A search for variable stars in the four open star clusters

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Abstract. We present a CCD photometric survey for the search of variable stars in four open clusters namely Berkeley 69, King 5, King 7 and Berkeley 20. The time series observations were carried out for 1 and/or 2 nights for each of the clusters in the year 1998, which have led to identify nineteen variable stars in these clusters. Out of these 19 variable stars, five stars show δ Scuti-like variability and two stars show W UMa type variability. In other stars, we could not find the periods, and hence the type of variability due to the lack of sufficient data. The periods of δ Scuti type stars are found to be in the range of 0.13–0.21 days, whereas the two stars in the cluster Berkeley 20, which showed W UMa type variability have orbital periods of 0.396 and 0.418 days, respectively. Using the Gaia data, the basic parameters of the clusters Berkeley 69, King 7 and King 5 are also revised. The age and reddening are estimated to be 0.79 ± 0.09 Gyr and 0.68 ± 0.03 mag for Berkeley 69, 0.79 ± 0.09 Gyr and 1.22 ± 0.03 mag for the cluster King 7 and 1.59 ± 0.19 Gyr and 0.63 ± 0.02 mag for the cluster King 5, respectively. The signature of mass segregation is found in the clusters King 7 and King 5.

Keywords. Star cluster: individual (King 5, King 7, Berkeley 69 and Berkeley 20)—star: astrometry—stars: variable.

1. Introduction

Variable stars play an important role in understanding the stellar structure and evolution. The variable stars in open clusters are more useful because their parameters, e.g., reddening, age and distance are better known in comparison to those in the field region. It would be very important for observational studies of multi periodic pulsating variable stars such as δ Scuti stars, γ Dor stars and SPBS (slowly pulsating B stars), etc., because they require accurate time series data to analyze their complicated light curves. There is currently much interest shown by various groups to search the variable stars in open clusters (see e.g. Jeon et al. 2016; Popov et al. 2017; Hutchens et al. 2017; Schaefer et al. 2018; Smith et al. 2019; Yepez et al. 2019). Further, one of the most effective and productive usages of the 1-m class telescope may be CCD time series photometry of variable stars in star clusters (see e.g. Joshi et al. 2012; Lata et al. 2014, 2016; Dutta et al. 2019). Simultaneous CCD photometry of all stars in the cluster enables us to perform efficient observations. Moreover, one can obtain precise time series data by observing the stars under the same weather conditions.

We have therefore searched for the variable stars in four northern intermediate age clusters King 5, King 7, Berkeley 20 and Berkeley 69. Previously, we have studied these clusters in detail using CCD U, B, V, R and I photometric data taken from 104-cm Sampurnanand telescope of ARIES, Nainital (Durgapal et al. 1996, 1997, 1998, 2001; Pandey et al. 1997; Durgapal and Pandey 2001; Durgapal 2001). In our previous papers, we have determined the fundamental properties of these clusters and studied their dynamical state. Apart from our analysis, other studies for these clusters have also been carried out in the past. For example, Bukowiecki and Maciejewski (2008) searched variable stars in the region of King 7 and found a total of 16
variable stars. Out of which only five stars lie within the cluster’s tidal radius. Oralhan et al. (2015) studied King 5, using CCD $UBV(RI)_C$ photometric data from the 84-cm telescope and determined the fundamental astrophysical parameters, $E(B - V)$ as 0.70 mag, $Z = 0.01$ and heliocentric distance as 1.74 kpc. Hoq and Clemens (2015) have studied King 5 and King 7 using 2MASS data in near-IR wave-band and derived the fundamental parameters as $\log(\text{age}) = 9.15 \pm 0.12$, distance = 1.87 kpc, $E(B - V) = 0.71 \pm 0.08$ mag for King 5 and $\log(\text{age}) = 8.03 \pm 0.12$, distance = 3.82 kpc, $E(B - V) = 1.46 \pm 0.07$ for the cluster King 7. These results are in good agreement with the results reported by us earlier. The present work is an effort to detect the variable stars in the above mentioned open clusters. We have also revisited the fundamental properties of King 5 and King 7 using the Gaia DR2 data. General information about the clusters under study are listed in the Table 1, which are taken from the WEBDA database.

