Wide-field NIR instrument suite for the wide-field ground-layer AO system (ULTIMATE-SUBARU)

- Science cases and instrument concepts -

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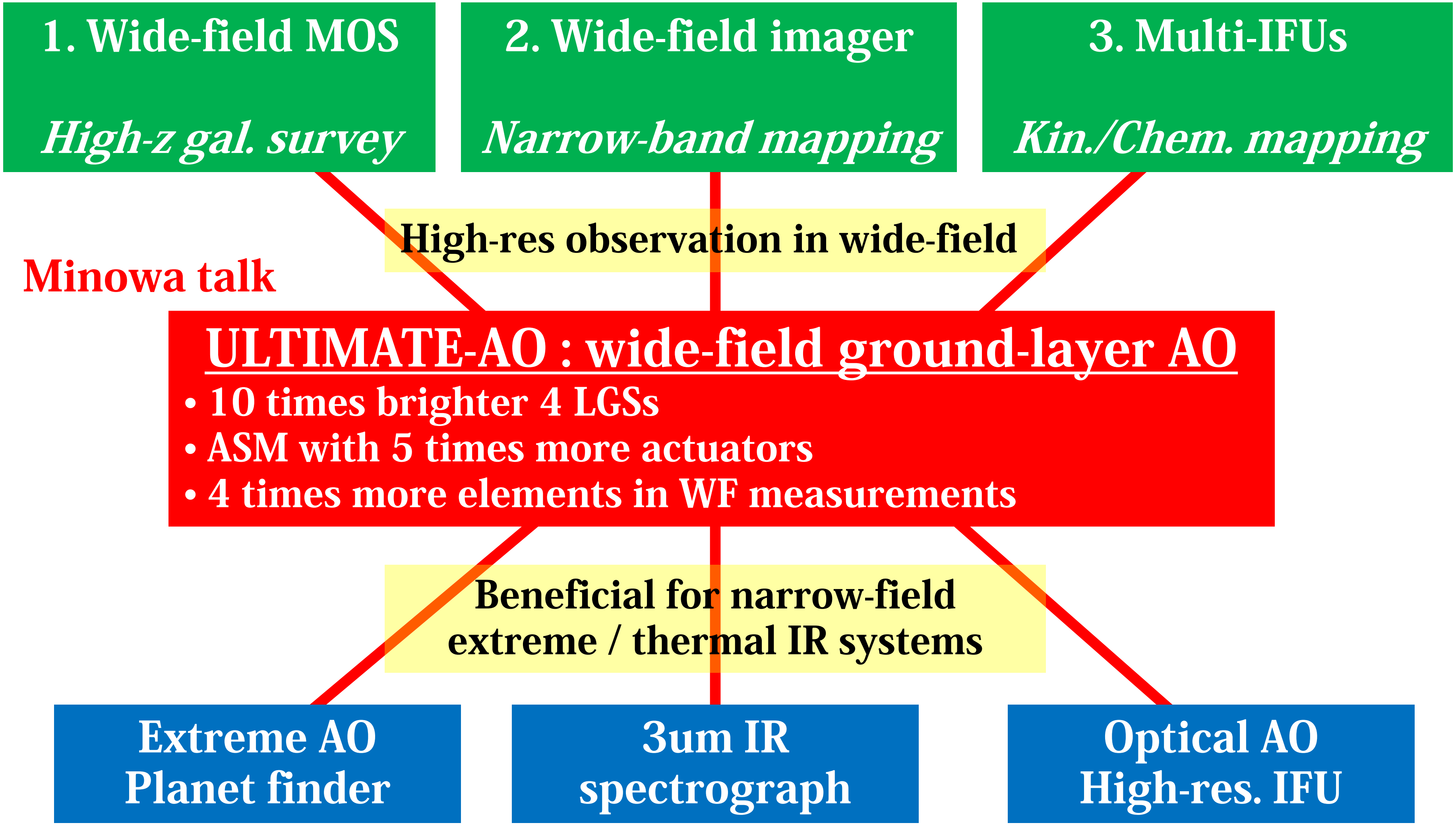
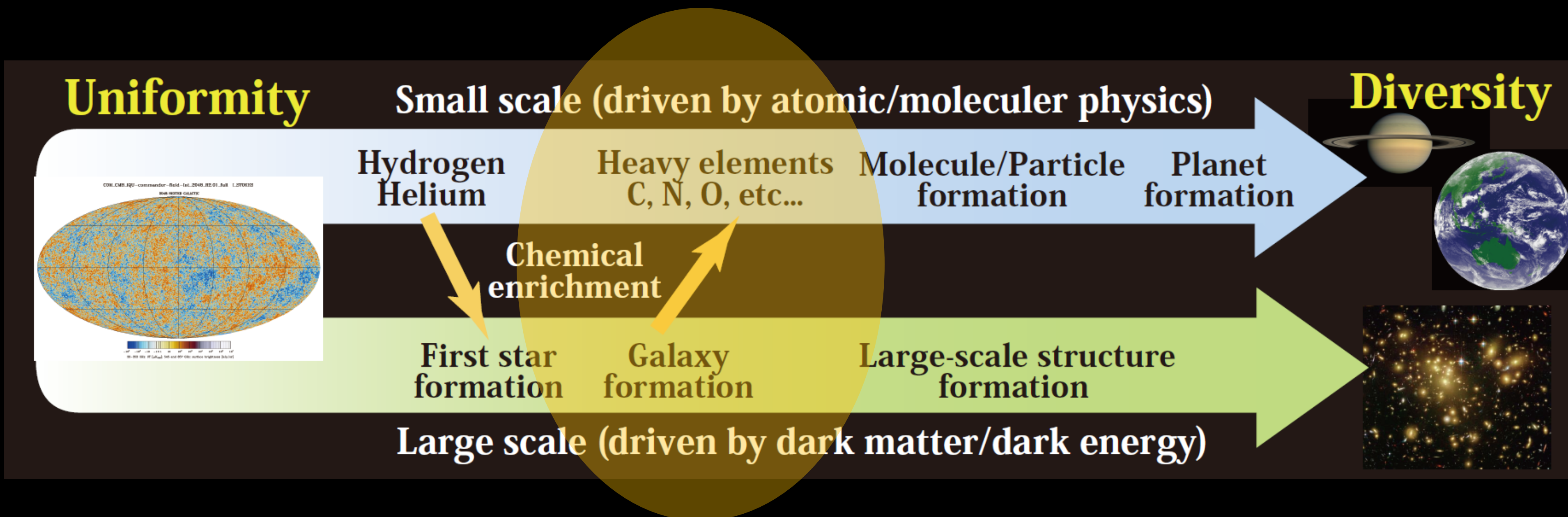
on behalf of the ULTIMATE team

2017/03/22

ULTIMATE-SUBARU instrument suite



How the *diversity* is originated from the *uniformity* of the early universe



Origin of the Universe → Evolution of the Universe → Origin of life

Key science questions

“ How is gas in galaxies enriched / recycled at the peak of the galaxy formation at z=1-3 ? “

