University of Padova
Astronomy Department

Not-so-short summary of PhD thesis

MULTIWAVELENGTH ANALYSES OF FAINT INFRARED GALAXIES

by **Stefano Berta**

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The development of new efficient infrared detectors, operating at the focal plane of Space Observatories and large ground-based Telescopes, has opened a new window to the exploration of the distant Universe. The extension of cosmological observations to longer wavelengths, with respect to the traditional optical spectral domain, opened new frontiers to the study of galaxy formation and evolution.

By these means, not only are the effects of dust extinction minimized, but also dust re-radiation in the mid- and far-infrared and the sub-millimeter (between $\lambda \sim 10$ and 1000 μm) can be detected.

This Thesis follows a chronological outline, covering the development of infrared space facilities in the last decades. The IRAS (launched in 1984), ISO (1995), Spitzer (August 2003) and, later, ASTRO-F, Herschel, JWST satellites constitute a logical sequence in the study of galaxy infrared properties, with a well modulated improvement of observing capabilities. Climbing space-time is the logical consequence, modern instruments detecting more distant sources.

Various important aspects of galaxy's infrared emission are addressed, including both the physical phenomena intervening and the cosmological significance of the infrared galaxy population as a whole.

Some of the best datasets available up to date are exploited, including — among others — spectroscopic and imaging optical data from ESO Very Large Telescope, high resolution optical images by the Hubble Space Telescope's Advanced Camera for Surveys and mid-to-far infrared data obtained with the newly launched Spitzer facility.

Optical, near- and mid-IR spectroscopy, optical spectropolarimetry and broad-band UV to sub-mm analysis of nearby Ultra Luminous Infrared Galaxies are used as "local laboratory" for studying distant IR, active, dusty galaxies.

The detection of a substantial population of distant ($z \sim 0.5-1.5$) infrared galaxies, by ESA's Infrared Space Observatory, allowed the study of dusty starbursts to be extended over a cosmological framework. Optical and near-IR spectroscopy of 15 μm ISO-detected sources is analysed; a comparison of the broad-band spectral energy distributions of such objects to those of intermediate-redshift early-type galaxies and distant Lyman-break sources follows.

The advent of Spitzer was warmly welcome by the astronomical community. The Spitzer Legacy cosmological surveys SWIRE and GOODS aim at answering the many, still open questions on the formation and evolution of galaxies in the Universe. Early SWIRE data are used here to study the optical to near-IR restframe SEDs of galaxies up to redshift $\sim$3, exploiting both near- and mid-IR observations by IRAC and MIPS. The evolution of actively star-forming sources is analyzed through modeling of differential mid-IR source counts. A subsample of field galaxies from the GOODS survey is finally compared to the members of the RDCS 1252.9-2927 cluster, lying at a redshift z=1.237.

Local Ultraluminous IR Galaxies

Discovered by IRAS in the '80s, local luminous and ultra-luminous infrared galaxies are believed to be the analogues of the high redshift objects discovered in the sub-millimeter with SCUBA on JCMT and in the mid-IR by ISO. Understanding the nature of the energy source in this population has major cosmological implications: low-redshift ULIRGs can be considered the ideal "laboratory" where to test our knowledge of the physical phenomena ruling galaxies in the high-z universe.

The first part of the Thesis deals with the multiwavelength analysis of different samples of local ULIRGs, exploiting optical, near-IR and L-band spectroscopy. Optical spectropolarimetry has been included in the study. The broad-band spectral energy distributions of ULIRGs have been finally modeled by combining different physical components, from the UV to the sub-mm spectral domain.

Hydrogen and forbidden emission lines (both at optical and NIR wavelengths) are used for estimating the ongoing rates of stellar formation in the sample members and the values of extinction affecting their spectra. After correction for extinction and aperture, the derived SFRs are compared to those obtained from bolometric IR luminosities. Spectral lines systematically underestimate the ongoing starburst activity, with respect to the far-IR diagnostics (Berta et al., 2003; Valdés et al., 2005).

