Quantitative Spectroscopy of BA-type Supergiants

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Luminous BA-type supergiants have enormous potential for modern astrophysics. They allow topics ranging from non-LTE physics and the evolution of massive stars to the chemical evolution of galaxies and cosmology to be addressed. A hybrid non-LTE technique for the quantitative spectroscopy of these stars is discussed. Thorough tests and first applications of the spectrum synthesis method are presented for the bright Galactic objects eta Leo (A0 Ib), HD111613 (A2 Iabe), HD92207 (A0 Iae) and beta Ori (B8 Iae), based on high-resolution and high-S/N Echelle spectra. Stellar parameters are derived from spectroscopic indicators, consistently from multiple non-LTE ionization equilibria and Stark-broadened hydrogen line profiles, and they are verified by spectrophotometry. The internal accuracy of the method allows the 1sigma-uncertainties to be reduced to <=1-2% in Teff and to 0.05-0.10dex in log g. Elemental abundances are determined for over 20 chemical species, with many of the astrophysically most interesting in non-LTE (H, He, C, N, O, Mg, S, Ti, Fe). The non-LTE computations reduce random errors and remove systematic trends in the analysis. Inappropriate LTE analyses tend to systematically underestimate iron group abundances and overestimate the light and alpha-process element abundances by up to factors of two to three on the mean. This is because of the different responses of these species to radiative and collisional processes in the microscopic picture, which
is explained by fundamental differences of their detailed atomic structure, and not taken into account in LTE. Contrary to common assumptions, significant non-LTE abundance corrections of ~0.3dex can be found even for the weakest lines (Wlambda<10mA). Non-LTE abundance uncertainties amount to typically 0.05-0.10dex (random) and ~0.10dex (systematic 1sigma-errors). Near-solar abundances are derived for the heavier elements in the sample stars, and patterns indicative of mixing with nuclear-processed matter for the light elements. These imply a blue-loop scenario for eta Leo because of first dredge-up abundance ratios, while the other three objects appear to have evolved directly from the main sequence. In the most ambitious computations several ten-thousand spectral lines are accounted for in the spectrum synthesis, permitting the accurate reproduction of the entire observed spectra from the visual to near-IR. This prerequisite for the quantitative interpretation of
intermediate-resolution spectra opens up BA-type supergiants as versatile tools for extragalactic stellar~astronomy beyond the Local Group. The technique presented here is also well suited to improve quantitative analyses of less extreme stars of similar spectral types.

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