The Subaru Deep Field

～ 6 years journey ～

Nobunari Kashikawa

(National Astronomical Observatory of Japan: NAOJ)

Subaru Deep Field (SDF) Project

- Systematic imaging+spectroscopic survey to explore the universe as deep as, and as early as possible with Subaru.
- The major goal is to sample and understand the high-z (4<z<7) populations
- Conventional methods of “Lyman-drop” and “narrow-band”
- Taking advantage of a wide FoV of Suprime-Cam
- Measuring the fundamental observables such as LF, CF
- Subaru Observatory Project;

  2002.Apr. ~ 2004.Mar.

  ~30nights /2years +5nights (Intensive, PI: Y.Taniguchi)
  - SDF (Subaru Deep Field Project) deeper
  - SXDS (Subaru/XMM Deep Survey) wider

SDF team are

N.Kashikawa[1]、M.Ajiki[2]、M.Akiyama[3]、H.Ando[1]、K.Aoki[3]、M.Doi[4]、S.Fujita[2]、H.Furusawa[3]、T.Hayashino[2]、H.Karoji[1]、F.Iwamuro[5]、M.Iye[1]、N.Kobayashi[4]、T.Kodama[1]、K.Kodaira[6]、Y.Komiyama[1]、Y.Matsuda[2]、S.Miyazaki[3]、 T.Morokuma[4]、K.Motohara[4]、T.Murayama[2]、T.Nagao[1,7]、K.Nariai[8]、S.Okamura[9]、M.Ouchi[10]、T.Sasaki[3]、Y.Sato[1]、 K.Shimasaku[9]、Y.Shioya[2]、H.Tamura[2]、I.Tanaka[3]、Y.Taniguchi[2]、T.Yamada[3]、N.Yasuda[11]、M.Yoshida[9]

and

Subaru Telescope、Mitaka Subaru office、

Subaru Telescope builder

1. NAOJ, mtk
2. Tohoku U.
3. NAOJ, Hawaii
4. Tokyo U., IoA
5. Kyoto U.
6. GUAS
7. INAF
8. Meisei U.
9. Tokyo U.
10. STScI
11. Tokyo U., ICRR

Subaru Deep Field (SDF)

- **Subaru Deep Field (SDF)**
  - α 13:24:21.38 δ +27:29:23.0
  - 34’x27’ FOV
  - Previous deep NIR imaging 2’x2’ K<25.35 (9.7hrs)
  - No nearby bright stars
  - No known cluster of galaxies
  - Low galactic HI column density
  - Easy to access from Mauna-Kea

GOODS-N-FOV size

HDFN-FOV size

real SDF image

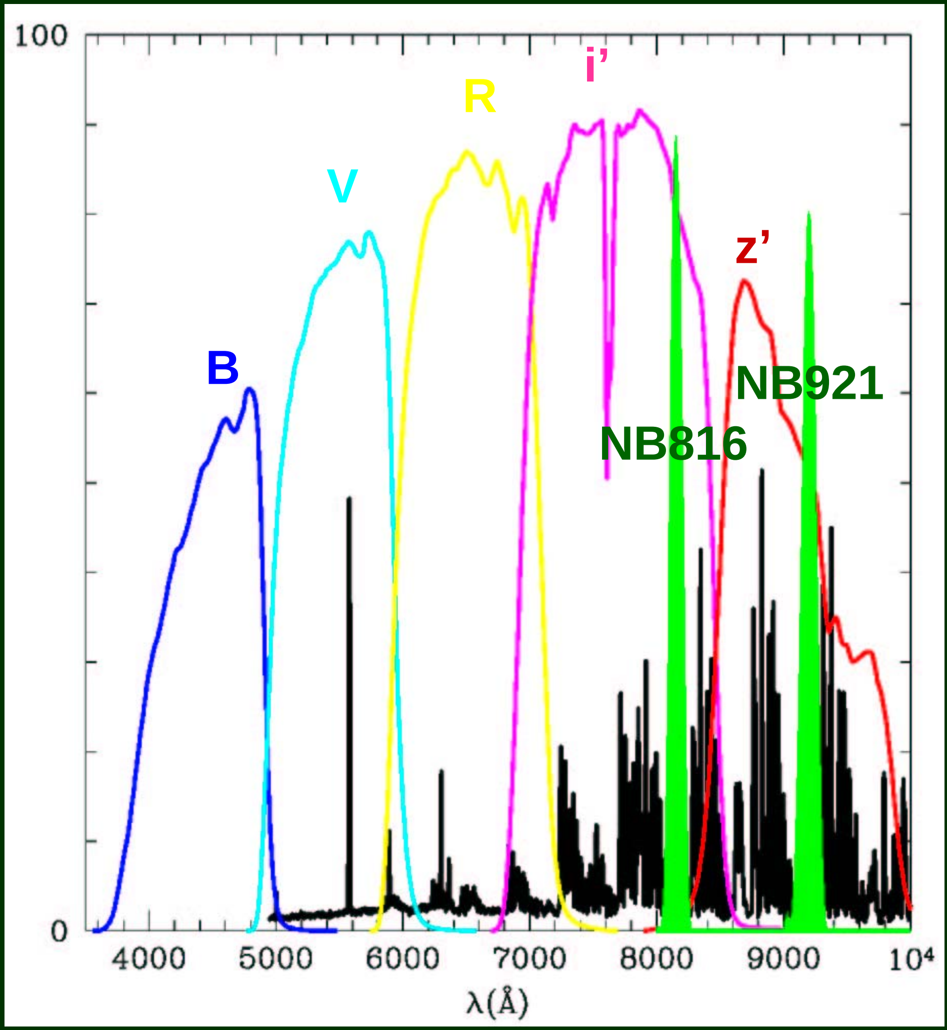
Optical imaging

- Optical imaging with S-Cam http://soaps.naoj.org/sdf/

  Suprime-Cam 1-FOV (34'x27')
  - B<28.5 (9.91hr integ.)
  - V<27.2 (6.0hr)
  - R<27.4 (10.0hr)
  - i'<27.5 (11.25hr)
  - z'<26.6 (9.4hr)

