SUMMER 2002 PHOTOMETRIC MULTISITE CAMPAIGN ON THE OPEN CLUSTER NGC 6633

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Abstract

NGC 6633 is a solar metallicity, young open cluster. In addition to providing useful information from an asteroseismic point of view, it has the additional attractiveness of being located in the potential field of view of the COROT space mission (indeed, it is currently included in the primary target selection list). We report on some preliminary results from a multisite photometric monitoring campaign intended to search for variability in NGC 6633. The detection of δ Scuti stars is a determining factor in the choice of this open cluster as target of the COROT Seismology program. We report the detection of new δ Scuti stars together with other types of pulsating variables (γ Doradus, SPB, Ap stars, etc.) and some binary systems.

Key words: Stars: variables – open clusters and associations: NGC 6633 – techniques: photometric

1. Introduction

Over the past two years important efforts have been devoted to the selection the most interesting and suitable targets for the space mission COROT (COnvection, ROtation and planetary Transits; Baglin et al. 2002). Potential targets for the seismological program are B and A-F pulsating stars found in the two possible COROT observing zones. These zones are centered at $\alpha = 18^{\rm h}50^{\rm m}$, $\delta = 0^{\circ}$ (galactic center direction) and $\alpha = 6^{\rm h}50^{\rm m}$, $\delta = 0^{\circ}$ (galactic anticenter direction), and both have a semi-aperture of 10°. At least ten primary targets ($V < 6$) will be observed during the five long runs. Their positions in the Seismology camera will depend on the secondary targets ($V < 9$) selected around each primary target. A complete description of the selected stars together with their main characteristics and positions on the sky are reported by Poretti et al. (2003). The ground-based photometric observations of the open cluster NGC 6633 presented here form part of the preparatory work for COROT field selection. The multisite campaign carried out in summer 2002 was designed to confirm existing candidate pulsating stars and to search for new variability in A–F stars located in or close to the cluster, as well as to perform a new photometric survey in order to complete previous works (Sanders 1973; Jeffries 1997; Jeffries et al. 2002).

2. Motivation

At the beginning of 2002, we saw the possibility of including an open cluster within the target list of the COROT mission. From a seismological point of view, the study of pulsating stars belonging to the same cluster provides supplementary information with respect to field objects. Considering that NGC 6633 ($\alpha = 18^{\rm h}27^{\rm m}$, $\delta = +06^{\circ}34'$) is located in the COROT visibility zone in the galactic center direction and close to the δ Scuti stars HD 170782 and HD 170699, the cluster (or part of it) might be observed in the COROT seismology CCD. With $\log age = 8.63$, $E(B-V) = 0.18$ and $(V-M_V)_0 = 7.77$, this cluster has its turn-off point above the blue edge of the instability strip and several A stars below the turn-off. Suárez (2002) elaborated a list of bright cluster members ($V < 9.5$) which were possible candidate δ Scuti stars and carried out a study on the feasibility of photometrically monitoring the cluster. NGC 6633 was found to present the necessary requirements for being observed by the satellite.

Previously to this campaign, during systematic observations of NGC 6633 in the Strömgren photometric system, two γ Doradus candidate stars were found[1]: HD 169577 (NGC 6633 15) and NGC 6633 275 (Martín & Rodríguez 2002). Several other stars showed signs of variability both on long and short time scales (Martín 2000) but it was not possible to confirm their nature. This was yet another good reason to observe this open cluster again.

3. Observing strategy

The multisite observing campaign consisted of two parallel programs, carried out simultaneously depending on the type of instrument used.

[1] The numbering system of Kopff (1943) is used.

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The first program consisted in observing the whole open cluster using CCD systems in order to search for variability, specially in the A-F type cluster members. An observing area of $1.6 \times 1.6\,^{\circ}$ centered on ($\alpha = 18^{\rm h}28^{\rm m}20^{\rm s}$, $\delta = +06\,^{\circ}35\,'23\,''$) was covered, embracing all the objects of interest. Observing times were chosen to achieve a S/N ratio better than 100 down to $V = 13$ (Johnson system).

The second program consisted in obtaining multi- and single-colour photoelectric photometry for the γ Doradus candidates HD 169577 and NGC 6633 275, and for other possible variable stars with $10 < V < 12$. The number of observed objects as well as the magnitude limit attained depended on the size of the telescope(s) used at each observatory. In order to achieve a high precision, the data were reduced by means of differential photometry. Therefore, we two comparison stars were included in the observing sequence: C1 = NGC 6633 92 and C2 = NGC 6633 125, which were found to be constant during previous campaigns.

