Photometric Study of 4 Open Clusters in the Second Quadrant:

NGC 7245, King 9, King 13 and IC 166

Introduction:

Open clusters are defined as group of stars believed to be formed from the same parent molecular cloud hence these stars of any clusters are located at same distance as well the stars will have the same age. In principal the basic parameters, like age, distance, reddening, elemental and chemical abundances etc. can be determined for an open cluster more accurately than for a single star.

Open cluster are the best testing grounds for stellar evolutionary theories. The open clusters are the galactic plane/disk objects and properties of the clusters are good tracers for the galactic structure and to estimate the radial gradient of chemical abundance in the Galactic disk.

Data on Observations:

In context of galactic studies based on open clusters one needs to improve the knowledge of numbers of open clusters observed. Trumpler (1930) compiled the first data set on Open clusters based on their visual appearances in the sky and classified as Trumpler Classes of these cluster.

Janes & Adler (1982) and Lynga (1983) made efforts to bring together all observational data on most comprehensive way and Lund Catalogue of Open cluster was compiled having data for about 1200 clusters.

More recently Dias et al. (2002, 2004, http://www.astro.iag.usp.br/~wilton/) and WEBDA have made data available online for approx. 1700 open clusters.

Although these all studies present an important step in our understanding of general properties of the cluster populations, but they suffer from incompleteness of the cluster samples and from inhomogeneity of the cluster parameters.

During all these years considerable improvements have been made for the new and homogeneous observations which could be used for the determination of basic cluster parameters and for a systematic approach to confirm the probable clusters as designated by above catalogues.

HCT OBSERVATIONS:

Looking in same directions, we have also started a long term project to obtain UBV CCD photometry of open clusters which have little been studied before using the 2-M HCT telescope.

The primary aim of this project is to make a homogeneous data set of open clusters:

1. which were not well studied before with the CCD systems as well
2. the other group of stars identified as clusters for which, we have none of the information on physical parameters.

The high altitude location of HCT, it is very ideal for observations in the U passband, since the extinction in this band is considerably low as well in B and V passbands.

Thus, we have taken this project to create a database of CCD photometric UBV data of stars in the open clusters. The data can be used to estimate reddening and distances more accurately for considerably faint stars. The data thus obtained will be homogeneous, as the telescope as well as the reduction methods are same. Such data is ideal for any stellar evolutionary studies and to group the open clusters according to their properties in reference of the galactic structure.

In this series of observations we have come to present our first set of data on open clusters, NGC 7245, King 9, King 13 and IC166. These are observed from 2-M HCT during Sept. 2003.

These four clusters are located between l=100-130 deg, in the second quadrant. These clusters are found to be embedded in rich galactic field.

NGC 7245	22:15:11, +54:20:36	101.368, -1.852	0.60mag 0.47mag 0.40mag	1925pc 2106pc 2800pc	- 176Myr 320Myr	RGU photometry (Yilmaz, 1970). WEBDA, private commn. UBV photographic obs. Karaali (1971) and DeGiocia-Eastwood (1992). BV CCD obs. Viskum et al (1971).
King 9	22:15:30, +54:20:00	101.439, -1.831	-	-	-	Uncalibrated VI photom. Phelps et al. (1994).
King 13	00:10:06, +61:10:00	117.968, -1.306	-	-	1730pc	Marx & Lehman (1979) UBV Photographic obs
IC 166	01:52:30, +61:50:00	130.071, -1.189	0.80mag 1.050ma 0.50mag	3300pc 3970pc 4500pc	- 430Myr 1Gyr	Photographic. Obs. Burkhead (1969) WEBDA IR Obs. Veenari et al (2000).

