Adaptive Optics Lectures

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3. SOAR Adaptive Module (SAM)

SAM web pages: SOAR--> SAM

http://www.ctio.noao.edu/new/Telescopes/SOAR/Instruments/SAM/

Paper (2016, PASP, 128, 125003):

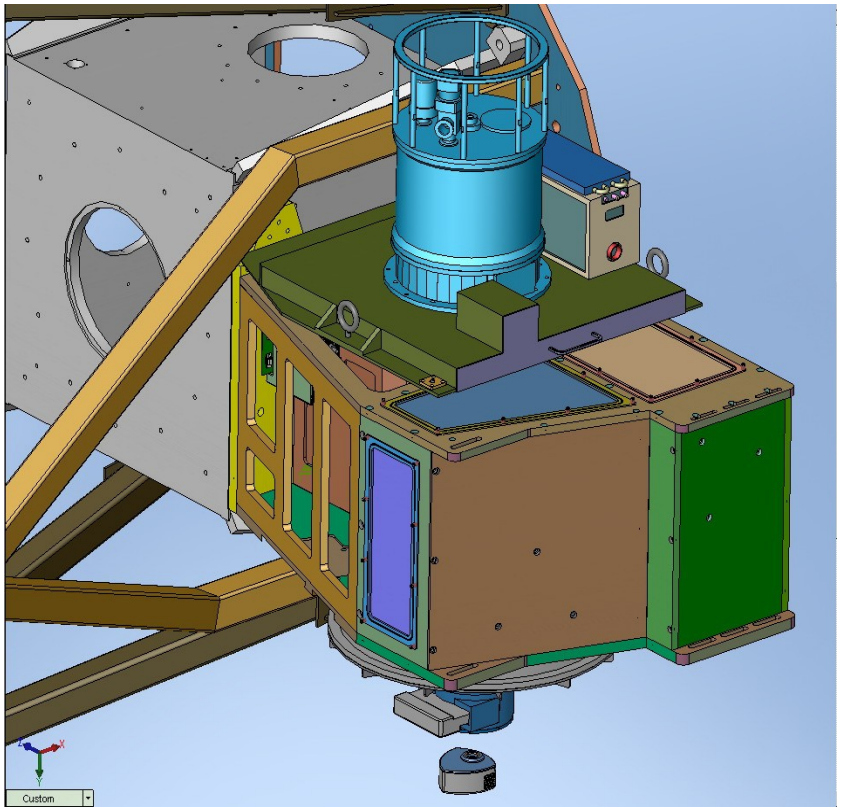
http://www.ctio.noao.edu/~atokovin/papers/SAM-PASP.pdf

History:

http://www.ctio.noao.edu/~atokovin/papers/sam_history.pdf

Plan

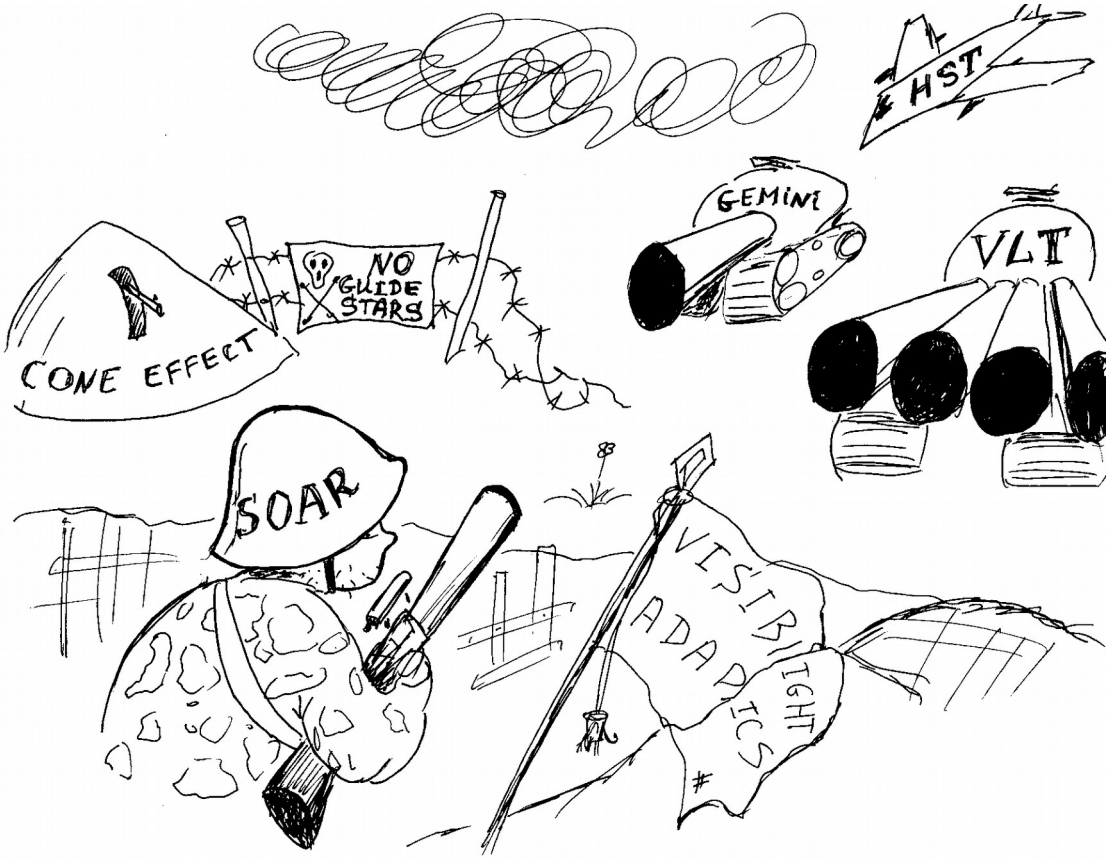
- Goals and concept evolution
- System overview
- Optics & Mechanics
- WFS, tip-tilt, laser system
- Performance on the sky
- Science use and operation



Goals of SOAR AO = SAM

- SOAR: narrow field, good resolution. But... 0.7”?
- SOAR community interested in the visible, not IR.
- Tip-tilt is not sufficient, needs AO.
- Must work in the visible, on faint targets
- Competitors: HST, Gemini, etc.
- Solution = GLAO!
- Must be simple (facility instrument)

SOAR: the competition

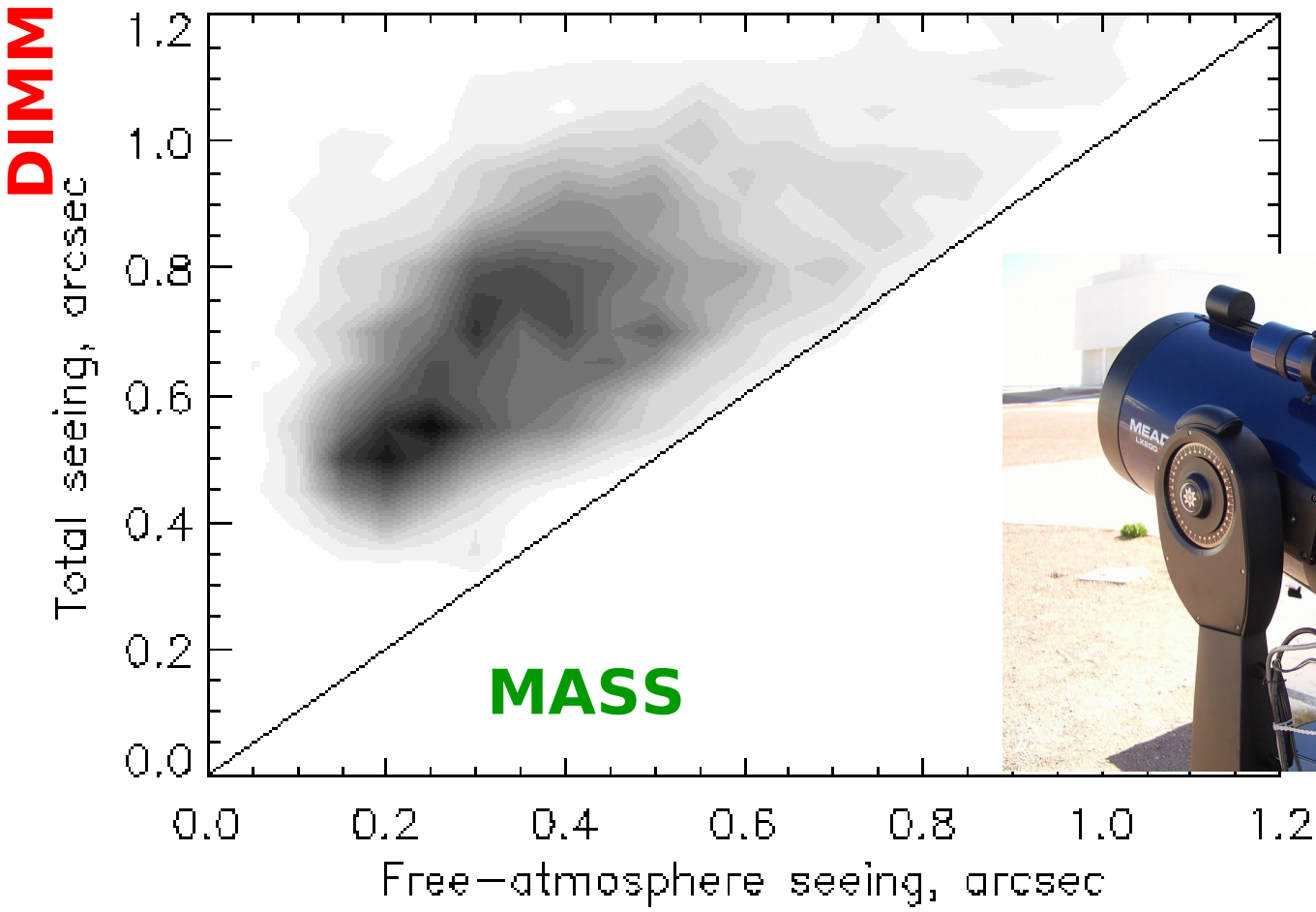


The idea of GLAO

- F. Rigaut (2001): improve seeing by correcting only <1km, using tomography to separate the ground layer
- Gain: uniformity of correction in wide field
- Loss: spatial resolution! Performance is measured in FWHM, not in Strehl.

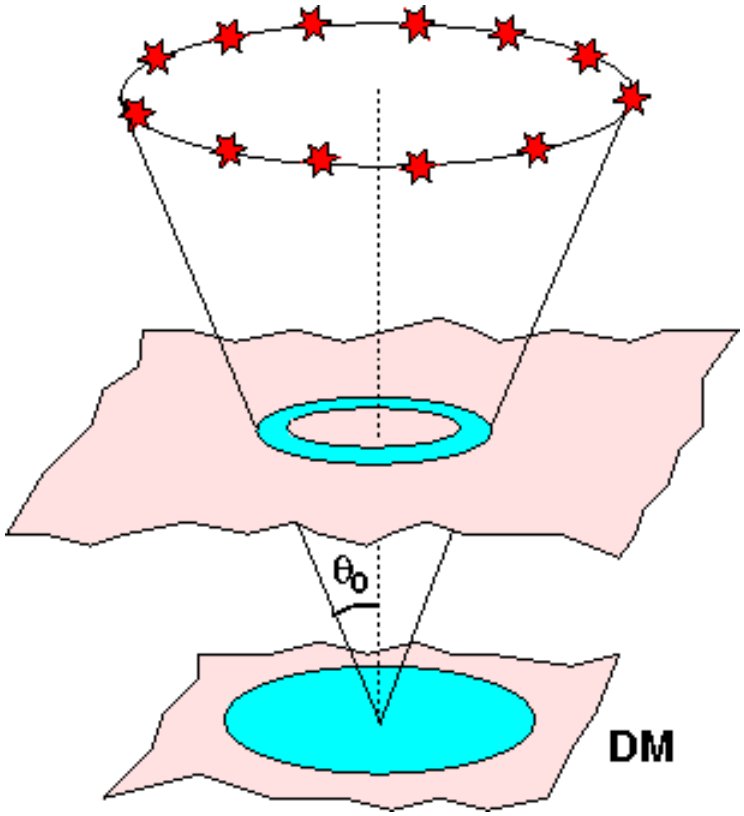
Strongest turbulence is located near the ground and in the dome

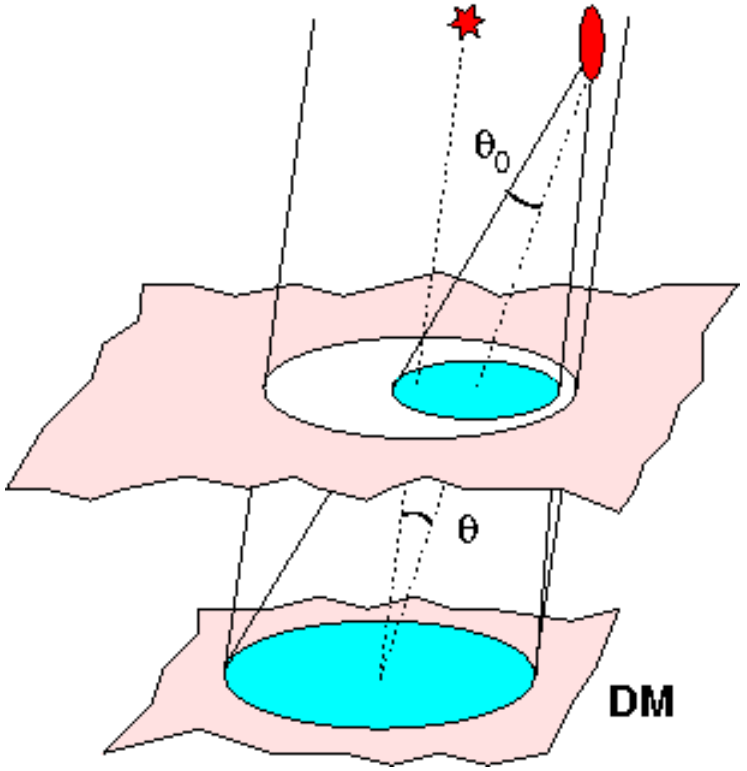
MASS-DIMM: turbulence @ Cerro Pachon, 2005



Calm nights with FA seeing <0.25” happen at every site!

