THE CHEMICAL EVOLUTION OF THE GALACTIC DISC, INVESTIGATED BY ABUNDANCE ANALYSIS OF F STARS: A PROGRESS REPORT*

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ABSTRACT. An extensive project for the investigation of abundances, especially of light elements, in F-type stars is described and some preliminary results are given.

1. PURPOSE OF THE PROJECT

Several models of the chemical evolution of the Galaxy exist at present, but only limited and often specialized observational tests have been performed.

We have undertaken to make a large statistically significant investigation of chemical abundances, especially of the lighter elements, for stars of different ages and different over-all metal abundances ([M/H]). For this purpose we have selected some 200 bright F stars, close to the main sequence, distributed over the whole sky. The stars were selected from uvby photometry, giving estimates of Teff, log g, [M/H] and age for each star. The stars were divided into nine groups according to [M/H] and a significant number of low-metal abundance stars was included in the investigation.

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* Based on observations carried out at the European Southern Observatory, La Silla, Chile.

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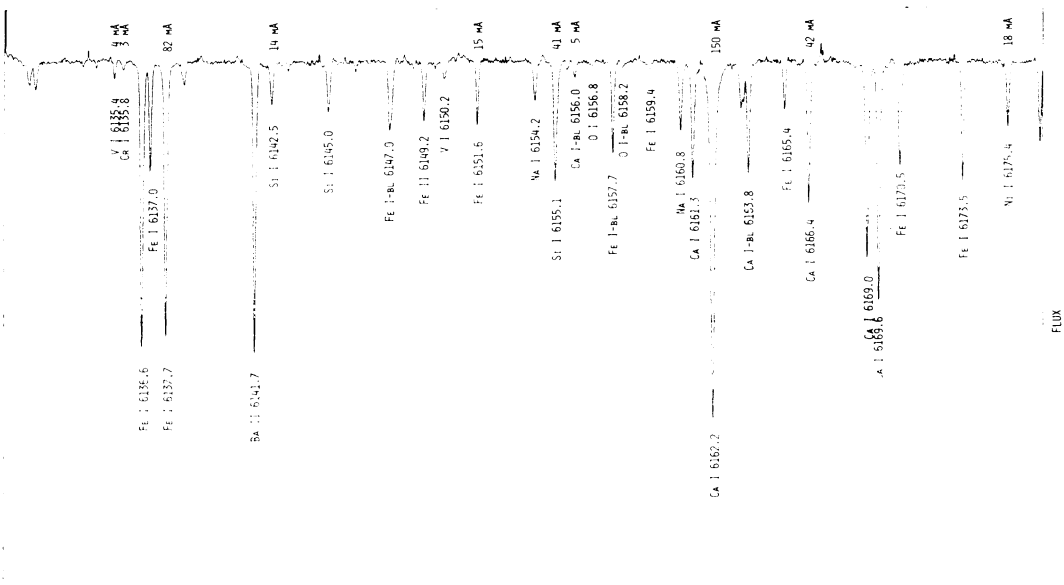

Fig. 1. This is a typical example of a spectrum used in the analysis. It is a 45 minute exposure of the star BS 3018, V=5.4, in the region 6130 - 6177 Å. The resolving power is 100,000. A signal of $350 \cdot 10^3$ photons is typical for one of the about 1830 channels shown.

2. OBSERVATIONS AND REDUCTIONS

The stars in the southern sky are observed at ESO with the 1.4-m Coudé Auxillary Telescope and the Coudé Echelle Spectrograph using a 1870 diode Reticon array as the detector. The resolving power is about 80,000 and a signal-to-noise ratio of about 100 for each spectral resolution element is typical.

In all five different wavelength regions are observed, each about 50 Å wide, containing weak spectral lines from O, Na, Mg, Al, Si, Ca, Ti, V, Cr, Fe, Co, Ni, Y and Ba.

The reductions of the spectra have been carried out with the ESO IHAP system, and the equivalent widths were measured with the very convenient PHYS program written in Uppsala. The equivalent widths measured refer to a continuum defined by a number of narrow spectral regions selected to be free of lines in the solar and the Procyon spectra.

A typical spectrum, of BS 3018, V=5.4, is shown in Fig. 1. This star has been observed independently on two different occasions with different Reticon arrays, and the two spectra have been reduced and measured independently by the two observers. The resulting sets of equivalent widths,ranging from 3 to 87 mÅ, are compared in Fig. 2. The mean difference in the widths obtained is 0.4 mÅ, with a standard deviation of 3.3 mÅ for a line. We conclude that it seems possible to obtain very accurate equivalent widths with the present instrumentation.

