THE MISSING PIECE IN THE REIONIZATION

Quantifying the ionizing flux of extremely metal-poor massive stars

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Centro de Astrobiología (CAB, CSIC-INTA),
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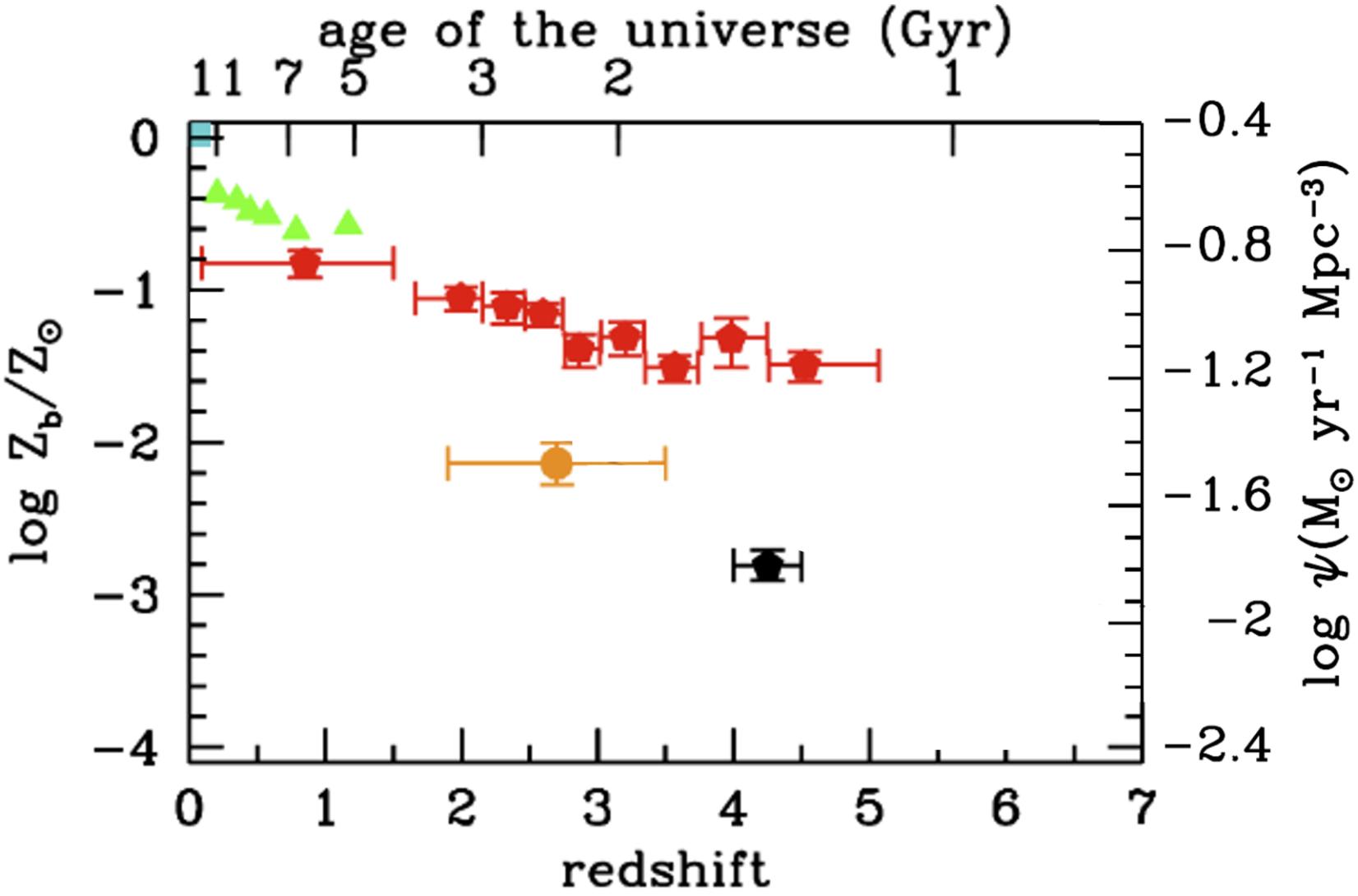
18-21 April 2023
OAC, Kolymbari, Crete

Universidad Autónoma de Madrid

CENTRO DE ASTROBIOLOGÍA
CSIC - INTA

WHY ARE WE INTERESTED IN LOW-Z ENVIRONMENTS?



Madau & Dickinson 2014

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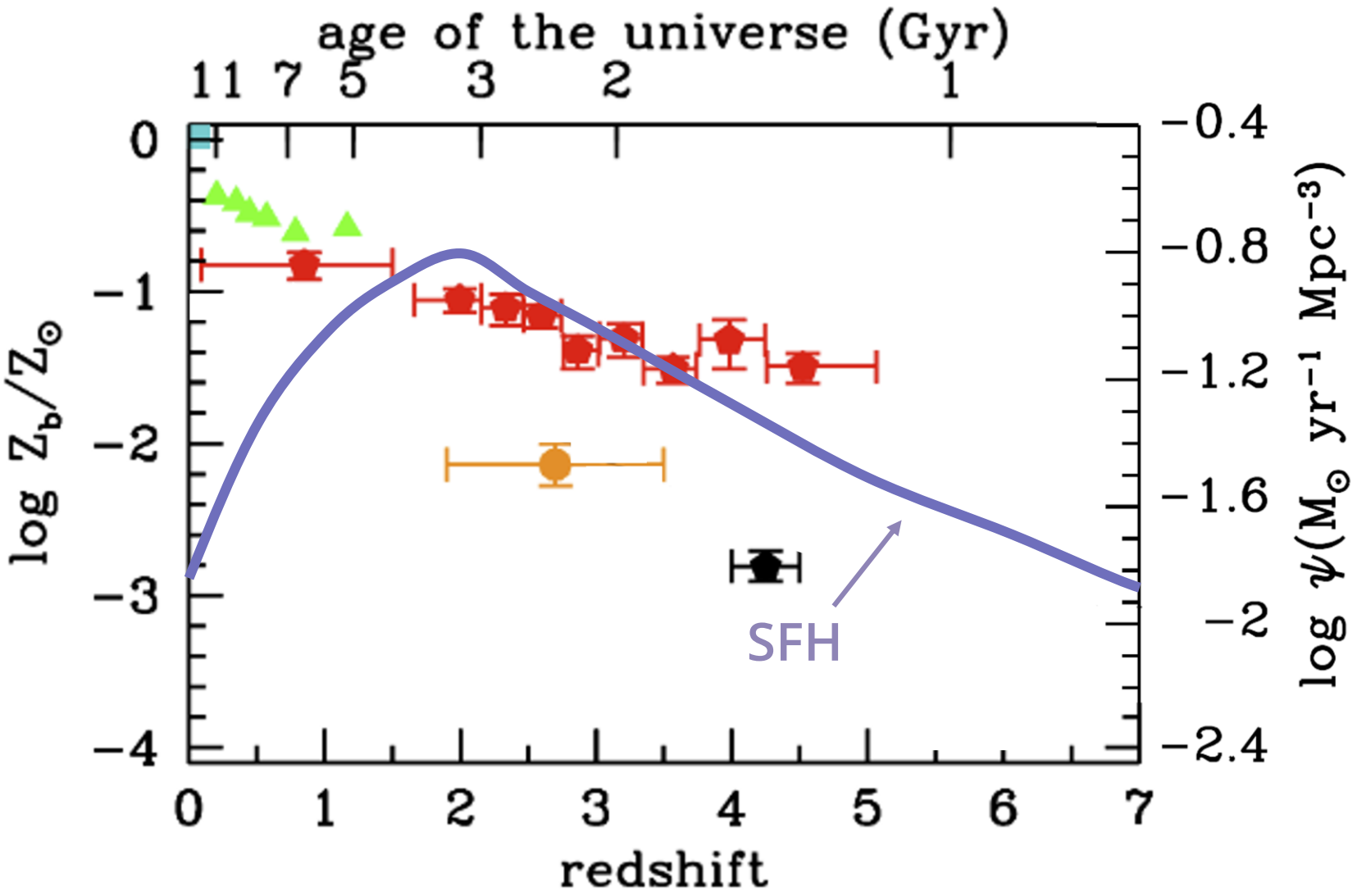

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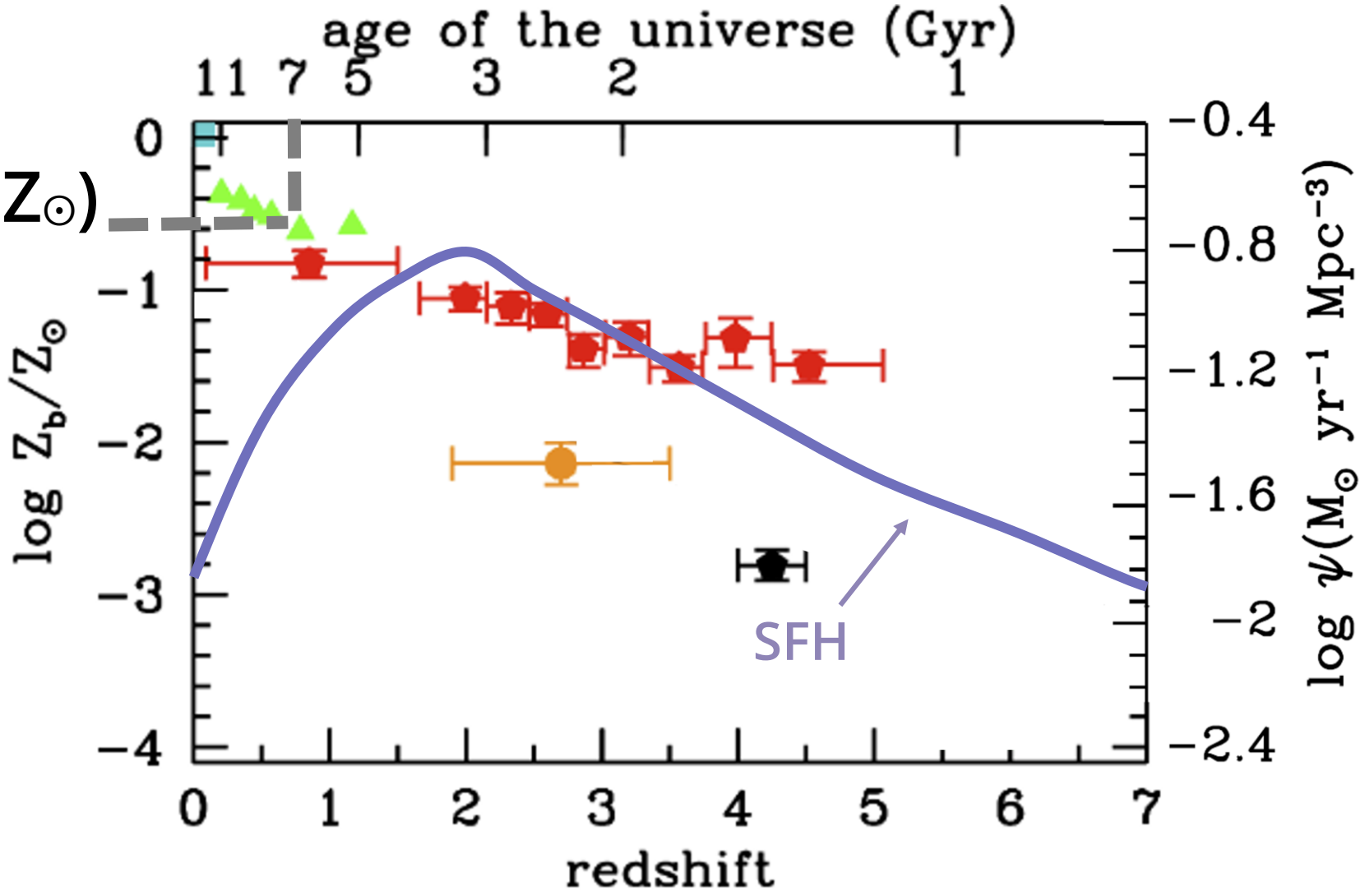
SMC (1/5 $Z_\odot$)



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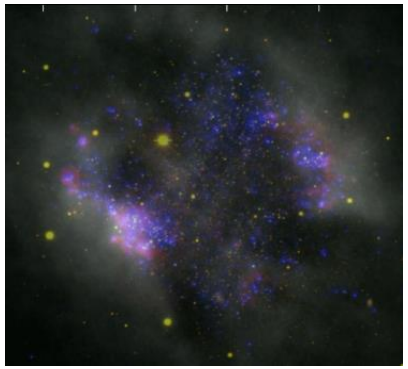


SMC (1/5 $Z_\odot$)

Sextans A (1/10 $Z_\odot$)

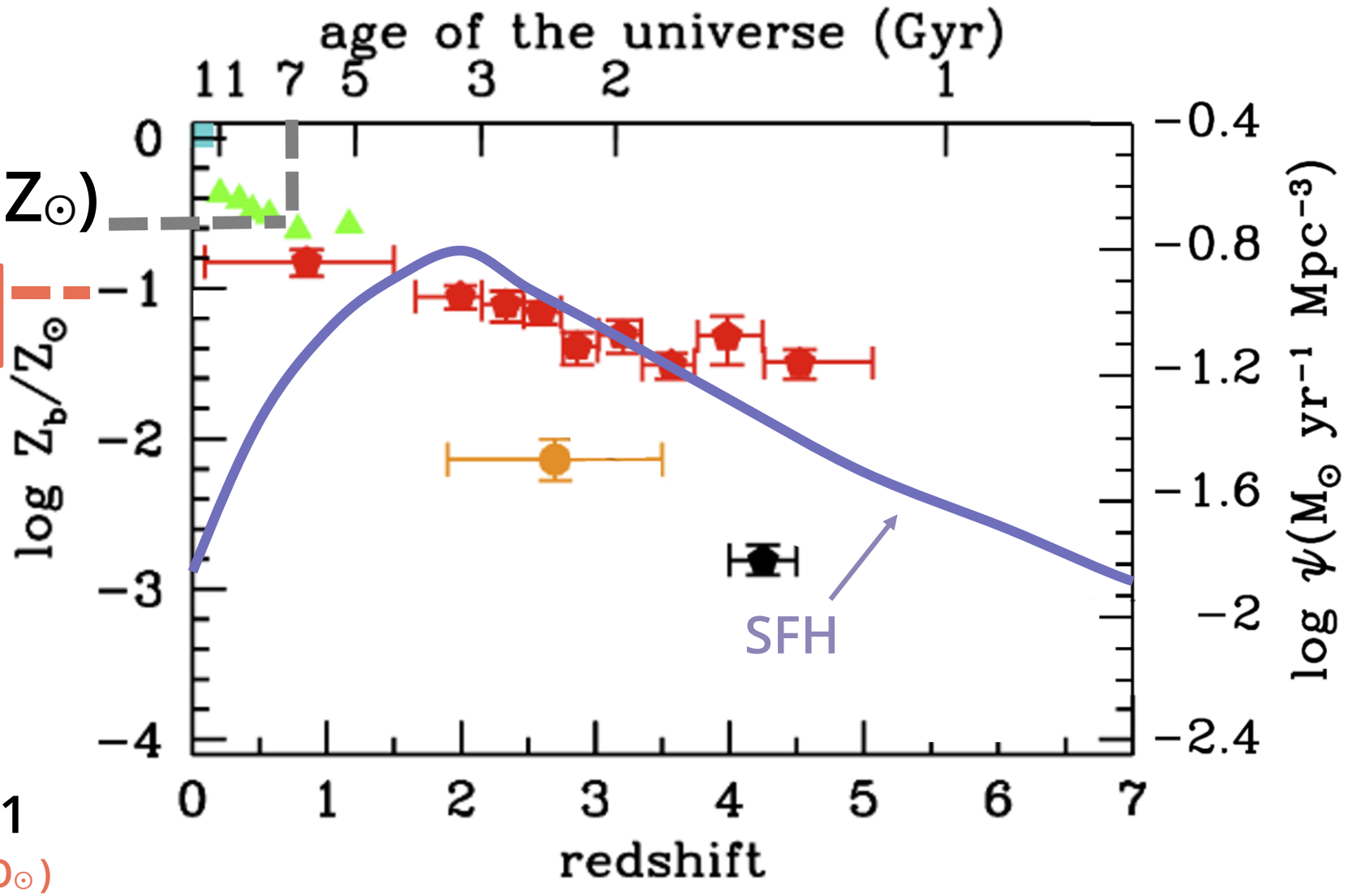
- 1.3 Mpc
- E(B-V)$_{fg}$ = 0.044
- ⟨[Fe/H]⟩ = -0.99

  (1/10 $Fe_\odot$)

  Kaufer+2004, Garcia+2017, Telford+2021
- 12 + log(O/H) = 7.49-7.71

  (1/10 - 1/15 $O_\odot$)

  Skillman+1989, Pilyugin+2001, Kniazev+2005, Berg+2012



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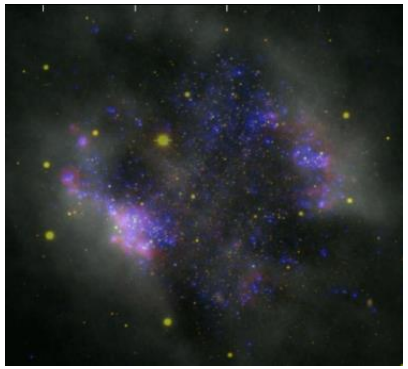

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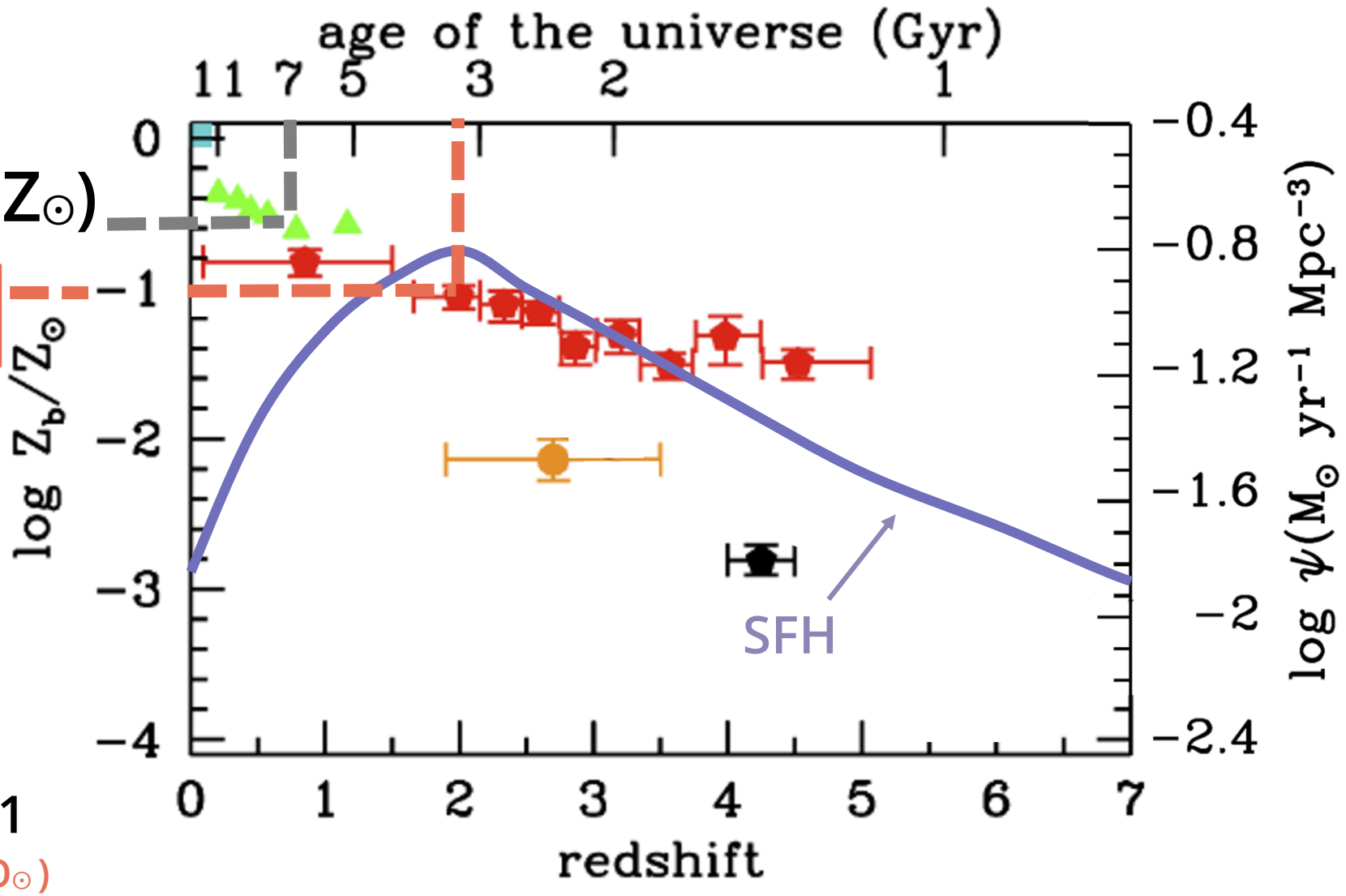
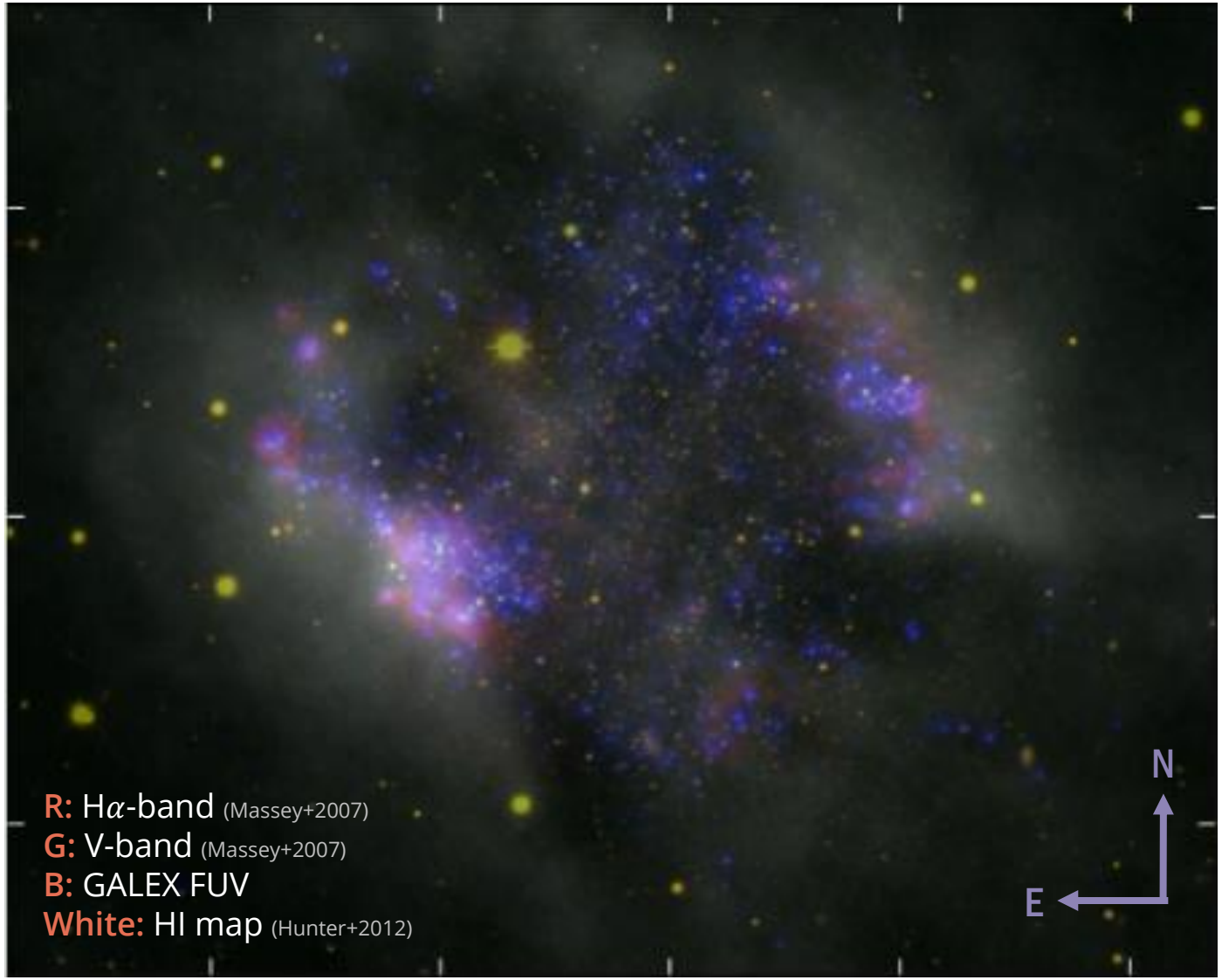


