ASTERICS
Connecting multi-messenger astrophysics

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what is ASTERICS?

Astronomy ESFRI & Research Infrastructure Cluster

A major collaboration (23 partner institutions) in astronomy, astrophysics and astroparticle physics.

It is funded by EC Horizon 2020 framework at € 15M for 4 years *(2015-2019)*

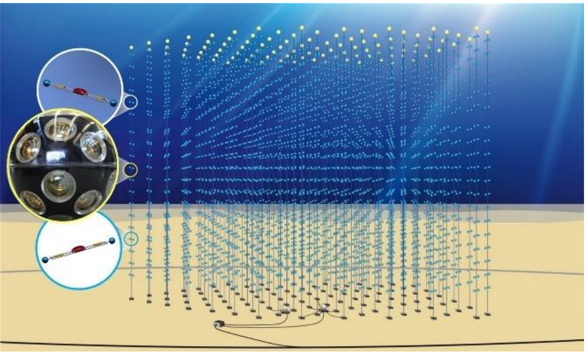
Scope of ASTERICS:

To help solve the **Big Data** challenges of European astronomy
To provide direct interactive access to the best European astronomy data in an international framework
Cross-cutting synergies and common challenges

concept and approach

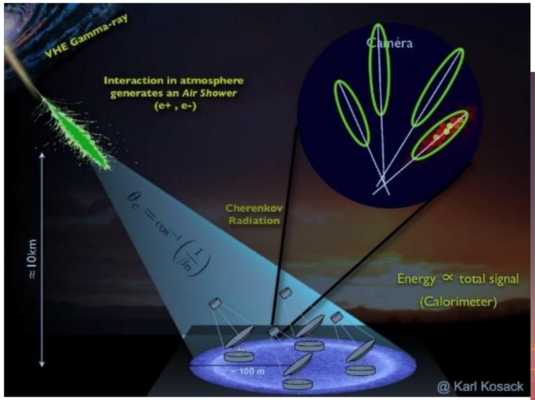
- Supporting the European Strategy Forum on Research Infrastructures (ESFRI)

European Strategy Forum
on Research Infrastructures



A multi-km^3 neutrino telescope

Exploring our galaxy for high energy neutrino sources
KM3Net2 on timescale of 2020



Very high energy γ-ray observatory
Two arrays of 100 (N) and 20 (S) telescopes
Event re-construction
Complex metadata
Streaming and processing challenges
Precursors: MAGIC and HESS

SKA-LOW, Australia

Phase 1: 130,000 dipoles over 80 km
Phase 2: 500,000 dipoles over 250 km

SKA-MID, South Africa

Phase 1: 200 dishes over 150 km
Phase 2: 2500 dishes over 3500 km

Phase 1 *(2018-2023)*
Phase 2 *(2025-2033)*

Challenges everything…

General purpose optical/infrared telescope

- high redshift galaxies
- star formation
- exoplanets
- protoplanetary systems

39m European-Extremely Large Telescope
First Light targeted for late 2024

concept and approach

- Supporting the European Strategy Forum on Research Infrastructures (ESFRI)
- Aspiring ESFRI projects + pathfinders
- Other world-class research infrastructures
  - e.g. LOFAR, Euclid, LSST, Virgo

European Strategy Forum on Research Infrastructures
ESFRI

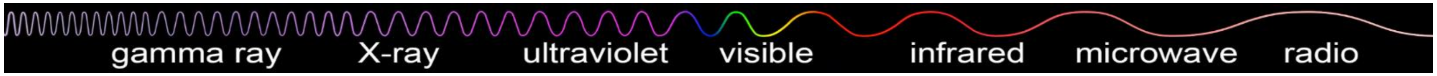
Together, the ESFRI projects – and their pathfinders – open new windows on the universe, significantly extending our observational capabilities across the electromagnetic spectrum, in addition to neutrino detectors and gravitational waves

addressing common challenges
in astronomy and astroparticle physics

- ***supporting*** and ***accelerating*** the implementation of a new generation of observatories
- ***enhancing performance***
- helping scientists to access data

ESFRIs interoperating as an integrated multi-λ, multi-messenger facility

multi-λ, multi-messenger

- messengers: **photons, ν, gravitational waves, VHEγ**
- multi-λ: 

