VISTA & VISTA Surveys

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With input from VISTA, CASU, and the ESO public surveys team

Science & Technology Facilities Council

Overview

- VISTA Facility
  - Integrated system approach
- Current Status
  - Some lessons from commissioning
- Survey Outlines
- Timeline
- Some considerations for wide-field E-ELT imaging

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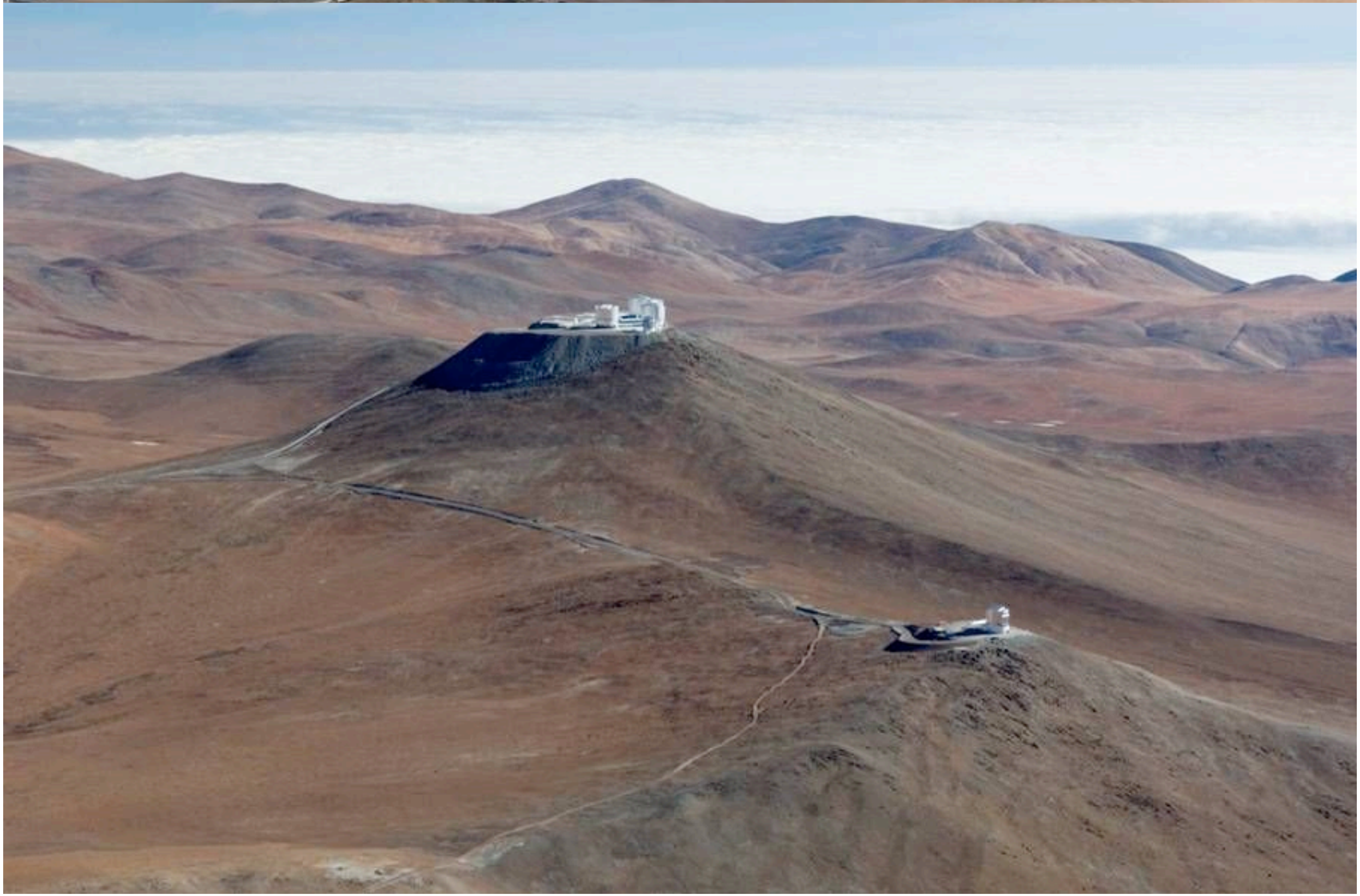
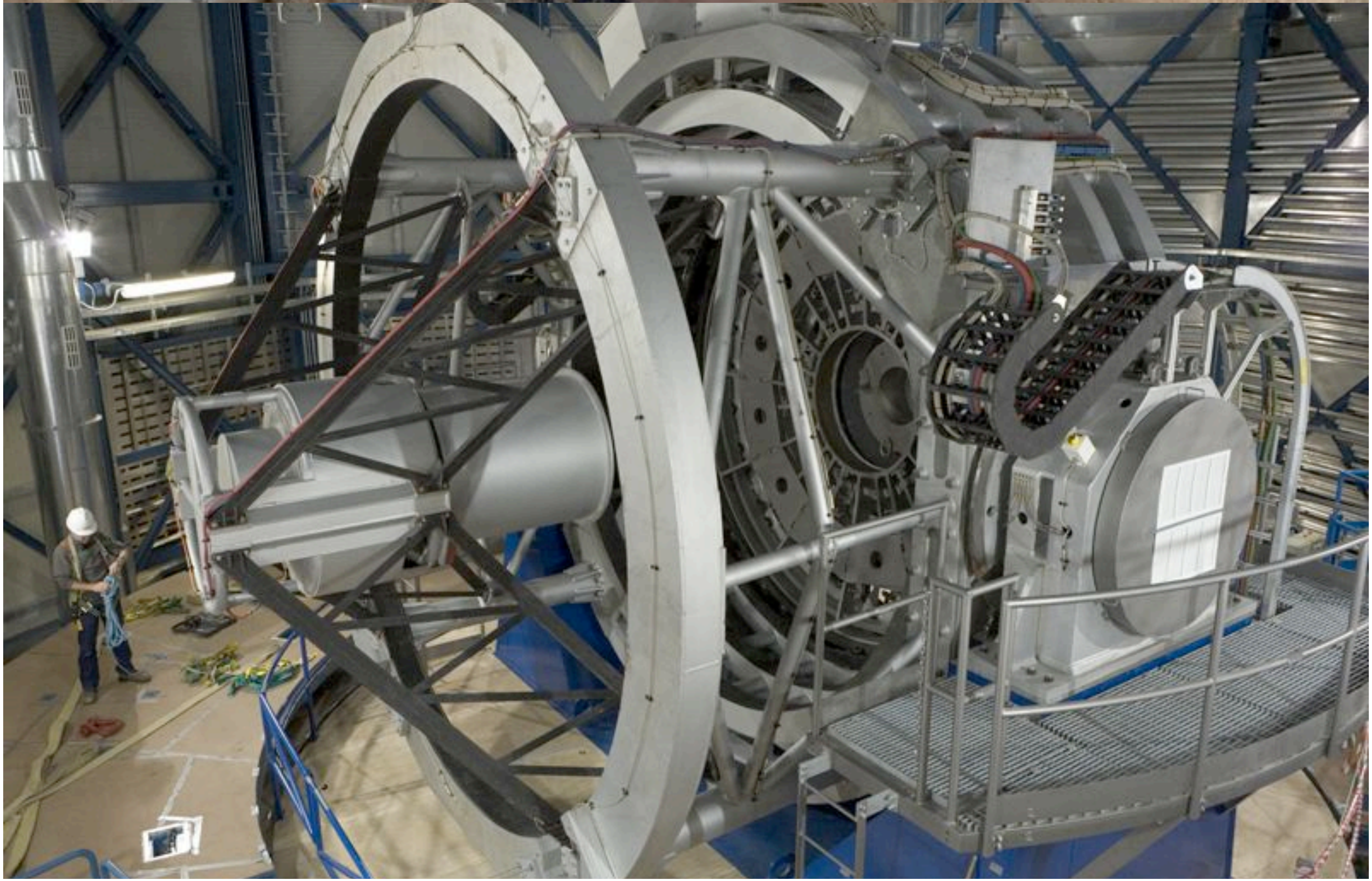
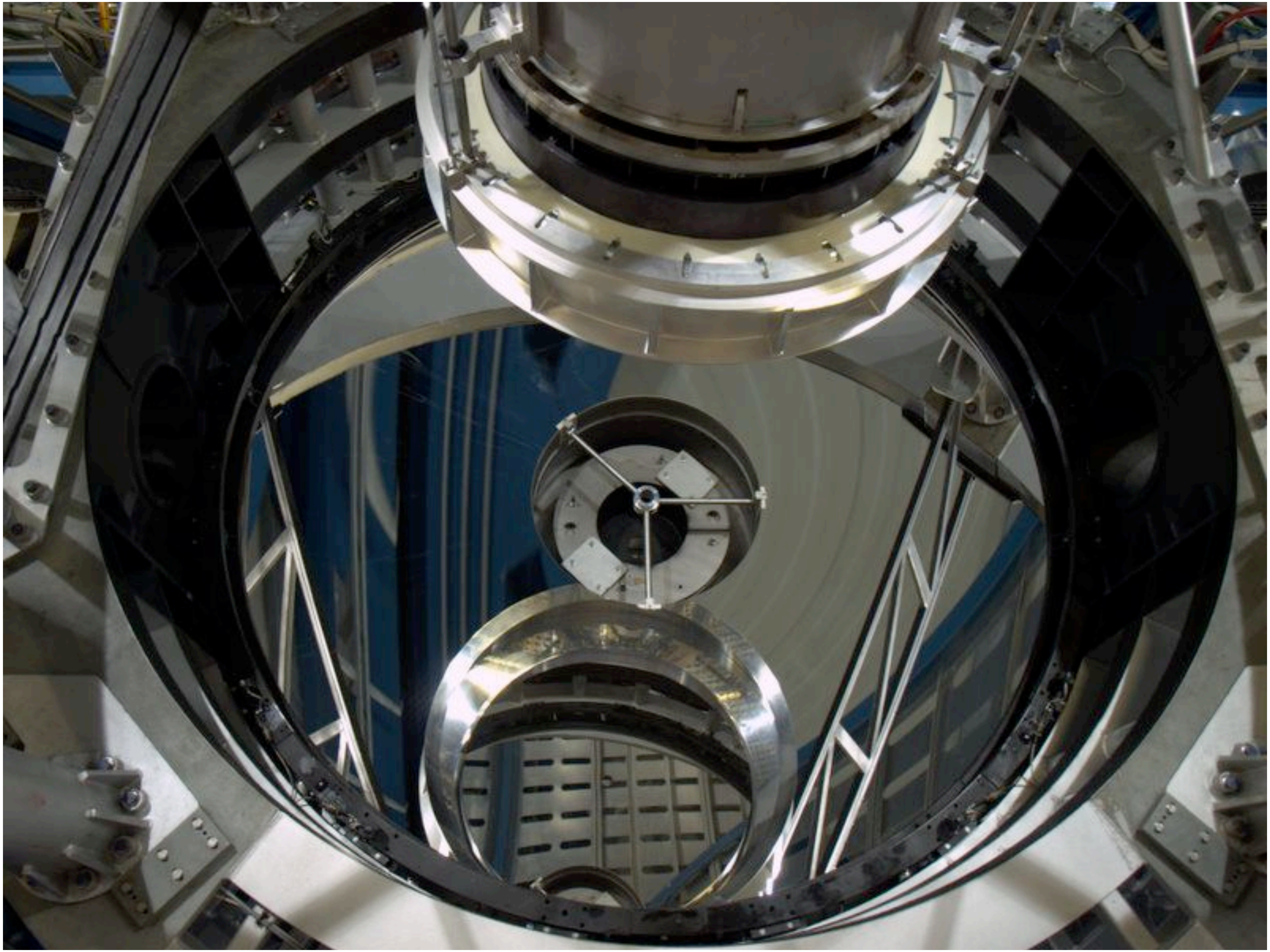
ESO Paranal Observatory, Chile





