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Star formation history of the young cluster NGC602 in the Small Magellanic Cloud

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Abstract. Within the framework of a large coordinated HST effort to study the star formation processes and history of several fields in the SMC, we present the detailed history of the young cluster NGC602. In particular, we explore the characteristics of the many candidate pre main sequence (PMS) stars. We combine a new set of PMS stellar tracks for the metallicity Z = 0.004 with a stellar population synthesis model that takes into account all evolutionary phases. The best star formation is searched by comparing observed and synthetic CMDs.

Key words. (Galaxies:) Magellanic Clouds - Galaxies: stellar content - (Stars:) Hertzsprung-Russell (HR) and C-M - Stars: pre-main sequence

1. Introduction

The proximity of the Small Magellanic Cloud (SMC) provides an excellent target for detailed studies of resolved stellar populations. Deep optical photometry was performed on images from the Hubble Space Telescope (HST) Advanced Camera for Surveys (ACS) at different locations in the SMC as part of a program to study the global Star Formation History (SFH) of this galaxy.

The goal here is to derive the SFH for NGC 602, a very young cluster located in the "wing" of the SMC. The NGC 602 region offers a valuable laboratory to study infant stars

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(few Myr old, members of the cluster) as well as billion year old objects (part of the SMC field). As already discussed in Carlson et al. (2007) using both HST optical data and Spitzer Space Telescope IR data, the region hosts a rich population of pre-main sequence (PMS) stars and candidate Young Stellar Objects (YSOs).

To recover the SFH of NGC 602 we follow a two step process: 1) a base of theoretical CMDs is built by means of a well tested synthetic population code (Tosi et al. 1991); 2) the best SFH is searched with an effective maximum likelihood technique see e.g. (Cignoni et al. 2006).

2. PMS stars

The discovery of low mass PMS stars in nearby galaxies (see also Romaniello et al. 2004; Nota et al. 2006; Gouliermis et al. 2007) is an excellent benchmark for stellar evolution calculations, since it provides the opportunity to study rather large samples of PMS stars characterized by similar distance and chemical composition. Moreover, the detection of PMS stars with precise photometry represents an additional channel to constrain the recent SFH: the short time spent in PMS by a 1 $M_\odot$ star ($\sim$ 50 Myr) roughly corresponds to the time spent by an 8 $M_\odot$ star on the main sequence, with the obvious advantage that stars of 1 $M_\odot$ are much more frequent than 8 $M_\odot$ stars.

In order to properly account for the PMS phase, new PMS tracks at $Z = 0.004$ (see Fig. 1) have been specifically computed with an updated version of the FRANEC evolutionary code (see e.g. Degl'Innocenti et al. 2007).

To convert all stellar tracks from the Luminosity-Temperature plane to the CMD we used the transformations by Origlia & Leitherer (2000) for the HST Vegamag photometric system. The transformed PMS tracks are shown in Fig. 2.

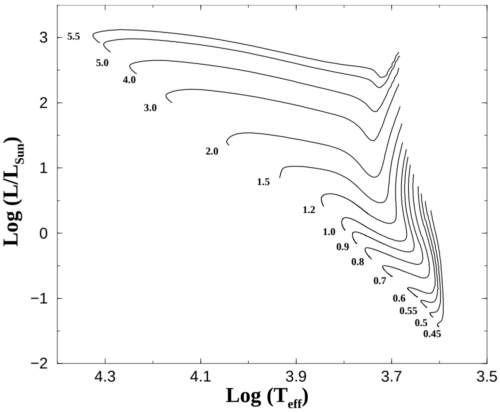

Fig. 1. PMS evolutionary tracks for $Z = 0.004$, where the characteristic mass for each track is labelled, in solar masses.

