THE CHEMICAL COMPOSITION OF GIANTS IN THE GLOBULAR CLUSTER ω CEN

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ABSTRACT: High-resolution, high S/N spectra have been obtained for 22 giant stars in the globular cluster ω Cen. These stars span a wide range of temperature and position on the giant branch and include some of the S-type and Barium star members. Spectra were obtained on the CTIO 4m telescope with the echelle spectrograph and CCD detector. Initial abundance results for Iron, Calcium, and Oxygen are presented for three stars: one of the most luminous cluster red-giants, a giant on the blue edge of the ω Cen giant branch, and an extreme Barium star member.

I. INTRODUCTION

The globular cluster ω Centauri is unique among globular clusters in showing a large spread in (B-V) color at fixed V along the giant branch. Studies using a variety of techniques show that this spread in color reflects a spread in the metal abundances: (1) low-resolution spectroscopy of RR Lyraes by Freeman and Rodgers (1975), (2) spectrophotometry and IR photometry of red giants by Rodgers *et al.* (1979) and Persson *et al.* (1980), and (3) synthesis of low-resolution spectra by Dickens and Bell (1976). This abundance spread raises obvious questions; are the abundance variations primordial or perhaps quasi-primordial (i.e., created early in the life of the cluster), or are the variations the result of internal nucleosynthesis within the current cluster members? To answer these questions, one must obtain abundances of many elements, such as a sample of light elements (O, Mg, Al, Si), Fe-peak elements and some of the heavier elements: Y, Zr, Ba and Eu, for example. The Dickens and Bell (1976) study used low-resolution spectrum synthesis of some 30 stars and noted large variations in the abundances of Nitrogen and s-process elements.

Thorough element-by-element analyses provide more detailed information, but have been restricted by the difficulties in obtaining high-resolution spectra of the faint cluster stars. True, high-resolution studies of selected stars in ω Cen have been carried out by Mallia and Pagel (1981) using 0.5 Å resolution spectra from the AAT RGO-Cassegrain spectrograph, and Cohen (1981) using 0.3 Å resolution from the CTIO 4m echelle spectrograph with image-tube photographic plates. Both Mallia and Pagel (1981) and Cohen (1981) found variations in [Fe/H] (-1.2 to -1.9 and -1.5 to -1.9, respectively). In addition, Gratton (1982) observed a sample of ω Cen giants with the CTIO 4m and image-

G. Cayrel de Strobel and M. Spite (eds.), The Impact of Very High S/N Spectroscopy on Stellar Physics, 541–544.

tube plus echelle combination and obtained [Fe/H]'s ranging from -1.8 to -1.2. In all studies, variations comparable to that seen in Iron are observed for elements spanning the range from Carbon to Neodymium. Variations in [Fe/H] suggest primordial variations as the low-mass stars currently evolving into giants (turnoff mass ~ 0.8 $M_{\odot}$) would not be expected to alter internally their Iron-abundances. On the other hand, low-mass stars can produce changes in their C and N abundances as well as s-process elements. The chemical evolution of ω Cen is interesting from the points of view of both stellar evolution and nucleosynthesis. In addition, as the largest globular cluster, ω Cen, may share some traits in common with some dwarf spheroidal galaxies, such as Sculptor and Ursa Minor, which also show the wide (B-V) giant-branches (Norris and Bessell, 1978).

With the advent of high quantum-efficiency CCD detectors, new studies of ω Cen via high-resolution spectroscopy are timely, as evidenced by the similar probing of ω Cen by Francois, Spite, and Spite (1987, this volume) using the ESO 3.6m telescope and CASPEC spectrograph.

2. OBSERVATIONS AND ANALYSIS

Spectra were obtained with the CTIO 4m echelle spectrograph with the air-Schmidt camera and GEC CCD detector. This particular combination yielded a resolution of about 0.34 Å (two pixels) and complete wavelength coverage from about 6200 - 7600 Å. A total of 22 stars in ω Cen were observed over four nights in May of 1986. In Figure 1 we show a color-magnitude diagram of the stars observed, with the star designations as well as V-magnitudes and (B-V) colors from Woolley (1966).

