The NIR spectroscopy of the galaxies in the SSA22 protoclsuter at z=3.09

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Abstract

- We conducted the **NIR spectroscopy** of the K-band selected galaxies with z_phot~3.1 in the SSA22 protocluster at **z=3.09.**
- 67 objects were observed by using Subaru MOIRCS. We used newly developed **“VPH-K” grism**.
- Redshifts of about half of the targets were successfully confirmed and a number of them are certainly at z≈3.09.
- We also confirmed the counterparts of the LABs and the AzTEC 1.1um submm source.

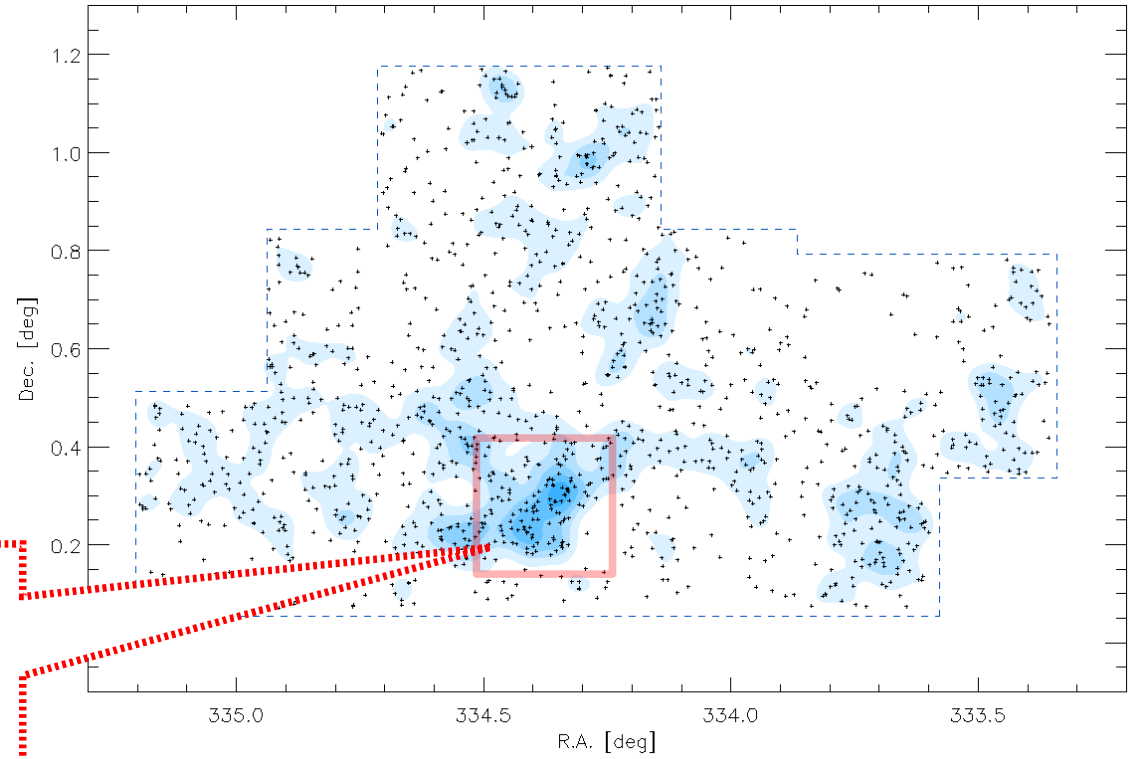
1. Introduction
1.1 The SSA22 protocluster at z=3.09

Significant high density region of the LBGs & LAEs at z=3.09

(Steidel et al. 1998, Steidel et al. 2000, Hayashino et al. 2004, Yamada et al. 2012)

The density excess of the LABs, (Matsuda et al. 2004) and ASTE/AzTEC sub-mm sources(Tamura et al. 2009) are also reported.

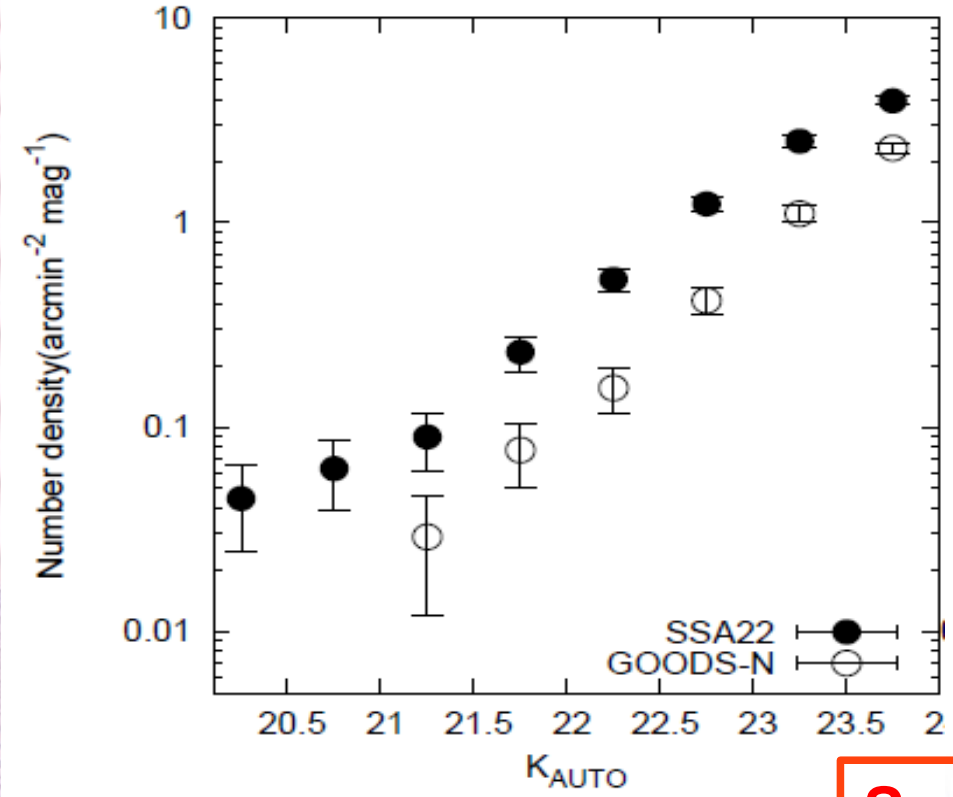
Observed with MOIRCS JHKs-bands
for 111.8arcmin^2 , with K_AB<24