The structure of the article is as follows. In Section 2 we discuss the observational data and its reduction. Member selection method and criteria are discussed in Section 3 In Section 4 we determine the fundamental parameters of the clusters using Gaia data. We discuss the variable stars detected in the clusters in Section 5 We discuss the mass segregation in the clusters in Section 6 and we conclude our analysis in Section 7

### Table 1. Fundamental parameters of Berkeley 69, King 7, King 5 and Berkeley 20 taken from WEBDA database, where $d$ is the heliocentric distance of the clusters.

| Cluster      | $\alpha$ (J2000) | $\delta$ (J2000) | $l$ (degree) | $b$ (degree) | $d$ (kpc) | $\log(t)$ | $E(B - V)$ (mag) | $[\text{Fe/H}]$ |
|--------------|------------------|------------------|--------------|--------------|-----------|-----------|-----------------|----------------|
| Berkeley 69  | 05:24:36         | +32:39:00        | 174.435      | -01.787      | 2.86      | 8.95      | 0.65            | -              |
| King 7       | 03:59:00         | +51:48:00        | 149.774      | -01.019      | 2.20      | 8.80      | 1.25            | -              |
| King 5       | 03:14:45         | +52:41:12        | 143.776      | -04.287      | 1.90      | 9.00      | 0.76            | -0.30          |
| Berkeley 20  | 05:33:00         | +00:13:00        | 203.483      | -17.373      | 8.40      | 9.78      | 0.12            | -0.61          |

### Table 2. Details of the observations for the clusters Berkeley 69, King 7, King 5 and Berkeley 20.

| Cluster      | Filter | Exposure time (s) | Date        | Observing span (s) |
|--------------|--------|------------------|-------------|--------------------|
| Berkeley 69  | V      | $150 \times 086$ | 09 Dec. 1998| 12,900             |
|              |        | $150 \times 042$ | 25 Dec. 1998| 06300              |
| King 7       | V      | $150 \times 115$ | 19 Nov. 1998| 17,250             |
| King 5       | V      | $150 \times 085$ | 22 Oct. 1998| 12,750             |
| Berkeley 20  | V      | $150 \times 123$ | 10 Dec. 1998| 18450              |
|              | V      | $150 \times 130$ | 15 Dec. 1998| 19,500             |

2. Observations and data reduction

We have observed four clusters (Berkeley 69, King 7, King 5 and Berkeley 20) in the $V$ band for about 5–6 hours on six nights during October–December 1998 using a CCD camera mounted on 104-cm Sampurnanand reflector telescope of ARIES, Nainital. The CCD camera consists of $1024 \times 1024$ pixels with each pixel size of 24 $\mu$m. The field-of-view of the CCD is $\sim 6.0 \times 6.0$ arcmin$^2$, where each square pixel covers a $0.37 \times 0.37$ arcseconds$^2$ of the sky. The read-out noise and gain of the CCD are 7.0 e$^-$ and 11.98 e$^-$ per ADU, respectively. In order to improve the S/N ratio, the observations were taken in the binning mode of $2 \times 2$ pixels. All the observations have been taken in the $V$ filter with an exposure time of 150 s. The log of the observations are listed in Table 2. Bias and flat-field frames were also taken along with the science frames for pre-reduction processes. The standard process of image cleaning was employed using ESO-MIDAS software. The photometry of cleaned cluster images was done by using DAOPHOT package by Stetson (1987). Since we are using the differential magnitudes of the stars in the present analysis, we performed only aperture photometry. The identification charts for the clusters Berkeley 69, King 7, King 5 and Berkeley 20 are shown in Figure 1 and the variable stars identified by us are also shown by open circles.
Figure 1. The $R$ band $7' \times 7'$ image of the clusters (a) Berkeley 69, (b) King 7, (c) King 5 and (d) Berkeley 20 taken from DSS. Variable stars identified in the cluster region are encircled.

