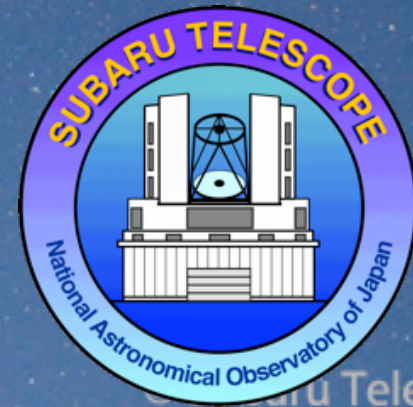


Uniqueness of ULTIMATE & possible survey design

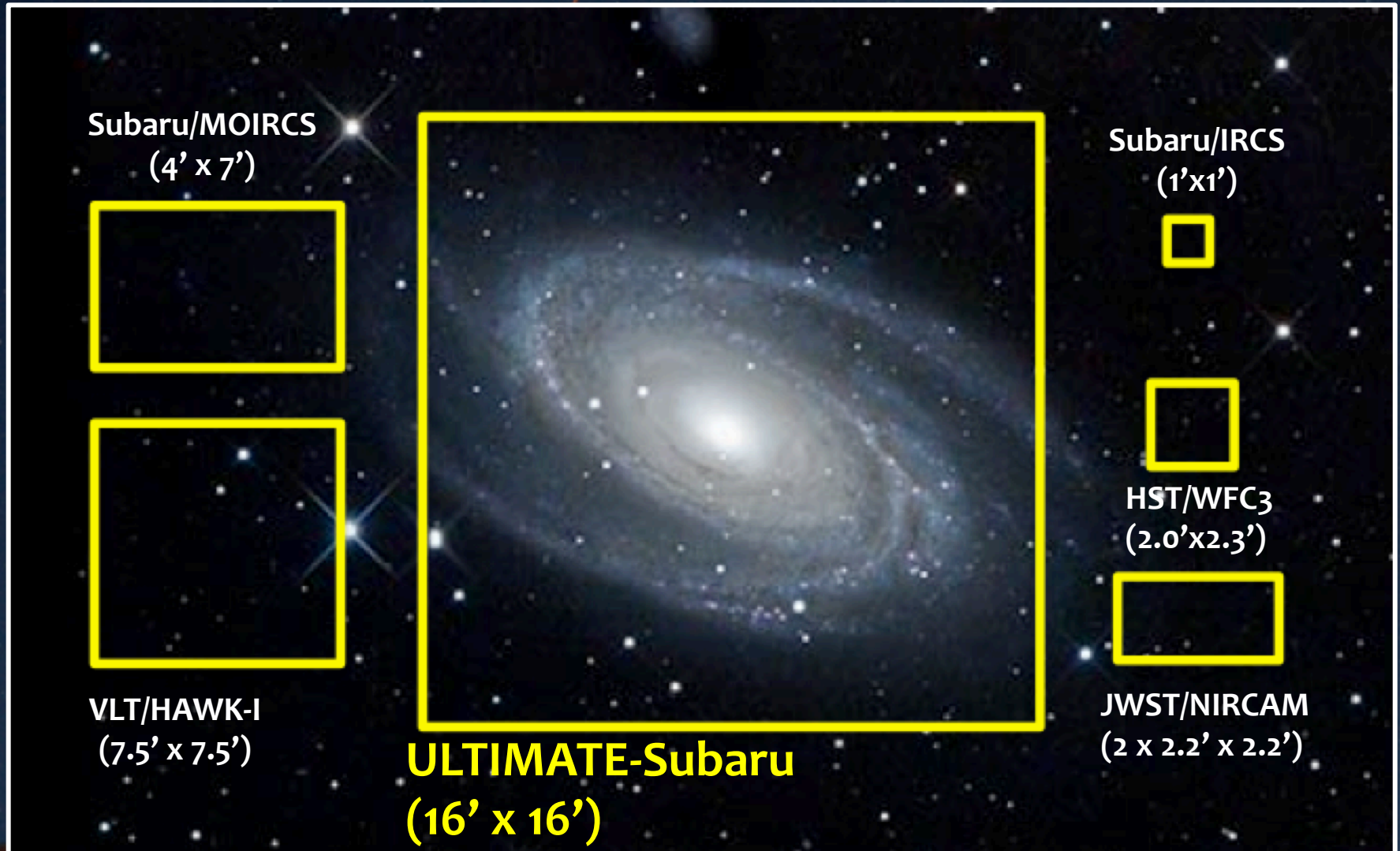
Yusei Koyama
(Subaru Telescope)



