He+ Lyman continuum in lowmetallicity starbursts

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

Bergeron (1977) noted λ 4686 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.)



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 → HeIII region



Narrow HeII 4686 emission in HII galaxies



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 (hv >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_53 Terlevich: explanation of AGN by such hot (WOs): <u>'Warmers</u>'

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 $H\alpha = R (red) [SII] = 6 (green) [OIII] = B (blue)$ Highly excited (blue) nebula \rightarrow mostly around WR stars (WN)

Outlying HII region MA1 in M33



NOAO





Kehrig+: HeII 4686net



WR stars in MA1



MC8 λ 4686: EW = 110 AN/B = 0K10-01= 12 A= 12

HeII4686 N/B in some local Warmers



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



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 WNE grid: • = existing models



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 $\lambda < 228 \text{ A}$ (hv> 4Ryd), i.e. emission of He+ LyCont \rightarrow HeIII region

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

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

possibly log g effect ?

03 05 04 05 05 05 05 06 07 05 08 05 09 05 10 05 11 05 12 05 13 05 14 05 15 05 18 05 17 05 18 05 19 05 03_06 04_06 05_06 06_06 07_06 08_08 09_06 10_06 11_06 12-06 13-06 14-06 15-06 16-06 1.5 03-07 04-07 05-07 06-07 07-07 08-07 09-07 10-07 11-07 12-07 13-07 14-07 15-07 16-07 17-07 03-08 04-08 05-08 06-08 07-08 08-08 09-08 11-08 12-08 13-08 14-08 15-08 16-08 03.09 04.09 05.09 06.09 07.09 08.09 09.09 10.09 12.09 12.09 13.09 14.09 15.09 15.09 17.09 15.09 18.09 19.09 03-10 04-10 05-10 06-10 07-10 08-10 09-10 10-10 11-10 12-10 13-10 14-10 15-10 16-10 17-10 18-10 19-10 [₀1.0 ⁺ [B₀] B₀l 03.11 04.11 05.11 08.11 07.11 08.11 09.11 10.11 11.11 12.11 13.11 14.11 03-12 04-12 05-12 08-12 07-12 08-12 09-12 10-12 11-12 12-12 13-12 14-12 15-12 18-12 17-12 03-13 04-13 05-13 08-13 07-13 08-13 09-13 10-13 11-13 12-13 13-13 14-13 03-14 04-14 05-14 08-14 07-14 08-14 09-14 10-14 11-14 12-14 13-14 14-14 15-1 03-15 04-15 05-15 08-15 07-15 08-15 09-15 10-15 11-15 12-15 13-15 14-15 15-15 18-1 03_18 04_18 05_18 08_18 07.18 08_18 09.18 10_18 11.18 12.18 13_18 14.18 15.18 16.18 17.18 18.18 19.18 0.5 03-17 04-17 05-17 06-17 07-17 05-17 09-17 10-17 11-17 12-17 13-17 14-17 15-17 16-17 17-17 18-17 18-17 19-17 03.18 04.18 05.18 06.18 07.18 08.18 09.18 10.18 11.18 12.18 13.1 14 18 15.18 03-19 04-19 05-19 06-19 07-19 08-19 09-19 10-19 11-1 12-0 13-1 14 19 19-19 03-20 04-20 05-20 06-20 07-20 08-20 09-20 10-20 11-20 12-20 13-20 14-20 15-20 16-20 17-20 18-20 03.21 04.21 05.21 06.21 07.21 08.21 09.21 10.21 11.21 12.21 13.21 14.21 15-21 16-21 0.0 4.5 4.64.8 4.9 5.24.7 5.0 51 5.3log T₁ [K]

03 04 04 04 05 04 06 04 07 04 08 04 09 04 10 04 11 04 12 04 13 04 14 04 15 04 16 04 17 04 18 04 19 04

WNE grid: • = existing models









2 " slit width





« Shift & Subtract »

HST Ha

Ηβ

HST Ha $H\beta$ 4686

HST Ha $H\beta$ 4686 4686/ β

Brown et al. 2002

HST: continuum

- region of highest ionisation

I Zw18

Brown et al. 2002

HST: continuum

- region of highest ionisation

I Zw18

Brown et al. 2002

HST: continuum

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