Several explanations for this discrepancy are discussed. The possible presence of a buried AGN has been ruled out for the majority of sources, on the bases of X-ray and Radio data, spectropolarimetry and broad-band SEDs. The most likely interpretation explains the apparent lack of ionizing photons in terms of the presence of differential extinction. The star formation activity in test case IRAS 20100-4156 is modeled by mixing two different young stellar populations: one characterized by strong SFR, but heavily absorbed, the other representing a weaker, less-extinguished burst. The former emits strong far-IR luminosity, but its contribution to optical-NIR emission lines is negligible. The contrary happens for the latter. In other words, the estimation of extinction based on optical-NIR spectral lines systematically under-predicts the color excess in these galaxies, because of the existence of young stars completely embedded in thick dusty medium and invisible at short wavelengths. However, the decisive test to understand the reason for the missing ionizing photons will be to look at the Brα ($\lambda = 4.05\ \mu$m) line emission.

Spectro-polarimetry, L-band spectroscopy and SEDs analyses are used to constrain the contribution of a possible AGN to the emission of a sub-sample of ULIRGs (Pernechele et al., 2003; Risaliti et al., 2003; Berta et al., 2003). The case of IRAS

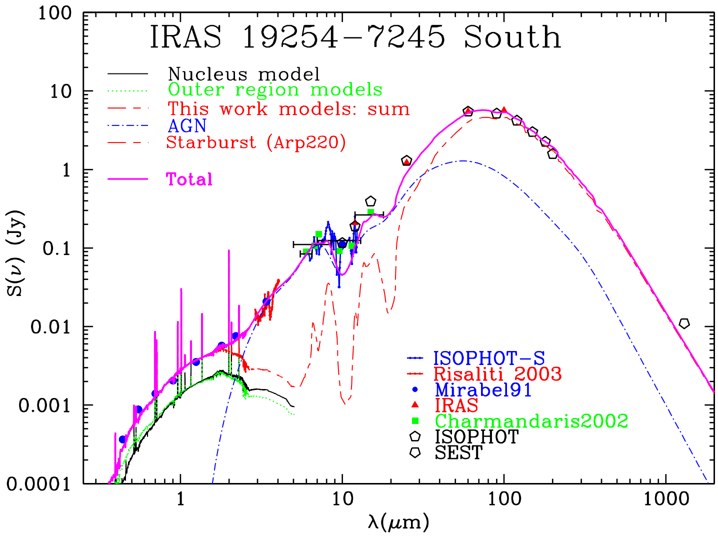

Figure 1: Spectral energy distribution of the southern nucleus of Superantennae. The thick solid line is the fit to the global SED, obtained combining an optical–NIR spectral sytnthesis model (dashed line shortward 5 μm) with an AGN model obtained with the code DUSTY (dot-dashed line) and a semiempirical starburst Arp220-like template (long-short dashed line longward 5 μm).

19254-7245, hosting a Seyfert-2 nucleus, exemplifies the potentiality of such studies in detecting buried AGNs.

Very faint but significant polarization signal is detected in two out of the four ULIRGs observed in our spectro-polarimetric campaign: IRAS 19254-7245 (the Superantennae) and IRAS 20551-4250. Concerning the former, the polarized Hα line is possibly broadened to $\sim 2000 - 3000$ [km s^{-1}]. Present observations tend to confirm that ULIRGs display faint signals in optical polarized light (e.g. Young et al., 1996; Tran et al., 1999; Hines et al., 1999). These results are consistent with either very weak AGN components in the source nuclei (otherwise dominated by starburst emission), or a dust distribution covering the nuclear source and producing dichroic transmission. The signal-to-noise ratio of the data does not allow the possible polarization mechanism (i.e. electron scattering, dust scattering or dichroism) to be identified. In the IRAS 19254-7245 case, polarization of the continuum is detected, showing a slight decreasing trend at increasing wavelength. This effect excludes the presence of electron scattering, which is independent of wavelength.

Through L-band spectroscopy of IRAS 19254-7245 (Risaliti et al., 2003), the 3.3 μm PAH feature and the carbonaceous dust absorption dip at $\sim$ 3.4 μm are directly measured. The former spectral feature has a much lower equivalent width than typical starburst-dominated sources; and the depth of the latter suggests the presence of an absorbed point source like an AGN. The rather steep continuum slope above $\sim$ 3 μm, further supports the presence of warm, AGN-heated dust.