IR Camera in ground floor of VISTA Enclosure

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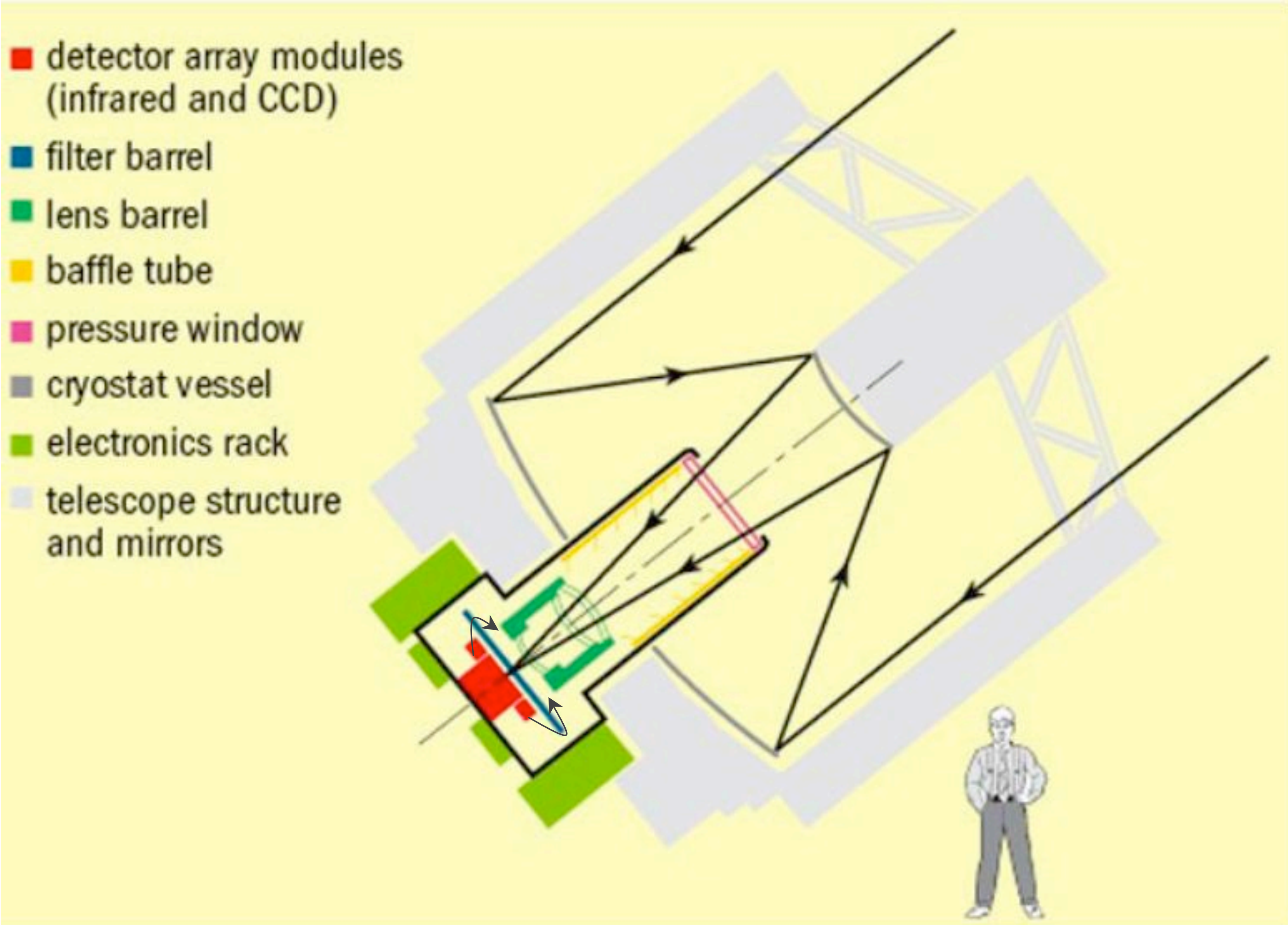
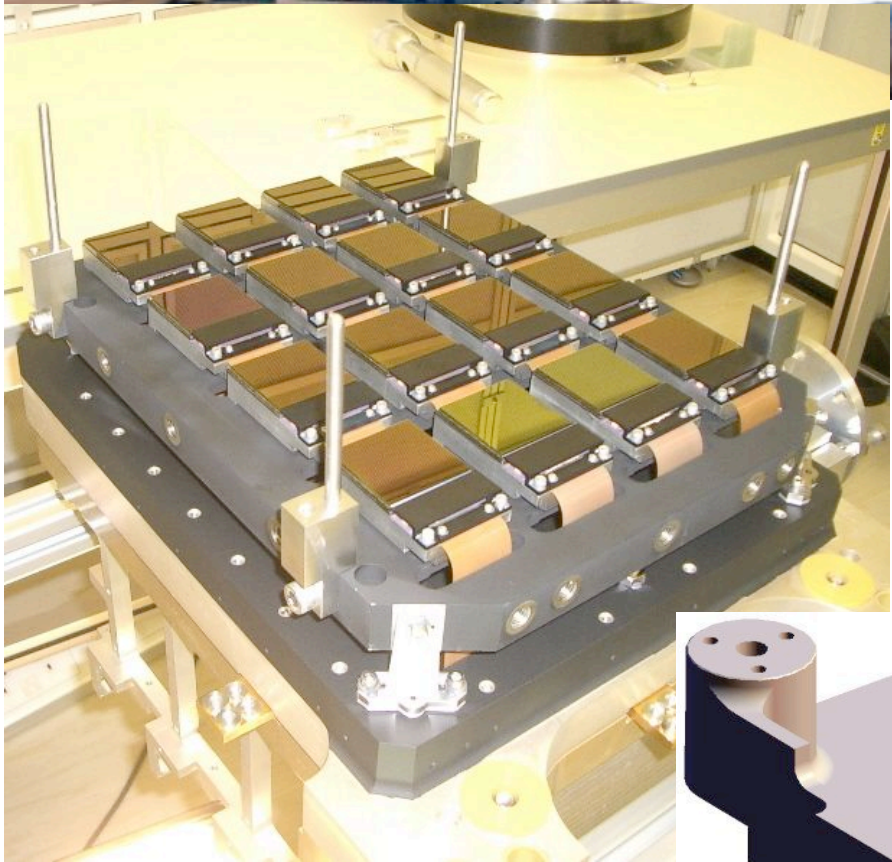
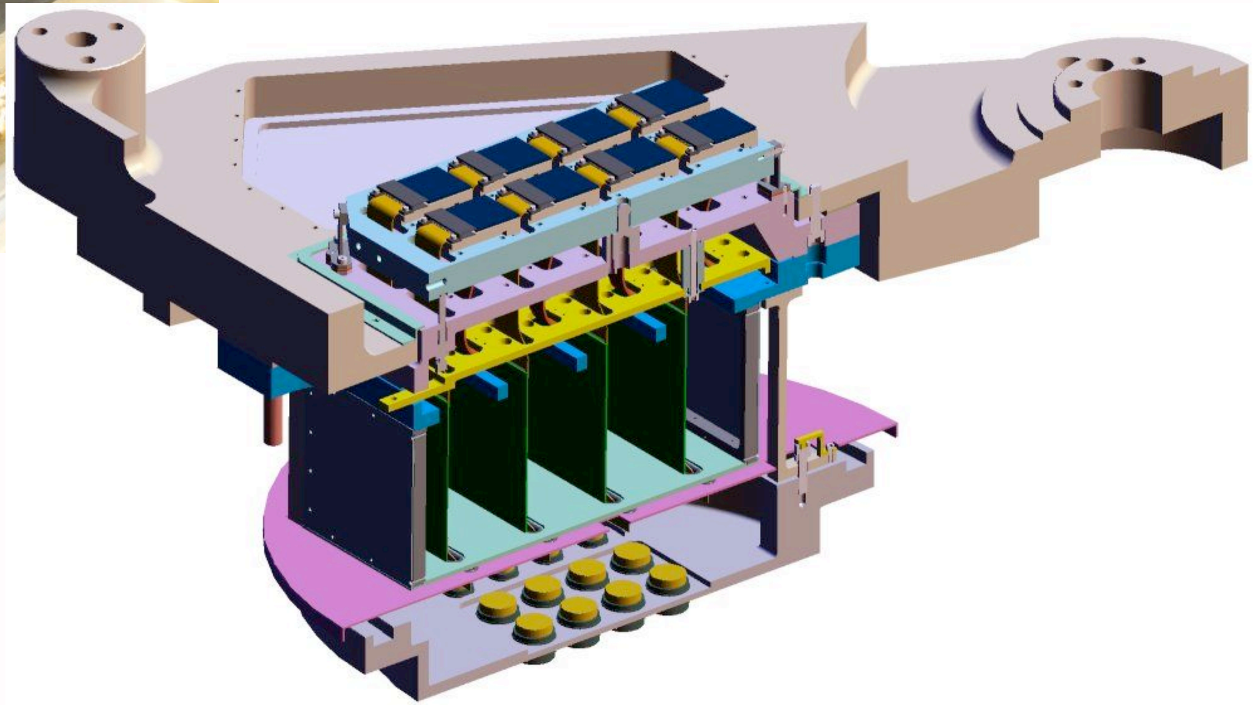
Integrated System Approach



IR Focal Plane

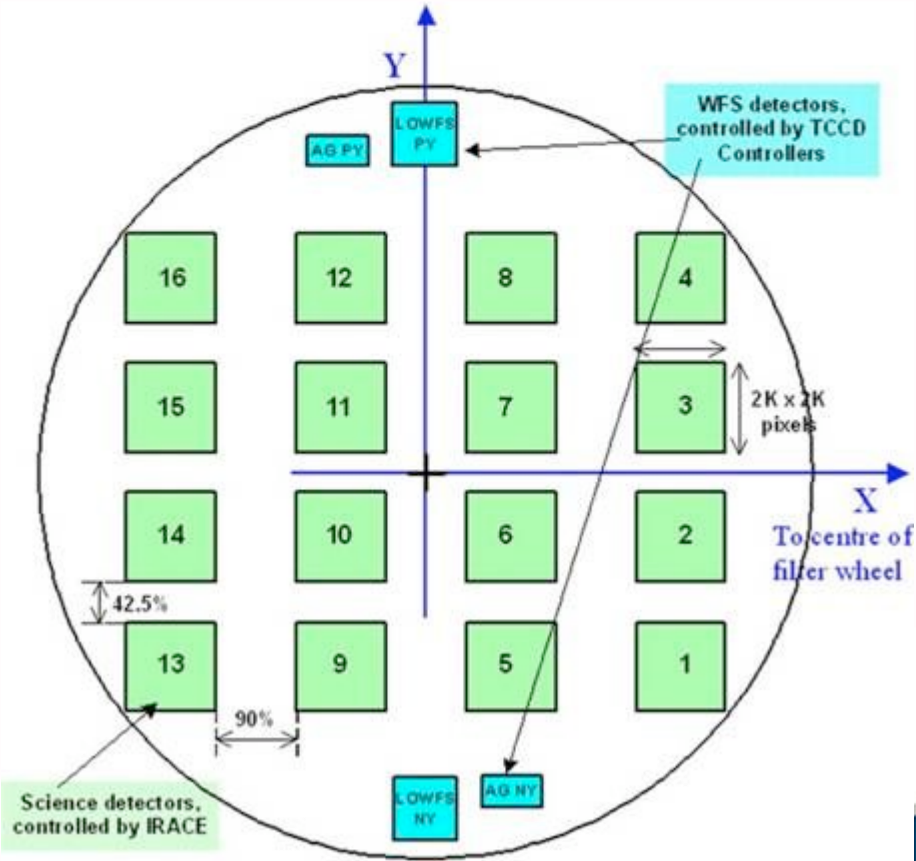


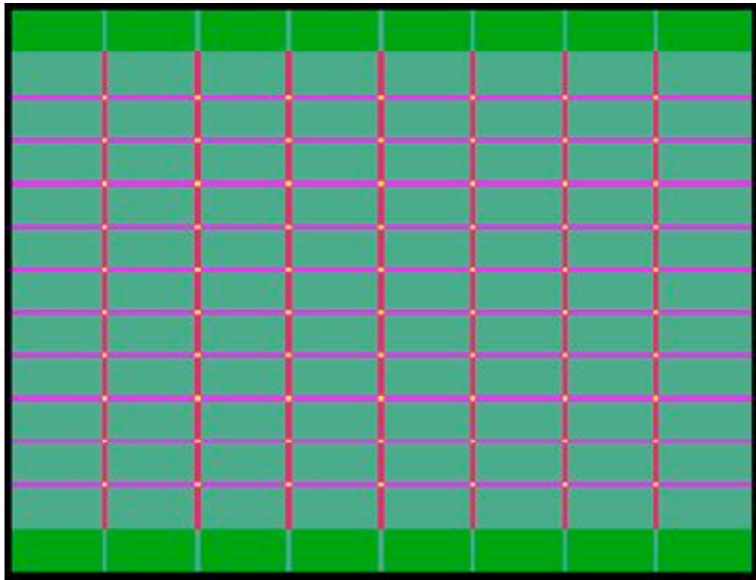
Detector co-planarity: all pixels within ±25μm



IR focal plane:

- **16 arrays, 67 Mpix = 0.60 deg^2 = 2150 $arcmin^2$ on-pixels , 0.34 arcsec/pixel.**
  - 6 offset `pawprints' gives 1.5 x 1.0 $deg^2$ `tile' , every star covered by ≥ 2 pawprints.





