Mon. Not. R. Astron. Soc. **357,** L40–L44 (2005) doi:10.1111/j.1745-3933.2005.00014.x

The density of very massive evolved galaxies to $z \simeq 1.7$

P. Saracco,[1]★ M. Longhetti,[1] P. Severgnini,[1] R. Della Ceca,[1] V. Braito,[1] F. Mannucci,[2] R. Bender,[3,4] N. Drory,[5] G. Feulner,[3] U. Hopp[3] and C. Maraston[4]

[1] *INAF - Osservatorio Astronomico di Brera, Via Brera 28, 20121 Milano, Italy*
[2] *Istitudo di Radioastronomia-CNR, Large E. Fermi 5, 5012 Firenze, Italy*
[3] *Universitäts-Sternwarte München, Scheiner Str. 1, 81679 München, Germany*
[4] *Max-Plank-Institut fuer extraterrestrische Physik, Giessenbachstrasse, 85748 Garching, Germany*
[5] *University of Texas at Austin, Austin, TX 78712, USA*

Accepted 2004 November 30. Received 2004 November 29; in original form 2004 September 22

ABSTRACT

We spectroscopically identified seven massive, evolved galaxies with magnitudes $17.8 < K < 18.4$ at $1.3 < z < 1.7$ over an area of ~160 arcmin^2 of the MUNICS survey. Their rest-frame K-band absolute magnitudes are $-26.8 < M_K < -26.1$ ($5L^* < L_K < 10L^*$) and the resulting stellar masses are in the range 3–6.5 × 10^{11} M$_\odot$. The analysis we performed unambiguously shows the early-type nature of their spectra. The seven massive, evolved galaxies account for a comoving density of $(5.5 \pm 2) \times 10^{-5}$ Mpc^{-3} at $\langle z \rangle \simeq 1.5$, a factor 1.5 lower than the density $[(8.4 \pm 1) \times 10^{-5}$ Mpc$^{-3}]$ of early types with comparable masses at $z = 0$. The incompleteness (~30 per cent) of our spectroscopic observations accounts for this discrepancy. Thus, our data do not support a decrease of the comoving density of early-type galaxies with masses comparable to the most massive ones in the local Universe up to $z \simeq 1.7$. This suggests that massive evolved galaxies do not play an important role in the evolution of the mass density outlined by recent surveys in this redshift range, evolution which instead has to be ascribed to the accretion of the stellar mass in late-type galaxies. Finally, the presence of such massive evolved galaxies at these redshifts suggests that the assembly of massive spheroids has taken place at $z > 2$ supporting a high efficiency in the accretion of the stellar mass in massive haloes in the early Universe.

Key words: galaxies: elliptical and lenticular, cD – galaxies: evolution – galaxies: formation.

1 INTRODUCTION

The epoch of formation of high-mass ($\mathcal{M}_{\rm star} > 10^{11}$ M$_\odot$) early-type galaxies is one of the open questions relevant to the whole picture of galaxy formation and evolution. The uniform properties shown by the local ellipticals suggested the simple monolithic collapse scenario of galaxy formation (Eggen, Lynden-Bell & Sandage 1962; Arimoto & Yoshii 1987). On the other hand, the recent picture outlined by hierarchical models (White & Frenk 1991; Kauffmann 1996; Somerville & Primack 1999) depicts the formation of local ellipticals through subsequent mergers: the higher the final stellar mass of the galaxy, the later it has been assembled. The most massive of them (10^{11}–10^{12} M$_\odot$), populating the brightest end ($L \gg L^*$) of the luminosity function of galaxies, are those reaching their final mass most recently in this scenario, possibly at $z < 1$. Therefore, looking for $z > 1$ early types with stellar masses comparable to those of the most massive local ones is one of the most direct ways to address the question of galaxy formation. This is what we are doing through a near-infrared (near-IR) spectroscopic survey of early-type galaxy candidates selected to be at $z > 1$ and to have stellar masses well in excess to 10^{11} M$_\odot$ (Saracco et al. 2003a,b). The candidates consist of a complete sample of 31 bright ($K' < 18.5$) extremely red objects (EROs) with colours $R - K' \geqslant 5.3$ selected over two fields (~320 arcmin^2) of the Munich Near-IR Cluster Survey (MUNICS; Drory et al. 2001). Here, we report the spectroscopic confirmation for a sample of seven high-mass ($\mathcal{M}_{\rm star} > 3 \times 10^{11}$ M$_\odot$) field early-type galaxies identified at $1.3 < z < 1.7$. Throughout this paper we assume $H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_0 = 0.3$ and $\Lambda_0 = 0.7$.