The broad-band spectral energy distributions of a sub-set of ULIRGs are reproduced with a stellar synthesis model in the optical-NIR and the sum of starburst and AGN templates in the mid-to-far infrared spectral domain. The energy absorbed by gas and dust at UV-optical wavelengths is reprocessed by the dust enshrouding the ongoing starburst and re-emitted longward of 5 μm (Fritz et al., 2004, in prep; Berta et al., 2003). The $J - L$ color (see the Superantennae example in figure 1) , or the NIR/MIR flux ratio, turns out to potentially be a powerful tracer for the presence of a hidden AGN, contributing to the IR emission of ULIRGs. The significant L-band excess detected in the Superantennae, with respect to NIR stellar continuum, is explained in terms of the emission by a dusty torus surrounding the Sy-2 nucleus. This property will be fully exploited by Spitzer/MIPS observation of luminous IR galaxies at any redshift, in order to identify Active Galactic Nuclei. The relative strengths contributions of starburst and AGN in local ULIRGs are quantified: in the case of IRAS 19254-7245, the AGN emits $\sim 40\%$ of the bolometric IR emission.

XMM-*Newton* observations of the same ULIRGs (Braito et al., 2002; Franceschini et al., 2003b) confirm the results obtained by spectro-polarimetry, L-band spectroscopy and SED fitting.

Intermediate-redshift galaxies

In the local Universe surveyed by IRAS, only 30% of the total energy output of galaxies emerges in the mid- and far-IR. On the other side, the cosmic infrared background (Puget et al., 1996; Hauser et al., 1998) appears to contain a large fraction (up to $\sim 70\%$) of the total extragalactic background energy from radio to X-rays, Cosmic Microwave Background excluded. The implication is that there likely exists a very significant contribution of dust-obscured star formation at high redshifts (e.g. Genzel & Cesarsky, 2000). Deep surveys carried out by the Infrared Space Observatory in the '90s represent the first pioneering exploration of the distant universe at mid- and far-IR wavelengths. The published work reports 15 μm detections of ~ 1400 sources, with flux densities between 30 Jy and 0.3 Jy.

In the second part of the Thesis, an accurate analysis of the physical properties characterizing the 15 μm ISO sources in the Hubble Deep Field South is performed (Franceschini et al., 2003a; Rigopoulou et al., 2005).

Extensive follow-up of the area has been carried out, as well as archive data mining. The study makes use of optical spectroscopy obtained with FORS1, FORS2 at VLT and with EMMI on NTT; near-IR spectroscopy by ISAAC/VLT; WFPC2/HST imaging, ESO archival EIS imaging, and mid-IR ISO data.

The available spectroscopy allows star formation rates and intrinsic extinctions of the analyzed galaxies to be computed. The mid-IR ISO galaxies turn out to be located at redshifts between 0.5 and 1.5. Modeling of broad-band SEDs is performed with a newly-developed synthesis code (based on Poggianti et al., 2001) and leads to IR-based SFRs and stellar mass estimates. As in the case of local ULIRGs, the presence of hidden young stellar populations seems to play an important role in the extinction and SFR estimates. The starburst activity inferred from optical emission lines — even after extinction correction — seems to be systematically lower than what found at the mid-IR wavelengths. AGN activity is detected only in a small fraction ($10-20\%$) of the sample. On the other hand, IR-derived SFRs are in good agreement with the radio estimate, as predicted by the well-known radio-FIR correlation.

