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Duration of star formation in young open clusters

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Abstract. Young Open Clusters have always been a platform for the star formation studies. It was assumed that all members in the cluster are coeval, on the other hand, recent studies show the presence of an age range among the members of young open clusters. Presence of pre-main sequence (PMS) stars are identified by combining optical and near-IR data for 13 young clusters. Age-wise and mass-wise distribution of PMS stars are analysed to study how star formation proceeded in the clusters. In all the clusters we studied, we find an age range among the PMS stars and the duration of star formation is found to be similar to the cluster age.

Keywords : stars: formation – stars: pre-main sequence – (Galaxy:) open clusters and associations: general

1. Introduction

Our study aims to find the spatial and temporal formation sequence of stars in Young Open Clusters. Termination of star formation process occurs abruptly through the devastating presence of one or more O stars in the rich embedded clusters and the expulsion of embryonic gas happens during the first 0-5 Myr. (Kroupa 2001). But recent observations show the existence of multiple populations in a cluster (Subramaniam et al. 2005; Bhavya et al. 2007; Joshi et al. 2008; Delgado et al. 2009; Mathew et al. 2010). How the star formation is happening subsequently in such a close entity is to be understood. Our study aims to identify the pre-main sequence stars (PMS) in clusters with age $\leq$ 30 Myr. The duration (difference between turn-off and turn-on age) in star formation tells us whether the star formation is either episodic or continuous. By analysing the age-wise and mass-wise distribution of PMS stars in the cluster, we aim to get snapshots of star formation events happened during the formation of the cluster.

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Table 1. Results.

Cluster Name	MS turn-off age(Myr)	No.of PMS Stars	Formation timescale (Myr)	Type of star formation	Remarks
NGC 457	7	74(705)	25(0.25-25)	Continuous	Low mass stars formed first Later high mass stars
NGC 2401	25±5	61(119)	25(0.25-30)	Continuous	Both low & high mass stars started forming together
NGC 581	16±4	34(245)	6(0.25-6)	Continuous	Continuous formation of low mass stars
NGC 2244	1-3	15(365)	12(0.25-12)	Continuous	Initially low mass stars Later high mass stars
NGC 6611	2	60(320)	11(0.25-11)	Continuous	Both low & high mass stars started forming together
NGC 6871	2-5	15(497)	12(1.5-12)	Continuous	Initially low mass stars followed by high mass stars Intense star formation till last 6Myr
NGC 3293	6.3	59(564)	14(0.25-14)	Continuous	Initially low mass stars Later high mass stars
Bochum 6	10±5	22(146)	25(0.25-25)	Continuous	Both low & high mass stars started forming together
IC 1590	3.5	9(56)	9(2-12)	Continuous	Initially low mass stars. Star formation continued to 1Myr after the formation of massive stars
NGC 6823	2-7	27(253)	7(0.25-7.5)	Continuous	Initially low mass stars. Star formation continued to 1Myr after the formation of massive stars
NGC 7380	2	34(277)	7(0.25-7.5)	Continuous	Initially low mass stars. Star formation continued to 1Myr after the formation of massive stars
h Persei	13	127(536)	10(0.25-10)	Continuous	Both low & high mass stars started forming together
χ Persei	13	72(420)	10(0.25-10)	Continuous	Both low & high mass stars started forming together

2. Evidence of continued star formation

The optical magnitudes of cluster members are taken from previous studies of the cluster and their near infra-red (NIR) magnitudes are taken from 2 MASS. The stars with NIR excess are identified using dereddened $(J-H)_0$ vs $(H-K)_0$ Color-Color diagram (NIR CCD). Since PMS stars have dust around it, they will have more flux in K band due to the emission in this band, resulting in NIR excess. In the optical color-magnitude diagram (CMD) pre-main sequence isochrones (Seiss et al. 2000) of various ages are plotted. Ages and masses of stars with excess are estimated from

