Astron. Astrophys. 352, L45–L50 (1999)

ASTRONOMY AND ASTROPHYSICS

LETTER

Letter to the Editor

New clues on the nature of extremely red galaxies*

A. Cimatti[1], E. Daddi[2], S. di Serego Alighieri[1], L. Pozzetti[1], F. Mannucci[3], A. Renzini[4], E. Oliva[1], G. Zamorani[5], P. Andreani[6], and H.J.A. Röttgering[7]

[1] Osservatorio Astrofisico di Arcetri, Largo Fermi 5, 50125 Firenze, Italy (cimatti@arcetri.astro.it)
[2] Università di Firenze, Dipartimento di Astronomia, Largo Fermi 5, 50125 Firenze, Italy
[3] CAISMI-CNR, Largo Fermi 5, 50125 Firenze, Italy
[4] European Southern Observatory, Karl-Schwarzschild-Strasse 2, 85748 Garching, Germany
[5] Osservatorio Astronomico di Bologna, via Ranzani 1, 40127 Bologna, Italy
[6] Osservatorio Astronomico di Padova, vicolo dell' Osservatorio 5, 35122 Padova, Italy
[7] Sterrewacht Leiden, Sterrewacht, Postbus 9513, Leiden 2300 RA, The Netherlands

Received 17 August 1999 / Accepted 19 September 1999

Abstract. We present near-infrared VLT-UT1+ISAAC spectroscopy of a sample of 9 extremely red galaxies (ERGs) with $R-K>5$ and $K<19.0$. Neither strong emission lines ($F_{\rm lim}$ <1–5$\times10^{-16}$ erg s^{-1} cm^{-2}) nor continuum breaks are detected. From near-infrared spectrophotometry, complemented with broad-band optical and near-IR photometry, we estimate "spectro-photometric" redshifts to be in the range of $0.8 \lesssim z_{\rm sphot} \lesssim 1.8$. We derive upper limits on the star formation rates in range of $SFR < 6$–$30 h_{50}^{-2}$M$_\odot$yr^{-1}. Two of the observed ERGs are dusty starburst candidates because they require strong dust reddening to reproduce their global spectral energy distributions. The other ERGs are consistent with being dustless old passively evolved spheroidals at $z \gtrsim 0.8$. We discuss the general implications of our findings in relation with the problem of the formation of early type galaxies.

Key words: galaxies: evolution – galaxies: formation – galaxies: general

1. Introduction

The combination of optical and near-infrared surveys has led to the discovery of a population of galaxies with extremely red colors (hereafter called ERGs, sometimes also called extremely red objects, EROs, e.g. Elston, Rieke & Rieke 1988; McCarthy et al. 1992; Hu & Ridgway 1994). However, depending on the depth of the surveys and on the adopted filters, different color criteria have been used to classify a galaxy as "extremely red". Here we adopt a color threshold $R-K>5$, which corresponds to the observed colors of cluster and field ellipticals at $z \gtrsim 1$ (e.g. Spinrad et al. 1997; Rosati et al. 1999) and to old passively evolving populations at similarly high redshifts according to the Bruzual & Charlot (1998) spectral synthesis models. According to such models, a color selection threshold $I-K>4$ is equivalent to $R-K>5$ in the selection of elliptical galaxy candidates at $z \gtrsim 1$ (see for instance Barger et al. 1999).

ERGs are ubiquitous objects, being found in "empty" sky fields (e.g. Thompson et al. 1999), in the vicinity of high-z AGN (McCarthy et al. 1992; Hu & Ridgway 1994) and as counterparts of faint X-ray (Newsam et al. 1997) and radio sources (Spinrad et al. 1997). Very little is presently known about ERGs mainly because their faintness hampers spectroscopic observations. Their colors are consistent with two radically different scenarios: (1) ERGs are evolved spheroidals at $z \gtrsim 1$, their colors being due to the lack of star formation and to the strong K-correction, (2) ERGs are high-z active or starburst galaxies heavily reddened by dust extinction. Such scenarios are relevant both to understand the formation and the evolution of elliptical galaxies and to investigate the existence of a population of dusty galaxies or AGN strongly reddened by dust extinction. Recent observations suggested the existence of at least two populations of objects contributing to the ERG population. On the one hand, near-IR spectroscopy and submillimeter observations showed that HR10 ($I-K \sim 6.5$, Hu & Ridgway 1994) is a dusty starburst galaxy at $z=1.44$ (Graham & Dey 1996; Cimatti et al. 1998; Dey et al. 1999). On the other hand, further observations suggested that other ERGs are likely to be high-z ellipticals (e.g. Spinrad et al. 1997; Stiavelli et al. 1999; Soifer et al. 1999).

