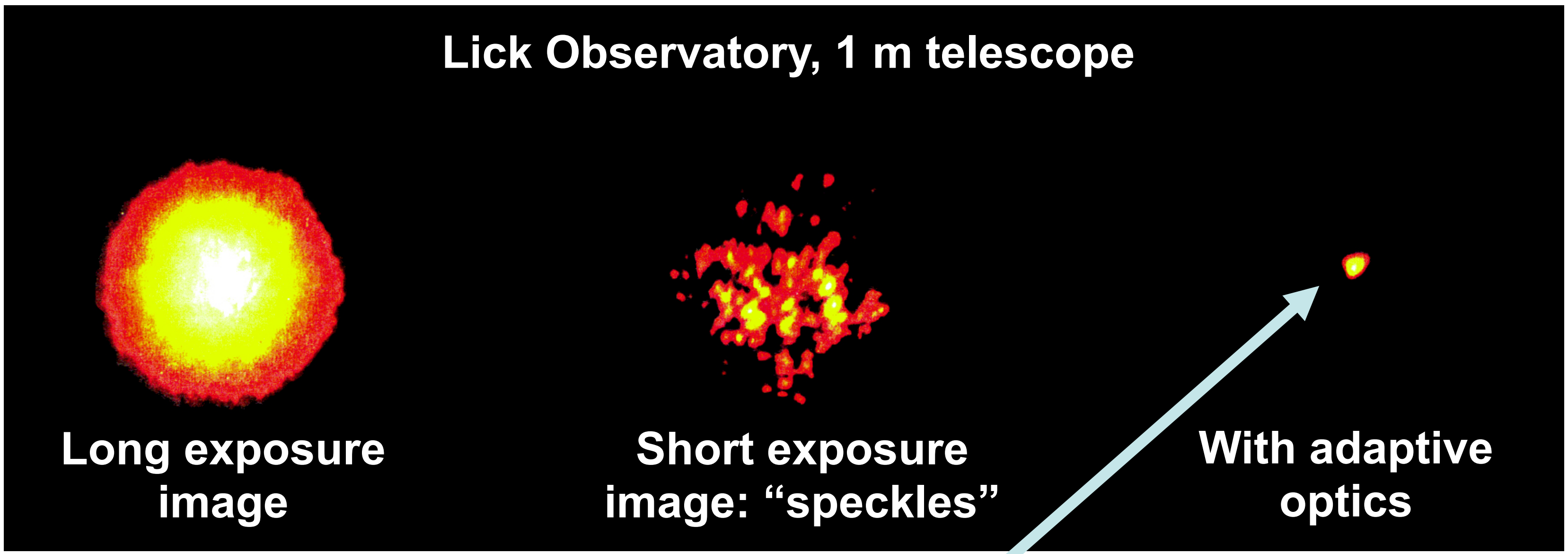
Why do astronomers need AO?

Three images of a bright star:

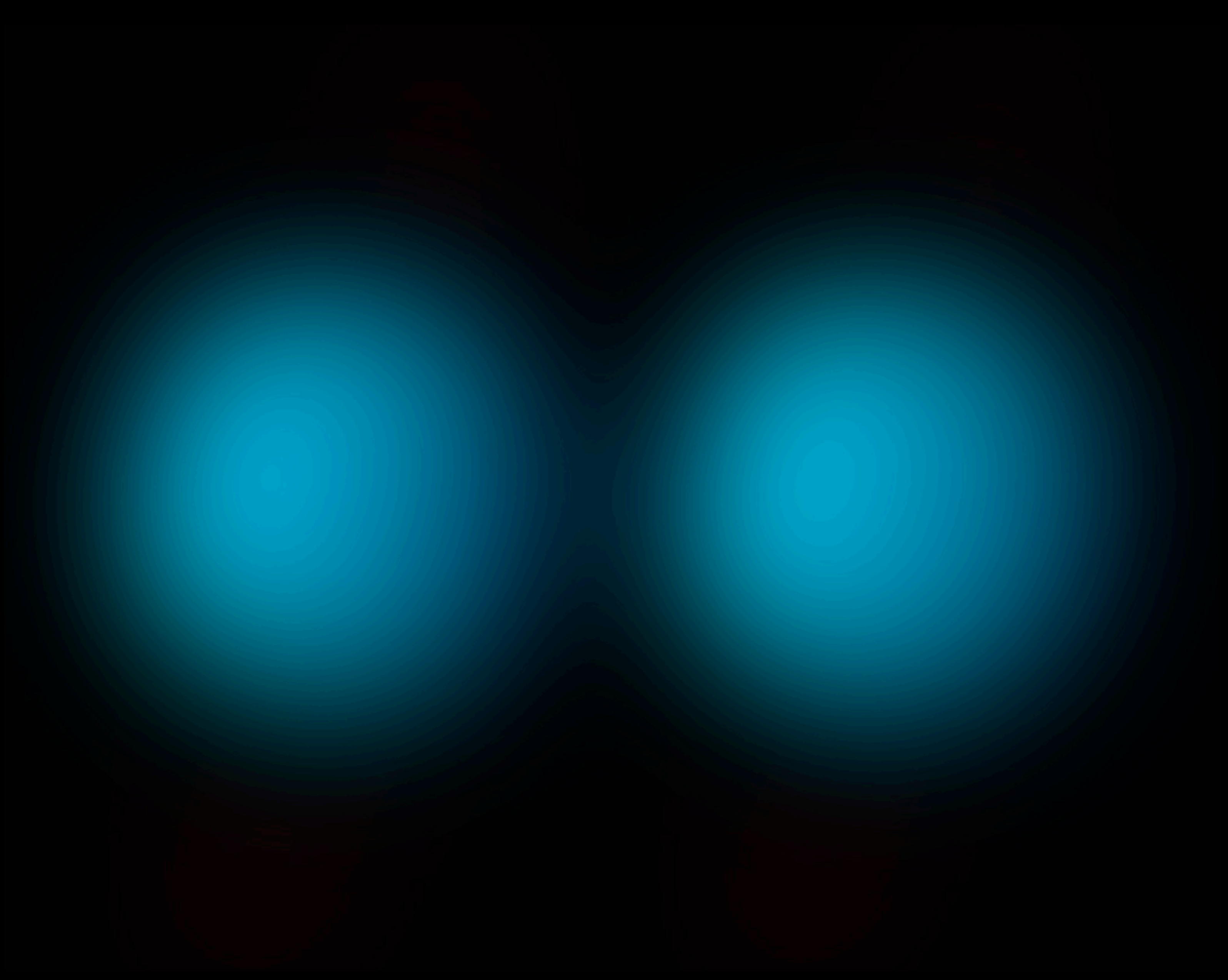


If image of a star is very small, your telescope will also be able to see fine details of galaxies, star clusters, ...

