# SPATIALLY RESOLVED LOCAL METAL-POOR WOLF-RAYET GALAXIES WITH NEBULAR HEII EMISSION


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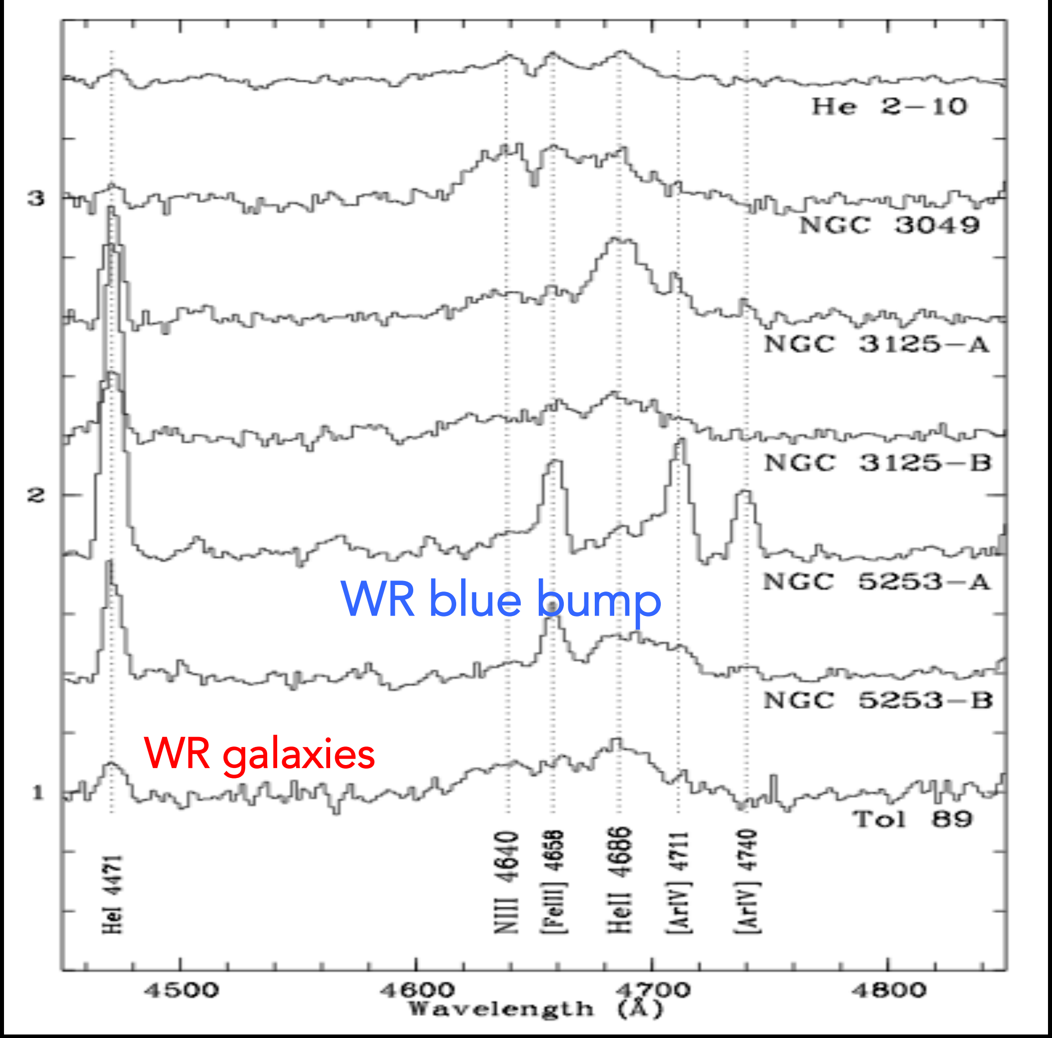
EWASS, Prague, June 26th, 2017

Wolf-Rayet galaxies: star-forming galaxies whose spectra show signatures from WR stars (broad emission feature at ~ 4680 A or WR blue bump)




Schaerer, Contini & Kunth (1999)

# Why local metal-poor WR galaxies with nebular HeII emission ?

✔ Representative of primordial distant star-forming galaxies that may be responsible for the Epoch of reionization (e.g., Bouwens+2011; Sun & Furlanetto 2016)

✔ Signpost of the transition between metal-free Population III stars and chemically enriched one (PopII stars), typically ocurring in the early universe (e.g., Maio+2010)

✔ WR population: stronger disagreement between models and data in metal deficient galaxies (e.g., Crowther & Hadfield 2006; Brinchmann+2008;Leitherer+2014)

✔ Long GRB: prefer metal-poor, star-forming galaxies with negligible metallicity gradients (e.g., Fruchter+2006;Modjaz+2008; Christensen+2008; Niino 2011) & WRs are the prime candidates for their progenitors (e.g., Woosley & Bloom 2006; Hammer+2006;Crowther 2007)

✔ Critical laboratories to test stellar population synthesis models at sub-SMC metallicities: constrains on WR star formation and possible progenitor population for GRBs

# Why is the study of nebular HeII line in metal-poor galaxies relevant ?

✔ HeII emission (λ1640, 4686 Å): the existence of sources of hard radiation field (E ≥ 54ev)

✔ HeII-emitters are observed to be more frequent among high-z galaxies than for local objects (e.g. Kehrig+2011; Cassata+2013) and the nebular HeII line is one of tracers of PopIII-stars (e.g., Schaerer 2003: Johnson+2009)

✔ Nebular HeII is stronger in low metallicity galaxies (e.g., Guseva+2000; Senchyna +2017) + empirical constrains on models for metal-poor massive stars are difficult to obtain (e.g., Herrero+2012; Georgy+2016) → nebular HeII line in metal-poor galaxies is a useful window into the ionizing spectrum of these stars and a signpost for upcoming long GRBs (e.g., Szécsi+2015)

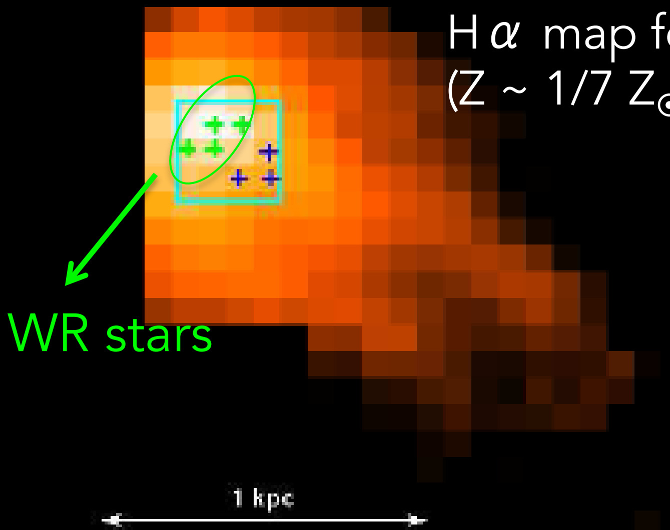
✔ Local Universe: nebular HeII line versus WR stars photoionization but the origin of this high-ionization emission is still an open issue in many cases (e.g. Kehrig+2011; 2013; Shirazi & Brinchmann 2012; Schaerer 2013)

Integral Field Spectroscopy (IFS) as a suitable tool: spectral and spatial information at the same time (e.g. Kehrig+2008,2012,2013,2015,2016; Perez-Montero+2011,2013) → *Avoid Aperture Effects & Provide Total Flux*

✔ Lower difficulty when doing the spatial correlation between massive stars and surrounding nebular properties

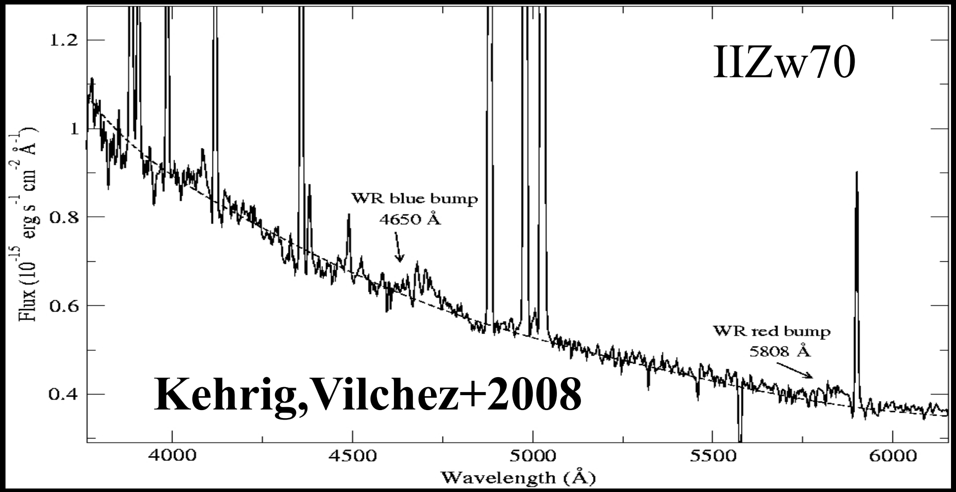
✔ Locate WR stars more precisely and find them where they were not detected before! (e.g. Kehrig+2008,2013; James+2013)

✔ Spatially resolved nebular HeII line emission: location; extension; total ionization budget; the origin of the nebular HeII

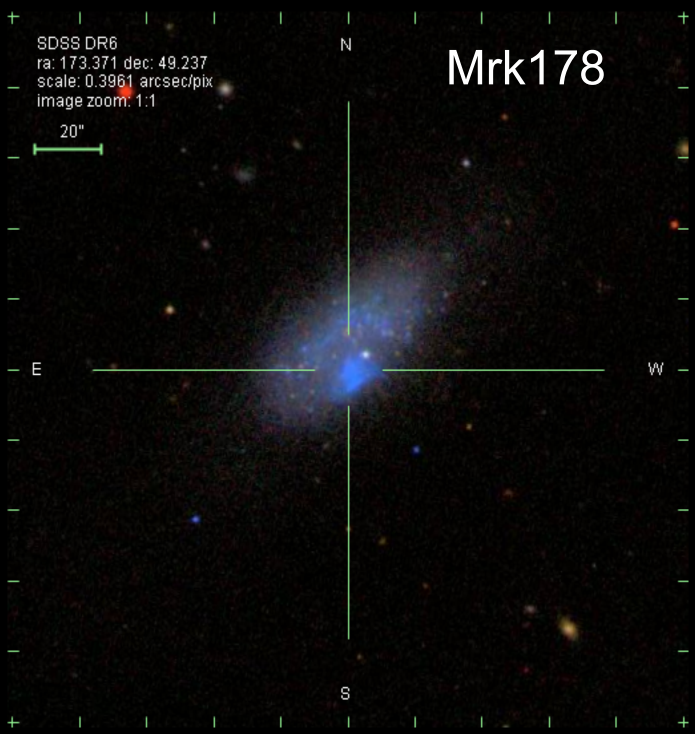


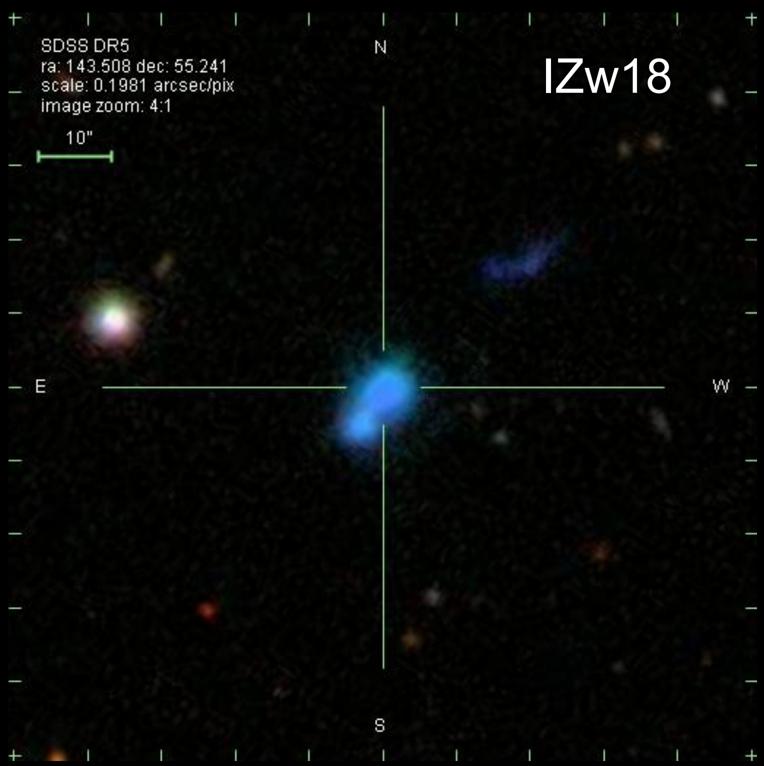

Hα map for IIZw70 ($Z \sim 1/7\ Z_\odot$)

Kehrig,Vilchez+2008



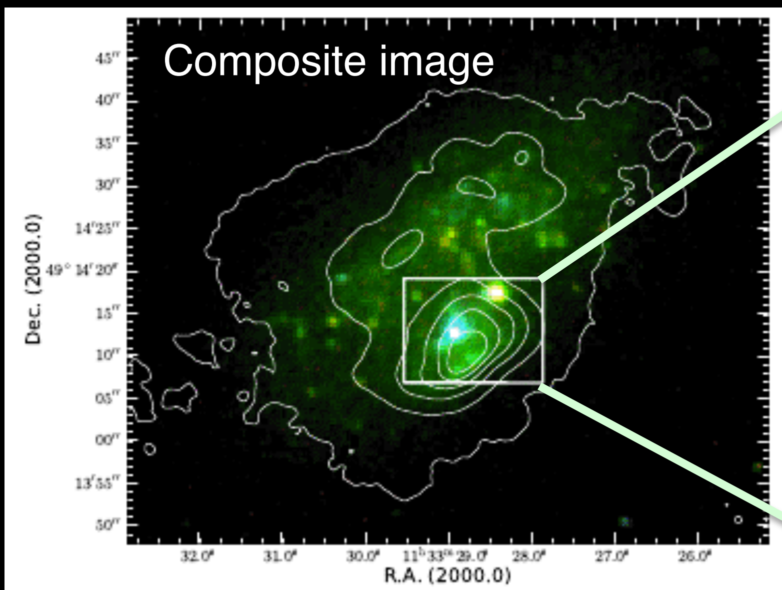
# Two first-class metal-poor WR galaxies with nebular HeII emission

