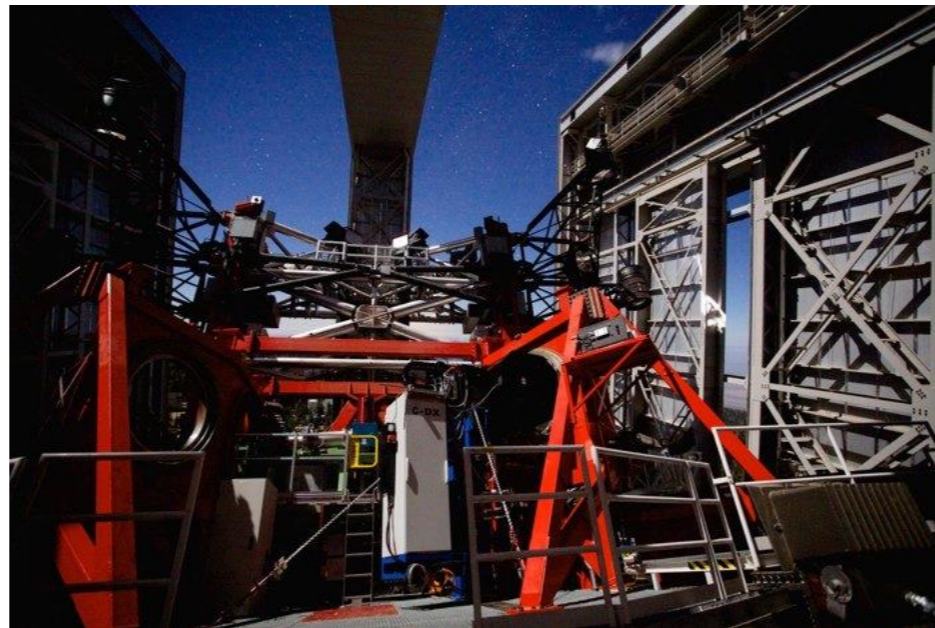
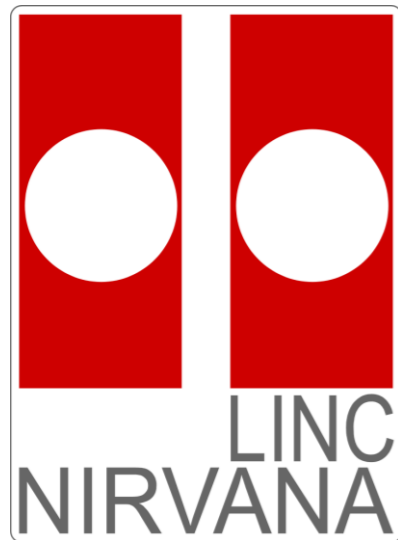


LINC-NIRVANA Pathfinder experiment: ground-layer wavefront sensor stairway to the sky



LABORATORIO
NAZIONALE
ADONI
OTTICA
ADATTIVA

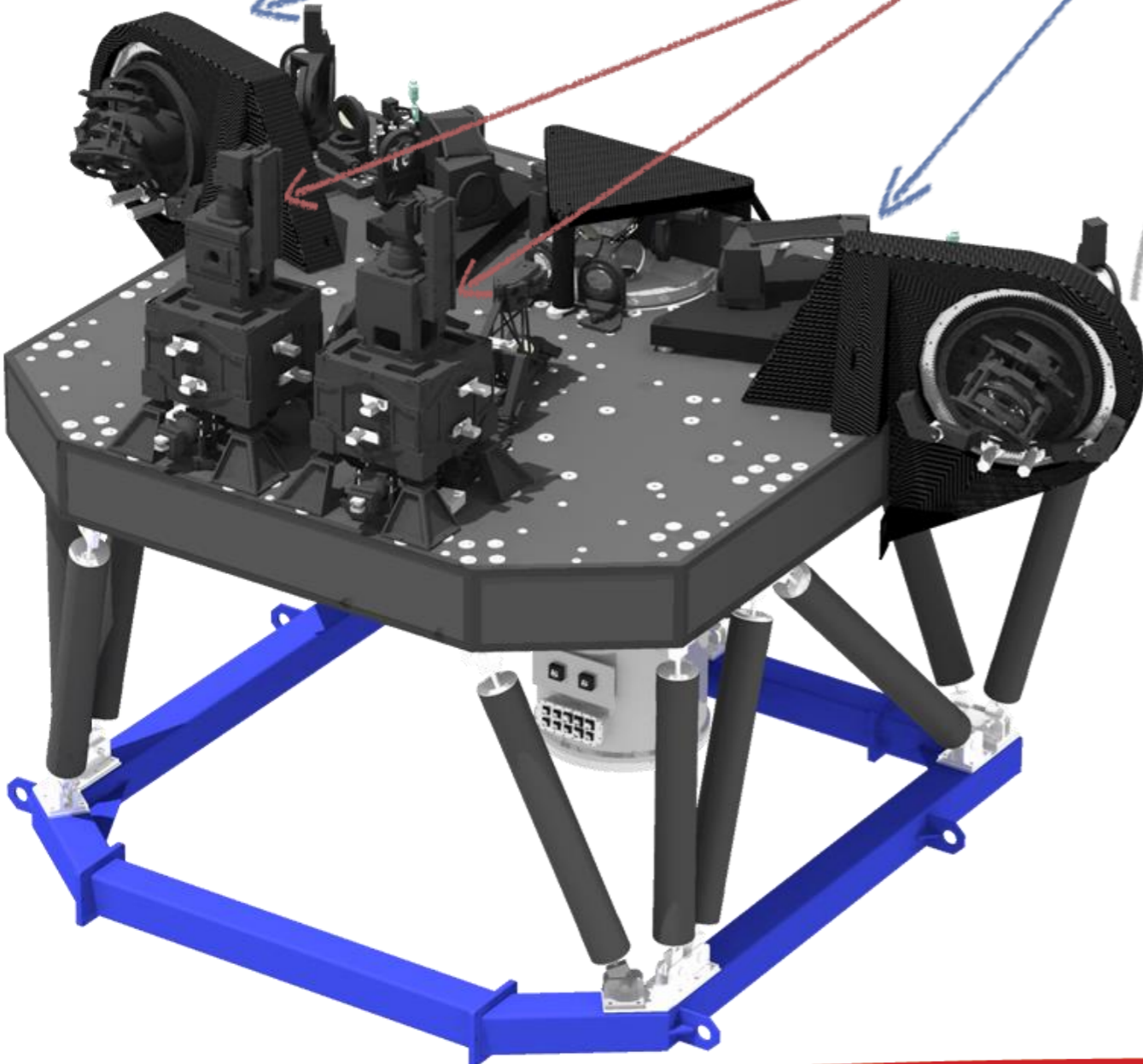
Maria Bergomi

V. Viotto, L. Marafatto, C. Arcidiacono,
J. Farinato, R. Ragazzoni, M. Dima, D. Magrin

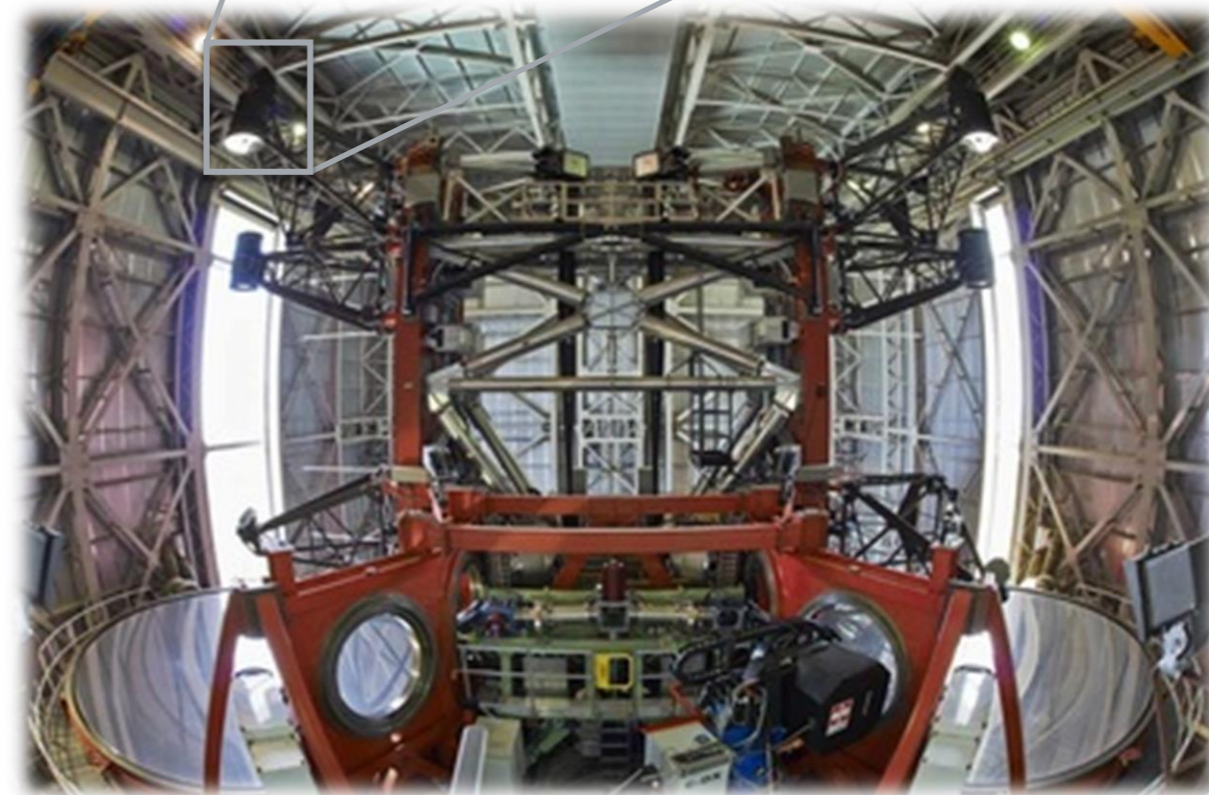
NIR Imager interferometrico
ad alta risoluzione

2 Ground-layer Pyramid WFS
(GWS)

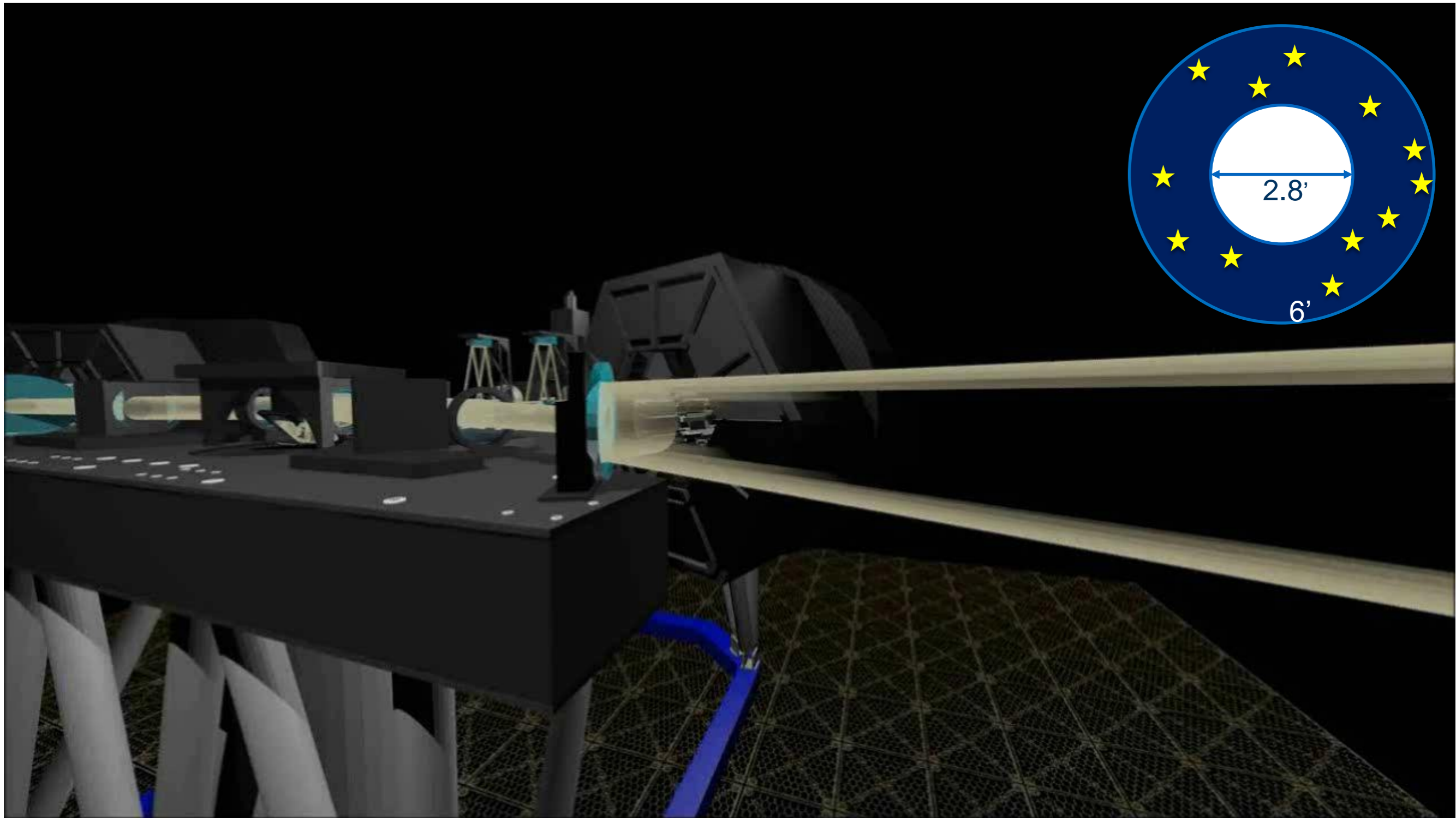
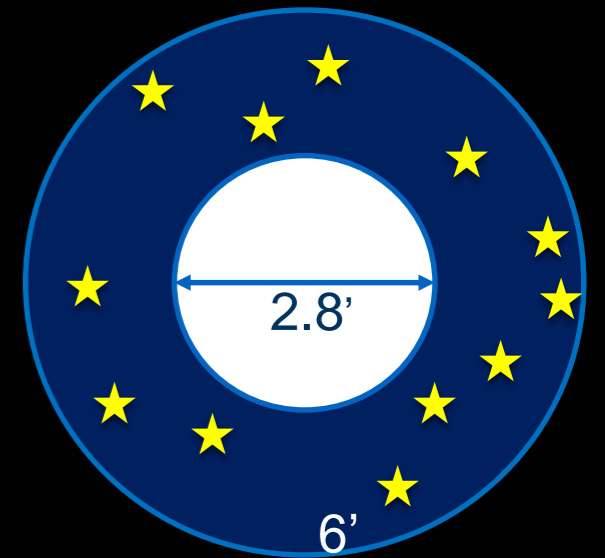
2 High layer Pyramid WFS



