Galaxies: Structure, formation and evolution

Lecture 17

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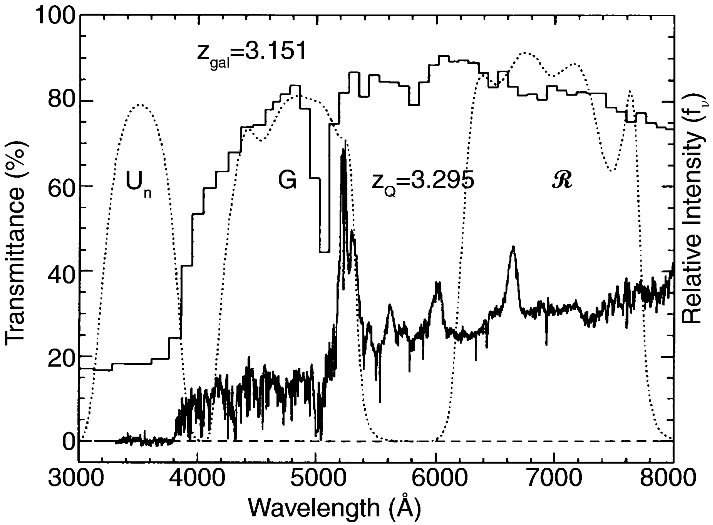
The dropout technique

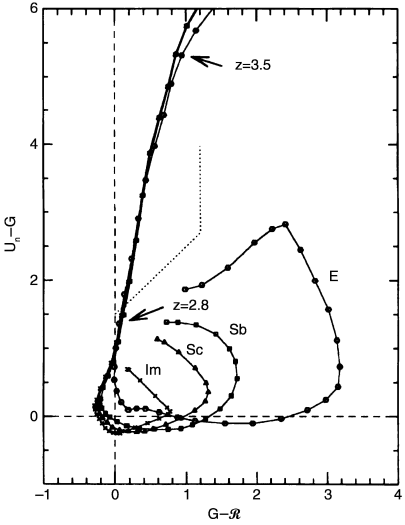


Method first extensively applied in 1996

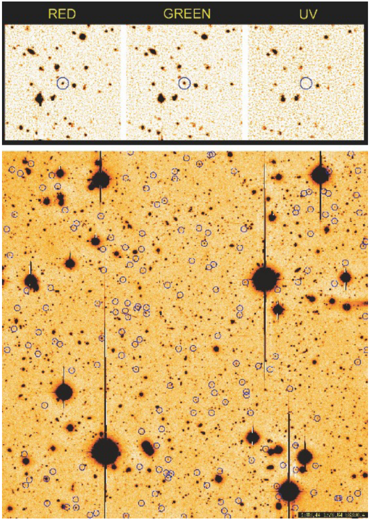
Question

A galaxy has $U - B = -0.2$, another has $U - B = 0.1$. Which galaxy is redder?

Does it work for all Hubble types?

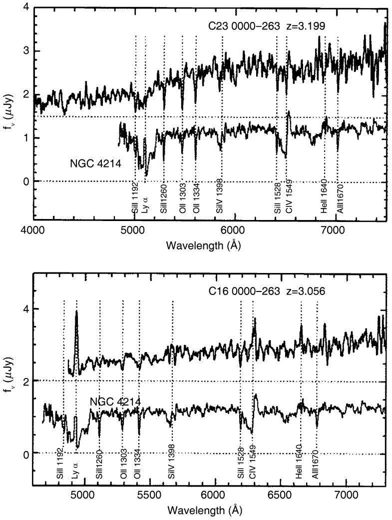


U band dropouts

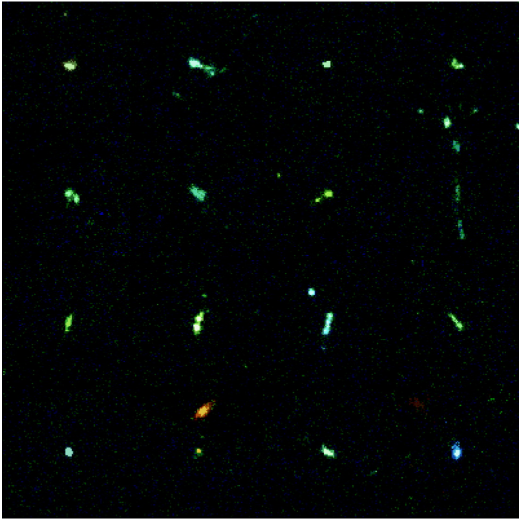


LBG candidate density: 1 arcmin^{-2}

Spectrum of two dropout galaxies



U band dropouts at $z \sim 3$



Wadadekar et al. (2006)

LBG selection bias

LBG color selection is biased towards strongly star-forming galaxies at high redshift. Why?

Question

Do you expect star-forming galaxies to be strongly clustered?

Where do LBGs lie?

