Slowly-rotating nitrogen-rich O stars in 30 Doradus

Frank Tramper[1], Hugues Sana[1], Joachim Puls[2], Norbert Langer[3], Alex de Koter[4,1], Nathan Grin[3], Daniel Lennon[5]

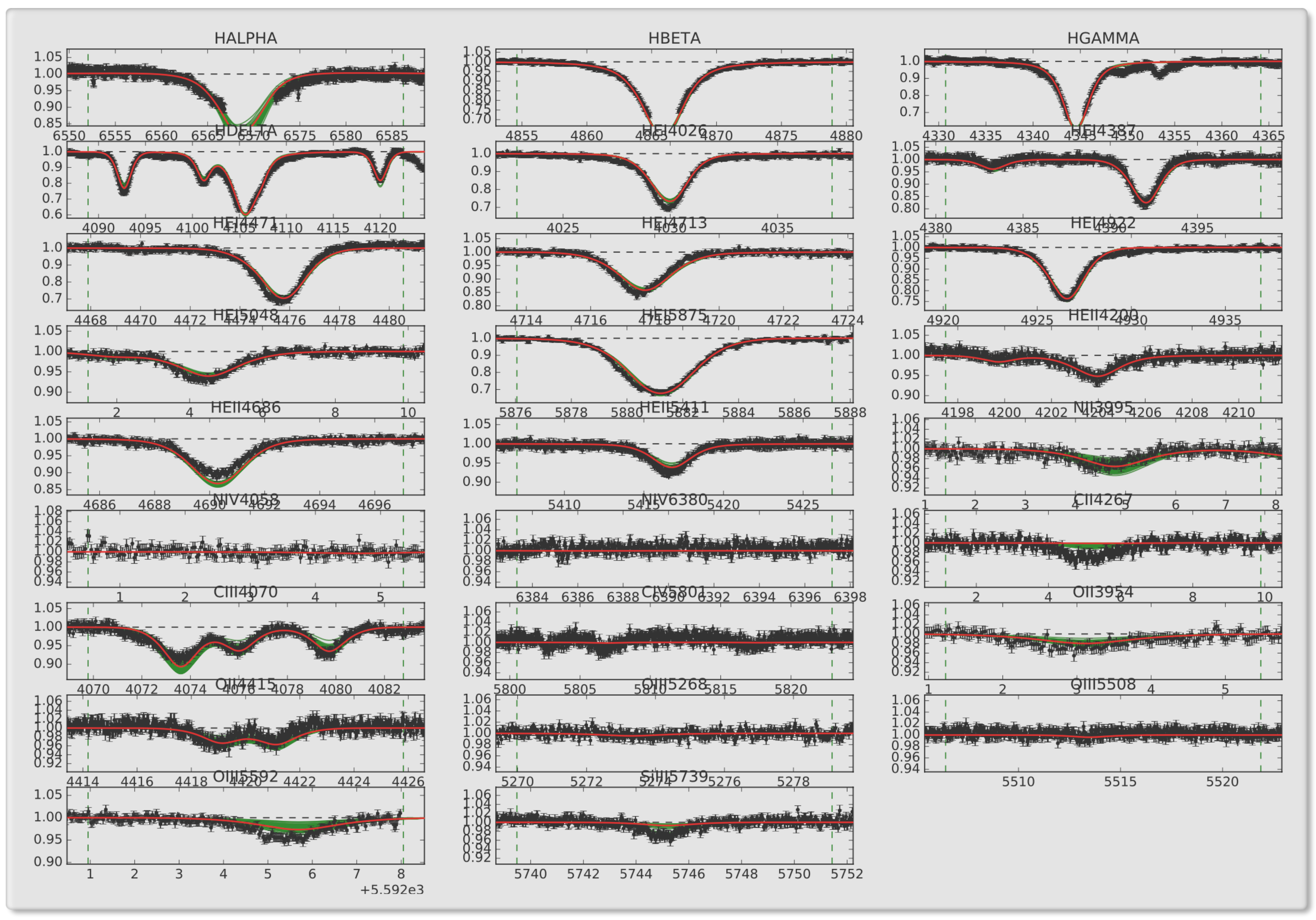
[1]KU Leuven, [2]Universitätssternwarte München, [3]Universität Bonn, [4]University of Amsterdam, [5]Instituto de Astrofysíca de Canarias

Introduction

Rotation is a key element affecting the evolution of massive stars. High rotation rates allow the mixing of material between the core and the envelope. As a consequence, more hydrogen becomes available in the core resulting in significantly longer main-sequence lifetimes (up to 30%, e.g. Brott et al. 2011). Simultaneously, CNO processed material is mixed into the envelope, increasing the nitrogen and lowering the carbon and oxygen surface abundances.
While the current generation of evolutionary models differ in the amount of mixing predicted and the rotation rate needed to have a significant impact on massive star evolution, they do agree on two important observational effects:

1) A strong correlation between surface nitrogen abundance and rotation rate, and
2) The almost complete absence of nitrogen enrichment for initially slowly rotating massive stars.