ASM
672 attuatori

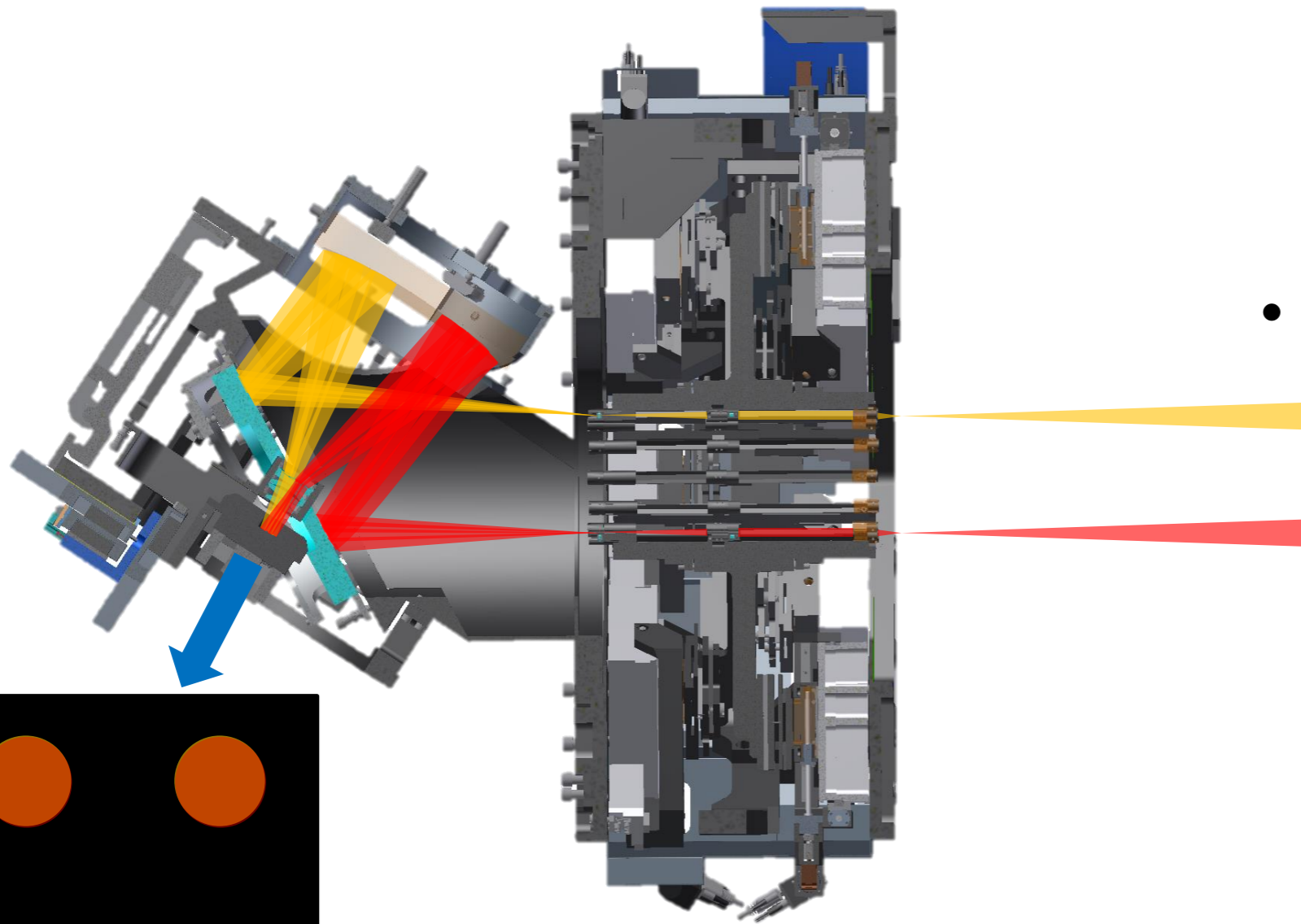


Ground-layer WFS

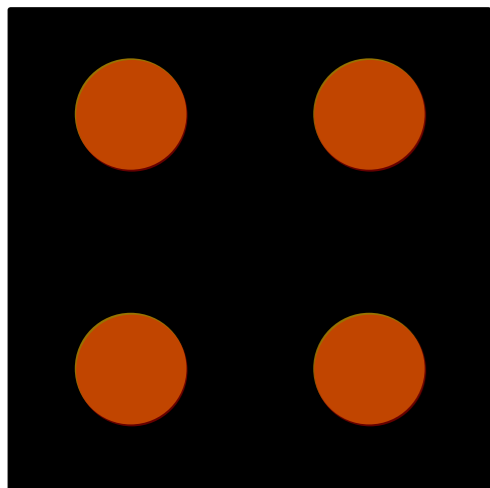


Credits V. Viotto

Componenti GWS



- 12 Star Enlarger
 - Cuscinetto
 - Pupil re-imager
- CCD (128x128 pixels)



Coniugato al ground-layer



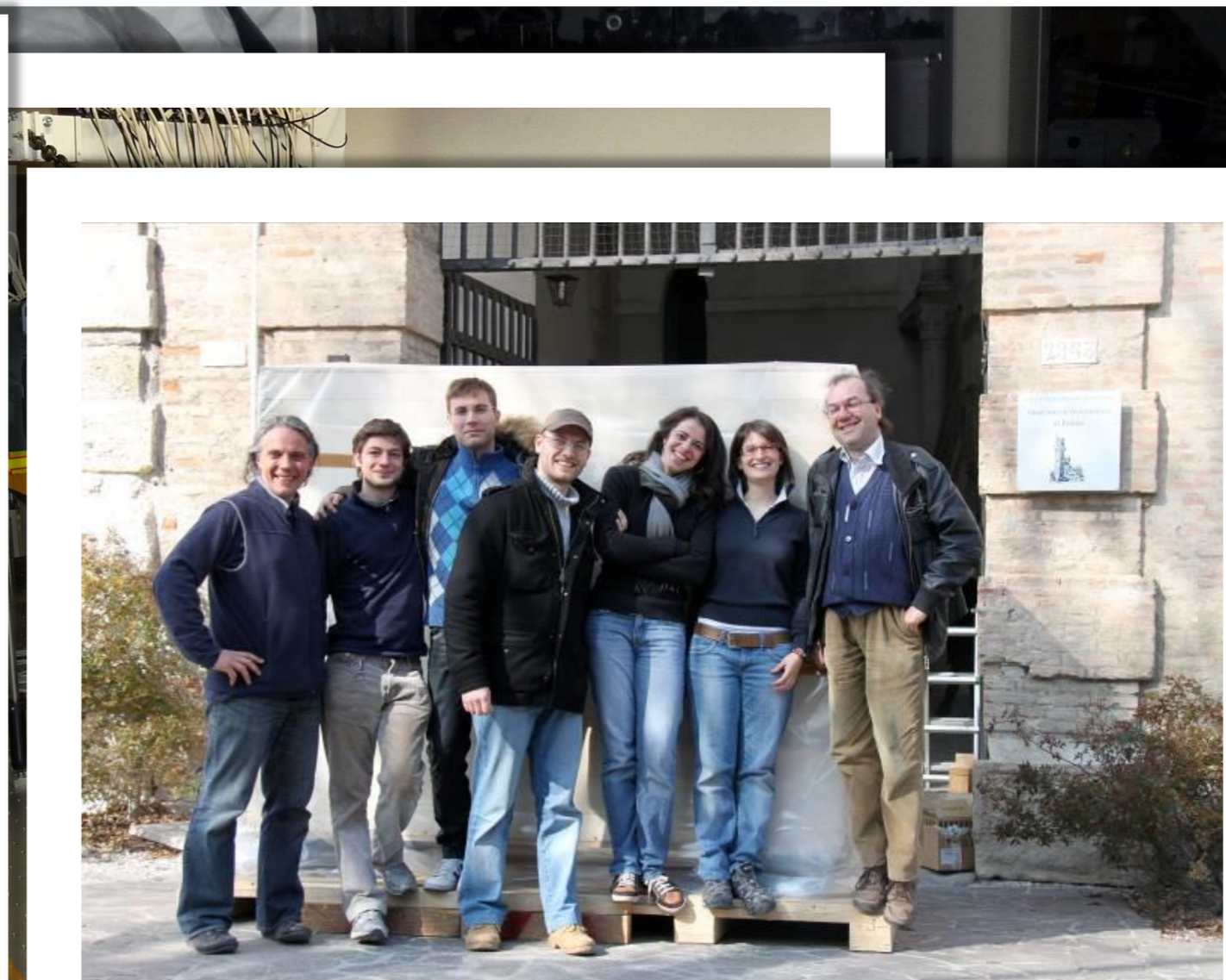
Error source	Test ref.	blur [μm]	blur[sub-ap]	WFE [nm]
GWS Components				
SE diffraction	C	7	0.15	30
Linear stages wobble	B	5	0.10	22
Pyramid chromatism	C	6	0.13	26
Pyramid vertex angle	A	5	0.10	22
Pyramid face orthogonality	A	1	0.02	4
GWS internal alignment				
SE enlarging factor k		5	0.10	22
SE relative tilt	A	5	0.10	22
Pyramid orientation	A	5	0.10	22
PR optical quality	B(A)(C)	13	0.27	57
Thermal effects				
SE lens misalign. (thermal)		/	/	/
Linear stage wobble (thermal)		/	/	/
PRI optical quality (thermal)		7	0.15	31
GWS misalignment wrt the bench				
Mismatch DM-WFS		5	0.10	22
GWS global defocus		N/A	N/A	N/A
GWS global tilt		N/A	N/A	N/A
GWS global de-center		N/A	N/A	N/A
Pupil matching on WFS		5	0.10	22
Bearing contribution				
Bearing wobble		1	0.02	4
Bearing runout		N/A	N/A	N/A
Bearing non-uniform rotation		N/A	N/A	N/A
Flexures				
GWS flexures	D	23	0.25	53
Bearing flexures	D	3.2	0.07	14
SE tilt due to support flex.	A(B)D	6	0.13	26
SE tilt due to ring flexures	A(B)D	4	0.08	17
SE tilt due to stage flexures	A(B)D	4	0.08	17
Annular mirror flexures		N/A	N/A	N/A
TOT WFE				143
				SR@J \approx0.60
				SR@K \approx0.85

Sistema complicato
→ error budget!

Essenziale per definire i vari **fattori** che possono **degradare le prestazioni** del sistema.

