ABUNDANCES IN STARS IN GLOBULAR CLUSTERS FROM PALOMAR CCD SPECTRA

E. Myckki Leep and George Wallerstein

University of Washington

J. B. Oke

California Institute of Technology

We have completed abundance analyses of stars in three globular clusters: M71, M4, and M22. Spectra of resolution 0.3 and 0.6 (two pixel) resolution have been obtained with the Palomar coudé spectrograph and a TI CCD. The analysis was carried out with model atmospheres and f-values derived from three sources: absolute f-values derived by theory for the 6300 line of OI and for CN bands, laboratory f-values for lines that are too weak in the sun to be useful, and solar f-values. The last introduce an uncertainty of about 0.25 dex because solar f-values derived via the Holweger-Muller model differ from those derived via the BEGN model.

Resulting abundances of iron are as follows: for M71, which is important as a calibrator of strong-lined globular clusters, we find that [Fe/H] lies between −0.6 and −1.0, depending on which model is used for solar f-values and which wavelength region is used. For M4 we find [Fe/H] to lie between −1.4 and −1.2, which is similar to photometric determinations. For M22, which has been reported to be inhomogeneous in composition, we find star III-3 to be richer in iron by 0.25 dex, as compared to star IV-102. This difference is similar to prior findings and confirms a small inhomogeneity in M22.

For CNO abundances we find the following: in M71 [O/H] = −0.6, which becomes a range from 0.0 to +0.4 for [O/Fe], depending on the iron abundances. For M4 we did not observe oxygen, but Geisler (Ph.D. thesis, 1983) found [O/Fe] = +0.9 from two stars in M4.

Our analysis of the 2–0 vibrational band of the red CN system yields a line in the (C/H, N/H) plane. A search for the λ8727 line of CI in two clusters was not successful.

For M71 an analysis of CN in three stars yields similar lines in the (C/H, N/H) plane, which can be understood if C/N is between 1 and 3, the main sequence values of [C/H] and [N/H] are near −1.0, and the expected CN cycling and mixing have modestly increased N at the expense of C.

For M4 two stars also show reasonable lines in the (C/H, N/H) plane, provided that their initial values of [C/H] and [N/H] were about −1.2.

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For M22 there is a gross difference between the relatively metal-rich star III-3 and IV-102, with CN stronger in the former star by about a factor 10. This favors the idea that C and N follows Fe and are all more abundant by about a factor of 3 in III-3, as compared with IV-102. In star III-3 we have detected the clump of ^{13}CN lines near λ8005 and find a ratio of $^{12}C/^{13}C$ near 4. At our resolution of only 0.6 Å this is very uncertain, despite the signal-to-noise of about 150. If correct, it indicates much deeper mixing than predicted by standard evolution and mixing theory.

Our results for various elements relative to iron are best shown in a table. We have rather little that is new for M22 and hence show relative abundances for the other two clusters in the following table.

TABLE I

[X/Fe] for Various Elements

Element	M71	M4 this work	M4 Geisler Thesis	Element	M71	M4 this work	M4 Geisler Thesis
O	+0.2		+0.8	Ca	+0.6	+0.6	+0.4
Na	+0.5	+0.4	+0.5	Sc	+0.3		+0.1
Mg		+1.1	+0.6	Ti	+0.4	+0.3	+0.6
Al	+0.6	+0.9	+1.4	Fe peak			+0.1
Si	+0.3	+0.9	+0.8	s-process			0.0

It is clear from the table that both clusters show a very substantial excess of the light metals relative to iron. The observed effect is noticeable for all the light elements, not just the integral-α nuclei and includes titanium. but not scandium. In M4 the iron-peak elements go with iron, as do the four s-process elements observed by Geisler. We confirm his high sodium and aluminum abundances.

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