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Young stars in the periphery of NGC 6822

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Abstract. Taking advantage of the wide (42′ × 28′) field of the CFH12K camera, we survey the young star population of NGC 6822 to unprecedented radial distances. We determine the age of the young stars by employing Gallart's et al. (1996b) method based on the presence of stars in different boxes in the CMD. We find that star formation took place up to ∼200 Myr ago in a wide area not always matching the current HI cloud. A ∼50 Myr old association is identified, next to the HI void where no young stars are seen.

Key words. galaxies: individual: NGC 6822 – galaxies: stellar content – galaxies: structure

1. Introduction

The comparison of the star formation history (SFH) of dwarf galaxies has been of particular interest in recent years because in these small galaxies, less complex than spirals, it should be, in principle, easier to interpret the observations to explain their SFH. Deep colour-magnitude diagrams (CMD) have been used to establish the SFH of the Local Group members, see Grebel (2001) and references therein for a review.

NGC 6822, being one of the nearest galaxies outside our halo, has been the subject of several SFH investigations. Hoessel & Anderson (1986) presented the first CCD investigation of NGC 6822 by acquiring photometry for 3475 of its stars. A few years later, Wilson (1992) targeted its numerous OB associations. Marconi et al. (1995) obtained deep B, V observations, reaching $V \sim 23$, while Gallart et al. (1996a, 1996b) concentrated on V, I photometry to study the old and young populations. The last ground based photometric investigation of NGC 6822 is the carbon star survey of Letarte et al. (2002). Wyder (2001) and Hutchings et al. (1999) analysed Hubble Space Telescope images to investigate the stellar population in a few small fields in NGC 6822. Essentially all photometric investigations, excepted for the recent survey by Letarte et al. (2002), employ CCDs covering small areas thus not permitting a global view of NGC 6822.

The SFH of NGC 6822 can be characterized by long episodes of modest activity separated by short intervals. This mode of star formation has been called *gasping* by Marconi et al. (1995). It is intermediate between blue compact dwarfs which show bursts of star formation and larger galaxies which have rather continuous formation. Gallart et al. (1996b) conclude that NGC 6822 shows an enhancement of star formation activity, over the whole main body of the galaxy, occurred in the last 100–200 Myr. These studies have shown that dwarf galaxies, of the size of NGC 6822, cannot be considered homogeneous systems with a single stellar population. It is thus obvious that in order to derive their global properties one needs to look at the whole galaxy.

2. Observations and approach

Our data consist of one R (400 s) and one I (300 s) exposure obtained in September 2000 with the CFH12K camera attached at the prime focus of the CFHT. The pixel size corresponds to 0.″206 and the field of view of the 12 CCD mosaic is 42′ × 28′. Details of the data reduction and calibration are given by Letarte et al. (2002), suffice to say that the instrumental magnitudes and $R - I$ colours were calibrated using Gallart et al. (1996a) photometry kindly provided to us.

We adopt for NGC 6822 the distance and the reddening derived by Gallart et al. (1996a), namely $(m - M)_0 = 23.49$ and $E(R - I) = 0.20$. Furthermore, for our data analysis, we follow Gallart et al. (1996b) approach who define boxes, in the CMD, corresponding to stars of different ages (based on the Padova evolutionary tracks, see Bertelli et al. 1994 for a summary of the properties of these models). Figure 1, similar to Gallart et al. (1996b) Fig. 1 but with $(R-I)_0$ instead of $(V-I)_0$, presents the global CMD of the whole field of NGC 6822. 87 000 stars