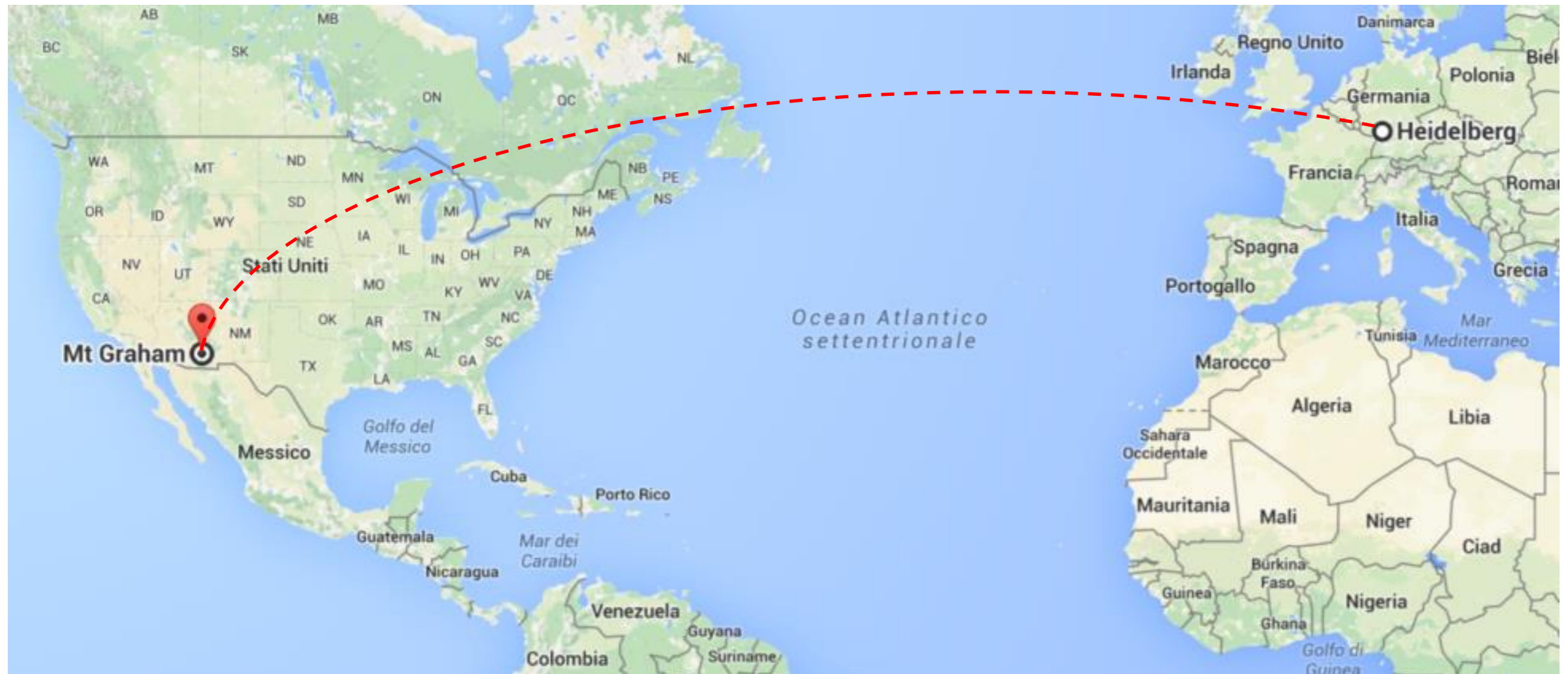
Test sui singoli componenti per verificarne la conformità con i **requisiti**.

Allineamento GWS @ Padova

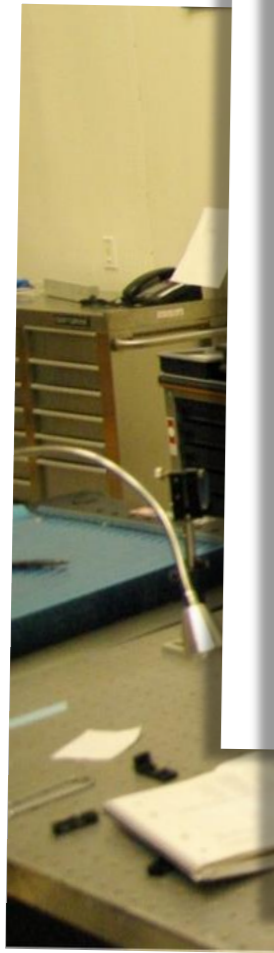
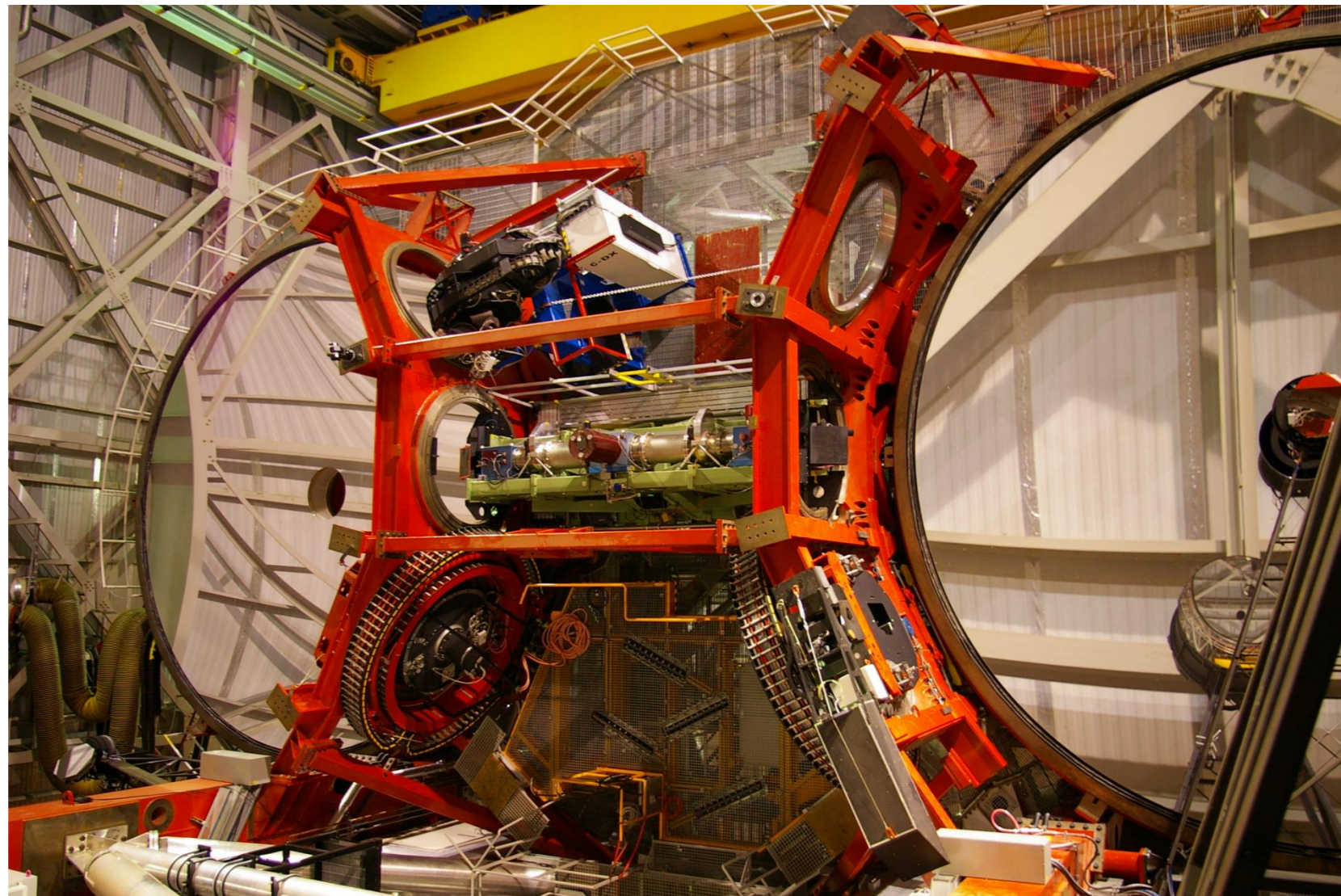


Test di flessione @ MPIA










GWS @ LBT → Pathfinder



Da marzo 2013 a novembre 2014 → 6 run al telescopio

- Ridurre rischi ed accelerare il commissioning di LINC-NIRVANA
- Comunicazione SW tra GWS, telescopio e ASM
- Calibrazione matrici di interazione

Principali obiettivi “on-sky”:

- Geometria piano focale GWS 
- Acquisizione e tracking di stelle singole 
- Chiusura del loop su 1 stella, in asse 
- Chiusura del loop su 1 stella, fuori asse 
- Acquisizione e tracking di stelle multiple 
- **Chiusura del loop su stelle multiple**

Novembre 2013: 2 x 0.5 notti + 1 notte
0.5 notti effettive con seeing > 2''

Dicembre 2013: 4 x 0.5 notti
0.4 notti effettive con seeing 1.5''

Marzo 2014: 2 x 0.5 notti
0.4 notti effettive con seeing 0.8''

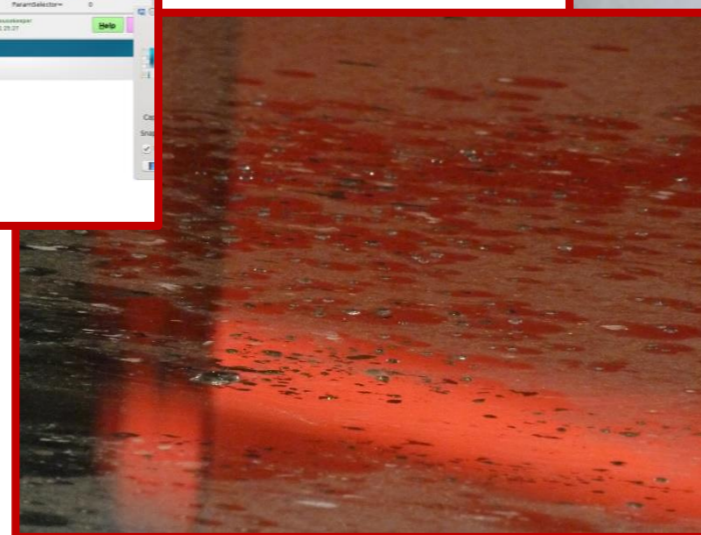
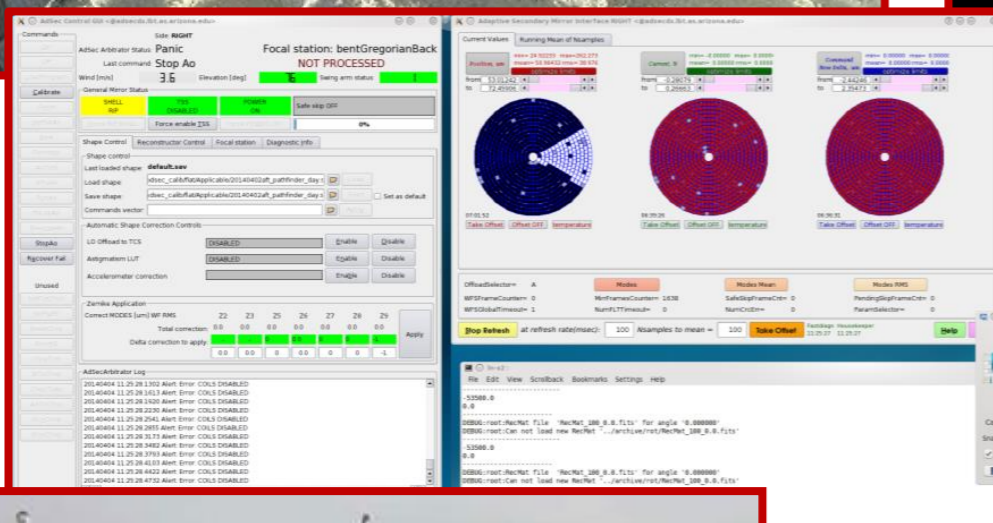
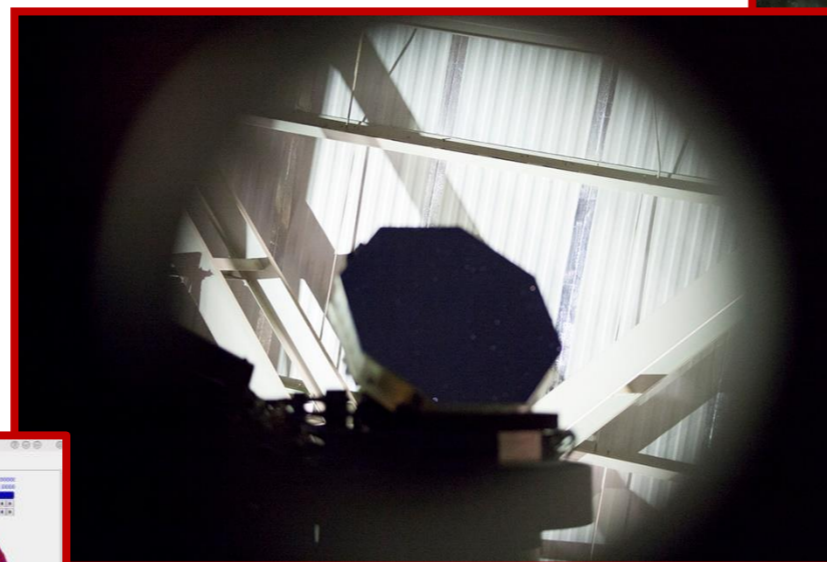
Luglio 2014: 2 x 0.5 notti
Nessuna notte effettiva

Novembre 2014: 2 X 0.5 notti
0.6 notti effettive

Tempo totale: 7 notti



Pioggia, Vento >20 m/s, Nuvole, Neve, Grandine, Umidità, ...
Problemi a M2, puntamento M3, pioggia in cupola, telescopio in generale



Novembre 2013: 2 x 0.5 notti + 1 notte
0.5 notti effettive con seeing > 2''

Dicembre 2013: 4 x 0.5 notti
0.4 notti effettive con seeing 1.5''

Marzo 2014: 2 x 0.5 notti
0.4 notti effettive con seeing 0.8''

