Measuring HI gas in 6 Lyman Break Analog

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Sterrewacht
Leiden

Outline

- Introduction : - Lyman break technique

  - Why we study LBG?

  - properties of Lyman Break Galaxies

  - properties of Lyman Break Analog
- The project : - data, object, status of my work

Introduction

- Some questions on galaxy evolution :

  - How nowadays galaxies evolve from early universe galaxies?

  - Do high-z galaxies differ from local? (mass, morphology, Star Formation Rates (SFR))

- How can we find galaxy at high z?

  (Partridge and Peebles, 1967)

  Direct Spectroscopy?, time consuming

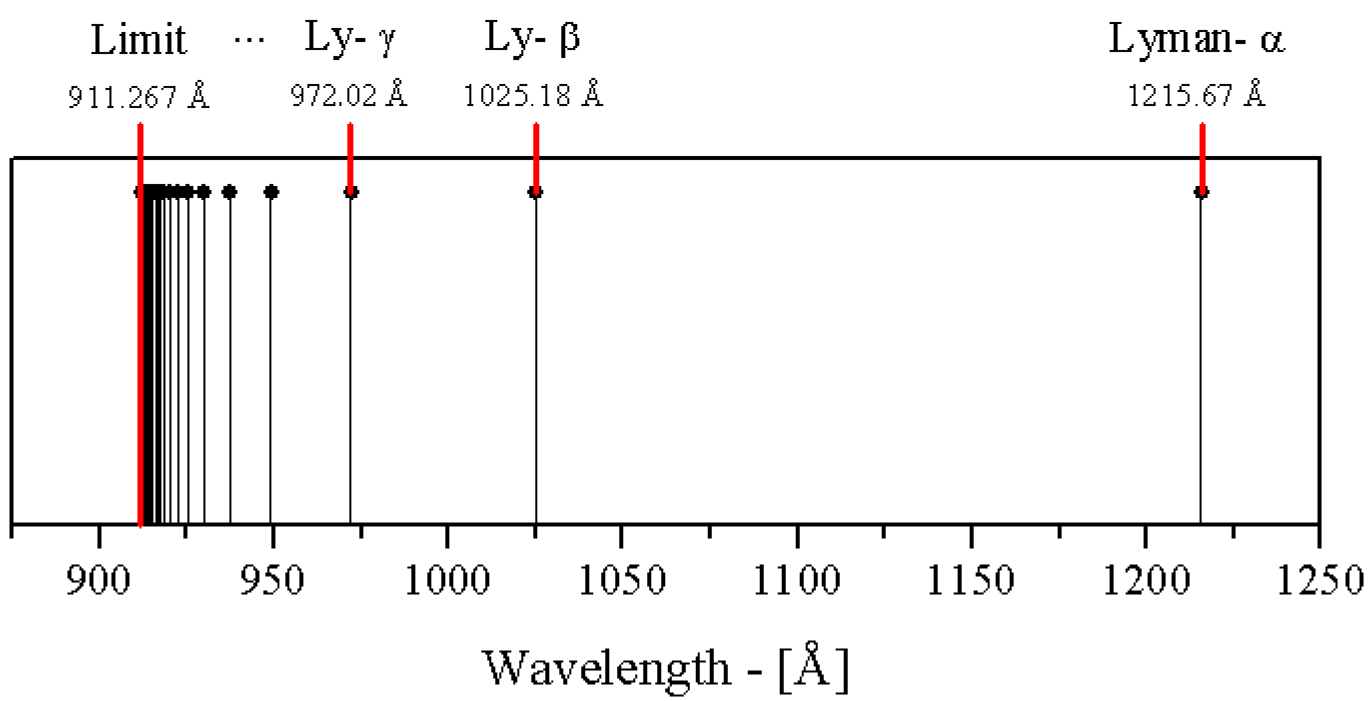
- Lyman Break technique (Steidel et al., 1999), use color selection (U,G,R) could efficiently save time (better telescope and CCD).

- LBG probes the galaxy evolution as far as 10% of universe age.

Lyman Limit

- What is Lyman break technique?

  Taking the advantage of the nature of Lyman limit



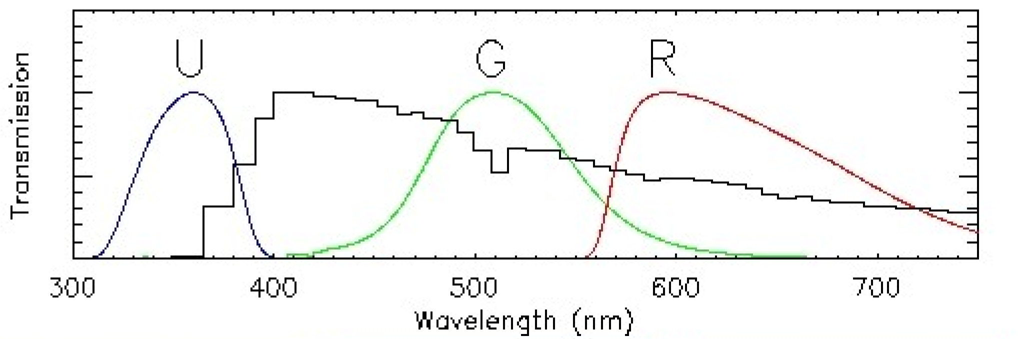
- Galaxies are opaque for $\lambda < 91.2\,nm$. Most photons are absorbed causing break at continuum bluer than 91.2 nm (Lyman break).