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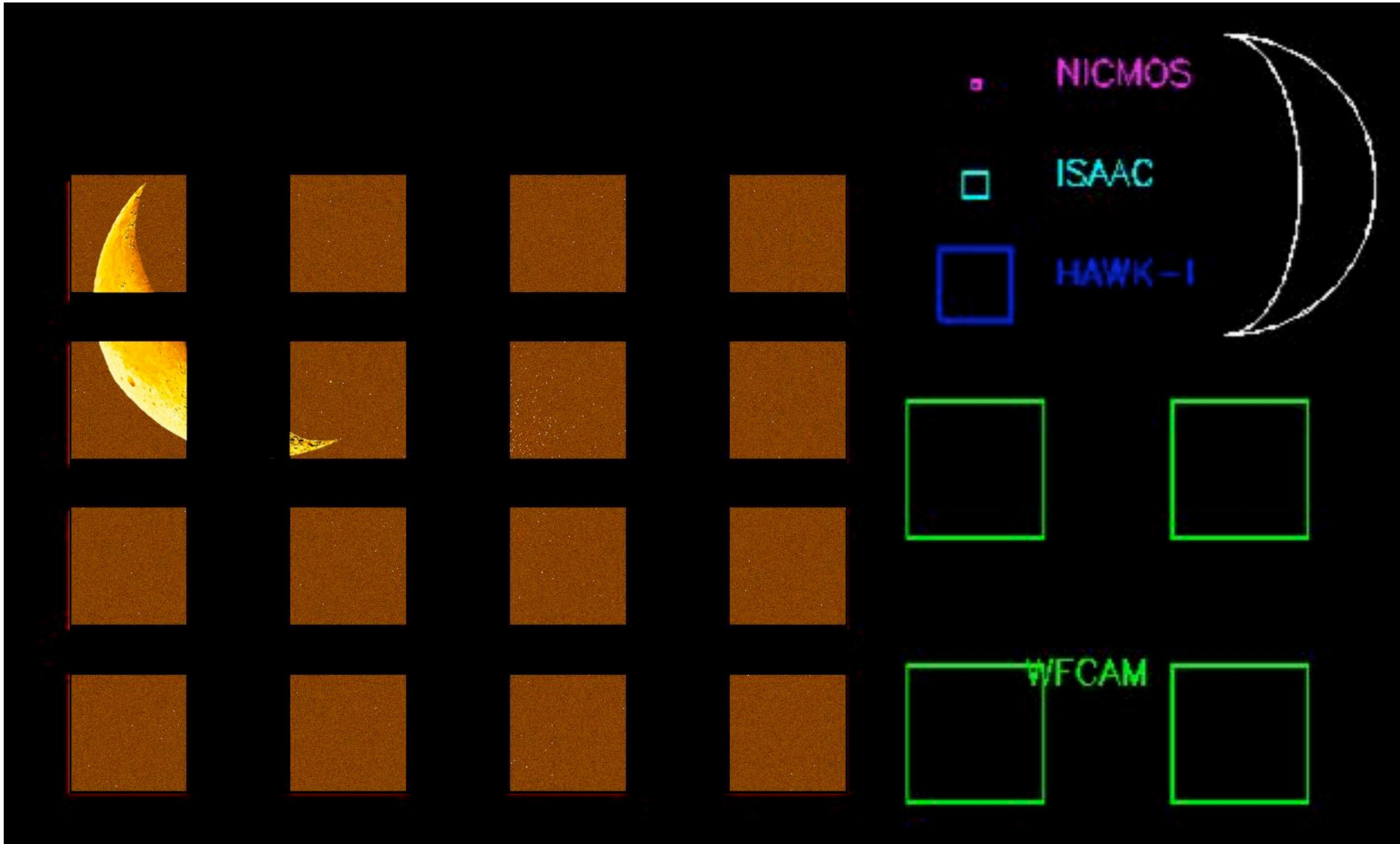
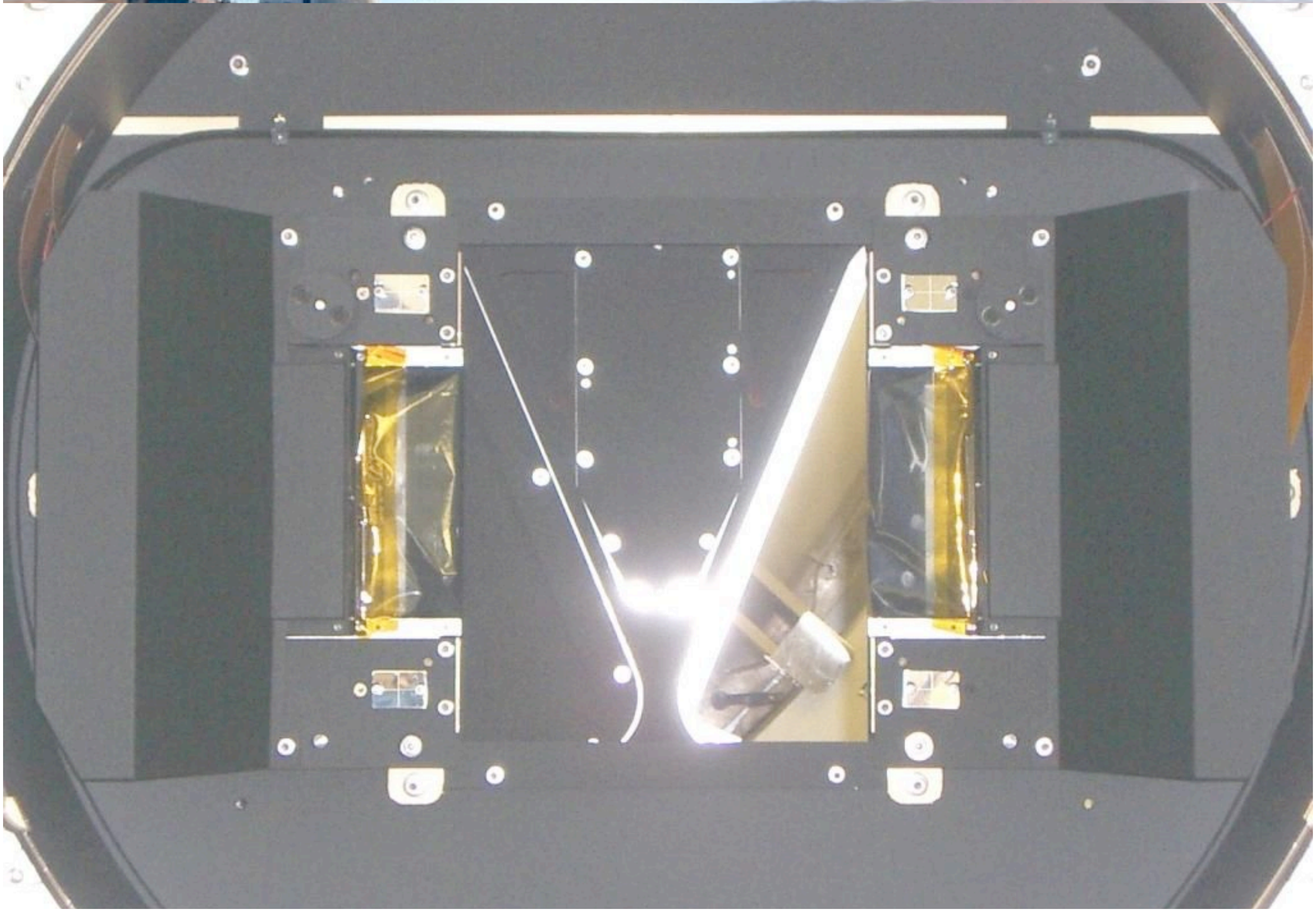
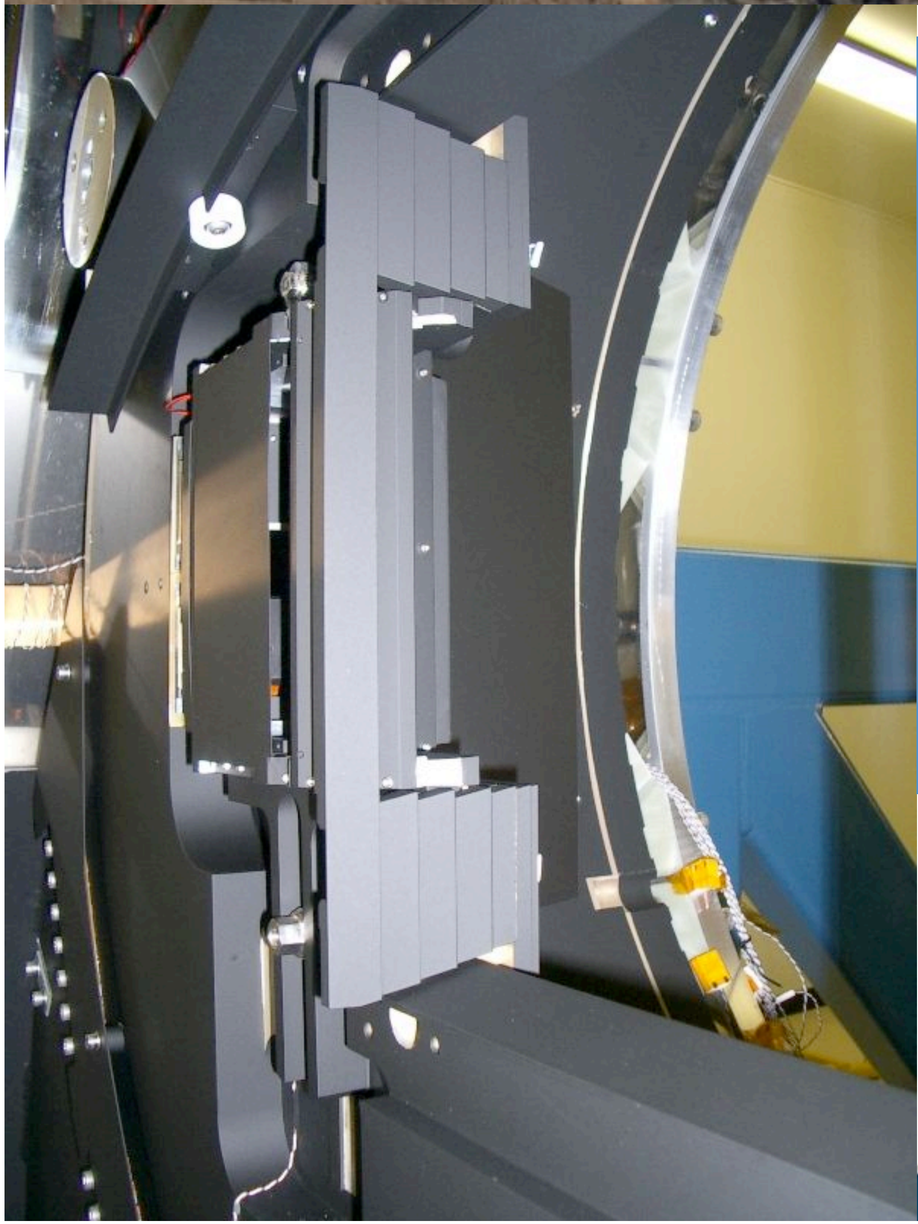
IR camera field size:

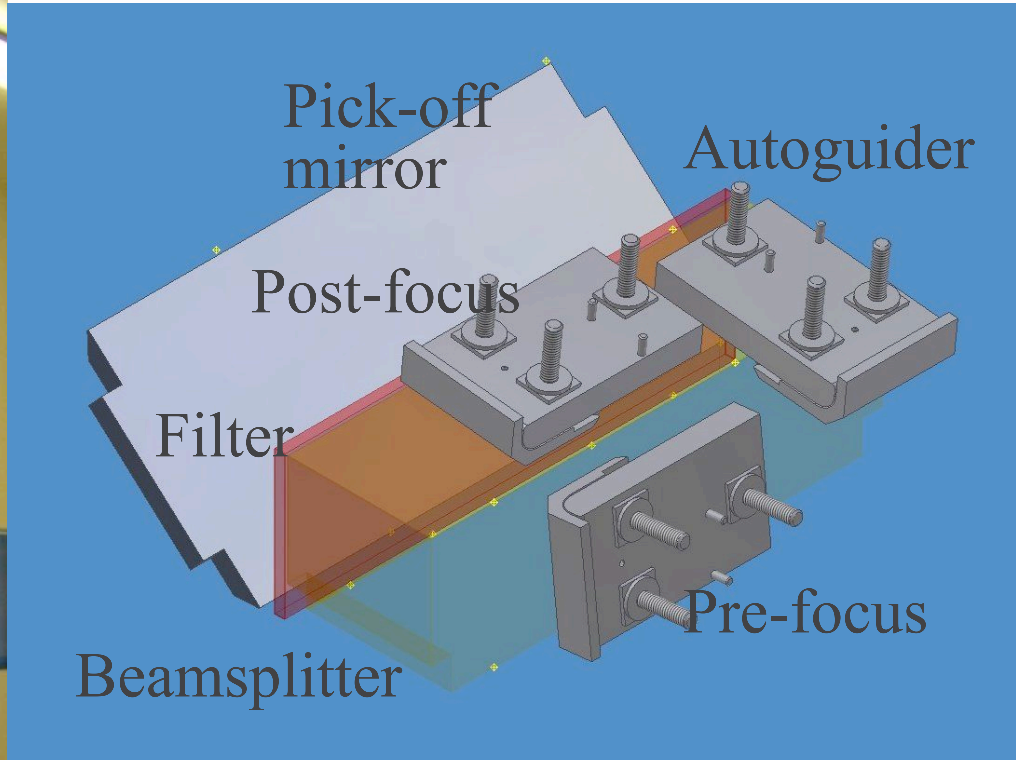


Wavefront Sensors



Wavefront Sensors





Current Status

- Now in final stages of commissioning
  - Verification and internal acceptance
  - Handover: VPO -> QMUL -> STFC -> ESO commences end 6/09
- Full end-to-end operability demonstrated
- System behaviour stable, optics well-aligned
- Image quality appears to be excellent
- End-end throughput (J) estimated at 64%

