The ESO view on the farthest galaxies

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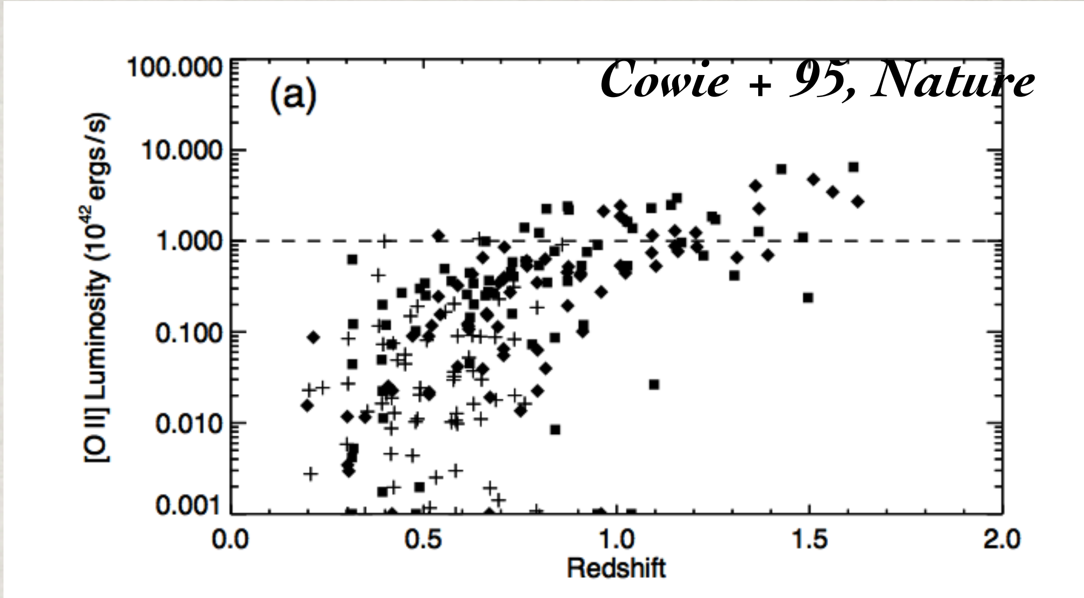
Table 1: Top 10 most distant galaxies (June 4, 2012)

Rank	ID	Coordinate	Red shift	Gyr	Paper	Date
1	SXDF-NB1006-2	J021856.5-051958.9	7.215	12.91	Shibuya et al.	2012.6
2	GN-108036	in GOODS NORTH field	7.213	12.91	Ono et al.	2012.1
3	BDF-3299	J222812.3-0350959.4	7.109	12.90	Vanzella et al.	2010.12
4	A1703_zD6	J131501.0+515004	7.045	12.89	Schenker et al.	2012.1
5	BDF-521	J222703.1-350707.7	7.008	12.89	Vanzella et al.	2010.12
6	G2-1408	J132357.1+272448	6.972	12.88	Fontana et al.	2010.12
7	IOK-1	J132359.8+272456	6.964	12.88	Iye et al.	2006.9
8	HUDF09_1596	J033303.8-275120	6.905	12.87	Schenker et al.	2012.1
9	SDF46975	in Subaru Deep field	6.844	12.86	Ono et al.	2012.1
10	NTTDF-6345	J120536.9-074522.3	6.701	12.84	Pentericci et al.	2011.12

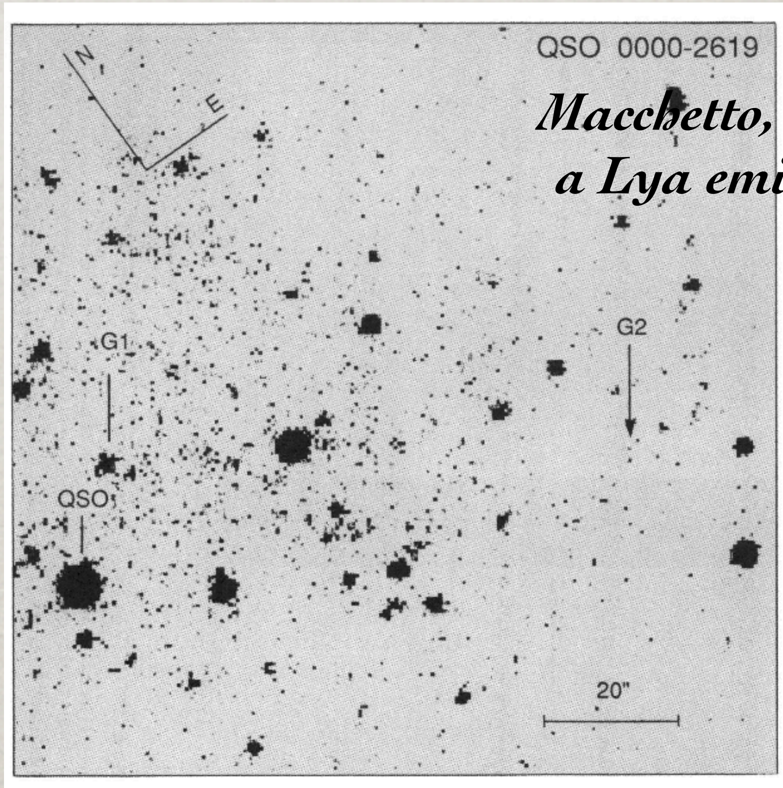
In mid 90s, deepest spectroscopic surveys were barely reaching z=1.5

Cowie + 95, Nature



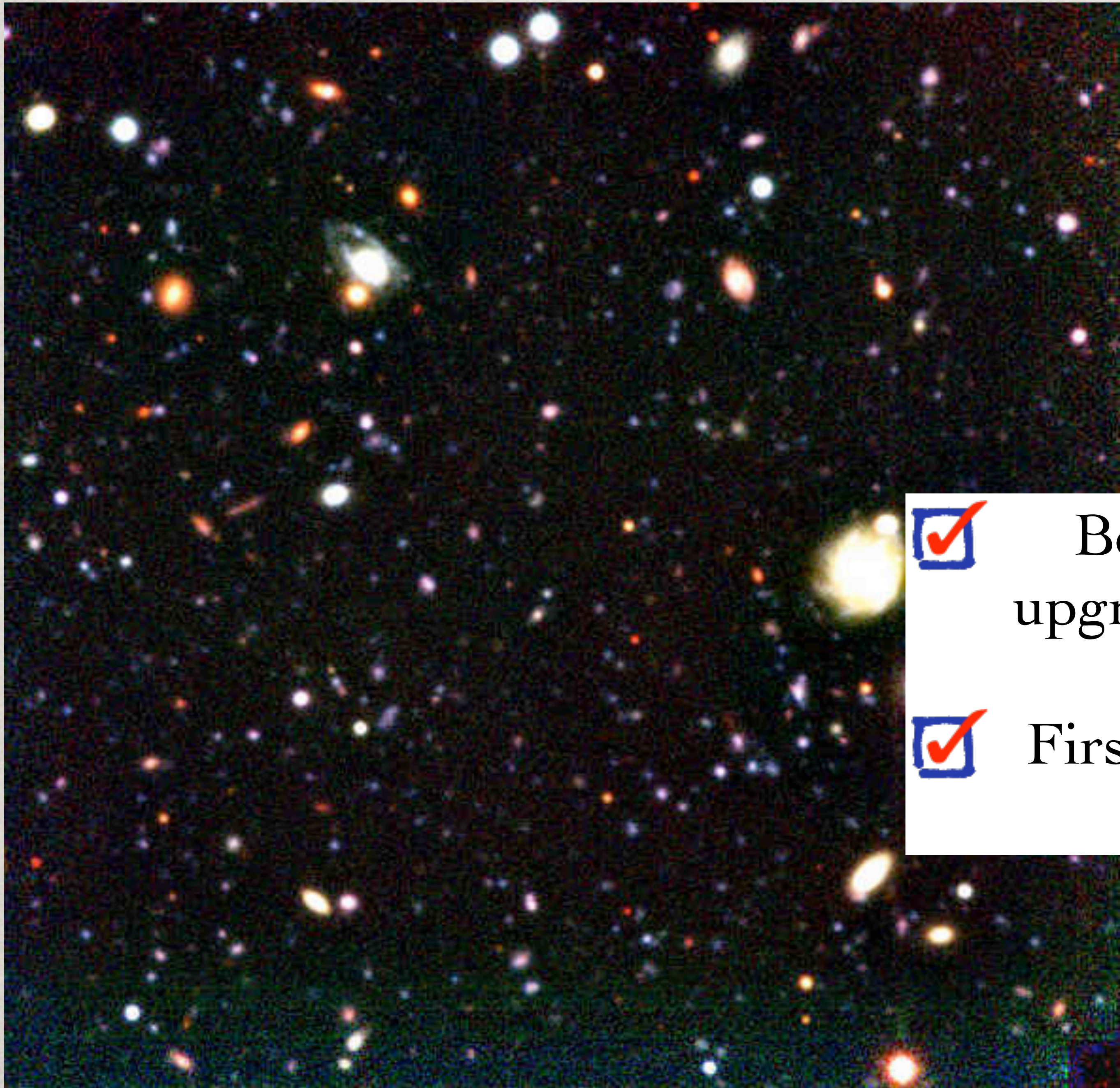
First "primeval" galaxy ever detected at z>3: a result from ESO telescopes.

