

5 June 2014, 銀河進化研究会

Studies of star-forming galaxies at $z \sim 1.6$ in COSMOS

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Outline

- Introduction
- FMOS-COSMOS survey
- Results *DK, Silverman et al. 2013*
 - Dust extinction
 - Star-forming main sequence
- Work in progress
 - Kinematics of global outflow
- Summary & Future

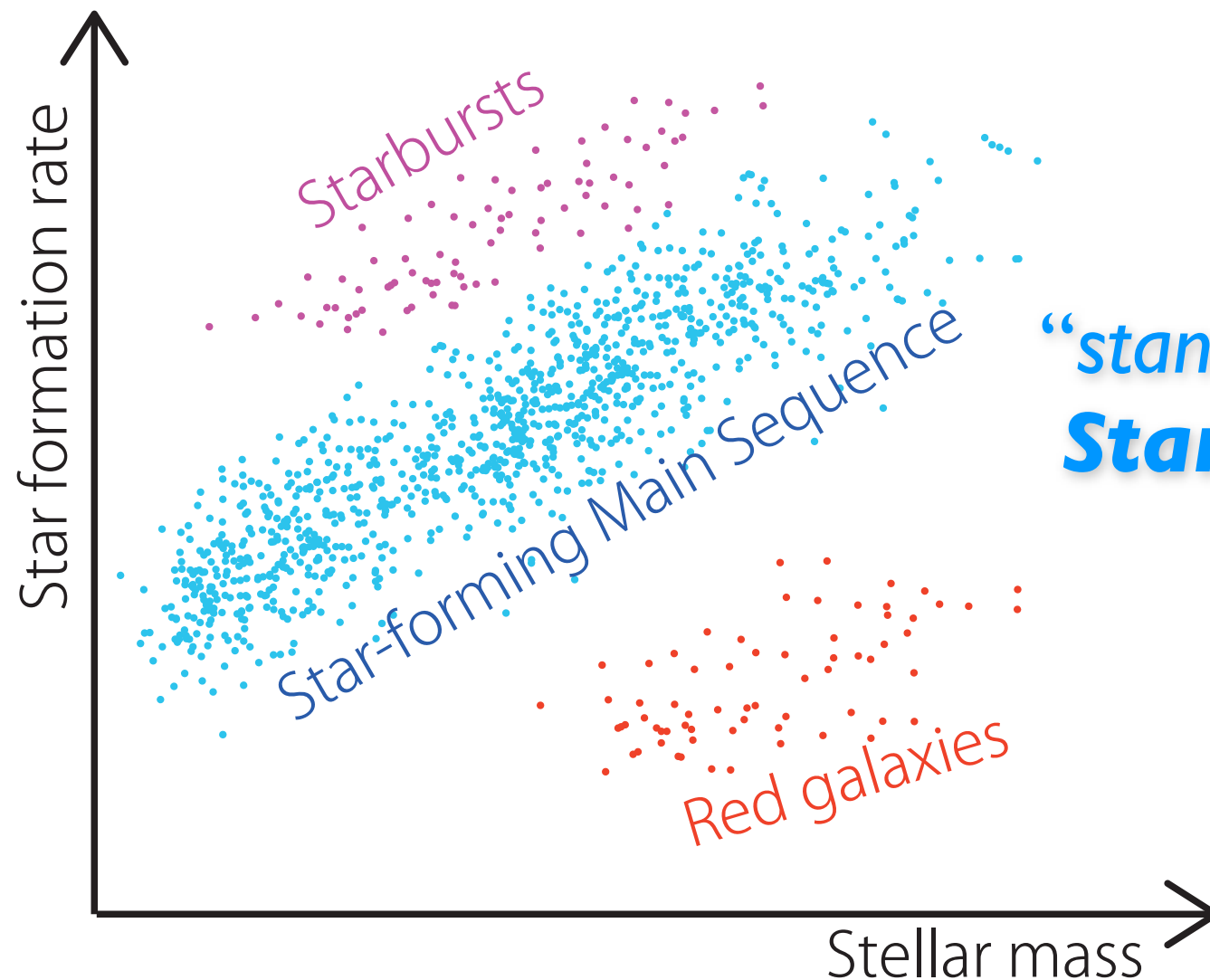
Key questions

What fundamentally impacts on star formation in galaxies?

- What triggers/prevents star formation activities?
- What is the role of the environment?
- How do they evolve over the cosmic time?

During the last several years, for star-forming galaxies, tight correlations b/w stellar mass and SFR have been reported.

e.g., Noeske+07, Elbaz+07, Daddi+07, Pannella+09, Rodighiero+11, Speagle+14



“standard” mode of star formation
Star forming main sequence

Difficulties

- many kinds of SFR indicators are used (e.g., UV, FIR, 24 μ m)
- beyond $z \sim 0.5$, H α is redshifted into near-IR window.
- the redshift desert ($1.4 < z < 2$)

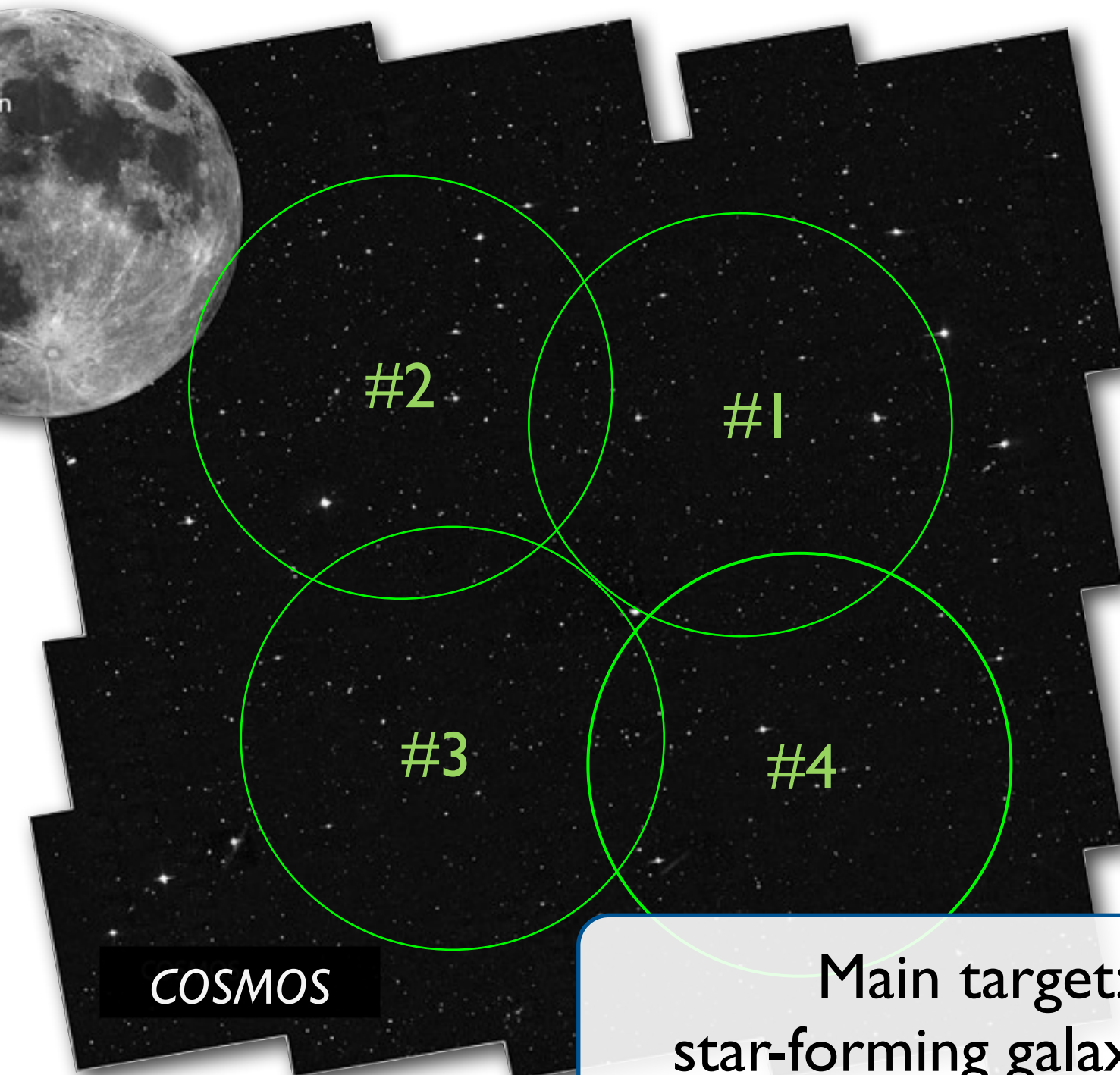
We want to survey many star forming galaxies in the redshift desert ($1.4 < z < 2$).