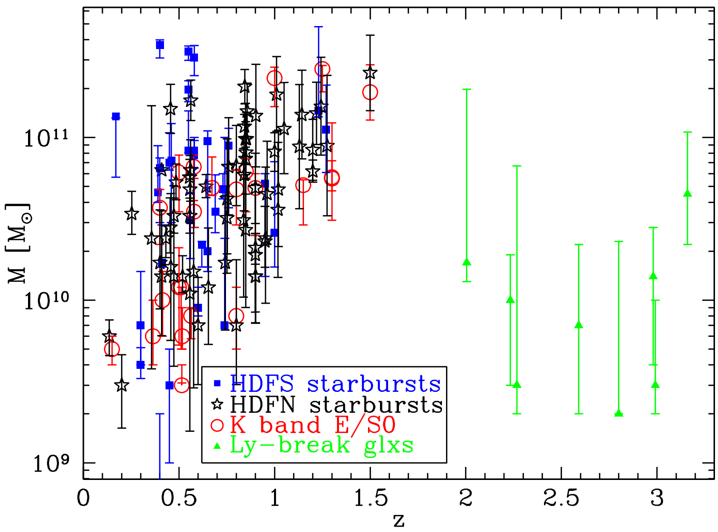

Figure 2: Comparison of stellar masses of mid-IR selected starburst (filled squares), K-band selected E/S0 (open circles) and Ly-break galaxies (triangles), as a function of redshift.

Concerning SED synthesis, a completely free-form, non-parametric approach is followed, in order to account in the most general way for bursting and discontinuous star formation histories, which are characteristic of starburst galaxies. It also provides easy implementation of age-selective extinction properties for the populations involved in the fit. For starbursts, dust re-radiation is expected in the mid- to far-IR; the relative contributions of young and old stars to the emitted SEDs are partially constrained exploiting mid-IR data from ISO.

As a result of SEDs synthesis, 15 μm ISO sources are found to be hosted by very massive ($M > 10^{11}$ $M_\odot$) galaxies. Normalizing masses by SFR, a timescale for stellar formation is defined. The data show a trend of t_{SF} to decrease with redshift: galaxies at $z \simeq 1$ and larger seem to be more actively forming stars than those in the local universe. The median value $t_{SF} \sim 1$ Gyr, compared with typical starburst timescales of ∼0.1 Gyr, implies that the ongoing starburst event may explain only a fraction of the whole stellar content. A few to several such episodes are then required to build up the observed large galactic masses, as part of a protracted SF history made up of a sequence of starbursting episodes on top of a lower-level secular SF.

The 15 μm population is compared to a K-band selected sample of early-type galaxies ($z = 0.5-1.2$) and to a test case of eight Ly-break U-drop galaxies ($z = 2-3$). For intermediate-redshift ellipticals, the inferred masses are comparable to those found for ISO starbursts, while Ly-break galaxies seem to be characterized by significantly lower values of the mass ($M \sim 10^{10}$ [$M_\odot$], see Figure 2).

Particular care is taken in estimating the uncertainties ΔM in the stellar mass due to degeneracies in the star formation history and extinction (Berta et al., 2004). Due to the presence of completely extinguished young stellar populations and to the poor sampling of the restframe near-IR light, ΔM turn out to be as high as a factor of 3−5 for starbursts. In the case of elliptical galaxies, $\Delta M \sim 2$, thanks to simpler star formation histories. The largest uncertainties occur for Ly-break sources, whose masses are uncertain up to an order of magnitude.

Accurate simulations highlight the need of sampling the near-IR (restframe) emission of galaxies at any redshift, in order to achieve as small uncertainties as a factor of ≤ 2 in stellar mass. This will be finally possible thanks to Spitzer/IRAC capabilities and promises to be good enough for statistically reliable determinations of galaxy evolutionary mass function.

Spitzer sources

The NASA Great Observatory Spitzer was launched in August 2003. Its Infrared Array Camera was specifically designed for probing the assembly of stellar mass in galaxies at redshift > 2, by observing in the $3-8$ μm spectral domain. At the same time deep sky imaging with the Multiband Imaging Photometer at 24, 70 and 160 μm is detecting dust re-radiation from distant actively star-forming galaxies. The cosmic rate of stellar formation is going to be measured with high accuracy, in a way completely independent from UV-optical estimates, subject to extinction uncertainties.

The first year of Spitzer in-flight operations has been mostly devoted to six different Legacy science Programs, representing projects of general and lasting importance to the broad astronomical community. Among these, the *Spitzer Wide-area Infra-Red Extragalactic* survey (SWIRE, Lonsdale et al., 2003, 2004) is the largest SIRTF Legacy Program. It consists in a wide-area, imaging survey to trace the evolution of dusty, star-forming galaxies, evolved stellar populations, and AGN as a function of environment, from redshifts $z \sim 3$, down to the current epoch. SWIRE includes 7 high-latitude fields, totaling ~ 50 [deg^2] in all the seven Spitzer bands.