Macchetto, Giavalisco+93
a Lya emitter at z=3.41
(EFOSC)

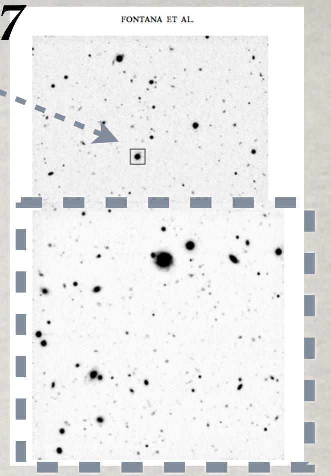


The NTT SUSI Deep Field

Arnouts et al 1999



BR1202-07



32h exposure in BVRI bands

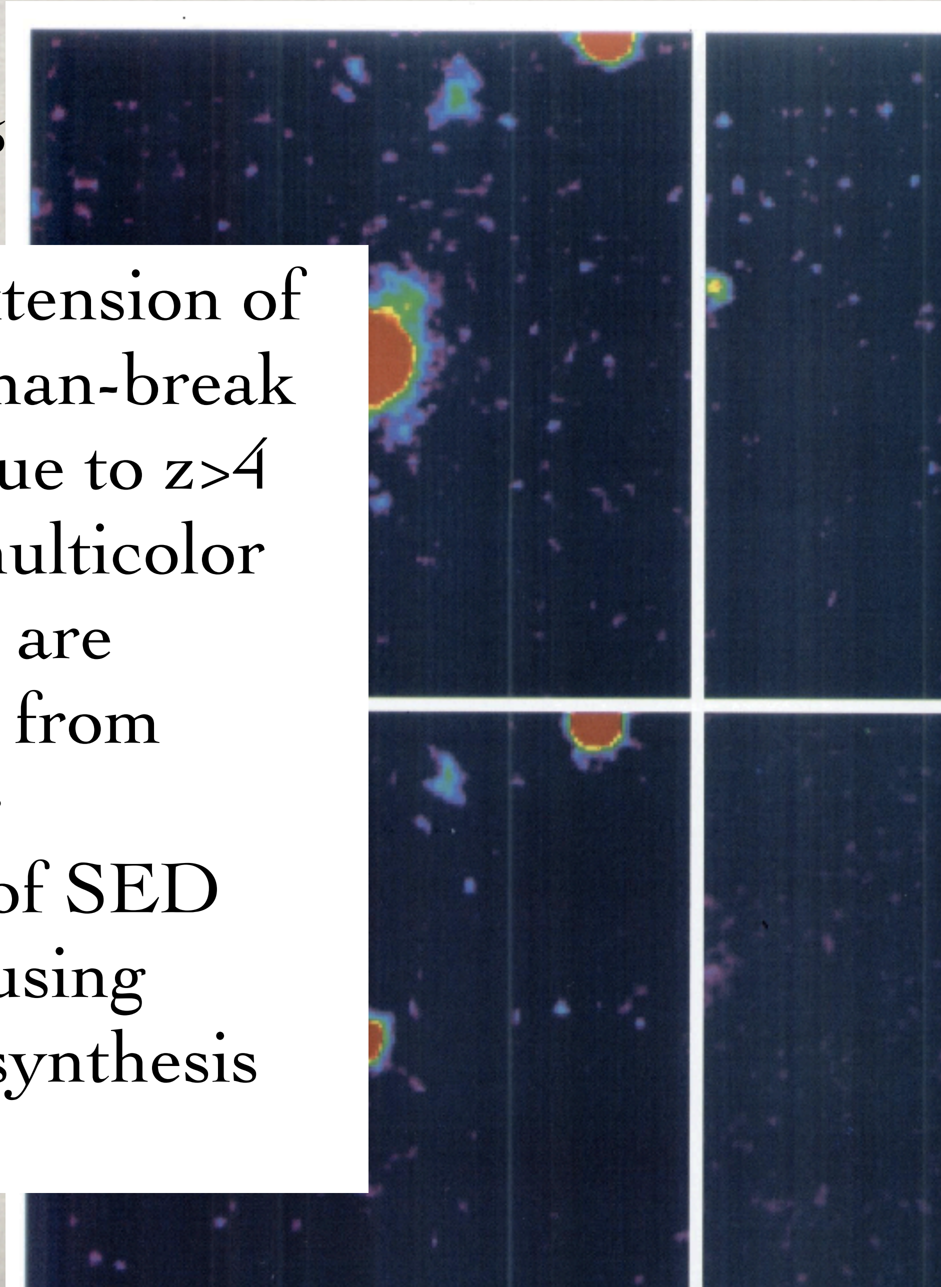
- ☑ Benchmark for the upgraded (VLT-like) NTT)
- ☑ First “public survey” at ESO.

Mon. Not. R. Astron. Soc. 279, L27–L30 (1996)

The optical identification of a primeval galaxy at $z \gtrsim 4.4$

Adriano Fontana,[1] Stefano Cristiani,[2,3] Sandro D'Odorico,[3] Emanuele Giallongo[1] and Sandra Savaglio[3,4]

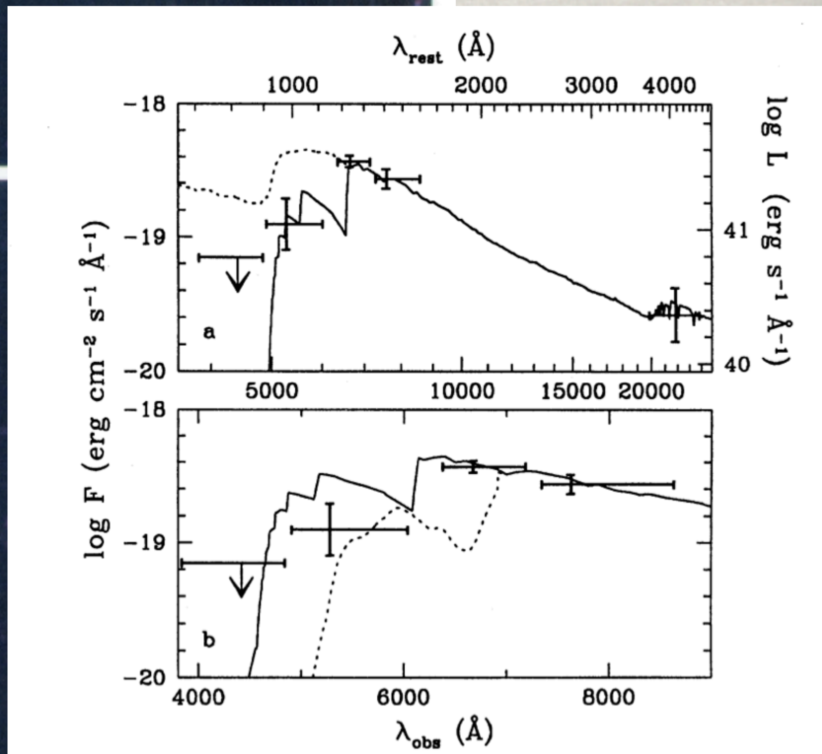
BR1202-0725
z=4.694



BVRI Grand-total: 11.4hr exposure (!)

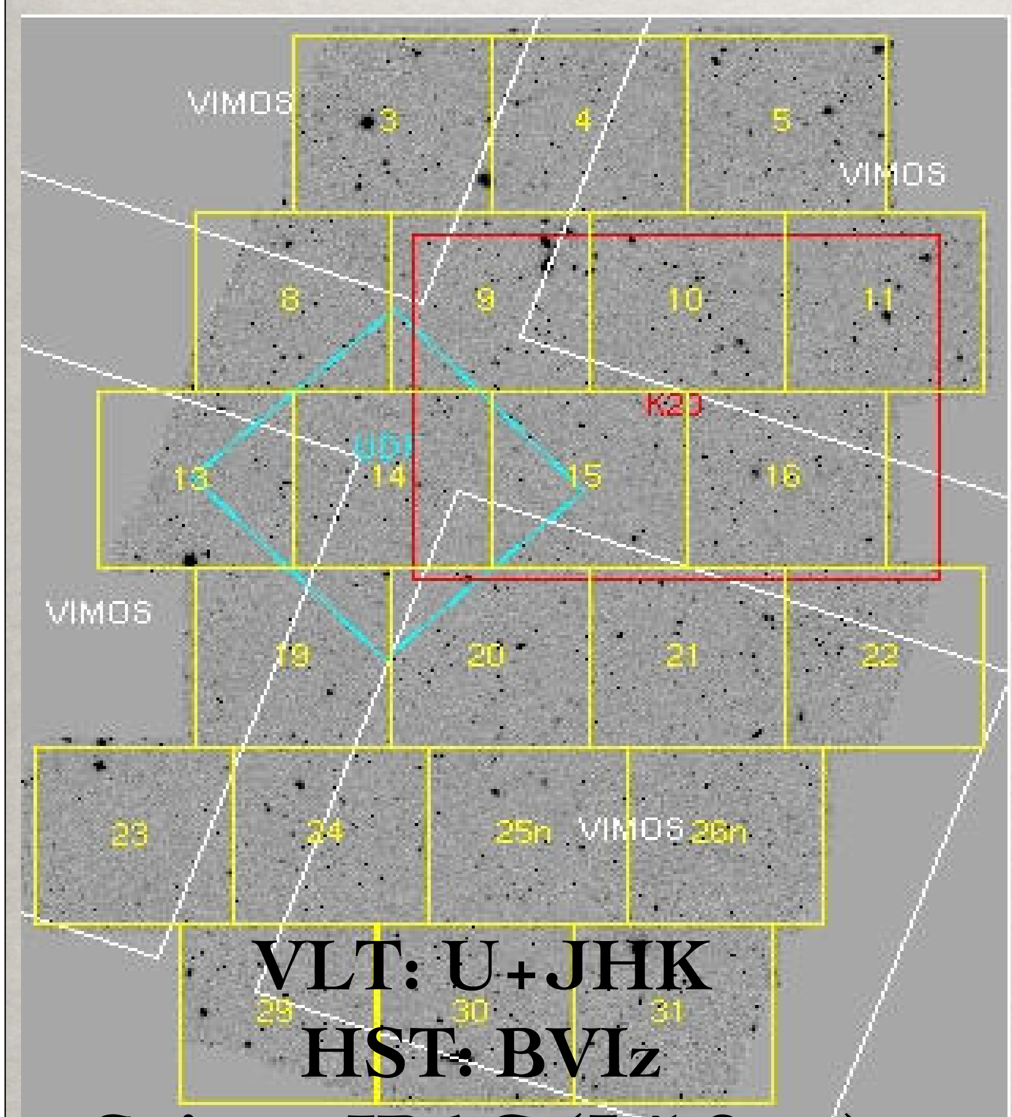
seeing: 0.45" (NTT)

- First extension of the Lyman-break technique to z>4
- Deep multicolor surveys are feasible from ground;
- Power of SED analysis using spectral synthesis models



Deep imaging and spectroscopic public surveys are the fundamental tool for extragalactic astronomy.

