highly biased

A glimpse on future observing facilities with relevance for Lyman escape studies

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Genoveva Micheva, Norberto Castro, Peter Weilbacher,
Christer Sandin, Sebastian Kamann, Andreas Kelz, ...

Outline

Prelude: Motivation

Part 1: Methodology

Part 2: BlueMUSE

Part 3: WST

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SUMMARY

- LCEs are diverse – no one unique property
- LyC escape is a multi-parameter problem
- High f_{esc} = low line-of-sight HI and dust
  - How? From SN feedback or radiative feedback (may vary)

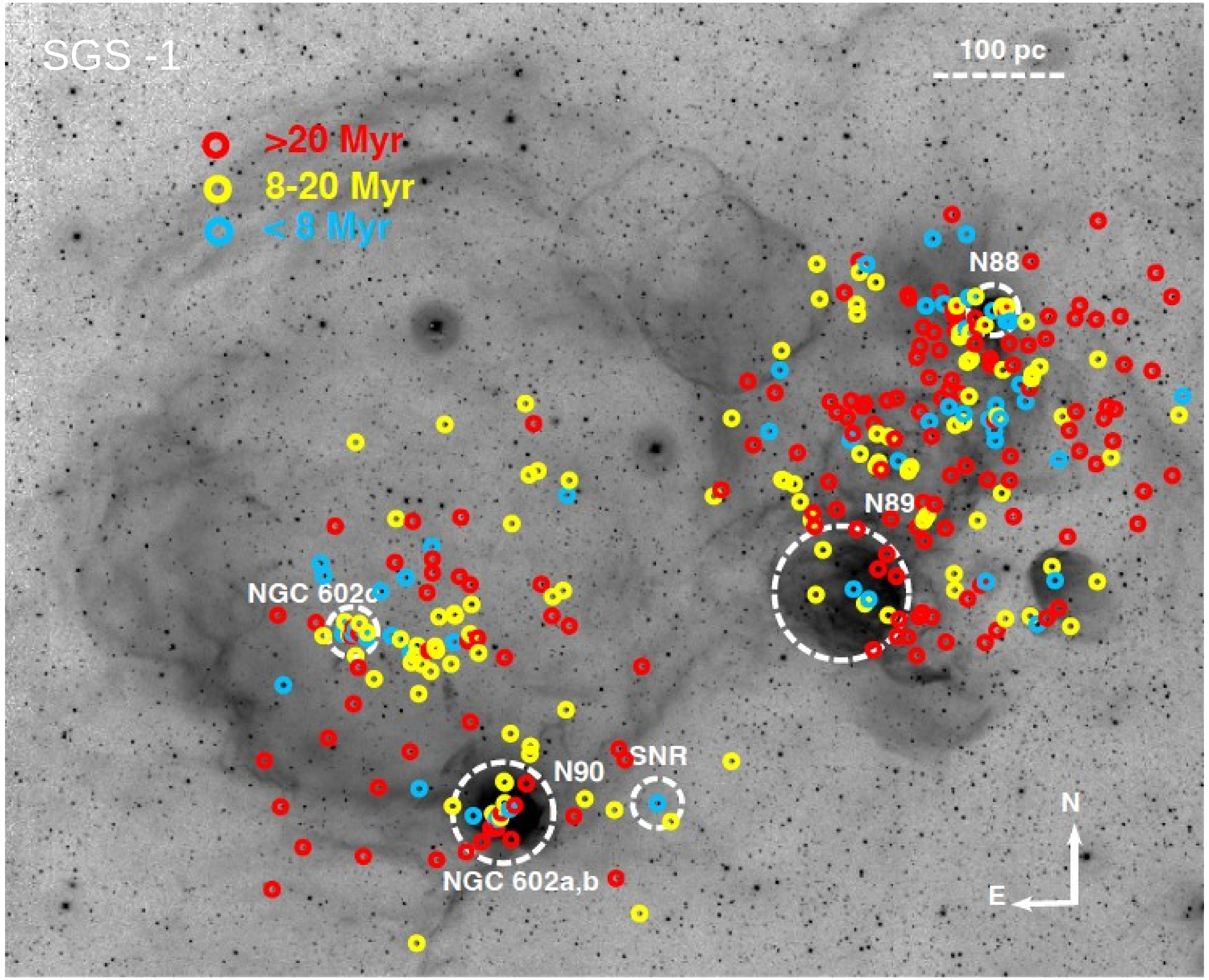
At z~0: Follow-up work on detailed properties, feedback processes, sites of LyC escape

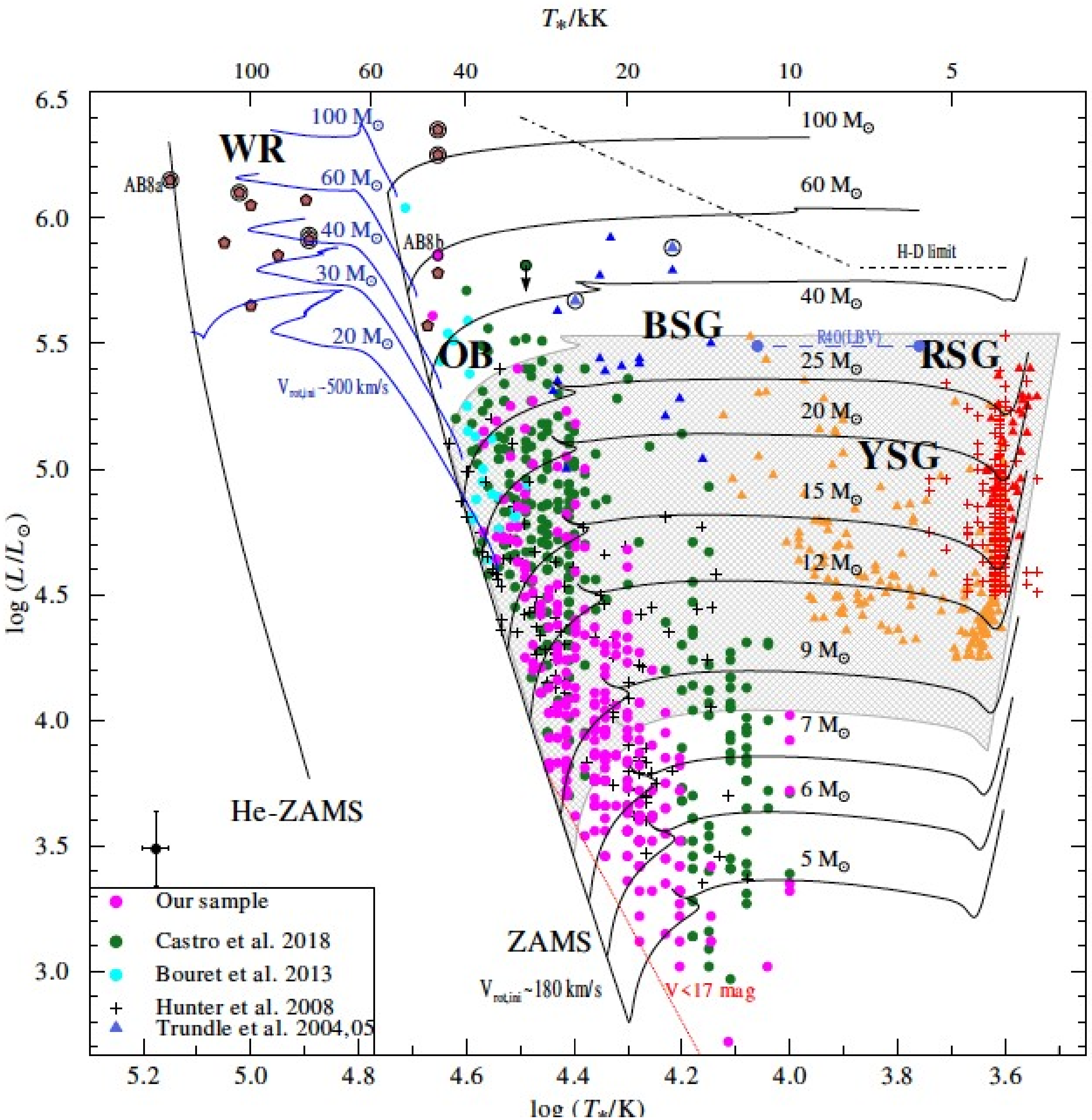
- z~3 galaxies seem to follow the same trends as z~0.3 LCEs

At z~3: Need more measurements of relevant properties to test

- At z>6, numerous strong LCEs with f_{esc} > 0.1
  - Multivariate predictions can differ from single variable estimates; use all available info

At z>6: Need more measurements, larger samples





Ramachandran et al. 2019, A&A 625, A104

Testing massive star evolution, star formation history, and feedback at low metallicity

Spectroscopic analysis of OB stars in the SMC Wing

mentioned by Andreas Sander

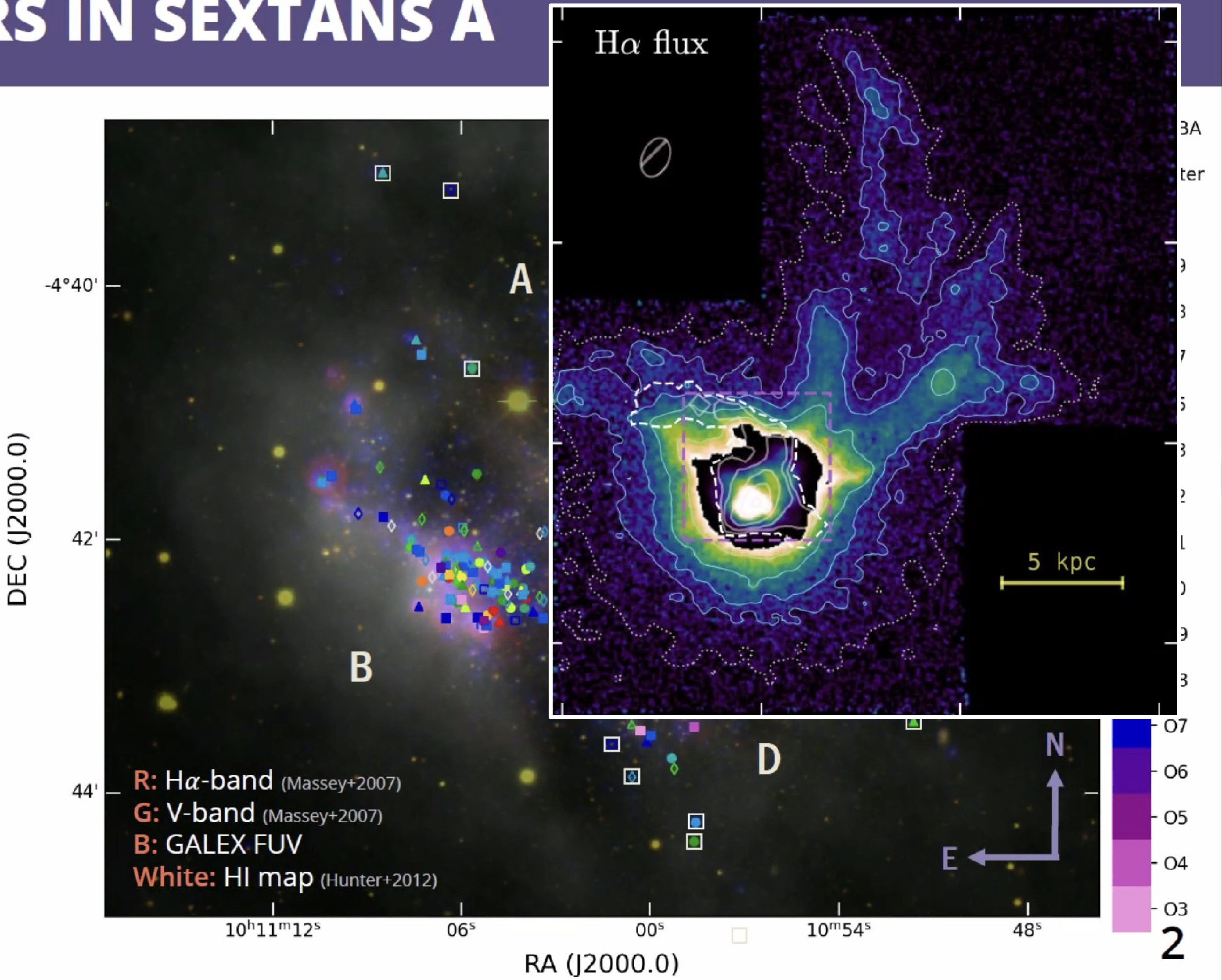
+150 OB-TYPE STARS IN SEXTANS A

Spectroscopy of
159 OB stars

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

Most of our sample OB stars are located in region B

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



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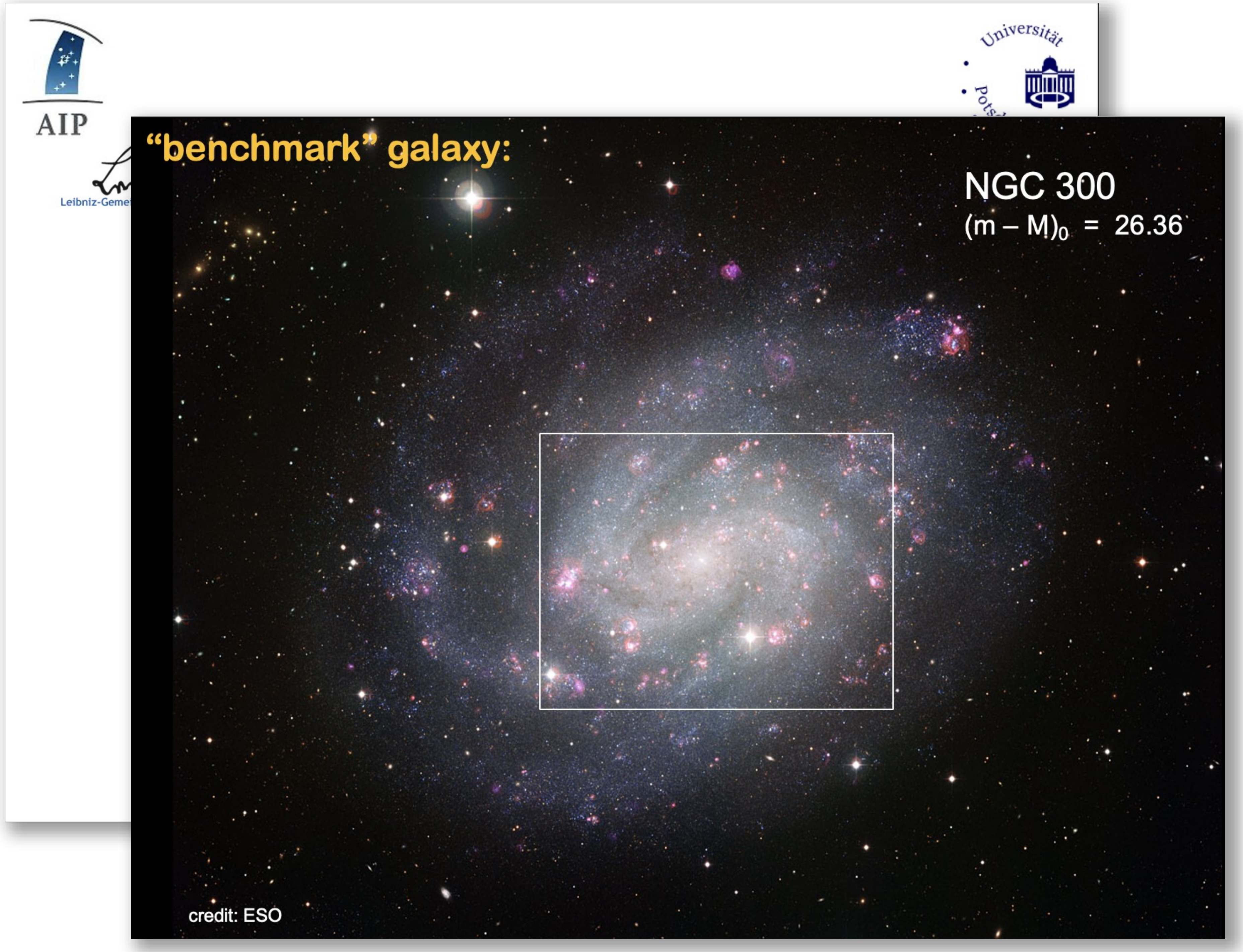
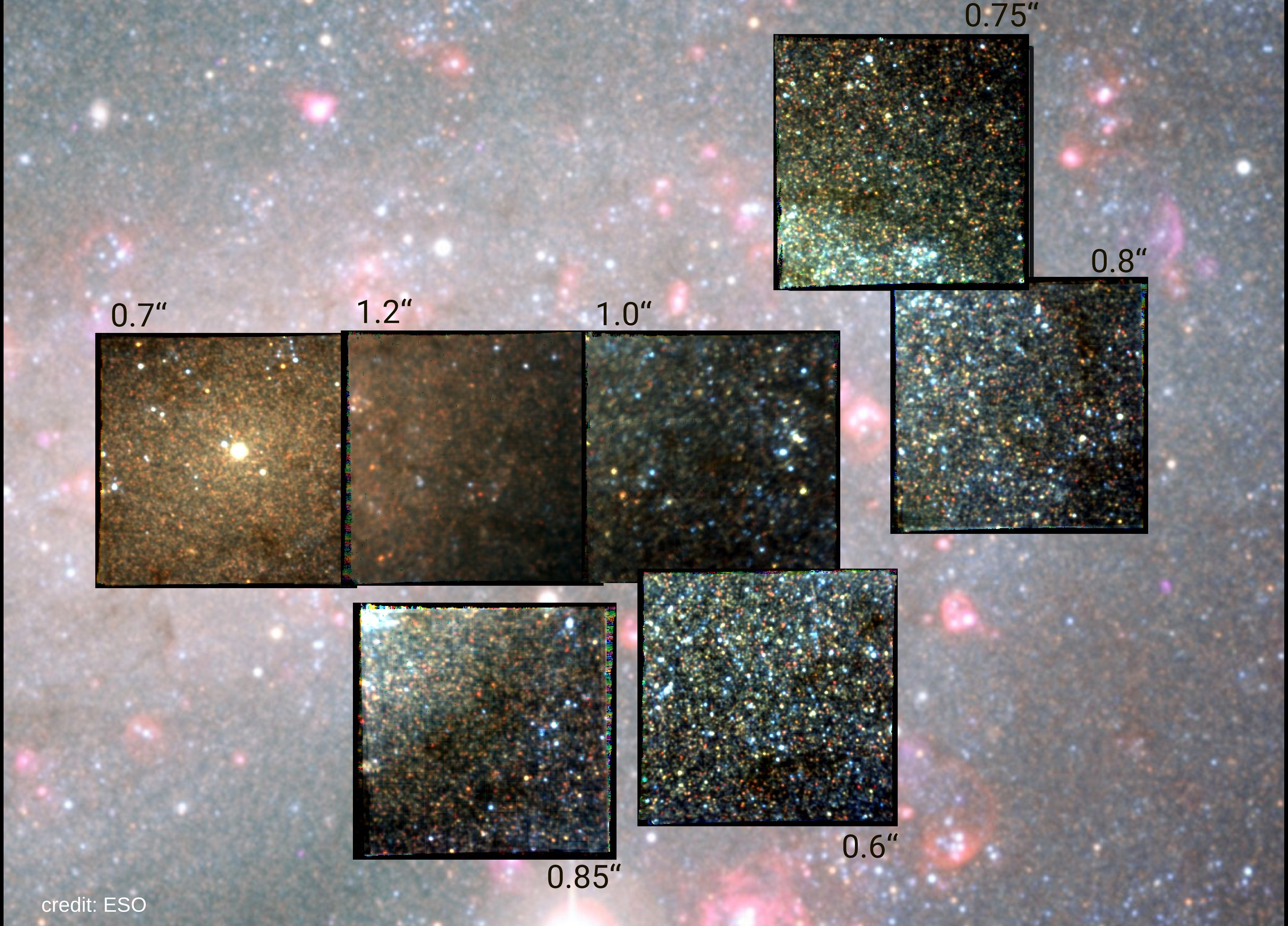
Part 1:

