Subaru AO in future

Outline

- Overview of AO systems at Mauna Kea and in the world.
- Ongoing plan of AOS at Subaru and Mauna Kea.
- What’s in future.

AO at Mauna Kea

- Keck
  - Open use, Keck II LGSAO. NIRC2, NIRSPEC, OSIRIS.
  - Ongoing, Keck I LGS upgrade. OSIRIS. IR-TT-WFS.
  - Future plan. Next Generation AO. (NGAO), 2’ patrol FOV, 7 LGSs, 3 NGSs, 30 arcsec Science FOV.
- Gemini North
  - Open use, Altair/LGS. NIRI, NIFS
  - No future plan.
- Subaru
  - Open use, AO188/NGS, IRCS, HiCIAO
  - Ongoing, AO188/LGS, IRCS, HiCIAO, SCExAO, K3DII
  - Future plan?
- CFHT
  - Future plan. IMAKA. 1deg FOV, GLAO.

Keck NGAO

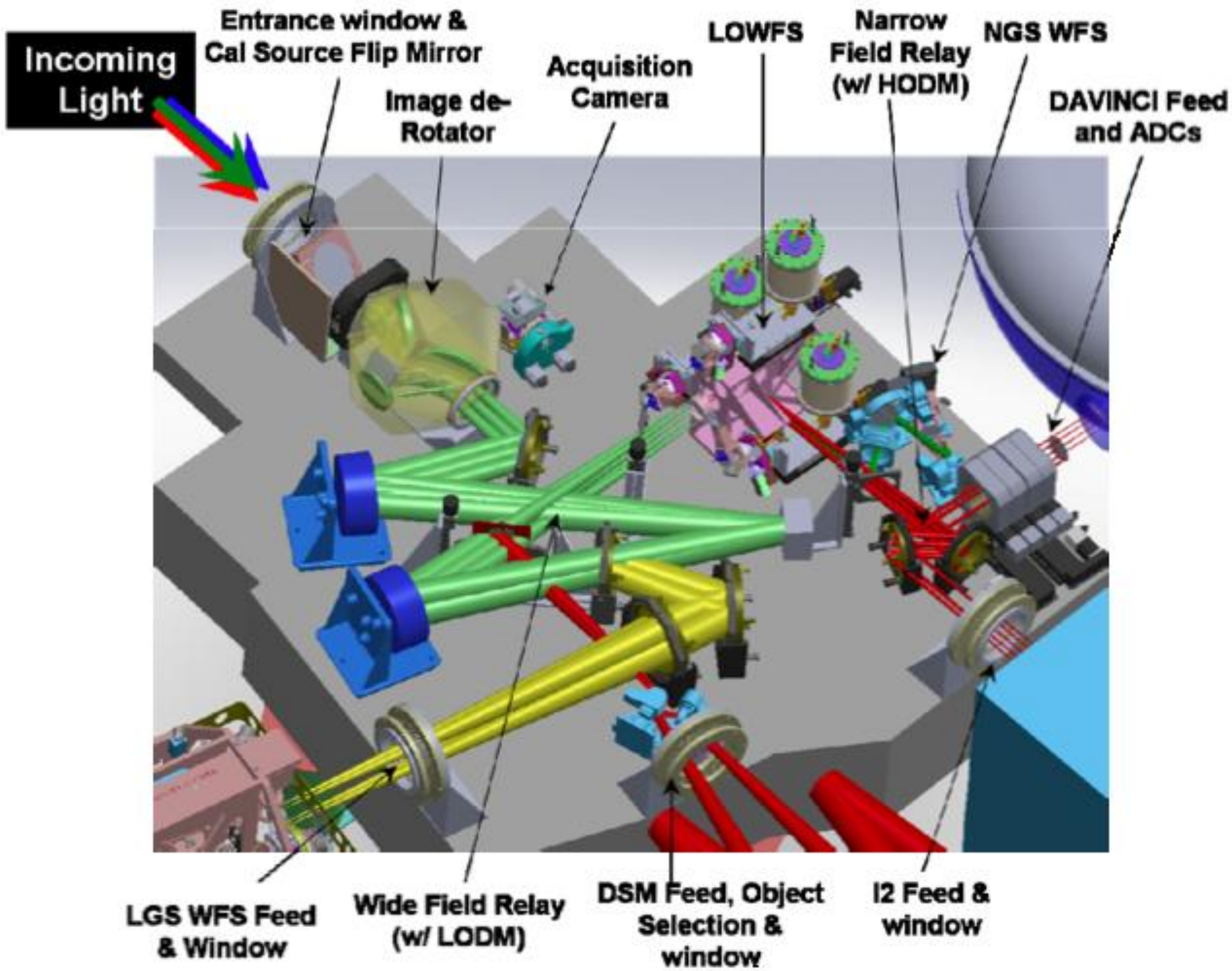


Figure 6: Perspective view of the AO bench with major components labeled.

