

26 October 2022, 10:55 - 11:50

The Extreme Universe Science Project



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University*



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Amsterdam*



ESCAPE

European Science Cluster of Astronomy &
Particle physics ESFRI research Infrastructures

ESCAPE to the Future

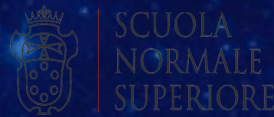
25-26 October 2022
Brussels, Belgium



Extreme Universe Project Overview

Elena Cuoco

European Gravitational Observatory and Scuola Normale Superiore

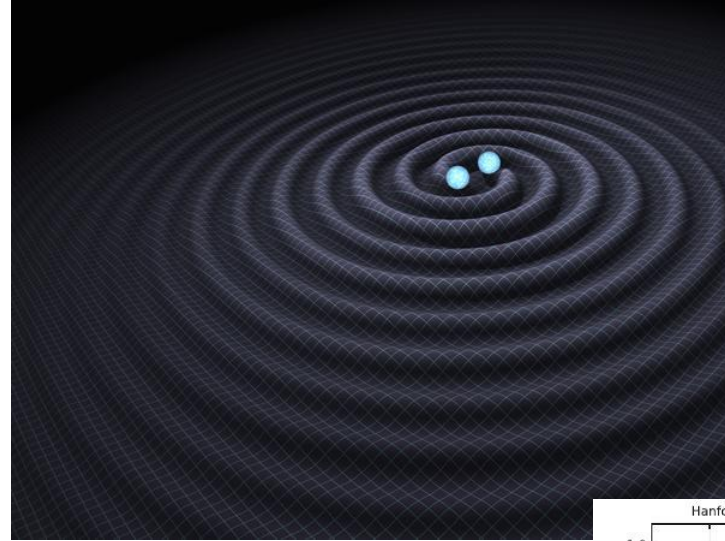


*I. Bird, A. Iess, A. Parisi, D. Vohl, H. Vedantham, J. Hessels, M. Smirnov, K. Graf, E. Pons,
D. Sanchez, S. Lloyd, A. Ain, G. Cella, G. Bertone, S. Markoff*

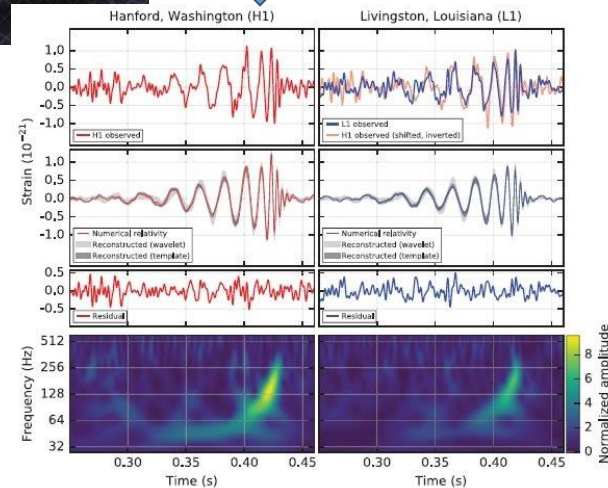


ESCAPE - The European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructures has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 824064.

