Stellar Populations - Planning for the Next Decade
Proceedings IAU Symposium No. 262, 2009
Gustavo Bruzual & Stéphane Charlot, eds.

doi:10.1017/S1743921310002681

An analysis of the composite stellar population in M32

P. Coelho[1], C. Mendes de Oliveira[2] & R. Cid Fernandes[3]

[1]Núcleo de Astrofísica Teórica, Univ. Cruzeiro do Sul, email: paula.coelho@cruzeirodosul.edu.br

[2]Depto. de Astronomia, Universidade de São Paulo, email: oliveira@astro.iag.usp.br

[3]Depto. de Física, Universidade Federal de Santa Catarina, email: cid@astro.ufsc.br

Abstract. We obtained long-slit spectra of high S/N of the galaxy M32 with the GMOS Spectrograph at the Gemini-North telescope. We analysed the integrated spectra by means of spectral fitting in order to extract the mixture of stellar populations that best represents its composite nature. As our main result, we propose that an ancient and an intermediate-age population coexist in M32, and that the balance between these two populations change between the nucleus and outside one effective radius ($1\,r_{\rm eff}$) in the sense that the contribution from the intermediate population is larger at the nuclear region. We retrieve a smaller signal of a young population at all radii whose origin is unclear, and may be a contamination from horizontal branch stars, blue stragglers or a true young population previously unidentified (Monachesi *et al.*, this volume). We compare our metallicity distribution function for a region 1 to 2 arcmin from the centre to the one obtained with photometric data by Grillmair *et al.* Both distributions are broad, but our spectroscopically derived distribution has a significant component with $[Z/Z_\odot] \leqslant -1$, which is not found by Grillmair *et al.*

Keywords. galaxies: individual (M32), galaxies: stellar content

1. Introduction

M32 is a controversial galaxy. This low-mass satellite of M31 has long been considered the prototype of the *compact elliptical* morphological classification Bender *et al.* (1992): low mass, high surface brightness galaxies, tidally truncated companions to massive galaxies. So far, few objects match this description (e.g. Ziegler & Bender 1998). The origins of the peculiar structural properties of M32 are still a matter of debate and the proposed models span a wide range of hypotheses, from a true elliptical galaxy at the lower extreme of the mass sequence to a threshed early-type spiral. Controversial or not, M32 is a galaxy we need to understand because it plays an important role in resolving controversies about how to interpret the integrated spectra of galaxies. Here we present our contribution to the study of the stellar population of this galaxy. We obtained spectra of M32 along its major axis out to a radius of 2 arcmin, with the Gemini-North Telescope and Gemini Multi-Object Spectrograph (GMOS). We adopt the code STARLIGHT (Cid Fernandes *et al.* 2005) and state-of-the-art stellar population spectral models to perform a pixel-by-pixel modelling of the integrated spectrum of M32. For the first time we extend the analysis of integrated spectra of M32 to the radii of the resolved CMD study by Grillmair *et al.* (1996). Based on observations obtained at the Gemini Observatory, observing run ID: GN-2004B-Q-74.

2. Observations and analysis

Long-slit spectra of M32 were obtained on Oct/2004 with the GMOS on Gemini-North. We used the R400 grating, a 0.75-arcsec slitwidth and an effective target wavelength at 6800 Å, resulting in spectra with coverage 4700 − 8930 Å and an average resolution of full width at half-maximum (FWHM) = 5.4 Å. Four exposures of 30 s each were taken with the slit positioned over the nucleus of the galaxy, along the major axis of the galaxy [position angle (PA) = 165°]. The slit was subsequently moved along the major axis off the central region to avoid contamination by scattered light (see Rose *et al.* 2005), and four long exposures of 3060 s each were taken. From the short exposure observations, we extracted the nuclear spectra with an aperture of diameter of 1.5 arcsec. From the long off-centre exposures, two apertures were extracted in each exposure: one covering the radius from 30 to 60 arcsec (hereafter, position 1), and another covering from 1 to 2 arcmin (hereafter, position 2).

