Gemini AO Workshop, Victoria, 19-21 June, 2012

New tecnologies for AO systems: adaptive secondaries and pyramid sensors.

A resume of existing AO systems using adaptive secondary mirrors and pyramid sensor discussing their performance, calibration and first scientific results.

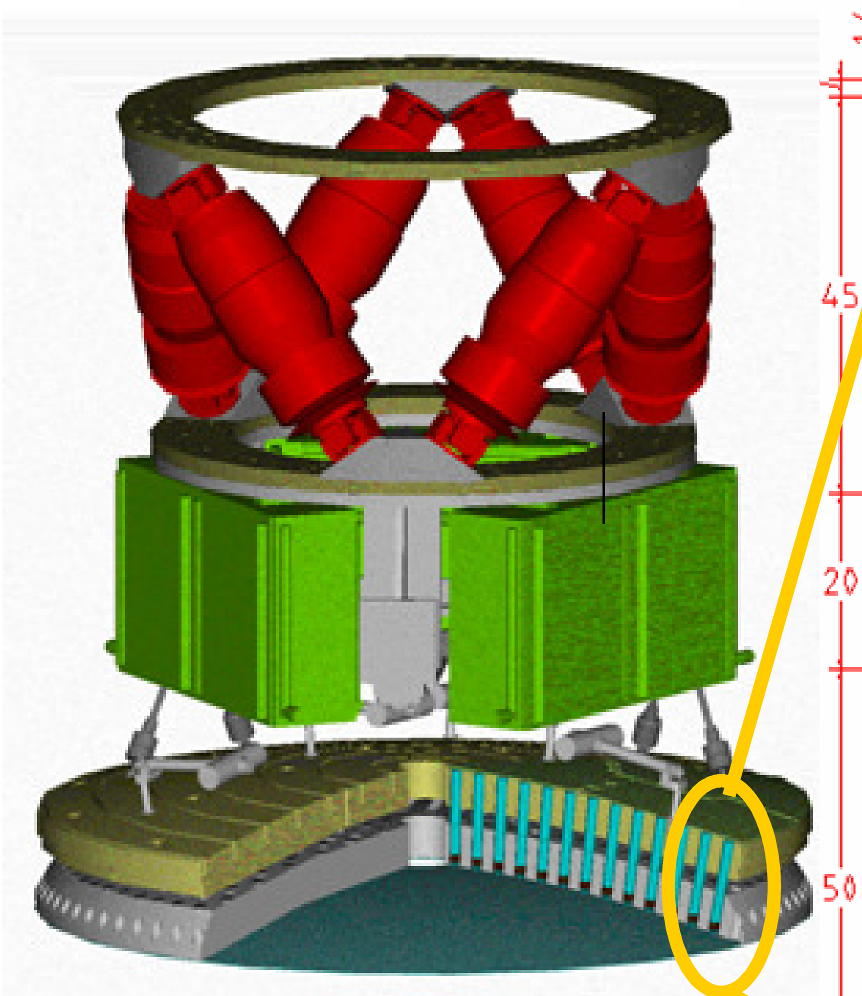
Presented by: **S. Esposito**

Talk overview

- Rationale for AdSEc and pyramids
- A short review of existing system: test, performance and calibration
- First scientific results

Talk material from Arcetri, LBTO, UoA, MPE. Thanks due to M. Hart, P. Hinz, S. Rabien, L. Close for material provided.

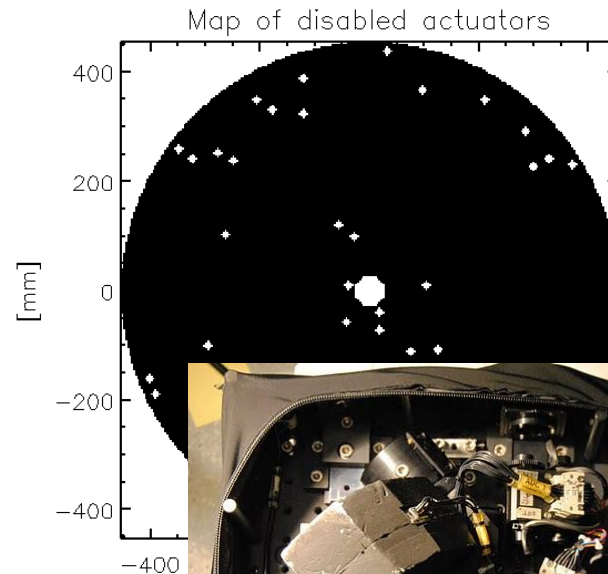
The LBT AdSec (672 acts)

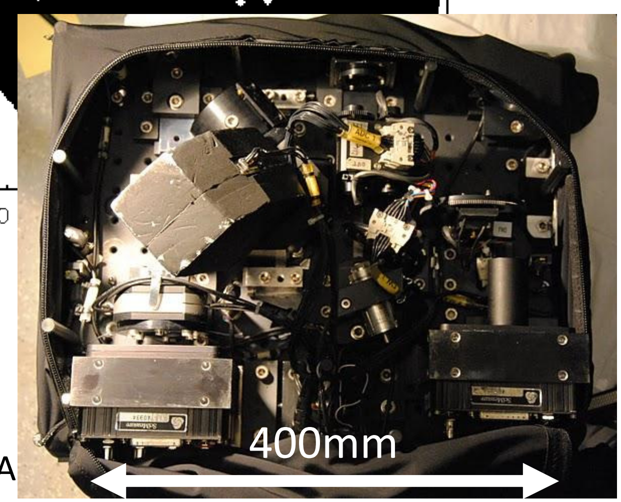


- 911mm diam., 1.6mm thickness
- 672 acts.
- Settling time < 1ms

Rationale for AdSec mirrors

- ✓ A single DM for multiple focal stations
- ✓ Fewer reflecting surfaces (exp. for GLAO)
  - ✓ more throughput
  - ✓ less emissivity
- ✓ Allows for high number of actuators (672LBT, 1170VLT)
- ✓ Minimal sensitivity to failed actuators
- ✓ Simplifies the optical design of AO system

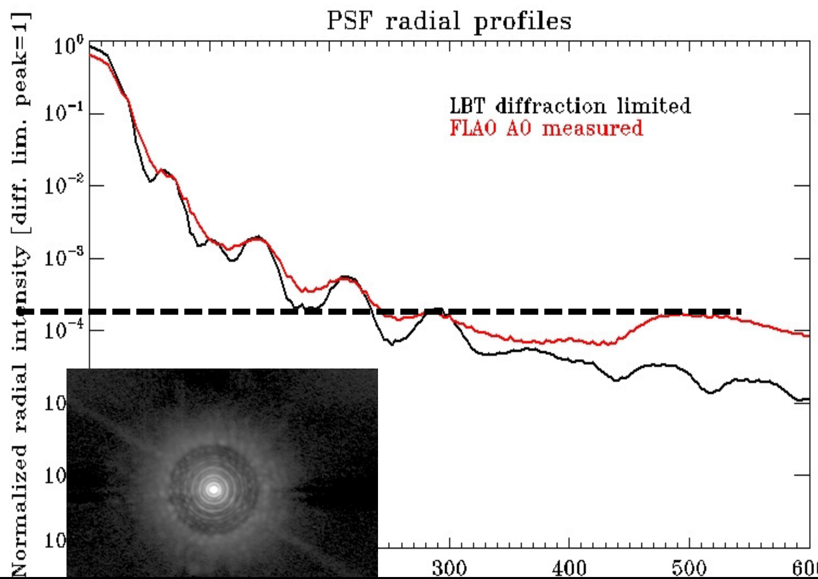




Gemini A

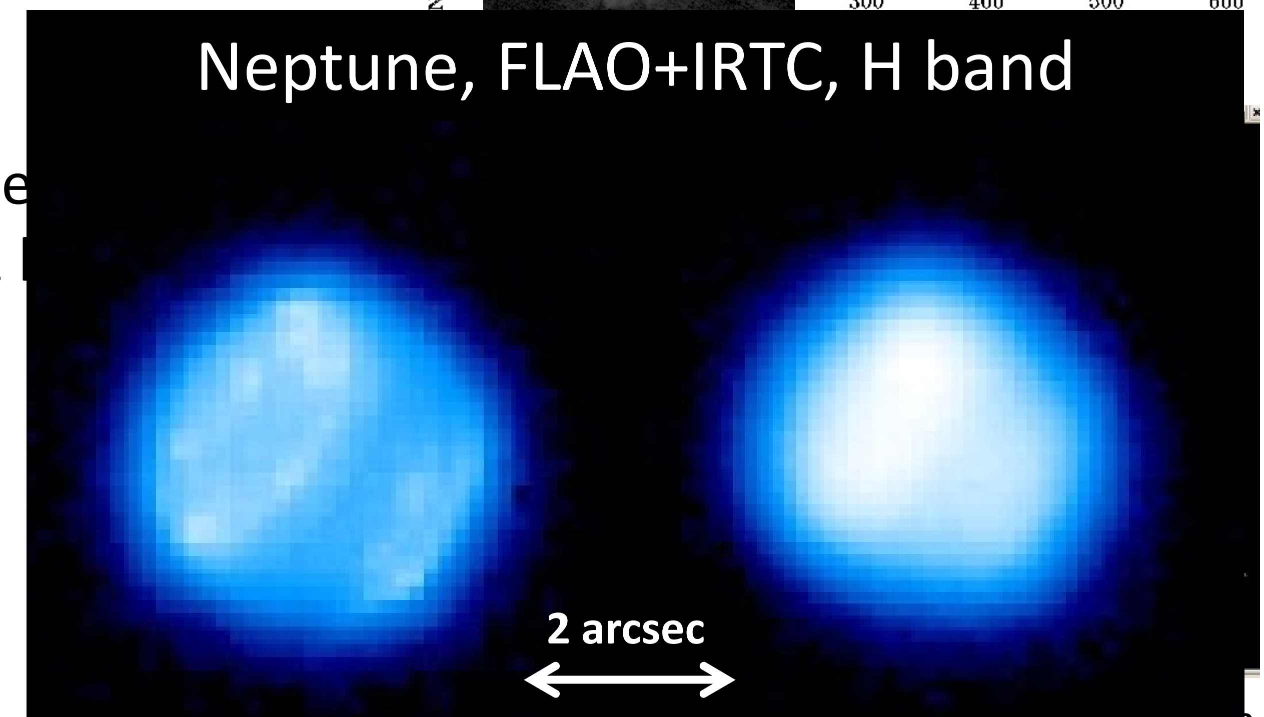
Rationale for Pyramid sensors

- ✓ Less affected by aliasing in bright end of SH (high SR>90 Hband, high contrast>10^4 H band)



- ✓ Better performance
  end of SH (FLAO#1
  mag around 17)

Able to close loop with extended object



Systems using AdSec/Pyramid:

GLAO:

- MMT(Cass.) (5LGS),
- LBT(Greg.) (3LGS), ARGOS
- VLT-AOF(Cass.) (4LGS), GALACSI, GRAAL

SCAO/XAO (NGS):

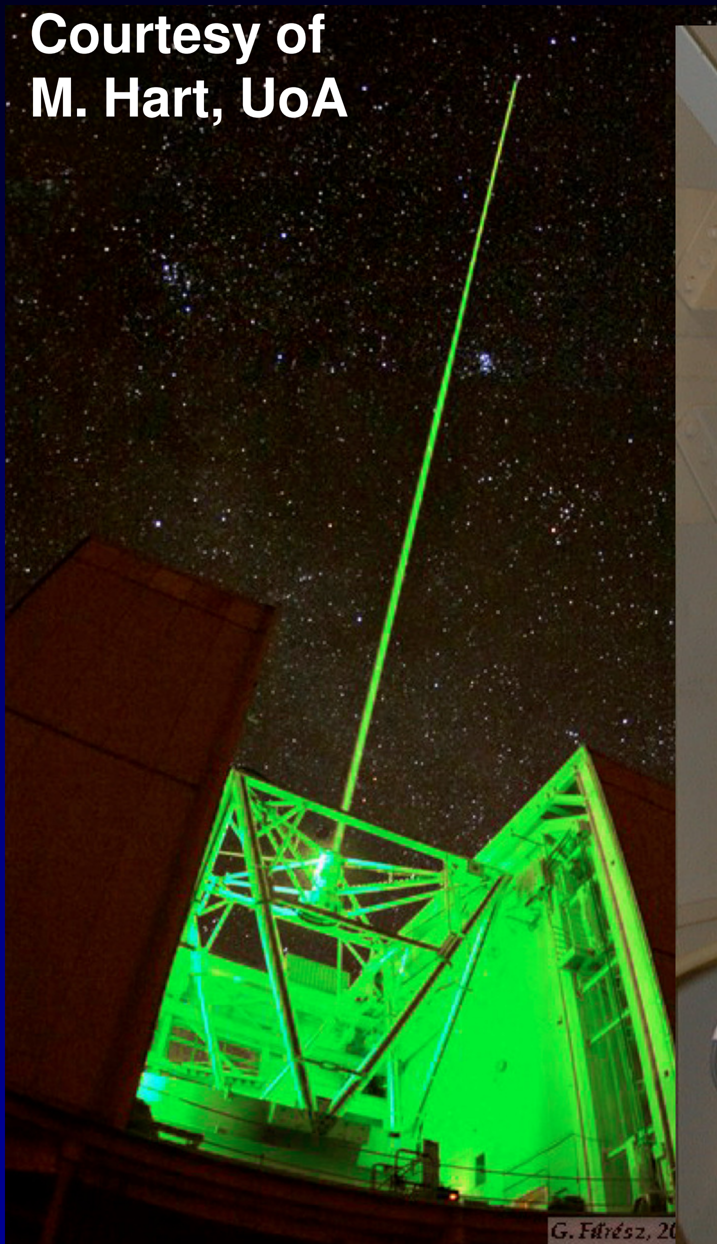
- LBT FLAO#1 & FLAO#2, 1-2.2 um
  LBTI AO, 2-10 um
- Magellan(Greg.) VisAO, 0.6-5um
- VLT-AOF : ERIS 1-5 um