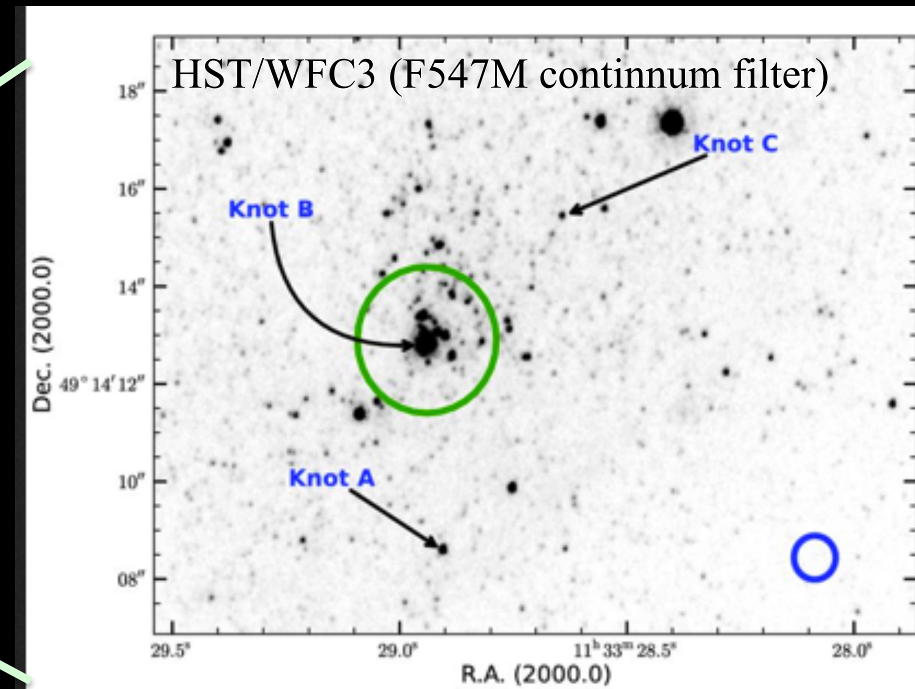


# The first IFS study of Mrk178: the closest (D~3.9 Mpc) metal-poor WR HII galaxy

*Kehrig et al. (2013)*

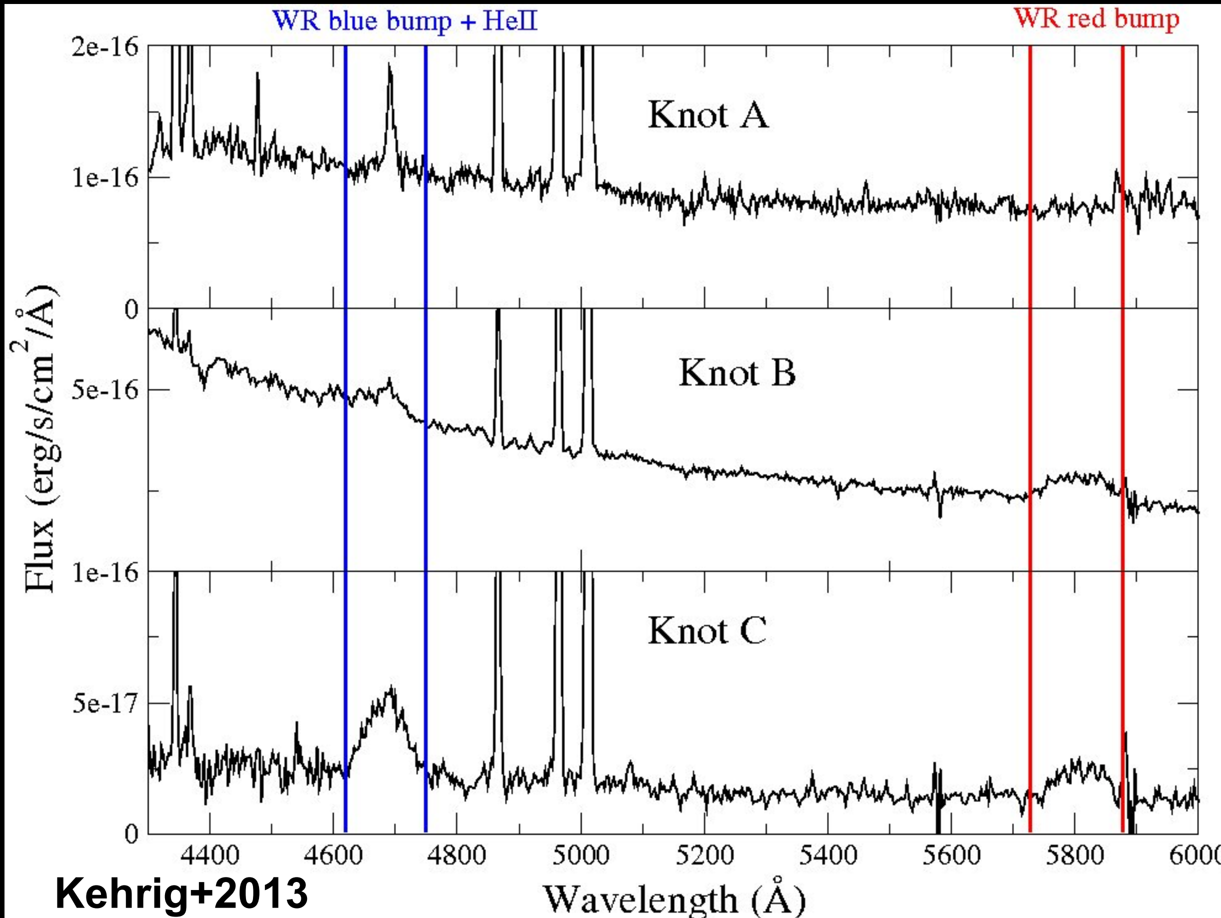



FOV ~ 300 pc x 200 pc

Optical spectra: INTEGRAL IFU @ WHT 4.2m

For the first time, we study the WR content in Mrk178 beyond its brightest star-forming knot uncovering new WR star clusters




*Kehrig et al. (2013)*

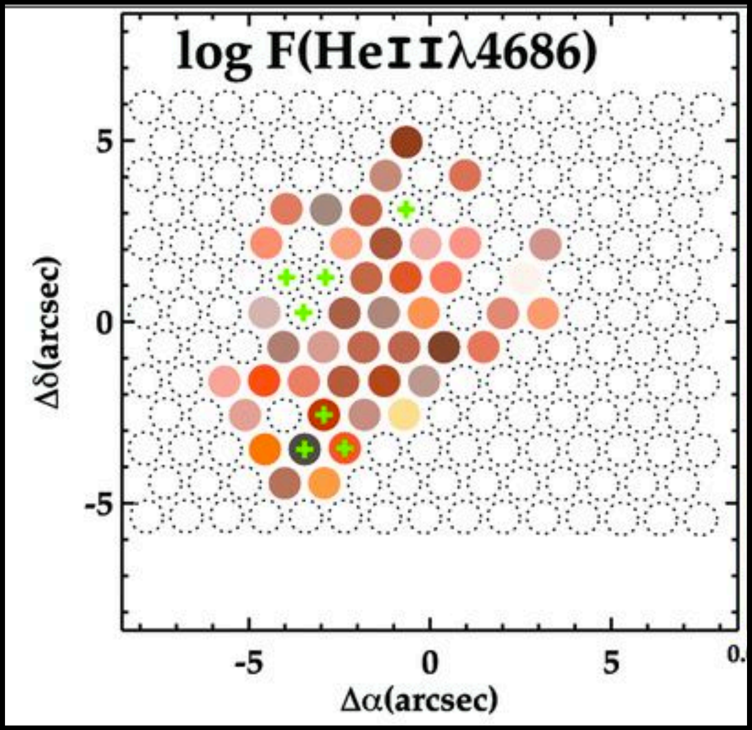
Using Large/Small Magellanic Cloud-template WR stars, we empirically estimate the presence of a minimum of ~ 20 WR stars within our FOV

The strength of the broad WR features and its low metallicity (~ 1/10 $Z_\odot$) make Mrk178 an intriguing object!

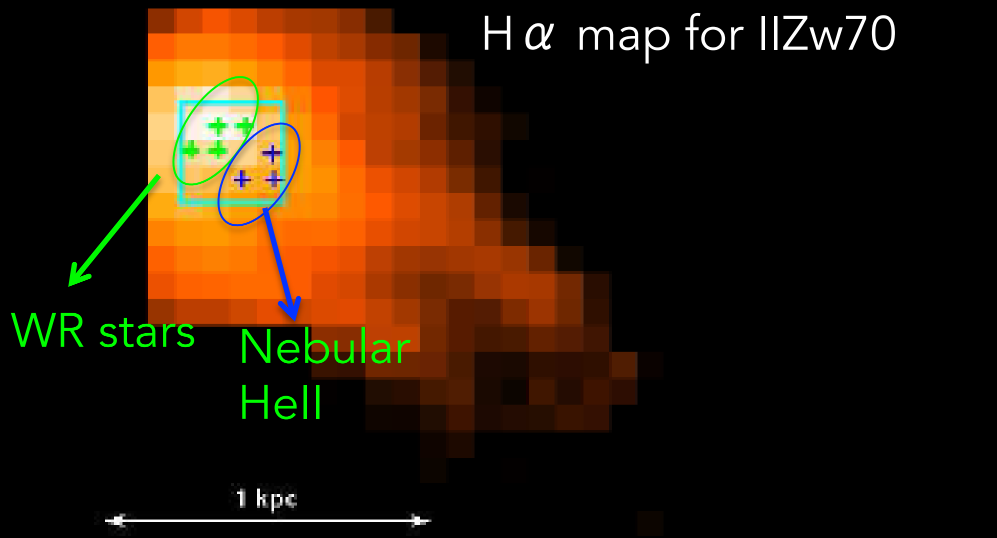
Current stellar evolutionary models for (rotating/non-rotating) massive stars predict very few, if any, WRs in low-Z environments (e.g., Leitherer+2014)

# Lack of connection between nebular HeII emission and WR stars

Mrk178 ($Z \sim 10\% Z_{\odot}$) and IIZw70 ($Z \sim 15\% Z_{\odot}$): HeII emission is extended and goes much beyond the location of WR stars




Kehrig,Vilchez+2013




Kehrig,Vilchez+2008

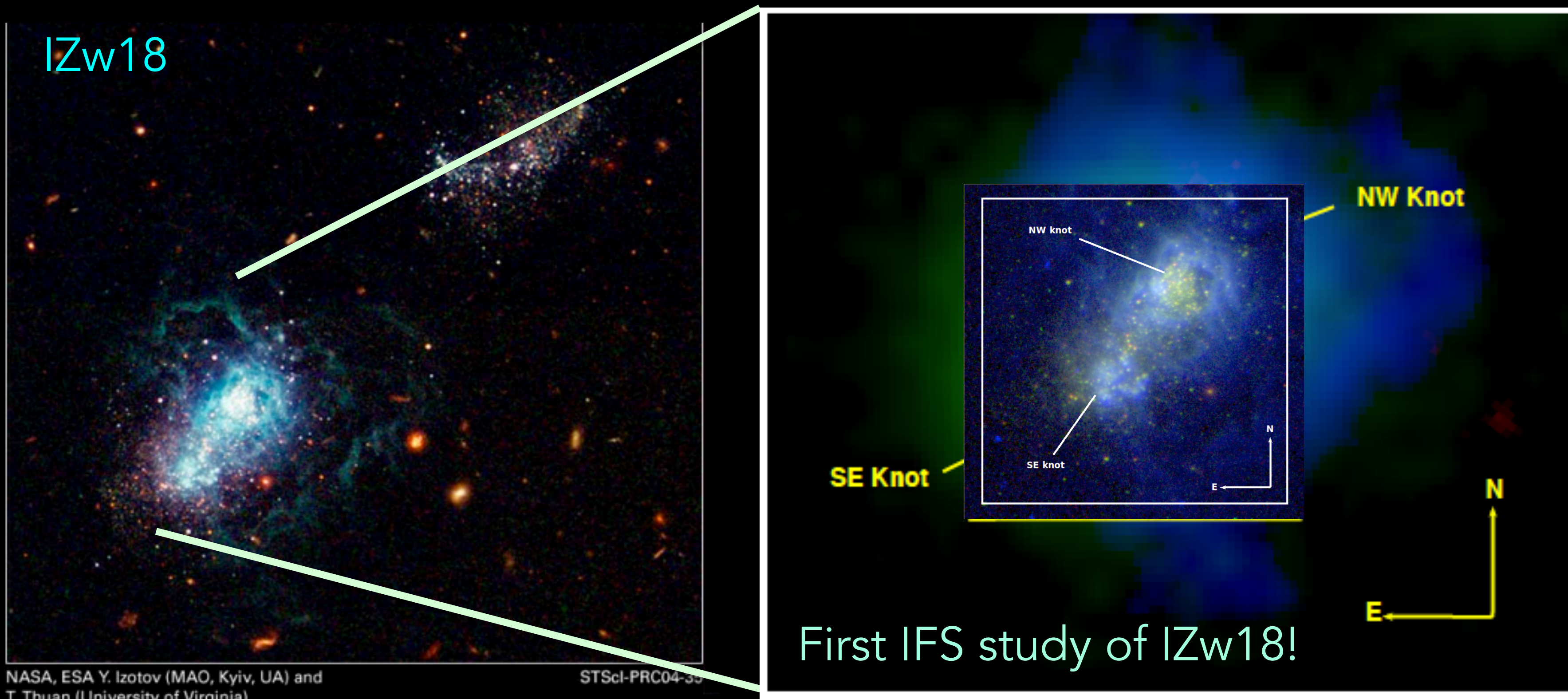
IFS: Spatial separation between WR stars and the HeII-emitting zone (see also Izotov+2006), and where the non-detection of WR features is unlikely to be an effect of the weakness of WR bumps (see also Shirazi & Brinchmann 2012)

# The first IFS study of IZw18!

*Kehrig, Vilchez et al. (2015,2016)*

The nearby (D ~ 19 Mpc) lowest-metallicity (Z~0.0004) SF galaxy and our best local analog of faraway starbursts (e.g. Skillman & Kennicutt 1993; Vilchez & Iglesias-Paramo 1998)

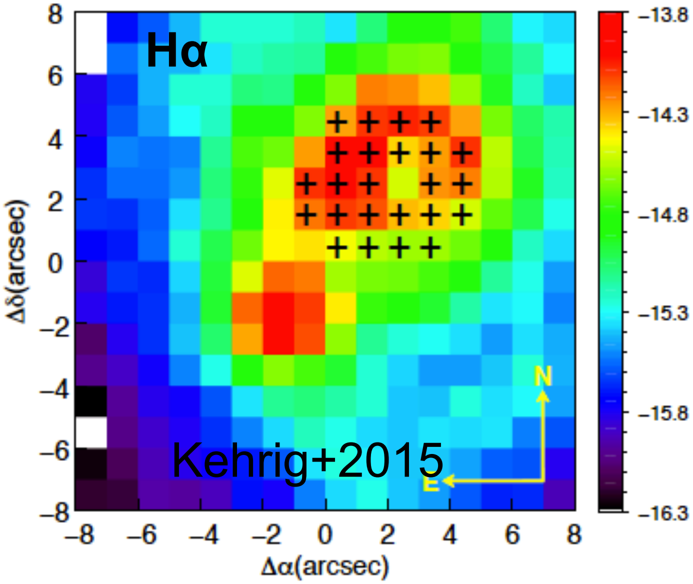
Natural local counterpart of distant HeII-emitters!

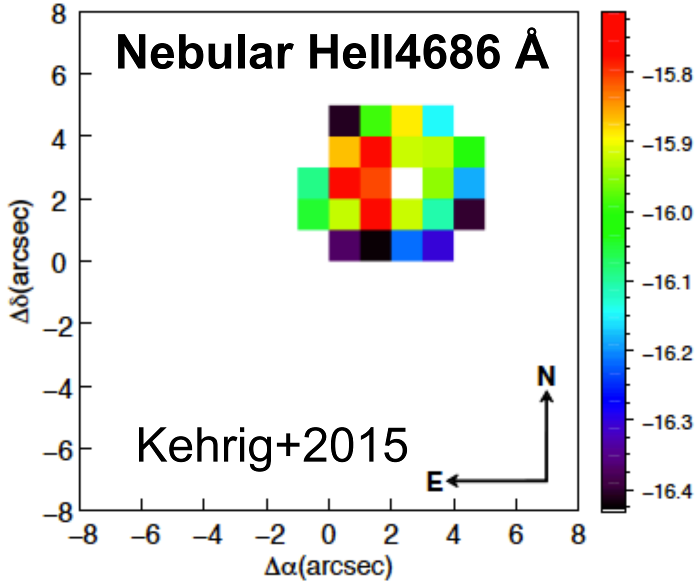


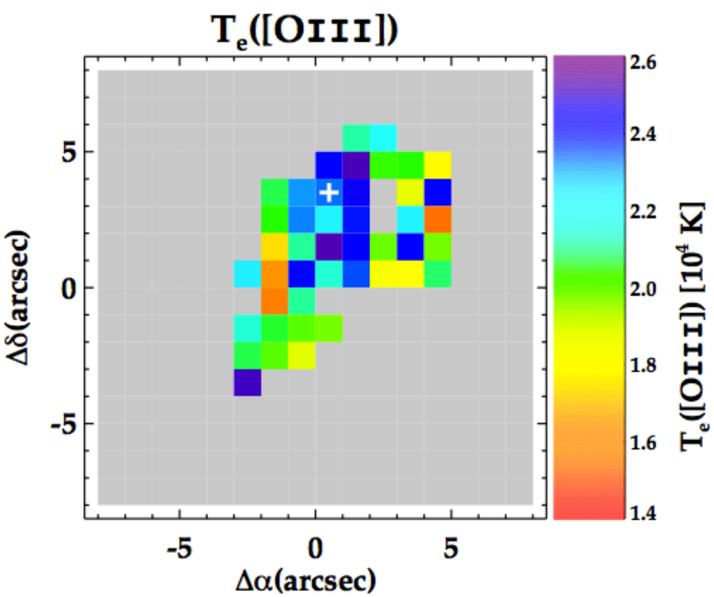

FOV ~ 1.4 kpc x 1.4 kpc

Optical spectra: PMAS IFU @ CAHA 3.5m telescope

# We discovered a large (D ~ 440 pc) nebular HeII4686-emitting region




*Kehrig, Vilchez+2015, ApJL*

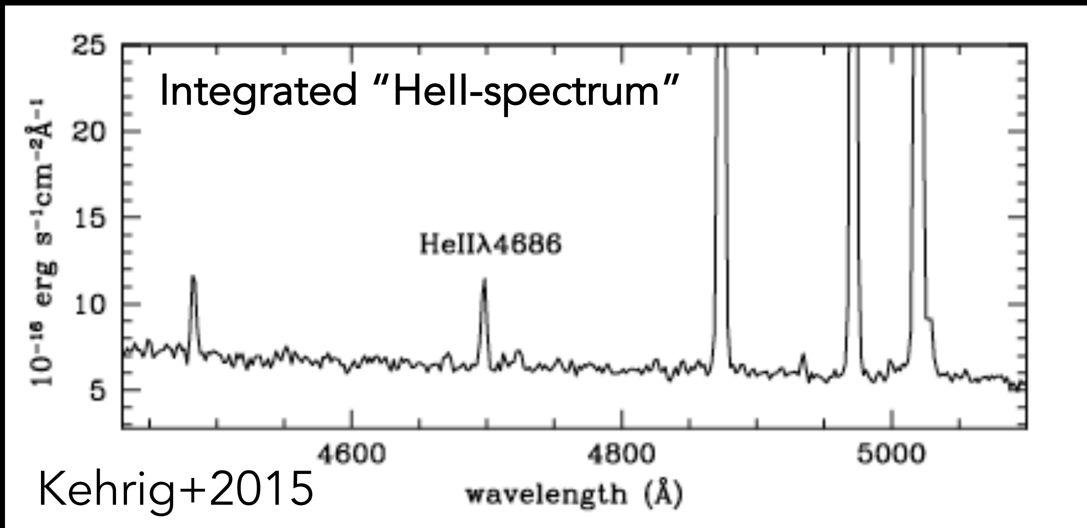
NW knot and thereabouts:

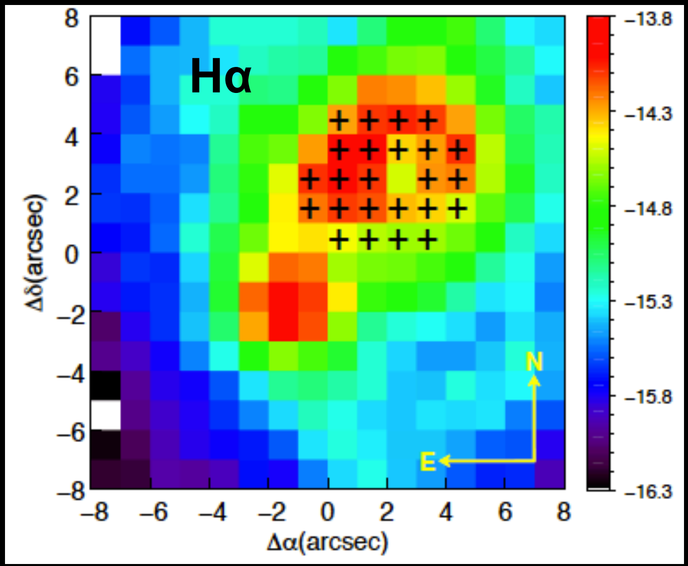
- ✔ Most of higher-Te[OIII] (> 22000 K) spaxels
- ✔ Higher excitation gas and ionization parameter
- ✔ Nebular HeII-emitting region

Existence of a harder radiation field

Our IFU data reveal for the first time: total spatial extent and precise location of the nebular HeII region, and the corresponding total HeII-ionizing flux in IZw18!

