



# LOFAR ERIC

## Activity Report 2024







# LOFAR ERIC Activity Report 2024

## Table of Contents

1.	Introduction .....	2
2.	Establishment of the LOFAR ERIC .....	3
3.	LOFAR ERIC Membership and Governance .....	4
4.	Features of the LOFAR telescope .....	5
5.	Highlights and developments in 2024.....	7
5.1	LOFAR ERIC Establishment and ILT to ERIC transfer.....	7
5.2	LOFAR 2.0.....	8
5.3	LOFAR Science Operations.....	11
6.	Expectations for the future.....	14
7.	LOFAR ERIC Financial Report.....	15

## 1. Introduction

The year 2024 marked a pivotal chapter in the evolution of LOFAR ERIC, as the organisation completed the transition from the ILT Foundation. Following its formal establishment by the European Commission on 20 December 2023, LOFAR ERIC has taken shape as a robust and collaborative European Research Infrastructure Consortium, dedicated to advancing the frontiers of low-frequency radio astronomy.

This inaugural year has been characterised by significant organisational developments, strategic planning, and technical progress. The LOFAR ERIC Council convened for the first time in January 2024, setting in motion the governance structures and leadership appointments that will guide the consortium in the years ahead.

A major focus of 2024 has been the continued implementation of the LOFAR 2.0 upgrade programme. Building on years of design and development, the project entered its integration and validation phase, with the successful deployment of pre-production and final hardware across several test stations. These efforts have laid the groundwork for the full-scale roll-out of the upgraded system, scheduled for 2025 and 2026. The enhancements introduced by LOFAR 2.0 will significantly expand the scientific potential of the telescope and ensure its relevance well into the next decade.

In parallel, the formal transition from the International LOFAR Telescope (ILT) Foundation to LOFAR ERIC was completed in July 2024, resulting in the legal transfer of assets, projects, and responsibilities. This milestone marks the successful conclusion of years of careful preparation and reflects the shared commitment of the member countries and partner institutions to the long-term success of the LOFAR enterprise.

This brief Activity Report provides an overview of the key activities, achievements, and strategic directions of LOFAR ERIC during 2024. It highlights the dedication of the scientific, technical, and administrative teams across Europe who continue to advance the mission of LOFAR – delivering world-class science and strengthening international collaboration in the field of radio astronomy.

## **2. Establishment of the LOFAR ERIC**

The LOFAR ERIC has its registered office in Dwingeloo (municipality of Westerveld) in the Netherlands. LOFAR ERIC was established on 20 December 2023 by the European Commission implementing decision (EU) 2023/2881.

The principal task of LOFAR ERIC is to assure coordinated exploitation of the LOFAR infrastructure, to produce world class scientific research and to pursue further development, with the aim to maximise productivity and impact for the Members and the international scientific community, positioning LOFAR ERIC as a world-leading distributed research infrastructure with a long-term perspective. LOFAR ERIC is the legal successor of the International LOFAR Telescope Foundation (ILT).

### 3. LOFAR ERIC Membership and Governance

The Founding Members of the LOFAR ERIC are the following:

- The Republic of Bulgaria represented by the Institute of Astronomy and National Astronomical Observatory (IANAO) of the Bulgarian Academy of Sciences,
- The Federal Republic of Germany represented by the Thüringer Landessternwarte (TLS),
- The Republic of Ireland, represented by Dublin Institute for Advanced Studies (DIAS),
- The Italian Republic, represented by the Istituto Nazionale di Astrofisica (INAF),
- The Netherlands, represented by Stichting Nederlandse Wetenschappelijk Onderzoek Instituten (NWO-I),
- The Republic of Poland, represented by the Ministry of Education and Science.

LOFAR ERIC has agreements in place with the following Collaborating Organisations:

- Centre National de Recherche Scientifique (CNRS) in France,
- Ventspils International Radio Astronomy Centre (VIRAC) in Latvia,
- Onsala Space Observatory (OSO) in Sweden, and
- Science and Technology Facilities Council - UK Research and Innovation (STFC-UKRI) in the United Kingdom

It is expected that these countries will apply to join LOFAR ERIC in the near future.

Each of the Members and Collaborating Organisations hosts one or more LOFAR stations that form part of the International LOFAR Telescope or have agreed to host a station in the next few years. The latter is the case for Bulgaria and Italy – these stations are expected to be completed in 2026. Each member commits to a contribution per station set by the Council at a rate of € 95,000 (in 2024 unchanged from previous years). These contributions can be provided partially in-kind, typically in the form of personnel or as compute and data storage resources.

