ESO 4LGSF: Integration in the VLT, Commissioning and on-sky results

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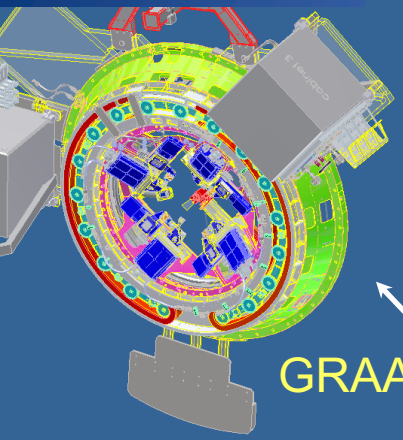
- AOF and 4LGSF Overview
- 4LGSF Top Level Requirements
- LGSU1 Integration and Commissioning step
- 4LGSF Integration
- 4LGSF Standalone Commissioning

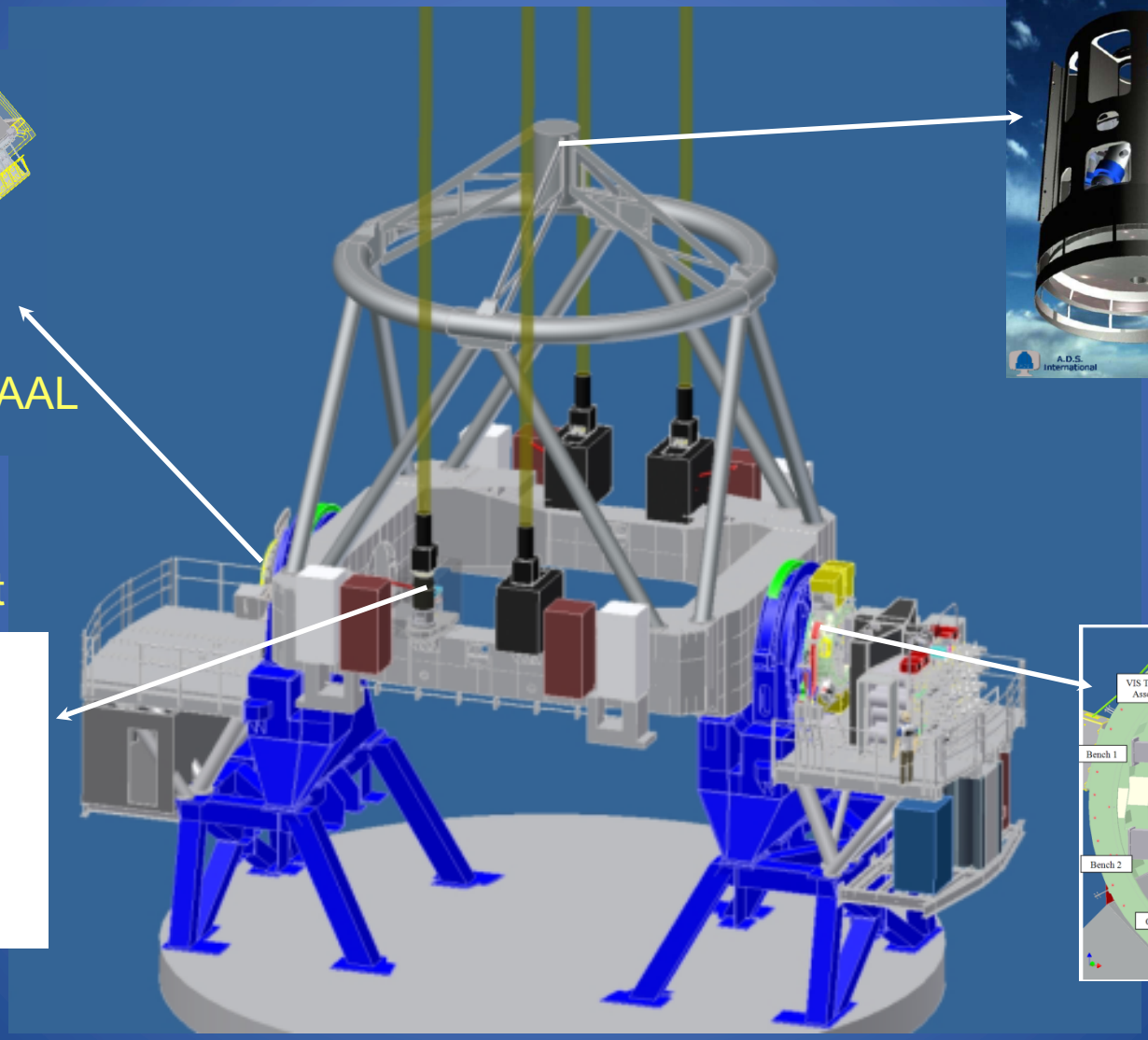
AOF main subsystems



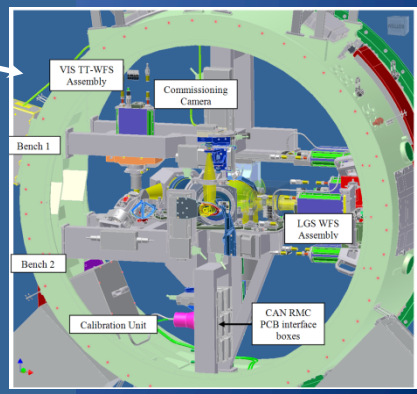
GRAAL

DSM

LGS Unit

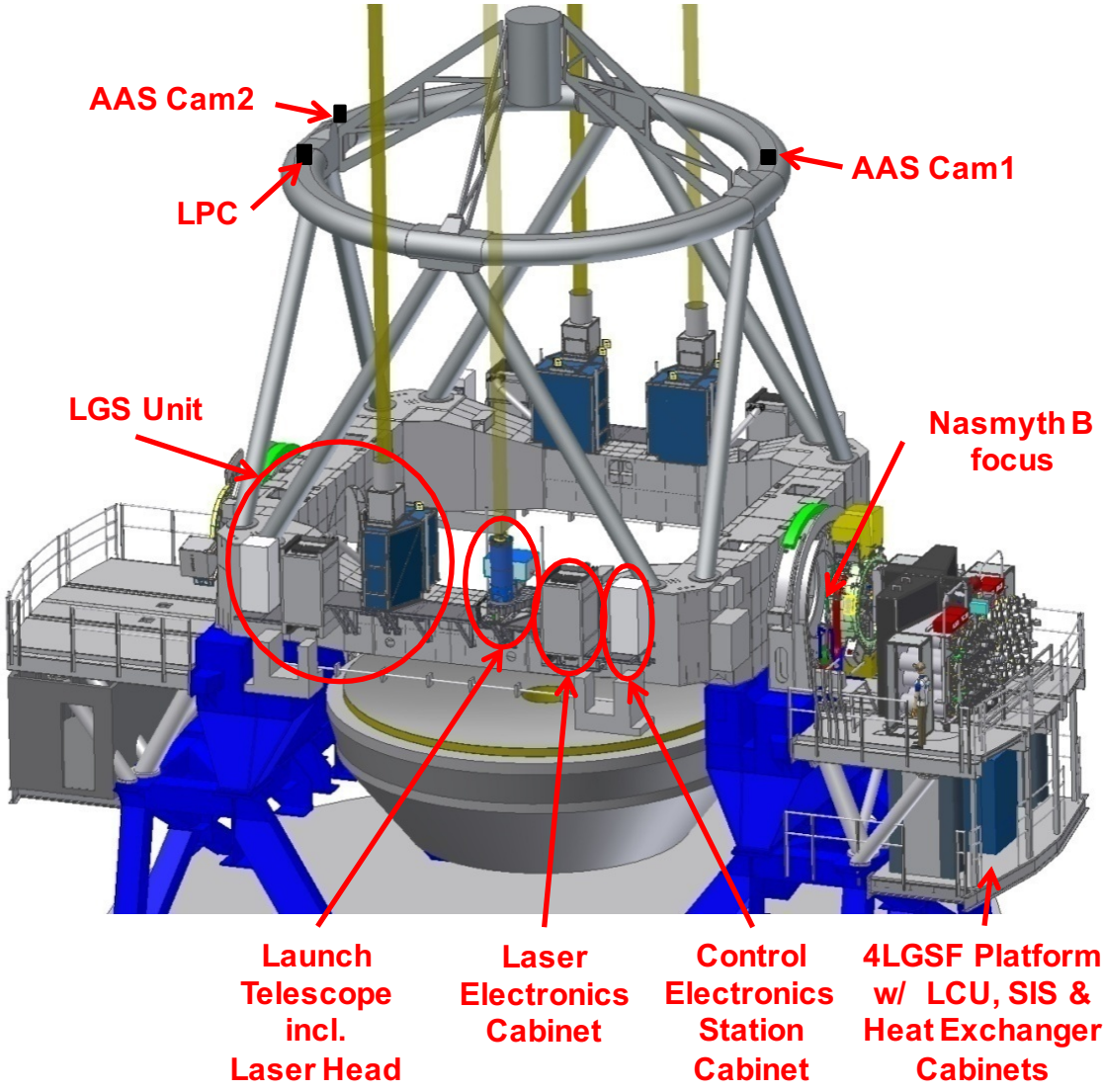


GALACSI

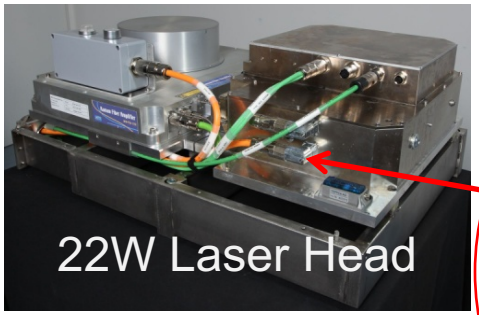


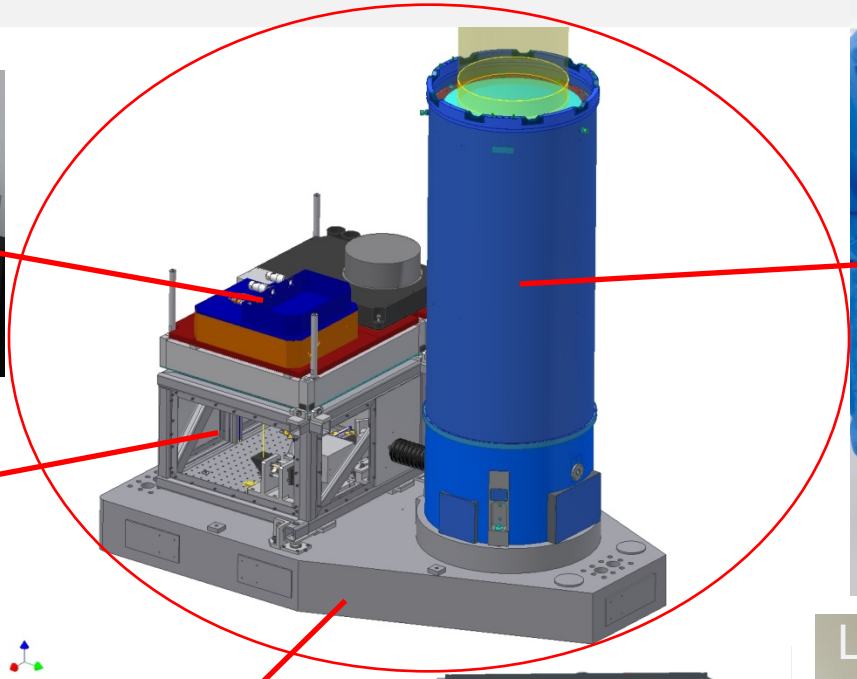
4LGSF Modular Design

- 4x LGS Unit (UT4 Centerpiece)
  - Laser Cabinet (Toptica/MPBC)
  - Laser Head (Toptica/MPBC)
  - Launch Telescope (TNO)
  - BCDS (ESO)
  - LGSU Control Electronic Cabinet (ESO)
- LCU cabinet (under Nasmyth B)
- Safety and Housekeeping System (under Nasmyth B)
- Toptica Heat Exchanger (under nasmyth B)
- Aircraft Avoidance Cameras (UT4 Top Ring) shared between LGSF and 4LGSF
- Laser Pointing Camera (UT4 Top Ring)