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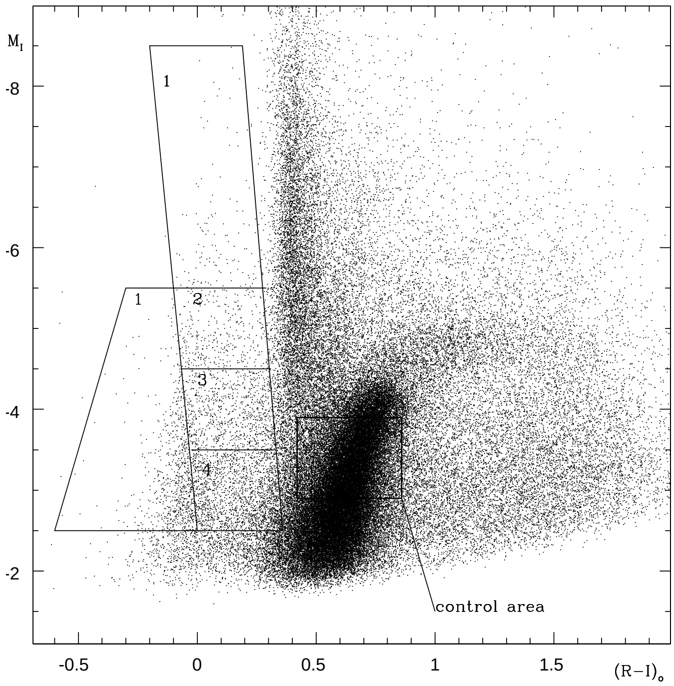

Fig. 1. The global colour-magnitude diagram of NGC 6822 with the boxes defined following Gallart et al. (1996b), see text for details.

with colour errors smaller than 0.1 mag are plotted. Since we are dealing with young stars, we select only four boxes along with a control box.

Box 1, in two parts, includes young main sequence stars and more luminous blue loop stars. These stars have the same age, taken to be younger than 50 Myr. Stars in the central helium burning phase populate box 2, correspond to ages 50 to 100 Myr. Box 3 contains stars that are 100 to 200 Myr old while box 4 corresponds to stars between 160 to 400 Myr old. The control box is limited, in the M_I vs. $(R-I)_0$ plane, by $-3.9 < M_I < -2.9$ and $0.42 < (R-I)_0 < 0.86$, and it contains stars born over almost all the galaxy's lifetime. We use the control counts as a normalization factor to compare different regions of the field.

3. Previous observations of NGC 6822

As explained in the Introduction, nearly all the previous photometric investigations of NGC 6822 were limited to its obvious optical body. Recent HI observations by de Blok & Walter (2000b) as well as mosaic photometry (Letarte et al. 2002) have clearly shown that the true size of the galaxy is far greater than its optical appearance. Since the goal of the present paper is to investigate the stellar content of the outer regions of the galaxy, we will limit our comparison to those previous studies which surveyed fields outside the main body: Marconi et al. (1995) external field; Hutchings et al. (1999) HST fields and Wyder (2001) C25 field. These fields are sketched in Fig. 2 over the CFH12K field of NGC 6822. It is worth noting that all these fields are well within NGC 6822. For instance, the external field in Marconi et al. (1995) (M Ext) is not located outside of the galaxy. We, however, confirm that no young stars are seen in that field. This shows how risky it is to extend conclusions, from a tiny field, to the whole galaxy. Because, at the edge of the HI envelope (see de Blok & Walter 2000a), the density of blue stars is so low one can find small regions with none.

We also confirm that blue stars are lacking in Hutchings et al. (1999) East field which is located outside of the HI disk (as defined by de Blok & Walter 2000b) while a few are present in the West field which lies inside the HI disk. Figure 3 shows the CMD of the region corresponding to Wyder (2001) field C25. With a handful of stars in boxes 1 and 2 one concludes that very few stars formed during the last 100 Myr. This is in agreement with Wyder's findings that, in this region, the star formation rate in the last 0.6 Gyr is lower than in the past.

4. Overall distribution of young stars

The very large field of the CFH12K camera allows us to investigate the star distribution over an extended area. The spatial distributions over the entire mosaic field of the stars in different boxes of the CMD (see Fig. 1), are shown in Fig. 4.

This figure reveals that the very young stars are found along the bar, with a clumpy distribution. The distributions shown in the two upper panels, age <100 Myr, are essentially identical even though there are more than twice as many stars in the youngest box. While stars in boxes 1 and 2 show a clumpy distribution, older stars, boxes 3 and 4, have a smooth distribution, similar to what was recently noted by Zaritsky et al. (2000) in the SMC where the visual appearence is dominated by irregular star formation. Such a similarity is quite striking since NGC 6822, unlike the SMC, is a fairly isolated system (with the possible exception of tidal interaction with an HI cloud suggested by de Blok & Walter 2000b). Beside the obvious bar of NGC 6822, old stars clearly outline the HI disk (visible in Fig. 5). Finally, the distribution of older stars, from the control box, do not show any evidence of a disk-like distribution. They indeed represent, as shown by Letarte et al. (2002), an halo of intermediate-age and old stars that extends well beyond our mosaic field.

