Subaru Telescope Ground Layer AO System and New Near-IR Instrument

2013/04/15
I. Iwata (New Development Group, Subaru Telescope, NAOJ)
Subaru Next-Gen AO Working Group

• Founded in 2011

• Members:
  • M. Akiyama, Y. Ohno (Tohoku Univ.)
  • K. Motohara (Univ. of Tokyo)
  • NAOJ:
    • PI: N. Arimoto
    • Y. Hayano, S. Oya, Y. Minowa, M. Hattori
    • T. Usuda, T. Kodama, N. Takato, H. Terada, I. Tanaka, T. Hattori, I. Iwata
    • H. Takami, M. Iye

• Public Meetings, Publications and Reviews:
  • 2011/09: Subaru Next-Gen AO WS @ Osaka Univ.
  • 2012/08: Study Report
  • 2012/11: Evaluation by Japanese Community (for various projects)
    • Science=S, Feasibility=S, Urgency=A
Ground Layer AO + New NIR Instrument

1. Ground Layer AO with Adaptive Secondary Mirror
2. New Near-IR Instrument (Wide-field Imager + MOS)
   • → Seeing Improvement (FWHM 0.4” → 0.2”) over FoV >15’
     • High Spatial Resolution Competitive to HST
     • Higher Sensitivity Equivalent to 2x Telescope Aperture*1
     • 6x Wider Field of View*2
   • Targeted to Start Operation in 2020

*1 For point sources.
*2 Relative to MOIRCS
Science Objectives

• Understanding History of Galaxy Evolution with Huge Imaging + Spectroscopic Sample of High-z Galaxies
  • ~Several Thousands of 1<z<3 Galaxies - Morphology, Kinematics, SF Diagnostics, Environmental Effects etc.

• Detection of the Most Distant Galaxies w/ Narrow-band Imaging
  • Finding Galaxies at z>7.5, Exploration of the Cosmic Reionization

• Unique Samples for TMT

• ‘Upgrade’ of Subaru Telescope, Benefit for Various Science Cases

Study Report by Many Contributions:
http://www.naoj.org/Projects/newdev/ngao/
Why GLAO+WFNIRIMOS?

• Need of Competitive NIR Instrument(s) - Based on Recommendations by SAC
• ‘Large Survey’ is Subaru’s Strategy in TMT era
• Uniqueness of GLAO + >10’ NIR instrument
• Mauna Kea is Suited for GLAO
• Key Elements of AO for TMT (Tomography, Multiple Laser and WFS, ASM)
• Pathway from Subaru to TMT
Ground Layer AO for Subaru
Ground Layer Adaptive Optics (GLAO)

- Adaptive Secondary Mirror (ASM)
- Multiple Laser Guide Stars, Multiple Wavefront Sensors
- Tomography of Earth Atmosphere
- Correct Ground Layer Turbulence with ASM

FoV: 10 arcmin fwhm: < 0.4 [arcsec] survey possible
Expected Performance of Subaru GLAO: FWHM Improvement

K–band

Distance from Center

10’ 15’ 20’

by S. Oya
Expected Performance of Subaru GLAO: FWHM Improvement

Distance from Center
10’ 15’ 20’

R–band

J–band

H–band

K–band

by S. Oya
Expected Performance of Subaru GLAO: Ensquared Energy Improvement

K-band

Seeing

GLAO

Size

0.24” 0.36” 0.48”

by S. Oya
Expected Performance of Subaru GLAO: Ensquared Energy Improvement

Size

0.24” 0.36” 0.48”

by S. Oya
Adaptive Secondary Mirror On-Source Performance

ASM can also be an excellent on-source AO
Wide-Field NIR Instrument for GLAO
Wide-Field Instrument for GLAO

• Requirements from Science Cases (So far):
  • **Imaging**: Wide-Field Near-IR Camera
    • Broad-band + Narrow-Band Filters
    • 0.9-2.5μm
  • **Multi-Object Spectroscopy**
    • Spectral Resolution $R > 2,000$
    • 0.9-2.5μm
  • **Multi-Object Integral Field Spectroscopy (IFS)**
    • (No specific requirement on multiplicity yet)
  • **Field-of-View**: $>100$ arcmin$^2$
  • **Spatial Resolution**: 0.1-0.2 arcsec
• Other possible instruments:
  • Optical spectrograph
  • K- and L-band Camera
So far we have studied the possible optical designs of wide-field Near-IR imager and multi-object spectrograph for the Cassegrain focus of Subaru Telescope.

Scale-Up version of MOIRCS, a current Subaru instrument (4’x7’ FoV)

We have explored two possible optical designs:

- A case without splitting FoV
  - maximum FoV: 13’x13’-16’x16’, depending on whether we can alter optical parameters of the secondary mirror of the telescope.

