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Near infrared photometry of the young clusters NGC 1960, NGC 2453 and NGC 2384

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Abstract. Infrared observations of young star clusters provide vital clues to the star formation process and evolution of stars. This brief report on my thesis gives a brief description of the observations and analysis of the young star clusters NGC 1960, NGC 2453 and NGC 2384 observed in the near infrared bands at the Mt Abu Infrared Observatory, Gurushikhar in February 2000. Estimates of distance and age for these clusters for the first time using JHK data have been obtained. The colour–magnitude diagrams of these clusters have been extended to the fainter end as far as possible. The observed data was compared to that obtained by 2MASS. A more detailed paper will be published elsewhere.

Keywords : NIR photometry– star clusters – colour-magnitude diagrams – 2MASS

1. Introduction

Present theories of star formation indicate that stars are formed in clusters and hence young clusters are the ideal objects to be studied for a deeper understanding of star formation and evolution. Stars in a cluster are at practically the same distance and of identical age and chemical composition, differing only in mass making them classic research objects in a wide range of stellar and galactic investigations. Young star clusters are usually embedded within dark molecular gas and dust and contain extremely young stars which radiate significantly in the infrared, but are heavily obscured in the optical. Hence, observations were made at the Mt. Abu Infrared Observatory using the NICMOS3 detector in February 2000 of the young clusters NGC 1960, NGC 2453 and NGC 2384.

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2. Observations and reduction

The three clusters selected for observations were NGC 1960, NGC 2453 and NGC 2384. All three clusters are young and hence the amount of gas and dust present should be large. Basic cluster parameters like distance, reddening and age have been obtained earlier using UBV data and can be found in the Lyngå catalogue (1987). The Two-Micron All Sky Survey (2MASS) uses 1.3 m dedicated telescopes at Mt Hopkins, Arizona USA, and Cerro Tololo, Chile (Kleinmann *et al.* (1994)). 2MASS data is available for these clusters in the JHK passbands, but has not yet been analyzed and published so far. These would be the first results obtained using JHK data of these clusters. The clusters were observed with exposure times ranging from 10 – 30 seconds in the J and H bands and 3 seconds in the K bands respectively. The field of view (FOV) is $2' \times 2'$ and therefore the telescope was moved in raster form to scan the entire area at different locations. Photometry was performed using IRAF/DAOPHOT for each separate location. Standard stars were also observed and used for calibration. The USNO B catalogue was used to determine the centers and radial extent of the clusters.

3. Reddening correction and membership

The data was corrected for interstellar reddening using the equations given by Bessell and Brett (1988). The colour excess $E(B-V) = 0.25$ (Sanner *et al.* (2000)), $E(B-V) = 0.47$ (Mallik *et al.* (1995)) and 0.25 (Subramaniam and Sagar (1999)) was adopted for NGC 1960, NGC 2453 and NGC 2384 respectively.

Membership was determined by kinematic, spectroscopic and photometric techniques. For NGC 1960, membership was established using proper motion data (Sanner *et al.* 2000) (47 stars) and the photometric technique (187 stars). The photometric technique of Walker (1965) identifies main sequence members in a cluster. In the case of NGC 2453, membership was established based on probable members identified by Moffat and FitzGerald (1974) (30 stars) and the photometric technique (108 stars). Cluster membership for NGC 2384 was established using the members identified by Vogt and Moffat (1972) (8 stars) and the photometric technique (111 stars).

4. Distance, colour–magnitude diagrams and ages of the clusters

For the analysis, a standard main sequence was constructed for stars of varied spectral types belonging to the main sequence using the Bright Star Catalogue (Hoffleit, 1982) and the infrared catalogue (Gezari *et al.* 1993). Distances to the clusters NGC 1960, NGC 2453 and NGC 2384 were obtained through sliding fit of the standard main sequence with the colour–magnitude diagram as 1380, 3311 and 3162 pc. The distance to NGC 1960 was also estimated as 1340 pc using spectroscopic data. The new distance to NGC 2453 implies a possible physical connection with the neighbouring planetary nebula NGC

2452. This possibility, earlier rejected by Mallik *et al.* (1995), needs to be reconsidered. The colour–magnitude diagrams were constructed for all the three clusters and the gaps in the main sequence and their significance using the method by Hawarden (1971) was also studied using our as well as 2MASS data.

The average ages were determined as 125 Myr, 200 Myr and 90 Myr for NGC 1960, NGC 2453 and NGC 2384 respectively using isochrones computed by Bertelli *et al.* (1994), for metallicity = 0.02 and are shown in Fig. 1. Table 1 summaries the results obtained for the three clusters in our work.