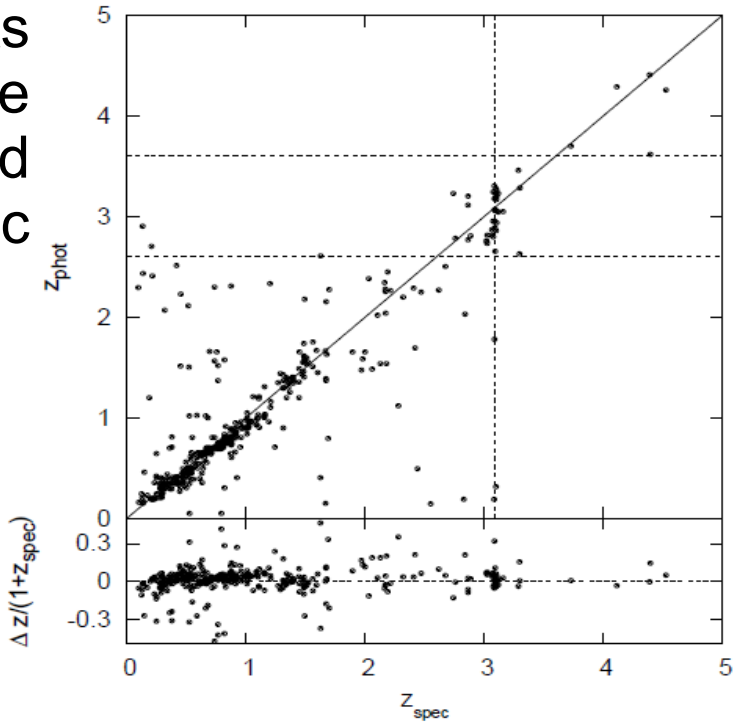


The sky distribution of the LAEs (Yamada et al. 2012)

1.2 MOIRCS imaging observations

We obtained the photometric redshifts from SED fittings and found the surface number density excess of the K-band selected the galaxies with photometric redshift z_phot~3.1.





z_spec v.s. z_phot

Surface number density of K-selected galaxies at z_phot=2.6-3.6 in SSA22 (filled) and GOODS-N(unfilled) field(Kubo+subitted).

Spectroscopic follow up is needed!

2. Observations

Targets: K-band selected galaxies with z_phot=2.6-3.6

Date: 2012/9/29-30 (Full), 2012/10/27-28 (half nights)

Instrument:

- Subaru telescope MOIRCS, Multi-Object Spectroscopy (MOS).
- Using newly developed **"VPH-K"** grism and HK500 grism. Slit width = 0.7",0.8"
- 2half and 2 full(4'×7') MOS masks were used.

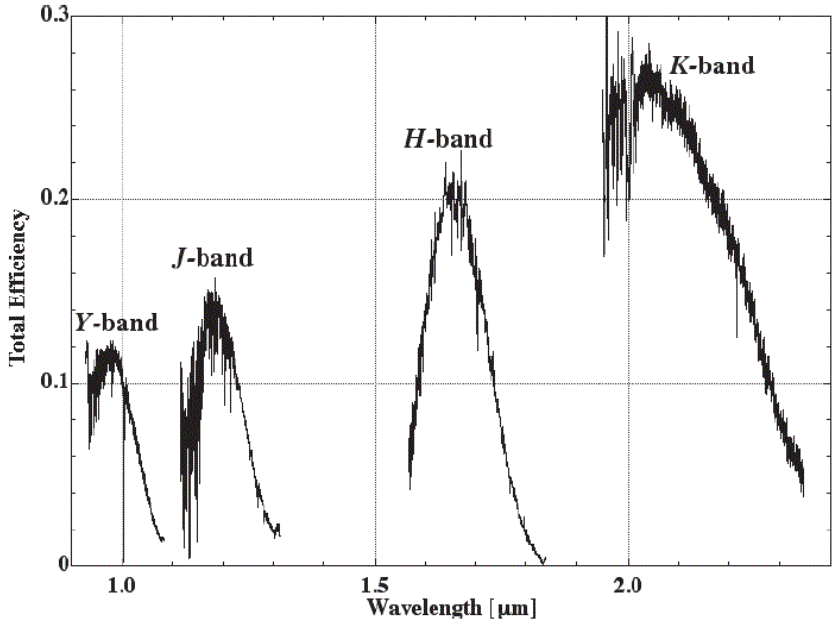
Seeing: 0.4"~0.7"

Exposure time: Each masks are observed for 3.6-5.5h

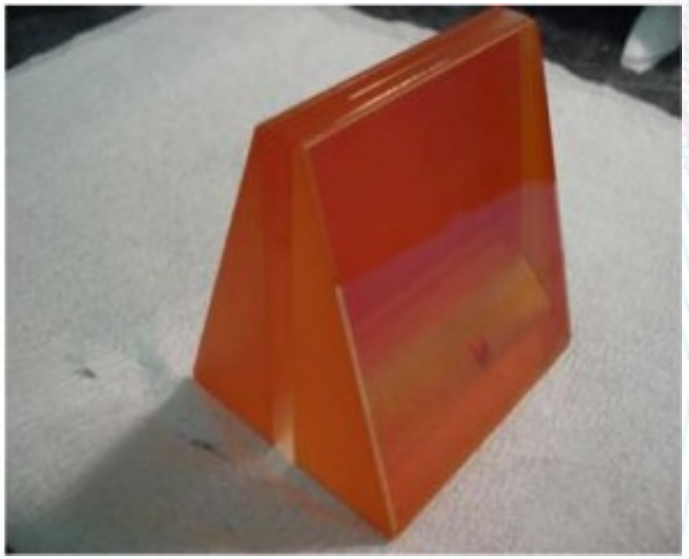
Data reduction: MCSRED (Tanaka et al.) was used.