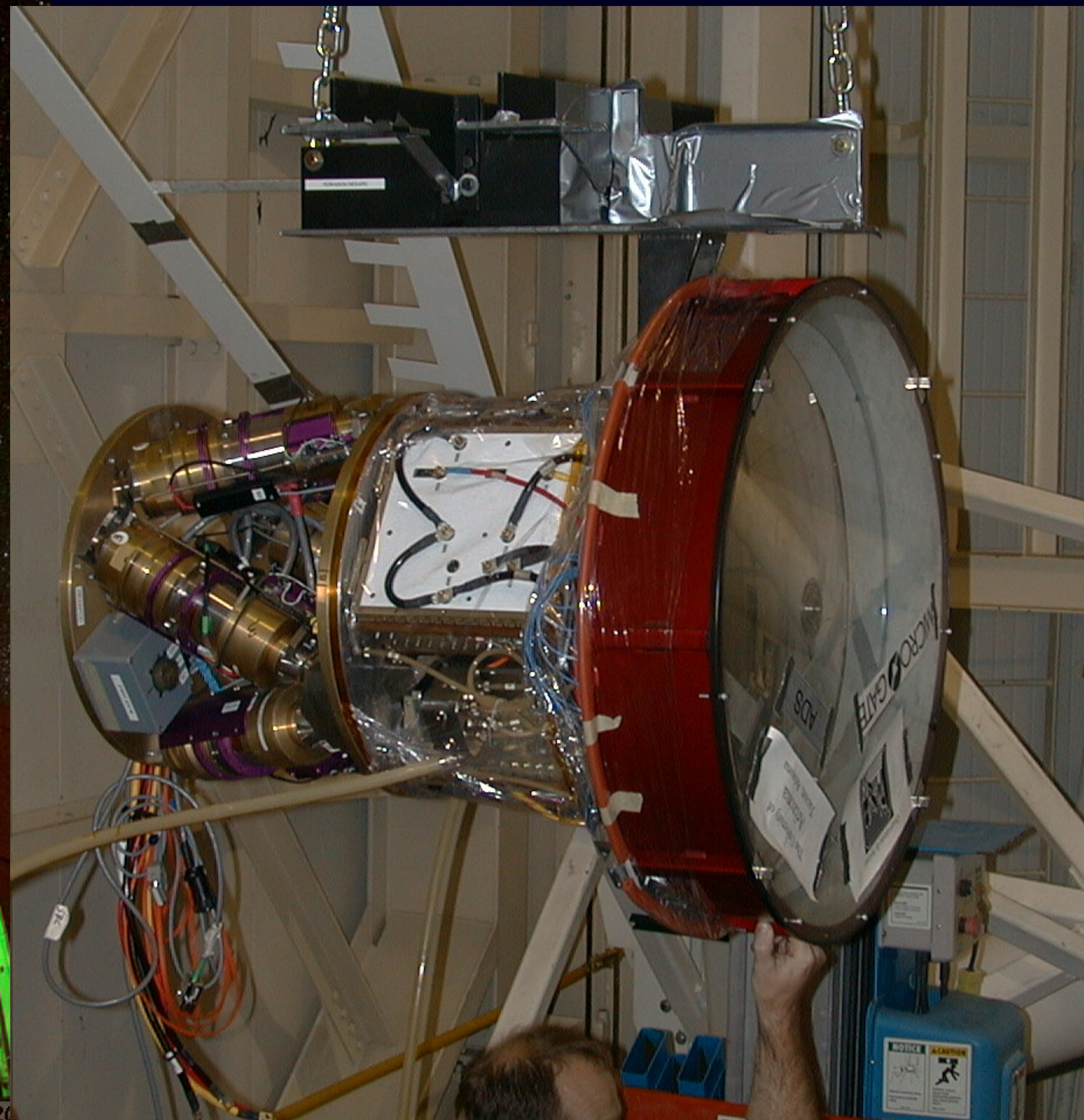
CAAO Center for Astronomical Adaptive Optics

Laser-guided GLAO at the MMT

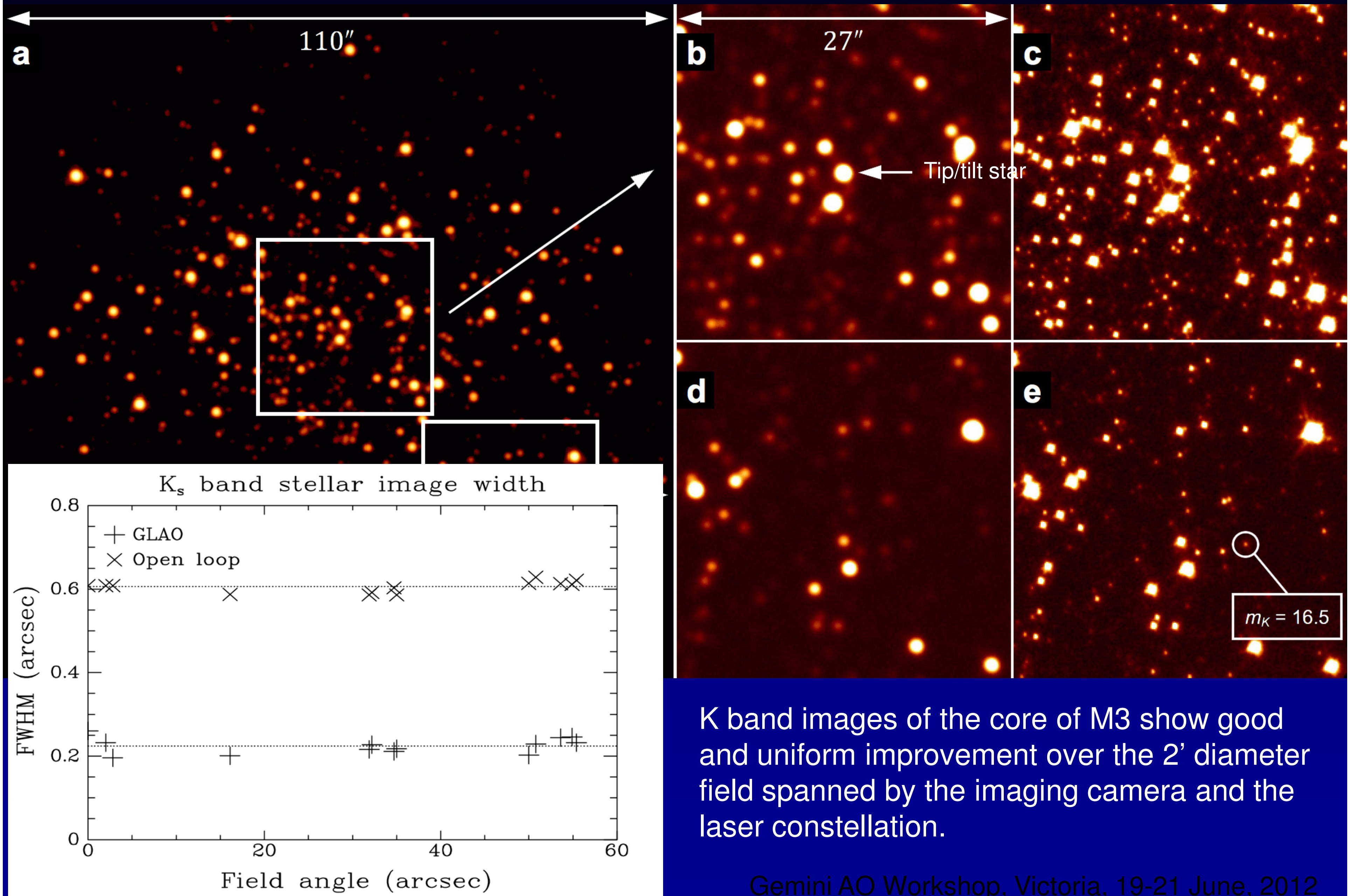
The University of Arizona
Tucson Arizona

Courtesy of M. Hart, UoA



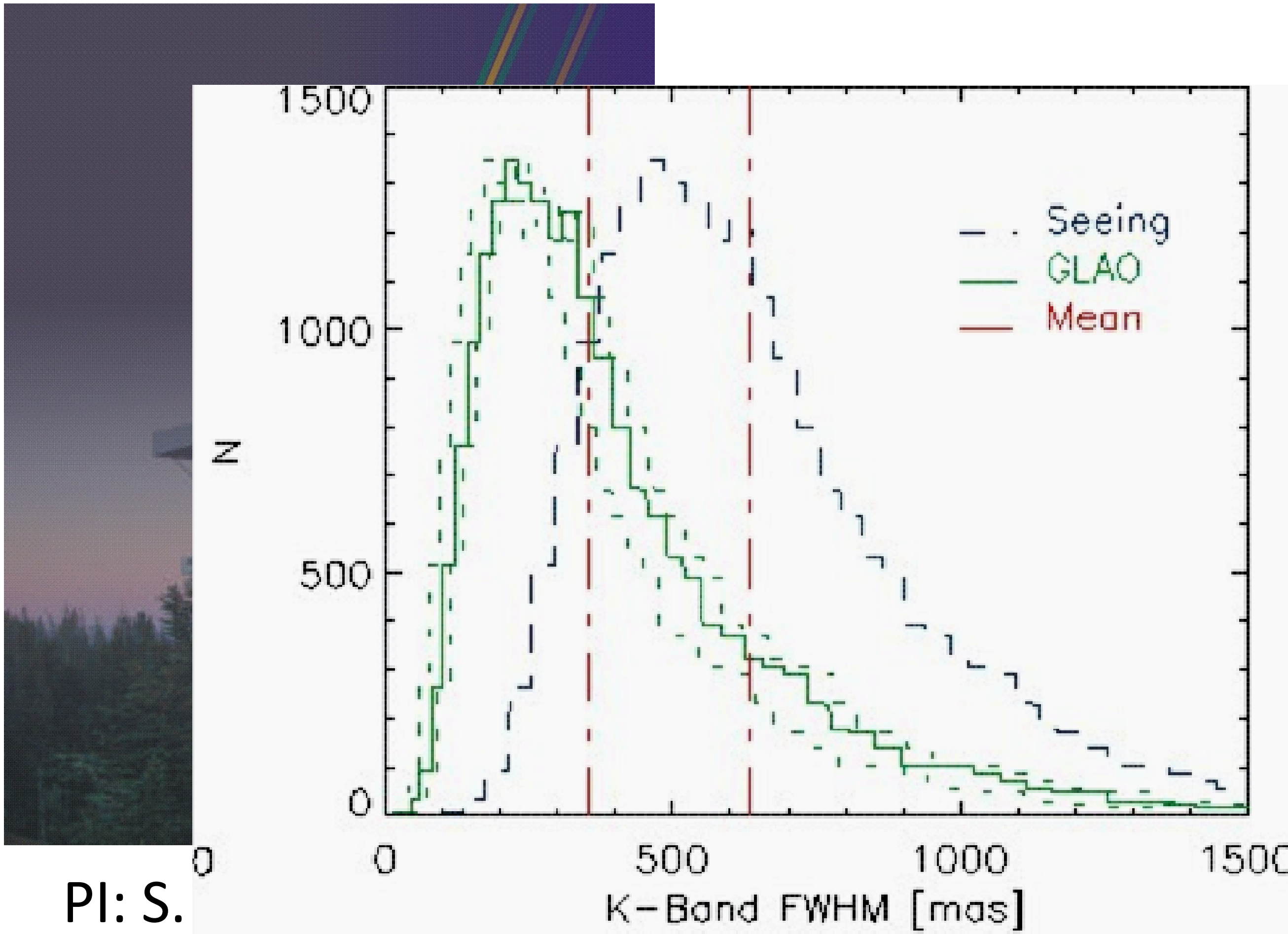


Performance across the field



K band images of the core of M3 show good and uniform improvement over the 2' diameter field spanned by the imaging camera and the laser constellation.

ARGOS: LBT GLAO system



Garching
Heidelberg
Firenze
, Bonn
rsity of Arizona,
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tsdam
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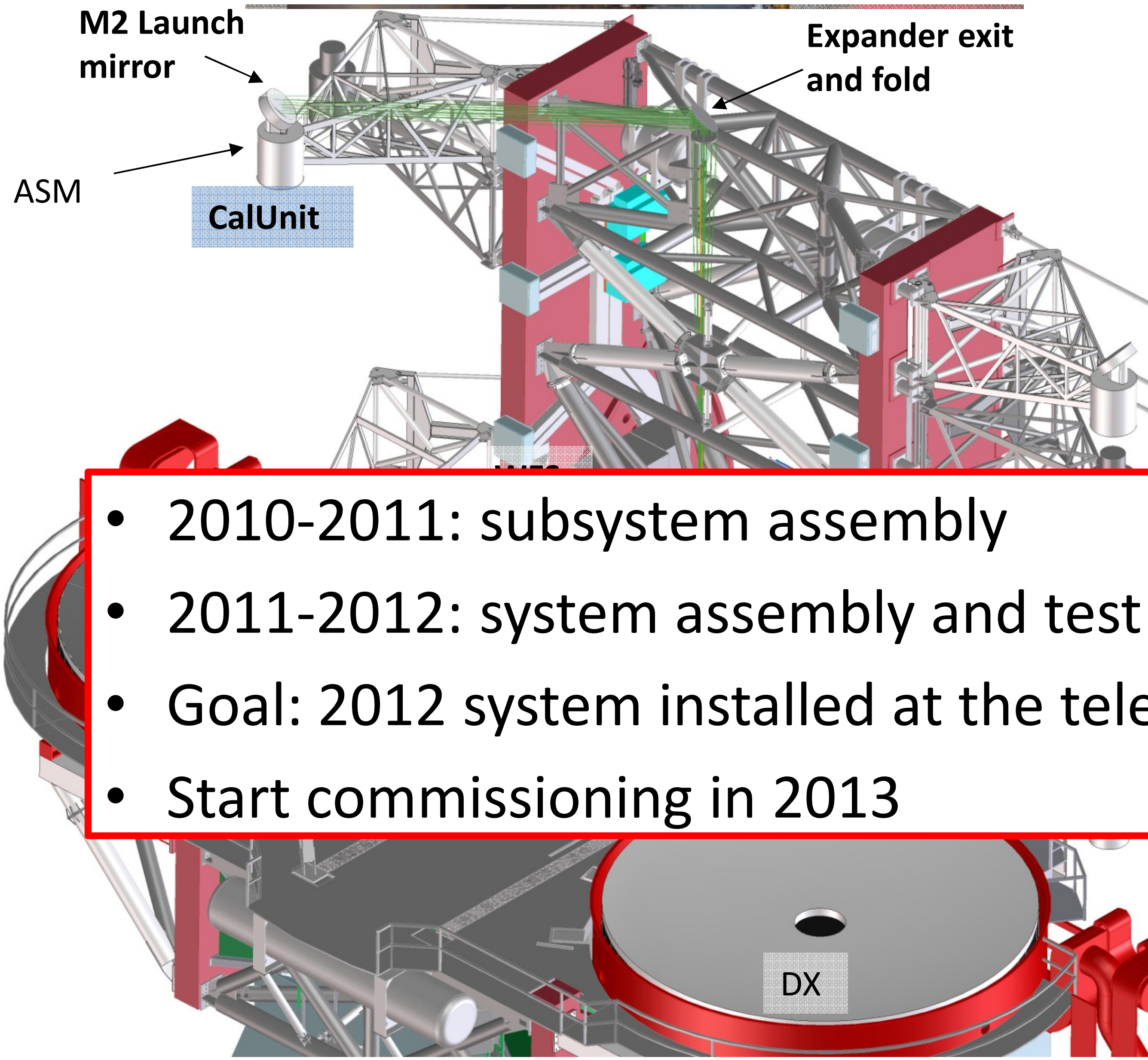
Tucson
NSensor

PI: S.

