Detailed Chemical Abundances of Globular Clusters in Local Group Dwarf Galaxies

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Abstract. We present detailed chemical abundances of Fe, Ca and Ba for 17 globular clusters (GCs) in 5 Local Group dwarf galaxies: NGC 205, NGC 6822, WLM, the SMC and LMC. These abundances are part of a larger sample of over 20 individual elements measured in GCs in these galaxies using a new analysis method for high resolution, integrated light spectra. Our analysis also provides age and stellar population constraints. The existence of GCs in dwarf galaxies with a range of ages implies that there were episodes of rapid star formation throughout the history of these galaxies; the abundance ratios of these clusters suggest that the duration of these burst varied considerably from galaxy to galaxy. We find evolution of Fe, Ca, and Ba with age in the LMC, SMC, and NGC 6822 that is consistent with extended, lower-efficiency SF between bursts, with an increasing contribution of low-metallicity AGB ejecta at late times. Our sample of GCs in NGC 205 and WLM are predominantly old and metal-poor with high [Ca/Fe] ratios, implying that the early history of these galaxies was marked by consistently high SF rates.

1 Introduction

Stars of all ages record the chemical enrichment of a galaxy throughout its history. To unravel the complete formation history of a galaxy, one must target both old and young stellar populations. While very young stars are conveniently luminous, and detailed abundances for a handful of young stars have been obtained out to distances of ~900 kpc [1], older stars are far too faint for detailed abundance analysis much beyond ~100 kpc. To enable measurements in more distant galaxies, we have developed a new method of abundance analysis that allows us to analyze high resolution spectra of the integrated light (IL) of globular clusters (GCs), both old and young. The method has been developed using a “training set” of MW and LMC GCs and has been demonstrated to provide abundances as accurate as obtained from individual stars — ±0.1 dex or better for [Fe/H] and [X/Fe] [234]. Using this method, we can target GC systems in galaxies at distances up to ~4 Mpc using 8-m class telescopes to probe their formation histories with the same fidelity that stellar abundances have provided in the Milky Way.

In these proceedings, we present partial results for an ongoing survey of detailed chemical abundances of GCs in Local Group dwarf galaxies. Data were obtained for 17 GCs in NGC 205, NGC 6822, WLM, and the Magellanic Clouds with the HIRES-r spectrograph on the Keck I telescope, the MIKE spectrograph on the Magellan Clay telescope, and the echelle spectrograph on the du Pont telescope.

2 Results: Local Group Dwarf Galaxies

Our results to date show that these samples of GCs have ages and abundances consistent with the field stars in their respective galaxies (where such abundances are available), demonstrating that these low mass galaxies had episodes of rapid star formation where massive clusters were able to form out of the same gas reservoir as field stars. Results for [Fe/H], [Ca/Fe], and [Ba/Fe] for the 17 GCs are listed in Table 1. In Figure 1, we plot these along with abundances taken from the literature for individual stars.

In the LMC, our cluster sample has [Ca/Fe] values that decrease with both [Fe/H] and age. This is consistent with available data for individual stars in the LMC [578], although few comparisons are available for the SMC. Note that [Ca/Fe] is representative of the true [α/Fe] in the GC integrated light, whereas the commonly-used low-resolution indexes that depend on [Mg/Fe] are strongly affected by self-enrichment within the GC stars and therefore not representative of the gas-abundance at the time of formation (see [3]). The old, metal-poor GC in NGC 6822 has solar [Ca/Fe]. The 3 GCs sampled in NGC 205 and the sole GC in WLM are reasonably metal-poor ([Fe/H]< -1), and are consistently enhanced in α-elements ([Ca/Fe]> +0.2). We note that our findings for NGC 205 are consistent with those of [9], who found these GCs had properties similar to MW GCs using low resolution spectroscopy. Our results disagree, however, with the estimates of solar [α/Fe] by [10] based on low resolution indexes, which we believe are unreliable, particularly at low metallicity (see [3]).

Ba, which is an s-process element, is measured here for the first time in most of these galaxies. We find that

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Table 1. Abundances in Local Group Dwarf Galaxies.

| Name   | [Fe/H]   | [Ca/Fe]   | [Ba/Fe]  |
|--------|----------|-----------|----------|
| NGC 205 |          |           |          |
| HI     | $-1.49 \pm 0.02$ | $+0.42 \pm 0.05$ | $+0.35 \pm 0.07$ |
| HII    | $-1.12 \pm 0.02$ | $+0.21 \pm 0.04$ | $+0.23 \pm 0.13$ |
| HVIII  | $-2.01 \pm 0.03$ | $+0.28 \pm 0.06$ | $+0.18 \pm 0.05$ |
| WLM    |          |           |          |
| WLM-GC | $-1.71 \pm 0.03$ | $+0.25 \pm 0.05$ | $-0.05 \pm 0.15$ |
| NGC 6822 |          |           |          |
| HVII   | $-1.61 \pm 0.02$ | $+0.01 \pm 0.07$ | $+0.22 \pm 0.13$ |
| HVI    | $-0.79 \pm 0.15$ | $+0.16 \pm 0.10$ | $+0.09 \pm 0.22$ |
| SMC    |          |           |          |
| NGC 121 | $-1.23 \pm 0.03$ | $+0.31 \pm 0.12$ | $-0.43 \pm 0.20$ |
| NGC 416 | $-1.22 \pm 0.03$ | $+0.26 \pm 0.08$ | $-0.07 \pm 0.18$ |
| NGC 419 | $-0.66 \pm 0.06$ | $-0.12 \pm 0.12$ | $+0.03 \pm 0.14$ |
| LMC    |          |           |          |
| NGC 2005 | $-1.54 \pm 0.04$ | $+0.27 \pm 0.08$ | $+0.47 \pm 0.30$ |
| NGC 2019 | $-1.67 \pm 0.03$ | $+0.21 \pm 0.05$ | $+0.07 \pm 0.09$ |
| NGC 1916 | $-1.54 \pm 0.04$ | $-0.38 \pm 0.10$ | $+0.15 \pm 0.30$ |
| NGC 1978 | $-0.74 \pm 0.07$ | $+0.12 \pm 0.26$ | $+1.10 \pm 0.09$ |
| NGC 1718 | $-0.64 \pm 0.25$ | $+0.20 \pm 0.26$ | $+0.38 \pm 0.11$ |
| NGC 1866 | $+0.04 \pm 0.04$ | $-0.10 \pm 0.04$ | $+1.05 \pm 0.13$ |
| NGC 1711 | $-0.82 \pm 0.15$ | $-0.01 \pm 0.32$ | $-0.09 \pm 0.40$ |
| NGC 2100 | $>-0.03 \pm 0.06$ | $-0.08 \pm 0.18$ | $+0.55 \pm 0.01$ |

3 Summary

We present the first detailed abundances for both old and young GCs in NGC 205, NGC 6822, WLM, the LMC and the SMC using a new analysis method. Differences in the SF histories of Local Group dwarf galaxies are evident in our high resolution analysis of GCs [2][3][4][5].

We now have the detailed abundances and ages necessary to begin to quantify the chemical evolution of several dwarf galaxy GC systems. Over 20 α−, Fe-peak, n-capture, and light element abundances, as well as age measurements, will be presented in a future paper. We are currently obtaining data for the GC systems in several galaxies in and beyond the Local Group.

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