FMOS-COSMOS survey of star-forming galaxies at z ~ 1.6

(Progress report on a Subaru intensive program)

John Silverman
(Kavli IPMU)

Daichi Kashino (Nagoya), Dave Sanders (IfA), Nobuo Arimoto (NAOJ), Alvio Renzini (INAF), Emanuele Daddi (CEA/Saclay), Jeyhan Kartaltepe (NOAO), Giulia Rodighiero (INAF), Jabran Zahid (IfA), Lisa Kewley (ANU), Tohru Nagao (Kyoto), Masato Onodera (ETH), Guenther Hasinger (IfA), Hyewon Suh (IfA), Mohammad Akhlaghi (Tohoku), Masaru Kajisawa (Ehime), Yoshi Taniguchi (Ehime), Henry McCracken (IAP), Olivier Ilbert (Marseille), Peter Capak (SSC), Simon Lilly (ETH), Marcella Carollo (ETH)
How are galaxies and their supermassive black holes built up with cosmic time?

Galaxy properties:  
\( z_{\text{spec}}, M_*, \text{SFR} \)  
ISM: metallicity, \( M_{\text{gas}}, M_{\text{dust}} \)

Central black black hole:  
\( L_{\text{bol}}, M_{\text{BH}} \)

Environment:  
\( \delta_{\text{local}}, M_{\text{halo}} \)
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An Hα survey of galaxies in COSMOS with Subaru/FMOS

- **large IR spectroscopic redshift survey (> 1000 spectra) with FMOS**
  - Effectively ~200 science fibers
  - Resolution ~2200
    - can separate Hα and [NII]
    - high emission-line sensitivity

- **accurate SFR**
  - measured in the same way at z=0 (i.e., Hα)
  - 1-1.7 µm (Hα between 0.5 < z < 1.8)
  - Hα less affected by dust extinction than [OII]3727, more responsive to the UV ionizing flux from young stars, not affected by variations in metallicity

- **characterization of the local density field**
  - general galaxy population
  - beyond z ~1 for the first time
Subaru - Fiber Multi-object Spectrograph (FMOS)

• Built by Kyoto University, UK & NAOJ (PI: T. Maihara)
• commissioned in 2007

• 0.9 - 1.8 μm
• 400 fibers; 1.2” diameter
• 30’ diameter FOV
• Echidna fiber system
• Airglow/OH suppression system (Iwamuro et al. 2006)
• Low (R=500) and high (R=2200) resolution
• 2048x2048 HgCdTe Hawaii-2 detectors
• Cross-beam switching (~200 fiber pairs can be assigned)
• two spectrographs (irs1 and irs2)

• Initial results (Yabe et al. 2012; Roseboom et al. 2012; Matsuoka, JDS et al. 2013)
FMOS observations

H-long (H\(\alpha\))

14 nights (S12A-S14A; Japan time)
[last 7 nights completed in S14A]

- Pilot survey: 5 nights in March 2012
- Additional time through IfA (J. Zahid)
- NAOJ Intensive program (PI: JDS)
  (8 nights awarded)
- 4-5 hour integration time per pointing

\[ H-long (H\alpha) \]

J-long (H\(\beta\)+[O\III])

14 nights (S12A-S14A; UH/IfA time)

- IfA time (PI: Dave Sanders)

Over 1200 spectra
(H-long; 1.6-1.8\(\mu\)m)

50% observations in hand

466 with a redshift
Target selection

- star-forming galaxies
  - K-selected ($M_\star > 10^{10} M_\odot$)
  - sBzK
  - along the star-forming main sequence
  - $f_{\text{H}\alpha} > 4 \times 10^{-17}$ erg cm$^{-2}$ s$^{-1}$

- Herschel/PACs sources
  - highly obscured SF galaxies
  - above or on M-S
  - near bright stars for future IFU/AO observations

Filler targets: AGNs, low-mass galaxies

Rodighiero et al. 2010
J-long (1.1-1.35 μm)

H-long (1.6-1.8 μm)

Hα

[NII]

[OIII]

Hβ
(a) $3 \times 10^{-17} < f(H\alpha) < 7 \times 10^{-17}$ \text{ erg s}^{-1}\text{cm}^{-2}$

(b) $7 \times 10^{-17} < f(H\alpha) < 11 \times 10^{-17}$ \text{ erg s}^{-1}\text{cm}^{-2}$

(c) $f(H\alpha) > 11 \times 10^{-17}$ \text{ erg s}^{-1}\text{cm}^{-2}$

(d) $T_{\text{exp}} = 1\text{ hour}$

$T_{\text{exp}} = 5\text{ hour}$
Ilbert et al. 2013

12482 galaxies
$\eta$: 2.1%
$\sigma_{\Delta z/(1+z)}$: 0.0096
Predicted vs. Observed Hα flux

- Flag = 2
-  = 1

- Predicted f(Hα) vs. FMOS f(Hα) for different figures with correlation coefficients f=0.44 and f=0.66.
Stacking analysis

We stacked 34 individual spectra in each three mass bins. Line properties change clearly with mass.

Kashino et al. 2013
Nebular versus stellar extinction

\[ f = \frac{E_{\text{star}}(B-V)}{E_{\text{neb}}(B-V)} \]

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Kashino et al. 2013
Star-forming main sequence at $z \sim 1.6$

Kashino et al. 2013
Mass-metallicity relation at high-z

Zahid, Kashino, JDS et al. arXiv:1310.4950
Mass-metallicity relation at high-z

Zahid, Kashino, JDS et al. arXiv:1310.4950
Comparison of different SFR indicators

G. Rodighiero et al. in preparation
CO (2-1) masses through ALMA followup (Cycle 1)

Daddi et al. (2010)
Galaxy associations at high-z
### Summary

**On our way towards a 1k NIR spectroscopic catalog**

- Dust extinction is similar to low-redshift galaxies (Kashino et al. 2013)
  - ★ Higher in high-mass galaxies
  - ★ More uniformly distributed

- SF main sequence in place (intrinsic width ~0.2-0.3 dex)

- Close relation between UV, Hα and FIR SFR indicators (Rodighiero et al.)

- Chemical enrichment (Zahid et al. 2013)
  - ★ High-mass galaxies have metallicities reaching the local relation
  - ★ Steeper mass - metallicity relation
  - ★ mass-metallicity-SFR relation is not so fundamental
Works in progress

- FMOS survey design and sample characteristics (Silverman)
- Comparison of star-formation rates (UV, Hα, FIR; G. Rodighiero, A. Renzini)
- Star formation timescales (E. Daddi)
- SF and metallicities as a function of UV morphology (M. Akhlaghi-Tohoku)
- Outflows using zCOSMOS deep UV spectra (D. Kashino)
- Proto-groups and environmental impact on star-formation (D. Kashino)
- AGN narrow emission-line properties at high-z (J. Chu, D. Sanders, L. Kewley)
- Properties of IR-selected galaxies (J. Kartaltepe, D. Sanders)
- Gas masses and star-formation efficiency with ALMA