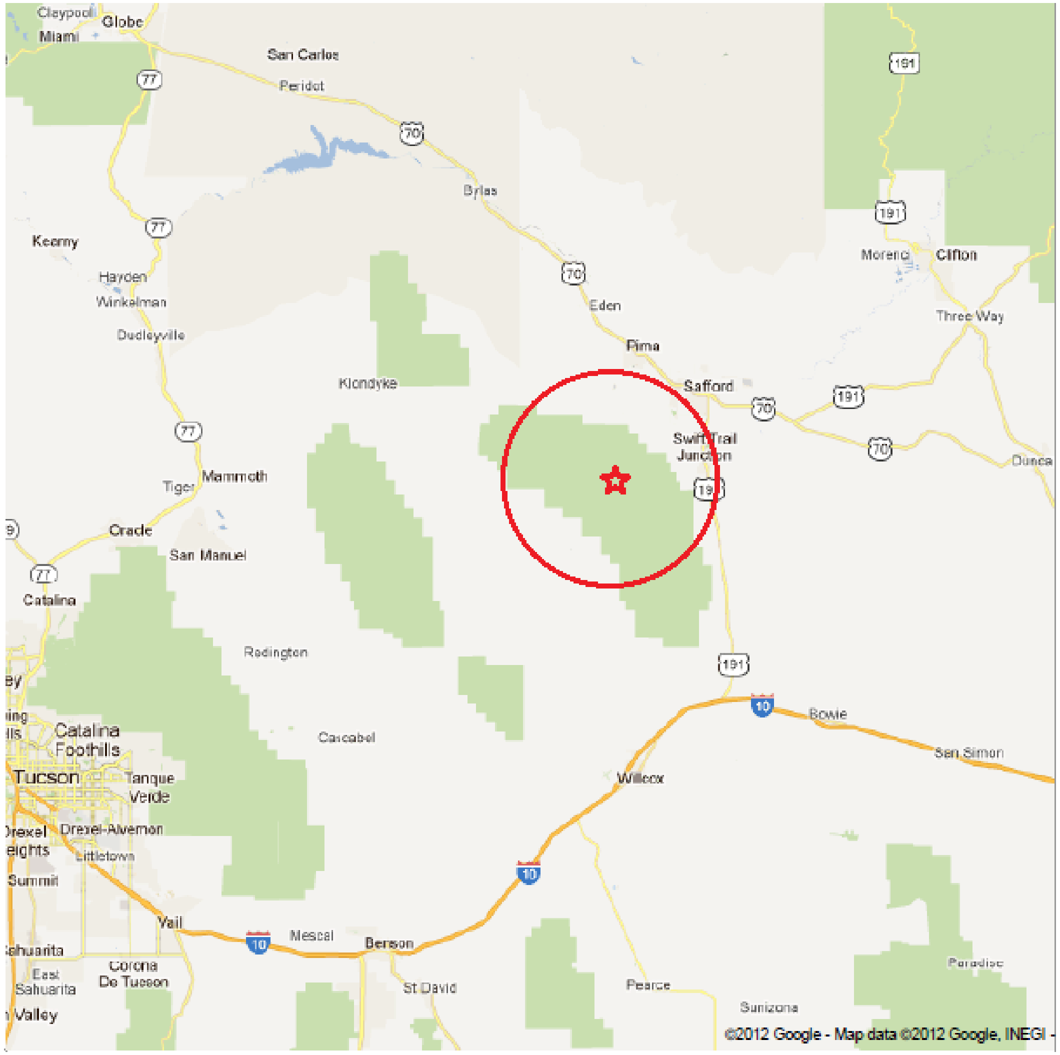
ARGOS

The Laser Guide Star System for the LBT

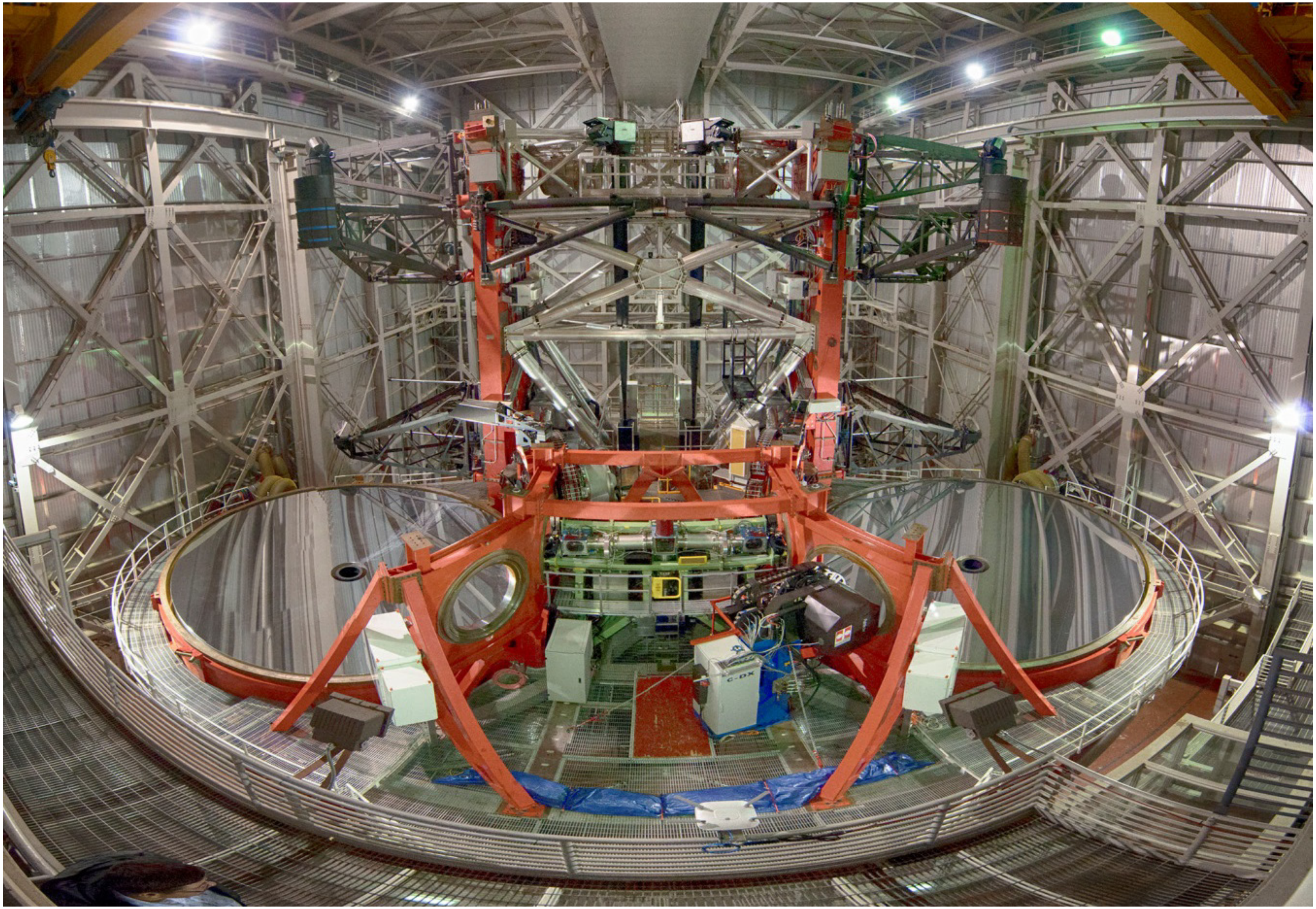
Gustavo Rahmer (LBTO/University of Arizona) for the ARGOS Collaboration