A deep optical follow-up of SWIRE ELAIS-S1 field is being carried out in Padova, as an ESO Large Programme (P.I. A. Franceschini) covering more than 5 [deg^2] in five photometric bands. The *ESO-SIRTF wide-area Imaging Survey* (ESIS) includes B,V,R WFI@2.2m and I,z VIMOS@VLT imaging down to B=26 and V,R=25.5. This project will provide optical identifications, colors and rough morphologies, photometric redshifts, for the roughly 200,000 IR sources detected by SWIRE in the 5 [deg^2] of the S1 area. Complemented by other ancillary datasets in the X-ray, ultra-violet, near-IR, and radio spectral domains, ESIS data will be the basis for building complete SEDs of Spitzer sources and derive the physical properties of distant galaxies in the ELAIS-S1 area, up to $z \sim 3$. The current status, the sophisticated data reduction and the preliminary results of the ESIS survey, led by Stefano Berta in parallel to the data-interpretation presented in the Thesis, are described in the Appendix.

In collaboration with the SWIRE team, an extensive analysis of the first available Spitzer data is in progress. The last part of this Thesis presents the first results on mid-IR Spitzer counts and SED modeling of three SWIRE sub-samples.

As an extension of the work presented by Franceschini et al. (2001), a new cosmic evolutionary model was developed in this Thesis, in the attempt to reproduce the observed number counts from mid-IR to sub-mm wavelengths. The adopted picture assumes that two main populations of IR galaxies contribute to the observed data: a family of galaxies whose properties do not vary with cosmic time, and a class of IR starbursts and AGNs, strongly evolving. Evolution of both luminosity and volume

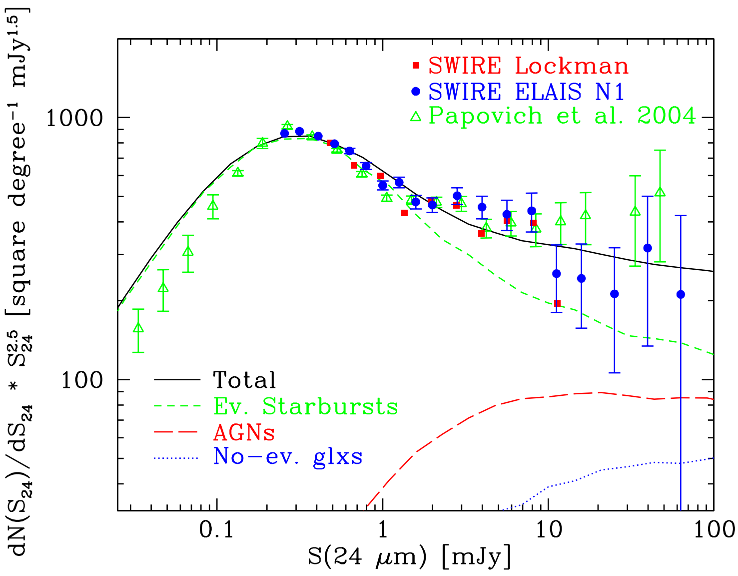

Figure 3: Normalized differential 24 μm counts and model predictions. Data are from Papovich et al. (2004), Lonsdale et al. (2004) and Shupe et al. (2005, in prep.). The four lines represent the contribution to the counts from the populations building up the model.

density of the latter population are required, in order to explain the sudden upturn in differential normalized counts, at $S_{24} < 3$ mJy, and the evidence for flattening below $S_{24} \sim 0.3$ mJy. Source luminosity and density increase as a power law in redshift, with exponent ~ 3.5, up to $z \sim 1$. The evolution then levels off, in order to be consistent with the observed redshift distribution of faint ISO galaxies. At the highest redshifts, a decrease of luminosity seems to be necessary, not to over-predict counts in the faint-flux tail. The predictions of the new model are consistent with SWIRE and GOODS number counts, as well as with old ISO and SCUBA data, on the whole wavelength range from 15 μm to 850 μm. Figure 3 shows the current best fit to the 24 μm MIPS differential counts.

