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

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Abstract. The present paper 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 found to agree reasonably well with that obtained by 2MASS. A more detailed paper will be published elsewhere.

Keywords : near infrared – young star clusters – colour-magnitude diagrams – 2MASS

1. Introduction

A star cluster is a gravitationally bound system of stars formed together. 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. Studies of stellar evolution, the interaction of stars with their nascent clouds, the chemical composition and spatial structure of galaxies are typical examples involving open clusters.

Although star clusters and associations contain but a small fraction of the stellar content of the galaxy, it is becoming increasingly clear that most stars originate in clusters and to understand how stars form, we have to consider clusters of stars and how such environments can affect their formation. Young star clusters are usually embedded within

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Table 1. Basic cluster parameters (Lyngå, 1987).

Parameter	NGC 1960	NGC 2453	NGC 2384
RA(2000.0)(h:m:s)	5 36 6	7 47 45	7 25 13
Decl.(2000.0)(d:m)	34 08	-27 14 30	-21 01
Galactic longitude(deg)	174.52	243.33	235.39
Galactic latitude(deg)	+1.04	-0.94	-2.41
Trumpler class		I3 m	IV 3 p
Ang.diameter(arc min)	10.0	4.0	5.0
Distance(pc)	1270	1500	2000
$E(B-V)$(mag)	0.24	0.47	0.29
log(age)	7.4	7.6	6.00
Radial velocity(km s^{-1})	-4		67.3
Linear diameter(pc)	2.2	1.1	1.5

dark molecular gas and dust and contain extremely young stars which radiate significantly in the infrared, but are heavily obscured in the optical.

This work involves near infrared photometry of the young clusters NGC 1960, NGC 2453 and NGC 2384. Observations were made at the Mt Abu Infrared Observatory using the NICMOS3 detector in February 2000.

2. Choice of clusters

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. 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 parameters of these clusters as catalogued in Lyngå (1987) are given in Table 1.

3. Observations and reduction

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.

4. Determination of cluster radius

For accurate determination of the cluster parameters, it is essential to have the knowledge of the radial extent of the cluster. As the field observed was small, a USNO B band image of radius 15' was used. The centers of the clusters were determined. The radius of the clusters was also found as the distance at which the star density becomes approximately equal to the field star density.

5. Reddening correction and membership

The data was corrected for interstellar reddening using the equations given by Bessell and Brett (1988). Due to lack of extensive spectroscopic data, a mean colour excess was adopted for the three clusters from literature. 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.

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, as there was no proper motion data for this cluster, 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 also through the photometric technique (111 stars).

6. Distance and colour–magnitude diagrams of clusters

For any kind of cluster analysis, it is necessary to have the zero-age main sequence (ZAMS) or at least a standard main sequence for comparison purposes. As neither of the two was available for near infrared passbands in the literature, 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).

The distance to the NGC 1960 was obtained through sliding fit of the standard main sequence with the colour–magnitude diagram which gave a true distance modulus of $10^m.7$ corresponding to a distance of 1380 pc. The distance was also estimated using spectroscopic data and was found to be 1340 pc. The distance to NGC 2453 was obtained by the sliding fit method, as 3311 pc and hence it's possible physical connection with the planetary nebula NGC 2452 whose largest distance to date is 3.5 kpc, earlier rejected by Mallik *et al.,* (1995), needs to be reconsidered. The distance to NGC 2384 was estimated through the sliding fit of the standard main sequence with that of the observed main