Where is the LBT?



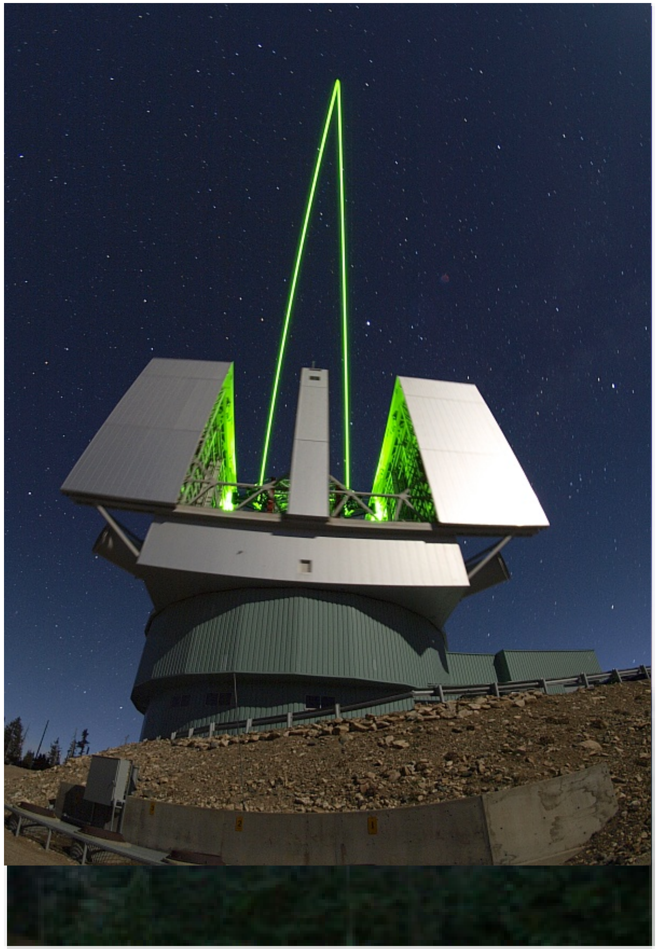
The LBT from a distance

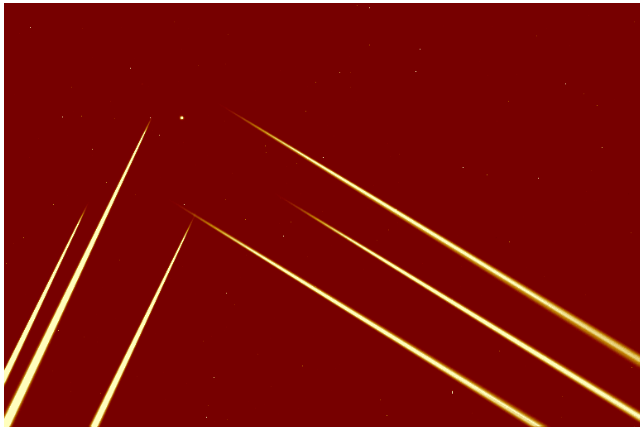
The LBT inside



What is ARGOS

- Ground-layer AO for wide-field corrections (4x4 arcmin)
- 3 “Rayleigh beacons” at 12 Km (above each mirror)
- Each laser: Nd:YAG, 18 W, pulsed @10KHz, 532 nm
- Designed to work with the two LUCI instruments (near-IR multimode)





Who is ARGOS

MPE (Garching)

- Project Management
- Science
- Sys Eng
- Laser System
- Electronics
- WFS CCD

MPIA (Heidelberg)

- Software
- Cal Unit
- Vibration Comp

Arcetri Obs. (Florence)

- WFS
- Science

CAAO (Tucson)

- Launch Sys
- Aircraft
- Space Com

AIP (Potsdam)

- Tip-Tilt

LSW (Heidelberg)

- Cal Unit

MPfIR (Bonn)

- Tip-Tilt

MPI HLL (Munich)

