

広視野補償光学系で探る LAE のアウトフローと金属量



National Astronomical Observatories of Japan (NAOJ)
The Graduate University for Advanced Studies (GUAS)



総合研究大学院大学

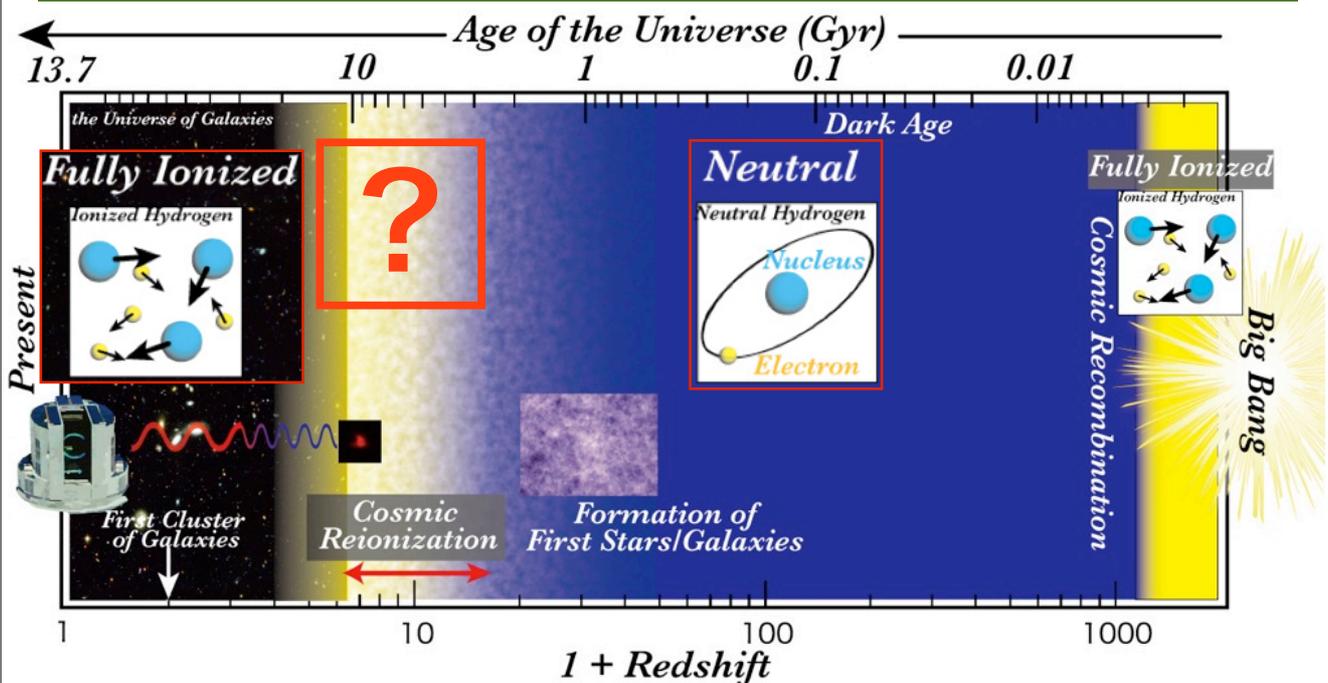
The Graduate University for Advanced Studies [SOKENDAI]

Ph.D Student **Takatoshi Shibuya**

Outline

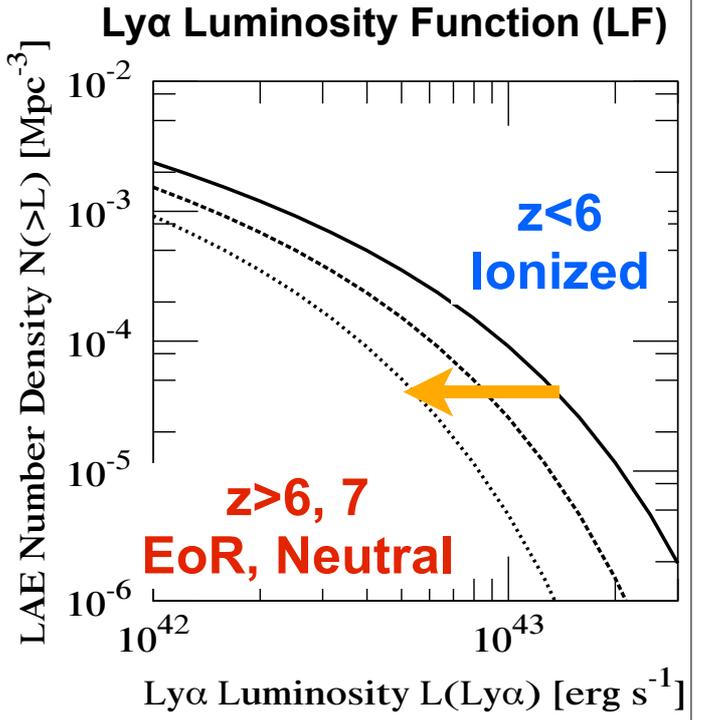
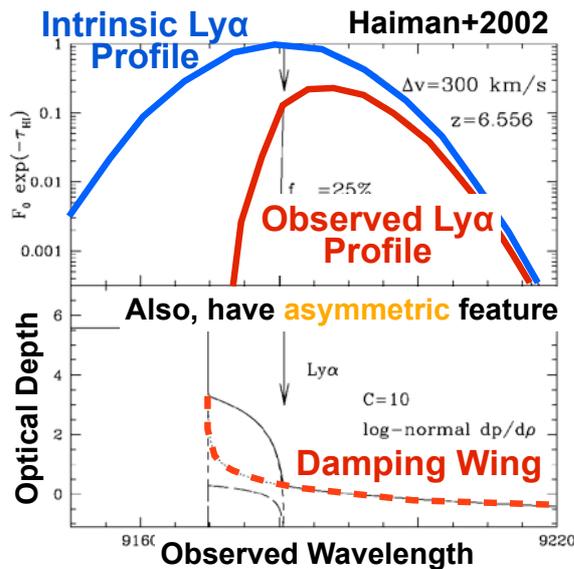
- ✓ **イントロ** - アウトフロー研究の重要性
- ✓ **先行研究の詳細**
- ✓ **GLAO survey for Outflow** - ターゲット, 観測時間
- ✓ **Summary**

