A High S/N Spectroscopic Study of Alpha Centauri A

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ABSTRACT. A fine analysis of Alpha Cen A relative to the Sun has been carried out. Over 500 absorption lines have been used in deriving a consistent solution involving abundances, Teff, log g, microturbulence and blanketing. Light elements, up to zinc, are overabundant by around 0.15 dex, while heavy elements have solar abundances.

1. INTRODUCTION

Alpha Centauri A is apparently bright and very similar to the Sun. These properties make it a rewarding object for a differential analysis with the Sun as the comparison star. The term "high S/N" in the title stems on a primary level from the basic observational data, but "high S/N" implies more than precise spectroscopic data in a full analysis of a stellar spectrum. In this work we have spent considerable efforts to carry reductions, measurements and analysis to a level where these different operations are commensurate with each other in "S/N".

2. DATA

The work reported here was carried out essentially as two separate, but coupled, model atmosphere projects with one part devoted to the Sun and one to Alpha Cen A.

The solar spectrum data were provided by the "Solar Flux Atlas from 296 to 1300 nm" (Kurucz et al., 1984). The resolution of the atlas spectrum was degraded by a Gaussian to a value of 80 000 to match the stellar data; the resulting effective S/N is around 10 000. The equivalent widths of over 500 well-behaved lines of 26 elements were measured, where well-behaved lines are defined as those which have at least one half of the profile free of visible or otherwise known blends.

All measured solar lines of iron, 197 lines of neutral iron and 19 lines of singly ionized iron, were used as input parameters for the Sun in the usual model atmosphere iteration scheme. The stellar models used in iterating until a consistent solution was found were taken from the grid by Kurucz (1979). The iteration process was terminated when no dependence could be discerned of the iron abundance on excitation

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potential, line strength, height of line formation or level of ionization. The converged values of Teff, log g and microturbulence (5800, 4.4, 1.0) were adopted for the Sun. The abundance of iron, as well as of all other elements, were then set equal to the standard set of solar abundances listed in the grid of models and "solar gf-values" determined for all lines measured using the adopted physical parameters.

The spectra of Alpha Cen A were obtained at the CAT of the ESO facility in Chile, using a Reticon as a detector. Around 100 frames cover most of the visible spectrum with integration times chosen to give S/N values in the reduced data of 500 - 600. Reductions were carried out in standard fashion, the resolution degraded to 80 000, dispersion solutions determined for each frame and continuum normalized values plotted for every 0.02 A. The solar spectrum was treated in exactly the same way so that the two spectra at this stage could be superimposed point by point. Great care was taken in placing the stellar continuum, and the solar flux atlas was consulted throughout this operation to ensure that the continuum was consistent between two stars.

3. ANALYSIS

The analysis of Alpha Cen A can be traced back to a "first look" at the spectrum, consisting of measured equivalent widths for around 25 iron lines. A preliminary abundance determination based on these lines only, led to an overabundance of iron in Alpha Cen A of around 65 % (Furenlid and Meylan, 1984). This limited set of data converged on physical parameters(except for the iron abundance) essentially equal for the Sun and Alpha Cen A. This result led to the use of metal-enhanced models with a metal abundance relative to the Sun of 0.2 dex in the first pass of the full analysis of Alpha Cen A.

Using the measured equivalent widths for Alpha Cen A and the solar gf-values it was found that the first pass of iterations with metal-enhanced models gave an overabundance of all the important electron donor elements of around 0.1 dex. A second pass of iterations was therefore made with models metal enhanced by 0.1 dex, which then resulted in stellar metal abundances up by around 0.15 dex. The iterations done by metal-enhanced models used sub-grids kindly computed for us by Dr. R. Kurucz. The final result is that using models with an overabundance of metals relative to the Sun of 0.1 dex a consistent solution for Alpha Cen A was found for a Teff of 5710°K, a log g of 4.0, a microturbulence of 1.0 km/sec and an average overabundance of light elements of 0.15 dex (formally 0.13 dex). The internal error in the abundance determination can be estimated by a comparison of abundances from neutral and singly ionized species of the same elements as shown in fig. 1; element, ionization stage and number of measured lines are marked over each point. The maximum difference is 0.03 dex, adopted as an error estimate. Significant abundance variations between different light elements were obtained. The average overabundance of the three major atmospheric electron donors (Mg, Si and Fe) is around 0.15 dex, the importance of these elements of course being their effect on the continuous (H-) opacity. The average overabundance of 0.15 dex reaches only to Z = 30 (zinc), whereas elements with Z larger than 30 have the same abundance as in the Sun as can be seen in fig. 2. We conclude that heavy elements occur in Alpha Cen A with nearly solar abundances but that elements up to and including the iron group are definitely overabundant by around 0.15 dex.

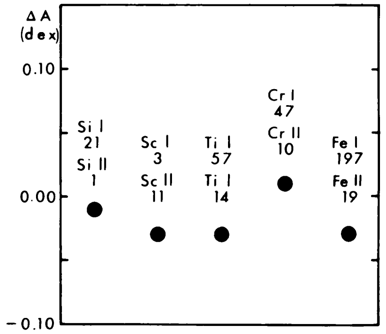

Fig. 1. The abundance difference, ΔA, between ionized and neutral species of five elements. Element, ionization stage and number of lines used in the abundance determination are marked over each plotted point.

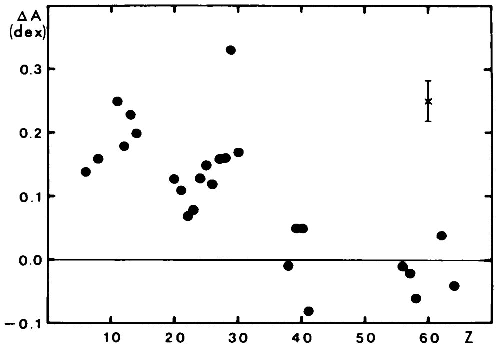

Fig. 2. The abundance difference, ΔA, between Sun and Alpha Cen A plotted versus atomic number, z. The estimated internal error in an abundance value is marked in the upper right part of the figure.

4. DISCUSSION

The first striking result of this analysis is the strong dependence of the derived physical parameters on the metal abundance of the models. It always seems possible to find a combination of physical parameters that yields a consistent solution within acceptable margins. Using a grid of solar abundance models for Alpha Cen A underestimates blanketing and continuous opacity in the star but leads nevertheless to a consistent set of parameters; Teff will be nearly solar, thereby compensating in a broad way for the smaller continuous opacity in the model. Making the overall metal abundances part of the iteration scheme by including them in the models, allows blanketing and opacity to be correctly evaluated and has a notable effect on the final parameters, particularly the effective temperature, which is now substantially lower (90°K) than the Sun's; the overabundance is also significantly reduced.

The second striking result is the remarkable dichotomy in the abundance pattern; light elements up to zinc are overabundant, those heavier than zinc have close to solar abundances. The overabundance of lighter elements, which are the abundant and therefore important ones, is interesting in the context of a recent discussion of interior models

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of Alpha Cen A and B by Demarque et al. (1986). In order to find an equal age for both components of the Alpha Cen system it is necessary to assume on overabundance relative to the Sun of around 0.15 dex for both stars, leading us to the prediction that Alpha Cen B is also overabundant by around 0.15 dex.

5. REFERENCES

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DISCUSSION

COTTRELL Could I make a request that we adopt a uniform method for describing the enhancement or depletion of the elements rather than percentage, factors relative to the Sun or logarithmic scale factors (dex).

FURENLID Good point ; the dex-scale makes most sense and will be used in the written version.

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