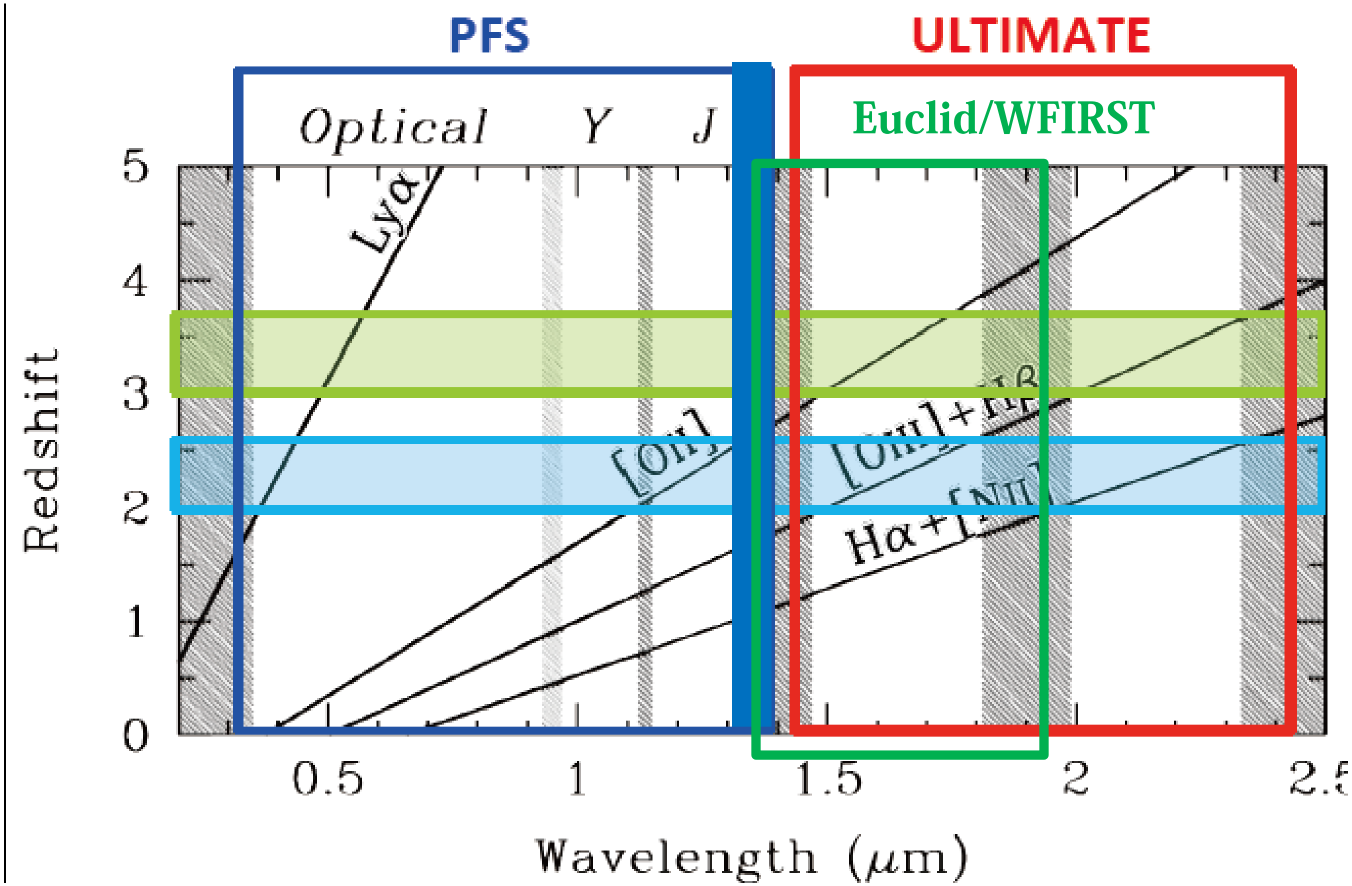
- Site of star formation inside galaxies and accumulation of stellar mass
- Chemical enrichment history (emission line diagnostics)
- Outflow / infall gas kinematics (ionized gas kinematics, systemic velocity and Ly-alpha line profile)
- Connection between outflow and AGN activity
- Quenching mechanism
- Connection between gas properties and Ly-c leaking : reionization

SDSS + SAMI/MANGA at the peak of the galaxy formation

1. Wide-field MOS

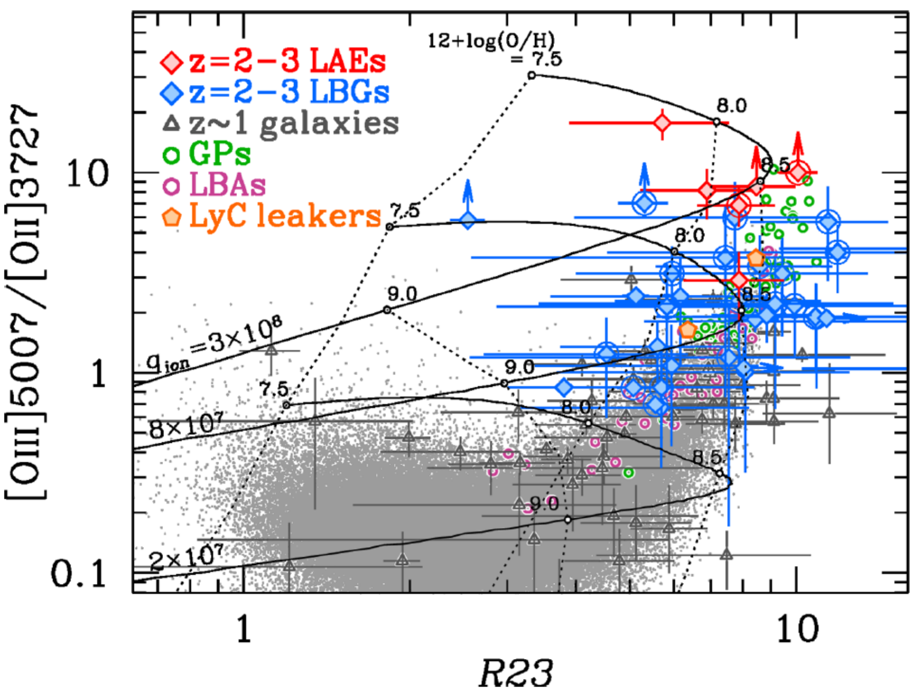
Science cases with the wide-field MOS

- Rest-frame optical emission-line survey of z~2, z~3 >20K galaxies.
- Extending PFS survey toward longer wavelength (line diagnostics) and higher-redshifts (z~3). NIR "follow-up" observations of PFS deep survey.
- Covers unique wavelength range compared to Euclid/WFIRST.

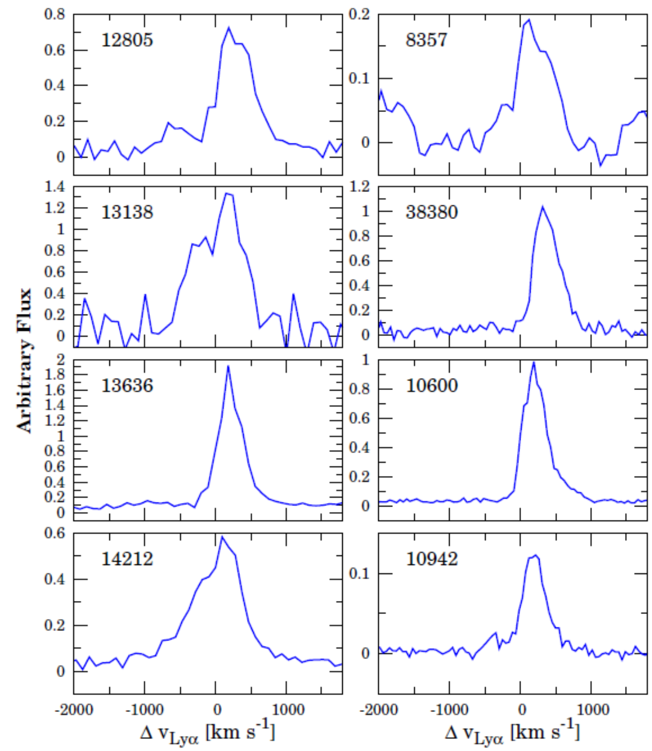


Science cases with the wide-field MOS

- Line diagnostics for gas-abundance, ionization parameter, dust-reddening, AGN contribution, and dynamical properties.
- Comprehensive view of star-forming galaxies at z=2-3. Base-line information for understanding galaxies with strong UV emission in the reionization era found / observed by JWST, TMT, etc.



