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# A SEARCH FOR VARIABLE STARS IN THE GLOBULAR CLUSTERS

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A simple method for detecting possible variable RR Lyr stars and checking the variability of stars with unknown periods has been applied. It is based on the analysis of a colour–magnitude diagram obtained from measurements of two plates (or CCD) taken simultaneously. A variable is thus at identical phase and the RR Lyrae stars are located in a definite strip. Using this method the globular clusters NGC 5286, NGC 6681, NGC 6934, NGC 6981 were investigated and about 50 new suspected variable stars were found.

KEY WORDS Globuar clusters: individual: NGC 5286, NGC 6681, NGC 6934, NGC 6981 – horizontal branch stars: RR Lyrae variables – stars

## 1 INTRODUCTION

A knowledge of the total number of variable stars belonging to a globular cluster is an important factor connected with the evolution of these objects. This applies in particular to the RR Lyr variables, the periods and total number of which play a significant role in the yet unsolved second parameter problem. Our detailed investigation revealed that at present the information on the structure of the HB of individual globular clusters is far from complete.

The search for variable stars in these objects has a long rich history. During the early stages of these studies it became clear that along with clusters with a small number of RR Lyr variables there exist clusters with a large number of these variables. The statistics for estimating the relative richness of these stars in globular clusters were first introduced by Kukarkin (1974). Our investigation (Kadla and Gerashchenko, 1982) showed that in both the Oosterhoff II and I groups there are variable-rich and variable-poor clusters. In the intermediate metallicity interval dividing these groups there coexist OoII variable-poor (IIVP) and OoI variable-rich (IVR) clusters. It was also evident that the central parts of most clusters had not been studied in detail and could contain a relatively large number of variable stars.

The present study is devoted to the investigation of the central parts of globular clusters in the above-mentioned intermediate metallicity interval: NGC 5286, NGC 6681, NGC 6934 and NGC 6981. The search for RR Lyr variables is based on colour-magnitude diagrams (CMDs) obtained under certain conditions.

## 2 OBSERVATIONS

The observations of the central parts of the above four clusters were made with the 90-cm ESO telescope in June 1993 by E. Brocato (Italy) and were lent to us for the study of variable stars. The detector was Tektronic (ESO #33, 512 x 512 pix). The linear scale was 0.44 arcsec pixel$^{-1}$ with a field of view of 13.7 arcmin$^2$. For three of the clusters Landolt's standards were used to reduce the instrumental magnitudes to the Johnson system and for NGC 6681 the photoelectric standards measured by Dickens (1972).

## 3 METHOD

In order to detect the RR Lyr variables in a globular cluster we used a method similar to that developed for the investigation of variable stars in NGC 5272 (Kadla and Gerashchenko, 1982). It is based on CMDs obtained from practically simultaneous $V$ and $B$ observations of stars. The RR Lyr variable in both exposures is at identical phase and in this case these stars occupy a definite strip in the CMD. Thus the identification of possible variables is quite simple and considerably reduces the number of stars which need further investigation. This method previously used for photographic observations was applied to the CCD observations of the aforementioned clusters in the narrow intermediate metallicity interval. The data for the four clusters are given in Table 1 which includes the name of the cluster, spectral class, metallicity found from the calibration of Zinn's index (Q39) (Zinn, 1980) and Gratton's spectroscopic determinations (Gratton and Ortolani, 1989) of [Fe/H] (Gerashchenko *et al.*, 1994), concentration class (CC), the apparent radius (Kukarkin, 1974), classification according to Oosterhoff and variable richness. The CMDs obtained from simultaneous $V$ and $B$ observations are shown in Figure 1.

**Table 1.** The parameters of the globular clusters studied

| *NGC* | *Spectral type* | *[Fe/H]* | *CC* | *R* | *Oo* |
|---|---|---|---|---|---|
| 5286 | F5 | −1.52 | V | 4.6 | IIVP |
| 6681 | F6 | −1.47 | V | 3.9 | IIVP |
| 6934 | F7 | −1.43 | VIII | 2.94 | IVR |
| 6981 | F7 | −1.43 | IX | 2.94 | IVR |

