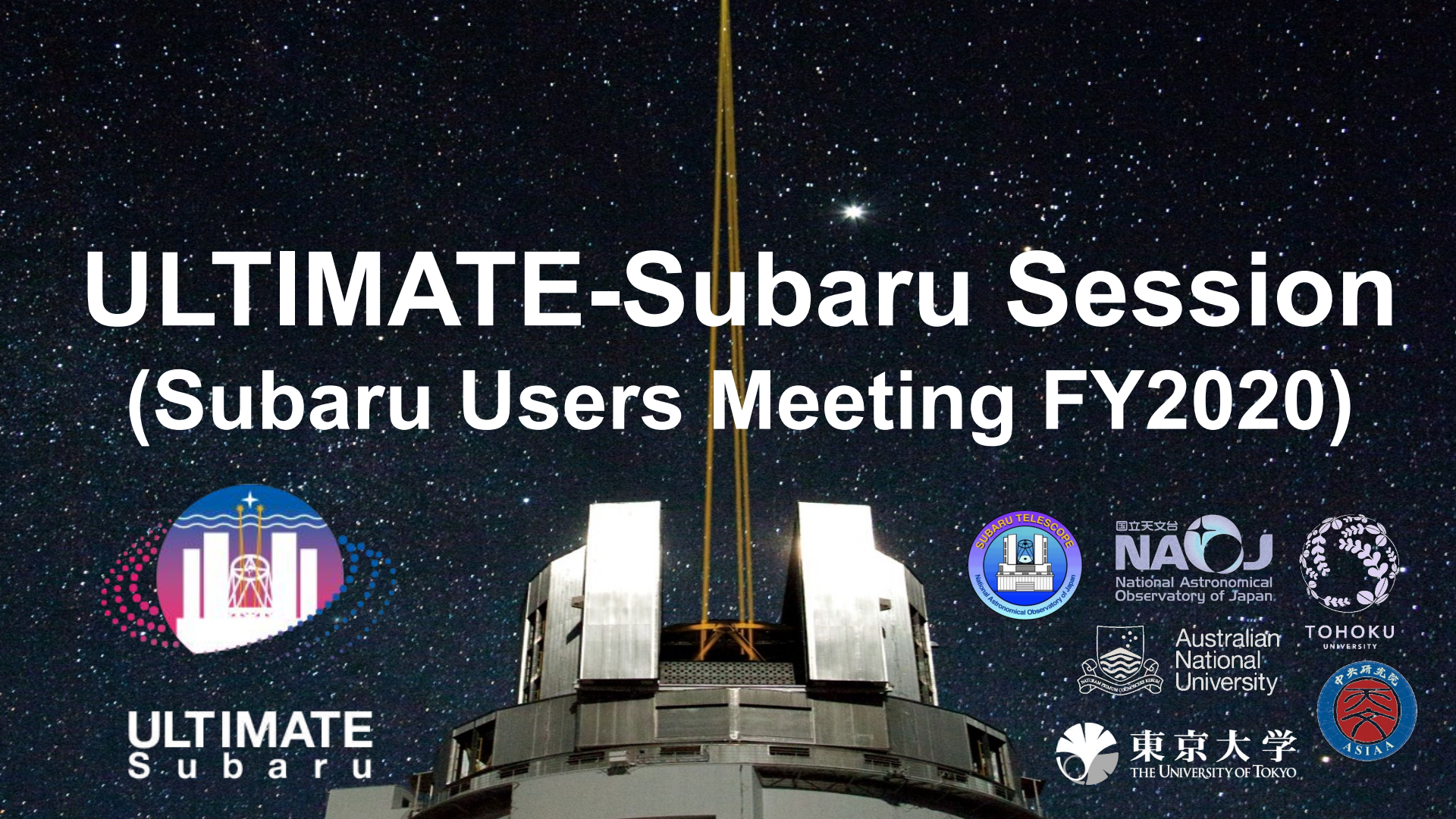
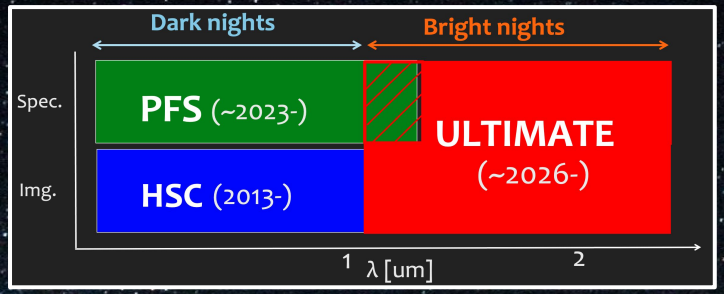

ULTIMATE-Subaru Session
(Subaru Users Meeting FY2020)
ULTIMATE
Subaru
SUBARU TELESCOPE
National Astronomical Observatory of Japan
国立天文台
NAOJ
National Astronomical
Observatory of Japan
TOHOKU
UNIVERSITY
Australian
National
University
東京大学
THE UNIVERSITY OF TOKYO
ASIAA

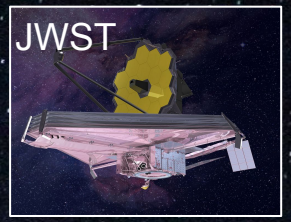
ULTIMATE = Subaru new AO + IR instruments

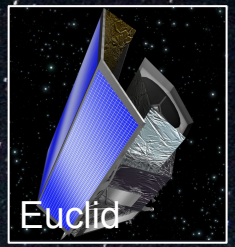


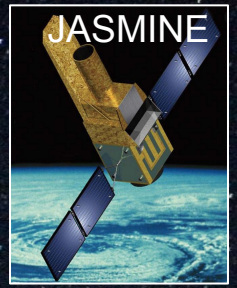
Talk on day-1 (Minowa/Koyama)

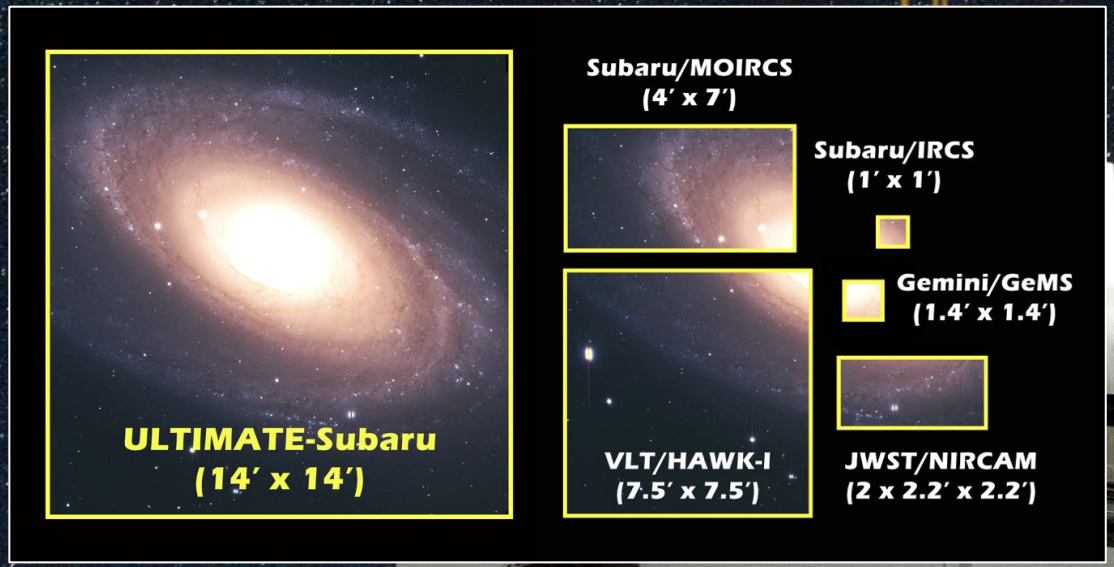
Wide-field mode
(GLAO→survey)

