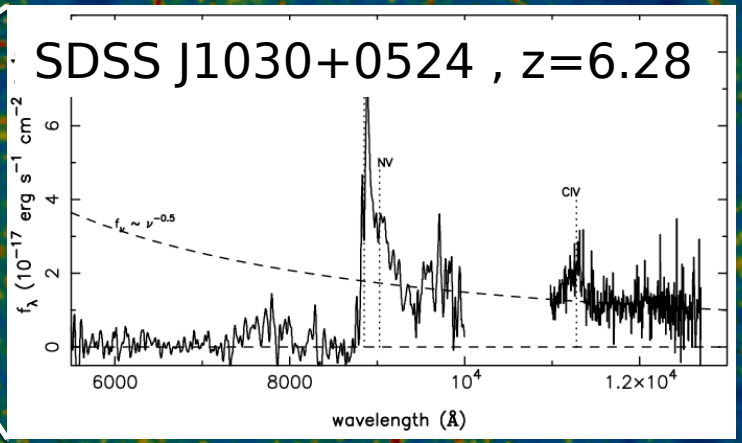
Large scale galaxy overdensities around z~6 QSOs

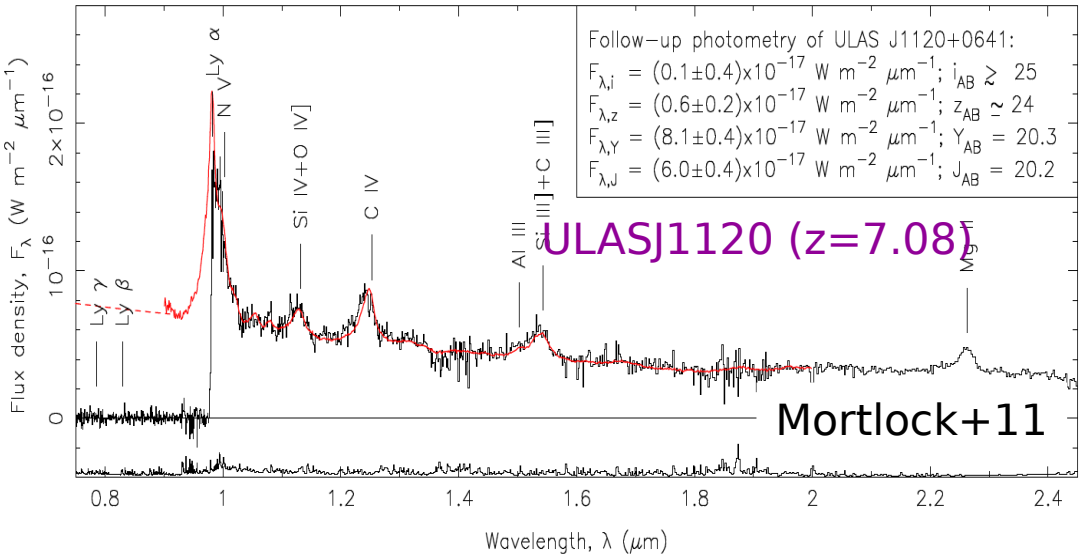


Roberto Gilli
(INAF – Oss. Astronomico di Bologna)

In collaboration with: M. Mignoli, B. Balmaverde, E. Vanzella, C. Vignali, N. Cappelluti, L. Morselli, E. Sani, F. Calura, A. Comastri, and many others

he persistent challenge of luminous z>6 QSO

i.e. SMBHs grown to 10^9 M_{sun} in less than 1 Gyr



- When, where, and how did they form and grow?

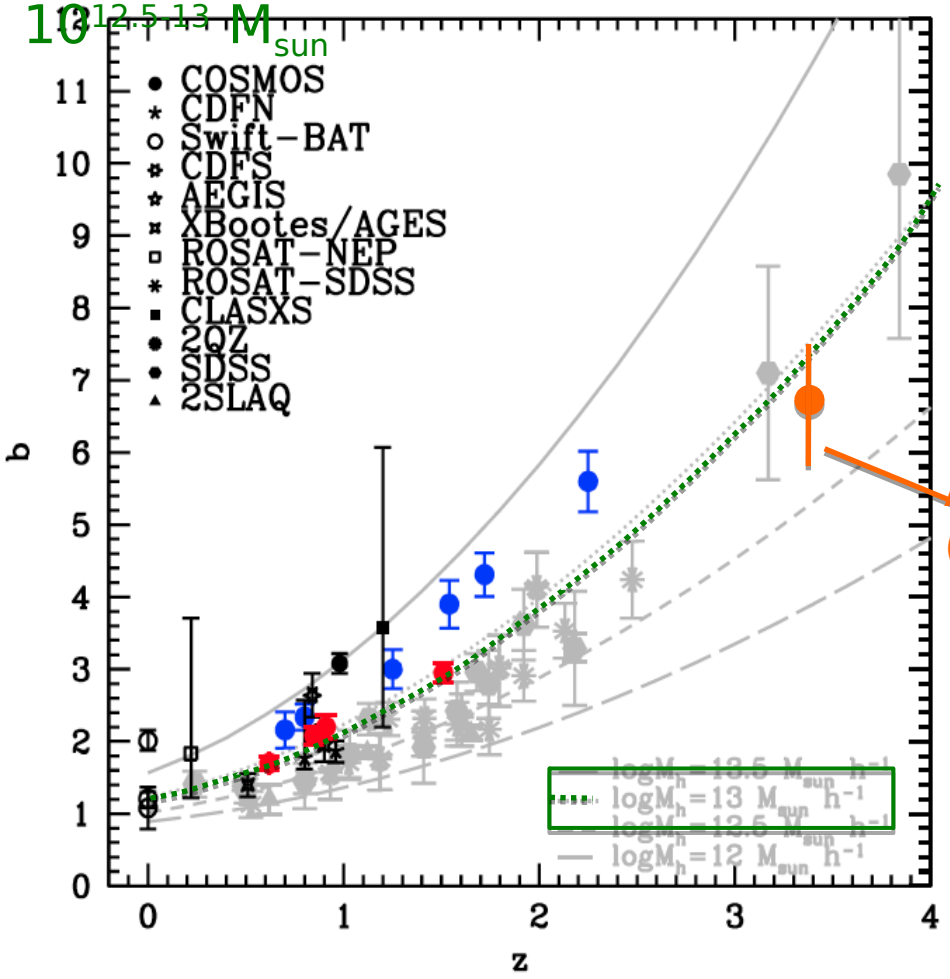
- What is their origin (seeds)?

Accreting SMBHs at z~6 are:

1) big: $M_{BH} = 10^9\ M_{sun}$ ✉ $M_* = 10^{11}\ M_{sun}$ ✉ $M_{halo} \sim 10^{12.5\text{-}13}\ M_{sun}$

2) rare: 1 per Gpc^3, like $10^{13}\ M_{sun}$ halos (for duty cycle=1)

3) likely highly biased: extrapolation from lower-z gives $M_{halo} \sim 10^{12.5\text{-}13}\ M_{sun}$

