SURVEY OF STELLAR POPULATIONS IN THE SMC

D.HATZIDIMITRIOU
Anglo-Australian Observatory, P.O. Box 296, NSW 2121, Australia

and

L.T. GARDINER
Department of Astronomy, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, U.K.

Abstract. A stellar population survey covering a total of 130 square degrees in the outer parts (beyond 2 kpc from the optical centre) of the Small Magellanic Cloud is presented, based on colour-magnitude diagrams constructed from COSMOS measurements of a series of UKST photographic plates.

1. Introduction

As a dwarf irregular galaxy distinguished by its membership of an interacting system of galaxies, the Small Magellanic Cloud (SMC) can provide us with insights into the evolutionary development of dwarf irregular galaxies as well as the role of external dynamical interactions in stimulating star formation events.

The aim of the present survey of the stellar content of the outer regions of the SMC is to achieve a complete description of its star formation history from the age spectrum and spatial distribution of its stellar population.

The data set comprises colour (B$-$R) and magnitude (R) information for 1.1×10^6 stars in the outer parts of the SMC, covering a total area of 130 square degrees on the sky. The photometry is photographic from UKST plates digitised with the COSMOS automatic microdensitometer. The limiting magnitude of the survey is R=20mag, and the completeness better than 90% down to R=19.5mag. Details on the accuracy and completeness of the data-set and on the methodology of the analysis can be found in Hatzidimitriou *et al.* (1989) and Gardiner and Hatzidimitriou (1991; hereafter, GH). Colour-magnitude diagrams (CMD) were constructed in a grid, consisting of 0.87-square-degree cells. A complete series of these diagrams is published elsewhere (GH).

2. The Age Distribution in the Outer Parts of the SMC

a. Populations Younger than 2Gyr: In the following, age estimates based on the main-sequence are derived using the Revised Yale Isochrones. The main-sequence (MS) stars visible above the survey limit correspond to ages younger than $\simeq$2 Gyr, for a distance modulus of 18.8. Fig.1 shows the distribution of these younger populations over the area studied. The Wing region is the most conspicuous feature of this distribution. The younger population also appears to be more extended in the NE parts of the SMC (to the North of the Wing). However, some –but not all– of this effect is due to the shorter mean distance modulus in these areas (see Hatzidimitriou and Hawkins 1989).

B. Barbuy and A. Renzini (eds.), The Stellar Populations of Galaxies, 157–160.

Luminosity functions were also constructed for the MS stars (with a limiting magnitude of R=19.5 in order to avoid incompleteness problems) over extended circular annuli (for statistical reasons). A detailed analysis can be found in GH. Generally, a mixture of stellar generations with a median age increasing with distance from the SMC centre was found. Only two stellar generations could be identified as discrete SF events: the well-known very young population in the Wing (5×10^7yr,

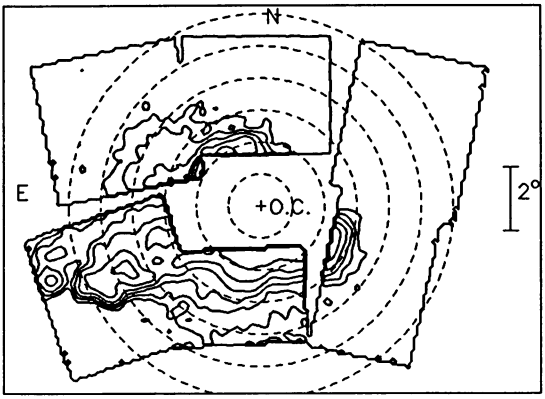

Figure 1. *Distribution of MS stars.*

see also Irwin *et al.* 1990) and a $4 - 6 \times 10^8$yr population most conspicuous in the NE area (near the 'outer arm'). There is evidence that the mean age increases with increasing distance from the optical centre of the SMC (always assuming that the IMF remains the same at least during the last 2 Gyr).

b. Populations older than 2Gyr: The clump/red horizontal branch(RHB) is the most conspicuous feature on the CMD in the SMC field beyond 2kpc from the centre (except for the Wing region). Stars belonging to a wide range of ages (from $\simeq 10^8$yr to $\geq$10Gyr) can populate the RHB.

