The VLT Survey Telescope

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&

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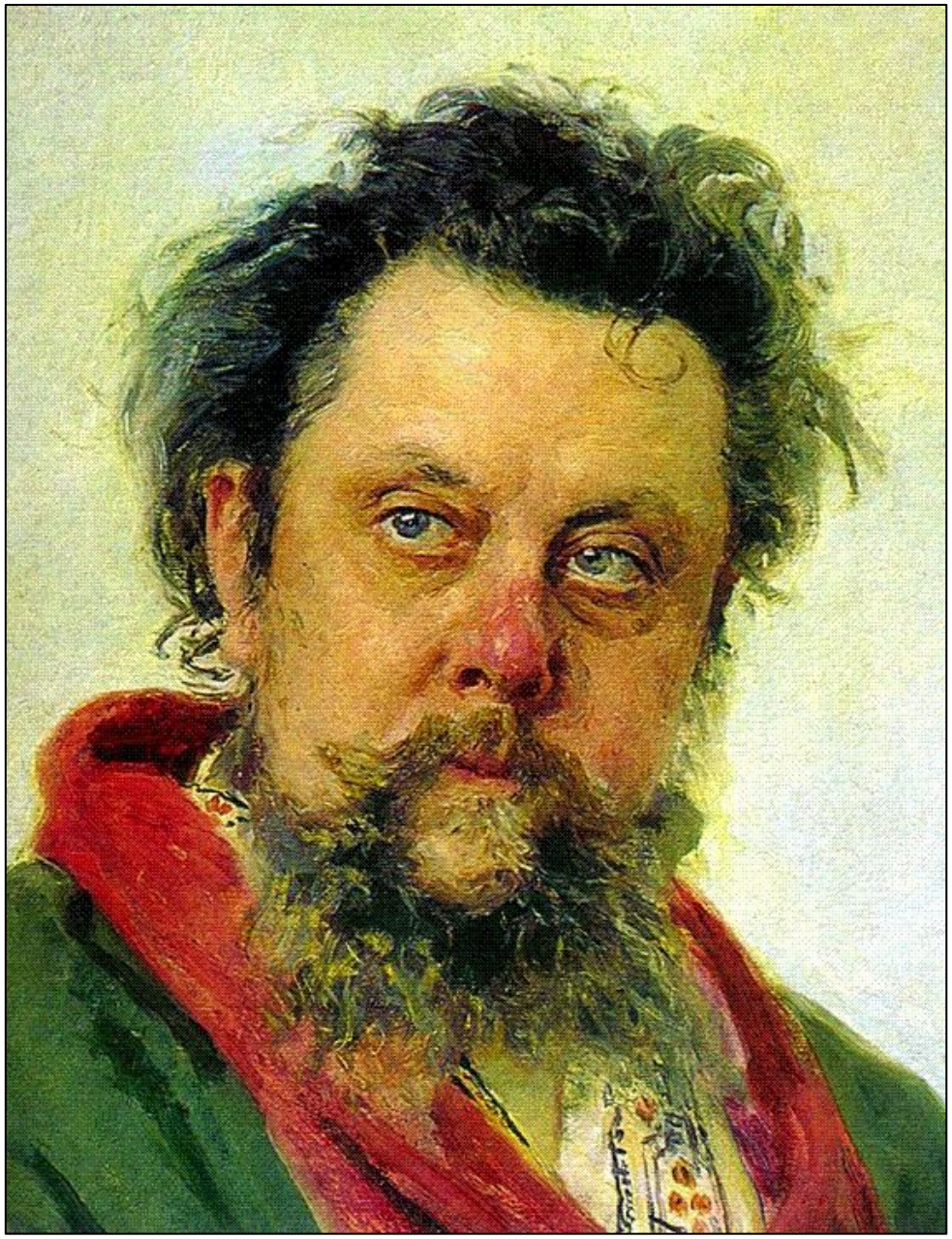
Atlas workshop, Durham: April 14-16, 2014

Ilya Repin: *Modest Mussorgsky*



VST was conceived
in a moment
of special lucidity …

1997: OAC proposal to ESO

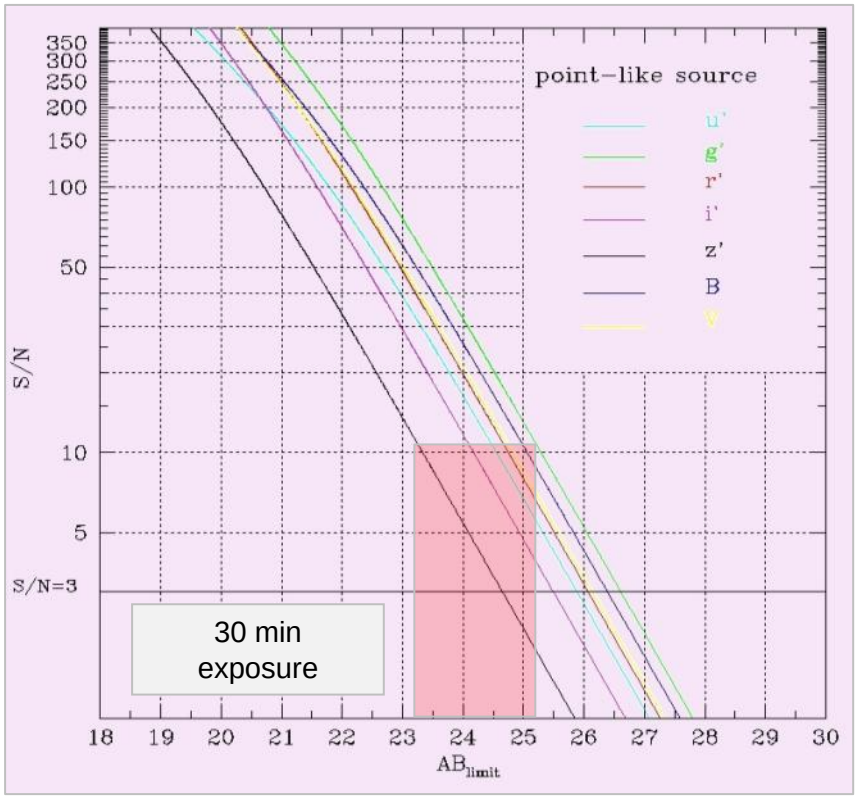
for a wide-field optical facility

performing 10 times better than WFI @ ESO/MPI 2.2m

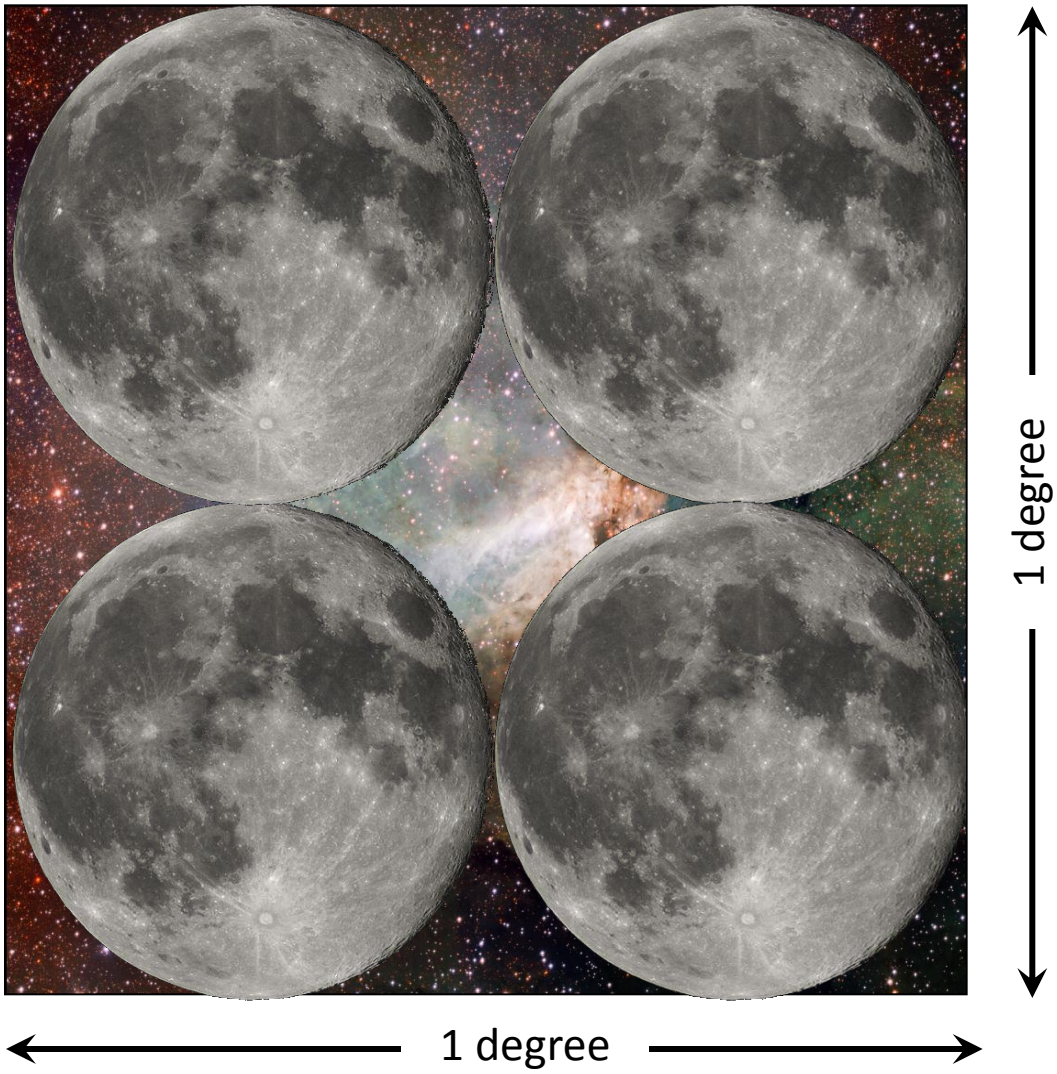
Broad Characteristics

- ✓ Class 2.5 m
- ✓ NTT type mount
- ✓ Active optics
- ✓ 1.46 deg corrected FoV (∅)
- ✓ 80% EE in 0.4 arcsec
- ✓ Scale ~ 0.2 arcsec
- ✓ Spectral range from U to I

Expected performances



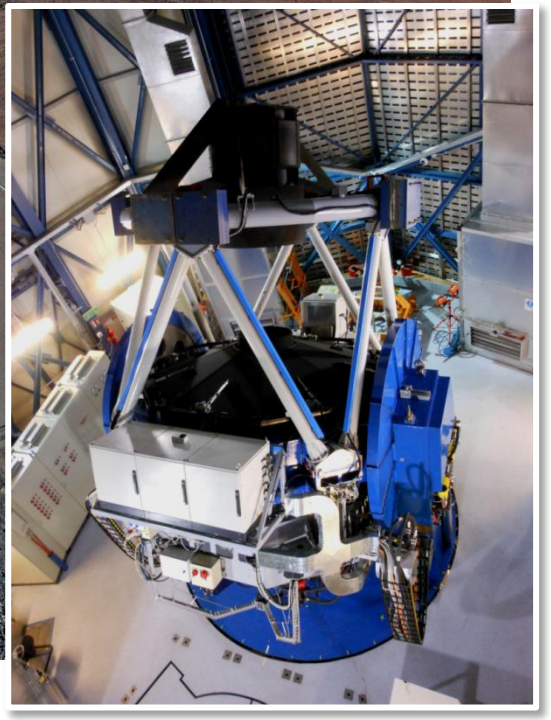
VST: a wide-field telescope for surveys. How wide ?



Given the scale of 0”.2/px, it implies a lot of pixels

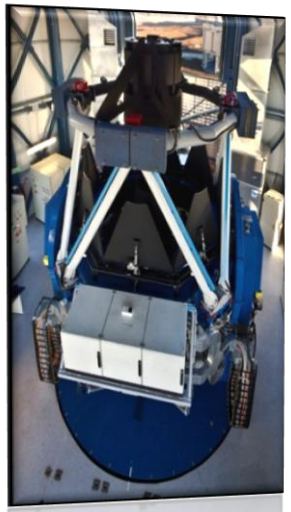
Where ? @ ESO Paranal Observatory

- ✓ 4 UTs + 4 ATs (ESO)
- ✓ VISTA (UK) – IR Surveys
- ✓ VST (It) – visible Surveys



1998: ESO accepted the OAC proposal

and the VST project started with the following **commitments and returns (WBS)**



OAC: procurement of the telescope at Paranal
in exchange of **some GTO @ VST & VLT;**

ESO: civil work and operation of the facility
for at least 10 years;

OmegaCam: procurement of the 16k×16k camera
in exchange of **some GTO @ VST.**

A simple project ... just an easy walk along the river bank

Ilya Repin: *Boat trackers on Volga river*

VST: acceptance of M1

Lytkarino Glass Factory (LZOS), September 7, 2001

June 2002:

first BIG problems along the VST “easy walk”

ЛЗОС

Illarion Pryanishnikovl: *1812*

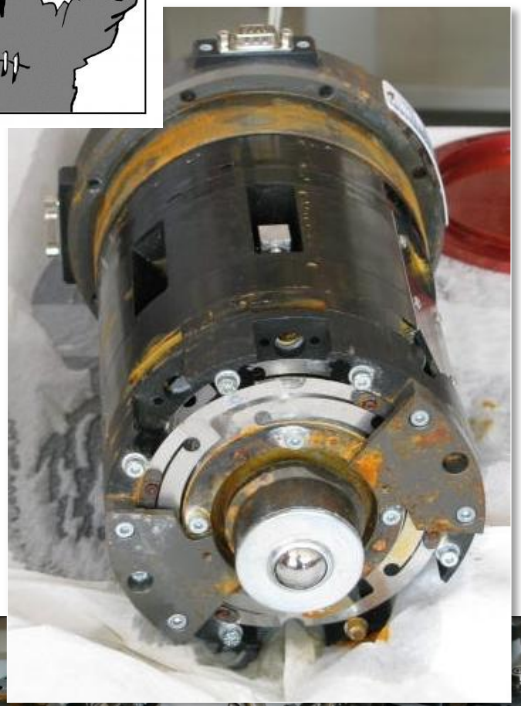
an easy walk and … a ready success

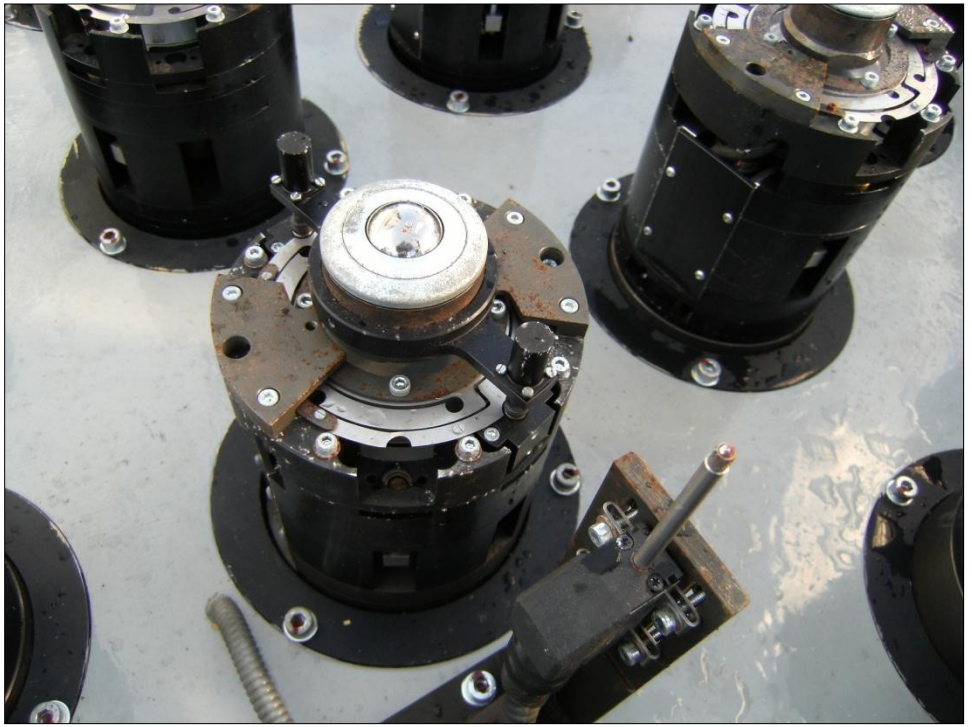
VST: the active M1 cell

July 2009:

second BIG disaster – damage of M1 cell

The situation ….

