Ultra-wide-field Laser Tomographic Imager and MOS with AO for Transcendent Exploration by SUBARU telescope.
Project overview

• Why we need ULTIMATE-SUBARU?
• GLAO System overview
• Seeing at Mauna Kea (next talk by Oya-san)
• GLAO simulation (next talk by Oya-san)
• Project organization
• Schedule and budget
• Technical studies
  – Adaptive secondary mirror study
  – Telescope modification study
  – Wide field imager
Key instruments at Subaru Telescope

HSC (vis)
PFS (vis)
GLAO
NIR instrument

HSC first light
1. Ground Layer AO with Adaptive Secondary Mirror (4 LGSs)

- Seeing Improvement (FWHM 0.4"→0.2") over FOV ~15'
- Higher Sensitivity Equivalent to 2x Telescope Aperture
- 6 Times Wider Field of View

*1 For point sources.  
*2 Relative to MOIRCS (seeing limited NIR instrument)
GLAO

Guide stars

Atmospheric turbulence

Feedback correction to deformable secondary mirror

Turbulence at ground layer

Estimation of ground-layer turbulence

Wavefront sensors
System Overview

1. Ground Layer AO with Adaptive Secondary Mirror (4 LGSs)

1. Wide-field Near-IR Instrument (Imager + MOS or M-IFU)

→ Seeing improvement (FWHM 0.4” → 0.2”) over FOV ~15’

• Higher sensitivity equivalent to 2x telescope aperture*1
• 6 times wider FOV*2
  – ~200 times wider FOV compared with AO188/LGS+IRCS

*1 For point sources.
*2 Relative to MOIRCS (seeing limited NIR instrument)
## GLAO - Specifications under Consideration

<table>
<thead>
<tr>
<th>Guide stars</th>
<th>4 LGSs + 3 NGSs</th>
<th>Secondary mirror</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>Secondary mirror</td>
<td>~1000 actuators, modification of VLT ASM.</td>
</tr>
<tr>
<td>High-order WFS</td>
<td>&gt; 8x8 SH</td>
<td>visible, EM-CCD(TBD)</td>
</tr>
<tr>
<td>Tip-tilt-focus WFS</td>
<td>2x2 SH or quad</td>
<td>visible</td>
</tr>
<tr>
<td>Laser</td>
<td>20 W CW</td>
<td>TOPTICA (589nm) (option: Rayleigh)</td>
</tr>
<tr>
<td>LGS constellation</td>
<td>15’ in diameter</td>
<td></td>
</tr>
<tr>
<td>Laser Launch</td>
<td>~25cm dia. (TBD)</td>
<td>side launch</td>
</tr>
</tbody>
</table>
# NIR Instrument - Specifications under Consideration

<table>
<thead>
<tr>
<th>Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>0.8-2.5μm</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>λ Dispersion</td>
<td>2000(TBD)</td>
</tr>
<tr>
<td></td>
<td>Under Investigation</td>
</tr>
</tbody>
</table>
Main Science Targets

• “Anatomy” of galaxies at z=1 – 3
  – What are the key parameters to drive the galaxy evolution?
  – What determines morphologies of the galaxies?
  – Large-Scale Near-IR Surveys (Imaging and spectroscopy) of about 5000 galaxies

• Discovery of the Most Distant Galaxies at z>7.5
  – Understand of the Cosmic Reionization
  – NBF imaging survey (∼180 arcmin²), 100 galaxies.
  → Target sample for TMT.
ULTIMATE-SUBARU organization

PI
N. Arimoto
Subaru Director

Project management
Y. Hayano, O. Lai

Adaptive Optics
2nd DM (Adoptica, MELCO, NAOJ)
WFS (NAOJ, others)
LGS (TOPTICA, NAOJ, others)
RTC (NAOJ, others)
Telescope Mod. (MELCO, NAOJ)
Test and Integration (NAOJ, etc)

Opto-mechanics (NAOJ, coll.)
Electronics (NAOJ, coll.)
Control (NAOJ, coll.)
Software (NAOJ, coll.)