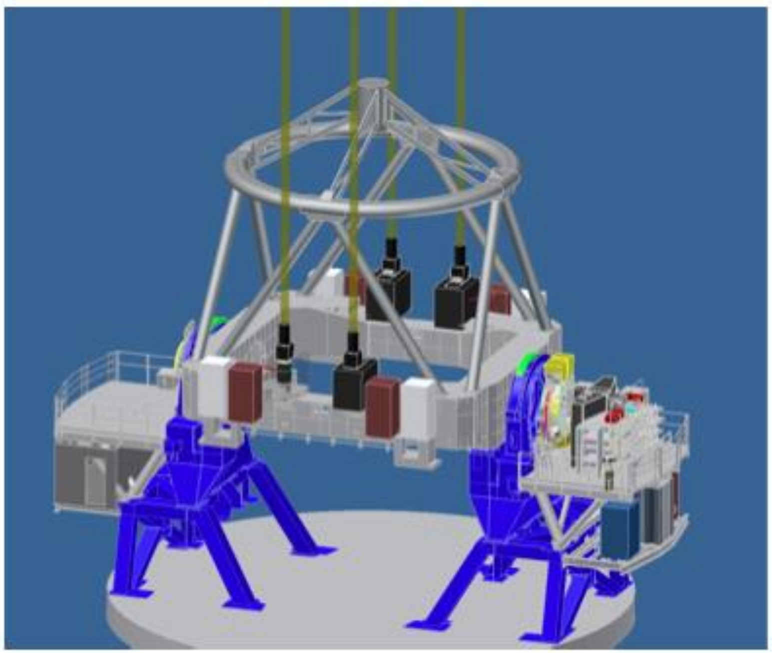
AO at Chile

- VLT
  - NAOS-CONICA (NACO) at UT4 NasB (Single conjugate LGSAO)
  - MACAO + CRIRES at UT1 NasA (Single conjugate NGSAO)
  - MACAO + SINFONI at UT4 Cas (Single conjugate LGSAO + IFU)

  - SPHERE + (IRDIS, IFS, ZIMPOL) at Nas (High contrast AO)
  - AO Facility (4 LGS, Deformable Secondary Mirror)
    - GRAAL + Hawk I at UT4 NasA (GLAO)
    - GALACSI + MUSE at UT4 NasB (GLAO, LTAO, 24 IFU modules)

- Gemini South
  - CS85, NICI
  - Ongoing, GeMS (Gemini MCAO System), FLAMINGO-2
  - Ongoing, GPI (Gemini Planat Imager)