The young stars (boxes 1 and 2) are displayed along with the HI disk (de Blok & Walter 2000b) in Fig. 5. The outermost HI contour shown in this figure corresponds to a gas density of 1×10^{20} cm^{-2}. We note that no young stars are seen in the HI hole, south east of the bar. There is, however, a group of young stars just south east of the hole. The CMD of this region, we call SE group, is discussed in the next section. We also note the presence of a few young stars in the north west corner of the CFH12K field. These stars coincide with a HI density peak. No such stars are seen at similar distances on the other side of the HI disk. Finally a string of young stars is seen on the western edge of the field, well outside of the HI disk. Many stars found in box 4 are also seen in this border area. These stars are investigated in Sect. 5.1.

Numerous young blue stars are associated with HII regions as can be seen in Fig. 6. Positions of the 147 HII regions are taken from Hodge et al. (1988) Hα survey. That survey does not, however, cover all the CFH12K field under investigation. More HII regions could possibly be found in the periphery of NGC 6822. A group of young stars in the NW of the main body of NGC 6822 is associated with Hubble 1, a huge HII region.

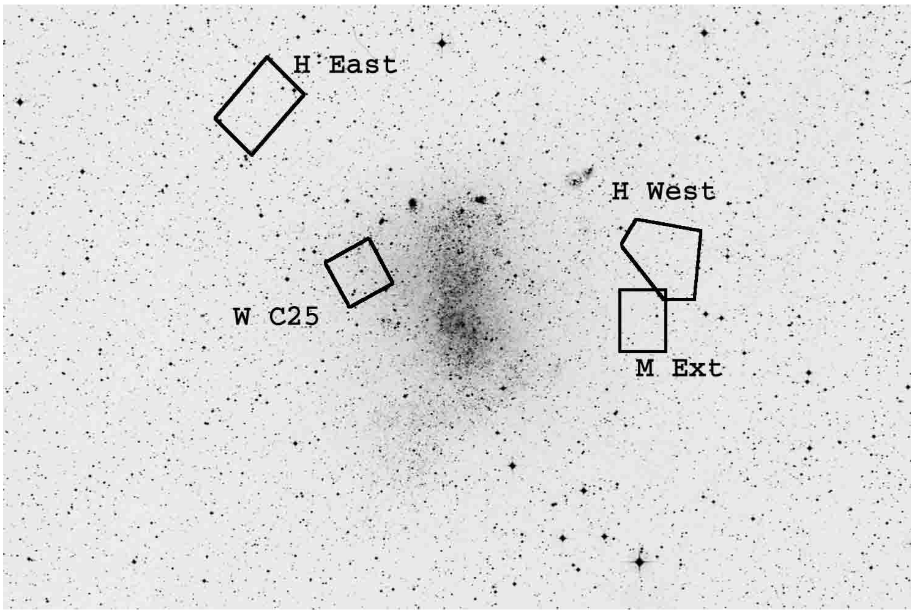

Fig. 2. The CFH12K field with the previous surveys marked. North on top, East to the left.

