The stellar populations in NGC 1705

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Abstract

We present HST photometry of the resolved stellar populations in the late-type dwarf NGC 1705. The galaxy has been observed both with WFPC2 and NICMOS. The colour-magnitude diagrams (CMDs) show that NGC 1705 hosts both young (a few Myr old) and very old (up to 15 Gyr old) stars, with the former strongly concentrated toward the galactic center and the latter present everywhere. The tip of the red giant branch (TRGB) is clearly visible and implies a distance modulus $(m-M)_0 = 28.63 \pm 0.40$, corresponding to a distance of 5.3 ± 1.0 Mpc.

1 Introduction

NGC 1705 is a dwarf irregular galaxy, often classified as Blue Compact galaxy, at $\alpha = 45^h 54^m$ and $\delta = -53°22'$ characterised by very blue colours: $(U-B)_0 = -0.45$ and $(B-V)_0 = 0.42$ (York et al. 1990). It is a gas rich system and has a bipolar filamentary Hα morphology, suggesting an outflow of ionised gas (Meurer et al. 1992). It shows one of the most spectacular examples of Super Star Cluster (SSC): 40%-50% of the optical/UV emission of the whole galaxy comes from the SSC.

In order to resolve for the first time its stellar populations and to study its star formation history, we have observed NGC 1705 with HST. We have acquired deep images with WFPC2 (F555W and F814W filters) and NICMOS (F110W and F160W bands). The optical frames cover almost the whole galaxy, while the infrared camera (NIC2) maps only the central region.

2 Observations and data reduction

We have obtained a 10400 sec exposure both in the F555W and F814W bands, and a 5120 sec exposure both in the F110W and F160W bands. To overcome the PSF undersampling problem, typical of HST data, both the optical and infrared data were acquired using the dither technique, and dithered images were combined with the Drizzle package (Fruchter et al. 1997)

The photometric analysis was perfomed with the IRAF package DAOPHOT. The optical photometry provides ~ 20000 objects down to $m_{\mathrm{F555}} \sim 29$ in the PC field and ~ 20000 in the WFs. Of these, 9224 stars have photometric error $\sigma_{\mathrm{DAO}} \leq 0.1$ in the PC, and 4691, 1551 and 2376 in the WF2, WF3 and WF4, respectively. In the infrared bands we find ~ 2400 objects down to $m_{\mathrm{F110}} \sim 26$ and 829 of these have photometric error $\sigma_{\mathrm{DAO}} \leq 0.1$.

The instrumental magnitude, obtained with the PSF fitting technique, of each optical object was calibrated in the HST VEGAMAG system, following the prescriptions given by Holtzman et al. (1995a, b), while the infrared data were calibrated into the VEGAMAG system, with the formula given by Dickinson (1999).

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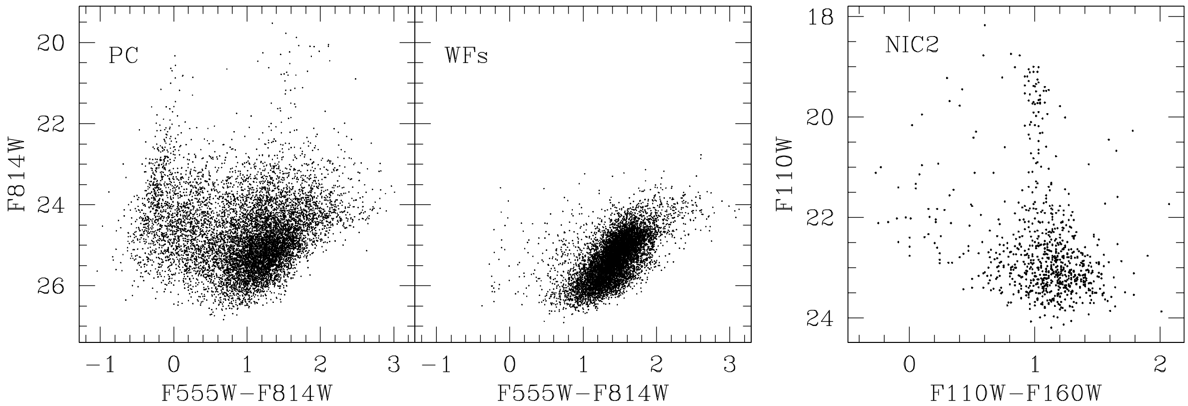

Figure 1: CMDs of the stars most tightly selected in the PC, WFs and NIC2 fields (left, middle and right panel respectively).