- WFS CCD

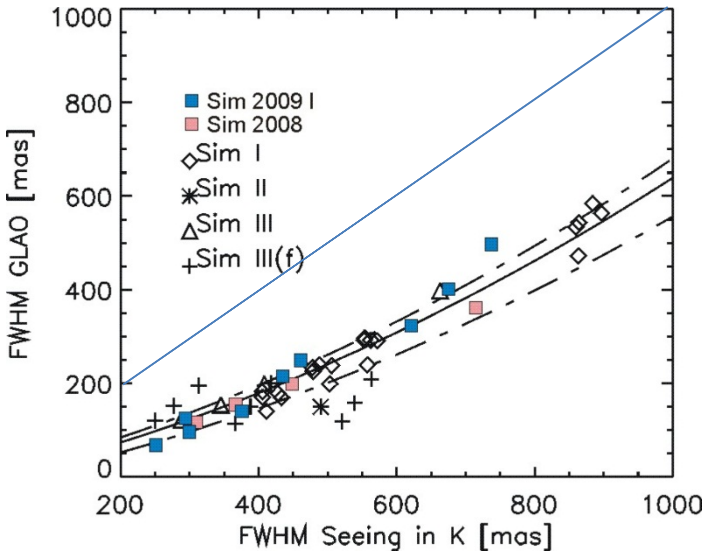
LBTO

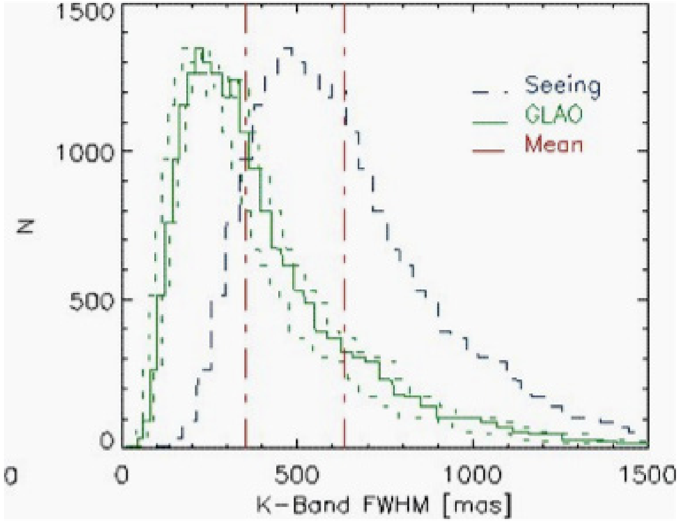
- Sys Eng
- Safety
- FAA/Space

PI: Sebastian Rabien (MPE)

Co-PIs: Wolfgang Gässler (MPIA), Simone Esposito (Arcetri), Michael Hart (CAAO)

ARGOS Performance





- Independent performance simulations with consistent results:
  - The FWHM is typically decreased by a factor of 2-3 over a 4 arcmin FOV
  - The flux in the LUCI 0.25'' slits is increased by a factor of 2-3 (gaining a factor 4-9 in observing time)

- Significant overall increase of "usable" nights.

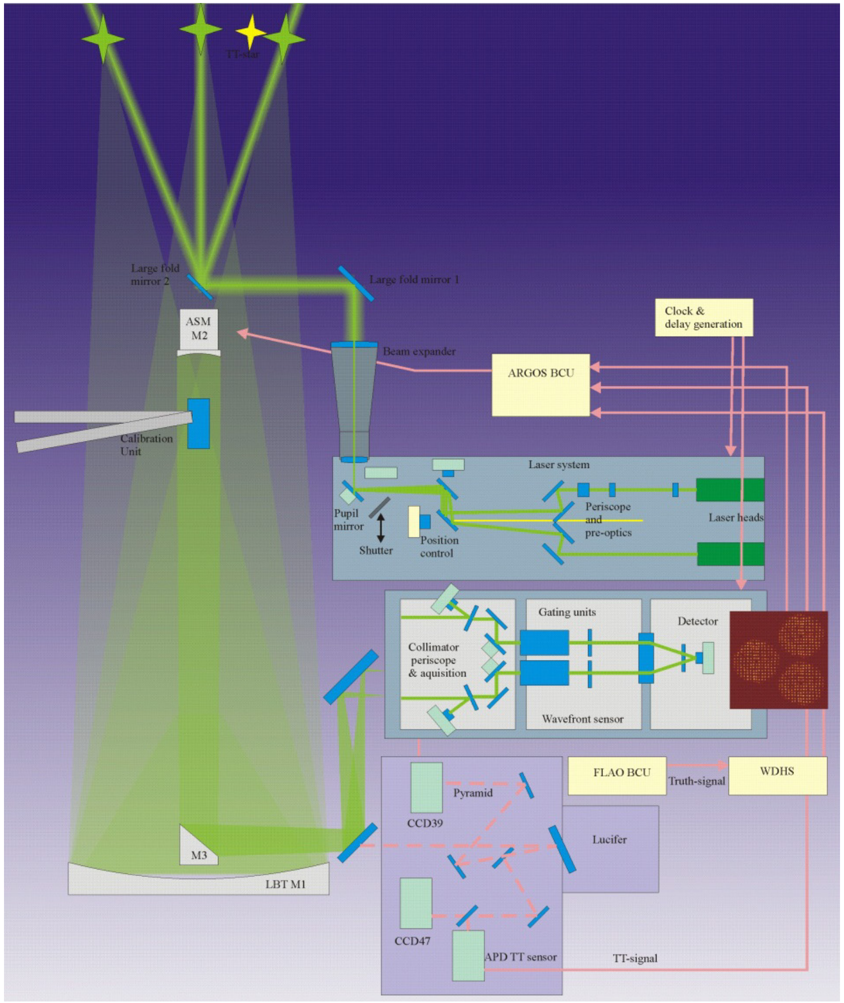
Science with ARGOS

- Increased point source sensitivity.
- Increased slit coupling efficiency.
- Reduced crowding noise.
- Enhanced spatial resolution.

