KECK SPECTRA OF GALAXIES AT REDSHIFT Z∼3 IN THE *HUBBLE DEEP FIELD*

J. D. LOWENTHAL, D. C. KOO, R. GUZMÁN, J. GALLEGO, and
A. C. PHILLIPS
UCO/Lick Observatory and Board of Astronomy and Astrophysics, Kerr Hall, University of California, Santa Cruz, CA 95064

We have obtained spectra with the 10-m Keck telescope of a sample of 24 galaxies having colors consistent with star-forming galaxies at redshifts $2 \lesssim z \lesssim 4.5$ in the Hubble Deep Field (HDF). Eleven of these galaxies are confirmed to be at high redshift ($z_{med} = 3.0$). The galaxies are small but luminous, with a wide range of morphologies. The observed number density of high-redshift galaxies in the HDF is comparable to estimates of the volume density of local galaxies brighter than L*. We suggest that many may be low-mass objects in an early burst phase of star formation and that they will soon merge with other similar objects to build massive galaxies, or else consume or expel their gas and thus quench their star formation.

1 Sample and Observations

Following the pioneering work of Steidel et al.[1], the DEEP team[a] has taken advantage of the unprecedented depth of the HDF[2] and the light-gathering power of the 10-m Keck telescope to identify and study star-forming galaxies at $z \sim 3$. We used all four HDF bands (F300W, F450W, F606W, F814W) to identify 43 objects with colors implying star-forming galaxies with Lyman-continuum and Lyα breaks at $z > 2.5$, i.e. blue but with little or no flux in U (or B; "U and B-band dropouts"). 25 objects with $I_{AB} < 25.5$ ($I_{AB,median} = 25.0$) were observed in 3 nights on 10-m Keck telescope using the LRIS multi-object spectrograph.

2 Properties

Eleven objects were confirmed to be at high redshift, with $z_{med} = 3.0$ and $2.2 < z < 3.6$. We find 6 Lyα emission sources, with EW(Lyα)$_{rest} \sim 40$ Å, and several **absorption-line-only redshifts**, based on rest-UV stellar and interstellar lines (SiII, OI, CII, SiIV, CIV) typical of starburst galaxies and hot stars. Rest equivalent widths are as high as 4 Å; however, they are probably **not directly useable** to measure galaxy masses[3]. The high-redshift galaxies

[a]DEEP = Deep Extragalactic Evolutionary Probe, a collaboration of the University of California, The Johns Hopkins University, CalTech, and the University of Chicago. See http://www.ucolick.org/∼deep/home.html for more information.

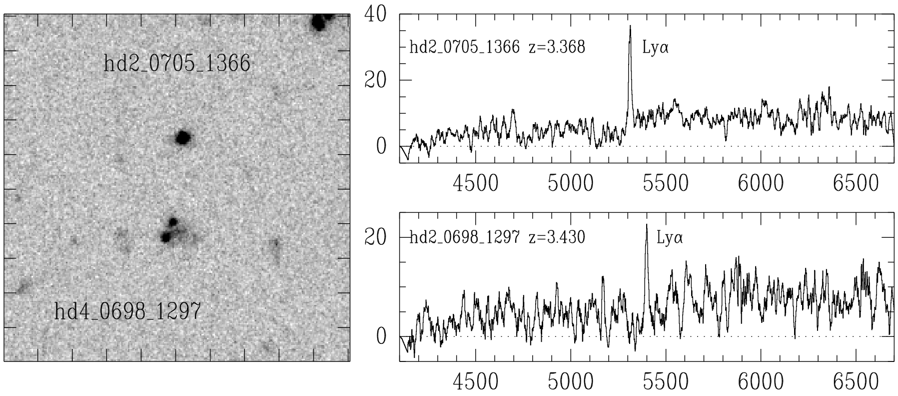

Figure 1: Image and Keck LRIS spectra of two confirmed high-redshift galaxies in the HDF. The image is extracted from the F814W HDF frame and is $10''$ on a side. Both objects have $I_{814,AB} = 25.0$. The spectra clearly show Lyα emission, a strong Lyα break, and absorption lines characteristic of hot stars and local starburst galaxies.

are small but luminous, with half-light radii $1.8 < r_{1/2} < 6.5$ h_{50}^{-1} kpc and absolute magnitudes $-21.5 < M_B < -23$. The median absolute magnitude is $M_B \sim -22.5$ ($\mathrm{H}_0 = 50$), or 1.5 mag brighter than L*. Combined with the 5 high-redshift galaxies in the HDF previously confirmed with Keck spectra by Steidel *et al.*, the 16 confirmed sources yield a comoving volume density of $n \geq 2.5 \times 10^{-4}$ h_{50}^{3} Mpc^{-3} ($q_0 = 0.05$), comparable to estimates of the volume density of local galaxies brighter than L*.

3 Speculations on the Nature of $z = 3$ Galaxies

The small sizes, high luminosities and star formation rates ($SFR \sim 10$ M$_\odot$ yr^{-1} – consistent with the UV absorption lines and Lyα emission), and the wide variety of morphologies (bright knots, tails, clumps, etc.) all favor a **pre-merger** scenario of multiple, low-mass bursts, rather than, e.g., a monolithic gE precursor. Subsequent significant merging is likely.

References

1. Steidel, C. C., Giavalisco, M., Dickinson, M., & Adelberger, K. L. 1996, ApJ, in press
2. Williams, R. *et al.*, 1996, AJ, in press
3. Conti, P. S., Leitherer, C., & Vacca, W. D. 1996, ApJ, 461, L87