Guido Agapito
Astrobingé 15/10/2013

GIANT MAGELLAN TELESCOPE – NATURAL GUIDE STAR AO
**Giant Magellan Telescope**

**Optical configuration**: gregorian

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>24m</td>
</tr>
<tr>
<td>Segments</td>
<td>7 X 8.4m</td>
</tr>
<tr>
<td>Collecting area</td>
<td>368m²</td>
</tr>
<tr>
<td>Diffraction limit @1µm</td>
<td>9mas</td>
</tr>
<tr>
<td>AO Systems</td>
<td>SCAO, LTAO, GLAO (6 Na Lasers)</td>
</tr>
<tr>
<td>Cost</td>
<td>700 M$</td>
</tr>
</tbody>
</table>

- **Location**: Las Campanas Observatory (near Magellan telescopes).
- **Headquarters**: Pasadena, CA.
- **Partners from**: USA, Australia, Korea
- **Schedule**:
  - Start construction, early 2014
  - Early science (4 segm, No AO) 2019
  - Final commissioning 7 segm w/ AO, 2022
GMT Instrumentation

Aplanatic Gregorian
No Nasmyth focus
Primary f/0.7
Gregorian focus f/8

High spatial Resolution instruments
Wide field instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Function</th>
<th>λ Range, μm</th>
<th>Resolution</th>
<th>Field of View</th>
<th>Loc</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMACS *</td>
<td>Optical Multi-Object Spectrometer</td>
<td>0.36 - 1.0</td>
<td>1500 – 4000, 10,000</td>
<td>40 – 80 arcmin²</td>
<td>DG</td>
</tr>
<tr>
<td>NIRMOS</td>
<td>Near-IR Multi-Object Spectrometer</td>
<td>0.9 – 2.5</td>
<td>2700 – 5000</td>
<td>42 arcmin²</td>
<td>DG</td>
</tr>
<tr>
<td>G-CLEF*</td>
<td>Optical High Resolution Spectrometer</td>
<td>0.35 – 0.95</td>
<td>20 – 100K</td>
<td>7 x 1° fibers</td>
<td>GIS</td>
</tr>
<tr>
<td>GMTNIRS*</td>
<td>Near-IR AO-fed High Resolution Spectrometer</td>
<td>1.2 – 5.0</td>
<td>50 – 100K</td>
<td>Single Object</td>
<td>FP</td>
</tr>
<tr>
<td>TIGER</td>
<td>Mid-IR AO-fed Imager and Spectrometer</td>
<td>1.5 – 14</td>
<td>300</td>
<td>0.25 arcmin²</td>
<td>FP</td>
</tr>
<tr>
<td>GMTIFS*</td>
<td>NIR AO-fed IFU / Imager</td>
<td>0.9 – 2.5</td>
<td>4000 – 10,000</td>
<td>10 / 400 arcsec²</td>
<td>FP</td>
</tr>
<tr>
<td>MANIFEST*</td>
<td>Facility Robotic Fiber Feed</td>
<td>0.36 – 1.0</td>
<td>300 arcmin²</td>
<td></td>
<td>DG</td>
</tr>
</tbody>
</table>

DG = Direct Gregorian
GIS = Gravity-Invariant instrument Station
FP = Folded Ports

First Generation
**GMT Adaptive Optics**

Adaptive secondary mirror feeding all the focal stations 7 deformable shells of 1.1m 4700 actuators

**Adaptive optics modes**

- **Natural Guide Star AO (NGSAO):**
  - Single Conjugate Adaptive Optics (SCAO)

- **Laser Tomography AO (LTAO):**
  - 6 sodium lasers.

- **Ground Layer AO (GLAO):**
  - Direct Gregorian instrumentation.

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High spatial Resolution instruments
Natural Guide Star AO

- Single Conjugate Adaptive Optics (SCAO):
  - Correction on a small FoV:
    - High Strehl Ratio.
    - High contrast.
  - Bright Guide Star (GS).
- Pyramid WaveFront Sensor (PWFS):
  - Sampling frequency up to 1kHz.
  - 92x92 sub-apertures.
- First AO system with GMTIFS (Near-IR IFU and Adaptive Optics Imager)

Arcetri Adaptive Optics group – contract

- GMTO contacts Arcetri AO group to develop the NGSAO:
  - Contract for *Preliminary Design Study* - Kick Off Meeting 01/2012
Segmented pupil → new problem

- Classic AO + co-phasing required:
  - Pyramid wavefront sensor can measure differential piston (PYramid Phasing Sensor - PYPS for the ESO Active Phasing Experiment - APE).

- Big separation between segments (w.r.t. wavelength):
  - “weak” signal.
  - High probability of “big” (> 1 wavelength) differential segment piston.

![Diagram of segmented pupil and phase correction](image)
WF phase 2πi ambiguity

- Single wavelength WFS is blind to wave multiples:
  - Simulations show that at times segments converge to $\lambda$–multiples ($\lambda = 750\text{nm}$).

- Two wavelengths technique implemented:
  - Firstly developed for APE (non-real-time, no AO correction)
  - Needs one WFS for each wavelength (real-time and AO correction).
Design

- The WFS design has two pyramids allowing parallel sensing at 2 wavelength.
Performance (E2E simulation)

• Condition:
  - Seeing 0.63"
  - Mean wind speed 13.5m/s
  - 8th magnitude GS
  - K band (2.2μm)
• SR = 95.6%
• Residual WF = 74nm RMS

Arcetri Adaptive Optics group – contract

• GMTO **APPROVED** Preliminary Design Study - 07/2013
• New contract for *Prototyping and Simulation Study* – Kick Off Meeting 10/2013 – end 02/2015
Science with GMT NGSAO

Natural seeing 0.6"

HST - NICMOS

Crowded fields
Simulated
K-band imaging of a dense star cluster

JWST NIRCAM

GMT Strehl Ratio 80%

Credit: P. McCarthy

Exoplanets
Simulated GMT observations of the β Pic system

... and much more!
(see science cases @ www.gmto.org)