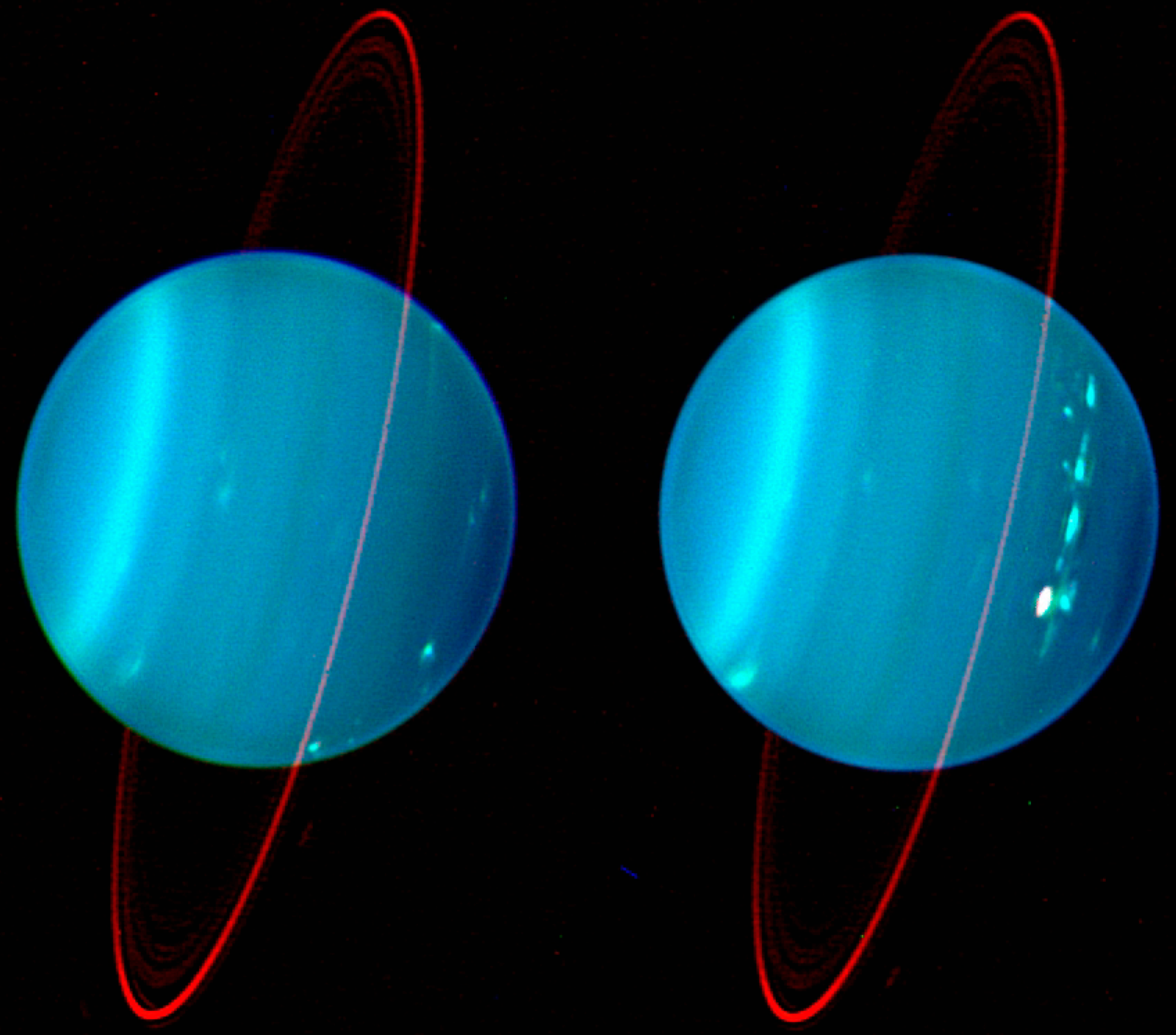
UC and Adaptive Optics

- UC and UCO have led the way in AO for astronomy
- 3m laser-guide star AO first to be put in use
- Keck is (by far) the leader in AO science productivity
- $9.3M gift from the Moore Foundation for the Lab for Adaptive Optics at Santa Cruz
- $40M NSF Science and Technology Center at UCSC

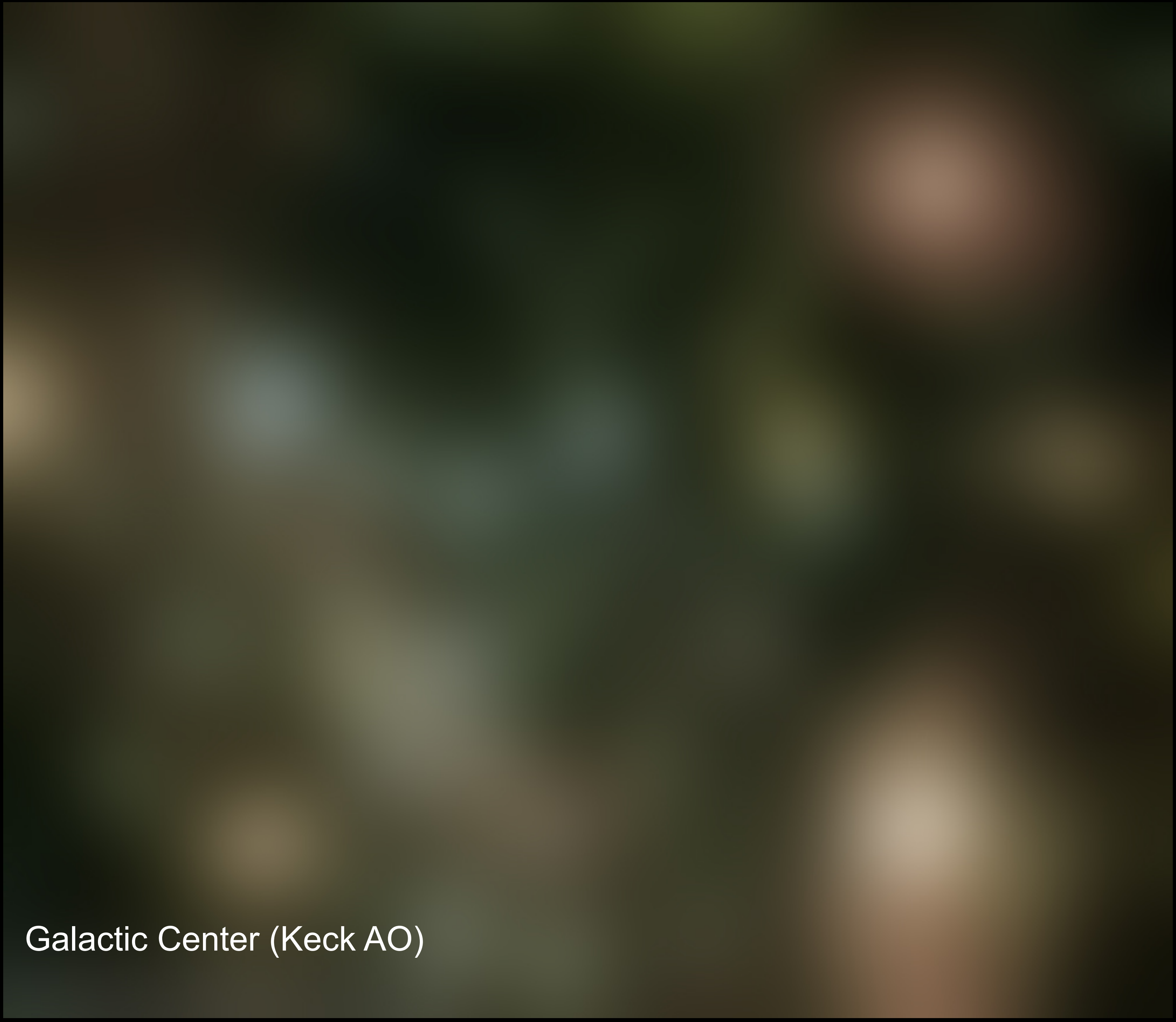
Keck Observatory Laser Guidestar



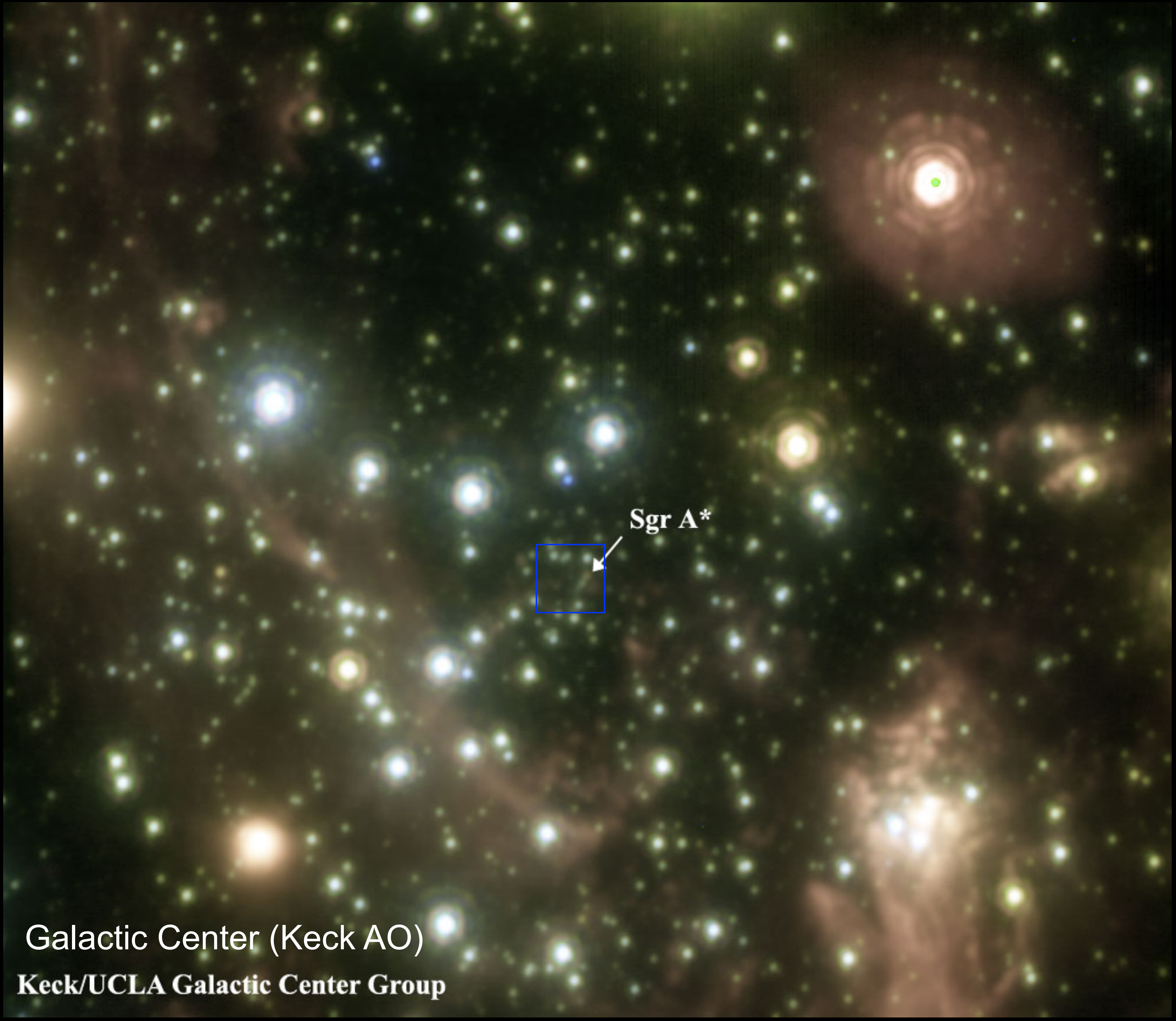
Neptune (Keck AO)



