RevMexAA (Serie de Conferencias), **33**, 35–37 (2008)

ACCURATE QUANTITATIVE SPECTROSCOPY OF OB STARS: C AND N ABUNDANCES NEAR THE MAIN SEQUENCE

M. F. Nieva[1,2] and N. Przybilla[1]

RESUMEN

Presentamos una avanzada técnica de análisis capaz de reproducir el espectro completo de H y He en estrellas de tipo OB en el visible y el IR cercano y de derivar simultáneamente abundancias metálicas de alta precisión (hasta el momento C y N). La síntesis espectral cuenta con una solución no-ETL híbrida usando nuestros modelos atómicos más recientes. Derivamos espectroscópicamente (a partir de líneas de H ensanchadas por efecto Stark y equilibrios de ionización de He I/II y C II-IV) parámetros atmosféricos exactos, prácticamente libres de errores sistemáticos, para una muestra de estrellas distribuidas al azar en la vecindad solar. Encontramos abundancias altamente consistentes, en contraste con previos resultados indicando amplia dispersión y grandes incertezas. Las mejoras resultan de evitar errores sistemáticos en la determinación de parámetros, que pueden ser mayores que los esperados en trabajos anteriores, y en una evaluación crítica de los datos atómicos para la construcción de los modelos atómicos.

ABSTRACT

We present a state-of-the-art analysis technique able to simultaneously reproduce the entire H and He spectra of OB-type stars in the visual and the near-IR and to derive highly accurate metal abundances (so far C and N). The spectrum synthesis relies on a hybrid non-LTE approach involving our most recent model atoms. Accurate atmospheric parameters, practically free of systematic errors, are derived spectroscopically (from Stark-broadened H lines and ionization equilibria of He I/II and C II-IV) for a sample of randomly distributed stars in the solar vicinity. Highly consistent abundances are found in contrast to previous reports indicating broad scatter and large uncertainties. The improvements result from avoidance of systematic errors in the parameter determination, which may be larger than expected in previous work, and a critical evaluation of atomic data for the model atom construction.

Key Words: line: formation — stars: abundances — stars: early-type

1. INTRODUCTION

Detailed chemical composition studies of early-type stars contribute to the understanding of broad fields like galactochemical and stellar evolution, providing observational constraints to theory. Therefore, the goal should be to derive chemical abundances as accurately as possible in order to provide tight constraints. The results rely on many model assumptions, since the quantitative analysis of observed spectra requires the solution of the atmospheric structure equations and the radiative transfer. In particular, the interaction of radiation and stellar plasma with a realistic description of the atomic processes involved has to be accounted for.

In a series of papers (Nieva & Przybilla 2006a,b, 2007a,b) we provide details of our state-of-the-art quantitative spectral analysis of H, He I/II and C II-IV for OB-type stars. Here, we report, in addition, preliminary results for N based on the parameters derived in the previous analysis and an improved version of the model atom by Przybilla & Butler (2001). We derive highly homogeneous abundances for C and slightly inhomogeneous N abundances, quantitatively consistent with predictions of stellar and galactochemical evolution models.

2. ANALYSIS & RESULTS

A hybrid approach is used for the non-LTE line formation computations. These are based on line-blanketed plane-parallel, homogeneous and hydrostatic LTE model atmospheres calculated with ATLAS9. Non-LTE synthetic spectra are computed with recent versions of DETAIL and SURFACE. These codes solve the coupled radiative transfer and statistical equilibrium equations and compute synthetic spectra using refined line-broadening data.

[1]Dr. Remeis Sternwarte Bamberg, Sternwartstr. 7, D-96049 Bamberg, Germany (nieva@sternwarte.uni-erlangen.de).

[2]Observatório Nacional, Rua General José Cristino 77 CEP 20921-400, Rio de Janeiro, Brazil.

A first sample of six apparently slow-rotating early-type dwarfs and giants from OB associations and from the field in the solar vicinity is analysed.

The stellar parameters are derived from application of an extensive iterative method resulting in simultaneous fits to almost all measurable H, He I/II and C II-IV lines. The iteration is performed on effective temperature and surface gravity (in order to achieve ionization balance) as well as the micro-, macroturbulent and projected rotational velocities (from carbon line profiles) and He and C abundances. The final set of stellar parameters is confirmed by the spectral energy distribution fits from the UV to the near-IR. This state-of-the-art analysis technique based on new model atoms with critically selected atomic data and observed spectra of excellent quality allows us to derive highly accurate stellar parameters and chemical abundances with extremely reduced systematic errors. A large quantity of spectral lines is analysed for the first time, giving simultaneously consistent parameters and abundances for all of them (H: $\sim$10 lines, He: $\sim$20, C: $\sim$30, N: $\sim$70).