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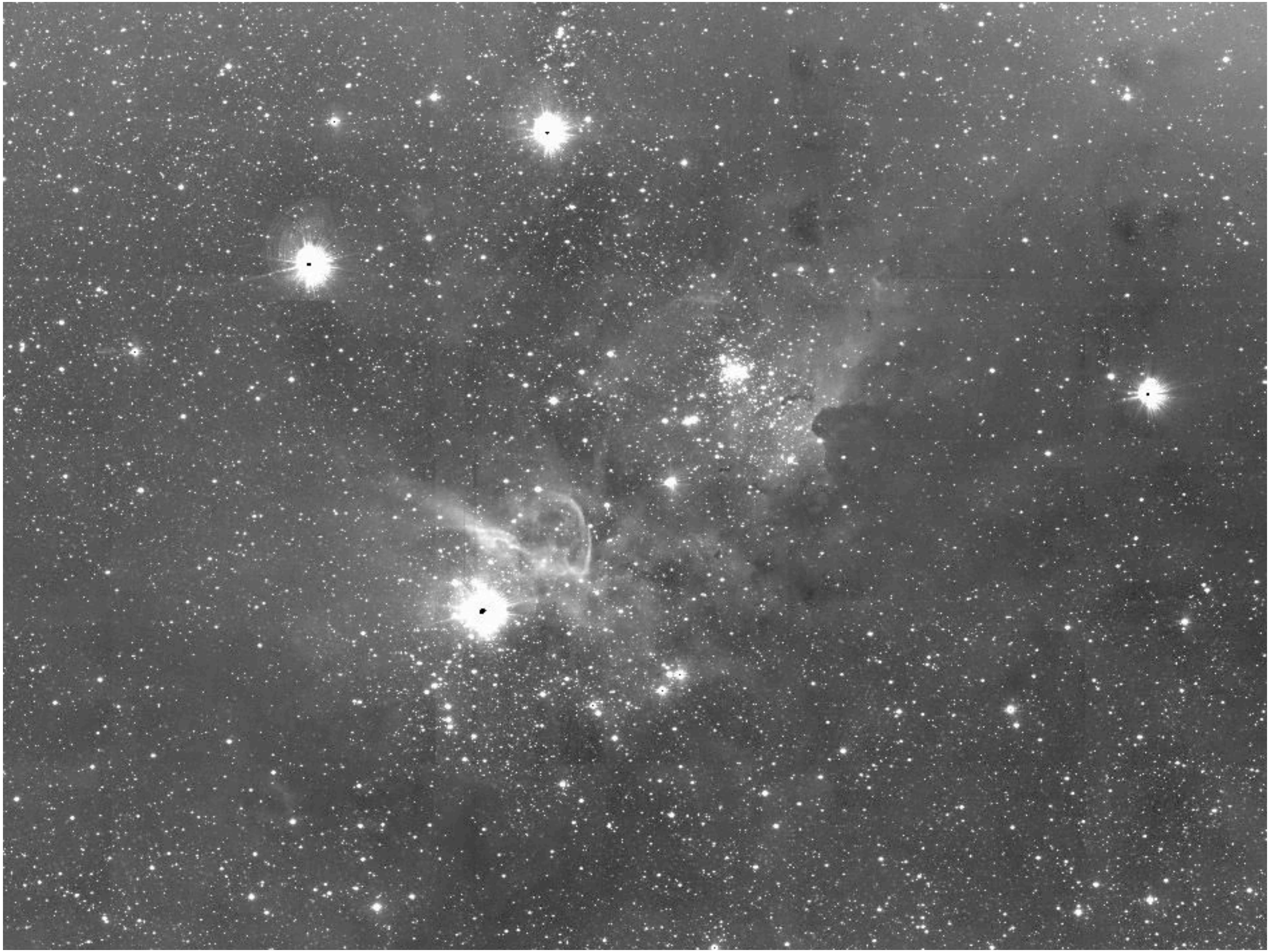
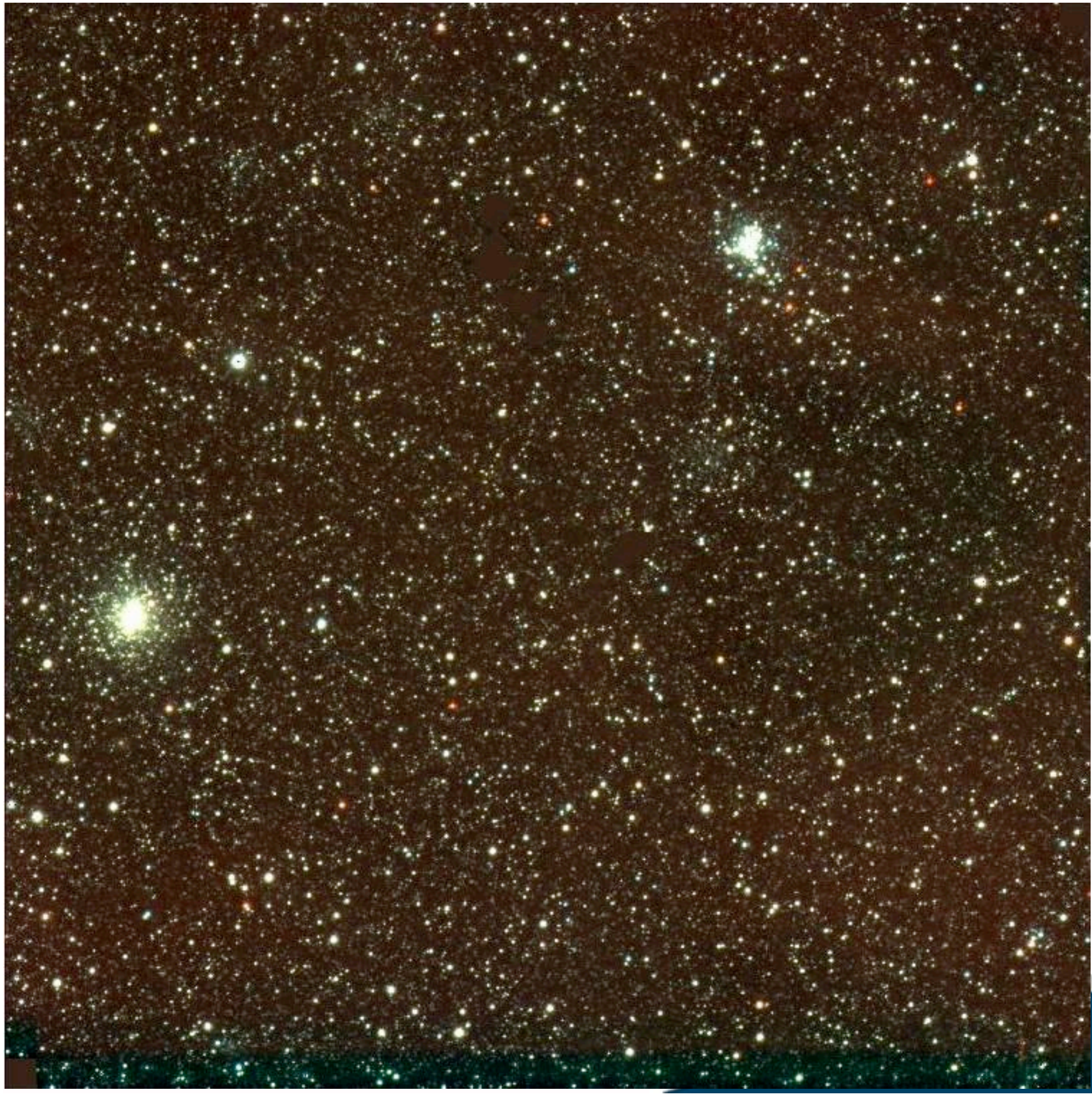


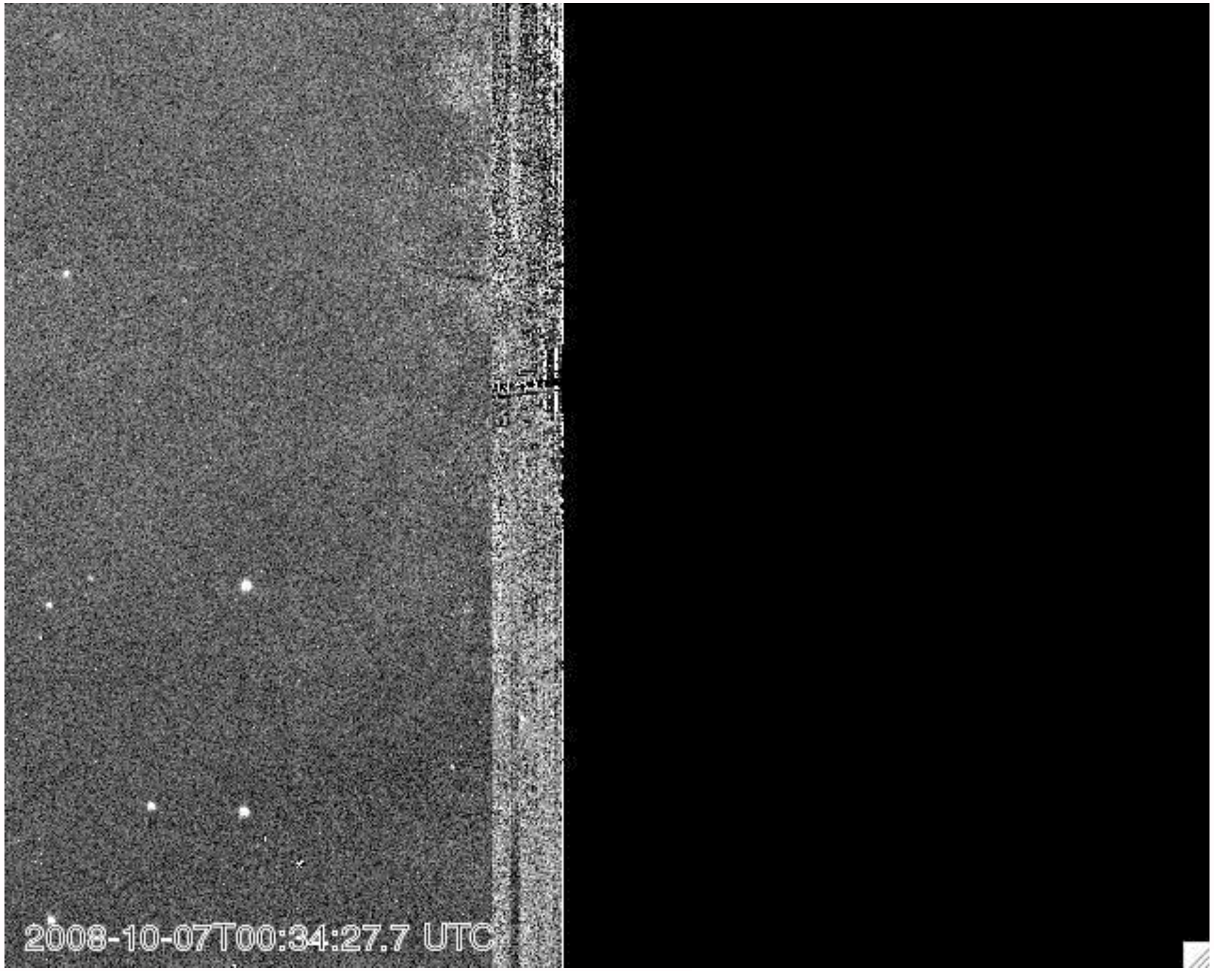
Some Images



LMC (one chip, October 2008)

0.7” PSF at 35° ZD

Some Images



2008 TC3 (1s frames)

2 hours before impact…

Shows potential of wide field IR for NEO detection

Some Images

M42, JHKs

November 2008

…but this is just one chip!

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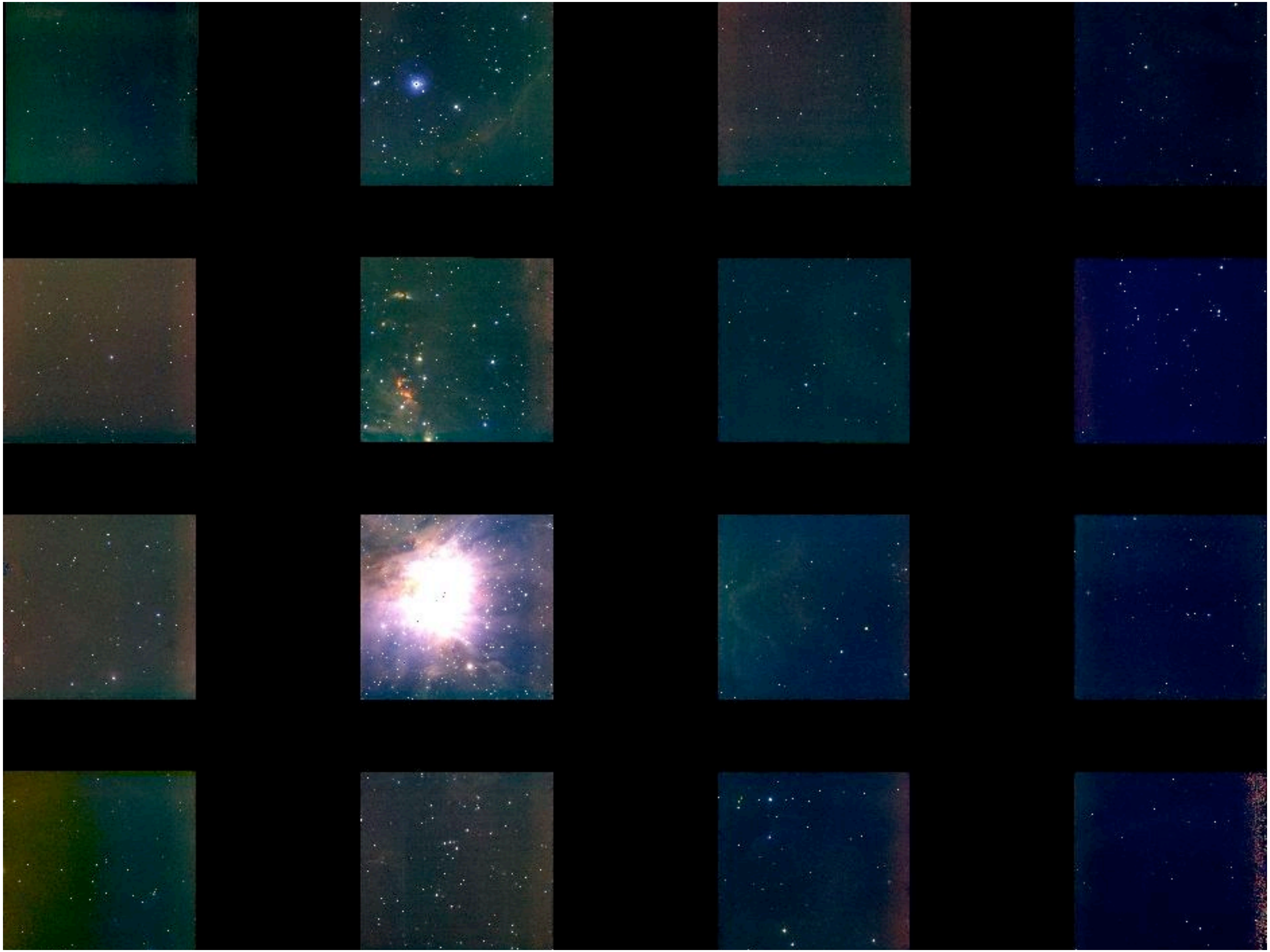
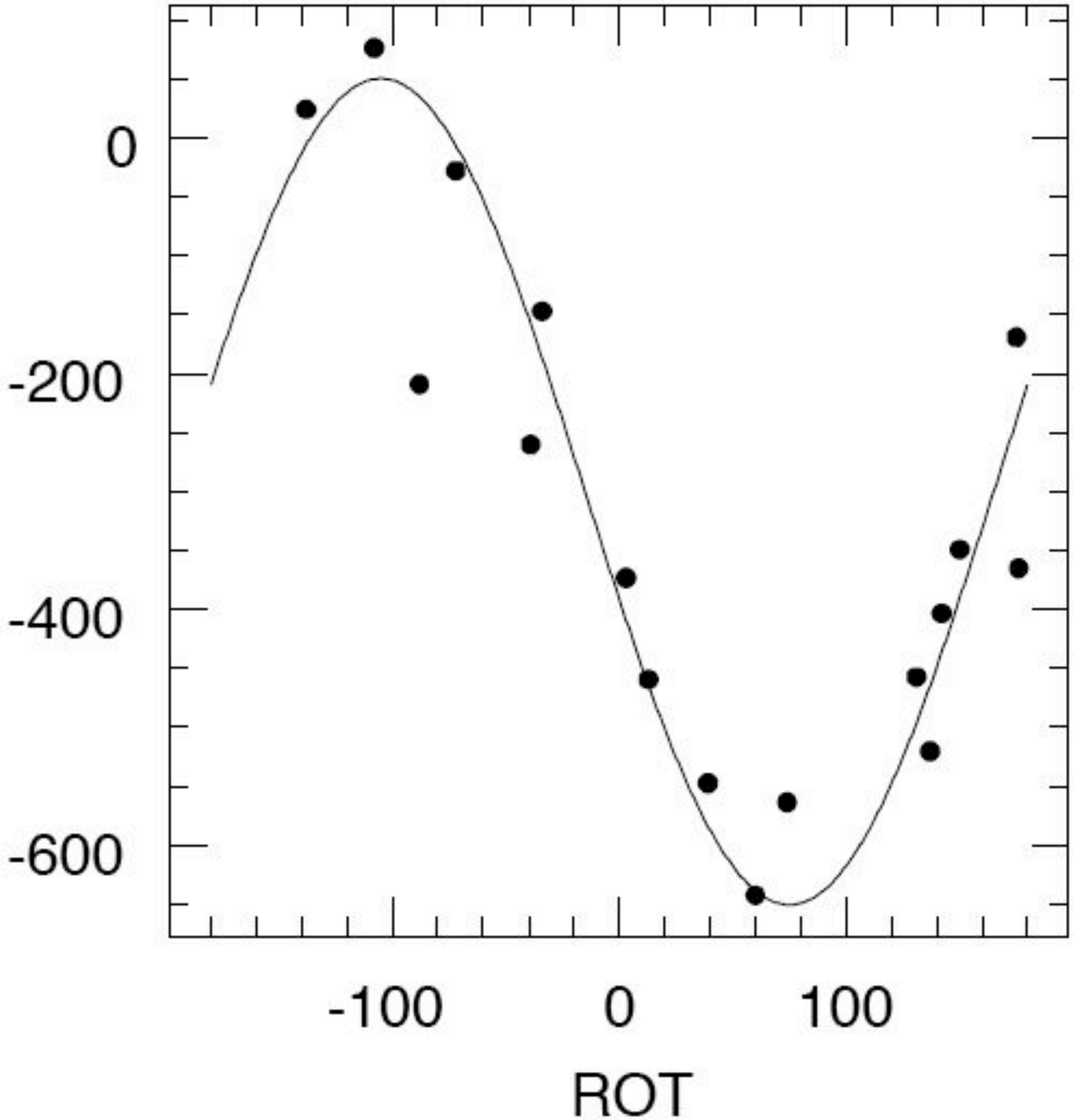