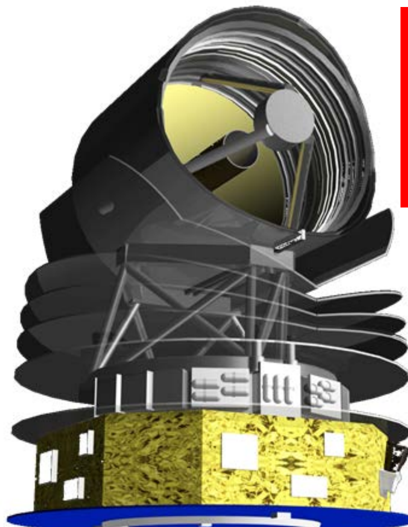
Metallicity and ionization parameter by [OII], [OIII], Hb measurements (Nakajima et al. 2014)

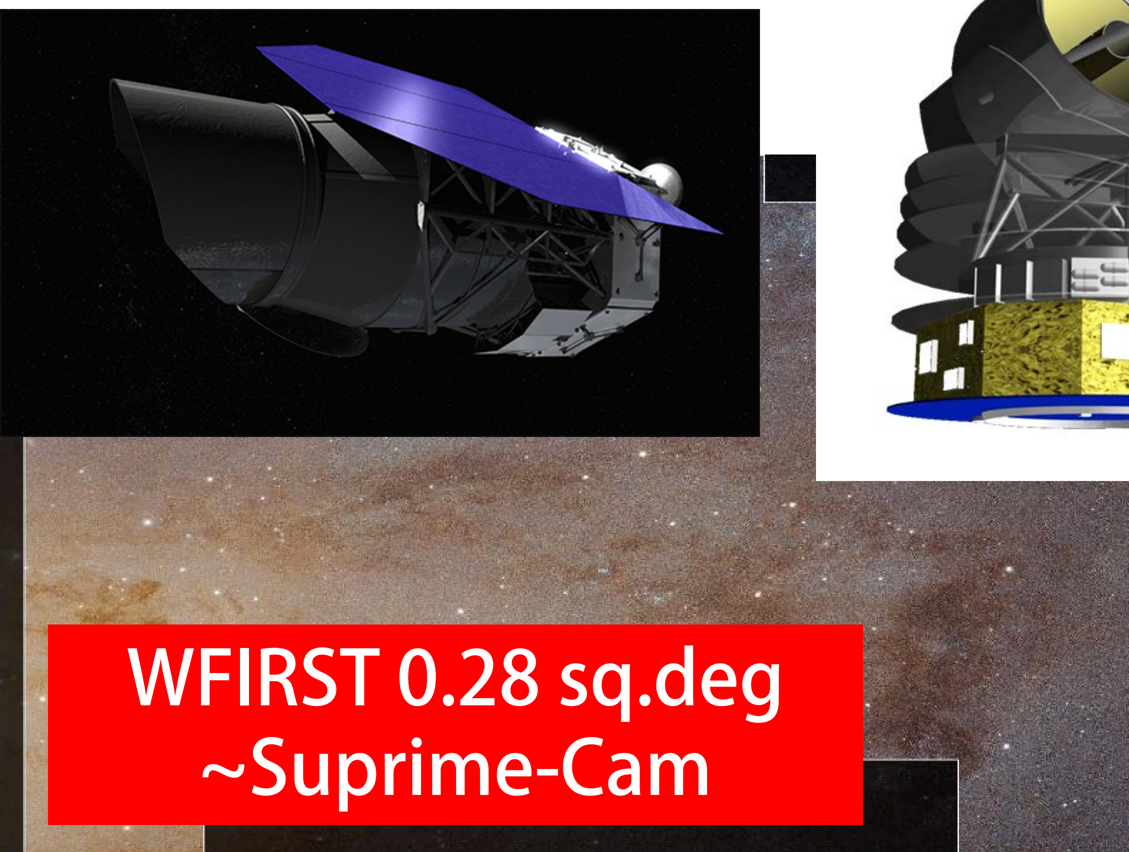


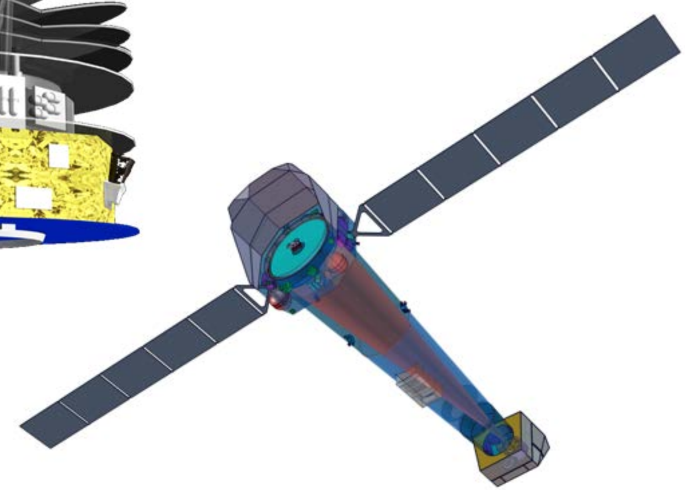
Understanding Lya line profile in relative to systemic velocity (Shibuya et al. 2014)

Science cases with the wide-field MOS

- Follow-up spectroscopy of candidates of high-z galaxies / AGNs picked up by future wide-field surveys from space (Euclid, WFIRST, SPICA, Athena, STARX, etc.).

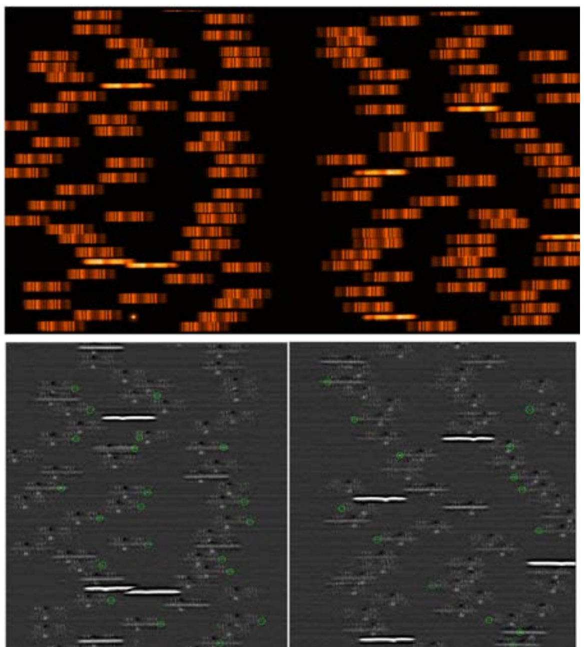




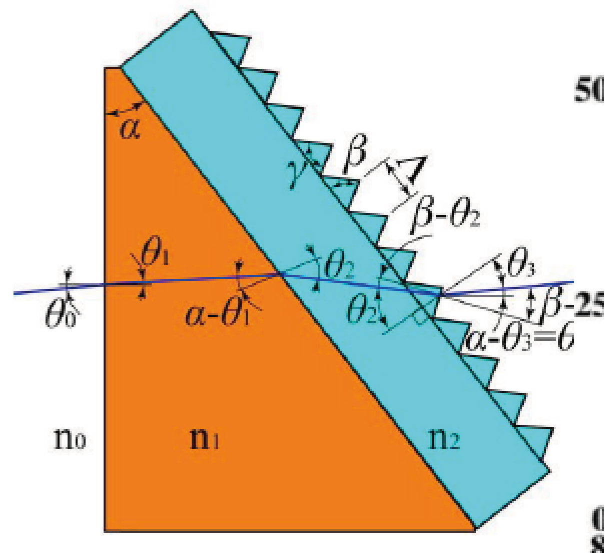


Wide-field MOS:
MOIRCS as the 1st light instrument for ULTIMATE

- MOIRCS on NsIR with wide-field corrector + inst.rotator
  - 4’ x 6’ FoV multi-slit instrument with HAWAII-2RG detector.
  - Narrower slits with higher spectral resolution
    R=600@0.8” → R=1700@0.3”
  - Grism upgrades : “hybrid grism” by Ebizuka : R~3,000@0.3”