VPH (Volume Phase Holographic)-K grism

- This was the first scientific observation with VPH-K grism
- Spectral coverage ~1.9-2.3μm
- R~1900(0”.7 slit) and ~1700 (0”.8 slit).
- High effeciency



Ebizuka et al. (2011)

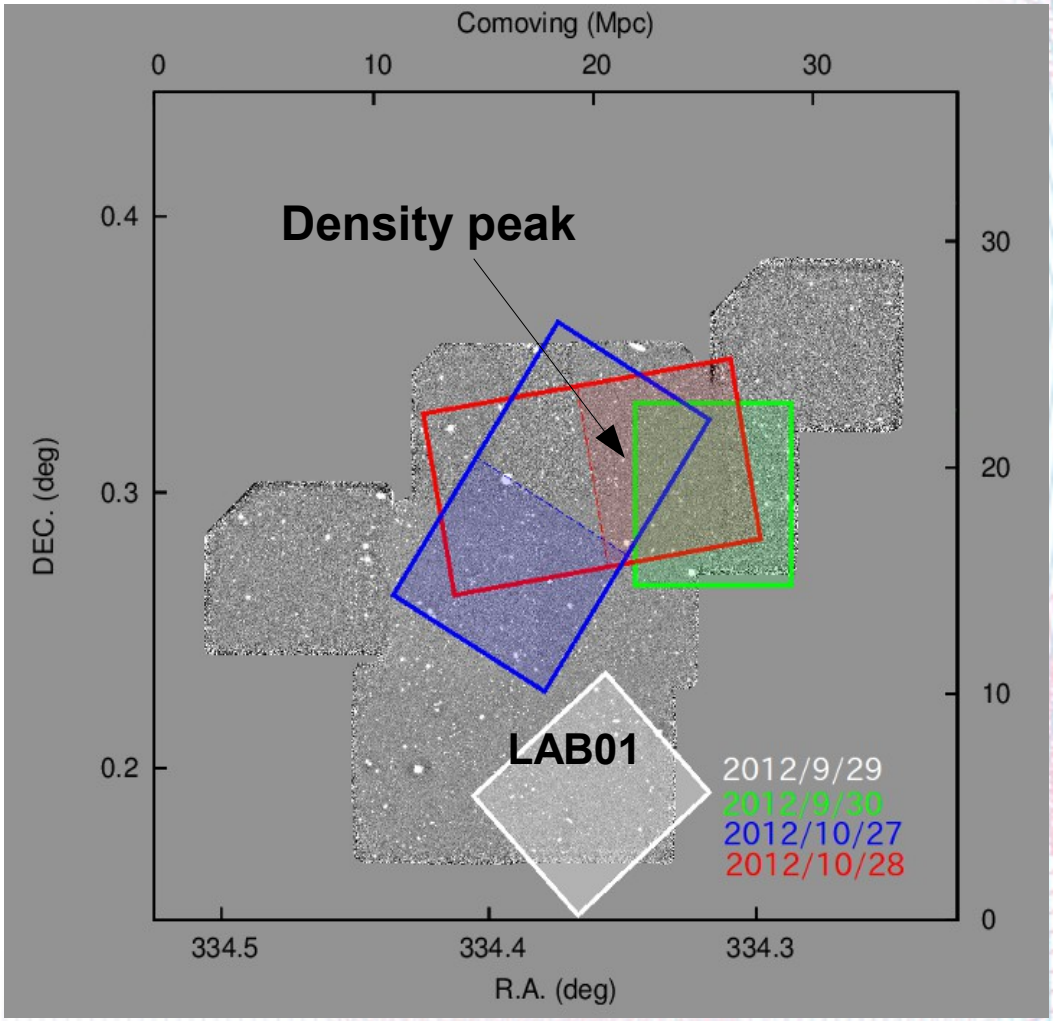


Picture from Subaru telescope website

For the galaxies at z=3.09, [OIII]5007Å shifted to ≈2.05μm

Targets

- K_AB<24 and z_phot=2.6-3.6
- We prefentialy observed DRGs(J-K>1.4), HEROs(J-K>2.1) and Spitzer MIPS 24um sources
- Totally 67 objects were observed (12 of which are filler objects with z_phot ≠2.6-3.6)

