KM3NeT & ASTERICS
CORELib
ROAst
CONTAINERISATION
CONCLUSIONS AND OUTLOOK

ASTERICS is a project supported by the European Commission Framework Programme Horizon 2020 Research and Innovation action under grant agreement n. 653477

KM3NeT CONTRIBUTIONS TO ASTERICS

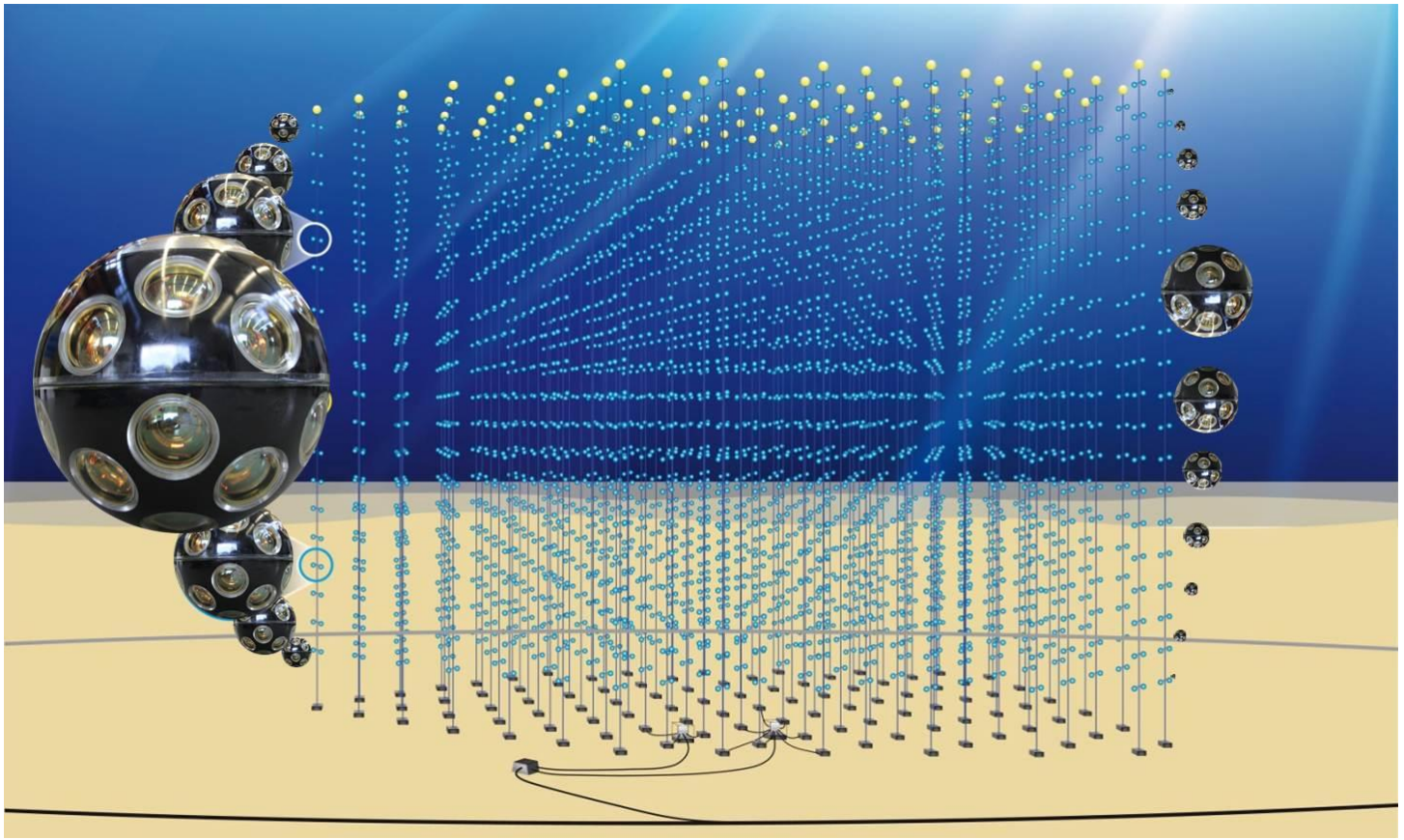
KM3NeT & ASTERICS

KM3NeT
Water Cherenkov
in deep sea

Building block:
115 DUs

Detection Unit (DU):
18 evenly spaced
DOMs

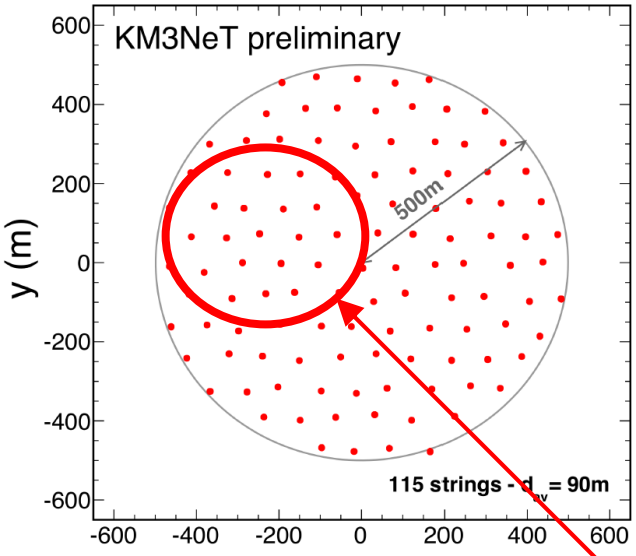
Digital Optical Module (DOM):
31 PMTs (+ other instruments)