The depicted scenario supports the hierarchical evolutionary scheme. Any single galaxy spends most of its lifetime in a quiescent (non-evolving) phase; occasionally it is triggered into a short-lived (few 10^7 yr) starbursting state, possibly because of interactions or mergers with other galaxies. The evolution of the "active" phase — detected in the mid- and far-IR — might simply reflect an increased probability to find a galaxy in such an excited mode in the past. Volume density scales with redshift as the rate of interactions, which was larger in the past due to a simple geometric effect. The luminosity evolution might, on the other hand, be interpreted with a larger gas reservoir to be transformed into stars in the past.

During the merger, violent relaxation likely redistributes old stars, producing the typical de Vaucouleur profiles of galaxy spheroids. During the violent starbursting phase, elliptical and S0 galaxies are formed in the most luminous IR sources (corresponding to the SCUBA high-z population). Bulges in later-type galaxies likely originate in lower IR luminosity starbursts (e.g. the ISO mid-IR population).

The usual spectro-photometric synthesis is applied to three sub-samples of SWIRE sources, including broad-band data from KPNO and INT telescopes, as well as Spitzer,

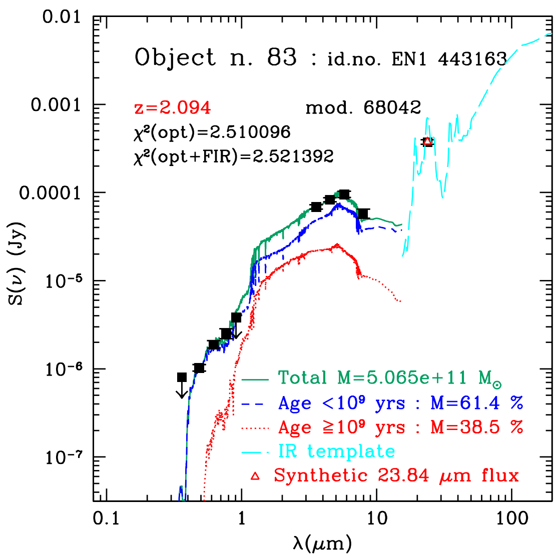

Figure 4: Example of SED-fitting of one SWIRE IB-source at redshift $z \sim 2$.

and Gemini, Keck and Wiyn optical spectroscopy. The interesting case of rare sources characterized by the detection of the 1.6 μm stellar bump in the IRAC wavelength range is studied (IB galaxies). The 24 μm flux, when available, turns out to be an effective constraint to the extinction affecting young stellar populations, when combined to IRAC detection of the restframe near-IR light.

Star formation rates, stellar masses and timescales for stellar formation have been derived for all the analyzed galaxies. The variation of the restframe Ks-band mass-to-light ratio was explored, as a function of redshift and far-infrared luminosity. In both cases, the M/L ratio turns out to decrease when considering more distant or intrinsically brighter galaxies. These trends are somehow expected, if brighter IR emitters are powered by stronger ongoing starbursts, and young stellar populations provide a more significant contribution to the light detected at higher z.

Very red (restframe $V - K \geq 4$) and distant IB galaxies in ELAIS-N1 are fitted by old stellar populations (age $\geq$ 1 Gyr, see figure 4). Extremely absorbed young populations would explain the observed SEDs as well, but would also require huge amounts of dust and produce very bright bolometric IR luminosities, hence violating the 24 μm observed constraint. Photometry in the JHK bands will sample the D4000 break, thus providing further constraints on the relative amount of young and old stars contributing to the SEDs. The resulting stellar masses for this class of high-redshift red IB sources exceed several 10^{11} $M_\odot$, at redshift $z > 2$. In correspondence with these sources, the trend of t_{SF} in decreasing with redshift seems to significantly flatten. This is an indication that the bulk of stars in these galaxies were already formed and evolved at these redshifts.