Unique capability of the slit-mask
>100 slits in one shot
(Tanaka et al. 2017)

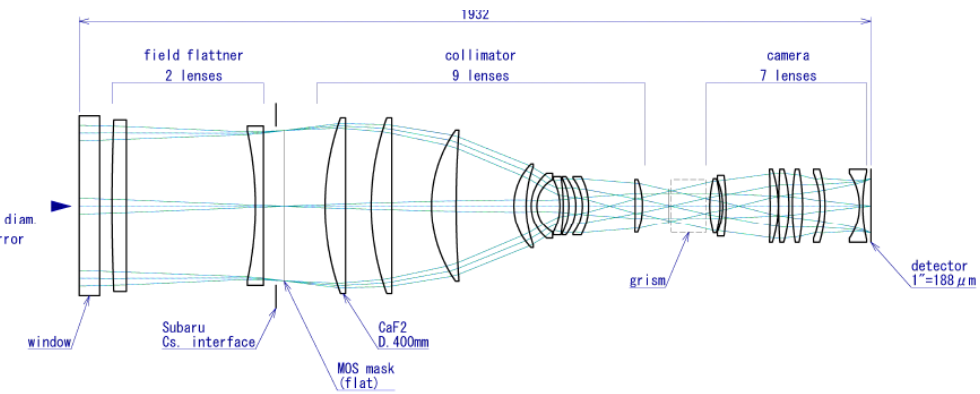


Hybrid grism proposal
(Ebizuka 2016)

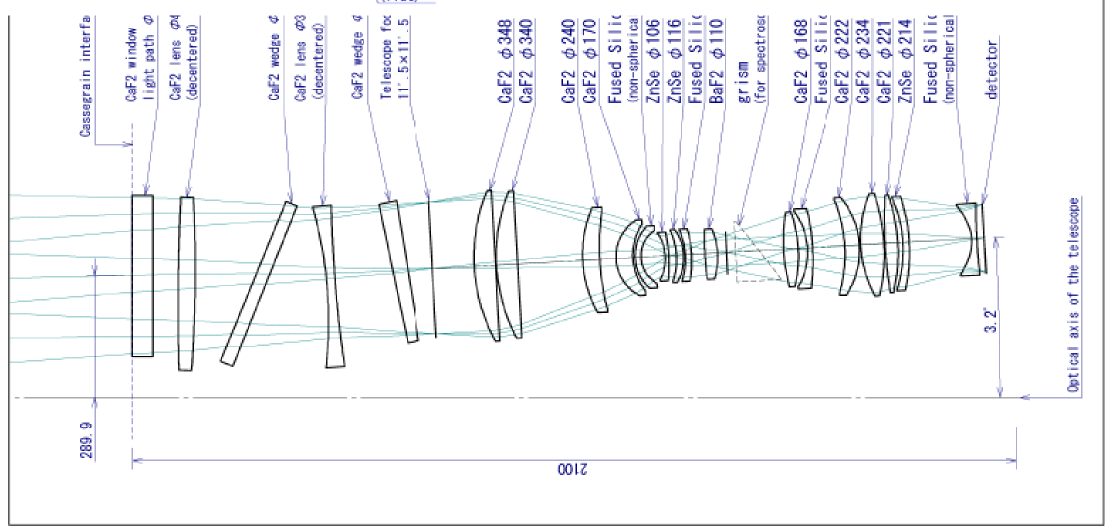
Wide-field MOS : beyond MOIRCS

- Future wide-field MOS possibilities

d=12.6' design



23'x23' design
(11.5'x11.5'x4)

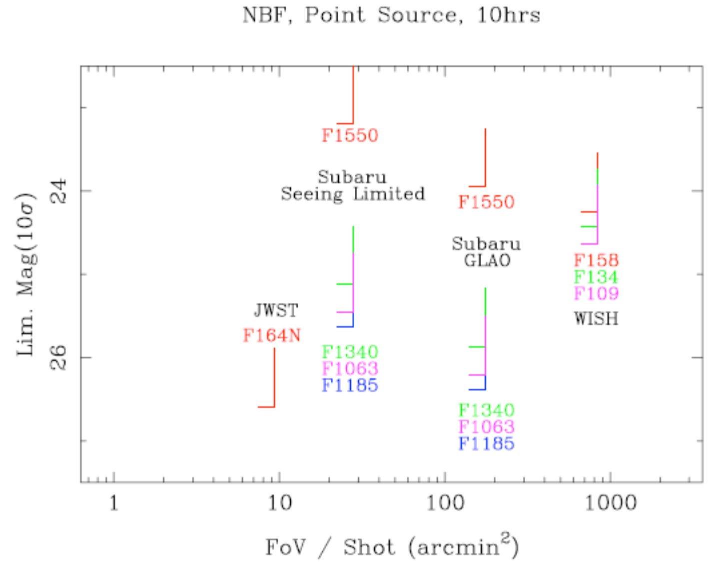


2. Wide-field imager

Science cases with the wide-field imager

- Search for high-redshift galaxies with a wide-field NIR narrow-band imaging is unique even in the era of JWST and good compliment to the wide-field broad-band images from WFIRST.

