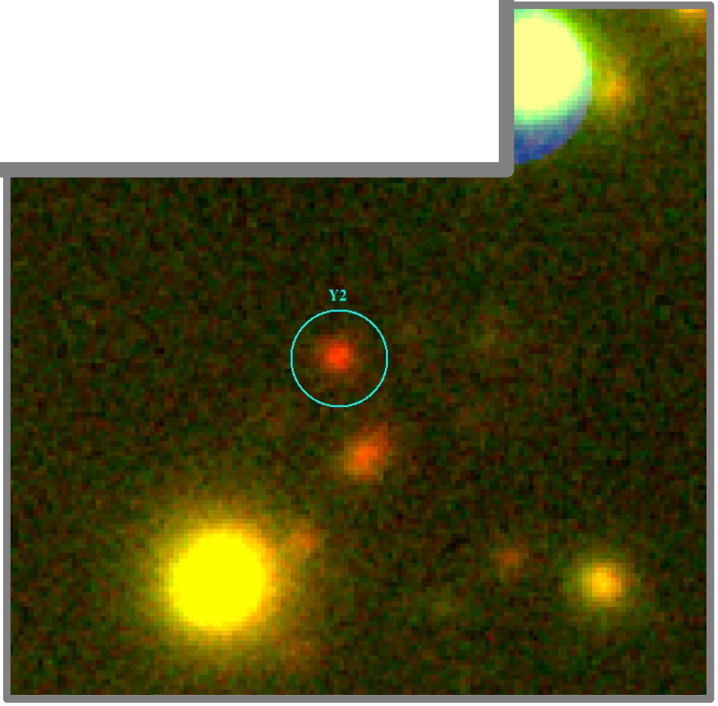
Contraintes sur les sources de la réionisation

R. Pello & D. Bina

Spectroscopic Redshift Surveys in OCEVU: Dark Energy, Galaxy Evolution and Reionization

GAHEC Group

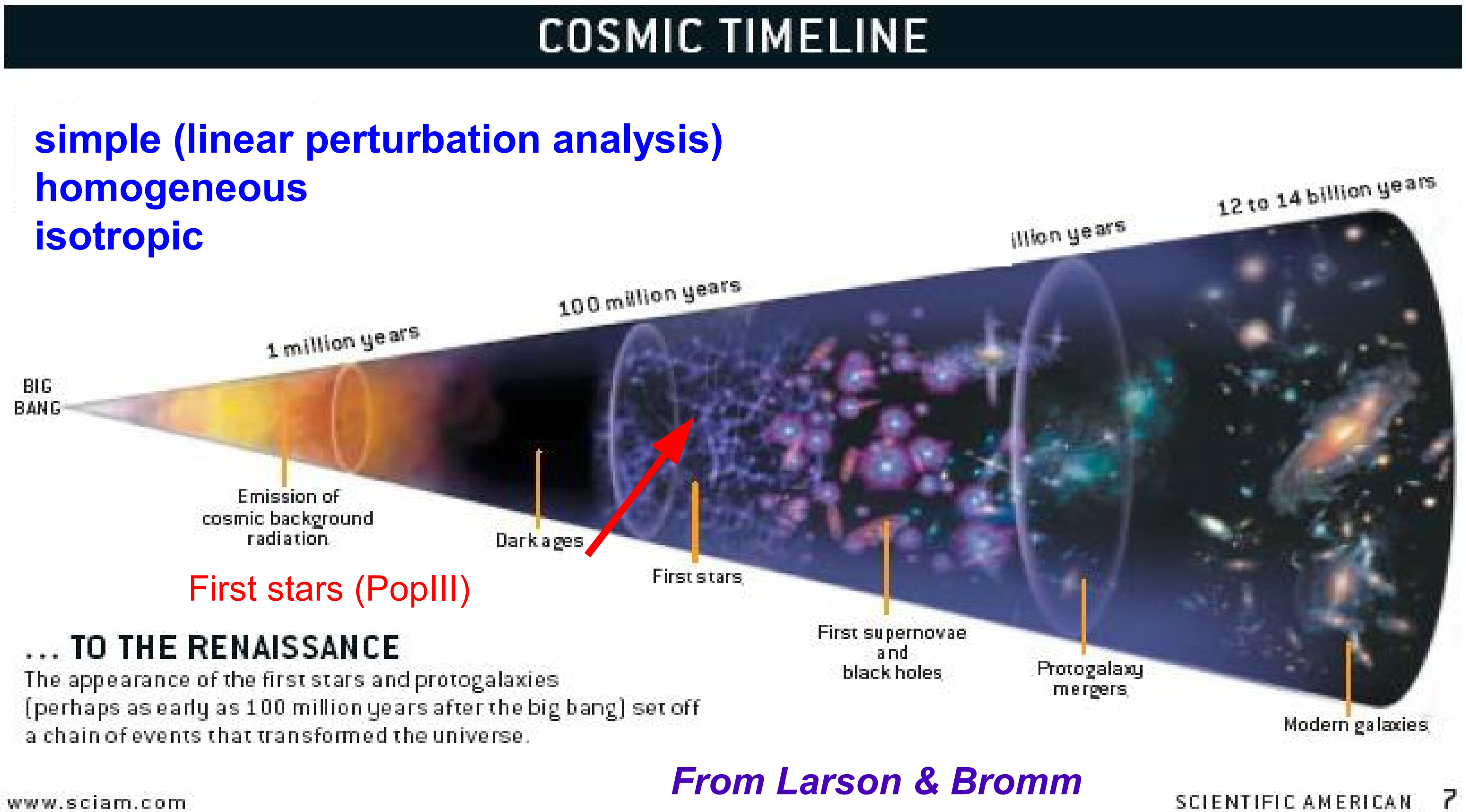
(IRAP, Toulouse)



General considerations

Science goal : Investigate the birth of the first objects out from the dark ages as well as structure assembly in the universe.

The formation of the first bounded objects marks the transition from simplicity to complexity …



simple (linear perturbation analysis)
homogeneous
isotropic

First stars (PopIII)

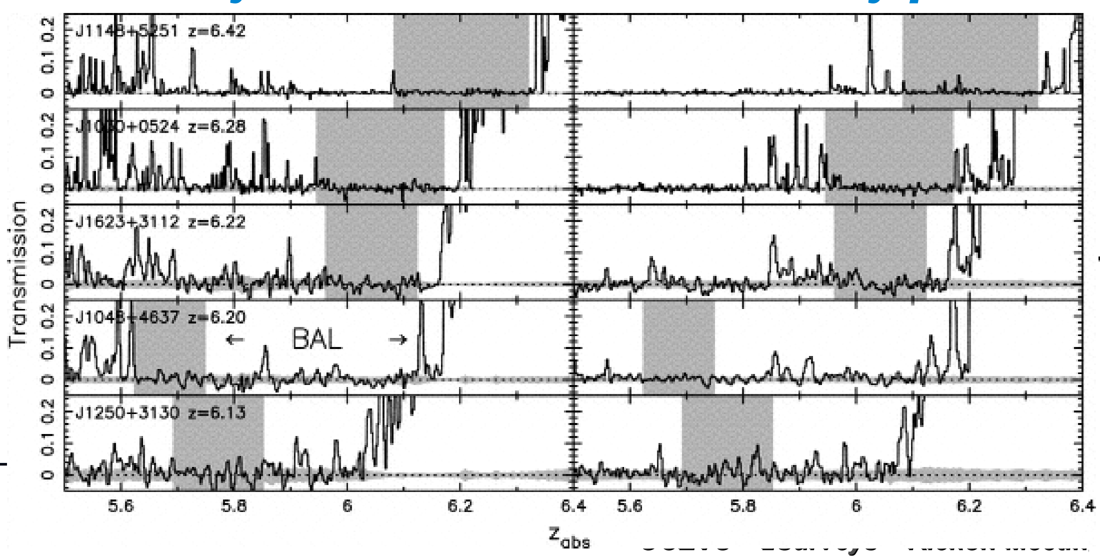
From Larson & Bromm

General considerations

The end of the reionization :

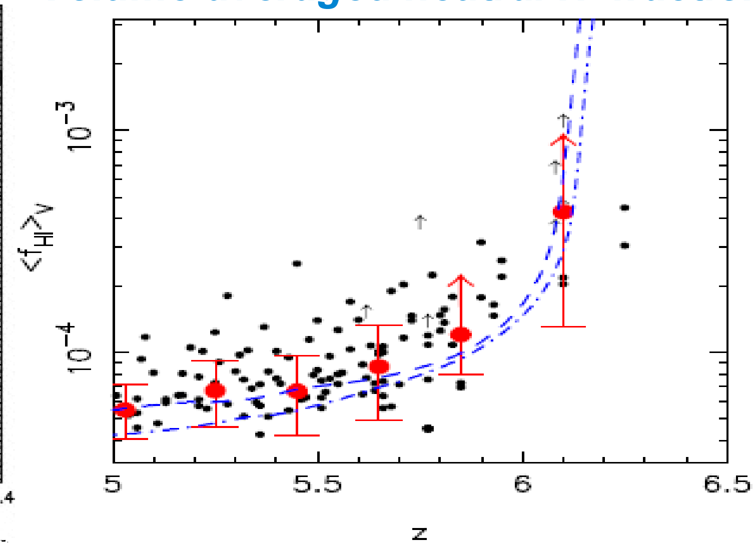
- **Evolution in the optical depth of Lyman absorption series (*Gunn & Peterson 1965*) observed in high-z quasars tells us about the end of the reionization (e.g. *Fan et al. 2000 to 2006*)**
- **Complete absorption expected even for a tiny neutral fraction (~10^{-4}, whereas the present value is ~10^{-5}) ==> this test is only sensitive when the IGM is "almost" ionized, and saturates for higher neutral fractions. Large line of sight variance is also observed!**

Ly α ***Ly β***



Fan et al (2006)

Volume-averaged neutral H fraction



General considerations

The beginning of the reionization probed by WMAP :

- Foreground electron scattering of CMB photons with an optical depth corresponding to z(reionization). Observed since year-1 (2003) at 4 sigma level.
- z(reionization)=11+/-1.2 (Komatsu et al. 2011). Large uncertainties remain. The actual value depends on the reionization process (instantaneous or more complex scenarios). **==> more with Planck !**

Some important questions remain:

What were the sources responsible for the reionization? Galaxies & AGNs? GRB contribution?

When and how reionization occurred? A gradual process? Multiple phases?

Current observational constraints

Extremely deep Surveys combining optical+near-IR data : HUDF09, UKIDSS Ultra Deep Survey, GOODS, CANDELS, Extended Groth Strip, Chandra Deep Field, …

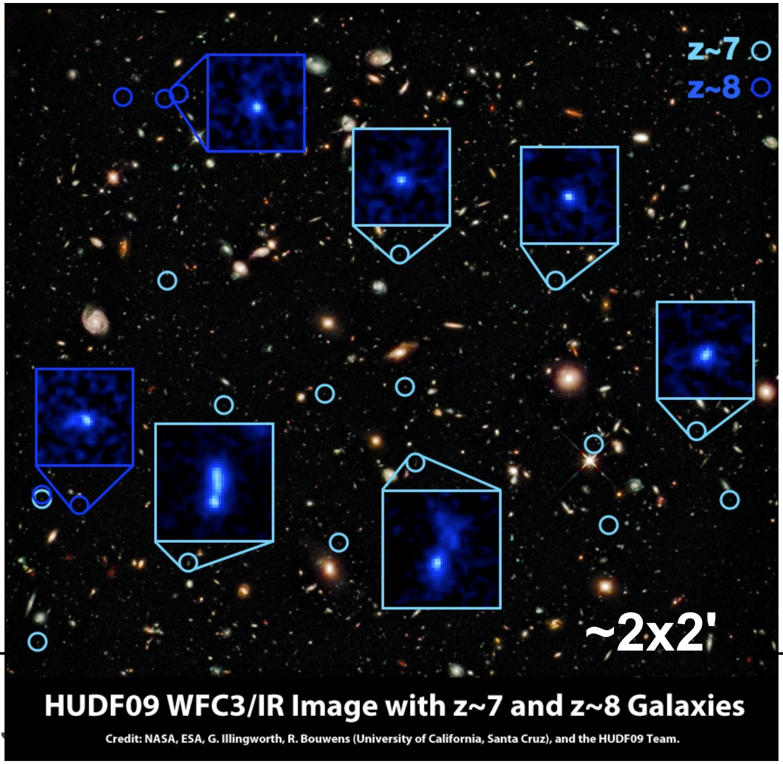
Bouwens et al. 2010+, Oesch et al. 2010
See also HUDF09 web site

Multi-wavelength data (HST, Spitzer,...)

