The Camera Challenge

Gavin Dalton

RALSpace

Science & Technology Facilities Council

Big: 2.5m

Heavy: 2.5T

Requires lots of consumables

IR Camera

Long gestation: >2yrs

Long lifetime: >25years

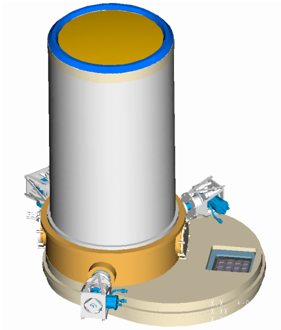
Produces vast quantities of output

Difficult thermal control

Difficult to control

Difficult to handle

Difficult to transport



Precision optics

Coplanar detectors

Cryogenic temperatures

The four basic personality types

Timeline

- System Design Phase (post CoDR): Apr 02
- PDR held December 02
- FDR held January 04
- Camera fully built May 06
  - Moved from assembly area
- Delivery to Paranal Jan 07

- On-sky mid-2008
  - Commissioning of camera + telescope through mid-2009

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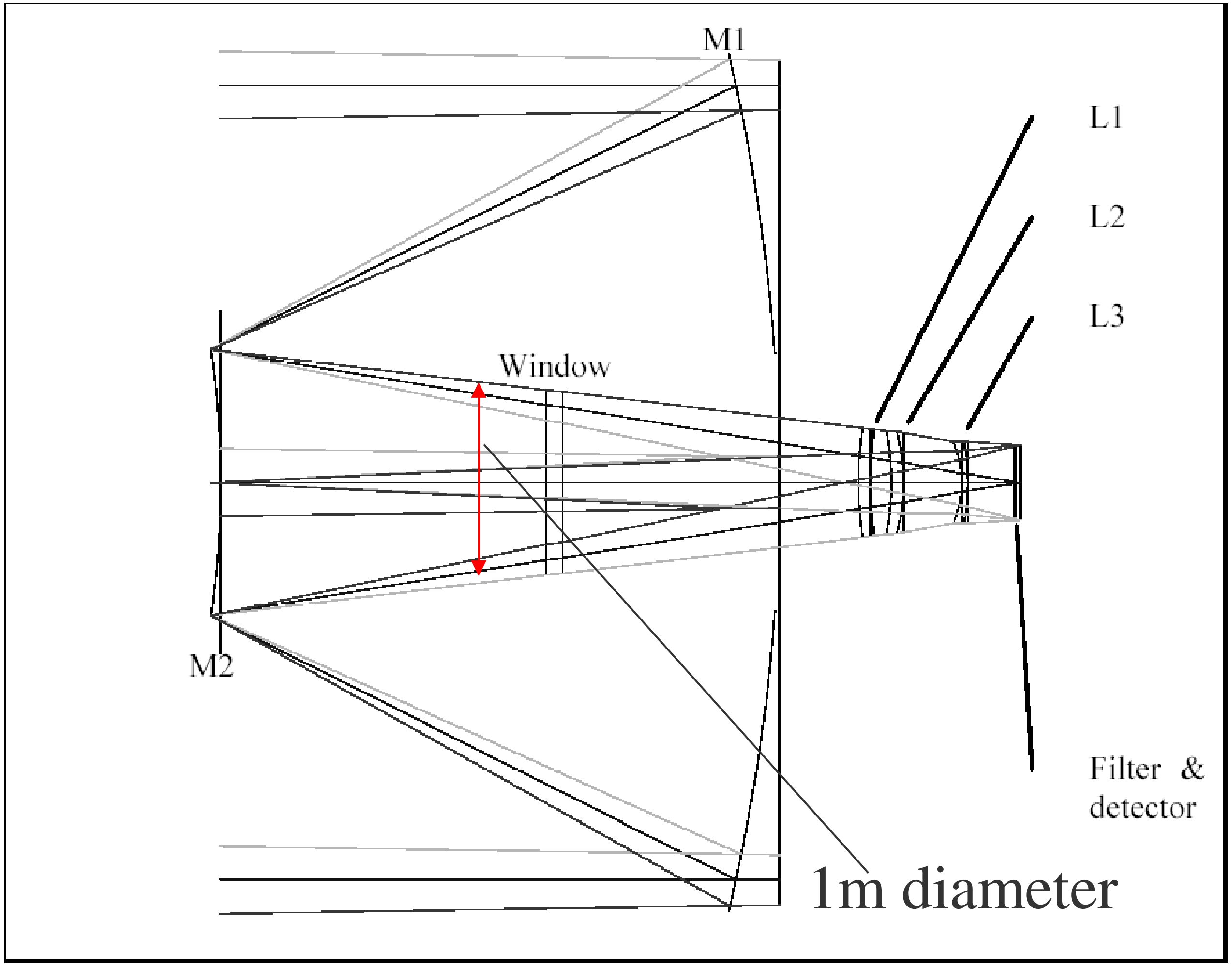
Basic Parameters

- Field of View 1.67 degrees @ f/3.3 (350mm focal plane)
- 16 2048x2048 Raytheon VIRGO HgCdTe Arrays (840µm-2.5µm sensitive)
- YJHKs baseline filter set (one filter per detector)
- 3 vacant slots in wheel (Z filter to take one)
- 4 2048x2048 E2V CCDs for wavefront sensing
- 2 2048x2048 E2V FT CCDs for autoguiding
- 7 nested 'dichroic' baffles for stray light control

Optical System



Telescope and camera design optimised as a single system

Full system delivers 0.5” images (50% EED). Image distortion < 2% at extreme edge of field

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Challenges

- Cryostat
- ~1m vacuum window
- Focal plane co-planarity (±25μm)
- Detector procurement (ITAR)
- Wavefront sensing (totally new)
- Stray light baffles
- Testing (optical system – 7000nm astigmatism)
- Handling (in the lab and to/at the telescope)

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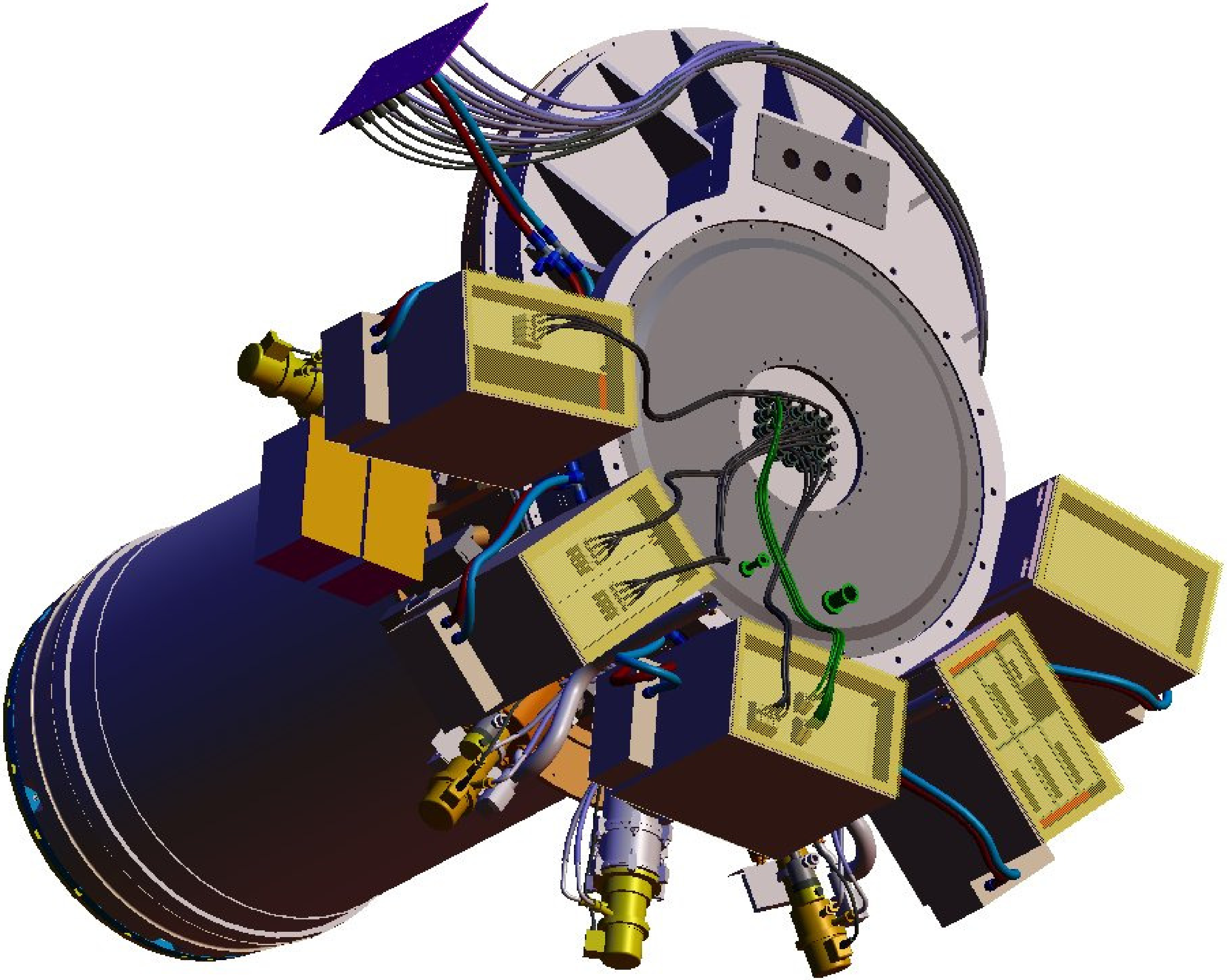
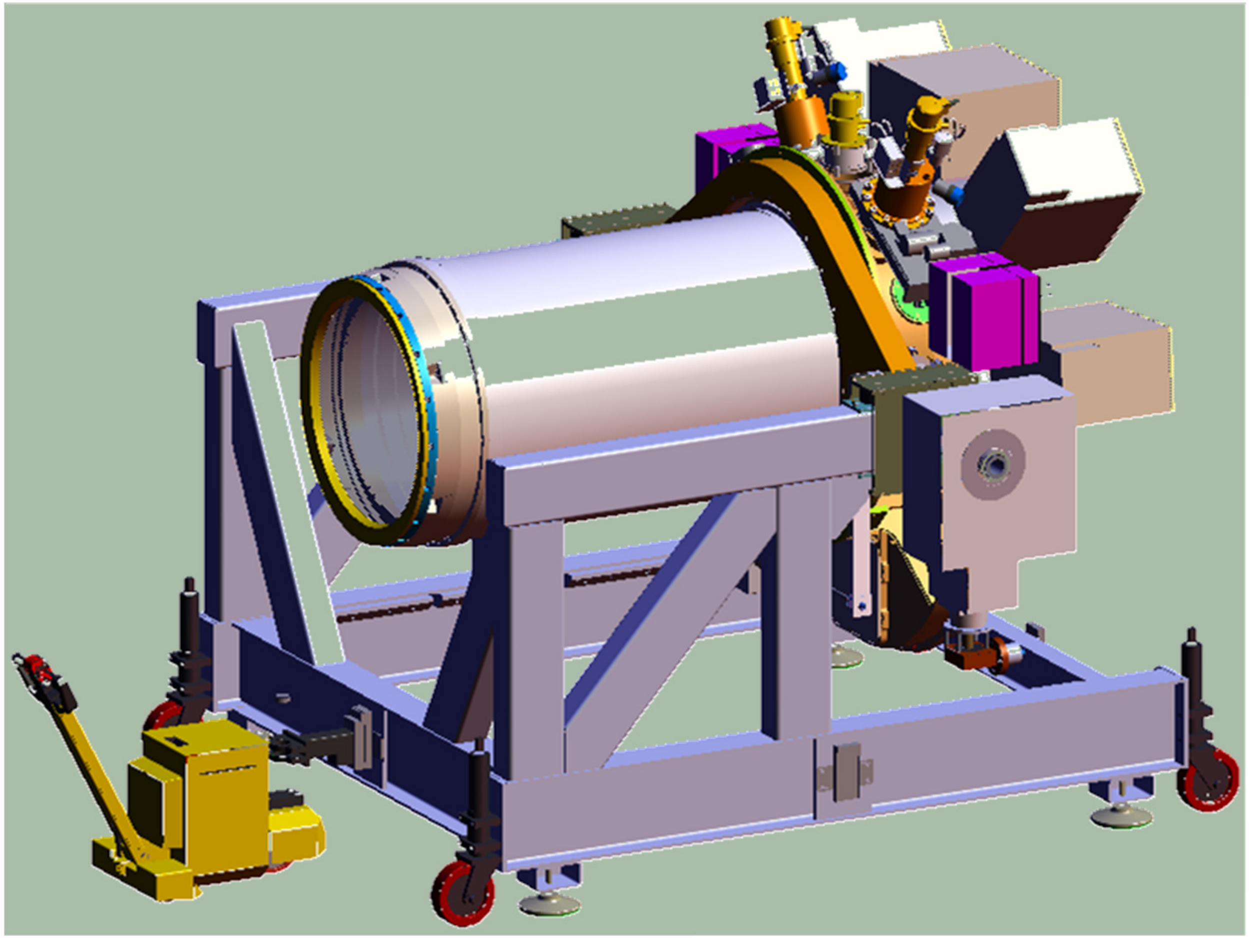
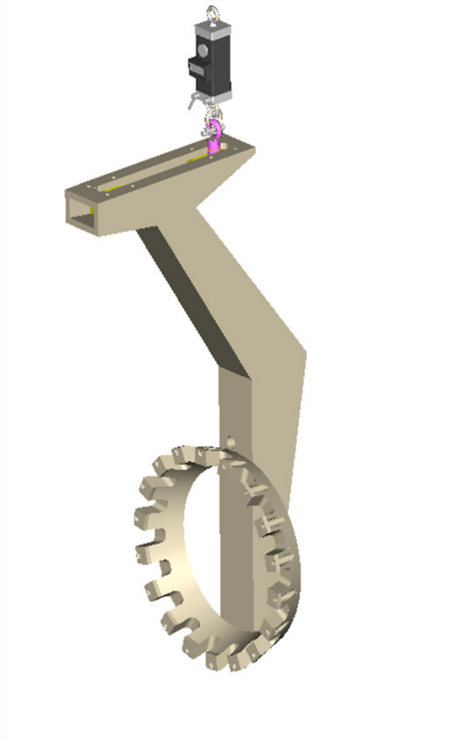
Cryostat

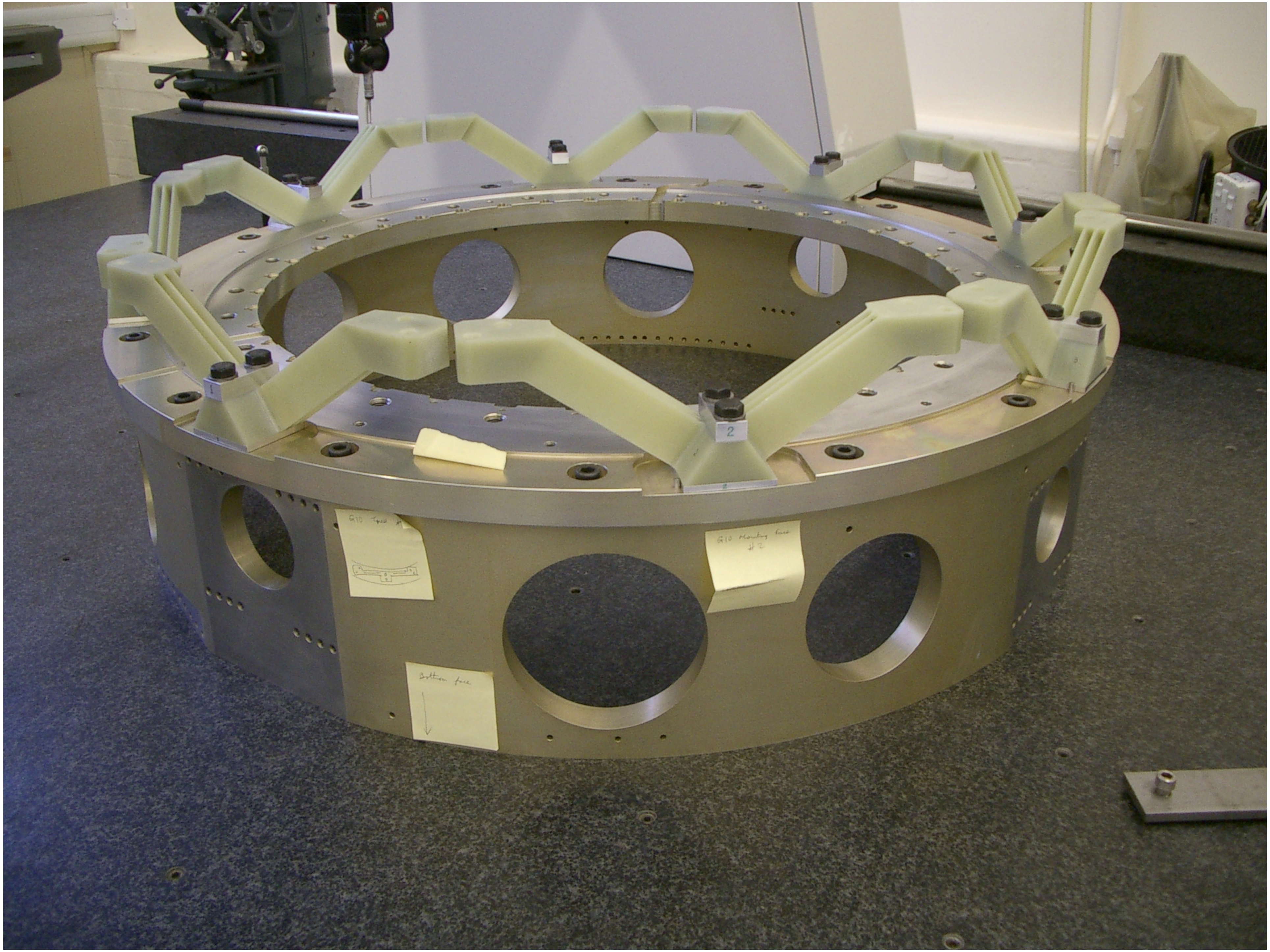
- 5 sections, 15m of o-rings
- Limited possibilities for suppliers
- Substantial CAD assistance needed from RAL
- Supplier staffing issues (non-work related injuries)
- Heat shields (use of MLI rejected)
- The ‘shrinkage’ problem