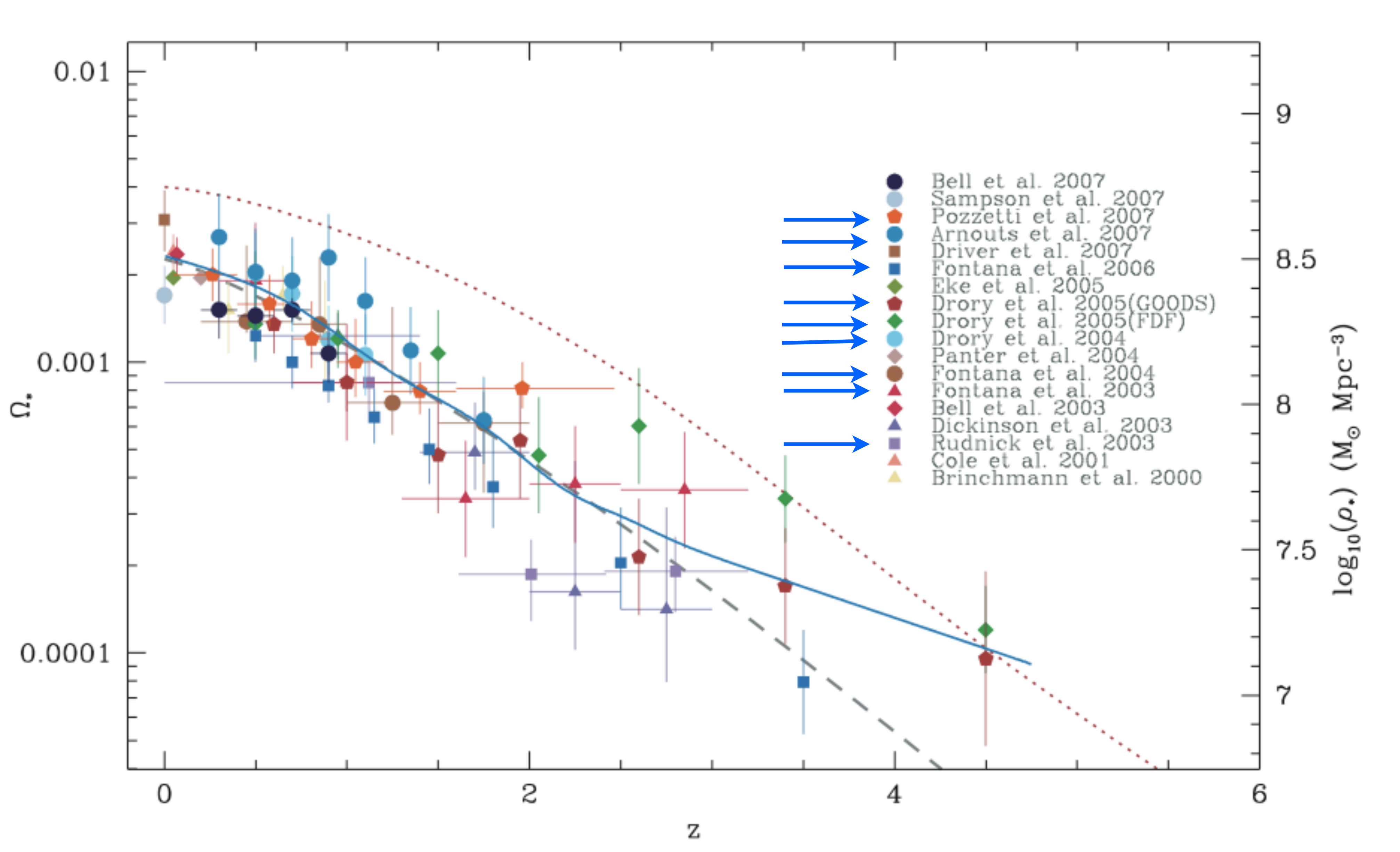
GOODS-South:
the GOODS-MUSIC sample
(Grazian +06, http://lbc.oa-roma.inaf.it/goods)



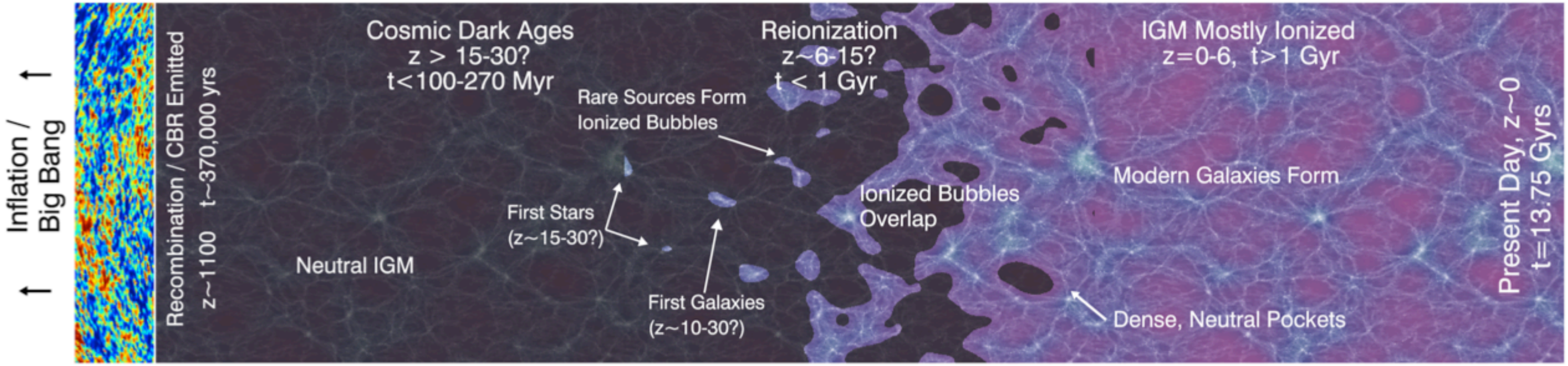
VLT: U+JHK
HST: BVIz
Spitzer:IRAC (3.5-8μm)

ESO contribution has been invaluable to all major (southern) surveys, for both imaging and spectroscopy:
COSMOS, GOODS, UDS

Cosmic Mass Density



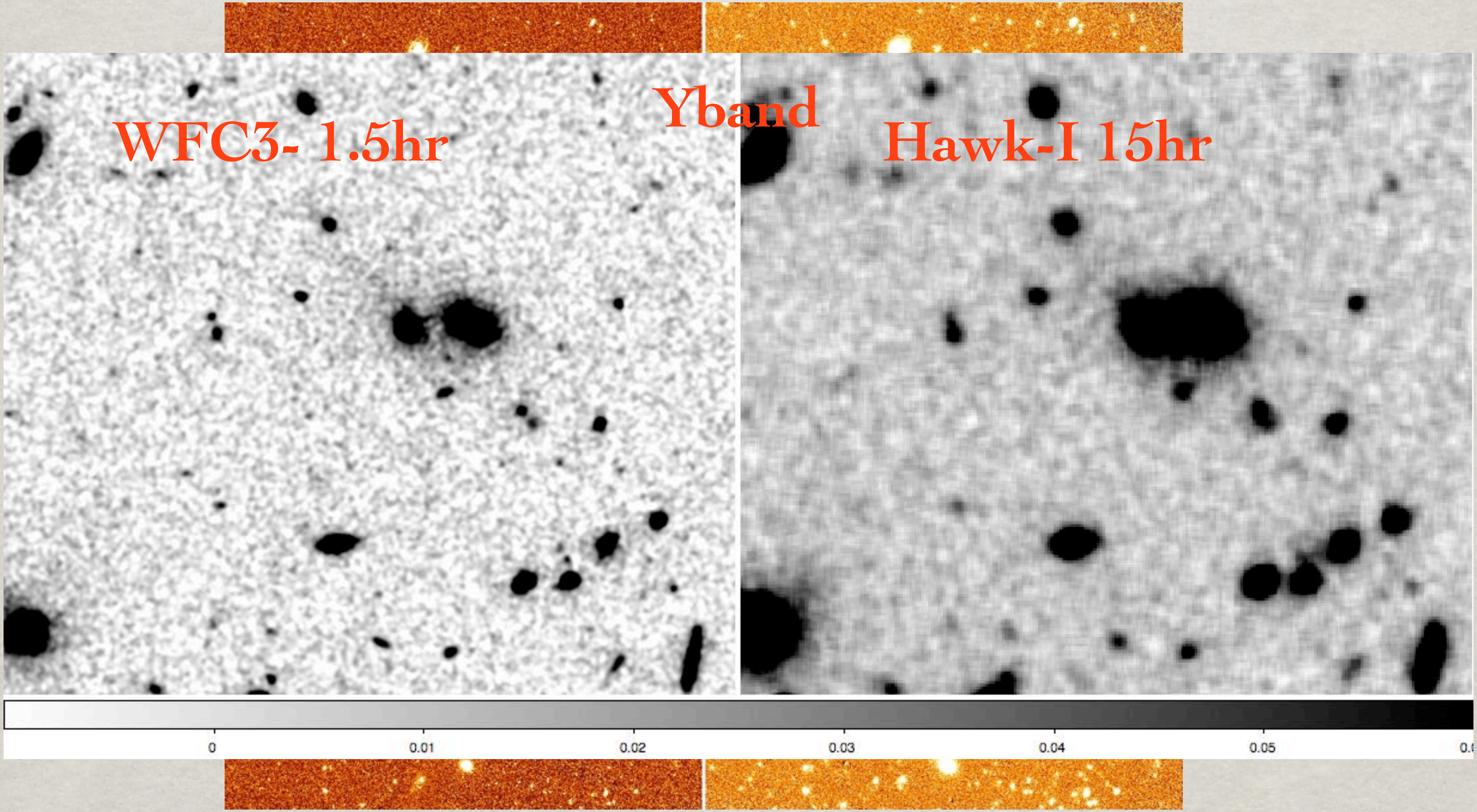
Open problem #1:
When did reionization occurred?
Which were the sources responsible of it?
Are "normal" sources enough or do we need anything more exotic?