- transient source astronomy

To make it happen…

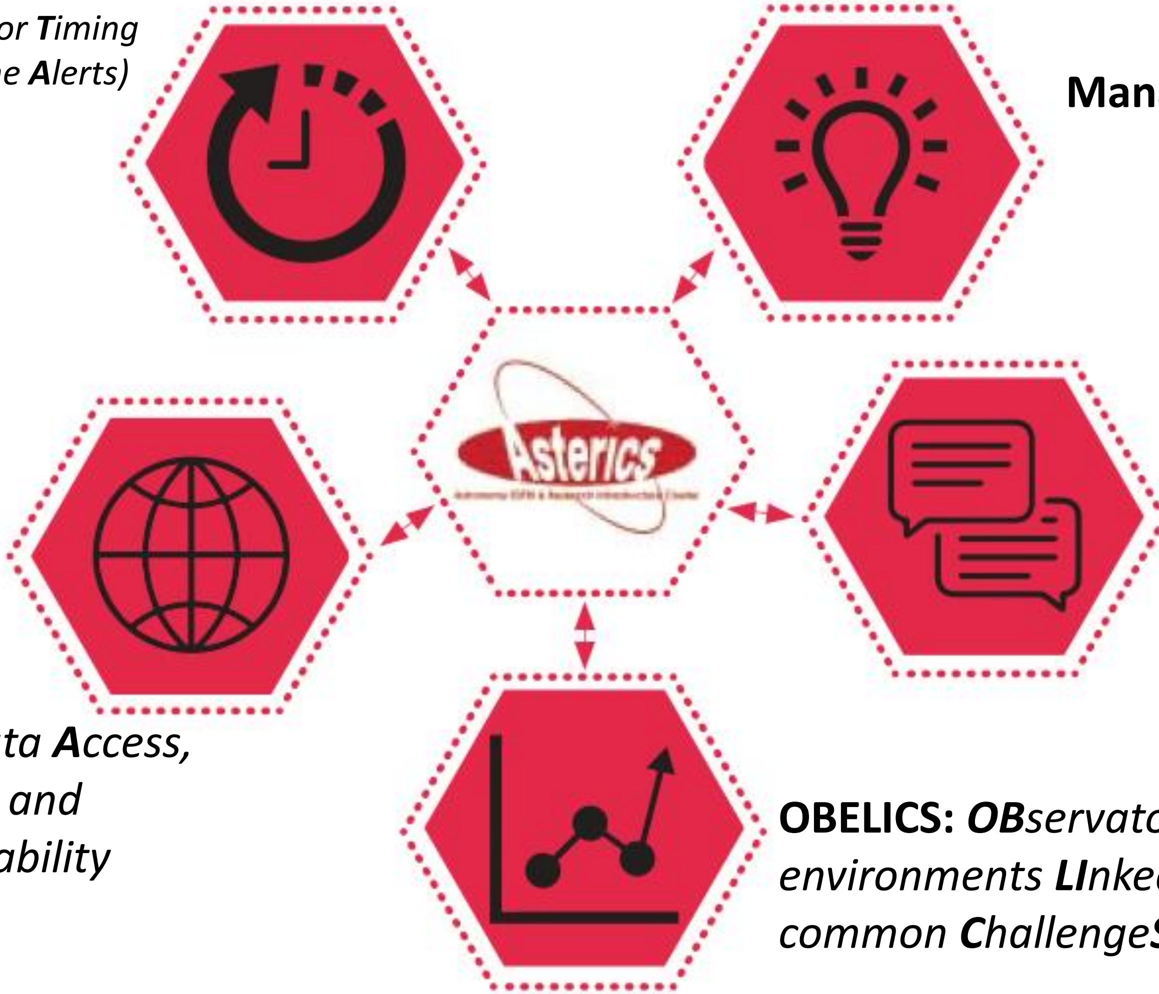
- Cooperation, Interoperability, Open Data
- Scalability – processing and analysis
- Big Data, Data mining, Data Access
- Streaming and timing

connections & openness

- connecting infrastructures: enhancing individual capabilities - necessary for science!
  - *ICT: high speed data transport/timing*
- Embracing ***Open Science, Open Access, Open Data***
  - improve knowledge circulation
  - many challenges, many opportunities
- Engage with society at large
  - Astro community, education, public

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)*

Management



DECS: ***D**isseminaton, **E**ngagement and **C**itizen **S**cience*

DADI : ***D**ata **A**ccess, **D**iscovery and **I**nteroperability*

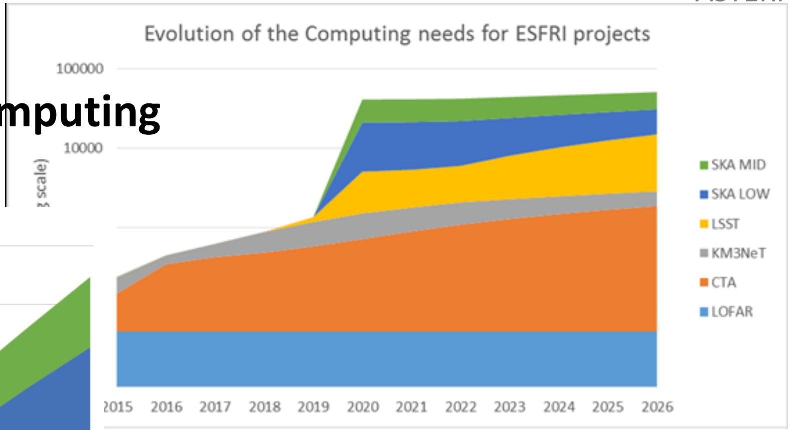
OBELICS: ***OB**servatory **E**-environments **LI**nked by common **C**hallenge**S***

Challenges

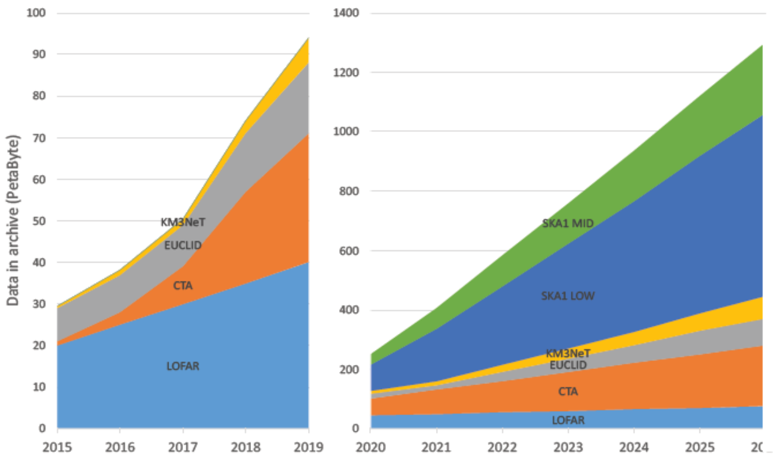
- Big Data
- Data Access
- Multi-Messenger
- Open Science

