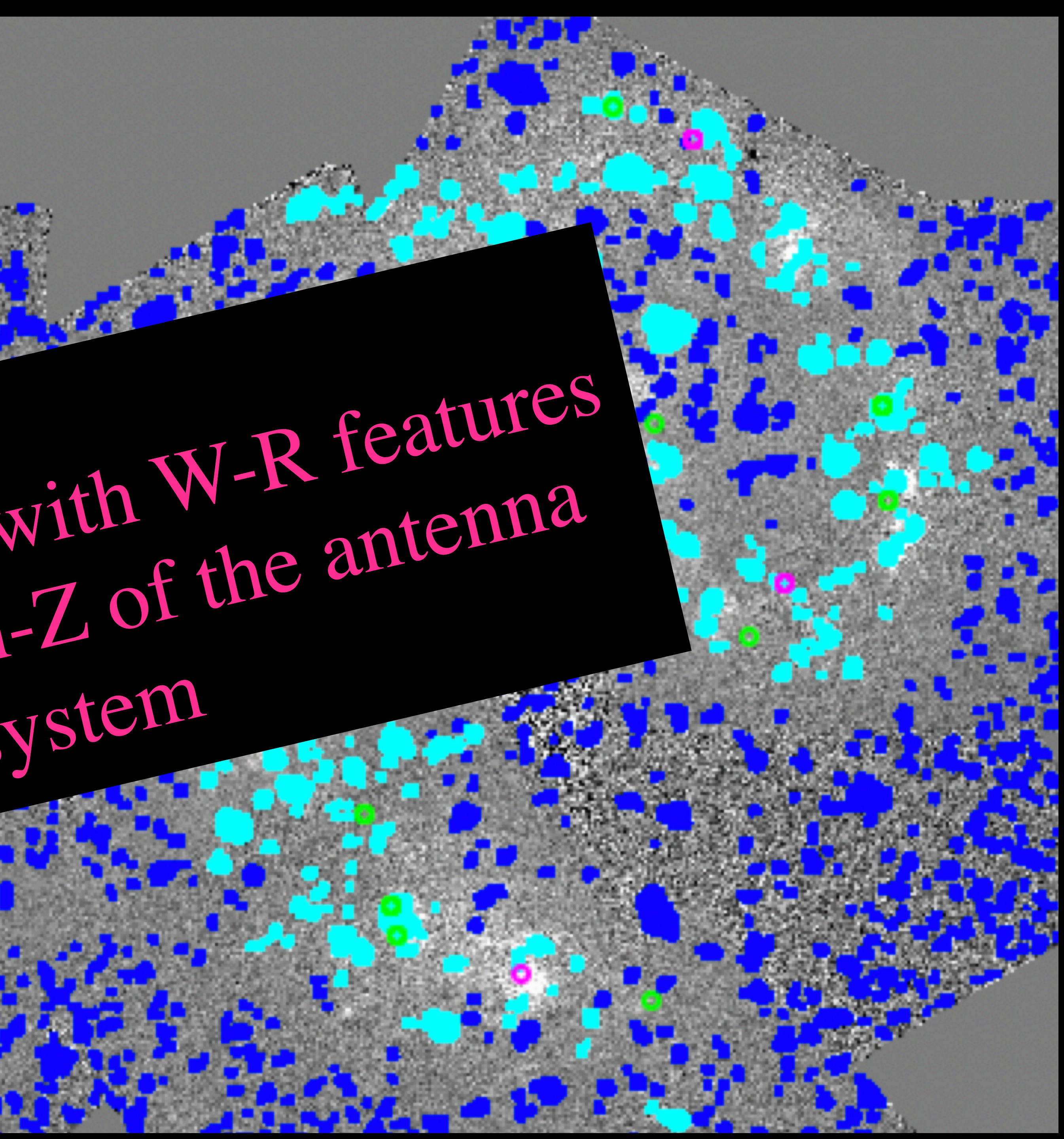


©Poutanen+(2013)

Also see Gunawardhana+2019  
(arXiv:1912.08151)



Complications with W-R features  
owing to high-Z of the antenna  
system



©Poutanen+(2013)





# MUSE Extremely Low Metallicity Objects Survey



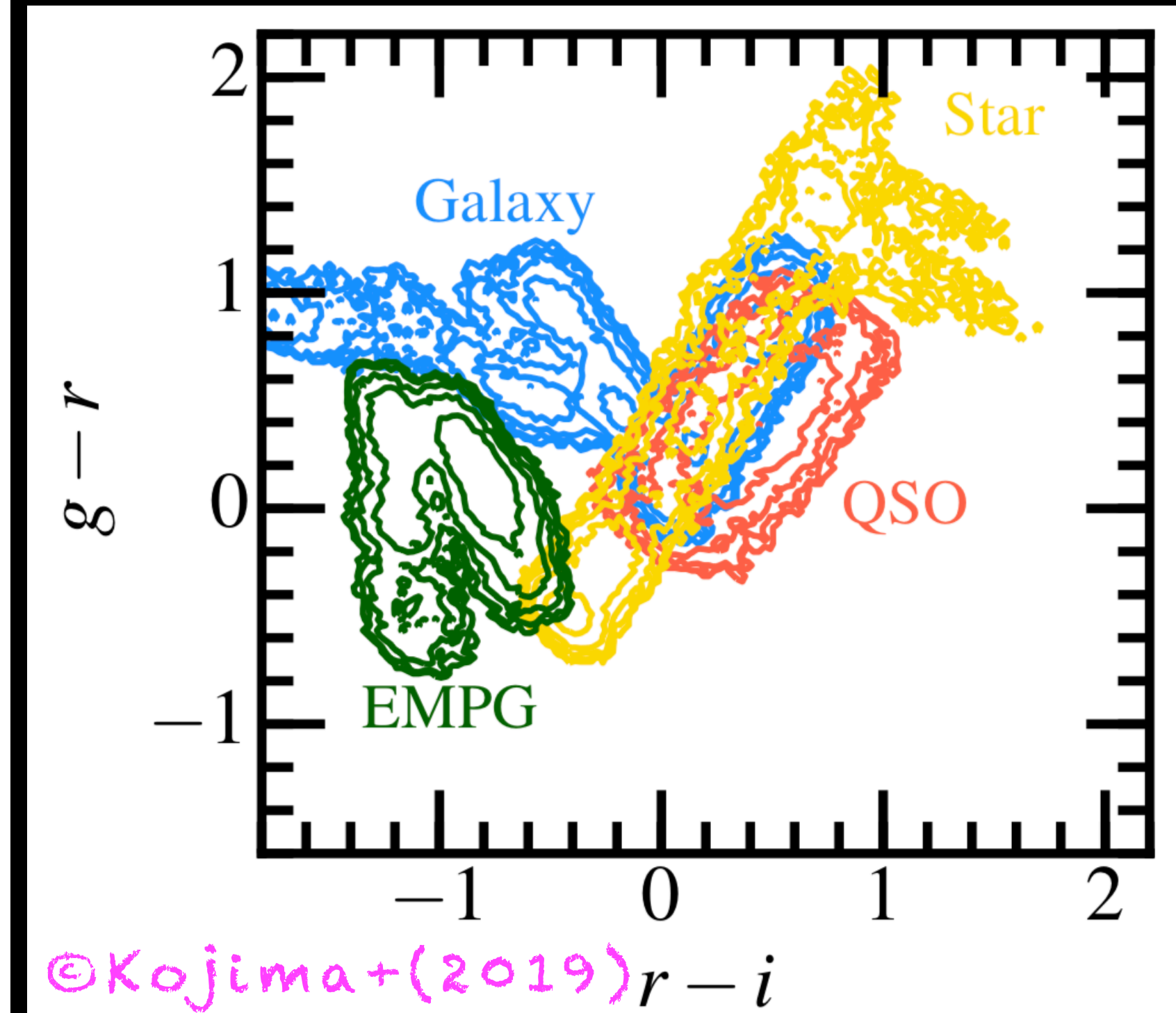
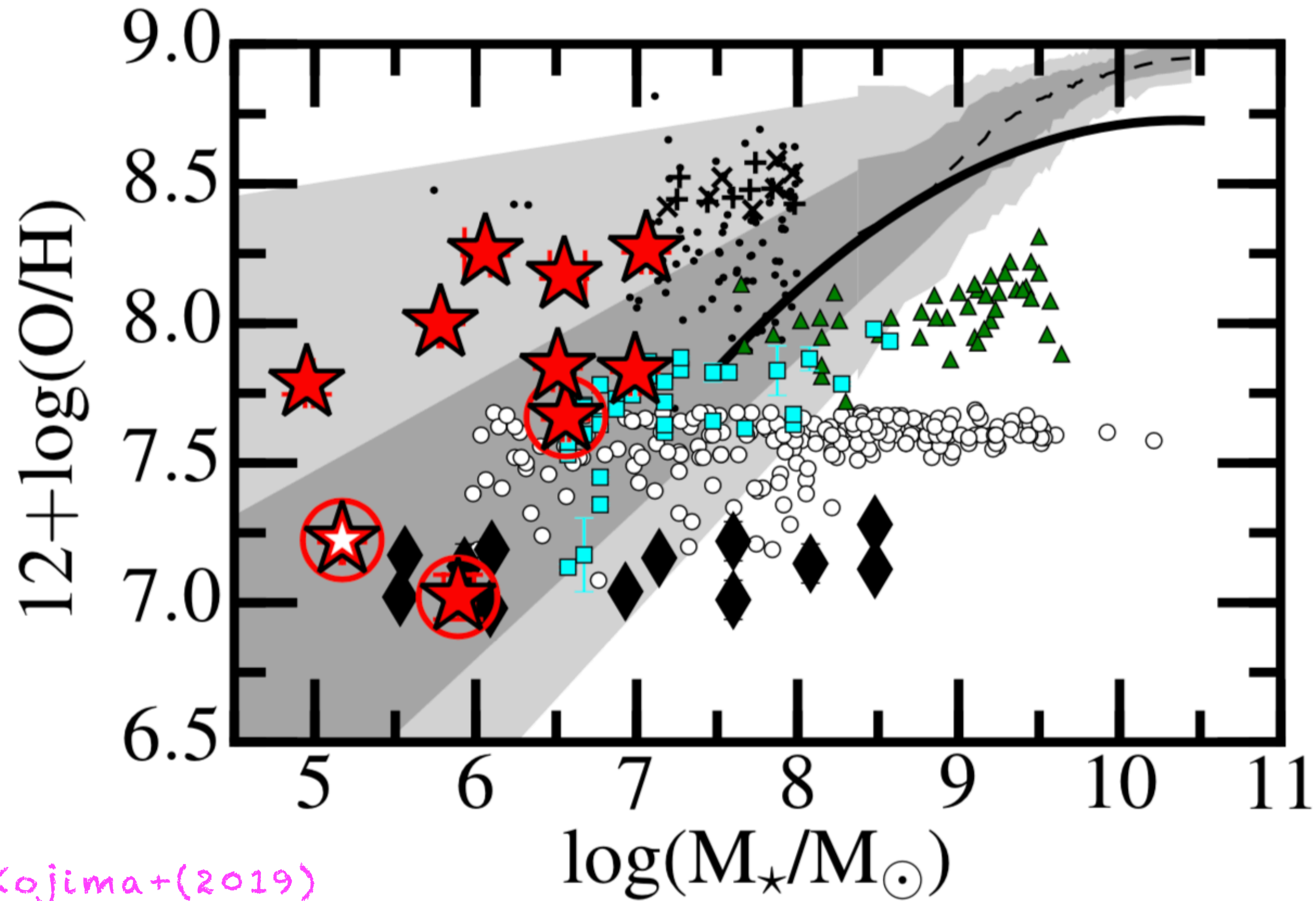
Michael Maseda, Themiya Nanayakkara, Haruka Kusakabe, Leindert Boogaard, Jarle Brinchmann, David Carton, Marijn Franx, Madusha Gunawardhana, Christian Herenz, Raffaella Marino, Jorryt Matthee, Ana Monreal- Ibero, Johan Richard, Joop Schaye, Peter Weilbacher