2 SAMPLE SELECTION, OBSERVATIONS AND SPECTROSCOPIC CLASSIFICATION

2.1 Sample selection

The main aim of our spectroscopic survey is to identify early-type galaxies at $z > 1.2$ having stellar masses comparable to the most massive early types in the local Universe (10^{11}–10^{12} M$_\odot$). The

---

★E-mail: saracco@brera.mi.astro.it

© 2005 RAS

Downloaded from https://academic.oup.com/mnrasl/article/357/1/L40/1060623 by U.S. Department of Justice user on 16 August 2022

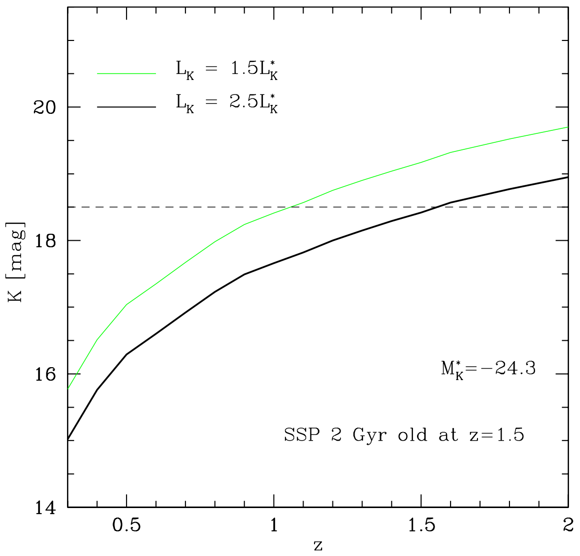

Figure 1. Expected K-band apparent magnitude for an $L_K = 1.5L^*$ (thin line) elliptical and for a $L_K = 2.5 \times L^*$ (thick line) elliptical as a function of redshift. The elliptical has been modelled by assuming a SSP model based on the evolutionary population synthesis of Maraston (1998, 2004). The elliptical is 2 Gyr old at $z \simeq 1.5$ and evolves passively down to $z = 0$. The dashed line marks the selection criterion $K \leqslant 18.5$.

red optical-to-near-IR colour ($R - K \geqslant 5.3$) favours the selection of $z > 1$ passively evolved galaxies while the magnitude $K' < 18.5$ assures the selection of systems with stellar masses well in excess of $\mathcal{M}_{\rm star} > 10^{11}$ M$_\odot$. Indeed, pushing back in time a local massive elliptical ($L = 2.5L^*$, 2–3×10^{11} M$_\odot$) it would be observed with a magnitude brighter than $K = 18.5$ up to $z \simeq 1.5$. This is shown in Fig. 1 where the expected K-band apparent magnitude of local bright ellipticals is plotted as a function of redshift (we considered $M^*{}_K = -24.3$, Kochanek et al. 2001) in case of pure passive evolution. We modelled the elliptical by assuming a simple stellar population (SSP) model (Maraston 1998, 2004) 2-Gyr old ($Z = Z_\odot$) at $z \sim 1.5$. It is worth noting that even little star formation would produce a brightening of the expected apparent magnitude. Thus, $K' < 18.5$ is a stringent criterion which, together with the colour criterion, assures that the resulting early types at $1.2 < z < 2$ are as massive as the most massive ones (10^{11}–10^{12} M$_\odot$) in the present-day Universe. The resulting sample of EROs comprises 31 galaxies. Thus, we measured a surface density of $R - K \geqslant 5.3$ galaxies of 0.10 ± 0.02 arcmin^{-2} at $K < 18.5$, in agreement with previous estimates over larger areas (e.g. Daddi et al. 2000; Martini 2001).