FMOS on Subaru enables us to achieve our purpose.

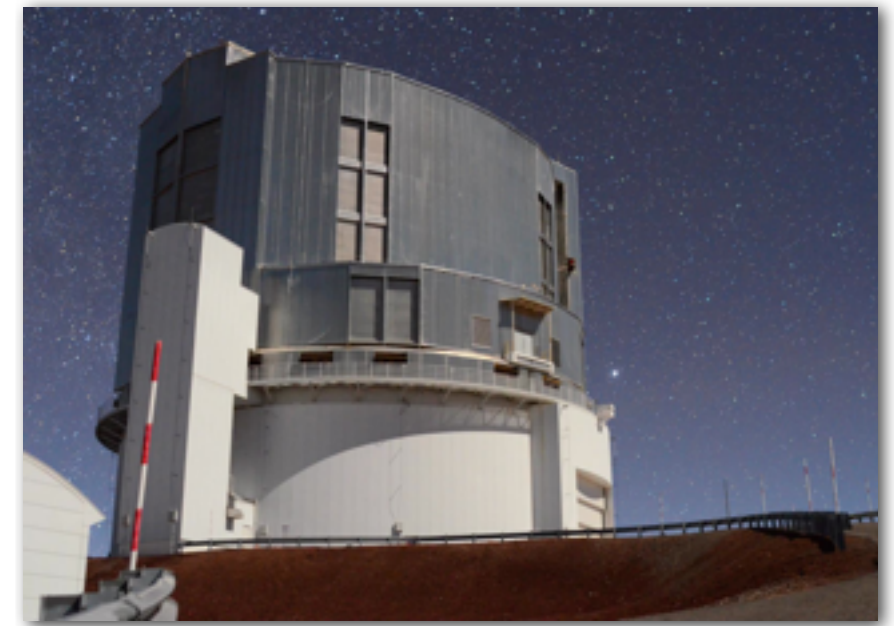
FMOS-COSMOS Survey

FMOS-COSMOS Survey

SI2B-SI4A | PI: J. Silverman (intensive)



Main target:
star-forming galaxies at
 $z \sim 1.4-1.7$



Subaru/
Fiber Multi Object Spectrograph

*High multiplex
with 400 fibers
and
Very wide FoV*

FMOS-COSMOS Survey

SI2B-SI4A | PI: J. Silverman, D. Sanders

FMOS can observe **H α** redshifted into NIR,
and also other lines such as **[NII]**, **H β** , **[OIII]**, etc...

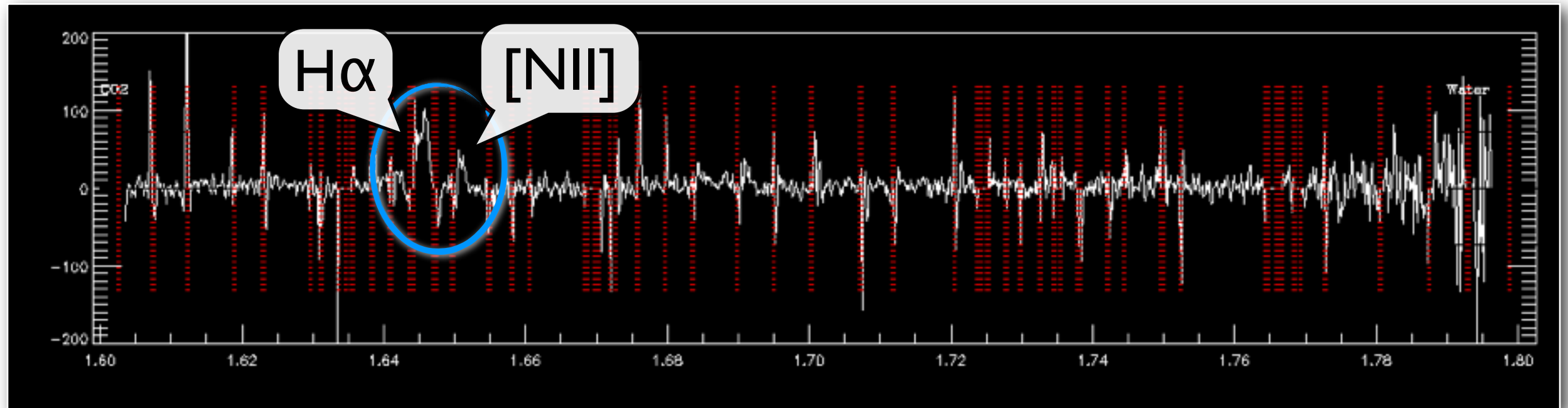
► redshift, SFR, dust, metallicity, AGN indicator etc...

COSMOS

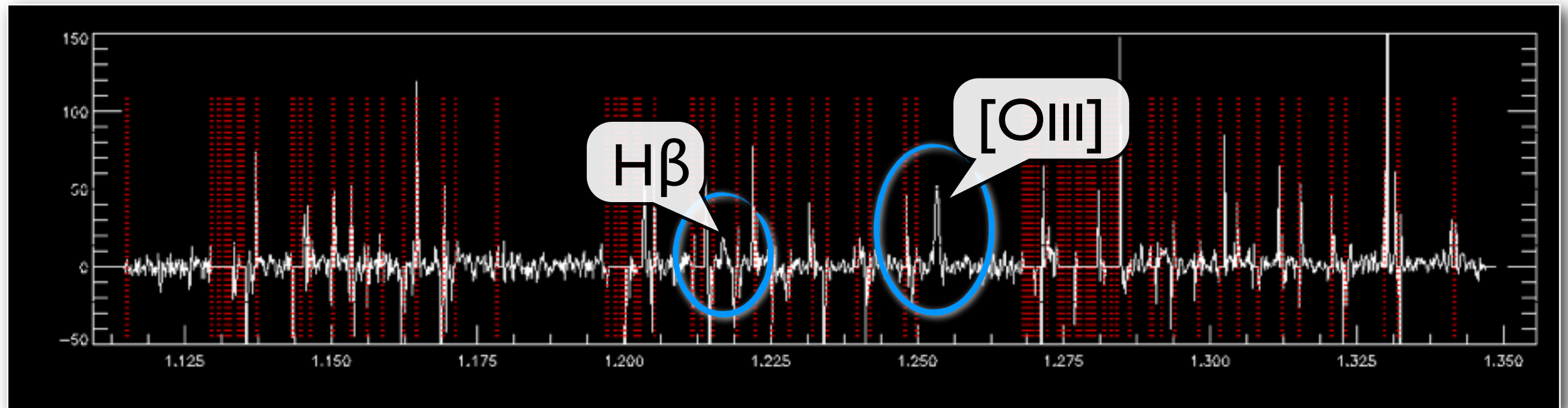
Main target:
SF galaxies at $z \sim 1.6$
selected by BzK

with 400 fibers
and
Very wide FoV

- H-long (1.6-1.8 μ m)