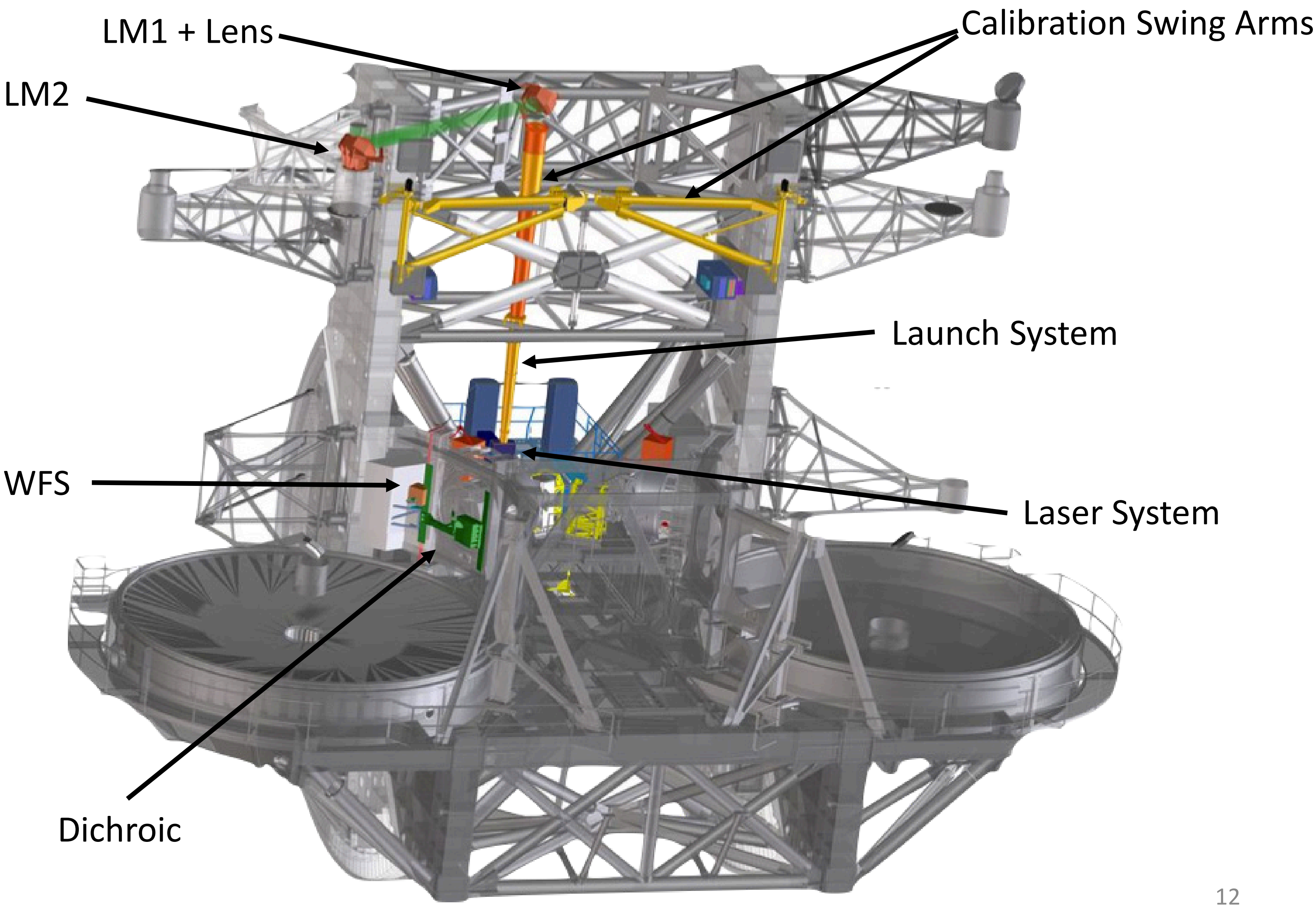
- Science cases:
  - **Dynamics & stellar populations in high redshift galaxies (z ~ 2-3).**
  - Post-starburst clusters in the Milky Way.
  - Understanding star formation in nearby galaxies.
  - High resolution imaging of Local Group starbursts.
  - Embedded starburst and super star clusters in the M31 spiral arms.
  - QSO host galaxies.
  - Black-hole growth and cosmic reionization history from spectroscopy of z>6 quasars.
  - Searching for planets around white dwarf stars.
  - Classical Cepheids as tracers of the galactic disk.
  - Imaging and spectroscopy of very high redshift galaxies.

ARGOS Operation Overview

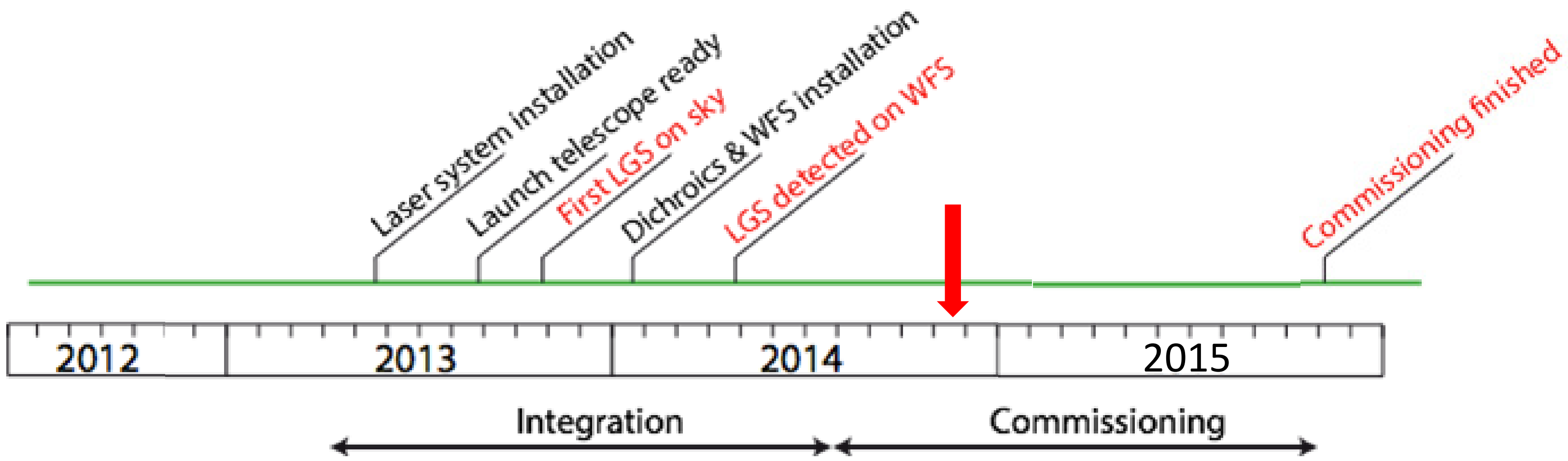
- Laser pulses are generated by the laser system, pre-expanded, steered to the proper location and sent via a fast TT mirror into the launch system.
- The launch system expands the beams to ~40 cm diameter and propagates the pulses on sky via large flat mirrors.
- After 80.06 µs, the photons scattered at 12 km arrive back at the telescope, are directed to the WFS (by a dichroic) where a shutter opens for 2 µs, equivalent to a path length of 300 m.
- The wave front error is calculated from the slopes of the WFS signals and fed to the ASM.



