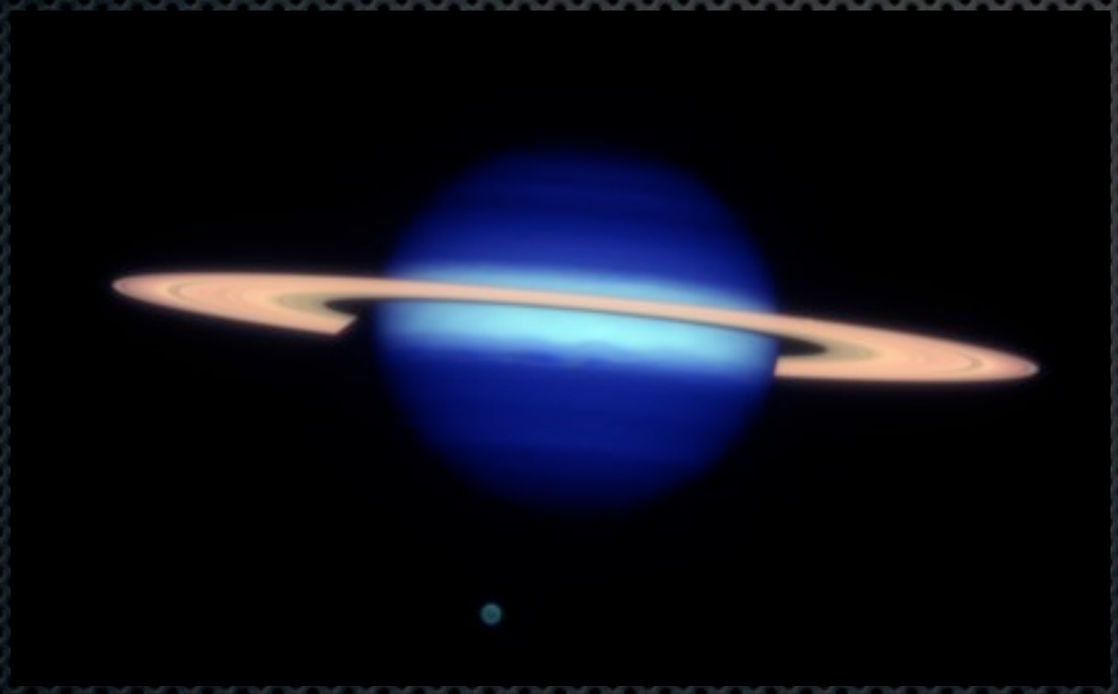
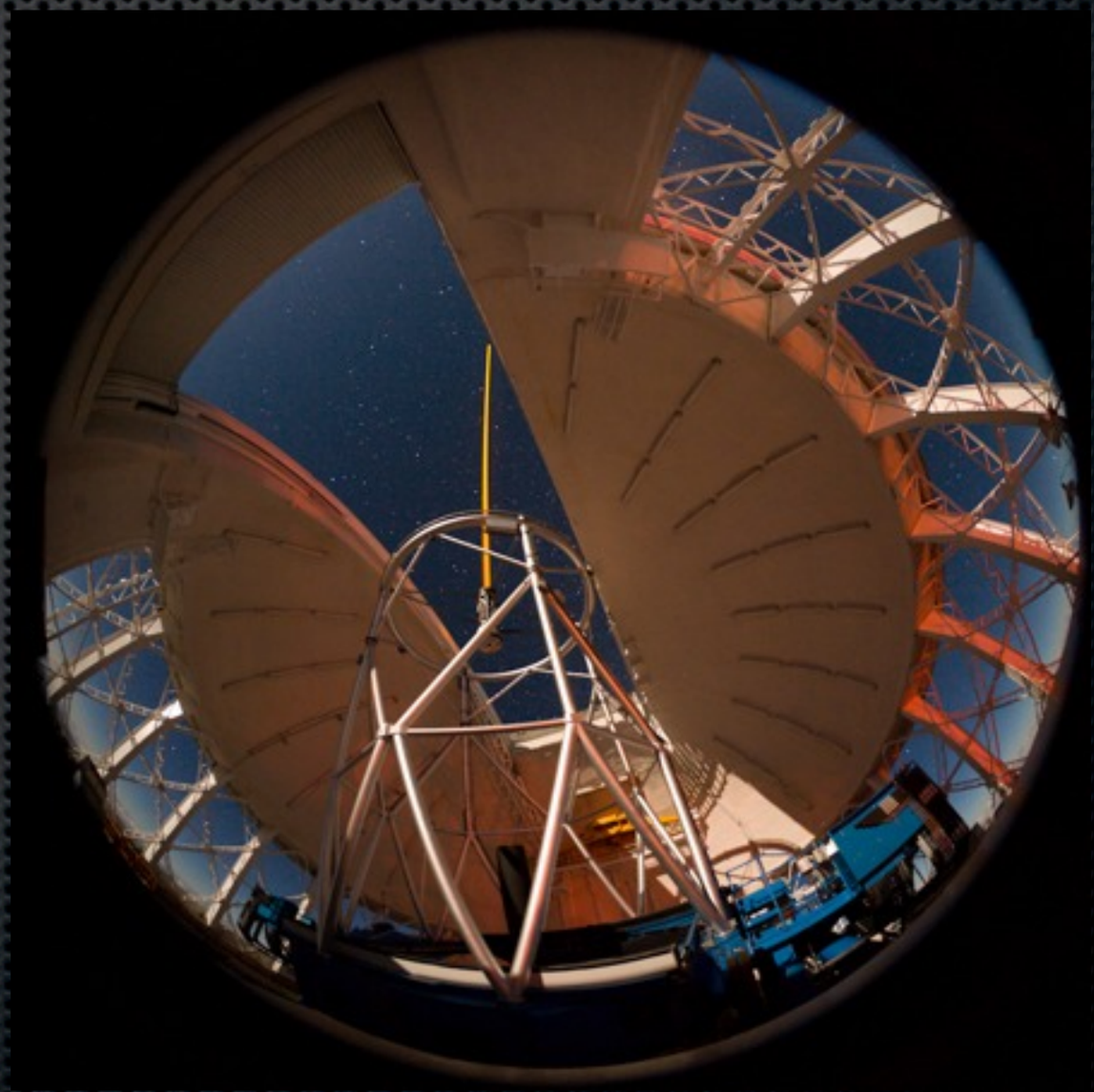
GEMINI OBSERVATORY

# GeMS

## (Gemini Mcao System)

Francois Rigaut, Gemini





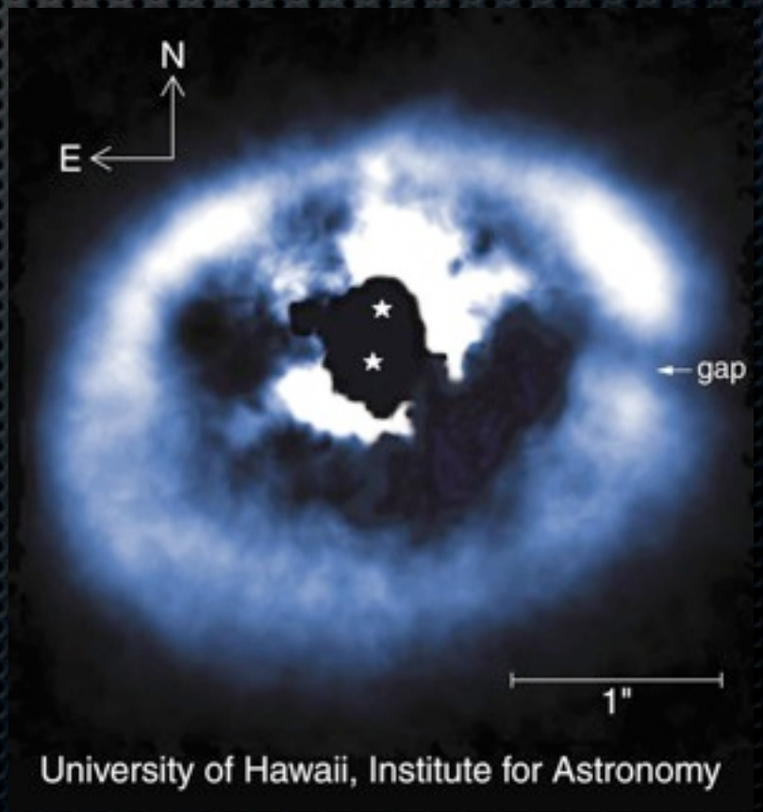
Mad workshop, ESO, June 8-10 2009

# Talk outline

- Briefs about the Gemini AO instrumentation and program
  - Program flow, some nice images
  - Lasers, lasers, lasers...
- GeMS: the Gemini MCAO System
  - Description
  - Expected performance
  - Schedule & Status



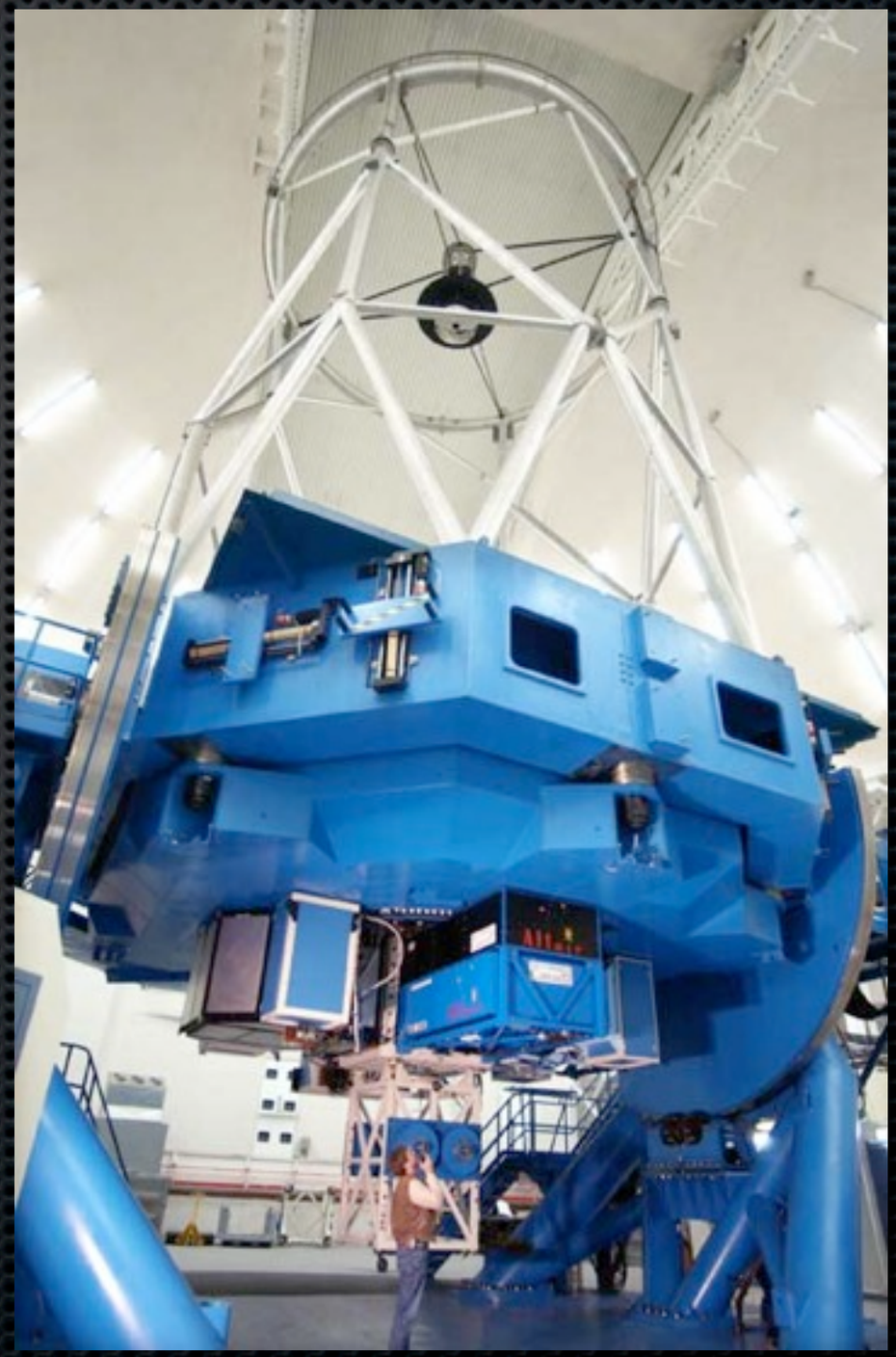

HST NICMOS




Ryder, 2008 (Altair LGS)

# Gemini: A specialized telescope

- Gemini international community
- Optimized for:
  - Thermal IR
  - High angular resolution
- Optimization choices:
  - silver coating
    - low emissivity (2.5% M1+M2)
  - F/16 narrow field
  - Thin spiders
    - low diffraction
  - LLT space planed behind M2
- Cass: 3 instr.+Cal unit + AO system
- 90% Queue