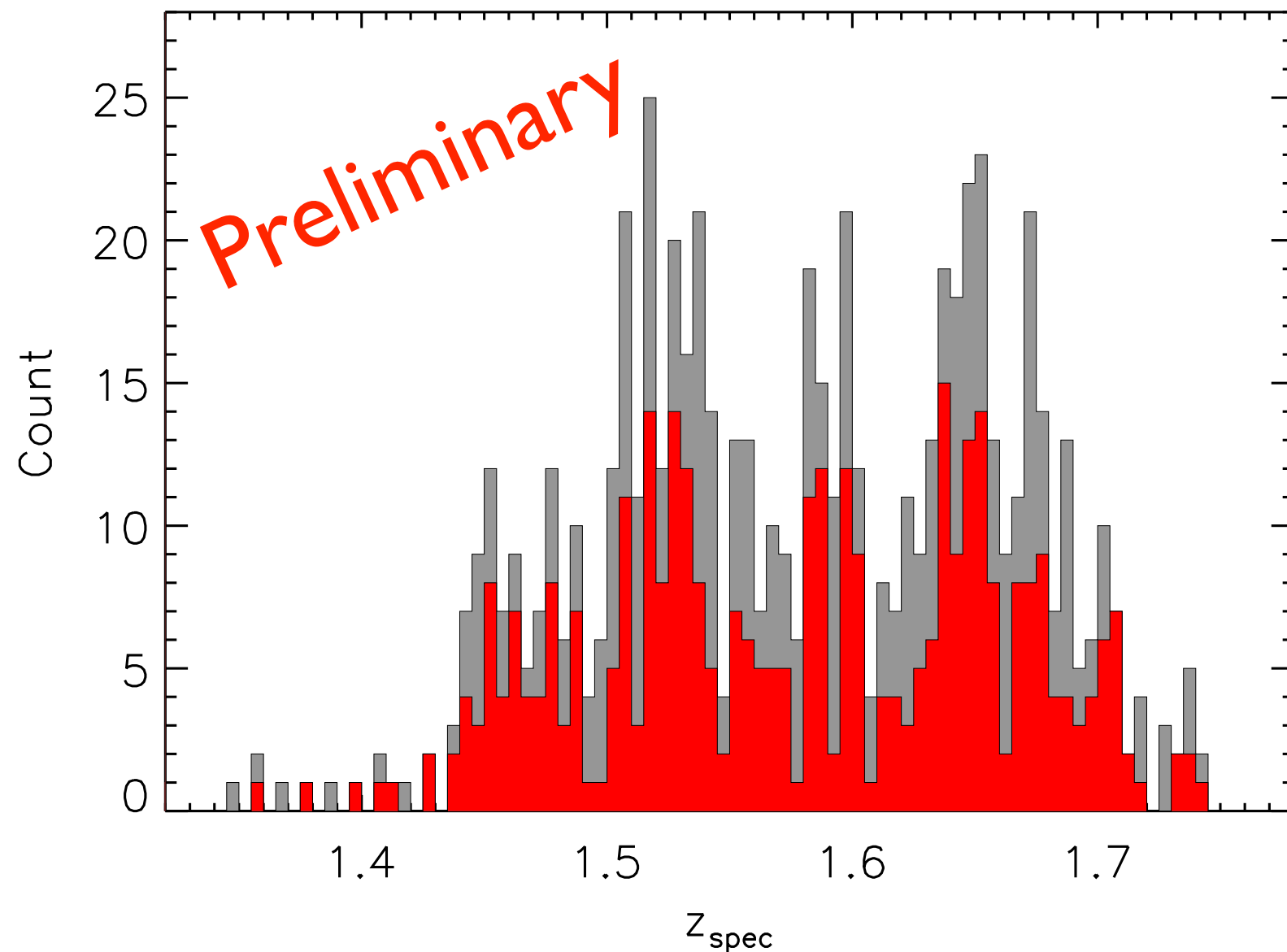


- J-long (1.11-1.35 μ m)



Observed gals.: ~2000 / H α candidates: >800!!

Secure's: ~500



Redshift catalog will be available soon!

Silverman et al. in preparation

Results

Dust properties

Star forming main sequence

based on 271 sBzK's with H α
DK, Silverman, Rodighiero et al. 2013

Differential extinctions toward **Continuum** (stars) and **Emission lines** (HII regions)

Extinction
toward Emission lines

toward Continuum

$$\underline{E_{\text{neb}} (B - V)} = \underline{E_{\text{star}} (B - V)} / \underline{f}$$

For nearby starbursts, $f = 0.44$ Calzetti+00

Is this valid for high-z galaxies?

Now different values b/w 0.44 and 1.0 are suggested for high-z

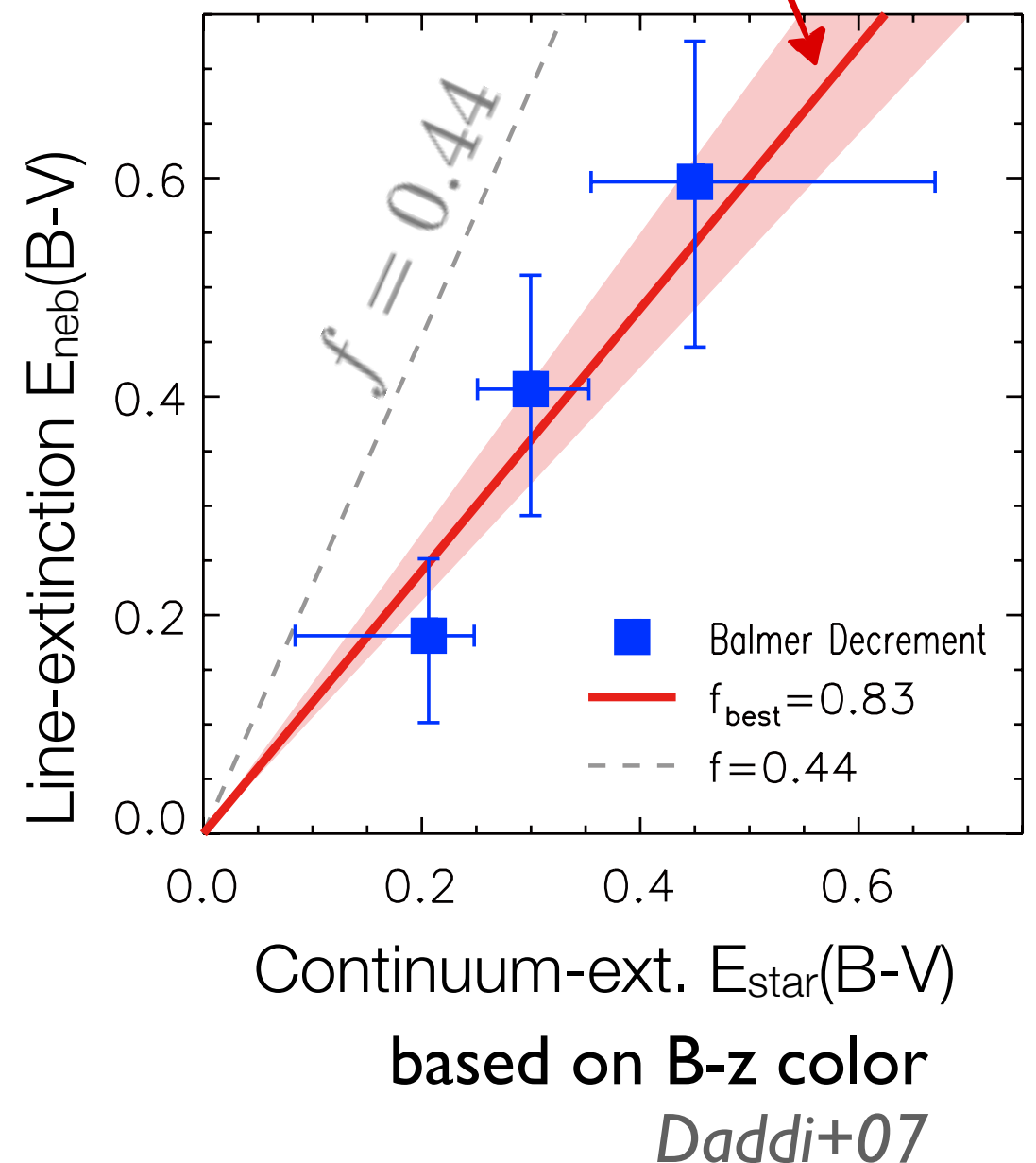
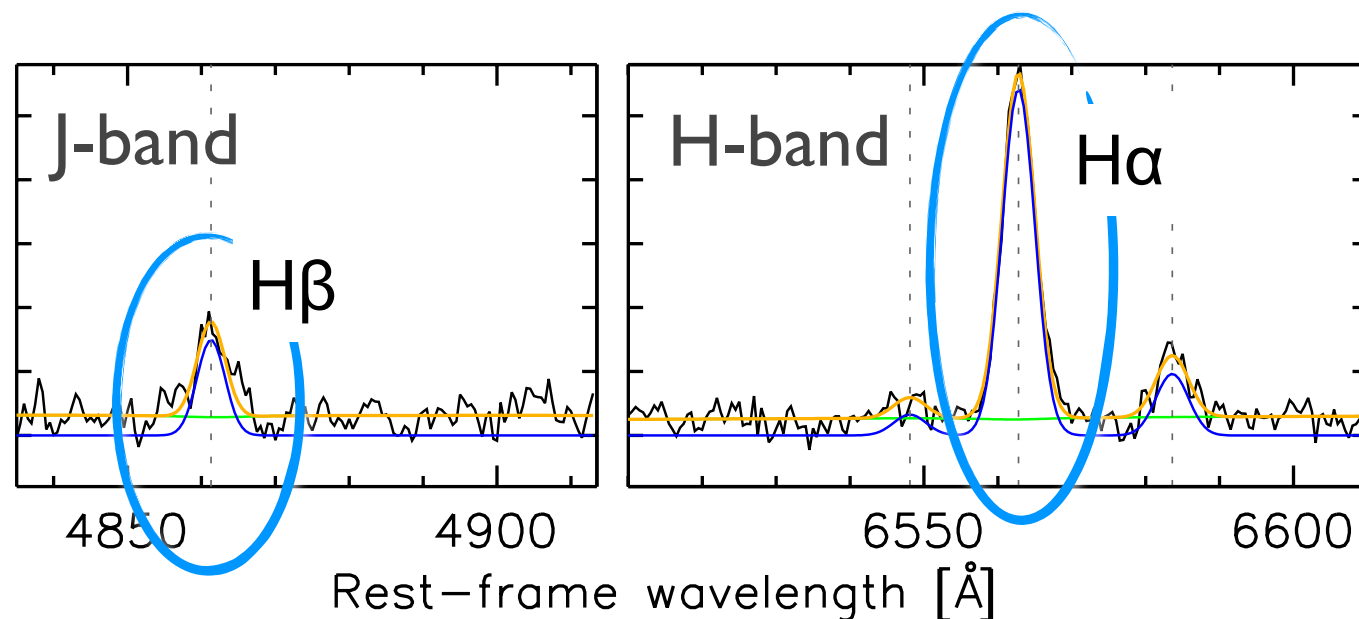
e.g. Förster Schreiber+09, Wuyts+11, Mancini+11, Reddy+10, Onodera+10,
Pannella+in prep, Wild+11, Price+13

