GeMS/GSAOI

“A New Generation of Adaptive Optic”

R. Carrasco, B. Neichel, F. Rigaut, M. Boccas, C. D'Orgeville, C. Trujillo, G. Trancho, V. Fesquet, M. Edwards + all GeMS/GSAOI teams

Gemini Observatory
Adaptive Optic

AO system: very basic scheme
GeMS: Gemini MCAO System

- Adaptive Optic facility for the Gemini South Telescope
- 3 main sub-systems:
  - Laser + Laser Launch Telescope (LTT)
  - Beam Transfer Optic (BTO)
  - Canopus (AO bench)
- Goal \(\rightarrow\) deliver (diffraction limited + uniform) image quality (Near IR) in a FoV > 1 arcmin^2
- Two dedicated instruments:
  - GSAOI (NIR imager)
  - Flamingos-2 (NIR Imager and spectrograph).

- Strehl ratio under median seeing 0.7” (expected): ~15% (J), ~35% (H), ~55% (K)
- Strehl uniformity: 5% (J), 2% (K)
- Requires 3 TTP WFS (R<17.5mag)
GeMS Introduction

Schematics of the three sub-systems
1 x 50W laser is divided in 5x10W beams placed on the corner and center of a 1’ FoV.
GeMS Introduction

- 1 x 50W laser is divided in 5x10W beams placed on the corner and center of a 1’ FoV
- 5 (16x16) SHWFS - 3DMs (totaling 917 actuators) - 800Hz conjugated at 0, 4.5, 9 km
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October 30, 2011

SGDW - SJ dos Campos
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- 1 x 50W laser is divided in 5 x10W beams placed on the corner and center of a 1’ FoV
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- 2 dedicated NIR instruments (GSAOI 4k²-80”-20mas, F2 MOS-2’)
- Many other loops, LUT, offloads…

Diagram:

- LGS light
- TT NGS light
- NIR light
- LGSs
- NGSs
- Laser
- GeMS
- RTC
- M2
- M1
- Cassegrain rotator
- 3 DMs (0, 4.5, 9 km)
- M2 Offload (200Hz)
- 1 flexure GS
- LGS ZOOM
- LGS MAG. CORRECTOR
- 5 WFS (16x16)
- LGS light
- TT NGS1
- TT NGS2
- TT NGS3
- Slow Focus Sensor
- Slow Steering mirrors
- Fast Steering mirrors
- Derotator
- LUT
GSAOI introduction

- Gemini South Adaptive Optic Instrument (GSAOI) – near-infrared adaptive optic camera for use with GeMS
- Diffraction limited images at 0.9 – 2.5 µm
- 4080 x 4080 Rockwell HAWAII-2RG HgCdTe/CdZnTe illuminated array (Mosaic of 2 x 2 detectors). Gaps of 2.6”-2.8” (2mm)
- 0.02”/pixel plate scale; 85" x 85” FOV
- Broad-band filters: Z, J, H, Ks, K', K
- 16 Narrow-band filters: zero-redshift emission lines
- On-Detector Guide Windows: User-selectable, one per detector mosaic quadrant
- Configurable ROIs
### Available GSAOI Filters