What is the main source powering nebular HeII emission in IZw18 ?




Total L(HeII4686)$_{obs}$ ➔ Q(HeII)$_{obs}$ = Total HeII-ionizing photon flux

Conventional HeII-ionizing sources (WRs, shocks, X-ray binaries) cannot convincingly explain the observed nebular HeII emission in IZw18

# Peculiar very hot stars in IZw18

Observations *versus* HeII-ionizing fluxes from radiation-driven wind models for the most massive (300 $M_{\odot}$), hottest O stars at the metallicity of IZw18 and below (Kudritzki 2002): the number of such stars needed to explain $Q(HeII)_{obs}$ implies a cluster mass ~ 10 - 20 x $M_{star}$ of the NW knot of IZw18

Szecsi+2015: models for fast rotating massive single stars which undergo chemically homogeneous evolution (CHE) at the metallicity of IZw18: Transparent Wind Ultraviolet INtense stars (TWUINs)

These models cannot produce the highest values of HeII4686/Hβ

# Peculiar very hot stars in IZw18
# metal-free ionizing stars (PopIII-like stars) ?

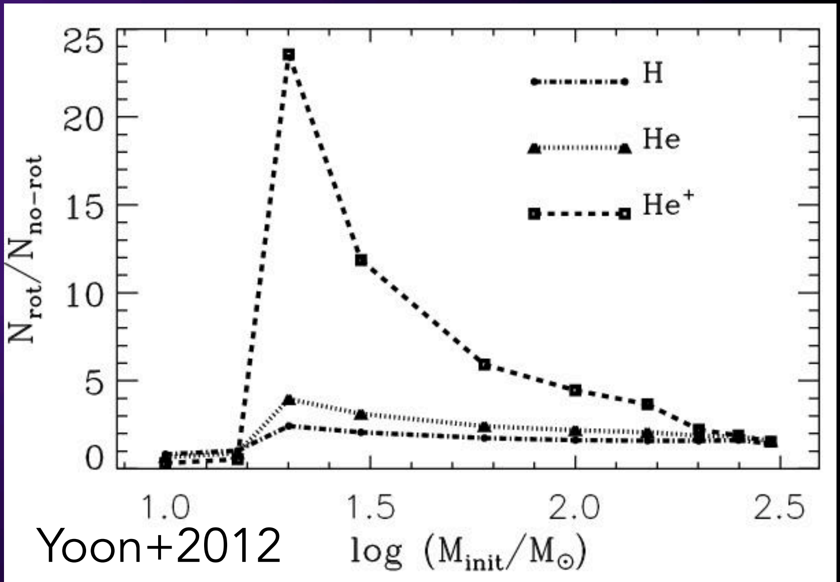
Searches for PopIII-hosting galaxies have been carried out using HeII lines because of the strong UV radiation expected at (nearly) Z=0 (e.g. Schaerer 2008; Visbal+2015)

Rotation → harder ionizing continuum (e.g., Maeder & Meynet 2012; Szécsi+2015)

**Compare the observations with HeII-ionizing fluxes from models for rotating Z=0 CHE stars** (Yoon, Dierks & Langer 2012):

100 $M_\odot$ star models → ~ 13 stars are needed

The harder spectra of these stellar models can explain the highest values of HeII4686/Hβ



Yoon+2012

Lebouteiller+2013: metal-free gas pockets could provide the raw material for making such (nearly) metal-free stars in IZw18 (see also Tornatore+2007;Sarmento+2012)

Senchyna+2017: for 3 HeII-emitting galaxies, stars with metallicity much lower than that of their HII regions are required

# Take-Away Points

Metal-poor, high-ionizing WR galaxies nearby challenge current, standard models for metal-poor massive stars

There is still a lack of understanding of nebular HeII emitters even at low redshifts and WRs are not the main HeII-ionizing sources in many case

Clues of the early-universe can be found in our cosmic backyard through nearby metal-poor HeII-emitting galaxies

IFS studies of metal-poor WR galaxies allow extended insight into their ‘realistic’ ISM and massive stars → constrain long GRB progenitors and their hosts, models for metal-poor massive stars and sources responsible for the Universe reionization

A major scientific objective of most of all future observatories (e.g., JWST; GTC-MEGARA; E-ELT Harmoni).

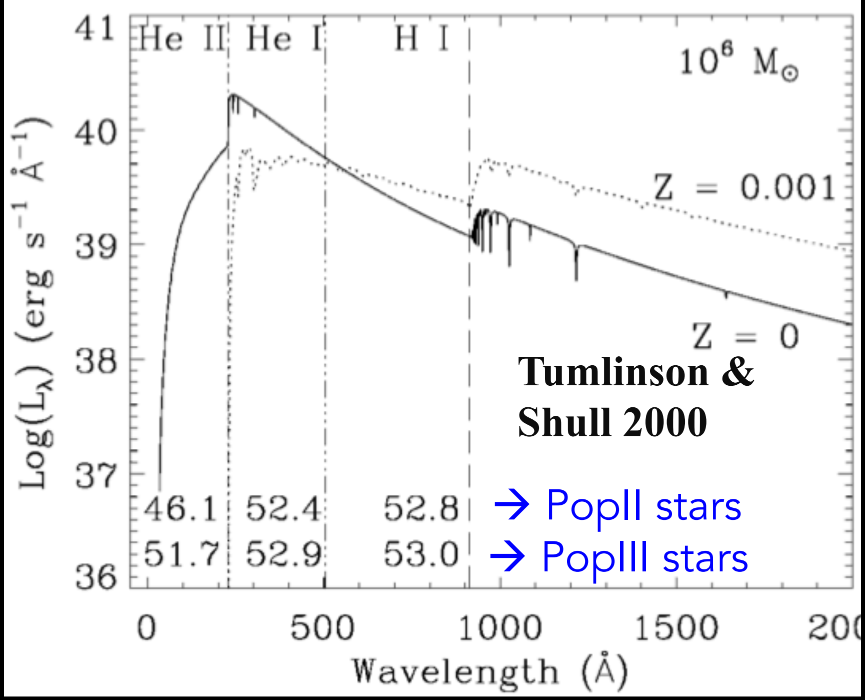
# Why is the study of the HeII line relevant ?

✔ HeII-emitters are observed to be more frequent among SF galaxies at high-z than for local SF objects (e.g. Kehrig+2011; Cassata+2013; ); PopIII-stars (the first metal-free stars) and nearly metal-free stars → extremely hard UV-emitting spectrum

✔ Significant transition in the ionizing spectrum of stars with metallicity

| Z | IMF | Q(H) | Q(HeI) | Q(HeII) |
|---|---|---|---|---|
| 0. | A | 46.98 | 46.75 | 45.54 |
| 0. | B | 47.29 | 47.10 | 46.26 |
| 0. | C | 47.98 | 47.80 | 47.05 |
| $10^{-7}$ | A | 46.94 | 46.65 | 43.45 |
| $10^{-7}$ | B | 47.30 | 47.06 | 45.61 |
| $10^{-7}$ | C | 48.01 | 47.78 | 46.39 |
| $10^{-5}$ | A | 46.90 | 46.55 | 42.39 |
| $10^{-5}$ | B | 47.30 | 46.99 | 44.56 |
| $10^{-5}$ | C | 48.02 | 47.73 | 45.35 |

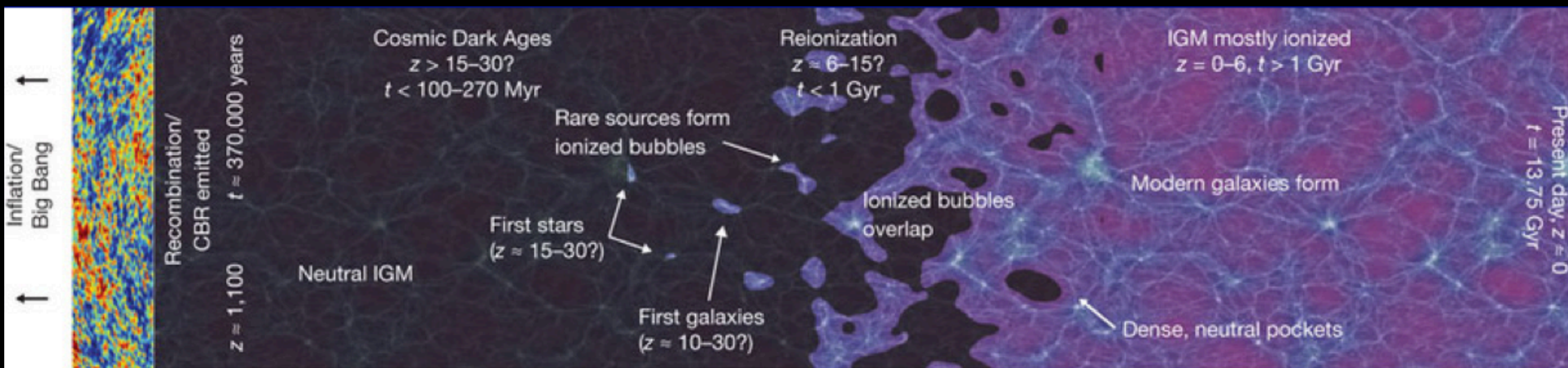
Schaerer (2003)
Q(X) [log(photon/s/$M_\odot$)]




Synthetic spectra of Population II and Population III clusters

# Why is the study of the HeII line relevant ?

✔ High-ionization lines in metal-poor galaxies: window into the ionizing spectrum of metal-poor hot stars and one of the tracers of PopIII-stars (e.g., Schaerer 2003; Johnson+2009) → such stars are believed to have contributed to the universe's reionization




Searching for PopIII galaxies is one of the main science drivers for next-generation telescopes (e.g. JWST; Johnson 2010; Visbal+2015)

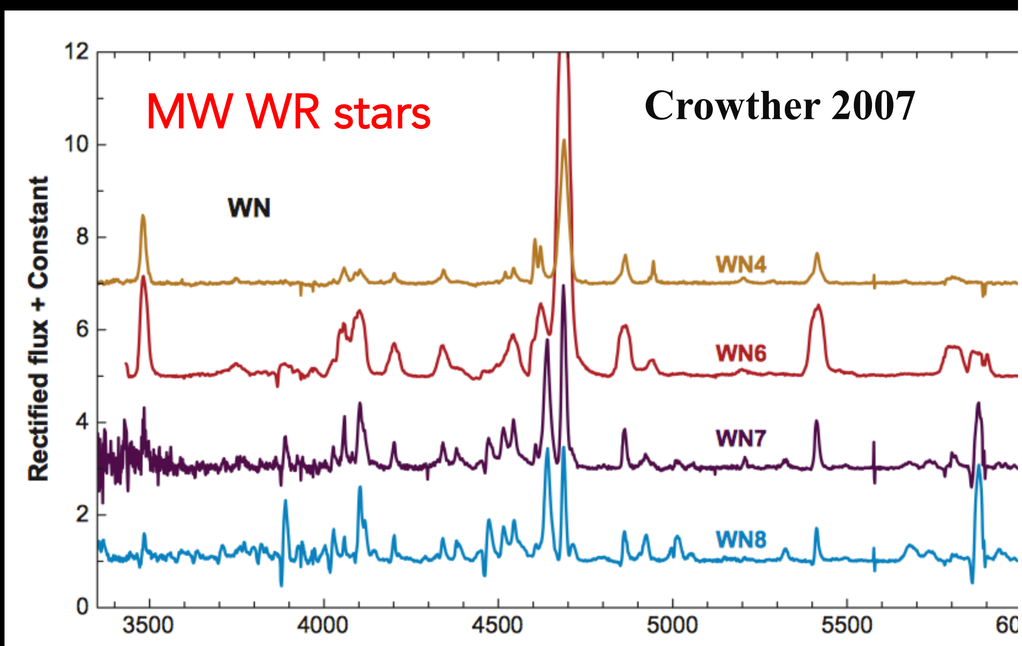
✔ The gas properties and stars necessary and sufficient to power such high-ionizing emission remains unclear at high-z; before interpreting high-z HeII-emitters & use HeII line to infer properties of distant starburst, it is crucial to understand the formation of HeII line in nearby metal-poor objects

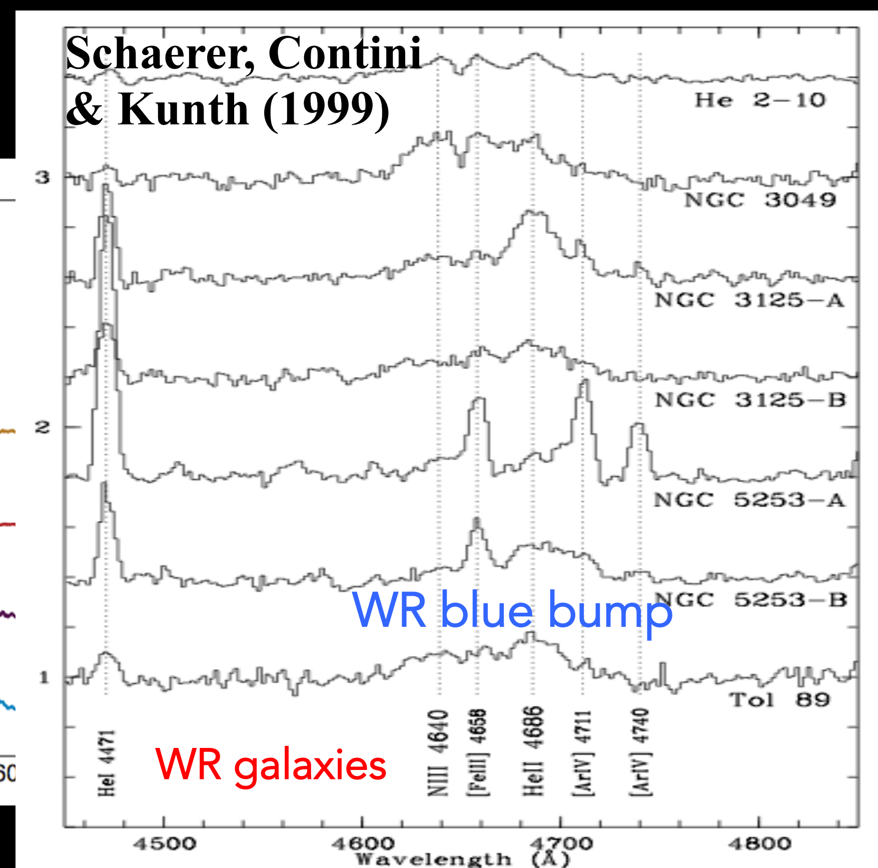
# HeII ionization

Sources of ionizing radiation (hot Wolf-Rayet (WR) stars, fast shocks, X-ray binaries) have been proposed to explain the HeII ionization in star-forming systems (e.g., Garnett+1991; Schaerer 1996; Thuan & Izotov 2005; Gräfener & Vink 2015)

