GNAO Science Cases

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With the GNAO science team
Why GNAO?

- GN ALTAIR system aging
- GeMS has shown the science capable with MCAO
- MK excellent site for an MCAO system
GeMS lessons learned

• GeMS+GSAOI provide exquisite image quality
• Instrumental for e.g. crowded fields
• Astrometric stability crucial for proper motion studies
• Relatively large field of view great asset.
Explosive outflows

Altair Image

Bally et al. 2015

NIRI Field of view 20”
Multi-epoch data shows material moving
High Spatial resolution

R136 in 30 Dor

GeMS/GSAOI K band 15"x10"

HST NICMOS2 F160W (Andersen et al. 2009),

Lawrence, Andersen et al. in prep
Accurate CMDs

J,K CMD of NGC 6624 with GeMS/GSAOI

Deep accurate photometry allows age determination
12+-0.5 Gyr

Saracino et al. 2016
Faint variable studies

GeMS/GSAOI imaging of CenA. Multi-epoch data will identify variable stars (LPVs).

Blakeslee et al. in prep
Faint variable studies

GeMS/GSAOI imaging of CenA. Color-magnitude diagram

Blakeslee et al. in prep
The Science team:

• Combination of Base of Gemini staff and external expertise for key areas
• Not exhaustive collection of science cases
• To explore which parameters are critical
Science team Members

M. Andersen (Gemini), J. Bally (Colorado)
J. Blakeslee (Gemini), R. Carasco (Gemini)
R. Diaz (Gemini), T. Dupuy (Gemini)
W. Fraser, A. Feldmeier-Krause (Chicago)
M. J. Jee (Yongsei), H. Kim (Gemini)
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C. Packham (San Antonio), M. Pierce (Wyoming)
T. Puzia (Univ. Catholica), J. Scharwächter (Gemini)
S. Sivanandam (Toronto), G. Sivo (Gemini)
P. Turri (NRC, HAA), C. Trujillo (N. Arizona)
Science cases:

*Driving science cases* expected to define the design
Return timely science made capable by an MCAO system

*Enabling science cases* expected to take advantage of an MCAO system

The driving science cases are discussed in this talk
Separate talks by Michael Pierce and Jessica Lu
Extragalactic Science cases:

- Central parsecs around AGNs
- AO assisted survey of $0.7 < z < 2.7$ field galaxies
- Gravitationally lensed transients
- Nuclear star clusters in local and nearby galaxies
Central parsecs around AGNs

- The interplay between SMBHs and their immediate environment
- How is Star Formation enhanced/quenched?
- Spatial resolution of <~0.1” allows to resolve ~100pc scale
- Near-IR to compensate for extinction
- Emission lines to trace inflow/outflow and velocity flow.
- R~5000 to resolve emission lines and obtain v~100km/s
Survey of $0.7 < z < 2.7$ field Galaxies

- Period of peak of cosmic Star Formation
- Crucial to understand the SF enhancement and quenching
- Major and minor mergers play large role
- Emission lines and velocity structure crucial
Natural seeing KMOS IFU obs. of a sample of z~2 field galaxies. Although spatial gradients can be measured with this resolution, there is no information about mergers.

Wuyts et al. 2016
Gravitational lensed transients

- Deep HST surveys found new transient phenomena,
- Cluster dark matter studies,
- Massive star studies,
- Expansion rate of the universe
- Regular temporal sampling is crucial for these studies
Gravitational lensed transients

Lensing and temporal sources in two clusters

Kelly et al. 2018
Nuclear star clusters in nearby galaxies

• Nuclear Star clusters common in Galaxies
• What is their origin?
• Often deeply embedded => high spatial resolution near-IR
Galactic Science cases:

- Galactic Young Massive Star Clusters
- The Galactic Nucleus
- Chemodynamics of Galactic Globular Clusters
Galactic Young Massive Star Clusters

- Rare local analogues to distant star bursts.
- Key regions to search for variations in the IMF
- The formation of the clusters poorly known
- Can they remain bound or disperse into the field?
- More details in the talk by J. Lu.
F160W image of Westerlund 1 and a ground-based color-magnitude diagram. The HST observations reach down to 0.25 Msun whereas the ground-based color-magnitude diagram only reaches 2 Msun (50% completeness). GNAO can reach the brown dwarf limit (0.08 Msun).
Galactic Center:

• Unique target, only central region to be studied in
• Star formation in an extreme environment
• How was the Galactic Center formed?
Galactic Center:

Schematic of the Galactic Center region. Most notable clusters and objects are marked.
Chemodynamics of Globular Clusters:

- How did Globular clusters form? Do they contain a black hole?
- AO assisted NIR IFU observations:
  - Determine the velocity dispersion
  - Determine the chemical abundance of each star
  - Thus probe for any IMBH in the center of the GC and
  - Correlate velocity dispersion with the chemical abundances
Giant Planet Atmospheres and their disks
Lowest-mass products of star formation
Giant Planet Atmospheres and their disks

- Wind and turbulence phenomena on giants common.
- Opportunity to look into the atmosphere
- Ice giants analogues to many extra solar planets
Gaseous planets:

The scar. Image taken with Keck II.

Right: JHK image of the impact site in Jupiter's southern hemisphere.
Gaseous planets

- Due to their size MCAO important
- SCAO images often distorted
- Moons sufficiently bright to use as WFS
- But requires non-sidereal tracking
Icy Planets

Uranus over time in the near-IR
Sromovsky & Fry
Lowest-mass products of star formation

• What is the shape of the low-mass IMF?
• Necessary to target large samples of objects, NIR, Spec. and astrometry.
• Characterize their atmosphere, comparison with giant planets
• Proper motion crucial to associate membership
Summary

- GNAO will enable a range of science, from solar system, planets, TNOs etc, over Galactic astronomy, Star Formation, Globular clusters, to extragalactic astronomy.
- High Strehl and a large field of view crucial for science cases.
- Flexibility of MCAO over SCAO important.
- In particular, nimble use and flexible scheduling allow new high resolution possibility in transient astronomy.
## Summary of requirements

<table>
<thead>
<tr>
<th>Science case</th>
<th>Spectral range [μm]</th>
<th>Field of view</th>
<th>Strehl ratio</th>
<th>Astrometric accuracy [mas]</th>
<th>Photometric accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extragalactic and cosmology</strong></td>
<td></td>
<td></td>
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<tr>
<td>High-z galaxies</td>
<td>0.9-2.5</td>
<td>3&quot; (multi-IFU)</td>
<td>&lt;100</td>
<td>~10%</td>
<td></td>
</tr>
<tr>
<td>Nuclear star clusters &amp; disks</td>
<td>0.9-2.5</td>
<td>20&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central parsecs around AGN</td>
<td>0.9-2.5</td>
<td>&lt;=10&quot;</td>
<td>60% (K)</td>
<td>~10%</td>
<td></td>
</tr>
<tr>
<td>Gravitationally lensed transients</td>
<td>0.7-2.5</td>
<td>2'</td>
<td>&gt;30% (K)</td>
<td>10</td>
<td>2%</td>
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<tr>
<td><strong>Galactic and nearby extragalactic</strong></td>
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<tr>
<td>Galactic young massive star clusters</td>
<td>1-2.4</td>
<td>&gt;2'</td>
<td>50% (K)</td>
<td>&lt;0.3</td>
<td>few %</td>
</tr>
<tr>
<td>Globular clusters</td>
<td>1.5-2.4</td>
<td>Multi-IFU patrol field 2'</td>
<td>&gt;50% (K)</td>
<td>&lt;10</td>
<td>&lt;20%</td>
</tr>
<tr>
<td>Galactic Center</td>
<td>1-2.4</td>
<td>&gt;2'</td>
<td>&lt;0.2</td>
<td>few %</td>
<td></td>
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<tr>
<td><strong>Brown dwarfs, solar system</strong></td>
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<tr>
<td>The lowest-mass products of star formation</td>
<td>1-2.5</td>
<td>~1&quot;</td>
<td>~10'</td>
<td>FWHM/stable PSF</td>
<td>n/a</td>
</tr>
<tr>
<td>Giant planet atmospheres and their disks</td>
<td>1-2.4</td>
<td>1'</td>
<td>30% (JHK)</td>
<td>&lt;1</td>
<td>few %</td>
</tr>
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