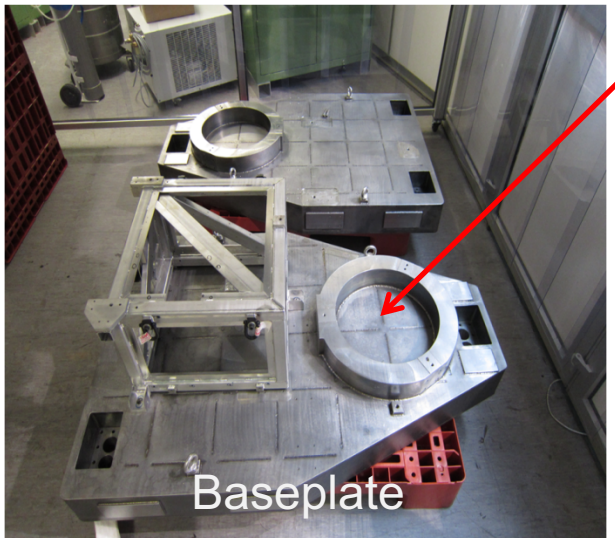
LGS-Unit

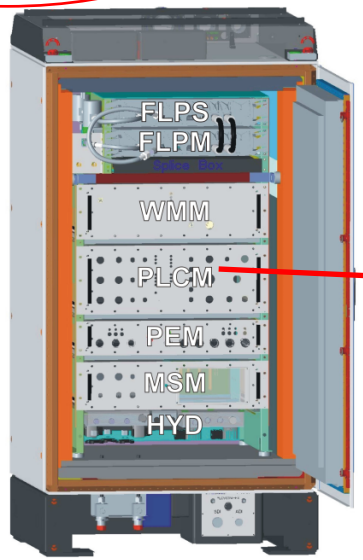

22W Laser Head

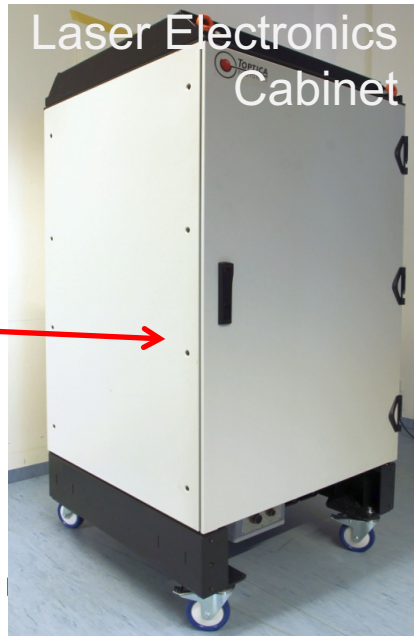



Optical Tube Assembly
TNO

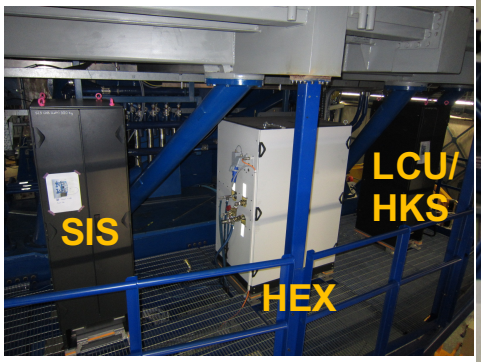

Beam Control &
Diagnostics System


Baseplate


FLPS
FLPM
WMM
PLCM
PEM
MSM
HYD

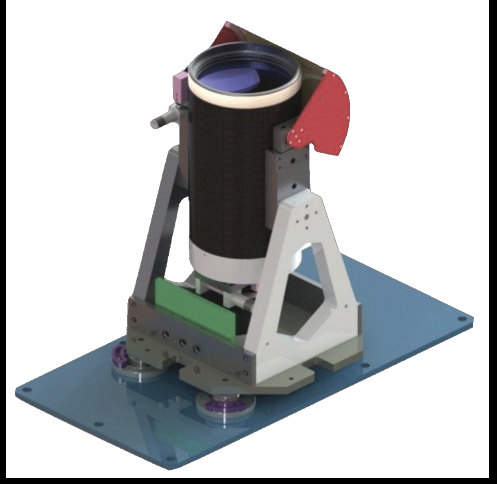

Laser Electronics
Cabinet

LGSU #1



Laser Pointing Camera

- Essential tool, all along the Commissioning (Pointing models, PM verifications, focus loops check, return flux) and in Operation.
- With LPC we will be able to automatically record photometry and PM corrections, when in AODRIVEN mode, during operations
- 8-14km scattering measurement/monitoring on-line (cirrus)
- Photometry calibration check. Accuracy 0.1 mag.
- Private p2p LAN for remote maintenance, outside UT4 network



LPC MAIN CHARACTERISTICS

The LPC is based on a 'smart' CCD camera with Johnson filters, with on-board computing processor, based on Linux OS. The CCD is mounted behind a compact, 15cm aperture Maksutov telescope equipped with an image rotator. It has a field of view of ~35x25 arcmin with subarcsec resolution.

The 70x45x45 cm housing protects the telescope from wind shake and dust. The total weight is 35kg. LPC does not have fans or water cooling to remove the heat generated; it uses thermal conduction with the telescope structure, instead.

LPC is thus a self-contained module, requiring 24V (optionally 12V), 35W power supply and LAN Ethernet.
LPC is able to identify and derive the absolute coordinates of the LGS and of the field natural stars, with 100% sky coverage; it derives the LGS relative position with respect to the UT4 optical axis, with a 3σ error ≤1 arcsec in ALT and AZ; it provides the ΔALT and ΔAZ corrections to apply, to position the four LGS at their targeted positions, within 60 seconds from the user request. In very crowded fields it may take 120 seconds.

LPC has been calibrated to optionally measure the LGS return flux (phot/s/m^2), the LGS fwhm in arcsec and the uplink scattering intensity parameter integrated in the range 8-14 km above the observatory, in units of phot/s/sec/arcsec^2

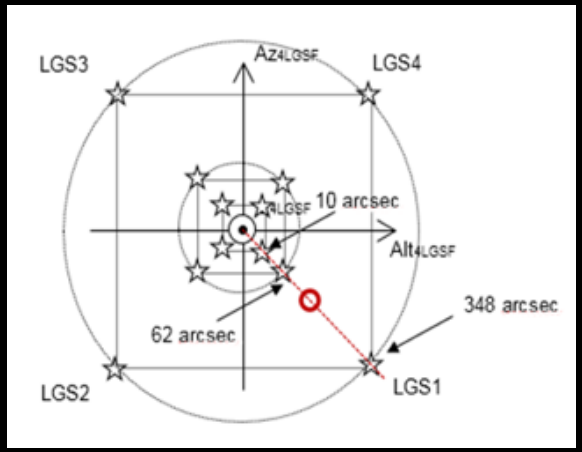
LPC: Linux Smartcamera on LAN

- Absolute coordinate astrometry
- Offsets of LGS while UT4 cycles
- LGS Photometry
- LGS FHWM and cirrus monitor

See LPC Poster today, 9909-198

4LGSF: Main Requirements from AO

- LGS Return Flux (TLR7): ≥ 7.7 × 10^6 photons/s/m^2 at the ground, pointing at zenith, with Sodium column density = 4 × 10^{13} m^{-2}
- LGS Spot Size (TLR 8): with 0.6” NGS fwhm, the short axis of the LGS fwhm shall be ≤ 1” at UT4 ALT 60˚, short exposure;
- Pointing Range (TLR 9): Radial pointing: from 0 arcsec to 6 arcmin with respect to VLT optical axis, square geometry asterism
- Open Loop Pointing Accuracy: Radial 2.5”



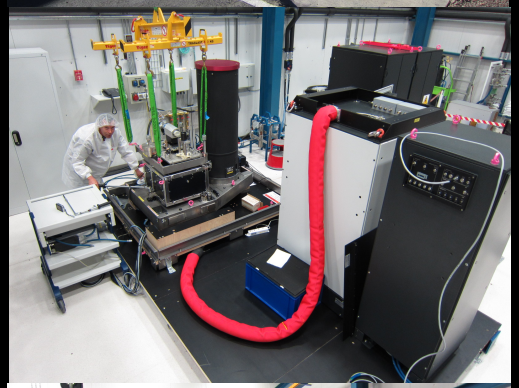
4LGSF Integration, Commissioning: stepped approach

- LGSU1 on VLT-UT4 integrated in Feb-Mar 2015
- Commissioned LGSU1 in 2Q15. With GRAAL 3Q15
- The team includes ESO and Toptica+MPBC staff
- From the LGSU1 commissioning, implemented changes in the LGSU2-4 back at HQ in Garching

