He+ Lyman continuum in low-metallicity starbursts

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Galaxies meet GRB at Cabo de Gata, 23-27. Sept. 2013

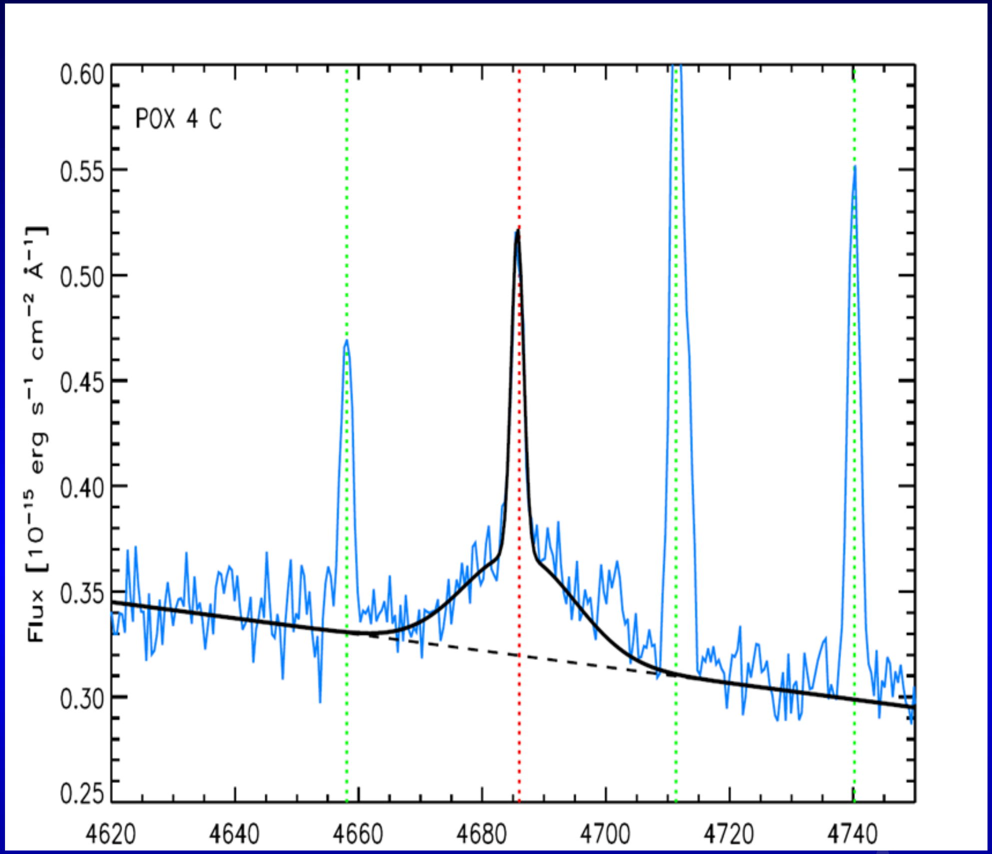
HeII λ4686 emission in HII galaxies

Bergeron (1977) noted λ4686 emission in IZw18

Often 2 components:

- B=broad : due to WR stars
- N=narrow (nebular): requires ionizing photons with hv > 54 eV (He+ Ly cont.)

also: high-excitation spectra i.e. high [OIII]/Hbeta ratio



Lopez-Sanchz & Esteban 2010:

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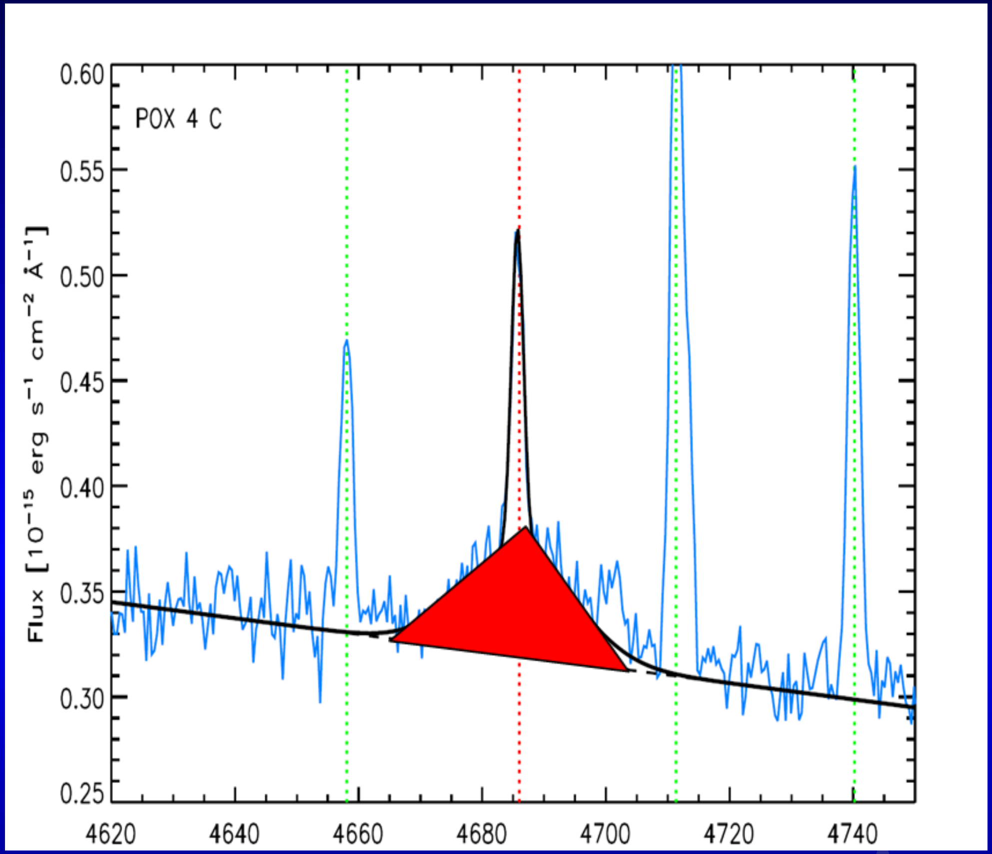

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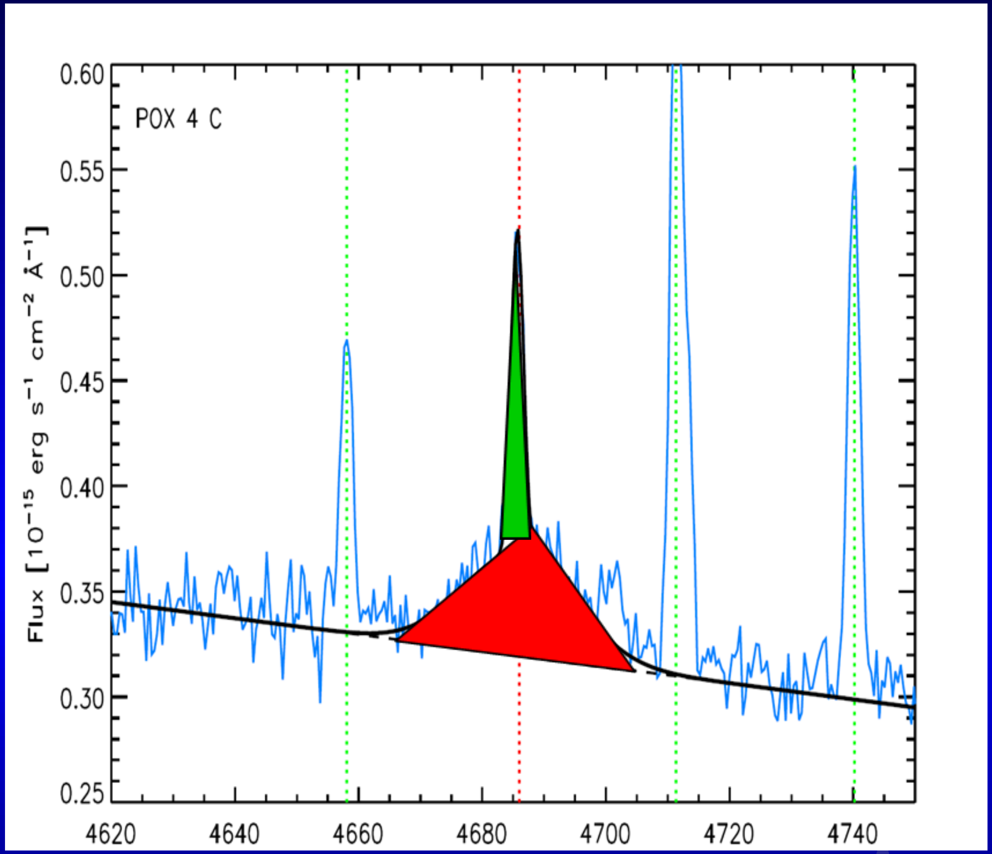

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POX 4: N/B =0.6

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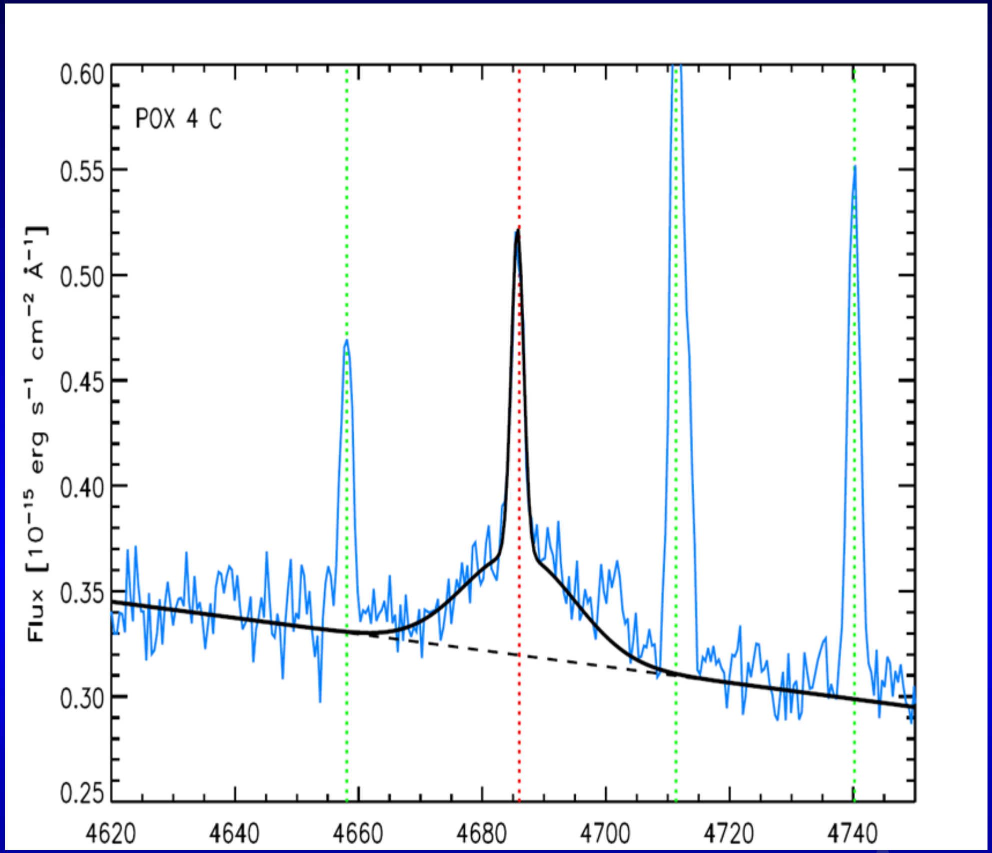
  → **HeIII region**

also: high-excitation spectra
i.e. high [OIII]/Hbeta ratio



Lopez-Sanchez & Esteban 2010:

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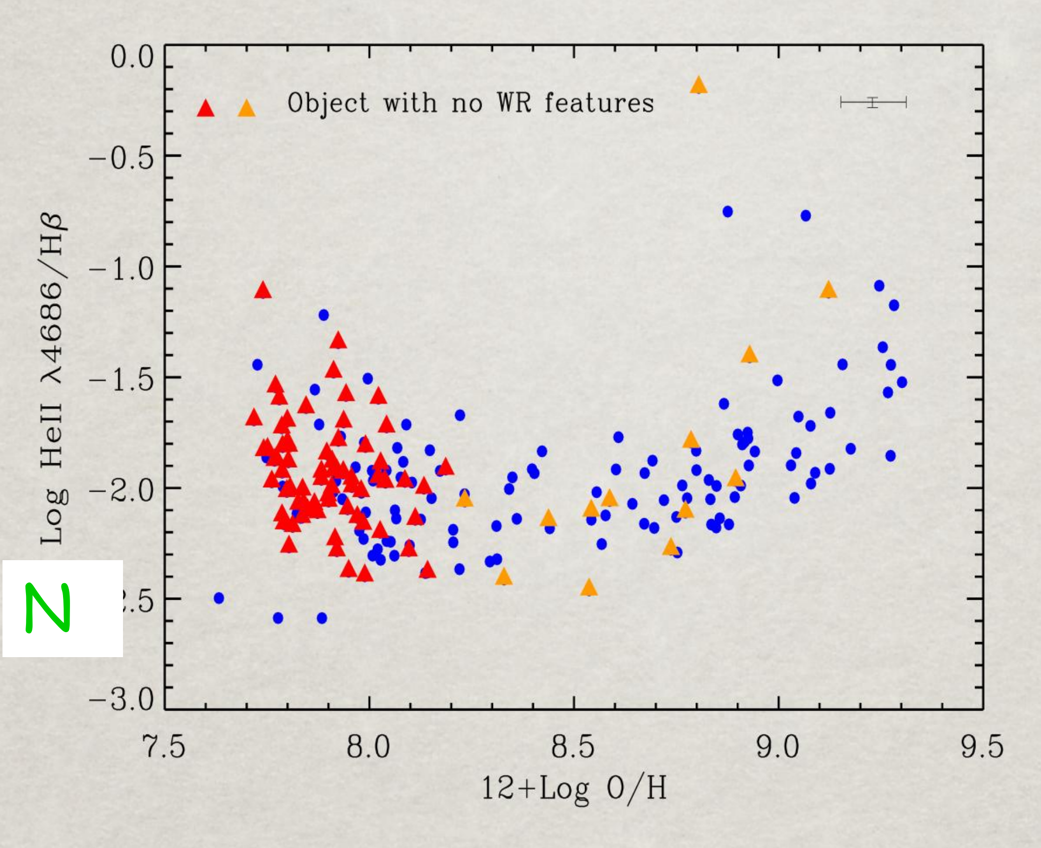
Narrow HeII 4686 emission in HII galaxies



At Z ~ solar: All have WR features
At Z ~ solar/10: ~30% have.

Guseva+00; Brinchman+09, Shirazi+12:

high Z: 4686N and 4686B are linked;

low Z: 4686N not associated with 4686B WR features

-> other ion. mechanism (?)

Sources of He+ Ly C (hν >54eV)

- hot MS *** ? (Teff > 70,000 K),
- Massive X-ray binaries ?
- population III stars ?
- hidden AGN ?
- fast shocks v_s > 300 km/s; in isolated SNR, not wind bubbles !
- Hot Wolf-Rayet stars ? WO, WNE, H-rich WN
- rapid rotators with chemically homogenous evolution ?
- Pec. massive binary evol. (N44C, some M33 objects) ?

HeIII regions around local WRs

-> 1990: two HeIII regions around WO stars: WR102 and IC1613_S3
Terlevich: explanation of AGN by such hot (WOs): 'Warmers '

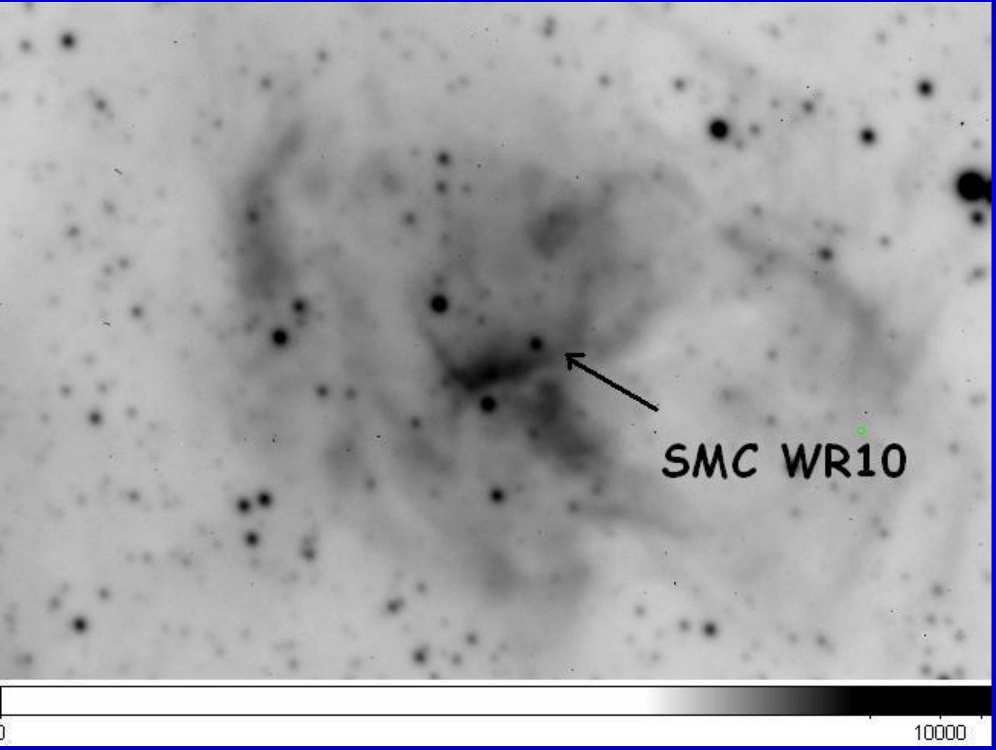
IAU 143: 2 WNEs in LMC (Br2, Br40a), 1 WNe in SMC (AB7) ionize HeIII regions, and not all WO's are "Warmers " (Niemela+1991; Pakull+1991) , and no HeIII around WCs !

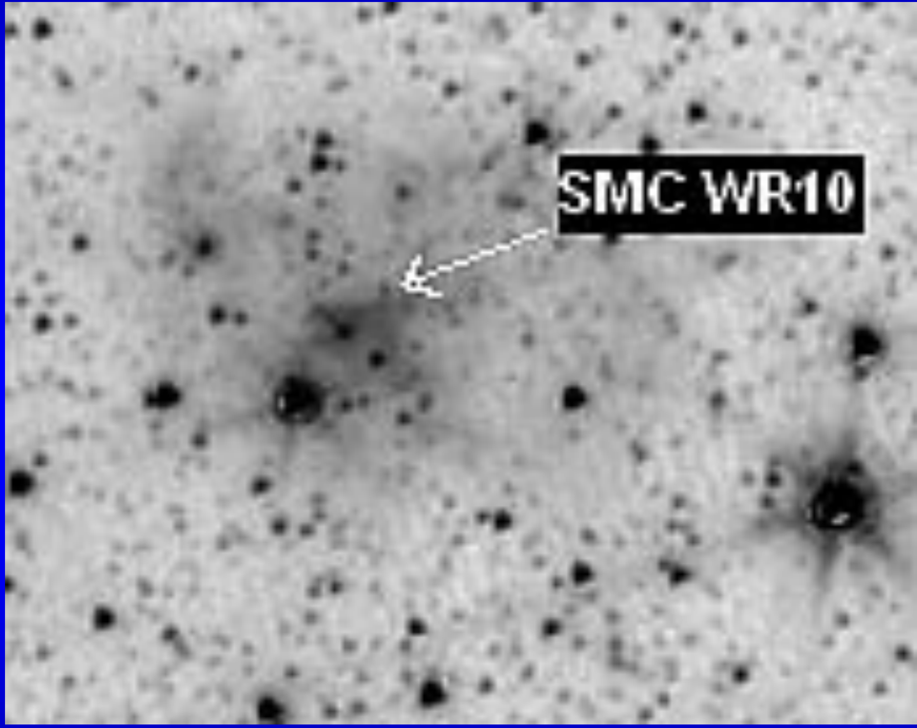
More recently HeIII regions around faint H-rich WNs in the SMC WR10, WR9 (Pakull 2007; 2013)

MW: 1/300
LMC: 2/150 WRs ionize HeIII regions
SMC: 3/12

i.e. fraction of "Warmers" increases with decreasing Z !