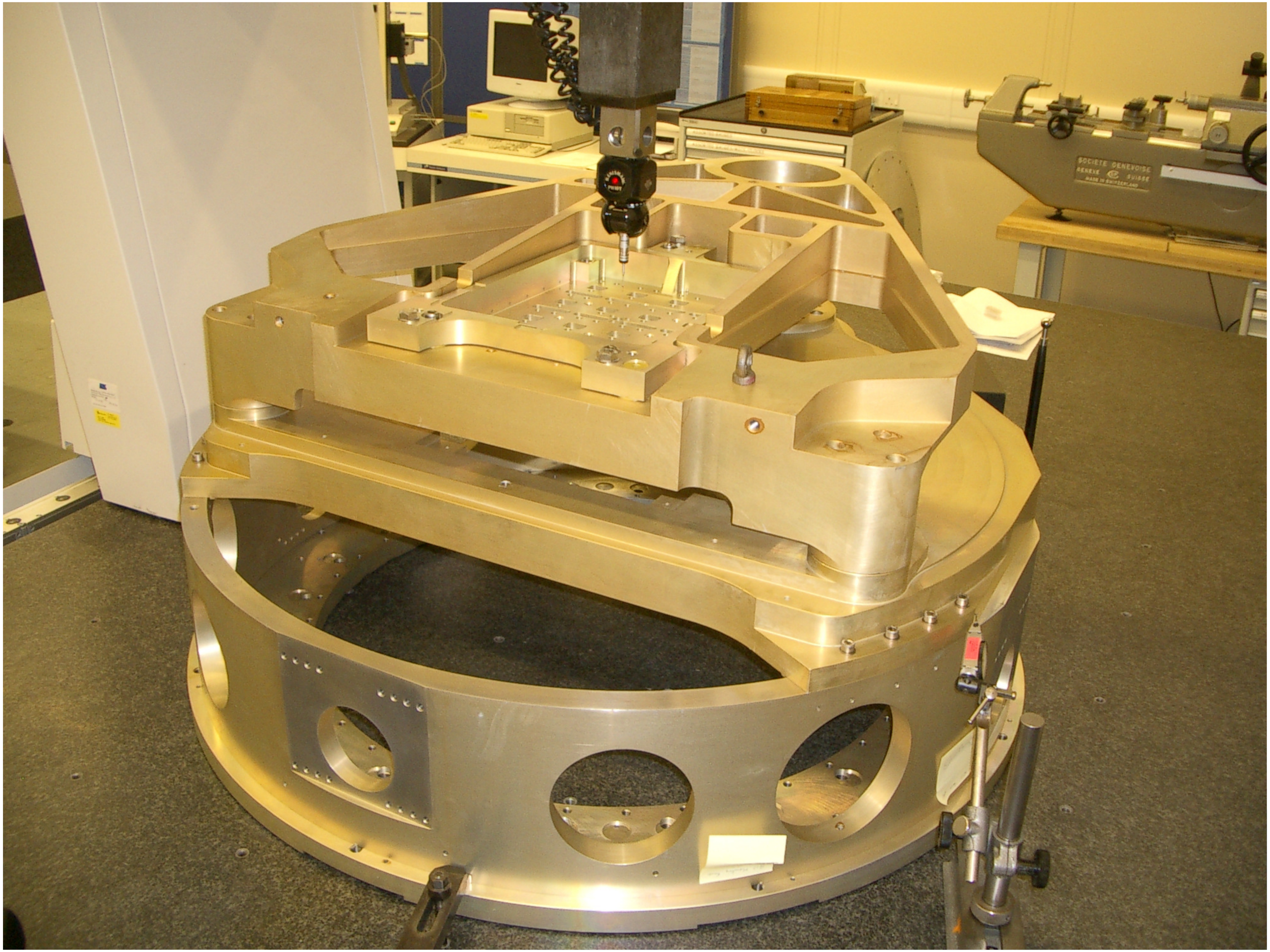


Handling Issues

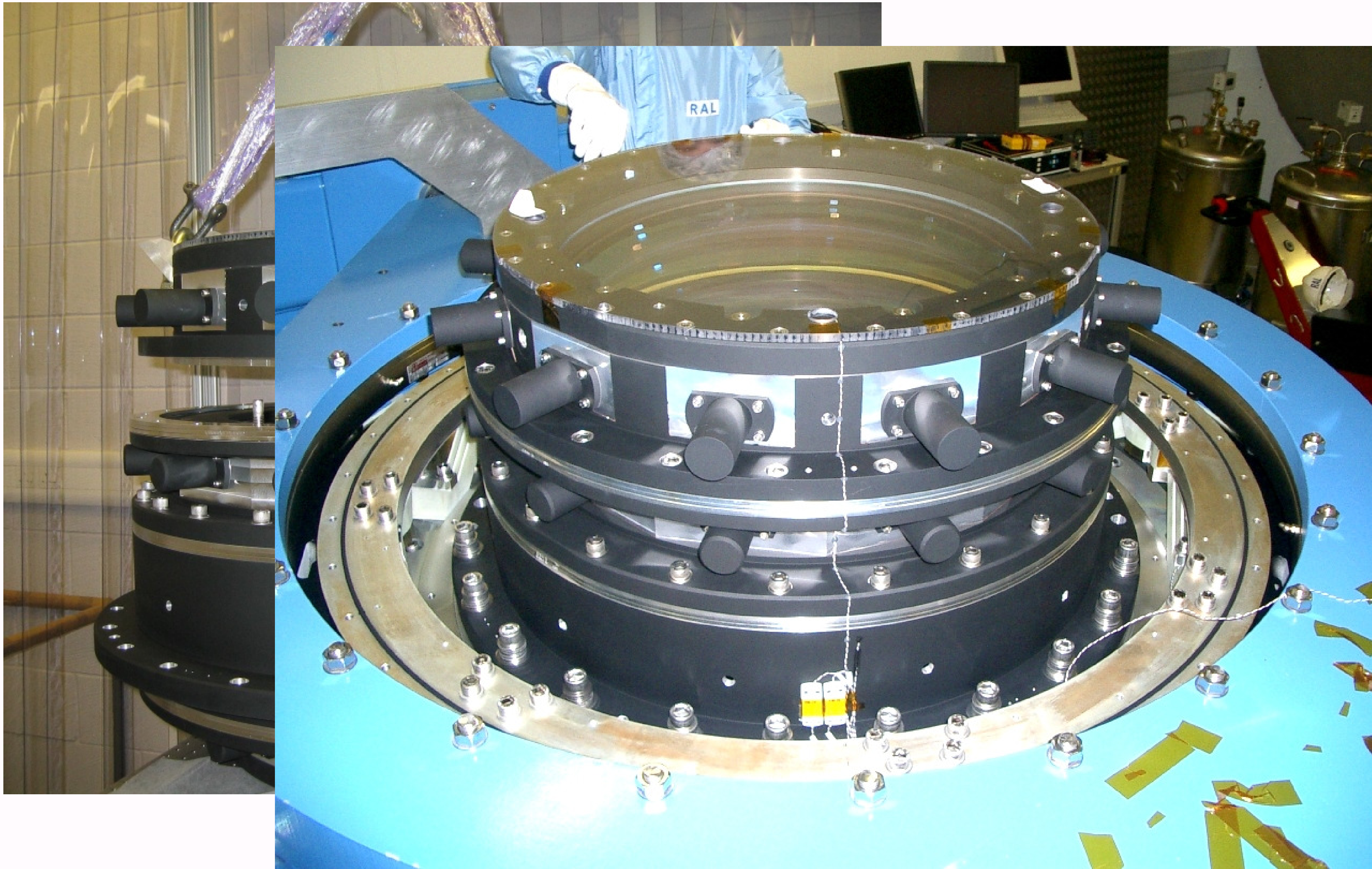





G10 Mounting face
#2
Bottom face


SOCIETE GENEVOISE
GENEVE SUISSE
MADE IN SWITZERLAND

Field Corrector



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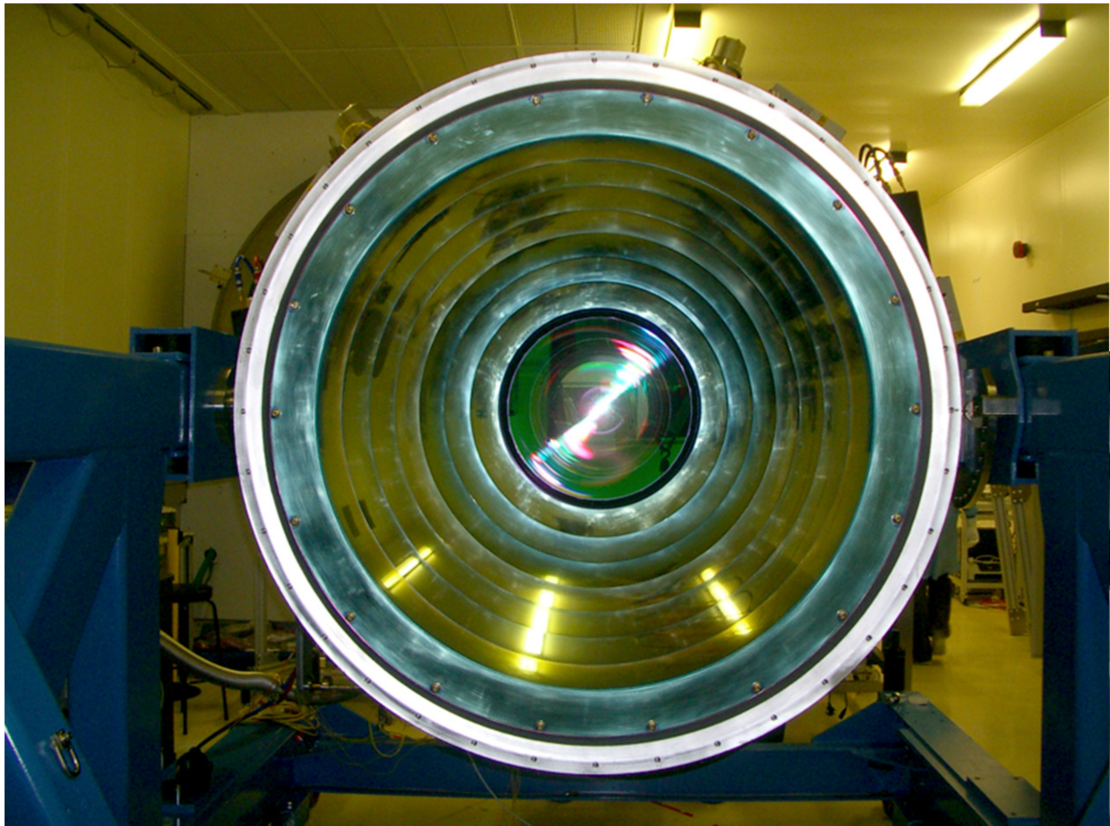
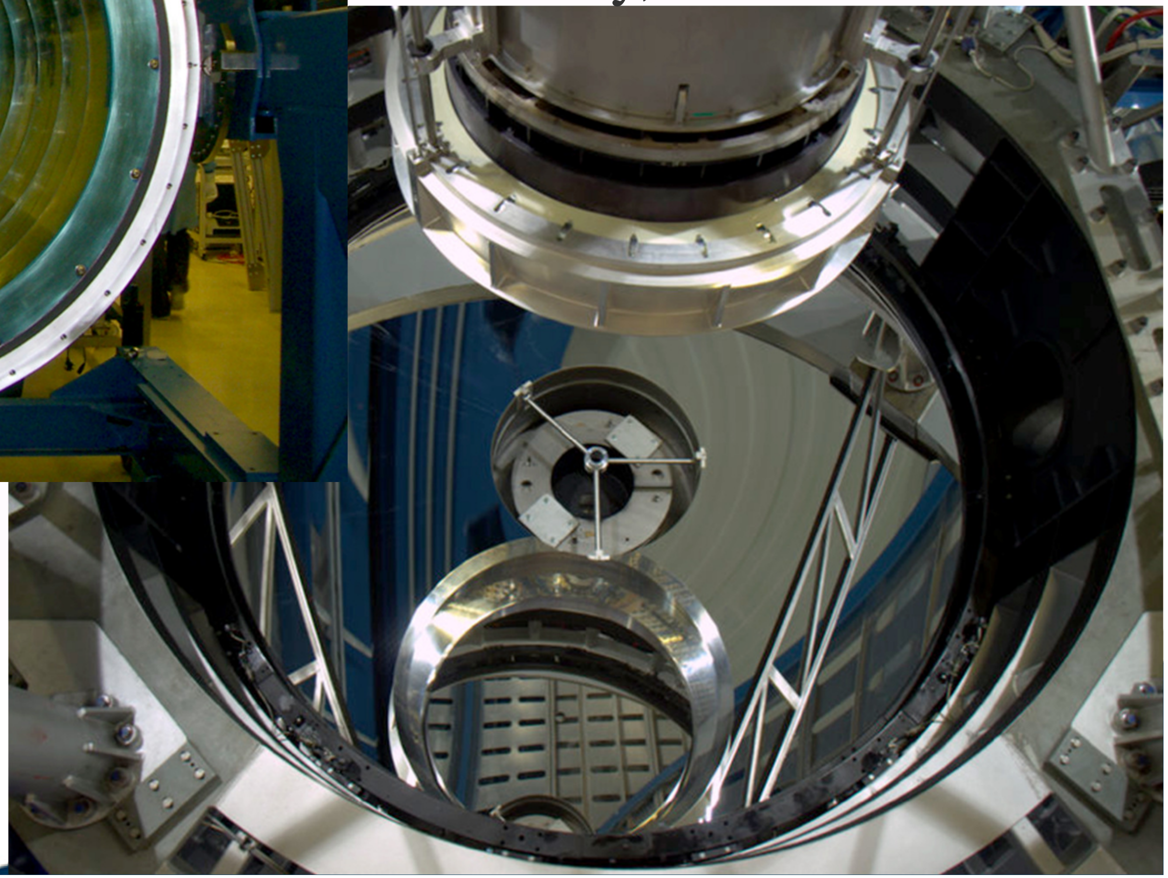
Baffle system

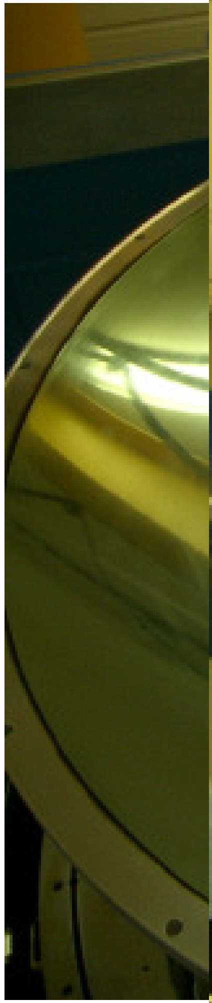


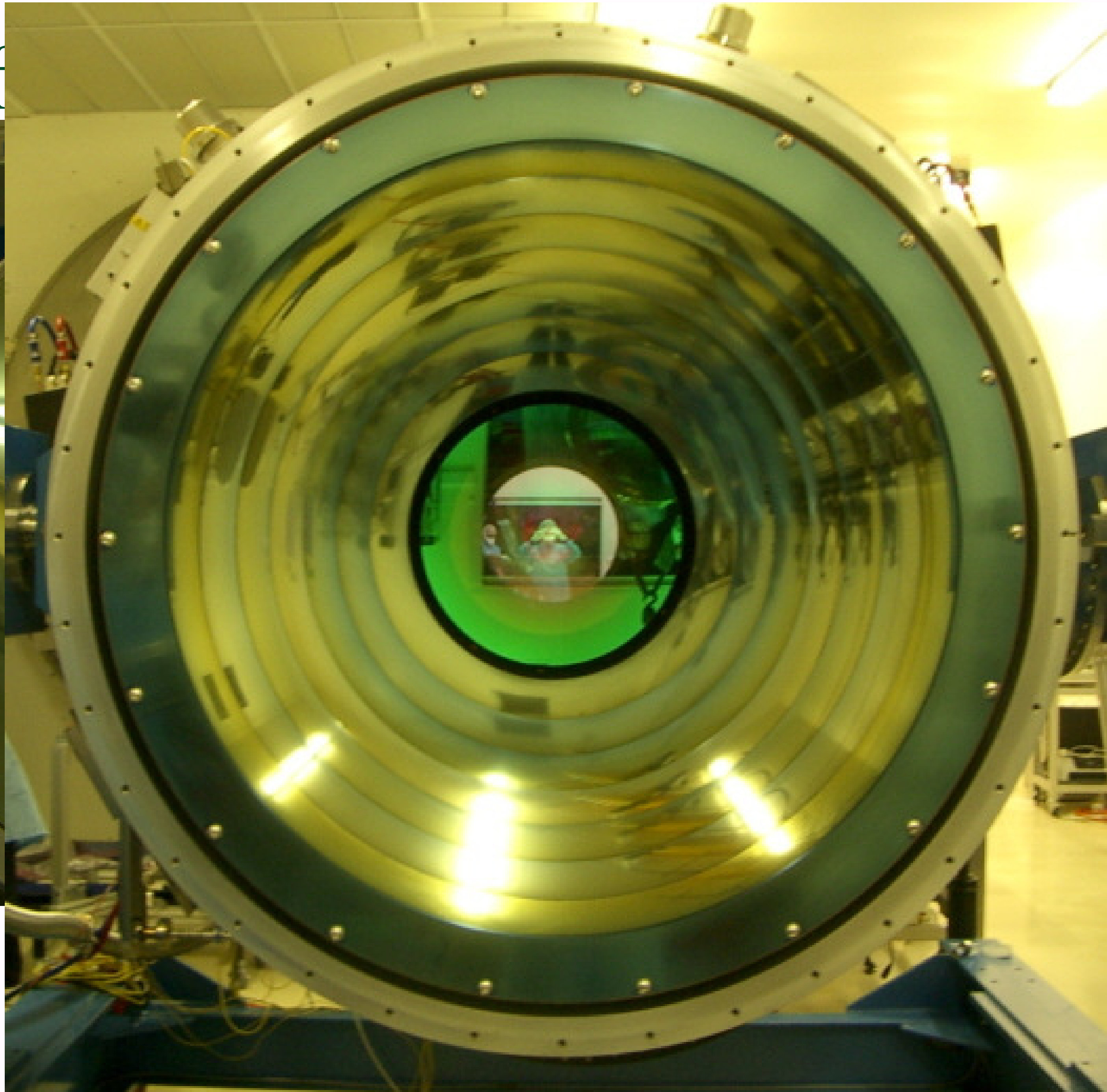
On-telescope: double reflective baffle around M2 restricts camera view past secondary, obstruction 1.4m.