Narrow-field mode
(LTAO→targeted)









Session overview

Part 1: ULTIMATE scientific capabilities

- ULTIMATE AO wide-field/narrow-field mode — Yoshito Ono (Subaru)
- ULTIMATE instruments — Kentaro Motohara (NAOJ)
- D-SHOOTER: a new concept for LTAO instrument — Takashi Moriya (NAOJ)
- Summary of ULTIMATE unique points — Yusei Koyama (Subaru)

Part 2: Scientific synergy with other space/ground missions in 2020s

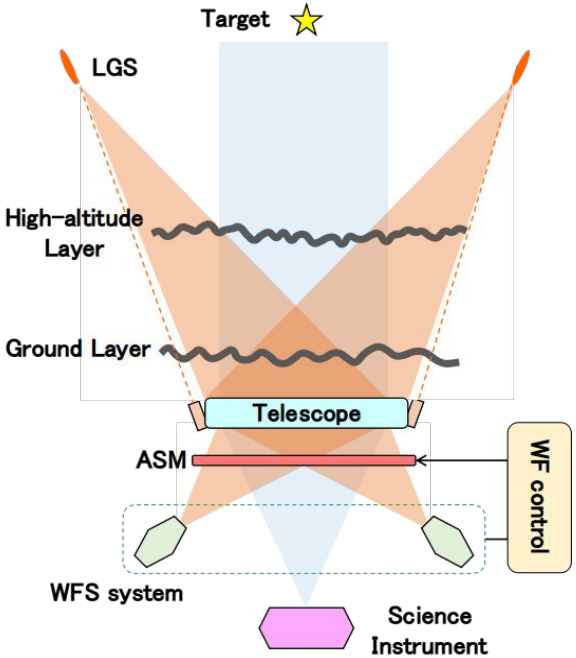
- ULTIMATE for NIR multi-object spectroscopy (w/ PFS) — Ken-ichi Tadaki (NAOJ)
- ULTIMATE high-redshift survey (w/ Roman/Euclid) — Akio Inoue (Waseda)
- Galactic center microlensing survey (w/ Roman) — Daisuke Suzuki (Osaka)
- Potential synergy with JASMINE — Daisuke Kawata (MSSL/UCL)

Part-1: ULTIMATE Capabilities

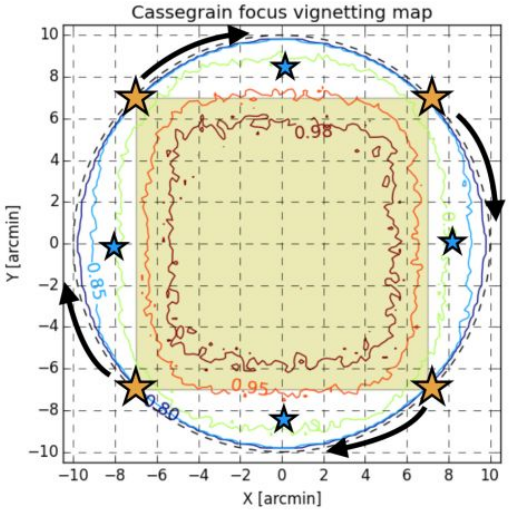
GLAO mode

Y. Ono

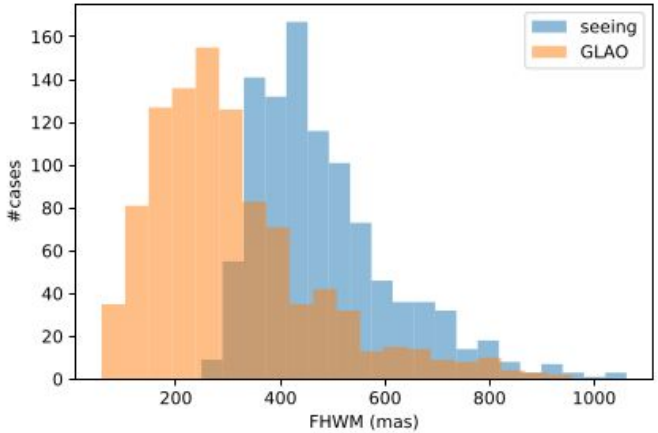
- Wide-field seeing improvement over 14'x14' science FoV by correcting the ground layer turbulence using ASM, 4 LGSs (10' off-axis), and 4 tip/tilt NGSs.
- ~0.2" in K-band FWHM (x2 gain comparing to seeing)
- More than 90% sky-coverage in major deep fields



Field configuration (Cs)