L. Barl, U. Beckmann, T. Blümchen, M. Bonaglia, J. L. Borelli, J. Brynnel, L. Busoni, L. Carbonaro, C. Conot, R. Davies, M. Deysenroth, O. Durney, M. Elberich, S. Esposito, V. Gasho, W. Gässler, H. Gemperlein, R. Genzel, R. Green, M. Haug, M. Lloyd Hart, P. Hubbard, S. Kanneganti, M. Kulas, E. Masciadri, J. Noenickx, G. Orban de Xivry, D. Peter, A. Quirrenbach, M. Rademacher, H. W. Rix, P. Salinari, C. Schwab, J. Storm, L. Strüder, M. Thiel, G. Weigelt, J. Ziegleder

Courtesy of S. Rabien, MPE

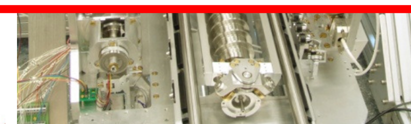
LUCI and GLAO mode



FER:

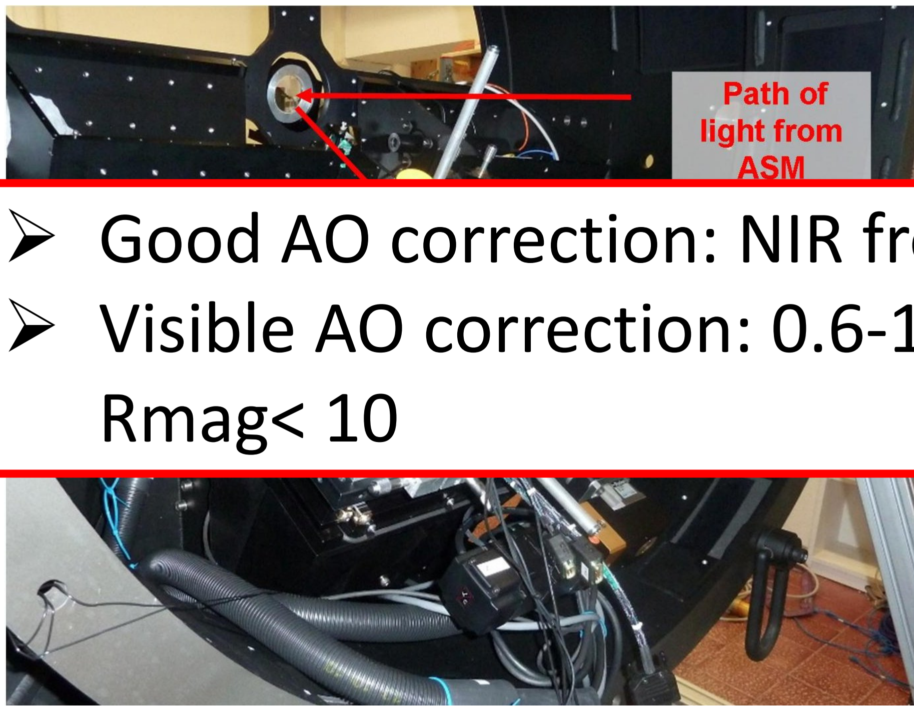
I,K bands
field and DL cameras
Imaging FOV
MOS FOV
exchangable Masks
Slits

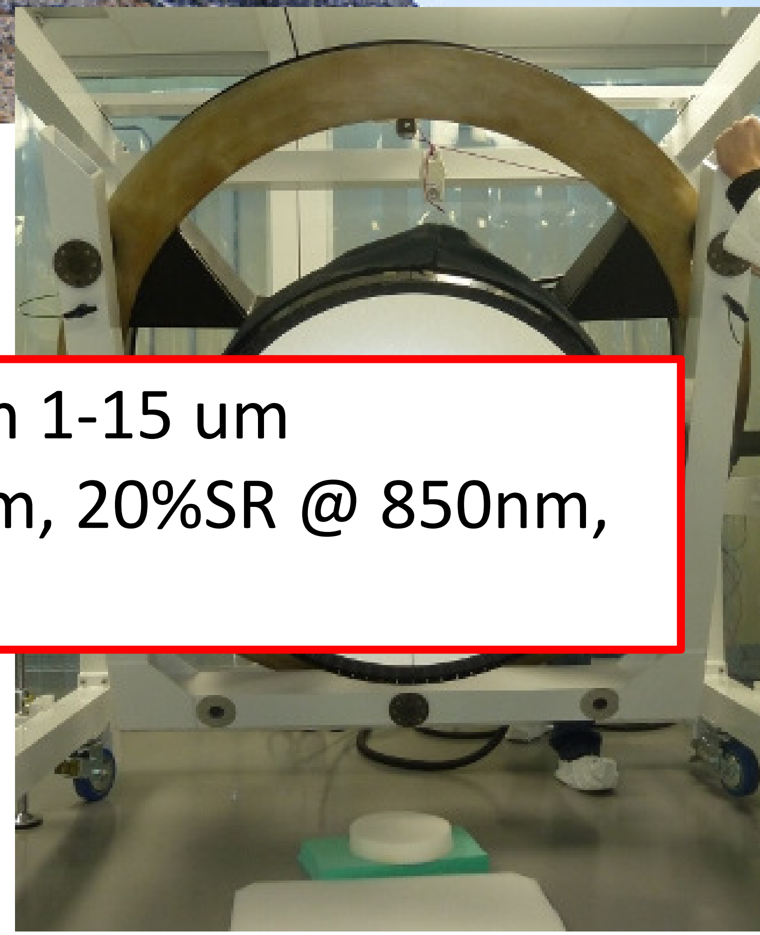
- 2010-2011: subsystem assembly
- 2011-2012: system assembly and test in Europe
- Goal: 2012 system installed at the telescope
- Start commissioning in 2013



MagAO system

The 6.5m twin telescopes close to La Serena, Chile.



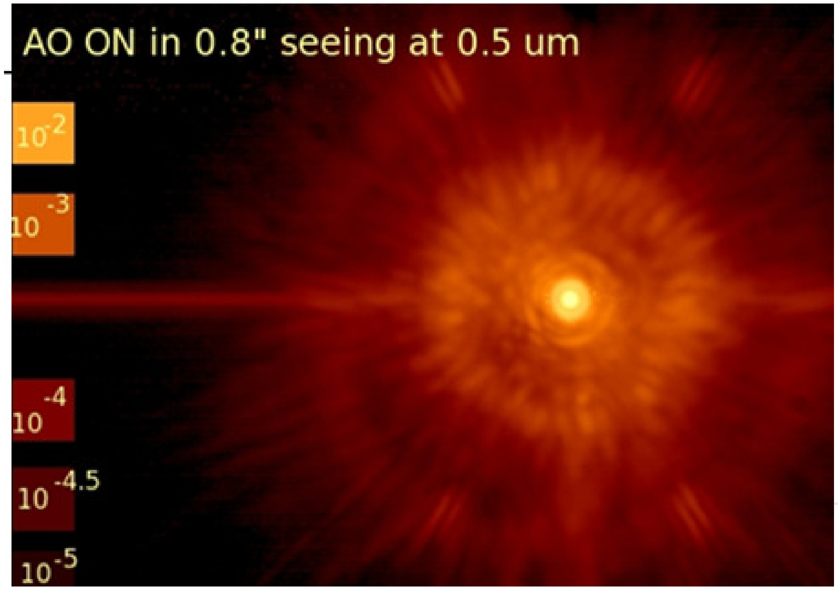


- ➢ Good AO correction: NIR from 1-15 um
- ➢ Visible AO correction: 0.6-1um, 20%SR @ 850nm, Rmag< 10

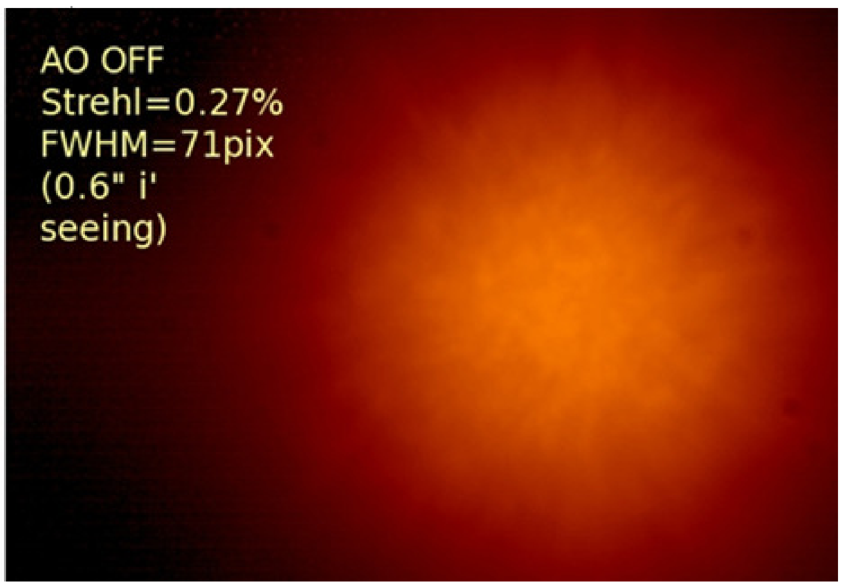
The NAS unit including the pyramid sensor and the visible camera

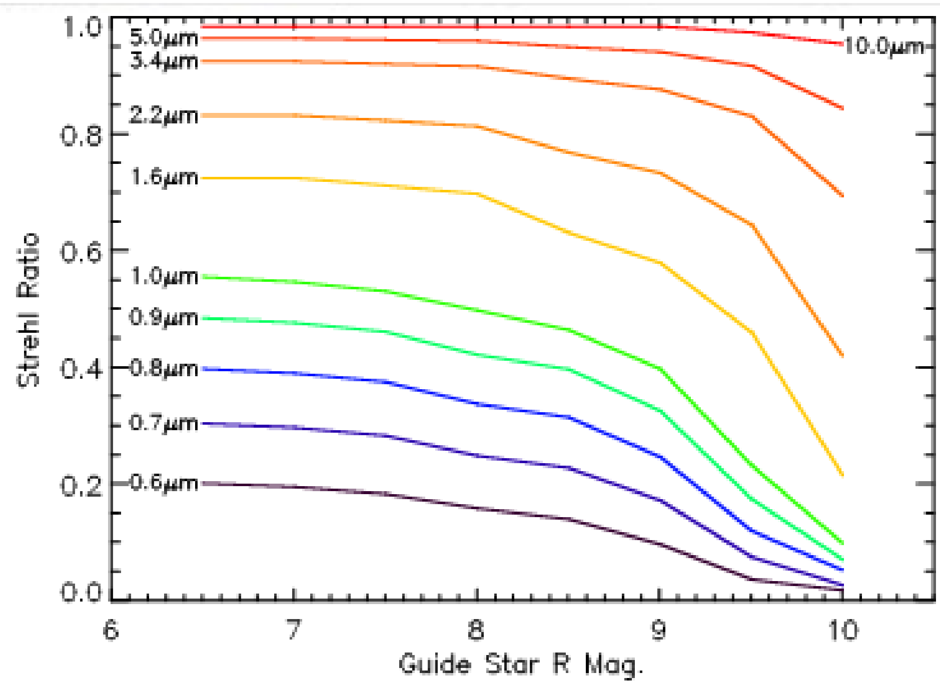
The Magellan AdSec unit (585 acts) received in Chile