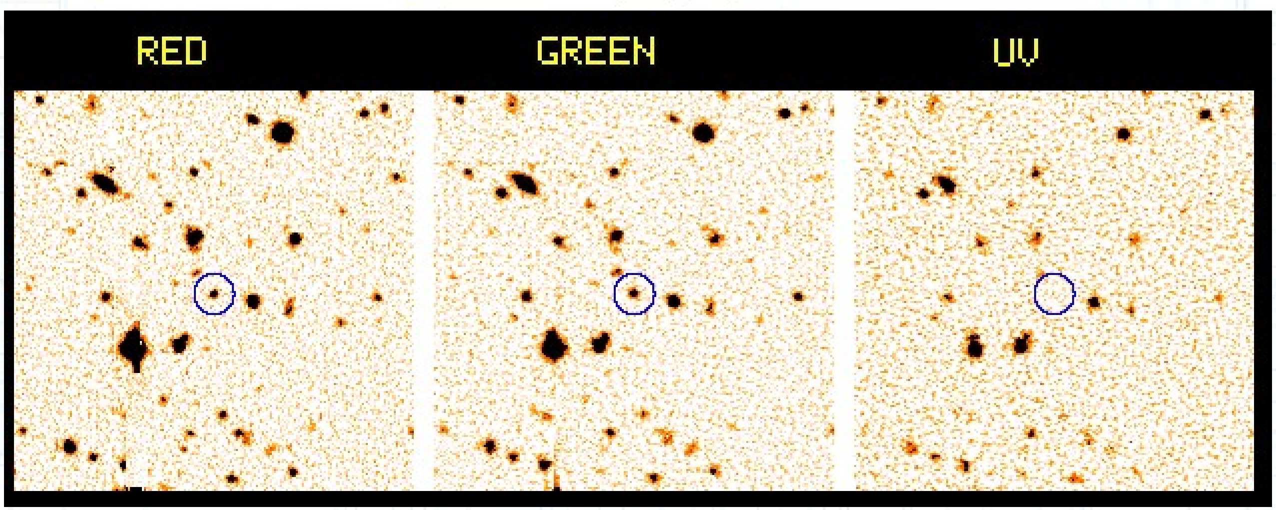
Lyman Break Technique

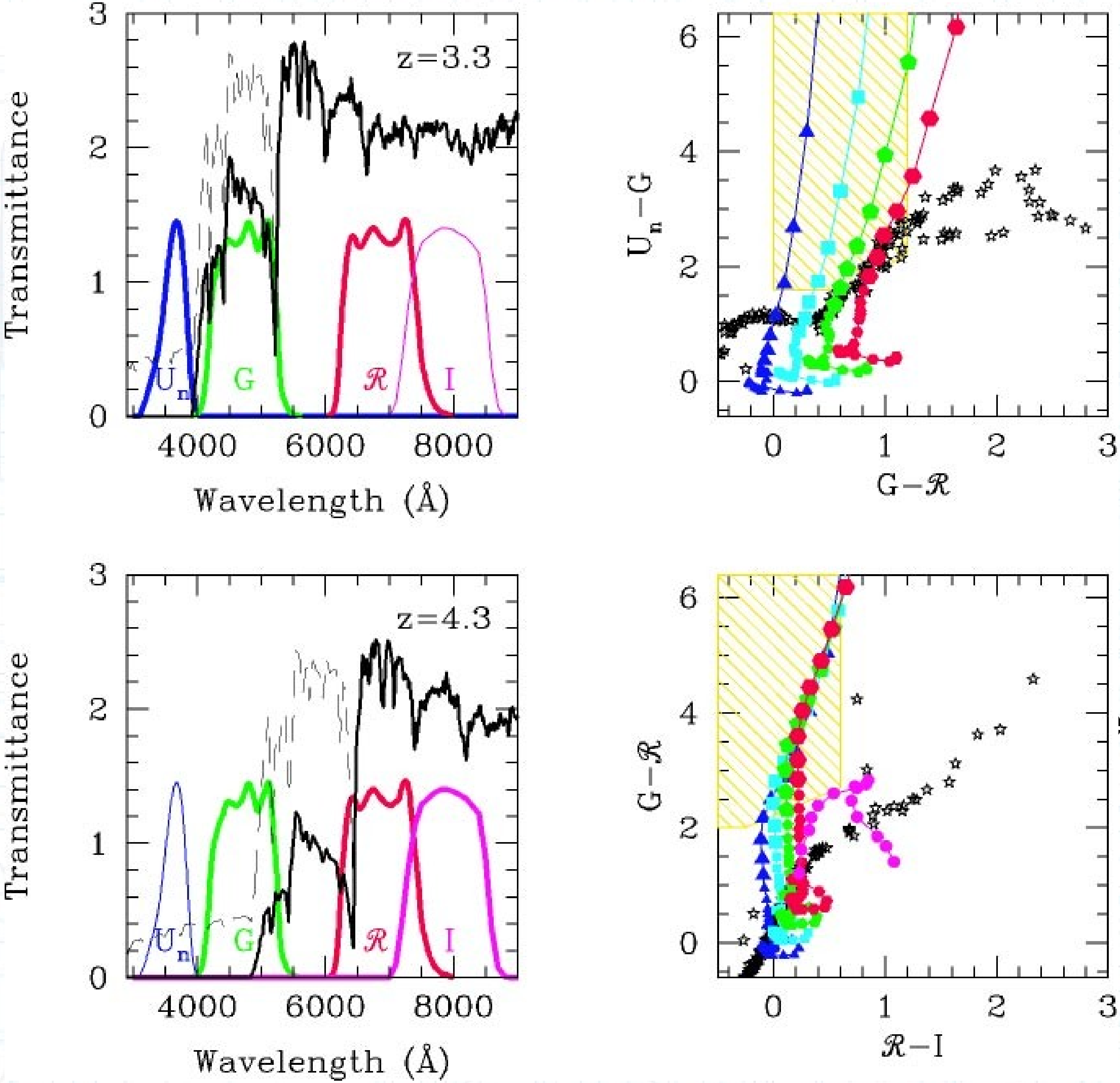
- For high-z galaxies, this break move to longer λ

  z~3 galaxies, Lyman limit ~ 364.8 nm (U band)