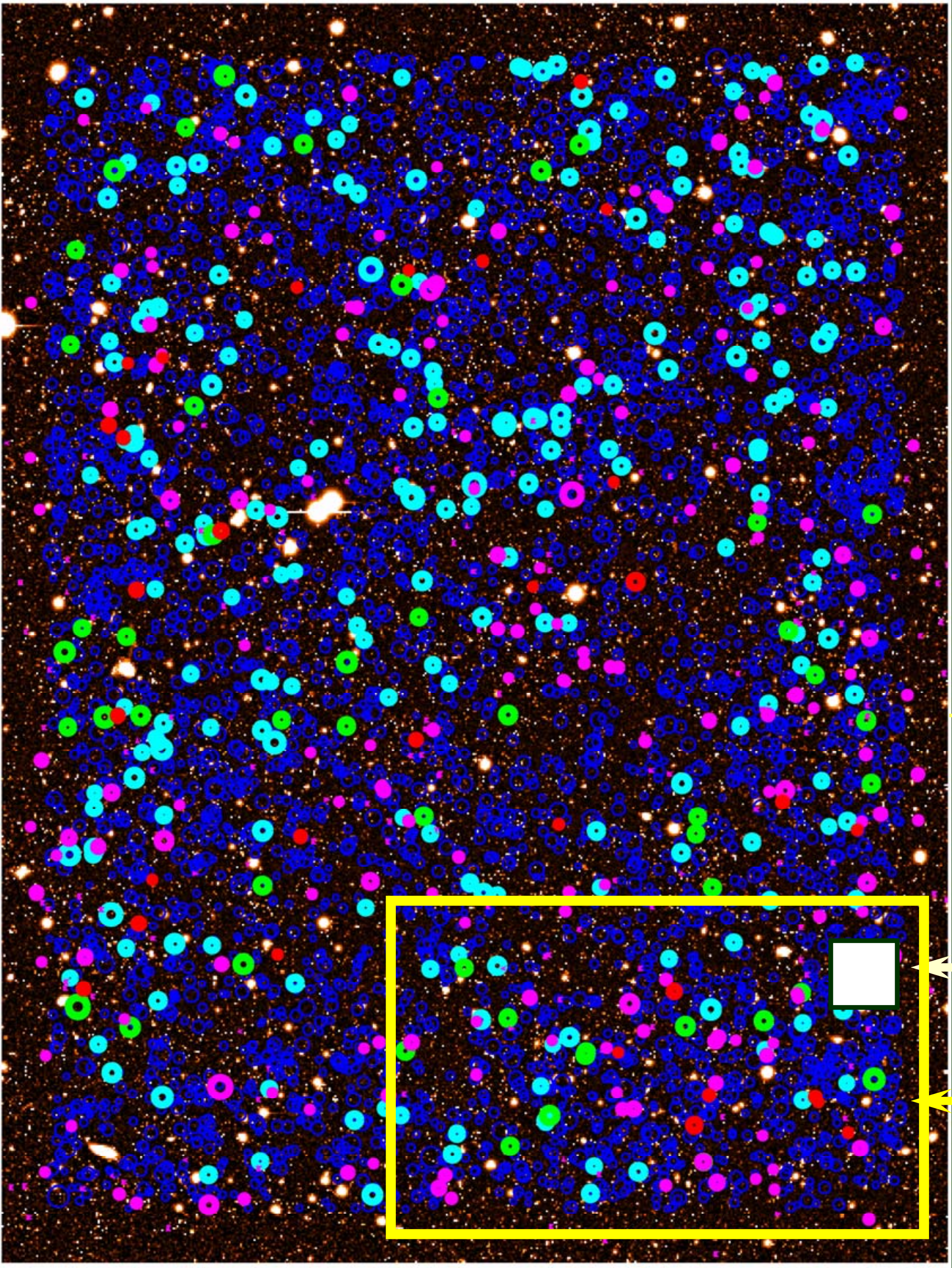
  - NB816<26.8 (10.0hr)
  - NB921<26.5 (15.0hr)

    (AB, 2σ, 2"ϕ)



Galaxies at 4<z<7 on SDF

- Lyman alpha emitters (LAEs)
  - NB816-selected galaxies → z=5.7LAEs (z=5.71±0.05)
  - NB921-selected galaxies → z=6.6LAEs (z=6.57±0.04)
- Lyman break galaxies (LBGs)
  - BRi'-selected galaxies → z~4LBGs (z~4.0±0.5)
  - Vi'z'-selected galaxies → z~5LBGs (z~4.7±0.5)
  - (i'z'-selected galaxies → z~6LBGs)



SDF optical images
effective area 773 $arcmin^2$

- LAE@z=6.6
- LAE@z=5.7
- (LBG@z~6)
- LBG@z~5
- LBG@z~4

They are waiting for spectroscopy!!!

cf.
HDF-N (WFPC2)

GOODS
~160sqmin x 2 fields

Follow-up Observations

- Optical Spectroscopy
  - Subaru/FOCAS (PI: H.Karoji, T.Nagao, NK)
  - KeckII/DEIMOS (PI: M.Malkan)
- NIR
  - deep images in 3 2'x2' fields w/ Subaru/CISCO
  - wide images w/ UKIRT/WFCAM ～400arcmin^2 (PI: K.Motohara)
  - deep Subaru/MOIRCS (PI: K.Motohara)
  - [deep HST/NICMOS] (PI: E.Egami)
- MIR
  - wide Spitzer/IRAC+MIPS (PI: M.Malkan)
  - deep Spitzer/IRAC+MIPS (PI: E.Egami)
- UV
  - GALEX (PI: M.Malkan)
- AO imaging (PI: Y.Yoshii)
- NB imaging
  - N711/N703 imaging (K.Shimasaku,M.Ouchi),
  - N973 imaging (PI: M.Iye)