2.2 Observations

The spectroscopic observations, with typical exposure of about 4 h for each source, were carried out in 2002 October and 2003 November at the Italian 3.6-m Telescopio Nazionale Galileo (TNG). The prism disperser Amici mounted at the near-IR camera NICS of the TNG was adopted to carry out the observations. This prism provides the spectrum from 0.85 to 2.4 μm in a single shot at a nearly constant resolution of $\lambda/\Delta\lambda \simeq 35$ (1.5-arcsec slit width). This resolution is best suited to describe the spectral shape of sources over a wavelength range of ∼15 000 Å and to detect strong continuum features such as the 4000 Å break in old stellar systems at $z > 1.2$. On the other hand, the extremely low resolution makes the detection of emission/absorption lines for sources as faint as our galaxies unfeasible. Until now, we carried out spectroscopic observations for ∼60 per cent of the whole sample identifying 10 early types. The analysis of the spectral properties of the whole sample of early types is presented in a forthcoming paper (Longhetti et al., in preparation) Seven of the 10 early types fall on one of the two selected fields, the S2F1 field (∼160 arcmin^2), where we collected 13 spectra out of the 19 EROs satisfying the selection criteria. In Table 1 we report the broad-band photometry of the seven early types in this field.

2.3 Spectral classification

In Fig. 2 the (smoothed) near-IR spectra (black thick histogram) of the seven galaxies are shown. The spectra drops very rapidly at ∼0.9–1 μm concurrent with the 4000 Å break placing the galaxies at $z > 1.3$ and suggesting an early-type spectral nature. We searched for the best-fitting template by comparing the observed spectral energy distribution (SED) of each galaxy, constituted by the broad band photometry (B, V, R, I, J and K) and by the observed near-IR continuum (from 0.9 to 2.3 μm), with a set of spectrophotometric templates [$Z = Z_\odot$ and Salpeter initial mass function (IMF)] based on the Bruzual & Charlot (2003) models and on the library of simple stellar population (SSP) of Maraston (1998, 2004). The best-fitting templates have been obtained through a χ^2 minimization applied over the whole wavelength range. Besides the SSPs, models with declining star formation with time-scales τ in the range 0.1–4 Gyr has been considered. All the observed SEDs are best-fitted by star formation histories (SFHs) with very short time-scales ($\tau \leqslant 0.3$) Gyr and extinctions $E(B - V) \leqslant 0.15$ (with the Calzetti et al. 2000, extinction law), providing ages in the range 1.5–4 Gyr. A comprehensive study of the properties of the stellar populations in our massive early types and of their dependence on different IMFs and metallicity is presented in (Longhetti et al., in preparation). In Table 1, the spectroscopic redshift and the best-fitting SFHs are summarized. It is worth of noting that a set of SSPs with ages in the range 1–3.5 Gyr also provides a good fit to all the observed SEDs. To rule

Table 1. Properties of the seven early-type galaxies. Magnitudes are in the Vega system. The SFHs, the stellar masses and the mass-to-K-band light ratio refer to $Z = Z_\odot$ models with Salpeter IMF.

ID	K	$R - K$	$z_{\rm spec}$	M_K	SFH [Gyr]	$\mathcal{M}_{\rm star}$ [10^{11} M$_\odot$]	M/L_K	$(L_{z=0}/L^*)$
S2F1_357	17.84±0.08	6.0	1.34±0.05	−26.6±0.12	SSP	5.0	0.5	3.0
S2F1_527	18.30±0.15	>5.7	1.35±0.05	−26.3±0.20	$\tau = 0.1$	3.0	0.4	2.3
S2F1_389	18.23±0.12	5.5	1.40±0.05	−26.5±0.15	$\tau = 0.3$	3.5	0.4	2.7
S2F1_511	18.14±0.15	6.1	1.40±0.05	−26.2±0.20	$\tau = 0.1$	3.0	0.4	2.1
S2F1_142	17.84±0.07	6.0	1.43±0.05	−26.6±0.12	$\tau = 0.3$	6.5	0.6	3.0
S2F1_633	18.20±0.12	>5.7	1.45±0.05	−26.1±0.15	$\tau = 0.1$	4.0	0.6	1.9
S2F1_443	18.40±0.15	>5.6	1.70±0.05	−26.8±0.20	$\tau = 0.1$	5.0	0.4	3.6