Some lessons…

- Trefoil aberration on secondary…
  - F/1 systems are hard!
  - M1 correction appears acceptable
- Focus gradient seen with high order WFS…
  - Useful to have multiple positions (beamsplitter in filter wheel)
  - Telescope out of alignment (mechanical and optical axes of M1 don't coincide)

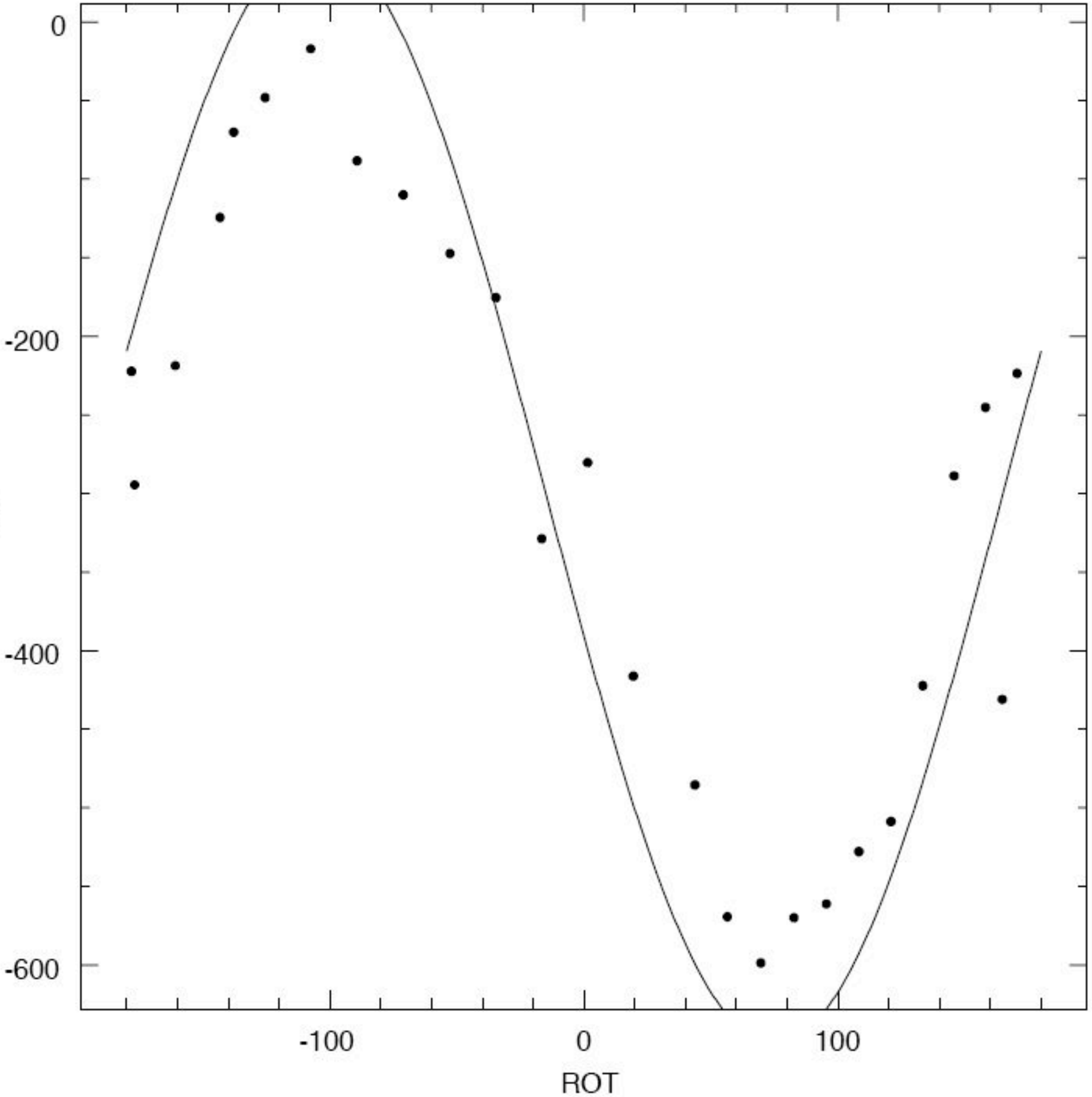
Focus Gradient (HOWFS)



October 2008

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

Focus Gradient (HOWFS)

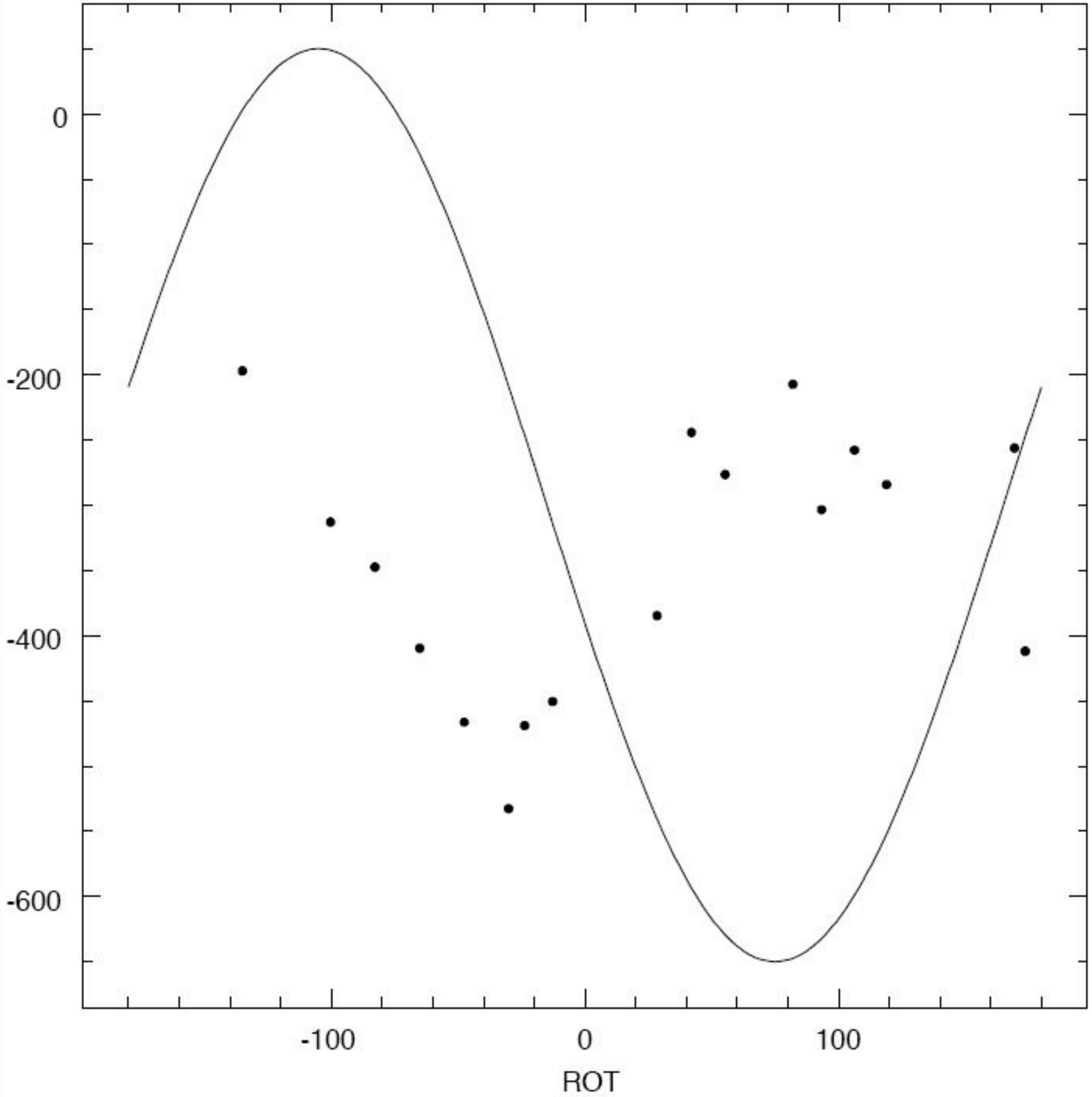


March 2009

Curve is fit to October data.

Points are after remounting M1 and camera following Ag coating and camera intervention

Focus Gradient (HOWFS)



March 2009

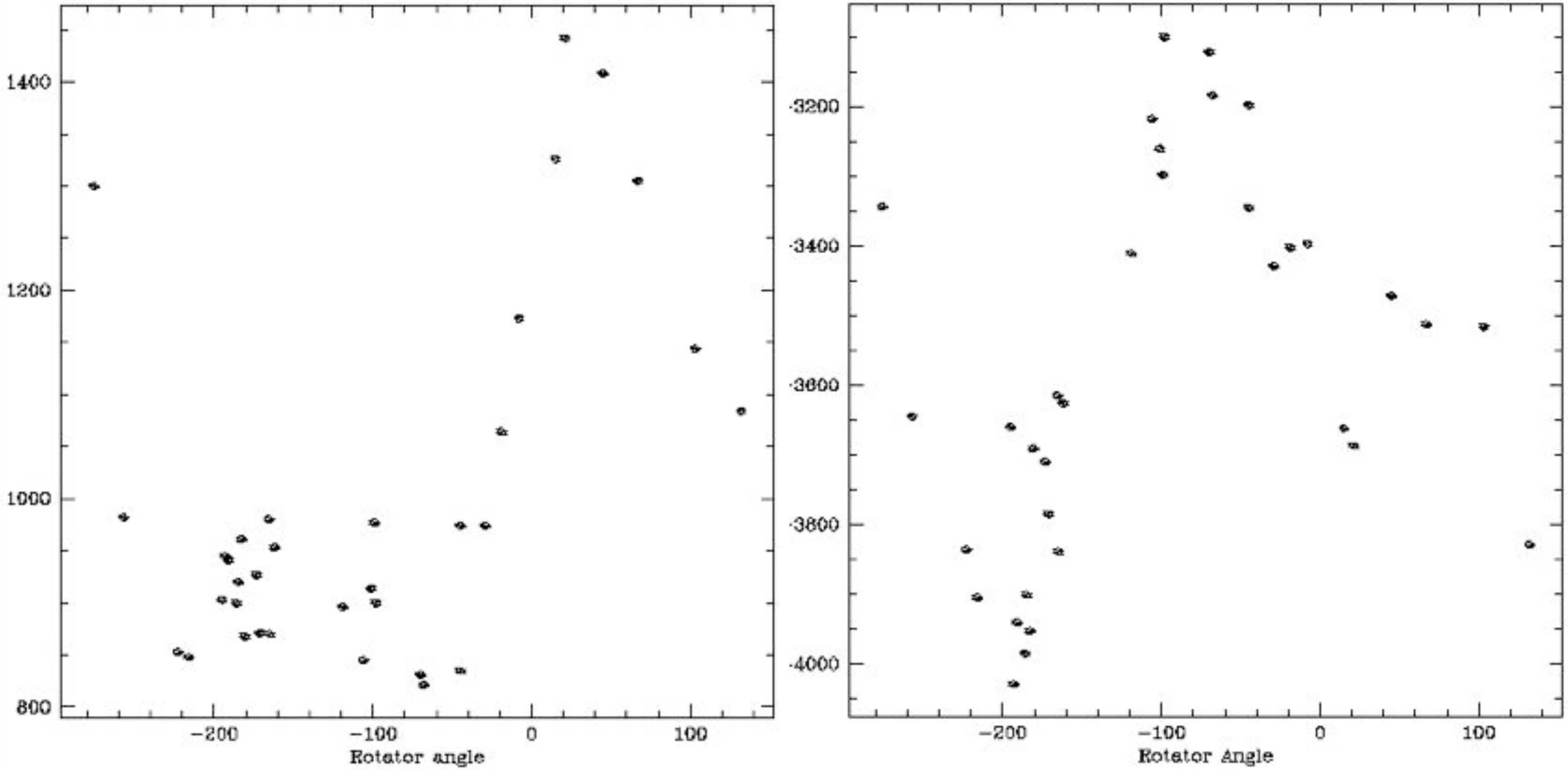
Same plot after lateral M1 position adjustment and recalibration of M2 positioning