Madau & Dickinson 2014

+150 OB-TYPE STARS IN SEXTANS A



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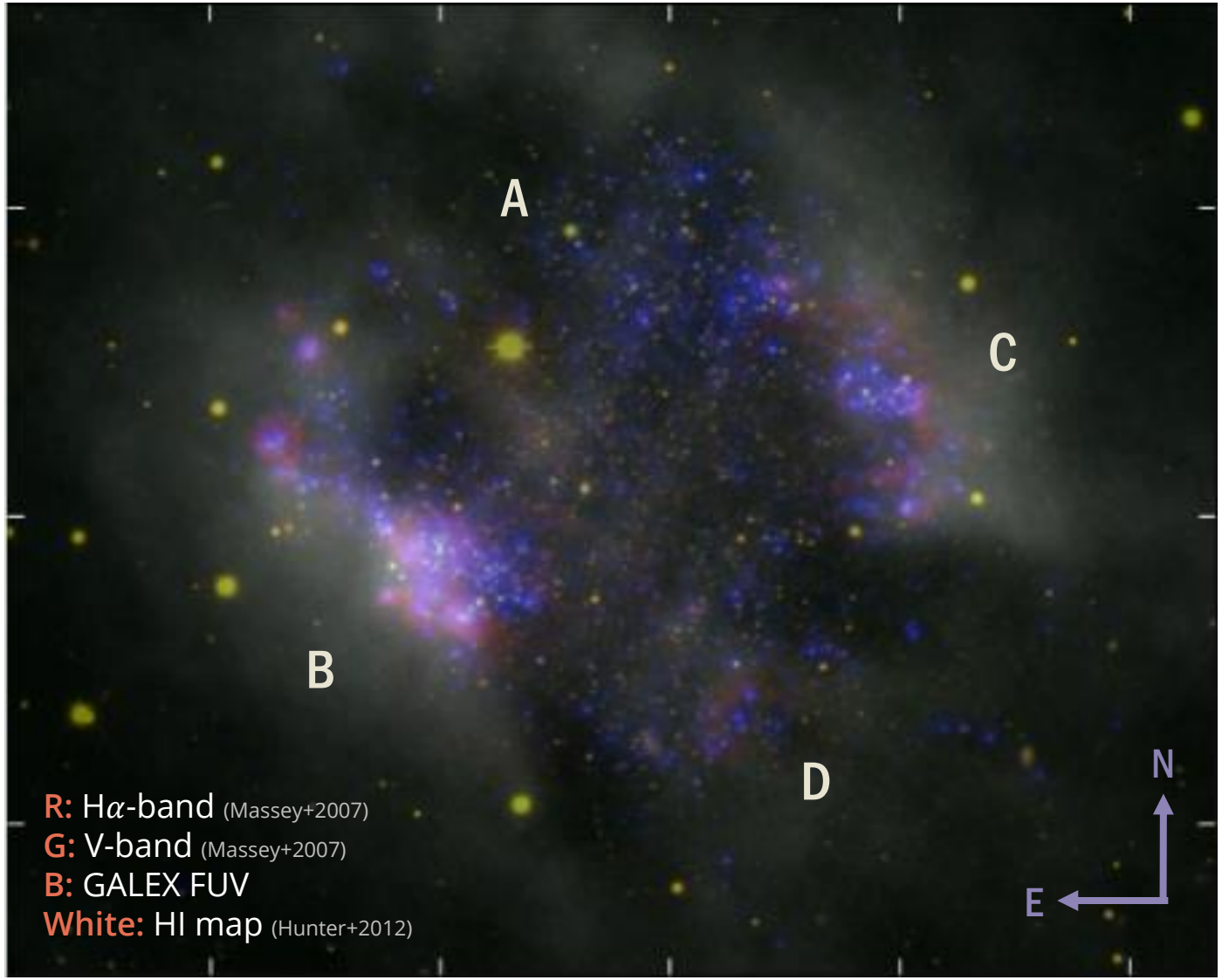
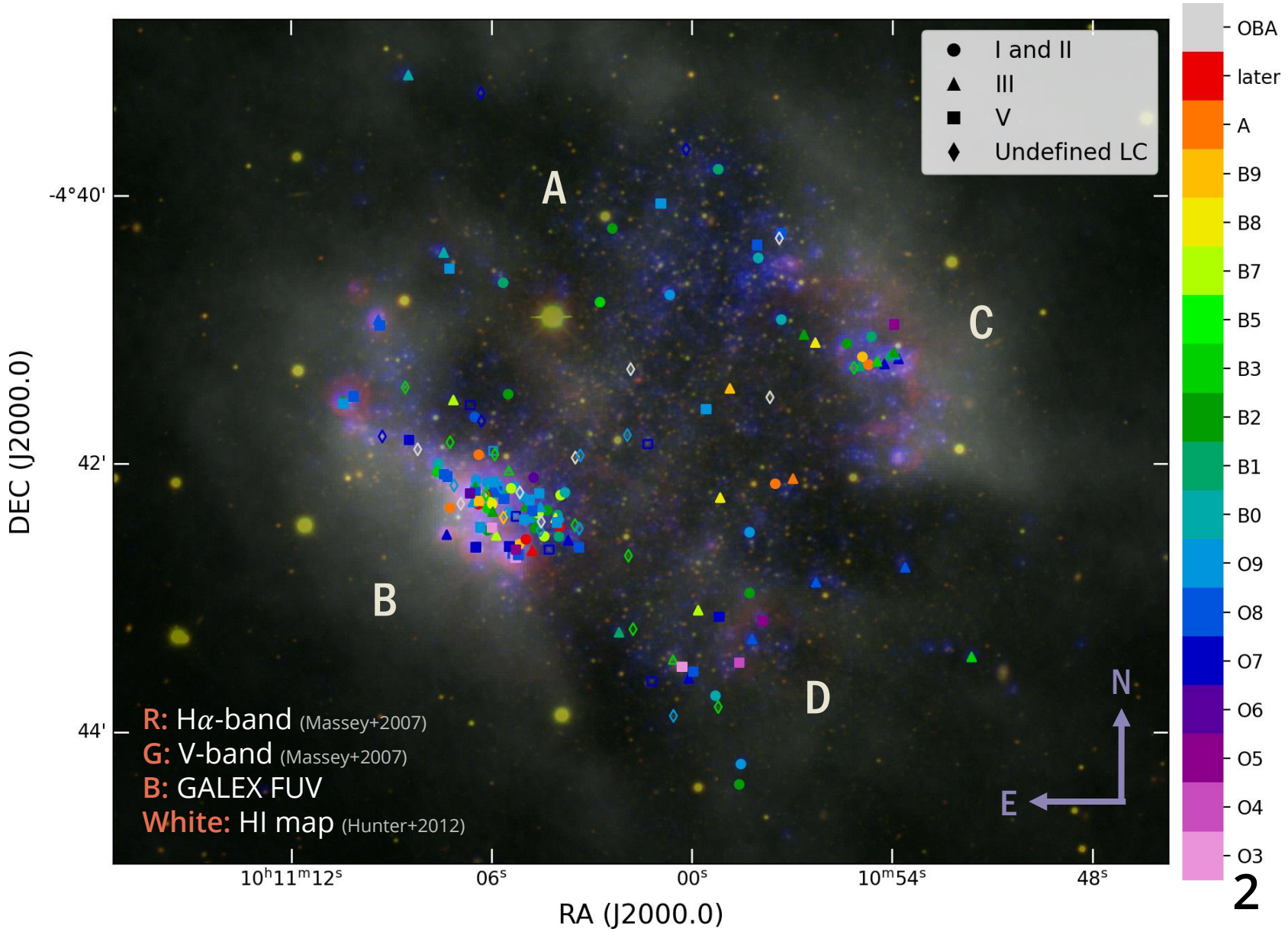


+150 OB-TYPE STARS IN SEXTANS A

Spectroscopy of **159** OB stars

Lorenzo et al. (2022), MNRAS, 516, 3

Largest catalogue of resolved massive stars at Z lower than the SMC



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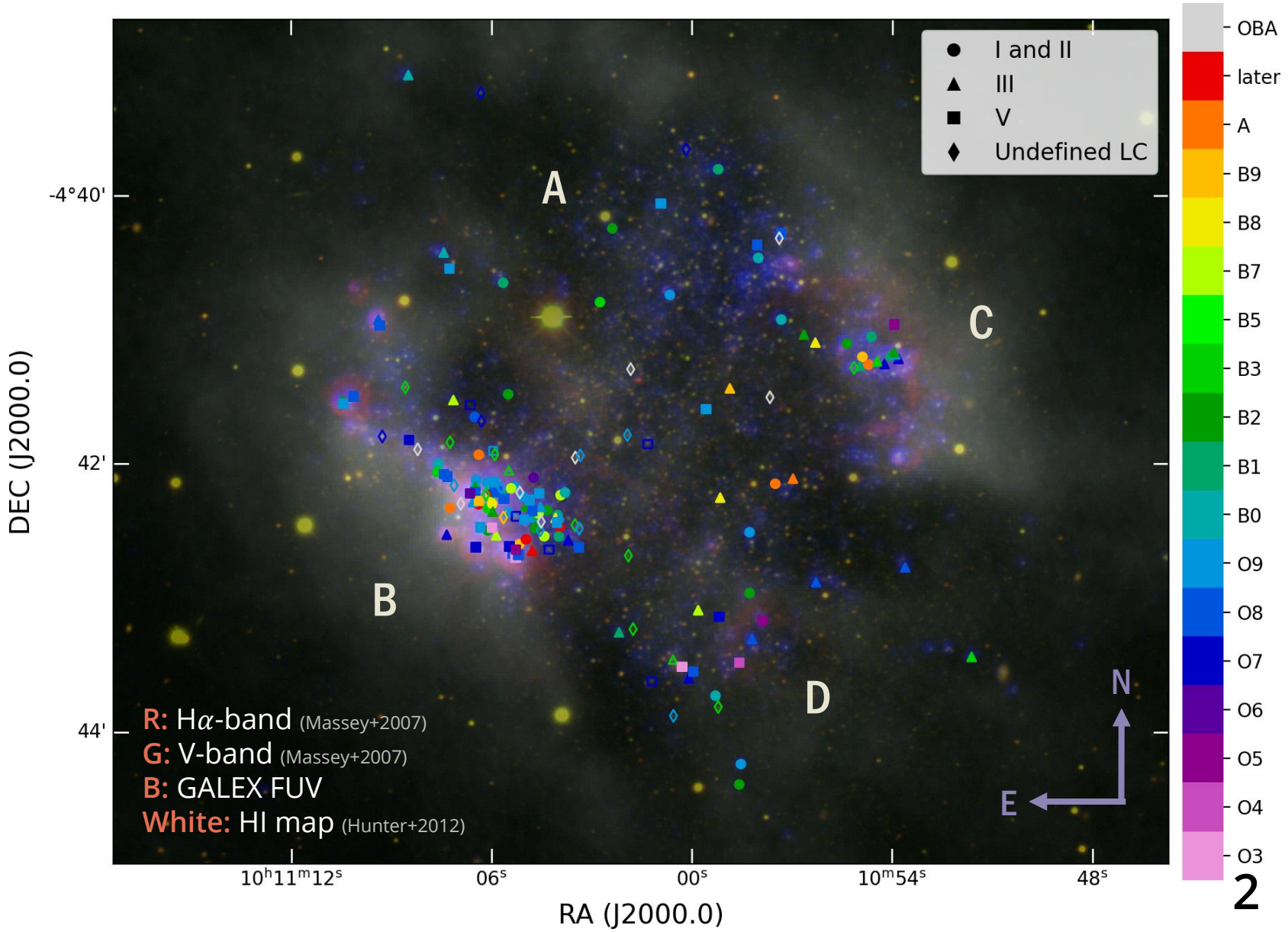
Most of our sample OB stars are located in region B



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Spectroscopy of 159 OB stars

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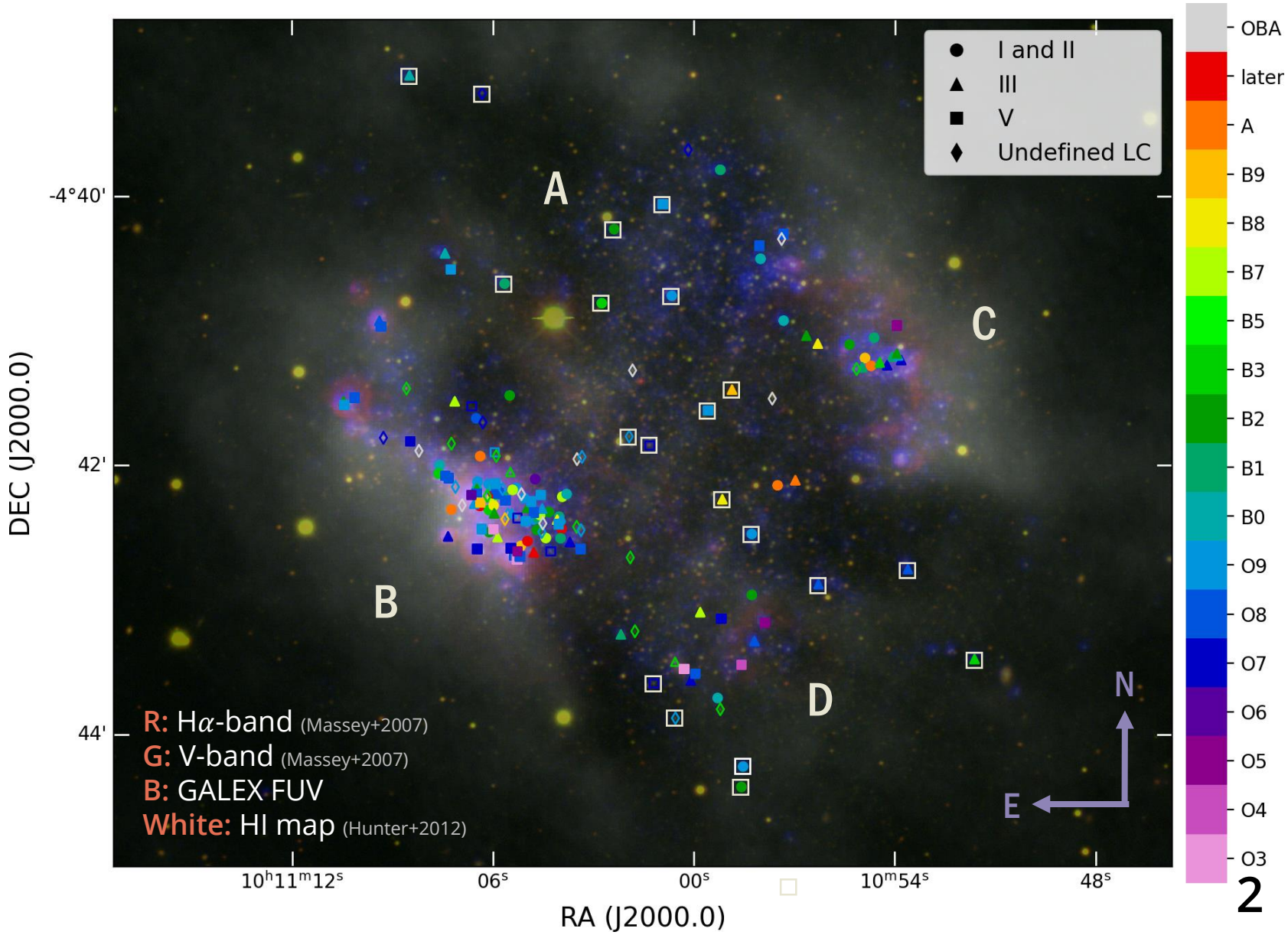
Most of our sample OB stars are located in region B

We also find massive stars isolated and in low gas density regions.



+150 OB-TYPE STARS IN SEXTANS A

Spectroscopy of
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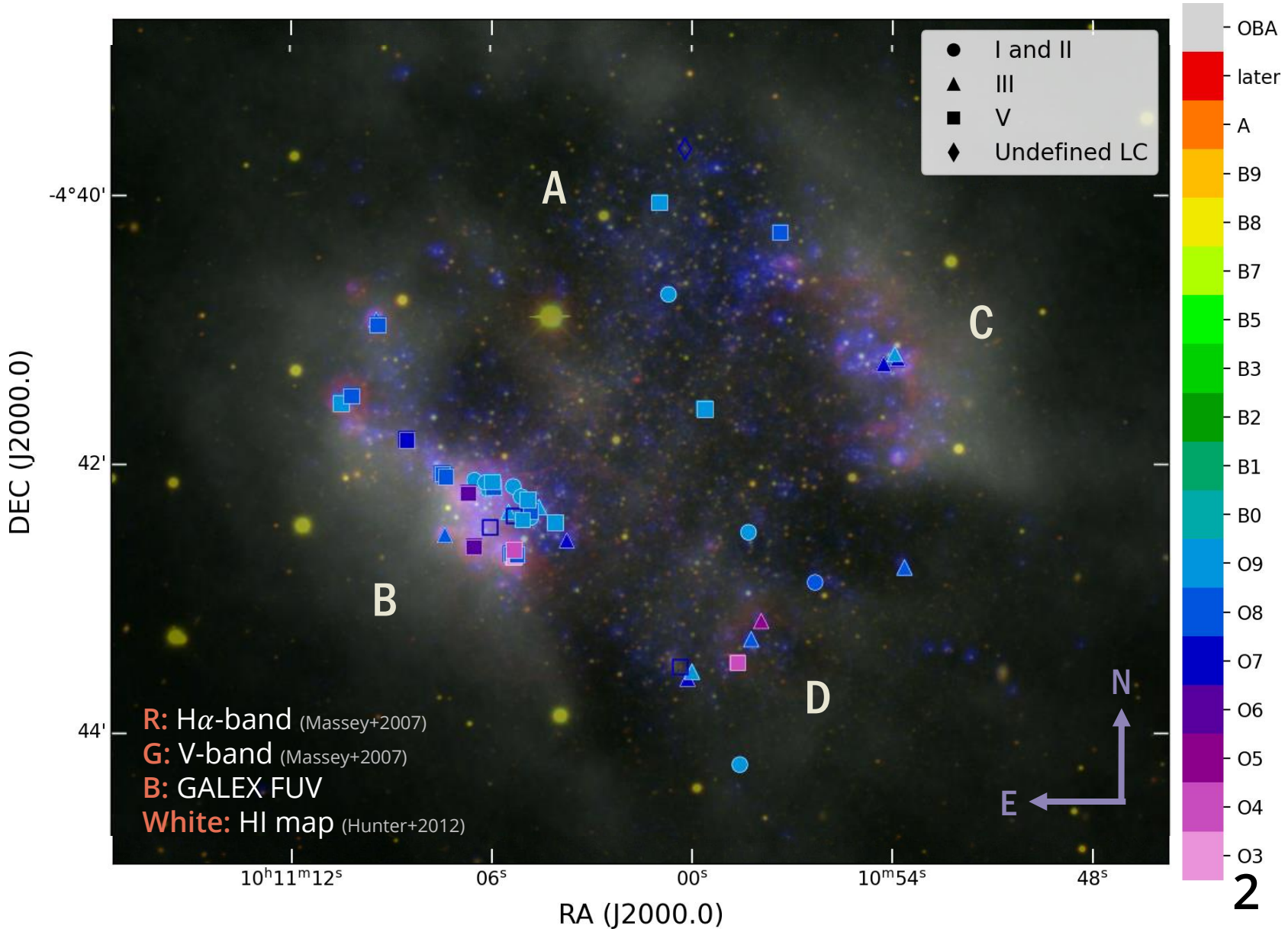
Analysis of
50 O-type stars

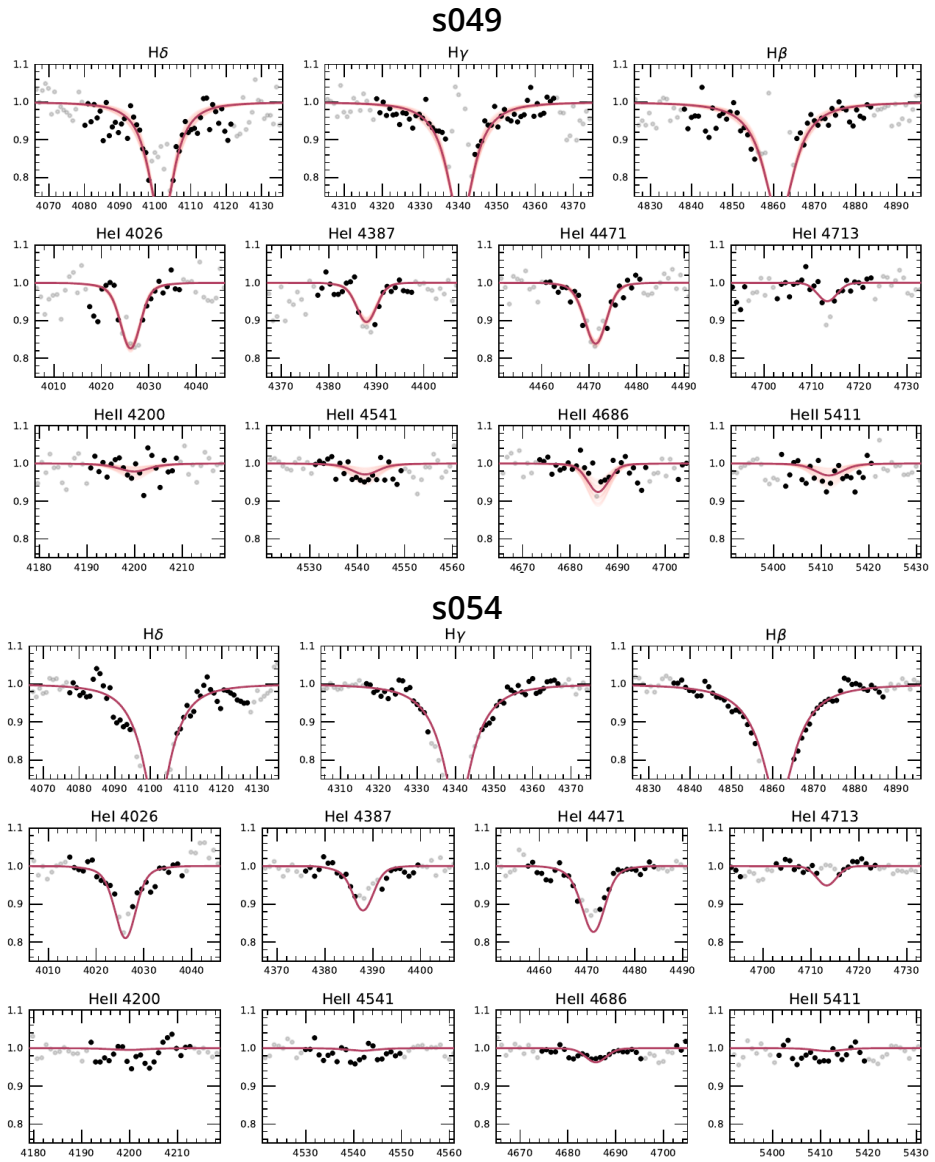
Lorenzo in prep. (2023a)



QUANTITATIVE ANALYSIS

Using the IACOB-GBAT tool

Based on an extensive grid of FASTWIND models



Lorenzo in prep. (2023a)

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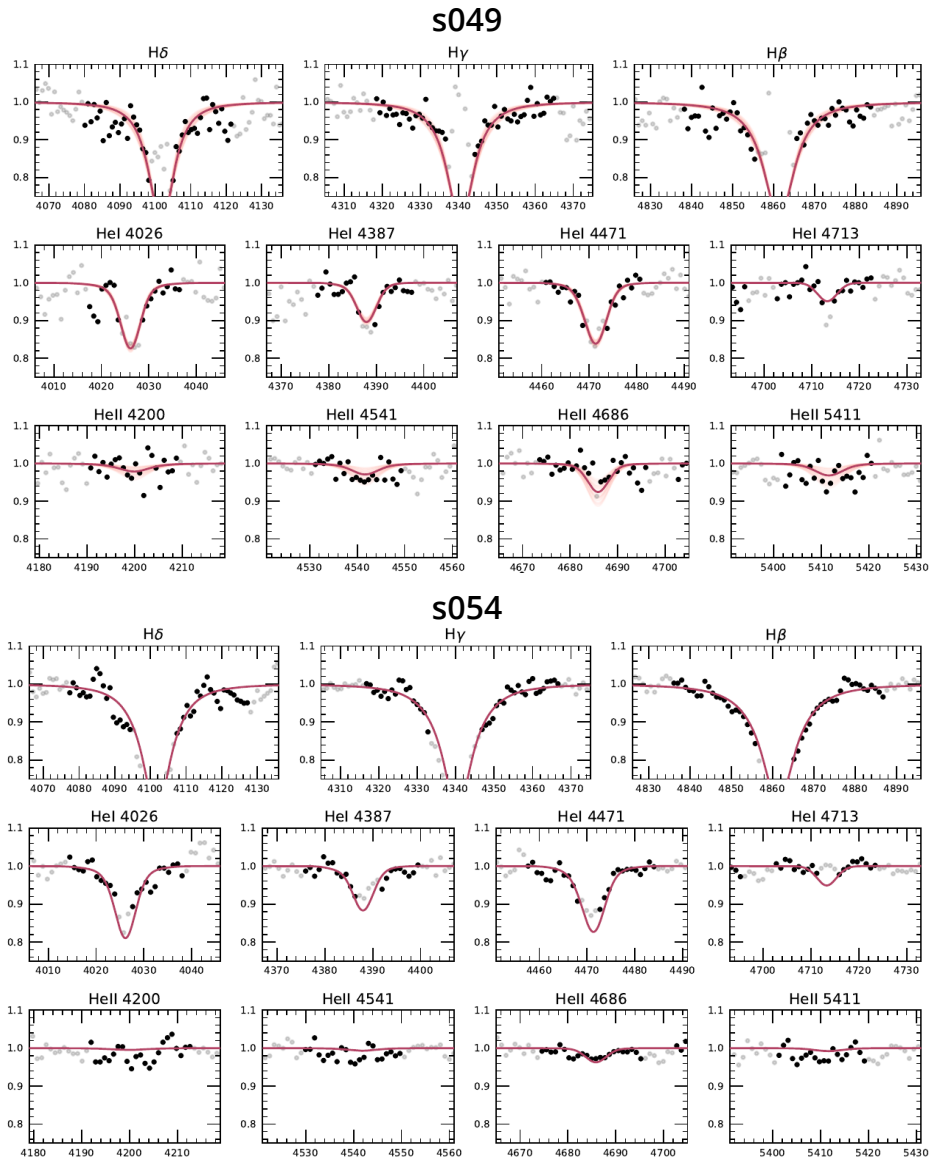
- Radiation driven-winds
- Line-blanketing
- Spherical symmetry



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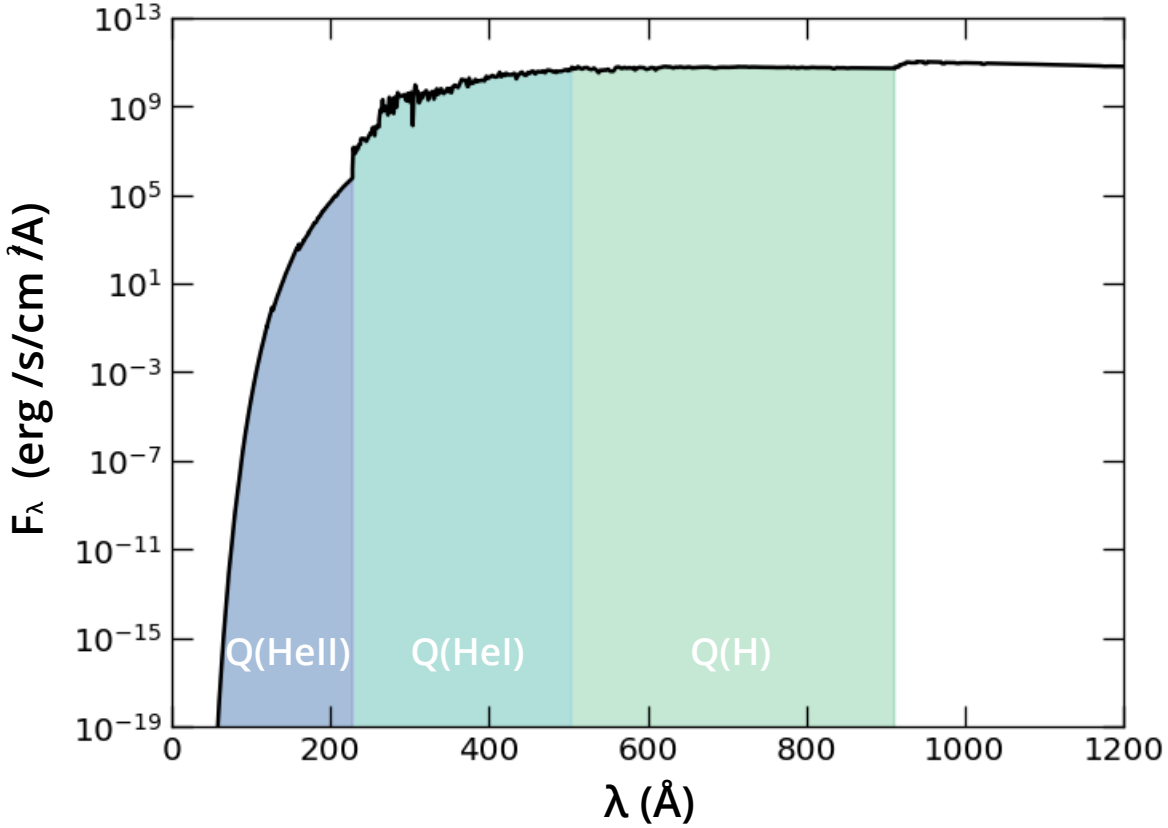