• Parallel software programming techniques, to adopt big-data software frameworks, to benefit from new processor architectures and e-science infrastructures.
• Software re-use and co-development of technology
•Adapt and optimise extremely large database systems
•Virtual Observatory and VOEvents
•Cooperation with the ESFRI pathfinders, computing centres, e-infrastructure providers and industry
•Public engagement and Citizen Science

Evolution of **storage needs and computing needs** for the ESFRI Projects



Evolution of the Computing needs for the ESFRI projects



Evolution of storage needs for the ESFRI Projects

Innovative application of the ***docker* container**

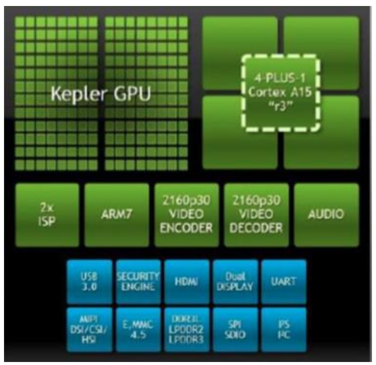
Jupyter notebook of the CASA 3C391 VLA continuum tutorial running inside a web browser on a tablet

Lossless compression algorithm produced for astro(particle) experiments. Now under discussion and tests in more ESFRI scenarios.

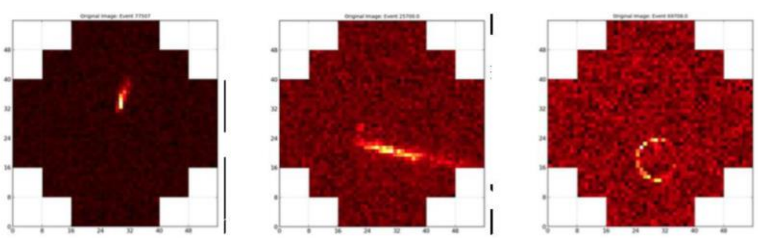
Libraries for **fast, vectorised, array reductions and moment calculations** written in C++ with Python binding, potentially have **an impact outside of astronomy** since they implement fairly generic operations

Big Data

Low power architectures benchmarking for building innovative computing, storage and data handling platforms.



Exploitation of LPC architectures **for map/reduce applications.**



Optimisation and parallelization of algorithms for data reduction and analysis in order to exploit the low-power computing facilities

- Development of **high performance computing solution**
- Notebook interface (VLBI in the Cloud) can be of use for **all radio interferometric data analysis**
- General-purpose library of **A&A** and **workflow management** systems
- Contribution to define specifications in an **open data format** within the gamma-ray community
- **Data streaming and architecture** of the data processing unit in SKA

Data Access

Virtual Observatory

- The VO can be seen as a kind of club of **data services** that all follow the same rules.
- International Virtual Observatory Alliance
  IVOA standards
- Interface between domain-specific & generic infrastructure
- New and archive data

DADI technology Forum	17-18 Sept 2015, Strasbourg
ASTERICS European Schools open call to European Astronomers (PhD, Post-doc) 50 participants	Dec 2015
ESFRI Forum and training event network, share lessons learnt, discuss requirements, training	Dec 2015
Data provider Forum open to all European Data providers	Nov 2016, Heidelberg