ESO AOF



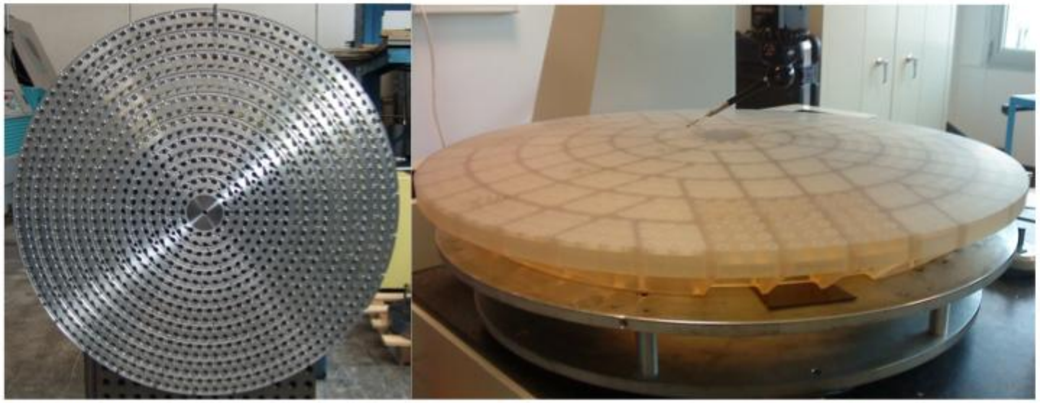
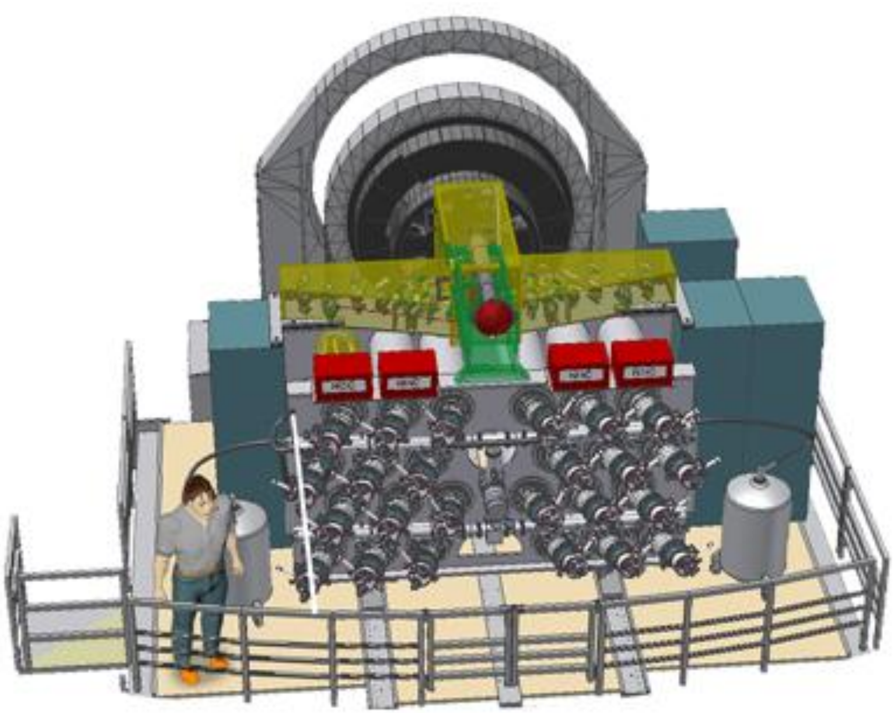


Figure 6: Left: the cold-plate. Right the Zerodur reference body: this optical component is manufactured by SESO (France) and an intricate light-weighting scheme brings the weight of this component to a mere 47 kg.

MUSE and Hawk I



HAWK-I at Paranal

ESO Press Photo 36d/07 (22 August 2007)