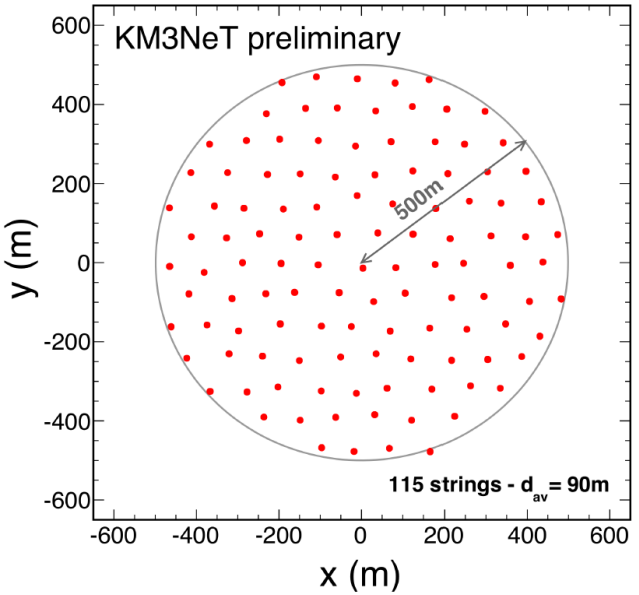
KM3NeT & ASTERICS

Astroparticle
Research with
Cosmics in the
Abyss

km^3 size building blocks (2×)
z DOM spacing 36 m

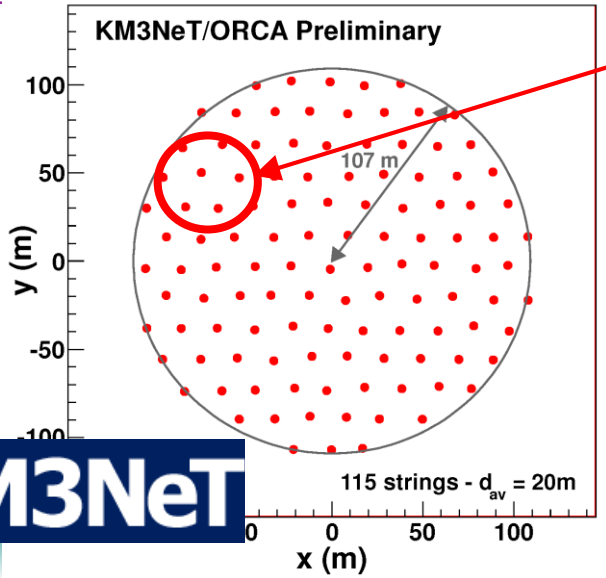


+



Oscillation
Research with
Cosmics in the
Abyss

1 building block
z DOM spacing 9 m

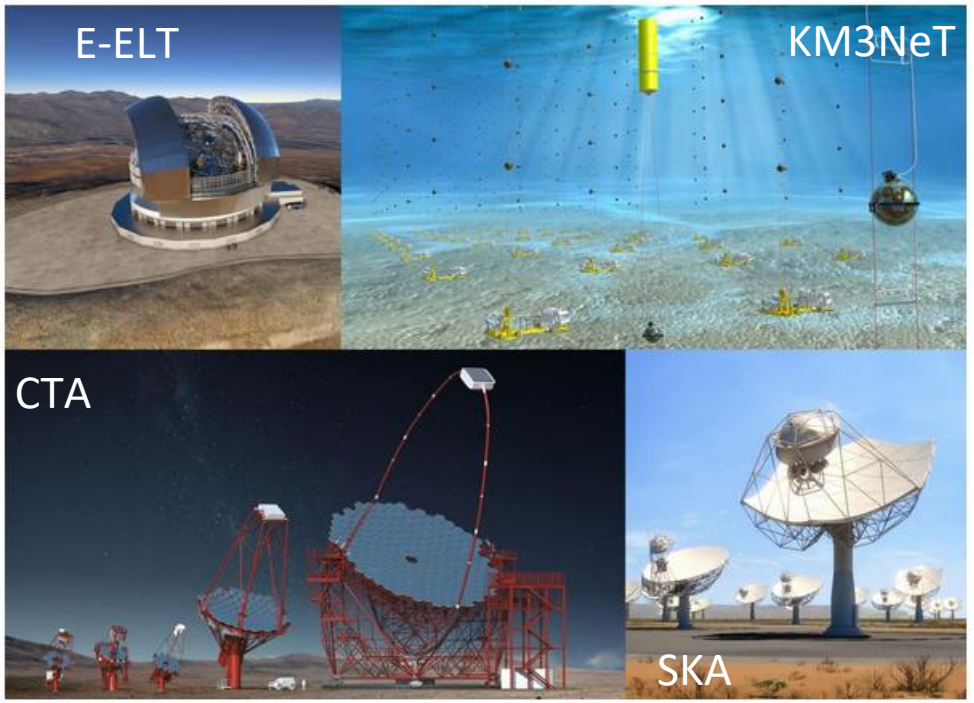


Phase1 (fully funded - deploy 2018/19)

Phase 2 (partially funded - deploy 2019/21)

KM3NeT 2.0 Letter of Intent:
arXiv:1601.07459 and
J.Phys. G43 (2016) 084001

KM3NeT & ASTERICS



***AST**ronomy **E**SFRI and **R**esearch **I**nfrastructure **C**luster*

KM3NeT & ASTERICS

ASTERICS WPs and KM3NeT involvement

- WP 2: Dissemination, Engagement and Citizen Science (DECS) *
- **WP 3: OBservatory E-environments LInked by common ChallengeS (OBELICS)**
- WP 4: Data Access, Discovery and Interoperability (DADI) *
- WP 5: Connecting Locations of ESFRI Observatories and Partners in Astronomy for Timing and Real-time Alerts (CLEOPATRA) *

Task 3.3 D-INT: Data systems INTegration
Task 3.4 D-ANA: Data ANAlysis/interpretation

* Other KM3NeT involvements, not in this presentation

CORELib (Task 3.4)

COsmic **R**ay **E**vent **Lib**rary: a service from KM3NeT to the scientific community

Cosmic ray showers are a common background source, but may also be the subject of observation depending on the experiment/application

CORELib includes events in a broad energy spectrum and with inclination up to 89° (focus not only on KM3NeT!)

Input to reconstruction/analysis algorithms (in particular, ML models: as good as the input data are!)

A common benchmark with well-documented and controlled conditions to evaluate algorithms and analysis techniques

Currently using CORSIKA as generator

CORELib (Task 3.4)

Pilot production - completed

Energy range (GeV)	Number of events
200-1000	10^7
10^3-10^4	10^7
10^4-10^5	10^6
10^5-10^6	10^5
10^6-10^7	10^4
10^7-10^8	10^3
10^8-10^9	10^2