System distributed around the telescope

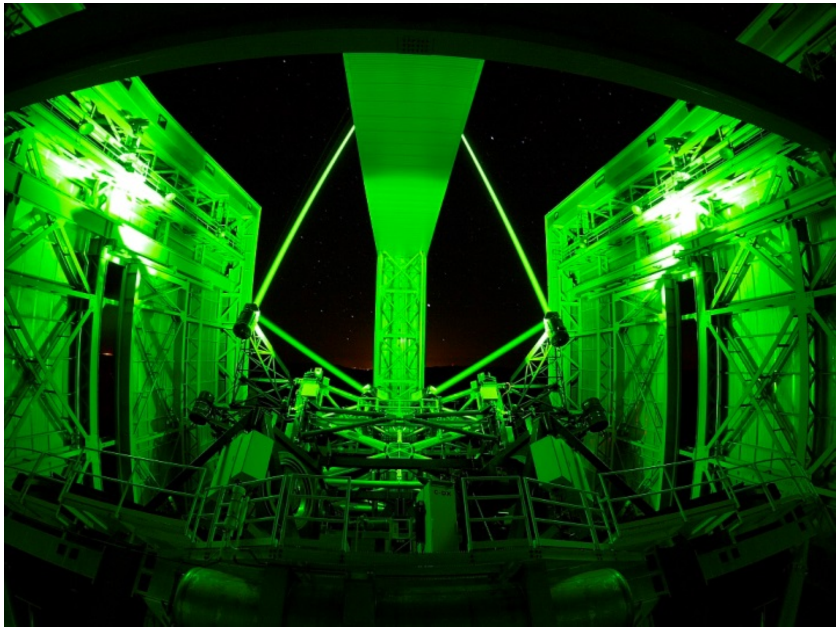


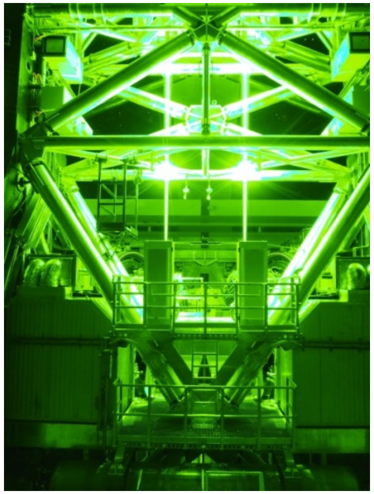
ARGOS Project Schedule

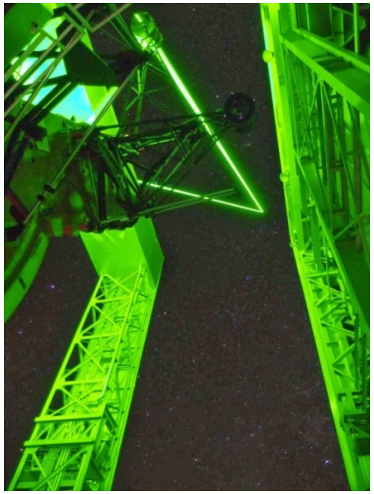


- Laser system installation: June 2013
- All components installed: September 2013
- First LGS on sky: November 5, 2013
- LGS on WFS: March 2014
- First closed-loop attempt on sky: May 2014
- Next big campaign (5 nights): Nov 28 – Dec 2, 2014
- Commissioning and science verification: until November 2015 (we hope!)

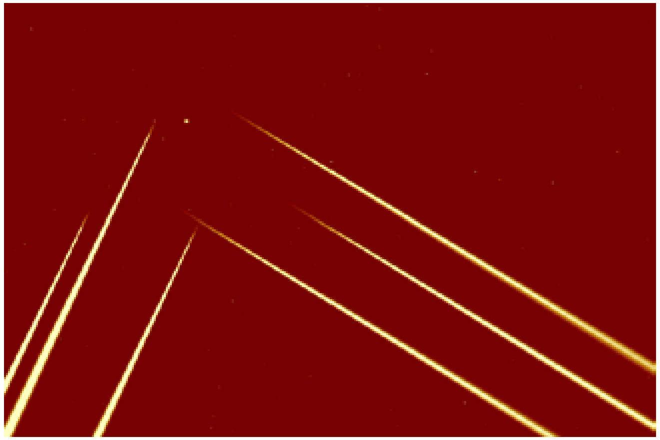
“First Light”: Nov 2013



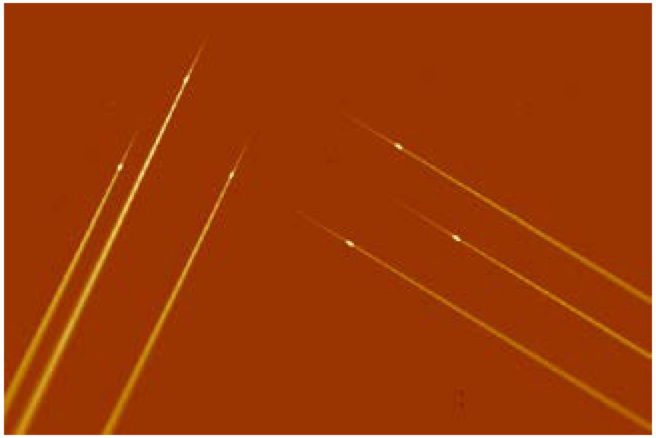




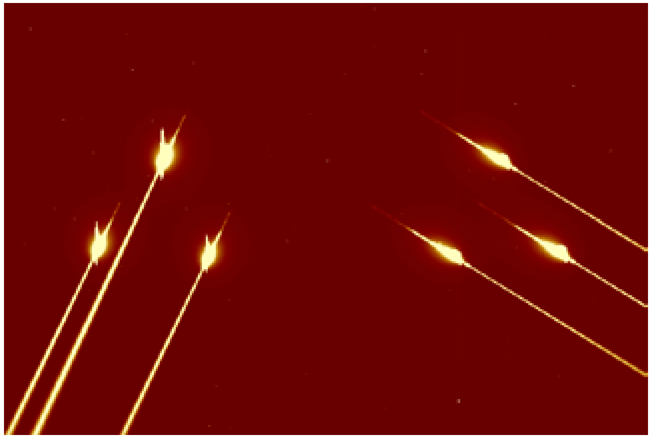
“First Light”: Nov 2013



- Camera FoV is ~13 arcmin.
- Constellation diameter is 4 arcmin.