For the analysis of the spectra, we employed the STARLIGHT code by Cid Fernandes *et al.* (2005), modified to allow the study of continuum-normalized spectra (as opposed to flux-calibrated spectra). STARLIGHT combines spectra from a user-defined base of individual spectra in search for linear combinations that match an input observed spectrum. We adopt medium spectral-resolution simple SSP models spanning different ages and metallicities as our spectral base, i.e., we describe the data in terms of a superposition of multiple bursts of star formation. We adopted four sets of SSP models: Bruzual & Charlot (2003), hereafter BC03; Le Borgne *et al.* (2004), hereafter PEGASE-HR; Charlot & Bruzual (in preparation), hereafter Charlot & Bruzual; Vazdekis *et al.* (submitted), hereafter Vazdekis *et al.*

3. Results and Conclusions

The results for the population mixture retrieved by our analysis are presented in Fig. 1, where the light-fraction vectors $\mathbf{x}_j$ are shown as a function of the SSP parameters log(age) and [Z/Z$_\odot$]. The projections of $\mathbf{x}_j$ in the log(age) and Z planes give the age distribution functions (ADFs) and metallicity distribution functions (MDFs), shown in Fig. 2.

We find that in the nuclear region, 30−60 per cent (depending on the model used) of the light at 5000 Å comes from an ancient population [older than log(age) = 10], and that intermediate-age populations [log(age) between 9 and 9.9] contribute to 20−50 per cent of the light. Beyond $1\,r_{\rm eff}$ ($r_{\rm eff} \sim 33$"), the light coming from the ancient population increases (55−95 per cent) and the contribution from intermediate-age populations decreases (5−40 per cent). There is signal of a young-population [log(age) younger than 9.0] that contributes up to 38 per cent at the nucleus, and up to 25 per cent beyond $1\,r_{\rm eff}$. Evidence of such young population has been found recently by Monachesi *et al.* (this volume). It is also possible nevertheless that part of this signal is due to hot horizontal branch stars (such as the ones identified by Brown *et al.* 2000) or blue-stragglers, not accounted for in the present SSP models.

The metallicity distribution peaks around solar values, and we retrieve a non-negligible contribution from a metal-poor population with [Z/Z$_\odot$] $\leqslant -1.0$. Such metal-poor population has not been identified in CMD analysis such as Grillmair *et al.* (1996). As our position 2 samples the same radius as the analysis by Grillmair *et al.*, this disagreement between integrated light studies and resolved stellar studies remains to be fully understood.

We computed the luminosity-weighted parameters of our population mixtures by adopting $\langle \log(\text{age}) \rangle = \sum_j x_j \cdot \log(\text{age})_j$ and $\langle [Z/Z_\odot] \rangle = \sum_j x_j \cdot [Z/Z_\odot]_j$ where the vector $\mathbf{x}_j$

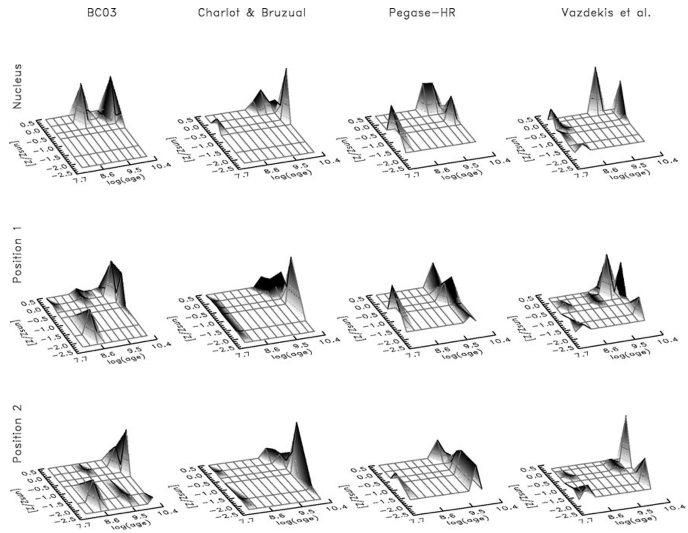

Figure 1. Representation of the light-fraction vectors x_j as a function of log(age) and $[Z/Z_\odot]$. The results for the nucleus, positions 1 and 2 are shown at the top, middle and bottom rows, respectively. Each column shows the results for a different set of base models, as indicated at the top of the figure.