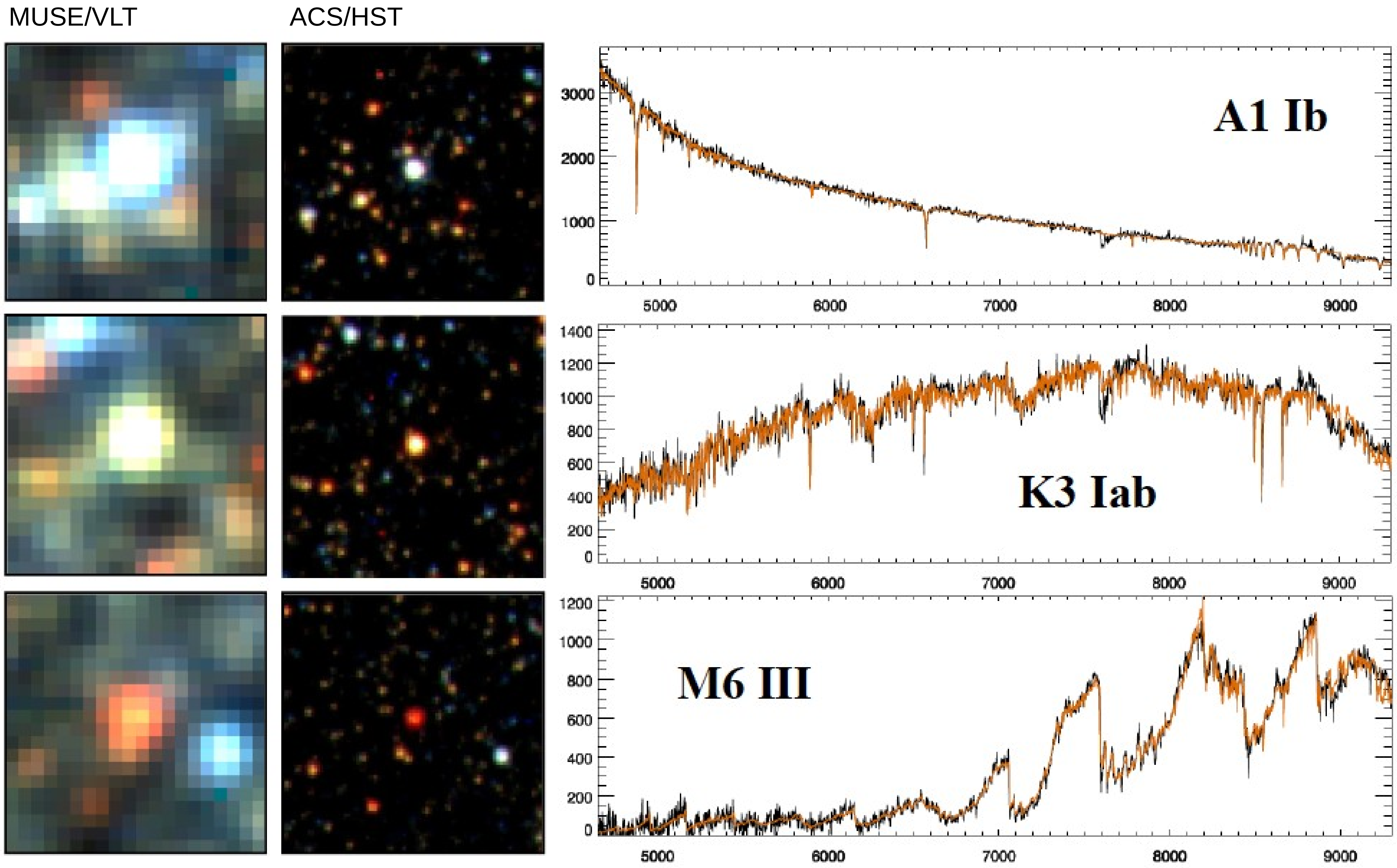
Methodology – an example case

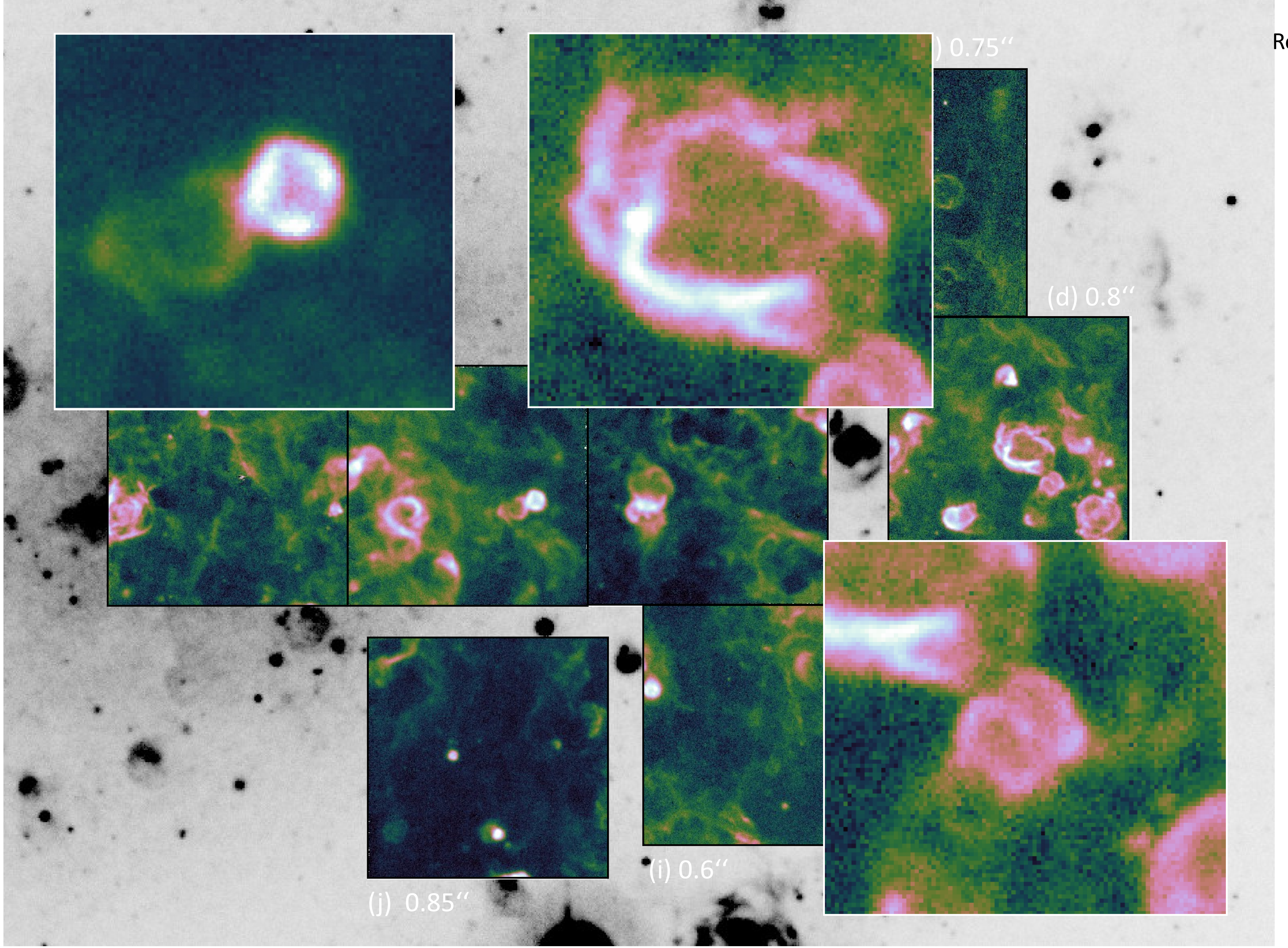
Escape of Lyman radiation, Kolymbari 2016




0.75"
0.8"
0.7"
1.2"
1.0"
0.85"
0.6"
credit: ESO

Roth et al. 2018





Roth et al. 2018

Roth et al. 2018

Summary (from 9 hrs exposure time)

	a	b	c	d12	e1	i	j	
Seeing	0.7“	1.2“	1.0“	0.8“	0.75“	0.6“	0.85“	
PN	5	7	6	4	9	3	2	36
PN candidates	4	0	0	1	4	0	0	9
HII regions	10	11	5	13	4	13	5	61
cHII regions [1)]	8	4	5	19	5	2	8	51
SNR	14	5	3	5	3	6	2	38
emStars [2)]	18	4	4	15	30	40	7	118
bgr. Galaxies [3)]	4	3	1	6	2	8	4	28
Stars [4)]	445:	77:	152:	265:	299:	**517**	91:	1846

1) compact HII regions
2) emission line stars
3) background galaxies
4) stars with spectral type

NGC 300 GTO Project

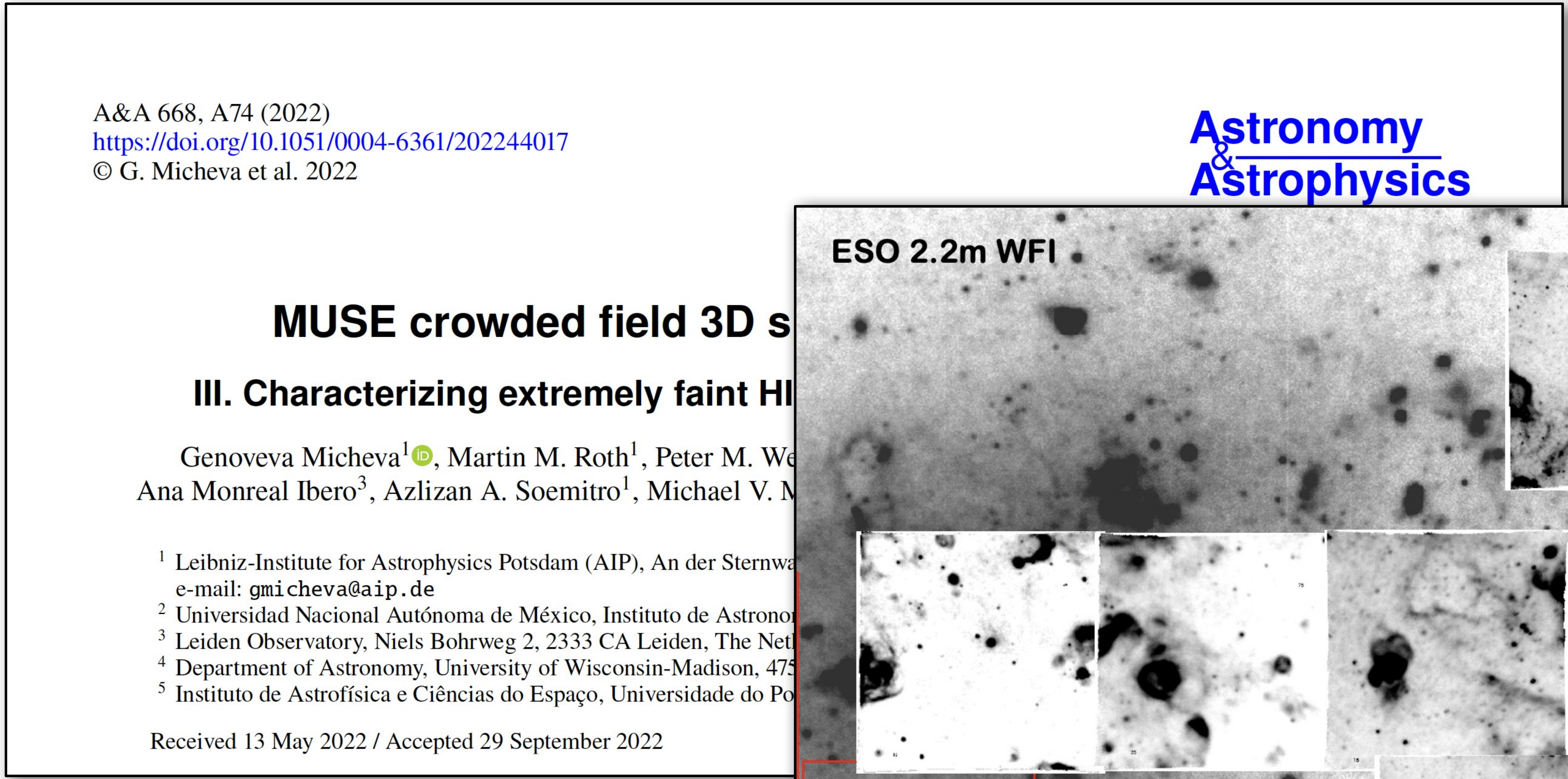
Roth M.M., Sandin, C., Kamann, S., Husser, T.-O., Weilbacher, P.M., Monreal-Ibero, A., Bacon, R., et al. (2018)
A&A, 618, *MUSE crowded field 3D spectroscopy in NGC 300.*
I. First results from central fields

González-Torà, G., Urbaneja, M.A., Przybilla, N., Dreizler, S., Roth, M.M., Kamann, S., Castro N. (2022)
A&A, 658, A117, *MUSE crowded field 3D spectroscopy in NGC 300.*
II. Quantitative spectroscopy of BA-type supergiants

Micheva, G., Roth, M.M., Weilbacher, P.M., Morisset, C., Castro, N., Monreal Ibero, A., Adhyaqsa Soemitro, A. (2022)
A&A, 668, A74, *MUSE crowded field 3D spectroscopy in NGC 300*
III. Characterizing extremely faint HII regions and diffuse ionized gas

Adhyaqsa Soemitro, A., Roth, M.M., Weilbacher, P.M., Ciardullo, R., Jacoby, G.H. (2023)
A&A, 671, A142, *MUSE crowded field 3D spectroscopy in NGC 300*
IV. Planetary Nebula Luminosity Function

Micheva et al. 2028



A&A 668, A74 (2022)
https://doi.org/10.1051/0004-6361/202244017
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Astronomy & Astrophysics

MUSE crowded field 3D s

III. Characterizing extremely faint HI

Genoveva Micheva[1], Martin M. Roth[1], Peter M. We
Ana Monreal Ibero[3], Azlizan A. Soemitro[1], Michael V. M

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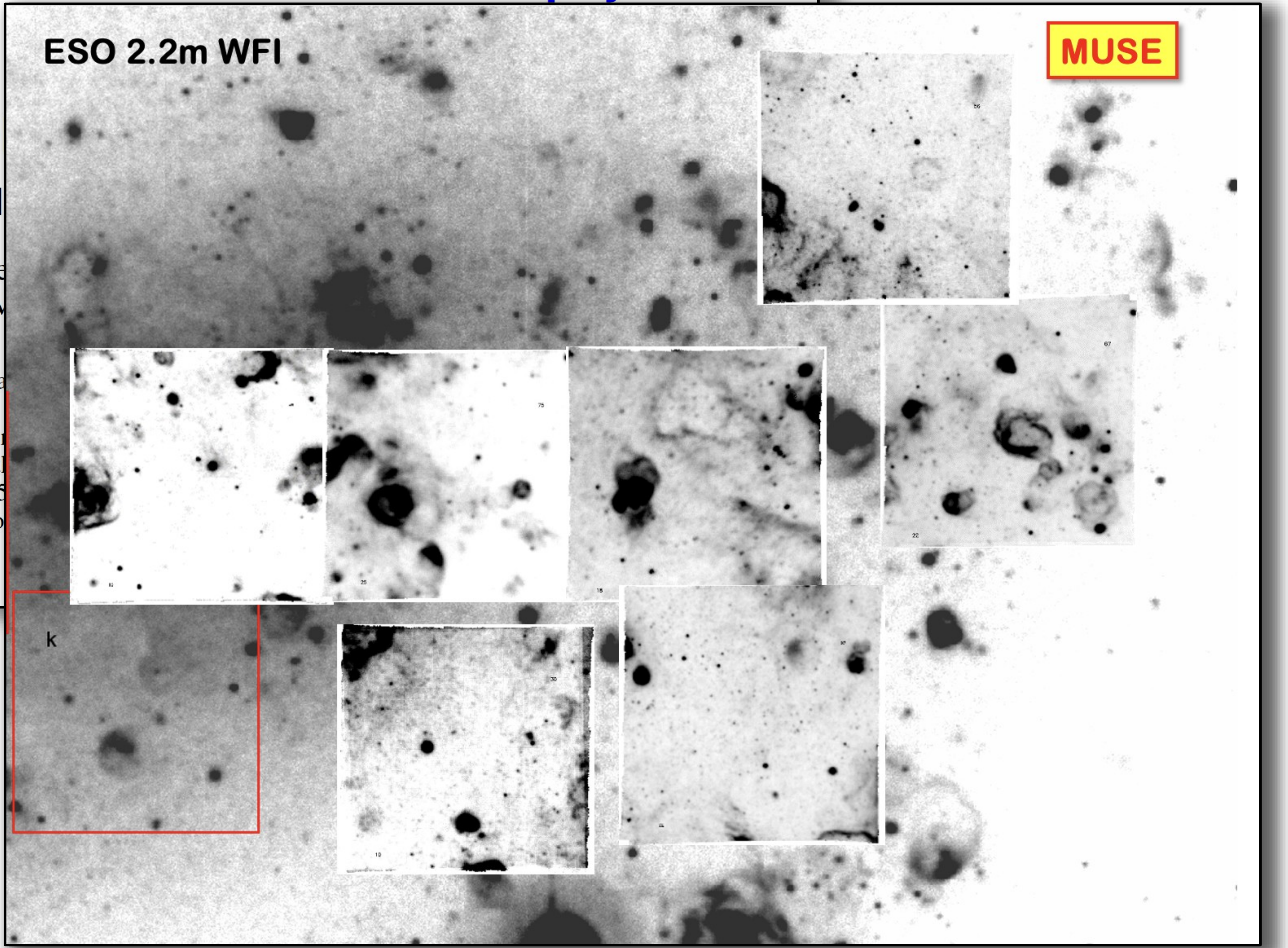
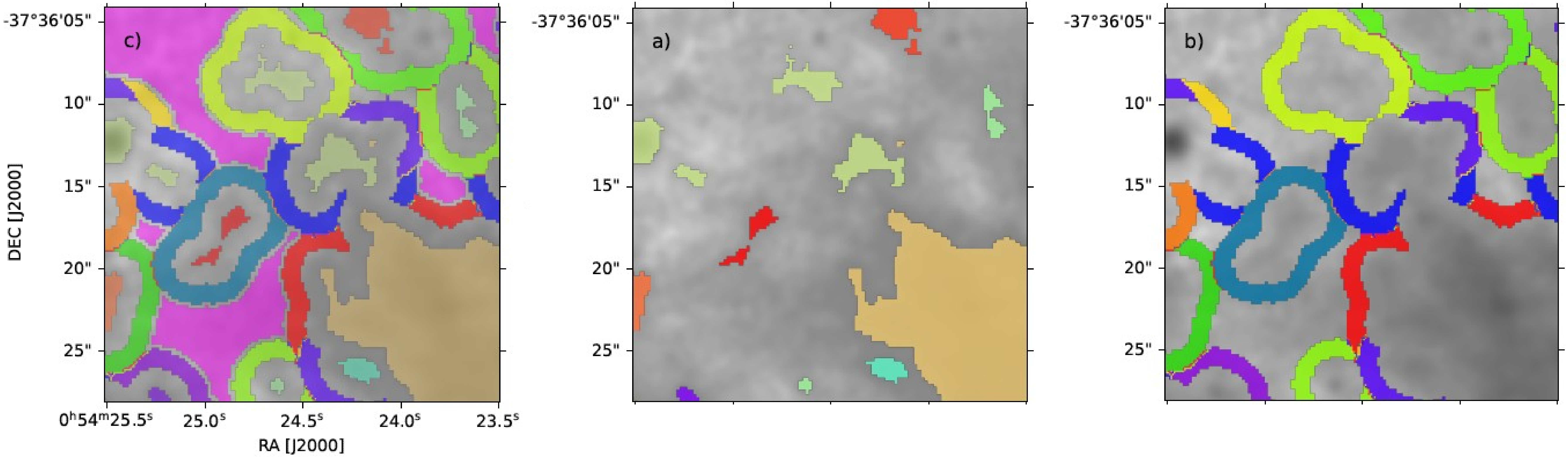
Received 13 May 2022 / Accepted 29 September 2022