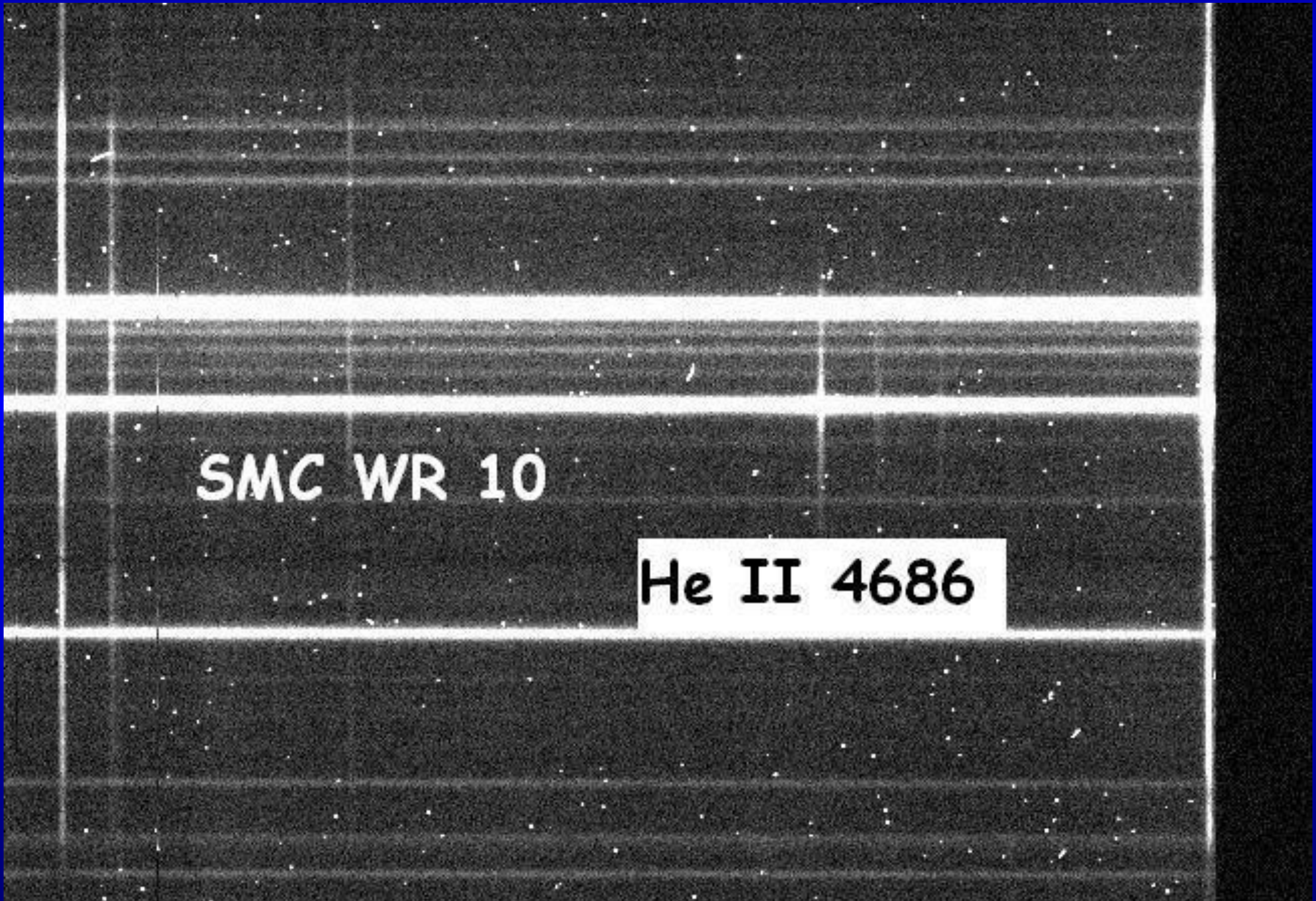
SMC WR 10 in NGC 249



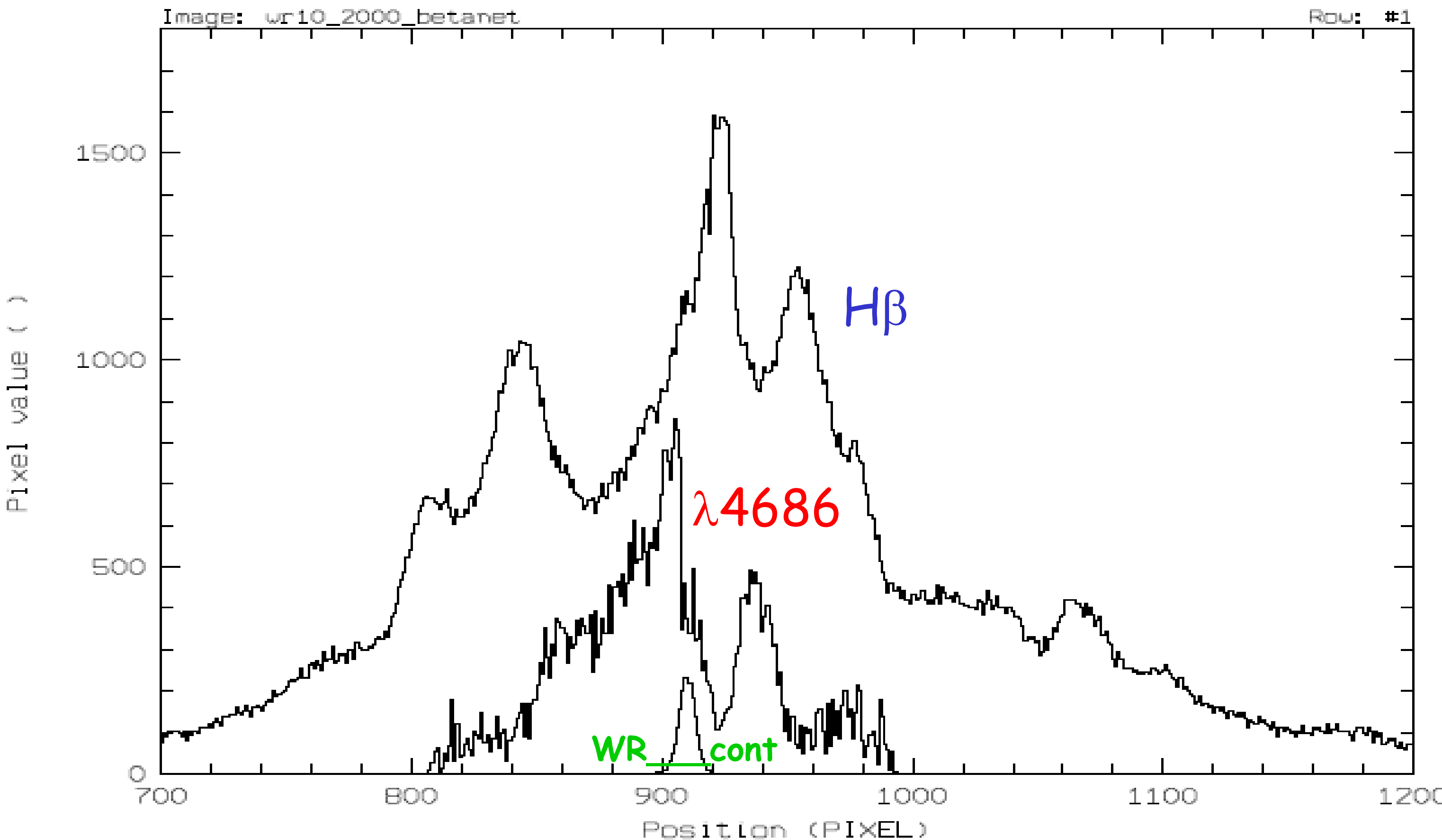


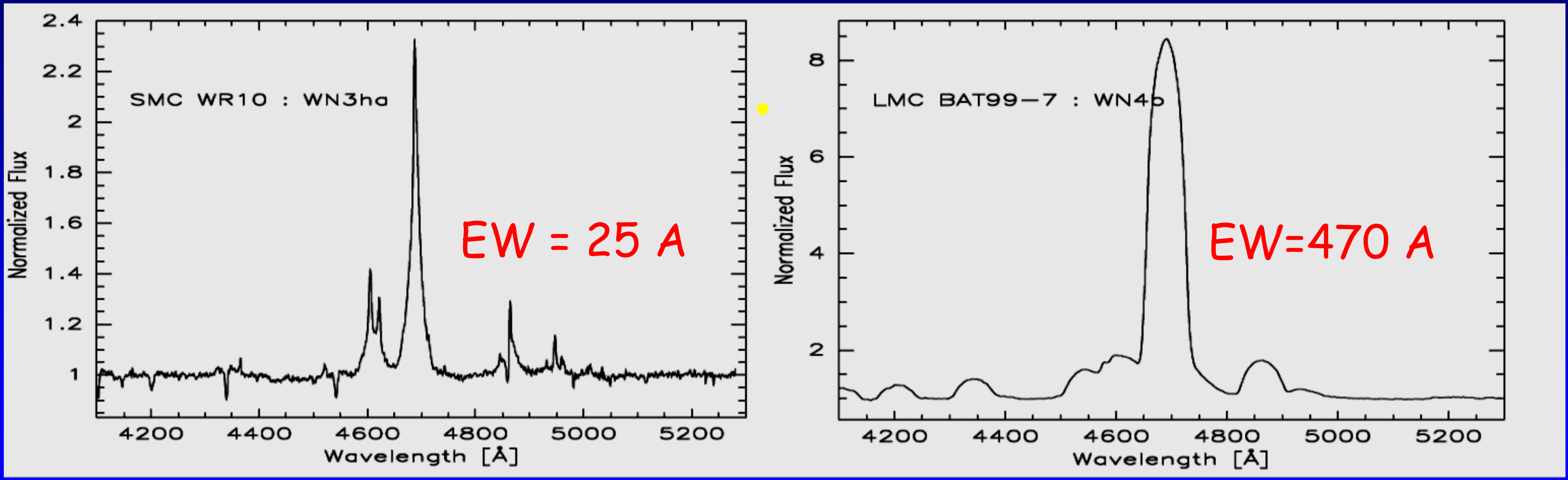
ESO H_alpha (Pakull 2007) Spitzer IR

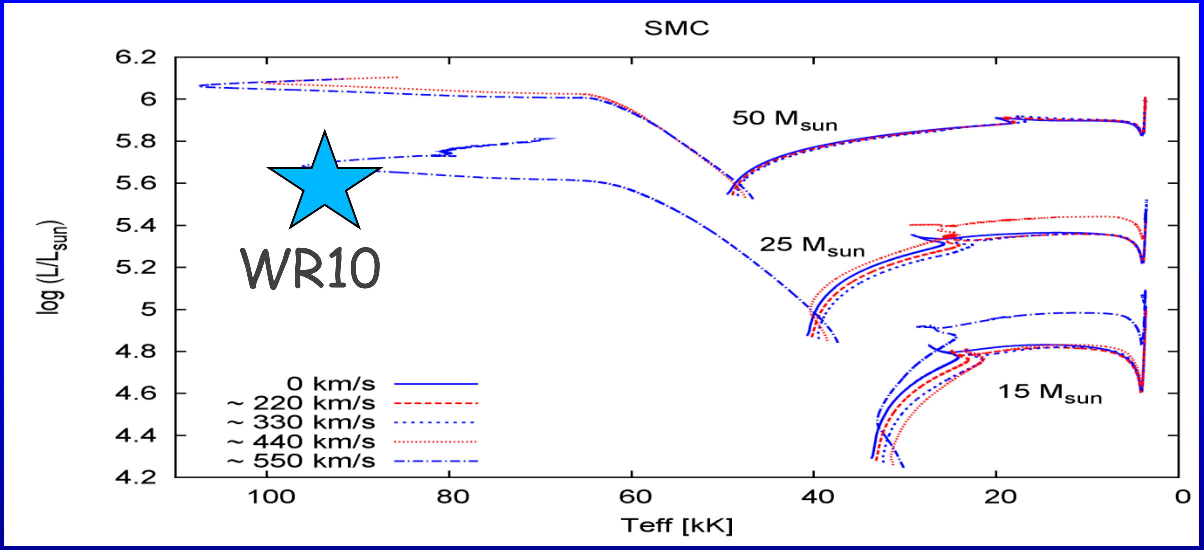
SMC WR 10: 2d spectrum



SMC WR 10 HeIII region

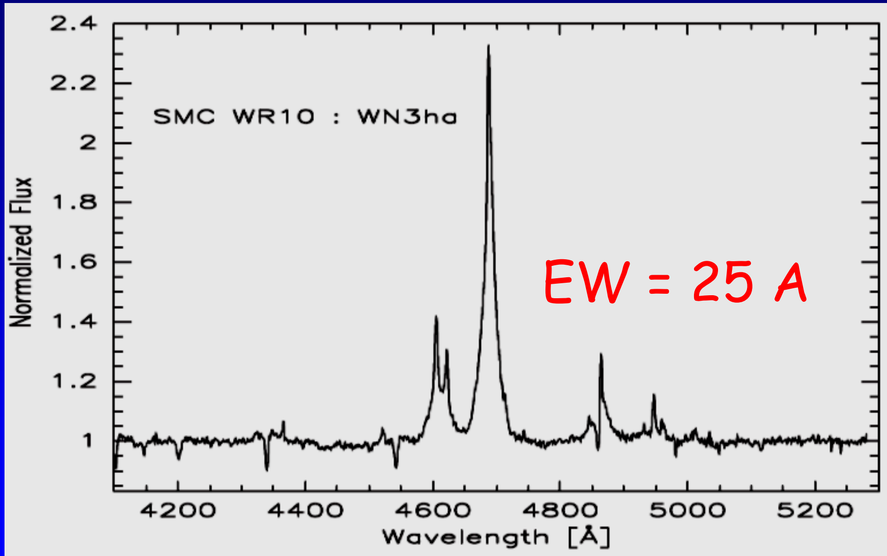


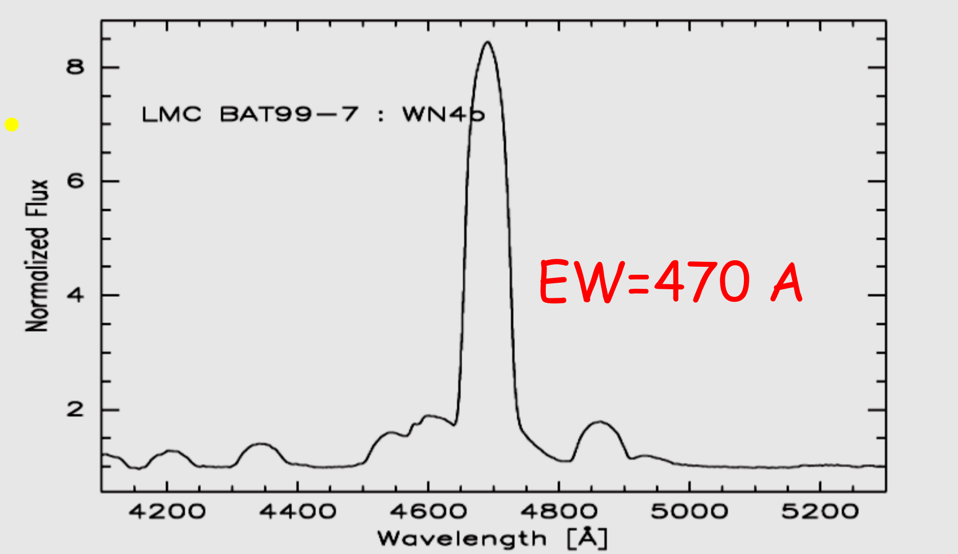


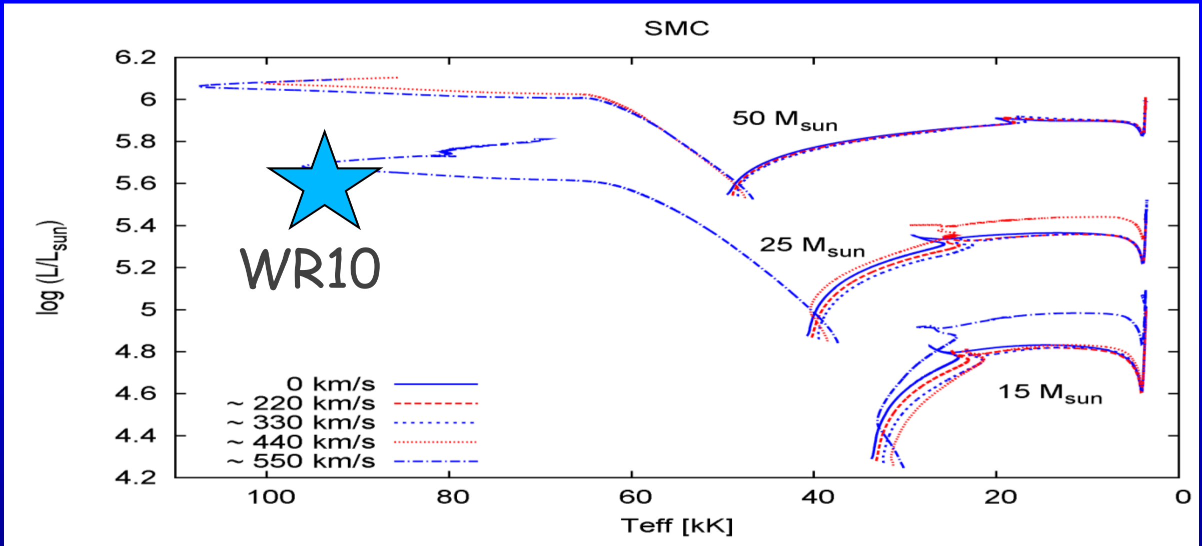


Foellmi 2005/6 :
WR10: single star; weak lines; hydrogen present