Neptune (Keck AO)



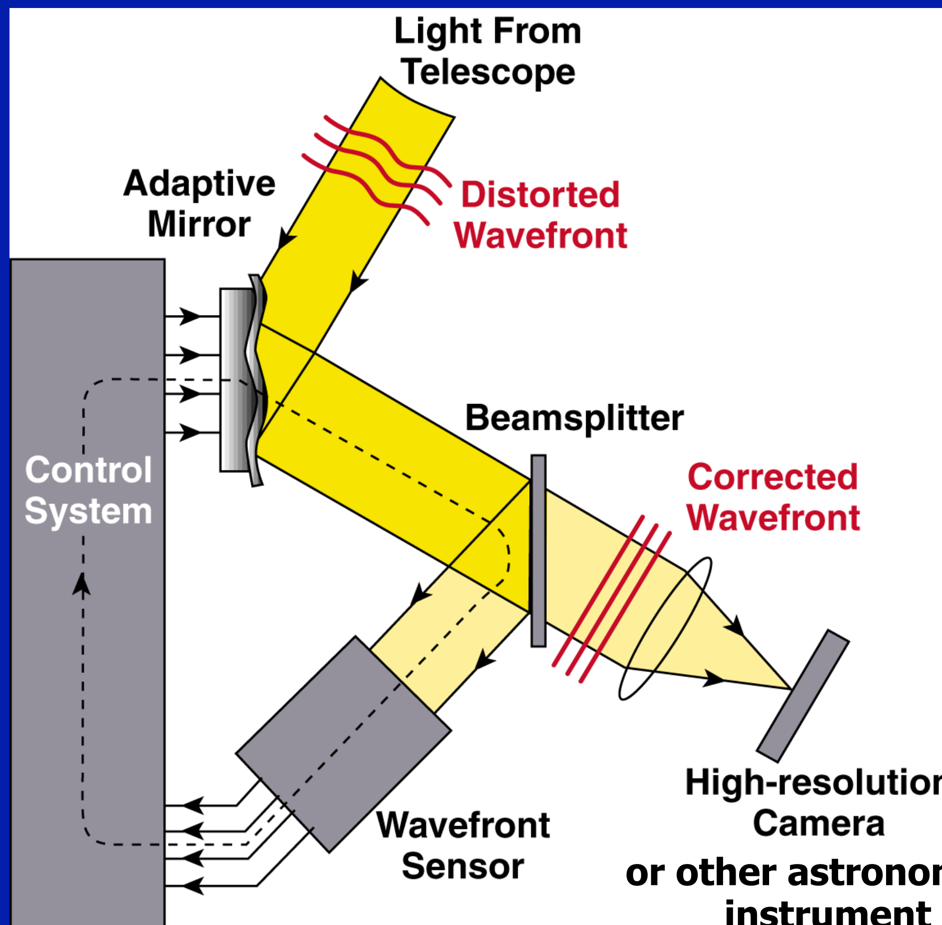
Galactic Center (Keck AO)


Sgr A*
Galactic Center (Keck AO)
Keck/UCLA Galactic Center Group

How Adaptive Optics Works

Invert the wavefront aberration with an "anti-atmosphere" (deformable mirror)

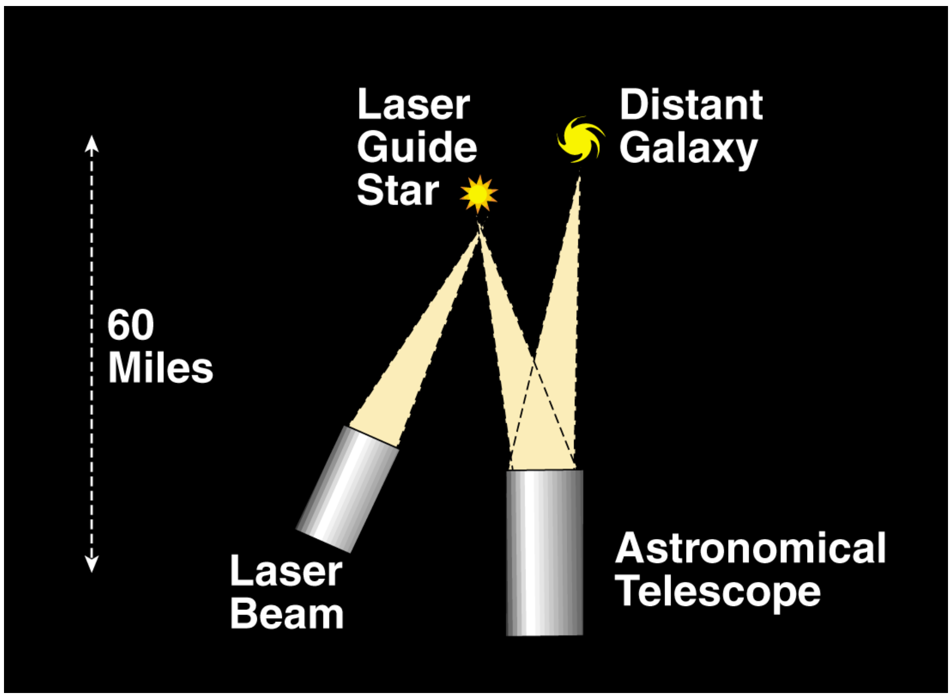
Feedback loop: next cycle corrects the (small) errors of the last cycle



