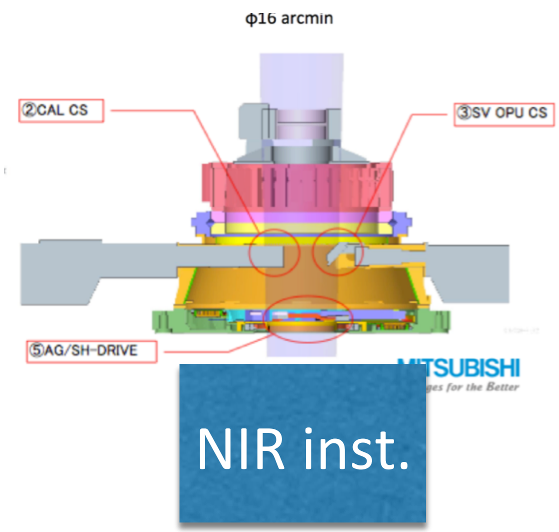
# ULTIMATE-Subaru
# AO / instrument fact sheets

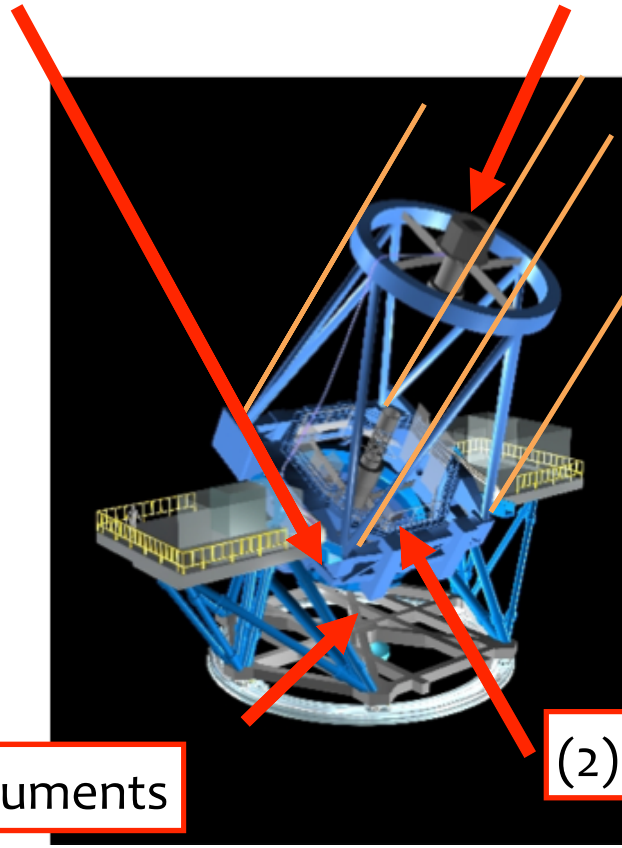
ULTIMATE-Subaru Working Group

# ULTIMATE-Subaru system overview

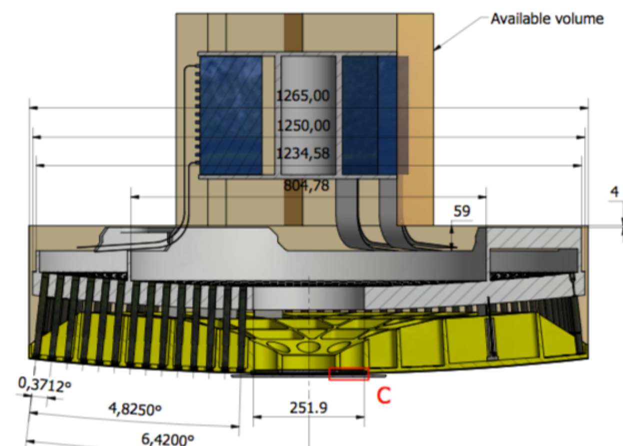
## (3) Wavefront Sensors

<u>4x LGS</u>
> 8x8 Shack-Hartmann for each
<u>3 x Tip/Tilt NGS</u>
2x2 Shack-Hartmann for each