Downloaded from https://academic.oup.com/mnrasl/article/357/1/L40/1060623 by U.S. Department of Justice user on 16 August 2022

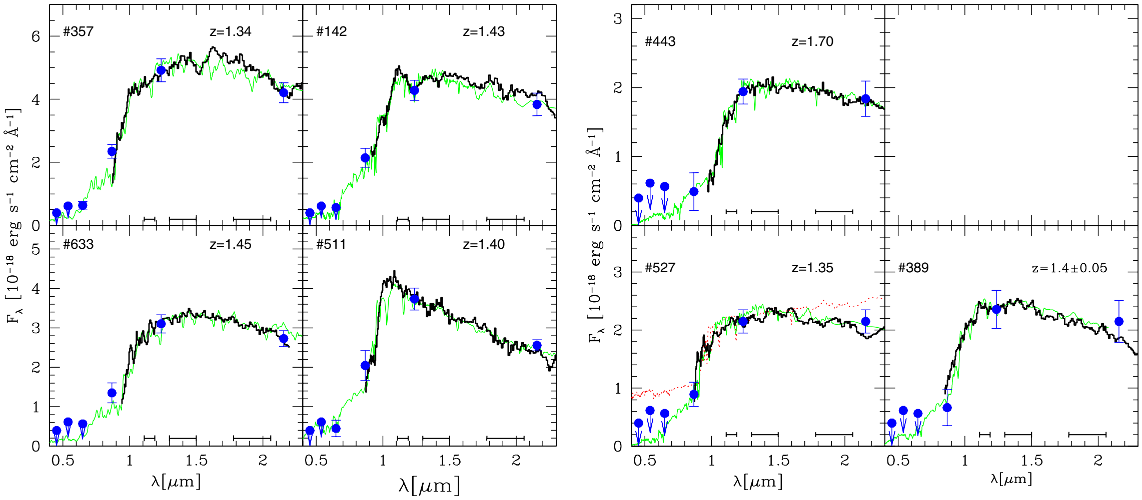

Figure 2. Near-IR spectra (black histogram) of four out of the seven early-type galaxies. The mean observed spectrum of local ellipticals (thin grey line) of Mannucci et al. (2001) and of Coleman et al. (1980) are superimposed on the observed spectrum of S2F1_357 and of S2F1_633 and on the observed spectrum of S2F1_443 respectively. A SSP that is 1 Gyr old at solar metallicity is superimposed on the observed spectrum of S2F1_511. For the other galaxies, we superimposed on the Amici spectra the best-fitting template (see Table 1). In the case of S2F1_527, the best-fitting starburst template is also shown (dotted line). The horizontal error bars represent the atmospheric windows with an opacity larger than 80 per cent. The filled symbols are the photometric data in the B, V, R, I, J and K' bands from the MUNICS catalogue (Drory et al. 2001).

out the possibility that some (or all) of the observed SEDs can be fitted by a young dusty starburst, we forced the fitting procedure to search for an acceptable fit among a set of templates made up by the six starburst templates (SB1–SB6) of Kinney et al. (1996) and a starburst model described by a constant star formation rate (cst). Extinction has been allowed to vary in the range $0 < E(B-V) < 2$ in the fitting procedure. We did not obtain an acceptable fit for any of the seven galaxies. In particular, we fail in simultaneously fitting the red part of the spectrum at $\lambda > 1.4$ μm and the blue part at $\lambda < 0.9$ μm. This is shown in Fig. 2, where we plot the best-fitting starburst template (dotted line) to the most favourable case represented by S2F1_527. Thus, dusty starbursts do not reproduce the sharp and deep drop seen in the continuum at $0.85 < \lambda_{\mathrm{obs}} < 1.0$ μm. This confirms the early-type spectral nature of the seven galaxies. For comparison, in Fig. 2, the mean observed spectrum of local ellipticals of Mannucci et al. (2001) (thin grey line) is superimposed on the Amici spectrum of S2F1_357 and of S2F1_663, while that of Coleman, Wu & Weedman (1980) is superimposed on the spectrum of S2F1_443. For the other galaxies, the best-fitting template is superimposed on the observed spectrum. It is worth noting that the highest redshift evolved galaxy of our sample (S2F1_443) is also one of the X-ray emitting EROs we detect on the S2F1 field (Severgnini et al. 2005).