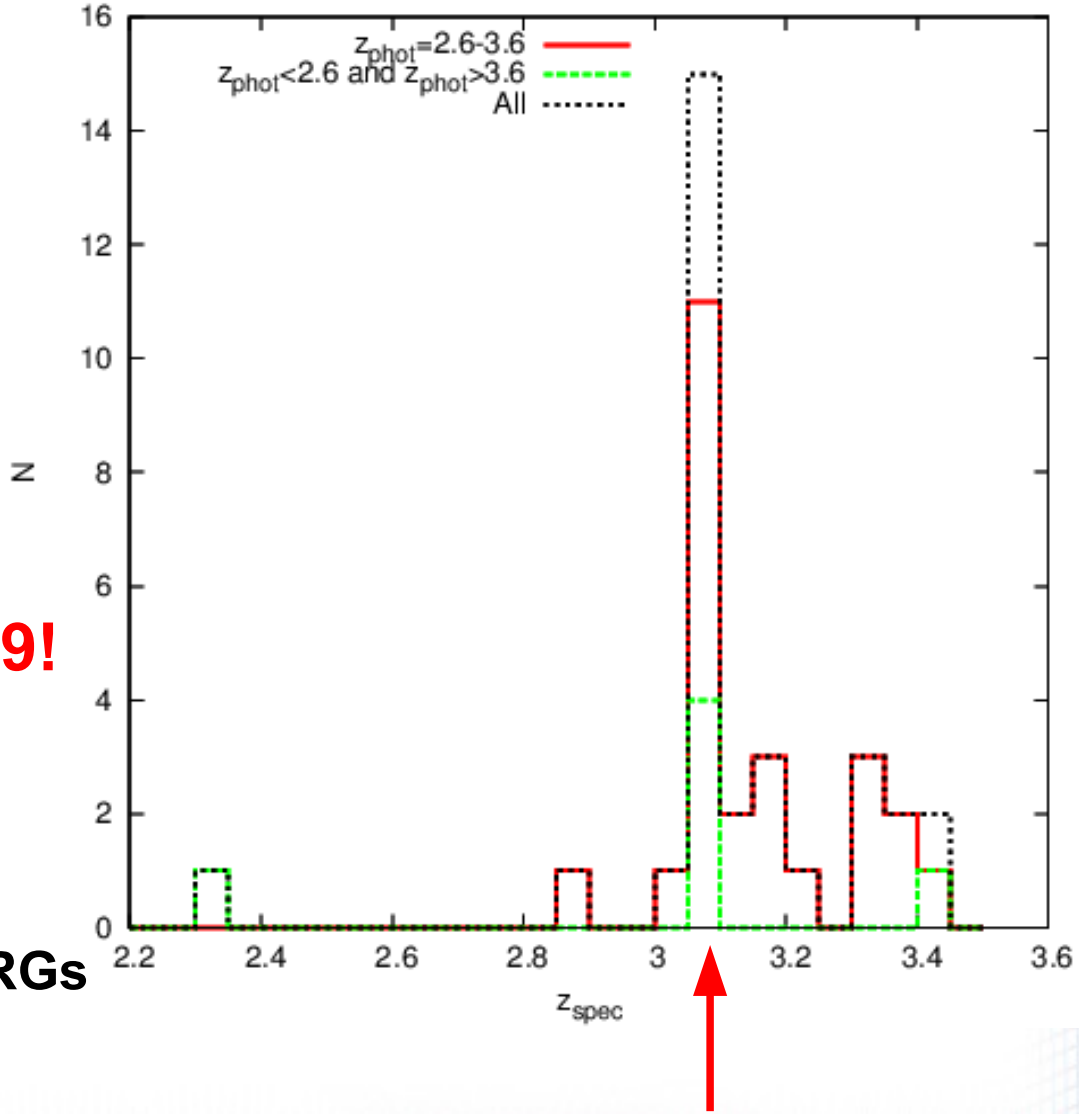


Shaded regions were observed with VPH-K grism

3. Result
3.1 The redshift distribution

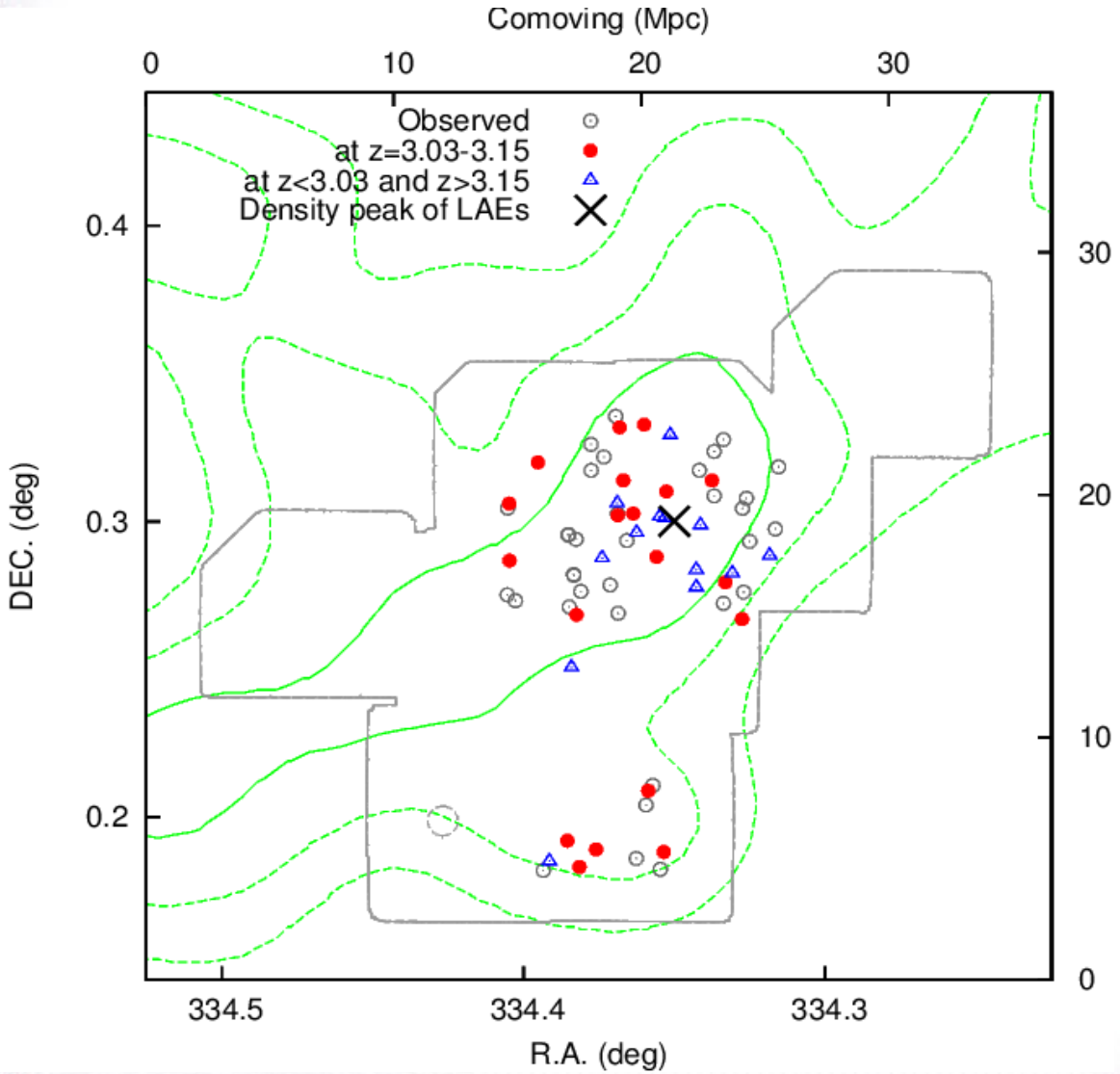
The emission lines
([OIII]5007Å or Hα) were detected in
32/67 of the targets.
(26 / 55 of zphot=2.6-3.6 &
6 /12 of fillar objects)

20/32 objects are at z~3.09!