Two options for GLAO tomography

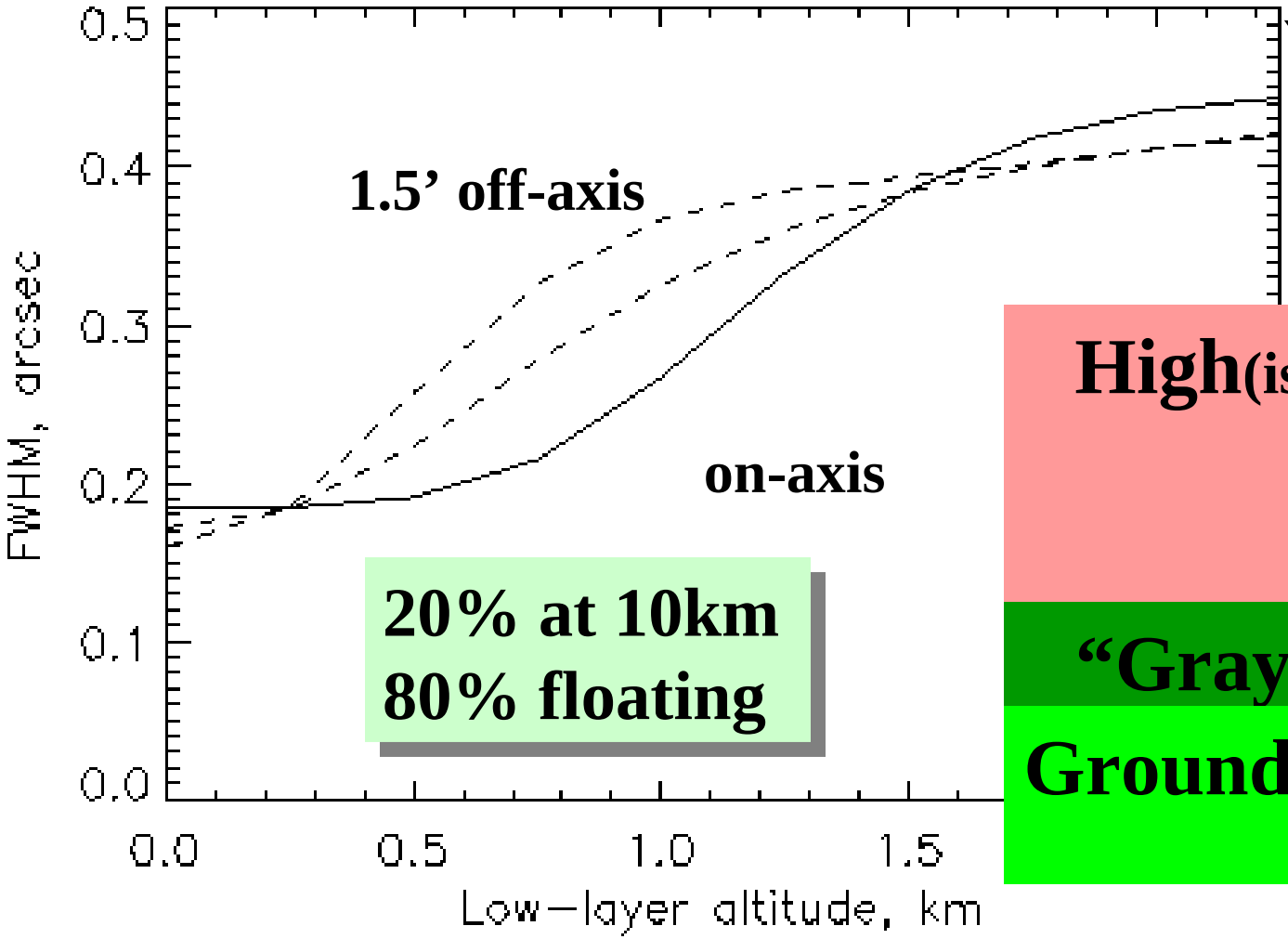




Several stars in a “ring”

One low-altitude LGS

The “gray zone”

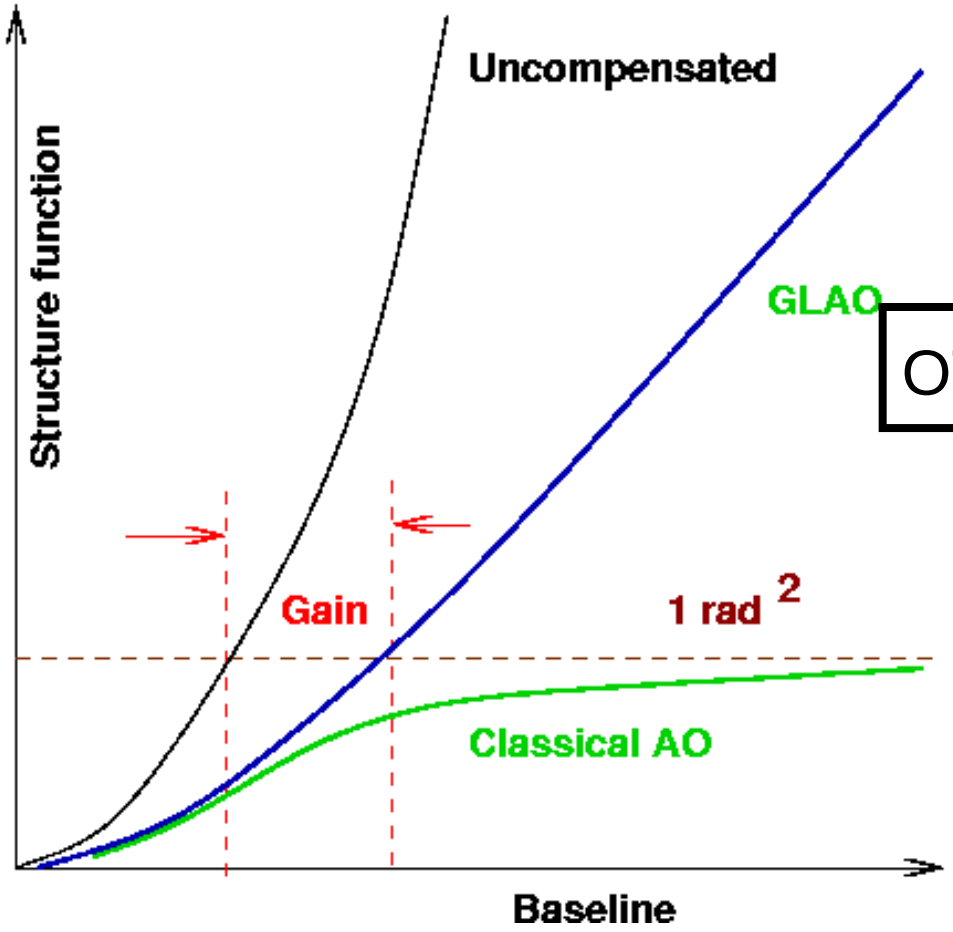


High(isoplanatic)

“Gray”(trouble)

Ground(isoplanatic)

The difference between GLAO and AO



$$OTF(f) = OTF_0(f) \exp[-D_\varepsilon(\lambda f)/2]$$

(Veran et al. 1997)

Classical AO: Strehl, σ^2

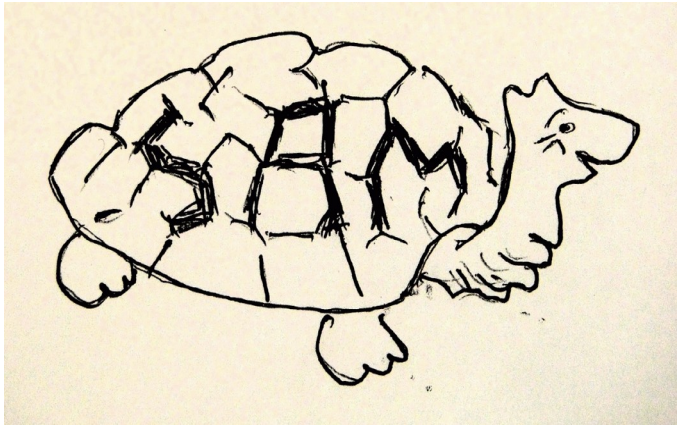
GLAO resolution:

$\beta \sim \lambda / r_{(SF=1\ rad^2)}$

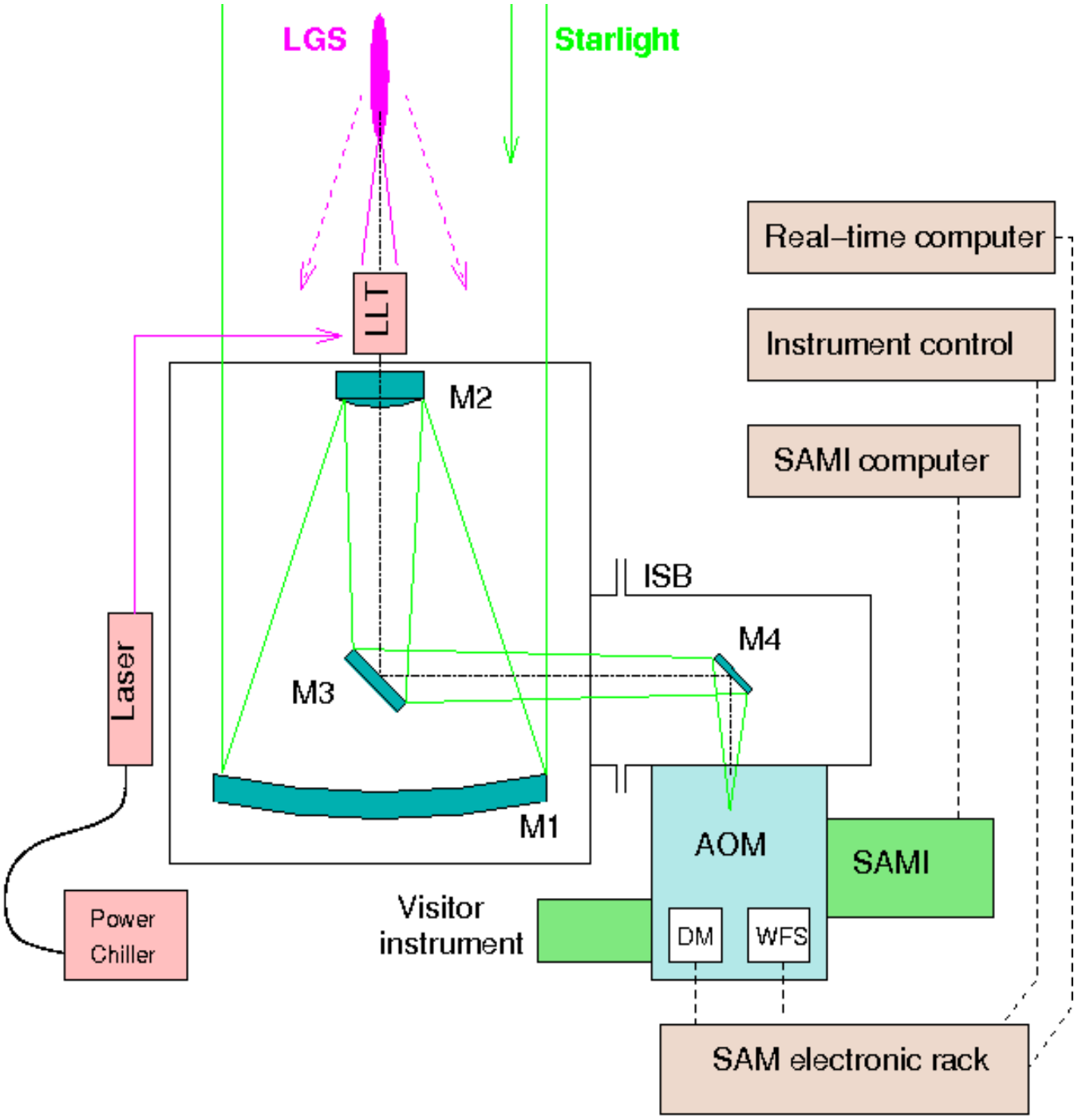
The SF only matters at baselines $r < \lambda/\beta \sim 0.5m$ if $\beta \sim 0.2$"