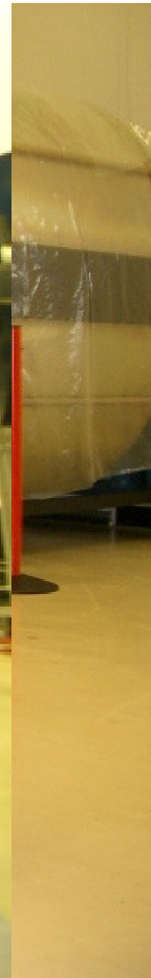


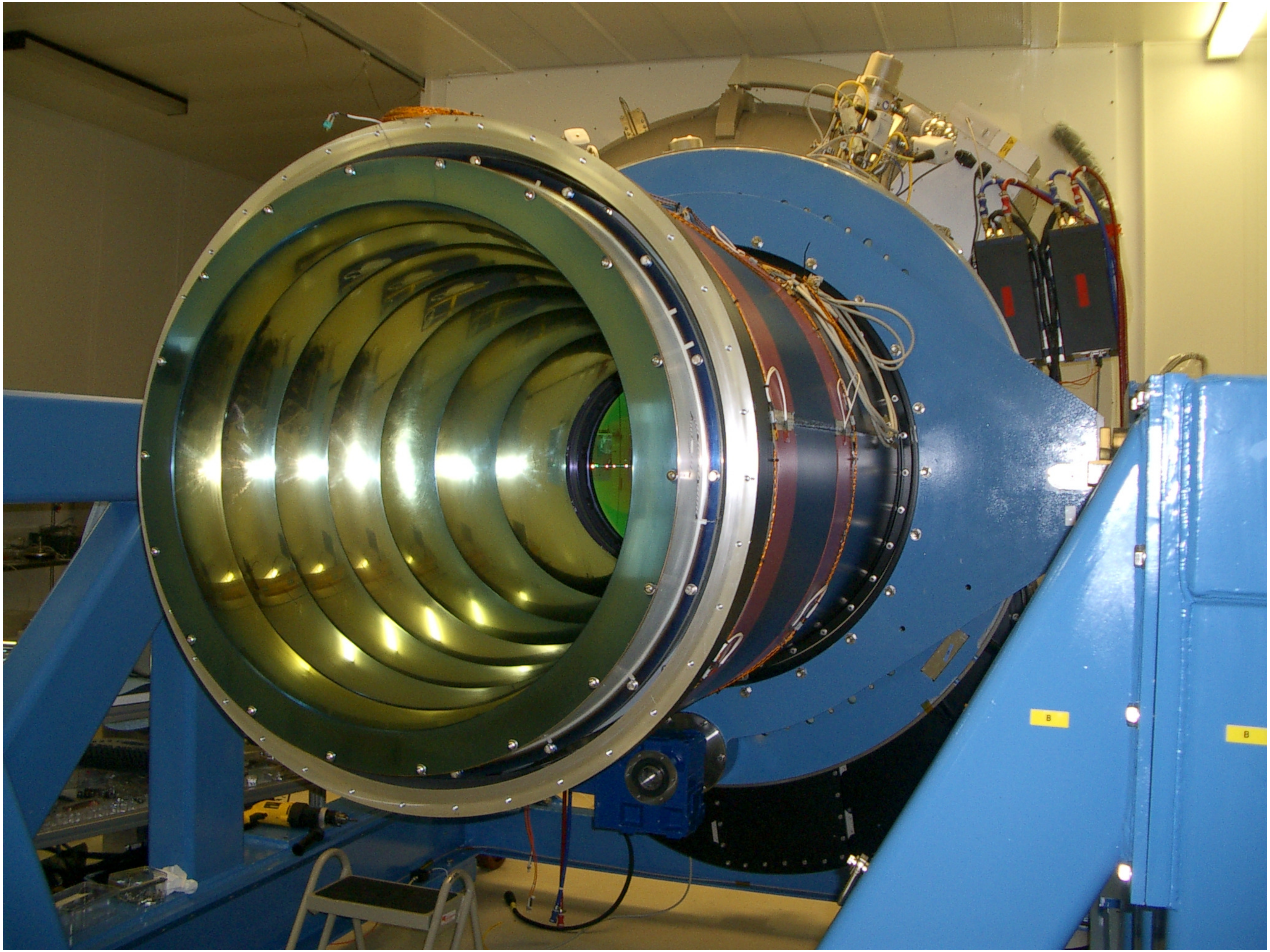
In Camera: 1 flat, 7 nested elliptical dichroic baffles, reject out-of-band thermal through dewar window.

Baff

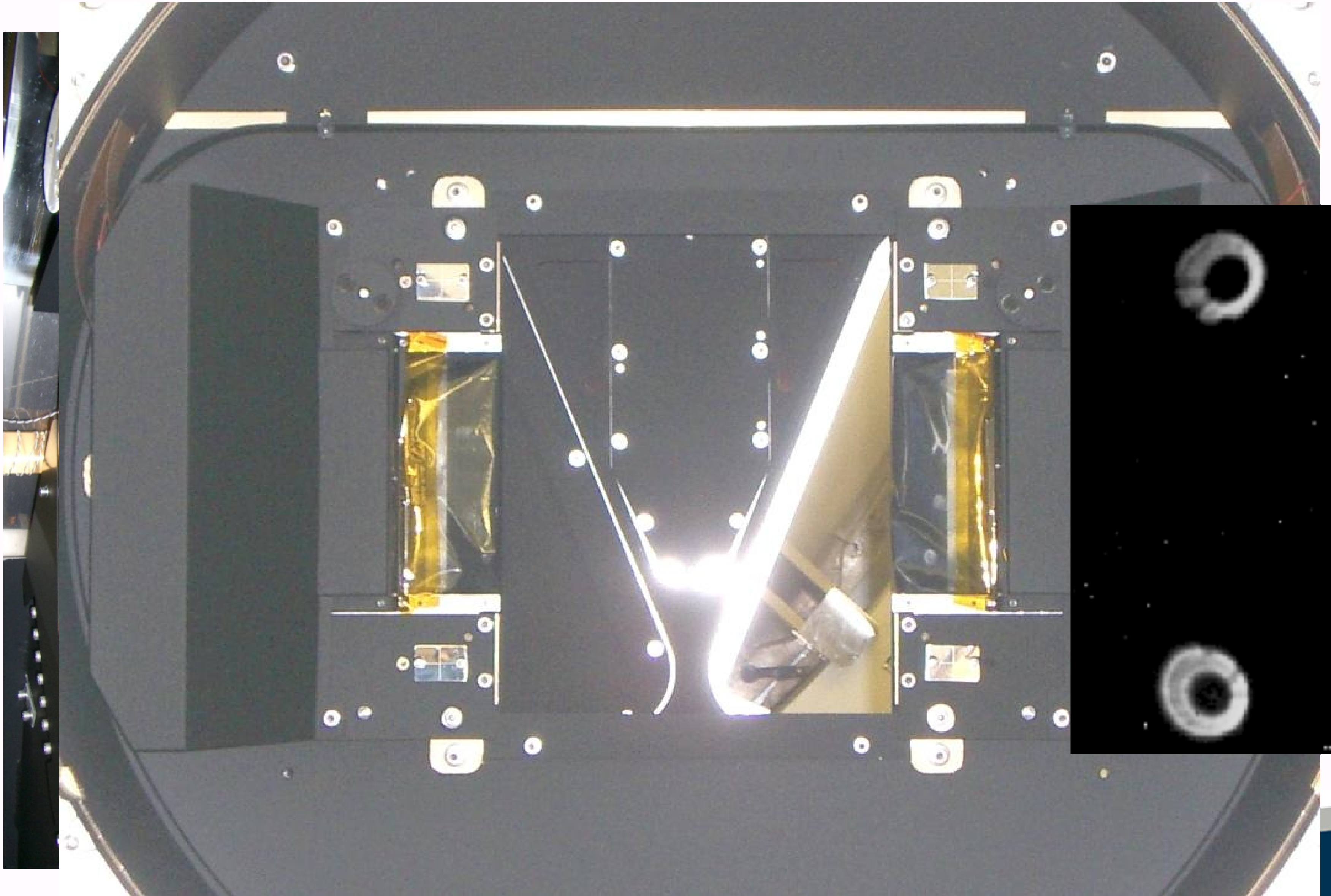






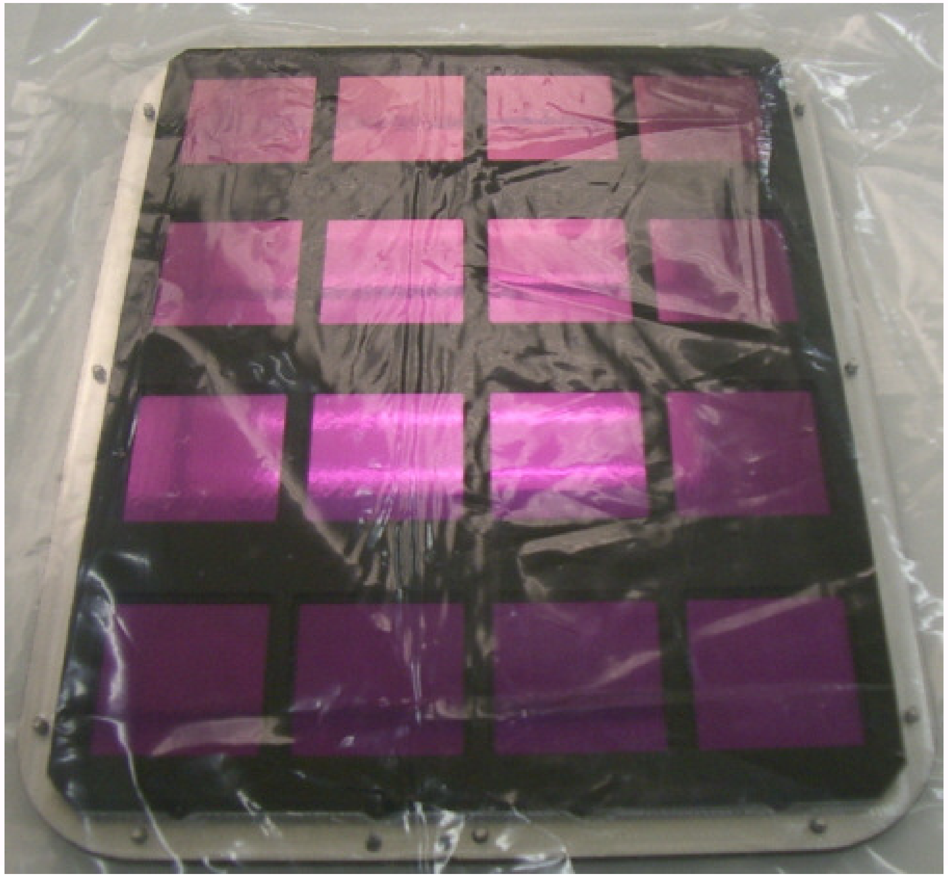

B
B

Wavefront Sensors/Autoguiders



Filter Wheel

Each tray has 160 separate components…



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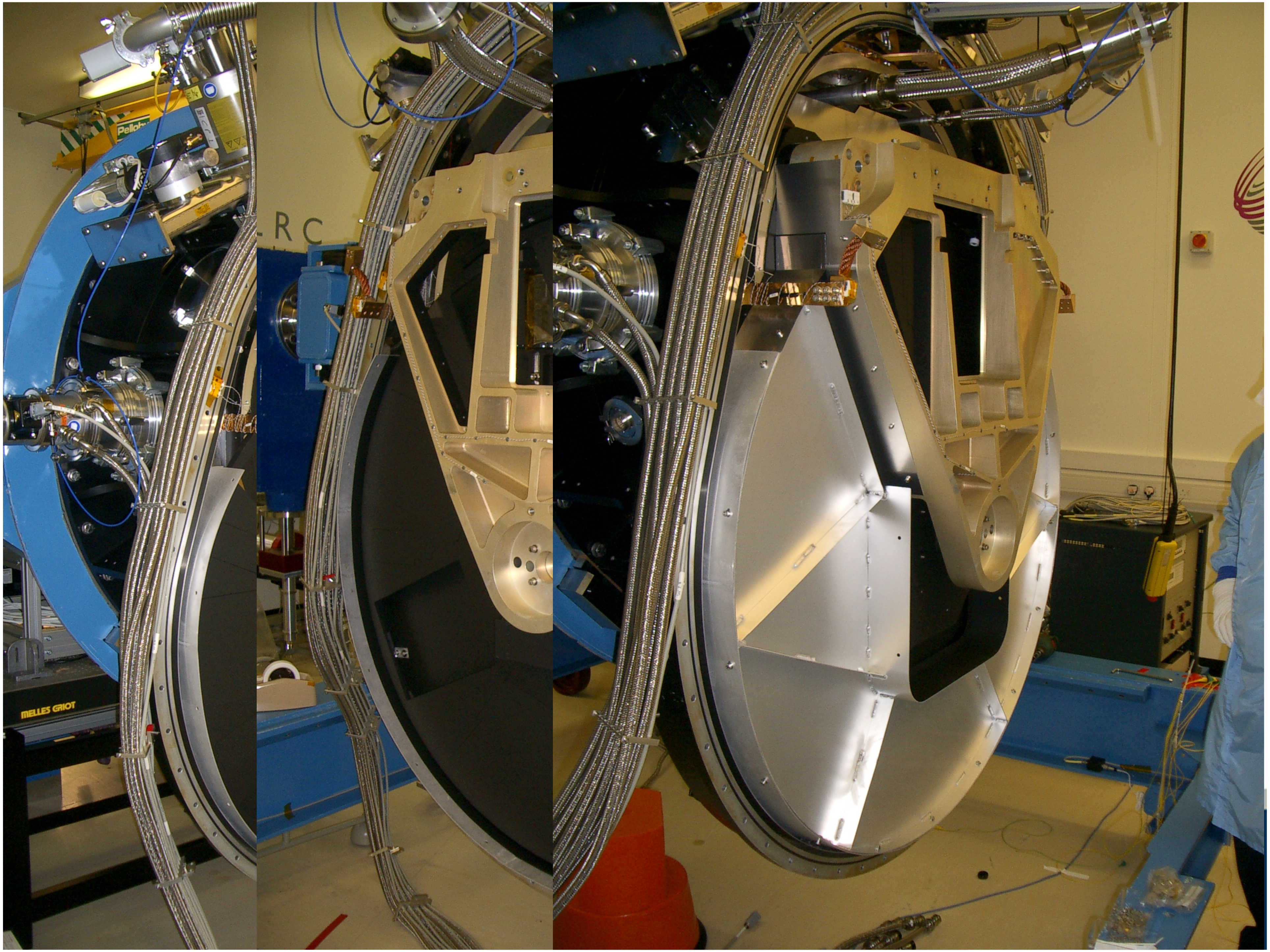
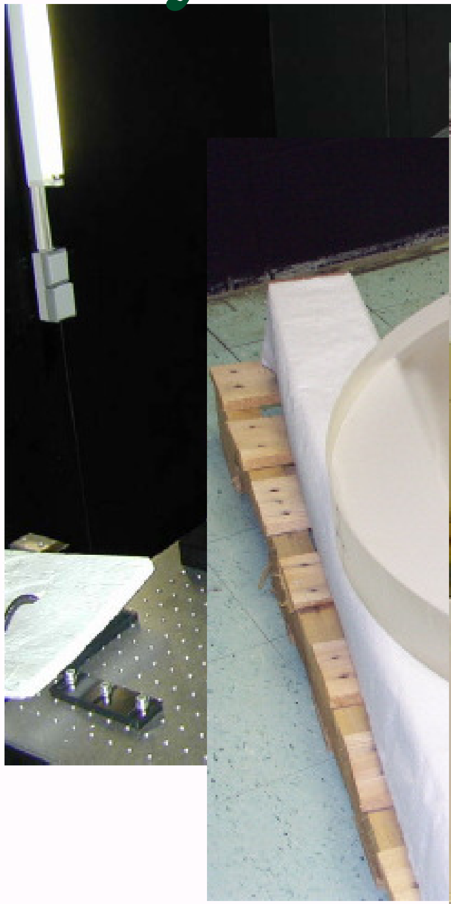
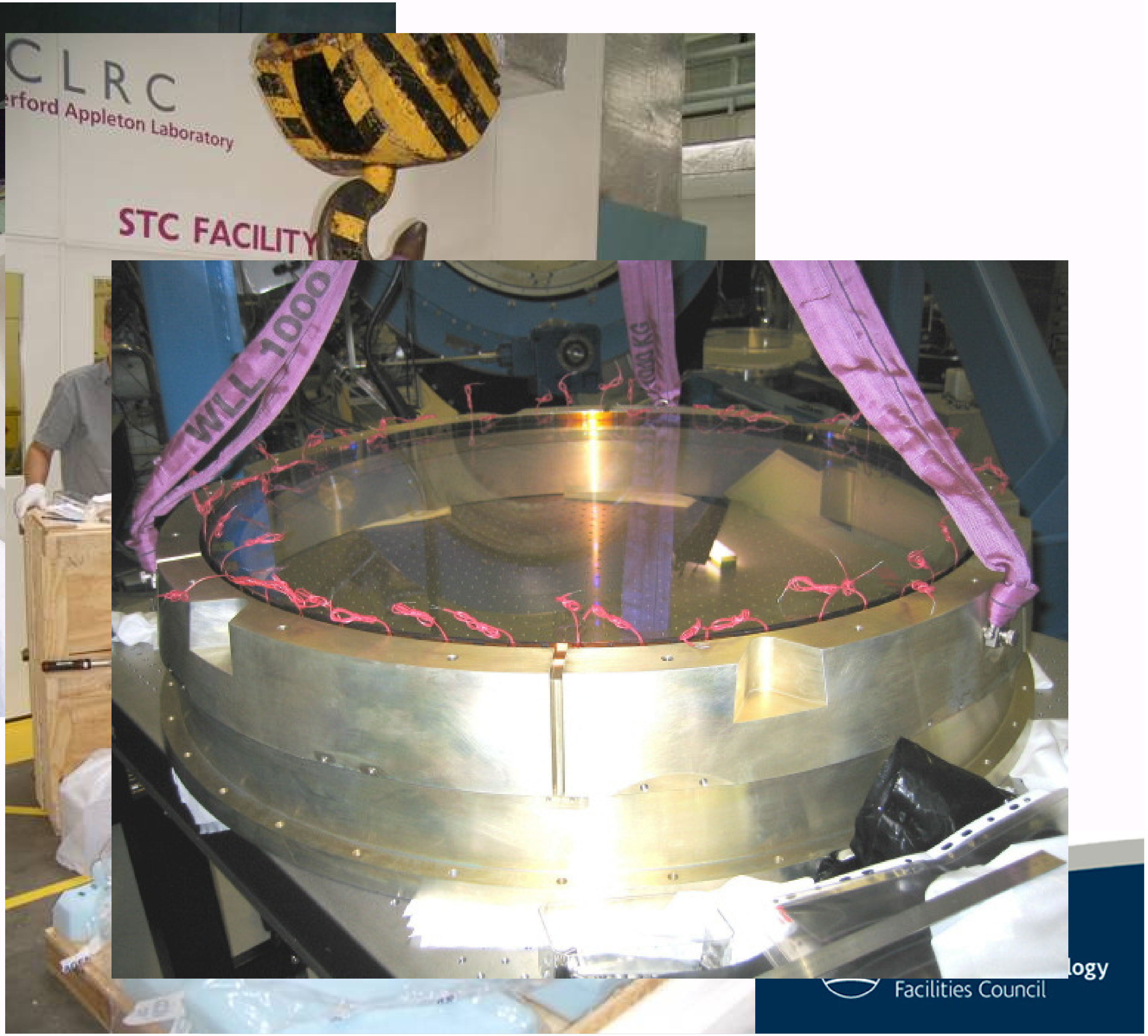