MagAO in solar Tower

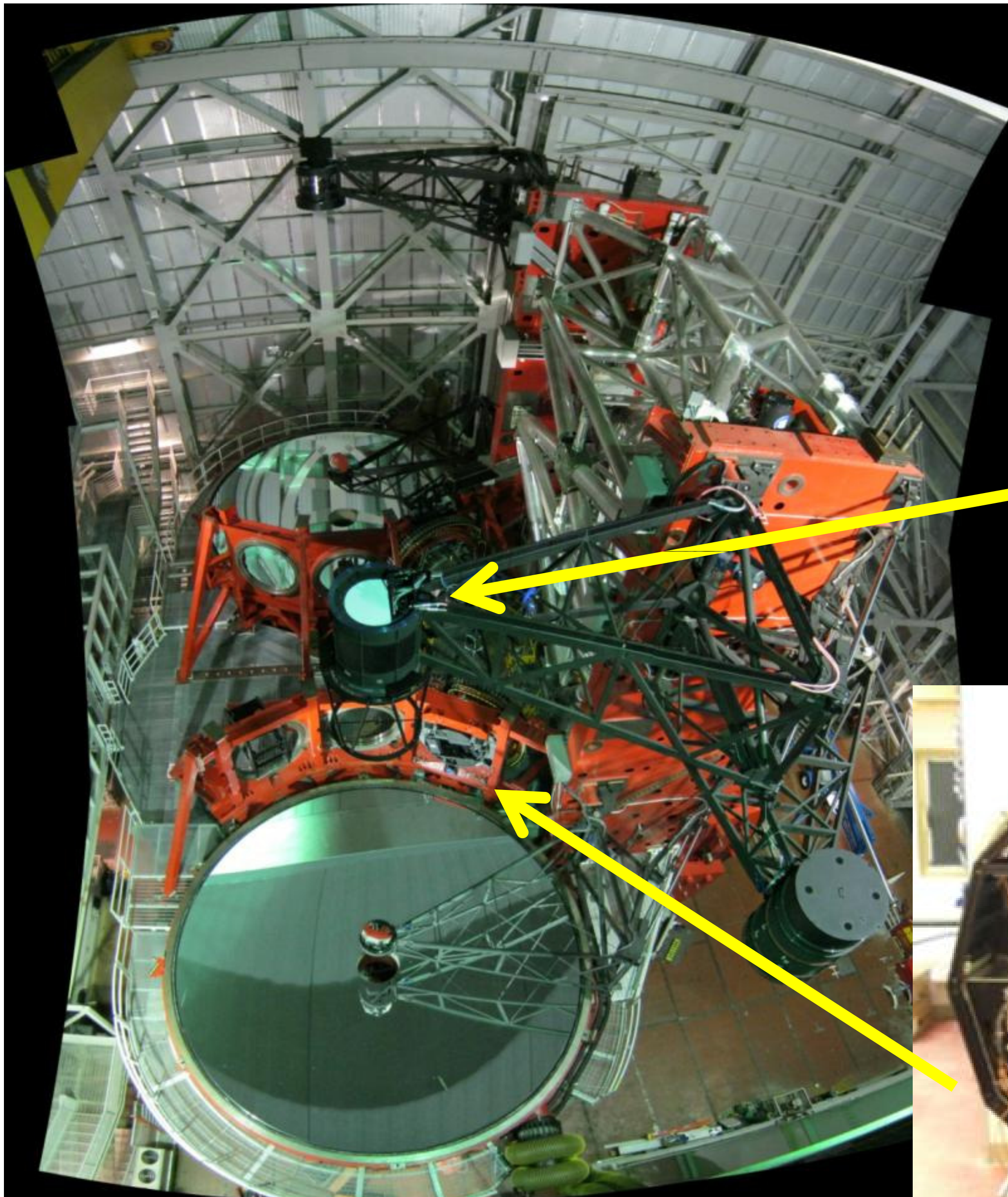


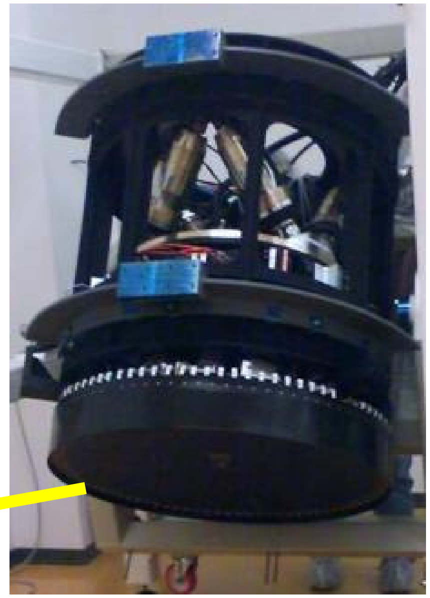
Images at 750nm taken with MagAo visible camera.
--400 modes
--800Hz
--SR=55%
--0.8 arcsec seeing (V band)





The LBT FLAOs systems

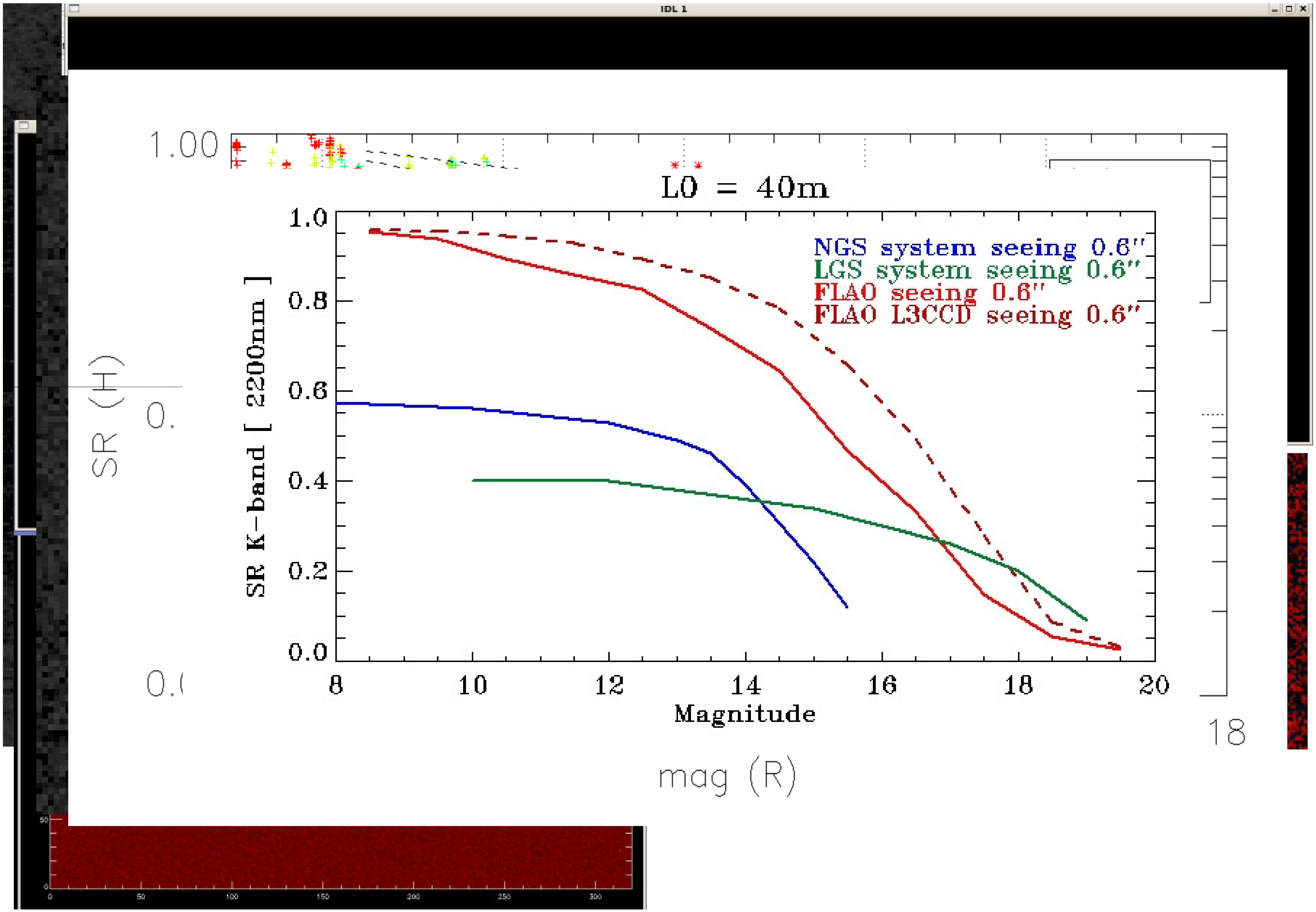




The adaptive secondary mirror with the thin shell covered

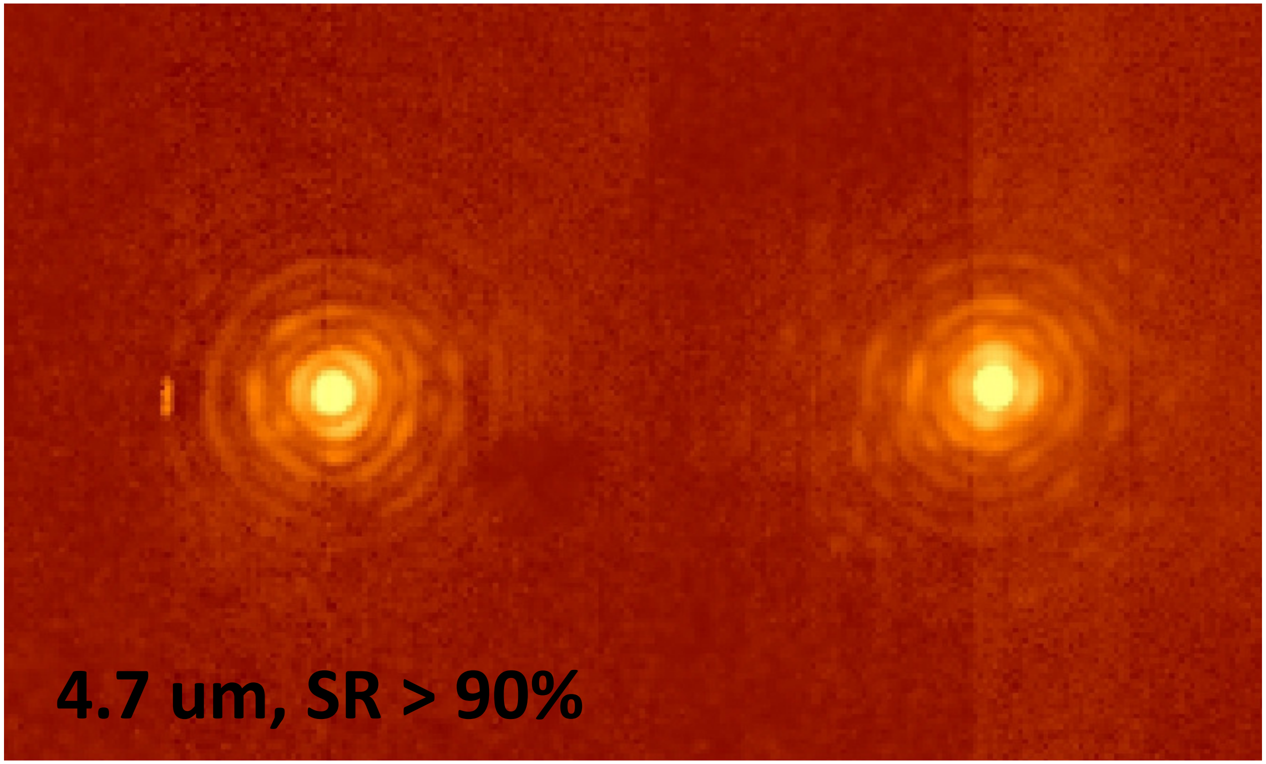
The Pyramid wavefront sensor in the AGW unit

FLAO#1, #2 results from commissioning



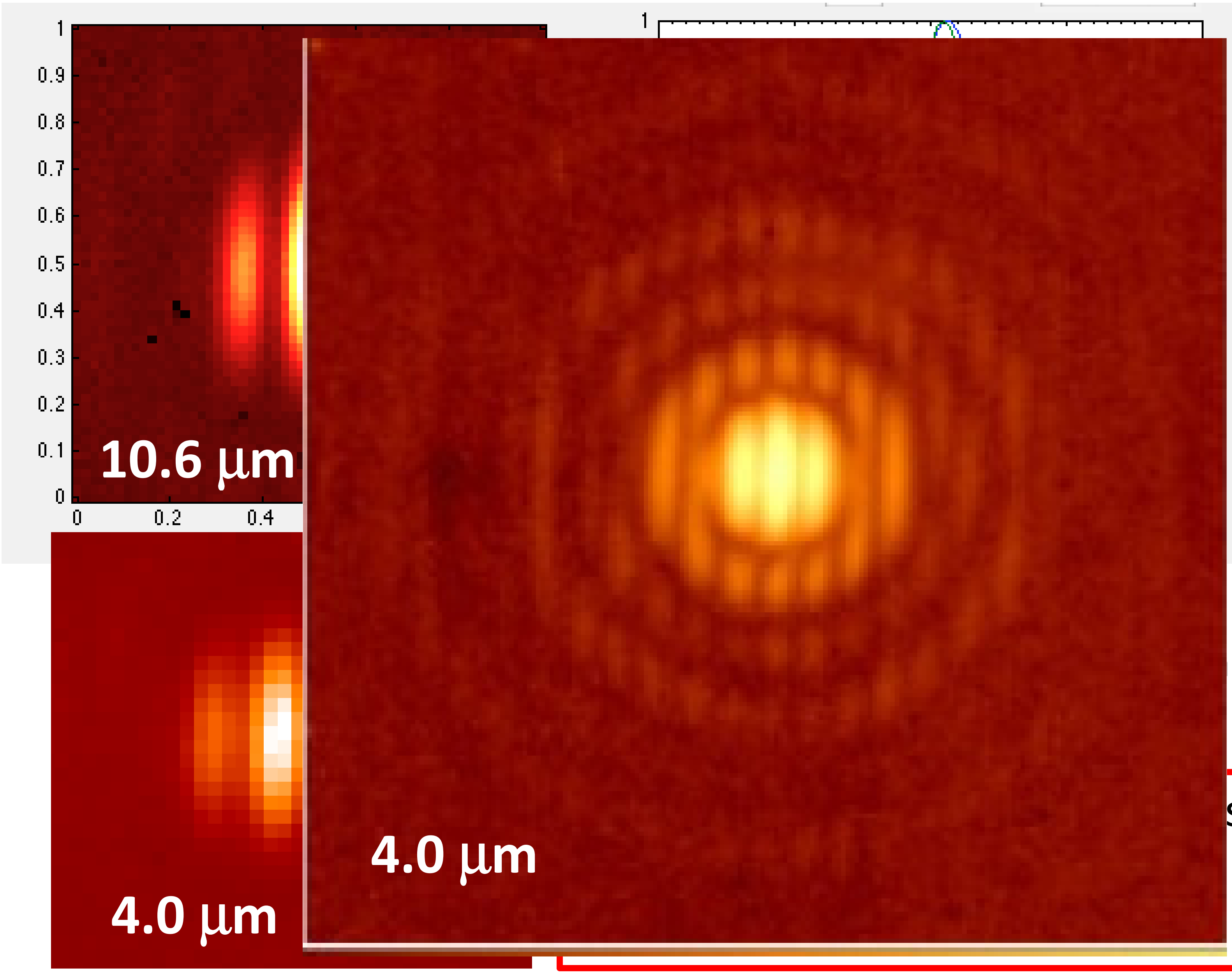
LBTI commissioning: AO in the thermal IR 3-20 um

- AO tests started in May 2011 up to now. Achieved 95% Strehl at M (4.7um)
- Very stable PSF allows subtraction to the background limit outside of 0.3 arcsec.