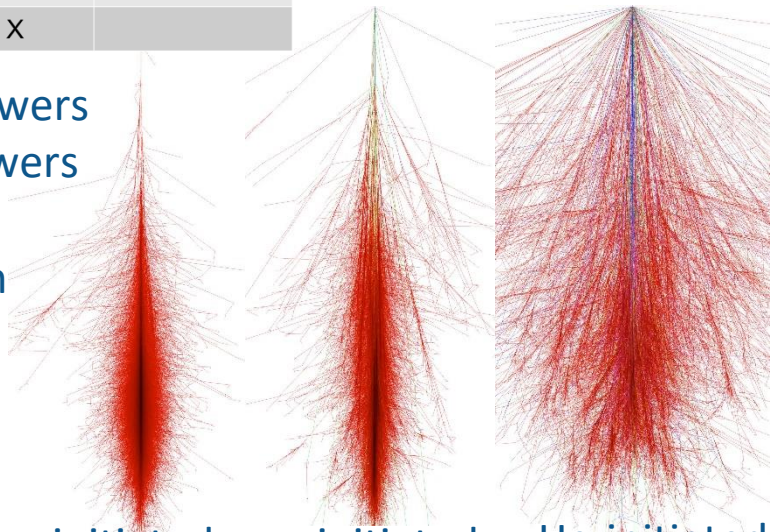
Spectral index -2

Interaction models

High energy model	Low energy model	Option	
		TAULEP	CHARM
QGSJET01	GHEISHA		X
QGSJET01	GHEISHA	X	
QGSJETII-04	GHEISHA	X	
EPOS LHC	GHEISHA	X	

- Proton-induced showers
- Nuclei-induced showers
- With and without Cherenkov radiation

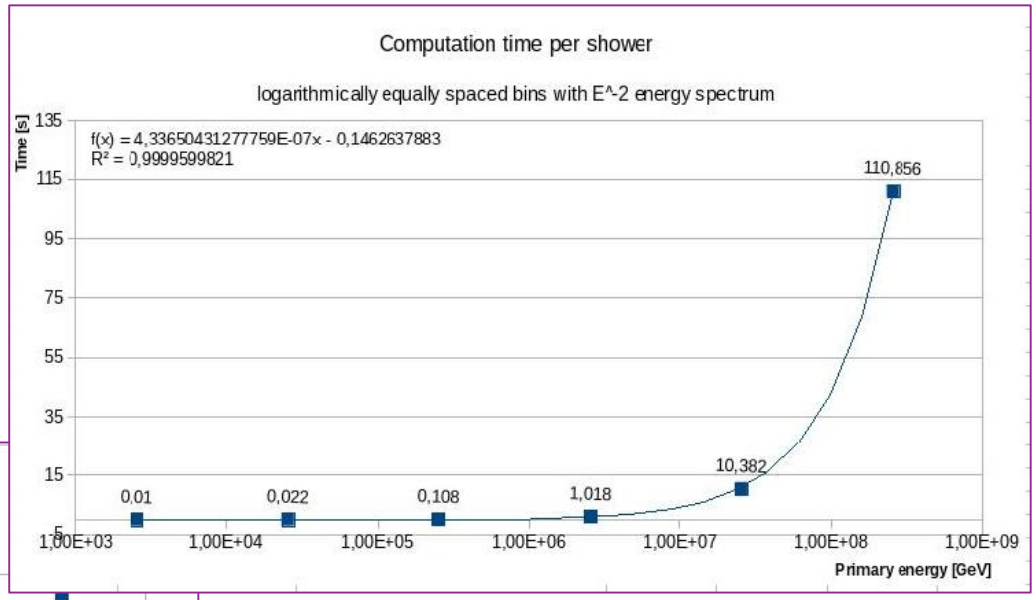
Observation station: sea level
Atmosphere: Standard European
Binary (CORSIKA) and ASCII format