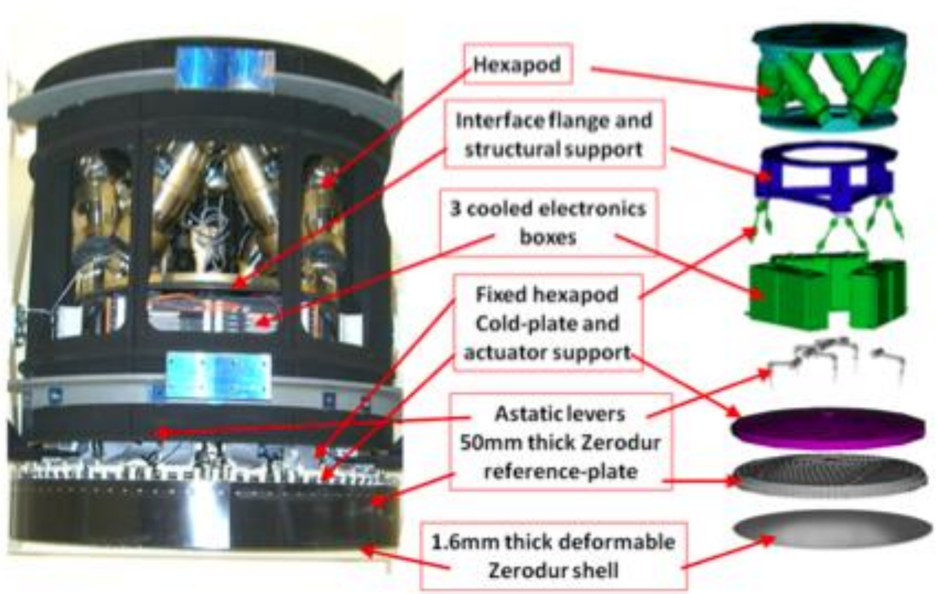
AO at LBT

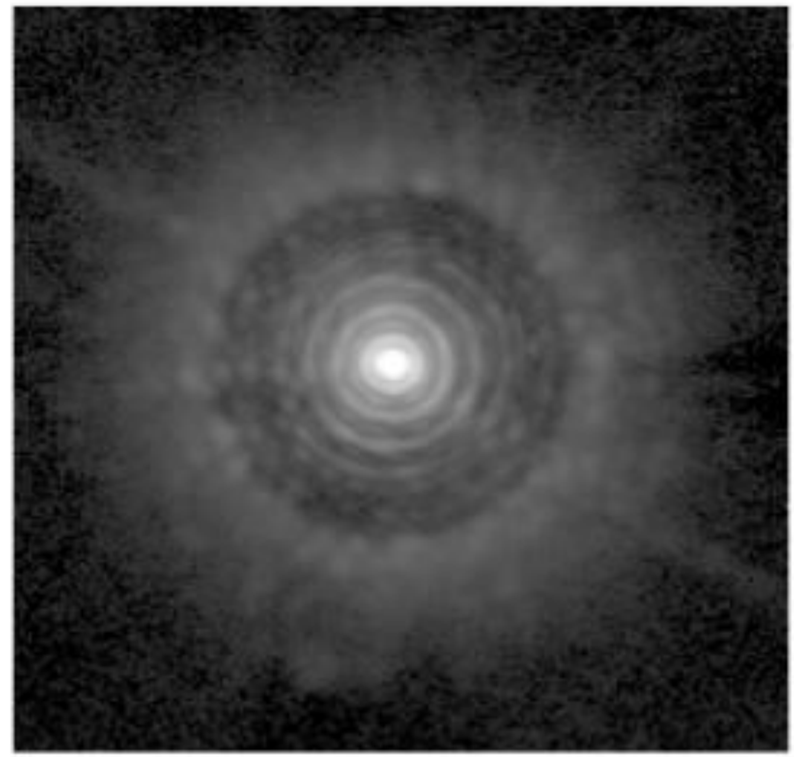
- FLAO (First Light AO)
  - Adaptive Secondary Mirror. (ASM)

- ARGOS (laser guide star system)

- LINC-NIRVANA (Interferometer)
- LUCIFER (IR-MOS)

ASM at LBT


Hexapod
Interface flange and structural support
3 cooled electronics boxes
Fixed hexapod Cold-plate and actuator support
Astatic levers
50mm thick Zerodur reference-plate
1.6mm thick deformable Zerodur shell



Lineup of AOS at Subaru.

- Single conjugate AO with 1 LGS.
  - AO188/LGS (Facility)
- Extreme or high contrast AO.
  - HiCIAO (PI)
  - SCExAO (PI)
- IFU
  - Kyoto 3D II (PI)
- MOAO
  - RAVEN. (Bringing-in)

AO at Mauna Kea

- Single conjugate AO with LGS.
  - Subaru, Keck I, Keck II, Gemini.
- Extreme or high contrast AO
  - HiCIAO, SCExAO at Subaru.

- Next Generation AO of Keck.
  - High SR AO with LGSs. 30 arcsec Science FOV.
- TMT NFIRAOS.
  - MCAO with multiple LGSs, 10-30 arcsec FOV

AO at Mauna Kea

- GLAO is missing.
- GLAO feasibility study has been performed by Gemini in 2005.
- Key components for GLAO.
  - Deformable secondary mirror.
  - Multiple LGSs and tomographic wavefront estimation.
- Which telescope is the best for GLAO?
  - Subaru, Keck or Gemini.

GLAO feasibility study

Table 6. Combined SLODAR/LOLAS turbulence strength versus altitude in units of $m^{1/3}$.