Virtual Observatory

Visualisation with VO tools

IceCube-40 String data

- 12,877 candidate neutrino events
- Event list managed using the Topcat VO tool

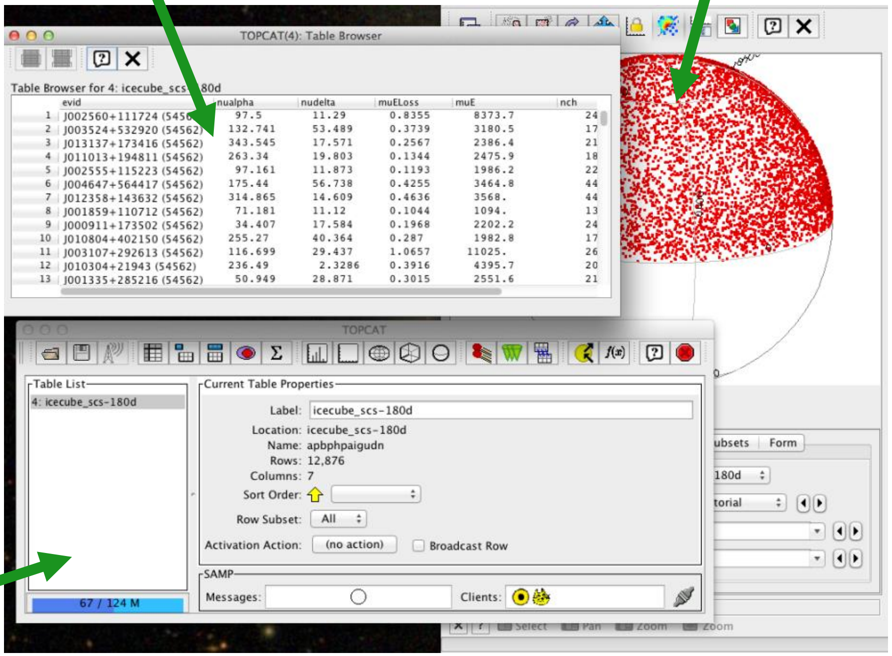
http://www.star.bris.ac.uk/~mbt/topcat/

- Visualisation through the Aladin VO portal

http://aladin.u-strasbg.fr/aladin.gml

view table

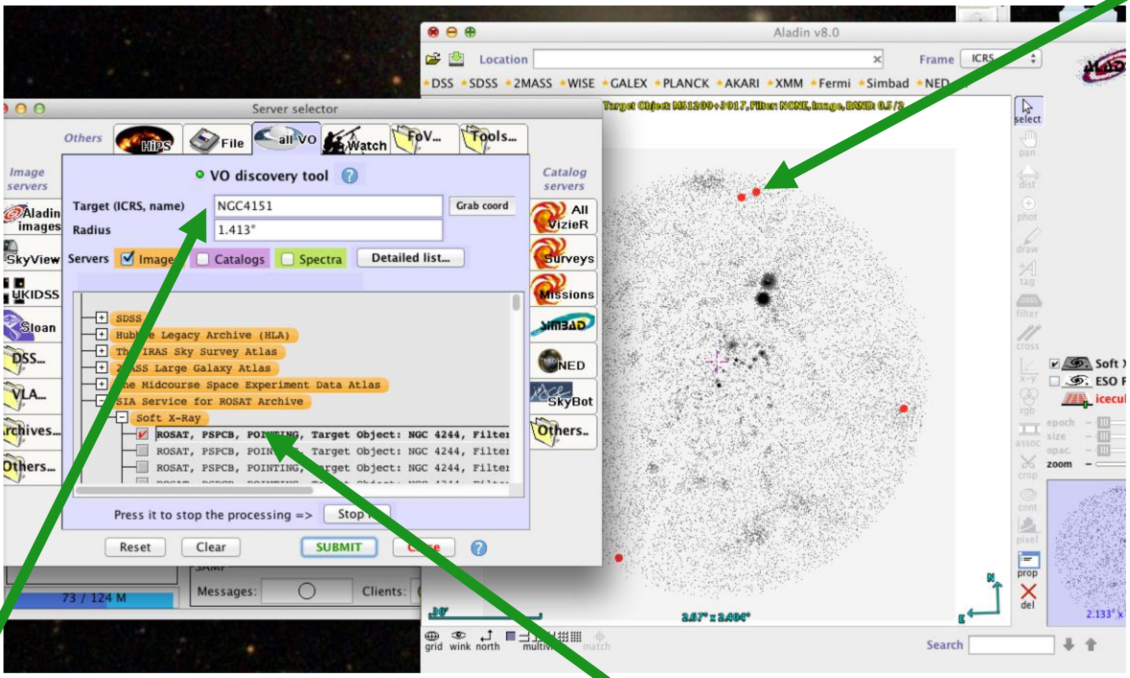
sky plot



database loaded into Topcat

Virtual Observatory

show neutrino events overlaid on X-ray image



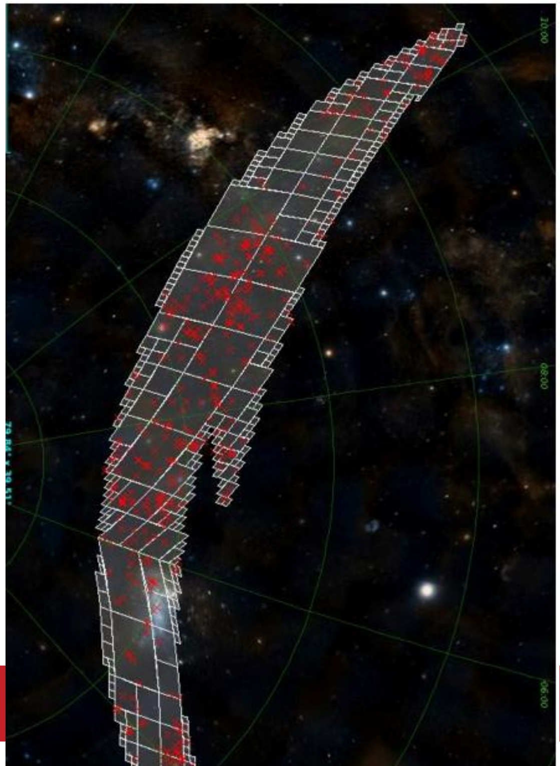
In Aladin, search for images of NGC 4151