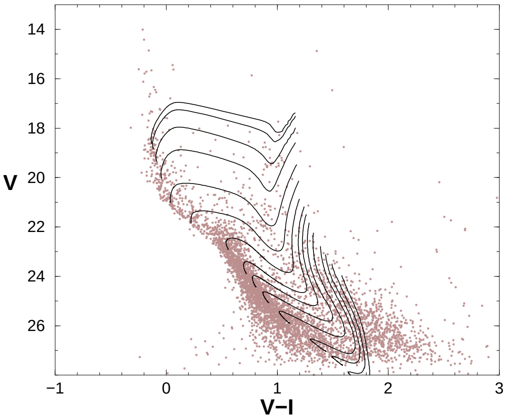

Fig. 2. FRANEC PMS stellar tracks ($Z = 0.004$) overlaid on the observed CMD of NGC602.

3. Isochrone fitting

Fig. 3 shows isochrone fitting of the young stellar population using Padua stellar models for Z=0.004 combined with the FRANEC PMS tracks, corrected for distance $(m - M)_0 = 18.9$ and reddening $E(B - V) \sim 0.08$. In the magnitude range $V = 15 - 19$ a group of stars is observed on the red side of the isochrones: if these stars are actually the massive counterpart of the observed faint PMS, these stars can be still surrounded by relics of their birthing cocoon material and suffer an additional amount of absorption.

Besides the upper main sequence, the PMS population gives constraints on our age estimates. Fig. 2 shows the observed CMD with the PMS tracks (masses from 0.45 to 5.5 $M_\odot$) for metallicity $Z = 0.004$ over-plotted. It is

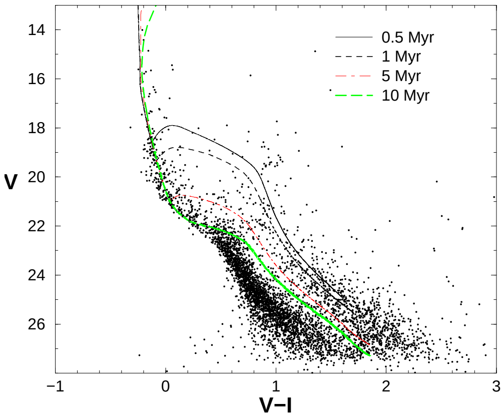

Fig. 3. 0.5, 1.0, 5.0 and 10.0 Myr isochrones for metallicity $Z = 0.004$ interpolated from the Padua tracks and FRANEC tracks for PMS overlaid on the observed CMD. Distance modulus and reddening are assumed equal to $(m - M)_0 = 18.9$ and $E(B - V) \sim 0.08$, respectively.

clear that the theoretical tracks comfortably encompass the red sequence, confirming the pre-main sequence nature of these sources. Even more interesting, the bulk of these stars seem to lie in the Hayashi region. Figure 3 shows the corresponding PMS isochrones for 0.5 Myr, 5 Myr and 10 Myr, and suggests that most of the PMS stars are younger than 5 Myr.

Concerning the contamination of SMC field stars, a well-defined sub-giant branch (SGB) along with a red clump (RC) are also evident. These phases are a robust indicator of an old population, being the SGB and the RC phases populated by low mass stars. Moreover, the compact morphology of the RC suggests that the metallicity does not vary in the sample in a relevant way.

By means of isochrone fitting, we find that luminosities and colors of RC and SGB can be simultaneously reproduced by assuming a metallicity of $Z = 0.001$, a distance modulus $(m - M)_0 = 18.9$, reddening $E(B - V) \sim 0.08$, and an age between 4 and 8 Gyr (see Fig. 4).

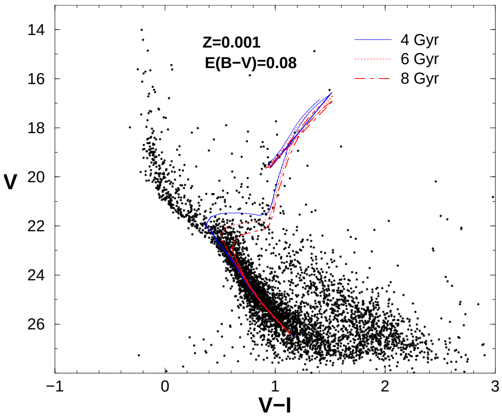

Fig. 4. 4.0, 6.0 and 8.0 Gyr Padua isochrones for $Z = 0.001$ (see Angeretti et al. 2007) at the distance modulus $(m - M)_0 = 18.9$ and reddening $E(B - V) = 0.08$ superimposed on the observed CMD.