Figure 2. Proper motion vector-point diagram (upper panels) and $(G_{bp} - G_{rp})$, $G$ CMD (lower panels) for the clusters Berkeley 69 and King 7. Left panels show the complete sample of the cluster, middle panels shows most probable cluster members and right panels show the field stars. Green points represent the variable stars identified in our analysis.
3. Kinematical data and member selection

Proper motion of any star provides velocity in two orthogonal directions, which are used to determine the membership criteria of the star in a star cluster (Sagar and Bhatt 1989). The second data release of Gaia mission (Gaia DR2) provides five-parameter astrometric data and photometric data in three filters. The astrometric data contains celestial position, parallax and proper motion data of more than 1 billion sources (Gaia Collaboration et al. 2018b). We used Gaia proper motion and parallax data to select the cluster members and photometric data in $G$, $G_{bp}$ and $G_{rp}$ filters for isochrone fitting.

To separate cluster stars from field stars, we plotted the vector point diagrams (VPD) in $\mu_\alpha \cos \delta$ and $\mu_\delta$ in top panels of Figures 2 and 3 for the clusters Berkeley 69, King 7 and King 5. $G$ versus ($G_{bp} - G_{rp}$) colour–magnitude diagrams are plotted in the lower panels. The VPDs of these clusters show a compact distribution of stars as compared to the scattered stars. We also plotted VPD for the cluster Berkeley 20 but could not find a separation between field and cluster stars. This may be because the cluster is at a large distance ($\sim 8$ kpc). The left panels of the figures represent total stars in our sample, middle panels show the stars with similar proper motion and right panels show stars with different proper motion. We drew a circle around the eye estimated centre of the stars in VPDs to separate cluster members from field stars. The chosen radius is a compromise between losing cluster members with poor proper motion and including field region stars. The circle radii are taken as 0.4, 0.5 and 0.5 mas yr$^{-1}$ for Berkeley 69, King 5 and King 7 respectively. We selected the stars in different magnitude bins based on the proper motion error described in Gaia Collaboration et al. (2018a). We calculated the mean parallax of the member stars for each cluster. Mean parallax are found as $0.25 \pm 0.15, 0.28 \pm 0.12$ and $0.34 \pm 0.13$ mas for the clusters Berkeley 69, King 7 and King 7 respectively. Finally, we consider a star as a member if it lies inside the circle in the VPD and has a parallax within $3\sigma$ of the mean parallax of the cluster. The stars shown in the middle panels of the VPDs in Figures 2 and 3 lie inside the circle and have parallax within $3\sigma$ of the mean parallax. Selected members show a clear main sequence for all the clusters. Green points in these VPDs are the variable stars detected in the cluster fields which is discussed in Section 5. However, in the VPD of Berkeley 69, cluster stars are not clearly distinguishable from field stars and hence main-sequence includes field non-members also.

Mean proper motions in $\mu_\alpha \cos \delta$ and $\mu_\delta$ of the clusters Berkeley 69, King 7 and King 5 are calculated with the help of histograms, shown in Figure 4. For these histograms, we used the most probable stars selected with the help of VPDs. Mean and standard deviation in $\mu_\alpha \cos \delta$ and $\mu_\delta$ are calculated by fitting Gaussian

![Figure 3](Image)

**Figure 3.** Same as Figure 2, but for the cluster King 5.

![Figure 4](Image)

**Figure 4.** Histograms in $\mu_\alpha \cos \delta$ and $\mu_\delta$ for the clusters Berkeley 69, King 7 and King 5. The blue curve represents Gaussian fitting for the calculation of mean proper motion.
function on the histograms. From this fitting, the mean proper motions of the clusters are found as 0.73 ± 0.02 and −1.96 ± 0.01 mas for Berkeley 69, 1.11 ± 0.02 and −1.19 ± 0.01 mas yr\(^{-1}\) King 7 and −0.26 ± 0.01 and −1.18 ± 0.01 mas yr\(^{-1}\) for King 5 in RA and Dec directions respectively.