MELLES GRIOT

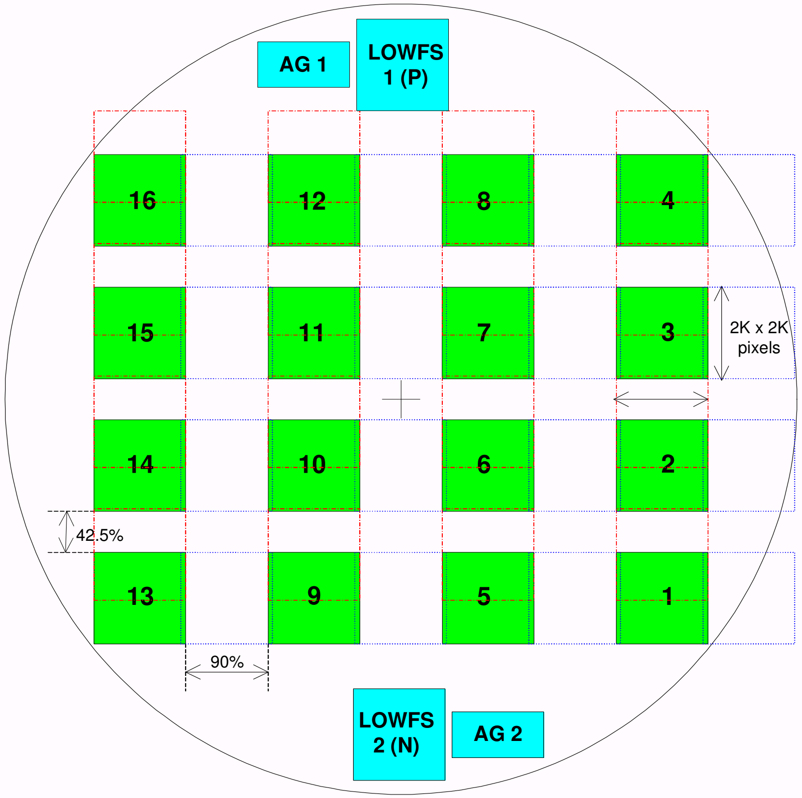
Cryostat Window

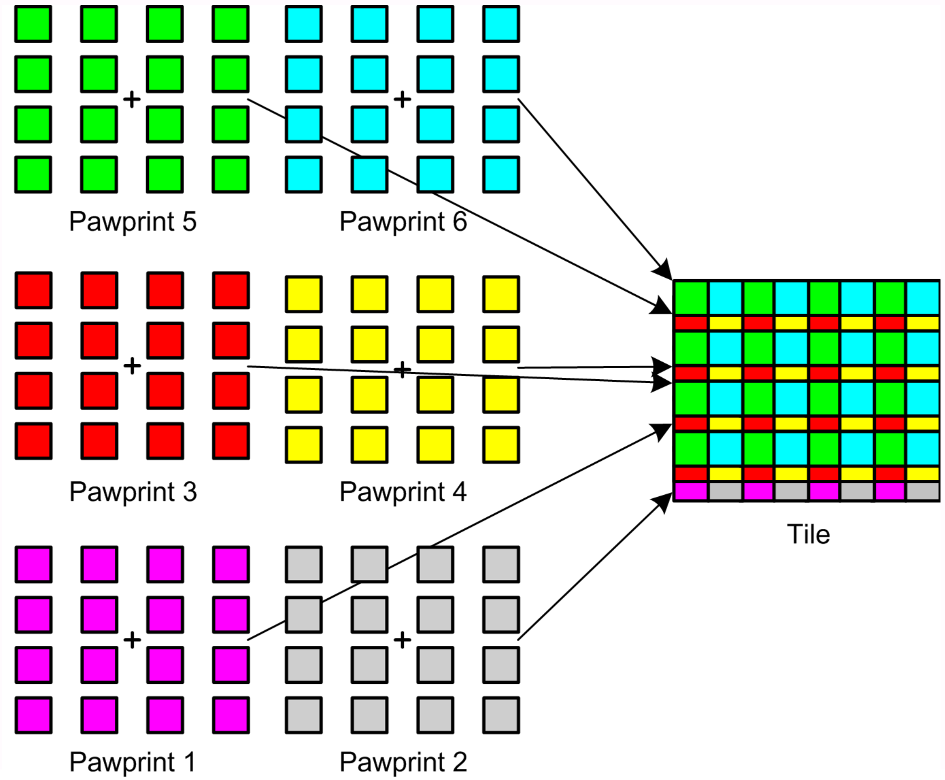




0.8MJ of stored potential energy due to pressure on the window!

Focal Plane Layout -> Images





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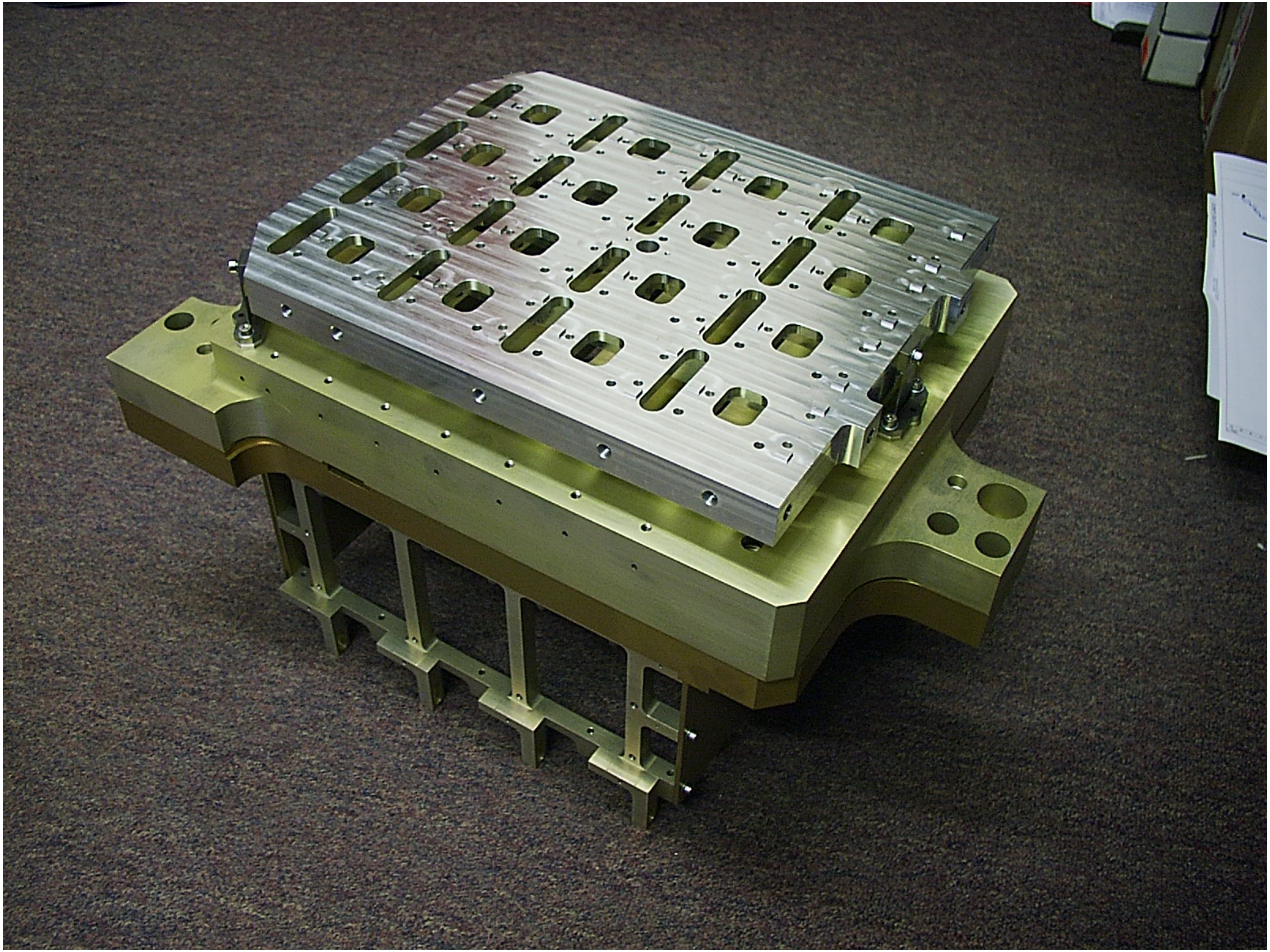
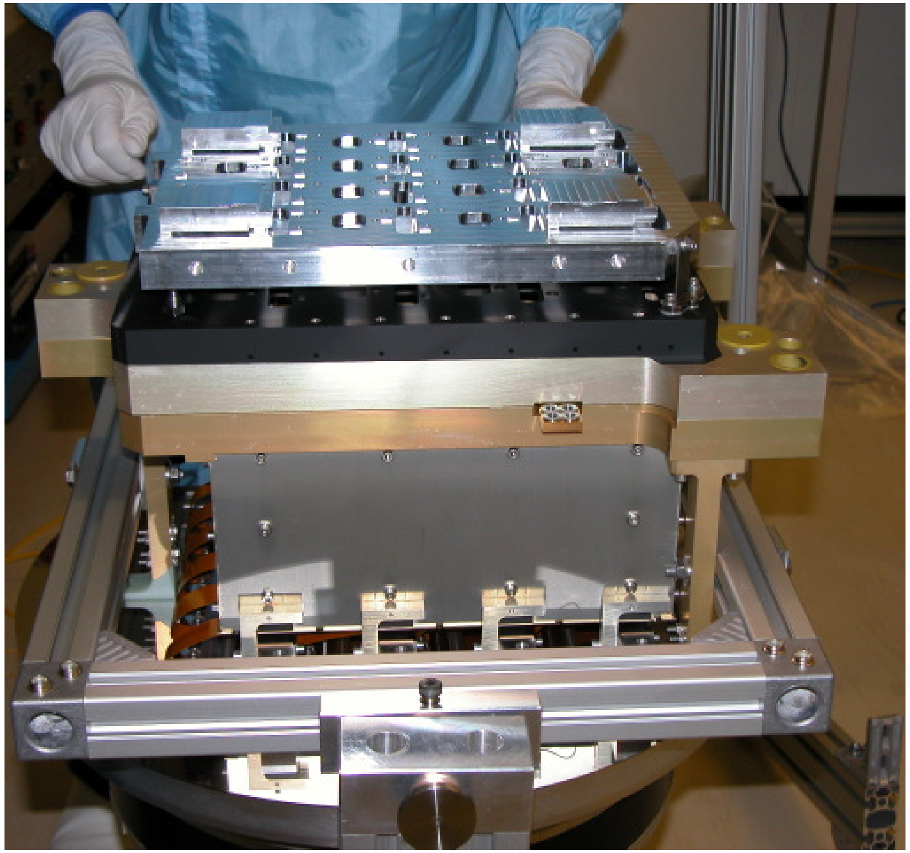
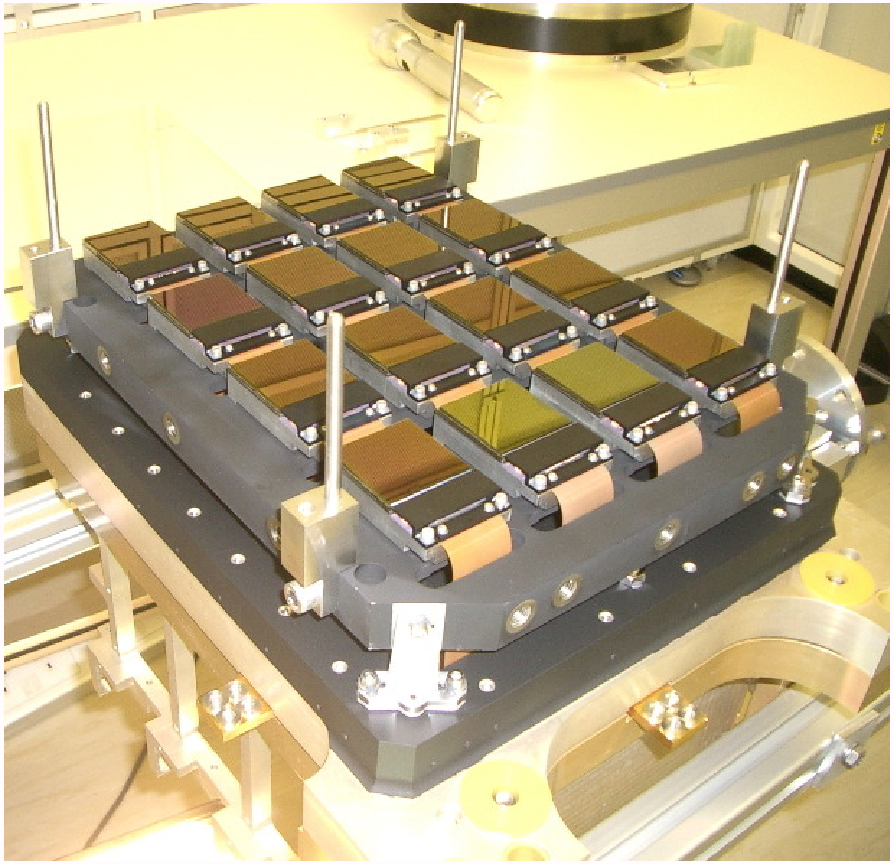


Focal Plane Assembly Details

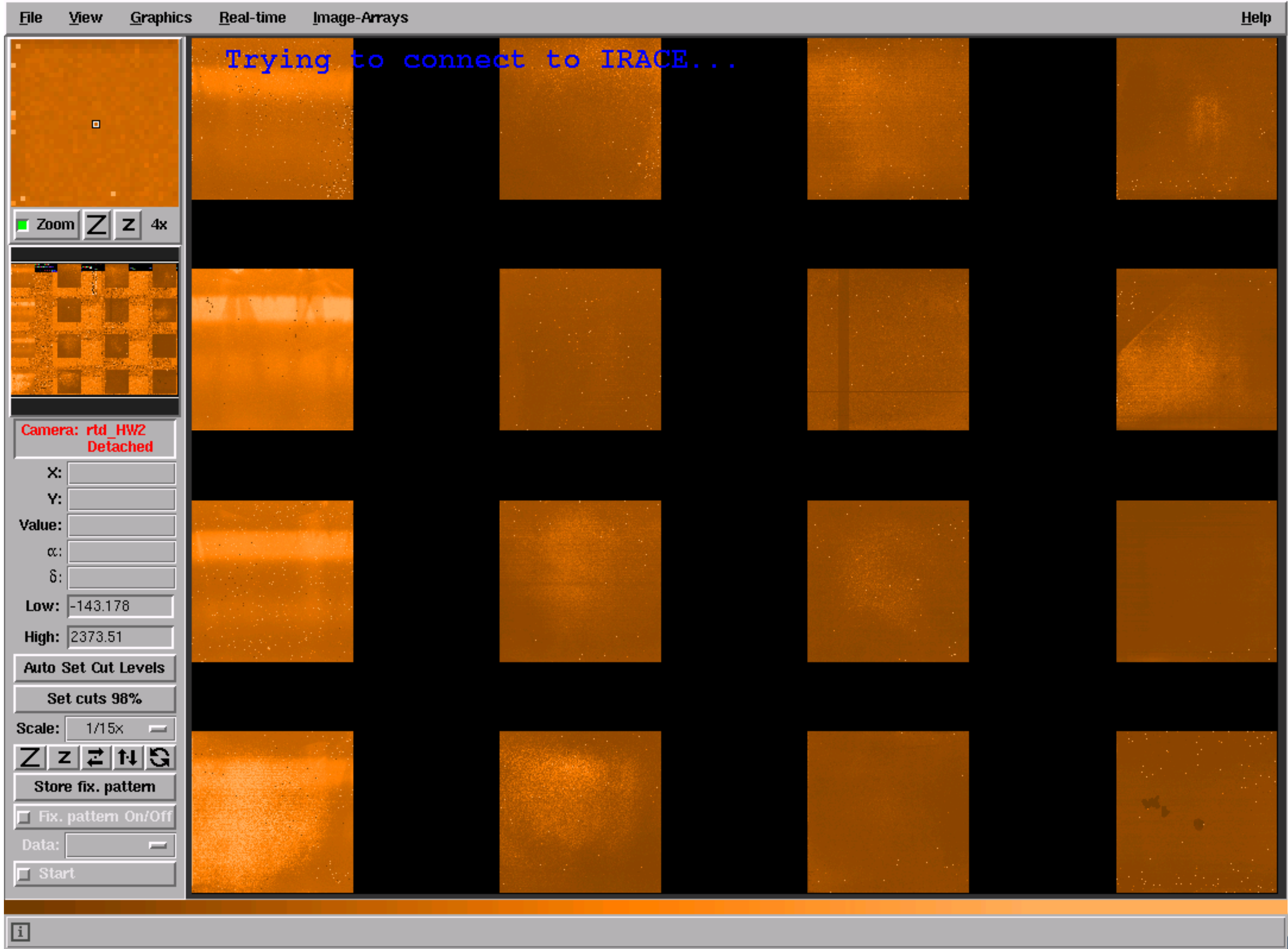




Detector co-planarity: all pixels within ±25μm (Thanks Raytheon!)