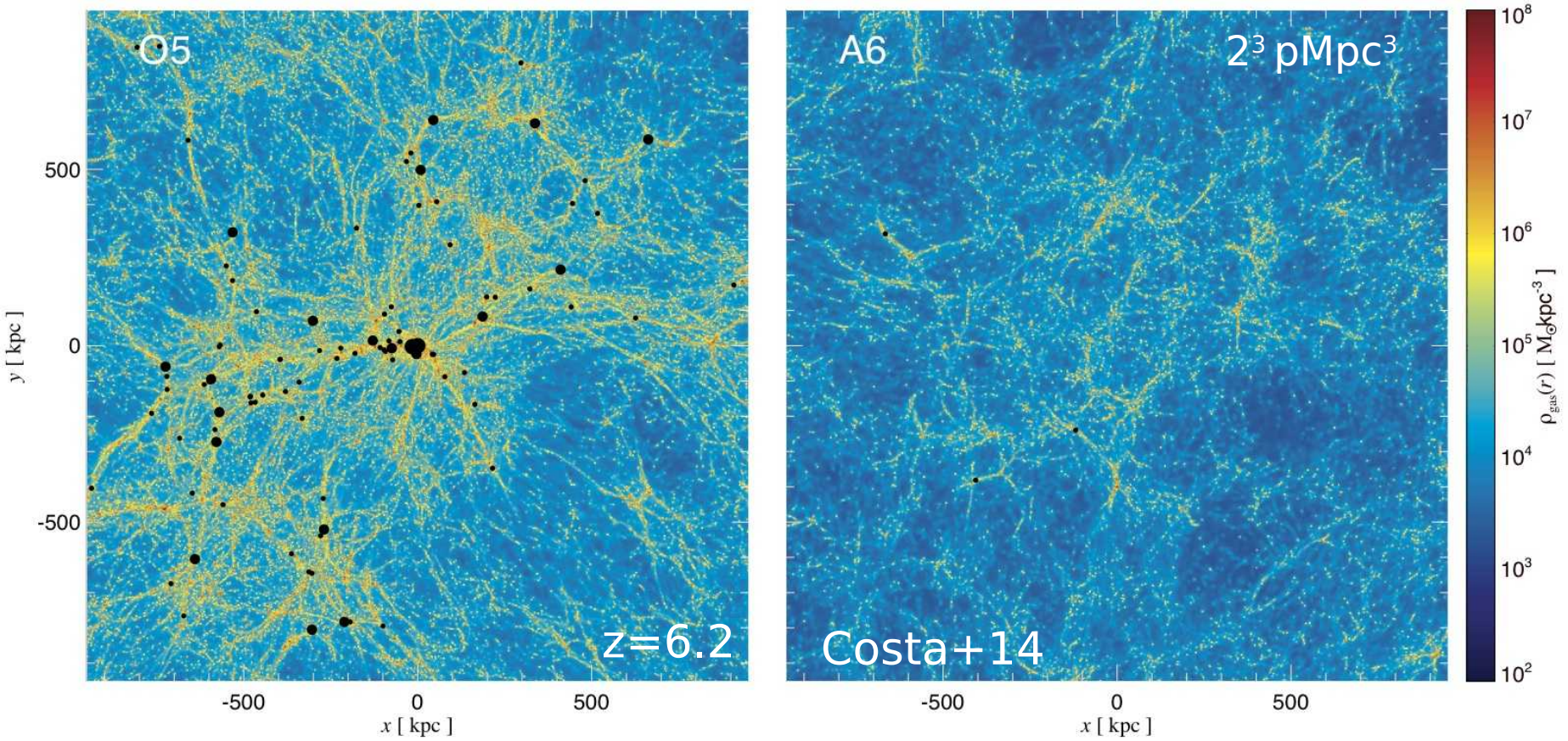


All indirect evidences that early QSOs form in the highest peaks of the density field

Allevato+16 submitted (COSMOS-Legacy)

Cappelluti+ 12

Simulations of early BH

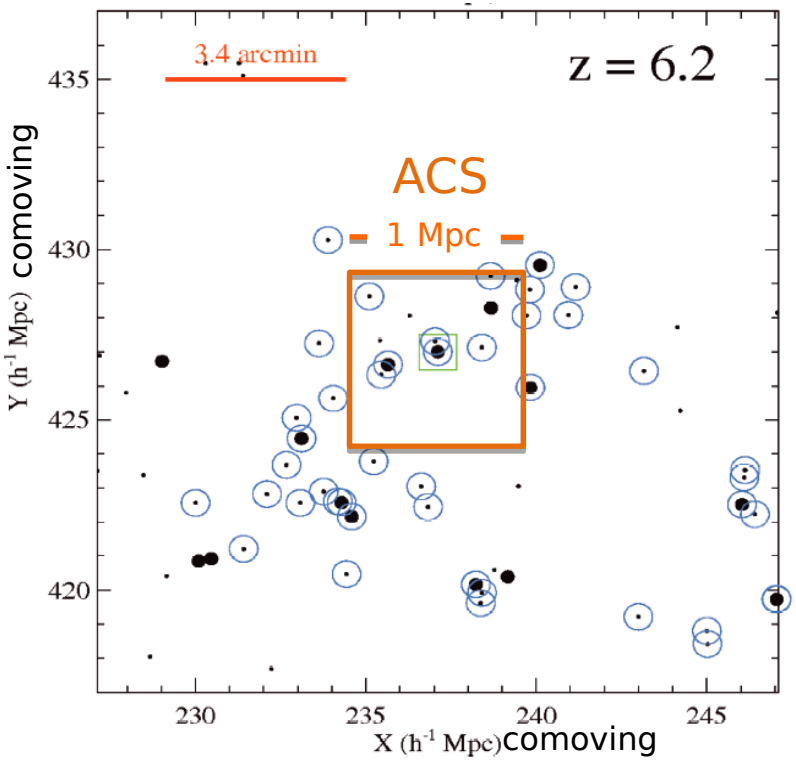


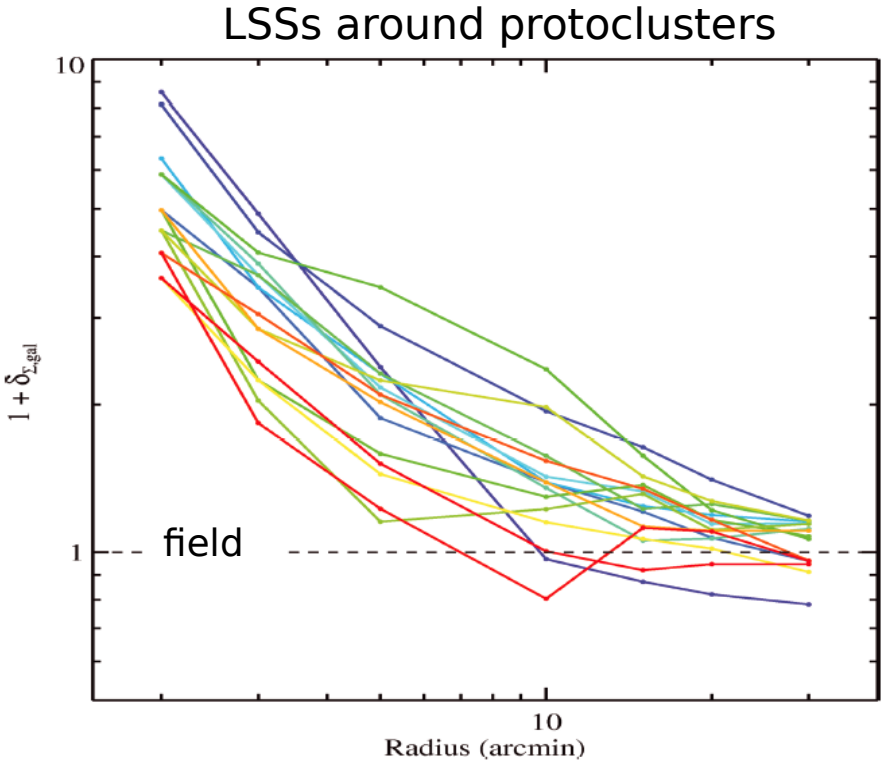
early SMBHs can only form in the most overdense environments
(Overzier+09,Di Matteo+12, Costa+14,... but see Fanidakis+13)

Searches for LBG overdensities inconclusive so far
Stiavelli+05, Kim+09, Husband+13, Banados+13, Simpson+14, Mazzucchelli's talk