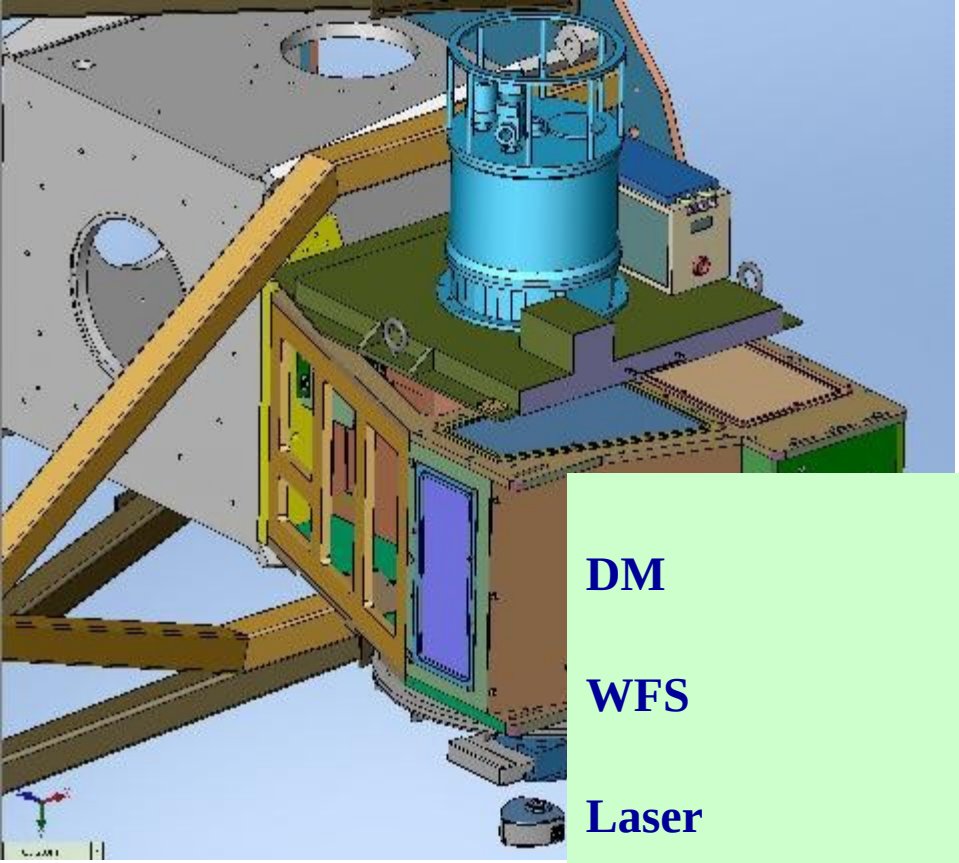
Development of the SAM concept

- LGS only (sky coverage!). Use single UV laser!
- NGS mode was foreseen, then dropped (speckle instead)
- Preserve F-ratio of SOAR (same instruments, e.g. SIFS)
- From small 35-mm DM to 50-mm bimorph DM
- Conservative approach (min. development)



SAM at a glance

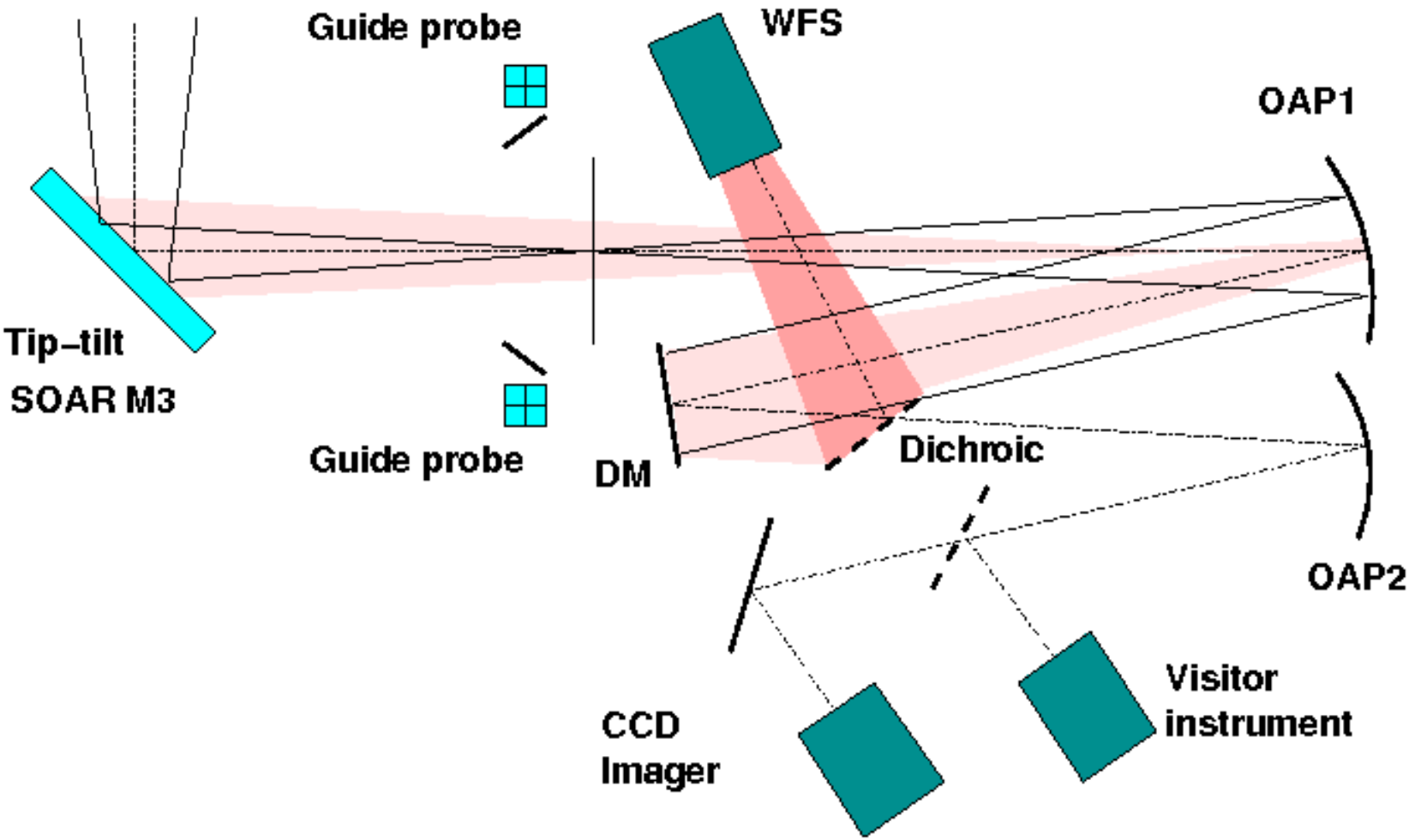




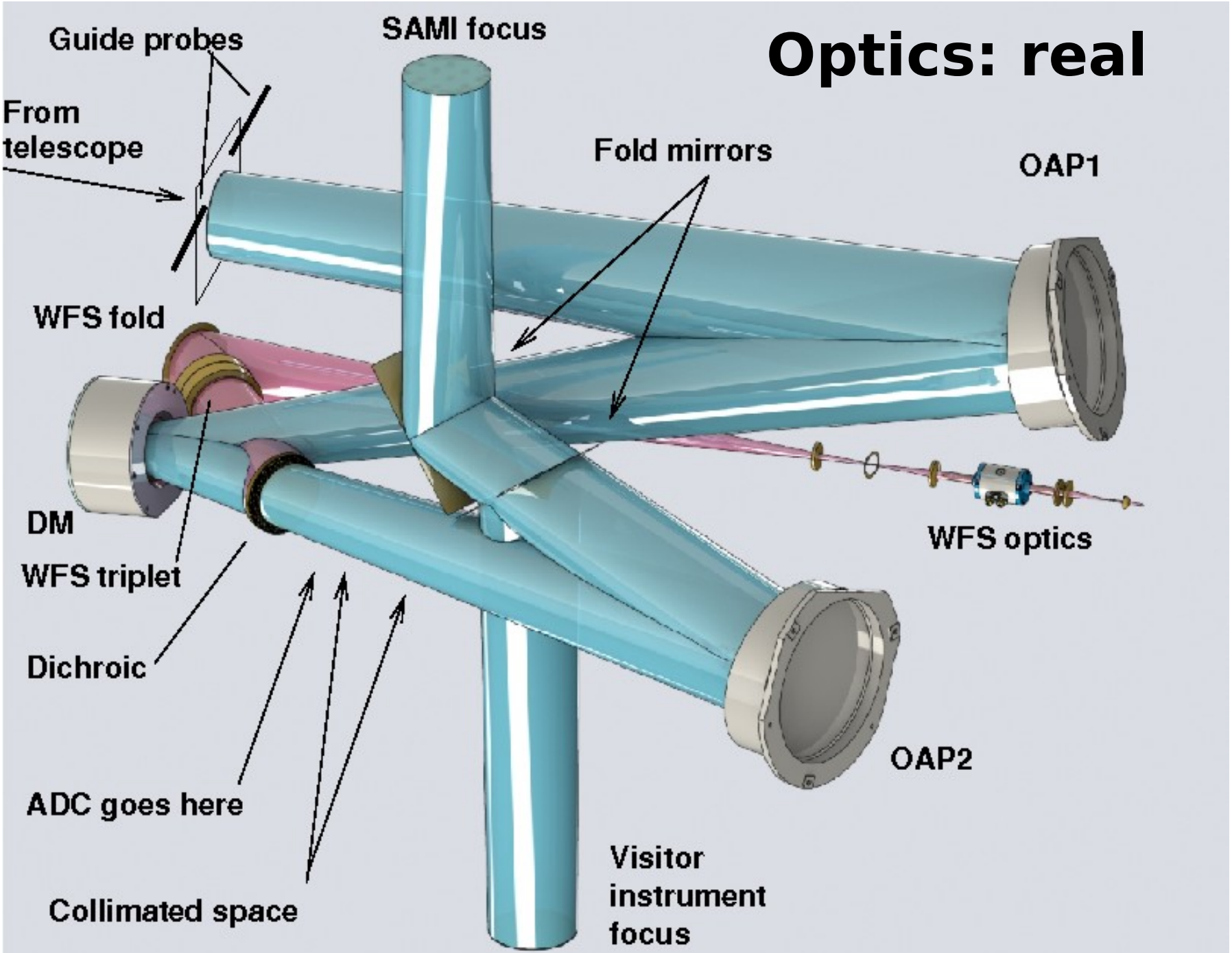
SAM components

DM	**Bimorph, 50mm pupil, 60 electrodes**
WFS	**S-H 10x10, CCD-39 pixel 0.41”**
Laser	**Tripled Nd:YAG 355nm, 10W, 10 kHz**
LLT	**D=25cm, behind secondary, H=7km**
Gating	**KD*P Pockels cell, dH>150m**
Tip-tilt	**Two probes, fiber-linked APDs, R<18**
FoV	**3’x3’ square, 3 arcsec/mm, f/16.5**
CCD imager	**4Kx4K, 0.045” pixels, 5 or 7 filters**