3 LUMINOSITIES AND STELLAR MASSES

The bright K'-band magnitudes $(17.8 < K' < 18.4)$ of our ellipticals and their redshifts imply luminosities $L \gg L^*$. Because local L^* galaxies have stellar masses of the order of 10^{11} M$_\odot$, we expect all seven early types to be more massive than 10^{11} M$_\odot$, leaving aside any model assumption. In order to derive the rest-frame K-band luminosity, the proper k-correction of each galaxy has been computed by means of the relevant best-fitting template. Each best-fitting template has been multiplied with the transmission curve of the K filter to derive the k-corrections. In Table 1 we report the K-band absolute magnitudes thus obtained. As expected, the seven early types have rest-frame near-IR luminosities $5L^* < L_K \leqslant 10L^*$. The stellar mass $\mathcal{M}_{\mathrm{star}}$ of each galaxy has been derived by the K-band luminosity through the mass-to-K-band light ratio relevant to the best-fitting template ($Z = \mathrm{Z}_\odot$ and Salpeter IMF) and by the scalefactor applied to the flux of the redshifted template to fit the observed fluxes. This latter estimate does not consider a certain band but takes into account the whole observed SED. The two estimates provides similar values (within a few per cent) as most of our data are in the near-IR and the uncertainty on them are lower than the uncertainty affecting the optical data. Consequently, the fitting procedure weights mostly the near-IR data. An analysis of the dependence of the stellar mass of the seven evolved galaxies on the IMF and on the metallicity is discussed in Longhetti et al. (in preparation). In Table 1 we report for each galaxy the rest-frame K-band luminosity, $\mathcal{M}/L_K$ and the relevant stellar mass. As expected, all the galaxies have stellar masses in the range 3–6.5 × 10^{11} M$_\odot$.

4 THE DENSITY OF VERY MASSIVE EARLY-TYPE GALAXIES

We estimated the co-moving spatial density of the seven massive early-type galaxies and its statistical uncertainty as:

$$\rho = \sum_i \frac{1}{V^i_{\mathrm{max}}}, \quad \sigma(\rho) = \left[\sum_i \left(\frac{1}{V^i_{\mathrm{max}}}\right)^2\right]^{1/2} \tag{1}$$

where

$$V_{\mathrm{max}} = \frac{\omega}{4\pi}\int_{z_1}^{z_{\mathrm{max}}} \frac{\mathrm{d}V}{\mathrm{d}z}\,\mathrm{d}z \tag{2}$$

is the comoving volume. The solid angle ω subtended by the S2F1 field is $\sim 1.3 \times 10^{-5}$ sr and z_{max} is the maximum redshift at which each galaxy would be still included in the sample. In the derivation of the z_{max} of each galaxy we computed the k-correction by using the relevant best-fitting template. The lower bound in the integration is set to $z_1 = 1.2$. It is imposed by the adopted spectroscopic wavelength range which does not allow us to detect the Balmer

Downloaded from https://academic.oup.com/mnras/article/357/1/L40/1060623 by U.S. Department of Justice user on 16 August 2022