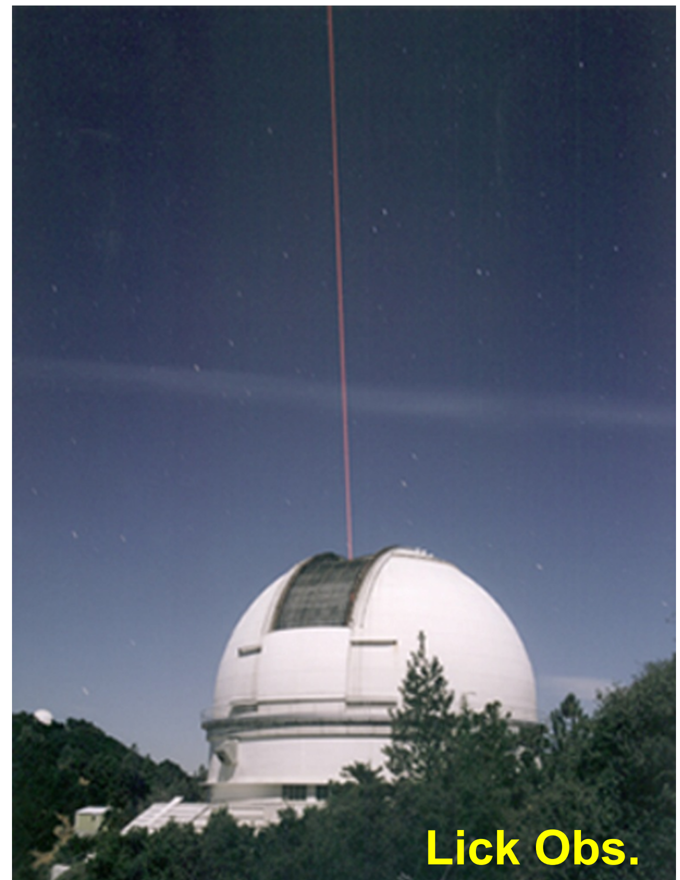
or other astronomical instrument

If there is no nearby star, make your own "star" using a laser

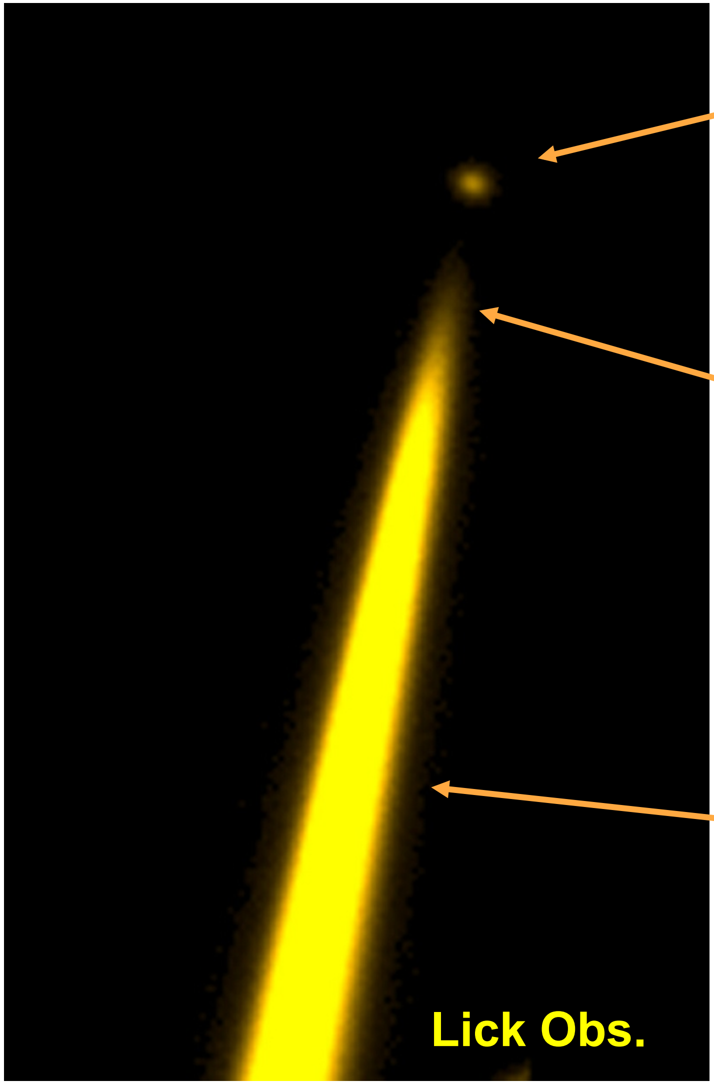
Concept



Implementation



Anatomy of a Laser Guide Star



The Guide Star: Fluorescent scattering by the mesospheric Sodium layer at ~ 95 km

Maximum altitude of (unwanted) backscatter from the air ~ 35 km

Back scatter from air molecules

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UCO/Lick Observatory
University of California, Santa Cruz

Laser Guidestar Structure in the Sodium Layer

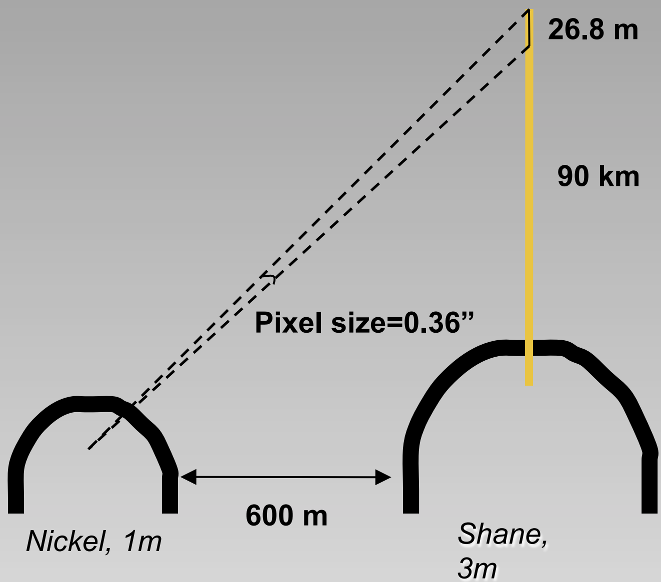
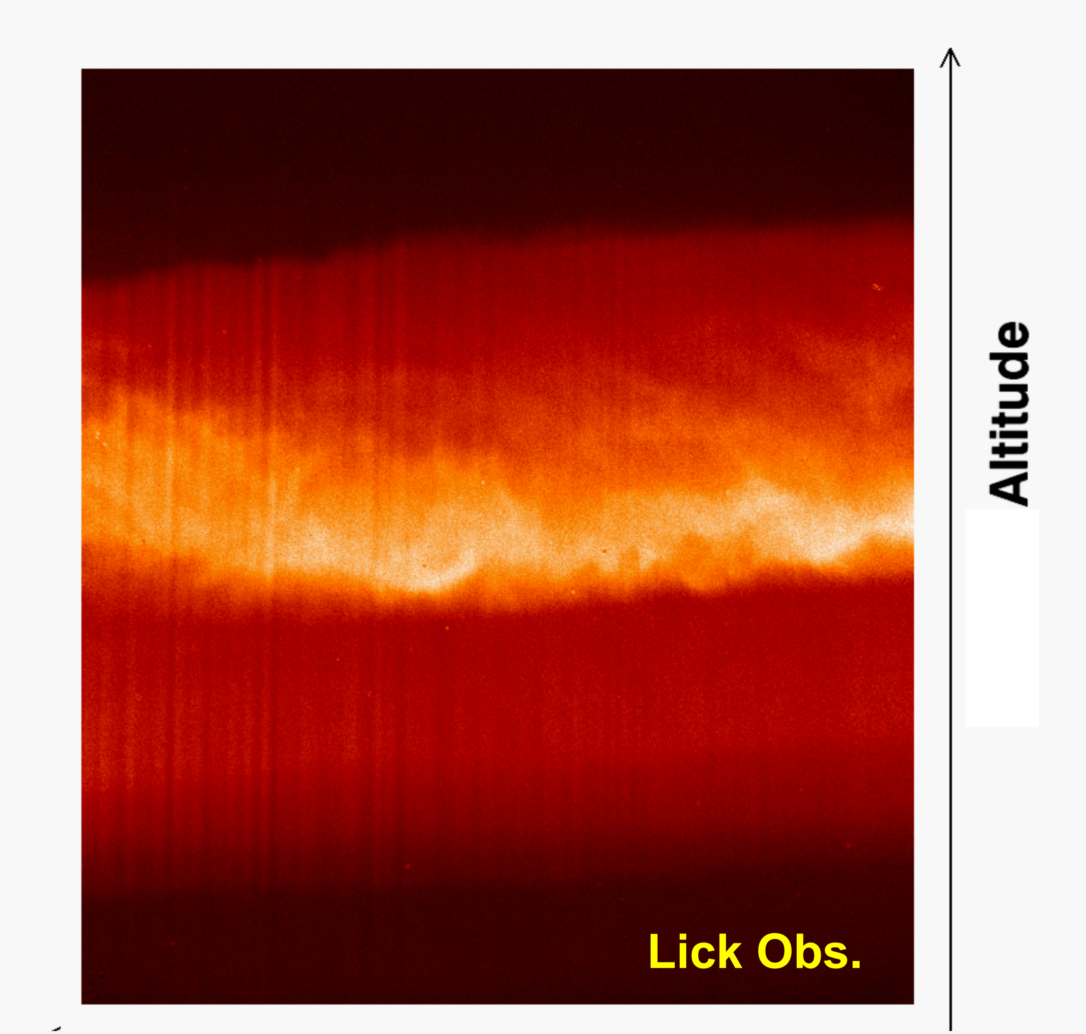


Figure 9. Variation of the mesospheric sodium density as a function of time and altitude was measured using the Lick Observatory Shane Telescope sodium laser. Drift-scan images from the Nickel, 600 meters to the west, enable us to resolve time and altitude dependence.



