# Asterics

Astronomy ESFRI & Research Infrastructure Cluster

Horizon 2020

The EU Framework Programme for Research and Innovation

ASTERICS is a project supported under grant agreement n.653477


Supporting organisations and networks






# addressing common challenges
## in astrophysics and astroparticle physics

The Astronomy ESFRI and Research Infrastructure Cluster, ASTERICS, is a €15 million Research Infrastructure funded by the European Commission's Horizon 2020 framework. ASTERICS will help solve the Big Data challenges of European astronomy and give scientists and members of the public direct interactive access to some of the best of Europe's astronomy images and data in an international framework.

The ASTERICS project is bringing together the astronomy, astrophysics and astroparticle physics communities for the first time, to promote synergy and address common challenges.

"[ASTERICS] will provide for a common and sustainable platform for the interoperability of cosmic observatories."
Prof.dr. M. de Jong,
Spokesperson KM3NeT

### ASTERICS is:

- supporting and accelerating the implementation of the new generation of cosmic observatories foreseen in the European Strategy Forum on Research Infrastructures (ESFRI),
- enhancing their performance beyond the current state-of-the-art,
- helping scientists to access data and interoperate as a single integrated, multi-wavelength and multi-messenger facility.

An important focal point is the management, processing and scientific exploitation of the huge datasets the ESFRI facilities will generate.

ESFRI European Strategy Forum on Research Infrastructures

ASTERICS finds shared solutions to these issues, through a large cooperative approach and exploring innovation paths, by directly engaging and collaborating with industry and specialised SMEs. The various ESFRI pathfinders and precursors are the perfect proving ground for new methodologies and prototype systems.

ASTERICS is also enabling astronomers throughout EU member states to have broad access to the reduced data products of the ESFRI telescopes through a seamless interface to the Virtual Observatory framework. This massively increases the scientific impact of the telescopes and greatly encourages use (and re-use) of the data in new and novel ways.

ASTERICS is ushering in a new era of multi-messenger astronomy by demonstrating cross-facility synchronicity, harmonising policies and creating a distributed and interoperable approach.

Through an active dissemination programme, including the development of educational resources and citizen scientist mass participation experiments, ASTERICS has the ambition to be a flagship for the scientific, industrial and societal impact ESFRI projects can deliver.

# concept and approach

ASTERICS supports the core ESFRI facilities: the Square Kilometre Array (SKA), the Cherenkov Telescope Array (CTA), Cubic Kilometre Neutrino telescope (KM3NeT) and the European Extremely Large Telescope (E-ELT). As well as these, ASTERICS engages with aspiring ESFRI projects (e.g. the Einstein Telescope, ET, under the umbrella of the European Gravitational Observatory, EGO), and several other world-class research infrastructures (e.g. LOFAR, Euclid, LSST and Virgo)

The general management, curation, comparison and scientific exploitation of data rapidly is a major challenge common to all facilities. The **OBELICS** work package (**OB**servatory **E**-environments **LI**nked by common **C**hallenge**S**) focuses on the raw data generated, processed, reduced, archived and accessed by the telescopes, while the **DADI** work package (**D**ata **A**ccess, **D**iscovery and **I**nteroperability) addresses the exploitation of the data products, including its combination from various multi-instrument, multi-wavelength and multi-messenger sources.

The **CLEOPATRA** work package (**C**onnecting **L**ocations of **E**SFRI **O**bservatories and **P**artners in **A**stronomy for **T**iming and **R**eal-time **A**lerts) also addresses some common data challenges, such as user access to data via optimised data transfer techniques originally developed for e-VLBI. CLEOPATRA also includes other connectivity challenges that are particularly important to many of the ESFRI facilities both individually and collectively.

## Guiding Principles

- Work package tasks are built around the ESFRI projects with a focus on advancing and contributing to their design, construction and implementation.
- Activities and their deliverables are of high impact and broadly relevant to as wide a range of the projects as possible, addressing common technical challenges.

