RevMexAA (Serie de Conferencias), **24**, 210–213 (2005)

EMISSION-LINE GALAXY SURVEYS WITH GTC: THE Hα UNIVERSE

J. Gallego,[1] J. Zamorano,[1] S. Pascual,[1] and V. Villar[1]

RESUMEN

Las galaxias con líneas de emisión son fácilmente detectadas y por tanto, son los objetos cuando se estudia el Universo a altos corrimientos al rojo. Han sido usadas para trazar la evolución de observables importantes en el Universo como la densidad de la Tasa de Formación Estelar (SFR), las propiedades de los brotes de formación estelar y las abundancias. La mayor parte de estas investigaciones se ha hecho usando las líneas en el UV así como [OII]3727; sin embargo, Hα es el mejor trazador de la Tasa de Formación Estelar y de las propiedades físicas de las galaxias con formación actual. En un estudio complementario a los estudios sobre evolución galáctica, nosotros estamos trabajando en un proyecto a largo plazo para estudiar la población de galaxias con formación estelar, seleccionadas utilizando Hα, a diferentes corrimientos al rojo. En 1995 determinamos la función de luminosidad local en Hα y, a partir de ella, la densidad de la tasa de formación estelar local. Después, utilizando imágenes de banda estrecha en el óptico, hemos extendido este estudio entre $z \simeq 0.24$ y $z \simeq 0.4$. El Gran Telescopio de Canarias, al poder trabajar en el cercano infrarrojo, va a ser una poderosa herramienta para estudiar la evolución de la población de galaxias con la línea de emisión Hα a diferentes corrimientos al rojo. Podremos tanto cuantificar la densidad de la SFR como caracterizar las poblaciones de estas galaxias comparando directamente los mismos observables hasta corrimientos al rojo de $z \simeq 2.5$.

ABSTRACT

Emission line galaxies are the most easily detected and studied objects in the high redshift Universe. They are being used to trace the evolution of critical observables of the Universe such as Star Formation Rate densities, starburst properties and abundances. Most of the research is being done using [OII]3727 and UV lines, but Hα is still one the best tracers for Star Formation Rate and physical properties of current star-forming galaxies. As a complementary contribution to studies of galaxy evolution, our team has focused into a long-term project to study the population of Hα-selected star-forming galaxies of the Universe at different redshifts. In 1995 we first determined the local Hα luminosity function, and from it the Star Formation Rate density (SFRd) of the local Universe. We then, using narrow-band imaging in the optical, extended this measurement to $z \simeq 0.24$ and $z \simeq 0.4$. Working in the near-infrared, GTC will be a very powerful tool to study the evolution of the Hα emission-line galaxy populations at different redshifts. We will both quantify the SFRd evolution and characterize the star-forming galaxy populations by directly comparing the same observables at all redshifts up to $z \simeq 2.5$.

Key Words: **GALAXIES: EVOLUTION — GALAXIES: STAR FORMATION**

1. INTRODUCTION

Deep redshift surveys suggest star-formation activity substantially increases with redshift until $z \simeq 1$ (see Ellis 1997 for a classic review). Detailed theoretical works (e.g., Lacey & Silk 1991; Kauffmann, white & Guiderdoni 1993; Kauffman, Colberg, Diaferio & White 1999; Cole,Aragón-Salamanca, Frenk, et al. 1994; Baugh, Cole, Frenk & Lacey 1998; Somerville, Primack & Faber 2001; Hoeft, Mucket & Heide 2002; Calura & Matteucci 2003), within the hierarchical clustering scenario, can provide a reasonable match to both the present-day characteristics of galaxies, as well as the properties of galaxies at high redshift. They are also able to predict the global star formation history of the Universe, i.e. the comoving number density of galaxies as a function of SFR and as a function of redshift. Studying the evolution of the SFR and the properties of the star-forming galaxy populations can thus provide important clues on galaxy formation and evolution.

2. Hα AS A TRACER OF THE STAR FORMATION PROCESSES

The Hα luminosity, related to the number of massive stars, is a direct measurement of the current star formation rate (modulo the IMF). Metallic nebular lines, such as [OII]3727 and [OIII]5007 (affected by excitation and metallicity), and far-IR fluxes (affected by dust properties) are rather

[1]Dpto. Astrofísica, Universidad Complutense de Madrid, Spain.