# **Example 2**

## **HSCJ2314+0154**

**In collaboration with the HSC team**

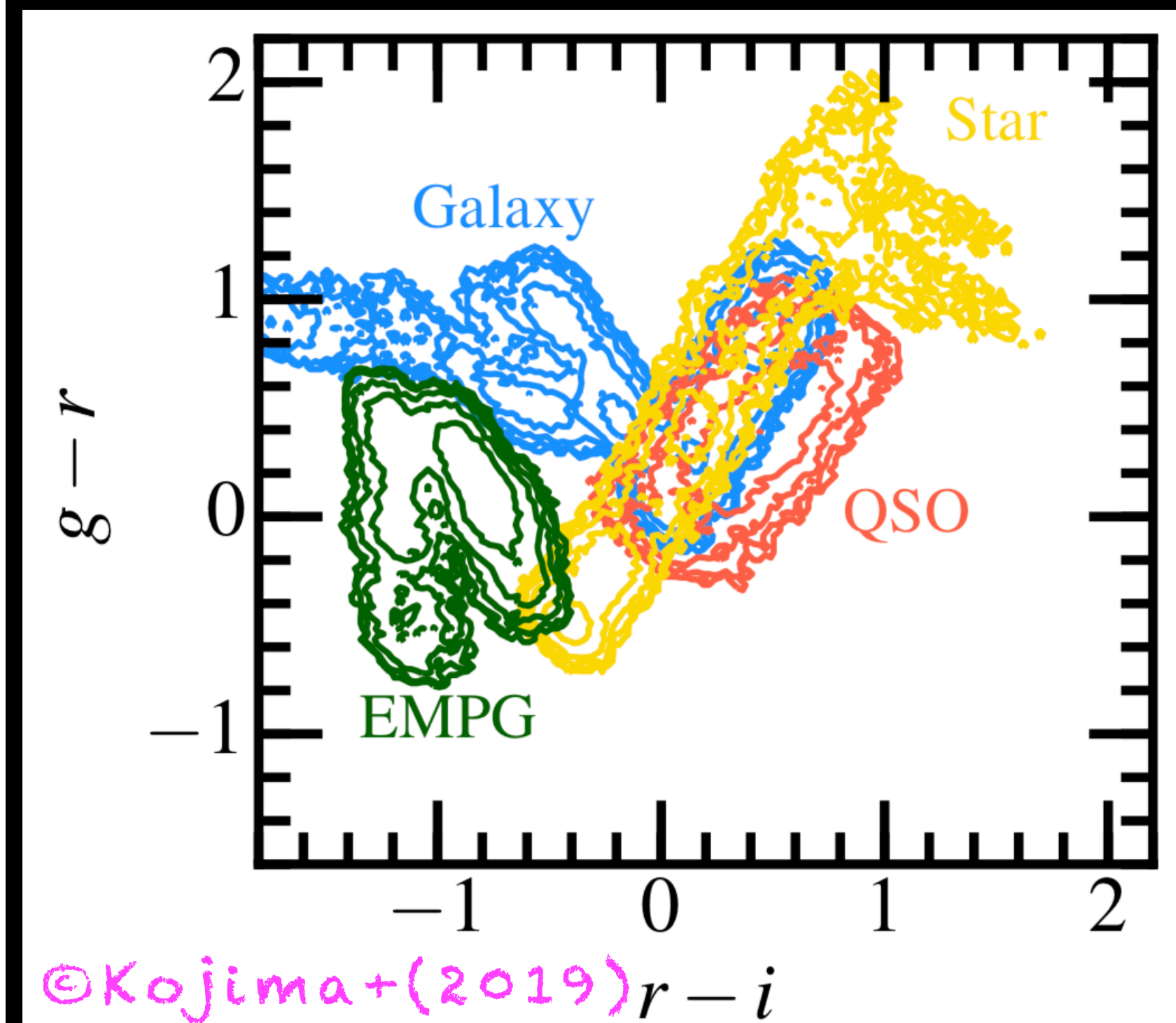
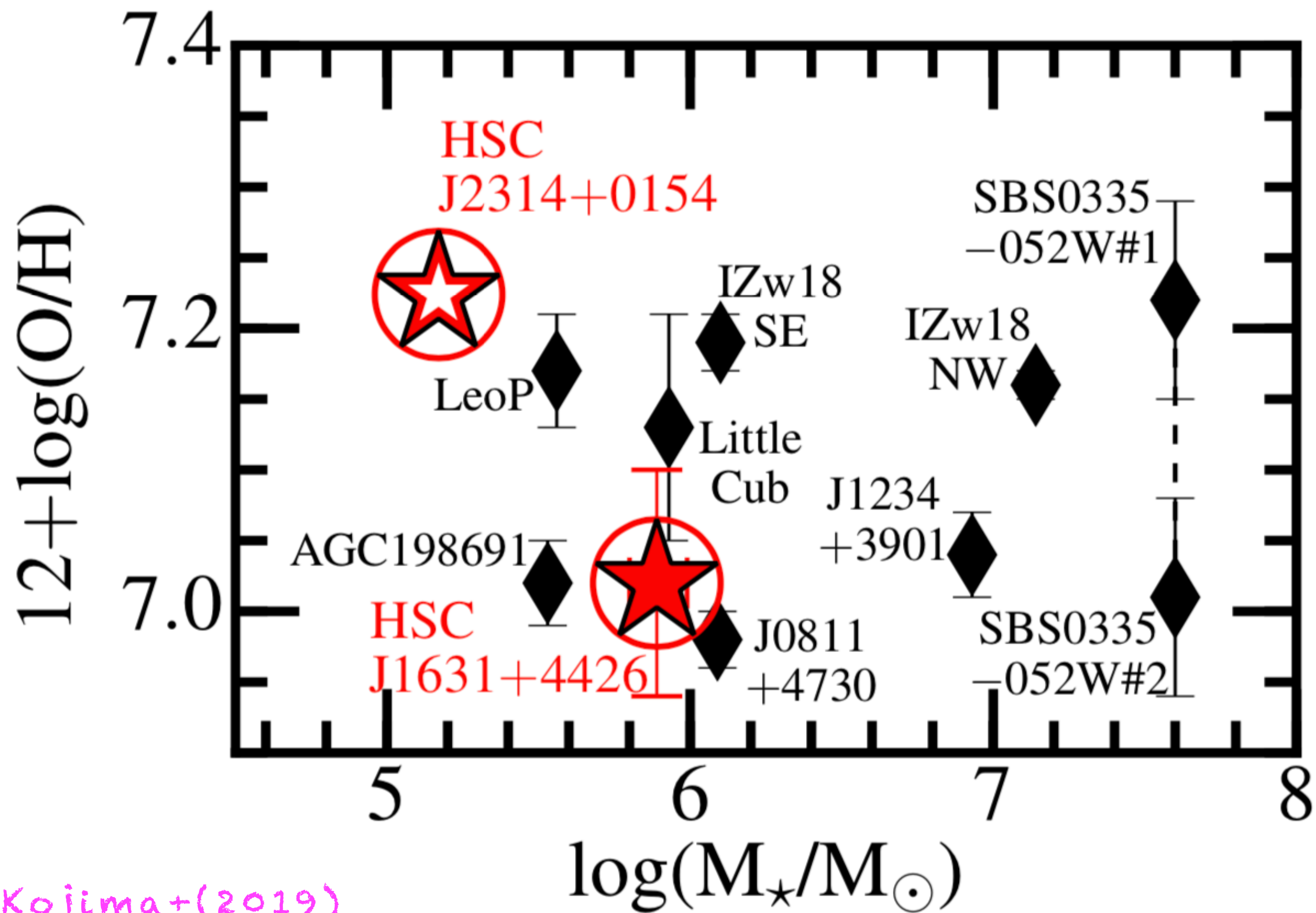
# ML techniques to select EMPGs



©Kojima+(2019)

©Kojima+(2019)