  Z~3 galaxies show drop-out at U band



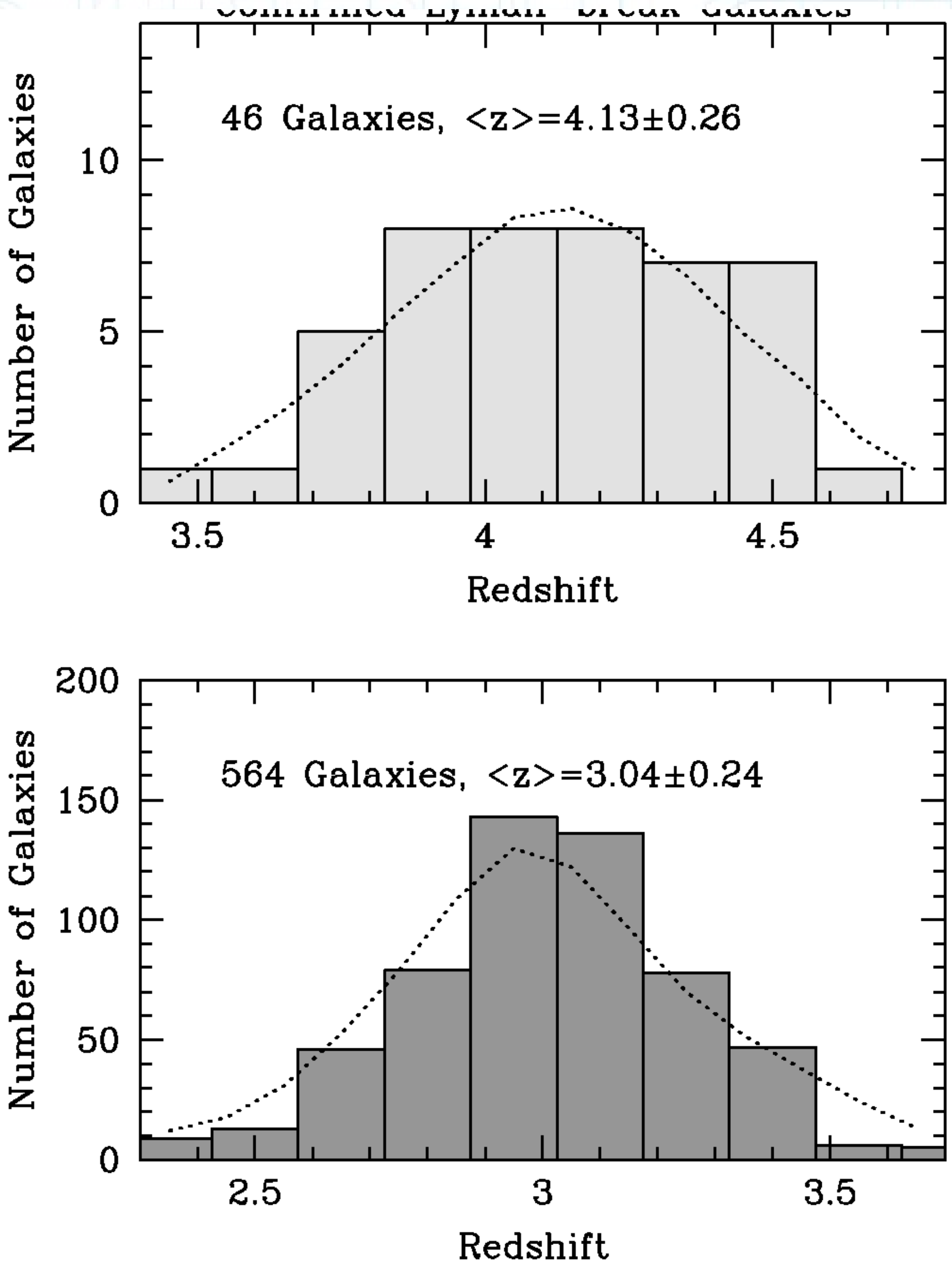




≤27

ect

Giavalisco,



Steidel et.al (1999)

