[WN] central stars of planetary nebulæ

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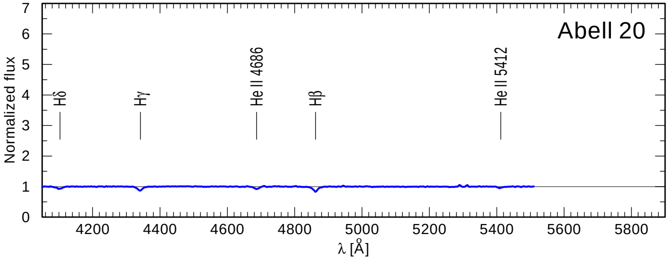
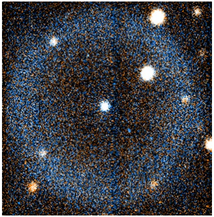
Central stars: H-normal vs. [WC] – Spectra

H-normal CS: weak absorption lines of H, He





Schwarz et al. 1992

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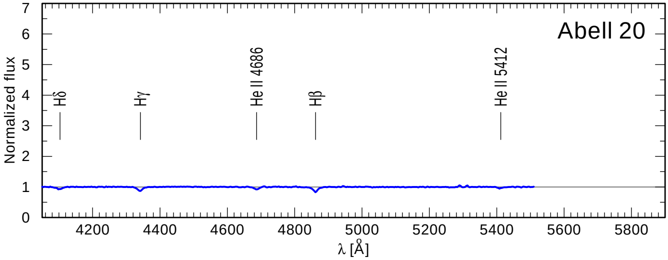

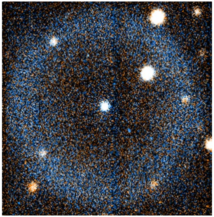

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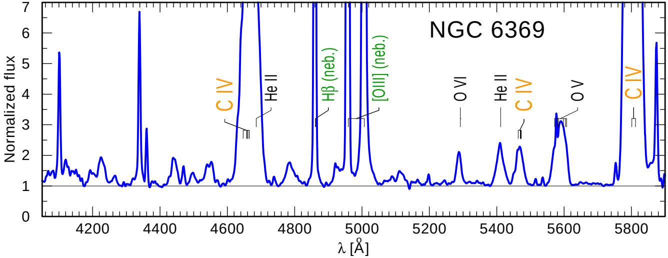
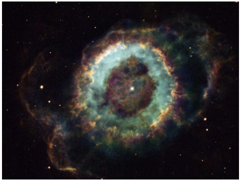
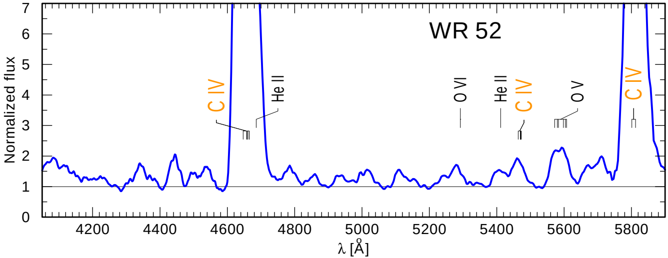




Hubble/NASA

Wolf-Rayet stars: massive WC vs. low-mass [WC]

Massive WC: strong, broad emission lines of C, He, O



ESO/R/MAMA+SERC/J/DSS1

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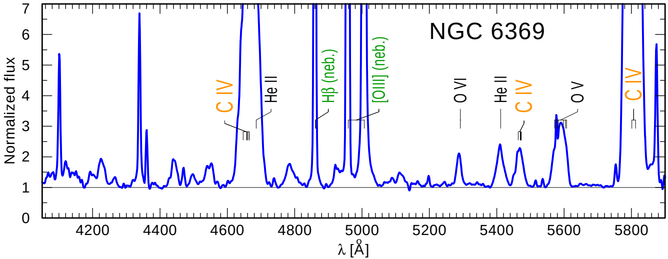

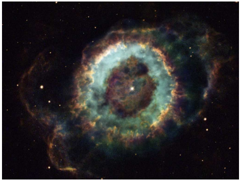

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Wolf-Rayet stars: WC and WN, WN/C