Red: zphot=2.6-3.6
Green:fillar objects.
e.g.,MIPS sources, DRGs
Black dash: All confirmed.

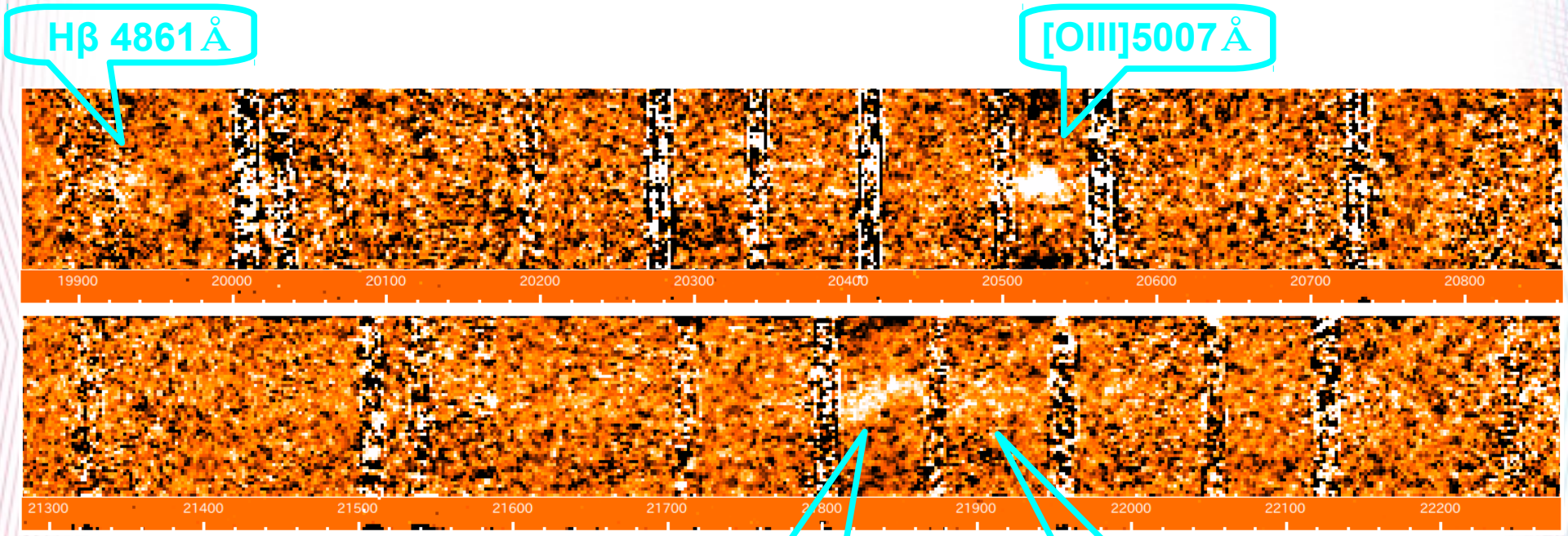
3.2 Sky distributions of the objects



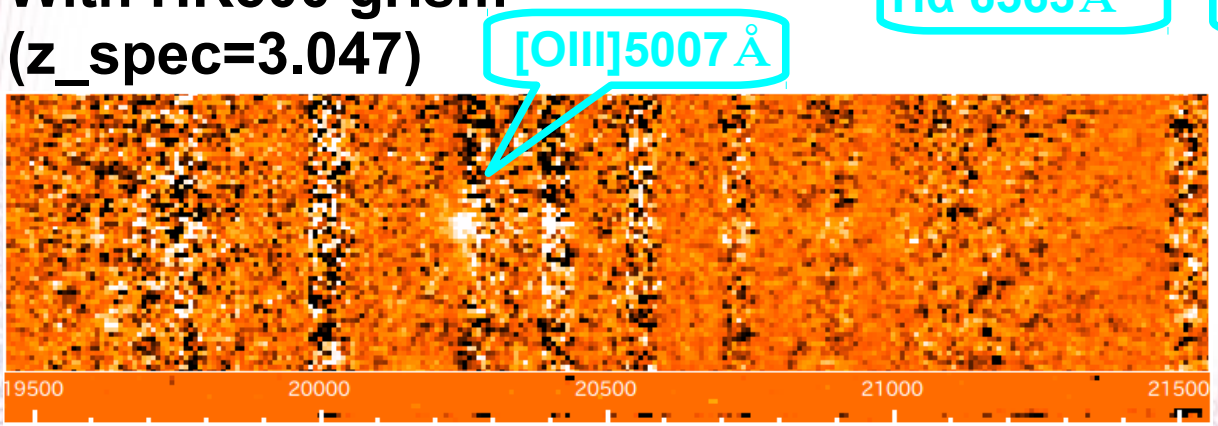
Gray; No detection
Red; z_spec=3.03-3.15
Blue; z_spec<3.03
or z_spec>3.15
Cross; Density peak of the LAEs