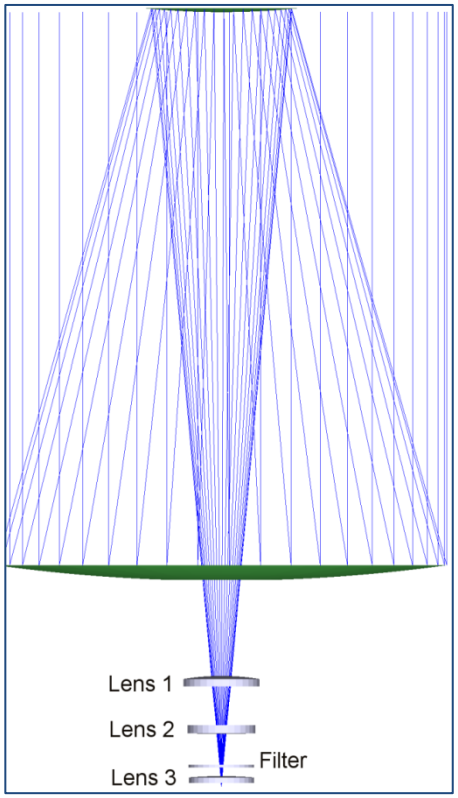




The end of the trail

By October 2011
VST enters in operation

VST in a nutshell

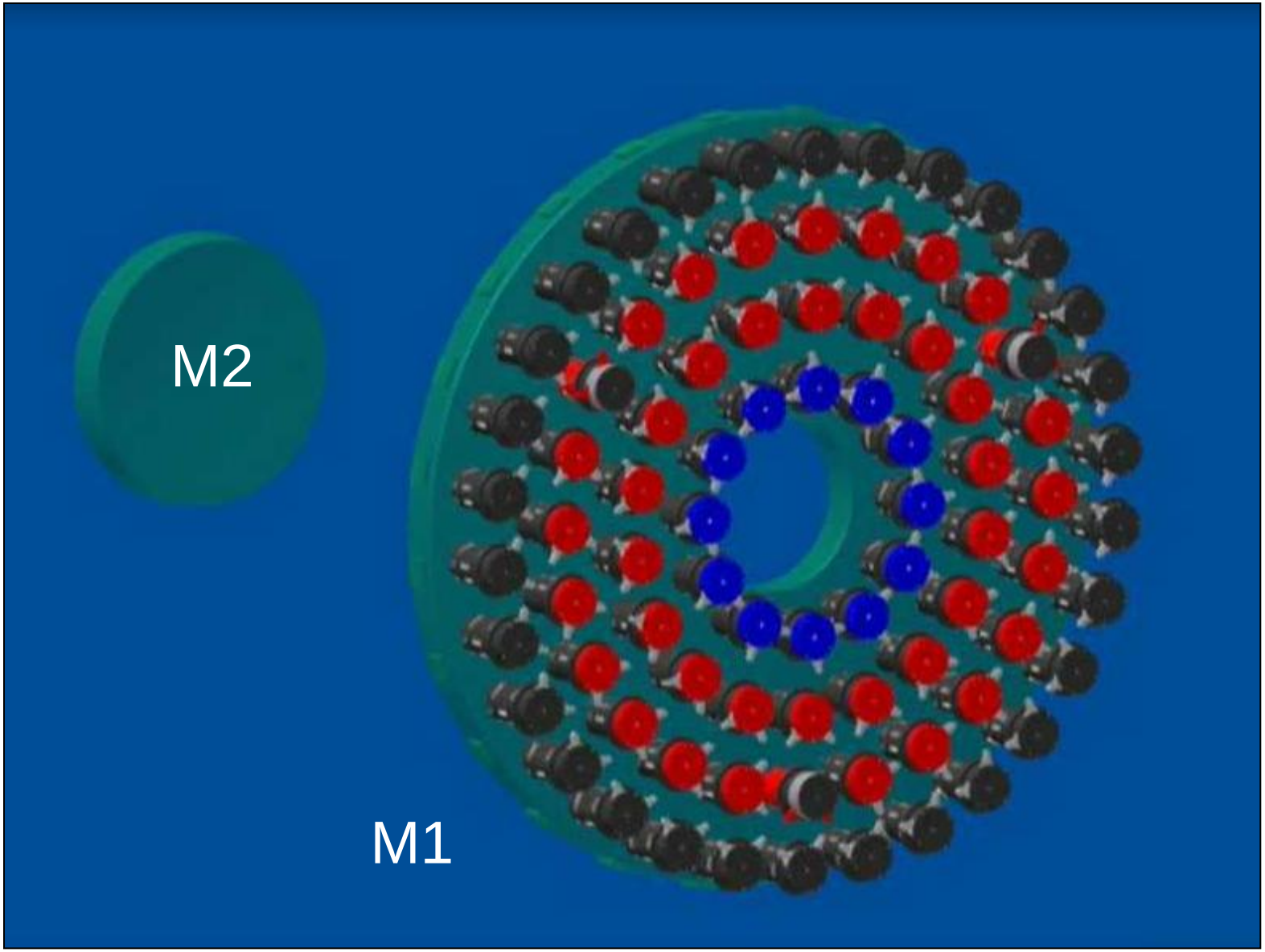


Optical System

- Primary mirror: 2.6m
- Secondary mirror: 0.9m
- F# 5.5
- Field corrector with 3 lenses (2 in the telescope + 1 in the camera)
- Field: 1° x 1°
- Curvature Wavefront Sensor with in- and out-focus CCDs (or Shack-Hartmann)
- Active M1 shape control (81 active axial support + 3 axial fixed points)
- Active M2 positioning in 5 dof (hexapod)
- Autoguiding with two outer CCDs (or probe in *R*,*q* coordinates)

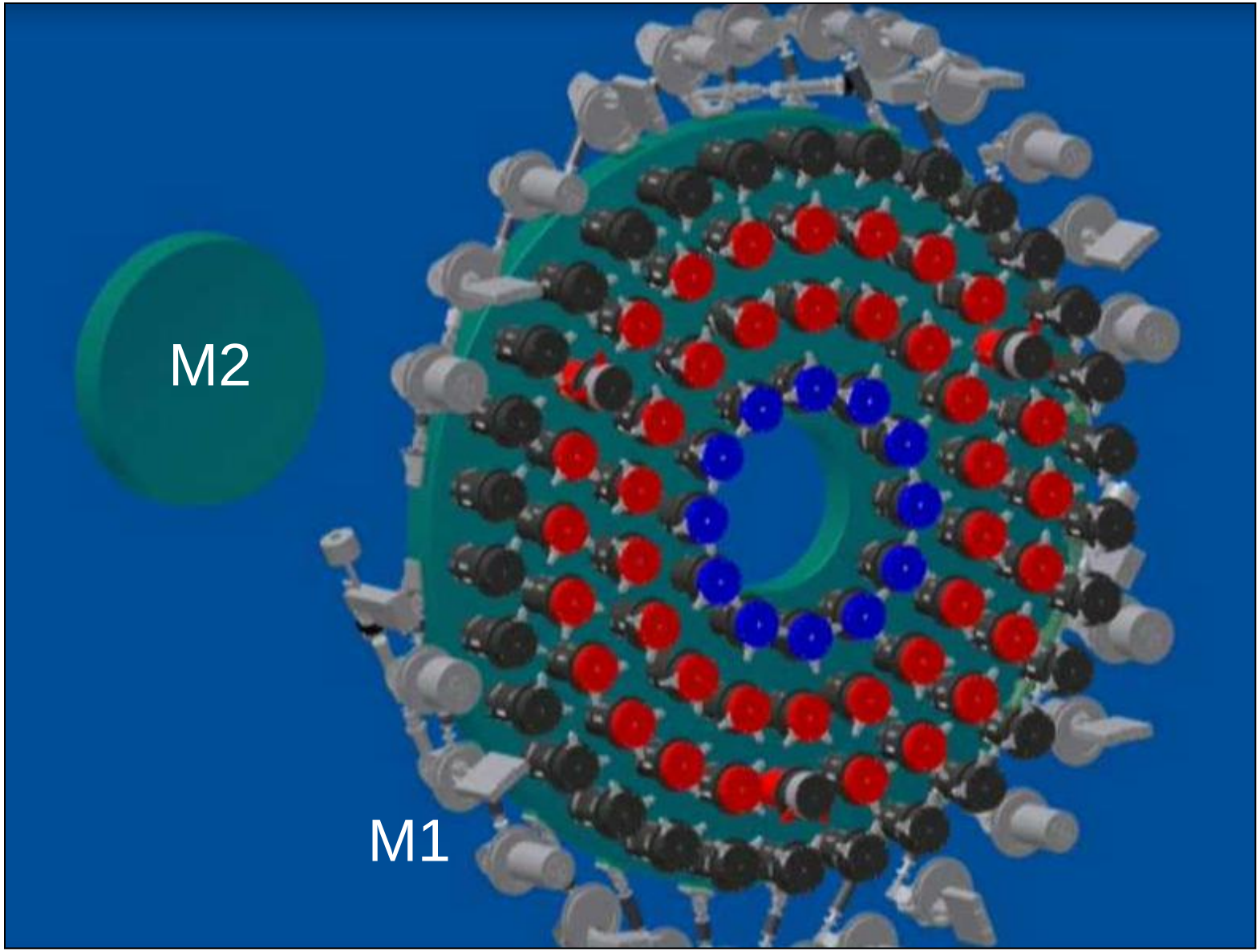
VST active optics:

M1 axial actuators & fixed points

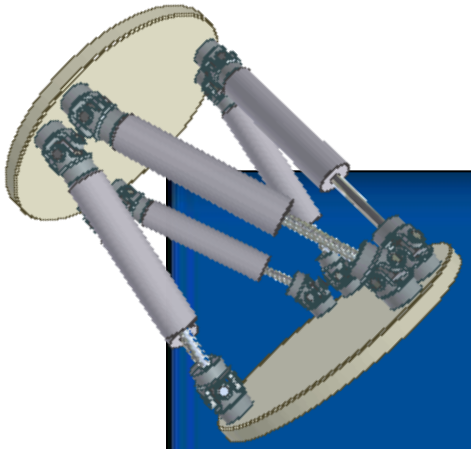


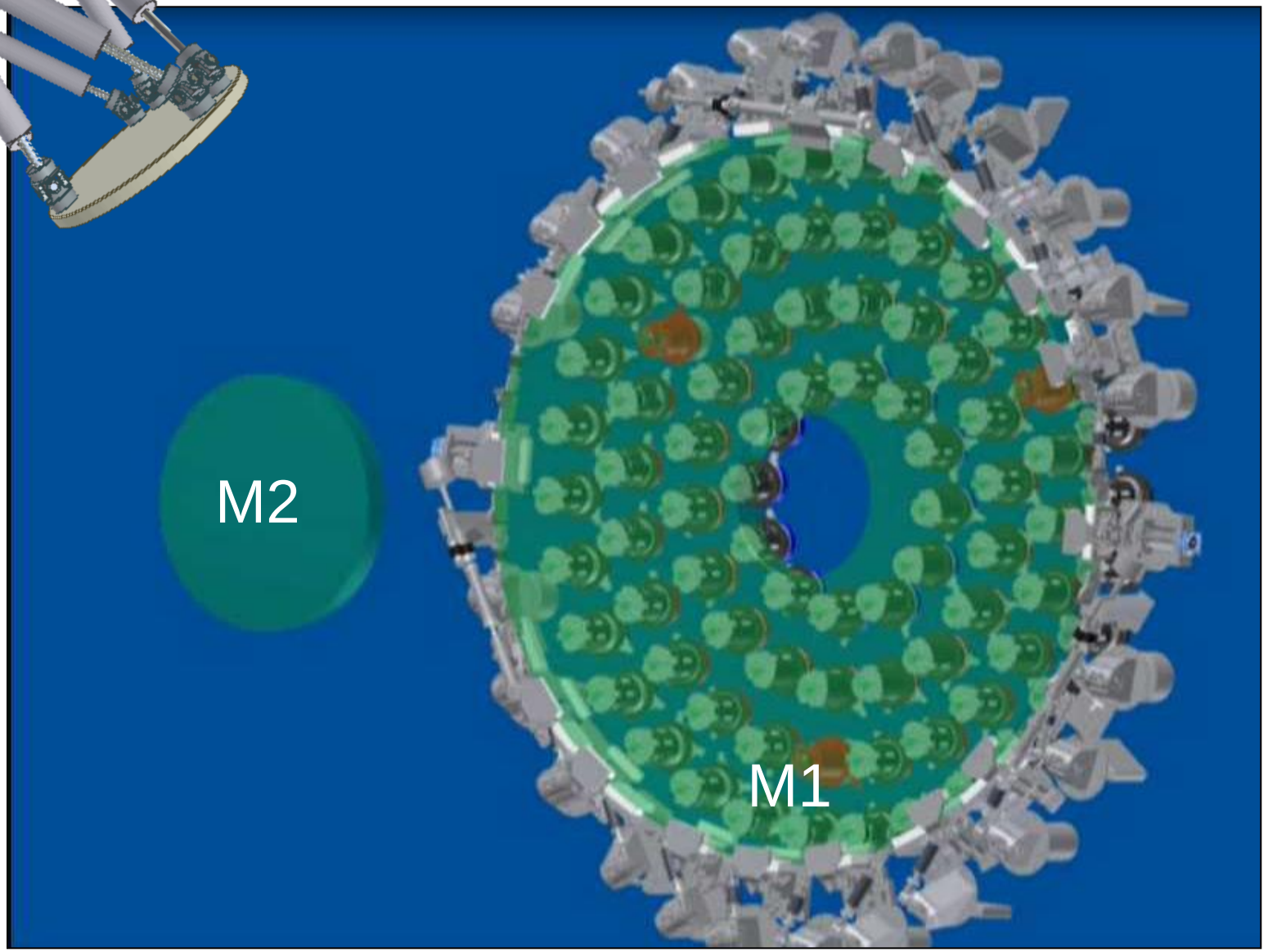
VST active optics:

M1 axial & radial actuators



VST active optics:
hexapod at M2

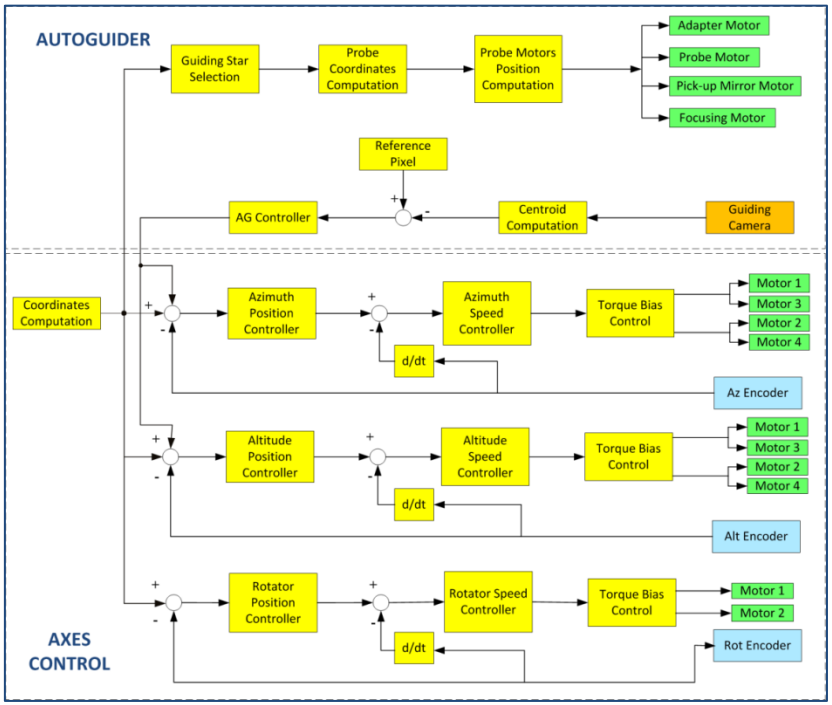




VST in a nutshell

Control System

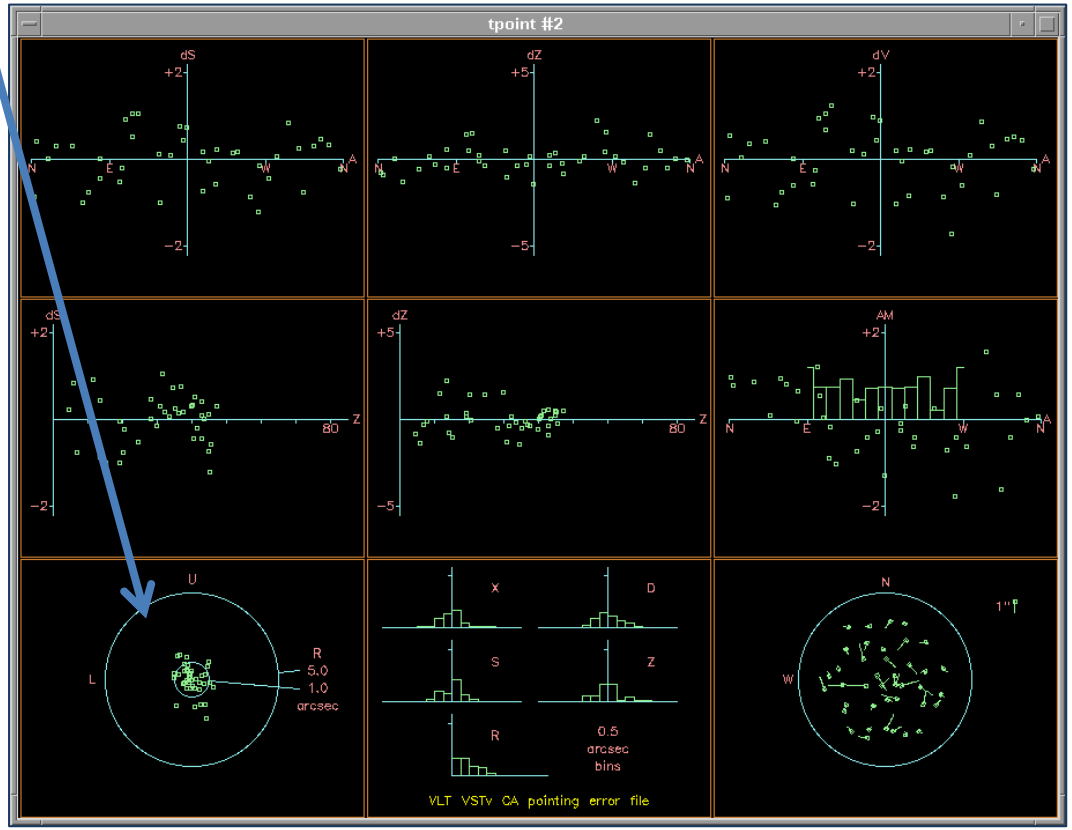
- Alt-az mount, 4 motors per axis with glass encoders (4 reading heads)
- ESO standard hardware
- 1 TCS Workstation + 8 VxWorks LCUs
- 10 electrical cabinets
- > 60 TCS SW modules
- MANY control loops!