Observations: The clusters are observed on September 18-19, 2003 with 2-M HCT with HFOSC. The CCD central area of 2kX2k we used for observations. The pixel size is 15micron and plate scale is 0.296are-sec/pix. NGC 7245 and King 9 area is imaged in same frame only. Log of observations is given below:

Cluster	Date of observations	Filter	Exp. Times in sec.
NGC 7245/King 9	Sept. 19, 2003	V B U	1,10,60,120 10,20,300 60,300X2
IC 166	Sept. 19, 2003	V B U	10,60,120 30,180,300 180,600
King 13	Sept. 18, 2003	V B U	5,30,20 10,60,300 180,600

The nights were photometric and Landolt standards were used for photometric calibrations. Initial CCD reductions were carried out using IRAF and magnitude estimation and calibrations were done using the DAOPHOT-II. The transformation equations are given below.

$$V = v + 0.725 - 0.060(B-V) + 0.094X$$

$$B = b + 1.190 + 0.049(B-V) + 0.180X$$

$$U = u + 3.447 - 0.097(U-B) + 0.327X$$

The zero point errors are 0.010, 0.013 and 0.018 magnitudes in V,B and U respectively.

NGC 7245:

Central cluster region region of 2-3 arc-min.
Field region is defined as region close to the periphery of the cluster region

King 9:

Cluster region right below faint and condensed.

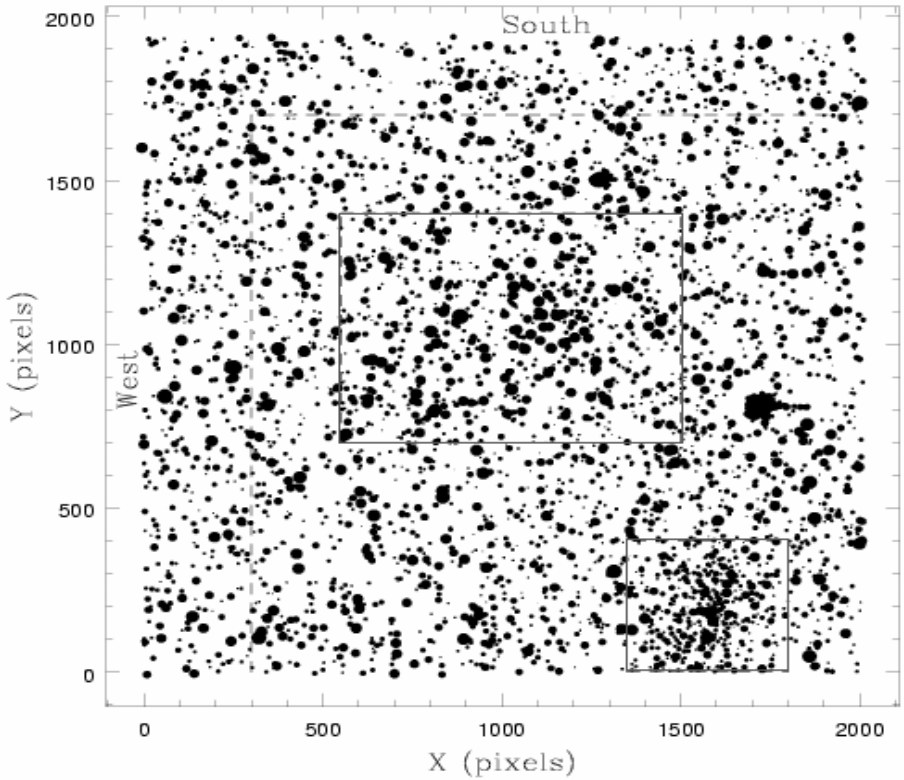


Figure 1. The observed region of the cluster NGC 7245. North is down and East is to the right. The cluster area considered is shown in the center. The location of King 9 is also shown in the lower right side of the figure. The field region considered as control field is shown on the top and left side of the figure.

Color-magnitude diagram (CMD) for cluster region and field region.

Cluster region shows a well defined MS. Therefore, existence of a cluster in the region of NGC 7245 is clearly evident.