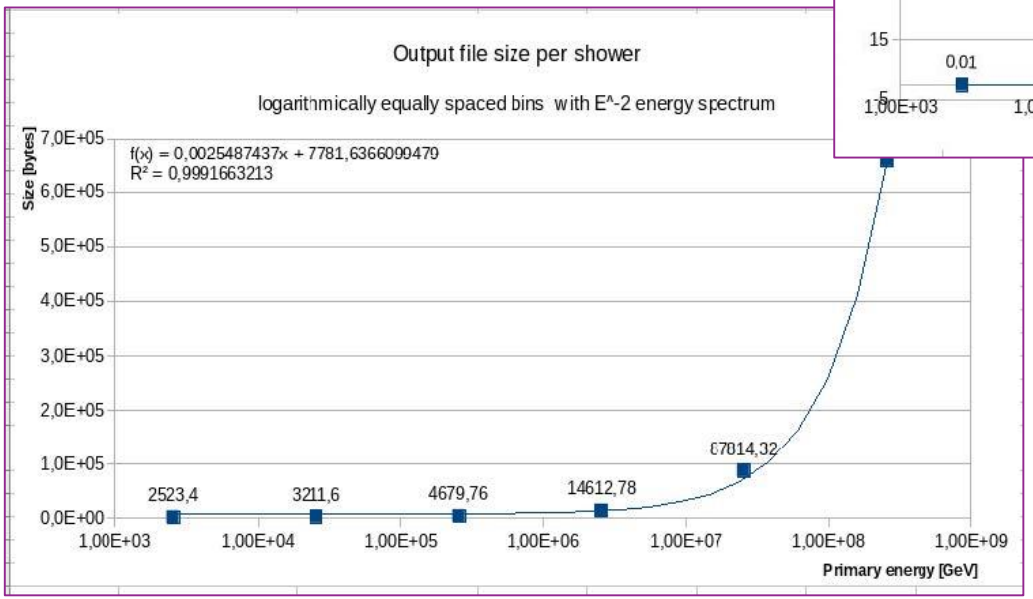


CORELib (Task 3.4)

Energy matters!

Computation time and output file size as a function of energy





CORELib (Task 3.4)

Full production – ongoing (~4 months to go) Using 1064 cores at ReCaS

Energy range (GeV)	Number of events
200-1000	15 x10^5
10^3-10^4	15 x10^5
10^4-10^5	15 x10^5
10^5-10^6	15 x10^5
10^6-10^7	15 x10^5
10^7-10^8	15 x10^5
10^8-10^9	15 x10^5

High energy model	Low energy model	Option	
		TAULEP	CHARM
QGSJET01	GHEISHA		X
QGSJET01	GHEISHA	X	
QGSJETII-04	GHEISHA	X	
EPOS LHC	GHEISHA	X	

Done, "EPOS" remaining

Flat (log) spectrum
3 M high energy events (vs. 1100 of pilot production)
32× size increase!
Binary and ASCII format (ASCII output files already split by particle types)
(ν, γe^+e^- , $\mu^+\mu^-$, $\tau^+\tau^-$, hadrons/nuclei, Cherenkov γ)

CORELib (Task 3.4)

Accessing data

Pilot production: SFTP to Salerno server (corelib@193.205.188.227 pwd Asterics2020)
~600 GB

Full production: currently hosted in ReCaS GRID SE, underway to be moved to CNAF
~50 TB expected
Access via Indigo-DataCloud, DIRAC, other?

Next steps:

- Starting discussions to involve other Collaborations (possible joint work in ESCAPE)
- Increase number of stations (2200m, 4000m) to match possible sites
- Simulate below 200 GeV
- Consider different atmospheres

ROAst (Task 3.4)

ROOT extensions for **Ast**ronomy

ROOT is the standard tool for HEP analysis but does not offer much related to Astronomy

Our goal: a library for many Astronomy-related activities that is natively developed in ROOT

- Unified and seamless access to catalogues
- Coordinate transformations
- Sky Map
- Precise modeling of Moon and Sun position

Find everything at https://gitlab.com/Spisso/ASTERICS-ROAst (including docs/tutorial)

ROAst (Task 3.4)

Access to catalogues

Offline catalogues:
- UCAC4 (USNO CCD Astrograph Catalog v.4)
- URAT1 (USNO Robotic Astrometric Telescope v.1)

Online catalogues:
- Virtual Observatory (VO) catalogues
- VizieR catalogue repository (> 17,000!)

