



# Exploring the high- $z$ universe in the SXDS/UDS and COSMOS/UltraVista Fields

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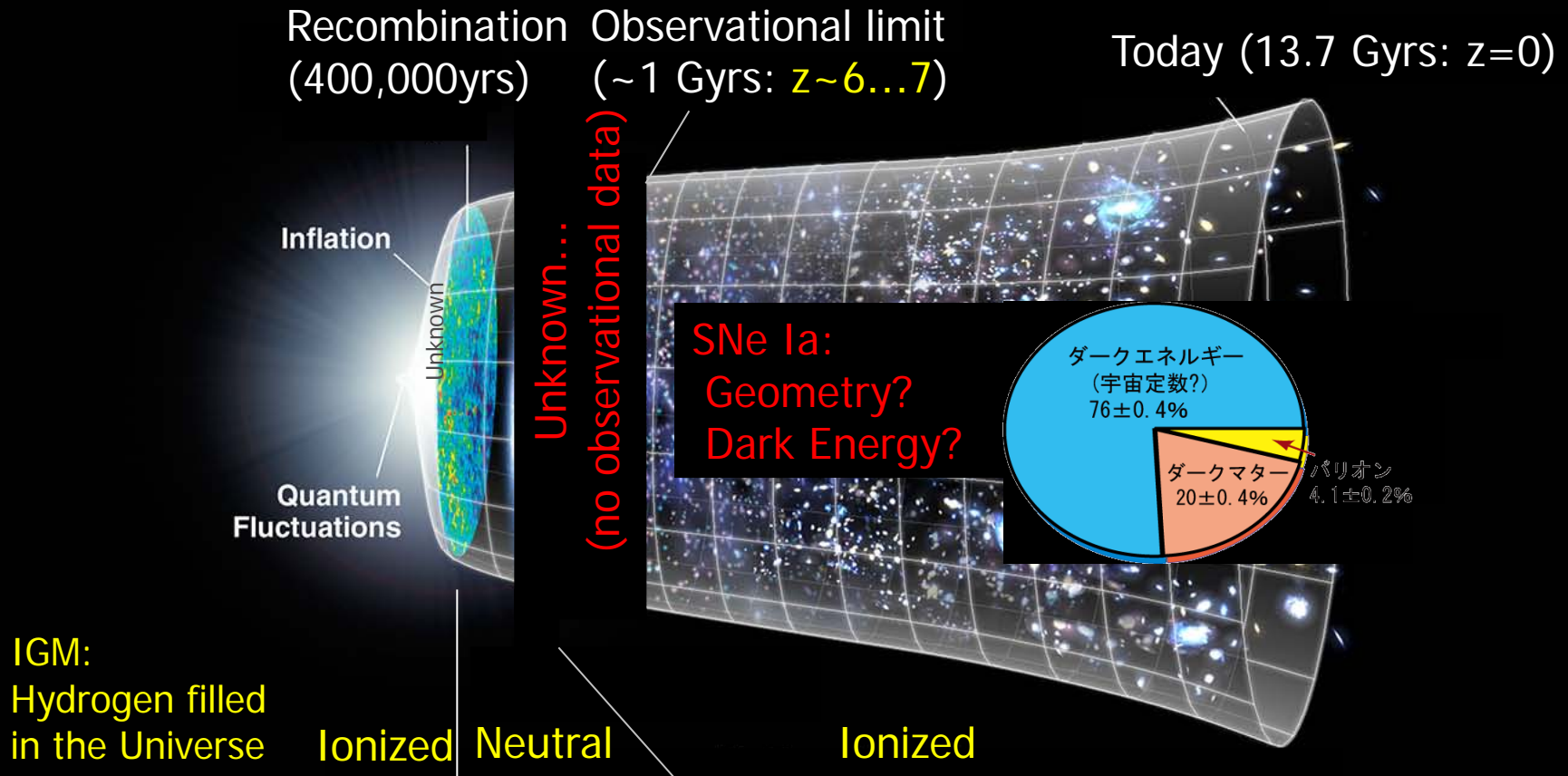
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# 1. Scientific Drivers and Goals

1. Galaxy Formation and Reionization at  $z > \sim 7$
2. Sciences with high- $z$  SNe Ia

# Major Questions in High-z Astronomy



- How did galaxies/stars form from the primordial gas?
- How was the Universe reionized?

We address these problems with LBGs (dropouts) and Ly $\alpha$  Emitters from our observations



# 1-1. High-z Galaxies at $z \sim 7$

# UV LF of Dropout Galaxies at $z > \sim 7$

- Due to the small survey volume and small sample, no strong constraints yet..

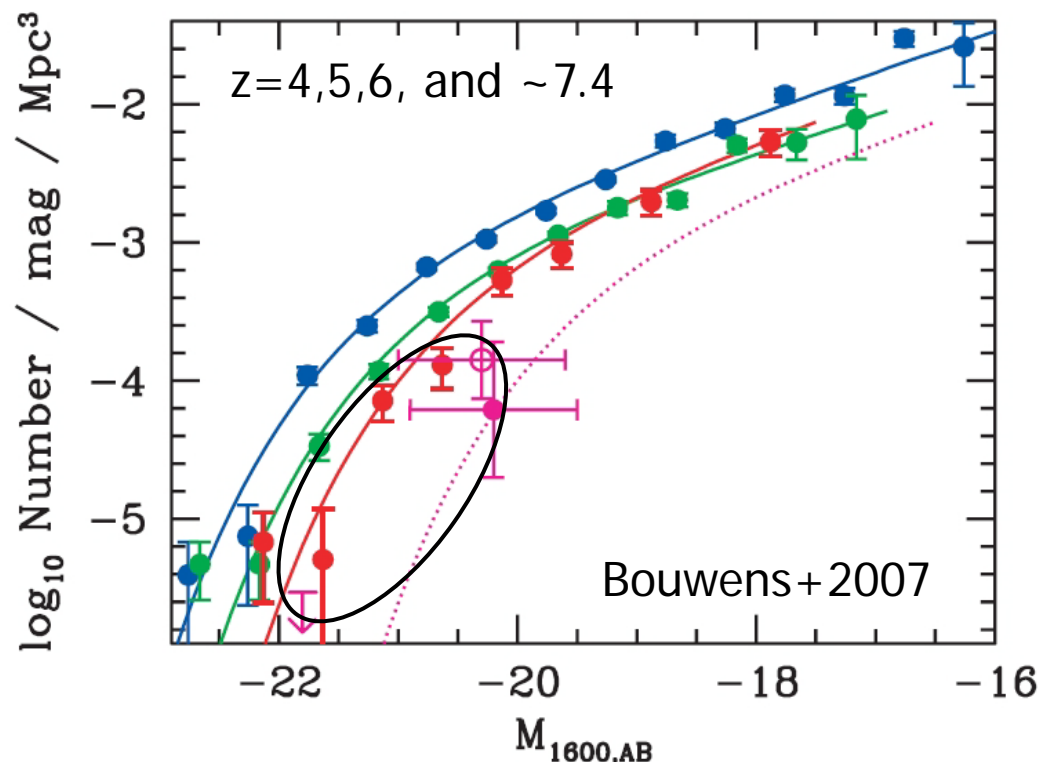
## ■ Dropouts

- Area  $\sim 20$  arcmin<sup>2</sup>
- Only a few faint candidates (Bouwens+07,08, Bradley+08)
- WFC3  $< 0.1$  sq.deg