Further repositioning of M1 in May 2009 corrected this residual

Some lessons…

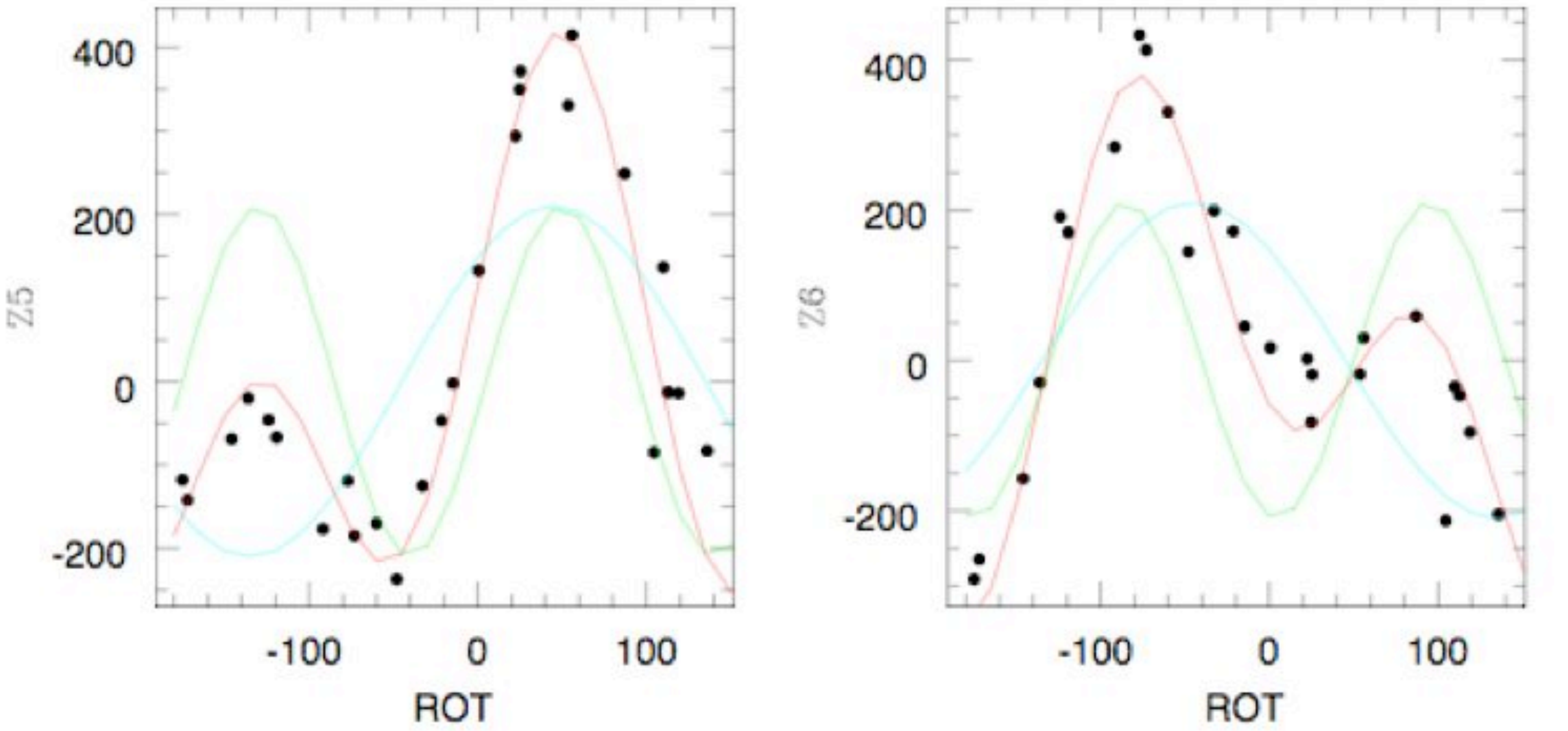
- Trefoil aberration on secondary…
  - F/1 systems are hard!
  - M1 correction appears acceptable
- Focus gradient seen with high order WFS…
  - Useful to have multiple positions (beamsplitter in filter wheel)
  - Telescope out of alignment (mechanical and optical axes of M1 don't coincide)
- M1 correction for trefoil yields 'phantom' astigmatism at WFS locations…

M2 tilt (field dep. astig)



Early indication of peculiar behaviour of the M2 tilt measurements

M2 tilt (field dep. astig)

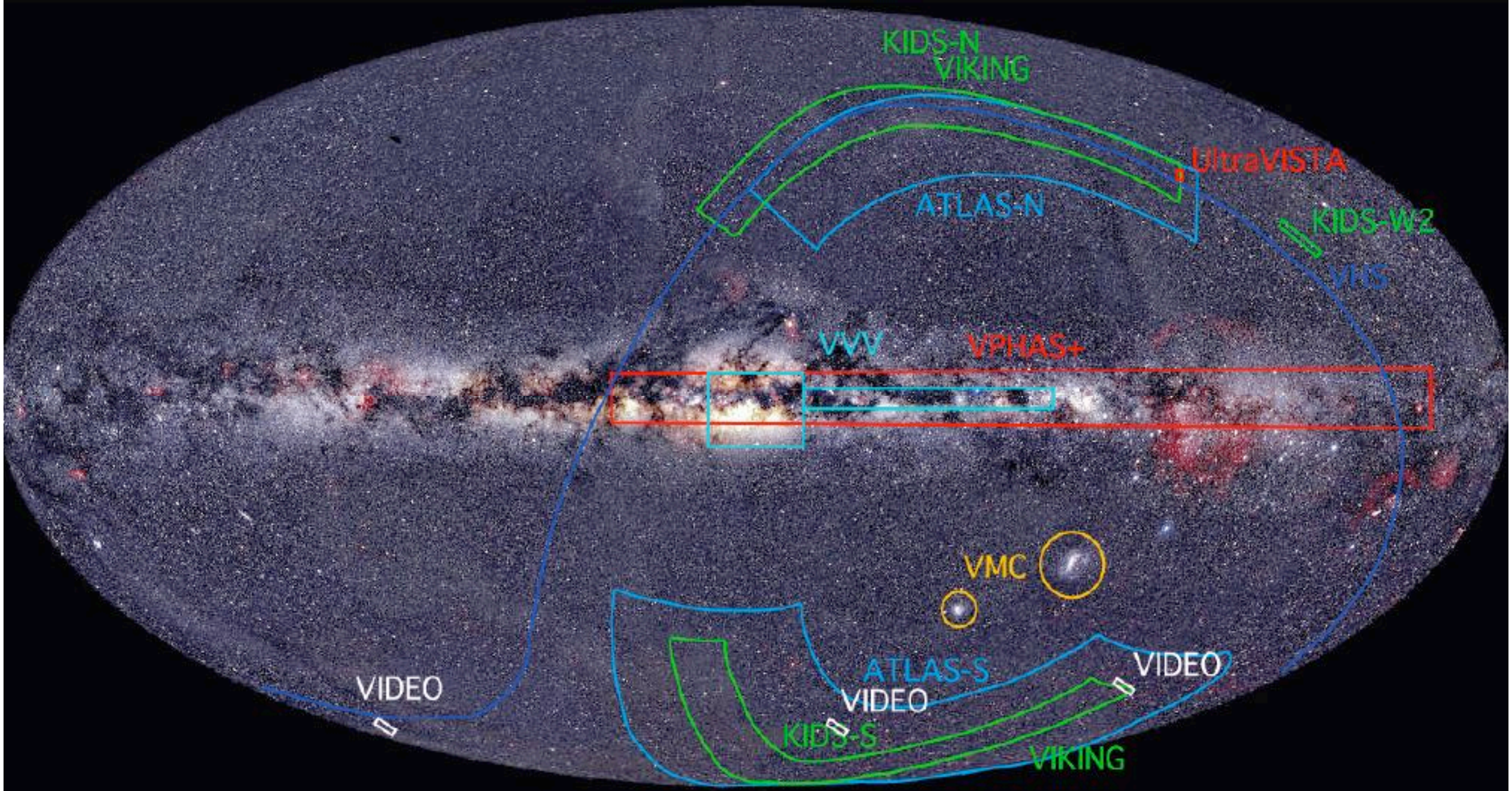


2 component model with a true field corrector mis-alignment term and a ‘phantom’ 2-theta term from the gradient of the M1 trefoil correction

Some lessons…

- Trefoil aberration on secondary…
  - F/1 systems are hard!
  - M1 correction appears acceptable
- Focus gradient seen with high order WFS…
  - Useful to have multiple positions (beamsplitter in filter wheel)
  - Telescope out of alignment (mechanical and optical axes of M1 don't coincide)
- M1 correction for trefoil yields 'phantom' astigmatism at WFS locations…
- Some residual tilt between camera and telscope (expected, but hard to measure until other effects understood - tilted camera-telescope shim in procurement)
- Integrated system approach provides excellent calibration to the instrument focal plane

Summary of VISTA/VST Public Surveys



VST and VISTA will image the equivalent of more than 1 1/2 x full southern sky each year

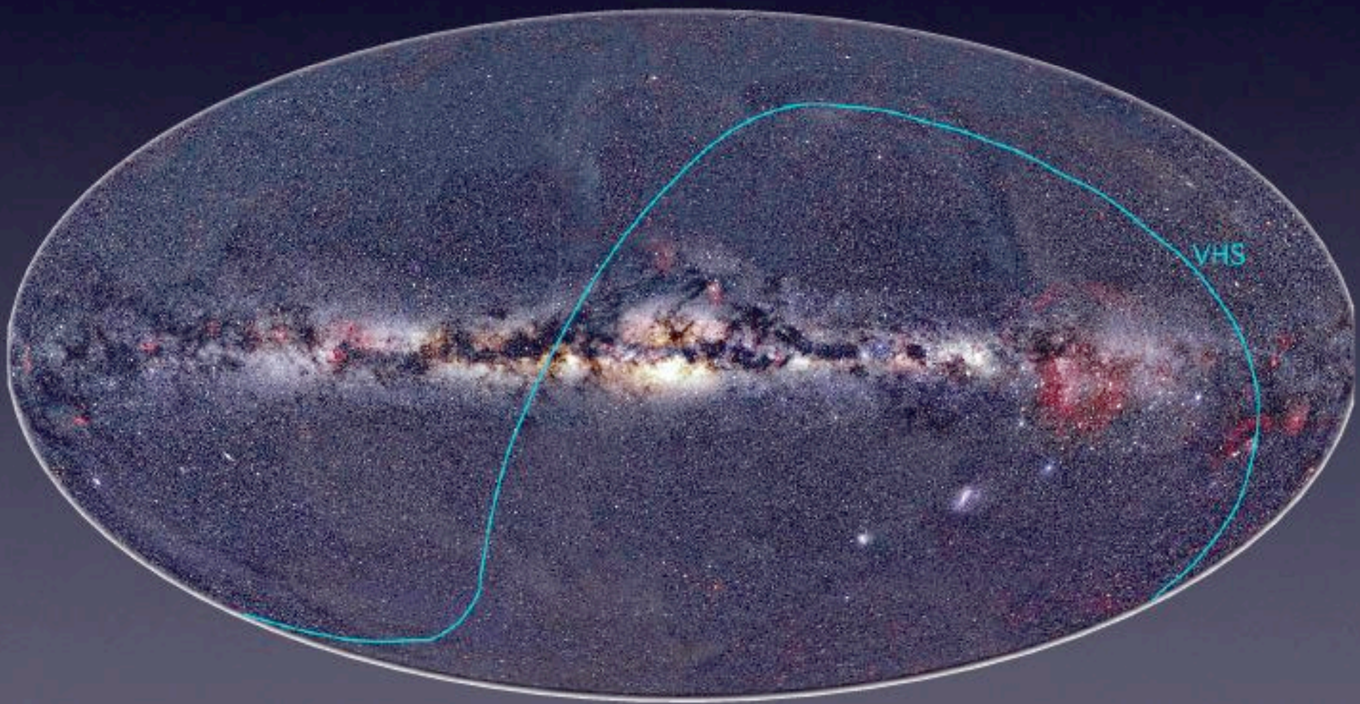
Summary of Public Surveys

Survey synergy	Area (deg^2)	Filters and limits (5σ AB mag.)										
		u'	g'	Hα	r'	i'	z	Y	J	H	Ks	NB
1. KIDS [2,8]	1500+	24.8	25.4	-	25.2	24.2	-	-	-	-	-	-
2. ATLAS [1,5]	4500	22.7	22.9	-	22.9	22.0	21.2	-	-	-	-	-
3. VPHAS+ [7]	1800	22.5	23.2	23.2	23.2	22.5	-	-	-	-	-	-
4. Ultra-VISTA	0.73	-	-	-	-	-	-	26.7	26.6	26.1	25.6	24.1
5. VHS [1,2,8]	20000	-	-	-	-	-	-	21.2	21.1	20.6	20.0	-
6. VIDEO	12	-	-	-	-	-	25.7	24.6	24.5	24.0	23.5	-
7. VVV [3]	520	-	-	-	-	-	22.5	21.9	21.1	19.6	20.0	-
8. VIKING [1]	1500	-	-	-	-	-	23.1	22.3	22.1	21.5	21.2	-
9. VMC	184	-	-	-	-	-	-	23.3	23.0	-	22.9	-