<table>
<thead>
<tr>
<th>Filter Name</th>
<th>Central Wavelength (μm)</th>
<th>Coverage (μm)</th>
<th>50% cut-on Wavelength (μm)</th>
<th>50% cut-off Wavelength (μm)</th>
<th>Gemini Filter Number</th>
<th>Transmission Curves</th>
<th>Filter ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broad-band filters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>1.015</td>
<td>0.170</td>
<td>0.930</td>
<td>1.100</td>
<td>G1102</td>
<td>plot / data</td>
<td>ED205-1</td>
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<tr>
<td>J</td>
<td>1.250</td>
<td>0.160</td>
<td>1.170</td>
<td>1.330</td>
<td>G1103</td>
<td>plot / data</td>
<td>ED191-1</td>
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<tr>
<td>H</td>
<td>1.635</td>
<td>0.290</td>
<td>1.490</td>
<td>1.780</td>
<td>G1104</td>
<td>plot / data</td>
<td>ED169-1</td>
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<tr>
<td>K(prime)</td>
<td>2.120</td>
<td>0.340</td>
<td>1.950</td>
<td>2.290</td>
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<td>K(short)</td>
<td>2.150</td>
<td>0.320</td>
<td>1.990</td>
<td>2.310</td>
<td>G1106</td>
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<tr>
<td>K</td>
<td>2.200</td>
<td>0.340</td>
<td>2.030</td>
<td>2.370</td>
<td>G1107</td>
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<td>ED192-1</td>
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<td>Narrow-band (zero redshifted) emission- and absorption-line filters</td>
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<td></td>
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<tr>
<td>J-continuum</td>
<td>1.207</td>
<td>0.018</td>
<td>1.198</td>
<td>1.216</td>
<td>G1108</td>
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<td>ED190</td>
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<tr>
<td>H-continuum</td>
<td>1.570</td>
<td>0.024</td>
<td>1.558</td>
<td>1.582</td>
<td>G1109</td>
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<td>ED141</td>
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<tr>
<td>CH$_2$(short)</td>
<td>1.580</td>
<td>0.100</td>
<td>1.530</td>
<td>1.630</td>
<td>G1110</td>
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<td>CH$_4$(long)</td>
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<td>0.100</td>
<td>1.640</td>
<td>1.740</td>
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<td>K(short)continuum</td>
<td>2.093</td>
<td>0.031</td>
<td>2.078</td>
<td>2.108</td>
<td>G1112</td>
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<tr>
<td>K(long)continuum</td>
<td>2.270</td>
<td>0.034</td>
<td>2.253</td>
<td>2.287</td>
<td>G1113</td>
<td>plot / data</td>
<td>ED163</td>
</tr>
<tr>
<td>He I 1.083μm</td>
<td>1.083</td>
<td>0.016</td>
<td>1.075</td>
<td>1.091</td>
<td>G1117</td>
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<td>ED185</td>
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<tr>
<td>H I Pγ</td>
<td>1.094</td>
<td>0.011</td>
<td>1.089</td>
<td>1.100</td>
<td>G1118</td>
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<td>ED186</td>
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<tr>
<td>H I Pδ</td>
<td>1.282</td>
<td>0.019</td>
<td>1.272</td>
<td>1.292</td>
<td>G1119</td>
<td>plot / data</td>
<td>ED231</td>
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<tr>
<td>[Fe II] 1.644μm</td>
<td>1.644</td>
<td>0.025</td>
<td>1.631</td>
<td>1.656</td>
<td>G1120</td>
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<td>ED150</td>
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<tr>
<td>H$_2$O</td>
<td>2.000</td>
<td>0.080</td>
<td>1.960</td>
<td>2.040</td>
<td>G1121</td>
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<td>ED188</td>
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<tr>
<td>He I (2p2s)</td>
<td>2.058</td>
<td>0.031</td>
<td>2.042</td>
<td>2.073</td>
<td>G1122</td>
<td>plot / data</td>
<td>ED165</td>
</tr>
<tr>
<td>H$_2$ 1-0 S(1)</td>
<td>2.122</td>
<td>0.032</td>
<td>2.106</td>
<td>2.138</td>
<td>G1123</td>
<td>plot / data</td>
<td>ED162</td>
</tr>
<tr>
<td>H I Brγ</td>
<td>2.166</td>
<td>0.032</td>
<td>2.150</td>
<td>2.182</td>
<td>G1124</td>
<td>plot / data</td>
<td>ED166</td>
</tr>
<tr>
<td>H$_2$ 2-1 S(1)</td>
<td>2.248</td>
<td>0.034</td>
<td>2.231</td>
<td>2.265</td>
<td>G1125</td>
<td>plot / data</td>
<td>ED164</td>
</tr>
<tr>
<td>CO Δv=2</td>
<td>2.360</td>
<td>0.080</td>
<td>2.320</td>
<td>2.400</td>
<td>G1126</td>
<td>plot / data</td>
<td>ED187</td>
</tr>
</tbody>
</table>
### GSAOI introduction