High-z samples are "faint", typically m~28-29 at z~7-8

+ lensed sources (e.g. CLASH SURVEY & Frontier Fields)

Spectroscopic follow up is difficult with 8-10m class telescopes! The situation is rapidly evolving with the arrival of multi-object NIR facilities (e.g. KMOS/VLT or EMIR/GTC) … **for the brightest candidates !**



Current observational constraints

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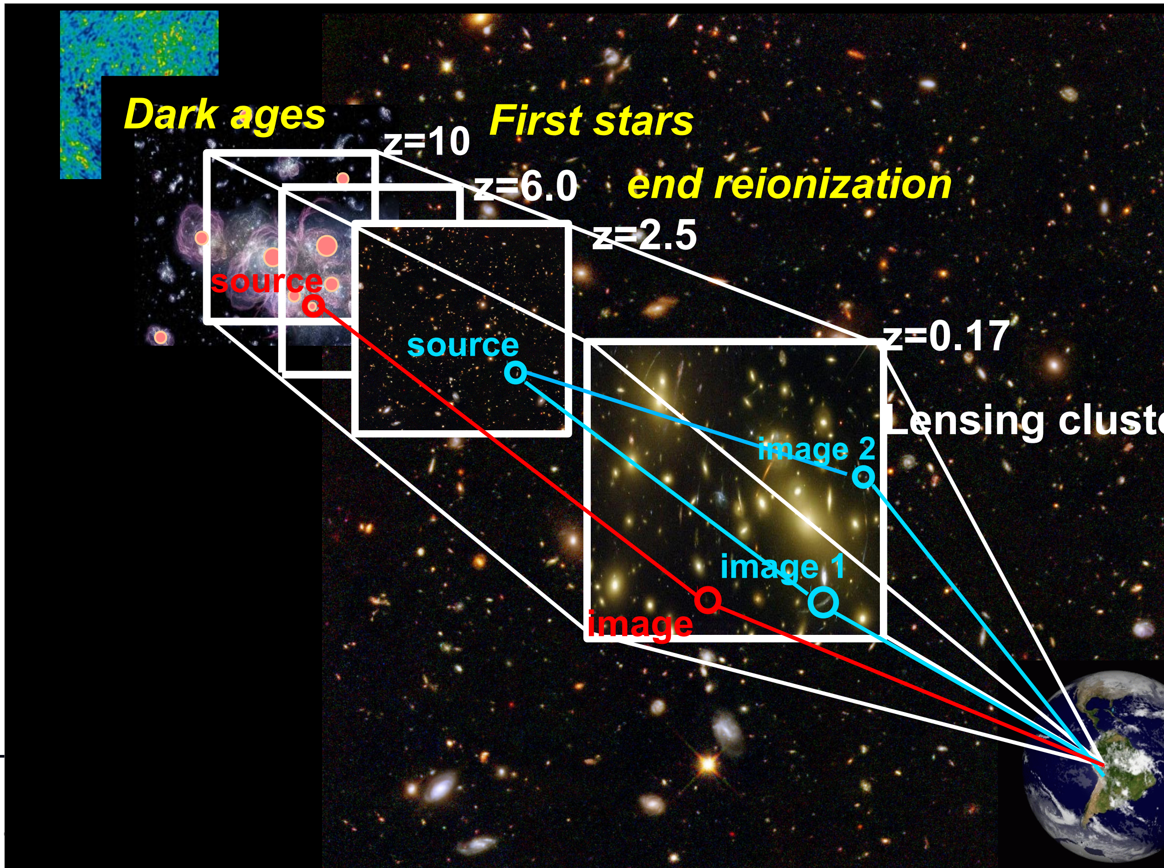
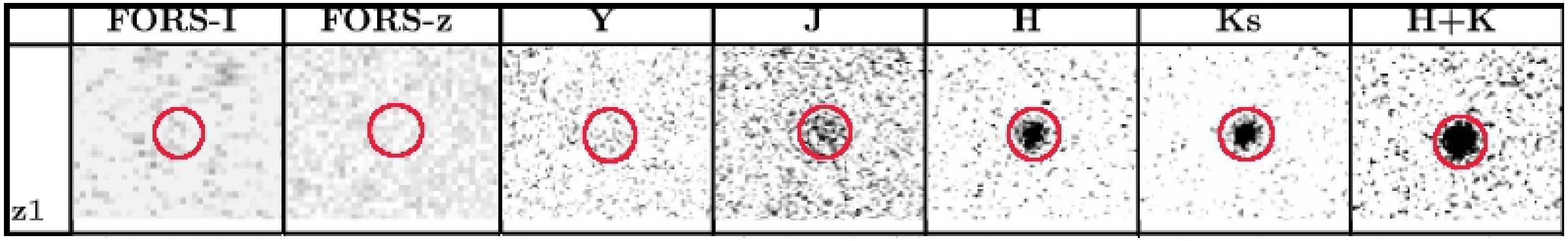


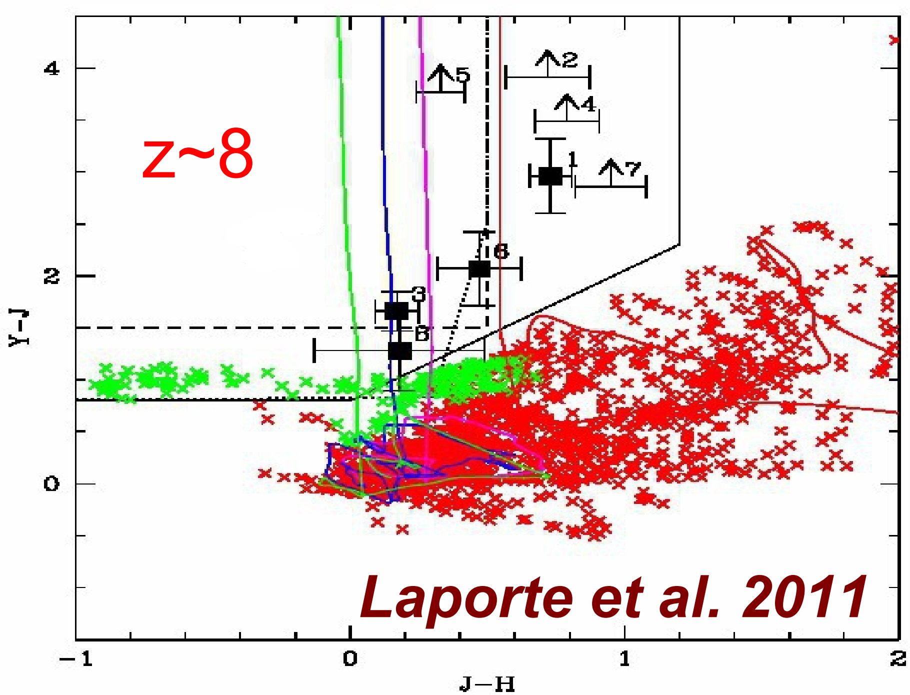
Observational constraints

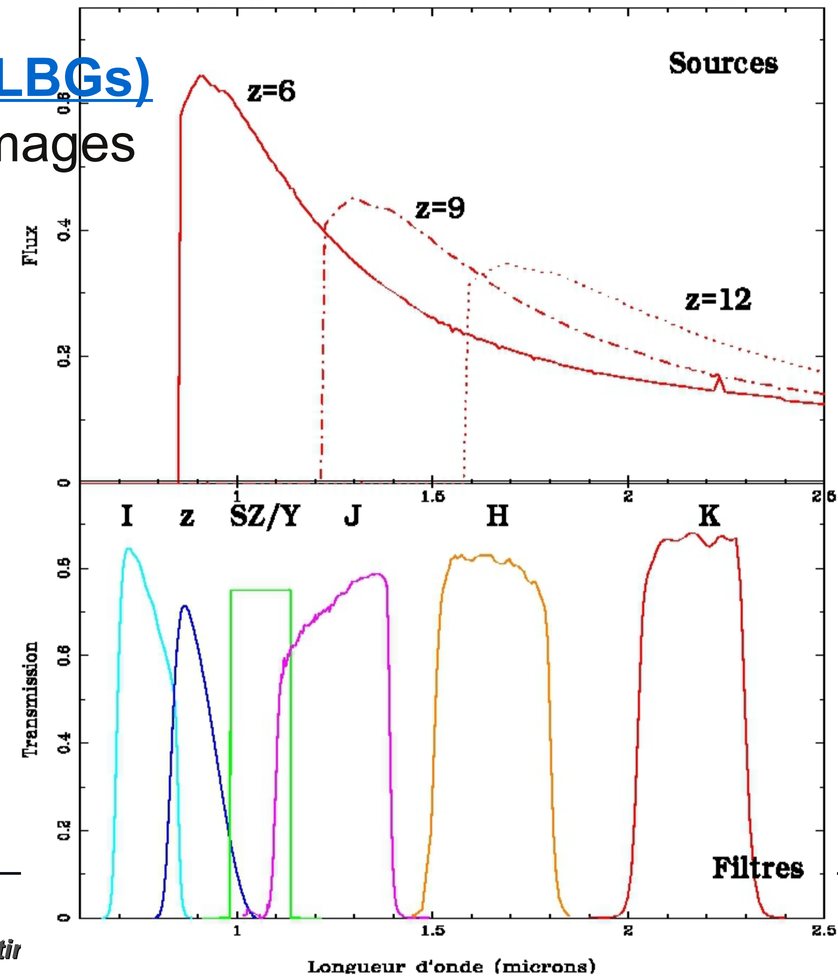


Identification of Lyman Break Galaxies (LBGs)