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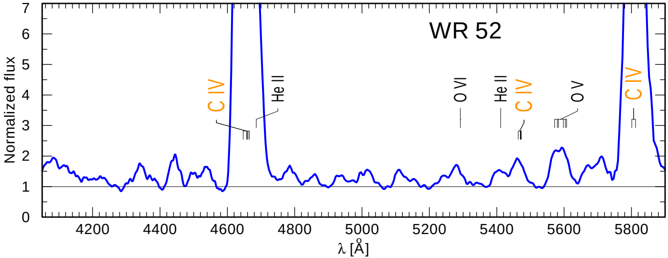

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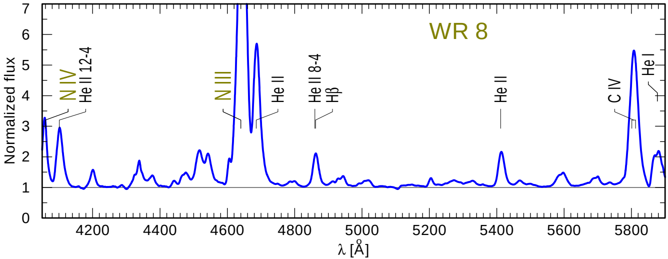
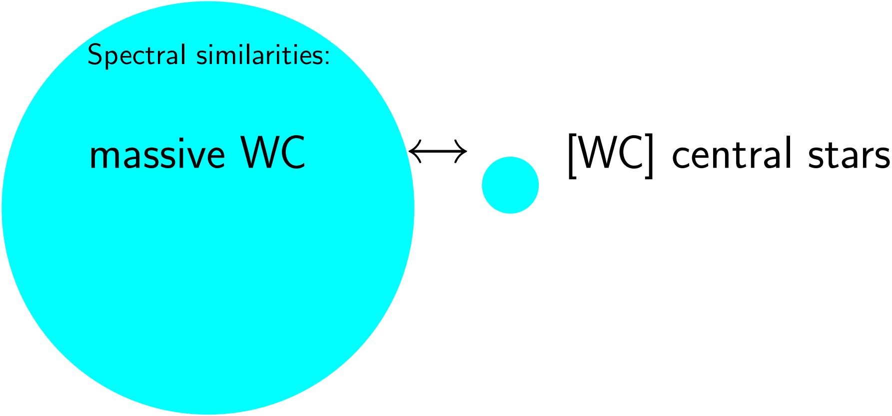
Massive WN/C: strong, broad emission lines of N, H, He, C



ESO/R/MAMA+SERC/J/DSS1

A naive question



A naive question

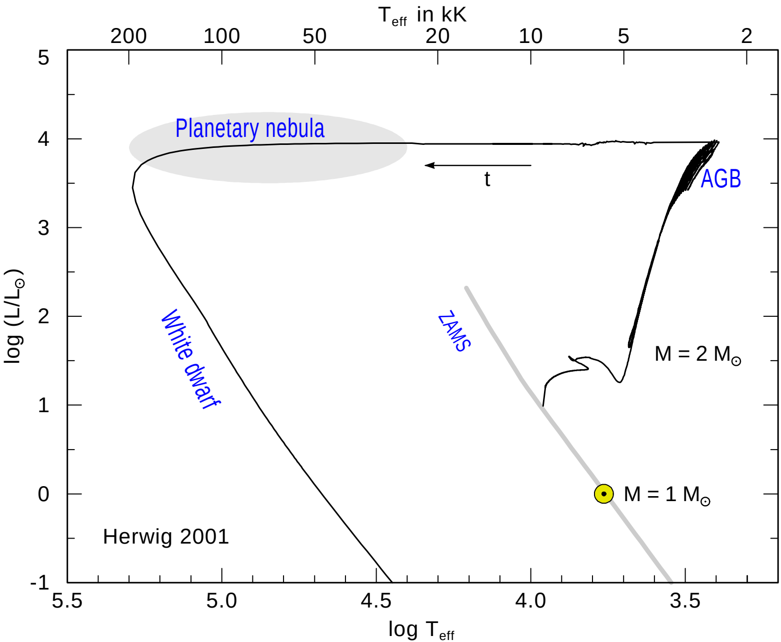
Spectral similarities:

massive WC ⟷ [WC] central stars

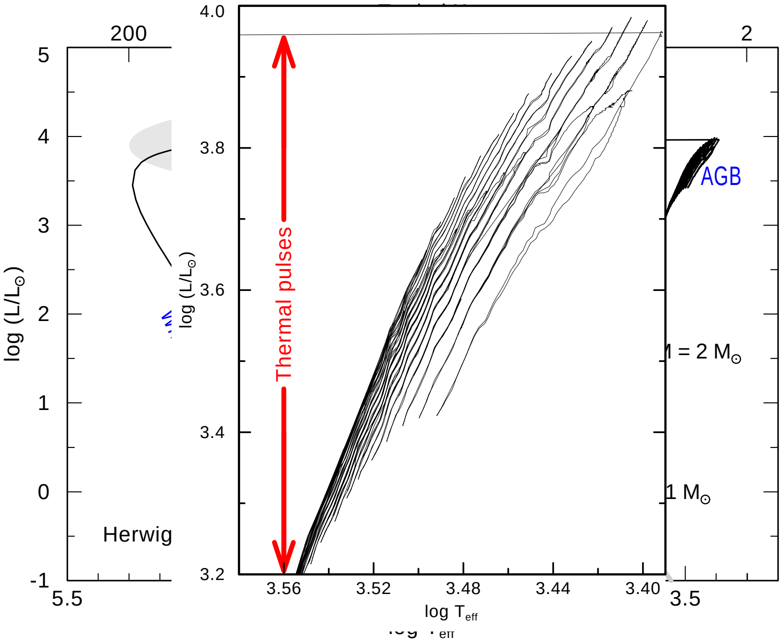
massive WN ⟷ [WN] central stars?

Are there [WN] central stars?

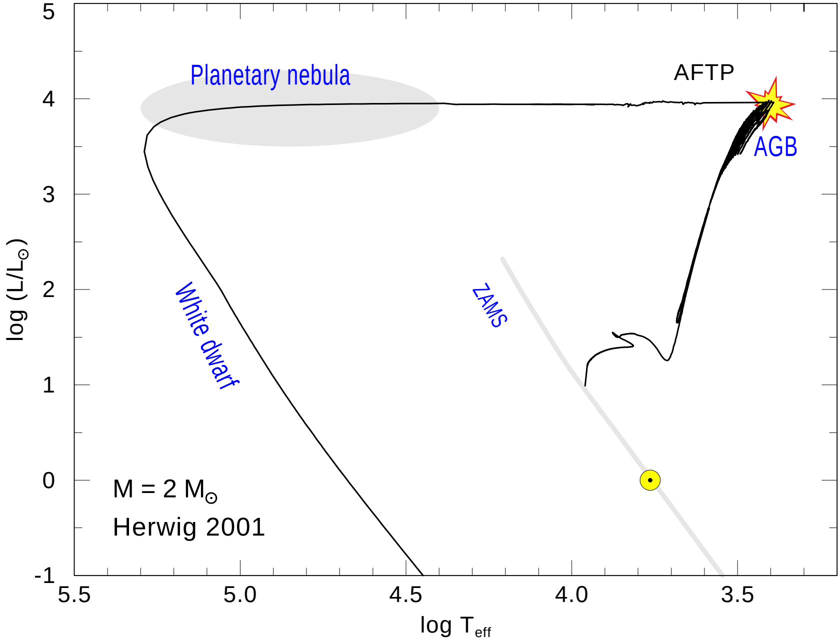
Evolution through the PN phase



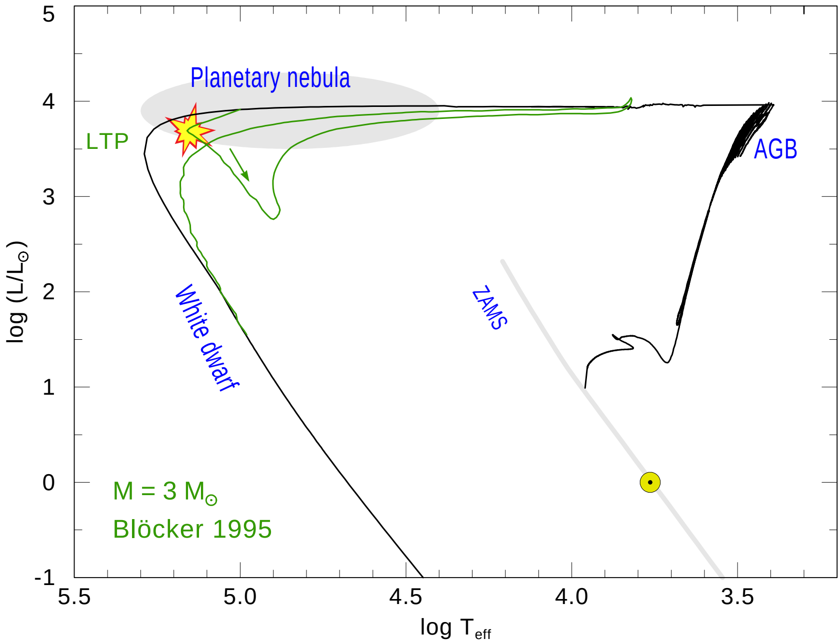
Evolution through the PN phase – Thermal pulses