Rationale for large-scale observations

Overdensities might extend up to 30arcmin, i.e 10 phys. Mpc



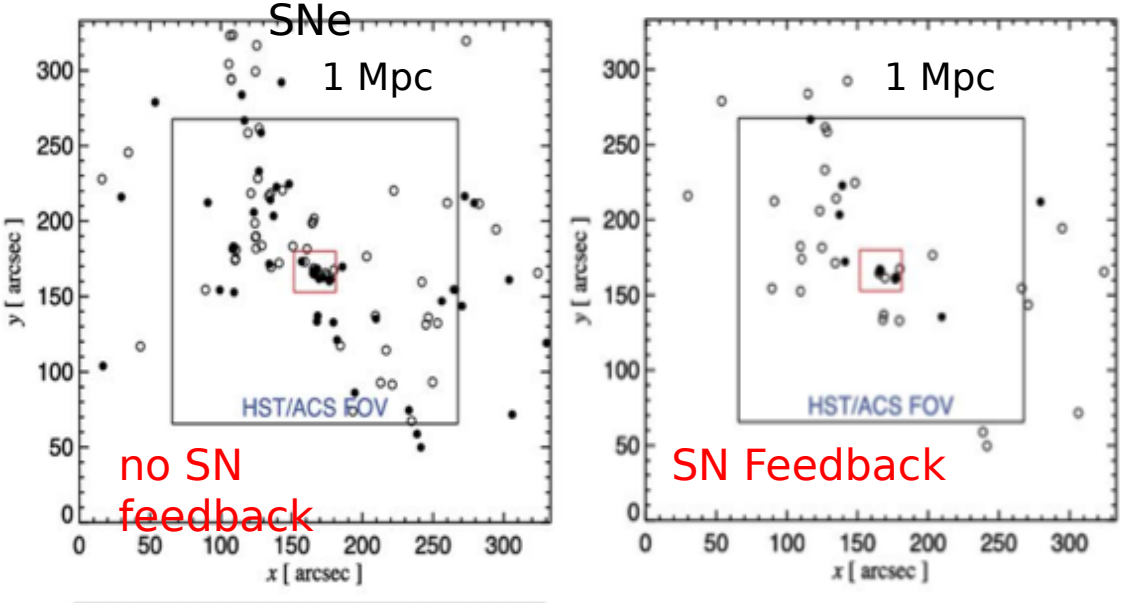


Overzier+09

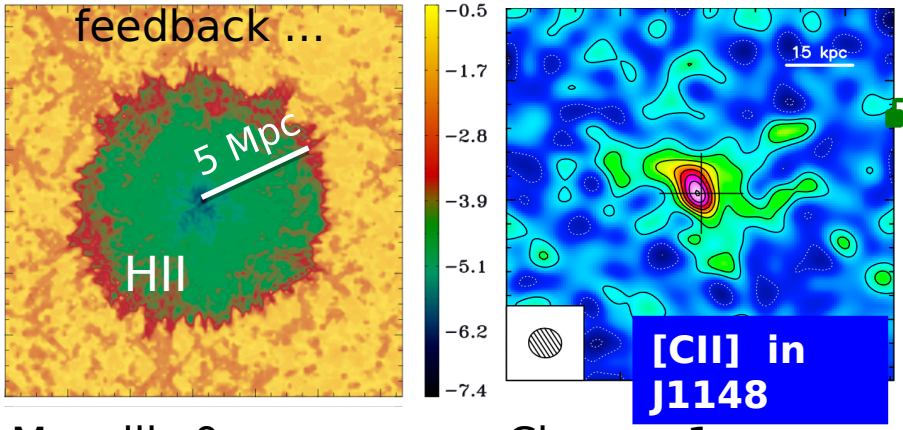
Galaxy formation depressed on ~Mpc scales?

Effects of stellar winds from SNe

Costa+14



+ QSO radiative and kinetic feedback ...



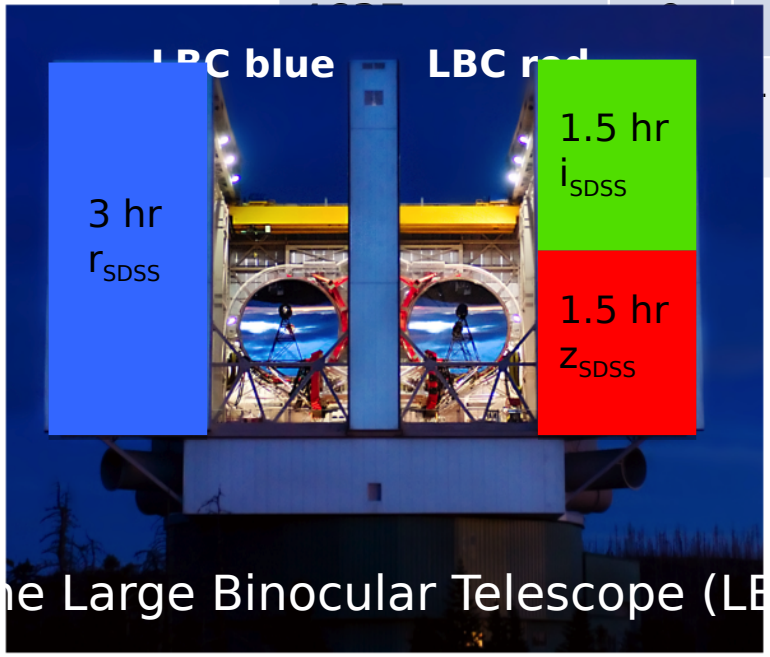
Maselli+0

Cicone+1

use LBC@LBT: FoV ~ 25'x25'

LBT/LBC observations of four z~6 QSOs fields

Target	z	M_{1450}	$M_{BH}10^9M_{sun}$	z_{AB}
SDSSJ1148+5251	6.41	-27.8	4.9	20.1
SDSSJ1030+0524	6.28	-27.2	3.2	20.0
SDSSJ1048+	6.2	-27.6	3.9	19.9
		26.8	1.2	19.6



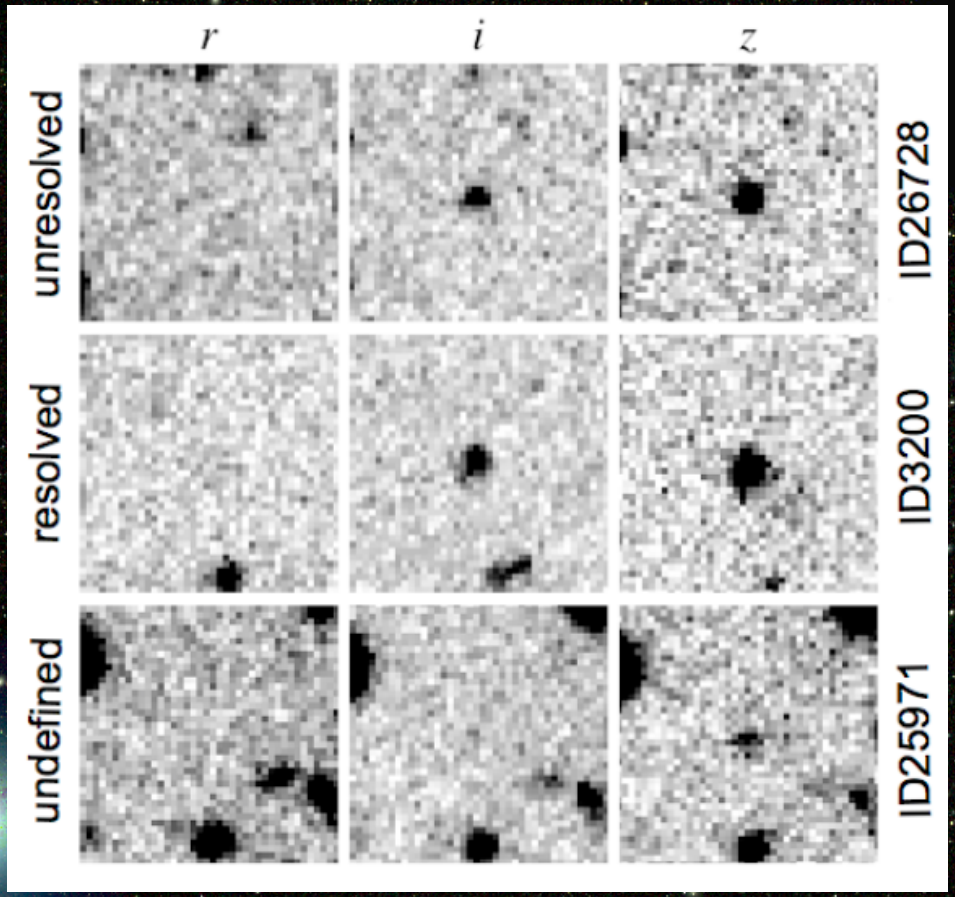
z_{AB}~25 (5σ, 50% compl.) ;
i~27; r~28

~ 25,000 z-band objects per field

BT = 2 x 8.4m telescopes – Mt. Graham (AZ)