Discretization of emission line objects

HDendrograms H II DIG



ASTRODENDRO package
Robitaille+2019

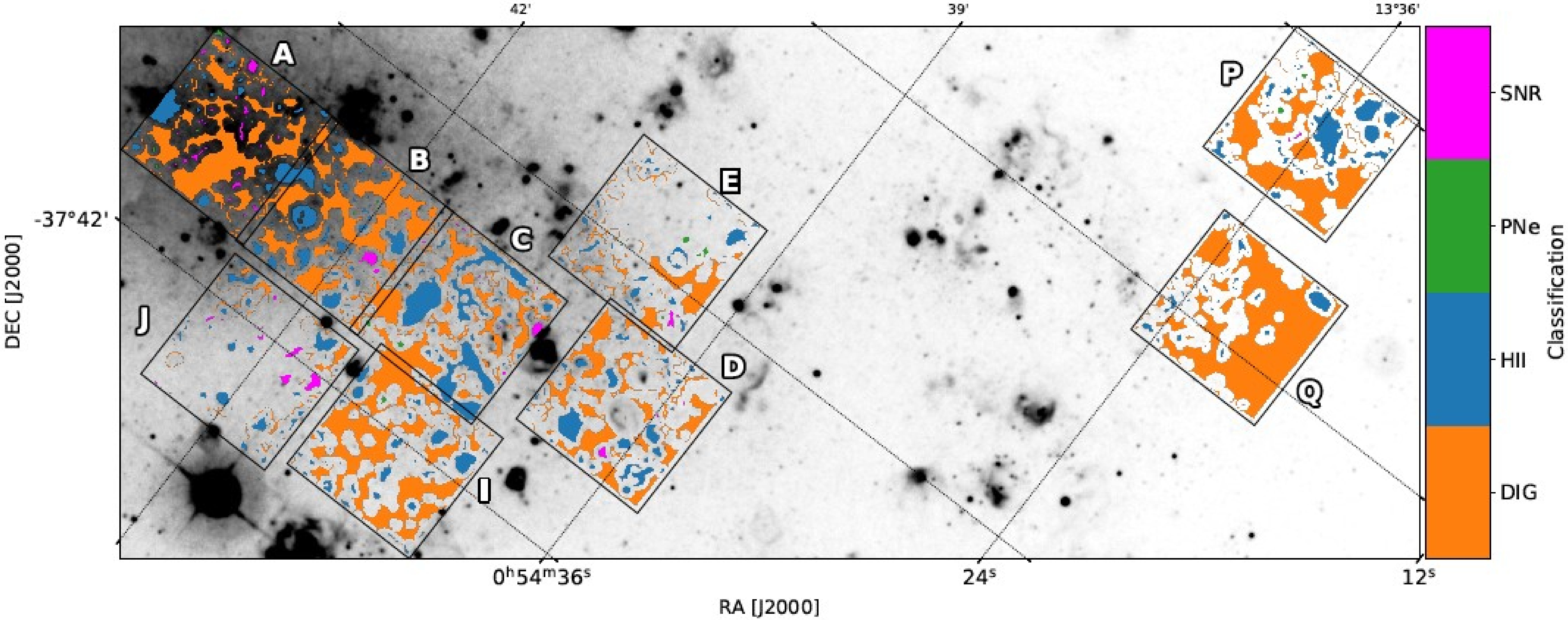
Micheva et al. 2028

Map of BPT diagram classification

total score:

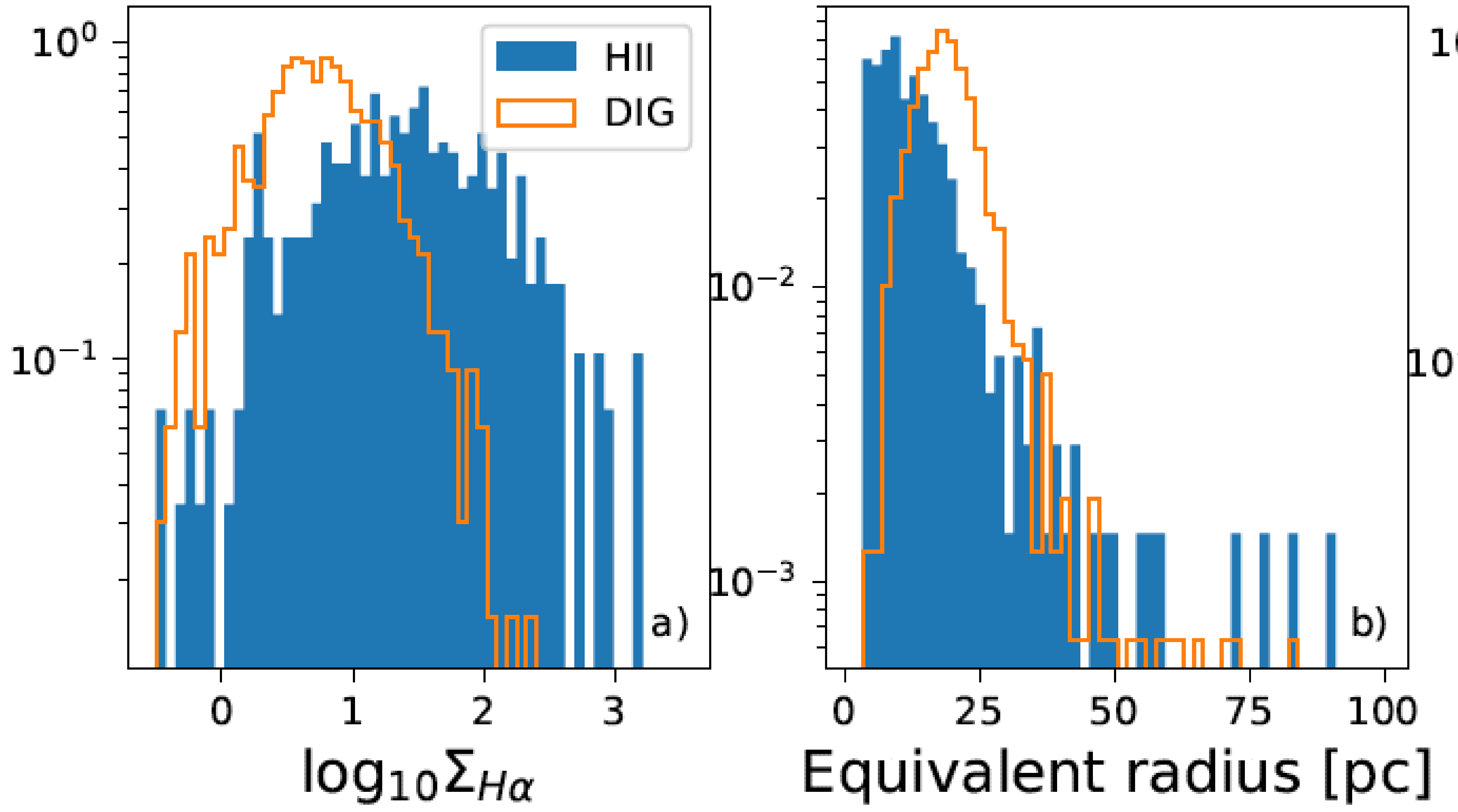
390 H II — 82 SNR

696 DIG — 27 PN



Micheva et al. 2028

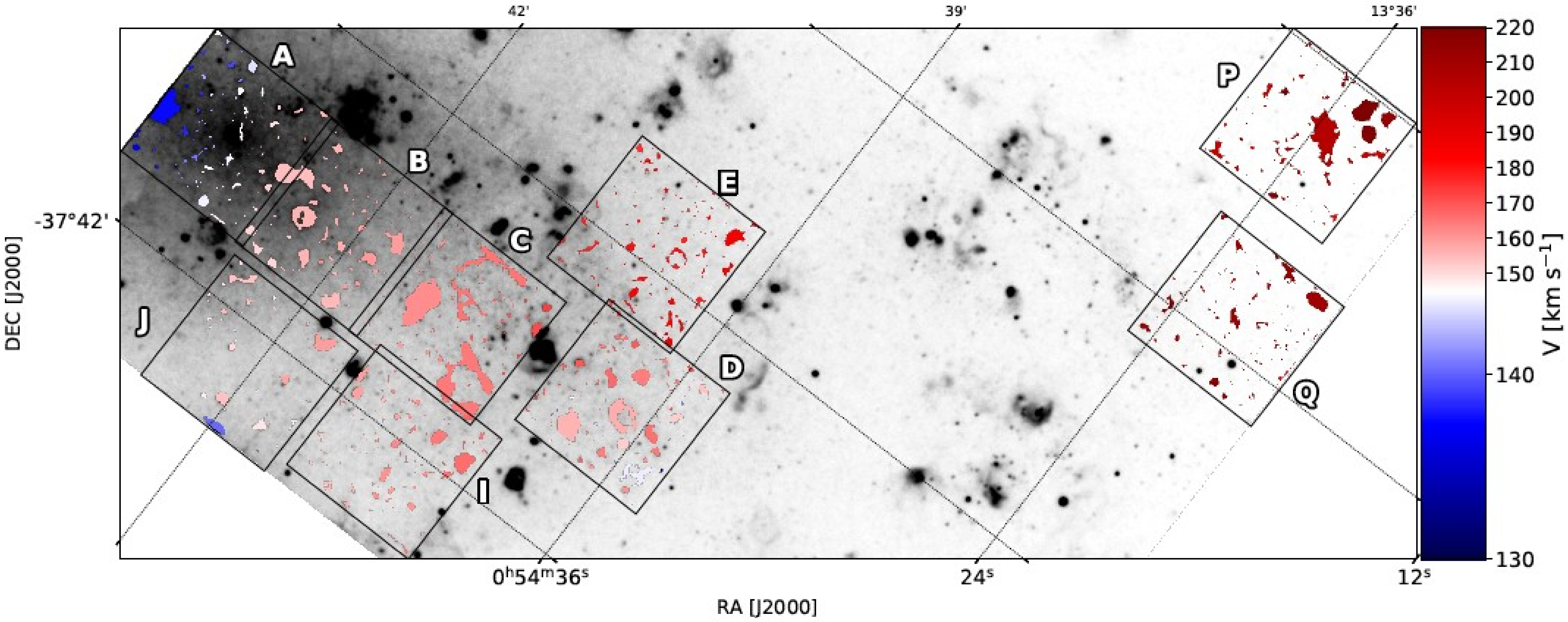
Histograms of H II and DIG regions



$[10^{-20}$ erg cm^{-2} s^{-1} arcsec$^{-2}]$

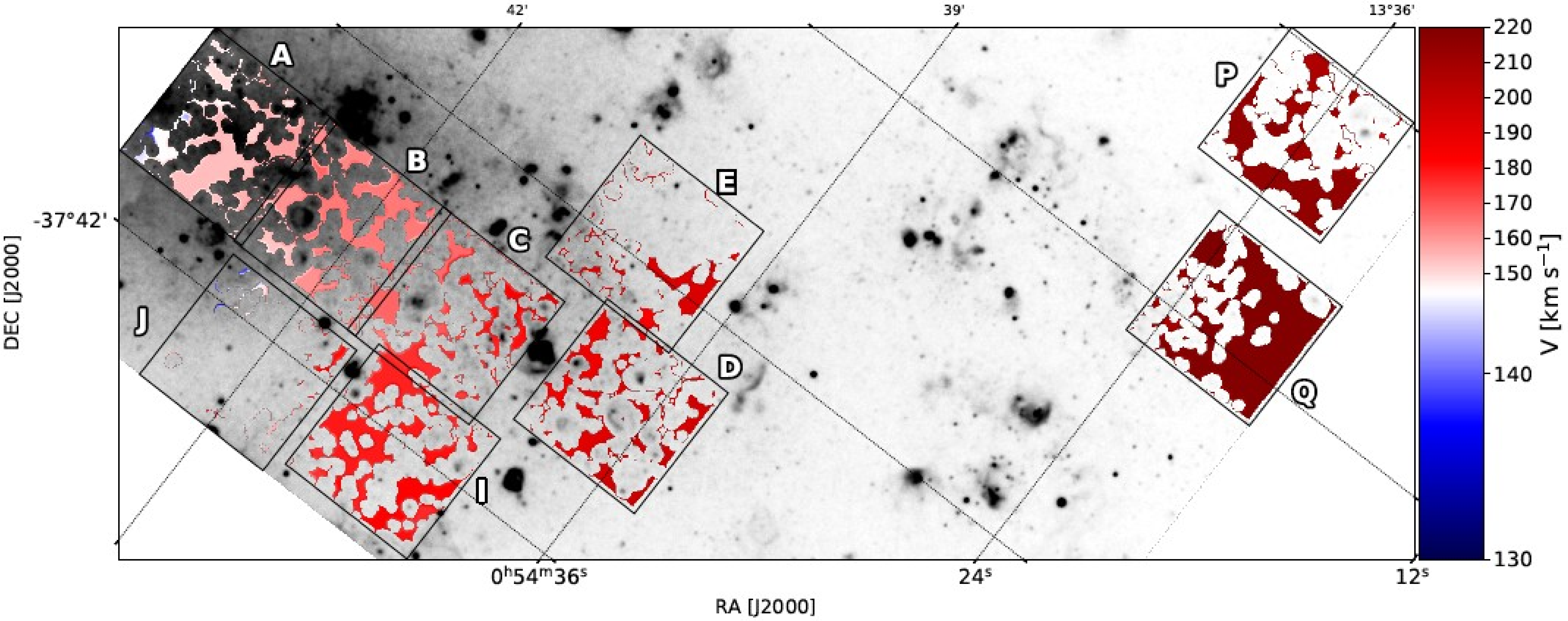
Micheva et al. 2028

Radial velocities (stars)



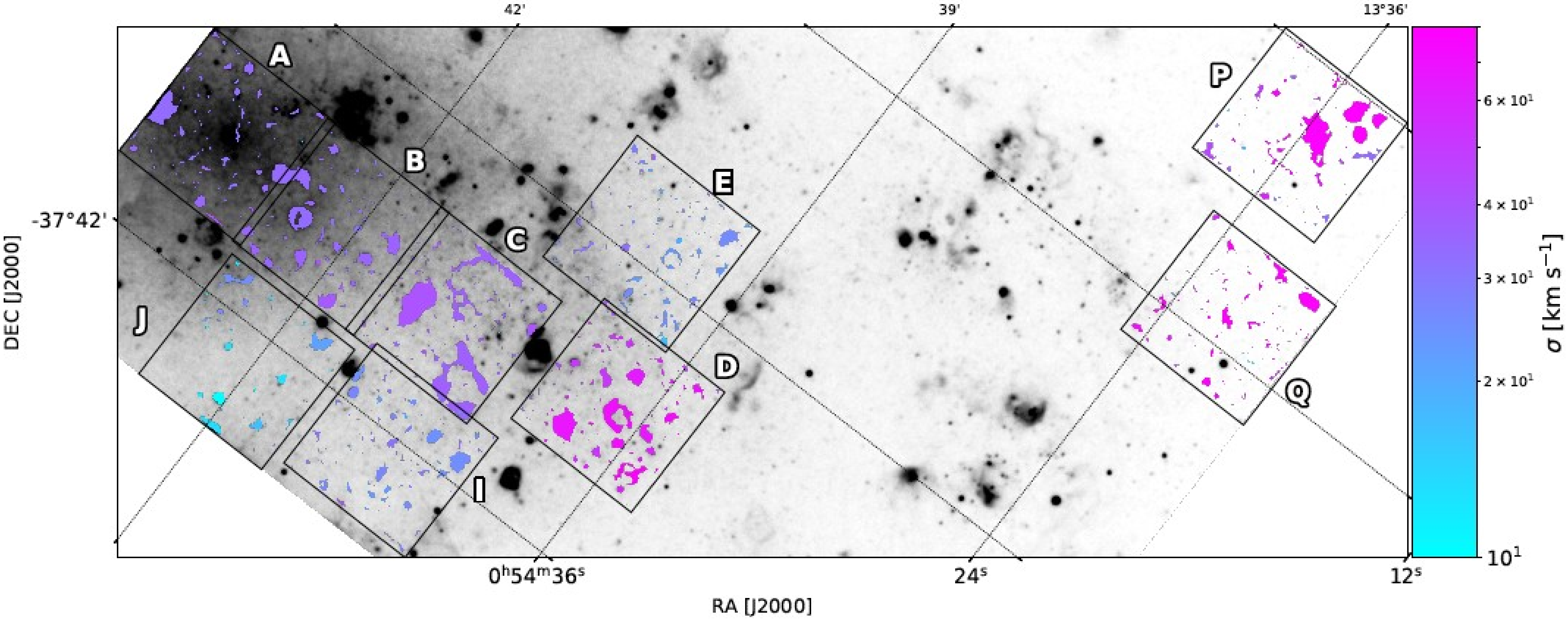
Micheva et al. 2028

Radial velocities (DIG)



Micheva et al. 2028

Velocity dispersion (stars)



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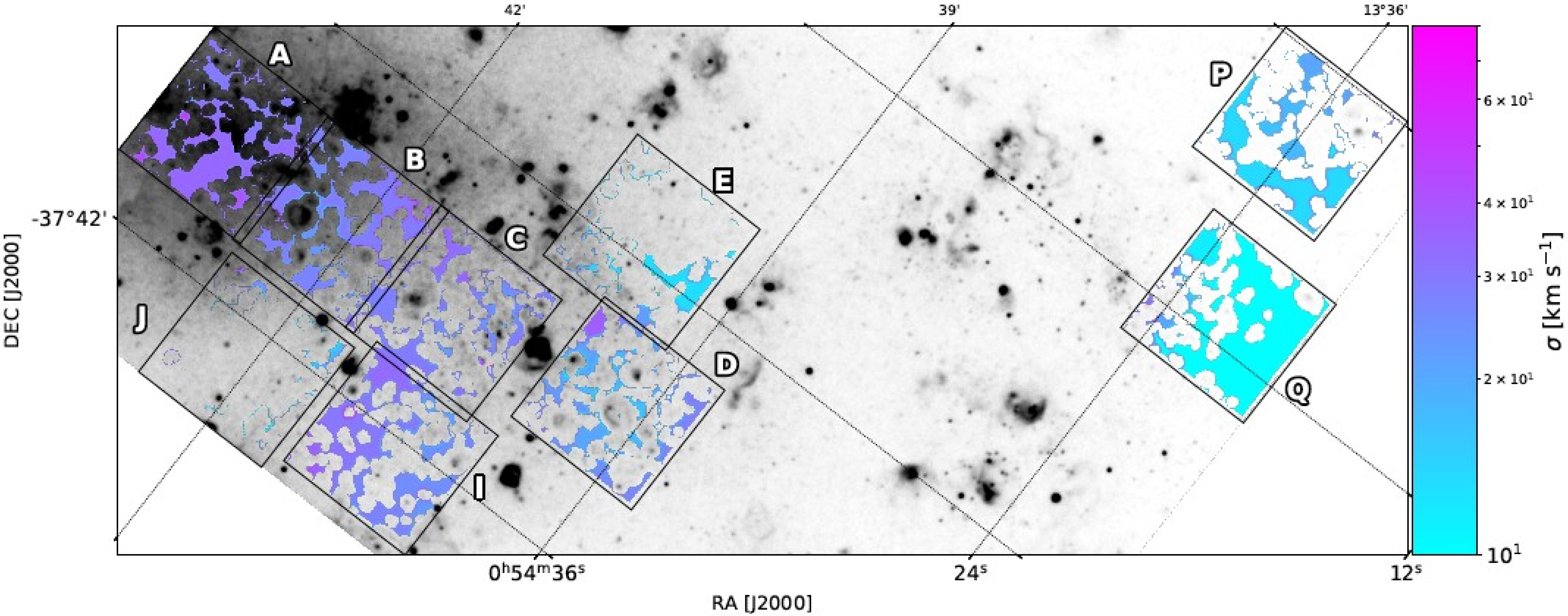
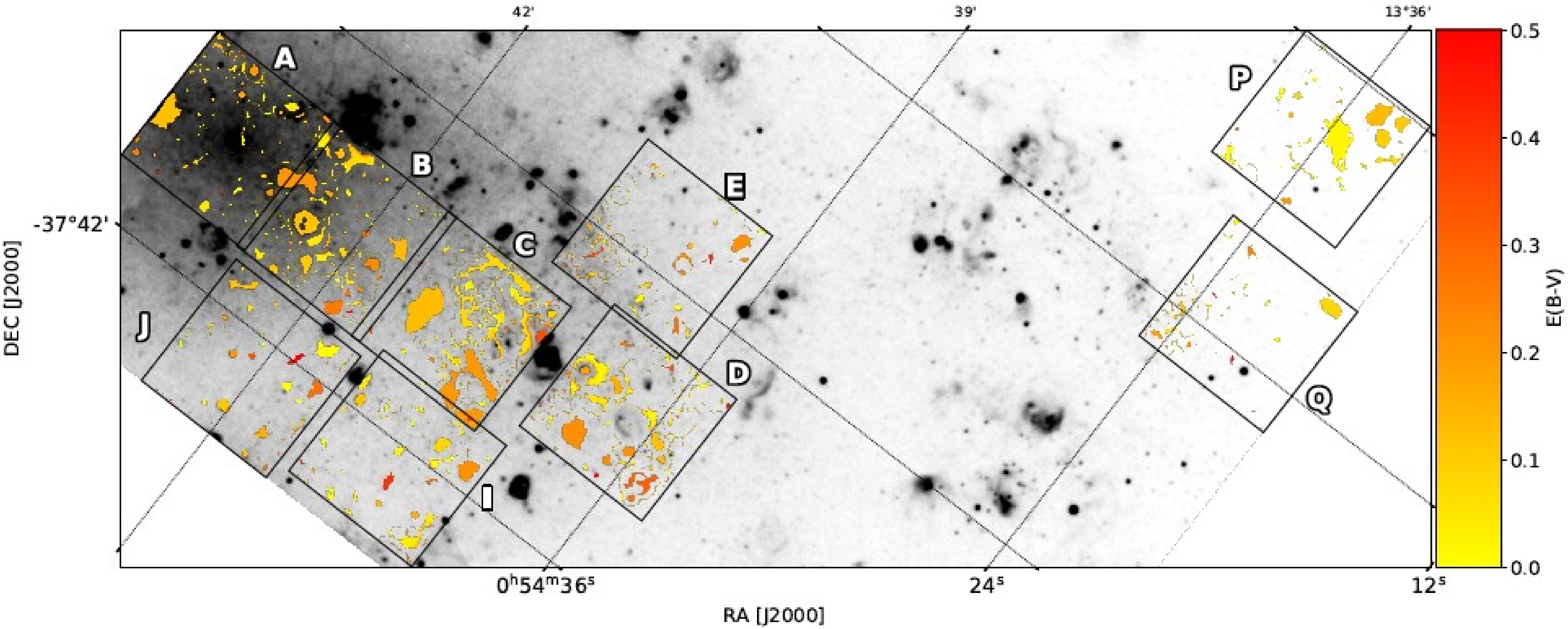
Velocity dispersion (DIG)