LOFAR ERIC Members are represented on the Council by up to two delegates. Collaborating Organisations can also appoint up to two (non-voting) representatives. The Council elects a Chair and Vice-Chair from among the delegates for a two year term, renewable twice. The Council is advised by two committees, one responsible for financial and the other responsible for scientific and technical aspects of the LOFAR ERIC activities. Members of these two committees are appointed by Council upon recommendation by the Members and Collaborating Organisations. A third committee, the Scientific Advisory Committee, is also foreseen but has not yet been installed.

The LOFAR ERIC Council convened five times in 2024: on 22 January (online), 27 February (online), 11 June (hybrid meeting in Dwingeloo and online), 1 October (in person), and 10 December (online). Key matters addressed by the Council included the transition from the ILT Foundation to LOFAR ERIC, the appointment and establishment of various governance and advisory committees, and the oversight of LOFAR ERIC's principal investment initiative – the LOFAR 2.0 upgrade programme.



**Figure 1:** Map showing the distribution of LOFAR stations. The Netherlands hosts a total of 38 stations, while the other points on the map each host a single station. LOFAR stations in Medicina (Italy) and Rozhen (Bulgaria) will be constructed in 2026.

#### 4. Features of the LOFAR telescope

The LOFAR telescope comprises radio-astronomical antenna stations with receivers located in the Netherlands and other member countries (see Figure 1). The Netherlands hosts 38 stations, Germany 6, Poland 3, while France, Ireland, Latvia, Sweden and United Kingdom host a single station. These antenna stations are owned by different organisations, each is responsible for local maintenance, local operating costs and for the national part of their network connection. Two further stations will be built in Italy and Bulgaria in 2026.

All stations are connected via a dedicated fibre-optic network to the central data processing facilities, which are hosted at the Centre for Information Technology of the University of Groningen in the Netherlands. This central processing facility includes networking and computing equipment, along with the necessary software to conduct observations and perform the initial processing of incoming data.

LOFAR data are archived at three main sites: SURF, the IT cooperative for Dutch education and research institutions in Amsterdam; the Jülich Supercomputing Centre in Germany; and the Poznań Supercomputing and Networking Center in Poland. Over the years, LOFAR has amassed what is arguably the world's largest astronomical data archive, exceeding 50 petabytes.



LOFAR ERIC itself is supported by a small office team, comprising the Executive Director, Finance Officer, and Office Support staff. The operational coordination of LOFAR – and thus the majority of the workforce involved in the telescope’s exploitation – is provided as an in-kind contribution to LOFAR ERIC by ASTRON, the Netherlands Institute for Radio Astronomy.

Observing opportunities are made available to researchers from the global scientific community, based on submitted research proposals. These proposals are evaluated by an independent Programme Committee, with observing time and computing resources allocated primarily on the basis of scientific merit.

## 5. Highlights and developments in 2024

### 5.1 LOFAR ERIC Establishment and ILT to ERIC transfer

As noted in Section 2 of this report, LOFAR ERIC was officially established by the European Commission on 20 December 2023. The Council convened for the first time on 22 January 2024, during which Drs Jacqueline Mout (NL) was elected as Council Chair. At the second meeting, held on 27 February, Professor Gianfranco Brunetti was elected Vice-Chair of the Council.

On 1 March, Dr René Vermeulen, the Founding Director of LOFAR ERIC and former Director of the International LOFAR Telescope (ILT), stepped down. He was succeeded by Wim van Cappellen, who assumed the role of Interim Director. A search for a permanent successor was launched shortly thereafter, resulting in the appointment of Dr Michiel van Haarlem as Executive Director of LOFAR ERIC on 1 August. Dr van Haarlem has a long-standing association with LOFAR, having been involved in its design and development since its inception in 1997, and serving as Managing Director of the LOFAR Foundation during the original construction phase from 2007 to 2011.

The establishment of LOFAR ERIC also marked the formal transition from the ILT Foundation to LOFAR ERIC, following years of meticulous preparation. This process was completed in just over six months. On 10 July, the Deed of Transfer was signed and notarised in Dwingeloo (NL), effecting the transfer of all assets and liabilities – including ongoing projects and activities – from the ILT Foundation to LOFAR ERIC. The ILT Foundation was officially deregistered by the Chamber of Commerce on 8 August 2024.