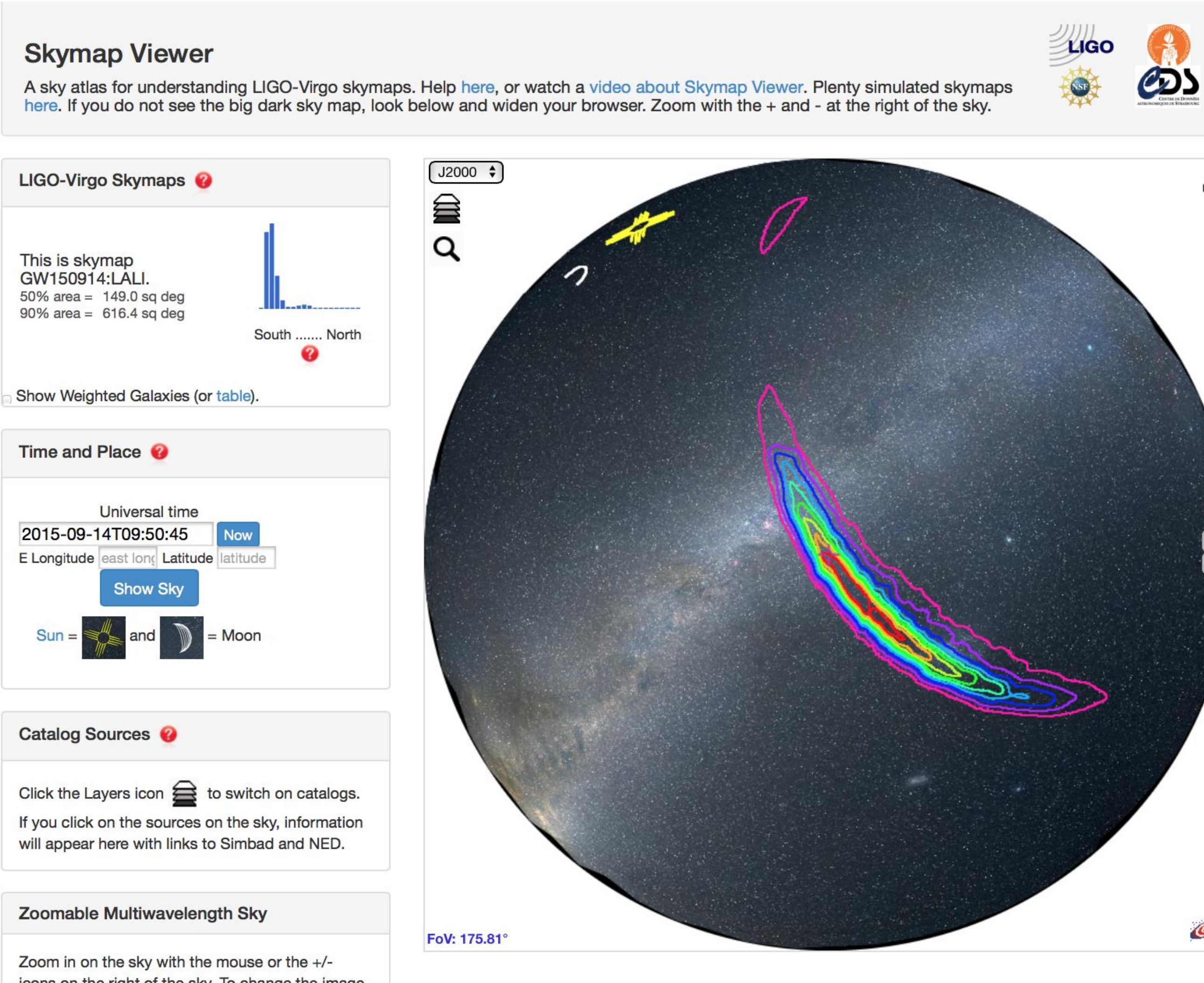
pick this ROSAT image

Astronomy ESFRI & Research Infrastructure Cluster
ASTERICS - 653477

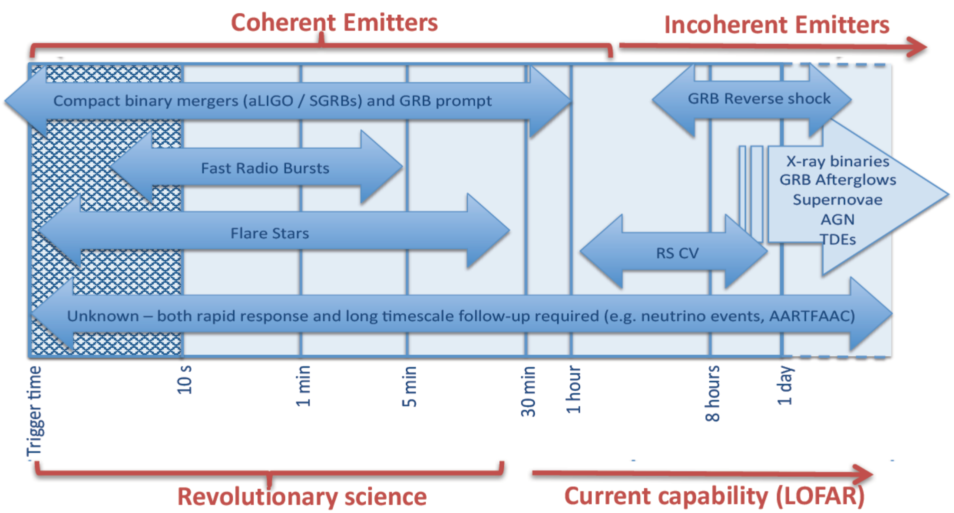
ASTERICS connections: *gravitational waves*

