California Extremely Large Telescope (CELT)

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- **Status**

California Extremely Large Telescope

- CELT is a study to build a 30-m telescope
- UC and Caltech are partners
- Funding is not yet in hand
- Site is unknown (several candidates)

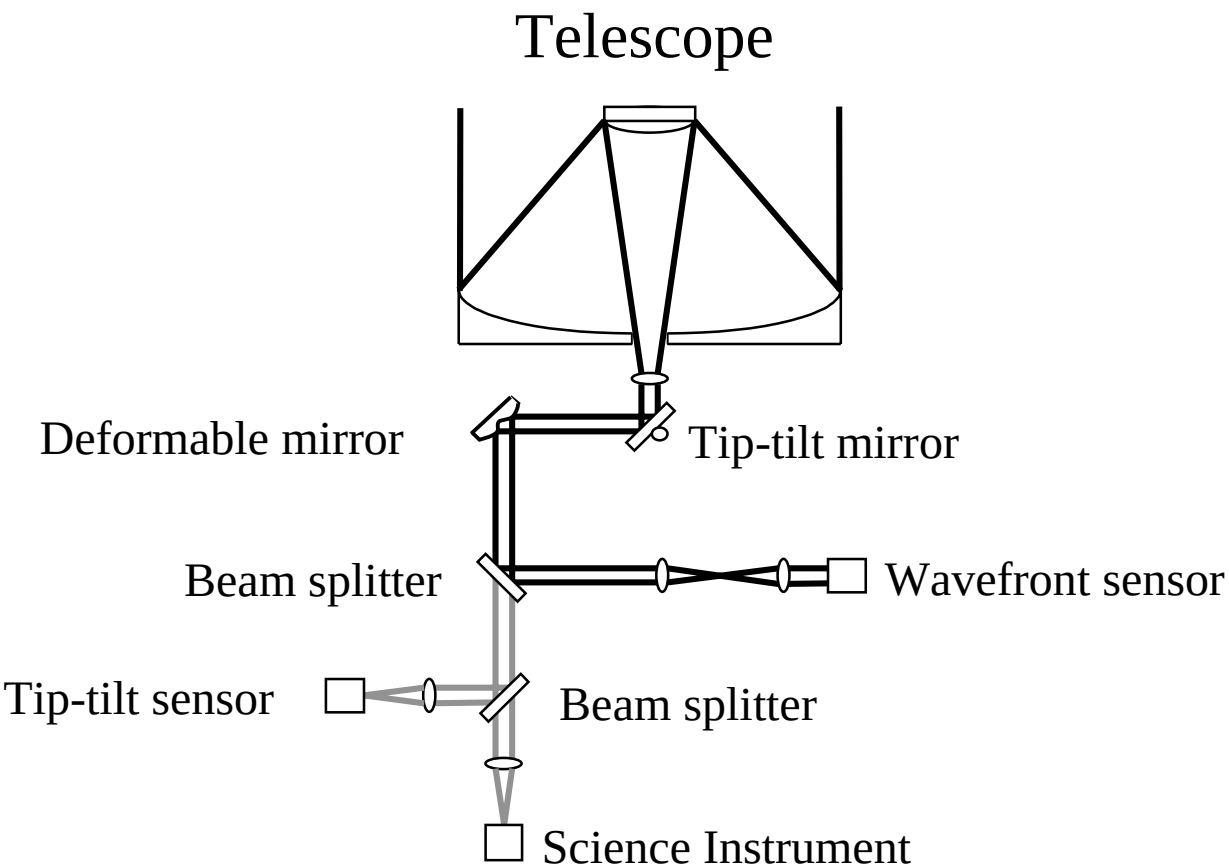
Science Potential for CELT

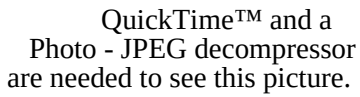
- **Increased angular resolution**
  - With AO can reach 0.007 arc second resolution (100x improvement)
  - Study morphological details of most distant galaxies (cosmology)
  - Study details for star and planet formation
  - Study stellar evolution in globular clusters
  - Quasars and Active Galactic Nuclei (black holes)
  - Solar system objects
- **Increased light gathering power**
  - With CELT can collect 9x the energy from an object (over Keck)
  - Spectroscopy of most distant objects known
  - Planet searches and their study