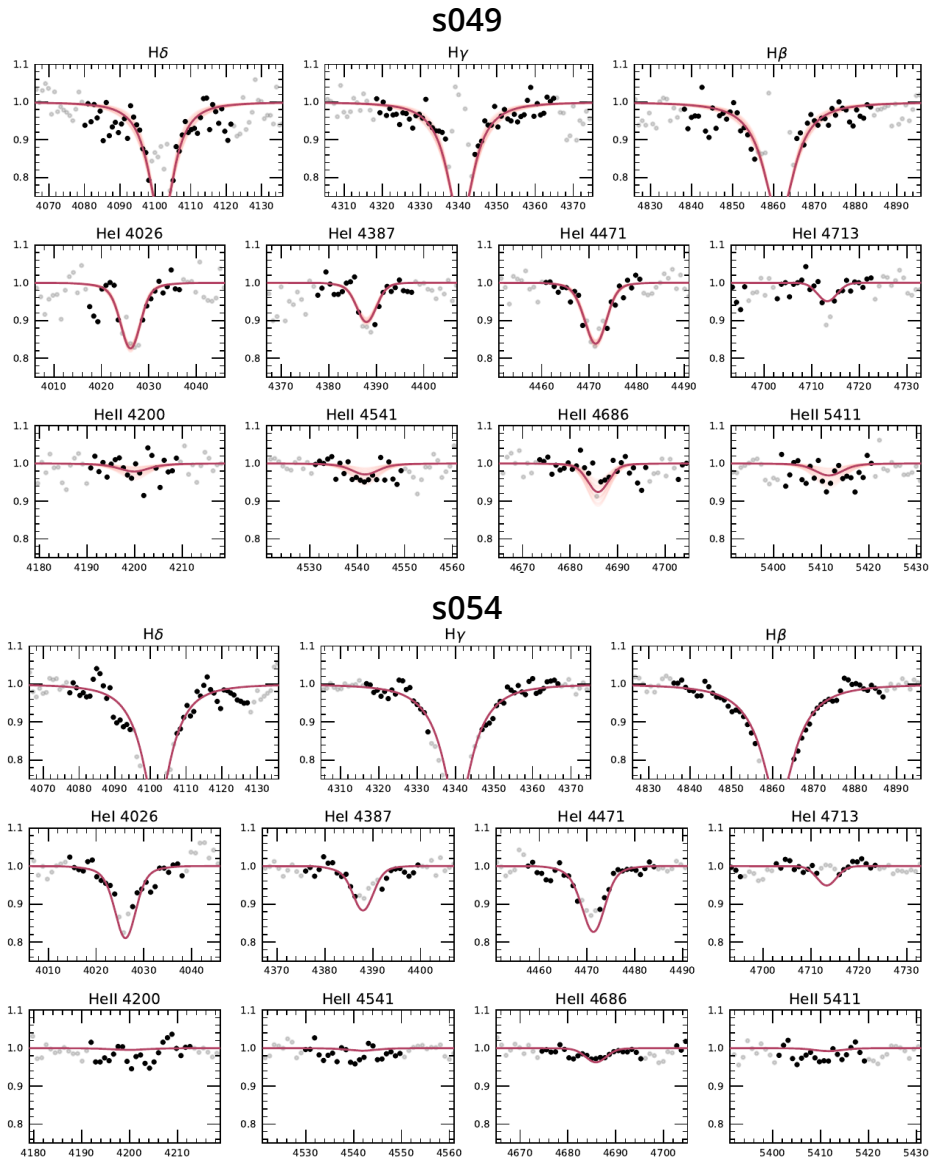

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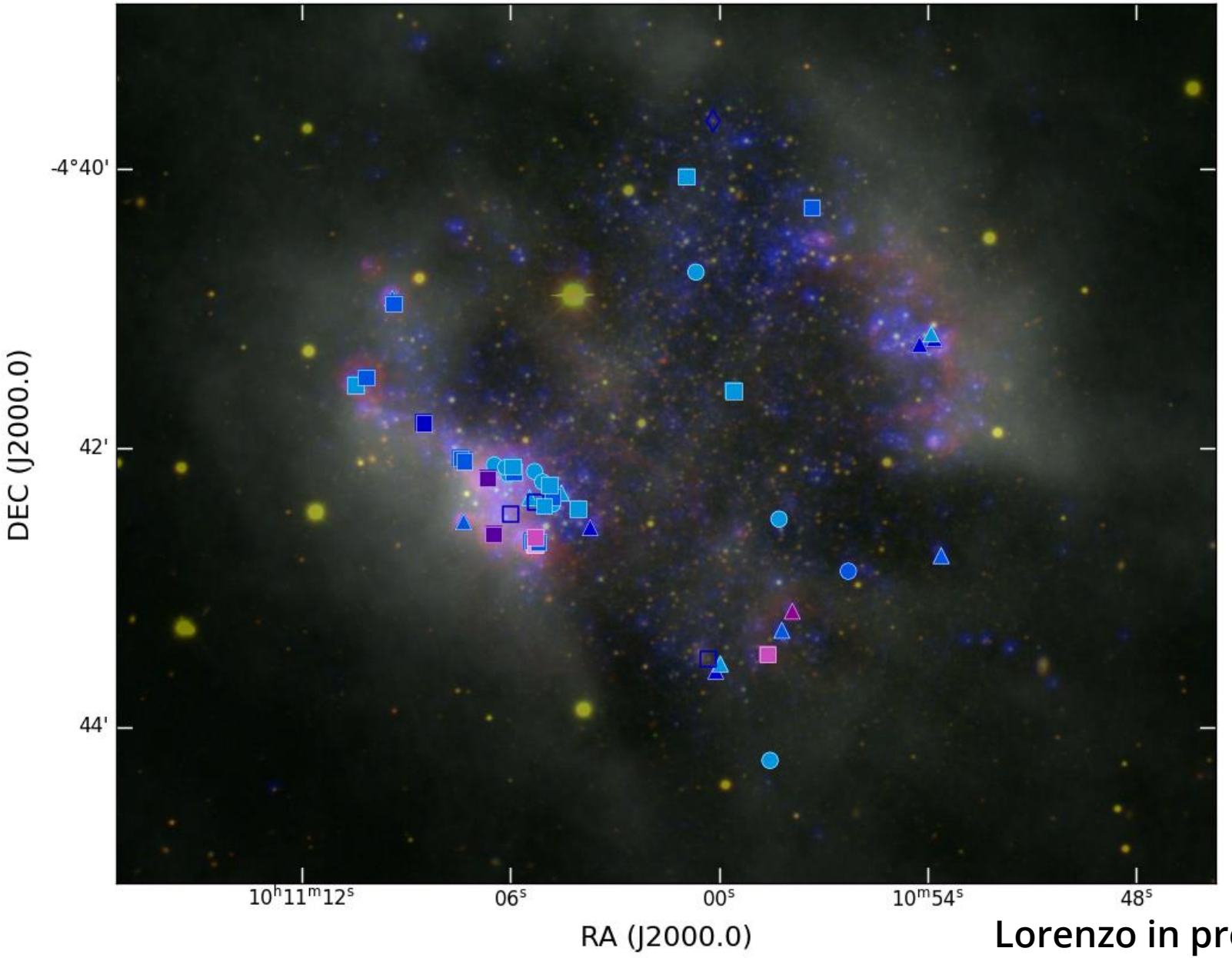
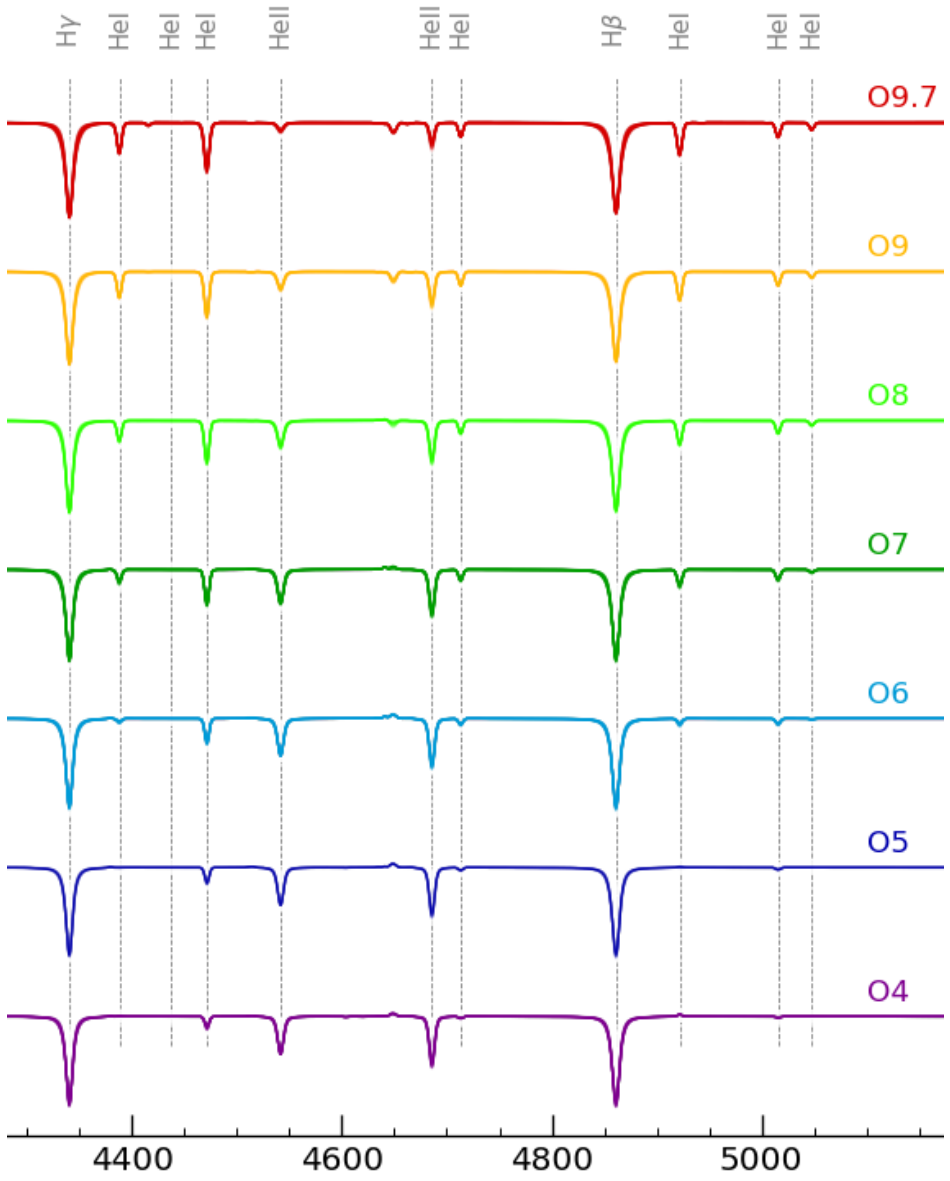
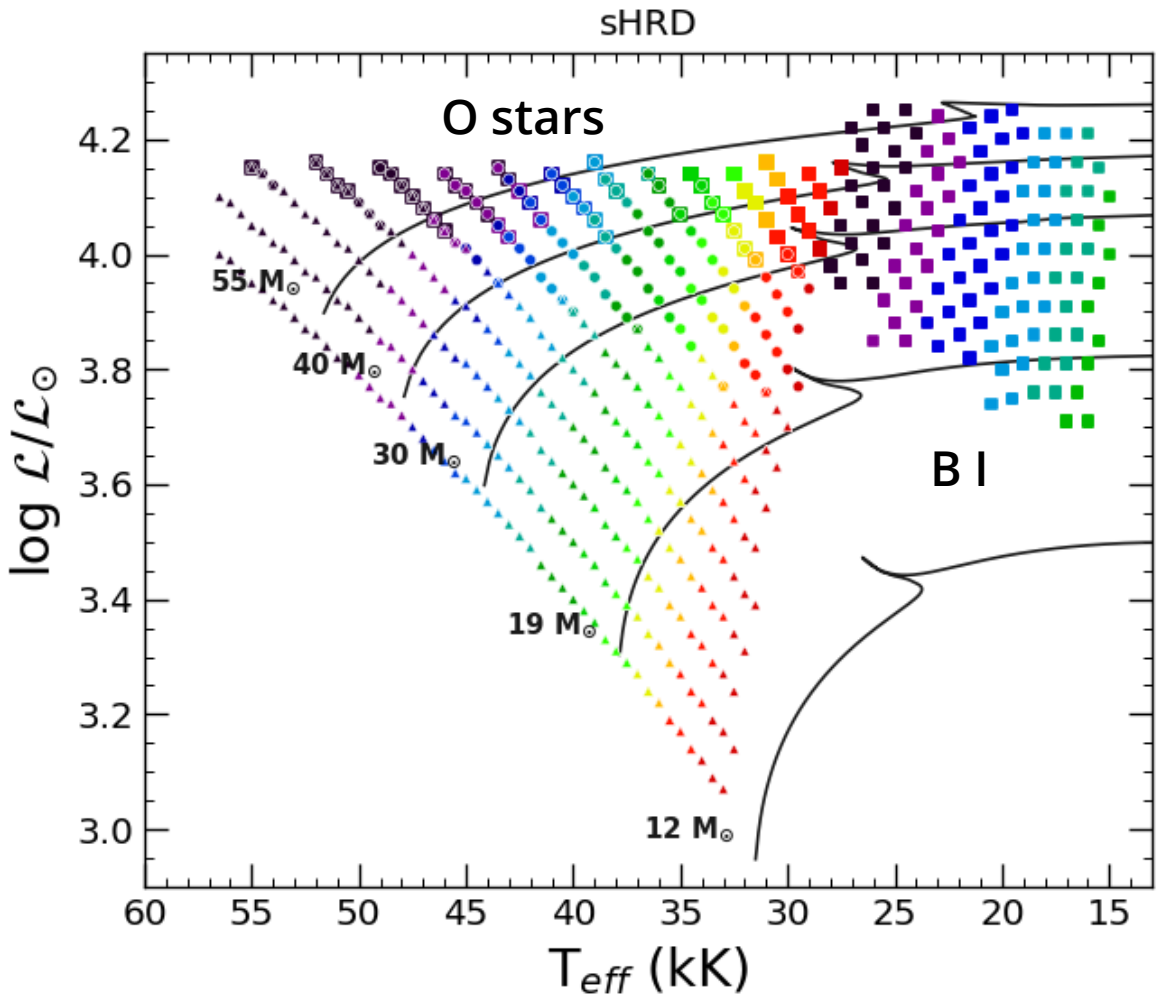


Lorenzo in prep. (2023a)

METAL-POOR CALIBRATION





Lorenzo in prep. (2023b)

METAL-POOR CALIBRATION

LORENZO IN PREP. (2023b) **vs.** **MARTINS ET AL. (2005)**

METAL-POOR CALIBRATION

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1/10 $Z_\odot$

$Z_\odot$

METAL-POOR CALIBRATION

LORENZO IN PREP. (2023b)	vs.	MARTINS ET AL. (2005)
1/10 $Z_\odot$		$Z_\odot$
O stars and early-B supergiants		O stars

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LORENZO IN PREP. (2023b)	vs.	MARTINS ET AL. (2005)
1/10 $Z_\odot$		$Z_\odot$
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Range of logg and $\dot{M}$ for (SpT, LC)		Unique logg and $\dot{M}$ for (SpT, LC)

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1/10 $Z_\odot$

O stars and early-B supergiants

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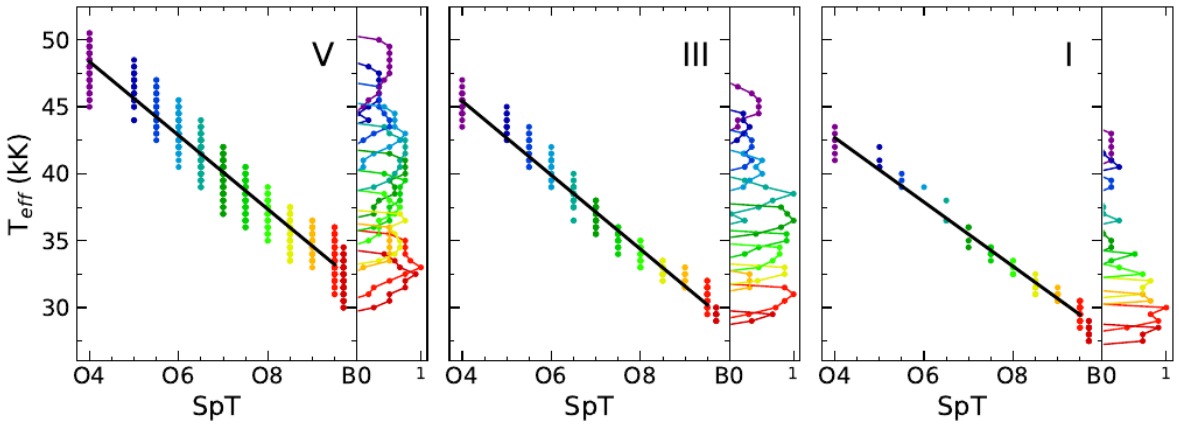

$Z_\odot$

O stars

Unique logg and $\dot{M}$ for (SpT, LC)

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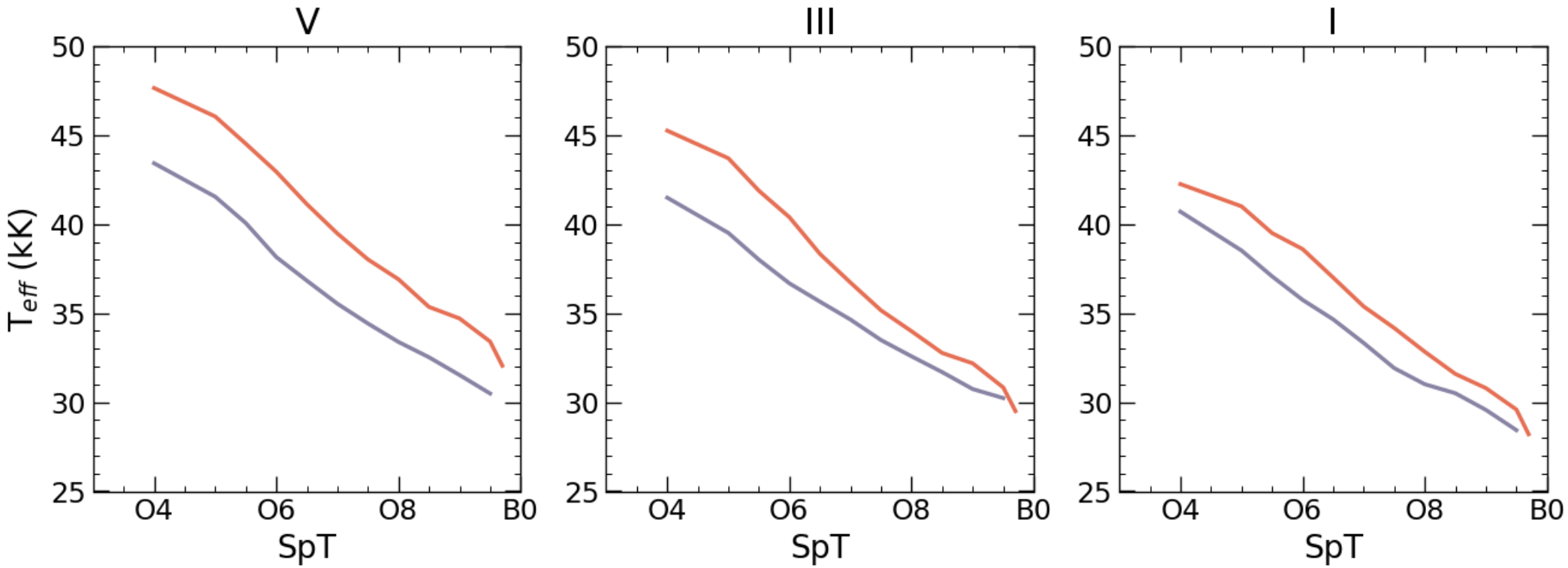

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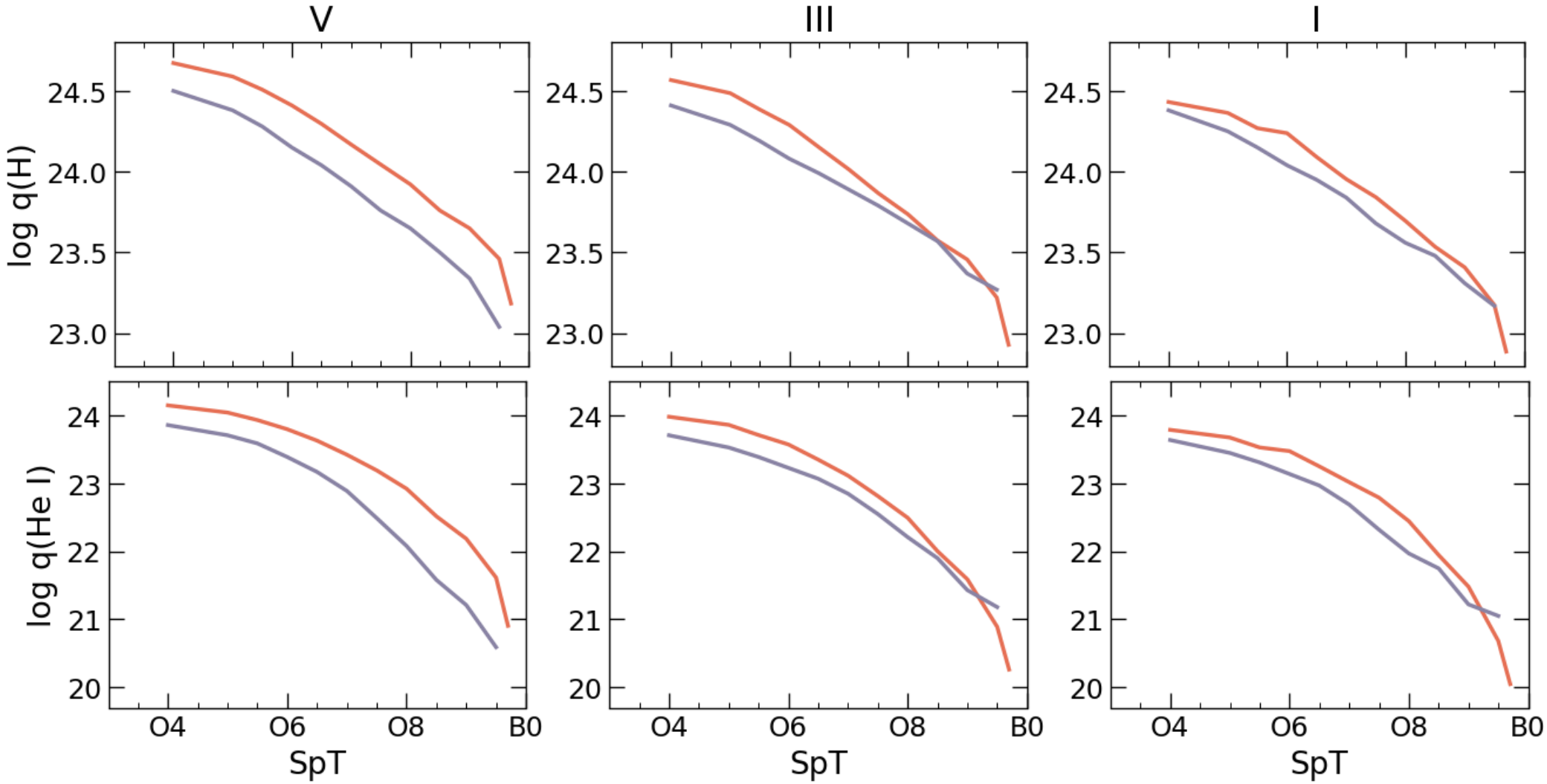