The first detection of Gravitational Waves

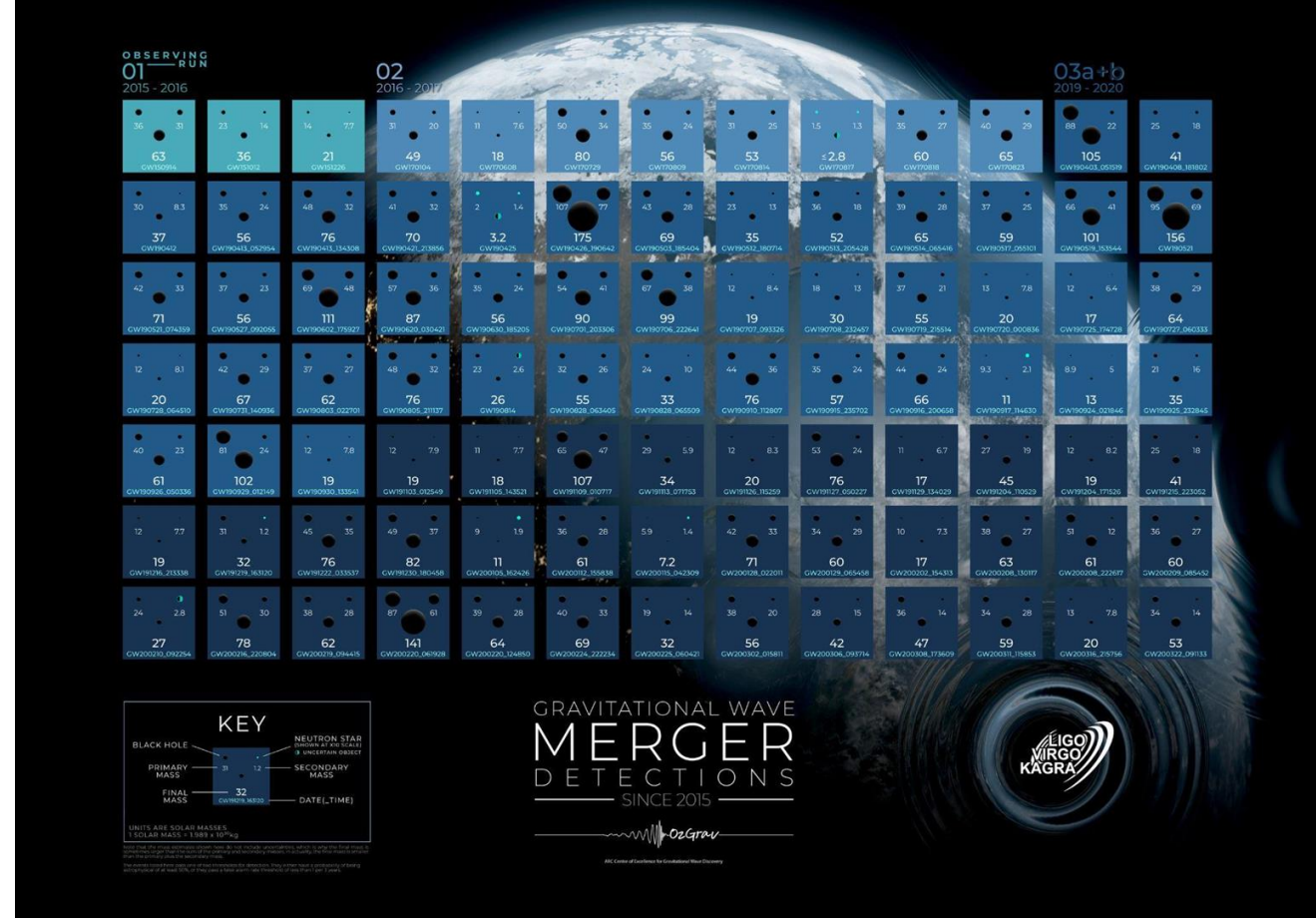


Black hole merger

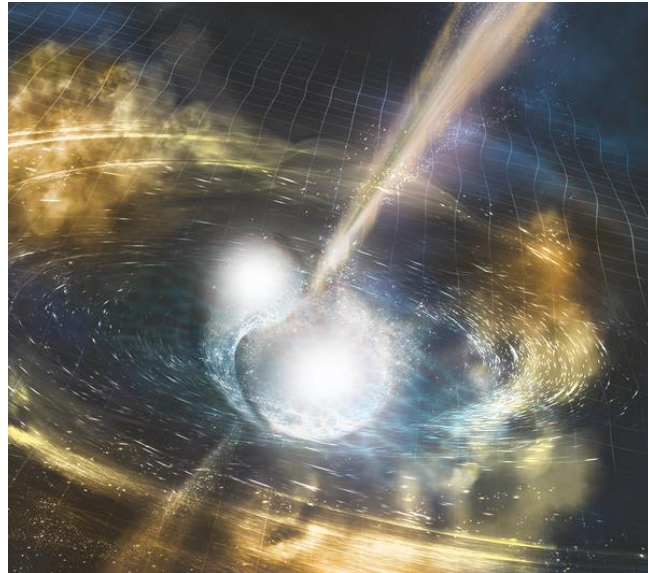


GW150914

Credits: R. Hurt (Caltech-IPAC)

