

A Panoramic Search for Lya Blobs at $z=3$

**Yuichi Matsuda
(NAO Japan / Durham)**

T. Yamada, Y. Nakamura, T. Hayashino,
K. Kousai, N. Morimoto (Tohoku),
M. Umemura (Tsukuba)

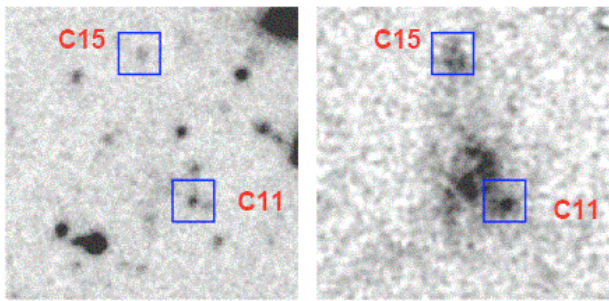
Contents

- 1. What are Ly α blobs?**
- 2. A Panoramic Search for Ly α Blobs at $z=3$**
 - Data: NB497 Imaging with Suprime-Cam (the same data in Nakamura's talk)
 - Area: $\sim 3 \text{ deg}^2$ (E-SSA22 / SXDS / SDF / GOODS-N)
 - Depth: $\sim 2 \times 10^{-18} \text{ ergs s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$ (5-10 hrs)
 - Result: ~ 100 LABs (size $> 30 \text{ kpc}$)
- 3. On-going Ly α Imaging Surveys for proto-clusters around Giant LABs & HzRGs with Giant Ly α Halos**

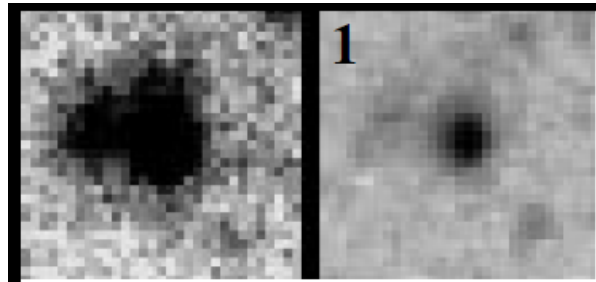
What are LABs?

- **Spatially Extended Ly α Nebulae** (Moller & Warren 1998, Keel et al. 1999, Fynbo et al. 1999, 2003, Steidel et al. 2000, Francis et al. 2001, Palunas et al. 2004, Matsuda et al. 2004, Dey et al. 2005, Nilsson et al. 2006, Saito et al. 2006, 2008, Smith & Jarvis 2007, Greve et al. 2007, Ouchi et al. 2008, Prescott, Smith, Yang's talks/posters)

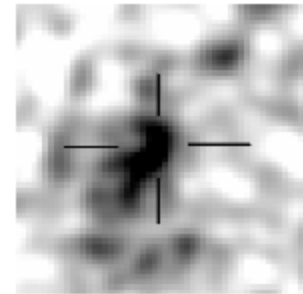
BLOB 1



40''

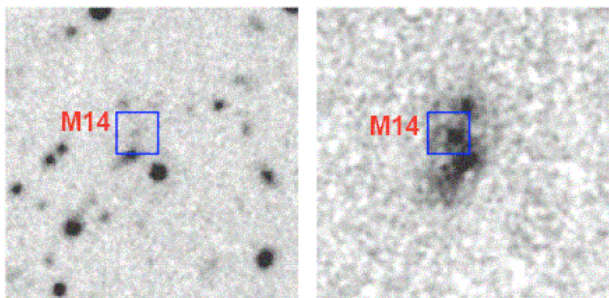


Keel et al. 1999

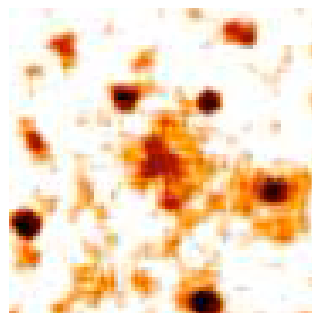


Smith & Jarvis 2007

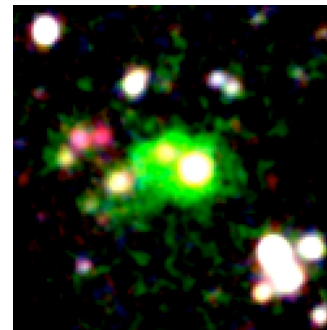
BLOB 2



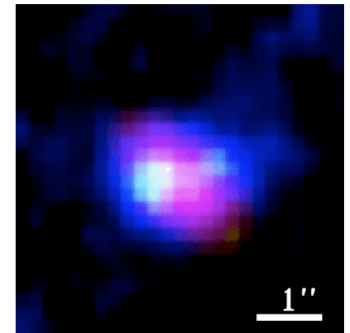
Steidel et al. 2000



Nilsson et al. 2006



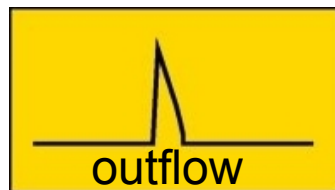
Matsuda et al. 2004



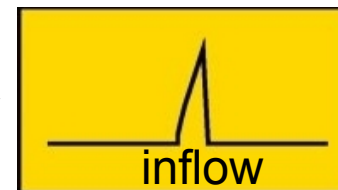
Ouchi et al. 2008

What are LABs?