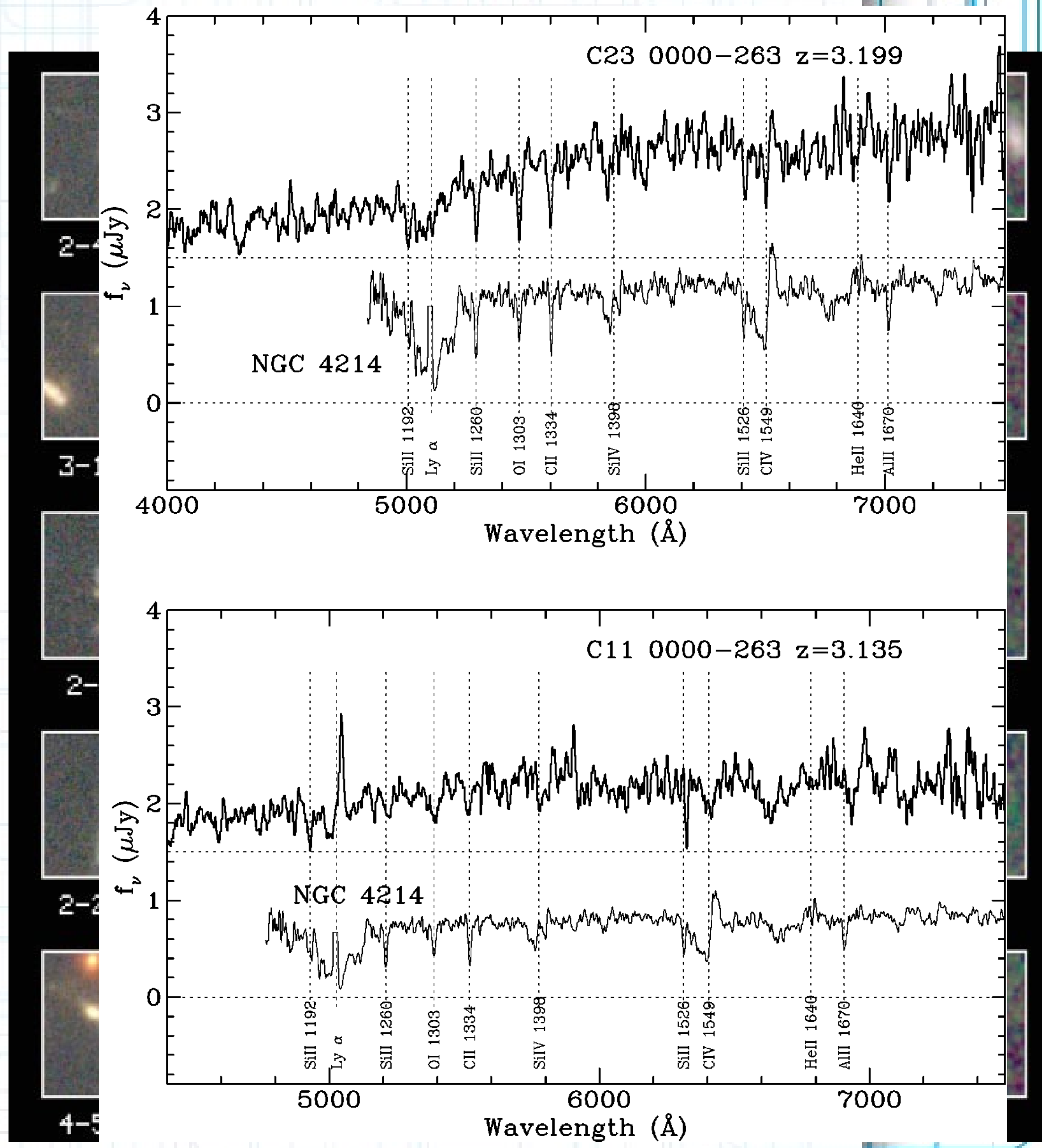
Morphology and Spectrum of LBG

- Broad range of shape :

  - Smaller, more compact, more irregular ($r_{1/2} \sim 0.7 - 1.5\,kpc\,h^{-1}$) on optical and UV

  (Overzier et al. 2009)

- No clear Hubble type
- Close companion, tail, fragmented (merging?)
- Star formation sites? It seems that the underlying structure of galaxy is not clear



Giavalisco, A&A, 2002

SFR properties

- Similar to local starburst galaxy with higher luminosity in far-UV
- Assuming constant SFR

$$SFR(M_{\odot}\, yr^{-1}) = 1.4 \times 10^{-28} L_{\nu(\lambda 1500)}$$

  Madau et.al (1998)

- Other SFR indicator, not sensitive to dust

$$SFR_{1.4\mathrm{GHz}}(M_{\odot}/yr) = \frac{L_{1.4\mathrm{GHz}}}{2.72 * 10^{21}}, if\ L_{1.4\mathrm{GHz}} > L_c$$

$$\frac{L_{1.4\mathrm{GHz}}}{2.72 \times 10^{21}\left[0.1 + 0.9(L_{1.4\mathrm{GHz}}/L_c)^{0.3}\right]} \quad \text{if } L_{1.4\mathrm{GHz}} \leq L_c$$

