Yebes Observatory Station Report

Sardinia TOG meeting 4-5 September 2025

1 General status

Over the past few years, the 40-m radio telescope has undergone several upgrades to enhance its performance. The commissioning of the subreflector wobbler system and the new K-band ASTROREC receiver was completed by the end of 2024. However, a mechanical failure of the subreflector in May 2025 has prevented Yebes from participating in EVN observations since then.

2 VLBI Equipment

Following is the description of the equipment used to support the EVN observations:

• DBBC2 backend:

- 4 CoMo boards (Unica4).
- 4 ADB2.
- 4 Core2.
- Internal Fila10G.
- Software available:
    - DDC:
        - v105_1 (June 10 2015). This firmware is used with channel bandwidth narrower than 4 MHz.
        - v107 (beta 4) (June 7 2019). This firmware is used with 4 MHz channel bandwidth or wider.
    - PFB (mode not regularly used):

        - v16_2 (October 13 2017).
    - Fila10G:
        - fila10g_v4_1 (reported as 2.8.0, October 20 2017).

• DBBC3 backend:

- DBBC3-6L-6H.
- Internal Fila10G.
- Software available:
    - DDC:
        - v126U (June 23rd 2022). This firmware provides 16 BBCs with up to 128 MHz bandwidth.
        - v126E (October 25th 2022). This firmware provides 8 BBCs with up to 128 MHz bandwidth, but flatter bandpass.
        - V128E. Firmware version date: March 25th 2025. Preliminary local tests showed an improved bandpass response and the absence of spurious or ghost tones. This version was tested during GMVA 2025-S1 with satisfactory results.

• Flexbuffs: there are 3 units at the observatory dedicated to observation recording, plus and additional one used for testing and experimentation:

- flexastro:
    - 36 disks of 10TB capacity. Total capacity of 360TB
    - Software version: jive5ab : 2.9.0 : 64bit : dev : flexastro
- flexbuff: underwent major upgrade during 2023 to replace aging HHDs by 16 TB units (Seagate part number ST16000NM001G-2KK103)
    - 36 disks of 16TB capacity. Total capacity of 576TB
    - Software version: jive5ab : 2.9.0 : 64bit : dev : flexbuff
- flexcosmos:
    - 36 disks of 10TB capacity. Total capacity of 360TB
    - Software version: jive5ab : 2.9.0 : 64bit : dev : flexcosmos
- flexcorr (testing unit):
    - 36 disks of 4TB capacity. Total capacity of 144TB
    - Software version: jive5ab : 2.9.0 : 64bit : dev : flexcorr
- Two additional units (360 TB each) located at JIVE.

• Harrobox running Debian Bookworm (12) acting as a proxy between the FS and the DBBC to allow concurrent connections to DBBC2. JIVE correlator uses this feature to control the flow of data from the Fila10G when doing eVLBI. This host is in the public LAN but allows connections from the private LAN.

• Spare DBBC2 backends. This unit is ready to support tri-band observations until DBBC3 is commissioned by JIVE.

• Two H-masers at Yebes and two GPS receivers to keep the maser clocks synchronised. The masers are regularly checked by the manufacturer. Backup maser is currently in standby

mode due to low content of hydrogen. Primary maser could follow and therefore will not be able to perform VLBI observations. Contractor Safran to correct the problem at Santa María station and train our staff to correct the problem at Yebes masers.

- GPS/GNSS: Two systems: one CNS Clock II (acting as the primary) and one SAFRAN SecureSync 2400 (secondary). The latter was acquired and installed in the summer of 2025.

3 Field System

We run three Field System computers:

- RT40m: FS version 9.13.2 on Debian 7.11 Wheezy, kernel 3.2.0-6-686-pae
- RT13.2m: FS version 10.1.0 on Debian Jessie 10, kernel 4.19.0-19-amd64.
- A test computer which can be connected to any of the non-used backends. Debian Buster and FS 10.