break of galaxies at $z < 1.2$. We find that, at the average redshift $\langle z_{\rm max}\rangle \simeq 1.55$, the seven massive early types account for a co-moving density $\rho = (5.5 \pm 2) \times 10^{-5}\,{\rm Mpc}^{-3}$ over a volume of about $1.5 \times 10^5\,{\rm Mpc}^3$. Given the stellar masses of the seven early types, the resulting mass density is $\rho_{\rm star} = (2.3 \pm 0.9) \times 10^7\,{\rm M}_\odot\,{\rm Mpc}^{-3}$. Such densities are likely to be lower limits because of the incompleteness of our spectroscopic observations (13 spectra collected out of the 19 EROs in the field). In order to compare these densities with the local values, we integrated the *K*-band luminosity function (LF) of local early-type galaxies, derived by Kochanek et al. (2001), described by $M^*{}_K = -24.3 \pm 0.06$ and $\Phi^* = 1.5 \pm 0.2 \times 10^{-3}\,{\rm Mpc}^{-3}$. The lower bound to the integration has been derived in two independent ways. The first one lies in deriving the lowest luminosity that our galaxies would have at $z = 0$. This has been obtained by assuming a pure passive evolution from $z_{\rm spec}$ to $z = 0$. The luminosities thus obtained are reported in Table 1 and place the lower limit at $1.9L^*$ as imposed by S2F1_633. In the second way, we derived the *K*-band luminosity from the lowest stellar mass of our galaxies ($3 \times 10^{11}\,{\rm M}_\odot$) by means of the maximum mass-to-light ratio that our galaxies could have at $z = 0$. As their stellar populations have to be formed at $z > 2$, they would be ~11 Gyr old at $z = 0$. Thus, the maximum mass-to-light ratio is $\mathcal{M}/L_K \simeq 1.6$, given by a SSP 11-Gyr-old with Salpeter IMF. Also in this case we obtained a luminosity of about $1.9L^*$. It is worth of noting that other IMFs would produce lower values of $\mathcal{M}/L_K$ (e.g. $\mathcal{M}/L_K = 1.3$ with Kroupa IMF and $\mathcal{M}/L_K = 1.1$ with Miller–Scalo) and, correspondingly, higher luminosities ($2.3L^*$ and $2.7L^*$ respectively). By integrating the local LF of early-type galaxies at luminosities brighter than $1.9L^*$ we obtained a density of $(8.4 \pm 1) \times 10^{-5}\,{\rm Mpc}^{-3}$. We summarize our results in Fig. 3, where we also report the comoving density we derived for the three early types with $L_{z=0} > 3\,L^*$. The density we estimated at $z \simeq 1.5$ represents 65 per cent of the density of their counterparts at $z = 0$. Even if this difference is not statistically significant, this suggests that three more massive early types should be expected over the 160 arcmin^2 in case of no density evolution. On the other hand, our estimate is affected by a spectroscopic redshift incompleteness of about 30 per cent. When this incompleteness is taken into account the observed difference tends to vanish. Thus, we conclude that the number density of early types with stellar masses comparable to the most massive early types populating the local Universe does not show evidences of decrease up to $z \simeq 1.7$.

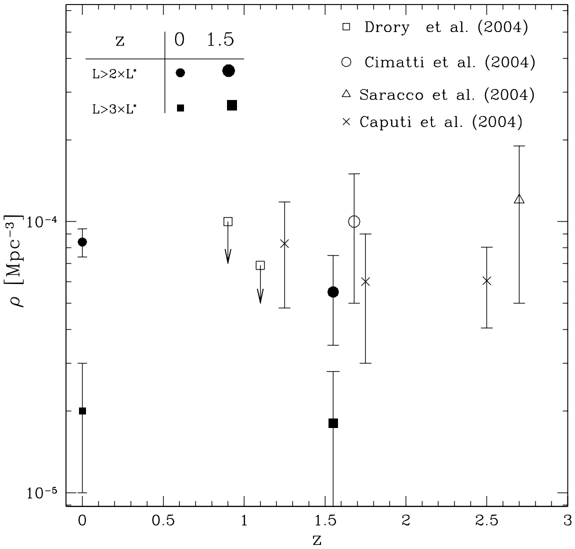

Figure 3. Number density of galaxies as a function of redshift. The large filled symbols represent the densities we derived at $z \simeq 1.5$ for the seven early types with $L_{z=0} > 2L^*$ (circle) and for the 3 with $L_{z=0} > 3L^*$ (square). The small filled symbols at $z = 0$ represent the number density of E/S0 galaxies brighter than $2L^*$ (circle) and $3L^*$ (square) respectively obtained by integrating the local LF of galaxies of Kochanek et al. (2001). The open circle is the density of spheroidal galaxies by Cimatti et al. (2004), the open triangle and the crosses are the density of $\mathcal{M} > 10^{11}\,{\rm M}_\odot$ evolved galaxy candidates by Saracco et al. (2004) and by Caputi et al. (2004) respectively and, finally, the open squares are the upper limit to the number density of galaxies with $\mathcal{M} > 2 \times 10^{11}\,{\rm M}_\odot$ by Drory et al. (2004).