LBC/LBT color (*r,i,z*) image of the SDSS J1030 field

i-band dropouts, i.e. LBG candidates at z~6

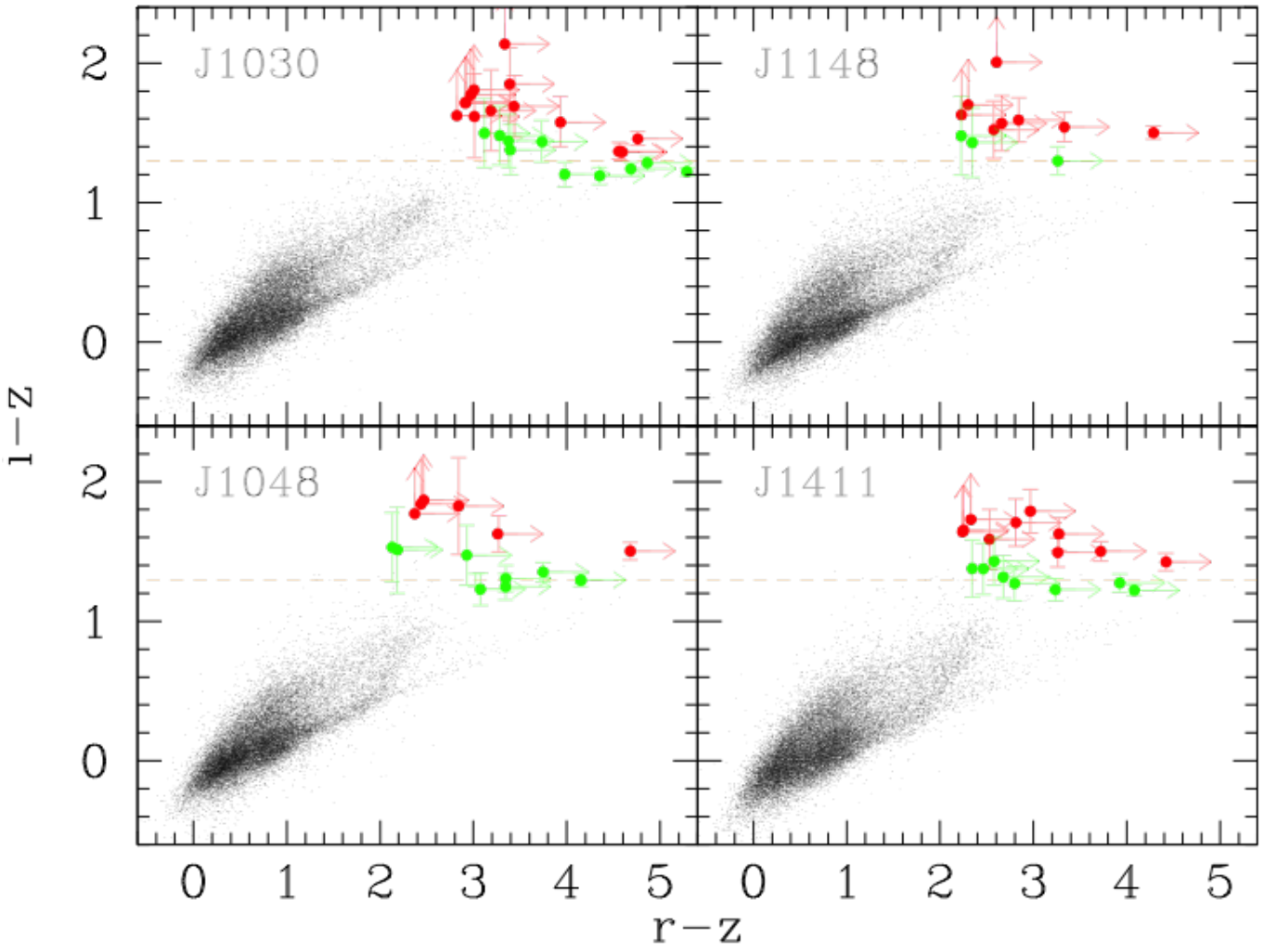


1 pMpc

3 arcmin

i-band dropout selection

Morselli+14

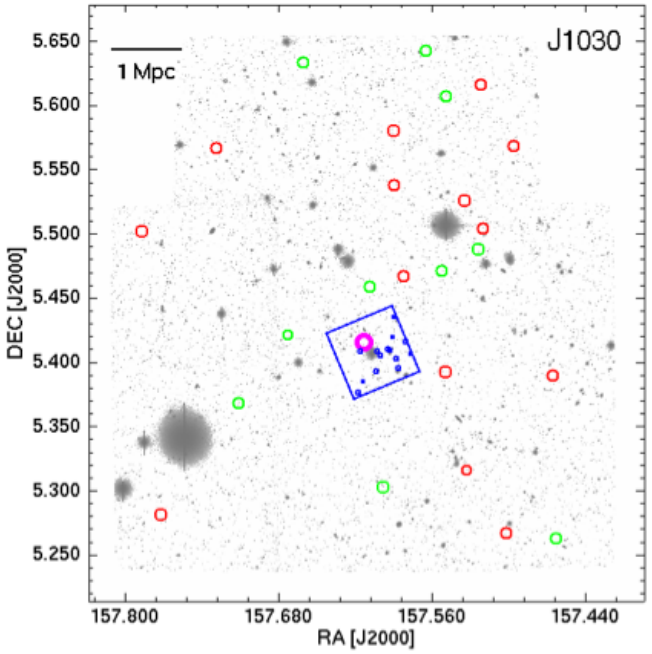


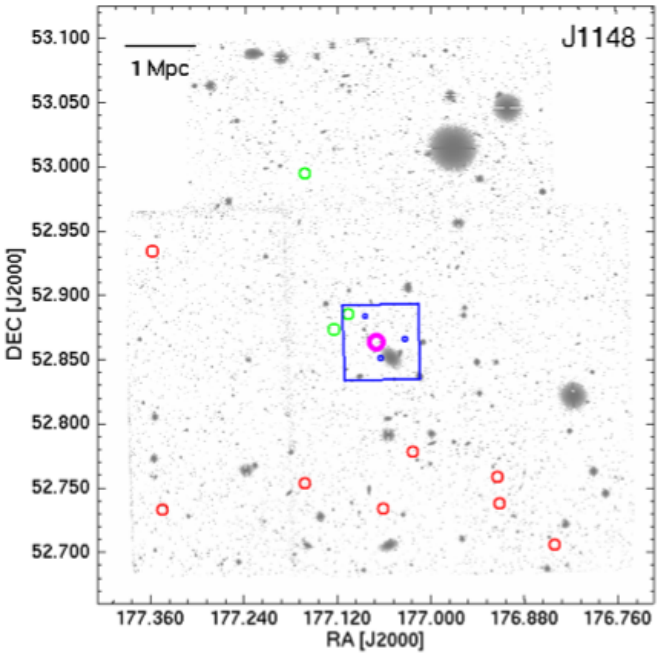
Dropouts:

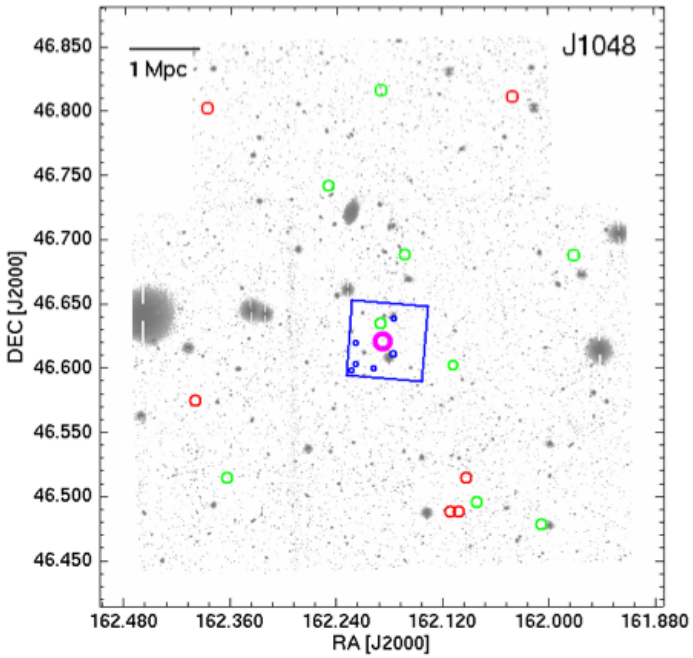
$z < 25$
no det in r (> 28)