VHS: VISTA Hemisphere Survey (PI: R. McMahon / Cambridge)

Science Case:

- catalogue of low-mass and nearby stars and merger history of our Galaxy
- properties of dark energy via the large-scale structure to z ~ 1
- search for extreme redshift quasars (z > 7)



VHS

Observational Areas:

VHS - ATLAS (5000 deg^2): divided ~evenly between N & S Galactic caps
60 sec. exposures in Y, J, H, and Ks

VHS - Dark Energy Survey (4500 deg^2): SGC
120 sec. exposures in J, H, and Ks

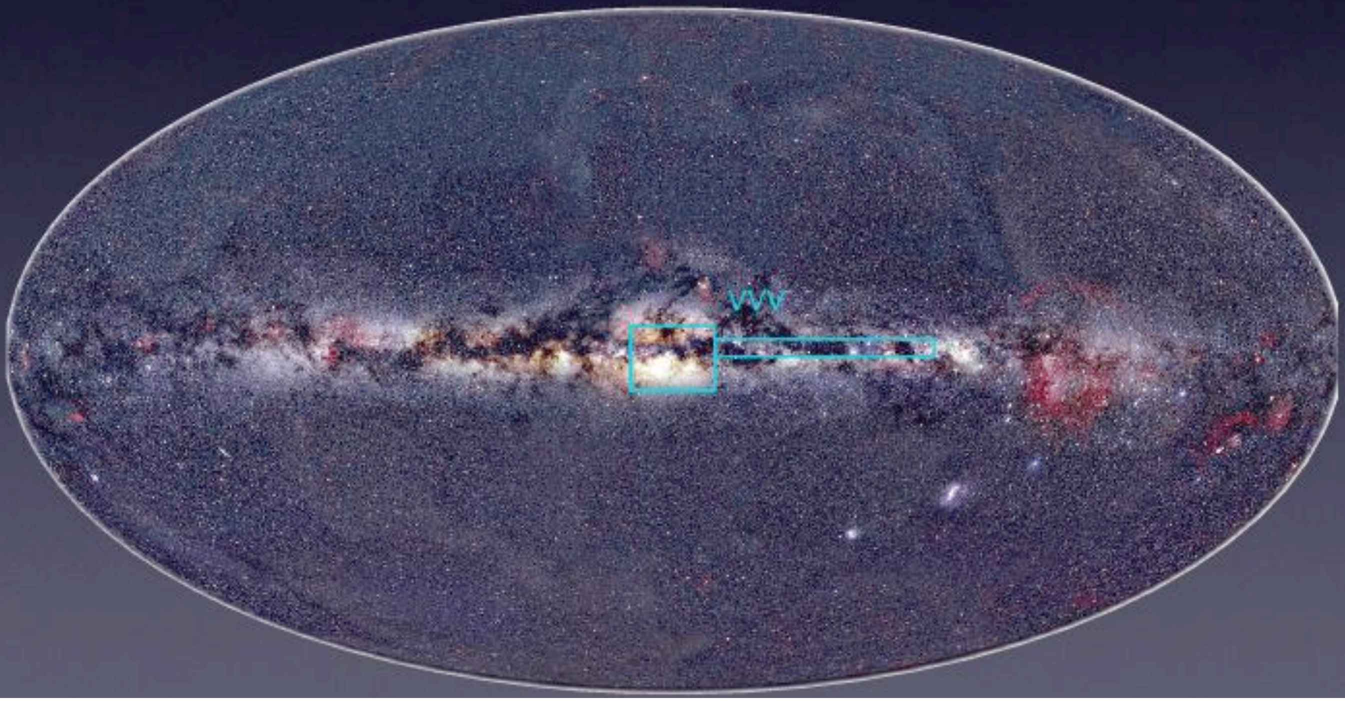
VHS - GPS (8200 deg^2): Galactic Plane Survey (excl. VVV)
60 sec. exposures in J, and Ks

VVV: VISTA Variables in Via Lactea (PI: D. Minniti / Univ. Catolica)

Science Case:

- multi-epoch survey: Catalogue variable objects + high proper motion stars
- create a 3-d map of the Galactic bulge (RR Lyrae stars)
- cluster evolution (350 open and 33 globular clusters)
- ages of stellar populations and steller IMF

520 deg^2 of Galactic bulge and adjacent plane



VVV

Constraints:

- seeing <= 0.8 arcsec / CLR / any moon
  applicable for both bulge and disk

Strategy:

- mock first year covers entire bulge/disk area (520 deg^2) in:
  all 5 filters (Z, Y, J, H, and K_s) => *concatenation*
  then when complete repeat tiling in K_s at 5 further epochs
  with a 3 day time interval between successive epochs => *time link*

		Z	Y	J	H	Ks
depth:	bulge	21.6	20.9	20.6	19.0	18.0
	disk	21.5	20.7	20.2	19.3	18.3
DIT:	bulge	10	10	6	4	4
	disk	20	20	10	10	10
nDIT x nJitter x nPAW:	bulge	1x2x6	1x2x6	2x2x6	1x2x6	1x2x6
	disk	1x2x6	1x2x6	2x2x6	2x2x6	2x2x6
Total Exp. (sec):	bulge	120	120	144	48	48 x 6 epochs
	disk	240	240	240	240	48 x 6 epochs

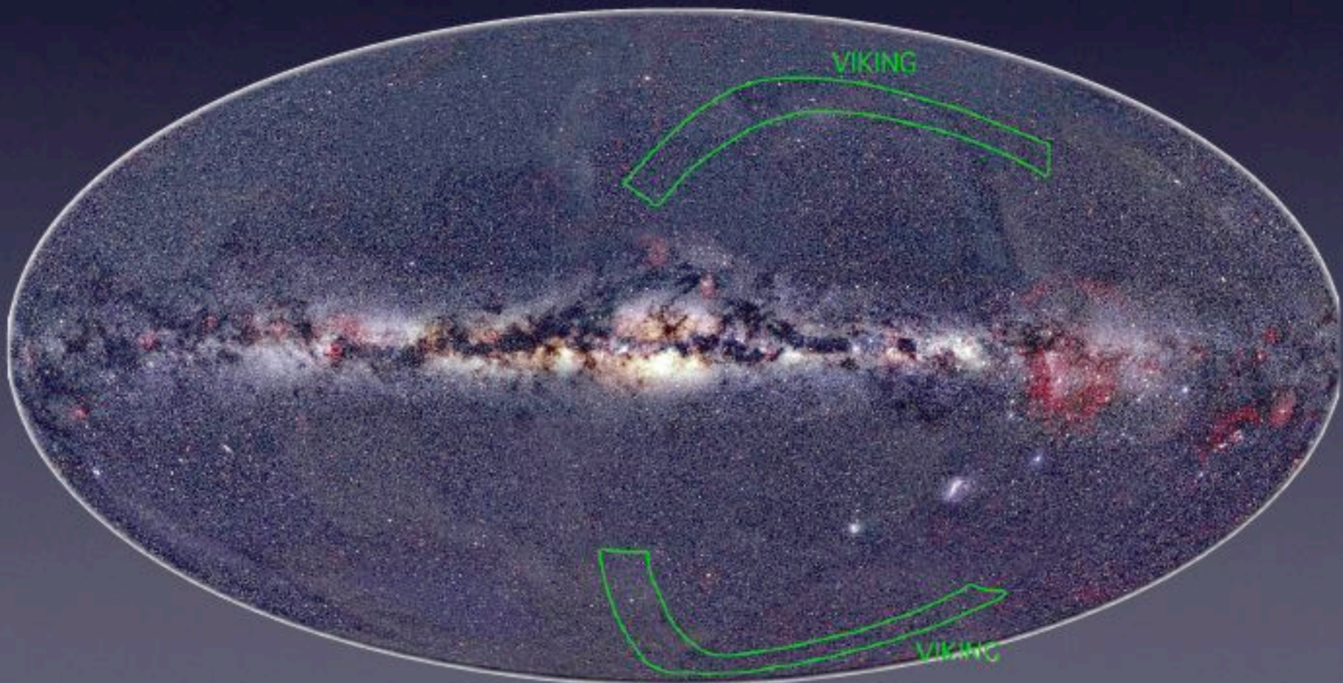
VIKING: VISTA Kilo-Degree INfrared Galaxy Survey
(PI: W. Sutherland / Cambridge)

Science Case:

- key complement to VST/KIDS (9 bands => very accurate photo z's: $\Delta z/(1+z) \sim 0.03$ to $z = 1$)
- with KIDS: weak lensing and baryonic oscillations

detection of very high redshift QSO's ($z>7$), ultra-cool brown dwarfs, galaxy evolution and morphology, and clustering

1490 deg^2 covering all KIDS fields in: Z, Y, J, H, Ks



VIKING

Constraints:

- seeing <= 1.0 arcsec & THN
- 1 Tile => 2 OB's:

  OB_1: Z,Y, J_1 (dark or grey)

  OB_2: J_2, H, Ks (any moon)

- OB_1 and OB_2 should be observed within one month of each other

(addressed using p2pp *groups*)

Strategy:

- locate field centers along *tramlines* of constant declination (matching those of KIDS)

  => 2 arcmin overlaps (N/S); 1 arcmin overlaps (E/W)

  => 49 x 10 tiles (SGP) and 61 x 9 tiles (NGP) x 1.435 deg^2 per tile = 1490 deg^2

filter	Z	Y	J	H	Ks
depth (vega 5 sigma)	22.6	21.7	21.3	20.2	19.4
DIT	50	50	25	10	10
nDIT x nJitter x nPAW	1x5x6	1x4x6	2x2x6	5x3x6	6x4x6
Total Exp (sec)	1500	1200	600	900	1440

VISTA Survey of the Magellanic Cloud System (PI Cioni)

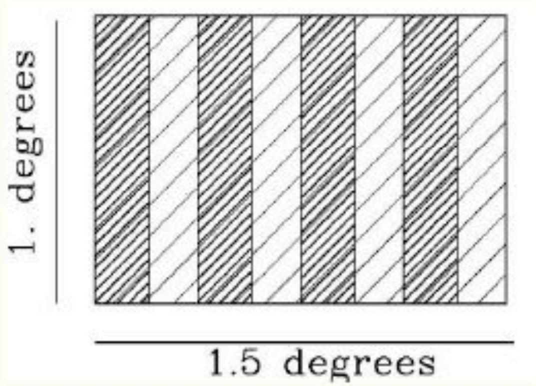
- Goal: Study the evolution of stellar population and history of galaxy interaction
- Outline: Observe LMC, SMC, Bridge, and Stream in $\mathrm{YJK_s}$. Total area 184 deg^2.
- Constraints: Moon: any, transparency: THN, seeing: $1\overset{''}{.}0$
- Strategy:
  - Concatenation: in $\mathrm{YJK_s}$
  - Time link: 15 different epochs, 15 days interval between each epoch, 5 days interval validity for each OB $2 \times \mathrm{Y} + 2 \times \mathrm{J} + 11 \times \mathrm{K_s}$
- First year: Only 100 deg^2 on LMC, $10 \times 10\,\mathrm{deg}^2$ rectangle centered on 05:23:34, -69:45:22.

VISTA Deep Extragalactic Observations (VIDEO) (PI Jarvis)

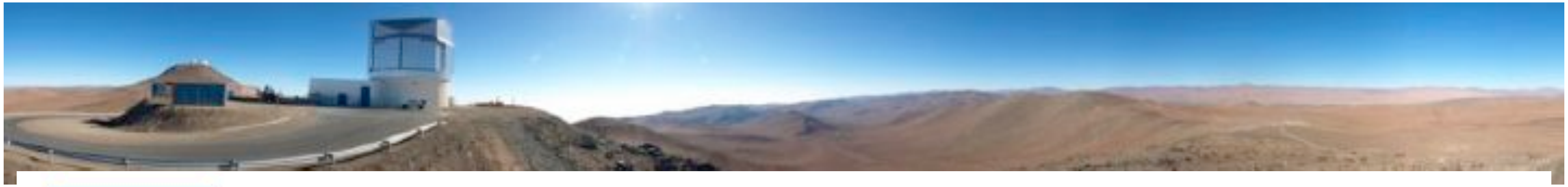
- Goal: Galaxy and structure evolution out to $z = 4$.
- Overview: $2 \times 4.5\,\text{deg}^2 + 1 \times 3\,\text{deg}^2$ fields in $\mathrm{ZYJHK_s}$
  - XMM-LSS (02:18:00, $-$05:00:00), high priority
  - ELAIS-S1 (00:34:00, $-$43:00:00), medium priority
  - CDF-S (03:22:00, $-$27:00:00), low priority
- Z (dark), J (grey), and $\mathrm{K_s}$ (bright) have higher priority than H (bright) and Y (grey). Implemented via different OB priorities in OB groups.
- Seeing: $0\farcs8$, tranparency: THN
- First year: Finish one tile before moving to the next, i.e., only one tile in each field will be observed in year 1.

