Subaru's GLAO System vs. Megaconstellations: A Space Odyssey

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Credit: NAOJ
ULTIMATE-Subaru: Instrument Overview

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

**GLAO assisted wide-field NIR instruments**

- ASM finished the final design. Procurement started for long-lead optical components.
- GLAO preliminary design study completed, PDR in Nov 2022, Starting final design phase.

**Subaru/NAOJ-led project in collaboration with**

- Australian National University (Australia)
- Tohoku University (Japan)
- Academia Sinica Institute of Astronomy and Astrophysics (Taiwan)
- University of Tokyo (Japan)
4 laser beams are propagated from the front/rear side of the telescope center section.

Use two TOPTICA 20W lasers, split the laser beam into two (~10W each)

LGSF is composed by the diagnostic part (power, wavelength, alignment), beam transfer part (expand, split the beam, jitter control), and launching part (LLT, field steering mirror)

The asterism can be configured at any diameter within 0 – 20 arcmin.

Martinez, N. et al. 2022 Proc. SPIE
Science goals of ULTIMATE-Subaru:

1. Birth of galaxies: galaxies in the very early universe, redshifts >>7
2. Present-day of galaxies: systematic survey of nearby galaxies
3. Growth of galaxies: history of star formation and origin of galaxy structures

LGS Photon return map @ Maunakea
Holzlöhner et al. 2010
ULTIMATE-Subaru: Science Cases

Fraction of the observing time planned to be used for the science target field.

<table>
<thead>
<tr>
<th>Field</th>
<th>Fraction</th>
</tr>
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<tbody>
<tr>
<td>Celestial Equator Deep Field: -5.0 &lt; δ &lt; 5.0</td>
<td>60 %</td>
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<tr>
<td>Galactic Center: δ ~ -29.0</td>
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<td>Other fields: various δ</td>
<td>20 %</td>
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<tr>
<td>North Ecliptic Pole: δ ~ 66.0 (Euclid northern survey field)</td>
<td>5 %</td>
</tr>
</tbody>
</table>

LGS Photon return map @ Maunakea
Holzlöhner et al. 2010
Subaru Laser Guide Star System Upgrade

Laser upgrade (2019-2022)
- Use a TOPTICA laser
- Laser transfer by a relay of mirrors

→ Open use restarted since 2023
Subaru Laser Guide Star System Upgrade

GLAO prototyping activities

1. **TOPTICA laser characterization**
   - Photon Return at MaunaKea
   - Spot size
   - Response to the Laser polarization state

2. **Laser beam jitter control**
   - Active control of the jitter in the long relay path (~20m)
   - Compensation of the slow beam mis-alignment due to the telescope deflection
   - Laser jitter PSD including atmosphere

3. **Laser Safety**
   - Development of a new laser safety system based on a PLC
   - Establish an Administrative Control procedure

4. **Multiple-Laser beam (LGS asterism)**
   - Split the laser beam into 4
   - Control the asterism configuration

Fundamental technology for the future GLAO system and more

- **ULTIMATE-Subaru**
Subaru Laser Guide Star System Upgrade

Single BEAM CONFIGURATION

Telescope Truss & Spider

LLT (behind Secondary Mirror)

PM

SSM

PSD

WFS

CCD

Beam Expander

Electronics Rack

TOPTICA Laser Head

TOPTICA Laser Electric Cabinet

Heat Exchanger Unit

NsiR platform

Center Section

Na Cell

PM

SSM

Thin Film Polarizer

1/2λ WP

1/4λ WP

1/2λ WP

Alignment Laser

Exit Window

DB Shutter (Mirror)

WFS

LH shutter

Beam Damper

Area reserved for the 4-beam generator

From Relay

LLT OPT side

LLT REAR side

Expander (x6)

LLT [x12.5]

M8

M5

M6 (FSM2)

M7

M3

M2 (FSM1)

M4

M1
Subaru Laser Guide Star System Upgrade

March 2nd, 2022

Saw a LGS right away with the very first launch!
From past to present: satellite closures @ Subaru Telescope

Histogram of the open shutter duration at the fixed Az/EL

Data from the Predictive Avoidance Approval Messages (PAM)
From past to present: satellite closures @ Subaru Telescope

Histogram of the open shutter duration at the fixed Az/EL

Data from the Predictive Avoidance Approval Messages (PAM)
From past to present: satellite closures @ Subaru Telescope

2014 – 2023

Number of the shutter close events
From past to present: satellite closures @ Subaru Telescope

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2014 – 2023
Number of the shutter close events
January 23 – SpaceX opts out of the Laser Deconfliction
From past to present: satellite closures @ Subaru Telescope

2014 – 2023
Number of the shutter close events
From past to present: satellite closures @ Subaru Telescope
## Into the future

### COMPANIES PLANNING TO LAUNCH > 1000 SATELLITES

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Total proposed satellites, constellations > 100 satellites: ~162000, ~437000

Credit: Therese Jones, Satellite Industry Association
Into the future
Effect to ULTIMATE-Subaru Science

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Holzlöhner et al. 2010
Effect to ULTIMATE-Subaru Science

Fraction of observing time

| Celestial Equator Deep Field | 60 % |
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- The number of short open shutter duration is significantly increased in 2022 compared with 2014-2019.
- SpaceX opting out of the Laser Deconfliction protocol considerably reduced the shortest open shutter time.
- Future looks crowded.
- An increased number of very short shutter open time with less than 10 sec will severely hamper the science observations that require long exposure time.
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THANK YOU

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