## Social Impact

**A key goal of ASTERICS is to engage with society at large. ASTERICS is embracing the principles of Open Science, developing Citizen Science applications and deploying an ambitious programme of public engagement and education.**

ASTERICS is achieving these objectives through the **DECS** work package (**D**issemination, **E**ngagement and **C**itizen **S**cience) in a spirit of 'open innovation' via a close collaboration with the ESFRI projects, other research bodies, industrial players, and local specialised SMEs.

Educating, training and interacting with ESFRI facility staff, industry and the wider user community is also an essential objective. ASTERICS has made a conscious choice to invest in the training and education of both users and ESFRI facility staff. Implicit goals of ASTERICS are capacity building and the training of a new generation of scientists and engineers that will go on to fully exploit the ESFRI facilities.

# trans-disciplinary benefits

Much of the technology development associated with ASTERICS has its origins outside astronomy and astroparticle physics.

Over the last decade, astronomy and astroparticle physics have been able to take great advantage of the huge investments being made in the ICT industry and the resulting advances in high-speed data transport, digital processing, high performance computing and storage capacity.

These ICT and other technological advances led to the establishment of a new set of facilities, the ESFRI telescopes being the latest and most innovative examples.

Astronomy is not only an early adapter of the latest ICT developments but it is also pushing the envelope of the current and projected state-of-the-art.

ASTERICS is bringing significant momentum to these efforts, particularly for the co-development and dissemination of new software frameworks, parallel programming standards and also through transversal training initiatives with broad participation from other fields.

The rise of the Data Scientist in the era of Big Data raises another area where ASTERICS can contribute to human capital development – creating the kind of scientists and engineers that have a skill-set highly sought after in the market place.

What ASTERICS does is to focus on the most challenging areas where there is already evidence of on-going and rapid technical innovation and where innovative paths forward can greatly enhance the effective capacity, impact and scientific return of the ESFRI facilities.

## Ambition & Vision

The astronomy related ESFRI facilities are set to radically change the way we perceive the universe and our place within it. The ambition of ASTERICS is to support and accelerate the implementation of these instruments, to enhance their performance beyond the current state-of- the-art, and to see them interoperate as an integrated, multi-wavelength and multi-messenger facility.

Together, the ESFRI projects open new windows on the universe, significantly extending our observational capabilities across the electromagnetic spectrum, in addition to neutrino detectors and gravitational waves.


"[ASTERICS] will be an invaluable instrument to enable the further progress of the ESFRI projects it unites, addressing the strategic objectives [and] connecting the different facilities to enhance combined science capabilities."
Dr. Ronald Stark, Chair, ASTRONET Board

# structure of ASTERICS - five packages for success

## ASTERICS is split into five work packages.

The Management work package deals with the governance and management of the project and plays a crucial role in terms of maintaining oversight of the project. It also supports ESFRI facilities harmonising their joint and efficient scheduling, operation and interoperability.

The **D**issemination, **E**ngagement and **C**itizen **S**cience (**DECS**) work package ensures the dissemination of the results from ASTERICS as well as engagement with project stakeholders and the general public are adequately addressed.

The **OBELICS** (**OB**servatory **E**-environments **LI**nked by common **C**hallenge**S**) and **DADI** (**D**ata **A**ccess, **D**iscovery and **I**nteroperability) work packages have a strong and interrelated focus on delivering common solutions, standards and analysis techniques to fully exploit large volume data streams. Training, to ensure facility users and staff are fully engaged, is also a key aspect.

Finally, **CLEOPATRA** (**C**onnecting **L**ocations of **E**SFRI **O**bservatories and **P**artners in **A**stronomy for **T**iming and **R**eal-time **A**lerts) is a coherent collection of common challenges related to synchronisation, scheduling and cross-facility coordination – crucial in terms of rapid response to (multi-messenger) transient alerts.