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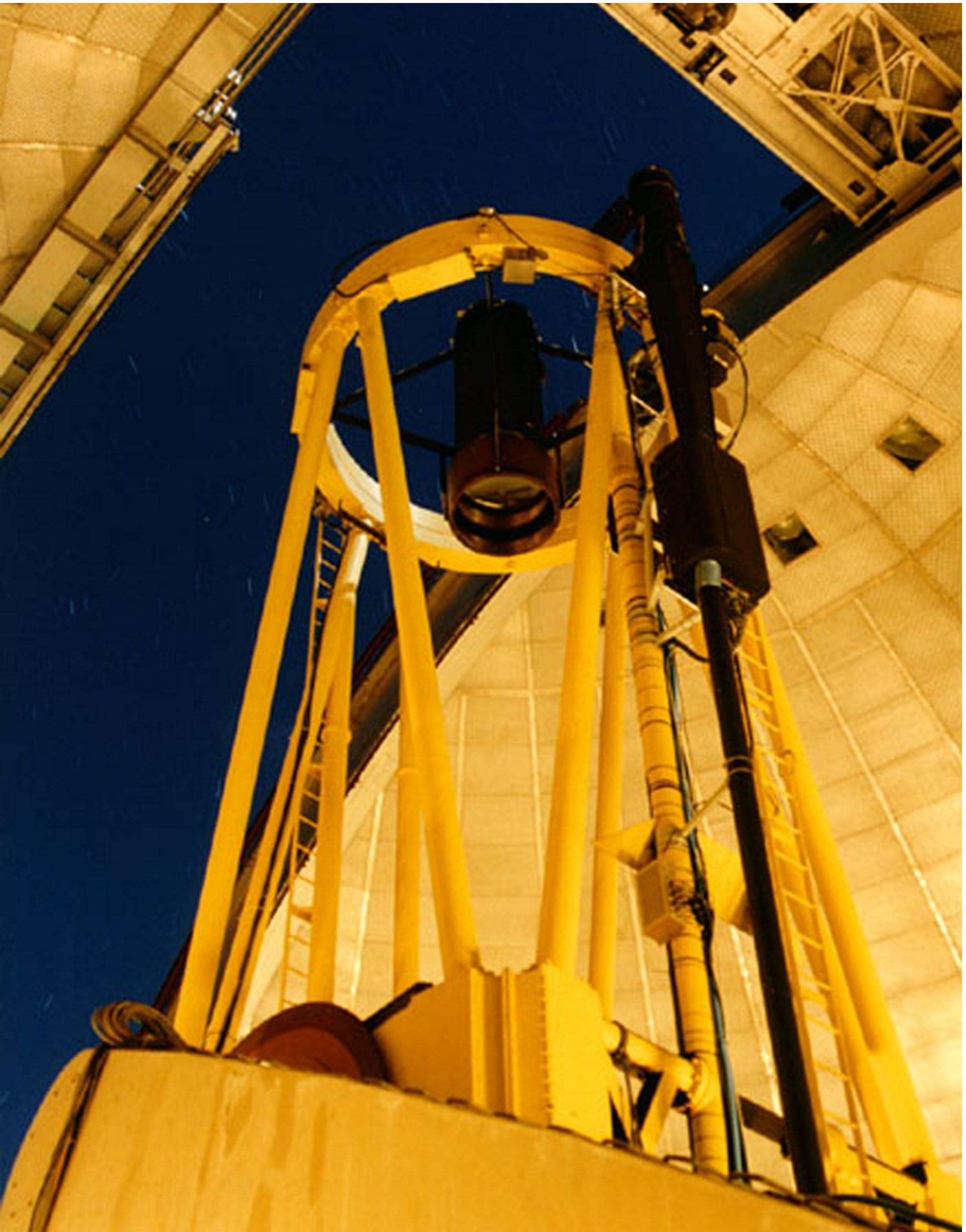
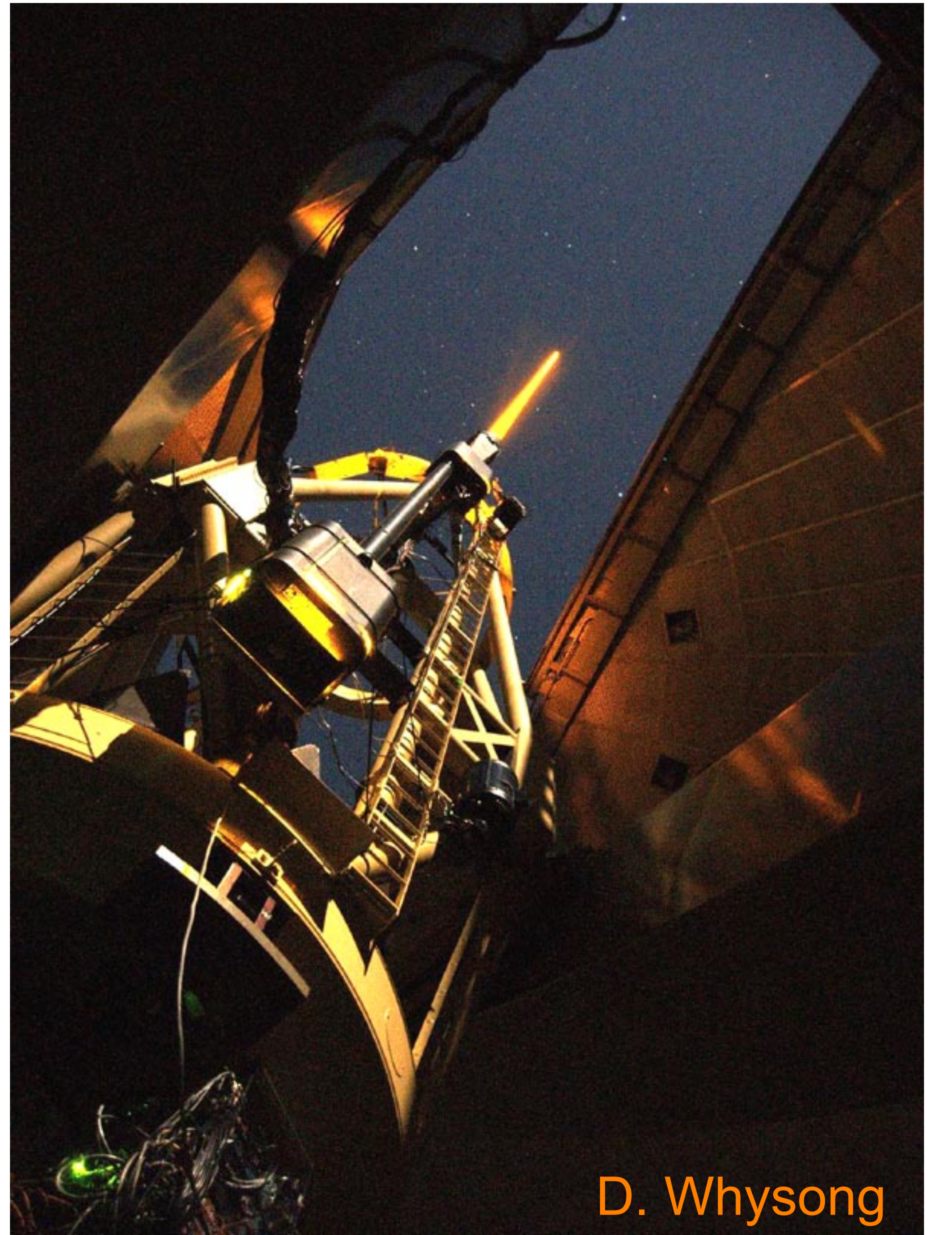
Laser system on the Shane Telescope

Lick Observatory, Mt Hamilton, CA

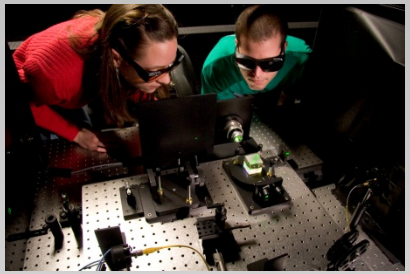




D. Whysong

Mt. Hamilton
Photo: Marshal Perin

Laboratory for Adaptive Optics

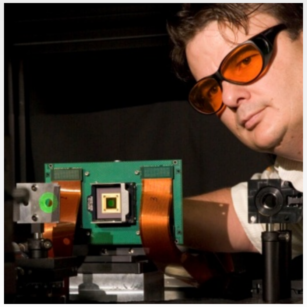


Claire Max, Principal Investigator
Joseph Miller, co-Investigator
Jerry Nelson, co-Investigator
Donald Gavel, Laboratory Director