✓ X, Radio --- no plan

Scientific Results from the SDF

Only refereed papers

- Subaru Deep Survey I. Near-Infrared Observations, Maihara+ 01
- Infrared Star-Count Models and Their Application to the Subaru Deep Field, Nakajima+ 00
- Diffuse EBL versus Deep Galaxy Counts in the SDF: Missing Light in the Universe?, Totani+ 01
- NIR Faint Galaxies in the SDF: Comparing the Theory w/ Obs. for N(m), Colors, and Size Distrib. to K~24.5 Totani+ 01
- HEROs in the SDF: Evidence for Primordial Elliptical Galaxies in the Dusty Starburst Phase, Totani+ 01
- Galaxy Number Counts in the SDF: Multiband Analysis in a Hierarchical Galaxy Formation Model, Nagashima+ 02
- SDS. II. Luminosity Functions and Clustering Properties of Lyα Emitters at z=4.86 in the SDF, Ouchi+ 03
- SDS. III. Evolution of Rest-Frame LFs Based on the Photometric-z for a K'-Band-Selected Galaxy Sample, NK+ 03
- SDS. IV. Discovery of a Large-Scale Structure at Redshift ~=5LSS at z=5, Shimasaku+ 03
- The Discovery of Two Lyman α Emitters beyond Redshift 6 in the SDF, Kodaira+ 03
- SDS. VI. A Census of Lyman Break Galaxies at z~=4 and 5 in the SDFs: Clustering Properties, Ouchi+ 04
- SDS. V. A Census of Lyman Break Galaxies at z~=4 and 5 in the SDFs: Photometric Properties, Ouchi+ 04
- Large Cosmic Variance in the Clustering Properties of Lyα Emitters at z ~= 5, Shimasaku+ 04
- A Strong Lyα Emitter at z = 6.33 in the Subaru Deep Field Selected as an i'-Dropout, Nagao+ 04
- Submillimetre constraints on hyper-extremely red objects in the Subaru Deep Field, Coppin+ 04
- The Subaru Deep Field: The Optical Imaging Data, NK+ 04
- Subaru Super Deep Field with Adaptive Optics. I. Observations and First Implications, Minowa+ 05
- New High-Redshift Galaxies at z = 5.8-6.5 in the Subaru Deep Field, Shioya+ 05a
- The SUBARU Deep Field Project: Lymanα Emitters at a Redshift of 6.6, Taniguchi+ 05