4 EVN observations

Below are the metrics for the participation of the Yebes 40-m radio telescope in the EVN observations, since the report at the last TOG meeting.

EVN mini-session 2024-3: participated in a total of 4 observations (plus 1 CL calibration run and 2 NMEs, one of them demonstrated fringes for first time with new K-band ASTROREC receiver).

C-band: performed 2/2 successful observations. Note: for gg088 some scans were lost due to software problems (jive5ab 3.1.0 crash).

K-band: performed 2/2 successful observations. Notes: for gc040a some scans were too short (<10sec), providing not enough time for gap calibrations with hot/cold loads (noise diode not available for new K-band receiver yet).

EVN session 2025-1: participated in a total of 26 observations (plus 2 CL calibration runs and 3 NMEs).

C-band: performed 12/13 successful observations. Note: most observations affected by bad weather (rain and wind), es116c not performed due to a problem with the 40m antenna controller.

X-band: performed 8/8 successful observations. Note: some observations affected by bad weather (rain).

K-band: performed 6/6 successful observations. Note: some scans of ey045b and gc040b were impacted by a problem with the SR.

EVN session 2025-2: Yebes 40m not operational, 40-m antenna SR major failure from May 16th 2025.

EVN e-VLBI: Yebes 40-m participated in 7 of the 9 C-band e-VLBI sessions requested during the reported period. All observations were successful except for the ea077a run (7/10/24) which was affected by an antenna problem and ew040d which could not be calibrated due to a noise diode control problem. The e-VLBI in June was not observed, impacted by the major 40-m SR failure.

EVN ToO: Yebes 40-m participated in the 2 C-band ToO requested during the reported period. Both observations were successful, with few missing scans due to flexbuff recording failure during rl008.

EVN OoS: Yebes 40m participated in 1/3 X-band observations. Note: gb082d was cancelled by the PI and gb082f failed due to the antenna controller problem. The observation gb082e was performed but was affected by accumulation of ice in the CX receiver feed (SEFD ~ 600Jy).

5 Storage

Since the last TOG meeting, no storage purchases have been made for the EVN.

6 Spares

One Mark5B+ system together with some old DBBC2 pieces are available at the station.

7 Internet connection

Internet connectivity is provided by RedIRIS, the Spanish National Research and Education Network (NREN). In January 2023, new network elements were installed at the observatory and the upgrade to a 100 Gbps link was completed. This outside 100 Gbps connection is available to the correlator and the VLBI traffic for e-transfer can be routed through aggregated 10 Gbps uplinks to take advantage of the higher bandwidth. Currently, the observatory supports disk recording (flexbuff) and e-VLBI with maximum data rates of 8 Gbps each.

8 Upgrades and repairs of the 40-m radio telescope

The commissioning of the **new K-band linear polarisation receiver, ASTROREC**, covering the 18-32.3 GHz frequency range, was completed in November 2024 (López-Pérez et al., in preparation). Since then, it has been used to support the EVN and VLBI projects in this band. The first interferometric fringes demonstration occurred during the NME n24k3 in EVN session III 2024. Circular polarization was detected by installing a quarter-wave plate in front of the receiver cryostat window. Strong signal-to-noise ratios were obtained, around 100 for Ys-Sr and 10 for Ys-Ky in a 4-second integration scan. The level of cross-polarization was approximately 15-20%. System temperature (Tsys) and System Equivalent Flux Density (SEFD) values were affected by poor weather during the NME observation, with values of 120 K and 600 Jy, respectively. Under good weather conditions, these typically improve to 80 K and 430 Jy. The noise diode and phase calibration unit has not yet been developed; therefore, calibration is performed with hot/cold loads during gaps. Figure 1 shows the auto-correlation and cross-correlation plots for the Yebes-Sardinia baseline (Ys-Sr), for scan 22 on source J2203+3145.