**Figure 2:** (left) Guests touring the LOFAR core area, observing the antenna stations up close. (right) Group photo of attendees at the LOFAR ERIC inauguration celebration.

On 10 June 2024, the establishment of LOFAR ERIC was formally celebrated with a special event attended by representatives from all member countries and contributing organisations. The gathering marked the milestone in the evolution of LOFAR, recognising the collaborative efforts that led to the formation of the European Research Infrastructure Consortium. The day featured speeches, reflections on LOFAR’s journey, and a visit to the LOFAR core area.

## 5.2 LOFAR 2.0

The LOFAR telescope has been in continuous operation since 2011. The system comprises numerous components, each with varying lifespans and maintenance requirements. While much of the physical infrastructure – such as antennas, cables, fibres, cabinets, and buildings – has a relatively long operational life, certain critical elements of the original system require replacement after approximately 15 years of use. This is particularly true for the station electronics, including receivers, digitisers, and control and monitoring systems.

Around eight years ago, initial plans were developed for an upgrade to the LOFAR telescope to ensure its continued operation well into the 2030s. This upgrade, known as LOFAR 2.0, will replace virtually all station-based signal processing hardware and introduce new, enhanced software systems. Additionally, the upgrade will involve the replacement of much of the central signal processing infrastructure in Groningen, including a new correlator/beamformer (COBALT3), a new central processing cluster (CEP6), and an upgraded network infrastructure.

LOFAR 2.0 builds upon existing investments and leverages advances in enabling technologies. The increased integration of electronics will enable three times more powerful real-time processing within the same LOFAR station cabinets. Further improvements include:

- Higher dynamic range digitisation (upgrading from 12-bit to 14-bit analogue-to-digital converters)
- Enhanced thermal design
- Centralised clock distribution to all Dutch stations using White Rabbit technology
- A modernised monitoring and control system based on TANGO and OPC-UA

These upgrades will deliver several highly anticipated new capabilities for the astronomical user community:

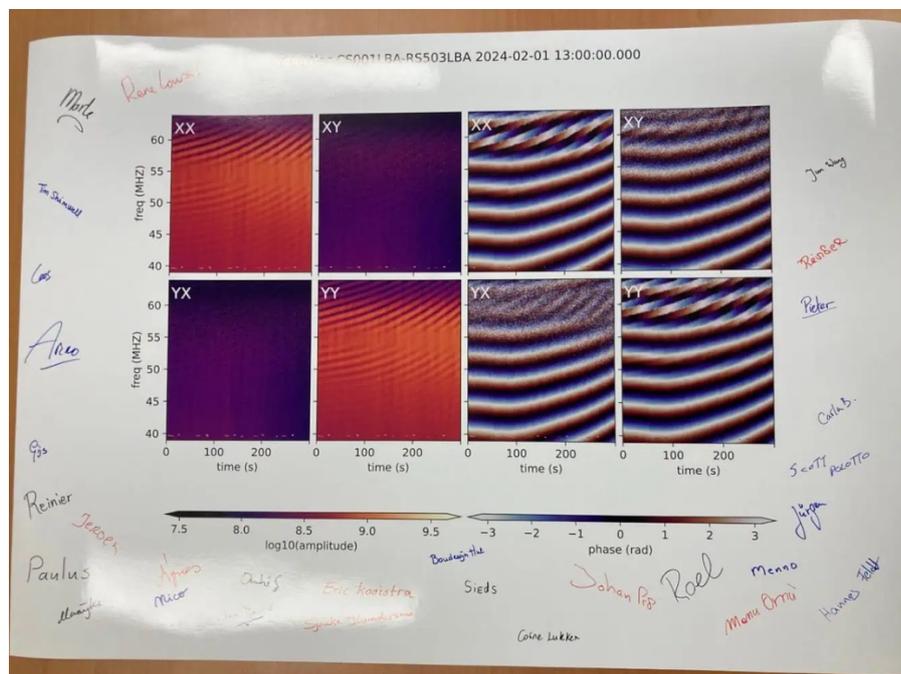
- Access to all LOFAR antenna data all the time, supporting simultaneous observations using both the LBA (10–80 MHz) and HBA (120–240 MHz) antennas
- Synchronised antennas to within nanosecond precision
- Concurrent imaging and beamformed observations
- Improved system linearity
- A new correlator that integrates the NenuFAR station in Nançay, France, into the LOFAR array
- A doubling of the field-of-view for more efficient surveys
- A new proposal tool designed to simplify and streamline the preparation, validation, and submission of observing proposals

The LOFAR 2.0 project has been funded by LOFAR ERIC members and collaborating organisations. In 2024, the project successfully concluded its design and testing phase. The full deployment of the LOFAR 2.0 hardware and software systems is scheduled to take place in 2025 and 2026, with preparatory work continuing steadily throughout the year.