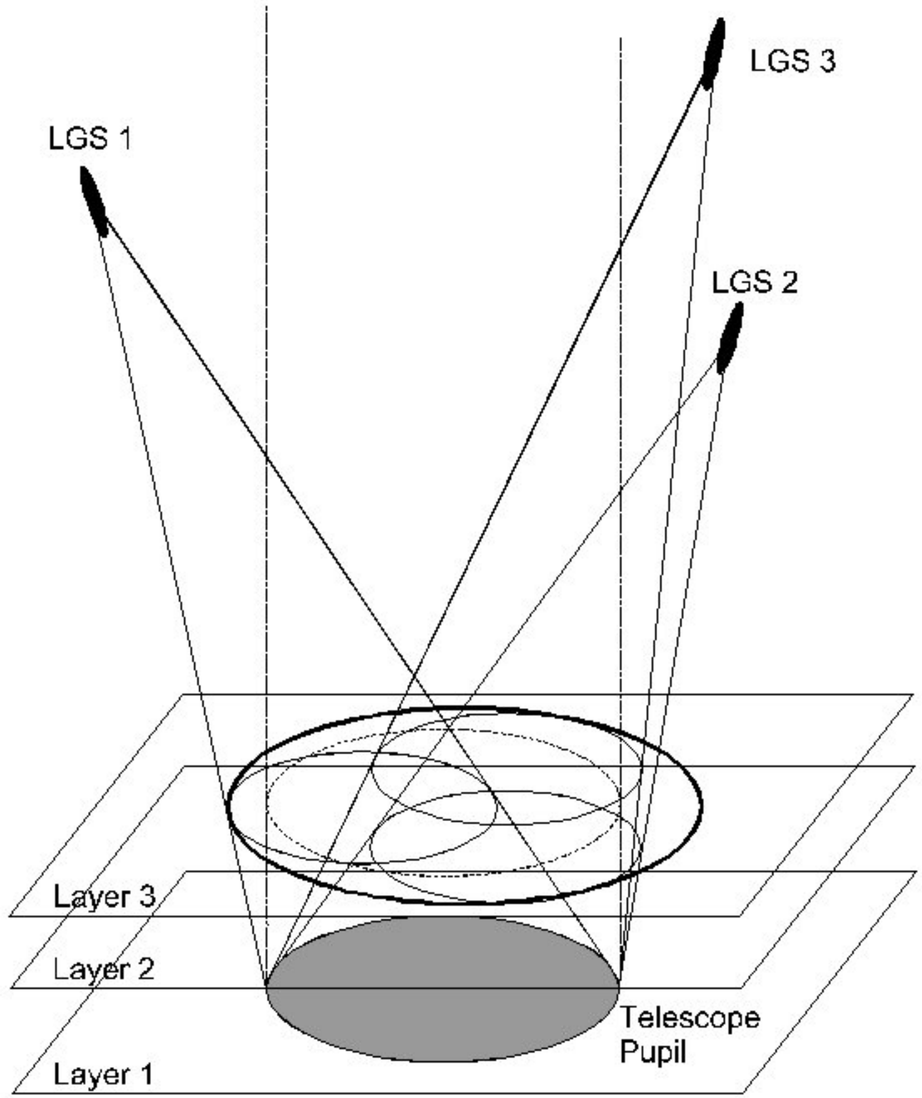
- A permanent facility within the UCO/Lick Observatory located at the UC Santa Cruz campus
- Presently funded by a grant from the Gordon and Betty Moore Foundation

LAO Goals

1. Develop Adaptive optics technology and methods for the next generation of extremely large ground-based telescopes
2. Develop and build a planet finder instrument using “extreme” adaptive optics technology
3. Develop, test, and evaluate new components and key technologies for adaptive optics
4. Provide a laboratory where students and postdocs will be trained in adaptive optics design, modeling, and implementation



Next Generation Adaptive Optics
Multiple Guidestar Tomography + Volume Correction = MCAO



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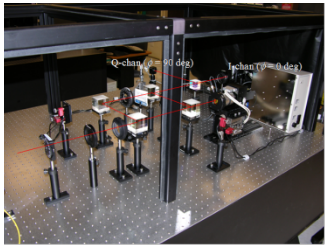
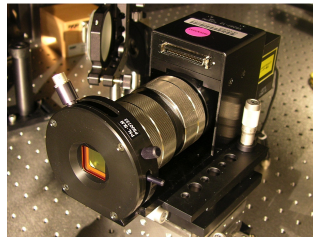
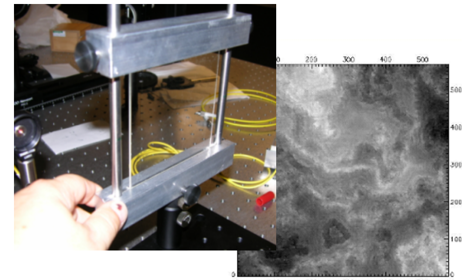
University of California, Santa Cruz

MCAO / MOAO Testbed

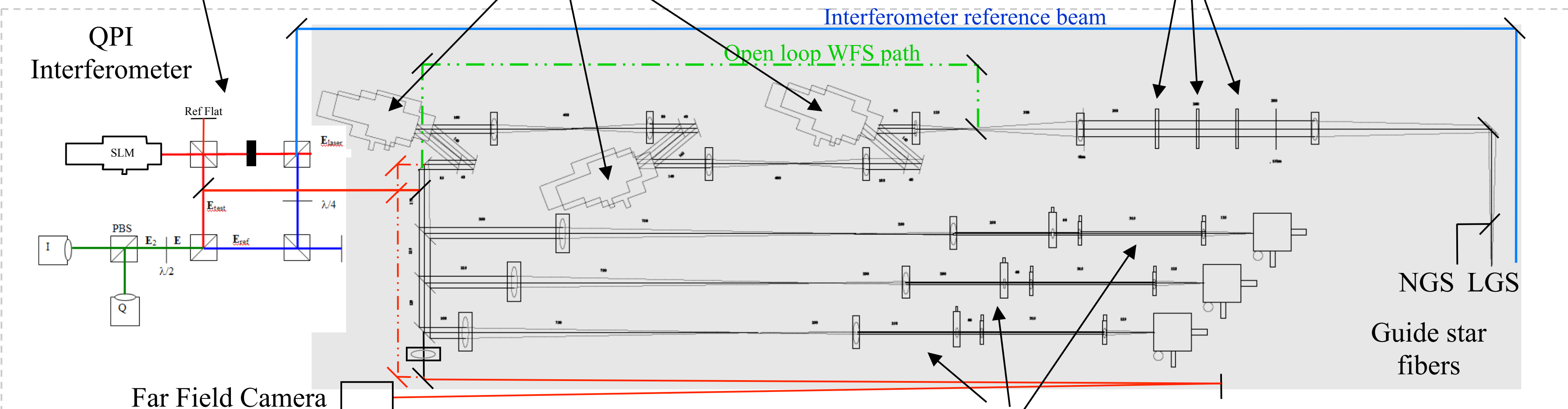




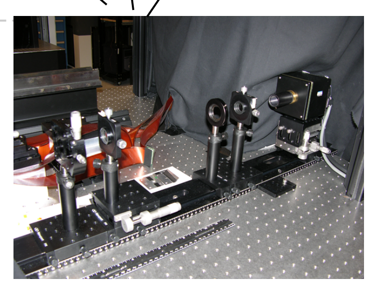
Deformable Mirrors (SLMs)



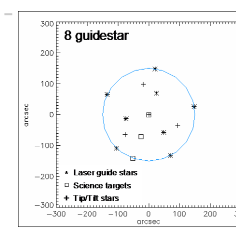
Kolmogorov Atmosphere phase aberrator plates



- Up to 8 wavefront guide stars and 4 tip/tilt stars
- 10,000 DOF per DM (100x100 subaperture Hartmann sensors)
- Up to 3 DMs (MCAO) or 1 DM and open loop WFS path (MOAO)
- 5 Hz sample & control rate
- Moving phase plates (wind)
- Moving LGS fibers in z to simulate LGS elongation, or laser pulse