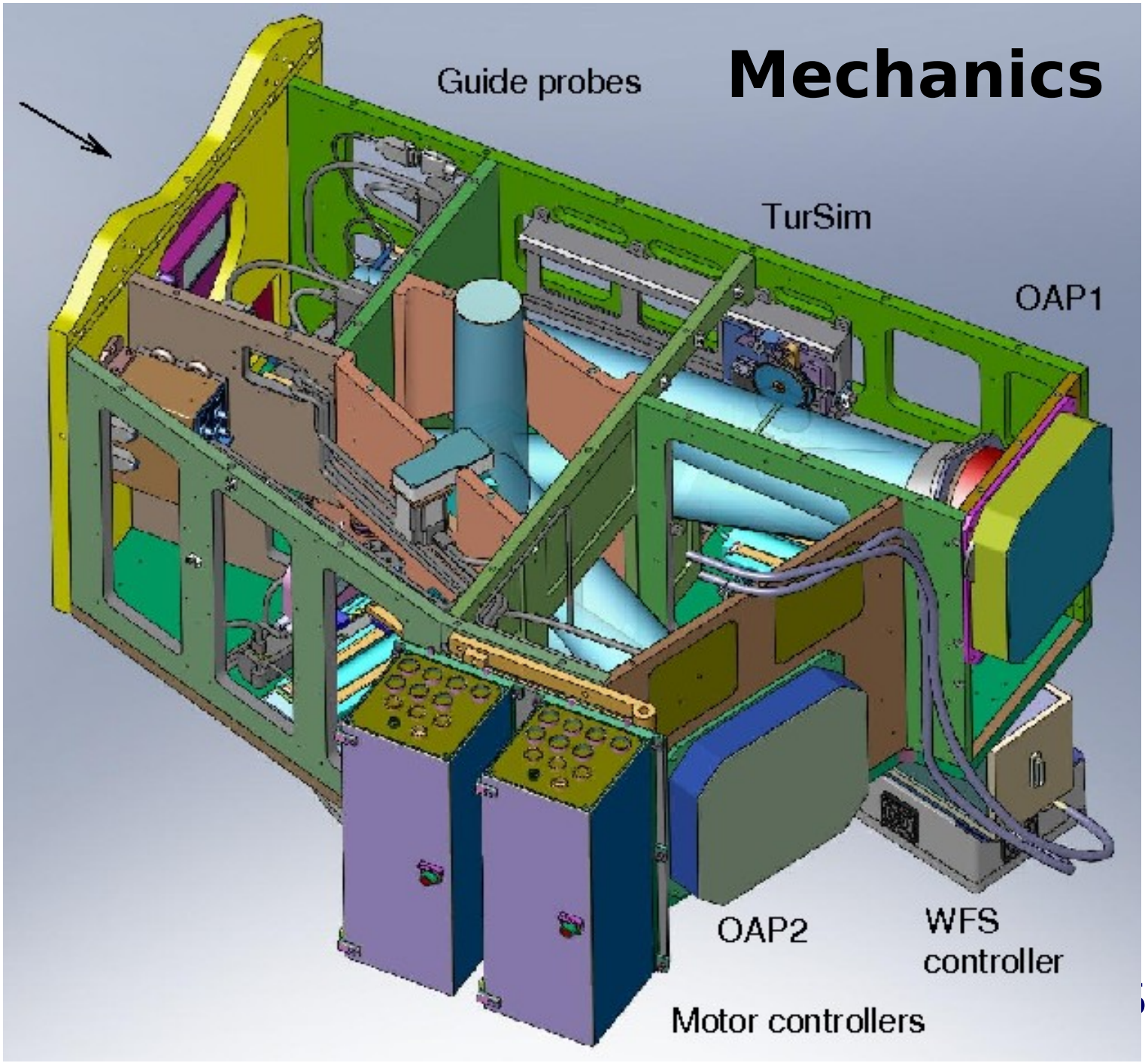
Optics: the components



Optics: real


Guide probes
SAMI focus
From telescope
Fold mirrors
OAP1
WFS fold
DM
WFS triplet
WFS optics
Dichroic
OAP2
ADC goes here
Collimated space
Visitor instrument focus

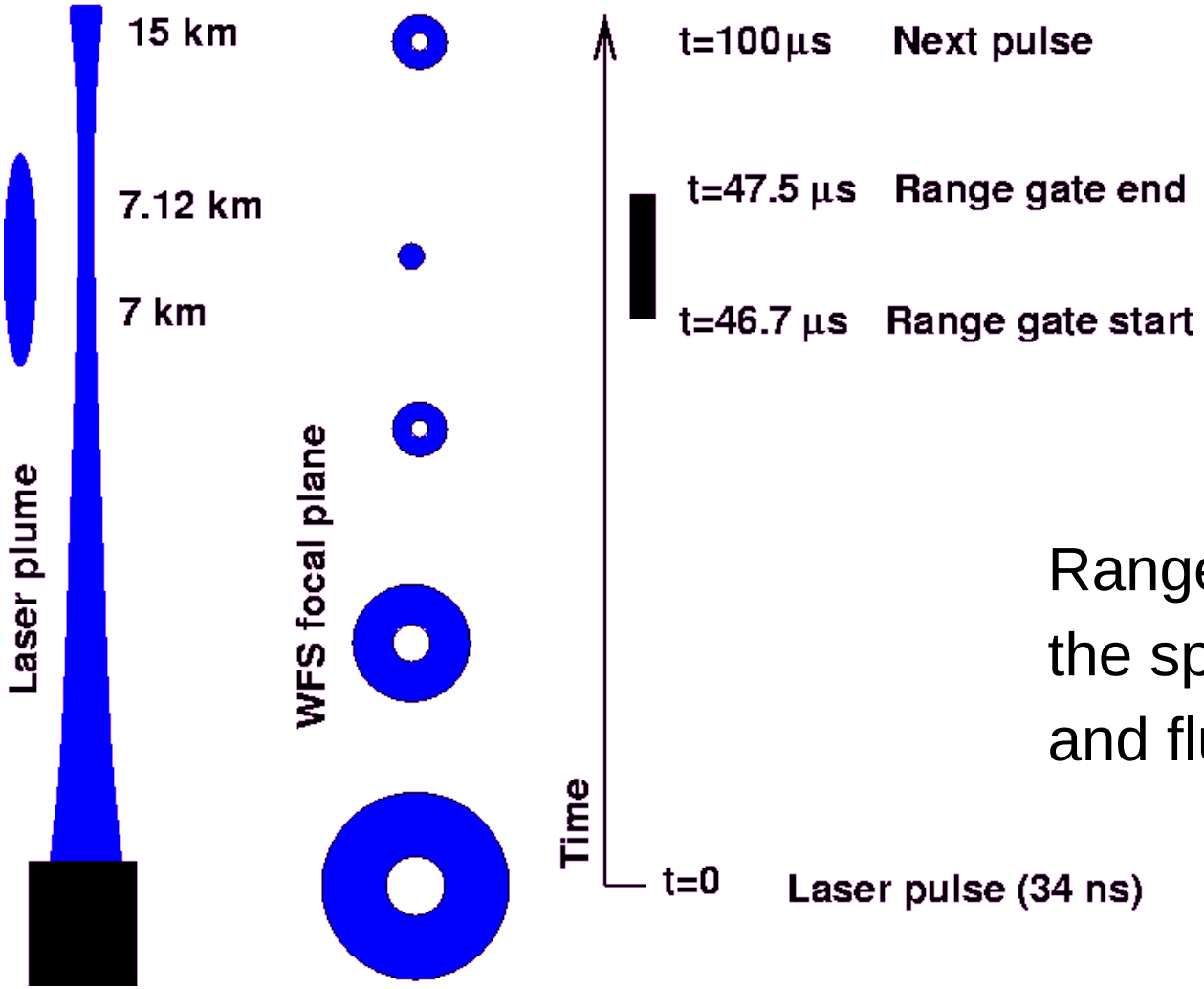
Mechanics

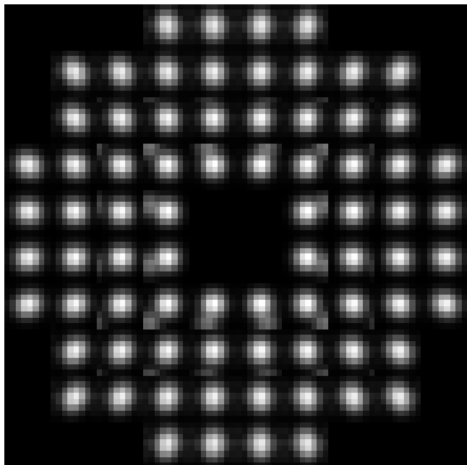


Space
Flexure
Access

~300kg

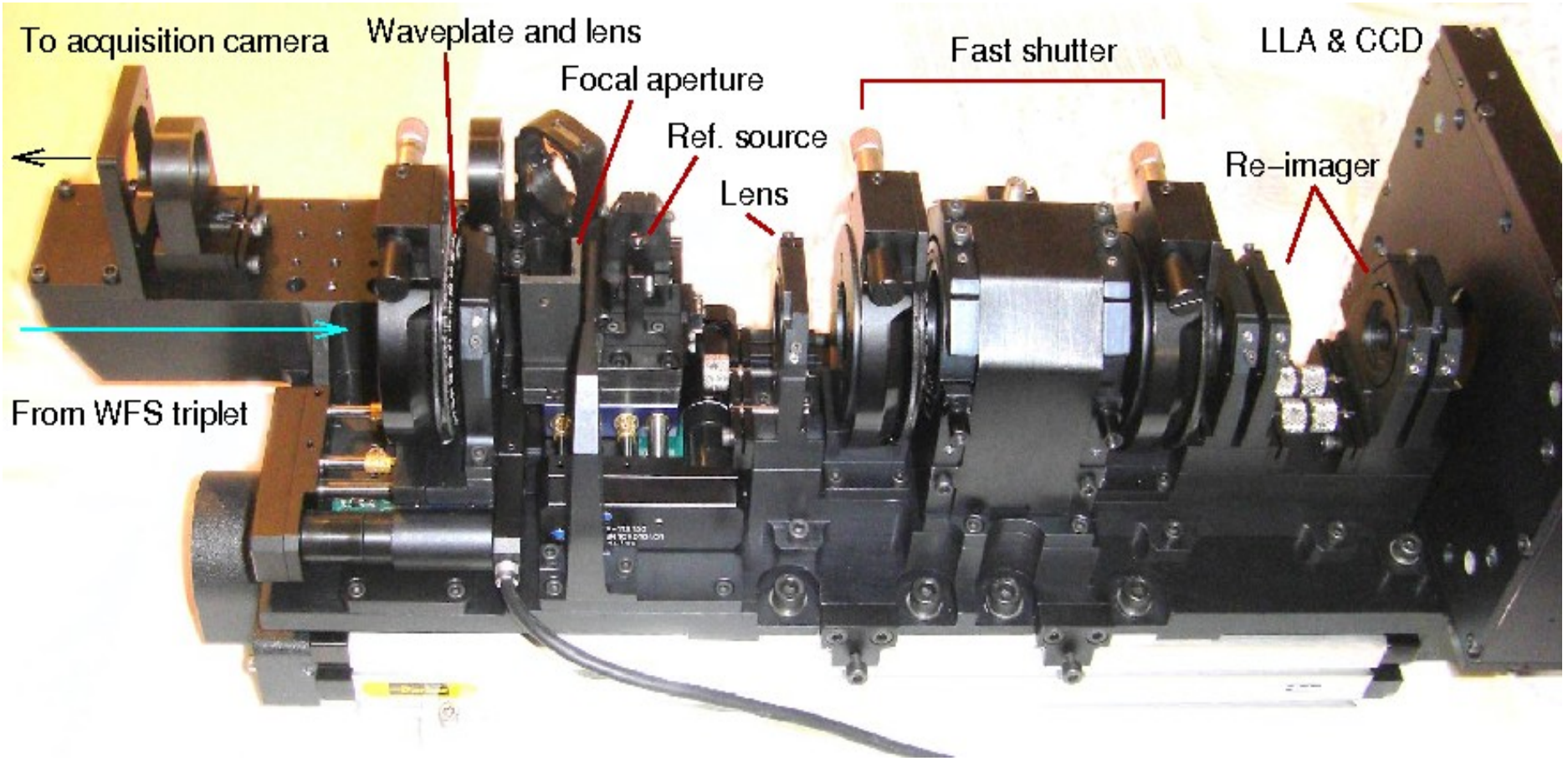
Rayleigh LGS timing





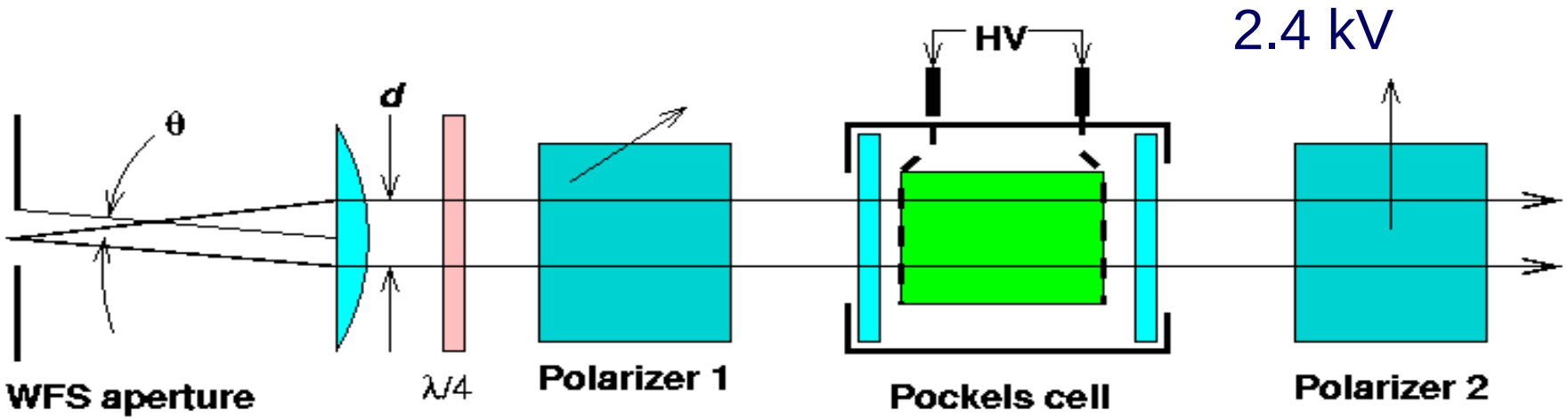
Range gate defines the spot elongation and flux