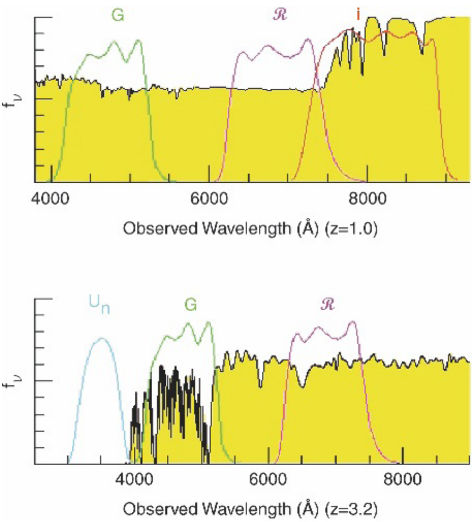
LBGs are rare objects and thus correspond to high-mass dark matter halos. Comparing the observed correlation length r_0 with numerical simulations, the characteristic halo mass of LBGs can be determined, yielding $\sim 3 \times 10^{11} \mathrm{M}_\odot$ at redshifts $z \sim 3$, and $\sim 10^{12} \mathrm{M}_\odot$ at $z \sim 2$. The correlation length is observed to increase with the luminosity of the LBG, indicating that more luminous galaxies are hosted by more massive halos, which are more strongly biased than less massive ones.

What are the local counterparts of LBGs?

If these results are combined with the observed correlation functions of galaxies in the local Universe and at $z \sim 1$, and with the help of numerical simulations, then this indicates that a typical high-redshift LBG will evolve into an **elliptical galaxy** by today. LBGs also lie at the centre of protoclusters.

LBGs drive strong galactic winds

Using the 4000 Å break to find galaxies at $z \sim 1$



What kind of galaxies will this selection technique find?

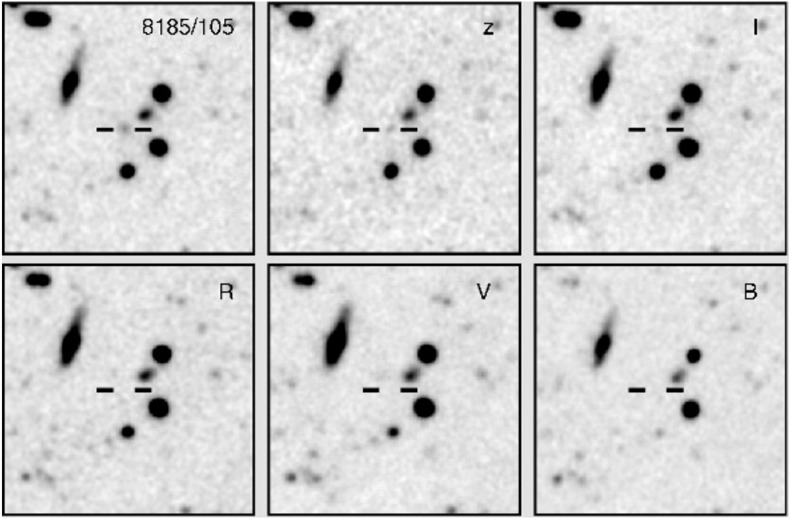
LBGs at low redshift - the redshift desert

We found galaxies at $z \sim 3$ more easily than at $z \sim 1 - 2$. Why?

LBGs at low redshift

In recent years GALEX has found 2 populations of low redshift star-forming galaxies. One compact population corresponding to high-z LBGs and a non-compact star-forming population of large disk galaxies.

Higher redshift LBGs $z = 5.74$

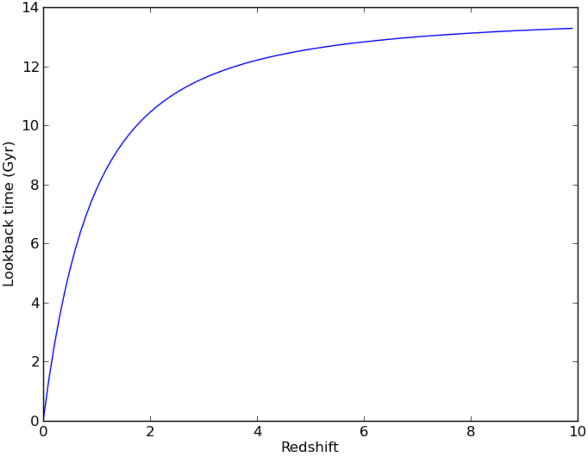


Hubble Deep Field North- Ergodic principle

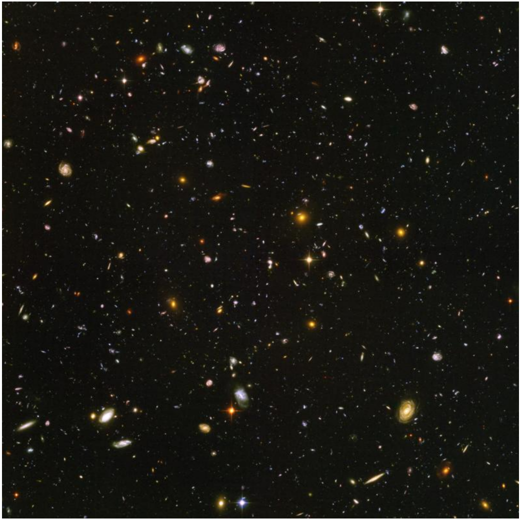
followed by GOODS, GEMS, COSMOS, CANDELS