## Management Support Team (MST)

This work package guarantees the smooth execution of all financial, administrative and reporting elements of the project. It also exercises central control and oversight of the scientific and technical progress of the project, as measured by the successful receipt of deliverables and secured milestones.

The culmination of ASTERICS will be a grand Integrating Event to show-case the results of the project and their relevance to the ESFRI telescopes.

# Dissemination, Engagement & Citizen Science (DECS)

The DECS work package aims to promote ASTERICS and facilitate engagement with the ESFRI facilities from the widest possible audience. The primary channels for this interaction are:

- High quality promotional, coordination and engagement materials (print and web-based) that embrace the principals of Open Science.
- Web-based interfaces that open up the ESFRI facilities and ASTERICS to the general public via open educational resources and learning journeys.
- Four Citizen Science mass participation experiments (MPEs) for SKA, CTA, KM3NeT, and E-ELT.
- Internal dissemination of ASTERICS' results and promotion of the project within the community.
- A series of sixty-second animations highlighting the science of the ESFRI facilities inviting the viewer to participate in the related mass participation experiment.
- Attendance of high-level events and meetings where ASTERICS results can be showcased to external stakeholders, including industrial and commercial concerns.

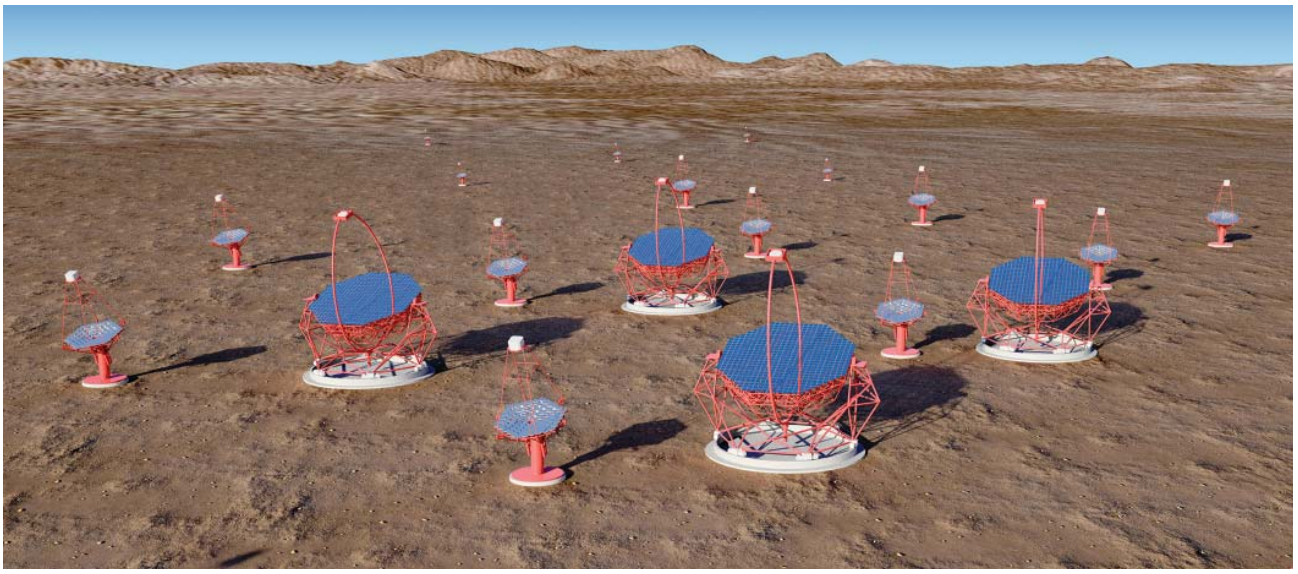
Many of the resources are translated and adapted for different international communities and face-to-face interaction is a key method of testing and evaluating these resources. The primary driver here is attracting and facilitating ongoing engagement by young people with the 'learning journey' leading them to further educational resources outside of ASTERICS.