VST in a nutshell

Performances:

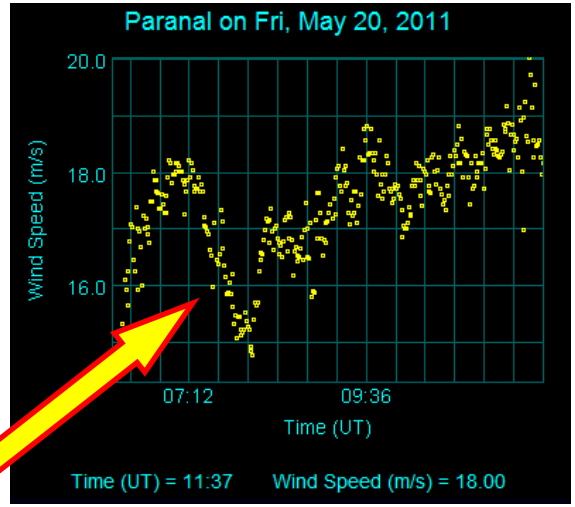
- Pointing error ~1 arcsec RMS
- Fit results typically between 0.8 and 1.1 arcsec
- A model with 40 stars is built in less than 1 hour



Servo Control

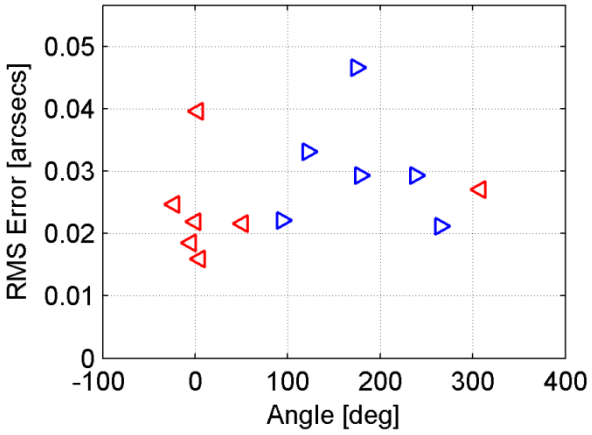
- Speed loop (soft-tacho)
- Position loop – Variable Structure Control
- Commercial amplifiers
- 4 motors with torque bias

- Tracking Map - Representative of all tracking conditions
- Frequent Offsets
- Wind rejection

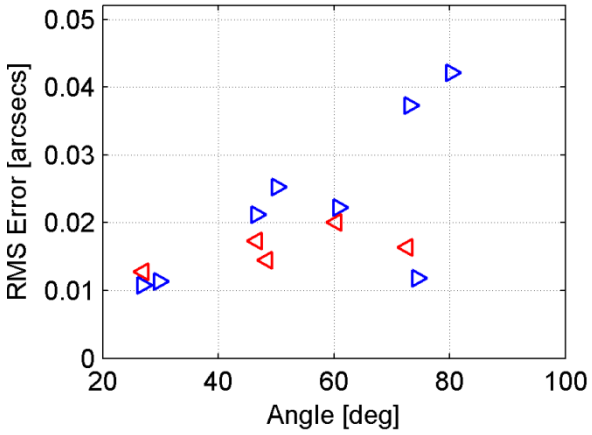


<u>Performance</u> (in a windy night 15 < *v* < 20 m/s):

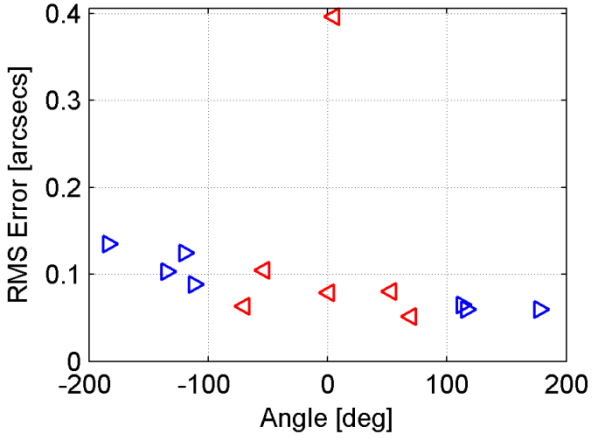
Azimuth



Altitude



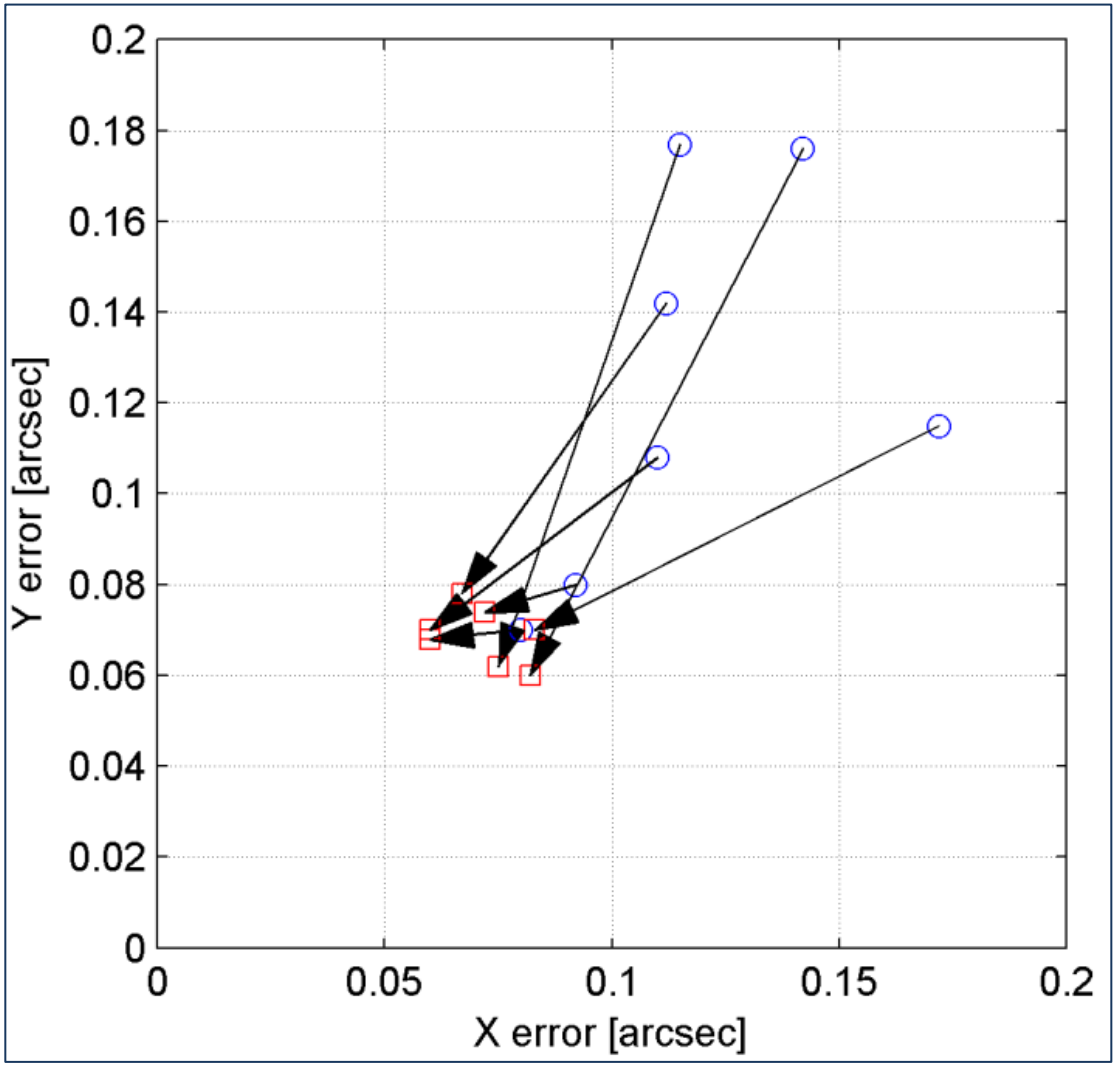
Rotator



Autoguiding System

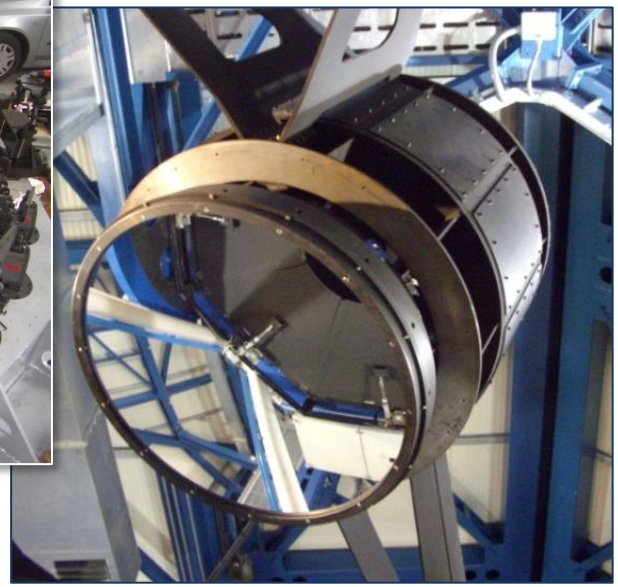
Performance:

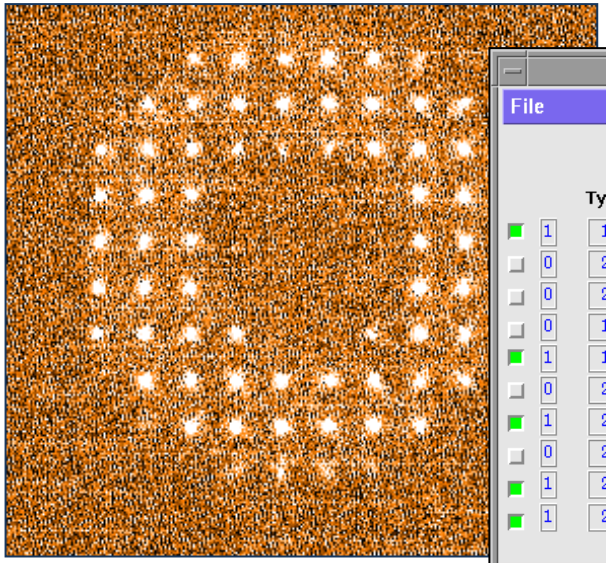
With autoguiding active the error measured on the guide probe is
≤ 0.1 arcsec RMS



Active Optics

- M1 system
- M2 system
- Wavefront Sensor
- Software





Active Optics Coefficients – @wtvst

File Help

		Type	Symm.	Order	Coeffs On LCU Modulus	Coeffs On LCU Angle	Recalculated Modulus	Recalculated Angle	Average Modulus	Average Angle	Average d80%"	Filtered (Enable filter) Modulus	Filtered (Enable filter) Angle
■	1	1	0	2	376.7	0.0	376.7	0.0	376.7	0.0	0.000	376.7	0.0
□	0	2	0	2	55.4	0.0	10.3	0.0	10.3	0.0	0.018	10.3	0.0
□	0	2	0	3	1.5	0.0	4.8	0.0	4.8	0.0	0.016	4.8	0.0
□	0	1	1	1	3018.9	-130.1	3018.9	122.0	3018.9	122.0	0.000	3018.9	122.0
■	1	1	1	2	96.6	-137.3	96.6	129.2	96.6	129.2	0.029	95.1	129.2
□	0	2	1	2	36.0	32.2	36.0	-40.3	36.0	-40.3	0.128	35.9	-40.3
■	1	2	2	1	51.5	-179.2	51.5	162.9	51.5	162.9	0.068	51.5	162.9
□	0	2	2	2	12.6	156.5	12.6	-172.7	12.6	-172.7	0.037	12.6	-172.7
■	1	2	3	1	26.0	121.6	26.0	-145.9	26.0	-145.9	0.047	26.0	-145.9
■	1	2	4	1	26.1	-111.8	26.1	79.3	26.1	79.3	0.059	26.0	79.3

Numbers of spots in the pattern

Reference	107
Star	57
Residual r.m.s.	137.867
Max. Pixel	2311
5th Max. Pixel	2172
Background	1004
Pairs	57
Inner Radius	0.444
Outer Radius	1.018
sumD80	0.172

It converges

VST camera OmegaCam

P.I. Konrad Kuijken
OmegaCAM Consortium: the Netherlands, Germany, Italy, ESO

- ✓ Format: 268 Mpixel mapping a 1°×1° field
- ✓ Scale 0.21 arcsec/pixel
- ✓ 32 scientific CCDs + 4 outer CCDs
- ✓ Autoguiding

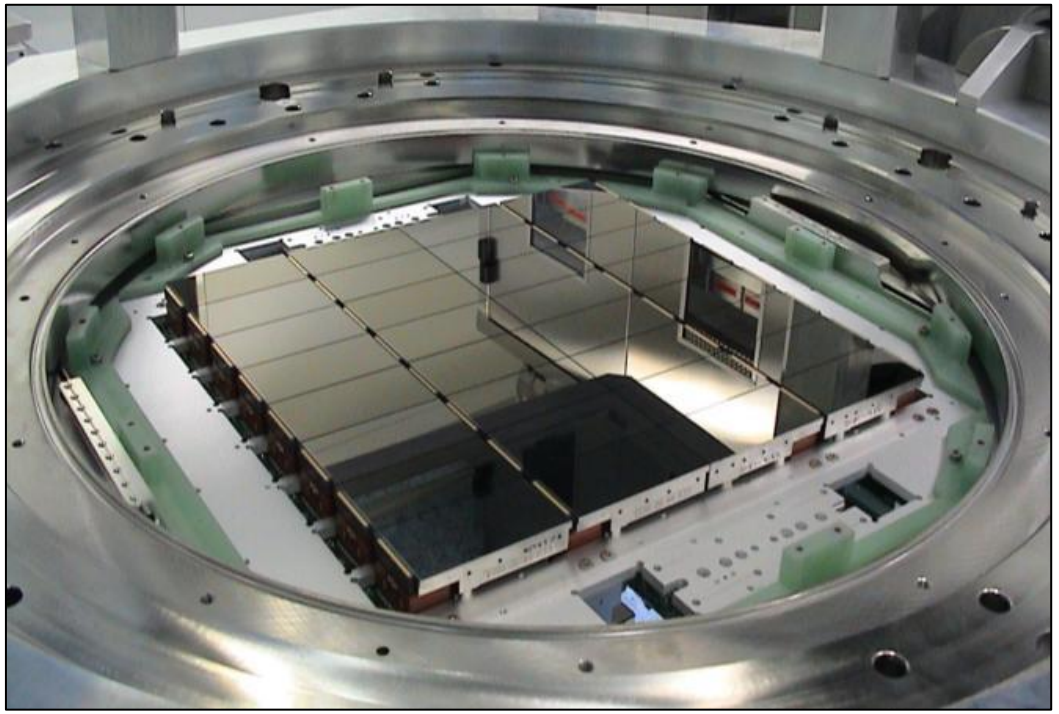
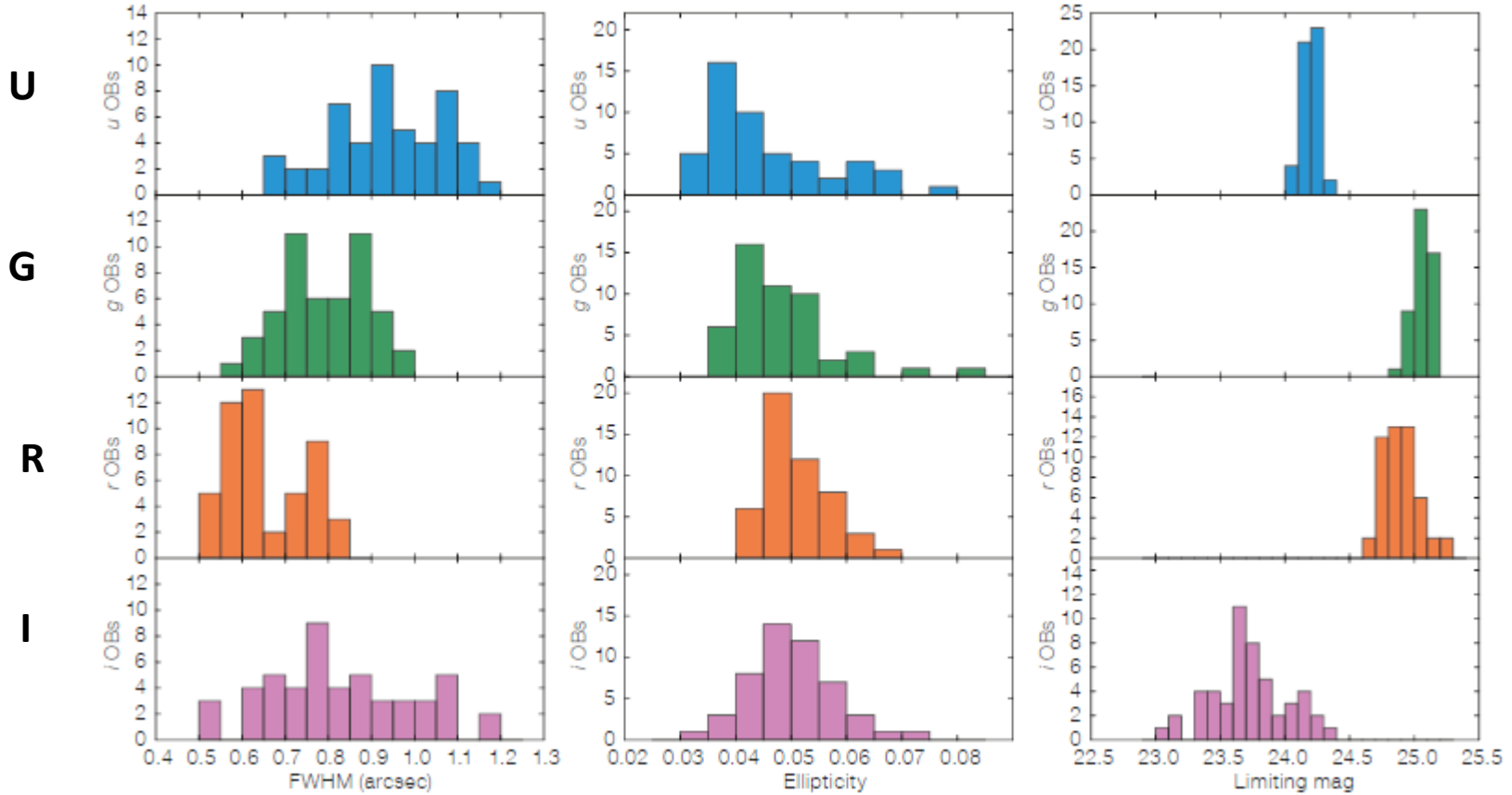


Image quality results

Data quality of KiDS-ESO-DR1

(from De Jong, Kuijken et al., *ESO Messenger*, 154)



PSF FWHM distribution | Average ellipticity distr. | Limiting magnitude distr. (5σ in a 2” aperture)

Image quality (FWHM) results

- In 2.5 years of operation VST has regularly delivered images down to

0.5-0.6 FWHM

over the whole field under good seeing conditions.