Cosmic Dawn



Not clear **WHEN & HOW**
the Reionization ended.

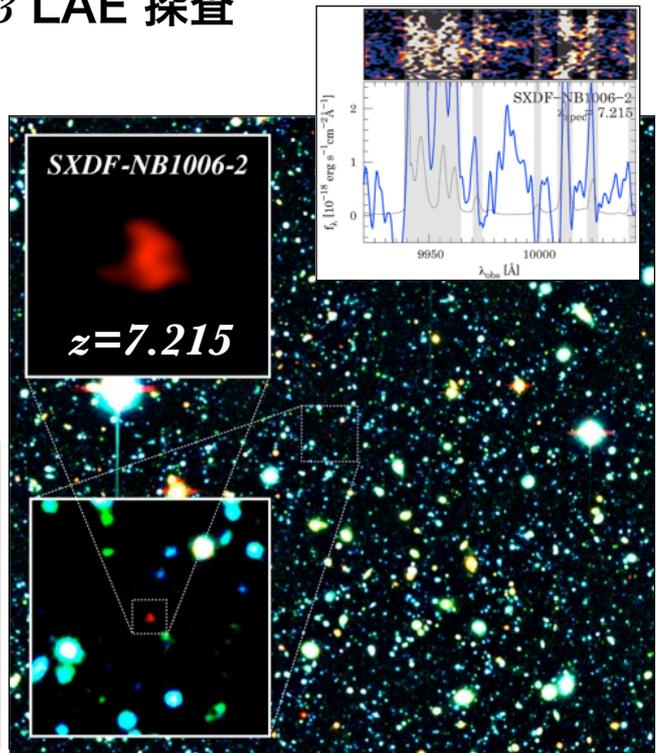
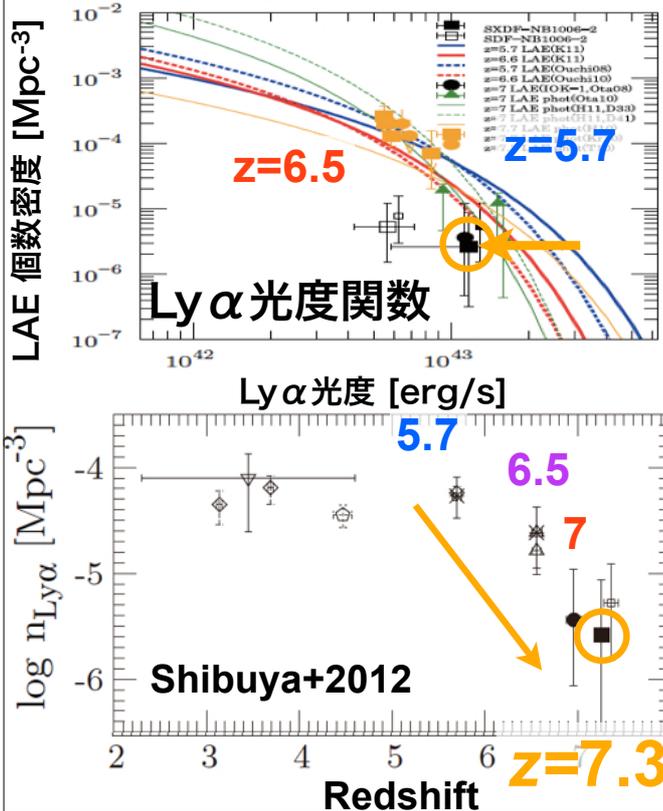
Ly α Attenuation by HI gas



Epoch of Reionization (EoR) probed by LAEs.
 Construct Ly α LF to constrain the neutral fraction at high- z .