Detection limit with 10hours integration

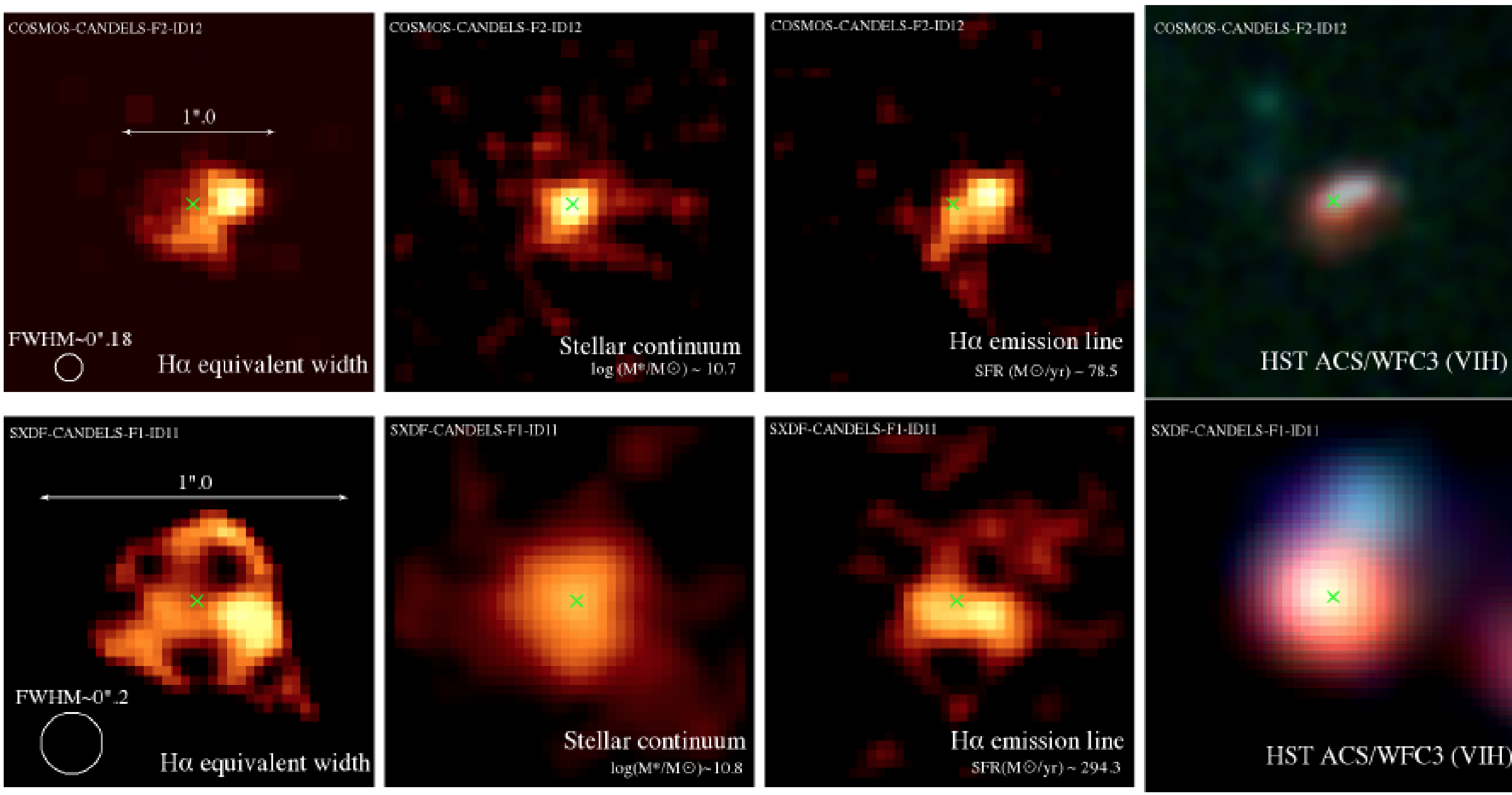


Expected number of Ly-alpha emitters per 186 sq.arcmin 8 hours integration. In combination with WFIRST broad-band imaging

Filter	redshift	$L_{\rm lim}$	No ev.	Slow ev.	Rapid ev.
NB1063	7.7	1.62×10^{42}	36	17	1.8
NB1185	8.7	1.98×10^{42}	31	8.6	0.19
NB1340	10.0	2.91×10^{42}	9.7	1.5	5.3×10^{-3}

Science cases with the wide-field imager

- Mapping star-formation activities inside galaxies in the peak of the star-formation (at z~2).
- HST/WFIRST (UV-optical stars) – ULTIMATE (ionized gas) – ALMA (molecular gas / dust)



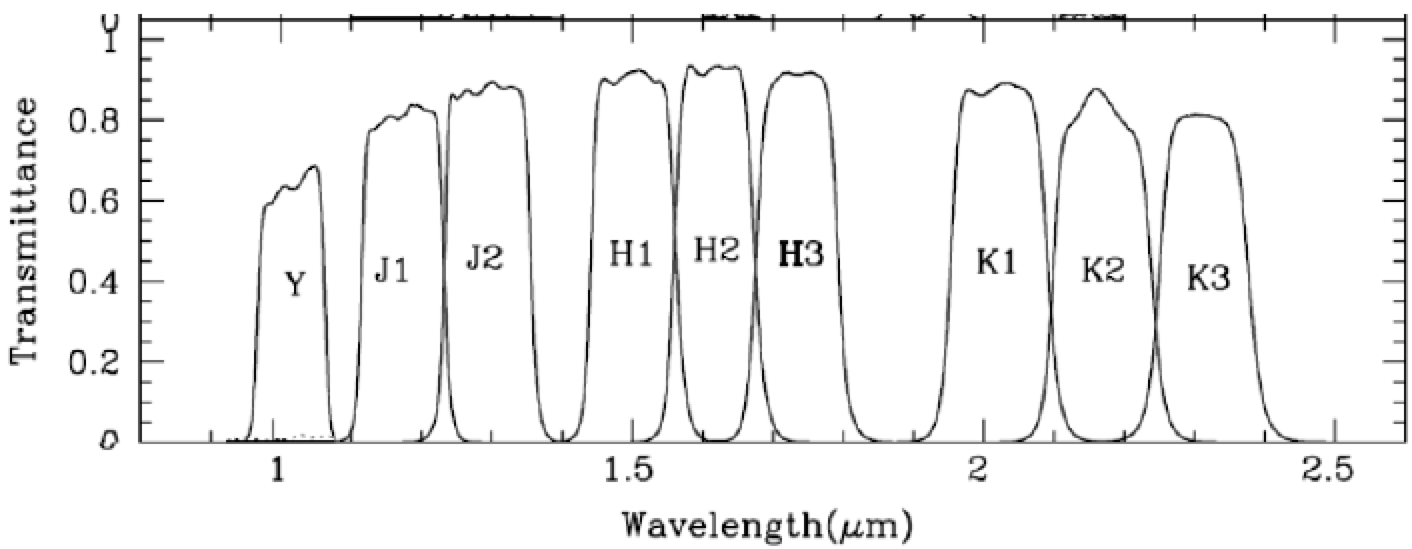
AO-assisted Halpha mapping of z~2 galaxies
(Minowa, Koyama et al. in prep.)

Science cases with the wide-field imager

- Narrow-band / medium-band mapping of the universe

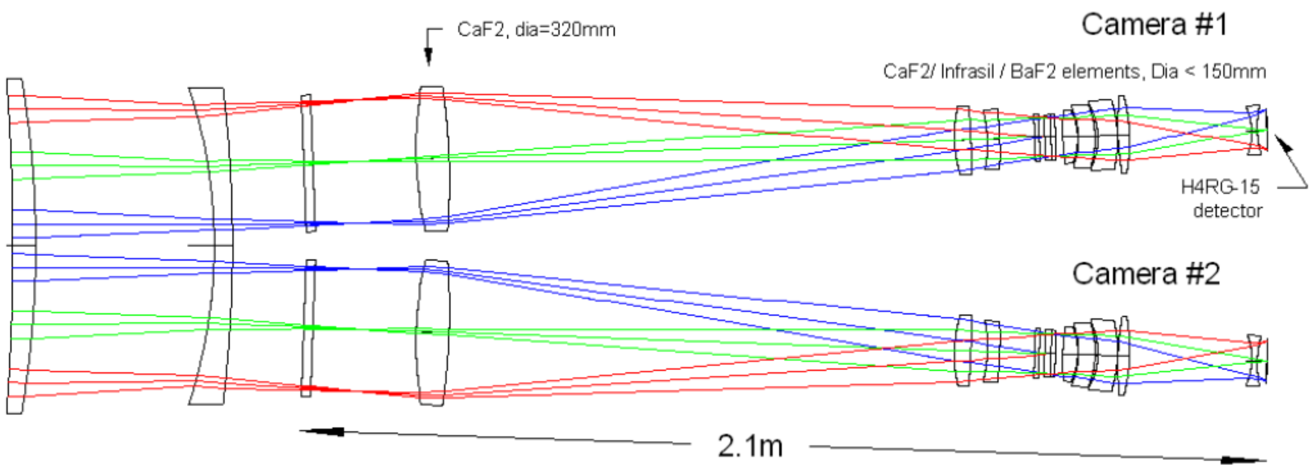
Survey type	Filters	Exp. time per FoV (including overheads)	Limit mag. (5σ, AB)	N. of nights
NB imaging	$NB_J \times 2$	8.0 (10.0)	27.0	64
	$NB_H \times 2$	4.0 (5.0)	24.2	32
	$NB_K \times 2$	4.0 (5.0)	24.1	32
MB imaging	*K1*	10.0 (13.0)	26.1	42
	K2	10.0 (13.0)	26.1	42
	K3	10.0 (13.0)	26.1	42
BB imaging	*K*	3.0 (4.5)	26.1	15
Total time	–	–	–	269