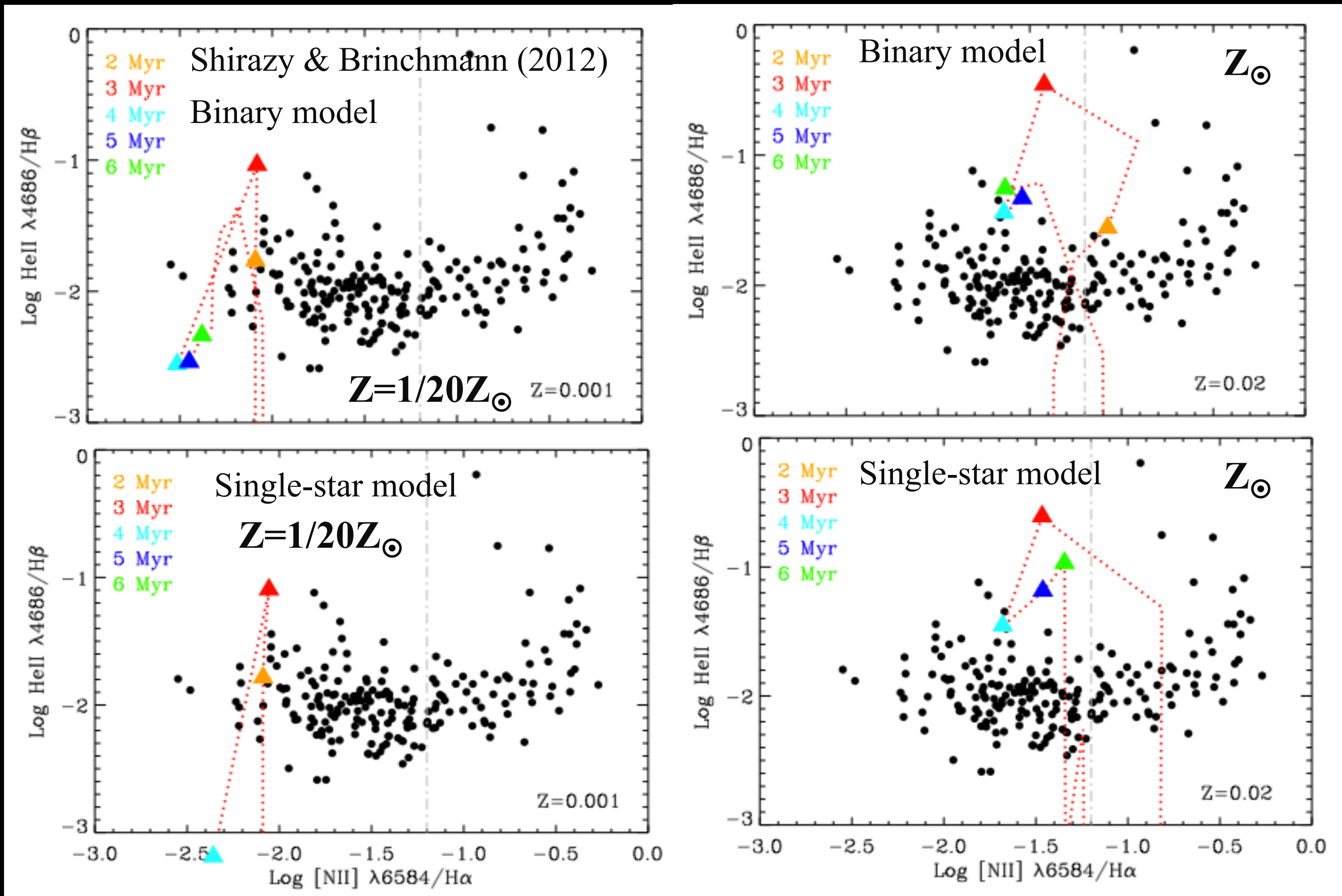
✔ Post main-sequence stars; a late phase in the evolution of very massive stars

✔ Strong emission lines formed in their dense, fast winds; the two main classes of WR stars are: WN (products of H-burning – He and N lines) & WC (products of He-burning – C and O lines)



# HeII ionization: WR stars and the effect of binarity evolution on the HeII using the BPASS code (Eldridge+2008,2009,2011)

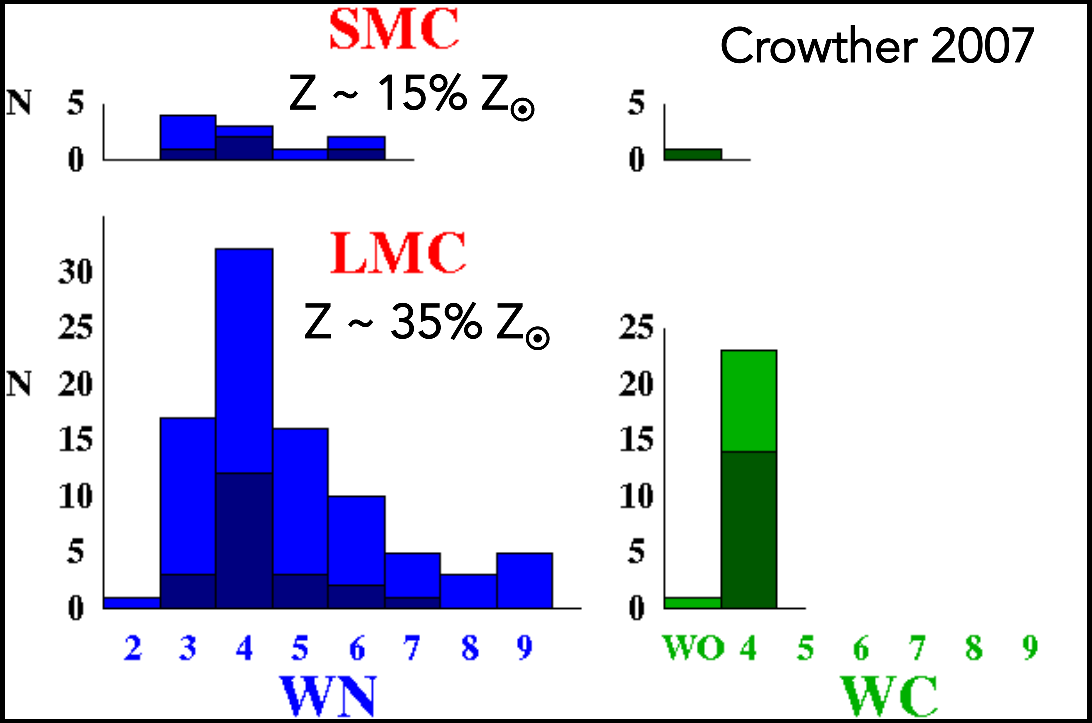



Predicted peak for HeII/Hβ is similar between binary and single-star models, but binary model predict an elevated HeII/Hβ for a longer period of time

# HeII ionization: WR stars → What can one expect ?

★ WR stars (late phase in the evolution of massive O-type) are more common at high metallicity → metallicity dependence of winds (e.g. Crowther+2002; Mokiem +2007; Leitherer+2014)

Subtype distribution of Small Magellanic Cloud (SMC) and Large Magellanic Cloud (LMC) WR stars

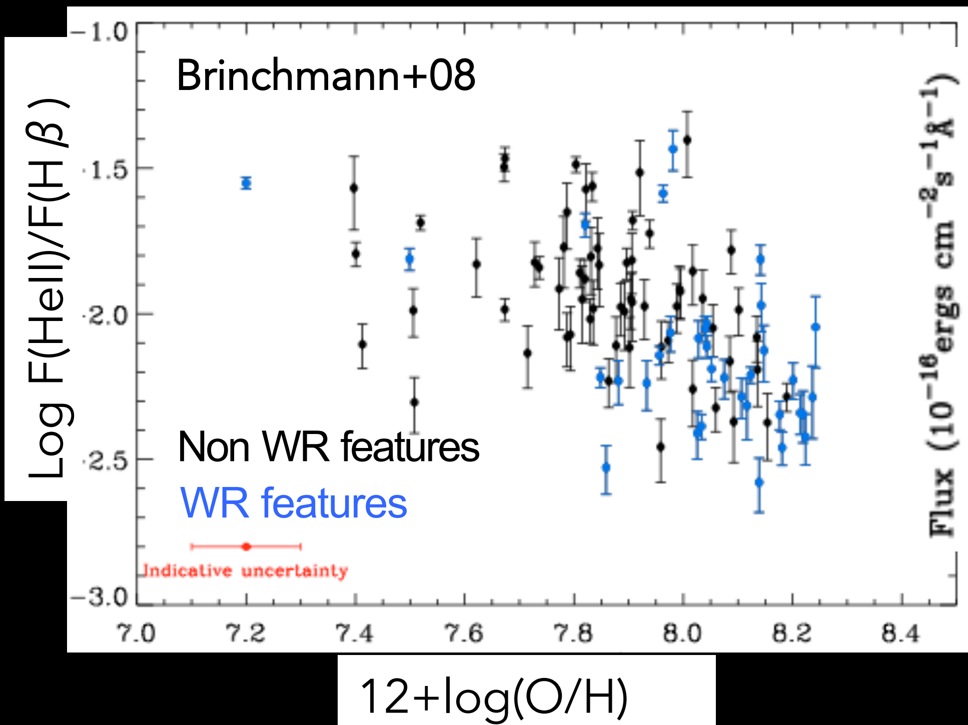


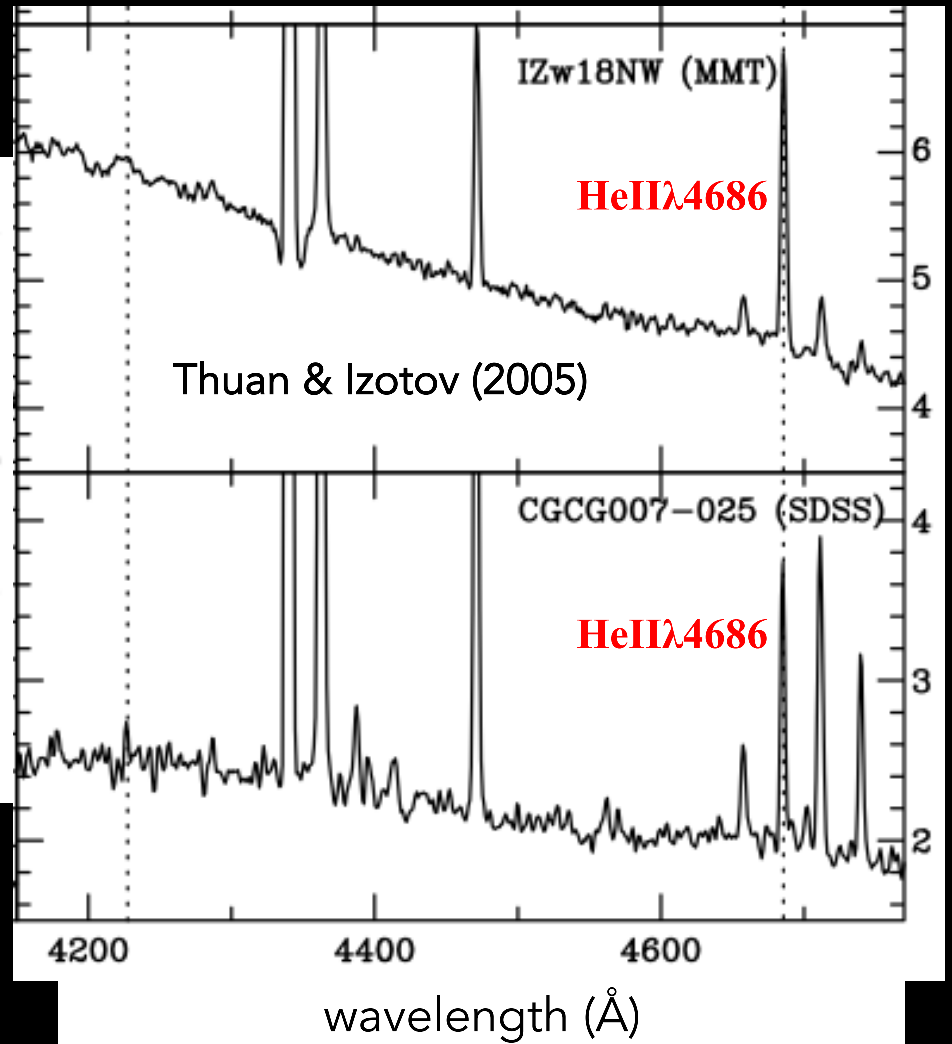

★ Rotation is expected to increase the WR population (Meynet & Maeder 2005) but stellar evolutionary models for rotating massive stars predict very few, if any, WRs in low metallicity environments (e.g. Leitherer+2014)

★ HeII ionizing photons come mainy from hot WR stars → nebular HeII should be seen when such hot WRs are present and is expected to be weaker/non-existent at very low metallicity

# HeII ionization: The observational reality!

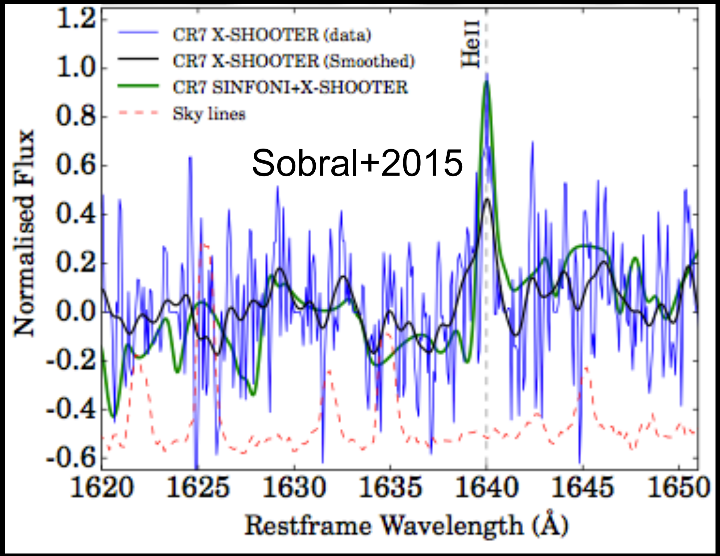
Nebular HeII line is observed to be stronger at low metallicities (e.g., Guseva +2000; Schaerer 2003; Thuan & Izotov 2005; Senchyna+2017)



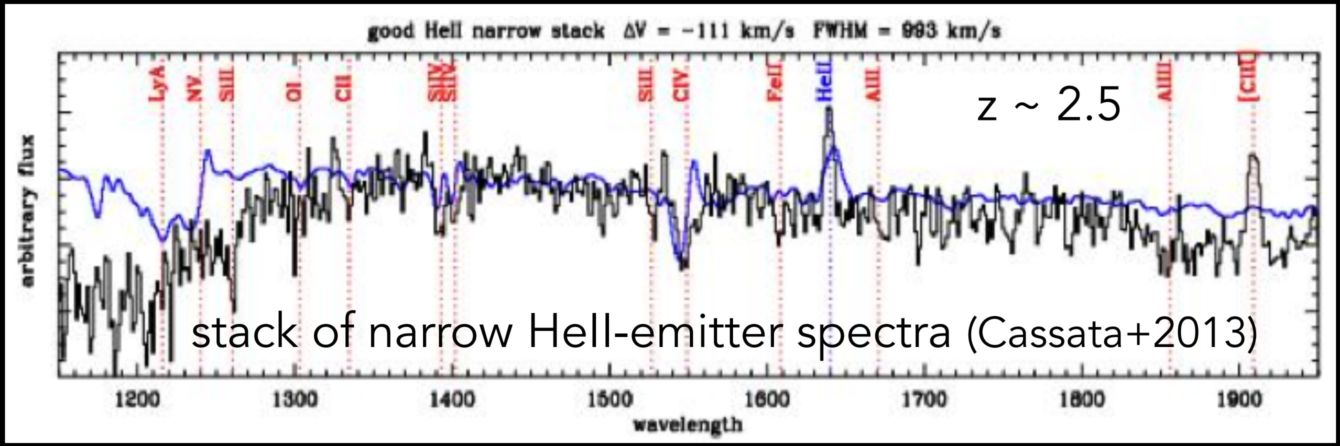



# HeII ionization: The observational reality

Nebular HeII does not appear to be always associated with WRs → WRs cannot explain the HeII ionization in all cases, particularly at low metallicity (e.g. Guseva+2001; Shirazi & Brinchmann 2012; Kehrig+2013)




CR7 (the brightest Ly $\alpha$ emitter at z = 6.6): WR stars interpretation is strongly disfavoured. PopIII stars or Black Hole ? (Sobral+2015; Agarwal+2017)