Reion. probed by LAE

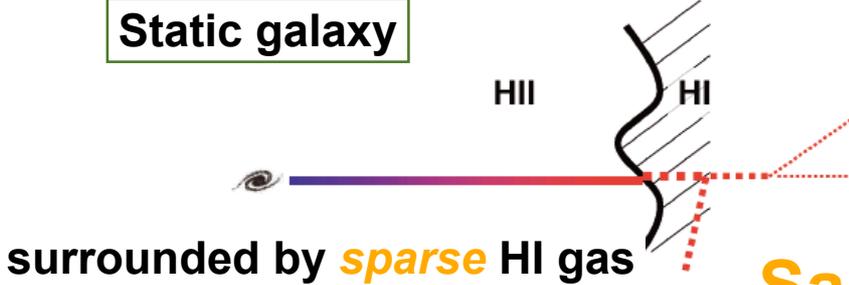
NB1006 フィルターによる $z=7.3$ LAE 探索



If Galaxy Blows Out Gas

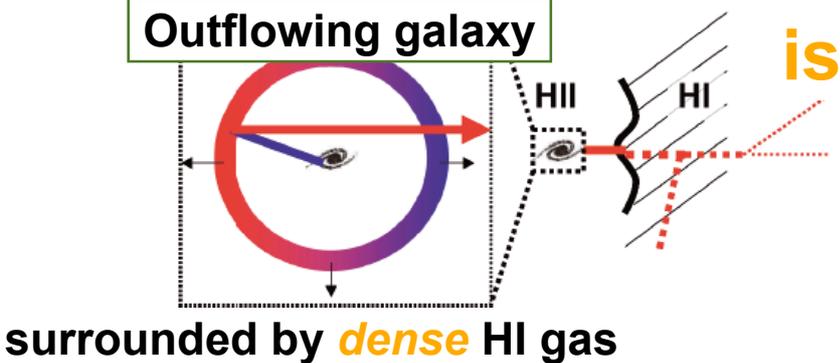
Static galaxy

Dijkstra+2010



Same Ly α flux is observed.

Outflowing galaxy



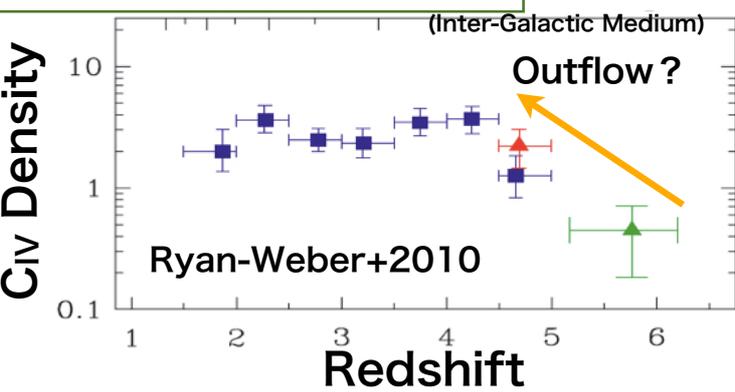
M82



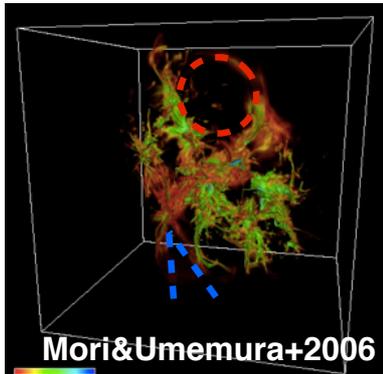
✓ Need to examine the *gaseous outflow* from the galaxy which could be related to Ly α escapes

Many Roles in High-*z*

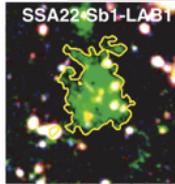
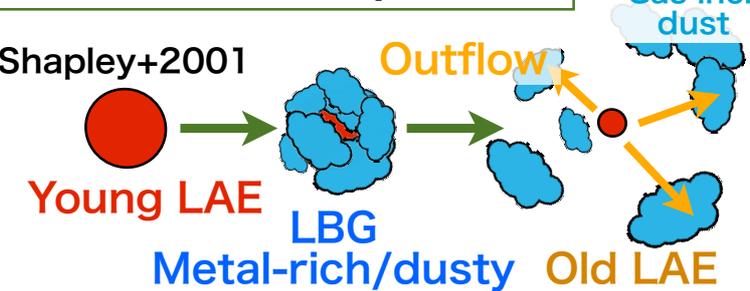
Metal Enrichment in IGM