↓  
Bouwens+08;  
Ouchi+09

## ■ This work

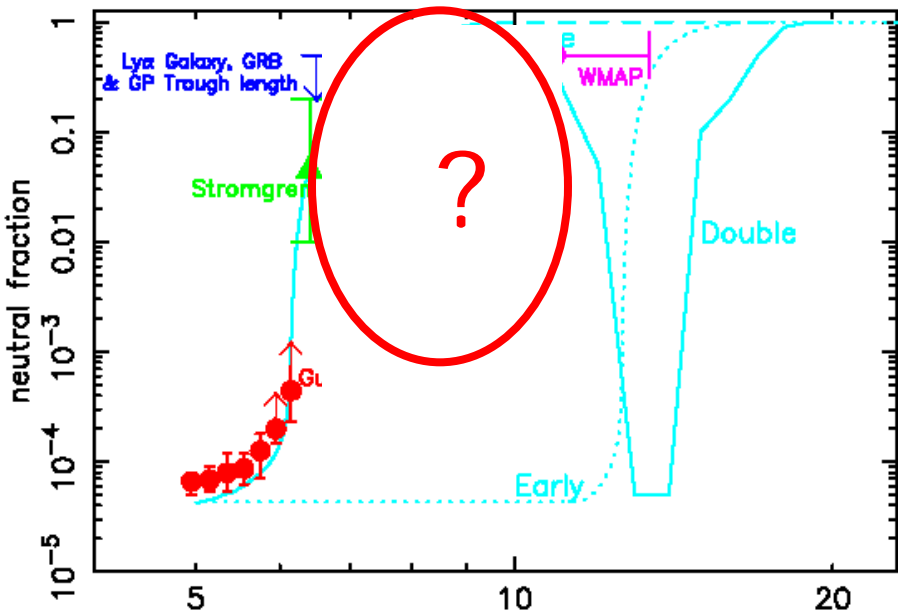
- Area  $\sim 2$  sq.deg
- $\sim 200$  bright candidates (based on McLure+ 2008)



# Cosmic Reionization

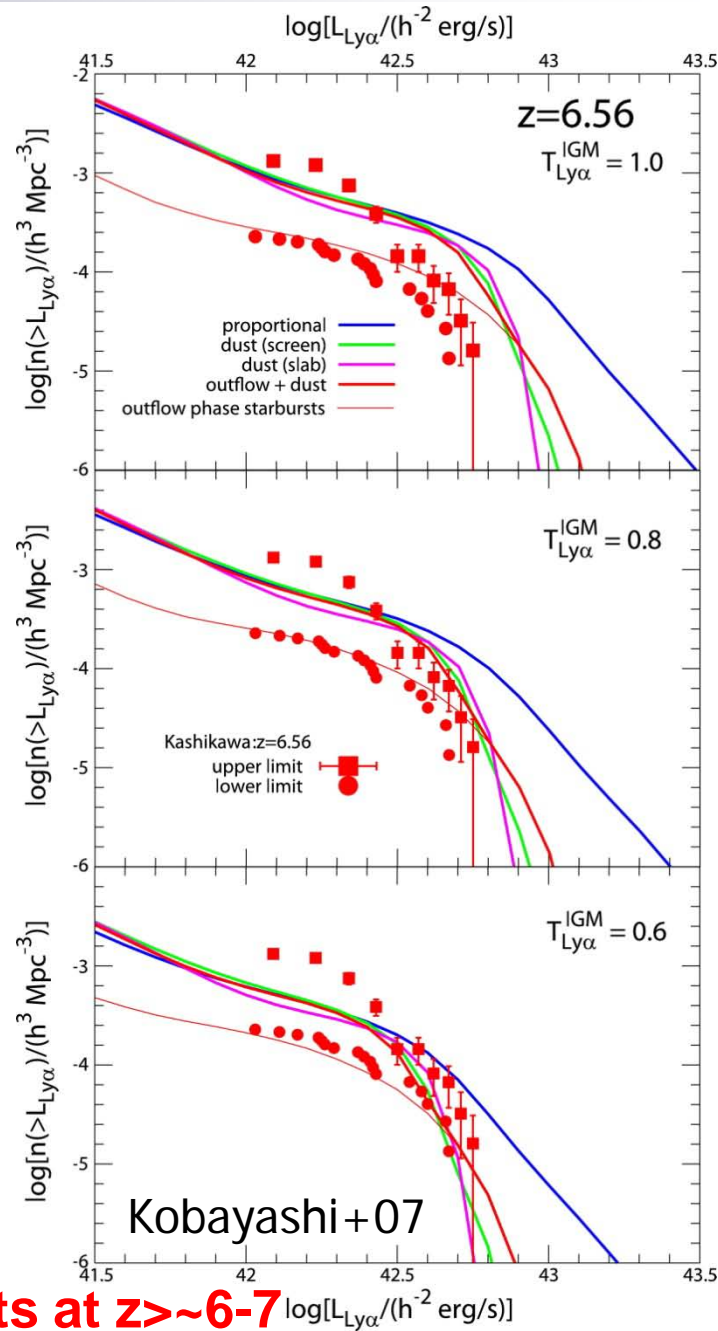
High-z dropout 銀河のUV LFはLAEのLy $\alpha$  LFと相補的。銀河形成と宇宙再電離の効果を議論

Evolution of neutral fraction of IGM  
(Fan et al. 2006)



- $z \sim 6$ : Final stage (GP trough; Fan+06)
- $z \sim 11$ : WMAP5+inst. Model (Komatsu+08)
- $z \sim 6-11$ : Transition of IGM status

$z \sim 6$  is the limit of GP test  $\rightarrow$  LAEs and dropouts at  $z > \sim 6-7$