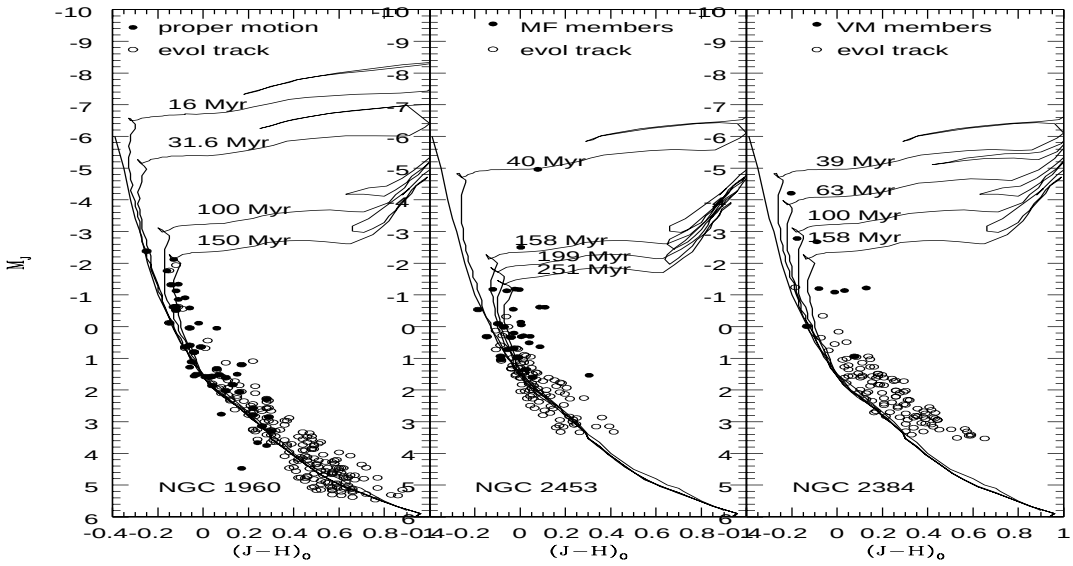

Figure 1. Isochrones fit to the colour–magnitude diagrams of NGC 1960, NGC 2453 and NGC 2384.

sequence and obtained a true distance modulus of $12^m.5$ corresponding to a distance of 3162 pc.

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. A binary main sequence formed by unresolved binaries above the main sequence was noticed in NGC 1960 as suggested by Sanner *et al.*,(2000). In cases where the total cluster area has not been observed, gaps were studied using the 2MASS data which covers the complete cluster area.

7. Ages of the clusters

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 2 summaries the results obtained for the three clusters in our work.

Table 2. 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

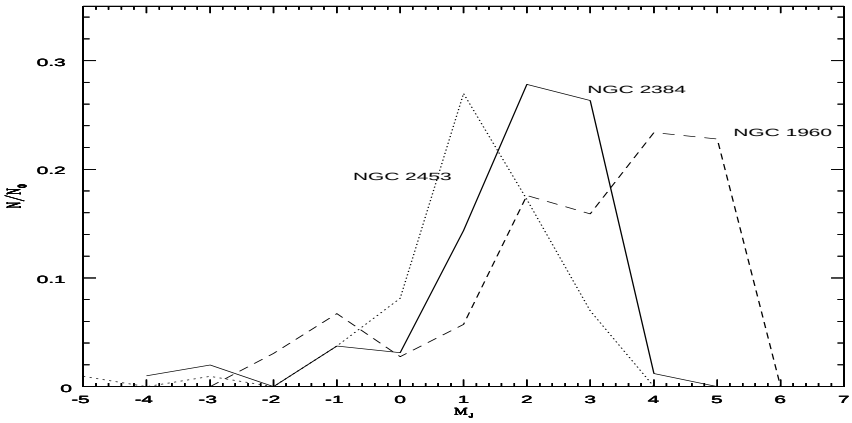

Figure 2. Comparison of the luminosity functions of NGC 1960, NGC 2453 and NGC 2384.

8. Luminosity functions

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 comparison of the corrected luminosity functions of NGC 1960, NGC 2453 and NGC 2384.

9. Comparison with 2MASS

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)). It is in the same passbands using a similar array as used for this work. Hence a comparison has been made with our observations and the 2MASS observations for each of the clusters. Figure 3 shows the comparison of 2MASS data and our data for NGC 1960 where ΔJ, $\Delta(J-H)$ and $\Delta(H-K)$ denote the differences between repective values from our data and 2MASS.

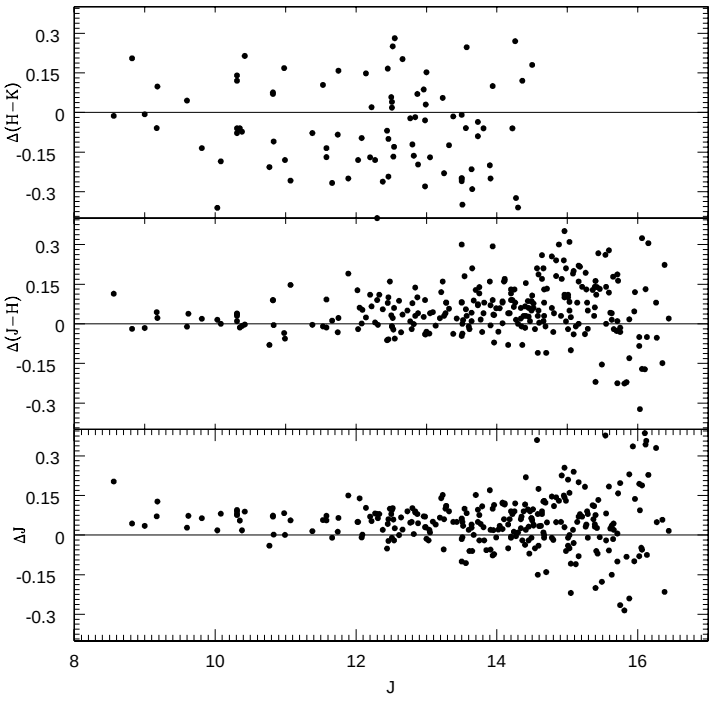

Figure 3. Comparison of 2MASS data and our data for NGC 1960.

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