If confirmed by future further investigations, these results would imply that very massive, evolved galaxies were already in place at redshifts between 2 and 3. Daddi et al. (2004) report the properties of nine K-band luminous galaxies at $1.7 < z < 2.3$, selected in the K20 survey, deriving SFRs of $100 - 500$ [$M_\odot$ yr^{-1}] and stellar masses of $M \simeq 10^{11} - 5 \times 10^{11}$ [$M_\odot$]. Yan et al. (2004) studied the SEDs of 17 high-redshift extremely red objects in the GOODS/HST Ultra Deep Field, lying at redshifts between 1.6 and 2.9: they found stellar masses in the $0.1 - 1.6 \times 10^{11}$ $M_{\odot}$ range. Studying the stellar mass function of galaxies in the FORS Deep and GOODS/CDFS fields, Drory et al. (2004) find that massive galaxies with $M > 10^{11}$ $M_{\odot}$ exist even at very high redshifts ($z = 2 - 5$). At these redshifts, these galaxies provide, however, only a small contribution to the stellar mass function, their number density being less than one tenth of that obtained for $M > 10^{10}$ $M_{\odot}$ galaxies. Saracco et al. (2004a) and Saracco et al. (2004b) studied high-redshift massive galaxies in the HDFS and in the MUNICS survey respectively, suggesting that massive evolved galaxies do not play an important role in the evolution of the mass density outlined by recent surveys between $z = 1.3$ and ~ 2, in support to the monolithic cosmic scenario. Juneau et al. (2004) studied the cosmic star formation history and its dependence on galaxy stellar mass, in the redshift range $z = 0.8 - 2$, by using data from the Gemini Deep Deep Survey (GDDS). The main result of this work is that the SFR density strongly depends on the galaxy stellar mass. The most massive galaxies formed most of their stars in the first ~ 3 Gyr of cosmic history, moderate-mass objects continued to form their dominant stellar mass for an additional ~ 2 Gyr, while the lowest mass systems have been forming over the whole $z = 0.5 - 2$ range. Current models of hierarchical galaxy formation are consistent with global properties like the stellar mass function, but seem to be challenged by the ages of local massive galaxies (Thomas et al., 2004). A more detailed comparison to other works is discussed in Chapter 5.

However, it is worth noticing that *no information is currently available on the nature of the environment surrounding the high-redshift, very massive, evolved galaxies, which are being discovered by modern surveys.* Further investigations into this kind of objects, will need also to explore the neighbouring environments, in order to correctly interpret their nature and their contribution to the stellar mass function and its evolution. Such an analysis will be of fundamental importance also for testing any possible "progenitor bias" between local ellipticals and the newly discovered high-z massive galaxies.

Comparison between high-redshift cluster and field galaxy populations

It is well known that local clusters consist of evolved galaxies, while the bulk of star formation happens into low-density environments. There should have been an epoch, in the past, when the situation was reversed and the masses of cluster ellipticals seen today had been assembled. To this end, it is crucial to study clusters out to as high redshifts as possible, when fractional age differences among the galaxies were proportionately larger.

Whereas the hierarchical merging model predicts a substantial difference in the star formation histories of early-type galaxies in the field and in clusters, observational data lead to discrepant conclusions: some authors report that only small differences are inferred from observational data (e.g. Willis et al., 2002; van Dokkum & Ellis, 2003), others show evidence of large differences (Thomas et al., 2004).

More stringent tests of hierarchical models come from observations of field and cluster galaxies beyond $z = 1$. The last part of the Thesis presents the preliminary results of the spectral synthesis investigation carried out on the members of RDCS1252.9-2927 (Rosati et al., 1998). Lying at $z = 1.237$, this is one of the most distant clusters known.

The physical properties (mainly stellar masses and ages) inferred for the member galaxies are compared to field objects in the GOODS CDFS area, taking advantage of what is arguably the best multiwavelength dataset for both field and cluster samples. This comparison suggests that the reddest galaxies in field and cluster, between redshift 1 and 1.5, have similar masses and ages. Several tests have been run, in order to explore possible biases in the comparison between the two samples, including evolution correction, clustering of field CDFS red sources and computational uncertainties.