- A case with splitting FoV into 4 segments
  - maximum total FoV: 17’x17’ - 23’x23’

We are now examining how FoV is limited with vignetting by telescope structures.
Wide-Field NIR Imager + Multi-Object Spectrograph (A case without FoV splitting)

- Optical Design by Dr. Yamamuro (Optcraft)
Wide-Field NIR Imager + Multi-Object Spectrograph (A case with FoV splitting)

- Optical Design by Dr. Yamamuro (Optcraft)

Telescope + Cass Instrument Optical Layout
No modification on mirror shapes
Wide-Field NIR Imager+Multi-Object Spectrograph
(A case with FoV splitting)

- Optical Design by Dr. Yamamuro (Optcraft)
<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>0.8-2.5(\mu\text{m})</td>
</tr>
<tr>
<td>Plate Scale</td>
<td>0.06-0.1”/pix</td>
</tr>
<tr>
<td>FoV</td>
<td>approx.13‘x13’</td>
</tr>
<tr>
<td>Filters</td>
<td>Broad+Narrow</td>
</tr>
<tr>
<td>MOS</td>
<td>Multi Slit Mask</td>
</tr>
<tr>
<td>(\lambda) Dispersion</td>
<td>2000(TBD)</td>
</tr>
</tbody>
</table>

- Wider with Split FoVs?
- Under Investigation
## Comparison: Imaging

<table>
<thead>
<tr>
<th></th>
<th>Subaru MOIRCS</th>
<th><strong>Subaru GLAO</strong></th>
<th>TMT IRIS</th>
<th>HST WFC3/IR</th>
<th>JWST NIRCam</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Telescope Aperture</strong></td>
<td>8.2m</td>
<td>8.2m</td>
<td>30m</td>
<td>2.4m</td>
<td>6.5m</td>
</tr>
<tr>
<td><strong>Wavelength Coverage</strong></td>
<td>0.9-2.5μm</td>
<td>0.9-2.5μm</td>
<td>0.84-2.4μm</td>
<td>0.9-1.7μm</td>
<td>0.9-2.3μm / 2.4-5.0μm</td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
<td>0.117”/pix</td>
<td>~0.1”/pix</td>
<td>4 mas</td>
<td>0.13”/pix FWHM~ 0.25”</td>
<td>32 mas / 64 mas</td>
</tr>
<tr>
<td></td>
<td>0.4”@2μm</td>
<td>0.2”@2μm</td>
<td>10 mas@1μm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Field of View</strong></td>
<td>28 □’</td>
<td>~180 □’</td>
<td>0.075 □’</td>
<td>4.65 □’</td>
<td>9.7 □’</td>
</tr>
</tbody>
</table>
## Comparison: Spectroscopy

<table>
<thead>
<tr>
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<th>Subaru MOIRCS</th>
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<th>HST WFC3/IR</th>
<th>JWST NIRSpec</th>
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<td>0.84-2.4μm</td>
<td>0.9-1.7μm</td>
<td>0.6-5μm</td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
<td>0.117”/pix</td>
<td>~0.1”/pix</td>
<td>4 - 50 mas</td>
<td>0.13”/pix FWHM~ 0.25”</td>
<td>0.2”x0.45”</td>
</tr>
<tr>
<td></td>
<td>0.4”@2μm</td>
<td>0.2”@2μm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Field of View</strong></td>
<td>~25 □’</td>
<td>~120 □’</td>
<td>0.2-10 □’</td>
<td>4.65 □’</td>
<td>12.24 □’(MSA) 3”x3”(IFS)</td>
</tr>
<tr>
<td><strong>Functions</strong></td>
<td>Single-Slit MOS IFS</td>
<td>MOS Multi-IFS?</td>
<td>IFS</td>
<td>Slitless</td>
<td>Slits Microshutters IFS</td>
</tr>
<tr>
<td><strong>Spectral Resolution</strong></td>
<td>600-3000</td>
<td>-2000?</td>
<td>4000-10000</td>
<td>TBW</td>
<td>100, 1000, 2700</td>
</tr>
</tbody>
</table>
How fine can we resolve them?

@ 2μm

Seeing

GLAO

JWST NIRCam

TMT IRIS

1kpc

100 pc

Arcsec

Redshift
How fine can we resolve them?

Seeing

@ 2μm

GLAO

JWST NIRCam

TMT IRIS

1 kpc

100 pc
Emission-Line Sensitivities

GLAO
Seeing
JWST NIRSpec
TMT IRIS

Emission Line Sensitivities

\[ \text{erg/s/cm}^2 \]

Redshift

1e40 erg
1e39 erg
Emission-Line Sensitivities
Schedule and Resources
## Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive Secondary Mirror</td>
<td>5-10M</td>
</tr>
<tr>
<td>Laser System</td>
<td>4-8M</td>
</tr>
<tr>
<td>Wavefront Sensor System</td>
<td>~3.5M</td>
</tr>
<tr>
<td>Computers</td>
<td>~0.2M</td>
</tr>
<tr>
<td>Telescope Modifications</td>
<td>15-25M</td>
</tr>
<tr>
<td>Instruments</td>
<td>5-15M</td>
</tr>
<tr>
<td>(Additional) Human Resources</td>
<td>~2M</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>35-60M</strong></td>
</tr>
</tbody>
</table>
Issues

• Are Science Cases Strong Enough?
  • Instrument: MOS or Multi-IFS (KMOS-like)?

• Funding
  • Grant-in-Aid: 15M max.
  • Telescope Modification by NAOJ Budget?
  • International Partnership

• Human Resources
  • Conflict with Resources for TMT?
  • International Collaborations?
Current Activities and Plans for 2013

• Conceptual Study
  • Feasibility of WFNIRIMOS
    • Compatibility with Subaru Telescope Structure
    • Opt-Mechanical Design
  • GLAO Development Plan
    • ASM - based on R&D for VLT
    • Laser system, WFS, RTC
  • More Detailed Simulations for GLAO and Observations
• GLAO Science WS: 2013/6/13-14 in Sapporo
• Internal Review in Summer 2013
  • Review Points: Scientific Importance, Technical Feasibility, Funding, Consistency with Overall Roadmap of NAOJ / Subaru Telescope / TMT