



Next-Generation Adaptive Optics System for the Keck Observatory

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Keck Next-Generation Adaptive Optics (NGAO) is designed to provide powerful new capabilities



1. Near diffraction-limited in the near-IR (Strehl $>80\%$)
 - A PSF with unprecedented precision, stability and contrast.
2. Vastly increased sky coverage and multiplexing
 - Enables a much broader range of science programs.
3. AO correction at red optical wavelengths (0.6-1.0 μm)
 - Highest angular resolution of any filled-aperture telescope.



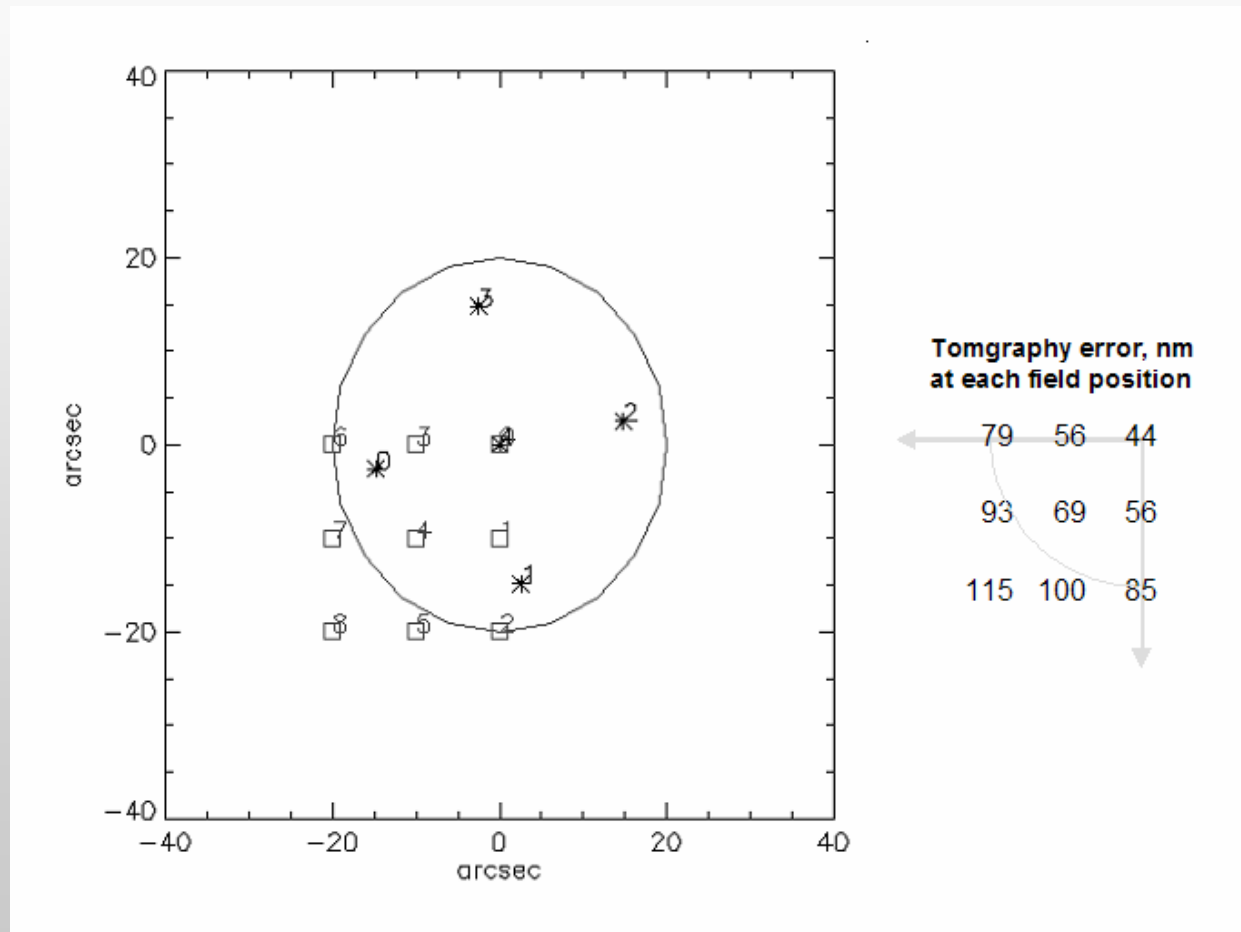
Laser Guidestar Concepts for NGAO



- **Multi-laser guidestar tomography**
 - Counter the cone effect
 - Wide contiguous field and multi-object AO
- **Variable configuration**
 - Compact constellation for high on-axis Strehl
 - Wider constellation for wider field correction and MOAO
 - Point some LGS at tip/tilt stars