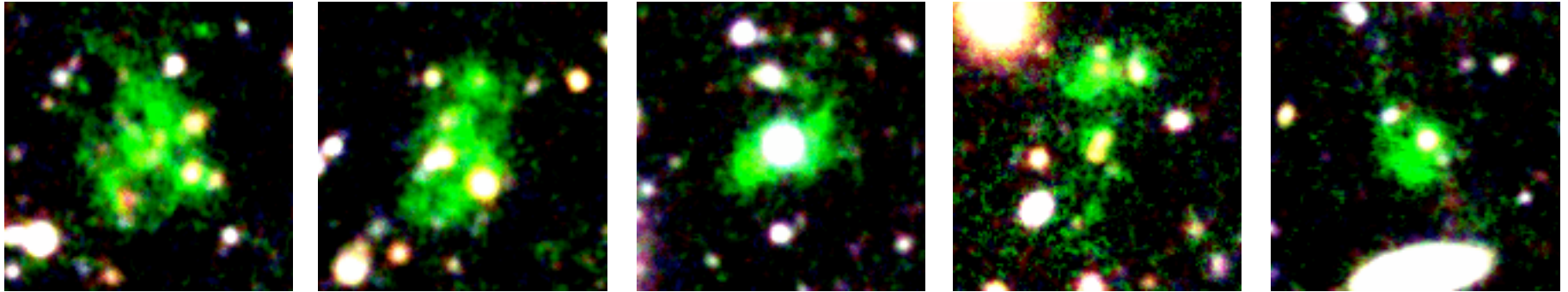
- The followings are still being debated.
 - **Basic Statistical Properties** - Number Density, Size & Luminosity Distribution, Clustering Properties, Equivelent Width, Environment, Redshift Distribution? (Keel et al. 1999, Steidel et al. 2000, Palunas et al. 2004, Matsuda et al. 2004, 2005, Saito et al. 2006, 2008, Prescott et al. 2008, Ouchi et al. 2008, **This Talk**, see also Ouchi, Prescott, Smith, Yang, Saito's talks/posters)
 - Power Sources - Starburst, AGN, Superwind, Gravitational Cooling? (Taniguchi & Shioya 2000, Haiman et al. 2000, Chapman et al. 2001, Smail et al. 2003, Basu-Zych & Scharf 2004, Geach et al. 2005, Colbert et al. 2006, Yang et al. 2005, Dijkstra et al. 2006a,b, Mori & Umemura 2006, Nilsson et al. 2006, Smith & Jarvis 2007, Greve et al. 2007, Matsuda et al. 2007, Beelen et al. 2008, Smith et al. 2008, see Hatch, Scarlata, Geach, Colbert's talks)
 - Gas Kinematics - Outflow, Inflow, Inflow+Outflow, Rotation? (Ohyama et al. 2001, Bower et al. 2003, Wilman et al. 2005, Dey et al. 2005, Matsuda et al. 2006)



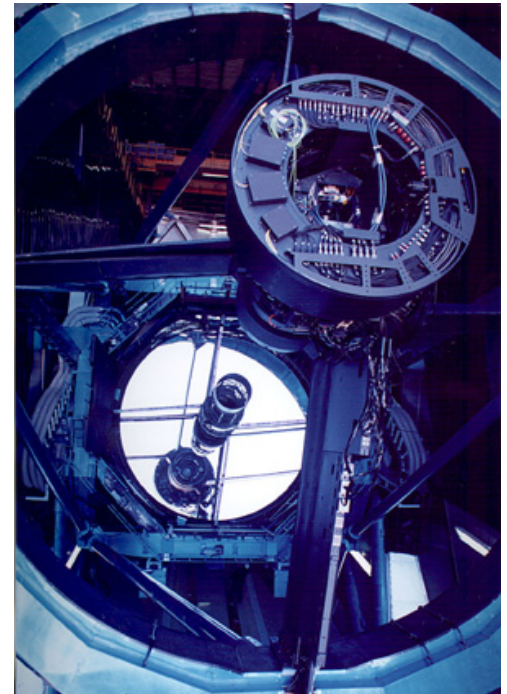
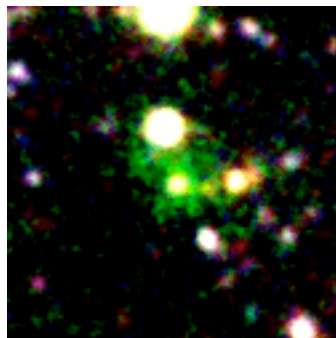
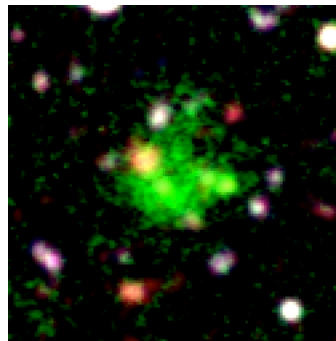
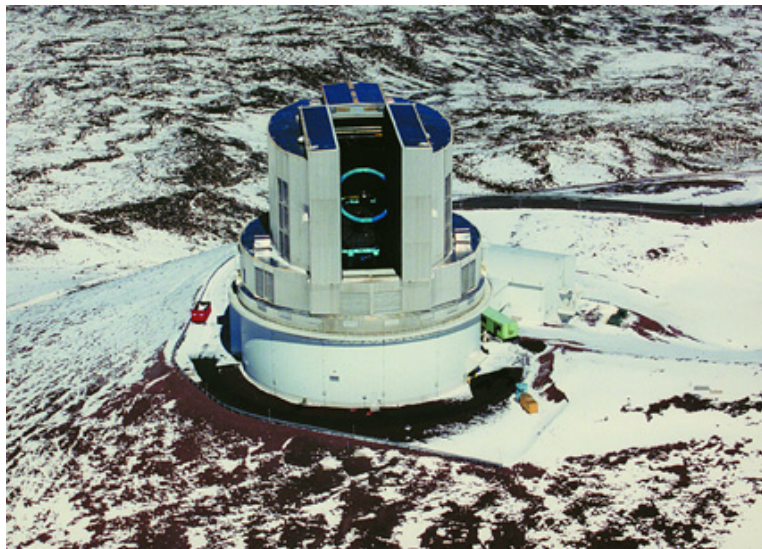
or



?



