Asterics

Astronomy ESFRI & Research Infrastructure Cluster

ABOUT ASTERICS

ASTERICS is a collaborative project in astronomy and astroparticle physics that has the following goals:

- Work together on common solutions for shared challenges by different research infrastructures, instead of solving them for each research infrastructure independently.
- Share and expand knowledge, experience and developments to advance innovation and science.
- Collaborate to make exchanges among people and instruments and create the right conditions for multi-messenger astrophysics.

This work is done in the context of ESFRI research infrastructures and other related infrastructures in astronomy and astroparticle physics.

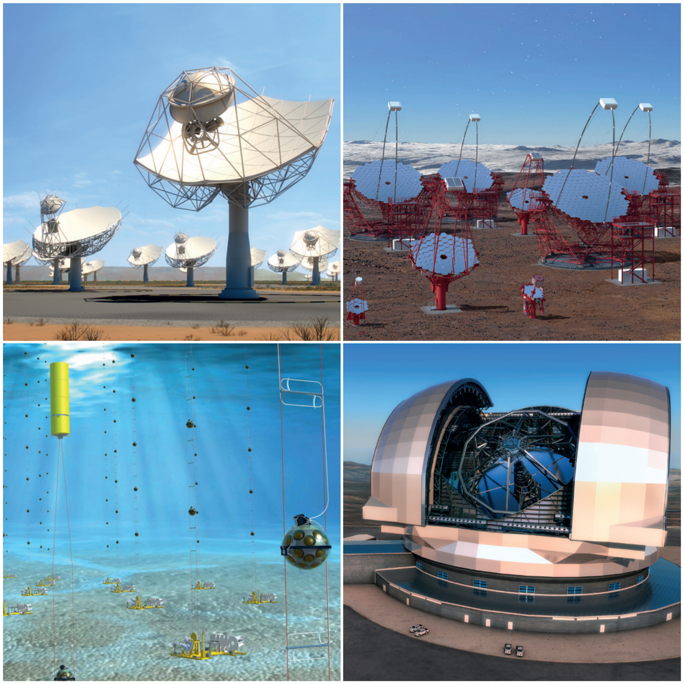
In this brochure you will find a short overview of the ASTERICS project results. Since the project is ongoing, new results are expected and will be added to our website.

The results in this brochure are divided in three main categories:

- Data: collection, handling, preservation and analysis.
- Multi-messenger astrophysics: getting a more comprehensive understanding of events and objects in space by looking at different messengers and wavelengths simultaneously with different telescopes.
- Timing: this is important to link facilities for multi-messenger astrophysics.

ESFRI RESEARCH INFRASTRUCTURES

An ESFRI research infrastructure is a facility, resource or service with the unique ability to conduct top-level research activities according to the European Strategy Forum for Research Infrastructures (ESFRI). An ESFRI is identified and classified based on its importance for European research and innovation for the coming decades. The Extremely Large Telescope (ELT), the Cherenkov Telescope Array (CTA), the km^3 Neutrino Telescope (KM3NeT) and the Square Kilometre Array (SKA) are research infrastructures in astronomy and astro(particle) physics that are classified as ESFRIs. ASTERICS was created around these four ESFRIs. The European Solar Telescope (EST) received ESFRI project status in 2016.



Credits: Top left: SKA, top right: CTA, bottom left: KM3NeT, bottom right: ELT

COLLABORATION OPPORTUNITIES

We are looking for new collaboration opportunities – also outside the fields of astronomy and astroparticle physics

Besides the work carried out by partners directly involved in ASTERICS, the collaboration aims to establish connections with external partners, in other research fields or in industry. The goal of these connections is to use developments made in the ASTERICS community for other applications outside of astronomy and astro(particle) physics, or to use developments made outside of these research fields to advance developments in the ASTERICS community.