Formation Mechanism of Ly α Blob



Relation of Gal Populations

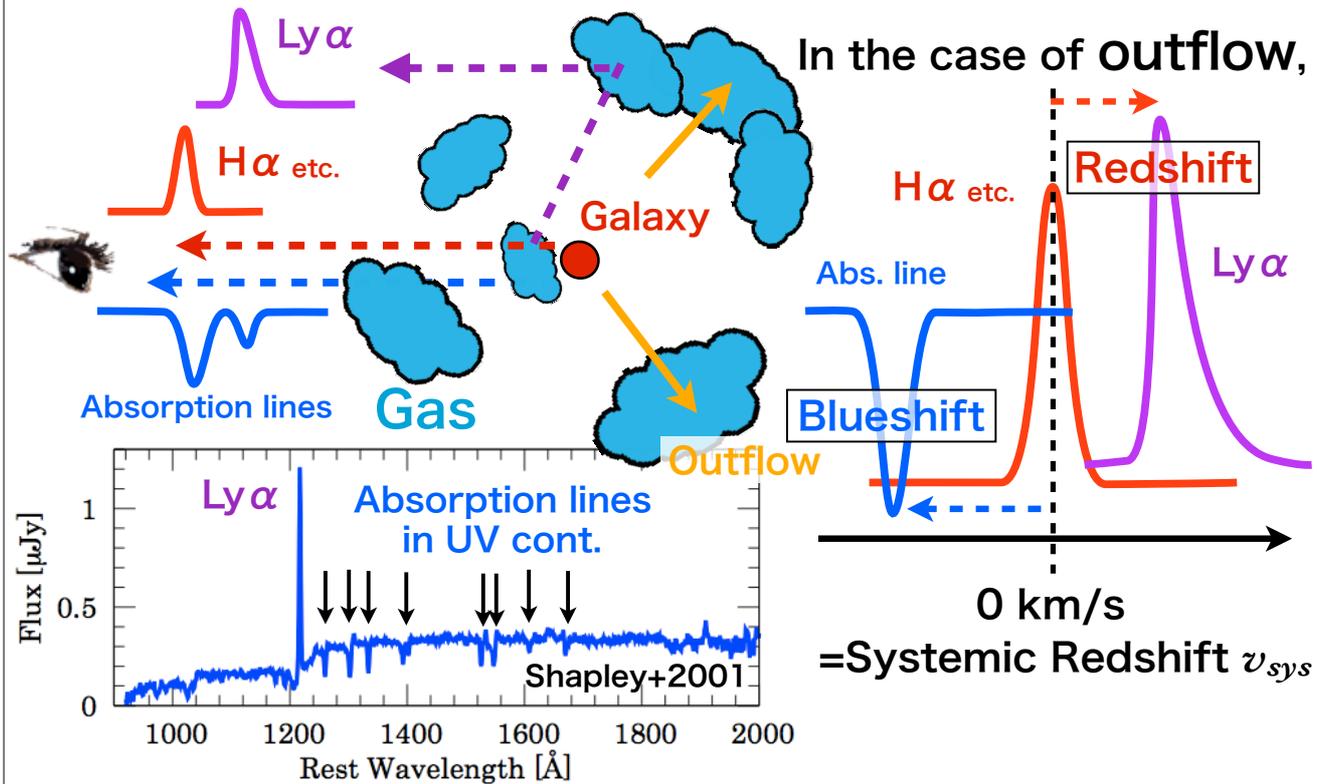


Matsuda+2011



(Shibuya, Gronwall+in prep.)

How to Research Outflow



Measure the velocity shift b/w Ly α /UV & Nebular lines

再 Previous Studies on Outflow

2011年版@大阪大学

>100 obj.

(e.g. Steidel+2010, Kulas+2011)

$\Delta v \sim 300-400$ km/s

H α , H β , [OII], [OIII]

IBG

Subaru/GLAO

$z=3$

2 obj.

(McLinden+2010)

$\Delta v \sim 0-150$ km/s

[OIII]

$z > 4$ Outflow

lensed 銀河 @ $z \sim 4.5$ を

Subaru/AO188などで.

(MOAO)

No

No

$z \sim 2, 3$ LAE Outflow

Previous Studies on Outflow

2012年版@Subaru

LBG

(e.g. Steidel+2010, Kulas+2011)
 $\Delta v \sim 300-400$ km/s
 $H\alpha, H\beta, [OII], [OIII]$

Z=2~3

>100 obj.

z > 4 Outflow

lensed 銀河 @ z~4.5 を
 Subaru/AO188などで
 (MOAO)