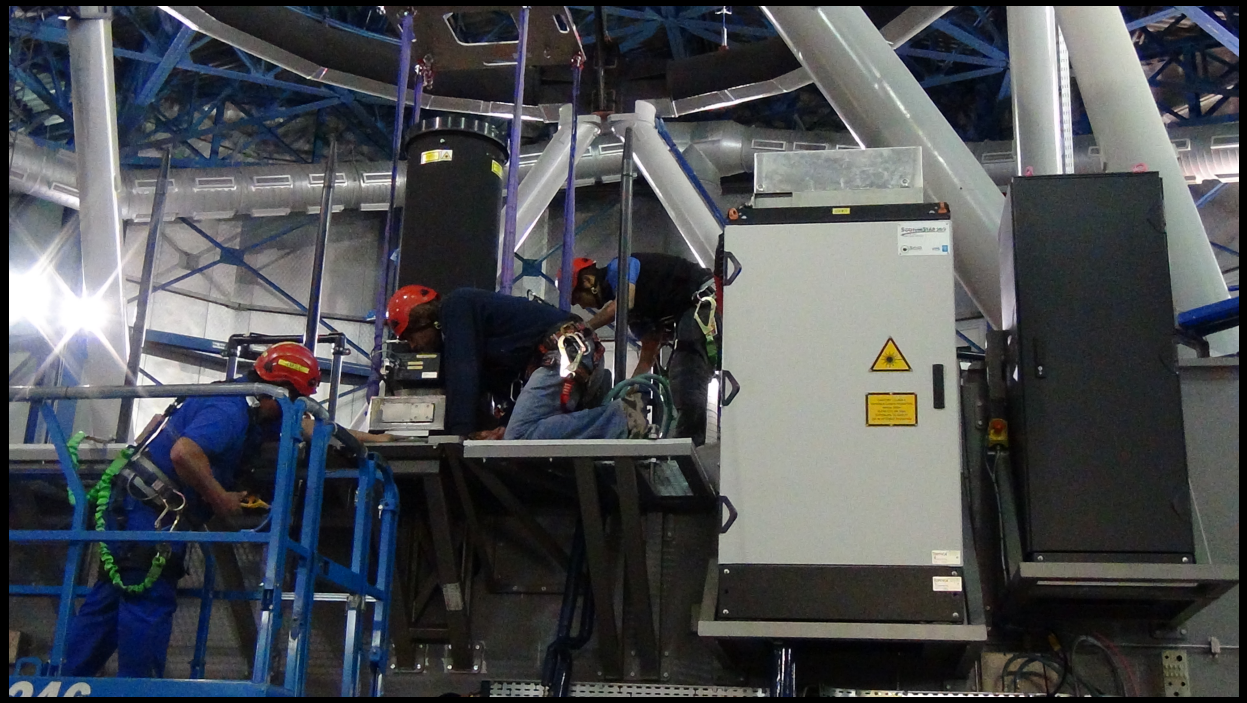
- Full 4LGSF reintegration at base camp first, test that everything works (Jan 2016)
- Permission to Install on UT4: Feb 2016
- Daytime verification on UT4: Mar 2016
- First calibrations on Sky: Mar 2016
- Full Commissioning Nights:

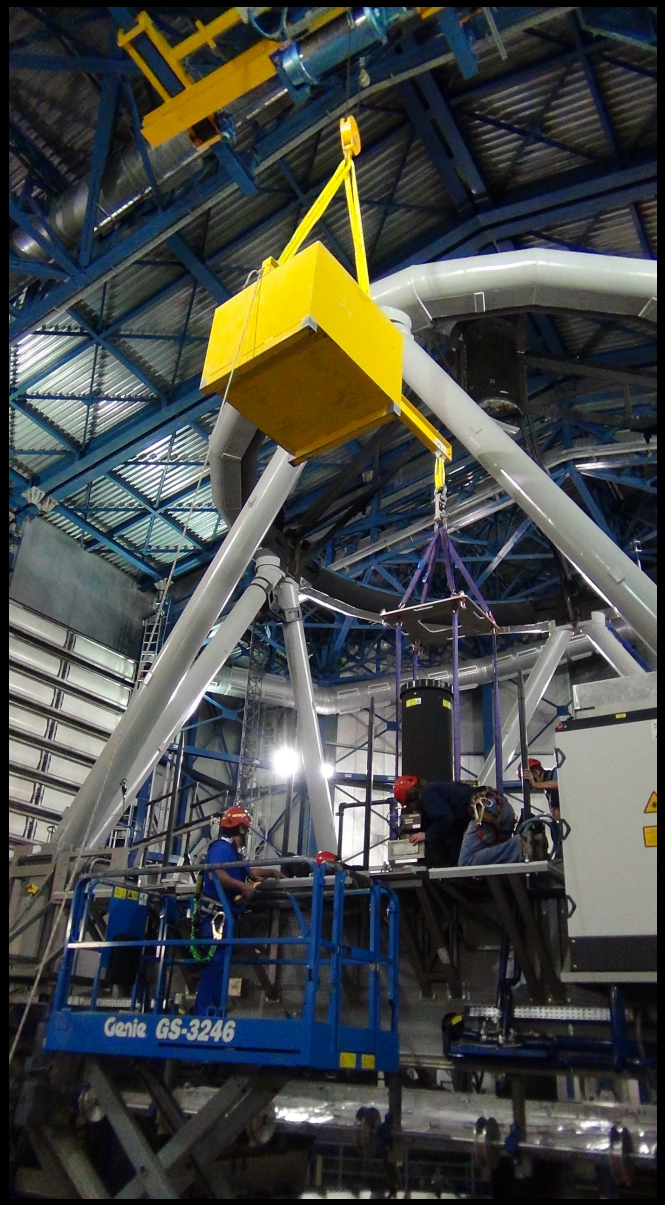
  26 April-4 May, 15June-21 June

ESO 4LGSF: Integration in the VLT

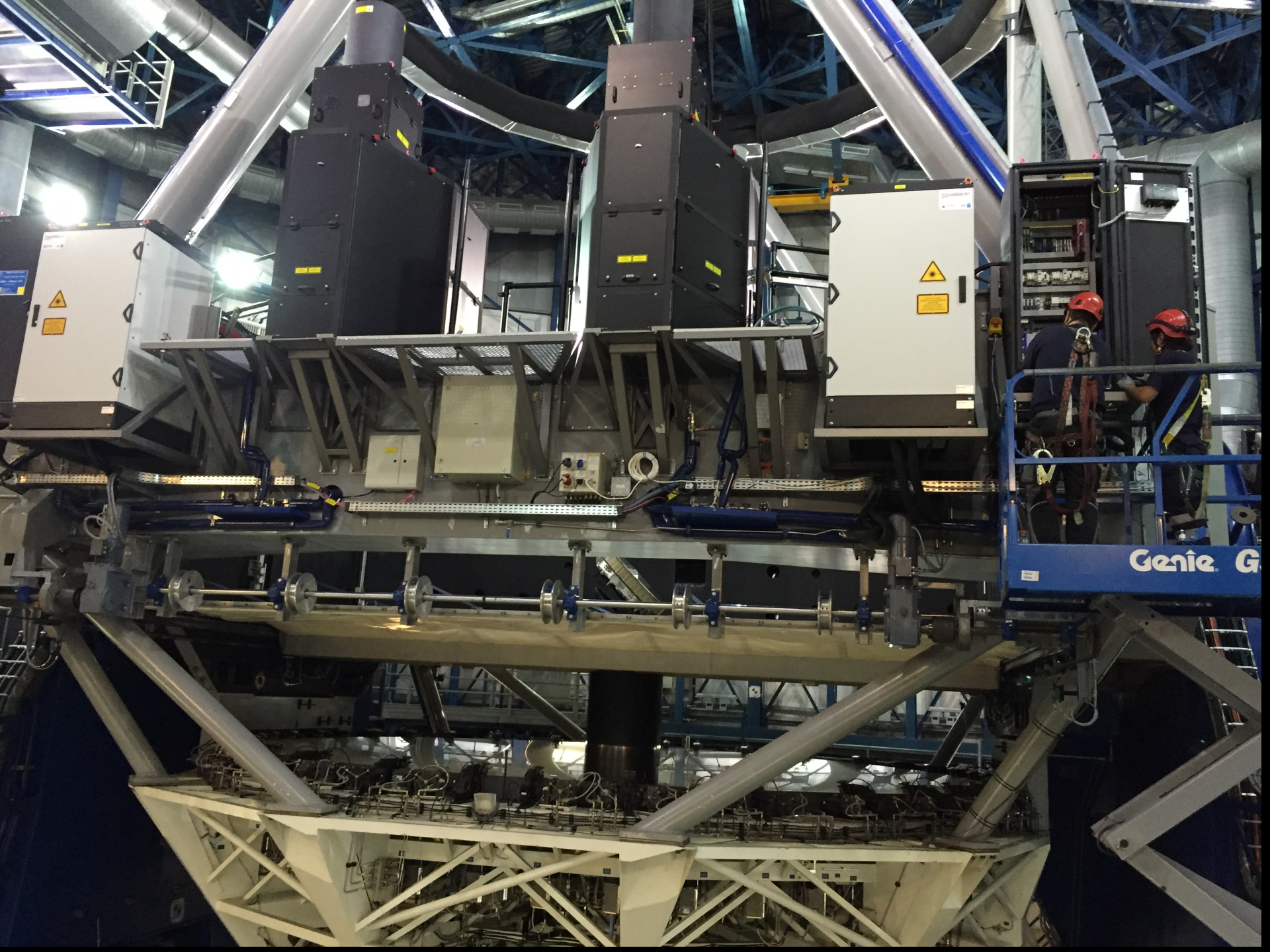


ESO 4LGSF: Integration in the VLT

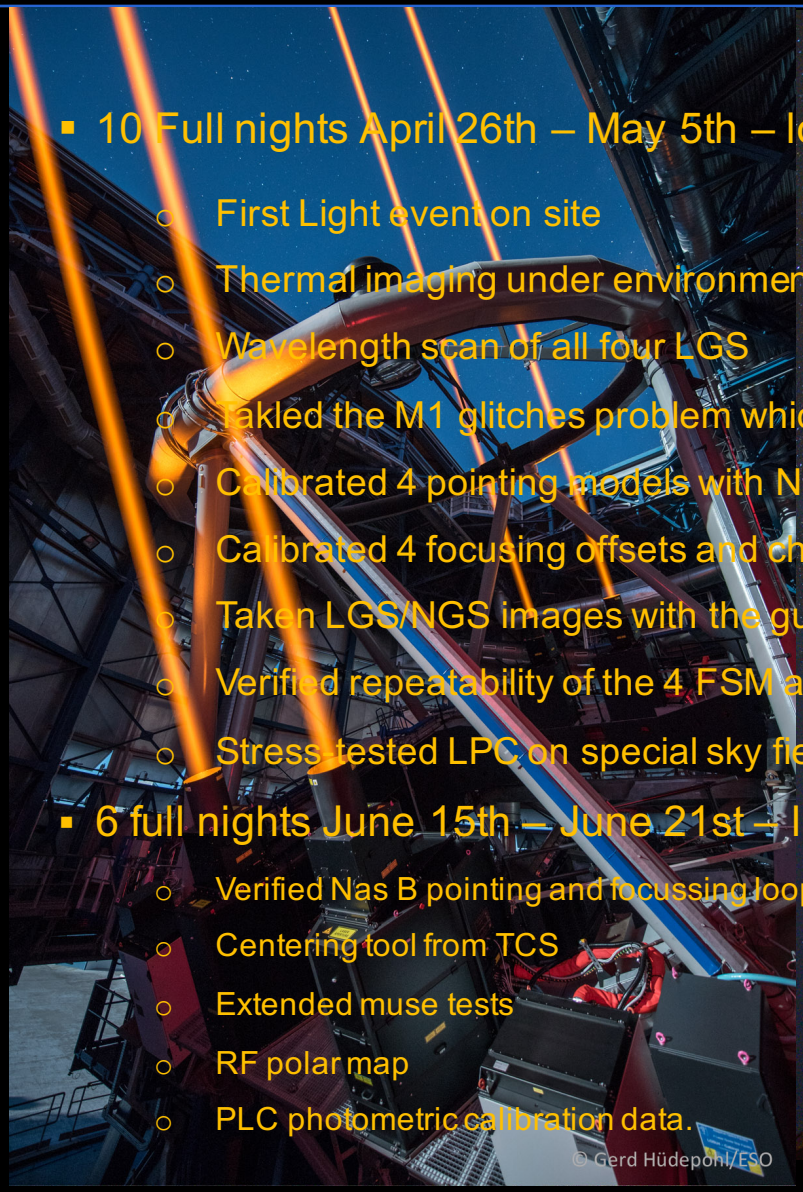


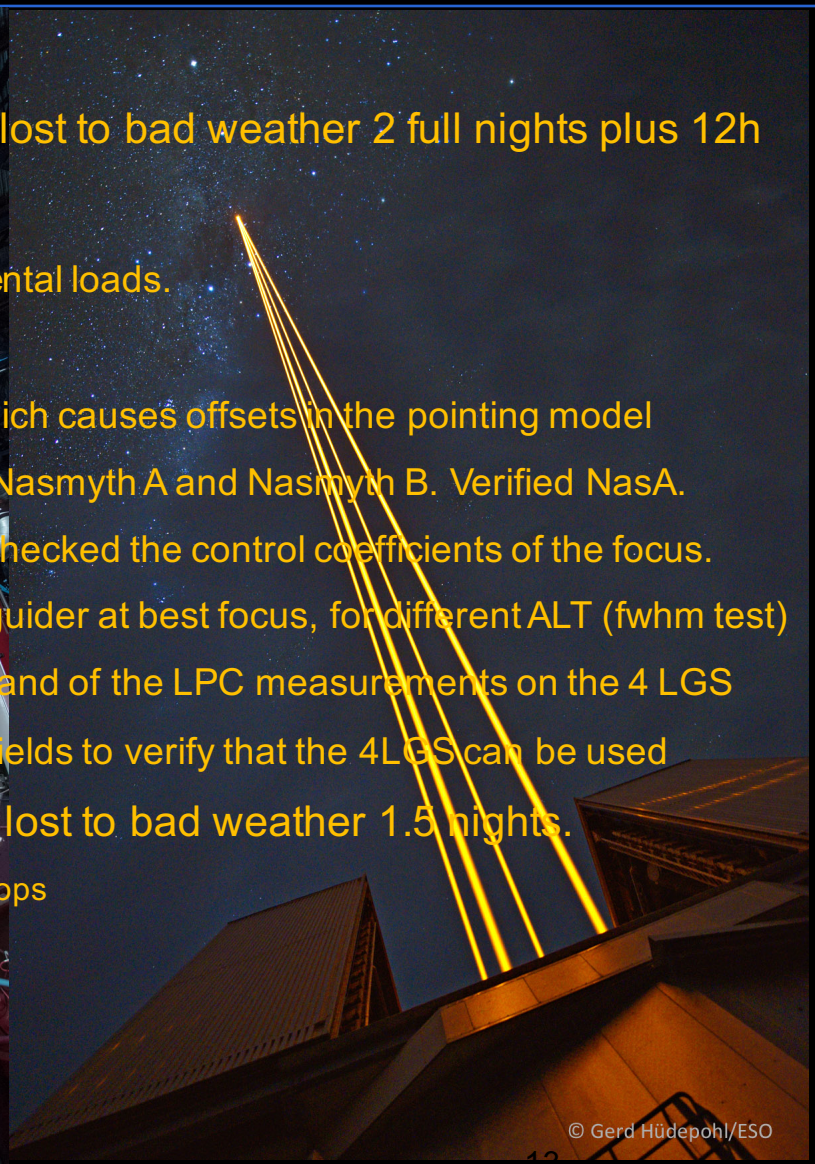


- UT4 structure prepared
- 10 days UT4 Full Access
- Mar 2015 and Feb 2016
- Intense team activities


Genie

4LGSF Commissioning and on-sky results





- 10 Full nights April 26th – May 5th – lost to bad weather 2 full nights plus 12h
  - First Light event on site
  - Thermal imaging under environmental loads.
  - Wavelength scan of all four LGS
  - Tackled the M1 glitches problem which causes offsets in the pointing model
  - Calibrated 4 pointing models with Nasmyth A and Nasmyth B. Verified NasA.
  - Calibrated 4 focusing offsets and checked the control coefficients of the focus.
  - Taken LGS/NGS images with the guider at best focus, for different ALT (fwhm test)
  - Verified repeatability of the 4 FSM and of the LPC measurements on the 4 LGS
  - Stress-tested LPC on special sky fields to verify that the 4LGS can be used
- 6 full nights June 15th – June 21st – lost to bad weather 1.5 nights.
  - Verified Nas B pointing and focussing loops
  - Centering tool from TCS
  - Extended muse tests
  - RF polar map
  - PLC photometric calibration data.

On Sky wavelength calibration

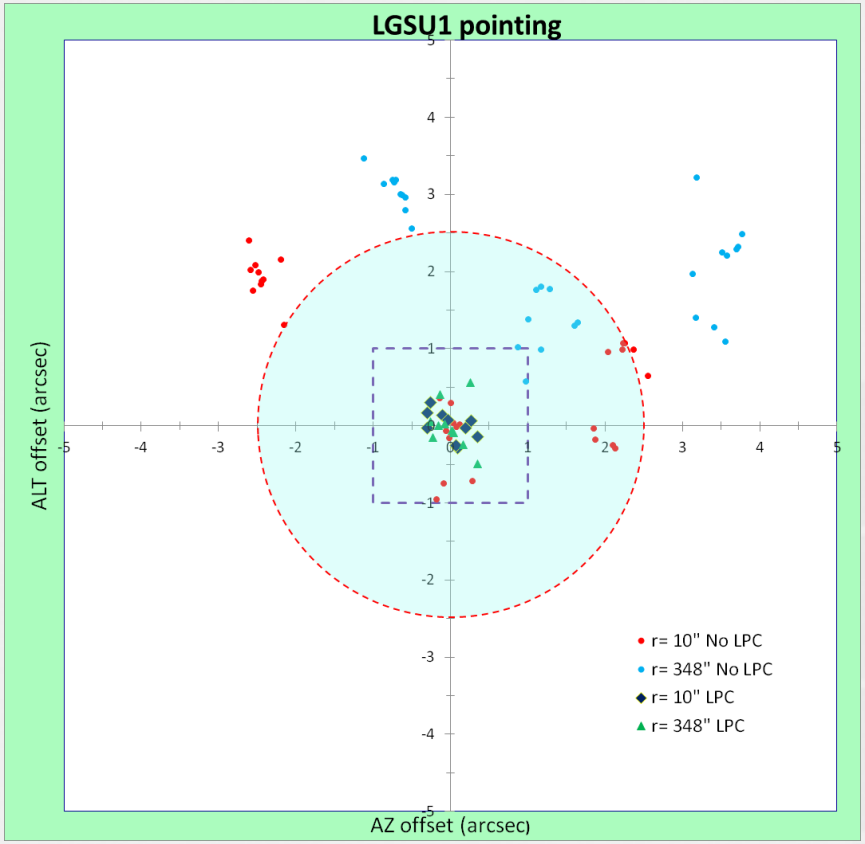
- Performed the LUs wavemeter calibrations
- Assigned set wavelength to the seed WL control and measured the RF
- Lasers are tuned OK.

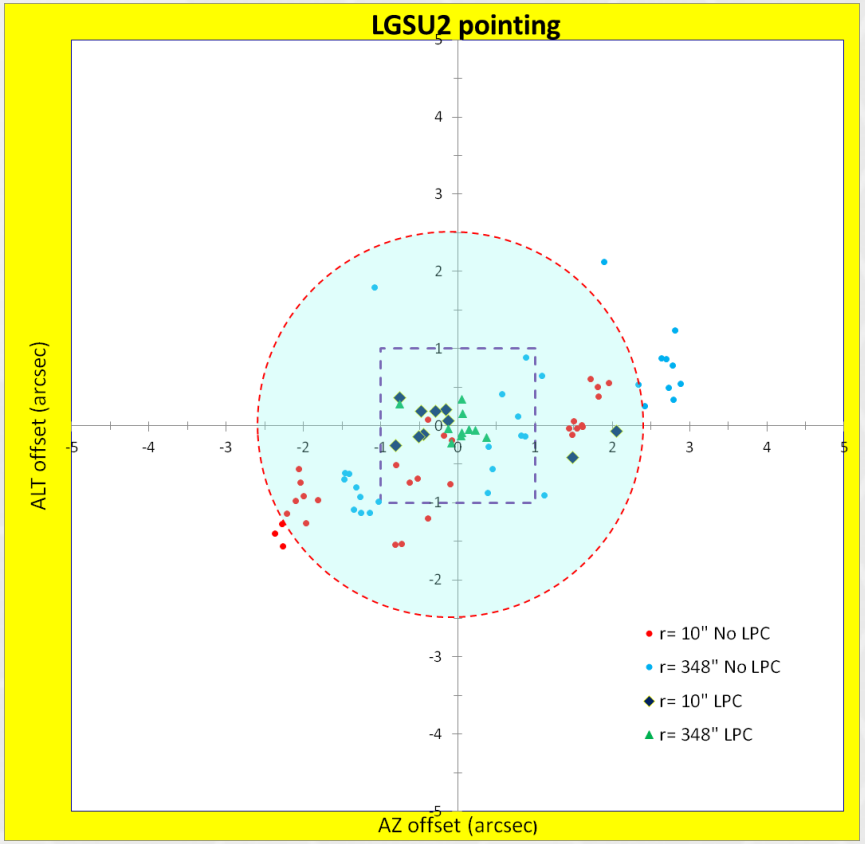
		LGSU3								LGSU2				
Emission wl (nm)	Delta (MHz)	seed wl (nm) in vacuum	ADU Intensity (10 sec exp)	Dark ADU	Flux	Relative flux		Emission wl (nm)	Delta (MHz)	seed wl (nm) in vacuum	ADU Intensity (10 sec exp)	Dark ADU	Flux	Relative flux
589.16	-400	1178.32	3900	1890	2010	0.264126150		589.16	-400	1178.32	3300	1890	1410	0.198312236
589.159969	-375	1178.31994	4100	1890	2210	0.290407359		589.159969	-375	1178.31994	3500	1890	1610	0.226441632
589.159679	-250	1178.31936	6500	1890	4610	0.605781866		589.159679	-250	1178.31936	5350	1890	3460	0.486638537
589.15939	-125	1178.31878	8900	1890	7010	0.921156373		589.15939	-125	1178.31878	7650	1890	5760	0.810126582
589.15910	0	1178.3182	9500	1890	7610	1.000000000		589.15910	0	1178.3182	9000	1890	7110	1.000000000
589.158811	125	1178.31762	8400	1890	6510	0.855453351		589.158811	125	1178.31762	8750	1890	6860	0.964838256
589.158521	250	1178.31704	5900	1890	4010	0.526938239		589.158521	250	1178.31704	6650	1890	4760	0.669479606
589.158232	375	1178.31646	3900	1890	2010	0.264126150		589.158232	375	1178.31646	4520	1890	2630	0.369901547
589.157942	500	1178.31588	3100	1890	1210	0.159001314		589.157942	500	1178.31588	3320	1890	1430	0.201125176

