CHEMICAL COMPOSITIONS OF SOUTHERN GLOBULAR CLUSTERS: 47 TUCANAE, NGC3201, AND NGC6752

Catherine A. Pilachowski* and Christopher Sneden*
University of Washington

R. Canterna*
University of Wyoming

The metallicities of the globular clusters 47 Tucanae, NGC3201, and NGC6752 have been determined from high dispersion spectra obtained with the echelle spectrograph at CTIO. The mean iron deficiencies of NGC3201 and NGC6752 are -1.0 and -1.3, respectively. Oxygen is enriched by a factor of two in NGC3201; no oxygen data are available in NGC6752 due to the small radial velocity of this cluster. The atmospheric parameters and the abundances, relative to the Sun, of individual elements for two stars in 47 Tuc are tabulated below. Star identifications are taken from Hesser and Hartwick (1977). The stellar effective temperatures were established from the spectroscopic data; the data do not permit temperatures much in excess of those quoted. Surface gravities were calculated from the cluster's distance modulus and other reasonably well-known quantities, with the assumption that the mass of a cluster giant is 0.8 $M_{\odot}$.

	Star 1005	Star 2027	Uncertainty
T_{eff}	4000K	4100K	±150K
log g	0.95	0.75	± 0.2
[O/H]	-	-0.7	± 0.2
[Ca/H]	-0.8	-0.6	± 0.3
[Ti/H]	-0.8	-0.6	± 0.2
[Fe/H]	-1.1	-1.3	± 0.2
[Ni/H]	-1.0	-1.2	± 0.2
[s-process/H]	-1.1	-1.0	± 0.3

Washington system photometry of six giant stars in 47 Tucanae also establishes that the metallicity of this cluster is lower than previously believed. The mean metal abundance from the $(M-T_1)$ color is -1.3±0.3, while the $(C-M)$ color indicates a metal abundance of -0.7±0.2. Because the C passband includes both CN and CH features in addition to metallic lines, and the M passband

---

*Visiting Astronomer, Cerro Tololo InterAmerican Observatory, which is operated by the Associated Universities for Research in Astronomy, Inc., under contract from the National Science Foundation.

James E. Hesser (ed.), Star Clusters, 467–470.

includes only metallic lines for stars in this spectral range, the high abundance derived from the *C-M* color may indicate that the CH or CN bands are enhanced in these 47 Tuc giants compared to stars of otherwise similar metal abundance.

From our spectroscopic and photometric results we conclude that the mean heavy element abundance for 47 Tucanae is approximately -1.2, with no evidence for large star-to-star variations. Oxygen is significantly enhanced relative to iron for star 2027. The (*C-M*) colors indicate that an enhancement of the CNO elements relative to iron peak elements is typical of giant stars in 47 Tuc. This analysis, and the result already presented by Judy Cohen that M71 giants are also metal poor, suggests that some revisions of the calibrations of photometric metallicity indices may be required. The metallicities of other possible metal rich clusters, particularly those near the galactic center, should be redetermined. 47 Tuc and M71 are two of the most well studied metal rich globular clusters. Both are located approximately 8 kpc distant from the galactic center. The revision of metallicity for these two clusters suggests that less well studied clusters at similar distances may also be more metal poor. Until the metallicities of globular clusters near the galactic center are redetermined, the question of a gradient in metal abundance in the inner halo cannot be answered.

This research was supported in part by NSF grant AST 78-20405.

REFERENCE

Hesser, J.E. and Hartwick, F.D.A.: 1977, *Astrophys. J. Suppl.* 33, 361.

DISCUSSION

VAN DEN BERGH: If nothing else I think your talk shows that it is very important to publish results that disagree with the pundits'.

CAYREL: I have a question - if it's abundance, I can always speak! Have you measured the slope of your abundance gradient, with the correction you gave?

PILACHOWSKI: No, I haven't. I think it's better to wait until there are more clusters checked.

CAYREL: How much does it go: 0.3 dex? 0.3 to 0.6 dex?

PILACHOWSKI: Why don't we measure it later? Until the abundances of clusters near the galactic center are remeasured, I don't think we should speculate about a gradient.

JANES: How much does the diagram of abundance versus galactocentric distance change if the metallicity calibrations of photometric systems are to be revised? Do you move all those points down, or just the ones that you've actually measured?

PILACHOWSKI: It's really not clear yet. My feeling is that many of them ought to be moved down. But it's entirely possible that for an abundance between -0.5 to -1.2, the observed color-magnitude diagrams are very similar. Some of those metal rich clusters may still be metal rich.

JANES: That means that since some of the calibrations of photometric indices are based on old abundances, the whole shape of the thing might change?

PILACHOWSKI: Yes, possibly, but I think it's too early to tell.

KING: I'd like to direct a question to you and the others who play this honest spectroscopic game. I have some integrated spectra at high dispersion of some clusters that no one else has looked at. Are they of any use for abundances?

PILACHOWSKI: I would be afraid to use them without careful calibration, but others with more courage can probably derive some sort of general metallicity parameter from them.

WALLERSTEIN: Could I add that I think if you establish a correlation first using measured features in the integrated spectra against abundances for the clusters as established by high dispersion spectroscopy, then you can continue to use this correlation for other clusters in which there is no high dispersion spectroscopy. I think it ought to work. But there is still some possibility that very blue horizontal branches will result in a filling in of lines where the lines really were fairly strong where the red stars dominate.

FREEMAN: I was just bewildered by NGC3201. I guess I need some advice. Carla Cacciari and I just measured Ca in the RR Lyraes in 3201 and in M5. Now this procedure is fairly straightforward and even just looking differentially between 3201 and M5 we found absolutely no difference. There's plenty of dynamic range in the thing: there's no question of saturation or anything like this. We have heard values for M5 between -1.3 and -1.5 during this meeting. We get almost identical Ca. What are we doing wrong? Is it likely to be some large [Ca/H] difference from cluster to cluster? What do you think it's all about?

PILACHOWSKI: Our iron deficiencies show more scatter from star to star in NGC3201 than we expected, and [Ca/Fe] may also vary, perhaps from cluster to cluster as well. I don't really think that's the answer. I'm not sure what it is. There is another discrepancy, too, which perhaps I could mention, and that is this M5 thing. From high dispersion spectra of M5 we get -1.3

for the metal abundance. Butler obtained -1.0 from calcium, and you obtain -1.5. Maybe we should just take the grand mean. The measurements of weak CaI lines and of strong CaII features are sometimes discrepant. We do, however, find a systematic difference in [Fe/H] between M5 and NGC3201.

FROGEL: One of the other things I've tried to do is to set up a metallicity calibration on the basis of the *V-K* colour at a given magnitude level on the giant branch. In response to both what you were saying and to the question that Freeman was asking, I find that M5 and 3201 are almost indistinguishable in terms of their giant branches. Both of them are definitely bluer than 47 Tuc or M71, and M4 is intermediate between them. So the giant branches seem to be saying something different than the fine analysis.

PILACHOWSKI: Yes, the photometric indices may be fooled by what appears to be a drastic change in the blanketing with a small change in metallicity in these stars. Judy mentioned it this morning. As metallicity increases, somewhere near -1 to -1.3 the blanketing increases markedly. The <S> index of Searle and Zinn effectively measures blanketing in the stellar spectrum. A plot of their <S> versus spectroscopic iron abundance, including Judy's measurement for M71, shows this enormous increase in blanketing at that metallicity. It's not surprising, I think, that some peculiar effects might arise under these circumstances.

FROGEL: Well, that could certainly be the case.