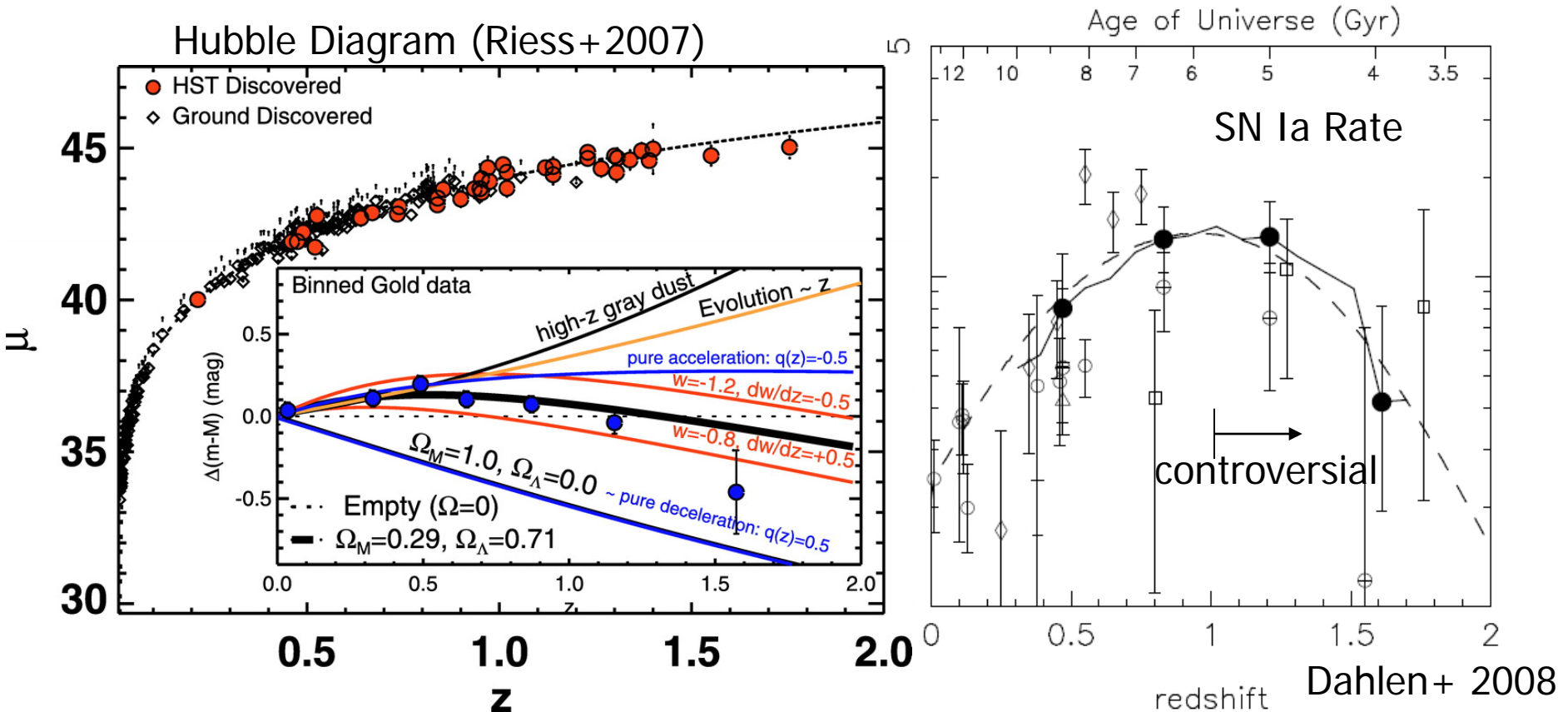


# 1-2. Sciences with High-z SNe Ia



# Sciences with High-z SNe Ia

- Subaru team have largely contributed to this field
- The number of sample at  $z > 1$  is to be increased



# Key Scientific Goals

## ■ $z'$ -dropouts Search with FDCCDs

By detection of  $\sim 200$   $z$ -dropout galaxies, we will study

- LF & CF less affected by statistical errors and field variance, to understand galaxy formation/evolution at the very early epoch
- Cosmic reionization by combining the dropout galaxy sample and LAE sample at the same epoch
- Major sources of the reionization and when it started by investigating stellar populations of  $z > \sim 7$  galaxies

## ■ SNe Search

By detection of  $\sim 100$  SNe Ia at  $z=1-1.5$ ,

- Constrain property of Dark energy ( $w$ ). Other future results (BAO surveys - FMOS/FAST-SOUND etc; HSC WL survey) combined with this project will lead to more strong constraints on  $w$ .
- Refine SN Rate & delay time distribution and give a good constraint to SN progenitor models, & as a precursor study for HSC survey



## 2. Strategy & Field Selection

# Only The Two Fields

To Perform Our  $z > \sim 7$  Sciences with new FDCCDs,  
Wide ( $> \sim 1$  sq.deg) & Deep Opt-NIR (J $\sim 26$ ) Data

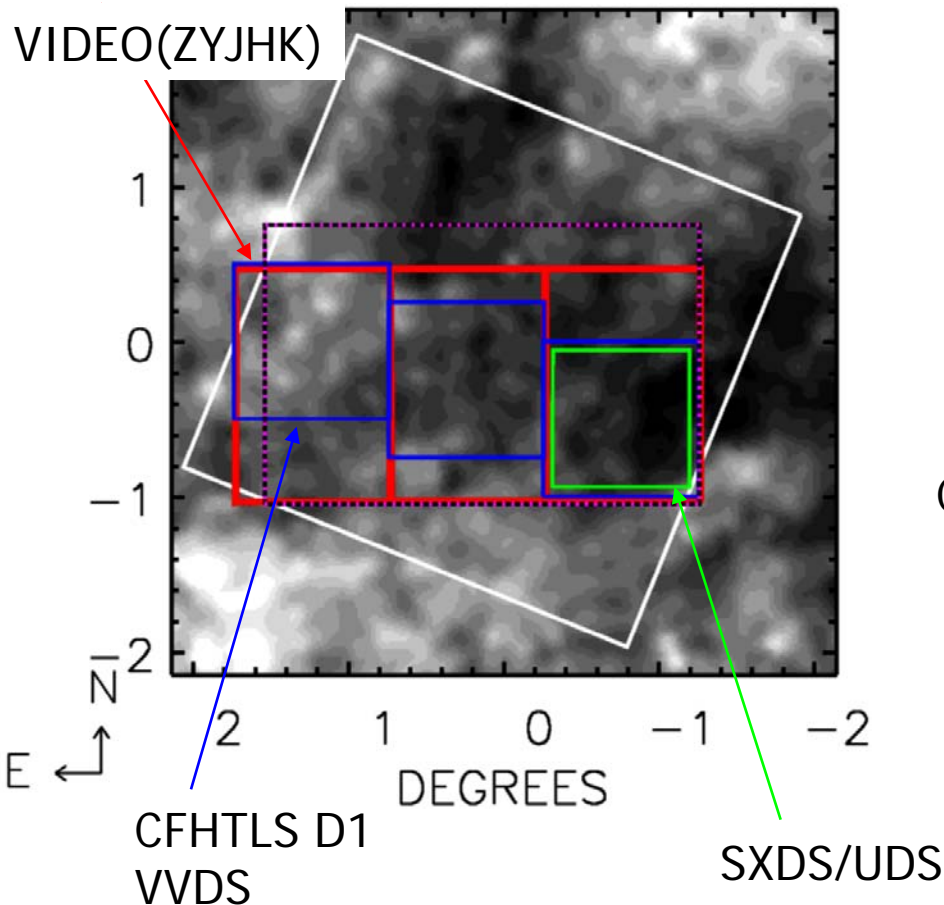
- **SXDS/UDS** (Opt+NIR=0.8 sq.deg)
  - Subaru BVRiz Data (Furusawa+ 2008)
  - **UDS J=26, H=25.4, K=25** (7 years from 2005, **complete in 2011**)
  - SpUDS Spitzer Data (IRAC $\sim 24.7$ )
  - Other wavelengths including SCUBA-2CLS
- **COSMOS/UltraVista** (Opt+NIR=0.75 sq.deg)
  - Subaru, COSMOS-21 (PI: Taniguchi, Capak+ 2007)
  - **UltraVista Y=26.7, J=26.6, H=26.1, K=25.6** (5years from late2008)
  - sCOSMOS Spitzer Data (IRAC $\sim 24.2$ )
  - Other wavelengths inc. SCUBA-2CLS

⌘ HST/WFC3 (Service mission 4; this fall?) : only for areas of  $\sim 0.1$  sq.deg

# Two Target Fields

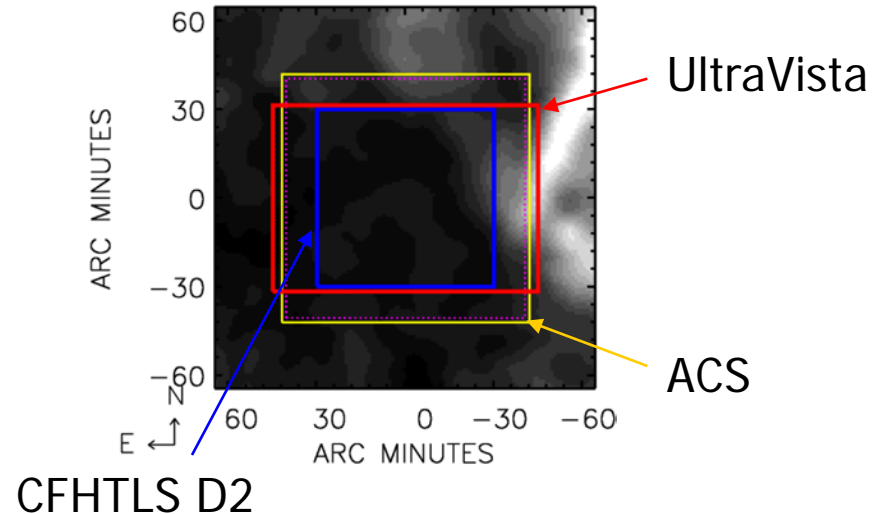
## SXDS/UDS

(02:21:02.0, -04:30:30) 1 sq. deg



## COSMOS/UltraVista

(10:00:30.0, +02:12:30) 1 sq. deg



**CFHT Large Program** → Unsuccessful  
– submitted end of Jan 2008  
~2000 hours over 5 years,  
r-, i- and NB1.06 micron imaging  
(PI Dunlop)