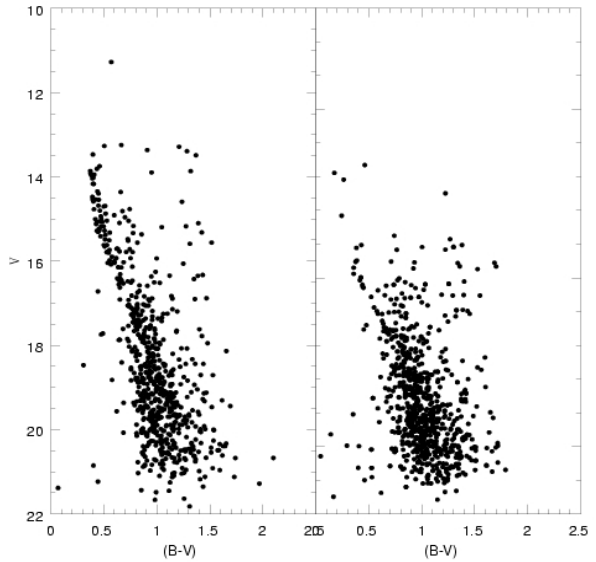


Figure 2. The CMDs of the cluster (left) and the field region (right) of NGC 7245.

Color-Color diagram (CCD) (U-B) v/s (B-V)

Best fit gives E(B-V) = 0.45 mag

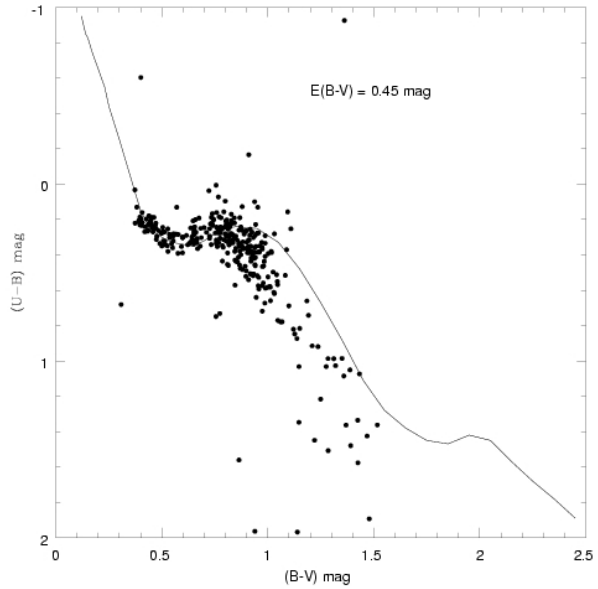


Figure 3. Estimation of reddening towards NGC 7245 using the (U−B) vs (B−V) diagram. The estimated value is also shown.

