High Dispersion Spectroscopy of GCs with a metallicity spread in M31

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Abstract

Until now, most spectroscopic analyses of extragalactic stellar populations have been based on relatively low resolution spectroscopy, combined with pre-computed simple stellar population models. In this work we are studying globular clusters in M31, using high dispersion spectroscopy both in the optical and the near-infrared. We combine the integrated-light spectroscopic observations with resolved photometry of individual stars in the clusters. Using stellar parameters derived from the observed colour-magnitude diagrams, we compute integrated-light spectra specifically for our target clusters. This allows us to determine chemical abundances by adjusting the abundance patterns in the model spectra until the best match to the observed spectra is obtained. With the E-ELT, this approach will be applicable to galaxies at distances of tens of Mpc, and will thus allow detailed chemical abundance analysis for globular clusters in the nearest large galaxy clusters, Virgo and Fornax.

Introduction

Low resolution spectroscopy has been used extensively to investigate chemical abundances and stellar metallicities for extragalactic stellar populations, including globular clusters. In this work, we present the preliminary results of an ongoing project to study extragalactic globular clusters through *high dispersion spectroscopy*. We combine optical photometry and optical and infra-red high resolution spectroscopy for the GC 225-280 in M31. Using the observed CMD, we derive stellar parameters for stars across the HRD and compute model atmospheres and synthetic spectra. These are then co-added, and the abundances are adjusted until the best match the observed spectra is obtained.

Optical Photometry

In Fig.1 we show the colour-magnitude diagram of the GC 225-280 in M31 obtained from HST/ACS HRC data in the F606W and F814W filters (V and I correspondingly). We compared the data with different empirical ridge lines, based on the ACS Survey of Galactic Globular Clusters (kindly provided by Maren Hempel; Sarajedini et al. 2007, AJ 133, 1658). We got the best fit with the one of NGC 104 (47Tuc), which has a corresponding metallicity of $z = 0.004$. When we tried to fit the same HR diagram using the synthetic isochrones from the Padova group (2008), we found that the data are best reproduced for a spread in metallicity that goes from z=0.006 to z=0.01 (half solar). The former result was in good agreement with the fit from the empirical ridge lines. The empirical 47 Tuc colour-magnitude diagram was used as input to modelling of the optical and IR spectra, with the addition of stars redder than V-I=2 from the 225-280 CMD.

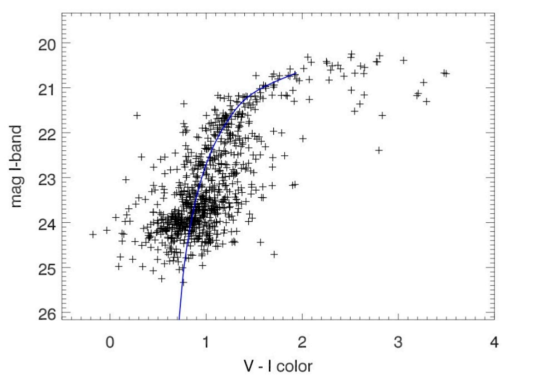

Fig1. HR diagram of GC225280 in M31. The blue line represents an empirical ridge line for NGC 104.

Optical Spectroscopy

In Fig.2 we show one echelle order (for the region around Mgb) from an optical spectrum of 225-280 obtained with the HIRES spectrograph (from 0.3 to 1.0 microns) on Keck. The data were reduced with the MAKEE package. Synthetic stellar spectra were computed with the Kurucz ATLAS9 and SYNTHE codes for about 60 bins across the HRD, then co-added and smoothed to match the data.

This is still a work-in-progress and we have many more spectral orders to compare with the theoretical stellar population models, but the good fit is encouraging. By varying the metallicity until the best fit is obtained, we get [Fe/H]=-0.85, in good agreement with the mean value based on the CMD. Here we have kept [α/Fe] fixed at +0.3, but in principle we can solve for any combination of individual elemental abundances.

Infrared Spectroscopy

The Infrared spectrum of 225-280 is shown in Fig.3. It was obtained with the high resolution near-Infrared echelle spectrograph (NIRSPEC) on Keck (range from 0.6 to 5 microns). The synthetic spectrum was modelled using the same procedure as for the spectrum in Fig 2.

We used the same fitting procedure to get information from the IR data. From the near-IR spectrum we get a somewhat higher metallicity of [Fe/H]~ -0.4. We suspect this difference is due to the metallicity spread within the cluster, as the very cool M-giants that dominate in the IR are likely preferentially metal-rich. *This potentially implies that a metallicity spread may be detectable from integrated light by including measurements over a wide wavelength range.*

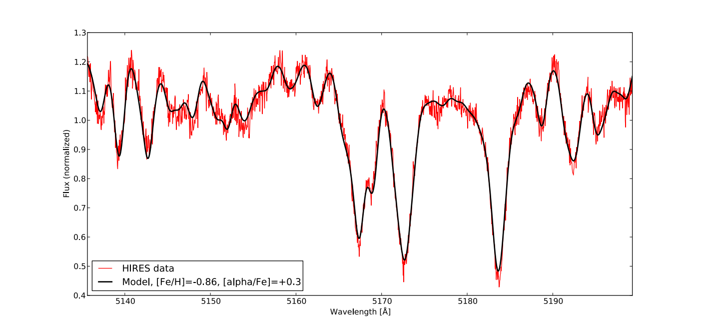

Fig.2. Optical spectrum of GC225280 in M31 and our best-fitting model for [Fe/H]=-0.85 and [α/Fe]=+0.3.

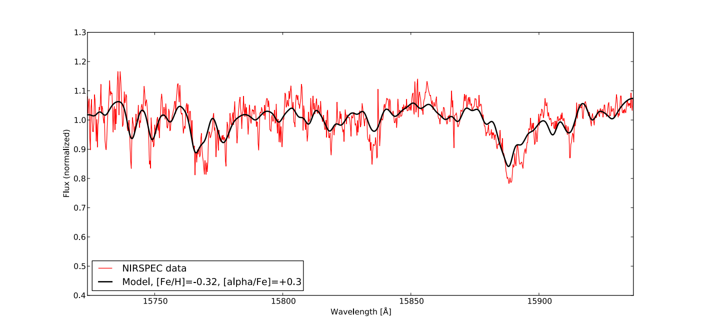

Fig.3. Infrared spectrum of GC225280 in M31 and a model spectrum with [Fe/H=-0.4 and [α/Fe]=+0.3.

Summary

- This is *the first study* of stellar population models in which both photometry and high resolution optical and Infrared spectra are compared to provide the metallicity and stellar abundances of extragalactic Globular Clusters. Our method can be applied to the study of GCs in the Virgo and Coma galaxy clusters once E-ELT will become available.
- We analysed the ACS H-R diagram and optical and IR high resolution spectra from Keck of the Globular Cluster 225-280 in M31. The colour-magnitude diagram was fitted with both empirical and synthetic isochrones, obtaining a *spread in metallicity* that varies from 0.004 to half solar.
- From modelling the optical spectra, we get a metallicity of [Fe/H]=-0.85 comparable with the photometric value. We also find a velocity dispersion of 28 km/s. From the IR spectra we get a somewhat higher value of [Fe/H]=-0.40, and suggest that this difference may be due to more metal-rich stars dominating the IR light.