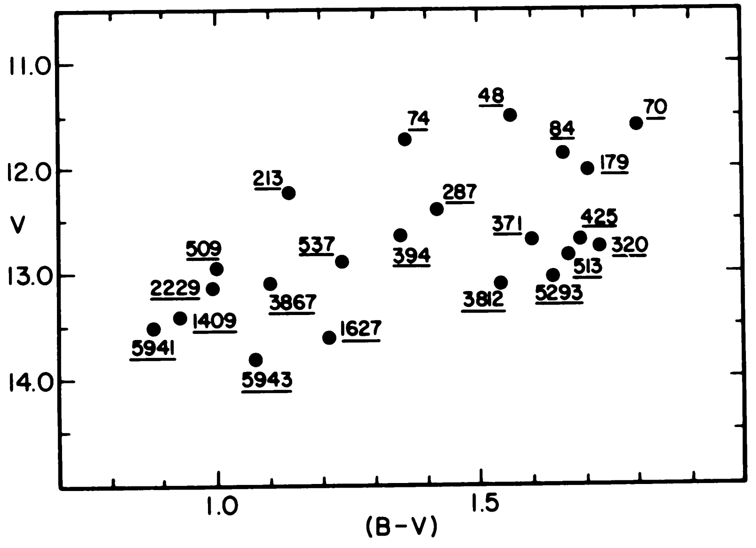

Fig. 1. The color-magnitude diagram of the stars observed in ω Cen.

The individual echelle orders were extracted and reduced using the NOAO reduction package IRAF. Final S/N of the spectra range typically from 50 to 100, depending upon V-magnitude and particular echelle order.

Analysis of the spectra utilize the grid of metal-poor model atmospheres from Bell *et al.* (1976-BEGN) and the bright red giants α Ser and γ Dra as standard stars. All abundance determinations are carried out differentially with respect to the standard stars. Our abundance analysis is just beginning, and we present some preliminary results for a few stars.

3. SOME INITIAL RESULTS

In Table 1 we present results for three ω Cen giants: ROA48, 213, and 371. ROA48 is one of the cluster's luminous red giants ($M_V \approx -2.4$), while ROA213 is a less-luminous giant near the blue edge of the wide giant branch, and ROA371 represents an example of an extreme barium star. Effective temperatures are derived from the IR-photometry of Persson *et al.* (1980), surface gravities are determined from stellar luminosities and an assumed mass of 0.8 $M_\odot$, and the microturbulent velocities are derived from demanding equal abundances from both weak and strong Fe-I lines. As our abundance analyses are just being started and our final line-selection is far from complete, we present results only for Fe, Ca, and O. An extensive analysis will follow.

Table 1

Stellar Parameters and Abundances

Star	T_{eff}(K)	Log g	ξ (km s^{-1})	[Fe/H]	[Ca/H]	[O/H]
ROA48	4050	0.5	3.5	-1.9	-1.6	-1.3
ROA213	4500	1.0	2.0	-2.0	-1.5	-1.5
ROA371	4000	1.0	2.5	-1.6	-1.4	-1.4

The internal dispersions of the derived abundances from the set of Iron and Calcium lines are about ± 0.2 dex. The observed [Fe/H]'s in these three stars are within the range found for ω Cen by previous high-resolution analyses. Note that ROA371 is slightly more metal-rich than ROA48 and ROA213 and displays greatly enhanced s-process spectral lines. No quantitative abundance analysis of the s-process elements has been carried out on our data yet; however, the rather large enhancements in the line-strengths of many s-process lines (such as Zr I, Y II, Ba II, and La II) suggest that ['S'/Fe] in ROA371 is comparable to that seen in extreme Barium stars. A complete analysis will shed some light on primordial or internal abundance variations within ω Cen.

I thank the CTIO staff for their assistance with the observing and Dr. David L. Lambert for valuable collaboration. This research is supported in part by the National

Science Foundation (grant AST 83-16635) and the Robert A. Welch Foundation of Houston, Texas.

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DISCUSSION

F. SPITE What is the resolution of your spectra ?

V. SMITH The resolution is about 0.34 Å or a $\lambda/\Delta\lambda \approx 20000$.

NISSEN I note that you have obtained some very accurate spectra down to magnitude $V \approx 14^m$. Is that your limiting magnitude or can you go fainter by using longer exposure times without being disturbed too much by e.g. cosmic ray events on the CCD ?

V. SMITH One can certainly go fainter. Our spectra at magnitude 14 required four exposures of 30 minutes per exposure, to minimize cosmic ray problems, which were then averaged.