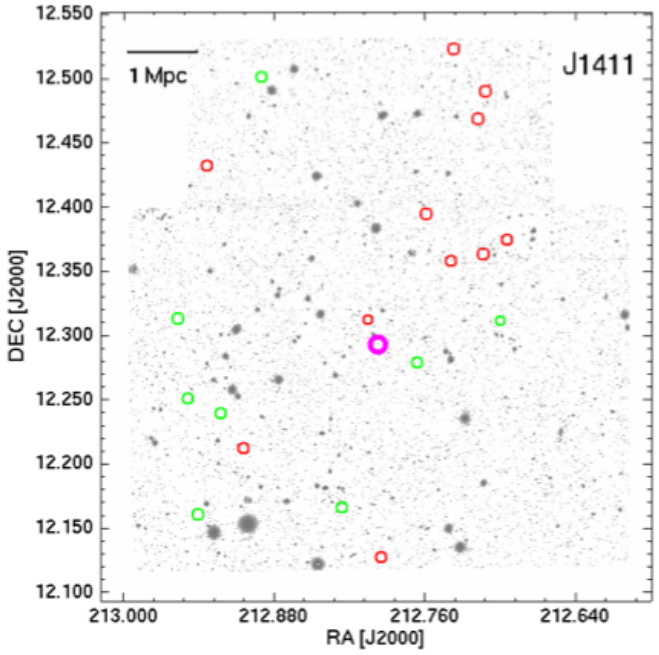
Primary
$(i-z) - \sigma_{(i-z)} > 1.3$

Secondary
$1.1 < (i-z) - \sigma_{(i-z)} < 1.3$



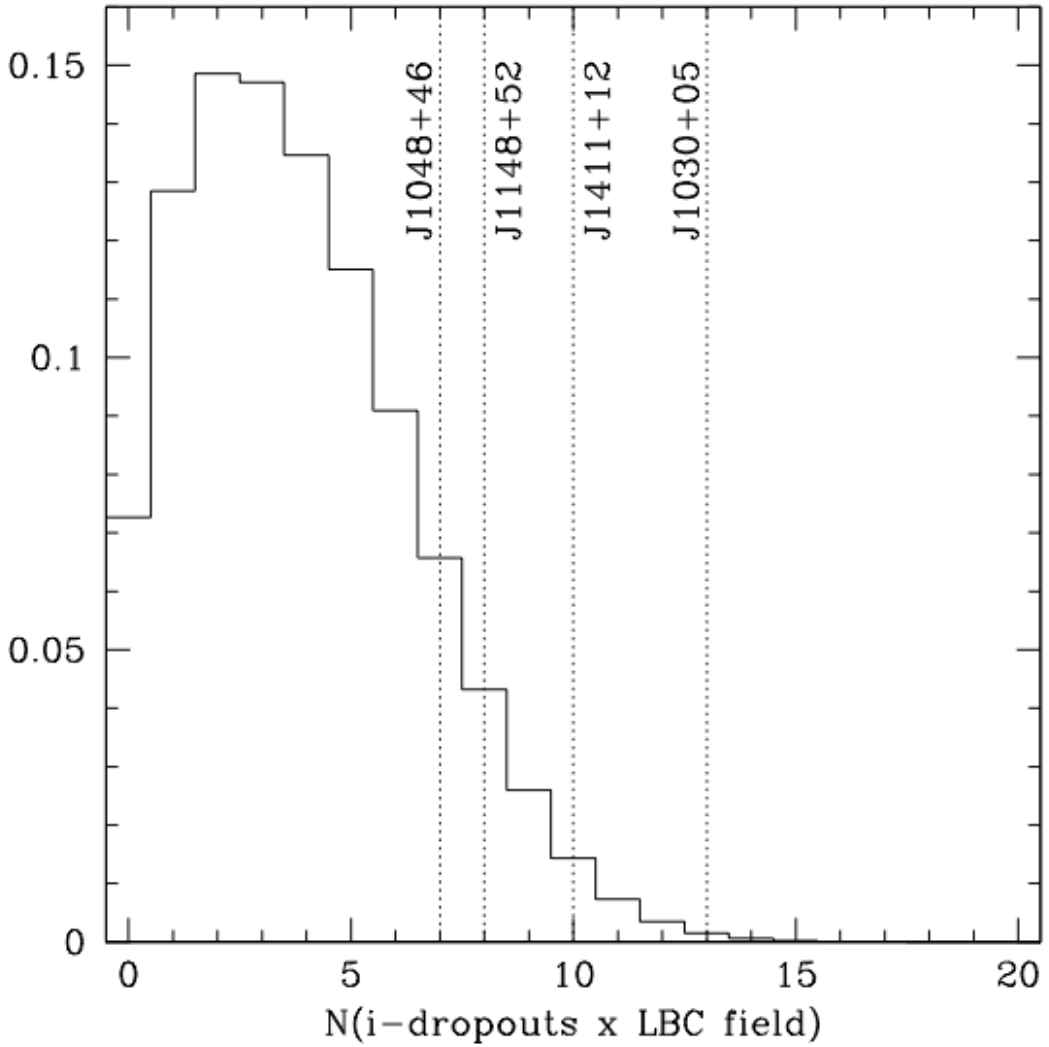






Asymmetric distribution in most fields (3σ)

Dropout overdensities



1 deg^2 SXDS (z_{AB}~26; Furusawa+08) used to evaluate the "background" of i-band dropouts

Significant overdensity measured (3.7σ combined)

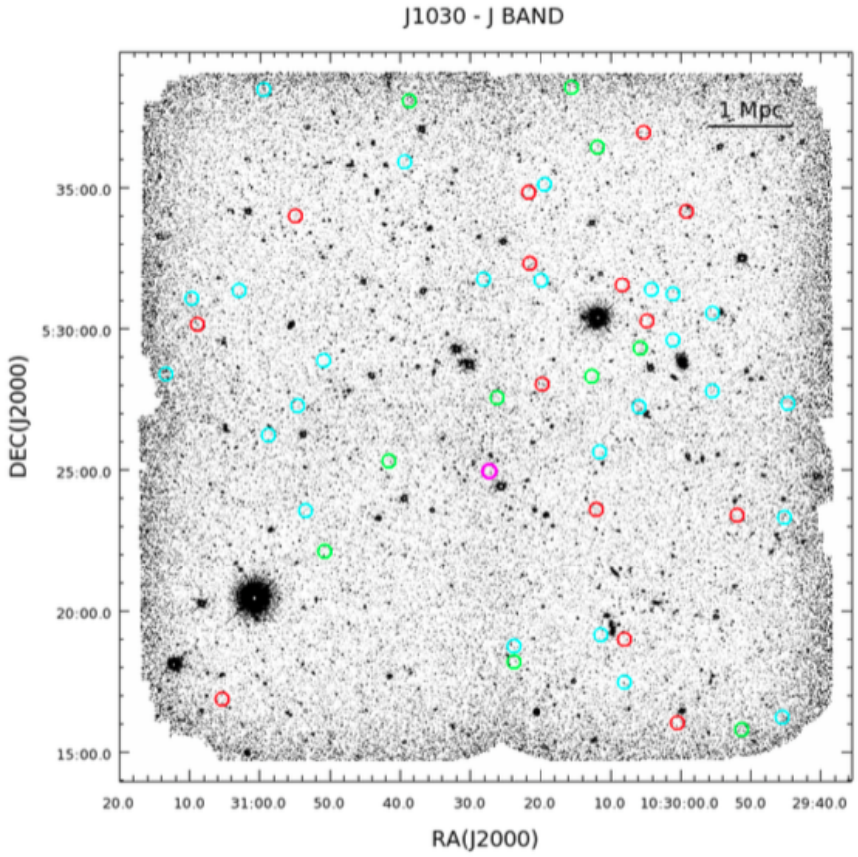
(it also accounts for cosmic variance and photometric errors)