Hartmann Wavefront Sensors



Configurable guide star constellation

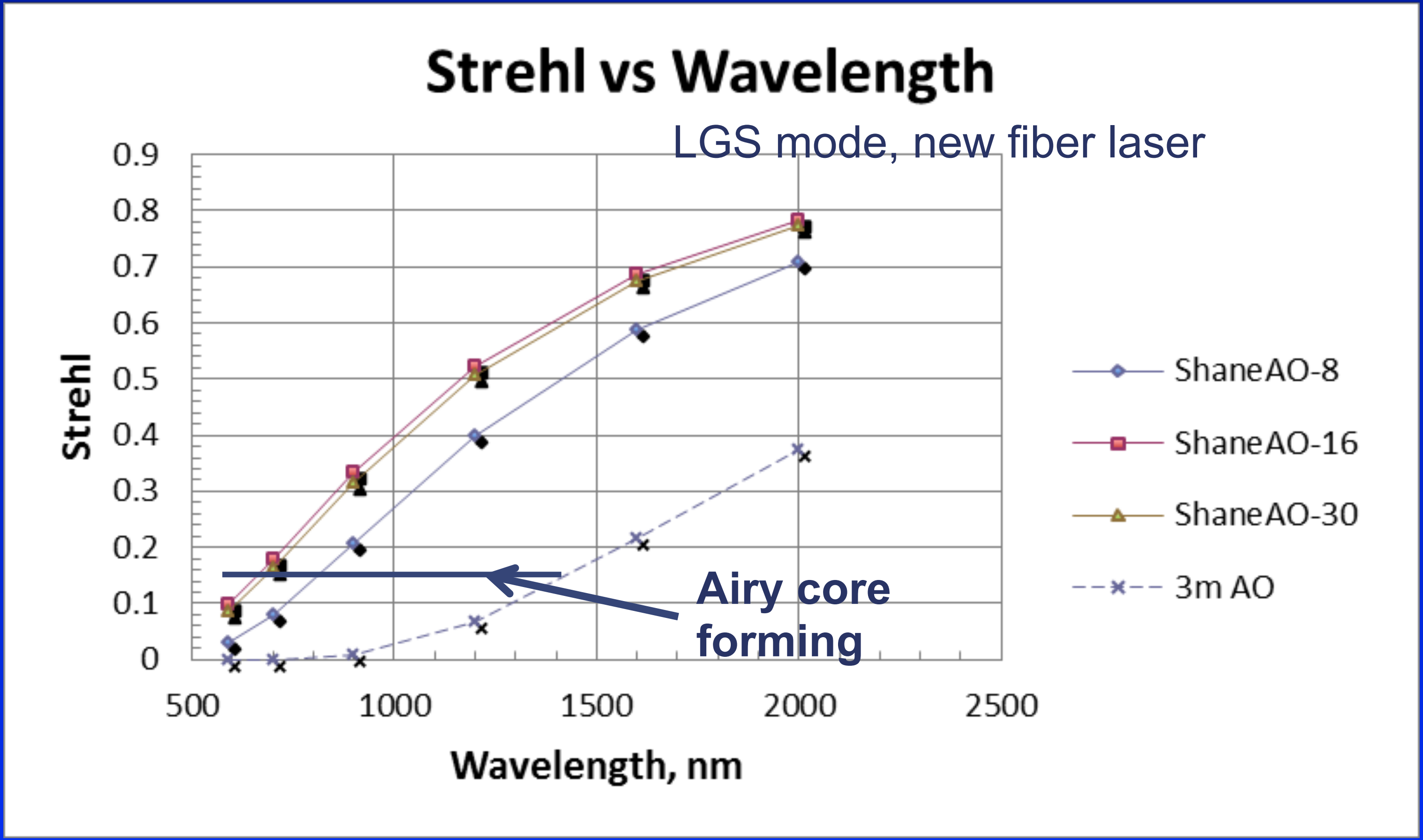
Adaptive Optics System and Infrared Instrumentation for the Shane 3-meter Telescope

UCO/Lick Observatory

University of California

Presented to the UCOAC Meeting May 6, 2012

ShaneAO expected performance



ShaneAO Technology development connection to Keck NGAO

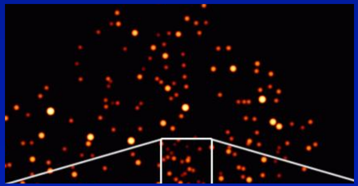
- MEMS deformable mirror
- Fiber laser tuned to atomic sodium transitions (optical pumping, re-pump line)
- Control system: woofer-tweeter, wind-predictive
- Other opto-mechanical stability design improvements

In the next few years, ShaneAO is the *only LGS-AO system* being planned (in the world) that will have the kind of low wavefront errors being contemplated by TMT NFIRAOS.

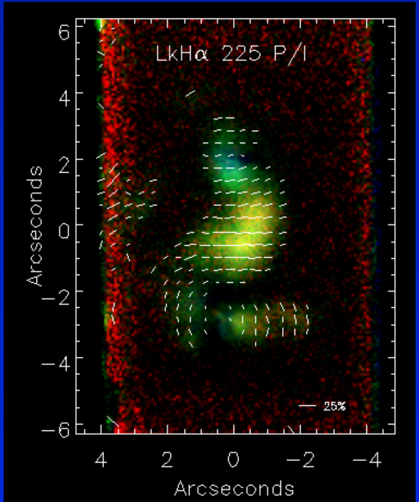
Thus ShaneAO is a TMT pathfinder in the system performance aspect, in addition to in the individual components.

ShaneAO Science Application

Crowded field imaging:
- Star counts, metallicity and ages in clusters within our Galaxy
- Star counts in Andromeda galaxy
- Astrometry – tracking the orbits of stellar companions



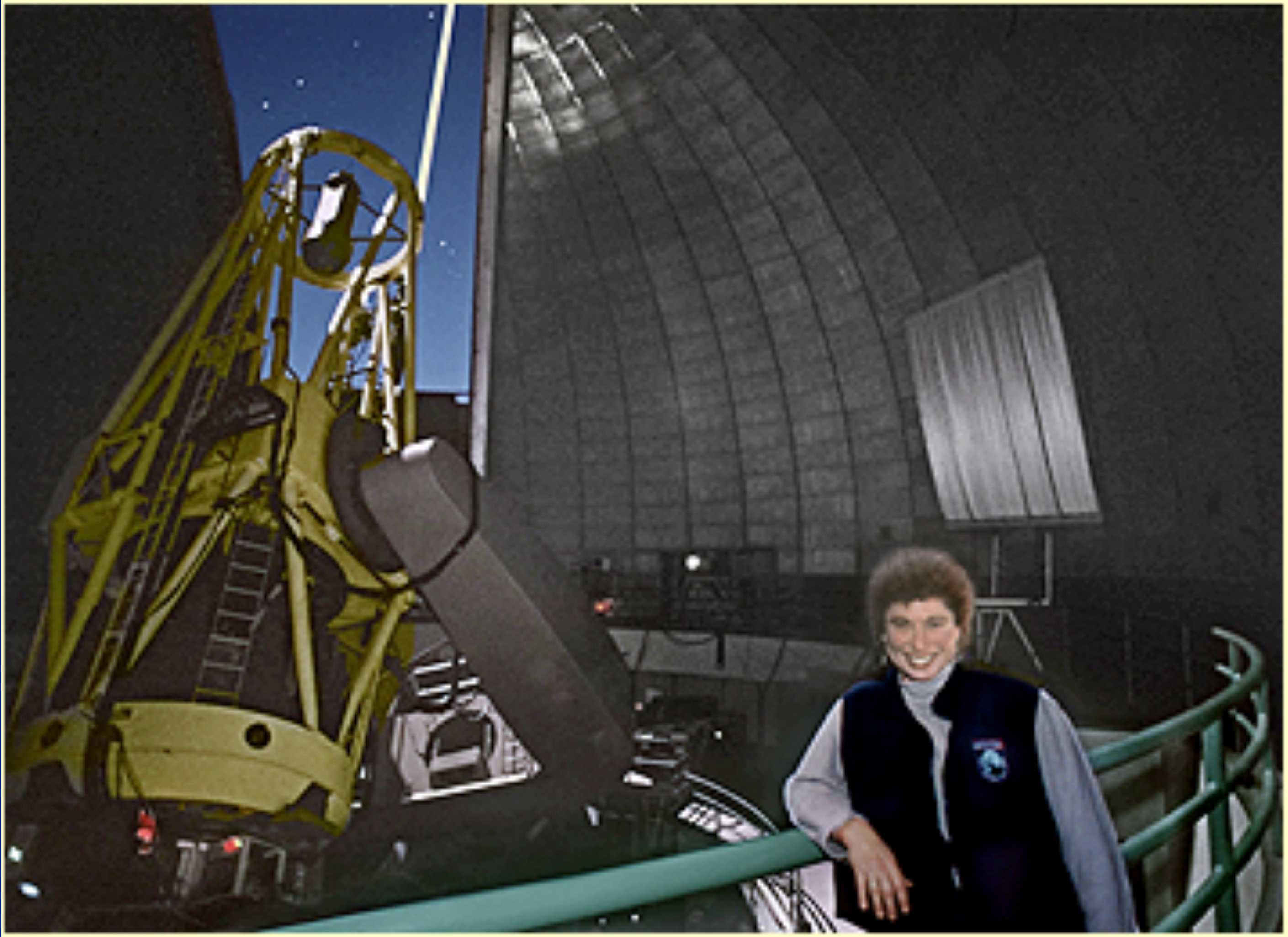
Detailed imaging of nebula and galaxies
- Gas and dust disks around young stars
- Multiple star systems in star forming regions
- Velocity dispersion of galaxies hosting active galactic nuclei
- Morphological detail of quasar host galaxies
- Details of morphology of merging galaxies