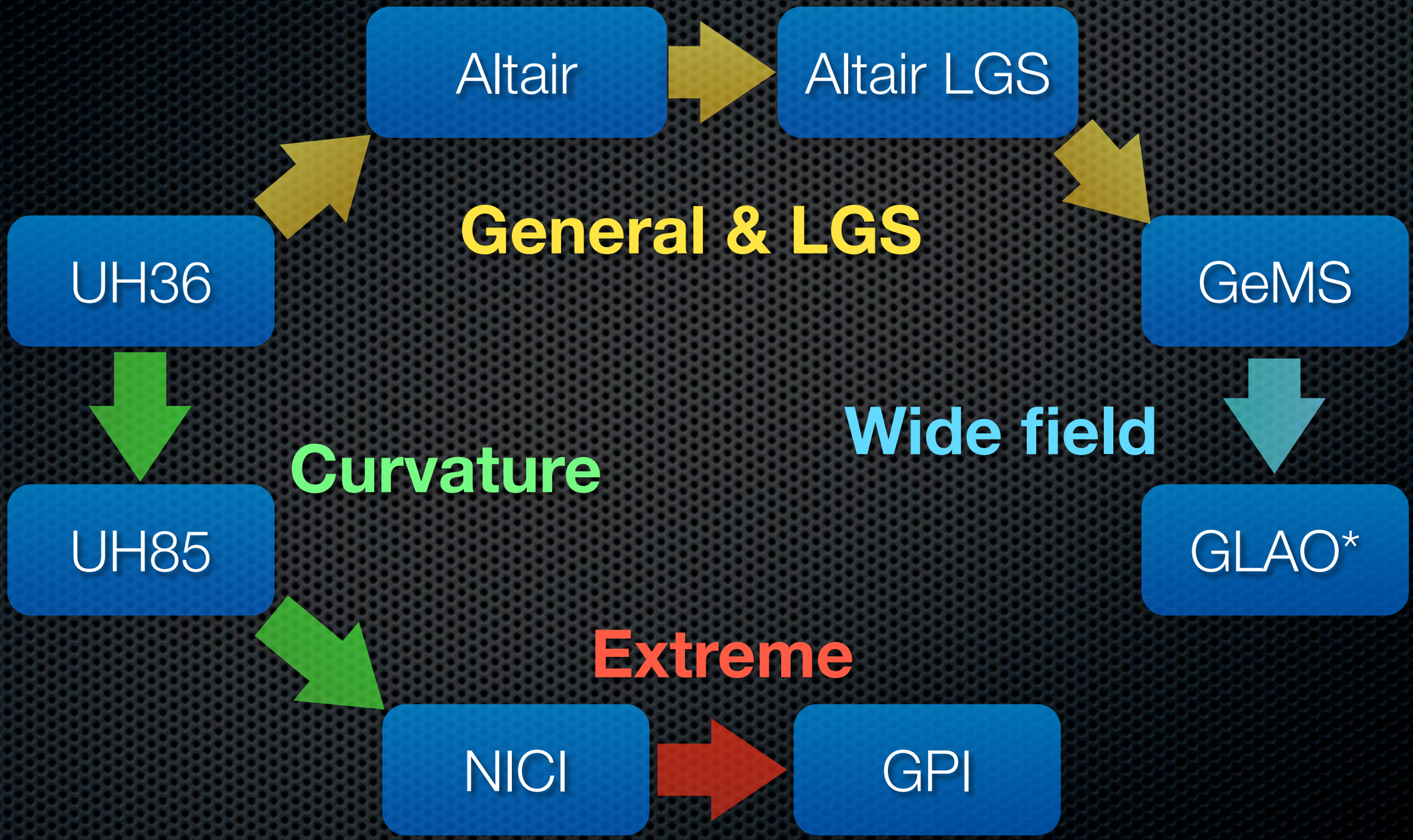


# AO instrumentation @ Gemini

## Past, present and future

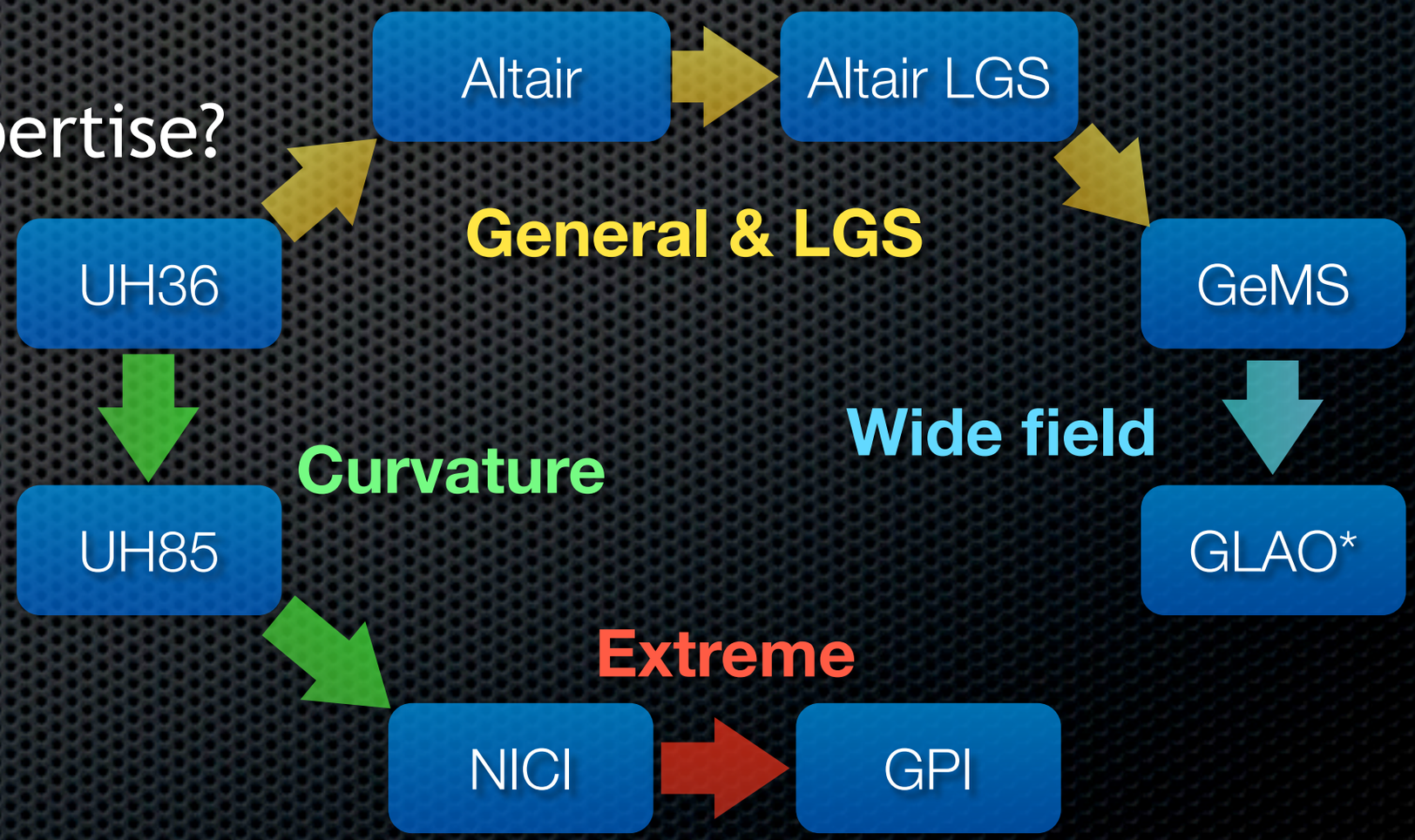
| AO | Instrument | FoV (“) | H Strehl | R lim (full/limit) | Sky cov (%) |
|---|---|---|---|---|---|
| UH36 | QUIRC | 20 | 15 | 15 | 1 |
| Altair NGS | NIRI / NIFS | 20 | 35 | 12/15 | < 1 |
| Altair LGS | NIRI / NIFS | 20/50 | 20 | 15/18 | ~ 30 |
| UH85 | ABU | - | - | - | - |
| NICI | Corono imager | 14 | 45 | 12/15 | < 1 |
| GeMS (MCAO) | GSAOI / F2 | 83 | 40 | 15/18 | ~ 30 |
| GPI | Corono / IFU | ? / 4 | 90 | 8/11 | < 0.1 |
| GLAO | all instruments | up to 360 | 5* | >15 | 100 |

# Program Flow

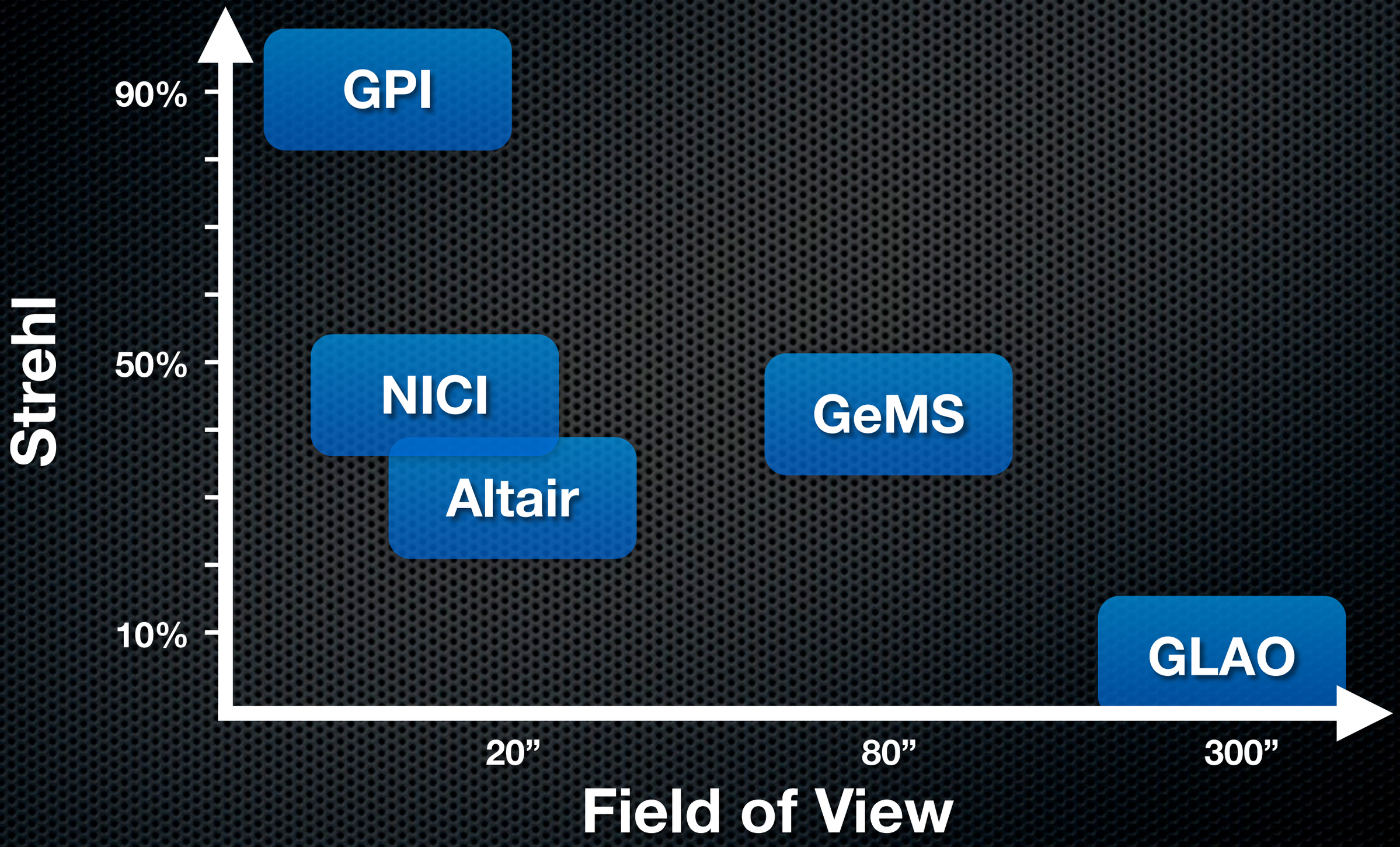


# Program Flow

- Broad but not redondant
- Stick to newest techniques and technology to retain competitiveness for our user community
- Ability to retain expertise?
- Too ambitious?



# Parameter space coverage



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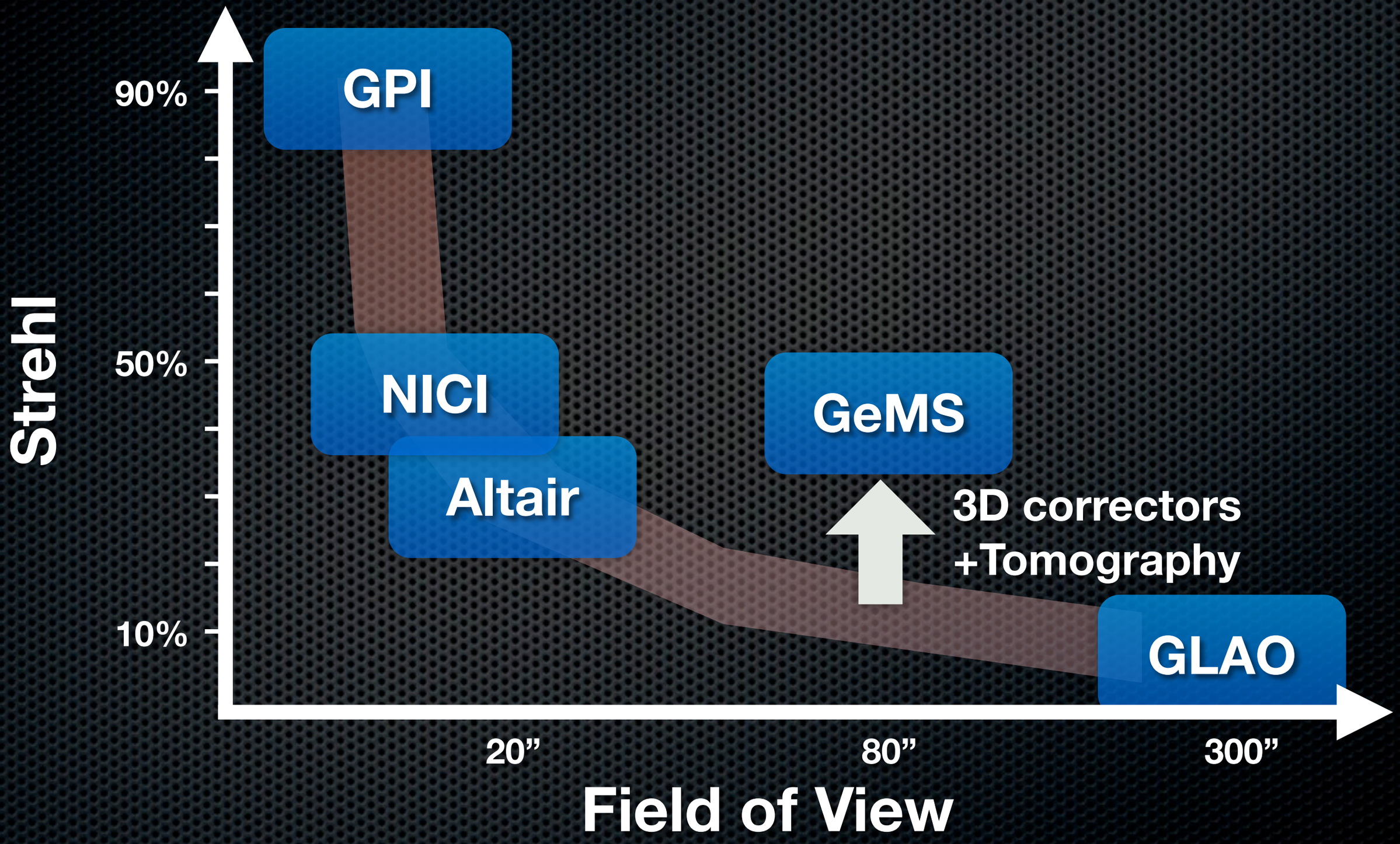
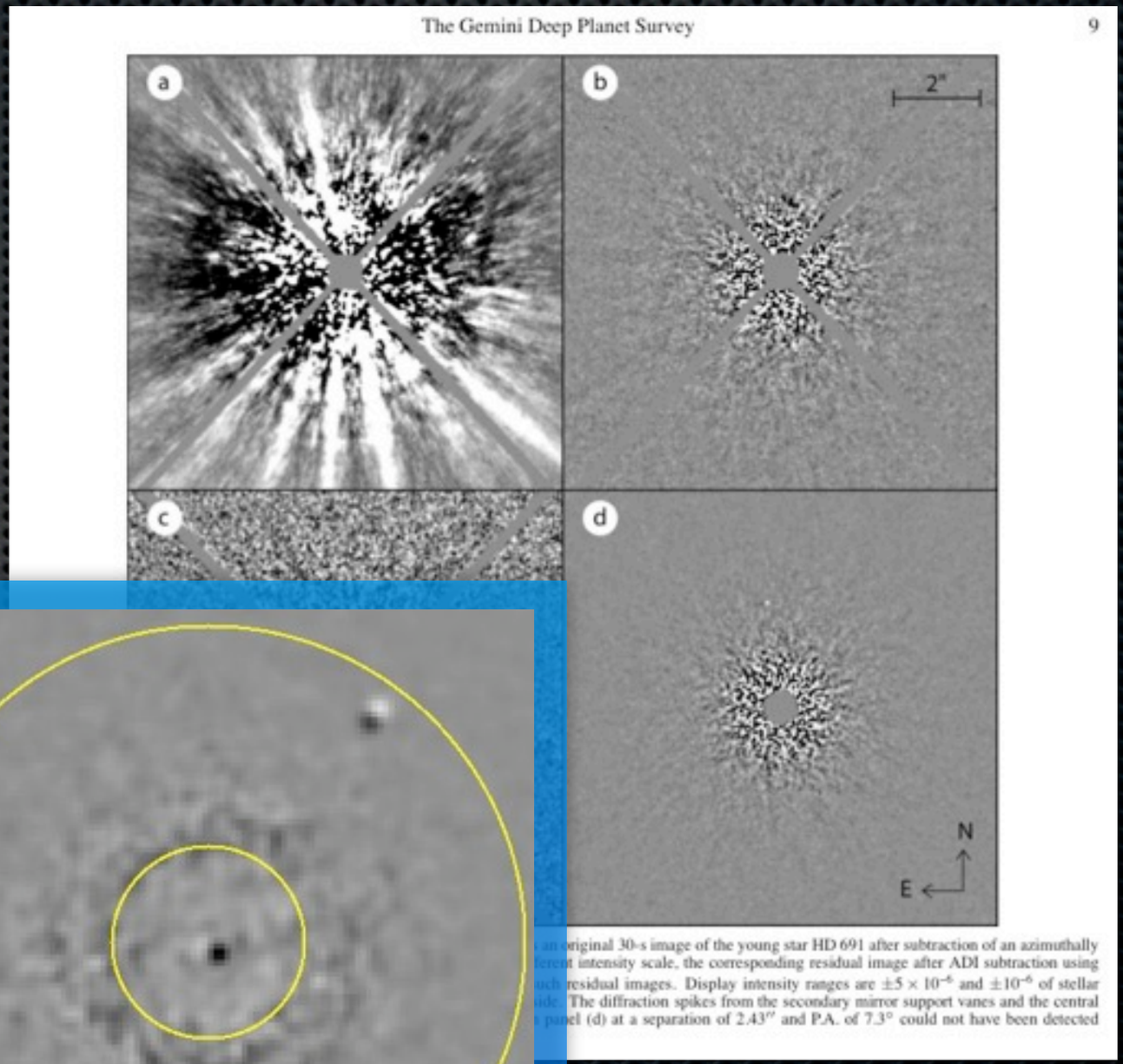


# Observing and DR Techniques

- ADI
- SDI
- PSF reconstruction
- Model fitting, minimization techniques
- Field-dependent-PSF photometry analysis
- etc...



# Instruments

- Huge progress in the past 10 years:
  - “Large(r)” field of view imager (GSAOI)
  - Integral field spectrographs (NIFS)
  - High performance coronographs (NICI)

# Science

- Recent Subaru/Gemini science conference with lots of talk and science results that were enabled by AO:
  - Solar system planets, minor bodies, extra-solar planets, YSO, PNs, supernovae, Galactic center, Galaxies dynamics, etc...