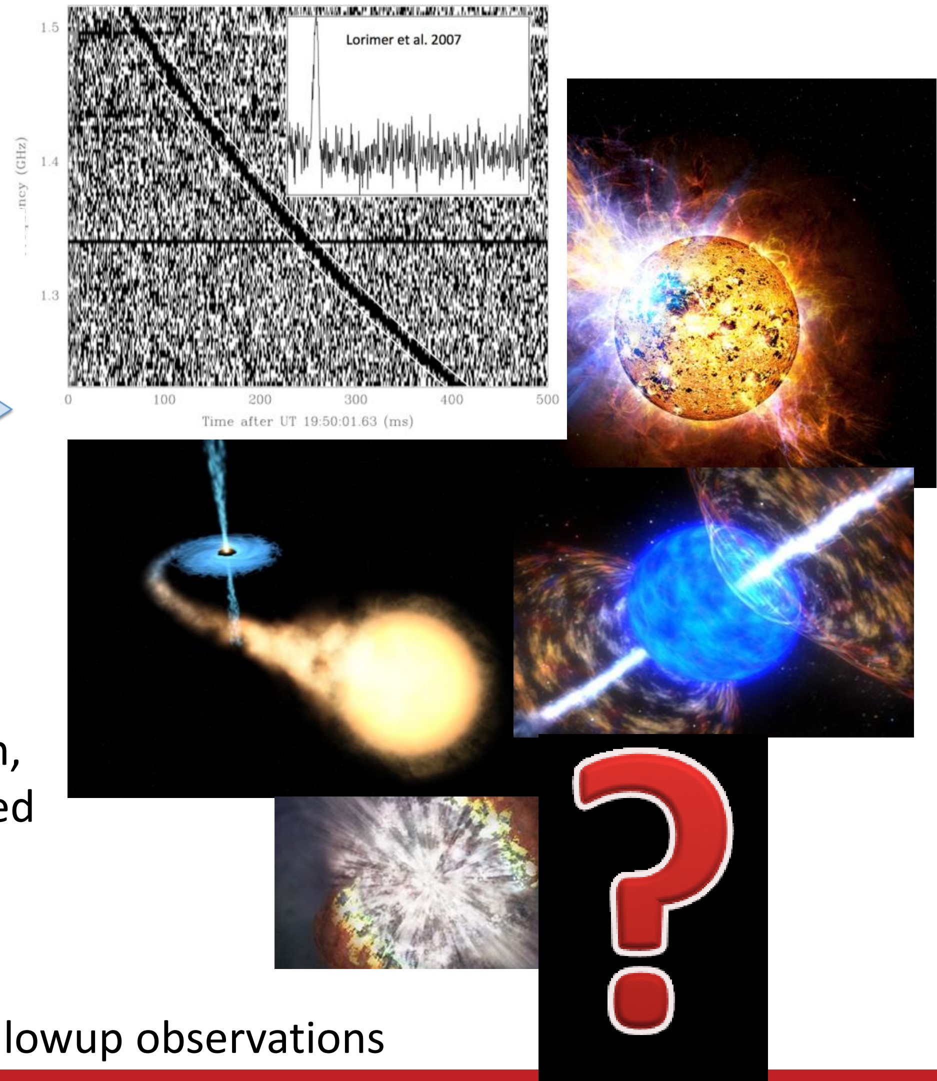
ASTERICS fostered use of VO for grav wave EM follow-up





Multi-Messenger Challenges





- Develop standards for generation, dissemination, distribution and reaction to transient events (based on **VOEvents**)
- Demonstration:

LOFAR, EVN, follow up a GW event

- Investigate scientific synergies for automated followup observations

multi-messenger timing and synchronisation

Connecting real facilities now as path to connected future facilities

- Building on success of e-VLBI
- EXPReS, NEXPReS

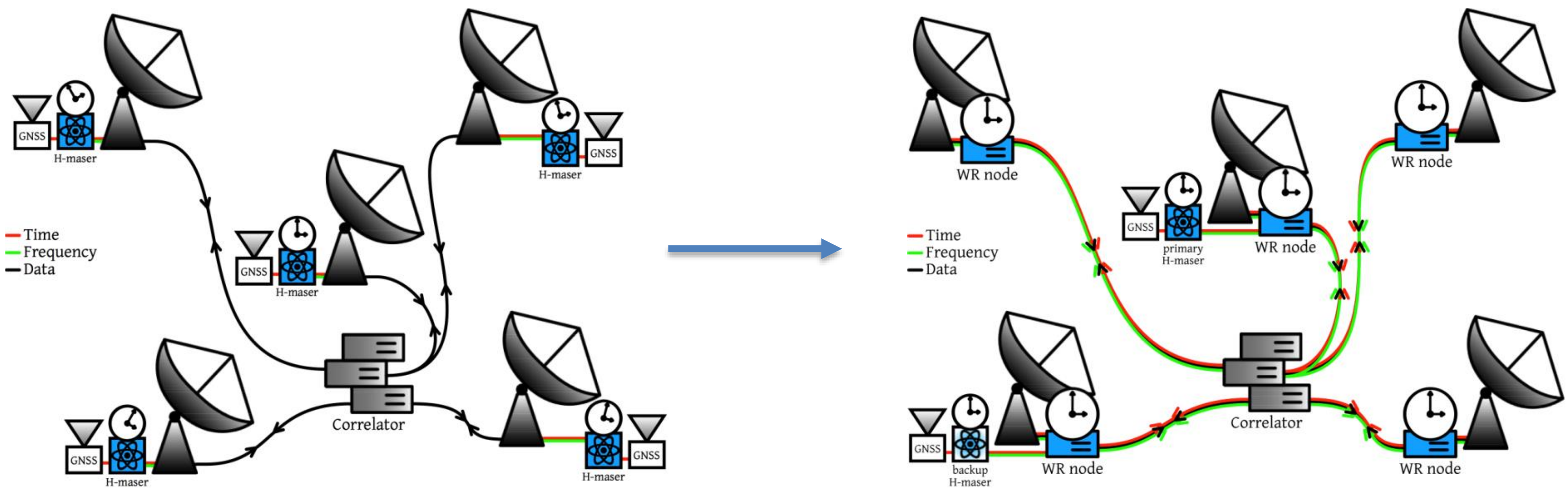
…here comes the White Rabbit

White Rabbit Ethernet (CERN, based on IEEE Precision Time Protocol)

- Time, frequency, and 1 Gb/s data in one
- 1 PPS, 10 – 125 MHz
- Designed for 1 ns timing
  over distances <10 km (LHC, CERN)
- Commercially available

- ASTERICS made real impact in WR community
  – Improvements are fed back → open source
- Generated serious outside interest

- Fed into tender for new photonic equipment for SURFnet
- WR timing in design of SKA-low
  – Frequency stability now good enough for frequency transfer
- Commercial applications under development



