Validation of the YLARA Station
Current status and future upgrades

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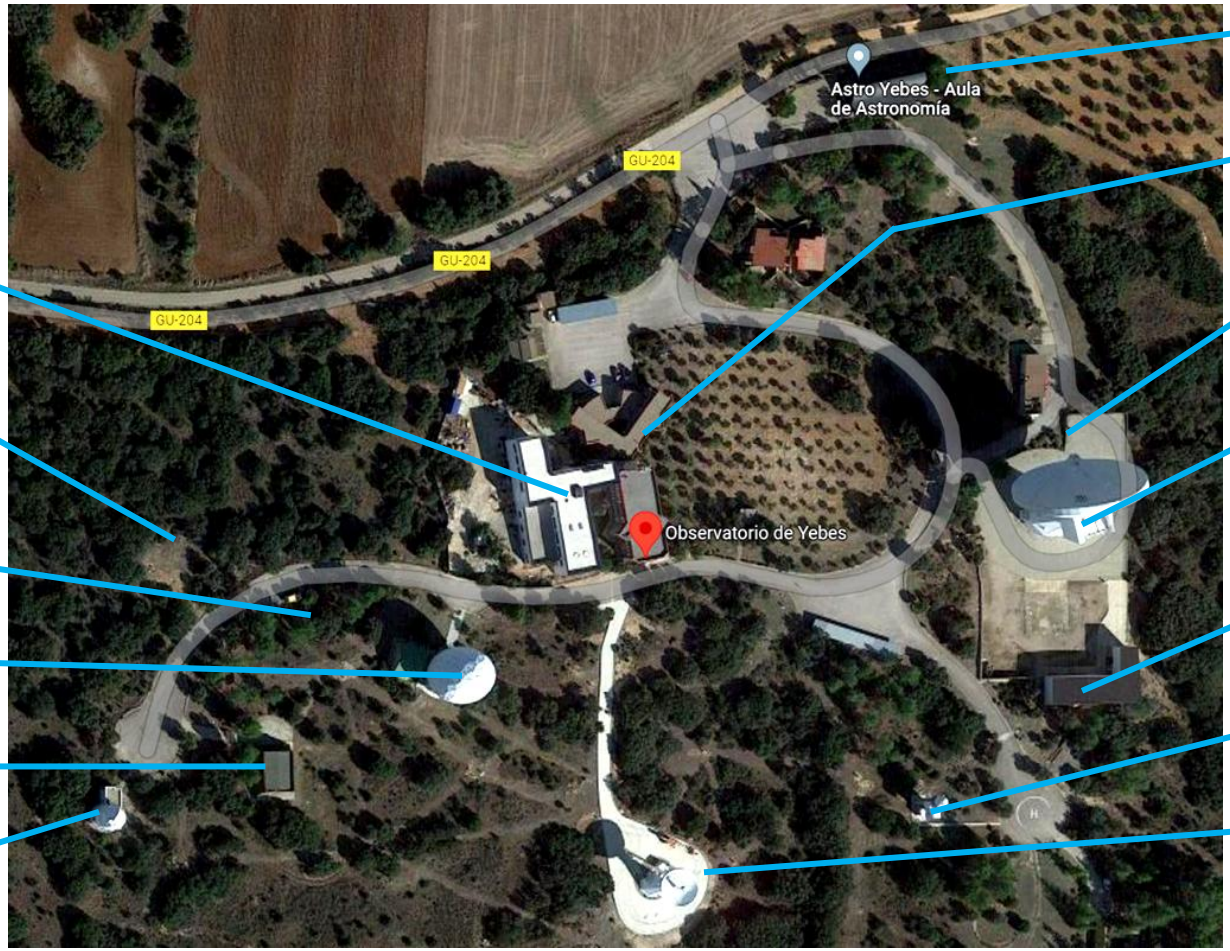
Yebes Observatory (IGN/CNIG), Guadalajara-Spain

23rd International Workshop on Laser Ranging, Kunming-China

21-10-2024

Yebes as a GGOS Core Site



Office buildings, laboratories and workshops

Yebes Laser Ranging (YLARA)

Meteo sensors

14 m RT

Gravimetry

Astrograph (2x40 cm)

Outreach pavilion

GNSS Receivers (x3)

Local tie (20 pillars) +2/3 more for SLR

40 m Radio Telescope + Hydrogen masers room

Anechoic Chamber

Solar Tower

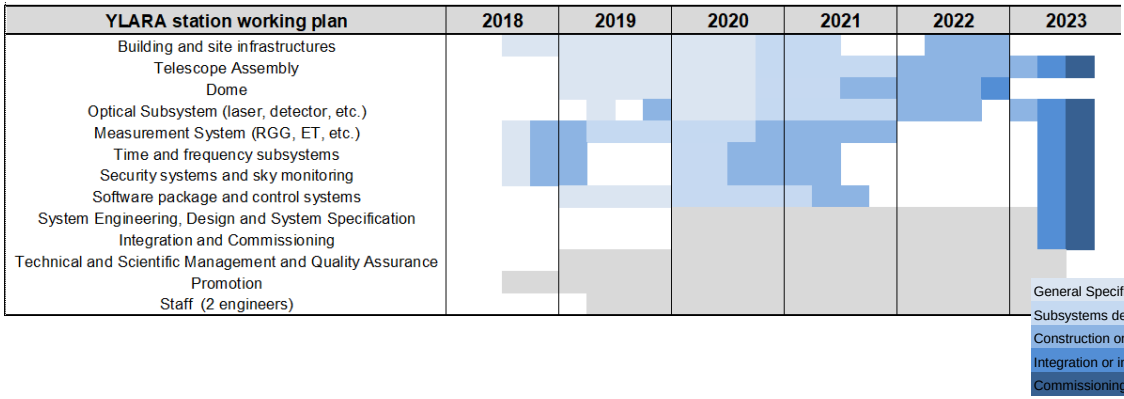
13.2 m VGOS Radio Telescope (2013) RAEGE Project

Project Development - Main Milestones

Telescope assembly installation: cable wrap, mount and receiver telescope (from left to right)

- ERDF for YDALGO Operation approval → January 2018
- General specifications definition → 2018-2019
- Turnkey contract TTI/Digos, Kick off → October 2020
- Subsystems design and construction → 2021-2022
- Building construction and dome installation → Autumn 2022
- Subsystems installation and integration on site → Spring 2023
- Commissioning → July - October 2023
- **Quarantine Procedure → Observations April - August 2024,**
  → Released 08 - October - 2024

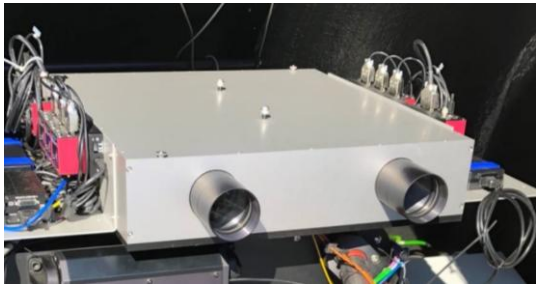
YLARA Building Overview

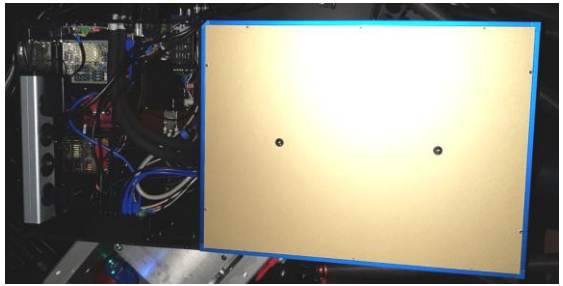


System Features Overview

Customized RC700 model by Officina Stellare

- M1 diameter: 700 mm
- 3 Nasmyth foci
- Operation rotation range on azimuth: -270º/+270º
- Atl-Azimuth Mount. Slew rate: 12°/s for Az and El
- Transmission path: Coudé path + beam expander





Laser and Detector packages. Subsystem designed and integrated by IWF-Graz

Telescope Assembly Overview (Officina Stellare)

Piggy-back configuration

- Laser package mounted directly on top of the main mirror cell
- Detector package mounted directly on the first Nasmyth focus