SFR properties

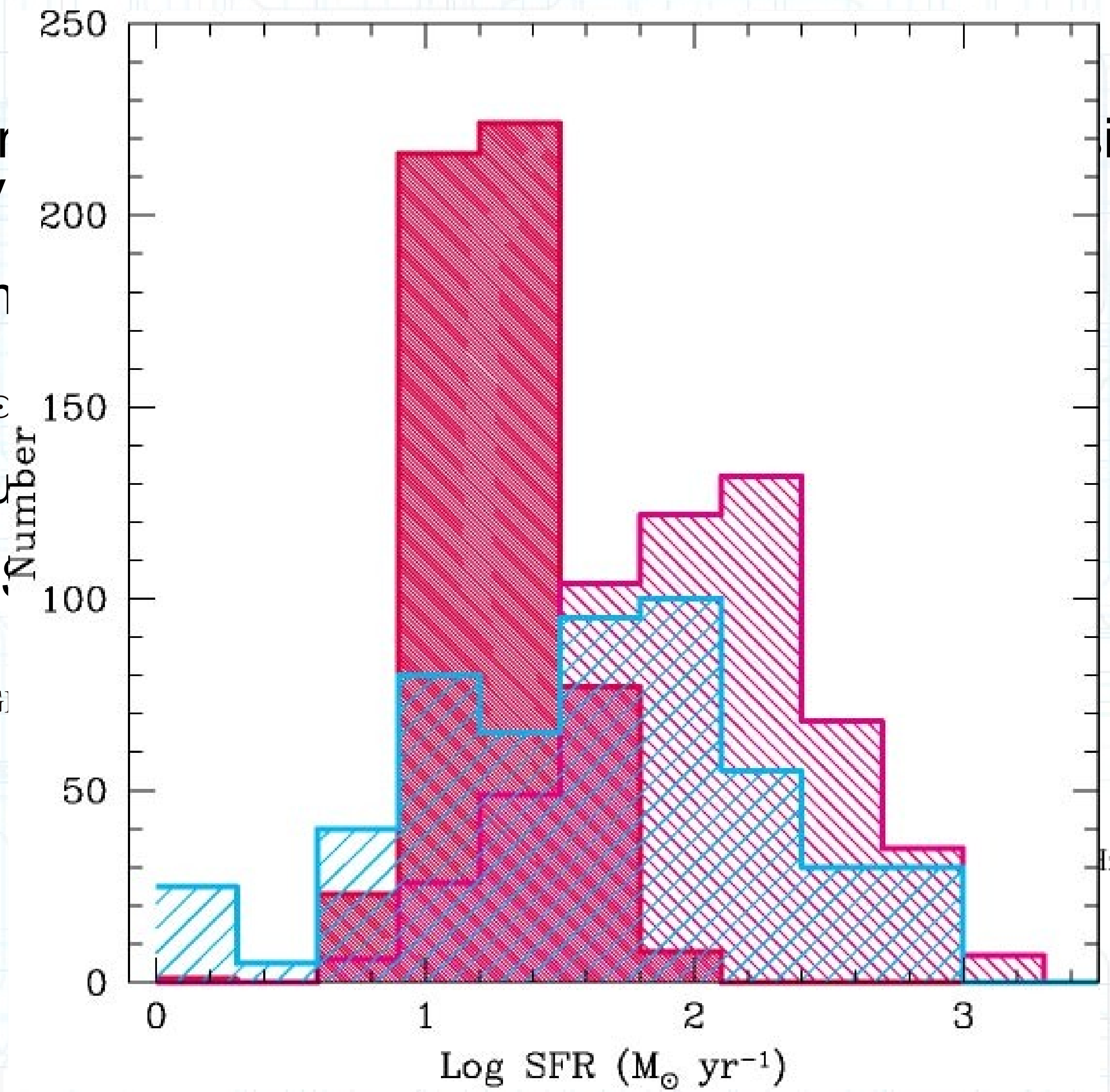
- Similar ... ity in far-UV
- Assum

$SFR(M_{\odot}$

Madau

- Other

$SFR_{1.4G}$ ... $_{z} \leq L_c$



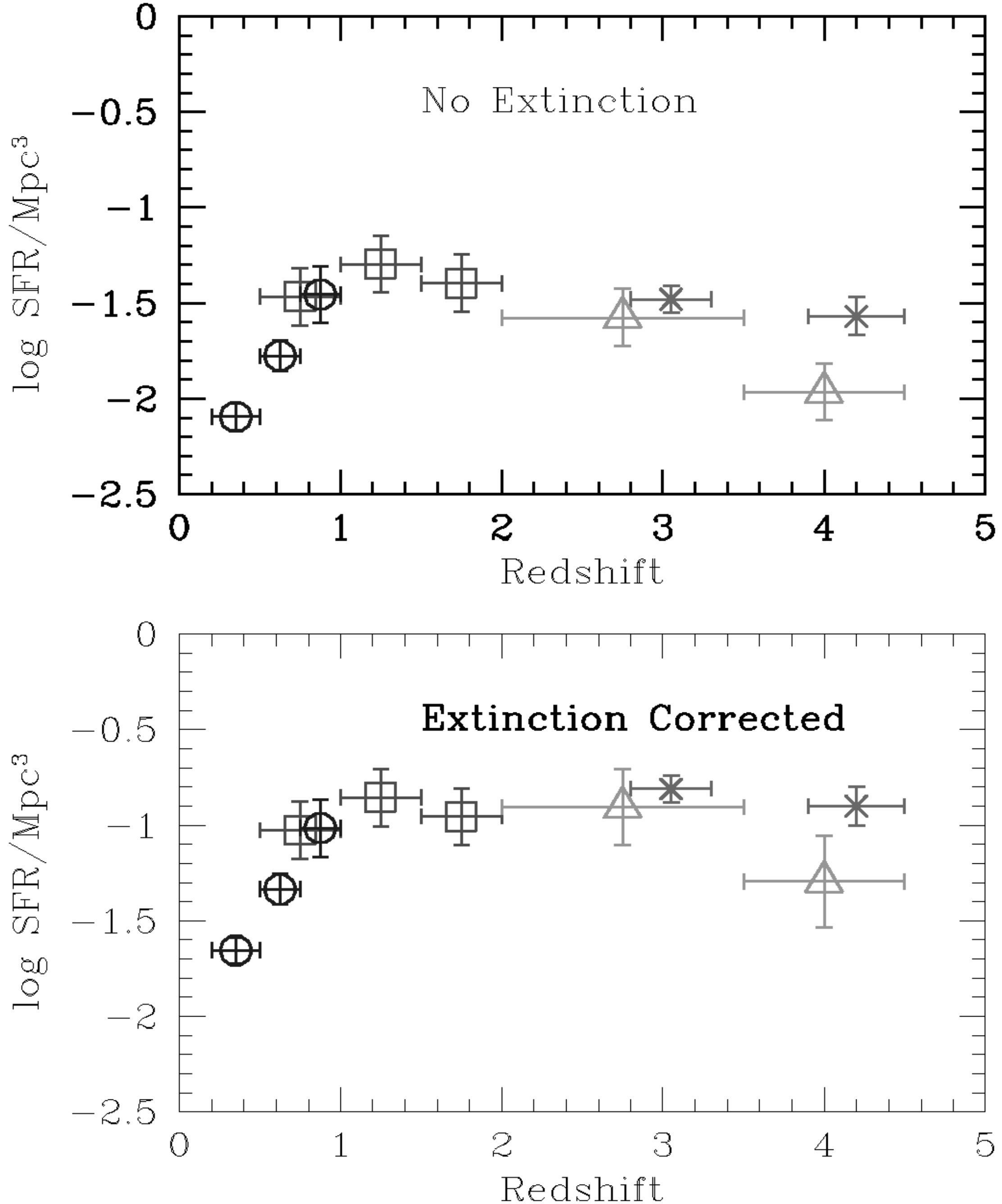
Giavalisco, A&A, 2002

LBG tracing the early cosmic SFR?

- We can measure the SFR density by integrating the far-UV luminosity of LBGs
- Steidel et. al (1999), shows that there is no clear SFR decline up to z~4, but the observational data is accumulating.

LBG tracing the early cosmic SFR?

- We can … g the far-UV lumi…
- Steidel … ar SFR decline … accumu…



LBG tracing the early cosmic SFR?

- We can ... g the far-UV lumi...
- Steidel ... SFR decline ... accumu...