4. Fundamental parameters of Berkeley 69, King 7 and King 5

Fundamental parameters of the clusters Berkeley 69, King 7 and King 5 are reported in our previous studies (Durgapal et al. 1996, 1997, 1998, 2001). In the present analysis, we revisited the parameters using the most probable cluster members selected with the help of Gaia DR2 proper motion data. We have plotted \(G\) versus \((G_{bp} - G_{rp})\) CMDs of Berkeley 69, King 7 and King 5. We have also plotted \(V\) versus \((B - V)\) CMDs using common stars between most probable cluster members selected by VPDs and photometric data used in our previous papers for Berkeley 69, King 7 and King 5. The fitted isochrones are shown in Figure 5. For isochrone fitting, we tried to fit several isochrones given by Marigo et al. (2017) on the cluster CMDs. For Berkeley 69, we find that isochrones of \(Z = 0.008\) and age 0.79 ± 0.09 Gyr show good fitting. For King 7, isochrones of \(Z = 0.008\) and age 0.79 ± 0.09 Gyr are found to be satisfactorily fitted. For King 5, best-fitted isochrones are of \(Z = 0.02\) and age 1.59 ± 0.19 Gyr. The colour-excess \(E(B - V)\) and \(E(G_{bp} - G_{rp})\) for Berkeley 69 are found as 0.68 ± 0.03 and 1.05 ± 0.01 mag. For King 7 these are determined as 1.22 ± 0.03 and 1.70 ± 0.02 mag respectively. For King 5, these values are estimated as 0.63 ± 0.02 and 0.85 ± 0.01 mag respectively. We also determined the distances of these clusters using the distance modulus in \(G\) versus \((G_{bp} - G_{rp})\) plot as 2.53 ± 0.02, 2.07 ± 0.28 and 2.08 ± 0.02 kpc for the clusters Berkeley 69, King 7 and King 5 respectively. For interstellar extinction, we adopted the value \(A_G/E(G_{bp} - G_{rp}) = 1.89 ± 0.02\) given by Wang and Chen (2019). The values of age, colour-excess, distance and metallicity are in good agreement with our previously determined values. The estimated parameters are also listed in Table 3.

5. Variable stars in the direction of the clusters

Light curves of all the stars in the cluster region were examined to detect the variability. A star was considered variable if its light curve shows a significantly (more than 3σ) larger dispersion than for the comparison stars. A careful search indicates variability in a few stars in

![Figure 5](https://via.placeholder.com/150)

**Figure 5.** Isochrones by Marigo et al. (2017) of \(Z = 0.008\) and age 0.79 ± 0.09 Gyr, \(Z = 0.008\) and age 0.79 ± 0.09 Gyr, \(Z = 0.02\) and age 1.59 ± 0.19 Gyr are fitted on the \((G, G_{bp} - G_{rp})\) and \((V, B - V)\) CMDs for the clusters Berkeley 69, King 7 and King 5 respectively. The green dots denote the variable stars detected in the clusters and the red lines are the isochrones.

**Table 3.** Fundamental astrophysical and kinematical parameters of Berkeley 69, King 7 and King 5 determined in the present analysis, where \(d\) is the heliocentric distance of the clusters.

| Cluster     | \(\mu_\alpha \cos \delta\) | \(\mu_\delta\) | \(d\) | Age | \(E(B - V)\) | Z          |
|-------------|-----------------------------|----------------|------|-----|--------------|------------|
|             | mas yr\(^{-1}\)            | mas yr\(^{-1}\) | kpc  | Gyr | mag          |           |
| Berkeley 69 | 0.73 ± 0.02                 | −1.96 ± 0.01   | 2.53 ± 0.02 | 0.79 ± 0.09 | 0.68 ± 0.03 | 0.008      |
| King 7      | 1.11 ± 0.02                 | −1.19 ± 0.01   | 2.07 ± 0.28 | 0.79 ± 0.09 | 1.22 ± 0.03 | 0.008      |
| King 5      | −0.26 ± 0.01                | −1.18 ± 0.01   | 2.08 ± 0.02 | 1.59 ± 0.19 | 0.63 ± 0.02 | 0.02       |
3.55
3.6
3.65
3.7
3.75
0 0.4 0.8 1.2 1.6 2
ΔV
Phase
Be 69 (V4)

Figure 6. (a) Light curves of the variable stars in the cluster Berkeley 69. Difference of two comparisons (s2–s1) is also shown in the bottom panels. (b) Power spectra of the star V4 in the cluster Berkeley 69, and (c) folded light curves of the star V4 along with the best-fit sine curve.