1. Contribution of field stars in the CMD removed identifying by using the ZAPPING method.

2. The corrected CMD is plotted with most probable cluster members.

3. ZAMS of Bertelli (1994) (V-Mv) = 12.9±0.1 mag estimates distance = 3800±170pc

4. Isochrones of Bertelli et al. (1994) for solar metallicity estimates, age=400Myr.

5. Binary Isochrones also plotted. Good population of Binary stars.

6. Strong indication of a MS gap at (B-V) = 0.7 mag corresponds to the Bohm-Vitense gap at (B-V)o = 0.25 mag

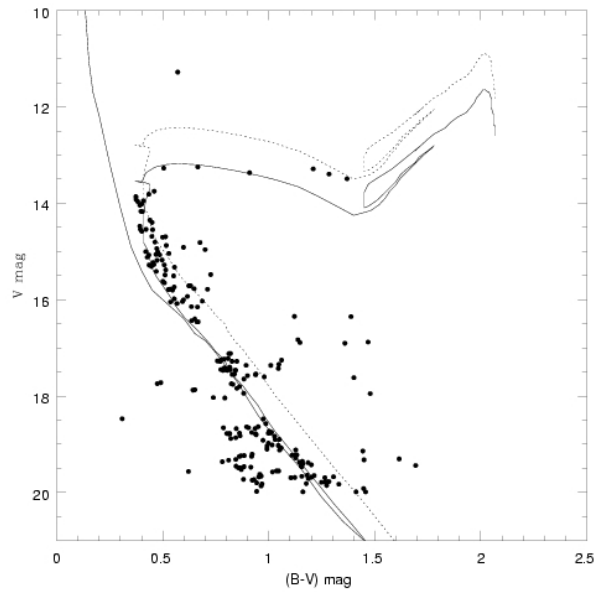


Figure 4. The field subtracted CMD of NGC 7245 is used to estimate the turn-off age using the isochrones. The ZAMS is also over plotted on the CMDs. The isochrone shown in continuous line is for an age of 400 Myr (log τ = 8.6) and the dotted isochrone corresponds to the location of binary stars with mass ratio equal to 1.

Color-magnitude diagram (CMD) for cluster region and field region.

Cluster region shows a well defined MS. Therefore, existence of a cluster in the region of King 9 is clearly evident

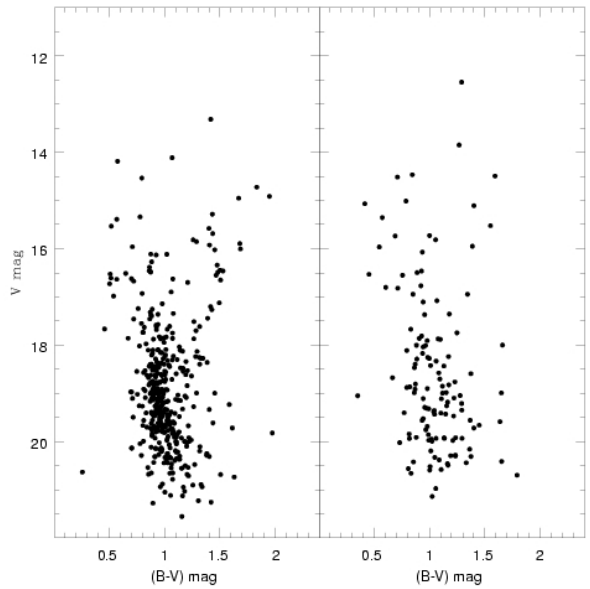


Figure 5. The CMD of the cluster region (left) and field region (right) of King 9.

Color-Color diagram (CCD) (U-B) v/s (B-V)

Best fit gives E(B-V) = 0.42 mag

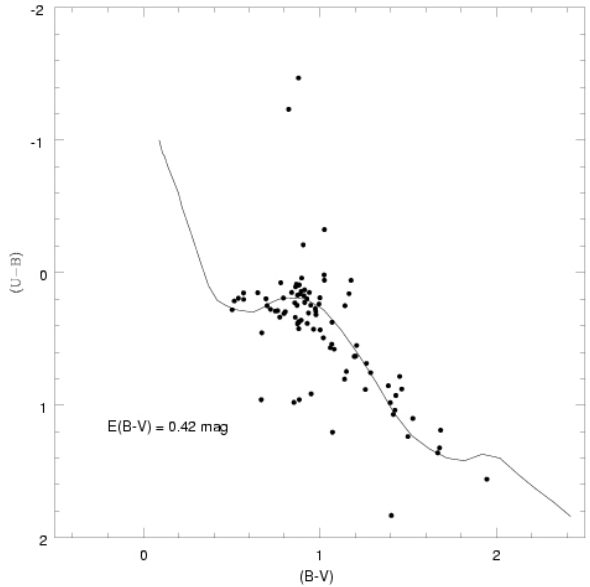


Figure 6. King 9 - reddening

ZAMS fit to a distance = 7.6kpc

Isochrones of Bertelli et al. (1994) for solar metallicity, age=2Gyr. Isochrones for binary is shown by dotted line