## (1) Adaptive Secondary Mirror




Preliminary Subaru ASM designed by Microgate with ~ 1000 actuators

## (2) Laser Guide Star system

TOPICA 20W CW fiber laser(589nm) x 2
Generate 4 laser guide stars

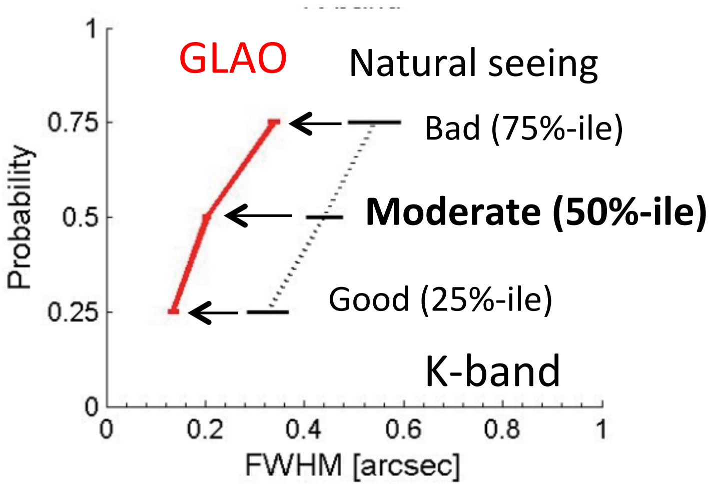
## (4) Wide-field NIR instruments

- Imager
- Multi-Object Slit spec.
- Multi-Object IFU spec.

FoV~16arcmin max.
at Cs. focus

# ULTIMATE-Subaru GLAO performance

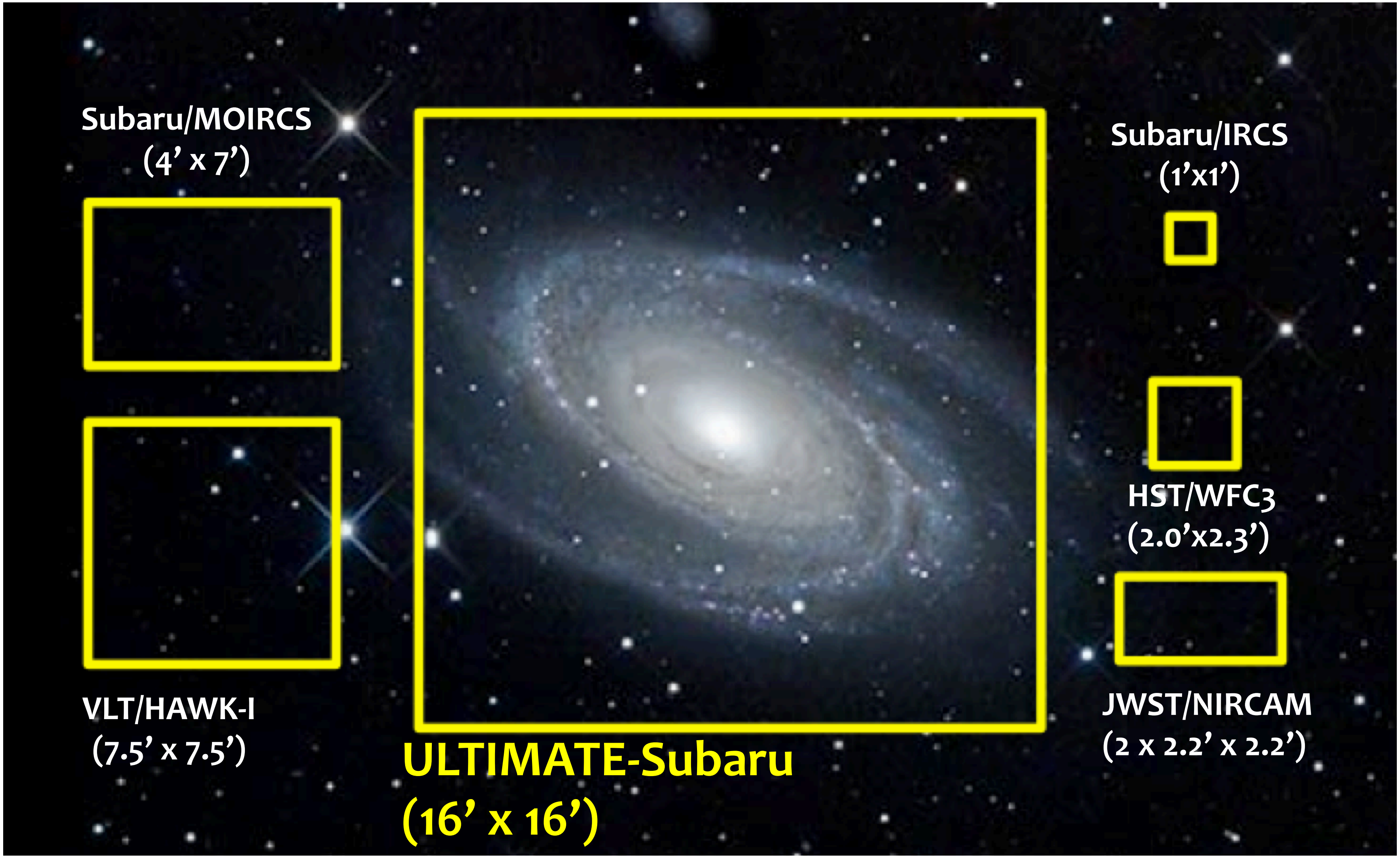
- Sky coverage: Almost entire sky!
- Seeing improvement ↓ ↓