# M16, Pillar details

HST V band

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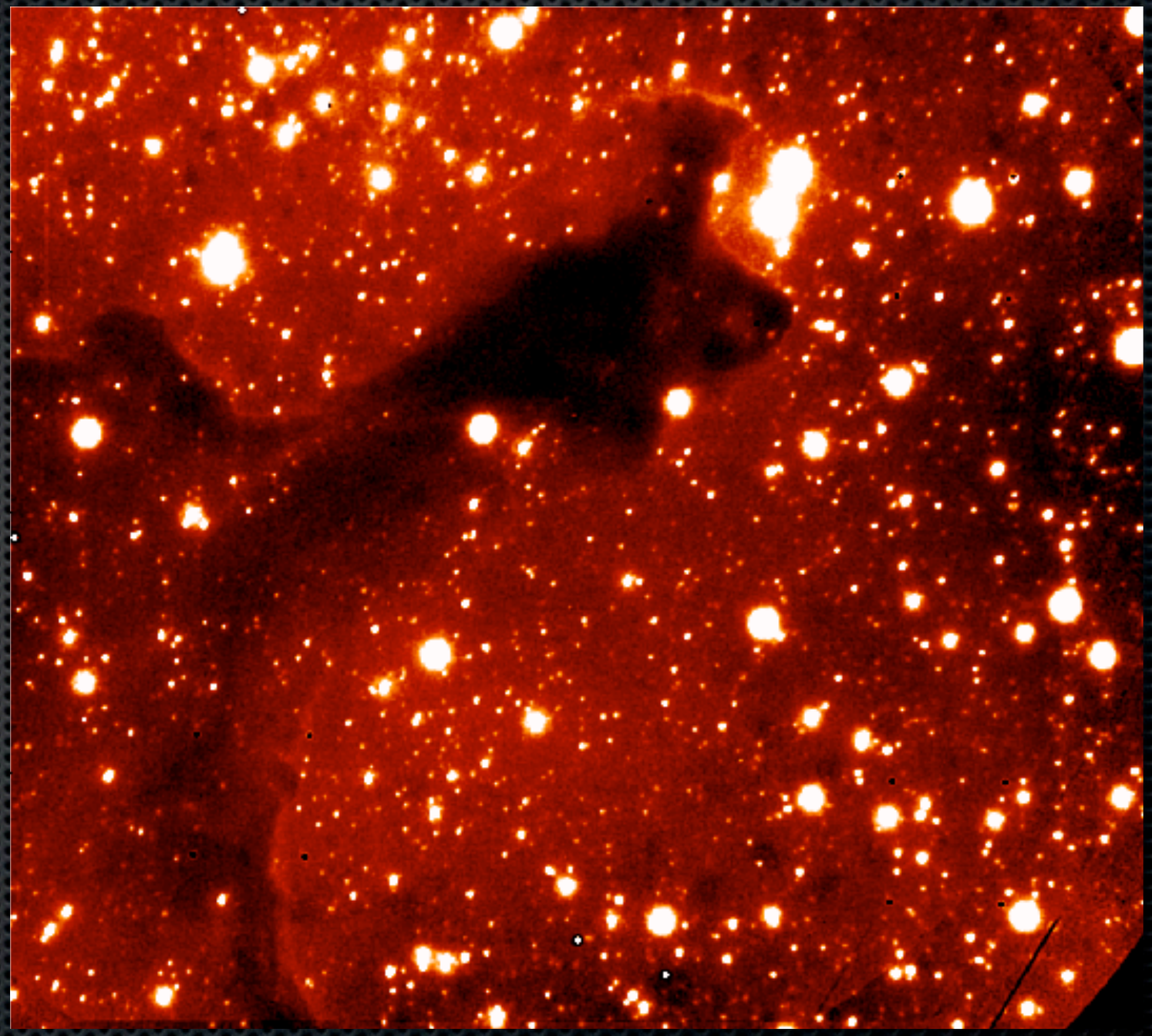
- HST:
  - V Band
  - WFPC2

HST V band

# M16, Pillar details

- HST:
  - V Band
  - WFPC2
- Gemini Altair LGS:
  - 4x120s
  - K' band
  - FoV 43”x40”
  - FWHM <100mas
  - Meets or exceeds HST V resolution



ALTAIR-LGS K’

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ALTAIR-LGS K’

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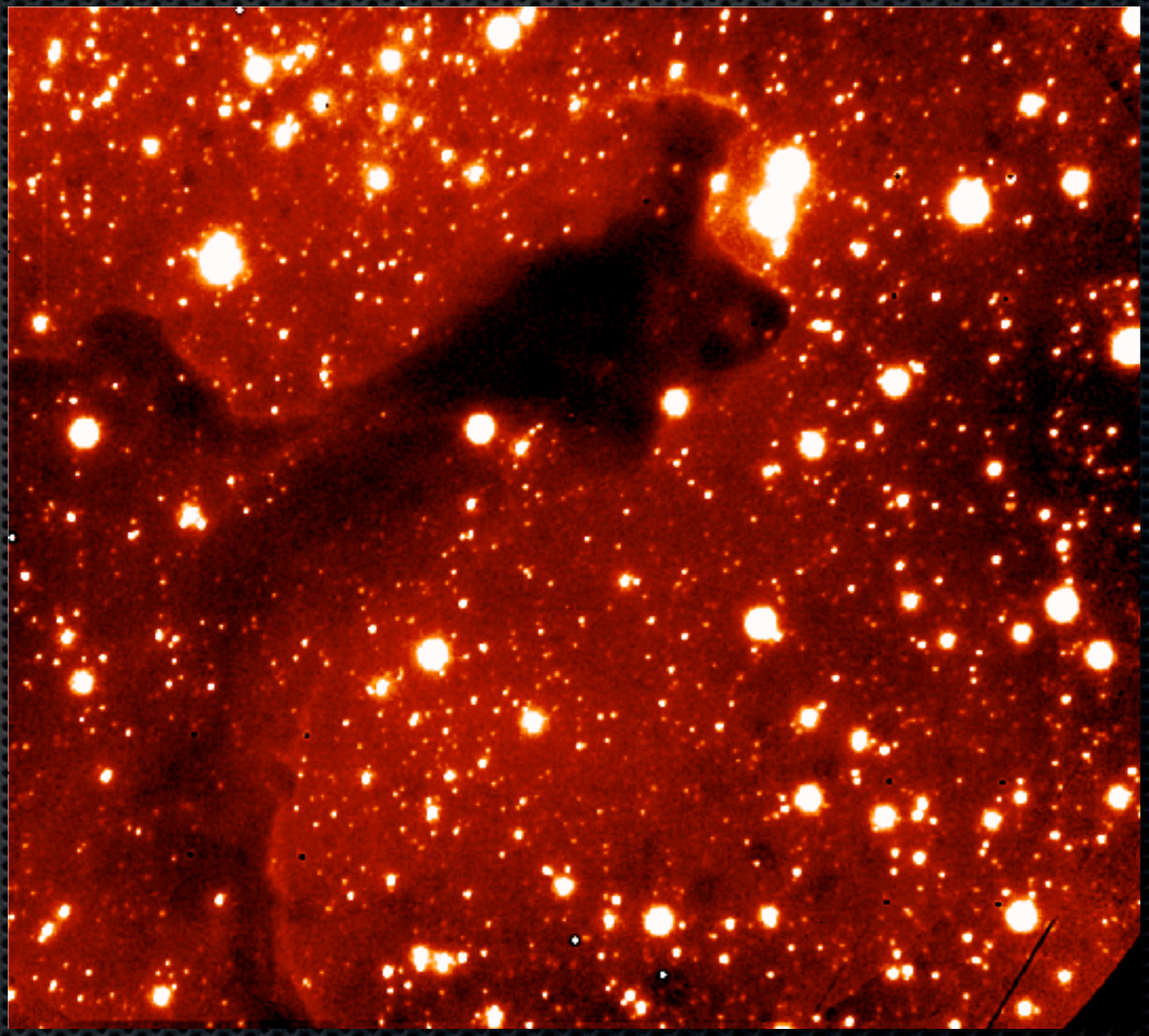
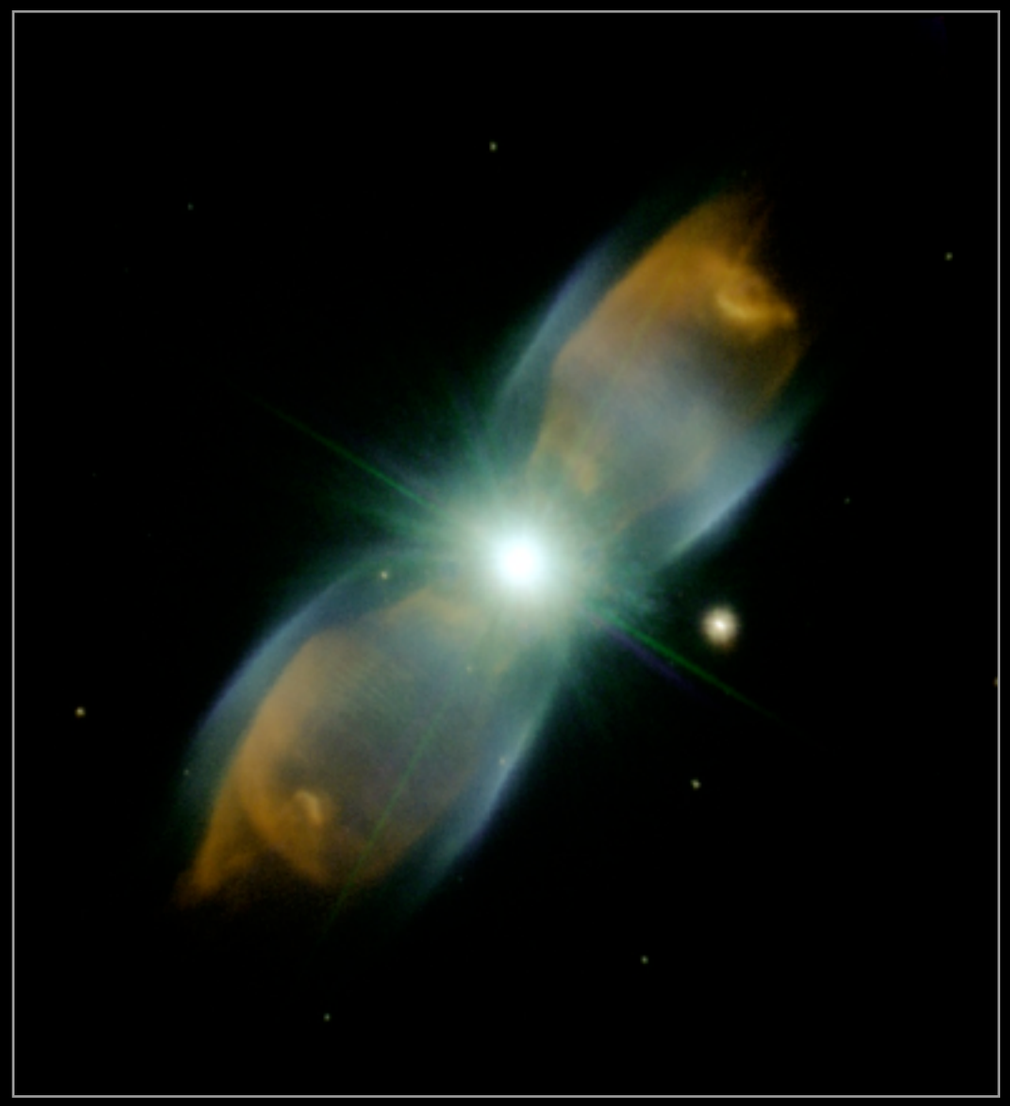
Similar resolution, different wavelengths: complementary

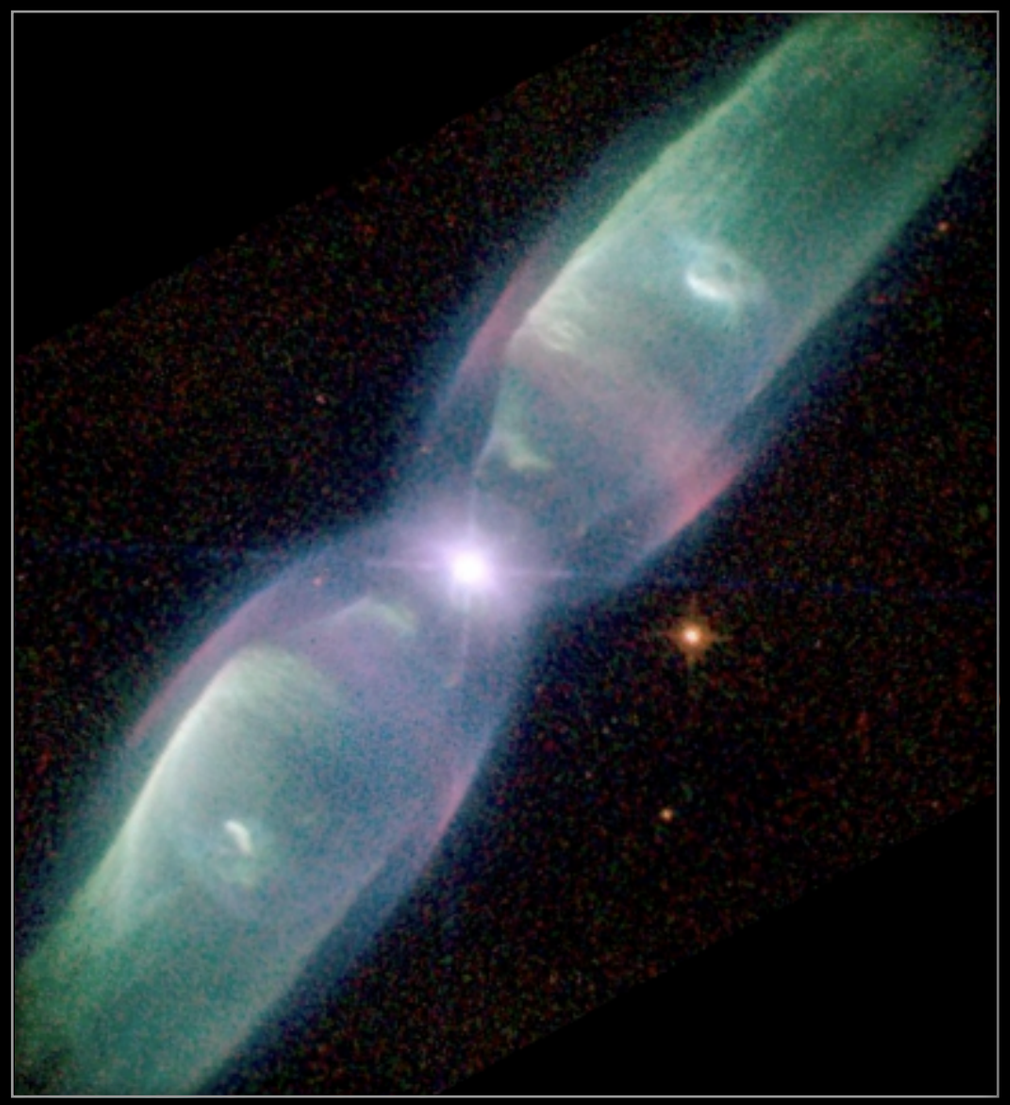


ALTAIR-LGS K’