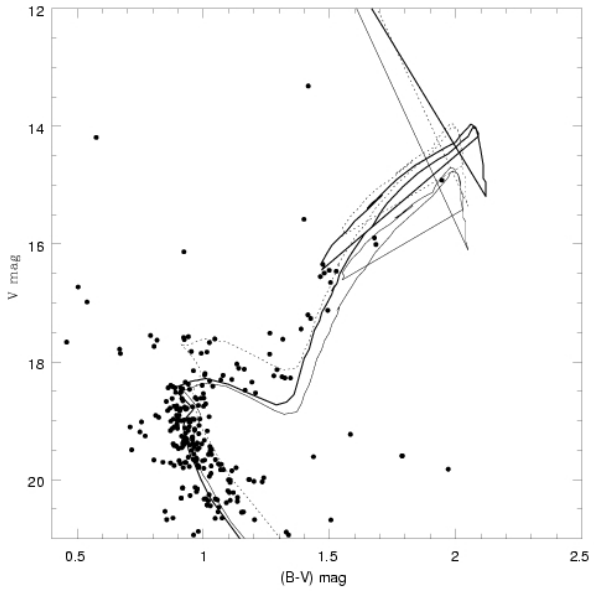


Figure 7. King 9 - age - 9.4 – 9.5

Field of King 13 marked near center

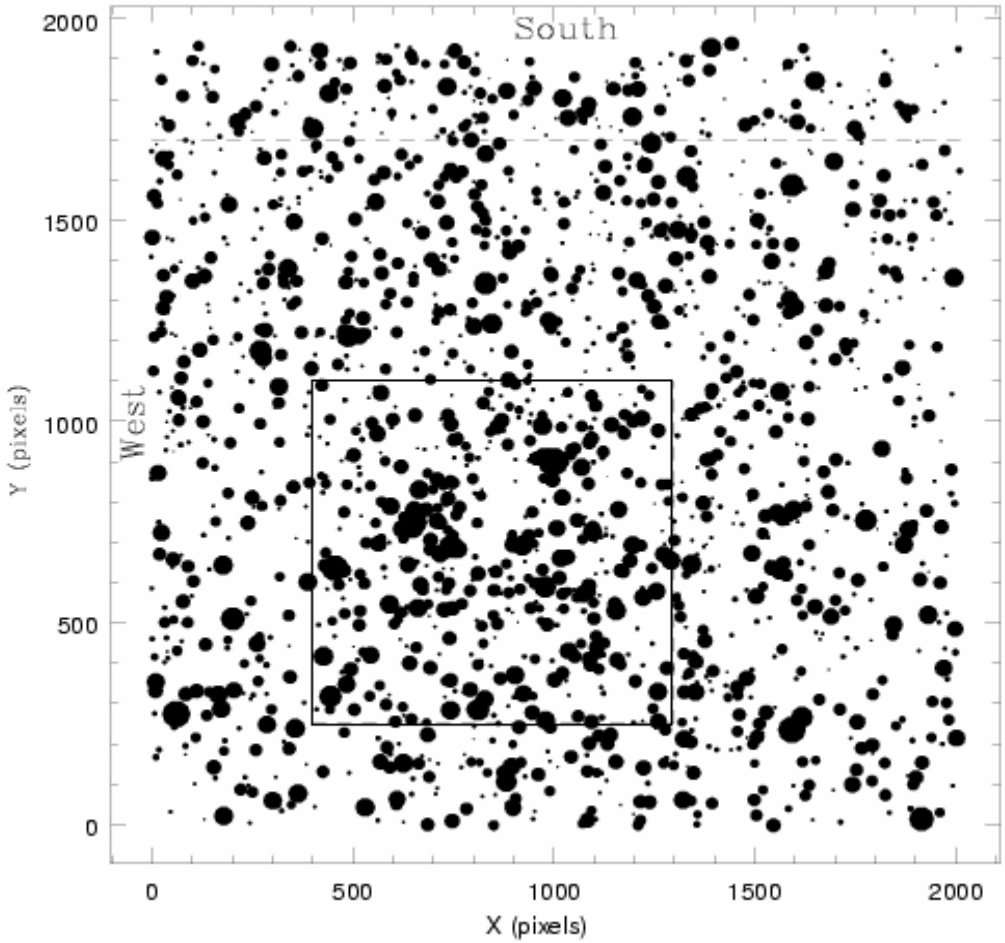


Figure 8. Field of King 13

CMD for King 13 central and field region

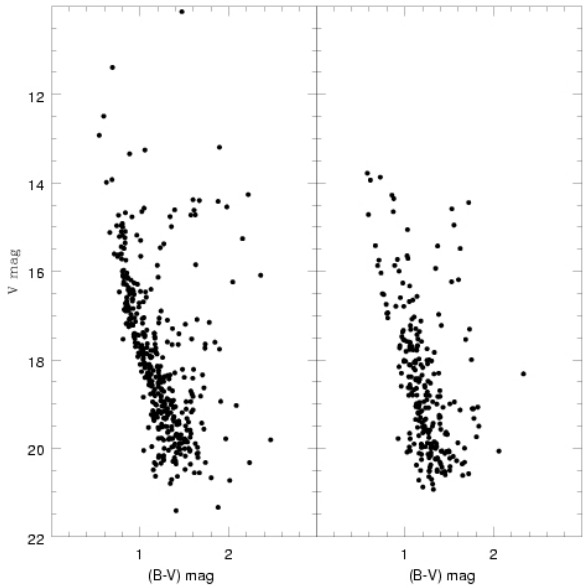


Figure 9. Observed CMD of King 13