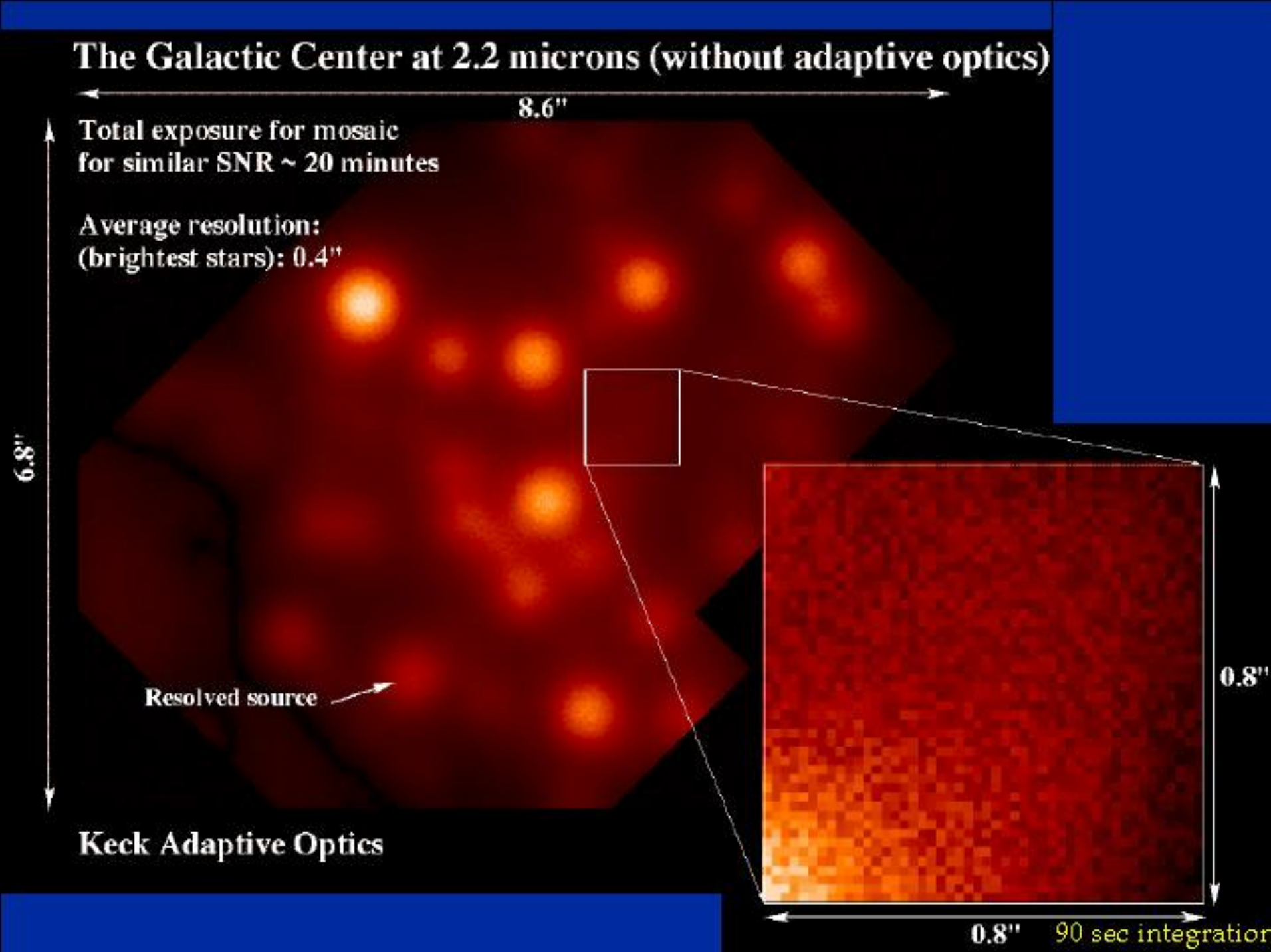
Scientific Potential

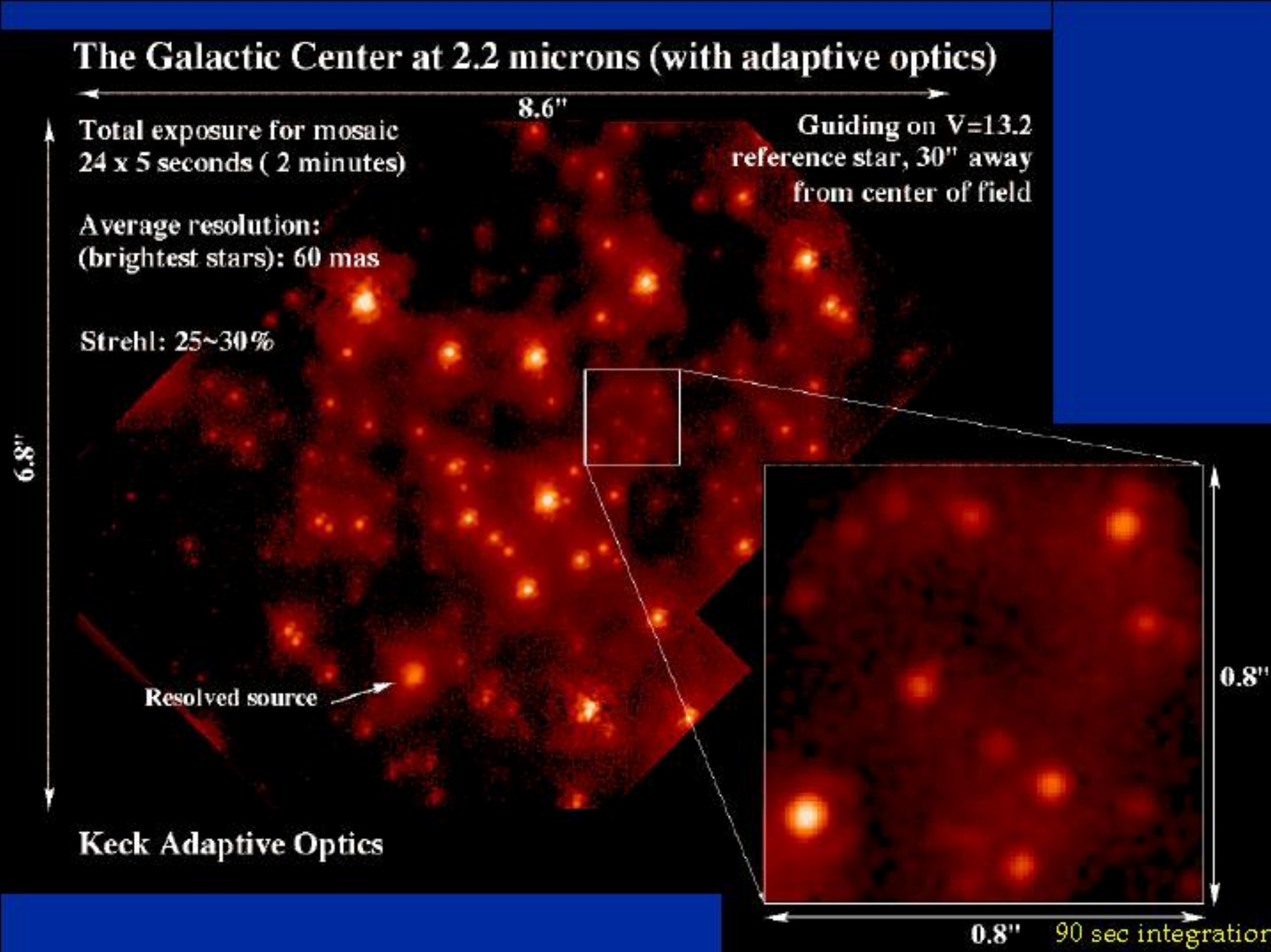
- **Seeing limited observations**
  - 0.3-1.0 µm
  - Scale 2.18 mm/arc second (f/15)
  - Wide field of view available: 20 arcminutes
- **Diffraction limited observations**
  - 1-25µm, mainly 1-2.5µm
  - Thermal IR possible, but not most important
  - At 1 µm angular resolution of 7 mas
  - Resolution element size: 15µm (at f/15, 1 µm wavelength)
  - Large field of view: 1 arc minute at 1 µm with multi conjugate AO