輝線と連続光に対する減光の比を見積もる

$$\text{Line-Extinction} \quad \text{Continuum-Ext.} \\ E_{\text{neb}}(B-V) = E_{\text{star}}(B-V) / f$$

$$f = 0.83 \pm 0.15$$

スタックトスペクトルの
バルマー輝線比から輝線
に対する減光を推定

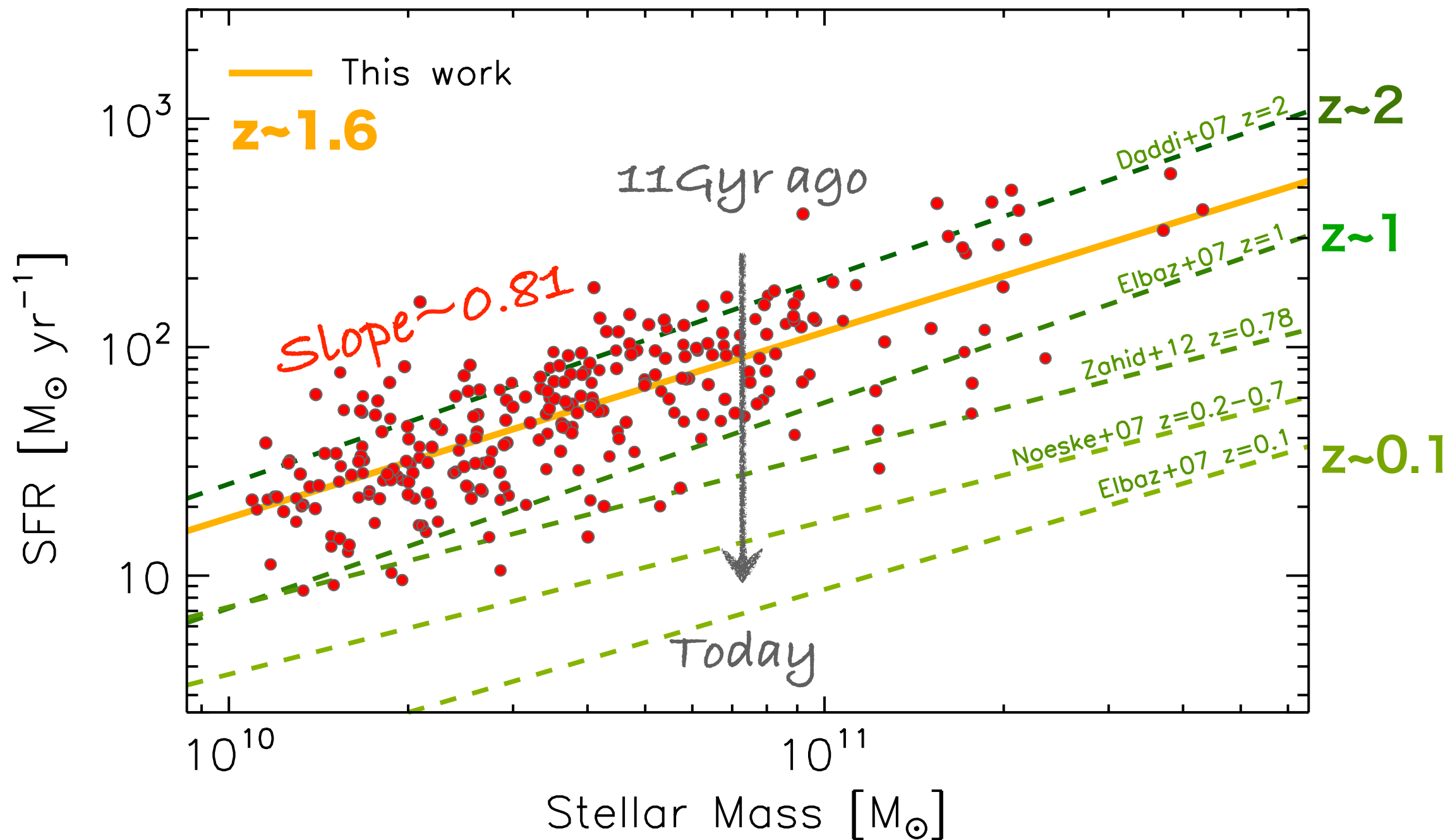


$f \sim 0.8$ (0.44より大きく1に近い)

$$E_{\text{neb}}(B - V) = E_{\text{star}}(B - V) / f$$

- 近傍の銀河に比べて、輝線と連続光に対する減光にあまり違いがない。
 - ▶ より一様なダスト分布
 - ▶ 星やダスト成分の分布（スケールハイト）の時間進化
 - ▶ 連続光のうち、HII領域中の非常に若い星からの寄与が大きい *Price et al. 2013*