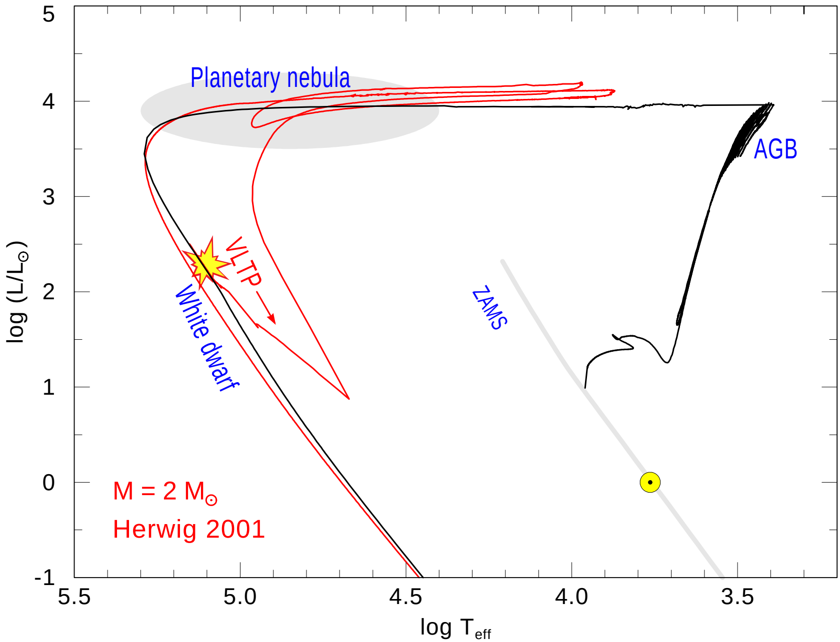
[WC] stars: AGB Final Thermal Pulse – AFTP



[WC] stars: Late Thermal Pulse – LTP



[WC] stars: Very Late Thermal Pulse – VLTP



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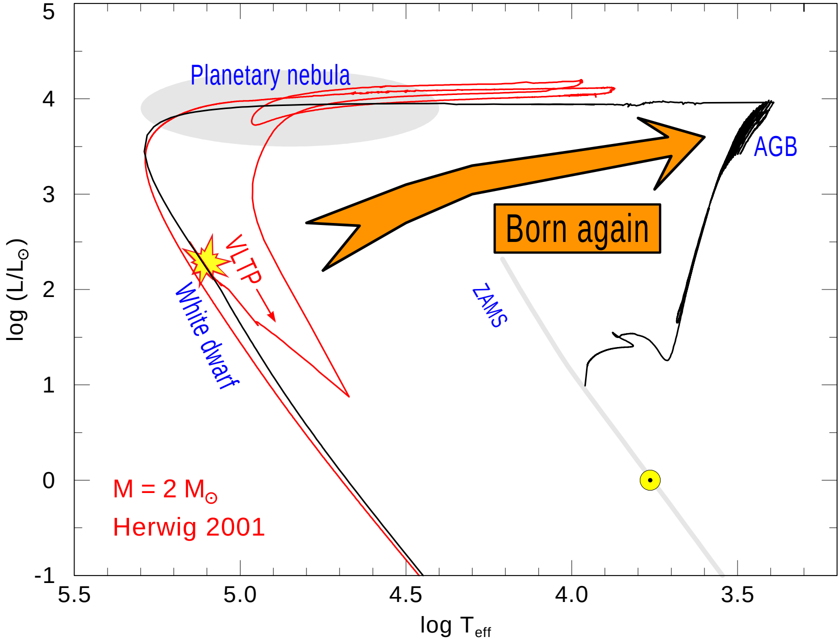
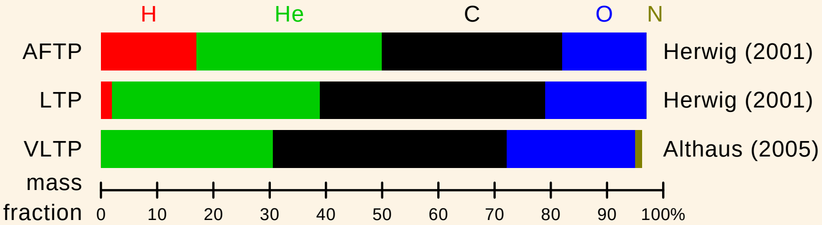