Ultra-deep space (HST) or ground-based images

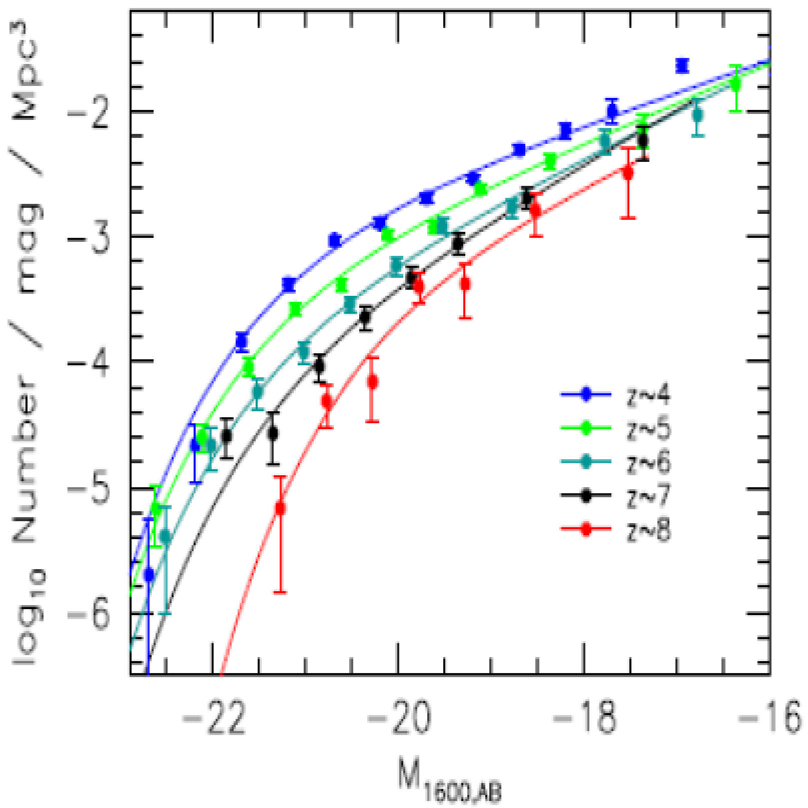
Near-IR coverage is mandatory

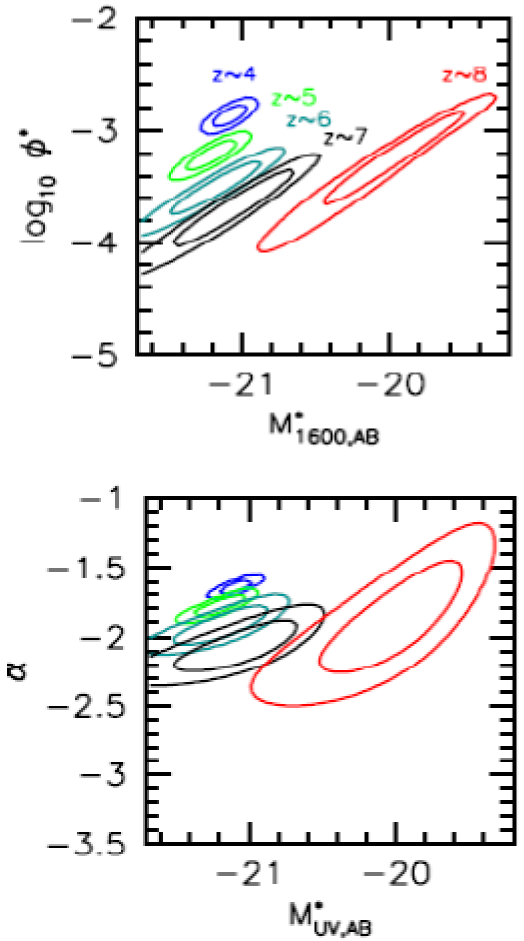




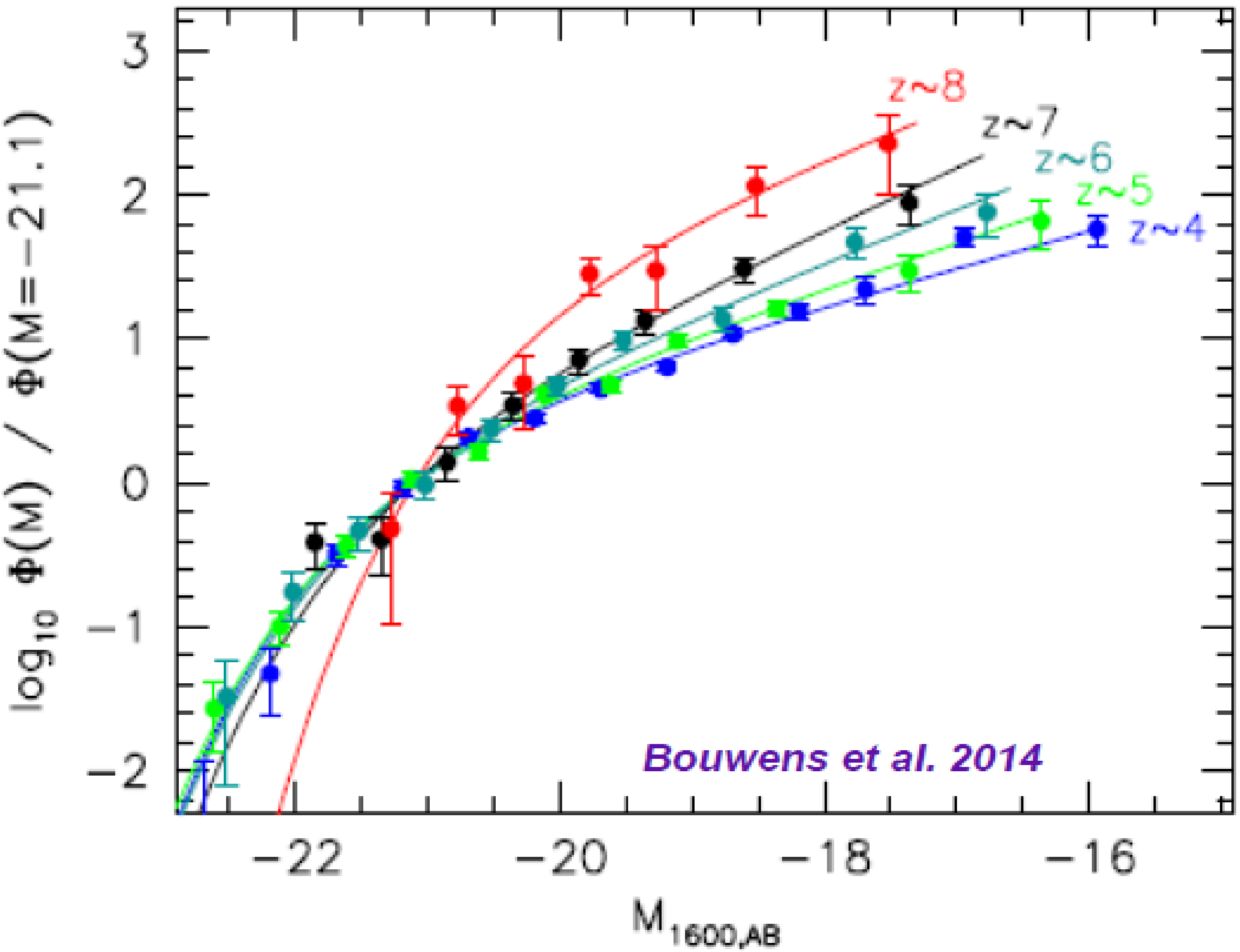
Present constraints : LBG Surveys

Bouwens et al. 2014





Present constraints : LBG Surveys

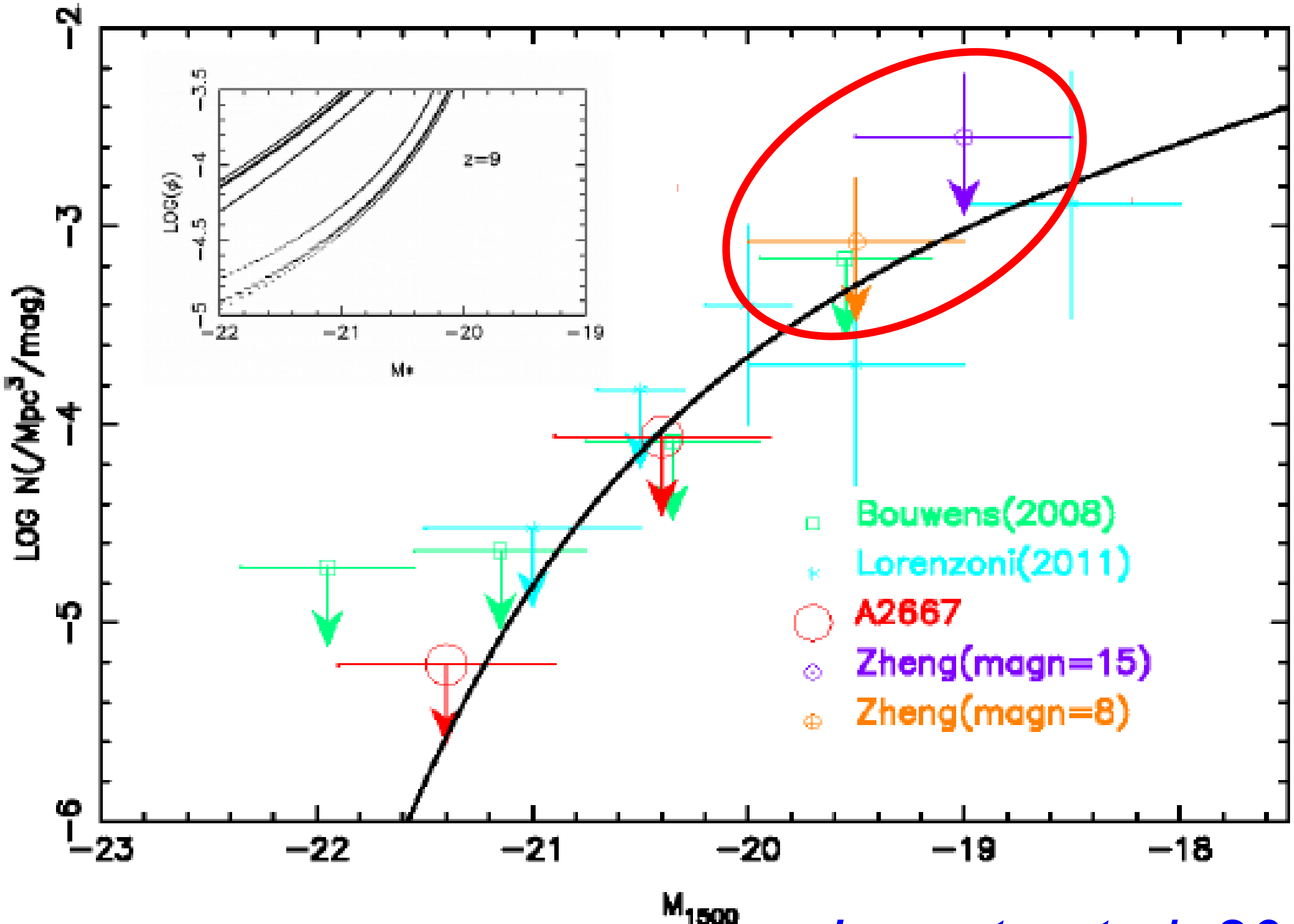


The slope of the LF becomes steeper

Present constraints : LBG Surveys

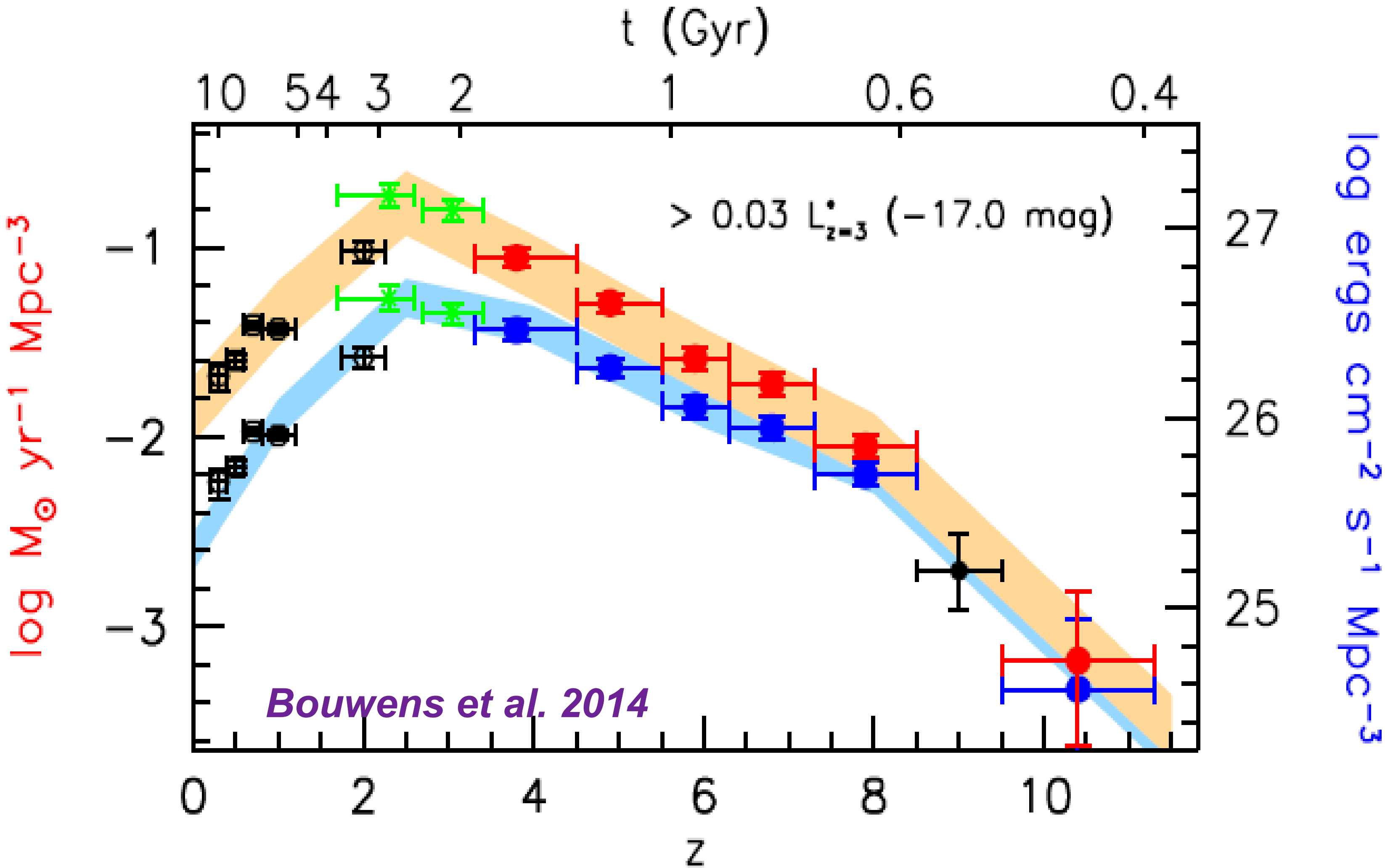
Z=9 LF(UV) constraints

Lensing LBG Surveys

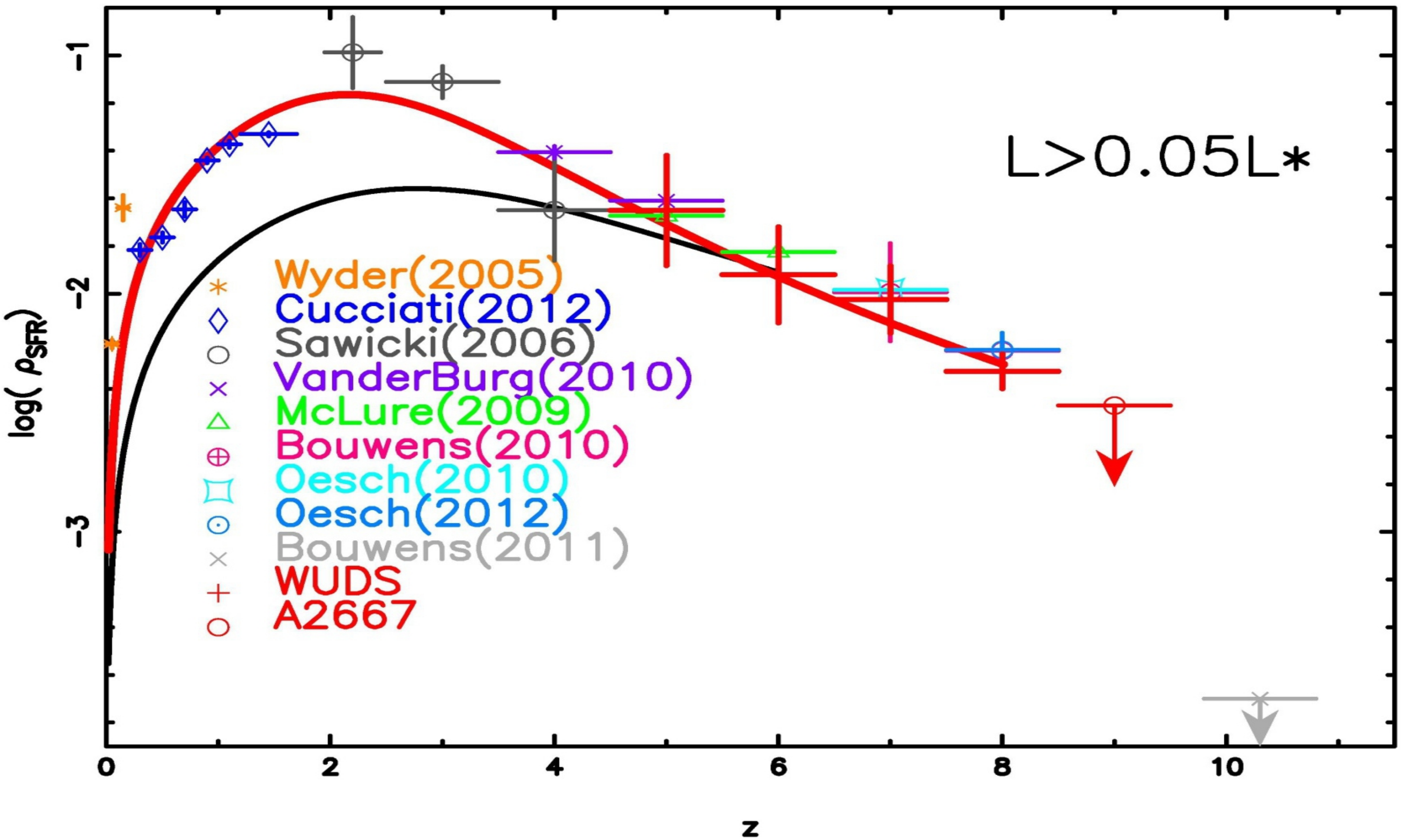


Laporte et al. 2012

Cosmic SF History



Cosmic SF History

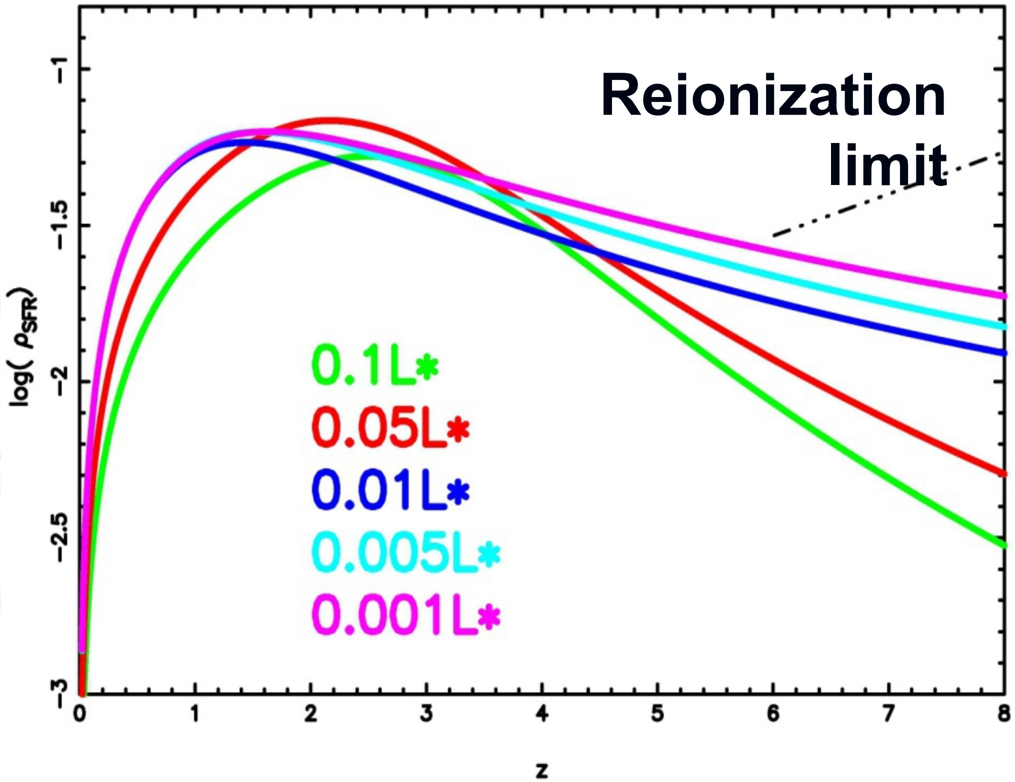


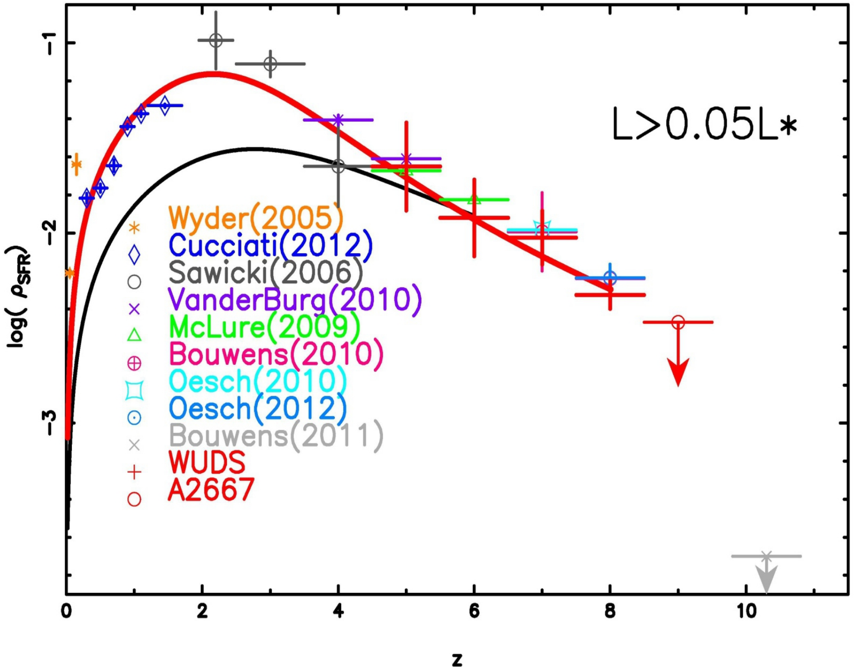
See also Filkenstein et al. 2012

from Laporte 2012

See also Filkenstein et al. 2012

$$\dot{\rho}_{UV} = \frac{6.43\times10^{25} erg.s^{-1}.Mpc^{-3}}{f_{esc}} \left(\frac{1+z}{9}\right)^3 \frac{\Omega_b h_{70}^2}{0.0458} \frac{C}{5}$$