Star forming main sequence at $z \sim 1.6$

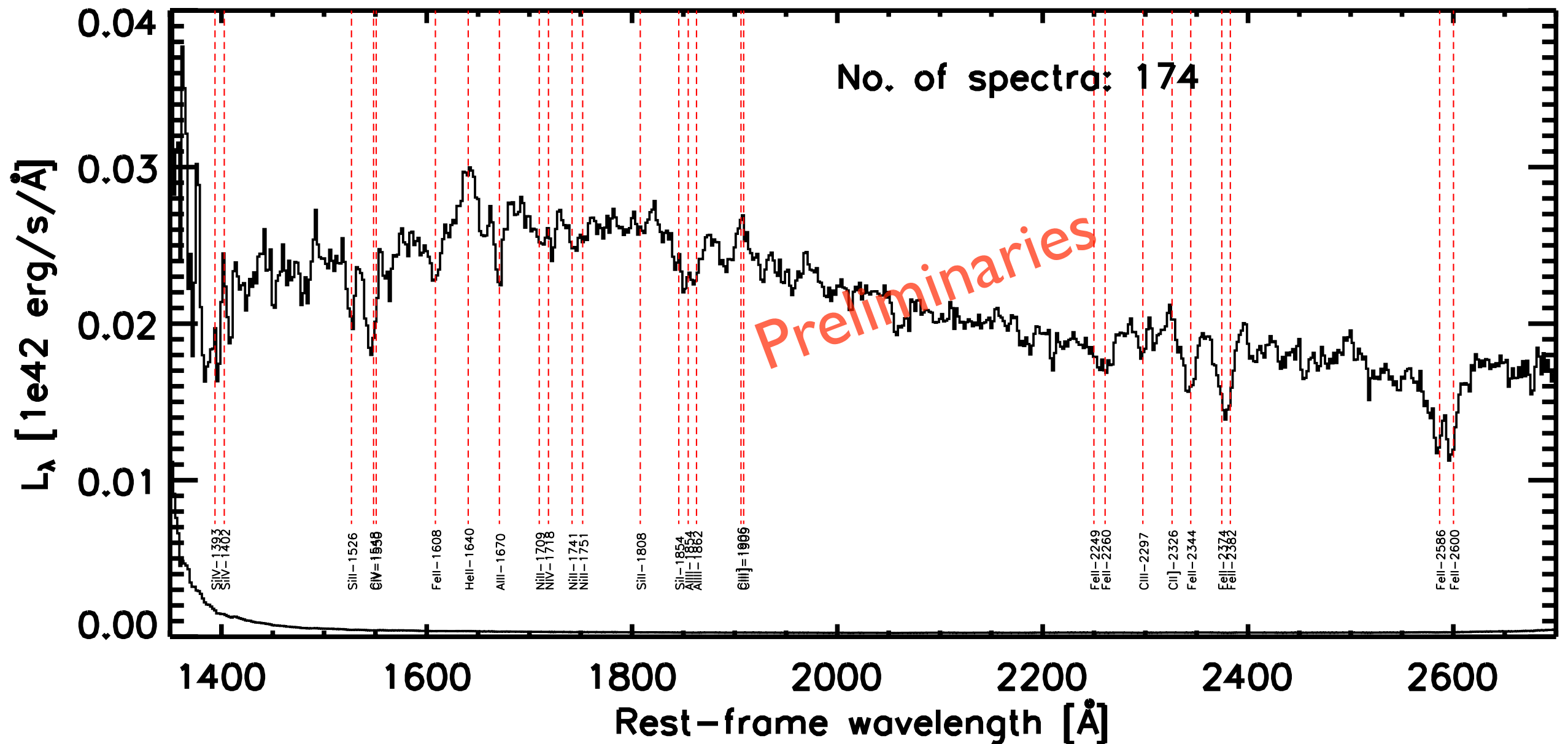


Works in Progress

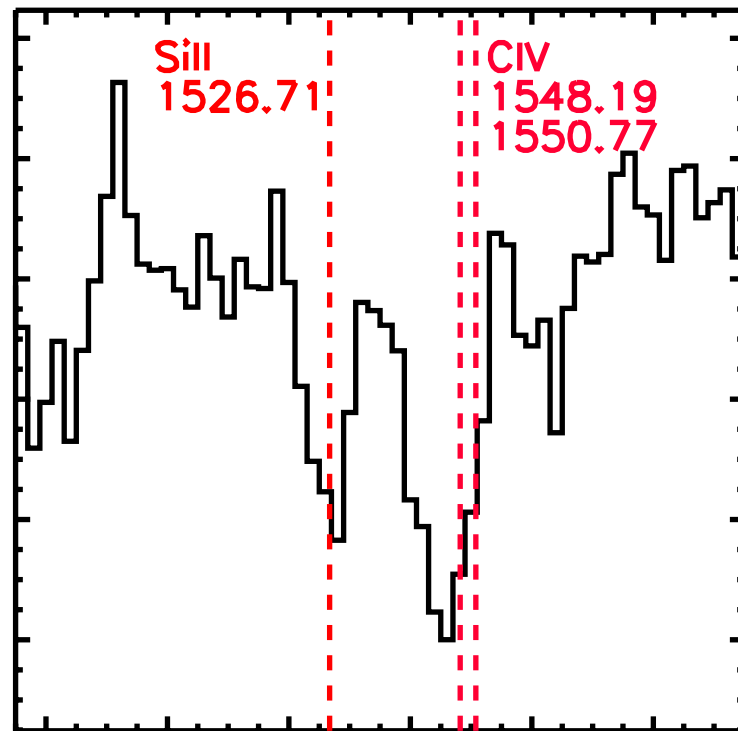
Kinematics of global outflow
w/ zCOSMOS-deep

Stacked zCOSMOS-deep spectrum

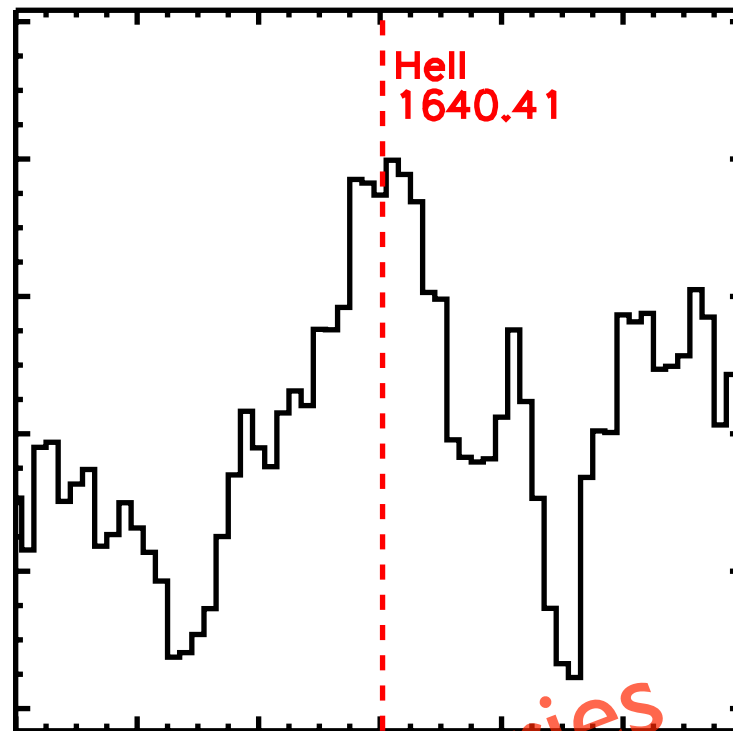
FMOSで測定した赤方偏移をもとに
zCOSMOS-deepスペクトルをスタック