1. A Panoramic Search for Ly α blobs at $z=3$



1. A Panoramic Search for Ly α Blobs at $z=3$

- Purpose: to examine the basic statistical properties of LABs
 - Number density
 - Size, Surface Brightness, Luminosity Distributions
 - Clustering Property
 - Equivalent Width

1. A Panoramic Search for Ly α Blobs at $z=3$

- Data (the same data in Nakamura's talk)
 - Instrument: Suprime-Cam, NB497(4977A/77A)
 - Area: 2.6 deg² (2×10^6 comoving Mpc³)
 - Proto-Cluster region & the Surrounding Fields
 - Extended SSA22 (1.4 deg²)
 - Blank Fields
 - SXDS (0.8 deg²)
 - SDF (0.2 deg²)
 - GOODS-N (0.2 deg²)
 - Exposure Time: 5 - 10 hrs / FoV
 - Depth: 2×10^{-18} ergs s⁻¹ cm⁻² arcsec⁻² (2 σ)

1. A Panoramic Search for Ly α Blobs at $z=3$

- Sample Selection Criteria:
 - Detection Threshold: 2×10^{-18} ergs s $^{-1}$ cm $^{-2}$ arcsec $^{-2}$
 - Photometry: Isophotal Area
 - Equivalent Width: $EW_{\text{obs}} > 80A$ ($EW_{\text{rest}} > 20A$)
 - Size:
 - Isophotal Area > 900 kpc 2 ($\sim 30 \times 30$ kpc) $\&\& > 2 \times$ expected from PSF

Size & Surface Brightness

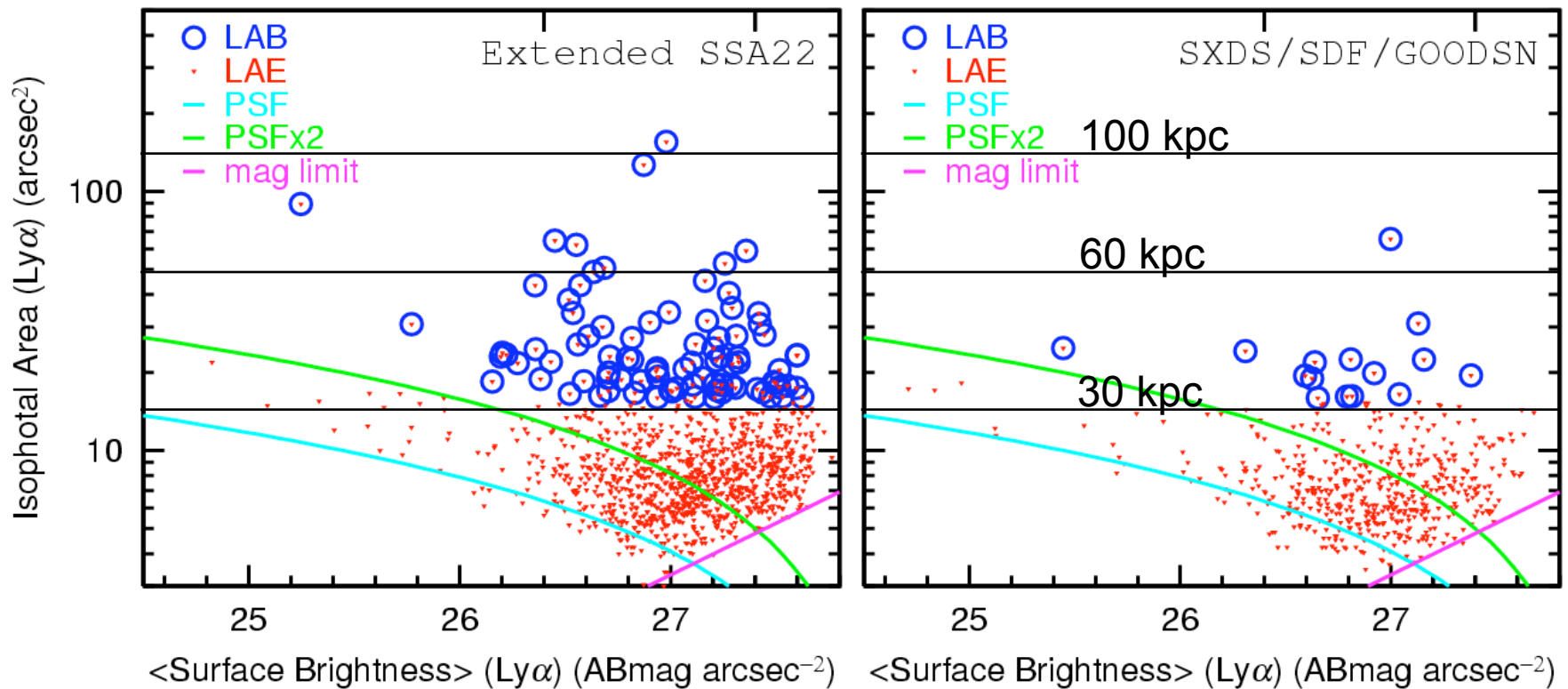
Emitters with $EW_{\text{rest}} > 20 \text{ \AA}$

($\text{ergs s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$)