Such similarity has strong implications on the evolutionary scenario describing galaxies in the universe. In the hierarchical picture, the formation redshift of galaxies with a given mass depends on environment (Diaferio et al., 2001), leading to substantial differences in age and mass between field and cluster galaxies at any redshift. Some authors claim that field early-type galaxies underwent secondary bursts of star formation at $z < 1$, hence evolving faster than cluster members (e.g. Treu et al., 2002), while others find that field and cluster galaxies evolve at comparable rates (e.g. van Dokkum et al., 2001). In hierarchical formation models field galaxies are predicted to be less massive than cluster sources, at any redshift (Diaferio et al., 2001). The results described above might indicate that the most massive early-type galaxies in both field and clusters were generally formed at $z \geq 2$, a much higher redshift than predicted by semi-analytic models, independently of environment.

The analysis of the Ks band (corresponding to restframe z-band) luminosity function (LF) of RDCS 1252.9-2927 and the comparison to low density environments were presented by Toft et al. (2004). Their results are consistent with a passively evolving population formed at $z \geq 2$, and show negligible differences in the LF of high-z clusters and field environments. On the other hand Thomas et al. (2004), find a substantial difference between the ages of *local* cluster and low-density environment galaxies. According to them, galaxy formation appears delayed of ~ 2 Gyr in the latter, with respect to high density environments.

The results on RDCS1252.9-2927 seem to disagree with semi-analytic hierarchical models, which predict cluster early-types to be redder, older and more massive than their field analogues; the faint end slope of the LF is expected to get steeper with redshift, as the massive cluster galaxies break up into their progenitors. The current findings prepare a new challenge for the hierarchical scenario.

Future development

Whether the evolution of the Universe and its basic components, galaxies, is ruled by a hierarchical (e.g. Kauffmann & Charlot, 1998), a monolithic collapse (e.g. Eggen et al., 1962) scenario, or a compromise between the two, is matter of the longest-lasting and most lively debate of modern observational cosmology.

In the latter case, the assembly of massive galaxies took place on rapid timescales at high redshifts, then galaxies evolved passively to present days. On the contrary, in the hierarchical picture, galaxy formation is predicted to be a more continuous process and massive elliptical galaxies to assemble through merging of lower mass disk galaxies at moderate redshifts.

Current and past data analyses have led to different and discordant conclusions, on the bases of galaxy properties in both local and distant Universe, and in both low- or high-density environments. For example, the statistical properties of mid- and far-IR galaxies (e.g. differential number counts, studied here) support a hierarchical galaxy merging-tree. The study of the stellar mass function of evolved galaxies (e.g. Drory et al., 2004) and the comparison between field galaxies and cluster members at high-z are, instead, consistent with the predictions of a monolithic-collapse scenario.

The Spitzer Space Telescope, recently become operative, promises to be the instrument for shedding new light on such a debate. The superb capabilities of the on board cameras, IRAC and MIPS, are allowing the detection of restframe near- and mid-IR emission of galaxies up to redshifts $z \simeq 3-5$. The Spitzer Legacy Program is providing a unique database of observations, covering all main branches of astrophysics. The SWIRE survey is exploring the distant universe in all Spitzer bands, over an area of ~ 50 square degrees and large enough volumes to determine the evolution of actively star-forming and passively evolving galaxies, as well as AGNs, in the context of cosmic structure galaxy formation histories. The GOODS project is trying to constrain galaxy history up to as high redshifts as possible, through very deep, pencil-beam multiwavelength observations.

The evolution of the global star formation rate provides a sensitive probe of galaxy formation and evolution. The earliest determinations of the evolving star formation rate density (Madau et al., 1996; Lilly et al., 1996) showed a steep decline from $z \sim 1$ to the present day. It is now generally accepted that galaxies produced stars more actively in the past than today, but the true rates of star formation are affected by a variety of uncertainties and biases, especially related to the amount of dust in galaxies and its effect on the SFR tracers. Complementary insights in the star formation history can be gained from other physical properties of galaxies. Stellar mass is the key parameter. The integral of the past stellar formation activity in galaxies provides the logical completion to the current view of galaxy evolution.

Spitzer/IRAC wide-area and deep observations allow the cosmic stellar mass function and its evolution to be measured, at least to redshift $z = 3$, avoiding cosmic variance biases. The work presented in this Thesis shall be extended over large samples and large cosmic volumes. It is mandatory to accurately study the environment hosting distant sources and its effects on their transformation to present-day galaxies, in order to build a self-consistent model of galaxy evolution, and converge to a *universally-accepted cosmic scenario.*

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