[WC] stars: Stellar evolutionary models

Chemical abundances after last TP

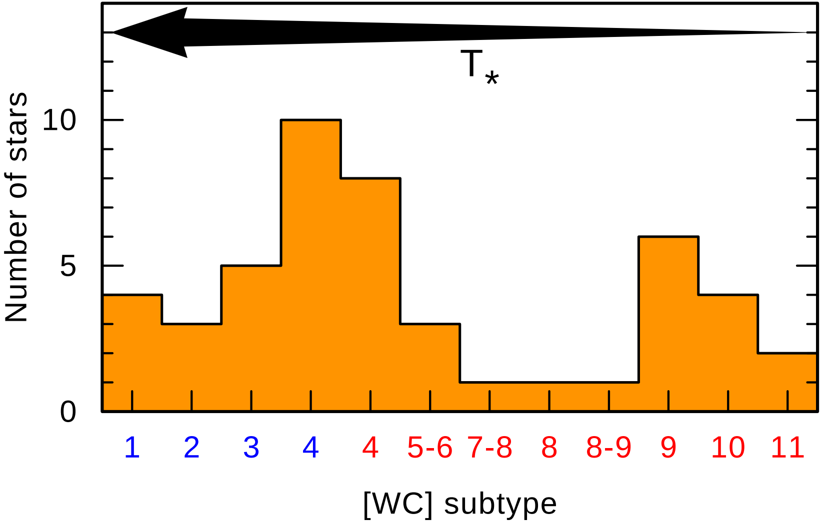


→ C- and O-rich stellar atmosphere

For comparison:

→ NO [WN] stars expected

Our campaign: Do [WC] subtypes form an evolutionary sequence?



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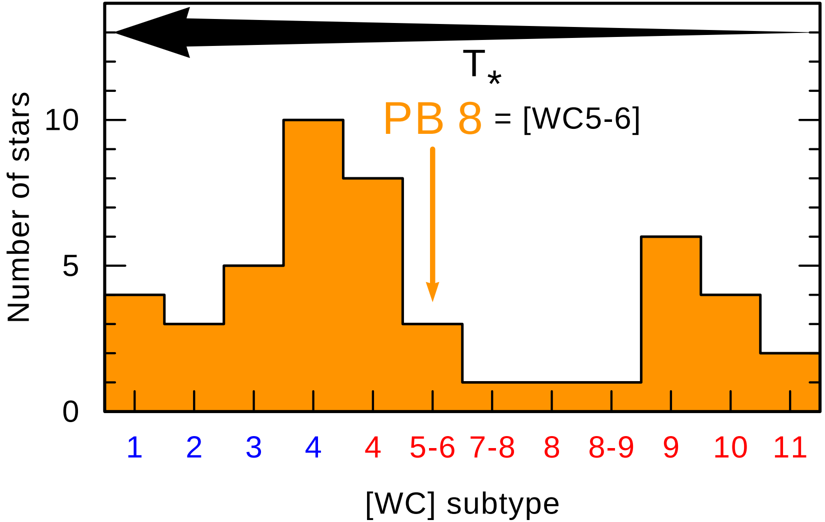
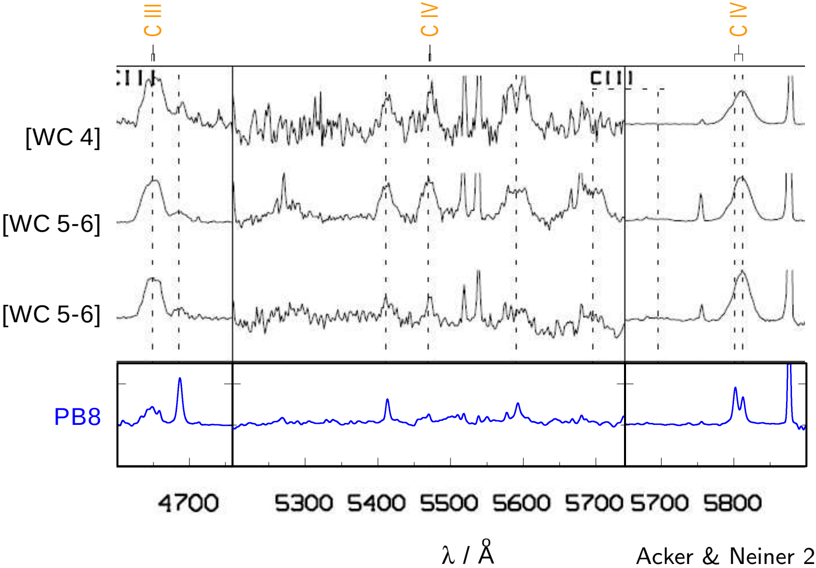