LAE

10 obj.
 (e.g. McLinden+2010)
 $\Delta v \sim 0-150$ km/s

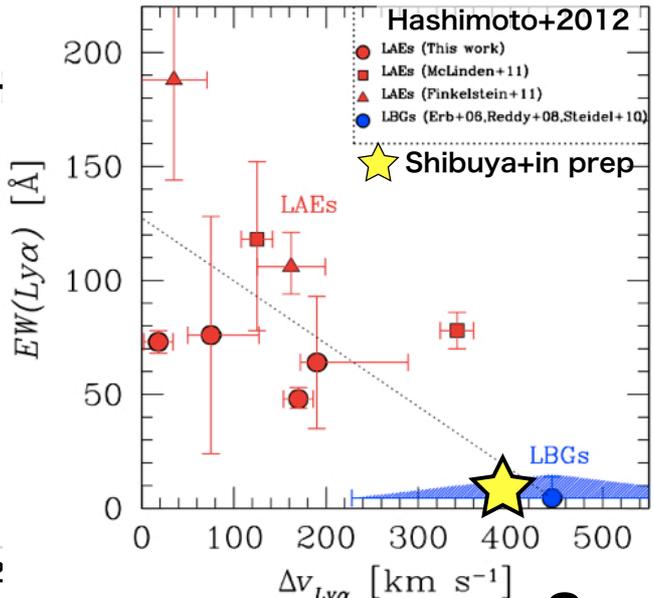
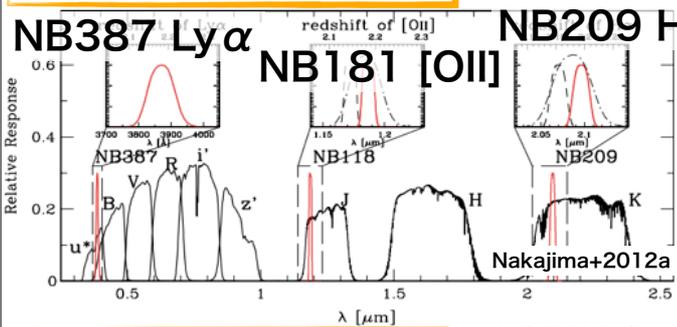
Hashimoto+2012
 4 LAEs
 SCam+NB387

Finkelstein+2011
 2 LAEs
 HETDEX-P

Christensen+2012
 2 LAEs
 X-shooter (後述)

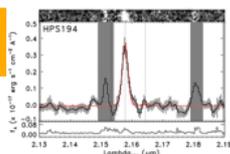
(現行) LAE アウトフロー研究

Hashimoto+2012 $z=2.2$ LAE

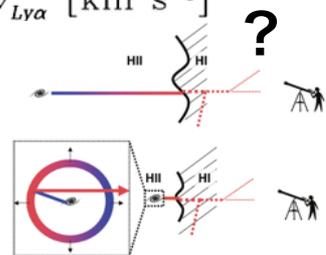
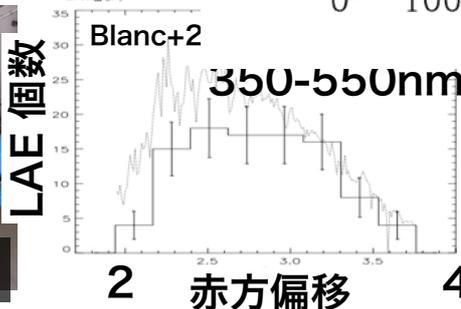


Finkelstein+2011

2.7m Harlan J. Smith
 Telescope/VIRUS-P

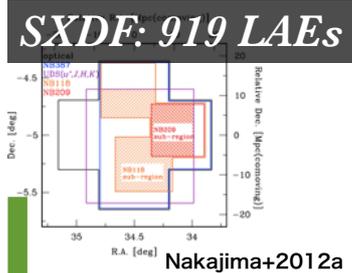


HETDEX-pilot survey

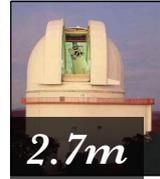


ターゲットは？ 2020年代, ということも踏まえて

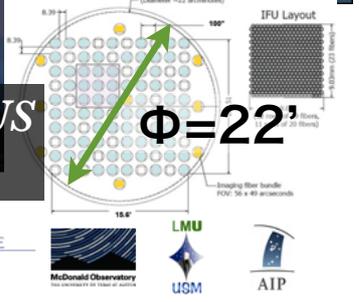
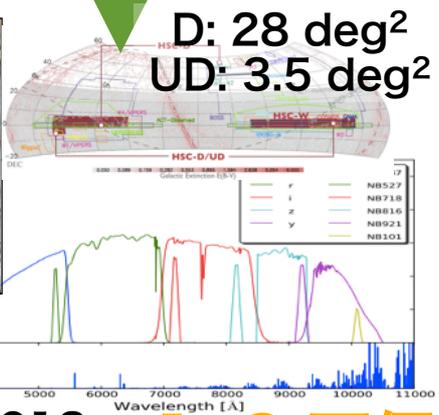
Subaru/SCam w/ NB387



HETDEX-Pilot



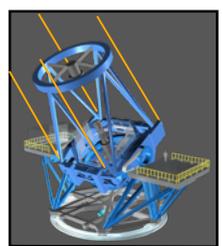
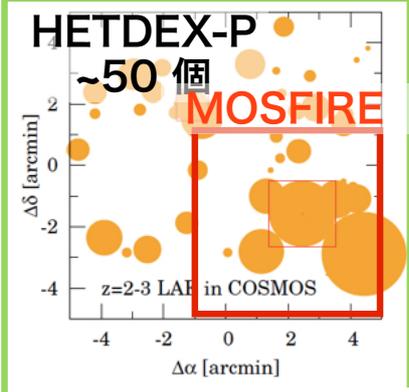
103 LAEs