Coudé Focus

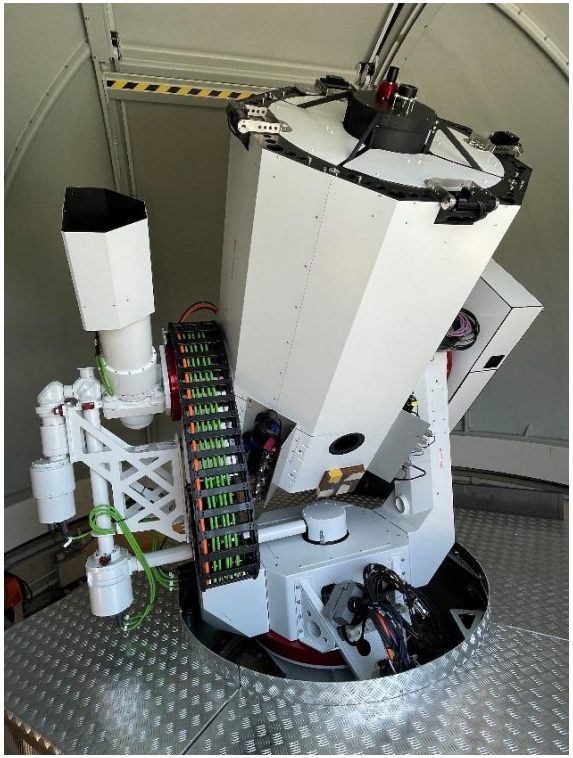
- Laser installation in a conditioned room, transmitting the pulses through the Coudé path

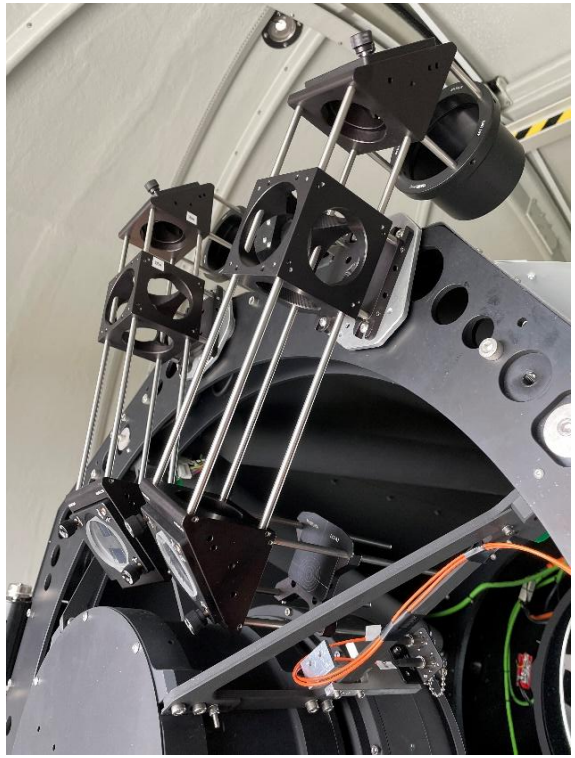
Model	Compiler Compact Passat
Pulse Repetition rate	1000 Hz (adjustable)
Energy per pulse	355 µJ avg @ 532 nm 543 µJ avg @ 1064 nm
Pulse width	7 ps @ 532 nm 8,5 ps @ 1064 nm

Detector	λ	Diameter	QE @ λ
C-SPAD	532 nm	200 µm	> 40 %
IR-SPAD	1064 nm	80 µm	max 30 %

System Features Overview

Coudé path transmitting telescope, receiving telescope, detector package and laser package



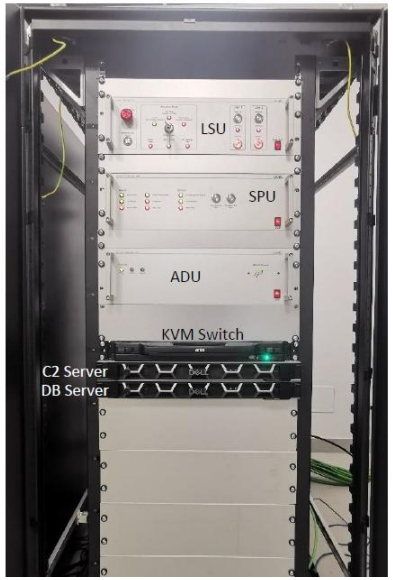


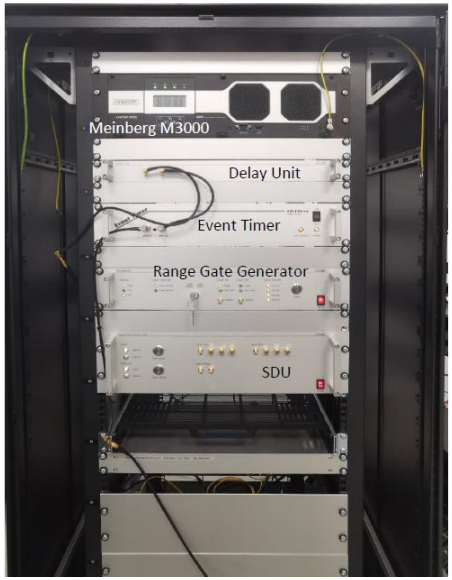
Fiber calibration
+ mountable external target

System Features Overview

Baader dome

- 5,3 m diameter
- Slit-type: horizontal lower flap and shutter + solar shield protection
- Installed October 27th, 2022





Racks installed in the Coudé room

Rack 1

- Laser Safety Unit, SLU
- Station Protection Unit, SPU
- Aircraft Detection Unit (ADU)
- Command & Control (C2) & Database (DB) Servers

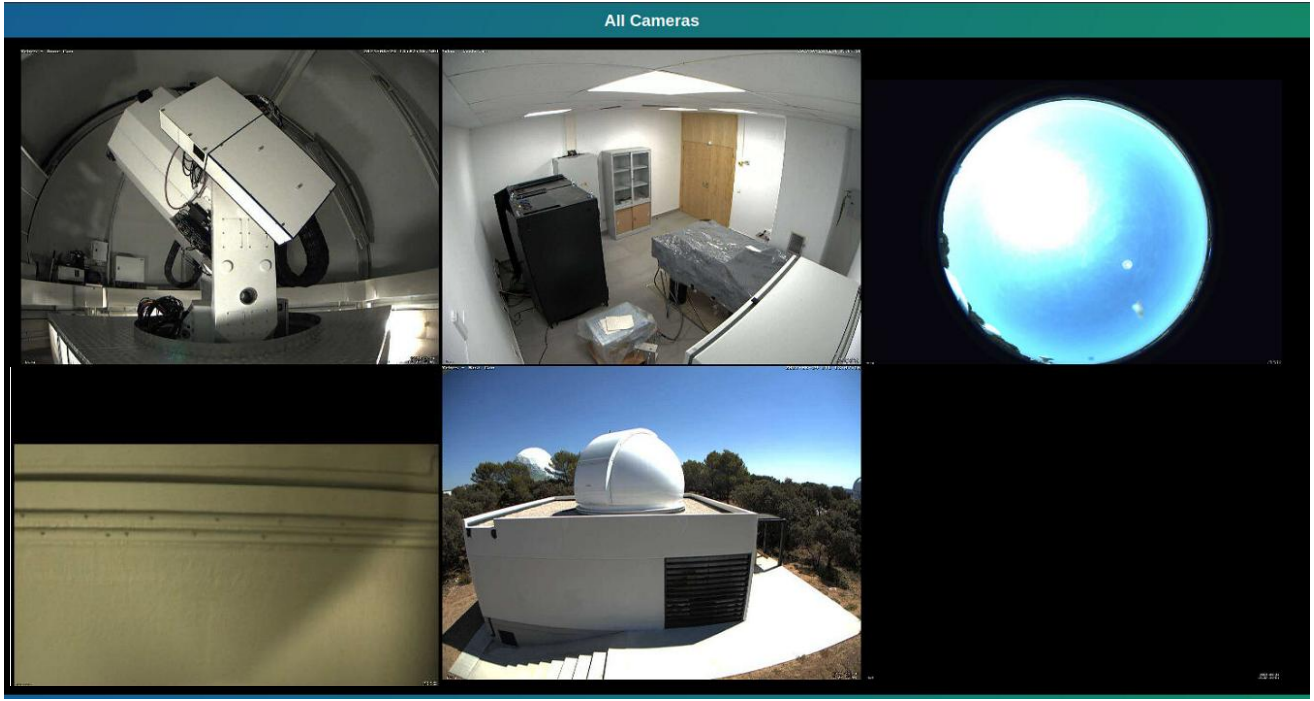
Rack 2

- Lantime M3000 + Timing Antenna
- Riga Event timer A033-ET/USB
- Range Gate Generator, RGG
- Signal Distribution Unit, SDU

System Features Overview

Meteorological mast + Laser Safety Subsystems (aircraft safety)

- Temperature, humidity and pressure sensors, rain sensor ON/OFF, cloud and wind speed sensor
- ADS-B and FLARM receivers, OMEA 8C all sky camera