ULTIMATE-Subaru (~2023-)

- **Wide-field adaptive optics (GLAO)**
 - 0.2'' at K-band (0.2''-0.3'' at J/H) over 15' FoV
 - available almost everywhere on sky
- **Powerful wide-field NIR instruments**
 - Wide-field imager, multi-IFU spec., MOS spec.

FoV comparison of NIR facilities in 2020s available at $\lambda > \sim 2\mu\text{m}$



Strengths of ULTIMATE (1)

- Imaging:
 - Available at **K-band**, where future wide-field space telescopes (Euclid/WFIRST) do not cover.
 - **Narrow-band, medium-band**, and potentially **tunable filter** at NIR.
 - Spatial resolution $\sim 0.2''$, comparable to HST/WFIRST over ~ 15 arcmin FoV, allowing to spatially resolve high- z galaxies on \sim kpc scale.

Strengths of ULTIMATE (2)

- Multi-object IFU:
 - VLT/KMOS-like observation assisted by GLAO – factor $\sim 2-3x$ improvement in spatial resolution.
- MOS spectroscopy :
 - High sensitivity at all Y-K (potentially even more sensitive than MOSFIRE thanks to GLAO).

If your science requires:

- Deep/sharp & wide-field imaging at K-band
- Deep/sharp & wide-field NIR NB/MB imaging
- Sharp NIR IFU spec. for statistical sample
- Ultra-deep NIR MOS spec. for statistical sample

then ULTIMATE is the best choice !

Preliminary survey design

(assuming the current framework of SSP = 300 nights)

Here we list 5 EXAMPLE survey designs. All these are very preliminary just to demonstrate what levels of survey can be done with reasonable obs. time.

(A) ULTIMATE imaging survey # 1

- “Balanced” survey: use several NBs (in all JHK) & MB+BB (in K-band) to exploit as many “unique points” as possible.
- Assume 2-deg² survey in COSMOS & SXDF.
- Assume broad-band J/H will be taken by WFIRST.
- Take long exposure for NB(J)s because these filters are for detecting very high- z ($z>7$) LAEs.

Survey type	Filters	Exp. time per FoV [hrs] (including overheads)	Limit mag. (5σ , AB)	N. of nights
NB imaging	NB _J ×2	8.0 (10.0)	27.0	64
	NB _H ×2	4.0 (5.0)	24.2	32
	NB _K ×2	4.0 (5.0)	24.1	32
MB imaging	<i>K1</i>	10.0 (13.0)	26.1	42
	<i>K2</i>	10.0 (13.0)	26.1	42
	<i>K3</i>	10.0 (13.0)	26.1	42
BB imaging	<i>K</i>	9.0 (13.5)	26.7	45
Total time	–	–	–	299

(B) ULTIMATE imaging survey # 2

- “NB-only” survey: e.g. 10 NB filter survey to maximize NB capability of ULTIMATE – not available with e.g. WFIRST.
- “Ultra-deep” for 30’ x 30’ field + “Deep” for 2-deg².
- Again, we assume we can use broad-band J/H from WFIRST.

U-Deep (0.25deg ²)	Exp. time per FoV	(with overhead)	Limit mag.	N. of nights
NBJ x 3	16-hrs	(20-hrs)	27.4	24.0
NBH x 3	16-hrs	(20-hrs)	25.0	24.0
NBK x 4	16-hrs	(20-hrs)	24.9	32.0
K	8-hrs	(12-hrs)	26.4	4.8

84.8
nights

+

Deep (2 deg ²)	Exp. time per FoV	(with overhead)	Limit mag.	N. of nights
NBJ x 3	4-hrs	(5-hrs)	26.6	48.0
NBH x 3	4-hrs	(5-hrs)	24.2	48.0
NBK x 4	4-hrs	(5-hrs)	24.1	48.0
K	2-hrs	(3-hrs)	25.6	9.6

169.6
nights

||

254.4
nights

Note: Alternatively, you can also consider to use tunable filter instead of many NBs.