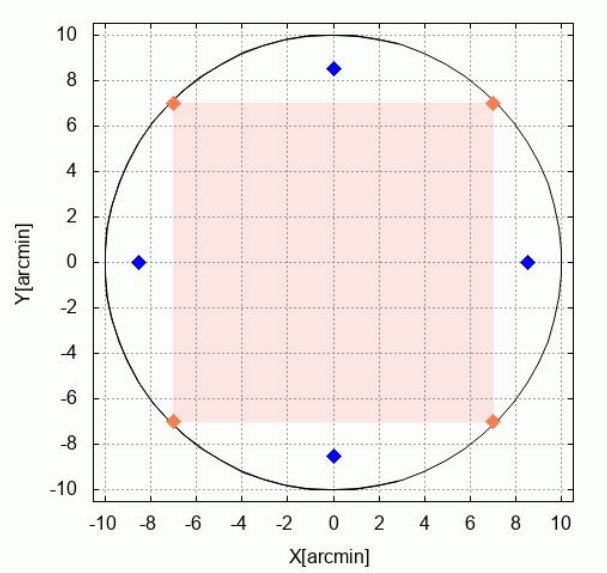
Statistical GLAO simulation

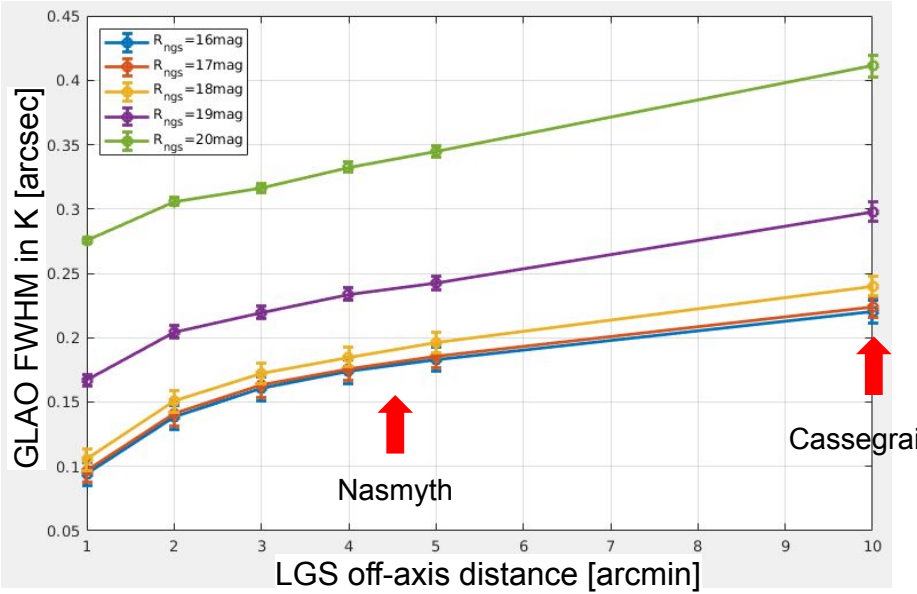


Narrow-field GLAO mode

Y. Ono

- Better performance by narrowing the GS configuration and science field.
- <0.2” FWHM in K-band at Nasmyth IR focus (LGS = 4’-5’ off-axis)
- In the current design, the GLAO system can go down to 1’-2’ LGS separation (<0.15” FWHM)
- WFI and MOIRCS are not optimized to <0.15” FWHM
- Less sky-coverage for narrower-field modes (Quantitative evaluation is on-going)



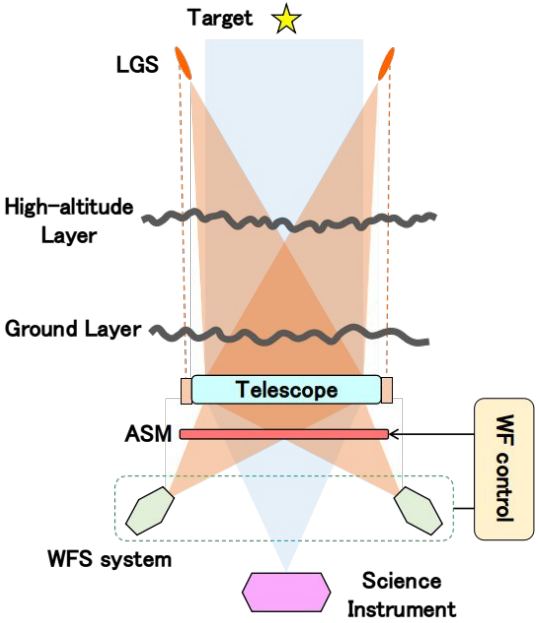


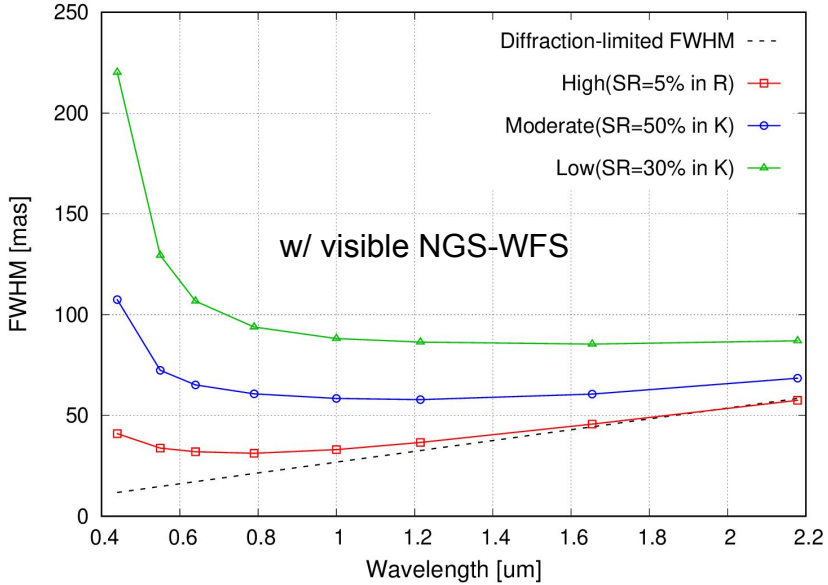
LTAO mode

See a poster by M. Akiyama (ULTIMATE-START)

Y. Ono

- On-axis diffraction limited AO (like LGS-AO188 but much better performance)
- GLAO ASM and LGS system + new dedicated WFS system at Nasmyth IR focus
- One NGS is needed for low-order WF control
- Trade-off study is on-going (performance vs sky-coverage)
  - High (SC=1.5-5%), Moderate (SC=10-30%), Low(SC=30-70%) for major deep fields





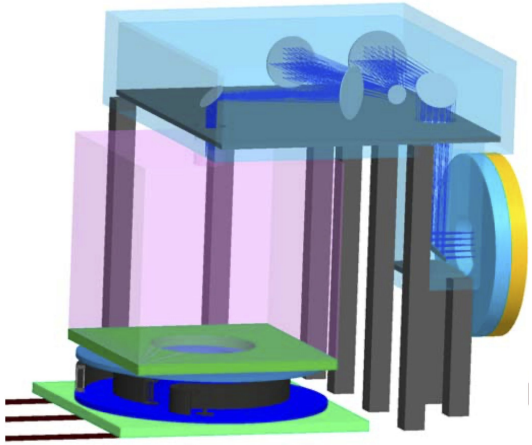
Instruments (Phase-1 : MOIRCS Relocation to NsIR)

Functions

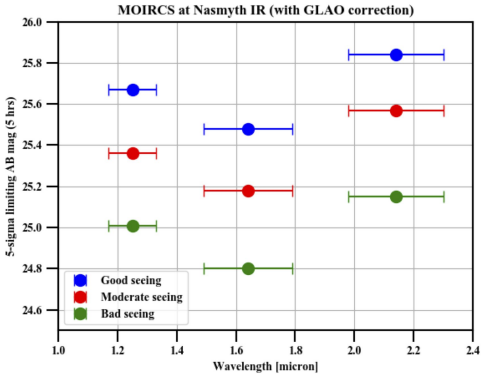
- Initial Imaging
- MOS spectroscopy

Sensitivity

- ~0.2mag deeper than seeing limited observations at CsIR
- >25.4magAB (5hr, 5σ) with good seeing condition



