TMT Science Instruments: First-Light and Beyond

Dave Andersen
Science Instruments Group Lead

April 25 and April 27
TMT at a “Sweet Spot”

• Provides a **dramatic increase in science performance** compared to today’s 8-10m telescope in terms of angular resolution ~ D^-1 and sensitivity ~ D^2 (for AO, point source sensitivity scales as ~ D^4)

• While **maintaining cost and technical challenges at reasonable levels**
  - Simple RC optical design
  - Steerable M3
  - Instruments all on gravity-invariant Nasmyth platforms
TMT Adaptive Optics

- TMT designed with Adaptive Optics (AO) in mind
  - Minimize vibration and uncorrectable errors
- AO Facilities
  - NFIRAOS – Multi-Conjugate Adaptive Optics (MCAO) system – **Completed Final Design Review**
  - Laser Guide Star Facility – **Preliminary Design Review in less than 6 months**
  - AO Software – **Real Time Controller** in production
500k stars in 34”x34” FOV - T. Do (UCLA)

NFIRAOS AO Simulation (L. Wang)
TMT Adaptive Optics Capabilities

- Uniform, high Strehl ratio (50% in H-band) performance over 30” field of view
- Designed to produce high sky coverage (>50% sky coverage near the North Galactic Pole)
- Enables high precision astrometry (<50 μas RMS)
TMT First Light Instruments

- **IRIS - InfraRed Imaging Spectrograph**
  - Near Infrared Imager and Integral Field Spectrograph
  - Fed by MCAO system NFIRAOS
  - PI: Larkin (UCLA) PS: Wright (UCSD)
    - Team: UCLA, UCSD, CIT, NRC HAA, NAOJ, TIO
  - **Final Design Phase**

- **WFOS - Wide-Field Optical Spectrograph**
  - Optical Multi-Object Spectrograph with Imaging Capability
  - PI: Steidel (CIT) PS: Peng (NOIRLab)
    - Team: CIT, ITCC, NAOJ, TIO
  - **Preliminary Design Phase**

- **MODHIS - Multi-Objective Diffraction-limited High-resolution Infrared Spectrograph**
  - Near Infrared High Spectral Resolution Precision Radial Velocity Spectrograph
  - Fed by MCAO system NFIRAOS
  - PI: Mawet (CIT) co-PI: Fitzgerald (UCLA) PS: Konopacky (UCSD)
    - Team: UCLA, UCSD, CIT, TIO
  - **Conceptual Design Phase**
TMT Instrument Layout

- Large Nasmyth Platforms will support all first decade instruments
- Flexible space will allow TMT instrumentation to grow and evolve over observatory lifetime
First light instruments match top priorities in Astro2020:
- Adaptive Optics
- Multi-Object Spectroscopy
- High-Resolution Spectroscopy
## Instrumental Capabilities: Beyond First Light …

<table>
<thead>
<tr>
<th>Instrument and Description</th>
<th>λ Range (μm)</th>
<th>Spectral Resolution</th>
<th>Modes</th>
<th>Field of View</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLAO/Ground Layer Adaptive Optics (feeds WFOS and HIROS)</td>
<td>0.31 – 1.0</td>
<td>N/A</td>
<td>GLAO</td>
<td>Large enough to cover WFOS</td>
</tr>
<tr>
<td>MIRAO/Mid-Infrared Adaptive Optics (feeds MICHI)</td>
<td>4.5 – 28</td>
<td>N/A</td>
<td>LGS MIRAO, high contrast</td>
<td>&gt;10’ (1’ goal)</td>
</tr>
<tr>
<td>PSI PFI/Planet Formation Instrument</td>
<td>0.6 – 5.3</td>
<td>(fiber fed) High resolution R &gt; 100K, IFS Medium resolution R &gt; 5,000, IFS Low resolution R &gt; 50</td>
<td>ExAO</td>
<td>2–5.3 μm only: 1.2’’ x 1.2’’ (low resolution) 0.15’’ x 0.15’’ (medium resolution)</td>
</tr>
<tr>
<td>MICHI MURES/ Mid-Infrared Echelle Spectrometer</td>
<td>3.4 – 13.8</td>
<td>Imager &lt; 100, IFS 600–1,000, Spectrometer 120,000</td>
<td>MIRAO</td>
<td>Imager: 28.1’’ x 28.1’’ @ 11 mas/pix N band, IFU: 0.175’’ x 0.07’’ (35 mas/spaxel)</td>
</tr>
<tr>
<td>HROS/High-Resolution Optical Spectrograph</td>
<td>0.31 – 1</td>
<td>Single Object: 100,000 &amp; 50,000 (fibers), 40,000 &amp; 20,000 (slits), Multi-Object: 25,000</td>
<td>Seeing-limited GLAO</td>
<td>&gt; 10’ in diameter (single object mode) 10’–20’ diameter (multi-object mode)</td>
</tr>
<tr>
<td>IRMOS/IR Multi-Object Spectrograph</td>
<td>0.8 – 2.5</td>
<td>2,000 – 10,000</td>
<td>MOAO</td>
<td>&gt; ten 3’ IFUs deployable within a 5’ diameter field</td>
</tr>
</tbody>
</table>
Discovery Space:
First-light & First-Decade Instruments
Want to learn more or get involved?

- TMT’s web page (tmt.org) has up-to-date information on all the first light instruments and AO systems
- Contact me: dandersen@tmt.org
- Contact Warren Skidmore: was@tmt.org
- Reach out to any of the Principal Investigators or Project Scientists
The TMT Project gratefully acknowledges the support of the TMT collaborating institutions. They are the California Institute of Technology, the University of California, the National Astronomical Observatory of Japan, the National Astronomical Observatories of China and their consortium partners, the Department of Science and Technology of India and their supported institutes, and the National Research Council of Canada. This work was supported as well by the Gordon and Betty Moore Foundation, the Canada Foundation for Innovation, the Ontario Ministry of Research and Innovation, the Natural Sciences and Engineering Research Council of Canada, the British Columbia Knowledge Development Fund, the Association of Canadian Universities for Research in Astronomy (ACURA), the Association of Universities for Research in Astronomy (AURA), the U.S. National Science Foundation, the National Institutes of Natural Sciences of Japan, and the Department of Atomic Energy of India.