Ergodic principle

Lookback time WMAP9 cosmology



Hubble Ultra Deep Field

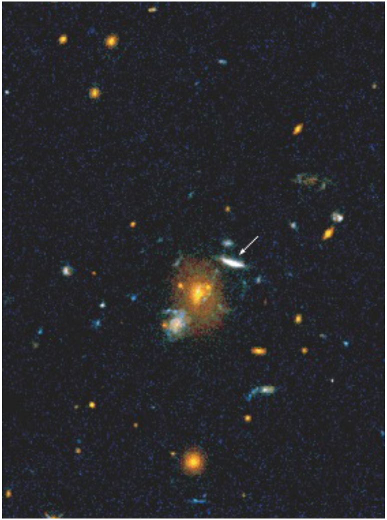


Results from deep fields

Lyman-break galaxies at $z \sim 6$ seem to have stellar populations with masses and lifetimes comparable to those at $z \sim 3$. This implies that at a time when the Universe was 1 Gyr old, a stellar population with mass $\sim 3 \times 10^{10} \mathrm{M}_{\odot}$ and age of a few hundred million years (as indicated by the observed 4000 Å break) was already in place. This, together with the apparently high metallicity of these sources, is thus another indication of how quickly the early Universe has evolved. The $z \sim 6$ galaxies are very compact, with half-light radii of ~ 1 kpc, and thus differ substantially from the galaxy population known in the lower-redshift Universe.

LBGs are very faint. Is there some geometric configuration that will make their detection easier?

Finding distant normal galaxies magnification ~ 30



Cluster z=0.37, galaxy z=2.72. Most distant normal galaxy known.

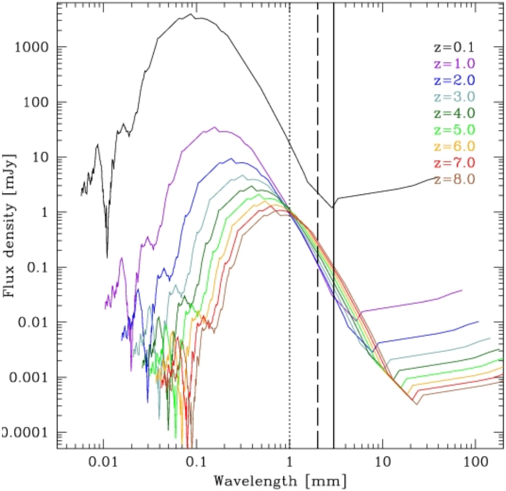
To learn more on LBGs

See review by Giavalisco et al. (2002) in ARAA

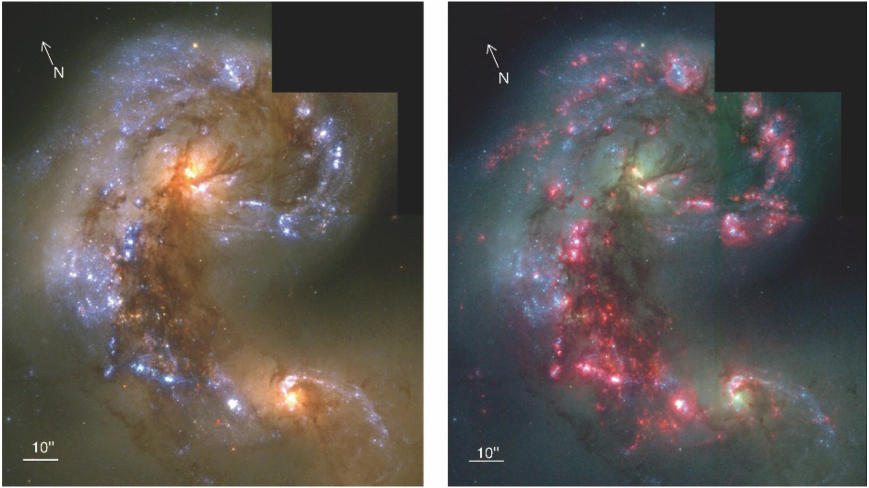
Starburst galaxies

Milky Way is forming stars with a rate of $\sim 3 M_{\odot}$/yr, the star formation rate in starburst galaxies can be larger by a factor of more than a hundred. Dust heated by hot stars radiates in the FIR, rendering starbursts very strong FIR emitters. Many of them were discovered by the IRAS satellite (IRAS galaxies"); they are also called ULIRGs (ultra-luminous infrared galaxies). Negative k-correction

Negative K correction- Arp 220



The Antennae- each knot $10^5 M_\odot$



Red and blue supergiants also seen.

The Antennae - IR emission