Brott+ 2011: SMC abund. with rot. mixing





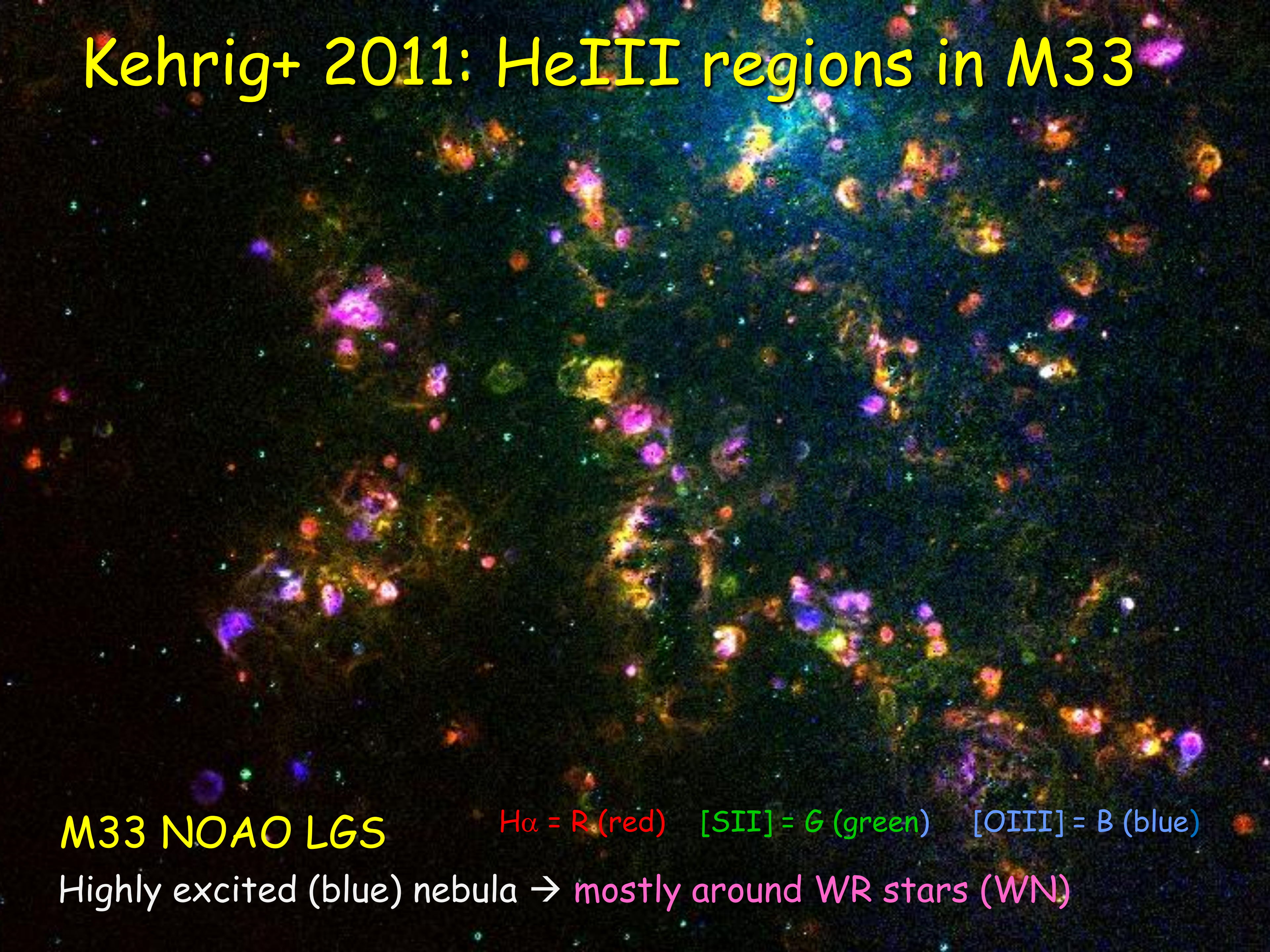


Foellmi 2005/6 :
WR10: single star; weak lines; hydrogen present

Problem:
Vrot << 550 km/s

Brott+ 2011: SMC abund. with rot. mixing

Kehrig+ 2011: HeIII regions in M33

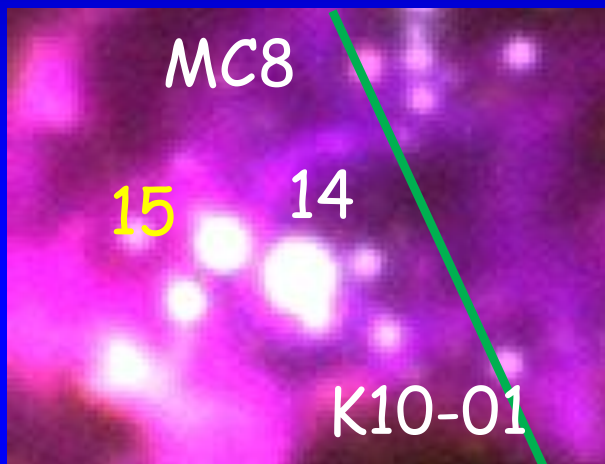


M33 NOAO LGS

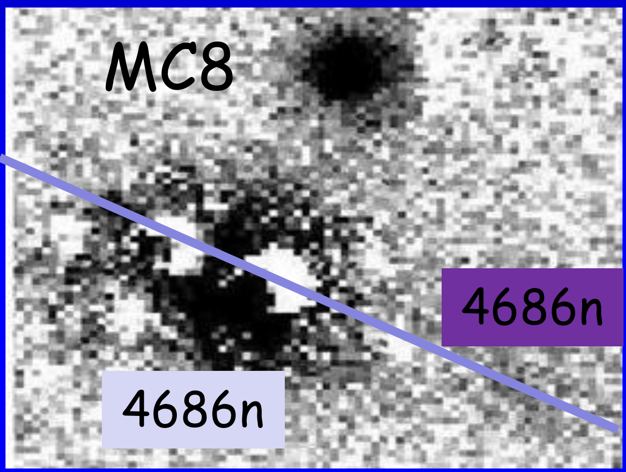
Hα = R (red) [SII] = G (green) [OIII] = B (blue)

Highly excited (blue) nebula → mostly around WR stars (WN)