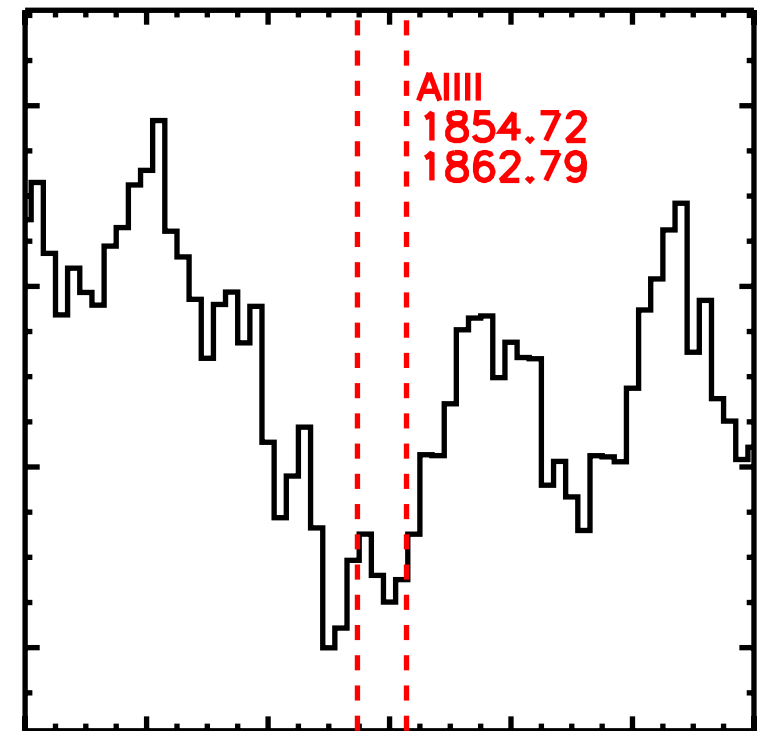
Zoom-in



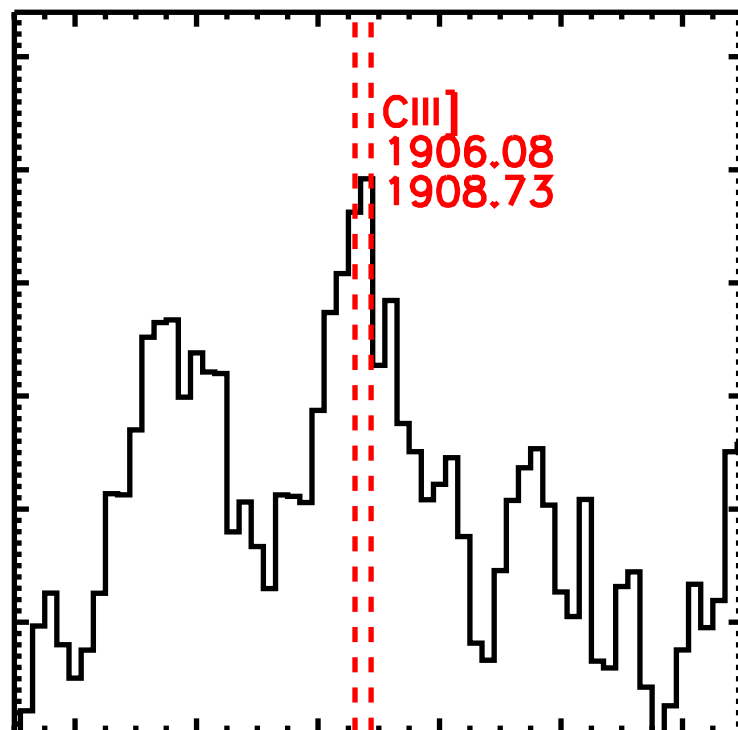
1480 1500 1520 1540 1560 1580



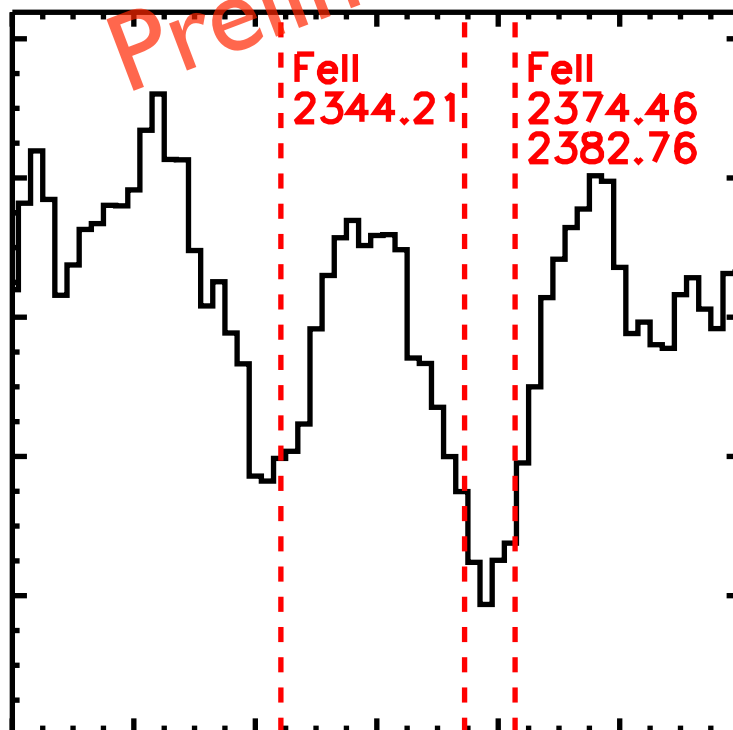
1580 1600 1620 1640 1660 1680 1700



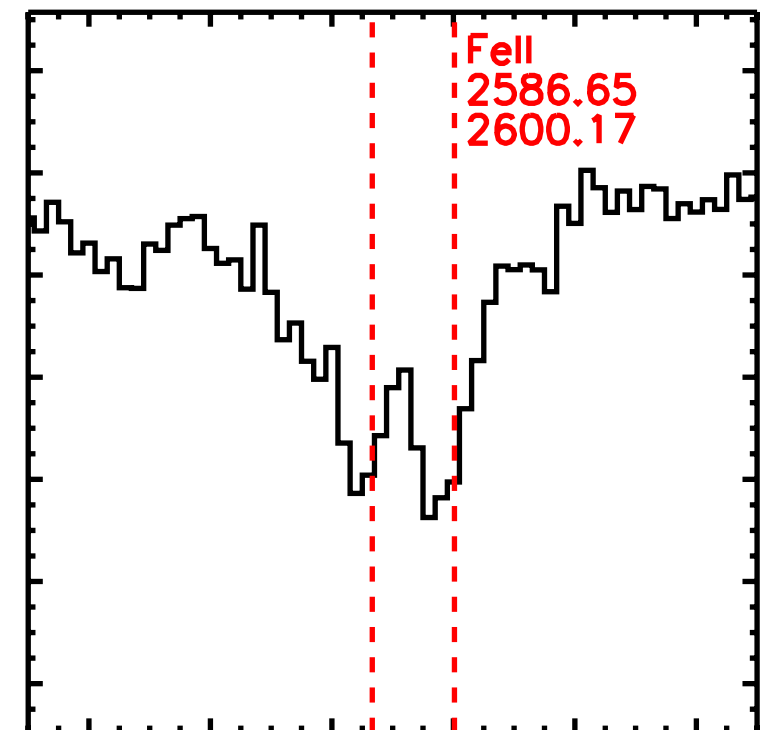
1800 1820 1840 1860 1880 1900 1920



1860 1880 1900 1920 1940 1960



2300 2320 2340 2360 2380 2400 2420



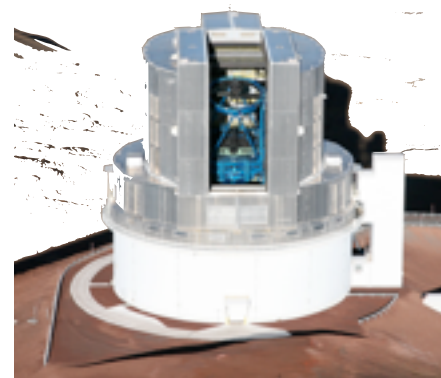
2540 2560 2580 2600 2620 2640

Preliminaries

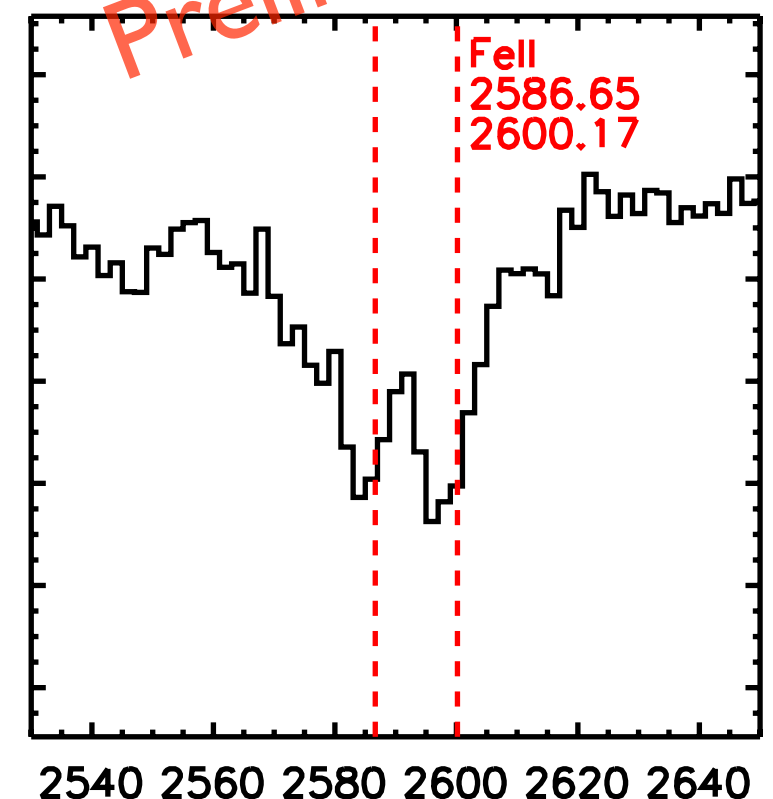
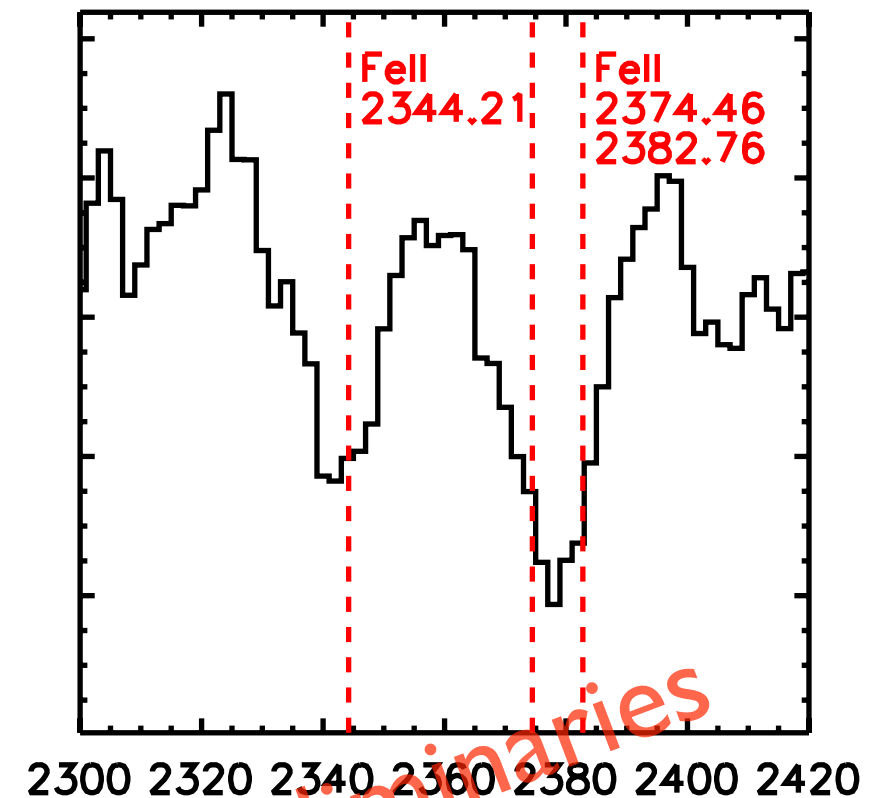
stellar component