In Fig. 3 we also report the density relevant to the four old spheroidal galaxies (empty circle) spectroscopically identified at $z > 1.6$ by Cimatti et al. (2004), the density of massive ($10^{11}\,{\rm M}_\odot$) evolved galaxy candidates at $z > 2$ (open triangle) found by Saracco et al. (2004) on the HDF-S and the density found by Caputi et al. (2004) on the GOODS/CDF-S area (crosses), both on the basis of photometric analysis. Finally, the upper limit to the number density of galaxies with masses larger than $2 \times 10^{11}\,{\rm M}_\odot$ (open squares) by Drory et al. (2004) is shown.

5 CONCLUSIONS

We spectroscopically identified seven bright ($17.8 < K < 18.4$), massive, evolved galaxies at $0 < z < 1.7$ over an area of about 160 arcmin^2 of the MUNICS survey. These galaxies turned out to have rest-frame *K*-band luminosities $5.5L < L_K \leqslant 11L^*$ and stellar masses in the range 3–6.5 × $10^{11}\,{\rm M}_\odot$. At the mean redshift of $z \simeq 1.5$ these seven early types sample a volume of about $1.5 \times 10^5\,{\rm Mpc}^3$ and account for a comoving number density $\rho = (5.5 \pm 2) \times 10^{-5}\,{\rm Mpc}^{-3}$ and a stellar mass density $\rho_{\rm star} = (2.3 \pm 0.9) \times 10^7\,{\rm M}_\odot\,{\rm Mpc}^{-3}$. These densities represent 65 per cent of the values at $z = 0$ for early types with comparable mass. The incompleteness of our spectroscopic observations (30 per cent) accounts for this deficiency. Thus, our results show that the number density of the most massive early types in the present-day Universe remains essentially constant down to $z \simeq 1.7$. This suggests that massive early types do not take part in the evolution of the stellar mass density in the redshift range $0 < z < 1.7$ and that the decrease of the stellar mass density detected in this redshift range by recent surveys (e.g. Rudnick et al. 2003; Drory et al. 2004; Fontana et al. 2004) has to be ascribed to the accretion of the stellar mass in massive late-type galaxies. This qualitatively agrees with the concurrent increase of the cosmic star formation rate due to late-type galaxies seen in the same redshift range (e.g. Madau, Pozzetti & Dickinson 1998). The high stellar masses and the number density of the seven massive, evolved galaxies imply that they were fully assembled at the observed redshift pushing their formation at $z > 2$, as is also argued by Calura & Matteucci (2003) and suggested by the recent discovery of an evolved spheroidal galaxy at $z \simeq 1.9$ (Cimatti et al. 2004). This is in agreement with the results based on the spectral analysis of the stellar populations in our sample of massive early types at $z \simeq 1.5$, which suggest a formation redshift $z_{\rm f} > 2$ (Longhetti et al., in preparation). It is worth of noting that similar results are also derived by the analysis of the absorption lines indices of local samples (Thomas, Maraston & Bender 2002; Thomas et al. 2005) which suggest short time-scales (~0.4 Gyr) and high-*z* of formation for massive early types. Thus, at variance with the expectations of hierarchical models, the most massive early types in the local Universe do not seem to be the last galaxies to complete their assembly. The high formation redshift suggests a high efficiency in the accretion of the stellar mass of early types in the early Universe and a high star formation preferentially in massive haloes.