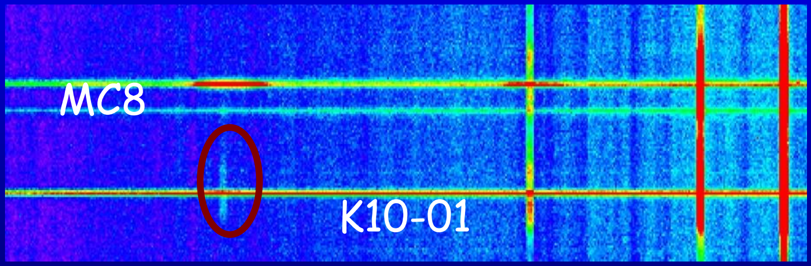
Outlying HII region MA1 in M33

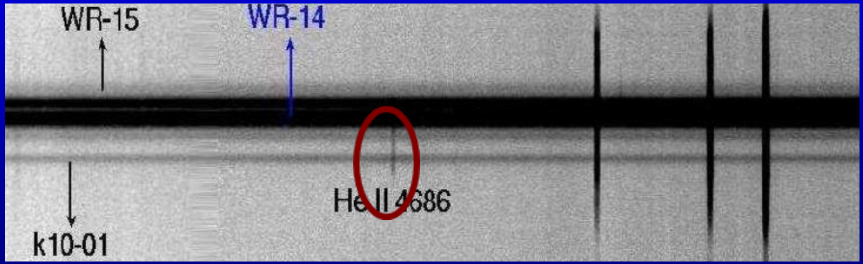


NOAO

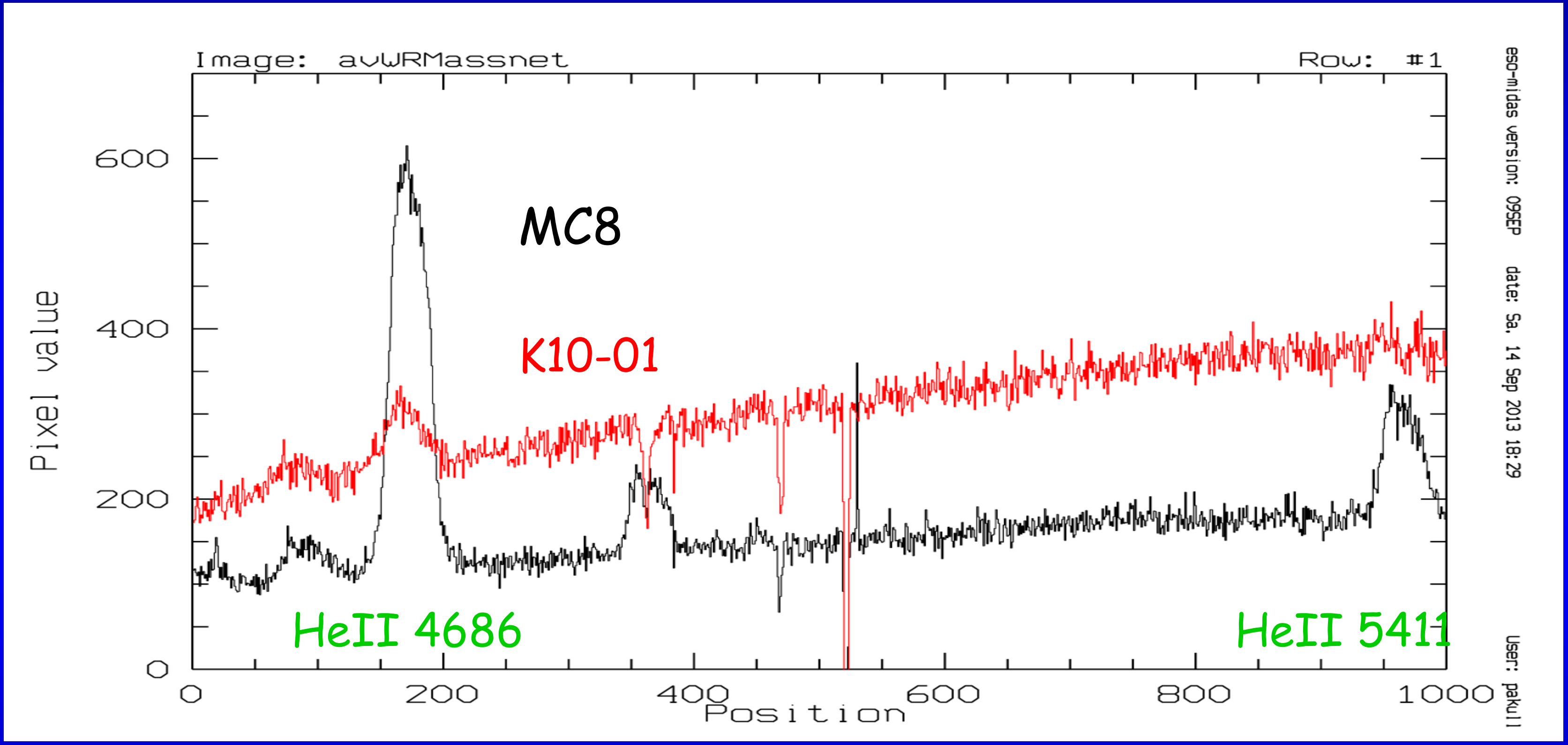


Kehrig+: HeII 4686net





WR stars in MA1



MC8	λ4686: EW = 110 A	N/B = 0
K10-01	= 12 A	=12

HeII4686 N/B in some local Warmers

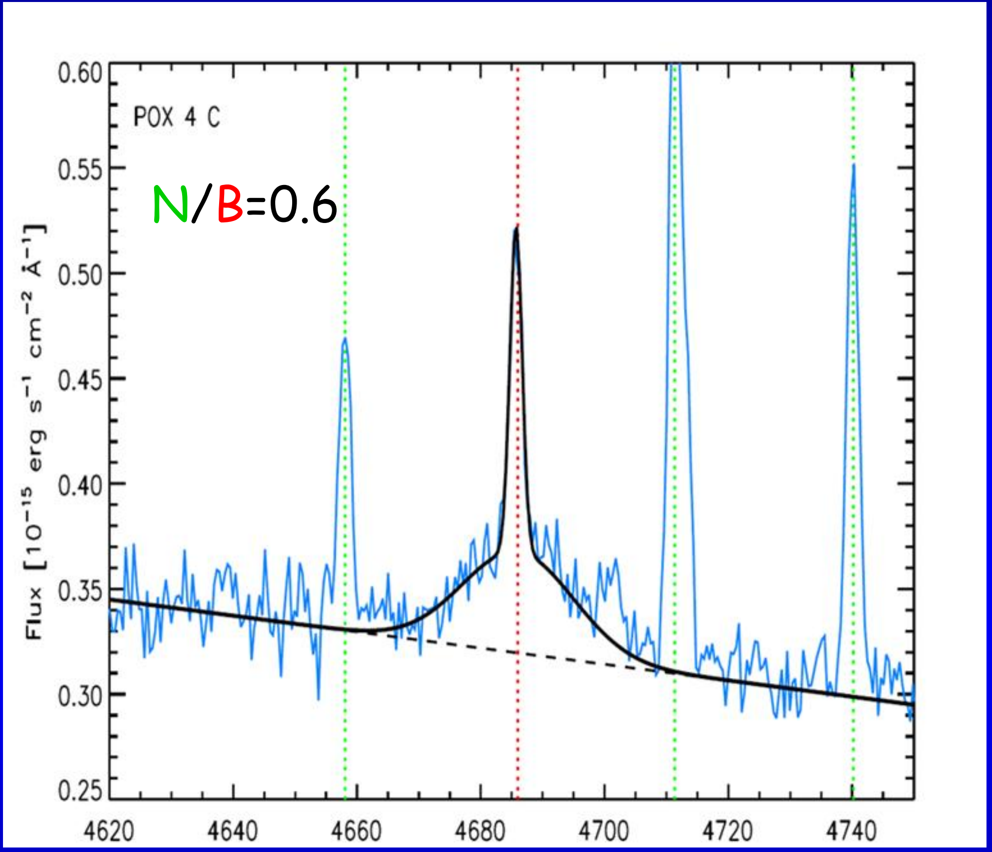
4686 N/B =

- 6.8 Br2 LMC
- 8.0 WR7 SMC
- 5.0 WR10 SMC
- 1.7 *14 M33
- 12 K10-01 M33

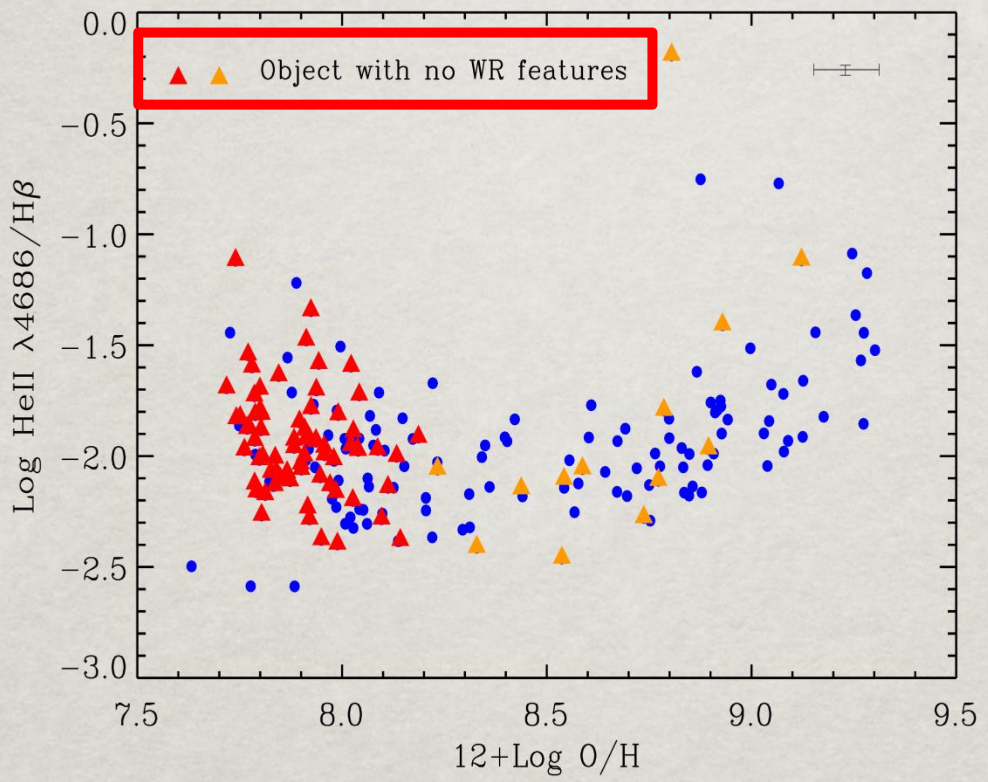
→ Relatively narrow range suggesting similar atmosphere conditions

Further away from home ...

Only the narrow component visible if N/B > 2 - 3



Narrow HeII 4686 emission in HII galaxies



At Z ~ solar: All have WR features
At Z ~ solar/10: ~30% have.

