A Photometric Method for estimating CNO Abundances 
in Globular Clusters

David Peat  
Dept. of Physics & Astronomy, University of Leeds, Leeds, UK.

Raymond Butler  
Dept. of Physics, National University of Ireland, University Road, Galway, Ireland

1. Introduction

The estimation of variations in CNO abundances within globular clusters yields information on the evolutionary history of the clusters, and possibly also on the physical processes involved in their formation. This paper describes some preliminary results from a new photometric method to estimate these variations. The method can be used for any globular cluster, but M22 was chosen for a first investigation because it is known (Richter, Hilker, & Richtler 1999) to exhibit large internal variations in CN absorption strength, and these variations, unlike in most clusters, are believed (Anthony-Twarog, Twarog, & Craig 1995) to be positively correlated with CH variations.

2. Details of the Method

The method uses the Stromgren indices v and b, the broad band index I, together with a new index, defined as p, which consists of the shorter wavelength half of the Stromgren v band. The v band includes the CN absorption band at 4215Å, but the p band does not. The index 2(v-p), at a given I magnitude, is thus a measure of the CN absorption, and is independent of differential reddening effects. The colour index (p-I) provides a suitably wide wavelength baseline for estimates of colour temperature, and contains only little CN or CH absorption. A colour-magnitude diagram of I/(p-I) can be plotted, and a “p anomaly” can be defined as the displacement of an individual star parallel to the (p-I) axis from the mean CMD. A “b anomaly” is defined in the same way, using (b-I). Correlations between the CN index and the p anomalies can then be sought.

The evolutionary track of a star on the CMD depends on the molecular weight of the material of the star, and this depends primarily on the CNO abundances, together with a smaller dependence on the metal abundances. The “p anomaly” is thus an overall measure, through the molecular weight, of variations in the CNO abundances. Since the p and I bands contain little CN or CH absorption, any correlation between CN absorption and p anomaly would be suggestive of primordial CNO variations, which have affected the subsequent evolutionary tracks through the molecular weight. Estimated abundances, defined as del(log Z) where Z is the usual mean abundance parameter for the cluster,
can be derived from the p and b anomalies for each star observed, using theoretical isochrones for different chemical compositions. Relative CN abundances can be derived from the CN index, on the assumption that the logarithmic index is proportional to the product of the C and N abundances at a given value of I. Assuming the oxygen and metal abundances, it is then possible from the two observations of CN and del(log Z), to estimate the two unknowns, the C and N abundances.

3. Results

Results derived for a preliminary group, consisting of 26 giants and 29 subgiants in M22 were as follows:

(1) There are substantial variations of both CN strengths and p anomalies within the cluster, suggesting large variations of C and N abundances.

(2) There seem to be three possible groups of stars, each group showing a positive correlation between CN strength and p anomaly. The simplest explanation is that within each group there are carbon abundance variations, with increasing carbon abundance increasing both the CN strength and the molecular weight. This would favour a primordial origin for the abundance variations.

(3) The differences between the three groups are, we suggest, due to nitrogen abundance variations. However, the "strong CN" stars show p anomalies broadly comparable to those of the "weak CN" stars, suggesting that, for the molecular weights, increased nitrogen abundances are offset by decreased carbon abundances.

(4) Estimates of the relative nitrogen abundances in the three groups were made from simple isochrones and the spectroscopic assumption that the CN index is approximately proportional to the logarithm of the product of the C and N abundances. Results suggested log(N3/N1) = 1.3 & log(N2/N1) = 0.7, with errors 0.3 and 0.2 respectively, for the subgiants; and log(N3/N1) = 0.9 & log(N2/N1) = 0.5, with similar errors, for the giant stars. The errors arise from uncertainties in the evolutionary and spectroscopic models, as well as from uncertainties in the oxygen abundances which affect the molecular weights.

(5) It is possible that the relative nitrogen abundances in the three groups can be expressed in the form 1:k:k^2, with k approximately 4 for the subgiants, and 3 for the giants. These relative abundances might be explained by postulating two processes of star formation after an initial burst - with CNO cycling synthesising nitrogen, subsequent ejection in supernovae outbursts, followed by star formation from the same material in a proto-cluster - each process increasing the nitrogen abundance by a factor k.

Further work will consist of analysis of a larger number of stars, and also of analysis of a photometric band measuring the strength of CH molecular absorption.

References

Anthony-Twarog, B. J., Twarog, B. A., & Craig, J. 1995, PASP, 107, 32
Richter, P., Hilker, M., & Richtler, T. 1999, A&A, 350, 476