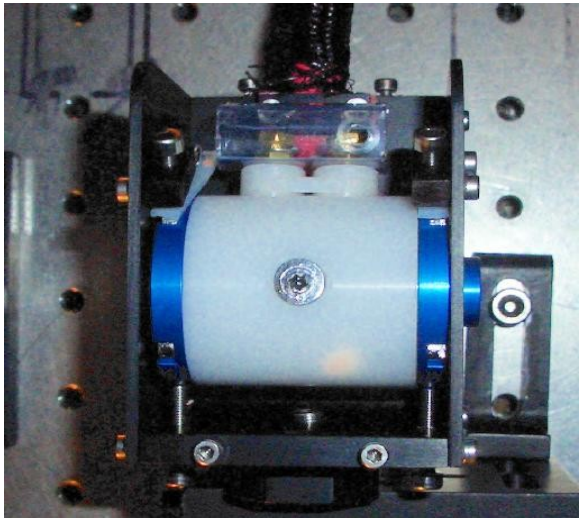
LGS WFS

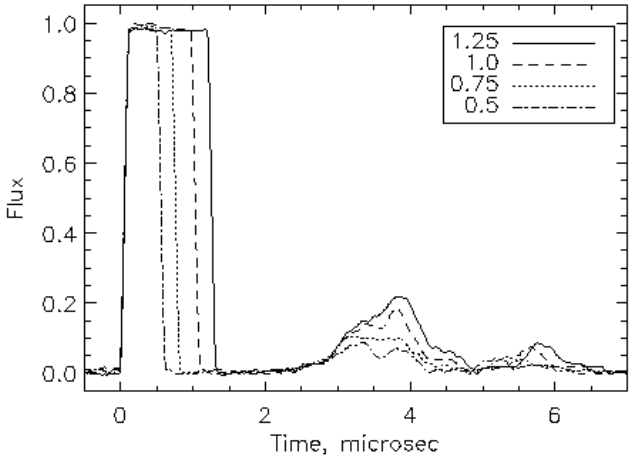


Two moving elements + Focus

Fast shutter: Pockels cell

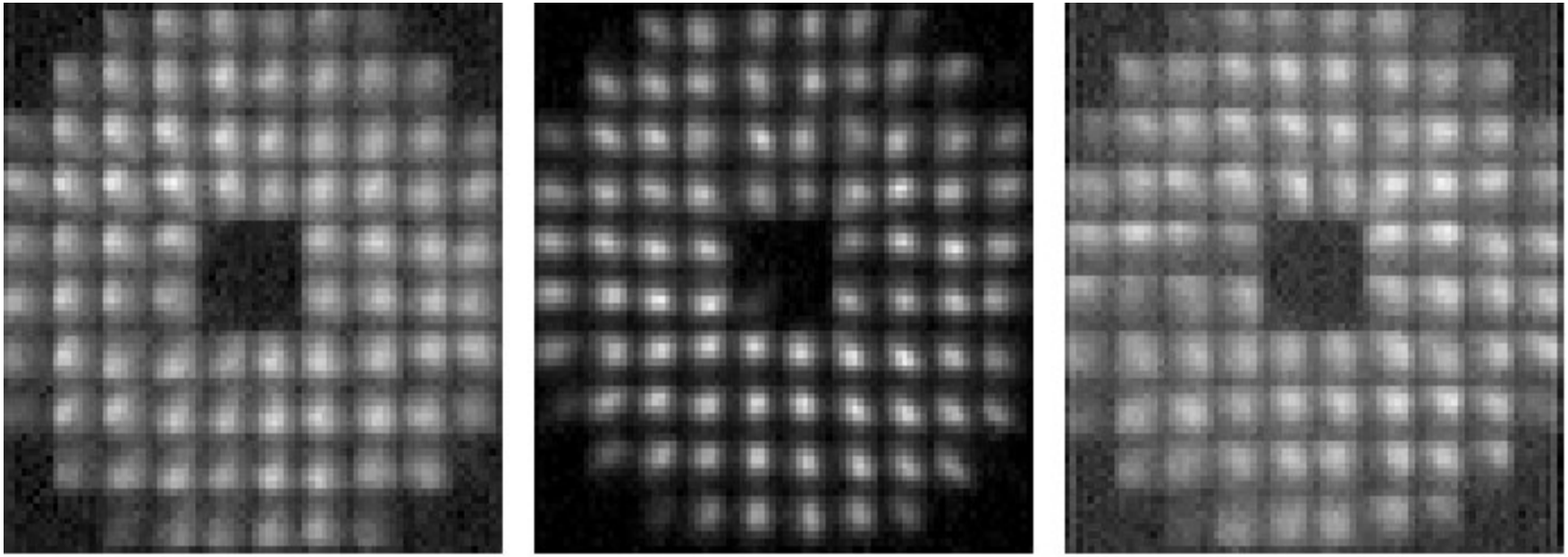






KD^2P

Real LGS spots

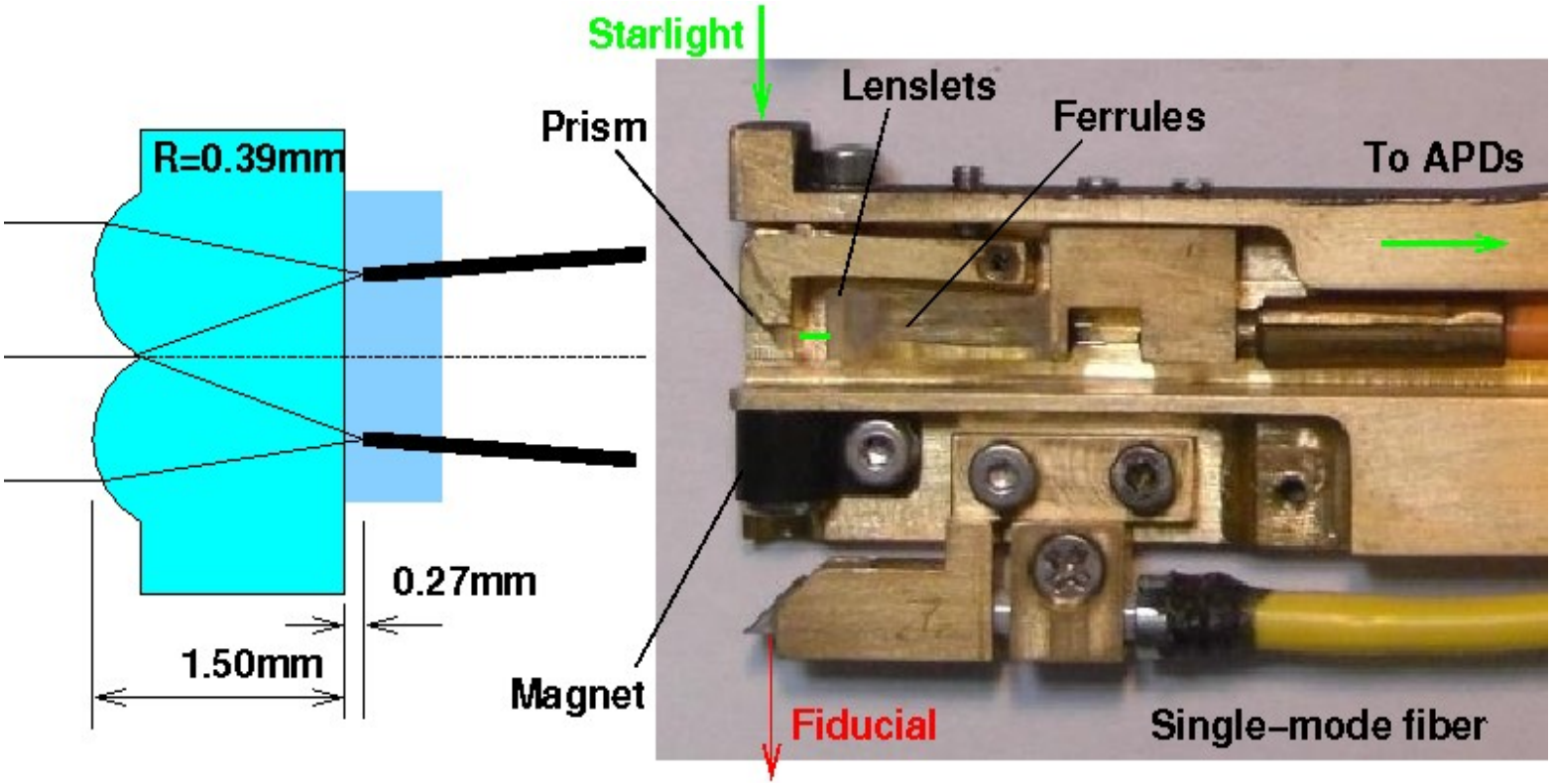


The spot size is determined mostly by the local seeing

Now the 2x2 binning is used: less noise, faster

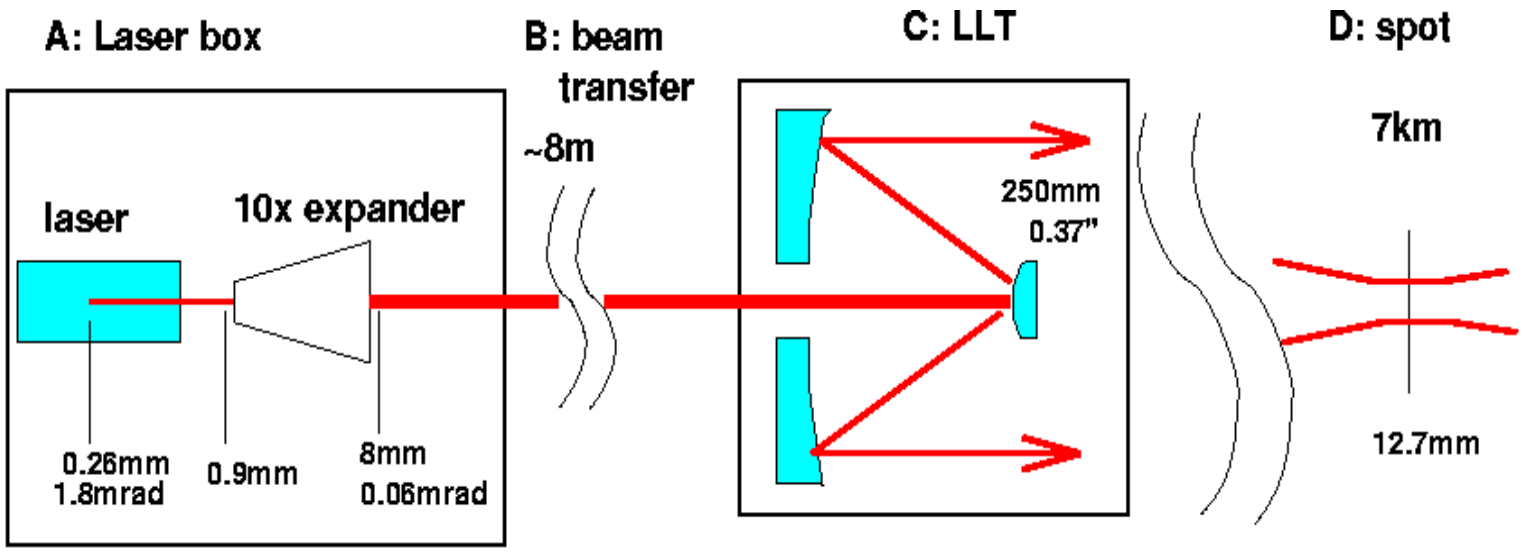
Tip-tilt guiding

- LGS cannot measure tilts, need NGS
- Measure & correct tilt upstream (M3 and 1st focus)
- Two guide probes, quad-cell principle, fibers