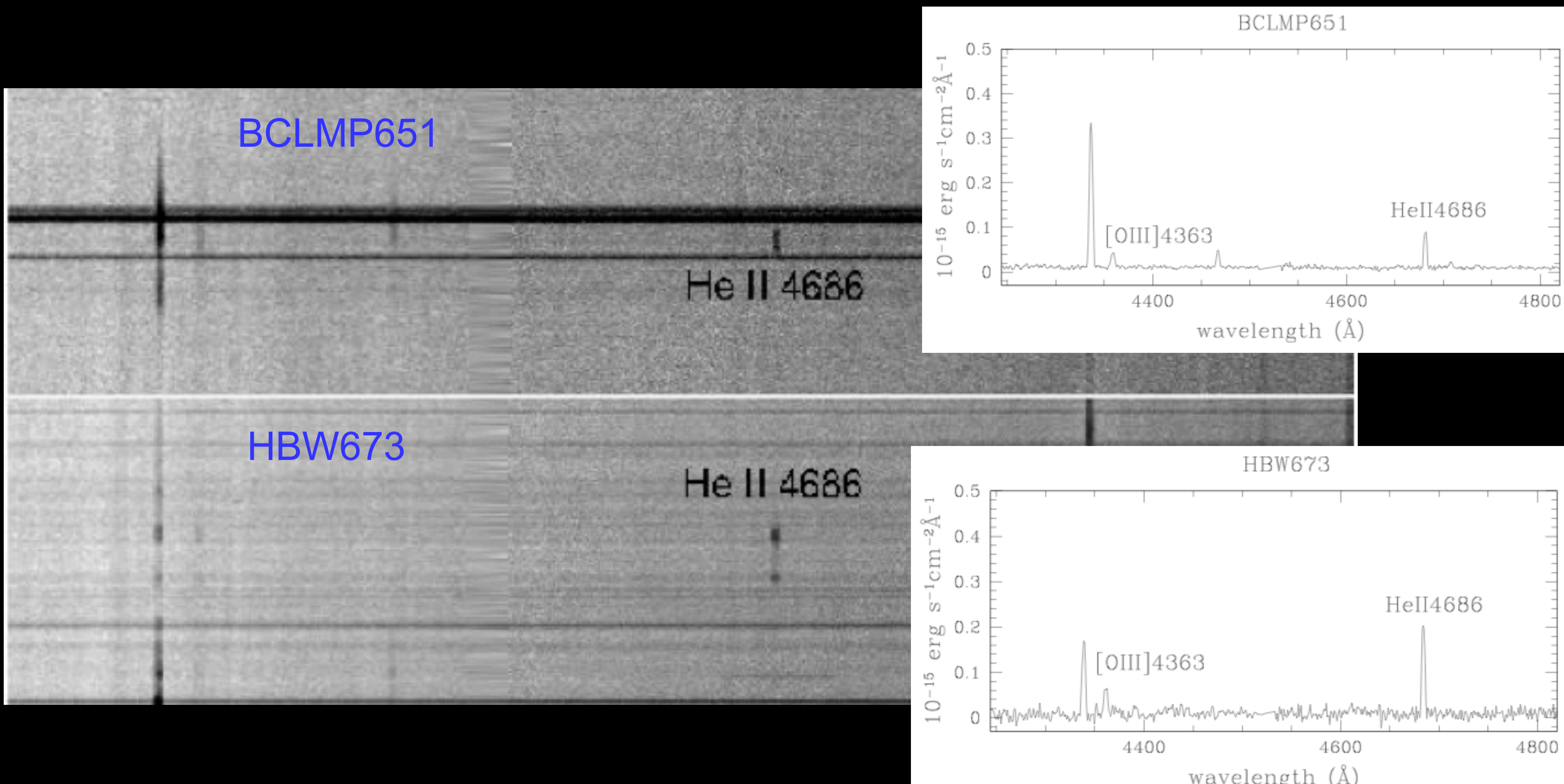



Stellar population models including WRs do not reproduce the properties of the narrow HeII emitters. PopIII stars (see also Grafener & Vink 2015)

# HeII ionization at low-redshift: The observational reality

The origin of the nebular HeII still remains difficult to understand in many cases

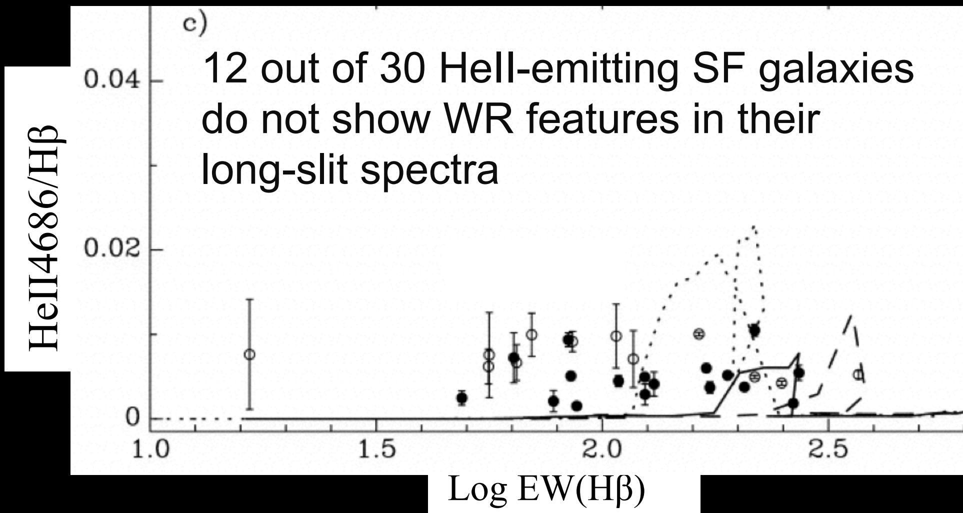
GMOS spectroscopy of HeII nebulae in M33 (Kehrig, Oey, Crowther+2011)




2 new HeII nebulae in M33 not associated with any hot massive star

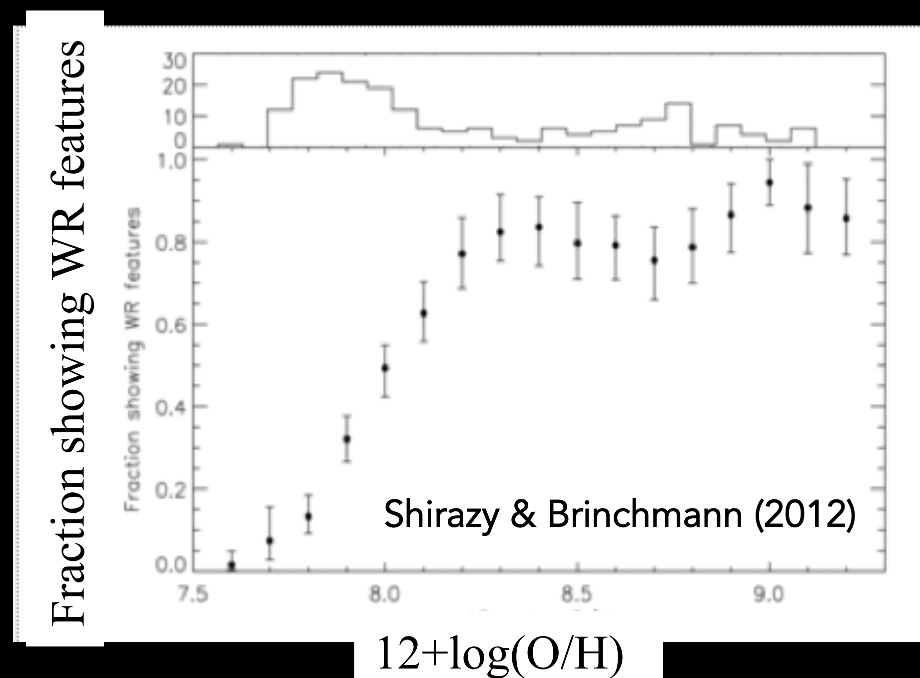
# HeII ionization at low-redshift: The observational reality

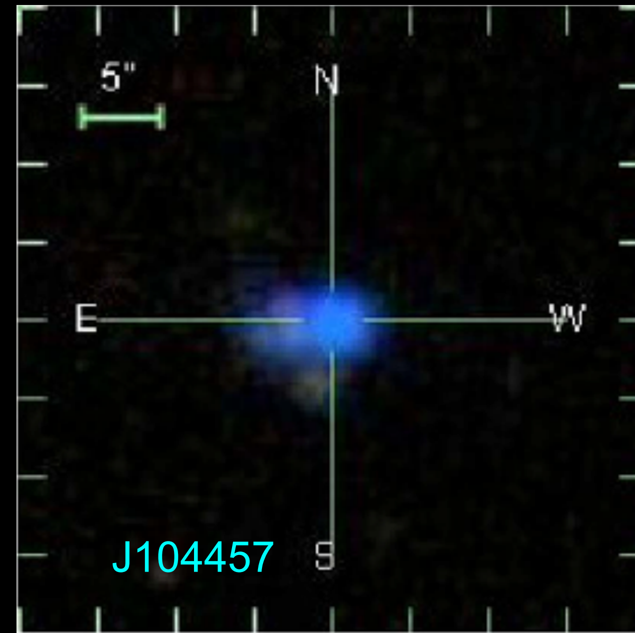
Guseva et al. (2000)



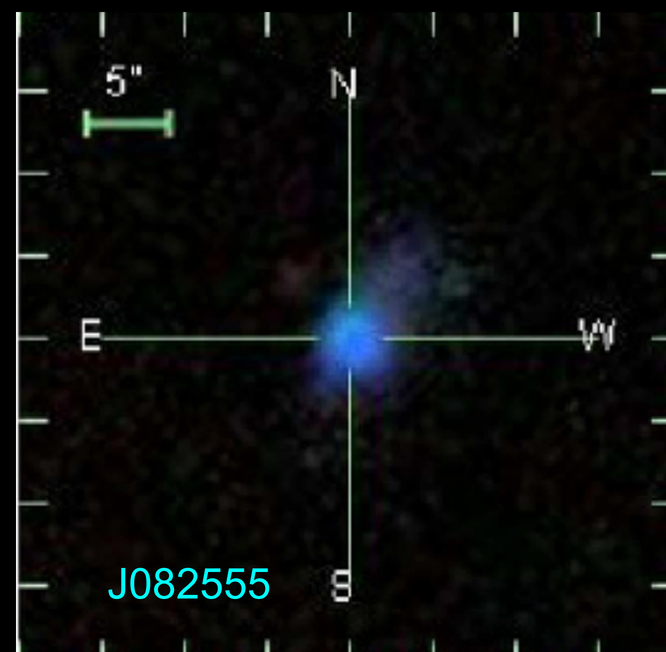

galaxies with detected and nondetected WR features are indistinguishable and other mechanisms for the origin of nebular HeII need to be invoked

40% of the HeII-emitting SF galaxies from SDSS do not show WR signatures → lack of WR features does not seem to be a S/N issue



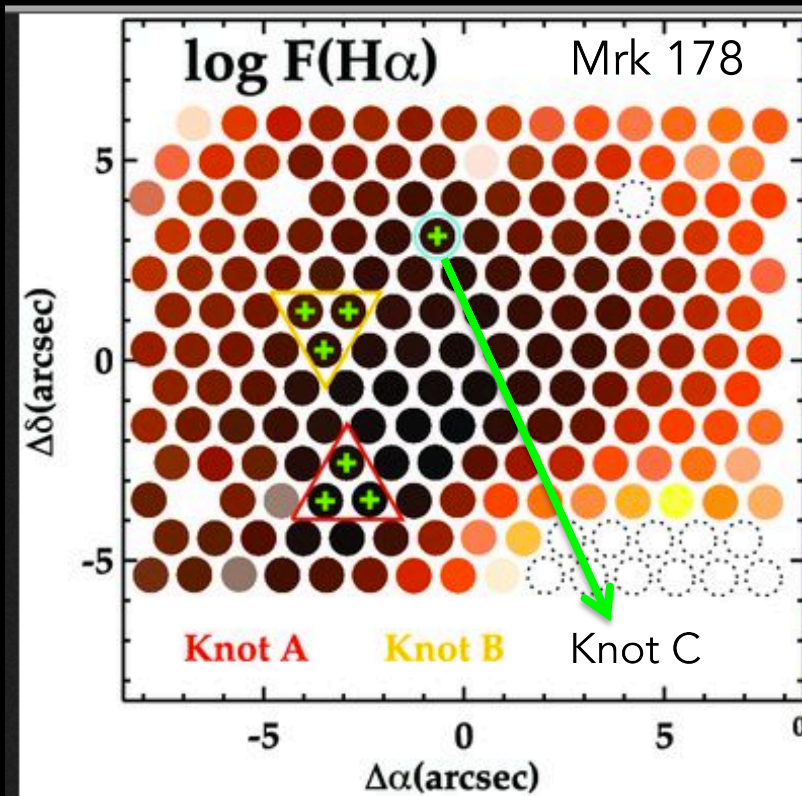




✔ SDSS composite images of metal-poor HeII-emitters: bright blue appearance and compact morphologies

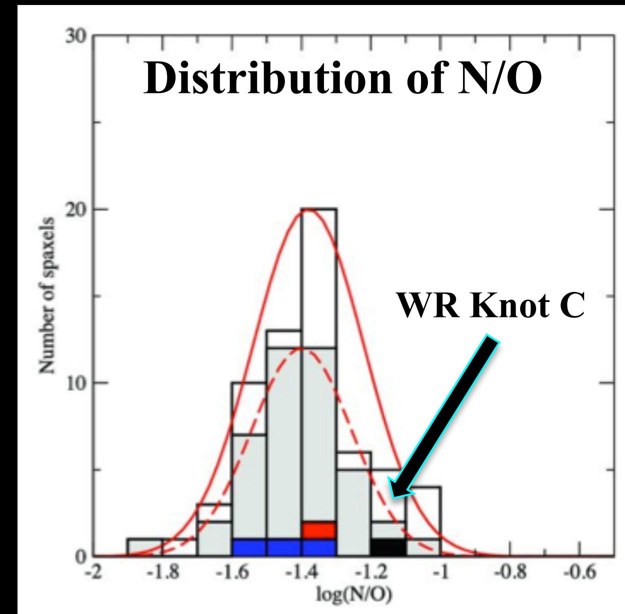


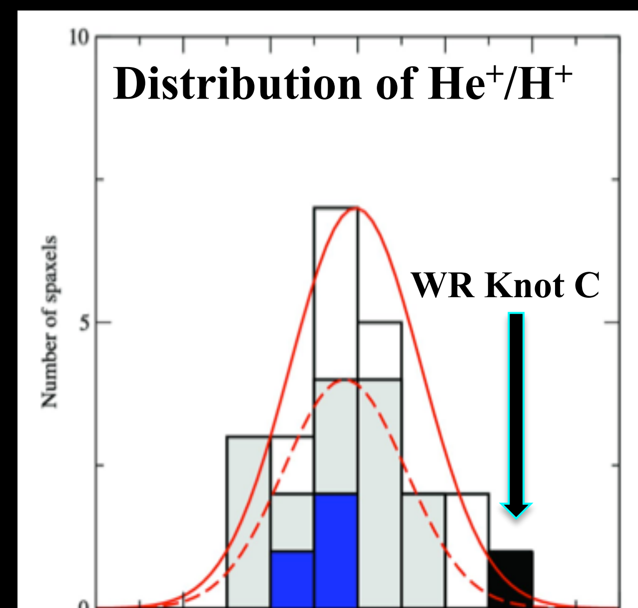
# Mrk178: ISM chemical abundances

Spatial correlation between the location of the WRs and the ISM properties




D=3.9 Mpc, ~ 0.9"/spaxel, ~ 20 pc/spaxel



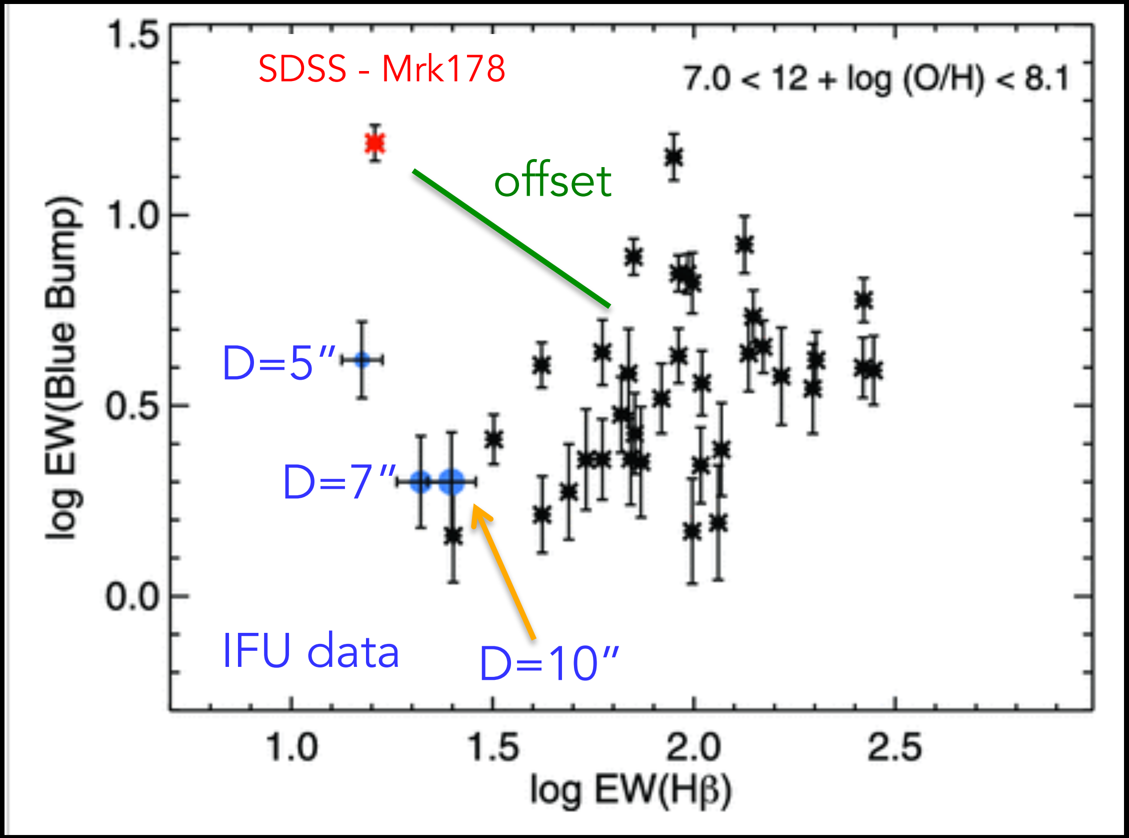

Localized N and He enrichment, spatially correlated with WR Knot C (see also e.g. Esteban & Vilchez 1992; Lopez-Sanchez+2011; Perez-Montero+2013)