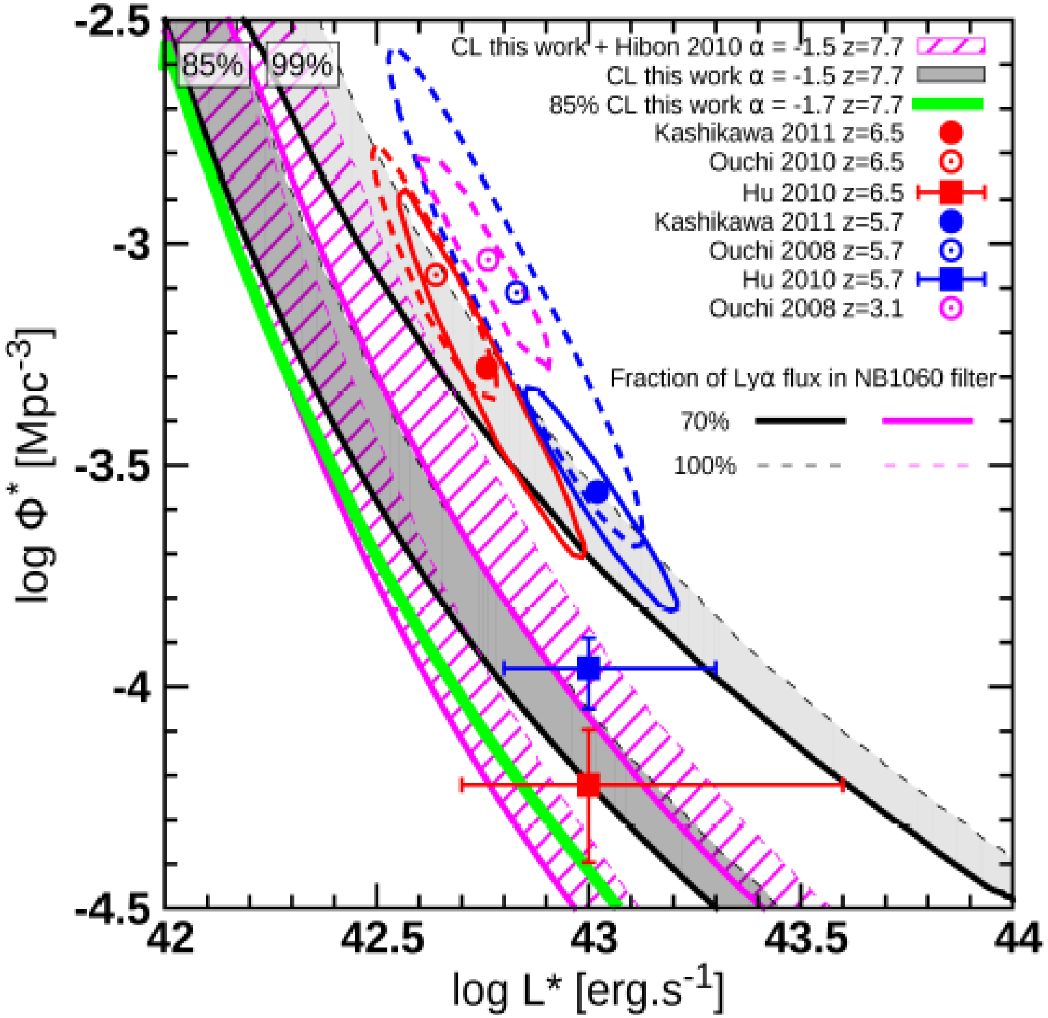


$$\rho_{UV} = \int_{0.05L^{\star}_{z=3}}^{\inf} L_{1500}\Phi(L_{1500})dL_{1500}$$

from Laporte 2012

Present constraints : LAEs

Clément et al. 2012



LAE from NB Surveys

LF based on NB surveys shows a strong decline between z~5.7 and 7

==> increase in the neutral fraction?

Other factors could be important: variations in the host-galaxy number densities, properties of interstellar gas, kinematics, dust, etc...

Project

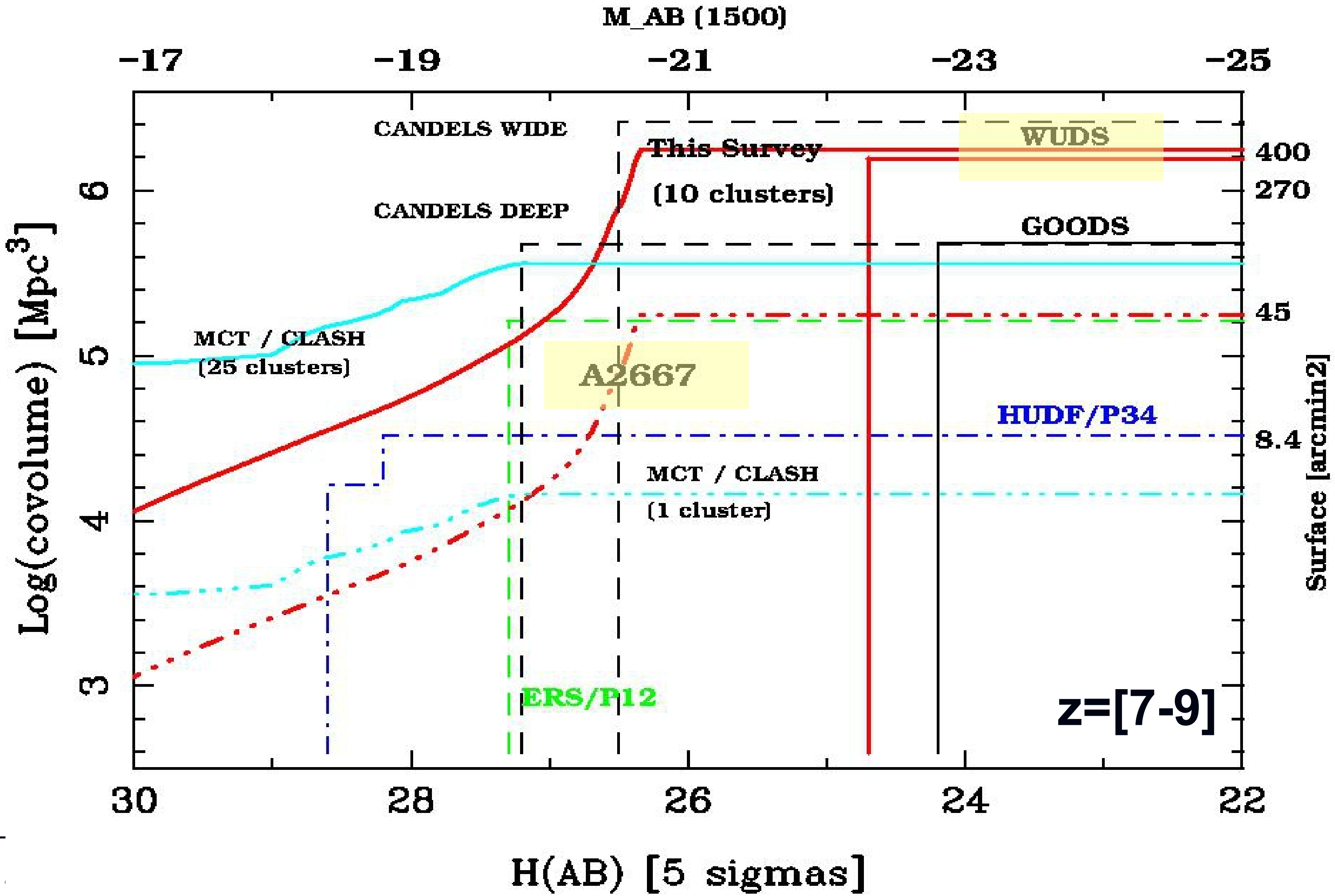
- Science goal : to ***study the first galaxies in the early universe*** and the reionization process.
- Project :

➔ to conduct a **complete census of sources responsible for the reionization** in a limited representative volume at **z~5-10**, based on 3D spectroscopy (VLT/KMOS and **MUSE**).

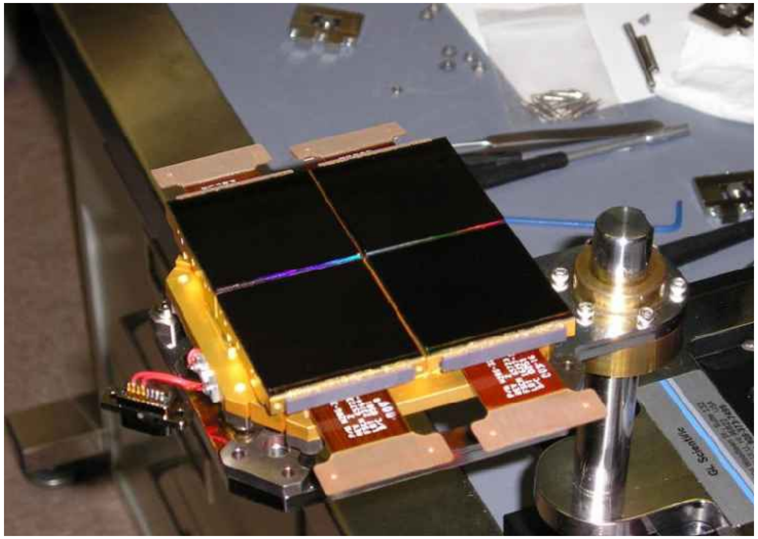
➔ to **build up and to characterize** a statistically significant sample of galaxies at $z \gtrsim 7$ with secure spectroscopic redshifts, together with an additional sample of **robust candidates based on photometric redshifts and wide multi-wavelength coverage**

An overview of the Survey

Lensing & BF survey (WUDS), looking for luminous LBGs



The blank field Survey WUDS

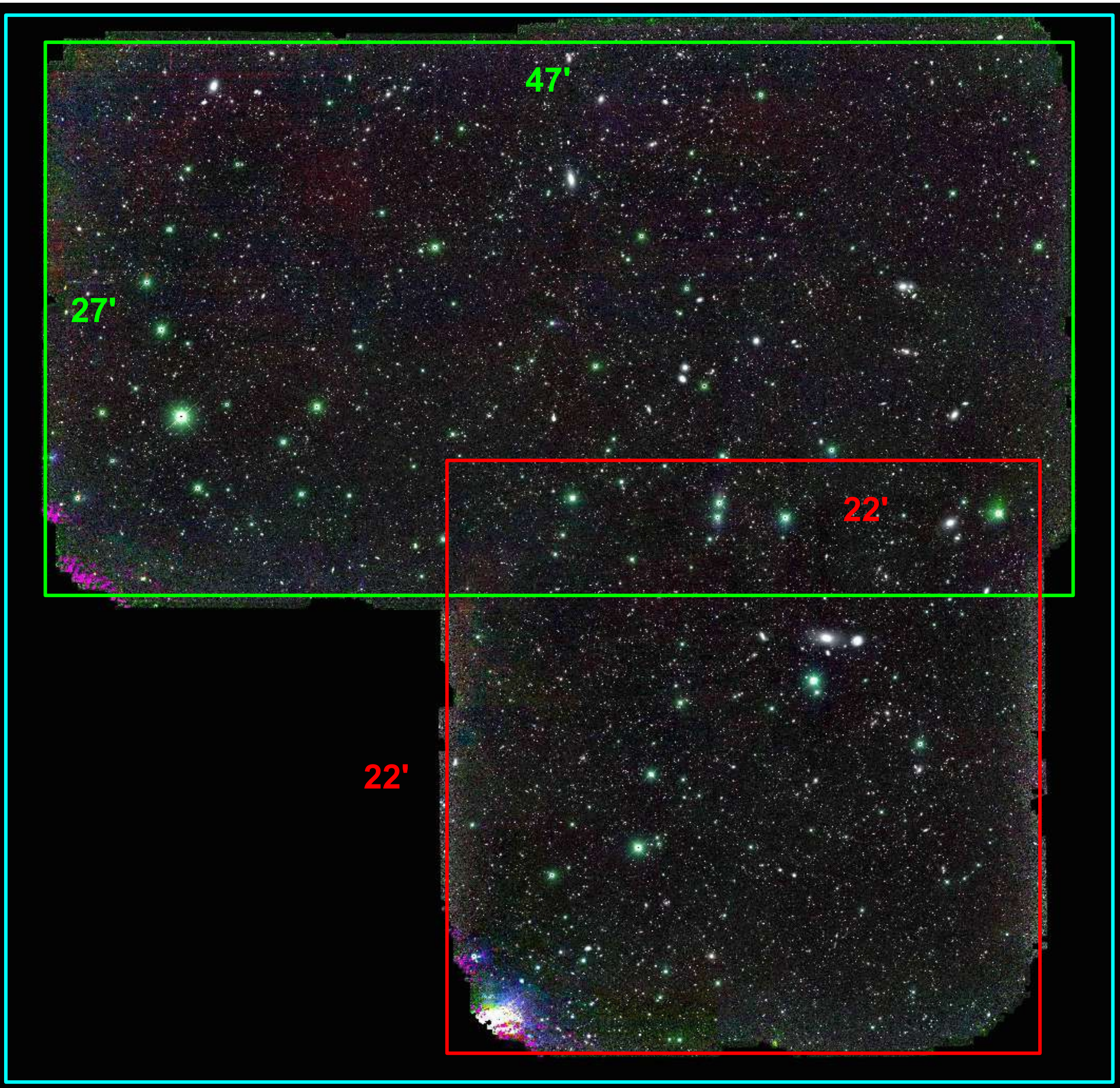


WUDS (WIRCAM Ultra-Deep Survey)