1.0×10^{-17} 4.0×10^{-18}

($\text{ergs s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$)

1.0×10^{-17} 4.0×10^{-18}



Extended SSA22 (1.4 deg^2)
Proto-cluster & The Surrounding Regions

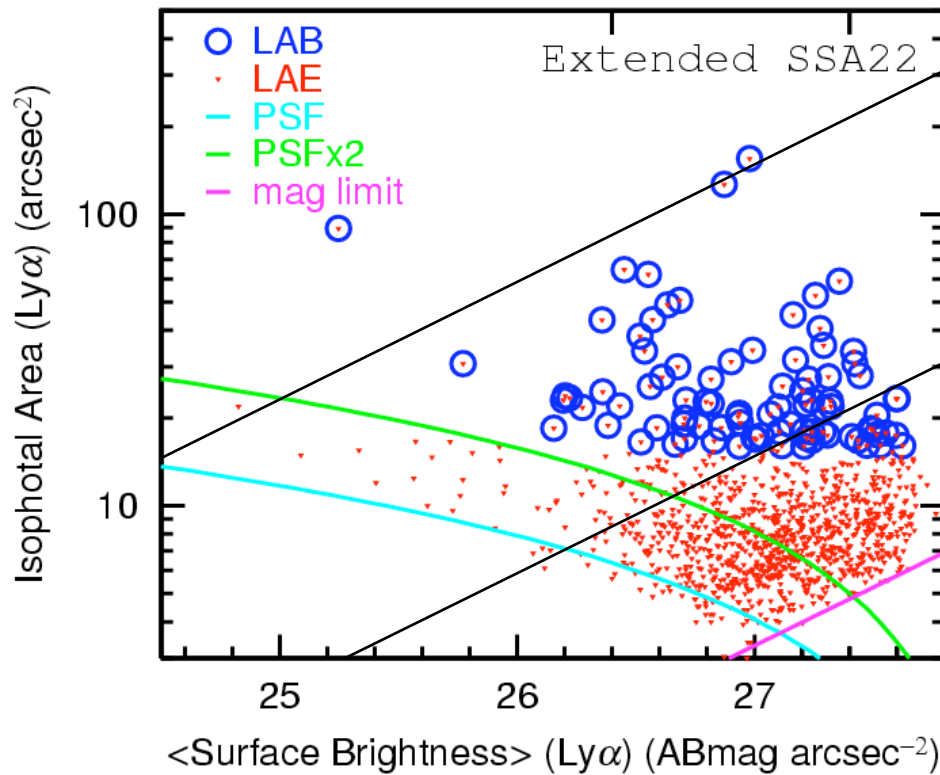
SXDS/SDF/GOODSN (1.2 deg^2)
Blank Fields ⁹

Ly α Luminosity

Emitters with $EW_{\text{rest}} > 20 \text{ \AA}$

($\text{ergs s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$)

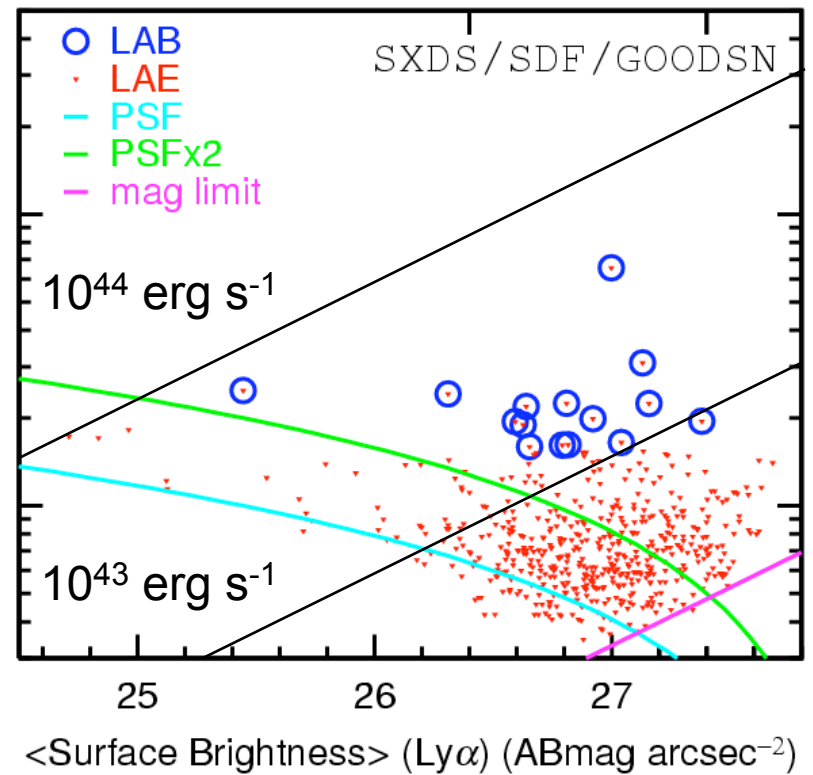
1.0×10^{-17} 4.0×10^{-18}



Extended SSA22 (1.4 deg^2)
Proto-cluster & The Surrounding Regions

($\text{ergs s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$)

1.0×10^{-17} 4.0×10^{-18}



SXDS/SDF/GOODSN (1.2 deg^2)
Blank Fields ¹⁰

Number & Number Density

LABs (size > 30 kpc)

Field Name	Number	Survey Volume (Mpc ³)	Number Density (Mpc ⁻³)
Extended SSA22	89 (8)	1.1×10^6	8×10^{-5} (7×10^{-6})
SSA22 ProtoCluster	29 (4)	1.5×10^5	2×10^{-4} (3×10^{-5})
Blank Fields	16 (1)	0.9×10^6	2×10^{-5} (1×10^{-6})
All	105 (9)	2.0×10^6	5×10^{-5} (5×10^{-6})