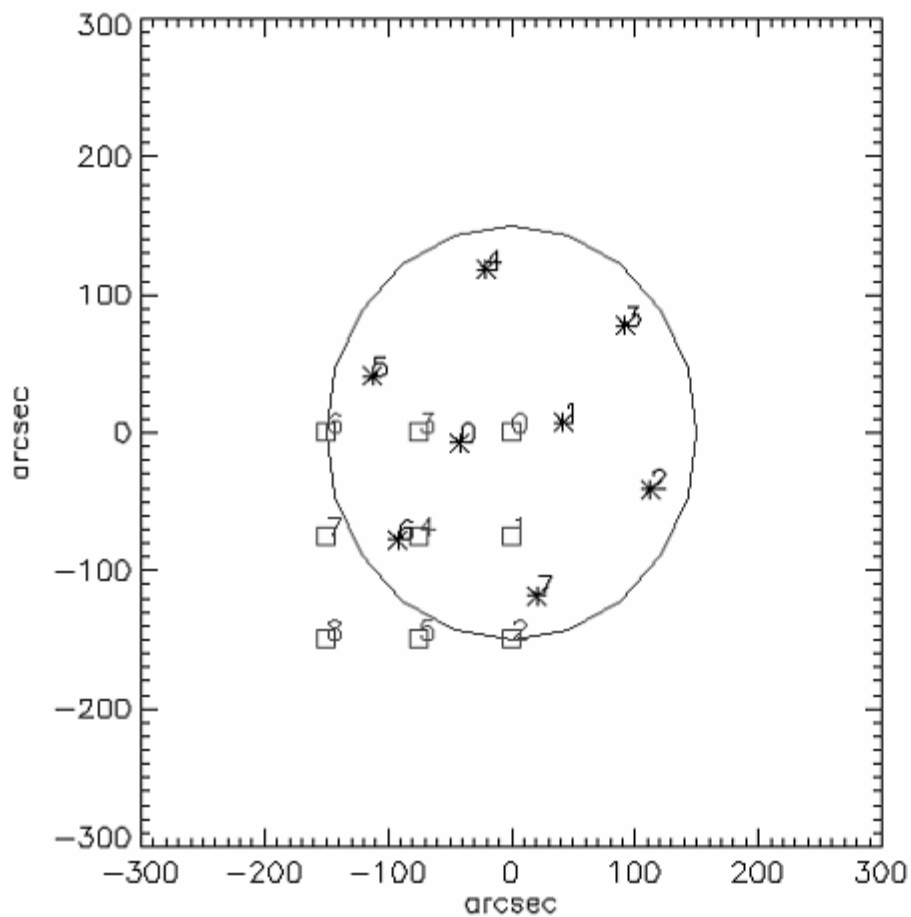


Narrow field constellation

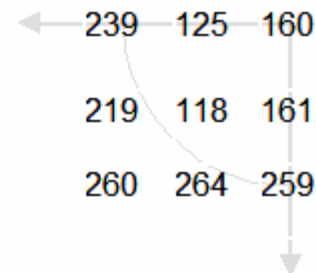




Wide field constellation



Tomography error, nm
at each field position



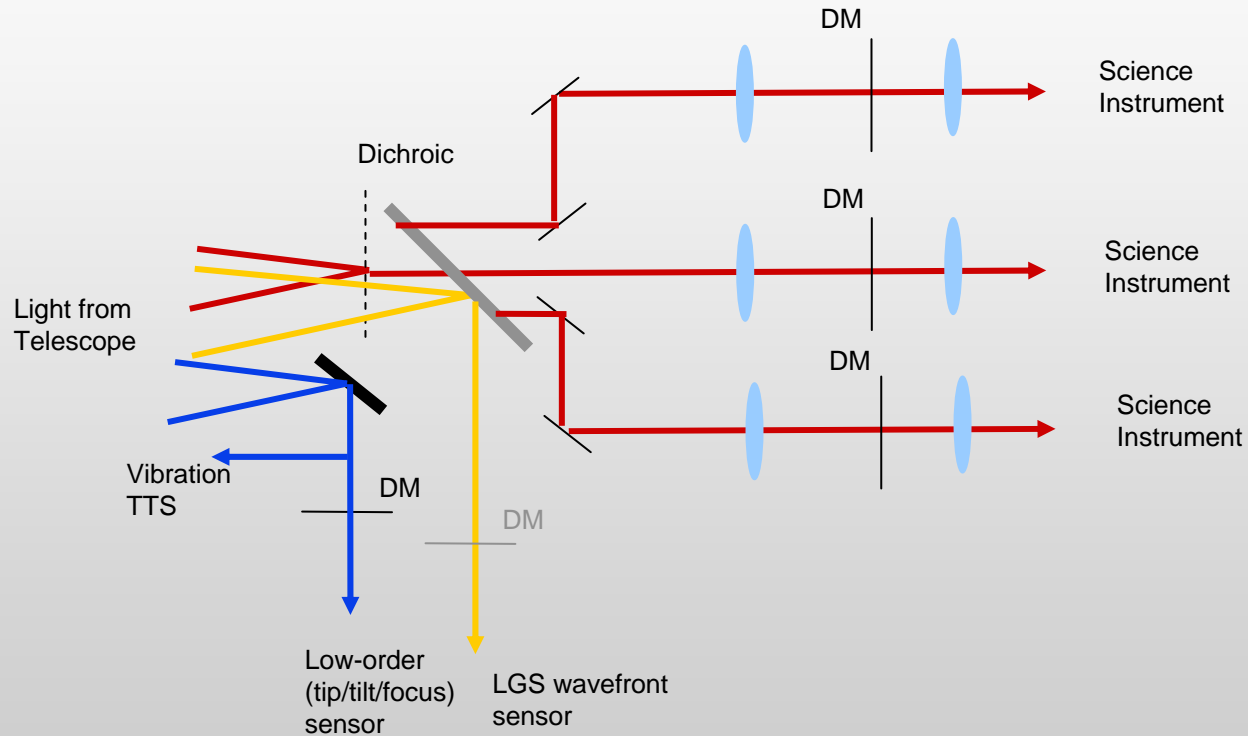


Closed-loop multi-conjugate (MCAO) architecture





Open-loop multi-object (MOAO) architecture

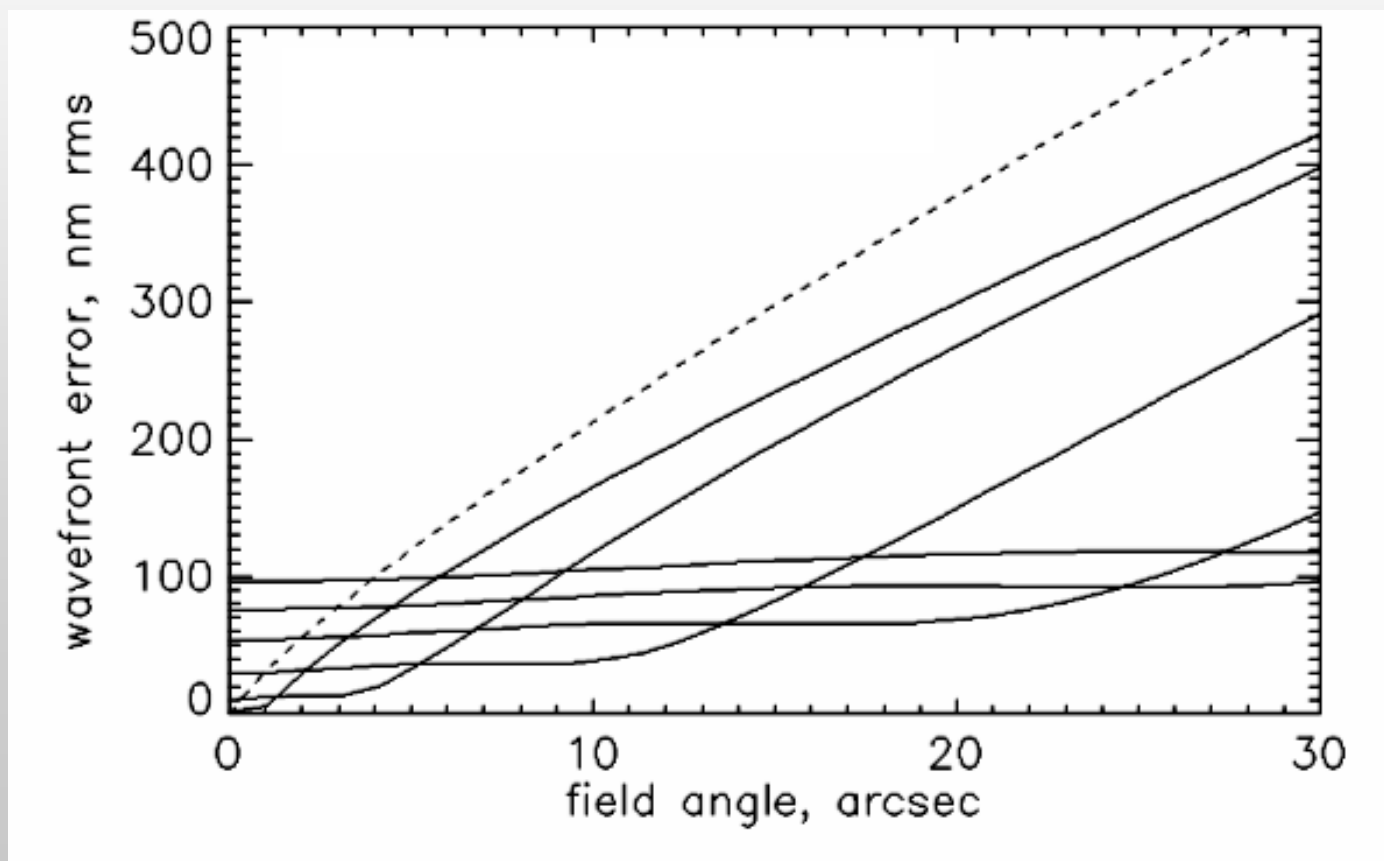




MCAO anisoplanatism



- DMs conjugate to 0, 5, and 10 km
- Correction optimized for 1, 5, 15, 30, 45, 60 arcsec radius field





Performance Budgets Development



- Wavefront error vs sky coverage
- Encircled energy vs sky coverage
- Photometric accuracy
- Astrometric accuracy
- Polarmetric accuracy
- Companion sensitivity
- Observing efficiency
- Observing uptime



Ongoing trade studies



- Number of LGS, and constellation configuration
- AO architecture (MCAO, MOAO, hybrid)
- NGAO vs Keck AO upgrade options
- Adaptive secondary
- K & L band science
- Interferometer support
- Instrument balance
- Ground Layer AO (GLAO) for seeing-limited instruments
- Science instrument reuse
- Telescope wavefront errors