Comparison of the observed numbers of MS stars ($\tau < 1-2$Gyr) and of clump/RHB stars in conjunction with stellar evolutionary arguments indicates that the majority of the clump/RHB stars in the outer areas studied here are older than 1-2Gyr. Fig.2 shows a contour map of the surface number density of the clump/RHB stars. Although this distribution is much smoother than that of Fig.1, there are indications of asymmetries especially in the N and E areas.

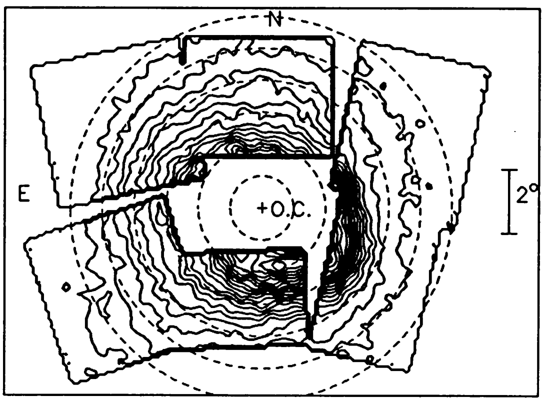

Figure 2. *Distribution of RHB stars.*

Using the colour difference between the clump/RHB and the red giant branch at the level of the RHB as a *median* age indicator (see Hatzidimitriou 1991 for the definition and calibration of the indicator), we find that beyond 2–2.5kpc from the optical centre, the SMC field has a *median* age of 10 ± 2Gyr.

There is a weak 'horizontal extension' of the red clump towards bluer colours (but to the red of the instability strip). This can be interpreted (using the above age indicator) as belonging to a population older by 2-3Gyr than the median population represented by the main clump. This population –if present– would account for $\simeq$7% of the mass of the total population. This estimate agrees with that by Frogel (1984) on the relative contribution of the mass of old stars (inferred by the number of RR-Lyrae stars) to the total mass of the SMC.

3. Kinematics of intermediate age stars in the outer parts

In the SMC, young stars and gas are known to have very complex kinematics (e.g. Torres and Carranza 1987), and they form four apparently distinct velocity groups. This kinematical behaviour along with (still controversial) claims for large line-of-sight depth in the SMC has led some authors to the conclusion that the SMC is in the process of 'irreversible disintegration' (Mathewson *et al.* 1988). A recent study based on RHB stars has shown that large line-of-sight depths exist among populations older than $\simeq$1-2Gyr (see Hatzidimitriou and Hawkins 1989; Gardiner and Hawkins 1991; Mateo & Hatzidimitriou, this volume).

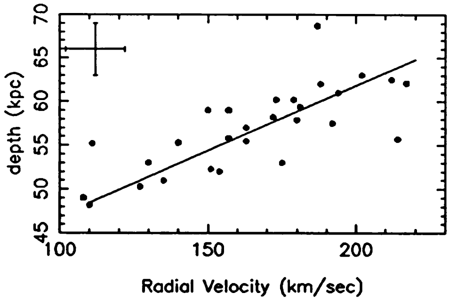

Figure 3. *Radial Velocity-Distance correlation for RHB stars in the NE.*

Radial velocities for a sample of RHB/clump stars in a 40arcmin field in one of the 'deep' regions in the NE (at 2.7kpc from the optical centre) were recently obtained using the fibre spectroscopic facility Autofib at the 3.9m AAT (Hatzidimitriou *et al.*, in prep.). Figure 3 shows the discovered correlation between radial velocity and line-of-sight distance for these stars. If this is due to simple streaming motion, the timescale of the motion is a few 10^8yr, which coincides with the recent encounter between the LMC and the SMC (Fujimoto and Murai 1984). This result, in conjunction with the large depth in extended areas in the N and E, confirms that the recent close encounter between the LMC and the SMC had a profound effect on the dynamical stability of the latter.