The two AO loops of LBTI system simultaneously closed at the LBT, 4.7um

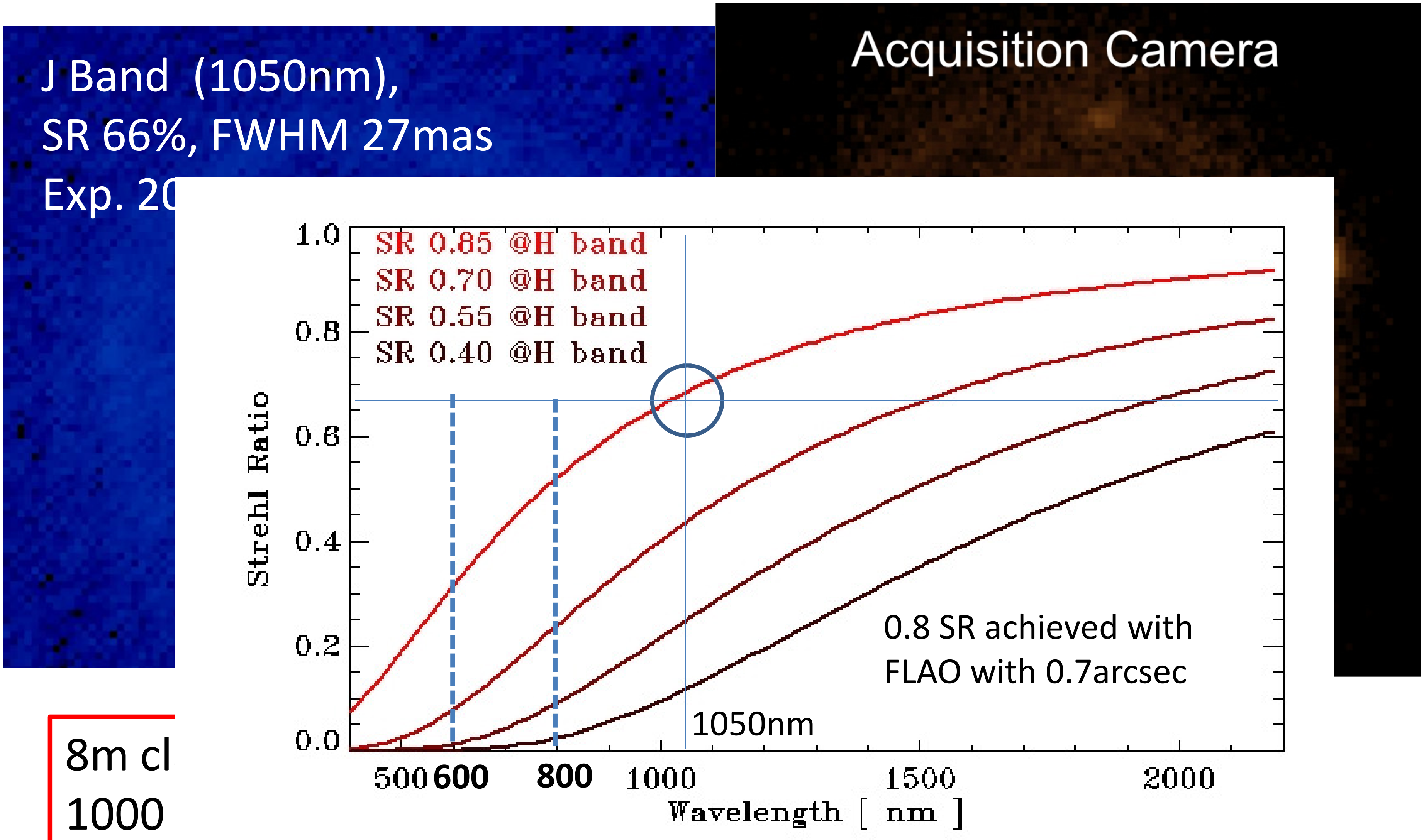
LBTI: AO correction & LBT fringes



nd

scope
igh SR

AO at shorter wavelengths... FLAO#1&2



8m cl
1000
secondary able to achieve
resolution of 15mas at 0.6um.

Exp. 20s

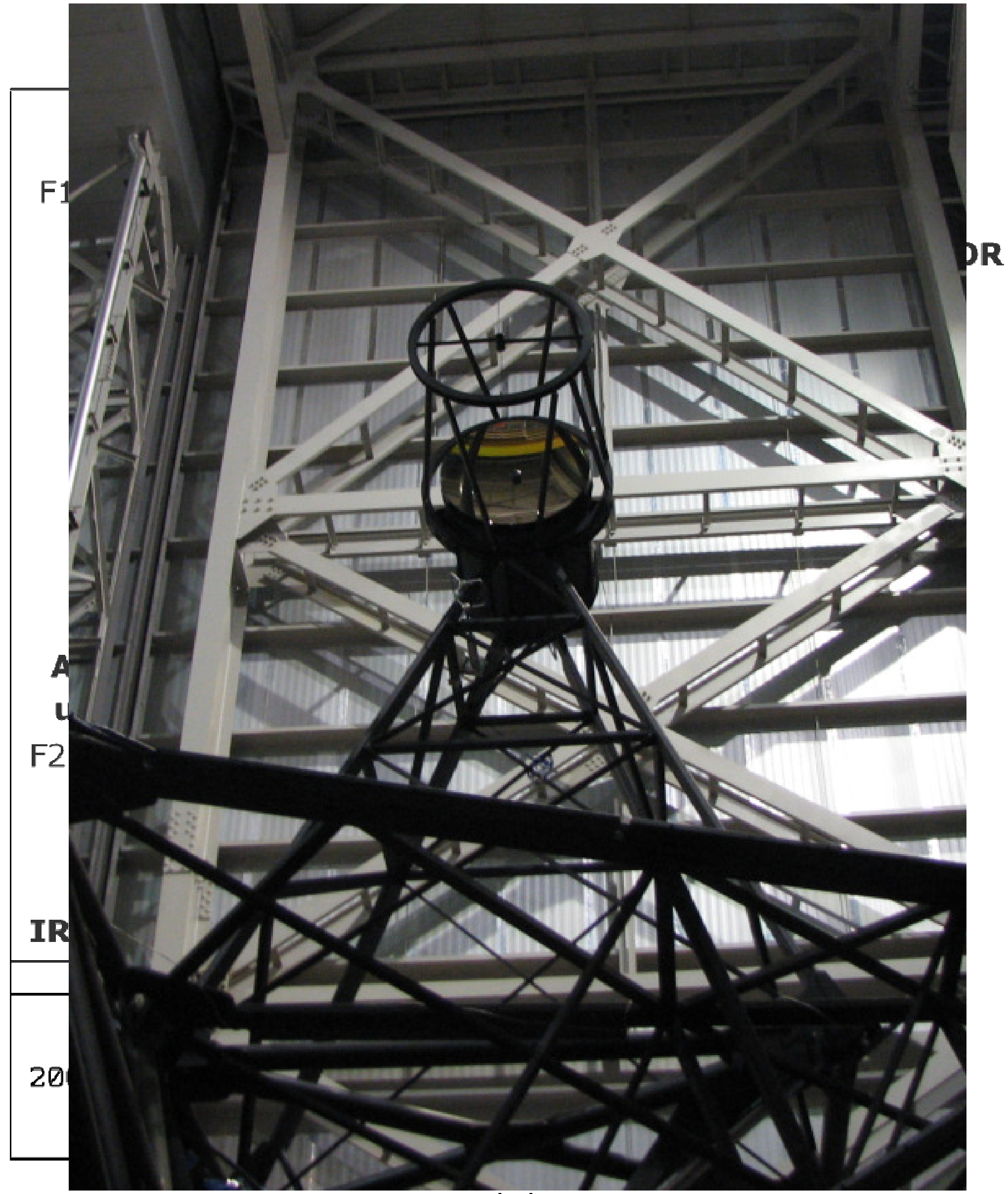
AO System calibration

For Gregorian telescopes calibration of AdSec based AO system is doable with external fibers and reflecting optics (single or double pass)

For Cassegrain telescopes more complicated systems required:
MMT Scimulator.
VLT DSM assist

Alternative approches to AO calibration:

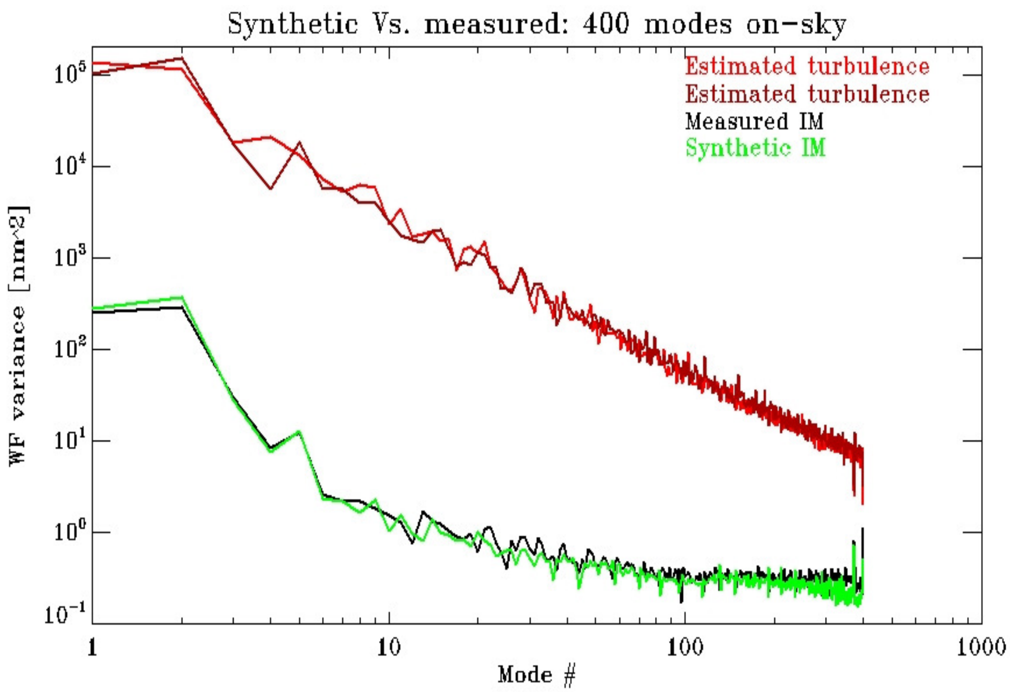
- Syntetic Interaction Matrix
- On sky acquired Interactin Matrix

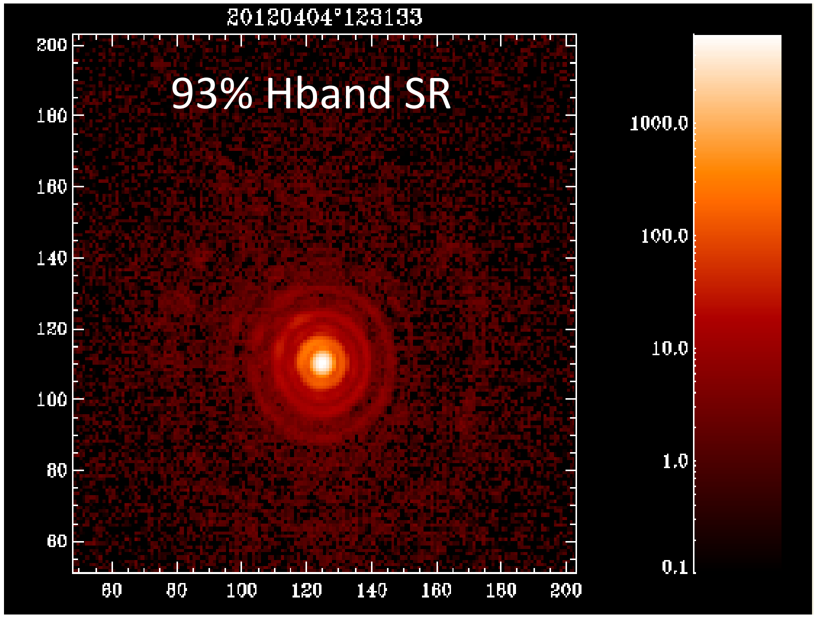


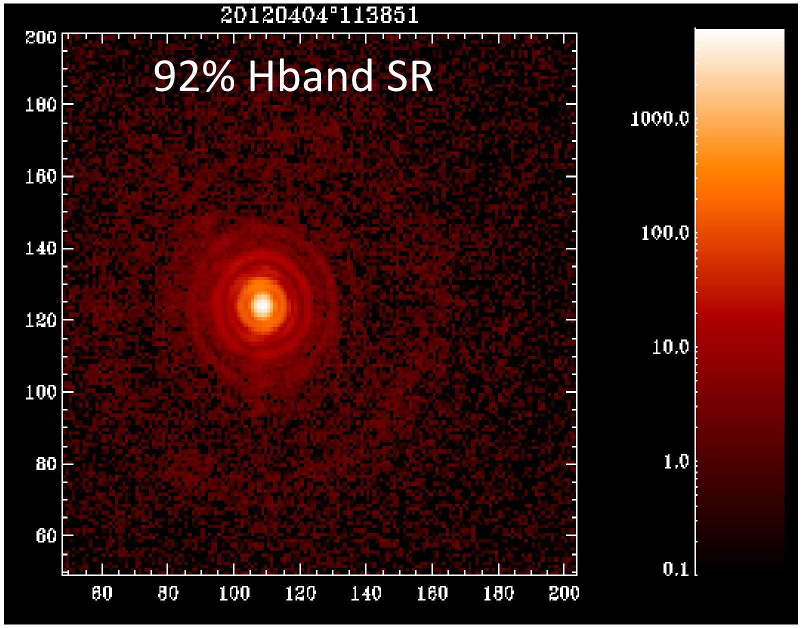
Synthetic IM on sky test

- Reference star mag 8.0
- 400 modes
- 1kHz
- 0.7 arcsec seeing

Modal residual for the two cases



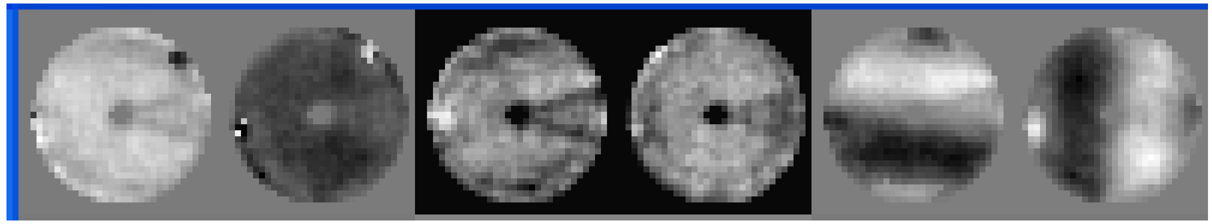


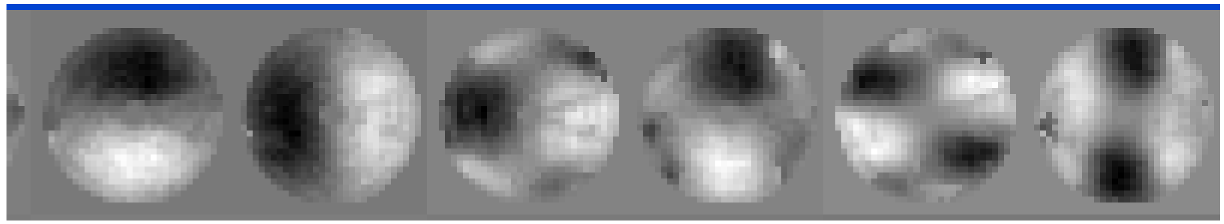


On sky measured IM test results

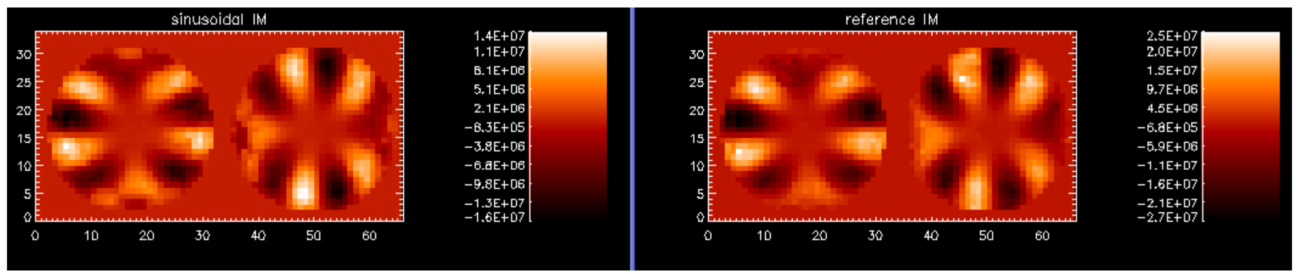
Take into account :