Depends on 3 unknown parameters:

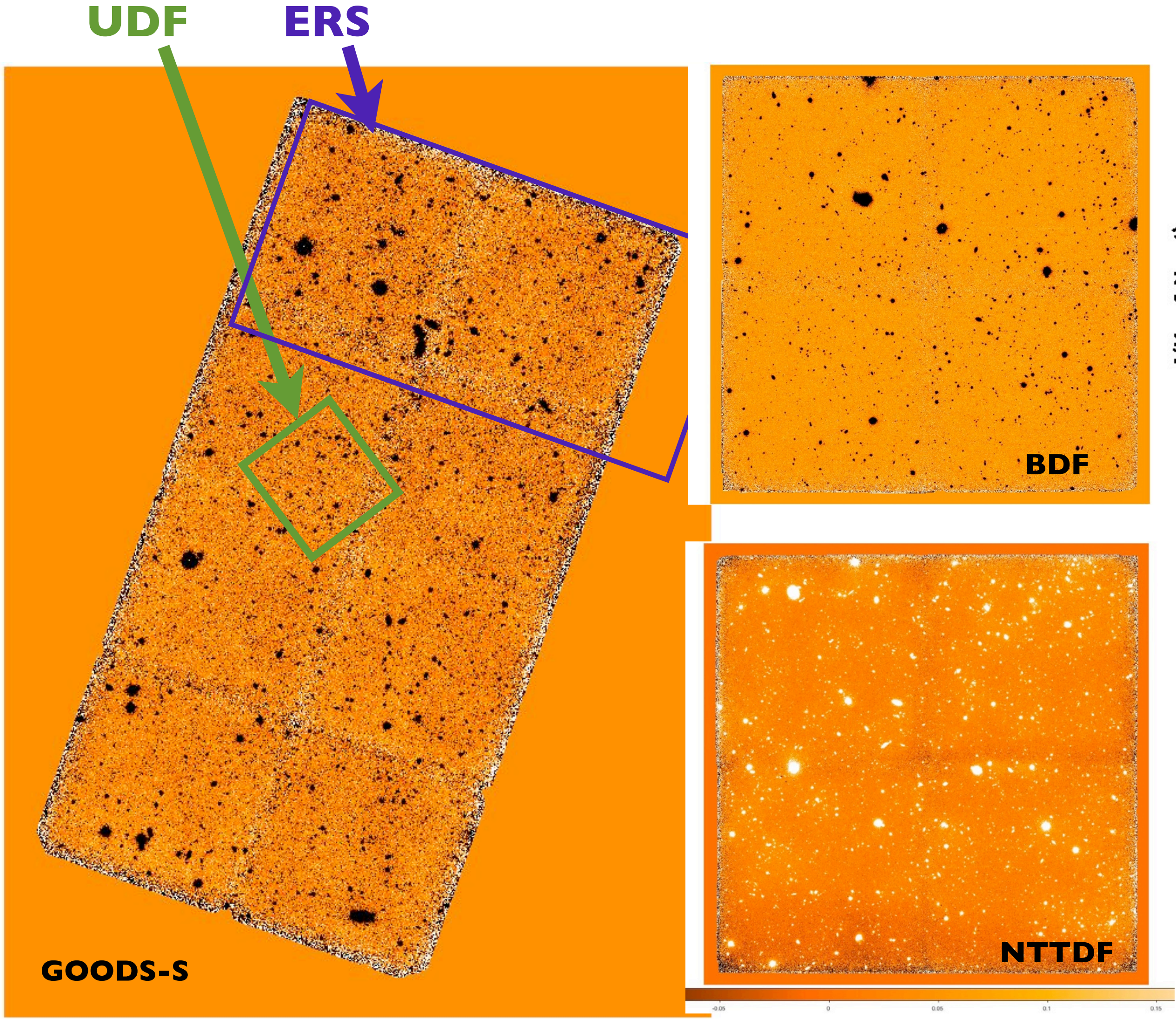
1) The total amount of ionizing photons -> luminosity density -> integral of Luminosity Function
2) The fraction of such photons that can escape the galaxies
3) The "clumpiness" of the IGM

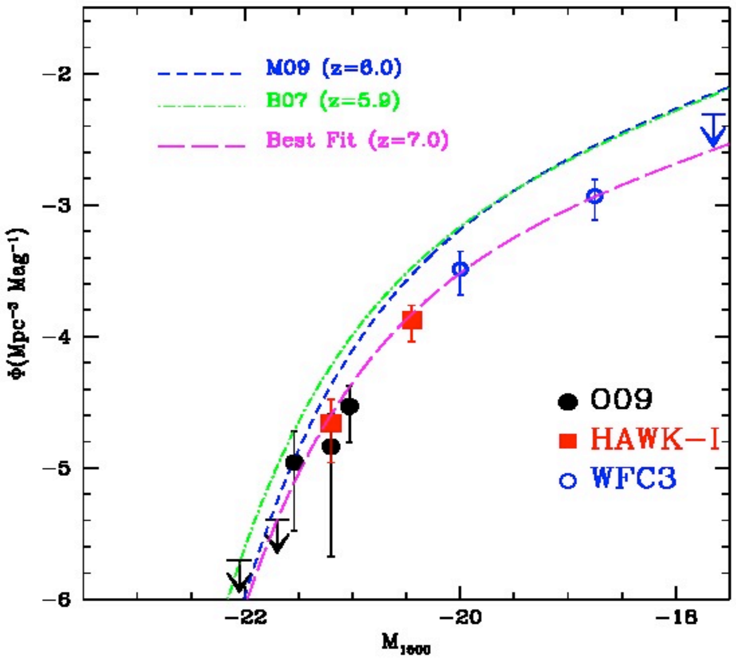
Ground-based 8m are still competitive @z=7 over large areas (i.e. bright, luminous objects at z=7) even in WFC3 era.



Searching for z~7 galaxies with a deep Hawk-I survey

Hawk-I Science Verification
+
ESO LP (HAWK-I+FORS2) -*PI A. Fontana*
~ 160hr VLT time

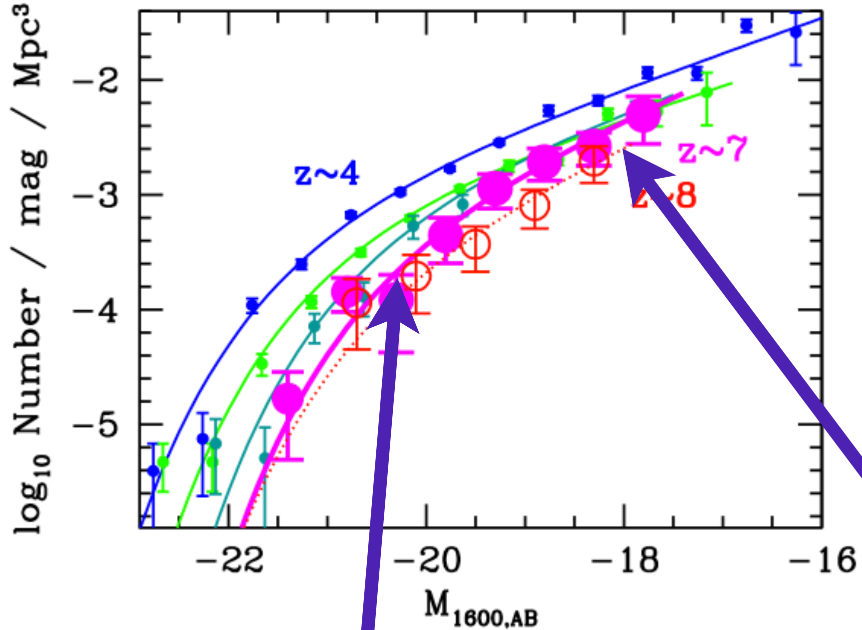


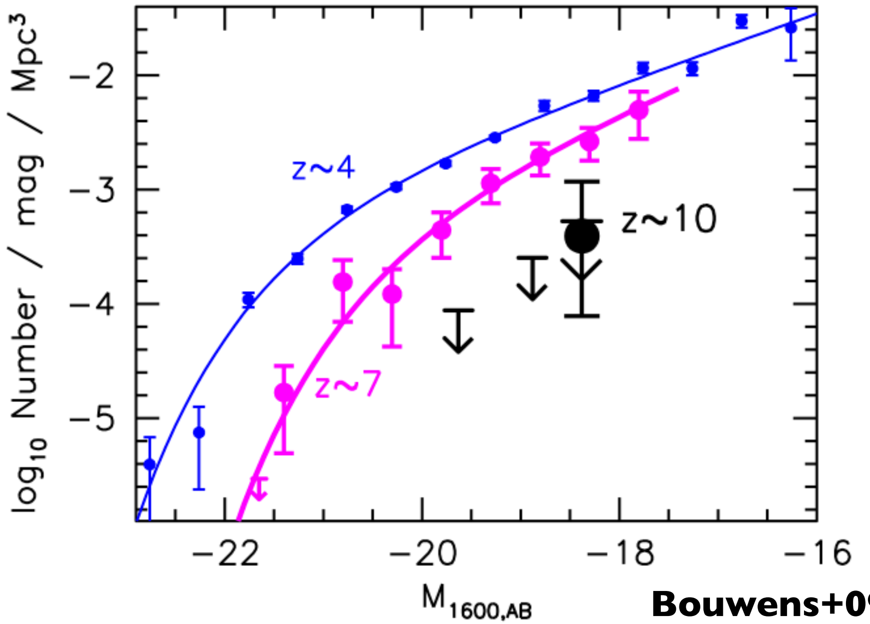


Castellano+ 10a,b

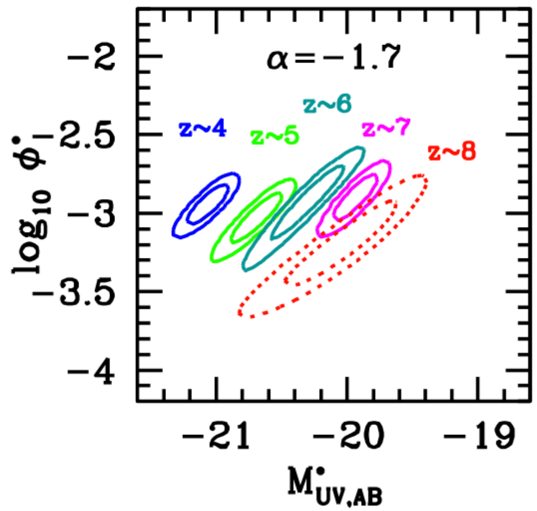
Hawk-I: bright &rare
ERS: intermediate
HUDF: faint & numerous

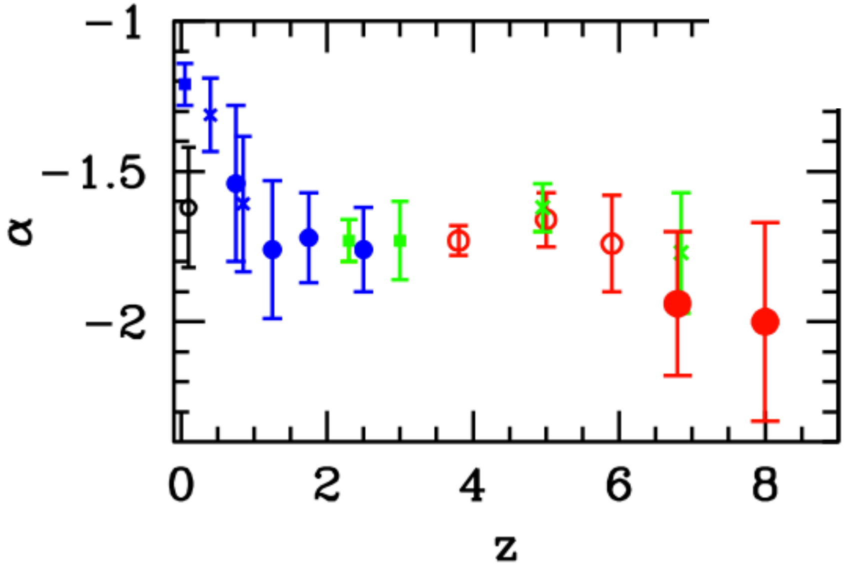
Evolution of the UV Luminosity Function from z=4 to z=8 (10??)