- Number Density of Bright Lyman-Break Galaxies at z ~ 6 in the Subaru Deep Field, Shimasaku+ 05
- A Survey of NB921 Dropouts in the Subaru Deep Field, Shioya+ 05b
- Spectroscopy of i'-Dropout Galaxies with an NB921-Band Depression in the Subaru Deep Field, Nagao+ 05
- Properties of Stars in the Subaru Deep Field, Richmond+ 05
- Clustering of LBGs at z = 4 and 5 in the SDF: Luminosity Dependence of the Correlation Function Slope, NK+ 06a
- Lyα Emitters at z = 5.7 in the Subaru Deep Field, Shimasaku+ 06
- The End of the Reionization Epoch Probed by Lyα Emitters at z = 6.5 in the Subaru Deep Field, NK+ 06b
- A galaxy at a redshift z = 6.96, Iye+ 06
- The LF and Star Formation Rate between Redshifts of 0.07 and 1.47 for Narrow-band Emitters in the SDF, Ly+ 07
- Luminosity Functions of Lyman Break Galaxies at z~4 and z~5 in the Subaru Deep Field, Yoshida+ 07
- High-z LAEs w/ a large EW Properties of i-dropout galaxies w/ an NB921-depression in the SDF, Nagao+ 07
- Luminosity Dependent Clustering of Star-Forming BzK Galaxies at Redshift 2, Hayashi+ 07

z>4 studies

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- Subaru Deep Survey I. Near-Infrared Observations, Maihara+ 01
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- Submillimetre constraints on hyper-extremely red objects in the Subaru Deep Field, Coppin+ 04
- The Subaru Deep Field: The Optical Imaging Data, NK+ 04
- Subaru Super Deep Field with Adaptive Optics. I. Observations and First Implications, Minowa+ 05
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- A galaxy at a redshift z = 6.96, Iye+ 06
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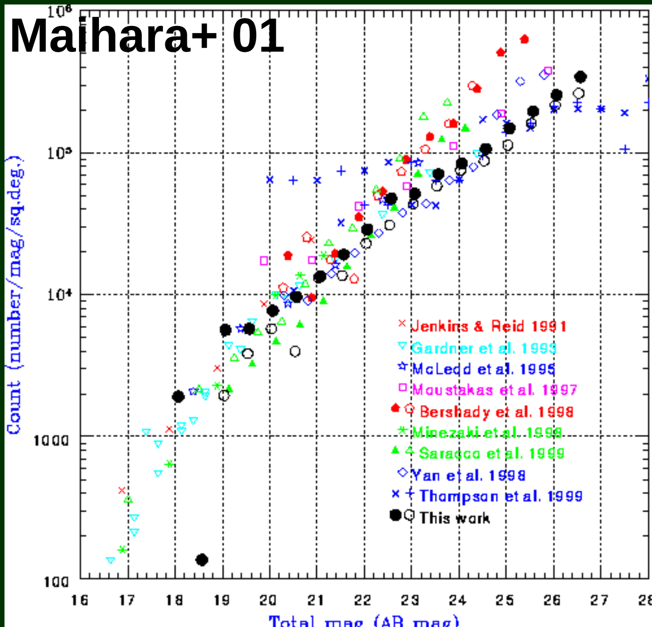
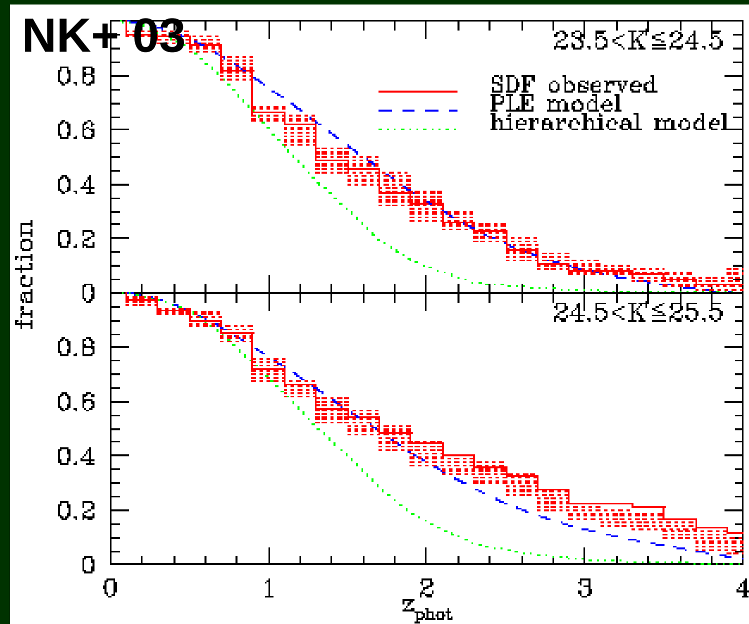
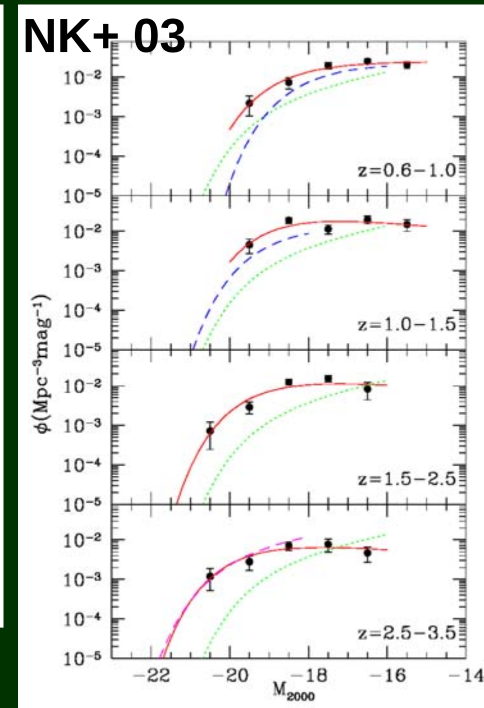
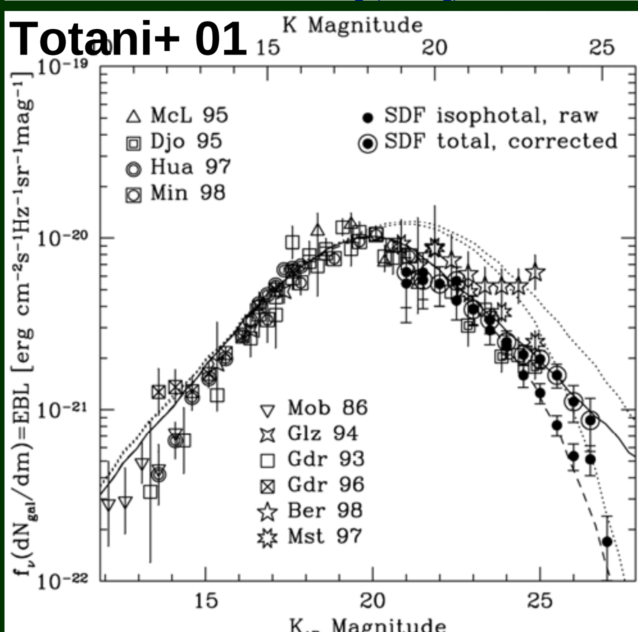
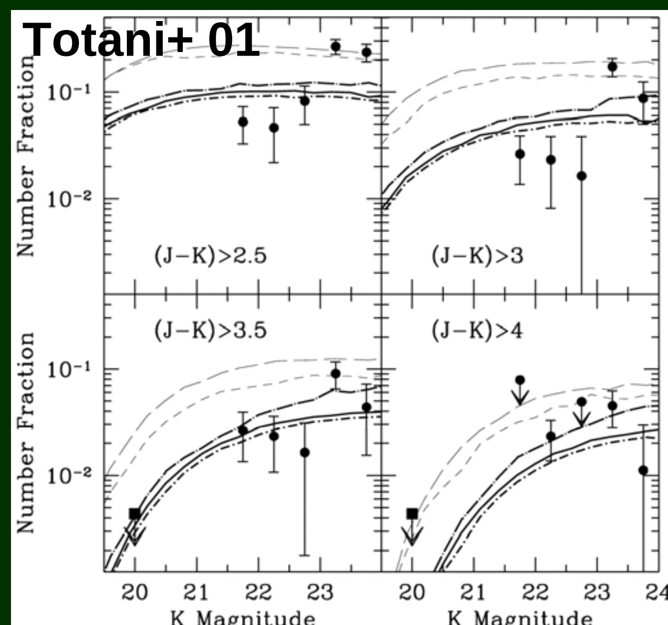
SDF Scientific Results Digest – CISCO field