| Band | Natural Seeing (”) | | | GLAO(”) | | |
|---|---|---|---|---|---|---|
| | Good | **Moderate** | Bad | Good | **Moderate** | Bad |
| J | 0.38 | **0.50** | 0.71 | 0.17 | **0.26** | 0.44 |
| H | 0.38 | **0.46** | 0.60 | 0.15 | **0.23** | 0.39 |
| K | 0.33 | **0.44** | 0.54 | 0.14 | **0.20** | 0.34 |

Note: Spatial resolution is comparable to WFIRST or HST/WFC3 (particularly at K-band)

# FoV comparison of NIR facilities in 2020s available at λ>2um



# ULTIMATE Instrument plans

1) Wide-field imager
2) Multi-object integral field spectrograph
3) Multi-slit spectrograph

| | Imager | MOS | Multi-Object IFU[a] |
|---|---|---|---|
| Wavelength Coverage | 0.8–2.5$\mu$m | | 0.9–1.8 $\mu$m |
| Plate Scale | 0.10 arcsec/pix | | 0.15 arcsec/spaxel |
| FOV | $\phi$=16′ | $\phi$=6′ – 16′[b] (TBD) | IFU: 1″.18×1″.18, Patrol area: $\phi$ ~15′ |
| Filters | YJHK + NBF/MBF/TBF[c] | — | — |
| Spectral Resolution | – | ~3000 (0″.4 slit) | 500–3000 |
| Multiplicity | – | ~100 slits (TBD) | 8–13 IFUs (TBD) |
| Detector | 4×H4RG(Teledyne) | | 2×H2RG(Teledyne) |
| Efficiency[d] | ~ 48%(J,H), ~40%(K) | ~33%(J),~35%(H,K) | ~7%(J),~10%(H) |

[a] In case of using MOIRCS as a spectrograph.
[b] FoV will be limited to 6′ if the instrument is installed at NsIR.
[c] NBF, MBF, and TBF indicate narrow-band, medium-band, and tunable filters, respectively.
[d] Total Efficiency includes atmosphere, telescope, and instrument (optics + detector).

Note: There are three instrument plans, with wide-field imager being the highest priority (according to the review meeting in February), but we would like to have your comments on the priority during the workshop.