# Gemini AO (NIR) vs HST (visible)



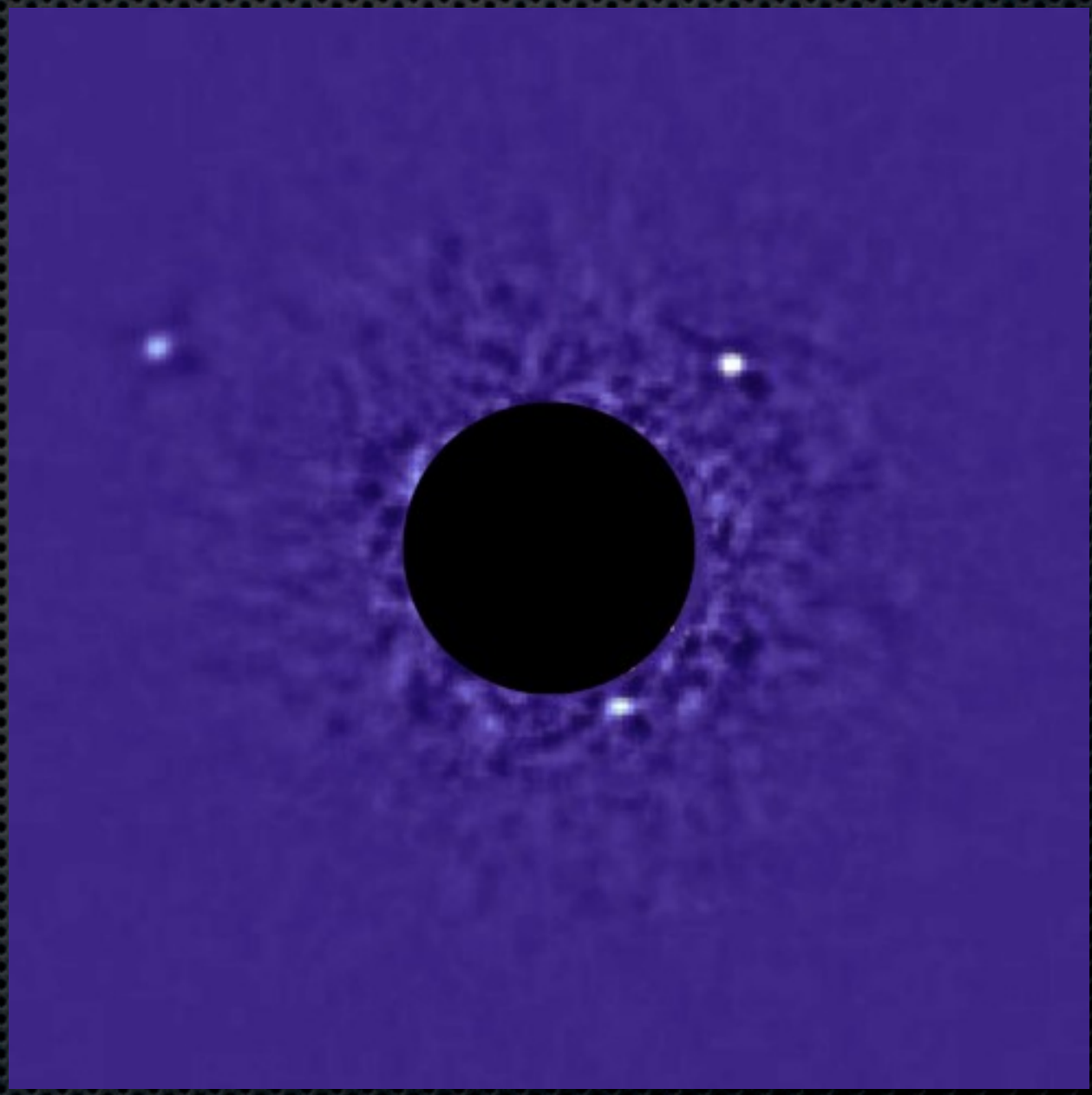
M2-9, Gemini, NIR, 2005



M2-9, HST, Optical, 1997

# First planetary system around a main sequence star (HR8799)

- Gemini (Altair) & Keck
- First direct imaging of multiplanetary system
- 24, 38 & 68 AU from star
- approx 10, 10, 7 $M_{JUP}$
- Angular Diff. Imaging
- Canada/US consortium

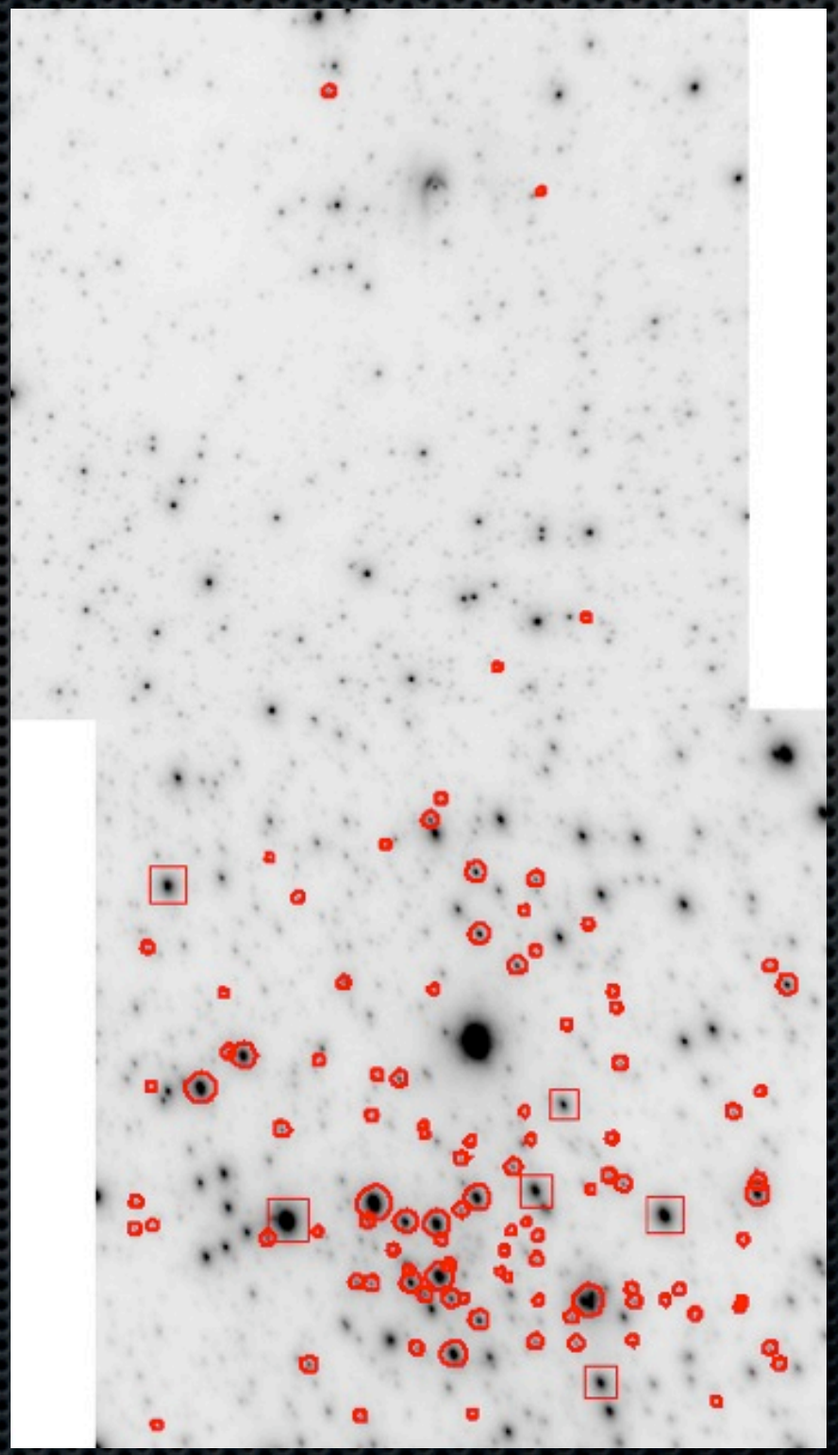


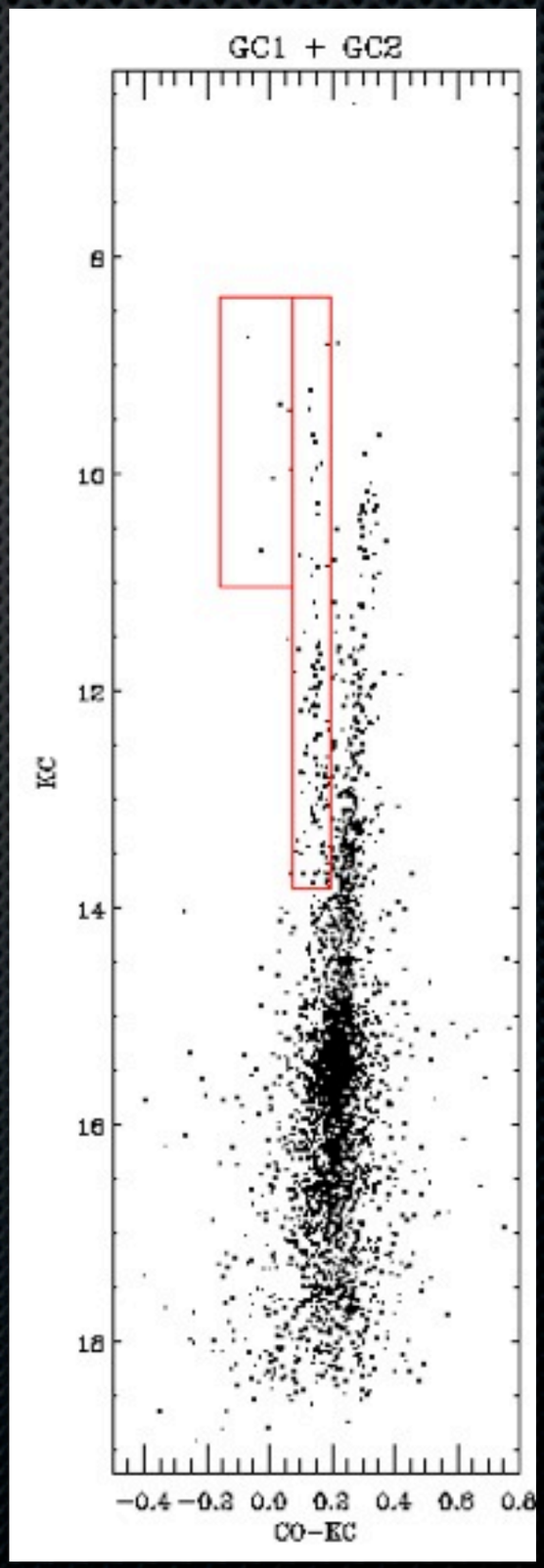
Credit: Christian Marois et al, CNRC
arXiv:0811.2606v1 [astro-ph]