Guseva+00; Brinchman+09, Shirazi+12

At low Z: many HIIG lack WR features
* evol. fewer WR expected

Probably ionisation by 'Warmers' with high N/B

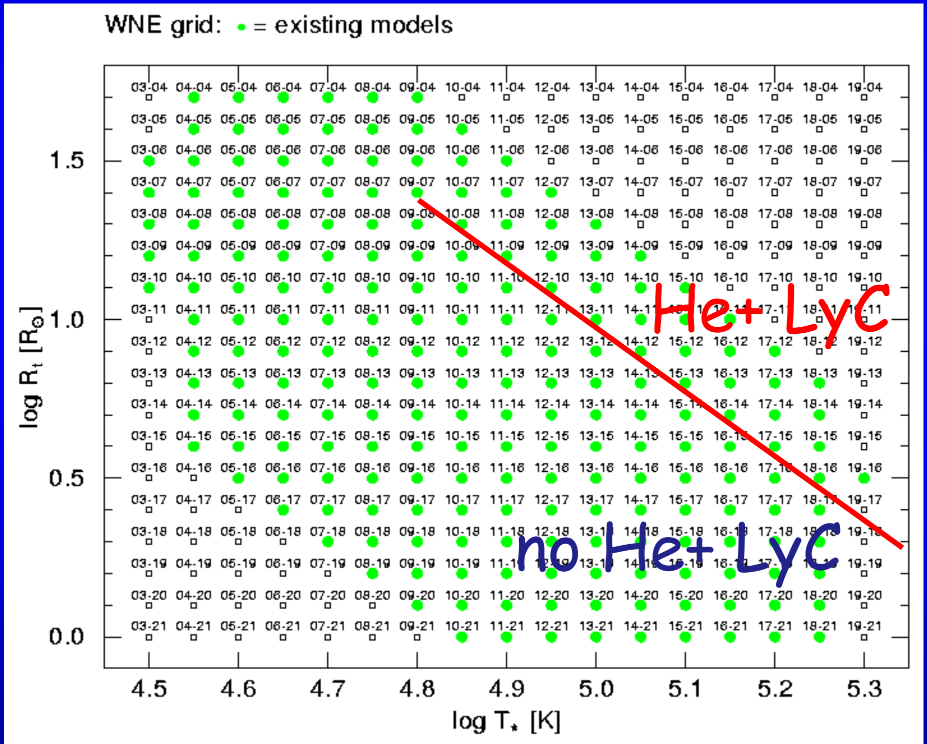
WR model atmospheres

Schmutz et al 1992: spectrum mainly determined by:

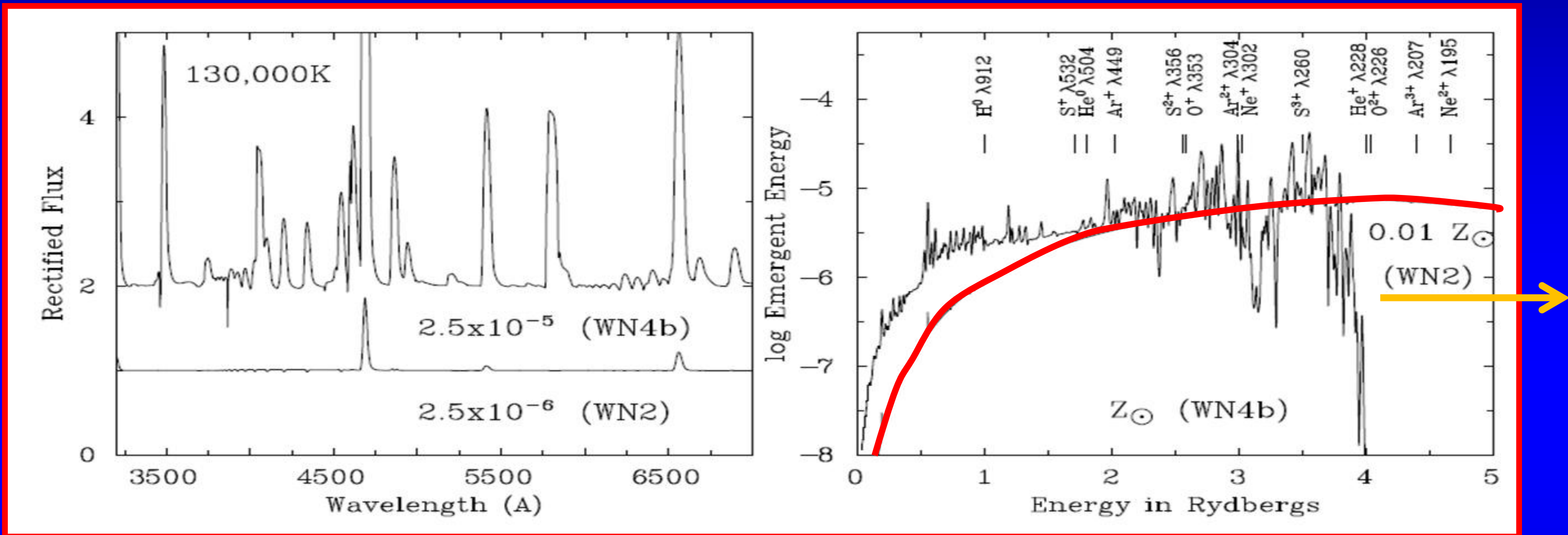
Tc , Rt ~ R* $(v/Mdot)^{2/3}$

Hamann & Gräfener (2004)

WR model grid PoWR



WR star models: dependence on mass loss rate (or R_t)



Smith+2002; Crowther+2009

If we decrease mass loss rate, wind abruptly becomes optically thin for λ < 228 A (hv> 4Ryd), i.e. emission of He+ LyCont → HeIII region

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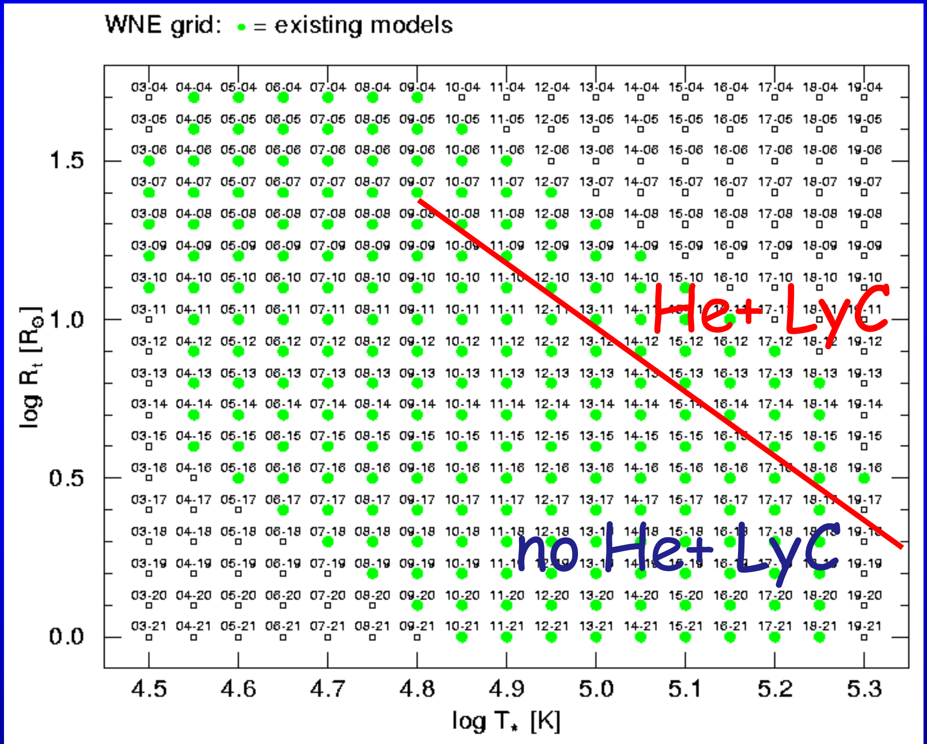
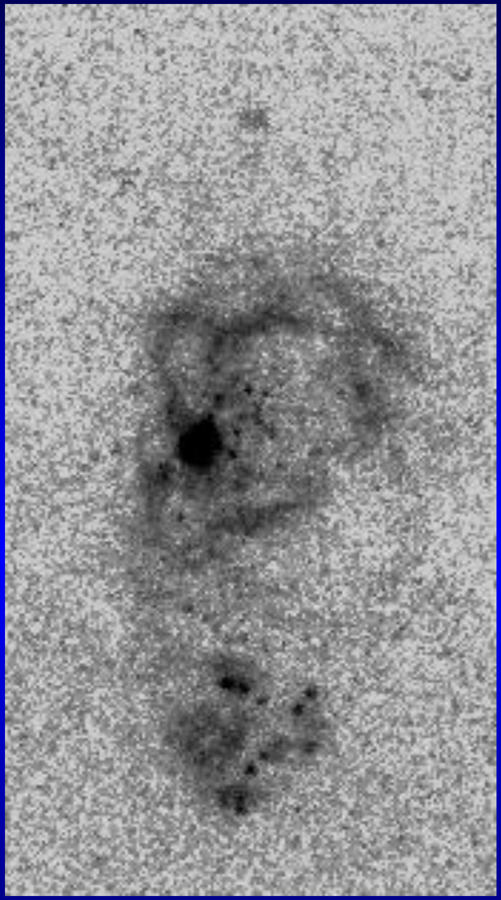


Comparison of PoWR and CMFGEN (Smith et al 2002) for He+ LyC of weak wind WN reveals factor 10 difference !

possibly log g effect ?