4. Star formation history in NGC602

Synthetic stellar populations are created following the procedure originally described by Tosi et al. (1991) and subsequently updated (Greggio et al. 1998; Angeretti et al. 2005). In order to make a rigorous comparison between synthetic and observed CMD, we apply a maximum likelihood classification algorithm as presented in Cignoni et al. (2006).

Following the isochrone fitting results, all synthetic stars younger than 3 Gyr are created with a metallicity $Z = 0.004$, and the older ones with $Z = 0.001$; the distance modulus and reddening are fixed at $(m - M)_0 = 18.9$ and $E(B - V) \sim 0.08$ respectively.

The best SFH is shown in Figure 5. The maximum activity is reached in the last 2.5 Myr (about 0.3×10^{-3} $M_\odot\, yr^{-1}$).

4.1. Robustness against IMF variations

To assess how the recovered SFH is influenced by the IMF, the star formation is re-determined adopting different IMF exponents. Figure 6 shows that the mean SFR systematically increases with steepening IMF. In fact, for a fixed total mass, a flatter IMF implies fewer stars surviving in the final sample (because it causes

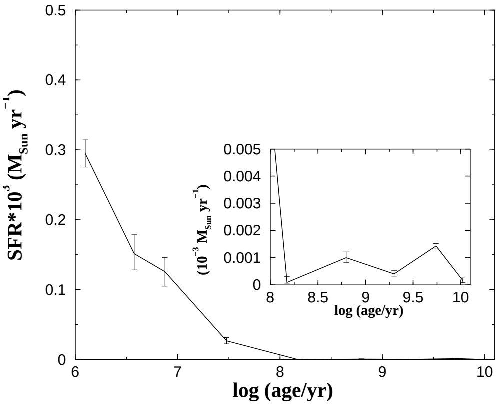

Fig. 5. Recovered star formation rate using an IMF exponent $\alpha = 2.5$ and a binary fraction of 30%. The old star formation activity is enlarged in the small panel.

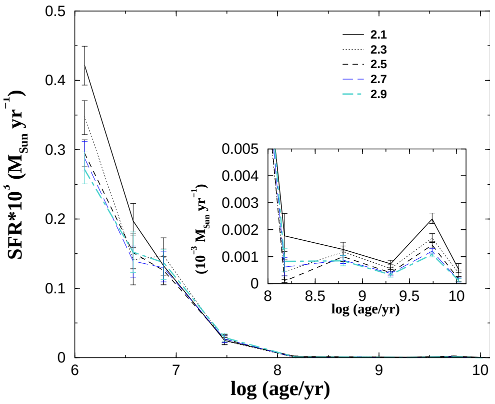

Fig. 6. Recovered SFH for different assumptions on the IMF exponent.

a deficit of low-mass long-lived stars), hence a higher SFR is required to produce the observed star counts. The overall trend of the SF activity with time does not change significantly, though, varying at most by a factor smaller than 2. We can thus conclude that the recovered SFH is quite robust against IMF variations.

5. Conclusions

We have used our population synthesis model to analyze the SFH of the region (see Cignoni et al. 2009 for details). The star formation activity has been increasing with time on a time scale of tens of Myr. The star formation in the recent 10 Myr has been quite high, reaching a peak of (0.3 – 0.7)× 10^{-3} $M_{\odot}$/yr in the last 2.5 Myr. The current star formation is approximately 100 times higher than the average from 4-8 Gyr ago. Any activity earlier than 8 Gyr ago seems to be negligible.

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