Luglio 2014: 2 x 0.5 notti
Nessuna notte effettiva

Novembre 2014: 2 X 0.5 notti
0.4 notti effettive con seeing 1.4''
0.2 notti effettive con seeing > 2''

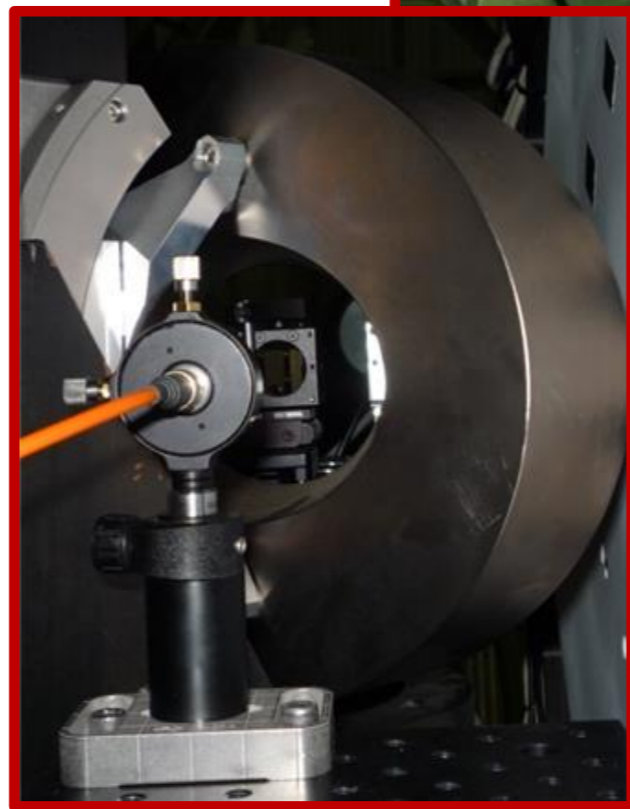
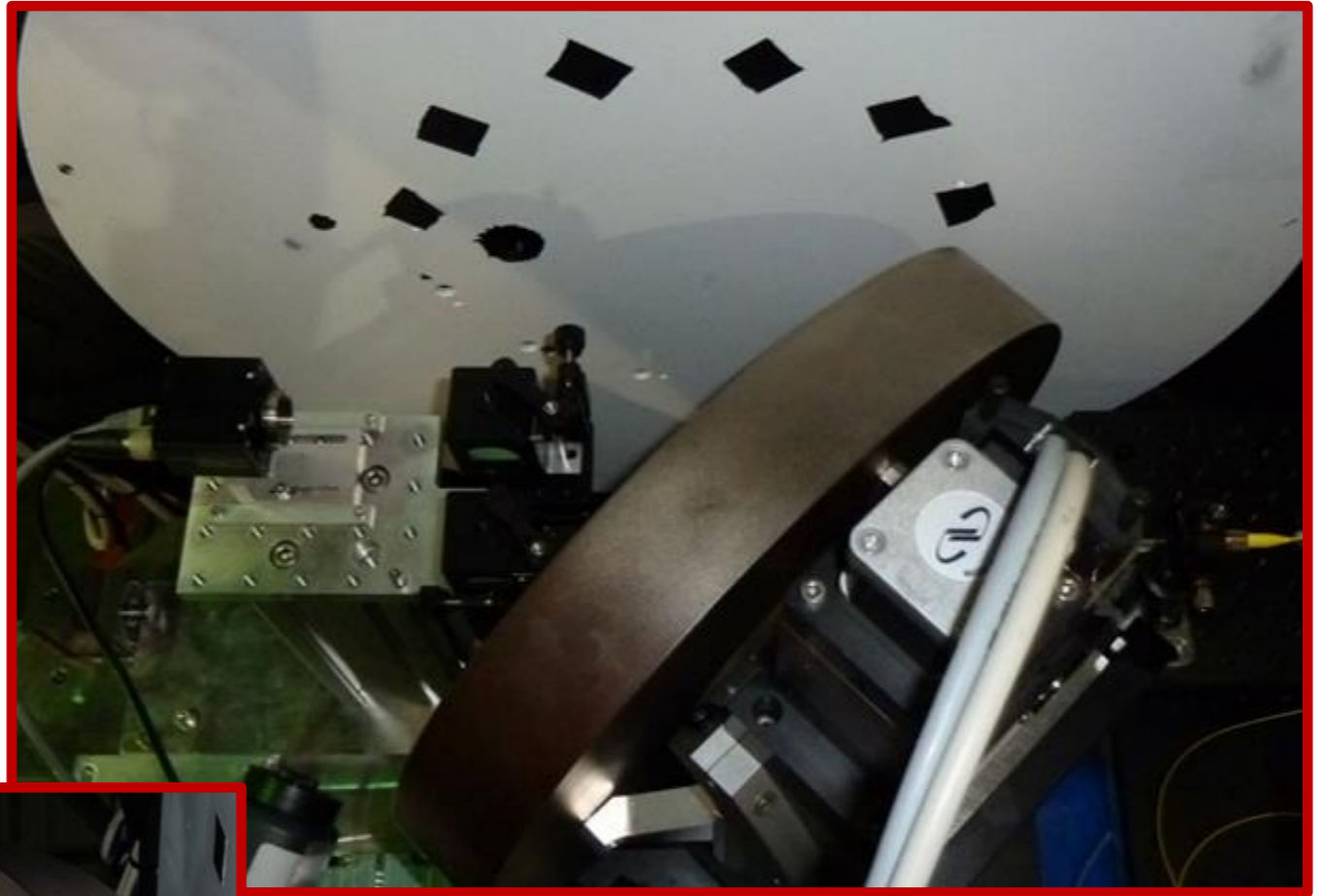
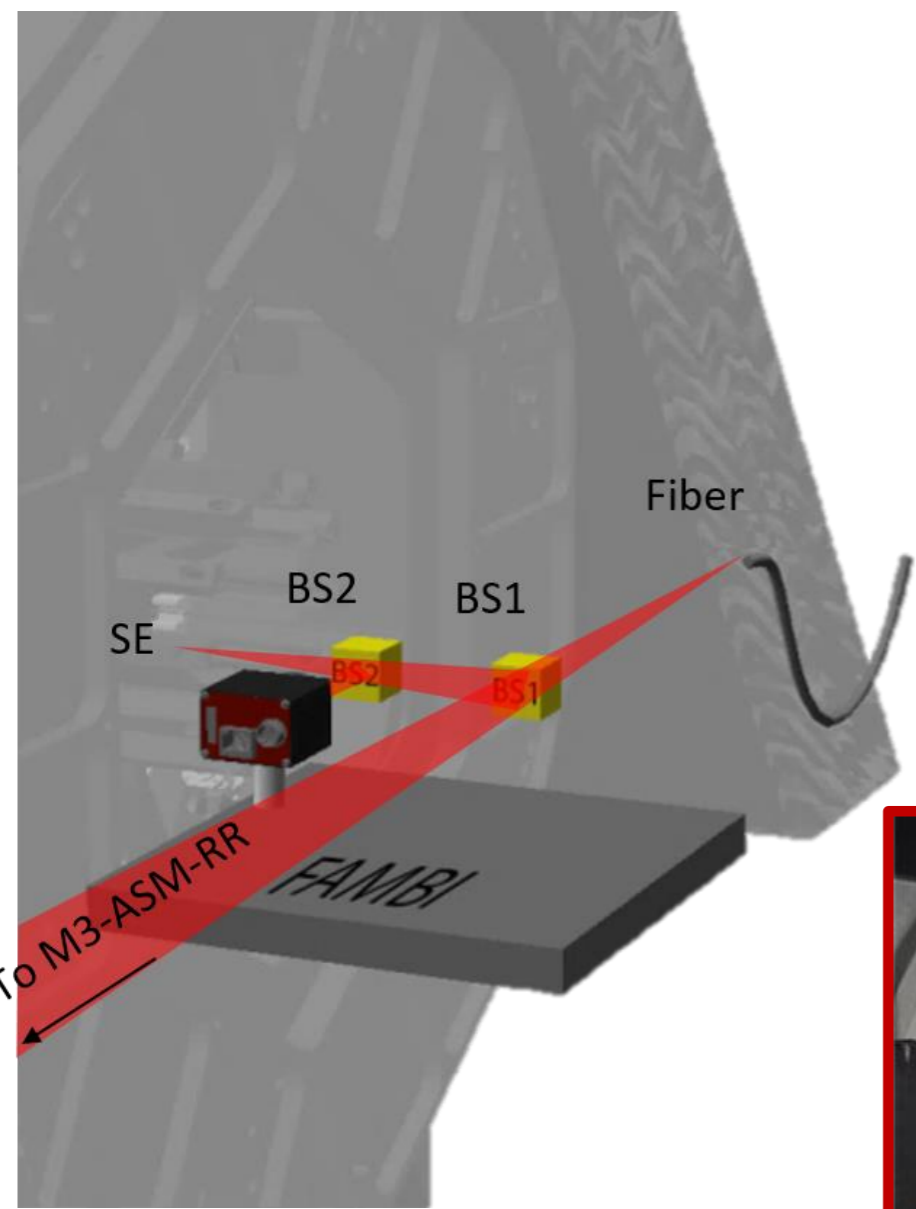
Tempo totale: 7 notti