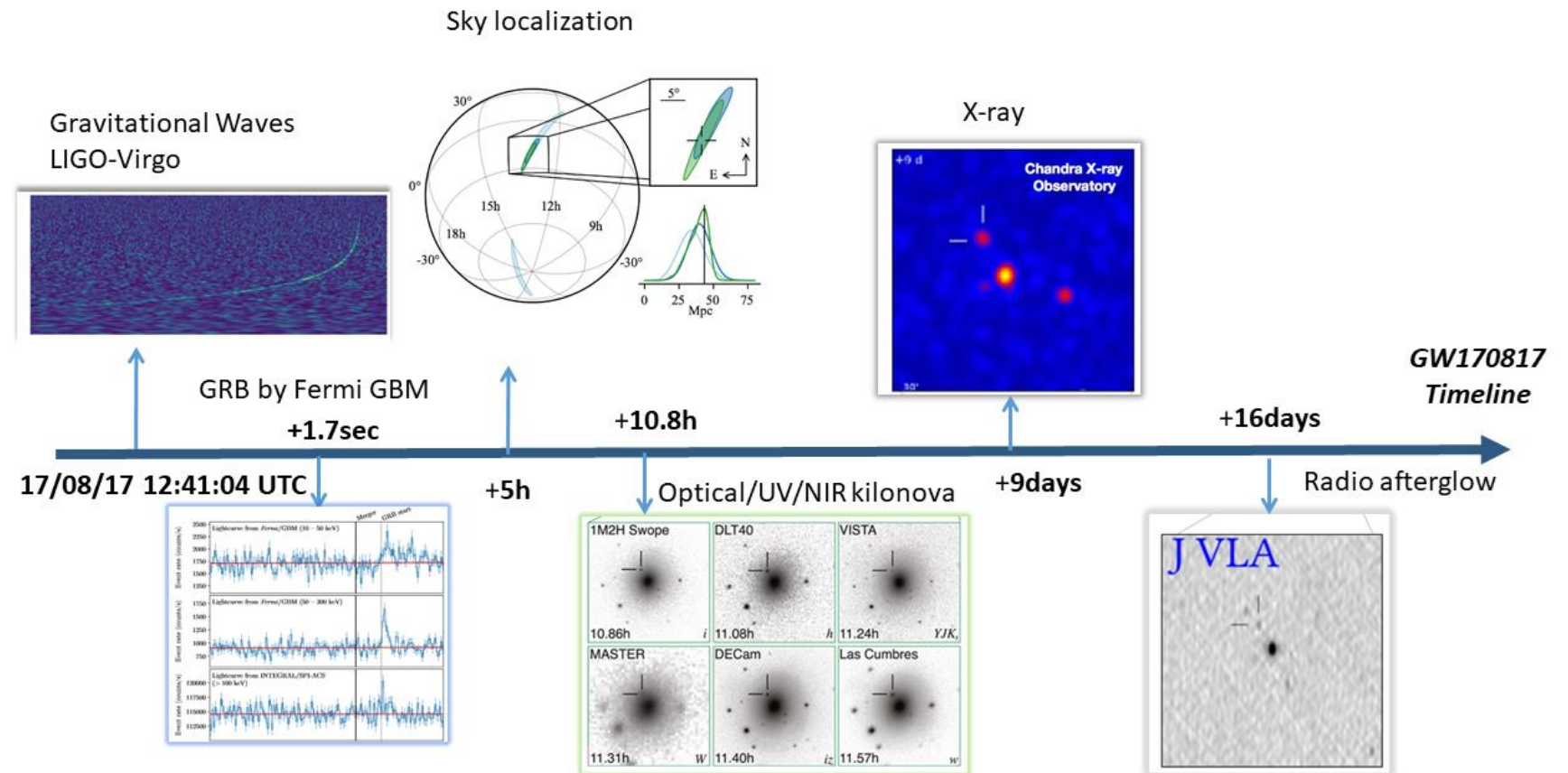


GW170817: Multi Messenger Astrophysics

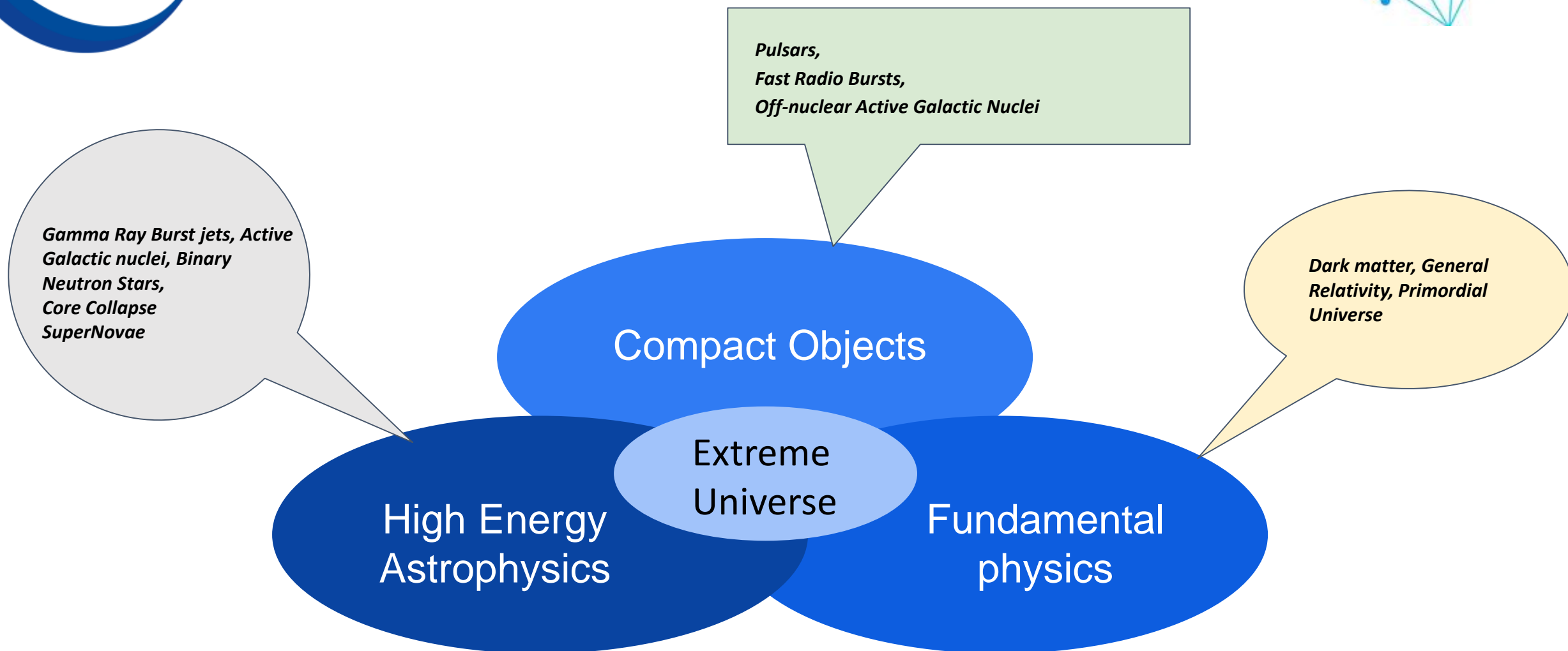


Credit: NSF/LIGO/Sonoma State University/A. Simonnet

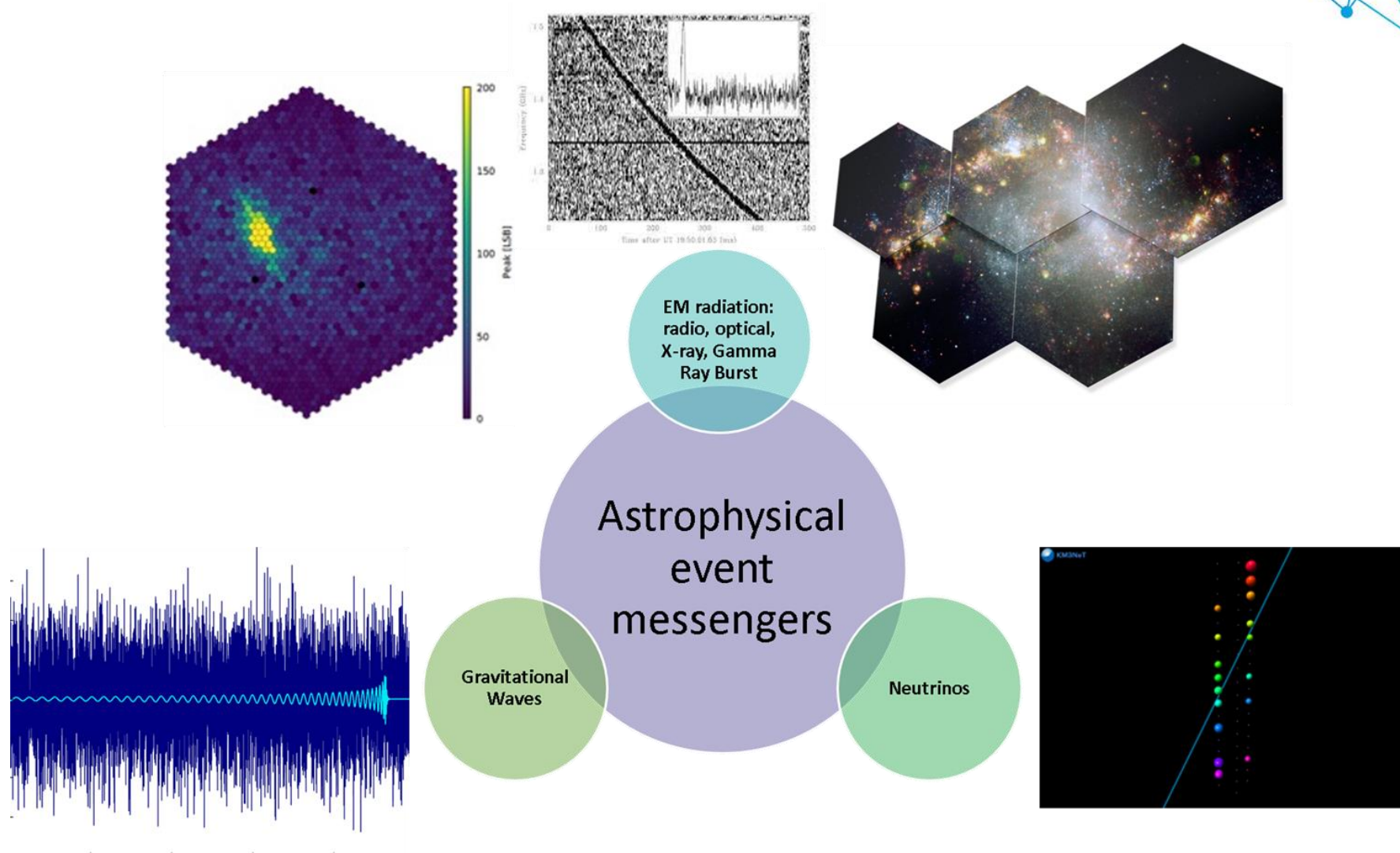
Binary Neutron
Star Mergers



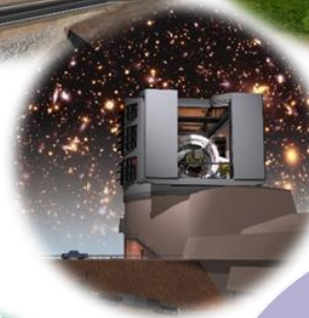
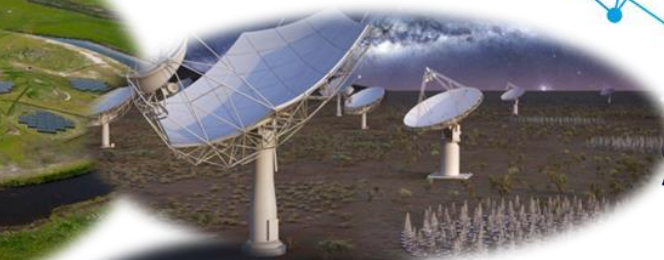
- **Gravitational wave discoveries and multi messenger astronomy** opened windows to new perspectives for the study of events in the Extreme Universe. New discoveries and new mysteries
- **Collaboration** among scientists of different disciplines is mandatory
- **Artificial Intelligence** tools, **innovative solutions**, easy to use data analysis platforms, **big data** tackling are common problems in astroparticle research.
- Integration with **ESCAPE EOSC services**: Common AAI, DataLake, OSSR software catalogue, **Virtual Research Environment**



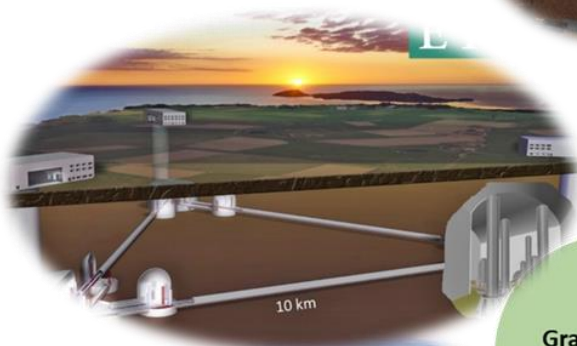
Multi-messenger observations provide key insight into the physics of the most energetic events such as SN, GRBs, AGN



Extreme Universe facilities



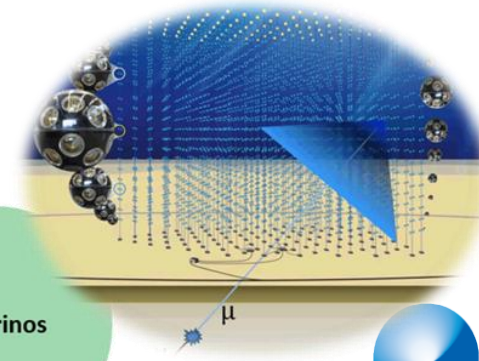
EM radiation:
radio, optical,
X-ray, Gamma
Ray Burst



Astrophysical
event
messengers

Gravitational
Waves

Neutrinos



Extreme Universe Science Project goals

Leveraging EOSC to remove sociological barriers among **different communities**, exploiting synergies and complementarities across different communities