*Kehrig et al. (2013)*

# Mrk178: aperture effects on the detection of WR features

WR galaxies from SDSS: the most deviant point belongs to Mrk178

From our IFU data: 1D spectra by combining fibers within circular apertures of increasing diameters




✔ Mrk178 gets closer to the bulk of metal-poor systems as the aperture size increases. The offset is caused by aperture effects

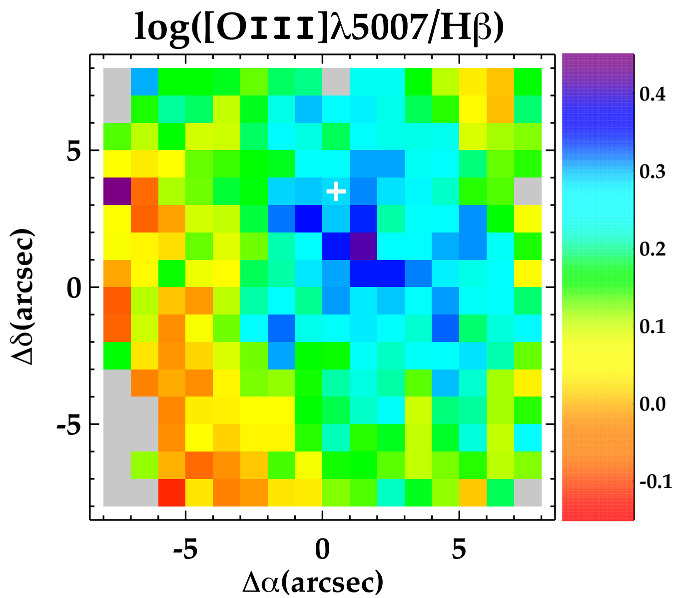
✔ For apertures with D > 10″, we no longer detect the WR bump

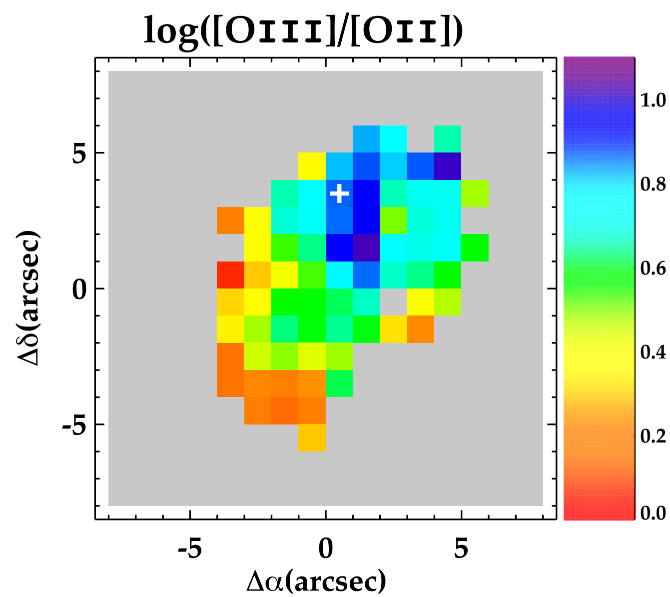
WR galaxy samples based on single fiber/long-slit spectrum may be biased in the sense that WR signatures can escape detection

*Kehrig et al. (2013)*

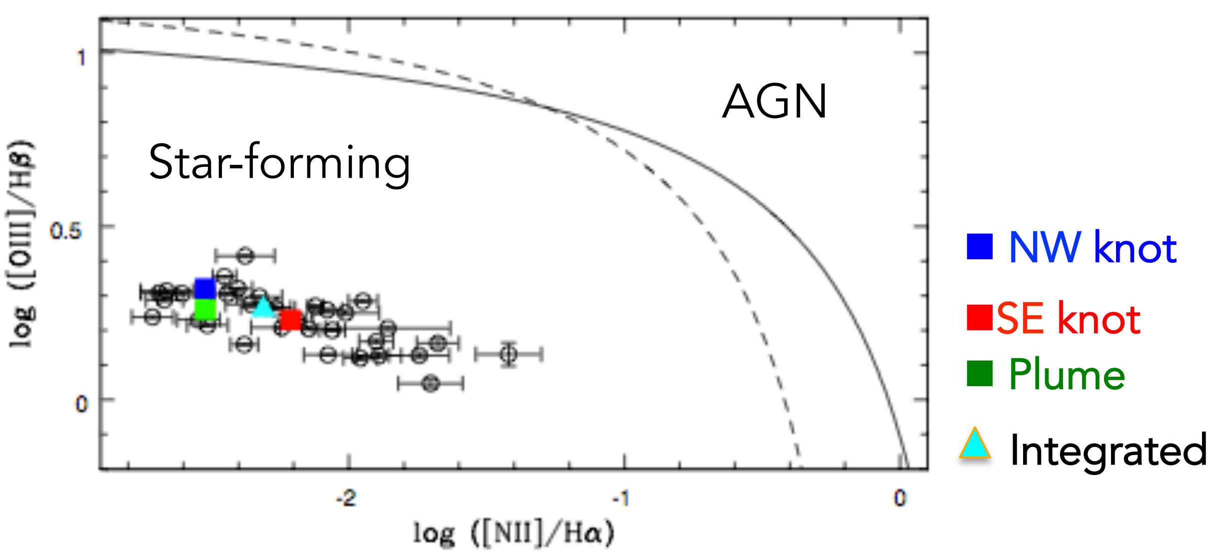
# Spatially Resolved Ionization Structure of the ISM

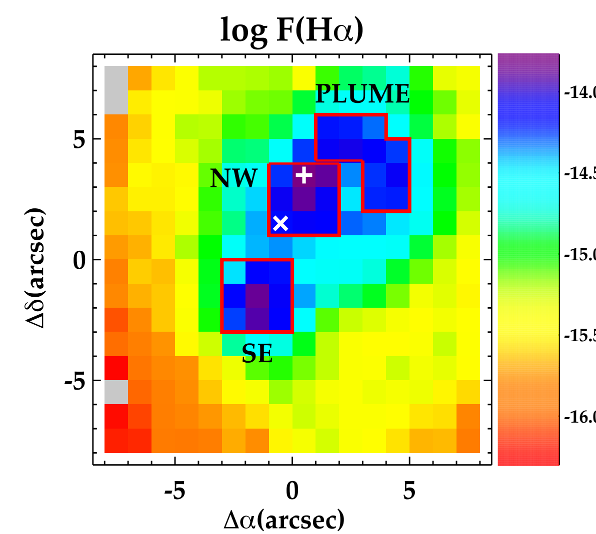
D=18.2 Mpc, ~ 1"/spaxel ~ 88 pc/spaxel *Kehrig, Vilchez+2016*



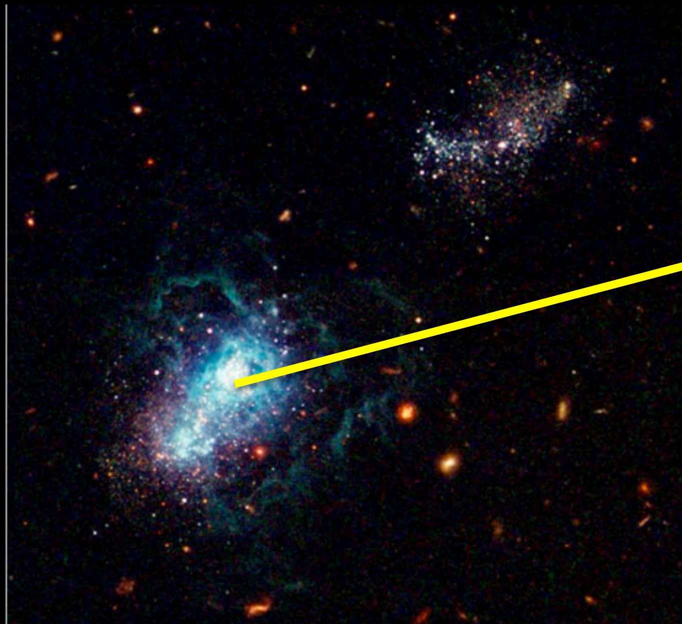




diagnostic diagrams on a spaxel-by-spaxel basis and integrated values

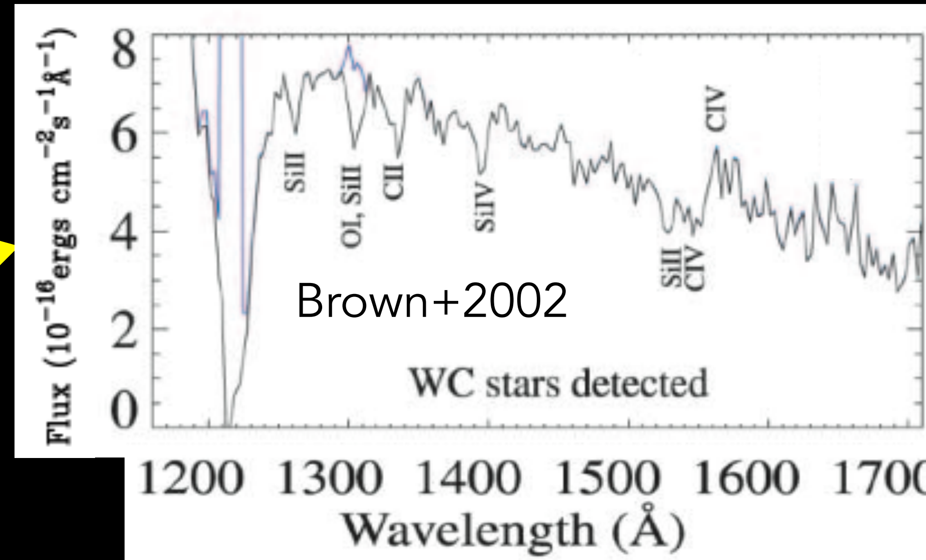


# What is the main source powering nebular HeII emission in IZw18 ?



NASA, ESA Y. Izotov (MAO, Kyiv, UA) and T. Thuan (University of Virginia) STScI-PRC04-35




(see also Legrand+1997; Izotov+1997; Kehrig +2016)

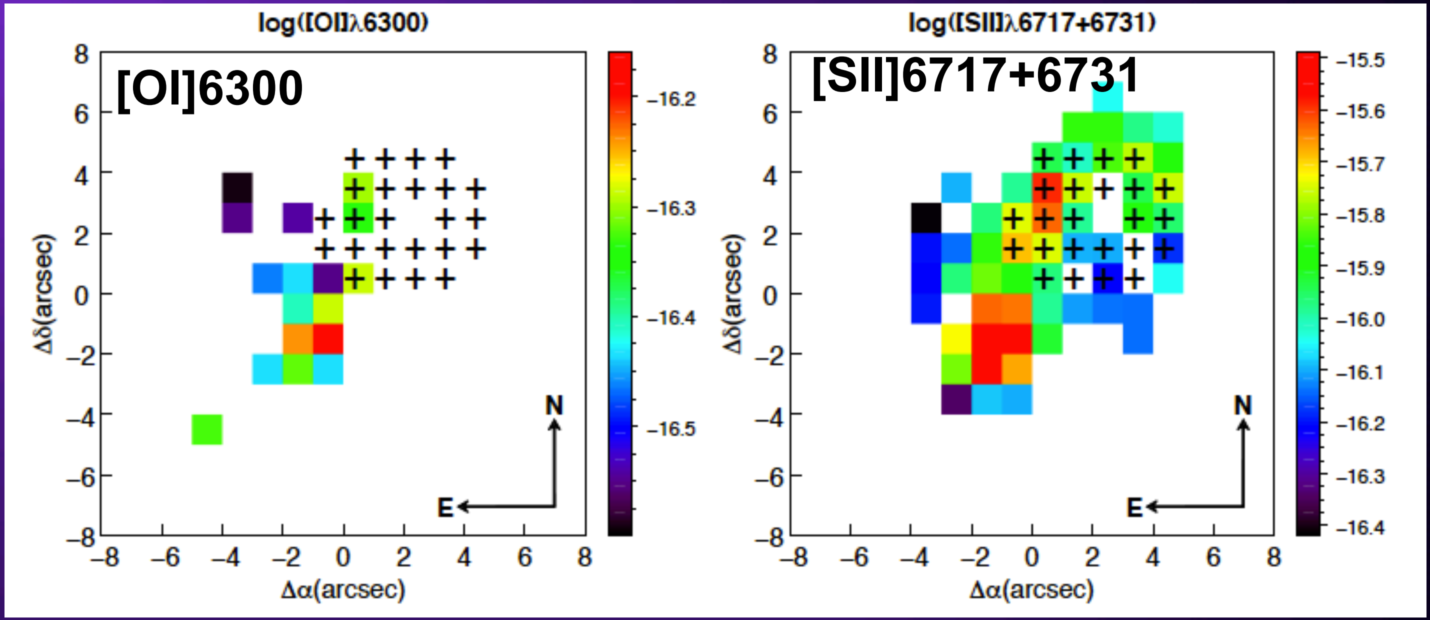
1) WR stars ? based on the HeII-ionizing flux expected from "IZw18-like" WRs (Crowther & Hadfield 2006), ≥ 100 WRs is required to explain the $Q(HeII)_{obs}$ , but such very large WR population is not compatible with:

✗ (> 8 times) Total stellar mass of the NW cluster

✗ WR/O stars ratio at the metallicity of IZw18 (e.g. Maeder & Meynet 2012)

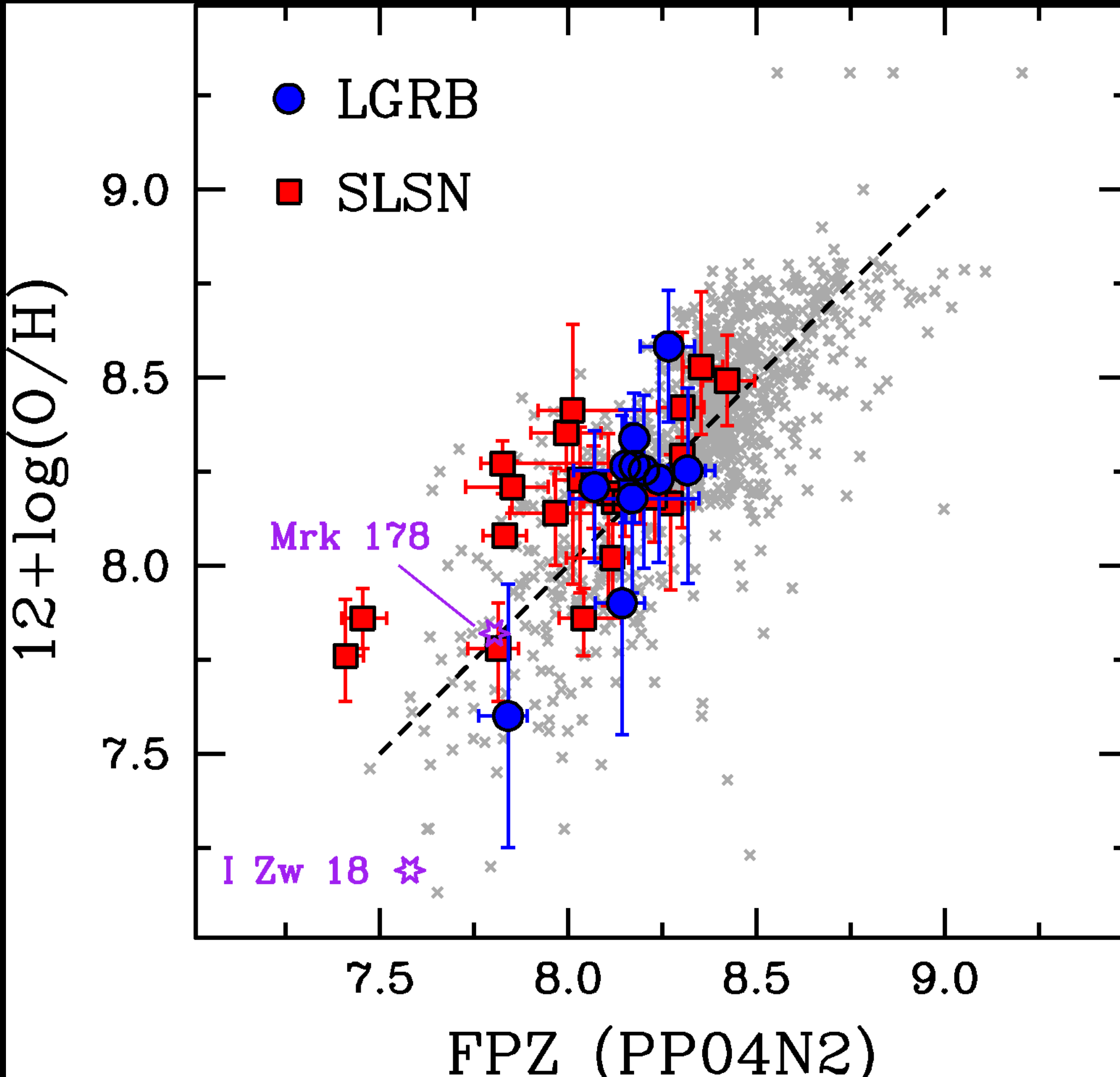
✗ Stellar evolutionary models for (rotating/non-rotating) massive stars in low-Z environments (e.g., Leitherer+2014)