Effettive: < 1.5 notti

- molto frazionate

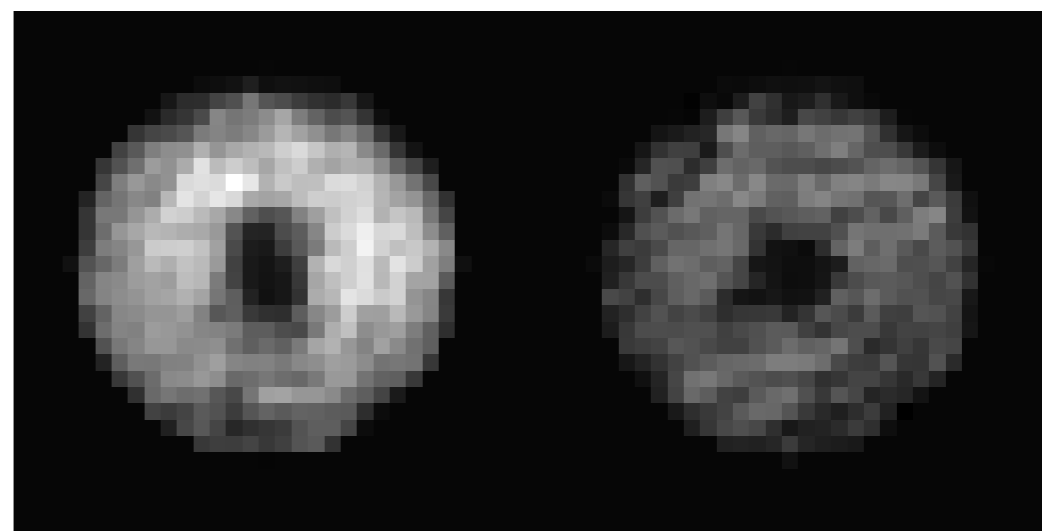
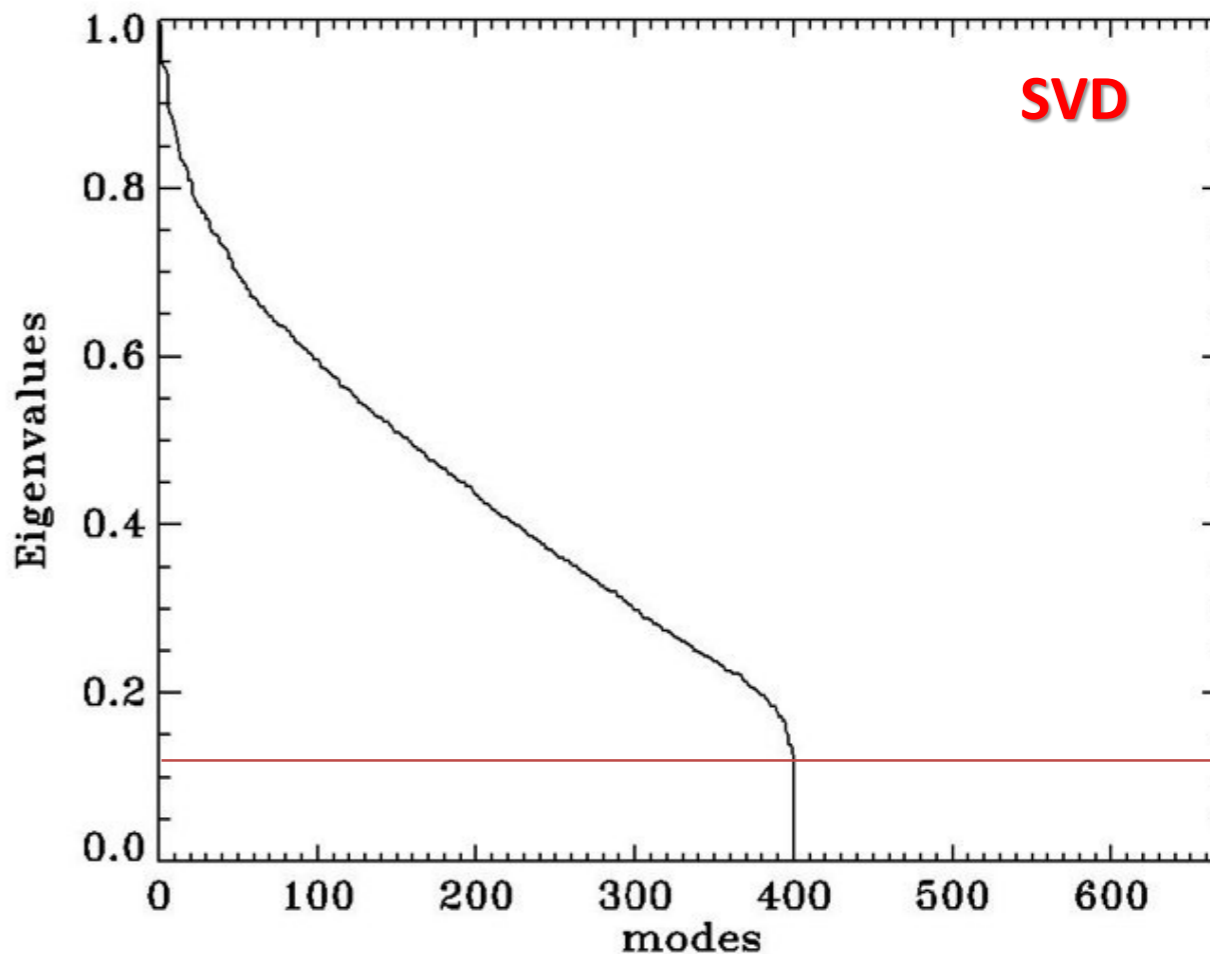
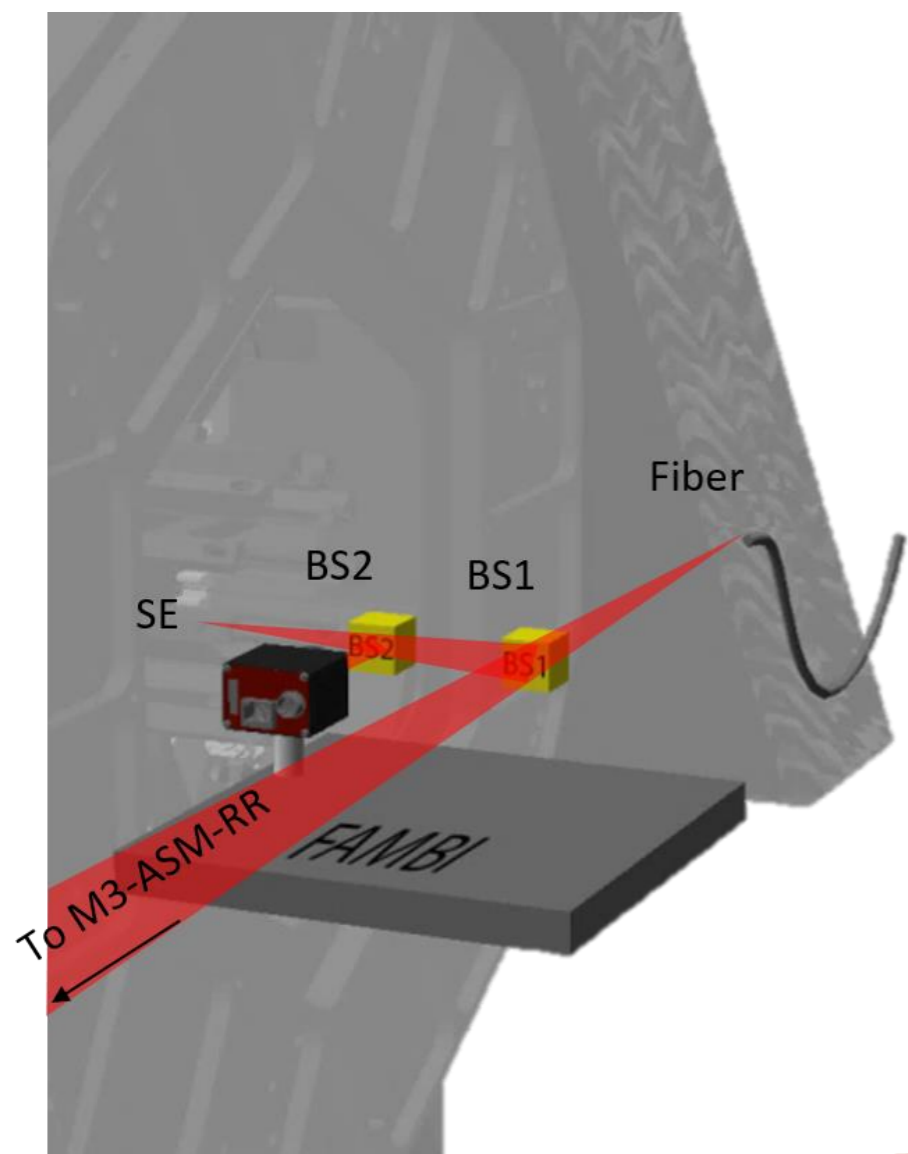
- con valori di seeing < 1.5''





Metodo push-pull per calcolare la mappatura tra le basi modali (Karhunen-Loève) applicate all'ASM e i segnali misurati dal WFS fino **400 modi**.

Media di 12 Matrici di Interazione (IM)

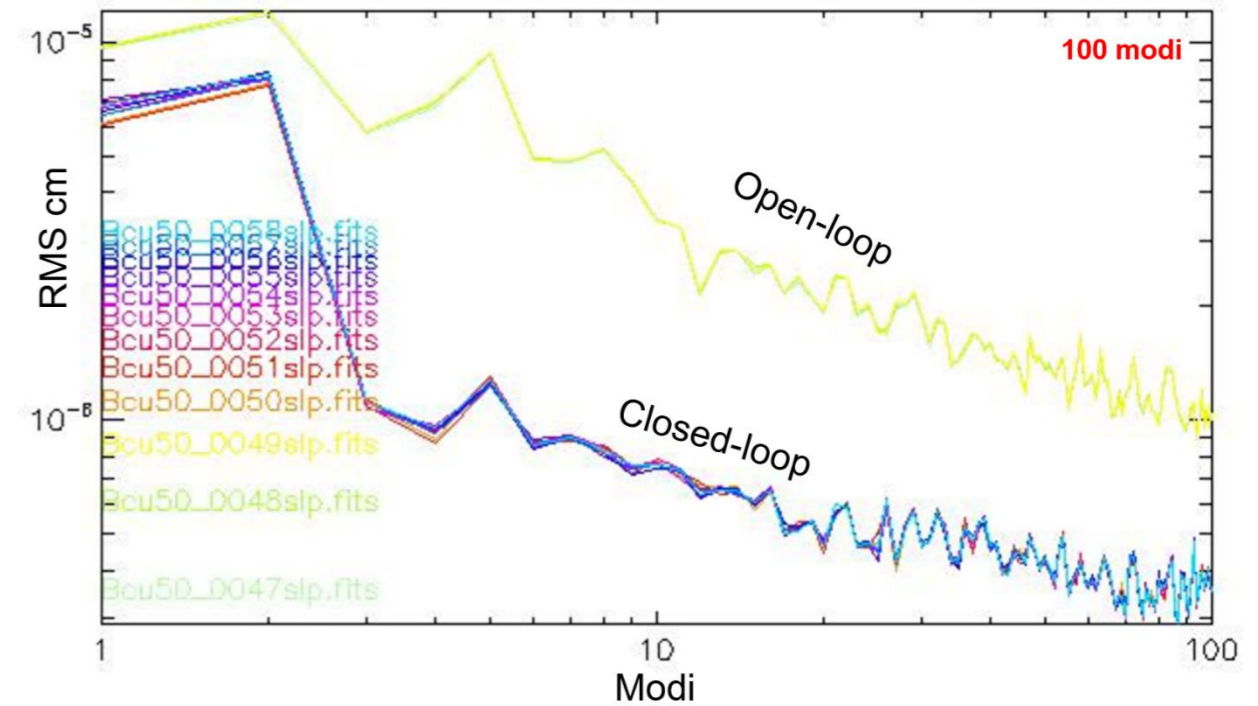
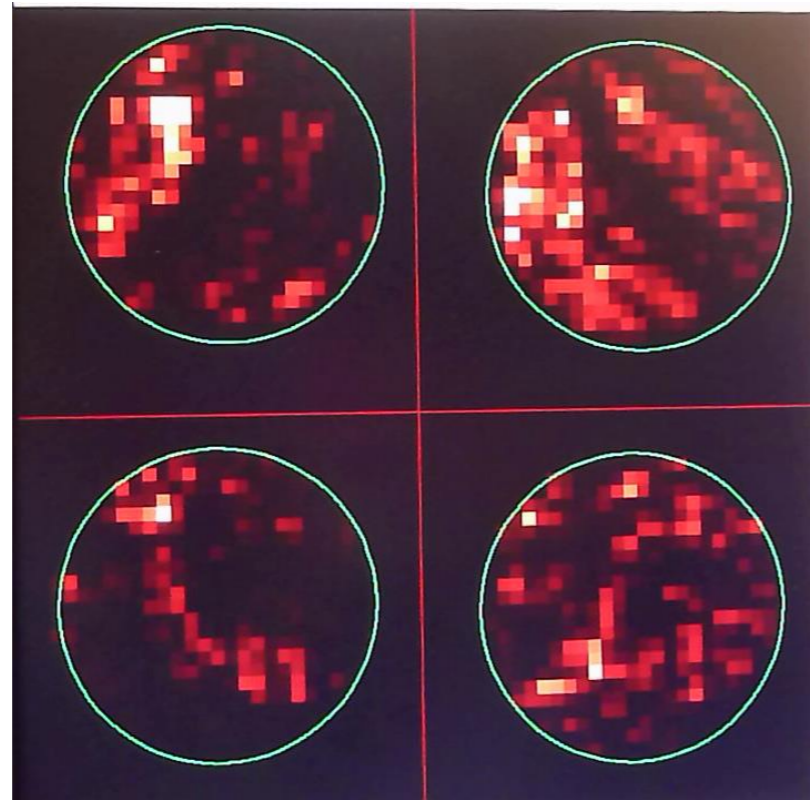


Slope x

Slope y

CCD50

128 x 128 pixels
 2x2 binning
 24 sub-aperture
 per pupilla
 884Hz



Per confermare la qualità delle IM ottenute, si caricano **il file del ricostruttore e il file con i vettori di guadagno** alla BCU dell'ASM.

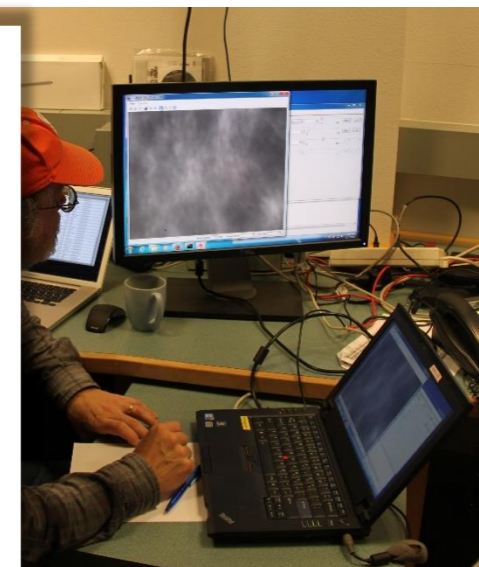
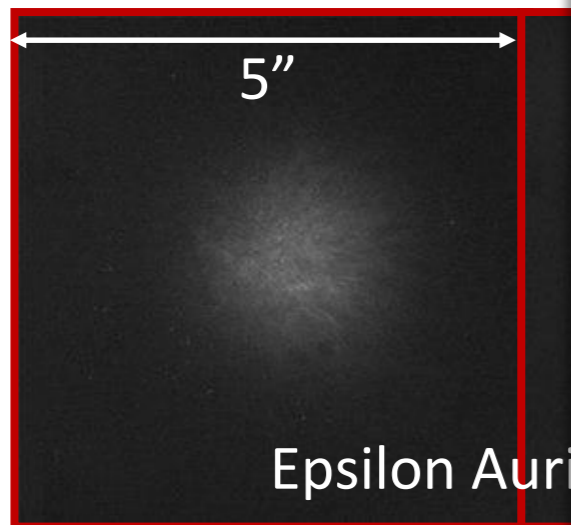
Si applica un set di comandi che simula l'andamento della turbolenza con spettro di Von Karman. Nel nostro caso: **0.8" seeing e vento 15 m/s.**

First light (stella in asse)

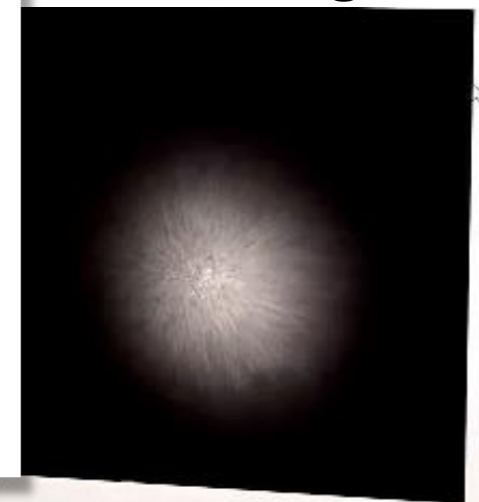
NONE			ENC
HA	-00:00:24.70	ZD	-0.000
AIR	1.000	Temperature °C	Dew Point °C
	-2.9		-20.2
		Wind Dir. Front °	191.7

