COMPACT GALAXIES IN THE HDF

A. C. Phillips, R. Guzmán, J. Gallego, D. C. Koo & N. P. Vogt
UCO/Lick Observatory & Univ. California at Santa Cruz

Abstract

We have observed a sample of small, high-surface-brightness galaxies in the HDF flanking fields. The majority of the objects are found to be emission line galaxies at redshifts $0.4 < z < 1.0$, although a small fraction of absorption line systems in the same redshift range is also found. The properties of the emission-line systems – sizes, luminosities, velocities, line ratios – resemble those of local H II galaxies. These seem to represent a rapidly evolving population, and may produce nearly half of the total star formation occurring in the universe at $0.7 < z < 1$.

Introduction:

We present a study of 63 compact galaxies in the Flanking Fields of the HDF. Here we define "compact" as small objects with high surface brightness — these are relatively bright objects that are so small their HST WFPC images reveal little about their nature. Sample objects were selected from the WFPC2 images and observed with the 10-m Keck Telescope and the Low Resolution Imaging Spectrograph (LRIS). We obtained spectra in the range $\lambda\lambda 4200 - 8200$ Å ($\sim$3.1 Å resolution), and also V-band images to provide color information. Spectroscopic identifications could be made for all but seven objects. For the majority of emission-line objects, we measured emission line equivalent widths and velocity widths.

Sample Selection Criteria

Semi-major axis radius :	$0.16'' \leq a_{1/2} \leq 0.5''$
	(lower limit to exclude stars)
Avg. Surface Brightness :	$\mu_{I814} \leq 22.22$ mag arcsec^{-2}
Limiting Magnitude :	$I_{814} \leq 23.74$ mag *(Vega-based)*

Major Results:

- About 1/2 of the identified galaxies are low mass-to-light systems resembling local H II galaxies, while about 1/4 are emission-line systems, usually of higher metallicity, which could be small, high surface brightness spirals. These conclusions are based on sizes, luminosities, colors, emission line ratios and velocity widths (Fig. 1 & 2).
- About 1/4 of the identified sample are small but apparently normal early-type systems.
- Two objects are high redshift, $z > 2$, and only one is an AGN-dominated system. Thus, only a small fraction ($\sim$5%) are "exotic" objects.

- Only a small fraction ($\leq$5%) are at redshifts $z < 0.4$.

- About one quarter of the sample are consistent with the "bursting dwarfs" described by Babul & Ferguson[1] whereas their model would predict about twice as many such objects (we are not sensitive to the proposed $z \sim 1$ peak, however). Most of the strong emission-line objects in our sample appear to be "bursting galaxies" but with luminosities an order of magnitude higher than the defined bursting dwarfs.

- Star formation rates per unit mass show a peak value similar to that of local H II galaxies. At redshifts $z \geq 0.7$, some of these bursting systems are considerably more massive than those seen at lower redshifts, supporting the idea that bursts of star formation occur in galaxies of progressively smaller mass as the universe evolves (Fig. 2).

- Comoving volume densities indicate that the number of compact emission-line galaxies has declined by at least an order of magnitude between $0.4 < z < 1$ and the present, supporting a rapidly-evolving population.

- Compact emission-line galaxies may account for ~45% of the star formation in the universe at $0.4 < z < 1$ (Fig. 3).

These results are presented with full detail in *The Nature of Compact Galaxies in the Hubble Deep Field — I & II.*[2,3] (Preprints are available from the DEEP Web Pages at http://www.ucolick.org/~deep.)

References:

1. Babul, A., & Ferguson, H. C. 1996, ApJ, 458, 100
2. Phillips, A. C., Guzmán, R., Gallego, J., Koo, D. C., Lowenthal, J. D., Vogt, N. P., Faber, S. M., & Illingworth, G. D. 1997, ApJ, in press
3. Guzmán, R., Gallego, J., Koo, D. C., Phillips, A. C., Lowenthal, J. D., Faber, S. M., Illingworth, G. D., & Vogt, N. P. 1997, ApJ in press
4. Koo, D. C., et al. 1995, ApJ, 440, L49
5. Gallego, J., Zamorano, J., Rego, M,. & Vitores, A. G. 1997, ApJ, in press
6. Pei, Y. C., & Fall, S. M. 1995, ApJ, 454, 69