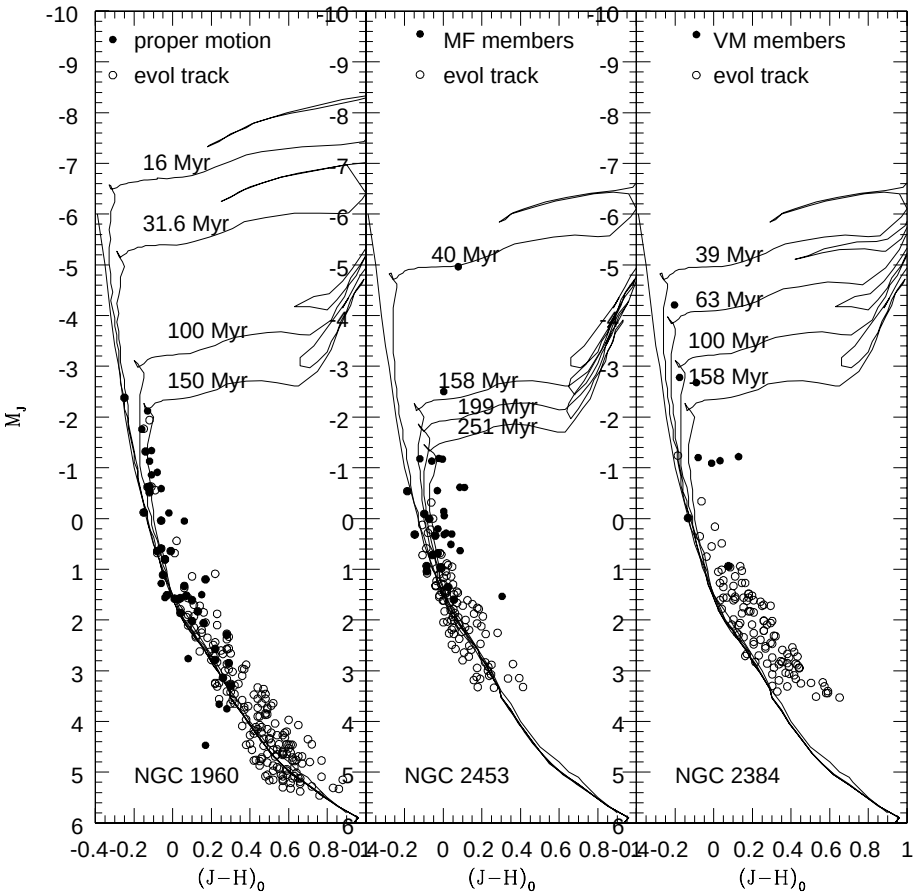

Figure 1. Isochrones fit to the colour–magnitude diagrams of NGC 1960, NGC 2453 and NGC 2384.

Table 1. Cluster parameters

Parameter	NGC 1960	NGC 2453	NGC 2384
Ang.Diameter (arc min)	10	10	5
$E(B-V)$(mag)	0.25	0.47	0.25
Distance (pc)	1380	3311	3162
Age (Myr)	125	200	90

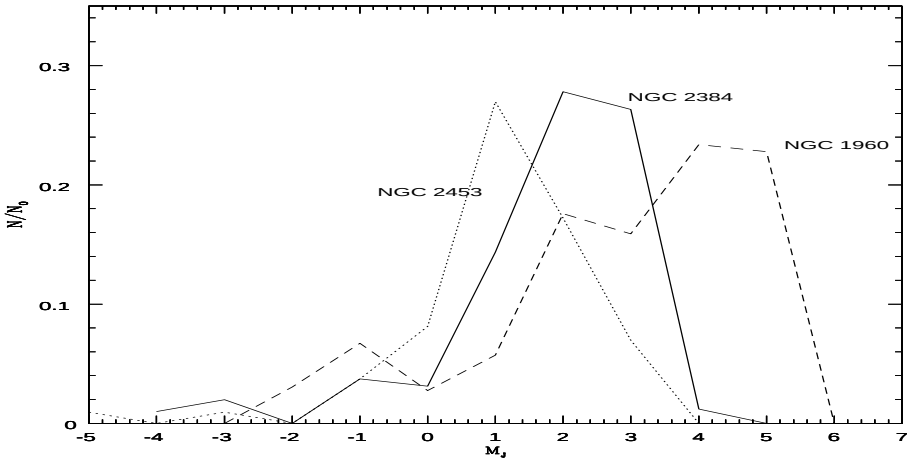

Figure 2. Comparision of the luminosity functions of NGC 1960, NGC 2453 and NGC 2384.

5. Luminosity functions and comparison with 2MASS

A comparative study of the luminosity functions of all the observed clusters was made. The luminosity functions were corrected for fraction of the observed cluster, field star contamination and completeness respectively. Figure 2 shows the corrected luminosity functions of NGC 1960, NGC 2453 and NGC 2384. A comparison was made of the photometry as well as cluster parameters using 2MASS data for these clusters.

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