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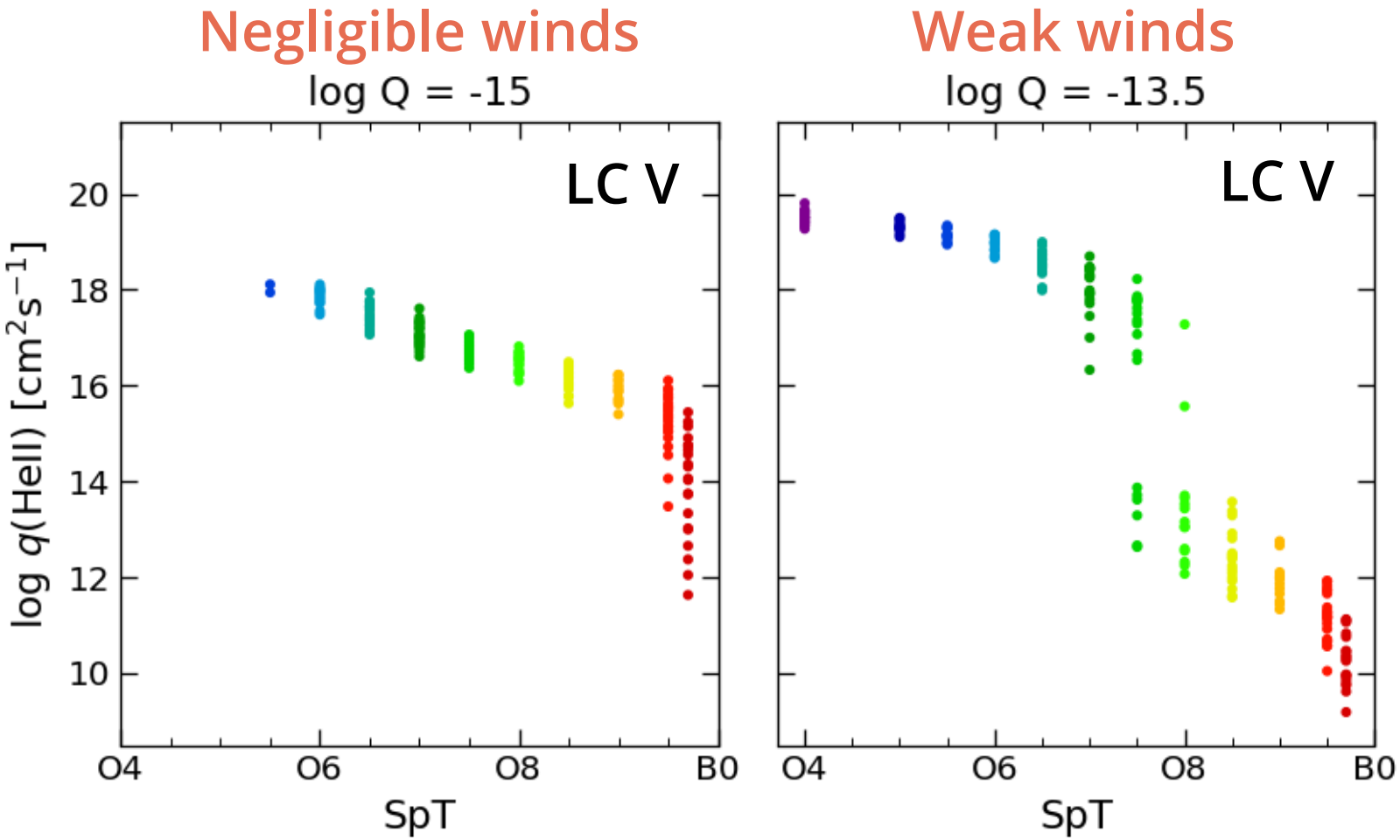

Lorenzo in prep. (2023b)

(see also Martins & Palacios, 2021)

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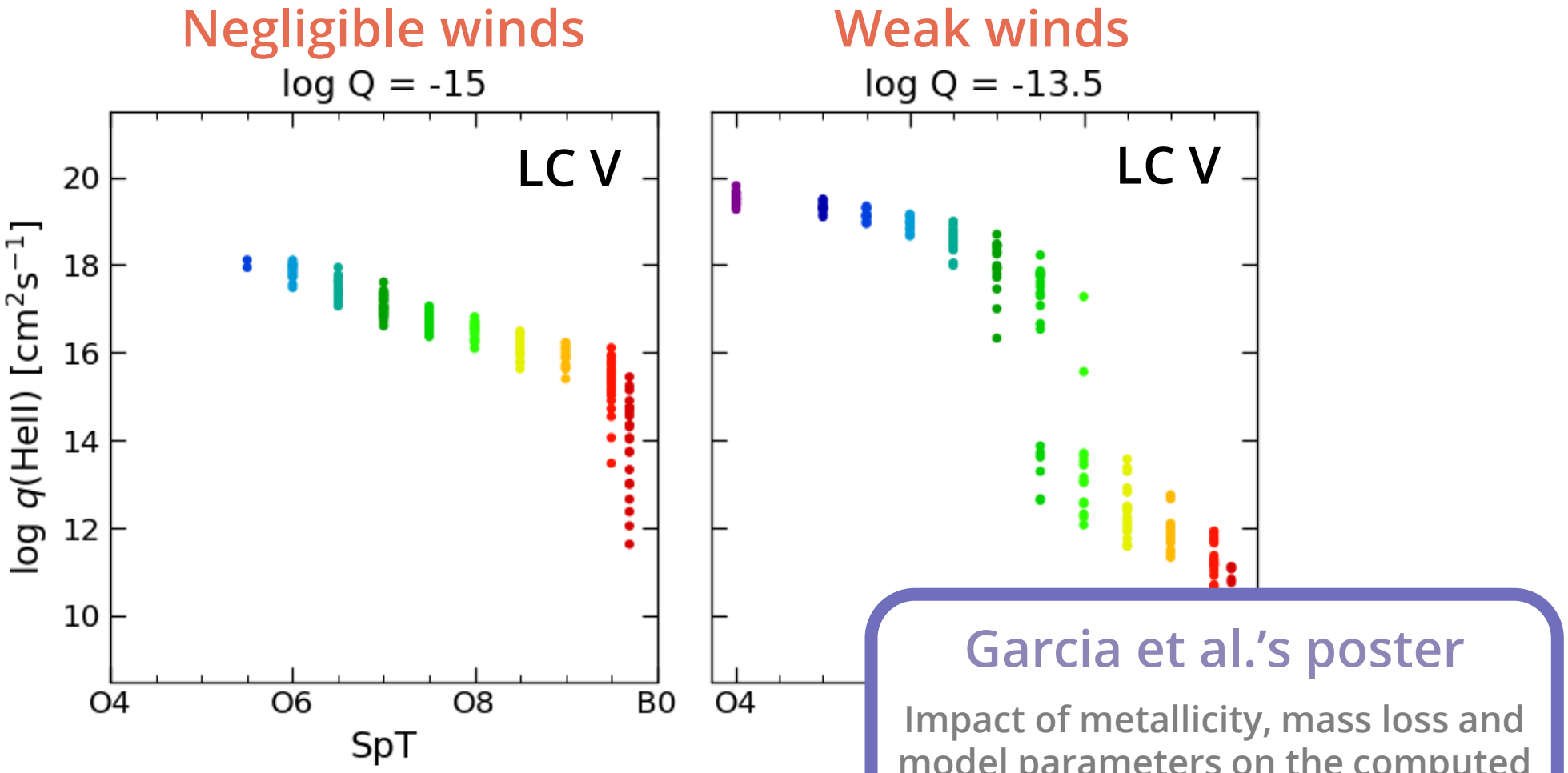

Lorenzo in prep. (2023b)

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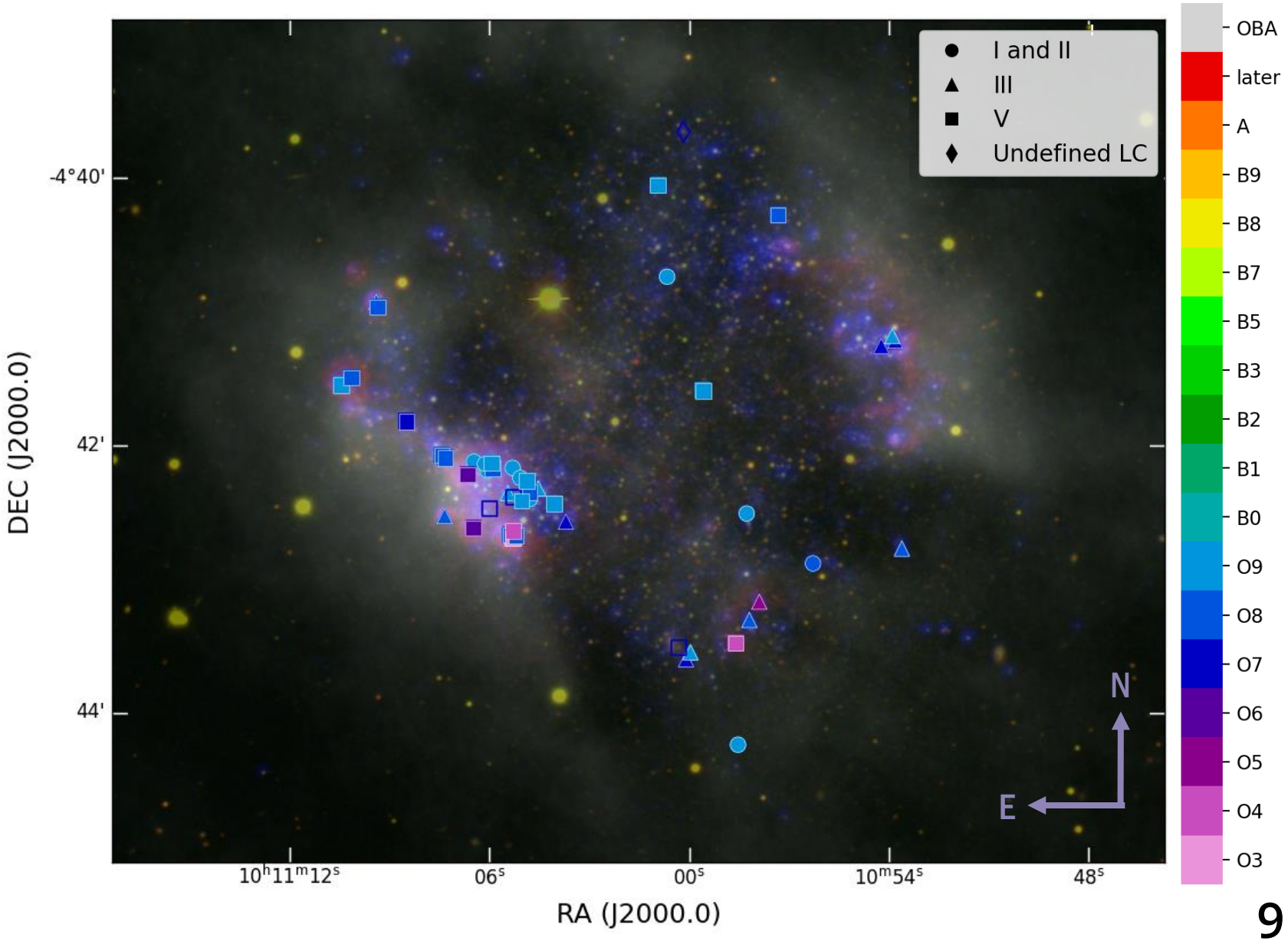
Garcia et al.'s poster

Impact of metallicity, mass loss and model parameters on the computed ionizing photons from massive stars

THE IONIZING PHOTON BUDGET OF SEXTANS A



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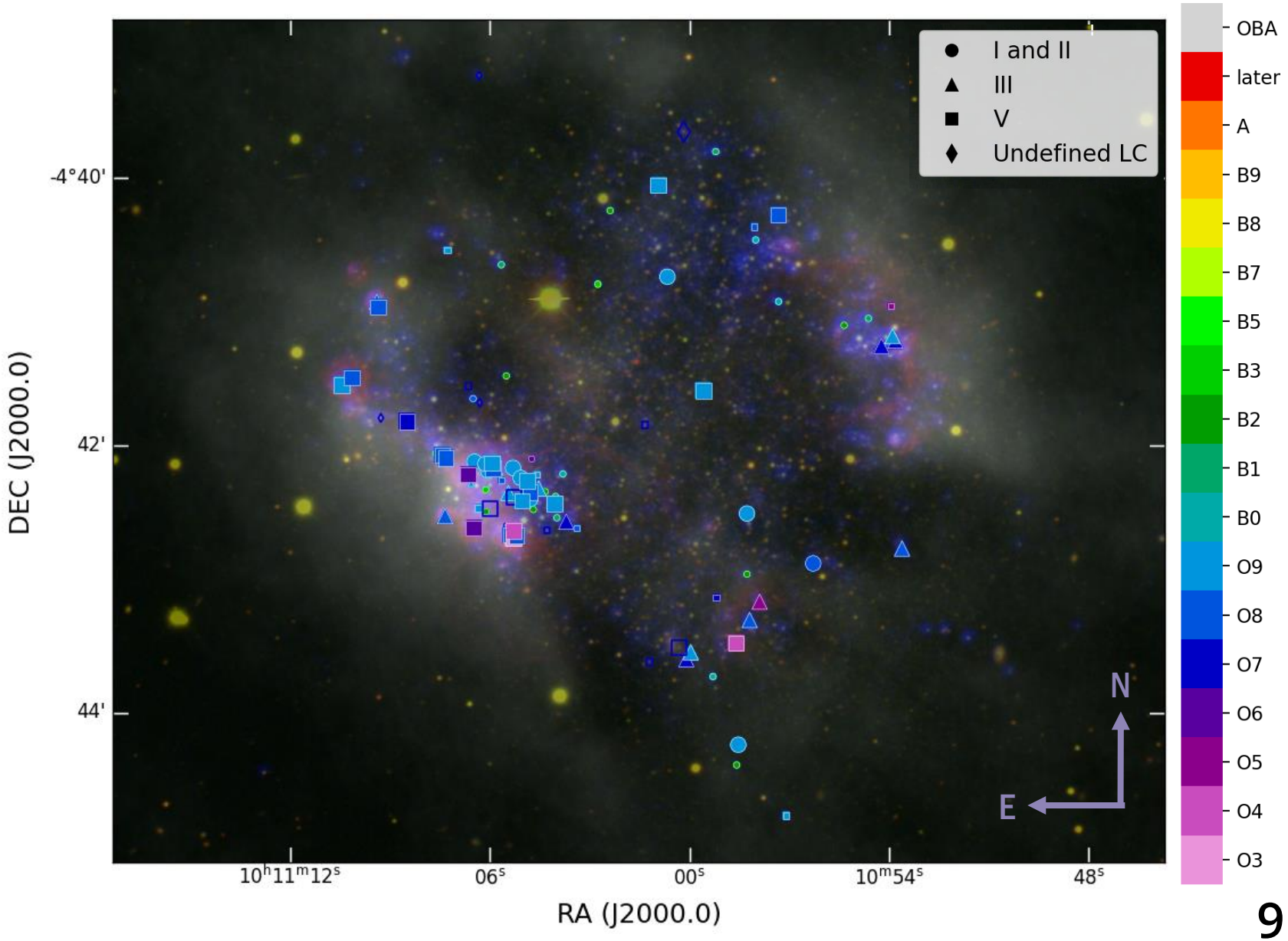
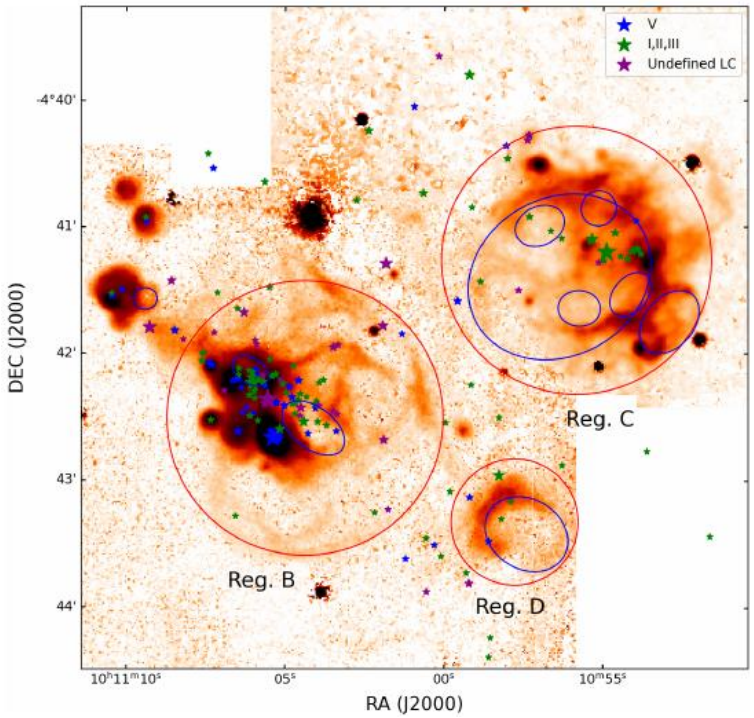
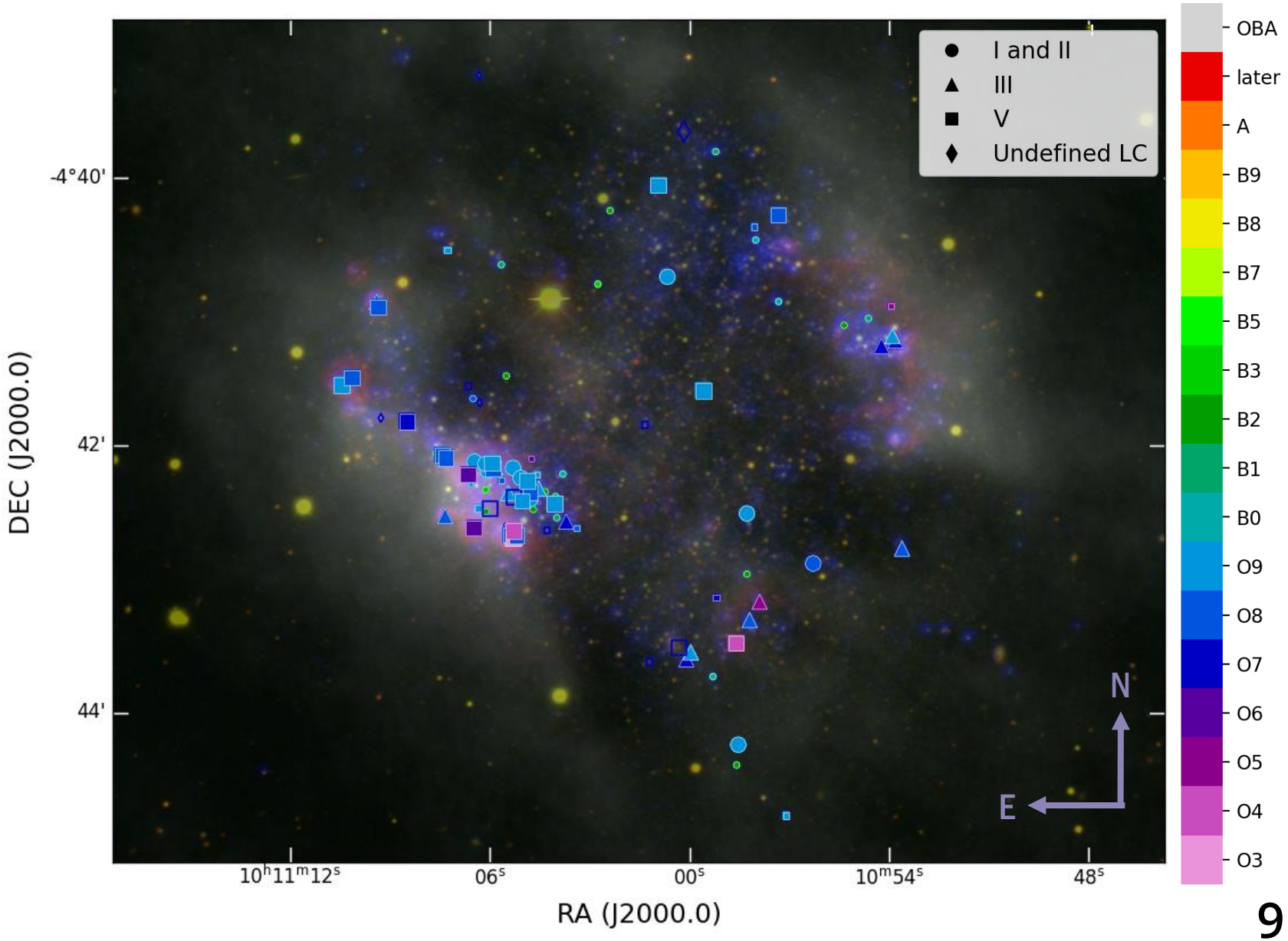


THE IONIZING PHOTON BUDGET OF SEXTANS A

Hα image



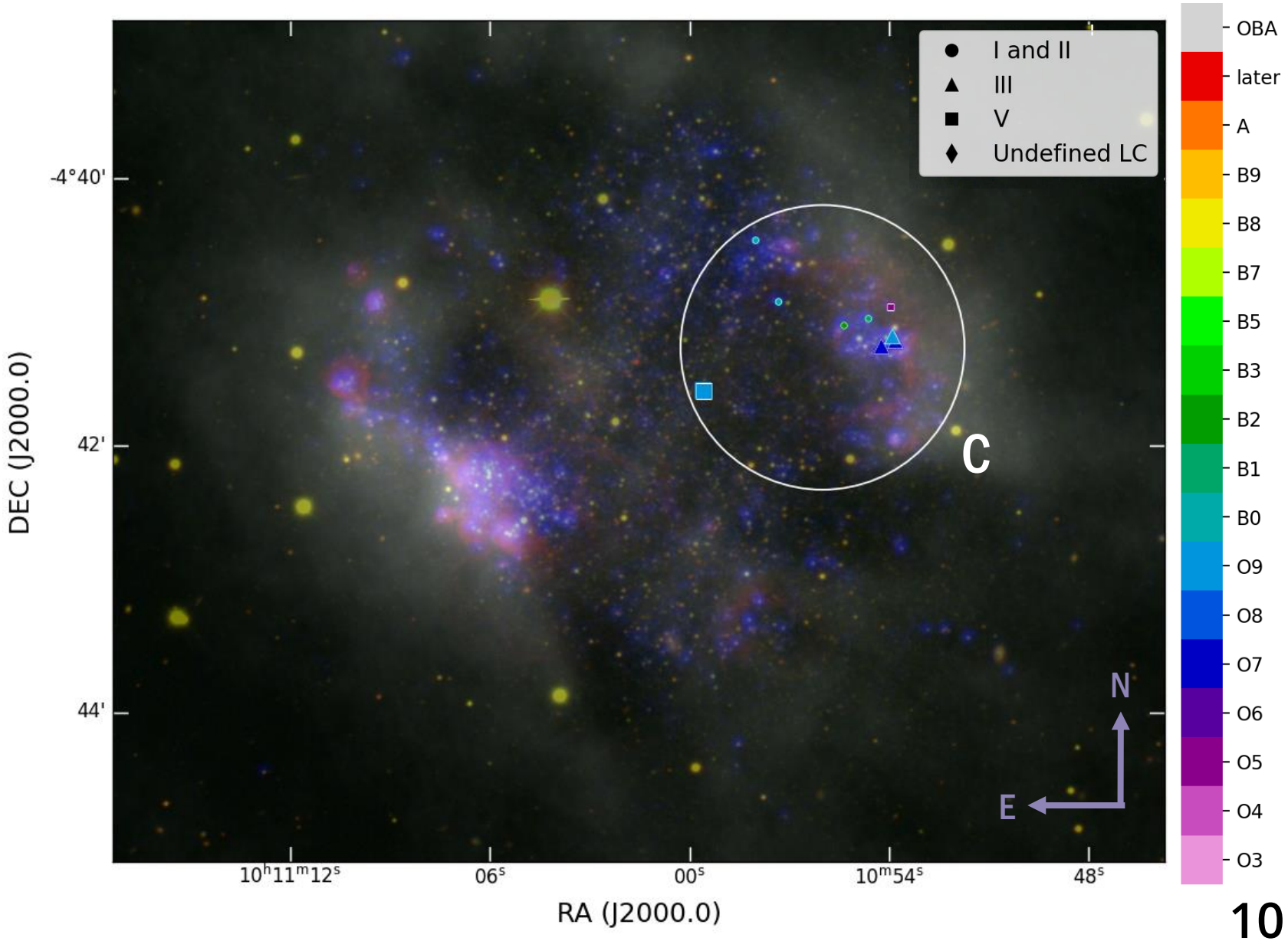
Gerasimov et al. (2022)



THE IONIZING PHOTON BUDGET OF SEXTANS A

$Q(H)_{H\alpha} = 7.57\ 10^{49}\ cm^{-2}\ s^{-1}$

$Q(H)_{stars} = 4.87\ 10^{49}\ cm^{-2}\ s^{-1}$



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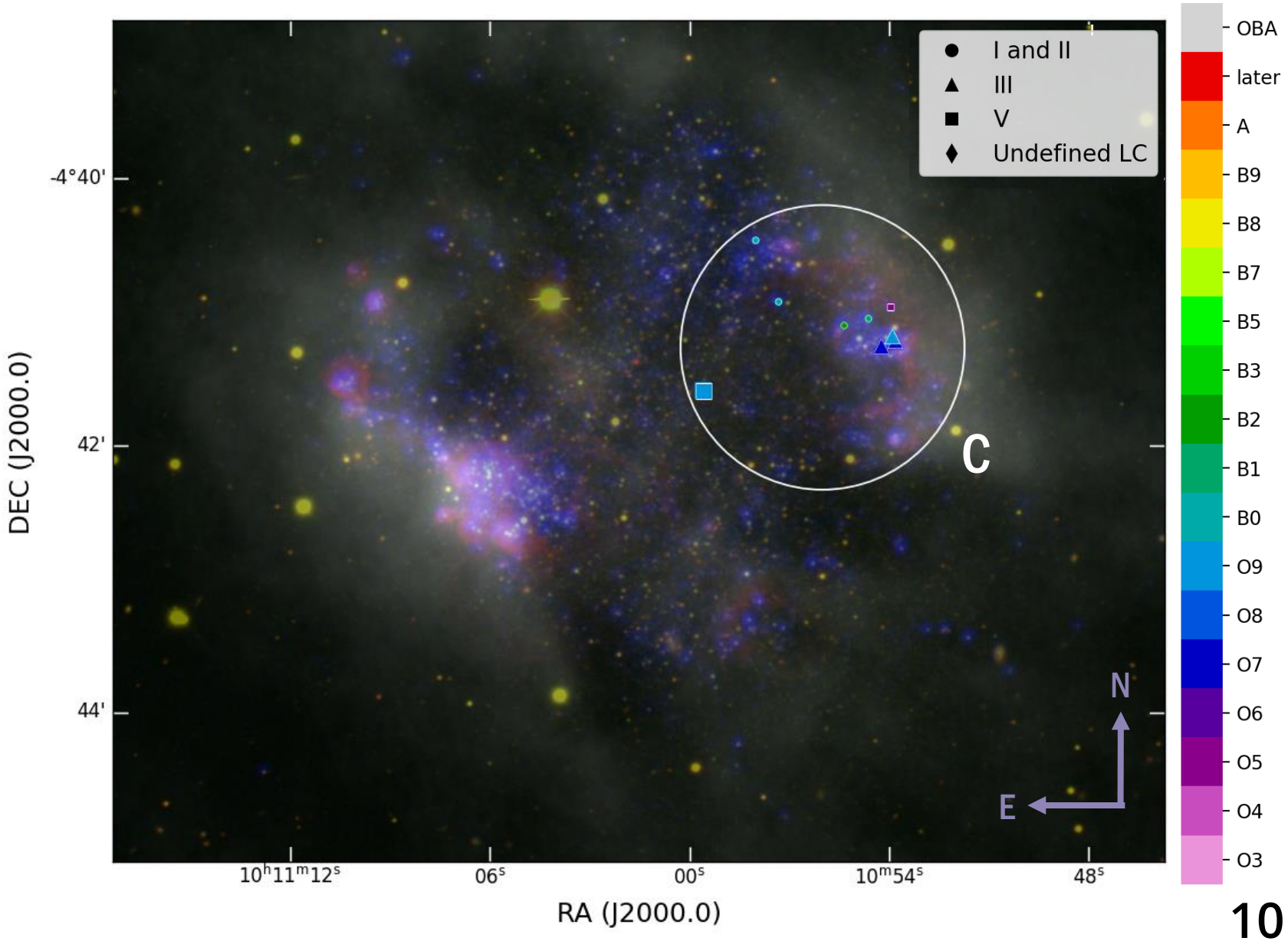
$$Q(H)_{H\alpha} > Q(H)_{stars}$$