* Numbers in () are for larger LABs (size > 60 kpc).

cf. Number density of LAEs at $z=3 \sim 10^{-3} \text{ Mpc}^{-3}$

(see Gronwall, Ouchi, Gawiser's talk)

Sky Distribution

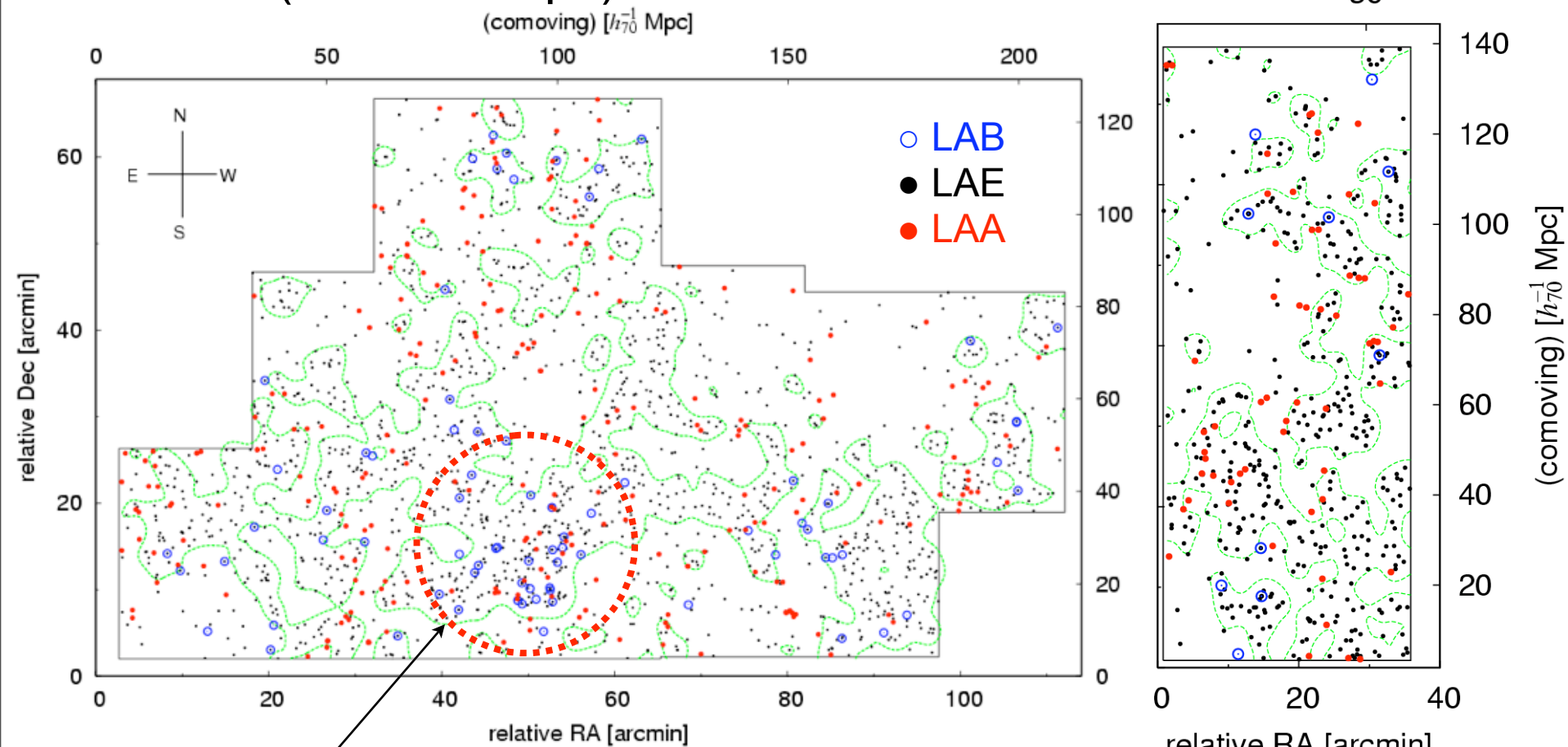
Extended SSA22 (1.4 deg²)

LABs (size > 30 kpc)

SXDS-CNS (0.8 deg²)

(comoving) [h_{70}^{-1} Mpc]

50



Strong Clustering (Number density is 10 x larger than in blank fields)

Sky Distribution

Extended SSA22 (1.4 deg²)

LABs (size > 60 kpc)

(comoving) [h_{70}^{-1} Mpc]