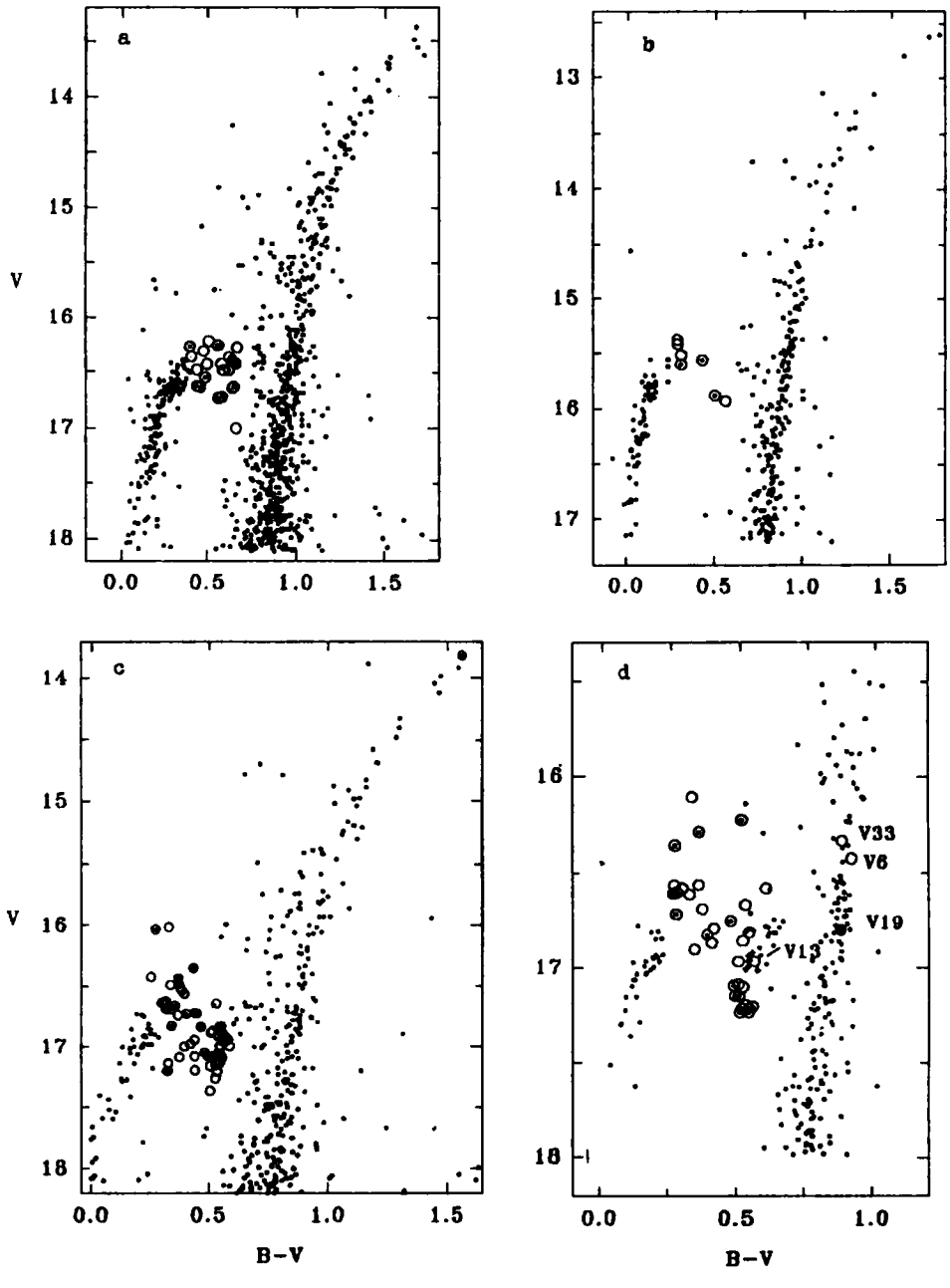


**Figure 1** The colour – magnitude diagram for the central parts of the globular clusters: *a*, NGC 5286; *b*, NGC 6681; *c*, NGC 6934; *d*; NGC 6981. The known RR Lyrae stars are denoted by ○, the suspected variables by ⊙, and possible variable stars located at the intersection with the RHB by +.

## 4 DISCUSSION

### *4.1 NGC 5286*

According to the data published in *A Third Catalogue of Variable Stars in Globular Clusters* (SHC) (Sawyer–Hogg, 1973) and a later investigation by Liller and Lichten (1978) altogether 16 variables have been discovered within the apparent radius of this cluster. Ten of these stars are classified as RRAB and six as RRC. With Pab and Nc/Nab the cluster is classified as OoII variable-poor (IIVP). The CMD obtained for stars within the investigated area $0.7 < r < 2.7$ is shown in Figure 1*a*. In the instability strip besides 11 of the above variables there are 12 stars which may be RR Lyr variables. The positions and photometric data for the latter are given in Table 2.

**Table 2.** The positions and photometric data for suspected RR Lyr, NGC 5286

| *N* | *X* (arcsec) | *Y* (arcsec) | *V* | *B–V* |
|---|---|---|---|---|
| 1 | 24.3 | −59.7 | 16.28 | 0.67 |
| 2 | 40.8 | 9.2 | 16.28 | 0.44 |
| 3 | −14.9 | 41.4 | 16.31 | 0.48 |
| 4 | −23.2 | −75.9 | 16.36 | 0.41 |
| 5 | −18.1 | 99.8 | 16.37 | 0.62 |
| 6 | 74.7 | −55.3 | 16.43 | 0.58 |
| 7 | 79.1 | −41.6 | 16.43 | 0.66 |
| 8 | −18.8 | −37.2 | 16.43 | 0.50 |
| 9 | −65.5 | 10.9 | 16.48 | 0.44 |
| 10 | 67.4 | −42.1 | 16.49 | 0.62 |
| 11 | −2.0 | −52.8 | 16.49 | 0.59 |
| 12 | −7.6 | −86.8 | 16.64 | 0.65 |

### *4.2 NGC 6681*

In the field studied by Liller (1983) she discovered 18 variable stars, only three of which (one RRAB, one RRC and one without a determined period) belong to the cluster. The investigated area ($0.3 < r < 1.9$) contains both of the RR Lyr variables. The CMD (Figure 1*b*) has a sparsely populated instability strip. Besides the two known RR Lyr variables there are only four other stars. The available photometric data confirmed the variability of the former two and only one of the latter four stars. The CMD indicates that this is a variable-poor cluster (IIVP).