K. Motohara

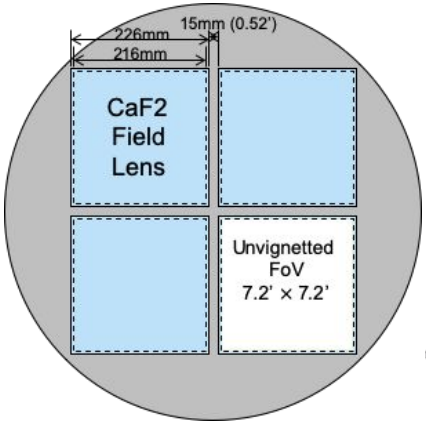


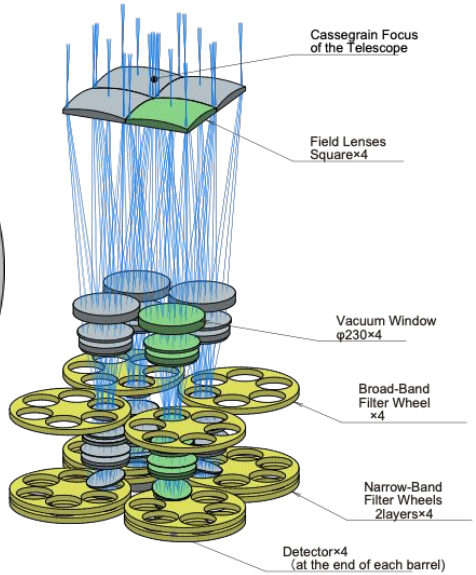
Instruments (Phase-2 : WFI)

K. Motohara

Specifications

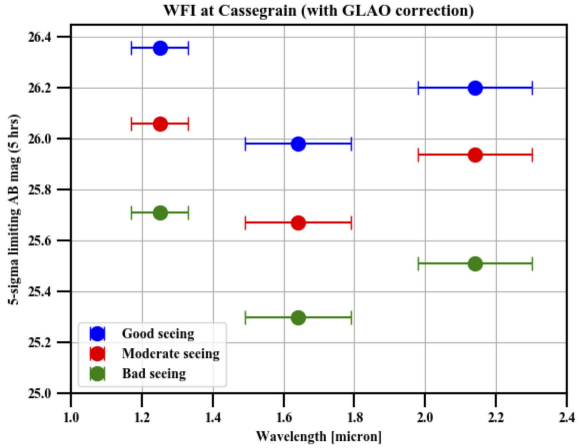
- 14’ x 14’ FoV covered by Four H4RGs
- Four-barrel optics with <0.11” PSF (@0.9-2.5 μm)
- 15 filters per barrel





Sensitivity

- ~0.4mag deeper than seeing limited observations
- >26magAB (5hr, 5σ) with good seeing condition



Instruments (Phase-3 : MO-IFU)

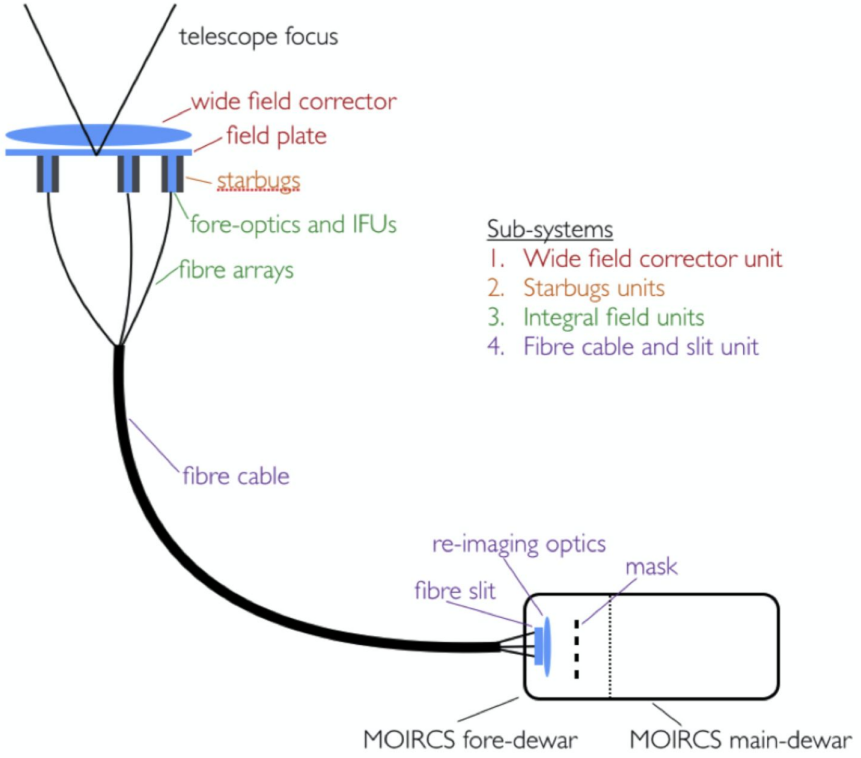
K. Motohara

Multi-object Fiber-Fed IFU ?

Starbug system?

Wavelength coverage beyond 2μm will be a challenge, due to

- Limited material for optical fibers
- Thermal emission



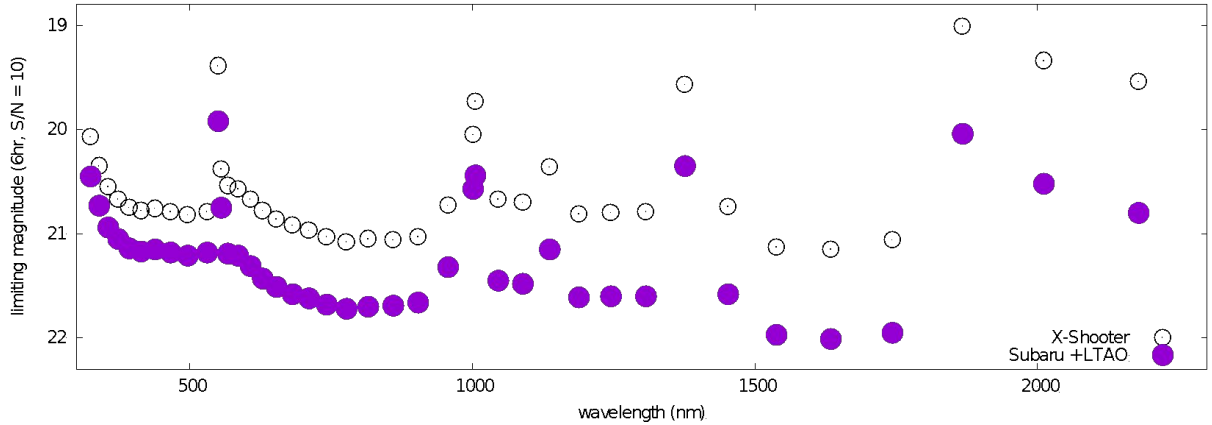
D-SHOOTER

Working members: Y. Koyama, Y. Minowa, M. Yoshida, K. Motohara, S. Ozaki, Y. Ono, M. Ouchi, Masaomi Tanaka, N. Tominaga, N. Takato, Y. Matsuoka, T. Nagao, Y. Hayano, M. Akiyama

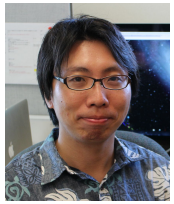
T. Moriya

X-Shooter-like spectrograph combined with LTAO (“Daughter of X-Shooter”)

- Simultaneous wide wavelength coverage (~400 - ~2000 nm, TBD) like X-Shooter.
- Better sensitivity (~ 1 mag gain at NIR) thanks to LTAO.
- Attractive instruments for many science cases (e.g., time domain, etc)!
- JSPS proposal to get budget submitted. If you’re interested, please contact us!