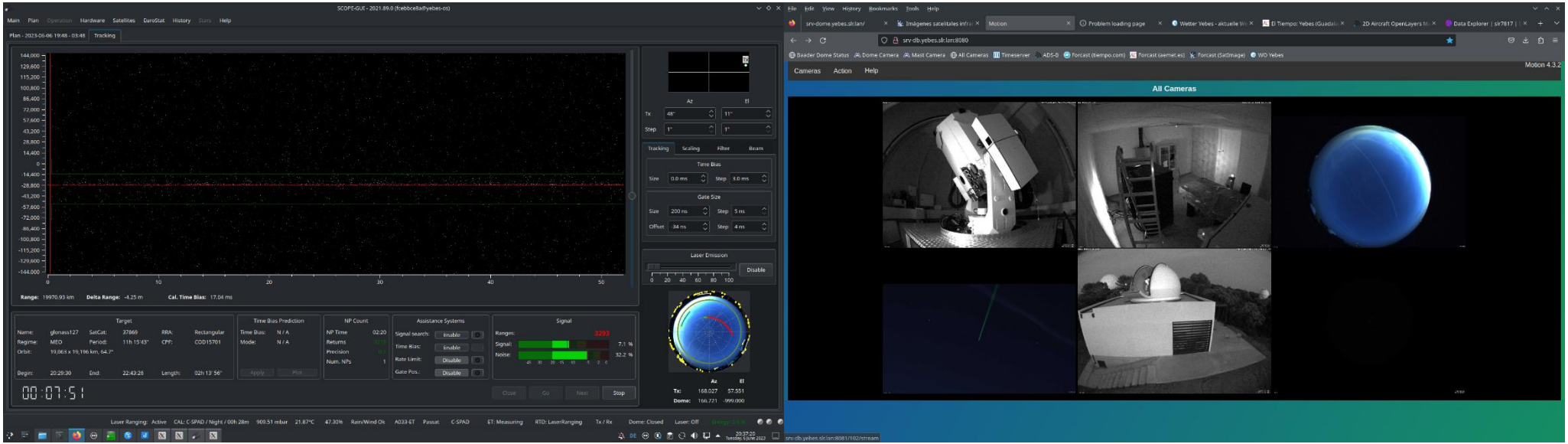


Monitoring of relevant parts (Dome + Telescope, Coudé room, Allsky, Laser Beam, Station, Satellite Camera)

System Features Overview

SCOPE - Centralized complete station operation, control, monitoring, data analysis and processing

- All items integrated via a modular platform with intuitive and modern IFs (SCOPE GUI, Motion, Grafana, …)
- The full station can be controlled completely via one PC and even just one screen, both locally or remotely
- Is running in Potsdam, Tenerife, Tsukuba, Matera and Yebes



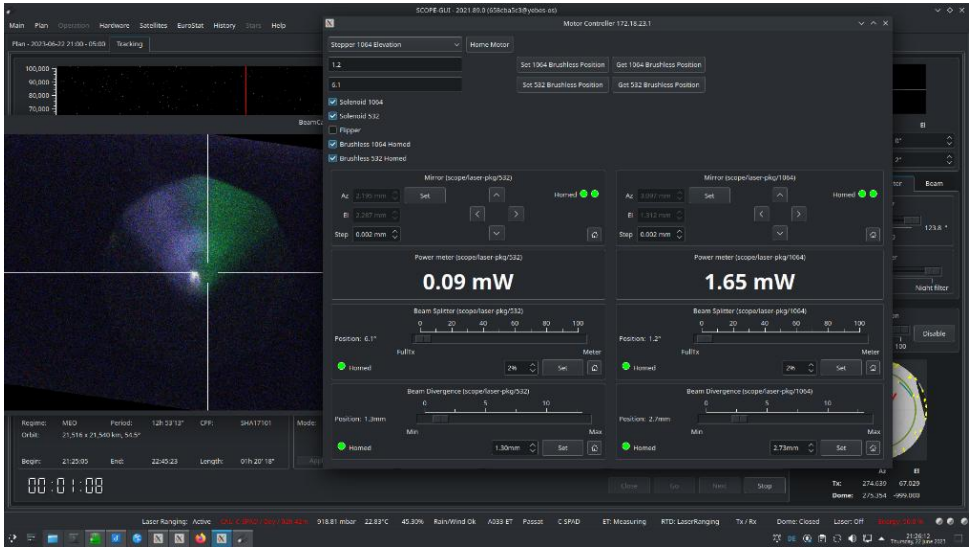
Satellite tracking in SCOPE GUI with surveillance camera IF in browser (Developed by DIGOS)

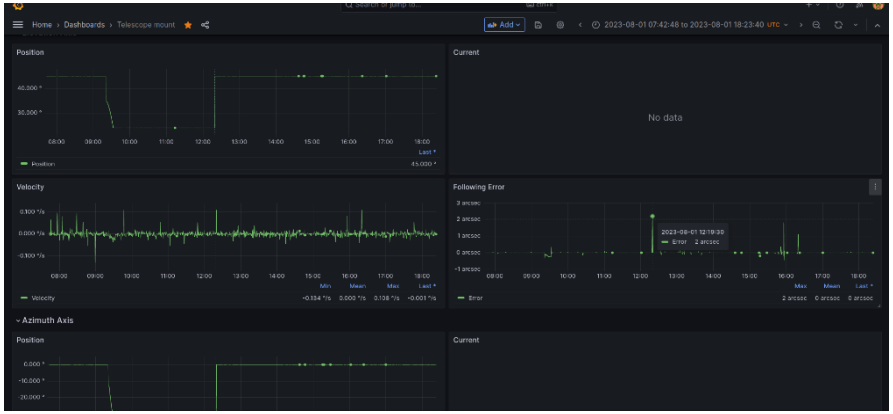
System Features Overview

End to end fully integrated SW and HW solutions

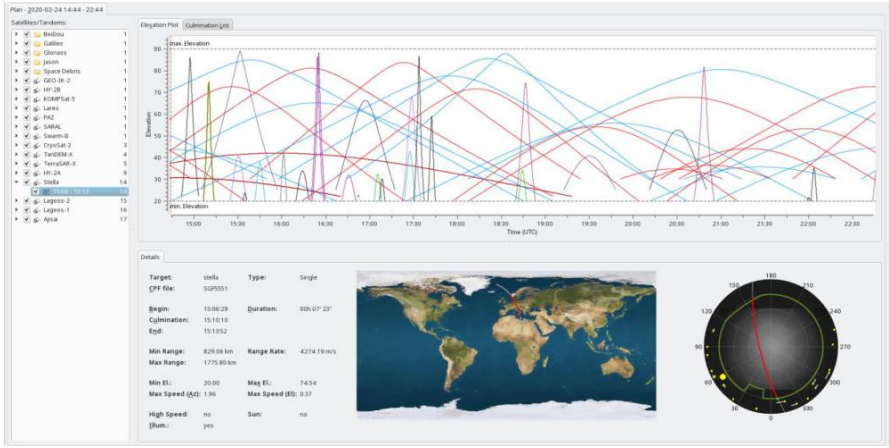
- Complete configuration, adjustment, alignment, surveillance as well as monitoring possible

Laser and alignment control IFs and camera showing the 532 nm and 1064 nm laser beam as well as the satellite