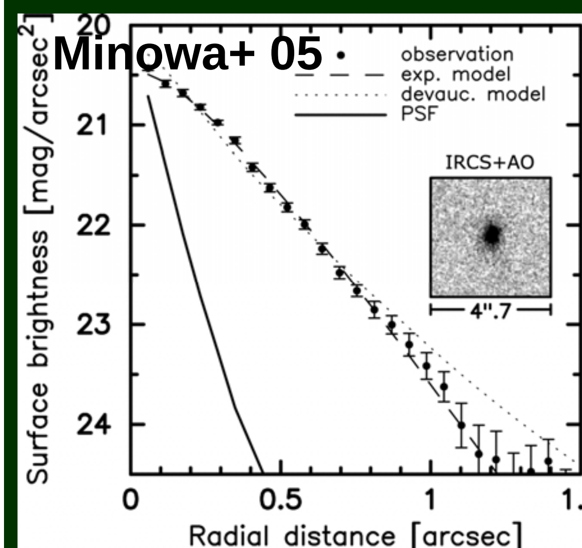




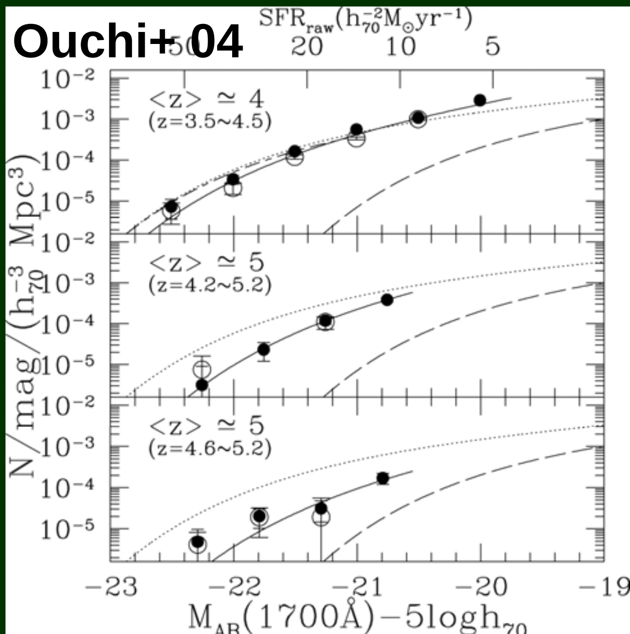


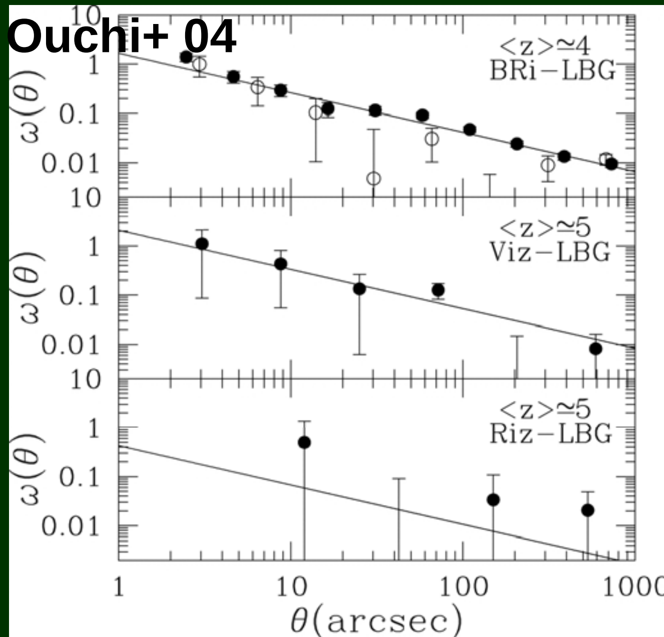


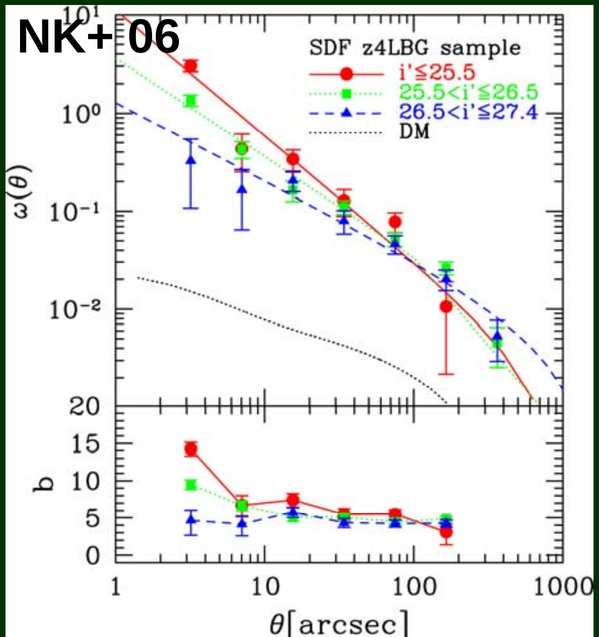


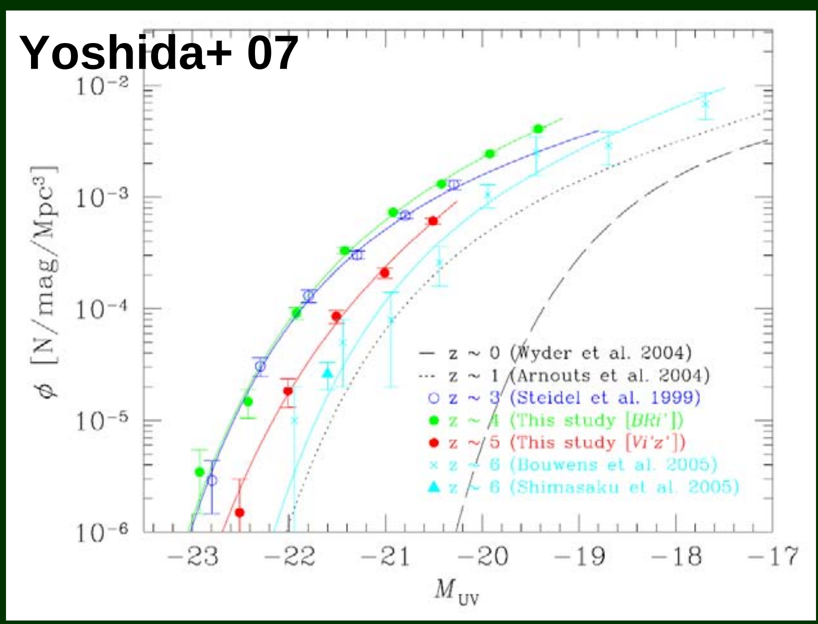


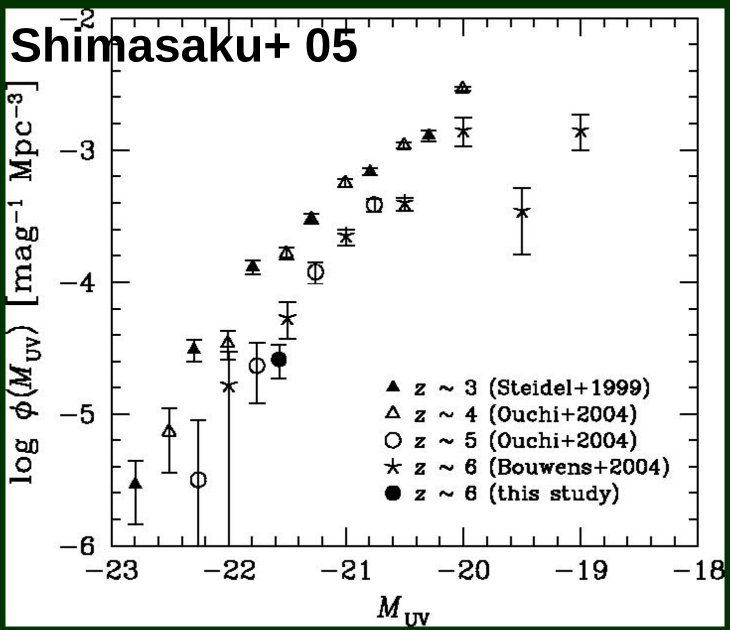
SDF Scientific Results Digest - LBGs



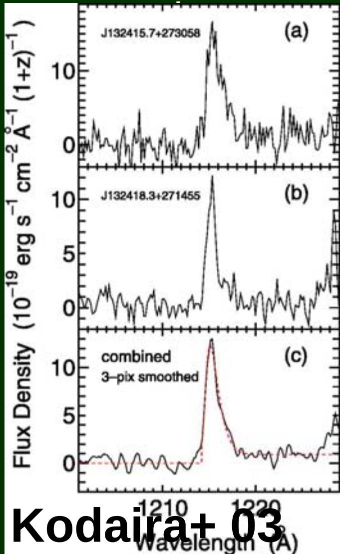




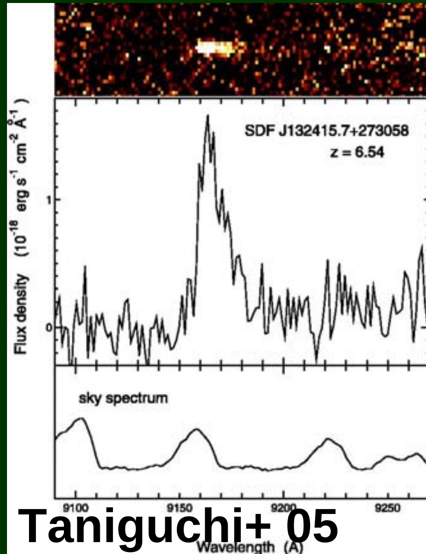




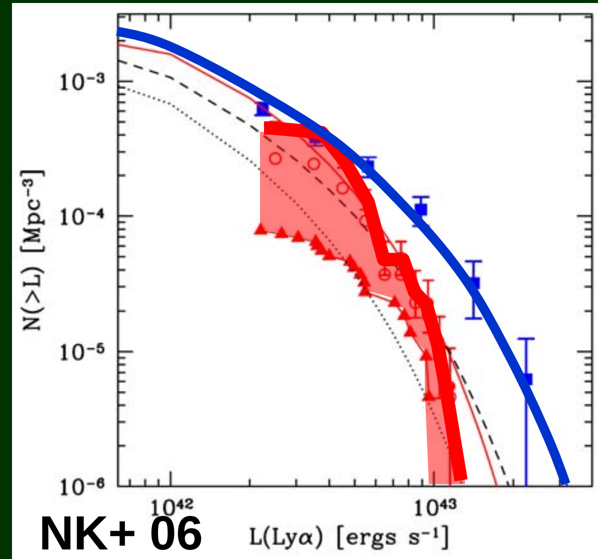