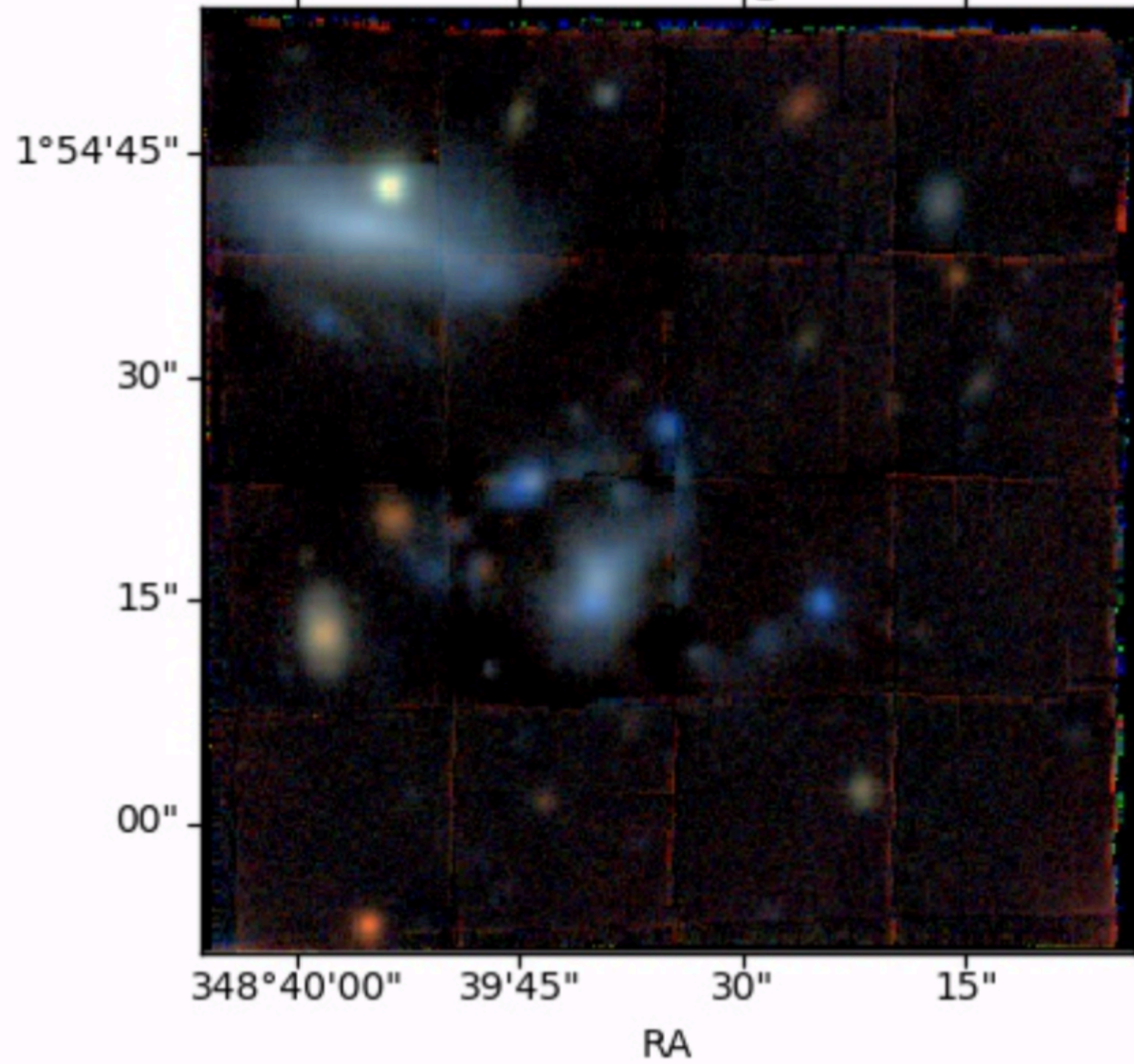
# ML techniques to select EMPGs



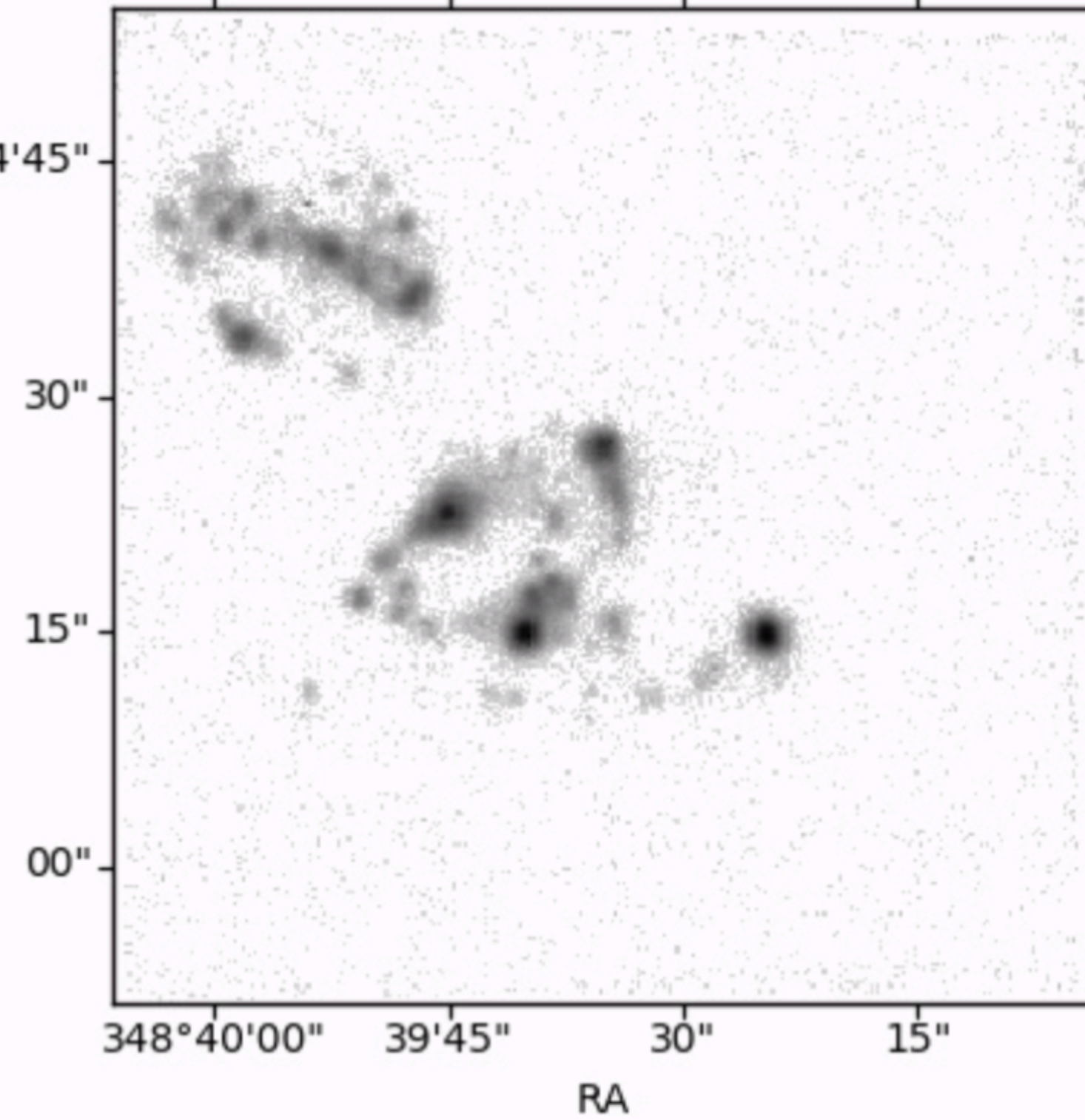
# HSCJ2314+0154

Seeing  $\sim 0.9''$

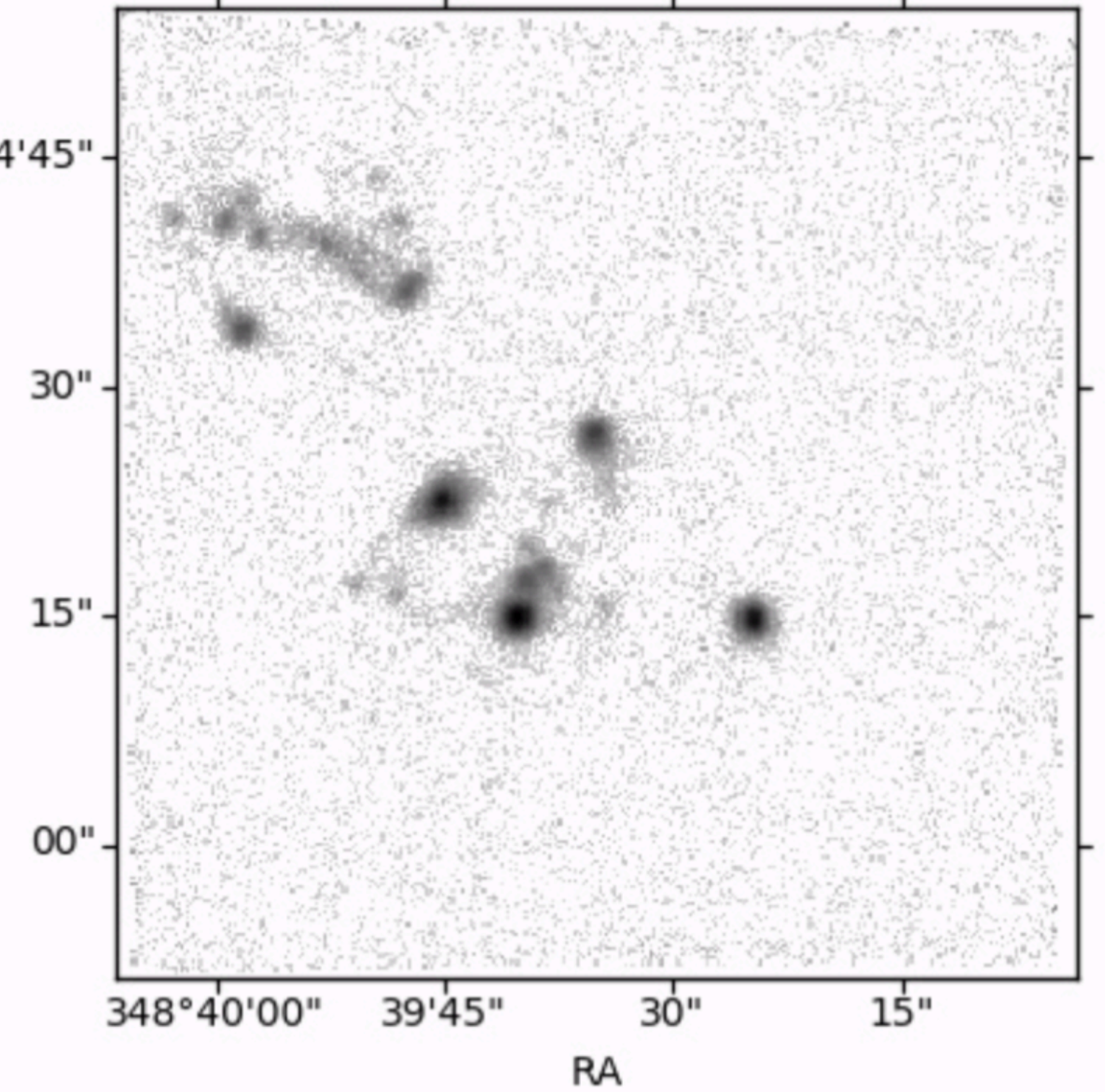
VRI Image



H $\alpha$  Narrowband



[OIII] Narrowband



**Example 3**

**SDSSJ0908+0517**

# SDSS J0908+0517

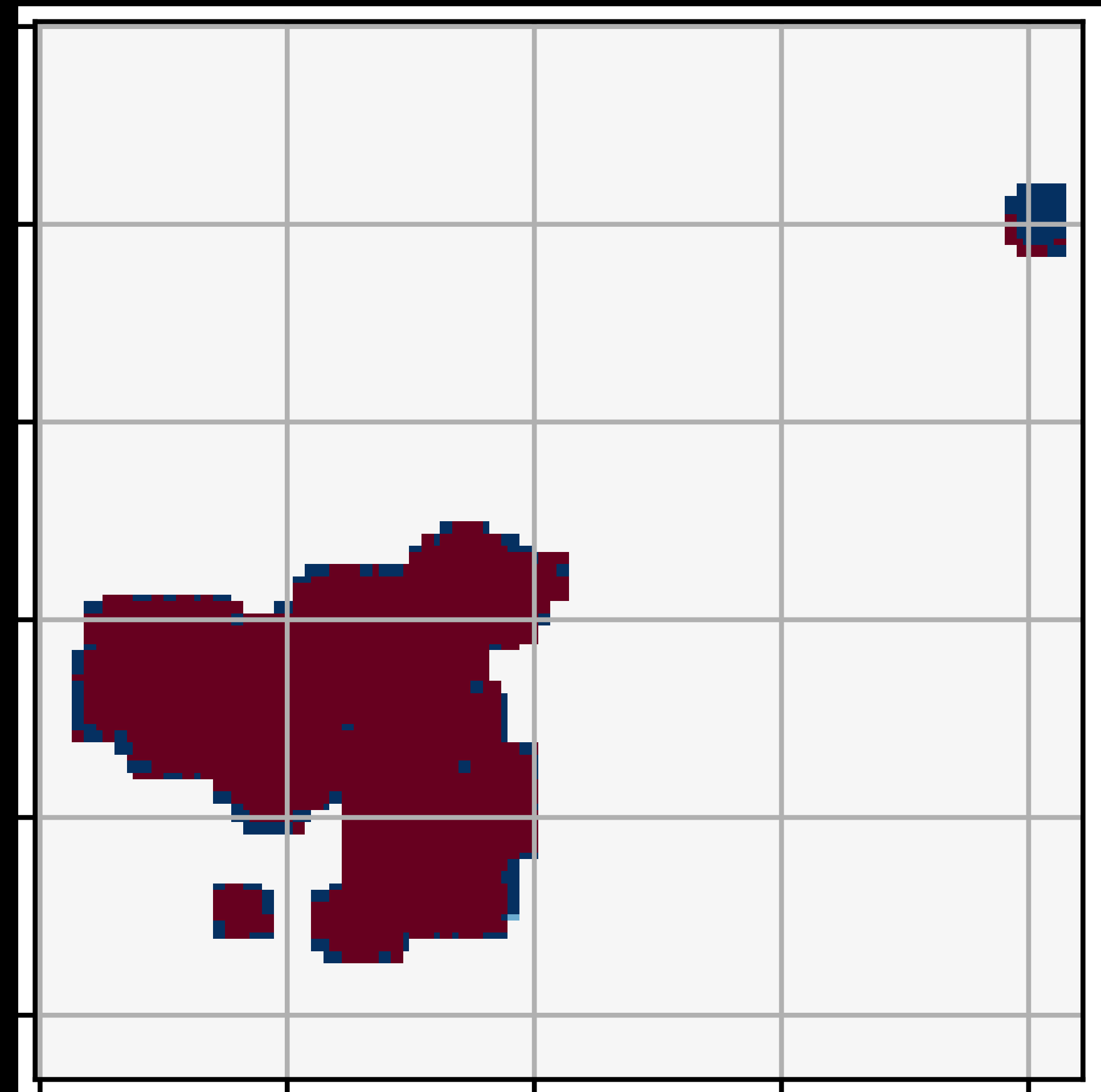
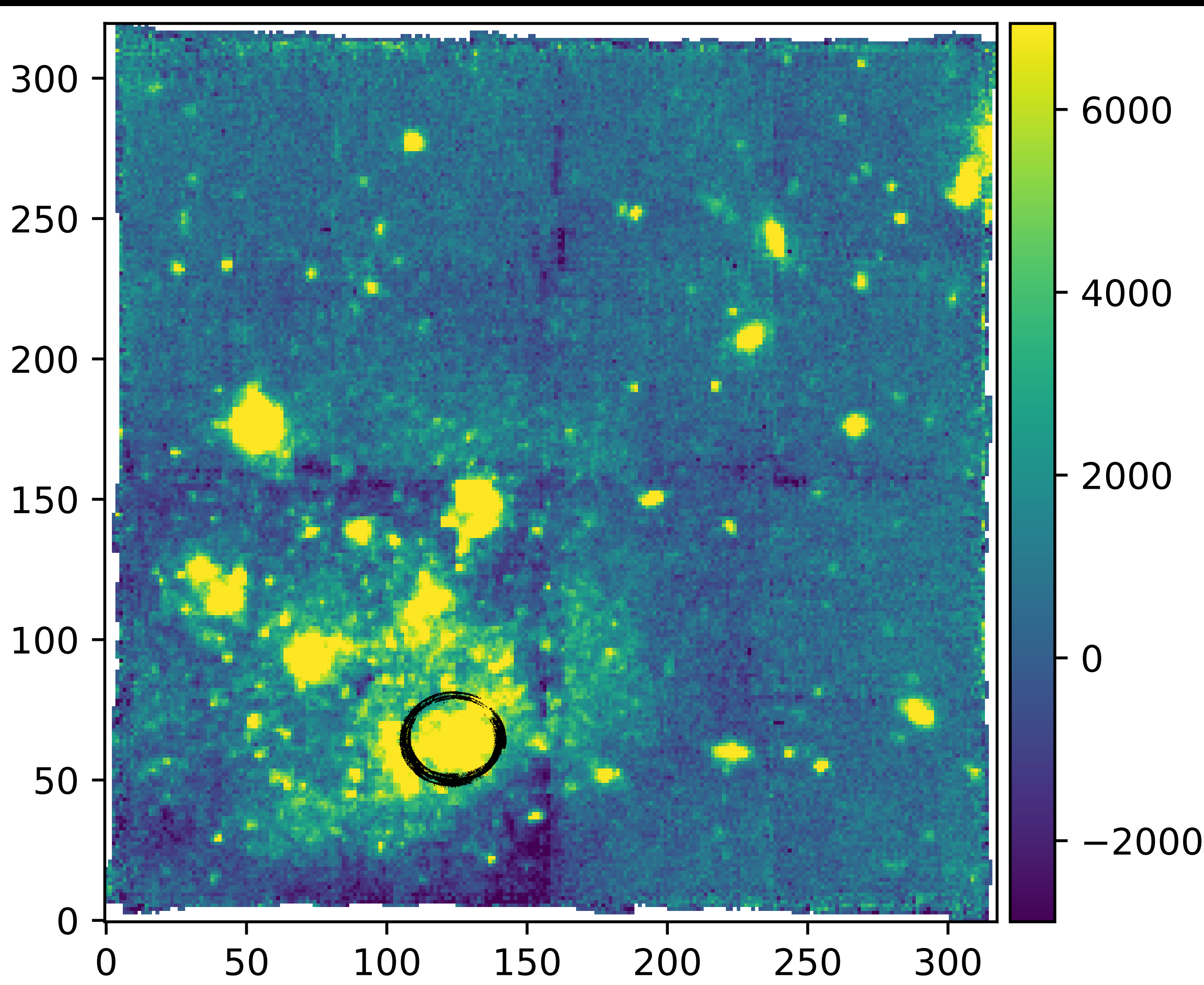
$$12+\log(\text{O}/\text{H}) = 7.39$$



©SDSS DR16

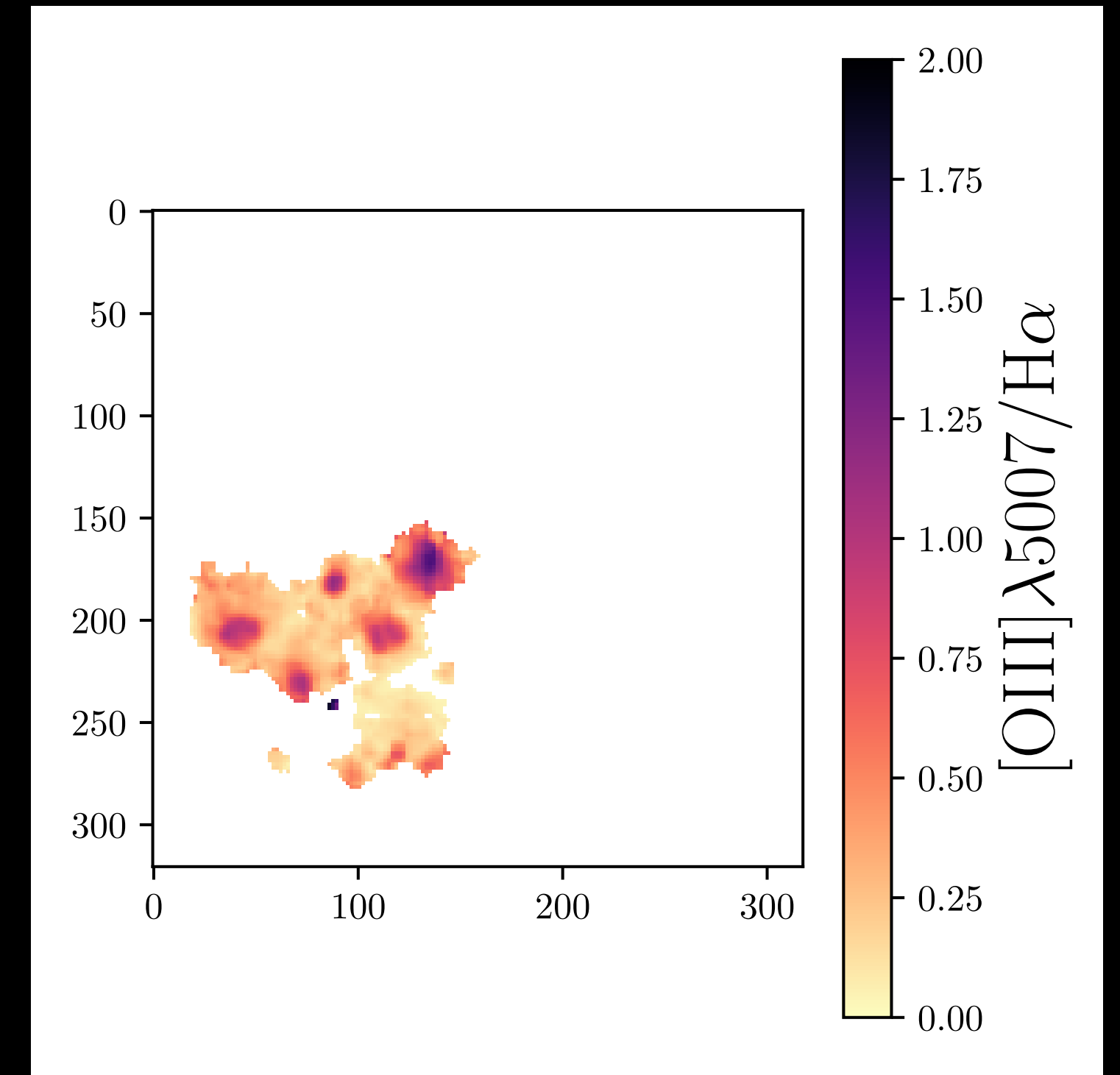
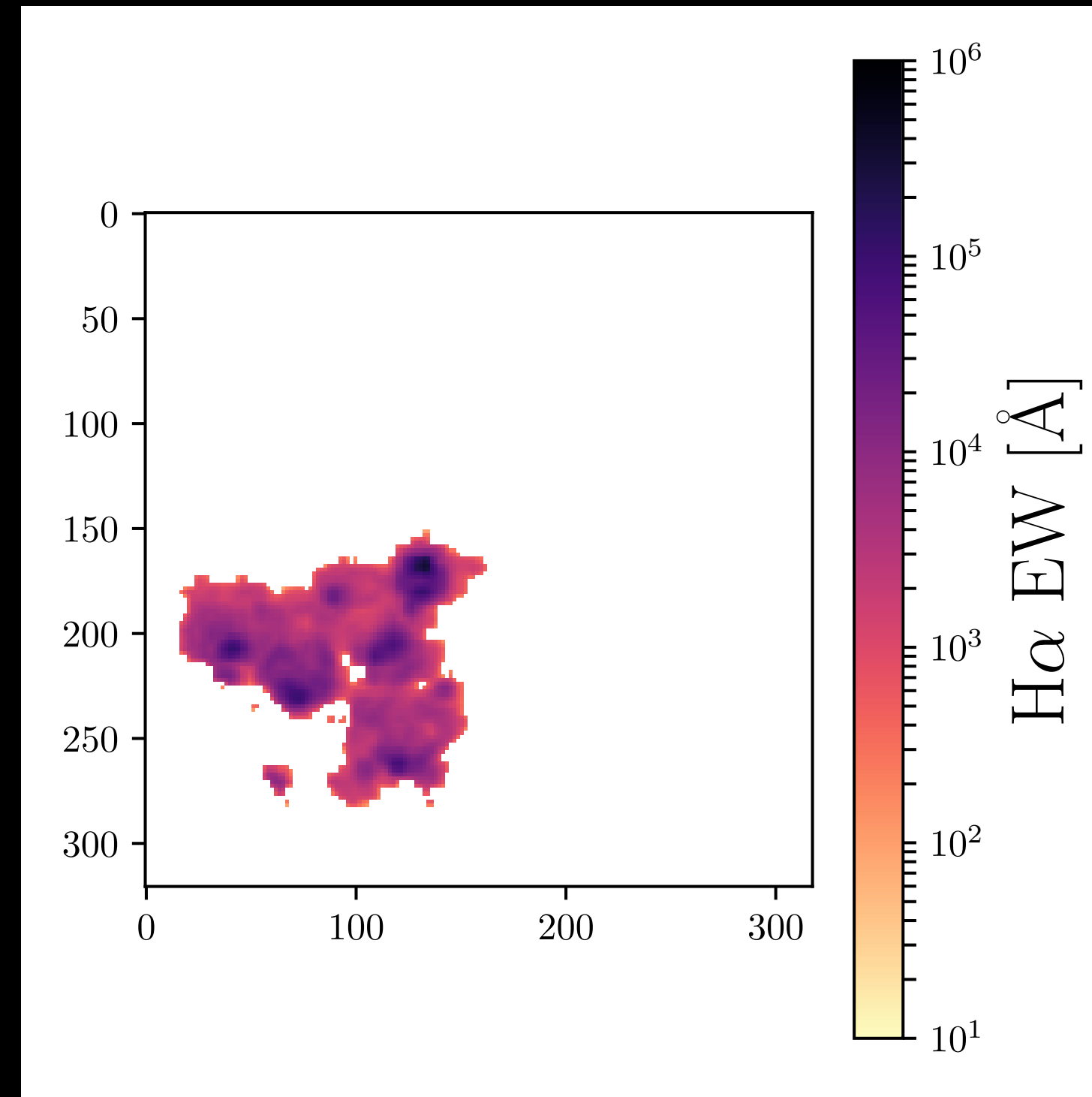
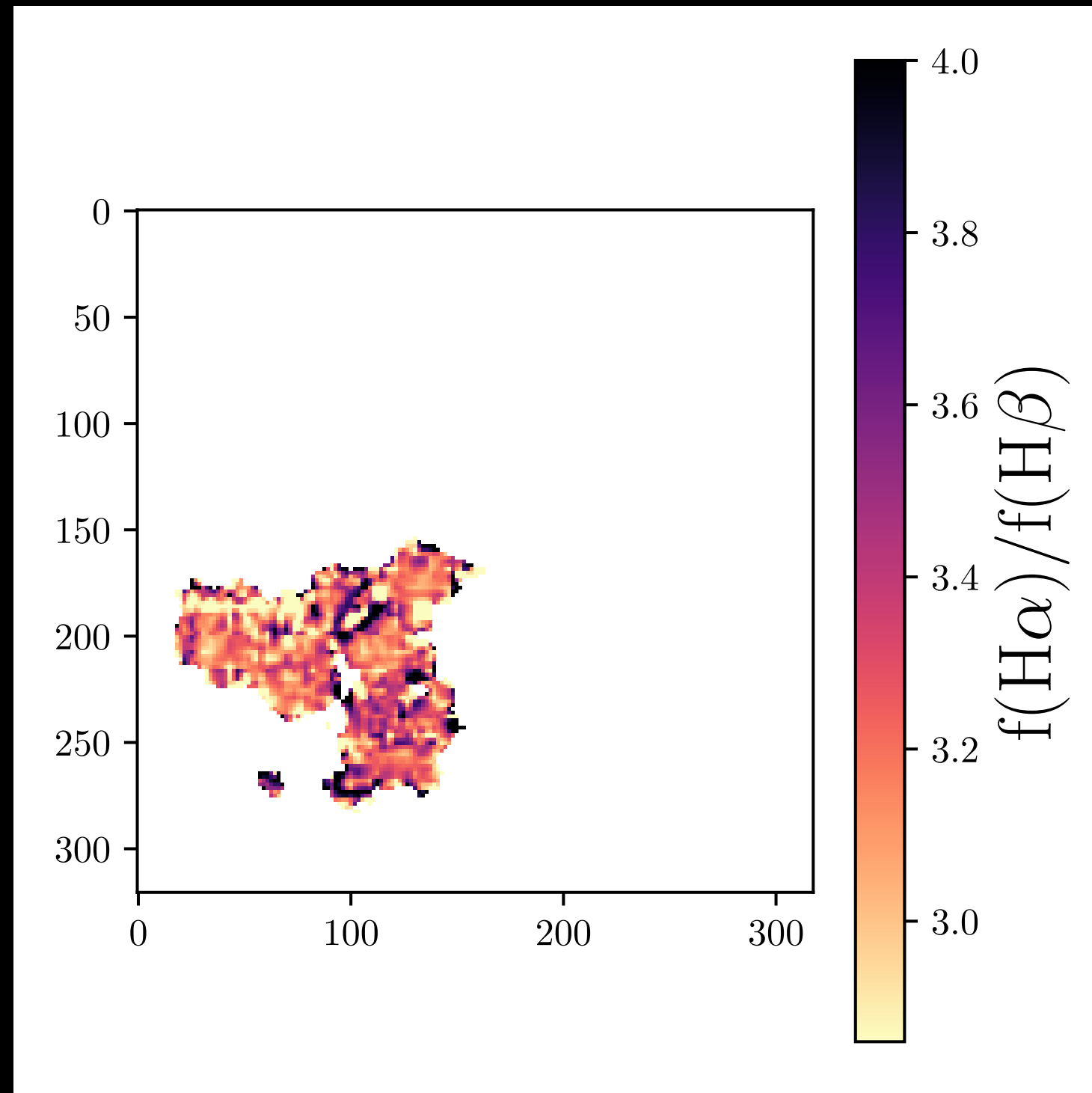
# Why MUSE?

