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On the Question of a Metallicity Spread in Globular Cluster M22 (NGC 6656)

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Abstract. Results from early photometric and spectroscopic studies for M22 showed a metallicity spread similar to, albeit significantly smaller than, that found in ω Cen, the most massive cluster in our Galaxy. Numerous studies of M22 over the last few decades have yielded conflicting results: depending upon the sample and analysis techniques, some authors find no significant variations whereas others find metallicity variations of ~0.5 dex. In our investigation of a sample of ~30 stars, we are employing high resolution high signal-to-noise spectra and a variety of spectroscopic approaches in determining the stellar metallicities. In this contribution, we report some of the preliminary results from our investigation of the question of metallicity variations in M22, employing a set of models derived by applying chemical constraints.

Key words. Globular clusters: general – Globular clusters: individual (NGC 6656) – Stars: abundances – Stars: fundamental parameters

1. Introduction

M22 is located on the sky near the Galactic Bulge region and is one of the brightest globular clusters visible in the Northern hemisphere. In spite of its proximity to us, M22 suffers from dust extinction. Its reddening has been estimated in the range of $0.3 < E(B-V) < 0.5$. However, the extinction also appears to be variable across the face of the cluster, variations apparent in far-infrared IRAS 60 and 100μm images and in measurements of interstellar features.

As shown in the left panel of Figure 1, a colour-magnitude diagram of M22 possesses a significant width in the red giant branch. This width has been observed in both $B-V$ and Strömgren colours, and has been attributed to reddening variations, to metallicity variations, and sometimes, to both. If the range in colour

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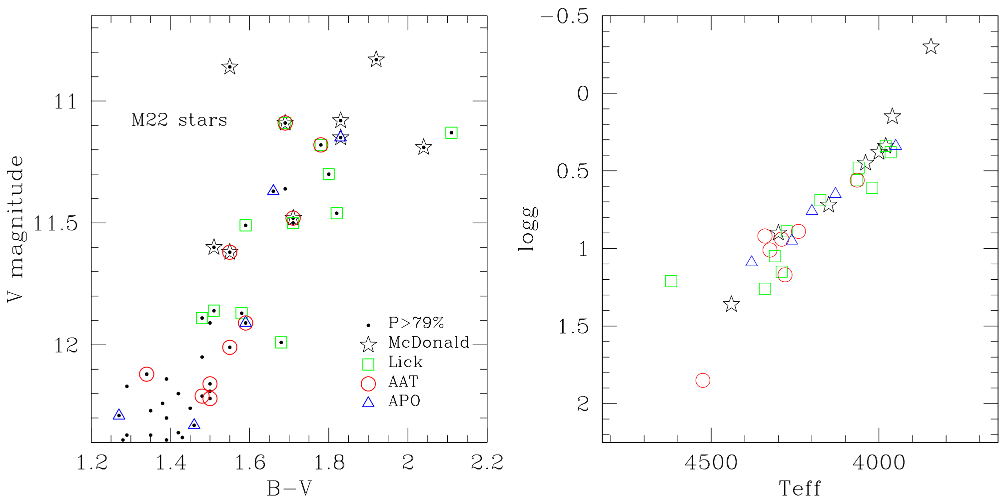

Fig. 1. Left panel: colour-magnitude of M22 (photometry from Peterson & Cudworth 1994), showing the positions of our program stars. The symbols correspond to the four observatories used to acquire the spectra employed in our study. Right panel: derived stellar model atmosphere parameters applying chemical constraints.

at a particular magnitude is due to a range in metallicity, the variations imply that M22 has experienced a most unusual star formation and chemical enrichment history (with respect to the bulk of the Galactic globular cluster population). If, however, reddening-free colours, and thus accurate effective temperatures (Teff) can be deduced, then the bright stars of this relatively nearby metal-poor cluster can be employed in chemical abundance studies to address other astrophysically interesting questions.

2. Observational Background and Material

Attempts to disentangle abundance variations from colour variations in this cluster has a long history with conflicting results. Here, we only briefly highlight the results of selected investigations. Hesser et al. (1977) were the first to note the peculiar similarities of M22 and ω Cen. Norris & Freeman (1983) showed that CN variations in M22 were correlated with Ca II H and K line variations, similar to those in ω Cen. However, more recent large photometric studies have found no evidence for a spread in [Fe/H].

Spectroscopic results are in similar disagreement. Cohen (1981; 3 stars) and Gratton (1982; 4 stars) found no significant metallicity variations (but both note interesting abundances in other elements). Whereas Pilachowski et al. (1984; 6 stars) found $-1.4 <$ [Fe/H] < -1.9 and Lehnert et al. (1991; 4 stars) found Ca and Fe variations that also correlated with variations in CH and CN band strengths. However, Brown & Wallerstein (1992; 7 stars) found no Ca abundance differences between CN-strong and CN-weak stars. But, they *did* find differences in [Fe/H] correlating with CN-strength.