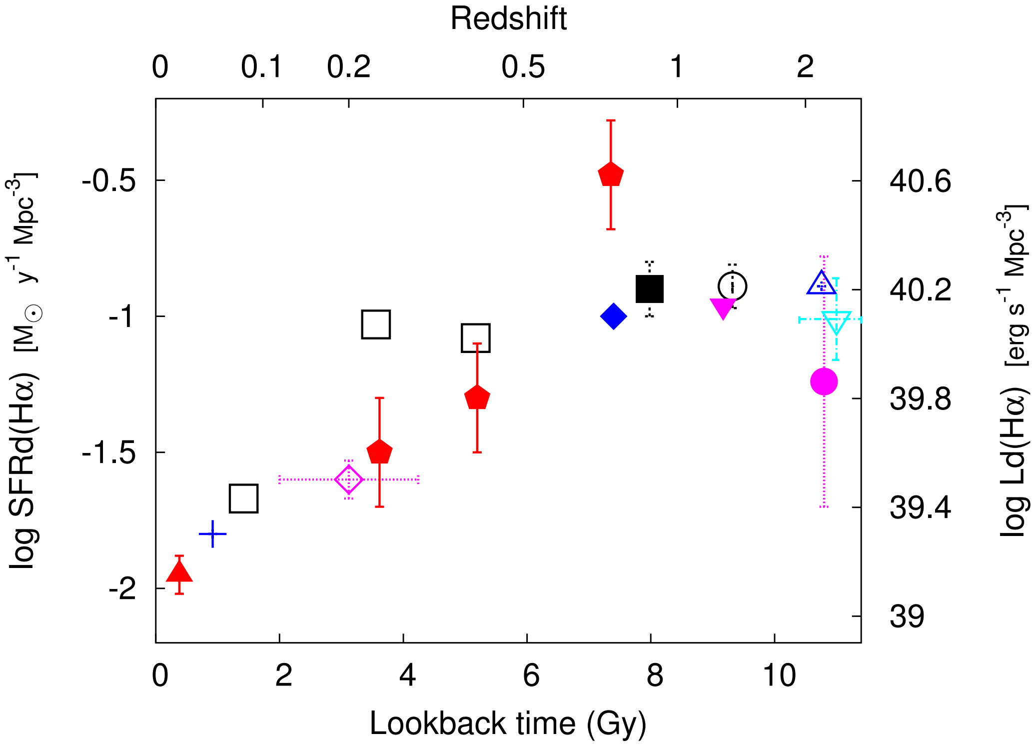

Fig. 1. Evolution of the SFR density from the Balmer lines. The solid triangle at z = 0.01 is from Gallego et al. (1995). Solid pentagons at z = 0.24, z = 0.4 and z = 0.8 correspond to Pascual et al. (2001), Pascual (2004) and Villar, Gallego, Zamorano & Koo (2004), respectively. The rest of points are from the papers cited in the corresponding section: Open squares are from Jones & Bland-Howthorn (2001), and high-redshift values are those from Pettini et al (1998 and 2001).

star-formation *indicators* than *quantitative* measurements (see, e.g., Gallagher, Hunter & Bushouse 1989; Kennicutt 1992). One of the best ways to quantify current star formation is by using an Hα-selected sample of galaxies (Charlot 1998). Quoting Charlot & Longhetti (2001): "while insufficient by itself, the Hα line is essential for estimating the star formation rate from the optical emission of a galaxy."

Although star formation in heavily obscured regions could not be revealed by Hα, if we select the galaxies with the same criteria at all redshifts, the samples —and the derived SFRs— will be directly comparable.

3. THE Hα-BASED SFR DENSITY AT INTERMEDIATE REDSHIFTS

One of the major problems that arises when analyzing galaxy evolution is how to make a meaningful comparison between high-z data and local samples. To test directly whether substantial evolution in the star-formation activity has occurred we need to measure the Star Formation Rate (SFR) density of the Universe and the properties of the corresponding star-forming galaxy populations at different redshifts using similar techniques.