Scheduling of large astronomical infrastructures

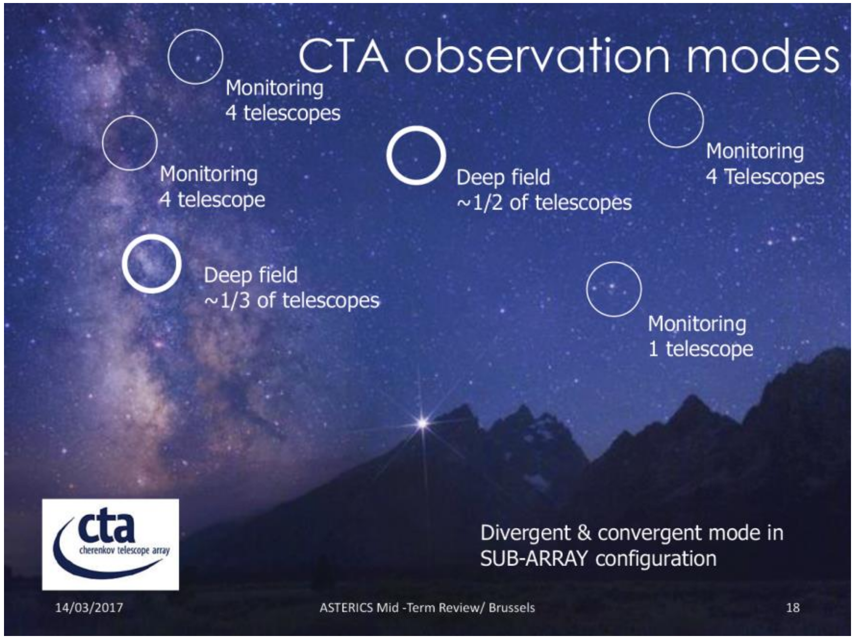
- Complex, many-element detector arrays

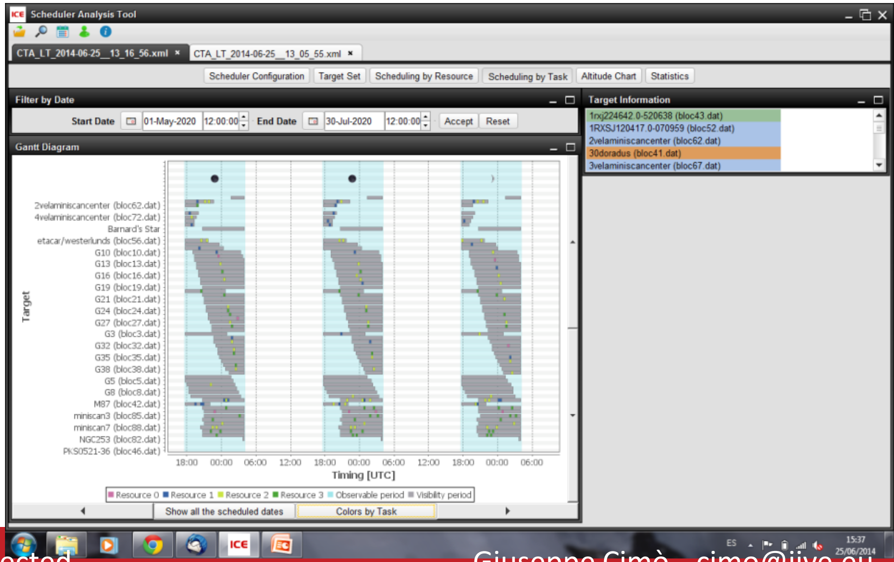
- Artificial Intelligence (AI) techniques to optimize procedures
  – Metaheuristic Optimization: Genetic Algorithms, Multi-objective Evolutionary Algorithms
  – Constraint-Based Reasoning: constraint propagation

- Maximize science return of SKA and CTA
  – But ensure solutions are applicable for other instruments

- Incorporate multi-frequency, multi-messenger astrophysics

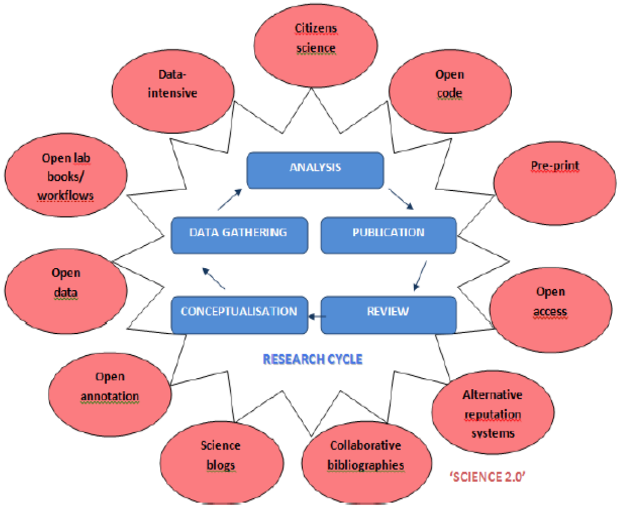
- Provide a framework to coordinate and schedule multiple facilities.





Open Science

- Open ESFRI facilities to wider stakeholders through citizen science (Open Science, or 'Science 2.0')
- Audiences: scientific & technical communities, academia, private industry, other public research centres, SMEs, policy makers, general public
- Coordinated citizen science experiments to open ESFRIs & pathfinders/precursors to public
- Educational resources & efficacy metrics



Citizen Science is not outreach!