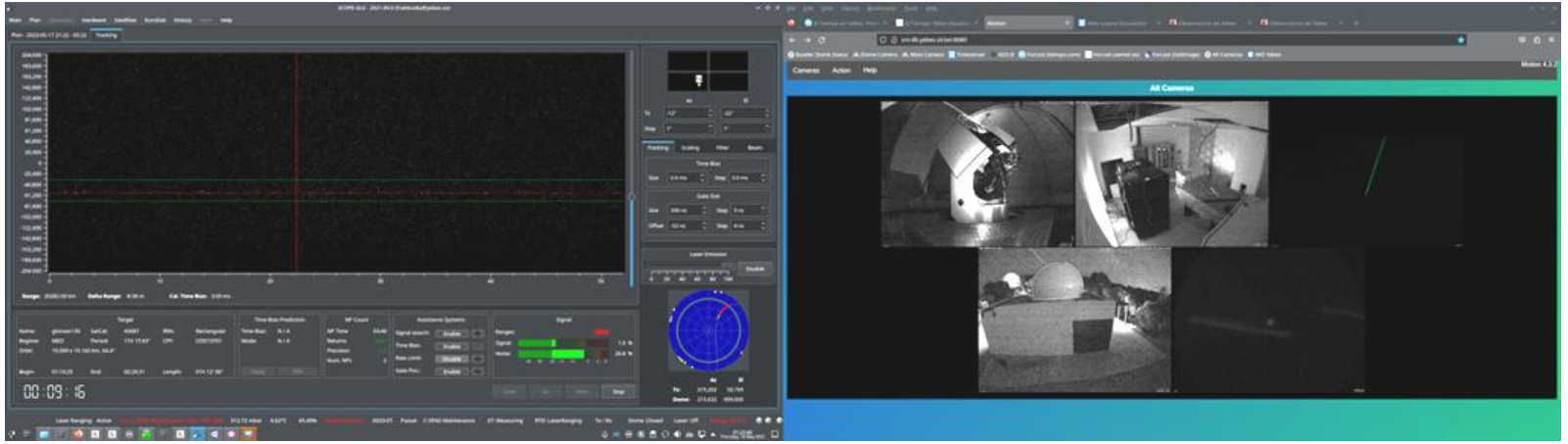


Monitoring database and visualization IF

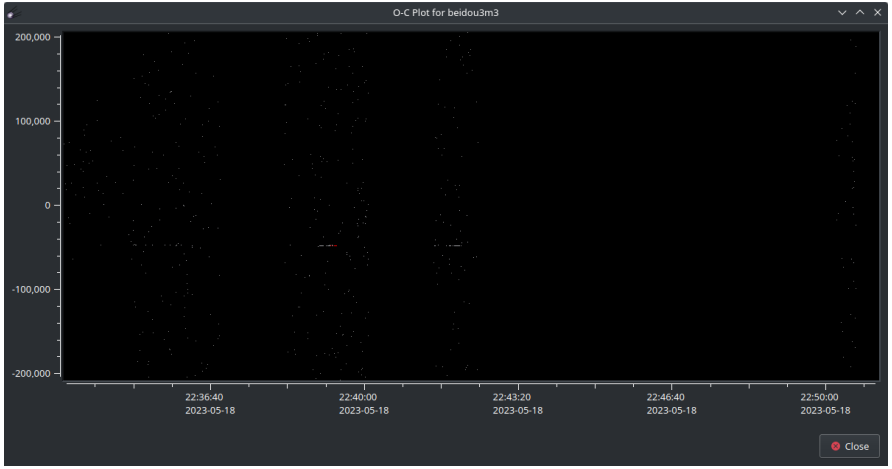


SCOPE screenshot, visible passes for 8 hours

May 18th, 2023 → First SLR Observation



532 nm: GLO139 2023-05-18, 00:24 UTC

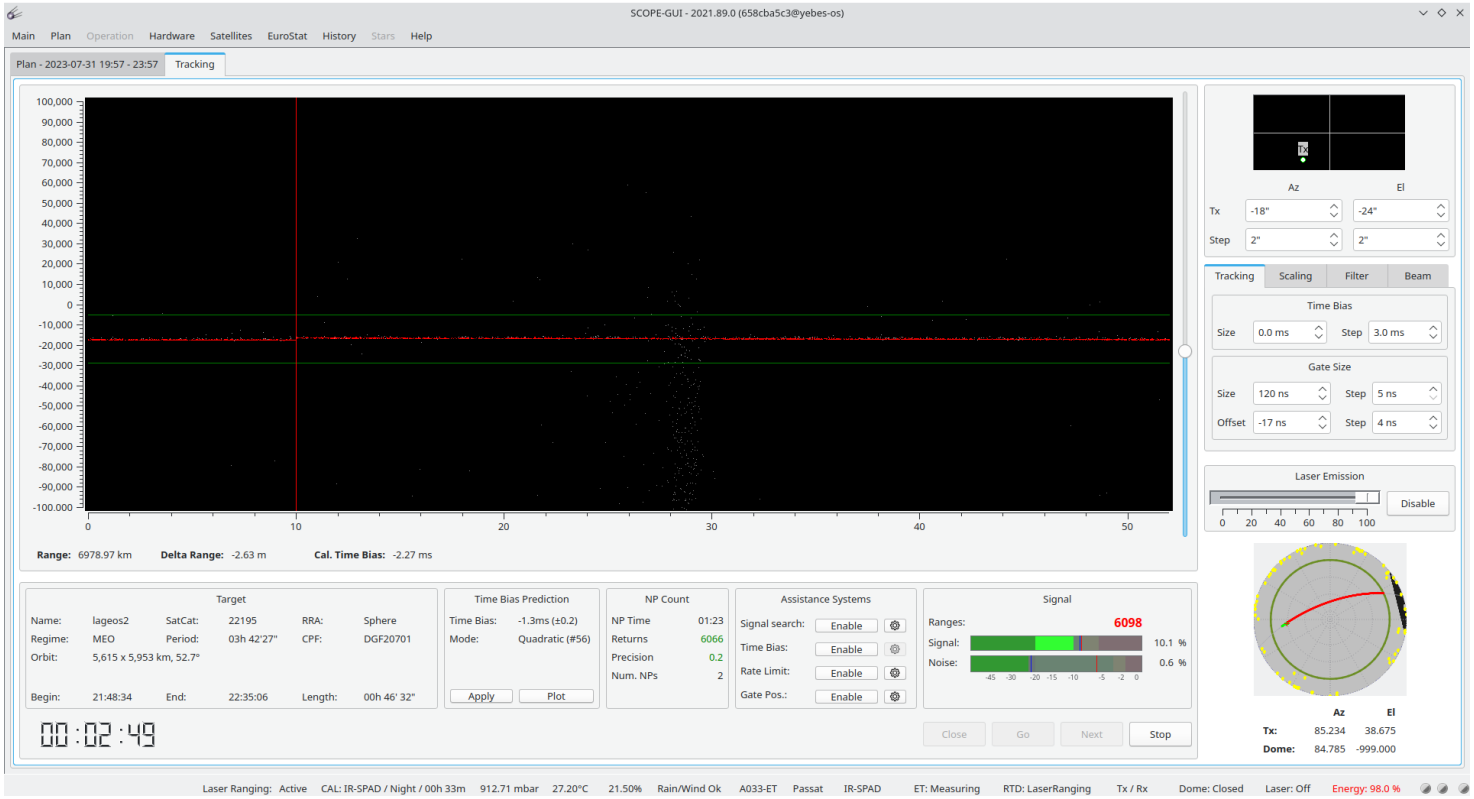


1064 nm: Beidou 3M3
18-05-2023, 22:30 UTC
(short pass due to weather)

Observation example

Lageos 2 in 1064 nm from 31-07-2023 21:50 UTC

- 6066 FR returns in 83s formed into 1 NP at return rate of 10% instantaneous and 7% average at 38° elevation

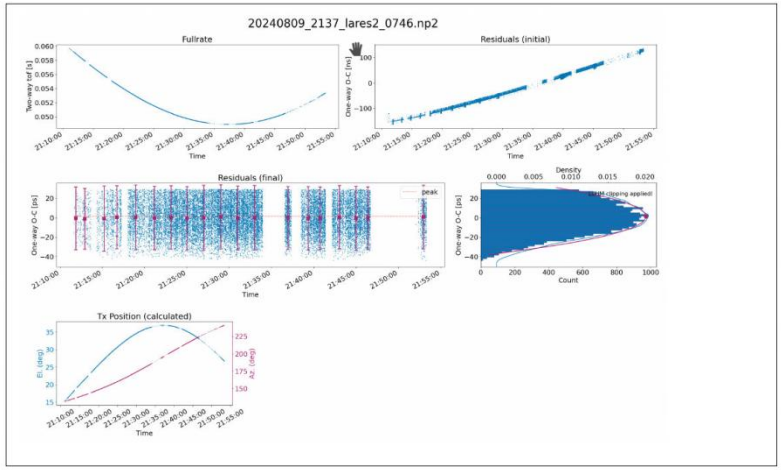


Satellite tracking IF in DiGOS SCOPE SW

Automatic Processing Examples

LARES-2 in 1064 nm from 09-08-24 21:37 UTC

- 25295 FR returns with a 4,9 mm RMS formed into 19 NPs with 0,19 mm Stderr



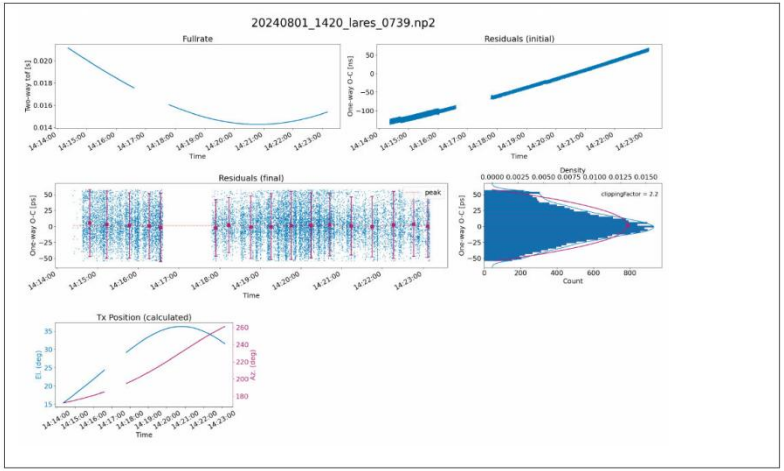
TARGET	
lares2	
WAVELENGTH (nm)	
1064.0	

EVALUATION	
Total Returns	59109
FR Obs.	25295
Num. NPTs	19
Obs. per NP	1331
SigRate (%)	1.11
Stderr (mm)	0.19
RMS (mm)	4.90
RMS w/o cal	-1.55
Baseline RMS	3.08
Baseline STD	1.04
TB (ms)	-0.84
RB (m)	-2.90