Altitude (m)	25 percentile	50 percentile	75 percentile
0.0	8.06E-14	1.04E-13	1.40E-13
15.0	3.31E-14	5.32E-14	8.56E-14
30.0	1.60E-15	1.41E-14	2.10E-14
45.0	0.00	6.34E-16	1.03E-14
80–160	5.20E-16	7.27E-15	2.43E-14
160–240	0.0	3.51E-15	1.01E-14
240–320	0.0	2.91E-15	9.01E-15
320–400	0.0	1.87E-15	6.91E-15
400–480	0.0	4.10E-16	4.97E-15
480–560	0.0	0.0	1.67E-15
560–640	0.0	0.0	0.0
FA	2.46e-13	1.57e-13	9.37e-14

Chun et al. 2009

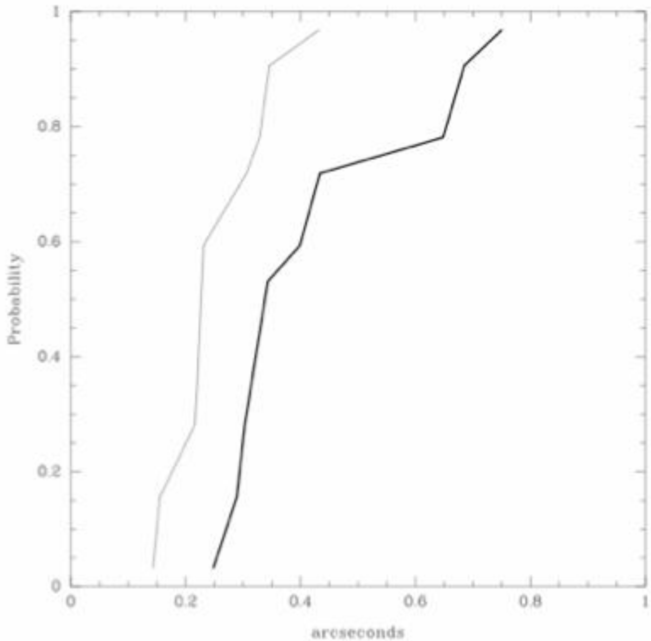


Figure 9. Image quality probability of GLAO (line on left) versus natural seeing (right) in K band using the 9 model atmospheres discussed in the text. The improvement in FWHM that GLAO provides translates into greatly increased probability of achieving a given image quality; conditions yielding the best 20% of image quality currently would be present roughly 70% of the time at most scientific wavelengths using GLAO. Simulations of image quality improvement for other scientific wavelengths are presented in Appendix F.2, Section 4.

Gemini GLAO feasibility study, 2005

Deformable secondary mirror.

- 5 - 10 years from now.
- Only Subaru Telescope could mount DSM stably.

- DSM is applicable for
  - GLAO.
  - CIRMOS (MOAO) woofer.
  - Cassegrain and Nasmyth foci.
- Upgrade AG/SH unit to AG/WFS unit.

Upgrade path to DSM.

- IRM2 with MOIRCS.
  - Tip tilt compensation only.
  - 2 to 4 guide stars outside of MOIRCS FOV.
  - Estimate wavefront using tomographic algorithm.
  - Wavefront sensing up to a few tens of Zernike mode.
  - Use space of AO36 or Cs AG/SH/SV for wavefront sensors.

AO at prime focus

- Stabilized image at prime focus.
- Compensate M1 error. (semi-realtime active optics.)

- Small CCDs (500x500 pixels) mounted on the TT/focus adjustment mechanism.
- Mosaic up to ~200 detectors, covered 30' FOV. Filling factor might be 70% - 80%.
- Each CCD has FOV within an TT-isoplanatic angle.
- Several CCDs, which has a relatively bright TT guide star, is used for TT wavefront sensing.
- Tomographic TT estimation.
- TT compensation done by these movable CCD mounts individually or the orthogonal transfer CCD technique.
- Upgrade to IR detectors.

Summary

- Future plan of AOS at southern hemisphere is well covered. (MCAO, GLAO, LTAO etc.)
- No future plan of GLAO (wide field AO) at Mauna Kea, even though Mauna Kea is the best site to compensate the GL turbulence.
- Deformable secondary mirror is the major component.
- IRM2+MOIRCS, Prime focus AO.

Discussion

- Deformable secondary mirror.
  - First generation DSM has been manufactured .
  - Just purchase a first generation DSM or develop a second generation DSM.
- Primary focus AO.
  - Active optics.
  - Performance of TT/Focus compensation.
  - Field segmented imaging with tip-tilt/focus compensation.