# Photometric accuracy

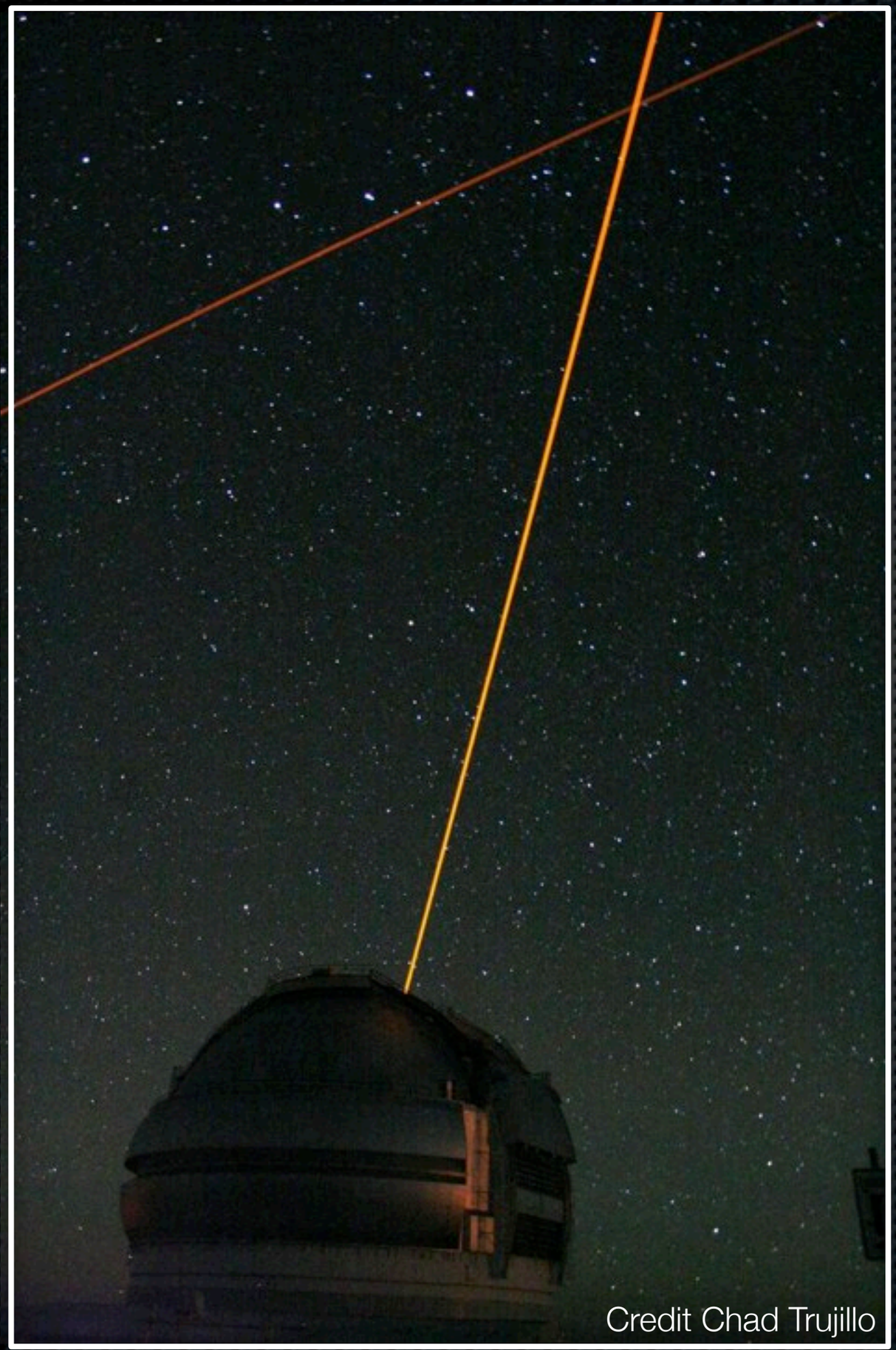
Challenging but doable

- error = 0.02 mag rms
- GC 20”x30” FoV (crowded)
- Need proper calibrations

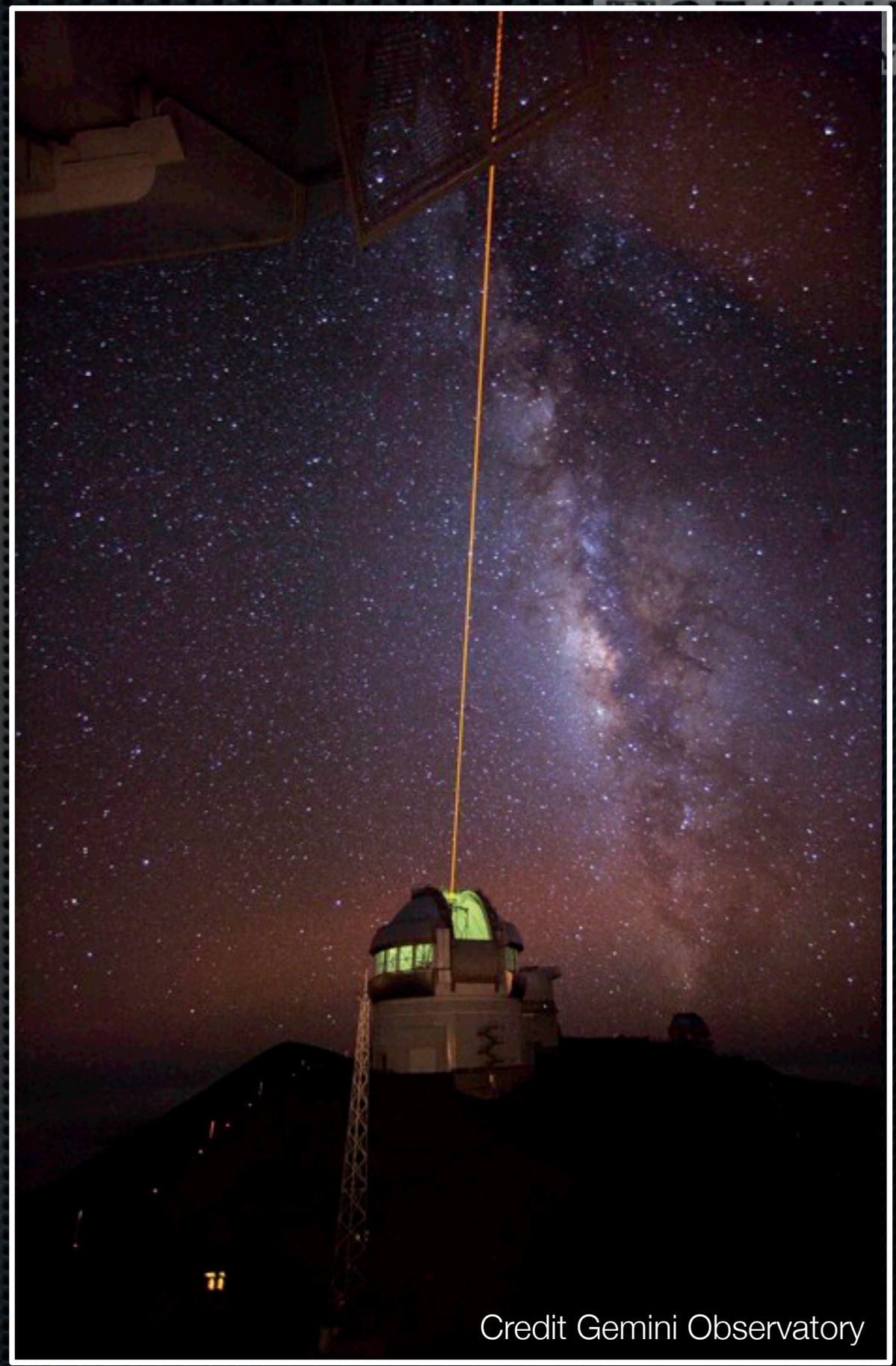




# Lasers, lasers...



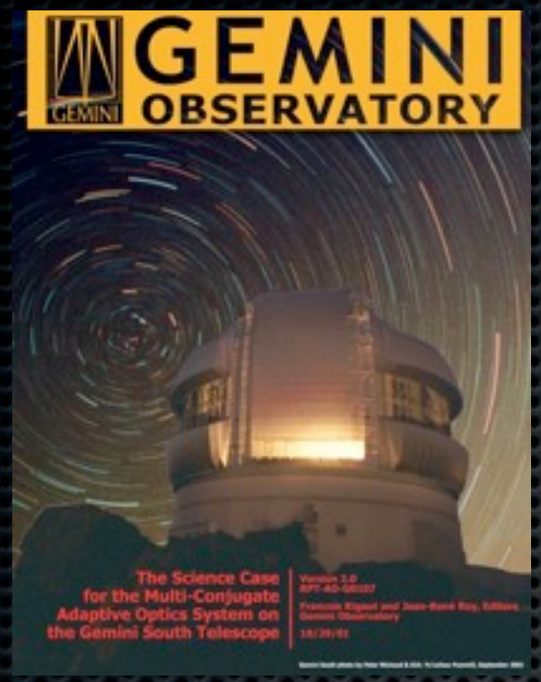
Credit Chad Trujillo



Credit Gemini Observatory

# GeMS (MCAO)

**Demonstrated Science**

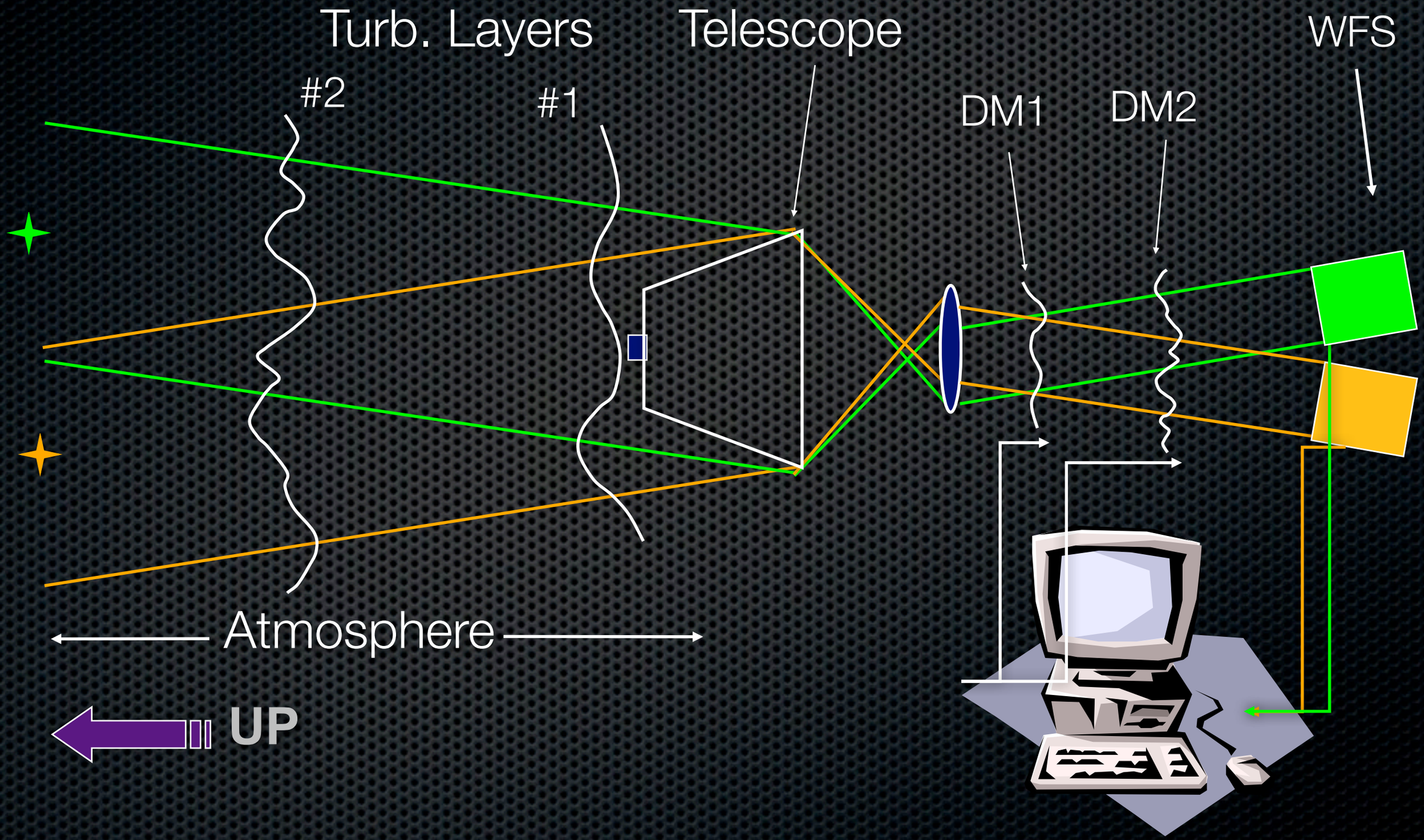



**Demonstrated physics**

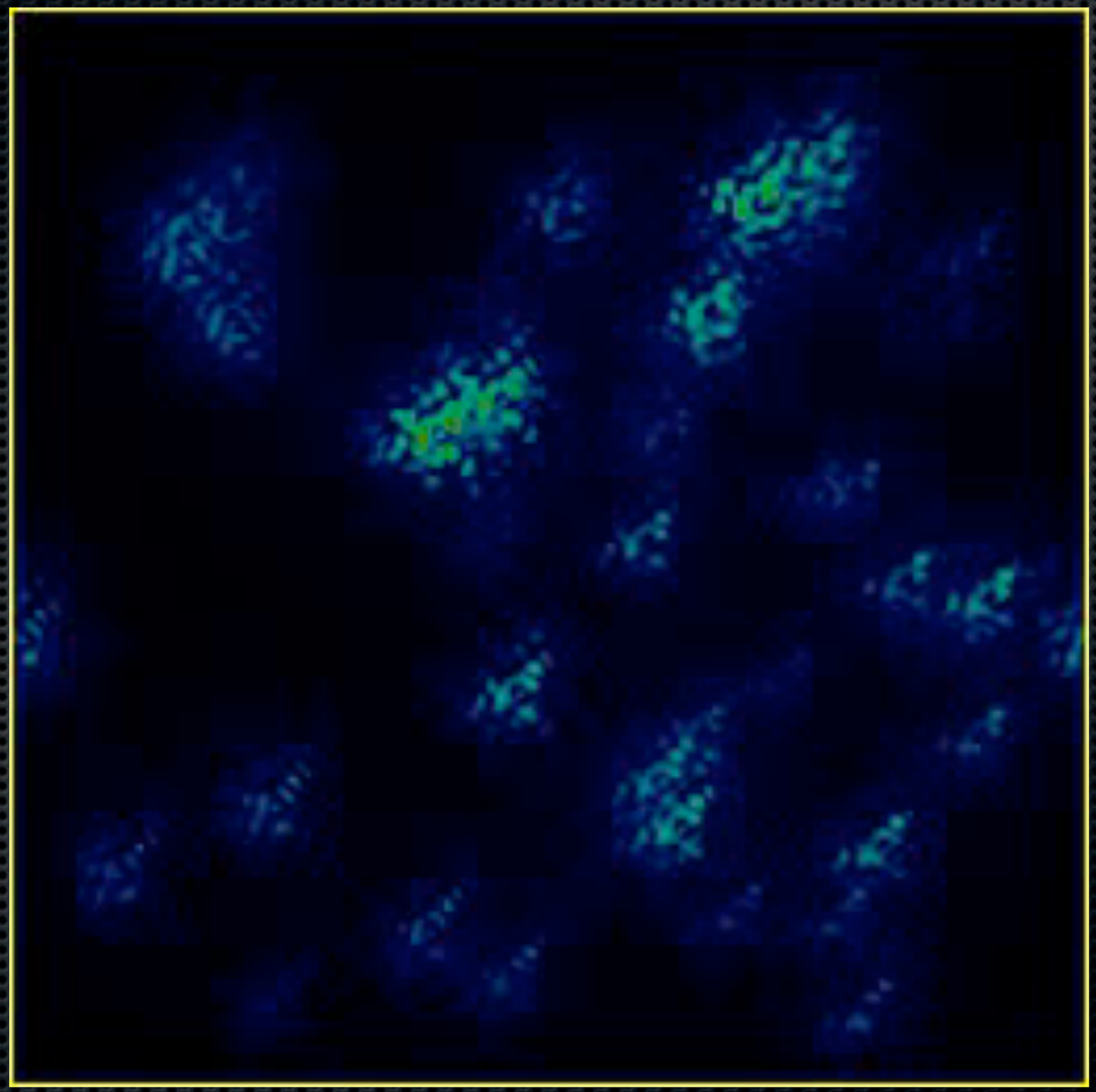

- Major limitations of AO:
  - Sky coverage
  - Small field of view
- MCAO provide ~30% sky coverage (LGS) and ~80” FoV
- Photometric accuracy (8x gain w.r.t AO)

- Gemini MCAO:
- Work started mid 99
- Funding was secured 2001-2002
- Being integrated in La Serena
- First light in 2010

# The multi-conjugate AO concept



# MCAO efficiency



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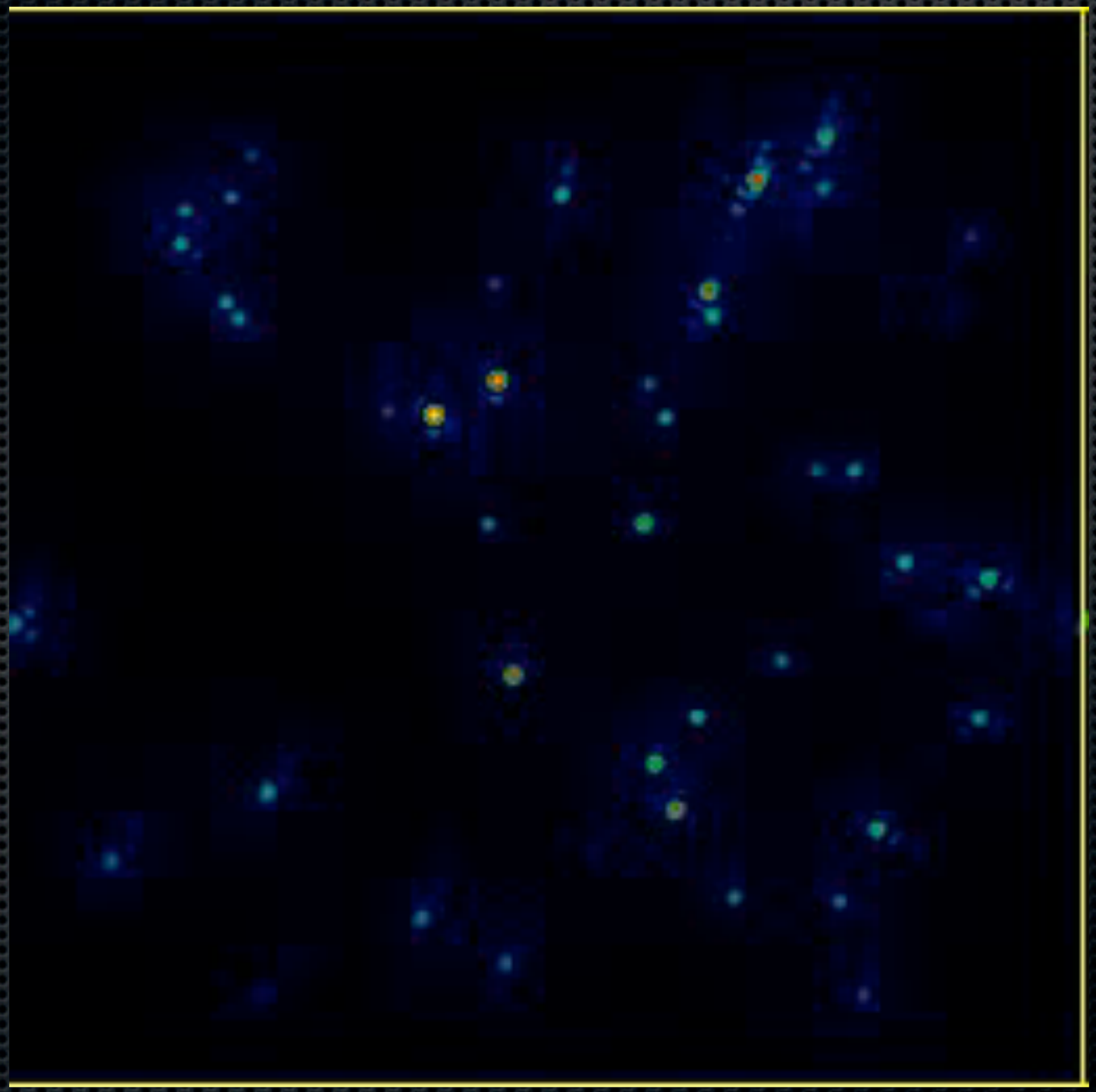
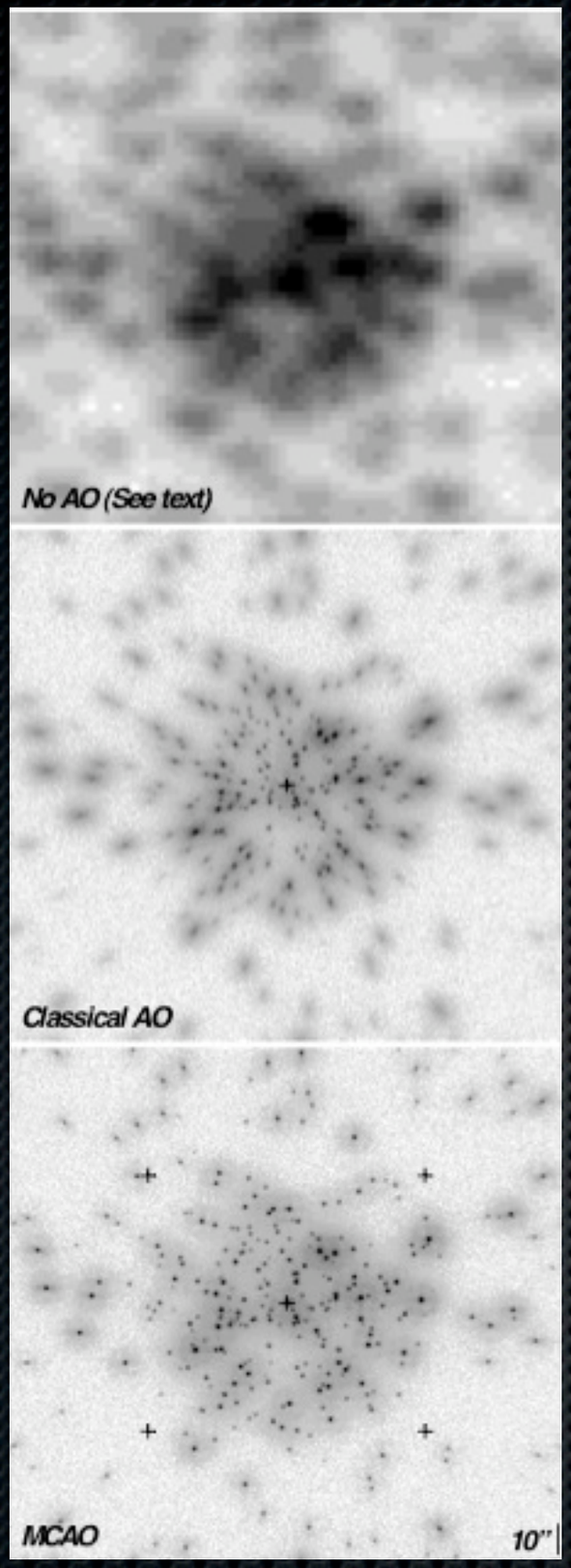
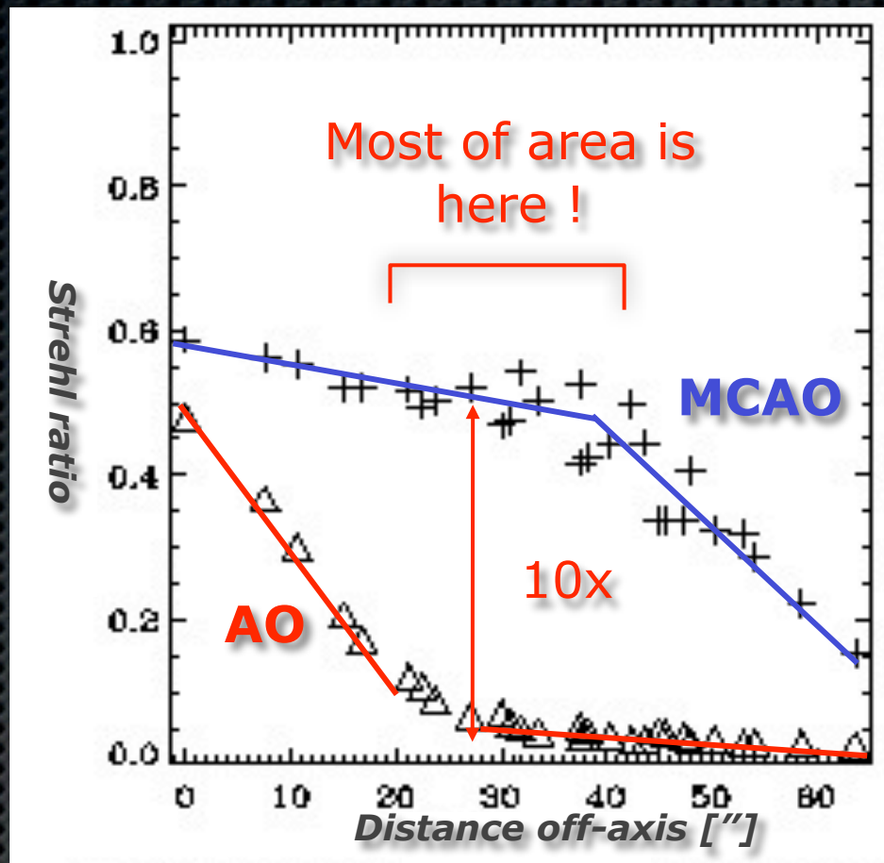
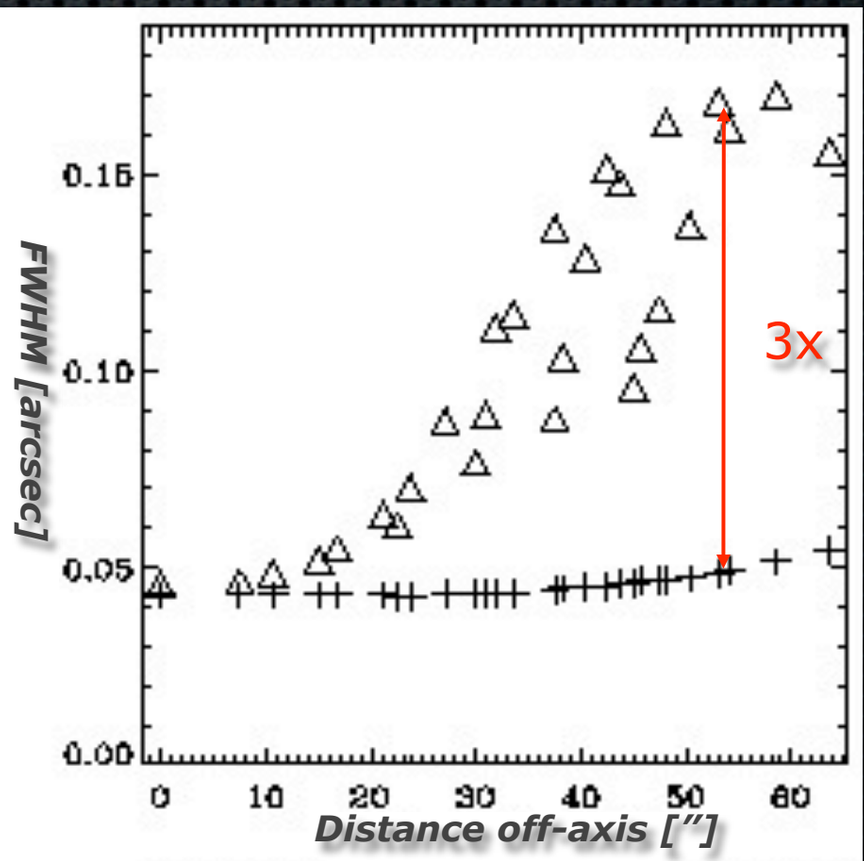