4. Observatories

Seven observatories participated in our campaign in summer 2002 during the months of July and August. The telescopes, instruments and dates were the following:

1. At the Observatorio de Sierra Nevada (OSN – Granada, Spain), a multi-channel photometer attached to the 0.9 m telescope was used to monitor the candidate variables and the A star list proposed by Suárez in the $uvby\beta$ bands of the Strömgren-Crawford photometric system. A CCD camera (with a FOV of 7×7 arcmin) attached to the 1.5 m telescope was also used in combination with Johnson B and V filters. In spite of the small FOV, multiple cyclical exposures of $0.6 \times 0.6\,^{\circ}$ per night were performed covering a total area of $1.2 \times 1.2\,^{\circ}$. The observing nights for both telescopes were 1–17 July.
2. At the Observatorio el Teide (Tenerife, Spain), a CCD camera (with a FOV of $6.1 \times 6.1\,^{\circ}$) attached to the 9.9 cm STARE telescope was used to monitor the whole cluster in the Johnson V filter during the nights of 13, 15 and 16 July.
3. At Siding Spring Observatory (Australia), a CCD camera (with a FOV of $2 \times 3\,^{\circ}$) connected to the 0.5 m Automated Patrol Telescope (APT) was used to monitor the whole cluster in the Johnson V filter during five nights in July and seven in August.
4. At Bohyunsan Optical Astronomy Observatory (Korea), a 2k CCD camera (with a FOV of 11.6×11.6 arcmin) was used in conjunction with the Johnson B and V filters. As in the case of the Observatorio de Sierra Nevada, 25 sub-frames were necessary to cover the whole cluster. The weather during the observations was not very good and only few hours during three nights in June yielded useful measurements.
5. At the Seoul National University Observatory (SNUO – Seoul, Korea), a CCD camera (with a FOV of 19.5×19.5 arcmin) attached to the 61 cm telescope was used to monitor the two γ Doradus candidates and comparison stars in the Johnson V filter during four nights in July. The observations were dominated by clouds and bad weather.
6. At Ege University Observatory (EUO – Izmir, Turkey), a photoelectric photometer was used to monitor the brightest program star of the list, HD 169577, together with the check stars, in the Johnson B and V filters, during two nights in July and four nights in August.

Another telescope located at West Mountain Observatory (Utah, USA), which was intended to join this campaign, was not able to because of some technical problems in the CCD camera.

5. Preliminary results

Reduction and analysis of our data are currently in progress. Nevertheless, we are able to present some interesting preliminary results.

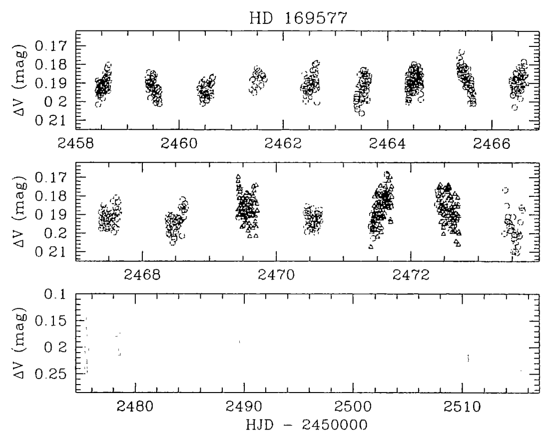

Figure 1. Light curve of HD 169577 (NGC 6633 15): OSN (circles), STARE (triangles) and EUO (squares). Due to the low S/N ratio for the last dataset, a different scale was used.

Membership was established using the BDA database developed by Mermilliod (1995), Sanders (1973) and Hiltner et al. (1958). The differential light curves for all stars were calculated with respect to the same comparison star C1 = NGC 6633 92. The first results confirm the multiperiodicity of the γ Doradus stars HD 169577 and NGC 6633 275 (see Figs. 1 and 2). These results also allowed us to discover new variable stars: seven objects brighter than $V = 9.5$ were found to be variable in our sample. Two of them are the cluster members HD 169842 (NGC 6633 39;

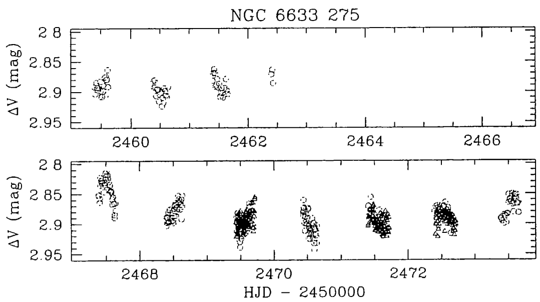

Figure 2. Light curve of NGC 6633 275: OSN (circles) and STARE (triangles).