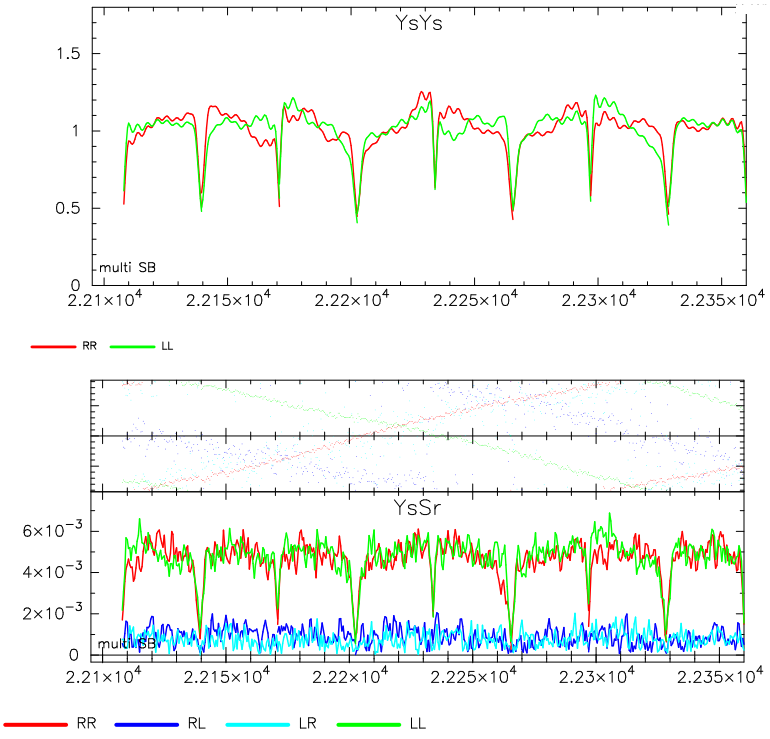

Figure 1: Auto-correlation (top) and cross-correlation (bottom) plots for scan 22 on source J2203+3145 that show the Yebes bandpass for every frequency channel, affected by the DBBC2 digital backend response for 32 MHz wide channels, and the amplitude and phase of the Yebes-Sardinia correlation showing a low level of cross-polarization or leakage (cyan and blue curves).

Regarding the status of the **wideband CX linear polarisation receiver,** covering the 4-18 GHz frequency range, it is still under development/commissioning. It is expected to become operational by next year.

Meanwhile, the **CX receiver (4.6-9 GHz)** is undergoing troubleshooting. The amplification problem encountered last year was traced to ice accumulation on the cryostat window caused by a misalignment of the IR filter (see Fig. 2). During the summer of 2025, several issues at the IF-stage post-amplification and noise diode attenuation were resolved, and investigations are ongoing to diagnose internally generated RFI in the receiver cabin.

Figure 2: CX-band receiver water condensation at the cryostat window degraded Yebes 40m performance for EVN session II 2024. Found the IR filter not properly positioned, causing the problem.

Regarding progress in supporting VLBI observations in simultaneous K/Q/W bands for **Frequency Phase Transfer (FPT) applications**, the KVN correlator recently reported successful fringes demonstration for K/Q observations conducted in late 2024 and early 2025. These were achieved using zoom-band correlation with DiFX, enabling the combination of KVN 512 MHz bandwidth channels with Yebes 64 MHz bandwidth channels (see Figure 3). Additional tests scheduled for June 2025 could not be supported due to the major failure of the 40m telescope.