#### Detector Characteristics

<table>
<thead>
<tr>
<th>Type</th>
<th>Rockwell HAWAII-2RG HgCdTe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Array sizes</td>
<td>2048 x 2048 pixels each (2040 x 2040 active)</td>
</tr>
<tr>
<td>Detector area</td>
<td>4080 x 4080 pixels (~ 85&quot; x 85&quot;)</td>
</tr>
<tr>
<td>Physical Pixel size</td>
<td>18 µm</td>
</tr>
<tr>
<td>Pixel scale</td>
<td>0.02&quot; (TBC)</td>
</tr>
<tr>
<td>Spectral Response</td>
<td>0.9 µm to 2.6 µm (data / plot)</td>
</tr>
</tbody>
</table>

#### Gains

- ~ 2.8 e-/ADU (TBC)
- ~ 0.01 e-/s/pix (~12 e- in the maximum integration time of 20 minutes)
- ~ 48,000 ADU (TBC)

#### On-Detector Guide Windows (ODGW)

- One programmable ODGW per detector

<table>
<thead>
<tr>
<th>Mode</th>
<th>Nº of Fowler Samples (LNRS)</th>
<th>NDR (non-destructive reads)</th>
<th>Read-Out Time (*)</th>
<th>Read Noise (ADU)</th>
<th>Read Noise (e-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bright Object</td>
<td>1</td>
<td>2</td>
<td>5.3 sec</td>
<td>~ 8.9 (TBC)</td>
<td>25 (TBC)</td>
</tr>
<tr>
<td>Faint Object</td>
<td>8</td>
<td>16</td>
<td>42.4 sec</td>
<td>~ 4.3 (TBC)</td>
<td>12 (TBC)</td>
</tr>
<tr>
<td>Very Faint Object</td>
<td>16</td>
<td>32</td>
<td>84.8 sec</td>
<td>~ 2.9 (TBC)</td>
<td>8 (TBC)</td>
</tr>
</tbody>
</table>
GSAOI introduction

Sensitivity Table

For additional information see the GSAOI public Web page.