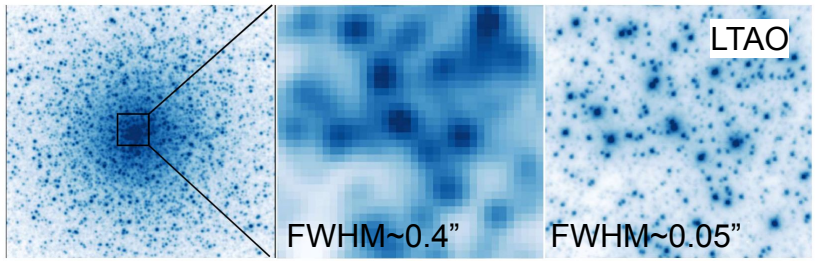
Uniqueness of ULTIMATE - 1


Y. Koyama

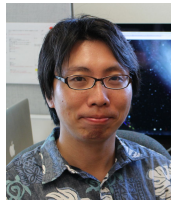
- Phase-1: GLAO + MOIRCS @NsIR
  - PSF<0.2” in moderate conditions.
  - Enhanced sensitivity in both imaging and MOS spectroscopy with improved image quality.
  - For spectroscopy - we can use narrower slits (hence higher resolution).
  - Spectroscopy at H+K wavelength - complementary to PFS.
  - K-band spectroscopy would be most unique - Roman/Euclid grism does not cover λ>1.9um.
    - Our only competitors would be Keck/MOSFIRE and NIRSPEC/JWST

- Phase-1: LTAO mode
  - Diffraction limit (<0.1”) at all λ from optical to NIR, if suitable guide stars are available.
  - Potentially an ideal tool to follow-up your targets with highest sensitivity and resolution before TMT.
  - ULTIMATE team is collecting scientific demands.

Madec+2019
(NGC6388 w/ VLT)