# Synergy with Other Studies

## ■ LAE survey (Ouchi+ 2008-2009)

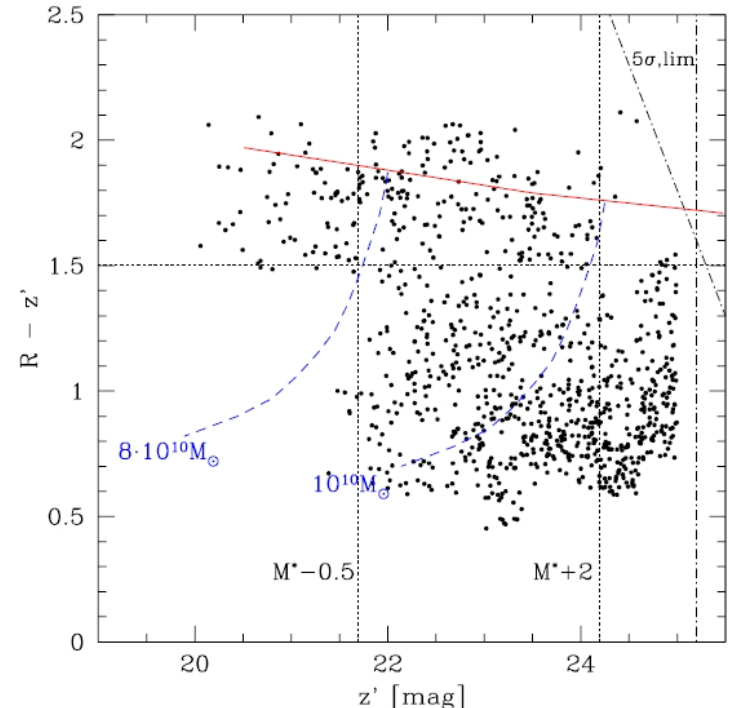
- NB921 imaging (SXDS deep 0.2sq.deg & COSMOS 2sq.deg)
- Galaxy evolution of LAEs and dropouts, Reionization
- Sharing the z'-band data from this program

## ■ Follow-up Spectroscopy

- z-UDS (PI Almaini; VIMOS and FORS2)
- VVDS in CFHT-LS D1
- Applying for telescope times for SNe Ia
- For  $z=7$  galaxies, we will apply for MOIRCS and FMOS times

## ■ Studies for Lower Redshifts

- SCUBA-2 Cosmology Legacy Survey
  - submm galaxies (450um, 850um)
- Mass assembly and SFH at  $z > 1$ 
  - Balmer-break galaxies (e.g., zJK)
- AGN w/ multi-wavelength data

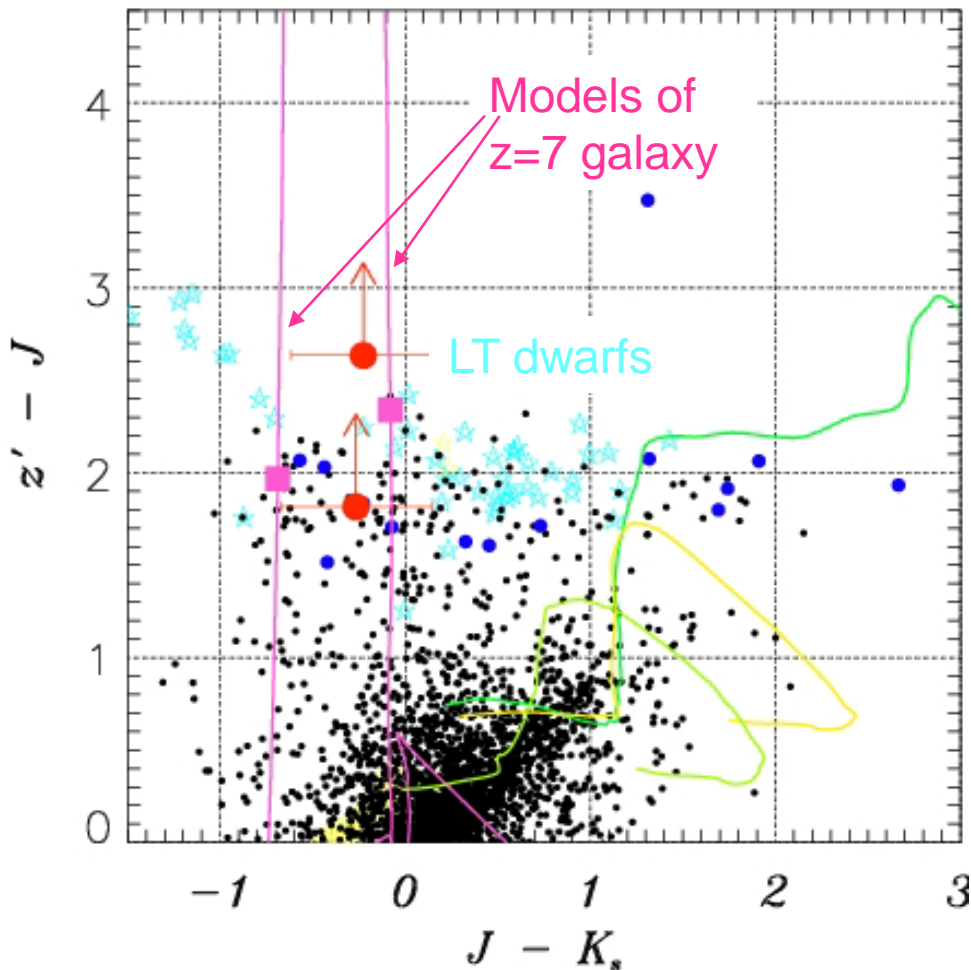


Balmer-break (4000Å break) gals.  
Kodama+04 in SXDS  
Extend the study of downsizing  
@ $z=1$  up to @ $z=2$  with zJK bands



# 3. Method & Observing Plan

# Detection Criteria for $z > \sim 7$ Galaxies



- Color criteria ( $z=6.5-7.5$ )
  - $z-J > 2.5$ (clean) 2.0(fair)
  - $J-K < 1.0$

- Needs deep  $z'$  & NIR

$z' \sim 28.5$  (2sigma)

$J > 26$

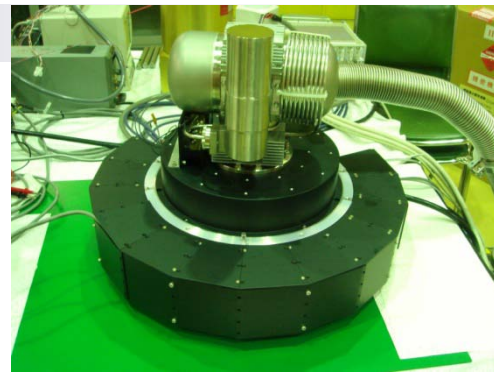
$K > 25$



$\sim 200$  LBGs at  $z=6.5-7.5$   
(based on McLure+ 2008)