16 novembre

Loop chiuso 50 modi s
Camera v
2.3" se



HR3275
V=4.25
2" seeing



Cielo ruota



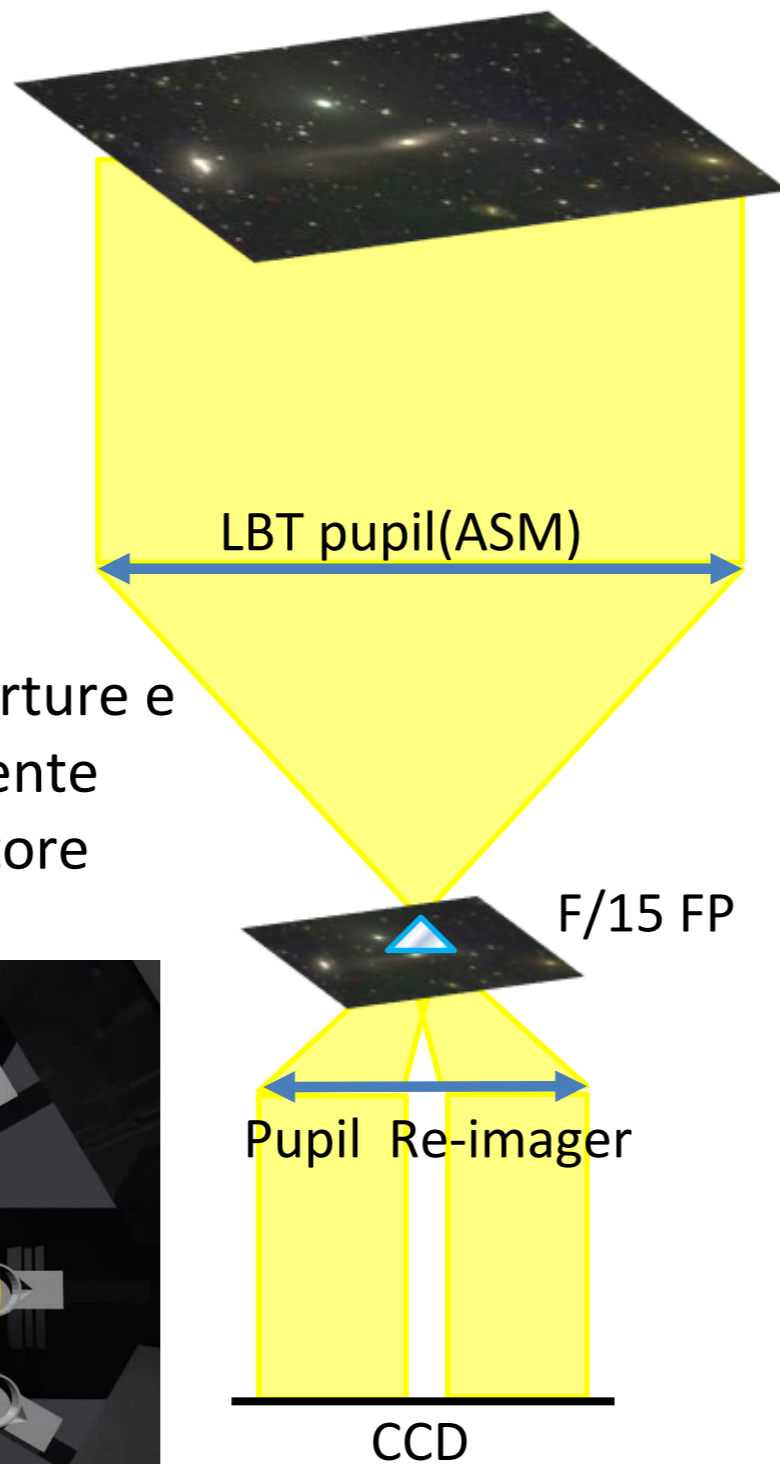
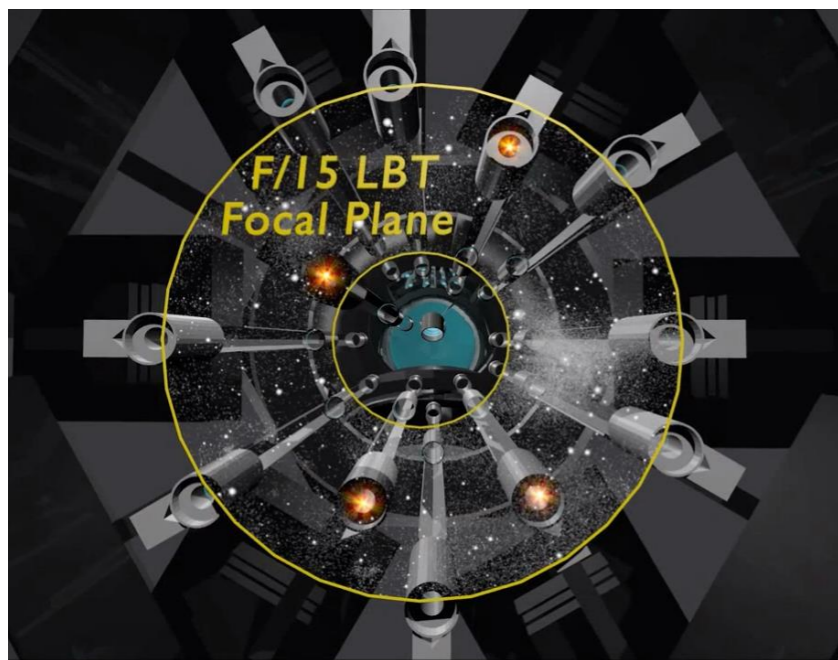
Derotatore ruota per seguire le stelle



ASM Non ruota

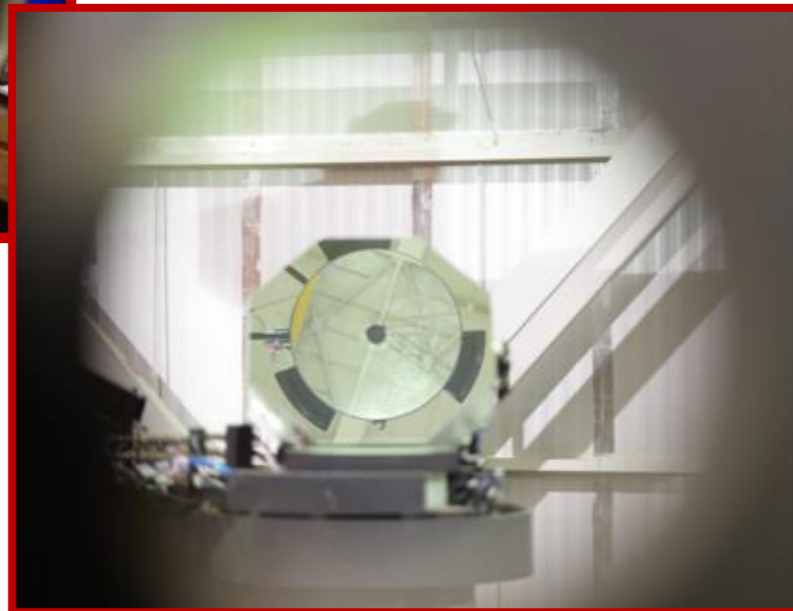
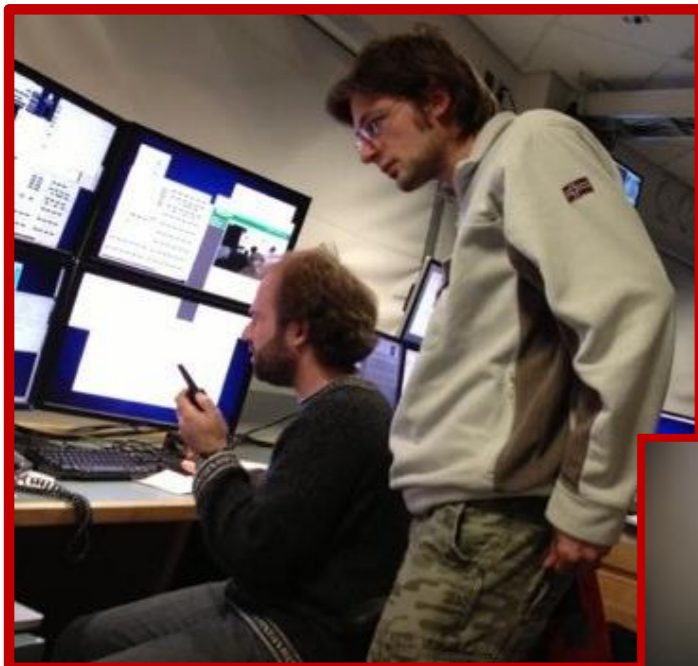


Relazione tra WFS subaperture e attuatore ASM dipendente dall'angolo del derotatore



	Static Setup	Field de-rotation
Sky		
LBT Pupil		
F/15 FP		
Re-imaged Pupils		



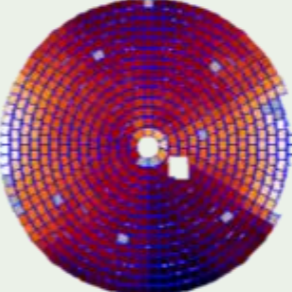
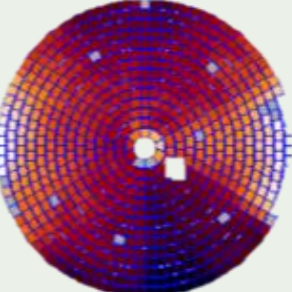


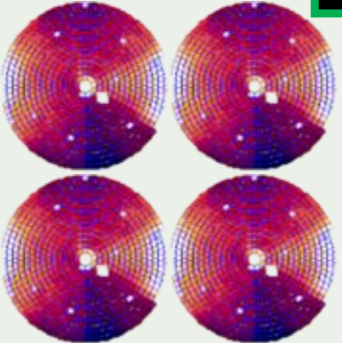
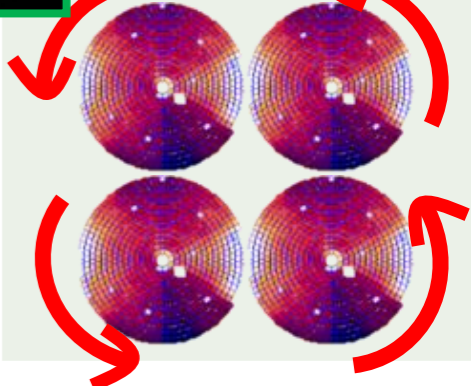
Varie matrici calibrate per alcuni angoli di rotazione, interpolate e poi ruotate numericamente per generare **ricostruttori sintetici** da 100 modi.