Catalano & Renson 1998) and HD 169959 (NGC 6633 58), which show Ap type variability. Frequency analyses were performed on these variables for all four *uvby* bands. The corresponding phase diagrams for both stars are presented in Figs. 3 and 4 respectively. The remaining objects probably do not belong to the cluster. In addition to the well-known HD 169577, we detected the δ Scuti star BD+06 3737 (NGC 6633 8), the two long period variables HD 169597 (NGC 6633 16) and HD 170412 (NGC 6633 139), and the W UMa eclipsing system HD 170451 (NGC 6633 147, NVS 10892; Koppelman et al. 2002). Fig. 5 shows the light curves for the stars BD+06 3737 and HD 170451.

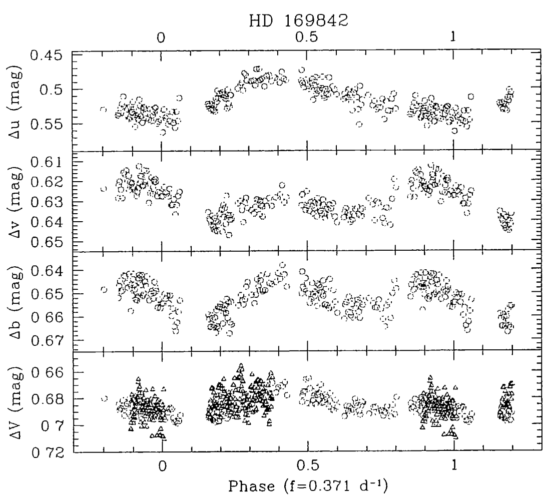

Figure 3. Phase diagrams for HD 169842 (NGC 6633 39) in uvbV: OSN (circles) and STARE (triangles). The frequency is 0.371 d^{-1}.

In the case of objects fainter than $V = 9.5$ the short period variability increases and six out of eight variable stars

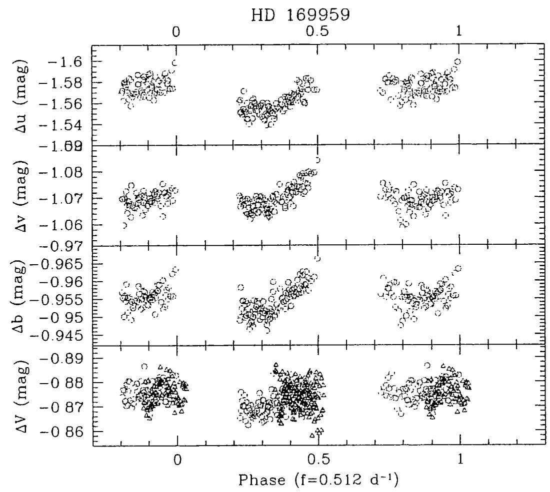

Figure 4. Phase diagrams for HD 169959 (NGC 6633 58) in uvbV: OSN (circles) and STARE (triangles). The frequency is 0.512 d^{-1}.

belong to NGC 6633. Among these objects, in addition to the γ Doradus star NGC 6633 275, we detected a possible long period variable BD+06 7348 (NGC 6633 31). The short period group is represented by two δ Scuti stars, NGC 6633 89 and BD+06 3803 (NGC 6633 131). Besides these pulsating variables, the final part of an eclipse was detected in BD+06 3802 (NGC 6633 132). The number of short period variables is higher if we take into account the faint possible non-members NGC 6633 14 and NGC 6633 108 (see Figs. 6 and 7).

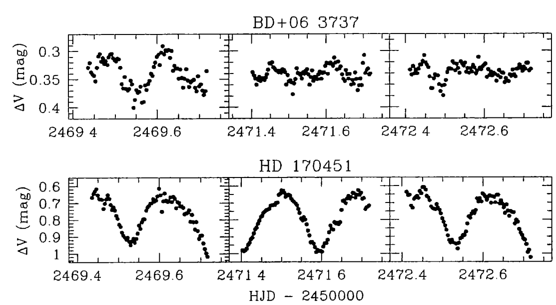

Figure 5. Light curves for BD+06 3737 (NGC 6633 8) and HD 170451 (NGC 6633 147): STARE data.