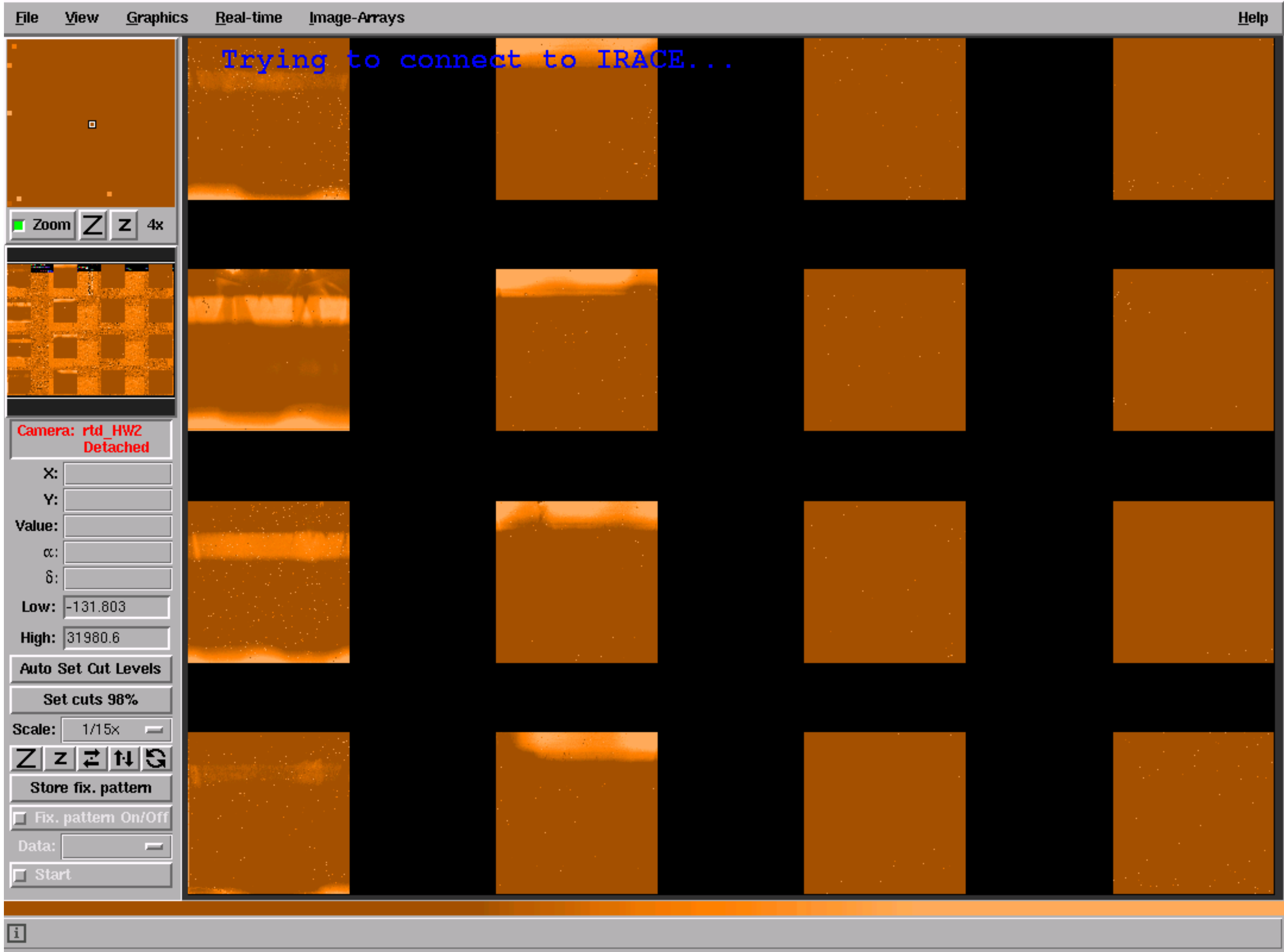
ATC testing: Detector output not quite as expected… 1024 new Op Amps…

The scattered light puzzle…



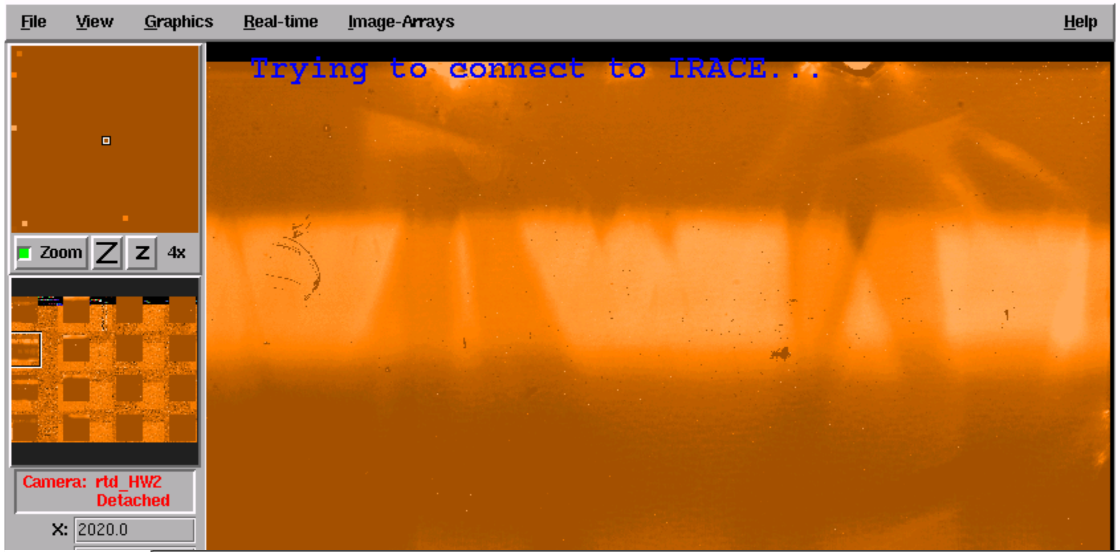
Dark image

The scattered light puzzle…



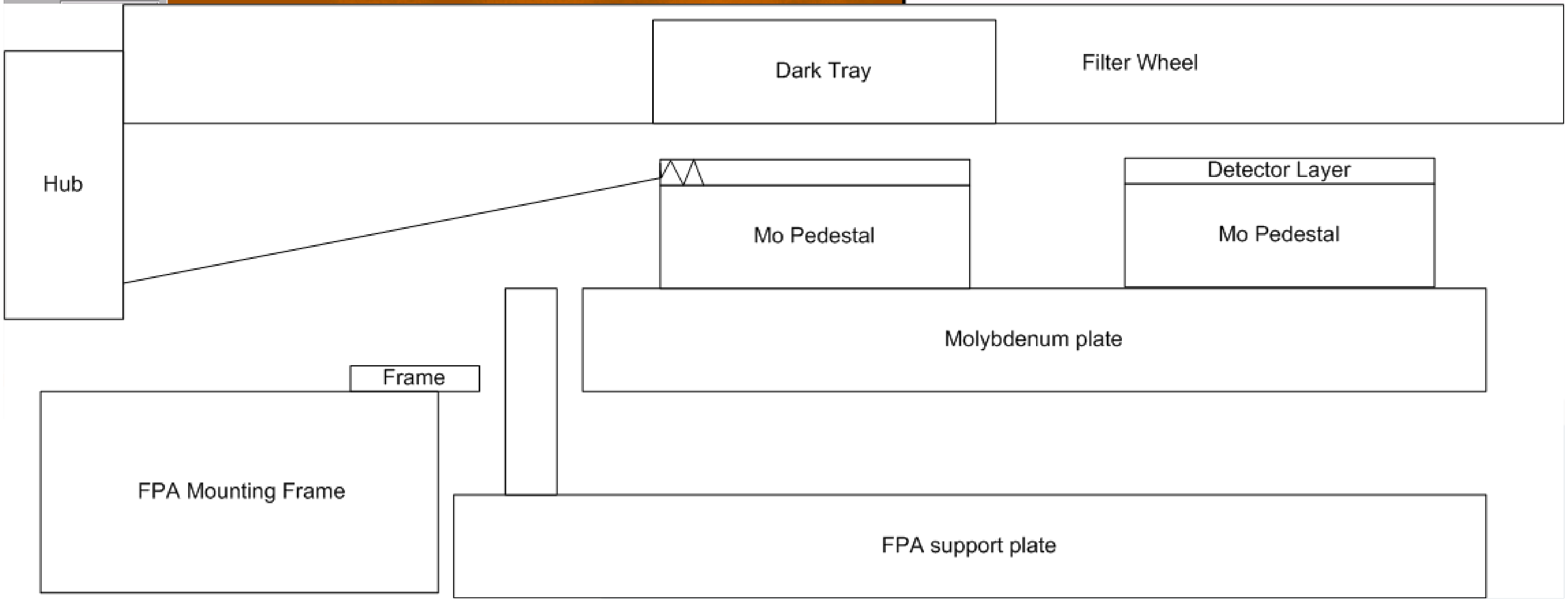
Dark image

The scattered light puzzle…



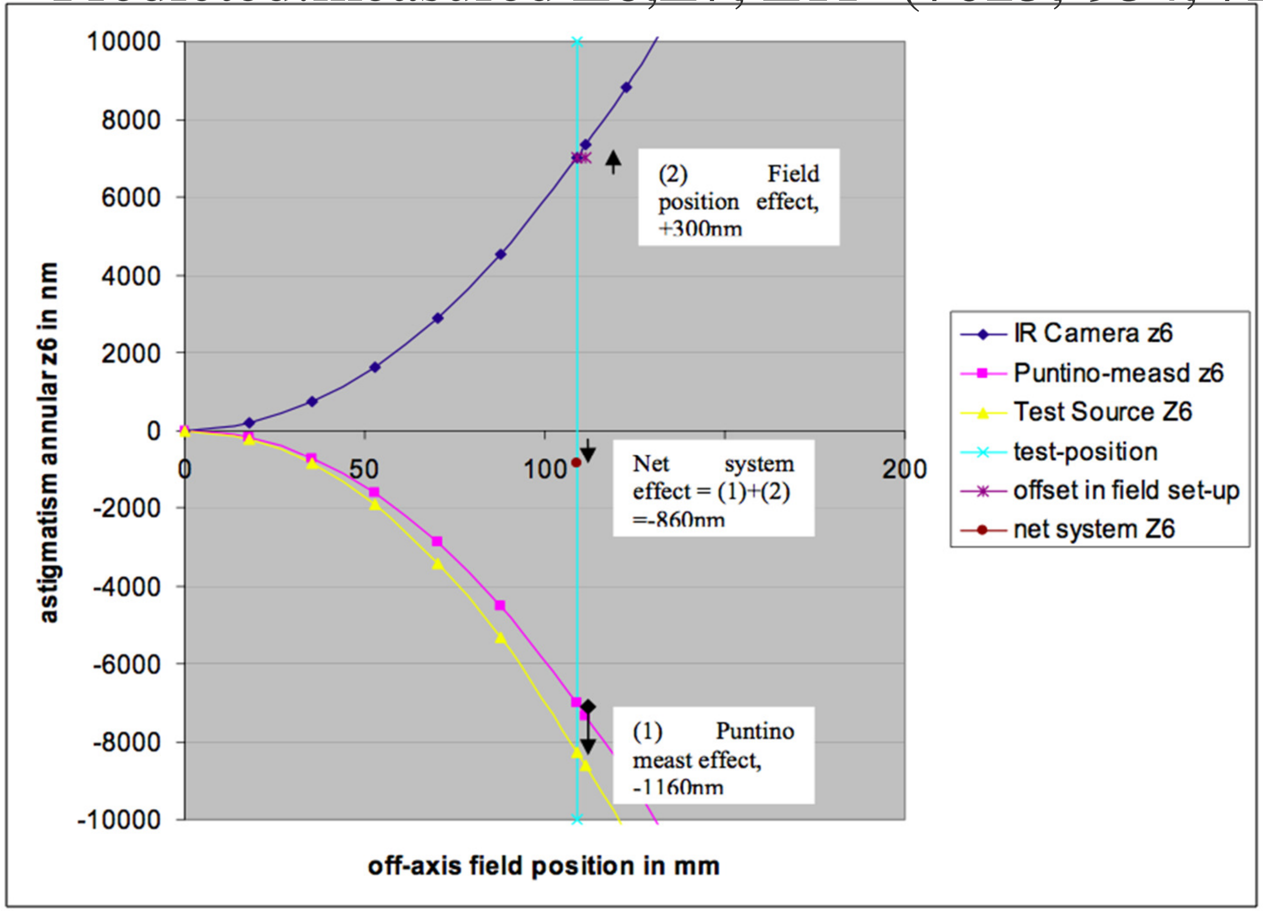
Key to explanation came from chips on the edge of one detector…

-a side effect of 800µm thick substrates… (should have been 20µm)



Laboratory image tests

Two-mirror + corrector injection source to simulate telescope aberrations. Align to generate a spot in the focal plane, then measure the source configuration with Shack-Hartmann test camera.
Predicted:measured Z6,Z7, Z11=(7025,-954, 729):(-6957,944,-742nm



Cross-check Z6 measurements against through-focus (±2mm) spot images:
Error in camera optics < 130nm (111.5mm field) or < 240nm (113.5mm field)

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CCLRC
Rutherford App
RAL
RAL

Shipped intact and at vacuum…

Cross-channel ferry (roughest night of the year) then 3 days by 747 (just fits). Finally by road from Santiago

Arrived at Paranal and unpacked (still at vacuum).

…not everything arrived in such good shape (3/5 He compressors damaged in transit)

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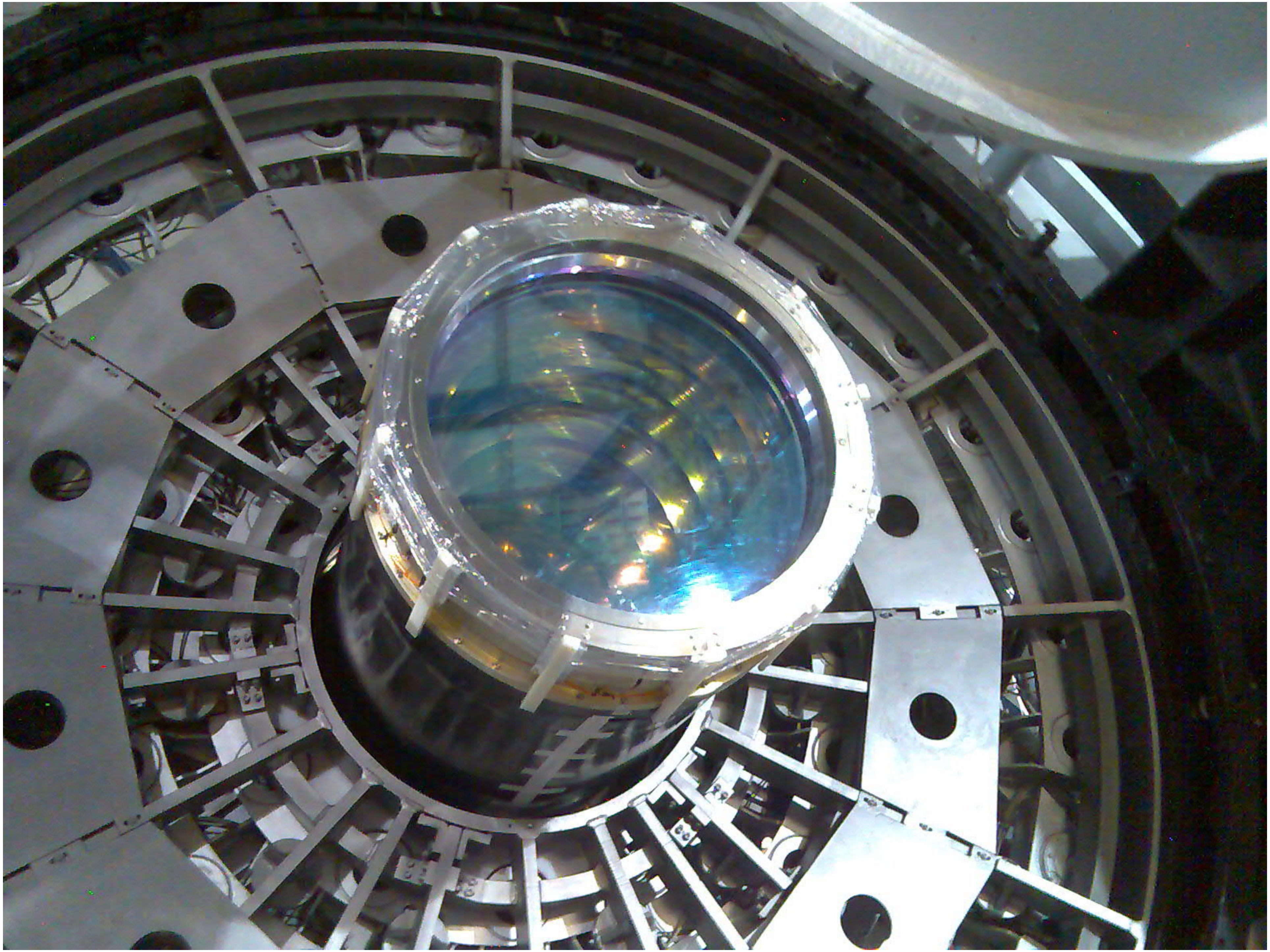
IR Camera in ground floor of VISTA Enclosure

First Light

•Early July 2008

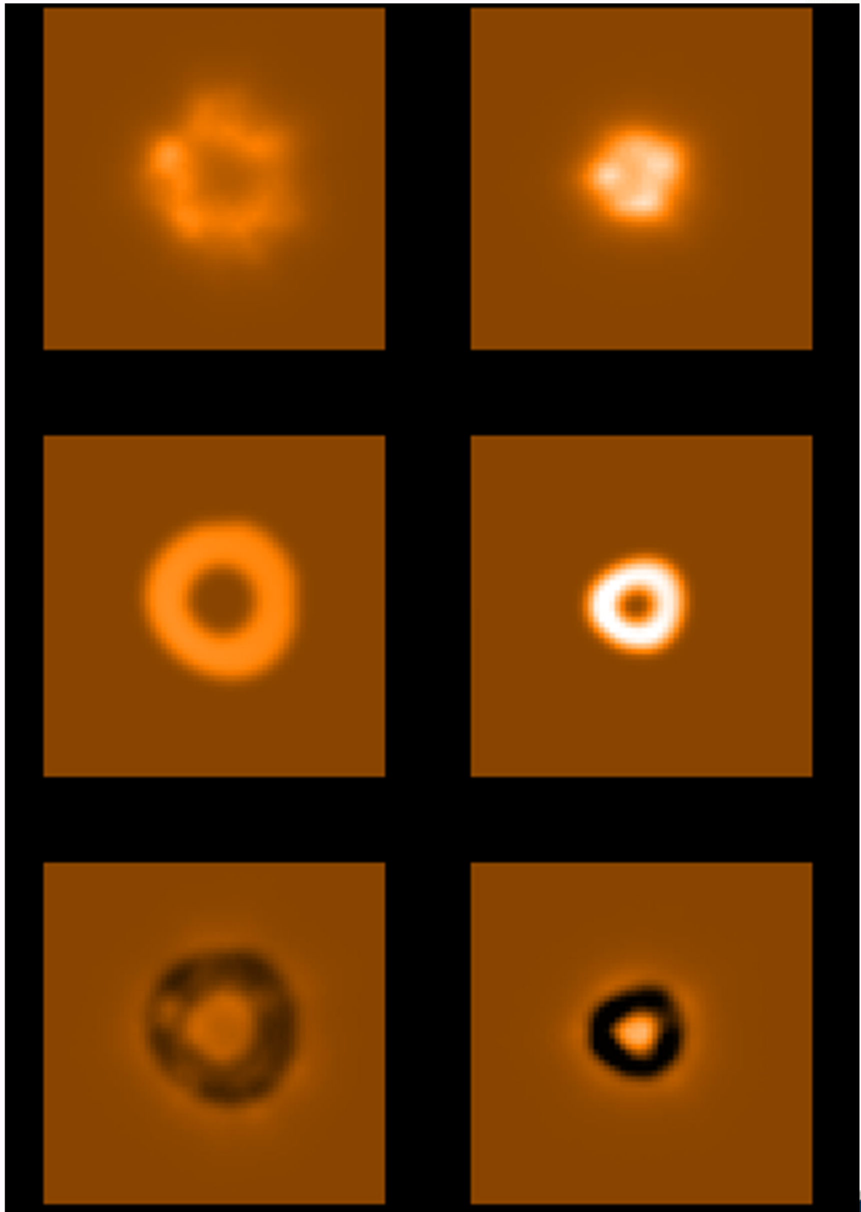
•M1/M2 setup taken from nominal test-camera data

•AGs not set up
•WFS -> M2 not set up
•WFS-> M1not set up
•WFS returning plausible Zernike values
Apply corrections by hand, can estimate correct focus to ~200nm in Z4 by eye (WFS does a lot better).