SDF Scientific Results Digest - LAEs



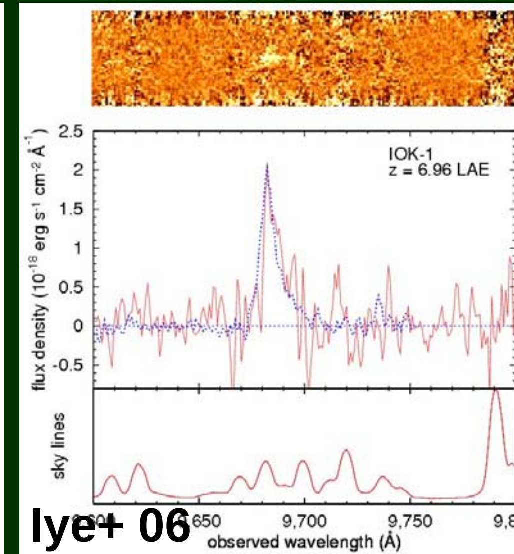
Kodaira+ 03



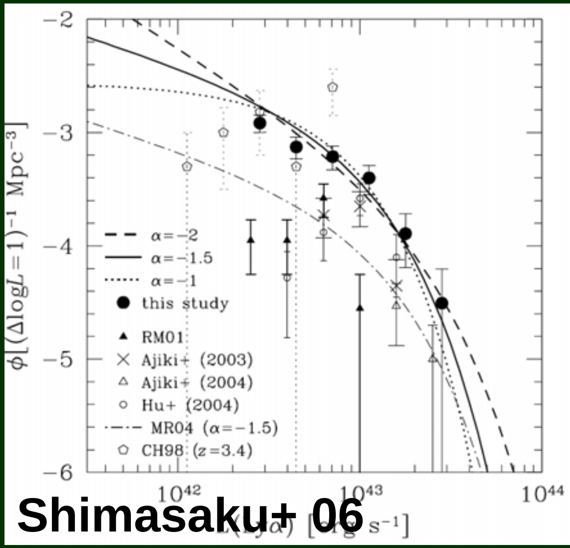
Taniguchi+ 05



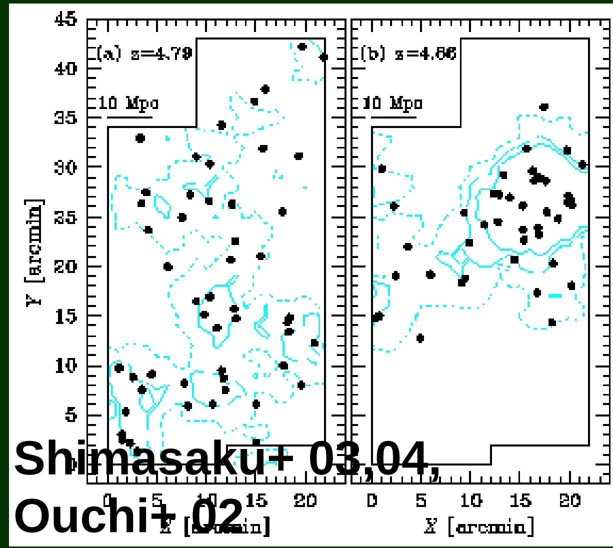
NK+ 06



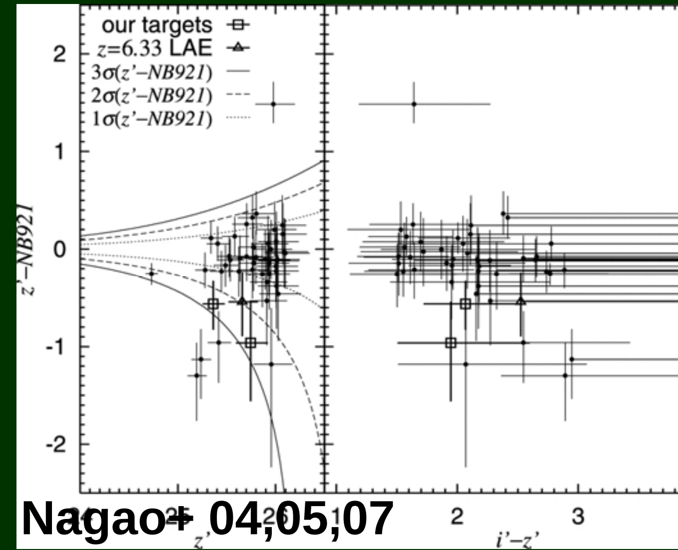
Iye+ 06



Shimasaku+ 06



Shimasaku+ 03,04,
Ouchi+ 02



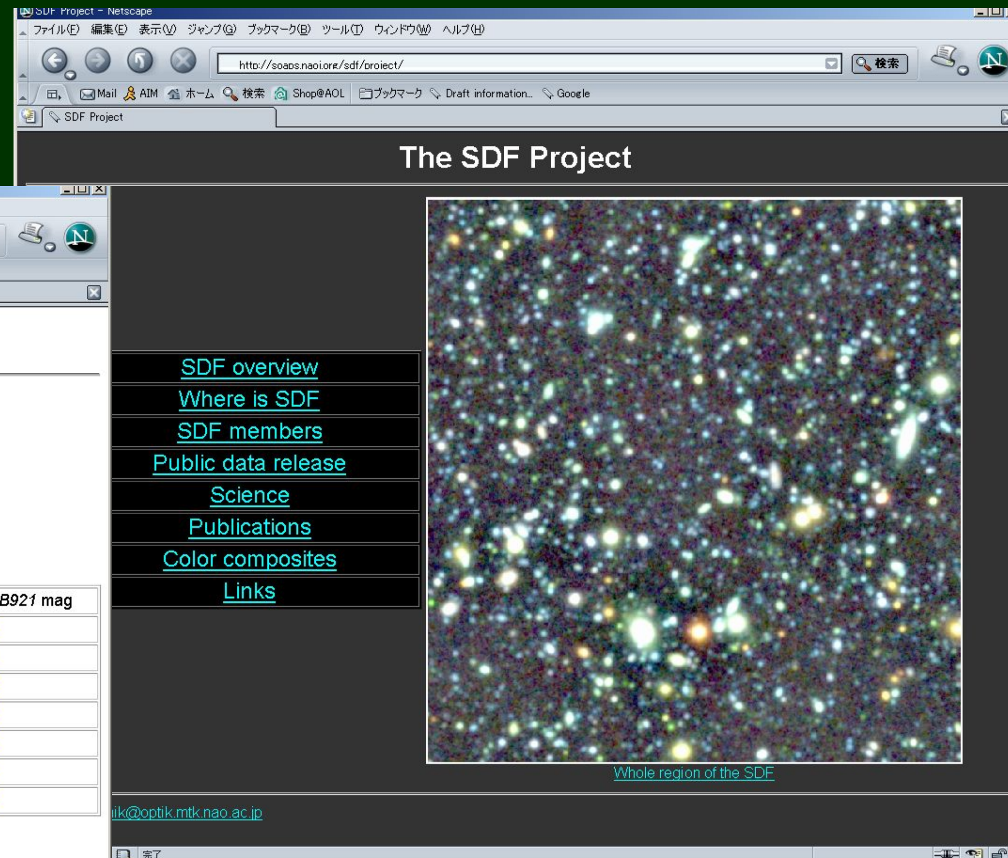
Nagao+ 04,05,07

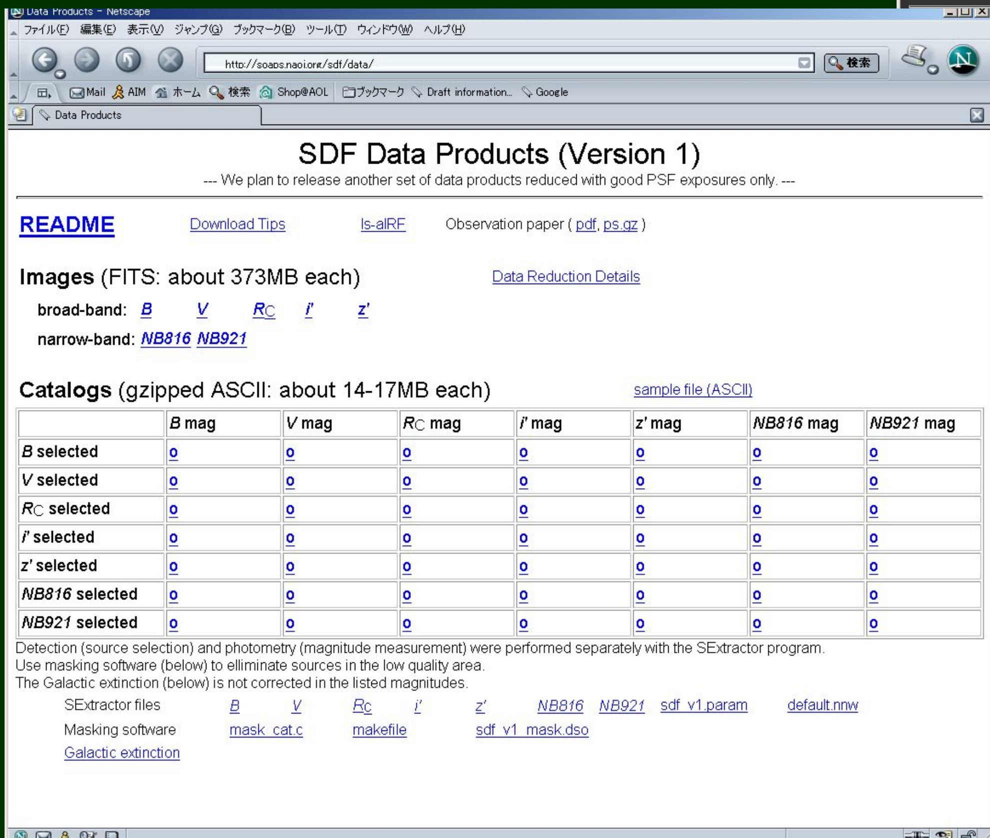