### *4.3 NGC 6934*

Sawyer–Hogg (1938) discovered 51 variables in this cluster. All of them, with the exception of V15 (a red irregular variable), are RR Lyr stars (45 RRAB and five

**Table 3.** The positions and photometric data for suspected RR Lyr, NGC 6934

| *N* | *X* (arcsec) | *Y* (arcsec) | *V* | *B–V* |
|---|---|---|---|---|
| 1 | –9.0 | –23.2 | 17.08 | 0.49 |
| 2 | 11.9 | 21.1 | 16.03 | 0.27 |
| 3 | –6.7 | 59.3 | 16.48 | 0.37 |
| 4 | –4.8 | –18.1 | 16.53 | 0.38 |
| 5 | 7.6 | –66.9 | 17.16 | 0.50 |
| 6 | 9.8 | 107.9 | 16.43 | 0.37 |
| 7 | 24.0 | 16.5 | 16.66 | 0.35 |
| 8 | 18.2 | 0.8 | 16.63 | 0.30 |
| 9 | –22.6 | 30.0 | 17.08 | 0.44 |
| 10 | 11.4 | 48.2 | 16.94 | 0.44 |
| 11 | 19.3 | 17.7 | 16.83 | 0.55 |
| 12 | –50.6 | –71.7 | 16.87 | 0.51 |
| 13 | 26.4 | 22.8 | 16.95 | 0.56 |
| 14 | 52.1 | –56.2 | 16.88 | 0.51 |
| 15 | –12.6 | 63.1 | 16.96 | 0.56 |
| 16 | –57.5 | 18.8 | 16.93 | 0.57 |
| 17 | -1.7 | 14.4 | 17.14 | 0.32 |
| 18 | 29.6 | 9.5 | 16.72 | 0.40 |
| 19 | –13.5 | 21.0 | 16.83 | 0.54 |
| 20 | –80.4 | 4.2 | 17.00 | 0.58 |
| 21 | 89.9 | –41.7 | 16.89 | 0.54 |
| 22 | –69.6 | 3.7 | 16.99 | 0.54 |
| 23 | –27.6 | –27.0 | 16.89 | 0.63 |
| 24 | 135.4 | 6.1 | 16.94 | 0.58 |
| 25 | –56.2 | 103.2 | 17.06 | 0.54 |

RRC) (Sawyer–Hogg and Wehlau, 1980). This is one of the richest variable star clusters in our Galaxy. With Pab = 0.552 and Nc/Nab = 0.1, the cluster is classified as IVR. The investigated area contains 40 of the stars listed in the SHC. In the instability strip of the CMD (Figure 1*c*) besides the 40 previously discovered variables there are 25 stars. The positions and photometric data for the latter are given in Table 3.

### *4.4 NGC 6981*

According to the SHC the field of this cluster contains 42 variable stars. The periods have been determined for 28 (27 RRAB and one RRC) of them. We note that the $X$ coordinates of V29 and V41 should have an opposite sign. The small values of Nc/Nab and Pab = 0.55 indicate that the cluster should be classified as IVR. The investigated area ($r < 2.7$) contains 33 of the variables listed in the SHC, 21 of which have a determined period. One of the listed variables (V19) is a non-variable star. Besides the above 21 variables there are nine stars in the instability strip (Figure 1*d*). Data for the latter are given in Table 4. Three of the variables (V6, V19 and V33) listed in the SHC without a determined period lie

**Table 4.** The positions and photometric data for suspected RR Lyr, NGC 6981

| *N* | *X* (*arcsec*) | *Y* (*arcsec*) | *V* | *B–V* |
|---|---|---|---|---|
| 1 | –44.9 | –36.5 | 16.60 | 0.27 |
| 2 | –15.9 | –9.5 | 16.83 | 0.38 |
| 3 | –10.0 | –4.5 | 16.61 | 0.26 |
| 4 | –0.4 | –11.9 | 17.20 | 0.54 |
| 5 | 0.4 | 2.7 | 16.29 | 0.34 |
| 6 | 5.4 | –17.5 | 16.22 | 0.50 |
| 7 | 9.6 | –2.4 | 16.36 | 0.26 |
| 8 | 13.6 | –9.0 | 16.72 | 0.27 |
| 9 | 24.9 | –9.0 | 16.75 | 0.46 |

on the giant branch and one possible field variable (V13) at the blue edge of the RHB.

## 5 CONCLUSIONS

The search for variable stars by the traditional method requires extensive observational data. Although the data for the clusters available to us was very limited as regards observing time by applying the method of simultaneous $V$ and $B$ observations we were able to detect about 50 possible RR Lyr variables in the four clusters investigated. Our investigation showed once again that the central parts of the globular clusters have not been studied with enough detail.

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