In order to assess the relative contribution of different galaxy types to the overall ERG population and their respective role in galaxy evolution, we started a project based on optical and near-IR observations made with the ESO and *Hubble Space Telescope* (HST) telescopes. We present here the first results of near-IR spectroscopy of a sample of ERGs. $H_0 = 50$ kms^{-1} Mpc^{-1} and $\Omega_0 = 1.0$ are assumed throughout the paper.

Send offprint requests to: A. Cimatti

* Based on observations made at the European Southern Observatory, La Silla and Paranal, Chile

LETTER

2. Sample selection, observations and analysis

We surveyed about 95 arcmin^2 in high-z AGN fields and in "empty" sky fields (Cimatti et al.; Daddi et al.; Pozzetti et al., in preparation), and we selected a complete sample of ERGs with $K < 19.0$. Since homogeneous optical imaging was not always available to us for all the observed fields, we adopted a color selection threshold $R - K > 5$ or $I - K > 4$ depending on the available optical photometry. We do not expect contamination by low mass stars or brown dwarfs (e.g. Cuby et al. 1999) because our color-selected ERGs turned out to have non-stellar morphologies. Here we present the first results for an incomplete "pilot" subsample that was selected according to the observability of the targets during the allocated VLT nights.

$ZJHKs$-band imaging was done on 27–30 March 1999 with the imager-spectrograph SOFI (Moorwood, Cuby & Lidman 1998) at the ESO 3.5m New Technology Telescope (NTT). In addition, H and Ks images of the J2027-217 field (with 10 and 14 minutes exposure respectively) were obtained with the near-IR imager- spectrograph ISAAC (Moorwood et al. 1999) at the ESO Very Large Telescope (VLT) UT1 (*Antu*) on 28 April 1999. Both SOFI and ISAAC are equipped with 1024^2 Rockwell detectors with scales of 0.″292/pixel and 0.″147/ pixel respectively. The observations were made during photometric conditions and with the seeing 0.7″-1.0″ and 0.4″-0.5″ for SOFI and ISAAC respectively. During the observations the telescope was moved between exposures according to a random pattern of offsets. The total integration times of the SOFI images were 30, 20, 15, 25 minutes in the $ZJHKs$ bands respectively. The $ZJHK$ photometric calibration was achieved with the standard stars of Persson et al. (1998) and Feige 56 and LTT 3864 (Hamuy et al. 1994). The night-to-night scatter of the zero points was about 0.02 magnitudes. Basic information on the optical photometry can be found in the captions of Fig. 1 and 2, and more details will be given in forthcoming papers.

Photometry was carried out with SExtractor (Bertin & Arnouts 1996) using a 3″ diameter aperture and taking into account aperture losses due to the different seeing conditions. The magnitudes were dereddened for Galactic extinction using the maps of Burnstein & Heiles (1982). The results in Sects. 3.2 and 3.3 do not change if dereddening is made with the Schlegel, Finkbeiner & Davis (1998) dust maps.

JHK-band spectroscopy was obtained with ISAAC at the ESO VLT-UT1 (*Antu*) on 25–27 April 1999 in photometric and 0.5″-1.0″ seeing conditions. The slit was 1″ wide, providing a spectral resolution FWHM of $\sim$ 24 Å, 32 Å and 48 Å in J-, H-, and K-band respectively. The observations were done by nodding the target along the slit between two positions A and B with a nod throw of 10″. The integration time per position was 10 minutes. For instance, a total integration time of 1 hour was obtained following a pattern ABBAAB. When possible, two targets were observed simultaneously in the slit. The spectral frames were flat-fielded, rectified, sky-subtracted, coadded and divided by the response curve obtained using the spectra of O7-O8 stars. The spectra were extracted using a 8 pixel wide aperture. Absolute flux calibration was achieved by normalizing the spectra to the $JHKs$ SOFI or ISAAC broad-band photometry. Table 1 lists the main information about the targets and their observation.