2000s  $\sim 0.4''$  seeing

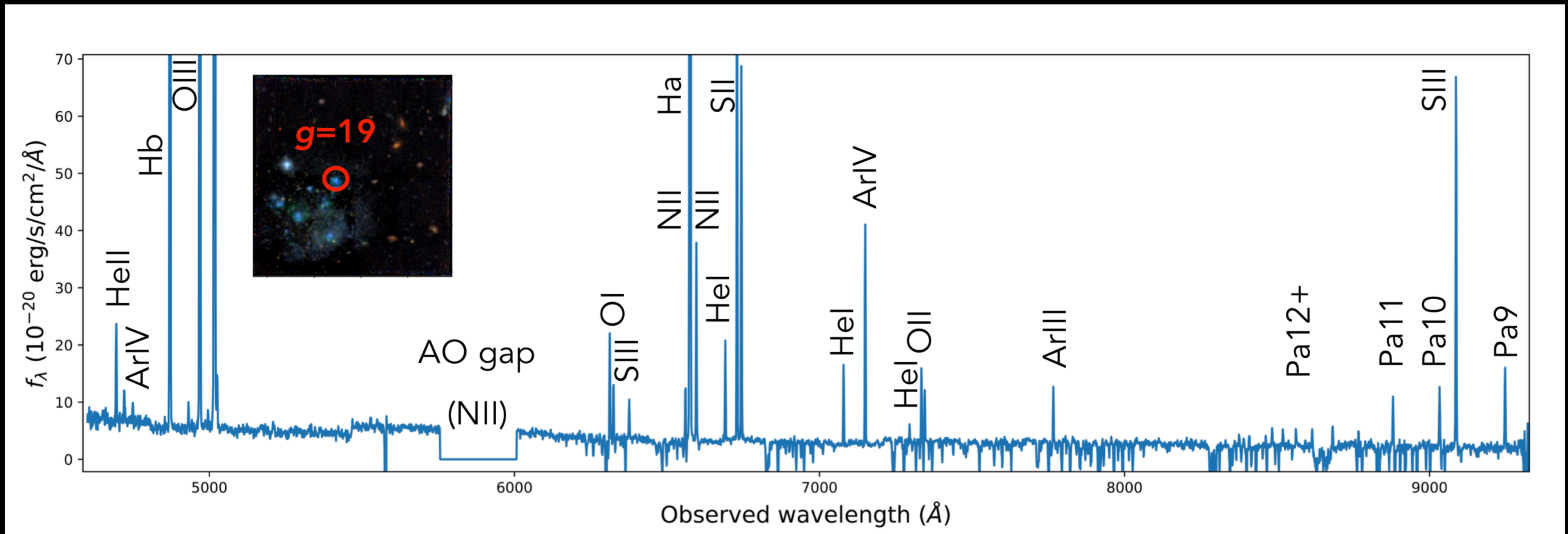


©Nanayakkara

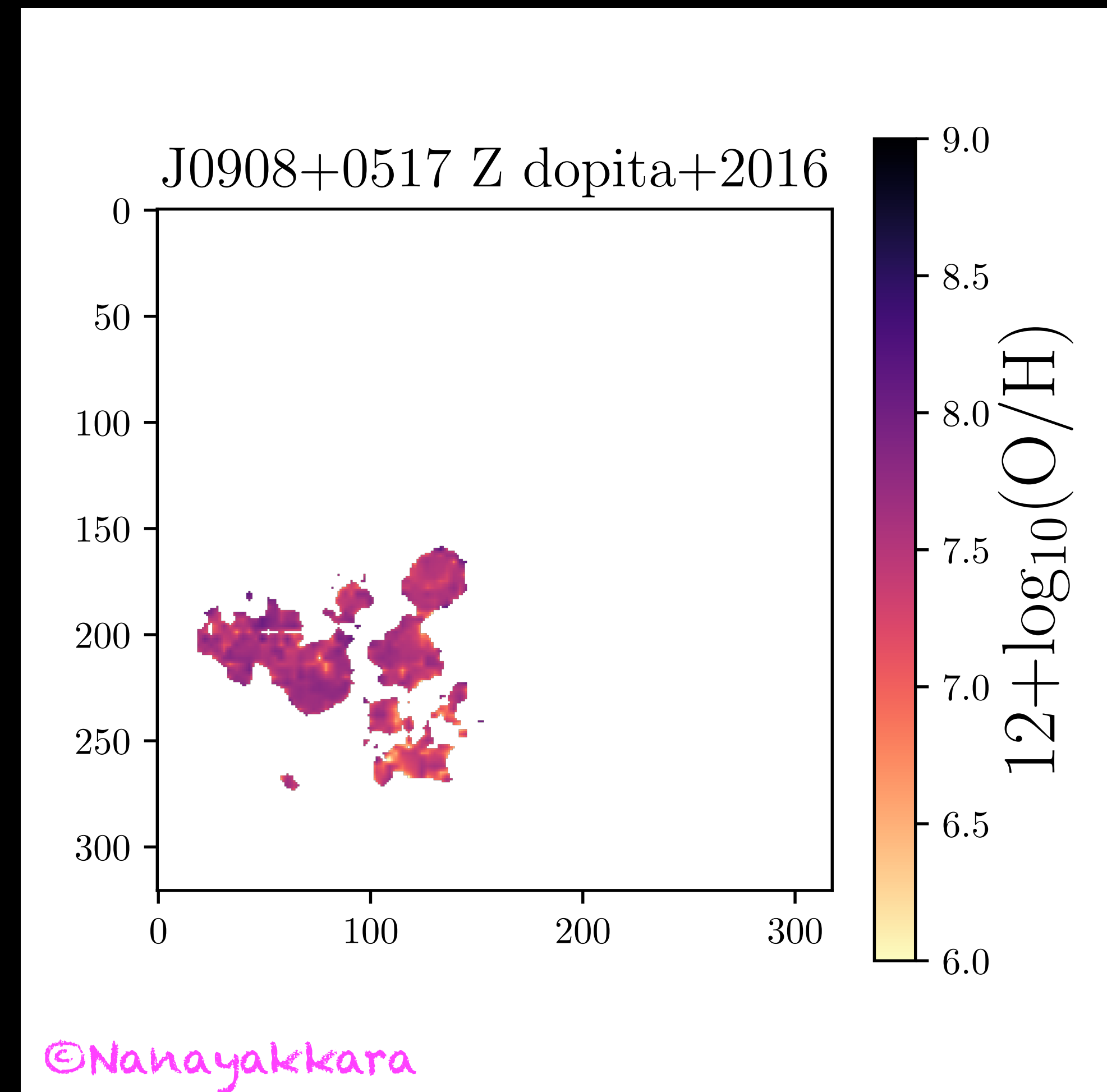
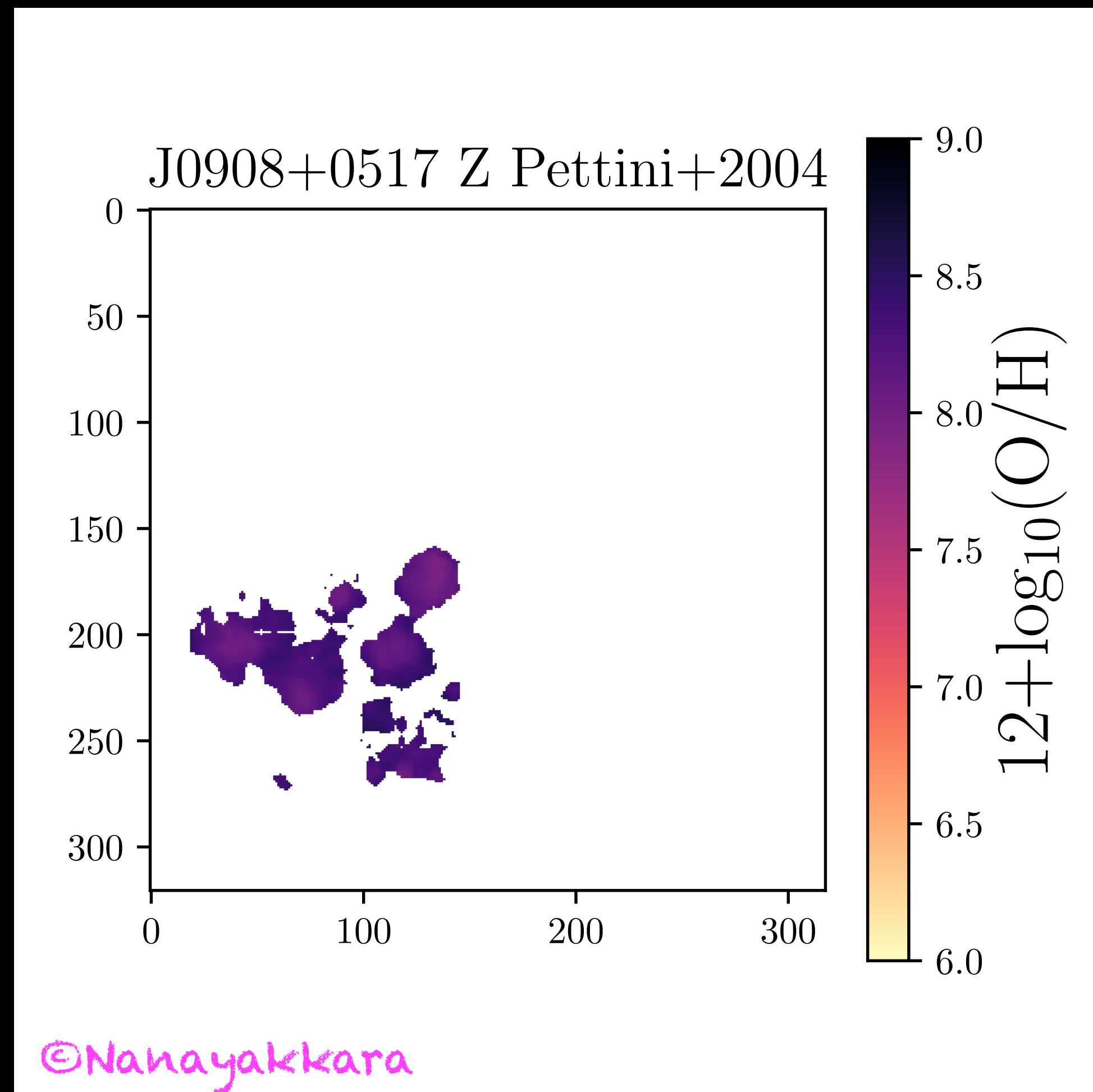
# Spatially resolved analysis of analogues provides new insights to high-z galaxies



