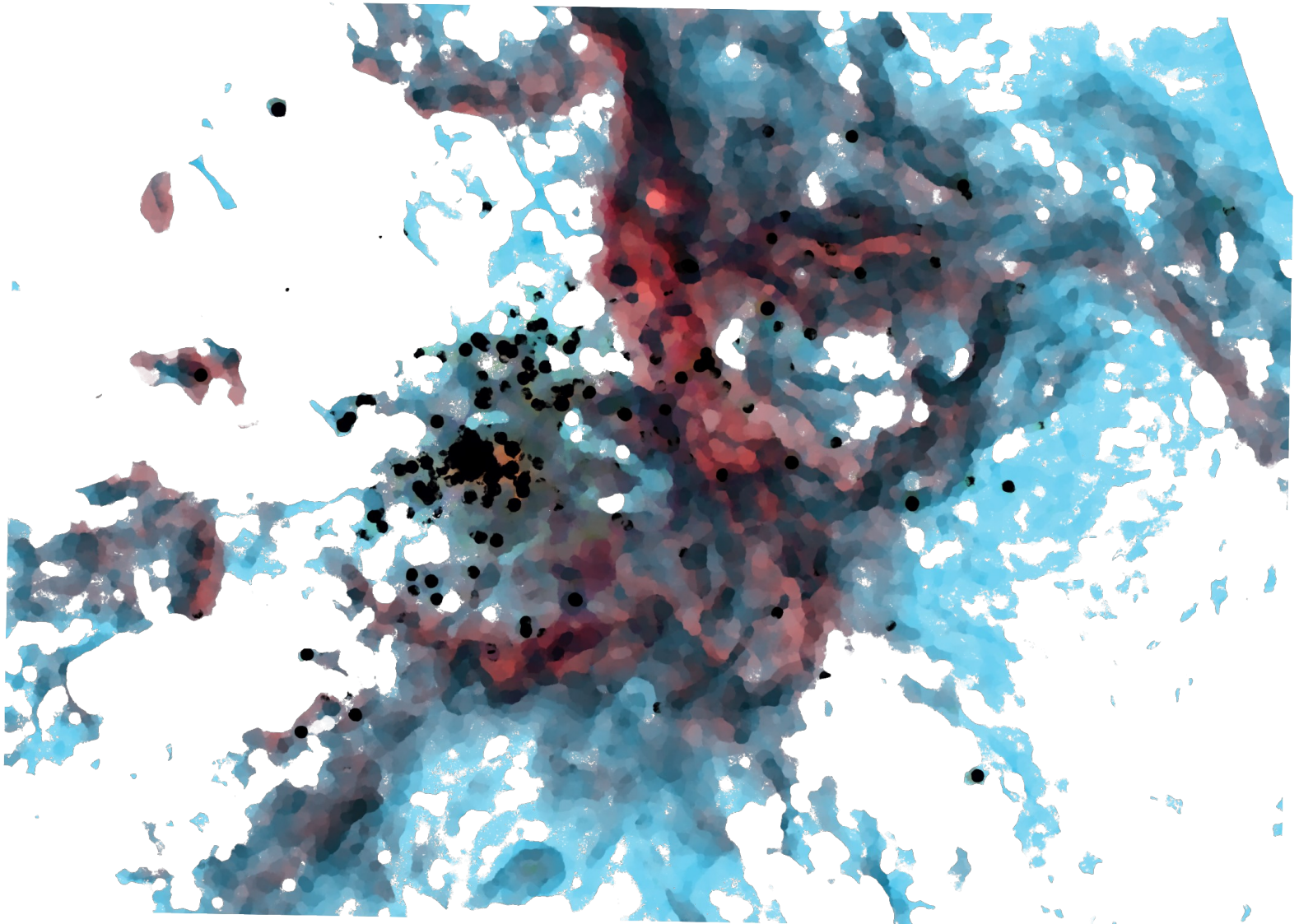
# Systematic mapping of the most massive stars with BlueMUSE