METEO	
Temp. (°C)	29.0
Hum. (%)	21.2
Press. (mbar)	915.4

LARES in 1064 nm from 01-08-24 14:20 UTC

- 20251 FR returns with a 7,49 mm RMS formed into 17 NPs with 0,24 mm Stderr



TARGET	
lares	
WAVELENGTH (nm)	
1064.0	

EVALUATION	
Total Returns	53401
FR Obs.	20251
Num. NPTs	17
Obs. per NP	1191
SigRate (%)	3.97
Stderr (mm)	0.24
RMS (mm)	7.49
RMS w/o cal	1.49
Baseline RMS	4.06
Baseline STD	3.71
TB (ms)	-0.07
RB (m)	-3.78

METEO	
Temp. (°C)	35.0
Hum. (%)	11.7
Press. (mbar)	910.9

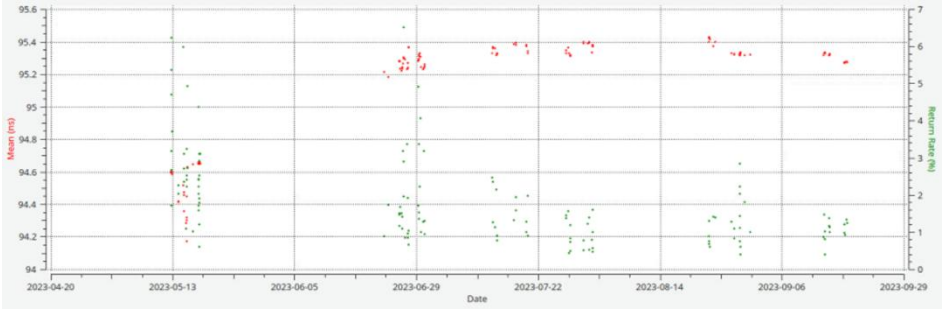
NPs formed with automatic DiGOS NPgo module

Station Commissioning and First Performance Analysis

λ	LEO	Lageos	Etalon	GNSS	IRNSS	Total
0532	9	12	4	23	0	48
1064	11	21	3	9	2	46
Both	20	33	7	32	2	**94**

Number of passes collected from 18-05-2023 until 31-07-2023 (Digos)

1064 nm calibration history during Commissioning

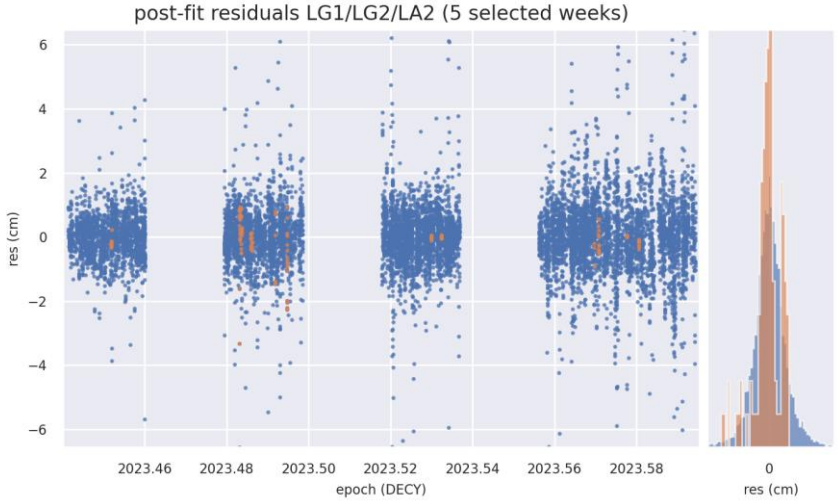


Calibration statistics

- Calibration history was stable
- 532 nm calibration RMS = ~ 25 ps
- 1064 nm calibration RMS = ~ 21 ps

Lageos-1/2 , Lares-1/2 data statistics for 23 of the 33 collected passes, on average

- FR data RMS = 5.79 mm
- NP data RMS = 0.26 mm



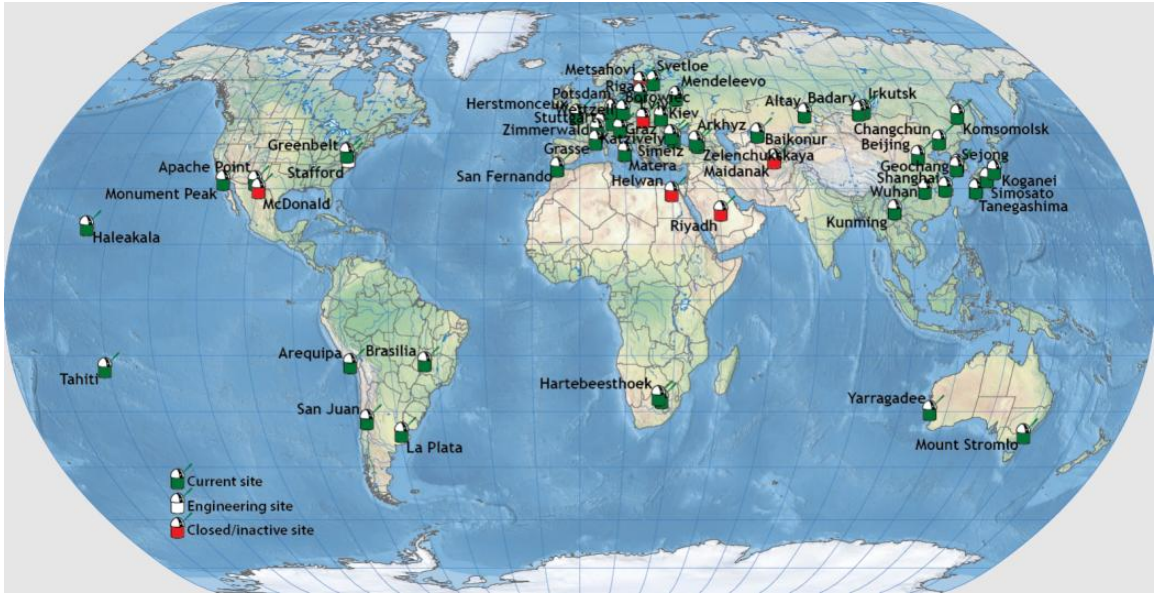
Quality of observations assessed with geodetic solutions

- **Yebes NPs to LAGEOS-1/2, Etalon-1/2, and LARES-2 included in global solutions**
- **5 weeks available**
- **Setup similar to ILRS ASC**

Quarantine - Facing the Challenge

ILRS Station Quarantine Procedure

- Notify to ILRS CB
- Station Site Log establishment
- sFTP account for uploading data to the EDC
- **Validation criteria: observations to a min. of 20 acceptable passes on each satellite (LAGEOS-1 and -2 and LARES-1 and -2) within a 60-day sliding window**
- To be an ILRS core site: standard deviation in the Normal Points to the mentioned satellites under 10 mm in standard deviation; minimize any systematic errors and their variability, such as range biases



To be included as Active Station in the ILRS network

Yebes, Spain (7817)

Common information

Station-ID:	7817
Site	Yebes, Spain
Code:	YEBL
Datacenter:	EDC
Longitude:	3.0905 W¹
Latitude:	40.5245 N¹

Status of the latest SOD

SOD	Start Date	End Date	Active
78176201	2024-10-08	active	Validated
78176201	1970-01-01	2024-10-08	Quarantine (released)

https://edc.dgfi.tum.de/en/stations/7817/

Quarantine - Facing the Challenge

SEMANA DEL 12 AL 18 DE AGOSTO

Adolfo
Álvaro
Bea

Fecha	Hora INICIO	FIN	ELEV	Satélite	Tiempo / Operador / Notas
2024 Aug 12	06:07:34	07:04:19	65.6	LAGEOS 2	1 hora
2024 Aug 12	06:14:49	06:20:34	23.4	LARES	
2024 Aug 12	10:17:59	11:13:28	82.0	LAGEOS 2	3 horas TODOS LOS PASES
2024 Aug 12	11:09:05	11:56:24	68.2	LAGEOS 1	
2024 Aug 12	12:19:14	12:29:47	36.8	LARES	
2024 Aug 12	12:33:35	13:06:30	31.6	LARES-2	
2024 Aug 12	20:34:14	21:17:24	35.6	LARES-2	2 horas
2024 Aug 12	21:25:46	22:13:19	83.5	LAGEOS 1	
Tareas: alineamiento, modelo de puntería					
2024 Aug 13	08:21:19	09:18:09	74.4	LAGEOS 2	2 horas, pases sueltos
2024 Aug 13	09:48:54	10:28:43	40.9	LAGEOS 1	
2024 Aug 13	12:29:01	13:13:59	44.5	LAGEOS 2	3 horas TODOS LOS PASES
2024 Aug 13	13:12:09	13:25:16	77.4	LARES	
2024 Aug 13	13:20:03	14:05:20	66.2	LAGEOS 1	
2024 Aug 13	14:42:35	15:35:21	79.5	LARES-2	
2024 Aug 13	15:13:04	15:18:06	22.8	LARES	