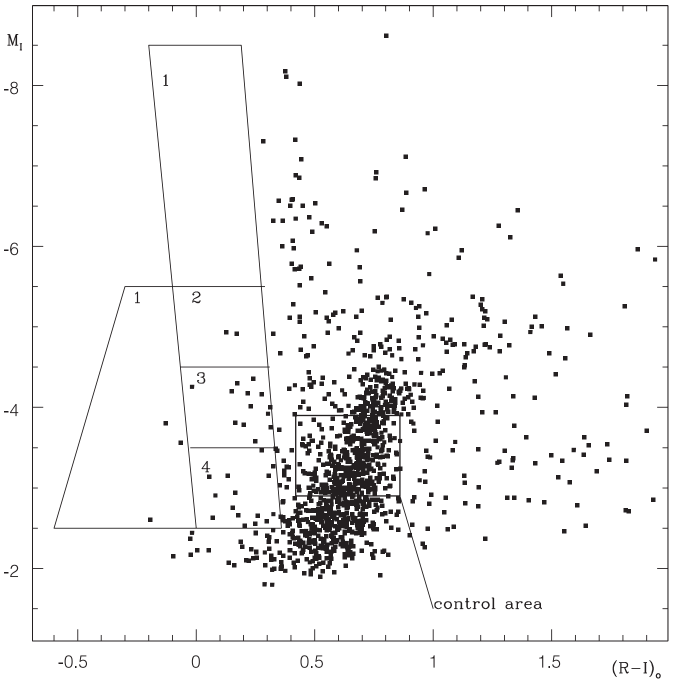

Fig. 3. Colour-magnitude diagram of the C25 region measuring 4.5 arcmin^2.

5. Colour-magnitude diagrams

CMDs of the three regions, along with a fourth control field located in the north east corner, are presented in Fig. 7. Each one corresponds to a rectangular region of 25 arcmin^2.

The NE and NW regions are located at the same distance from the center of NGC 6822. On both of their CMDs one can detect the old population giant branch. The total lack of young blue stars in the NE corner supports the fact that the blue stars seen in the other regions are neither foreground stars nor photometric errors. We remind the reader that in these plots we select only stars with a photometric error in $R-I$ smaller than 0.1 mag. The CMD, not shown, of a $5' \times 5'$ area in the SE corner, where there is hydrogen, is identical to the CMD of the NE corner: devoid of blue stars. All the blue stars seen in these diagrams have also been detected in CN and TiO and have (CN–TiO) $\approx$ 0.0, as expected for early type stars. The colour position of the ridge of brighter stars (corresponding to G dwarfs seen along the line of sight) implies that the reddening of the NE corner is slightly higher than in the other regions.

The tip of the giant branch is seen in the four panels. It is however more difficult to distinguish in the two right panels, probably because of the presence of a younger stellar component. All the blue stars in the SE group are found within 1.2 arcmin of the center of the 25 min^2 region. A diameter of $2.4'$ corresponds to $\sim$350 pc at the distance of NGC 6822. This is similar in size to some of the associations identified by Hodge (1977). The SE group CMD shows a narrow lane of stars which could be identified to a main sequence (see Fig. 8). Indeed, a 50 Myr isochrone, from Bertelli et al. (1994) fits well the observations. The best match is obtained if we adopt for the reddening of the region $E(R-I) = 0.22$ rather than the global value of $E(R-I) = 0.20$. This young region is not associated with any of the 147 known HII regions of NGC 6822. Among the IRAS discrete sources detected by Israel et al. (1996) the closest to the SE group is at $\approx 11'$, thus well outside (about 9 radii) the group itself. It is, however, located just next to the HI void, possibly in a region where the hydrogen was compressed to give birth to stars.

Star counts, in the five boxes of the CMDs, are listed, in Table 1, for the four regions of the field. Distance, in arc minutes, to the NGC 6822 center are also given.

Comparison of the number of stars in the control box (N_c) between the four regions reveals that the numbers of old giants in the three regions on the periphery are quite similar. This is expected since these regions are roughly at the same distance from the centre of NGC 6822. The SE group being closer