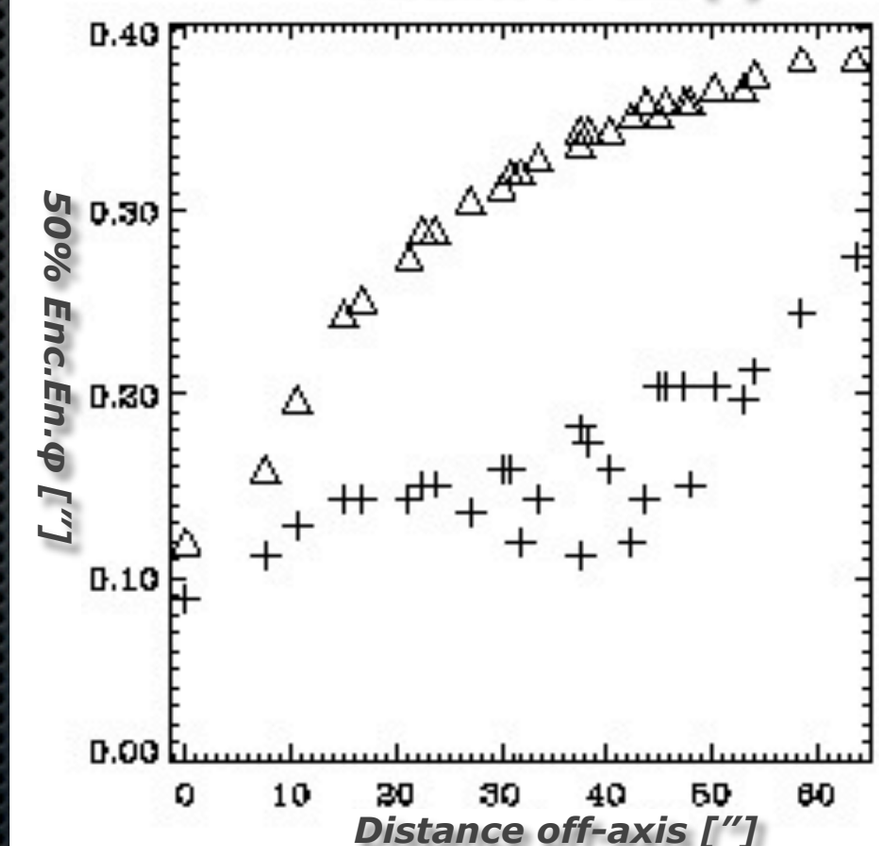
# MCAO efficiency

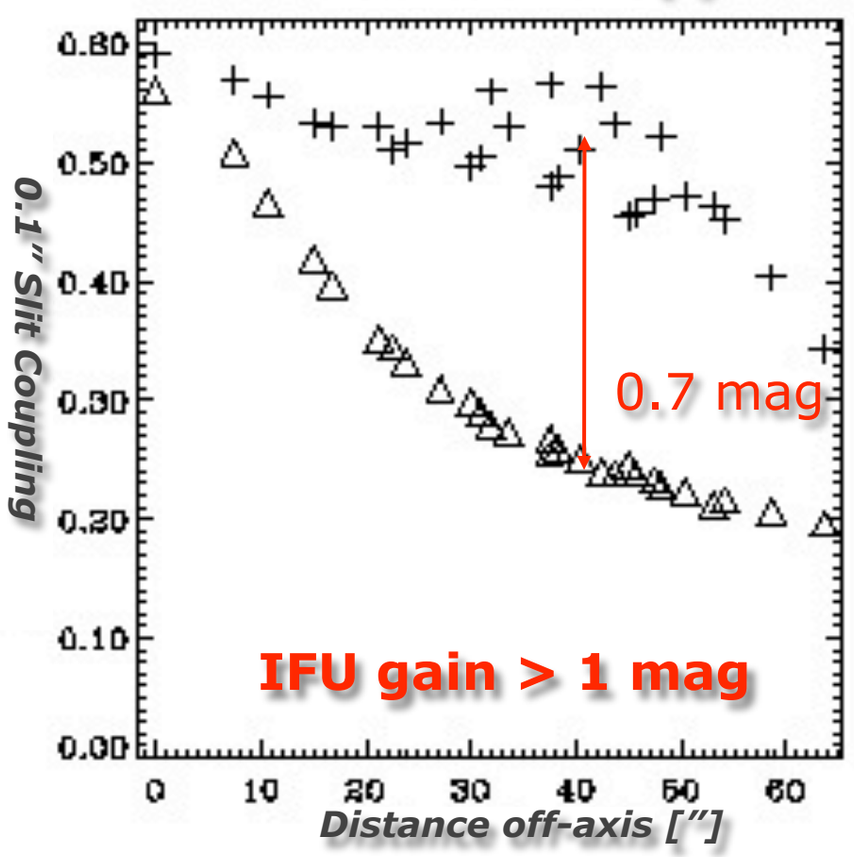
# MCAO vs AO gains



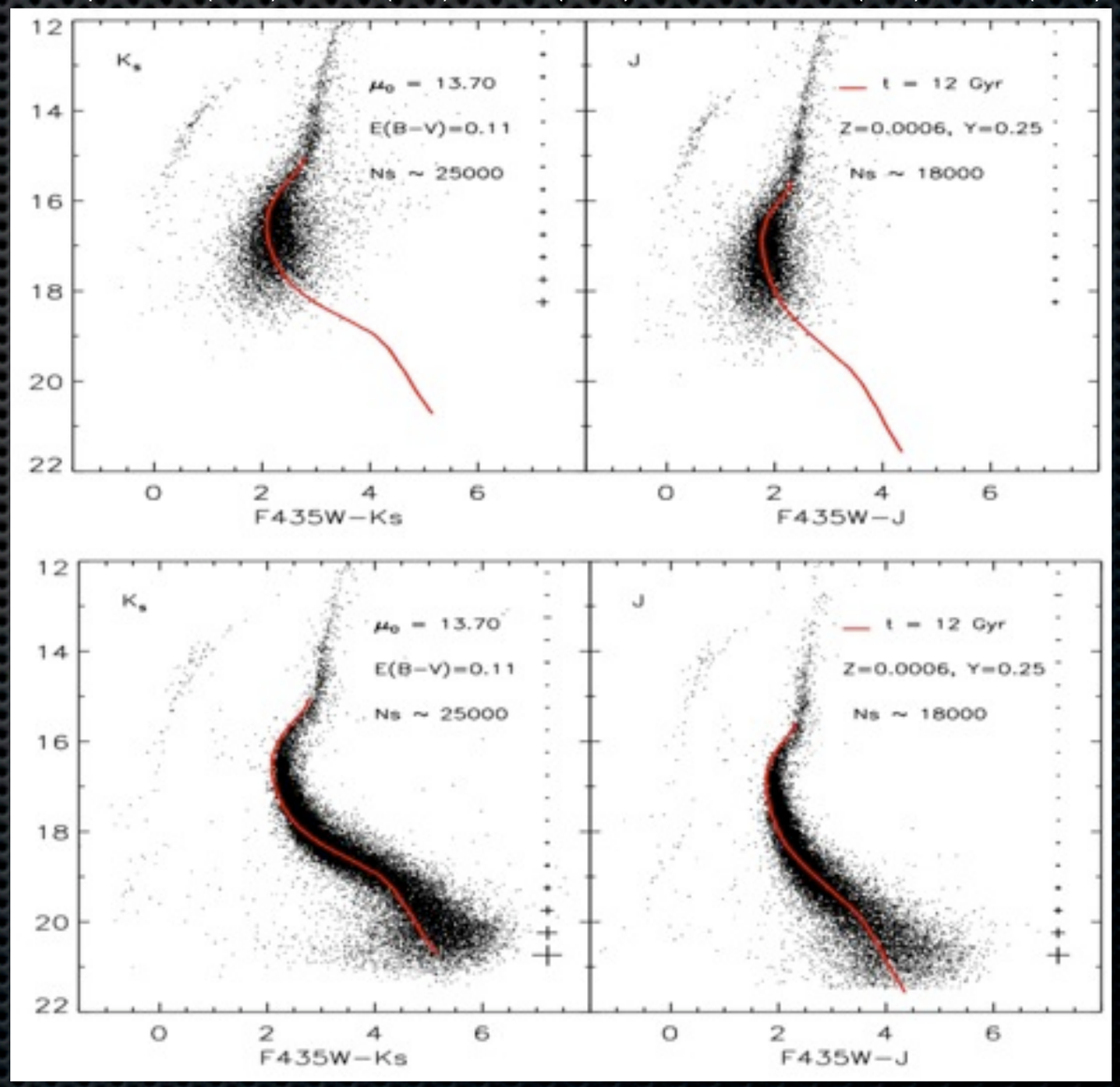



# A taste of the upcoming science with GeMS: MAD results @ the VLT

- A few (4-5) runs of technical commissioning + science (~25 nights)
- 0.5” seeing (ISAAC) -> 90mas (MAD) lead to a 3 magnitude gain in crowded region (see plot). MCAO should improve that by another 1.5 magnitude. In less crowded fields, expected limit = 24.9 (Ks), 26.3 (J) 5sigmas, 1hr
- MAD soon shipped back to Garching (out of targets?).
- MAD has demonstrated that MCAO and GLAO work. Gemini will do better in terms of (1) performance (684 actuators vs 120 for MAD) and sky coverage (LGSs vs NGSs for MAD)

Omega Cen central region. G.Bono et al, astro-ph 0803.2207
Top: SOFI(NTT)/ISAAC(VLT) + ACS(HST). Bottom: MAD(VLT) + ACS(HST)



# GeMS history overview

| | |
|---|---|
| **April 1999** | MCAO recommended as GS AO system |
| May - Sept 1999 | MCAO feasibility study |
| Dec 1999 – May 2000 | CoDR phase + review |
| June 2000 – May 2001 | PDR phase + review |
| Oct 2001 – May 2004 | CDR phase, RFP and external contract setup |
| 2005 | GN Altair LGS integration and commissioning |
| Dec 2005 | MCAO internal project definition and launch |
| Jan – Oct 2006 | In-house design phase |
| Oct 2006 – Mar 2010 | Mix of on-going design, fabrication and I&T |
| Apr 2010 | Scheduled first light |
| **Apr - Dec 2010** | On-sky technical and science commissioning |

# GeMS in numbers

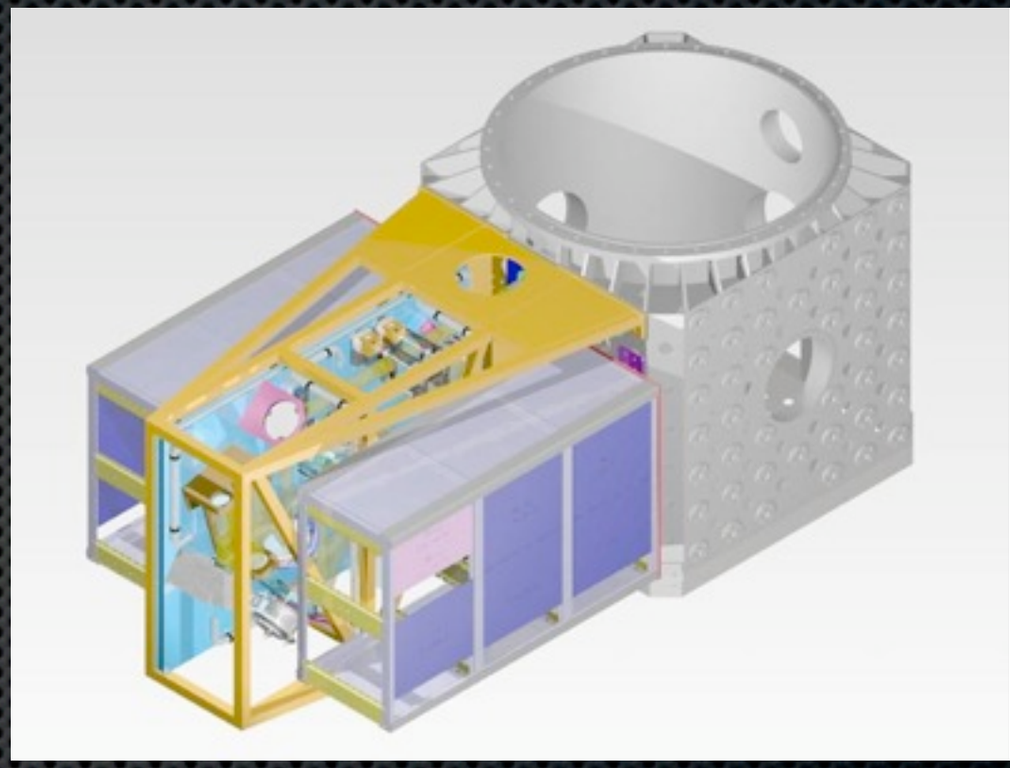
- 5 LGS WFS 16x16 Shack-Hartmann
- 3 Deformable Mirrors totaling ~800 actuators, conjugated to 0, 4.5 and 9km ranges
- 3 APD based NGS Tip-Tilt WFS
- 1 NGS slow focus WFS