Color-Color diagram for King 13.
Best fits gives E(B-V) = 0.65

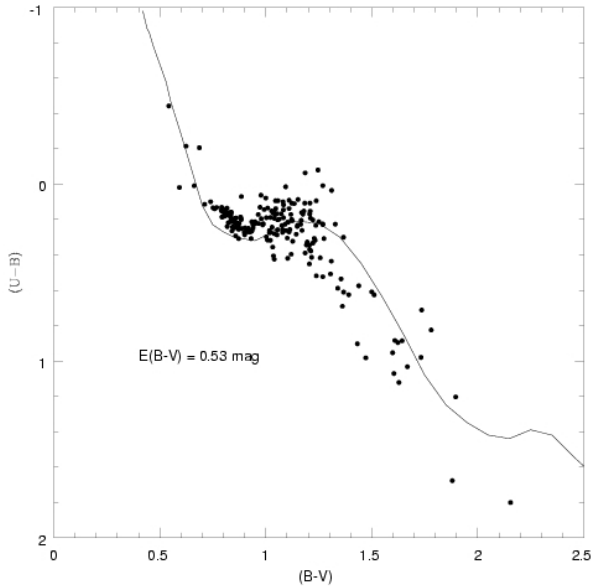


Figure 10. King 13 - reddening

Color Magnitude diagram for King 13 and ZAMS fit gives a distance of 3.1 kpc.

Isochrones fit gives an age of 500 Myr. Binary isochrones fitting is shown with dotted line.