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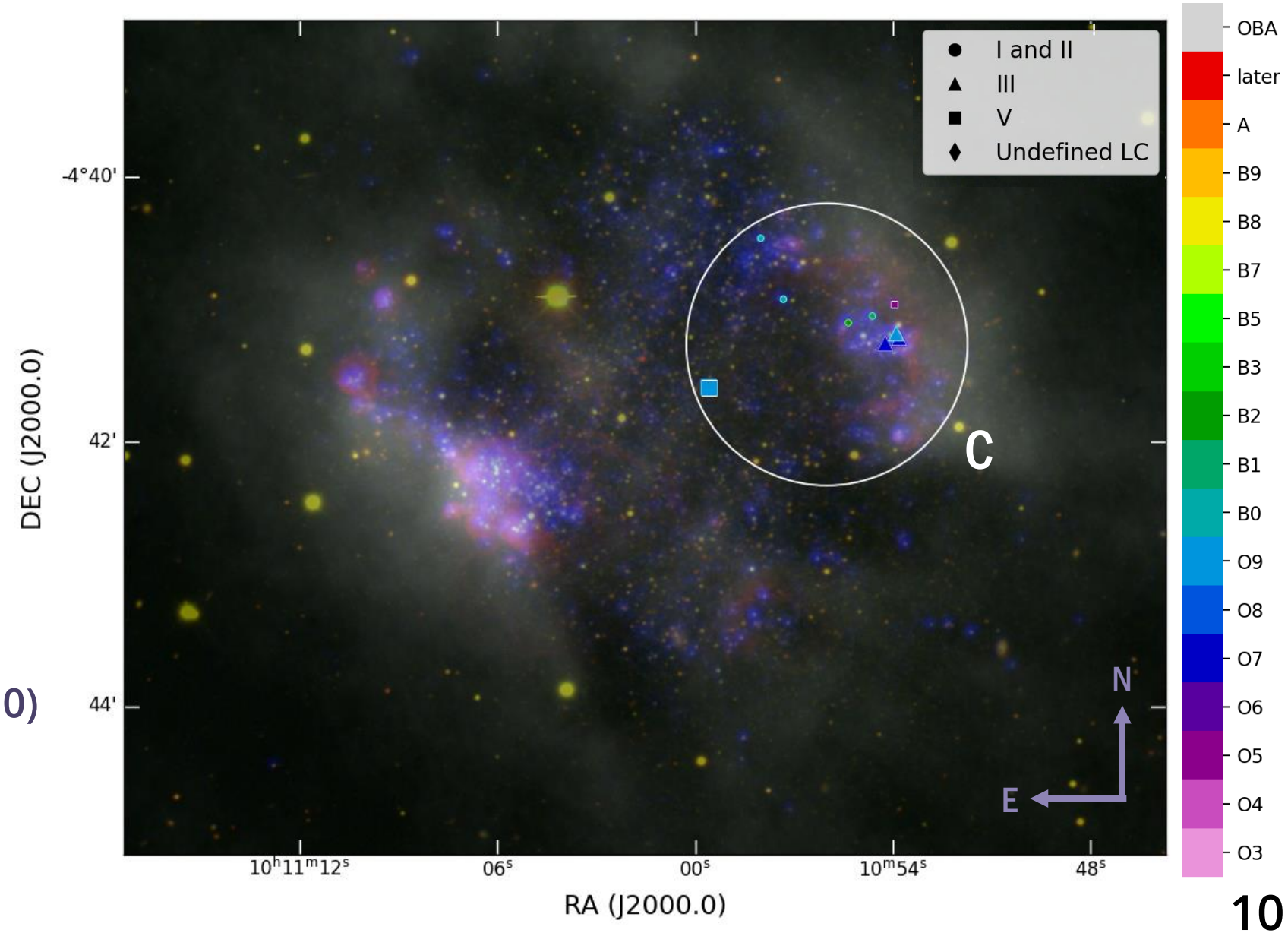
$Q(H)_{H\alpha} > Q(H)_{stars}$

Missing ~ 6 O7 Vs

(assuming $f_{esc} = 0$)

0.1 Z : $\log Q(H)_{O7\,V} = 48.71$

1 Z : $\log Q(H)_{O7\,V} = 48.63$



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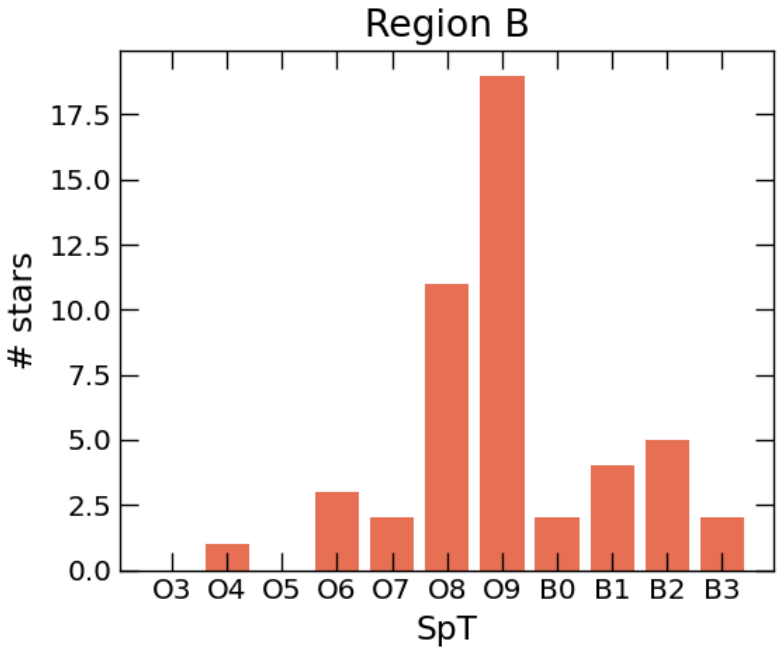

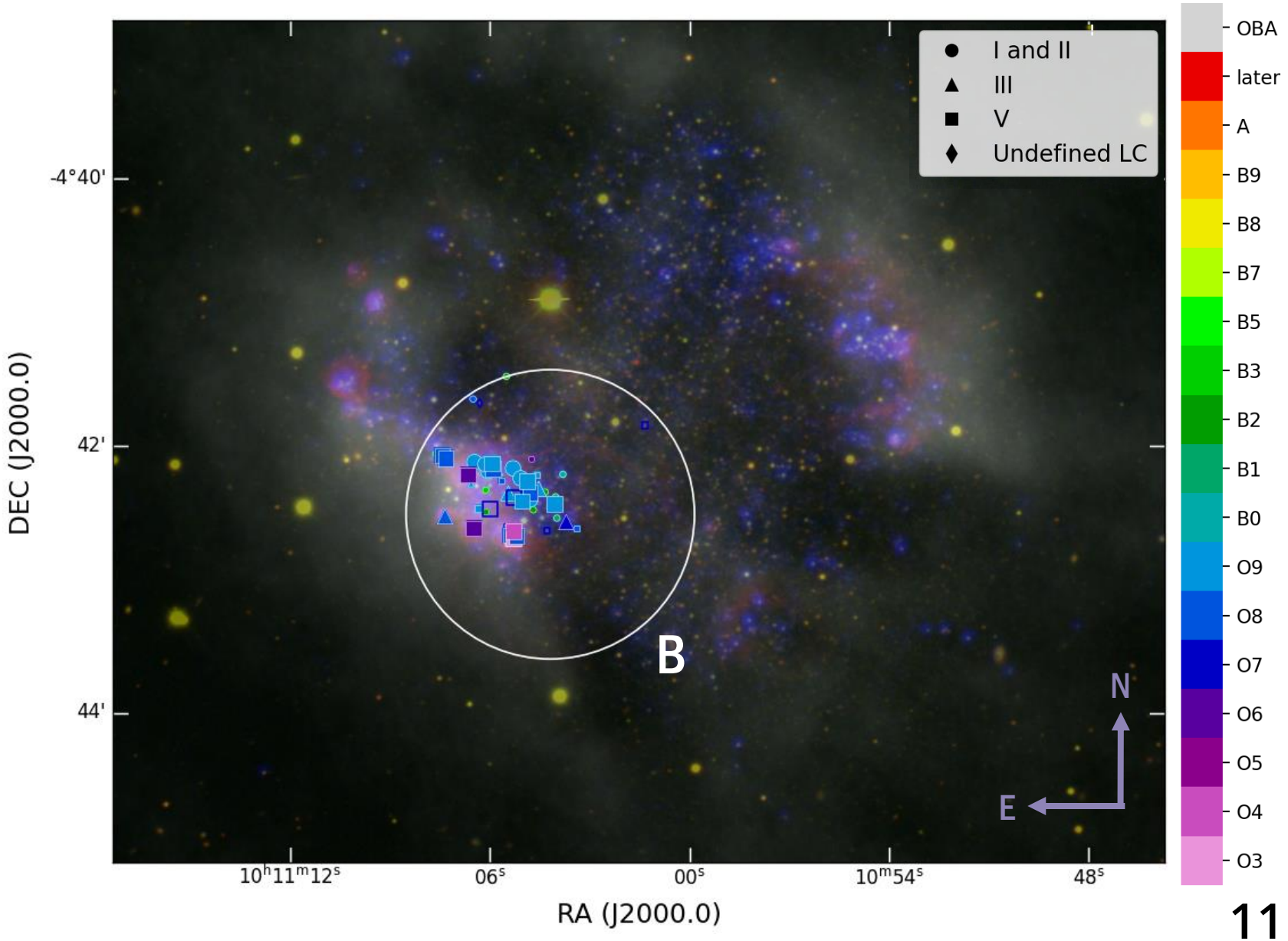

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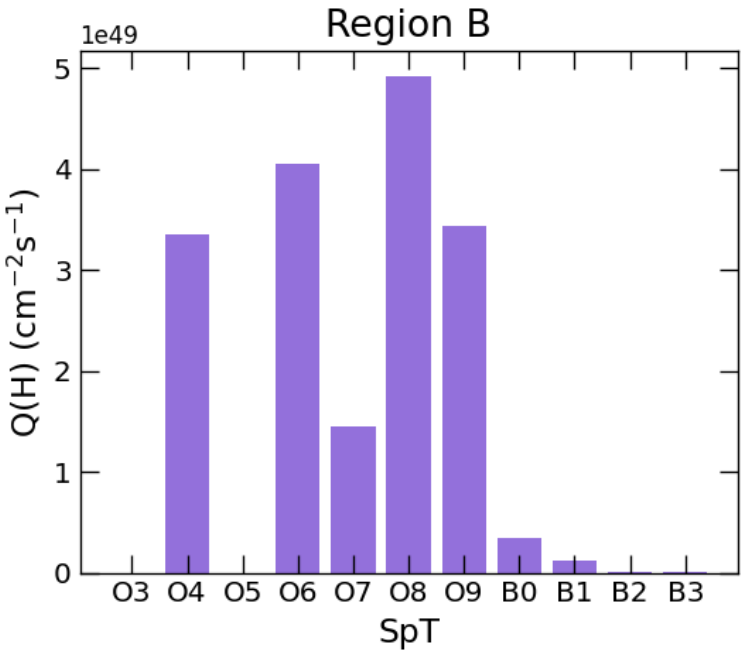

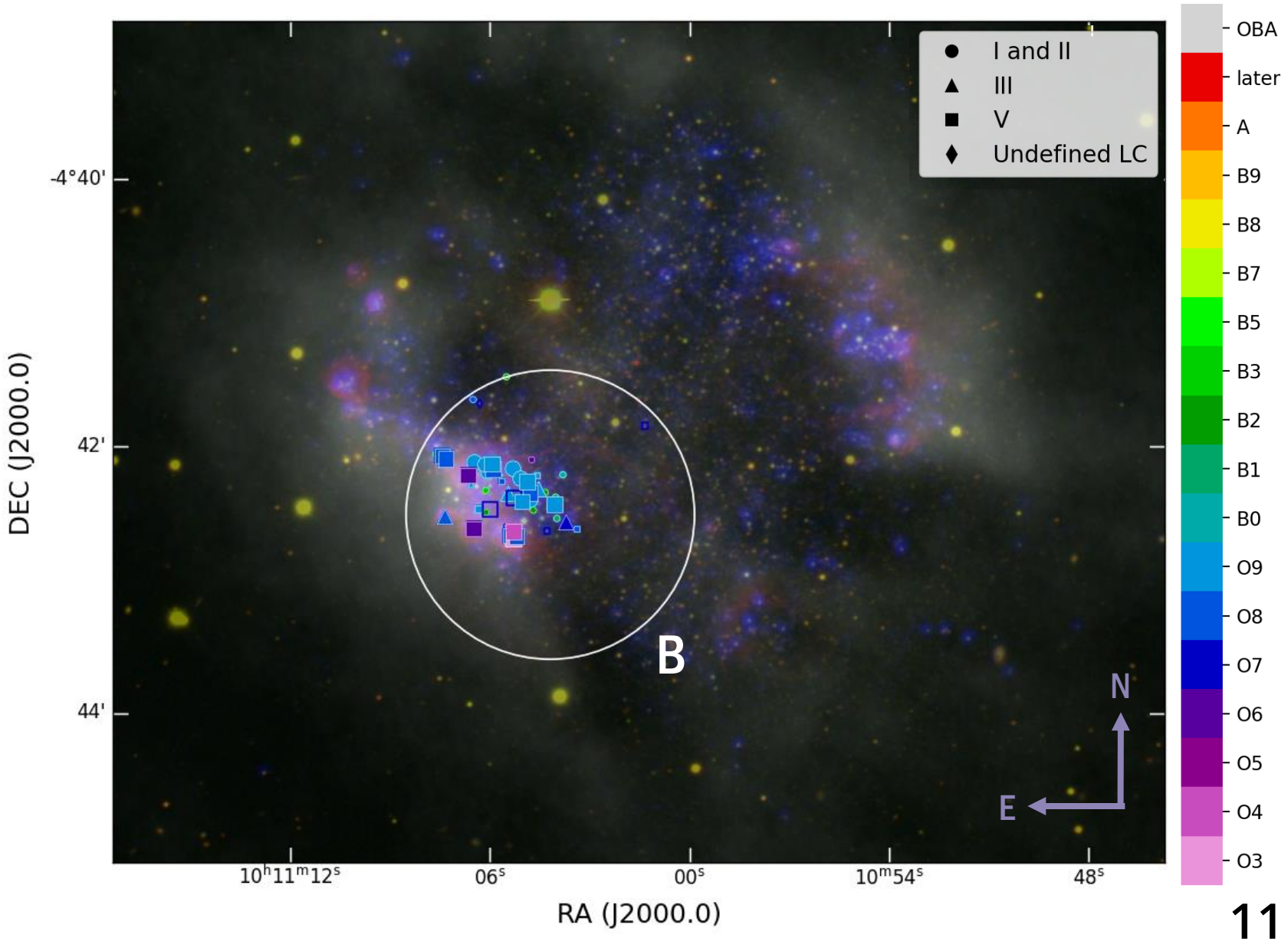

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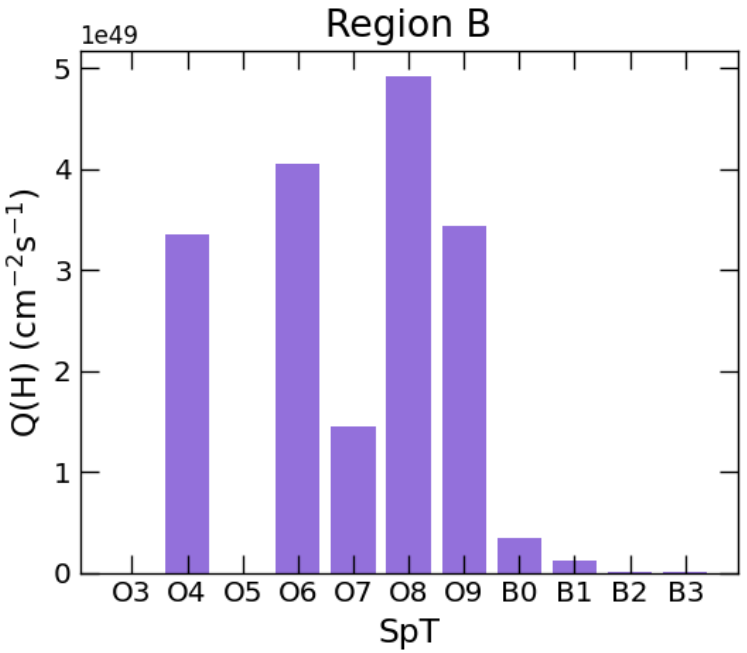
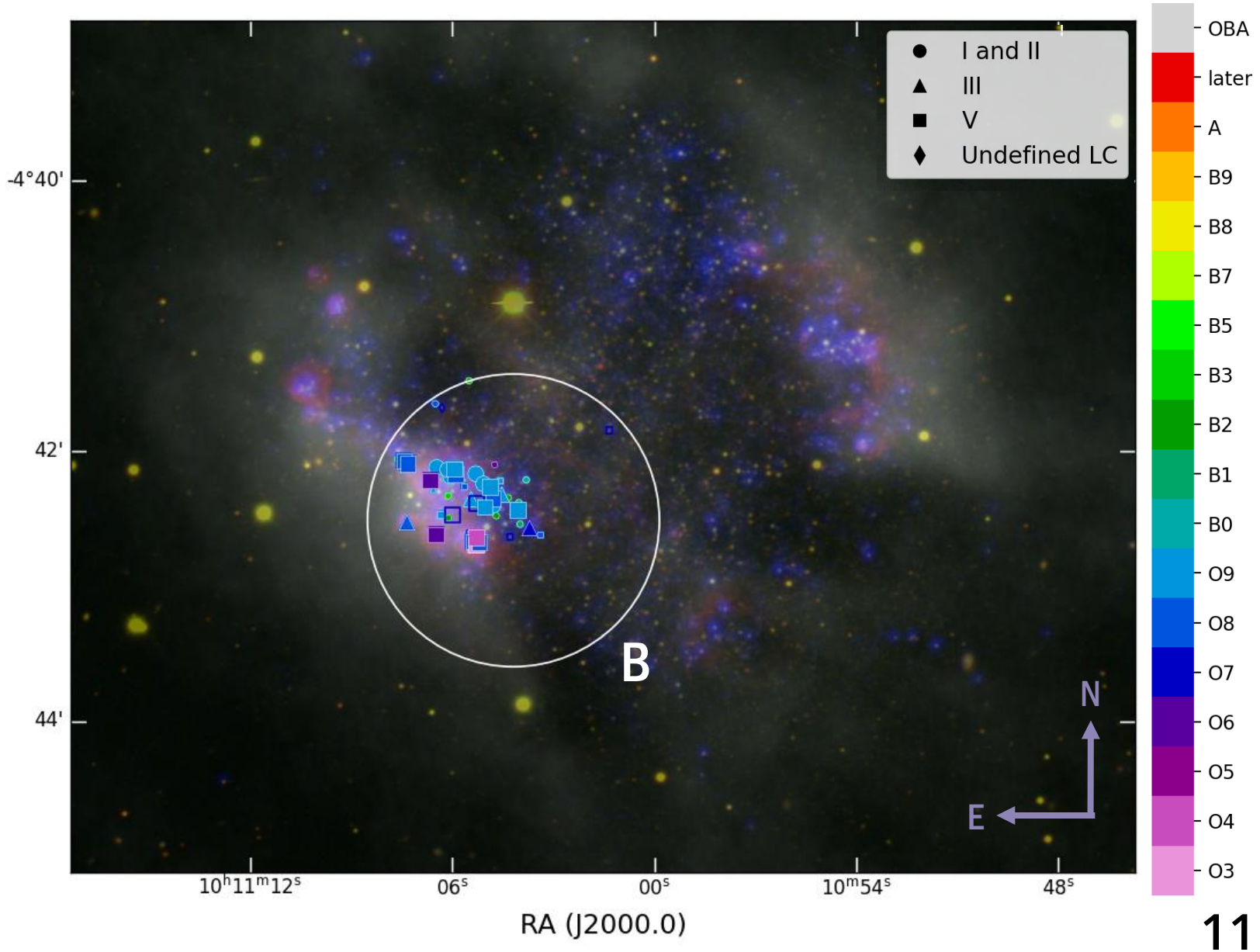


$Q(H)_{H\alpha} = 1.08\ 10^{50} cm^{-2} s^{-1}$

$Q(H)_{stars} = 1.77\ 10^{50} cm^{-2} s^{-1}$



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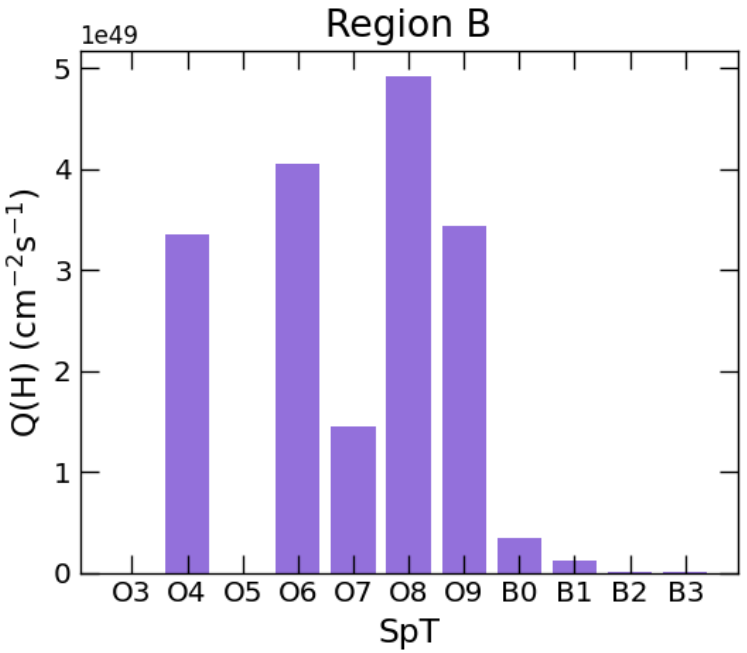
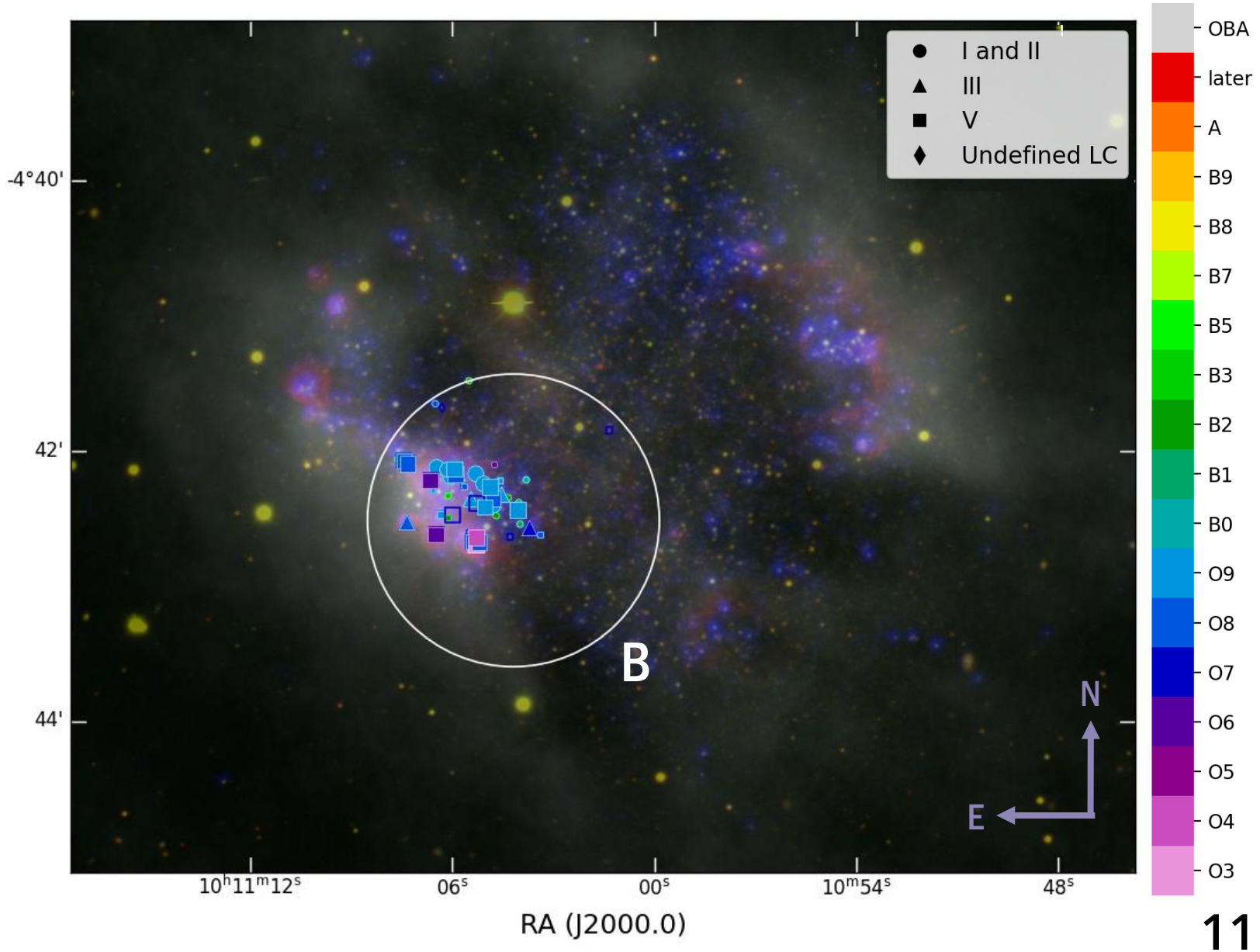