"[ASTERICS] has the potential to take [Citizen Science] to a new level for multiple facilities, to deliver exciting new science and to provide a major and highly visible public outreach activity." Professor Philip Diamond, Director General of the SKA

### National & International Innovation

The Open University's Wolfson Open Science Laboratory (the portal for the Open Science activities) is already a successful platform for Citizen Science experiments, and is an area of active pedagogic and learning research.


DECS will also make use of the Zooniverse project (through Oxford University), which itself is a highly successful and scientifically productive international crowdsourcing resource. Even before the start of ASTERICS, Galaxy Zoo had generated 44 papers, Planet Hunters 8 papers, and there had been nearly 20 published papers from several other Zooniverse.org scientific crowdsourcing projects. Some of these are also highly relevant to ASTERICS e.g. Spacewarps and Radio Galaxy Zoo.



## OBservatory E-environments LInked by common ChallengeS (OBELICS)

OBELICS is enabling interoperability and software re-use for the data generation, integration and analysis of the ASTERICS ESFRI and pathfinder facilities. OBELICS is creating an open innovation environment for establishing open standards and software libraries for multi-wavelength/ multi-messenger data. OBELICS is also developing common solutions for streaming data processing and extremely large databases, as well as studying advanced analysis algorithms and software frameworks for data processing and quality control.

The specific objectives are:

- Train researchers and data scientists in the ASTERICS ESFRI and pathfinder projects to apply state-of-the-art parallel software programming techniques, to adopt Big-Data software frameworks, to benefit from new processor architectures and e-science infrastructures.
- Maximise software re-use and co-development of technology for the robust and flexible handling of the huge data streams generated by the ASTERICS ESFRI and pathfinder facilities.
- Adapt and optimise extremely large database systems to fulfil the requirements of the ASTERICS ESFRI projects.
- Study and demonstrate data integration across ASTERICS ESFRI and pathfinder projects using data mining tools and statistical analysis techniques on Petascale data sets.

All tasks are built upon the state-of-the-art in ICT, in cooperation with major European e-infrastructures and are conceived to minimise fragmentation. Communications and links with other communities and e-science service providers are considered in order to contribute to the effectiveness of the OBELICS objectives.

### National & International Innovation

The partners of OBELICS are major contributors to the innovation of distributed computing infrastructures and new computing architectures, as well as national integrated supercomputing facilities. Previous European initiatives and the expertise gained from them will certainly contribute to OBELICS' activities, as well as the outcomes of some running public-private initiatives, particularly in the field of astronomical image data processing, support facilities and services for data management.

The active participation in key open-source software solutions for data management or data format standards is a central pillar of OBELICS' approach and the FITS (Flexible Image Transport System), the most commonly used digital file format in astronomy, is a historical example of astronomical long term research and innovation activities feeding into the ASTERICS programme.

Open source software projects providing solutions for authentication, authorisation and trustworthy exchange of information and work flow systems, as well as the outcomes of some running public-private initiatives, will provide a direct flow of expertise and knowledge into OBELICS and thus support the concerned ESFRI projects towards their implementation phase.

# Data Access, Discovery and Interoperability (DADI)

DADI aims to make the ESFRI and pathfinder project data available for discovery and usage by the whole astronomical community, interoperable in a homogeneous international framework, the Virtual Observatory (VO), and accessible with a set of common tools.

The objectives of DADI are to:

- Train and support ESFRI project staff in the usage and implementation of the VO framework and tools, and make them active participants in the development of the VO framework definition and updates, thus contributing to relevance and sustainability of the framework.
- Train and support the wider astronomical community (with specific focus on students at the PhD and post-doc level) in scientific use of the framework, in particular for pathfinder data (i.e. test data from facilities such as LOFAR, MAGIC and IceCube), and gather their requirements and feedback.
- Adapt the VO framework and tools to the ESFRI project's needs, and make sure European astronomers remain lead actors in the IVOA, highlighting the needs of the European infrastructures and the European scientific community.