○ LAB

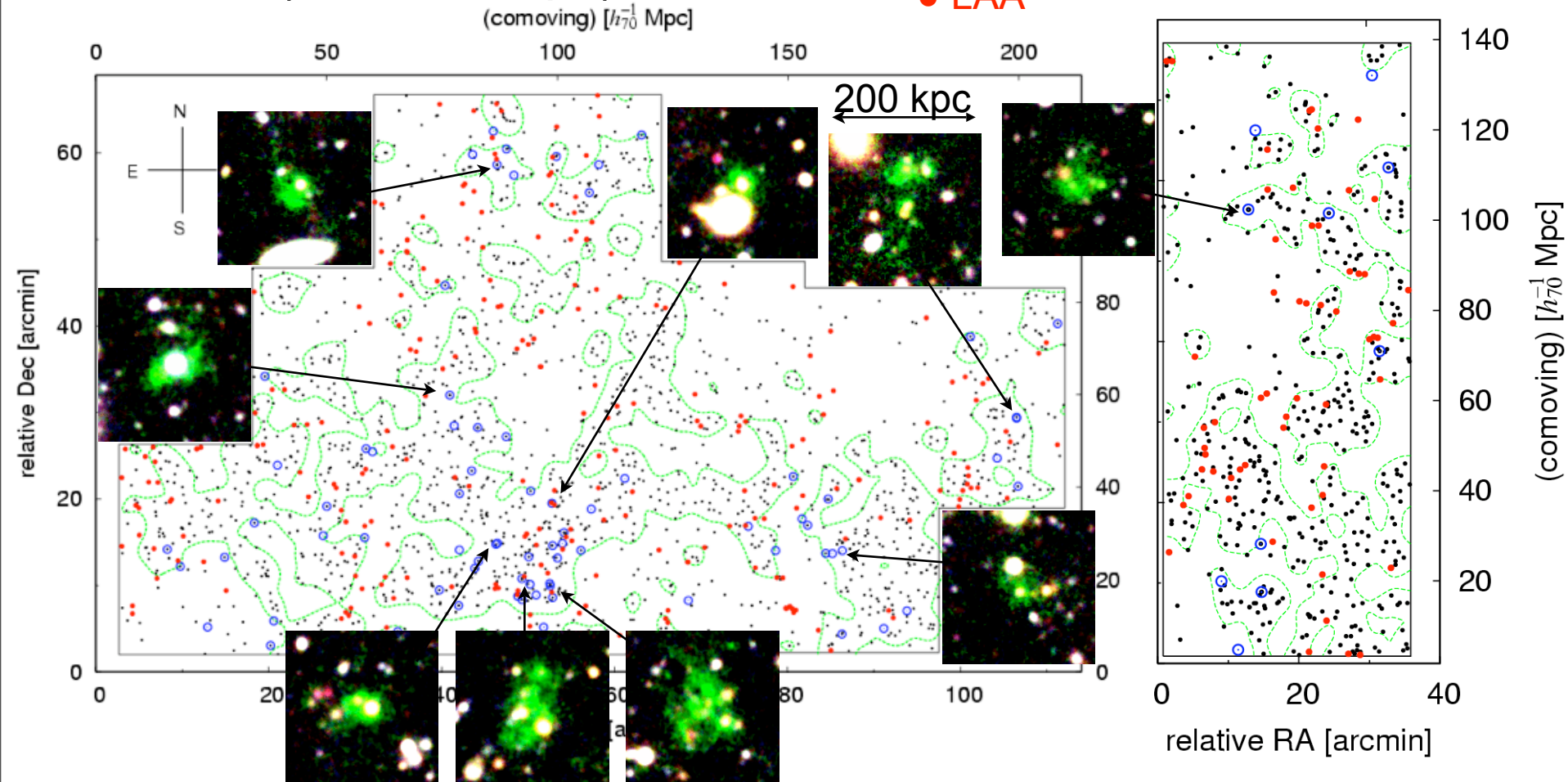
● LAE

● LAA

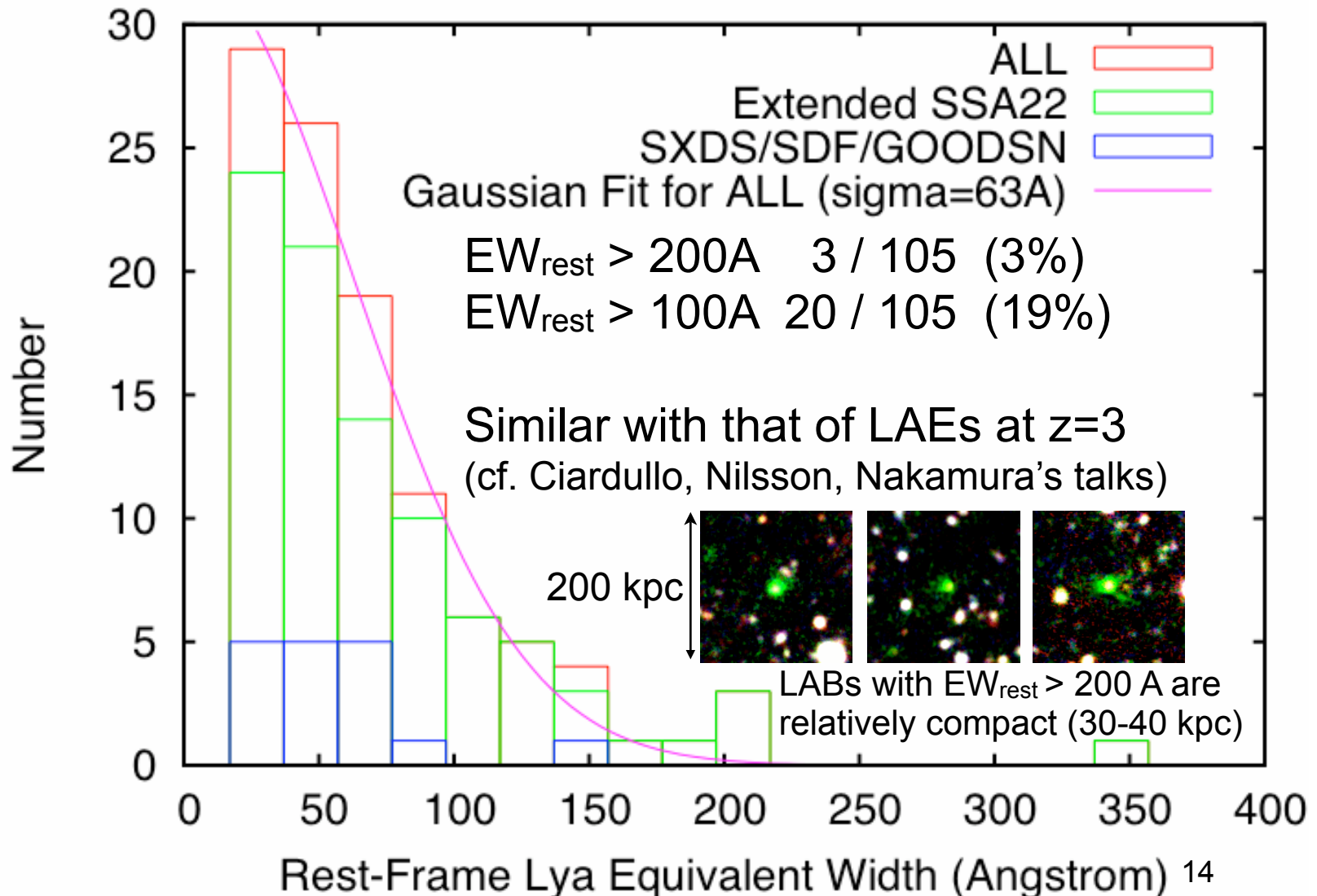
SXDS-CNS (0.8 deg²)