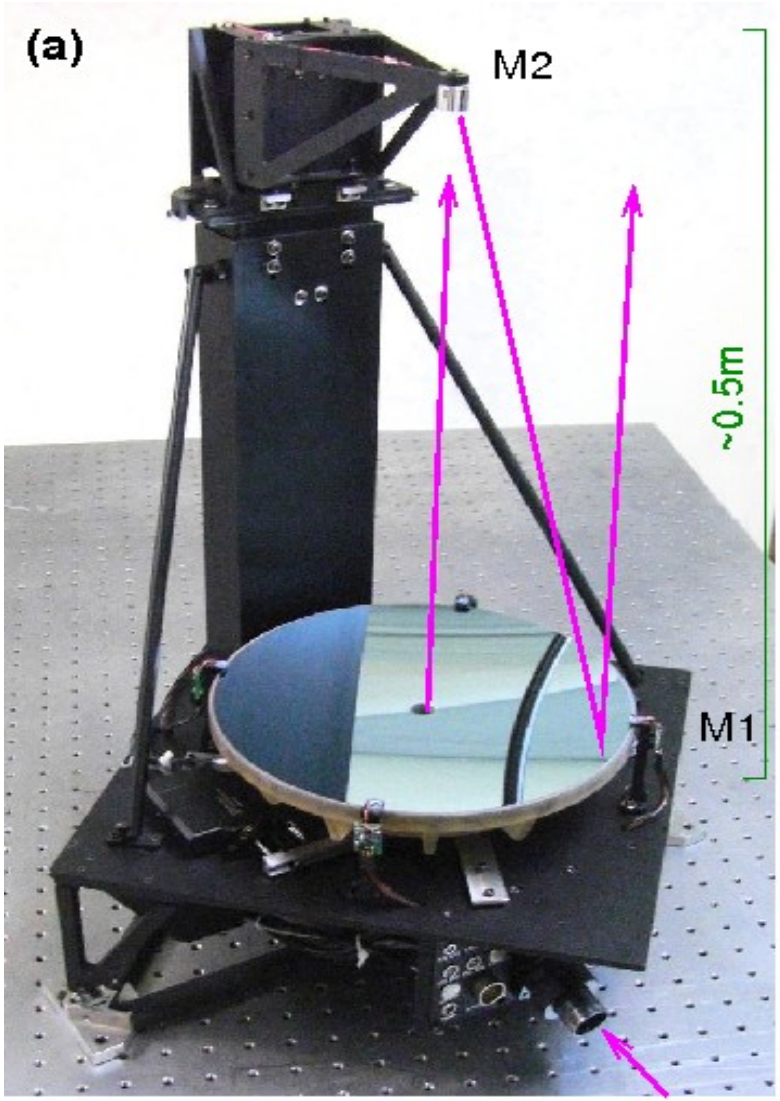


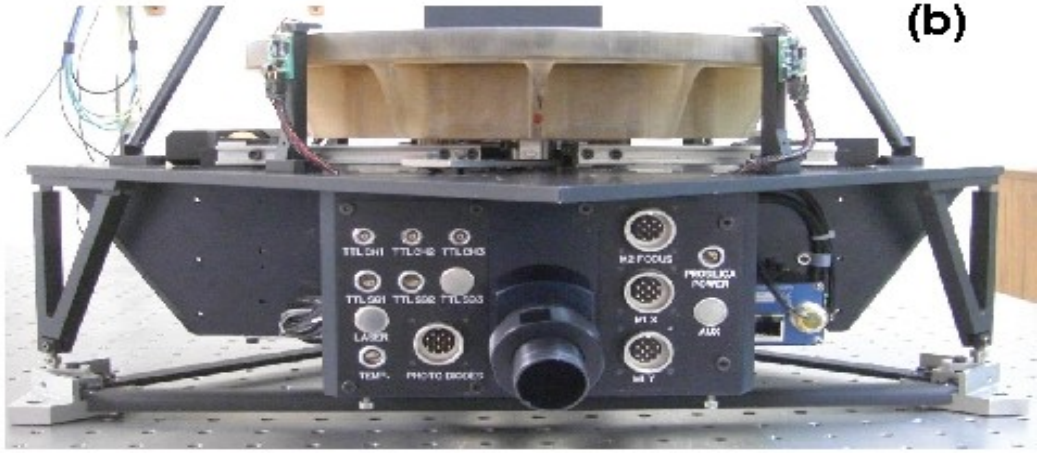
The laser system

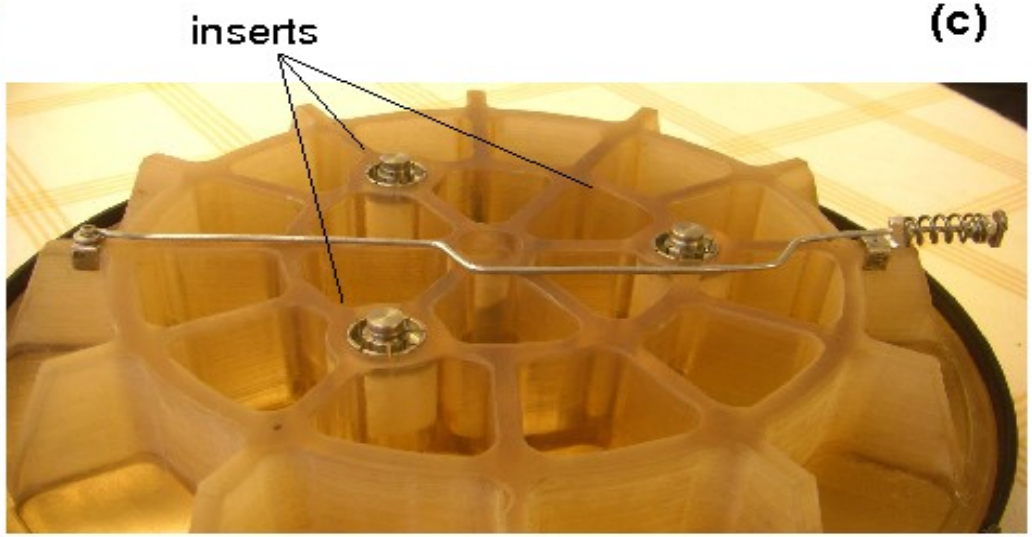
- Laser: 10W, 10kHz, 34ns pulse, 355nm tripled Nd:YAG
- Beam expander (~8x) & transport (laser-M4)
- Laser Launch Telescope (LLT), D=25cm



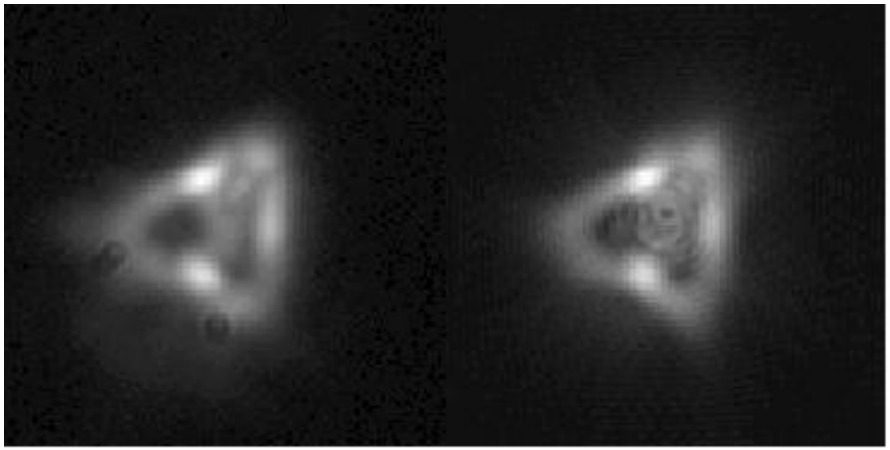
Laser Launch Telescope

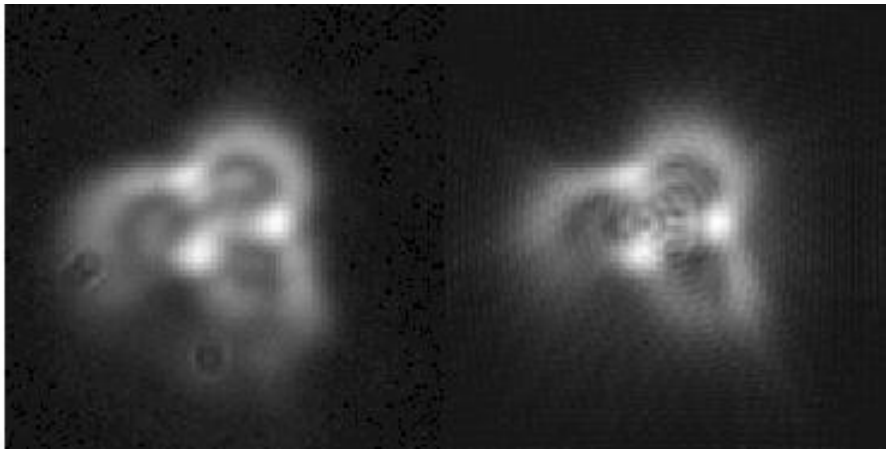






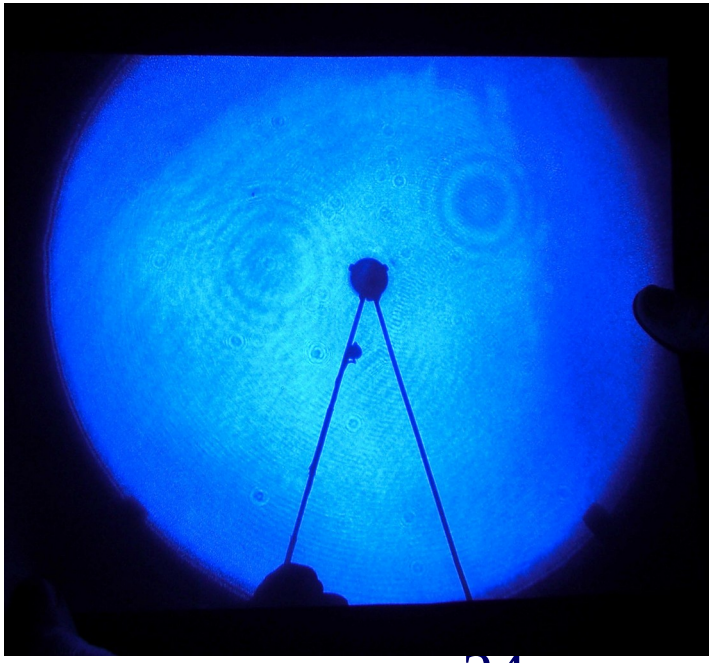
Extra-focal images (June 2011)





Laser safety

- SAM is safe in normal operation
- Airplane-safe
- US Space Command: propagation windows
- Maintenance of laser system: qualified personnel only!



Laser safety for insects

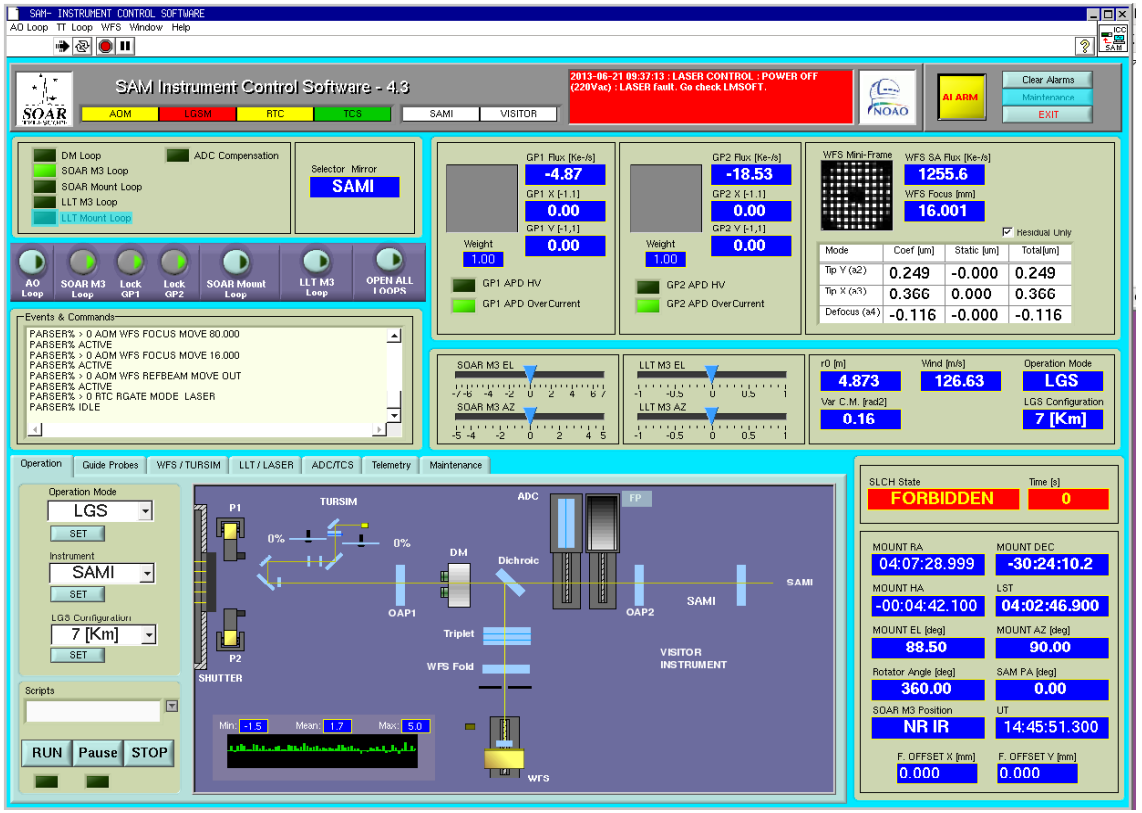
- They like the UV light! Massive attack in March 2014.