# Observing Plan

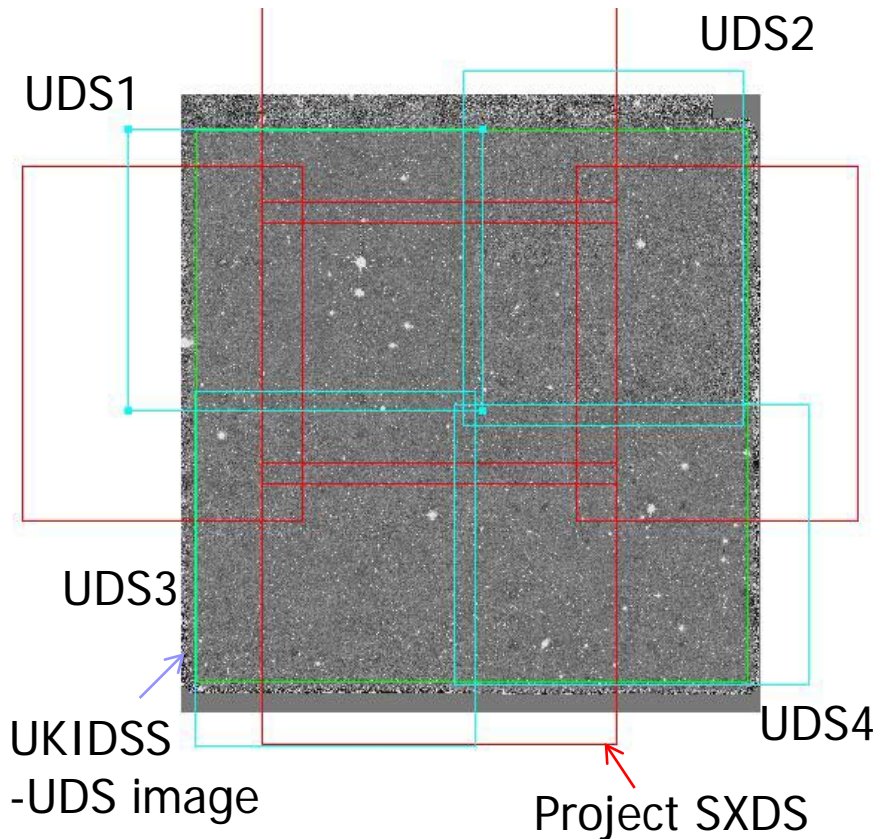


- To achieve  $z'=28.5$  ( $2\sigma$ ) for the entire fields
  - S08B & S09A (20 nights) allocated
    - SXDS/UDS field 1sq.deg = 4 pointing x 20 hours
    - COSMOS field 1sq.deg
    - S08B: mainly in SXDS, S09A: mainly in COSMOS
- To detect SNe Ia and measure light curves
  - Observing nights should be split into 2 to 3 allocations in each run (beginning, end + $\alpha$ ) and span for 3-4 months
  - 90-min is a set of integration ( $z'=26$ )

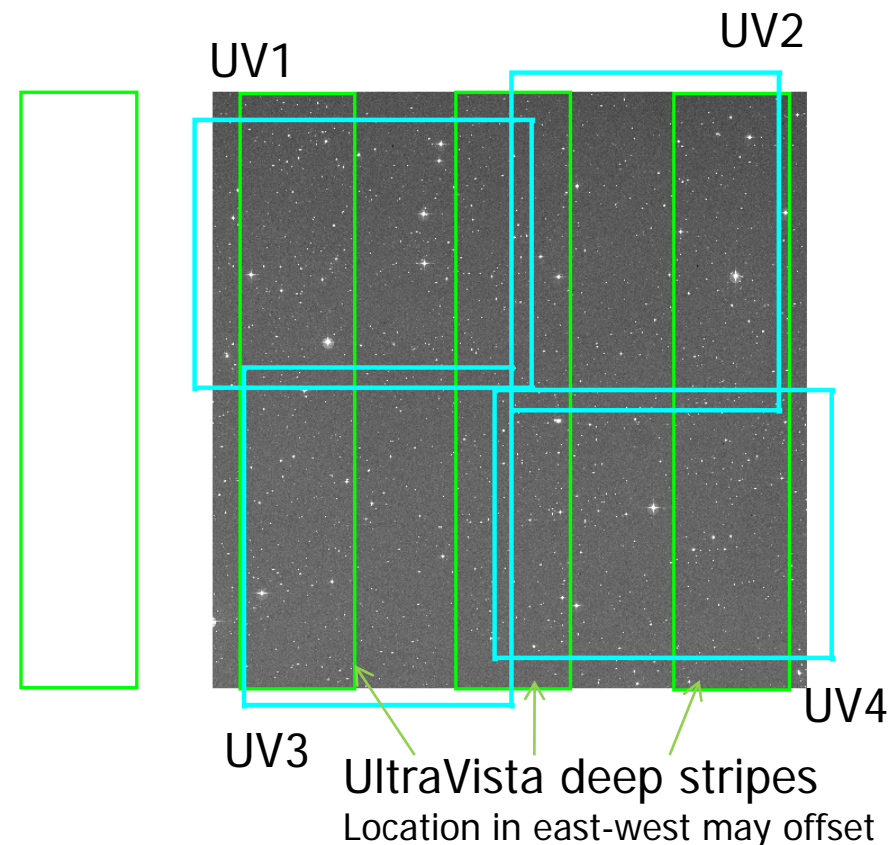
# Pointing Strategy

- Each 1sq.deg field is covered with 4 FOVs

SXDS/UDS Field



COSMOS/UltraVista Field



# Co-Is

- H. Furusawa, K. Sekiguchi, M. Akiyama, T. Takata, T. Kodama, M. Ouchi, K. Shimasaku, N. Yasuda, M. Doi, Y. Ihara, S. Miyazaki, F. Nakata, K. Maeda, T. Totani, Y. Okura, J. Furusawa, T. Yamada, T. Morokuma, Y. Taniguchi, J. Dunlop, C. Simpson, R. McLure, M. Cirasuolo, O. Almaini, M. Franx, J. Fynbo, O. Le Fevre, R. Carlberg, C. Pritchett, R. Ellis



# 4. Current Status

# Observing nights & Achievements

■ SuccessRate: S08B 40%; S09A 26%

	UDS1	UDS2	UDS3	UDS4	UV1	UV2	UV3	UV4
10月24日	0	0	0	0	0	0	0	0
11月3日	0	93	0	0	0	0	0	0
11月26日	0	54	50	0	88	71	0	0
11月27日	66	94	94	88	50	81	0	0
12月2日	0	120	89	147	0	0	100	96
12月3日	80	90	60	0	82	67	0	0
12月24日	0	50	0	0	0	0	0	0
1月1日	0	0	0	0	0	0	0	0
1月23日	0	116	0	0	83	83	79	16
1月28日	0	26	0	0	0	0	0	0
2月20日	0	0	0	0	0	0	0	0
3月1日	0	0	0	0	0	0	35	30
3月2日	0	0	0	0	0	60	30	0
3月24日	0	0	0	0	0	144	178	0
3月31日	0	0	0	0	0	0	10	0
4月2日	0	0	0	0	0	0	80	0
4月22日	0	0	0	0	0	60	124	0
4月29日	0	0	0	0	0	34	62	0