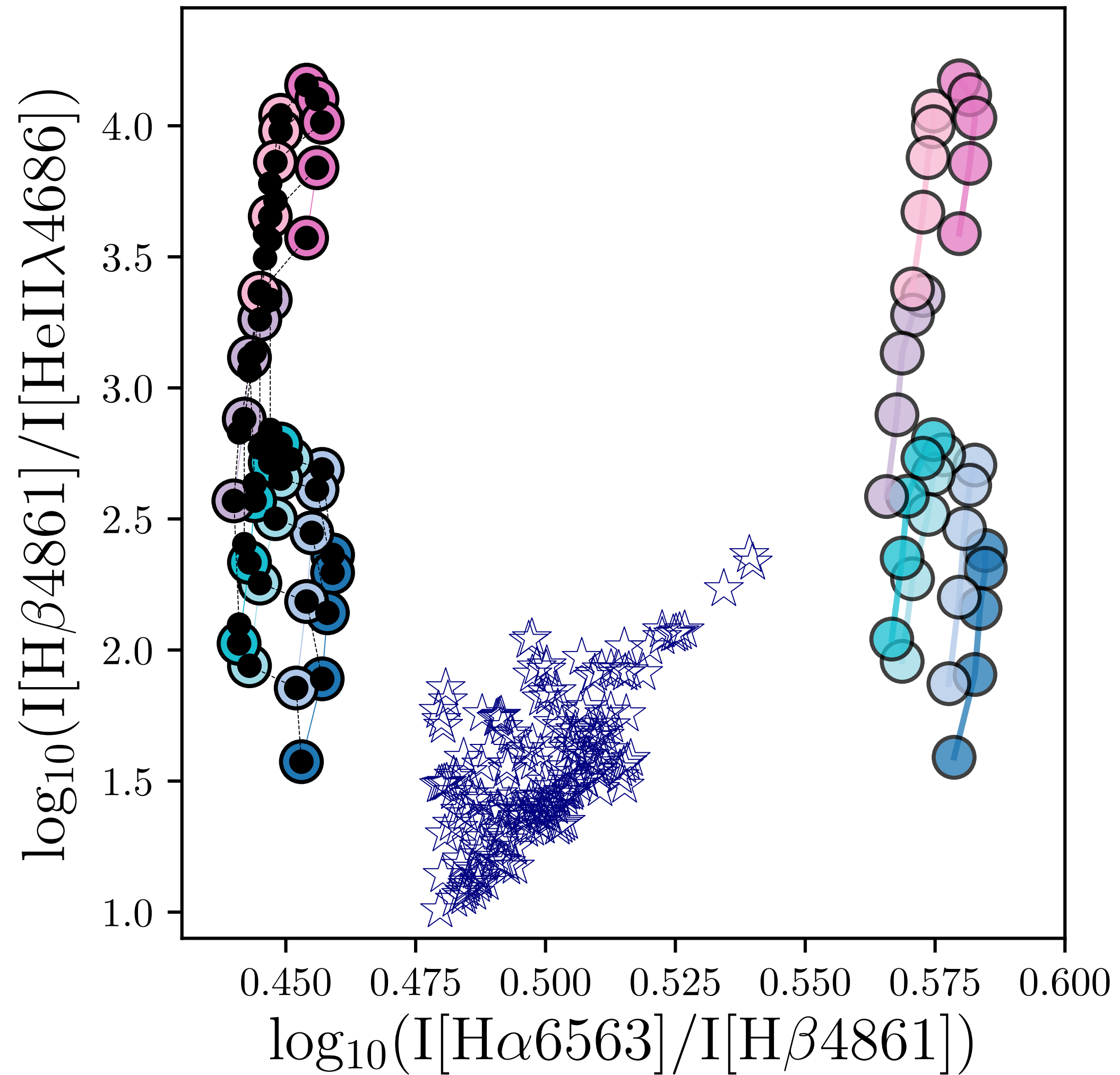
# Spatially resolved analysis of analogues provides new insights to high-z galaxies