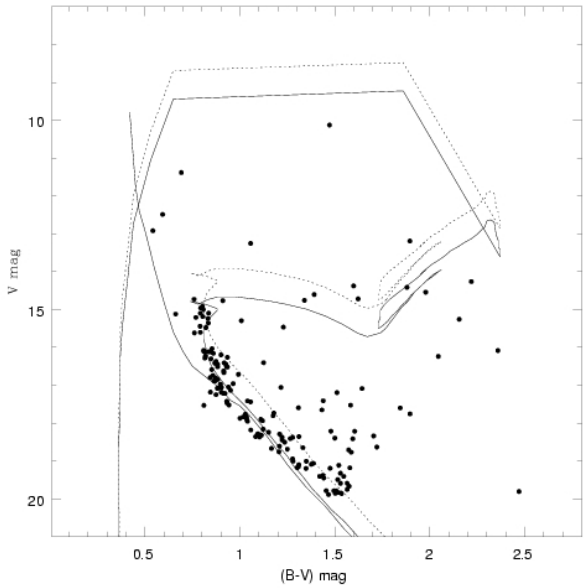
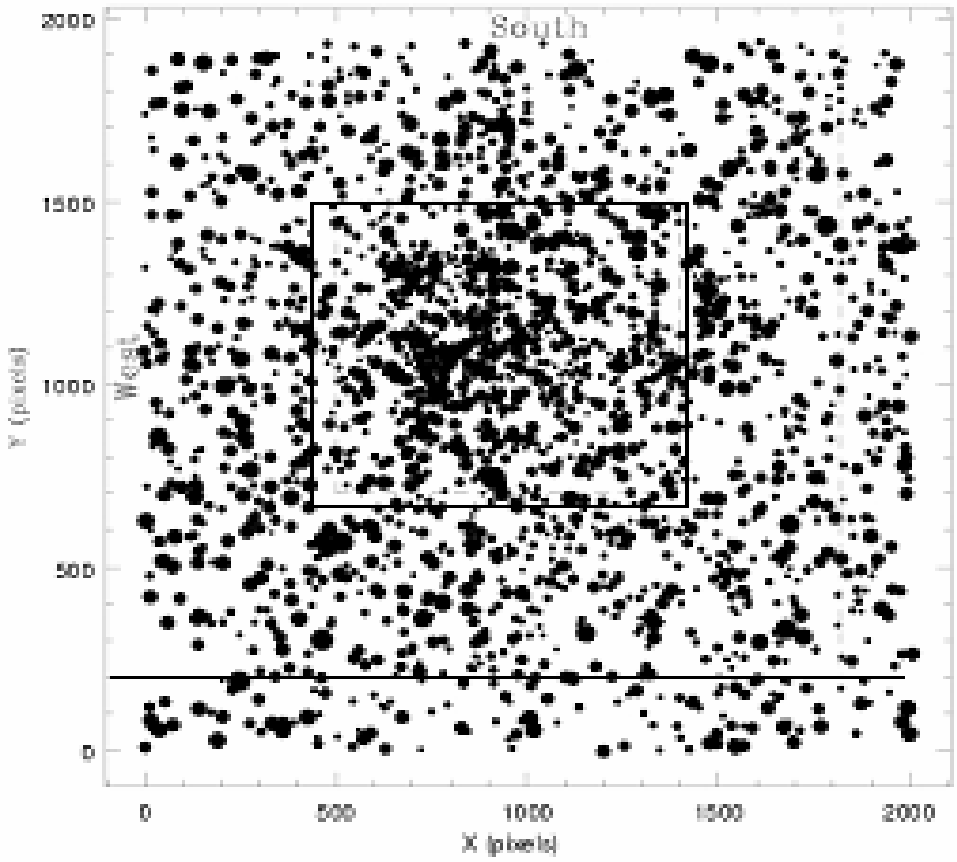


Figure 11. King 13 - age: 8.7: 500 Mys

Central field of IC 166 marked.