Bouwens+09,10,11
Castellano+10a,b
Grazian+11
McLure+10
Yan+10
etc





CANDELS: the largest HST program ever approved
WFC3 deep/wide exposures over 5 extragal. fields
P.I.: S. Faber, H. Ferguson.

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 197:35 (39pp), 2011 December GROGIN ET AL.

Table 1
CANDELS at a Glance

Field	Coordinates	Tier	WFC3/IR Tiling	HST Orbits/Tile	IR Filters[a]	UV/Optical Filters[b]
GOODS-N	189.228621, +62.238572	Deep	~3 × 5	~13	*YJH*	*UV,UI(WVz)*
GOODS-N	189.228621, +62.238572	Wide	2 @ ~2 × 4	~3	*YJH*	*Iz(W)*
GOODS-S	53.122751, −27.805089	Deep	~3 × 5	~13	*YJH*	*I(WVz)*
GOODS-S	53.122751, −27.805089	Wide	~2 × 4	~3	*YJH*	*Iz(W)*
COSMOS	150.116321, +2.2009731	Wide	4 × 11	~2	*JH*	*VI(W)*
EGS	214.825000, +52.825000	Wide	3 × 15	~2	*JH*	*VI(W)*
UDS	34.406250, −5.2000000	Wide	4 × 11	~2	*JH*	*VI(W)*

HUGS (Hawk-I UDS and GOODS Survey): A complete view of the first 2 billion years of galaxy formation

Large Hawk-I@VLT program (208hr)

A Rome-Edinburgh program
A.Fontana (PI), J. Dunlop, Faber, Ferguson et al...

Data Reduction by:
Diego Paris (Rome Obs)
Thomas Targett (ROE)

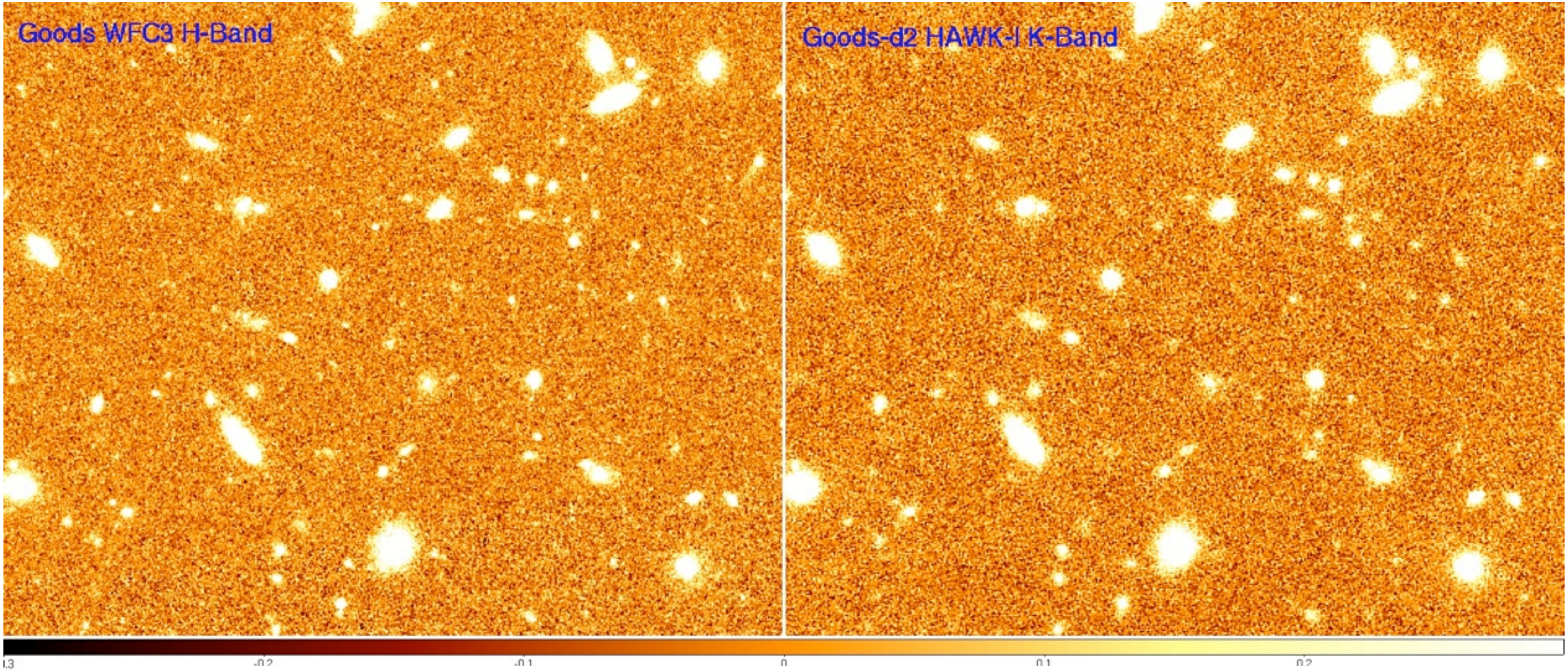
Observing plan:

- 2 targeted fields: GOODS-S (K) and UDS (Y and K)
- Required depths tuned to expected depths of WFC3 data
- 4 semesters of VLT time

Science goals:

1. Locating and measuring the Balmer break at z>3.5
2. Assembling complete sample of galaxies at z>4
3. Improving photo-z accuracy for z>4 (Balmer break)
4. Improving photo-z accuracy for z>7 (Lyman break)

First 1/3 of the data
Seeing: 0.38"

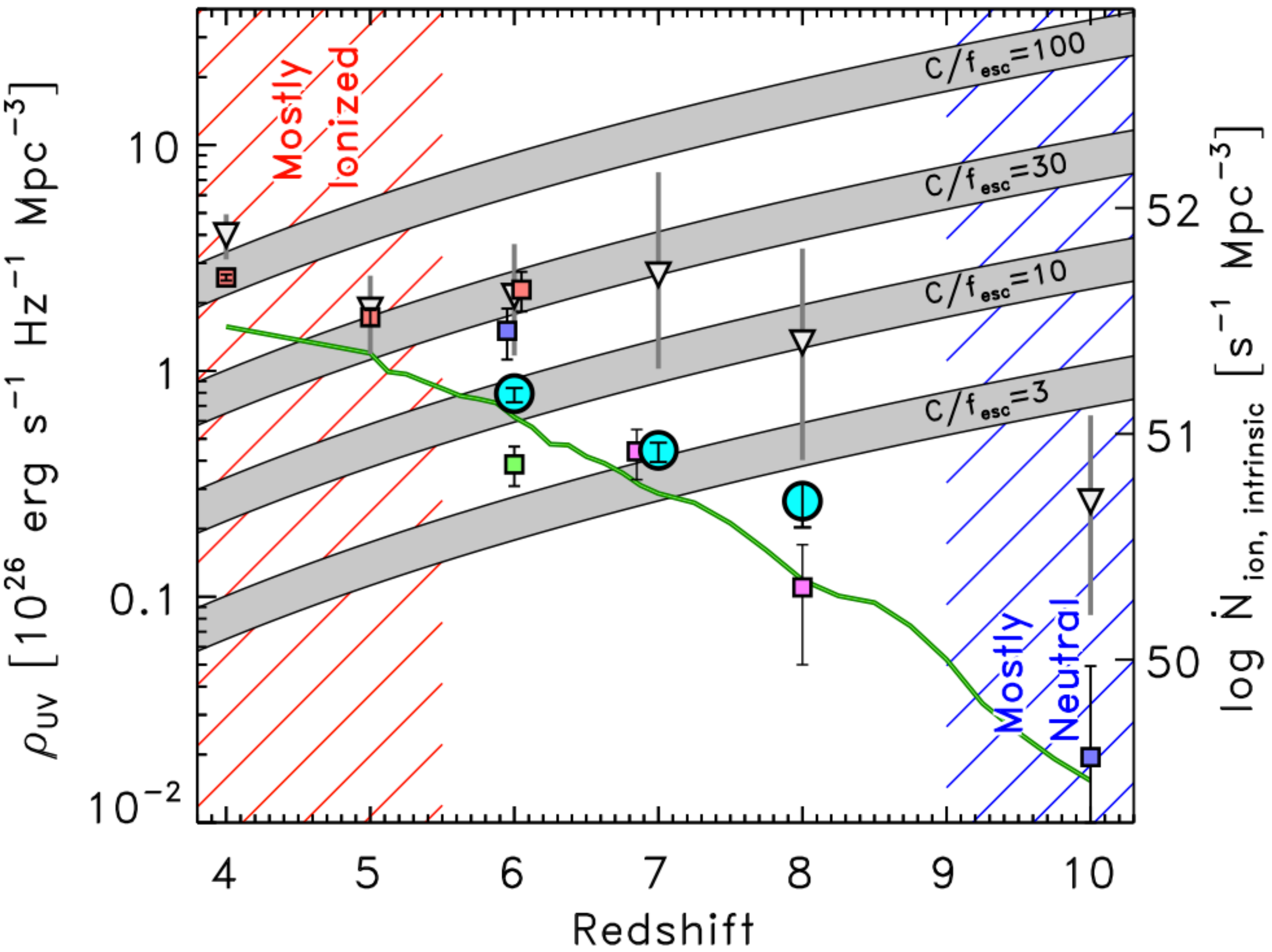


maglim (1σ - 1sqarcsec): 27.88

maglim (5σ - 2FWHM): 27

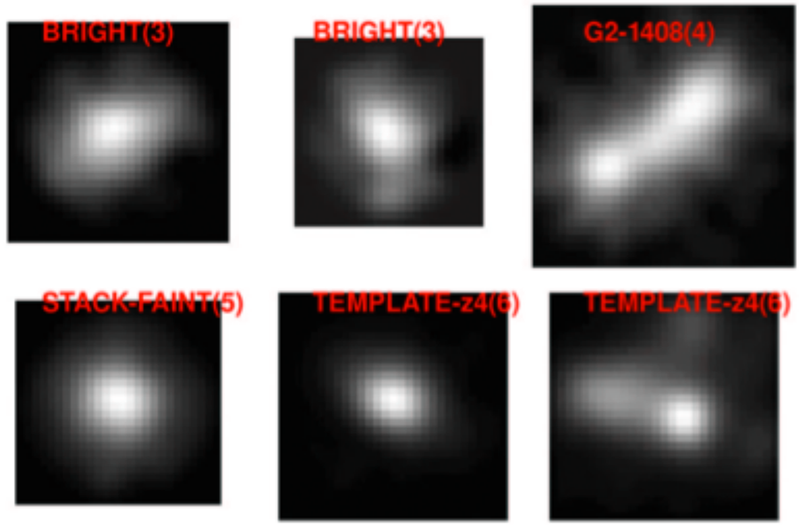
85% of H=27 galaxies already detected in K
60% of H=28 (!) galaxies already detected in K