Creating a unique link between RIs' data, the **fundamental science** question of understanding the origin of the most violent phenomena in the universe and the computational-cloud tools needed to answer it.

Building through EOSC Future the **transversal environment** to provide frontier AI, analysis methods and a cloud-based analysis dashboard that allows users to exploit the e-infrastructure services.

Bringing the European research community at the leading edge of multi-messengers' modern astrophysics in an international context and driving the global synergies by promoting the EOSC concept implementation. Both ESCAPE SPs will be novel and **innovative demonstrations of the power of open science and cross-RI collaboration**, and can be seen as model demonstrators of capabilities that many other communities will benefit from through the EOSC

Different pilot projects to deal with Extreme Universe Science

Compact objects

- **MAP - MM/MWL Analysis Pipeline for AGN Model**
- Postdoc University of Amsterdam

Compact objects

- **Broadband spectral energy distribution fitting of blazars**
- Postdoc LAPP

Compact objects

- **FRB persistent radio source counterpart in dwarf galaxies.**
- Postdoc ASTRON

Fundamental Physics

- **Detecting Dark Matter with Einstein Telescope**
- Postdoc SNS and University of Amsterdam

Fundamental Physics

- **Study of angular correlation signatures induced on GW stochastic background by lensing effects**
- Postdoc INFN