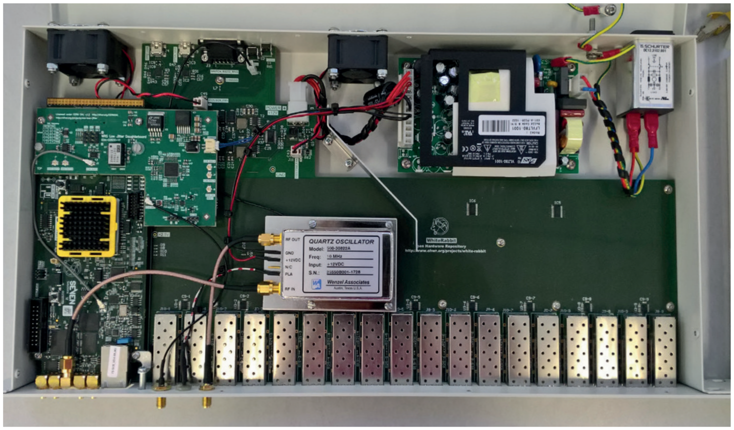
Are you interested in collaboration or are you looking for more information? We invite you to contact us at asterics@astron.nl.

INTO THE FUTURE

ASTERICS is the first step towards bringing our different research communities together to solve common challenges. At the end of the project we expect to have made many concrete advances in the development of ESFRI facilities. In addition, important advances in collaboration between our research communities are already being made, for example by defining policies around scheduling and operations. This offers a base for future collaborations. This will be especially important as the focus in research shifts from looking at one wavelength or one messenger at a time towards multi-messenger and multi-wavelength science. The network built under the ASTERICS name can continue to serve this larger research community, and also be expanded to include other research fields dealing with similar challenges.

TIME DISTRIBUTION

In an extensive network of instruments it is important for each instrument to know the correct time. The obvious choice would be to give every instrument a reference clock. White Rabbit (WR) Ethernet can distribute the signal from one clock to many clients even over public fiber-optic networks, and thus presents an attractive and cheaper solution.



WR hardware with the added low jitter daughterboard and phase locked oscillator (photo credit: OPNT/Chantal van Tour).

Improving and testing in the laboratory

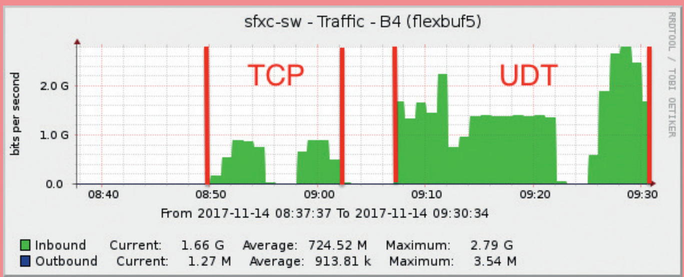
Several ASTERICS groups work on improving WR hardware:

- Upgrade with a low jitter daughterboard and a phase locked oscillator. Time and frequency are transferred in a stable way from a single reference clock to multiple clients in a wide-area fibre-optic network.
- Adaptation of WR to enhance data bandwidth for large amounts of data that will be produced by instruments like SKA and CTA. More than 500 Mb/s of reliable data throughput was achieved while synchronizing over the same network to a fraction of a nanosecond.
- Setup of a hierarchical WR network to get a high relative timing precision between different telescope cameras. We used 32 WR timing nodes to mimic 32 CTA telescopes.

IACT telescope of the TAIGA project, where WR hardware is tested in field conditions in conjunction with an array of Cherenkov light detectors (photo credit: DESY/Ralf Wischnewski).

Improving and testing in field conditions

Many instruments are in remote locations and operate under harsh conditions, such as extreme temperatures and drought. A good place to study the stability of WR hardware in long-term exposure to harsh conditions is Siberia. This is the location of the Tunka Advanced Instrument for Gamma ray and cosmic ray Astrophysics (TAIGA) project. We use it as a test facility for devices like WR that are also used in other facilities.



A large amount of data was transferred three times faster using UDT (on the right) than using TCP (on the left). (Image credit: JIVE/Harro Verkouter)

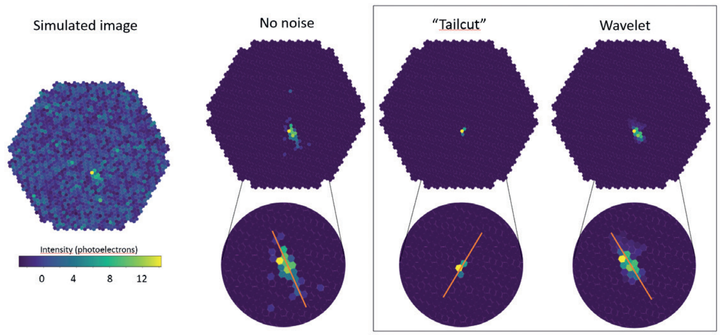
A new, simple tool for faster transport of large data sets

The currently used network protocol (TCP) stems from a time when data files were small and collaborations were not as global as today. A new tool using another protocol (UDP) was written and it has been shown that it can transfer a large amount of data from the Netherlands to New Zealand three times faster than TCP.
Astronomy is a field with an immediate need for this, as new instruments will generate large data sets.