After about 5 hours of this we stopped to take a picture…
(6x30s pawprints in J, dithered ‘by hand’)


35° elevation, 0.85"
images over most of

Wavefront Sensors

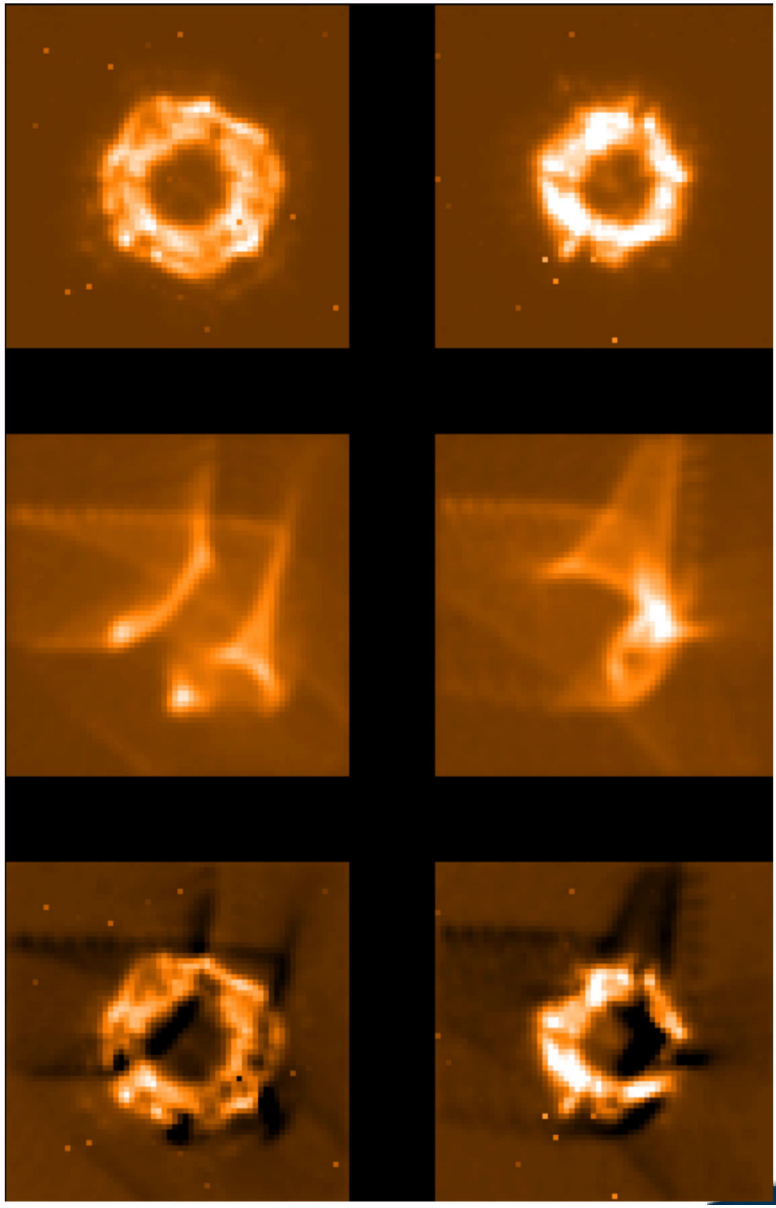


Pair of pre/post-focal images (LOW order)

Analysis fit to the image-pair

Residuals

Wavefront Sensors



High Order

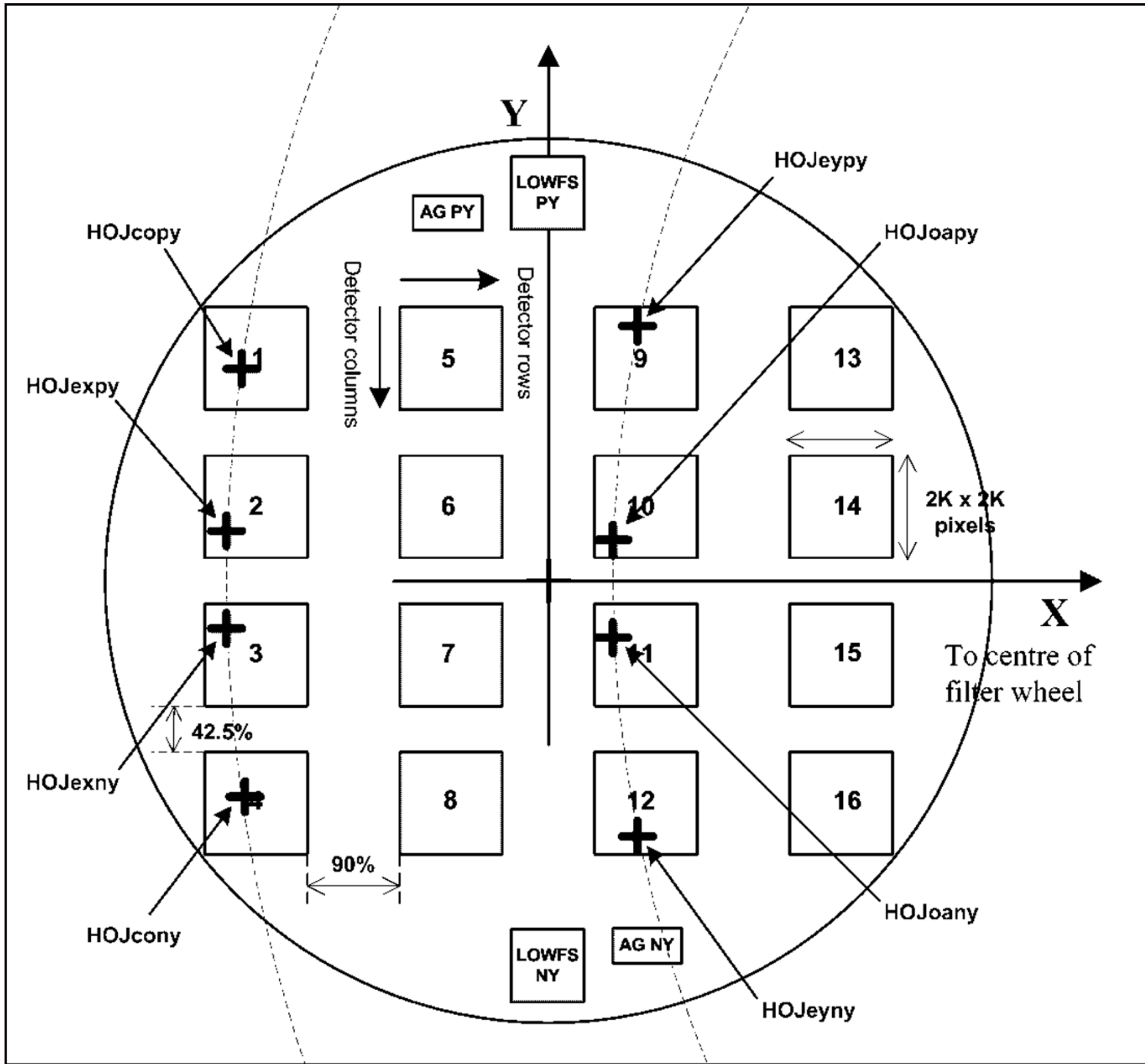
25 Zernike terms fitted

(Spherical terms not applied, but no significant level detected)

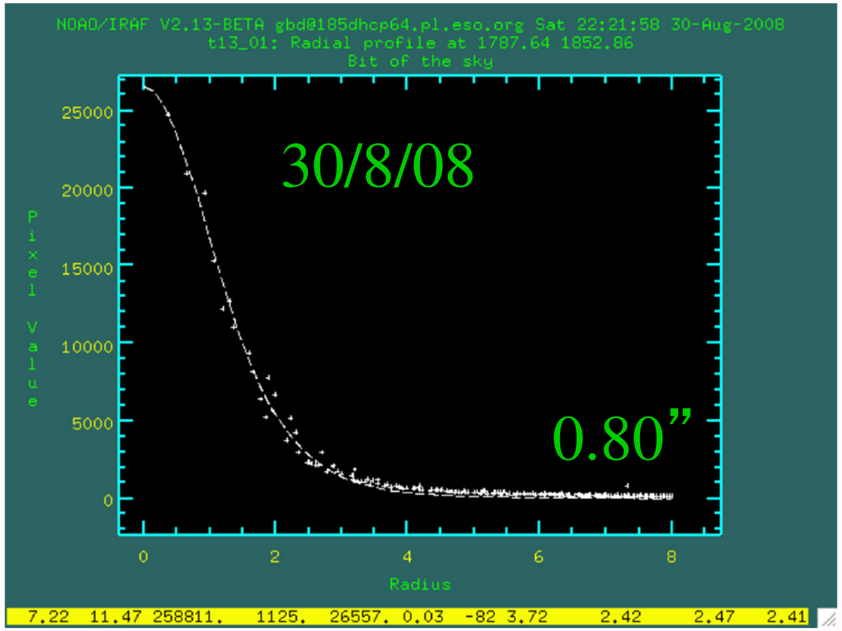
M2 trefoil (~800nm) seen with test S-H camera recovered well

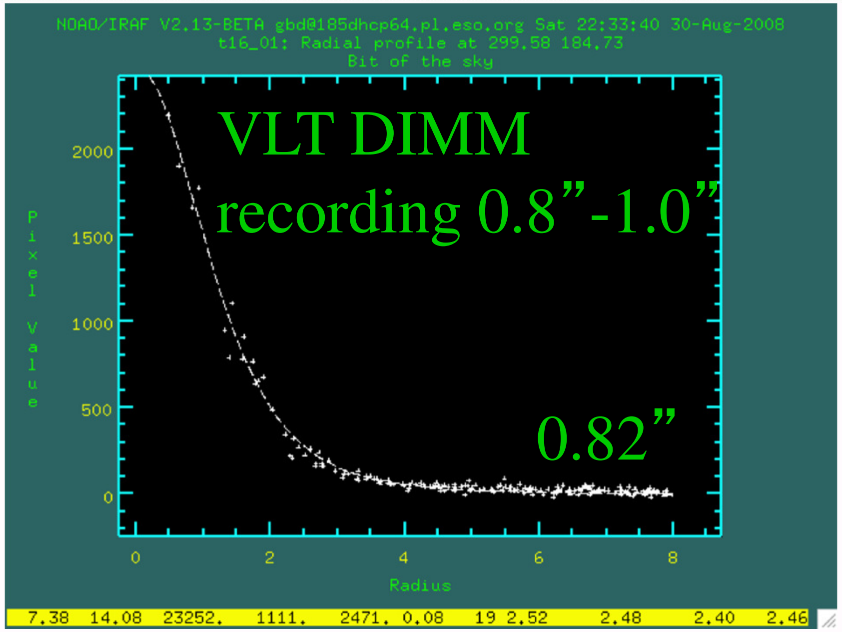
Can sometimes fail to converge…

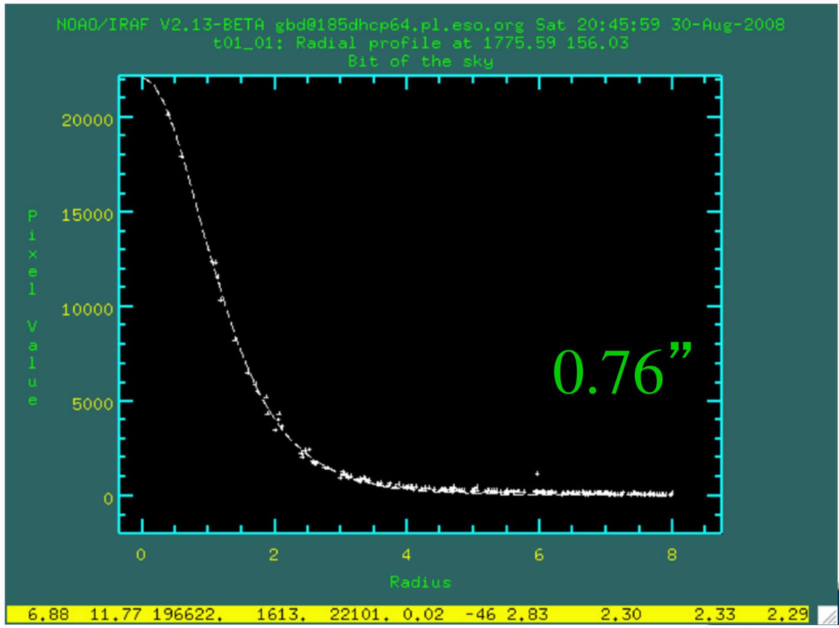
Beam-splitter cubes in-between filter positions can be deployed to 8 pre-determined locations for high-order curvature sensing measurements.

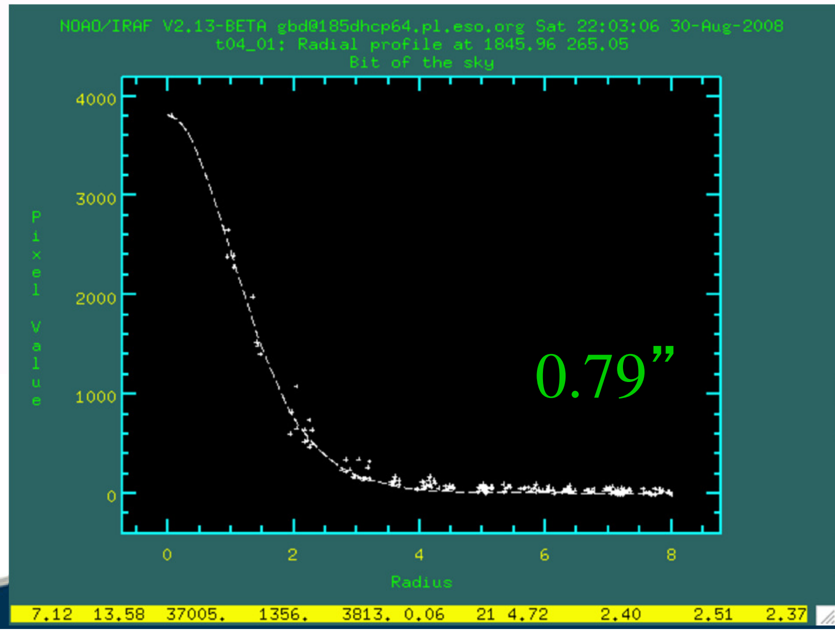


Calibrating M1/M2

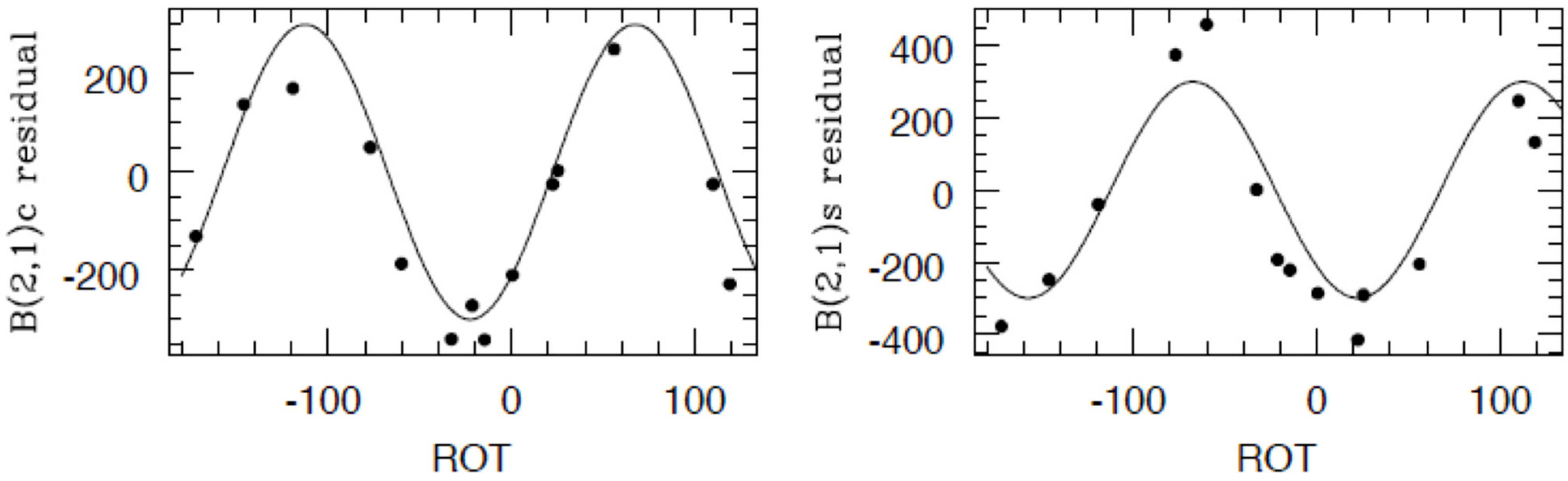






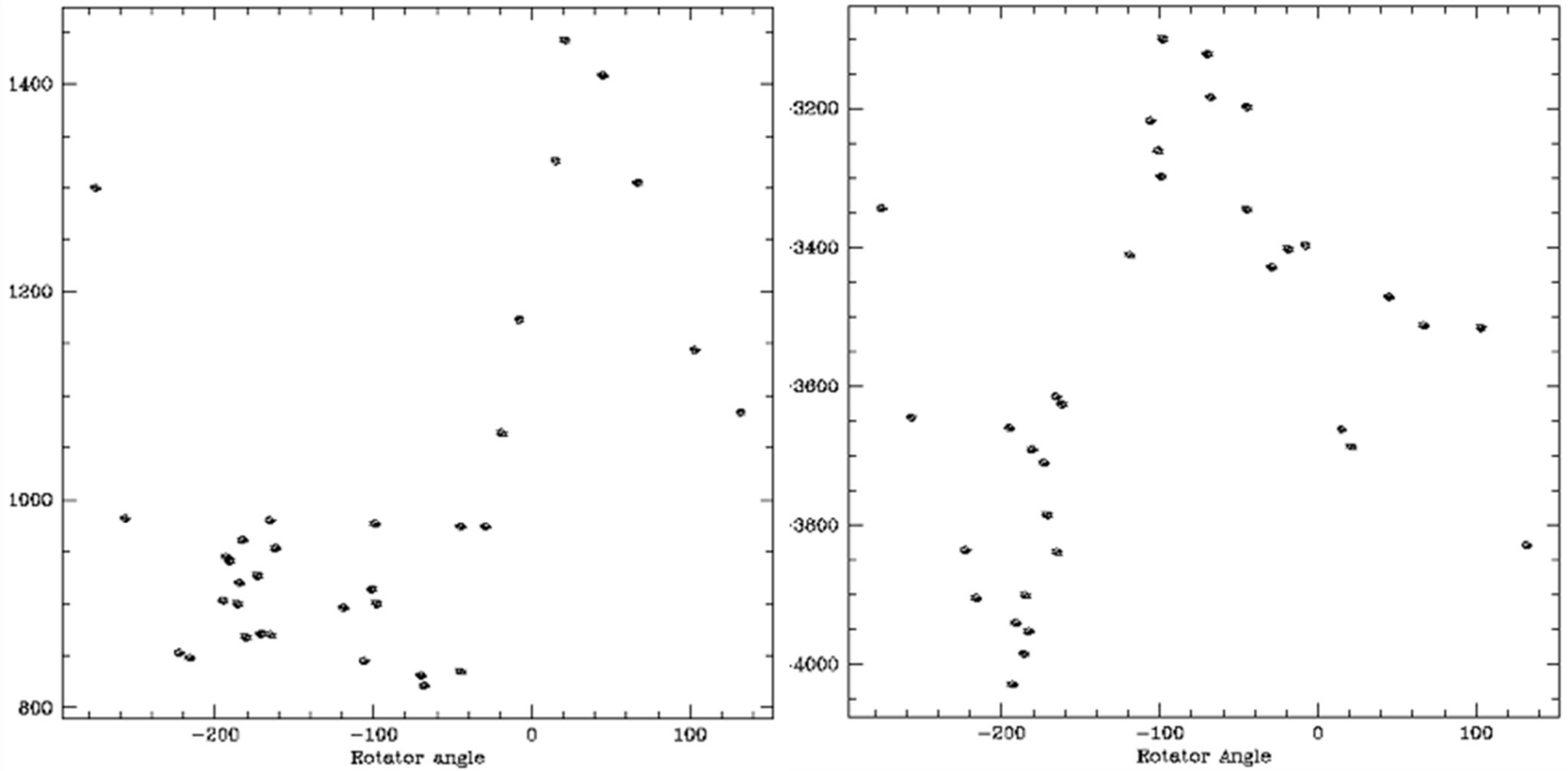


Residual Camera Astigmatism



Rotational variation of M1 astig corrections suggest a small camera term, consistent with the laboratory measurements.
-Add a term to the active optics controls to apply this as f(rotator) in open loop.