**N. Castro**
Georg-August-Universität, Göttingen
Leibniz-Institut für Astrophysik, Potsdam

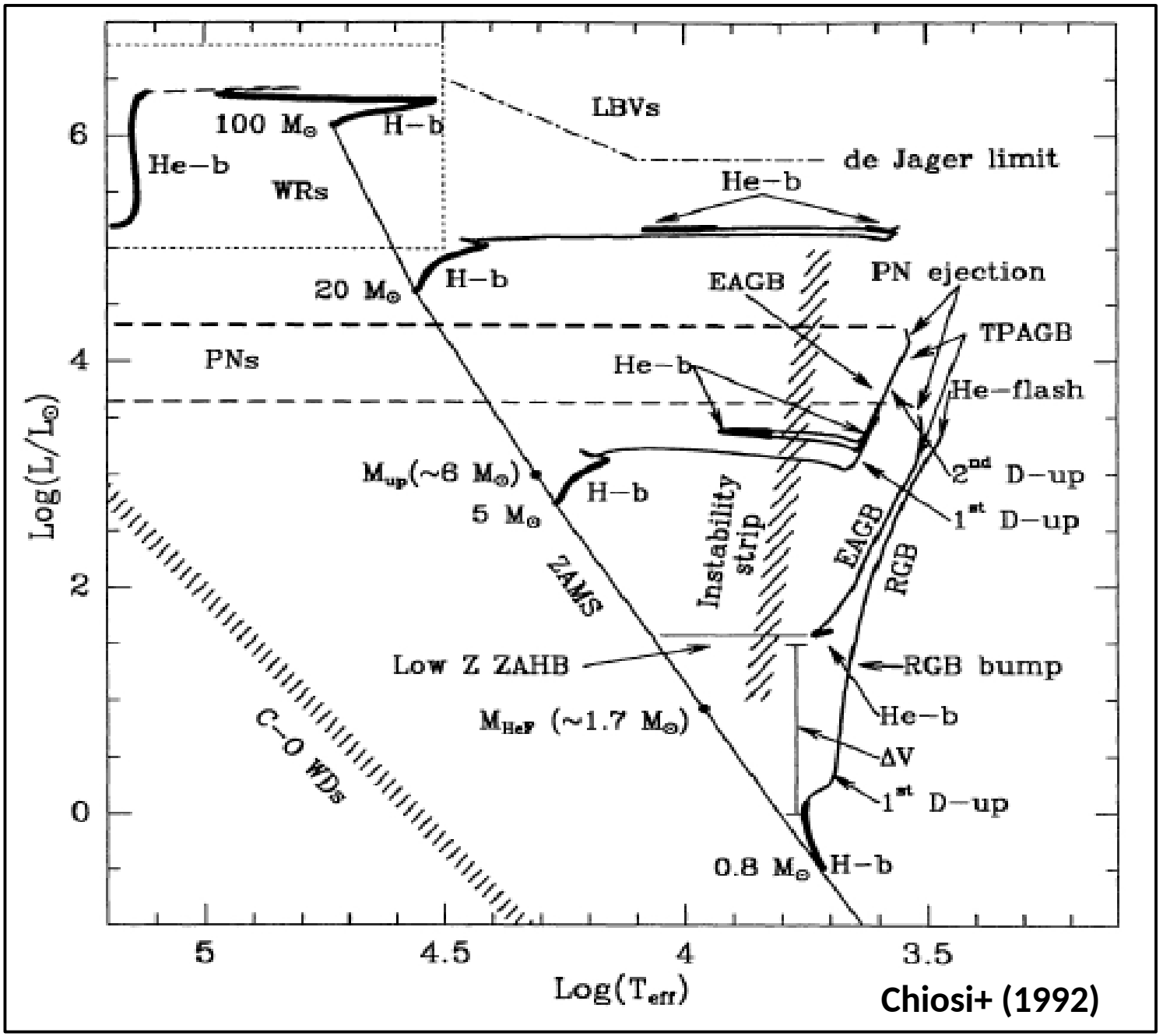


innoFSPEC
Innovative faseroptische Spektroskopie und Sensorik

AIP

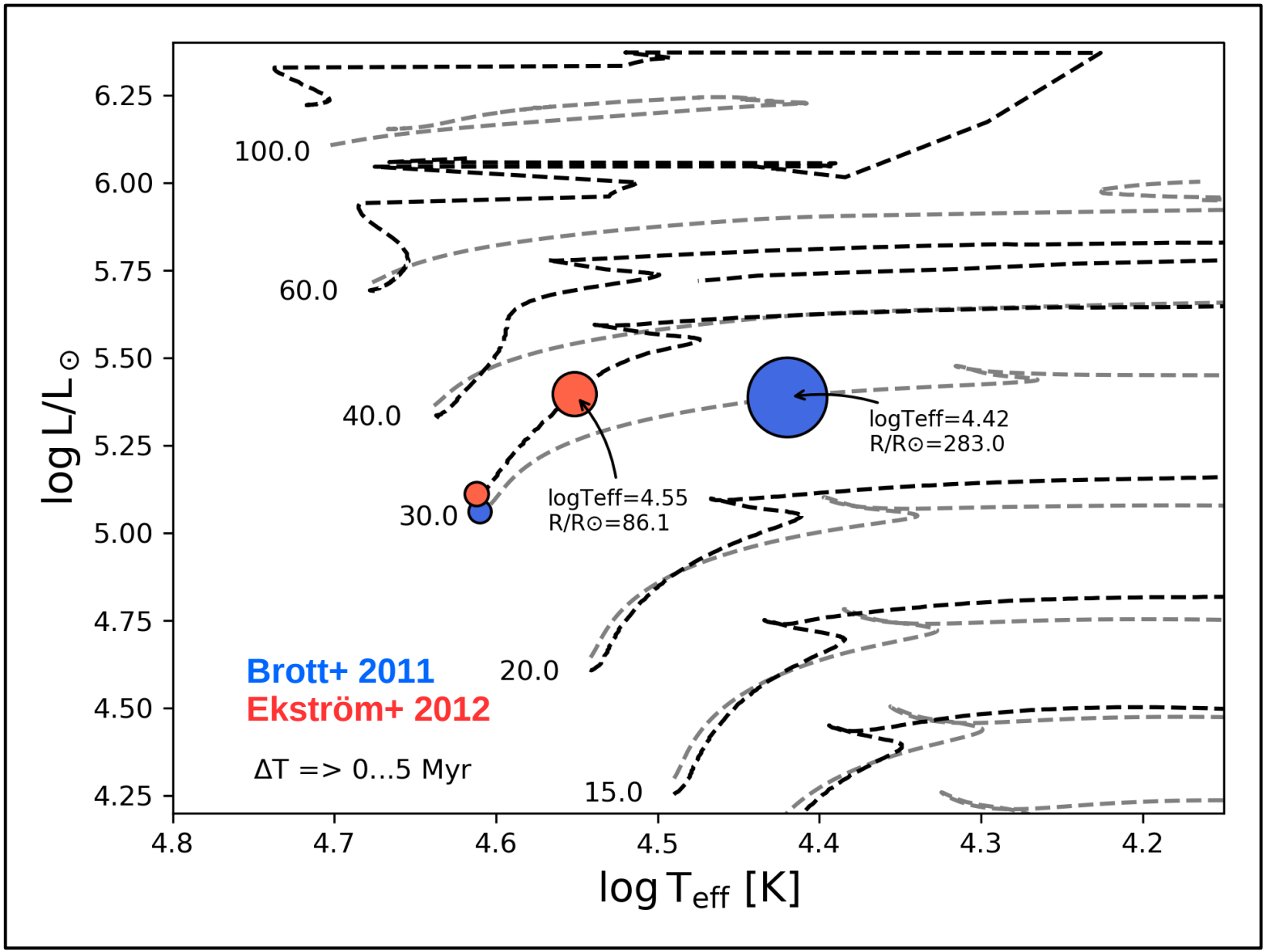
DFG

# How do massive stars evolve?:

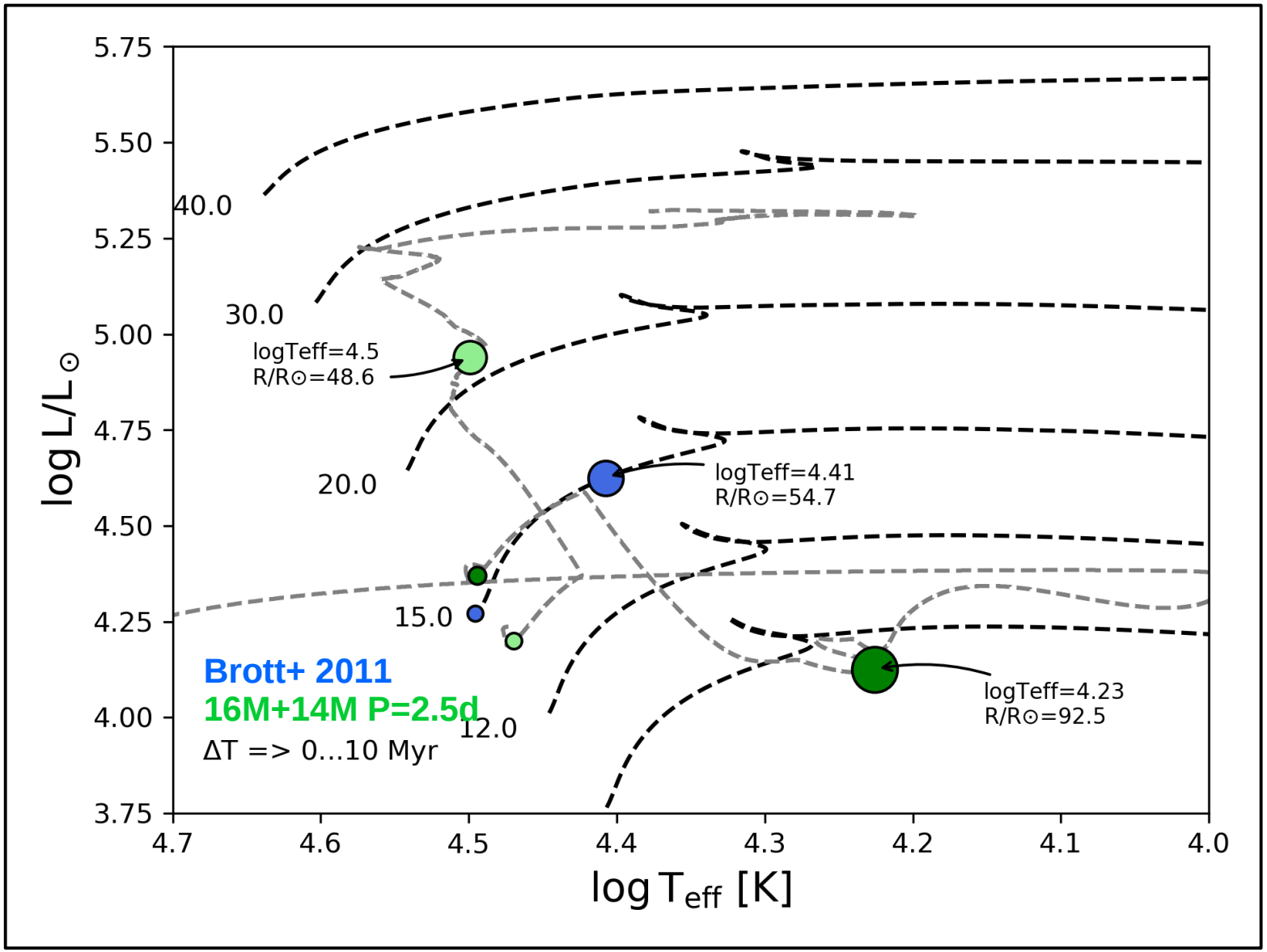



Chiosi+ (1992)

# How do massive stars evolve?:

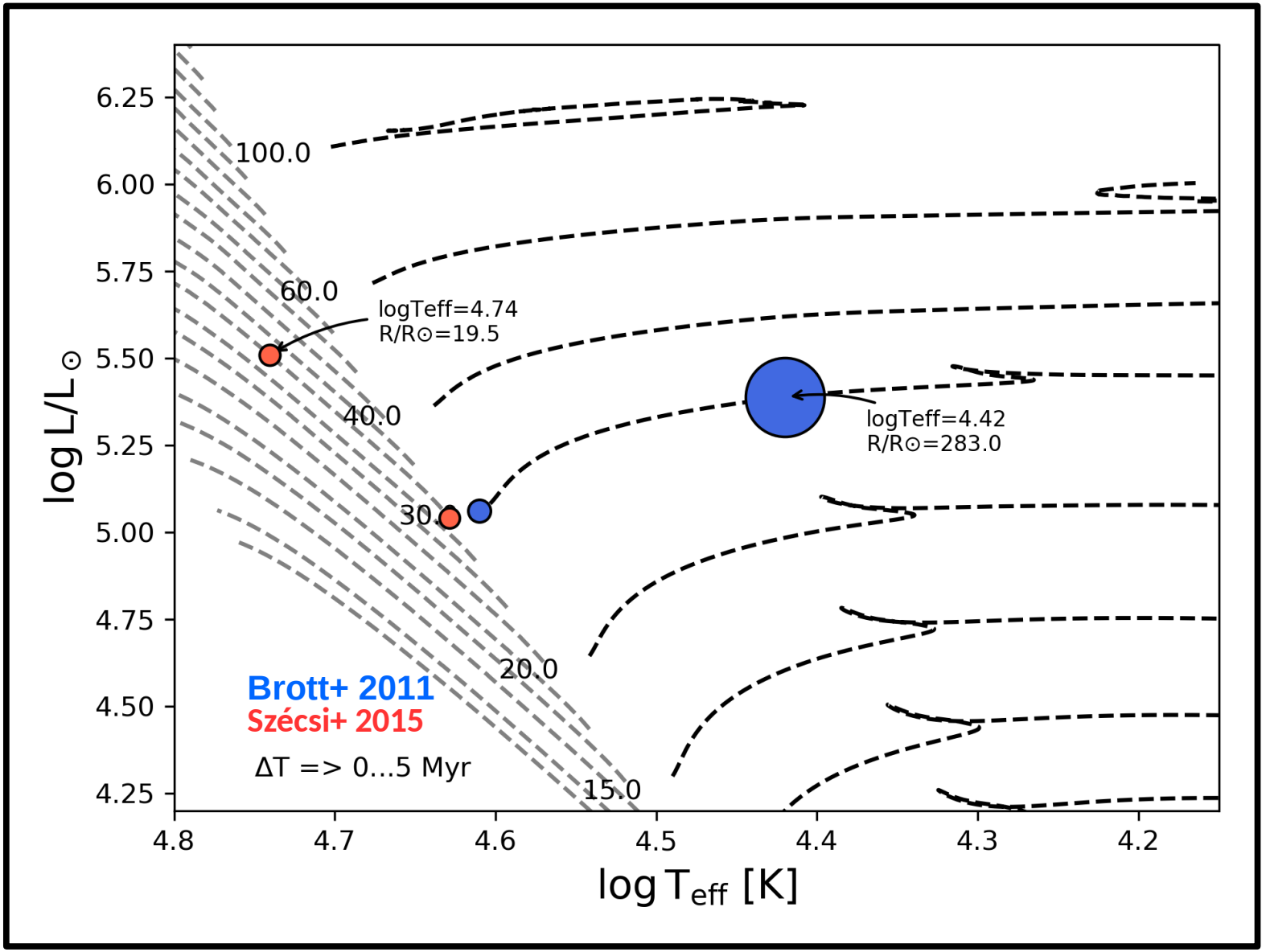


# How do massive stars evolve?:

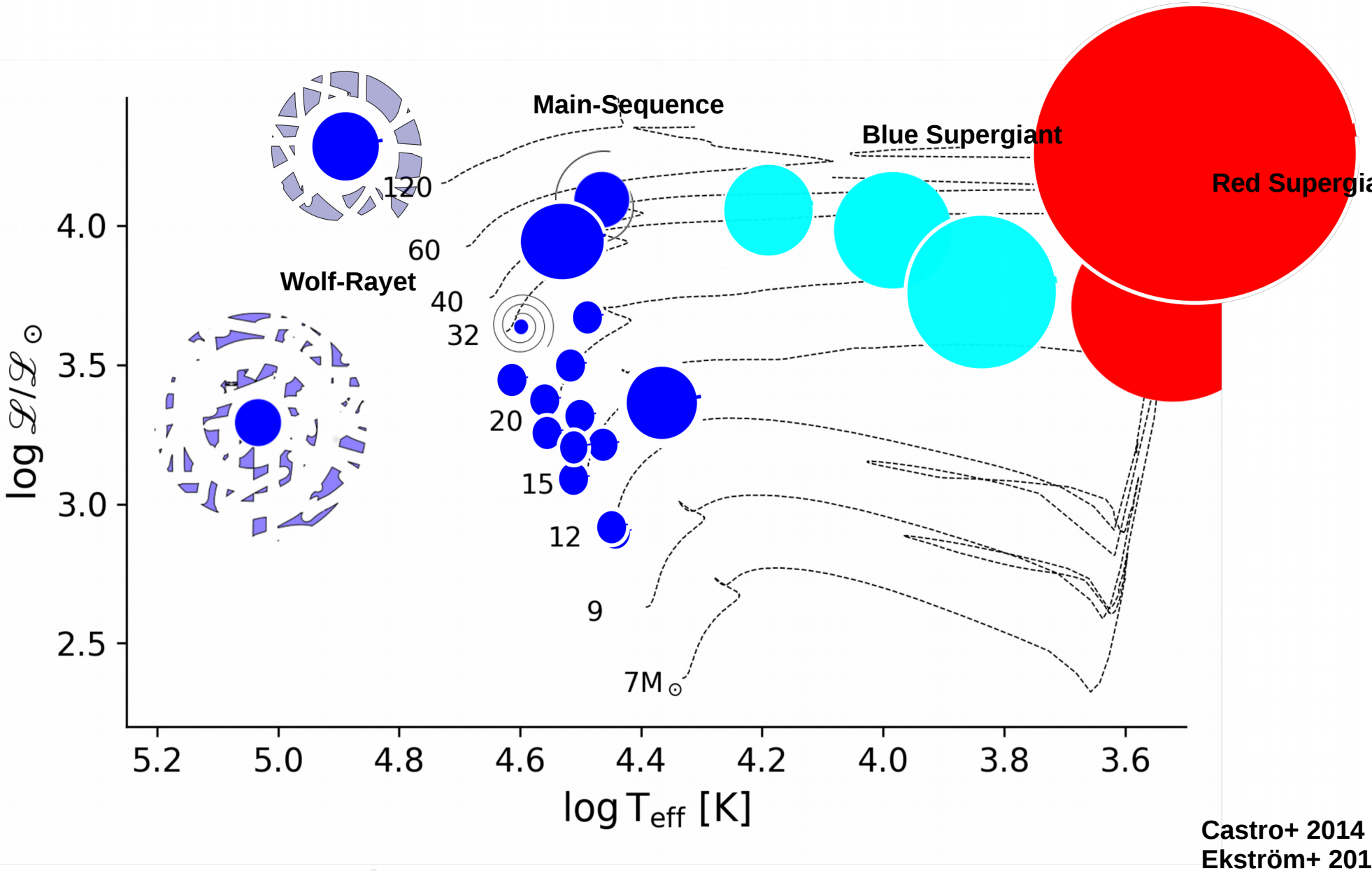



(see Langer & Kudritzki 2014)
(Wang+ 2020, 2022)