3. Results

3.1. ISAAC spectroscopy

The main aim of ISAAC spectroscopy was to check for the presence of redshifted emission lines such as Hα at $z > 0.7$, [OIII]λ5007 at $z > 1.2$ and [OII]λ3727 at $z > 2.0$ in order to assess what fraction of ERGs is made by objects such as starburst or active galaxies. For four targets we could cover the whole JHK spectral range.

Continuum emission was detected in all the targets. However, neither strong emission lines nor evident continuum breaks were detected in the ISAAC spectra. The absence of emission lines favours these ERGs being high-z ellipticals, although this does not prove it. In case of elliptical galaxies, the absence of the 4000 Å continuum break in the observed J-band spectra contrains the redshifts to be at $z < 1.8$. The possibility that Hα emission falls in the "blind" region between J and H bands (for 1.1< z <1.2) with [OIII]λ5007 not yet entered in the J band, seems unlikely to occur for all the targets.

The upper limits for the flux of emission lines are rather similar for all the spectra. However, each spectrum shows a variation of this limit as a function of wavelength because of the enhanced noise in regions corresponding to bright sky emission lines. The deepest limits are $F_{\rm lim}$ <1.0$\times 10^{-16}$ erg s^{-1} cm^{-2} and $W_{\rm lim} < 50$ Å, increasing by a factor of $\approx$ 2 in the parts of the spectra most contaminated by sky line residuals. Due to its fainter and noisier spectra, the exception is J100544-0742.2 which has $F_{\rm lim}$ <4.5$\times 10^{-16}$ erg s^{-1} cm^{-2} and $F_{\rm lim}$ <3.5$\times 10^{-16}$ erg s^{-1} cm^{-2} in J and H, respectively. With the exception of J100544-0742.2, our spectra would allow to significantly detect emission lines such as the Hα observed in HR10 (Dey et al. 1999), or in a major fraction of the Hα emitters at $1.1 < z < 1.9$ discovered by McCarthy et al. (1999).

3.2. Spectro-photometric redshifts

In absence of distinctive spectral features, we attempted to estimate what we call the "spectro-photometric" redshifts ($z_{\rm sphot}$) by using the ISAAC continuum spectrophotometry together with the available broad- band photometry in order to derive the global optical to near-IR spectral energy distributions (SEDs) of the observed ERGs. The resulting SEDs were then fitted by means of a χ^2 comparison with a set of 240 Bruzual & Charlot (1998) synthetic templates: 80 simple stellar population (SSP) spectra with $Z = Z_{\odot}$, 80 with constant star formation (CSF) and $Z = Z_{\odot}$, and 80 SSP spectra with $Z = 2.5 Z_{\odot}$. The template spectra have Salpeter IMF (0.1<M$_{\odot}$ < 125) and ages from 0.1 Myr to 10 Gyr. Such a set of templates was chosen in order to encompass a wide range of galaxy SEDs spanning from young starbursts to old ellipticals with super-solar metallicity. The dust extinction was treated as a free parameter adopting the Calzetti (1997) extinction law with $E_{\rm B-V}$=0.0–1.0. The J

Table 1. The observed sample

Target	$K(3'')$	Color	Spectra	Integration (hours)	$z_{\rm sphot}$	$F_{\rm lim}$	SFR (h_{50}^{-2}M$_\odot$yr^{-1})	Morphology	Class
J100551-0742.4	18.6	$I-K$=4.8	JHK	1,1,1	1.80±0.10	<1.8	<31	c,r	E
J100544-0742.2	18.4	$I-K$=4.6	JHK	1,1,1	0.80±0.30	<4.5	<13	e,i	D
J101948-2219.8	18.7	$R-K$=6.6	H	1	1.52±0.12	<1.8	<22		E
J101950-2220.9	18.6	$R-K$=6.9	H	1	1.50±0.25	<1.8	<23		E
J124027-1131.0	18.2	$I-K$=4.6	JHK	2,1,2	0.90±0.30	<1.7	<7	c,wd	D
J202759-2140.8	17.9	$R-K$=5.1	JHK	1,2.2,1	0.80±0.12	<2.0	<7		E
J202800-2140.9	18.1	$R-K$=5.1	JH	1,2.2	0.82±0.20	<2.0	<6		E
J202807-2141.1	17.7	$R-K$=5.9	HK	1.3,1.3	0.88±0.15	–	–		D?
J202807-2140.8	18.4	$R-K$=5.9	HK	1.3,1.3	0.96±0.15	–	–		E