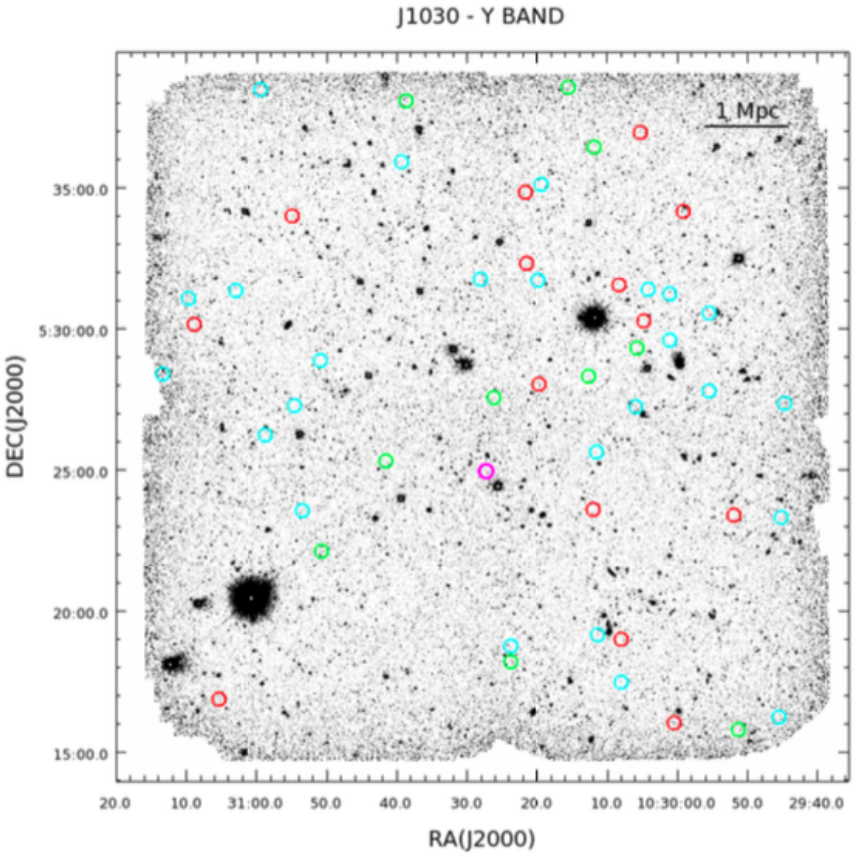
data products available at http://oabo.inaf.it/~LBTz6

Recently acquired or planned optical/IR follow-ups

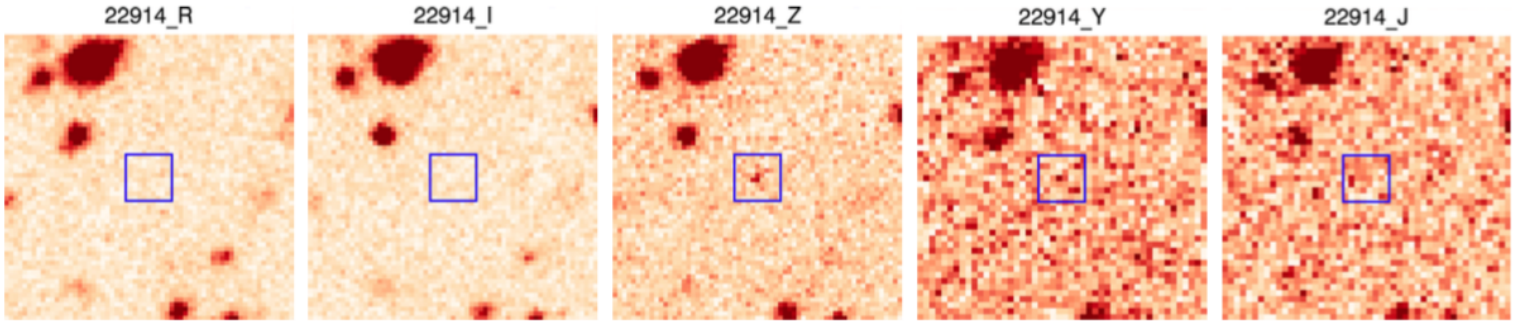
Observation	Telescope/ Instrument	Exposure time	Status
Optical MOS on J1048, J1148, J1411	MODS-LBT	30hr	Data acquired, analysis on-going
additional rizY imaging in J1148, and riz in J1411 (z_{AB}~25.5, 5σ)	LBC-LBT	24hr	Data acquired, analysis on-going
J-band imaging on J1141 and Y,J imaging on J1030 (AB ~24, 5σ)	WIRCAM-CFHT	9hr	Data received, analysis on-going
Optical MOS on J1030	DEIMOS-Keck	10hr	Sched 1-2 Dec. 2016