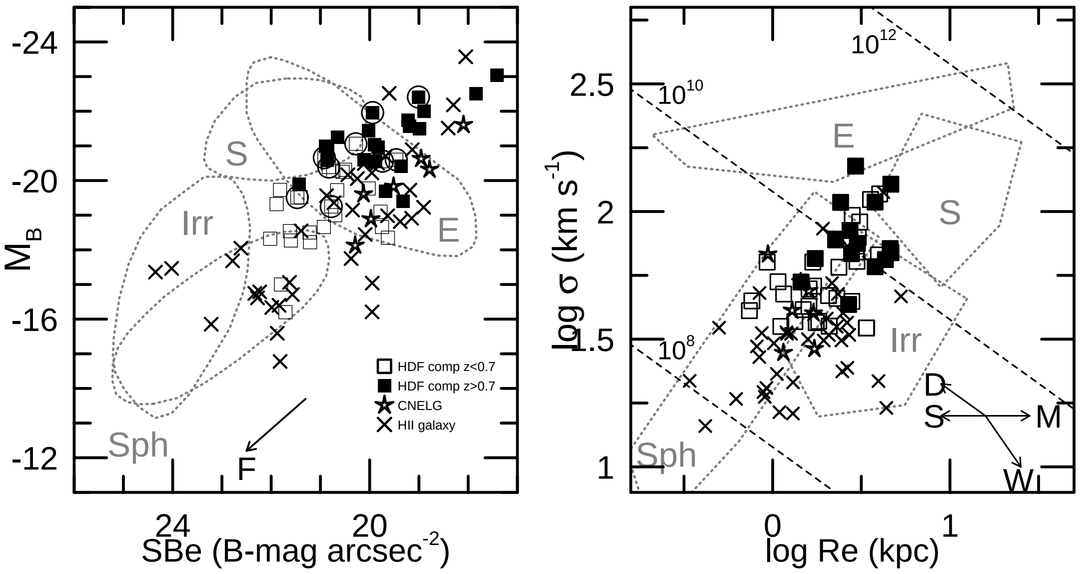

Figure 1: Global properties of the sample galaxies. (*left*) Surface brightness vs. luminosity. The vector represents simple fading. (*right*) Size vs. velocity width for emission-line compacts. Dashed lines represent constant mass (in $M_{\odot}$); the vectors represent expected effects of winds (W), stripping (S), merging (M), and dissipation (D). In both cases, the similarity of most to local H II galaxies is apparent. The extreme CNELGs[4] are also plotted. ($h_{100} = 0.5$ and $q_0 = 0.05$ unless noted.)