**Figure 3:** Laboratory test setup used to verify the performance of one of the LOFAR 2.0 sub racks which house the station electronics.

Following the completion of the design in December 2023, the project entered its next phase, which involved the gradual assembly, integration, verification, and validation of the various components of LOFAR 2.0. The initial step was the upgrade of a single station using new pre-production hardware. Alongside two additional stations, these Production Test Stations were used to validate every stage of the LOFAR station upgrade process prior to the commencement of mass production of the final hardware.

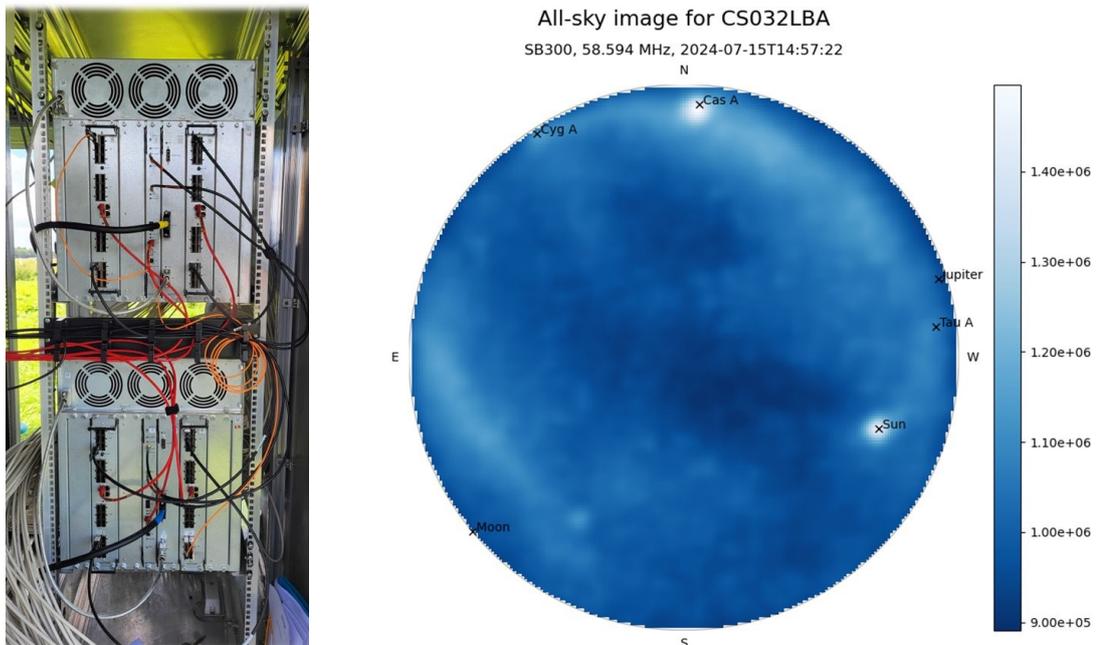


**Figure 4:** On February 1st, the signals from the first LOFAR2.0 station (CS001) were correlated with those from a LOFAR remote station (RS503) resulting in these fringes which represent a major milestone in the verification of the LOFAR2.0 hardware, firmware, and software.

The first successful measurements – known as fringes – were obtained with the upgraded LOFAR 2.0 station CS001 on 1 February (see Figure 4). Two further Test Stations, RS307 and CS002, were equipped with the final LOFAR 2.0 hardware in July.

Following another series of successful tests, the hardware design was approved for full-scale production. By the end of the year, deliveries of the new, final hardware had begun.

Besides the development, production and deployment of new hardware, the LOFAR 2.0 upgrade also includes the development of essential new software and tooling. Controlling a complex and distributed instrument such as LOFAR required frequent human intervention, which is both costly as well as inflexible. The new Telescope Manager Specification System (TMSS) addresses this challenge through the introduction of a dynamic scheduling engine, an integrated data quality assessment workflow, and a flexible specification framework. This gives the operators greater control over observations as well as subsequent processing steps. The system now supports both the use of version-controlled, predefined observing configurations and the fine-tuning of individual observations and processing pipelines. Maintainability and extensibility of TMSS has also been a key consideration throughout.