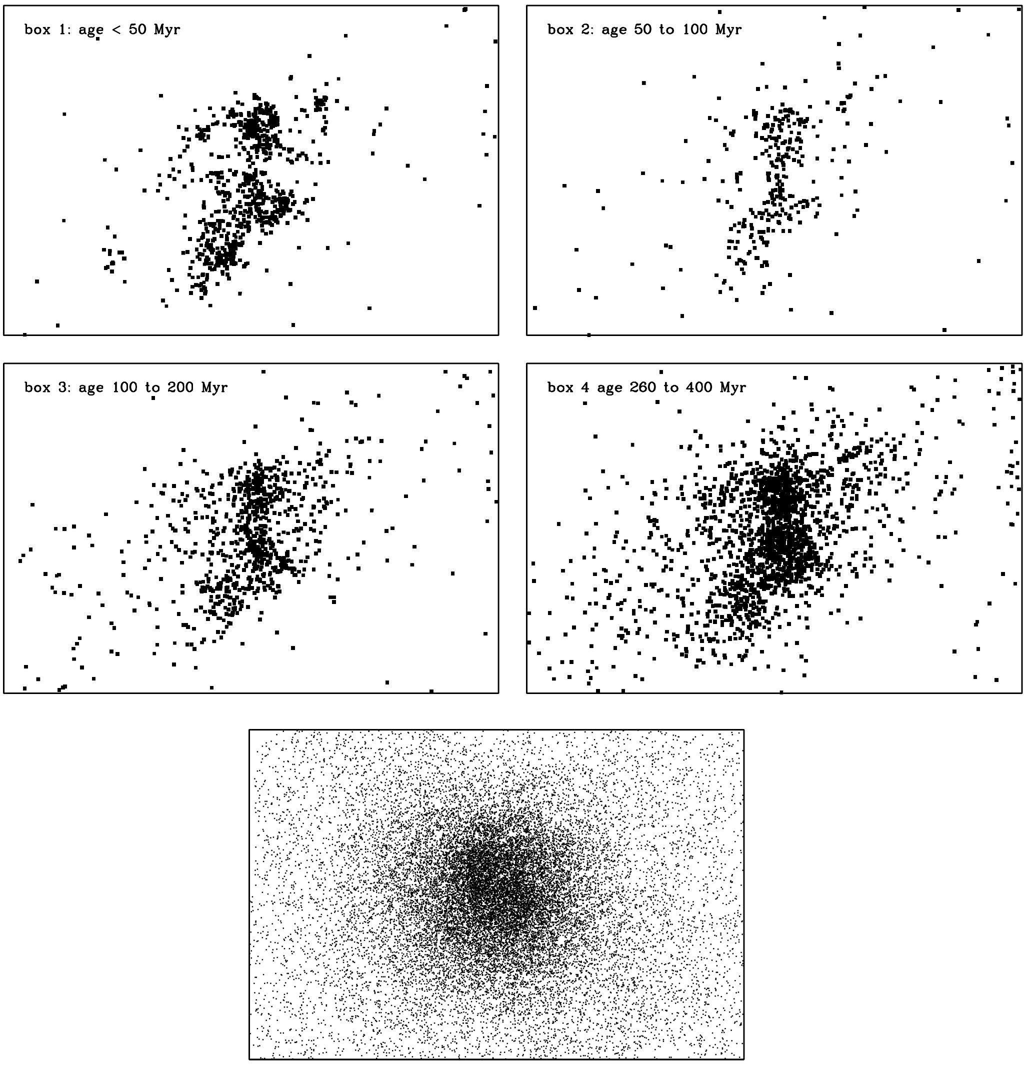

Fig. 4. Spatial distributions of stars in different boxes of the CMD. The number of stars in boxes 1, 2, 3 and 4 are 882, 344, 897 and 2019 respectively. The control box contains 23 000 stars. North on top, East to the left.