- spiders obstructions
- real pupil
- reflectivity
- precise registration actuators/subaps for HO modes

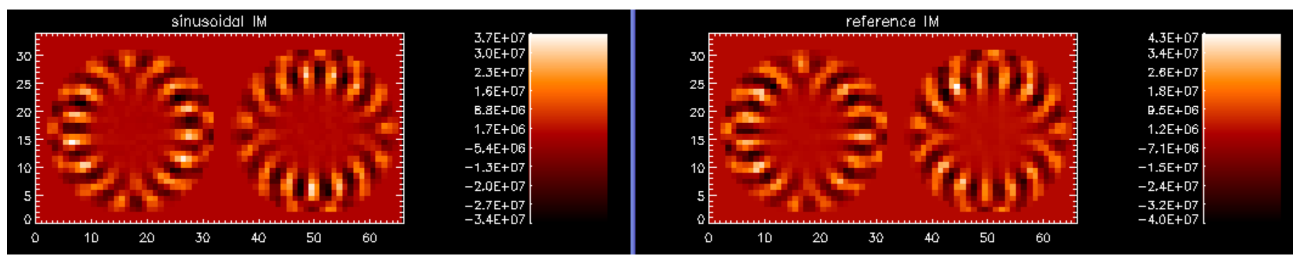




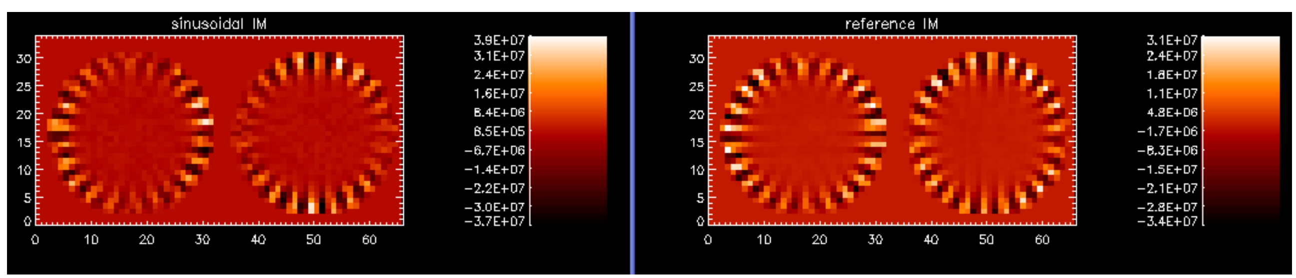
m20



m120

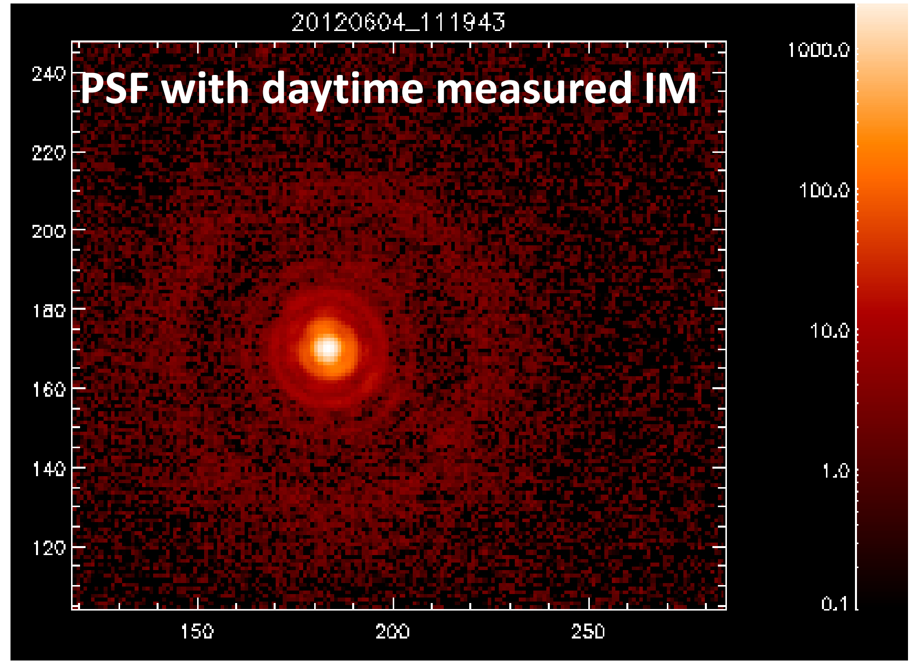


m194

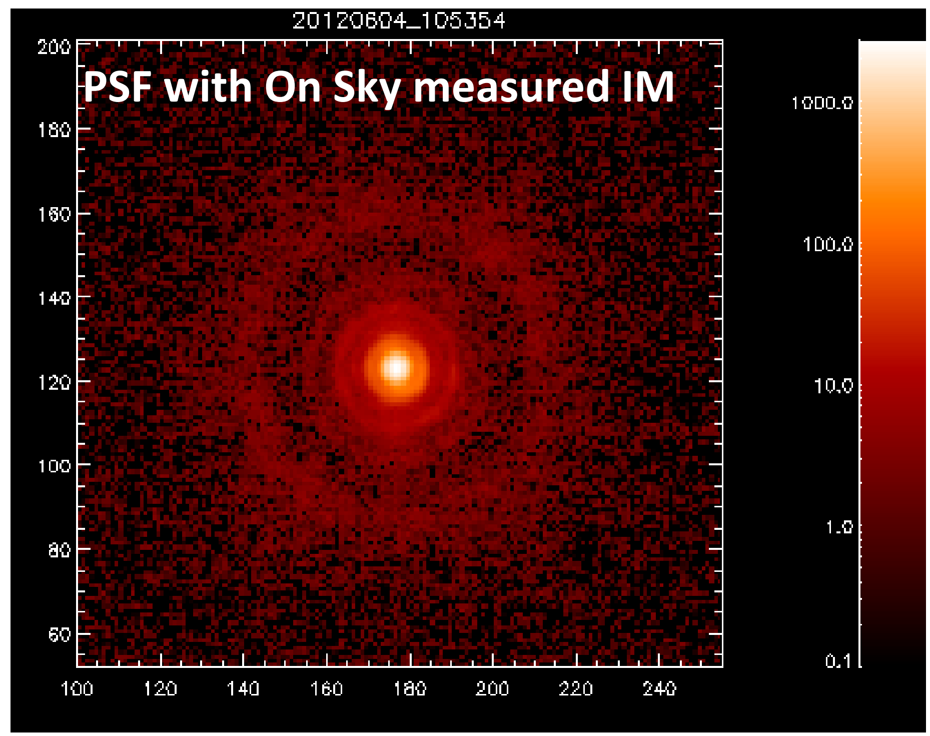


On sky test II

H band PSF (SR = 74%) obtained controlling 250 modes IM measured in daytime.



H band PSF (SR = 68%) obtained controlling 200 modes with IM measured on sky.

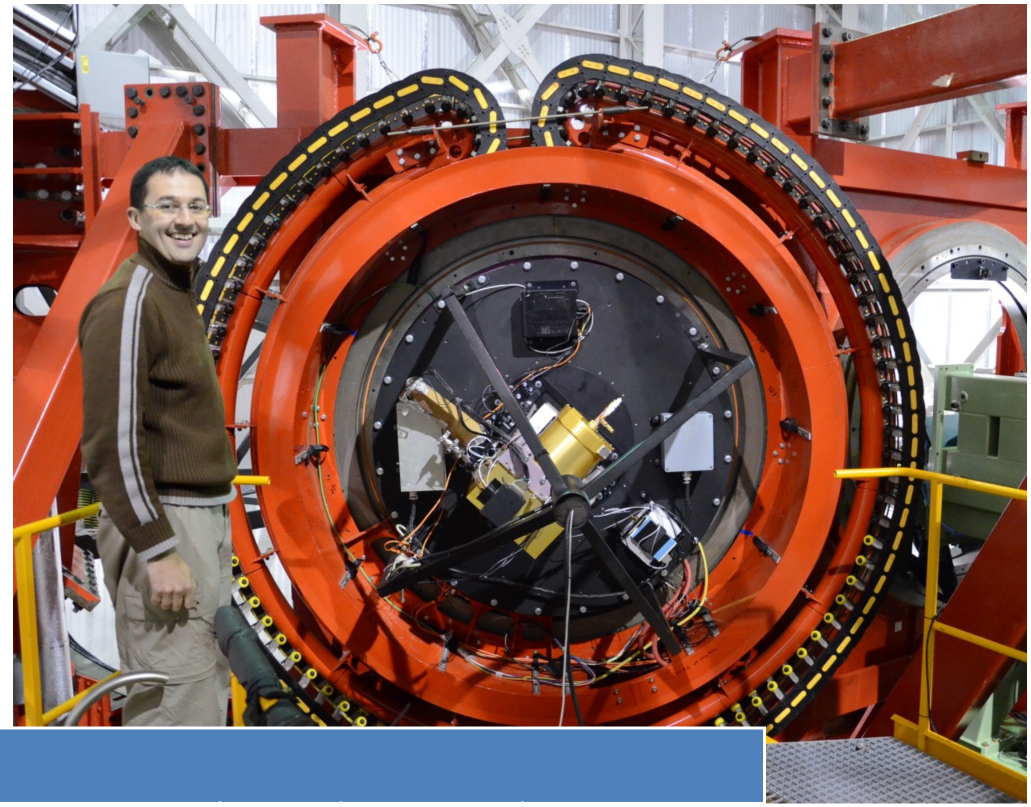


First scientific observations: PISCES

Instrument P.I.: D. McCarthy (UoA)

Performance summary:

Parameters.	Detector.
Format.	1024x1024
Plate scale.	18.2mas/pix
Wavelength.	1-2.2μm
Quantum efficiency.	>50% (60% in J,H,K)
Dark current	0.02 e-/s/pix
Read noise.	~17e
Gain.	~4.3e/ADU
Pixel defects.	<2%
Strehl Ratio. Arcetri tool	0.75



Available filters							
J	H	Ks	FII(1.64 um)	H2 (2.12um)	Brϒ	2.086	2.140

Predicted sensitivity (AO mode, 10sigma, 1h)		
J	H	K
24.6	24.2	23.4

Possibility to install a coronographic mask at the pupil location

Scientific observing with FLAO#1 & LBTI

Draft version May 29, 2012

arXiv:1203.2619v2 [astro-ph.SR] 28 May 2012

Astronomy & Astrophysics manuscript no. hr8799 © ESO 2012
March 14, 2012

arXiv:1203.2735v1 [astro-ph.EP] 13 Mar 2012

LBT observations of the HR 8799 planetary system *

First detection of HR8799e in H band

S. Esposito, D. Mesa, A. Skemer, C. Arcidiacono, R.U. Claudi, S. Desidera, R. Gratton, F. Mannucci, F. Marzari, E. Masciadri, L. Close, P. Hinz, C. Kulesa, D. McCarthy, J. Males, G. Agapito, J. Argomedo, K. Boutsia, R. Briguglio, G. Brusa, L. Busoni, G. Cresci, L. Fini, A. Fontana, J.C. Guerra, J.M. Hill, D. Miller, D. Paris, A. Puglisi, F. Quiros-Pacheco, A. Riccardi, P. Stefanini, V. Testa, M. Xompero, C. Woodward

Received / Accepted

ABSTRACT

We have performed H and Ks band observations of the planetary system around HR 8799 using the new AO system at the Large Binocular Telescope and the PISCES Camera. The excellent instrument performance (Strehl ratios up to 80% in H band) enabled detection the inner planet HR8799e in the H band for the first time. The H and K_s magnitudes of HR8799e are similar to those of planets c and d, with planet e slightly brighter. Therefore, HR8799e is likely slightly more massive than c and d. We also explored possible orbital configurations and their orbital stability. We confirm that the orbits of planets b, c and e are consistent with being circular and coplanar; planet d should have either an orbital eccentricity of about 0.1 or be non-coplanar with respect to b and c. Planet e can not be in circular and coplanar orbit in a 4:2:1 mean motion resonance with c and d, while coplanar and circular orbits are allowed for a 5:2 resonance. The analysis of dynamical stability shows that the system is highly unstable or chaotic when planetary masses of about 5 M_J for b and 7 M_J for the other planets are adopted. Significant regions of dynamical stability for timescales of tens of Myr are found when adopting planetary masses of about 3.5, 5, 5, and 5 M_J for HR 8799 b, c, d, and e respectively. These masses are below the current estimates based on the stellar age (30 Myr) and theoretical models of substellar objects.