Notes:
(1) $F_{\rm lim}$: emission line limiting flux in units of 10^{-16} erg s^{-1} cm^{-2}.
(2) The field J1019-223 includes a radiogalaxy at $z=1.77$ (McCarthy et al. 1996).
(3) The field J2027-217 includes a radiogalaxy at $z=2.63$ (McCarthy et al. 1992).
(4) J202759-2140.8 and J202800-2140.9 were called respectively "a" and "c" by McCarthy et al. (1992).
(5) Morphology in I_{814} band: c=compact, e=extended, r=regular, i=irregular, wd= weakly disturbed.
(6) Class: classification based on SED fitting: E=elliptical, D=dusty (see text for more details).

and H spectra of J100544-0742.2 were not used in the fitting analysis because too noisy.

During the fitting analysis, the ISAAC JHK spectra were first cleaned by excluding the edge regions and, in the H-band, the regions corresponding to the four strongest sky emission lines. The ISAAC spectra were then binned to 800 Å wide bins in order to balance the relative contribution of spectrophotometry and broad-band photometry during the fitting analysis, and, at the same time, to conserve the spectral information (i.e. the slope of the spectra). Broad-band $JHK_{\rm s}$ photometric points were not used during the fitting if corresponding near-IR spectra were available. The $z_{\rm sphot}$ shown in Table 1 are relative to the best absolute fit. The formal 1σ uncertainties on the redshifts, estimated with the $\Delta\chi^2$ method (Avni 1976), are $\sigma_{z_{\rm sphot}} \sim 0.1$–$0.3$ (see Table1). Figs. 1 and 2 show that a good agreement between the observed and the model spectra is generally achieved. In the case of J100551-0742.4, the absence of an observed 4000 Å break in the J-band spectrum constrains $z_{\rm sphot} < 1.8$, whereas the broad-band photometry would allow to derive formally acceptable redshifts up to $z > 2$.

3.3. Dustless and dusty ERGs

According to the results of the fitting analysis, we attempted to preliminarly divide the observed ERGs into two classes at a 95% confidence level.

(A) Galaxies with SEDs that can be reproduced by evolved stellar population spectra without dust extinction. 6 ERGs fall into this class (see Fig. 1 and 2). This does not necessarily mean that these galaxies are dustless, but it only means that their SEDs are consistent with those expected for passively evolved high-z ellipticals with no dust extinction, old ages ($\sim$ 1–3 Gyr) and metallicity up to $Z=2.5Z_\odot$. However, because of the degeneracy between ages and dust extinction, acceptable fits can be found also with younger stellar populations and $0 < E_{\rm B-V} < 0.4$. Thus, we can summarize saying that *at most* 6 ERGs of our sample can be high-z ellipticals. In such a case, their rest-frame K-band absolute magnitudes ($M_{\rm K}$ $\sim$-24.4÷-25.0) imply luminosities $L \lesssim L^*$ (adopting $M^*_{\rm K}$=-25.16 for the local luminosity function of elliptical galaxies; Marzke et al. 1998), and their stellar masses are intermediate (M$_* \sim 1$–$4 \times 10^{11} h_{50}^{-2}$ M$_\odot$).

(B) Galaxies with SEDs that require significant dust extinction. Two ERGs are present in this group: J100544-0742.2 and J124027-1131.0. Their SED fitting is characterized by a large degree of degeneracy among spectral templates, ages and amount of dust reddening. Nevertheless, the minimum amount of dust extinction required to provide acceptable fits ($E_{\rm B-V} > 0.5$) suggests that these two ERGs are systems affected by strong dust reddening. A third galaxy, J202807-2141.1, falls formally into this class because an acceptable fit is obtained only with $E_{\rm B-V} \gtrsim 0.3$, with an age of ≈0.7 Gyr and with $Z = 2.5Z_\odot$. However, we consider this case ambiguous because of the unusual set of parameters provided by the fit. Deep submillimeter continuum observations will help to establish if these three dusty ERGs are HR10-like objects (e.g. Cimatti et al. 1998).

HST WFPC2 deep imaging is available from the public archive only for three of the observed ERGs (see Table 1). The I_{814}-band morphologies strengthen the indications given by the SED fitting analysis: J100544-0742.2 has an extended, irregular and disturbed morphology consistent with being a dusty starburst galaxy; J100551-0742.4 has a compact and elliptical-like morphology. The case of J124027-1131.0 is more ambiguous because its morphology is compact and weakly disturbed.