CFHT/WIRCAM imaging of SDSS J1030





selection of fainter i-dropouts : 25 obj. with $25 < z_{AB} < 26$

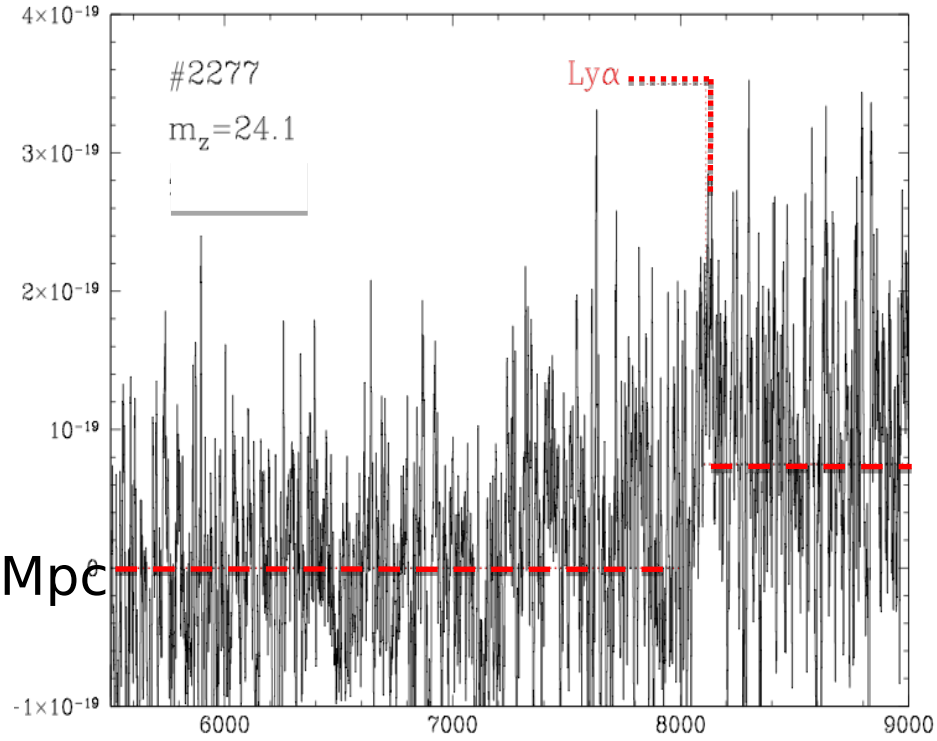


Spectroscopic follow-up with MODS@LBT

i-drop observed in 5 masks (in SDSS J1048, J1411, J1148), 6hr per mask

BGs at z>=5.7 (3 foreground, 2 likely within QSO LSS)
tar
no-z

Example of foreground LBG
in the SDSS J1048 field



z_{LBG} = 5.7 , z_{QSO}=6.2 ✉ d~30 pMpc

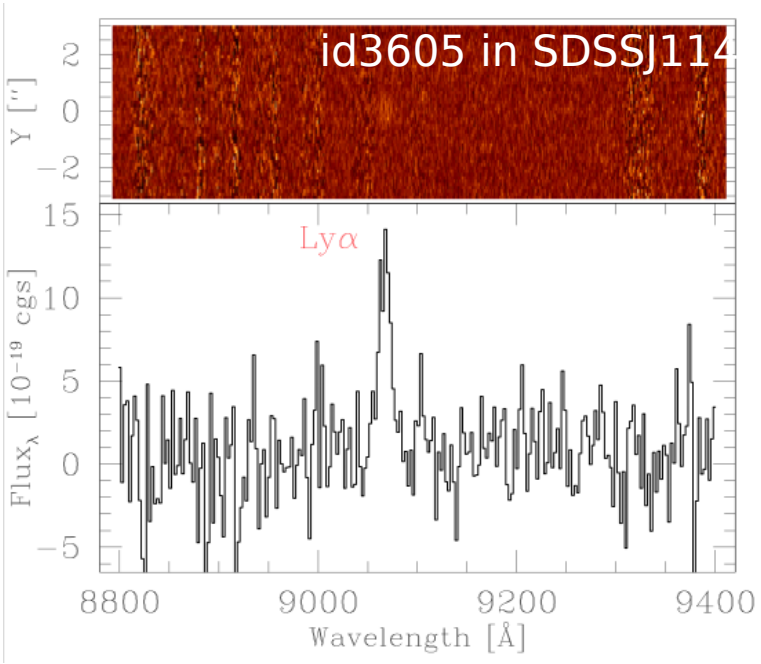
0 pMpc at z=6 is Δz=0.15

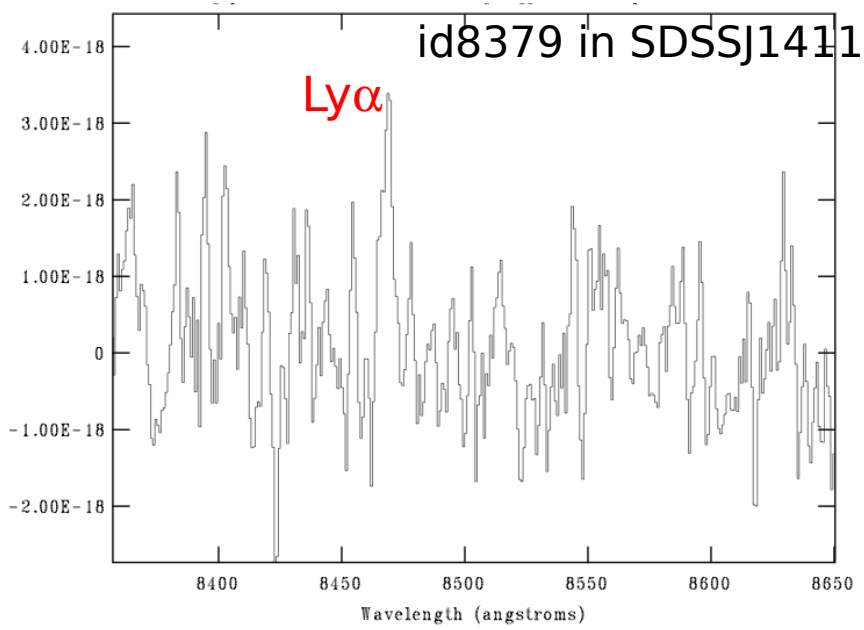
Spectroscopic follow-up with MODS@LBT

i-drop observed in 5 masks (in SDSS J1048, J1411, J1148), 6hr per mask

BGs at z>=5.7 (3 foreground, 2 likely within QSO LSS)
tar
no-z

LBGs likely within QSO LSS





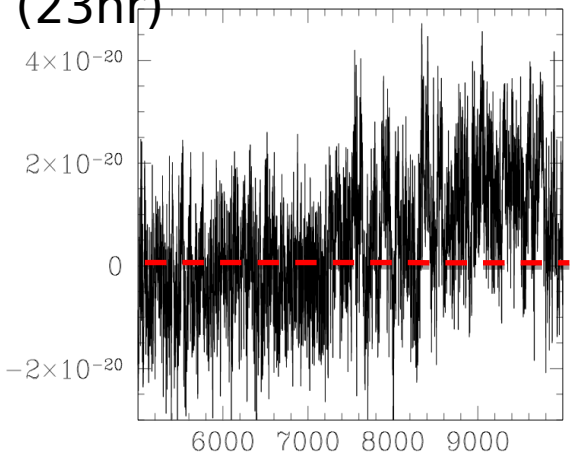
z_{LBG}=6.456, z_{QSO}= 6.42 ✉ d~ 4 pMpc

z_{LBG}=5.964, z_{QSO}= 5.903 ✉ d~ 5 pMpc

Spectroscopic follow-up strategies

LBGs (M_{UV}<-21.5) have faint or absent Lyα
ed, dusty; Ando+06, Vanzella+09).
alaxies in overdensities more massive
sty than in the field (Yajima+15)

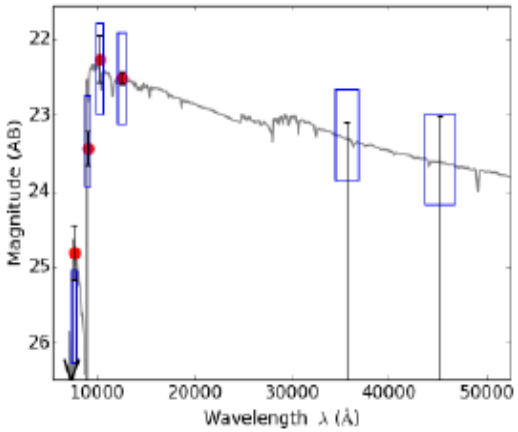
stack of 4 i-drop in J1411 (23hr)



other strategies. In SDSS J1030:

hr with 17'x17' VIMOS@VLT
posed in P98 to get continuum break

r with ALMA (4 targets) proposed in Cycle 4
et [CII]158μm



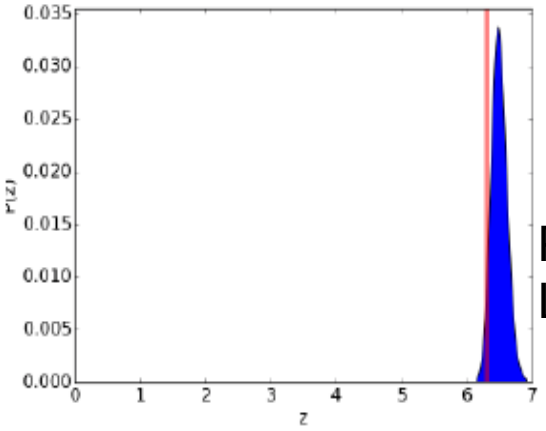


Photo-z using
LBT(riz) + CFHT(YJ) + IRAC

Chandra LP (500ks ACIS-I) on J1030 approved in Cycle 17

scheduled in Jan 2017, deepest X-ray obs. of a z=6 QSO

Goals

1) detecting faint satellite AGNs

   ⇒

   growth of SMBHs in early LSSs

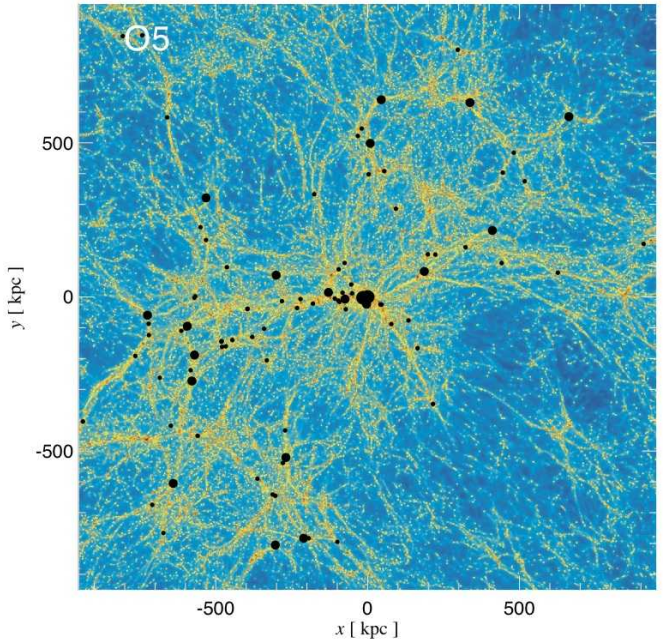
   feedback mechanisms (winds, rad.)