The SFR density of the Universe is one of the key observables needed for our understanding of galaxy evolution. In a pioneering but now classic work, our group measured it locally using a sample of Hα-selected galaxies (Gallego, Zamorano, Aragón-Salamanca & Rego 1995). A few pioneering works have estimated average SFR densities measuring in the Hα luminosities at the near IR for small samples at z = 1 (Glazebrook, Blake, Economou et al. 1999; Yan, McCarthy, Freudling et al. 1999; Tresse, Maddos, Le Févre & Cuby 2002) and z ∼ 2 (Iwamuro, Motohara, Maihara et al. 2000; van der Werf, Moorwood & Bremer 2000; Moorwood, Van der Werf, Cuby & Oliva 2000) and Hβ luminosities for a few objects at z = 3 (Pettini, Kellogg, Steidel et al. 1998; Pettini, Shapley, Steidel et al. 2001). The z = 0.0-0.4 redshift range is now well covered (SDSS, Brinchmann, Charlot, White et al. 2004; Pascual, Gallego, Aragón-Salamanca & Zamorano 2001) and those of Tresse & Maddox (1998) and Jones & Bland-Hawthorn (2001). However, all these samples have

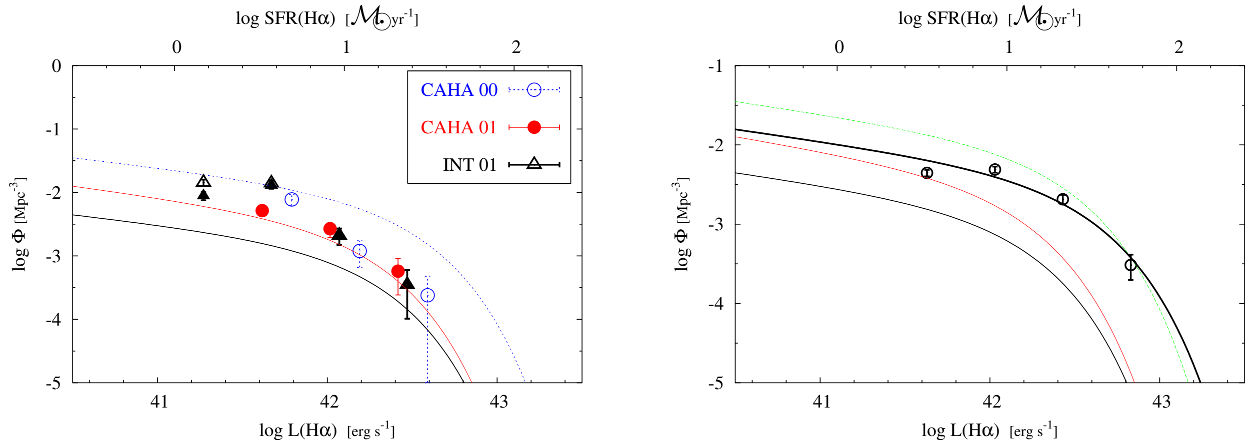

Fig. 2. **Left:** Hα-luminosity function of the Pascual (2004) samples by observing runs (CAHA Calar Alto 2.2m; INT La Palma 2.5m) at z = 0.24 compared with the Schechter best fit of Gallego et al. (1995); Tresse & Maddox (1998) and Tresse et al. (2002). Empty symbols are when not contamination by other high-z emitters is considered.
Right: Hα-luminosity function of the Pascual (2004) sample at z = 0.40 (and its corresponding Schechter fit), compared with the Schechter best fit of Gallego et al. (1995), Tresse & Maddox (1998) and Tresse et al. (2002).