(comoving) [h_{70}^{-1} Mpc]

50

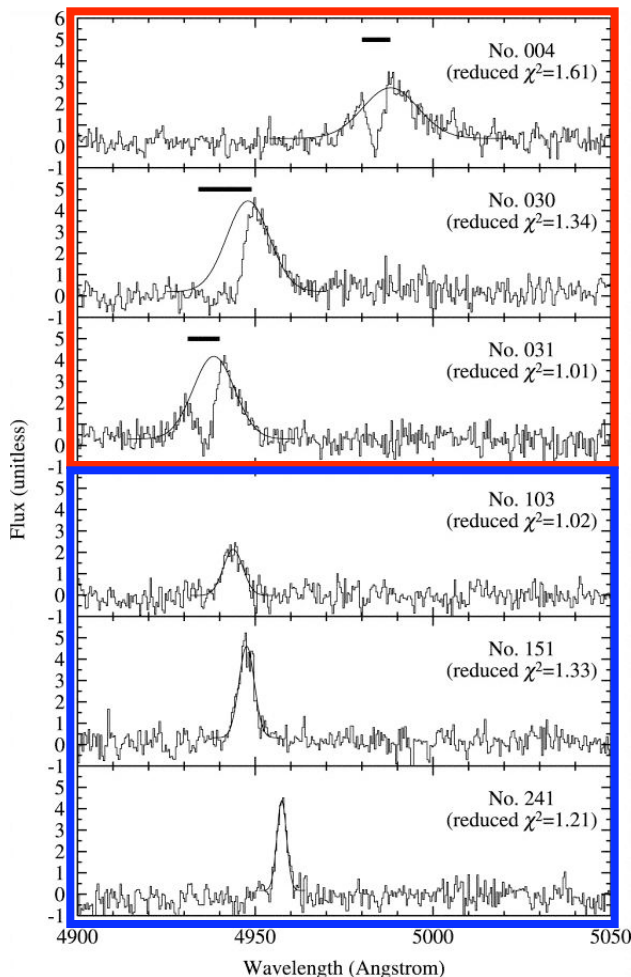


Lya Equivalent Width

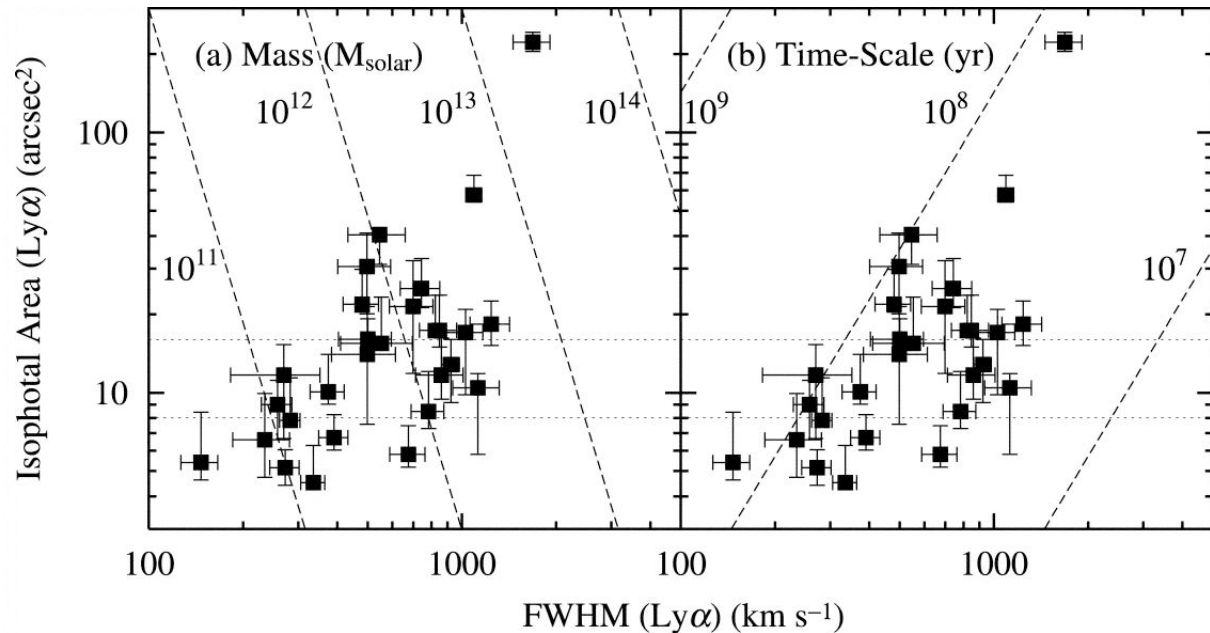


Spectroscopy of LABs

- 28 LABs (~30%) of our sample have already been spectroscopically confirmed (low-z contamination is 0%)