	Static Setup	Field de-rotation
Sky		
LBT Pupil		
F/15 FP		
Re-imaged Pupils		

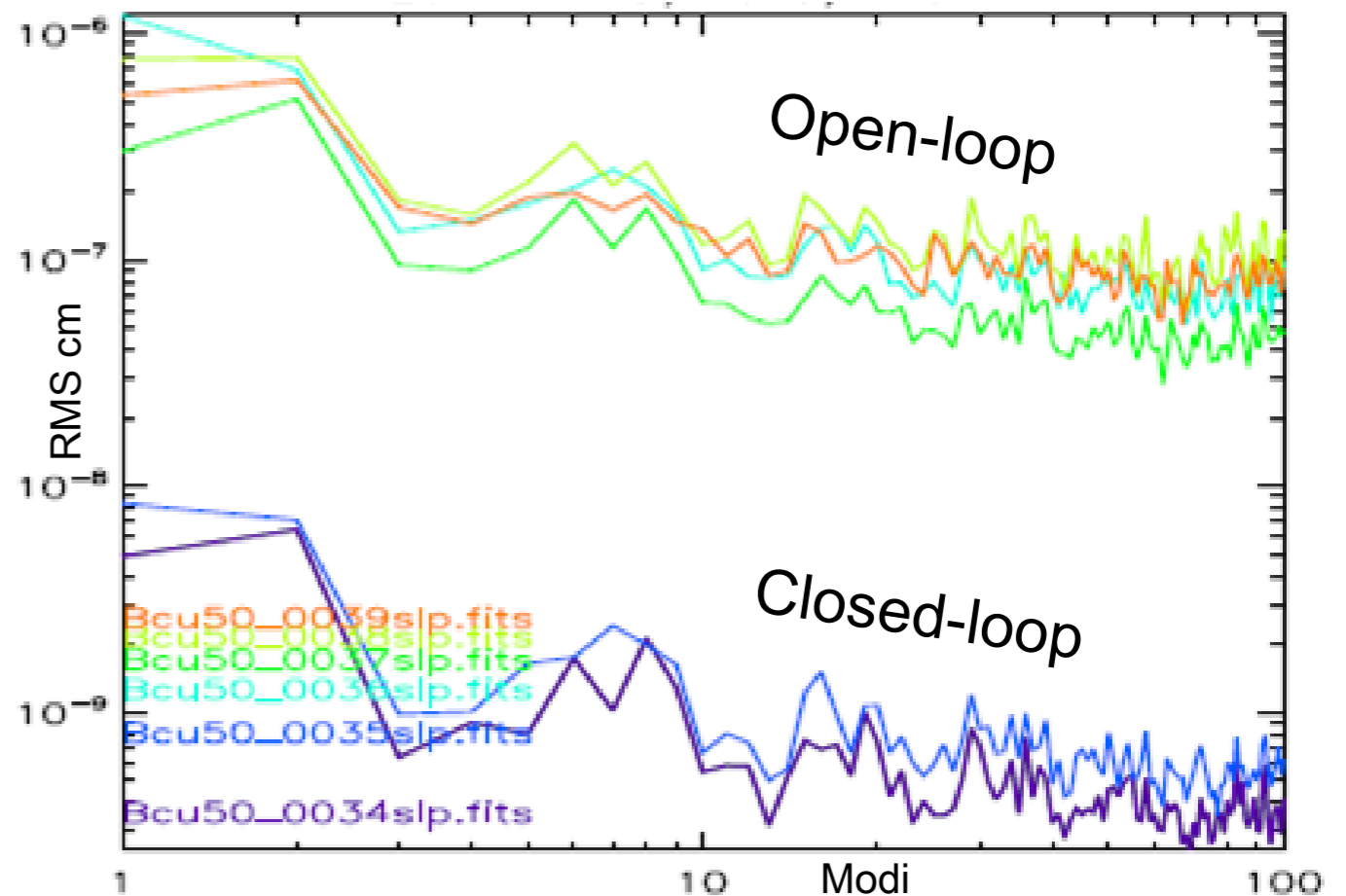
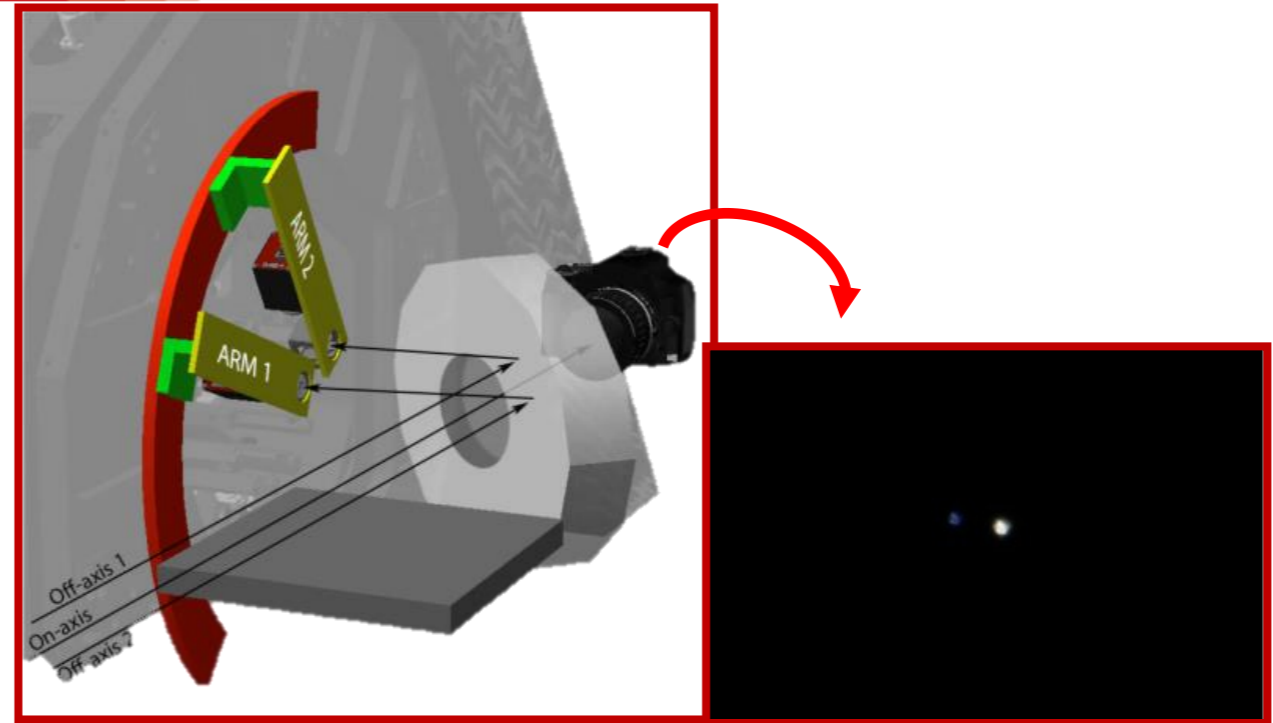
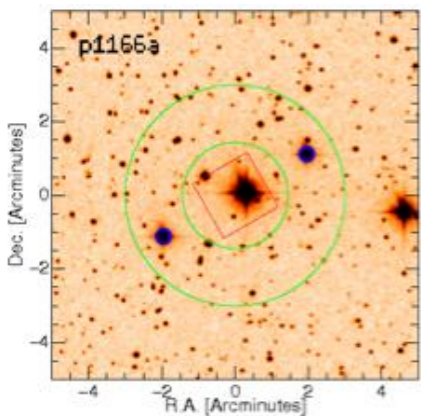
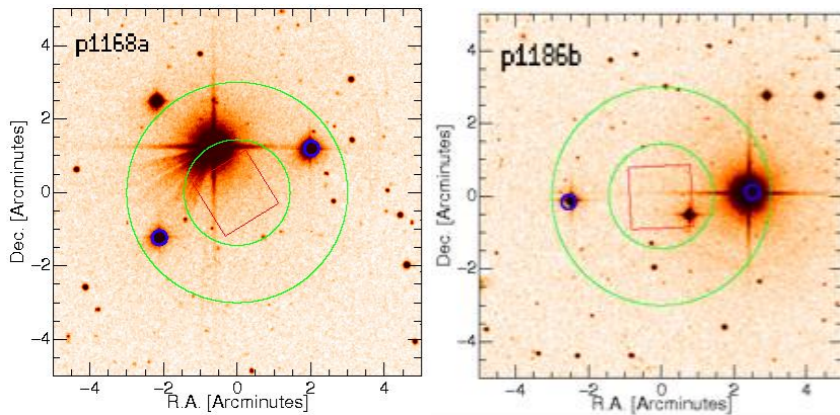
Varie matrici calibrate per alcuni angoli di rotazione, interpolate e poi ruotate numericamente per generare **ricostruttori sintetici** da 100 modi:

- Loop chiuso per **60° di rotazione!**
- **Stesso ricostruttore** utilizzato in con diverse temperature, configurazioni e SE

	Static Setup	Field de-rotation
Sky		
LBT Pupil		
F/15 FP		
Re-imaged Pupils		

Seeing $\sim 1.5''$

- **Loop chiuso su stella fuori asse** (riflessa dall'AM): correggendo fino a 60 modi



Acquisizione stelle multiple

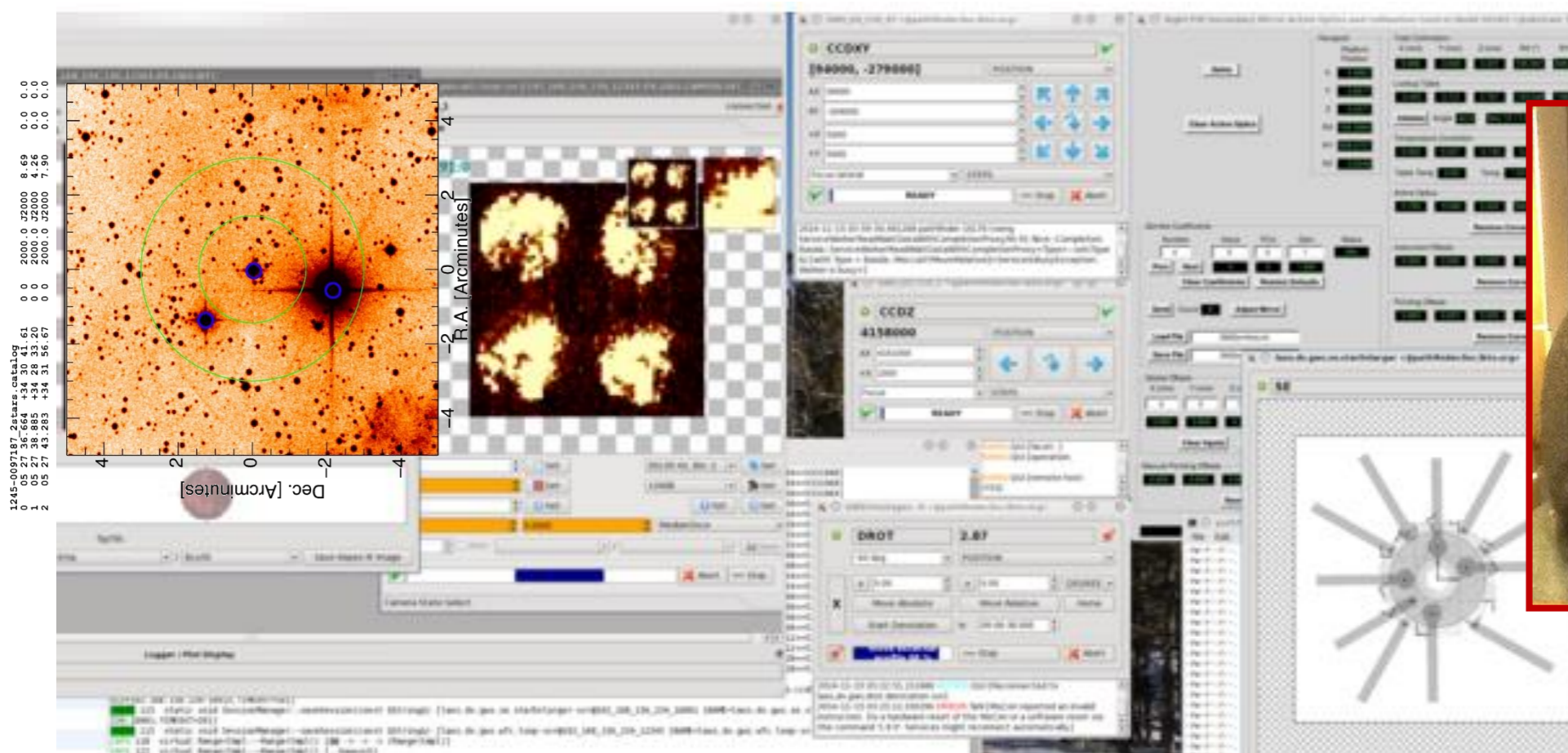


Log night 14-11-2014

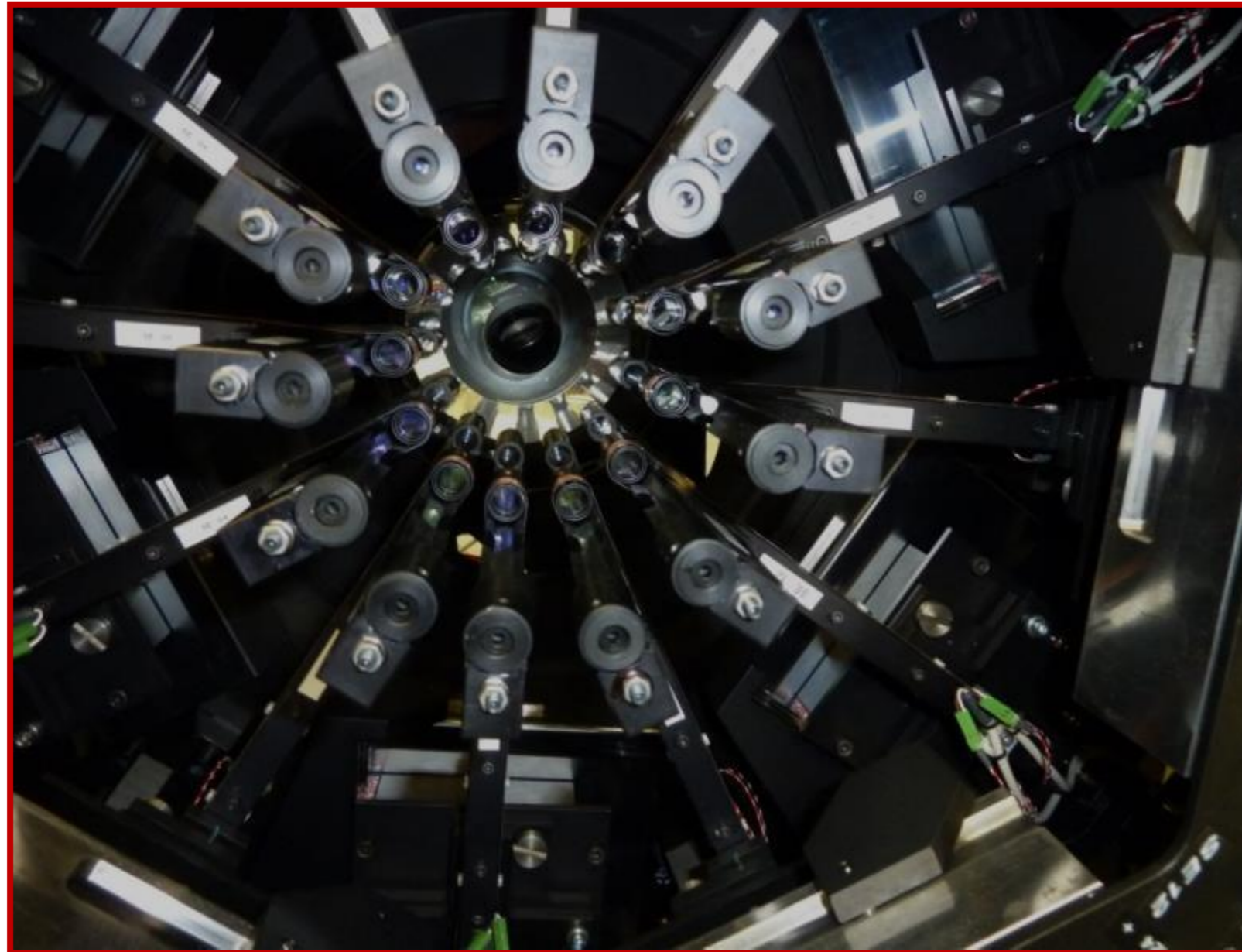
04:22 Acquired both sources simultaneously! (finally! - and <20 minutes after pre-set)

Professor Ragazzoni's immediate reaction: AN historical landmark in mankind history that makes landing on Moon and comets fading away. We acquired in fact two extremely faint stars, one 4.26 and the other of 7.9 onto two stars enlarger while we were correcting a total of $N_A/N_A - 1$ modes. Unbelievable.