High Energy astrophysics

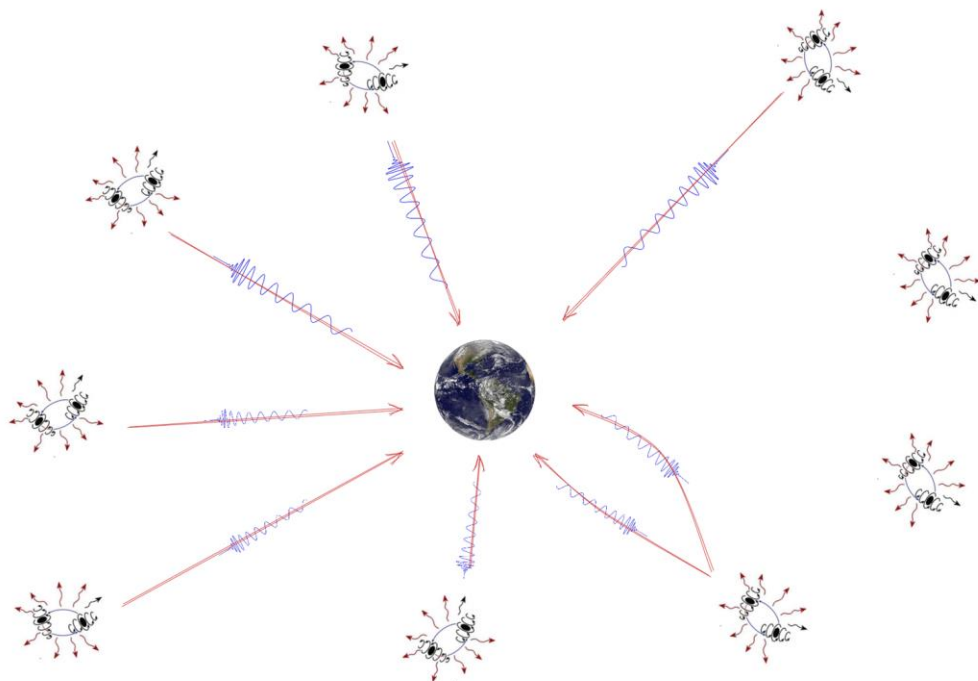
- **Wavefier: a Multi-messenger platform**
- Postdoc SNS

High Energy astrophysics

- **KM3NeT Instrument Response Function for point source analysis**
- Postdoc FAU

Study of angular correlation signatures induced on GW stochastic background by lensing effects

Anirban Ain, INFN-Pisa (supervised by Giancarlo Cella)



Approach: generalization of map reconstruction algorithm [PHYSICAL REVIEW D 105, 122001 \(2022\)](#) in presence of angular correlations. Redesign of demodulation procedure.

- Simulation of gravitational wave astrophysical like stochastic background signals with correlation signatures (toy model) [months 1-3]
- Reconstruction of GW skymaps with existing algorithm, bias effects study [months 4-10]
- Bayesian search and parameter estimation to the data (correlation signature estimation) [months 11-18]

Integration with data lake/VRE

Release of simulation/estimation code

Release of typical sets of data

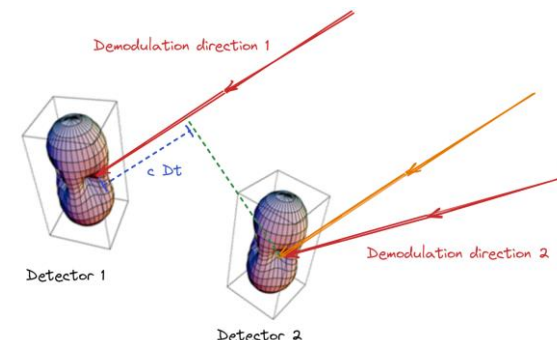
Notebook interface for data generation on cloud

FTE

1 postdoc

2 undergraduate students

1 senior (10%)



$$\langle \tilde{h}_A(f, n) \tilde{h}_B(f', n') \rangle = \delta_{AB} \mathcal{C}(n, n', f) \delta(f - f') P(f, n)$$

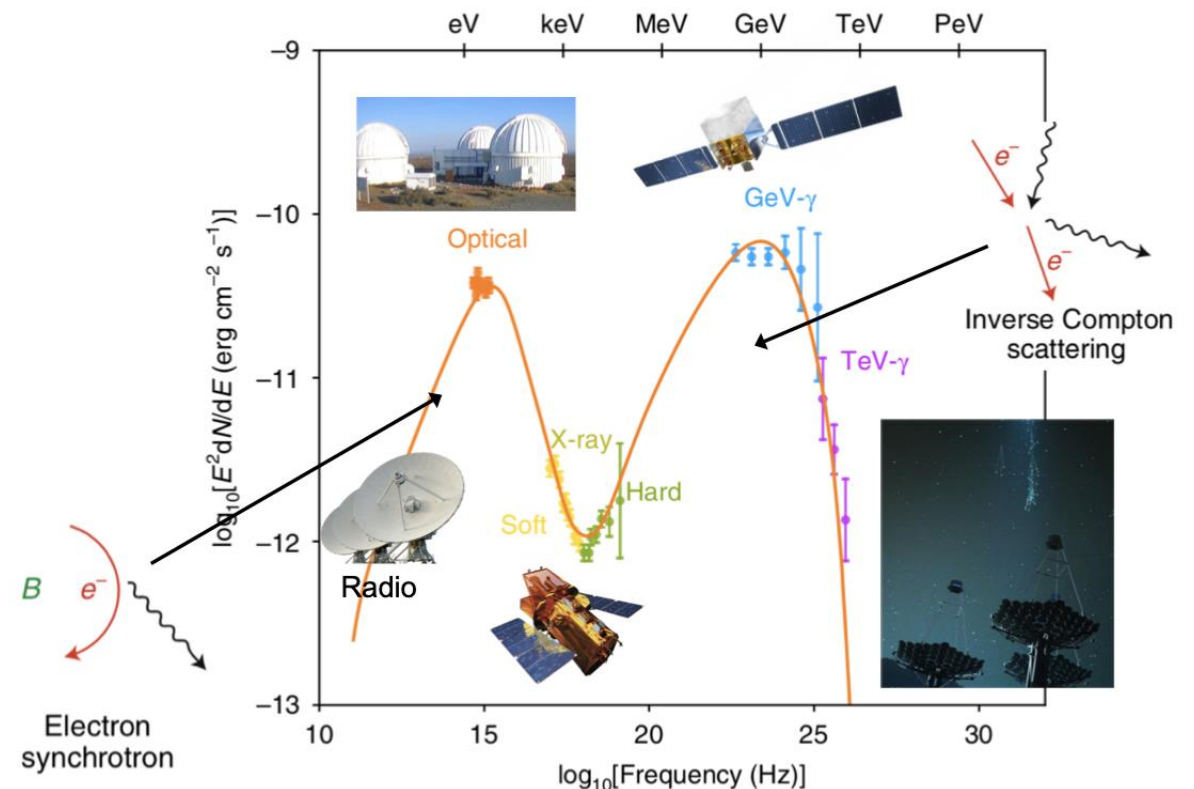
Broadband Spectral Energy Distribution fitting of Blazars