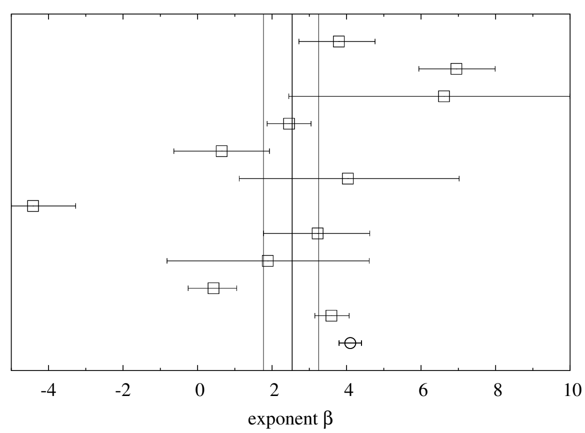

Fig. 3. Values of β for different surveys. From top to bottom, Lilly et. (1996), Hammer et al. (1997), Rowan-Robinson et al. (1997), Hogg (1998), Cowie et al. (1999), Flores et al. (1999), Mobasher et al. (1999), Haarsma et al. (2000), Jones & Bland-Howthorn (2001), Lanzetta et al. (2002) and previous Hα combined. The last point (circle) is the one obtained by our group.

been built using very different selection effects, which translate into incoherences when directly comparing the results (see for example the inconsistency revealed by Treyer 2002 when using the [OII]3727, UV or Hα for the same sample). Moreover, we still do not know the recurrence of the star-forming processes or the role of excitation, reddening and metallicity (Contini, Treyer, Sullivan & Ellis 2002).

3.1. *The Hα-based SFR density at $z = 0.24$ and $z = 0.4$*

We have extended the local Hα-based measurement between $z \simeq 0.24$ to $z \simeq 0.4$ (Pascual 2004), the maximum redshift for which Hα can be reached with CCDs. To select the emission-line galaxies by their Hα emission, we successfully used our own optical narrow-band filters tunned to the wavelength of the redshifted Hα line (8140 Å for z=0.24 and 9190 Å for z = 0.4). The photometric redshift technique allowed us to successfully confirm the redshift of the targets (Pascual, Gallego, Aragón-Salamanca, & Zamorano 2004). In Figure 1 we have produced the so-called "Madau diagram" when only the SFR densities obtained from Balmer line luminosities are considered.

In Figure 2 we have represented the Hα luminosity functions at z = 0.24 and z = 0.4 obtained using the narrow-band technique. Based on photometric redshifts, emission-line luminosities and multi-band photometry for a sample of Hα galaxies at z = 0.24, the physical properties of these galaxies appear to be remarkably similar to those of local galaxies selected in the same way. It seems there is little change in the overall properties of z = 0.24 current star-forming galaxies when compared with today. Our results support the idea that the higher Star Formation Density measured at intermediate redshift is due to an increase of the density of bursting galaxies and not to an intrinsic change on overall galaxy properties.

3.2. *The Hα-based SFR density at z=0.8*

Our current work now is to extend this study of the star-forming galaxy population to z $\simeq$ 0.8 using the same narrow-band technique in the near-infrared J band. The aim is to test whether substantial evolution in the star-formation activity has occurred in the past by covering a large look-back-time baseline with the same SFR tracer and, even more important, to characterize the way this evolution took place.

We have carried out some pilot narrow band imaging with a 100 Å filter centered at 11810 Å, corresponding to Hα redshifted to z = 0.8. This filter was used with the INGRID near-IR camera at the 4.2m WHT telescope. This specific wavelength was selected to be where the night sky emission has local minima. Red-shifted Hα emission are detected by using the differences in the flux between a deep narrow-band exposure and a broad-band exposure taken in J. The advantage of this strategy over a broad-band selected redshift survey is that the galaxies in our sampled are Hα (i.e. SFR) selected at all redshifts, providing the first direct measurement of the evolution of the SFR density at moderate redshifts. The corresponding SFR density at z = 0.8 is plotted in Fig 1.

When an evolution law as $\propto (1+z)^{\beta}$ is considered, we obtain different β values depending on the SFR tracer used. Using only Hα selected samples we get $\beta = 4.1 \pm 0.1$. This result is compared with β obtained for different surveys in Figure 3.

4. A COORDINATED EFFORT: THE STAR-FORMING GALAXY POPULATION OF THE UNIVERSE AS TRACED BY Hα USING GTC

A large theoretical and observational effort is being invested to understand the evolution of the SFR density of the Universe at all redshifts. Because most of the studies focus on UV, color or infrared selected objects, it is very important to build and analyze Hα selected samples, as a complementary effort.