outflow gas

アウトフローガスにとって、
光は赤方偏移して見えるの
で、本来より短い波長の光
が吸収される。

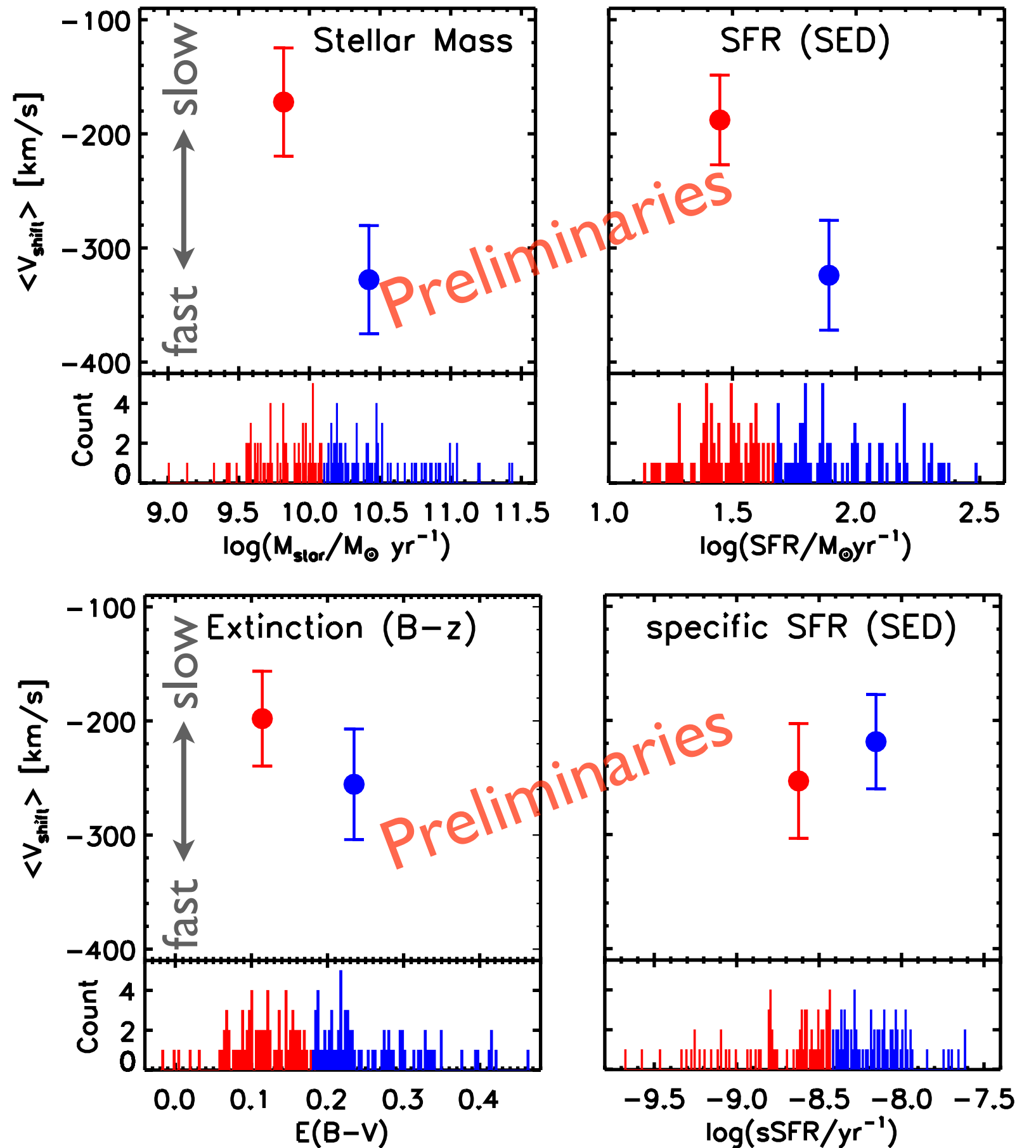


Observer

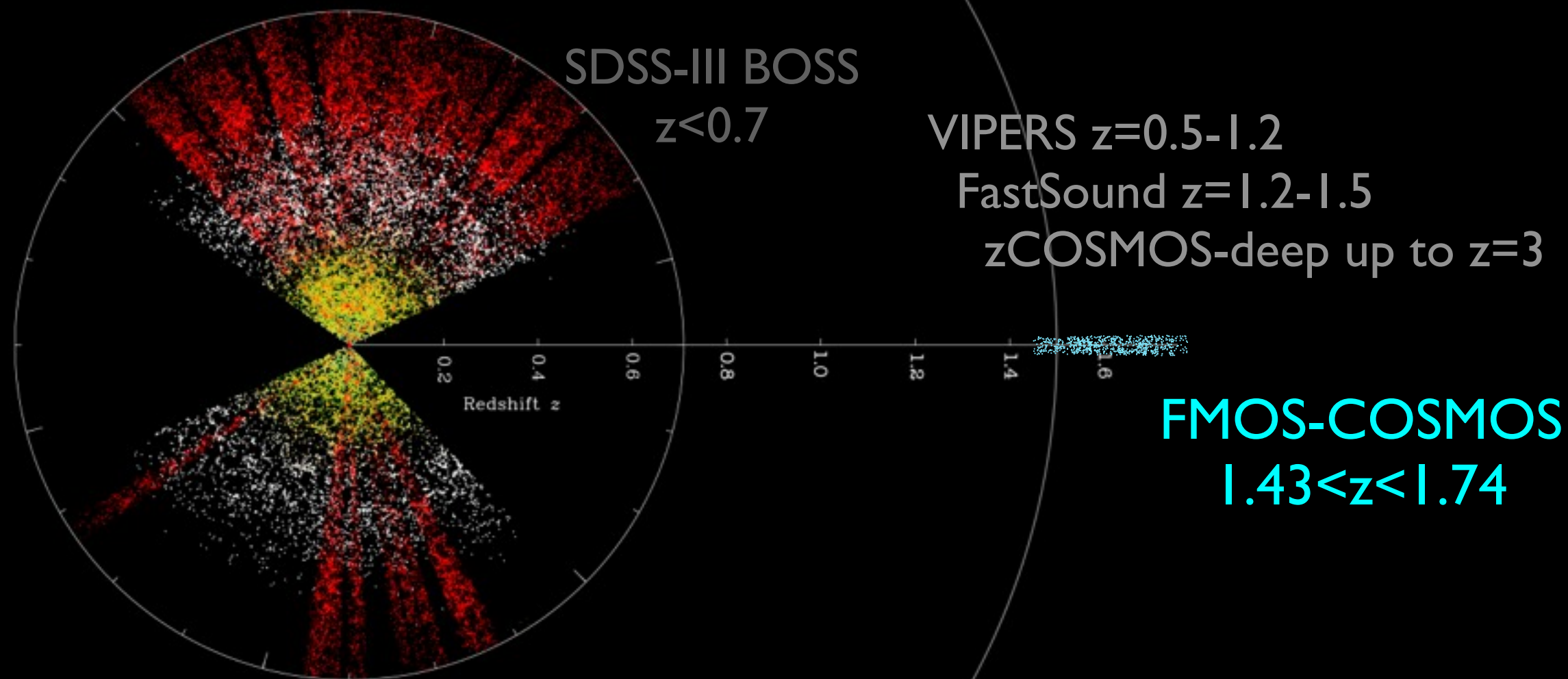


Velocity shift (average of 5 FeII) vs.