Contrary to these predictions, Hunter et al. (2008) found a group of slowly-rotating nitrogen-rich B-type stars in the framework of the VLT-Flames Survey of Massive Stars (Evans et al. 2006). More recently, a similar group of O-type stars has been found in 30 Doradus (aka the Tarantula nebula) by Grin et al. (2017, see Figure) in the VLT-Flames Tarantula Survey (Evans et al. 2011). Here we present preliminary results of a further investigation of a representative subsample of these stars.



Future steps

The results of this work will be used to investigate the origin of the anomalous nitrogen abundances. When the final carbon and oxygen abundances have been derived, the first step will be to see if they are compatible with CNO equilibrium values.

The derived parameters will be used to investigate several scenarios which might explain the nature of these stars, e.g.:

- The presence of other mixing processes (e.g., by macroturbulent motions)
- Stripping of the envelope of the stars through prior binary interactions
- Stripping by prior giant mass ejections (e.g., an earlier LBV stage)

References

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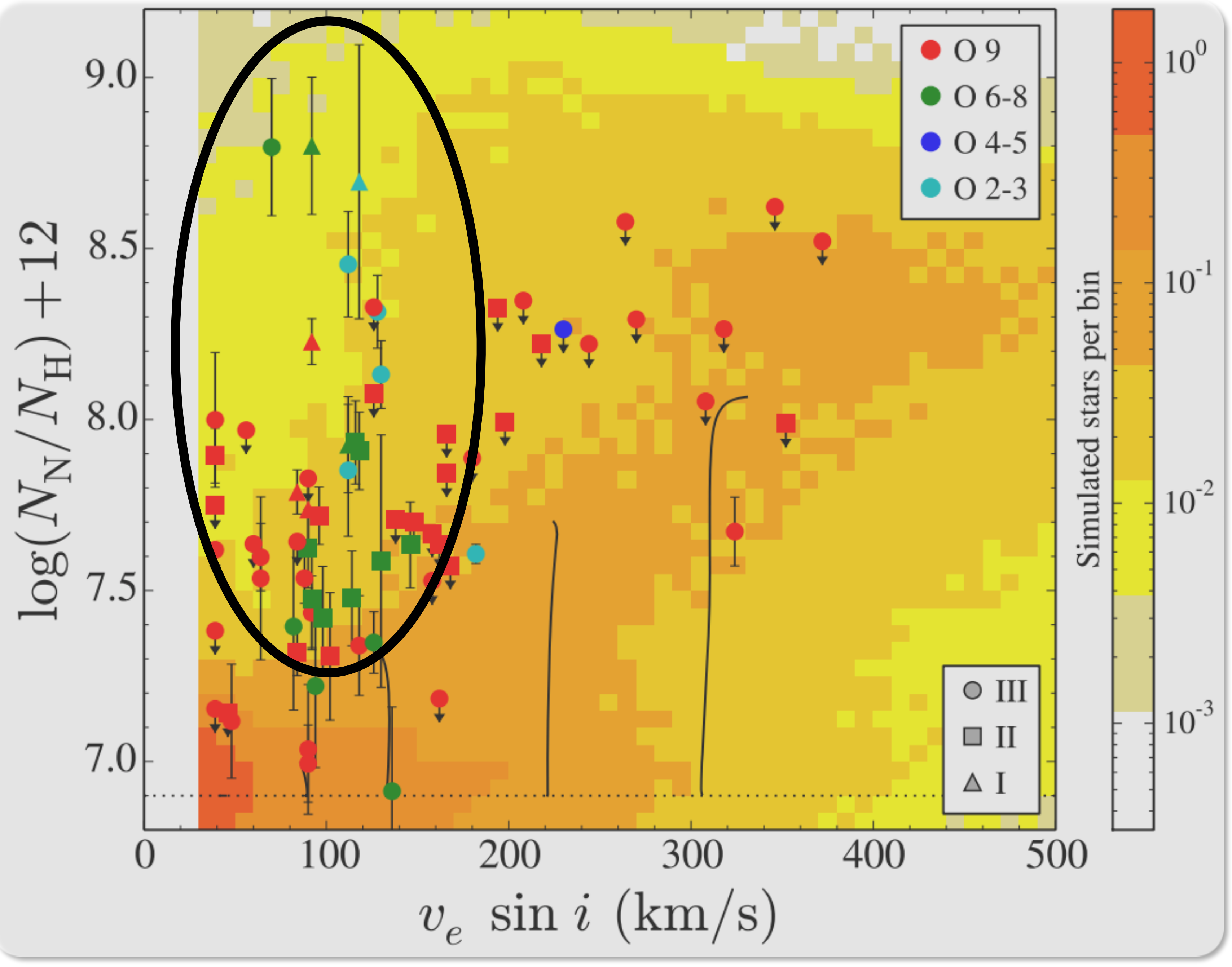