		LGSU4	Mean	Dark 1800						LGSU1				
Emission wl (nm)	Delta (MHz)	seed wl (nm) in vacuum	ADU Intensity (Mean)	Dark ADU	Flux (ADU)	Relative flux		Emission wl (nm)	Delta (MHz)	seed wl (nm) in vacuum	ADU Intensity (10 sec exp)	Dark ADU	Flux	Relative flux
589.16	-350	1178.32000	2850	1800	1050	0.218750		589.16	-400	1178.32	2900	1890	1010	0.179715302
589.15968	-250	1178.31936	4020	1800	2220	0.462500		589.159969	-375	1178.31994	2970	1890	1080	0.192170819
589.15939	-125	1178.31878	5500	1800	3700	0.770833		589.159679	-250	1178.31936	4340	1890	2450	0.435943060
589.1591	0	1178.3182	6600	1800	4800	1.000000		589.15939	-125	1178.31878	6210	1890	4320	0.768683274
589.15881	125	1178.31762	5680	1800	3880	0.808333		589.15910	0	1178.3182	7510	1890	5620	1.000000000
589.15852	250	1178.31704	4300	1800	2500	0.520833		589.158811	125	1178.31762	7150	1890	5260	0.935943060
589.15823	375	1178.31646	3150	1800	1350	0.281250		589.158521	250	1178.31704	6100	1890	4210	0.749110320
589.157942	500	1178.31588	2500	1800	700	0.145833		589.158232	375	1178.31646	4320	1890	2430	0.432384342
								589.157942	500	1178.31588	3230	1890	1340	0.238434164

Open Loop Pointing

- LGS Open loop pointing: explored ALT range 30-85 deg, NasA , 3 asterisms
  LPC needed to meet OL pointing requirement. M1 glitches.
- In Spec with LPC : r< 2.5”

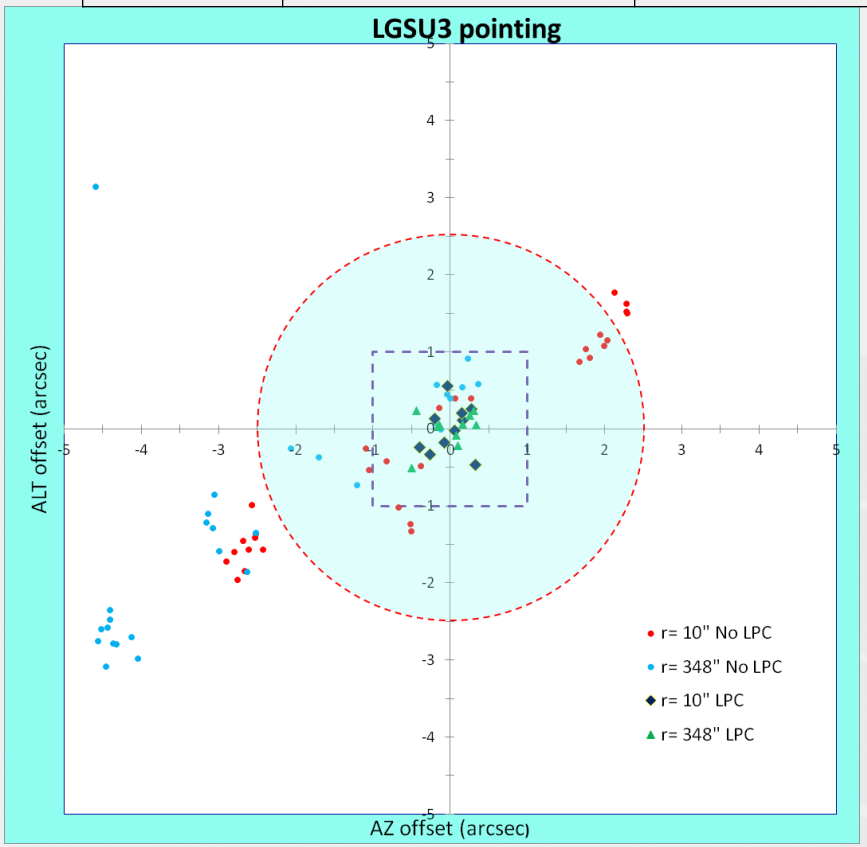


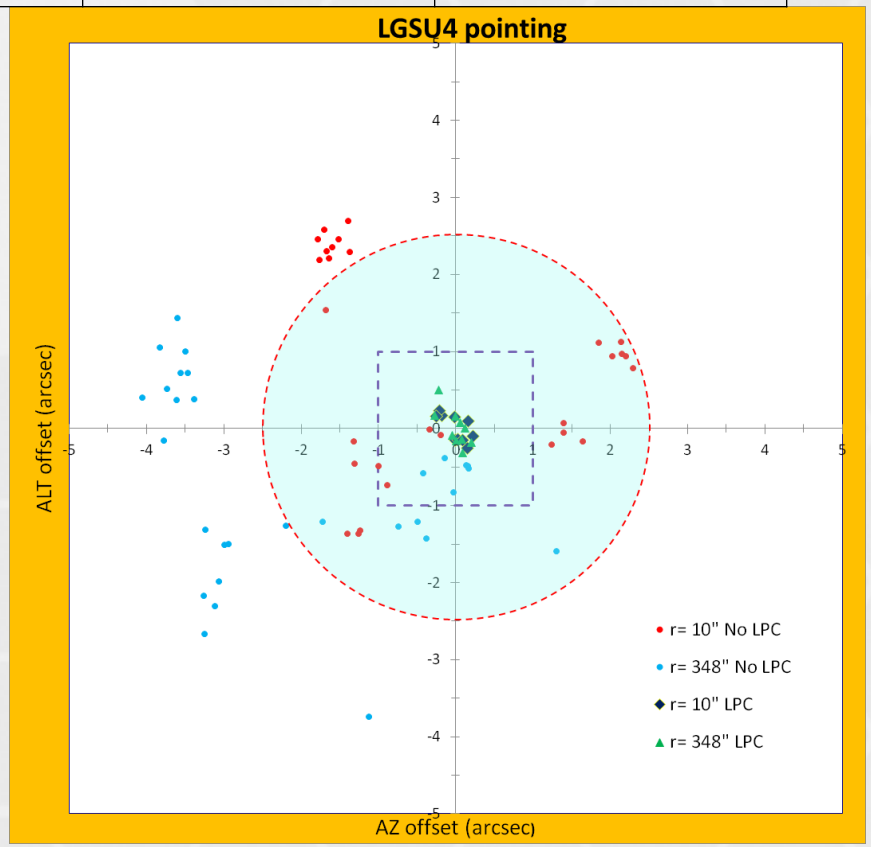


Open Loop Pointing (2)

- Repeatability LPC measurements (rms):

Asterism	LGSU1 rms		LGSU2 rms		LGSU3 rms		LGSU4 rms	
	ALT (")	AZ (")	ALT (")	AZ (")	ALT (")	AZ (")	ALT (")	AZ (")
10"	0.19	0.22	0.26	0.23	0.33	0.25	0.18	0.16
62"	0.28	0.31	0.26	0.32	0.32	0.36	0.13	0.27
348"	0.32	0.22	0.20	0.32	0.24	0.32	0.25	0.16





Open Loop Pointing (3)

- M1 glitches, 4” steps. Offsest the LGSU pointing models. Problem solved with LPC
- Large PM offsets can be created by the M1 glitch during operations. Up to 35”

LGSU1		LGSU2		LGSU3		LGSU4	
ALT (")	AZ (")	ALT (")	AZ (")	ALT (")	AZ (")	ALT (")	AZ (")
5.4	8.7	5.9	7.2	7.4	6.8	4.2	7.3
-24.3	-8.8	-23.2	-9.2	-25.3	-7.7	-22.7	-8.8
-7.6	-6.1	-9.9	-4.4	-11.5	-5.1	-6.7	-4.0