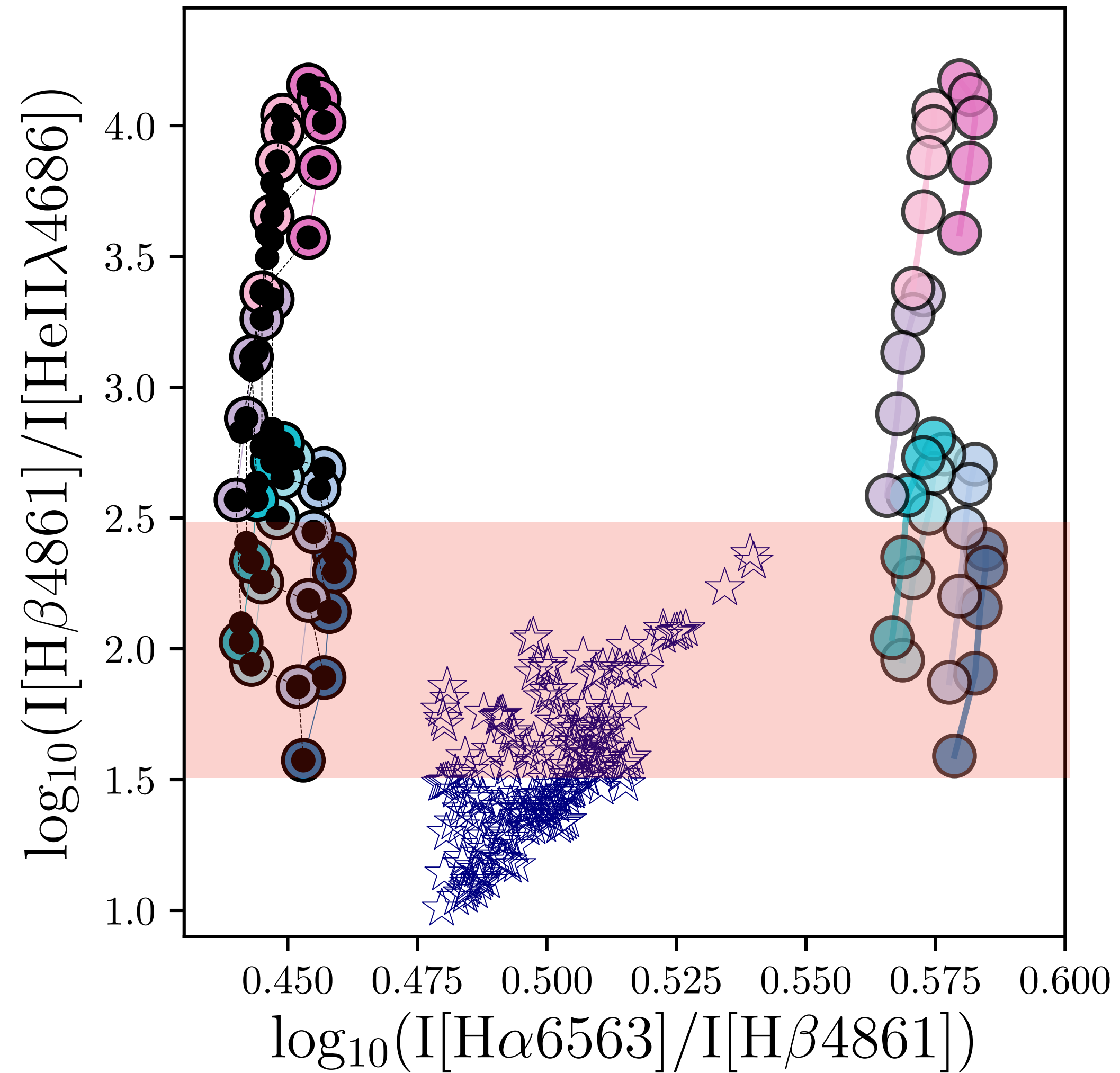
# Tighter constraints to ISM properties



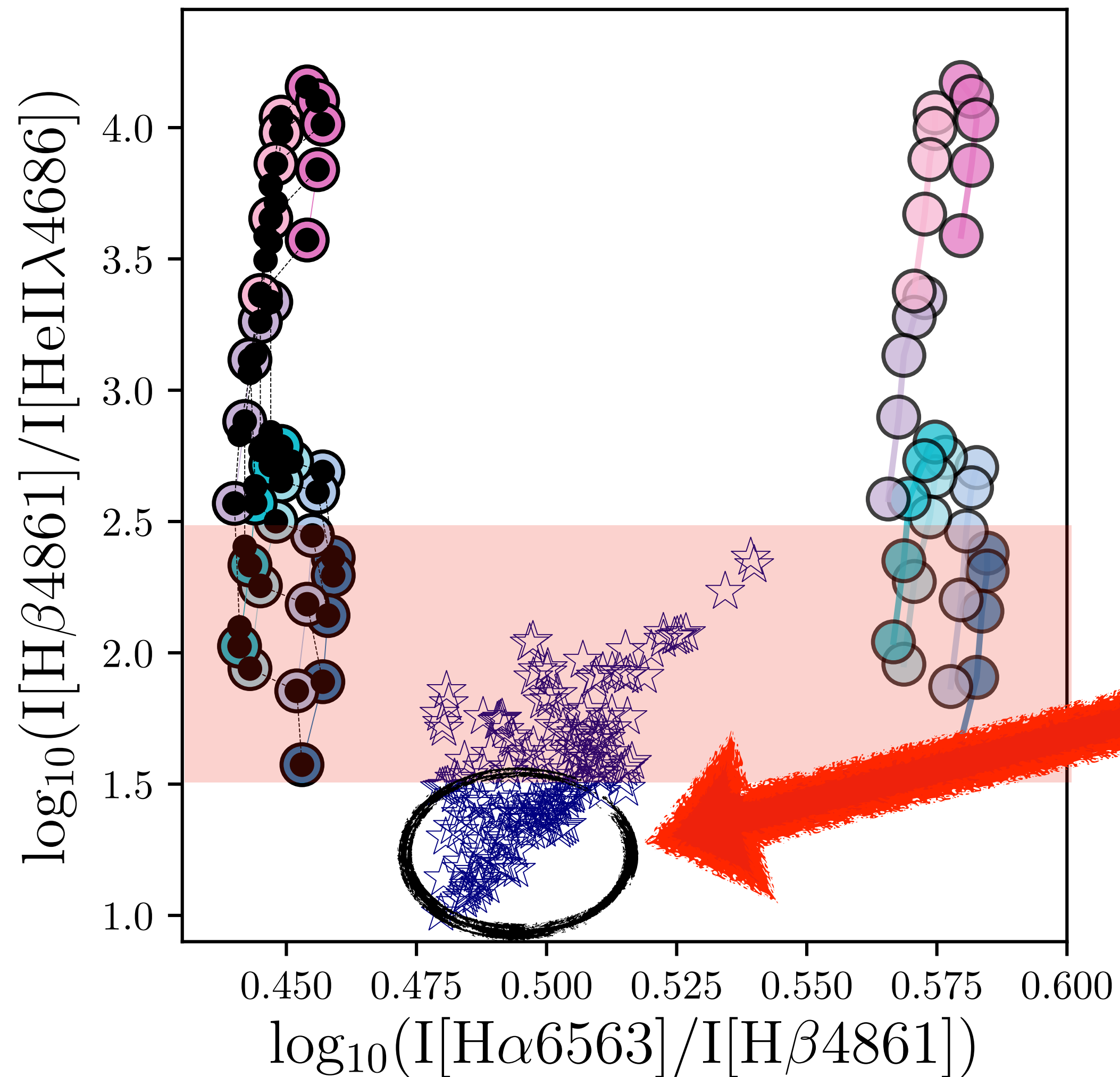
# Tighter constraints to ISM properties



# Tighter constraints to ISM properties



# Tighter constraints to ISM properties

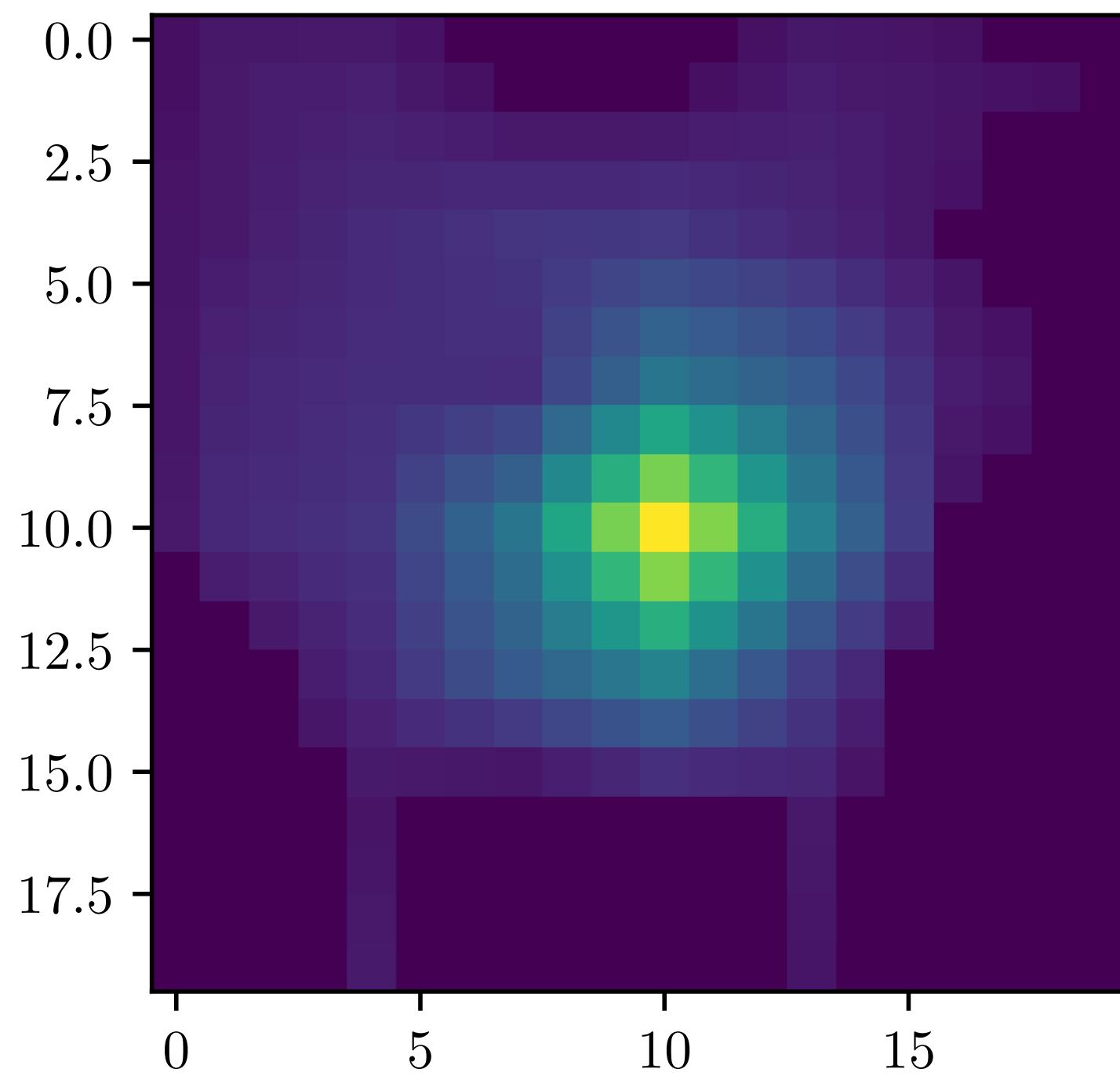


©Nanayakkara

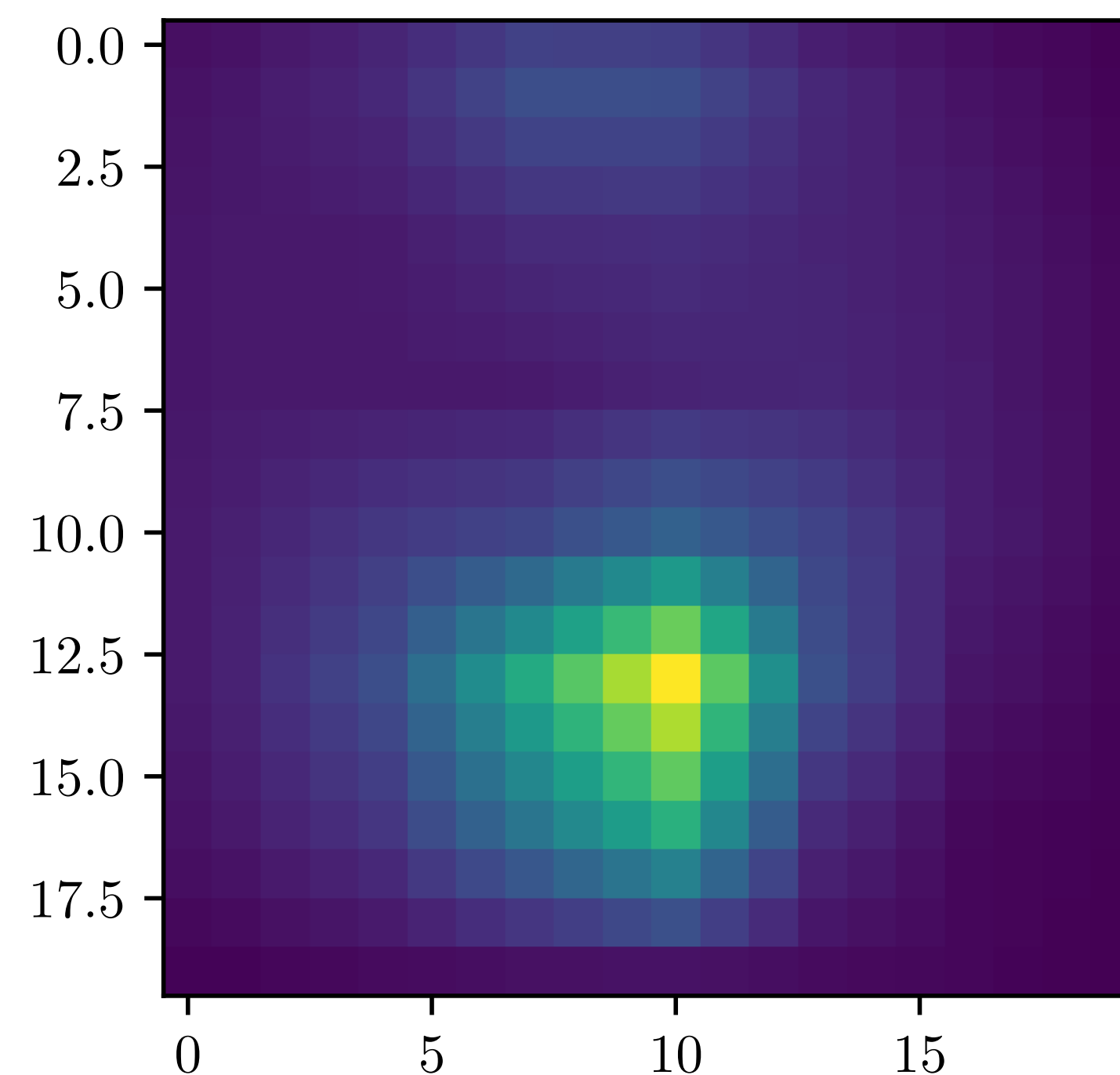
**Mechanisms  
can be probed  
with spatial  
resolution**

# What drives the variation in spatial offsets?

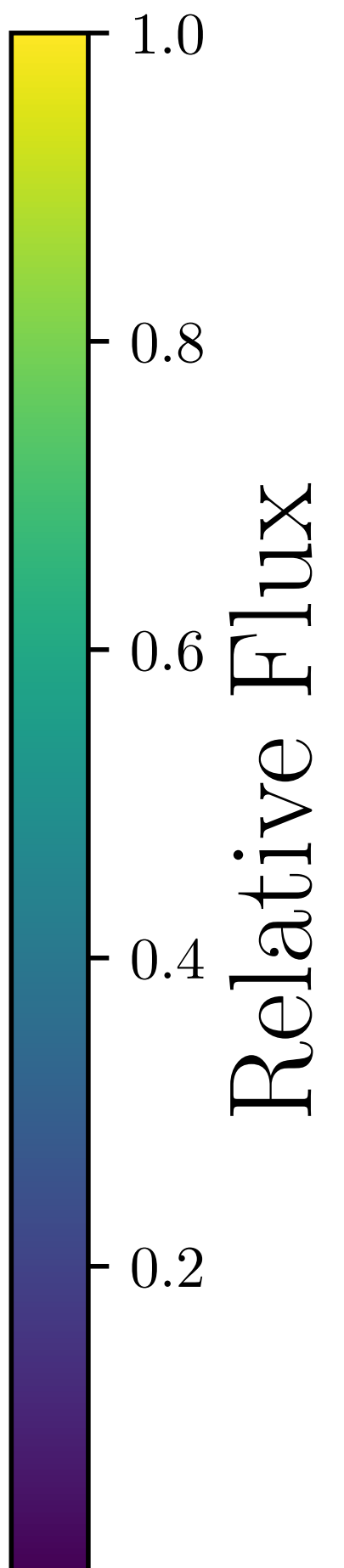
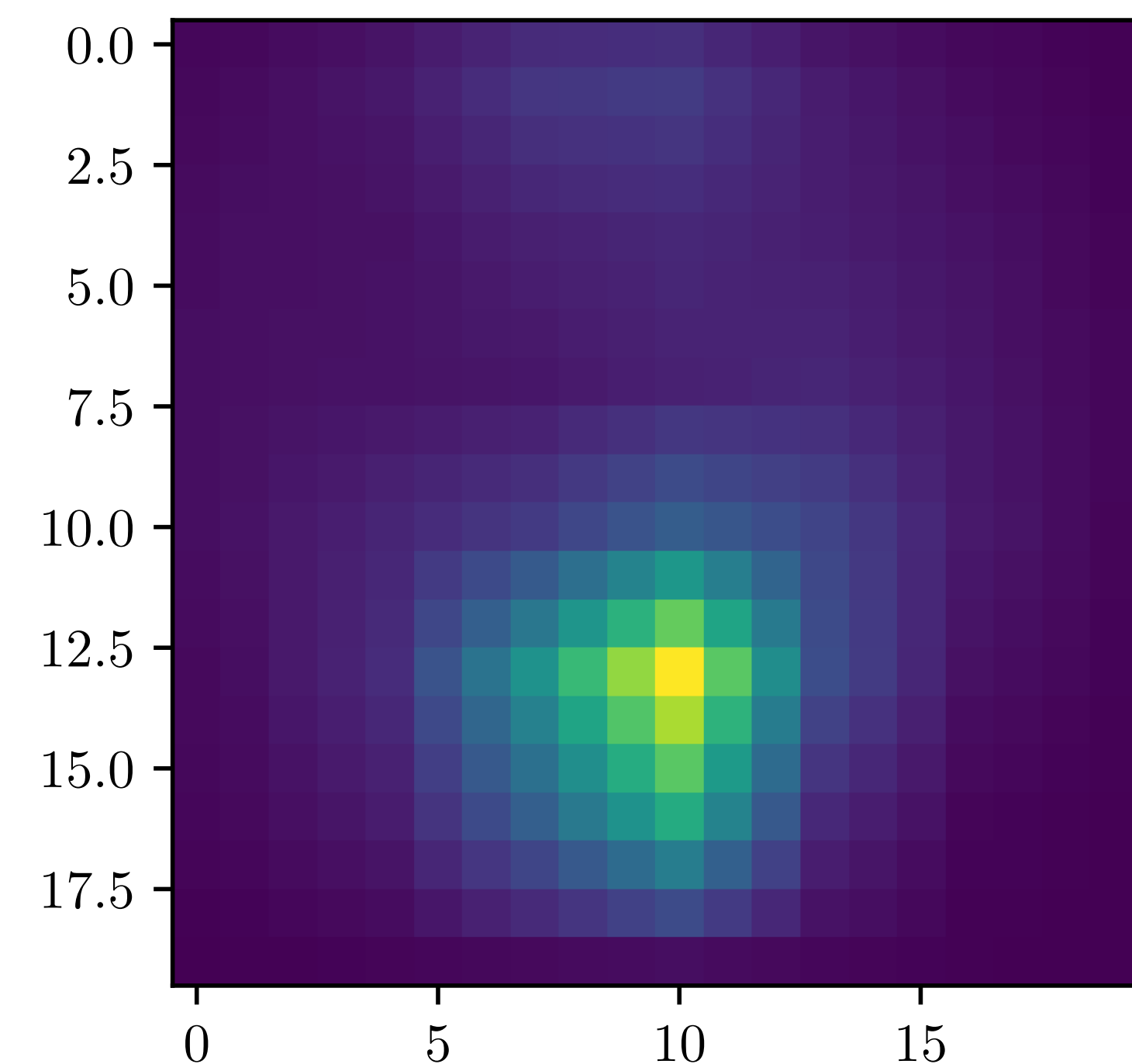
HeII 4685