Schematic of astronomical AO system




QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

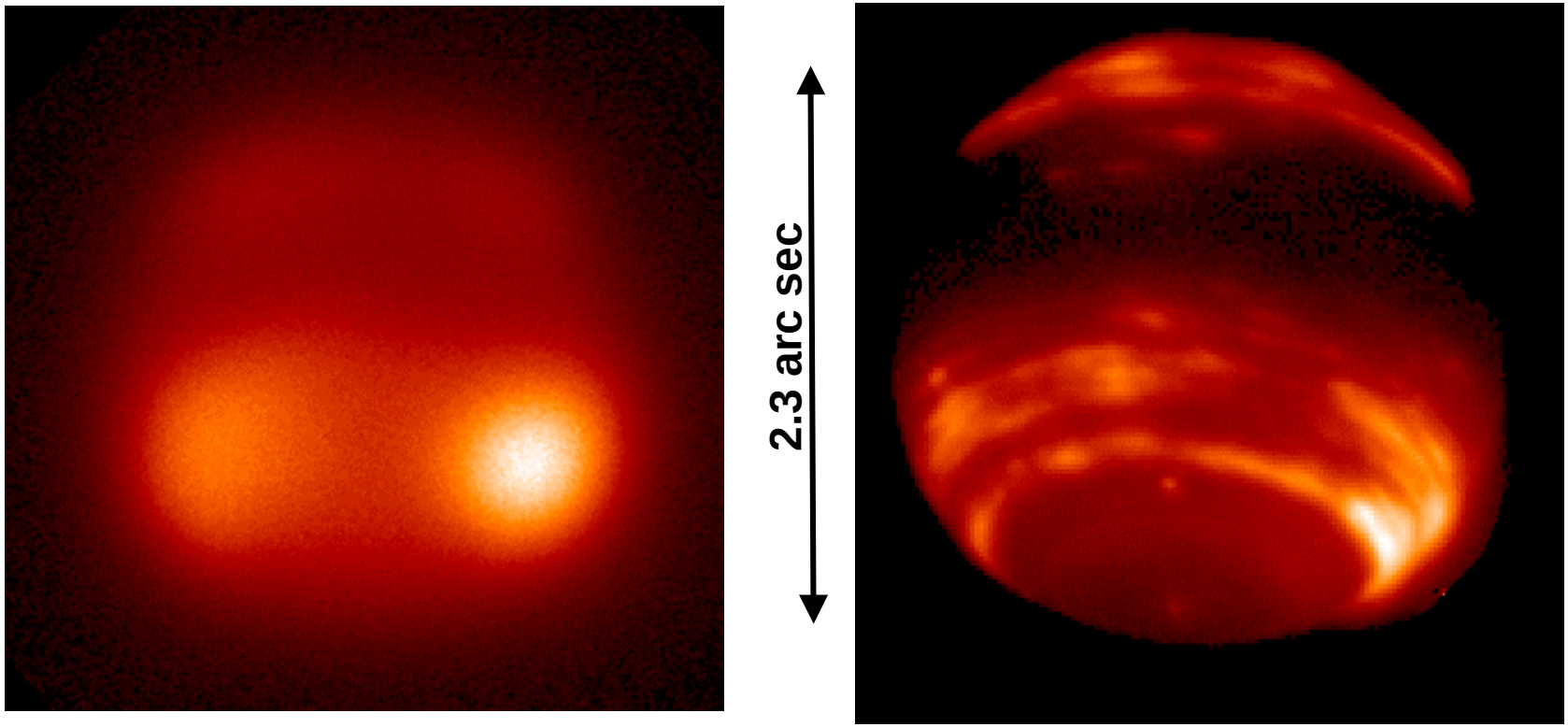

The Galactic Center at 2.2 microns (without adaptive optics)
8.6"
Total exposure for mosaic
for similar SNR ~ 20 minutes
Average resolution:
(brightest stars): 0.4"
6.8"
Resolved source
0.8"
0.8"
90 sec integration
Keck Adaptive Optics


The Galactic Center at 2.2 microns (with adaptive optics)
8.6"
Total exposure for mosaic
24 x 5 seconds (2 minutes)
Guiding on V=13.2
reference star, 30" away
from center of field
Average resolution:
(brightest stars): 60 mas
Strehl: 25~30%
6.8"
Resolved source
0.8"
0.8"
90 sec integration
Keck Adaptive Optics

Neptune at 1.65 microns

Without adaptive optics

With adaptive optics



May 24, 1999

June 28, 1999

The future of AO in astronomy

- **More powerful AO systems**
  - More energy concentrated into diffraction limited image
  - Better resolution at shorter wavelength
- **Larger diffraction limited fields of view**
  - Multi-conjugate AO systems to cancel aberrations “where they occur”
  - Multiple laser beacons
- **Larger telescopes with AO**
  - NAS AASC recommended a ground based 30-m telescope
- **California Extremely Large Telescope (CELT)**
  - University of California-Caltech partnership
  - 30-m diameter
  - Adaptive optics working down to 1 μm (λ/D =0.007 arcsecond resolution)