3.2 The examples

With VPH-K grism (top; z_spec=3.100, middle z_spec=2.328



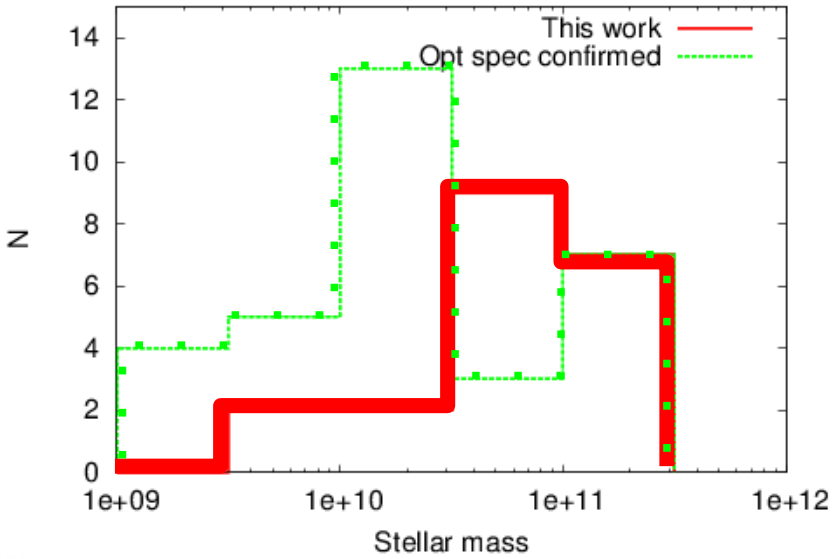
With HK500 grism (z_spec=3.047)

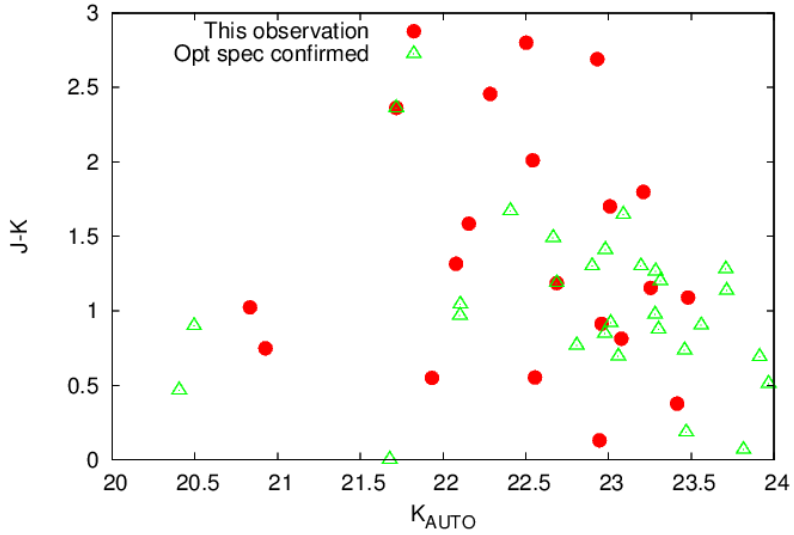


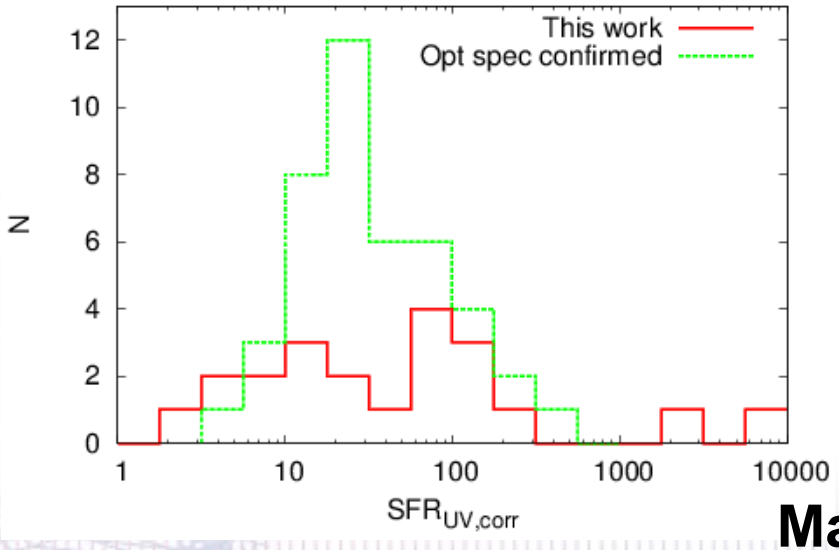
Effective to avoid OH airglow emissions. Resolving kinematics

4.Discussion

4. 1 Comparison with the objects confirmed from optical spectroscopy



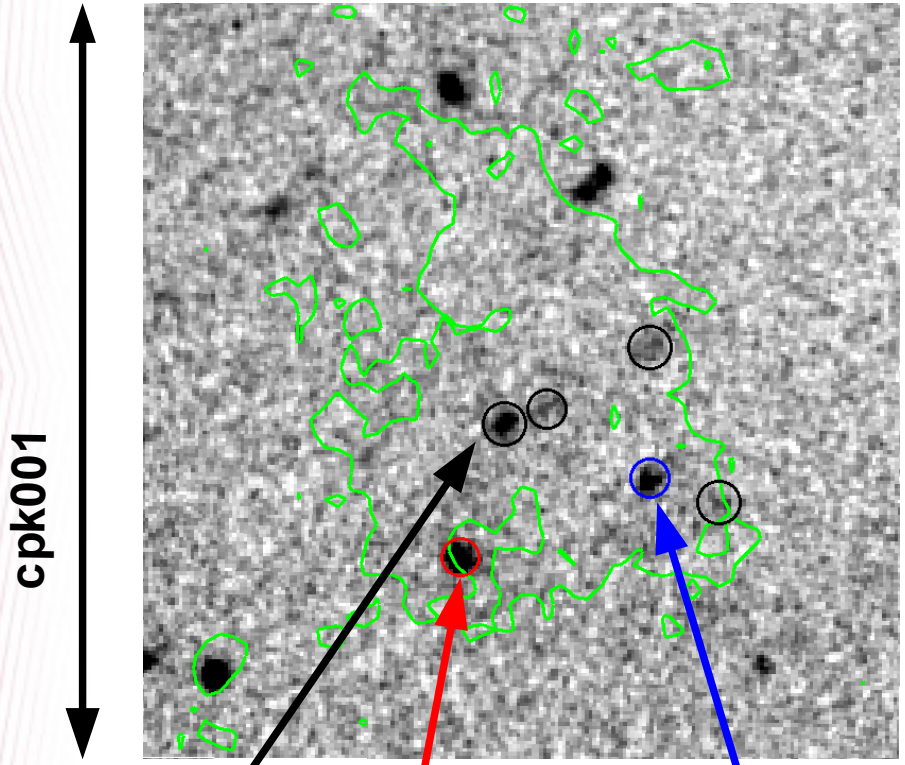




Top left: Stellar mass (K<24),
Top right: J-K color v.s. K-band mag
Bottom left: SFR_UV.corr,
of the galaxies with z≈3.09 in the SSA22 field from this work (red) and other works (Confirmed by optical spectroscopy, green).
*Stellar mass & SFR are estimated from SED fitting with u*BVRizJHK & Spitzer IRAC