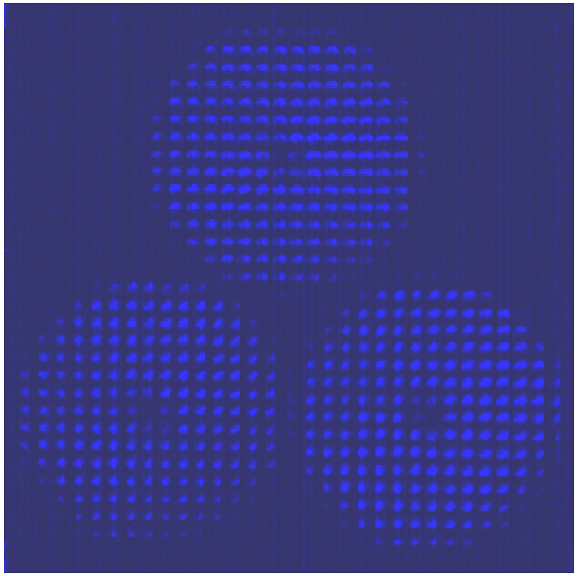


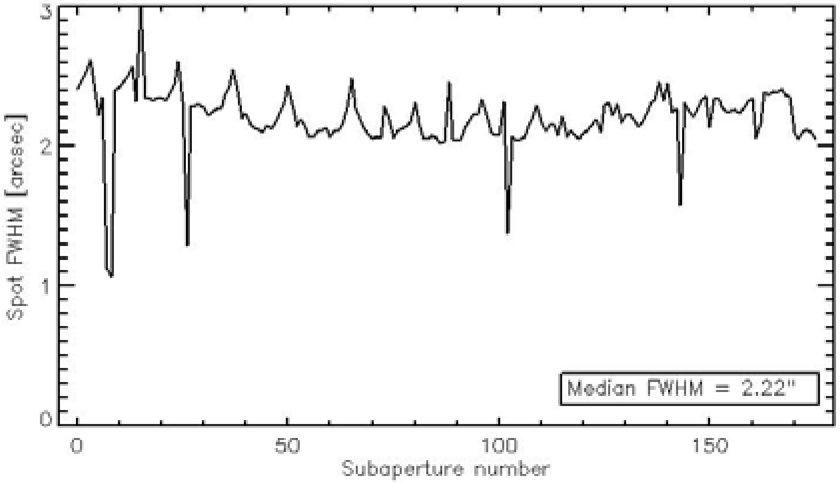
High layer cirrus clouds enhance the scatter



A strong cloud layer starts to fully attenuate the lasers

Second Campaign: March 2014

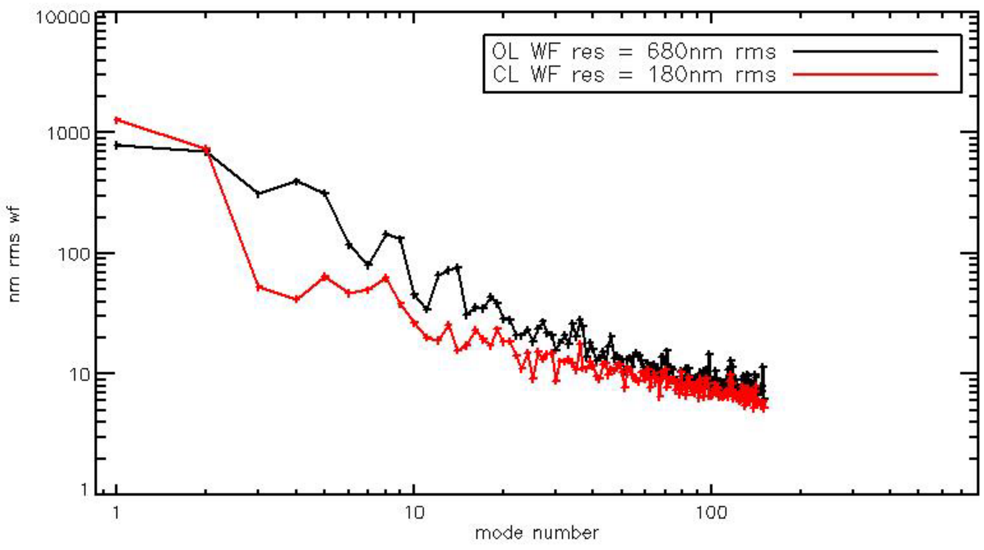




- First LGS light on WFS.
- Measured flux: ~1600 ph/ms/subap (calculated 1800).
- **Problem**: Spots are astigmatic and more than double the expected size (1 arcsec). Aberrations are consistent with one or two of the launch mirrors being deformed spherically by up to 2 microns p-v.
- **Solution**: add a corrector.

Third Campaign: May 2014

- First closed-loop on sky (although only on one beacon).
- Launch optics aberration confirmed.