**2) Shocks ?** Spectral features of shock ionization indicate that the HeII region is unlikely to be produced by shocks

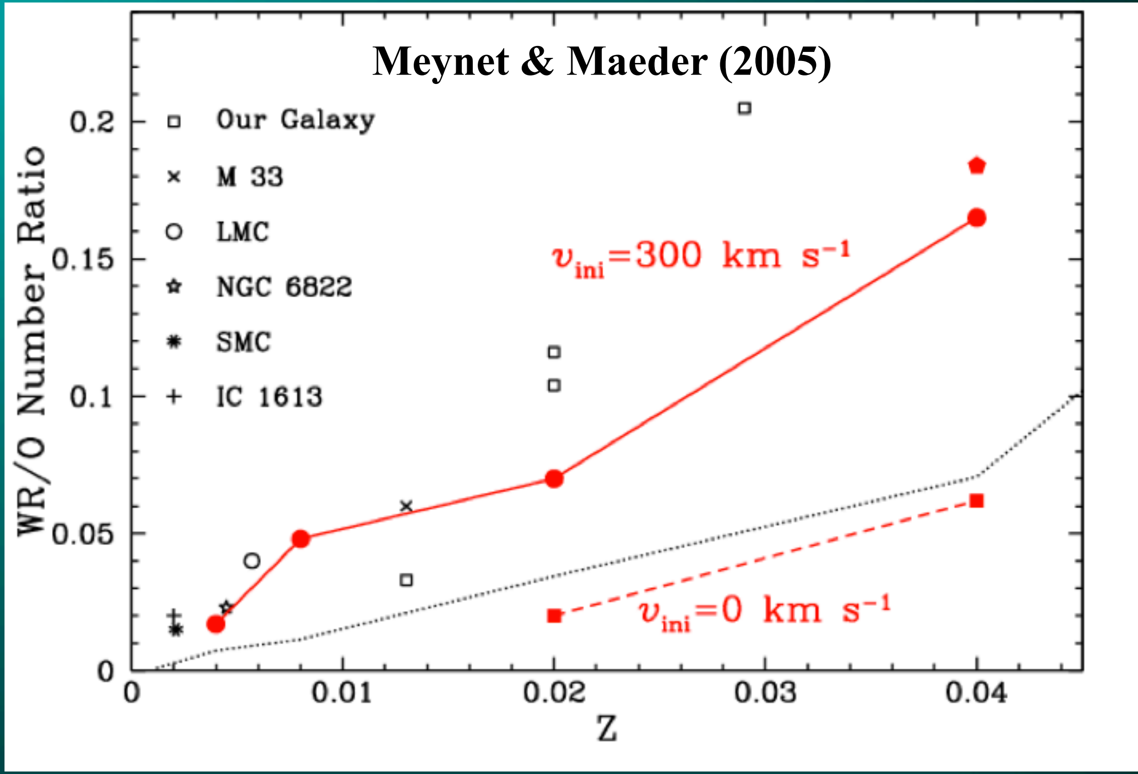



**3) X-ray binaries ?** CLOUDY photoionization model using as input a SED with the characteristics ($L_{x\text{-ray}}$; column density, slope) reported for the single X-ray binary in IZw18 (Thuan+2004) give L(HeII4686) < 100 $L(HeII4686)_{obs}$

**Conventional HeII-ionizing sources (WRs, shocks, X-ray binaries) are not sufficient to explain the observed HeII emission in IZw18.**



LGRB
SLSN
Mrk 178
I Zw 18
9.0
8.5
8.0
7.5
12+log(O/H)
7.5
8.0
8.5
9.0
FPZ (PP04N2)



Meynet & Maeder (2005)
Our Galaxy
M 33
LMC
NGC 6822
SMC
IC 1613
$v_{ini}$=300 km s$^{-1}$
$v_{ini}$=0 km s$^{-1}$
WR/O Number Ratio
0
0.05
0.1
0.15
0.2
0
0.01
0.02
0.03
0.04
Z

# Hα and HeII Total Flux & Ionization Budget

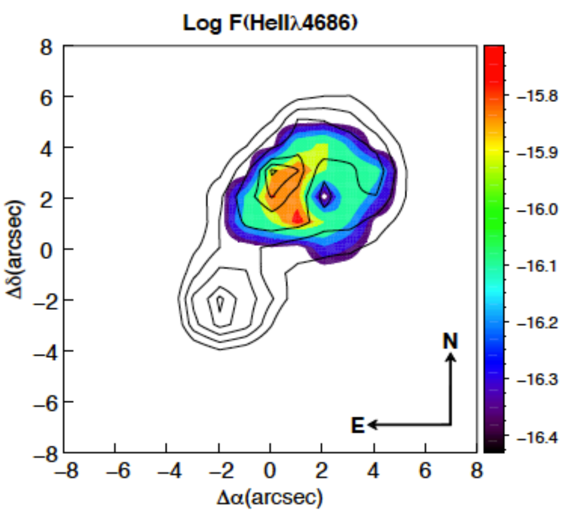
| | NW Knot | SE Knot | "Plume" | "Halo" | Integrated |
|---|---|---|---|---|---|
| c(Hβ) | 0.13 | 0.13 | 0.09 | 0.00 | 0.04 |
| -EW(Hβ) (Å) | 76 | 150 | 320 | 23 | 350 |
| F(Hβ) (erg $s^{-1}$ $cm^{-2}$) | $3.95\times10^{-14}$ | $3.23\times10^{-14}$ | $3.16\times10^{-14}$ | $4.50\times10^{-14}$ | $1.59\times10^{-13}$ |
| F(Hα) (erg $s^{-1}$ $cm^{-2}$) | $1.09\times10^{-13}$ | $8.87\times10^{-14}$ | $8.70\times10^{-14}$ | $1.16\times10^{-13}$ | $4.36\times10^{-13}$ |

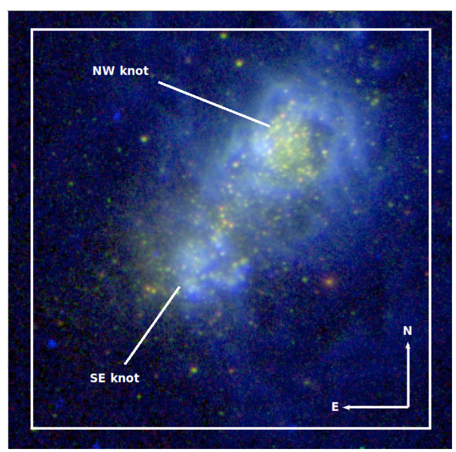
(K15; K16)

**$Q_{obs}$(H) = 2.4 $10^{52}$ (phot $s^{-1}$)** (+20% far extended halo; ≤ 2.88x) **OBSERVED**

Flux (HeII 4686) = 2.84 +/- 0.18 $10^{-15}$ (erg $cm^{-2}$ $s^{-1}$) => L($HeII_{4686}$) =1.12 +/- 0.07 $10^{38}$ (erg $s^{-1}$)

**$Q_{obs}$(HeII) = 1.33 $10^{50}$ (phot $s^{-1}$)**

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THE EXTENDED He II λ4686-EMITTING REGION IN IZw 18 UNVEILED: CLUES FOR PECULIAR IONIZING SOURCES

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J. Brinchmann[3], D. Kunth[4], F. Durret[4], and F. M. Bayo[1]
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**EXPECTED**

~3000 O stars in IZw18 =>

(Guseva et al 2000; $Q(H)_{O7V}$ =$10^{49}$ phot $s^{-1}$ Leitherer 1990)

**$Q_o$(H) ≈ 3 $10^{52}$ (phot $s^{-1}$)** (slightly larger)

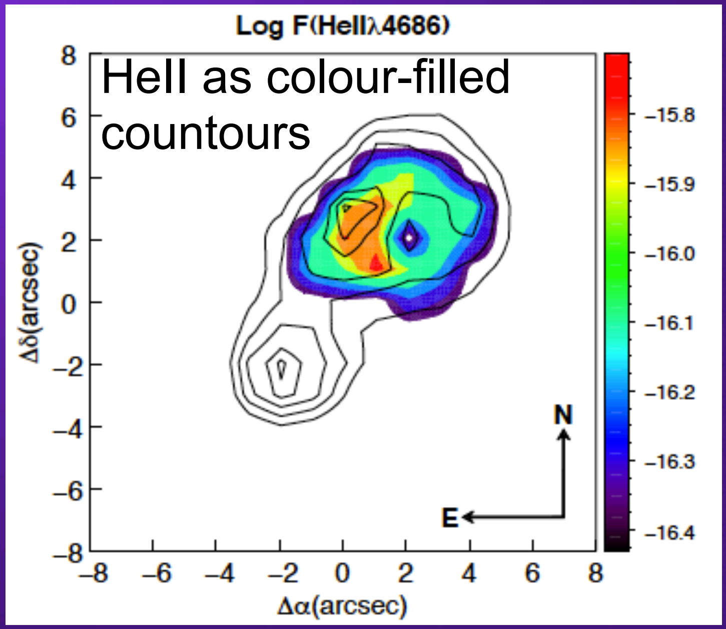
IF **extra $He^{++}$ => ≈ 10% $Q_o$(H) more!**

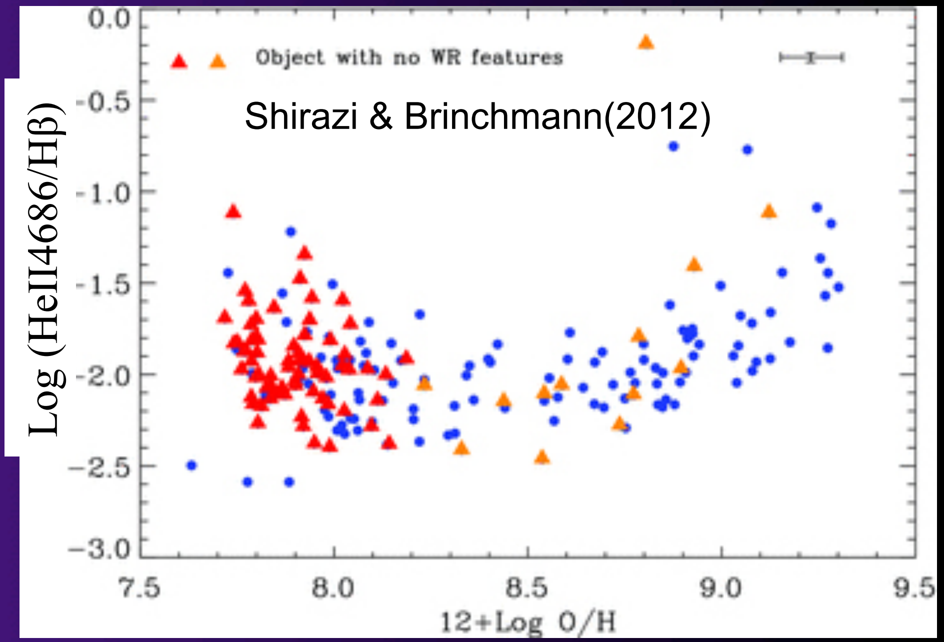
(10 Min=150 $M_\Theta$ see below)

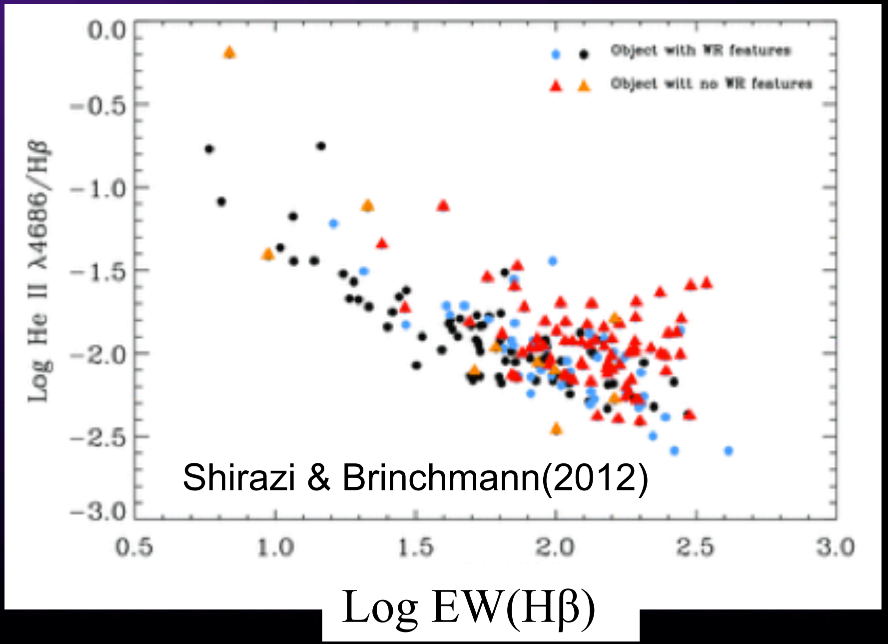
Assuming $Q_o$(H) popIII models

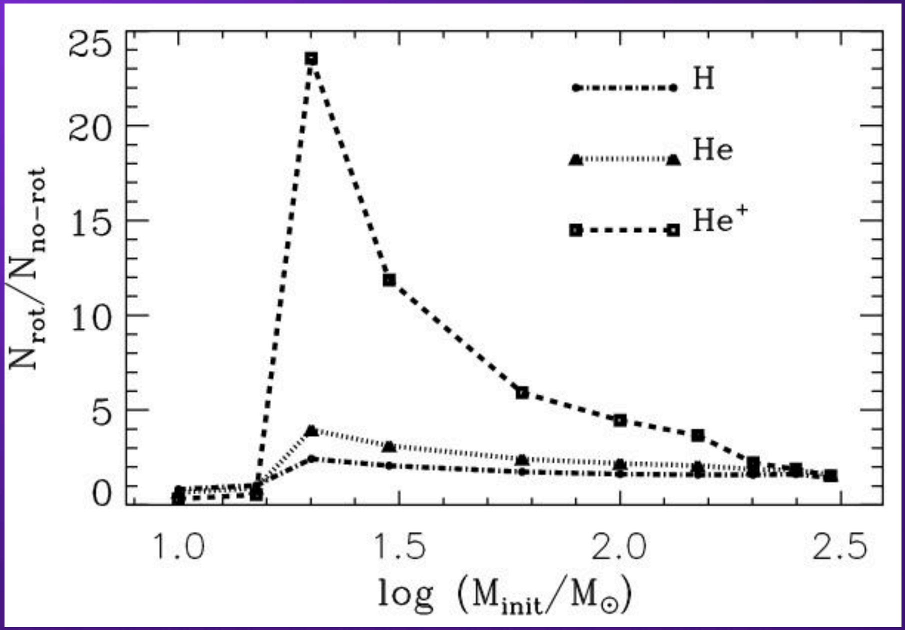
Min=150 $M_\Theta$ => 2.7 $10^{50}$ (phot $s^{-1}$)

Min=100 $M_\Theta$ => 1.5 $10^{50}$ (phot $s^{-1}$)

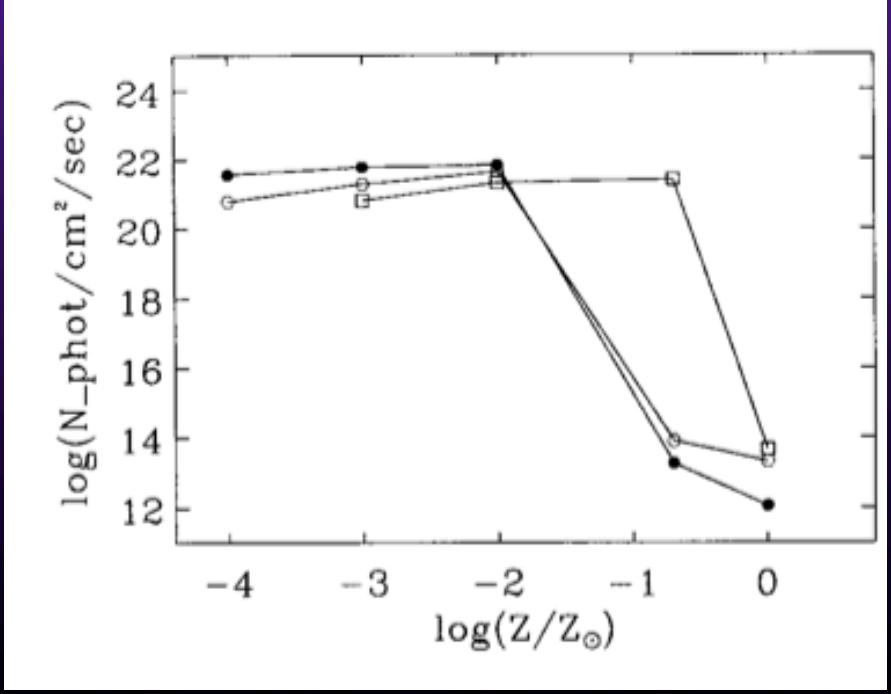

Log F(HeIIλ4686)
HeII as colour-filled countours
Δδ(arcsec)
Δα(arcsec)
N
E
−15.8
−15.9
−16.0
−16.1
−16.2
−16.3
−16.4

