Four Color Photometry of the Young Open Cluster Collinder 140

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Abstract:
Cluster member candidates of the young open cluster Collinder 140 are selected by means of four–colour \textit{BV(RI)_C} CCD photometry. We show that a reasonably small number of candidates can be separated from the background field contamination even with non–photometric data by matching the red clump of background stars in the colour–magnitude diagrams to the one expected towards this sky region.

1. Introduction
Within the framework of a study of angular momentum evolution in young low–mass stars, we are photometrically identifying low–mass members of open clusters of a range of ages for follow–up spectroscopy. Among the clusters under study are IC 2391 (age = 36 Myr, Rolleston & Byrne, A&AS, in press), Stock 2 (age = 100 Myr, Foster et al., A&AS in prep., and 1998 in this proceedings) and, in this paper, Collinder 140 (age = 21 Myr, Claria & Rosennzweig 1978).

The general problem is that the cluster field is highly contaminated by both background and foreground objects because of its low galactic latitude ($b = -8^\circ$), especially for the faint low–mass stars. Cluster members can be identified in an effective way:

1. Through their common proper motions differing from background stars (Foster et al. 1998);
2. By comparing colour magnitude diagrams (CMDs) with isochrones of the known cluster age.

2. Observations
More than 100 CCD frames have been taken to cover a field of approximately 0.05 square degrees centered on the open cluster Col 140 ($\alpha = 7^h22^m$, $\delta = -31^\circ56'$, 1950) at the South African Astronomical Observatory (SAAO) 1m telescope, equipped with a TEK $512 \times 512$ pixel CCD, in late December 1994. The data reduction has been performed using DAOPHOT (Davis 1994) under

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IRAQ (Tody 1986). Unfortunately, it turned out that the weather conditions, though clear, were not good enough to reliably calibrate the data to the standard system. Extinction changed from day to day, extreme values in V being 0.1 and 0.5. However, we found a way to achieve a reasonably good calibration for the purpose of identifying probable cluster members for follow-up spectroscopy.

The mean color transformation equations of the instruments used are known and thus applied as constant values in the calibration. The resulting extinction coefficients are not very accurate, and the zero points cannot be determined accurately. We can however make use of the background objects to make an effective calibration.

3. Remedy for the Calibration Problem

The open cluster IC 2391 (Rolleston & Byrne, A&A in press) is situated at a similar galactic latitude to Col 140 (IC 2391: $b = -6.8$, Col 140: $b = -8.0$), and the reddening towards both clusters is very similar ($E_{B-V} = 0.04$ and 0.05, respectively). Therefore, we expect that the clump of red faint background stars in the CMDs of both cluster fields are very similar. We can determine zeropoints for the Col 140 photometry in such a way that the red clump matches that of IC 2391 photometry as well as possible (Fig. 1). In practice, this has been done by cross-correlating the number density distribution of stars in the color magnitude plane, resulting in a shift in color and magnitude to the final calibration. This procedure has been carried out for each observing night individually, accounting for the different quality of the nights.

The procedure described above is demonstrated in Fig. 1 which shows contour plots of the number density distribution in the color magnitude planes of IC 2391 (calibrated data, solid contours) and Col 140 (uncalibrated data, dashed contours). Constant values added to $V, B-V, R,$ and $R-I$ (indicated by arrows in Fig. 1) of the Col 140 photometry yields in calibrated photometry, and the density distribution of ‘clump’ stars will match.

4. Results

The resulting CMDs are shown in Fig. 2. Overplotted are isochrones of the cluster age (20 Myr, solid lines) and a younger and older isochrone (7 and 40 Myr, dashed lines), assuming a generously high uncertainty in cluster age. Errors in distance modulus ($V - M_V = 7.78 \pm 0.1$) and reddening ($E_{B-V} = 0.05^{+0.03}_{-0.02}$, both values from Claria & Rosenzweig (1978)) are applied in such a way that the isochrones are shifted to extreme positions, allowing as many member candidates to be selected as possible. Diamonds denote $\approx 200$ stars found as such. They are defined as stars which lie between the youngest and oldest isochrone in both the $B, B-V, R, R-I$ CMDs, or close to them according to errors in photometry (internal + calibration) and the possibility of binarity (shifting the upper brightness limits in V and R by 0.8 mag, corresponding to an unresolved, slightly more massive companion; Dabrowski & Beardsley 1977). This member candidate list is obviously still contaminated by background stars, especially at $0.7 \leq B - V \leq 1.5$, $0.5 \leq R - I \leq 0.9$ (above the red clump of background
Figure 1. Contour plots of the number density distribution in the color magnitude planes of IC 2391 (calibrated data, solid contours) and Col 140 (uncalibrated data, dashed contours). Contour levels are 90%, 80%, and 50% of maximum. Most of the stars ($\approx 2700$, compared to $\approx 200$ cluster member candidates) are background stars forming the 'clump' in the CMD as seen here. Constant values are added to $V$, $B-V$, $R$, and $R-I$ in such a way that the red background clump of Col 140 matches the one of IC 2391 (indicated here by arrows). This results in calibrated CMDs for Col 140 as shown in Fig. 2.
Figure 2. Color magnitude diagrams of Col 140. Overplotted are isochrones of the cluster age (20 Myr, solid lines) and a younger and older isochrone (7 and 40 Myr, dashed lines). Diamonds denote \( \approx \) 200 stars found as cluster member candidates, to be confirmed by low resolution spectroscopy. For details see text.
stars), but now small enough to be verified by means of low resolution multi-
object spectroscopy.

Some stars have been observed twice on overlapping CCD frames. The results are compared in Fig. 3, where the half difference of two measurements in $V$, $B - V$, $R$, and $R - I$ is plotted against $V$ or $R$ (upper plots). The mean scatter in this diagram is used as an internal calibration error in the cluster member selection process described above.

Internal photometric errors are illustrated on the lower plots in Fig. 3. The errors increase at different magnitudes due to differences in seeing in each night.

References

Tody, D. 1986, IRAF User Manual, NOAO Laboratory