2013-2018? **1~2 万個**

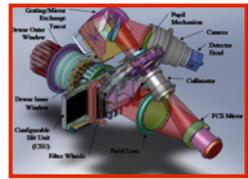
2013-2016? **80 万個 !!!!**

GLAO-Survey for Outflow Study

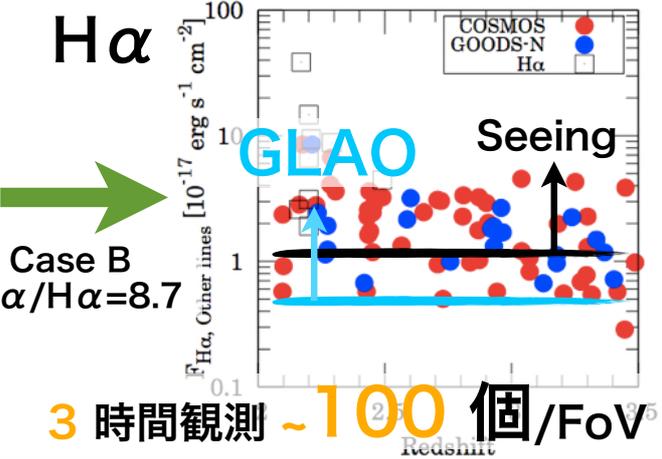
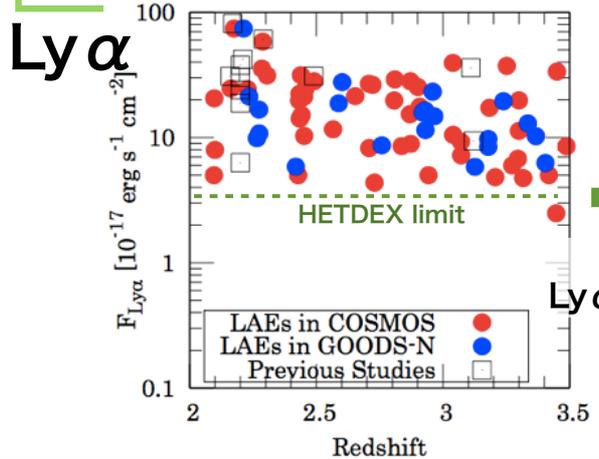
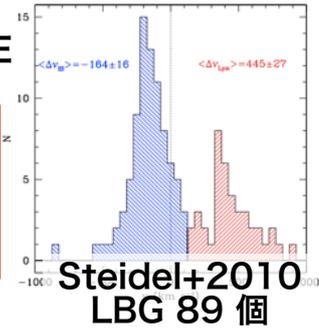


GLAO FoV
13.6' x 13.6' (?)
~ 100 天体

Keck/MOSFIRE
6' x 6'



この LAE 版



HSC Survey Plan

各バンドの限界等級

LAE 検出期待値

SSP より.

Layer	Filter	Exp. ^a (# of epochs)	Lim. mag. ^b (5 σ , 2'')
Wide	<i>g, r</i>	10 min (3)	26.5, 26.1
Wide	<i>i</i>	20 min (6)	25.9
Wide	<i>z, y</i>	20 min (6)	25.1, 24.4
Deep	<i>g, r</i>	2 hrs (10)	27.5, 27.1
Deep	<i>i</i>	3 hrs (10)	26.8
Deep	<i>z, y</i>	3 hrs (10)	26.0, 25.3
Deep	N387	2 hrs (≈ 10)	24.8
Deep	N816	2 hrs (≈ 10)	25.3
Deep	N921	4 hrs (≈ 10)	25.1
UD	<i>g, r</i>	10 hrs (20)	28.1, 27.7
UD	<i>i</i>	20 hrs (20)	27.4
UD	<i>z, y</i>	27 hrs (20)	26.8, 26.3
UD	N387	20 hrs (≈ 10)	26.1
UD	N527	15 hrs (≈ 10)	26.5
UD	N718	10 hrs (≈ 10)	26.0
UD	N816	15 hrs (≈ 10)	26.4
UD	N921	20 hrs (≈ 10)	26.4
UD	N101	25 hrs (≈ 10)	26.4

narrowband redshift	NB387	NB527
	2.18 \pm 0.02	3.33 \pm 0.03
N_{UD}^b	4.0k (120)	6.3k (150)
N_D^b	9.0k (730)	–
V_{UD}^c	0.75	0.96
V_D^c	6.0	–
$L(\text{Ly}\alpha)_D^d$	0.9	0.7
$L(\text{Ly}\alpha)_D^d$	2.7	–