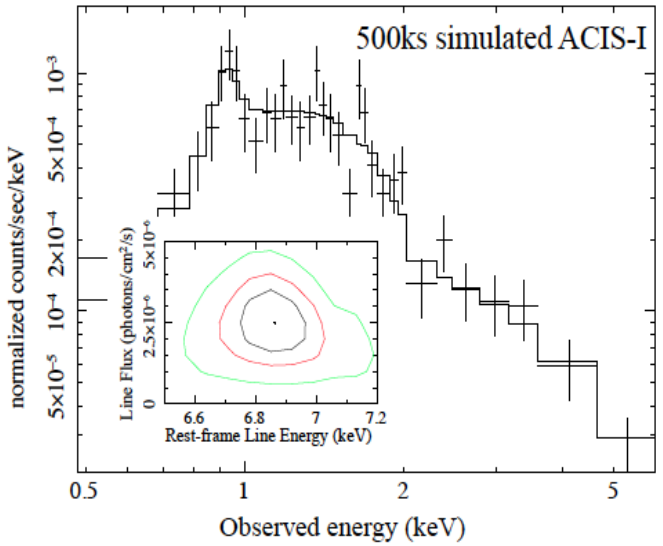
2) get high quality spectrum of SDSSJ1030,

   best ever for z>6 QSOs

   ⇒

   Fe features, slope, UFOs, disk/wind physics





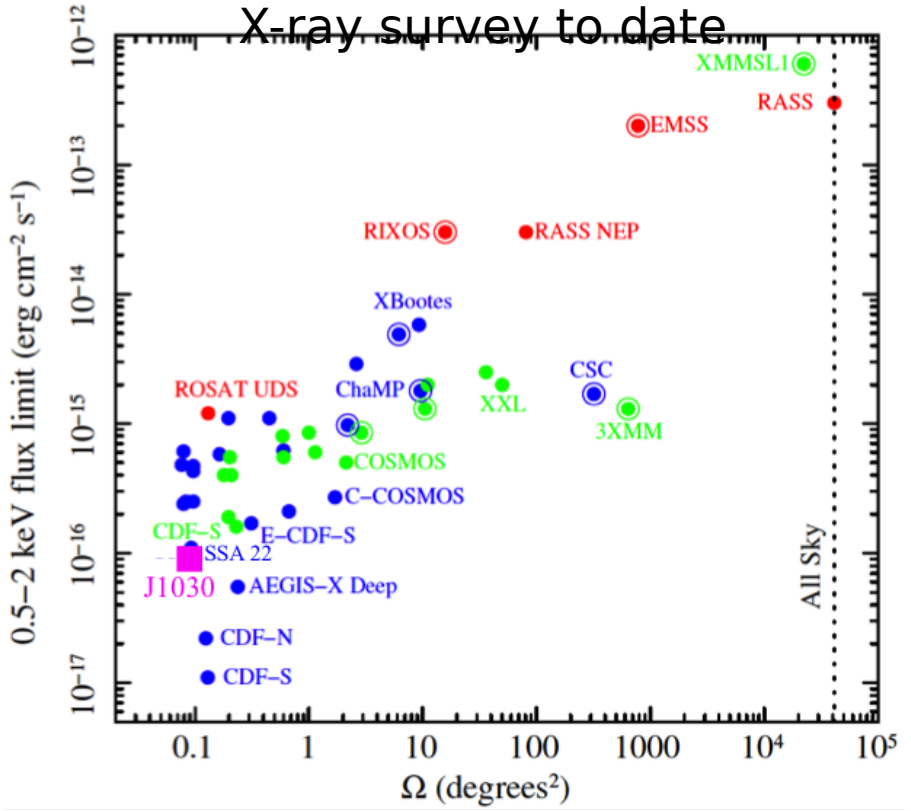
Chandra LP (500ks ACIS-I) on J1030 approved in Cycle 17

scheduled in Jan 2017, deepest X-ray obs. of a z=6 QSO

Goals

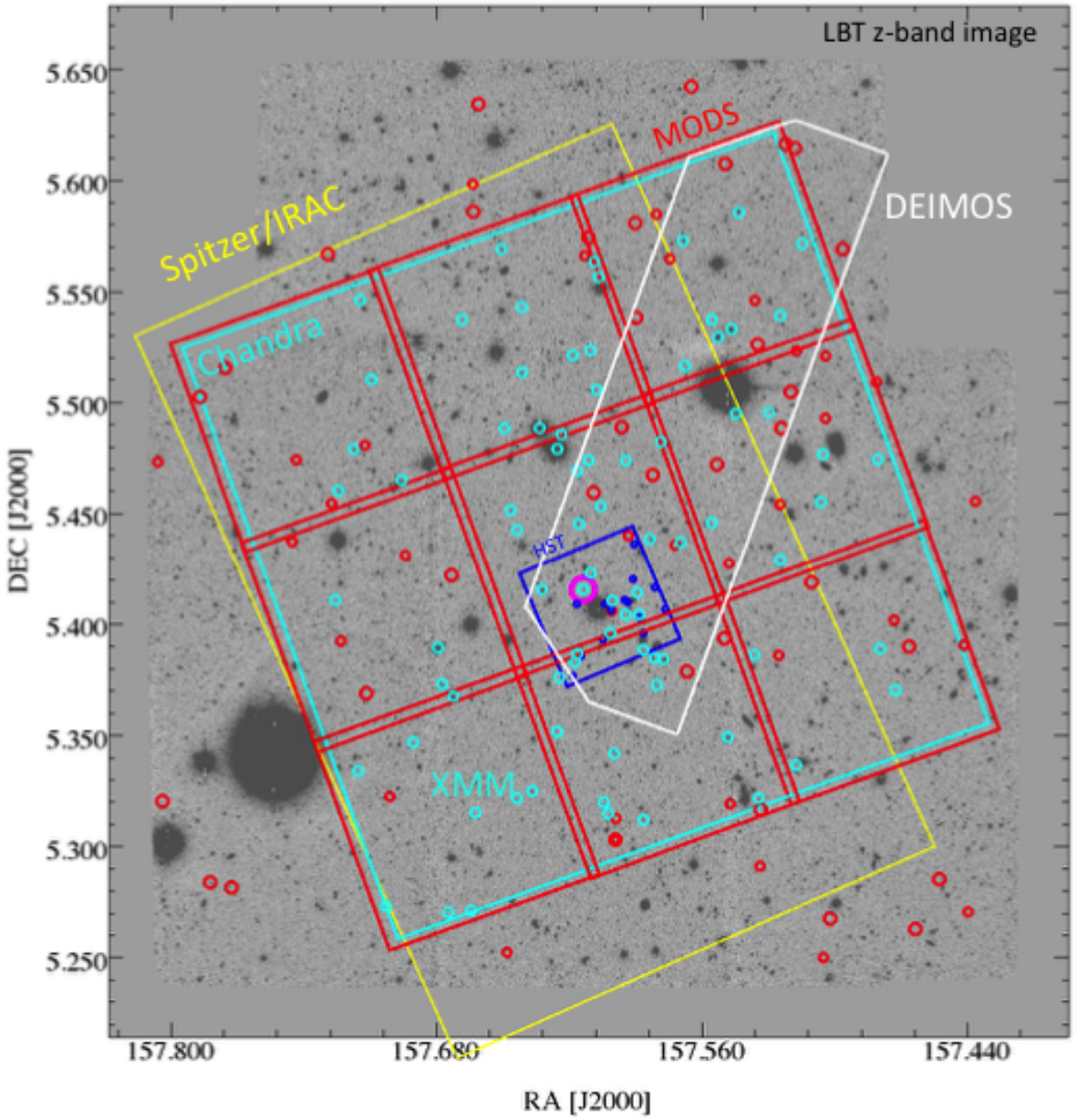
3) deep multi-λ survey: 200 X-ray sources down to ≈10^{-16} erg/cm^2/s

expected to be the 4th deepest X-ray survey to date



Adapted from Brandt&Alexander

A deep multi-λ survey in the SDSS J1030 field



Entire field covered by

MUSYC (Multiwavelength survey from Yale-Chile, Gawiser+06)
UBVRIzJHK

*

LBC
riz (Morselli+14)

*

WIRCAM
YJ (Balmaverde+ in prep.)

*

Subaru
rizNB$_{CIV}$ (Diaz+14,15)

QSO is being pointed by
MUSE + ALMA

Summary

- z~6 QSOs are surrounded by asymmetric, large scale (>4 pMpc radius) overdensities of LBG candidates (at 3.7σ) ✉ support for early SMBHs forming and growing in dense environments

- Spectroscopic confirmation challenging: 5 (33%) of i-dropouts are z~6 LBGs (2 within QSO LSS, 3 foreground). Couldn't get redshifts for the other 66%: 6hr MODS not enough). Massive and dusty galaxies with weak or no Lyα?

- Possible ways out: ultra-deep (~20hr) optical spectra to get the Lyman continuum break or ALMA detection of [CII]158um

- Intensive multi-λ follow-up ongoing: the most overdense field SDSS J1030 to become the 4th deepest X-ray field (satellite AGN, QSO X-ray spectrum, ...)