- The median full width at half maximum (**FWHM**) of images, as measured during the first year of operation, was about

0.80 arcsec

in the i'-band (Mieske et al., *Messenger*, 154)

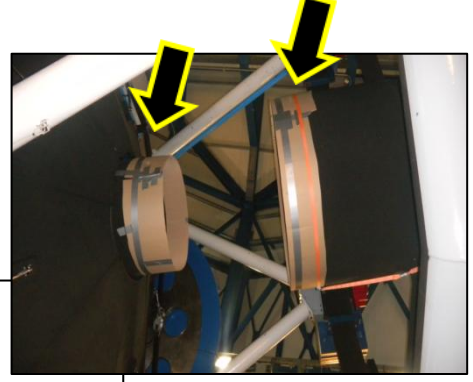
Future improvements

Ongoing joint efforts (ESO-VST-OmegaCAM) on:

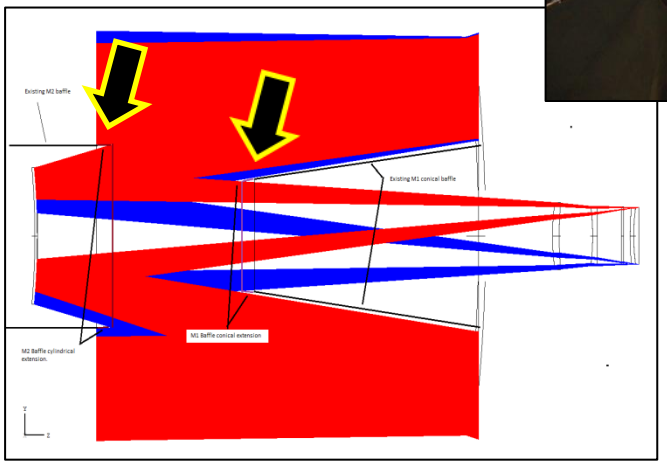
- Baffling
- Curvature Wavefront Sensor Algorithm
- «Image based» wavefront sensing
- Servo algorithms

Telemaco Signorini: *The river bank*

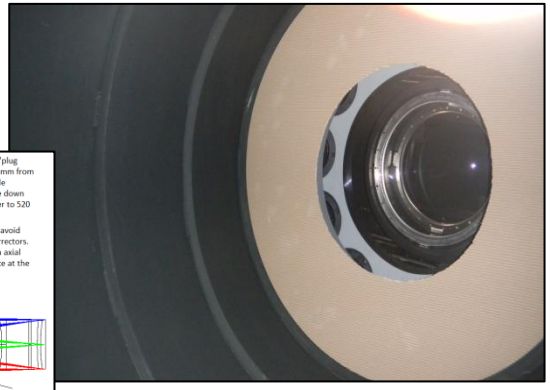
Improved baffling

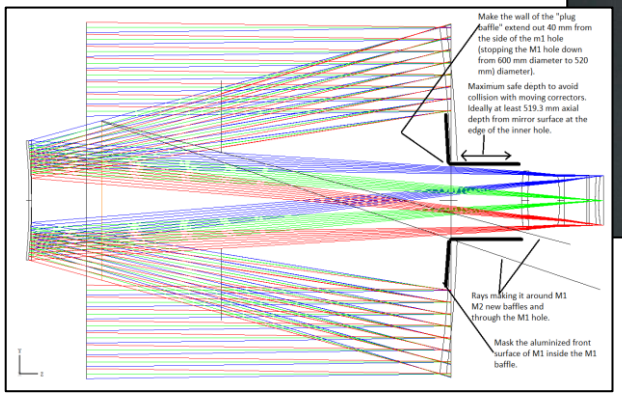


- M1 & M2 baffles extended (ESO, Jan 2014)



- Mask M1 aluminized surface inside baffle (in progress)





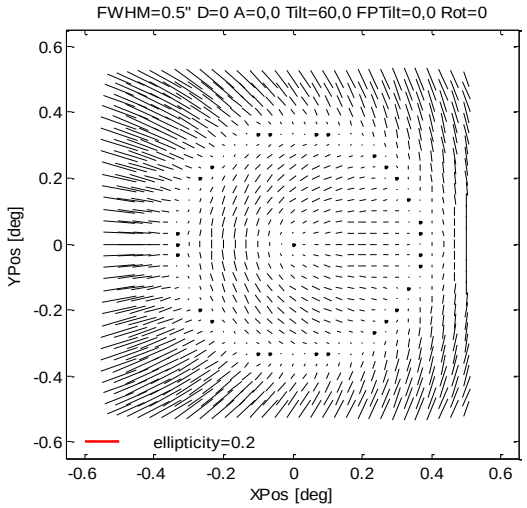
Solution of straylight problems → better efficiency

Coming improvements in Wavefront Sensing

- Curvature Wavefront Sensor Algorithm

  Upgrade in progress to include measure of linear astigmatism (K. Kuijken) → possibility to recover the perfect alignment in open or closed loop.

- «Image based» wavefront sensing



Compute corrections directly from PSF anisotropies (ESO-INAF-OmegaCAM). Longer timescale

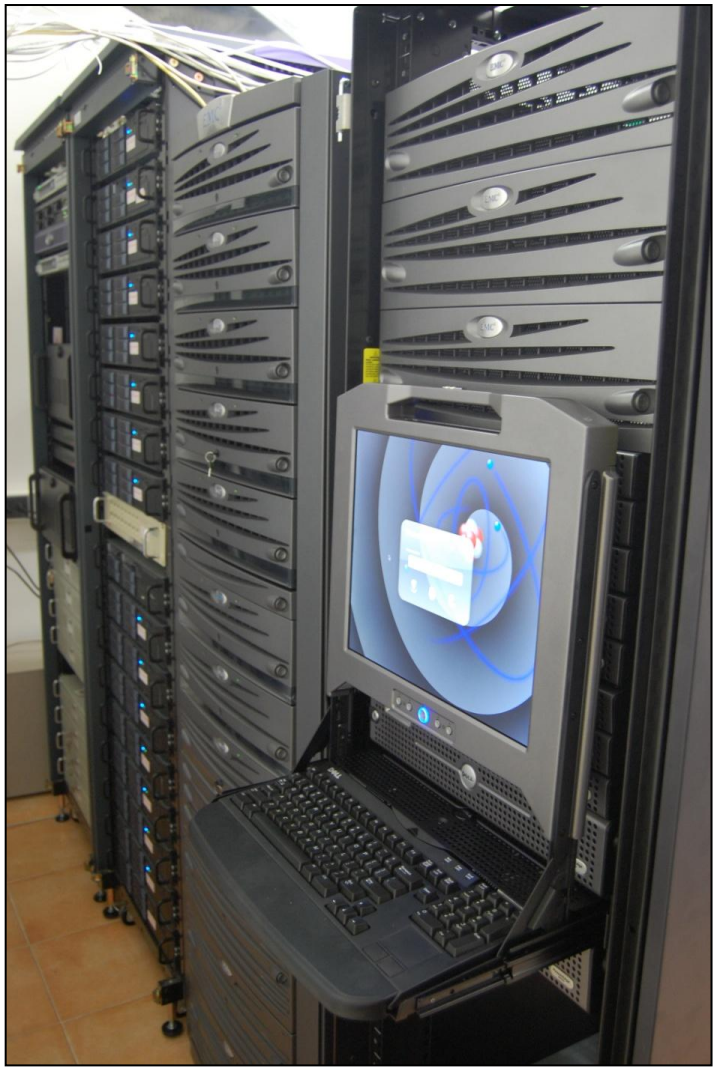
Coming improvements in Servo Algorithms

- Project to install on VST new servo algorithms design and implementation strategies developed on Matlab/Simulink/Stateflow platform.
- Activity in progress (ESO) for all Paranal telescopes (INAF in this loop for VST)
- Small improvements possible (e.g. offsets time reduction, etc.)

OmegaCam@VST
VST-Tube

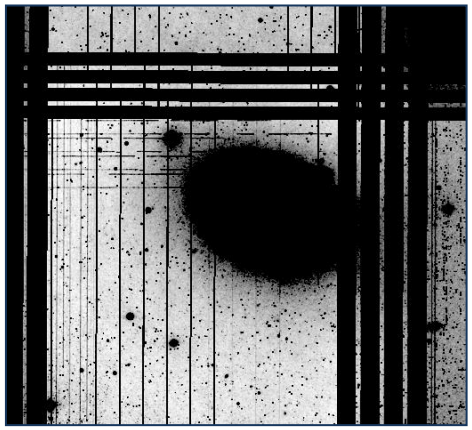
VST Data Center@OAC: HW

- ✓ Cluster 300 cores for data processing and analysis
- ✓ 10 Gb network
- ✓ ~ 500 TB storage

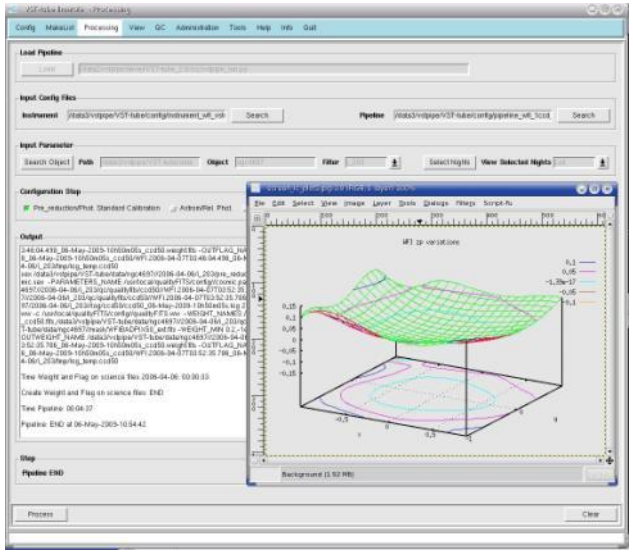


VST image processing dedicated software

- from raw to fully calibrated images
- tailored on surveys needs
- GUI to facilitate processing and administration
- includes a growing set of analysis tools
- not only VST …… (*e.g.* Subaru, VLT FORS, CFHT, WFI@2.2)
- presently supporting 9 independent surveys (2 on Chilean GTO)

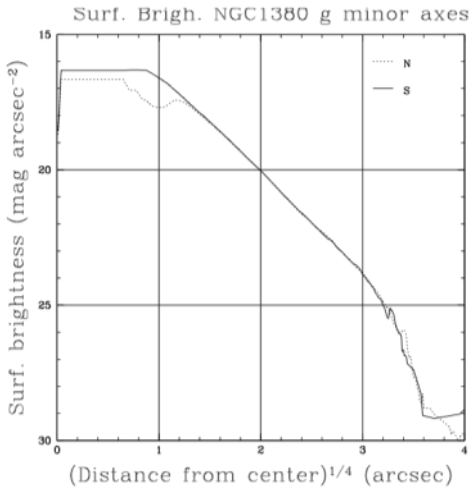


True noise map propagation
NGC4697 weight map section

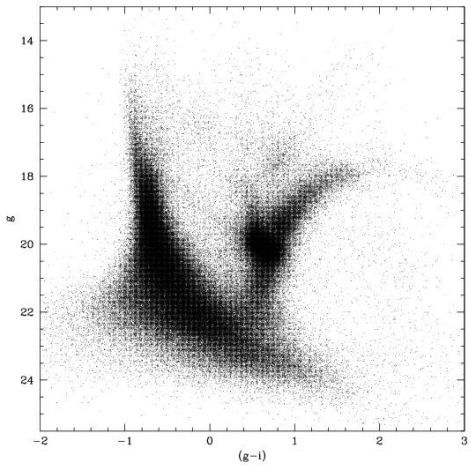


First VST image fully processed
(Omega Centauri)

Science verification data
(NGC253)



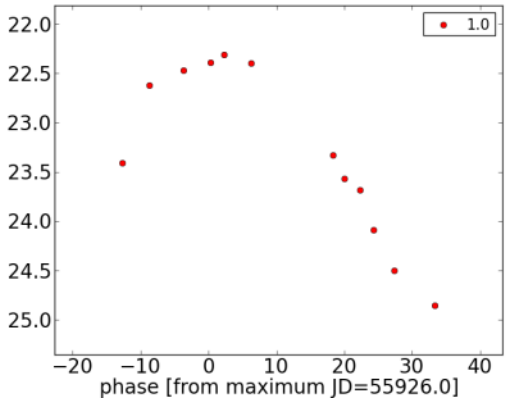
VEGAS:
faint surf. bright. profiles



STEP: SMC SFH

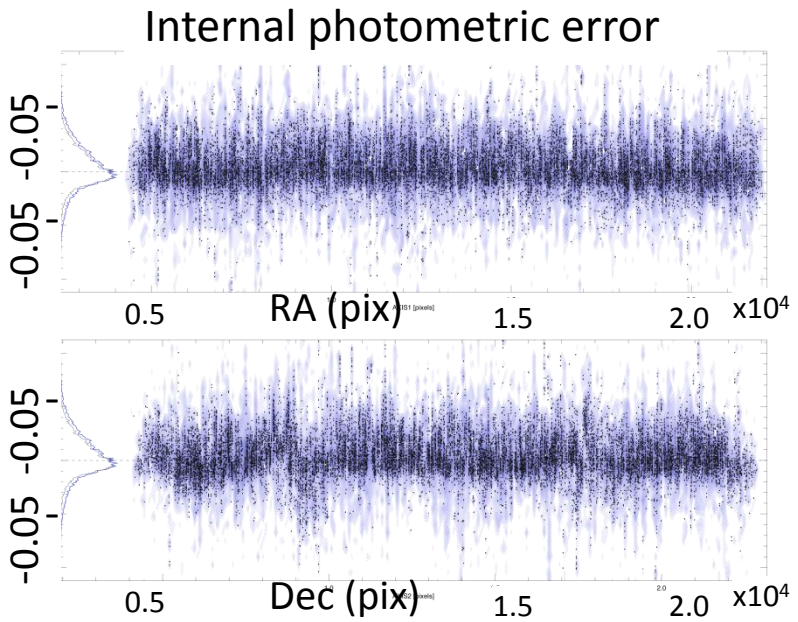
Vst Tube

ACCESS: identification of transforming
galaxies by morphology



SUDARE: first VST SN detected.
12 hours between VST obs. and
VLT spectr. confirmation

VST-Tube performance



Photometric accuracy:

0.017 mag RMS internal

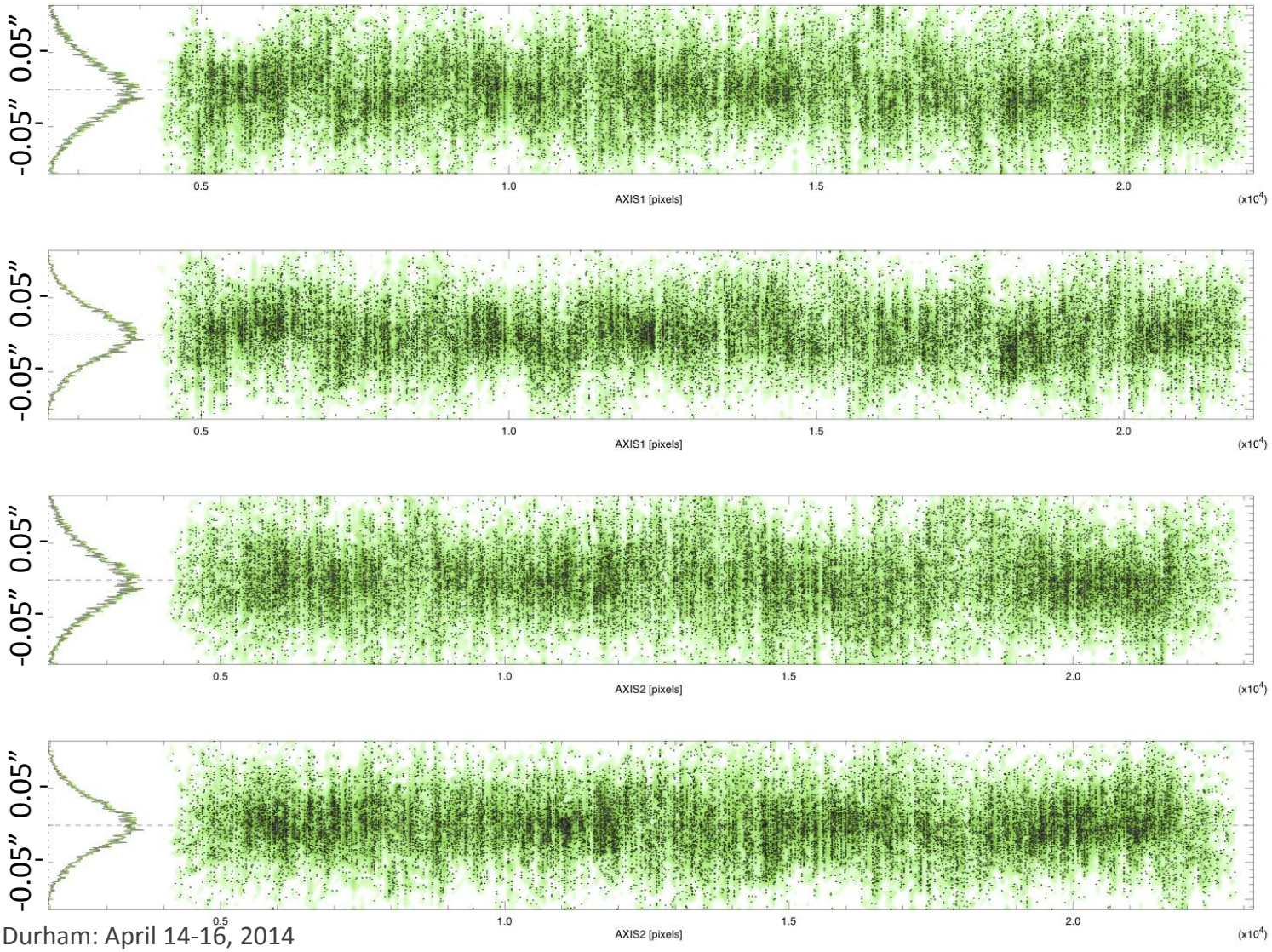
Astrometric accuracy:

0.03” internal

0.3” absolute (it depends on the reference catalogue)