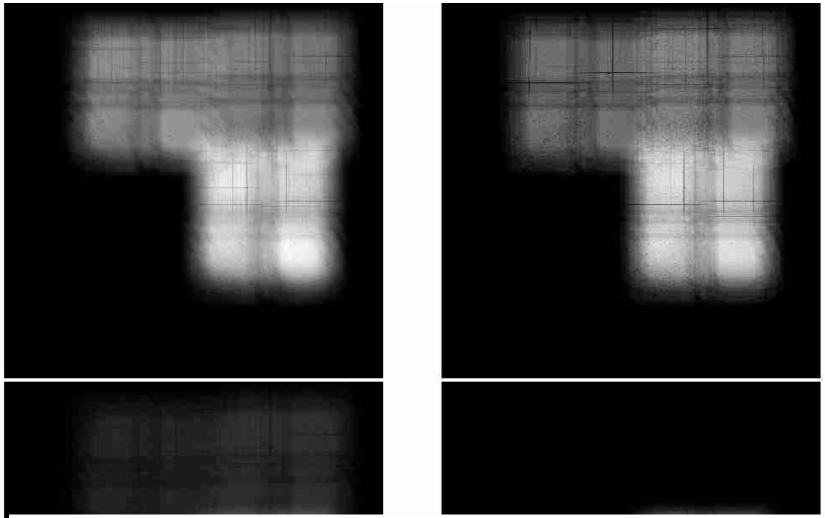
- Prime focus near-IR camera
- 2*2 CCD chips (2040*2040 pixels)
- Spatial scale = 0.306”/pixel
- FOV = 21.5 arcmin
- CCD gaps = 45”

Data processing at TERAPIX / IAP and CFHT

- 2 papers in preparation
- Public data release expected ~summer 2014



CFHTLS-D3 (0.8955 deg2) ugriz
WIRDS “shallow”region (1260 arcmin2) JHKs
WUDS Deep region (~400 acmin2) YJHKs

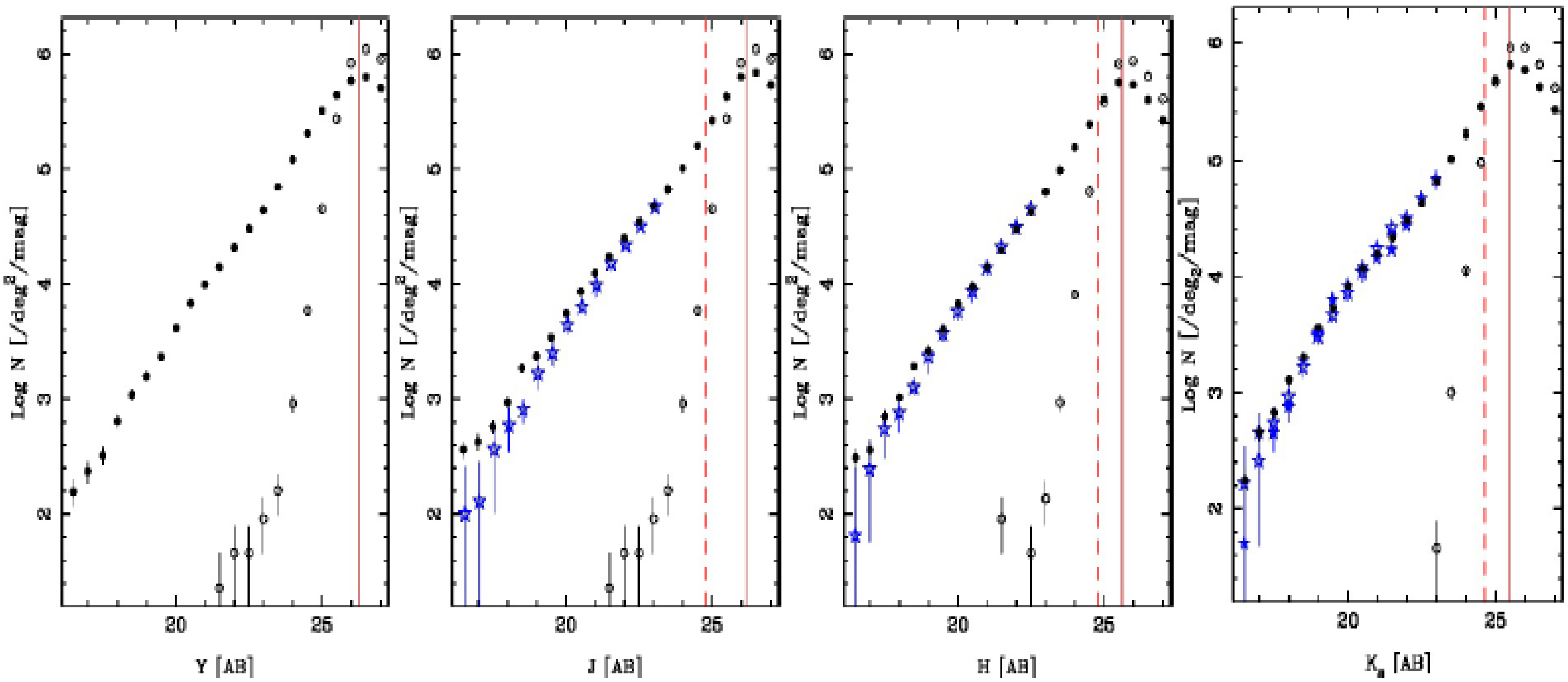


ank field Survey WUDS

Completeness analysis & depth

Reference	Filter	λ_{eff} [nm]	$\Delta\lambda_{eff}$ [Å]	C_{AB} [mag]	t_{exp} [ksec]	m(3σ) [mag]	m(50%) [mag]	seeing [″]	Area (>50%) [arcmin^2]
CFHTLS-D3	u^*	382	544	0.312	76.6	28.52	26.97	0.89	3224
CFHTLS-D3	g	490	1309	-0.058	79.6	28.94	26.79	0.84	3224
CFHTLS-D3	r	625	1086	0.176	142.8	28.57	26.30	0.78	3224
CFHTLS-D3	i	766	1330	0.404	249.4	28.24	25.95	0.76	3224
CFHTLS-D3	z	884	1033	0.525	175.4	27.09	25.46	0.69	3224
WUDS	Y	1027	1077	0.632	44.9	26.78	26.26	0.63	392
WUDS	J	1256	1531	0.949	50.4	26.69	26.17	0.60	396
WIRDS	J				26.3	25.80	24.80	0.60	437
WUDS	H	1636	2734	1.390	39.6	26.06	25.61	0.55	477
WIRDS	H				15.5	25.73	24.80	0.55	681
WUDS	K_s	2154	3071	1.862	25.9	25.93	25.46	0.56	450
WIRDS	K_s				17.5	25.59	24.63	0.56	547

WUDS



Pello et al. 2014

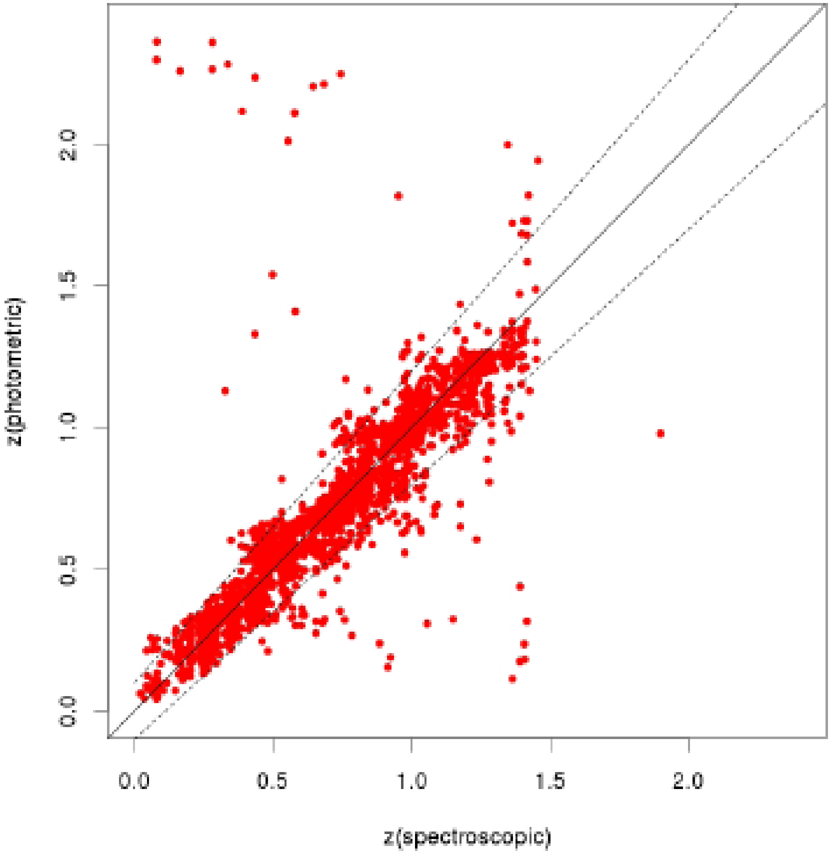
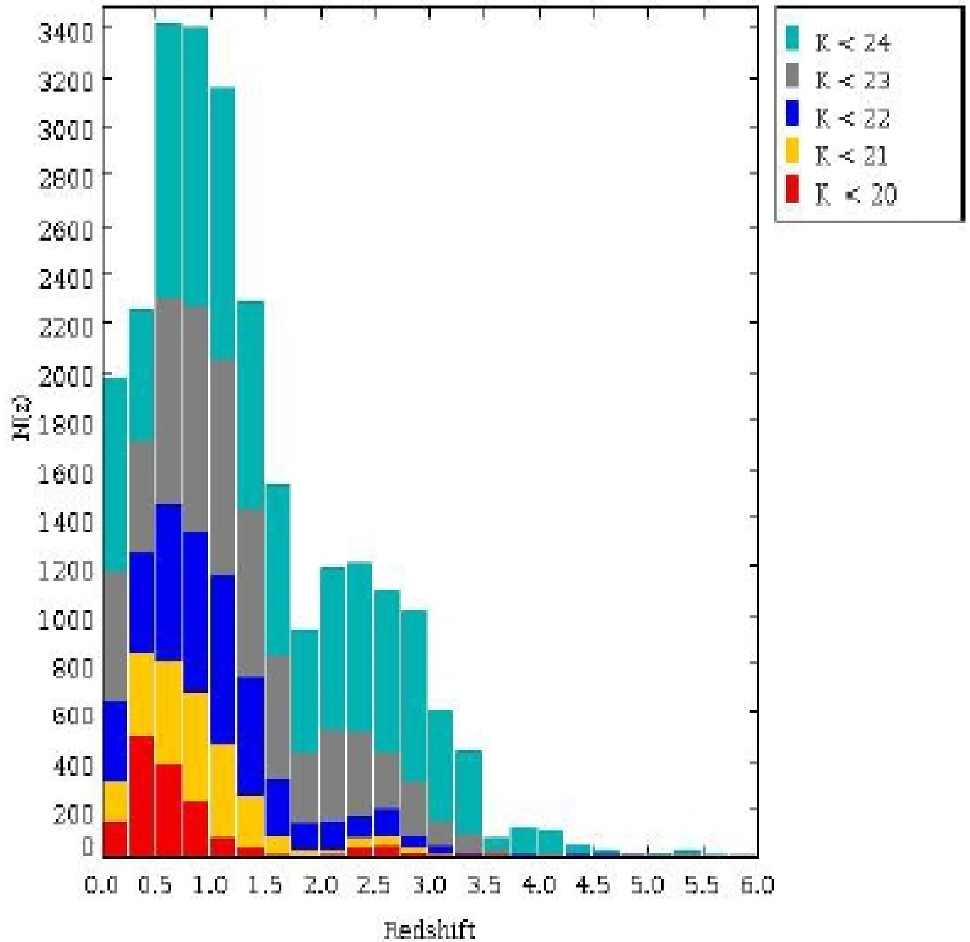


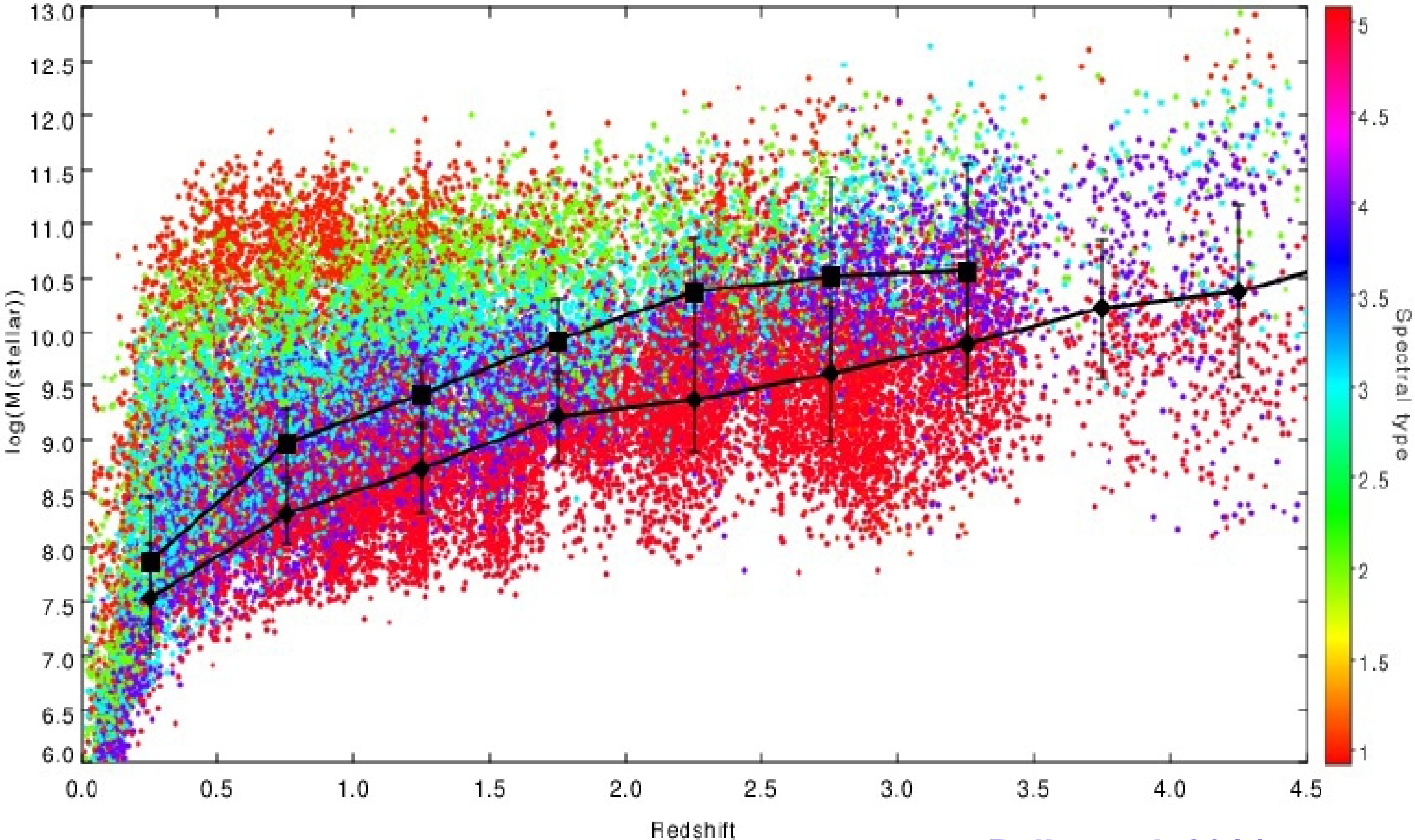
Table 4. Summary of the z_{phot} quality achieved with *New–Hyperz* on the WUDS/CFHTLS D3 field.