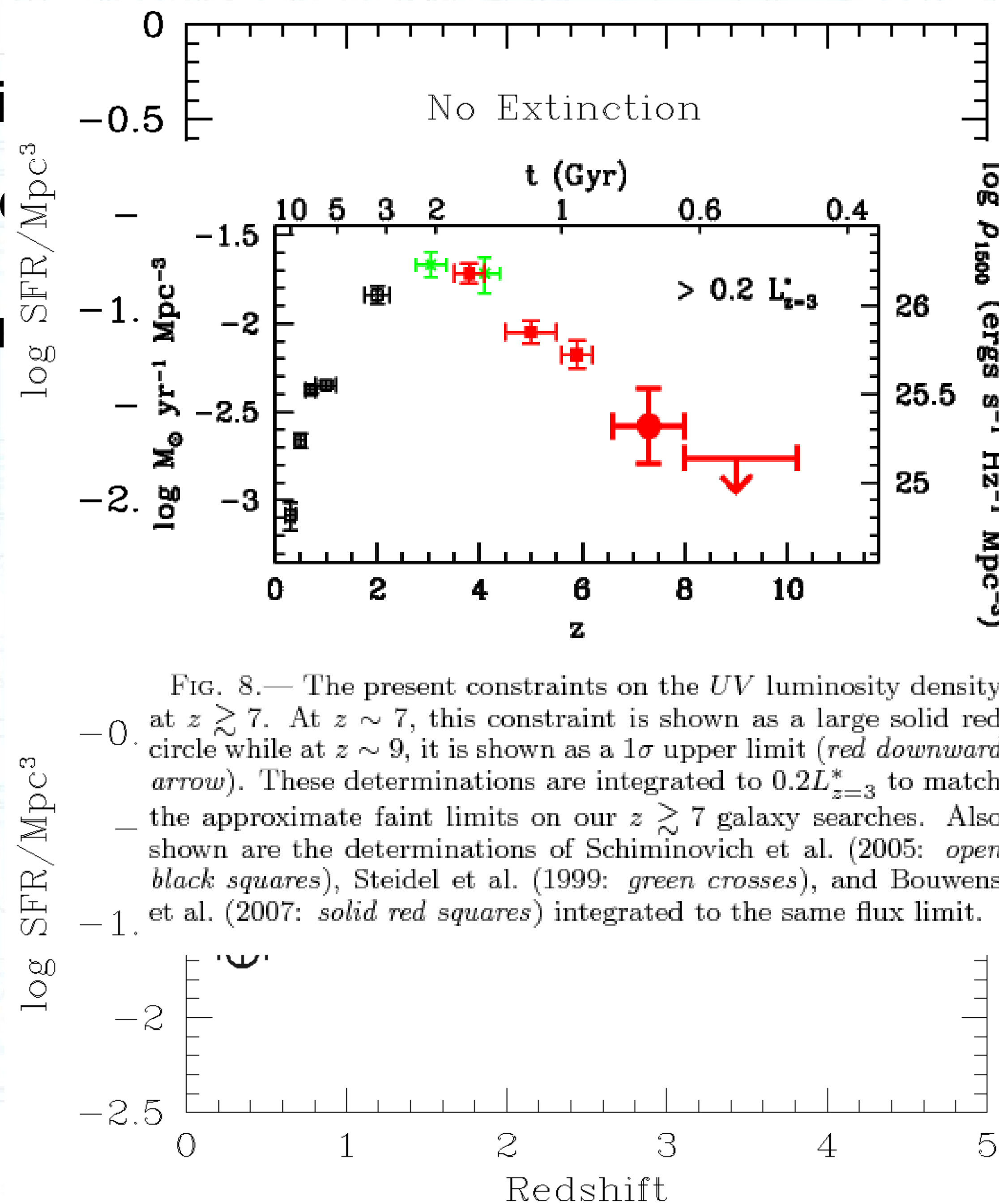


FIG. 8.— The present constraints on the *UV* luminosity density at $z \gtrsim 7$. At $z \sim 7$, this constraint is shown as a large solid red circle while at $z \sim 9$, it is shown as a 1σ upper limit (*red downward arrow*). These determinations are integrated to $0.2L^*_{z=3}$ to match the approximate faint limits on our $z \gtrsim 7$ galaxy searches. Also shown are the determinations of Schiminovich et al. (2005: *open black squares*), Steidel et al. (1999: *green crosses*), and Bouwens et al. (2007: *solid red squares*) integrated to the same flux limit.

Why LBA?

- LBGs are faint and small ⟶ much more difficult to observe
- If we can find local counterparts of high-z LBGs we can study them in great details.
- LBGs is less obscured than local starburst galaxy with the same SFR, maybe they undergo different mechanism?

  Heckman et al. (2005) and Hoopes et al. (2007) find rare nearby (z < 0.3) population of galaxies with similar characteristic as LBGs in GALEX (compact UVLGS).

  LBGs criteria is applied : $L_{FUV} \geq 10^{10.3} L_{\odot} \wedge I_{FUV} \geq 10^{9} L_{\odot}\, kpc^{-2}$
- Study by Heckman et al. (2005) :

Overzier et al. (2009)

Why LBA?

