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Age, Helium Content and Chemical Composition of Globular Clusters in the M31 Neighborhood and in our Galaxy

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Abstract—We present the results of determinations of age, helium abundance (Y), metallicity ([Fe/H]), and estimations of abundances of the elements: C, N, O, Mg, Ca, Ti, Cr, Ni, Sr, and Ba of four globular clusters in the neighborhood of the Andromeda galaxy ([SD2009] GC7, Mayall II, Mackey-GC1 (MGC1), and Bol 298 (MGC6)) and of six Galactic clusters. Medium-resolution long-slit integrated-light spectra from the clusters under study were used to determine the parameters. Observations of extra-galactic objects were carried out with the 6-m SAO RAS telescope using the SCORPIO-1 multimode focal reducer. Galactic globular clusters NGC 6341 (M92), NGC 6838 (M71), and NGC 7078 were observed with the CARELEC spectrograph at the 1.93-m telescope of the Haute-Provence Observatory. The integrated-light spectra of Galactic globular clusters NGC 104, NGC 6121 (M4), and NGC 7078 (M15) were taken from the spectral library by Schiavon. We selected the best isochrone for each cluster by comparison of the shapes and intensities of the observed and theoretical Balmer line profiles.

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1. INTRODUCTION

According to the modern photometric and spectroscopic data, globular clusters are not simple systems containing stars of the same age and chemical composition [1, 2]. This fact distinguishes them from open clusters [3]. Along with stars having chemical abundances similar to that of the objects in the Galactic halo, globular clusters contain stars formed from the material passed through the full CNO cycle and proton capture reactions of light nuclei. Despite of the fact that most globular clusters are chemically homogeneous in terms of the abundance of iron and the s-process elements [4], numerous spectroscopic studies revealed significant variations in light-element abundances often appearing as anticorrelations: C–N, O–Na, Mg–Al ([1, 3] and references therein). The effect of multiple stellar populations was detected using "color–magnitude" diagrams (hereafter: CMDs) also in clusters of different ages in the Magellanic Clouds (for example, [5–7]).

A detailed study of ages and abundances of various chemical elements using high-resolution spectroscopy and the study of deep CMDs is possible today only for the brightest and closest extragalactic globular clusters (for example, [8] and the references therein). The developed method of population synthesis of the integrated radiation of star clusters in accordance with a given mass function by Chabrier [9] and using the models of stellar atmospheres allows us to accomplish this task for extragalactic star clusters [10–14]. The major difference from other papers on the population synthesis of integrated-light spectra of globular clusters that appeared in the literature recently (for example, in [8, 15, 16]) is that we analyze the shape and intensity of the hydrogen line profiles, which allows us to judge about the age, helium abundance, and type of the horizontal branch of a globular cluster. We make use moderate-resolution integrated-light spectra of clusters (the width at half intensity of the absorption line profile FWHM ≤ 5 Å). To successfully complete the task, it is necessary that the signal-to-noise ratio in the spectrum to be of the order of a hundred or more. Stellar evolutionary isochrones of the Padova group [17], including the horizontal (HB) and asymptotic giant branch (AGB) stages along with other stages of stellar evolution, provide a necessary and sufficient set of parameters ($T_{\rm eff}$, $\log g$, [Fe/H]) for synthesizing the spectra of

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