4. On the Star Formation History of the SMC

On the basis of the results briefly described in the previous paragraphs, the following comments can be made on the star formation (SF) history of the SMC and its possible connection with tidal interactions with the LMC and the Galaxy (details in GH):

(i) The major SF period in the SMC outer regions appears to have occurred $\sim$10 Gyr ago, although there is evidence for the presence of an older population amounting to $\sim$7% in mass.

(ii) There is a progressive aging of the stellar populations with distance from the optical centre. This effect may be connected to the density of the gas available for SF as a function of time and radius (e.g. critical-density SF scenario by Kennicutt 1989).

(iii) There is some evidence of a dynamical disturbance of the SMC in the Eastern and Northern outer regions (for both young and old populations), which appears to be connected with the most recent close encounter between the SMC and the LMC. However the effect of such interactions to the SF rate is difficult to assess. In the last 1-2 Gyr, there appear to be two distinct stellar generations which may be connected with dynamical events: the Wing and the 0.4-0.6Gyr population in the NE. In earlier periods the situation becomes very unclear. The age distribution of star clusters and of the general field populations in the two Clouds are significantly different (see also Mateo, this volume). Using the RHB dating method used above for published CMDs in the LMC, we find that the major SF event in the LMC occurred probably 2-3Gyr later than in the SMC (see also GH). It is therefore difficult to connect the SF histories of the two Clouds in this respect. However, we should keep in mind that the LMC and SMC were not necessarily always bound to each other and that the perigalactic distance may have been progressively larger (and hence the encounters less disruptive) in the past.

5. References

Frogel, J.A. 1984. *P.A.S.P.*, **96**, 856.
Fujimoto, M. and Murai, T. 1984. *IAU symp.No.108*, p.115, Reidel.
Gardiner, L.T. and Hawkins, M.R.S. 1991. *M.N.R.A.S.*, **251**, 174.
Gardiner, L.T. and Hatzidimitriou, D. 1991. *M.N.R.A.S.*, submitted.(GH)
Hatzidimitriou, D. 1991. *M.N.R.A.S.*, **251**, 545.
Hatzidimitriou, D., Hawkins, M. and Gyldenkerne, K. 1989. *M.N.R.A.S*, **241**, 645.
Hatzidimitriou, D. and Hawkins, M.R.S. 1989. *M.N.R.A.S*, **241**, 667.
Hatzidimitriou, D., Cannon, R.D., Hawkins, M.R.S., and Teo, A. *in prep.*
Irwin, M.J., Demers, S. and Kunkel, W.E. 1990. *Astron.J.*, **99**, 191.
Kennicutt, R.C. 1989. *Ap.J.*, **344**, 685.
Mathewson, D.S., Ford, V.L. and Visvanathan, N. 1988. *Ap.J.*, **333**, 617.
Torres, G. and Carranza, G.J. 1987. *M.N.R.A.S*, **226**, 513.

DISCUSSION

SERRANO: Can you tell the dependence of ρ(r) in your old population?

HATZIDIMITRIOU: In the North the projected surface density profiles are relatively well represented by an exponential law $N \propto e^{-r/l}$, with $l \simeq 1.2$kpc (Gardiner and Hawkins 1991). However one should be aware of the very different distribution of populations of different ages.

ZINNECKER: I am a little confused about the evidence on interaction-triggered SF in the SMC. While you concluded that there is good evidence, Mario Mateo told us before that there is no such evidence. Could you clarify the situation?

HATZIDIMITRIOU: I agree with M.Mateo's conclusion that there is no evidence of major SF events triggered by tidal interactions in the MCs for at least the first $\sim$10 Gyr of their lives. But there is evidence of both dynamical disturbance and of discrete SF events in the E and NE in the SMC outer parts. There is also evidence for an increase of the enrichment rate in the last 2 Gyr in the SMC (Da Costa 1991; IAU 148). All these effects could be due to the recent close encounter of the MCs with the Galaxy and of the LMC and SMC with each other.