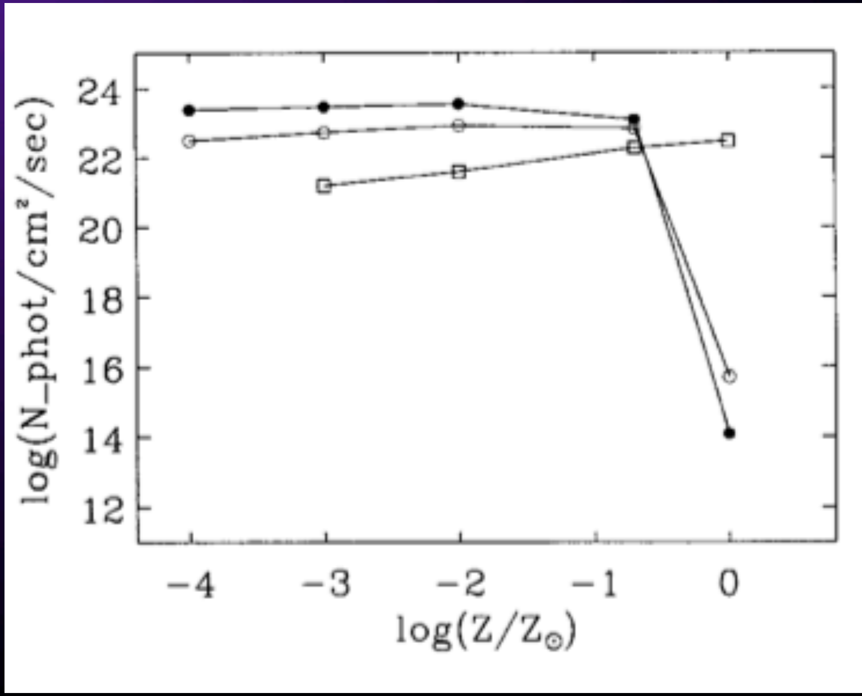

Object with no WR features
Shirazi & Brinchmann(2012)
Log (HeII4686/Hβ)
12+Log O/H

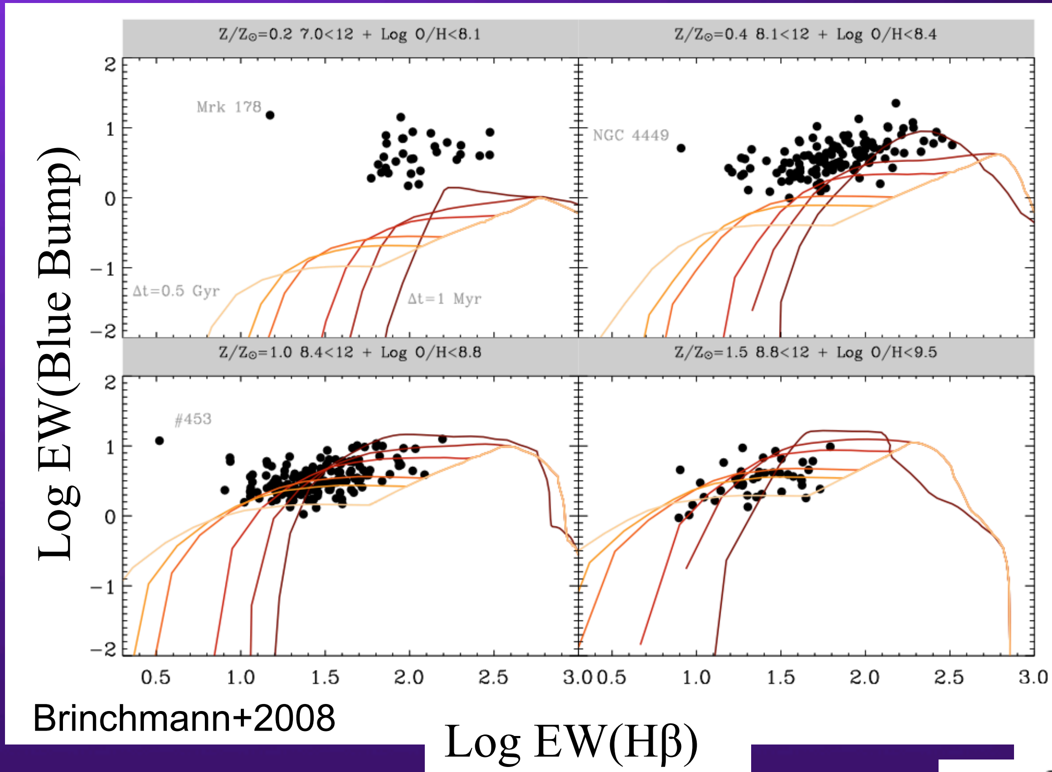

Object with WR features
Object with no WR features
Log He II λ4686/Hβ
Shirazi & Brinchmann(2012)
Log EW(Hβ)

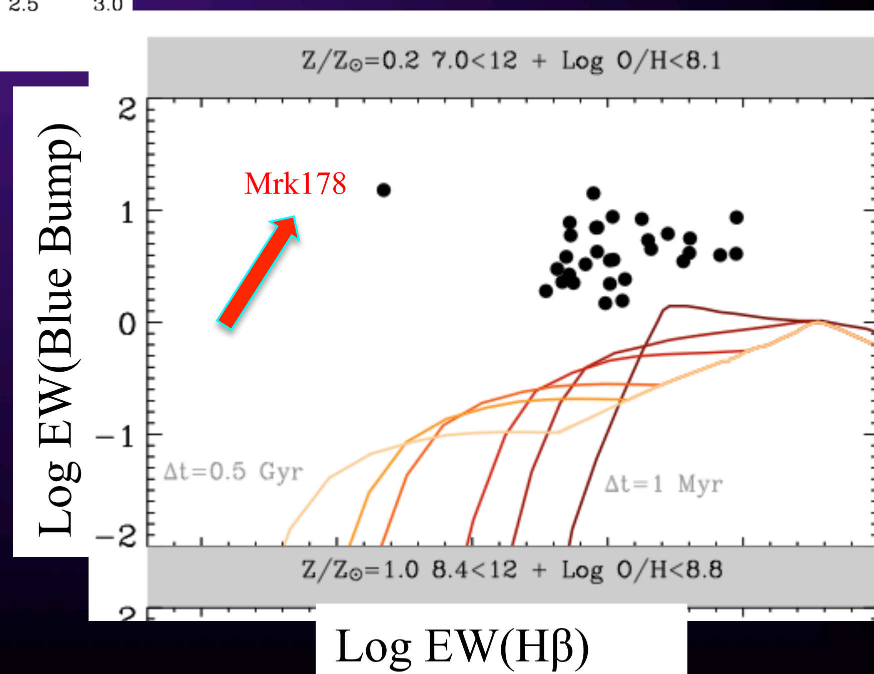



Ratio of the total number of ionizing photons from non-rotating models to that from rotating models with *v*init/*v*K = 0.4. The connecting lines of filled circles, triangles and squares give the values for hydrogen and first and second helium ionization, respectively.






**Mrk178 as a significant outlier among WR galaxies from SDSS**

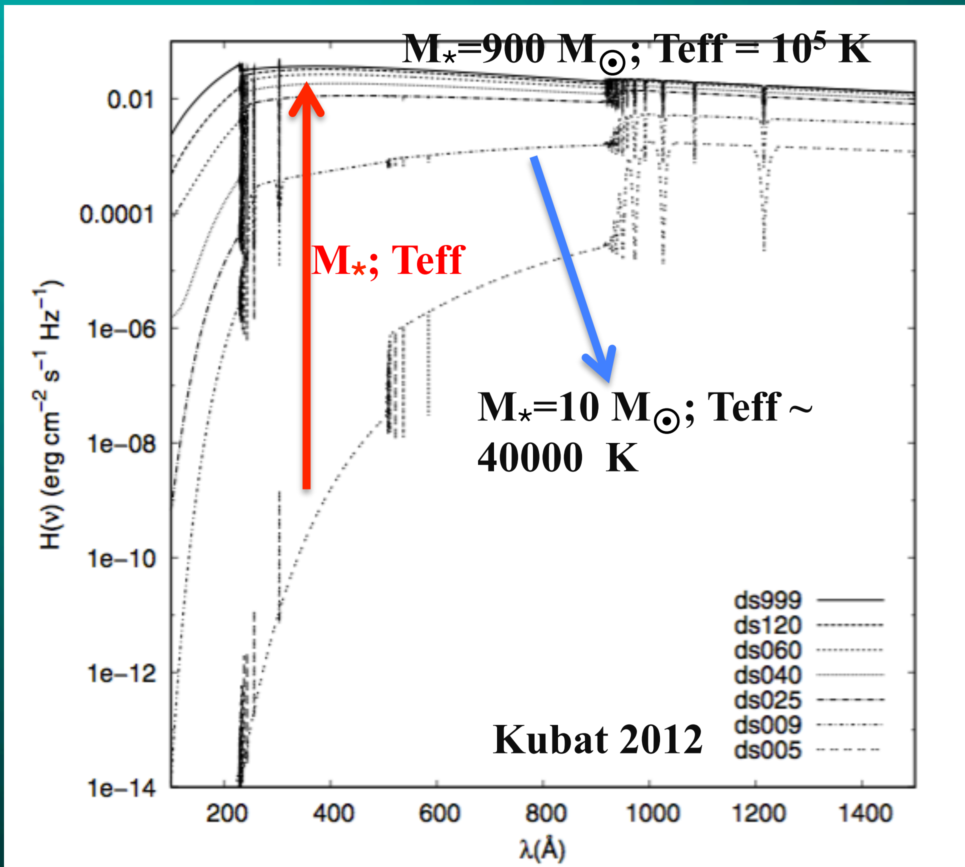
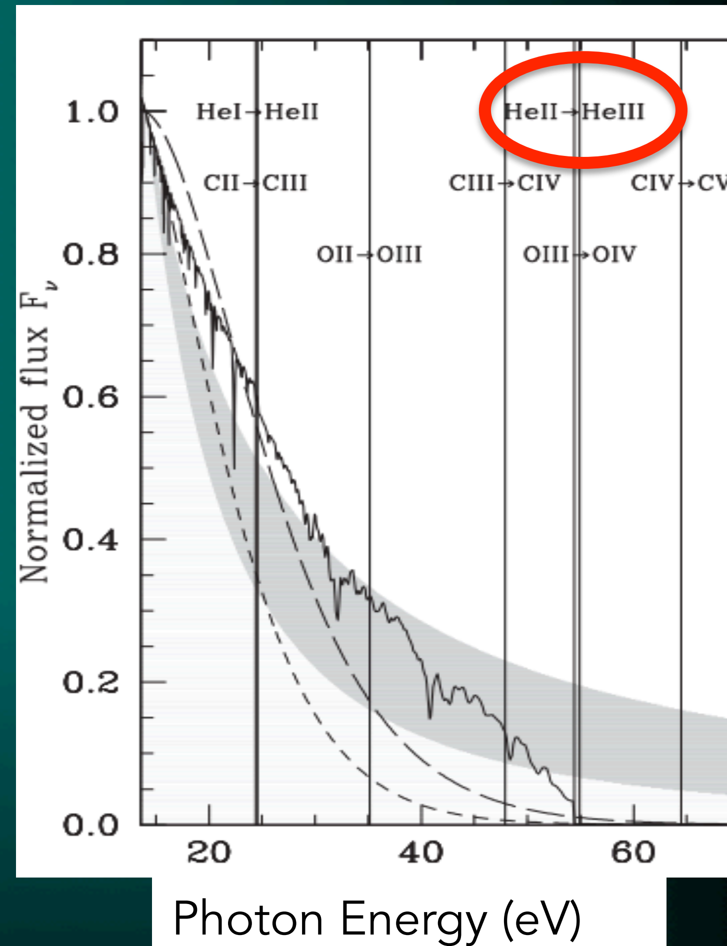



**Figure 3.** Plot of ultraviolet fluxes from selected model atmospheres of first stars with parameters from Schaerer (2002). Labels correspond to the first column of



# Why are local metal-poor WR galaxies important ?

■ **“template” systems → understand the evolution and feedback from massive stars in distant starburst galaxies which cannot be studied to the same depth**

■ **Disagreement between observations and predictions for the WR content in metal-poor galaxies** (e.g. Brinchmann+2008)**: more data are needed to constrain the models**

■ **Usually nebular HeII line is associated with WR stars but the origin of high-ionization nebular lines, like HeII, is still an open issue** (e.g. Guseva +2001; Kehrig+2011; Shirazi & Brinchmann 2012; Schaerer 2013)

# Summary & Concluding Remarks

## On IZw18: the nearby most metal-poor WR galaxy

- Our IFU data reveal the total spatial extent (D ~ 440 pc) of the nebular HeII4686 emission
- Conventional HeII-ionizing sources (WRs, shocks, X-ray binaries) cannot convincingly explain the observed nebular HeII4686 emission
- If HeII-ionization is due to stellar sources, these might be peculiar very hot stars
- We invoke the PopIII-like stars scenario in IZw18 for the first time - This scenario is getting popular (see Heap+2015)

## On Mrk178: the closest metal-poor WR HII galaxy:

- By using SMC/LMC template WR stars, we estimate ~ 20 WR stars, already higher than that found in the literature
- Localized N and He enrichment, spatially correlated with WR stars
- Spatial offset between extended nebular HeII emission and WR stars
- WR galaxy samples constructed on single fibre/long-slit spectrum basis may be biased: WR features can scape detection depending on the distance of the object and on the aperture size

## Summary & Concluding Remarks

- There is still a lack of understanding of narrow HeII emitters even at low redshift

- WR features are not seen whenever HeII is observed

- IFS → spatial offset between nebular HeII-emitting zone and WR stars can be a possible explanation for the non-detection of WR features in some galaxy spectra

- Nearby HeII emitters, specially metal-poor ones, are fundamental to better constrain models for metal-poor massive stars and understand high-z HeII emitters

- IZw18: our IFU data reveal for the first time its total HeII-ionizing flux and conventional HeII-ionizing sources (WRs, shocks, X-ray binaries) cannot convincingly explain the observations

- We invoke the PopIII-like stars scenario in IZw18 for the first time (Kehrig et al. 2015)

## Some ongoing & future work …

- Comparison between IZw18 observations and new BPASS models (collaboration with J.Eldridge, A.Wofford et al.)

- UV spectra of HeII-emitting SF galaxies: observing time awarded through Cycle 23 COS/HST(collaboration with J.Brinchmann et al.)

# WR stars as GRB progenitors

- Prime candidates for precursors of Type Ib/c SNe & long/soft GRBs. Progenitors:
  - Associated with young massive stellar populations,
  - Compact (excludes RSG progenitors),
  - Rapidly rotating core.
- Primary challenge for single/binary GRB progenitors is requirement for rapid rotation at core-collapse (at $Z_{\odot}$ core slowed down during RSG/WR phase).

# Why is the study of the nebular HeII line relevant in metal-poor galaxies ?

✔ HeII emission: the existence of sources of hard radiation field (E ≥ 54ev)

✔ HeII-emitters are observed to be more frequent among high-z galaxies than for local objects (e.g. Kehrig+2011; Cassata+2013) and the nebular HeII line is one of the tracers of PopIII-stars

✔ High-ionization HeII line: one of the tracers of PopIII-stars (the first very hot metal-free stars) (e.g., Schaerer 2003; Johnson+2009) → such stars are believed to have contributed to the universe's reionization

✔ Metal-poor massive stellar evolution is poorly constrained by observations (e.g. Tramper+2011; Herrero +2012; Georgy+2016) → HeII line in metal-poor galaxies is a useful window into the ionizing spectrum of these stars

✔ This is consistent with the GRB/SN-ratio in the local Universe being significantly smaller (Podsiadlowski et al. 2004) due to the observed preference for GRBs to occur in low-metallicity dwarf galaxies (Langer & Norman 2006; Niino 2011). As a consequence, we can consider large He II-emission in low-metallicity star-forming dwarf galaxies (Sect. 10.4) as a signpost for upcoming GRBs in the same objects.

■ **Usually nebular HeII line is associated with WR stars but the origin of high-ionization nebular lines, like HeII, is still an open issue** (e.g. Guseva+2001; Kehrig+2011; Shirazi & Brinchmann 2012; Schaerer 2013)

✔ Before interpreting high-z HeII-emitters & use HeII line to infer properties of distant starburst, it is crucial to understand the formation of HeII line in nearby metal-poor objects HeII line is stronger at low metallicities