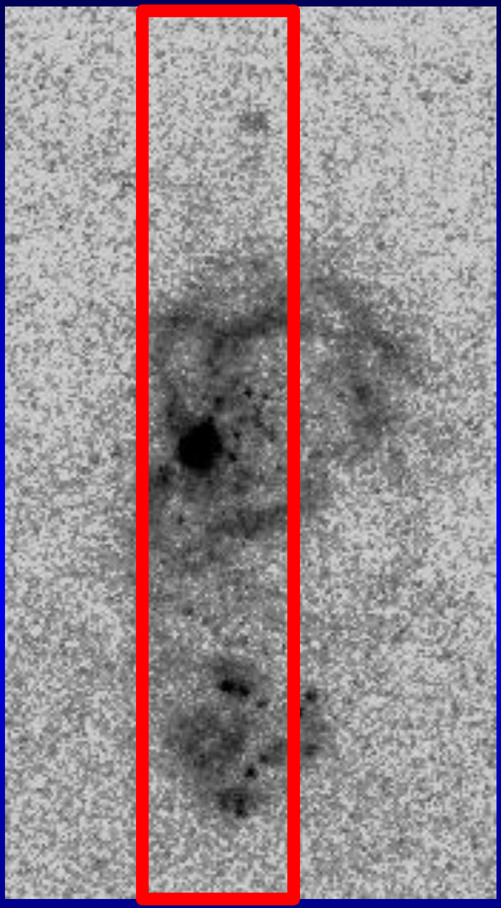
Gemini-N Gmos Broad Slit Spectra



HST Ha

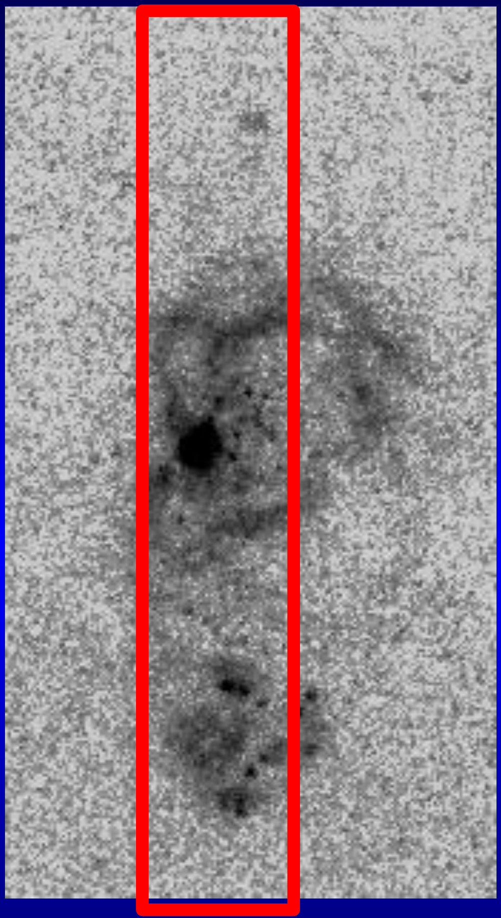
I Zw 18

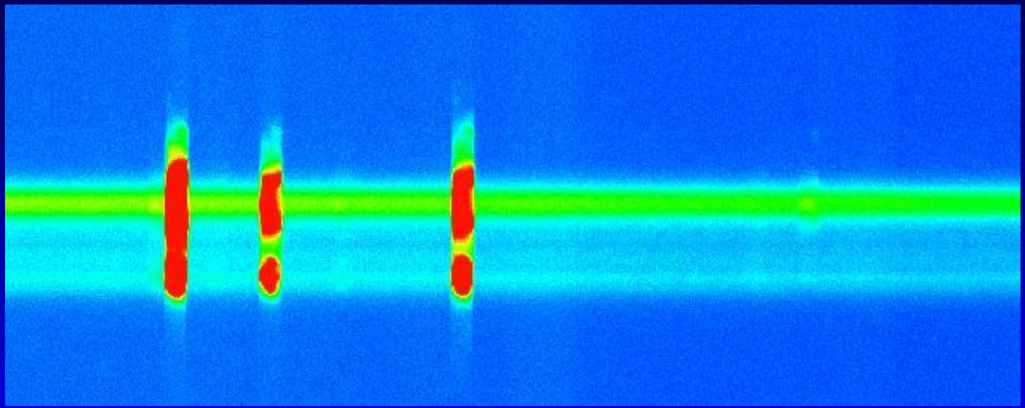
Gemini-N Gmos Broad Slit Spectra

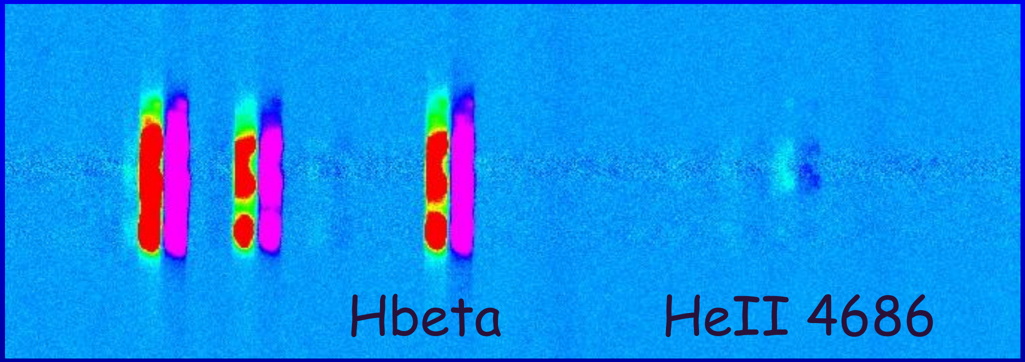


2 " slit width

Gemini-N Gmos Broad Slit Spectra







« Shift & Subtract »

IT about 1h

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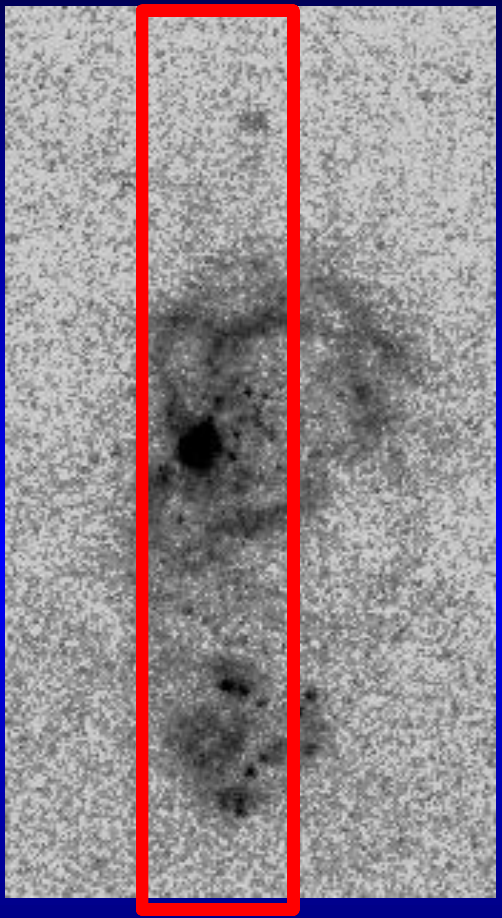
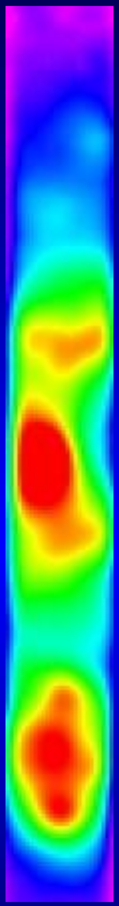
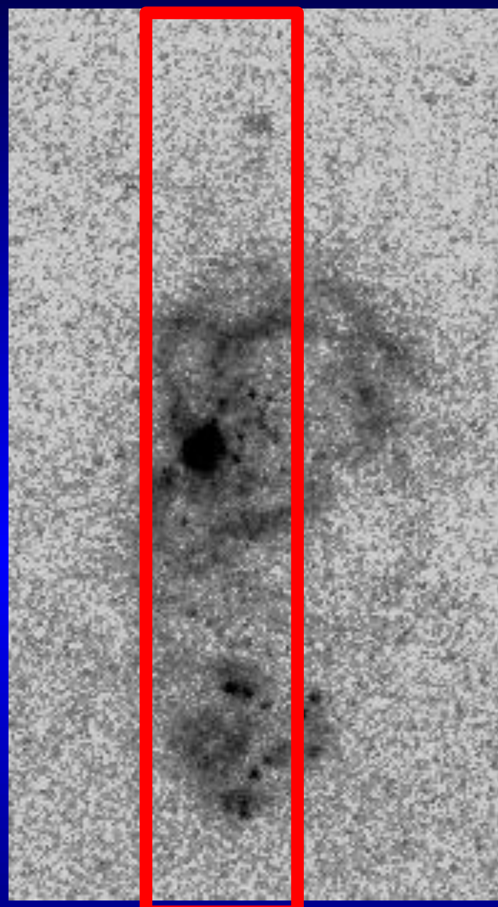