Detection	$H+K$ (1)	(2)	$i+z$ (1)	(2)
$\sigma(\Delta z/(1+z))$	0.047	0.048	0.051	0.050
$\sigma(\lvert\Delta z/(1+z)\rvert)$	0.031	0.031	0.032	0.032
Median $(\Delta z/(1+z))$	0.0016	0.0017	-0.0017	-0.0012
$\sigma_{z,MAD}$	0.043	0.043	0.046	0.045
Outliers	4.4%	4.4%	4.9%	4.9%

Notes.
(1) Flat prior
(2) LF prior



Pello et al. 2014



Pello et al. 2014

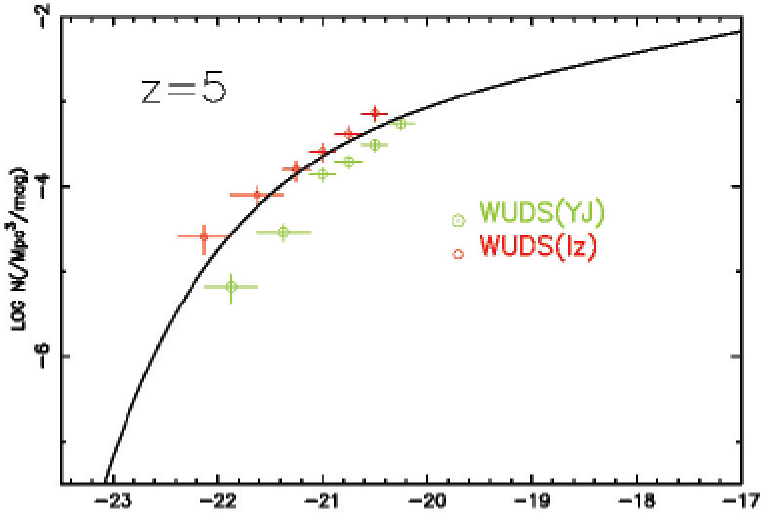
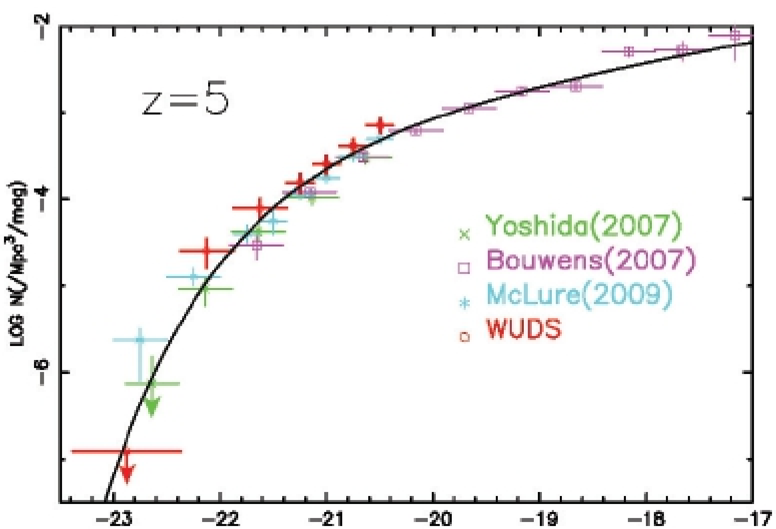


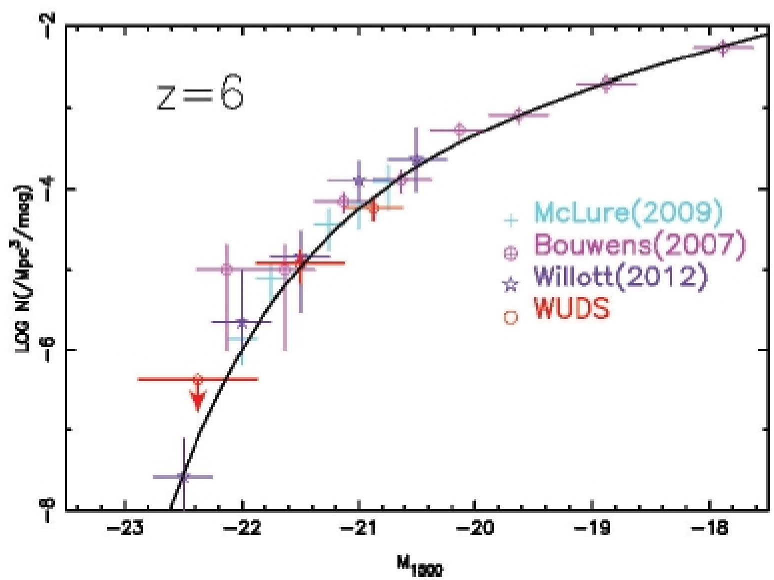
Figure 9. Comparison between the LF points at z=5 derived from two different detection images : $i + z$ (in red), and C1 ($Y + J$, in green).

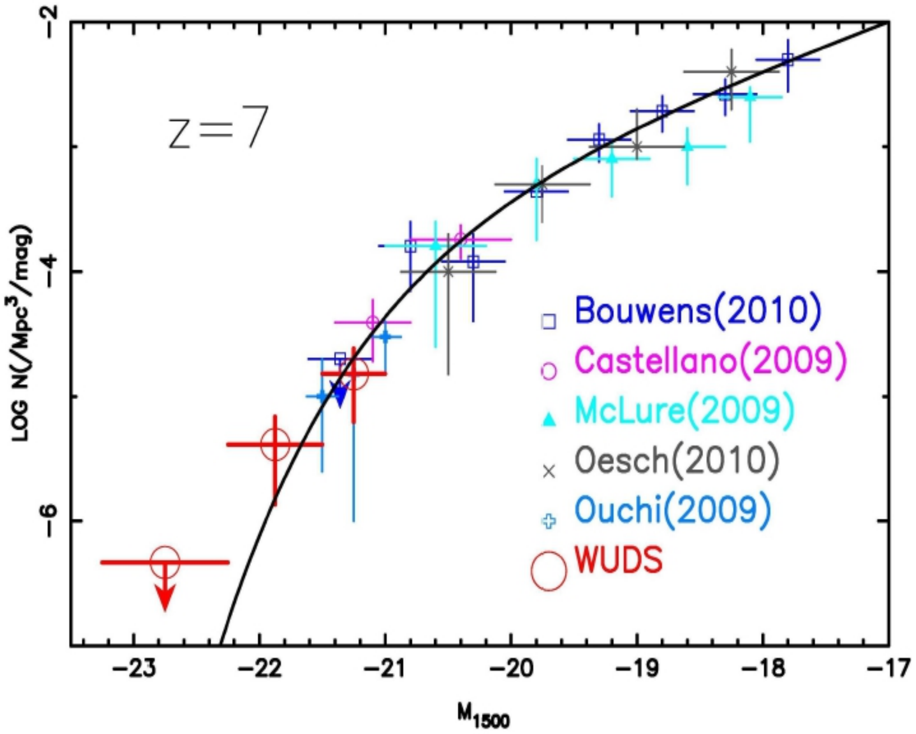
Table 5. Number of sources included in the different redshift bins, for the different selection criteria and input catalogs.

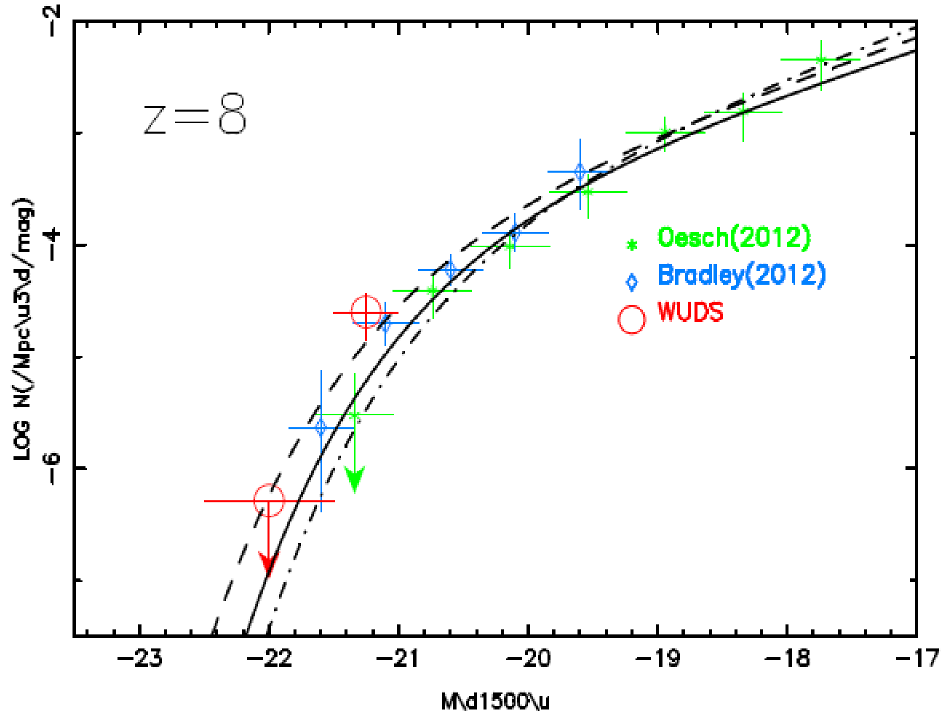
Criteria	$(i + z)$ N	C1 $(Y + J)$ N	C2 $(H + K_s)$ N
r–dropout (raw)	2016	2591	2797
z~ [4.5 - 5.3] CC window	863	1085	1205
CC window corrected	817	711	-
i–dropout (raw)		166	134
i–dropout (corrected)		91	71
z~ [5.3 - 6.4] CC window		98	66
CC window corrected		48	32
z–dropout (raw)		212	256
z–dropout (corrected)		142	132
z~ [6.3 - 7.2] CC window		36	30
CC window corrected		14	11