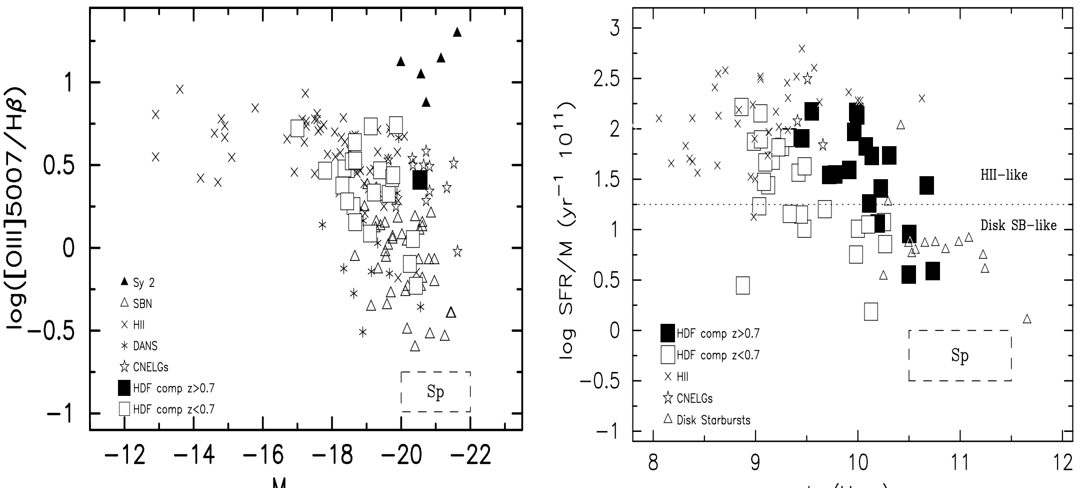

Figure 2: Spectral properties of the emission line-compacts. (*left*) Excitation (5007/Hβ) vs. luminosity, compared to local emission-line galaxies[5]. Note again the similarity of most of the sample galaxies and H II galaxies. (*right*) Estimated mass vs. star formation rate per unit mass. While the majority of the emission-line compacts have SFR/M values similar to H II galaxies, at $z > 0.7$ their masses are greater than those of local counterparts.

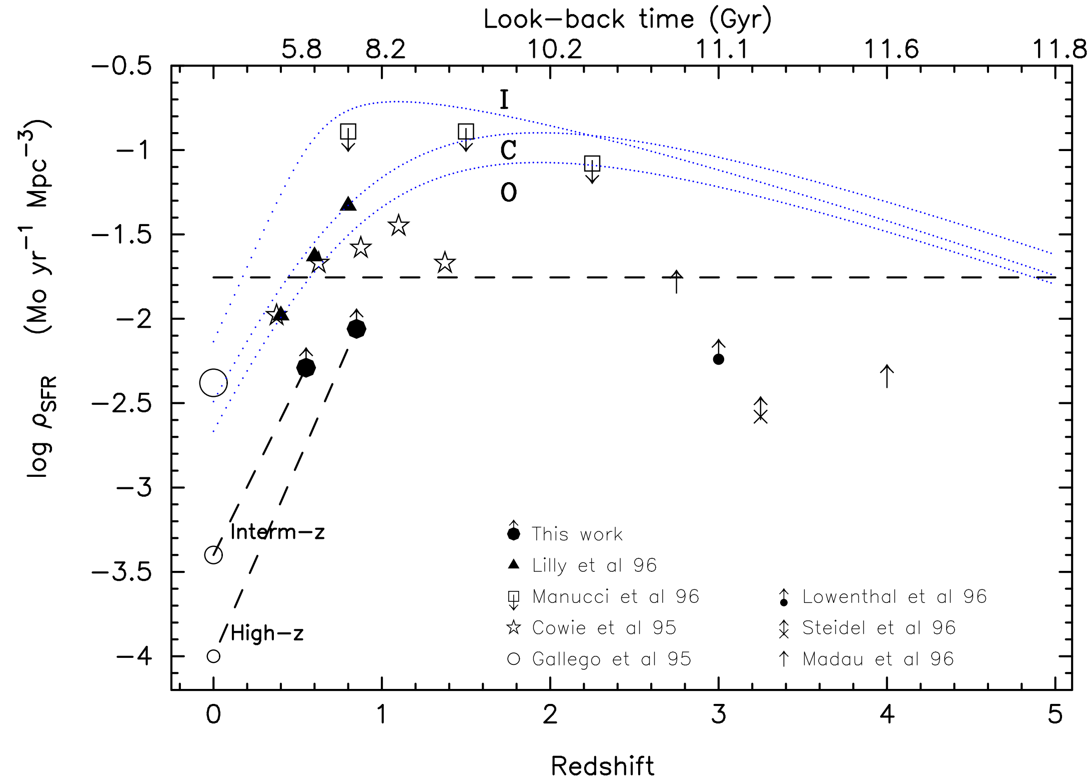

Figure 3: Star formation rate per comoving volume as a function of redshift. Filled circles are the estimates for compact galaxies, while the open circles labeled "Interm-z" and "High-z" represent values for *similar samples* of nearby compact galaxies (this adjusts for our somewhat unusual section criteria). Dotted lines are models of Pei & Fall[6]. We have adjusted all data to $h_{100} = 0.5$ and $q_0 = 0.5$.

Mail to:
Mario Livio
Space Telescope Science Institute
3700 San Martin Dr.
Baltimore MD 21218
410-338-4700
From:
Andrew C. Phillips
UCO/Lick Observatory