Massive and Red objects are confirmed

4.2 counterparts of LABs
4.2.1 LAB01



z_spec=3.109

Confirmed by this observation

Black circles are with zphot=2.6-3.6

We confirmed one K-band counterpart of LAB01.

$z_{spec} = 3.099$

$M_{star} = 9.1 \times 10^{10} \pm 4.8 \times 10^{9} M_{sun}$

$SFR_{MIPS24um} = 1250^{+2000}_{-850} M_{sun}/yr$

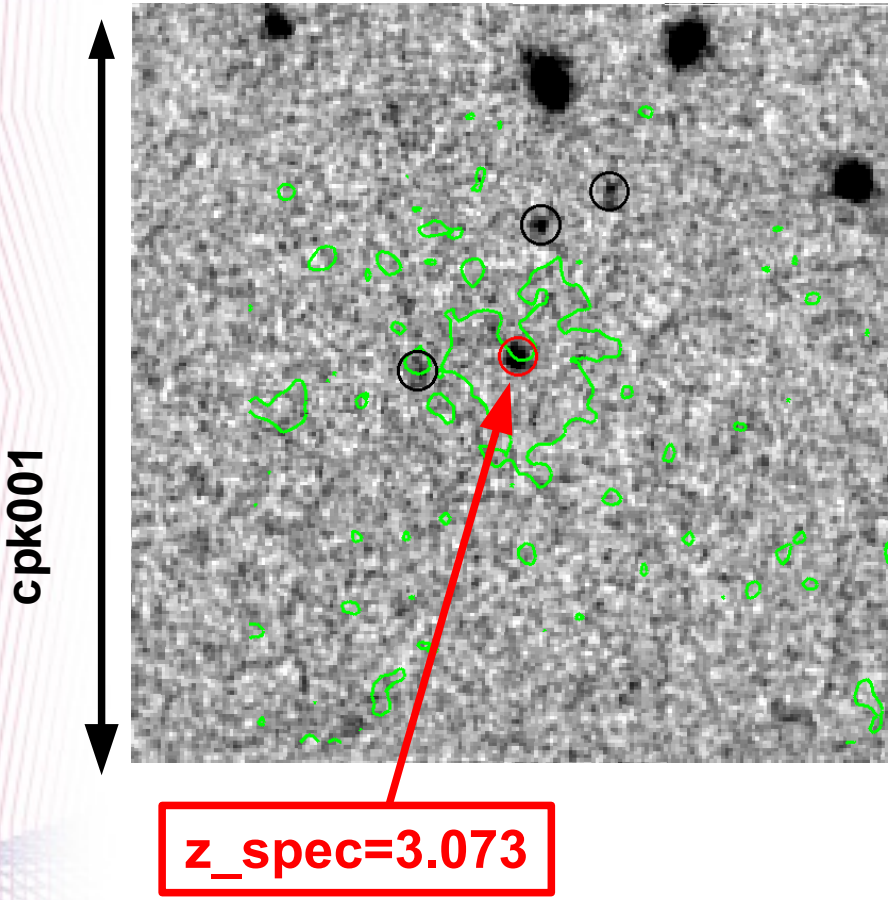
Sum of the stellar mass of the confirmed galaxies

$M_{star} = 2.1 \times 10^{11} \pm 2.1 \times 10^{10} M_{sun}$

This object was also confirmed by Mclinden et al. (2013, AAS)
But we also detected Hβ line.