# Appendix

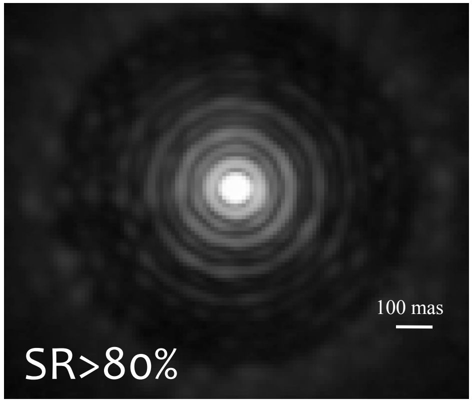

SUBARU TELESCOPE
National Astronomical Observatory of Japan

# Additional capabilities with ASM and 4 laser guide stars

- In addition to the wide-field GLAO, the adaptive secondary mirror (ASM) with **~1000** actuators can provide high Strhel ratio (> 80%) with narrow-field single-conjugate AO or laser tomography AO even in the optical wavelength.

→ Largely improve the performance of the existing narrow-field instruments.

H-band PSF obtained with LBT ASM




- Extreme AO with SCExAO
- High-Dispersion (R~160,000) Optical Spectroscopy with HDS
- Thermal infrared imaging/spectroscopy with IRCS/COMICS

→ TMT 1st gen. instruments will not offer such capabilities.

## (1) Wide-field imager

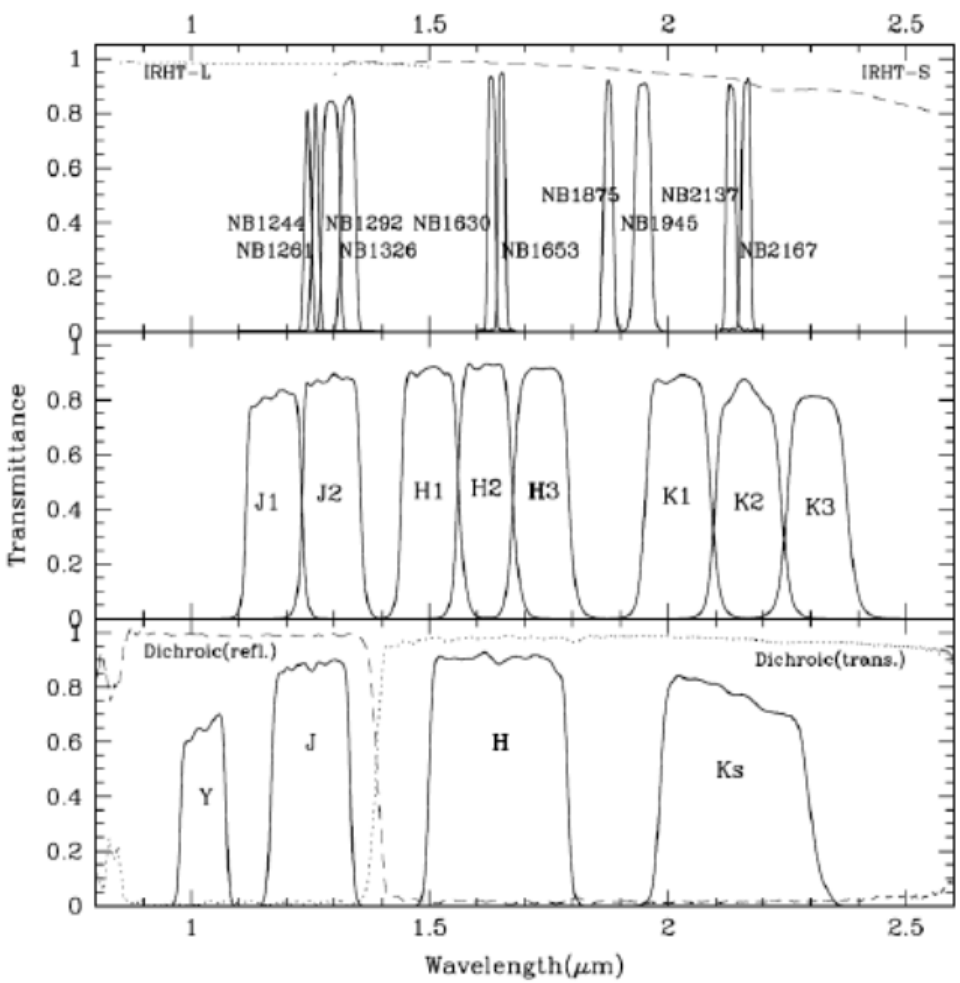
# Wide-field Imager (WFC) : overview

| | | |
|---|---|---|
| Wavelength coverage | 0.8-2.5um | |
| Plate scale | 0.10"/pix (TBD) | 1pix=15um |
| FoV | 4 x 6.8' x 6.8' (TBD) | Separation of 4 areas TBD |
| Filters | BB / MB / NB<br>(+ tunable filter ?) | see example of filter set next page |
| Detectors | 4 H4RGs (4k x 4k) | |