and … Stay tuned

- Subaru Super Deep Field using Adaptive Optics
  Minowa, Y.
- Formation and Evolution of the Star-Forming Galaxies at z~2
  Hayashi, M.
- Galaxies at z~7: Evolution, Probing Re-Ionization of the Universe
  Ohta, K.

Data release

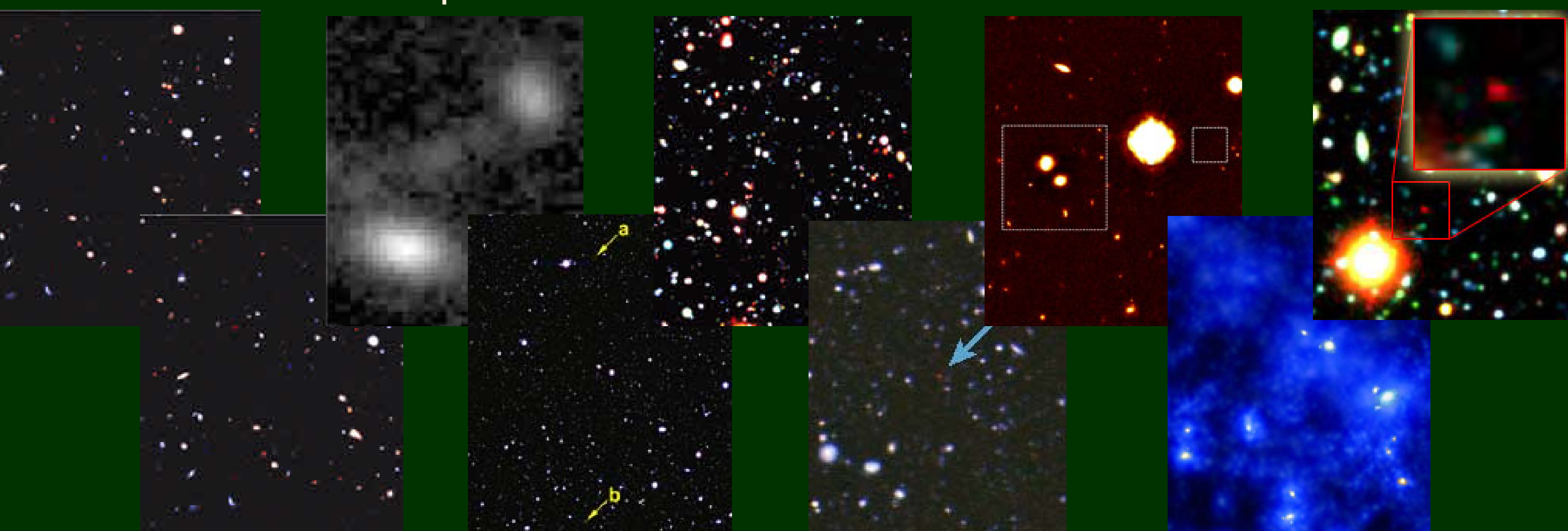
- http://soaps.naoj.org/sdf/
  - 2004.11.01 The final data/catalogs release
  - details --- NK+04, PASJ, 56, 1011