3 Color-magnitude diagrams

The optical CMDs, shown in Fig.1 contain only the stars selected with the tightest criteria ($\sigma_{\rm DAO} \leq 0.1$). The PC-CMD presents the standard features of irregular galaxies: a well defined blue plume at $m_{\rm F555} - m_{\rm F814} \sim 0$, reaching mags as bright as $m_{\rm F814} \sim 20$, a red plume at $m_{\rm F555} - m_{\rm F814} \sim 1.7$, extending up to $m_{\rm F814} \sim 19.5$ and a crowded concentration of stars with $1 \leq m_{\rm F555} - m_{\rm F814} \leq 2$ and $24.2 \leq m_{\rm F814} \leq 26$.

The stellar populations in the WFs are old (red giant branch stars) and the position of the tip of the branch (TRGB) is clearly visible in the CMD while bright young stars are very rare.

From the field positions of the selected stars, shown in Fig.2, where the PC field is mapped, we see that the brighter and younger objects are concentrated toward the galactic centre, whereas faint stars are uniformly distributed over the whole galaxy, even if they are more easily resolvable in the external regions, where the crowding conditions are less intense.

The infrared CMD of Fig.1 contains the stars with $\sigma_{\rm DAO} \leq 0.1$. In this case only few stars are found in the bluest part of the diagram. This is not due to a physical lack of young stars (as we know from their cospicuous presence in the optical PC-CMD), but to the intrinsic faintness of hot stars in the infrared bands. On the other hand, the red plume is very well sampled and shows a tight vertical finger with $m_{\rm F110}$ from 19 to 21 plus a clump of fainter stars with $0.6 \leq m_{\rm F110} - m_{\rm F160} \leq 1.6$.

By inspecting the objects rejected by DAOPHOT selection criteria, we have recognized several candidate star clusters and background galaxies. We have 17 star clusters (besides the SSC) in the PC, 9 of which have been clearly cross-identified also in the NIC2 images, 4 in the WF2, 5 in the WF3 and 3 in the WF4. The candidate background galaxies are 13 in the WF2, 11 in the WF3 and 18 in the WF4. In the latter case, we are presumably dealing with a real, yet unclassified, galaxy cluster, since the derived galaxy density (18 arcmin^{-2} down to $m_{\rm F814} = 22$) is almost a factor of 5 higher than that predicted by deep field galaxy counts (Pozzetti et al. 1998).

We have cross-identified the stars falling both in the PC and NIC2 cameras. There are 1822 stars measured in all the F555W, F814W, F110W and F160W frames. To check what fractions of the objects with equal coordinates in the four filters have physically meaningful colours and have therefore been correctly identified, we have checked the position of the 1822 objects in all the possible combinations of CMDs in the four bands. We find that the objects keep consistently their colors in the various combinations of bands. Therefore we are dealing with intrinsic, physical features of real stars and not with spurious colors due to spatial coincidence of different objects.