2.35
2.4
2.45
0 0.6 1.2 1.8
ΔV
King 7 (V1)
esahPesahP
2.2
2.25
2.3
2.35
0 0.6 1.2 1.8
ΔV
King 7 (V2)
esahPesahP
2.25
2.34
2.43
2.52
0 0.6 1.2 1.8
ΔV
King 7 (V5)
esahPesahP
1.15
1.2
1.25
1.3
1.35
0 0.6 1.2 1.8
ΔV
King 7 (V6)
esahPesahP

Figure 7. (a) Light curves of the variable stars in the cluster King 7. Differential light curve of comparison stars is shown in the left bottom panel. (b) Power spectra of four stars V1, V2, V5 and V6 in the cluster King 7, and (c) folded light curves of the stars V1, V2, V5 and V6 along with the best-fit sine curve.

For each cluster, locations of these detected variable stars are also shown in the cluster identification chart in Figure 1, as well as in the CMD as shown in Figure 5. Since we did not have spectroscopic observations, we determined the suspected spectral class of the variables with the help of standard data (Gray 2005).

For each variable star in these clusters, the differential photometric magnitude were obtained by subtracting comparison from the variable. Light curves of these variable stars are shown in Figures 6a, 7a, 8a and 9a. The detailed information about these stars is given in Table 4. A total of 4 stars in the cluster Berkeley 69, 7 stars in the cluster King 7, 5 stars in the cluster King 5 and 3 stars in the cluster Berkeley 20 were found to be variable. In order to find the periodicity in these variables, we have performed a periodogram analysis by using the method of Lomb–Scargle periodogram (Lomb 1976; Scargle 1982).

5.1 Berkeley 69

Berkeley 69 was observed in two nights on 9 December and 25 December 1998. A total of four stars were found to be variable in this cluster. The light curves of these variable stars along with differential light curve of comparison stars are shown in Figure 6a. The average photometric error of the measurements as given by DAOPHOT is \( \sim 0.02 \) mag. All the stars which are detected as variables in the cluster Berkeley 69 showed irregular behaviour in their light variations. No periodicity was seen in the light curves of V1, V2 and V3.
2.1 Light curves

2.17 Power spectra

2.24 ΔV

2.31 Phase

2.38

2.45

ΔV

(a) Light curves

Figure 8. (a) Light curves of the variable stars in the cluster King 5. Differential light curve of comparison stars is shown in the left bottom panel. (b) Power spectra of the star V5 in the cluster King 5, and (c) folded light curves of the star V5 along with the best-fit sine curve.

(b) Power spectra

(c) Folded light curve

Figure 9. (a) Light curves of the variable stars in the cluster Berkeley 20. Differential light curve of comparison stars is shown in the bottom panels. (b) Power spectra of the stars V1 and V3 in the cluster Berkeley 20, and (c) folded light curves of the stars V1 and V3.

However, the star V4 was found to be a periodic variable. Figure 6b shows the power spectrum of the star V4, where the highest peak corresponds to a period of 0.225 days (or 5.4 hours). In order to check whether this period is a real period, we have folded the data using an arbitrary ephemeris and period of 0.225 days. Figure 6c shows the folded light curve of the stars V4 in the cluster Berkeley 69, where a clear signature of periodic variability was seen in this star. Further, a sine curve was also fitted in the folded light curve, which is shown by a curve in Figure 6c. The best-fit sine curve also indicates the period of this star as 0.225 days. The location of the star V4 on the VPD of the cluster indicates that this may be a field star with spectral type F0. Only V1 and V2 are cluster member stars because they have similar proper motion as the cluster stars. Locations of these variables in the ID chart are also shown by the green circles in Figure 1a.