<table>
<thead>
<tr>
<th>Filter</th>
<th>Limiting Magnitude (mag)</th>
<th>Saturation Magnitude (mag)(1)</th>
<th>Assumed Strehl Ratio</th>
<th>Sky Brightness (mag/arcsec²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>25.6</td>
<td>14.8</td>
<td>0.2</td>
<td>17.1</td>
</tr>
<tr>
<td>J</td>
<td>24.1</td>
<td>13.9</td>
<td>0.2</td>
<td>14.9</td>
</tr>
<tr>
<td>H</td>
<td>24.1</td>
<td>14.0</td>
<td>0.4</td>
<td>14.0</td>
</tr>
<tr>
<td>K(prime)</td>
<td>23.9</td>
<td>13.3</td>
<td>0.6</td>
<td>13.5</td>
</tr>
<tr>
<td>K(short)</td>
<td>23.8</td>
<td>13.2</td>
<td>0.6</td>
<td>13.4</td>
</tr>
<tr>
<td>K</td>
<td>23.7</td>
<td>13.2</td>
<td>0.6</td>
<td>13.3</td>
</tr>
<tr>
<td>J-continuum</td>
<td>23.1</td>
<td>11.7</td>
<td>0.2</td>
<td>15.0</td>
</tr>
<tr>
<td>H-continuum</td>
<td>22.9</td>
<td>11.5</td>
<td>0.4</td>
<td>14.1</td>
</tr>
<tr>
<td>CH₄(short)</td>
<td>23.6</td>
<td>13.1</td>
<td>0.4</td>
<td>13.9</td>
</tr>
<tr>
<td>CH₄(long)</td>
<td>23.4</td>
<td>12.7</td>
<td>0.4</td>
<td>13.8</td>
</tr>
<tr>
<td>K(short)</td>
<td>22.7</td>
<td>10.9</td>
<td>0.6</td>
<td>13.6</td>
</tr>
<tr>
<td>K(long)</td>
<td>22.5</td>
<td>10.6</td>
<td>0.6</td>
<td>13.5</td>
</tr>
<tr>
<td>He I 1.083 µm</td>
<td>23.7</td>
<td>12.0</td>
<td>0.2</td>
<td>16.1</td>
</tr>
<tr>
<td>H I Py</td>
<td>23.5</td>
<td>11.5</td>
<td>0.2</td>
<td>16.2</td>
</tr>
<tr>
<td>H I Pβ</td>
<td>22.5</td>
<td>11.5</td>
<td>0.2</td>
<td>14.0</td>
</tr>
<tr>
<td>[Fe II] 1.644 µm</td>
<td>22.7</td>
<td>11.4</td>
<td>0.4</td>
<td>13.8</td>
</tr>
<tr>
<td>H₂O</td>
<td>23.3</td>
<td>11.8</td>
<td>0.6</td>
<td>13.9</td>
</tr>
<tr>
<td>He I (2p2s)</td>
<td>22.5</td>
<td>10.8</td>
<td>0.6</td>
<td>13.3</td>
</tr>
<tr>
<td>H₂ 1-0 S(1)</td>
<td>22.6</td>
<td>10.8</td>
<td>0.6</td>
<td>13.4</td>
</tr>
<tr>
<td>H I Brγ</td>
<td>22.6</td>
<td>10.7</td>
<td>0.6</td>
<td>13.5</td>
</tr>
<tr>
<td>H₂ 2-1 S(1)</td>
<td>22.5</td>
<td>10.6</td>
<td>0.6</td>
<td>13.5</td>
</tr>
<tr>
<td>CO Δν=2</td>
<td>22.4</td>
<td>11.2</td>
<td>0.6</td>
<td>12.6</td>
</tr>
</tbody>
</table>

(1) Assumes a Strehl efficiency of 0.75
GeMS/GSAOI Science

Key Science drivers for GSAOI identified by Gemini Community
Santa Cruz, CA, October 2000

- Low mass stellar and sub-stellar mass functions in young star-forming regions
- Stellar population variations in star-forming regions (e.g. Ophiuchus).
- Open cluster mass functions to the bottom of the H-burning sequence and the end of the white dwarf cooling sequence to provide independent age determinations.
- Mass functions in nearby globular clusters over a range of metallicities.
- Stellar populations of super-star cluster analogs in the Galaxy and Magellanic Clouds such as NGC 3603 and 30 Doradus.
- SN1a zero point calibration via red giant branch tip star distances to E/S0 galaxies.
- Stellar populations in starburst regions of nearby galaxies.
- Evolution of dIrr versus dE galaxies in different environments.
- Early chemical histories of nearby galaxy spheroids.
- Intergalactic stars in nearby galaxy clusters.
- Color distributions among extragalactic globular clusters.
- Spatially resolved spectral energy distributions of high redshift field galaxies.
- Evolution of galaxies in high redshift clusters.

10 Years later still important science!
GeMS status: a Long Path

- 2007 – 2010 → Canopus characterization and integration of the opto-mechanical components
- March 2010 – July 2010 → Laser arrives and integration starts in the Lab
- July 2010 – Laser passed the AT and installed in the Laser enclosure (LSE)
- October 2010 – Laser high power spec achieved (57.6 Watts)
- January 2011(4 days) – First LGSF → the Laser is propagated
- February – May 2011 → Canopus Commissioning + GSAOI pre-commissioning blocks – May lost due to weather.
- April 2011 – fist light
- November 2011 – commissioning resumes
- 2012A – SV, 2012B → offer to community
GeMS status: a Long Path
Commissioning team

Australia National University (ANU):
- Peter McGregor (PI)
- Peter Young (PM)
- Matt Doolan (SE)
- Jan van Harmelen

Gemini Science Team:
- Rodrigo Carrasco (IS, PM)
- Michelle Edwards
- Claudia Winge
- Peter Pessev
- Ariel Lopez
- Felipe Colazo *

Core Gemini Team:
- Maxime Boccas (PM: GeMS)
- Francois Rigaut (PI: GeMS)
- Benoit Neichel (IS, GeMS)
- Chad Trujillo (GeMS)
- Mathieu Bec (PM: Canopus)*
- Celine D'Orgeville (PM: LGSF)
- Gelys Trancho (SE)*

Gemini Engineering Group
Gemini Software Group
At the summit → up to 22 people!!