(C) ULTIMATE imaging survey # 3

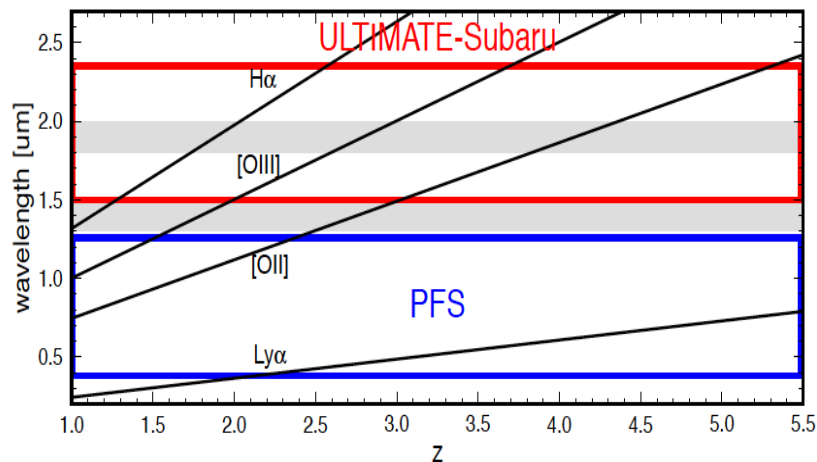
- “K-only” survey : This is another extreme case to maximize synergy with WFIRST (and HSC), and to enhance the use from broad science interests.
- Simply K-band imaging (5-hrs on-source, 7.5-hrs incl. overhead, down to 26.2 mag [5σ , AB]).
- Take 120-hrs to complete 1-deg² – yielding total 240 nights to cover 20 deg².
 - Note1: UKIDSS-UDS covers ~0.8 deg² down to ~25 mag [5σ , AB].
 - Note2: WFIRST typical depths – J=26.9, H=26.7.
- Survey area size is comparable to “HSC-deep”.
- Again, we need to completely rely on WFIRST for J/H.

K-only (20 deg ²)	Exp. time per FoV	(with overhead)	Limit mag.	N. of nights
K	5-hrs	(7.5-hrs)	26.2	240

(D) ULTIMATE MOS spec. survey

(Preliminary design by Tadaki-san et al.)

- “Completely mass-limited sample” : H+K spectroscopy for a mass-complete sample of $\sim 15,000$ galaxies with $\log M > 10.5$ at $z=2-2.6$ selected from 3 deg^2 field.
- “PFS follow-up survey” : NIR (H+K) spectroscopy of $\sim 10,000$ higher- z targets (LAEs/LBGs) with PFS spectra.
- 200 nights in total.



Target selection	Redshift range	N_{gal}
Mass-selected ($\log M_* > 10.5$)	2.0 – 2.6	15k
Lyman break (w/ PFS spectra)	2.0 – 2.6	4k
Lyman break (w/ PFS spectra)	3.0 – 3.7	2.5k
Lyman break (w/ PFS spectra)	4.4 – 5.2	0.5k
$\text{Ly}\alpha$ emitter (w/ PFS spectra)	2.2, 3.3, 4.9	3.2k

(E) ULTIMATE IFU spec. survey

According to Study Report by AAO:

http://www.naoj.org/Projects/newdev/ngao/20160113/20151211AAO_ULN_PLN_002_v5_Prototyping.pdf

- 3000 galaxies at $z=0.7, 0.9, 1.4$ from $\sim 1\text{-deg}^2$ region of COSMOS and SXDF-UDS (total 2-deg^2).
- Target galaxies are within the HSC-ultra-deep field.
- $\sim 2\text{-hrs}$ exposure for each target, down to (roughly) $\text{SFR} \sim 10 M_{\odot}/\text{yr}$ at $z=1$.
- Simultaneous observation of 13 targets.
- Total 50 nights.
- Direct extension of SAMI project toward high- z .
 - See talk by Chris Lidman (AAO)

This workshop

1. “Key science” with ULTIMATE in mid-2020s
2. Establish strong science team
3. Discuss the instrument plans
4. Community’s input on survey design
5. Accelerate collaboration with our partners
6. Synergy with other future missions