Key words. (Stars:) individual: HR 8799 - Planetary systems - Instrumentation: adaptive optics - Techniques: high angular resolution - Planets and satellites: dynamical evolution and stability - Planets and satellites: physical evolution

1. Introduction

accepted for publication in the Astrophysical Journal on Feb 20, 2012

High Resolution Images of Orbital Motion in the Orion

arXiv:1203.2638v1 [astro-ph.SR] 12 Mar 2012

arXiv:1203.2615v2 [astro-ph.EP] 27 Apr 2012

First Light LBT AO Images of HR 8799 bcde at 1.6 and 3.3μm: New Discrepancies between Young Planets and Old Brown Dwarfs[1]

Andrew J. Skemer[1], Philip M. Hinz[1], Simone Esposito[2], Adam Burrows[3], Jarron Leisenring[4], Michael Skrutskie[5], Silvano Desidera[6], Dino Mesa[6], Carmelo Arcidiacono[2,7], Filippo Mannucci[2], Timothy J. Rodigas[1], Laird Close[1], Don McCarthy[1], Craig Kulesa[1], Guido Agapito[2], Daniel Apai[1], Javier Argomedo[2], Vanessa Bailey[1], Konstantina Boutsia[8,9], Runa Briguglio[2], Guido Brusa[8], Lorenzo Busoni[2], Riccardo Claudi[6], Joshua Eisner[1], Luca Fini[2], Katherine B. Follette[1], Peter Garnavich[10], Raffaele Gratton[6], Juan Carlos Guerra[8], John M. Hill[8], William F. Hoffmann[1], Terry Jones[11], Megan Krejny[11], Jared Males[1], Elena Masciadri[2], Michael R. Meyer[4], Douglas L. Miller[8], Katie Morzinski[1], Matthew Nelson[5], Enrico Pinna[2], Alfio Puglisi[2], Sascha P. Quanz[4], Fernando Quiros-Pacheco[2], Armando Riccardi[2], Paolo Stefanini[2], Vidhya Vaitheeswaran[1], John C. Wilson[5], Marco Xompero[2]

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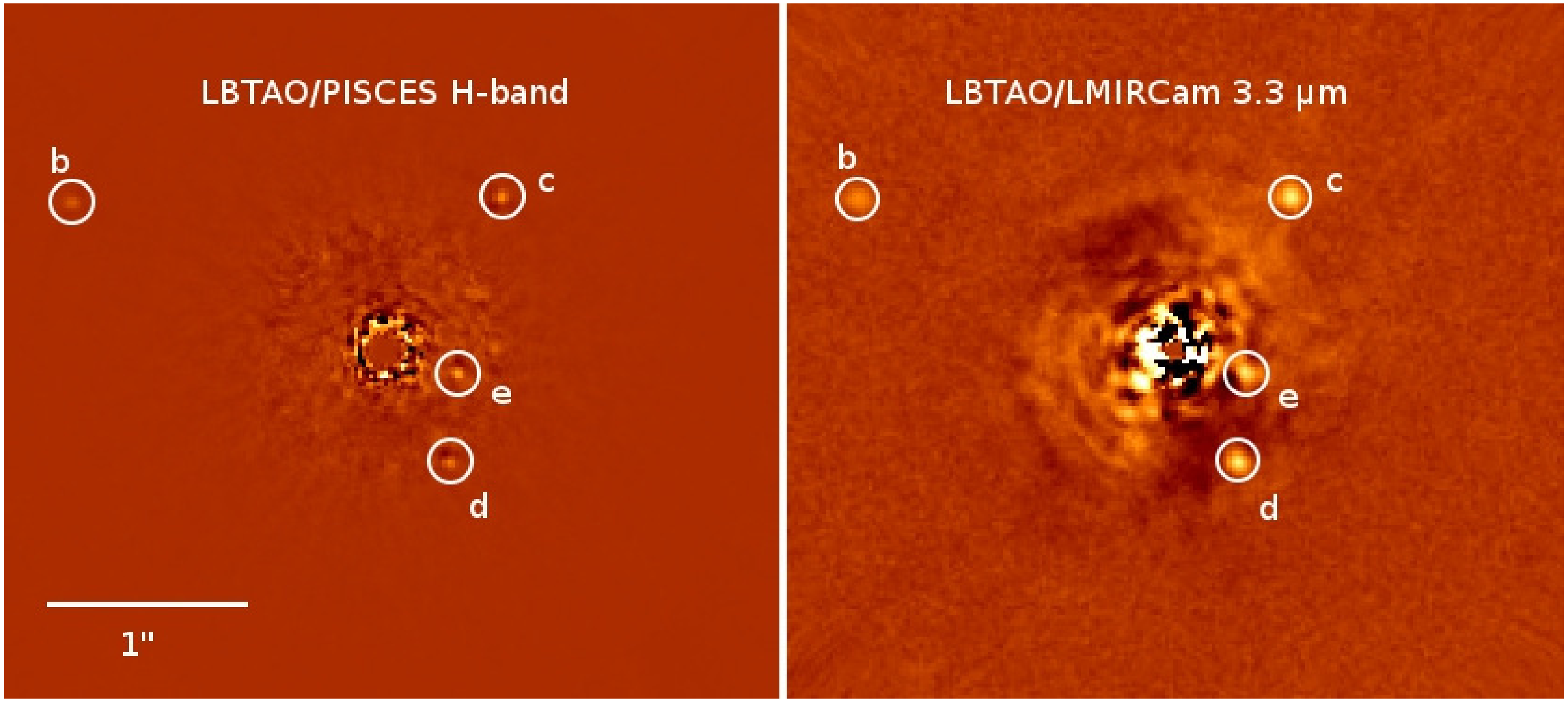
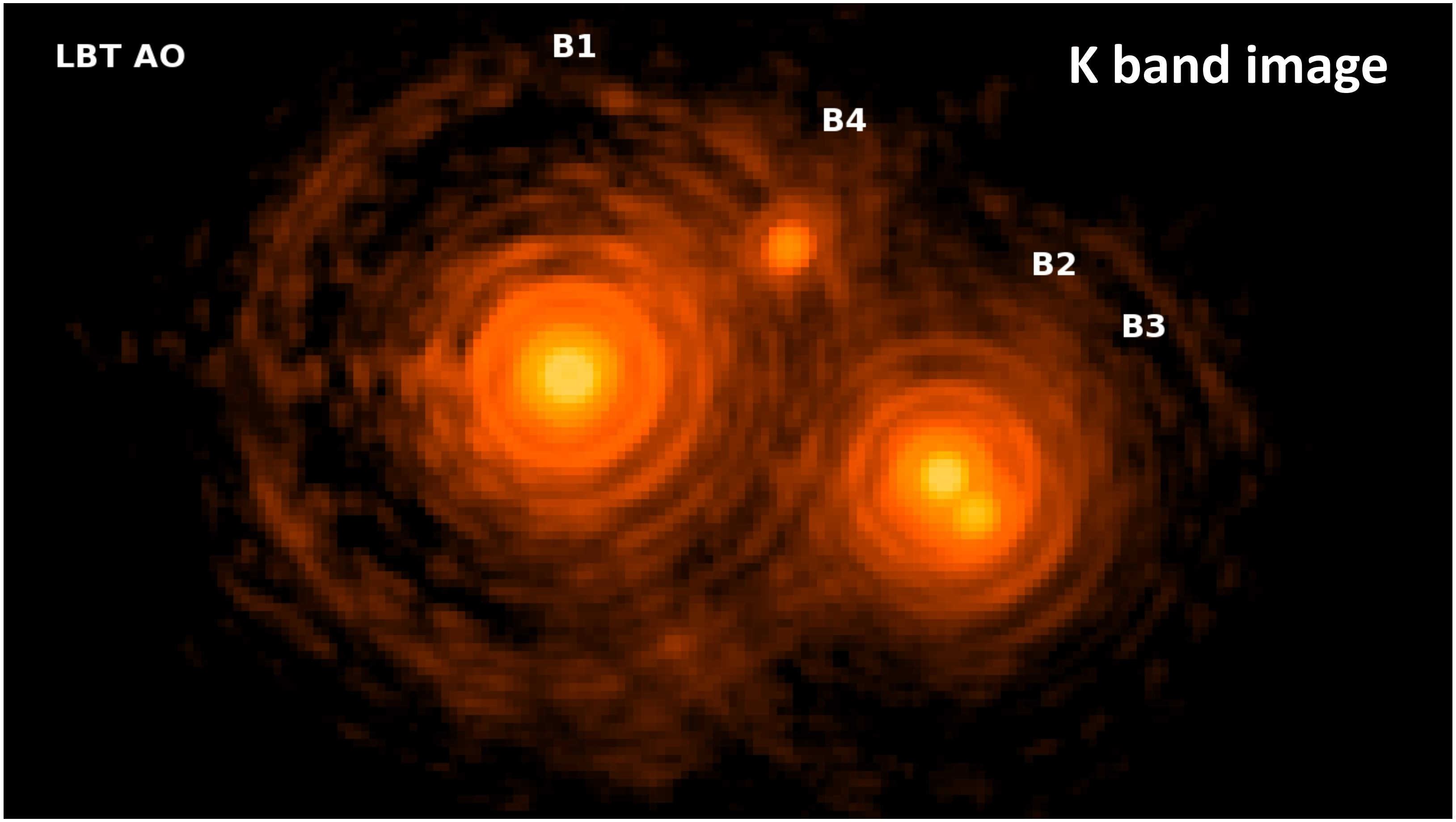
The four planets of HR8799



A look at the HR8799 planetary system from two different infrared wavelengths; left *H* band (1.65 microns), right narrow band centered on 3.3 microns which is sensitive to absorption by methane. All four planets are visible.

This is the first time the innermost planet, HR8799e, has been imaged at either wavelength thanks to the high contrast (10^4) achieved with FLAO#1

Star formation in trapezium region

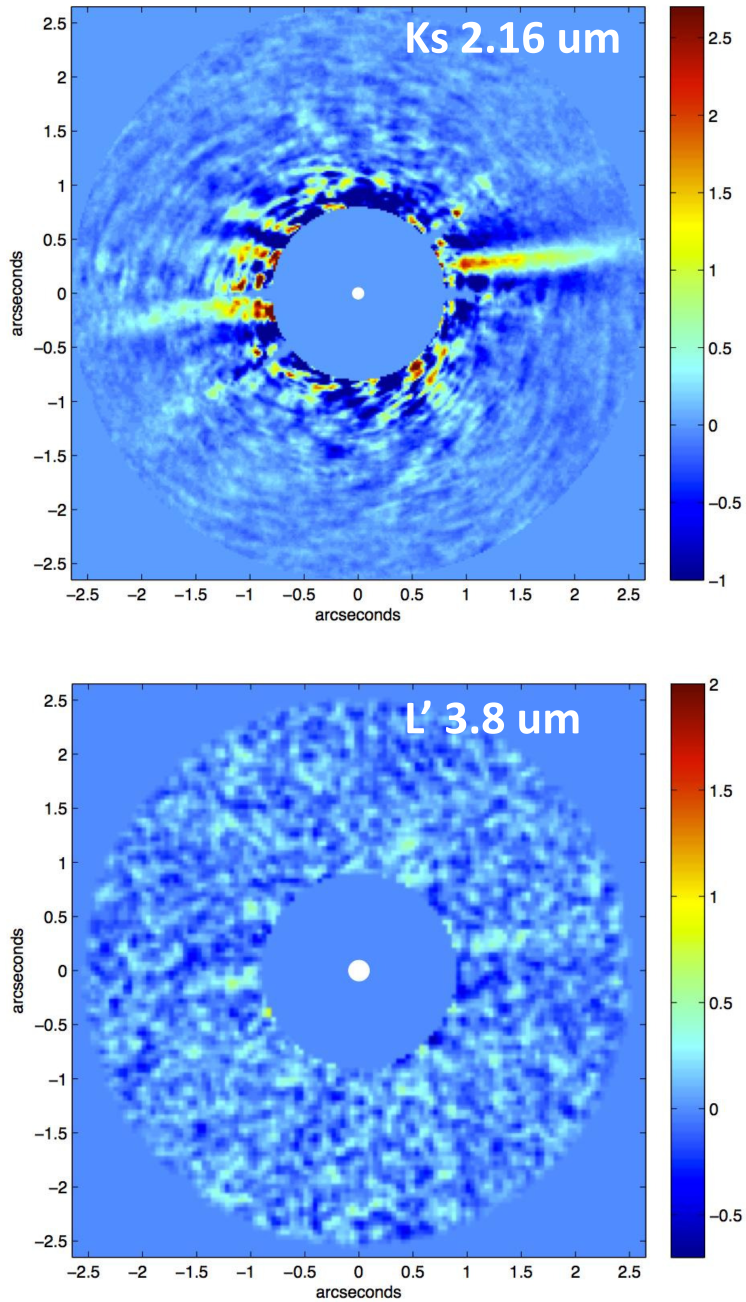


A view of four young stars in the Orion Trapezium cluster 1,350 light-years away. This is the best image ever taken of these stars, which are all tightly located within 1 arcsecond of each other. By comparing this 2.16 micron infrared image to past images astronomers can now see the motion of each star with respect to the others. The movements show that the mini-cluster of young stars were born together, but will likely fall apart as the stars age and interact with each other.

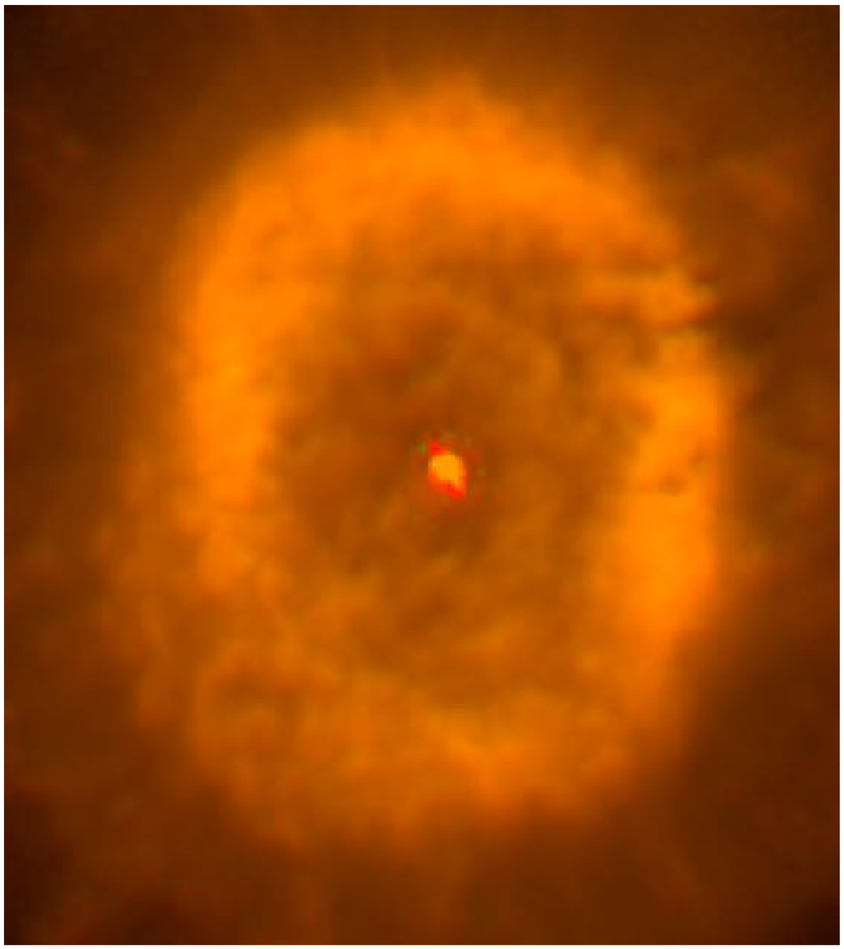
A new view of HD15115 intriguing debris disk

Images of the debris disk of HD15115 in *Ks* band (2.16 microns) and *L′* band (3.8 microns).