Figs. 8 shows a colour-magnitude diagram of the field, indicating all variable stars detected. The isochrone shown, corresponding to log(age) = 8.63, was calculated using the models of Claret (1995) for stars with $(X, Y, Z) =$

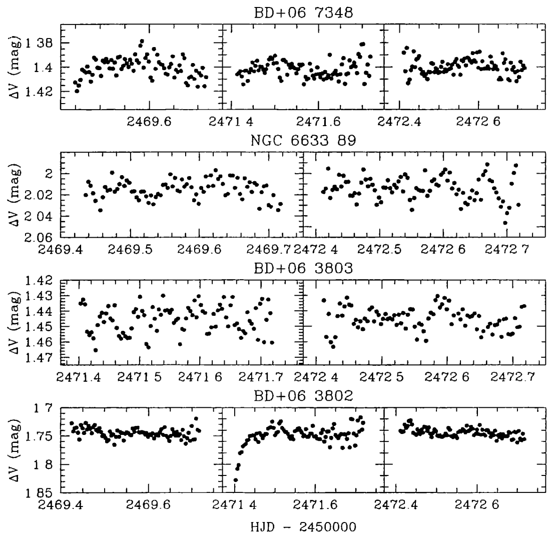

Figure 6. Light curves for BD+06 7348 (NGC 6633 31), NGC 6633 89, BD+06 3803 (NGC 6633 131) and BD+06 3802 (NGC 6633 132): STARE data.

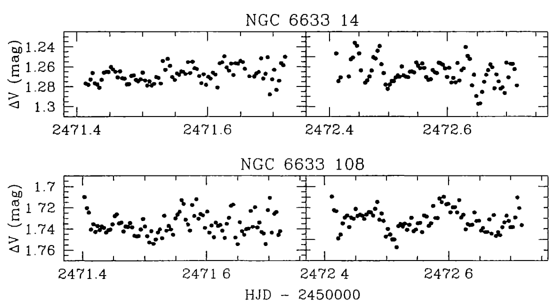

Figure 7. Light curves for NGC 6633 14 and NGC 6633 108: STARE data.

$(0.70, 0.28, 0.02)$, $\alpha_{\rm ov} = 0.20$ and $\alpha = l/H_{\rm p} = 1.52$. The V and $B-V$ values used to fit the isochrones on the diagram were taken from the WEBDA data base (Mermilliod 1995). At the age and distance modulus of the cluster, the magnitude range $9.5 \leq V \leq 11.5$ fall into the lower part of the instability strip.

6. Conclusions

These results allowed us to construct preliminary statistics. To date, we have examined 192 objects in the field of NGC 6633. Out of the 60 stars with the $V < 12$ catalogued as belonging to the cluster, 12 % were found to be clearly variable, rising to 40 % if the suspected cases are included. If we restrict ourselves to the members situated on the lower part of the instability strip, the fraction of variable stars changes from 12 % to 20 %. Clearly, the rise in the incidence of variability is due to a higher number of bright stars in the sample, and therefore to the reliability of the results. The percentage of variable stars at fainter magnitudes is clearly biased by the loss of photometric precision. The reduction of all remaining data will provide a definitive analysis of stellar variability in NGC 6633. A detailed description of the reduction techniques employed, the final number of variable objects and, if applicable, their frequencies, will be published as soon as possible in a forthcoming paper.

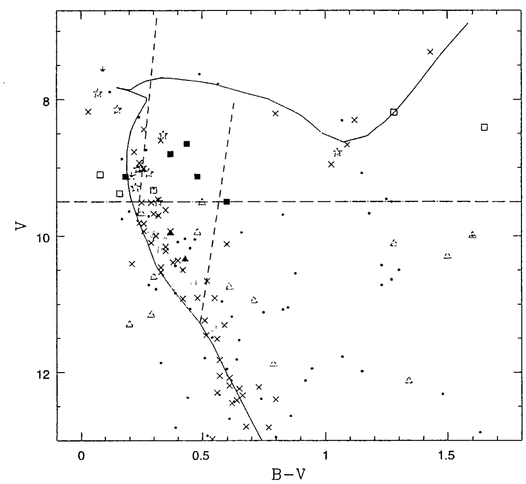

Figure 8. The variable stars on the CMD. Solid stars: variable members with $V < 9.5$. Open stars: suspected variable members with $V < 9.5$. Solid squares: variable non-members with $V < 9.5$. Open squares: suspected variable non-members with $V < 9.5$. Solid circles: variable members with $V > 9.5$. Open circles: suspected variable members with $V > 9.5$. Solid triangles: variable non-members with $V > 9.5$. Open triangles: suspected variable non-members with $V > 9.5$. Crosses: constant members. Dots: constant non-members.

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