## Summary

- WFC covers ~14'x14' FoV with ~0.1" pixel scale - although exact values of these parameters are still TBD. Your input is welcome.
- Tunable filter option is under discussion (recommended by reviewers).
- The WFC is currently the 1$^{st}$ priority instrument for ULTIMATE.
- We can expect sensitivity improvement by ~0.75-mag for point source.

# Possible filter set & sensitivity




Example filter set (from SWIMS-18).
Note that this is just an example !

- We plan to install many filters (BB/MB/NB) on WFC, as shown in left.
- You can expect sensitivity improvement by 0.75-mag compared with MOIRCS (for point source; see table below). See next page for extended source.
- Please contact us if you need sensitivity for NBs.

| Filter | Limit mag (1h, 5σ, AB) |
|---|---|
| J | 25.3 |
| H | 25.1 |
| Ks | 25.3 |

These estimates are from MOIRCS ETC by changing seeing size and/or aperture sizes.

# (2) Multi-object IFU spectrograph

(in collaboration with AAO/Australia team)

# Multi-Object Integral-Field Spectrograph

## Summary

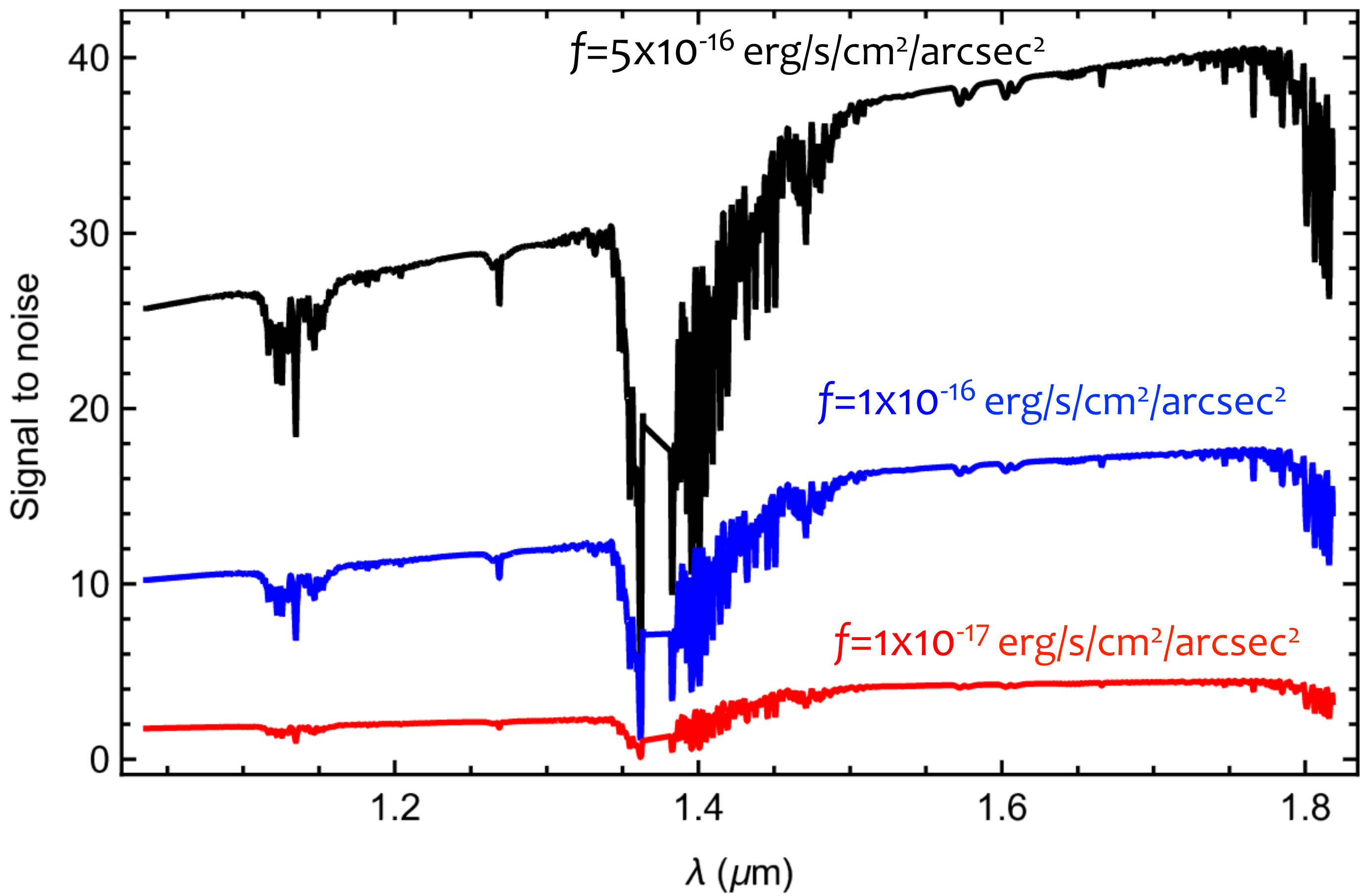
- >10 IFUs within ~15' FoV. Each IFU has 1.18 $arcsec^2$ with 0.15" spatial sampling.
- Wavelength coverage is < 1.8um – i.e. K-band is not available with current plan.
- Roughly speaking – you can imaging GLAO-assisted KMOS(VLT).
- See talk by S. Ellis (AAO) for more details of Starbug+IFU system.