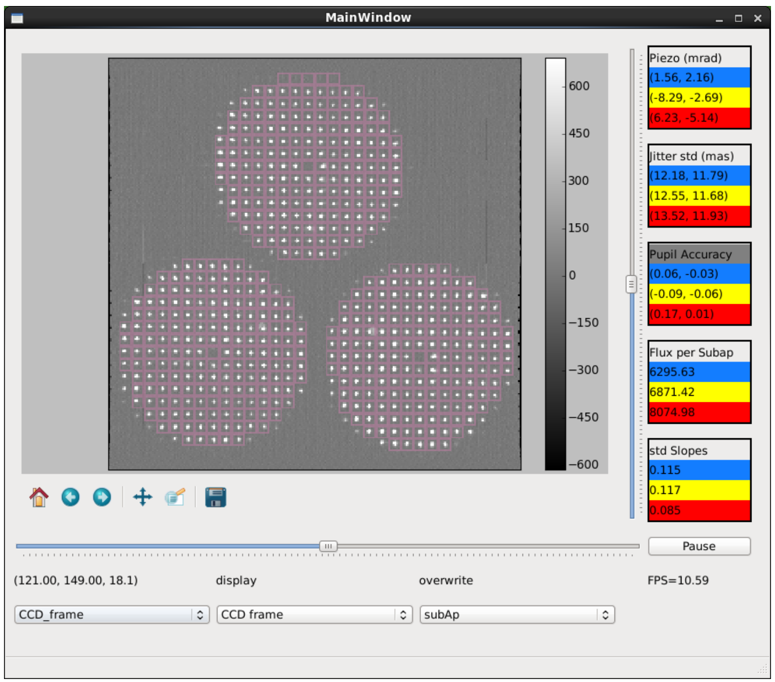


- Modal variance of slopes measured at 1kHz on-sky by one SH sensor.
- Black line: open loop. Red line: AO closed loop residuals.
- WF error reconstructed on the 150 modes (tip-tilt excluded):
    - OL: 680 nm rms.
    - CL: 180nm rms.

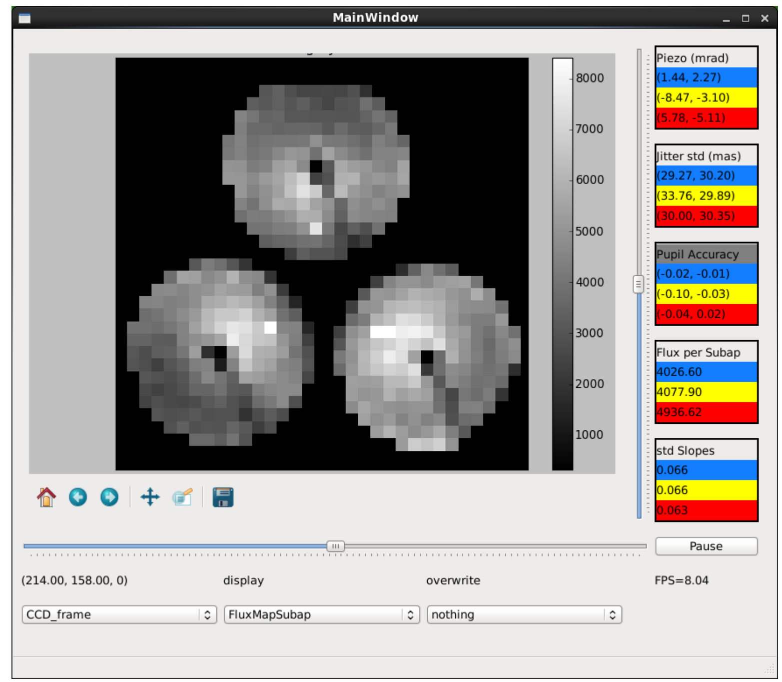
Fourth Campaign: November 2, 2014

Fourth Campaign: November 2, 2014

Closed-loop tests using Cal Unit sources



S-H spots on detector with subap regions overlaid



Integrated flux on each subap (notice shadow of Cal Unit arm)

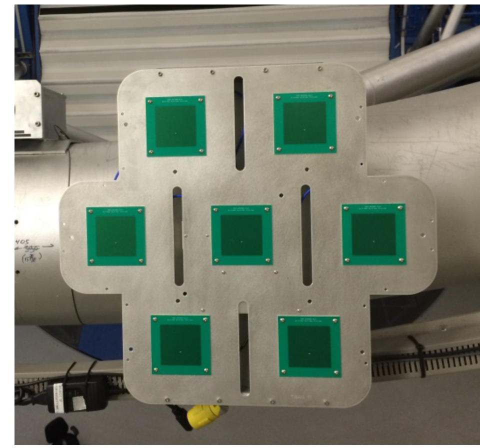
Operational Issues

- Personnel Safety
  - U of Arizona Safety Office is single point of contact with State Radiation Agency.
  - Protocols and documents in place.
  - Continuous personnel training.

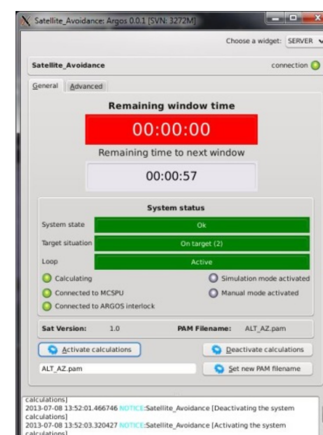
- Coordination with VATT (the other optical telescope on site)
  - Currently operator-to-operator coordination.
  - Future: LTCS (Laser Traffic Control System).

Operational Issues

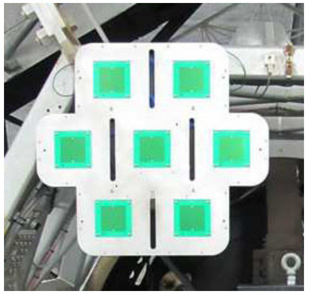
- Aircraft Avoidance
  - Operation approved by FAA
  - Military airspace coordination required
  - 2 human spotters required (to have full sky coverage)
  - Automated aircraft detection:
    - TBAD system installation in progress
    - Goal is to be ready for future FAA approval of automatic detection