Press / Web releases

- 2006 Cosmic Archeology Uncovers the Universe's Dark Ages
- 2005 Young Galaxies Grow Up Together in a Nest of Dark Matter
- 2005 Subaru Obtains the Deepest Infrared Image of the Universe
- 2003 Subaru Telescope Detects the Most Distant Galaxy Yet, part 2
- 2003 The Universe Had Large Scale Structure at a Very Early Age
- 2003 Subaru Telescope Detects the Most Distant Galaxy Yet
- 2001 Discovery of Seven New Distant Supernovae
- 2001 Light From All the Galaxies in the Universe
- 1999 Subaru Deep Field



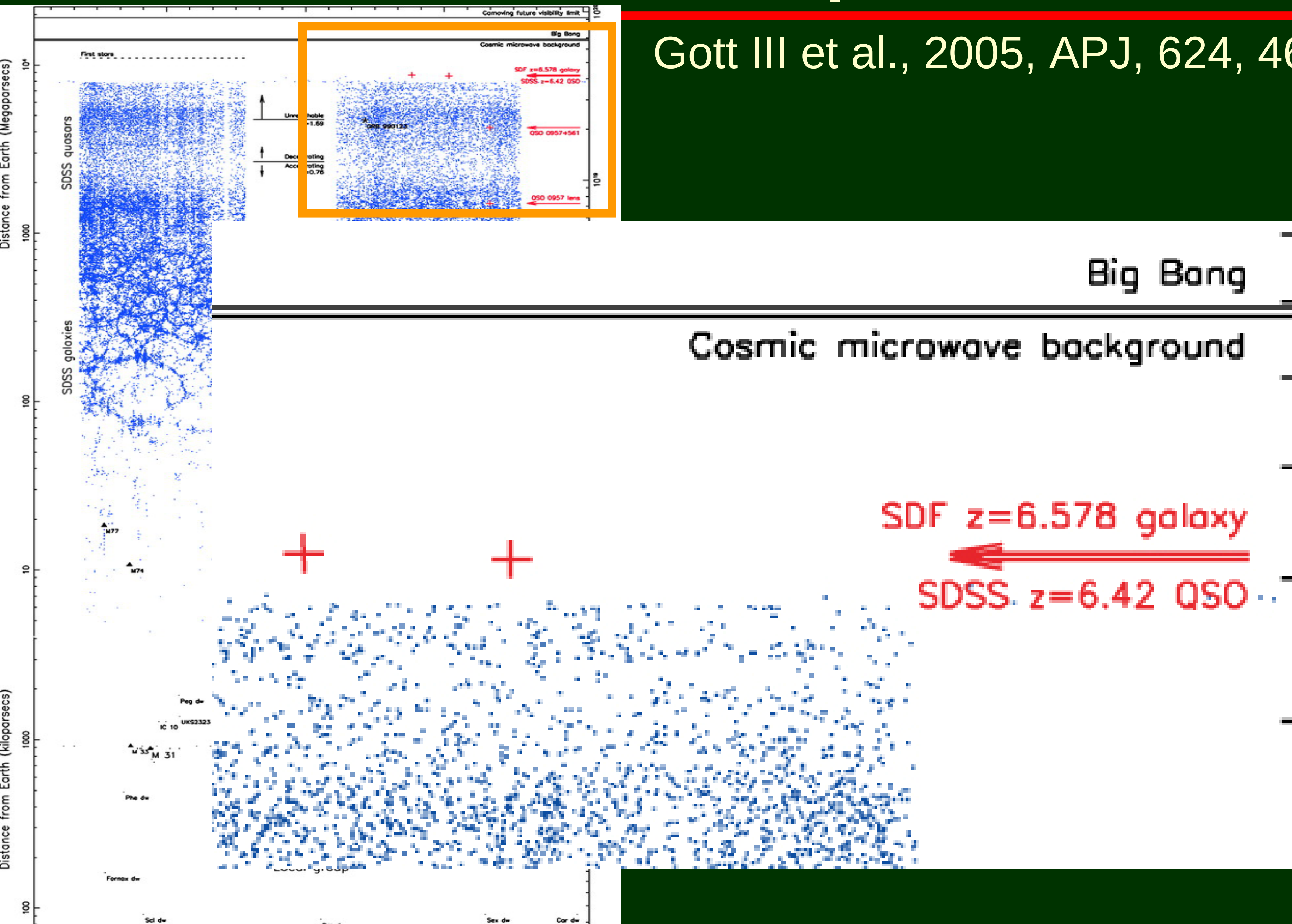

SDF
SOY SAUCE FLAVOR

Prizes

- 2005 ASJ PASJ Award（日本天文学会　欧文研究報告論文賞）
  Maihara et al. 2001
- 2004 ASJ PASJ Award（日本天文学会　欧文研究報告論文賞）
  Kodaira et al. 2003

A Map of the Universe

Gott III et al., 2005, APJ, 624, 463



SDF Pros & Cons

- STRENGTHS
  - Project lead by Japan/Subaru
    - global consensus as the Subaru's work
    - It is not a "Subaru follow-up" of "XXX survey" !
  - Prompt data analysis, data release, result output
    ← small membership & clear objectives
- WEAKNESSES
  - Poor initial organization for multi- λ observations.
    - Follow-up observations with our own efforts
    - insufficient outputs except high-z sciences


[独占インタビュー]
イビチャ・オシム
「日本オリジナル、
それが答えだ」
Takuya Sugiyama
mizuno

The first one small step, but one giant leap for Subaru

Sincerely respect to CISCO team who first observed the SDF where nobody has set foot in 6 years ago.