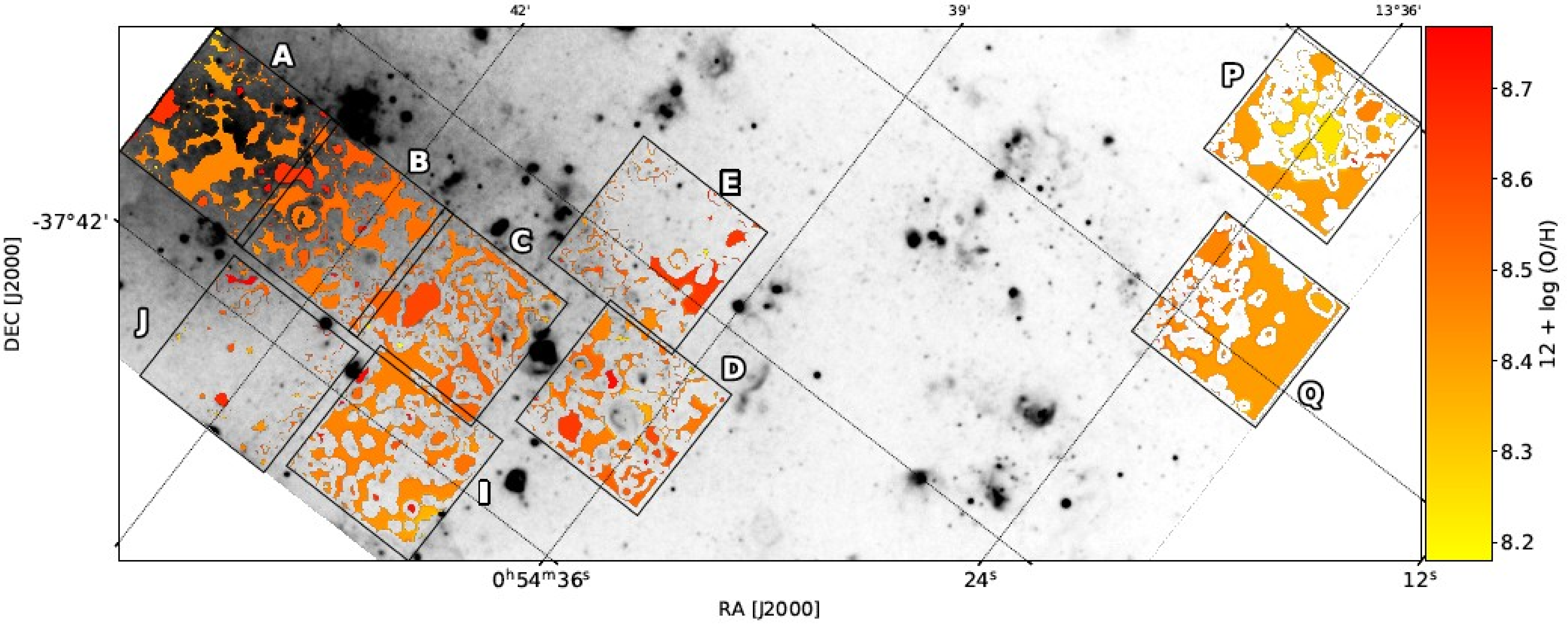
Micheva et al. 2028

Nebular extinction



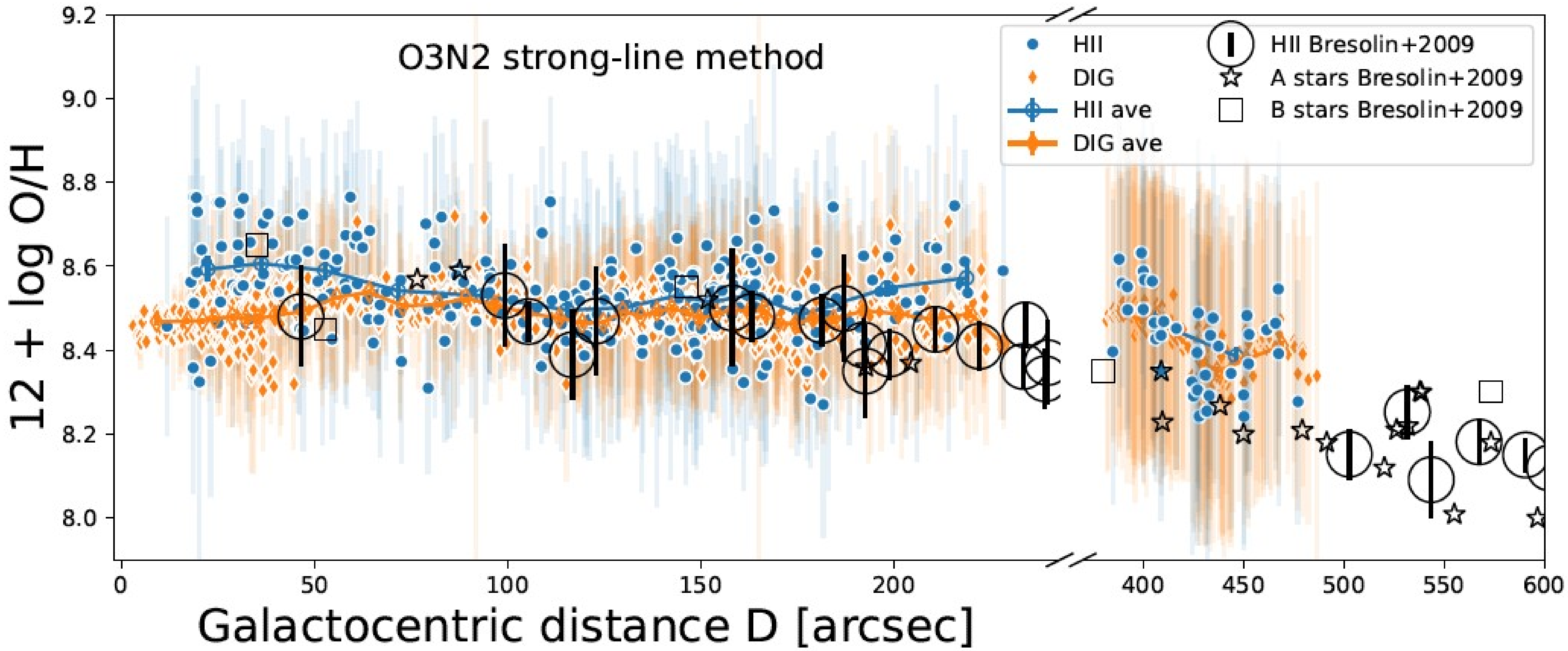
Micheva et al. 2028

Oxygen abundance



Micheva et al. 2028

Radial abundance gradient



Micheva et al. 2028

Conclusions

1. The distribution of [S II]λ6731/16 ratios for the H II and DIG regions peak at the extreme low-density limit.

2. Most of the DIG is consistent with no extinction, E(B−V) = 0.

3. The metallicity of the DIG, 8.48 on average, is consistent with that of the H II regions, 8.53 on ave

qH ???

4. The H II and DIG regions move together with similar velocities.

5. The average velocity dispersion is 21 km/s for H II gas and 25 km/s for DIG. Thermal velocity dispersion suggests DIG 1.8kK hotter than H II regions.

6. The DIG has an increased velocity dispersion in the central galactic region, consistent with models of a dominant (~60%) shock ionization.

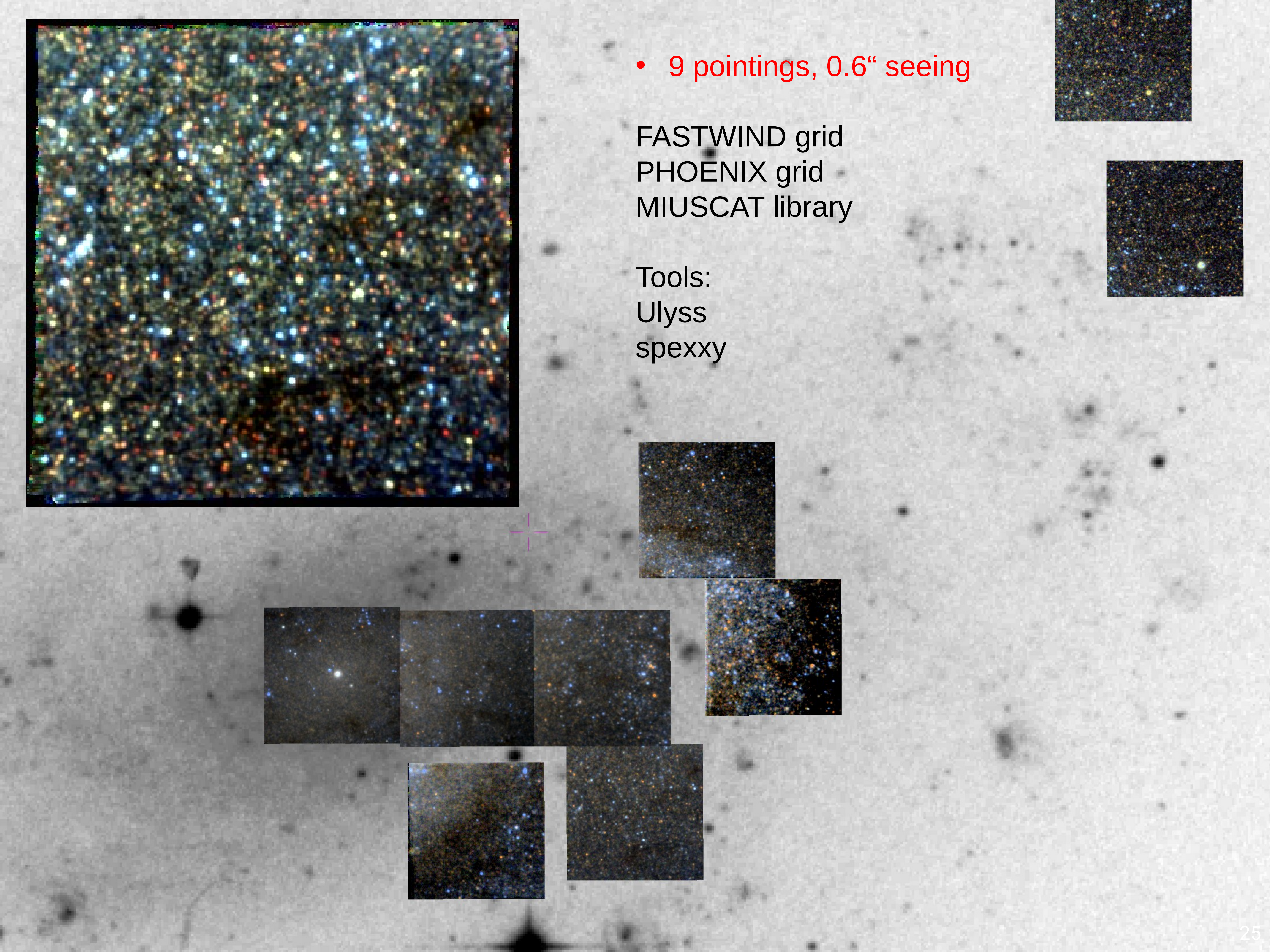
7. The DIG fraction per field varies between 42–77% of Hα. The inter-arm region field J shows a much lower DIG fraction of 15%.

8. The DIG has a lower ionization state than H II gas, as traced by the high-to-low ionization line ratio S III]λ9068/[S II]λ6716 + 31.

9. Signs of a contribution to DIG ionization by hot low-mass evolved stars are detected:
    (i) flat trend of the DIG [S III]λ9068/[S II]λ6716 + 31 ratio with Hα surface brightness, in contrast to a positive correlation for H II regions,
    (ii) low ionization line ratios show systematic enhancement toward small galactocentric distances, in contrast to a flat trend for H II regions.

10. Unsupervised machine-learning algorithms are unable to distinguish between DIG and H II regions, implying that both the DIG and the H II regions are so heterogeneous that the differences within hem are larger than between them.