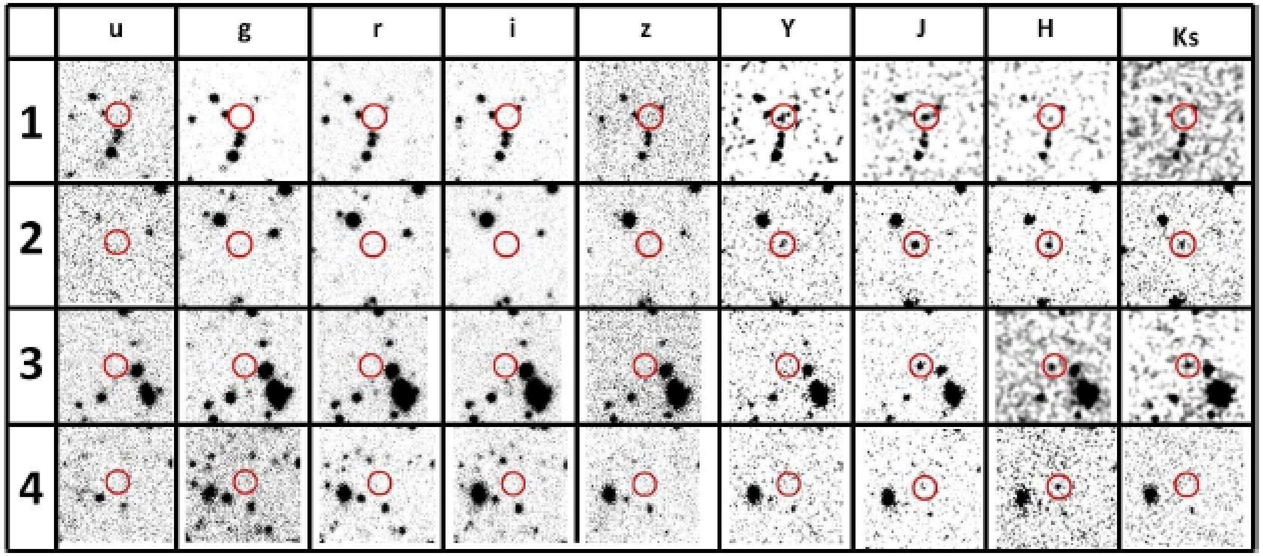
Pello et al. 2014
Laporte et al. 2014











Laporte et al. 2014

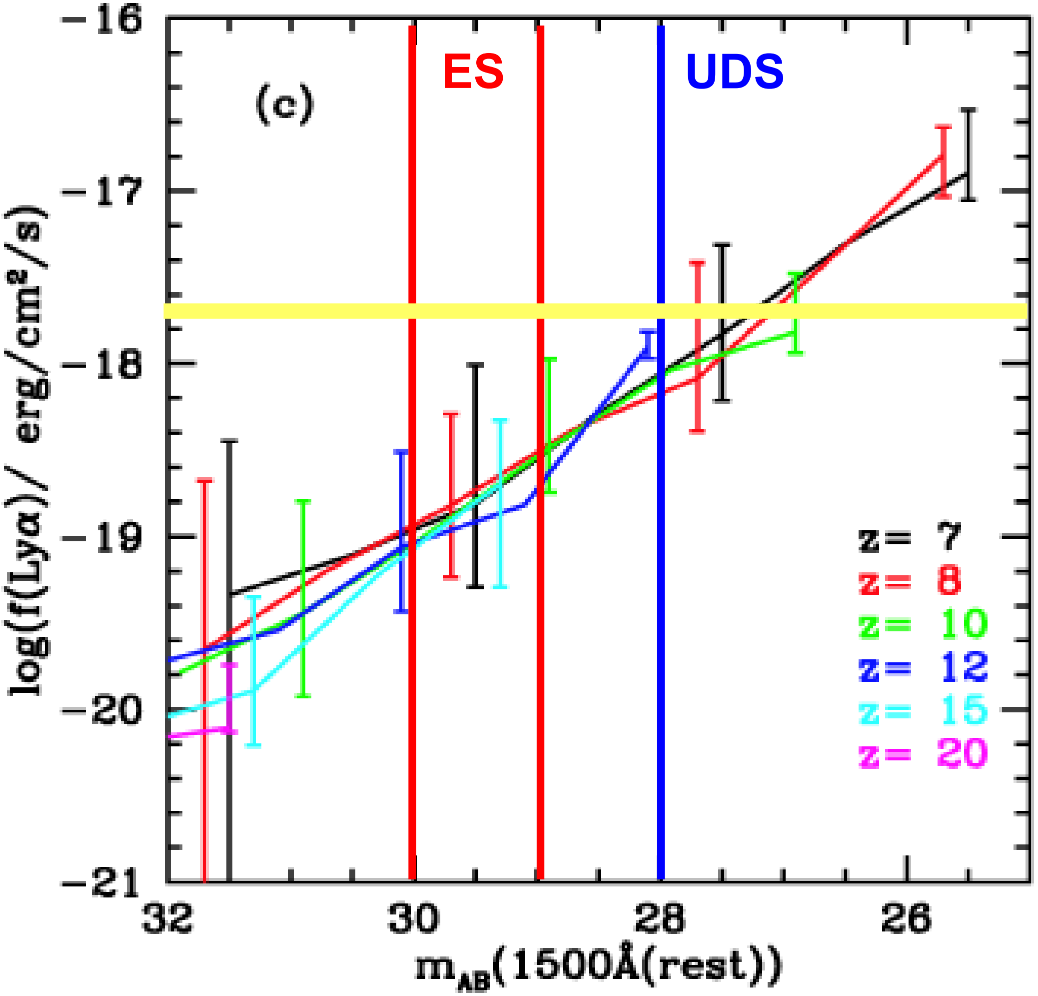
Survey Strategy for spectroscopy

Lyman alpha flux

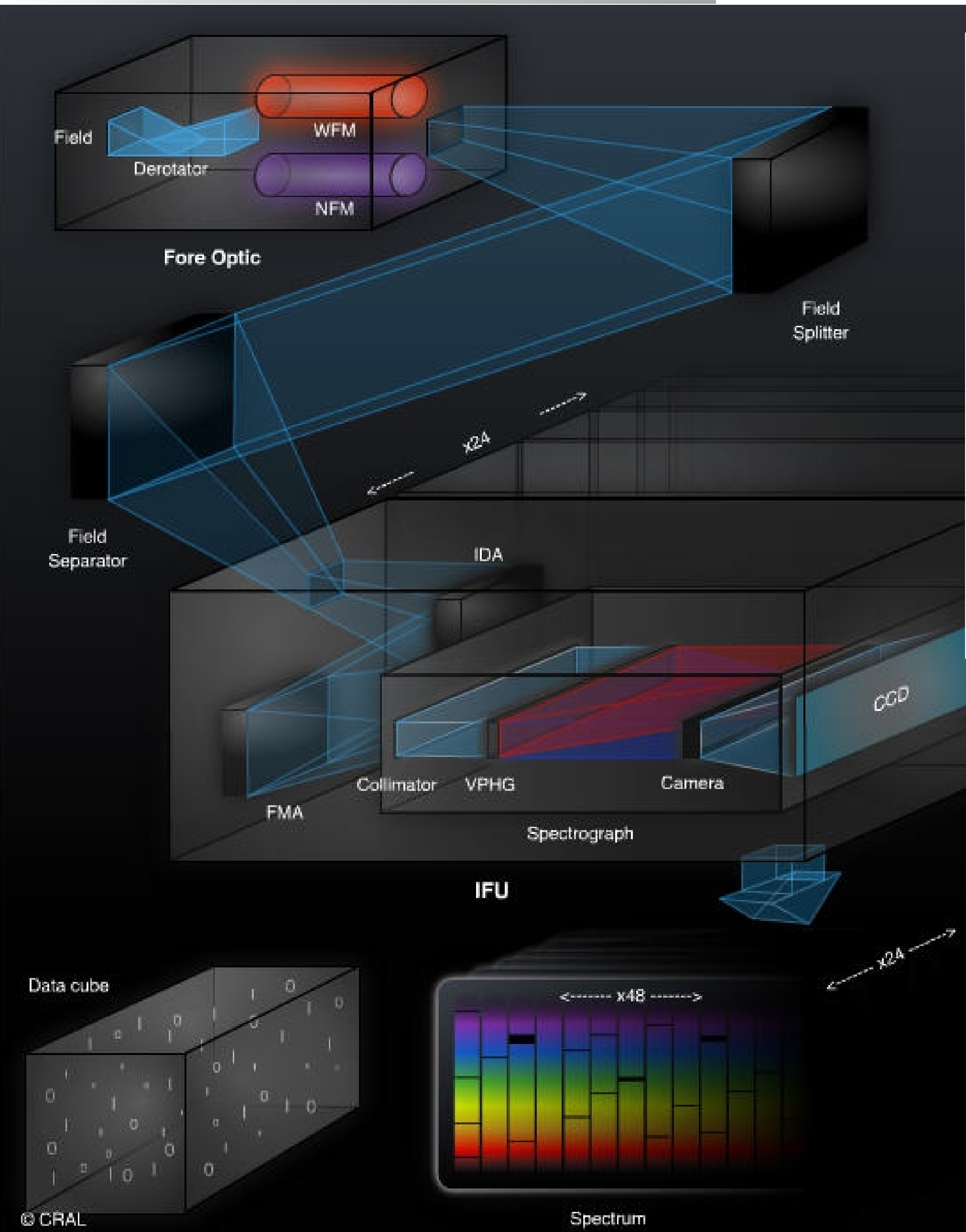
GALFORM
Lacey et al. 2011

Evolution of LBGs properties in the ΛCDM model

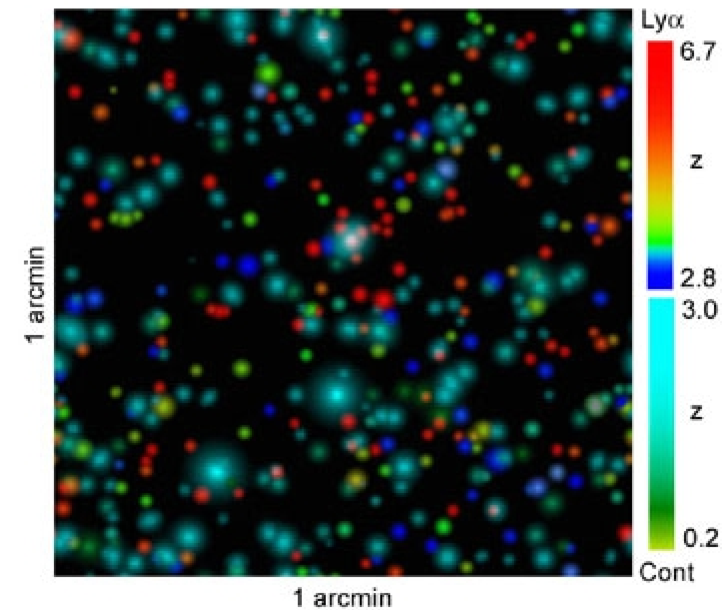
Ly alpha flux (assuming escape fraction 2%) ~ a few 10^{-18}- 10^{-19} erg/cm2/sec for LBGs with m~28-30 (within the reach of E-ELT)



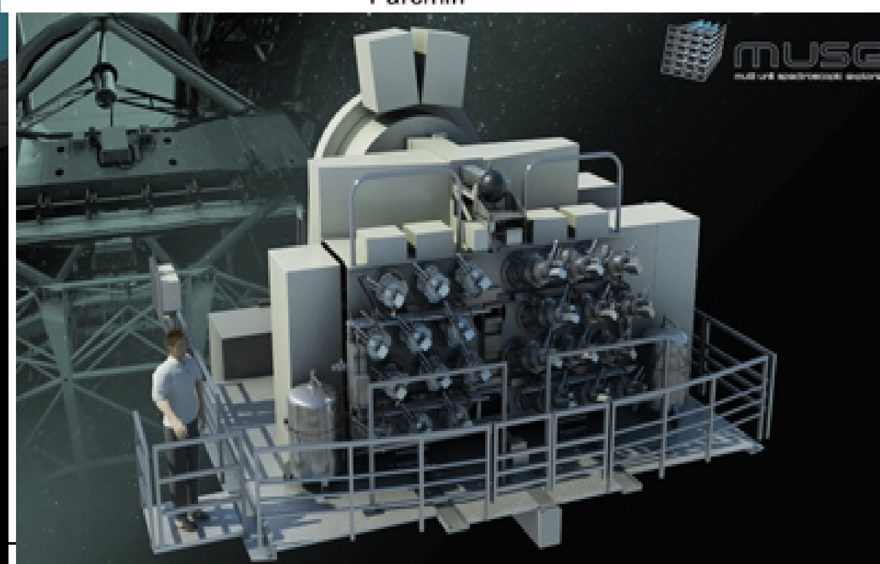
MUSE GTO



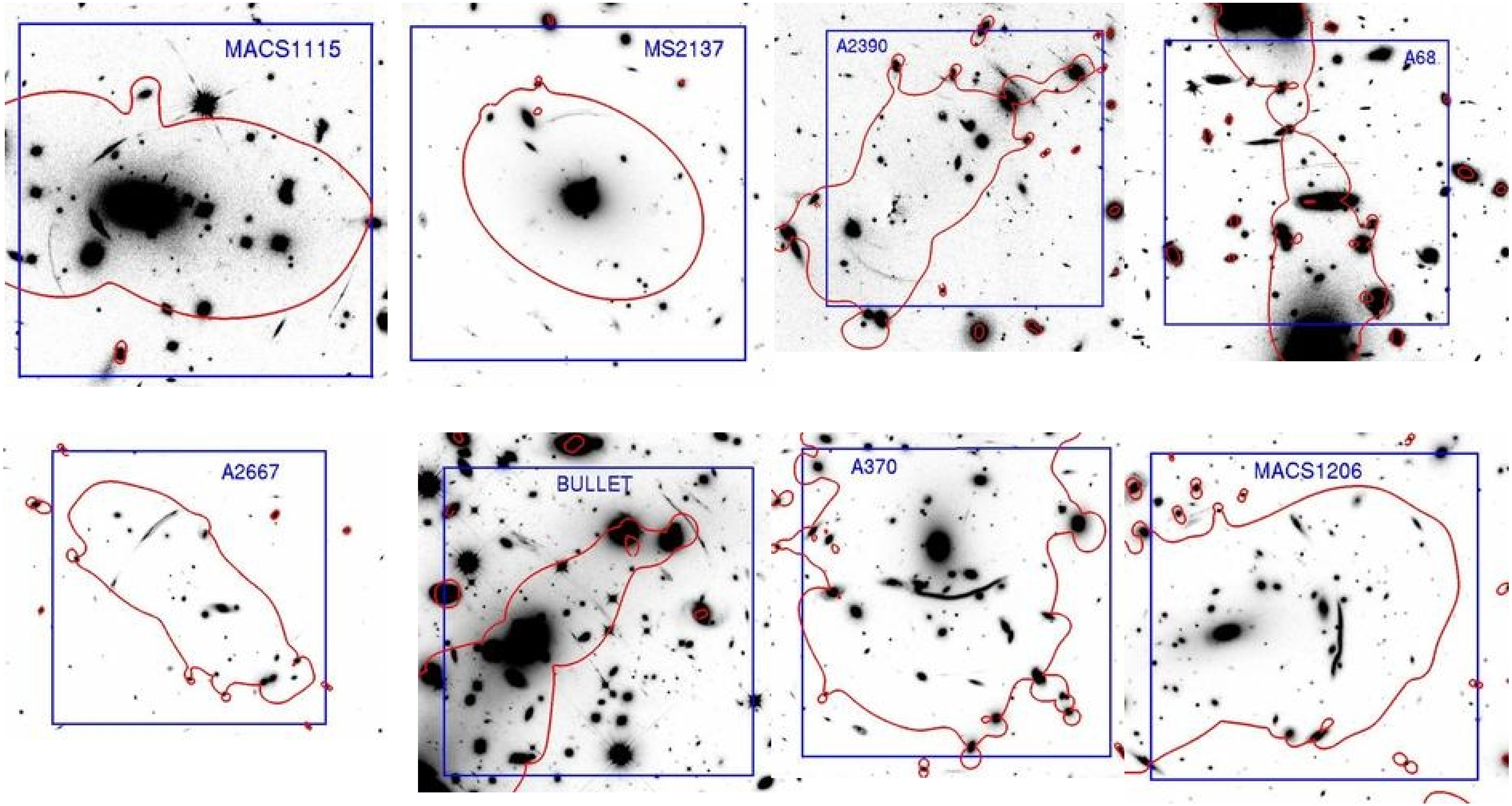
Field
Derotator
WFM
NFM
Fore Optic
Field
Splitter
x24
Field
Separator
IDA
CCD
FMA
Collimator
VPHG
Camera
Spectrograph
IFU
Data cube
<-------- x48 -------->
<-------- x24 -------->
© CRAL
Spectrum