# How do massive stars evolve?:



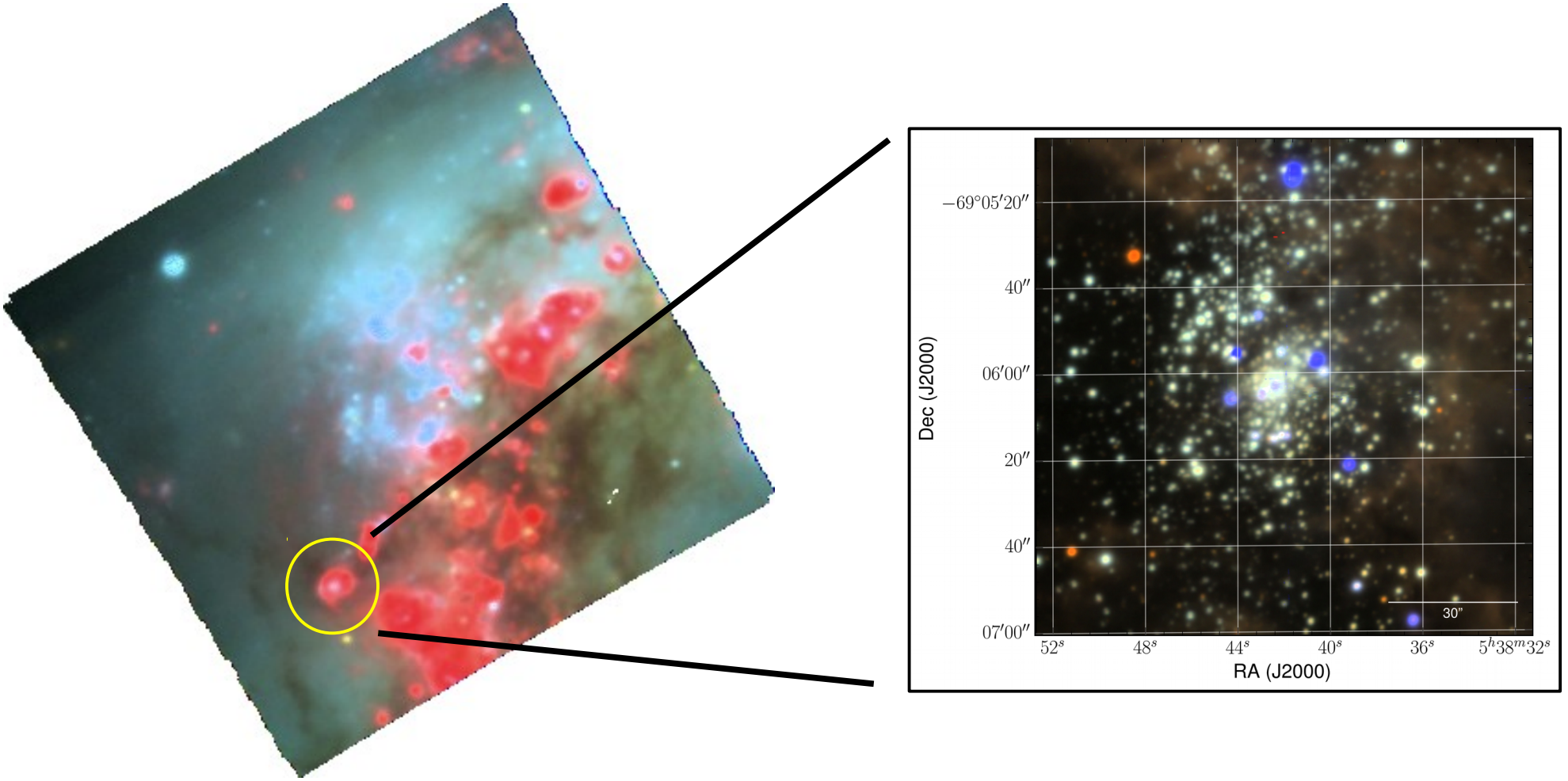
# Stellar archaeology:




Castro+ 2014
Ekström+ 2012

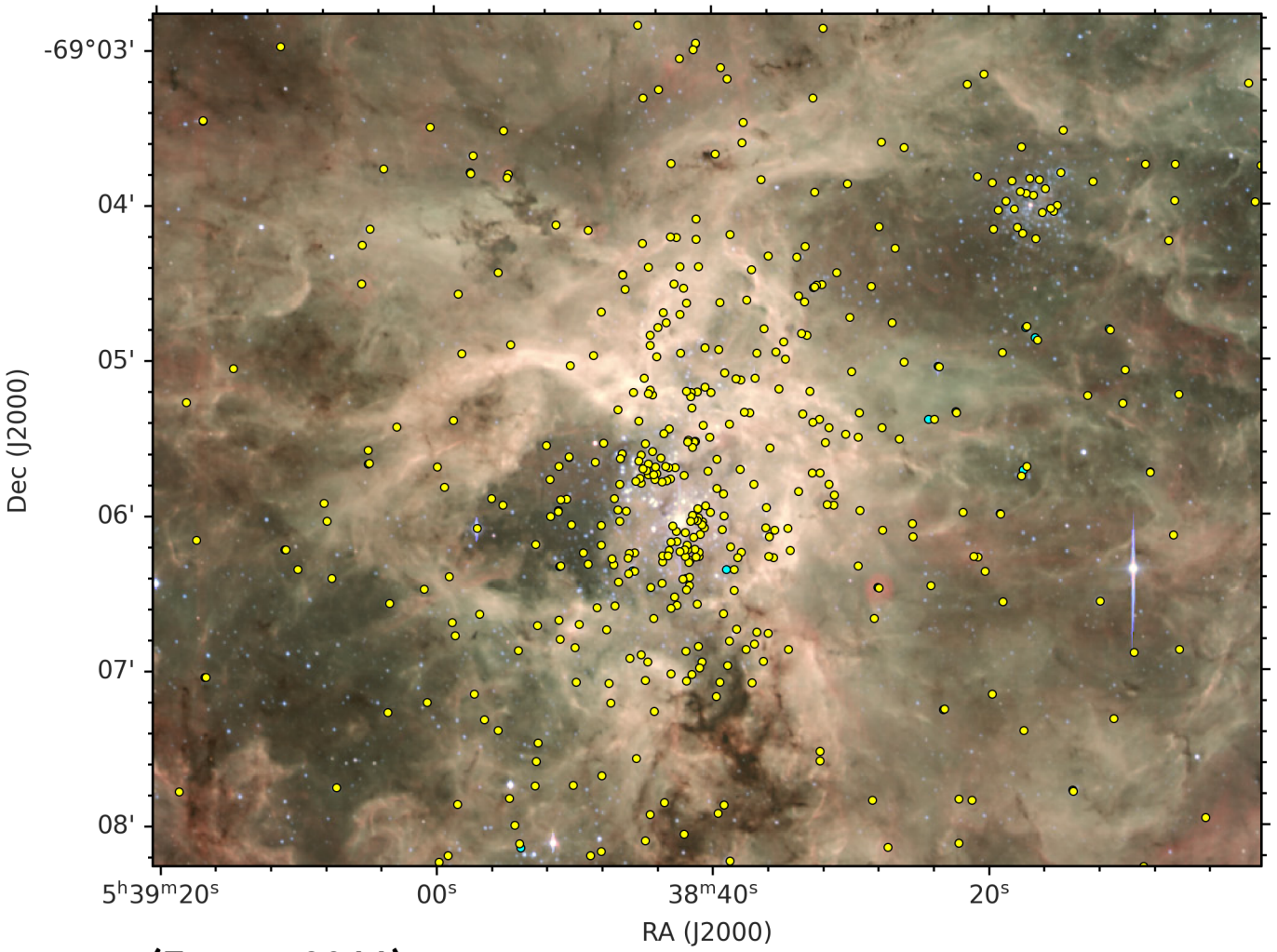
# Stellar archaeology further away:

## Antennae galaxies (22 Mpc)



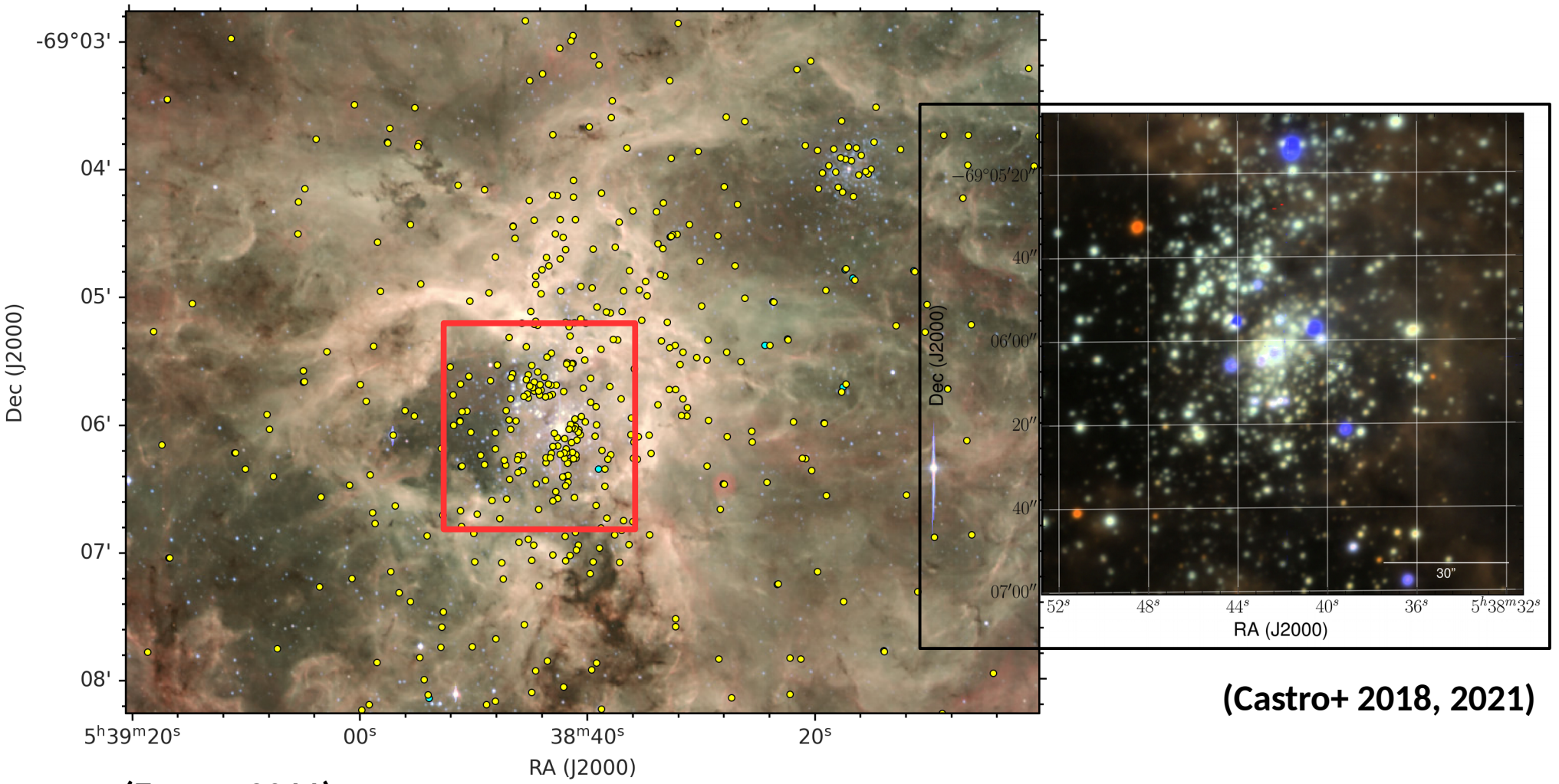

(Weilbacher et al.)

# Multi-object and integral field spectroscopy




**(Evans+ 2011)**

# Multi-object and integral field spectroscopy



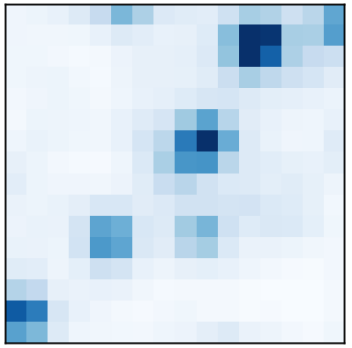

(Evans+ 2011)

(Castro+ 2018, 2021)

# Integral field spectroscopy on resolved stellar populations (Roth+ 2019)

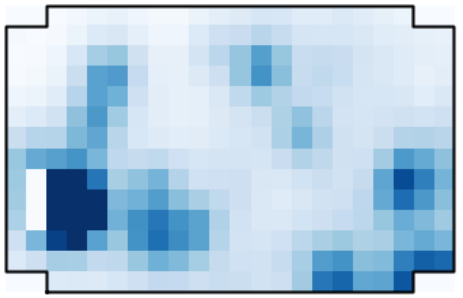
**M92**
(Kamann+ 2013)

**By PMAS**
(Roth+ 2005)



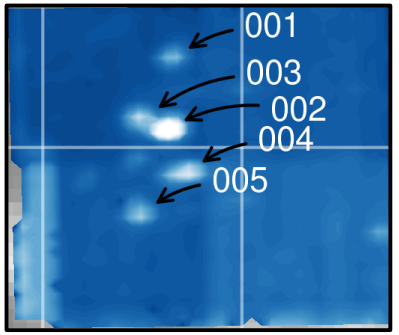
**NGC362**
(Kamann+ 2013)