CfAO

CELT Adaptive Optics Issues

- AO system requirement Strehl= 0.50 at 1 μm
- This implies a wavefront allowance of 133 nm
- Native atmosphere is roughly 2000 nm rms (tilt removed)

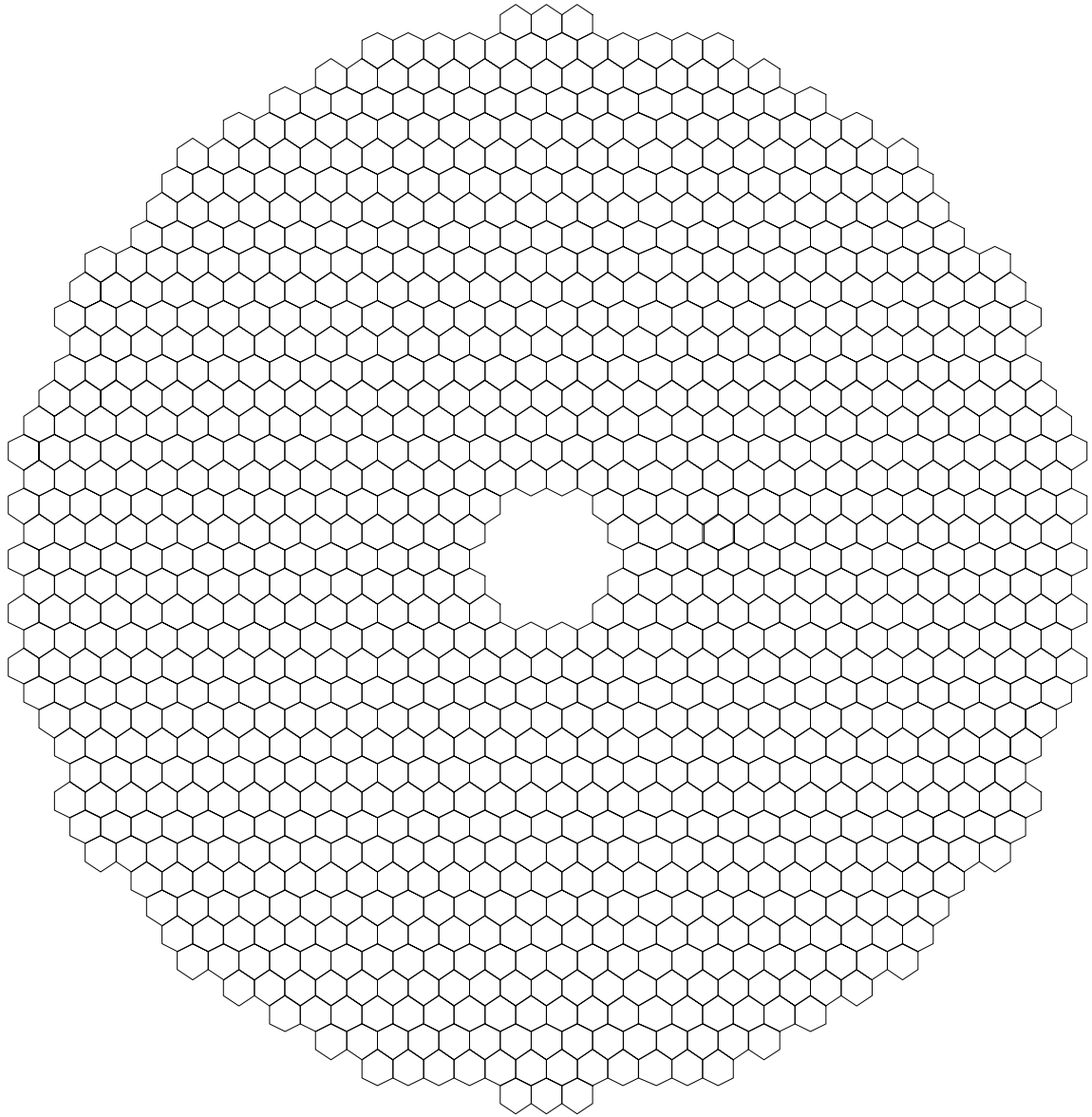
- System will require ~ 5000 actuators
- MCAO will require ~ 3 layers, each with 5000 actuators
- Wavefront sensing will require 80x80 lenslet arrays, advanced detectors
- Sky coverage will require ~5 Na laser beacons
- Computations currently impractical (need better alg and computers)