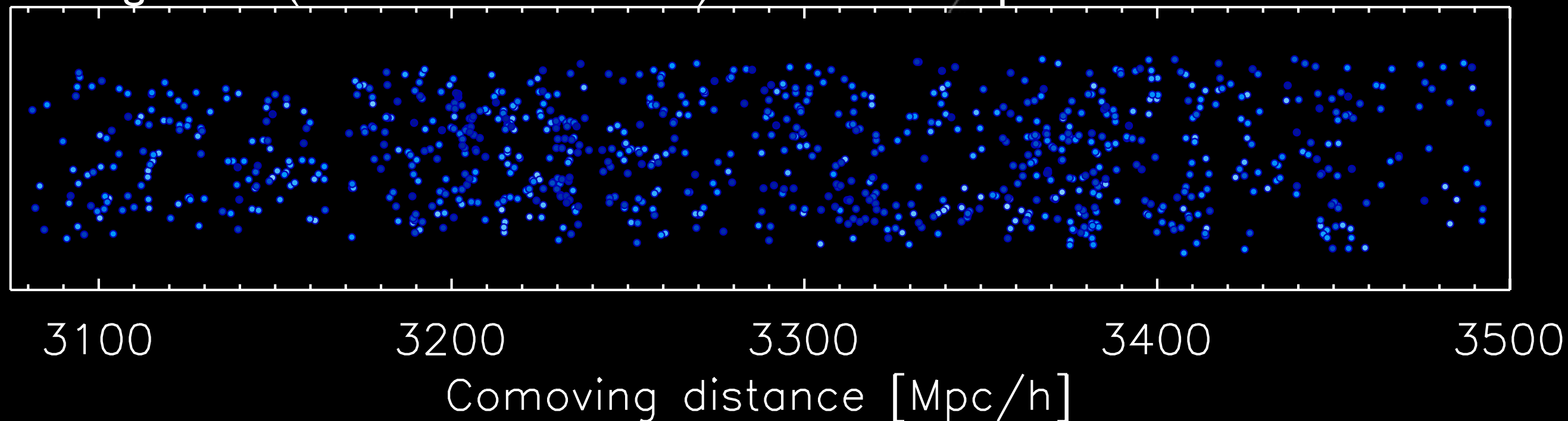
- stellar mass
- SFR
- sSFR
- extinction



Preliminaries



922 galaxies (FMOS 724 + zC 198) in $V \sim 3 \times 10^6 \text{ Mpc}^3$



Preliminaries

SDSS-III BOSS
 $z < 0.7$

VIPERS $z = 0.5 - 1.2$

FastSound $z = 1.2 - 1.5$

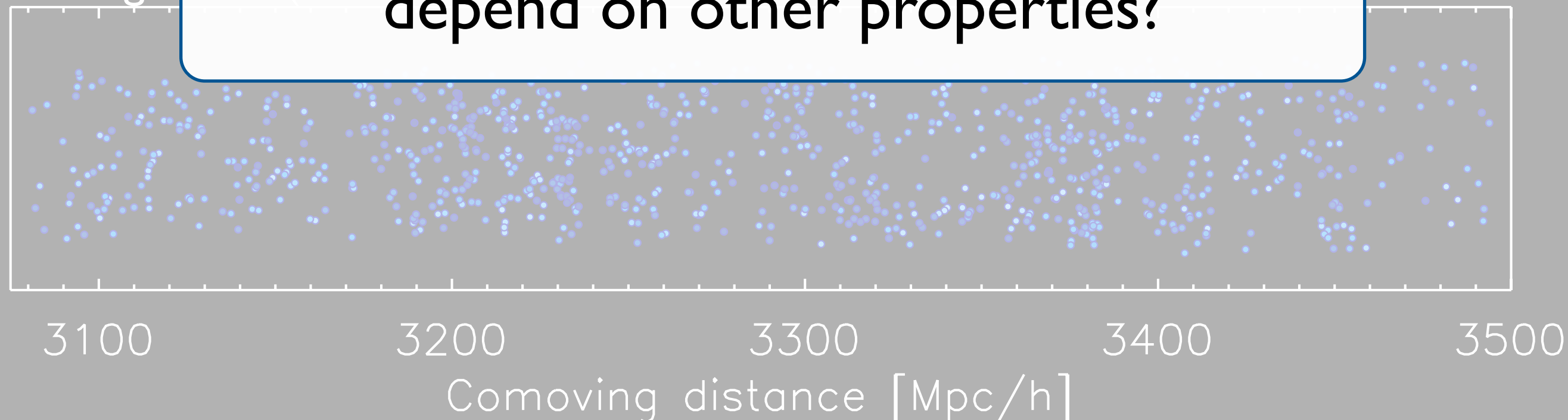
zCOSMOS-deep up to $z = 3$

FMOS-COSMOS
 $1.3 < z < 1.74$

How does the environment impact
on star formation?

How does the galaxy clustering
depend on other properties?

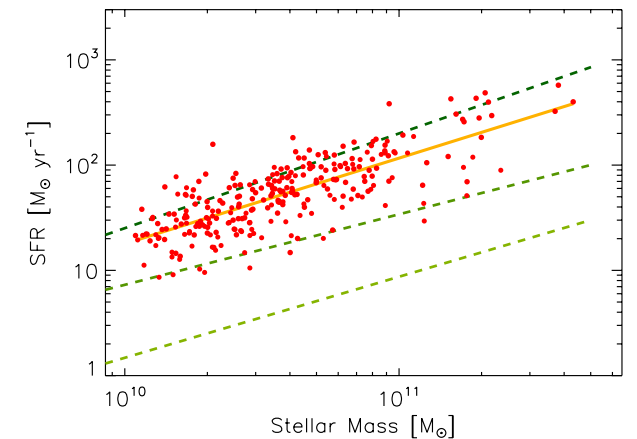
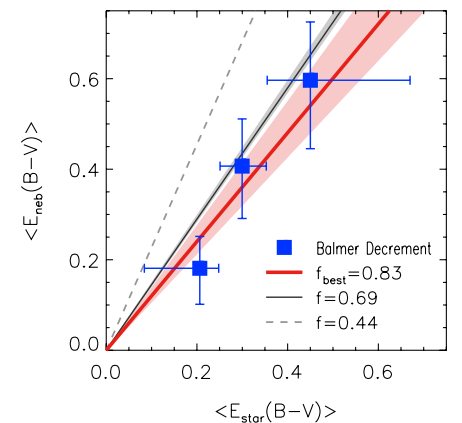
922 galaxies (FMOS 724 + zCOSMOS 198) in $V \sim 3 \times 10^6 \text{ Mpc}^3$



Summary & Future

Published results

- ▶ ダスト減光: 輝線と連続光に対する減光の差が、近傍宇宙よりも小さい
- ▶ $H\alpha$ 光度から星形成主系列を定量化
先行研究と無矛盾な結果を得る



Works in progress

- ▶ アウトフローと銀河の性質との関係
- ▶ 密度場の測定に十分な数密度を達成
- ▶ 星形成の環境依存性・銀河クラスタリング
- ▶ 系統誤差の評価が重要