CANOPUS

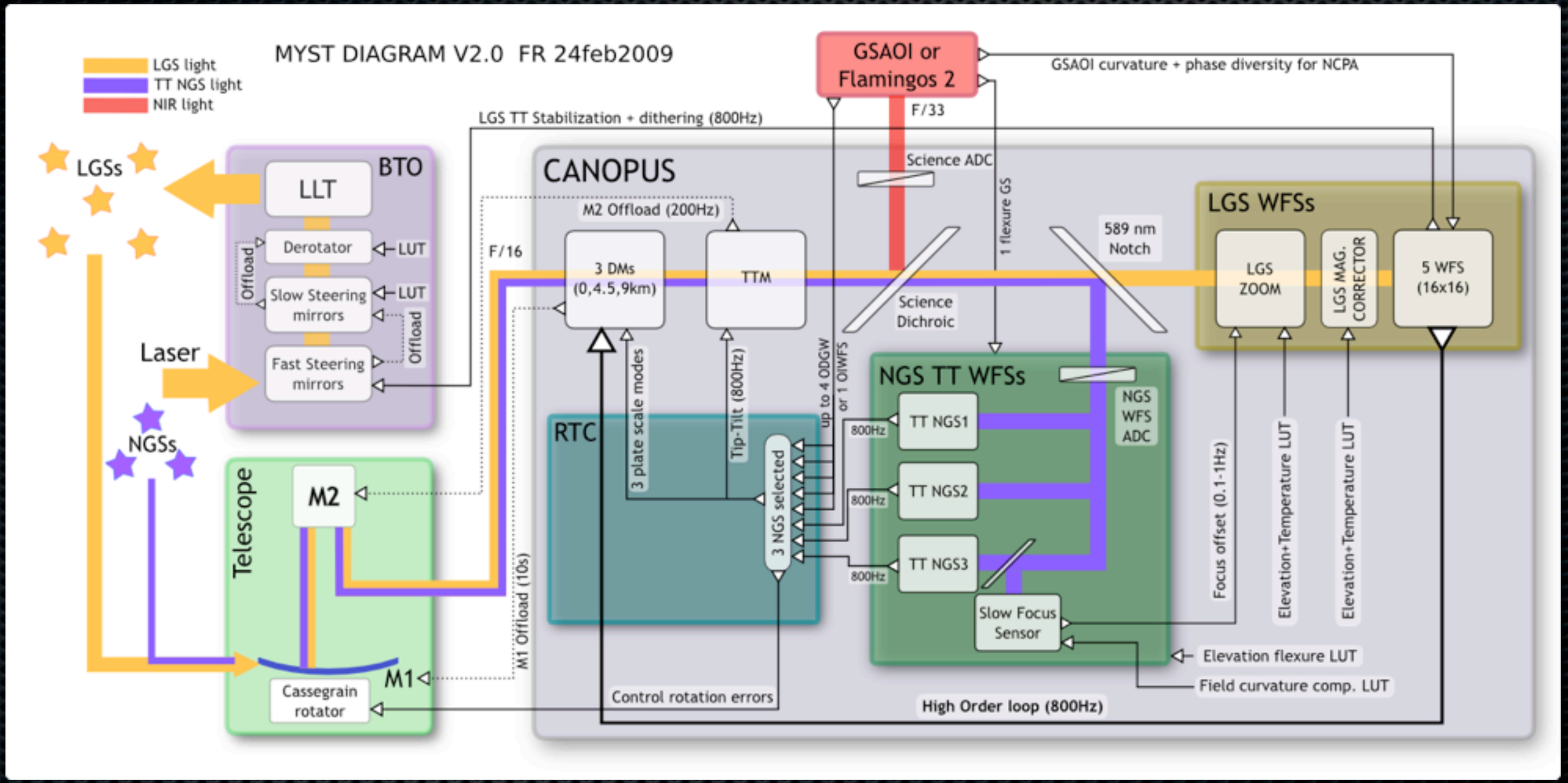
- 1 x 50W laser divided in 5 x 10W beams placed on the corners and center of a 1' FoV
- 2 dedicated instruments:
  - GSAOI (4k2 NIR imager), 80” FoV (20mas pixels)
  - Flamingo II (NIR MOS), 2' FoV
- Many subsystems: ASCAM, Safety systems, infrastructure, laser(s), BTO, LLT, etc...

# GeMS Subsystems

- Canopus = AO module (EOST)
  - includes all optomechanics
  - bench electronics+control
- Real-Time Computer (tOSC)
  - 2x6 CPUs TIGERSharks (RISC)
- LGS WFS (tOSC)
- Deformable Mirrors (CILAS)
- Off-axis parabola (U.Arizona OSC)
- Diagnostic WFS (in house)
- AIT (in house)
- laser, BTO, LLT, LSE, Safety systems



# GeMS block diagram



# “Side” subsystems (infrastructure)

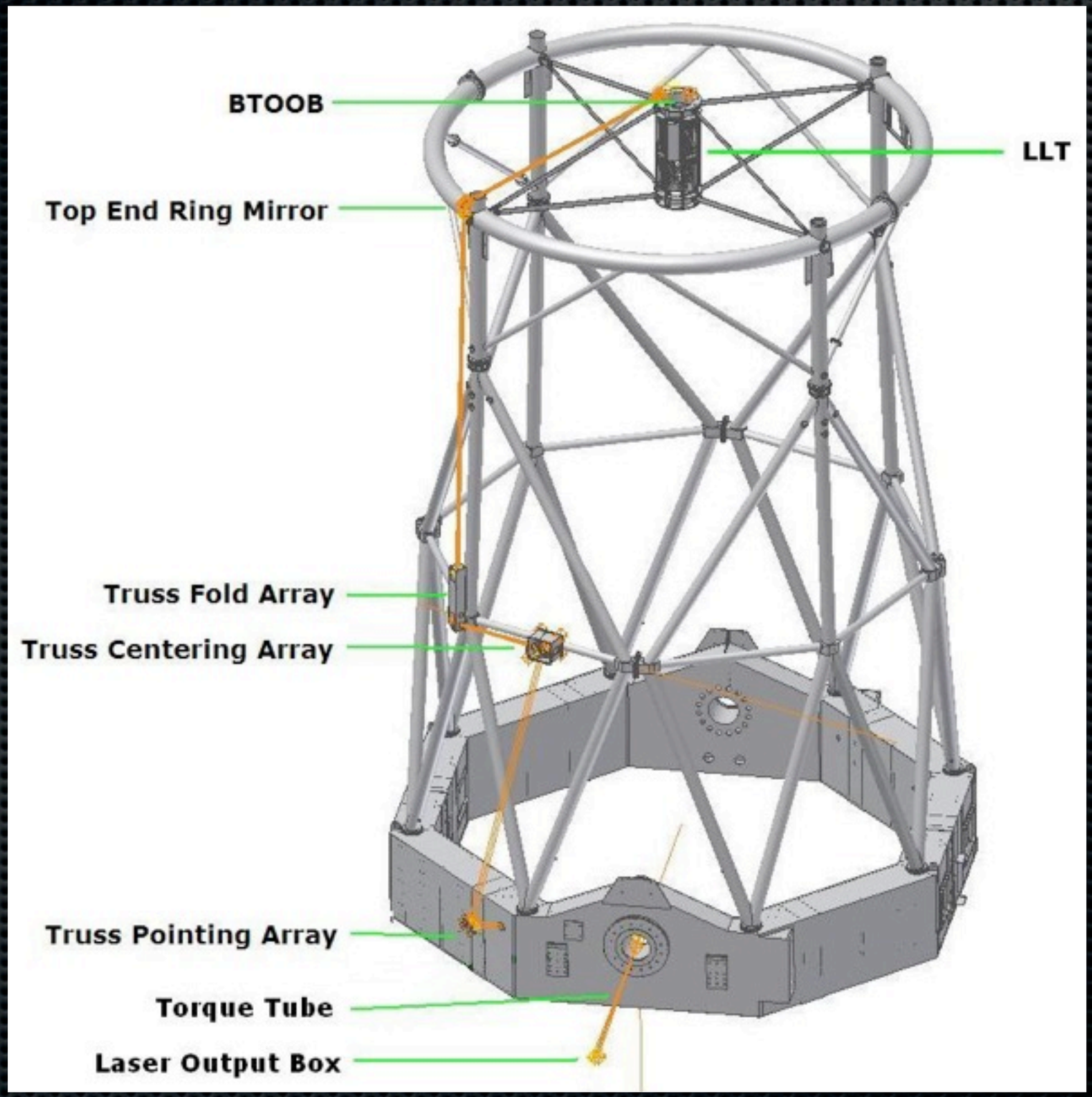
## Elevation platform extension

# Laser Infrastructure (LSE)

# Altair LGS woes and lessons learned

- Beam quality is primordial (LLT problem)
- Vibration can also occur @ launch (vibrations induced by M2 positioners)
- Laser stray light is powerful
- Operation is much more complex than NGS
- Requires interaction with
  - space command → issue for Queue scheduling
  - FAA (aircraft) → spotters / all sky camera
  - neighbors telescopes (beam collisions) → LTCS
- Spotters, insurance, laser maintenance is high cost
- Non-Common Path aberrations are an issue

# Beam Transfer Optics



# A modern GeMS Status Display

ASCAM - /export/data/ascam/2007jul10/*.fit*

Window Menu | Displays | Help

Camera Control

exptime 6

temp-ctrl -3

Start | Pause | Stop | Exit

Detect Aircrafts

Init | Start | Pause | Step

Detection paused (Start to continue)

Status

CCD temp **STALE**

CCD power **STALE**

Frame 20070709T214052.fits

Proc. time 0.46 sec

Detection Aircraft -> 30el !

ASCAM SIMULATED

Trajectory Log

| | TIME | MXL | SPD | PA | IMP | NPT |
|---|---|---|---|---|---|---|
| | 21:38:39 | 63 | 1005 | 35 | 29 | 39 |
| | 21:41:09 | 77 | 835 | 51 | 15 | 23 |

System : 1 ( 0.0000, 752.6220)