CELT and Stonehenge

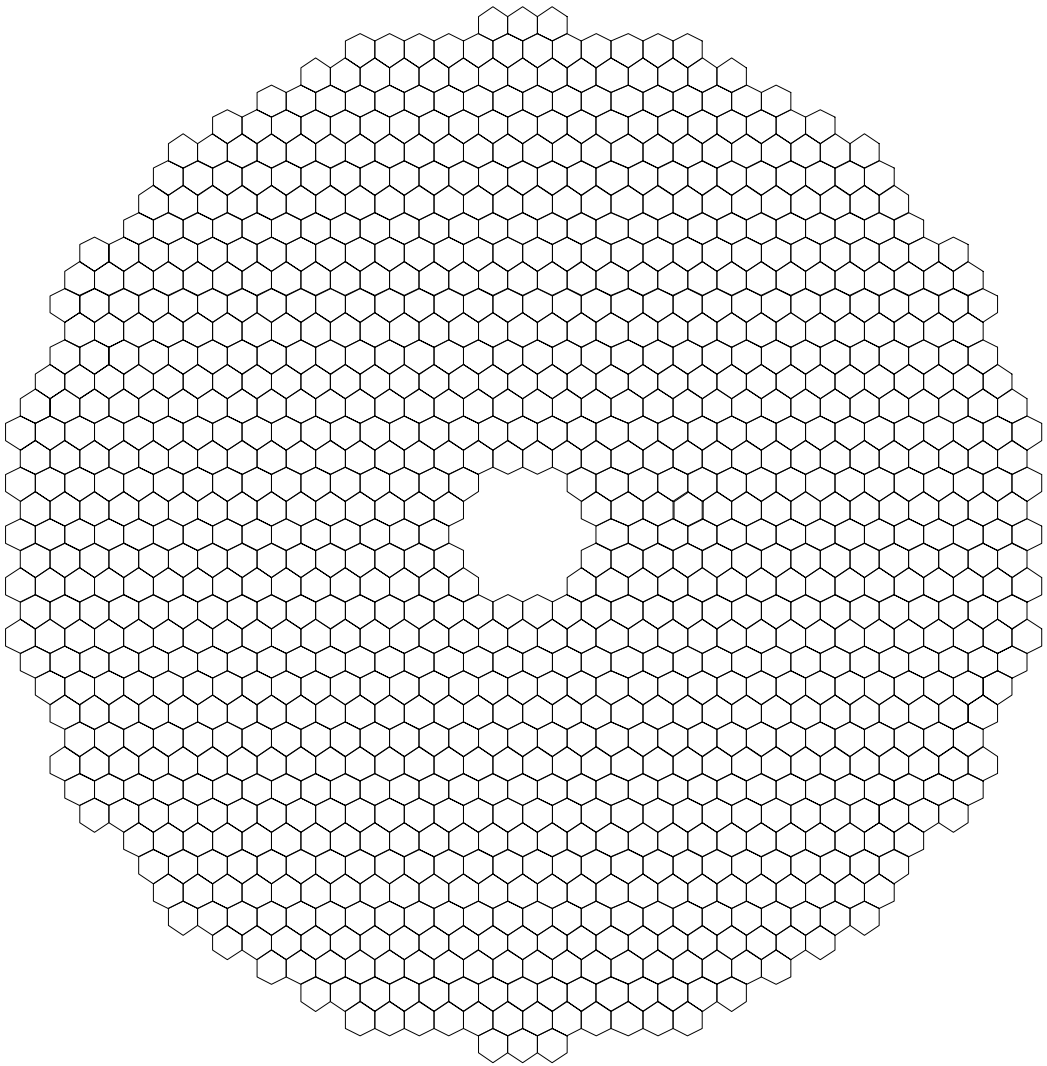
CELT Optical Design

- **Primary is 30m in diameter**
  - 1080 segments, 1m dia each
  - Shape actively controlled (segment piston, tip, tilt)
  - f/1.5 hyperbola
- **Final: f/15 Ritchey-Chretien**
  - Secondary 3.9m in diameter
  - 20 arc minute field of view with 0.5 arc second images
  - 1 arc minute FOV with 0.001 arc second images (design)
- **Instruments at Nasmyth platforms**
  - Articulated tertiary allows direct feed to multiple instruments with no additional optics (3 mirrors total)
  - 2 platforms: 15x30 m
  - Possible lower or upper platforms

