Massive Stars Near and Far
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Slowly-rotating nitrogen-rich O stars in 30 Doradus

F. Tramper

Institute of Astronomy, KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium
email: frank.tramper@kuleuven.be

Abstract. The VLT/FLAMES Tarantula Survey (Evans et al. 2011) identified a group of slowly-rotating nitrogen-rich O-type stars that cannot be explained by current evolutionary models. Here we present high-quality VLT/UVES observations of four of these stars that allow a detailed quantitative spectroscopic analysis. We present the analysis of the spectra with a genetic algorithm, and discuss the future steps to be taken to further investigate the cause of the nitrogen enrichment.

Keywords. stars: abundances, stars: atmospheres, stars: chemically peculiar, stars: early-type, stars: evolution, stars: fundamental parameters

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1. 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 decreasing 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 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) in the VLT-Flames Tarantula Survey (Evans et al. 2011).

2. Analysis

To investigate the nature of the slowly-rotating nitrogen-rich stars in 30 Doradus we obtained high-quality (R $\sim$ 40000, S/N $>$ 100) spectra of four representative stars using VLT/UVES. These spectra allow the accurate derivation of 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, Fig. 1). This method allows us to

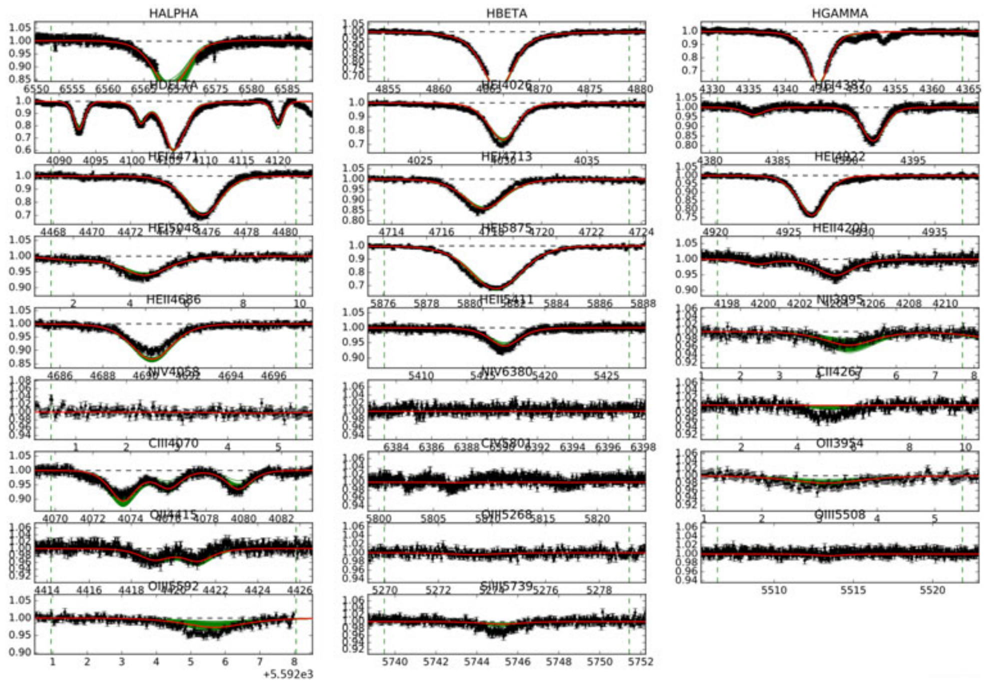

Figure 1. Example of a GA fit to the spectrum of VFTS178.

thoroughly explore the 11-dimensional parameter space (see below) in a reasonable amount of CPU time. Additionaly, the method provides robust error bars on the derived parameters.

The key stellar parameters that are derived from the GA fits are the effective temperature ($T_{\rm eff}$), surface gravity, mass-loss rate, microturbulent velocity, projected rotational velocity, and surface helium abundance. Luminosity and radius are derived based on the absolute magnitude and $T_{\rm eff}$ (see Mokiem et al. 2005). Compared to earlier versions of the GA (Mokiem et al. 2005, Tramper et al. 2011, 2014), we also implemented macroturbulence and surface abundances of C, N, O, and Si as fitting parameters.

3. Future steps

The results of this work will be used to investigate the origin of the anomalous nitrogen abundances. Using the derived carbon and oxygen abundances, 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).

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Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1743921322002307.

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References

Brott, I., de Mink, S. E., Cantiello, M., et al. 2011, *A&A*, 530, A115
Evans, C. J., Lennon, D. J., Smartt, S. J., et al. 2006, *A&A*, 456, 623
Evans, C. J., Taylor, W. D., Hénault-Brunet, V., et al. 2011, *A&A*, 530, A108
Grin, N. J., Ramírez-Agudelo, O. H., de Koter, A., et al. 2017, *A&A*, 600, A82
Hunter, I., Brott, I., Lennon, D. J., et al. 2008, *ApJ* (Letters), 676, L29
Mokiem, M. R., de Koter, A., Puls, J., et al. 2005, *A&A*, 441, 711
Puls, J., Urbaneja, M. A., Venero, R., et al. 2005, *A&A*, 435, 669
Tramper, F., Sana, H., de Koter, A., et al. 2011, *ApJ* (Letters), 741, L8
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