Keck Observatory
Adaptive Optics: Future Plans

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For Keck AO team & AOWG

CfAO Retreat
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Presentation Sequence

- Where have we been?
- Where are we going?
- How do we get there in the near term?
# Major Milestones

<table>
<thead>
<tr>
<th>Date</th>
<th>Telescope</th>
<th>Milestone</th>
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<tbody>
<tr>
<td>2/99</td>
<td>K2</td>
<td>AO 1&lt;sup&gt;st&lt;/sup&gt; light with KCAM</td>
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<tr>
<td>8/99</td>
<td>K2</td>
<td>AO/KCAM available for science</td>
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<tr>
<td>2/00</td>
<td>K2</td>
<td>NIRSPEC 1&lt;sup&gt;st&lt;/sup&gt; light with AO</td>
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<tr>
<td>8/00</td>
<td>K2</td>
<td>AO/NIRSPEC available for science</td>
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<tr>
<td>12/01</td>
<td>K1</td>
<td>AO 1&lt;sup&gt;st&lt;/sup&gt; light with KCAM</td>
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<tr>
<td>3/01</td>
<td>K1&amp;2</td>
<td>Interferometer 1&lt;sup&gt;st&lt;/sup&gt; light w/ both AO systems</td>
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<tr>
<td>8/01</td>
<td>K2</td>
<td>NIRC2 1&lt;sup&gt;st&lt;/sup&gt; light with AO</td>
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<tr>
<td>9/01</td>
<td>K2</td>
<td>AO/NIRC2 available for science</td>
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<tr>
<td>12/01</td>
<td>K2</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; laser projection</td>
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<tr>
<td>7/03</td>
<td>K1&amp;2</td>
<td>Interferometer 1&lt;sup&gt;st&lt;/sup&gt; published science</td>
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<td>9/03</td>
<td>K2</td>
<td>LGS AO 1&lt;sup&gt;st&lt;/sup&gt; light with NIRC2</td>
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AOWG Strategic Recommendations

1. Improved performance of the present AO systems
2. Completion of the LGS system & associated instrumentation
3. Next generation, advanced AO systems

The Observatory’s 30-year plan’s strategic science goals highlight adaptive optics and interferometry.
Keck AO Future: AOWG Roadmap

- Design studies funded by CfAO
- $2M proposal submitted to Keck Foundation
- Preliminary requirements only – Needs design funds
AOWG: Ranked list of specific recommended near-term projects

1. K2 LGS AO facility available for science
2. Performance characterization of current system
3. OSIRIS implementation with K2 AO
4. New wavefront controller implementation
5. Implementation of an NSF funded K1 Laser
6. KPAO studies
7. XAOPI interface design support & design review

Additional Priorities

8. Operations (NIRC2, NIRSPEC, Interferometer)
9. Modifications to support Interferometer development
1. LGS AO Facility

- Top-level milestones (as of fall/02):
  - ✔ 9/03 - 1st corrected images on NIRC2 with laser
    - Achieved Sept. 18 & 19, 2003
  - 12/03 – LGS AO facility operable by AO experts
  - 3/04 – 1st engineering science
  - 6/04 – 1st shared risk science
  - 3/05 – Operable for science by OA & 1 expert
  - 6/05 – 1st queue scheduled science

Keck II laser guide star adaptive optics
star s00582+1801, V = 14.0
2.1 μm, 30s exposure

natural guide star
fwhm: 70.3 mas
strehl: 18.6%

laser guide star
fwhm: 49.7 mas
strehl: 36.2%
2. Performance Characterization

- Significant progress in understanding & improving the NGS performance in FY03. Will continue on several fronts:
  - Performance characterization & improvement
  - Improvements in reliability, operations ease & capabilities
  - Improvements in facility reliability / cleanliness
  - Atmospheric characterization tools
  - NIRC2 characterization
  - Telescope characterization & optimization

- Seeing = 0.45” at H

\[ V = 7.5 \]
\[ \text{SR} = 0.38 \]
\[ \text{FWHM} = 36.5 \text{ mas} \]

\[ V = 12 \]
\[ \text{SR} = 0.23 \]
\[ \text{FWHM} = 41 \text{ mas} \]
3. OSIRIS Implementation

- AO optimized spectroscopy
  - Complex object geometry
  - High sensitivity
4. New Wavefront Controller

- To stay competitive mid-term we need to improve Keck AO performance.
- Keck Foundation proposal for new wavefront sensor cameras & real-time processors for K1 & K2
  - + improved maintainability & flexibility for optimization
5. NSF funded laser for K1

- **Rationale:**
  - A commercial facility class laser on K1 should improve reliability of LGS at Keck.
  - Major non-AO driver - laser would relieve the current instrument imbalance between K1 and K2 by bringing LGS/OSIRIS to K1.
  - It may also open up unique interferometry opportunities
- **NSF funding received for laser, not implementation**
  - Original proposal requested 2 facility-class lasers (1 each for Gemini & Keck) + funds for advanced laser development
  - USAF provided funds used to develop AFRL laser + NSF & Gemini partner funds used to fund CTI laser for Gemini
- **RFP to be issued in Jan/04. AoA distributed in Oct/03.**
6. KPAO Studies

- Long term success relies on our ability to maintain leadership in high resolution observations. Requires a new more advanced AO system.
- Science cases range from climatic changes on Pluto to low mass stellar population studies to star formation in quasar host galaxies.
- High Strehl (2 cases being evaluated: 120 & 180 nm rms), high Strehl stability, well known PSF, moderate fov, near complete sky coverage, 0.45 to 14 um for science.
- Prioritized FY04 tasks
  - Complete requirements & error budget. Spring/04 meeting.
  - Identify a project scientist?
- Proposed schedule:
  - 4/05 CoDR for KPAO & science instrument(s) complete
  - ... 10B 1st shared risk science
7. XAOPI Interface

- XAOPI offers the Keck community a unique opportunity to perform very high dynamic range AO science (e.g. companions and disks)
- This is a very modest effort in FY04 but could have big long term science payoff.
- FY04/ Support CoDR & PDR preparation
  - Primarily thru interface & requirements definition
8. NGS AO Operations

- 65-75 NGS AO science nights / year
- 25-30 Interferometer nights / yr

Science
- 37 papers
- 17 in 2002
9. Interferometer

- AO modifications in support of
  - V2 science mode Operational Readiness Review (Jan/04)
  - Nulling & Differential Phase
Next Generation Interferometer: 
OHANA
(Optical Hawaiian Array for Nanoradian Astronomy)

• Largest optical astronomical site of quality in the world

• 3 4m-class telescopes and 4 8-10m-class telescopes with adaptive optics

Unique opportunity to build the most resolving and sensitive interferometer with no competitor for more than a decade if telescopes are combined using single-mode fibers
The LGS AO Team in Celebration (Sept/03)