VST-Tube performance

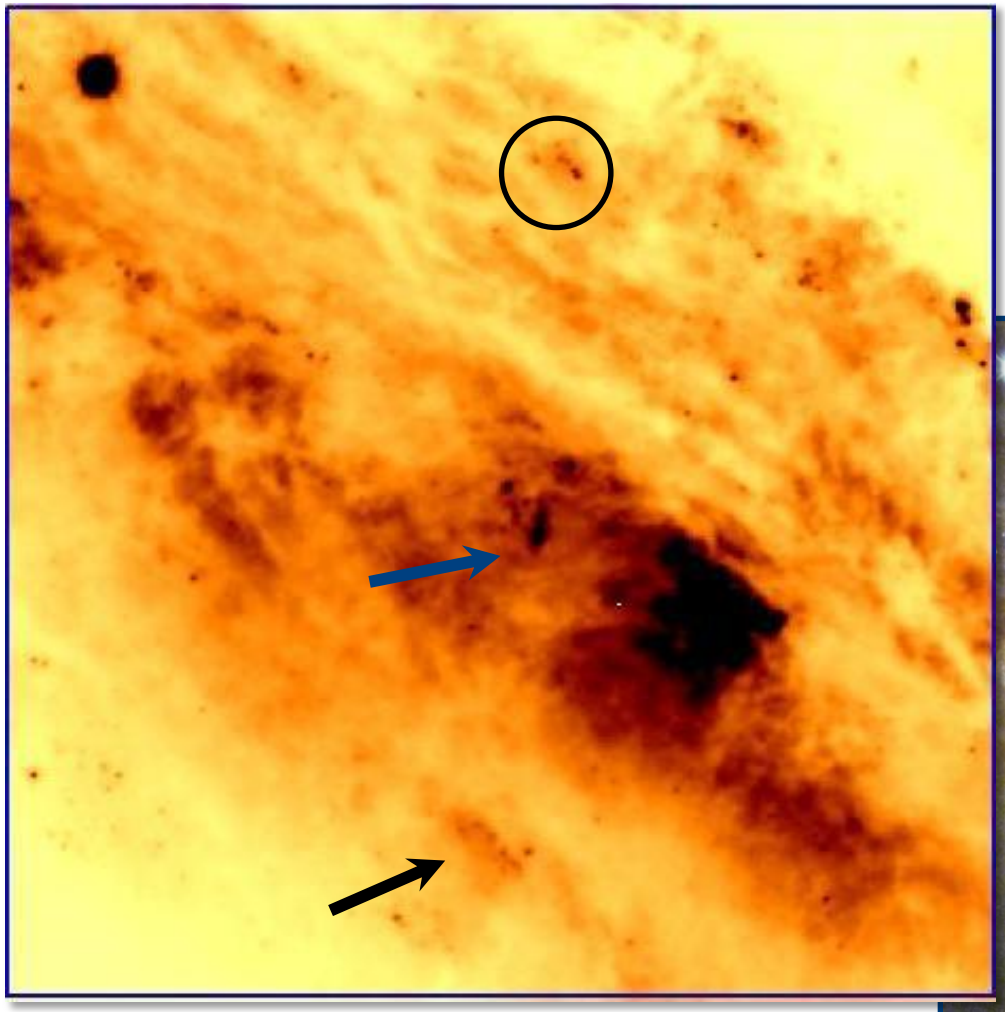
Internal astrometric error



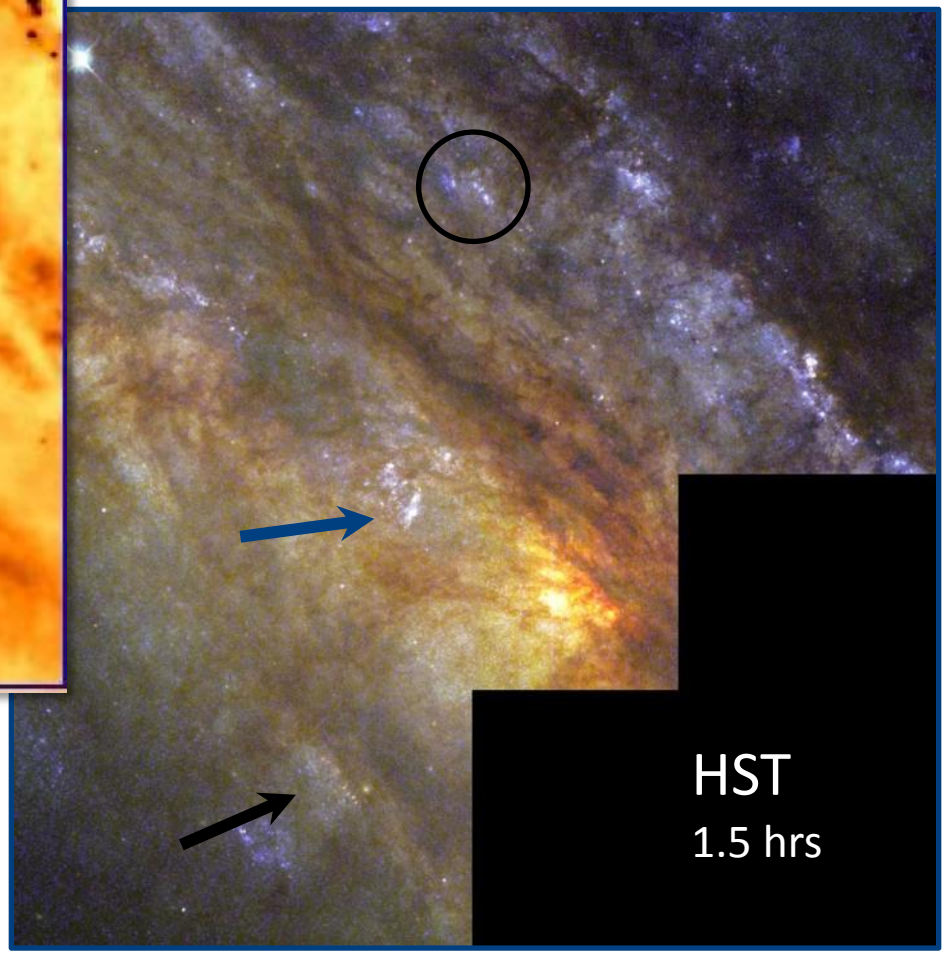
VST Capability: resolution

Survey ACCESS on Shapley mosaic (5 dithering)
with median FWHM of 0.49 arcsec (from 0.45” to 0.52”)

VST vs HST image of the NGC 253



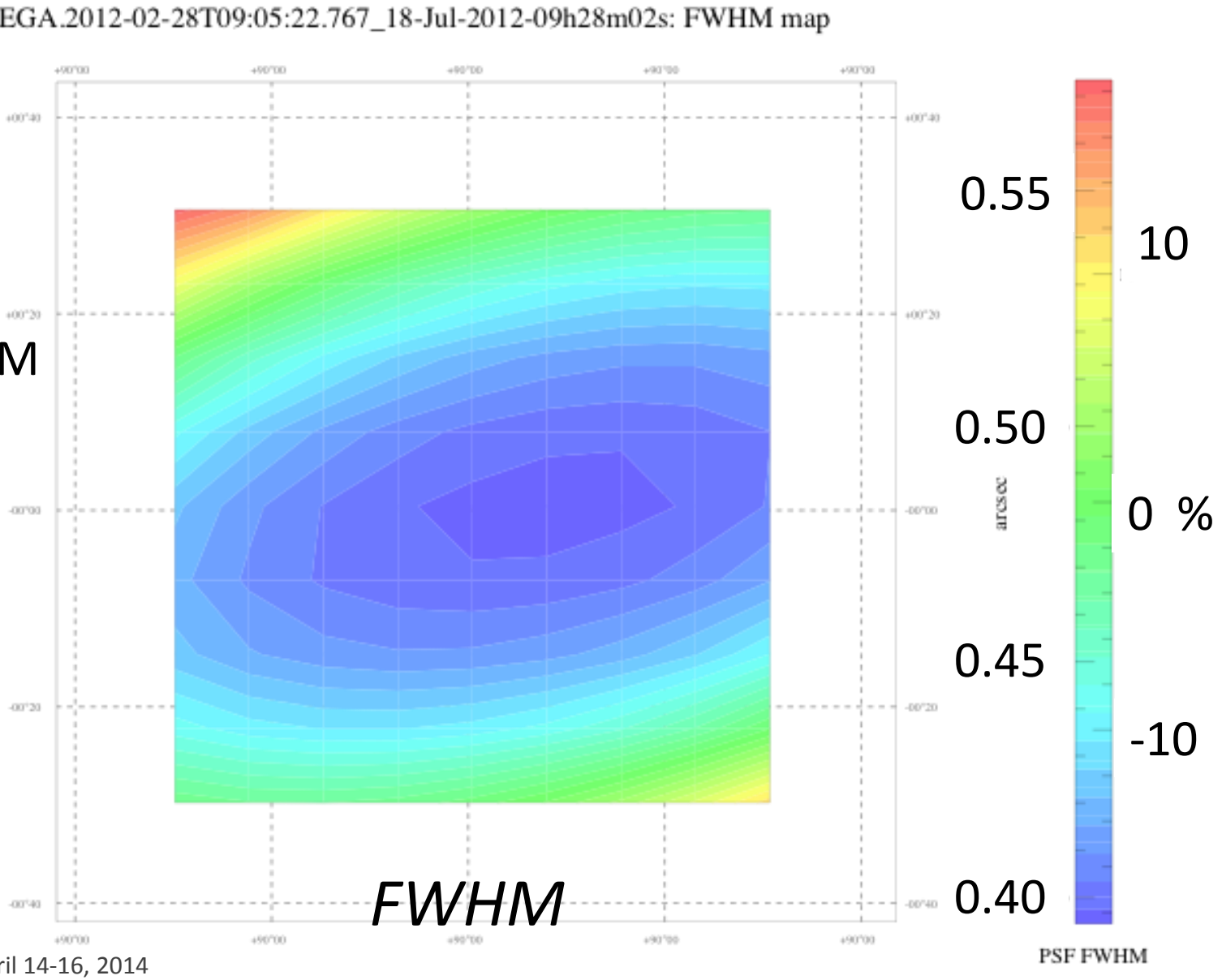
VST
1.03 hrs



VST Capability: FWHM

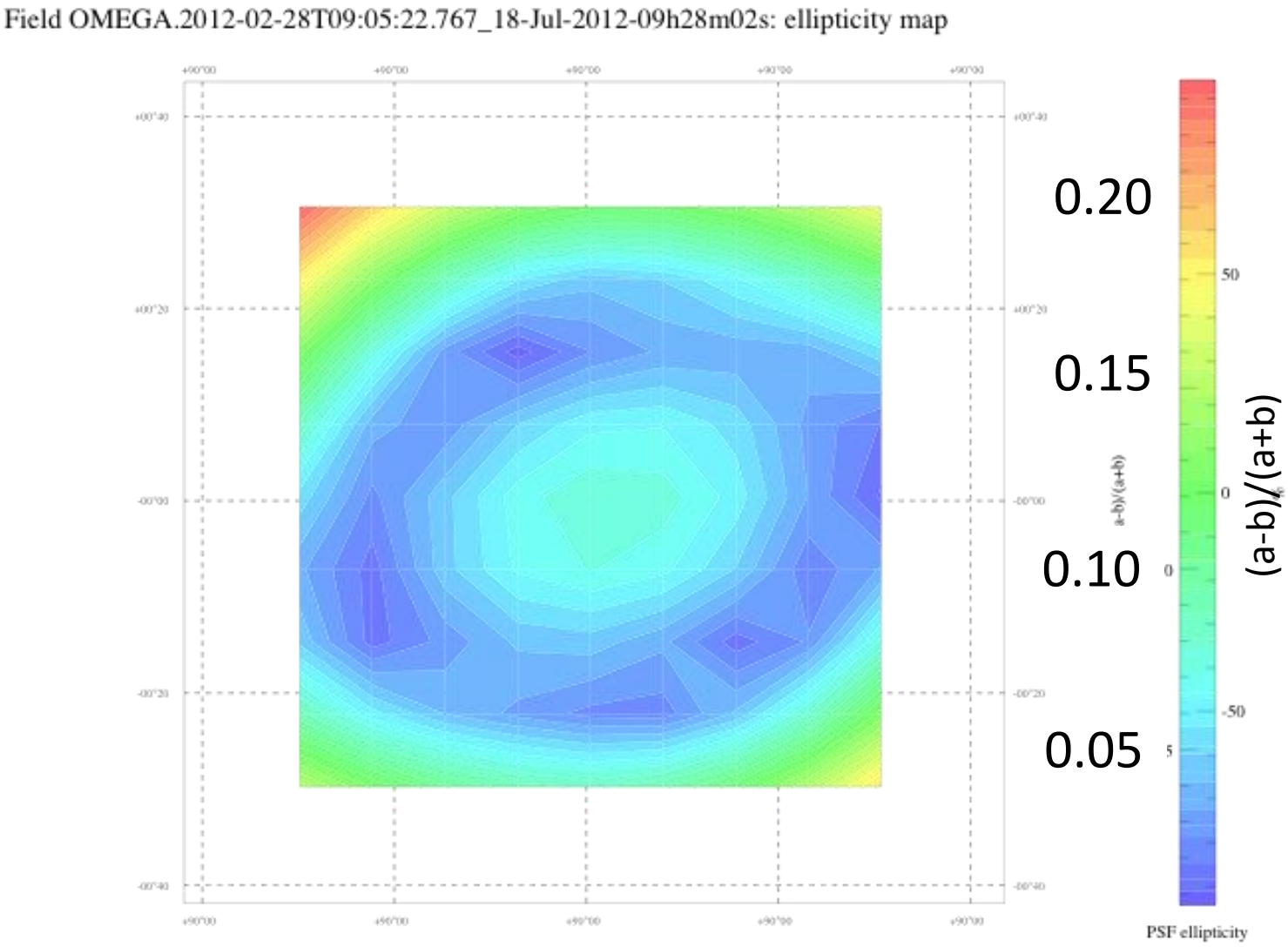
i band

Median FWHM = 0.45” !!!!