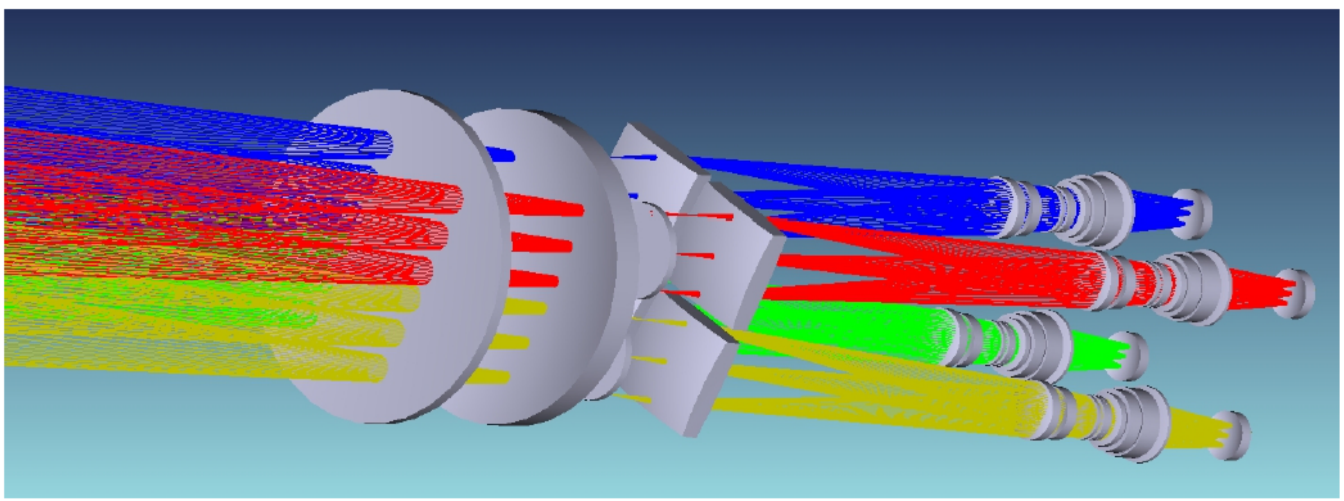
Table 3.7: A preliminary plan for the ULTIMATE legacy survey (covering 2-deg^2 overlapped with HSC ultra-deep fields) using the wide-field imager.



Wide-field imager design

- Four barrel imager (6.8’x6.8’x4) design proposed by J.Pazder (HIA).

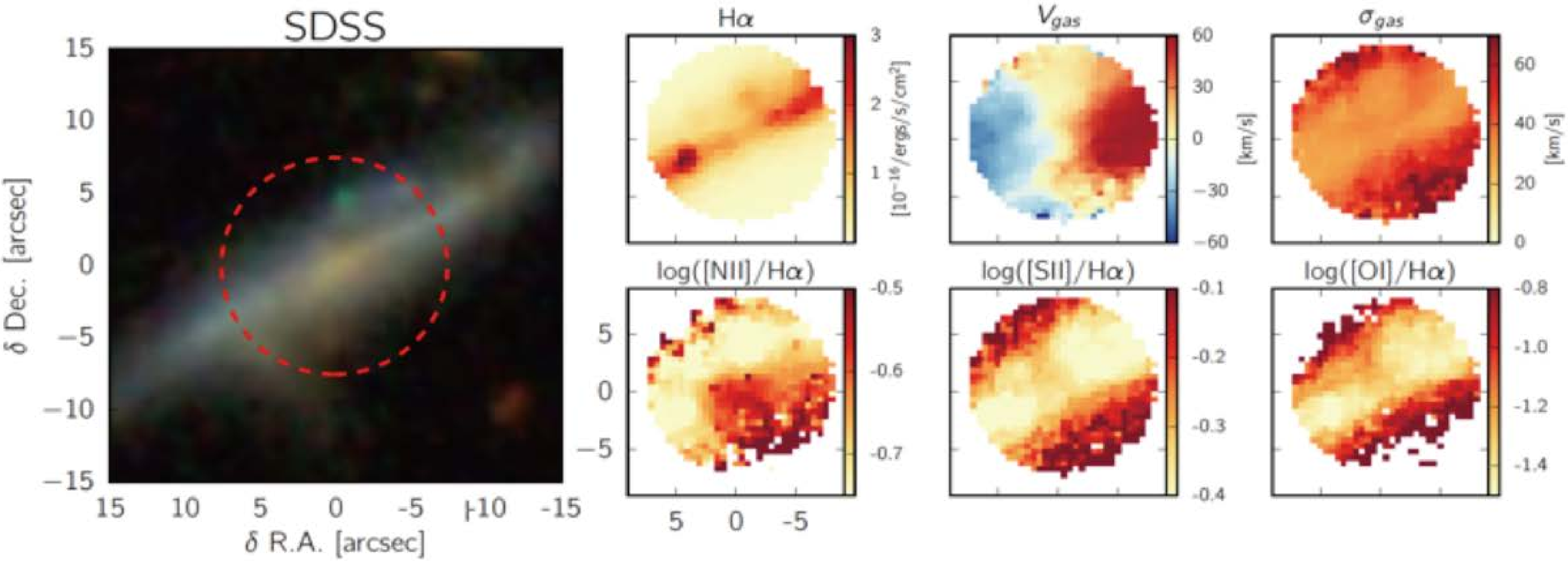




3. Multiple-IFUs

Science cases with the multiple-IFUs

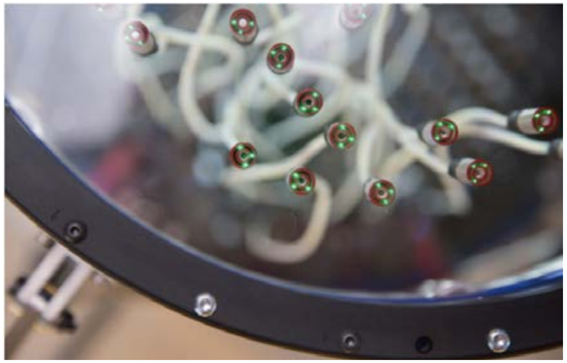
- Mapping chemical and kinematical properties of galaxies at z=0.6-1.4.



SAMI multi-IFU survey of local galaxies (Ellis 2016)