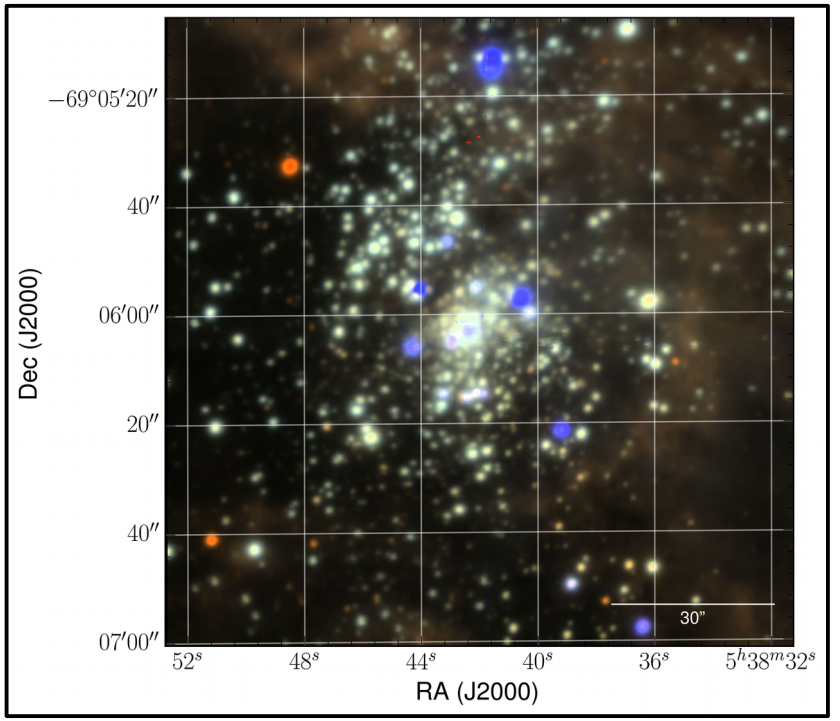
**By ARGUS**
(Pasquini+ 2002)



**IC1613**
(M. Garcia priv. Com.)

**By VIMOS**
(Le Fèvre+ 2003)

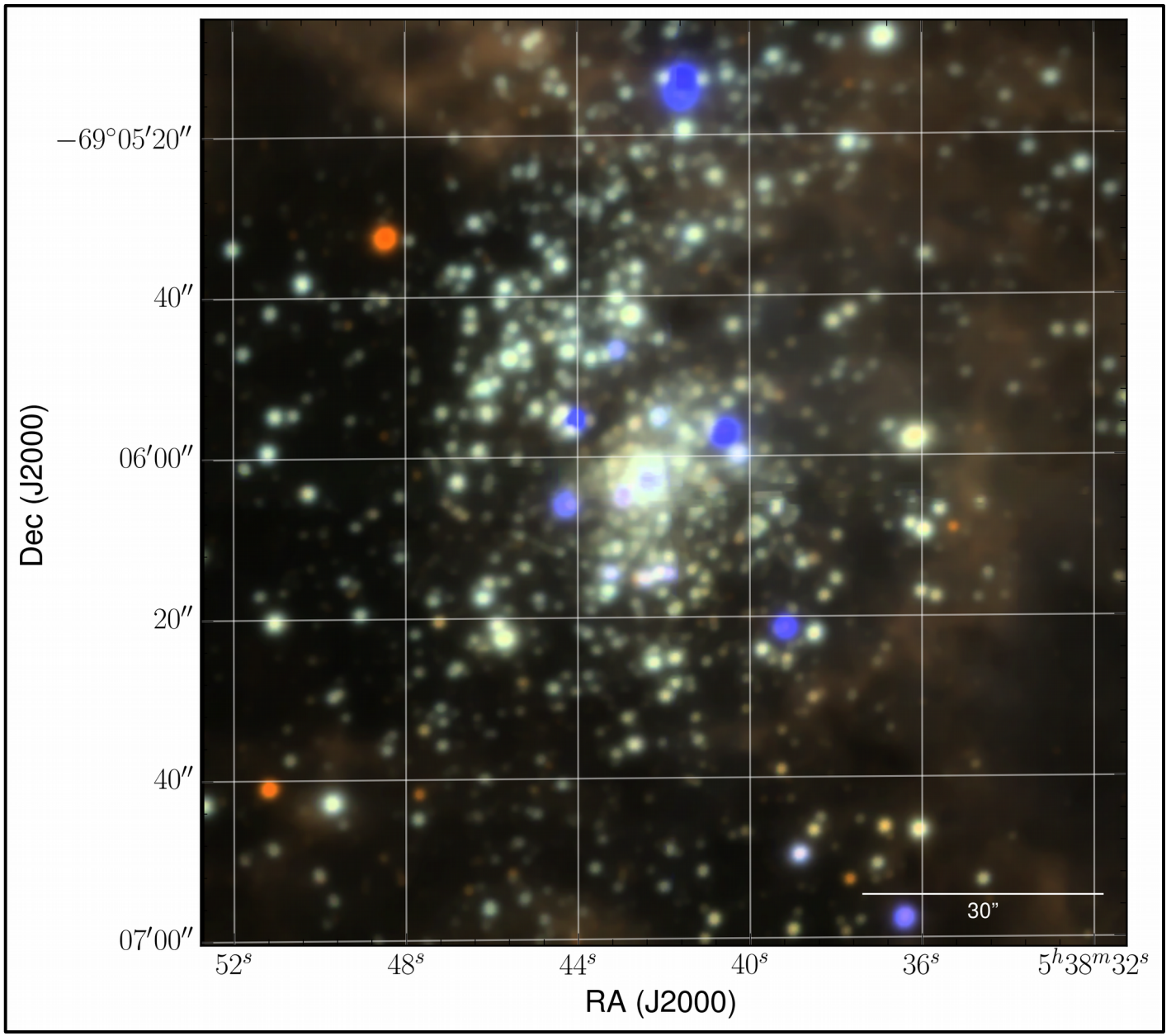



**NGC2070**
(Castro+ 2018,2021)

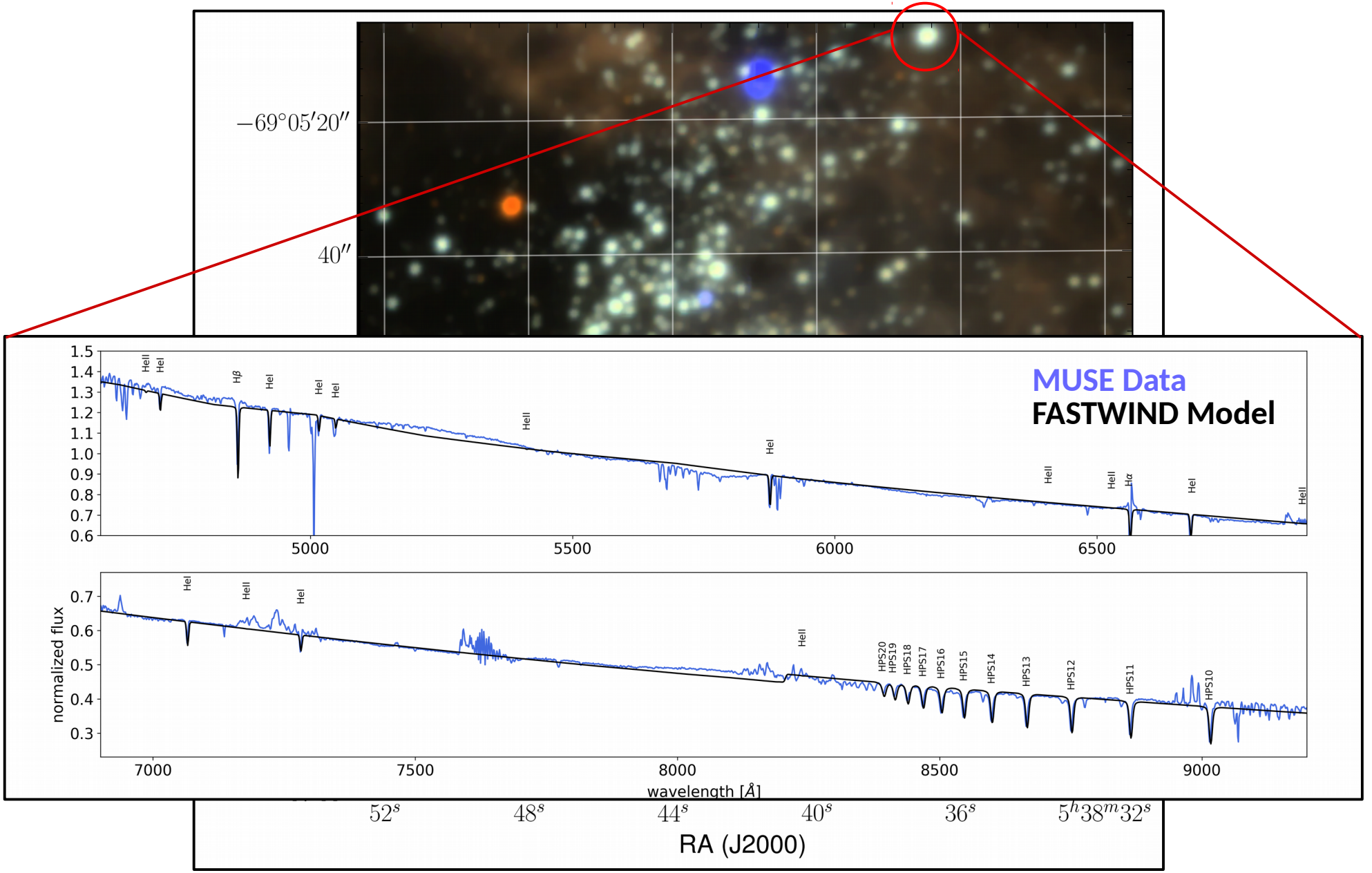
**By MUSE**
(Bacon+ 2014)

# Comprehensive analyses with MUSE:



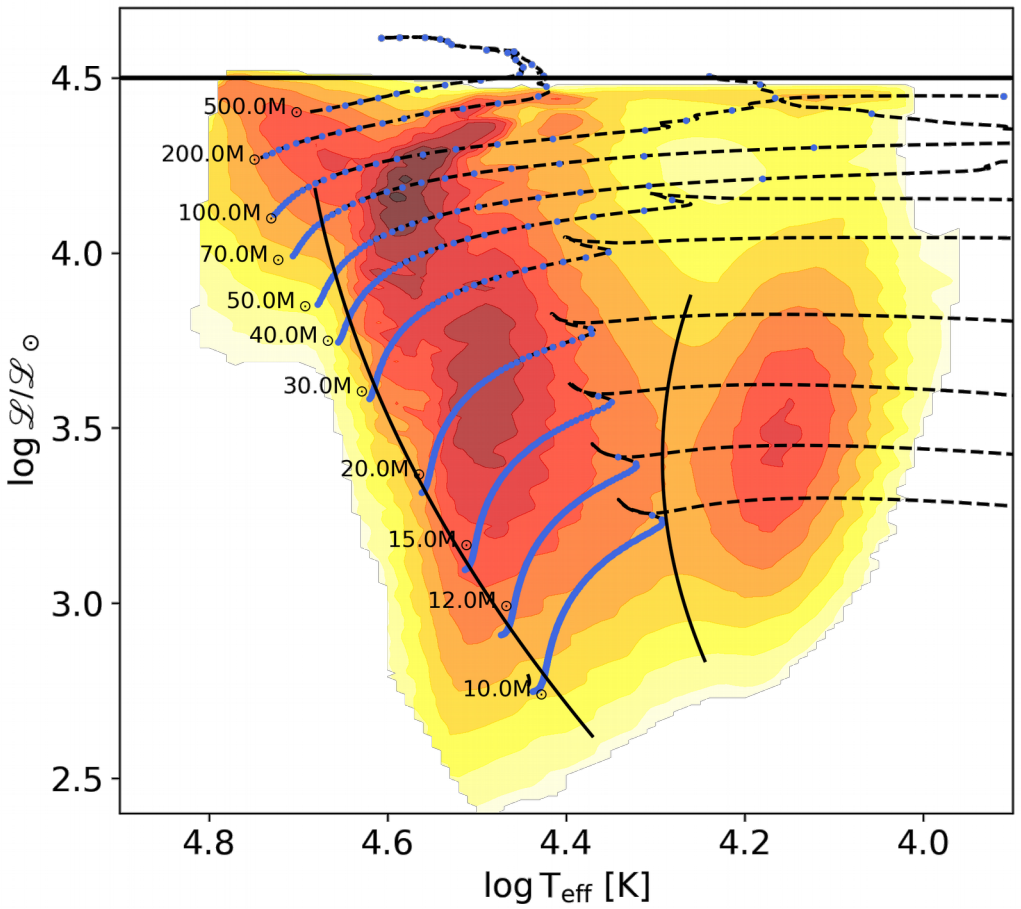

(Crowther+ 2017: Castro+ 2018)

# Comprehensive analyses with MUSE:




(Crowther+ 2017: Castro+ 2018)