Optimized schedule focus on the 4 main satellites

The two color dilemma

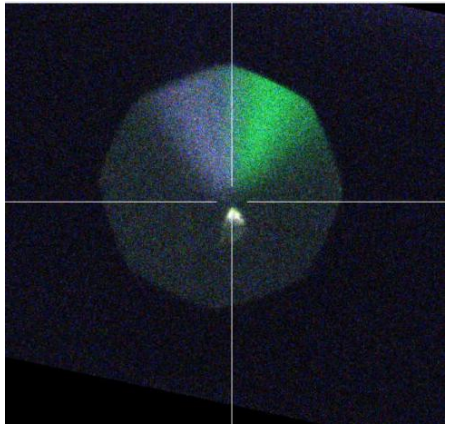
- Two color capability → observations in two color → 20 passes of each satellite in both color → A TOTAL OF 160 PASSES! → Not possible currently for us
- Focus on IR observations since July

YLARA operation stuff during quarantine

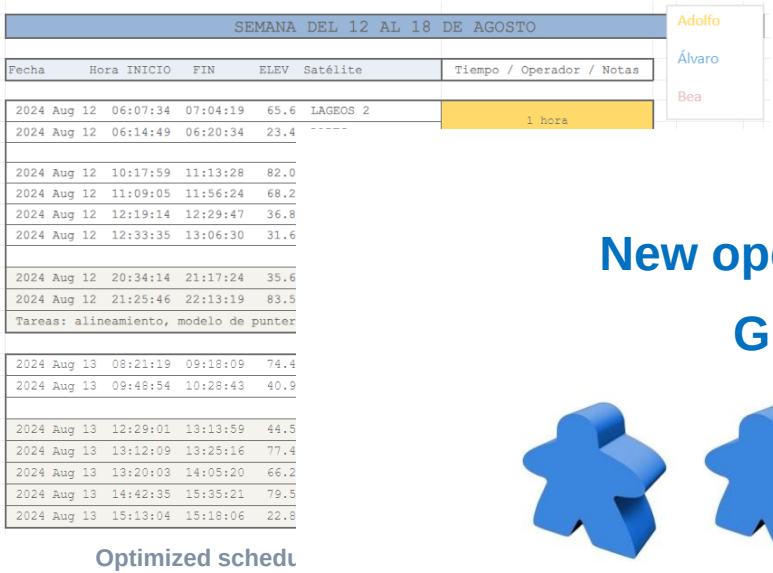
- Equivalent to 3 operators dedicating 20% of their time → ~21 hour per week (2-3 shifts per person)
- Establishment of schedules focus on the 4 priority satellites
  - ✓ + Other satellites observation
- Availability for shift changes in case of bad weather
- Dealing with usual issues in a new system
  - ✓ Operation + training + learning
- Digos support

Sat	Green	IR
LG-1	7	9
LG-2	5	26
LR	3	24
LR-2	2	9

Acceptable passes from April to June
ILRS ASC (Frank Lemoine)



Quarantine - Facing the Challenge



SEMANA DEL 12 AL 18 DE AGOSTO

Adolfo
Álvaro
Bea

Fecha	Hora INICIO	FIN	ELEV	Satélite	Tiempo / Operador / Notas
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2024 Aug 12	10:17:59	11:13:28	82.0		
2024 Aug 12	11:09:05	11:56:24	68.2		
2024 Aug 12	12:19:14	12:29:47	36.8		
2024 Aug 12	12:33:35	13:06:30	31.6		
2024 Aug 12	20:34:14	21:17:24	35.6		
2024 Aug 12	21:25:46	22:13:19	83.5		
Tareas: alineamiento, modelo de punter					
2024 Aug 13	08:21:19	09:18:09	74.4		
2024 Aug 13	09:48:54	10:28:43	40.9		
2024 Aug 13	12:29:01	13:13:59	44.5		
2024 Aug 13	13:12:09	13:25:16	77.4		
2024 Aug 13	13:20:03	14:05:20	66.2		
2024 Aug 13	14:42:35	15:35:21	79.5		
2024 Aug 13	15:13:04	15:18:06	22.8		

Optimized schedu

YLARA operation stuff during quarantine

- Equivalent to 3 operators dedicating 20% of their time → ~21 hour

ity satellites

ther

Don´t worry!

New operators next November

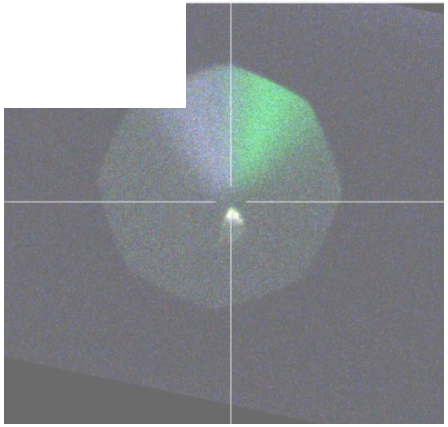
Green quarantine?

The two color dilemma

- Two color capability → observations in two color → 20 passes of each satellite in both color → A TOTAL OF 160 PASSES! → Not possible currently for us
- Focus on IR observations since July

Sat	Green	IR
LG-1	7	9
LG-2	5	26
LR	3	24
LR-2	2	9

Acceptable passes from April to June
ILRS ASC (Frank Lemoine)



Result of Quarantine Provided from ILRS ASC

LAGEOS-1

78176211 L1	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.4	-6.5
STD	1.2	13.5
RMS	2.7	14.9
Passes	40	40

LAGEOS-2

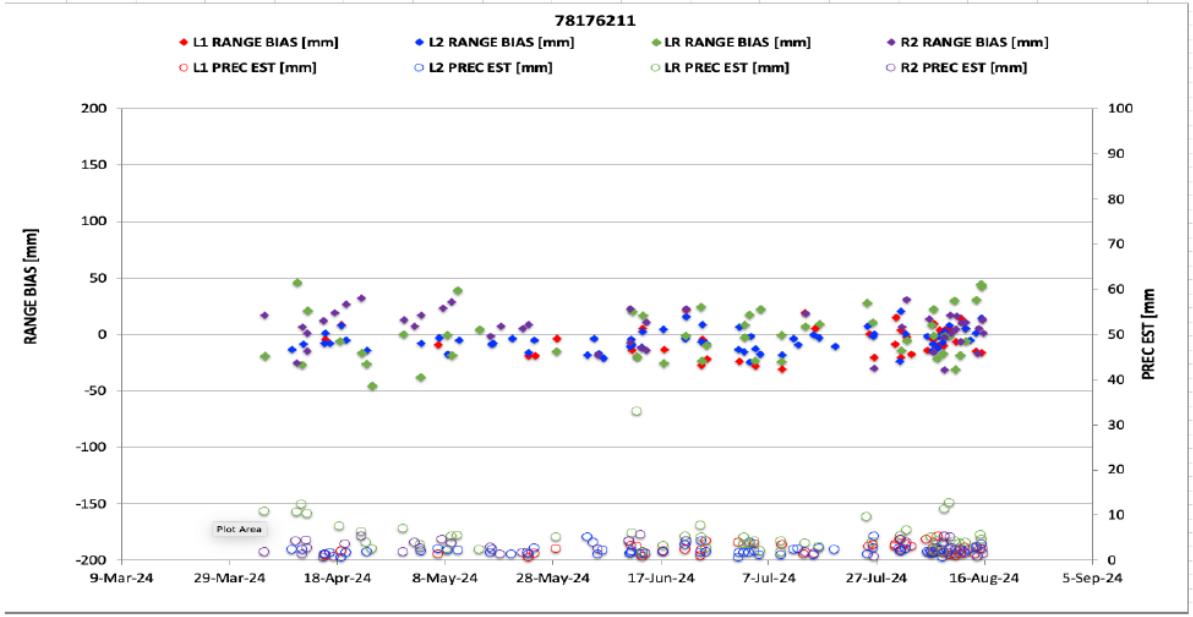
78176211 L2	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.1	-5.3
STD	1.0	9.3
RMS	2.3	10.6
Passes	65	65