✓ $z=2.2$: 4,000(+9,000) 個

✓ $z=3.3$: 6,300 個

✓ $z=2.2$ UD: 60 個/FoV 10 時間

✓ $z=2.2$ D: 17 個/FoV 1 時間

✓ $z=3.3$ UD: 90 個/FoV 120 時間

D: 28 deg²
UD: 3.5 deg²

LAE の金属量も

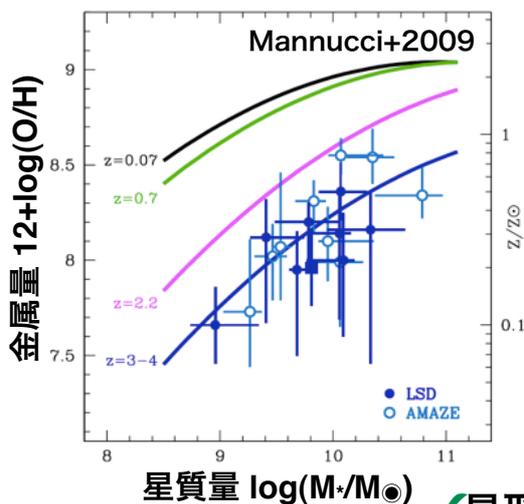
他の輝線も受ければ, 金属量も.

$$R_{23} = ([OII]\lambda\lambda 3726, 3729 + [OIII]\lambda\lambda 4959, 5007) / H\beta$$

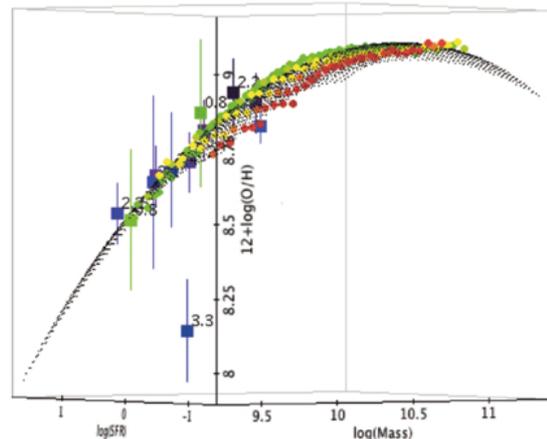
$$N2 = \log([NII]\lambda 6583 / H\alpha)$$