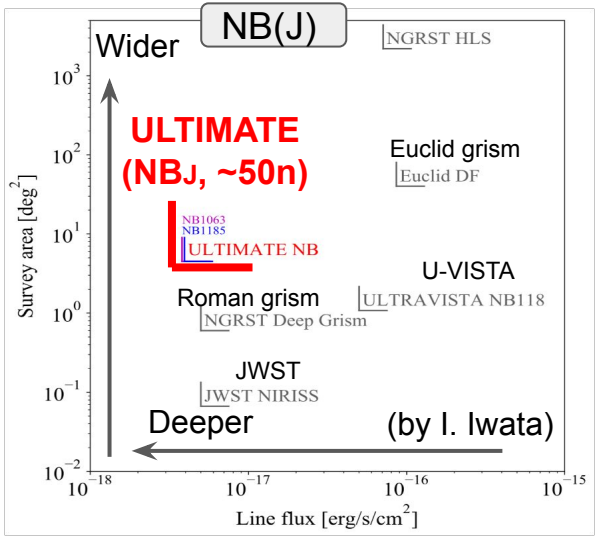


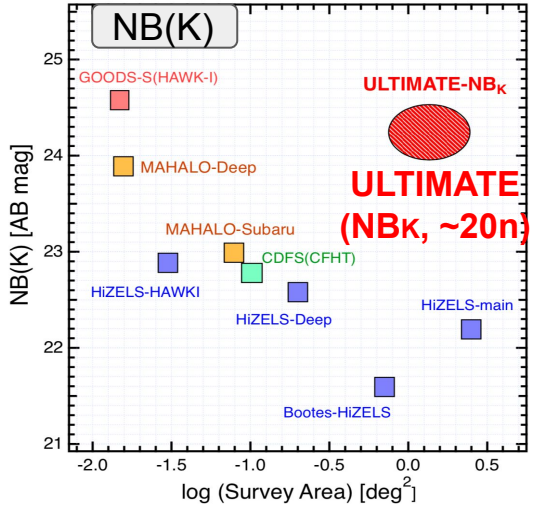
Uniqueness of ULTIMATE - 2

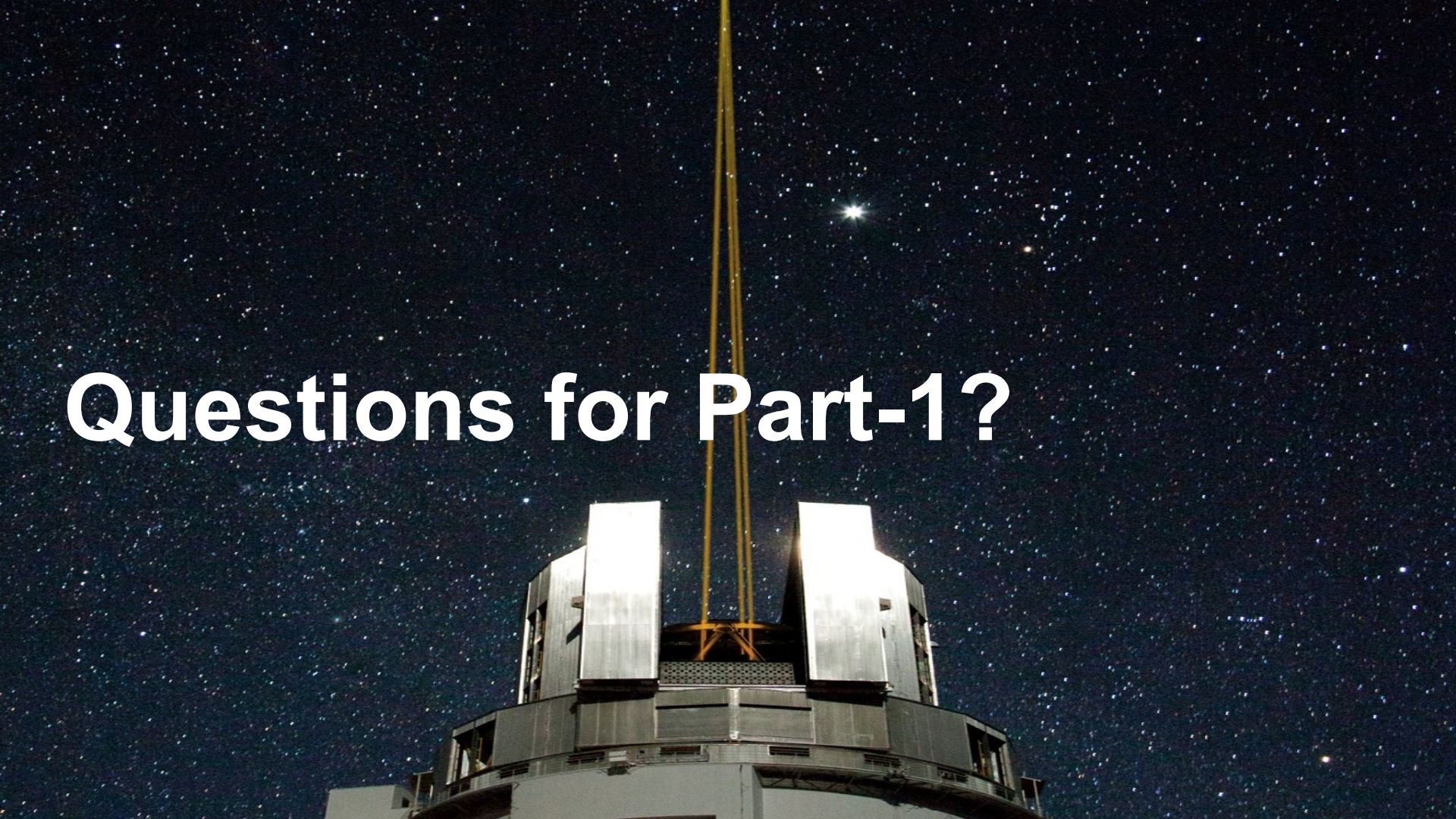


Y. Koyama

- Phase-2: GLAO + WFI @Cs
  - PSF~0.2” over ~14’x14’ in moderate conditions.
    - Achieve ~0.15” (better than Roman) in ~20% best conditions
    - Better GLAO image quality than GLAO @ VLT site
  - NB/MB/BB imaging (best performance in K-band)
  - Most powerful NB (+MB) imaging machine.
    - Potential to perform deepest + widest NB survey in NIR
    - No NB on Roman/Euclid
    - JWST has only a few NBs (no NB in J, only 1 in H)
    - NBs and MBs @ K-band are extremely unique.
  - Reach >26 mag (AB) in BBs with reasonable observing time
    - Comparable to Euclid Deep field
    - Roman can go much deeper and wider
    - JWST can easily go deeper, but not good at wide-field mapping
    - Long-term monitoring beyond the lifetime of space missions.

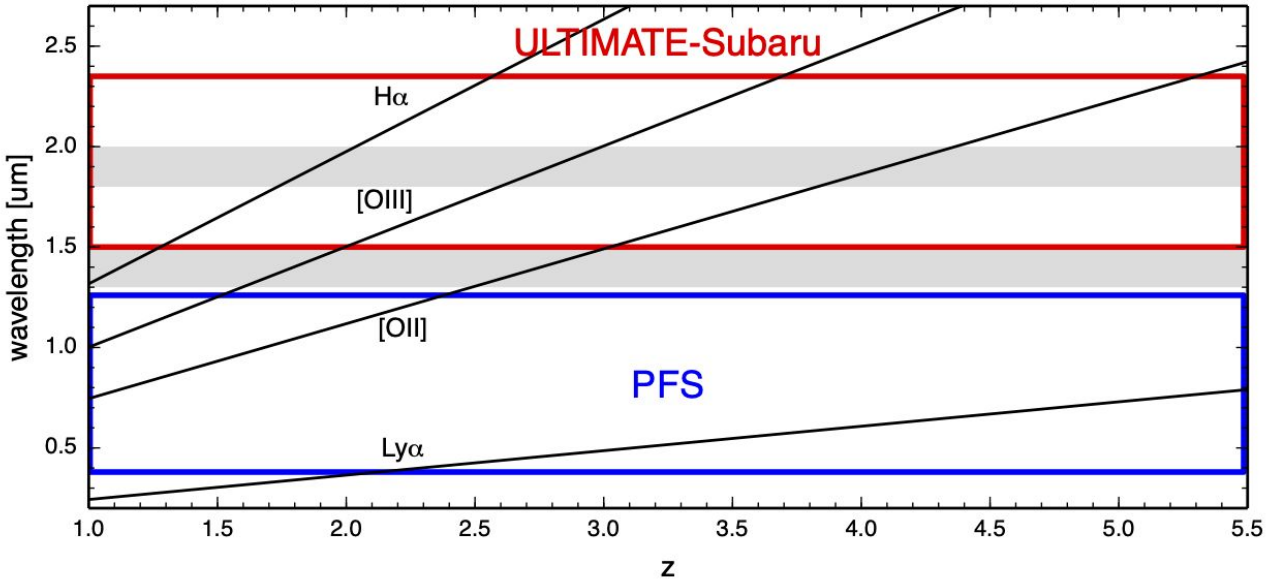





Questions for Part-1?

Part-2:
Synergy with Other Big Projects

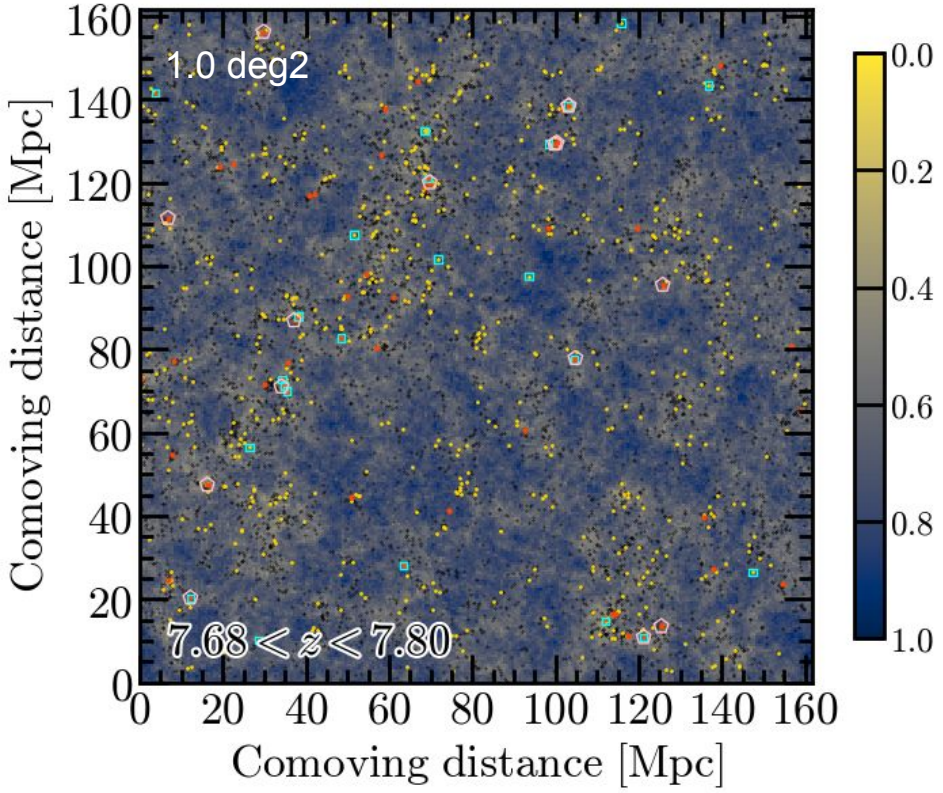
Synergy with PFS (K. Tadaki)