Estelle Pons, LAPP (supervised by David Sanchez)



Blazars are very bright sources, due to the relativistic beaming from the jet, and they are observed over the full range of wavelength from radio to gamma-rays. The broad band Spectral Energy distribution are easily identified by the presence of 2 humps.

- agnpy: modelling the radiative process of jetted AGN from radio to γ -rays (Nigro, Sitarek, Gliwny et al. 2022 A&A 660, A18)
 - Synchrotron and Inverse Compton scattering radiative processes from jet non-thermal electrons and external emitters (AGN accretion disc, torus and broad line region)
 - Open python package: <https://github.com/cosimoNigro/agnpy/>
 - Online tuto: https://agnpy.readthedocs.io/en/latest/tutorials/ssc_gammapy_fit.html
- VRE DLaaS environment with also gammapy / sherpa packages for the fitting



MAP - MM/MWL Analysis Pipeline for Active Galactic Nuclei Models

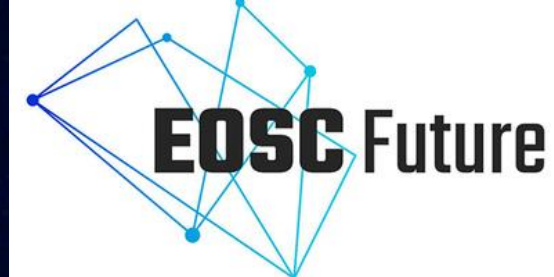
Sheridan Lloyd, UvA (supervised by Sera Markoff)

- MAP to be built to open / FAIR principles.
- Pipeline analysis using *Gammapy* with joint Poissonian likelihood in instrument space with statistical and systematic uncertainties treated correctly. (see Nigro et al 2019, *joint-crab*)
- MAP will use X-Ray, CTA and KM3Net IRFs to allow for energy dependent instrument response (Unbehaun Thesis 2020) with other bands radio, optical, and IR input directly .
- MAP will wrap and integrate existing MWL AGN jet emission model code to test hadronic and leptonic scenarios. The best fit model parameters to observations can also be determined.
- Will meet with FAU, CEA, CTA and *Gammapy* team to agree the approach and science cases.



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Wavefier: A Framework For Multi-messenger Astrophysics

Alberto Iess (*Scuola Normale Superiore*)

Supervisor: E. Cuoco (*European Gravitational Observatory, Scuola Normale Superiore*)

In collaboration with: E. Cuoco, F. Morawski, B. Patricelli, E. Marzini, A. Staniscia, S. Vallero

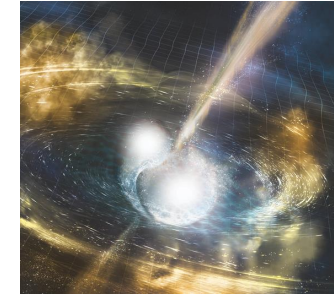


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Wavefier: A Framework For Multi-Messenger Astronomy

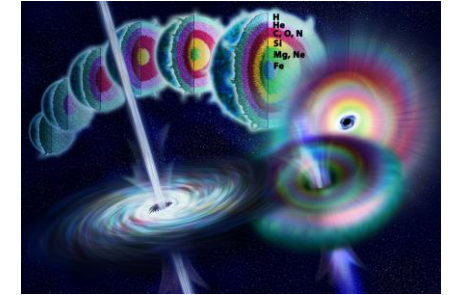
- **Multi-messenger** input
(Gravitational Waves, Gamma and X-Rays, neutrinos..)
- *Real-time* analysis
- *Scalability* for big data analysis
- *Portability*
- Transient classification
- *ICT services* supporting research infrastructures
- *FAIR* data principles
- Best practices for software management

Neutron Star Merger



NSF/LIGO/Sonoma State
University/A. Simonnet

Core-Collapse Supernovae



NSF/N.Rager Fuller

IN COLLABORATION WITH:

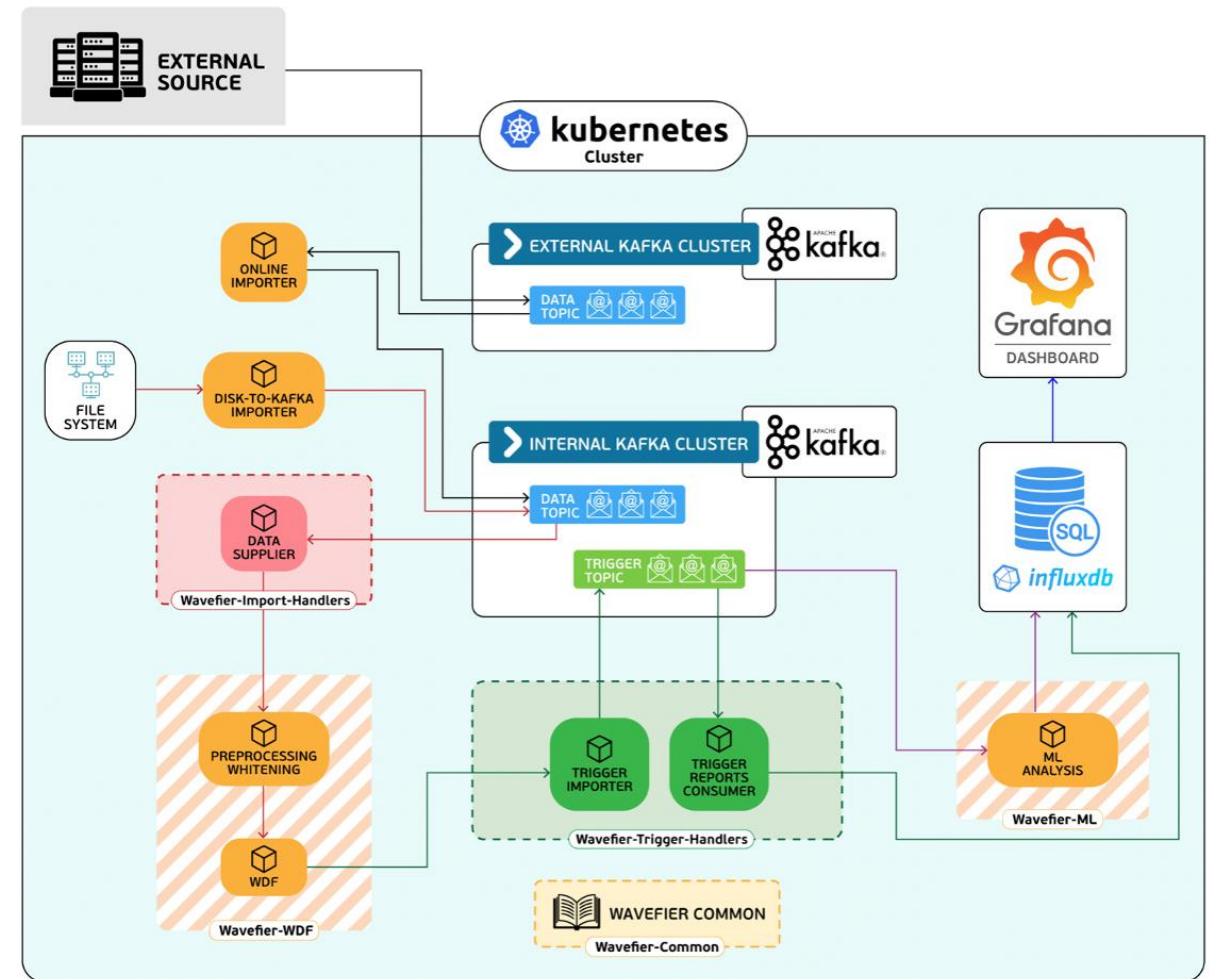
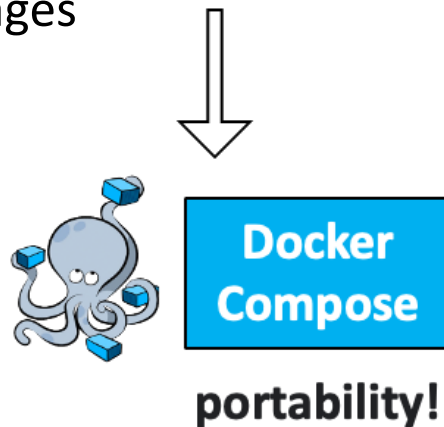
 **Trust-IT Services**
communicating to markets

This project acknowledges the computational resources and support provided by the following institutions: CNAF, Scuola Normale Superiore and the European Gravitational Observatory

Wavefier: Structure Breakdown

WAVEFIER's structure is composed of **python** modules:

- Dedicated [gitlab](#) project with a repository for each module.
- Continuous integration to build docker images



- **Website**

<https://wavefier.gitlab.io>

- **Gitlab repository**

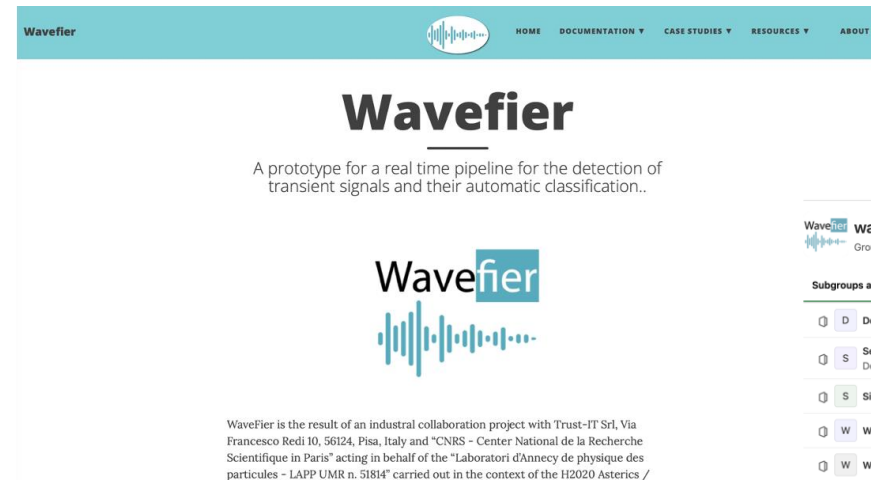
<https://gitlab.com/wavefier>

- **Docker Images**

<https://gitlab.com/wavefier/docker-images>

- **Zenodo entry**

<https://zenodo.org/record/3356656#.Y035zS8RpQI>



Wavefier

A prototype for a real time pipeline for the detection of transient signals and their automatic classification..