# - Continued

- SuccessRate: S09B (2 carryover + 4 buffer nights) 56%

	UDS1	UDS2	UDS3	UDS4	UV1	UV2	UV3	UV4
10月12日	90	108	108	80	0	0	0	0
10月21日	0	0	0	0	0	0	0	0
11月12日	0	0	0	0	0	0	0	0
11月13日	0	0	0	180	0	0	0	80
11月21日	0	117	0	259	0	79	0	82
11月22日	137	102	0	174	0	66	77	0
12月17日	0	0	0	0	0	18	0	90
12月22日	0	0	0	0	0	50	0	0

Sum: 373 970 401 928 303 813 775 394<sup>(min)</sup>

- 5 nights allocated (S10A-104) for UltraVista (COSMOS)

- Complete UltraVista field
- Try to obtain SNe rate with the UltraVista field data



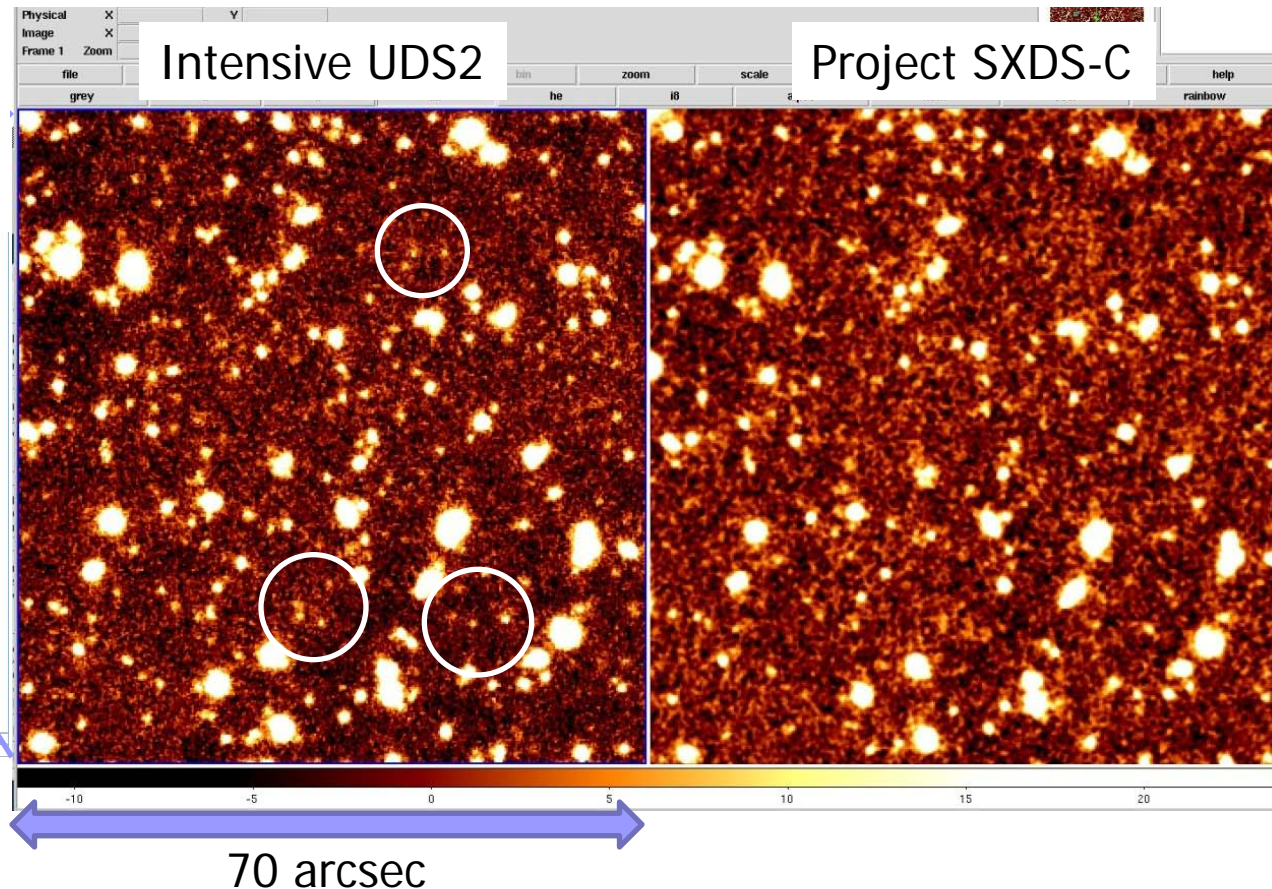
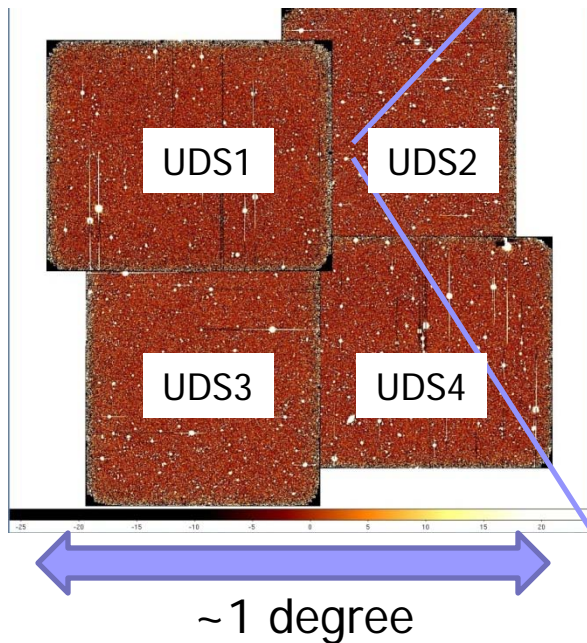
# Status of Data Reduction

- In progress with test version of SDFRED rev.
- Final image will be stacked into a large mosaic

""Preliminary""

TOBE CHECKED

UDS2 ~ 27.3 (1.5"φ; 5σ)



# SNe study

The exposure time is split for SN study

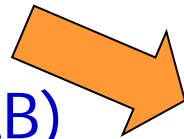
→ Make SN light curves in z'-band

For 1 epoch

○ Field S-Cam 4 field ( $\sim 1\text{deg}^2$ ) (UDS & UltraVista)