Adopting $z = z_{\rm sphot}$, for each object we estimated the limits on the Hα luminosity $L({\rm H}\alpha)$ and on the star formation rate (SFR) through the relation $SFR = 7.9 \times 10^{-42} L({\rm H}\alpha)$ [M$_\odot$ yr^{-1}] (Kennicutt 1998). This was not possible for J202807-2141.1 and J202807-2140.8 because no J spectra were available to us. We find limits in the range of $L({\rm H}\alpha) <$ 7–40 $\times$

LETTER

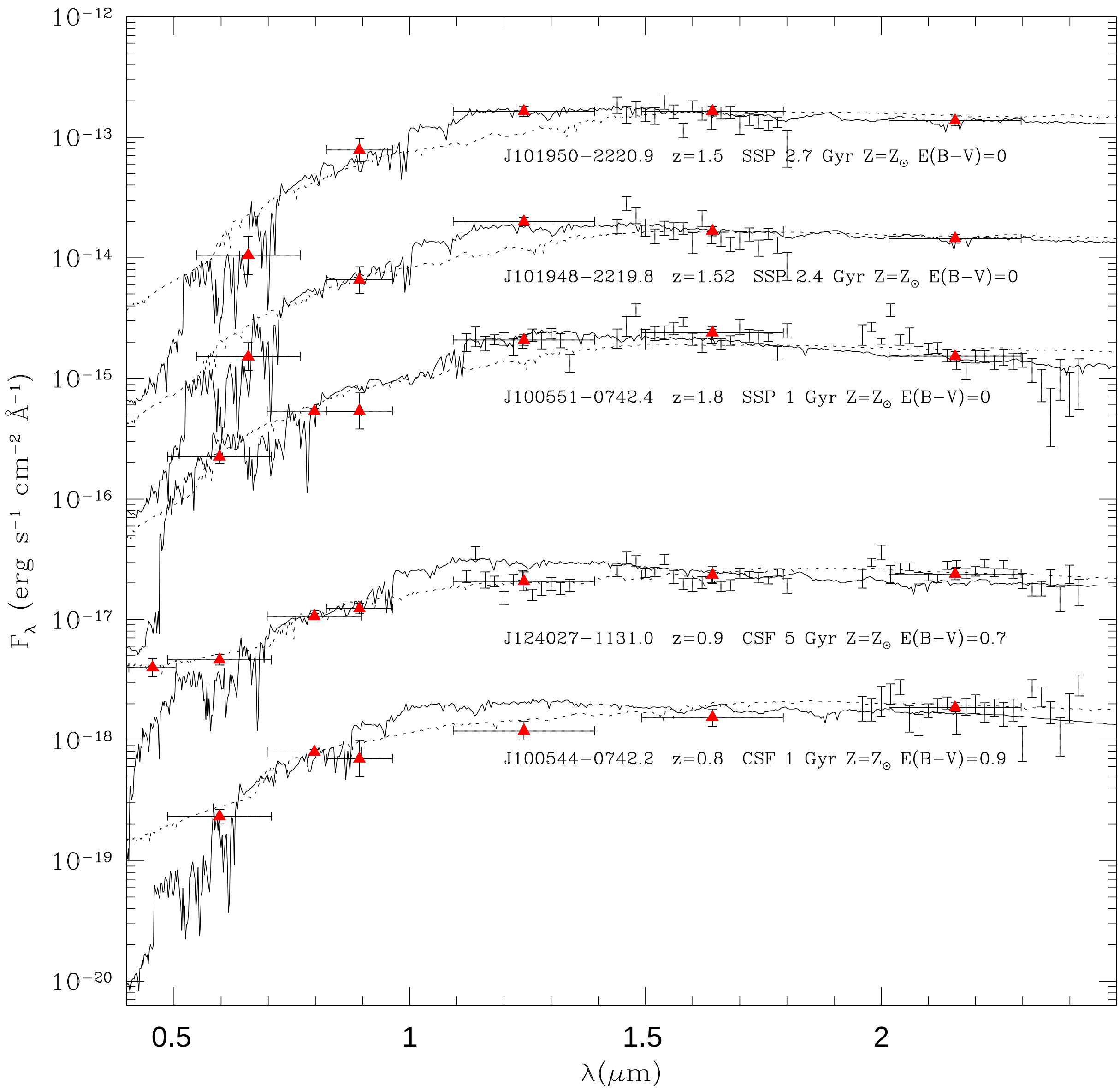

Fig. 1. The global optical to near-IR SEDs based on broad-band photometry (filled triangles) and ISAAC spectroscopy (vertical bars). The ISAAC spectra shown are binned to 200 Å. The first three SEDs from the top are those consistent with no dust extinction. The continuum and the dotted lines are the best fits obtained respectively with dustless SSP spectra and with dusty CSF spectra ($Z = Z_{\odot}$). Such fits are shown in order to provide a comparison between the dusty and the dustless cases. The best fitting parameters (z, ages and $E_{\rm B-V}$) are shown relatively to the best fit of the two cases (i.e. dusty or dustless). Optical photometry was obtained with the following telescopes, instruments and filters: ESO NTT+SUSI (R) for J101950-2220.9 and J101948-2219.8, HST+WFPC2 (V_{606}, I_{814}) for J100544-0742.2 and J100551-0742.4, and HST+WFPC2 ($B_{450}, V_{606}, I_{814}$) for J124027-1131.0. From bottom to top, the five SEDs are multiplied by $10^{0,1,3,4,5}$ respectively.

$10^{41} h_{50}^{-2}$ erg s^{-1}, corresponding to $SFR <$ 6–30h_{50}^{-2}M$_{\odot}$ yr^{-1} (Table 1). Taken at face value, these limits imply star formation rates at most as high as those of nearby gas rich spiral galaxies (see Kennicutt 1998). However, in case of dust extinction, such SFRs would increase by a factor of ≈2–30× for $E_{\rm B-V}$ = 0.2–0.9.

Finally, we noticed that the four ERGs in the J2027-217 field have all very similar $z_{\rm sphot}$ (Fig. 2), and may belong to a same cluster or group.

4. Summary and main implications

Our observations showed that neither strong emission lines nor continuum breaks are detected in the ISAAC spectra of 9 ERGs, and that only a fraction of them (2–3 out of 9 in our subsample) require strong dust reddening to reproduce their SEDs. On the other hand, up to 6 ERGs have properties that are formally consistent with the strict definition of being dustless, old and passively evolved spheroidals at $z \gtrsim 1$ and with $z_{\rm formation} > 2$. Although the observed sample is rather small and still incom-