Previous spectroscopic results have suffered from small sample sizes. To resolve the issue of metallicity variations in M22, we have assembled a data set of ~30 giant stars observed with high resolution spectrographs at four facilities. Some overlap exists between the sub-samples, useful for ensuring that the models and abundances are systematically derived.

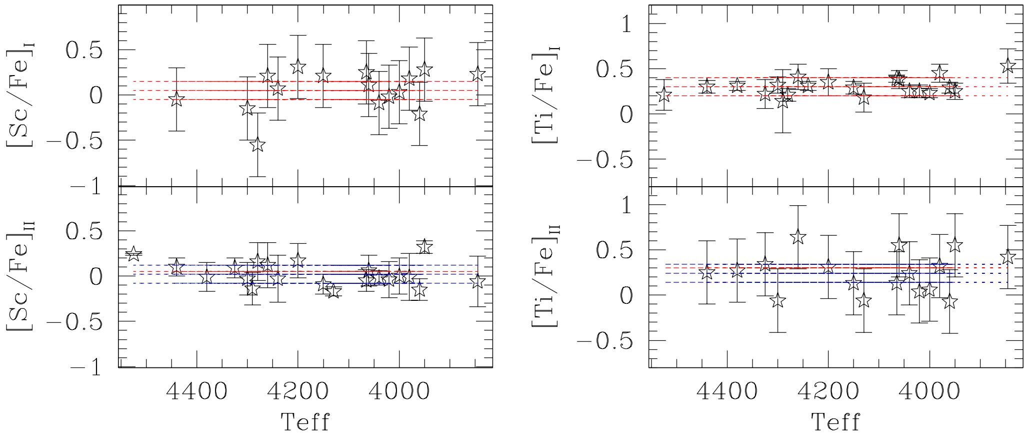

Fig. 2. Abundances derived from model parameters based on chemical constraints shown as a function of the effective temperature. Panels displaying abundances of the ratios of neutral elements show the mean abundance and standard deviation of the mean (sdom) in red. Ionized elemental abundance ratio means and sdoms are shown in blue. Overplotted on the panels for the ionized element ratios are the corresponding mean from the neutral element in red.

3. Preliminary Results of a New Investigative Trial

In our analysis, we have applied a variety of spectroscopic analytic techniques. Interested readers are welcome to contact the authors regarding the status of the complete investigation. In these proceedings, we describe only the preliminary results of an experiment based on the application of chemical constraints.

In the absence of metallicity variations, the colours of red giant stars are correlated with their Teffs. However, in the presence of metallicity variations, the colours of stars with otherwise equal Teff, will differ. Thus, one could reasonably expect that adopting an incorrect metallicity (eg. [Fe ɪɪ/H]) should induce variations in a resulting Teff/surface gravity (logg) plot of model parameters. To set the relative Teffs of the stars, we accepted models which yielded an abundance ratio of [V ɪ/Fe ɪ] = 0, the average abundance observed in most metal-poor stars. To set the relative loggs of the stars, we accepted models which yielded a ratio of [Fe ɪɪ/H] = –1.7 (a metallicity derived by employing transformations from the Q39 photometric index and Ca triplet W'; see Kraft & Ivans 2003).

The resulting model atmosphere parameters (which simultaneously satisfied both constraints) are shown in the right panel of Figure 1. A comparison with derived stellar parameters of stars in M3 (Sneden et al. submitted), M4 and M5 (Ivans et al 1999, 2001) shows *no* significant differences in the scatter of the from the ridgelines of the red giant branches. Thus armed with a consistent set of stellar parameters, we employed the same model atmospheres to derive the abundances of Ti and Sc. The abundances ratios with respect to iron that we deduced employing the models derived as described are presented in Figure 2. Some cautionary remarks are in order. This is an experiment. Not all of the stars for which we have spectra fit this analysis approach. Two objects, for which the data quality is especially low, are to be re-observed. Among the objects presented, there is less than satisfactory agreement between the derived stellar parameters, observed colours, and their corresponding expected $E(B-V)$ values. However, the error space has yet to be fully explored, and more than just $\Delta E(B-V)$ is likely to be at work.

4. Summary and Future Work

Based on 26 stars in M22 analysed so far, we have found a set of spectroscopic and chemical constraints that lead to reasonable stellar parameters and no variations in [Fe II/H]. Models based on those parameters yield reasonable agreement between multi-ion elemental ratios (eg. [(Sc,Ti)/Fe]). The same models will also be employed to derive other elemental abundances. The final outcome of this experiment will, at the very least, provide an alternative estimate of the errors in the derived abundances and stellar parameters deduced by the more traditional spectroscopic abundance analysis constraints we have also employed in this investigation of the metallicity variations in globular cluster M22.

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