4.2.2 LAB16 & LAB30

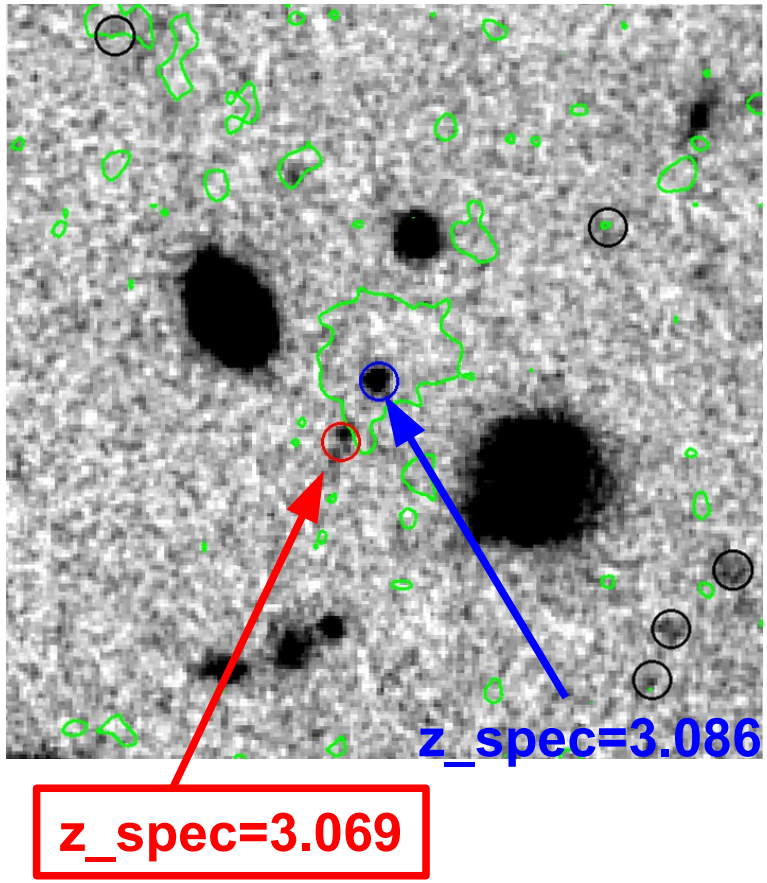
LAB16



$M_{star} = 6.4 \times 10^{10} \pm 2.1 \times 10^{9} M_{sun}$

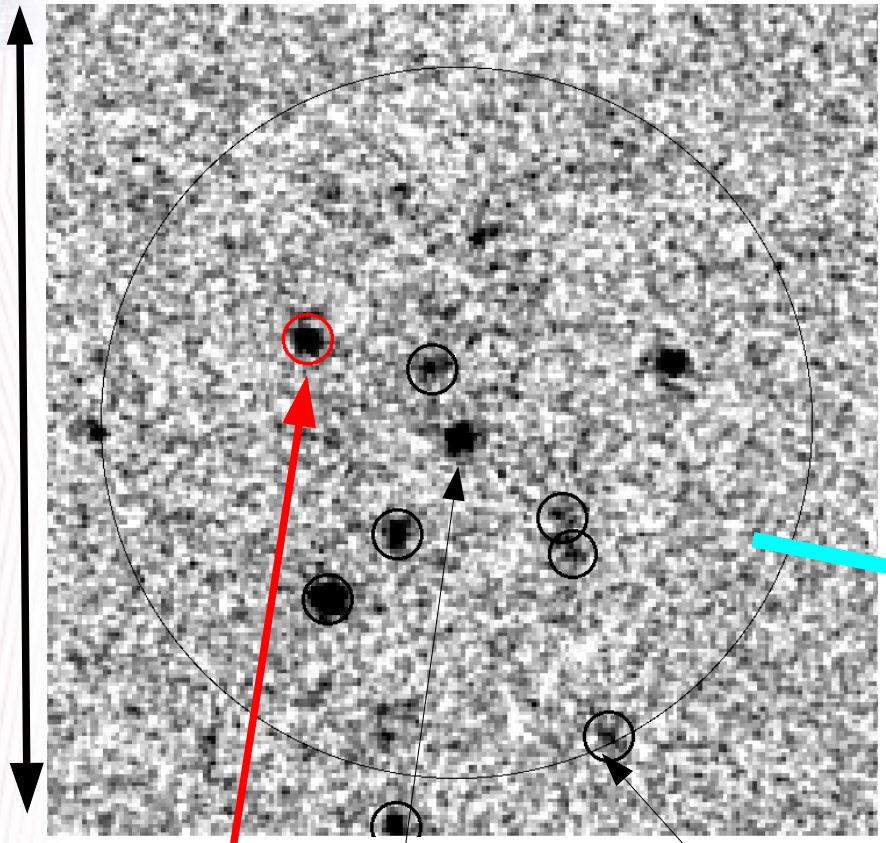
$SFR_{MIPS24um} = 2350^{+3770}_{-1590} M_{sun}/yr$

LAB30



$M_{star} = 5.4 \times 10^{10} \pm 6.3 \times 10^{9} M_{sun}$

4.3 counterpart of sub-mm source



z_spec=3.087

zphot=2.6-3.6

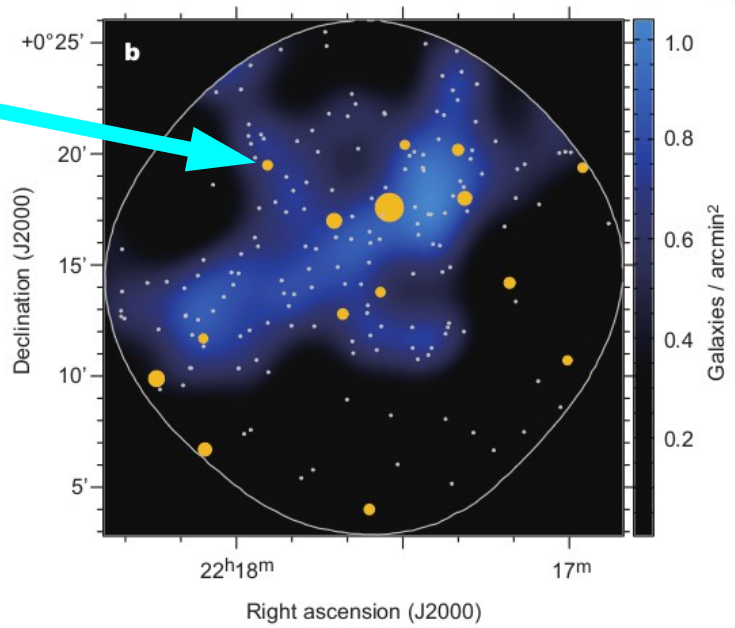
MIPS24um and X-ray source.
We observed but didn't detect any emission lines

We also confirmed one of the counterparts of AzTEC 1.1um sub-mm source (SFR>1000Mo/yr).

$z_{spec} = 3.087$

$M_{star} = 1.15 \times 10^{11} \pm 3.1 \times 10^{9} M_{sun}$

$L_{8-32keV} = 8.1 \times 10^{43}\ ergs\ s^{-1}$



The sky distribution of the ASTE/AzTEC Sub-mm sources (Tamura et al. 2009)

5.Conclusion

- We successfully confirmed K-selected galaxies with zphot~3.1 to be the members of the SSA22 protocluster.
- We also confirmed the K-band counterparts of LABs and AzTEC sub-mm source.
- **This was the first time to confirm such many galaxies from [OIII]5007Å at z~3.**

6. Future Works

- We're going to investigate the properties of [OIII]5007Å and Hβ emission lines.
- In this observation, we observed 1/6 of our K-selected candidates of the galaxies in the SSA22 protocluster. Further observations are needed to reveal the whole picture of the protocluster.