Thermal Infrared Observation using Adaptive Secondary Mirror (ASM)

Hiroshi TERADA
(Subaru Telescope)

Talk Contents
- Ground-based Thermal IR w/AO
- Subaru Thermal IR w/AOs
- Subaru Thermal IR w/ASM
Ground based Thermal IR Observation

Background Emissions

1-2μm
OH emission lines

>2μm
Thermal Radiation (from Sky and Ambient)

http://www.kusastro.kyoto-u.ac.jp/~iwamuro/LECTURE/OBS/atmos.html
Ground based Thermal IR Observation

Atmospheric Transmission

Subaru NGAO Workshop @ Osaka-U on 2011/09/08

Hiroshi TERADA @ Subaru Telescope
Higher Background
Longer wavelength
  -> Better correction
  -> Covering wider FOV
    (angle $\propto \lambda(1.2)$)

Image Quality Good Enough @ Mid-IR under Natural Seeing?
  (seeing $\propto \lambda(-0.2)$)
Subaru AO Observation

1st Generation AO (AO36)

AO36@Subaru Cassegrain focus

M3: Offaxis parabola, f=720mm
M5: Offaxis parabola, f=720mm with tip/tilt
M4: Deformable mirror, D=61 mm
M1/M6: Pickup mirror

Telescope focus by AO optics

Top view

Beam Splitter: COLD n instrument

IRCS
CIAO

Subaru NGAO Workshop @ Osaka-U on 2011/09/08

Hiroshi TERADA @ Subaru Telescope
Subaru AO Observation
1st Generation AO (AO36)

Background increase w/AO36 from w/o AO36

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>K'</td>
<td>-0.08 mag</td>
</tr>
<tr>
<td>L'</td>
<td>-0.33 mag</td>
</tr>
<tr>
<td>M'</td>
<td>-0.16 mag</td>
</tr>
</tbody>
</table>
Subaru AO Observation
2nd Generation AO (LGS/AO188)

AO188 @ Subaru Infrared Nasmyth

Bean Splitter: WARM outside instrument
Image Rotator: On AO188
Subaru AO Observation

2nd Generation AO (LGS/AO188)

Background increase w/AO188 from w/o AO188, ImgRot

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>K</th>
<th>L'</th>
<th>M'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.39 mag</td>
<td>-0.52 mag</td>
<td>-0.35 mag</td>
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</tbody>
</table>

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Subaru AO Observation

2nd Generation AO (LGS/AO188)

One More Thing...

✓ Warm dust / Coating defect on Optical Surface

Cf. Current
Subaru AO Observation
w/ and w/o AO188 L-band Observation

L-band Low-resolution Spectroscopy
Slit width: 0” 45 / 90sec * 24 = 2160sec

Slit width: 0” 225 / 50sec * 20 = 1000sec

✓ Comparable S/N w/ half an exposure time
Subaru Mid-IR Observation

COMICS @ Subaru Cassegrain

- Close to Diffraction Limited Image in N-band
- Stable Diffraction Limited Image in Q-band
- Technically Challenging for ASM Chopping

Data from 2009-02-01 to 2010-01-31

Wavelength [μm] vs. FWHM [arcsec]
Subaru Low Background Thermal IR Observation

Background decrease from [NsIR] AO188 to [Cs]

<table>
<thead>
<tr>
<th>Wavelength [μm]</th>
<th>K/K'</th>
<th>L'</th>
<th>M'</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>+0.46 mag</td>
<td>+0.86 mag</td>
<td>+0.56 mag</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

w/ AO188 (NsIR)
w/o AO36 (Cs)
On-source mode

- **Strehl > 0.8 in any case**
- **Sensitivity improvement for all background-limit observations.**
- **Concept Examples:**
  - IFU @ >3um (currently not existing)
  - Wider FOV @ L’, M’-bands
    
    Isoplanatic angle: $\theta_0 \propto \lambda^{1.2}$
    
    L’: 30” * $(3.77/2.2)^{1.2} \sim 57”$
    
    M’: 30” * $(4.68/2.2)^{1.2} \sim 74”$

from GLAO Simulation by Oya

H2RG (5.5um cut-off)
30mas/pix => 1’x1’
40mas/pix => 1.3’x1.3’
Even Lower Background @ Ls? Possible Removal of CH$_4$

- Bottle Neck

**CH$_4$ lines**

**Background [e$^{-}$/s/μm$^2$/arcsec$^2$] vs. Wavelength [μm]**

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**Observation**

- Radiance (Watts/str-cm)
- Wave number (cm$^{-1}$)

**Retrieval**

- CH$_4$
- Mixing Ratio (ppmv)

**Altitude (km)**

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Hiroshi TERADA @ Subaru Telescope
Low Background Observation @ Thermal IR w/ ASM

GLAO mode

Better performance than < 2um

from GLAO Simulation by Oya
GLAO mode

- Close to Diffraction Limited Image @ L’&M’ over Diameter~10’
  ⇒ Multi Object AO can be realized in this mode..
  ⇒ Not Widest FOV, but Patrol type Instrument..

Under average natural seeing
MOAO mode

◆ ASM beneficial as Woofer? -> No.
◆ Anyway additional optics is needed... ➔ Negative.
Summary

✧ Good AO performance (>2-3\textmu m)
✧ AO additional optics => S/N Down >2\textmu m
  # AO sharp image => S/N Up in the end.
✧ ASM => no degradation in background.
✧ MIR band may not need AO.
✧ Great On source performance (32x32 ASM)
  => Benefit for All the Thermal IR Obs.
✧ Good GLAO performance
  => Patrol covering Wide FOV.