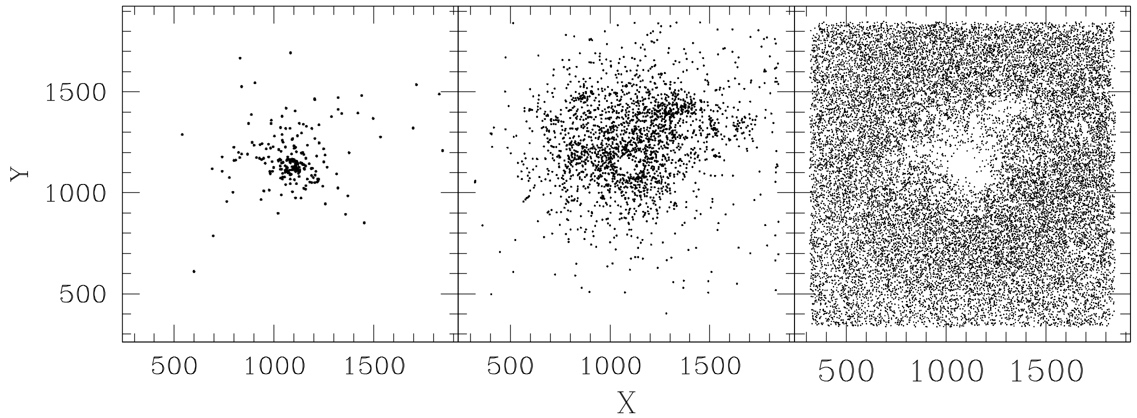

Figure 2: Distribution of stars detected in the F814W-PC field. The stars plotted in the left panel are brighter than $m_{\rm F814} \leq 22.5$, those in the right one are fainter than $m_{\rm F814} \geq 25.5$, stars of intermediate brightness are mapped in the central panel. It is apparent the segregation of the brighter stars.

4 The distance-modulus

To determine the distance modulus of NGC 1705, we have used the data obtained from the photometric reductions of the WFs. We haven't used the PC because there the TRGB is contaminated by brighter younger stars. We have applied the Sobel filter (Sakai at al. 1996) to the data, calibrated into the Johnson-Cousins photometric system. The tip magnitude is $I_{\rm TIP} = 24.62 \pm 0.08$. We used the equations of Salaris & Cassisi (1998) and Da Costa & Armandoff (1990) to determine the distance modulus of NGC 1705.

Taking into account the uncertainties related both to the photometry and the TRGB magnitude-distance relation, we find that the distance modulus of the galaxy is $(m - M)_0 = 28.63 \pm 0.40$, corresponding to a distance of 5.3 ± 1.0 Mpc.

5 Comparison with stellar evolutionary models

For an easier interpretation of the CMD in terms of stellar evolutionary phases, we have superimposed (Fig.3) on the CMD the Padova tracks with metallicity more likely to be appropriate for NGC 1705 ($Z = 0.008$, $Z = 0.004$, and $Z = 0.0004$, Fagotto et al. 1994a,b). The plotted tracks are for masses in the range 0.9-30 $M_\odot$. The theoretical tracks have been transformed into the observational plane adopting $E(B - V) = 0.045$ and $(m - M)_0 = 28.63$ and the photometric conversion tables by Origlia & Leitherer (2000).

Whatever the assumed metallicity, from this overlap it turns out that the blue plume si populated both by intermediate- and high-mass stars on the MS and by massive stars at the blue edge of the core helium burning phase, the red plume hosts red supergiants and AGB stars, and the faint clump with $1 \leq m_{\rm F555} - m_{\rm F814} \leq 2$ and $24.5 \leq m_{\rm F814} \leq 26.6$ is populated by RGB stars. The TRGB is approximately 2.5 mags brighter than our faint mag limit, so there is no doubt that the RGB is well sampled by our data.

6 Conclusions

We have acquired deep HST photometry of the nearby BCD NGC 1705 to resolve its stellar populations and derive information on its evolution. The excellent performance of the HST has allowed

