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THE GLOBULAR CLUSTER NGC 6981: VARIABLE STARS POPULATION, PHYSICAL PARAMETERS AND ASTROMETRY

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RESUMEN

Se presentan los resultados del estudio realizado al cúmulo globular NGC 6981. Dado que el presente cúmulo no disponía de estudios observacionales con fotometría CCD, implementamos un análisis de series de tiempo con fotometría CCD de alta precisión para un grupo de 10 noches de observación, con las cuales se logró clasificar adecuadamente las estrellas variables presentes en nuestro rango de observación. Reportamos 11 nuevas variables tipo RR Lyrae, 3 nuevas SX Phe, y descartamos como variables a 20 estrellas previamente clasificadas como variables o sospechosas de serlo. Confirmamos la variabilidad de 29 estrellas ya reportadas en la literatura y calculamos nuevas efemérides. Por medio la descomposición de Fourier de las curvas de luz de estrellas RR Lyrae y calibraciones semiempíricas disponibles en la literatura, determinamos los parámetros físicos de estas estrellas y por lo tanto los valores medios de metalicidad y distancia del cúmulo y obtuvimos los valores [Fe/H]$= -1.48 \pm 0.03$ en la escala de Zinn & West (1984) y una distancia de $\approx 16.73 \pm 0.36$ kpc.

ABSTRACT

We present the results of time-series CCD photometry of the globular cluster NGC 6981 for which no previous CCD photometry exist. Accurate photometry was achieved by the technique of difference image analysis. This allows to correctly classify the known variable stars, corroborate their variability and to discover new variables. In this paper we report 11 new RR Lyrae stars, 3 SX Phe. We show that 20 stars previously classified as variables are in fact non-variable and confirm the variability of 29 stars. News ephemerides are provided for all the variables in the cluster. By using the Fourier decomposition of light curves and semi-empirical calibrations available in the literature for RR Lyrae stars, we determined the physical parameters of these stars and hence the mean metallicity and distance of the cluster as [Fe/H]$= -1.48 \pm 0.03$ in the Zinn & West (1984) scale; and $\approx 16.73 \pm 0.36$ kpc.

Key Words: blue stragglers — globular clusters: individual (NGC 6981) — stars: evolution — stars: variables: RR Lyrae

1. INTRODUCTION

The study of globular clusters is very important in astronomy because they are the oldest objects in the Galaxy, thus they are useful indicators of the early formation, structure and evolution of the Galactic system. In the present study we focus on the globular cluster NGC 6981, because it has never been studied before using CCD photometry and with the new technologies numerical approaches to data reduction, high precision can be achieved even for faint stars in the crowded central regions of the cluster. Thus a good census and the properties of the variable star population in the cluster are on reach. Thus, the variable stars can be used to determine the mean metalicity and distance to the cluster.

2. DATA AND PHOTOMETRY

For this project we use a sample of 103, 110 y 3 CCD images in the filters V, R and I respectively. These images were taken in the Indian Astronomical Observatory, at the Indian Himalayas in Hanle, India with a 2.0 m telescope which is equipped with a 2048×2048 pixels CCD camera. The images cover 10.1×10.1 arcmin^2.

For the data reduction and astrometry we used the pipeline `DanDIA`[4], which includes a new algorithm that models the convolution kernel matching the point-spread function (PSF) of a pair of images of the same field as a discrete pixel array (Bramich 2008).

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[4]`DanDIA` is built from the DanIDL library of IDL routines available at `http://www.danidl.co.uk`.

3. CALIBRATIONS

We transform the instrumental v and i magnitudes into standard Johnson-Kron-Cousins photometric system (Landolt 1992) V and I, using the Photometric Standard Fields of Peter Stetson available via on line[5]. We could not transform our r photometry to the standard system because there are not standard stars available in this filter. A plot of the RMS of the mean magnitude vs. the mean magnitude, shows that we achieved accuracies better than 20 mmag scatter in the magnitude rank 14 to ≈18.5 mag, and ≈6–10 mmag photometry at the bright end in the filter V. In the filter R we achieve ≈8–12 mmag photometry at the bright end.

4. FINDING VARIABLE STARS

In the search of variable stars, we used methods that allows to make automatic or semi-automatic selection of variable stars candidates. One such method is the phase dispersion minimization (PDM) method, in which probe periods are used to phase the light curve, and selects the one that produces the minimum dispersion parameter (SQ). Stars with a smaller SQ are good candidates to be variables. Other method, uses the errors diagram and the fact that a stars that is changing its brightness will have a high RMS magnitude deviation for its given mean magnitude. Yet another method uses the difference image produced by `DanDIA` and by converting each difference image D_{kij} to an image of absolute deviations in units of sigma $D\prime_{kij} = |D_{kij}|/\sigma_{kij}$ and then constructing the sum of all such images $S_{ij} = \sum_k D\prime_{kij}$ for each filter, one can identify candidate variable sources as PSF like peaks in the image S_{ij}.

5. FOURIER DECOMPOSITION AND PHYSICAL PARAMETERS

To find the physical parameters of the RR Lyrae, we first make a Fourier fit of the light curve, which has the mathematical form

$$m(t) = A_0 \; + \; \sum_{k=1}^{N} A_k \; \cos\left(\frac{2\pi}{P} \; k \; (t - E) \; + \; \phi_k\right), \tag{1}$$

where $m(t)$ are the magnitudes in the t time, P is the period of the light curve and E is epoch maximum.

Then, using the amplitudes A_k and the phases ϕ_k we can find the Fourier parameters $\phi_{ij} = j\phi_i - i\phi_j$ and $R_{ij} = A_i/A_j$. Combining these parameters with calibrations available in the literature, we find the metallicity [Fe/H], absolute magnitude, luminosity, effective temperature and distance of each individual RR Lyrae star and hence the mean values for the globular cluster. Details on the calibrations employed, their zero points adjustments and a complete report on the results for NGC 6981 can be found in our paper Bramich et al. (2011). The interested reader can find detailed information about detection and characterization of variable stars in globular clusters and the use of these results to estimate the parameters of the host clusters in some of our previous works (e.g., Arellano Ferro et al. 2010 (NGC 5053); Arellano Ferro et al. 2008 (NGC 5466), and references therein).

6. RESULTS

Using the techniques described above we found 11 new RR Lyrae variables, 3 new SX Phe variables, confirm the variable nature of another 29 variables already reported as variables and refined their ephemerides. We have shown that 20 stars previously reported as variables or suspected of variability, are not varying within the uncertainties of our photometry. We found the mean values $[\mathrm{Fe/H}]_{\mathrm{ZW}} = -1.48 \pm 0.03$, $M_V = 0.623 \pm 0.002$, $\log(L/L_\odot) = 1.660 \pm 0.001$, $T_{\mathrm{eff}} = 6418 \pm 10$, a distance modulus of $\approx 16.117 \pm 0.047$ which corresponds to a distance of $\approx 16.73 \pm 0.36$ kpc for the RR0.

In the paper Bramich et al. (2011) we also provide astrometric positions of all known variables with an accuracy of ∼0.03 arcsec which offer an epoch for mid- and long-term astrometry of the cluster.

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