# Comprehensive analyses with MUSE:

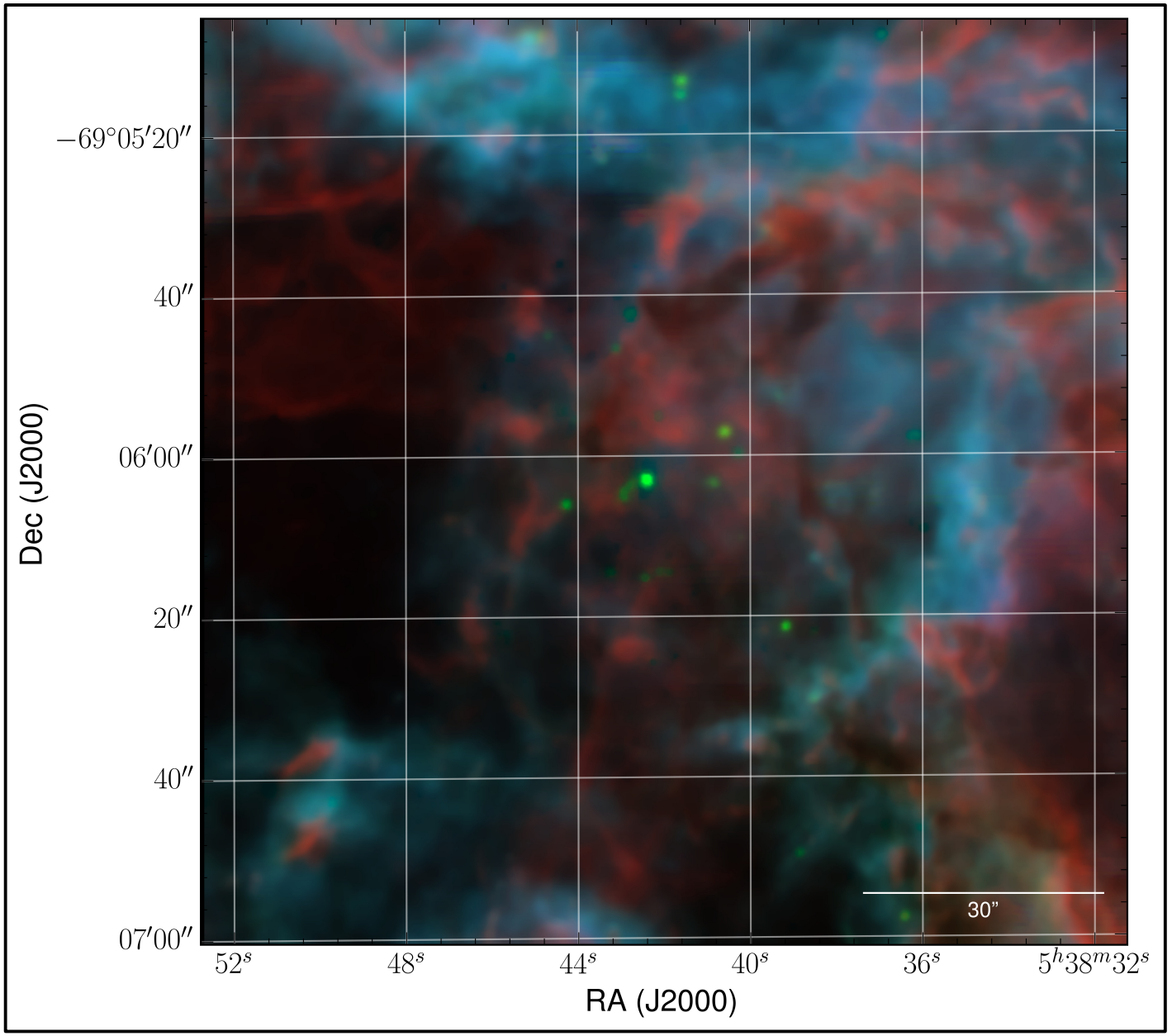



**NGC2070 analysis (Castro+ 2018,2021):**

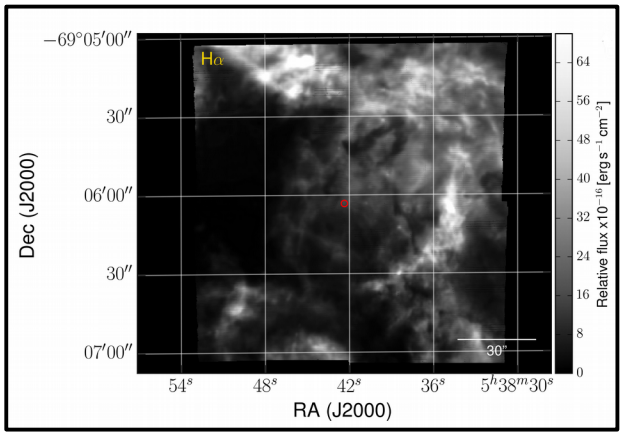
- We extracted more than 2200 sources
- Average radial velocity of 271 km/s
- Modeling 333 stars with S/N > 50
- We find two groups in the main sequence, with estimated ages of 2.1 ± 0.8 and 6.2 ± 2 Myr.
- A subgroup of 52 stars is apparently beyond the main sequence phase, which we consider to be due to emission-type objects (Castro+ 2018b)

**Castro+ 2014**
**Ekström+ 2012**

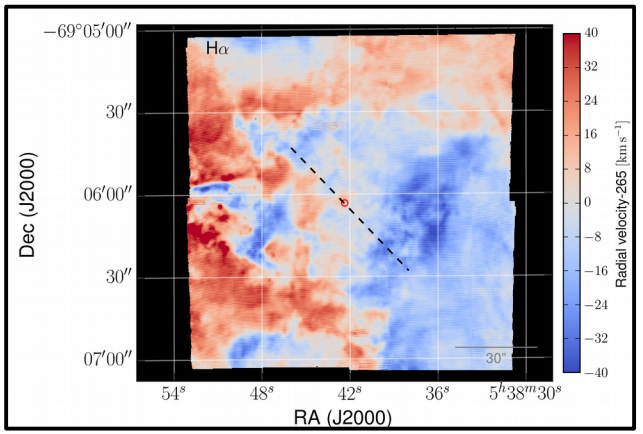
# Comprehensive analyses with MUSE:



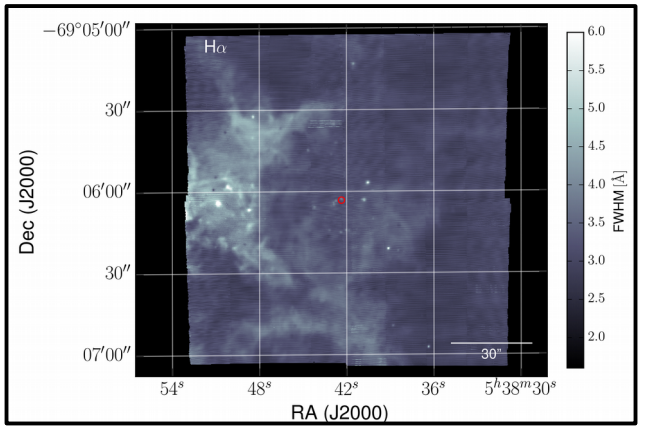
# Comprehensive analyses with MUSE:



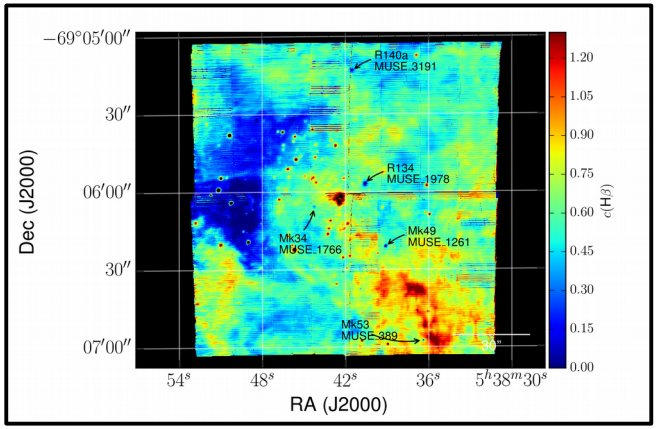

**Intensity maps**



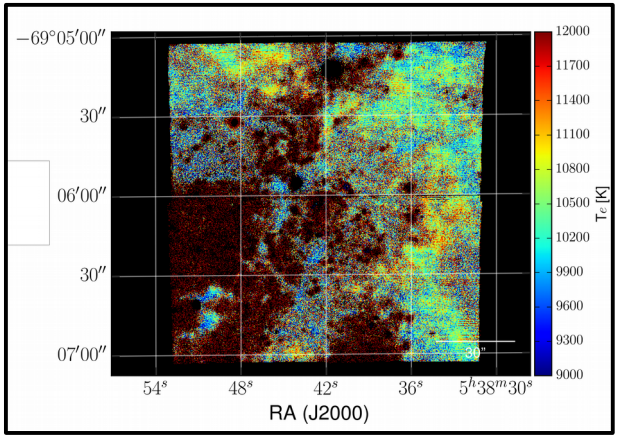

**Radial velocity maps**



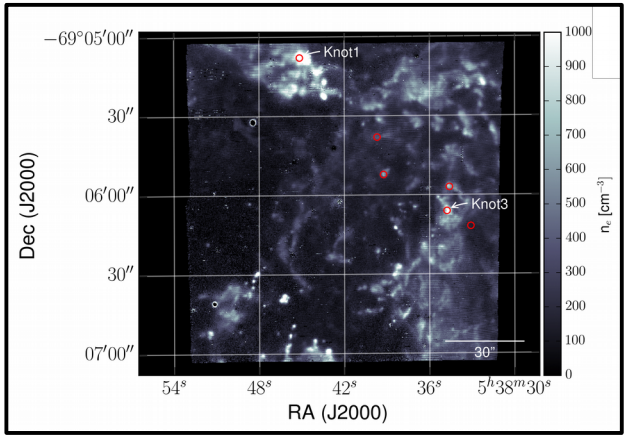

**Broadening maps**




**Extinction maps**



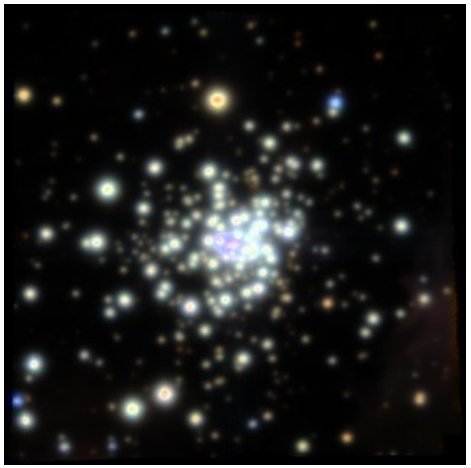

**Temperature maps**



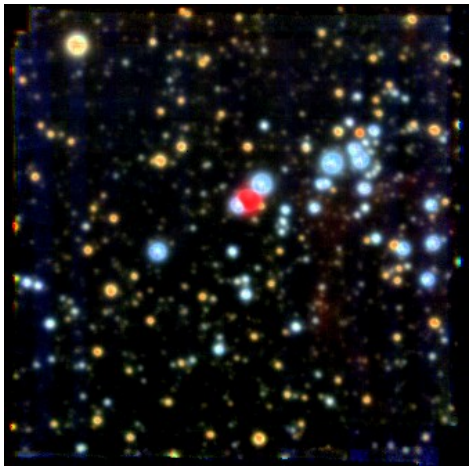

**Density maps**

**(Castro+ 2018)**

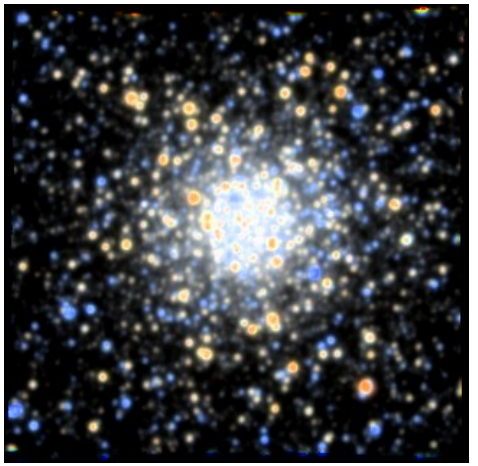
# Integral field spectroscopy on resolved stellar populations



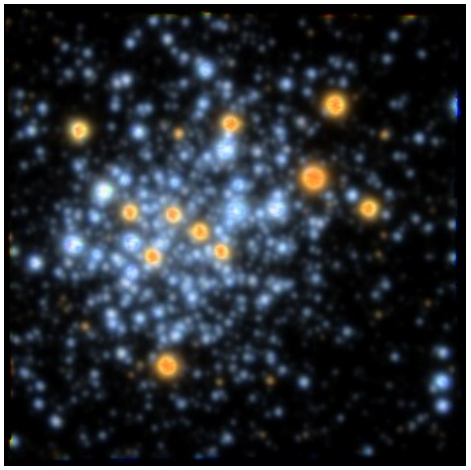
**NGC3603**
(Mahy et al.)