Spectrum - PB 8 vs. [WC 5-6]



Acker & Neiner 2003

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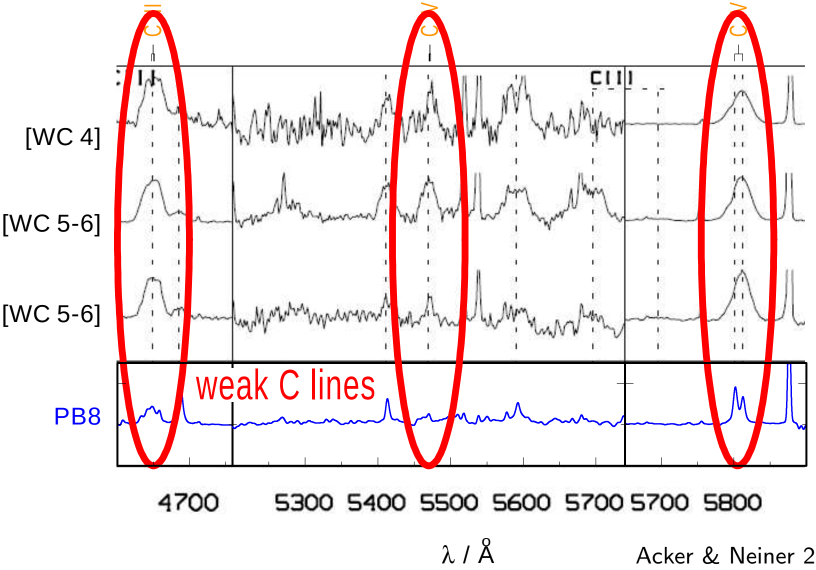

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PoWR

PoWR – Potsdam Wolf-Rayet model atmospheres

- Radiative transfer in co-moving frame ⟶ stellar winds
- Full Non-LTE calculation of population numbers
- Iron line blanketing by superlevel approach
- Micro-clumping (optically thin)

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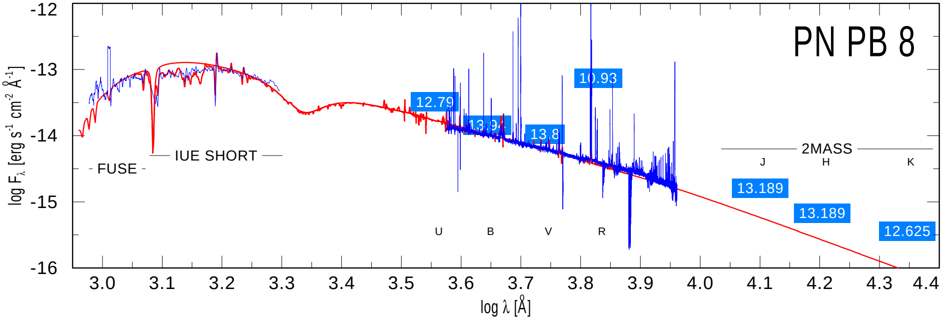
Parameters

- $\mathbf{L}_* = 4\pi \mathbf{R}_*{}^2 \cdot \sigma_{\mathrm{SB}} \mathbf{T}_*{}^4$
- $\dot{\mathbf{M}}$
- $\mathbf{v}_\infty$
- M_*
- element abundances

