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Chemical abundances of fast-rotating OB stars

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Abstract. Fast rotation in massive stars is predicted to induce mixing in their interior, but a population of fast-rotating stars with normal nitrogen abundances at their surface has recently been revealed (Hunter *et al.* 2009; Brott *et al.* 2011, but see Maeder *et al.* 2014). However, as the binary fraction of these stars is unknown, no definitive statements about the ability of single-star evolutionary models including rotation to reproduce these observations can be made. Our work combines for the first time a detailed surface abundance analysis with a radial-velocity monitoring for a sample of bright, fast-rotating Galactic OB stars to put strong constraints on stellar evolutionary and interior models.

Keywords. stars: abundances, stars: fundamental parameters, stars: rotation.

1. Introduction

By determining the abundances of the key elements expected to be affected by mixing (i.e., He, C, N, O) for a large sample of fast-rotating ($v \sin i > 200\,\mathrm{km\,s^{-1}}$), bright O 8-B 0 dwarfs in our Galaxy, our project aims at addressing the efficiency of rotational mixing in these objects. Several facilities are used: mainly el TIGRE (HEROS), complemented with archival data from the 1.93 m telescope at the Observatoire de Haute-Provence (SOPHIE, ELODIE), various ESO telescopes (FEROS, UVES), NOT, and AAT. In addition, XMM-*Newton* data will also be used to validate the results obtained in the optical and to give access to elements such as Ne, Si, Mg, and Fe that are not easily measured in the optical.

2. Parameters and CNO abundance determination

Prior to any determination of the atmospheric parameters, radial velocities and projected rotational velocities, $v \sin i$, are estimated. The effective temperature T_{eff}, surface gravity $\log g$, and helium abundance by number $y = N(\mathrm{He})/[N(\mathrm{H}) + N(\mathrm{He})]$, are derived by finding the best match between a set of observed H and He line profiles, and a grid of rotationally-broadened, synthetic profiles. These have been computed using the non-LTE line-formation code DETAIL/SURFACE and Kurucz models. A microturbulence of $10\,\mathrm{km\,s^{-1}}$ was adopted. An iterative scheme is used: the effective temperature is taken as the value providing the best fit to the He I and He II lines with the same weight given to these two ions, the surface gravity is determined by fitting the wings of the Balmer lines, and the helium abundance is determined by fitting the He I features.

After determining the effective temperature and the surface gravity, CNO abundances are estimated by fitting synthetic profiles to three spectral domains in which the contribution of other elements can be neglected (see Rauw *et al.* 2012).

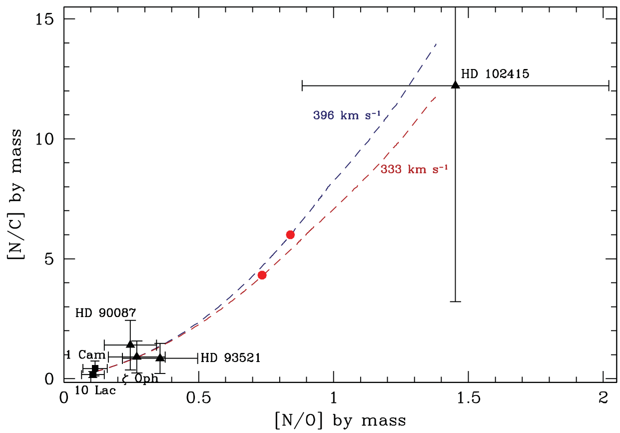

Figure 1. Dependence between the [N/C] and [N/O] abundance ratios (by mass). Except for 10 Lac, solid black symbols denote fast-rotating stars. Solid triangles and squares: archival and el TIGRE data, respectively. Dashed lines show the predictions of Geneva models (Georgy *et al.* 2013) for $15\,M_{\odot}$, $Z = 0.014$, and two initial rotational velocities. Solid circles indicate the beginning of the red supergiant phase.

3. Results

A slowly-rotating star, 10 Lac (O9 V), was analysed to validate the procedure used to derive the atmospheric parameters and abundances. This star has its parameters and abundances derived from standard, curve-of-growth techniques (see Rauw *et al.* 2012, for another validation test involving two other stars).

As seen in Fig. 1, the N enrichment and C depletion detected in some stars are consistent with the appearance of CNO-cycled material at their surface. The photosphere of HD 102415 appears to be nitrogen overabundant at a level expected for a red supergiant. A single star analysis is thus inappropriate to describe this main-sequence star, raising the possibility of a mass transfer in a binary (see, e.g., Ritchie *et al.* 2012).

4. Future work

New el TIGRE data are being acquired (up to 34 time-resolved spectra per star) in order to enlarge the sample of studied stars. Results will be compared to the predictions of models to investigate the relevance of the conclusions presented by Hunter *et al.* (2009). We will also account for the non-spherical shape due to fast rotation and the resulting gravity darkening. Moreover, a radial-velocity monitoring will be performed.

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