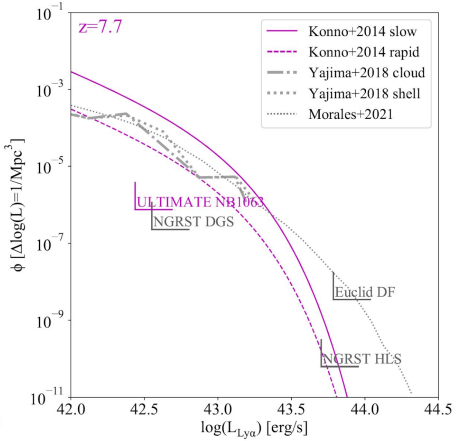


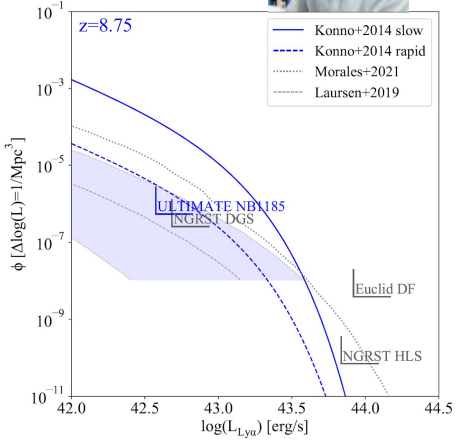
- PFS will provide a large sample of star-forming galaxies at z=1-3 with Lyα and/or [OII] detection
- ULTIMATE will allow us to detect the Hα/[OIII]/Hβ emission lines by deep H+K-band spectroscopy

Synergy with Euclid/Roman - high-z galaxies (Inoue)

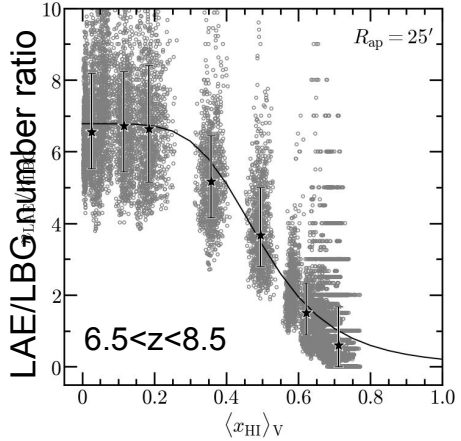
ULTIMATE narrowband imaging for Lyα emitter surveys in Eulcid/Roman broadband imaging survey areas







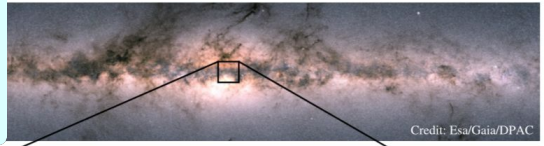
Number of LAEs
~100 at z=7.7 (NB1063)
~10 at z=8.8 (NB1185)

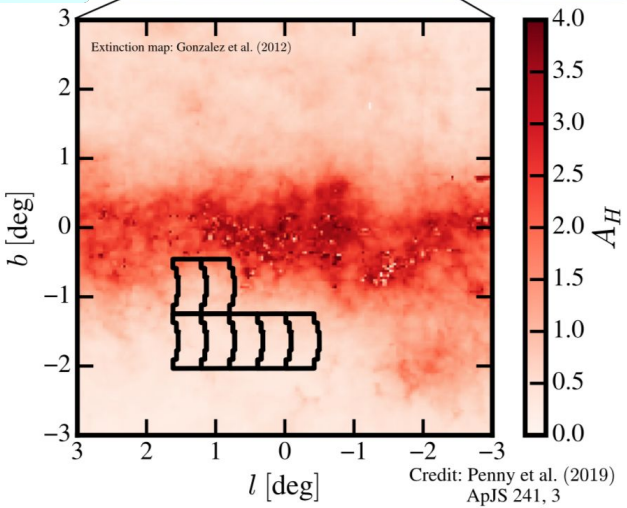


(Left)
Based on Inoue+18 simulations:
Cyan: LAEs to be detected with ULTIMATE/NB1063 (<26.8AB)
Pink: LBGs to be detected with Roman/J129 (<26.7AB)
Red: Halos with >1e11 Msun
Yellow: Halos with >3e10 Msun
Black: Halos with >1e10 Msun

Synergy with Roman - Galactic center microlensing

(D. Suzuki)

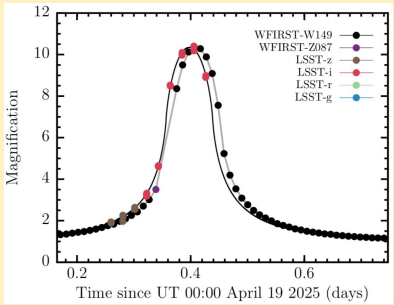




Roman Galactic Exoplanet Survey

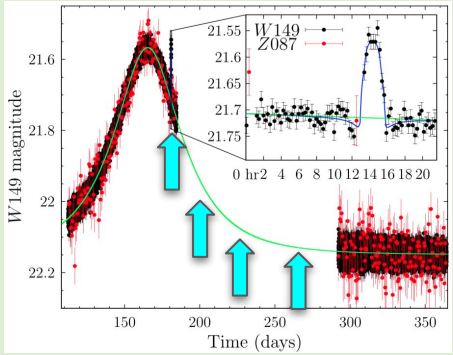
- ~2deg^2
- ~1/15 min. cadence for 72 days x 6 seasons = 432 days
- Mainly W149, occasionally Z087, F213 used

High cadence to measure the rogue planet mass



- 4 exposures/night during Roman window if it is visible from Hawaii
- Only the way for mass measurement of free-floating planets

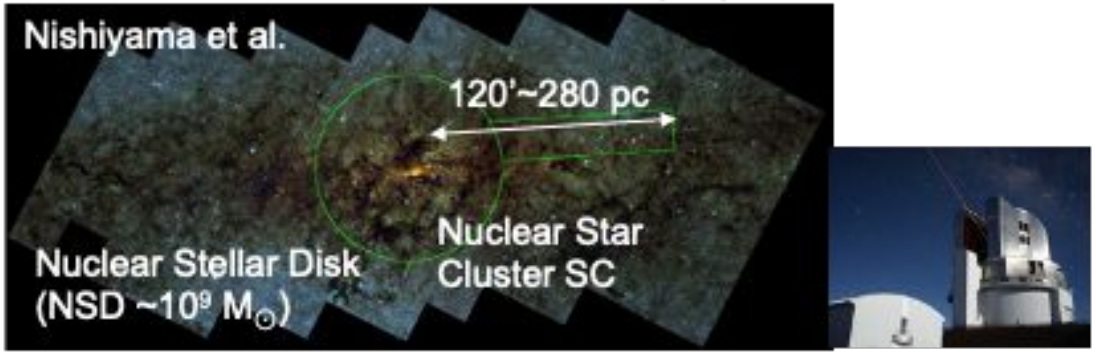
Low cadence w/ GLAO to measure the BH mass