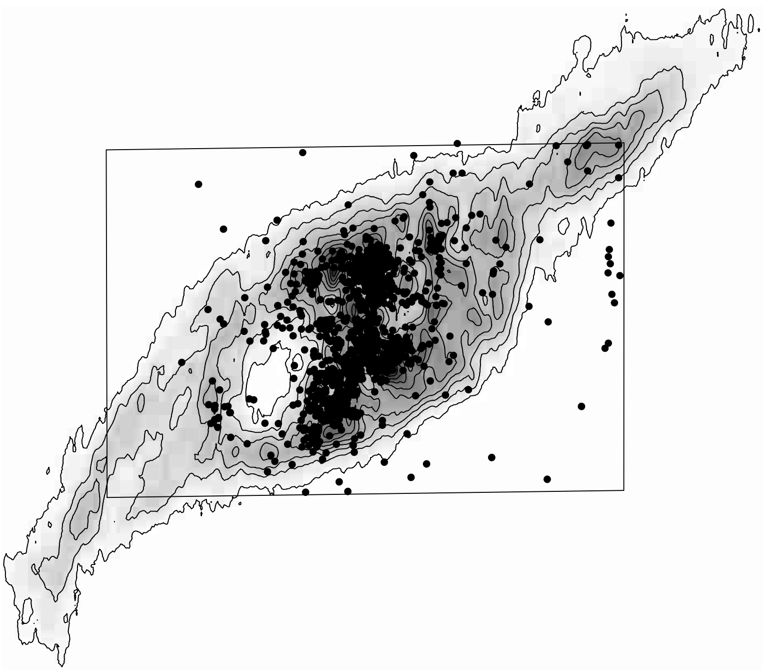

Fig. 5. Stars younger than 100 Myr (boxes 1 and 2) are plotted over HI isodensity contours from de Blok & Walter (2000b).

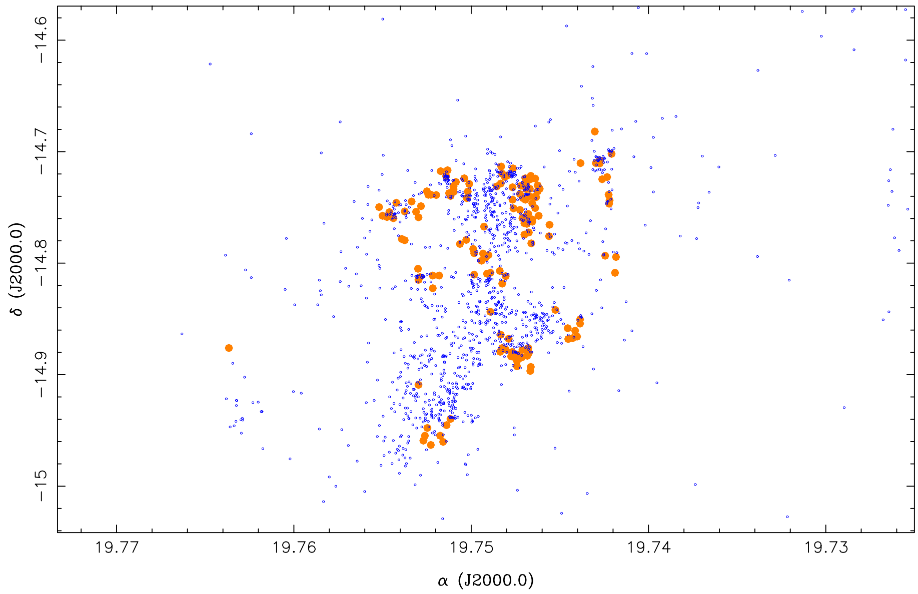

Fig. 6. The space distribution of young stars (boxes 1 and 2) is compared to the distribution of HII regions. Not the whole field has been surveyed in Hα.