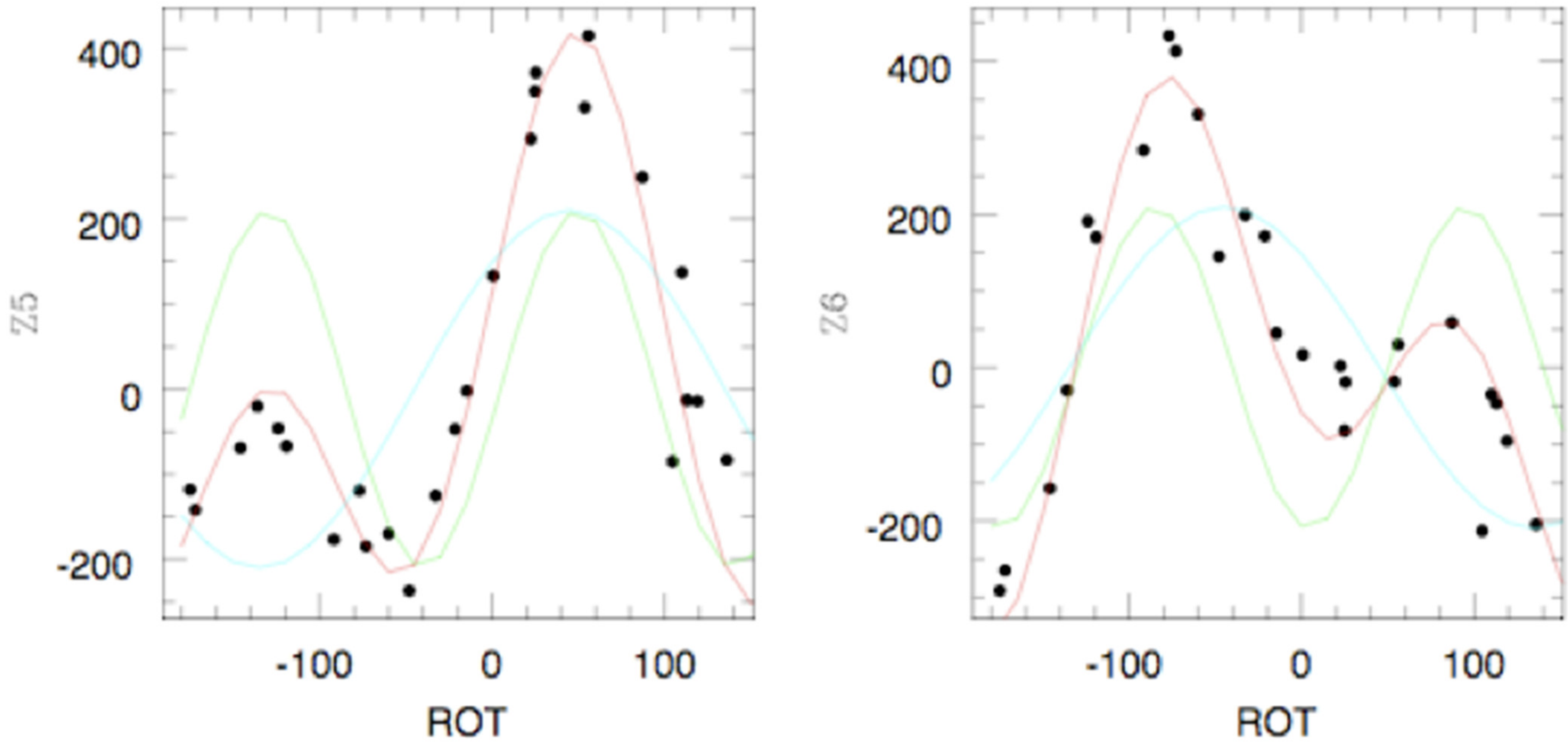
M2 tilt (field dep. astig)



Always appeared to see worse images in one, but not always the same, corner… Z5 and Z6 measurements initially confusing.

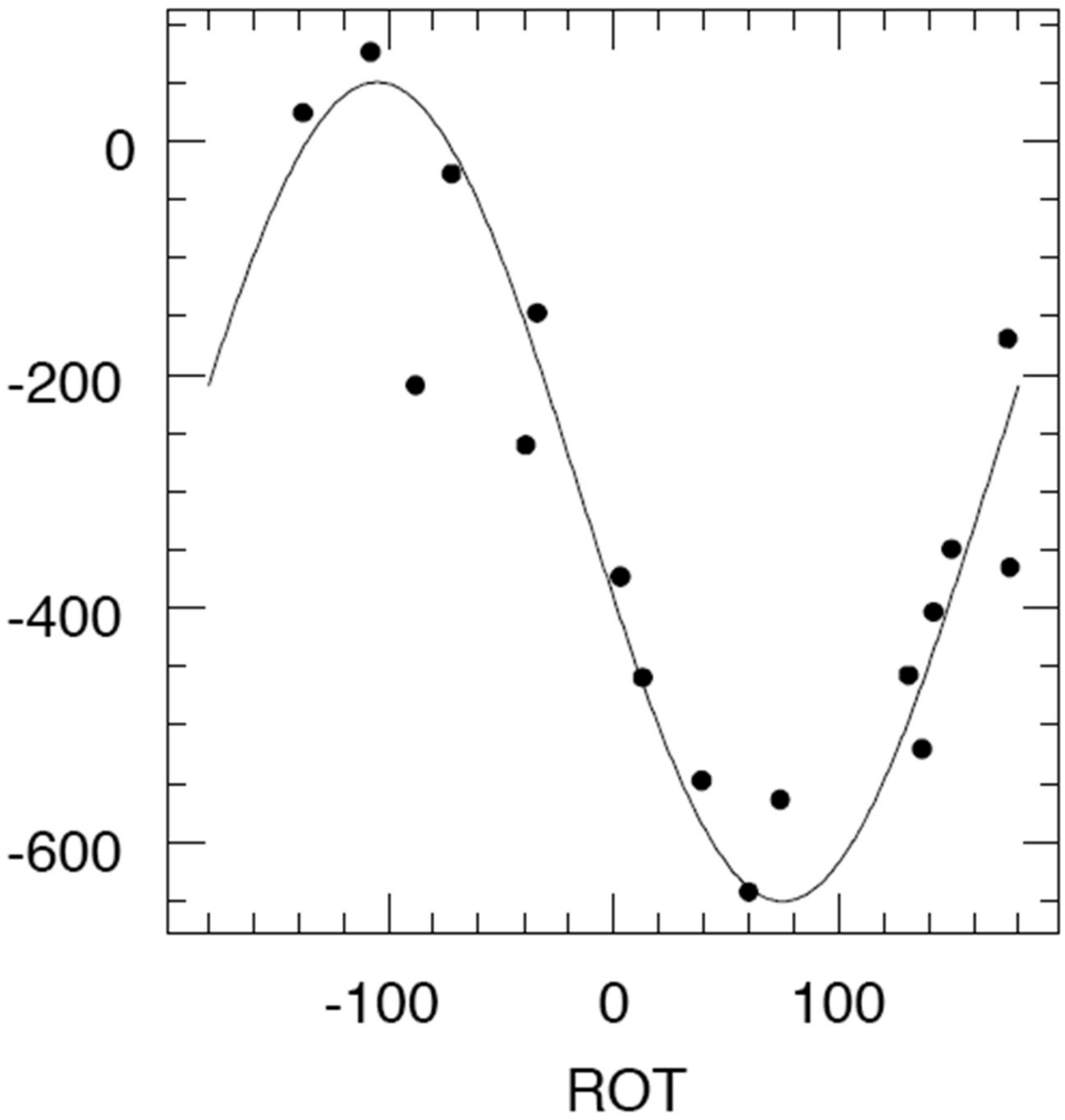
Model as two-component rotating term, and get better data…

M2 tilt (field dep. astig)



2 component model with a true field corrector mis-alignment term and a ‘phantom’ 2θ term from the gradient of the M1 trefoil correction. –Apply one term open-loop and ignore the other.

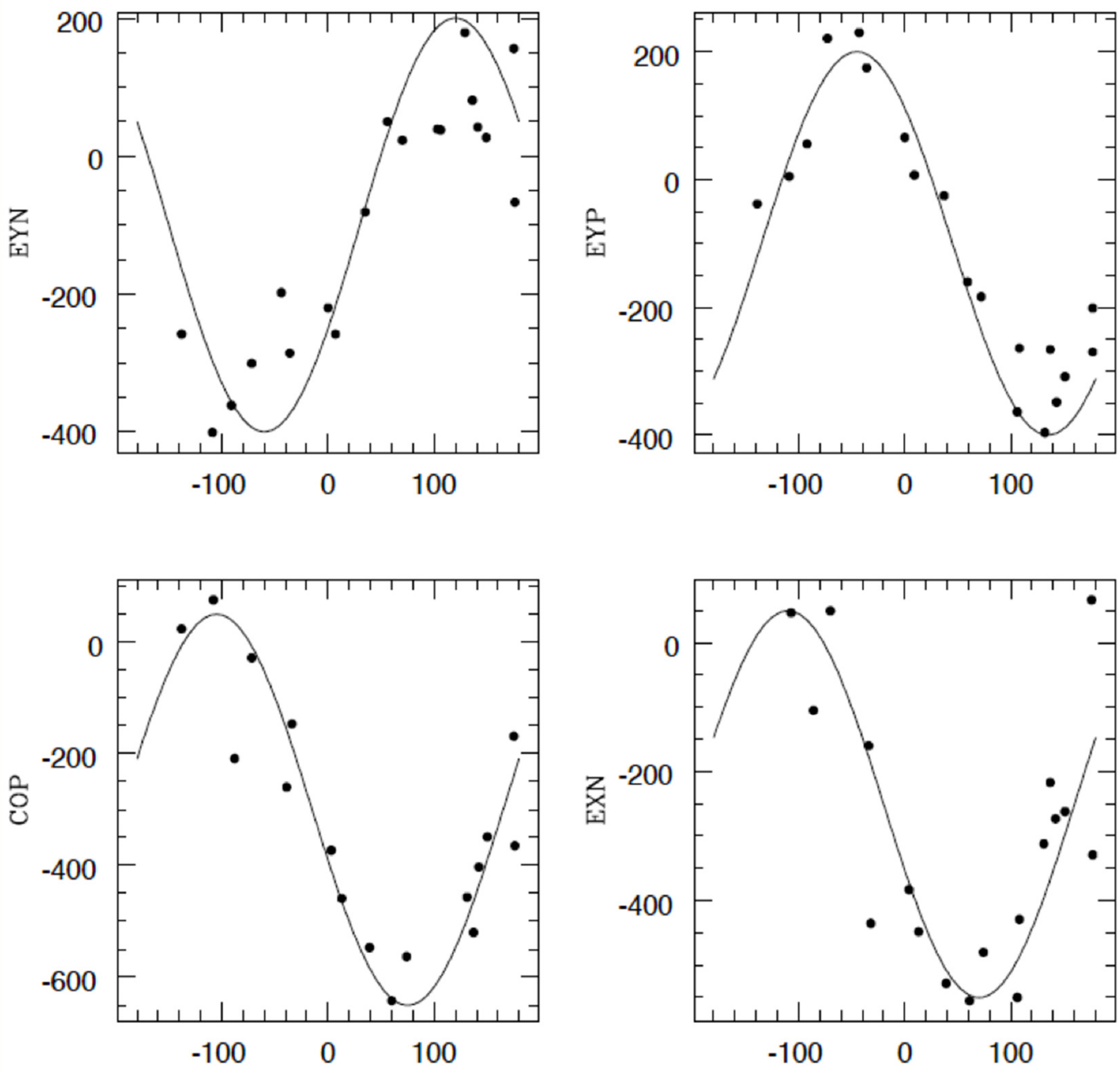
Focus Gradient (HOWFS)



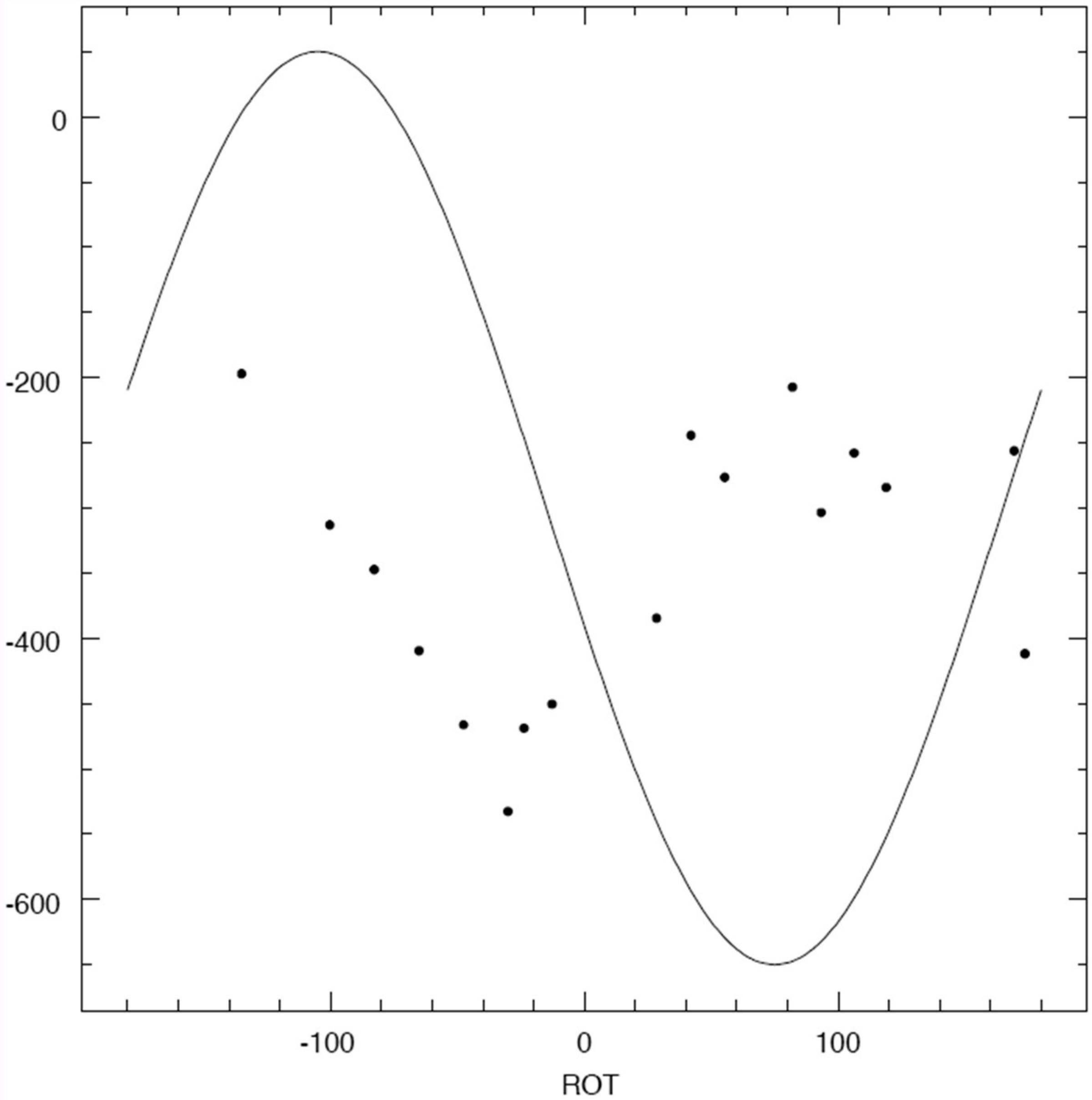
October 2008

Difference between focus measured at corner- and near-axis-HOWFS locations (nm of Z_4

Difference between extreme and near-axis positions for each rotator setting



Focus Gradient (HOWFS)

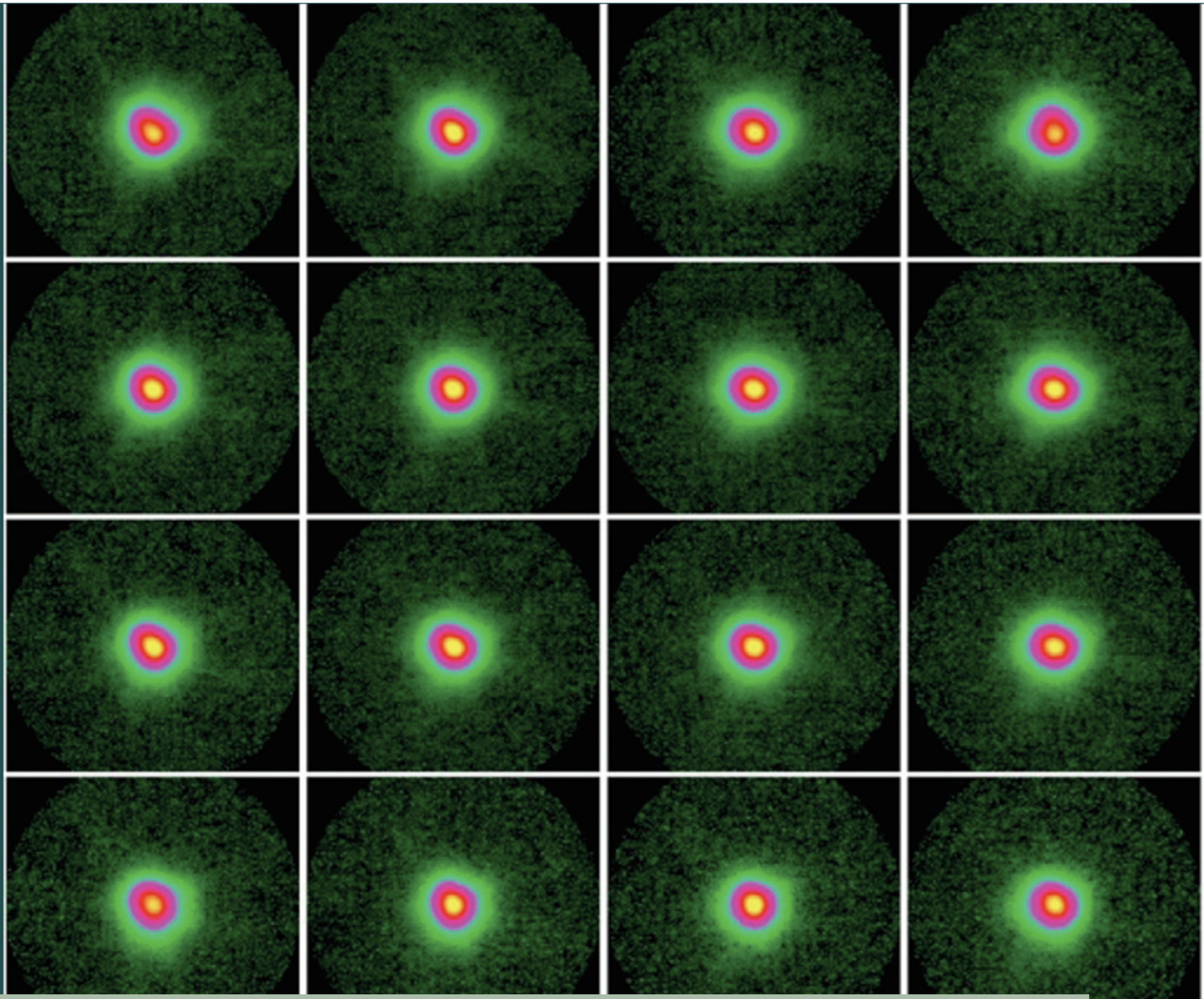


March 2009

Same plot after lateral M1 position adjustment and recalibration of M2 positioning