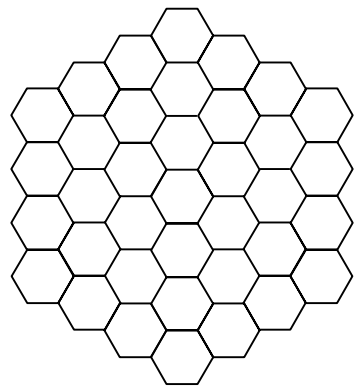
CELT basic layout-1080 segments



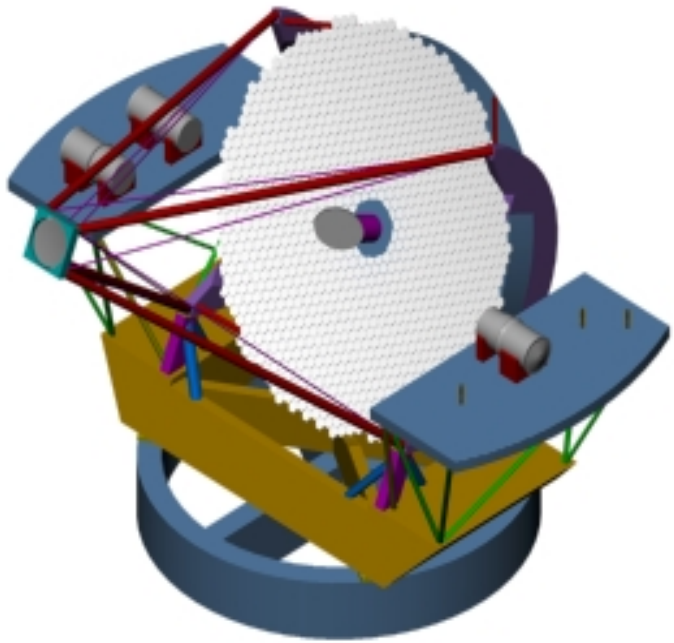
CELT

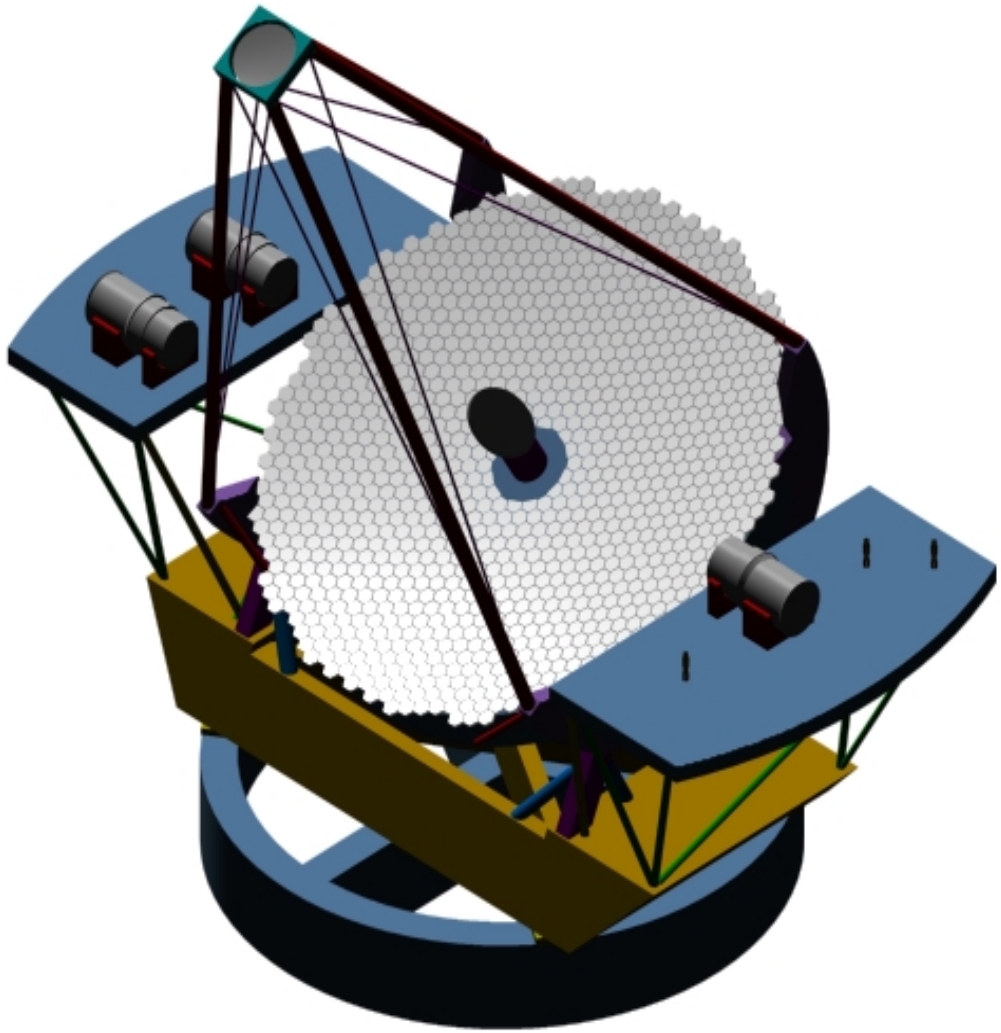


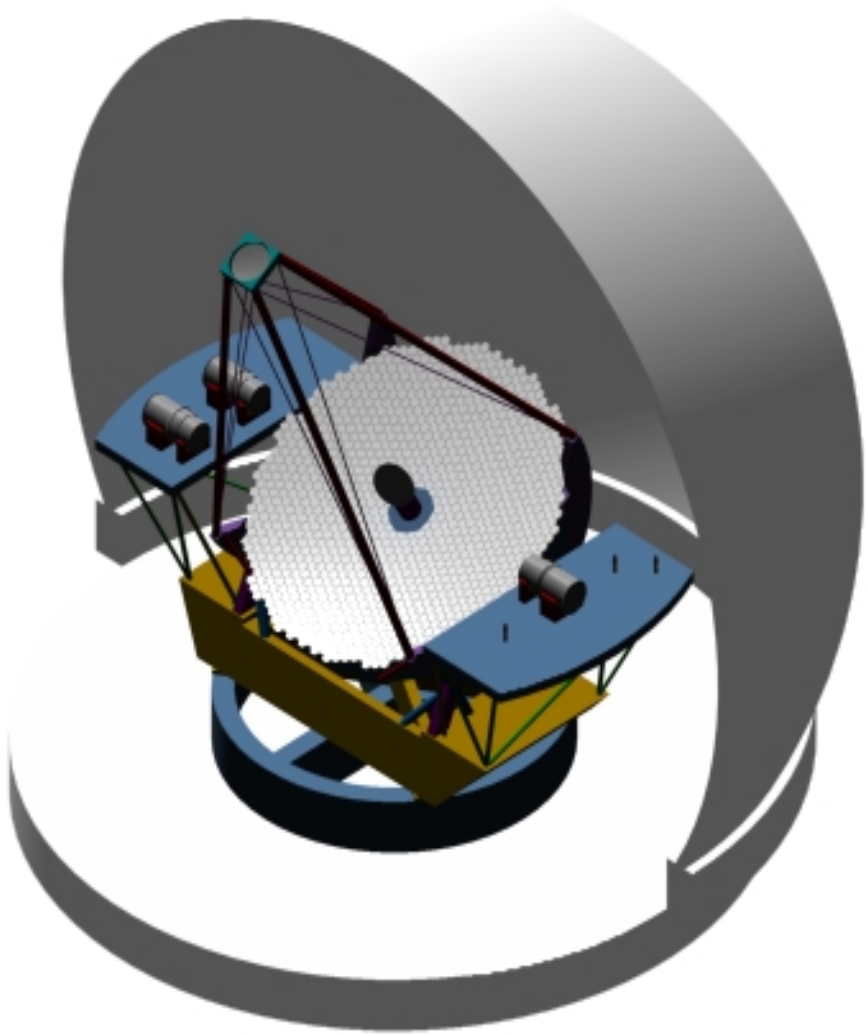
Keck



Progress on Telescope Layout







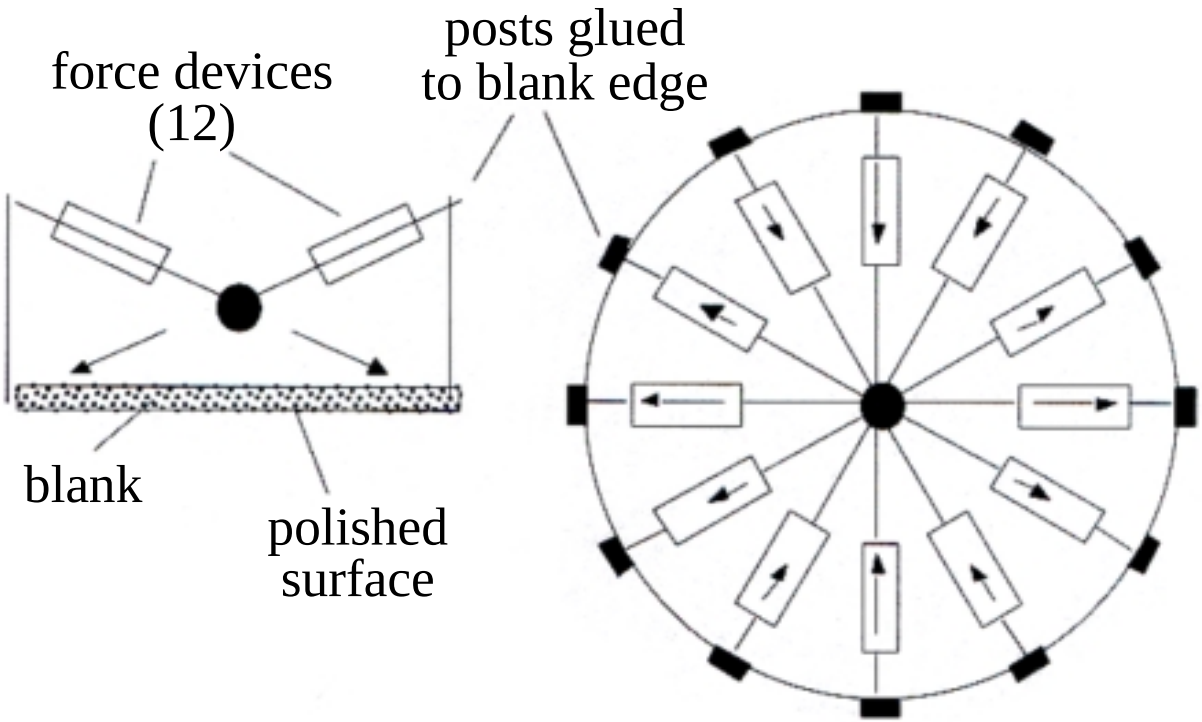
Segment Fabrication

- **Segments are off axis sections of hyperbola**
  - Requirements: ~ 20 nm rms surface (better than Keck)
  - ~ 20 μm deviation from sphere (Keck was ~ 100μm)