**Figure 5:** (Left) New LOFAR 2.0 hardware installed in LOFAR Core Station 32 (CS032). (Right) First low band (58.6 MHz) all-sky image made with the final LOFAR 2.0 hardware installed in station CS032 in July 2024.

In addition to the installation of new station processing hardware, the LOFAR 2.0 project will also include an upgrade of the central systems housed at the University of Groningen's Computing Centre. It involves replacing the current LOFAR Central Processing Cluster (CEP4 to CEP6), a new Correlator/Beamformer (Cobalt2 to Cobalt3), and upgrading the central network. These activities are critical for the LOFAR 2.0 upgrade – without them, LOFAR 2.0 will not be able to operate effectively. Steady progress was made in 2024. The design was completed and a start was made with the procurement.

### 5.3 LOFAR Science Operations

#### 5.3.1 Cycle 20 Operations

The year commenced while Cycle 20 was already underway. This cycle began on 1 June 2023 and concluded on 31 August 2024. Originally scheduled to end on 31 May 2024, a three-month extension was granted to allow for the completion of three specific groups of observations on a best-effort and shared-risk basis, prior to the observing system being taken offline for the LOFAR 2.0 upgrade:

- NenuFAR commissioning observations
- Opticon RadioNet Pilot project (up to 50 hours)
- Remaining Cycle 20 observations

Cycle 20 concluded with an average observing efficiency of 73% and a completion rate of 97%, delivering over 6,000 hours of successful observations to users. In addition, solar and ionospheric monitoring for the IDOLS project (Incremental Development of LOFAR Space-Weather), conducted with a single station, remained active throughout the entire cycle. International stations were also regularly operated by their respective owners for stand-alone scientific investigations (see section below).

Observing failures during Cycle 20 totalled approximately 350 hours, primarily due to issues with the recording systems (COBALT and CEP) and periods of heightened solar activity.

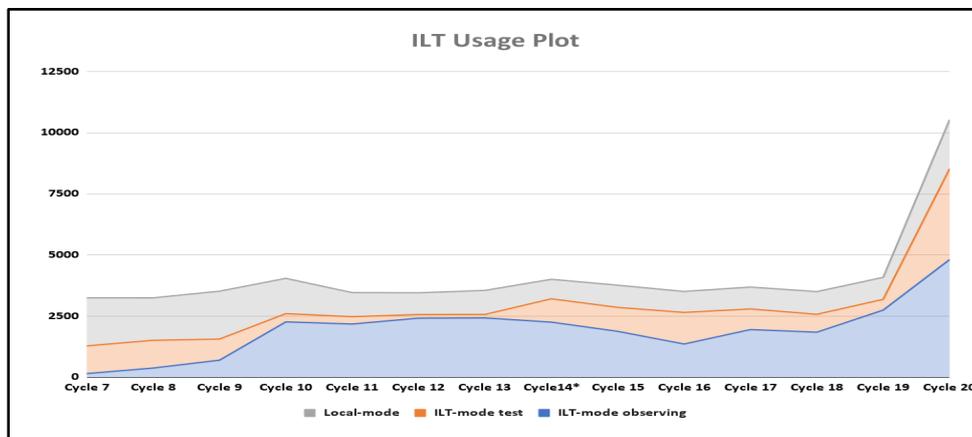


Figure 6: Usage of international stations

#### 5.3.2 Use of International Stations

The use of the international stations across observing cycles is illustrated in Figure 6. Three primary modes of operation are identified:

1. *ILT-mode* – where international stations are used in conjunction with Dutch stations for scientific observations.
2. *ILT-mode test* – similar to *ILT-mode*, but conducted for testing purposes.

3. *Local-mode* – where stations are independently operated by their respective international owners to conduct single-station science.

Over the operational lifetime of LOFAR, there has been a notable increase in ILT-mode observations, reflecting the growing interest and capability within the scientific community to conduct high-resolution research and manage the associated data.

International stations have regularly been switched to local-mode operation. To maximise the overall observing efficiency of the telescope, this switch was made whenever the schedule permitted, resulting in increased local-mode usage during certain cycles.