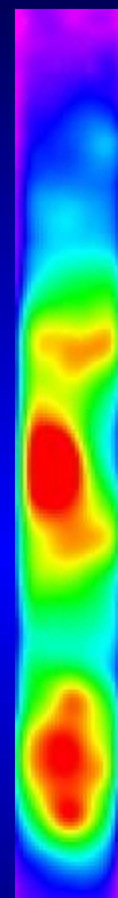


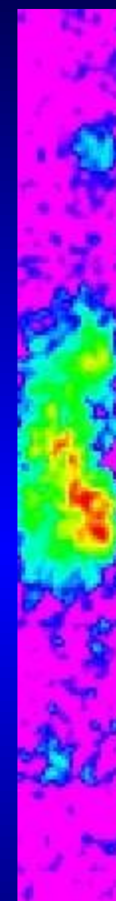
HST Ha

Hβ

Gemini-N Gmos Broad Slit Spectra



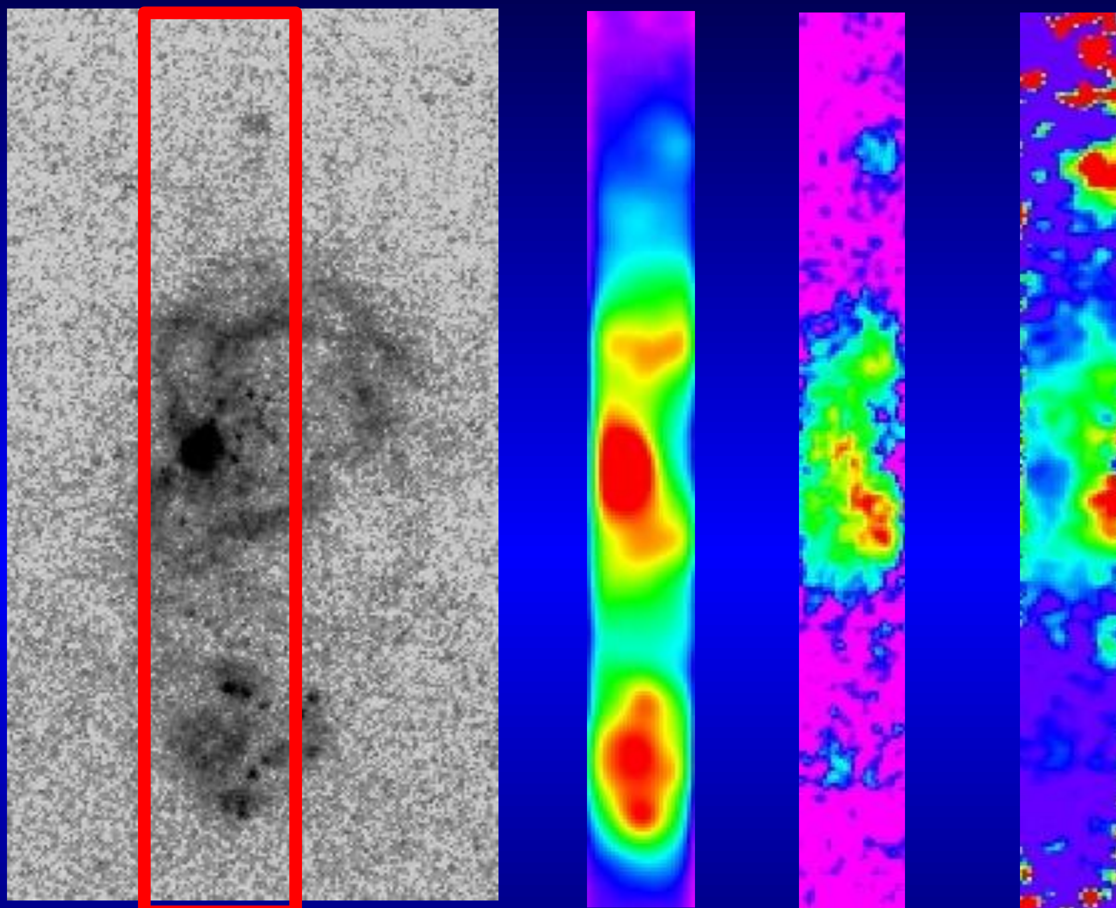




HST Ha

Hβ 4686

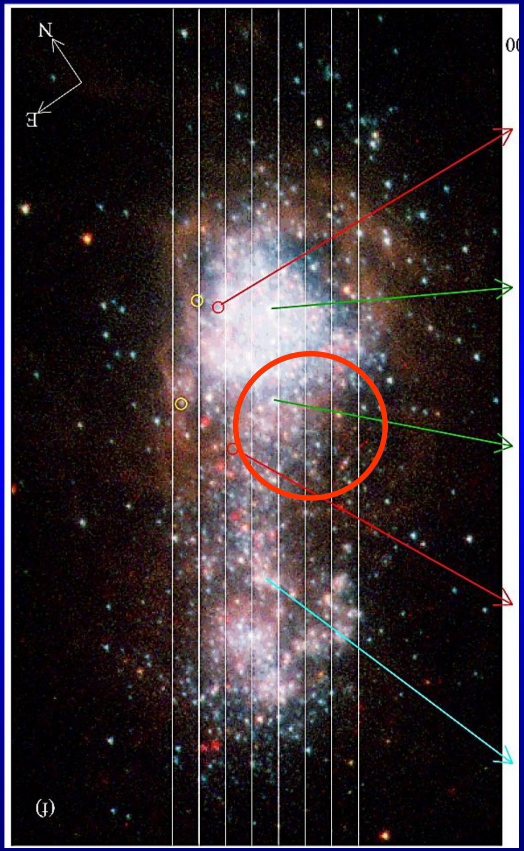
Gemini-N Gmos Broad Slit Spectra



HST Hα   Hβ   4686   4686/β

I Zw18

Brown et al. 2002

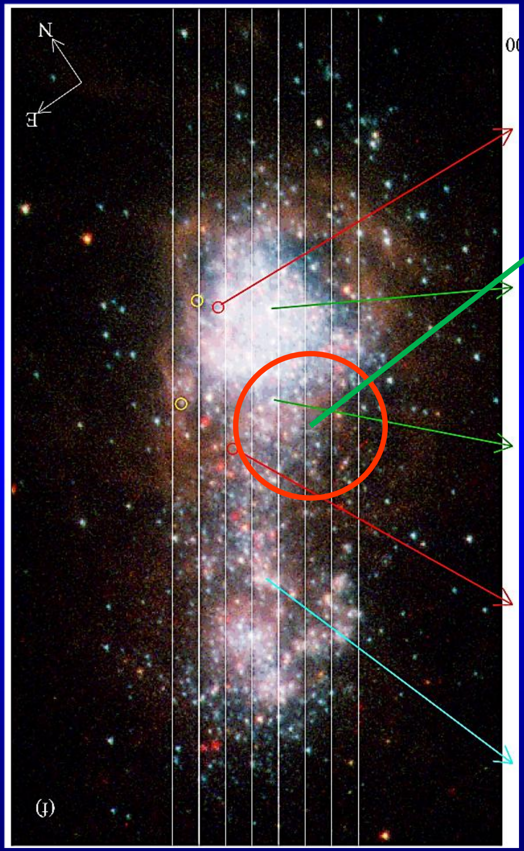


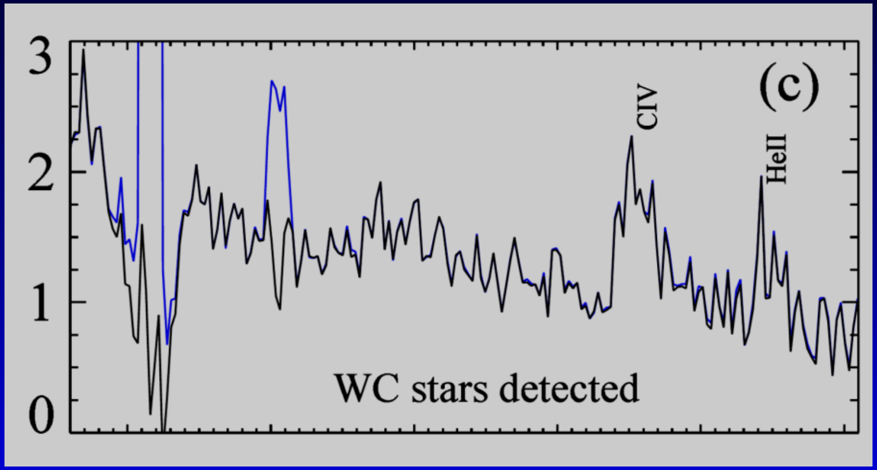
HST: continuum

- region of highest ionisation

I Zw18

Brown et al. 2002





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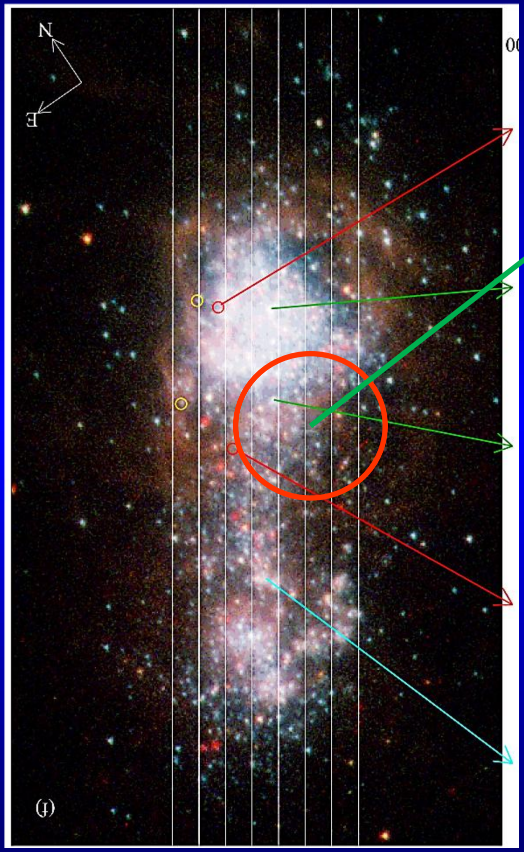

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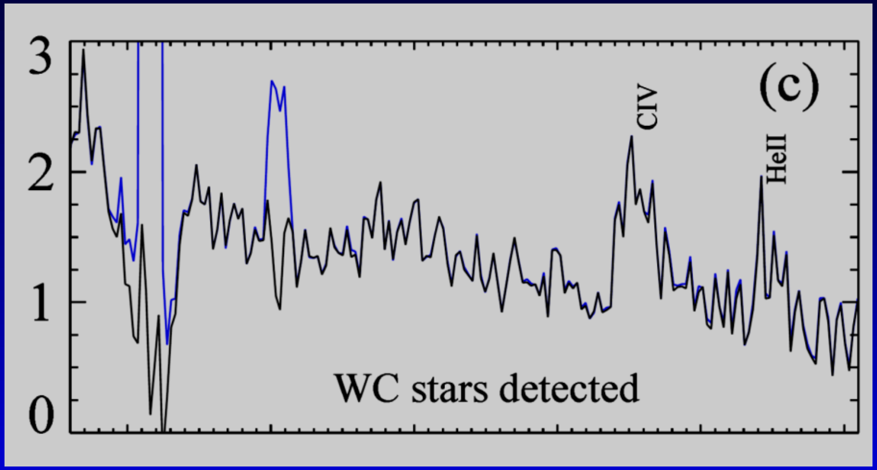
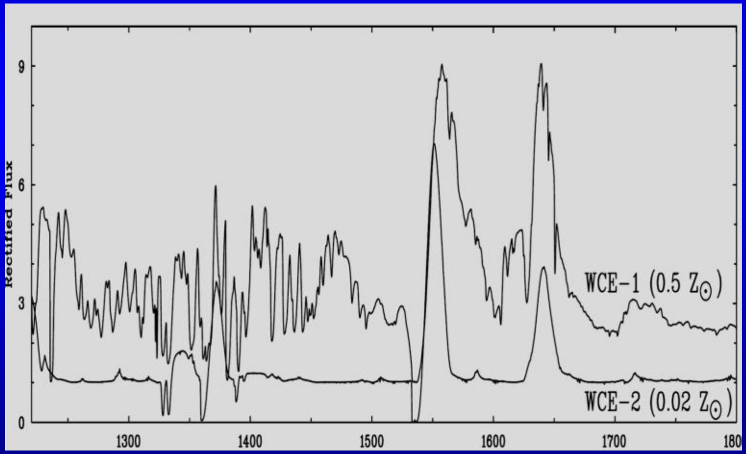


Crowther & Hadfield 2006

model:
weak He+ LyC

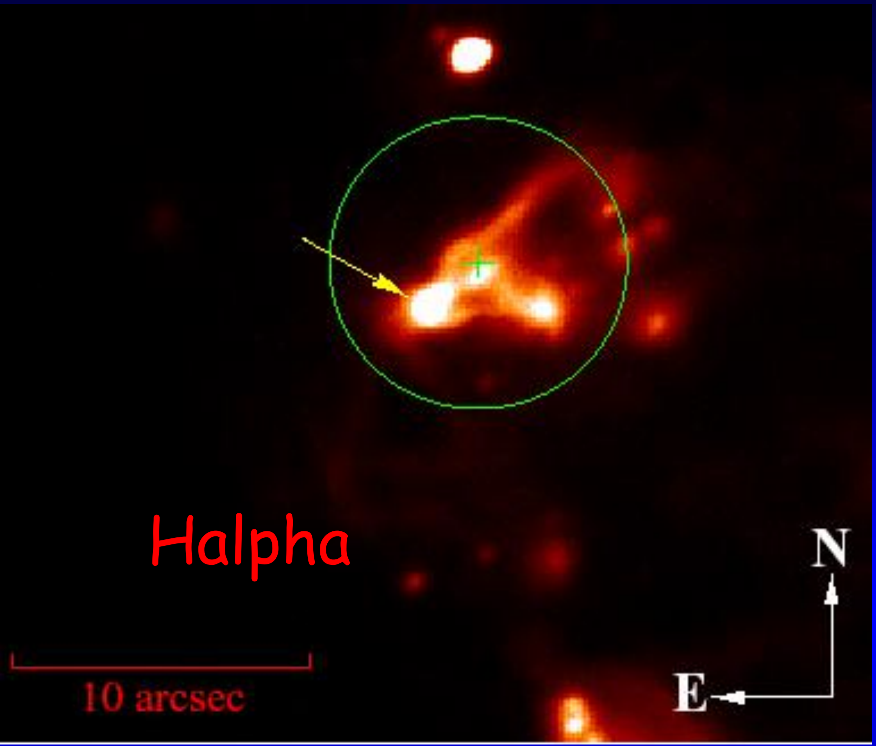


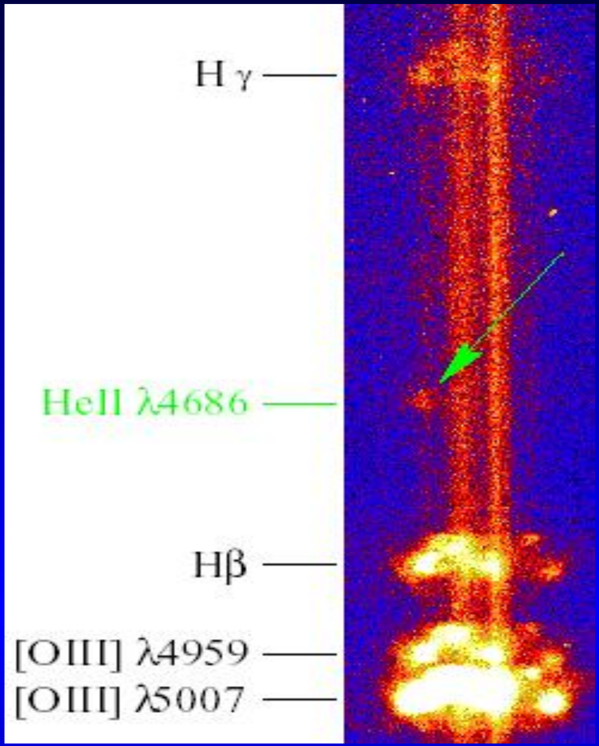
- region of highest ionisation

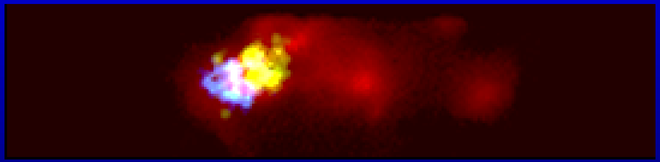
What have we learned ?

- Some rare hot Wolf-Rayet stars with weak winds emit strong He+ LyC :'Warmers';   HeIIλ4686 : **N/B ~2-10.**
- Distant Warmers can be detected through 4686N
- The fraction of Warmers increases with decreasing Z
- We don't yet understand evolution of WN Warmers; chemically homogeneous evolution ?
- POWR and CEMGEN WR models with same Tc and (low) Mdot differ in He+ LyC flux by 10; log g effect ?
- Don't trust spectral evolutionary models for λ<228 A !
- Broad slit (imaging) spectra can be useful, too.

Broad-slit spectroscopy: ULX bubble







Hbeta [OI]6300 HeII4686

Identification of X-ray ionized nebula around ULX Holmberg II X-1: « the foot »
Pakull & Mirioni 2002