Star-forming regions - polarimetry

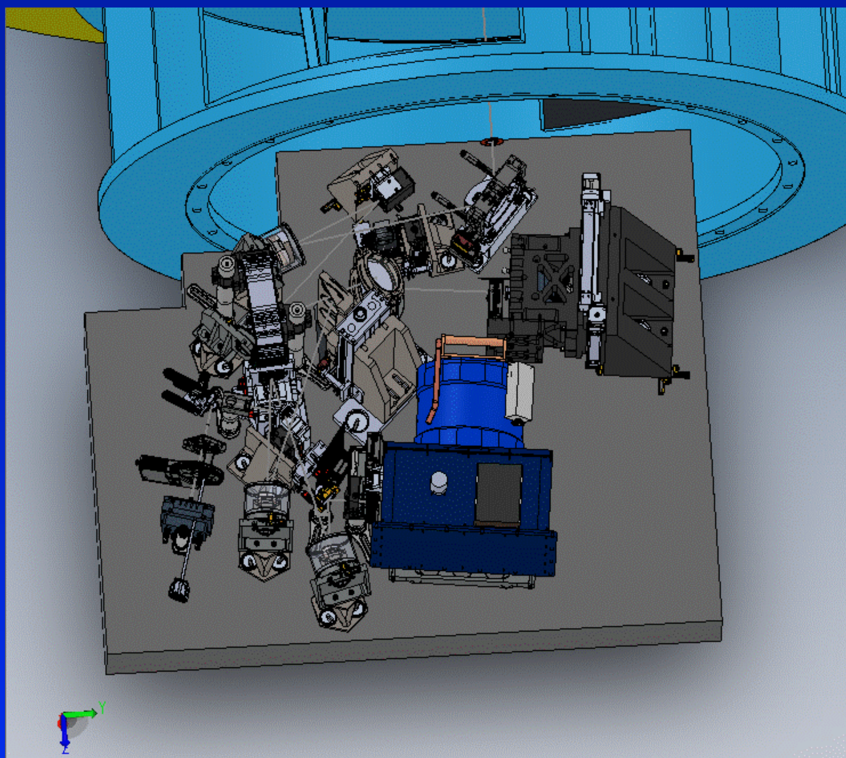
Exoplanets and planet formation statistics
- Follow up to radial velocity planetary systems (stellar companions)
- Follow up to Kepler survey stars (companions)
- Precursory work for Gemini Planet Imager target stars

Solar system
- Composition and orbital parameters of Kuiper belt objects
- Composition and orbital parameters of asteroids and asteroid moons
- Details of gas-giant ring structure and positions of ring-shepherding moons
- Details and evolution of gas-giant weather

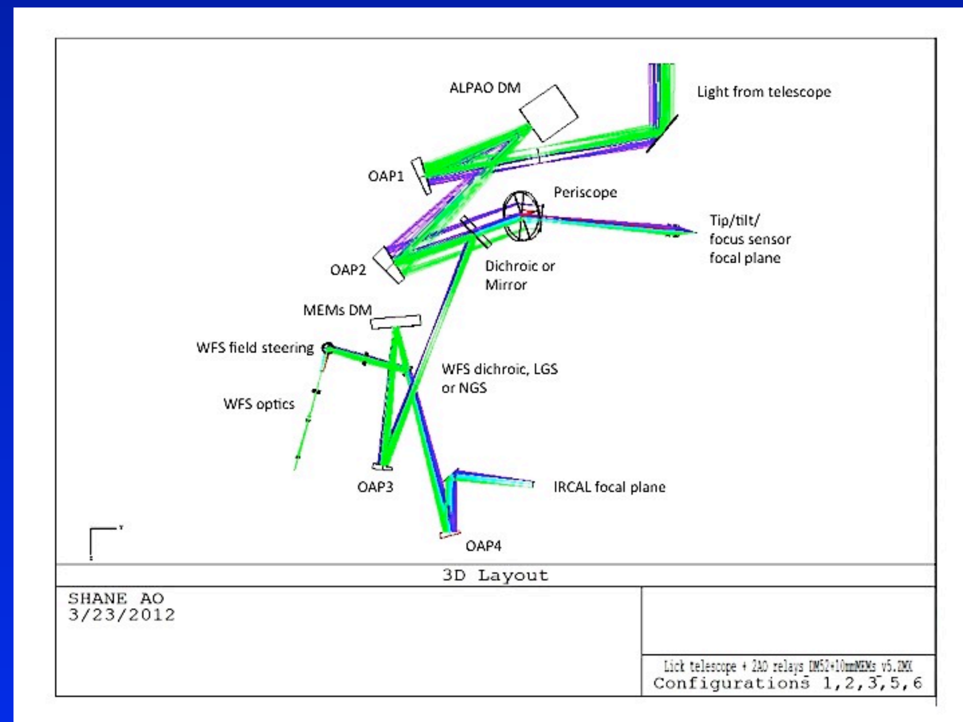


Claire Max stands next to the Shane Telescope at Lick Observatory on Mt. Hamilton. In the background, the bright straight line at the top of the photo is the laser beam from the laser guide star system Max designed as part of the telescope's adaptive optics system, which corrects for the blurring effect of the atmosphere. Photo by Laurie Hatch, Lick Observatory

Optomechanical Architecture



Cassegrain mount

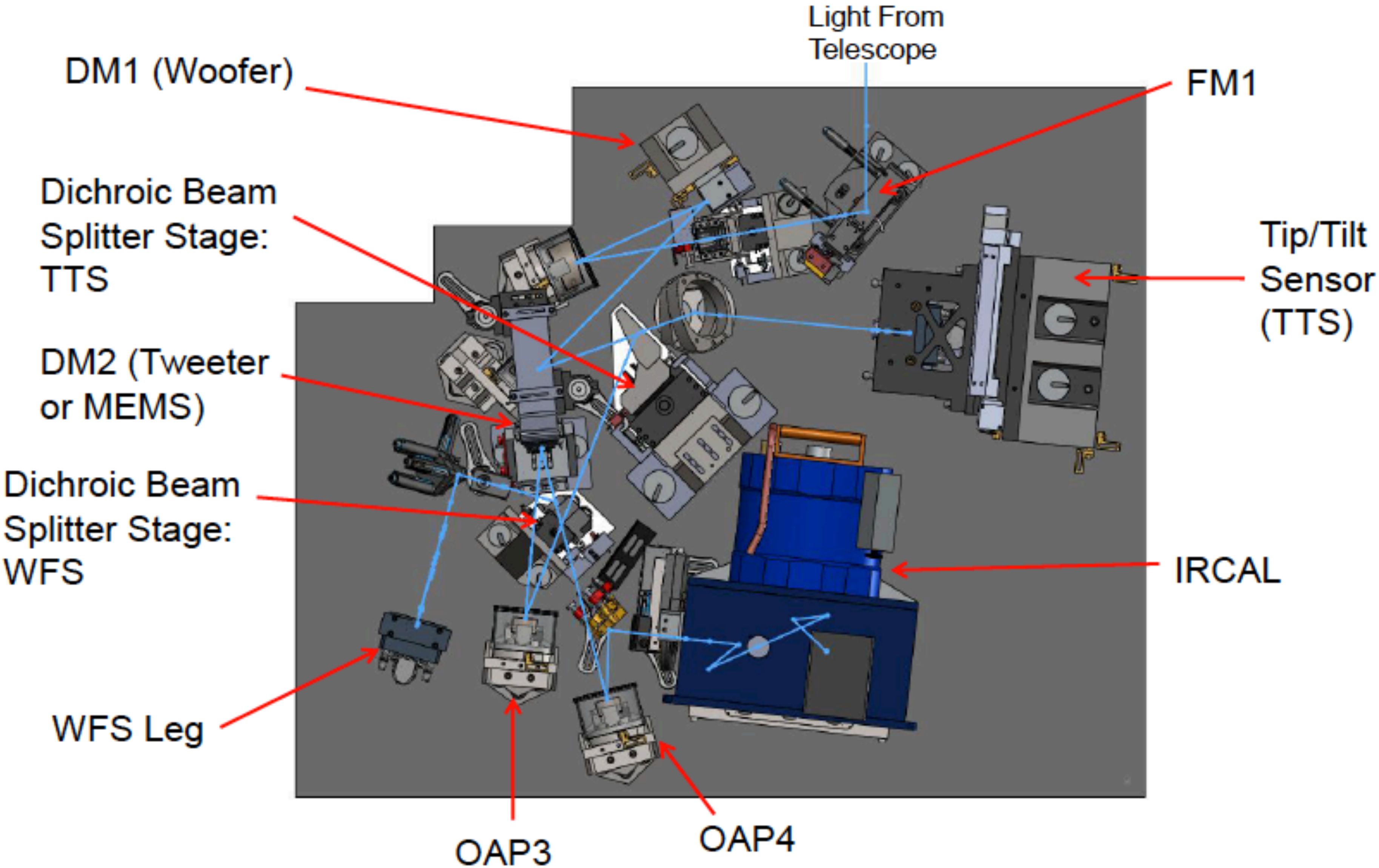


"Woofer-tweeter" architecture
- Closed-loop AO
- Partially corrected TT star

UC Observatories
Laboratory for Adaptive Optics
ShaneAO

Main Mechanical Subassemblies

UC Observatories Laboratory for Adaptive Optics
ShaneAO




ShaneAO Engineering Team
In the high bay of the Lick Optical Shops
During ShaneAO assembly, February, 2014