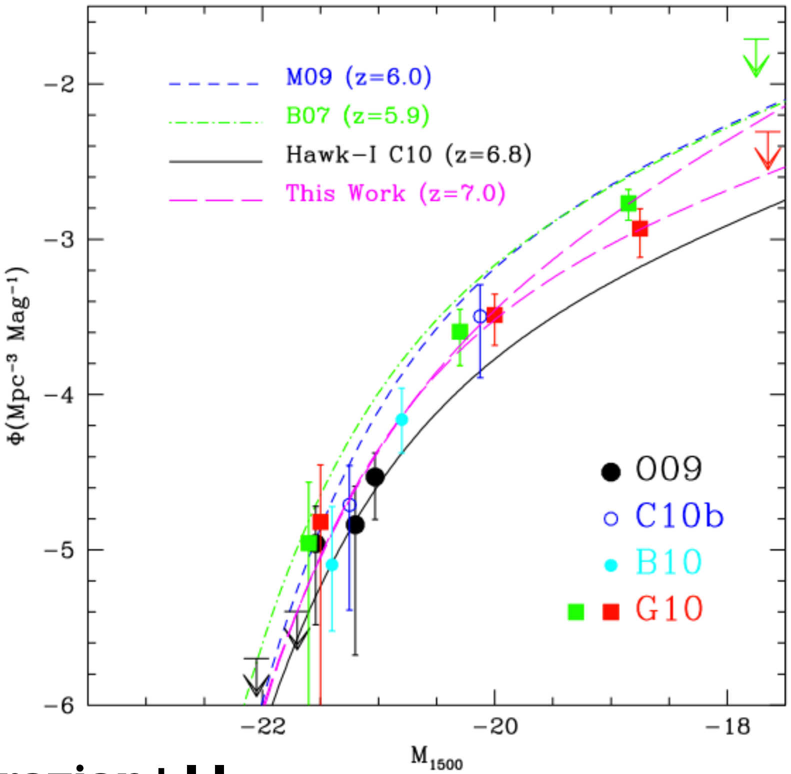
Reionizing photons: Contribution from OBSERVED galaxies