  - Stressed mirror polishing (oap to sphere)
  - Planetary polishing to increase efficiency (simultaneous polishing)
  - Low expansion material
  - Final corrections with ion figuring

  - In telescope warping harnesses
  - In telescope AO will correct low order errors

Planetary polishing to produce 1000 segments

Proposed CELT Stressed Mirror Polishing Set-up

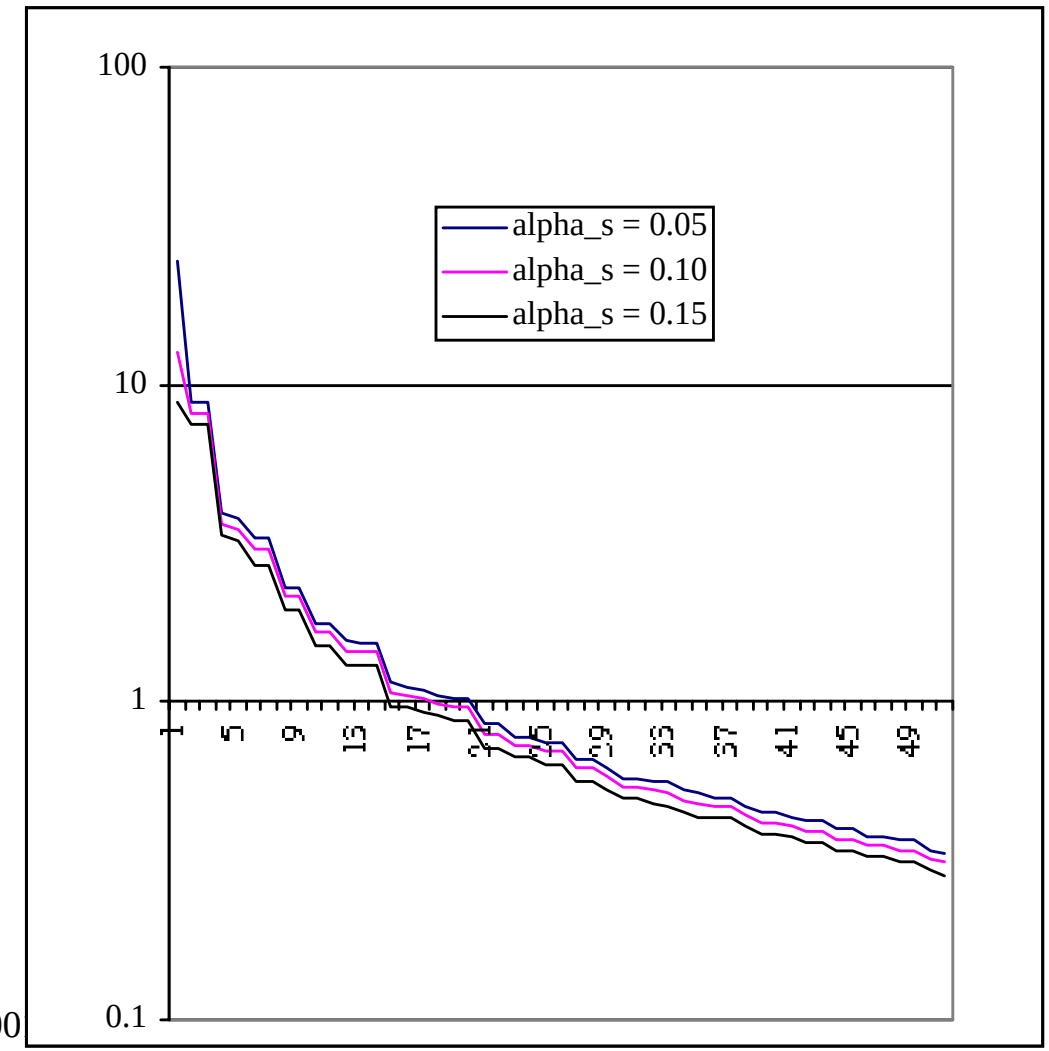


Arrows indicate force direction and magnitude
required to create / remove astigmatism