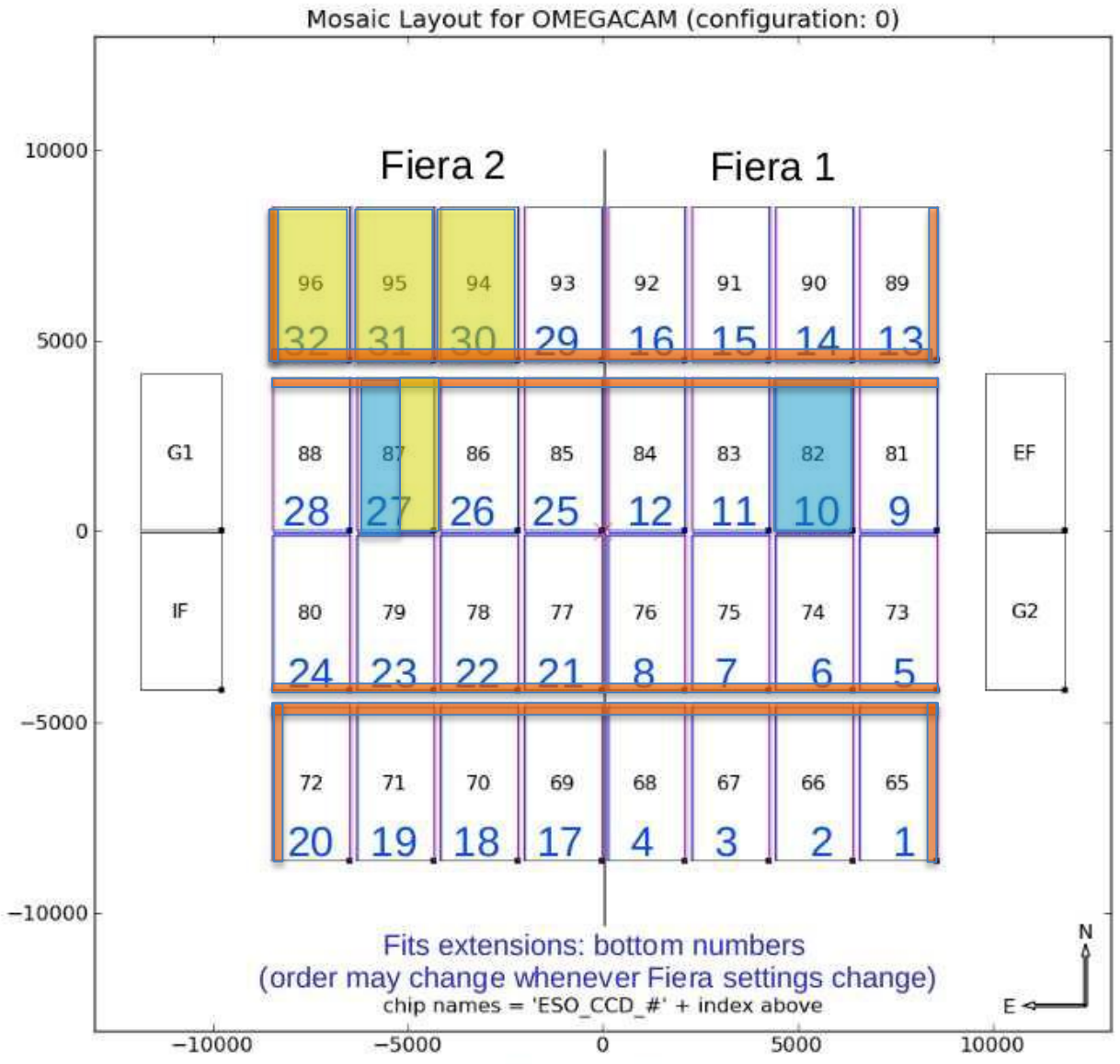
FWHM

VST Capability: ellipticity



ellipticity

VST camera mosaic issues

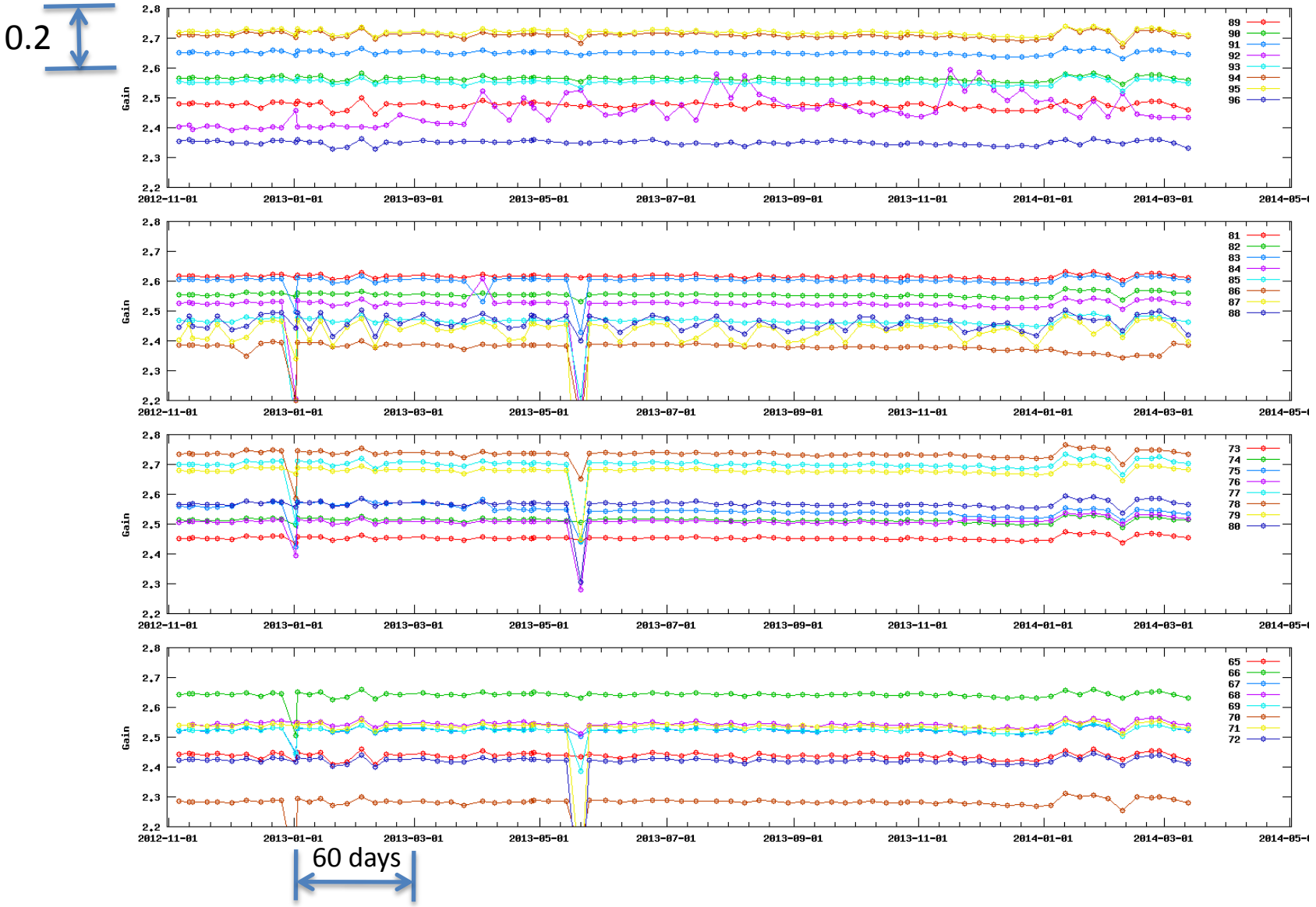


Gain variation

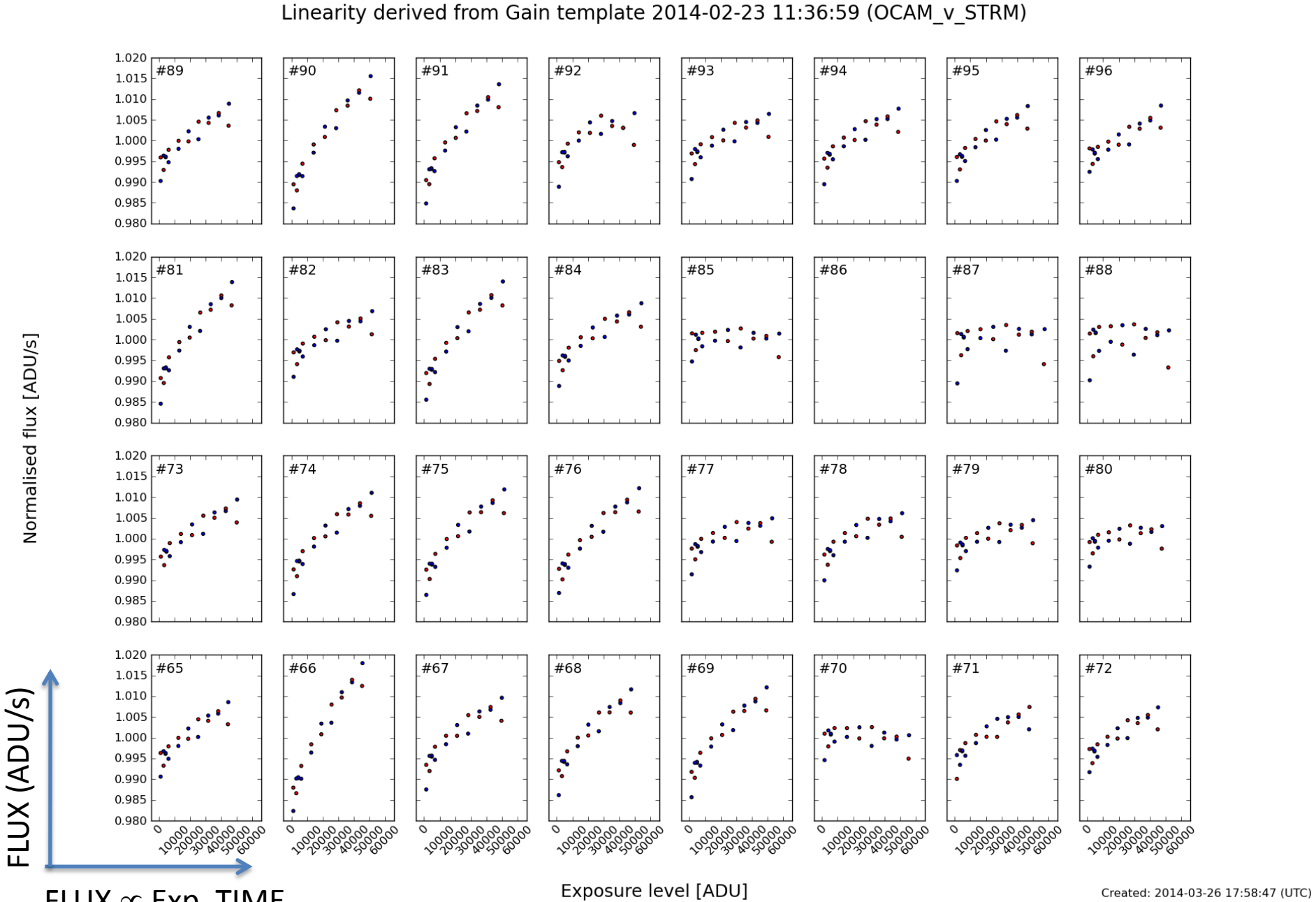
Light reflections

Cross talk

CCDs gain variations



CCDs gain variations


Linearity derived from Gain template 2014-02-23 11:36:59 (OCAM_v_STRM)
#89
#90
#91
#92
#93
#94
#95
#96
#81
#82
#83
#84
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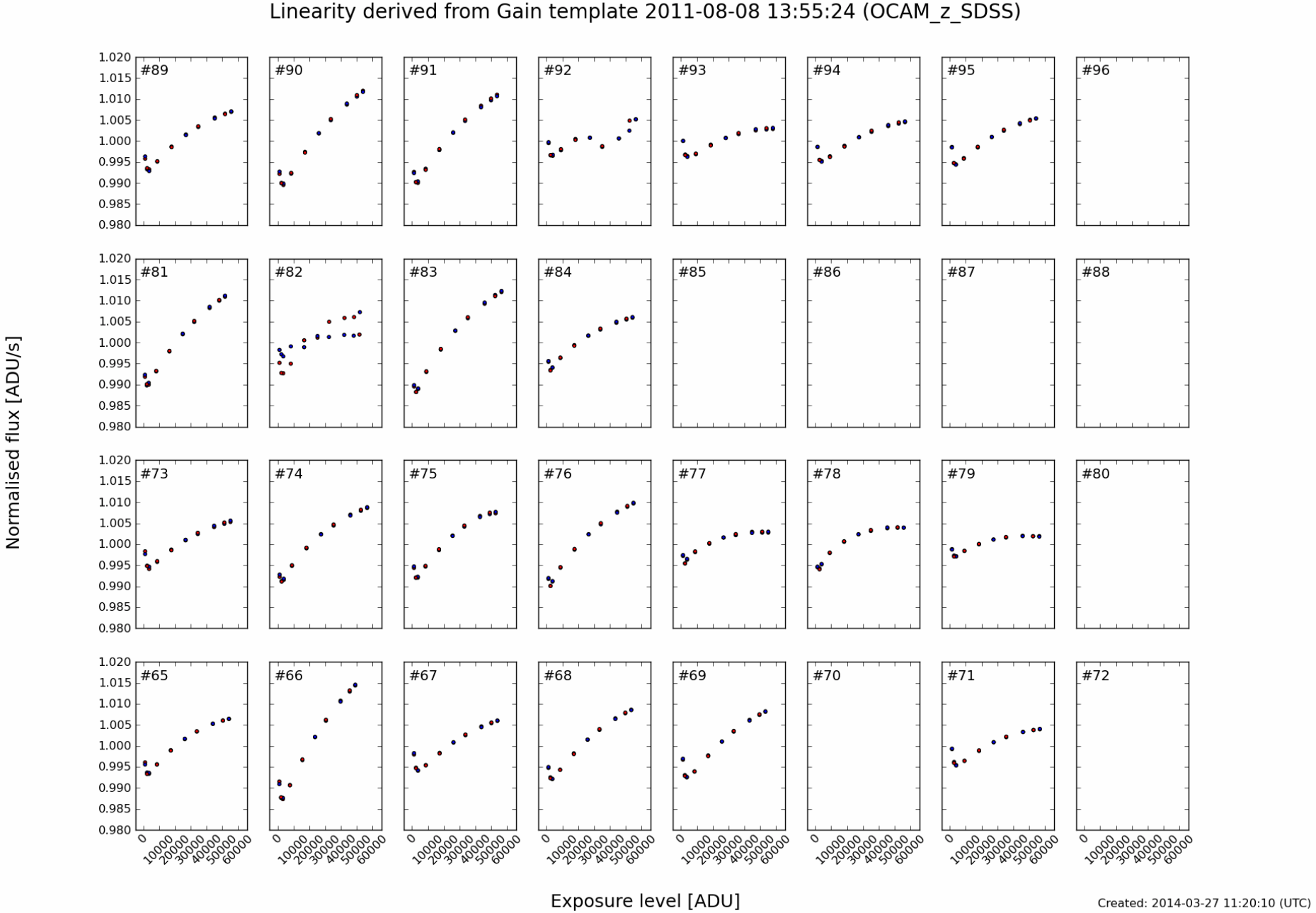
#88
#73
#74
#75
#76
#77
#78
#79
#80
#65
#66
#67
#68
#69
#70
#71
#72
Normalised flux [ADU/s]
FLUX (ADU/s)
FLUX ∝ Exp. TIME
Exposure level [ADU]
Created: 2014-03-26 17:58:47 (UTC)


Linearity derived from Gain template 2011-08-08 13:55:24 (OCAM_z_SDSS)
Normalised flux [ADU/s]
Exposure level [ADU]
Created: 2014-03-27 11:20:10 (UTC)
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#80
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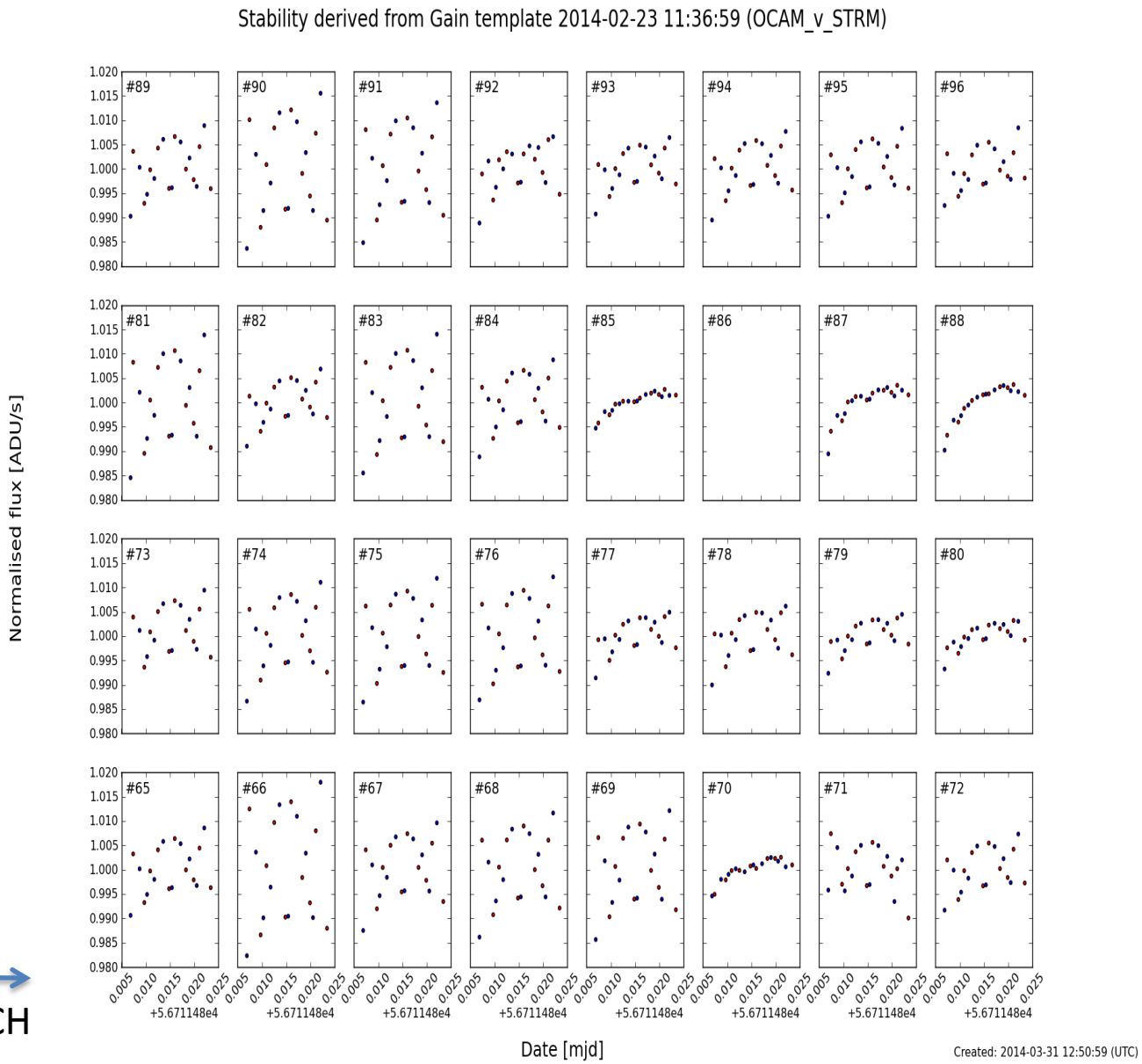
#69
#70
#71
#72

Linearity/gain issues: on going ESO effort to figure out



FLUX (ADU/s)