11. The differences between extremely faint H II and DIG regions follow the same trends as their brighter counterparts.



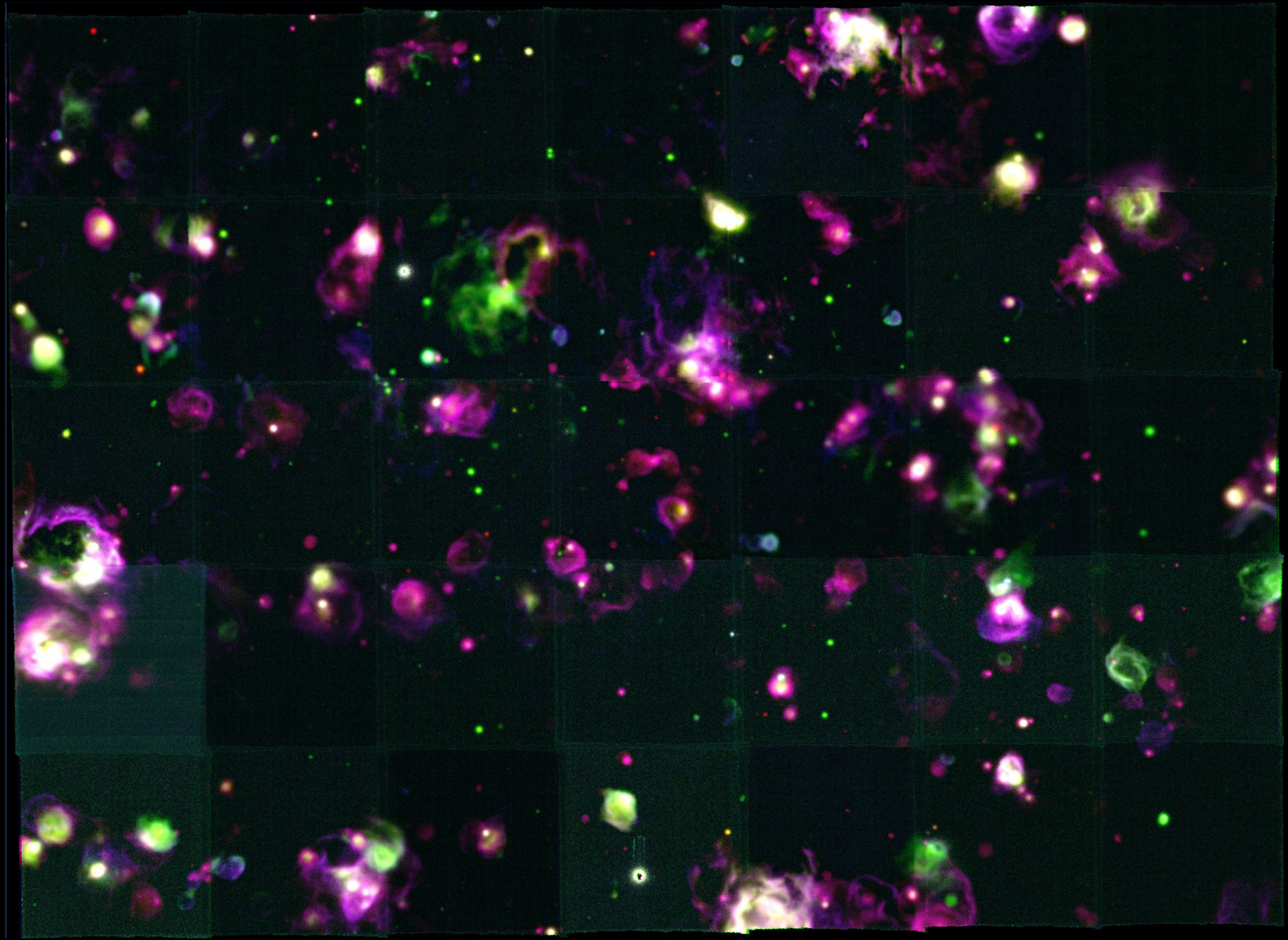
- 9 pointings, 0.6“ seeing

FASTWIND grid
PHOENIX grid
MIUSCAT library

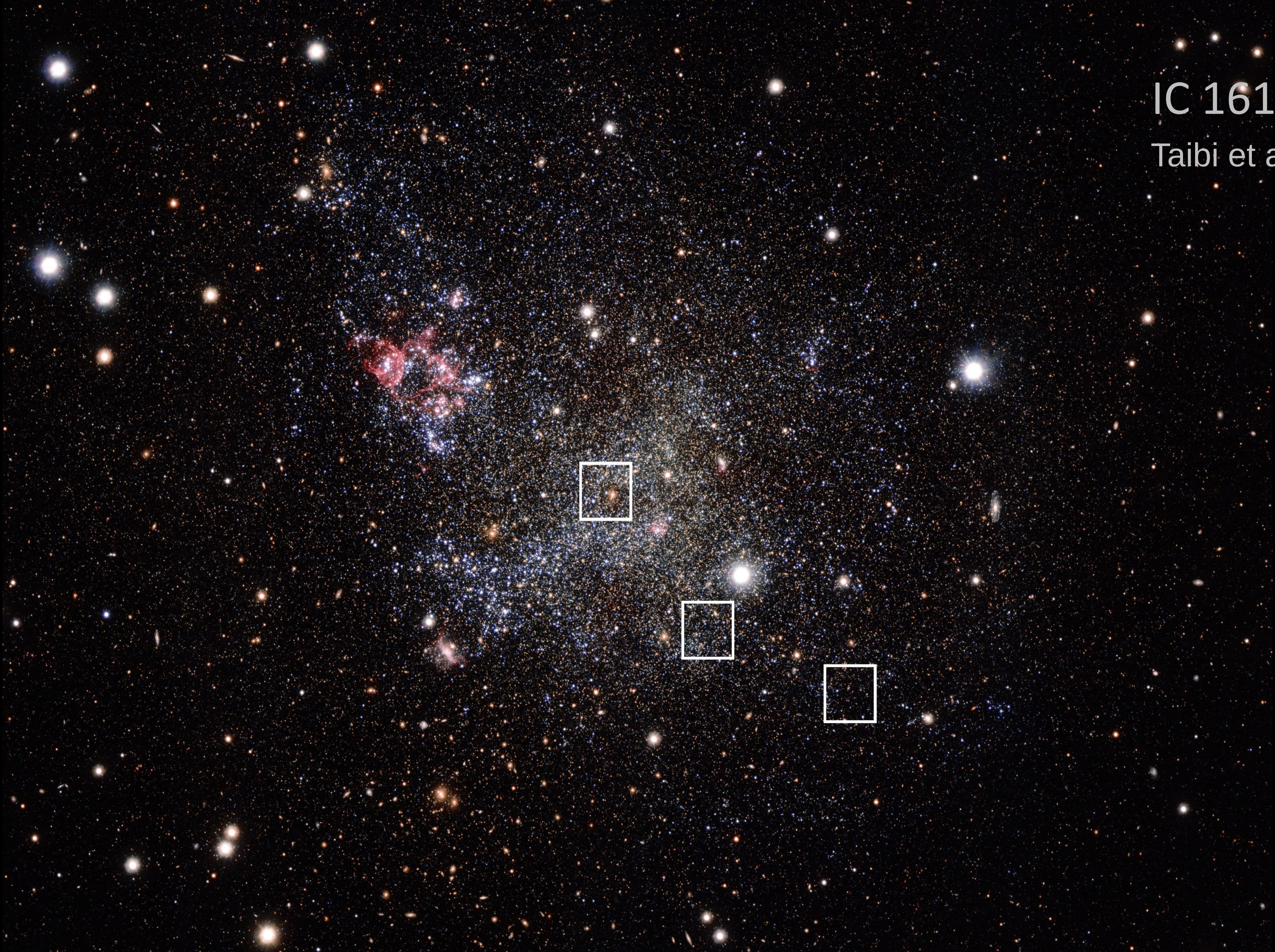
Tools:
Ulyss
spexxy

Joshua Jost

Norberto Castro

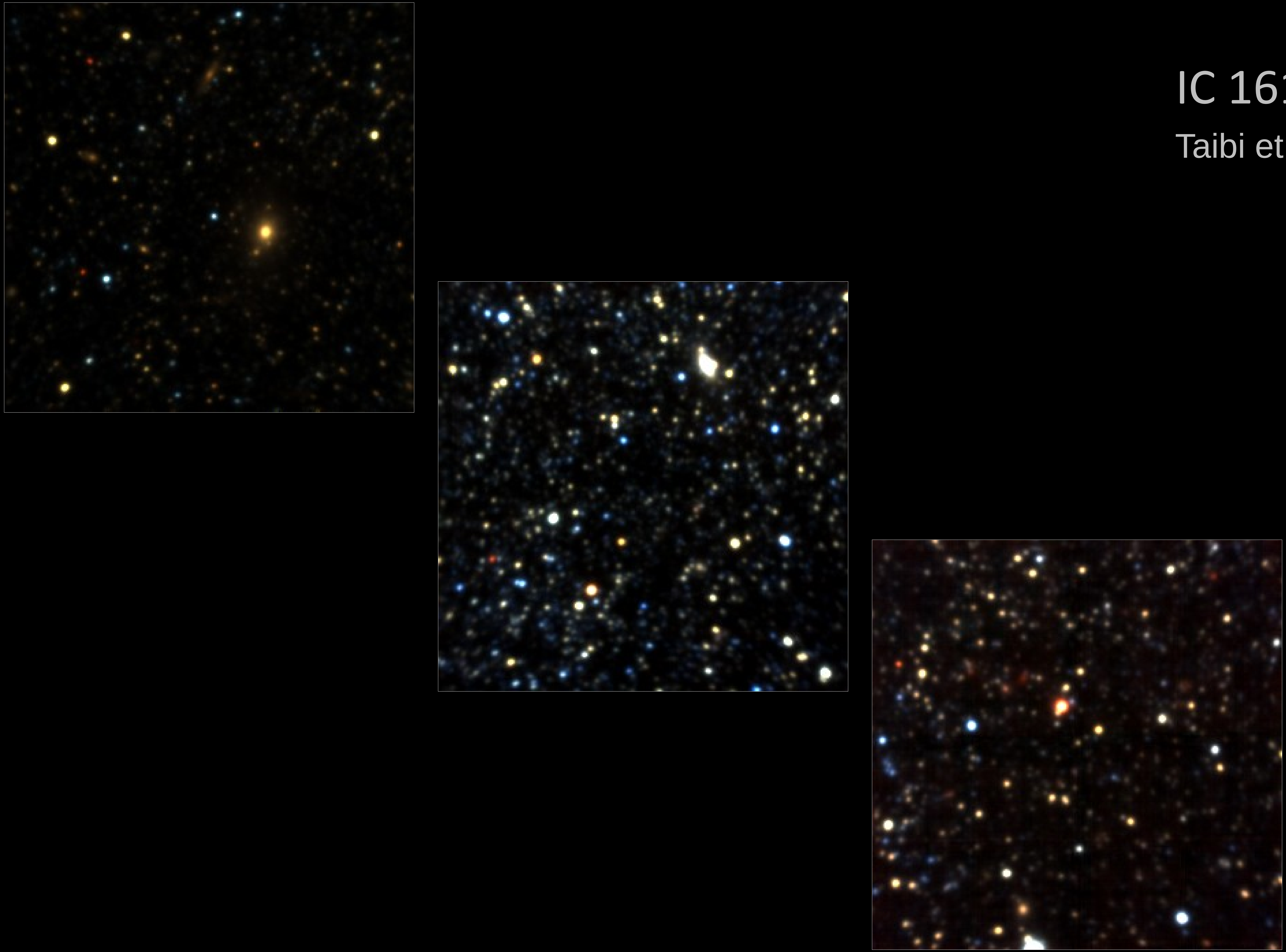


MUSE Survey
NGC 300
PI: A. McLeod


IC 1613
Taibi et al. (in prep)

IC 1613

Taibi et al. (in prep)




30 Dor - R136
Castro et al. (in prep)

Mapping the Youngest and most Massive Stars in the Tarantula Nebula with MUSE-NFM

DOI: 10.18727/0722-6691/5223

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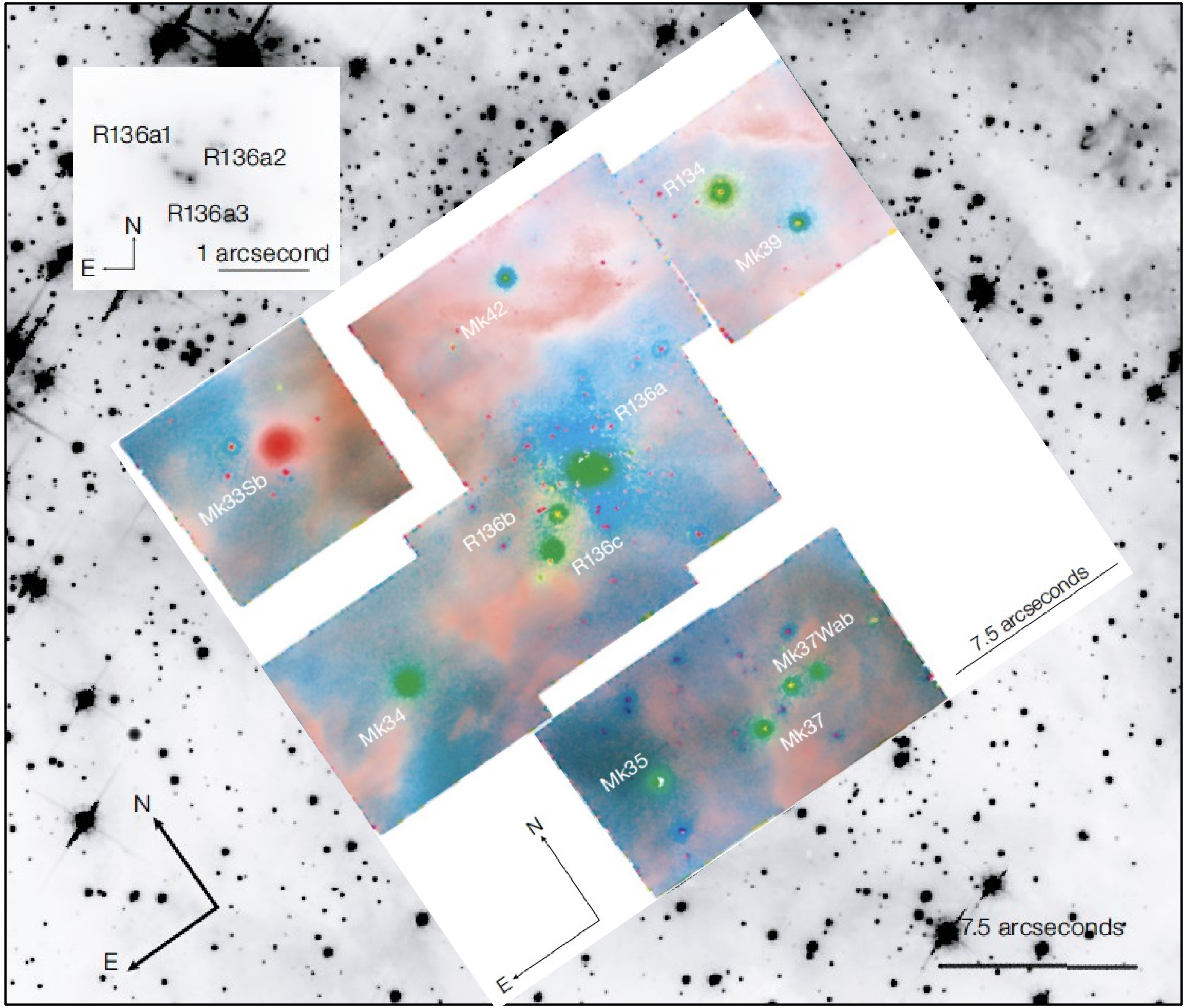
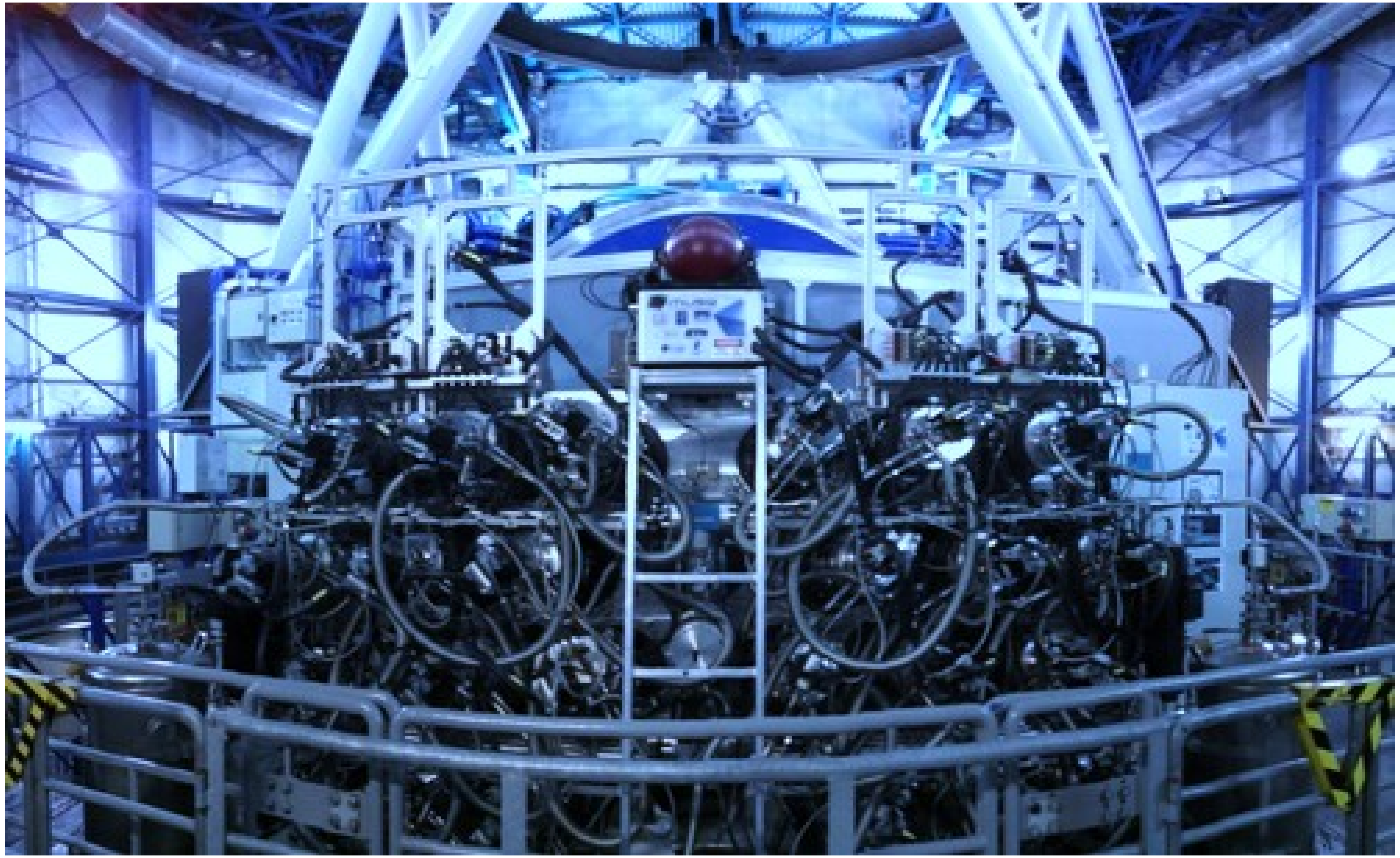


Part 2:

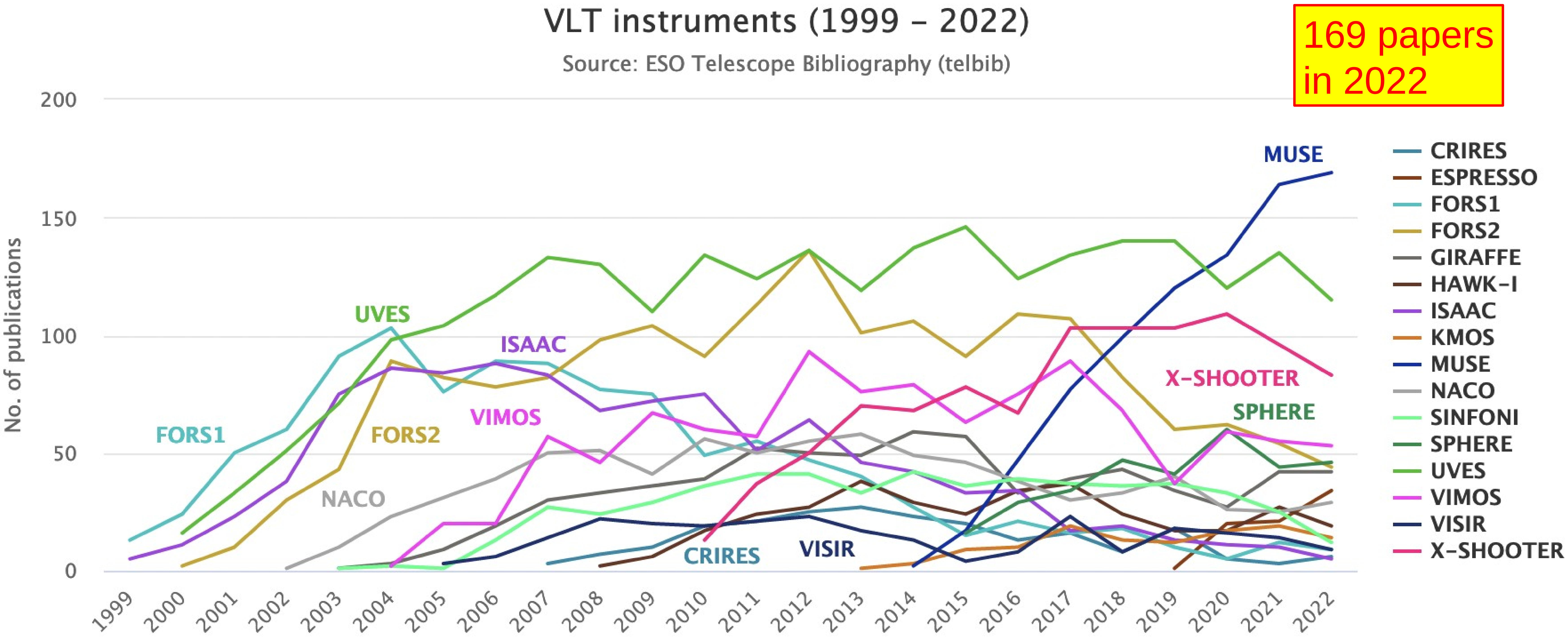
Blue MUSE

BLUE MUSE
multi unit spectroscopic explorer



3rd generation VLT instrument

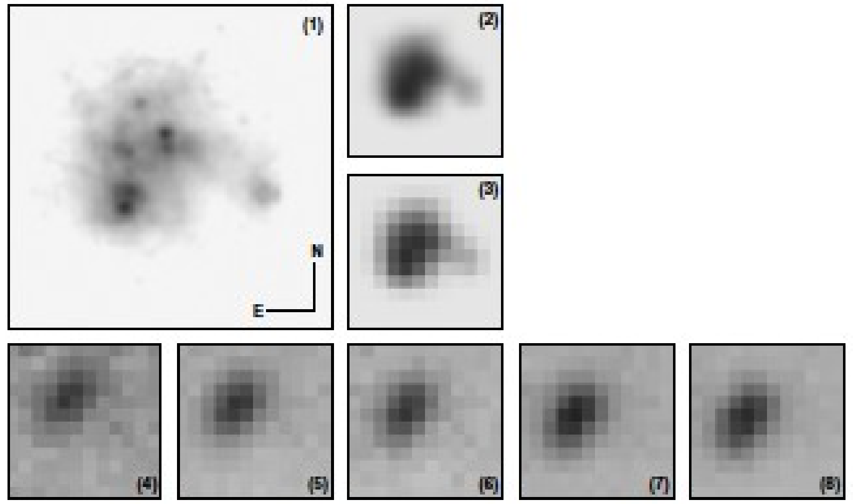
VLT Observatory Publication Statistics

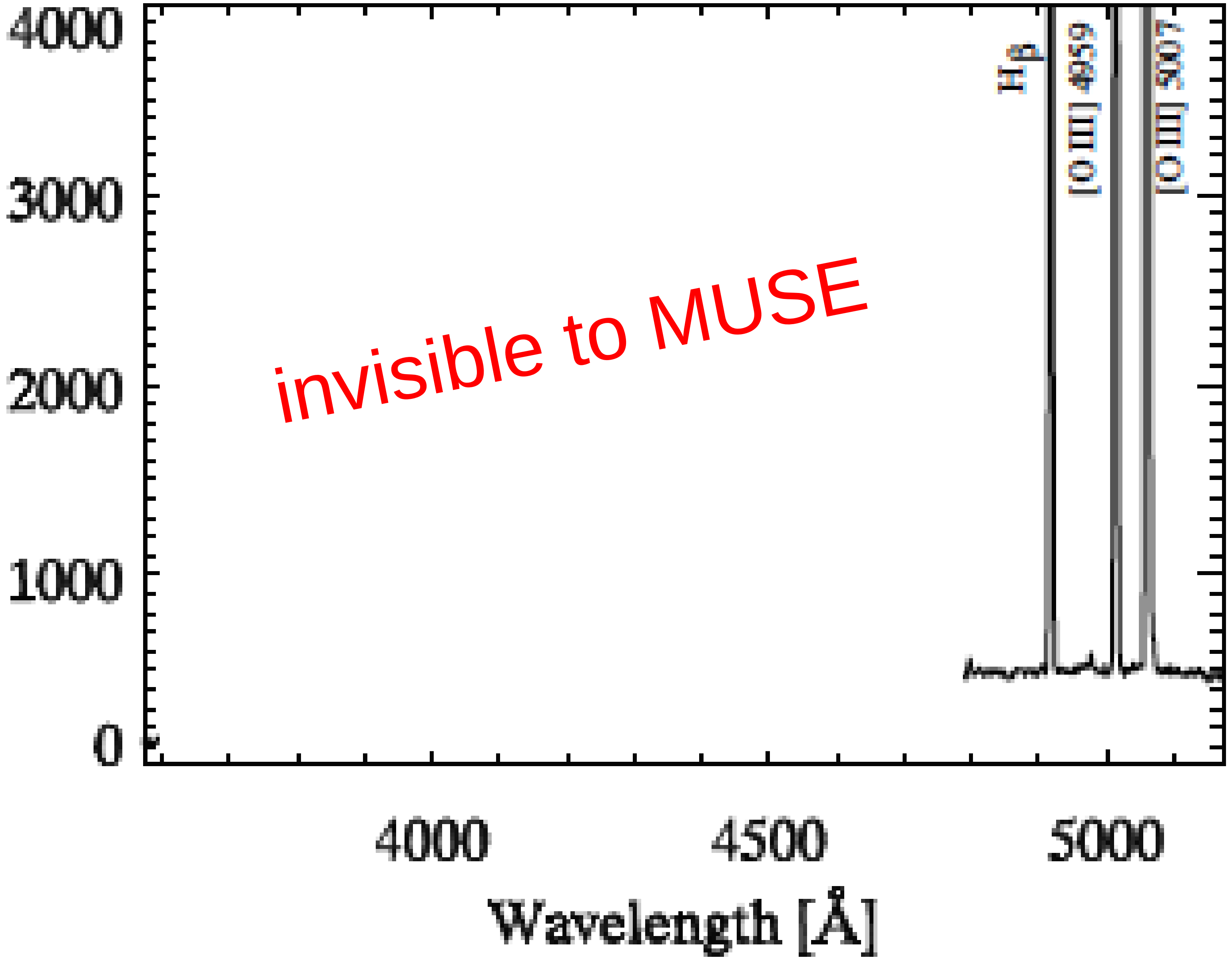


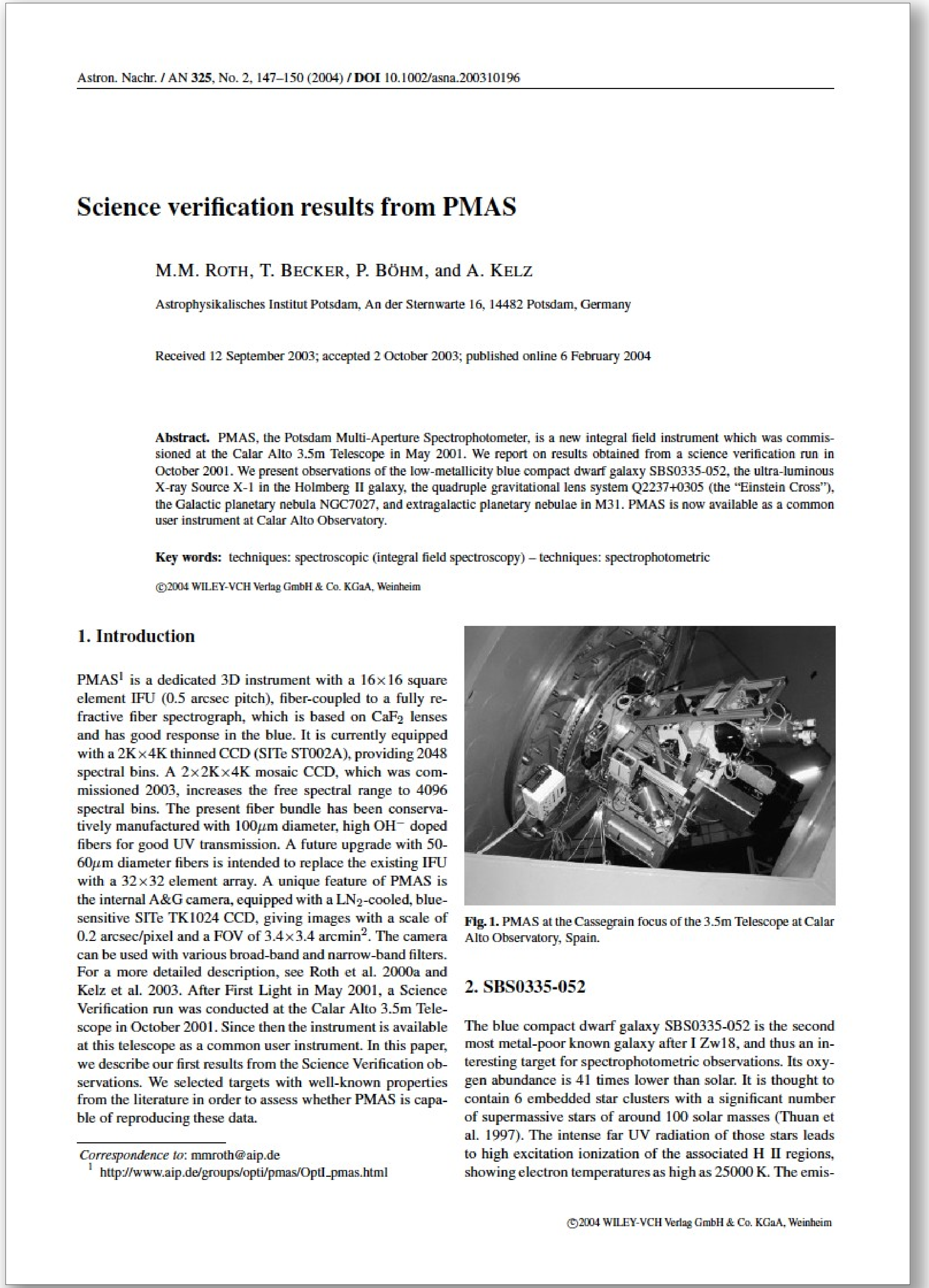
169 papers in 2022

BLUE MUSE
multi unit spectroscopic explorer

SBS0335-052
observed with PMAS







Astron. Nachr. / AN **325**, No. 2, 147–150 (2004) / **DOI** 10.1002/asna.200310196

Science verification results from PMAS

M.M. Roth, T. Becker, P. Böhm, and A. Kelz

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Received 12 September 2003; accepted 2 October 2003; published online 6 February 2004

Abstract. PMAS, the Potsdam Multi-Aperture Spectrophotometer, is a new integral field instrument which was commissioned at the Calar Alto 3.5m Telescope in May 2001. We report on results obtained from a science verification run in October 2001. We present observations of the low-metallicity blue compact dwarf galaxy SBS0335-052, the ultra-luminous X-ray Source X-1 in the Holmberg II galaxy, the quadruple gravitational lens system Q2237+0305 (the "Einstein Cross"), the Galactic planetary nebula NGC7027, and extragalactic planetary nebulae in M31. PMAS is now available as a common user instrument at Calar Alto Observatory.

Key words: techniques: spectroscopic (integral field spectroscopy) – techniques: spectrophotometric

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1. Introduction

PMAS[1] is a dedicated 3D instrument with a 16×16 square element IFU (0.5 arcsec pitch), fiber-coupled to a fully refractive fiber spectrograph, which is based on CaF_2 lenses and has good response in the blue. It is currently equipped with a 2K×4K thinned CCD (SITe ST002A), providing 2048 spectral bins. A 2×2K×4K mosaic CCD, which was commissioned 2003, increases the free spectral range to 4096 spectral bins. The present fiber bundle has been conservatively manufactured with 100μm diameter, high OH^- doped fibers for good UV transmission. A future upgrade with 50-60μm diameter fibers is intended to replace the existing IFU with a 32×32 element array. A unique feature of PMAS is the internal A&G camera, equipped with a LN_2-cooled, blue-sensitive SITe TK1024 CCD, giving images with a scale of 0.2 arcsec/pixel and a FOV of 3.4×3.4 arcmin^2. The camera can be used with various broad-band and narrow-band filters. For a more detailed description, see Roth et al. 2000a and Kelz et al. 2003. After First Light in May 2001, a Science Verification run was conducted at the Calar Alto 3.5m Telescope in October 2001. Since then the instrument is available at this telescope as a common user instrument. In this paper, we describe our first results from the Science Verification observations. We selected targets with well-known properties from the literature in order to assess whether PMAS is capable of reproducing these data.

Fig. 1. PMAS at the Cassegrain focus of the 3.5m Telescope at Calar Alto Observatory, Spain.

2. SBS0335-052

The blue compact dwarf galaxy SBS0335-052 is the second most metal-poor known galaxy after I Zw18, and thus an interesting target for spectrophotometric observations. Its oxygen abundance is 41 times lower than solar. It is thought to contain 6 embedded star clusters with a significant number of supermassive stars of around 100 solar masses (Thuan et al. 1997). The intense far UV radiation of those stars leads to high excitation ionization of the associated H II regions, showing electron temperatures as high as 25000 K. The emis-

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[1] http://www.aip.de/groups/opti/pmas/OptI_pmas.html

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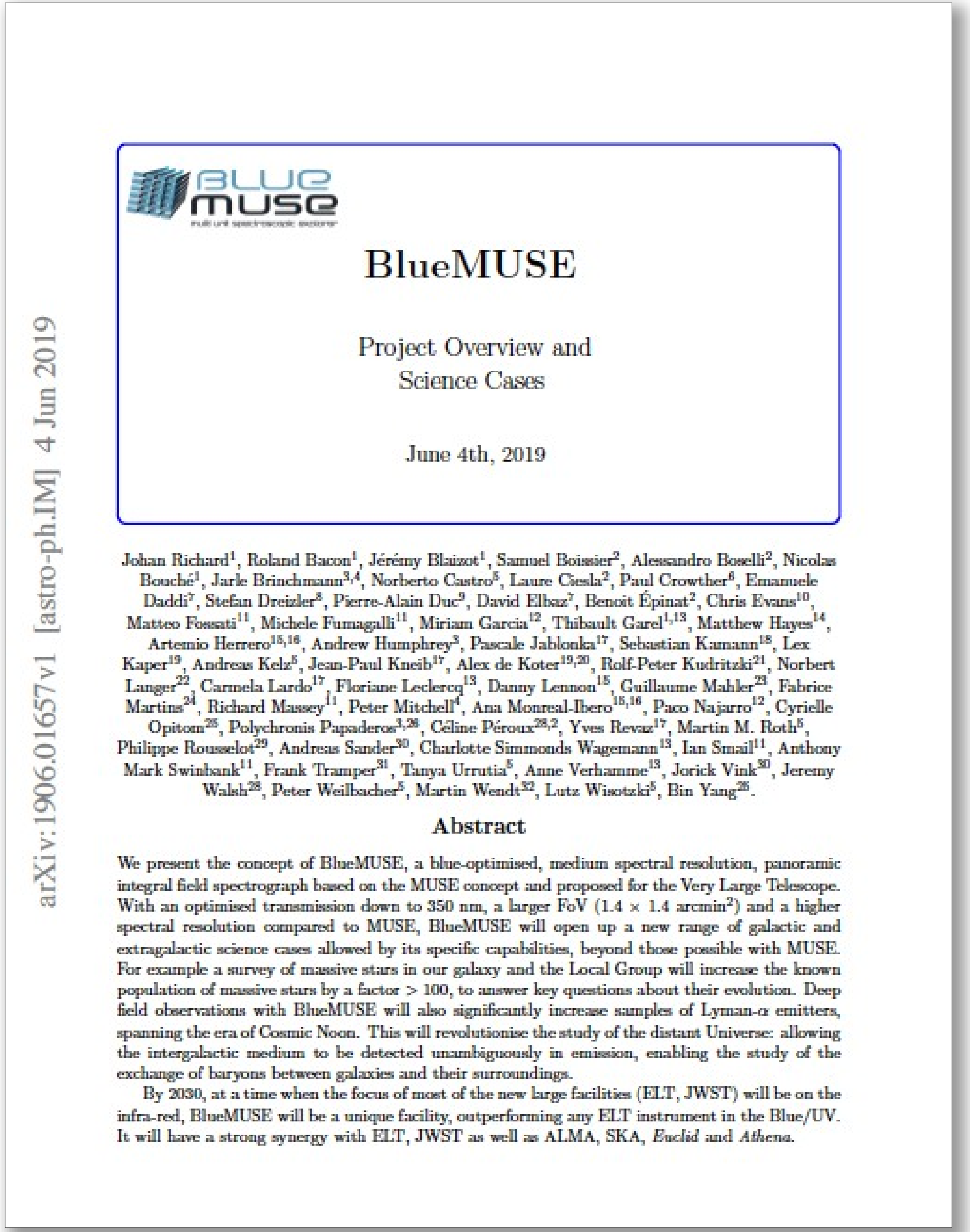
Massive Stars
Highlight Science Case

with input from 15 scientists from 12 different institutions out of 6 ESO member states:

Norberto Castro (AIP, Potsdam)
Paul Crowther (Univ. Sheffield)
Alex de Koter (Univ. Amsterdam)
Chris Evans (UKATC Edingburgh)
Miriam Garcia (CSIC-INTA, Madrid)
Artemio Herrero (IAC Tenerife)
Lex Kaper (Univ. Amsterdam)
Rolf-Peter Kudritzki (LMU Munich)
Norbert Langer (Univ. Bonn)
Danny Lennon (IAC, Tenerife)
Fabrice Martins (Univ. Montpellier)
Paco Najarro (CSIC-INTA, Madrid)
Andreas Sander (Univ. Potsdam)
Frank Tramper (NOA, Athens)
Jorick Vink (Armagh Univ.)



arXiv:1906.01657v1 [astro-ph.IM] 4 Jun 2019

BlueMUSE

Project Overview and Science Cases

June 4th, 2019

Johan Richard[1], Roland Bacon[1], Jérémy Blaizot[1], Samuel Boissier[2], Alessandro Boselli[2], Nicolas Bouché[1], Jarle Brinchmann[3,4], Norberto Castro[5], Laure Ciesla[2], Paul Crowther[6], Emanuele Daddi[7], Stefan Dreizler[8], Pierre-Alain Duc[9], David Elbaz[7], Benoit Épinat[2], Chris Evans[10], Matteo Fossati[11], Michele Fumagalli[11], Miriam Garcia[12], Thibault Garel[1,13], Matthew Hayes[14], Artemio Herrero[15,16], Andrew Humphrey[3], Pascale Jablonka[17], Sebastian Kamann[18], Lex Kaper[19], Andreas Kelz[5], Jean-Paul Kneib[17], Alex de Koter[19,20], Rolf-Peter Kudritzki[21], Norbert Langer[22], Carmela Lardo[17], Floriane Leclercq[13], Danny Lennon[15], Guillaume Mahler[23], Fabrice Martins[24], Richard Massey[11], Peter Mitchell[4], Ana Monreal-Ibero[15,16], Paco Najarro[12], Cyrielle Opitom[25], Polychronis Papaderos[3,26], Céline Péroux[28,2], Yves Revaz[17], Martin M. Roth[5], Philippe Rousselot[29], Andreas Sander[30], Charlotte Simmonds Wagemann[13], Ian Smail[11], Anthony Mark Swinbank[11], Frank Tramper[31], Tanya Urrutia[5], Anne Verhamme[13], Jorick Vink[30], Jeremy Walsh[28], Peter Weilbacher[5], Martin Wendt[32], Lutz Wisotzki[5], Bin Yang[25].

Abstract

We present the concept of BlueMUSE, a blue-optimised, medium spectral resolution, panoramic integral field spectrograph based on the MUSE concept and proposed for the Very Large Telescope. With an optimised transmission down to 350 nm, a larger FoV (1.4 × 1.4 arcmin^2) and a higher spectral resolution compared to MUSE, BlueMUSE will open up a new range of galactic and extragalactic science cases allowed by its specific capabilities, beyond those possible with MUSE. For example a survey of massive stars in our galaxy and the Local Group will increase the known population of massive stars by a factor > 100, to answer key questions about their evolution. Deep field observations with BlueMUSE will also significantly increase samples of Lyman-α emitters, spanning the era of Cosmic Noon. This will revolutionise the study of the distant Universe: allowing the intergalactic medium to be detected unambiguously in emission, enabling the study of the exchange of baryons between galaxies and their surroundings.

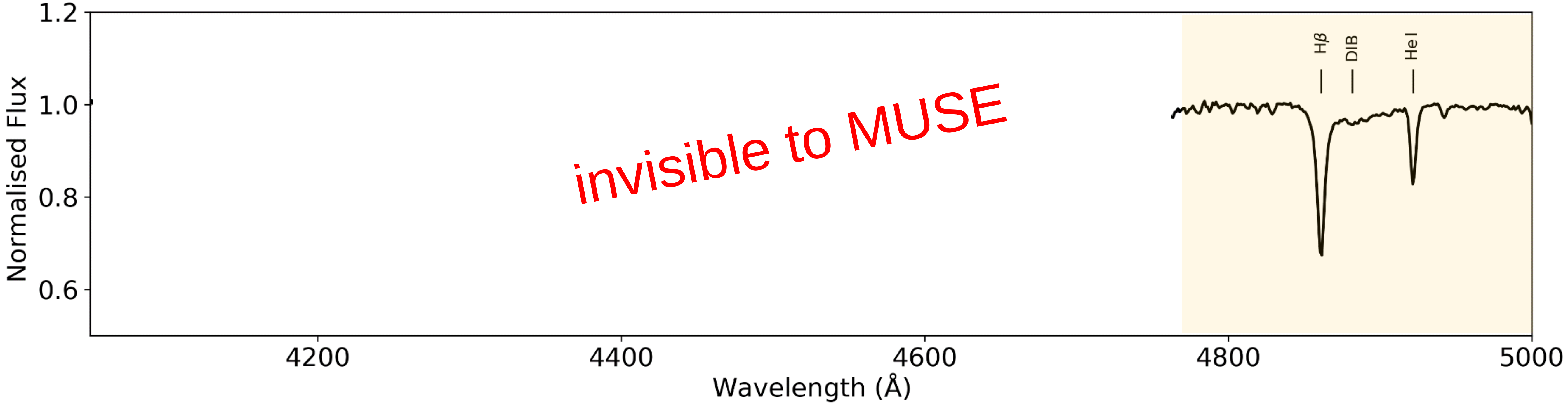
By 2030, at a time when the focus of most of the new large facilities (ELT, JWST) will be on the infra-red, BlueMUSE will be a unique facility, outperforming any ELT instrument in the Blue/UV. It will have a strong synergy with ELT, JWST as well as ALMA, SKA, *Euclid* and *Athena*.

Understanding massive stars:
astrophysical context and relevance

- Stellar winds → feedback
- Progenitors to SN II → feedback
- Ionizing sources for HII regions → SFR, DIG, Ly →
- Probing abundances of contemporary stellar populations → alternative to strong line nebular abundances
- Super star clusters
- Progenitors to BH binaries: gravitation waves
- Pop III stars, re-ionization

► quantitative spectroscopy of large samples of massive stars needed !