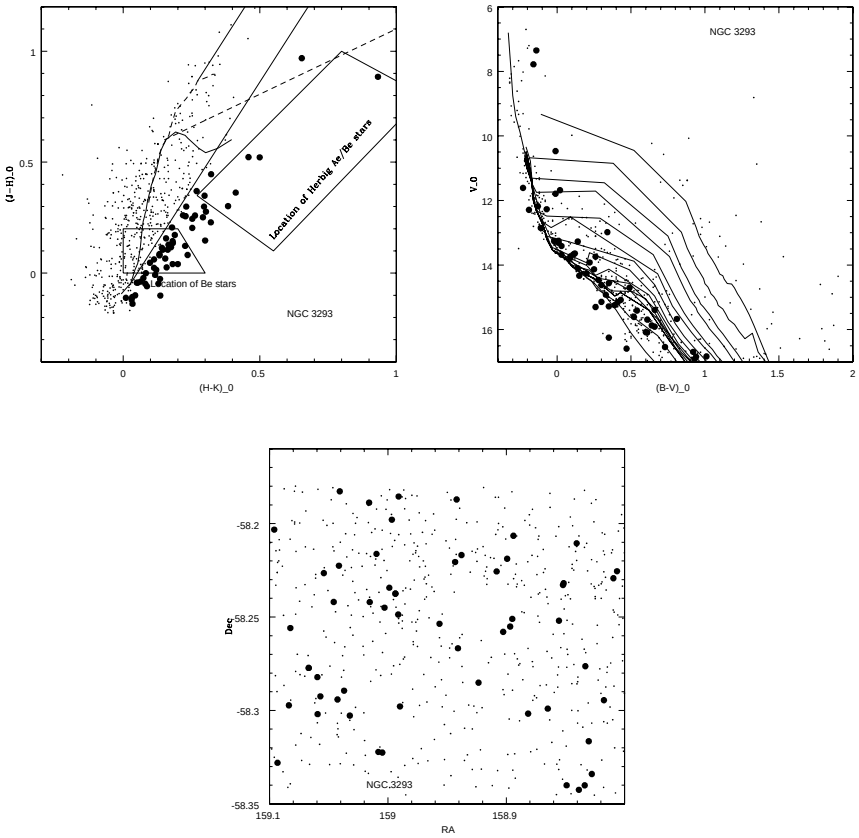

Figure 1. (Top left) NIR CCD of NGC 3293. Out of 564 cluster stars, 59 stars show NIR excess (big circles). Pre-main sequence isochrones of ages 0.25-14, 20Myrs are plotted in the optical CMD (Top right). From the location plot, it can be seen that PMS stars are distributed throught out the cluster vicinity. There is no preferential clustering of PMS stars.

their position on the PMS isochrones. The age-wise/mass-wise distribution of PMS stars in the cluster vicinity will give the snapshots of star formation events that have happened in the cluster. For the cluster NGC 3293, the NIR CCD, optical CMD and location plot are shown in the Fig. 1, as an example.

3. Results and discussions

We found the existence of pre-main sequence stars in all the 13 young clusters we studied. The PMS stars are found to have an age range, suggesting the presence of multiple populations. This implies that stars are formed with a non-zero duration in the cluster. The results for 13 clusters are shown in the table. It is found that star

formation is continuous within the duration for all the clusters. In the case of NGC 2401 and NGC 6823 star formation duration is equal to the cluster age itself. For the clusters Bochum 6, NGC 7380, IC 1590, NGC 6871, NGC 2244, NGC 457, NGC 3293 and NGC 6611, duration is greater than the cluster age. For these, star formation is continuing after the most massive stars are formed. In some of the clusters NGC 6871, NGC 3293, NGC 2244, NGC 457, IC 1590, NGC 6823 and NGC 7380 low mass star formation started in the beginning and later followed the formation of high mass stars. For some clusters (Bochum 6, NGC 6611, NGC 2401, h & chi Persei) both high and low mass stars started forming together.

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