Ultra-VISTA
(PI Dunlop)

- Goal: Study the Universe between $z = 6.5$ and $z = 10$
- $1 \times 1.5\,\mathrm{deg}^2$ on COSMOS field in $\mathrm{YJHK_s}$ and NB1185
- 3 vertical offsets will give 4 ultra-deep columns, 1 horizontal offset will fill the field

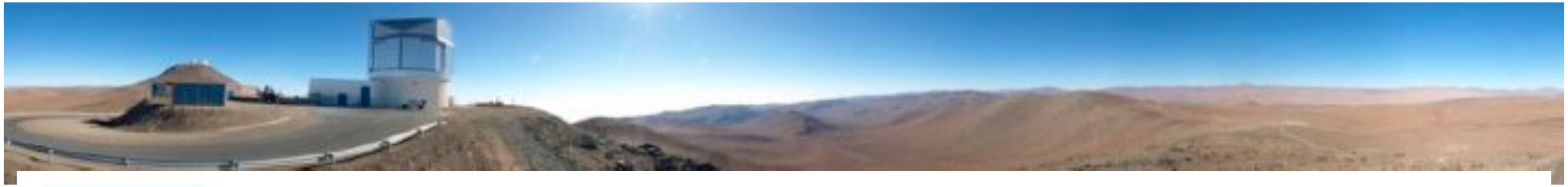


- Each offset is one single pawprint 1 h OB
- Constraints: Y and NB: dark, others: any, seeing: $0\farcs8$, transparency: CLR
- First year: This survey only gains depth, not area. Ensure homogenous progress



VISTA SV

- SV will take place after handover of telescope – beginning of 2009.
- A total of 11 nights – to be divided up into two mini-surveys Galactic and Extragalactic – about 50 hrs obs. each.
- The two mini surveys should not overlap with the VISTA public survey projects
- Test the whole end-to-end system – crucial to optimize QC parameters & spot checks for telescope and instrument monitoring
- Raw data will be publicly available.
- Data will be reduced with the VISTA Data Flow System (VDFS – CASU & WFAU) and AstroWISE. Reduced data products will be publicly available from SAF



VISTA SV

1. Extragalactic mini survey: deep survey of the stellar halo in a nearby spiral galaxy
2. Galactic mini survey: the star formation region in Orion

1. Goals:

Detect faint stellar halo

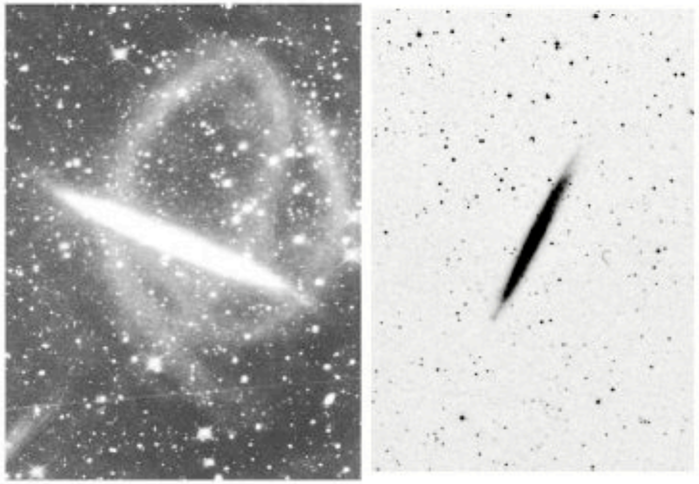
Detect and characterize the metallicities of satellites in the field

Detection of streams

Detection of GCs/UCDs

Narrow band imaging to map opacity

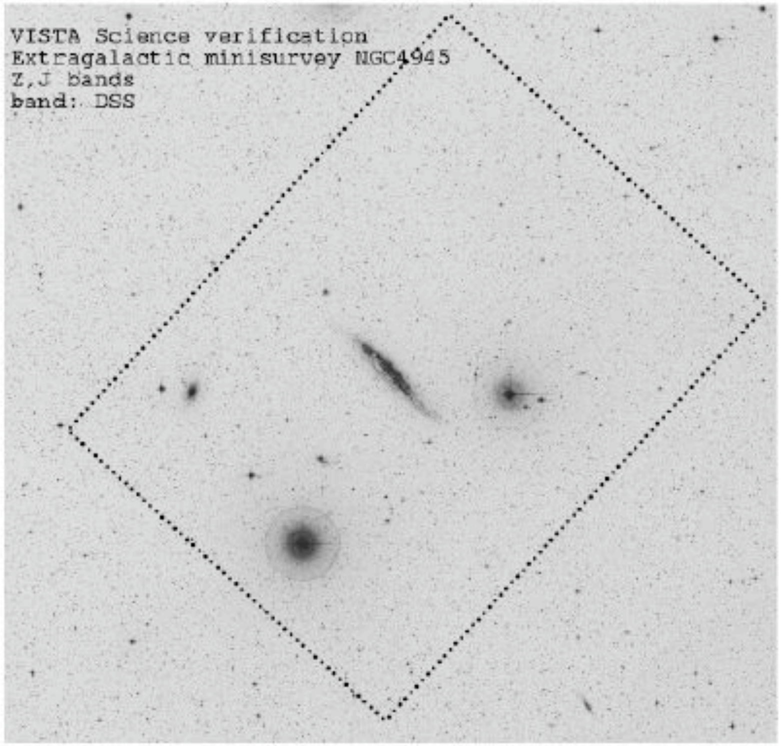
And star formation at z=0.84



NGC 5907 18'.2 x 27'.7
11.35 hrs BBRO image and DSS

VISTA SV -Target galaxy NGC 4945

1. NGC 4945 13 05 27 -49 28 05 (J2000); m-M = 27.63, D=3.9 Mpc
2. Detecting red giant branch stars in the diffuse stellar halo and streams using deep broad band Z and J
3. Satellites of M31 and MW are manly dSphs, within 300 kpc of the MW disk μ_V=23-26 mag arcsec^{-2}, V=-8.5 - 13, 11 Gyrs old, metal poor ([Fe/H]=-1.7).
4. For such a stellar population the absolute magnitude at the tip of the RGB is → Z=-4.51;J=-4.94
5. mz=23.3, mj =22.9



VISTA FOV ~ 102 x 68 kpc^2

VISTA SV - Observing strategy

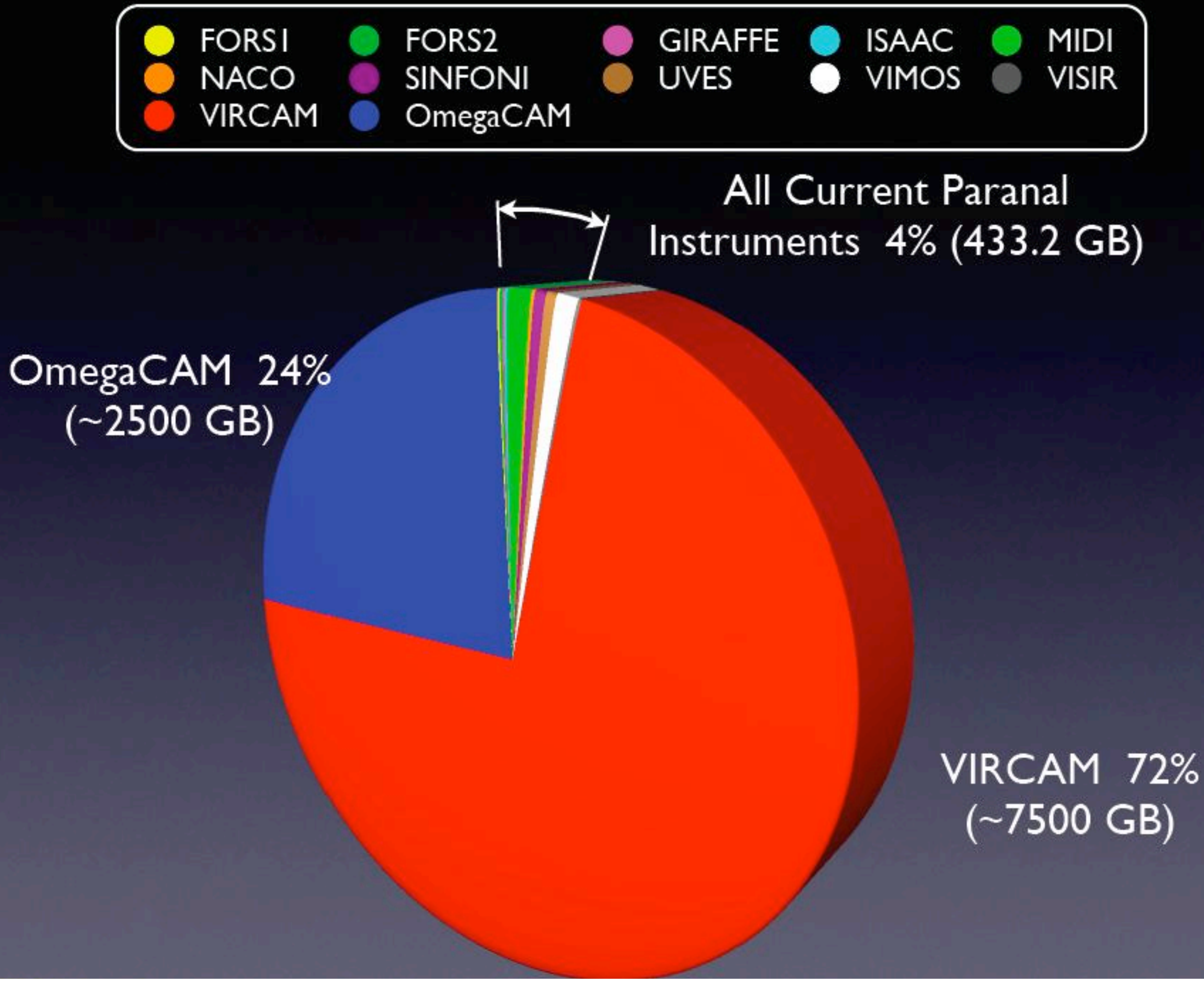
- In addition to brad band imaging we carry out a search for Halpha emitters in the background of NGC 4945 at 0.84 using the narrow band filter NB 118
- Goals: probe the opacity of the stellar halo and the star formation rate at this redshift,
- Observing strategy: 1 tile only, in Z,J, NB118.
- Exposure times: Narrow band 6 hrs, Broad band, see below:

Band	Abs. magnitude at RGB tip	App. magnitude at RGB tip	N_{obs}	Tot Exp. time	S/N (seeing = 0.8″)	S/N (seeing = 1.0″)
Z (MR)	−4.76	23.0	2	3.2h	10	8
Z (MP)	−4.51	23.3	4	6.3h	10	9
J (MR)	−5.65	22.1	4	5.9h	10	8.5
J (MP)	−4.94	22.9	15	22.1h	10	8

Band	DIT	N_{dit}	N_{jit}	N_{paw}
Z	60	3	5	6
J	35	6	4	6

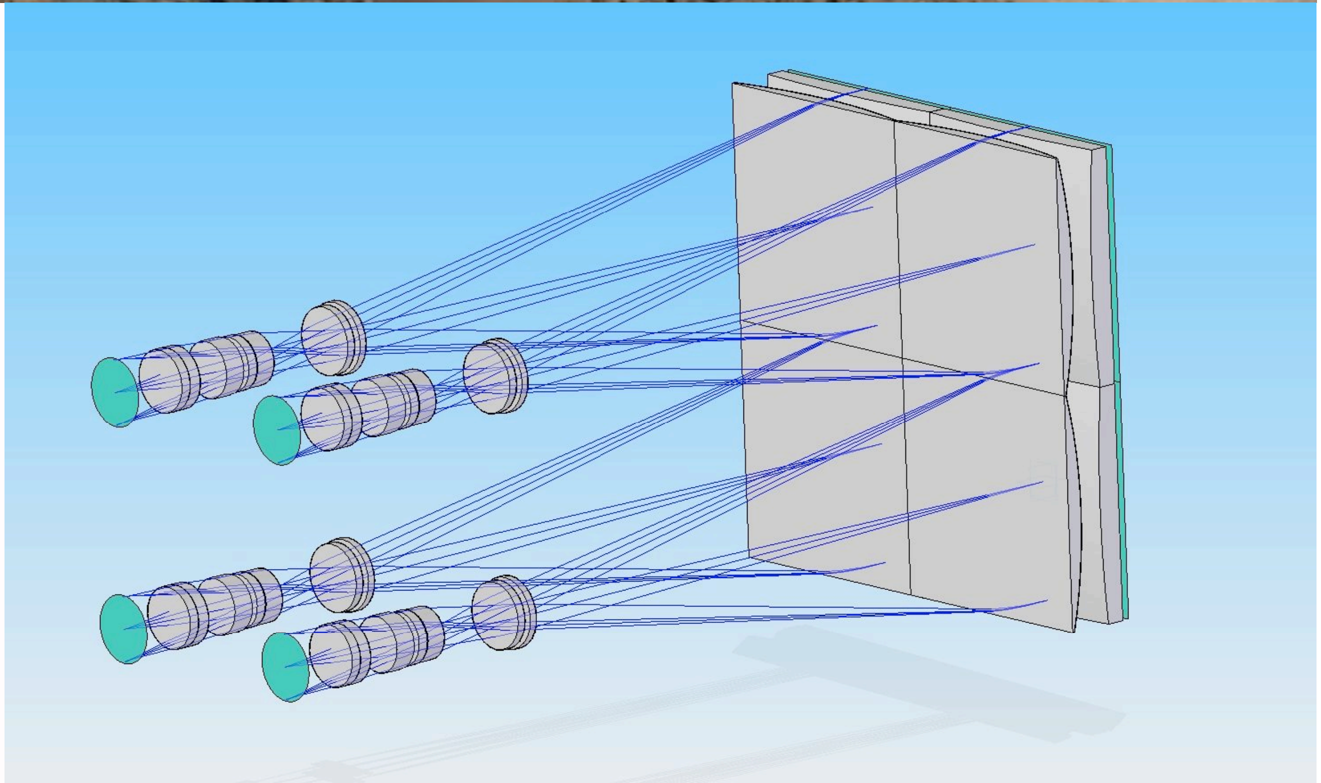
Survey	Image Size (TB)	Catalogue size (TB)	Total (TB) over 5 years	Total (TB) per period
Ultra-VISTA	0.0034	0.0069	0.01	0.001
VHS	36.2	2.37	38.6	3.9
VIDEO	0.027	0.018	0.05	0.005
VVV	2.4	7.4	9.8	1.0
VIKING	3.4	0.45	3.9	0.4
VMC	1.3	0.44	1.7	0.2
	Totals:		54	5.4

Paranal Monthly Data Rates



VIRCAM for ELT?

- Big cameras are easy, right?
  - 5' FOV @f/18 on E-ELT is 1.1m diameter
  - GLAO limited -> 0.1" pixels -> 350μm pixels
  - 10x focal reducer -> f/1.8 -> 35μm pixels
    - Looks better, but could we build it…?



F/5 field splitter, shown for a 7' FOV…
individual cameras now about VISTA sized…

100μm pixels, 4x1024x1024 arrays…

-see later talk!