○ Exposure **3600sec**

○ Limit mag  **$\sim 25.8$  mag (AB)**

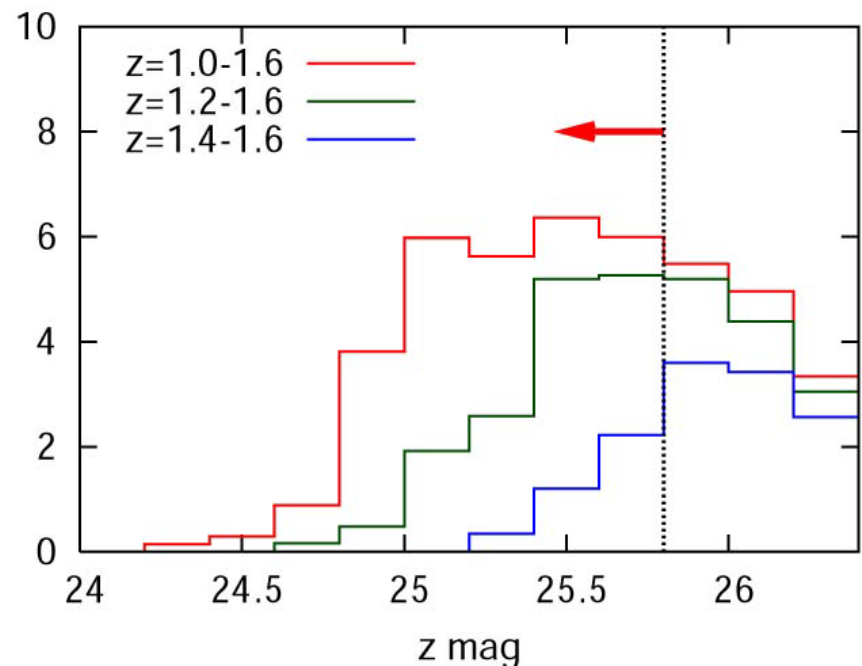
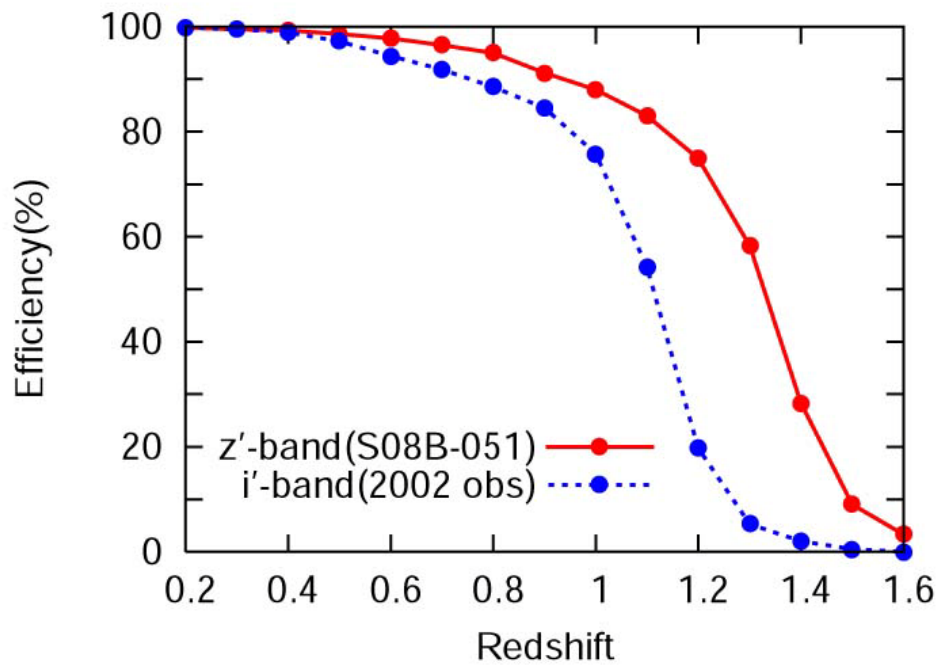


Expected SNe Ia

$\sim 15$  at  $z \sim 1.2$ ,  $\sim 5$  at  $z > 1.4$

per one semester ( $\sim 5$ -6 epoch obs.)