- Space Command
  - Software module handles PAMs

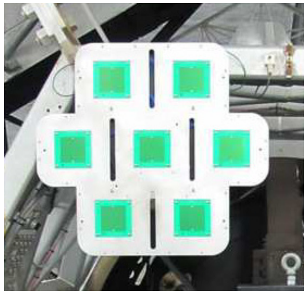


TBAD

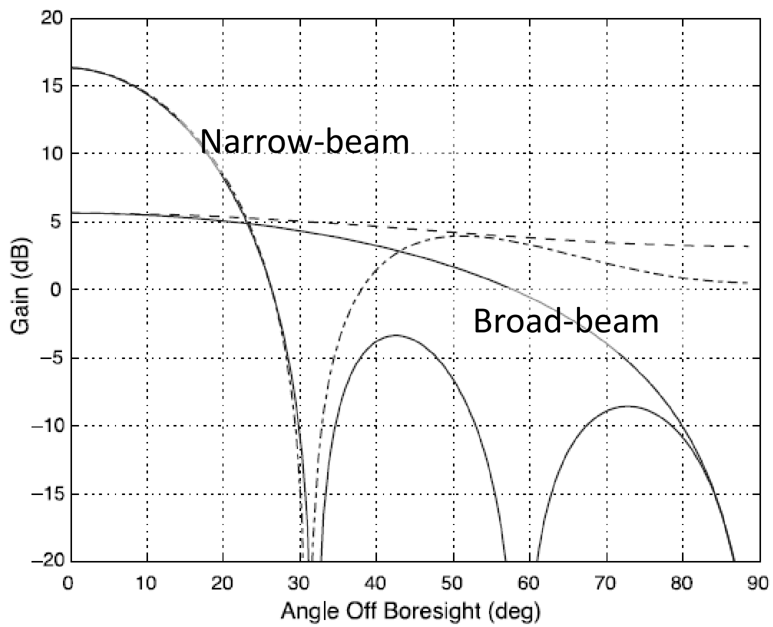


- Developed at UCSD (by Tom Murphy and Bill Coles) to protect aircraft from accidental illumination by lasers.
- Passive detection of omni-directional transponder signals at 1090 MHz from aircraft in response to external interrogations.
- Detection is determined by the ratio of the signal from a phased array antenna to that of a single antenna element (independent of transmitted power, distance, polarization, etc.).
- Detection cone: ~15^{o} around boresight direction.
- Currently installed at:
  - Keck I and II
  - Gemini N and S
  - Subaru
  - APO

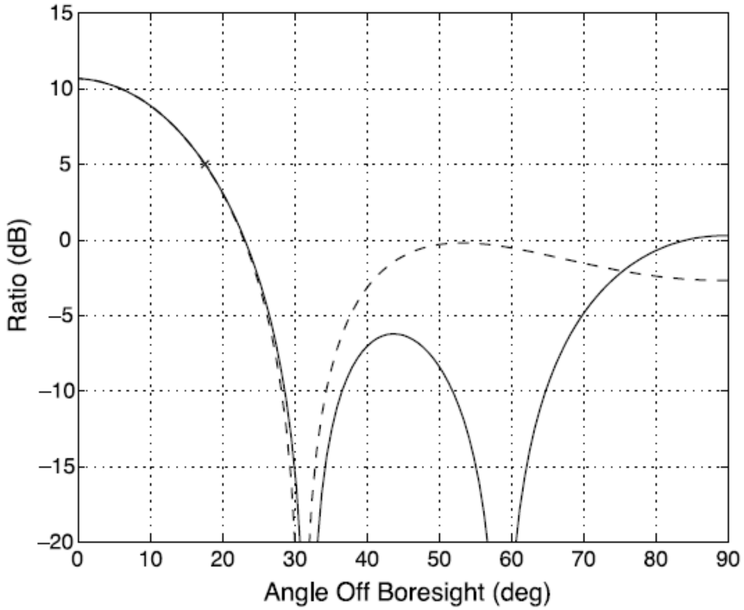
TBAD

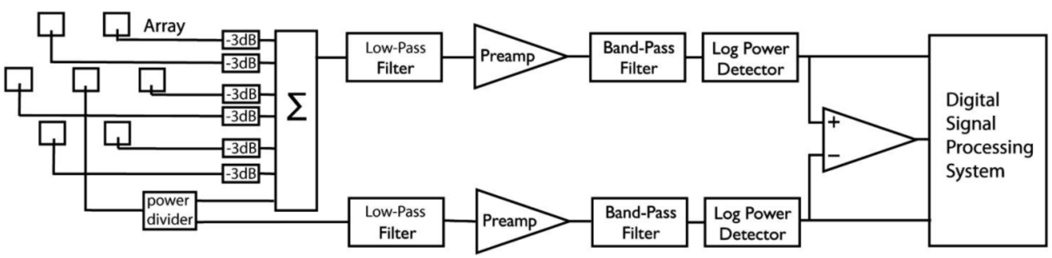


Antennas Gains



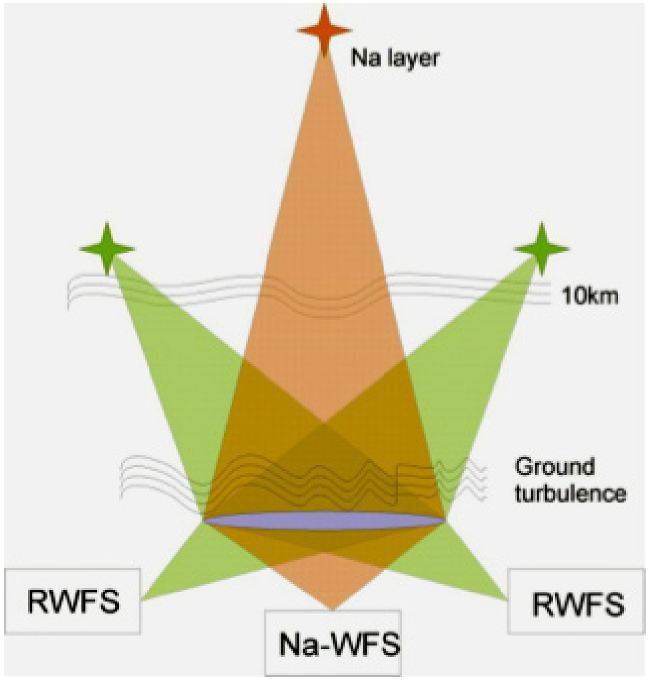
Ratio





Coming Next: Hybrid LGS

- Adding a sodium laser opens the path from GLAO to the diffraction limit:
  - High power GLAO correction “cleans up” the ground turbulence
  - Na-line laser samples high layer turbulences
- Only moderate power Na-laser is required.
- Provides a path to MCAO, as only a single TT-star is required



- The ARGOS system is already prepared for the upgrade