PB 8: Analysis - Observations

Spectral energy distribution



Observations vs. PoWR-model

optical: MIKE (6.5 m Magellan Telescope)

PB 8: Analysis – Results

T_*	52	kK
v_∞	1000	$\mathrm{km\,s^{-1}}$
$\dot{M}$	8.5×10^{-8}	$M_\odot\,\mathrm{a}^{-1}$
$E_{\mathrm{B-V}}$	0.41	mag
$d(L_* = 6000\,\mathrm{L}_\odot)$	4.2	kpc
H	40	% mass fraction
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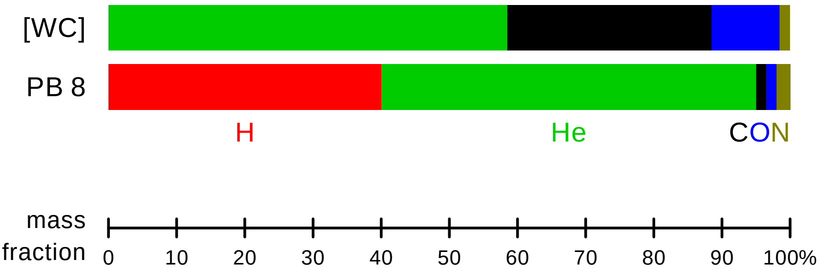

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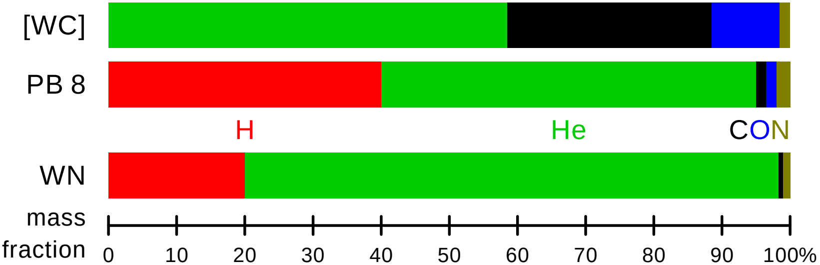

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Problem: unknown distance → L unknown

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WR star:	200 000	24.2 kpc	1.7 kpc	×

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PB 8 is indeed a central star of a planetary nebula.

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- NO shift of radial velocities of spectral lines (Méndez 1991)
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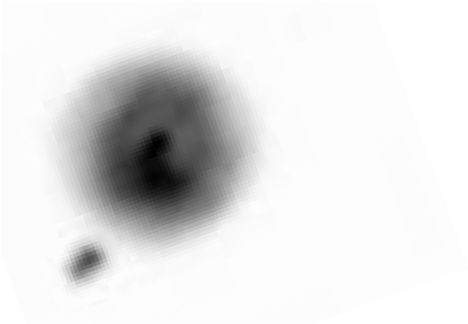

Composite picture

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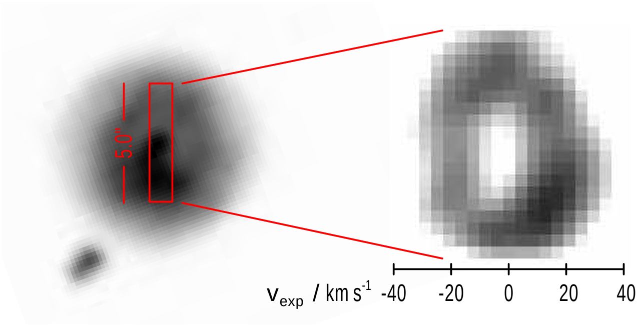

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Longslit spectrogram of [O III] 5007 Å

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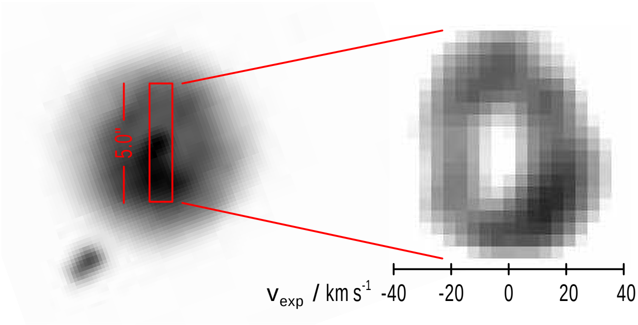