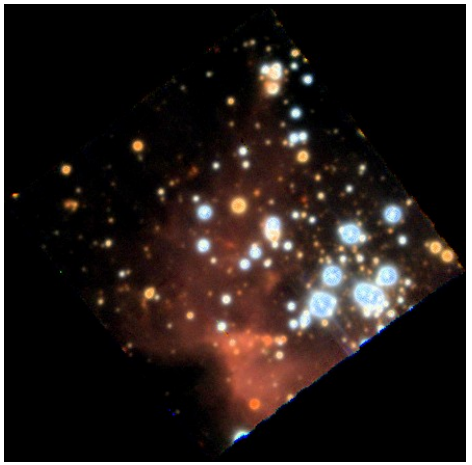
**SN1987A**
(Fransson et al.)



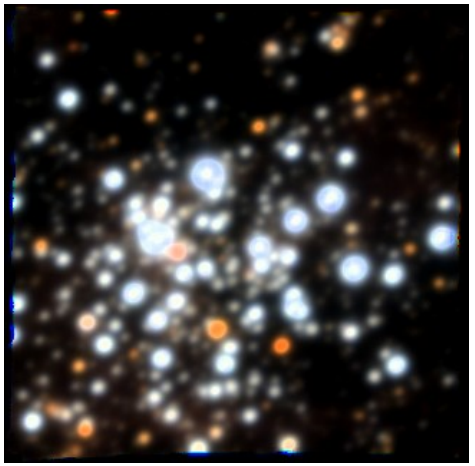
**NGC2005**
(Kamann et al.)



**NGC330**
(Bodensteiner et al.)



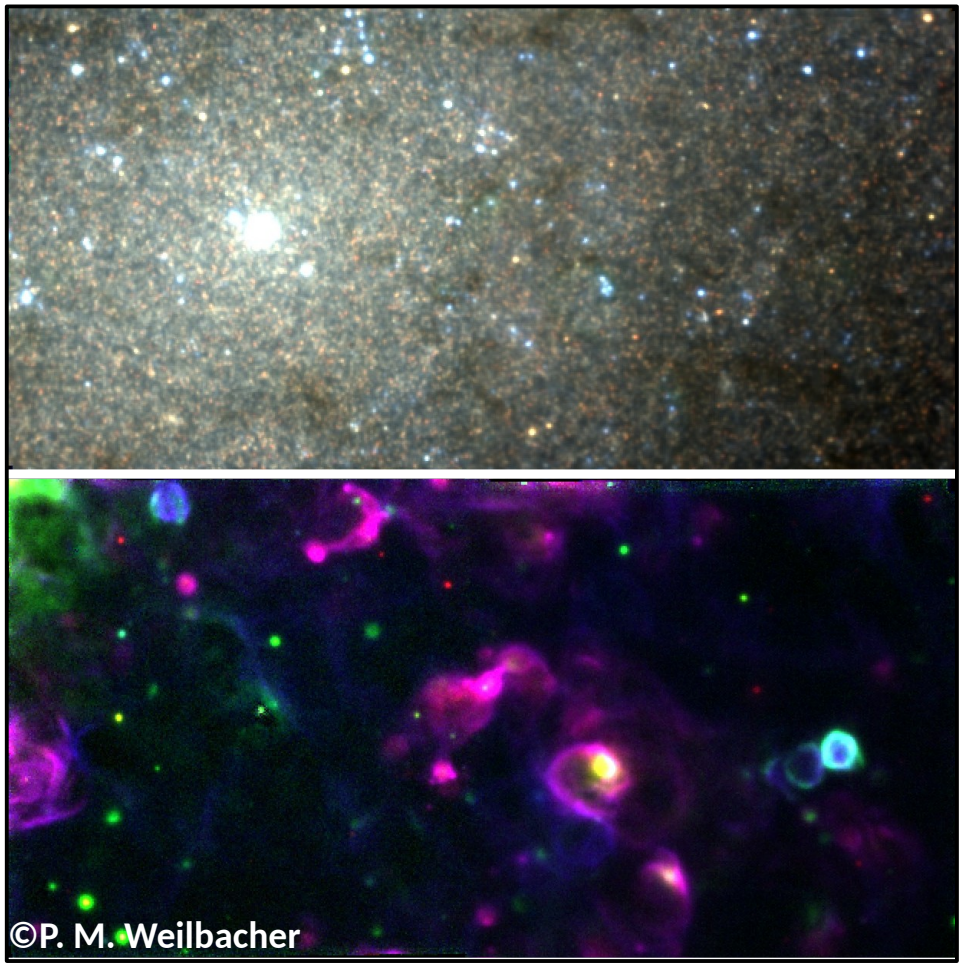
**NGC602**
(Zeidler et al.)



**NGC346**
(Hamann et al.)

# Resolved stellar population in the Local Group with MUSE:

## NGC300 (2 Mpc)

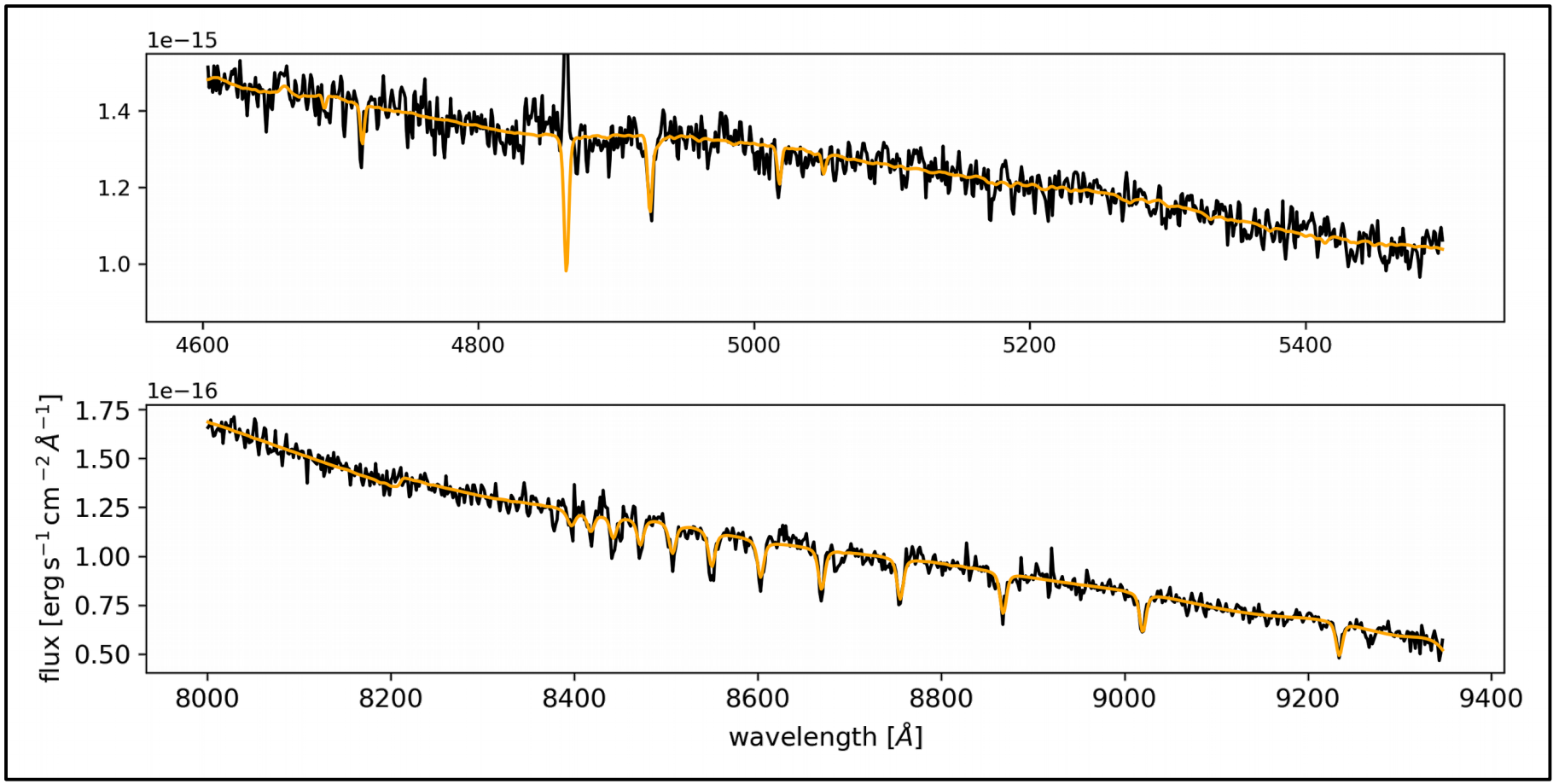



### Extragalactic goals:

- Resolved stellar populations (e.g. Castro+ 2012)
- Study the ISM and feedback mechanisms (e.g. Micheva+ 2022 )
- Galactic chemical compositions (e.g. Bresolin+ 2007)
- Distance candles (Kudritzki+ 2003)
- Galactic dynamical evolution (e.g. Kudritzki+ 2016)

# Resolved stellar population in the Local Group with MUSE:

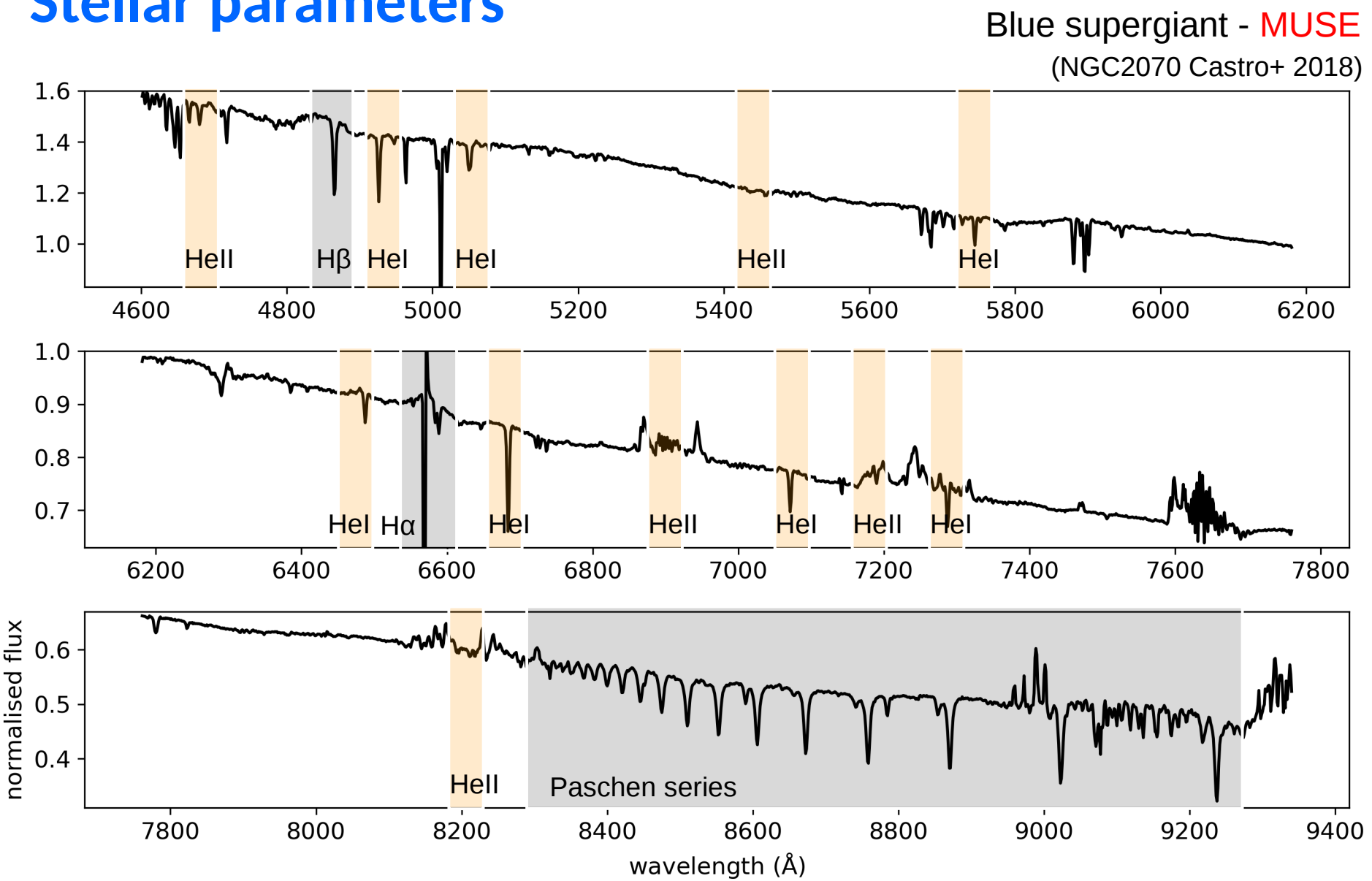
## NGC300 (2 Mpc)




(Jost+ in prep.)