Staff 3/Postdoc 3/Tech 2/coll.

Wide-field NIR inst.
Opto-mechanics (NAOJ, coll.)
Electronics (NAOJ, coll.)
Cryogenic system (NAOJ, coll.)
Detector, Camera (NAOJ, coll.)
Control (NAOJ, coll.)
Data analysis (NAOJ, coll.)

Staff 3/Postdoc 3/Tech 2/coll.

Science team
T. Kodama, I. Iwata.
ngAO working group members

International collaborators
## Cost estimation, budget

<table>
<thead>
<tr>
<th>Items</th>
<th>Cost</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASM system</td>
<td>6 M</td>
<td>Grant-in-aid Scientific Research, etc.</td>
</tr>
<tr>
<td>Laser system</td>
<td>0.5 – 4 M</td>
<td>Grant-in-aid Scientific Research, etc. (if Rayleigh LGSs, cost is 1/10)</td>
</tr>
<tr>
<td>Wavefront sensor unit</td>
<td>1 M</td>
<td>Grant-in-aid Scientific Research (International collaboration)</td>
</tr>
<tr>
<td>Realtime controller</td>
<td>0.5 M</td>
<td>Grant-in-aid Scientific Research, etc. (International collaboration)</td>
</tr>
<tr>
<td>Telescope modification</td>
<td>5 – 8 M</td>
<td>NAOJ budget</td>
</tr>
<tr>
<td>NIR instrument</td>
<td>0 – 10 M</td>
<td>Existing instrument at first. (MOIRCS or MOIRCS upgrade etc.)</td>
</tr>
<tr>
<td>Manpower</td>
<td>2 M</td>
<td>NAOJ budget and Grant-in-aid Scientific Research</td>
</tr>
<tr>
<td>Contingency</td>
<td>5 M</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20 – 36.5 M</td>
<td></td>
</tr>
</tbody>
</table>

2. Grant-in-Aid for Specially Promoted Research, 2016-2020
3. Grant-in-Aid for Scientific Research (Category S), 2020-2024
Technical studies
Adaptive Secondary mirror for VLT

- Thin shell mirror
- Thin shell supporting foam
- Reference plate
- Actuators
- Actuator plate
- Control electronics
- Interface cables (Power, Network, coolant)
- Hexapods will be located around control electronics.
ASM test unit at ESO (ASSIST) (2012/11/13)
ASM test at ESO with GRALL
(2013/3/27)
Subaru ASM model
897 actuators in optical area plus 27 slave actuators (1 ring) inside internal optical diameter (924 total)
Interface to existing IR M2
Vignetting by telescope structures

Cassegrain Unit

M3 Unit

M1 cell cover
Cassegrain Unit

φ16 arcmin
FOV at Cassegrain (current)
M3 unit

φ16 arcmin
Expandable FoV at Cassegrain

Only M1, M2

With M3 unit

\[ \approx 8' \]

\[ \approx 6' \]
Location of LLT and laser head

Candidate location

- Rear
- Front
- OPT
- IR

Walk way

- Winch for mirror cover
- No longer exist
- Terminal box (lower center section)
- Cable wrap and duct at elevation axis (IR)
- Cable wrap and duct at elevation axis (OPT)
- Cable tray area (Use during M1 coating)
- Balance weight
- Balance weight

Front
Candidate location for LLT
Rear side

Laser head and LLT location
Feasibility study for NIR instrument

• Optical design
  – w/wo field splitting
  – Change telescope optical parameters or not.
  – Optical components (CaF$_2$) < 400mm
  – Goal FWHM <0.15” over FoV and 0.8-2.5μm
Wide-Field NIR Imager + Multi-Object Spectrograph
(A case without FoV splitting)

Example of Optical Design

FoV 12.6'
Next step

• Conceptual design review
• International Collaboration
  – AAO, NRC, etc.
• Adaptive secondary mirror
  – Interface to IR M2 unit.
  – Further design study with ADS, Microgate.
• Fiber laser (TOPTICA/MPBC) upgrade
• Budget application