(0FGL) Fermi/LAT bright gamma-ray source list
(1FAV) Fermi-LAT flaring gamma-ray sources from FAVA
(1FGL) First Fermi-LAT AGN catalog (1LAC)
(1FGL) The Fermi-AT20G catalog (Mahony+, 201)
(1FHL) The first Fermi-LAT >10GeV catalog (Ackermann+,2013)
(1LAC) First Fermi-LAT AGN catalog (1LAC) (Abdo+, 2010)
(1PSZ) Planck Catalog of Compact Sources Release 1 (Planck, 2013)
(1RXH) ROSAT Results Archive Sources for the HRI
(1RXH) ROSAT HRI Pointed Observations (1RXH) (ROSAT Team, 2000)
(1RXP) ROSAT Source Catalog (Voges+ 1994)

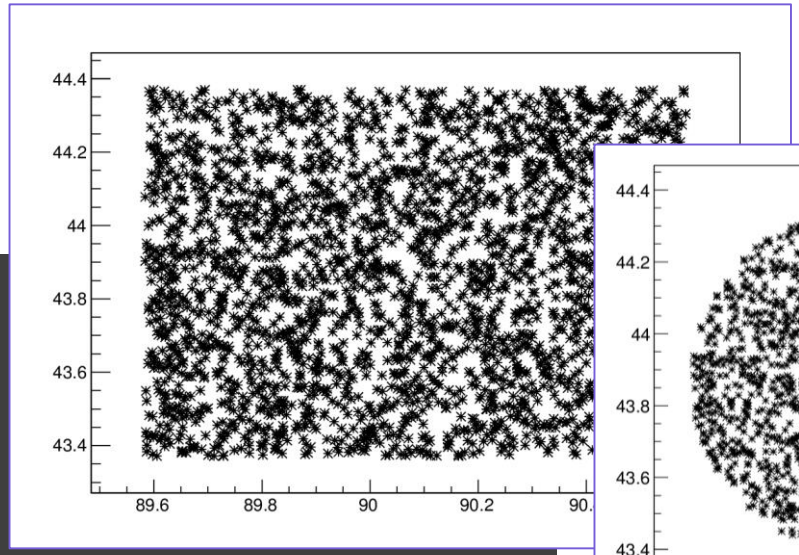
A core set of properties common to all catalogues are provided +
+ extended properties that depend on each catalogue (e.g. proper motion info)
Dynamic property browsing ensures flexibility

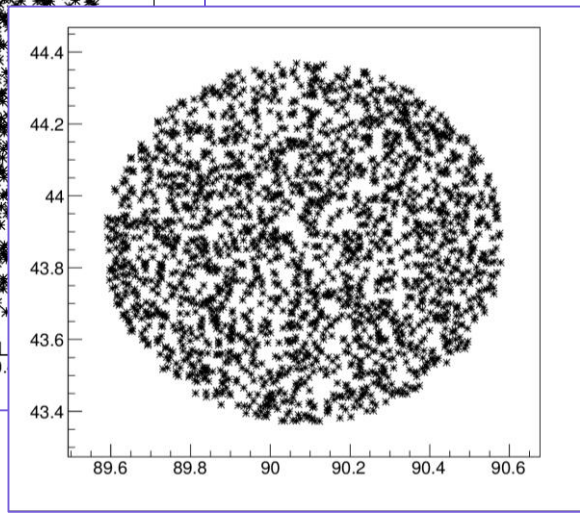
Regions of various shapes can be extracted from each catalogue
(Rectangle/Circle/Ellipse)

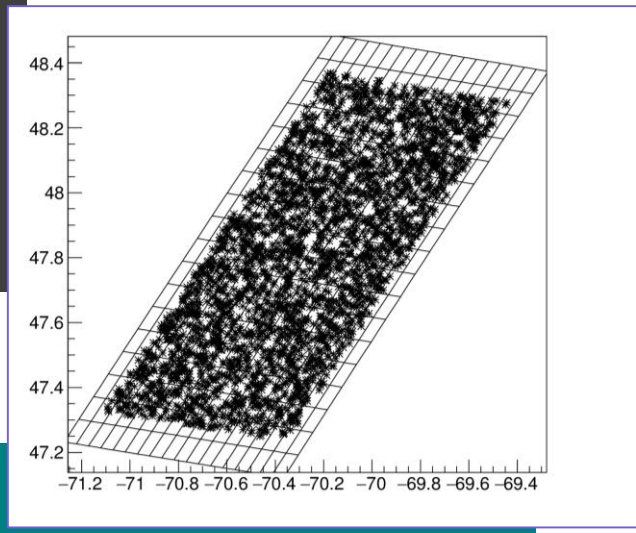
ROAst (Task 3.4)