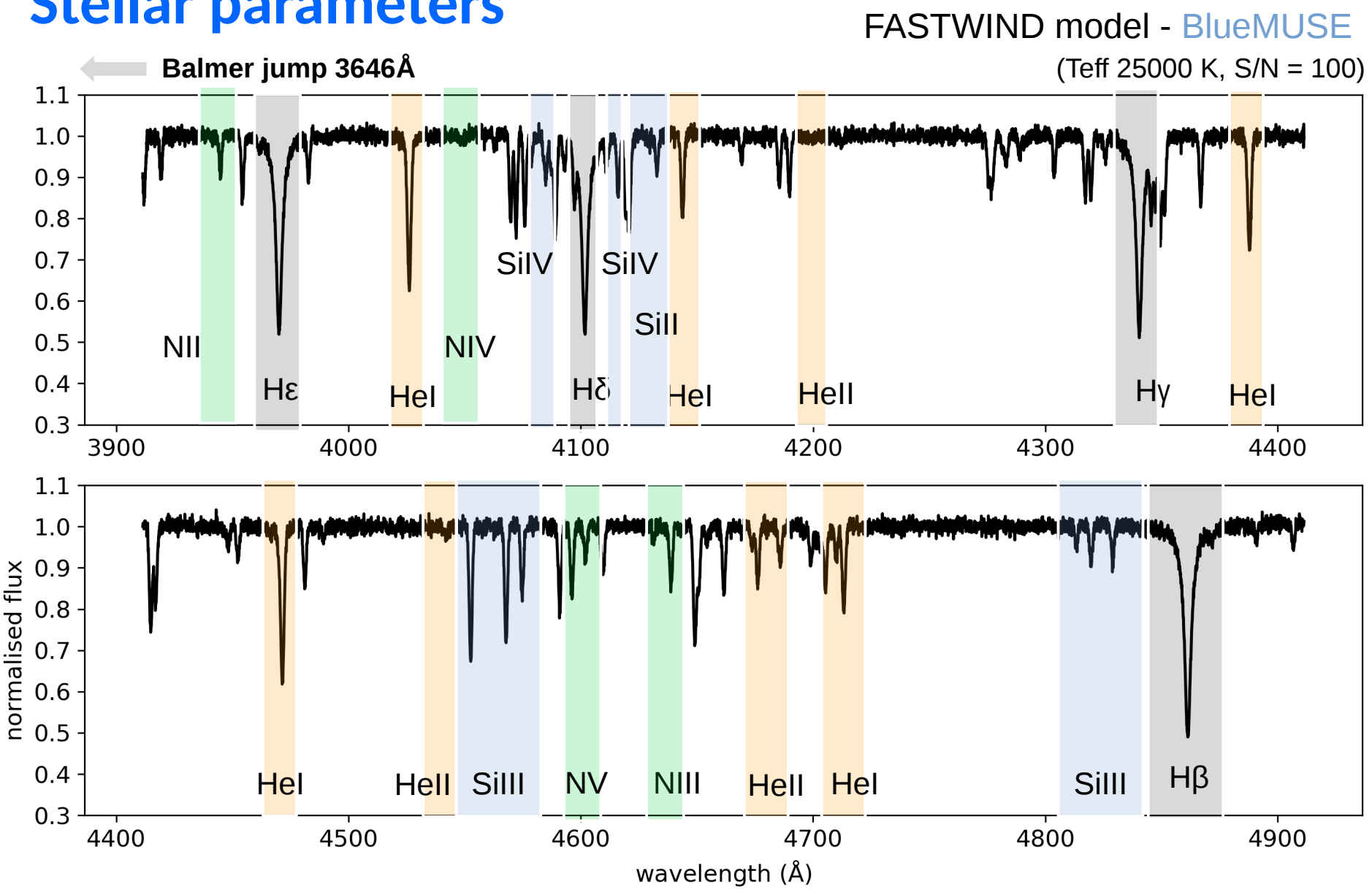
# Stellar evolution with BlueMUSE:

## Stellar parameters



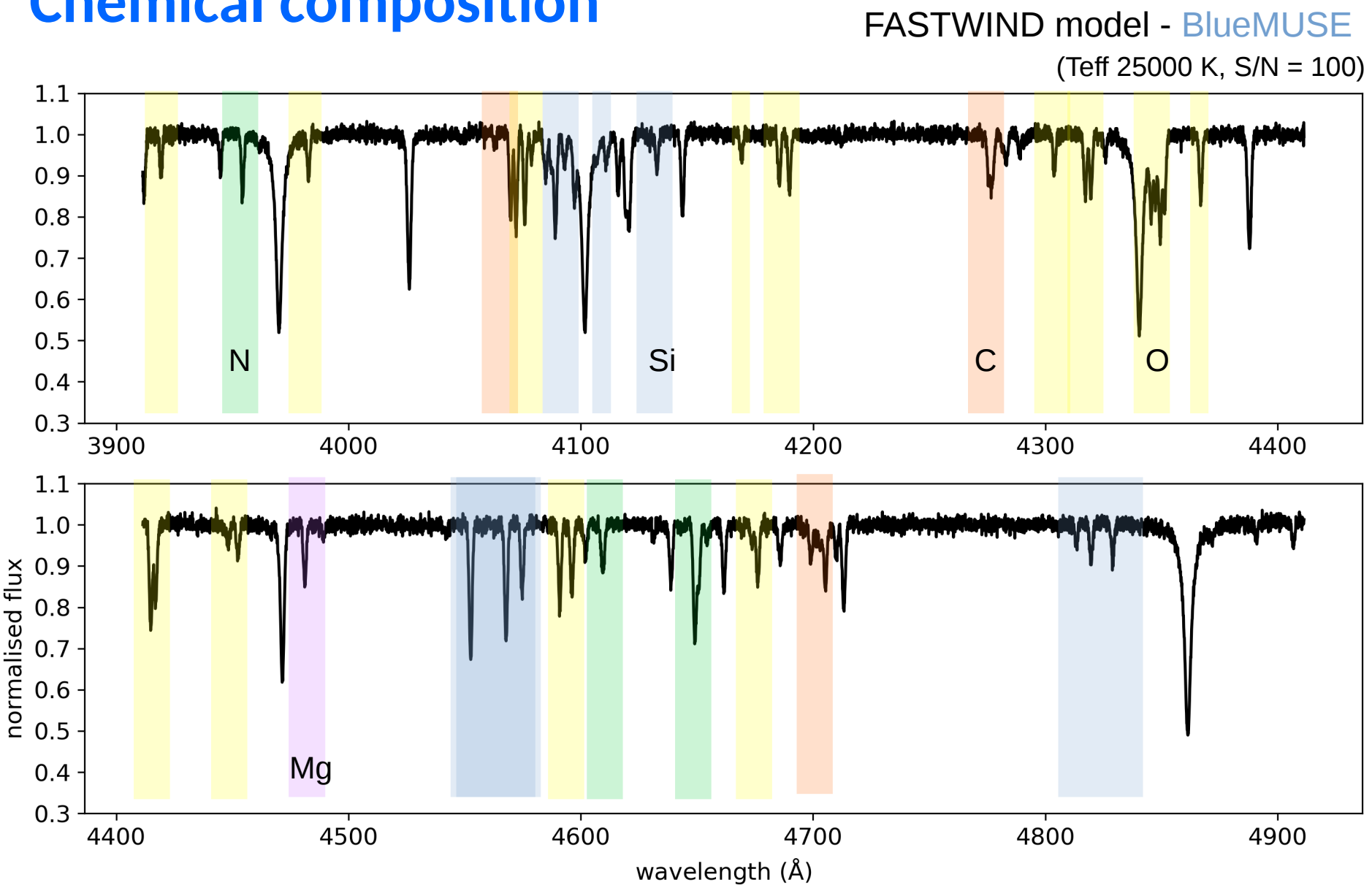
# Stellar evolution with BlueMUSE:

## Stellar parameters



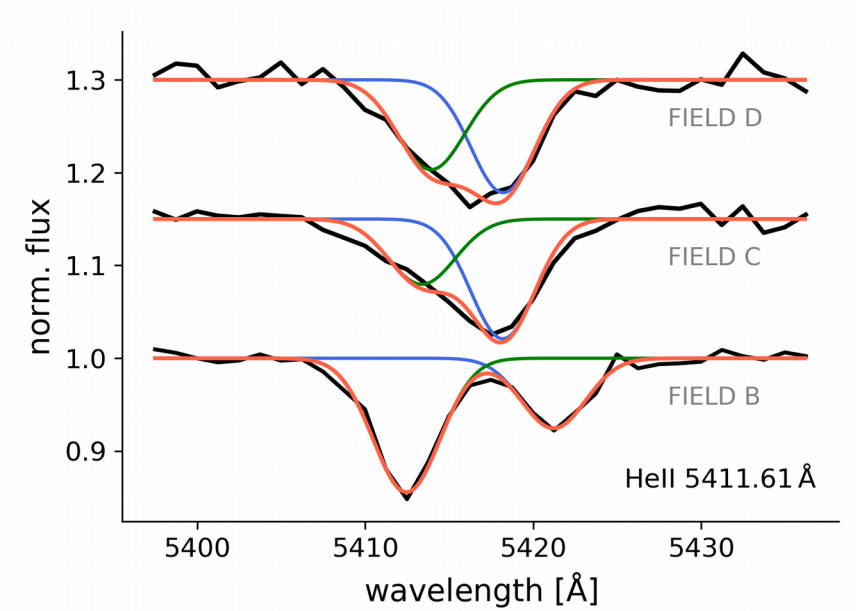
# Stellar evolution with BlueMUSE:

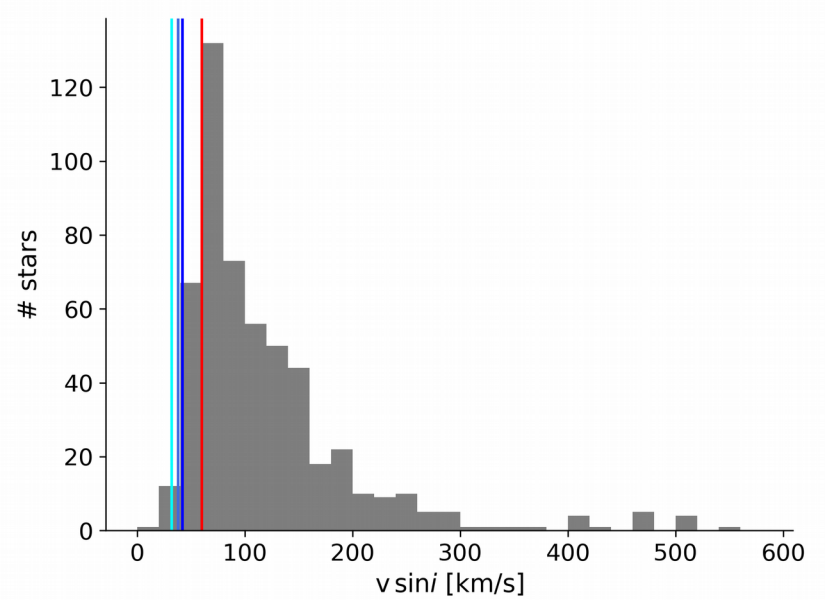
## Chemical composition



# Stellar evolution with BlueMUSE:

## Binary fraction and Rotation

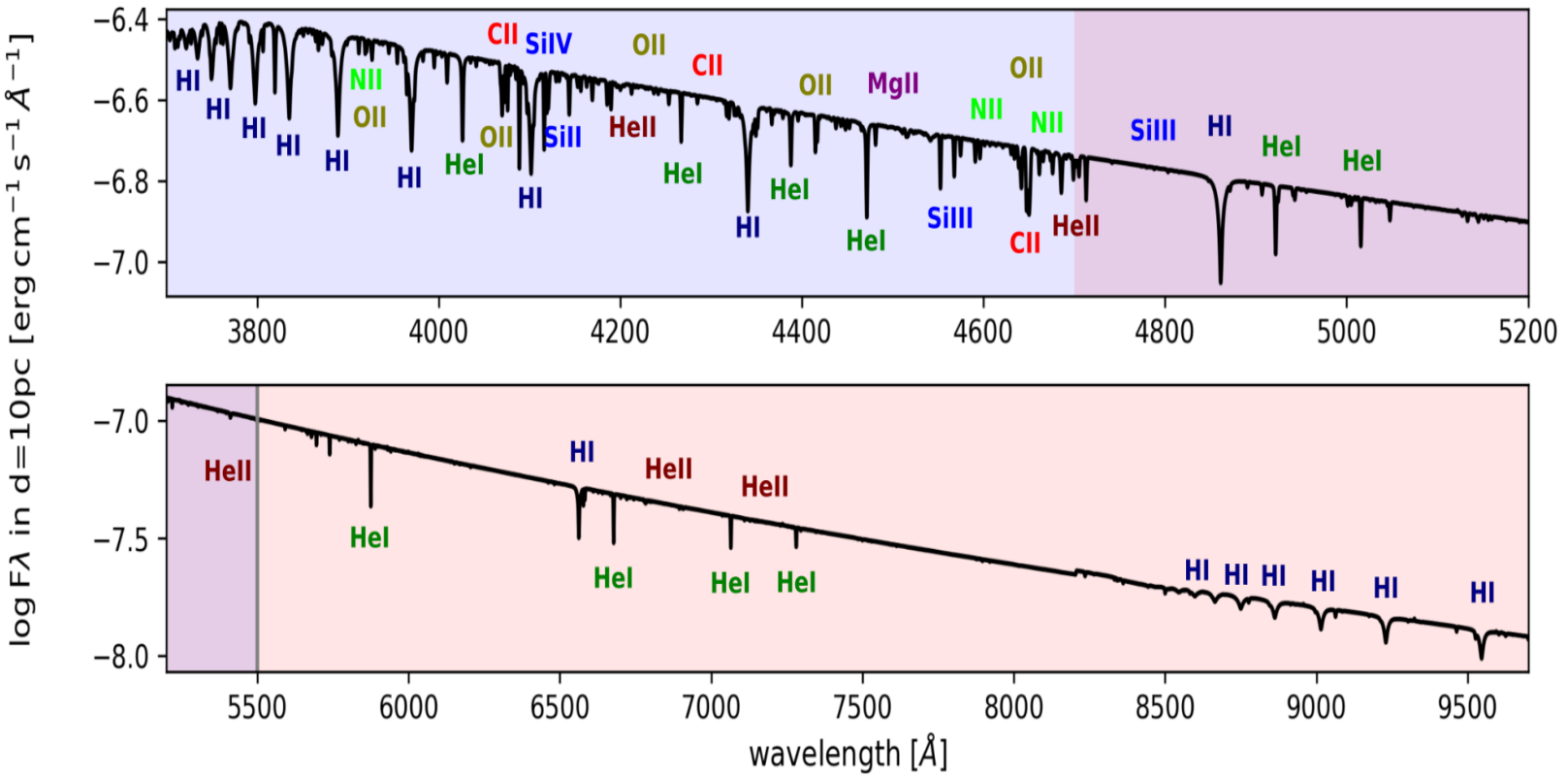



**Role of duplicity in the stellar evolution (e.g. Wang+ 2020) :**

- **Spectroscopic binary fraction**
  - **Limited by MUSE spectral resolution ~ 60 km/s**
  - **Close and contact massive binary detection (e.g. Almeida+ 2015)**

# Stellar evolution of massive stars



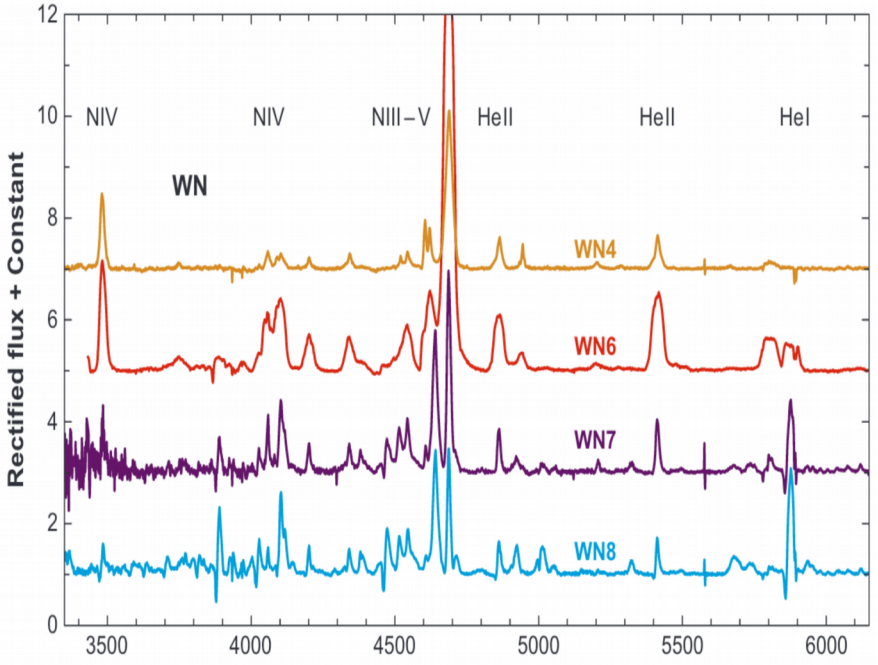

## Goals:

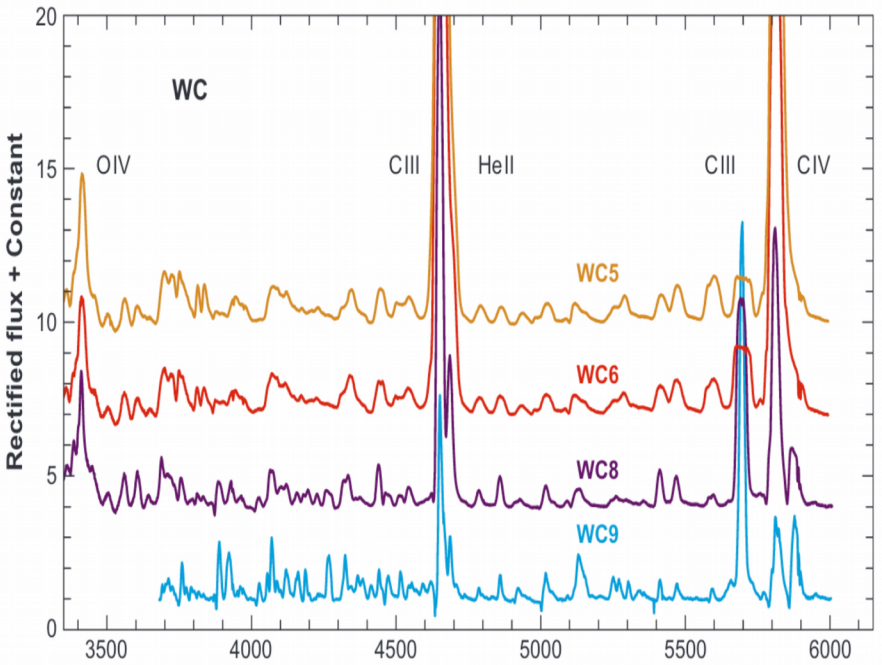
- Study the stellar formation and evolution of the most massive stars:
  - Determine stellar properties (e.g effective temperature, gravity, etc).
  - Chemical composition analysis
- Map the interaction of massive stars with the ISM
- Explore the kinematics of the stellar cluster.

## BlueMUSE:

- Ionization ratios for temperature (e.g. SiII4552/SiII4128), Balmer line widths for gravity.
- Key transitions for abundance measurements, e.g., N (4614), O ( 4448), C ( 4267), Si, Mg (4481) and Fe (Teff ≤ 10kK)
- Mapping of HII region (e.g. density, temperature) link stellar feedback (ionisation/winds) to ISM

# Wolf-Rayet massive stars



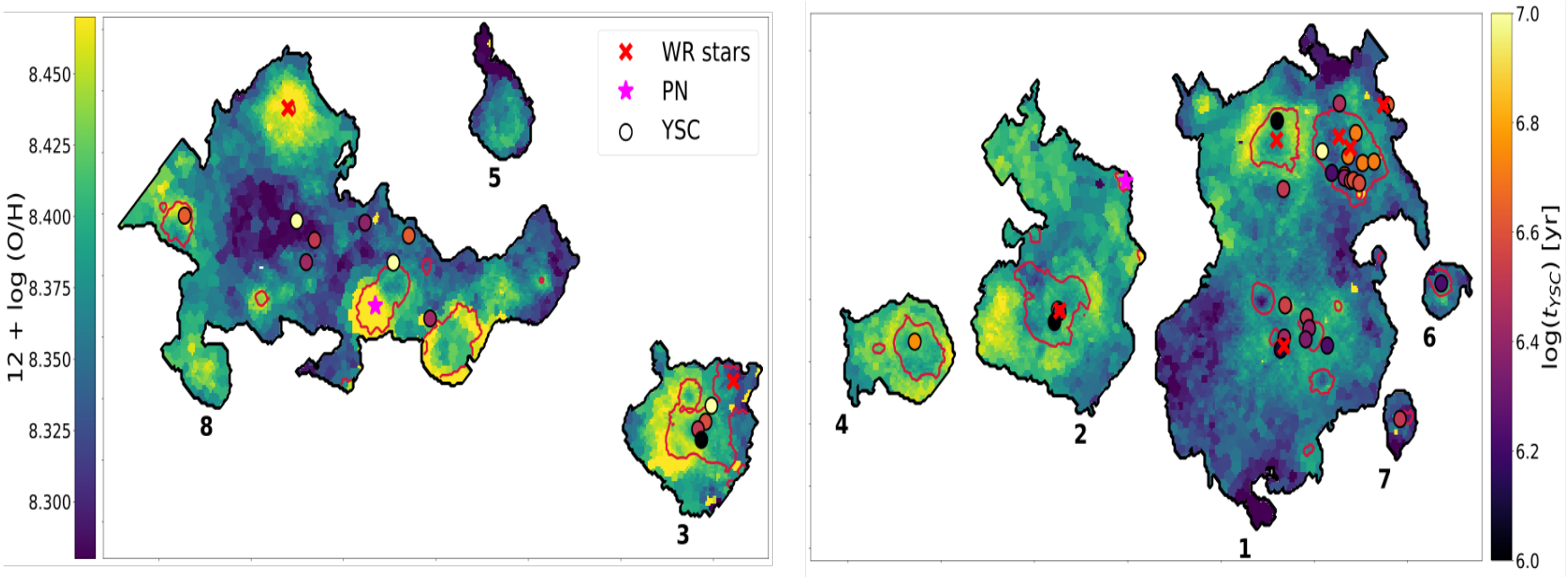

## Goals:

- Caracterise WR pop to constraint stellar evol. models
- WN/WC as a function of galactic environments

## BlueMUSE:

- Cover both the blue and red bump
- Stellar winds features: OIV 3411-34, CIII 4650, He II 4686

# HII regions (SNRs, and PNe) in the Local Volume:




## Goals:

- Census of the stellar and star cluster content
- Quantify physical properties (ne, Te)
- Trace abundance patterns and enrichment
- Kinematics

## BlueMUSE:

- **N_e** → [OII] 3729,3726, [Cl III] 5518,5535 , [Ar IV]4740,4711 but also [SII]6716,6731
- **T_e** → [OIII]4363,4958,5007; [NeIII] 3343,3968,3869 but also [NII] 5755,6583,6548 (with MUSE)
- High resolution spectral power will enable to disentangle **kinematics** (HII regions kinematics are <10 km/s so spectral resolution of 35 km/s)

# Evolved stars and stellar clusters

## Goals:

- Stars and Star clusters ages/metallicities/chemical composition
- Stellar kinematics (from single stars in low density fields to stellar pop.)
- Separate and understand the nature of multi-populations in globular clusters (GC)

## BlueMUSE:

- **Mg triplet at 517** nm important for kinematics, the reddest line of interest is the NaD at 5890 (MUSE)
- **NH molecular band at 336 nm** important to discern multiple populations in GCs. Extend investigations of multiple populations from red giants to turn-off and main sequence stars.
- **Call H & K lines**, as well as the strong diffuse interstellar molecular bands at 4430 A