Figure 1 shows a comparison of our first results for present-day C and N abundances of early B-type stars in the solar vicinity with results from representative sources in the literature and with recent solar values. The stars are located at distances shorter than 1 kpc from the Sun and at galactocentric distances within up to 500 pc difference with respect to the location of the Sun (see Nieva & Przybilla 2007b for details). Despite the small sample size, the programme stars provide homogeneous C abundances. Kilian (1992) performed the most consistent spectroscopic analysis at that time, but her abundances for our sample stars are systematically lower than ours and the spread is larger. For C we derive present-day abundances that are almost solar (Asplund et al. 2005) or slightly sub-solar (Grevesse & Sauval 1998). The derived N abundances show a slightly inhomogeneous distribution because of rotational mixing effects in the course of stellar evolution. This implies that the pristine C abundances (i.e. unaltered by stellar evolution) are slightly larger than indicated, and the N abundances lower. Using the constraint of number conservation in the CN cycle we can conclude that the pristine C and N abundances of these young stars are in excellent agreement with the solar values of Asplund et al. (a chemical peculiarity of one object cannot be excluded at present). The finding of a narrow distribution of C abundances remains basically unaffected by stellar evolution effects and it also agrees with predictions of galactochemical evolution (e.g. Chiappini et al. 2003).

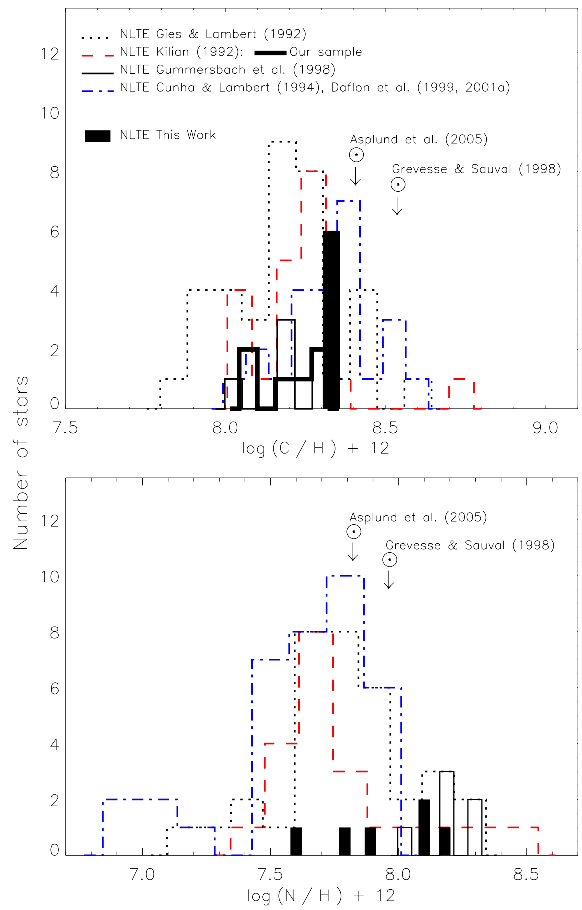

Fig. 1. C and N abundances of OB dwarfs and giants in the solar vicinity ($R_g - R_g^{\odot} \leq 500$ pc).

We conclude that the reduction of systematic effects in the whole quantitative spectral analysis leads to highly consistent values of chemical abundances. A larger sample has to be analysed in order to improve on the statistics.

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DISCUSSION

A. Herrero - You find now that the O abundance of B dwarfs/giants is higher than the Asplund et al. one. This would mean that significant O contamination took place in the last Gyr in the solar nighbourhood or that we have to revise the Asplund et al. value.

M. Nieva - The oxygen abundances from early-B dwarfs and giants in the solar vicinity as derived in our detailed analysis are in agreement with the Grevesse & Sauval (1998) abundance for the Sun. A further support to these results come from the analysis of BA supergiants which have evolved from OB dwarfs. The solar abundances are still under debate and we cannot contribute directly to the discussion. Concerning your results for similar stars, I suggest to cross-check our analyses in order to find sources of possible systematic effects.

Break in drinking and chatting for some important news.