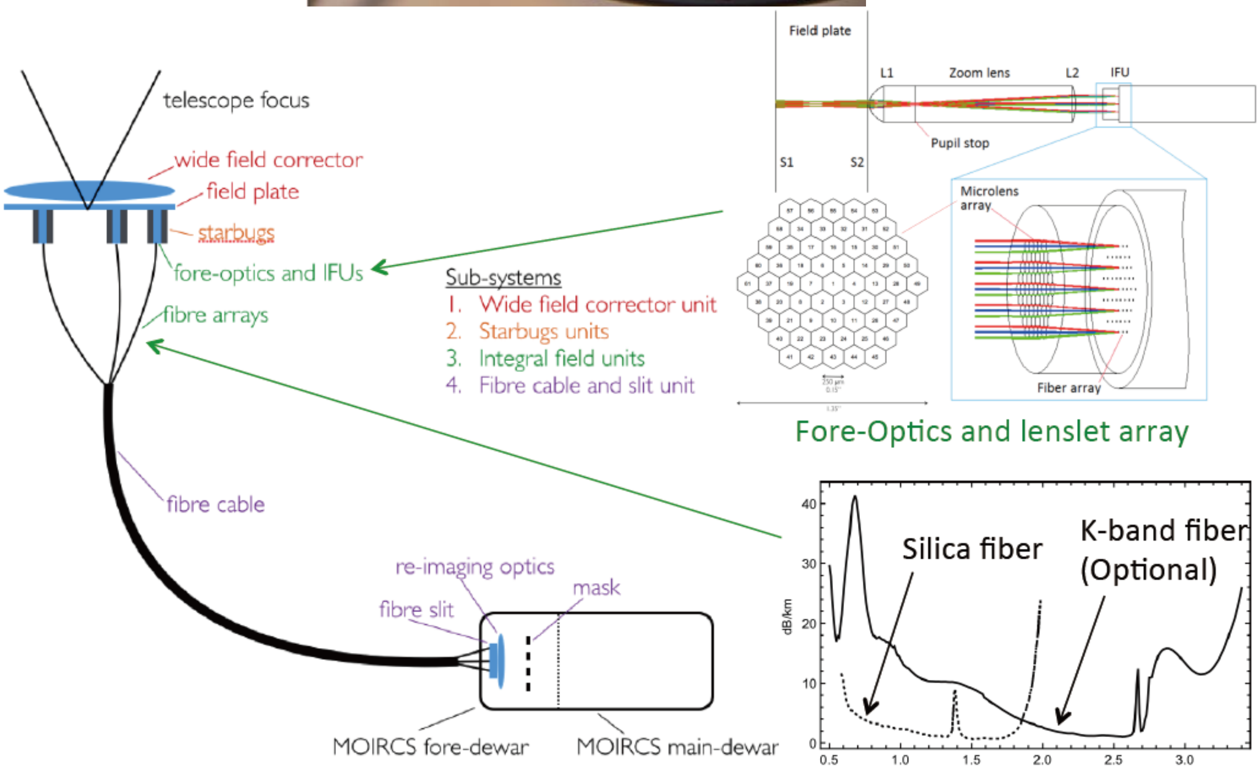
Multiple-IFUs design

- Fiber multiple IFU with “starbug”-system is proposed by AAO.



“Starbugs” on the focal plane

~10 IFUs on the ULTIMATE focal plane.

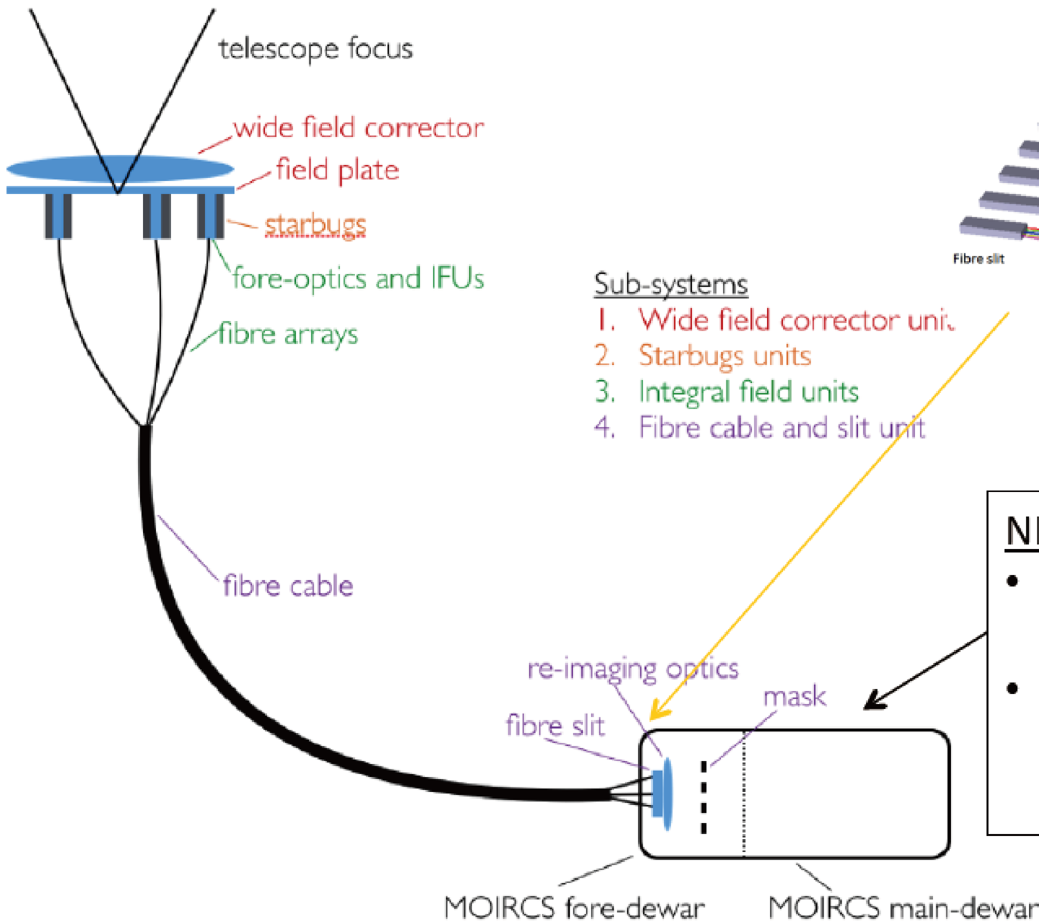


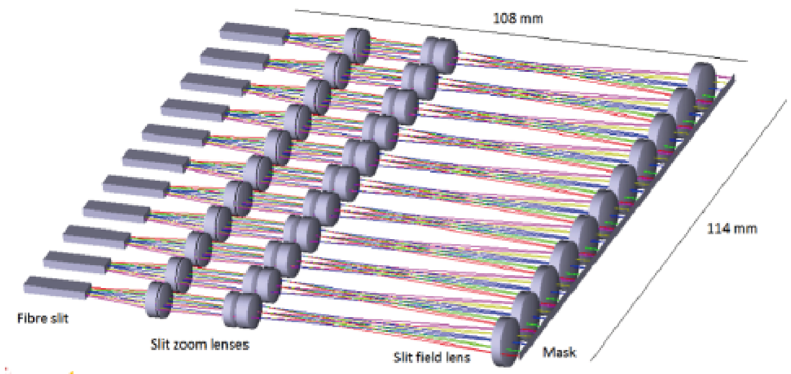
Fiber + MLA IFU unit with 61 elements

0.15” sampling
1.35” coverage

Multiple-IFUs design

- Fiber multiple IFU with “starbug”-system is proposed by AAO.