Further repositioning of M1 in May 2009 corrected this residual

Final image quality from SV data



Formal image quality 0.45" (50%EED)

VISTA Performance

Throughput:

Z 51%

Y 45% (Filter)

J 53%

H 66%

Ks 63%

Total system…

telescope+camera+detectors

Array striping: controller effect, removed as identical in four arrays/IRACE sub unit

Channel cross-talk: none

Persistence: 1st Mag star residual disapppears completely in < 1min

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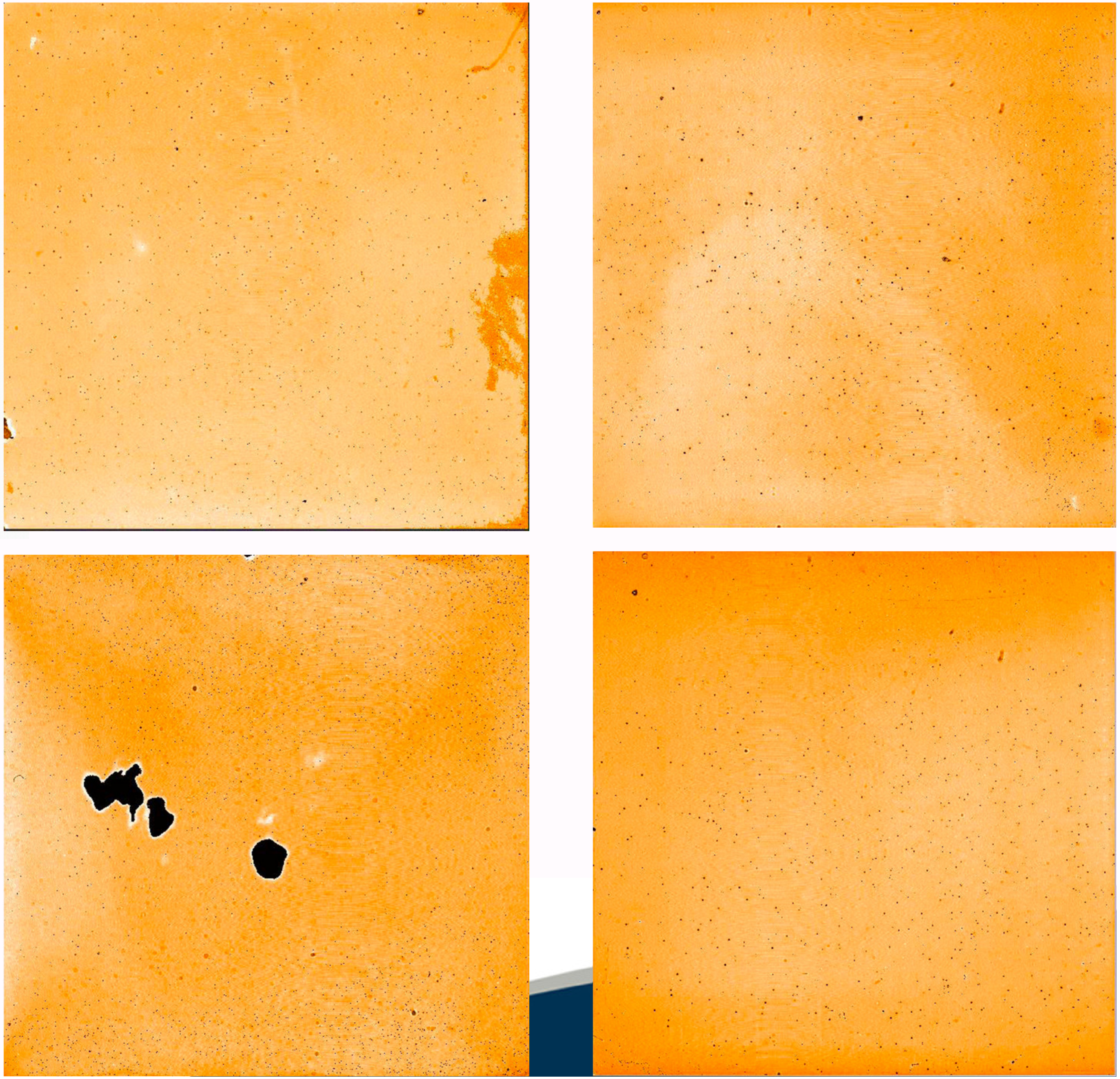
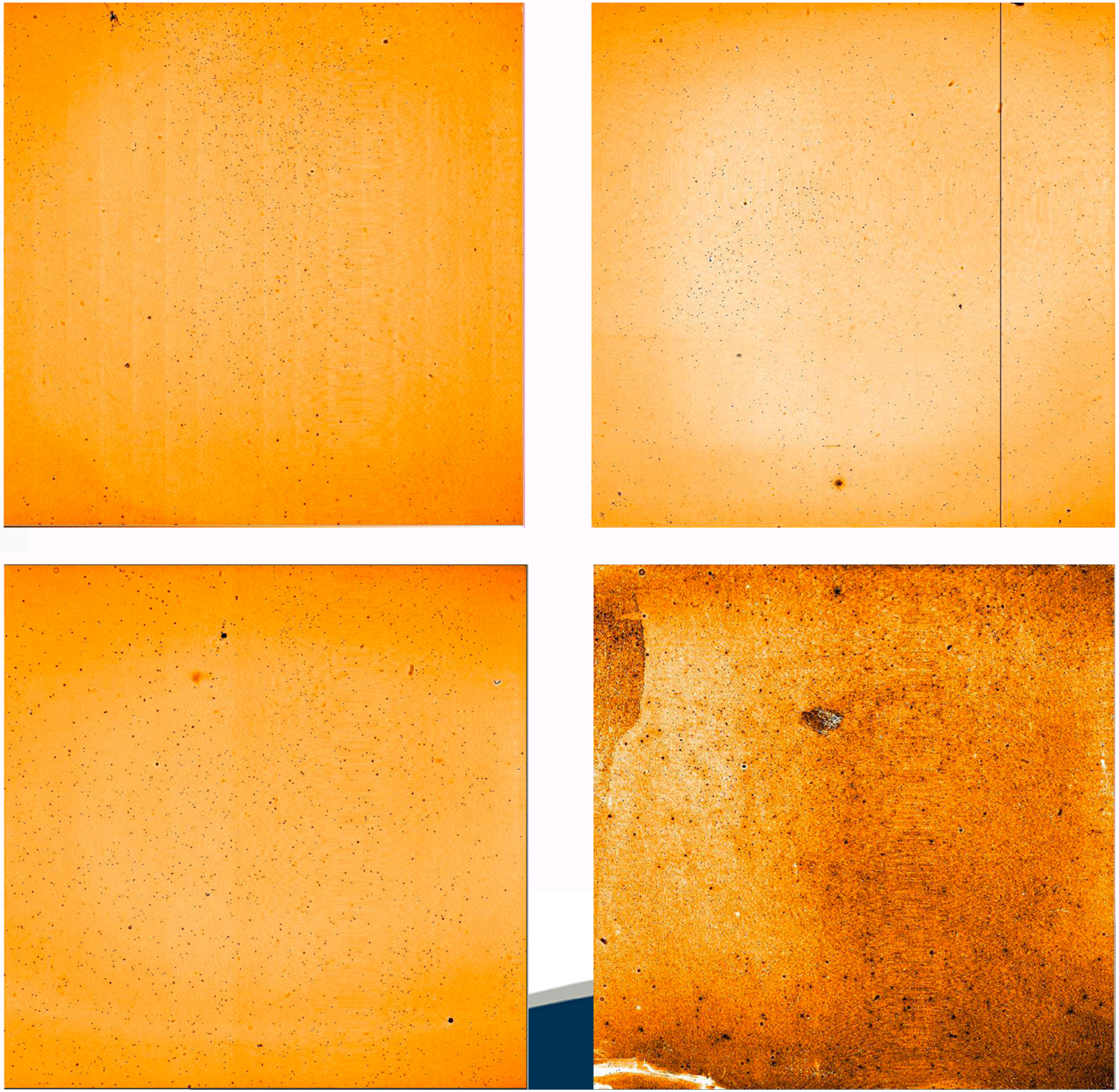
Detector FlatFields

Lower left corner



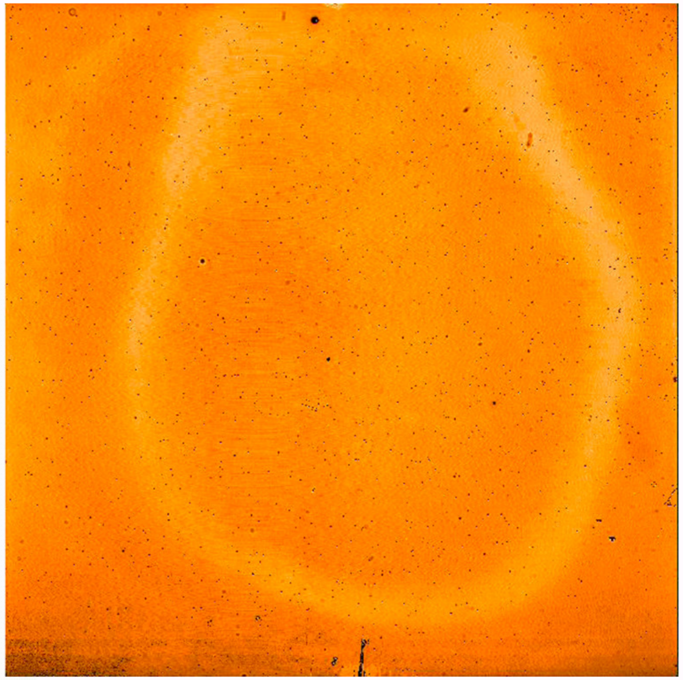
Detector FlatFields

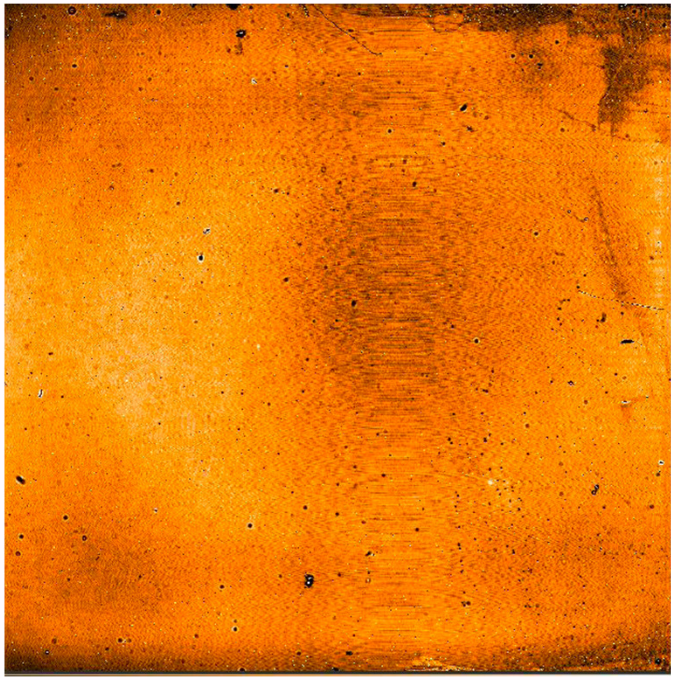
Lower right corner

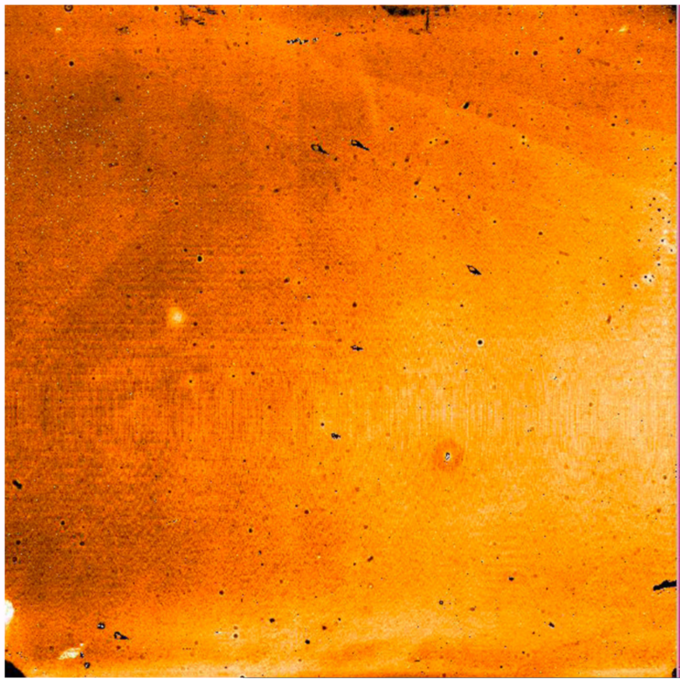


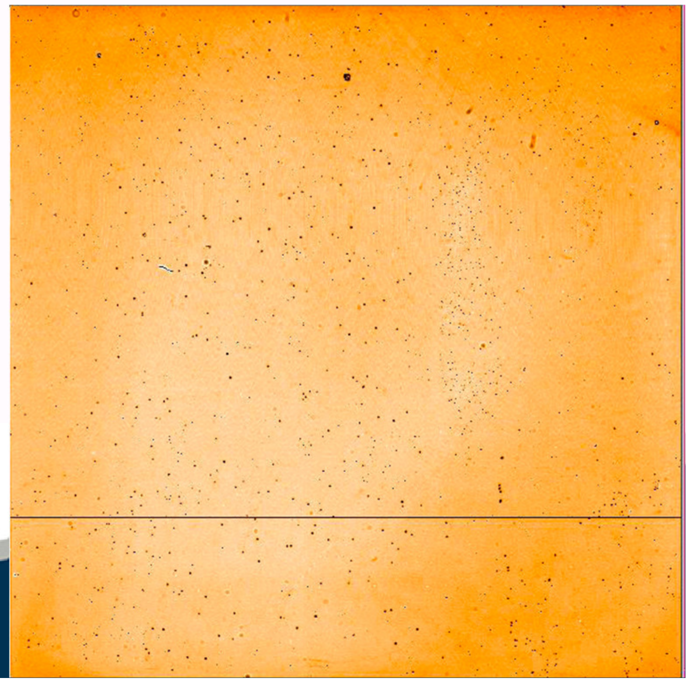
Detector FlatFields

Upper left corner



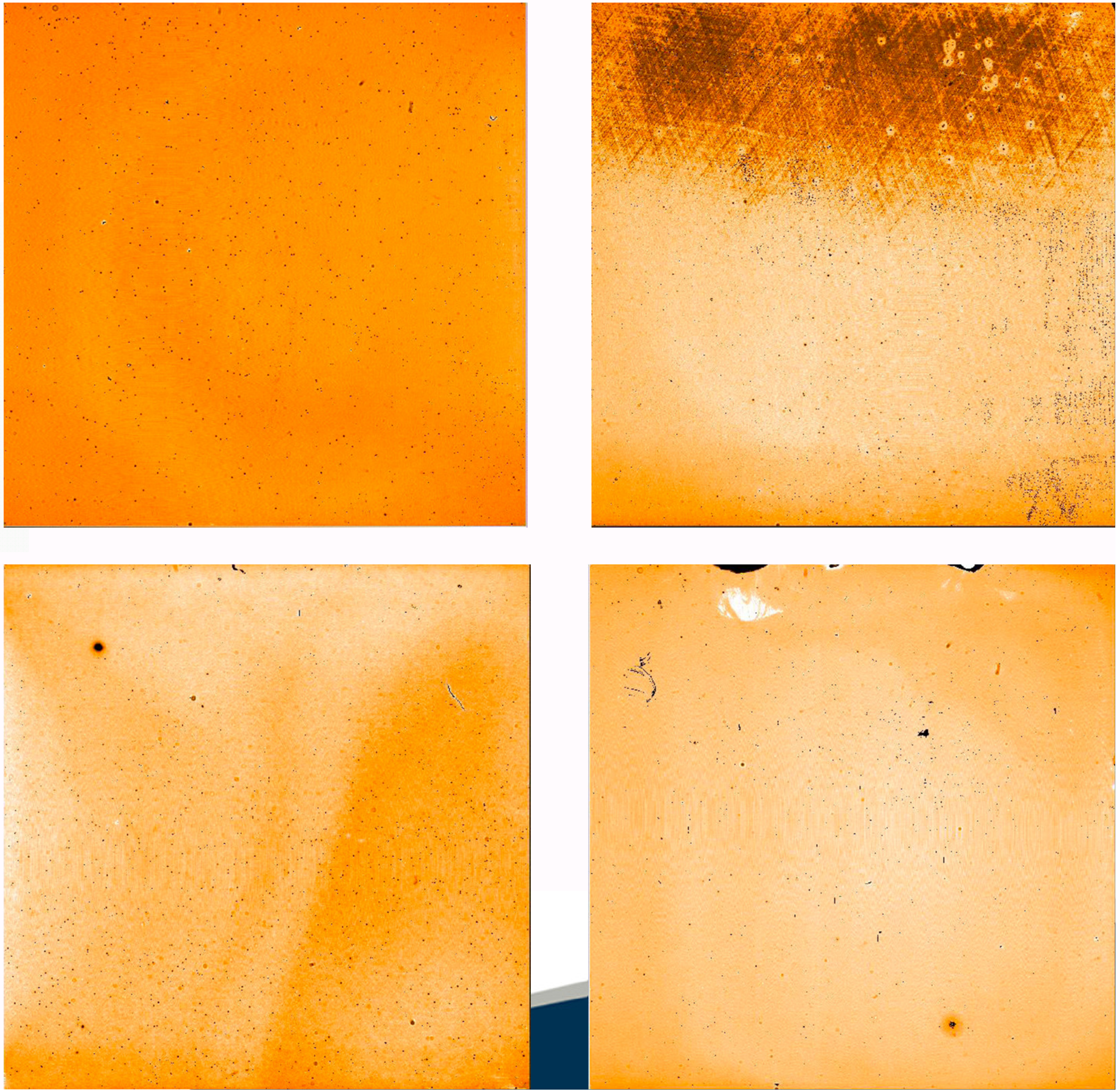






Detector FlatFields

Upper Right corner




2008-10-07T00:34:27.7 UTC