The full project is carried out in collaboration with D. Lambert and J. Tomkin, who perform the corresponding observations of the stars in the northern sky at the McDonald Observatory

3. ANALYSIS

The stars are compared with blanketed and convective model atmospheres, calculated with an updated version of the program presented in Gustafsson, et al. (1975; cf. also Nissen and Gustafsson 1978). The abundance analysis is differential relative to the Sun (the reflected light of which was also observed with the same instrumentation).

The analysis is based on the assumption of LTE; however, the effects of departures from LTE on the abundances derived are being studied theoretically (cf. Saxner 1984) and observationally. Another important source of uncertainty is the mixing-length theory adopted for convection. More detailed simulations, such as those made for the solar convection by Nordlund (cf. Dravins et al. 1981), will be attempted.

The temperature scale is also uncertain as a result of the uncertainty of the solar colors and the possibility of errors due to incomplete spectral line blocking in the calculated b band or due to the convection theory (cf. Gehren 1981). Although a recent study of the effective temperature scale of F stars using the integrated-flux method of Blackwell and Shallis (1977) by Saxner (1984) indicates that our scale should not be seriously in error, this source of error in the abundances must be studied further.

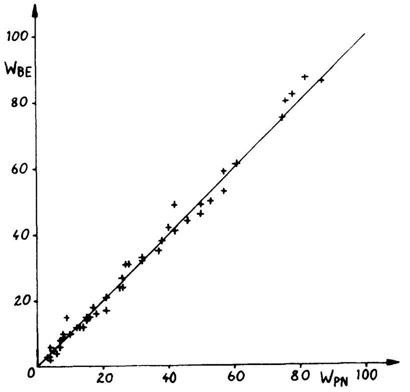

Fig. 2. Comparison of equivalent widths (in mÅ) obtained from different spectra, taken by different observers with different Reticon arrays and separately reduced and measured by the two observers. The mean difference is 0.4 mÅ with a standard deviation of 3.3 mÅ for a line. One of the four spectra used is that of Fig. 1.

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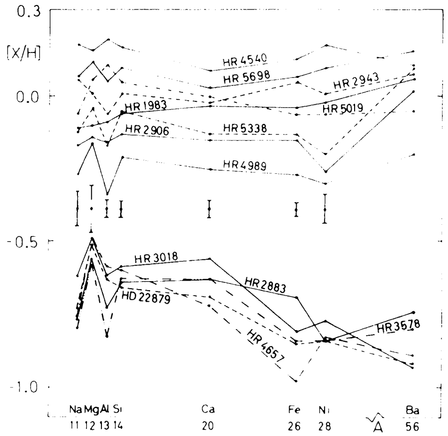

Fig. 3. Logarithmic abundances relative to the Sun, $[X/H]=\lg(N_X/N_H)_* - \lg(N_X/N_H)_\odot$, for the 13 stars analysed so far. Only 30 of the about 100 lines were used in this preliminary test. We will also determine abundances of O, Ti, V, Cr, Co and Y. Typical errors (standard deviation of the mean) are also shown in the plot.

4. RESULTS AND CONCLUSIONS

In Fig. 3 logarithmic abundances relative to the Sun, $[X/H] = \lg(N_X/N_H)_* - \lg(N_X/N_H)_\odot$, are plotted for various elements. Only a minority of the spectral lines were used in this preliminary analysis, and we shall also later derive abundances of O, Ti, V, Cr, Co and Y.

From Fig. 3 it is seen that the underabundances are less pronounced for the lighter elements than for the iron-peak elements. If this tendancy prevails when more stars have been analysed this will support the idea that the lighter elements relative to the heavier ones were more abundantly produced in stars when the galactic disc was less metal-rich. Also note the tendency for an odd-even effect, varying with overall metal abundance, for Na, Mg, Al and Si.

Further results of this study will be published in Astronomy and Astrophysics.

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DISCUSSION

HEINTZE: Please tell us how you disentangle abundance and NLTE effects.

GUSTAFSSON: This is not easy or even possible observationally if only lines from neutral atoms are measured, and "over-ionization", due to hot UV radiation from deeper atmospheric layers, is of importance. If so, as indicated by the study of Saxner (1984) for Fe in metal-poor F dwarfs, one has to use Fe II lines or try to calibrate the Fe I lines by detailed statistical-equilibrium calculations. These are, however, quite uncertain due to uncertain UV fluxes, collision cross-sections and necessarily primitive model atoms.