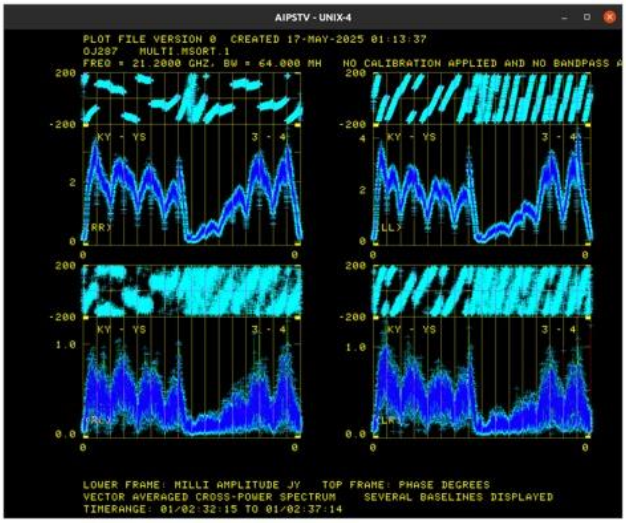

Figure 3: POSSM plot of the OJ 287 scan with highest SNR, detected only on the Yebes–KVN Yonsei baseline due to an issue with rest of KVN antennas (observation performed in Nov. 10th, 2024). IFs 1–8 correspond to the K band, while IFs 9–16 correspond to the Q band. The four panels, arranged from top left to bottom right, show RR, LL, RL, and LR correlations, respectively (Ro et al., private communication).

The DBBC3 system, equipped with six IF inputs, is an ideal backend for supporting tri-band, dual-polarisation observations. The **performance of the DBBC3** firmware version DDC_E v128beta was evaluated during GMVA Session I (April 2025) in piggyback mode for a 3mm observation. Its equivalent performance with respect to DBBC2 was confirmed by the Bonn correlator and the Onsala VLBI Friend (see Figure 4).

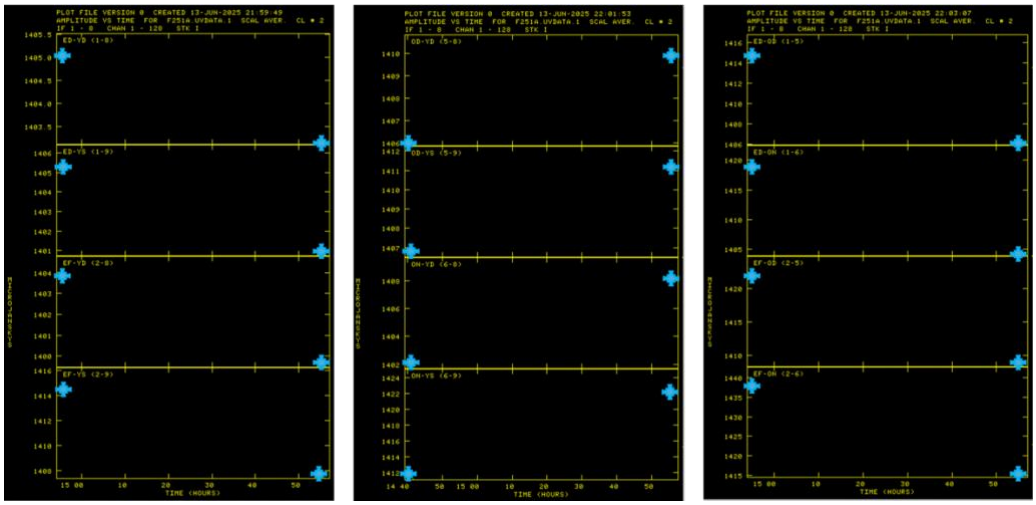

Figure 4: Fringe amplitude difference for 80min average time is less than 1% in all three baselines between DBBC3 and DBBC2 backends (Effelsberg, Onsala and Yebes). Results shown for a 3mm observation (4 Gbps continuum dual pol. observation, 64 MHz filters, 8 BBCs, 2-bit sampling).

Since May 16, 2025, the 40m antenna has been out of operation due to a **subreflector movement failure**. The problem was caused by one spindle of the hexapod becoming mechanically blocked, requiring inspection and repair by the manufacturer. As no spare was available, a new spindle has been ordered. Once delivered, it will replace the blocked unit. The spindle replacement is a complex operation: the hexapod ring has to be locked to prevent any movement prior to removal. Each spindle is fixed with a backlash-free swivel joint at both ends, which must also be dismantled. The spindles extend over the void (hidden by the bellow) and weigh about 50 kg, making manipulation difficult in such a confined space. The new spindle must be configured with exactly the same length and encoder reading as the old one to preserve coordinate calibration.