5.2 King 7

Time series data of the cluster King 7 were taken in one night on 19 November 1998. The average photometric error was of the order of ~ 0.015 mag. Using a similar approach as mentioned above, we detected a total of seven variable stars in this cluster (see also Figure 1). The differential light curves of these seven variable stars are shown in Figure 7a along with the differential light curve of comparison star. Periodogram analysis was carried out for all seven variable stars. Out of seven, only four stars V1, V2, V5 and V6 were found to be periodic variable. Figure 7b shows the power spectra of these 4
| Star      | $\alpha$          | $\delta$          | $M_v$  | $(B - V)_0$ | Probable period (days) | Probable spect. class |
|-----------|-------------------|-------------------|--------|-------------|------------------------|----------------------|
| Berkeley 69 |                  |                   |        |             |                        |                      |
| V1*       | 05:24:23.83       | +32:38:24.86      | 3.95   | 0.27        | –                      | F0                   |
| V2*       | 05:24:25.17       | +32:38:16.34      | 3.15   | 0.34        | –                      | F2                   |
| V3        | 05:24:24.46       | +32:38:24.65      | 0.61   | 0.04        | –                      | A1                   |
| V4        | 05:24:20.64       | +32:37:07.17      | 3.96   | 0.24        | 0.225 ± 0.001          | F0                   |
| S2        | 05:24:28.04       | +32:37:13.43      | 0.43   | 0.82        | –                      | –                    |
| King 7    |                  |                   |        |             |                        |                      |
| V1*       | 03:59:04.64       | +51:46:58.44      | 1.27   | 0.04        | 0.13 ± 0.02            | A2                   |
| V2*       | 03:59:06.75       | +51:45:47.93      | 1.00   | 0.07        | 0.21 ± 0.05            | A3                   |
| V3        | 03:59:11.60       | +51:48:51.52      | 1.50   | 0.02        | –                      | A1                   |
| V4        | 03:59:28.07       | +51:49:40.42      | 0.79   | 0.71        | –                      | G0                   |
| V5*       | 03:59:08.88       | +51:47:25.47      | 1.58   | 0.13        | 0.13 ± 0.02            | A5                   |
| V6*       | 03:59:04.35       | +51:46:17.00      | 0.05   | 0.06        | 0.16 ± 0.03            | A2                   |
| V7        | 03:59:14.49       | +51:45:06.57      | 1.08   | 0.08        | –                      | A3                   |
| S2        | 03:59:09.51       | +51:45:36.54      | -1.26  | 0.94        | –                      | –                    |
| King 5    |                  |                   |        |             |                        |                      |
| V1        | 03:14:54.15       | +52:42:08.27      | 1.57   | 0.33        | –                      | –                    |
| V2        | 03:14:39.87       | +52:44:04.74      | 1.02   | 0.27        | –                      | –                    |
| V3*       | 03:14:30.55       | +52:41:35.53      | 1.17   | 0.24        | –                      | A8                   |
| V4*       | 03:14:42.38       | +52:40:02.41      | 0.84   | 0.19        | –                      | A7                   |
| V5*       | 03:14:27.76       | +52:40:50.81      | 2.07   | 0.04        | 0.15 ± 0.04            | A2                   |
| S2        | 03:14:46.00       | +52:41:21.80      | -0.18  | 0.92        | –                      | –                    |
| Berkeley 20 |                |                   |        |             |                        |                      |
| V1        | 05:32:38.45       | +00:11:36.23      | 3.28   | 0.62        | 0.386 ± 0.002          | G0                   |
| V2        | 05:32:36.80       | +00:14:13.76      | 3.31   | 0.75        | –                      | G2                   |
| V3        | 05:32:35.82       | +00:11:19.74      | 2.26   | 0.58        | 0.438 ± 0.002          | G0                   |
| S2        | 05:32:33.63       | +00:12:33.39      | 0.63   | 0.97        | –                      | –                    |

* Cluster member.

5.3 King 5

The cluster King 5 was also observed for one night on 22 October 1998. The photometric error in determining the magnitude of these stars was ~ 0.015 mag. Our variability analysis revealed the variability in five stars of this cluster. Light curves of these variable stars are shown in Figure 8a. A periodogram analysis was performed to search the periodicity in these detected variables. We could not find variability period in any one of these variable stars. This could be due to their incomplete light curve, which is also evident from Figure 8a. However, the star V5 shows almost one cycle of observation, for which the highest peak in the power spectra showed a period of ~ 0.15 days (see Figure 8b). Folded light curve of the star V5 is shown in Figure 8c, where the continuous line curve shows the best-fit sine function. The best-fit sine curve also indicates that the period of the star V5 ~ 0.15 days. The amplitude of variability ~ 0.15 mag, period of 0.15 days (~ 3.6 hr) and variables, where the highest peak in the power spectra show the period in the range of 0.13 to 0.21 days for these four stars (see Table 4). To confirm the observed periodicity, we have folded the light curves of all four variables using an arbitrary ephemeris and the periods as mentioned in Table 4. Figure 7c shows the folded light curves of these variables along with the best-fit sine curve with the derived periods. Spectral type of the all four periodic variable stars is estimated to be early A-type. The amplitude of variability ranges from 0.05 to 0.2 mag. Their periods, amplitude of variability and spectral type indicate that these are probable candidates of $\delta$-Scuti type variables (see Breger 2000). Further, all these four stars were found to be members of the cluster King 7. These periodic variables are shown by green dots in the VPD and CMD in Figure 2. Other three stars V3, V4 and V7 are found to be non-members and the periodicity in these stars could not be found due to lack of long-term data. Locations of all the seven variables in the ID chart are shown in Figure 1b.
spectral type of A2 indicate that it is probably a $\delta$ Scuti type variable.