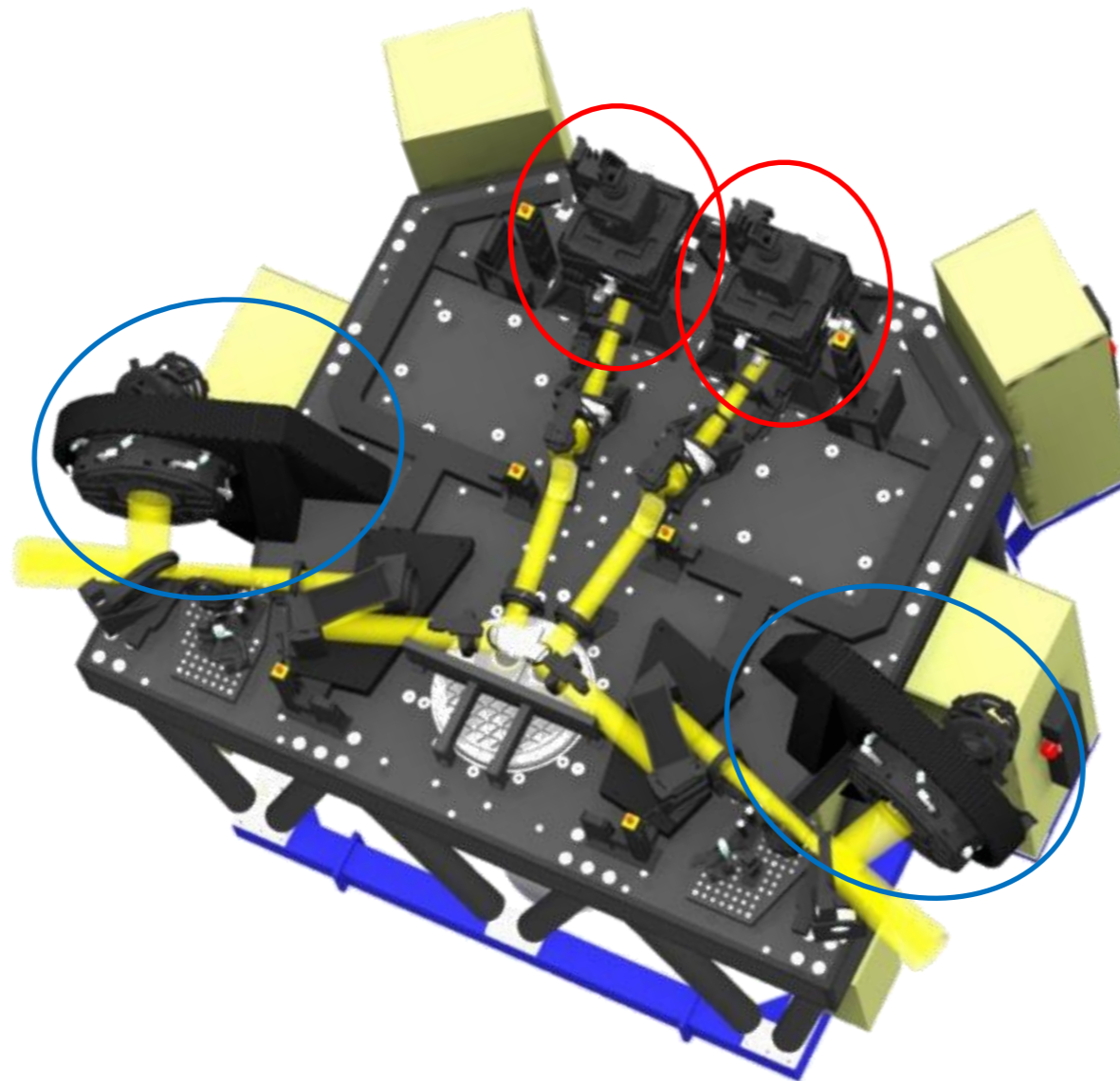
Tom's official response as PI: FUUU **CENSORED** JUUU!!!



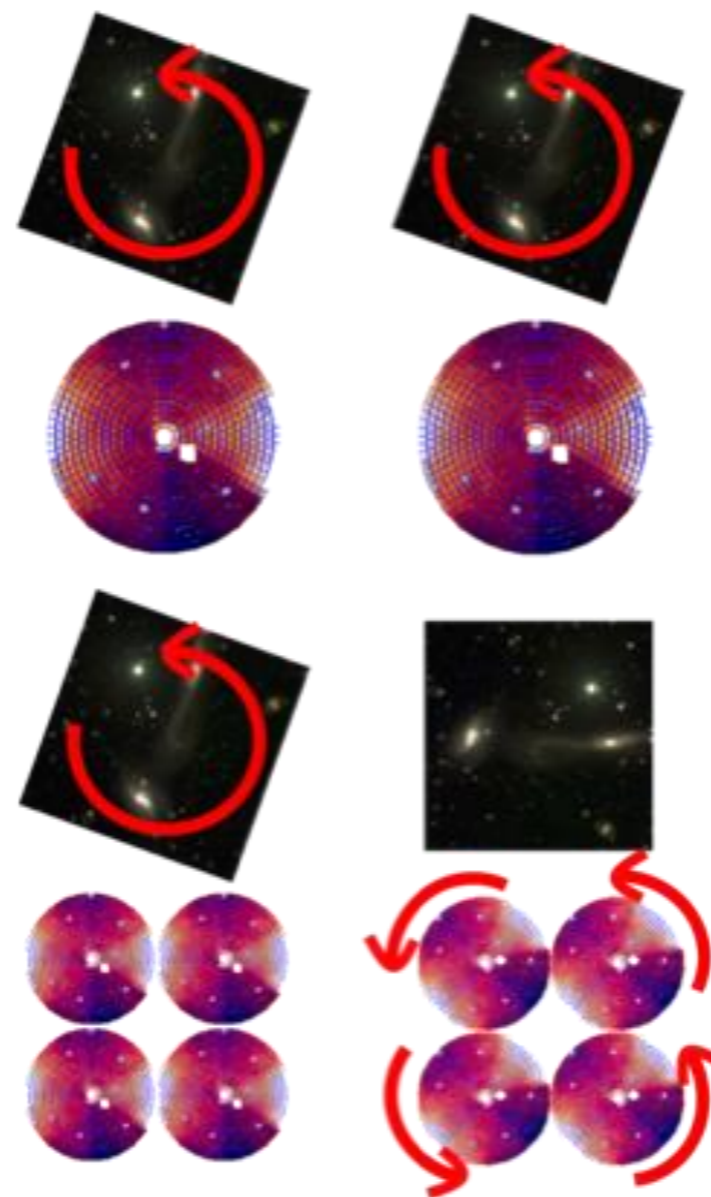
- **Geometria** e procedure per **acquisire e seguire stelle** con un WFS a 12 piramidi sono complesse...



- **Geometria** e procedure per **acquisire e seguire stelle** con un WFS a 12 piramidi sono complesse...
- **Calibrazione** diurna è fondamentale anche perché NIRVANA possiede 4 WFS.



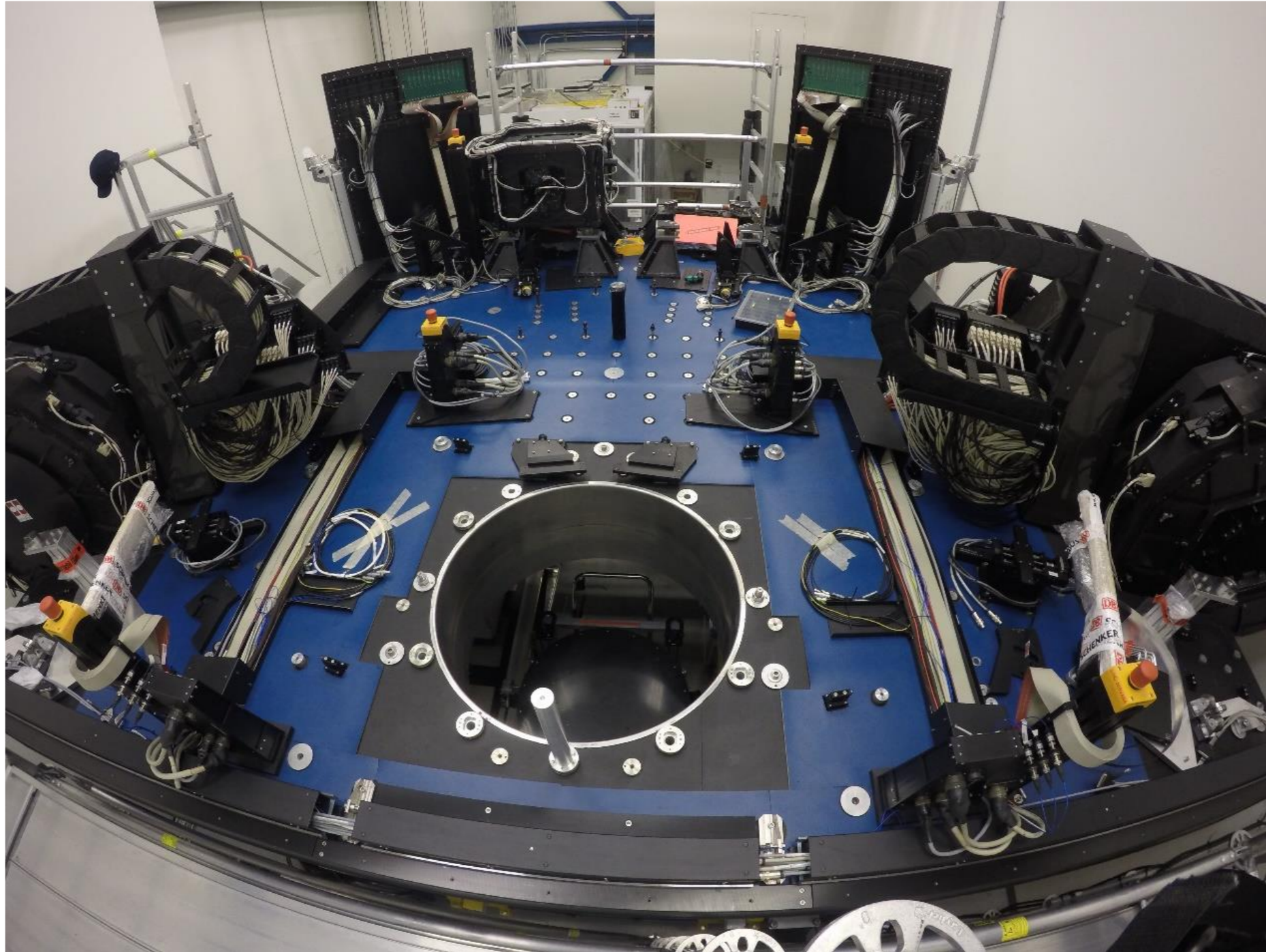
- **Geometria** e procedure per **acquisire e seguire stelle** con un WFS a 12 piramidi sono complesse...
- **Calibrazione** diurna è fondamentale anche perché NIRVANA possiede 4 WFS.
- Creazione di **matrici di interazione sintetiche** è molto robusta e rapida.



L'esperimento **Pathfinder** di **LINC-NIRVANA** a **LBT** ha permesso di raggiungere tutti gli obiettivi di base ed **acquisire conoscenze fondamentali** per il **commissioning** di **LINC-NIRVANA**.

Problemi tecnici e ambientali hanno impedito di completare alcuni obiettivi extra come chiudere il loop su stelle multiple e di provare l'efficacia del GLAO con l'utilizzo di una camera NIR.

Conclusioni



Grazie per l'attenzione!

Other members of the LN Pathfinder team:

Harald Baumeister, Al Conrad, Thomas Bertram, Jürgen Berwein, Florian Briegel, Tom Herbst, Ralph Hofferbert, Frank Kittmann, Derek Kopon, Martin Kürster, Lars Mohr, Kalyan Radhakrishnan