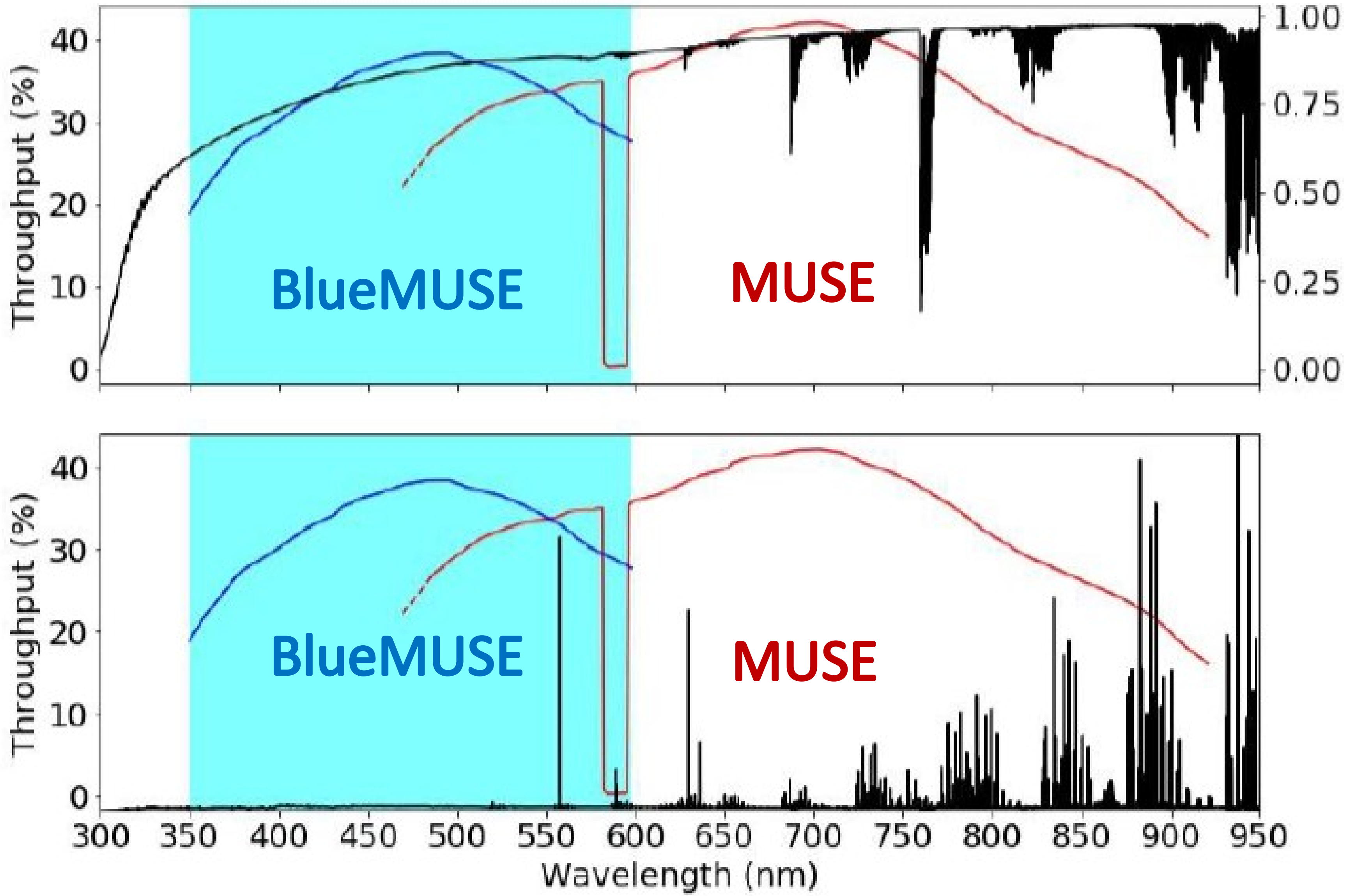
The need for BlueMUSE:



- Balmer lines ☷ **log (g)**
- Balmer jump at 3646 A ☰ **Teff**
- He II 4686 and nearby CNO lines: **wind + classification criteria**
- Si IV 4089/4116, Si III triplet 4552, Si II 4128/4130 , He I 4471/4387, He II 4200/4541 ☰ **Teff + helium abundance**
- **WR emission** (“blue bump”), O VI 3811
- **Stars hotter than 45.000 K**: N III, N IV and N V ☰ **Teff**
- C II, C III, N II, N III, N IV, N V, O II, O III, Si II, Si III, Si IV, Mg II ☷ **Teff, log (g), chemical abundances**

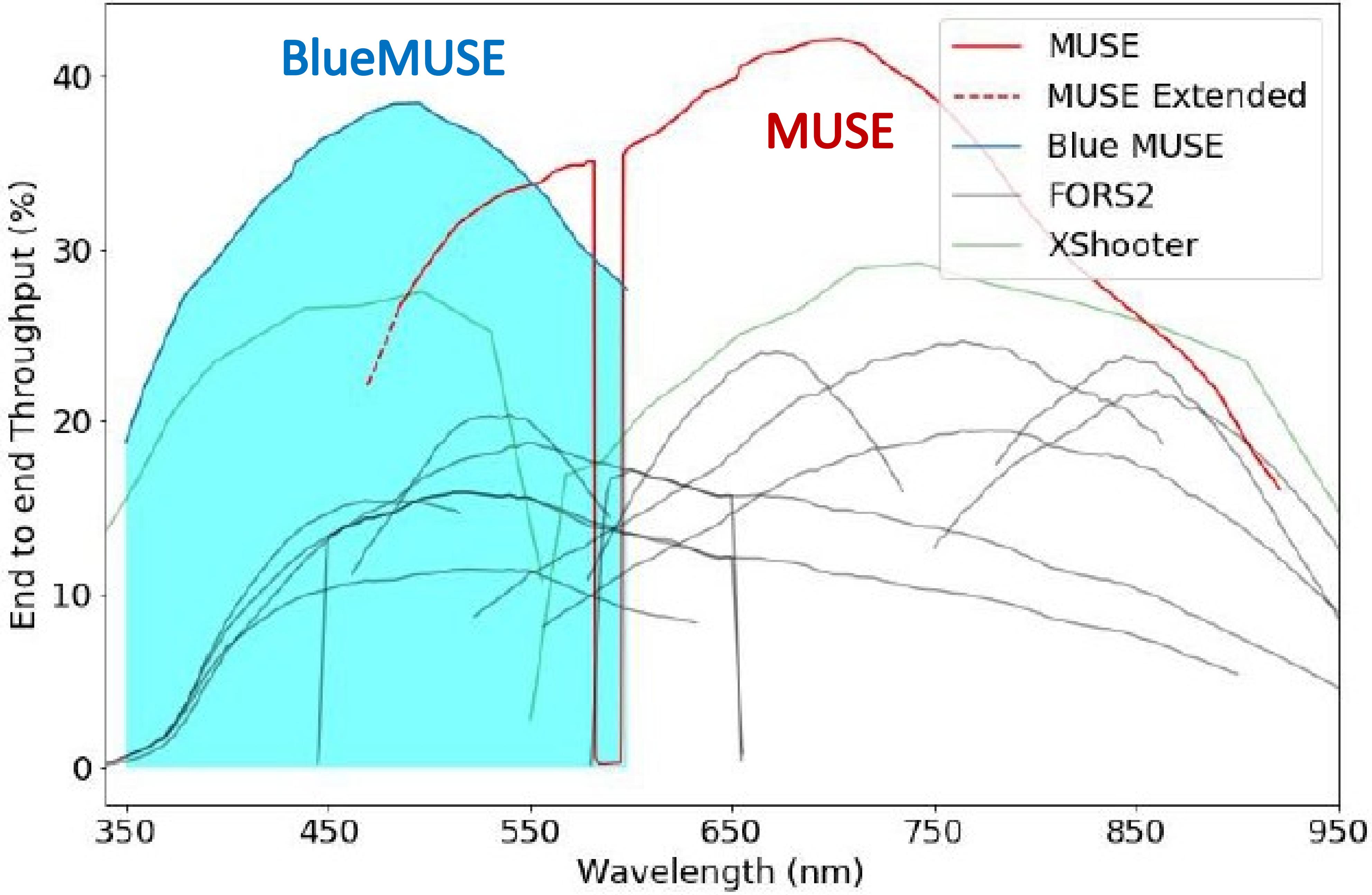
Blue wavelength coverage: 370 - 600 nm

- complementarity with MUSE
- blue limit adapted to atmosphere transmission
- red limit recovers AO notch filter gap



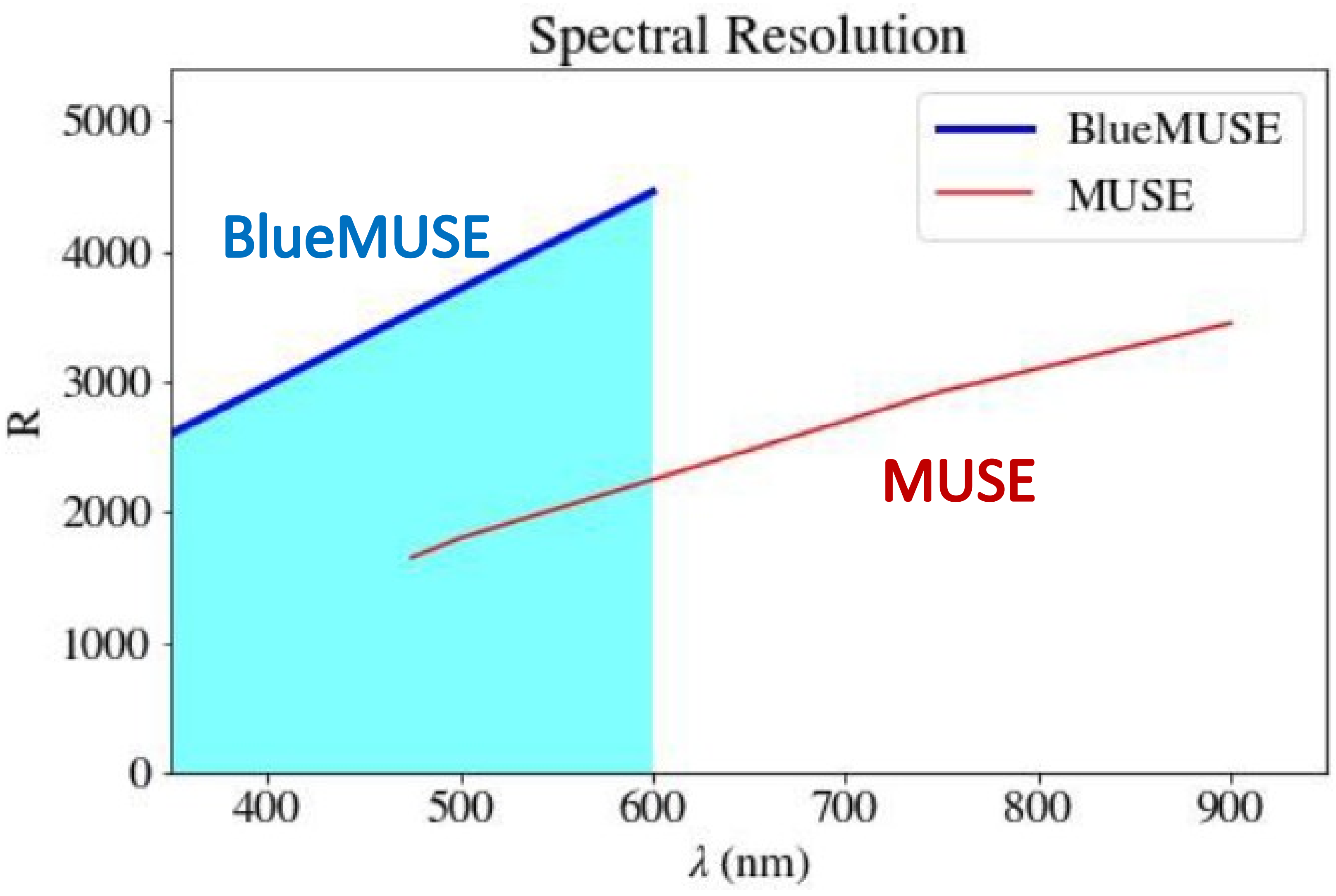
Comparison between BlueMUSE (blue curve) and MUSE (red curve) sensitivities and sky emission.

High throughput



Medium spectral resolution: R 4000

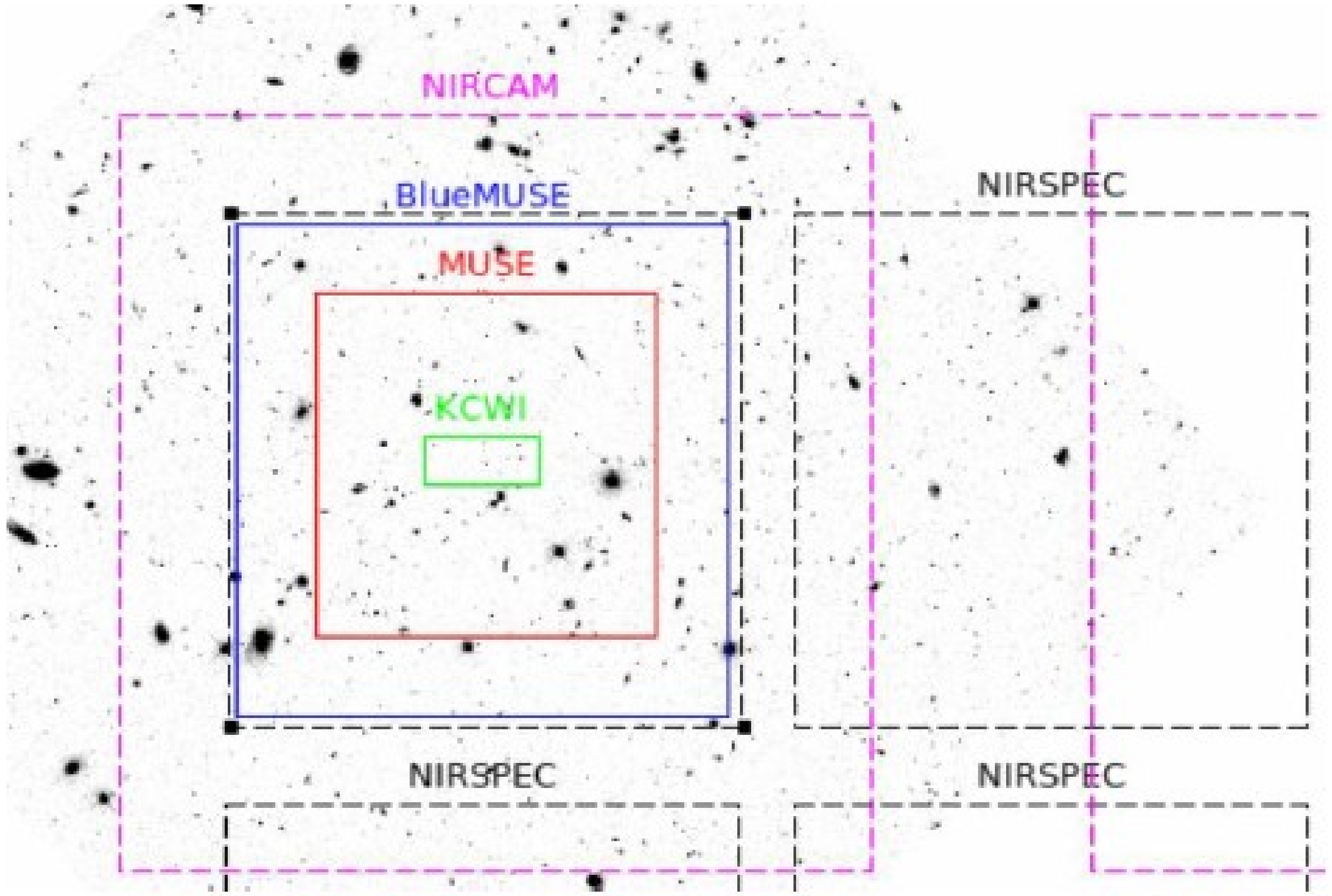
- corresponds to 30 km/s at 480 nm
- more than twice the MUSE spectral resolution at 500 nm < λ < 600 nm
- spectral sampling: 0.6 A / pixel



Comparison between BlueMUSE (blue curve) and MUSE (red curve) spectral resolution.

Field-of-View

- 1.4 x 1.4 arcmin^2
- spatial sampling 0.3 arcsec (0.8” median seeing)

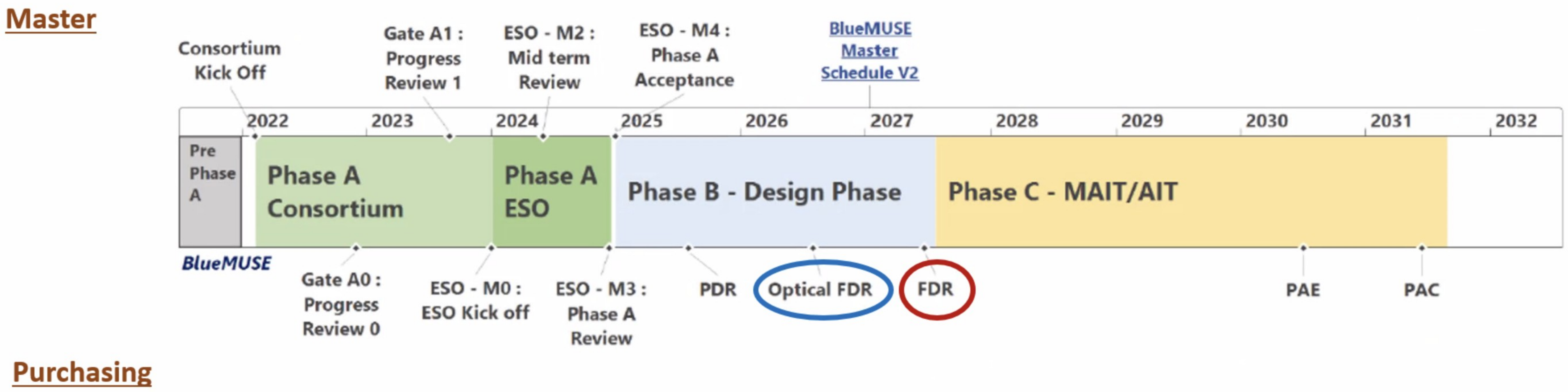


BlueMUSE (blue), MUSE (red), KCWI (green), NIRSPEC (black), NIRCAM (magenta) field of view overlaid on the Hubble UDF F775W image.

MUSE: 1’ x 1’
with sampling 0.2”

Keck Cosmic Web Imager
(KCWI): 8.24” x 20.4”

BlueMUSE Timeline



Optical FDR
(Early Procurement)
- Optical design mostly frozen
- Order of first detector

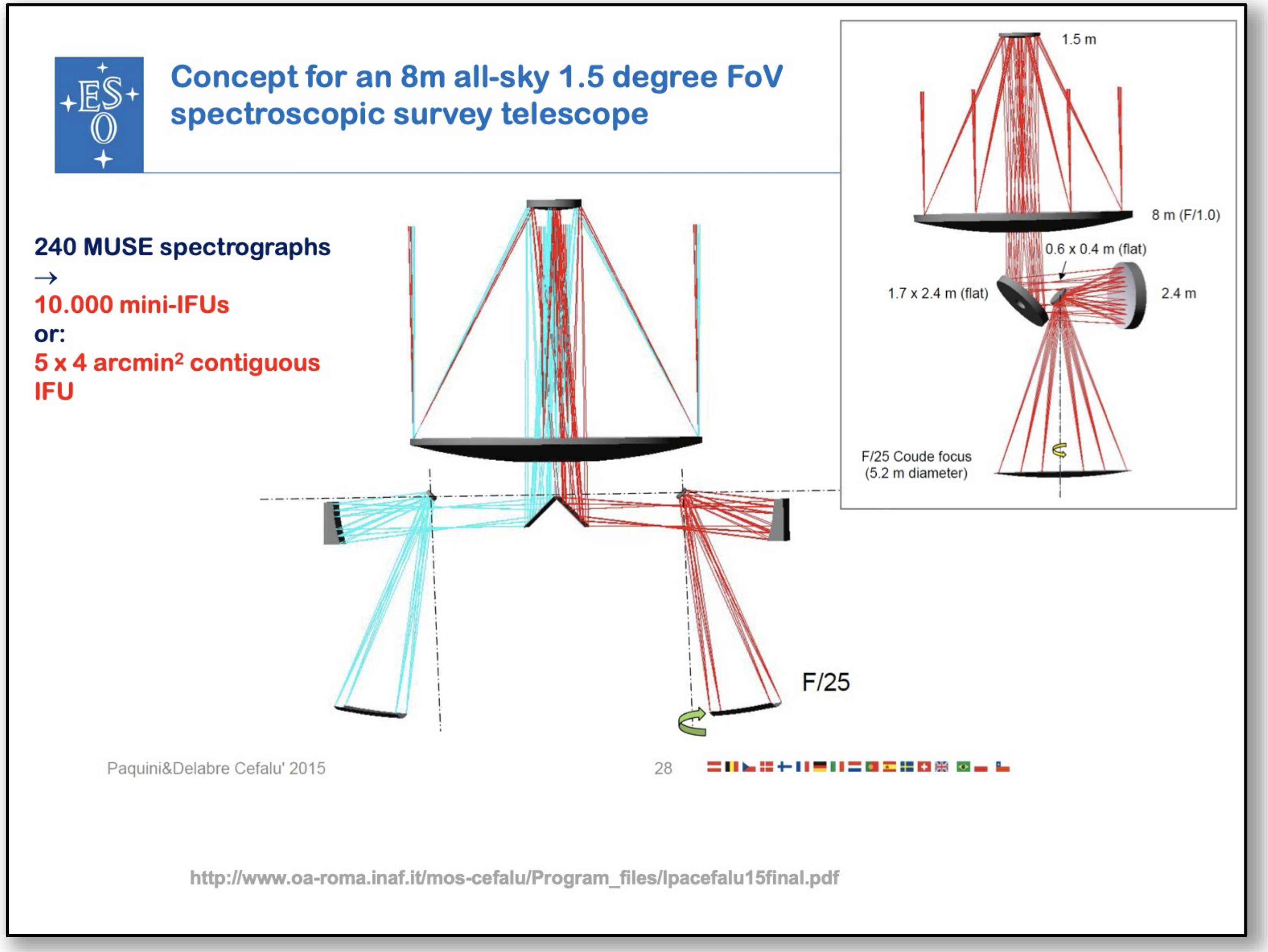
FDR
(All components)
- Design frozen
- Order remaining 23 detectors

Phase C
Manufacturing, Assembly, integration & Test

Part 3:

Wide Field Spectroscopic Survey Telescope (WST)

Lyman Continuum Escape, Kolymbari 2016



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ARTICLE TYPE

Detector System Challenges of the Wide-field Spectroscopic Survey Telescope (WST)

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The wide-field spectroscopic survey telescope (WST) is proposed to become the next large optical/near infrared facility for the European Southern Observatory (ESO) once the Extremely Large Telescope (ELT) has become operational. While the latter is optimized for unprecedented sensitivity and adaptive-optics assisted image quality over a small field-of-view, WST addresses the need for large survey volumes in spectroscopy with the light-collecting power of a 10 m class telescope. Its unique layout will feature the combination of multi-object and integral field spectroscopy simultaneously. For the intended capacity of this layout a very large number of detectors is needed. The complexity of the detector systems presents a number of challenges that are discussed with a focus on novel approaches and innovative detector designs that can be expected to emerge over the anticipated 20 years timeline of this project.