$$O3N2 = \log([OIII]\lambda 5007 / [NII]\lambda 6584)$$

星質量-金属量 関係



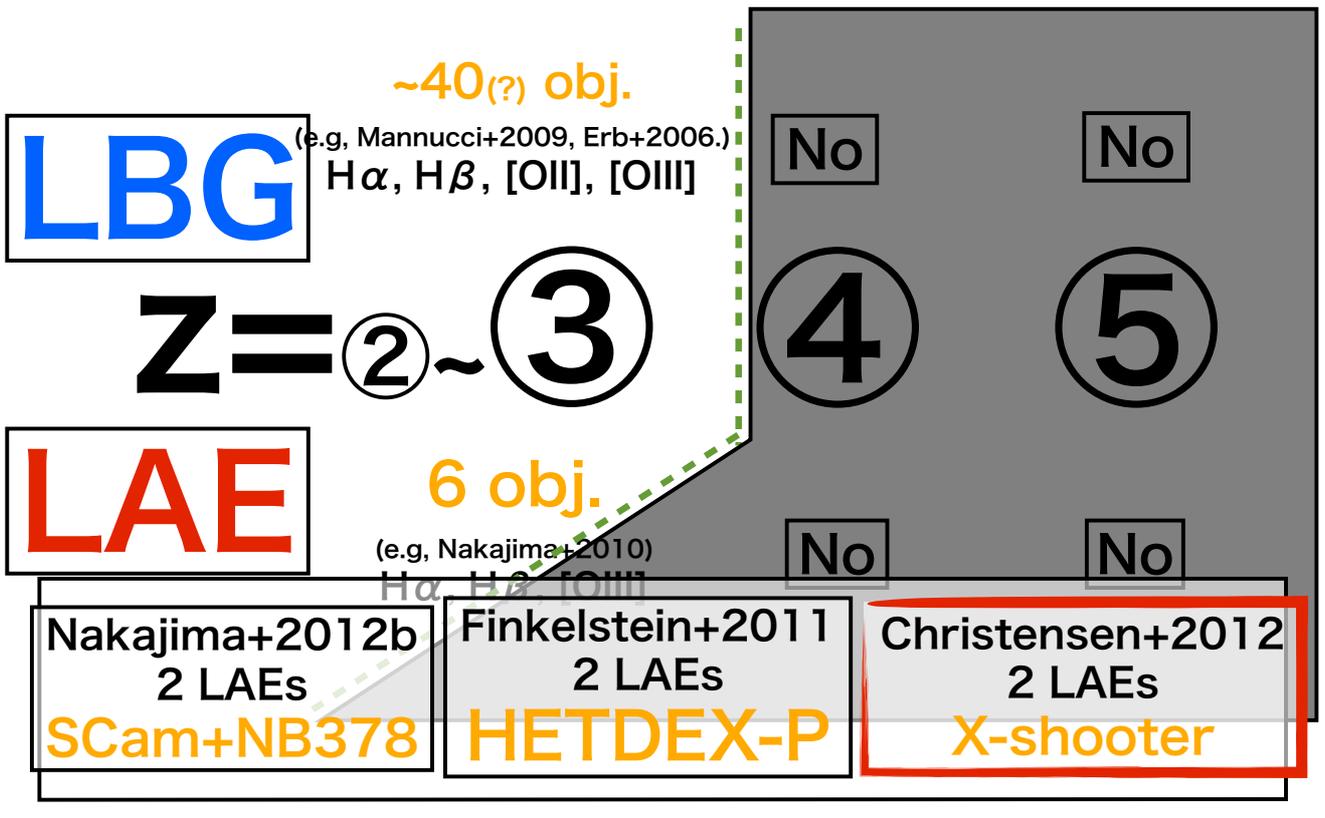
Mannucci+2010



星質量 $\log(M^*/M_\odot)$

✓ 星形成史を反映. infall, outflow などと関係.

Previous Studies on Metallicity

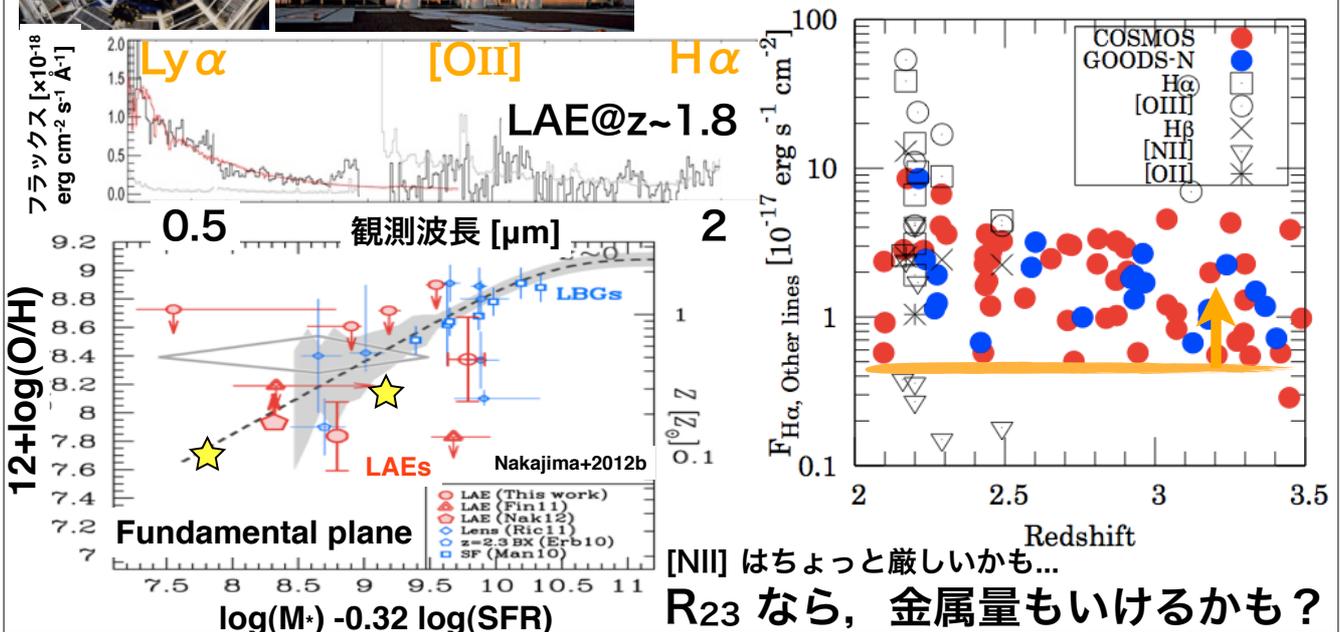


(現行) LAE 金属量研究

Christensen+2012b

3つのアームで広い波長帯域を同時分光

- ✓UVB, 300-559.5 nm
- ✓VIS, 559.5-1024 nm
- ✓NIR, 1024-2480 nm



Summary

✓ Subaru-GLAO で...

- ✓ $z \sim 2-3$ LAE のアウトフロー & 金属量を研究
- ✓ HETDEX, HSC による超大規模 LAE サンプル
- ✓ アウトフローだけ：数万天体， 金属量も数千天体くらいいけるかも。

銀河種族を超えた銀河フィードバック， 化学進化の徹底理解

✓ GLAO に付いてると嬉しいこと

- ✓ 多天体分光， → OK!
- ✓ $R \sim 1,500 \sim 3,000$ → OK(?)
- ✓ X-Shooter のような広観測波長帯， (せめて) JHK or HK

Picture: Subaru Next-Generation AO Working Group, Science Report