- LBGs are faint and small → much more difficult to observe
- If we ... n
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  LBG ... $\odot\ kpc^{-2}$
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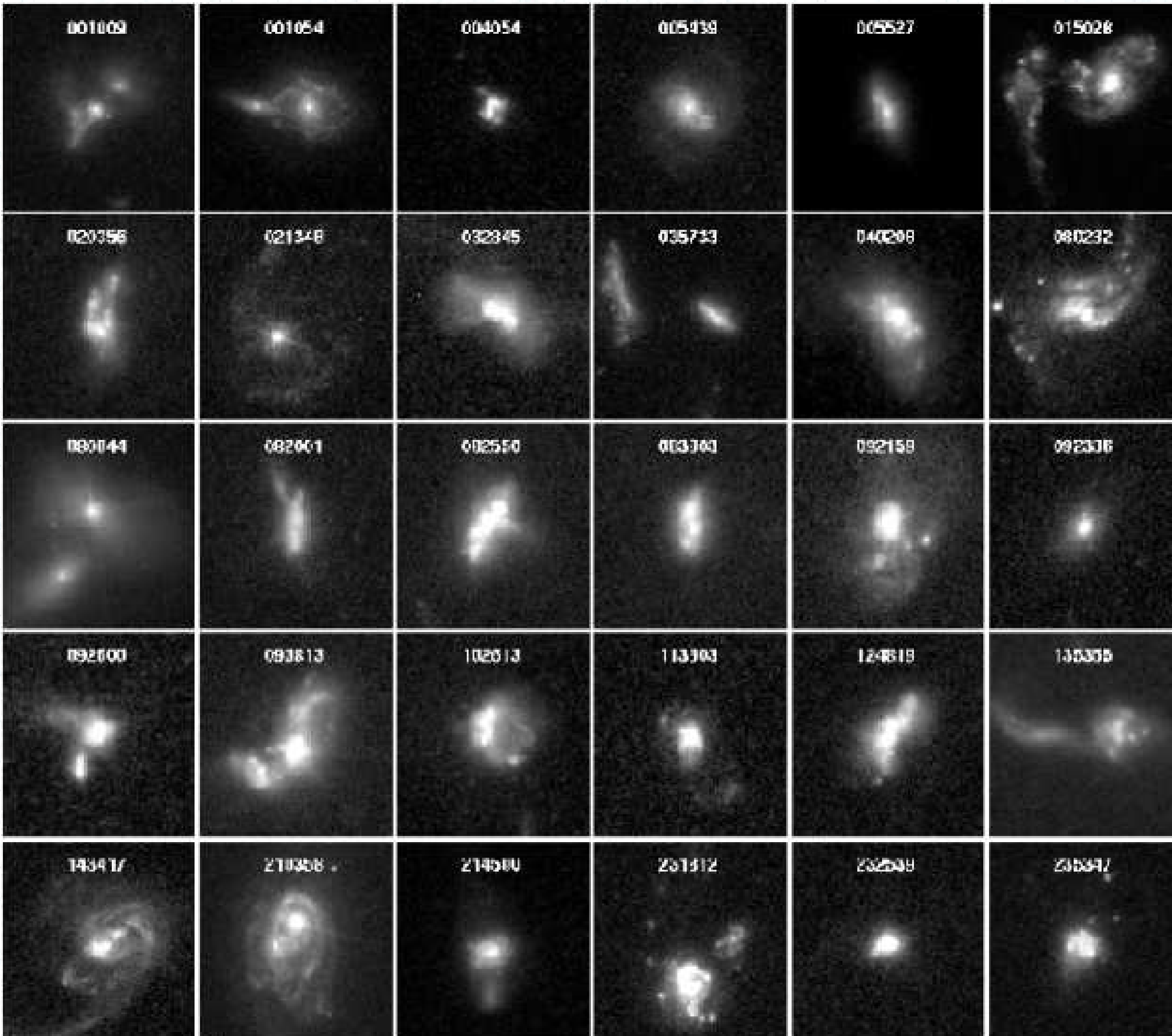
TABLE 1

SUMMARY OF PROPERTIES

Parameter	Large UVLGs	Compact UVLGs	LBGs
$\log L_{FUV}$ ($L_\odot$)	10.3–10.5	10.35–10.65	10.3–11.3
$\log R_{50,u}$ (kpc)	0.9–1.3	0.0–0.7	0.0–0.5
$\log I_{FUV}$ ($L_\odot$ kpc^{-2})	6.9–7.8	8.2–9.8	9–10
$\log M_*$ ($M_\odot$)	10.5–11.3	9.5–10.7	9.5–11
$\log M_{dyn}$ ($M_\odot$)	10.4–11.6	10.0–10.8	10.0–10.5
$\log \mu_*$ ($M_\odot$ kpc^{-2})	7.9–8.7	8.0–9.1	8.5–9.0
A_{FUV} (mag)	0.3–2.0	0.6–2.1	1–3
log SFR ($M_\odot$ yr^{-1})	0.6–1.2	0.6–1.4	0.5–2.5
log (SFR/M_*) (yr^{-1})	−10.5 to −9.5	−9.8 to −8.6	−9 to −8
FUV − r (AB mag)	1.8–2.9	0.6–2.1	0.2–2.2
D4000	1.2–1.7	1.0–1.3	...
12 + log (O/H)	8.55−8.75	8.2−8.7	7.7−8.8
$\log \sigma_{gas}$ (km s^{-1})	1.7−2.1	1.8−2.2	1.7−2.1