In the meantime, the SR has been positioned for best focus at approximately 45 deg. elevation, and a new pointing model has been developed to support the IVS project and cm-wavelength VLBI projects that do not require to focus the subreflector with the elevation.

In addition to the SR issue, one azimuth and one elevation power module have been replaced by spares due to different failures in the axis control system. Lastly, a monitoring system for the Vertex blinds has been installed to prevent mechanical failures of the type experienced in the past.

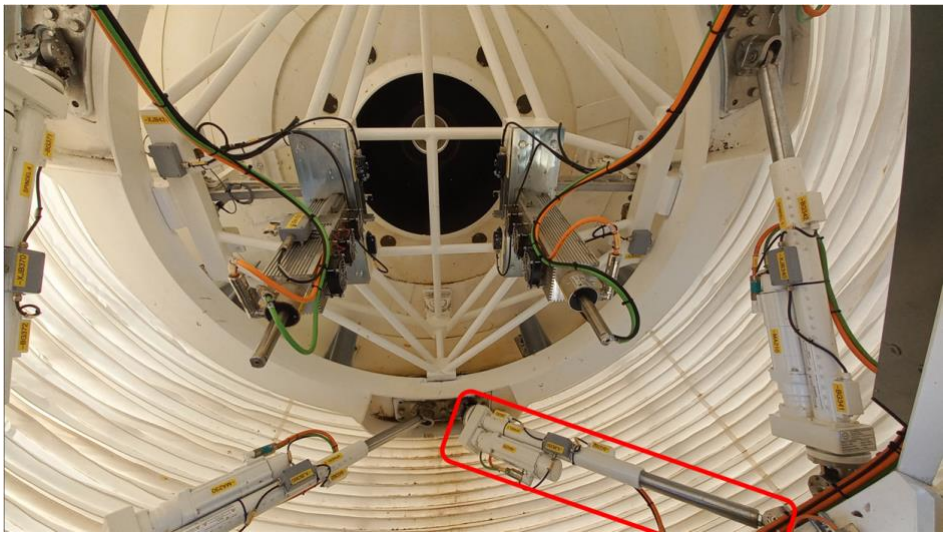

Figure 5: Subreflector hexapod control and detail of the blocked spindle.

9 News about Yebes Observatory

The RAEGE 13m radio telescope resumed operations in June 2025, following the severe damage to the azimuth wrap suffered last year. The repair contract was awarded to the Spanish company Asturfeito. Several components of the winding system, as well as the power and signal cables routed through the winder, required replacement (Figure 6). To prevent future failures, an automated anomaly detection system has been developed using optical sensors installed on the hanger arms to monitor reel operation (Figure 7). In addition, the VGOS receiver was upgraded with the replacement of the noise diode with a more powerful unit, reduction of the PCal tone spacing to 5 MHz, installation of a new cryostat monitoring system, and the implementation and installation of room-temperature filters for 5G signal rejection.