Citizen Science

Pulsar Hunters ++

- Lead: Rene Breton
- Science goal: Extend the successful Pulsar Hunters Zooniverse project to harder-to-find pulsars
- Activity: interactive data visualization of pulsar time and frequency domain data; future application to SKA

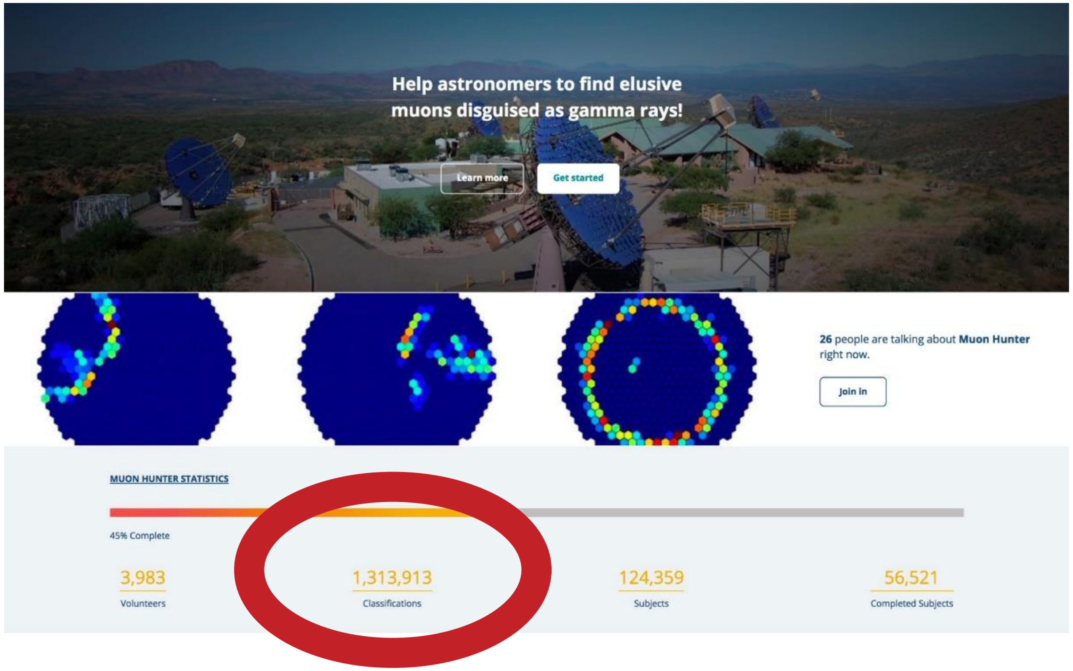
CREDO
Cosmic Ray Extremely Distributed Observatory

- Lead: Piotr Homola https://credo.ifj.edu.pl/
- Science objective: detect ultra-high-energy charged particles with a whole-Earth Cherenkov detector
- Activity: use mobile phones as charged particle detectors

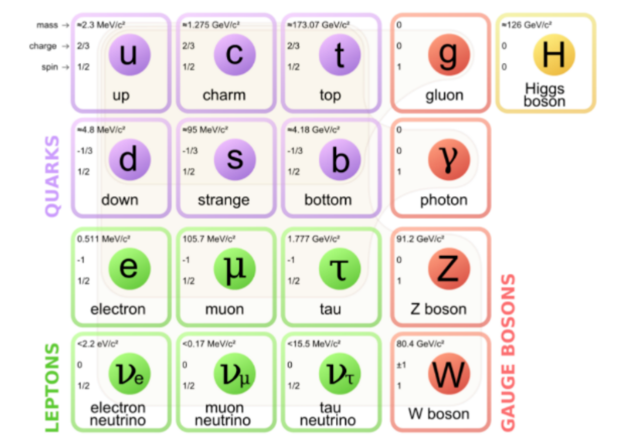
Citizen Science

Muon Hunters

- Lead: Lucy Forston, CTA
- Science goal: detect fainter Cherenkov events by visual classification
- Activity: classify hadron vs. photon events in the CTA telescopes, morphologically and in the time domain; apply first to simulations and to e.g. HESS



1.3 million classifications in the first five days!



The 'standard model' of particle physics. The electron and muon can be found in green boxes halfway down the diagram.

So what is a muon?

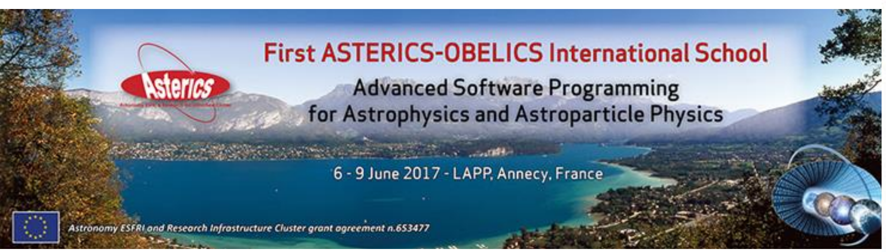
A muon is a type of subatomic particle, which is very similar to an electron – for instance, they both have the same negative electric charge. The main difference between a muon and an electron is their mass. A muon is 207 times more massive than an electron! For comparison, you might have known that the mass of a proton (the nucleus of a hydrogen atom), is about 1,800 times that of an electron. However, unlike the proton, which has substructure and is composed of other particles, the muon is a fundamental particle in its own right.

If you think the existence of the muon is strange, you're in good company. The world-famous physicist I. I. Rabi, when first told of the discovery of the muon, said in response, "Who ordered that?" There's good reason why the muon is such an unfamiliar particle: muons are radioactive; they decay with a mean lifetime of 2.2 microseconds. That's 2.2 x 10^{-6} seconds, or 2.2 millionths of a second. Muons don't stick around long enough to become part of the matter we encounter day to day.

However, there are lots and lots of muons all around us, created in interactions we don't usually think of…

Strengths from connections

- Enabling data science
  - Training and support
    - Skill sets for astronomy



Participating institutions

Supporting organisations and networks