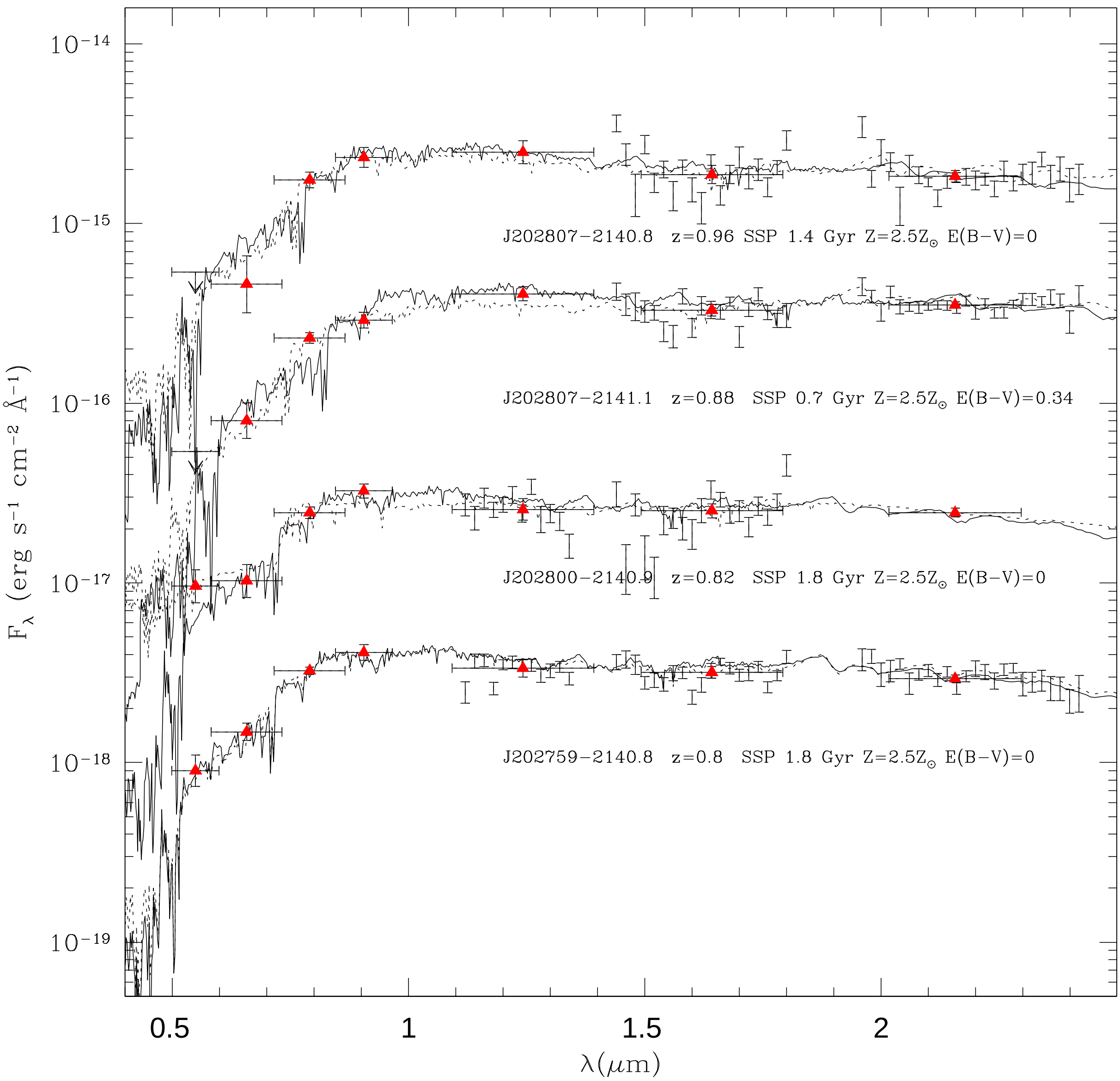

Fig. 2. The global optical to near-IR SEDs (same symbols as in Fig. 1). Here the continuum and the dotted lines are the best fits obtained respectively with dustless and dusty SSP spectra (all with $Z = 2.5Z_{\odot}$). Optical photometry comes from ESO NTT+EMMI observations with $VRIZ$ filters. From bottom to top, the four SEDs are multiplied by $10^{0,1,2,3}$ respectively.

plete, it is tempting to speculate on how the above results may have implications on the problem of the formation of elliptical galaxies.

In fact, the existence and the abundance of high-z ellipticals is one of the most controversial issues of galaxy evolution. Some works claimed that the number of galaxies with the red colors expected for high-z passively evolved spheroidals is lower compared to the predictions of passive luminosity evolution (e.g. Kauffmann, Charlot & White 1996; Zepf 1997; Franceschini et al. 1998; Barger et al. 1999). However, other works did not confirm the existence of such a deficit up to $z \approx 2$ (e.g. Totani & Yoshii 1997; Benitez et al. 1999; Broadhurst & Bowens 1999; Schade et al. 1999). This picture is complicated by the possibility that such spheroidals are bluer because of a low level of residual star formation, thus escaping the selection criteria based on red colors (e.g. Jimenez et al. 1999).

Thus, it is clear that a reliable comparison between the observed abundance of high-z ellipticals and the one expected from the various galaxy formation models can be performed only if the fraction of high-z ellipticals in ERG samples is firmly established. If taken at face value, our analysis suggests that a substantial fraction of ERGs are consistent with being *bona fide* high-z spheroidals. Should spectroscopy of complete and larger samples confirm such result, this would allow a reliable comparison of the observed and predicted numbers of spheroidals at $z \gtrsim 1$.

Acknowledgements. We are grateful to Jean-Gabriel Cuby, Chris Lidman and Leonardo Vanzi for their invaluable help during the observations, and to Gustavo Bruzual and Stephane Charlot for providing their synthetic spectral library. We also thank the referee, Massimo Stiavelli, for his constructive criticism.