Lyα
6.7
z
2.8
3.0
z
0.2
Cont
1 arcmin
1 arcmin

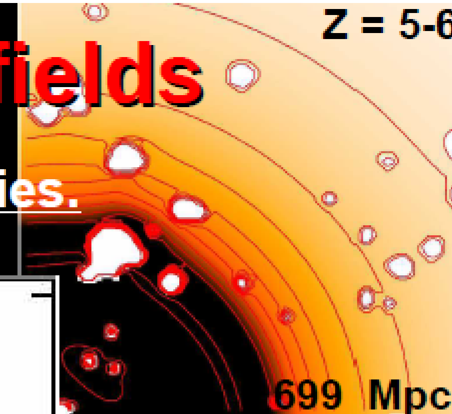


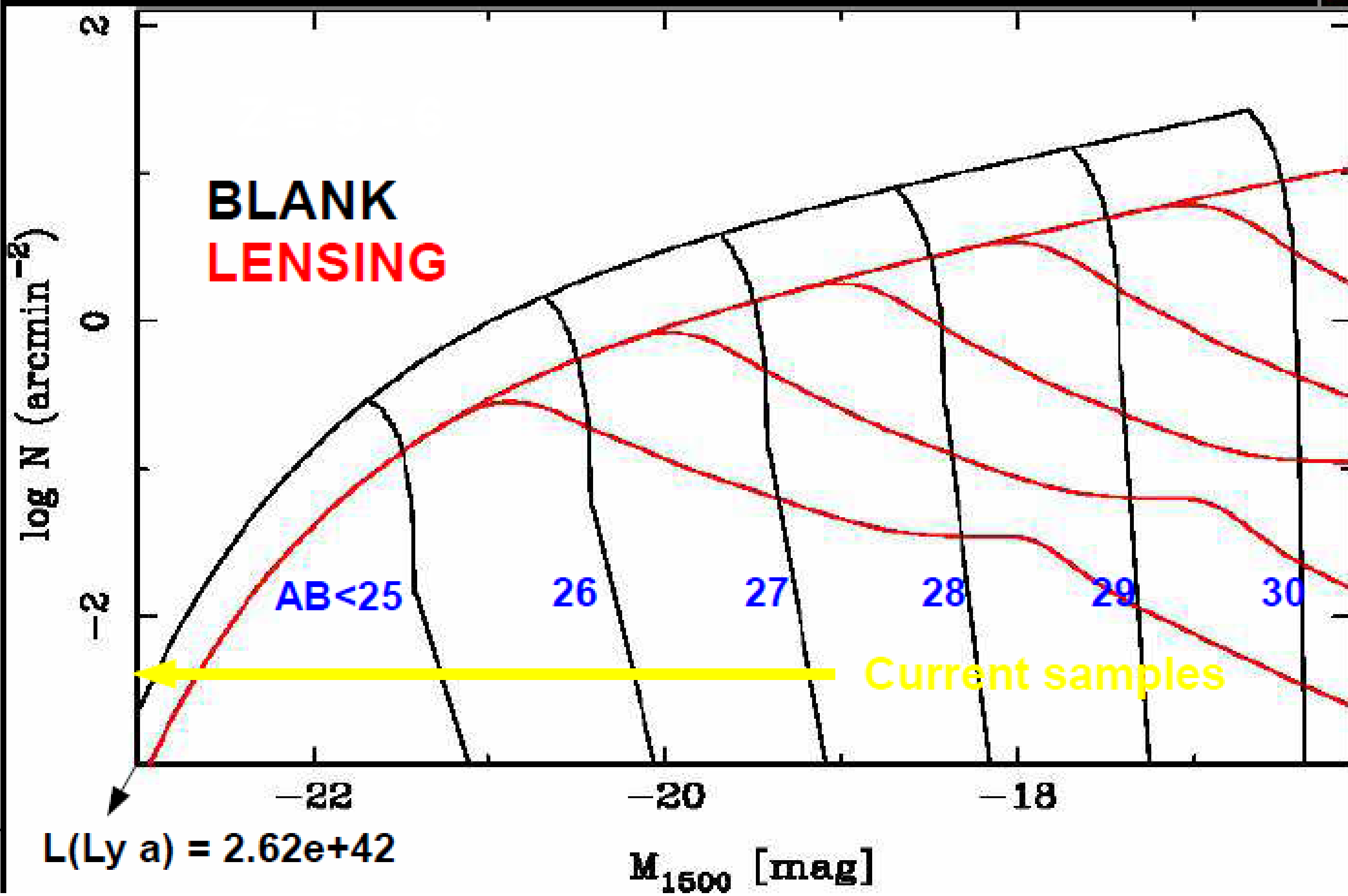
MUSE GTO



Blank Field versus lensing fields

- Lensing and BF sample **different intrinsic luminosities.**



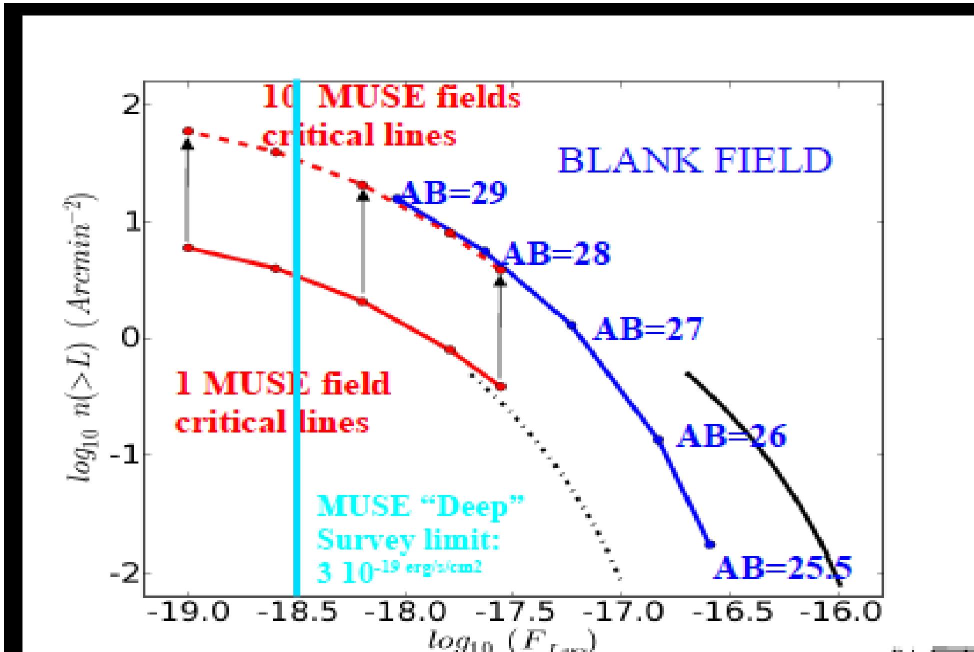


Mean magnification Factor μ ~ 34

When limited to μ < 100 : <μ> ~ 8.7 (median ~ 3.2)

34

MUSE GTO

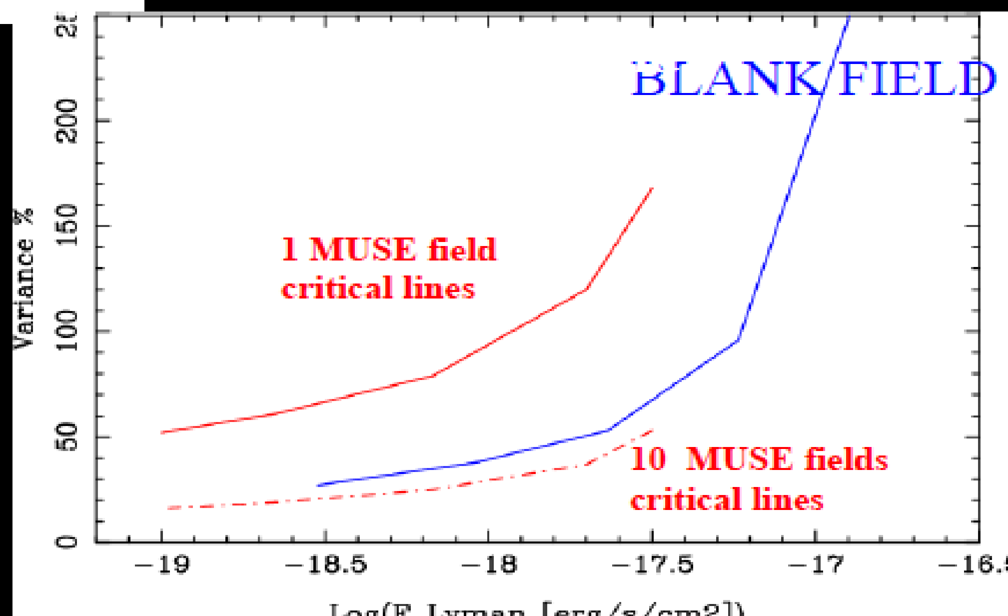


Errors in Lensing models:

m_AB=25.5 => 23%
m_AB=26.0 => 17%
m_AB=27.0 => 11%
m_AB=28.0 => 7%
m_AB=29.0 => 5%

$$\sigma_\nu^2 = \frac{\int_V \int_V d^3 x_1 d^3 x_2 \xi(|x_1 - x_2|)}{\int_V \int_V d^3 x_1 d^3 x_2}$$

Trenti & Stiavelly (2008)

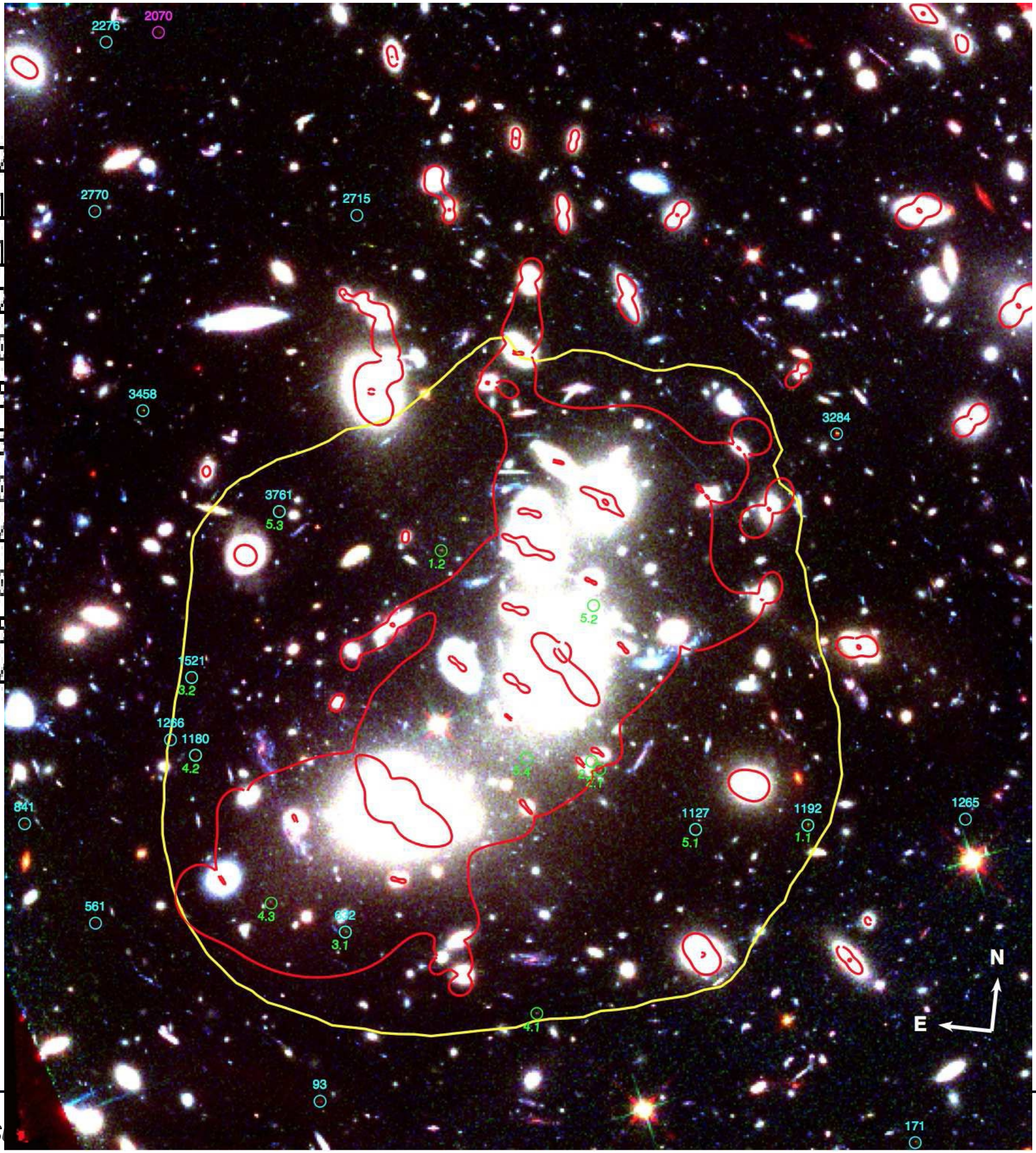


MUSE GTO

## TargetName	RA	Dec
A2744-01	00 14 23.8	-30 23 2
A2744-02	00 14 19.2	-30 23 1
A2744-03	00 14 18.5	-30 24 1
A2744-04	00 14 23.1	-30 24 2
M0416-01	04 16 09.1	-24 04 0
M0416-02	04 16 07.1	-24 04 5
RCS0224	02 24 34.2	-00 02 3
MACS1206	12 06 12.2	-08 48 0
A370	02 39 52.9	-01 34 4
A2667	23 51 39.4	-26 05 0
A2390	21 53 34.8	+17 41 5
BULLET	06 58 33.9	-55 56 4

Present data :
Comm1 (A1689) +
Comm2 (SMACS2031)
GTO : starting Sept 2014

Ongoing LBG analysis(David)



- Formation of galaxies : characterization of the **first star-forming galaxies (z~6-15)** **& complete census of LBG/LAE at z~5-10**

➔ Efficient & robust (photometric) selection of LBGs

➔ **Redshift** mesurements (based on Ly alpha + other strong e-lines)

➔ Determination of the **nature** of high-z galaxies

➔ ***Spectroscopy : Use of well-known indicators to determine the physical parameters surch as***

=> The Lyman alpha luminosity and equivalent widths. Combined constraint on the *maximum age / Initial Mass Function / metallicity*. Metallicity constraints If metal lines (e.g. CIV 1550...) measured.
=> HeII 1640 emission (+ detection or non-detection of metal lines) would be a unique indication of *extremely metal-poor stellar populations*.
=> Lyman alpha profiles and estimates of the *IGM transmissivity* will be used to place constraints on the contribution of these objects to cosmic reionization.

+ *Multi-wavelength characterization*

Future Plans

- **Exploitation of MUSE GTO (2014++). LAE & LBGs in lensing fields at z~5-7**
  - Comm1 + Comm2 available
  - GTO : Starting Sept 2014
- **Spectro follow up of WUDS candidates:**
  - Z<~7 with OSIRIS/GTC. First proposal cat B in 2014.
  - Z >~7 with EMIR/GTC GOYA Survey (2015++)

ANNEXES