Ly α blobs - FWHM = 500 - 1500 km/s

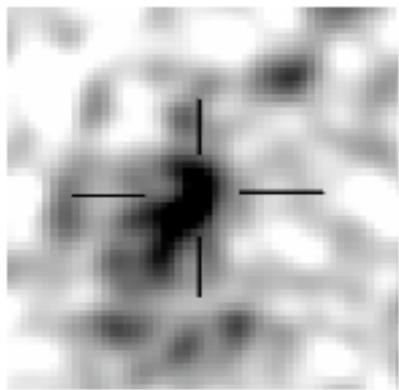


Matsuda et al. 2006

Ly α emitters - FWHM = 100 - 700 km/s

Summary

- We are undertaking a wide-field ($\sim 3 \text{ deg}^2$) survey for LABs in Extended SSA22, GOODSN, SDF, SXDF at $z=3$ with Suprime-Cam.
 - Our LAB sample ~ 100 ($> 30 \text{ kpc}$), ~ 10 ($> 60 \text{ kpc}$)
 - Size, surface brightness, luminosity distributions are continuous (in both protocluster & blank fields)
 - Luminosity $\sim 10^{43-44} \text{ ergs s}^{-1}$ (10 x more luminous than LAEs)
 - Number density - (100 - 1000 x less numerous than LAEs)
 - $2 \times 10^{-5} \text{ Mpc}^{-3}$ (size $>30 \text{ kpc}$, blank fields)
 - $1 \times 10^{-6} \text{ Mpc}^{-3}$ (size $>60 \text{ kpc}$, blank fields)
 - Strong clustering (Number density in the SSA22 proto-cluster is 10 x larger than those in blank fields) - **Characteristic phenomena in overdense environments!!**
 - EW distribution is similar to that of LAEs at $z=3$
 - 30% have been spectroscopically confirmed (0% contamination)



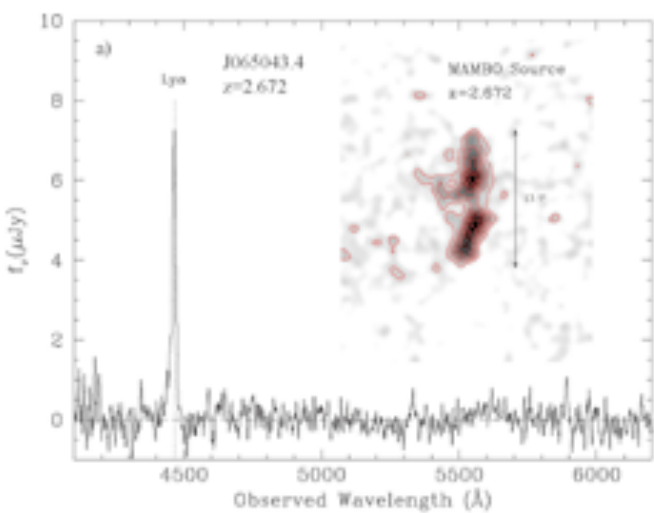
Smith & Jarvis 2007



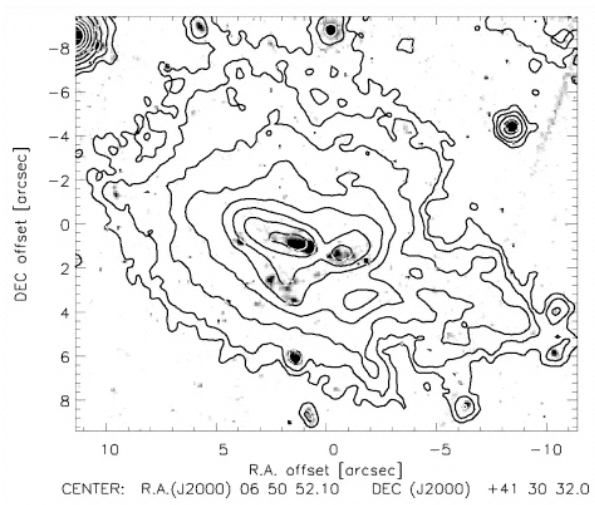
NASA/ESA/G. Miley (Leiden Observatory)/R. Overzier (Leiden Observatory)

Miley & Overzier

2. On-going Ly α Imaging Surveys for Proto-clusters around Giant LABs / HzRGs with Giant Ly α Halos



Greve et al. 2007



Reuland et al. 2003

2. On-going Ly α Imaging Surveys for Proto-clusters around Giant LABs / HzRGs with Giant Ly α Halos

- Purpose: to test whether giant LABs and HzRGs with giant Ly α Halos are always located in protoclusters or not
- Targets: almost all the known LABs and HzRGs with Ly α Halos (>100 kpc) at $z=2.5 - 4$ (the redshift coverage of Suprime-Cam IB filters with Ly α) visible from Hawaii
- Area: 0.25 deg^2 ($\sim 1-2 \times 10^5$ comoving Mpc^3) each
- Schedule:
 - 2008/06 Smith & Jarvis LAB ($z=2.8$), TN J1338 ($z=4.1$)
 - 2008/12 Greve et al. LAB ($z=2.7$), 4C41.17 ($z=3.8$)
 - 2009/01 TXS 0828 ($z=2.6$), B2 0902 ($z=3.4$)