$Q(H)_{H\alpha} = 1.08\ 10^{50} cm^{-2} s^{-1}$

$Q(H)_{stars} = 1.77\ 10^{50} cm^{-2} s^{-1}$

$f_{esc} \geq 0.4$



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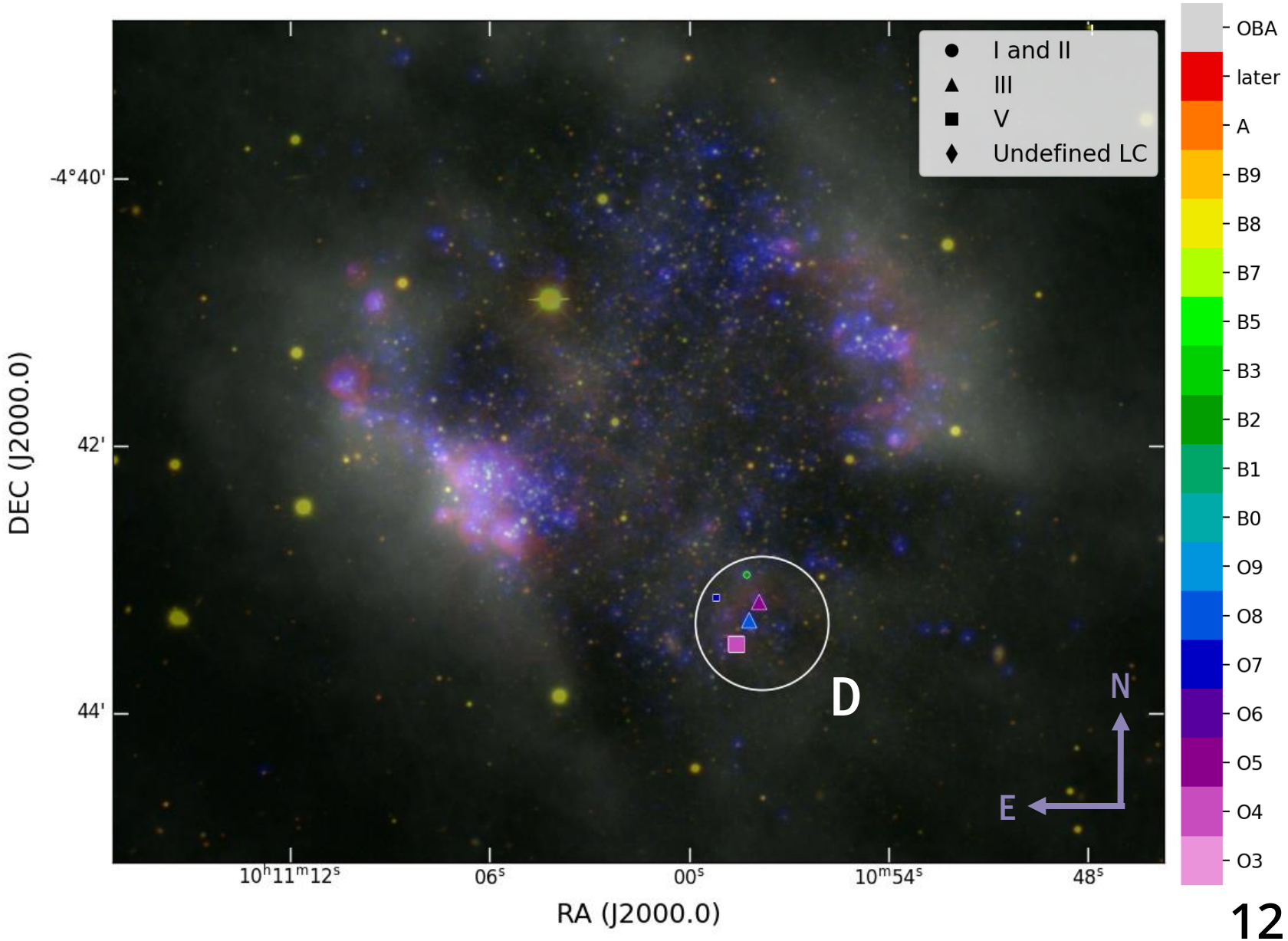
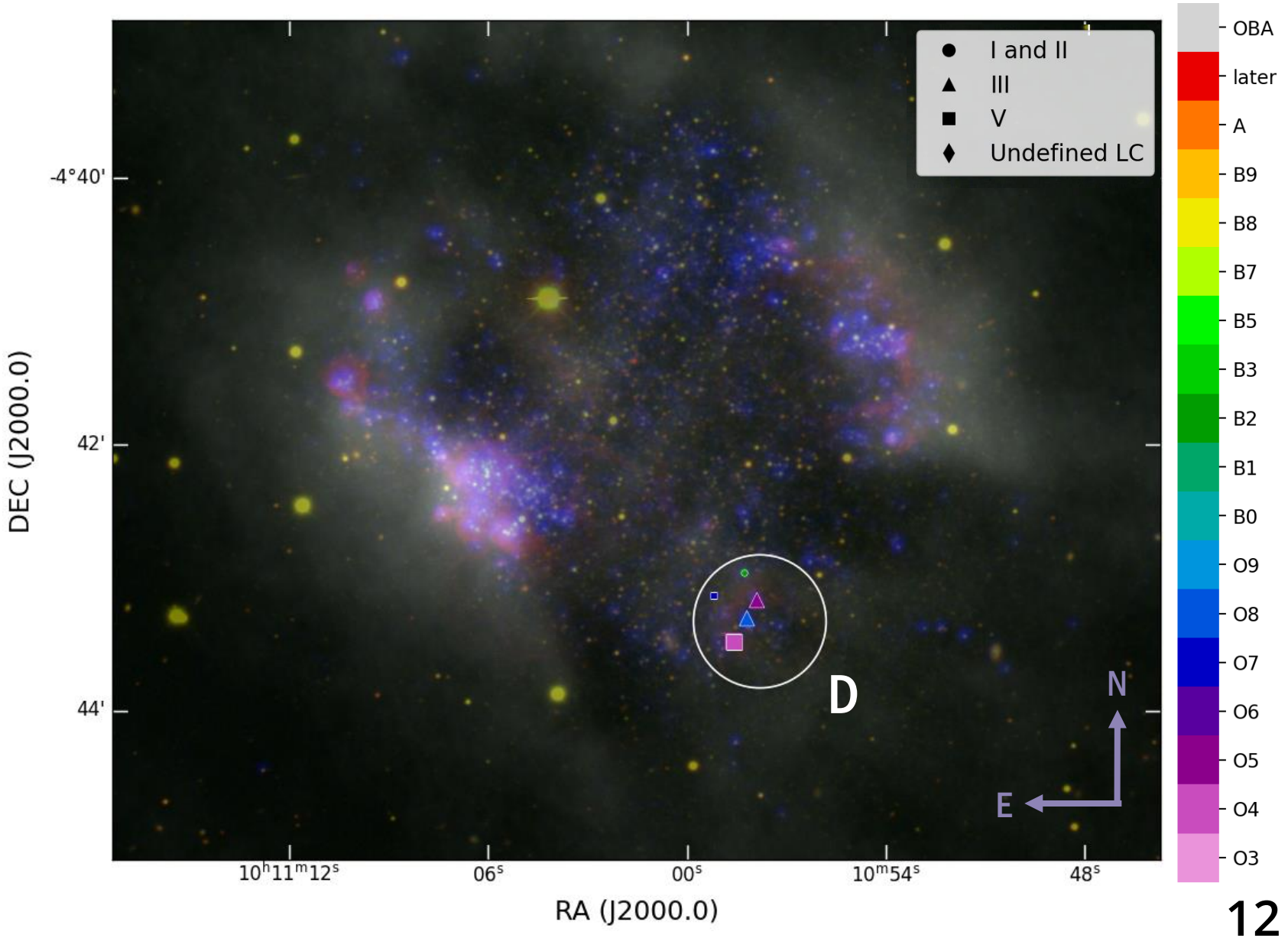


THE IONIZING PHOTON BUDGET OF SEXTANS A

$$Q(H)_{H\alpha} = 1.18\ 10^{49} cm^{-2} s^{-1}$$

$$Q(H)_{stars} = 5.90\ 10^{49} cm^{-2} s^{-1}$$



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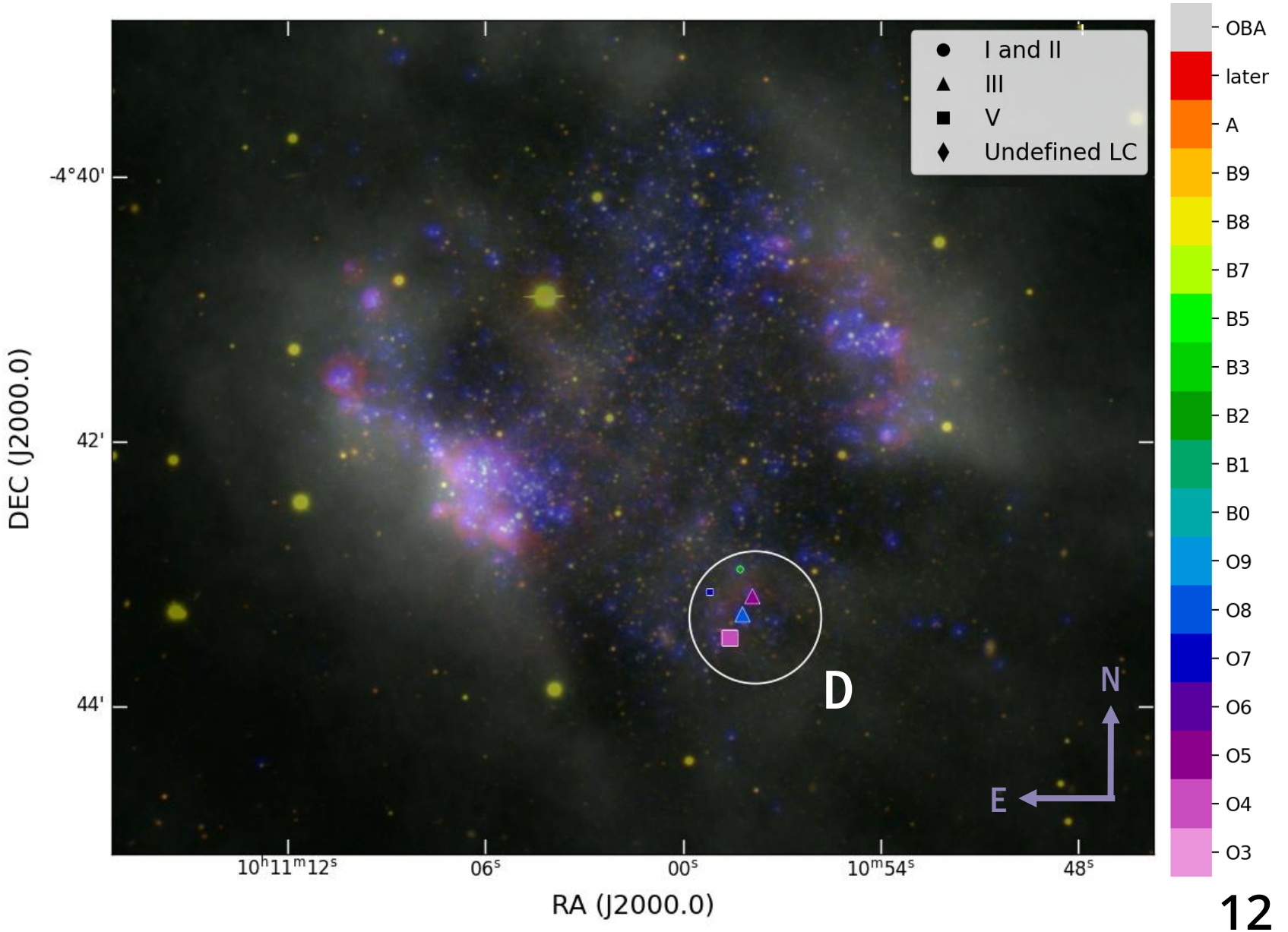
$Q(H)_{stars} = 5.90\ 10^{49} cm^{-2} s^{-1}$