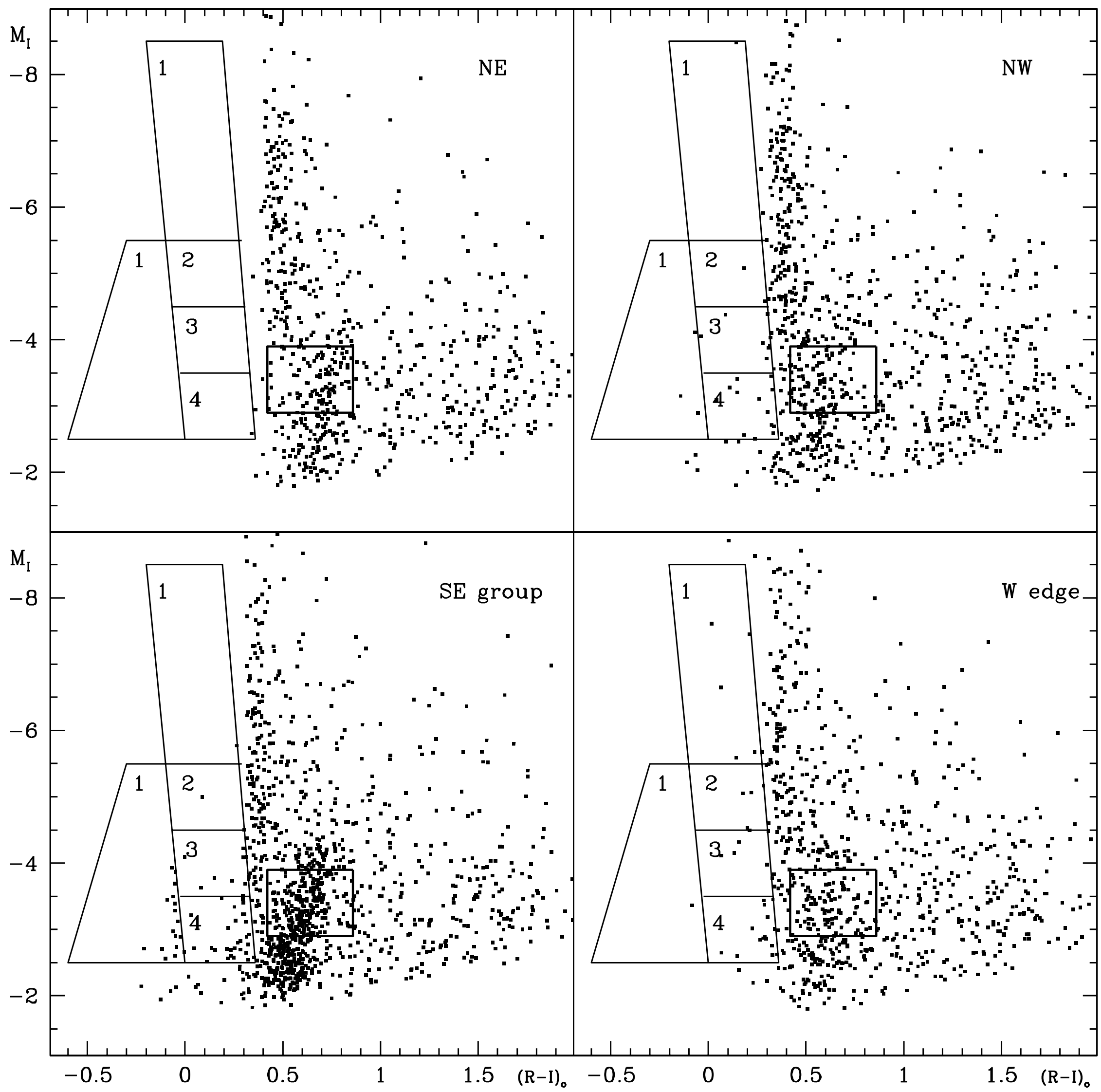

Fig. 7. Color magnitude diagrams of four 25 min^2 regions as described in the text.