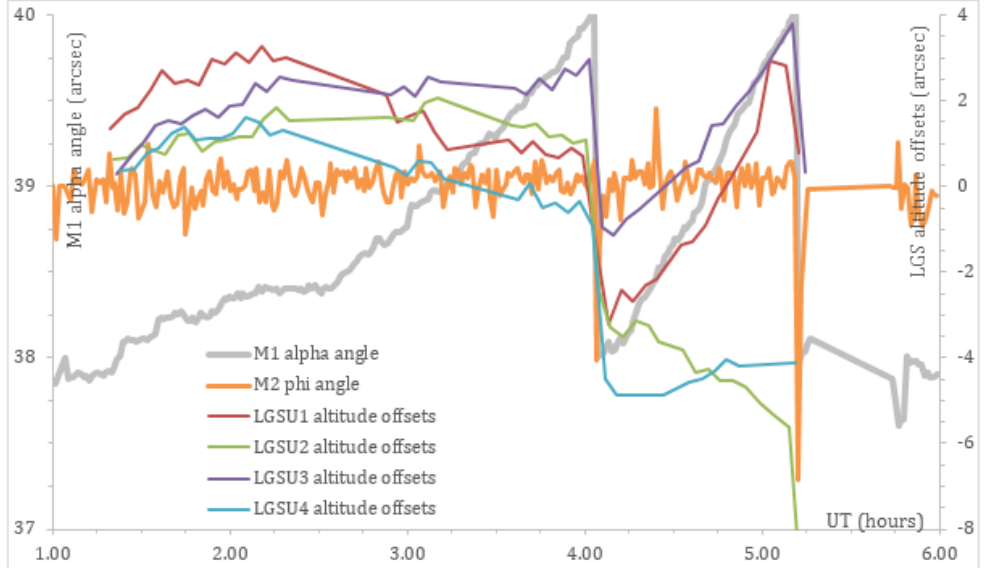
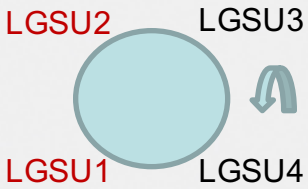
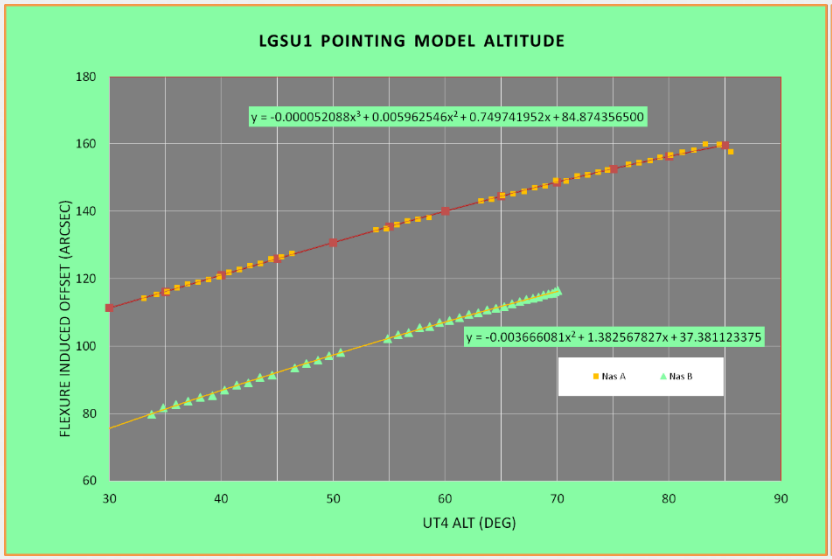
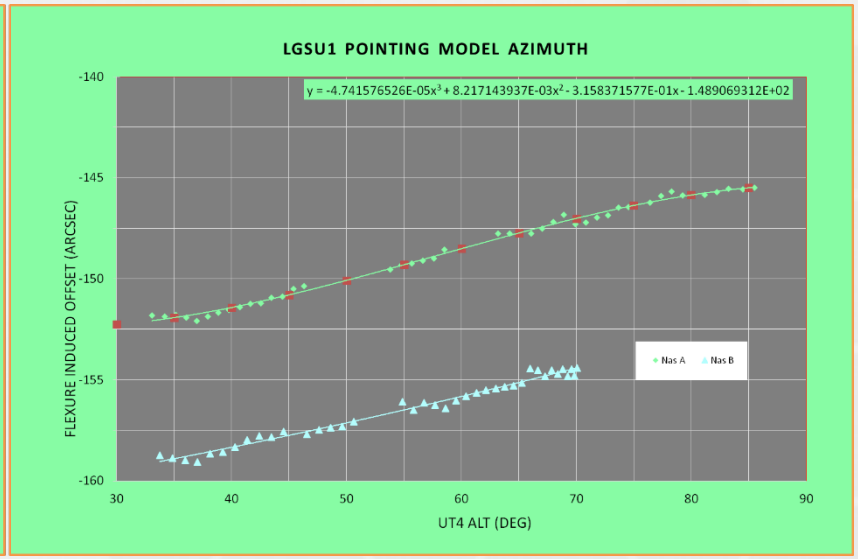


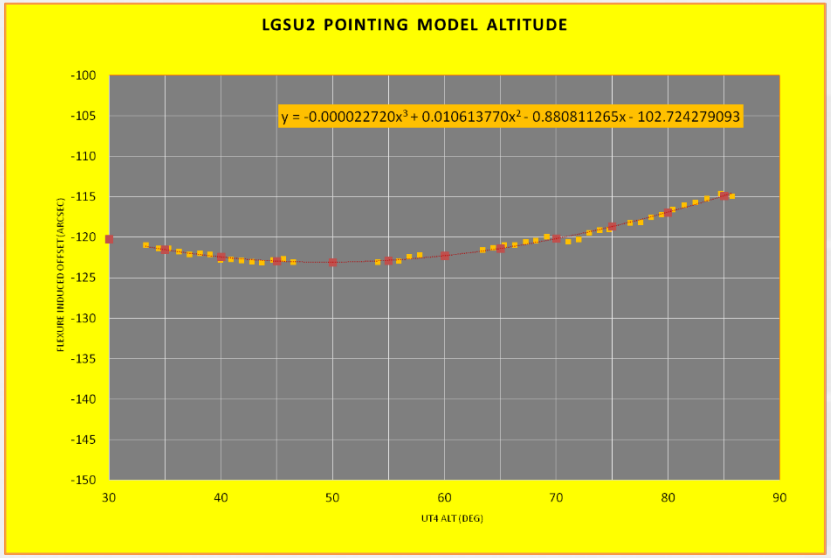
Figure 3: LPC altitude offsets, M1 alpha angle and M2 phi angle vs time – night from April 28th to 29th – M1 alpha angle is associated to the left vertical axis – all other parameters are associated to the right one