DATA PROCESSING

Camera image cleaning using wavelet filtering

CTA telescopes have cameras made of over a thousand photomultiplier pixels to capture Cherenkov light induced by gamma ray or cosmic ray particle showers in the atmosphere. In order to reconstruct the shower images with the best precision, we use wavelet filtering to remove the underlying night sky and electronic background noise. When we tried this technique on CTA simulated data, wavelet filtering gave better direction and intensity estimates than traditional techniques for all camera types in CTA, improving the subsequent discrimination of gamma rays against cosmic-ray background.



Example of a faint shower image cleaning (Gamma ray of 100 GeV in Nectarcam). From left to right: the simulated image, the image without noise, the result of the double threshold cleaning and the wavelet filtering. The red line shows the shower direction estimated from the available information. (Image credit: CEA/Thierry Stolarczyk)

Lossless data compression

Compression of data can solve the technical constraints of the large amounts of data produced by research infrastructures. The problem with compression is that it can alter physical data. The lossless compression algorithms used so far have compression speeds that are too low for large data quantities. We have developed a lossless data compression that achieves very good compression rates in a short time.

Technically the new method stores several values of data into one unsigned int and a basis that consists of the data minimal value and the range of data values.

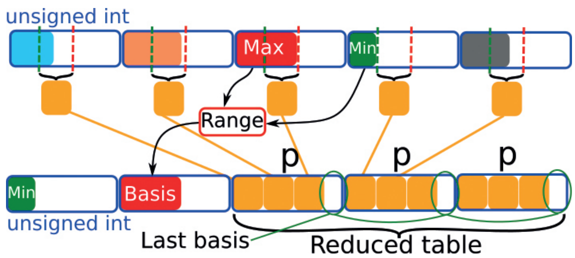
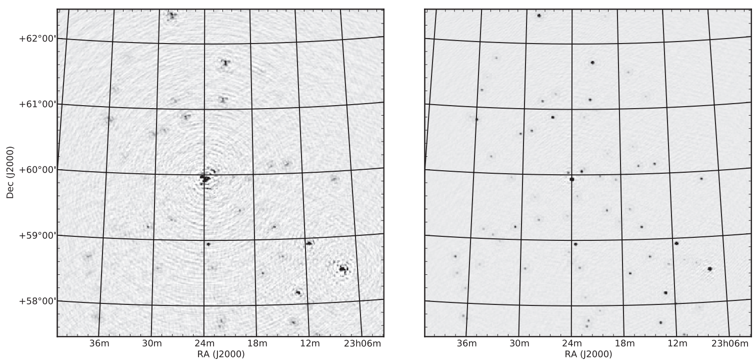


Illustration of the lossless data compression principle. (Image credit: Aubert et al.)

Image domain gridding

The ionosphere disturbs the radio signals detected by radio telescopes and causes blurred images. The current way to transform signals into images requires a great deal of computing, because the ionospheric effects change continuously. These computing needs would cause a problem for telescopes like SKA, which will produce huge amounts of data. We developed a new gridding procedure using parallel processing. With current trends in computing hardware improvements, processors are becoming faster, but the speed of the memory is not changing at the same rate. By creating an algorithm optimised for parallel processing, the processors are used more intensively, and less is required of memory. This leads to a faster and better gridding procedure.



Left: A radio signal (simulation) without ionospheric correction Right: With ionospheri correction (Image credit: ASTRON/Sebastiaan van der Tol)