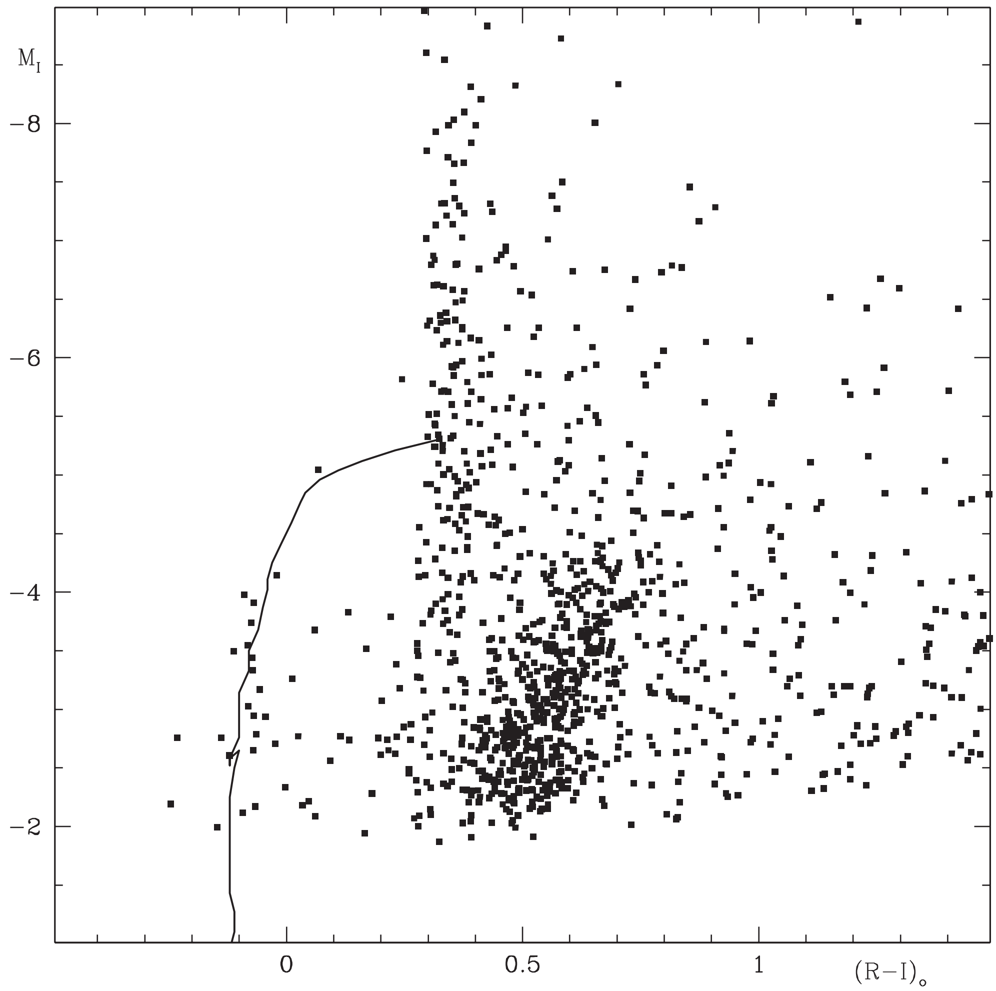

Fig. 8. The colour-magnitude diagram of the SE association. An isochrone of 50 Myr matches the blue stars.

contains necessary more stars. Since the number of young stars in each region is small, one must be careful not to over interpret the counts. r_{1234} in the last column, is the ratio of the total number of young stars divided by the number of stars in the control box. With the exception of the NE corner devoid of young stars, the three other regions have identical ratios implying that the SFH in these regions has been nearly identical in the last ~400 Myr. This SFH, however, is not dependent on the *current* amount of HI present. Figure 5 suggests that there is no HI near the western edge of the field; this is not the case, low density HI has been observed in a volume much larger than the CFH12K. See, for example HI maps by Roberts (1972) or de Blok & Walter (2000a).

Nineteen blue stars, are seen along the western border of the CFH12K field. This area do contain hydrogen but in a lower density than the disk. In order to confirm their blue colour, we have acquired, under non photometric conditions and very late in the season, *B* and *V* observations of the north west corner of the field. These observations were obtained with the Jacobus Kapteyn Telescope (JKT) on La Palma. The bulk of the stars in the JKT field have $(b - v) > 1.0$. The few stars in boxes 1 and 2 were found to be among the bluest with $(b - v) < 0.8$ thus confirming their blue nature.

Table 1. Star counts in different CMD boxes.

Regions	d'	N_1	N_2	N_3	N_4	N_c	r_{1234}
NE corner	22′	0	0	0	1	100	0.01
NW corner	22′	4	2	7	14	98	0.27
Western edge	19′	6	4	5	15	107	0.28
SE group	14′	17	2	9	30	239	0.24

6. Conclusions

The spatial distribution of stars in NGC 6822 reveals that:
1) Stars younger that 100 Myr are characterized by a clumpy and filamentary spatial distribution.
2) Older stars (160÷400 Myr) present a smoother distribution that well traces the HI disk.
3) Young stars are seen corresponding to the HI density peak detected by de Blok & Walter (2000b) in the NW region.
4) No star younger than 100 Myr is found in the HI hole in the SE of the galaxy. This set a lower age for the HI shell of 100 Myr, thus compatible with the 130 Myr estimated by de Blok & Walter (2000b). We note however that very few stars

with ages ranging from 100 to 200 Myr are present in the hole, suggesting a lack of a stellar population that might have been responsible for the shell formation.

5) Young stars are also seen in regions of low gas density. This is rare but not unusual. Indeed such young stars have been seen between the Magellanic Clouds (Demers & Battinelli 1998; Demers 2001). If stars form sporadically, at a low rate, then we should expect to find stars of all ages in the periphery of NGC 6822.

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