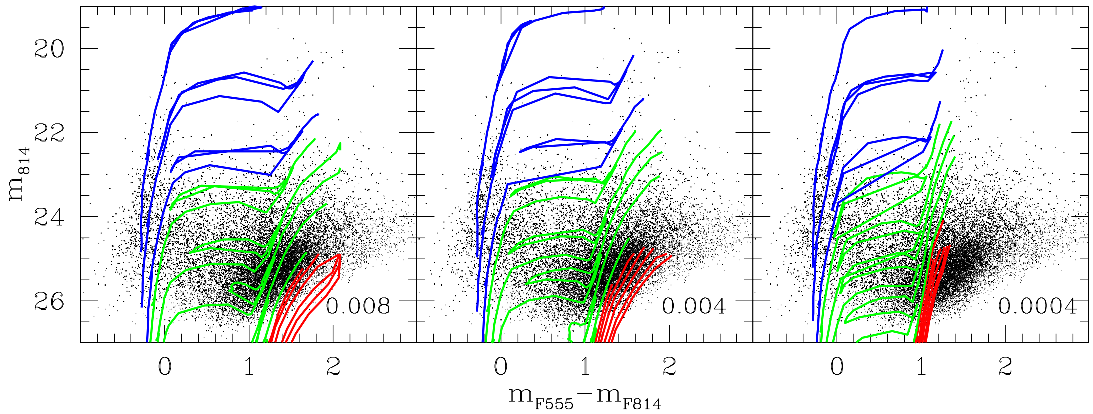

Figure 3: CMD of the stars selected in the PC and WFs fields with the Padova tracks superimposed. The tracks have metallicities of $Z = 0.008$, $Z = 0.004$, or $Z = 0.0004$ respectively.

us to measure also the fainter/older stars in the RGB phase and to clearly identify the TRGB in the WFs. Thanks to this result, we have derived from the TRGB luminosity a distance-modulus $(m - M)_0 = 28.63 \pm 0.40$, corresponding to 5.3 ± 1.0 Mpc.

Our data show that outside the SSC there are only a few stars more massive than 30 $M_\odot$, we thus suggest that the most recent conspicuous SF activity in the field of NGC 1705 has occurred approximately 15 Myr ago. This does not mean that the galaxy population is predominantly old. By separating, with the help of the Padova tracks, the observed optical CMD in three different zones corresponding to different stellar masses, we find in fact that in the PC field, of the 9224 stars mosty tightly selected, 50% have mass ≥ 3 $M_\odot$ and age lower than 500 Myr, and ~800 have mass ≥ 7 $M_\odot$, and thus younger than 60 Myr.

We can conclude that NGC 1705 is a post-starburst galaxy, since it does not appear to have had any cospicuous SF activity in the last few Myrs: our CMDs show that the last episod of SF in the field occurred around 15 Myr ago, preceded by several other episodes or by a continuous activity.

References

Da Costa, G. S., Armandroff, T. E. 1990, ApJ 100, 162
Dickinson, M. 1999, "NICMOS Data Handbook", Version 4.0 (Baltimore, STScI)
Fagotto, F., Bressan, A., Bertelli, G., Chiosi, C. 1994, A&AS 104,365
Fagotto, F., Bressan, A., Bertelli, G., Chiosi, C. 1994, A&AS 105,29
Fruchter, A., Hook, R. N. 1997, SPIE 3164, 120
Gallagher, J., Blades, J. C., Morton, D. C., Wamsteker, W. 1990, ApJ 351, 412
Holtzman, J. A., Burrows, C. J., Casertano, S., Hester, J. J., Trauger, J. T., Worthey, G. 1995, PASP 107, 1065
Holtzman, J. A., Hester, J. J., Casertano, S., Trauger, J. T., Watson, A. M., Ballester, G. E., Burrows, C. J., Clarke, J. T., Evans, R. W., Gallagher, J. S. III, Griffiths, R. E., Hoessel, J. G., Matthews, L. D., Mould, J. R., Scowen, P. A., Spapelfeldt, K. R., Westphal, J. A. 1995, PASP 107, 156
Meurer, G. R., Freedman, K. C., Dopita, M. A., Cacciari, C. 1992, AJ 103, 412
Origlia, L., Leitherer, C. 2000, AJ 119, 2018
Pozzetti, L., Madau, P., Zamorani, G. 1998, ASP conferences series 146, 214
Sakai, S., Freedman, W. L., Madore, B. F. 1996, ASP conference series 92, 584
Salaris, M., Cassisi, S. 1998, MNRAS 198, 166
York, D. G., Caulet, A., Rybsky, P., Gallagher, J., Blades, J. C., Morton, D. C. Wamsteker, W. 1990, ApJ 351, 412