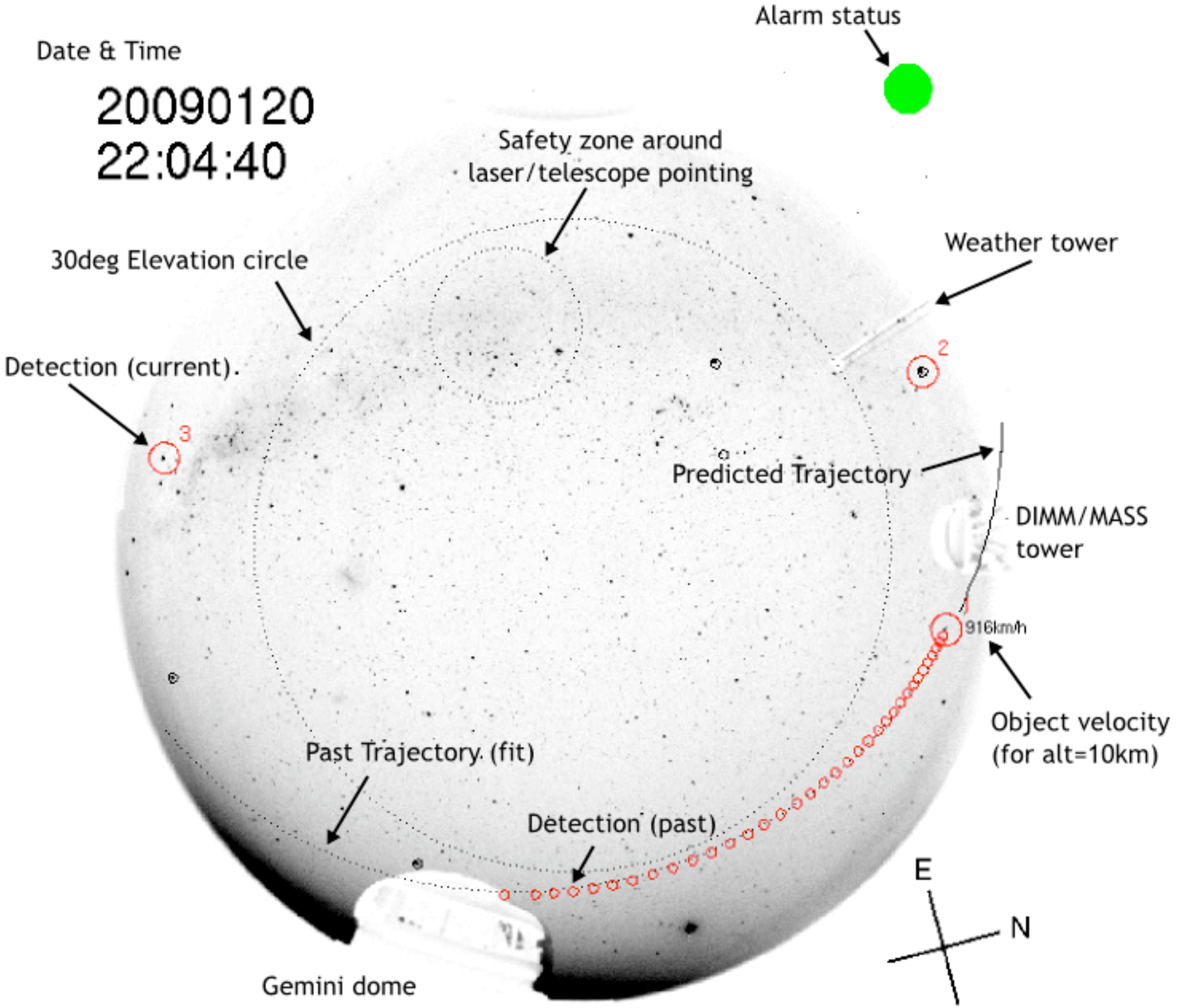
20070709
21:40:52

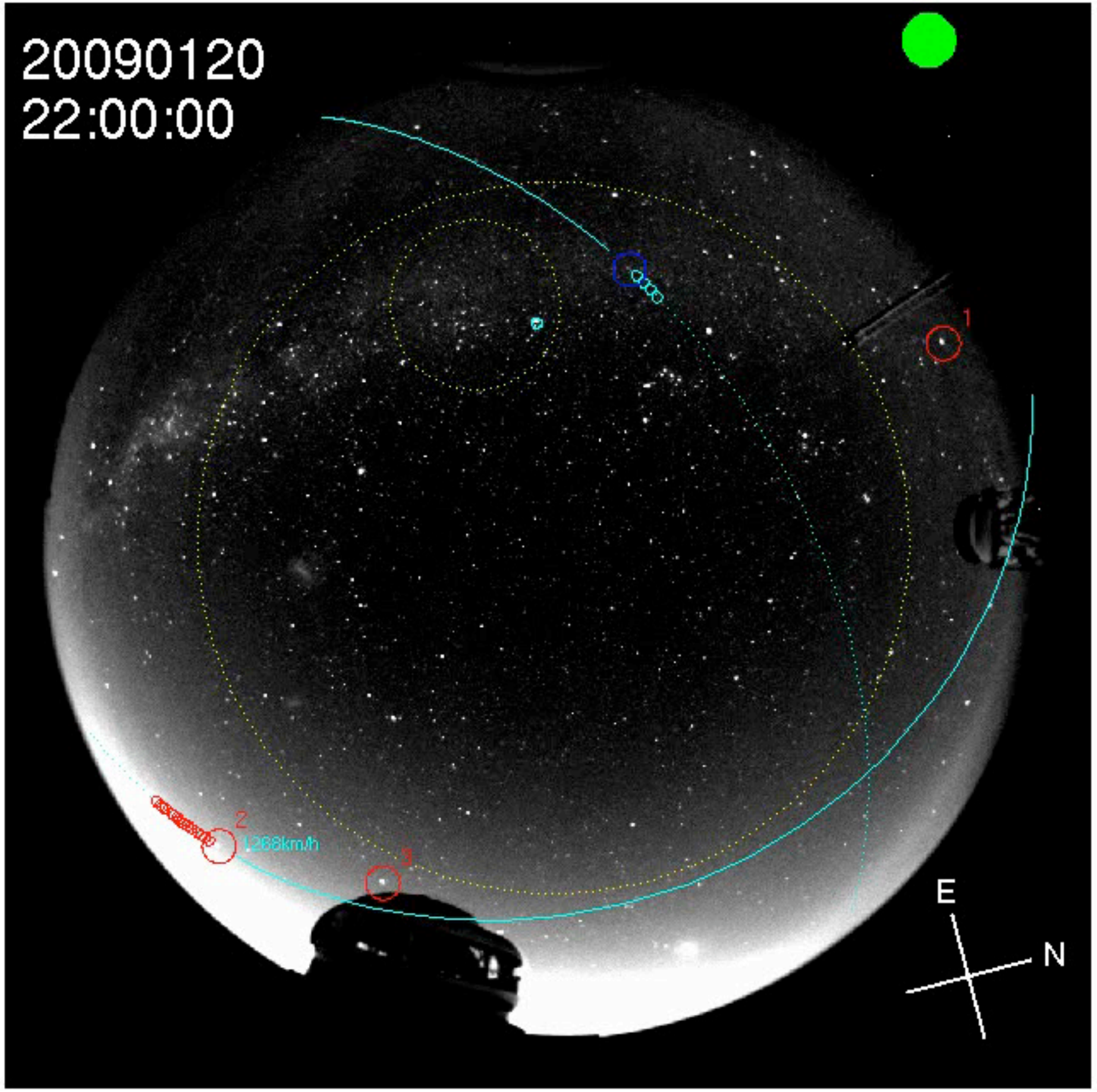
1
835km/h

2
1006km/h

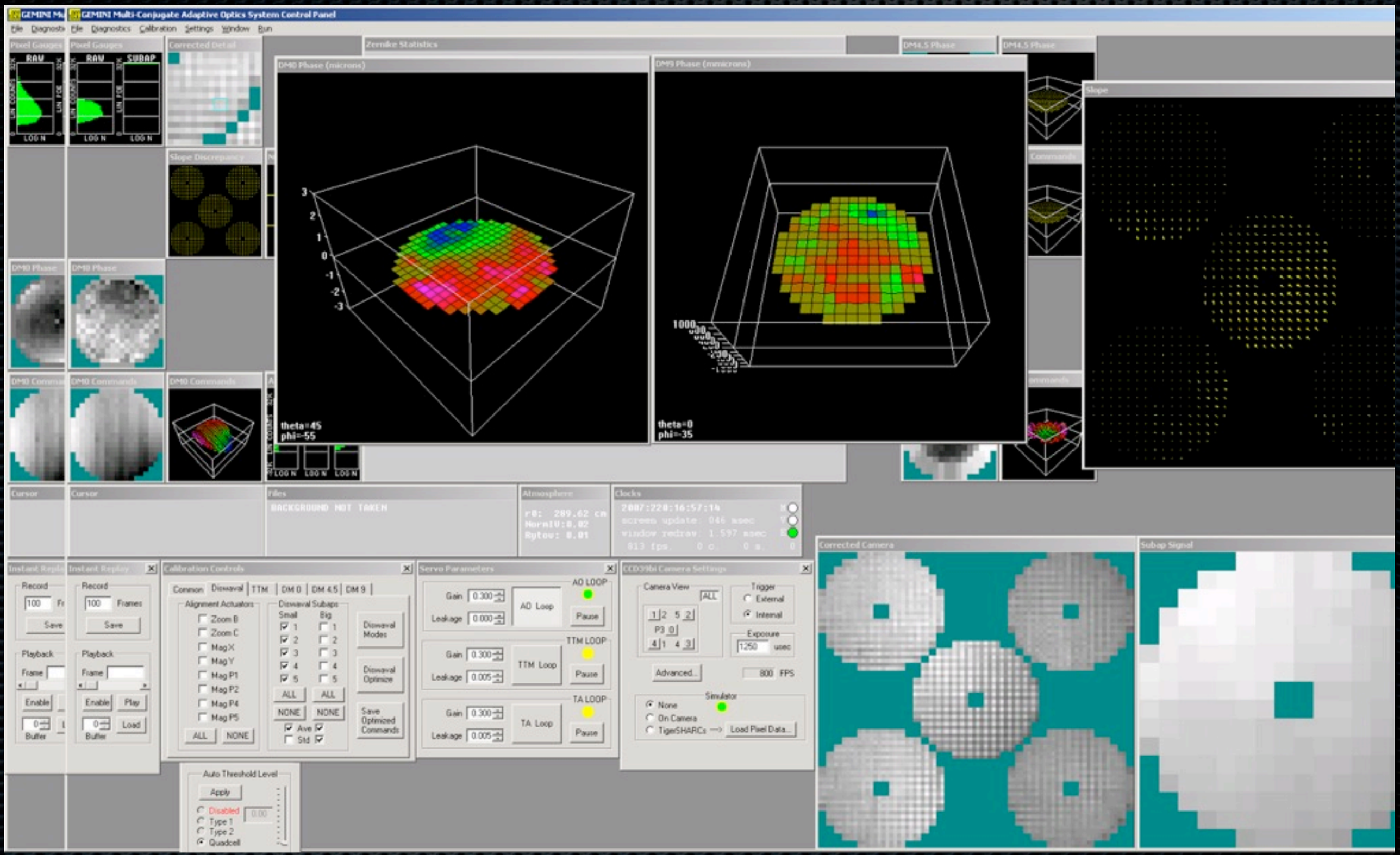
E

N


Alarm status
Date & Time
20090120
22:04:40
Safety zone around
laser/telescope pointing
30deg Elevation circle
Weather tower
Detection (current).
2
3
Predicted Trajectory
DIMM/MASS
tower
916km/h
Object velocity
(for alt=10km)
Past Trajectory (fit)
Detection (past)
E
N
Gemini dome


20090120
22:00:00
1
2
1268km/h
3
E
N

# All loops closed in the lab



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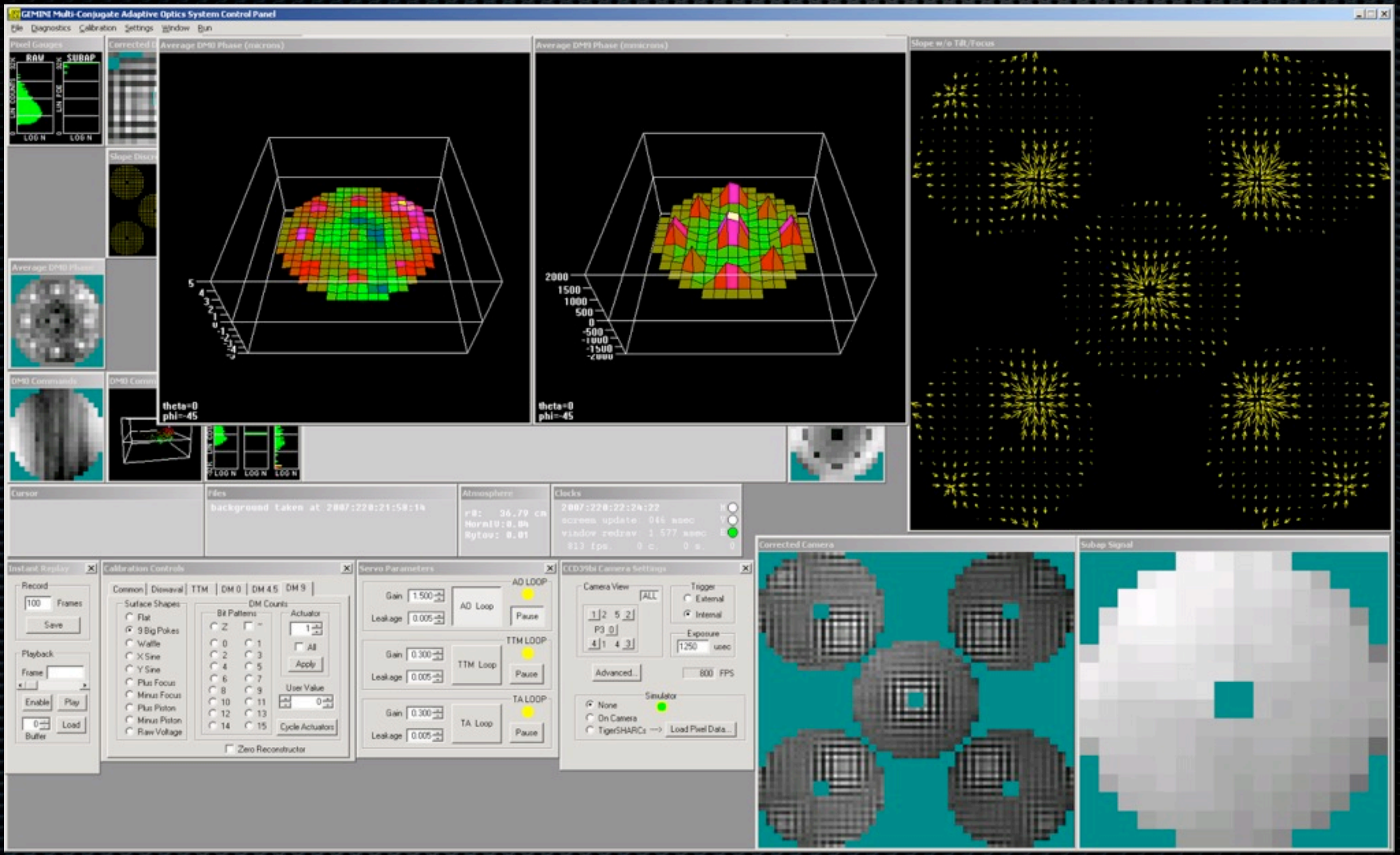

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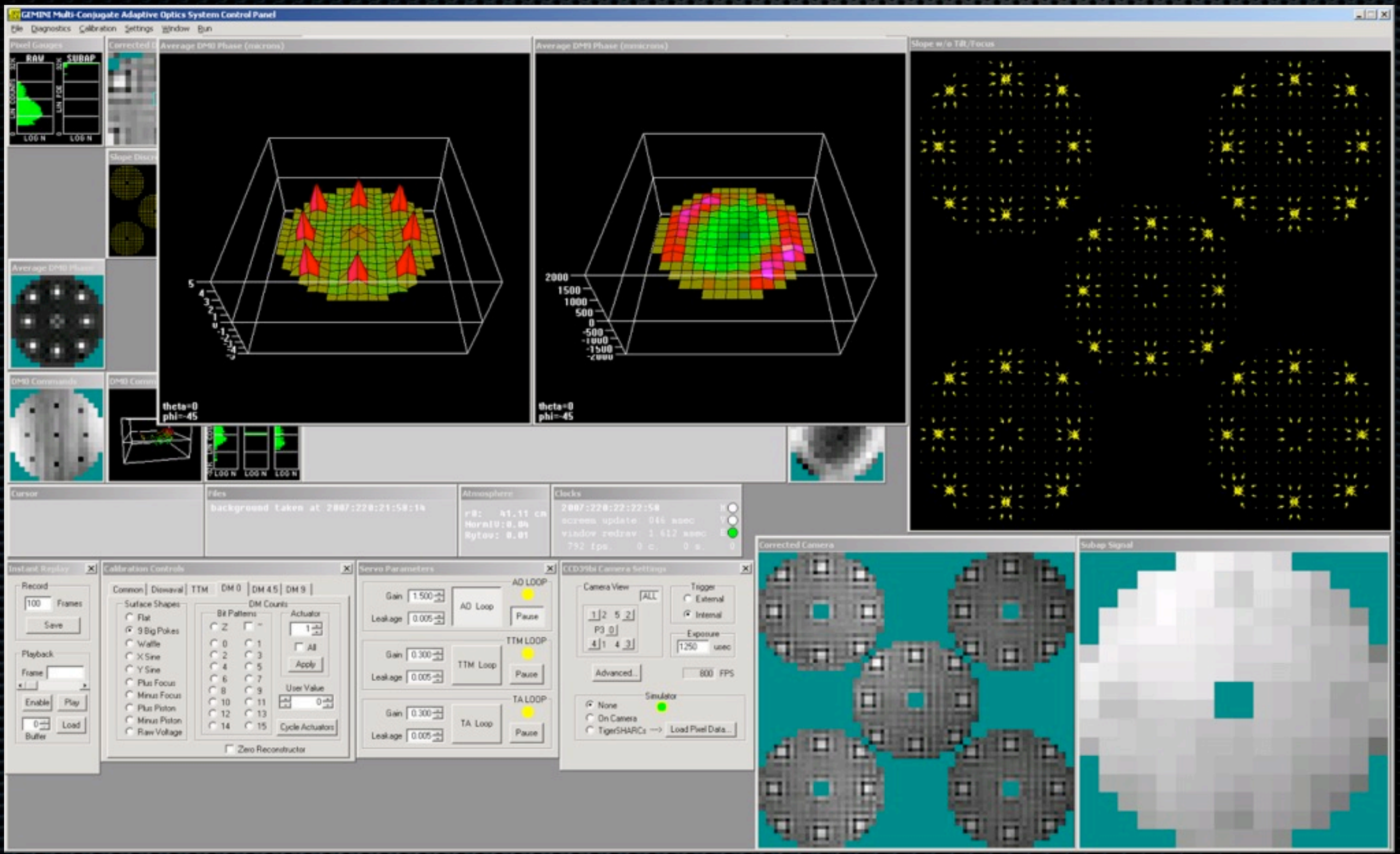

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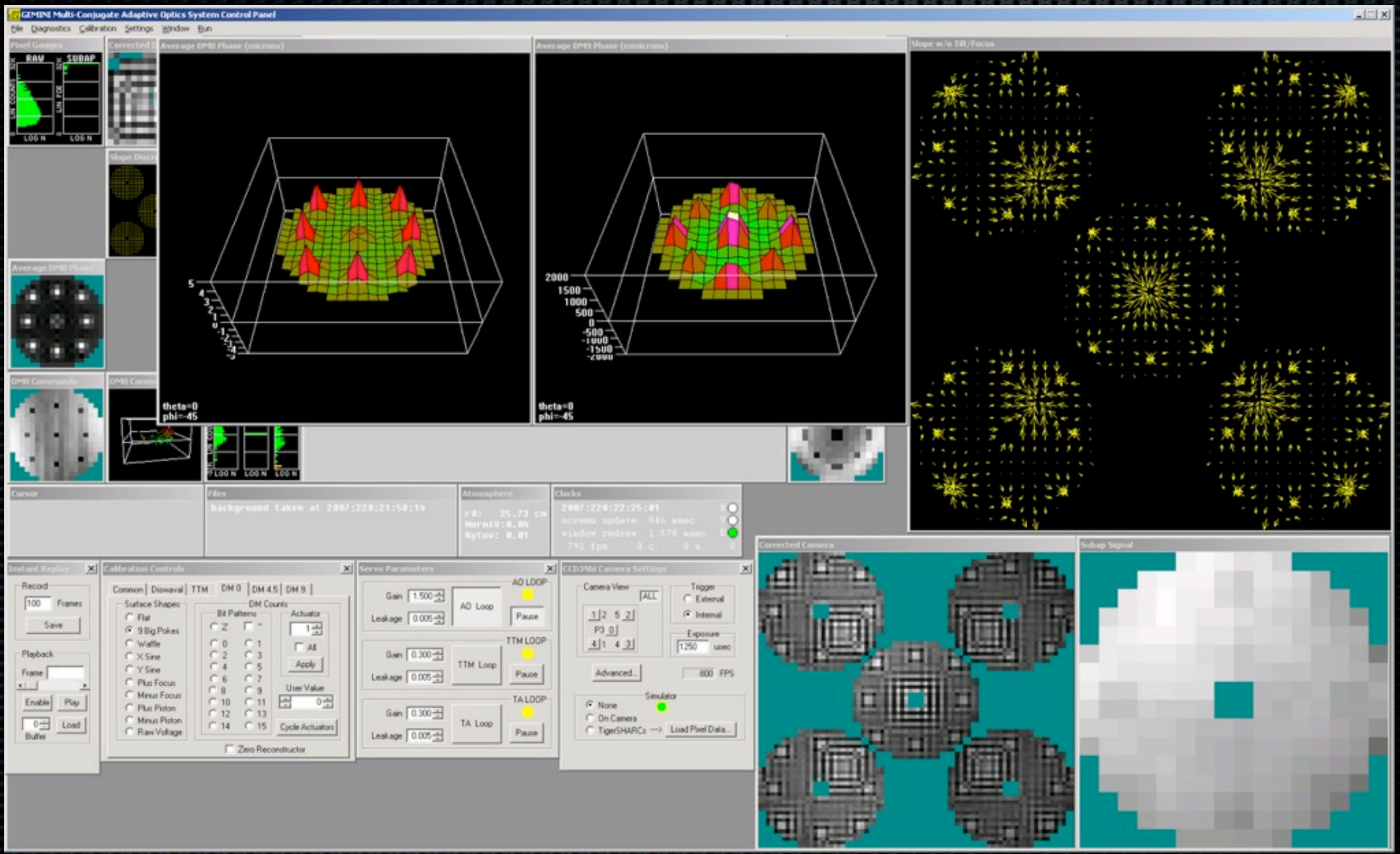

# GeMS Status

- Laser:
  - Keck laser going through AT as we speak (delivers 40W, 20W spec)
  - but, LMCT short in resources to finish laser (fuzzy)
  - Planned delivery date: August 2009
- CANOPUS:
  - Going through I&T in the Gemini SBF lab
  - No major performance issue to date
  - Big software integration/automation/optimization effort
  - Remaining issues: Cooling redesign, electronic integration, TTWFS throughput
- Other subsystems (BTO/LLT/Infrastructure/Safety) proceeding well
- First light 2010A