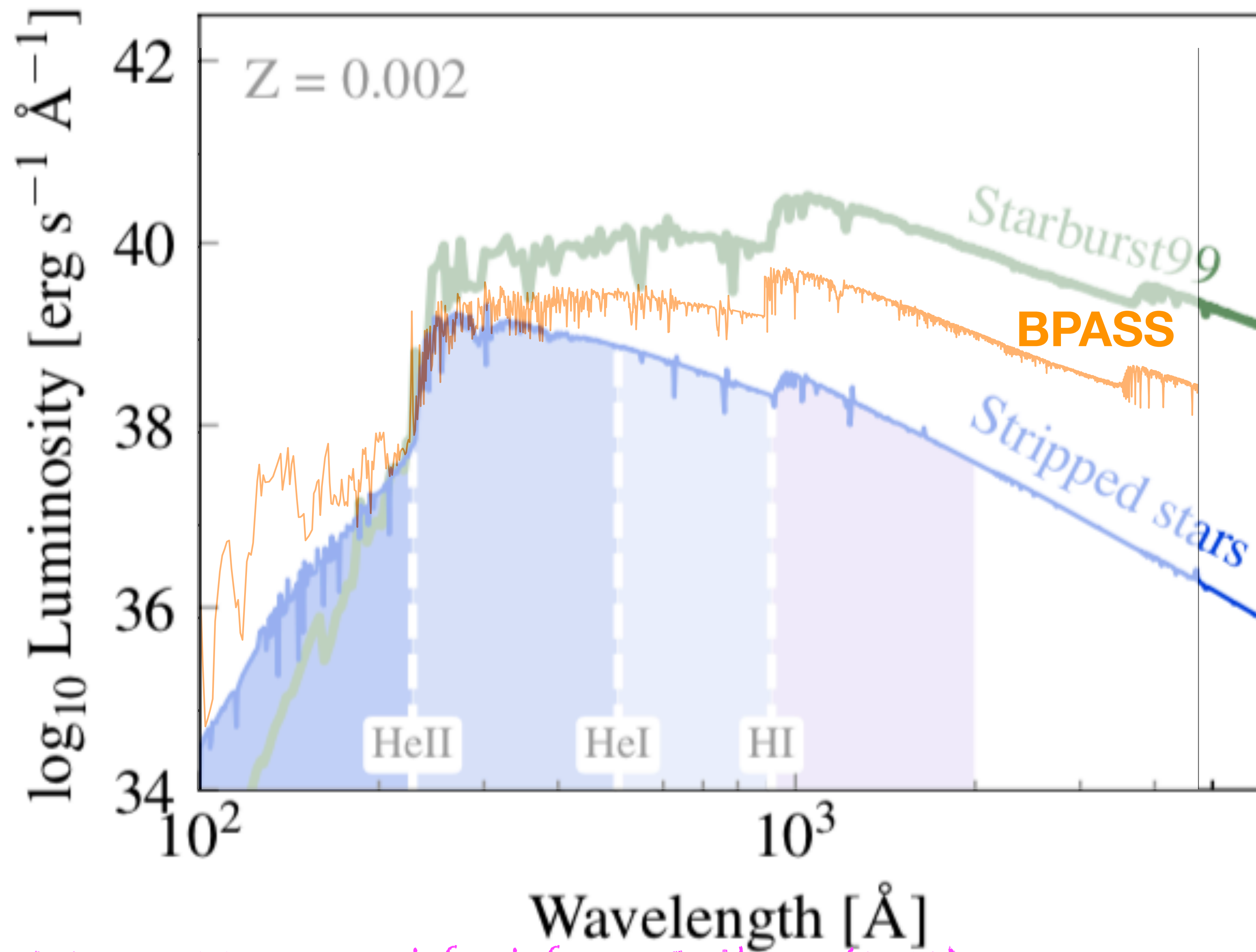


H $\beta$

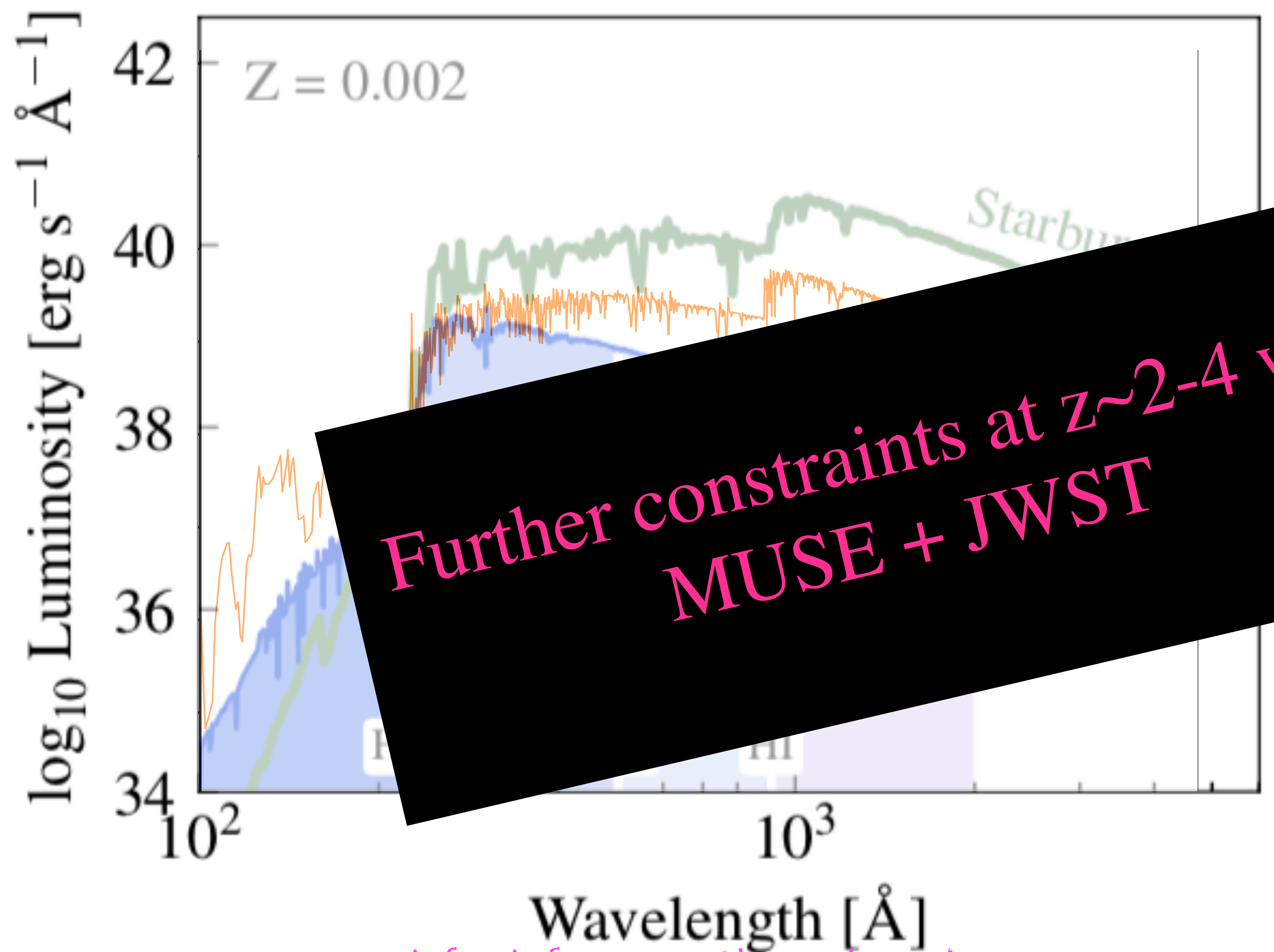


[OIII]5007



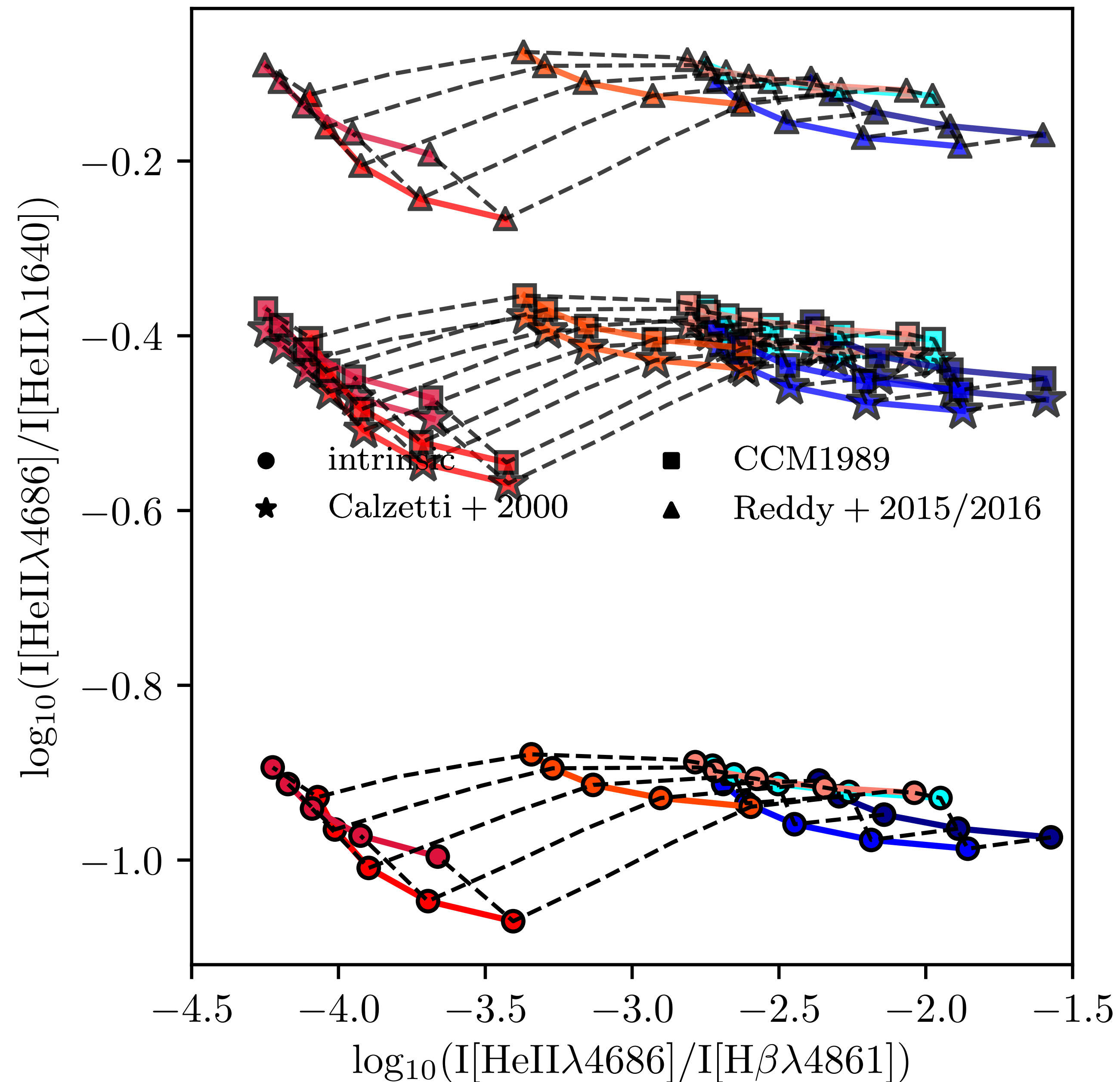


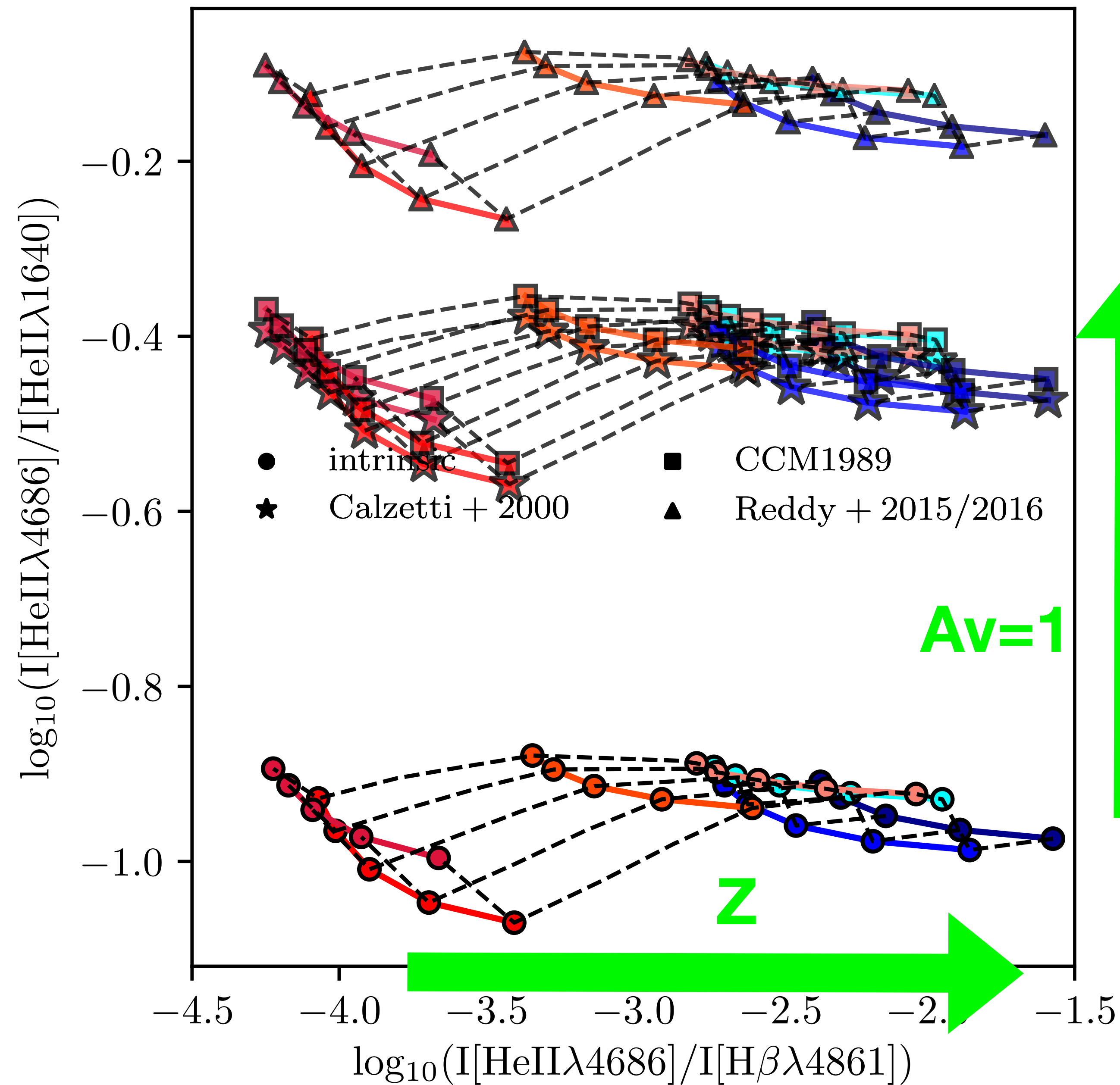
**Currently significant variations in the ionizing continuum of SSP models exist from HeII ionizing edge onwards**



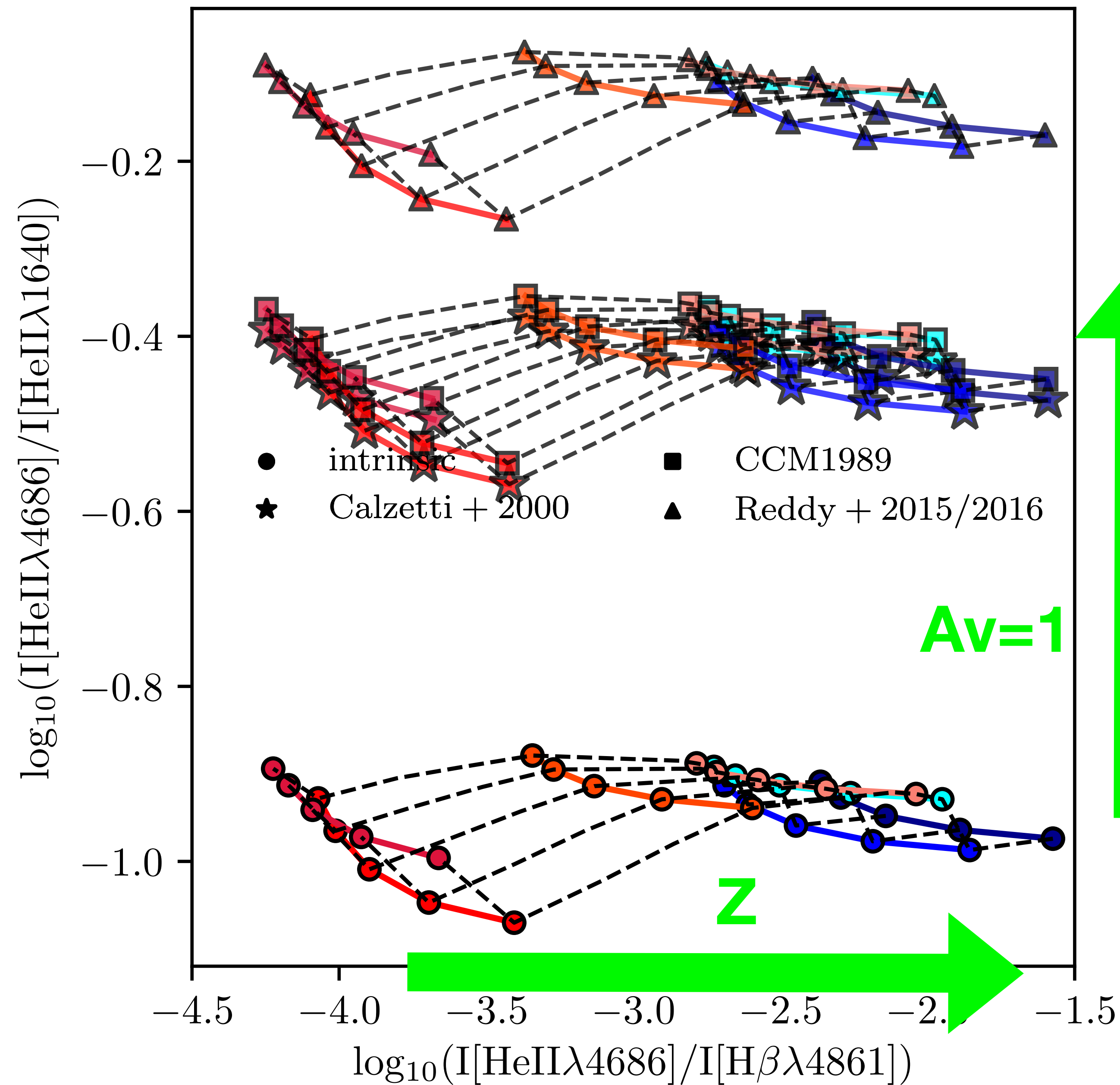
Currently  
significant  
variations in the  
ionizing  
photon spectrum  
of models exist  
from HeI  
ionizing edge  
onwards

How accurately can we combine UV + optical lines together without worrying about dust/systematics?



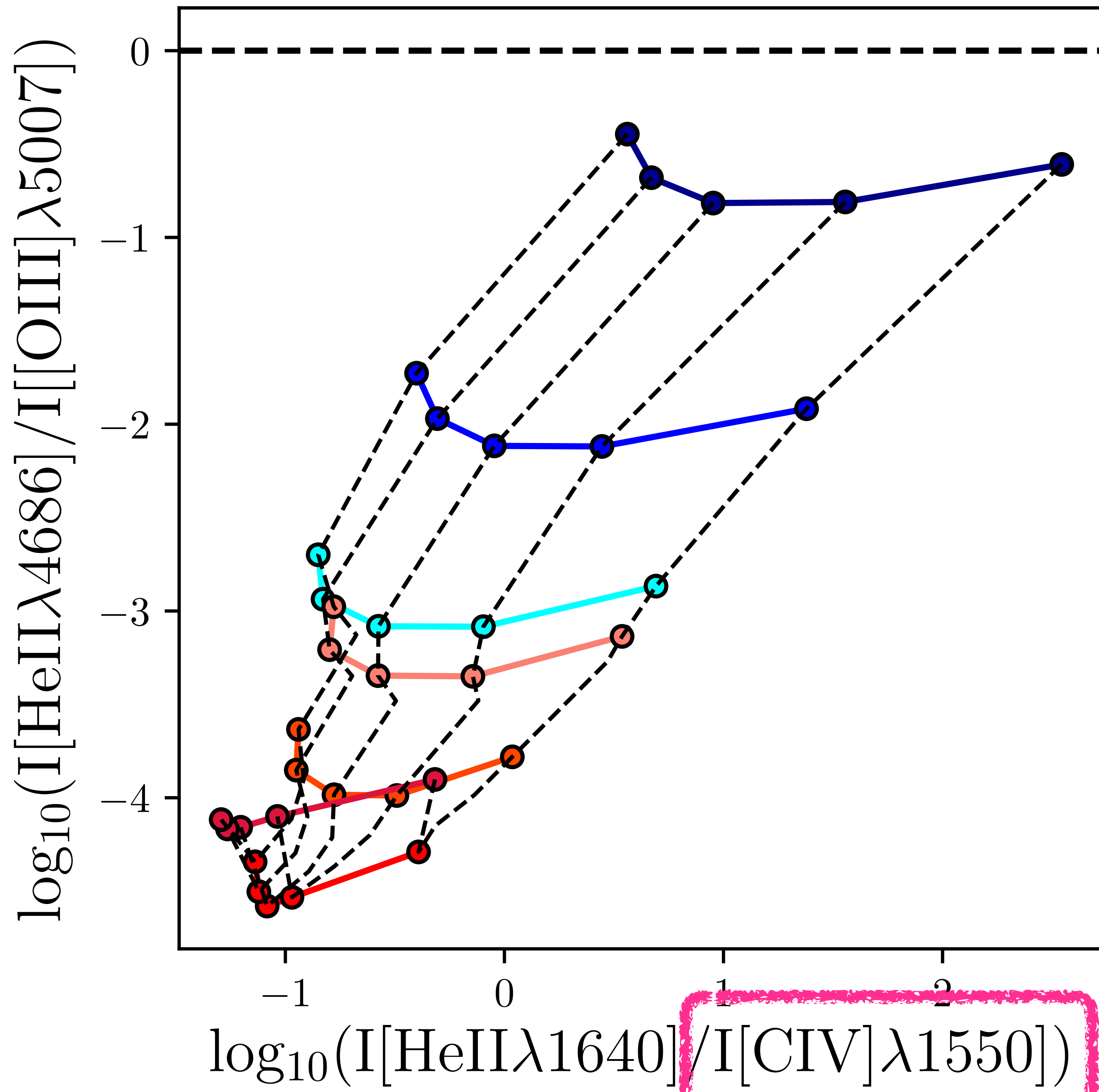


How accurately can we combine UV + optical lines together without worrying about dust/systematics?