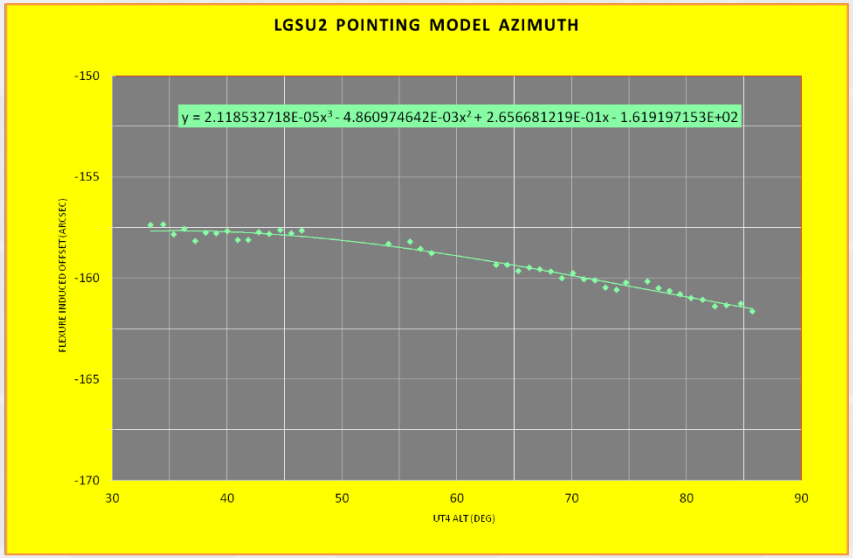
Pointing Models



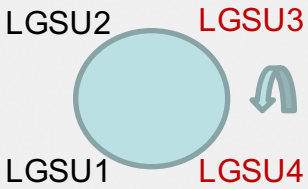


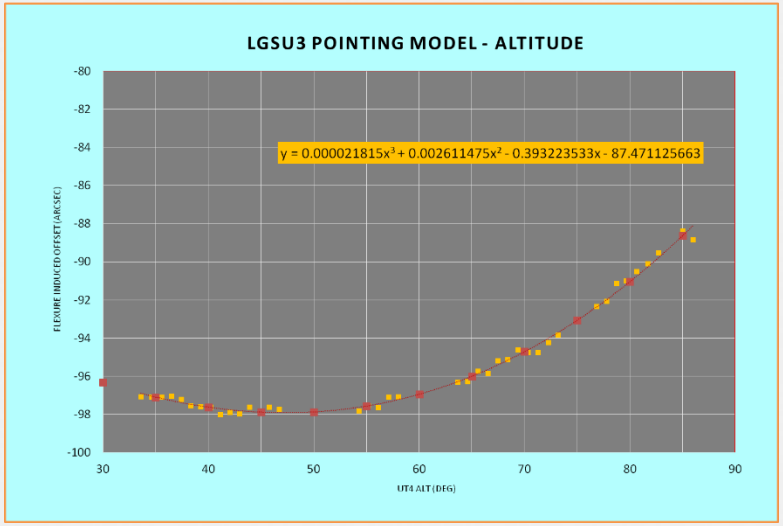


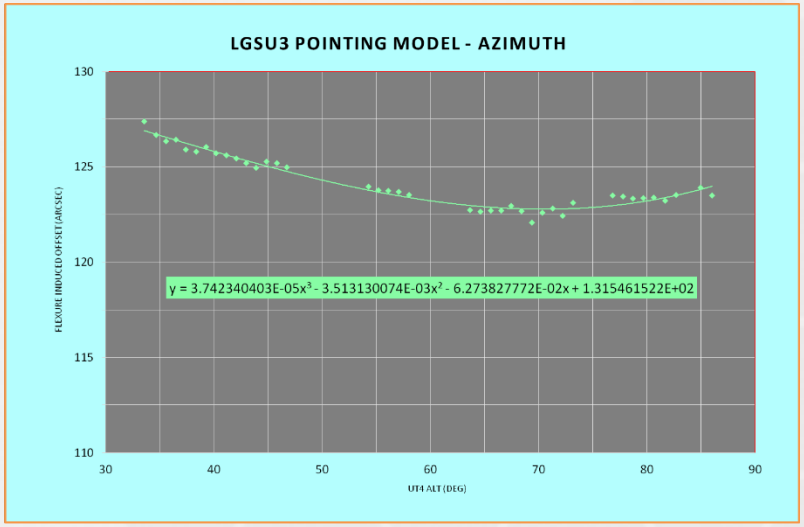


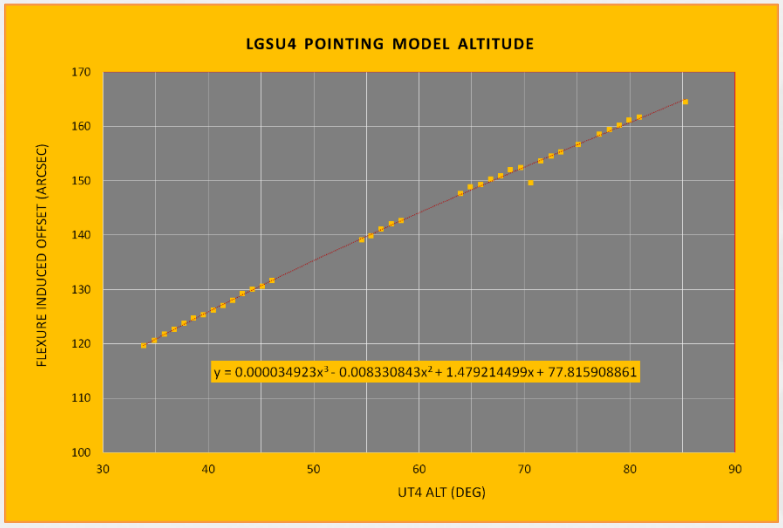


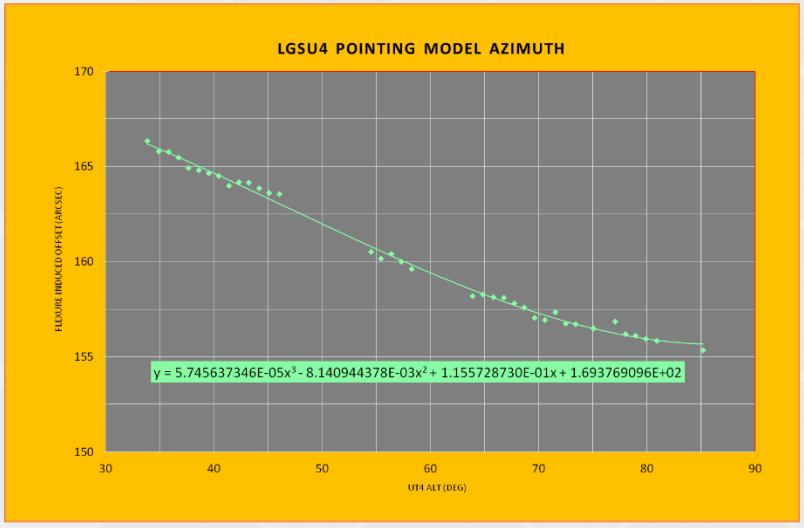
Pointing Models









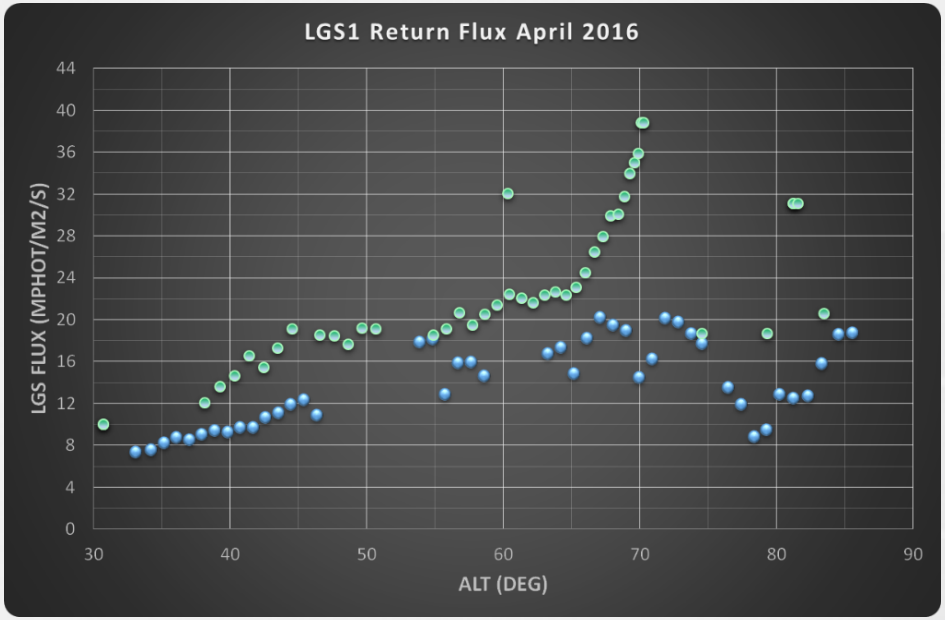


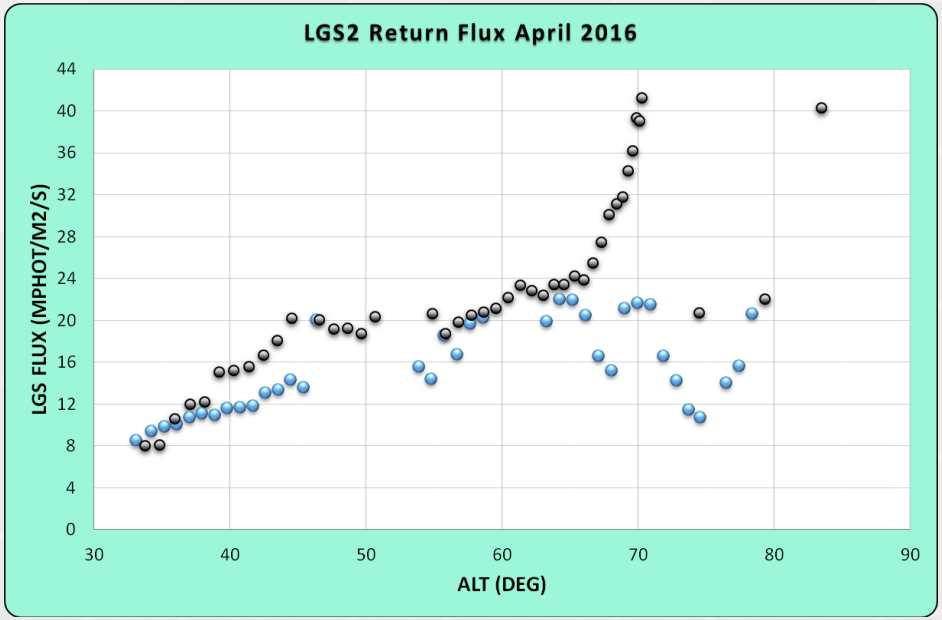
Summary Open Loop Pointing

- With the support of the LPC, open loop pointing is in spec
- We have verified that LPC can operate also at extreme fields (cluster, empty fields, extended objects in the background). Eta-Car exception.
- The pointing models are different between the lower and the upper LGSUs
- Difference between the Nas A and Nas B pointing models (UT4-M3 flexures)
- The UT4-M1 glitches affecting the PM can be overcome by procedures with LPC

LGS Return Flux

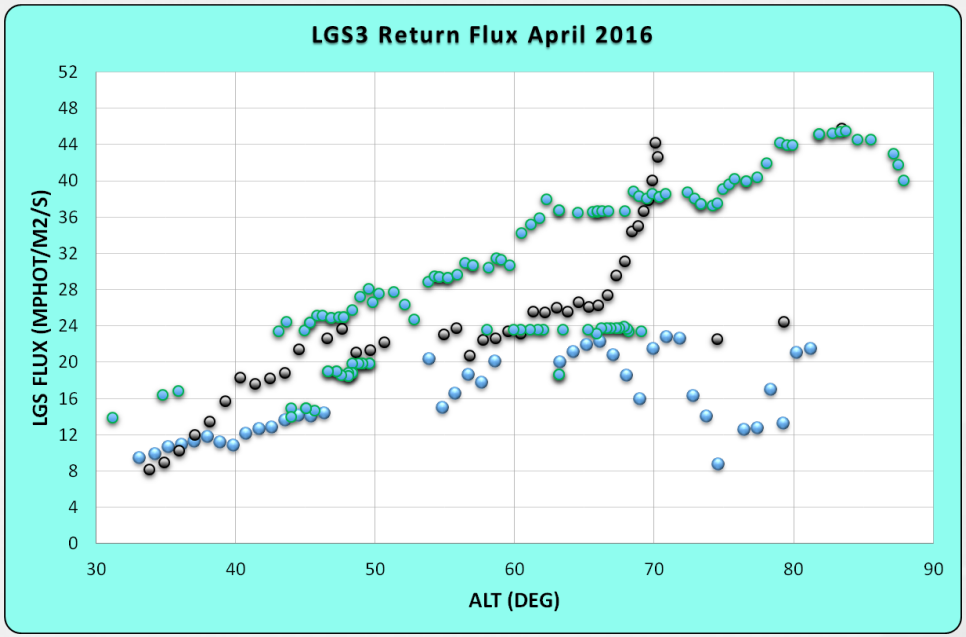
- TLR 7: LGS Return Flux in specification (7.7 Mphot/m2/s at Zenith)
- Always in spec. Sodium abundance has changed a lot during the runs
- Photometry calculation under review, do not expect big changes of the results

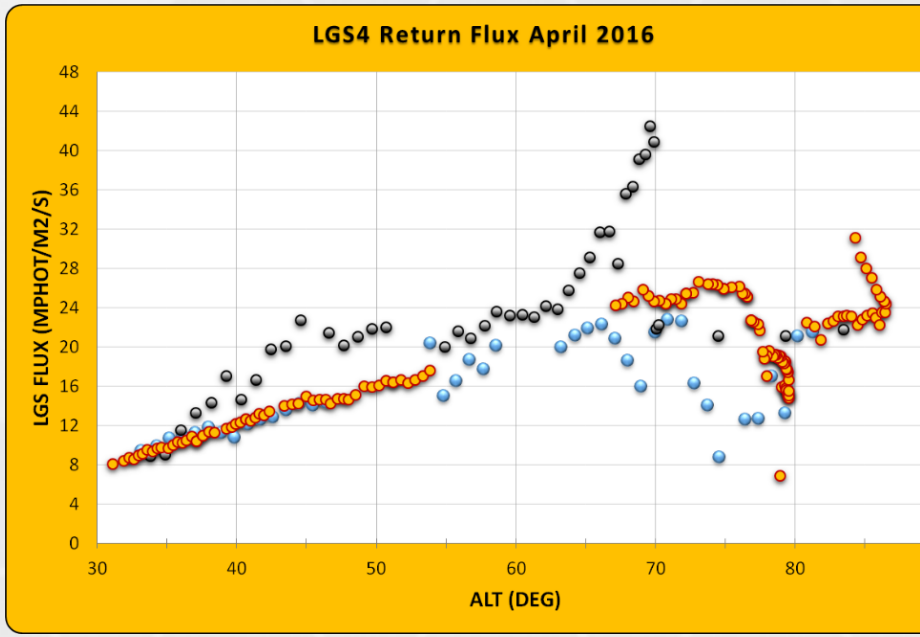




LGS Return Flux (2)

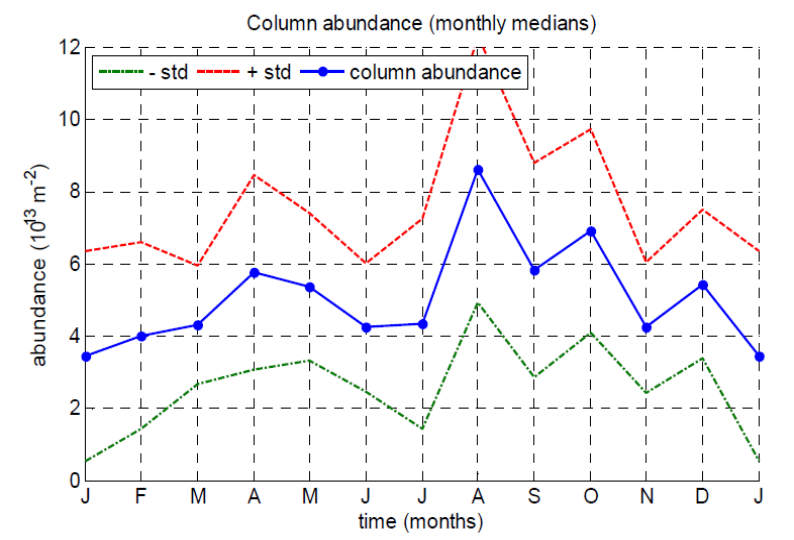
- Data will be placed on polar plots to see also the AZ dependence