Protected LLT with thin-wire mesh

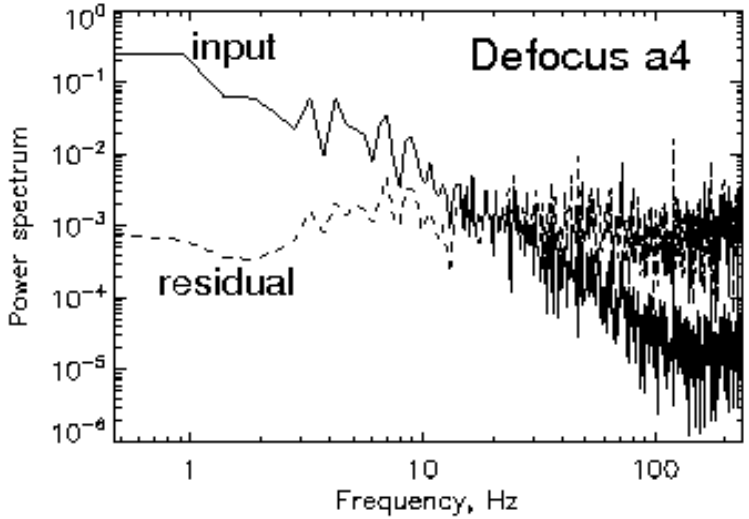
It worked until... a smaller bug in October 2016 burned on M3!

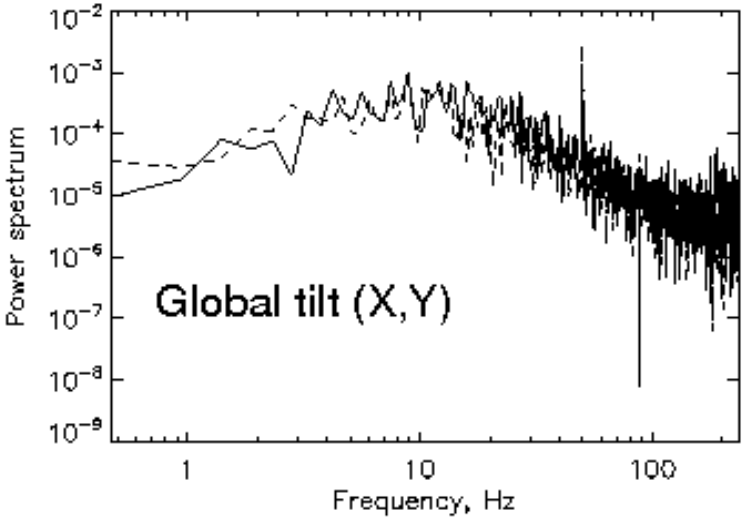
Computers & Software

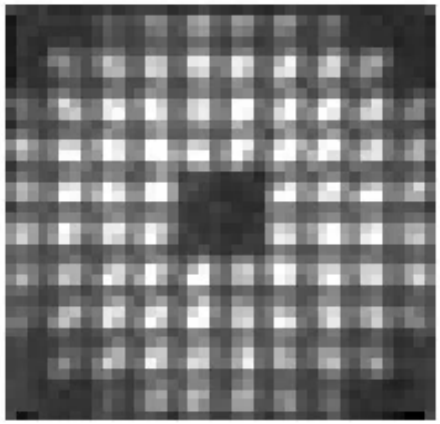
- Real-Time Computer +PXI
  - RTSoft (4 loops)
- AOM computer
  - AOM control
  - LGS control
  - Instrument control
  - Laser propagation
- SAMI computer
  - SAMI software



AO performance







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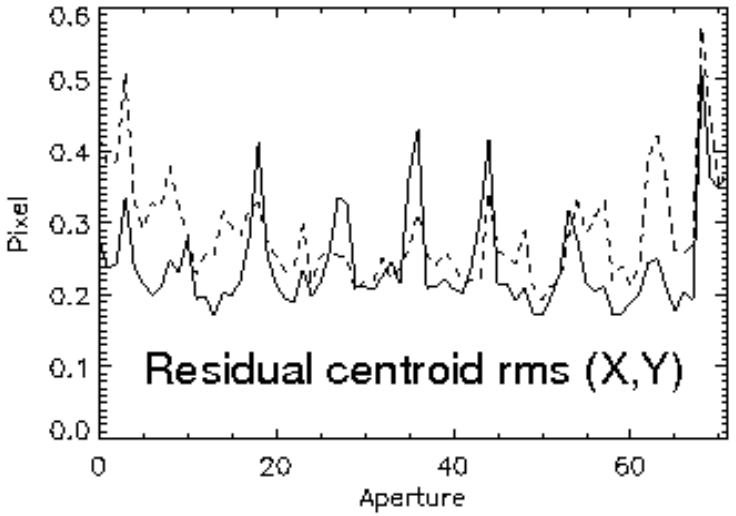
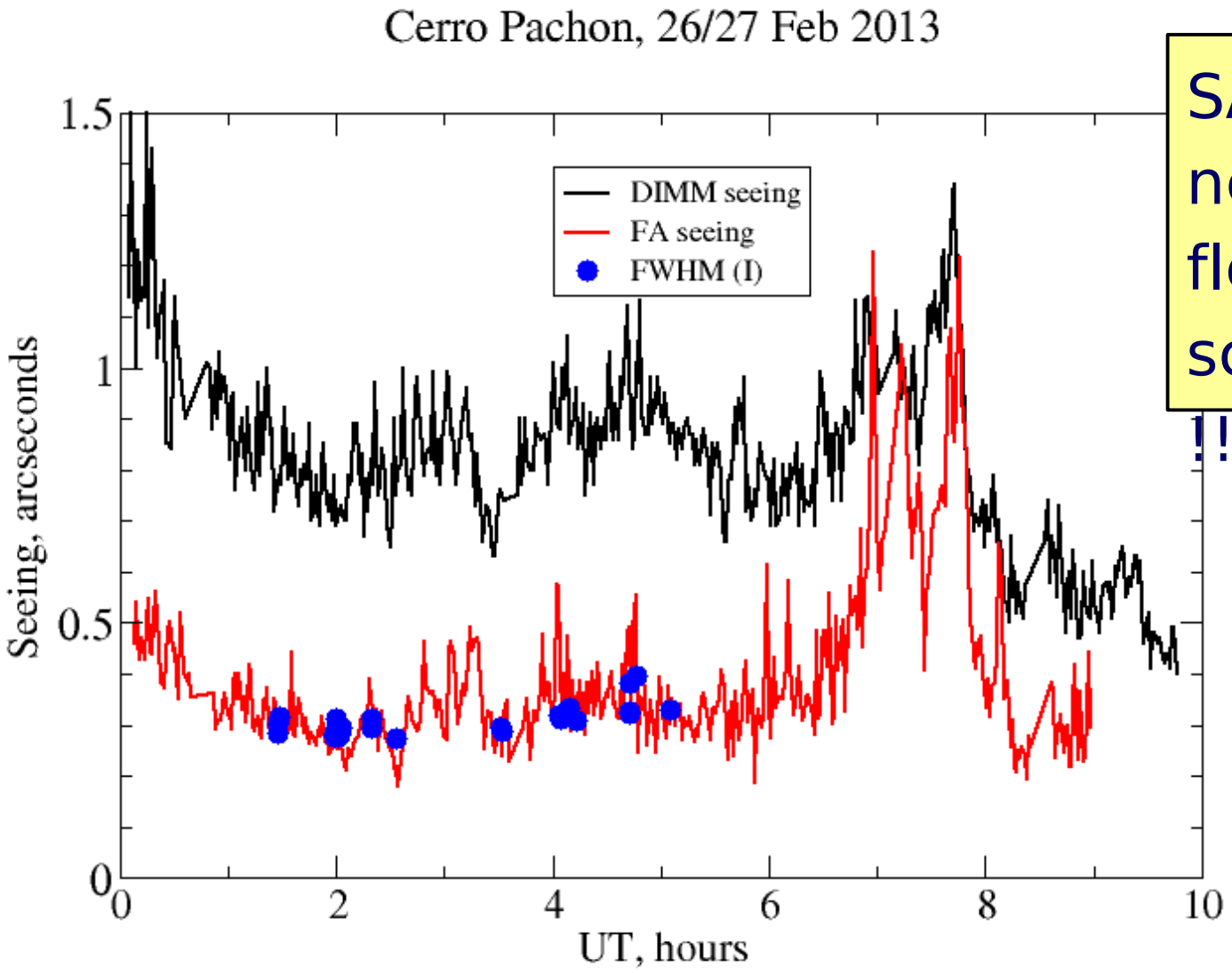


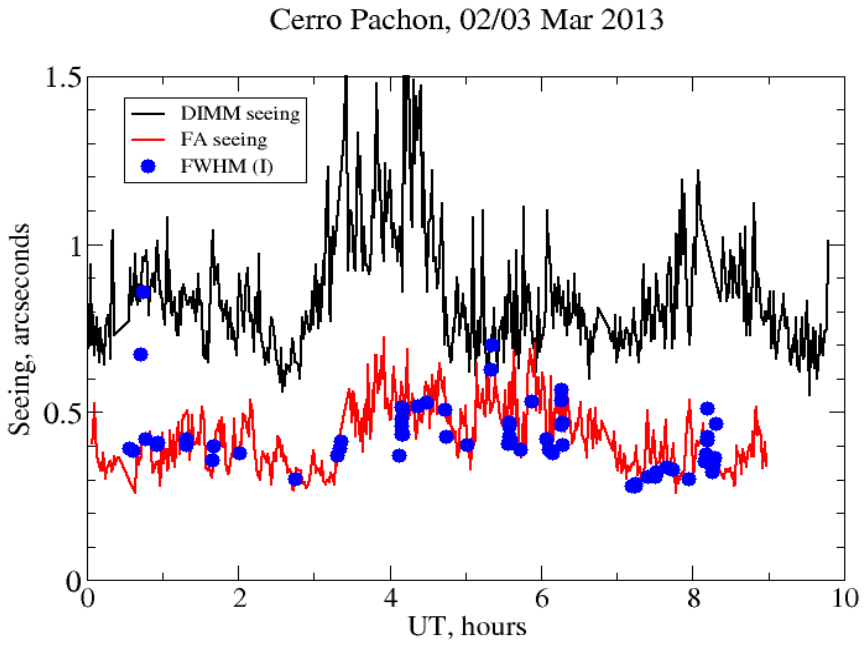
SAM performance depends on FA seeing

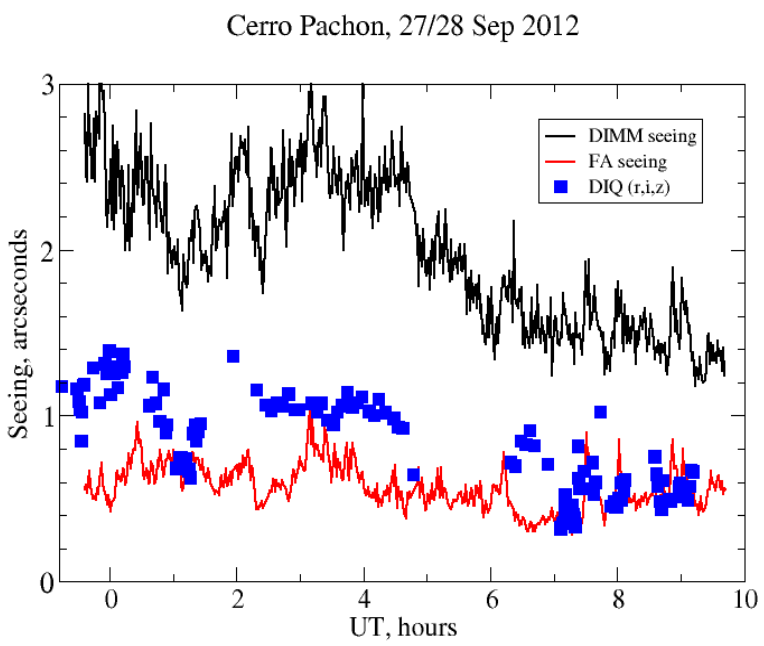


SAM needs flexible scheduling!

!!

More plots...