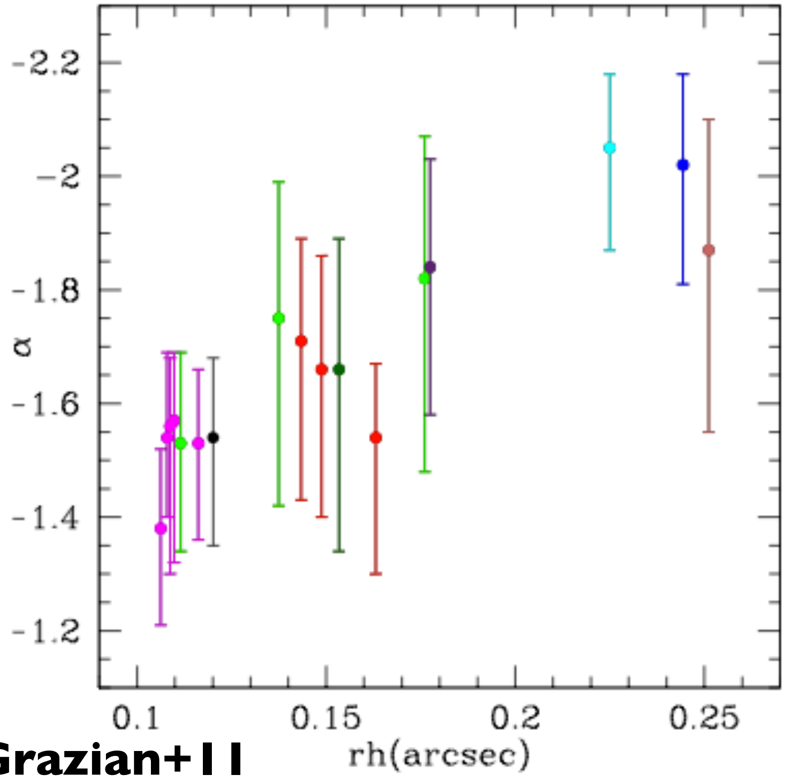
Finkelstein+12, astroph1206.0735

Completeness corrections at the faint side depend on the *assumed* morphology





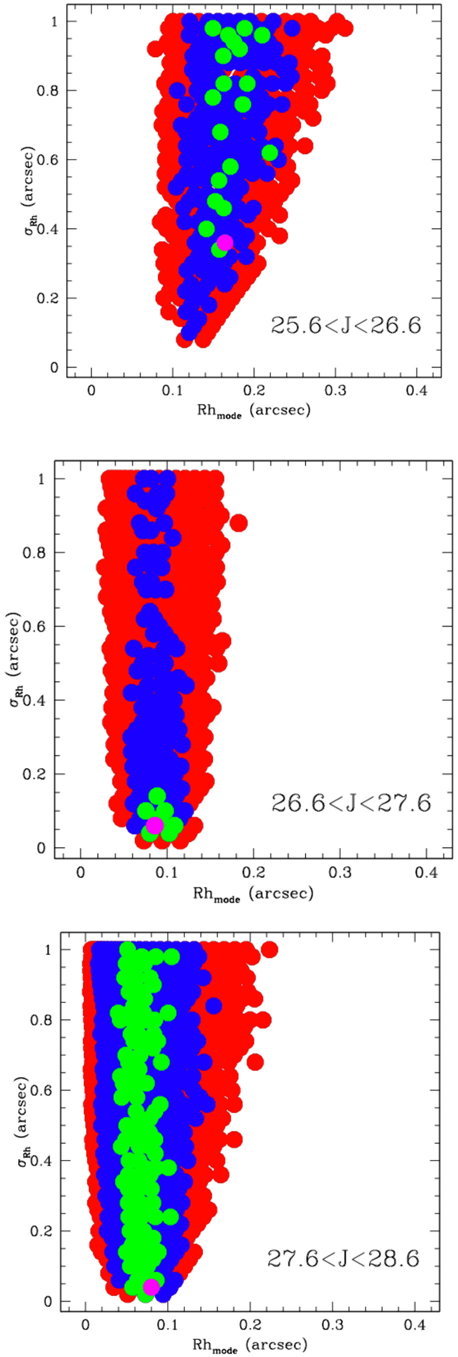
Grazian+11

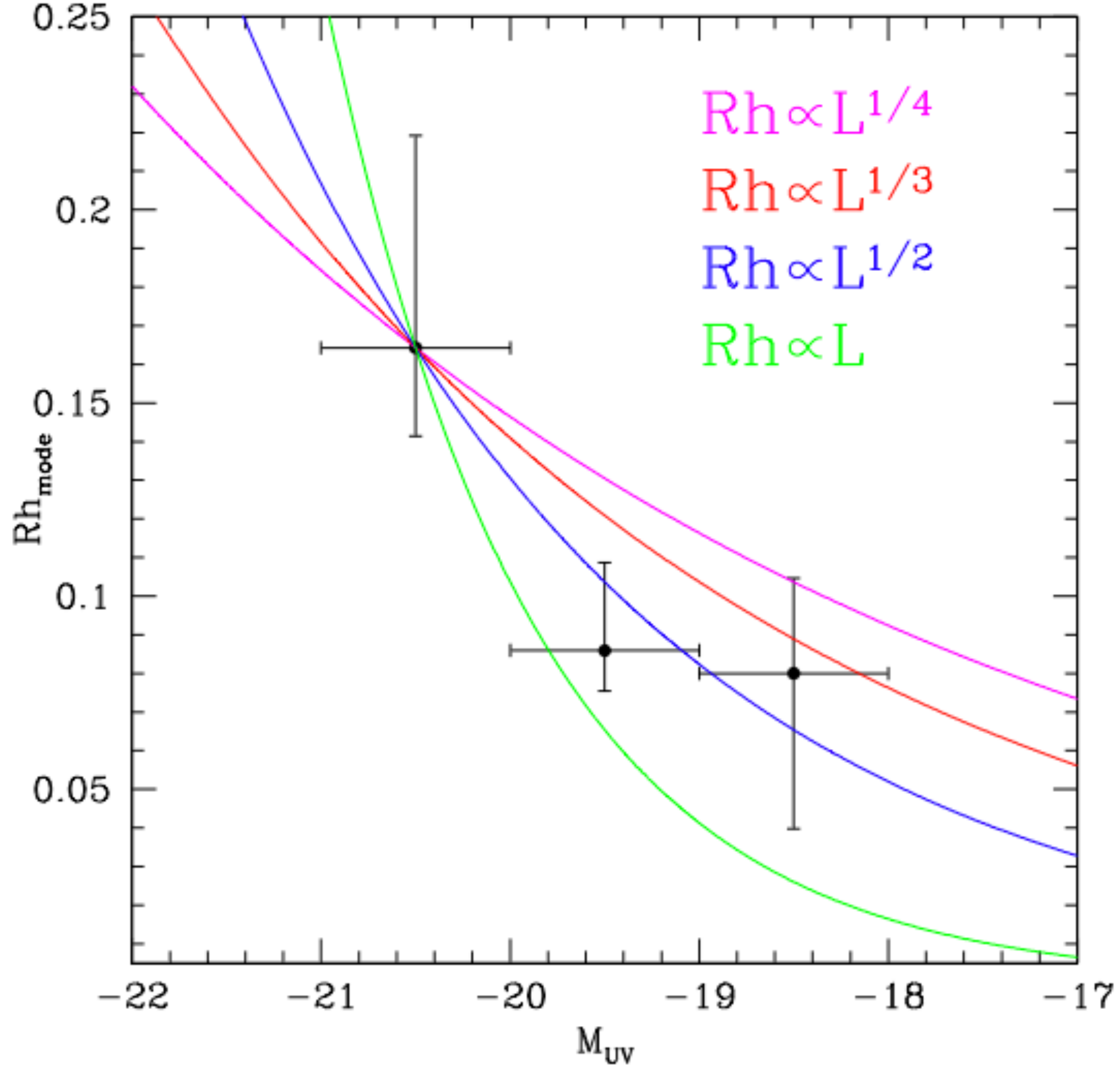


Grazian+11

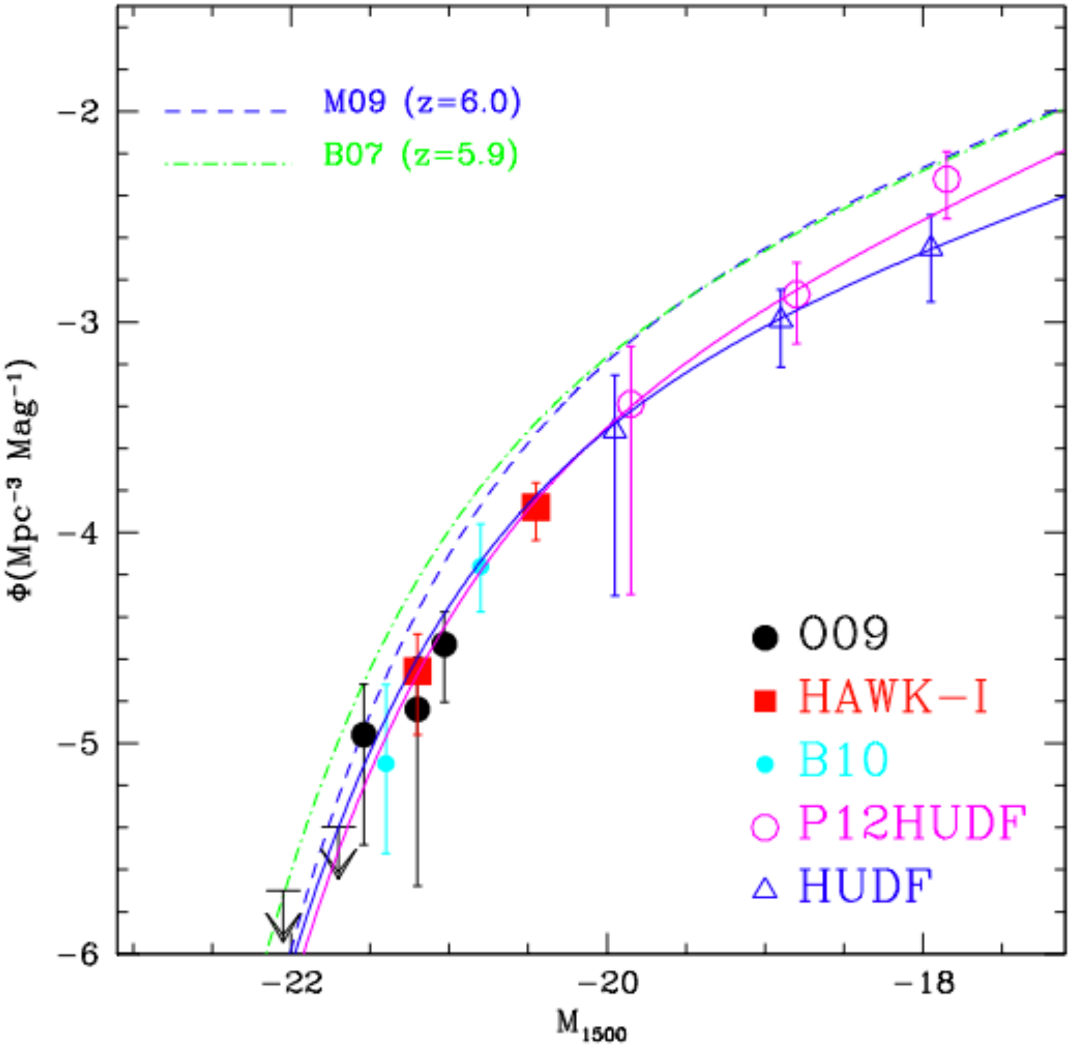
CANDELS+HUGS

Grazian et al 2012, A&A subm.



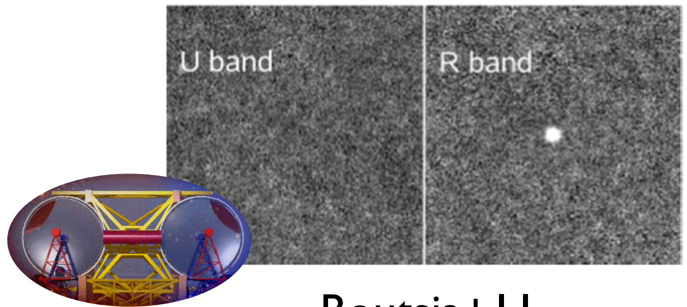


Grazian et al 2012, A&A subm.



Conclusion#1: slope =-1.7+/-1
Conclusion #2 at z~7, galaxies could keep the IGM ionized only if fesc>0.14C

We need a combination of low clumpiness and high escape fraction.



Boutsia+11
LBT data
11 gals at z~3.4
fesc<5%
(see also Vanzella+10,11, but Nestor+11)

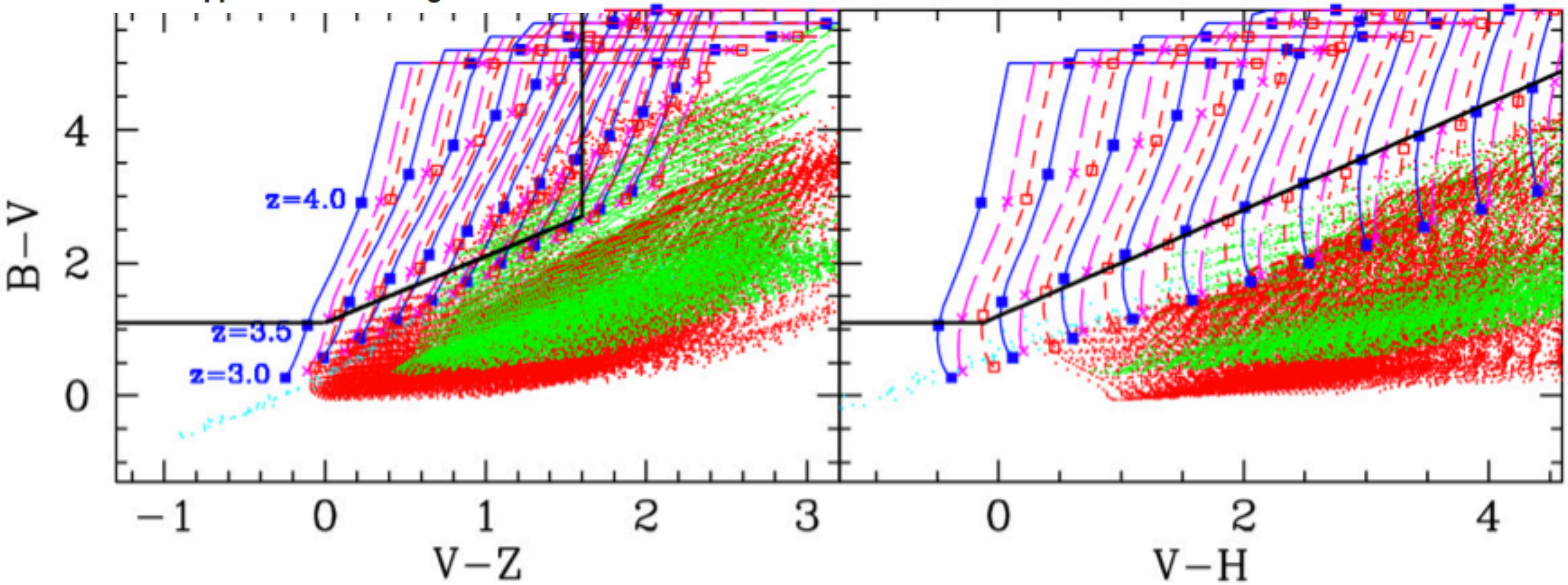
Galaxies alone at z~7 cannot "easily" reionize the Universe - we must "stretch" some of their properties.

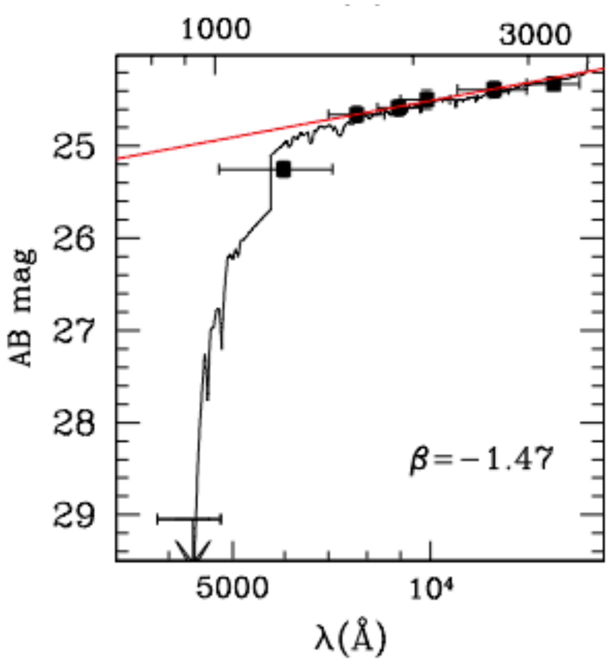
Is the SFR budget right? We need to account for dust corrections properly.

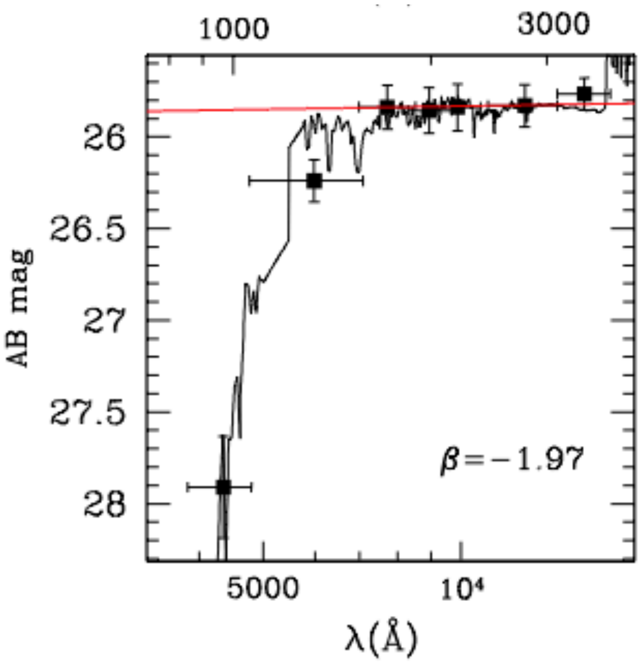
Are we able to understand the physical properties of high z galaxies?