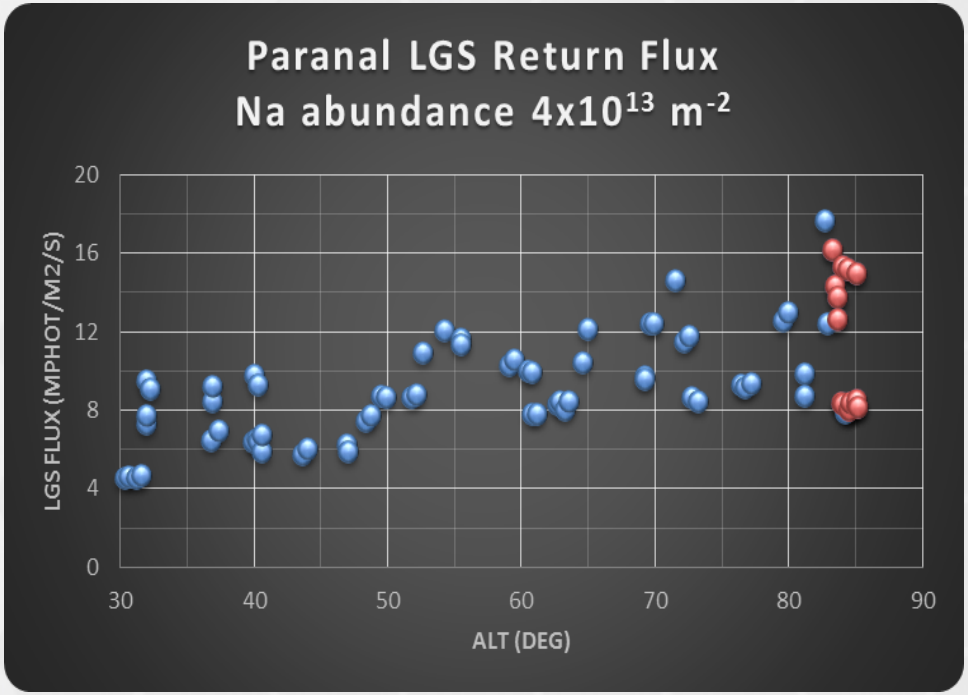




LGS Return Flux normalized to median sodium

- TLR 7: LGS Return Flux > 7.7 Mphot/m2/s at Zenith, and at $4x10^{13}$ m^{-2} sodium column density.
- Seasonal abundance $6x10^{13}$ m^{-2}
- Calculated normalized RF: in spec



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LGS FWHM

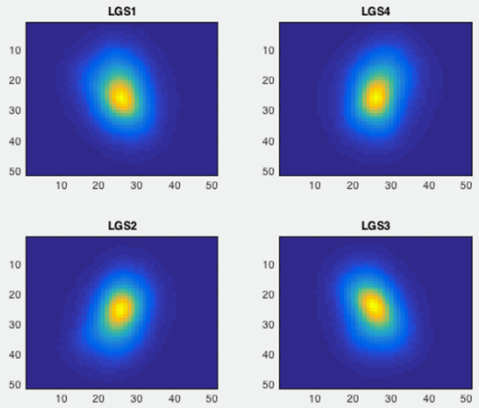
- TLR8 - for seeing 0.6": LGS 1.0" ; for 1" seeing, LGS fwhm = 1.35

ALT	LGSU1				
	LGS		NGS	Ratio	Mesosphere
	fwhm S	fwhm L	fwhm	lgs/ngs fwhm	spot size
83	**0.94**	**1.54**	**0.59**	1.59	0.67
79	1.09	1.65	0.60	1.82	0.77
73	1.21	1.94	0.48	2.53	0.86
68	1.13	1.68	0.66	1.70	0.80
51	1.11	1.47	0.76	1.47	0.79
38	1.21	1.50	0.61	1.96	0.85

	LGSU2				
	LGS		NGS	Ratio	Mesosphere
	fwhm S	fwhm L	fwhm	lgs/ngs fwhm	spot size
	0.85	**1.48**	**0.59**	1.45	0.60
	1.07	1.57	0.47	2.26	0.75
	0.98	1.50	0.46	2.15	0.70
	0.96	1.47	0.51	1.87	0.68
	1.06	1.46	0.54	1.97	0.75
	0.93	1.28	0.65	1.44	0.66

ALT	LGSU3				
	LGS		NGS	Ratio	Mesosphere
	fwhm S	fwhm L	fwhm	lgs/ngs fwhm	spot size
83	**0.97**	**1.54**	**0.38**	2.51	0.68
79	0.96	1.53	0.46	2.09	0.68
73	0.93	1.53	0.48	1.93	0.66
68	1.06	1.48	0.42	2.50	0.75
51	0.90	1.29	0.47	1.92	0.64
38	1.01	1.43	0.53	1.92	0.72

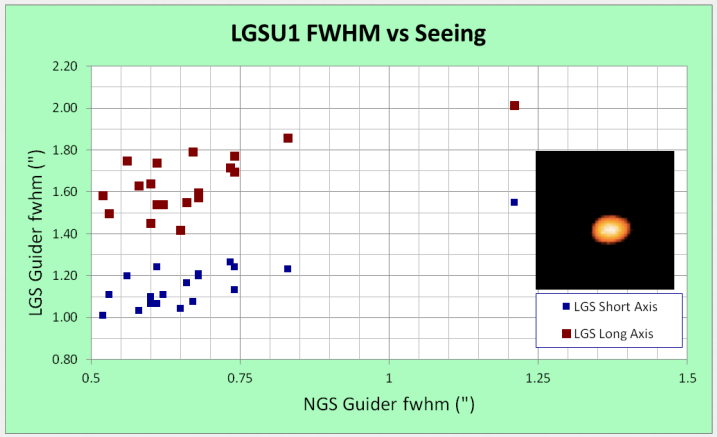
	LGSU4				
	LGS		NGS	Ratio	Mesosphere
	fwhm S	fwhm L	fwhm	lgs/ngs fwhm	spot size
	0.94	**1.57**	**0.38**	2.46	0.67
	1.20	1.59	0.58	2.07	0.85
	1.10	1.53	0.48	2.29	0.78
	0.95	1.45	0.42	2.25	0.67
	0.85	1.38	0.53	1.60	0.60
	1.04	1.39	0.45	2.31	0.73

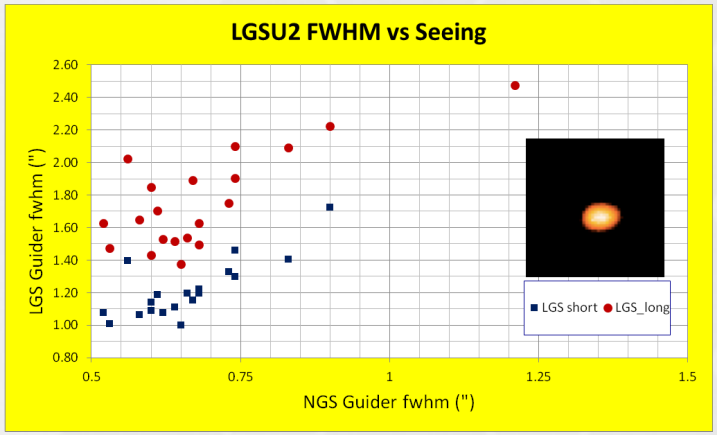


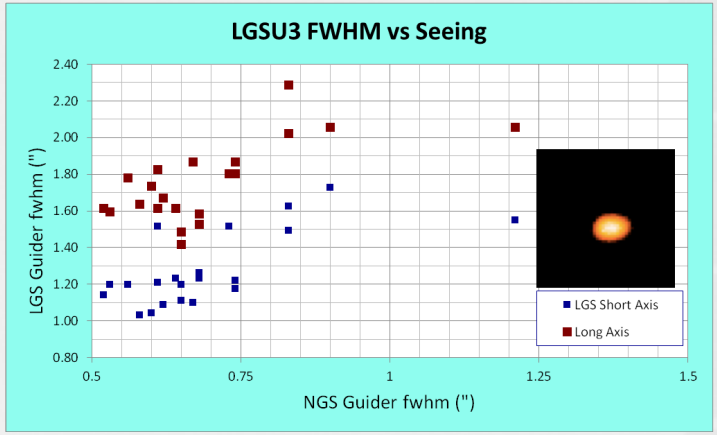
- LGS focus optimized on guider
- 10 measurements averaged
- NGS and LGS exposure time 0.2s
- OK, in spec. Matches Ron's simulations

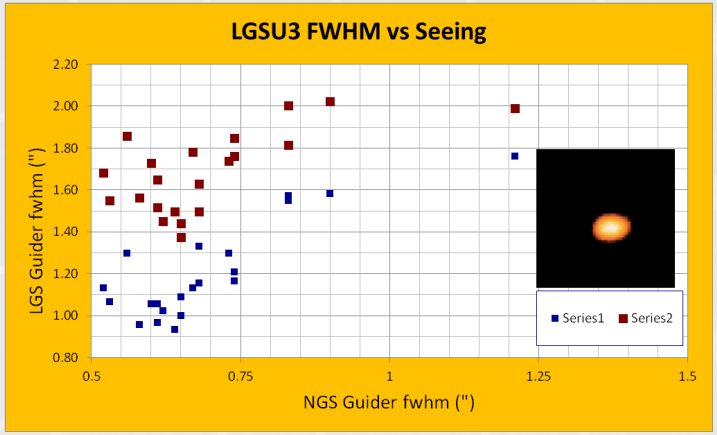
LGS FWHM

		fwhmx (px)	fwhmy (px)	fwhmx (")	fwhmy (")	NGS fwhm (")	BEU	ALT	AZ
SPEC POSITION	LGS1	13.7	8.8	1.507	**0.968**		-5194		
with TCS	LGS2	15.1	9.5	1.661	**1.045**	**0.57**	66313	ALT 63	AZ 154
Optimization	LGS3	14.6	9.8	1.606	**1.078**		34300		
	LGS4	15.1	10	1.661	**1.1**		41459		









Status at end of Standalone Commissioning

Ref.: Commissioning Plan ESO-253748 + Previous Run Summary ESO-286870 + Action Items ESO-286853 + Logbook ESO-286852

Performed 2 runs, 12 full commissioning nights, further 6 nights lost due to bad weather, part of 2 nights used for stray light tests - remainder given back to SciOps

Task #	Title	Result
4LC_0400	Calibration/Verification of Pointing Models	Passed.
4LC_0500	Verification of Tracking	Test with updated VLT SW pending (Dec)
4LC_0600	Calibration and Verification of LPC	Passed.
4LC_0700	Open Loop Pointing Accuracy	Passed.
4LC_0800	Validation of Focus Control	Passed.
4LC_0900	Verification of LGS spot size	Passed.
4LC_1000	Verification of LGS brightness	Passed.
4LC_1100	Operation Sequence Verification	Passed. Improvements to be implemented in AO acquisition template
4LC_1200	Documentation of Results	Ongoing
-	Straylight on MUSE, VST	MUSE finds Raman lines. Test with VST pending

Muchas Gracias! - Thank you!