| | |
|---|---|
| **IFUs** | |
| Number of IFUs | 8-13[a] |
| Number of elements per IFU | 61 Hexagonally packed |
| Spatial sampling per element | 0.15 arcsec |
| Total field of view per IFU | 1.18 square arcsec |
| Total patrol area | $\phi \sim 15$ arcmin[b] |
| Minimum separation between IFUs | 25 arcsec |
| **Spectrograph (MOIRCS)** | |
| Wavelength coverage | 0.9-1.8 $\mu$m |
| Spectral resolving power | 500-3000 |
| Dispersion | 1.6 Å per pix ($J$), 2.1 Å per pix ($H$) |
| Sampling | 2-5 pixels in FWHM |
| **Combined properties** | |
| Total efficiency | 9% ($J$), 12% ($H$) |

[a] This number can be increased by using a new larger spectrograph.
[b] FoV of the wide field corrector.

# Sensitivity

Expected sensitivity for emission-lines (S/N per spaxel with 1-hr on-source integration)



# (3) Multi-object slit spectrograph

# Multi-object slit spectrograph (MOS)

## Summary

- Technical study for ULTIMATE MOS spectrograph is very premature – but at this moment we assume "MOSFIRE-like" instrument with specification below.
- Sensitivity calculation follows next page.

| | |
|---|---|
| Wavelength coverage | 0.8-2.5um |
| Plate scale | 0.10"/pix (TBD) |
| FoV | 6' – 16' (TBD) |
| Spectral resolution | ~3000 (0.4" slit) |
| Multiplicity | ~100 slits |
| Efficiency | ~33% (J), ~35% (H,K) |

# Multi-slit spectrograph

Expected sensitivity for <u>emission-lines</u> (point source and extended source)