Access to catalogues

```
   ------------------------------------------------------------------
  | Welcome to ROOT 6.07/07                        http://root.cern.ch |
  |                                (c) 1995-2016, The ROOT Team |
  | Built for linuxx8664gcc                                           |
  | From heads/master@v6-07-06-745-g07cfe61, giu 27 2016, 17:57:06 |
  | Try '.help', '.demo', '.license', '.credits', '.quit'/'.q'      |
   ------------------------------------------------------------------

root [0] .L libTAstroCatalogue.so
root [1] .L libTAstroCatalogueGraphics.so
root [2] ROASt::TAstroCatalogueGraphics  VOCatalogueGraps
This is the ROASt-Astro Catalogue Graphics Class,  v 1.0
(ROASt::TAstroCatalogueGraphics &) Name:  Title:
root [3] ROASt::TAstroCatalogue*  Test
(ROASt::TAstroCatalogue *) nullptr
root [4] VOCatalogue = Test->CreateVOCatalogue()
This is the ROASt-VirtualObservatory Catalogue Class,  v 1.0
(ROASt::TAstroCatalogue *) 0x2c3ec70
root [5] VOCatalogue->ExtractObjectsCircle("Equatorial",53.084,-27.87,0.1,"http://www.nofs.navy.mil/cgi-bin/vo_cone.cgi?CAT=USNO-B1")

Executing query: http://www.nofs.navy.mil/cgi-bin/vo_cone.cgi?CAT=USNO-B1&RA=53.084000&DEC=-27.870000&SR=0.100000


  United States Naval Observatory Flagstaff Station       28Sep2017-01:35:48
  Astronomical Image and Catalogue Server:
           http://www.nofs.navy.mil/data/fchpix/
  Please send questions and problem reports to:
           sel@nofs.navy.mil


(Int_t) 302
root [6] VOCatalogueGraps.DrawAitoff(VOCatalogue,"AP*")
Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
root [7] VOCatalogueGraps.DrawSkyMap(VOCatalogue,"AP*")
Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
root [8]
```







ROAst (Task 3.4)

Coordinate transformations supported

Astronomical coordinate system	Geographical coordinate system	Time coordinate
Equatorial	N/A	N/A
Galactic	N/A	N/A
Horizontal	Lat-Long/UTM	Unix time/UTC/Local Sidereal
Equatorial rectangular	N/A	N/A
Ecliptic	N/A	N/A

ROAst (Task 3.4)

Skymaps and plotting

Astronomical coordinate system	Flat plot	Aitoff projection	Aitoff skymap
Equatorial	OK	OK	OK
Galactic	OK	OK	OK
Horizontal	OK	OK	OK

+ Precise Moon position model (ELP-2000-82)
+ Precise Sun position model (VSOP87)

CONTAINERISATION (Task 3.3)

Requirements

- Check old analyses
- Run similar analyses on own data for comparison
- Preserve “legacy” software (e.g. no Scientific Linux 6 in several computing centres!)
- Fulfill reproducibility (e.g. in FAIR principles in grant agreements)

Exploring possible solutions

Virtual Machines	Docker	Singularity
Slow, unflexible	Not supported on HPC clusters	Looks OK

	Commits	Contributors
Docker	31219	1627
Nix	2048	34
Singularity	5075	110
rkt	5167	177

CONTAINERISATION (Task 3.3)

Singularity Status:

- Works on Linux (native), Windows & Mac (Vagrant), several HEP-related computing centres
- Easy installation on own machine
- Highly compatible with Docker

Service to community: ANTARES (KM3NeT progenitor) main data processing tool chain fully containerised

KM3NeT applications ported so far

- Jpp (Data processing framework)
- KM3Pipe (Python-based data management and processing framework)

Next steps: containerisation also in continuous software integration

CONCLUSIONS AND OUTLOOK

- Participation in ASTERICS project proved beneficial to KM3NeT
- Dedicated HR for specific long-term tasks
- Setting up “bridges” with other Collaborations
- Set the foundations for possible evolutions and joint work
- KM3NeT contributions helped earning leading/coordination positions in future projects