Analysis

To investigate the nature of the slowly-rotating nitrogen-rich stars in 30 Doradus we obtained high quality (R ~ 40000, S/N > 100) spectra of four representative stars using VLT/UVES with the aim to accurately derive the key stellar parameters and the surface abundances of helium, carbon, nitrogen, oxygen, and silicon. The spectra were analysed by fitting synthetic spectra from the model atmosphere code *fastwind* (Puls et al. 2005) using a genetic algorithm (GA, see Figure). This method allows us to thoroughly explore the 11-dimensional parameter space in a reasonable amount of CPU time. Additionaly, the method provides us with robust error bars on the derived parameters.

Compared to earlier versions of the GA (Mokiem et al. 2005, Tramper et al. 2011, 2014), we implemented macroturbulence and surface abundances of C, N, O, and Si as fitting parameters.

ID	$T_{\rm eff}$ (K)	$\log g$ (cm s^{-2})	$\log \dot{M}/\sqrt{f_{\rm c}}$ ($M_\odot$ yr^{-1})	$v_{\rm micro}$ (km s^{-1})	$v_{\rm macro}$ (km s^{-1})	$v_{\rm rot} \sin i$ (km s^{-1})
VFTS087	29650^{+1150}_{-850}	$3.03^{+0.14}_{-0.02}$	$-6.25^{+0.2}_{-0.3}$	22^{+4}_{-3}	103^{+14}_{-20}	10^{+41}_{-5}
VFTS178	27950^{+350}_{-250}	$2.96^{+0.05}_{-0.06}$	$-5.85^{+0.05}_{-0.15}$	21^{+3}_{-3}	110^{+12}_{-7}	31^{+13}_{-25}
VFTS180	39800^{+100}_{-50}	$3.41^{+0.04}_{-0.03}$	$-5.05^{+0.05}_{-0.05}$	28^{+5}_{-20}	84^{+20}_{-57}	86^{+26}_{-42}
VFTS764	28100^{+550}_{-200}	$2.87^{+0.09}_{-0.04}$	$-5.4^{+0.1}_{-0.1}$	20^{+4}_{-3}	62^{+52}_{-16}	69^{+9}_{-61}

ID	$\log L/L_\odot$	$R/R_\odot$	v_∞ (km s^{-1})	$M_{\rm spec}{}^a$ ($M_\odot$)	$\log D_{\rm mom}{}^b$ (g cm s^{-2} $R_\odot^{1/2}$)
VFTS087	$5.26^{+0.05}_{-0.04}$	$16.34^{+0.27}_{-0.35}$	1308^{+221}_{-31}	$10.4^{+3.7}_{-0.5}$	$28.27^{+0.2}_{-0.3}$
VFTS178	$5.59^{+0.02}_{-0.01}$	$26.85^{+0.14}_{-0.19}$	1547^{+95}_{-101}	$24.1^{+3.2}_{-3.0}$	$28.85^{+0.05}_{-0.16}$
VFTS180	$5.82^{+0.0}_{-0.0}$	$17.42^{+0.01}_{-0.02}$	2091^{+99}_{-72}	$29.1^{+2.7}_{-2.3}$	$29.69^{+0.06}_{-0.05}$
VFTS764	$5.79^{+0.02}_{-0.01}$	$33.74^{+0.14}_{-0.37}$	1563^{+162}_{-70}	$31.6^{+6.3}_{-3.3}$	$29.36^{+0.11}_{-0.12}$

ID	$N_{\rm He}/N_{\rm H}$	$\epsilon_{\rm N}$	$\epsilon_{\rm C}$	$\epsilon_{\rm O}$	$\epsilon_{\rm Si}$
VFTS087	$0.09^{+0.03}_{-0.03}$	$7.95^{+0.3}_{-0.4}$	$7.4^{+0.25}_{-0.65}$	$8.0^{+0.2}_{-0.25}$	$6.85^{+0.65}_{-0.2}$
VFTS178	$0.07^{+0.02}_{-0.01}$	$8.0^{+0.2}_{-0.2}$	$6.1^{+1.0}_{-0.1}$	$7.9^{+0.1}_{-0.35}$	$6.85^{+0.3}_{-0.25}$
VFTS180	$0.24^{+0.14}_{-0.01}$	$8.45^{+0.1}_{-0.1}$	$6.45^{+0.45}_{-0.45}$	$8.45^{+0.35}_{-1.8}$	$7.55^{+0.75}_{-1.55}$
VFTS764	$0.09^{+0.03}_{-0.01}$	$8.25^{+0.2}_{-0.15}$	$6.45^{+0.75}_{-0.45}$	$7.6^{+0.25}_{-0.3}$	$7.2^{+0.45}_{-0.25}$

Baseline: 0.09 6.90 7.75 8.35 7.20