KEYWORDS:
multi-object spectroscopy, integral field spectroscopy, spectroscopic surveys, CCD, CMOS

First presented at
Scientific Detector Workshop
Potsdam, September 2022

SDW 2022 Potsdam

WST Layout

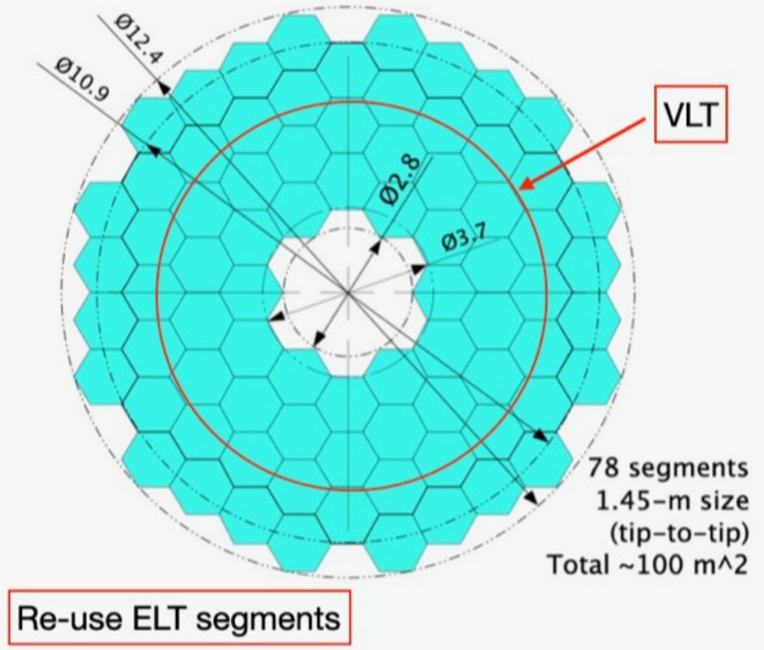
MOS

Cassegrain F/3.0
2.5° FoV

IFS

Coude F/26
10 arcmin FoV

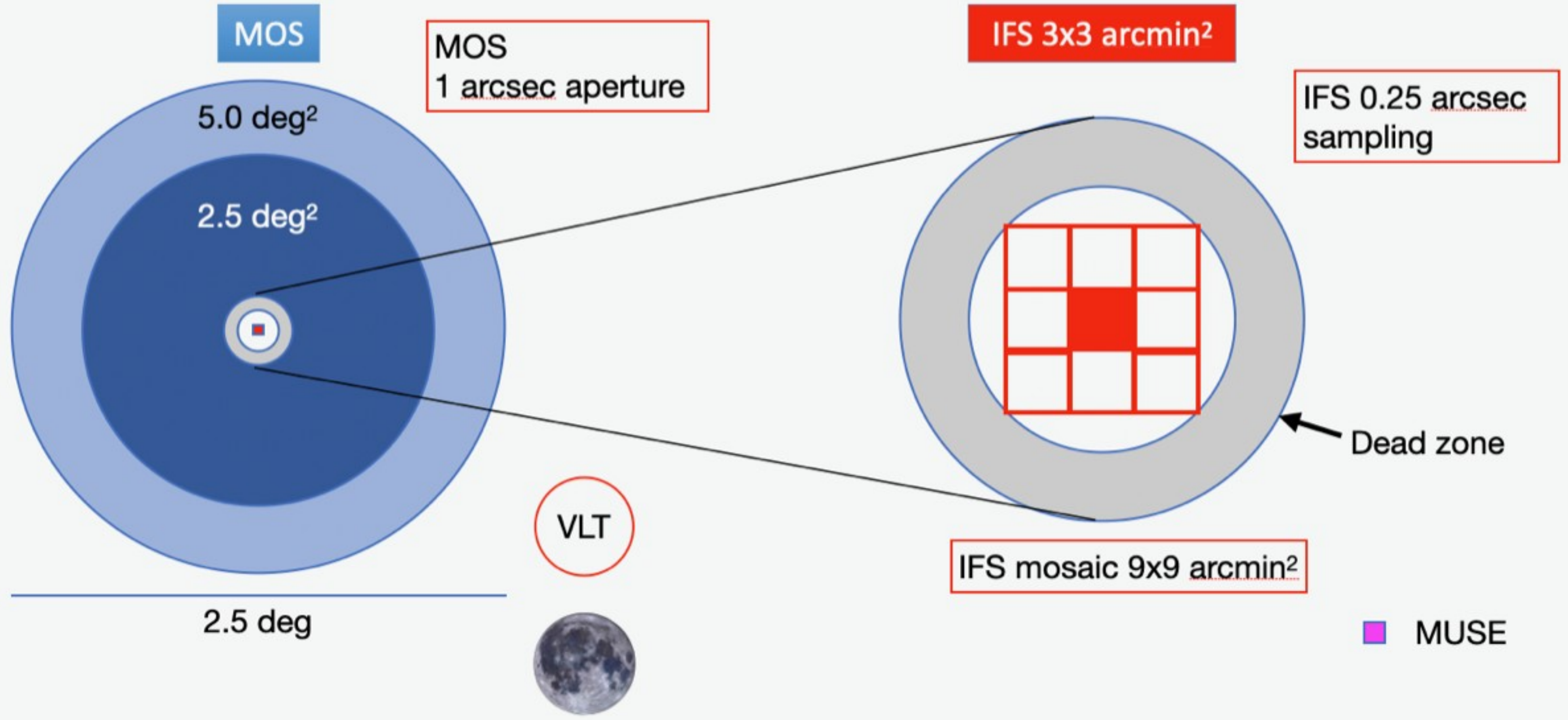
Preliminary TLR

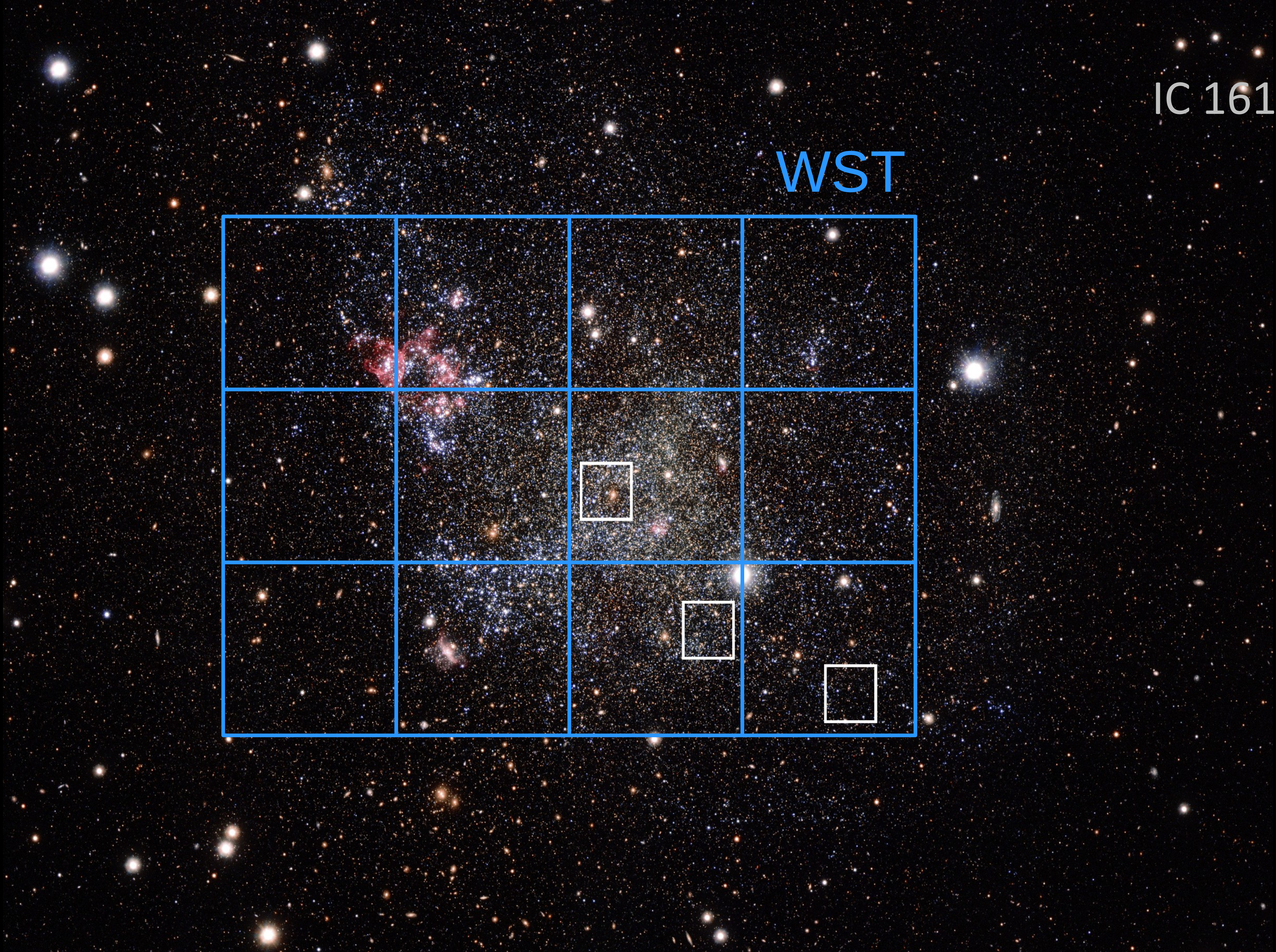


Telescope Aperture	12 m, seeing limited
Telescope FoV	2.5 - 5 deg²
MOS LR Multiplex	20,000
MOS LR Resolution	2,000-7,000
MOS LR Spec Range	370 (350) - 970 nm
MOS HR Multiplex	2,000
MOS HR Resolution	20,000-40,000
MOS HR Spec Range	3-4 regions in 350-970 nm
IFS FoV	3x3 arcmin²
IFS Resolution	3,000-5,000
IFS Spec Range	370-970 nm
IFS Mosaic	9x9 arcmin²
MOS & IFS simultaneous operation	

IR extension in a later stage

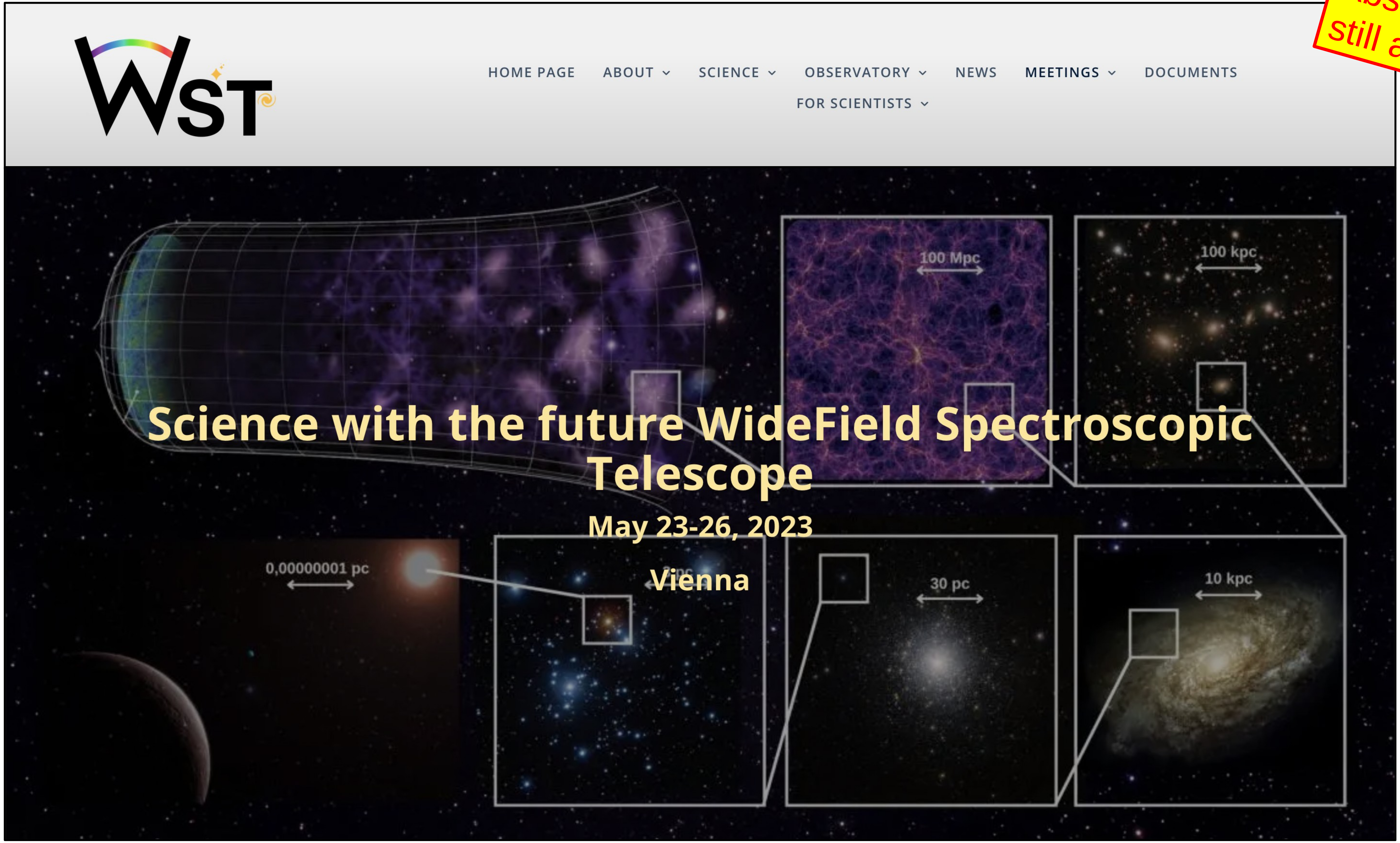
MOS & IFS FoV



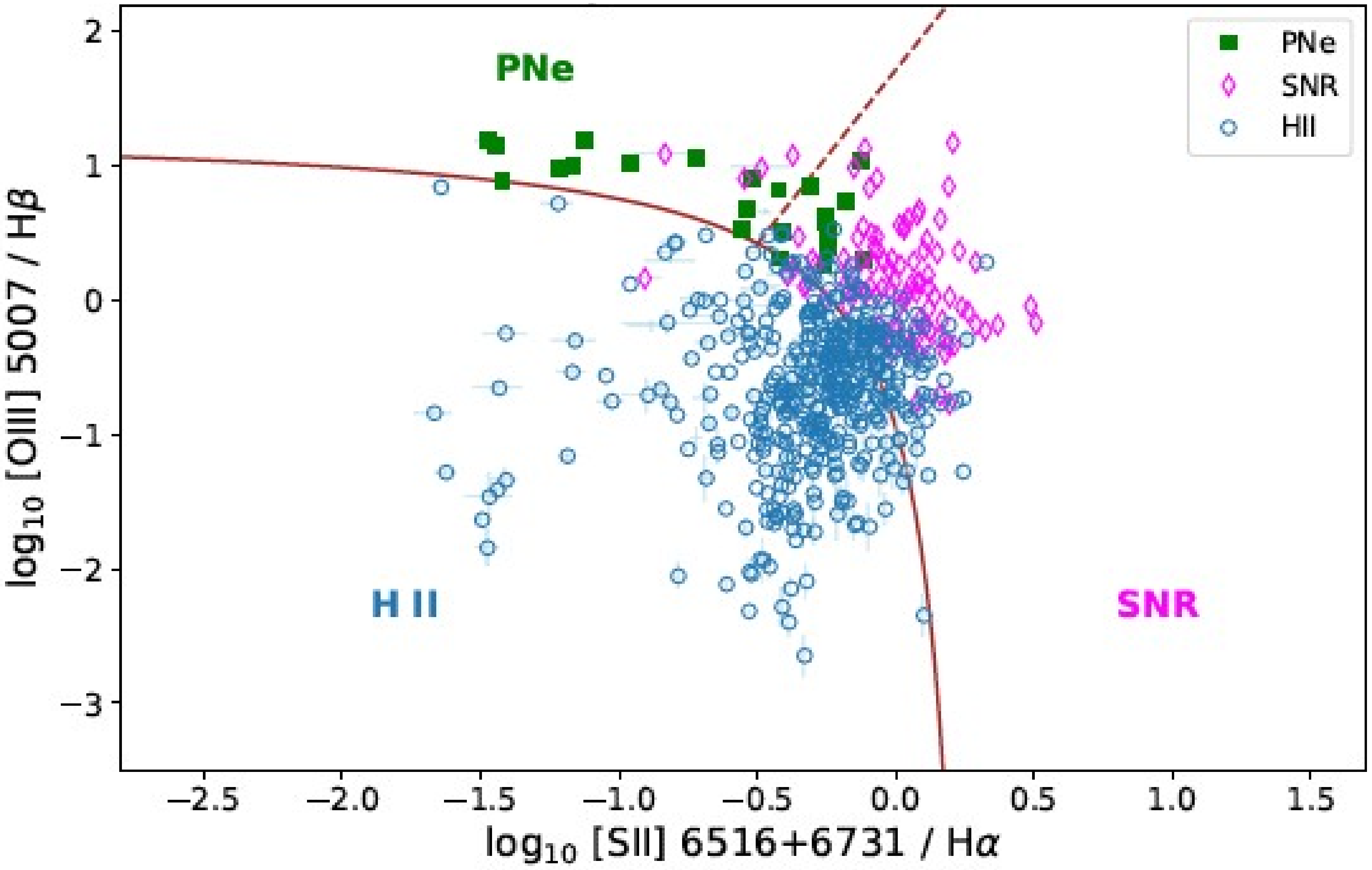

IC 1613
WST

https://www.wstelescope.com/meetings/symposium

Abstracts still accepted



BPT diagram classification



NGC 300 GTO Project

Roth M.M., Sandin, C., Kamann, S., Husser, T.-O., Weilbacher, P.M., Monreal-Ibero, A., Bacon, R., et al. (2018)
A&A, 618, *MUSE crowded field 3D spectroscopy in NGC 300.*
I. First results from central fields

González-Torà, G., Urbaneja, M.A., Przybilla, N., Dreizler, S., Roth, M.M., Kamann, S., Castro N. (2022)
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IV. Planetary Nebula Luminosity Function

NGC 300 GTO Project

MUSE
multi unit spectroscopic explorer

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