DATA ACCESS

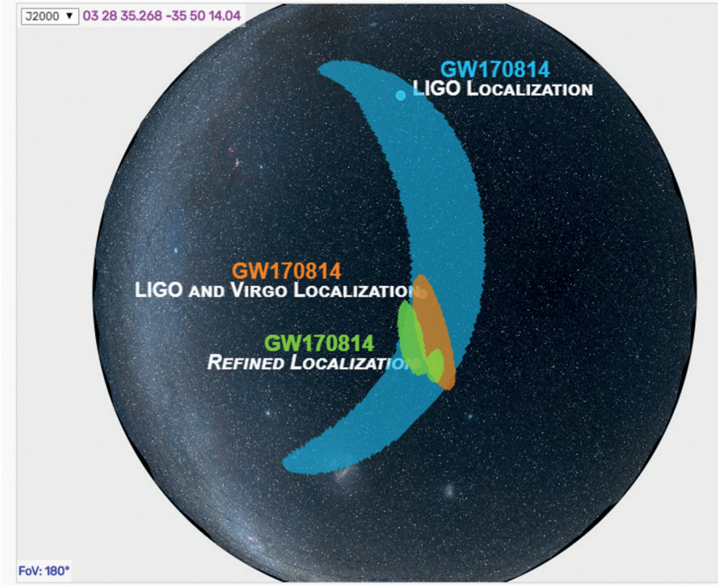
Open Access libraries

We developed several Open Access libraries for astronomical and astrophysical data. CORELib provides simulated cosmic ray events and ROAst is an extension for the ROOT framework. ROOT is commonly used in high-energy physics. CORELib is also interesting for other communities that use muon radiography. It could be used for geophysics (for example for imaging volcanic edifices and faults) and cultural inheritance (for example for imaging pyramids and other large structures).

Virtual Observatory: integration of astronomy and astro(particle)physics data, tools and services

The Virtual Observatory (VO) allows researchers to easily use astronomical data from instruments around the world and to use the VO's tools on this data. Within ASTERICS, the ESFRI facilities' data is prepared for the VO and scientists receive training on VO tools. We also work on the development of new International Virtual Observatory Alliance (IVOA) standards.

A recent example of how the astronomical and astroparticle physics community uses the VO is for gravitational wave follow-up. The GWSky script for gravitational waves in the Aladin Sky Atlas was developed in the context of ASTERICS.



Gravitational Wave researchers use VO tools to display results and to gather follow-up information. (Image credit: LIGO-VIRGO collaboration, Aladin Sky Atlas - Mellinger background survey.)

Citizen Science: engaging the general public in scientific research

Part of our mission is to engage with the general public as well as technical audiences. That is why we are developing citizen science experiments that address science questions, while involving the public in knowledge discovery. Our Muon Hunter project has been a runaway success. The goal of this project is to search for muons originating from cosmic rays. The project uses data from the Very Energetic Radiation Imaging Telescope Array System (VERITAS), which in turn is a precursor facility for the CTA. The public response has been spectacular, with 1.3 million classifications in the first five days.

Software and data preservation

In astronomy and astroparticle physics, software and data need to be preserved over long periods. This period can span over several decades, from the first data collecting to the final analysis.

We are developing solutions that package together a working operating system including the necessary software with the data to preserve the full information over long periods. These are called container images.

MULTI-MESSENGER ASTROPHYSICS

Scheduling algorithms for large and distributed infrastructures

In multi-messenger astrophysics, multiple facilities observe target objects using different messengers and wavelengths to obtain a more comprehensive picture of events. It is important to schedule the observations carefully in order to make efficient use of the assets and maximise their time on-source. Many factors must be taken into account, for example the weather, instrument availability, and target visibility at each facility. Data access policies and the provision of platforms to enable schedule sharing and optimization need also to be considered.