5.4 Berkeley 20

Time series observations of this cluster were taken in two nights with an interval of five days on 10 December 1998 and 15 December 1998. The average photometric error as given by DAOPHOT was $\sim$ 0.012 mag. Using a similar approach as mentioned above in Section 5.1, a total of three variable stars were identified in this cluster. Locations of these variable stars are also marked in Figure 1d, whereas Figure 9a shows their light curve along with the light curve of the comparison star. Periodogram analysis was carried out for all the variable stars detected in the cluster Berkeley 20. No significant peak was found for the star V2 in the power spectra, whereas for the star V1 and V3 significant peaks at periods of 0.193 and 0.219 days were found in their respective power spectra as shown in Figure 9b. Spectral types of these two variable stars were estimated as of G-type indicating these variables to be W UMa-type binary. Power spectra of W UMa type binaries show the peak power at half of its original frequency due to the fact that they consist of two minima in one cycle of their light curves. Therefore, the period of the stars V1 and V3 were estimated as 0.386 and 0.438 days, respectively. Light curve of the star V1 was folded using the ephemeris HJD = 2451158.391+0.396 E, whereas for the star V3, we have used the ephemeris JD = 2451163.298 + 0.438 E. The JD corresponding to a phase zero was determined by fitting the second-order polynomial to the minimum observed. Figure 9c shows the folded light curves of both the stars. The amplitude (minimum–maximum) of variation was found to be $\sim$ 0.3 mag for each V1 and V3. The current analysis suggests that the stars V1 and V3 in the cluster Berkeley 20 show the variability of W UMa type binaries.

Figure 10 shows the composite $M_V$, $(B-V)_0$ CMD of the clusters with detected variable stars. $\delta$ Scuti instability strip and isochrones of different ages given by Marigo et al. (2017) are also plotted in the figure. Two out of four variables detected in King 5 within instability strip show light curves comparable to the $\delta$ Scuti star. On the other hand, one star of Be 69 and one star of King 5 and five stars of King 7 are lying near the $\delta$ Scuti instability strip. Based on the position of the variable stars in the CMD, their suspected spectral class and their period, we can say that a few of them may be $\delta$ Scuti stars.

6. Mass segregation

Various studies in the literature have shown that massive stars are located towards the center of the cluster as compared to the less massive stars. This configuration may be due to the star formation processes or due to the dynamical evolution in the cluster. We study the mass segregation by assuming the cluster members
selected in this study. We divided the stars in different mass range and plotted the cumulative distribution as shown in Figure 11. This figure shows that mass segregation is present in the clusters King 7 and King 5. We also performed the Kolmogorov–Smirnov (KS) test to check whether these curves belong to the same population or not. We found that in the case of King 7 and King 5, the curves belong to the different population with a confidence level of 99 and 95% respectively whereas for Berkeley 69 the confidence level is just 30%. This shows that King 7 and King 5 have been influenced by mass segregation.

7. Conclusions

We have carried out time series photometry of the four clusters Berkeley 69, King 7, King 5 and Berkeley 20. A total of 19 variable stars (4 in Berkeley 69, 7 in King 7, 5 in King 5 and 3 in Berkeley 20) are identified in these clusters. Periodogram analysis of these variable stars showed the periodicity in eight of them with the period range of 0.13–0.43 days. In the other eleven stars, we could not find the periodicity due to the lack of sufficient data. Four stars in the cluster King 7 and one star in the cluster King 5 showed δ Scuti type of variability, whereas two stars in the cluster Berkeley 20 have shown W UMa type of the variability. We believe that this preliminary identification of new variable stars in these four clusters will help for further observations that could give more detailed properties of these variables. The mass segregation is observed in King 7 and King 5 clusters.

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