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Binarity rather unlikely

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He-sdO with similar composition, but without PN:

- KS 292, aka Hbg 292 (Rauch et al. 1991)

PB 8: Discussion – Evolutionary status

Observed *stellar* abundances vs. TP-models

- AFTP, LTP cannot explain supersolar N
- VLTP cannot explain remaining H

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Nebular properties

- kinematic age $t_{\mathrm{Neb}} \leq 3000$ years, low N / O and He / H
  $\rightarrow$ VLTP implausible
- low N / O (no HBB) points to lower mass CS
  $\rightarrow$ "slow" stellar evolution

PB 8: Discussion – Evolutionary status

Conclusion: perhaps

- *weak* VLTP (remaining H, supersolar N),

  $\longrightarrow$ then nebula from born-again (He-enriched)

  but: nebula not He-enriched

or:

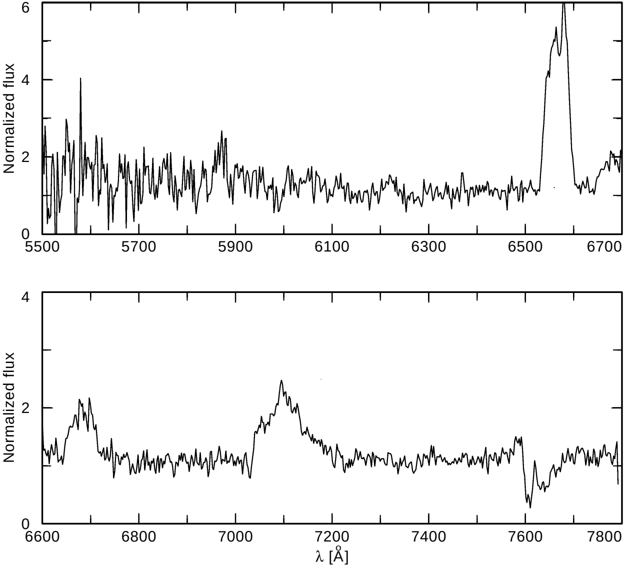
- *anomalous* AFTP (surface abundances),

  $\longrightarrow$ then normal nebula

  but: cannot explain stellar N-enrichment

PMR 5: Optical spectrum from Morgan et al. (2003)

Highly reddened: $E_{B-V} = 3\,mag$



PMR 5: Optical spectrum + PoWR model

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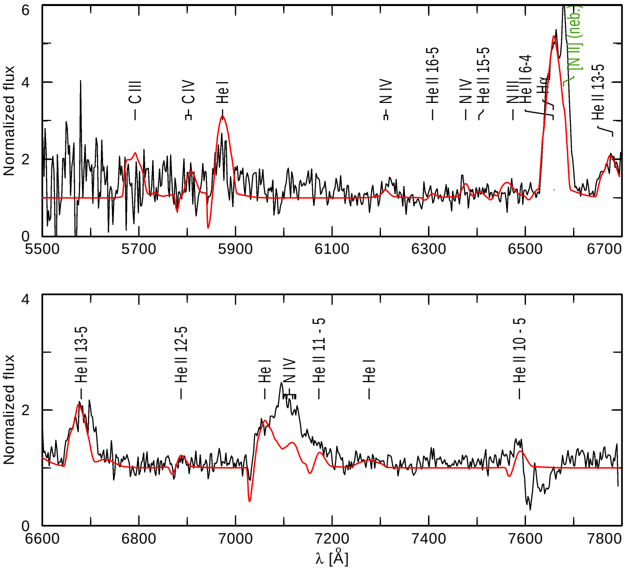

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H	20	% mass fraction
He	70	% mass fraction
C	< 1	% mass fraction
N	10	% mass fraction
O	–	% mass fraction

$\longrightarrow$ massive WN star?

PMR 5: Discussion of central star status

- Nebula of PMR 5:

  $v_{\mathrm{exp}} \sim 10 \times v_{\mathrm{exp}}(\mathrm{PN})$, typical for WR ring nebulæ

  but $n_{\mathrm{e}} \sim n_{\mathrm{e}}(\mathrm{PN})$, untypical for WR ring nebulæ

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- Luminosity distances: consistent with massive WR star

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Chemistry and $v_{\rm exp}$ point to a massive WN star.

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first detected [WNC] CS

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Thanks for your attention.