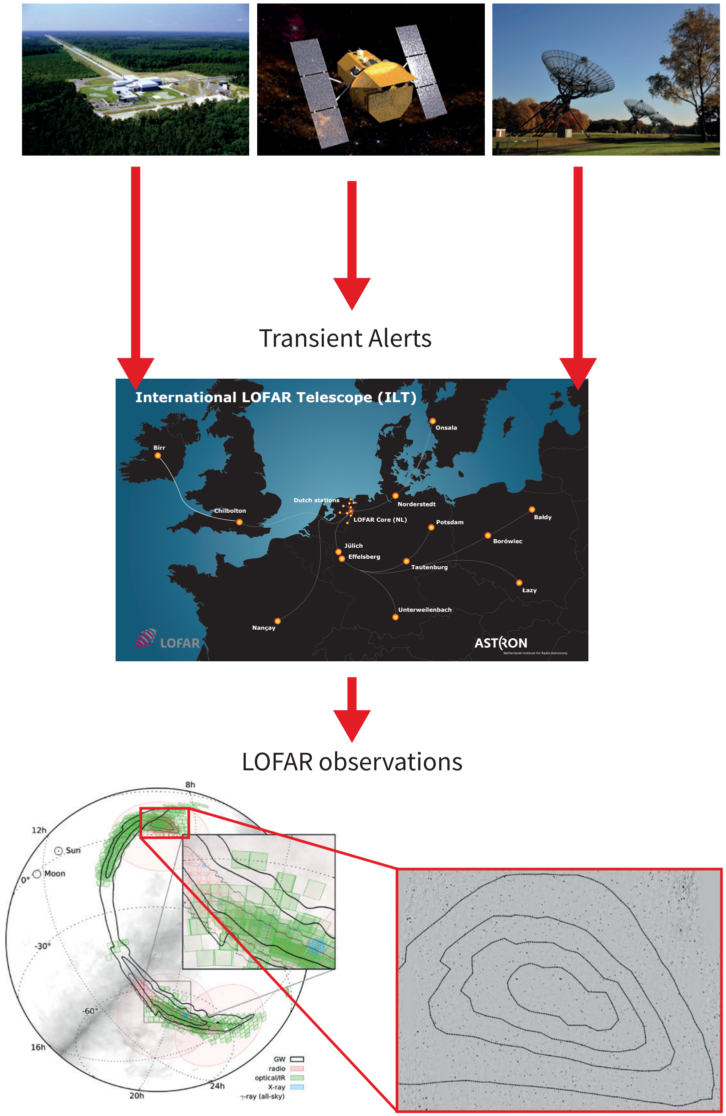
Using CTA and SKA as an example, we have developed an algorithm for scheduling pre-planned coordinated observations. We are extending this to enable quick follow-up campaigns after transient alerts, expecting there to be a flood of these from upcoming survey instruments.

Software development for responsive telescopes

A team of developers worked closely together with end users in a Scrum framework to develop software that allows the LOw Frequency ARray (LOFAR) telescope to respond rapidly to external triggers from other instruments. In 2017, we successfully implemented LOFAR's rapid response mode. LOFAR can now start conducting observations within 5 minutes of receiving an alert.

Responding to alerts with LOFAR

After receiving an alert, researchers can use the full capabilities of the LOFAR array. They search for bright, low frequency radio flashes from transients such as neutron star mergers and fast radio bursts. After a transient event we make a snapshot image of the region from which the gravitational wave source is thought to originate and search for new sources appearing in the images. In the future, the newly commissioned rapid response mode for LOFAR will be used to search for a bright radio flash at the time of the merger.



The LOFAR array (middle) receives alerts from other detectors such as LIGO, Swift Satellite and the Westerbork telescope (top). The bottom picture shows how a snapshot image is made with LOFAR in part of the gravitational wave source. (Image credits: Caltech/MIT/LIGO Lab) top left), NASA (top middle), ASTRON (top right), ASTRON (center), Abbott et al. The Astrophysical Journal Letters 2016 (bottom left), ASTRON/J. Broderick and A. Rowlinson (bottom right).

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Astronomy ESFRI & Research Infrastructure Cluster

Visit our website to learn more about ASTERICS and get involved!

www.asterics2020.eu

European Commission

Horizon 2020
The EU Framework Programme for Research and Innovation

ASTERICS is a project supported under grant agreement n. 653477

With contributions from:
Chantal van Tour and Jeroen Koelemeij (OPNT/Vrije Universiteit, the Netherlands), Javier Diaz (University of Granada, Spain), Heike Prokoph, Arnim Balzer and David Berge (University of Amsterdam, the Netherlands), Ralf Wischnewski (DESY, Germany), Josep Colomé Ferrer (IEEC, Spain), Alan Bridger (Science and Technology Facilities Council, United Kingdom), Auke Klazema, Jess Broderick, Antonia Rowlinson and Sebastiaan van der Tol (ASTRON, the Netherlands), Thierry Stolarczyk (CEA, France), P. Aubert, T. Vuillaume, G. Maurin, J. Jacquernier and G. Lamanna (CNRS, France), N. Ernad (UFR des Sciences and University of Versailles, France), Kay Graf (Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany), Cristiano Bozza (INFN, Italy), Harro Verkouter (JIVE, the Netherlands), Stuart Weston (Auckland University of Technology, New Zealand), Françoise Genova and Mark Allen (CDS/CNRS, France), Stephen Serjeant (Open University, United Kingdom)

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ASTRON, OPNT, DESY/Ralf Wischnewski,
ESO, KM3Net , CTA, SKA
SKA, CTA, ESO