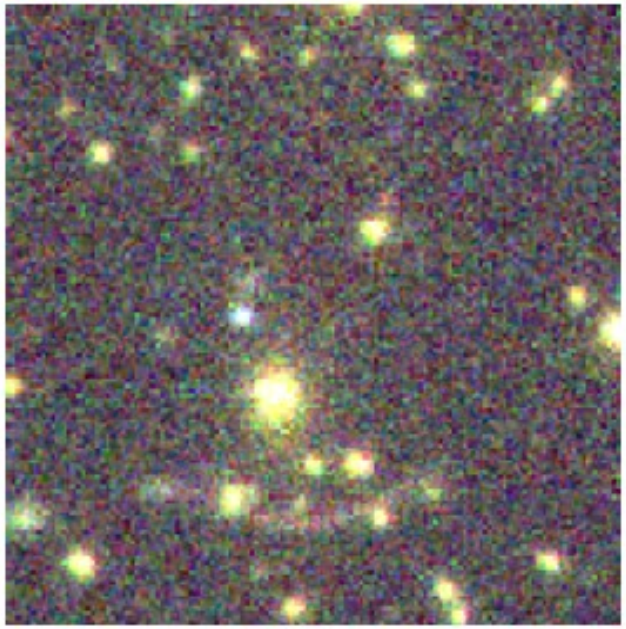

Cerro Pachon, 02/03 Mar 2013
DIMM seeing
FA seeing
FWHM (I)
Seeing, arcseconds
UT, hours
0
0.5
1
1.5
0
2
4
6
8
10


Cerro Pachon, 27/28 Sep 2012
DIMM seeing
FA seeing
DIQ (r,i,z)
Seeing, arcseconds
UT, hours
0
1
2
3
0
2
4
6
8
10

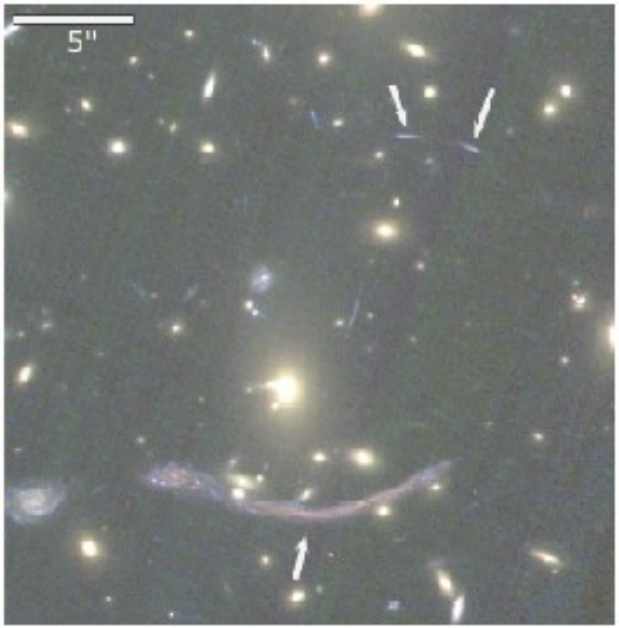
SAM does improve the “seeing”!

Typical FWM resolution: 0.6” in V, 0.5” in R, 0.4” in I.

FWHM variation few percent over 3'x3' FoV



SDSS

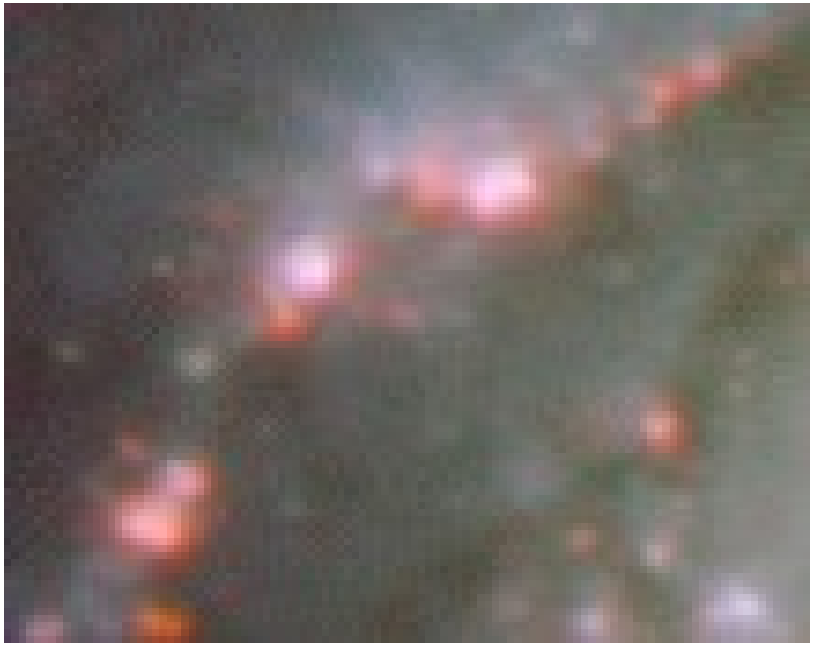


HST

SAM

NGC 1232: SAM vs. SOI

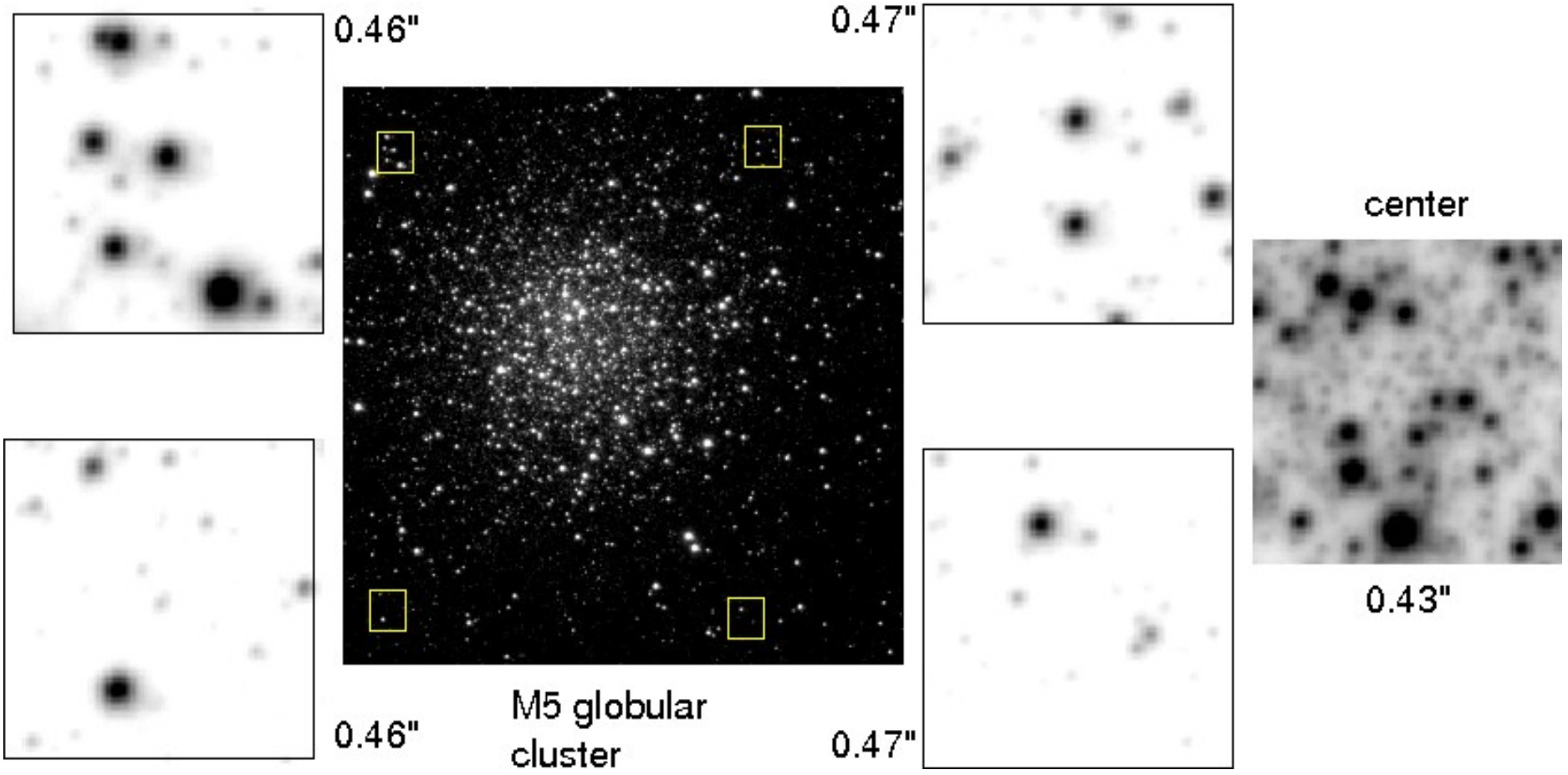
SAM



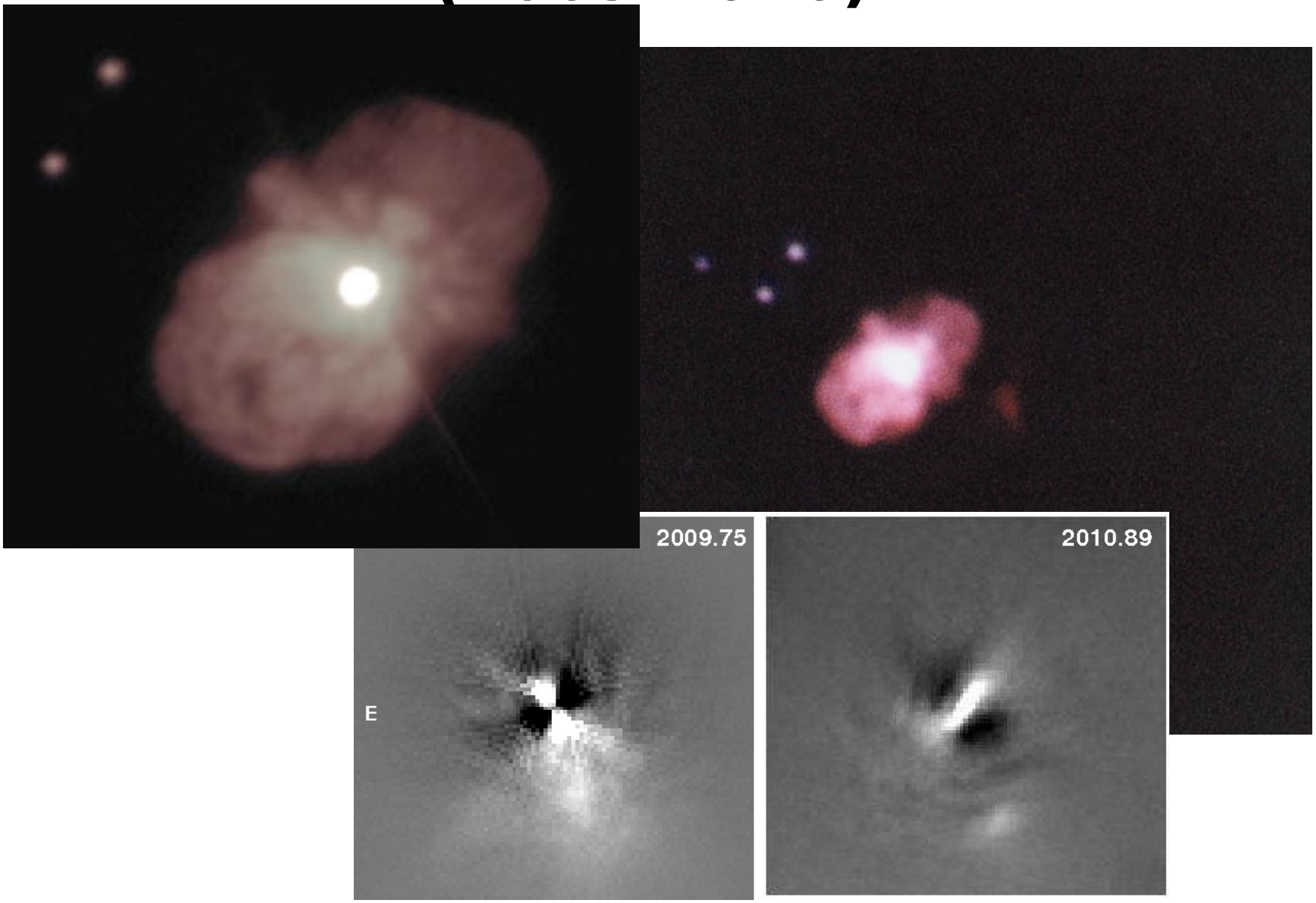
SOI

SAM project by A.Ardila (January 2014)

Correction uniformity



SAM in NGS mode (2009-2010)



Science projects

- Crowded fields: clusters (CMDs, variable stars)
- Lensed quasars
- Narrow-band imaging with filters
- Fabry-Perot imaging
- Binary-star surveys with LGS pre-compensation

SAM helped to develop speckle interferometry at SOAR

SAM's instruments

- SAMI: 4Kx4K, pixels 45mas, FoV 3'. Filters: BVRI, griz, narrow-band, user-defined.
- SAMI+Fabry-Perot (“visitor” mode supported by B.Quint)
- HRCam: speckle, res. 20mas, can be laser-assisted.
- SIFS: to be commissioned with SAM.
- SAMOS: multi-slit spectrograph, R~2000, FoV 3', uses DMD mirror technology. “Visitor”, ready in 2019?
- BTFI-2 (?) Fabry-Perot with EM CCD.

SAM operation

- Preparation: send target list to Space Command, define filters, backup in case of poor seeing or failure. Switch SAM on, do checklist.
- Point the target and acquire 1 or 2 guide stars. Close the M3 and mount loops (5-7 min).
- Acquire the laser, close the LLT and main AO loop (1 min).
- Take science data, keep an eye on SAM. Manage LCH interrupts.

S

- C