References

Avni Y. 1976, ApJ, 210, 642
Barger A.J., Cowie L.L., Trentham N., Fulton E., Hu E.M., Songaila A., Hall D. 1999, AJ, 117, 102
Benitez N., Broadhurst T.J., Bouwens R.J., Silk J., Rosati P. 1999, ApJ, 515, L65
Bertin E., Arnouts S. 1996, A&A, 117, 393
Broadhurst T.J., Bouwens R.J. 1999, ApJ, in press (astro-ph/9903009)
Bruzual G., Charlot S. 1998, private communication
Burnstein D., Heiles C. 1982, AJ, 87, 1167
Calzetti D. 1997, in The Ultraviolet Universe at Low and High Redshift: Probing the Progress of Galaxy Evolution, ed. W.H. Waller, M.N. Fanelli, J.E. Hollis, & A.C. Danks, AIP Conference Proceedings 408, (New York: Woodbury), 403
Cimatti A., Andreani P., Röttgering H., Tilanus R. 1998, Nature, 392, 895
Cuby J.-G., Saracco P., Moorwood A.F.M., D'Odorico S., Lidman C., Comeron, Spyromilio J. 1999, A&A, in press (astro-ph/9907028)
Dey A., Graham J.R., Ivison R.J., Smail I., Wright G.S. 1999, ApJ, 519, 610
Elston R., Rieke G.H., Rieke M. 1988, ApJ, 331, L77
Franceschini A., Silva L., Fasano G., Granato L., Bressan A., Arnouts S., Danese L. 1998, ApJ, 506, 600
Graham, J.R., Dey, A. 1996, ApJ, 471, 720
Hamuy M., Suntzeff N.B., Heathcote S.R., Walker A.R., Gigoux P., Phillips M.M. 1994, PASP, 106, 566
Hu E.M., Ridgway S.E. 1994, AJ, 107, 1303
Jimenez R., Friaca A.C.S., Dunlop J.S., Terlevich R.J., Peacock J.A., Louisa A. 1999, MNRAS, 305, L16
Kauffmann G., Charlot S., White S.D.M 1996, MNRAS, 283, 117
Kennicutt R.C. 1998, ARA&A, 36, 189
Marzke R.O., Da Costa L.N., Pellegrini P.S., Willmer C.N.A., geller M.J. 1998, ApJ, 503, 517
McCarthy P.J., Persson S.E., West S.C. 1992, ApJ, 386, 52
McCarthy P.J., Kapahi V.K., van Breugel W., Persson S.E., Athreya R., Subrahmanya C.R. 1996, ApJS, 107, 19
McCarthy P.J., Yan L., Freudling W., Teplitz H.I., Malumuth E.M., Weymann R.J., Malkan M.A., Fosbury R.A.E., Gardner J.P., Storrie-Lombardi L.J., Thompson R.I., Williams R.E., Heap S.R. 1999, ApJ, in press (astro-ph/9902347)
Moorwood A.F.M., Cuby J.-G., Lidman C. 1998, The Messenger, 91,9
Moorwood A.F.M., Cuby J.-G., Ballester P., Biereichel P., Brynnel J., Conzelmann R., Delabre B., Devillard N., van Dijsseldonk A., Finger G., Gemperlein H., Lidman C., Herlin T., Huster G., Knudstrup J., Lizon J.-L., Mehrgan H., Meyer M., Nicolini G., Silber A., Spyromilio J., Stegmeier J. 1999, The Messenger, 95, 1
Newsam A.M., McHardy L.M., Jones L.R., Mason K.O. 1997, MNRAS, 292, 378
Persson S.E., Murphy D.C., Krzeminski W., Roth M., Rieke M.J. 1998, AJ, 116, 2475
Rosati P., Stanford S.A., Eisenhardt P.R., Elston R., Spinrad H., Stern D., Dey A. 1999, AJ, in press (astro-ph/9903381)
Schade D. et al. 1999, ApJ, in press (astro-ph/9906171)
Schlegel D.J., Finkbeiner D.P., Davis M. 1998, ApJ, 500, 525
Soifer B.T., Matthews K., Neugebauer G., Armus L., Cohen J.G., Persson S.E. 1999, AJ, in press (astro-ph/9906464)
Spinrad H., Dey A., Stern D., Dunlop J., Peacock J., Jimenez R., Windhorst R. 1997, ApJ, 484, 581
Stiavelli M., Treu T., Carollo M., Rosati P., Viezzer R., Casertano S., Dickinson M., Ferguson H., Fruchter A., Madau P., Martin C., Teplitz H. 1999, A&A, 343, L25.
Totani T., Yoshii J. 1997, ApJ, 501, L177
Thompson D., Beckwith S.V.W., Fockenbrock R., Fried J., Hippelein H., Huang J.-S., von Kuhlmann, Ch. Leinert, Meisenheimer K., Phleps S., Röser H.-J., Thommes E., Wolf C. 1999, ApJ, in press
Zepf S.E. 1997, Nature, 390, 377