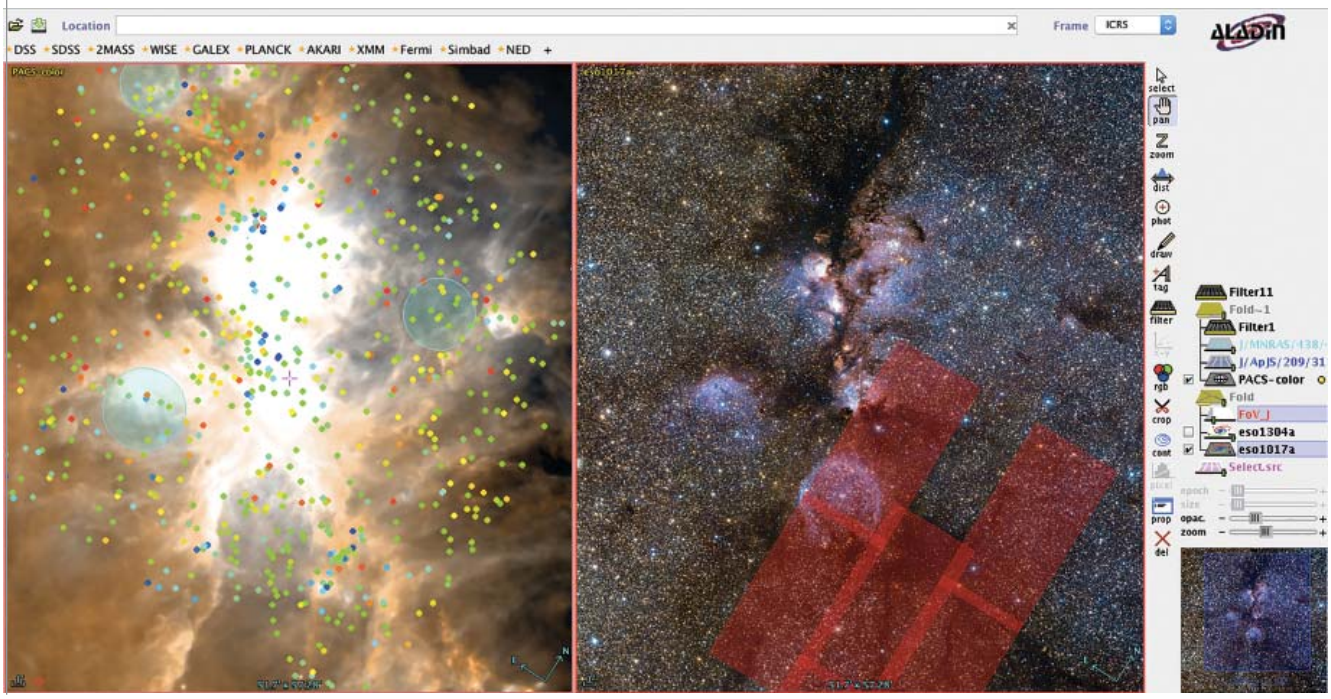
## National & International Innovation

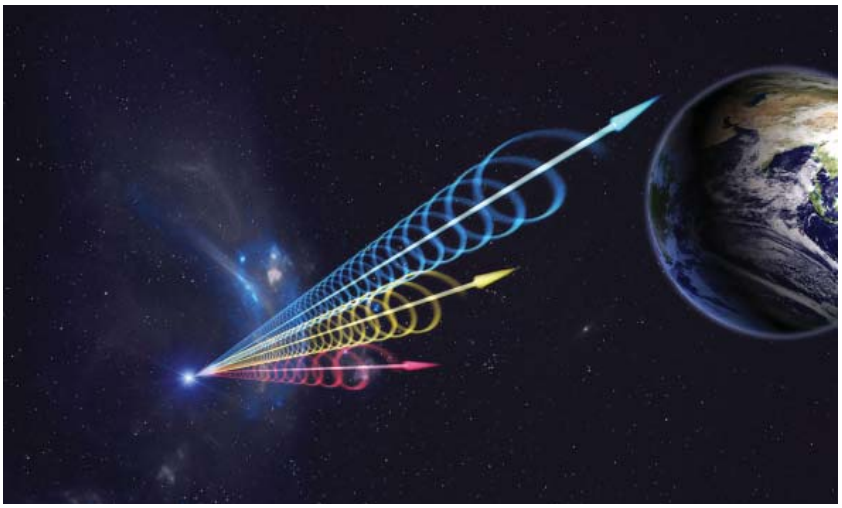
The activities of DADI build on the previous European Commission FP5-7 projects supporting the development of the European Virtual Observatory, Euro-VO. Like these projects, it will make use of, and participate in, the development of the VO framework as defined by the IVOA (International Virtual Observatory Alliance). Representatives of DADI will also participate in the IVOA Working Groups, in order to perform the work necessary to implement ESFRI needs within the framework.

More generally, the Research Data Alliance (RDA) builds the social and technical bridges that enable open data sharing across disciplinary borders. The way the generic framework defined by the RDA will interface with the disciplinary IVOA has to be assessed. Therefore the outputs of the RDA will be closely monitored and building blocks proposed thereby will be implemented within IVOA whenever relevant. DADI will also participate in the RDA activities to ensure the ESFRI requirements are properly accounted for.

The fact that ESO is an associate partner with several ASTERICS work packages ensures convergence with the other major European ground facilities under their responsibility.

"ESO recognises the strategic importance to exploit synergies to ensure harmonisation and interoperability between various ESFRI facilities..." Prof. Tim de Zeeuw, ESO Director General





## Connecting Locations of ESFRI Observatories and Partners in Astronomy for Timing and Real-time Alerts (CLEOPATRA)

The partners in ASTERICS share an ambition to use modern communication methods, such as fast broadband connectivity, to improve the scientific capabilities of their research infrastructures. The research activities aim specifically at synergetic observing modes and fast and reliable access to large data streams. CLEOPATRA is therefore a coherent collection of common challenges related to connectivity, synchronisation, scheduling and last but not least, cross-facility coordination – the latter being especially crucial in terms of response to (multi-messenger) transient alerts.