MJD = EPOCH

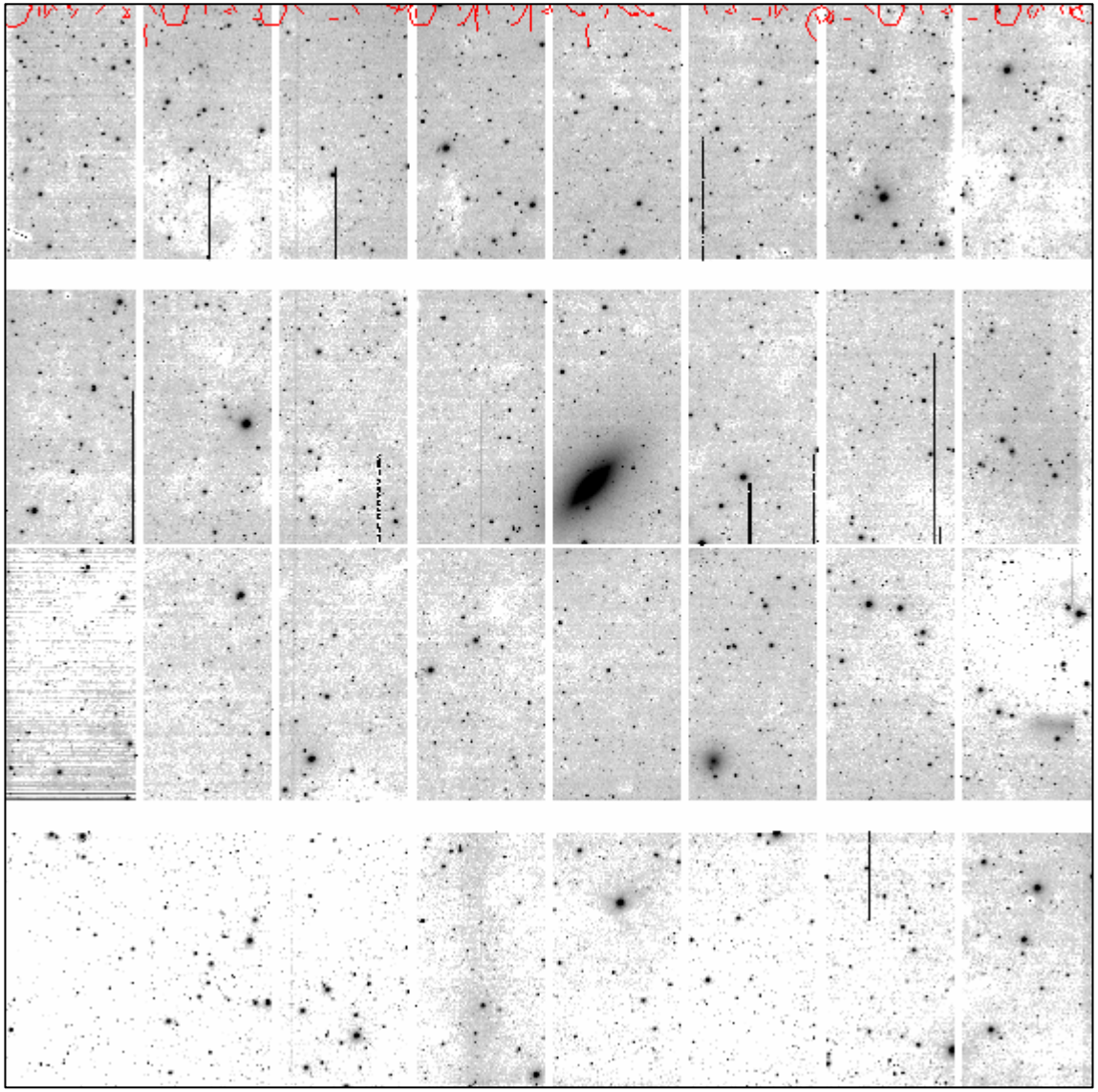
CCDs gain variations

Gain variation on short time scale

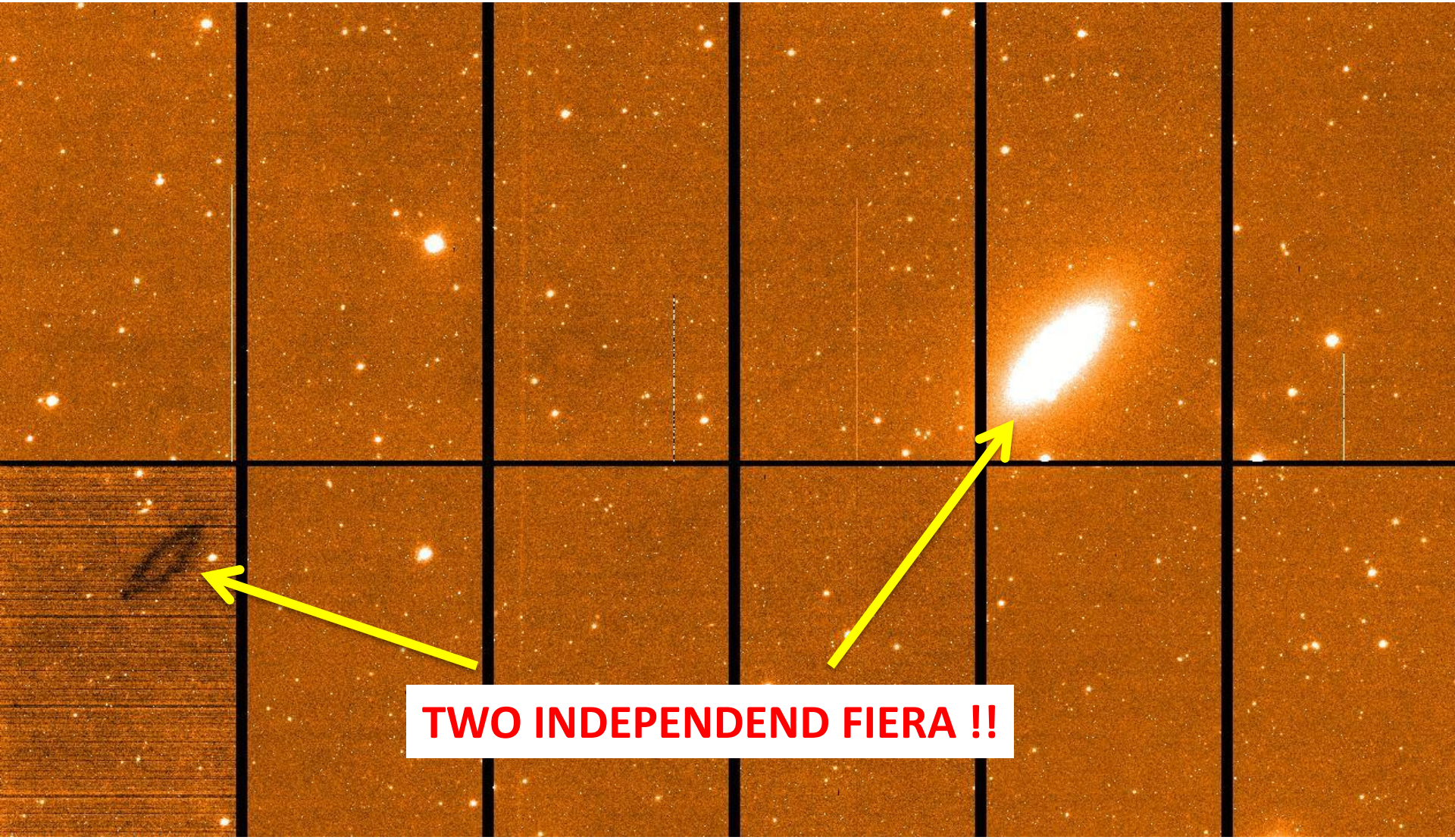
Survey: VEGAS

BAND: u_sdss

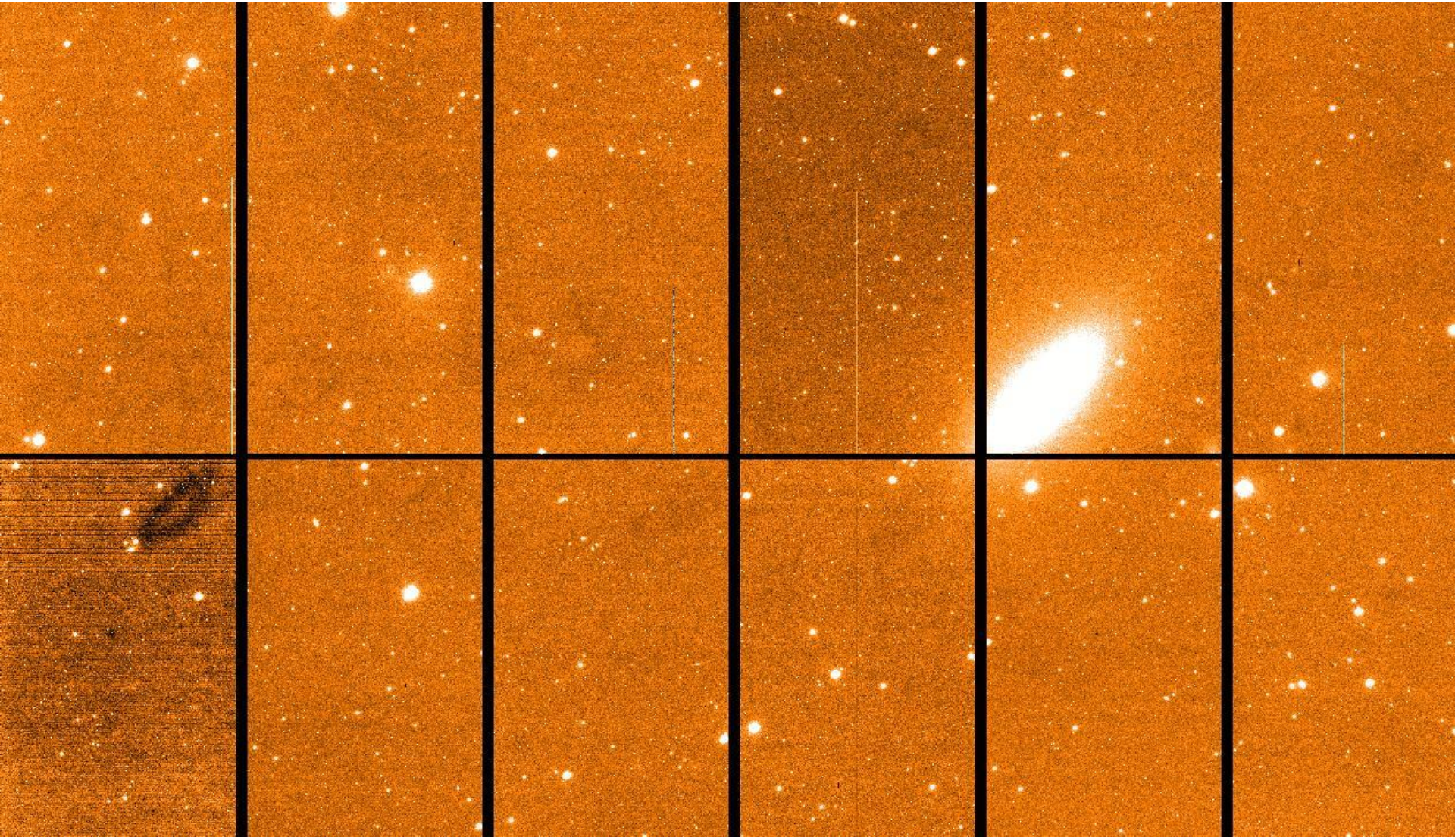
Night:
2014-02-25



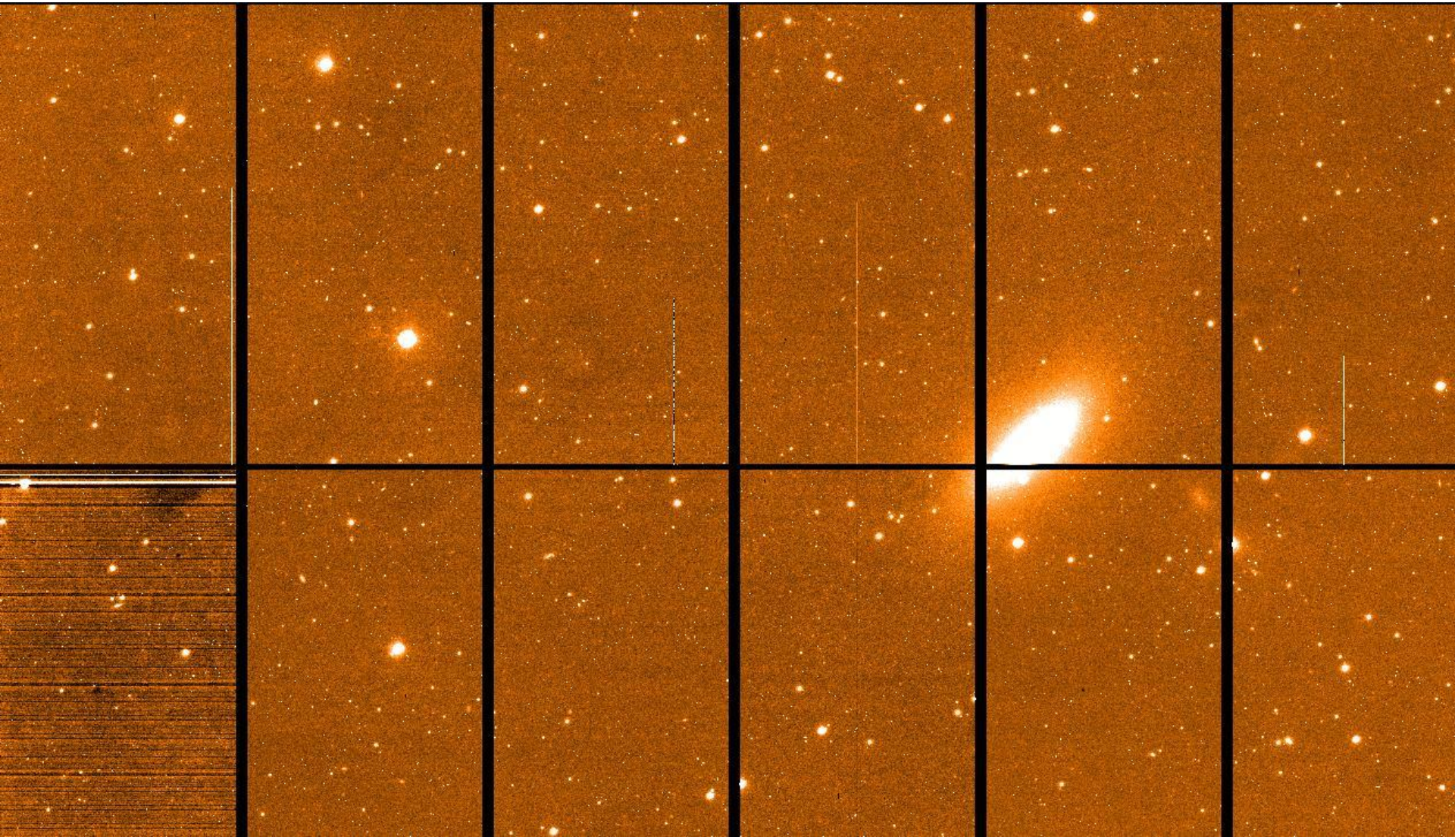
New (2014) issues on CCD 73 (noise and cross talk)



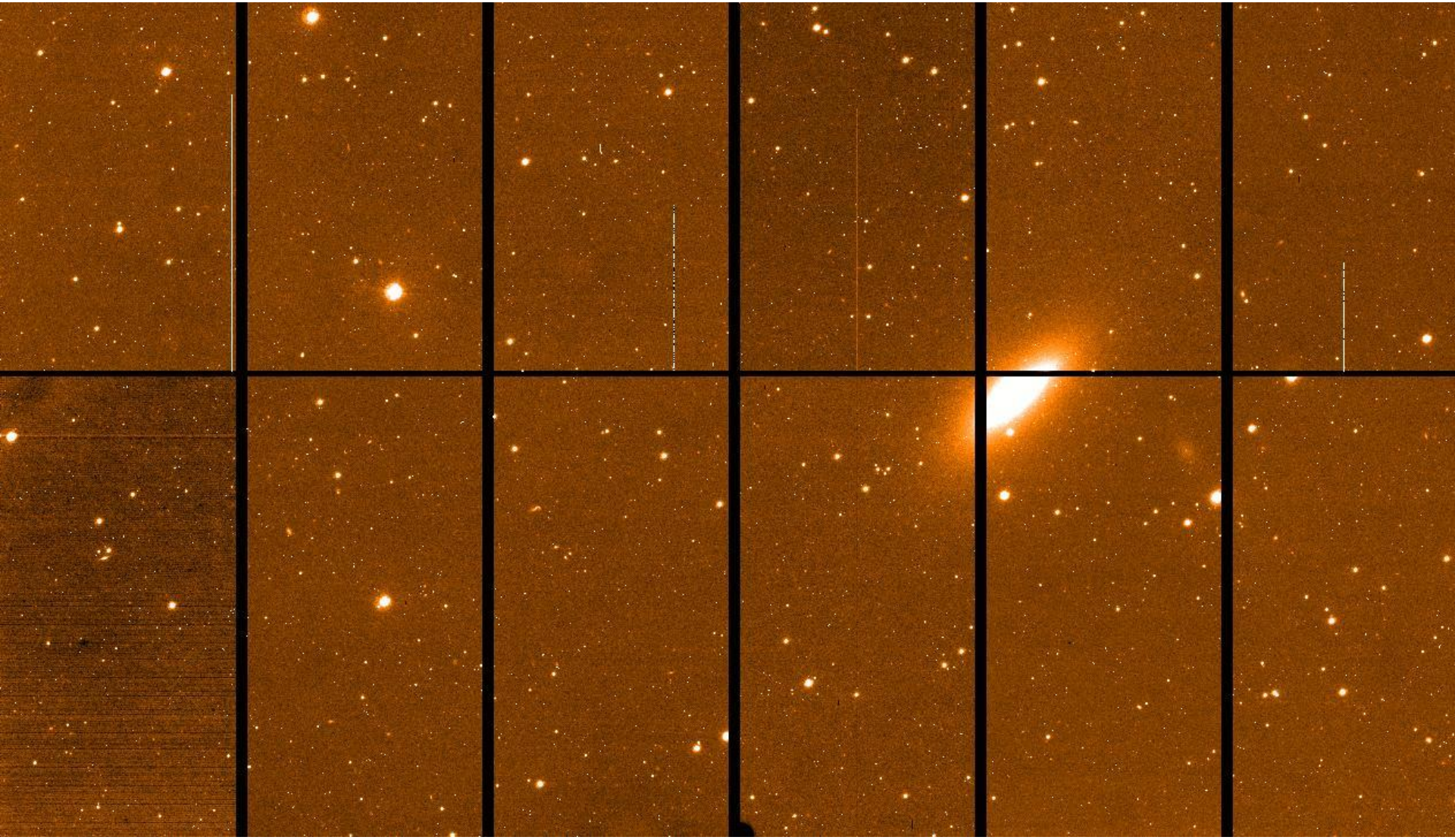
New (2014) issues on CCD 73 (noise and cross talk)



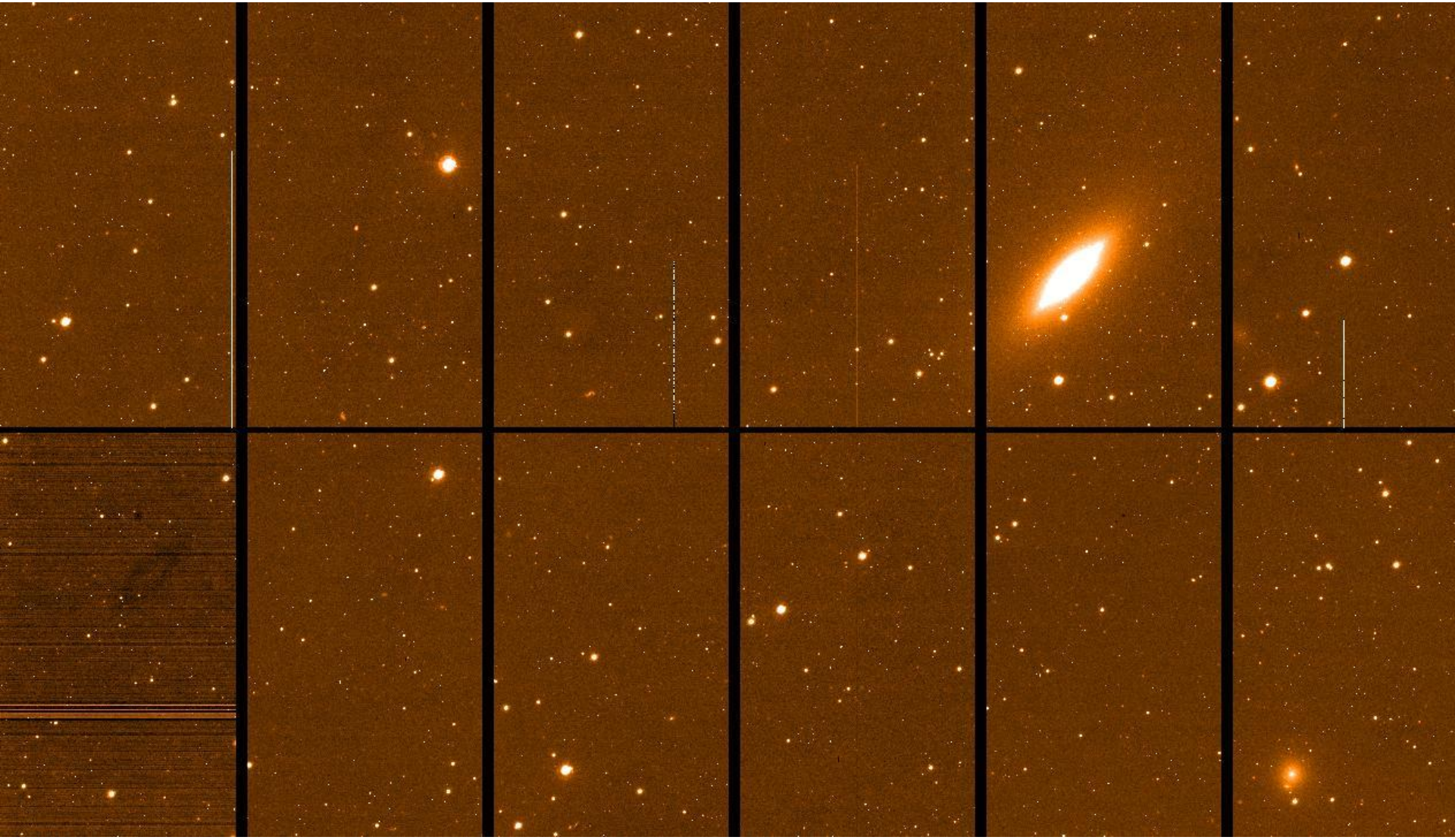
New (2014) issues on CCD 73 (noise and cross talk)