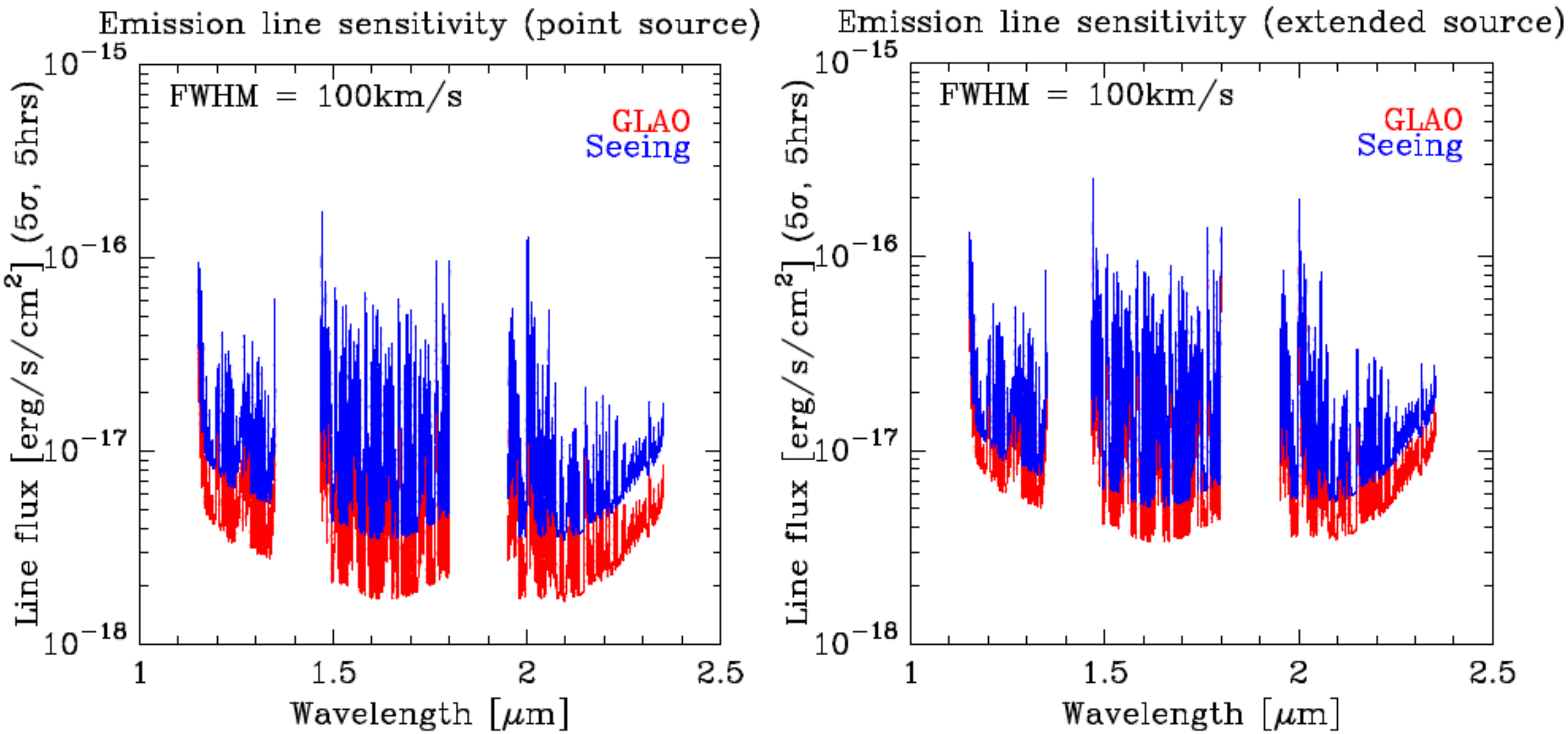



Figure 7.26: Expected emission line flux detected at 5 $\sigma$ in 5 hours integration time as a function of wavelength in NIR (1.0-2.5$\mu$m). Left and right panels show the limiting line flux for point sources and extended sources with the Sersic profile of $R_e$=0".25 ($\sim$ 2 kpc at $z = 1 - 3$) and $N = 1$, respectively. Red lines show the expected sensitivity of the ULTIMATE-Subaru (GLAO), while bleu lines show the expected sensitivity with no AO correction (seeing, equivalent to Keck/MOSFIRE). We assume that the emission line has a velocity dispersion of 100 km/s in FWHM.