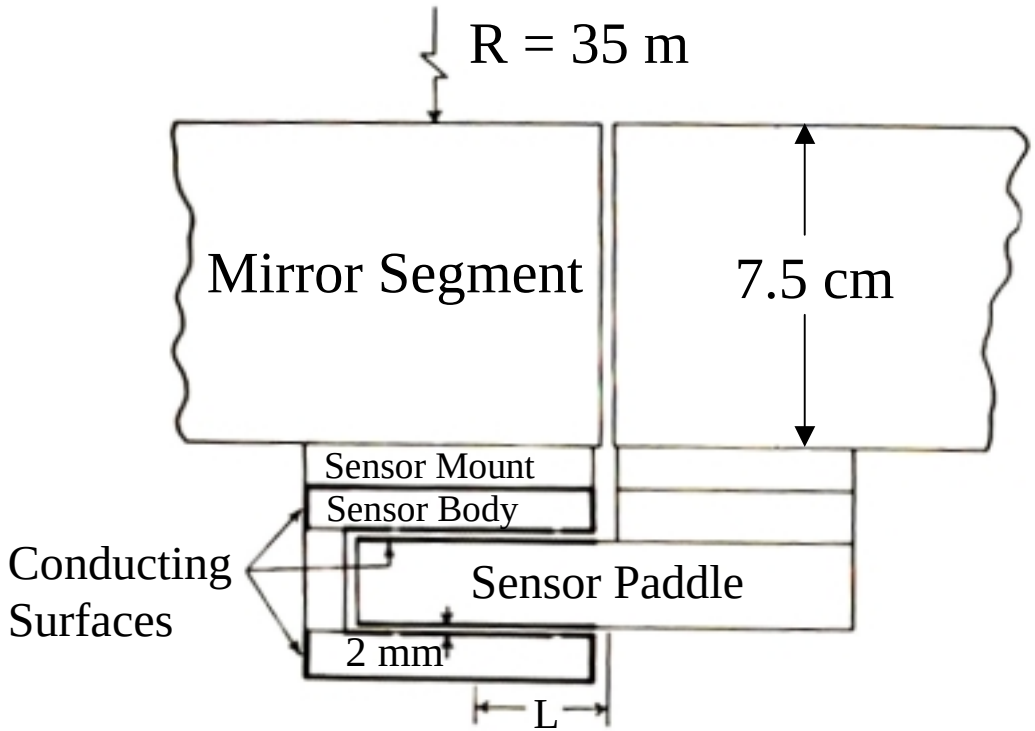
Active Control

- **Active control algorithm (details by G. Chanan)**
  - Same idea as Keck: edge sensors, actuators, least squares fitting
  - Error propagation calculated to be acceptable: ~ 20x sensor noise
- **Edge sensors**
  - Need low cost
  - Need no mechanical interlock
  - Solution is edge sensors on edge faces of segments
  - Much less expensive, also measures edge tilt
- **Actuators**
  - Keck actuators expensive, used roller screw
  - Present CELT idea is voice coil actuator
  - Much less expensive

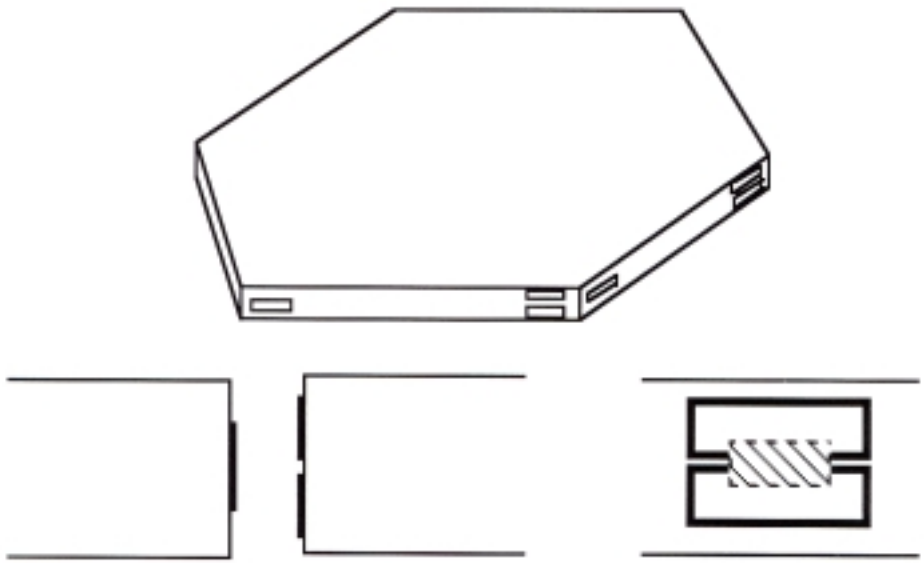
ACS noise multiplierrs



Keck Sensor Geometry



Proposed CELT Sensor Geometry



Non-Interlocking Sensors

CELT Plans

- **Conceptual design study underway**
  - Started sept 2000
  - End October 2001
  - + fund raising
- **Preliminary Design should start end of 2001**
  - + fund raising
- **Detailed design should start mid 2003**
- **Construction may begin 2005**
- **Completion ~ 2010**