Since September 2024, all international stations have been operating in local-mode. This arrangement will remain in place until the stations are required for the commissioning of the LOFAR 2.0 system.

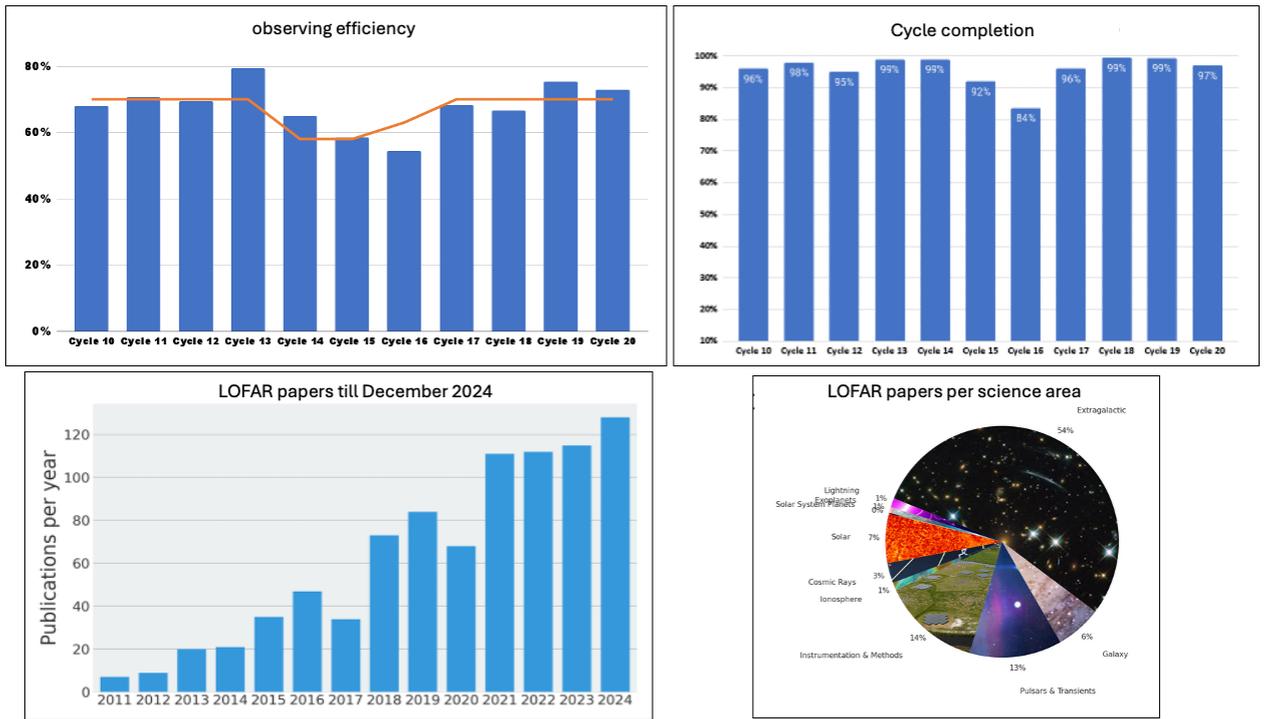
### **5.3.3 A Look Back at LOFAR1.0 Production Operations**

31 August 2024 marked the conclusion of LOFAR1 production operations. Since its official start on 1 December 2012, LOFAR has operated as a highly productive and innovative observatory. Over more than 12 years of continuous operation, the LOFAR team has made substantial progress in operating and handling the data of this unique facility.

The figures below illustrate the completion rates and observing efficiency across recent cycles, alongside the number and scientific domains of LOFAR-related publications since the beginning of operations. In total, 21 observing cycles have been completed, delivering over 65,000 hours of successful observations and distributing more than 60 petabytes of data to a growing international user community.

Observing efficiency has improved significantly since the early cycles, regularly reaching – and in several semesters exceeding – 70%. This progress was achieved while the array itself continued to expand in both size and capability. The collective efforts during this initial operational phase have firmly established LOFAR as a scientifically productive facility.

By the end of 2024, more than 864 peer-reviewed LOFAR publications had been produced, with the publication rate continuing at approximately two papers per week. This places LOFAR among the top 10% of astronomical facilities worldwide in terms of scientific output.