# Multi-slit spectrograph

Expected sensitivity for continuum (point source and extended source)

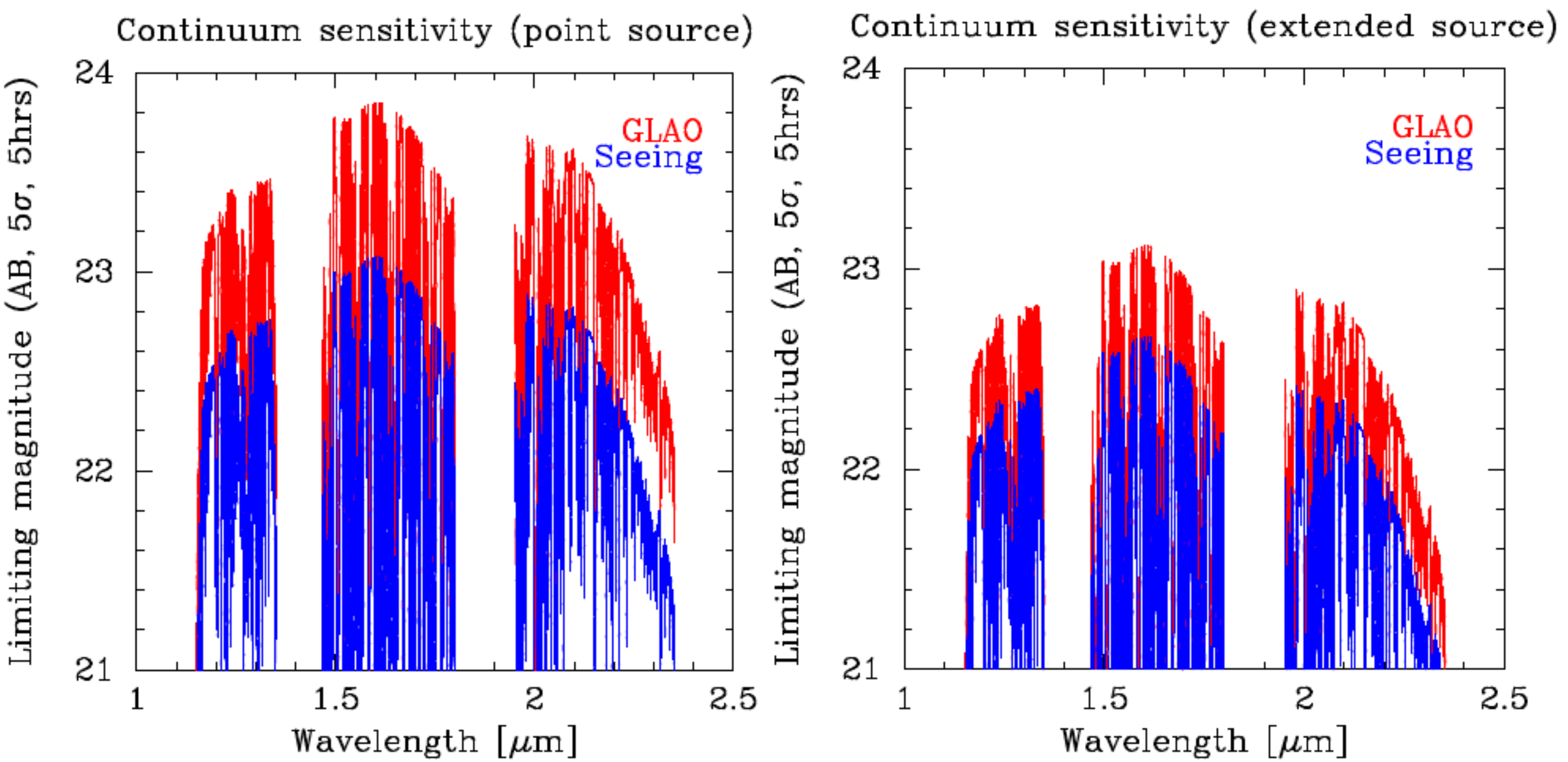



Figure 7.27: Expected continuum flux in AB magnitude detected at 5 $\sigma$ in 5 hours integration time. Left and right panels show the sensitivity for point sources and extended sources (same as Figure 7.26), respectively. Red and blue lines show the expected sensitivity for the ULTIMATE-Subaru (GLAO), and no AO (seeing, equivalent to Keck/MOSFIRE), respectively.