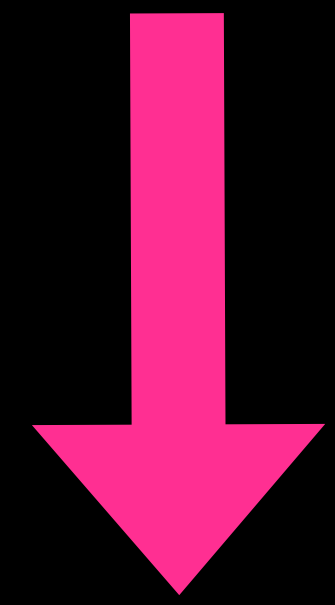
How accurately can we combine UV + optical lines together without worrying about dust/systematics?

  
 MUSE  
 +  
 JWST  
 synergies



©Nanayakkara

How accurately can we combine UV + optical lines together without worrying about dust/systematics?



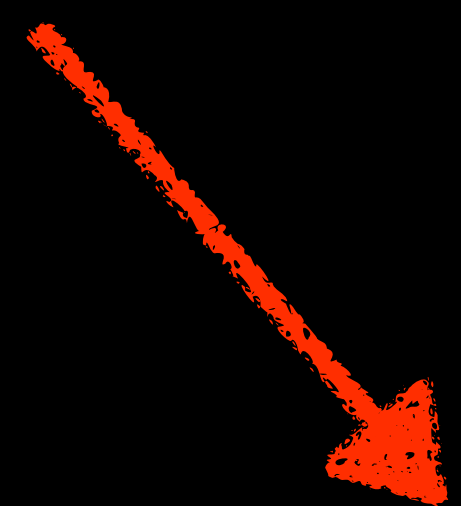
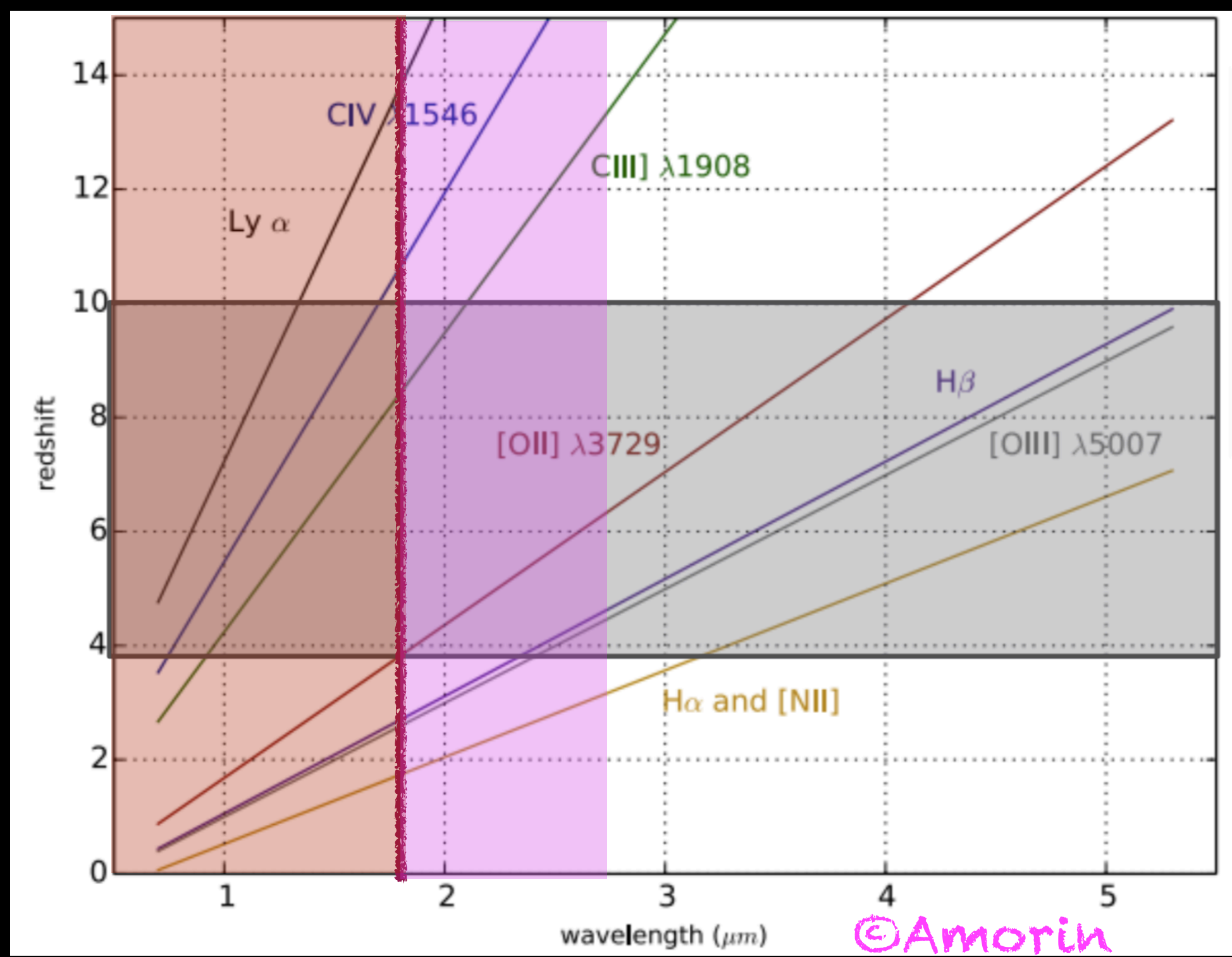
MUSE  
+  
JWST  
synergies

# Extreme low-Z galaxies at cosmic dawn will be a reality with ELTs ( $z \approx 10$ ) and JWST ( $z \approx 20?$ ) 🙌

Ly- $\alpha$ , He II, H $\alpha$ , H $\beta$ , Pa- $\alpha$  detections  
 High He II EW

Lower limits for no metal scenarios

$f(\text{metal})/f(\text{Hydrogen})$

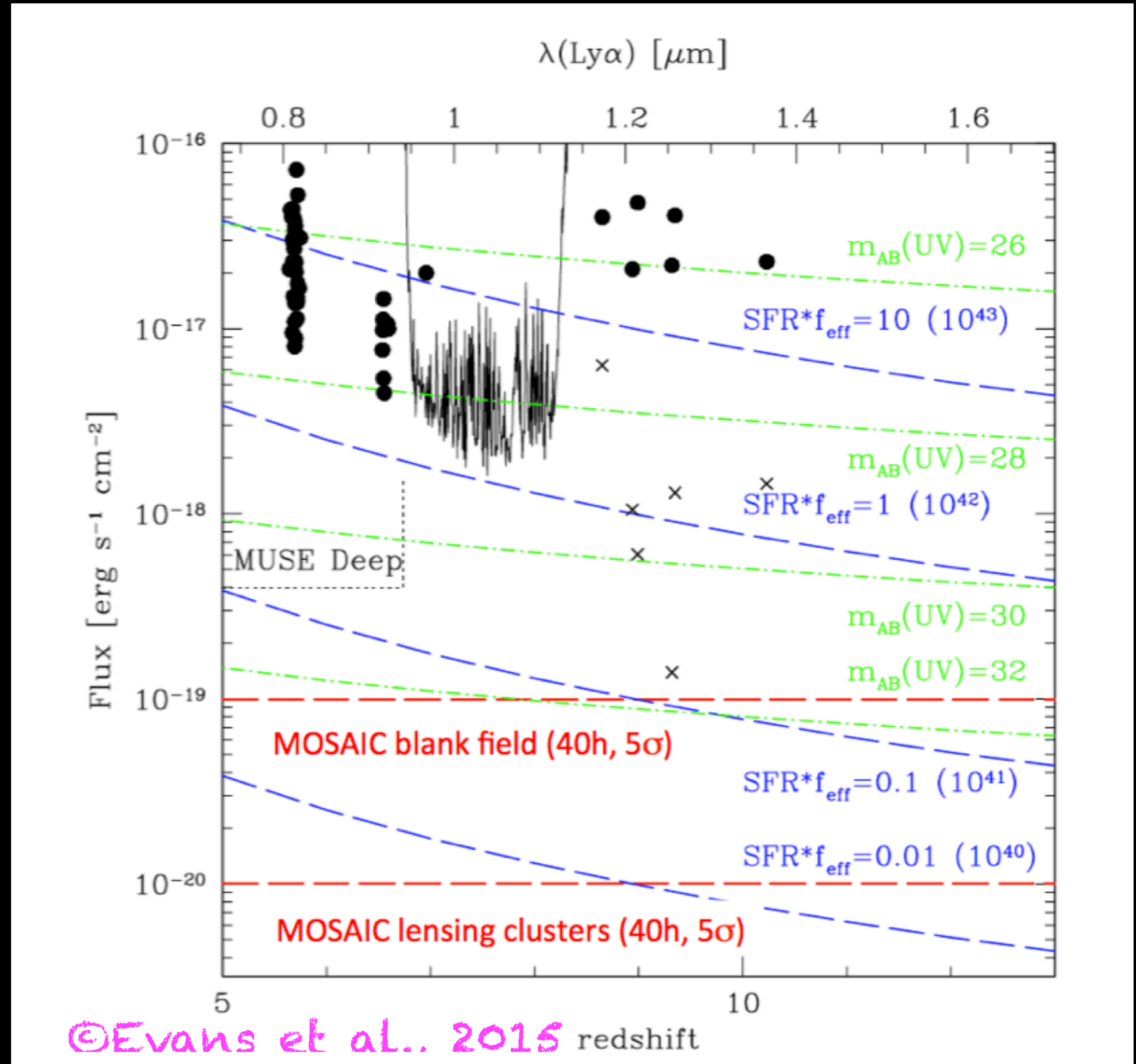
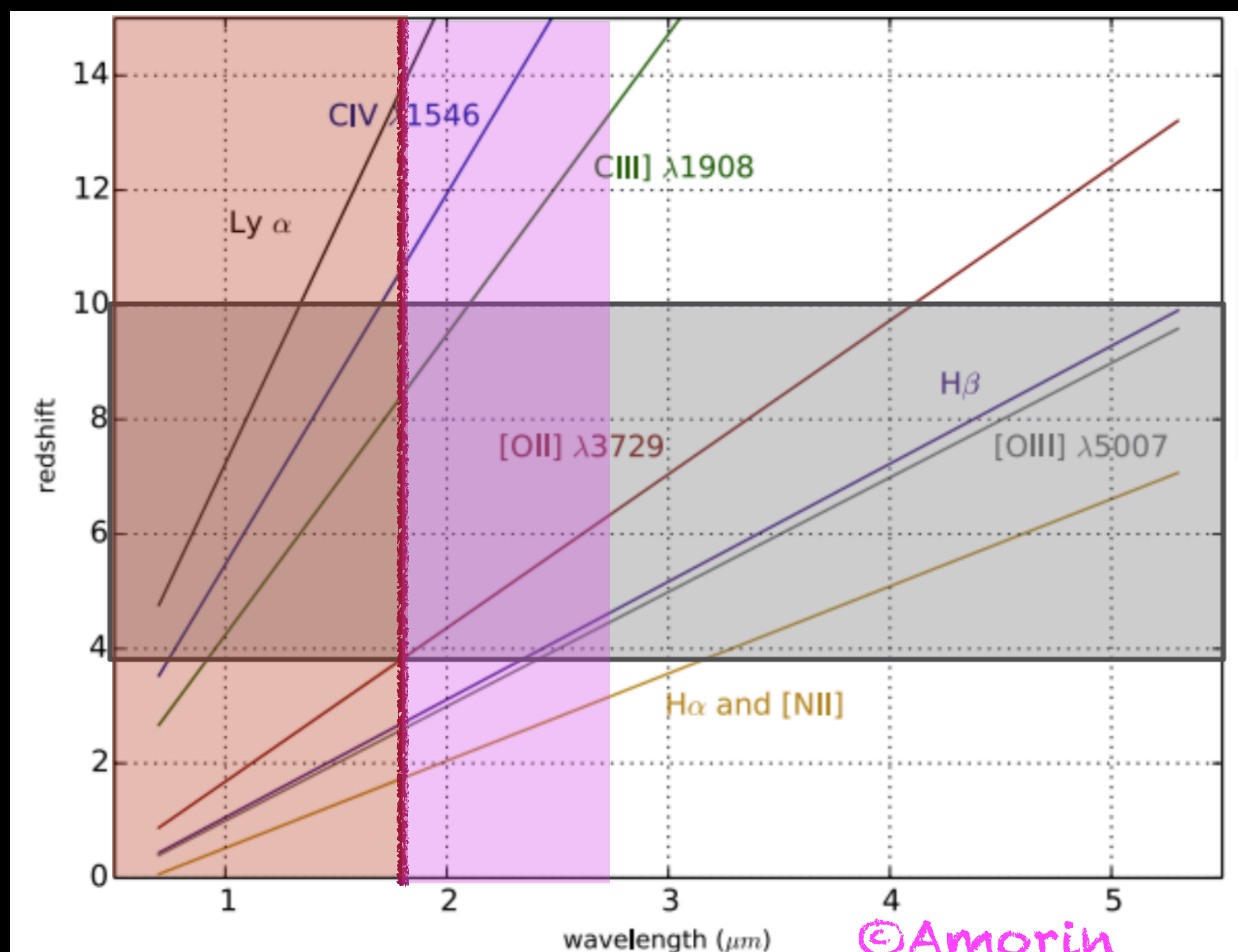


???

[NII]/Ha, R23, [OIII]/Hb, ALMA fine-structure lines

# Extreme low-Z galaxies at cosmic dawn will be a reality with ELTs ( $z \approx 10$ ) and JWST ( $z \approx 20?$ ) 🙌

Ly- $\alpha$ , He II, H $\alpha$ , H $\beta$ , Pa- $\alpha$  detections  
High He II EW





# JWST MASTER CLASS

MELBOURNE MARCH 16-18 2020



Melbourne March 16-18

<http://astronomy.swin.edu.au/JWST/jwstmasterclass2020melbourne/>