**Figure 7:** LOFAR 1.0 production observing statistics

## 6. Expectations for the future

The primary focus for LOFAR ERIC in 2025 will be the roll-out of the LOFAR 2.0 upgrade. Beginning in the second quarter, Dutch LOFAR stations will undergo hardware upgrades. Once each station has been validated, it will be handed over to the Observatory team for Commissioning. During this phase, the performance of the upgraded telescope will be evaluated against previously defined requirements. Scientists and engineers from LOFAR ERIC member institutions – many of whom are already involved in the LOFAR 2.0 Large Programme Teams – will play a key role in these commissioning activities. This work will include the development and testing of data processing pipelines and workflows in preparation for the resumption of routine LOFAR observations.

In parallel, efforts will continue to upgrade the central infrastructure. Procurement for the network upgrade is expected early in the year, followed by the acquisition and installation of the new central processor (CEP6) and correlator (COBALT3).

Once the upgrades to the Dutch stations are complete, attention will shift to the international stations in other member countries. These upgrades are expected to begin in the fourth quarter of 2025. Construction of two new LOFAR stations – located in Medicina, Italy, and Rozhen, Bulgaria – is scheduled for the first half of 2026.

The Programme Committee (PC) will initiate the process of allocating observing time by conducting a relative scientific ranking of the LOFAR 2.0 Large Programme proposals submitted in October 2023. This ranking will guide the prioritisation of development and commissioning activities leading up to the start of LOFAR 2.0 observations, currently anticipated in the second half of 2026. In the second stage of the review of the Large Programme Proposals, observing time, as well as the necessary storage and computing resources for data processing, will be formally allocated by the Council. Ensuring sufficient processing and archival capacity to support the timely launch of the Large Programmes remains a top priority.

## 7. LOFAR ERIC Financial Report

### Balance sheet per 31 December 2024 (after profit appropriation)

<b>Assets - amounts x EUROS</b>	<b>2024</b>	<b>2023 *</b>
<b>Current assets</b>		
Other claims	1.475.167	326.517
Liquid assets	11.485.459	8.630.464
<b>Total currents assets</b>	<b>12.960.626</b>	<b>8.956.981</b>
<b>Total Assets</b>	<b>12.960.626</b>	<b>8.956.981</b>
<b>Liabilities &amp; Equity - amounts x EUROS</b>		
<b>Equity capital</b>		
<b>Total Equity Capital</b>	<b>3.228.967</b>	<b>2.468.334</b>
<b>Current liabilities</b>		
Debt International Partners	8.857.060	5.650.299
Other debts	874.599	838.348
<b>Total current liabilities</b>	<b>9.731.659</b>	<b>6.488.647</b>
<b>Total liabilities &amp; Equity</b>	<b>12.960.626</b>	<b>8.956.980</b>

\* Note: 2023 figures are based on the ILT annual accounts

## Statement of financial performance 2024

Revenues - amounts x EUR0s	2024	2024	2023 *
	Actual	Budget	Actual
Contribution International Partners	5.035.000	5.035.000	5.035.000
Other revenues	428.543	335.259	351.637
<b>Total Revenues</b>	<b>5.463.543</b>	<b>5.370.259</b>	<b>5.386.637</b>

## Expenses - amounts x EUR0s

	Actual	Budget	Actual
Office & General activities	540.917	662.500	478.576
Online operations	1.086.031	1.235.500	1.289.917
Offline operations	1.727.000	1.827.000	1.727.000
Maintenance and infrastructure	565.648	585.000	603.661
Development	884.000	884.000	1.016.600
Other - Project costs	80.365	0	5.853
<b>Total Expenses</b>	<b>4.883.961</b>	<b>5.194.000</b>	<b>5.121.607</b>

<b>Result current year</b>	<b>579.582</b>	<b>176.259</b>	<b>265.030</b>
----------------------------	----------------	----------------	----------------

## Interest and other expenses - amounts x EUR0s

	2024	2024	2023 *
	Actual	Budget	Actual
Interest	211.832	40.000	43.523
Leave debt movement	-30.780		
<b>Total interest and other expenses</b>	<b>181.052</b>	<b>40.000</b>	<b>43.523</b>
<b>Total result</b>	<b>760.634</b>	<b>216.259</b>	<b>308.553</b>

## Profit and loss appropriation

	2024	2023 *
General reserve	760.634	-591.447
Designated funds	0	900.000
<b>Result</b>	<b>760.634</b>	<b>308.553</b>