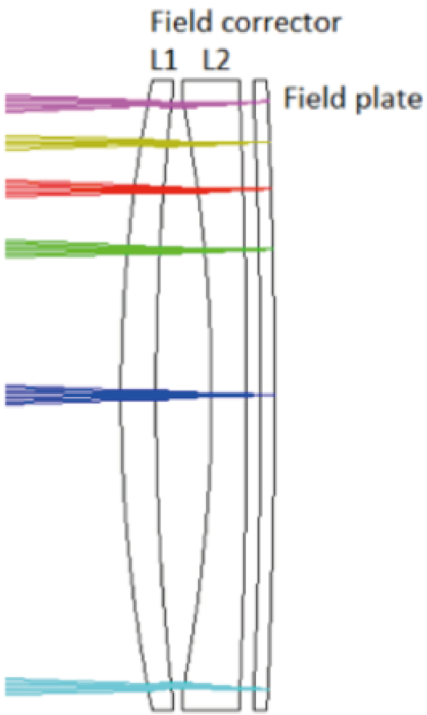
Fiber slit unit

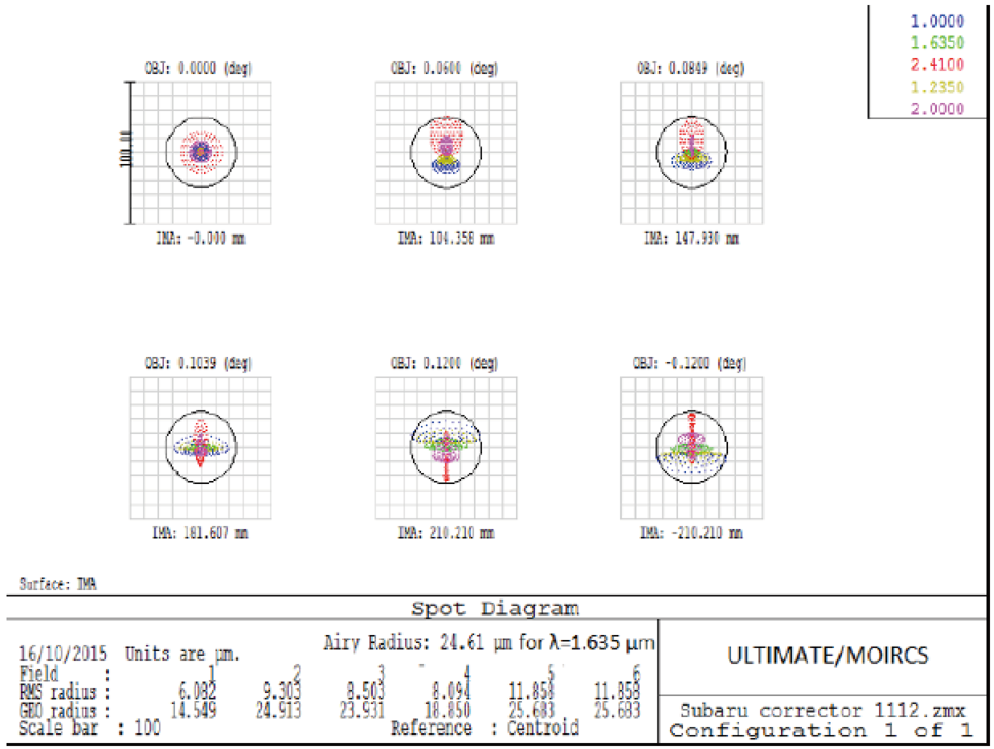
NIR spectrograph

- re-use MOIRCS for initial observations.
- Develop a new spectrograph or use PFS spectrograph (<1.2 μm) with higher multiplexity

Wide-field corrector design

- Wide-field corrector is a common component for all of the three instruments to realize good image quality in a wide field of view.





λ µm	Dispersion (arcsec)
0.9 – 1.15	0.17 arcsec
1.15 – 1.35	0.07 arcsec
1.35 – 1.8	0.12 arcsec

(Ellis 2016)

ULTIMATE-SUBARU instrumentation

" How is gas in galaxies enriched / recycled at the peak of the galaxy formation ? "

SDSS + SAMI/MANGA at the peak of the galaxy formation

1. Wide-field MOS

High-z gal. survey

2. Wide-field imager

Narrow-band mapping

3. Multi-IFUs

Kin./Chem. mapping

<u>ULTIMATE-AO : wide-field ground-layer AO</u>

- **10 times brighter 4 LGSs**
- **ASM with 5 times more actuators**
- **4 times more elements in WF measurements**

Phased and distributed approach is necessary

ULTIMATE-AO : wide-field ground-layer AO

1. Wide-field MOS

MOIRCS as the first light instrument. ULTIMATE-AO development is a key in the first phase.

2. Wide-field imager


Work-horse instrument with the ULTIMATE-SUBARU after the first light. Fully utilize the GLAO capability.

3. Multi-IFUs

Step-by-step / long-term development MOIRCS as the spectrograph at first.

Broader science questions

- *How is the MW bulge formed ?*
  - *HR-diagrams of the globular clusters in the MW bulge (Chiba et al.)*
  - *Astrometric monitoring of the Galactic center with wide-field imager (Nishiyama et al.)*
  - *Kinematical mapping of the bulge of the MW by spec. follow-up of WFIRST fields (Nataf et al.) [14<H<16]*

- *NIR mapping of nearby galaxies (Motohara et al., Koda et al.)*
- *IMFs in star-forming regions (Oasa et al.)*

ULTIMATE scientists

- CoDR in 2018.
- Please join ULTIMATE science team taking this opportunity !
  - Contribution from (potential) partner countries is very welcome.
- Please submit your 1-page science document by May 12.
  - We will organize international science team and contact you soon.
- Get LaTeX package from here:
  - http://www.naoj.org/Projects/newdev/ngao/20170316/index.html

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Subaru Telescope New Development Group

ULTIMATE-SUBARU

(Ultra-wide Laser Tomographic Imager and MOS with AO for Transcendent Exploration)

すばる望遠鏡 次世代広視野補償光学システム+広視野近赤外線装置
Subaru Next-Generation Wide-Field AO System+Wide-field Near-IR Instrument

Invitation to ULTIMATE-Subaru science case (mini) white paper toward CoDR 2018

[2017/03/22]

1. Background:

Thank you very much for your interests in ULTIMATE-Subaru and visiting this website. ULTIMATE-Subaru team is now preparing for the Conceptual Design Review (CoDR) scheduled in 2018. As a part of this activity, we are organizing international science core team to strengthen our science cases. The most recent version of our science cases is available in our "Study Report 2016" available from here. We now hope to invite as many scientists as possible from broader science community - not only from Japan but also from (potential) partner countries.

2. Preparing the document:

We expect a short (1-page) ULTIMATE-Subaru science document from each scientist - we do not expect a very detailed description. Please be aware that the main purpose of this document is to organize the international science core team of ULTIMATE-Subaru, and share our interests within the team. To prepare the document, please edit the "template.tex" file in the package available below and compile it in a standard way to create 1-page PDF file (including figures and tables). It may be helpful to look at "example.tex" and "example.pdf" as a very first step.

- LaTeX package [zip]

3. Submitting your manuscript:

Please submit your (1) TeX source files and (2) complete PDF file to (Dr.) Yusei Koyama (koyama@naoj.org) by **May 12 (HST)**. You can use this contact address whenever you have questions regarding the ULTIMATE-Subaru science related works. After receiving your manuscripts, ULTIMATE-Subaru WG will review and summarize interests from the community, organize the science core team, and contact you in June 2017. Please refer the timeline toward CoDR in 2018.

- Timeline of ULTIMATE-S science team activity in FY2017 [PDF]

Additional Slides

ULTIMATE-Subaru science team activity of FY2017 toward CoDR

(ver. 3/20/2017)

2017

3 — 3/22-24, International Science/Instrument WS: Announcement/invitation for new ULTIMATE science team, ask contribution with 1-page "white paper"

4 — Scientists: think about key science cases, new ideas (Phase-1)

5 — **May 12 : deadline of the 1-page white paper**

late-May: assign core person in each science case

6 — mid-June: Science core member meeting (1)

7 — early-July: start working separately by each science team

Science team: upgrading science cases (Phase-2)

8 — late-August: Science core meeting (2) for interim report/discussion

9 — Science team: upgrading science cases (Phase-3)

late-September: Complete document from each science category

10 — mid-Oct: Science core meeting (3) to balance the sections

Science team: finalizing each section (Phase-4)

11 — mid-Nov: final version from each section

12 — mid-Dec: Complete editorial work within ULTIMATE team, circulate within science team

Science team: Feedback phase (Phase-5)

2018

1 — mid-Jan: Deadline for comments/feedback

early-Feb: Final version ready

2

3 — **CoDR (March 2018?)**

Let’s get excited about Subaru “bright” future