Trade studies (continued)



- Observing model
- AO enclosure temperature
- Optical relay
- Field rotation strategy
- Dichroics and beam splitters
- Focus compensation schemes
- Rayleigh fratricide - do we need a pulsed laser?
- Laser pulse format
- Beam transport - can we use a fiber?



Questions for the science group



- How wide a contiguous field, and how high a Strehl on this field?
- How many multiplexed (MOAO) fields, and Strehl/EE goals vs λ ?
- What are the requirements for EE vs spaxel size and wavelength for the MOAO units?
- Instruments - switched or movable/deployable? Hot-swap time?
- Sharing of the IR bands with IR Tip/Tilt/Focus sensors. Should we swap bands use using deployable dichroics or do we use splitters that share the bands for simultaneous J,H,K science?
- Your input on the field rotation requirements and strategy?
- How much emmissivity is tolerable in each science case/wavelength band?



Science merit functions - something to consider



- The goal of any scientific instrument is to obtain sufficiently accurate data to make scientific conclusions quickly, assuredly, and at reasonable cost. Taking this a step further, one might hypothesize a quantitative merit function that incorporates cost, accuracy, and time to conclusions and then seek an architecture and a design subspace that is near the optimum.
- Example merit functions
 - **Science efficiency** $m = \text{Strehl} \times \text{sky_coverage} \times \text{multiplicity} \times \text{throughput}/\text{background_noise}$
 - **Crowded field science accuracy** $m = \text{resolution} \times \text{PSF_knowledge} \times \text{field_of_view} \times \text{confusion_limit_magnitude}(\text{Strehl}, \text{star_density}) \times \text{Strehl} \times \text{throughput}/\text{background_noise}$
 - **Wide field science accuracy** $m = \text{Encircled_energy} \times \text{field_of_view} \times \text{multiplicity} \times \text{sky_coverage} \times \text{throughput}/\text{background_noise}$
 - **Telescope use cost** $m = \sum_i (\% \text{time allocated to science case } i) \times (\text{performance merit for science case } i)$
- Challenge: unbiased determination of relative weights in the merit function