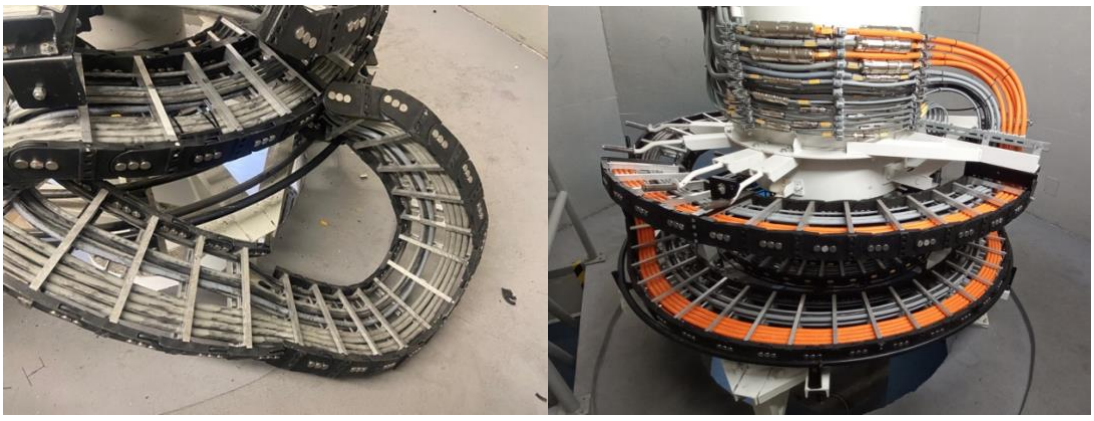

Figure 6: Detail of 13m cable wrap after the failure (left) and after the repair (right).

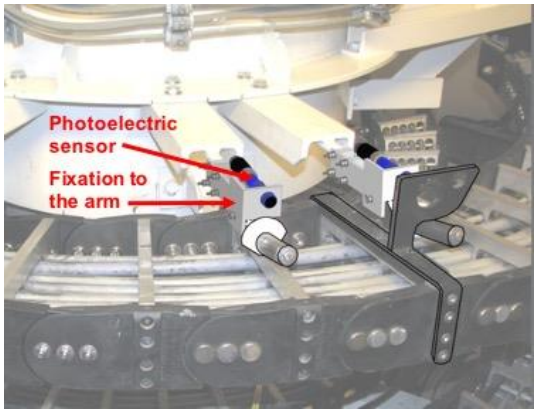

Figure 7: Detail of cable wrap monitoring system with optical sensors.

RAEGE antennas, thanks to their location and technical capabilities, have great potential for conducting astronomical studies, both in VLBI and in single-dish modes. In the summer of 2025, in collaboration with the Spanish Public University of Navarra (UPNA), **a pulsar observation system** has been implemented for the 13-meter antenna. This system is based on a software-defined radio (SDR) device and professional software for signal processing and pulsar detection (i.e., the PRESTO toolkit). Figure 8 shows the first detection of pulsar B0329+54.

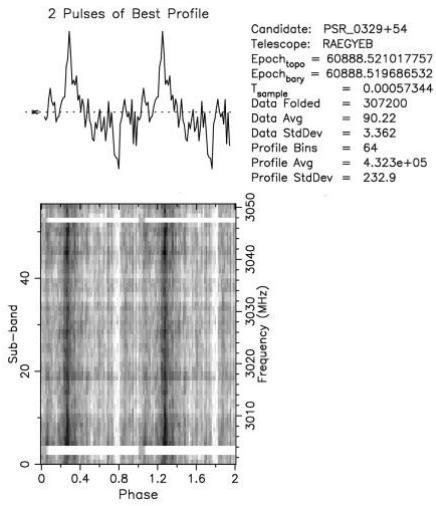

Figure 8: Pulsar PSR_0329+54 detection with RAEGE 13m antenna in Yebes.

10 Staff

The VLBI group consists of the following members:

- **VLBI Scientific Support:** Victor Pérez (GMVA/VGOS), Cristina García-Miró (EVN/IVS/GMVA/Global Astrometry).

- **VLBI Technical Staff:** Javier González (VLBI technical friend), Santiago de la Fuente (VLBI backends and RAEGE correlator), Francisco Muñoz (software development, VM). In addition, a team of operators and engineers supports the operation and various maintenance activities.
- **Yebes Schedulers:** Belén Tercero, Nuria Marcelino.

Staff news: At the beginning of 2025, Santiago de la Fuente has joined the VLBI group as an IGN intern. Within several months, he will become part of the Yebes permanent staff.

Contact:

Yebes VLBI group - astrovlbi@oan.es (schedules, observations, data transfer, antenna calibration, antabfs files, etc.)

Yebes VLBI technical group – vlbitech@oan.es (backends, firmware, etc.)