Galaxy Formation and Evolution since z = 1

François Hammer[1], Hector Flores[1], YanChun Liang[1], XianZhong Zheng[1], David Elbaz[2], and Catherine Cesarsky[3]

[1] GEPI, Observatoire de Paris, 92195 Meudon Principal, France
[2] CEA, Saclay-SAp, Ormes des Merisiers, 91191 Gif sur Yvette, France
[3] ESO, Karl-Schwarzschild-Strasse 2, D-85748 Garching bei München, Germany

Abstract. Determination of the star formation rate can be done using mid-IR photometry or Balmer line luminosity after a proper correction for extinction effects. Both methods show convergent results while those based on UV or on [OII]λ3727 luminosities underestimate the SFR by factors ranging from 5 to 40 for starbursts and for luminous IR galaxies, respectively. Most of the evolution of the cosmic star formation density is related to the evolution of luminous compact galaxies and to luminous IR galaxies. Because they were metal deficient and were forming stars at very high rates (40 to 100 $M_{\odot} yr^{-1}$), it is probable that these (massive) galaxies were actively forming the bulk of their stellar/metal content at z $\leq$ 1.

1 Introduction

Determining how galaxies formed and grew is one of the outstanding problems of modern astrophysics. The epoch at which half the stellar mass was formed has been estimated to be z=1-1.5 from simple integrations of the global star formation history of the Universe ([1]; [2]). Similar results have been found by estimating the growth of galaxies by calculating the stellar mass from SEDs with broad wavelength coverage ([3]; [4]; [5]). However, this method depends strongly on the estimated M/L of individual galaxies which is sensitive to the assumptions about their star formation history, dust distribution, metallicity, and IMF – all of which are usually poorly constrained. Many efforts have been made to study galaxies at redshifts higher than 1, in attempts to track the formation of half the present day stellar mass. However the situation at z> 1 is difficult, because of their faintness and because most of the important lines for diagnostics are redshifted to the near IR. Here we choose to investigate the properties of z $\leq$ 1 galaxies, for which the current generation of telescopes is able to provide accurate measurements of their properties (star formation rates, masses, metal abundances). In a cosmological model with H_0 =70km s^{-1} Mpc^{-3}, Ω_{Λ}=0.7 and Ω_M=0.3, z=1 corresponds to 58% of the Universe age. At z> 0.4, the emergence of two galaxy populations have been reported, namely the luminous infrared galaxies (LIRGs, [1]; [6]) and the luminous compact galaxies (LCGs, [7]; [8]). These two populations are responsible of most of the evolution of the IR and UV luminosity density evolutions, and then of a significant fraction of the cosmic star formation density at z$\sim$ 1.

In the following, we present a summary of results based on follow-up studies of the Canada France Redshift Survey (CFRS) using the Very Large Telescope

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(VLT), the Infrared Space Observatory (ISO) and the Hubble Space Telescope (HST).

2 Estimating Extinction and SFR at z $\sim$ 1

A prerequisite for estimating star formation from emission is to properly estimate the extinction. $H\alpha$ luminosity is one of the best indicator of the instantaneous SFR. However low resolution spectroscopy (R $<$ 500) often produces misleading results [9]. Only good S/N spectroscopy with moderate spectral resolution (R>600) allows a proper estimate of the extinction from the $H\alpha/H\beta$ ratio after accounting for underlying stellar absorption. SFRs can be otherwise underestimated or overestimated by factors reaching 10, even if one accounts for an *ad hoc* extinction correction. These effects are prominent for a large fraction of evolved massive galaxies especially those experiencing successive bursts (A and F stars dominating their absorption spectra). Further estimates of the cosmic star formation density at all redshifts mandatorily requires moderate resolution spectroscopy to avoid severe and uncontrolled biases.

Liang et al ([9]) have given an obvious warning for the studies based on low resolution spectroscopy aimed at measuring individual galaxy properties (gas chemical abundances, interstellar extinction, stellar population, ages as well as star formation rates and history), particularly for dusty spiral galaxies. For example, it has been shown ([10]) that 1/4 of the Lilly et al sample ([11]) of z $\sim$ 0.7 galaxies was made of LIRGs which are dust enshrouded systems (average A_V= 2.4). Assuming a constant extinction of A_V=1 for these LIRGs, leads to underestimate their [OII]λ3727/$H\beta$ ratio, providing an overestimate of their metallicity by 0.3 to 0.5 dex.

ISOCAM observations give us a unique opportunity to test the validity of our SFR estimates. It has been shown ([6], see also David Elbaz's contribution) that the mid-IR and radio luminosities correlate well up to z=1. Bolometric IR measurements derived from mid-IR are validated, unless if both the radio-FIR and the MIR-FIR correlations are invalid at high redshifts. Mid-IR photometry provides an unique tool to estimate properly the SFR of LIRGs (defined as $L_{IR} > 2\ 10^{11}\ L_{\odot}$) up to z=1.2, and of starbursts ($L_{IR} < 2\ 10^{11}\ L_{\odot}$) up to z=0.4. For a sample of 16 ISO galaxies at 0 $<$ z $<$ 1, SFRs have been derived from the extinction corrected $H\alpha$ luminosities ([12]). These values agree within a factor 2 with mid-IR estimates (median value of $SFR_{IR}/SFR_{H\alpha}$=1.05). Using moderate spectral resolution (R = 1200) with good S/N of 90 ISO galaxies (0.2 $<$ z $<$ 1), Liang et al [10] have shown that the extinction can be properly derived from the $H\beta/H\gamma$ ratio. Such measurements can be performed for all galaxies up to z=1 within an accuracy of 0.6 mag for A_V values, and then for SFR values.

It has been argued ([13]) that the [OII]λ3727 luminosity can provide an efficient way to derive SFRs of high redshift galaxies using spectrographs in the visible range. However preliminary results from [14] and [15] have shown that the correlation between $H\alpha$ and [OII]λ3727 is rather poor, because of extinction effects and also because it considerably depends on the galaxy metallicity,