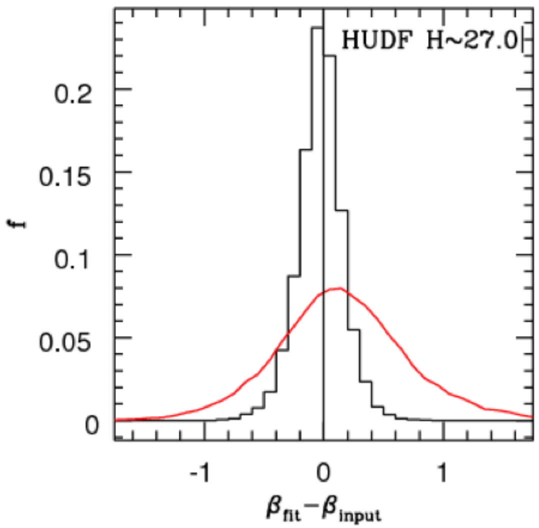
Are we estimating MF and LF properly at faint mags?

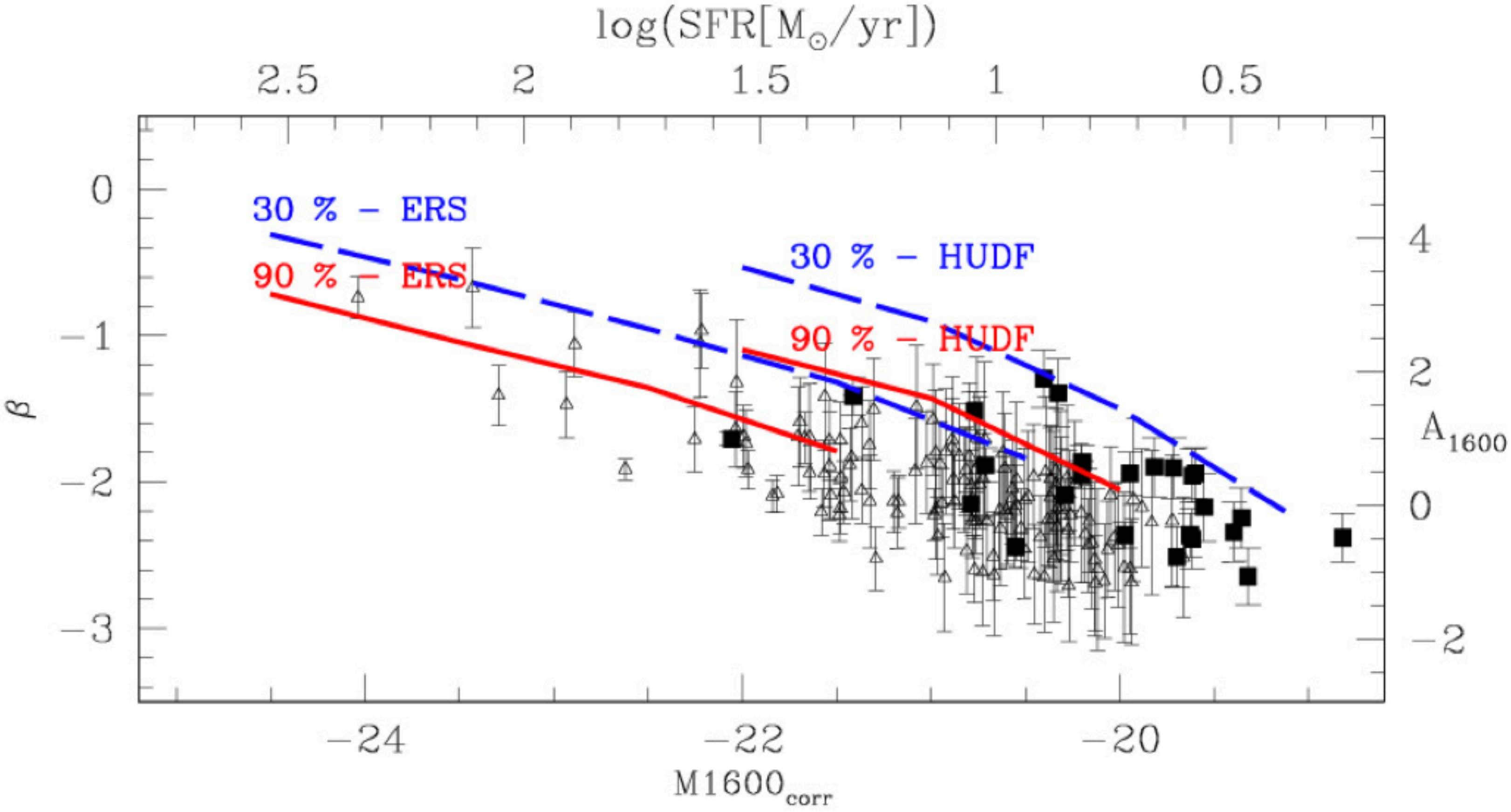
3. A new approach to selecting $z \sim 4$ LBGs



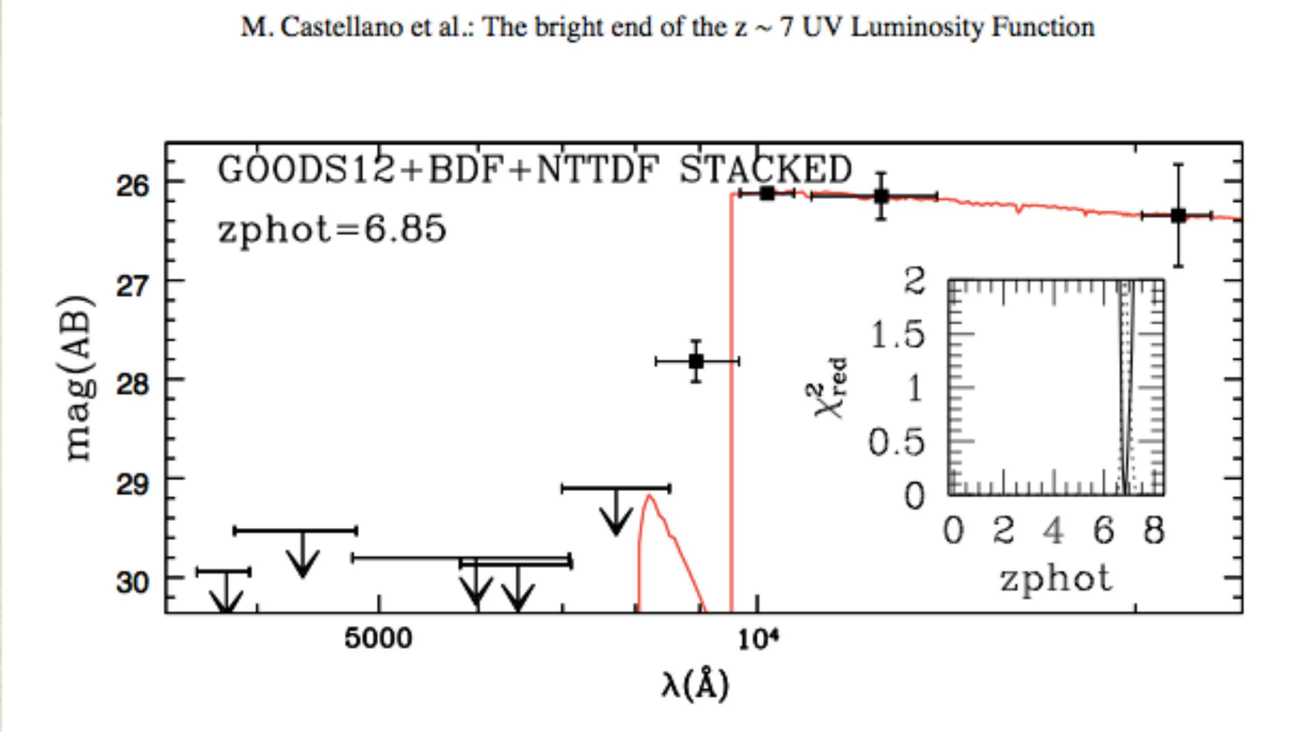




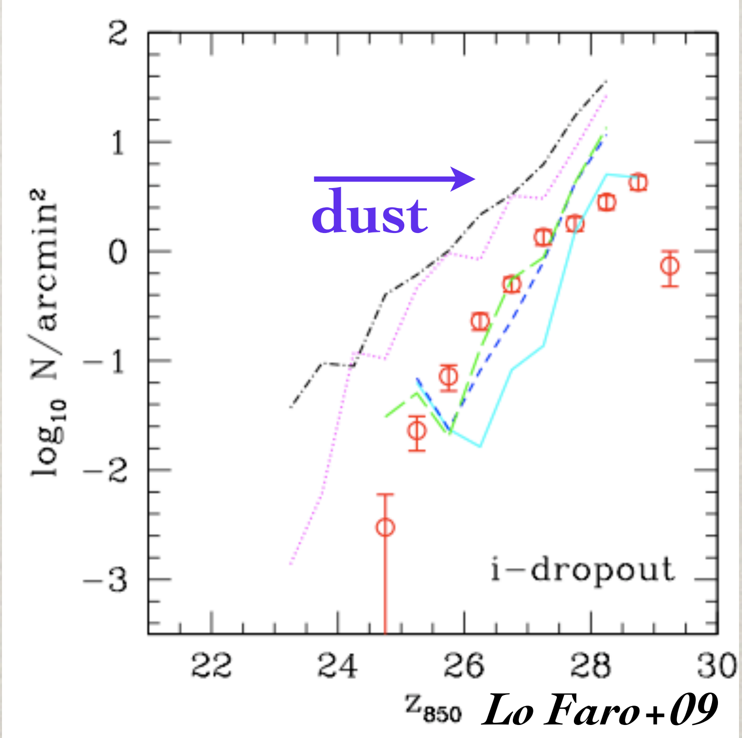



log(SFR[M$_\odot$/yr])
2.5
2
1.5
1
0.5
30 % - ERS
90 % - ERS
30 % - HUDF
90 % - HUDF
0
−1
−2
−3
β
4
2
0
−2
A$_{1600}$
−24
−22
−20
M1600$_{corr}$

The average extinction in observed Lyman Break Galaxies at z=7 is extremely low.



A problem for theoretical models?



Summary

- ESO instrumentation is extremely competitive in executing large extragalactic surveys (IR imaging + spectroscopy).

- Italian astronomers quite active in exploiting it.

- Galaxies alone at z~7 cannot "easily" reionize the Universe - we must "stretch" some of their properties.

- Lyman-Break Galaxies at z>4 are relatively dust-free: sfr corrections are small, possibly a problem for theoretical models.