Downloaded from https://academic.oup.com/mnrasl/article/357/1/L40/1060623 by U.S. Department of Justice user on 16 August 2022

ACKNOWLEDGMENTS

This Letter is based on observations made at the Italian Telescopio Nazionale (TNG, www.tng.iac.es) operated on the island of La Palma by the Centro Galileo Galilei of the INAF (Istituto Nazionale di Astrofisica). We thank the staff of the TNG for the very good support during the observations. PS acknowledges financial support by the Istituto Nazionale di Astrofisica (INAF). This work has received partial financial support from ASI (I/R/037/01, I/R/062/02) and from the Italian Ministry of University and the Scientific and Technological Research (MIUR) through grant Cofin-03-02-23. The MUNICS project is supported by the Deutsche Forschungsgemeinschaft, Sonderforschungsbereich 375, Astroteilchenphysik.

REFERENCES

Arimoto N., Yoshii Y., 1987, A&A, 173, 23
Bruzual A. G., Charlot S., 2003, MNRAS, 344, 1000
Calura F., Matteucci F., 2003, ApJ, 596, 734
Calzetti D., Armus L., Bohlin R. C., Kinney A. L., Koornneef J., Storchi-Bergmann T., 2000, ApJ, 533, 682
Caputi K. I., Dunlop J. S., McLure R. J., Roche N. D., 2004, MNRAS, 353, 30
Cimatti A., Daddi E., Renzini A. et al., 2004, Nat, 430, 184
Coleman G. D., Wu C.-C., Weedman D. W., 1980, ApJS, 43, 393
Daddi E., Cimatti A., Pozzetti L., Hoekstra H., Röttgering H. J. A., Renzini A., Zamorani G., Mannucci F., 2000, A&A, 361, 535
Drory N., Feulner G., Bender R., Botzler C. S., Hopp U., Maraston C., Mendes de Oliveira C., Snigula J., 2001, MNRAS, 325, 550
Drory N., Bender R., Feulner G., Hopp U., Maraston C., Snigula J., Hill G. J., 2004, ApJ, 608, 742
Eggen O., Lynden-Bell D., Sandage A., 1962, ApJ, 136, 748
Fontana A., Pozzetti L., Donnarumma I. et al., 2004, A&A, 424, 23
Genzel R., Baker A. J., Tacconi L. J., Lutz D., Cox P., Guilloteau S., Omont A., 2003, ApJ, 584, 633
Kauffmann G., 1996, MNRAS, 281, 475
Kinney A. L., Calzetti D., Bohlin R. C., McQuade K., Storchi-Bergmann T., Schmitt H. R., 1996, ApJ, 467, 38
Kochanek C. S. et al., 2001, ApJ, 560, 566
Madau P., Pozzetti L., Dickinson M., 1998, ApJ, 498, 106
Mannucci F., Basile F., Poggianti B. M., Cimatti A., Daddi E., Pozzetti L., Vanzi L., 2001, MNRAS, 326, 745
Maraston C., 1998, MNRAS, 300, 872
Maraston C., 2004, MNRAS, submitted (astro-ph/0410207)
Martini P., 2001, AJ, 121, 2301
Pozzetti L., Mannucci F., 2000, MNRAS, 317, L17
Rudnick G. et al., 2003, ApJ, 599, 847
Saracco P. et al., 2003a, A&A, 398, 127
Saracco P. et al., 2003b, in Bender R., Renzini A, eds, Proc. ESO/USM/MPE Workshop on Multiwavelength Mapping of Galaxy Formation and Evolution. Springer-Verlag, Heidelberg, in press (astro-ph/0312097)
Saracco P. et al., 2004, A&A, 420, 125
Severgnini P. et al., 2005, A& A, in press (astro-ph/0410434)
Somerville R. S., Primack J. R., 1999, MNRAS, 310, 1087
Thomas D., Maraston C., Bender R., 2002, Rev. Modern Astron., 15, 219
Thomas D., Maraston C., Bender R., Mendes de Oliveira C., 2005, ApJ, in press (astro-ph/0410209)
White S. D. M., Frenk C. S., 1991, ApJ, 379, 52

This paper has been typeset from a TEX/LATEX file prepared by the author.

Downloaded from https://academic.oup.com/mnrasl/article/357/1/L40/1060623 by U.S. Department of Justice user on 16 August 2022