Optic/Laser

SOS

Sys. Eng.

Spotter

GSAOI

Mech. P.M.

Electronics

Software

Visitors

Adaptive Optics

October 30, 2011

SGDW - SJ dos Campos
Commissioning preparation

Observing preparation → crucial step

- Includes: (Felipe Colazo)
  - Select the targets for a different commissioning runs
  - Prepare the list of target to submit to the Laser Clearinghouse (Space Command)
- Observations
- Results and Feedback
- Targets → different fields: standard stars, astrometric fields, open clusters, etc..
- Guiding capabilities define the type of targets for observation
  - 3 CWFS + 1 ODGW (flexure, 100Hz)
  - 1 CWFS (Slow focus) + 3 ODGW (flexure and Tip/Tilt at 800 Hz)
- Observing Tool, Mascot, and large catalogs.
Commissioning preparation

Target Selection

- For each commissioning run
  - Targets with elevations higher than 45 degrees
  - Bright sources to test and characterize the Canopus WFS and define the GSAOI Hot Spot position
  - Astrometric fields to derive the GSAOI IAA, WCS, etc

- Tools used
  - Mascot
  - Observing Tool
Canopus Field of View

➢ Almost 2’ FOV on the sky
Mascot

- Developed by F. Rigout
- Creates Strehl maps of a field with different triangular configuration of guide stars chose
- It delivers a very accurate model of what can be done by the AO
- Implemented in the Observing Tool (March 2012)
- Implementation in the PIT (2012B?)
Commissioning preparation

Good strehl map

Not so good strehl map
GeMS/GSAOI Commissioning

Commissioning preparation with Mascot soQware included (prototype)
Commissioning preparation

Science Targets with good constellations

Puppis, Messier 93

ESO 434-34
GeMS comm. results

GeMS Loops
- Loop closed
  - FSA (Fast Steering Mirrors) offloads
  - LGS high order
  - M1 offloads
  - M2 offloads
  - Tip/Tilt from 3 NGS
- Missing
  - Plate scale
  - Dithering
  - Slow focus WFS
GSAOI comm. results

Day time
- Pupil alignment
- Detector characterization: read noise, dark, bad pixel mask
- GCAL configuration and exp. times setup for all filters
- Extensively software testing. A lot bug and problems fixed
- Commissioning script in IRAF completed → base of the GSAOI reduction package.
- Derived the linearity correction and gains for all detectors

Night time
- Initial Instrument Alignment Angle and WCS solution (AO loop open)
- ODGW probe mapping → very good progress
GeMS/GSAOI comm. results

FIRST LIGHT IMAGE!!
April 2011
- Eng. First light (H2 filter)
- 6 loops/offloads closed
- No SFS
- No performance optimization
- No flexure compensation from ODGW
- Obtained after crude focus run
- Demonstrate basic features of MCAO
GeMS/GSAOI commissioning

Next few months

- November 2011/December 2011 – GeMS
  - Laser checks
  - Finish functionality and technical commissioning
  - Performance Optimization
  - Complete the integration into operation
  - Some GSAOI pending tasks (day time)

- January/February 2012 – GeMS/GSAOI
  - GSAOI commissioning: hotspot, IAA, WCS with loop closed
  - GSAOI detector performance: throughput, etc, on-sky
  - Science Commissioning

Stay tuned!!!
Thanks for your attention!!

Gracias por su atención!!

Obrigado pela sua atenção!!