The objectives of CLEOPATRA are to:

- Develop technology to enable long-haul and many-element time and frequency distribution over fibre connections.
- Develop methods for relaying alerts which will signal transient event detections between the facilities and enable joint observing programmes, including scientific strategies and methods for joint observing.
- Further development of existing data streaming software, building on the success of previous e-VLBI projects, and providing tools for robust and efficient data dissemination for all facilities in the user domain, including ESO facilities such as ALMA and the E-ELT.
- Foster the development of advanced scheduling algorithms, using artificial intelligence approaches for optimal usage of the ESFRI facilities.
- CLEOPATRA's tasks reflect a consistent set of enhancements of the facilities based on developments in connectivity and data transport.

### National & International Innovation

CLEOPATRA's work builds partly on the results generated from the highly successful European Commission FP6 & 7 projects, EXPReS (www.expres-eu.org) and NEXPReS (www.nexpres.eu). Similarly, the goal of enabling long-haul and many-element time and frequency distribution over fibre connections (which has the potential to increase the efficiency and affordability of all radio astronomy facilities) will make significant use of the advances already made via the White Rabbit Ethernet project (www.ohwr.org/projects/white-rabbit).

The work on transient detection is based on the previous IVOA VOEvent development which pioneered the rapid response mechanisms for heterogeneous telescope arrays and CLEOPATRA also takes advantage of many years of experience in space technology to use clever software solutions for complex scheduling problems.

## Acknowledgements

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