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The Stellar Population and Orbit of the Galactic Globular Cluster Palomar 3

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Abstract—Deep stellar photometry of one of the most distant Galactic globular clusters, Palomar 3, based on frames taken with the VLT in Johnson–Cousins broadband V and I filters is presented, together with medium-resolution stellar spectroscopy in the central region of the cluster obtained with the CARELEC spectrograph of the Observatoire de Haute Provence and measurements of the Lick spectral indices for the integrated spectrum. Computations of the orbital parameters of Palomar 3 and nine Galactic globular clusters with similar metallicities and ages are also presented. The orbital parameters, age, metallicity, and distance of Palomar 3 are estimated. The interstellar absorption is consistent with and supplements values from the literature. The need to obtain more accurate data on the proper motions, ages, and chemical compositions of the cluster stars to elucidate the origin of this globular cluster is emphasized.

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1. INTRODUCTION

Like other Palomar globular clusters [1], Palomar 3 (Pal 3) was discovered in the 1950s on photographic plates of the Palomar Sky Survey [2]. The main observational characteristics of this cluster from the literature are listed in Table 1. Pal 3 is ∼96 kpc from the Galactic center [1, 3, 4] in the Galactic halo, and is not a member of any known stellar streams, such as the Sagittarius stream [5, 6].

There are only seven globular clusters at distances of 40–120 kpc from the Galactic center [1]: AM 1, Eridanus, Pyxis, Pal 3, Pal 4, Pal 14, and NGC 2419. Their origin is not clear (see, e.g., [7]). Apart from NGC 2419, all have red horizontal branches, low stellar densities, and similar masses and metallicities [1, 8]. The range of their masses is $(1.8–6) \times 10^4\ M_\odot$ [8], and the range of their metallicities is $-1.3 < [\mathrm{Fe/H}] < -1.8$ dex.[1] NGC 2419 is a more massive object ($1.6 \times 10^6\ M_\odot$) with a low metallicity $[\mathrm{Fe/H}] < -2.1$ dex and a blue horizontal branch.

The first estimate of the metallicity of Pal 3 was obtained by Gratton and Ortolani [11] based on the object's color–magnitude diagram (CMD): $[\mathrm{Fe/H}] = -1.4 \pm 0.4$ (this value is $[\mathrm{Fe/H}] = -1.57 \pm 0.19$ [14] on the scale of Zinn and West [12]). Subsequent estimates of the metallicity of Pal 3 based on its CMD range from $[\mathrm{Fe/H}] = -1.4$ to -1.7 ([13] and references therein). Lee et al. [14] used the CMD of the cluster to determine the horizontal branch ratio, $HBR = (B - R)/(B + V + R)$, which serves as an index characterizing the numbers of stars in different parts of the horizontal branch, which they found to be −0.82 for Pal 3. Harris [1] presents another value in his catalog (Table 1). Catelan et al. [19] found that the dispersion of the masses of horizontal-branch stars in Pal 3 was significantly lower than for the cluster M3. According to estimates of the age of Pal 3 based on its CMD [13, 15–17], this cluster is approximately one to two billion years younger than clusters in the Galaxy belonging to the old halo subsystem, such as M3 and M13.[2] Borissova et al.

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[1] The iron content in solar units is $[\mathrm{Fe/H}] = \log(N_{\mathrm{Fe}}/N_{\mathrm{H}}) - \log(N_{\mathrm{Fe}}/N_{\mathrm{H}})_\odot$, where $N_{\mathrm{Fe}}/N_{\mathrm{H}}$ is the ratio of the abundances of iron and hydrogen in terms of numbers of atoms, or in terms of mass, which is related to the mass fraction of elements heavier than helium Z by an empirical formula (see, e.g., [9]). The solar mass fractions of hydrogen X, helium Y, and metals Z are given in [10]. Obviously, $X + Y + Z = 1$.

[2] There is currently no unique system for dividing globular clusters among various Galactic subsystems (see, e.g., [3, 4]). It is believed that clusters of the young halo were members of dwarf galaxies in the past. Such clusters are ∼1–2 billion years younger than objects of the old halo (13–14 billion years). Absolute ages in billions of years are known for only some objects. Only relative ages are known