CMD for central and field region for IC 166

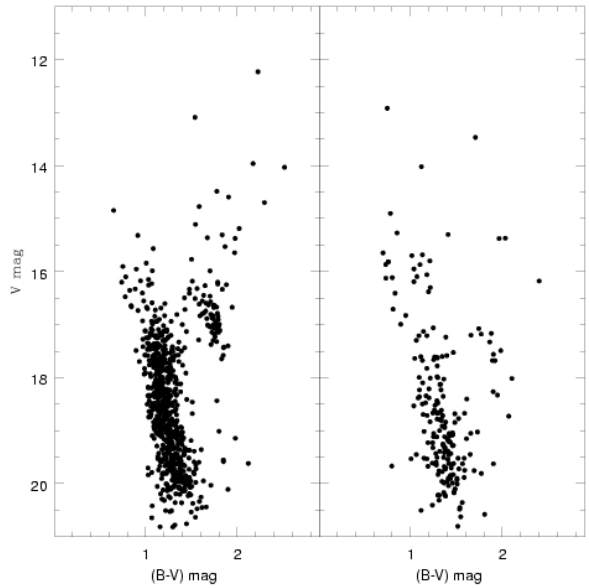


Figure 13. CMD - IC 166

CCD for IC 166. Best fit gives E(B-V) = 0.83 mag

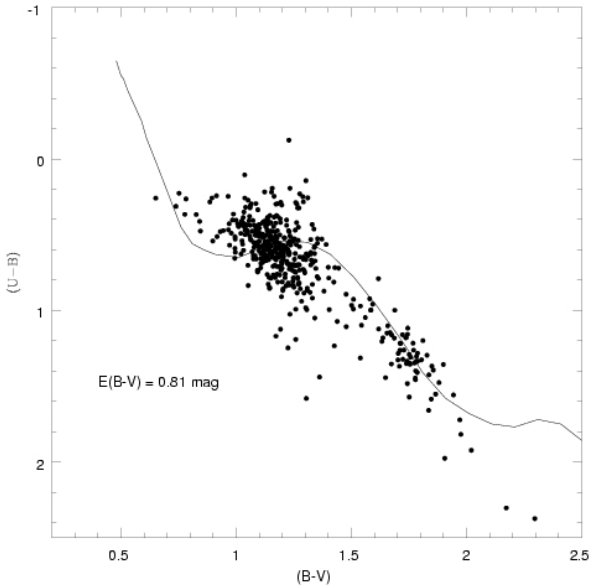


Figure 14. IC166 - reddening

CMD for IC 166. Best ZAMS fit gives a distance of 4.4kpc

Solar Metallicity isochrones poorly fits to red clamp as noticed is elongated and tilted.

The isochrones with Z=0.008 fits well with red clamp and for for age 1Gyr.

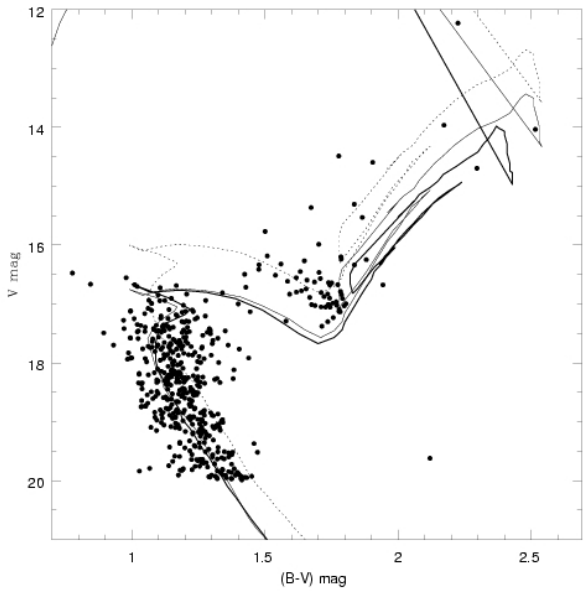


Figure 15. IC 166 -age 1 Gyr

Results:

1. **NGC 7245**: Reddening= 0.45 mag, distance=3600pc, age=400Myr. The stars are uniformly populated between the single and binary isochrones indicating a healthy population of binary stars in this cluster. MS gap at (B-V) = 0.7mag corresponds to (B-V)o = 0.25 mag is likely to be a real Bohm-Vitense feature in this cluster.
2. **King 9**: Reddening= 0.43 mag, distance=7600pc, age=2Gyr. This is the farthest cluster known in second quadrant.
3. **King 13**: Reddening= 0.65 mag, distance=3100pc, age=500Myr.
4. **IC166**: Reddening= 0.83 mag, distance=4300pc, age=1Gyr. Evidences of lower metalicity Red clump stars.