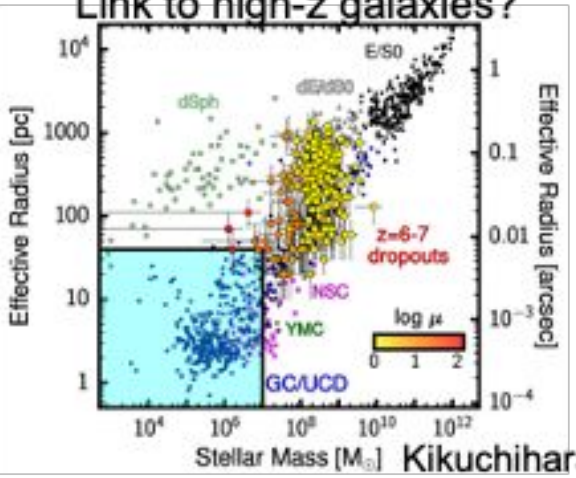
- 4 exposures/yr (Mar-Oct)
- Fill the gap of Roman
  - Orbital parallax for BHs
  - Refine / measure lens mass
- Astrometric microlensing for BHs
- Lens flux detection

ULTIMATE-JASMINE Synergy (Daisuke Kawata, MSSL/UCL)

JASMINE: NIR Astrometry mission by ISAS/JAXA, NAOJ (late-2020s)
for Galactic Centre Archaeology (Hw<15 mag) and Habitable Exoplanets Hunt
ULTIMATE: Denser, Fainter stars proper motion and stellar populations

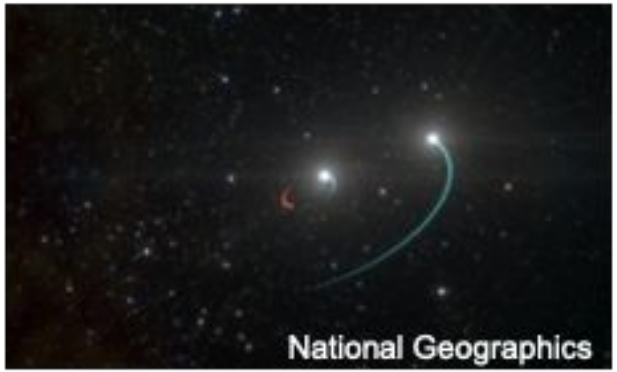


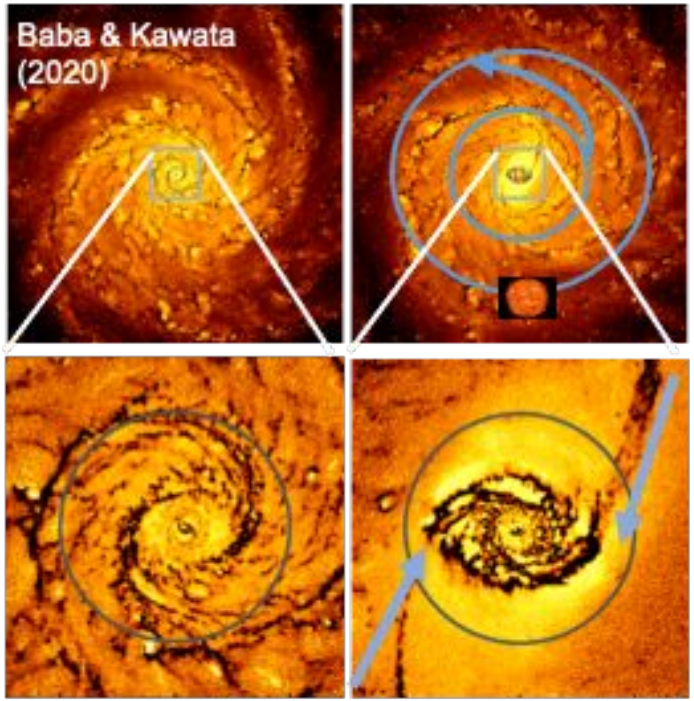
Link to high-z galaxies?



Kikuchihara et al. (2020)

IMBH-star binaries?





Bar formation epoch ~ Age of NSD
Impact to radial migration of the Sun?

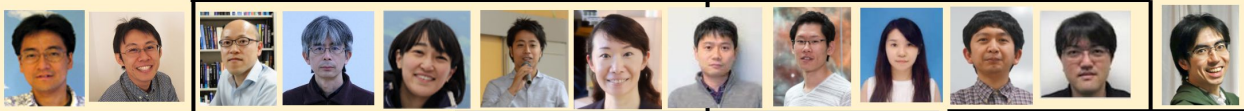

Questions for Part-2?

Development Team
(AO & instruments)

ULTIMATE core
(project management team)

Project scientist
(Y. Koyama)

ULTIMATE science team (ver. March 4th 2021)



A. High-redshift Universe
(T. Kodama / I. Iwata / A. Inoue / K. Tadaki / T. Suzuki)

M. Akiyama
T. Hashimoto
Y. Harikane
M. Hayashi
A. Inoue
I. Iwata
S. Kikuta
T. Kodama
K. Kohno
Y. Koyama
M. Kubo
Y. T. Lin
Y. Matsuda
Y. Matsuoka
Y. Minowa
T. Morishita
R. Momose
T. Nagao
K. Nakajima
K. Ogura
M. Onodera
C. Rusu
T. Shibuya
R. Shimakawa
D. Sobral
T. Suzuki
K. Tadaki
*I. Tanaka
M. Tanaka
J. Toshikawa
Y. Toba
K. Yabe
F. Bian
J. Bryant
J. Bloom
A. Casey
S. Croom
S. Leslie
C. Lidman
L. Lin
D. Nataf
L. Kewley
I. T. Ho
A. Shaefer
T. Yuan
T. Zafar

B. Local Universe & Milky Way
(T. Yamashita / S. Okamoto / S. Nishiyama / D. Suzuki / K. Morihana / T. Kamizuka / Y. Takagi)

D. Calzetti
M. Chiba
A.Fukui
O. Guyon
D. Iono
M. Ishigaki
K. Ito
T. Kamizuka
H. Kaneko
D. Kawata
J. H. Kim
J. Koda
T. Kokusho
S. Komugi
Y. Kono
N. Koshimoto
*Y. Koyama
C. H. Lee
*Y. T. Lin
N. Matsunaga
T. Michiyama
R. Miura
Y. Miyamoto
K. Morihana
T. Muto
Y. Nakada
S. Nishiyama
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C. Time Domain science
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JSPS core-to-core program (研究拠点形成事業)

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