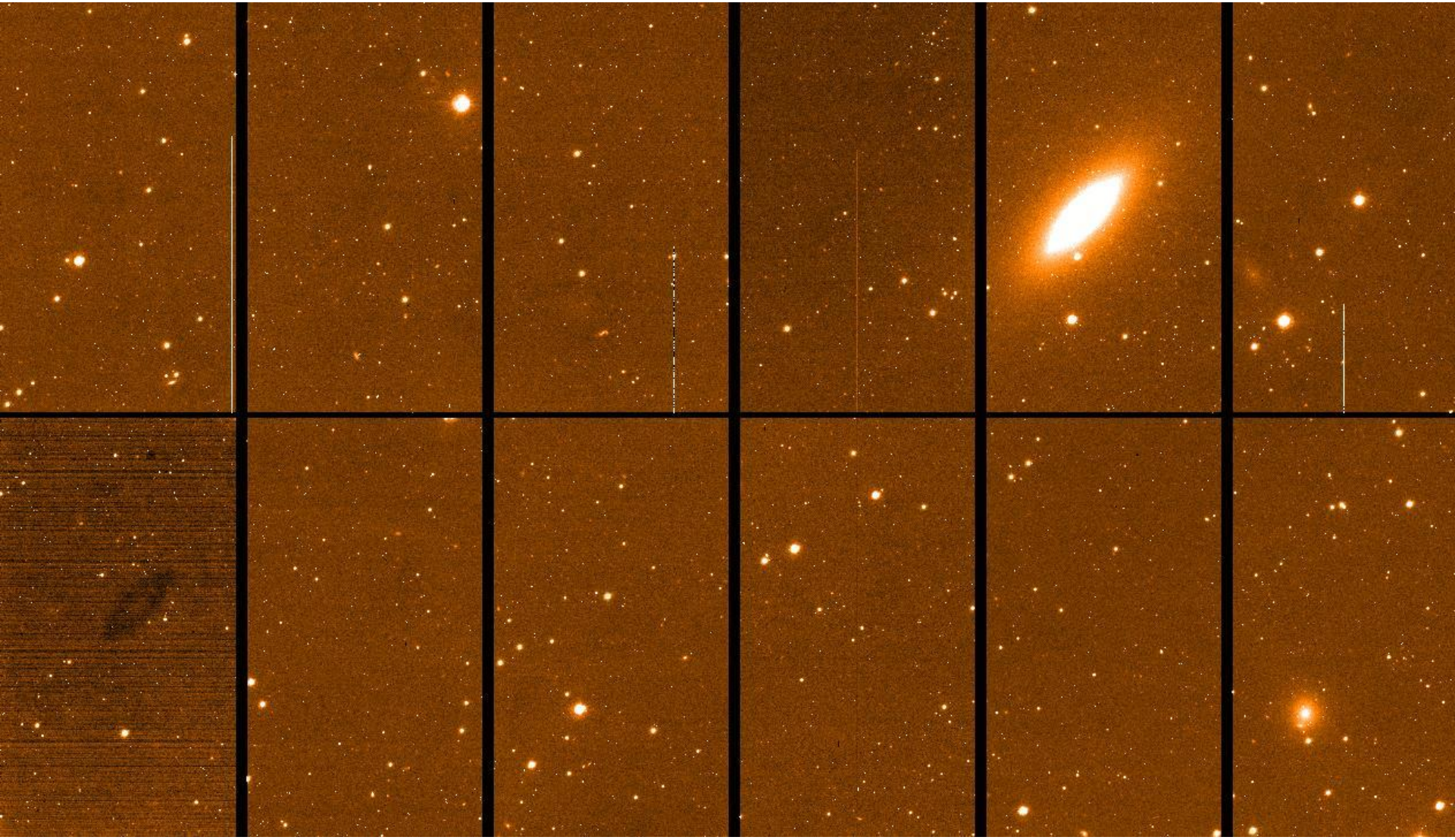
New (2014) issues on CCD 73 (noise and cross talk)



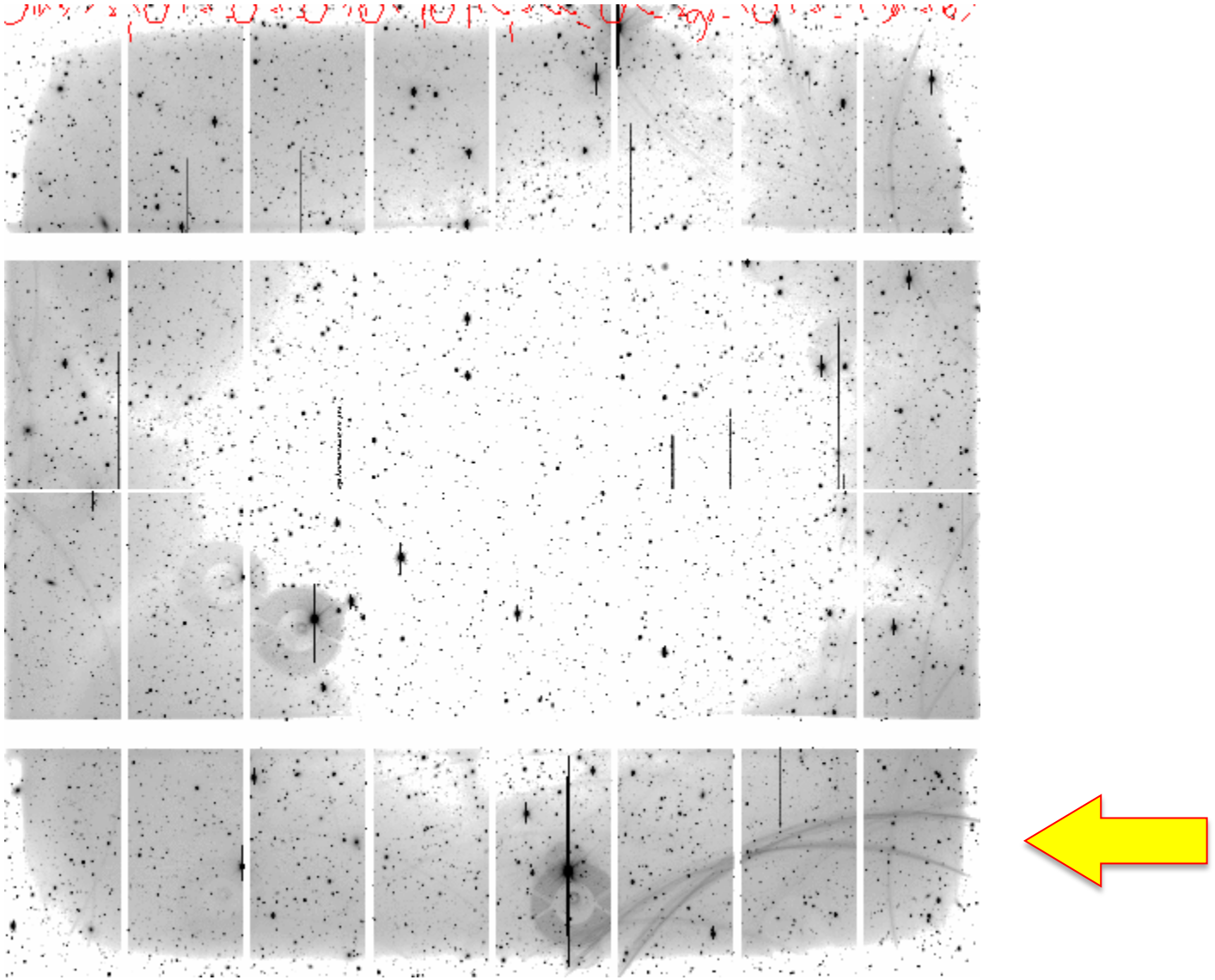
New (2014) issues on CCD 73 (noise and cross talk)



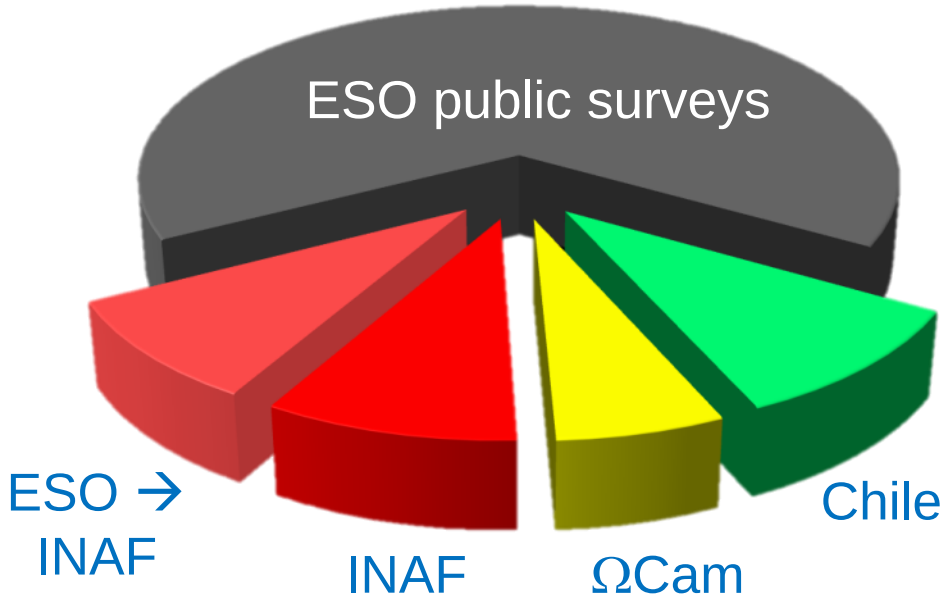
New (2014) issues on CCD 73 (noise and cross talk)



New (2014) baffling – new problems

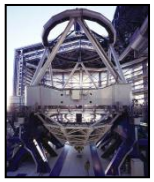


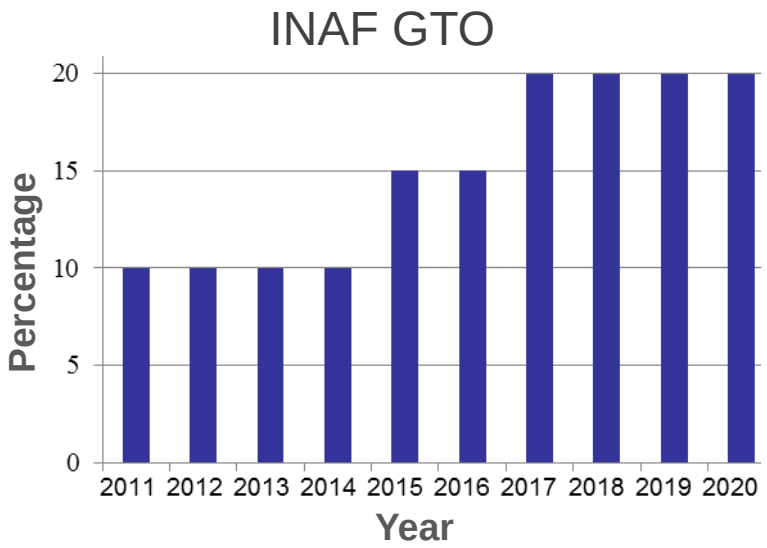
Share of VST observing time and scientific policy for the first 10 years of operation



+

3 VST nights/yr





Observations:

- service mode
- designated visitor mode

recent very positive experience

Some statistics

Available Time and Losses

Period	Available [h]	Tech. time	Tech. loss	Weather loss	Idle time	Chilean Sc.	Remain	INAF GTO
P88	1227.8	106.2	148.8	168.8	55.7	37.9	891.0	89.1
P89	1811.4	57.6	75.1	331.5	205.5	44.2	1192.7	119.3
P90	1446.3	45.5	208.7	126.7	101.6	14.4	1099.3	109.9
P91	1789.4	79.9	180.5	368.8	161.5	77.2	1091.7	109.2

Available time summary vs nominal night duration

Period	Available	Tech. time	TOTAL
P88 (>15 Oct)	1227.8	106.2	1334/1320
P89	1811.4	57.6	1869/1800
P90	1446.3	45.5	1492/1440
P91	1789.4	79.9	1869/1800

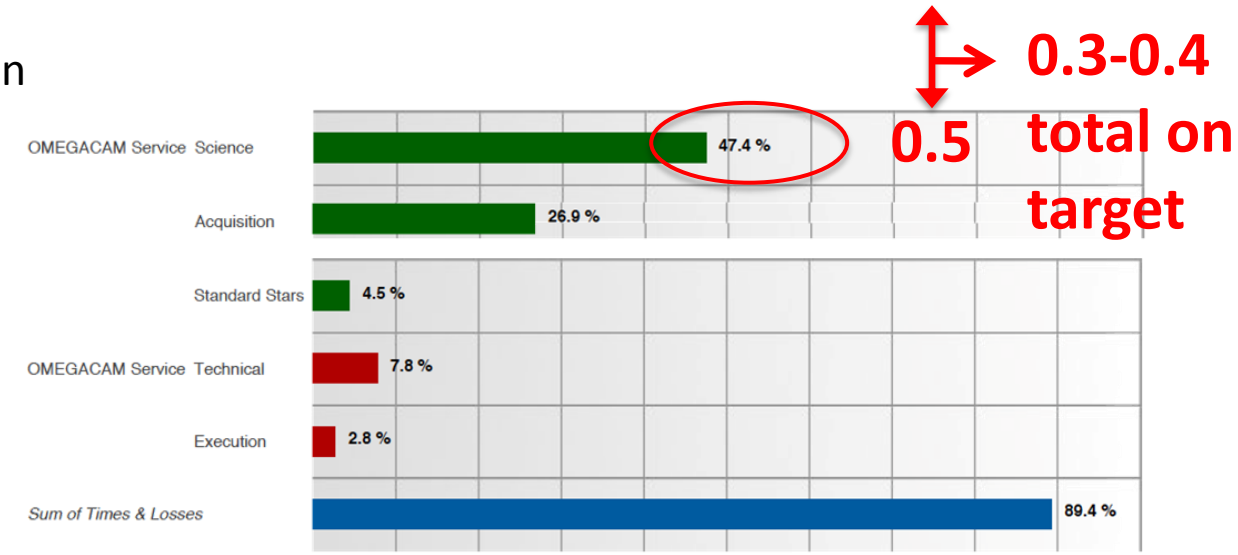
6monthsx30days
x8h/night in P88,P90 =1440h
x10h/night in P89, P91=1800h

Some statistics

Fractions of Observing Time and Losses vs Available Time

Period	Available	Tech./ TOTAL	Tech.loss/ Available	Wea.loss/ Available	Idle time/ Available	Chil.Sc./ Remain	Remain/ Available	INAF/Obs. (exp.d 0.1)
P88	1227.8	0.08	**0.11**	**0.13**	0.04	0.04	0.68	0.05
P89	1811.4	0.03	0.04	**0.18**	**0.11**	0.04	0.63	0.07
P90	1446.3	0.03	**0.14**	0.08	0.07	0.01	0.70	0.07
P91	1789.4	0.04	**0.10**	**0.20**	0.09	0.07	0.54	0.09

Typically in a service mode run

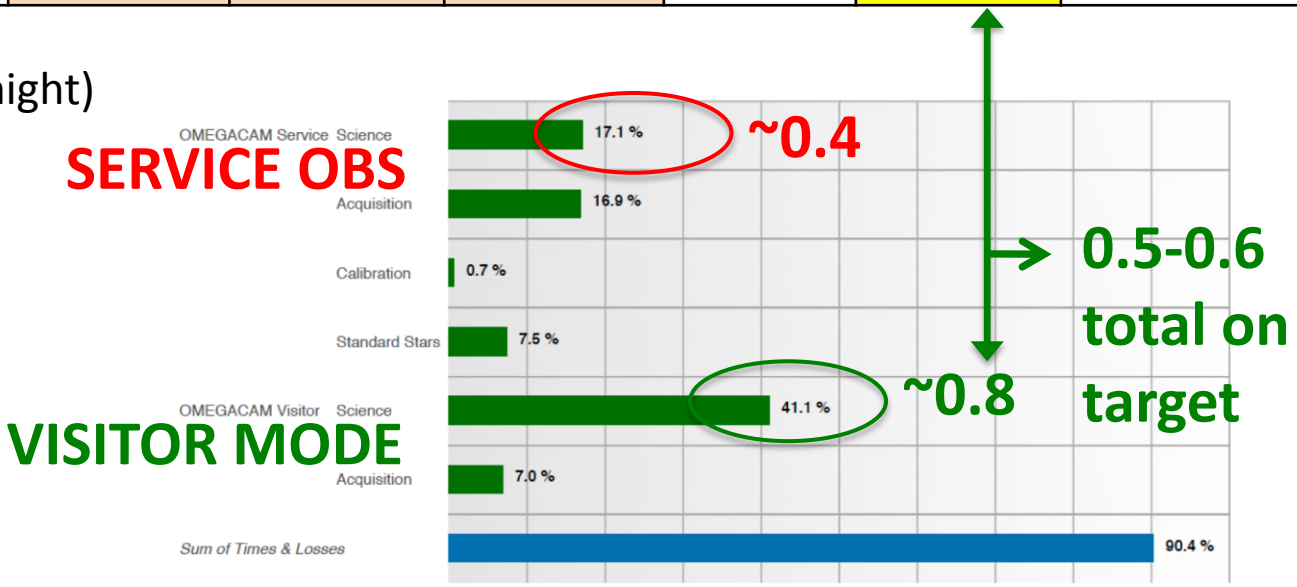


Some statistics

Fractions of Observing Time and Losses vs Available Time

Period	Available	Tech./ TOTAL	Tech.loss/ Available	Wea.loss/ Available	Idle time/ Available	Chil.Sc./ Remain	Remain/ Available	INAF/Obs. (exp.d 0.1)
P88	1227.8	0.08	**0.11**	**0.13**	0.04	0.04	0.68	0.05
P89	1811.4	0.03	0.04	**0.18**	**0.11**	0.04	0.63	0.07
P90	1446.3	0.03	**0.14**	0.08	0.07	0.01	0.70	0.07
P91	1789.4	0.04	**0.10**	**0.20**	0.09	0.07	0.54	0.09

Service vs Visitor run (half night)



Some statistics

ESO Public Surveys

Period	Remain [h]	KIDS [%]		ATLAS [%]		VPHAS+ [%]		INAF GTO [%]	Chil.Sc./ Remain [%]
P88	891.0	185.5	(0.21)	288	(0.32)	80.1	(0.09)	0.05	0.04
P89	1192.7	293	(0.25)	317	(0.27)	176	(0.15)	0.07	0.04
P90	1099.3	243	(0.22)	244	(0.22)	176	(0.16)	0.07	0.01
P91	1091.7	207	(0.19)	165	(0.15)	152	(0.14)	0.09	0.07

Public Surveys and GTO are competing


Thanks