LARES-2

78176211 R2	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.7	5.3
STD	1.5	16.0
RMS	3.1	16.7
Passes	44	44

LARES

78176211 LR	PREC EST [mm]	RANGE BIAS [mm]
Mean	5.6	-0.2
STD	4.9	22.4
RMS	7.4	22.2
Passes	50	50



NASA/GSFC & UMBC: M. Kuzmicz-Cieslak, F. G.Lemoine, A. Belli. October 3, 2024

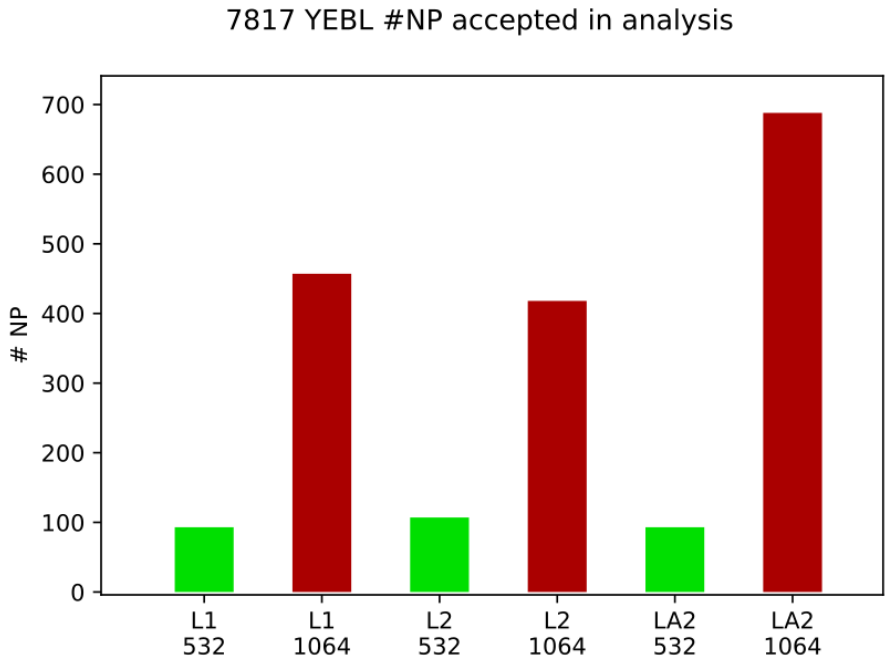
Sat	IR
LG-1	40
LG-2	65
LR	44
LR-2	50

Acceptable passes from April to August (ILRS ACS)

Analysis by the AAC IGN-Yebes

- NP data from 7817 YEBL analyzed in global solutions
- Period: April to August 2024 (quarantine)
- 7-day arcs of LAGEOS, LAGEOS-2, LARES-2
- Estimation: orbits, station positions, biases, EOP
- Two-color data treated as per ILRS ASC

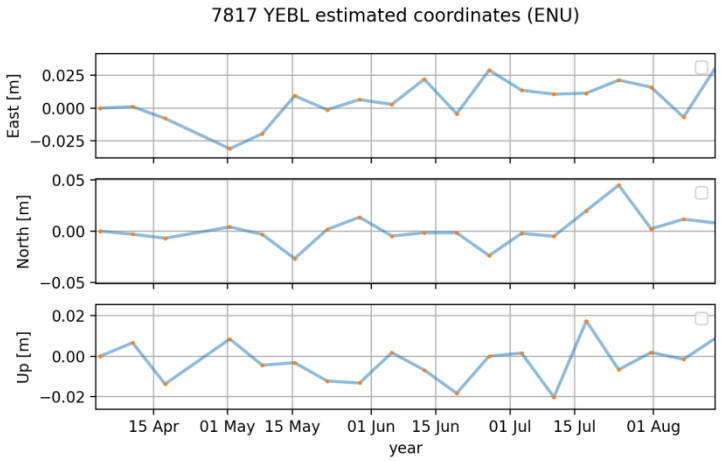
Satellite	Wavelength	NP	Weeks
LAGEOS-1	532	107	9
	1064	418	14
LAGEOS-2	532	93	8
	1064	688	18
LARES-2	532	93	6
	1064	457	17

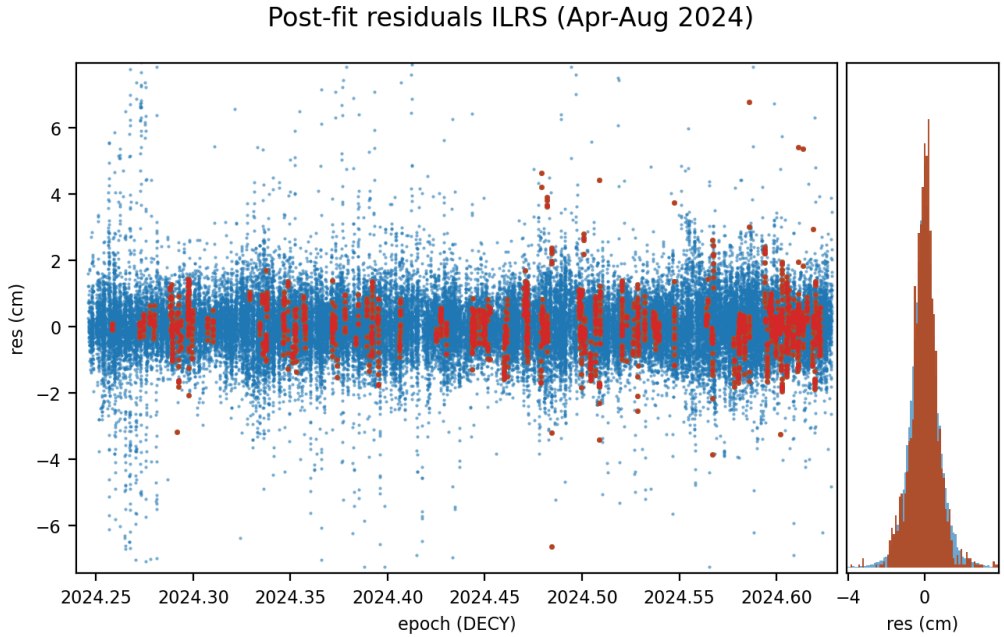


More IR data: easier tracking + quarantine requirements

Analysis by the AAC IGN-Yebes

- Good fits, no major problems
- A few outliers present in some weeks
- Sufficient data to estimate coordinates for all weeks of the period considered (20)
- Too early to estimate velocities reliably