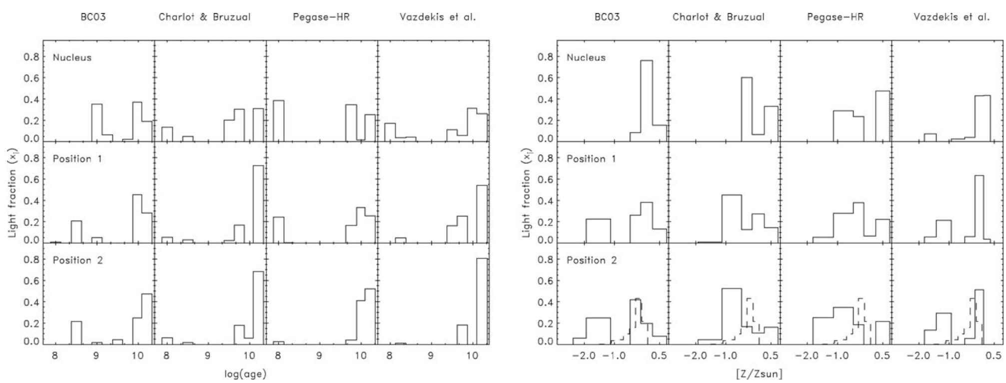

Figure 2. *Left panel:* Age distribution functions obtained for each observed aperture (in rows) and each set of models (in columns), according to the labels. *Right panel:* Metallicity distribution functions obtained for each observed aperture (in rows) and each set of models (in columns), according to the labels. The dashed line in the panels for position 2 correspond to the empirical metallicity distribution function by Grillmair *et al.* (1996).

gives the normalized light-fraction of the jth SSP component of the model fit ($\sum_j \mathbf{x}_j = 1$). In Table 1 we show the light-weigthed parameters obtained averaged on the four exposures, with their corresponding $1\,\sigma$ uncertainties.

A trend of higher ages and lower metallicities as one moves from the nucleus to position 2 can be seen in all cases, even though the gradient slopes and zero-points are model-dependent. These findings can be explained by two scenarios. Bekki *et al.* (2001) proposed that centralised star formation in M32 is triggered by the tidal field of M31, and hence a recent burst of star-formation on top of an ancient population would appear as a higher concentration of a younger and more metal-rich population in the nucleus. Alternatively, Kormendy *et al.* (2009) proposes that the young light in the centre would be the result of a starburst in the latest dissipative merger that made the galaxy. There is a gradual

Table 1. Average luminosity-weighted parameters.

Region	Age (Gyr)	[Z/Z$_\odot$]
	BC03	
Nucleus	4.3 ± 0.3	0.1 ± 0.1
Position 1	4.1 ± 0.9	-0.4 ± 0.2
Position 2	5.7 ± 1.5	-0.6 ± 0.1
	Charlot & Bruzual	
Nucleus	6.4 ± 0.3	0.0 ± 0.1
Position 1	10.4 ± 2.8	-0.2 ± 0.1
Position 2	11.9 ± 0.9	-0.4 ± 0.1
	Pegase-HR	
Nucleus	1.8 ± 0.2	0.0 ± 0.1
Position 1	2.3 ± 0.9	-0.3 ± 0.1
Position 2	5.8 ± 2.1	-0.6 ± 0.1
	Vazdekis	
Nucleus	2.5 ± 0.2	0.0 ± 0.1
Position 1	4.7 ± 0.6	-0.3 ± 0.1
Position 2	6.0 ± 1.6	-0.6 ± 0.1

change as radius increases, to more important contributions from older stars that formed before the most recent merger(s).

Our main result is that an ancient and an intermediate-age population co-exist in M32, in agreement with findings of photometric studies (e.g. Brown *et al.* 2000; Alonso-García *et al.* 2004; Davidge & Jensen 2007). Moreover, we propose that the balance between these two populations change from the nucleus to the halo (outside $1\,r_{\rm eff}$) in the sense that the contribution from the intermediate population is larger at the nuclear region. The smaller contribution of a young population might be a signal of hot horizontal branch or blue-stragglers (not included in the SSP models), the identification of a previously unidentified young population (Monachesi *et al.*, this volume), or a combination of both.

These results were recently published in Coelho *et al.* (2009).

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