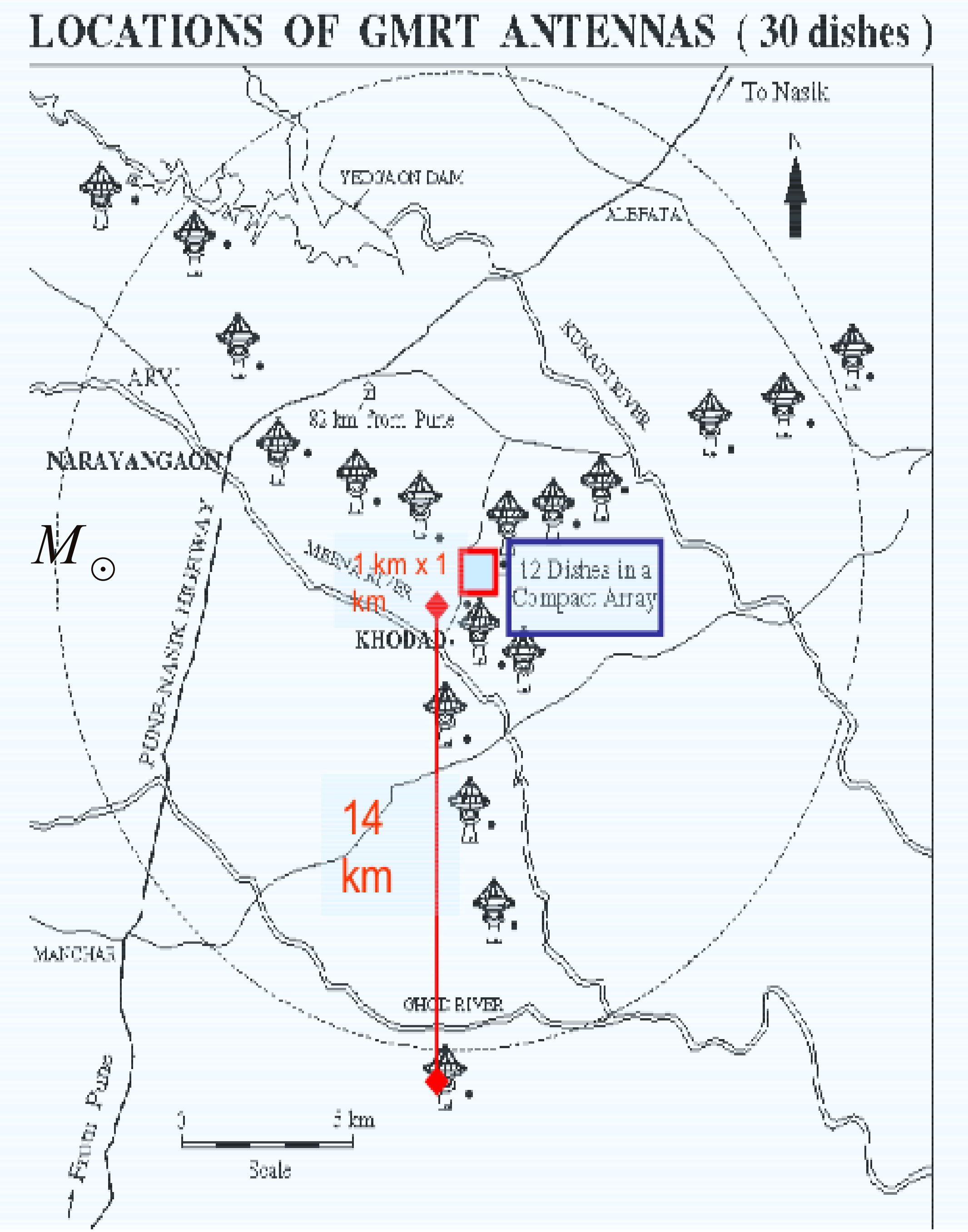

001054
004054
005439
005527
015028
032345
035733
080232
092158
093813

- Latitude : 19 deg N
- Longitude : 74 deg E

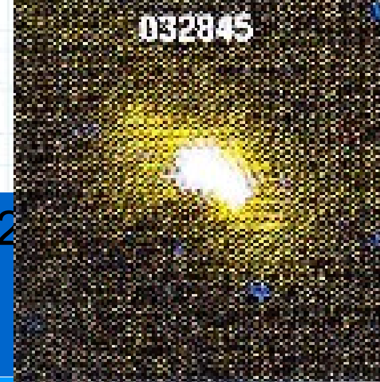
- About 70 km N of Pune, 160 km E of Mumbai.

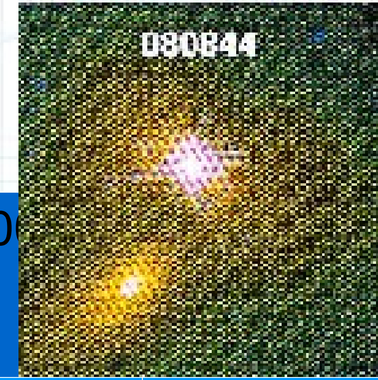
- 30 dishes; 45 m diameter
  - 12 dishes in central compact array
  - Remaining along 3 arms of Y-array

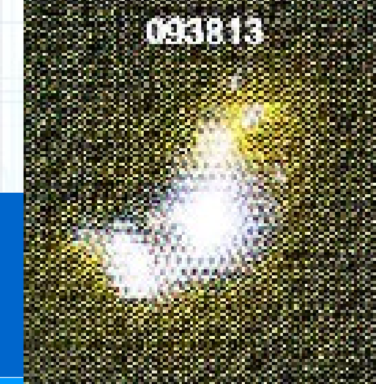
- Total extent : 14 km radius $\Rightarrow$ resolution of a 28 km size antenna is achieved !



No.	Name	RA (J2000)	Dec (J2000)	z	HI freq. (Mhz)
1.	005527	00h 55m 27.5s	-00° 21' 48.7”	0.167	1217.1
2.	015028	01h 50m 28.4s	13° 08' 58”.4	0.147	1238.4
3.	032845	03h 28m 45.9s	01° 11' 50.8”	0.142	1243.8
4.	080844	08h 08m 44.3s	39° 48' 52.3”	0.091	1301.9
5.	093813	09h 38m 13.5s	54° 28' 24.9”	0.102	1288.9
6.	210358	21h 03m 58s	-07° 28' 02.5”	0.137	1249.3







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Status of the project

- Finishing primary calibration steps (using AIPS) :

  - set calibrator source (3C48, 3C147)

  - flagging bad data (RFI, dead antennas)

  - bandpass calibration

  - gain calibration

- Starting self-calibration
- The next step : - make continuum image

  (detecting companion, SFR)

  - detecting HI

Summary

- LBG can be used to study evolution of high-z galaxies
- There are rare nearby Lyman break analog that has similar properties as LBGs that provide us with unique opportunity to study its evolution in great details

Thank you