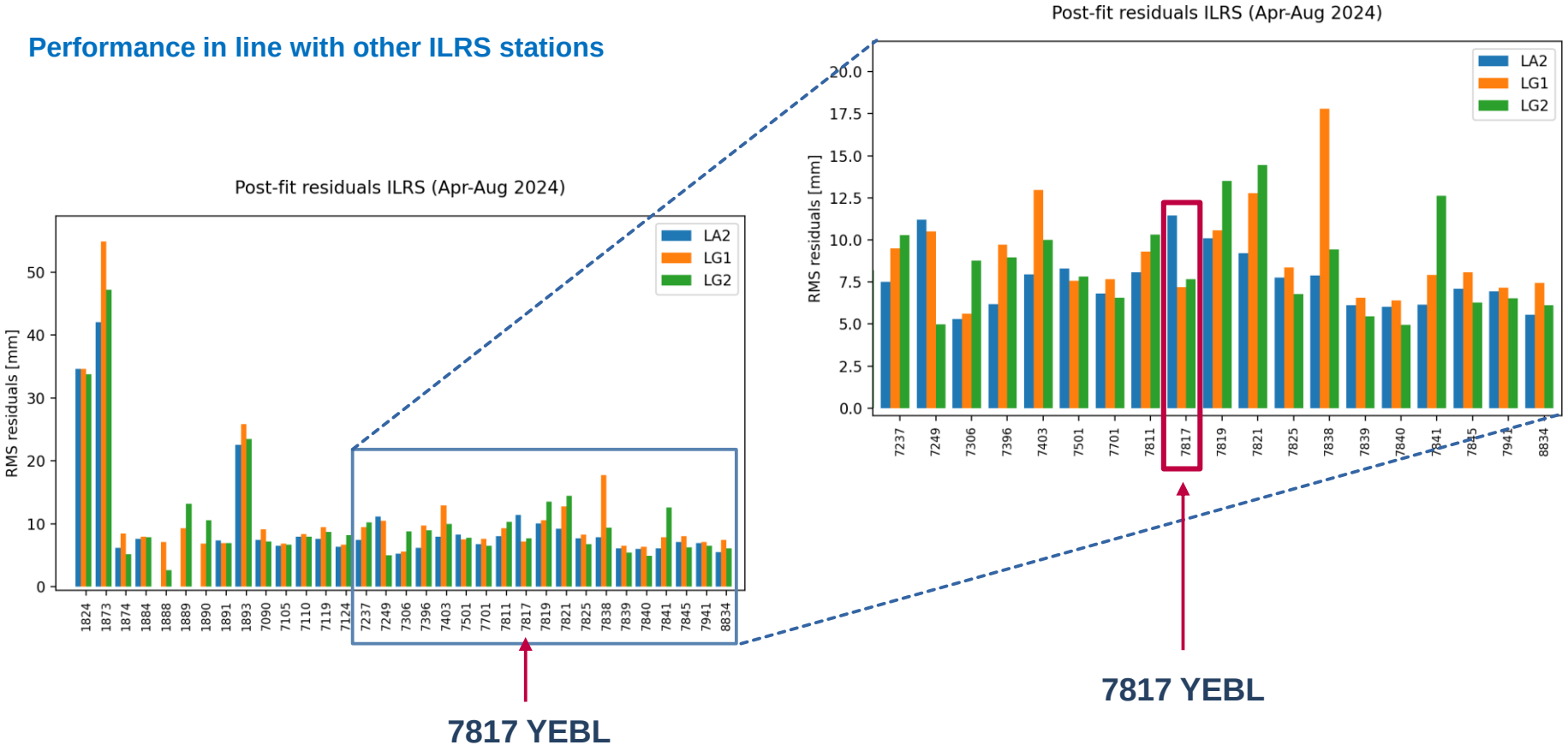




Red: YEBL residuals
Blue: rest of stations

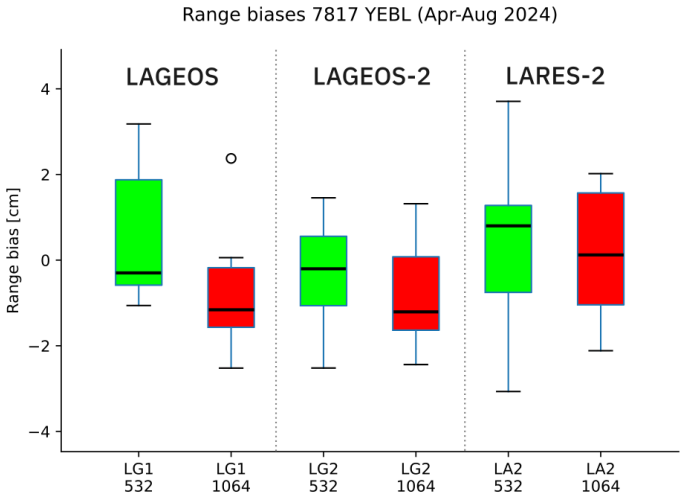
Analysis by the AAC IGN-Yebes

Performance in line with other ILRS stations

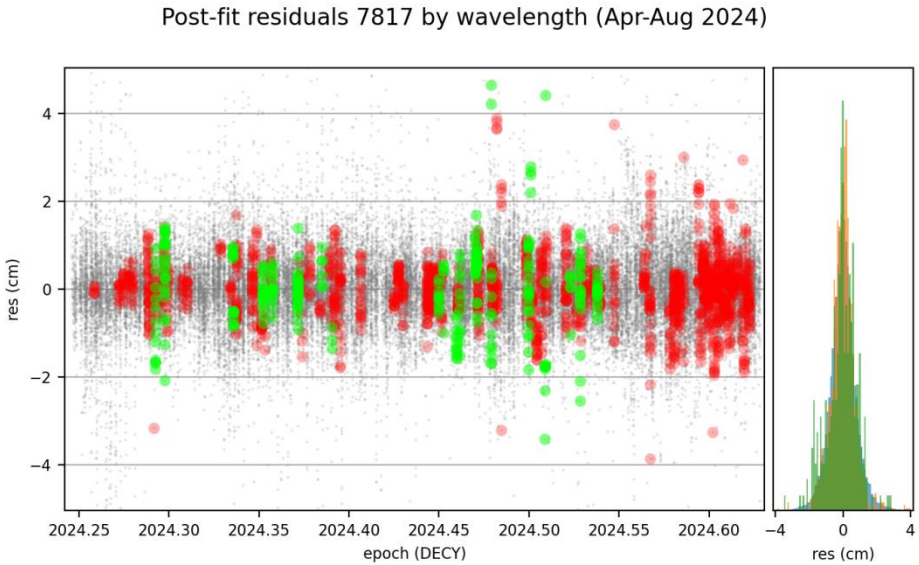


Analysis by the AAC IGN-Yebes

- No differences between wavelength in residuals
- Only IR data since July (quarantine requirements)
- RB at the cm level (~9 mm diff. between colors)



NB: default CoM applied

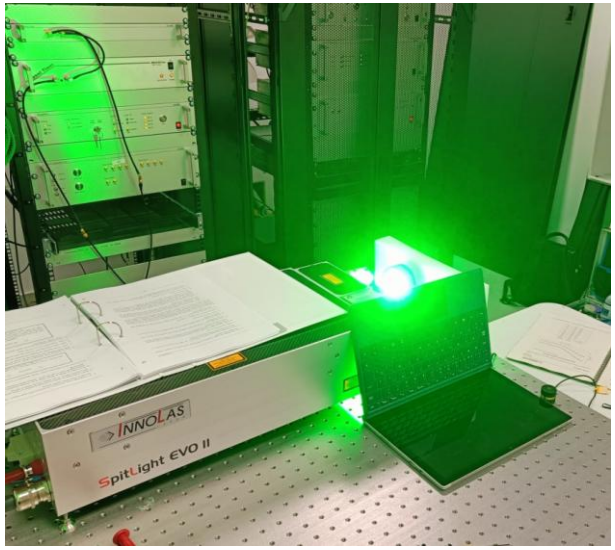


Red: YEBL 1064 nm
Green: YEBL 532 nm
Grey: rest of stations

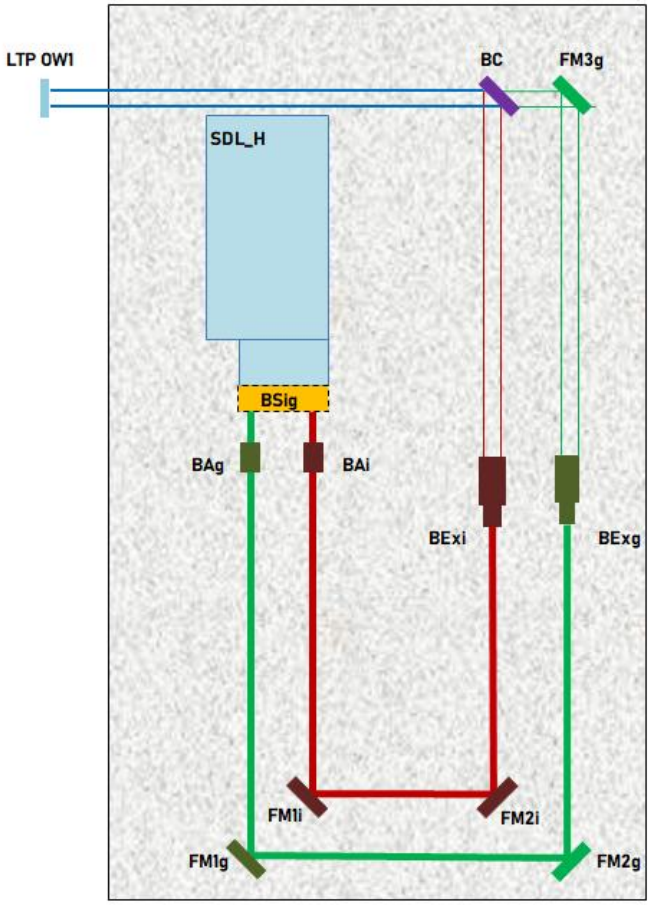
Laser system for space debris observation - SDLR

Delivery and pre-installation carried out on May 2023

Model	Innolas SpliLight EVO II
Repetition rate	200 Hz
Pulse Energy	> 350 mJ @ 1064 nm > 200 mJ @ 532 nm
Beam diameter	7 mm
Divergence	< 0,5 mrad full angle
Pulse duration	5 - 8 nm



SDLR Preliminary Design



Space Debris Laser (SDL) and SD Optical Package (SDOP) on optical bench

- Conceptual design

SDL_H: Space Debris Laser (Head)
BS: Beam shutter (dual)
BA: Beam Attenuator (automatic)
FM: Folding Mirrors
Bex: Beam Expander
BC: Beam Combiner
LTP OW1: Laser Transmission Path (optical window)
i: Infrared (1064 nm)
G: green (532 nm)

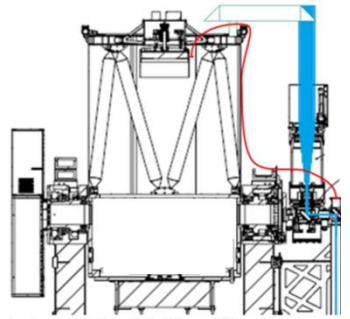


Figure 1: Integration concept of Coudé fibre calibration method for regular calibrations)

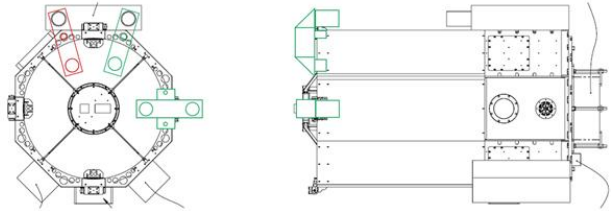


Figure 2: Concept for temporary attachable / removable calibration target (similar to piggyback cal target)

Specific calibration system

- Composed by: Permanent Fiber and temporary calibration Target (Digos)


THANK YOU!
谢谢