So far, our group has targeted some of the crucial redshifts. We have used CCD cameras in 2m class telescopes to target the z = 0.24 and z = 0.4 universes. Near-IR cameras at 4m class telescopes are being used to target the bright end of the z = 0.8 universe. In the near future we will use the CIRCE near-IR camera at GTC to extend the narrow-band technique to higher redshifts ($0.7 < z < 2.8$ for Hα) where most of the fun is supposed to happen. The follow-up spectrocopic study will be carried out using both OSIRIS and EMIR spectrographs at GTC.

REFERENCES

Baugh, C. M., Cole, S., Frenk, C. S., & Lacey, C. G. 1998, ApJ 498, 504
Brinchmann, J., Charlot, S., White, S. D. M., Tremonti, C., et al. 2004, MNRAS (astro-ph/03110600)
Calura, F. & Matteucci, F. 2003, ApJ, 596, 734
Charlot, S. 1998, 34th Liege Colloq, ESA-SP, 429, 135
Charlot, S. & Longhetti, M. 2001, MNRAS, 323, 887
Cole, S., Aragon-Salamanca, A., Frenk, C. S., Navarro, J. F., & Zepf, S. E. 1994, MNRAS, 271, 781
Contini, T., Treyer, M.A., Sullivan, M., & Ellis, R.S. 2002, MNRAS, 330, 75
Ellis, R. S. 1997, ARA&A, 35, 389
Gallagher, J. S., Hunter, D. A., & Bushouse, H. 1989, AJ, 97, 700
Gallego, J., Zamorano, J., Aragon-Salamanca, A., & Rego, M. 1995, ApJ, 455, L1
Glazebrook, K., Blake, C., Economou, F., Lilly, S., & Colless, M. 1999, MNRAS, 306, 843
Hoeft, M., Mucket, J. P. & Heide, P. 2002, ApJ, 570, 33
Iwamuro, F., Motohara, K., Maihara, T., Iwai, J., et al. 2000, PASJ, 52, 73
Jones, D. H., & Bland-Hawthorn, J. 2001, ApJ, 550, 593
Kauffmann, G., White, S. D. M., & Guiderdoni, B. 1993, MNRAS, 264, 201
Kauffmann, G., Colberg, J.M., Diaferio, A., & White, S.D.M. 1999, MNRAS, 303, 188
Kennicutt, R.C. 1992, ApJ, 388, 310
Lacey, C.G. & Silk, J. 1991, ApJ, 381, 14
Moorwood, A. F. M., van der Werf, P. P., Cuby, J. G., & Oliva, E. 2000, A&A, 362, 9
Pascual, S., Gallego, J., Aragón-Salamanca, A., & Zamorano, J. 2001, A&A, 379, 798
Pascual, S. 2004, Ph.D. Thesis, Universidad Complutense de Madrid
Pascual, S., Gallego, J., Aragón-Salamanca, A., & Zamorano, J. 2004, A&A, in press
Pettini, M., Kellogg, M., Steidel, C. C., Dickinson, M., Adelberger, K. L., & Giavalisco, M. 1998, ApJ, 508, 539
Pettini, M., Shapley, A.E., Steidel, C. C., Cuby, J.-G., et al. 2001, ApJ, 554, 981
Somerville, R., Primack, J., & Faber, S. M. 2001, MNRAS, 320, 504
Tresse, L. & Maddox, S. J. 1998, ApJ, 495, 691
Tresse, L., Maddox, S. J., Le Févre, O., Cuby, J.-G. 2002, MNRAS, 337, 369
Treyer, M. 2002, IAU Symp 212 Proceedings
van der Werf, P.P., Moorwood, A.F.M., & Bremer, M.N. 2000, A&A, 362, 509
Villar, V., Gallego, J., Zamorano, J. & Koo, D.C., 2004, ApJ, in press
Yan, L., McCarthy, P.J., Freudling, W., Teplitz, H.I., et al. 1999, ApJ, 519, L47

Jesús Gallego, Sergio Pascual, Victor Villar and Jaime Zamorano: Departamento de Astrofísica, Universidad Complutense de Madrid, E-28040 Madrid, Spain (jgm@astrax.fis.ucm.es).