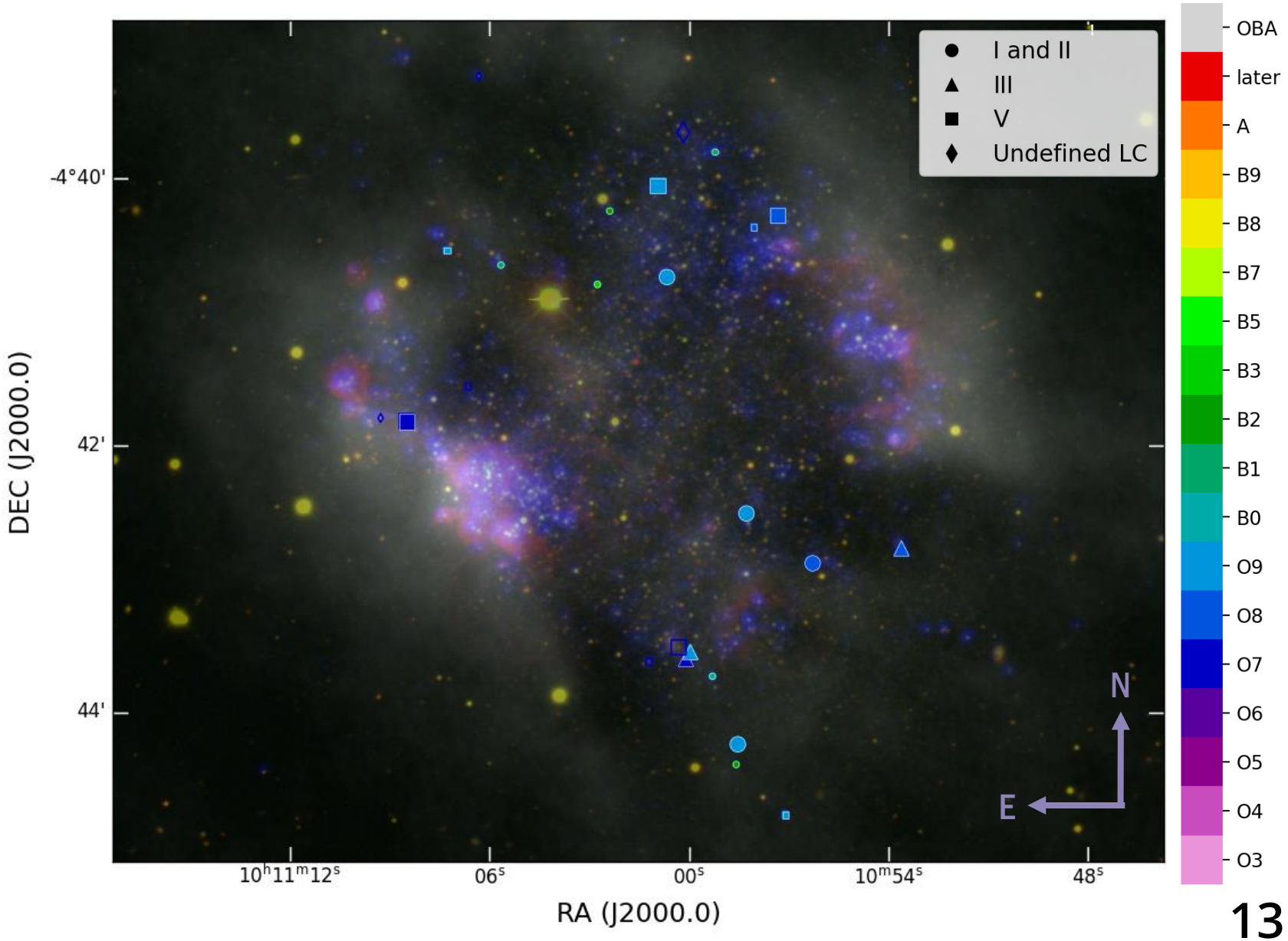
$f_{esc} \geq 0.8$



THE IONIZING PHOTON BUDGET OF SEXTANS A

$$Q(H)_{H\alpha} \sim 0$$

$$Q(H)_{stars} = 5.36\ 10^{49} cm^{-2} s^{-1}$$

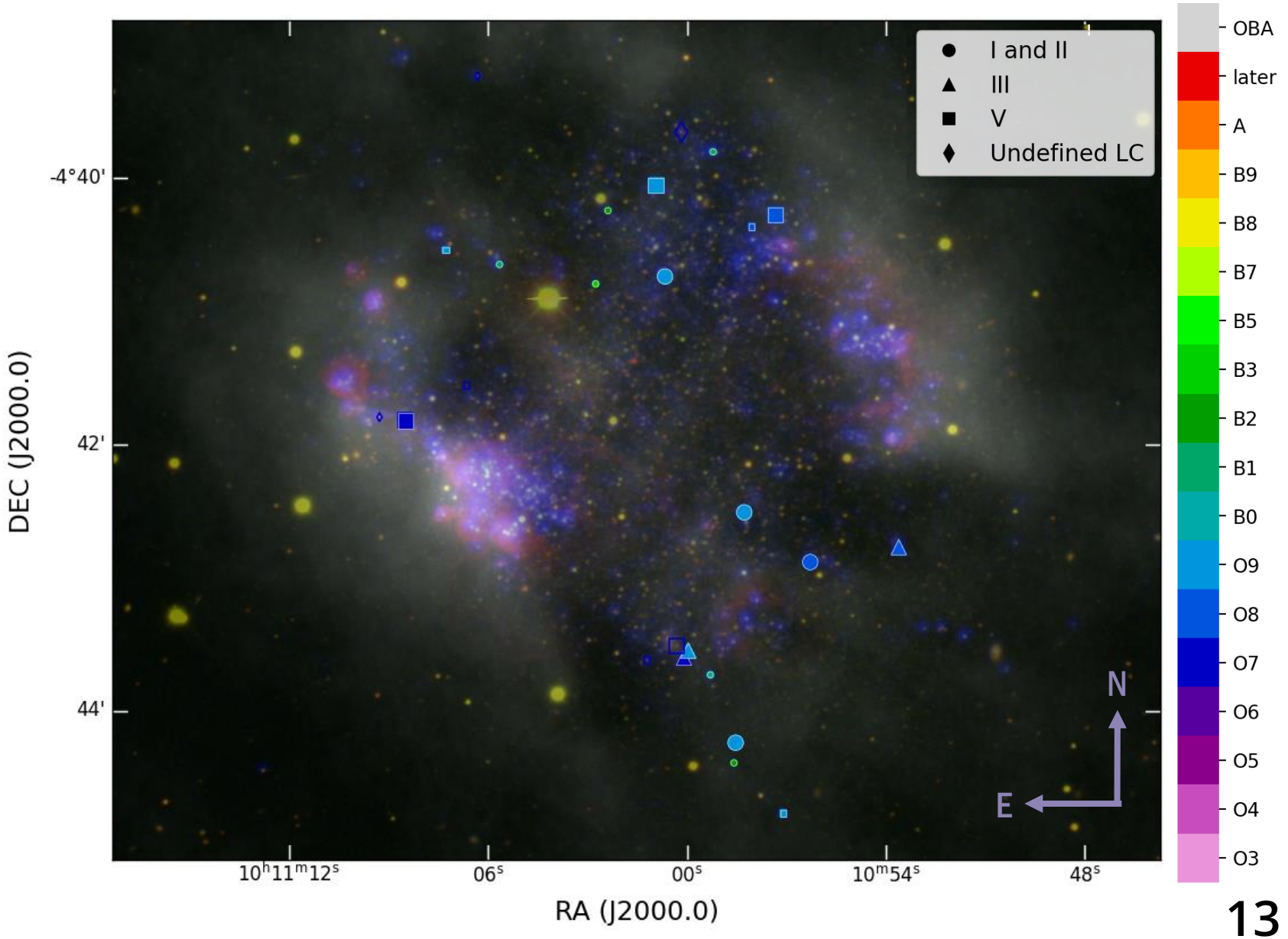


THE IONIZING PHOTON BUDGET OF SEXTANS A

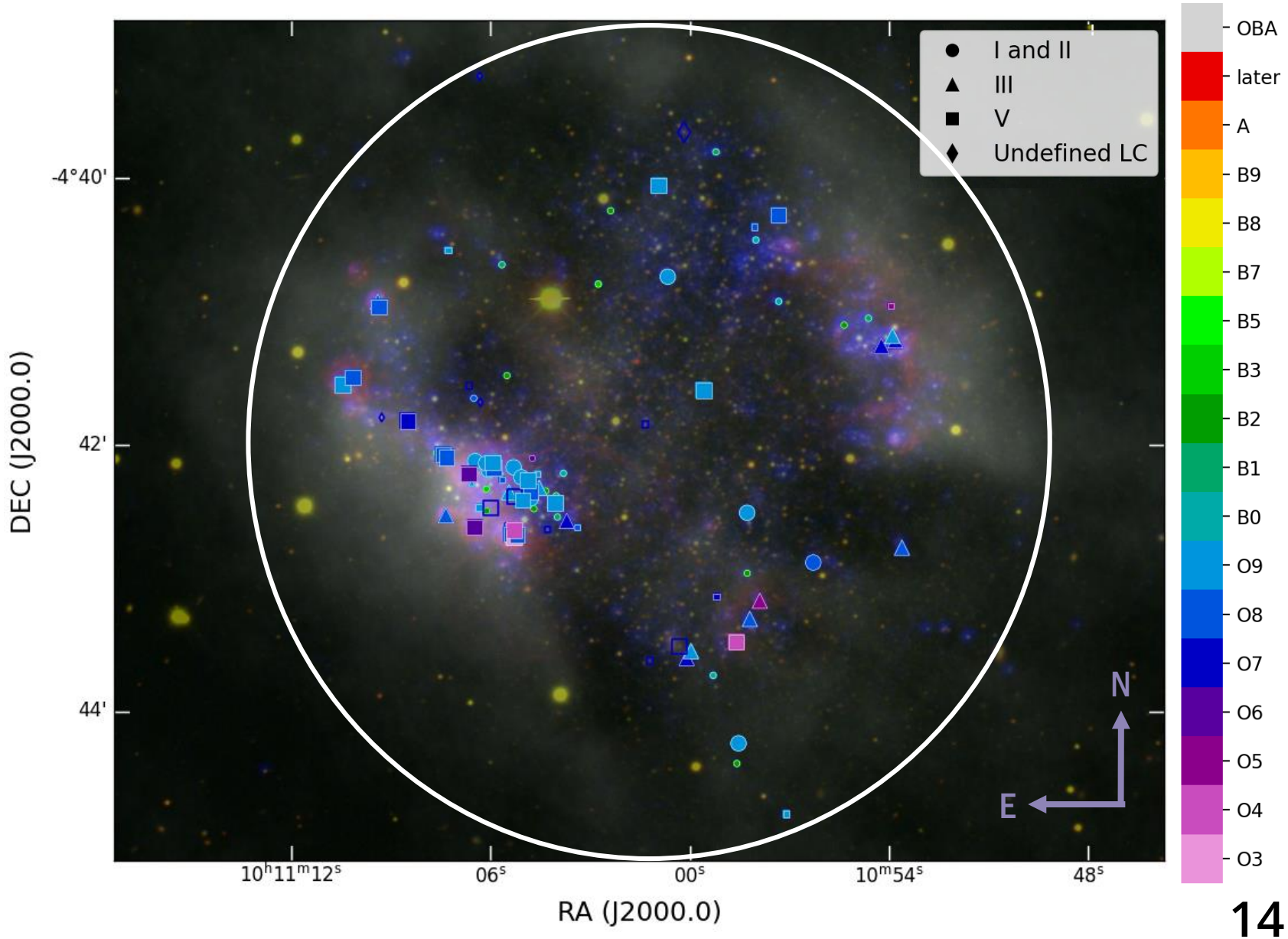
$$Q(H)_{H\alpha} \sim 0$$

$$Q(H)_{stars} = 5.36\ 10^{49} cm^{-2} s^{-1}$$

$$f_{esc} \sim 1$$

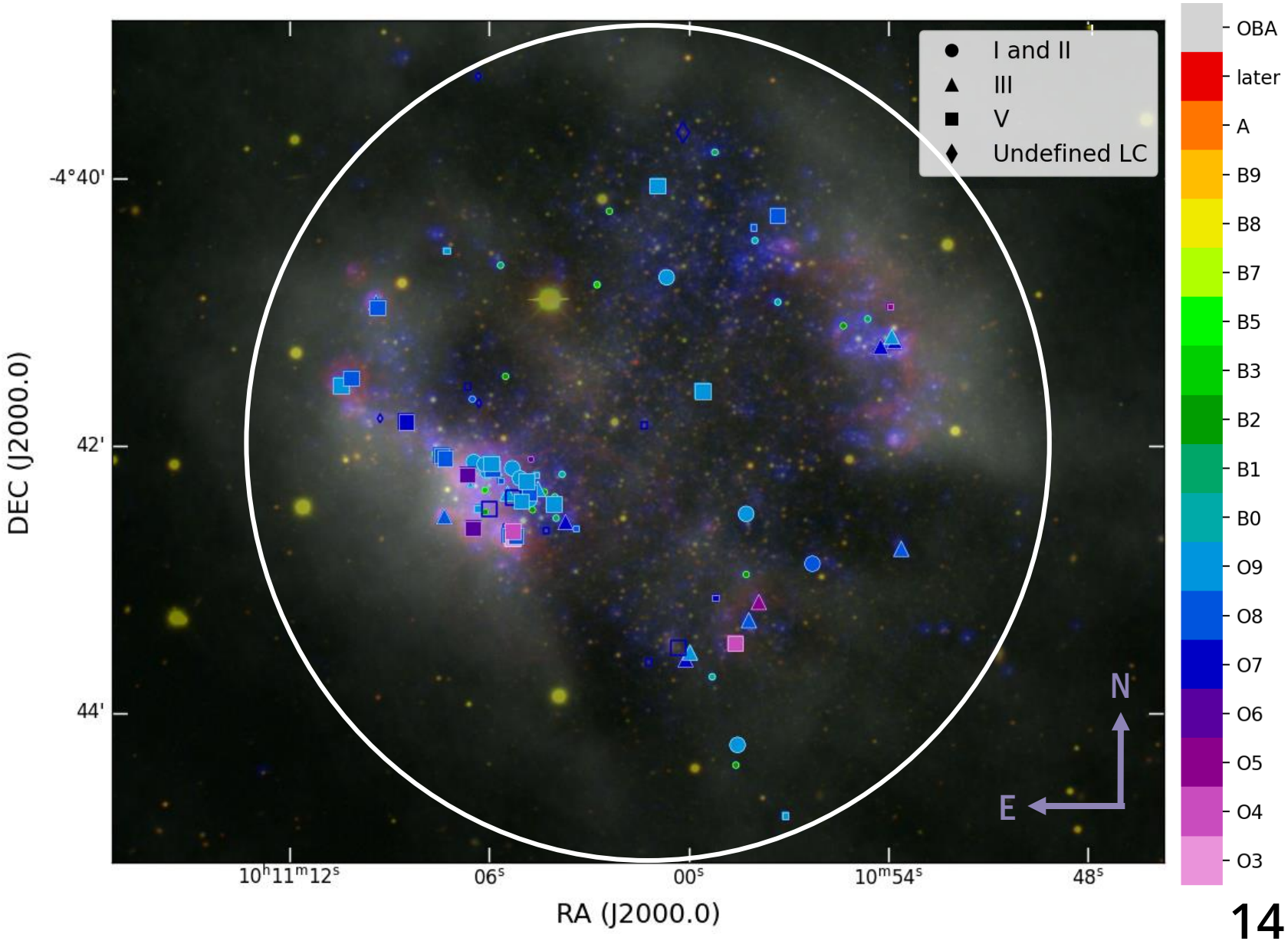


THE IONIZING PHOTON BUDGET OF SEXTANS A



THE IONIZING PHOTON BUDGET OF SEXTANS A

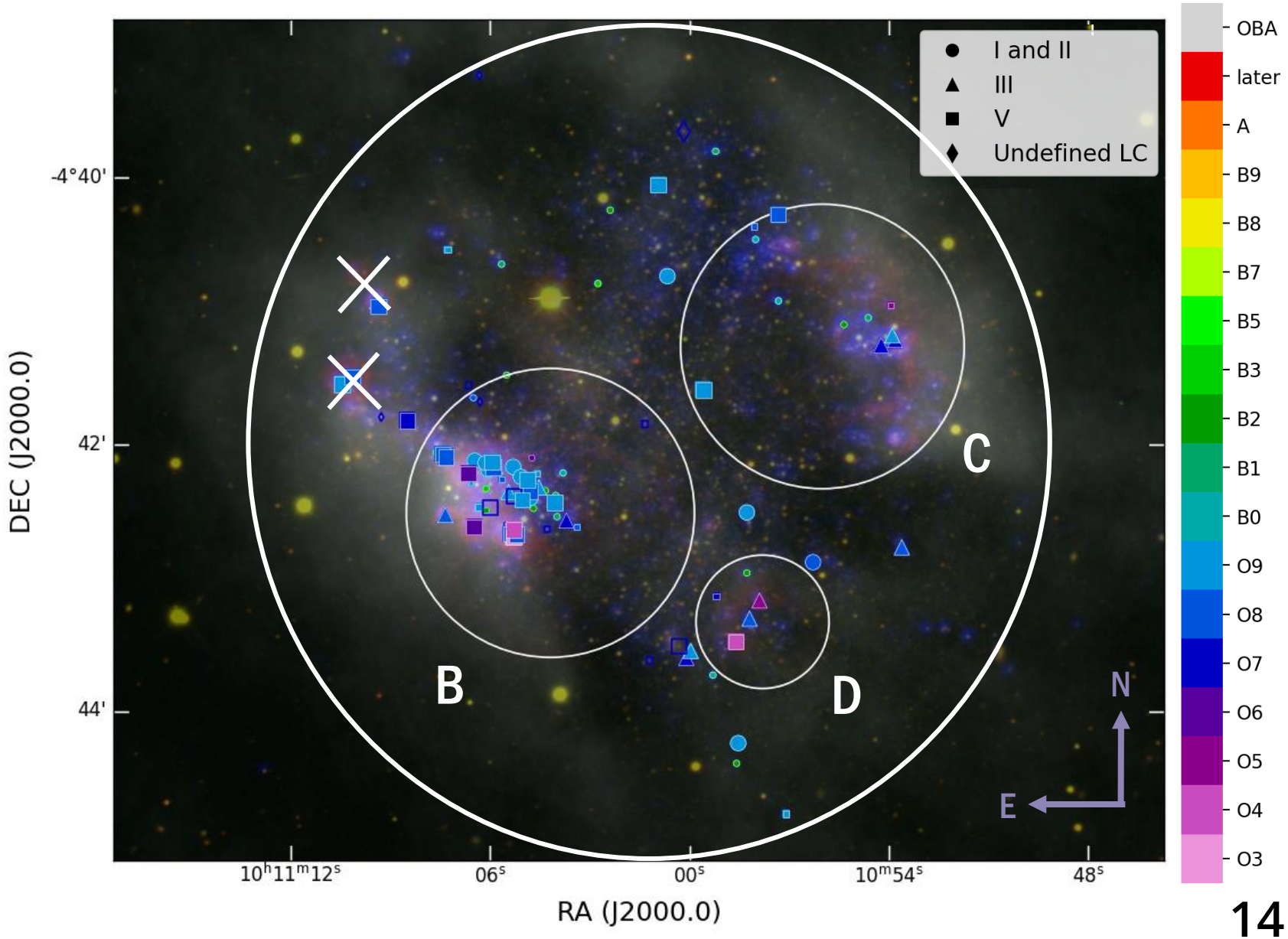
$Q(H)_{H\alpha} = 1.95\ 10^{50} cm^{-2} s^{-1}$



THE IONIZING PHOTON BUDGET OF SEXTANS A

B + C + D

$Q(H)_{H\alpha} = 1.95\ 10^{50} cm^{-2} s^{-1}$

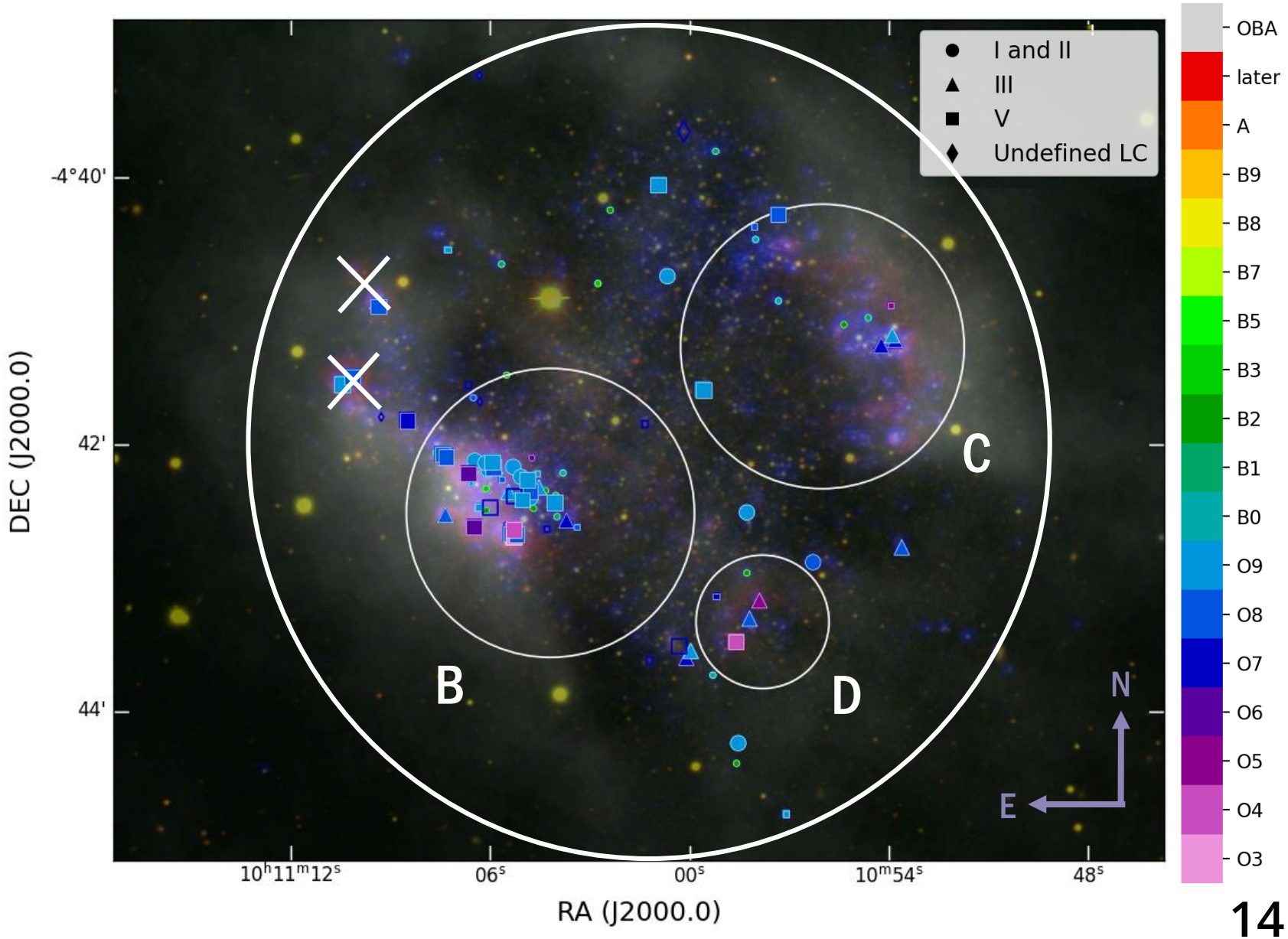


THE IONIZING PHOTON BUDGET OF SEXTANS A

B + C + D

$Q(H)_{H\alpha} = 1.95\ 10^{50} cm^{-2} s^{-1}$

$Q(H)_{stars} = 3.38\ 10^{50} cm^{-2} s^{-1}$



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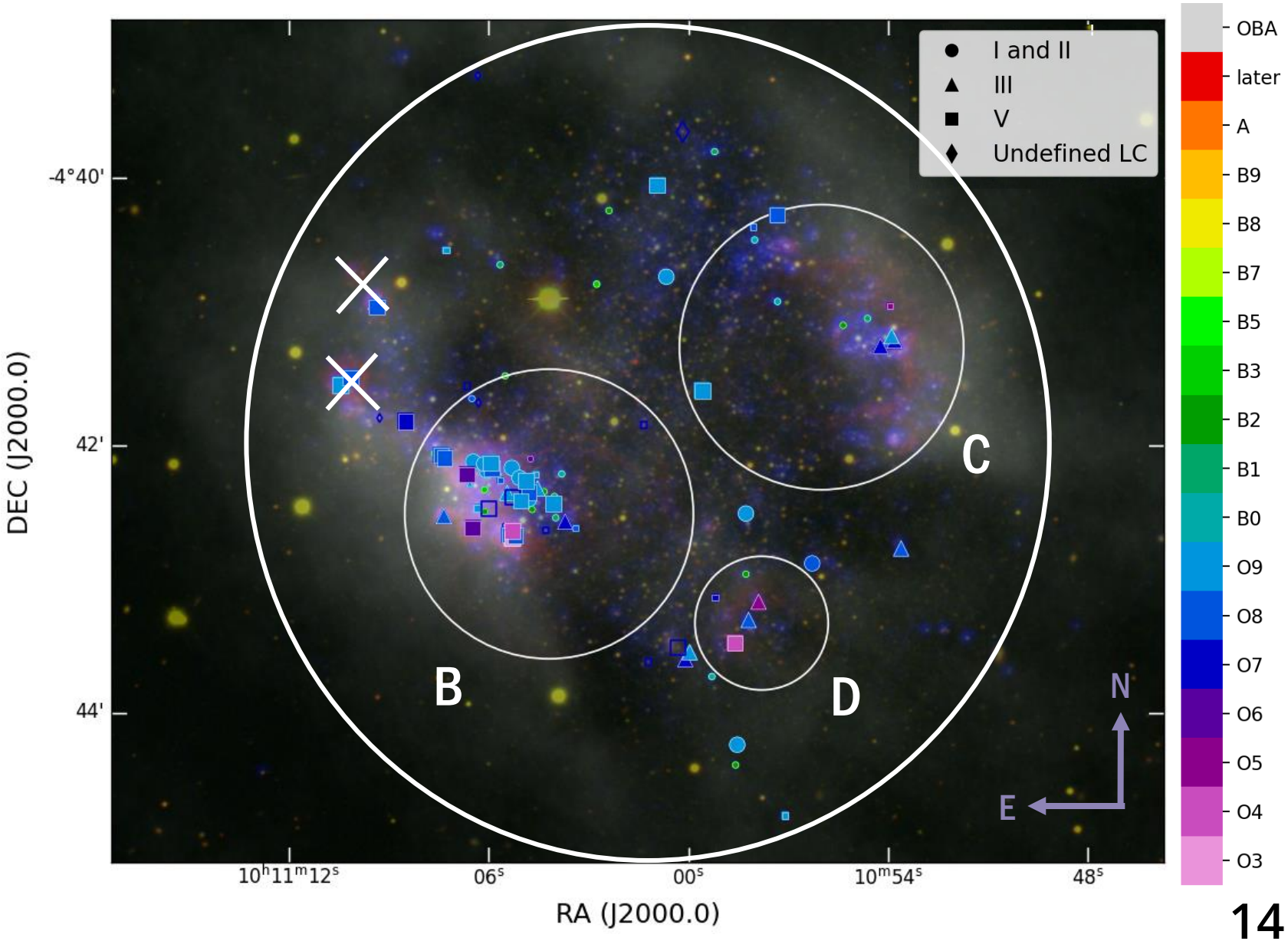
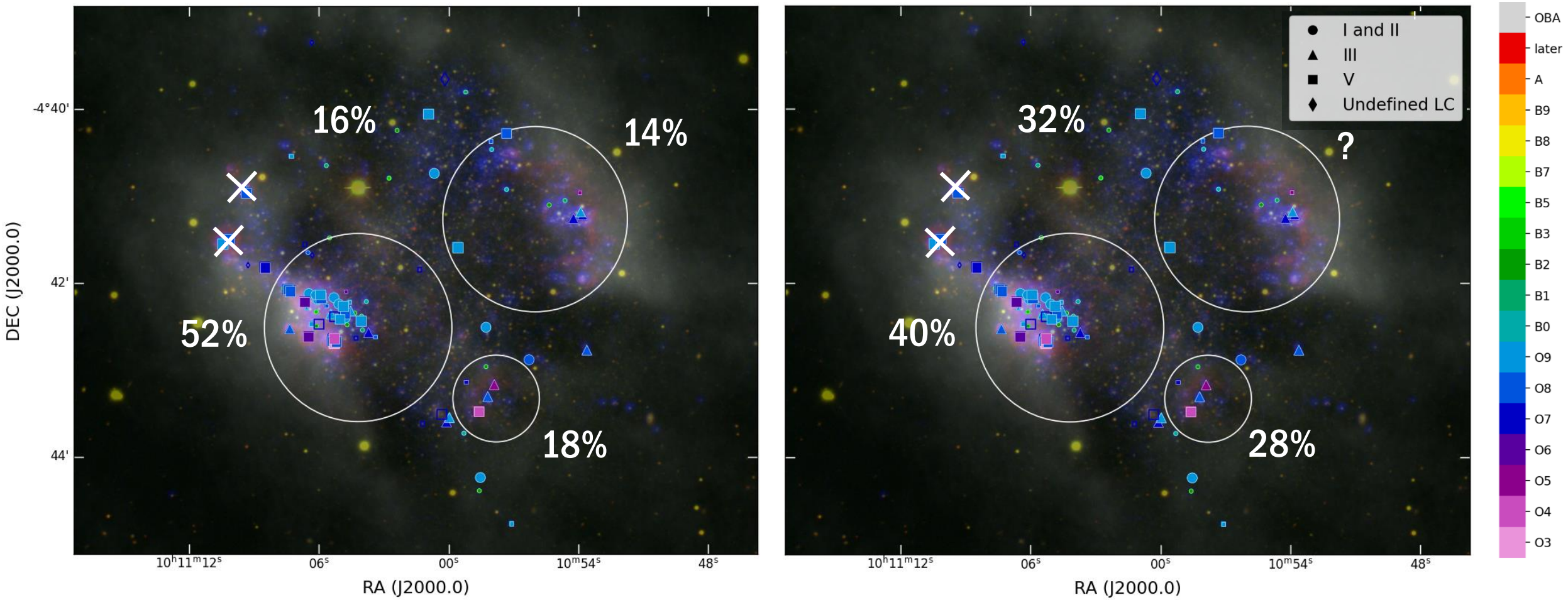
$f_{esc} \geq 0.42$



THE IONIZING PHOTON BUDGET OF SEXTANS A

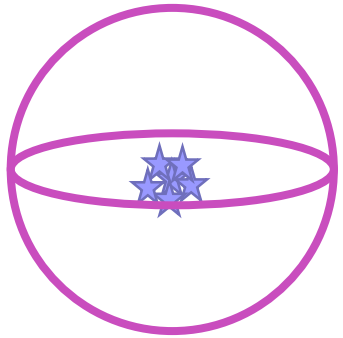
IONIZING PHOTONS PRODUCED

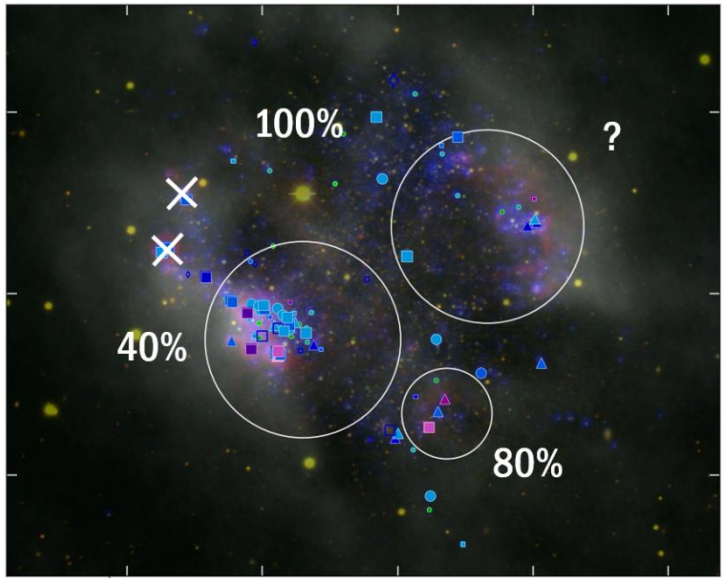
IONIZING PHOTONS ESCAPING



QUESTIONS FOR DISCUSSION

- Can we assume a uniform model when studying unresolved galaxies?





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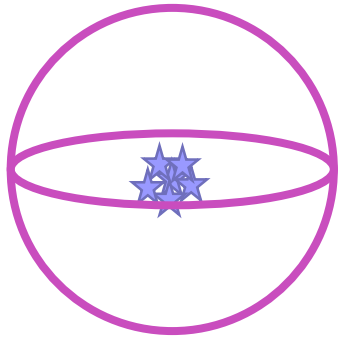

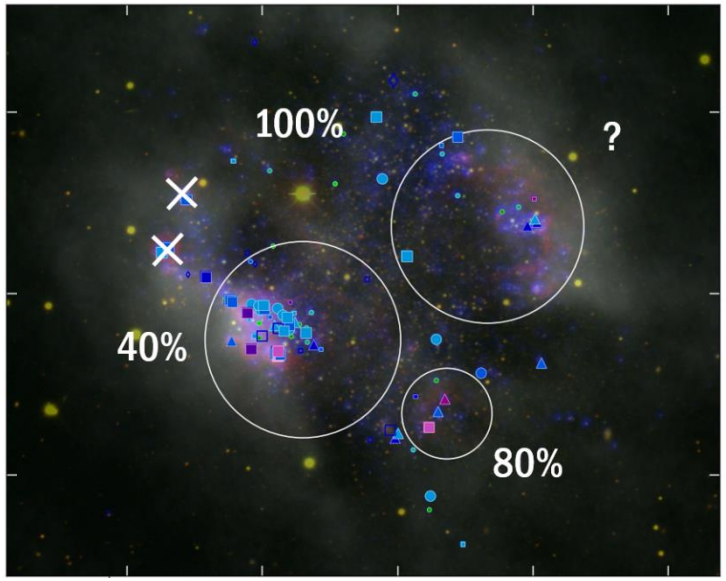

- Can we use Sextans A as a template of the early galaxies?

QUESTIONS FOR DISCUSSION

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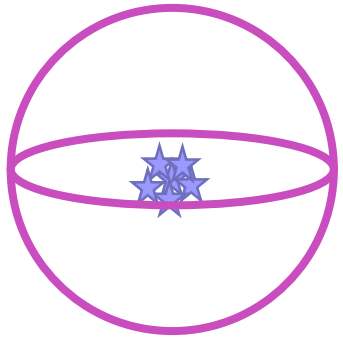
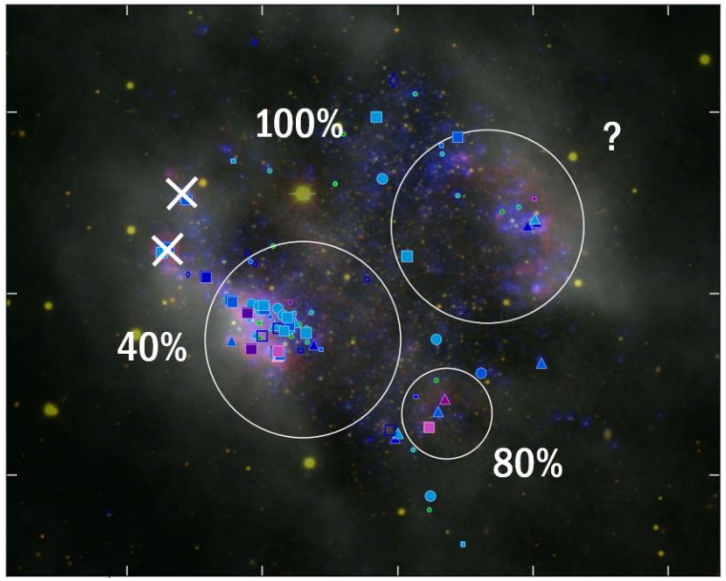
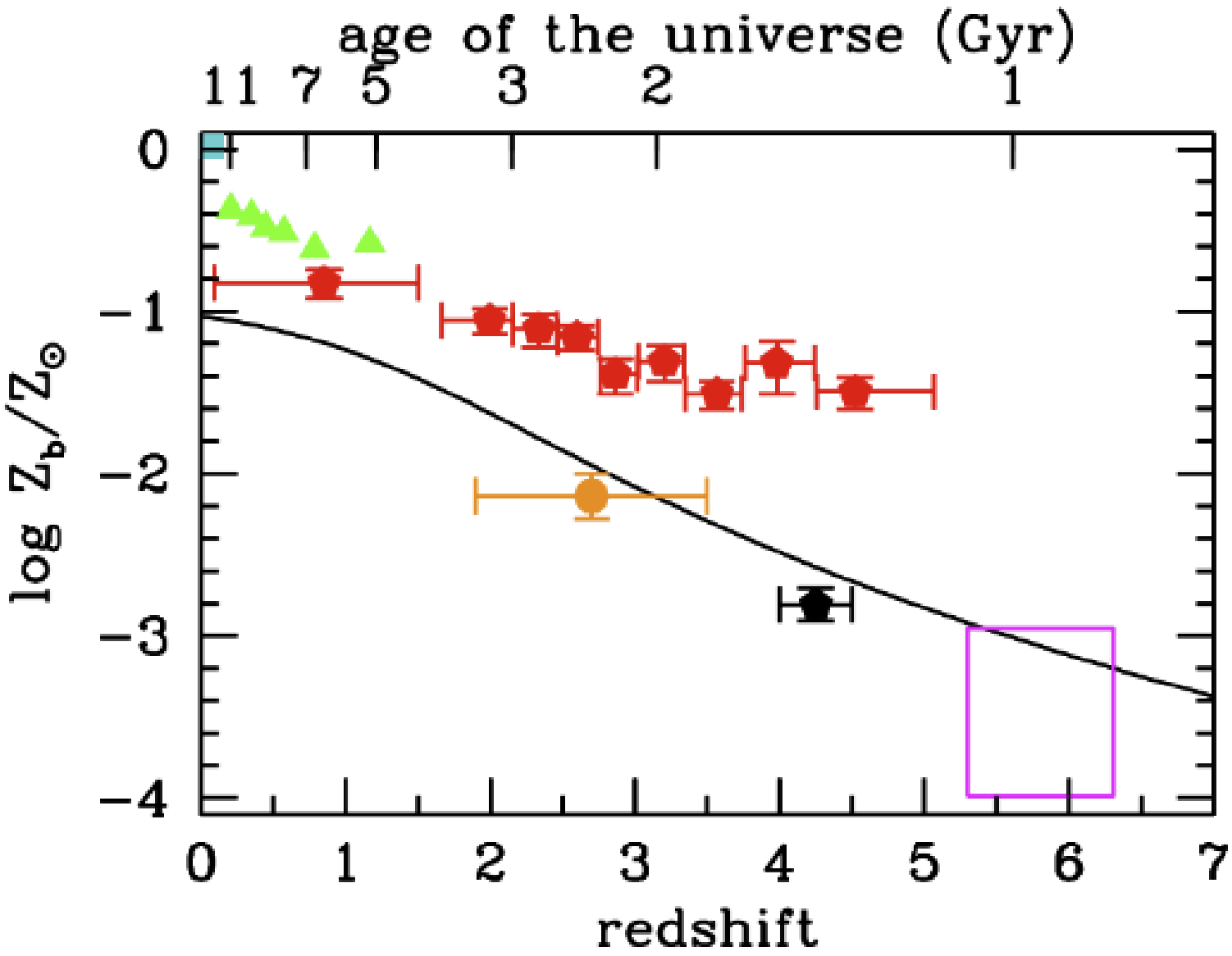




- Can we use Sextans A as a template of the early galaxies? How?