The LBT was able for the first time to probe more deeply into the interior of the debris disk surrounding the star HD 15115, revealing a symmetrical structure quite different from previous observations by other telescopes, including the Hubble Space Telescope.



BD30_3639 planetary nebula (2um)



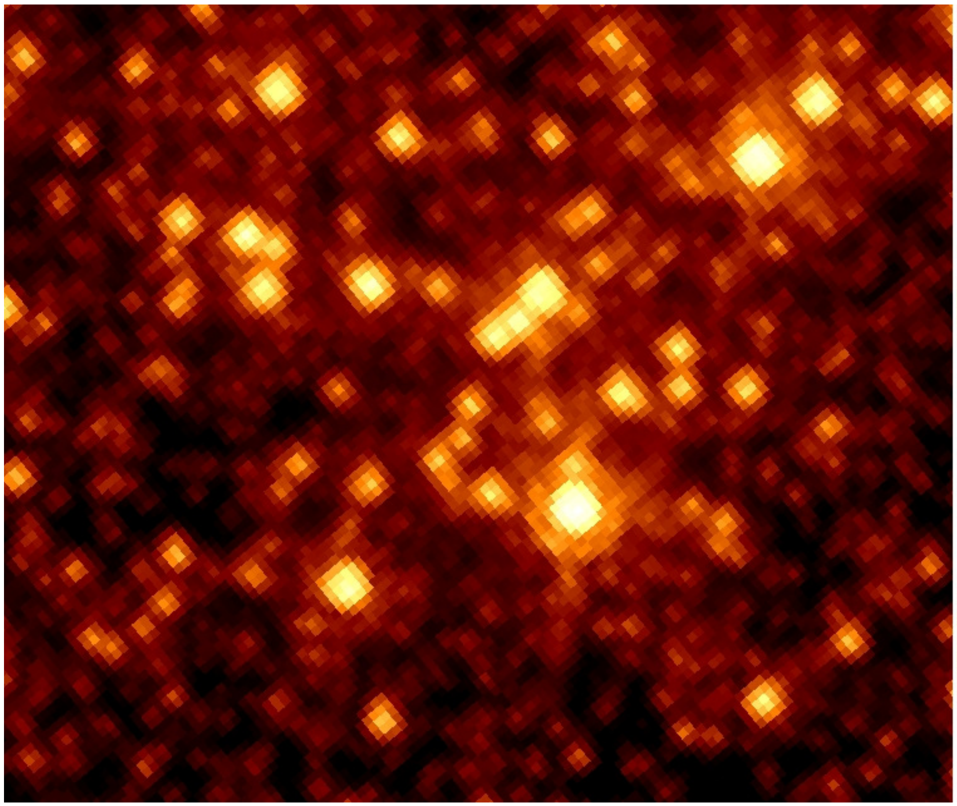
HST visible image

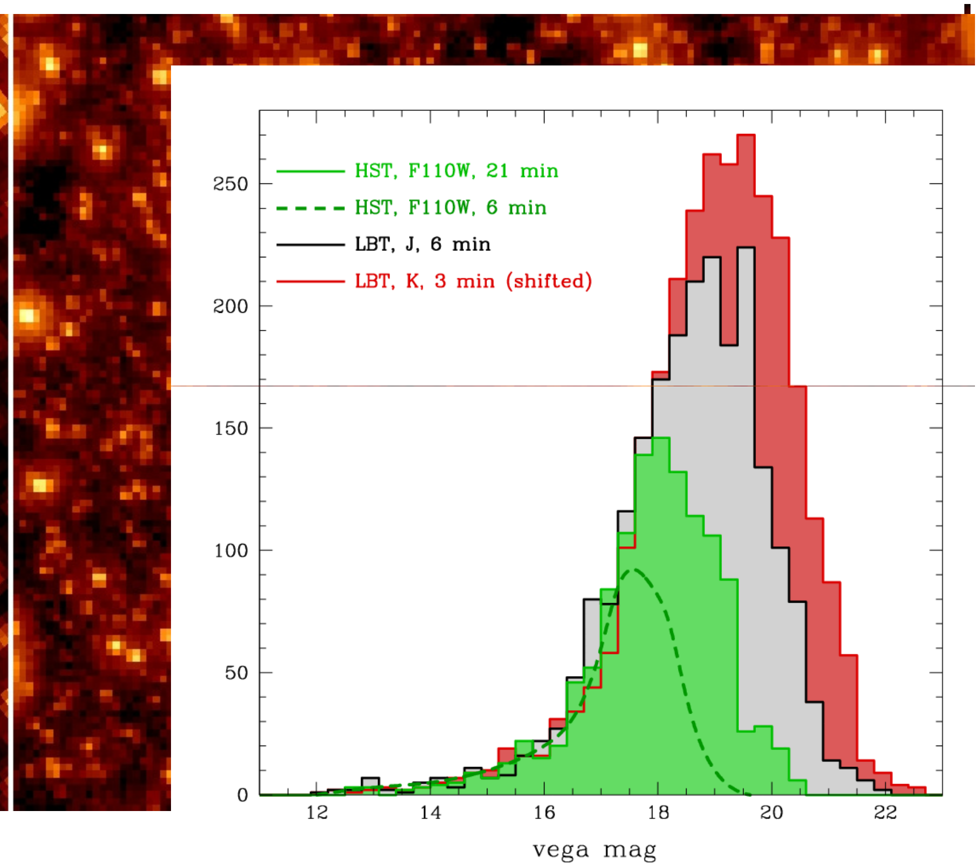
~5''

LBT AO, 100s, H2 filter (2.1um), ref. star Rband 11mag, 150modes, 500Hz

The Globular cluster M92

~15’’





HST WFPC3, H band, 20 min

Main data: Rmag 11.5, 0.7’’ seeing,

AO settings: 0.5KHz, 15x15 subaps, 153 correct

Gemi

HST J counts 890, 21 minutes

LBT J counts 1969, 6 minutes

LBT K counts 3300, 3 minutes

Conclusion....

Adaptive Secondaries and Pyramid sensors systems moved ground based Astronomy a step forward achieving:

- Large and uniformly corrected FoV (110arcsec, FWHM 0.2arcsec) at MMT
- High SR and contrast in H band (>90%, >10^4) with LBT (FLAO)
- Fringes at 4.0um over the 23m equivalent diameter of LBT (LBTI)
- AO corrected images at short wavelenghts 1.0 and 0.7 um (FLAO)

First scientific images taken in June 2011, data reduction started. Four paper published from 3 observing nigths. Initial results for M92 outperform HST results.

and...

AdSec for Gemini? ☺

8.0m primary F/1.8
1.02m secondary
Telescope F/16

A convex adsec:
1) 850 acts, LBT pitch
2) 672 acts, GMT pitch

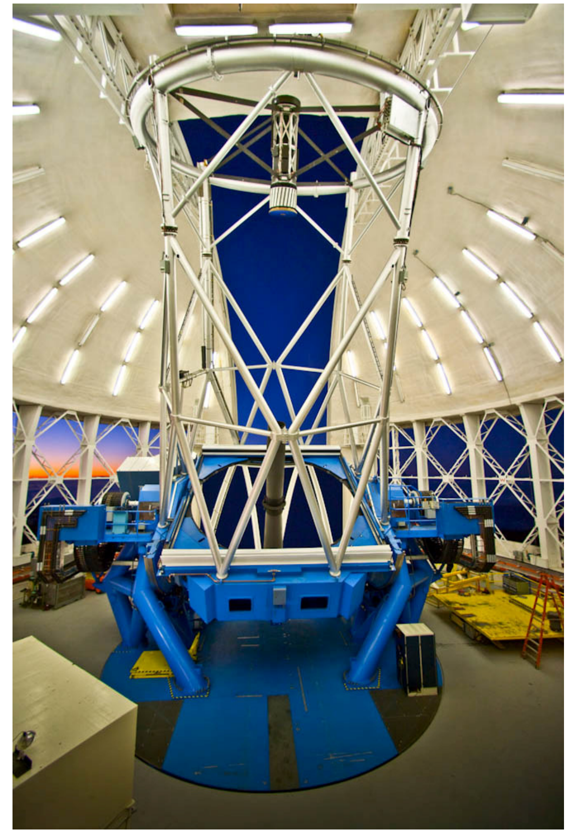


Image credits: Gemini Observatory/AURA

AO modes enabled:
1) **GLAO (MMT)**
- high troughput
- low emissivity
- simple WFS design

2) **SCAO with Pyramid WFS (LBT,LBTI)**
- XAO: High Contrast
- SCAO: Good sky coverage NGS

3) MCAO, MOAO......

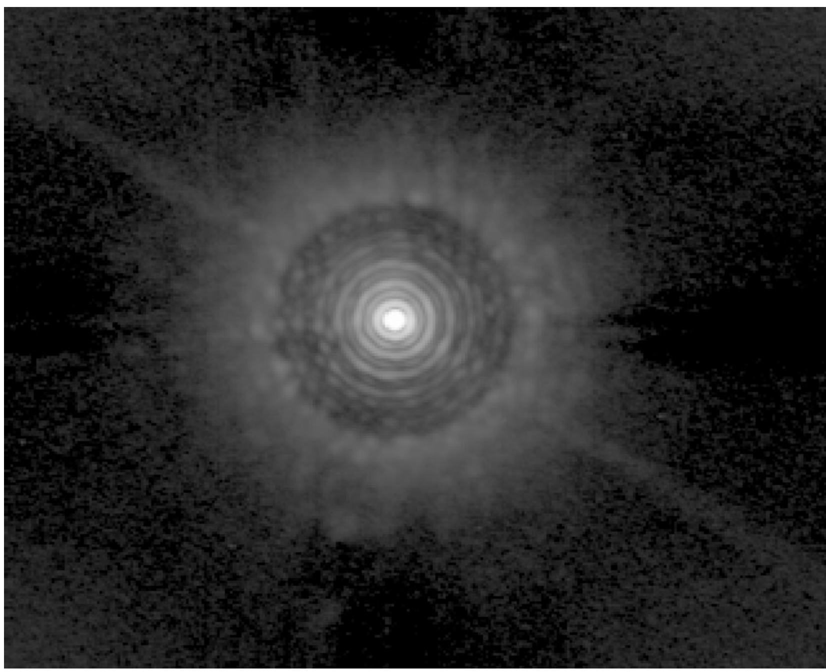
NGS AO benefits a lot from the very good seeing of Mauna Kea

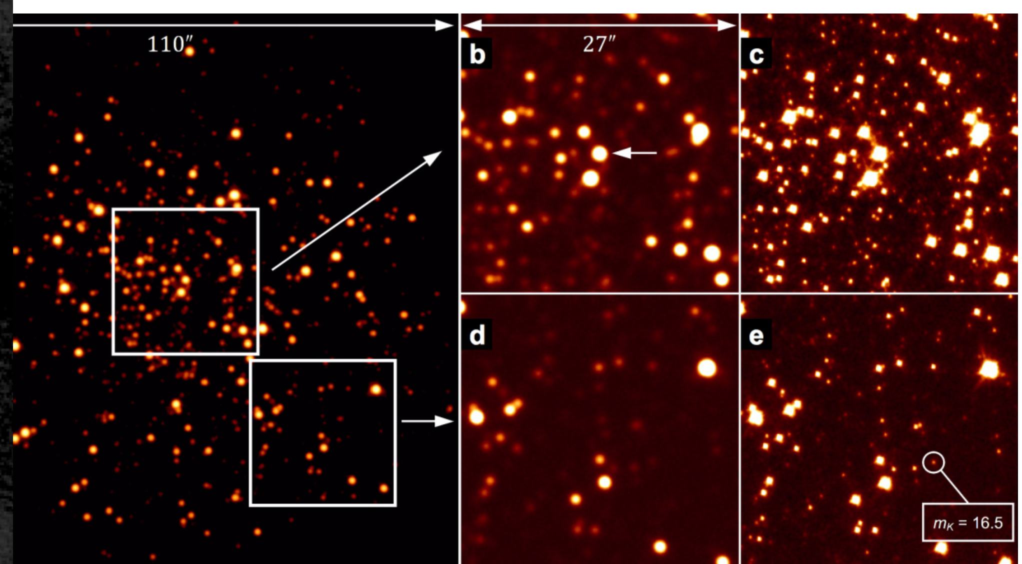
Projects for 8m/ELT telescopes...

MMT: 336 acts, ∅ ~ 600mm
LBT: 672 acts x2, ∅ ~ 900mm
Magellan: 585 acts, ∅ ~ 600mm
VLT: 1170 acts, ∅ ~ 1200mm
GMT: 672 acts x7, ∅ ~ 1050mm

Gained experience demonstrated

- LGS basef GLAO (MMT)
- XAO/SCAO (LBT,LBTI) with AdSec and Pyramid





Workshop inputs:

Wide field (~ 10 arcminutes) : GLAO/MOAO

Uniform PSFs with FWHM 0.2 arcsec, GLAO

Targeted high-order correction (diffraction-limited) distributed across the field, e.g. ~10 targets., MOAO

Medium field (~ 1 arcminute) : MCAO

uniform high-order diffraction-limited performance across the field. MCAO

Narrow field: SCAO/XAO

a) (~10" - 20") high-order diffraction-limited (Strehl ratios ranging from 30% - 90% - depending on wavelength)
b) (<5") high-contrast (~10^9), high-order systems.