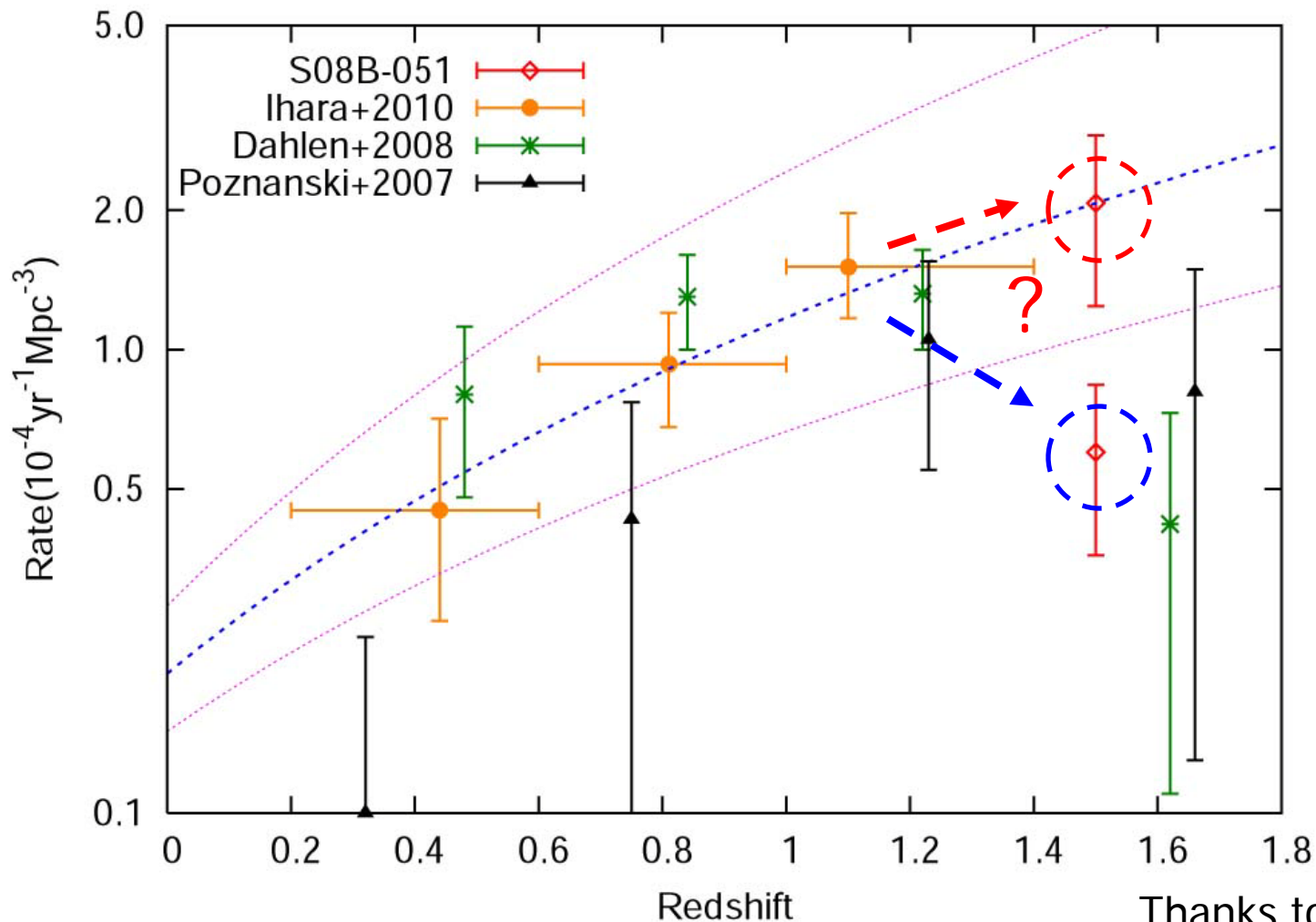
Thanks to Y. Ihara





# SN Ia Rates

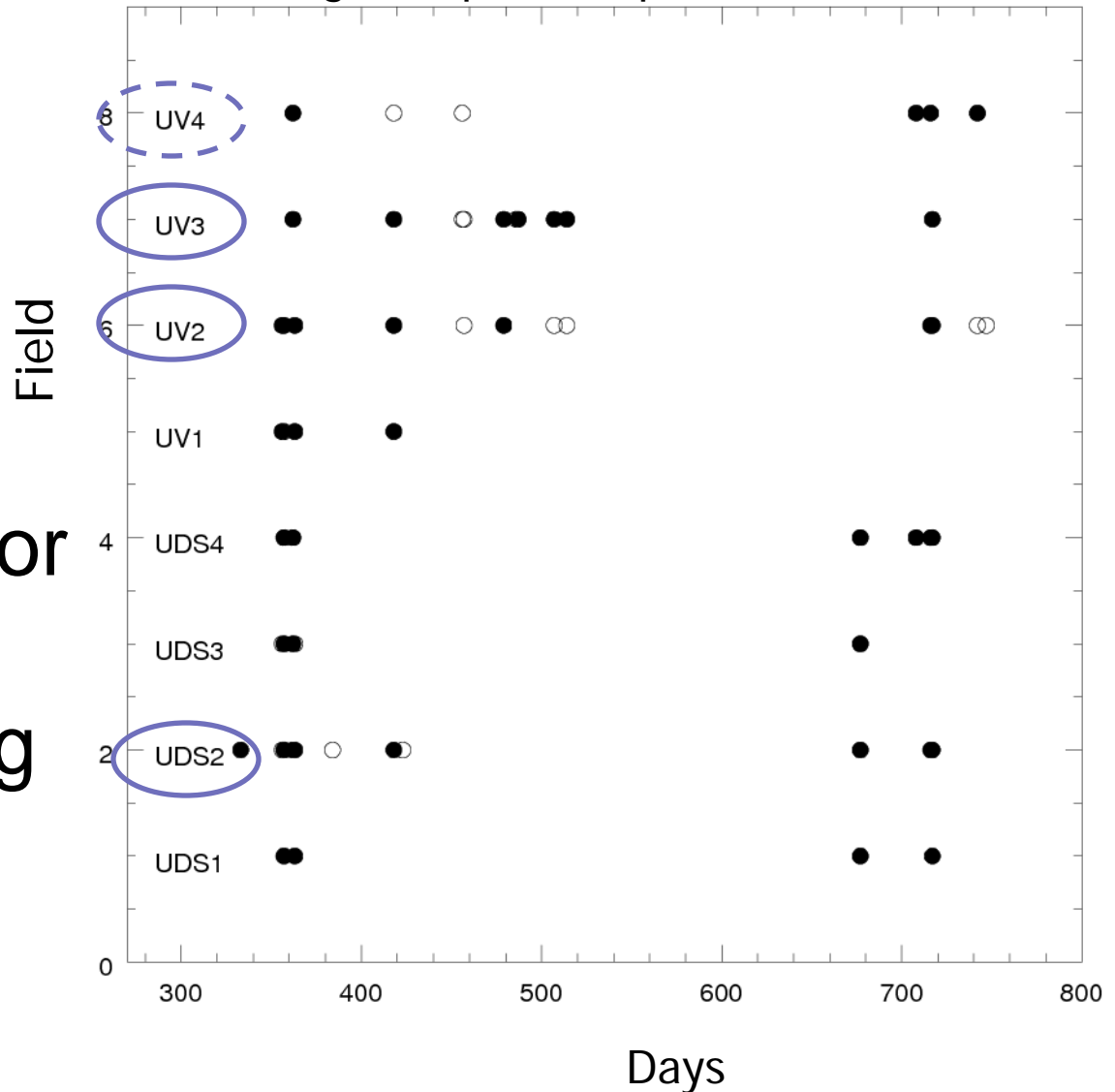
To add crucial data to determine the peak of SN Ia rates at  $z > 1.4$   
→ Show SNe Ia with short delay time ( $t \sim 0.1$  Gyr)



# SNe Efforts

- Suffering from unluckily lost nights
- Efforts to get telescope time for spectroscopy (GTC) & imaging in other bands, (MegaCam: Astier+08)

● Good epoch    ExpT > 60min  
○ No-good epoch    ExpT < 60min



# Current status (SXDS/UDS)

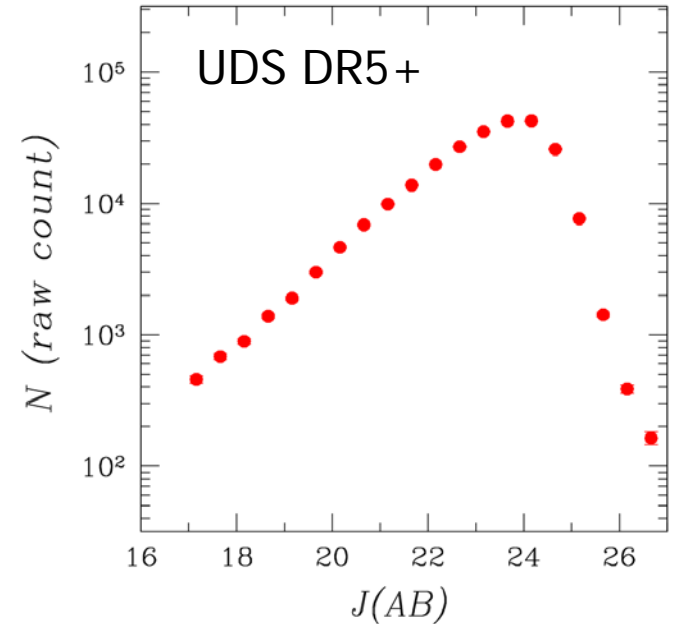
	11/3 (0)	11/26 (23)	11/27 (24)	12/2 (30)	12/3 (31)	12/24 (52)	1/1 (60)	1/23 (81)
Time	7.5h	7.0h	7.0h	6.5h	6.5h	5h	4.5h	2.5h
UDS1	×	×	24.81 3600s 1.2"	×	25.17 4980s 0.7"	×	×	×
UDS2	~24 6420s 0.8"	24.84 3600s 1.0"	25.55 5280s 0.8"	25.67 7200s 0.6"	25.46 5400s 0.7"	25.16 3380s 0.9"	×	~25 7040s 1.0"
UDS3	×	24.10 2520s 1.2"	25.41 5670s 1.0"	25.47 6280s 0.7"	25.51 5730s 0.6"	×	×	×
UDS4	×	×	25.30 5280s 0.8"	25.58 8520s 0.7"	×	×	×	×

# Current status (COSMOS/UltraVista)

	12/2,3 (Ref)	1/23 (0)	1/28 (5)	2/20 (28)	3/1,2 (36,7)	3/24 (59)	4/2 (68)	4/21 (87)	4/28 (94)
Time	8.0h	7.0h	7.5h	8.0h	8.0h	7.0h	6.5h	4.0h	4.0h
UV1	25.49 4360s 0.6"	25.31 4980s 0.8"	×	×	×	×	×	×	×
UV2	25.68 7980s 0.7"	25.48 4500s 0.9"	×	×	×	25.61 9720s 0.9"	×	25.05 3600s 0.6"	~25 2520s 0.9"
UV3	25.66 5700s 0.6"	25.21 4200s 0.8"	×	×	24.98 6200s 1.1"	25.85 11160s 0.6"	24.98 4800s 1.1"	24.88 6720s 0.7"	~25 3880s 0.8"
UV4	25.58 5760s 0.6"	25.11 4380s 1.1"	×	×	~25 4440s 1.1"	×	×		×

# Other Updates

- UltraVista will launch very soon
- UDS DR7 will be released in 2010H1 & J band will reach J~25AB
  - Can be used for studies on  $z \sim 7$  galaxies
- GTC time is allocated for SN followup
  - Expect some interesting results on SNe rate



# Summary

- The 1<sup>st</sup> year round is finished. Data reduction and compilation of data is underway and nearly to be done
- The deep z-band data will be used for the exploration of the young universe combined with latest UDS DR7 & UltraVista the first release
- ~200 z~7 dropout galaxies expected by the combination of Subaru ultra deep z' data and the final-depth releases of J,H,K data in ~2 sq.degree UDS and UltraVista fields
- SNe Ia at z=1-1.5 are being searched to investigate good constraints on the cosmology and SN Ia rate.