MADAU & DICKINSON (2014)



Mass weight stellar Z SDSS (Gallazi+2008)

Mean iron abundance in the central regions of Galaxy clusters (Balestra+2007)

Column density weighed metallicities by Liα absorption (rafelski+2012)

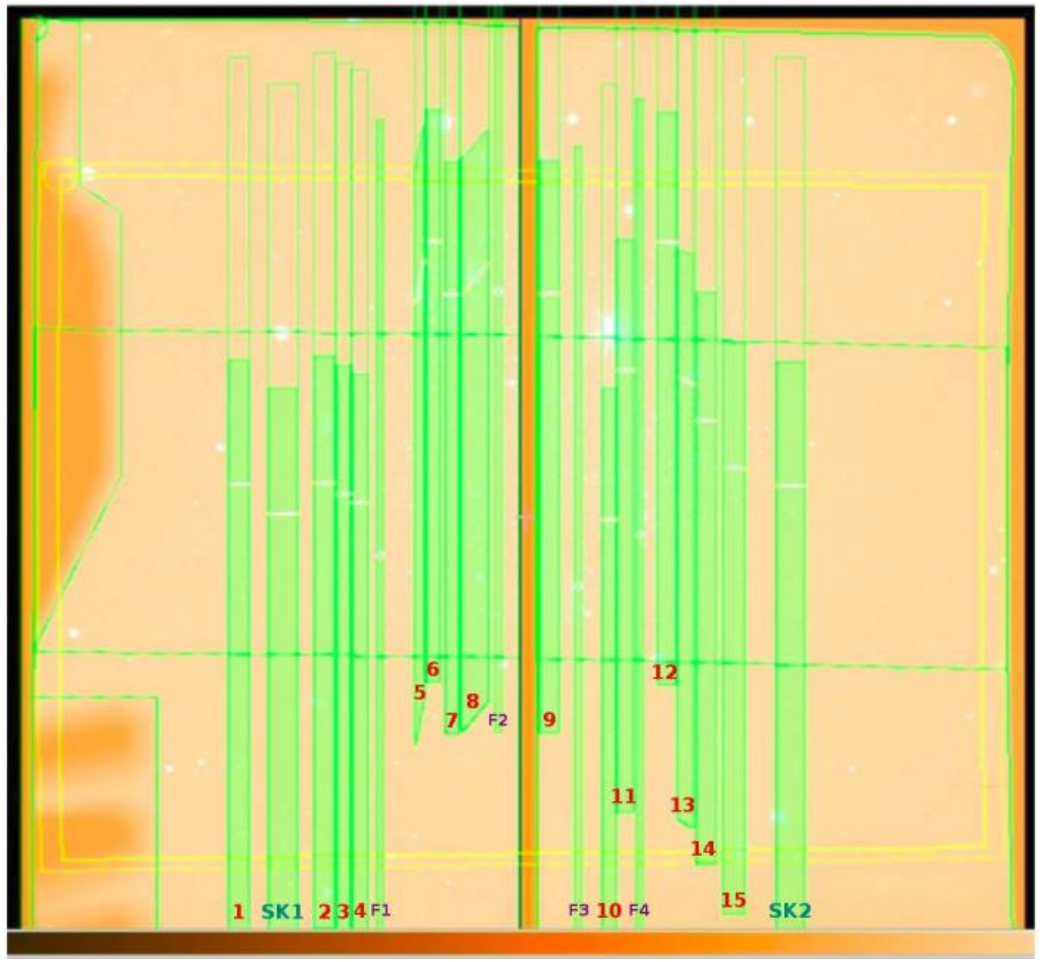
Z on the IGM by O VI in the Liα forest (Aguirre+2008)

Z on the IGM by CIV (Simcoe+2011)

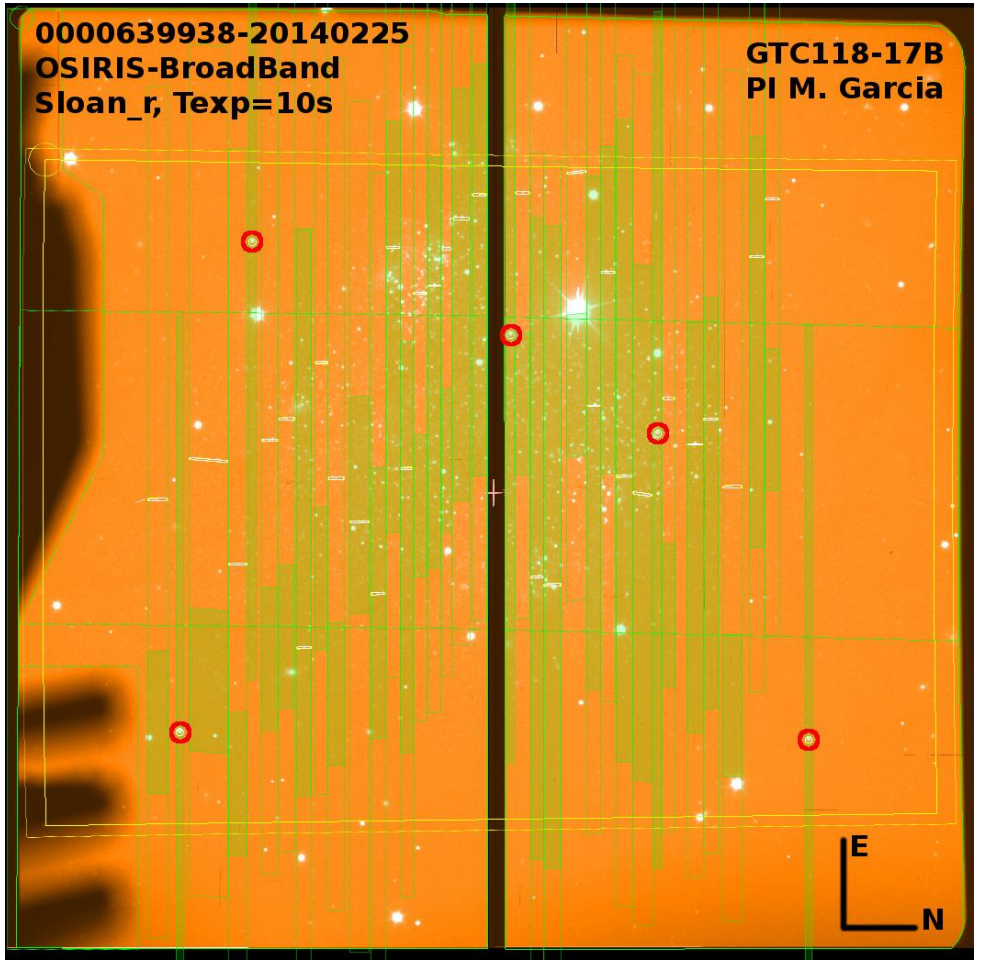
Z on the IGM by CI IV and CII absorption (Ryan-Weber+2009, Simcoe+2011, Becker+2011)

MULTI-OBJECT MASKS

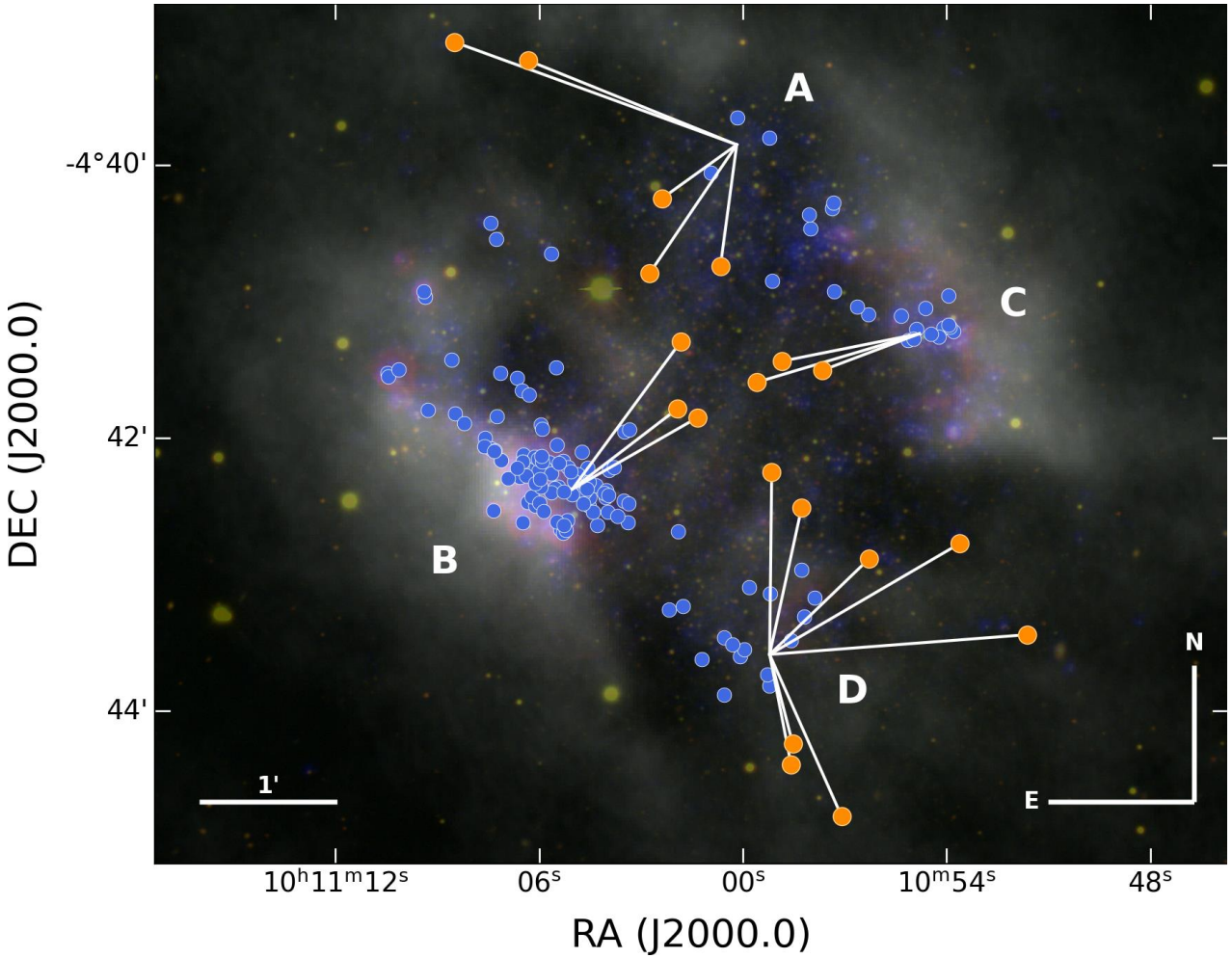
MOS1 run

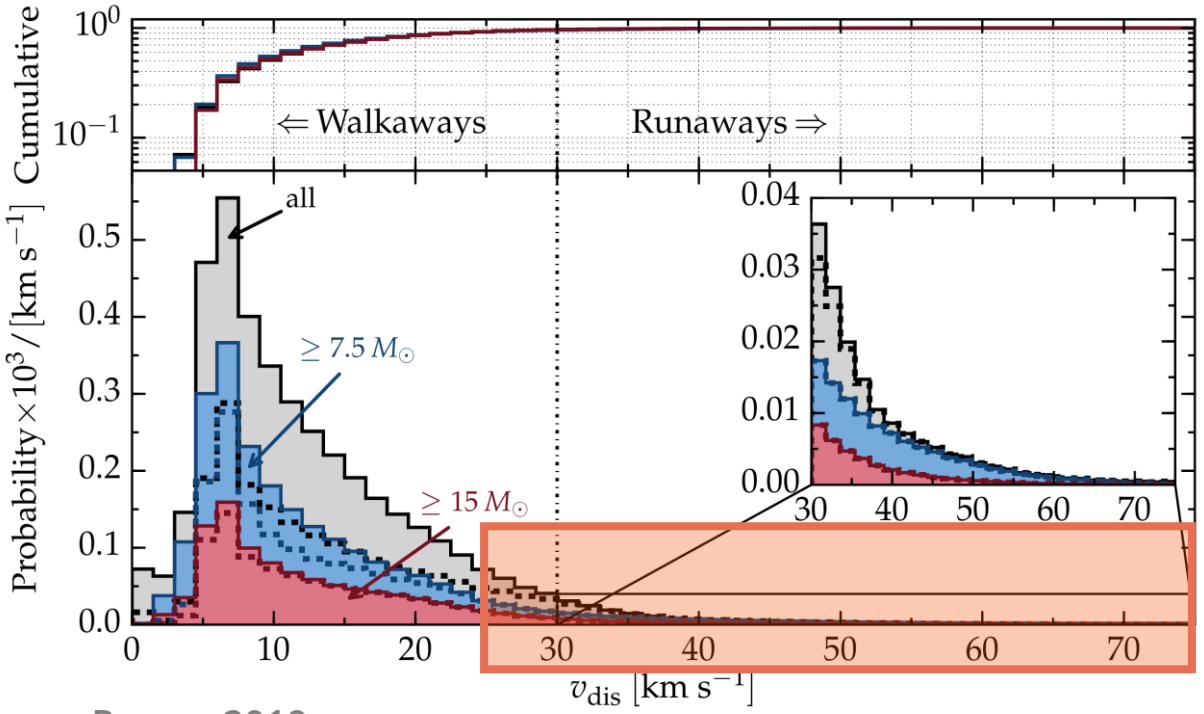


MOS2 run



BINARY RUNAWAYS?



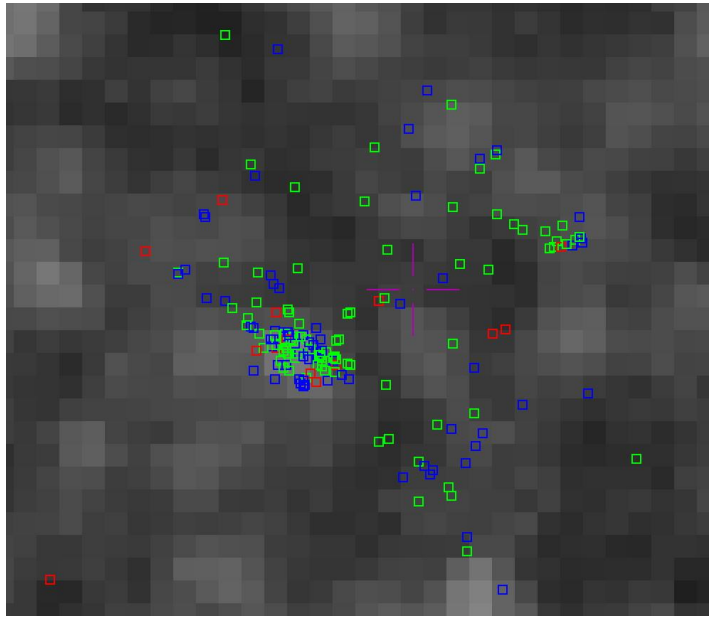


Renzo+2019

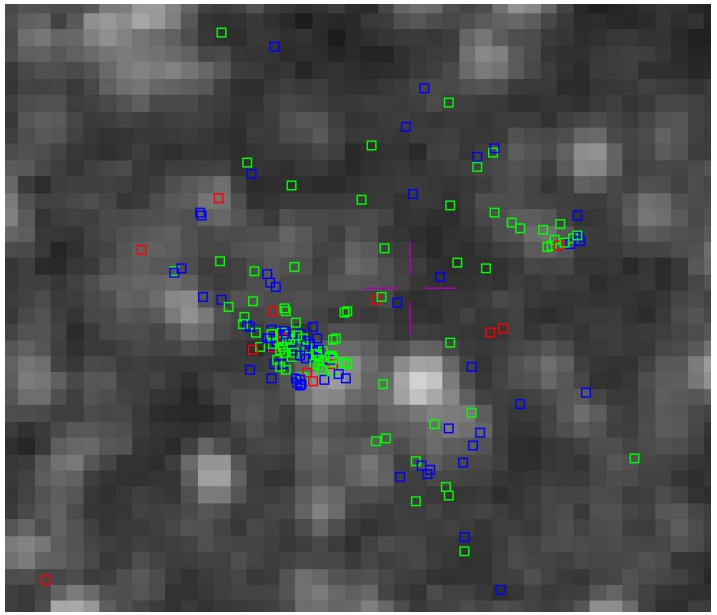
Estimated projected velocities

DUST MAPS OF SEXTANS A

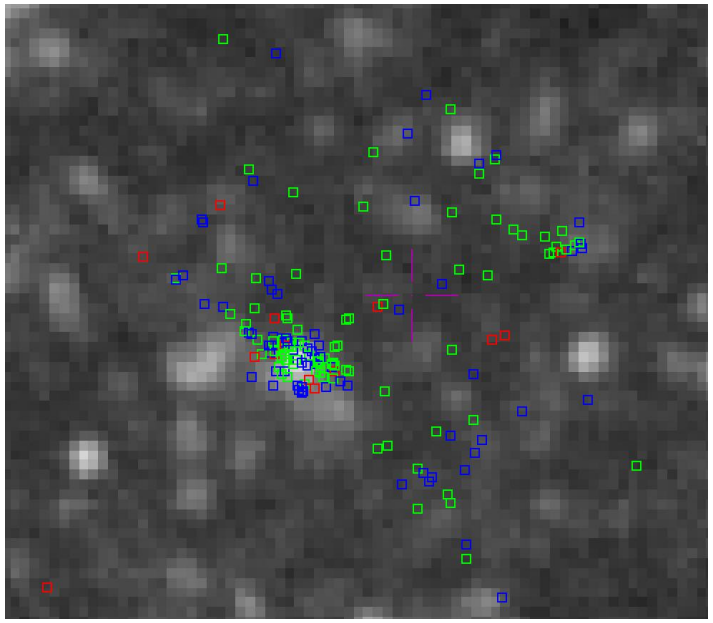
SPIRE 500 μm



SPIRE 350 μm

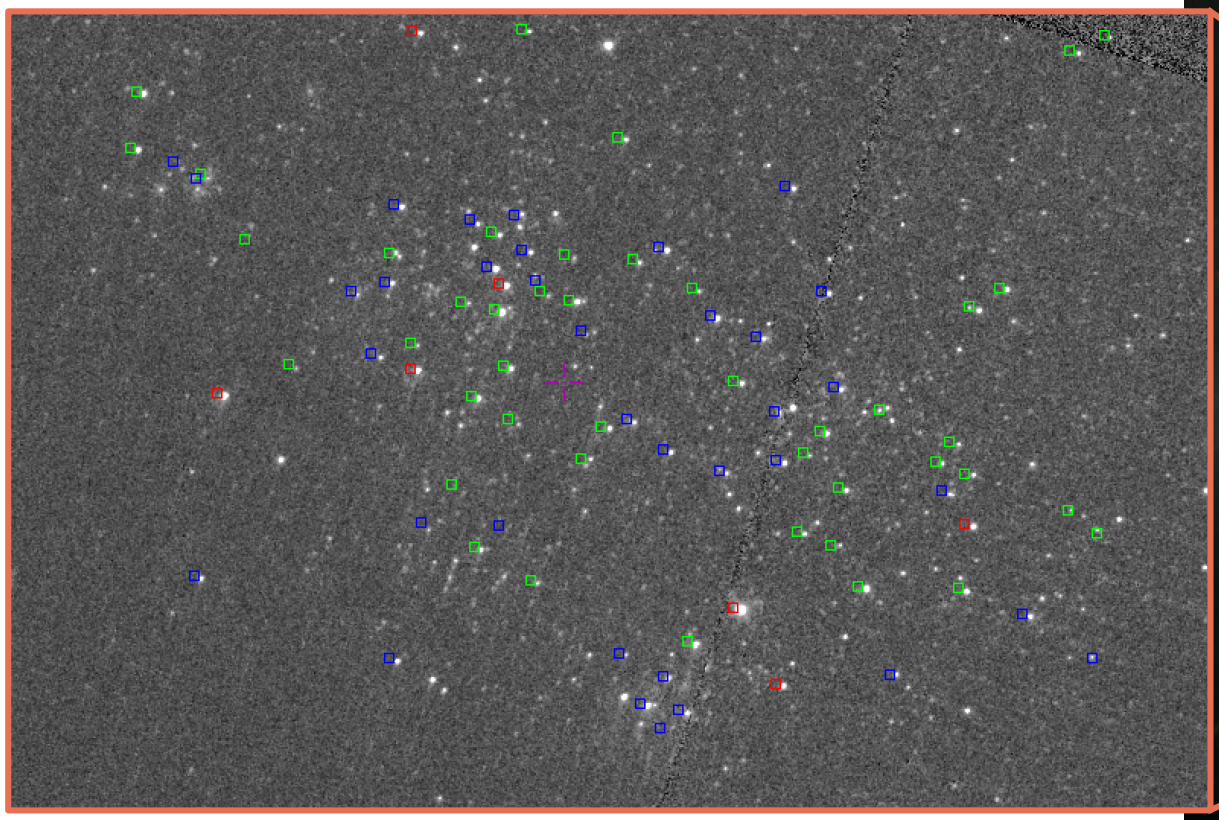


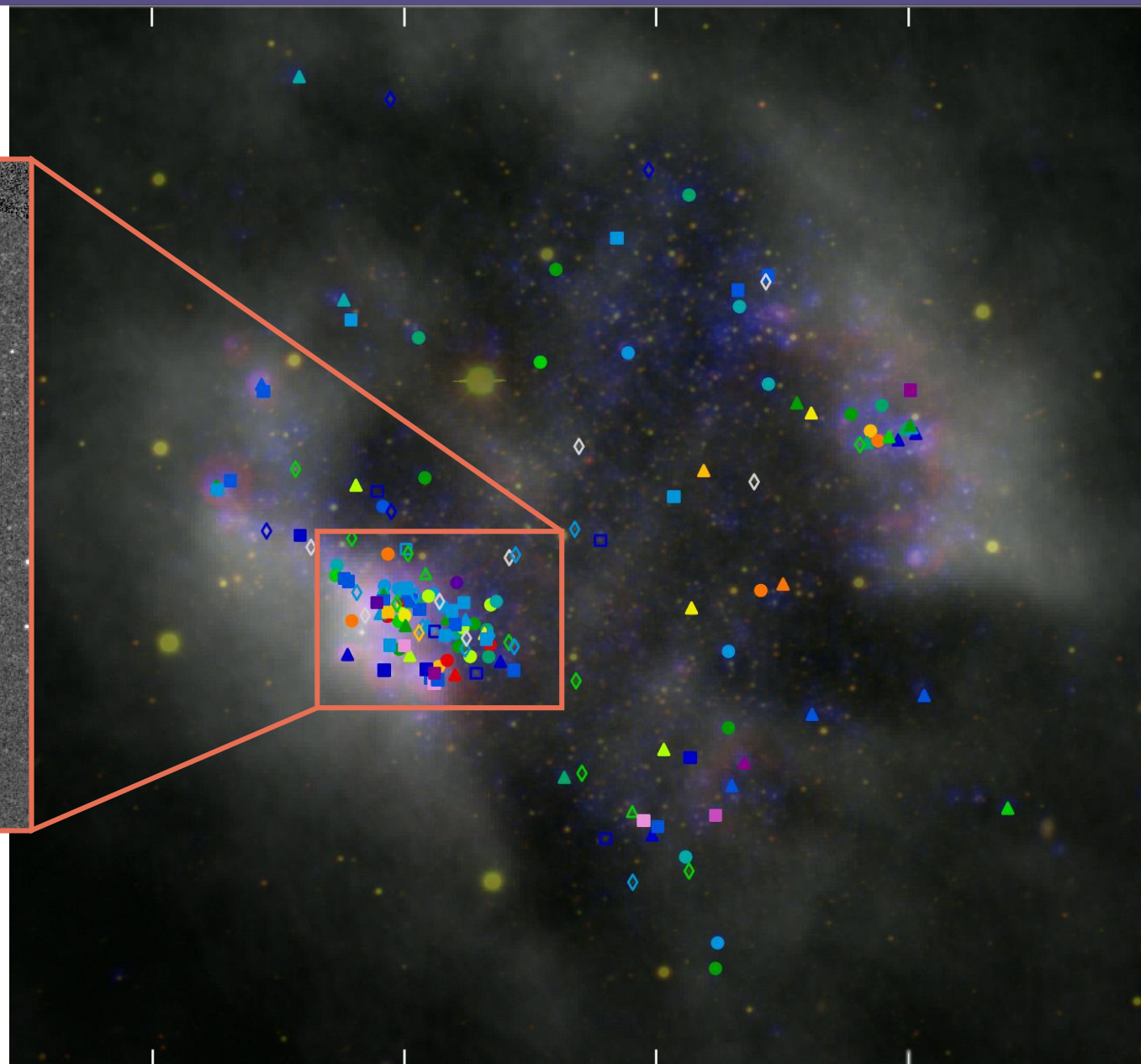
SPIRE 250 μm



- O stars
- B stars
- A stars and later types

HST F555W PHOTOMETRY OF SEXTANS A





- O stars
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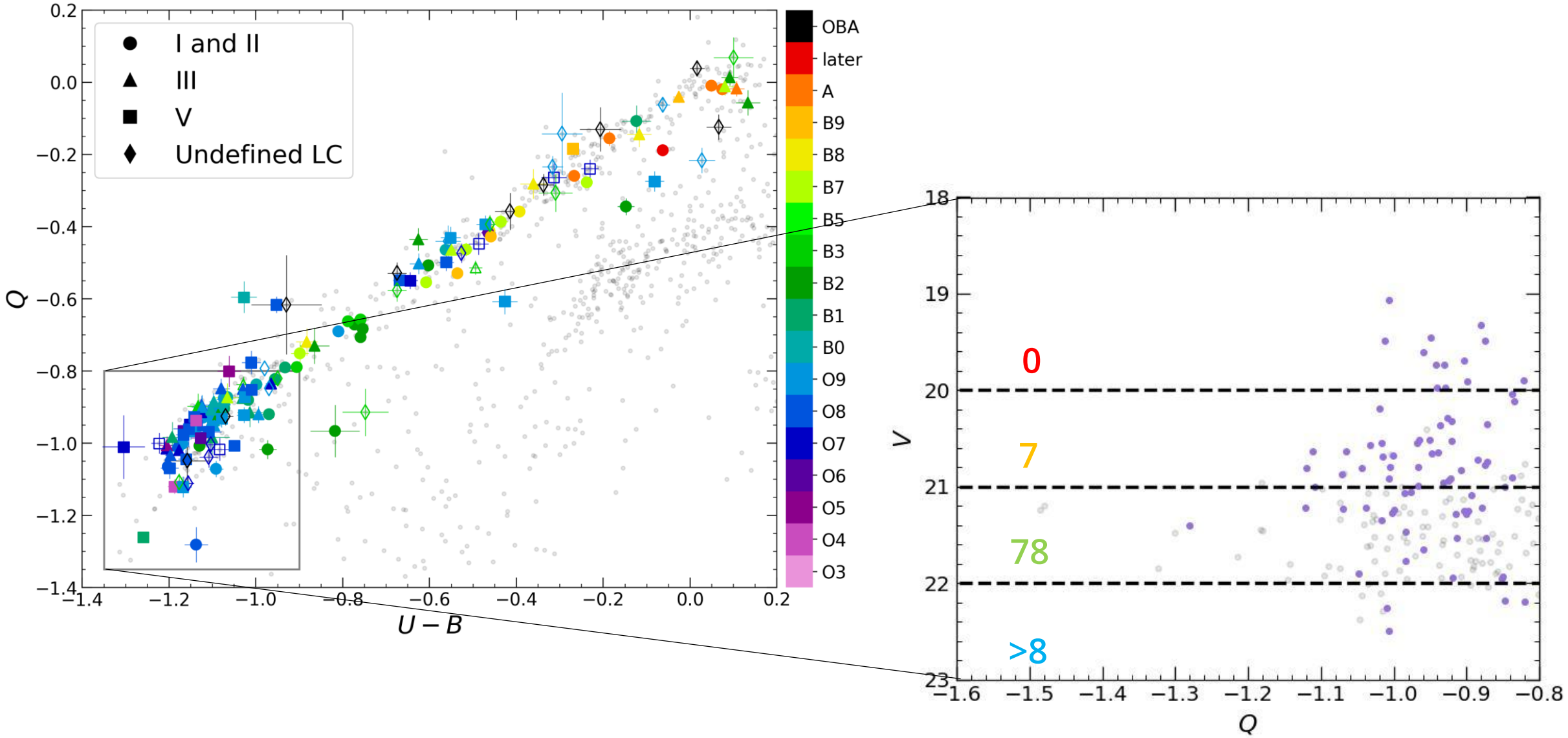
HOW COMPLETE IS OUR CATALOGUE?



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