Wavefier

Wavefier is the result of an industrial collaboration project with Trust-IT Srl, Via Francesco Redi 10, 56124, Pisa, Italy and "CNRS - Center National de la Recherche Scientifique in Paris" acting in behalf of the "Laboratori d'Annecy de physique des particules - LAPP UMR n. 51814" carried out in the context of the H2020 Asterics /



zenodo

August 1, 2019

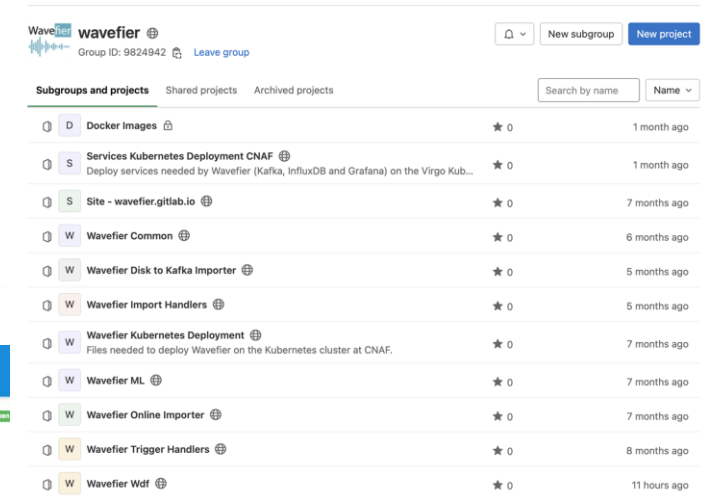
A prototype for a real time pipeline for the detection of transient signals and their automatic classification

Elena Cusco; Emanuel Marzini; Filip Morawski; Alessandro Petrocelli; Alessandro Stanicchia

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The detection of gravitational waves has inaugurated the era of gravitational astronomy and opened new challenges for the multi-messenger study of cosmic sources. Thanks to their sensitivity, the Advanced LIGO and Advanced Virgo interferometers will probe a much larger volume of space and expand the capability of discovering new gravitational wave emitters. However, noise identification and its removal remains one of the most challenging problem in GW data analysis. A single GW detector typically produces data with a rate of 7-8 Tb per day with a flux of 40Mb/s. These data have to be analysed in the faster and most efficient way to increase the detection confidence and to obtain information in real time, about likely noise sources and to help the fast alert system for Electromagnetic Follow Up systems.

Glitches are transient noise events that can impact the data quality of the interferometers and their classification is an important task. Outlier/noise detection has been studied for decades in time-series analysis. ML methods generally employ a semi-supervised approach, with a few others using supervised or unsupervised techniques. Supervised ML techniques require a training phase with labeled data, in order to learn the data model which classifies outliers and inliers. This can be an expensive operation with massive data since generating a labeled training data set can be time consuming, especially if the data need to be labeled manually. Characterizing the glitches is an important task to reduce the impact of transient noise on the detectors. Inspecting glitches manually is a time-consuming and error-prone task. Furthermore, the increase of sensitivity in advanced detectors will lead to more classes of glitches. The use of machine learning looks a promising

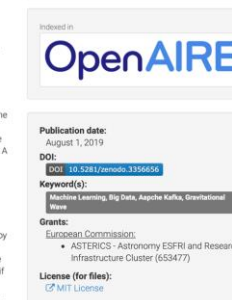


wavefier

Group ID: 9824942

Subgroups and projects

Subgroup	Project	Stars	Updated
D	Docker Images	0	1 month ago
S	Services Kubernetes Deployment CNAF	0	1 month ago
S	Site - wavefier.gitlab.io	0	7 months ago
W	Wavefier Common	0	6 months ago
W	Wavefier Disk to Kafka importer	0	5 months ago
W	Wavefier Import Handlers	0	5 months ago
W	Wavefier Kubernetes Deployment	0	7 months ago
W	Wavefier ML	0	7 months ago
W	Wavefier Online Importer	0	7 months ago
W	Wavefier Trigger Handlers	0	8 months ago
W	Wavefier Wdf	0	11 hours ago



OpenAIRE

Publication date: August 1, 2019

DOI: 10.5281/zenodo.3356656

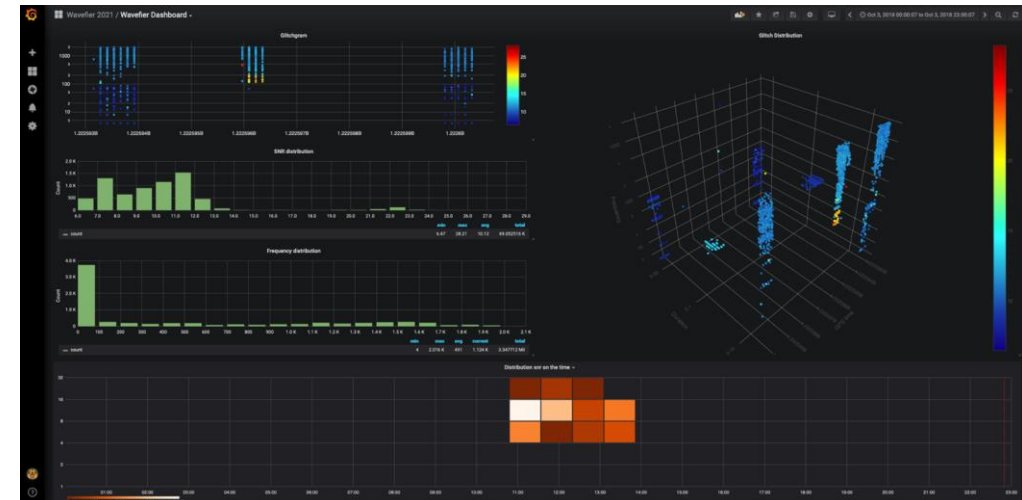
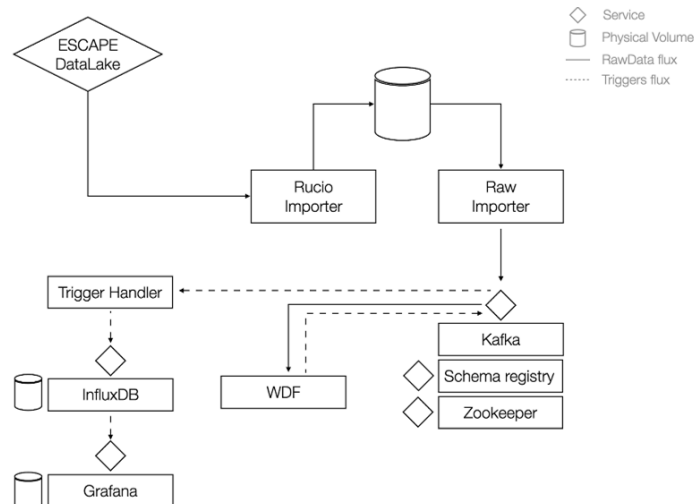
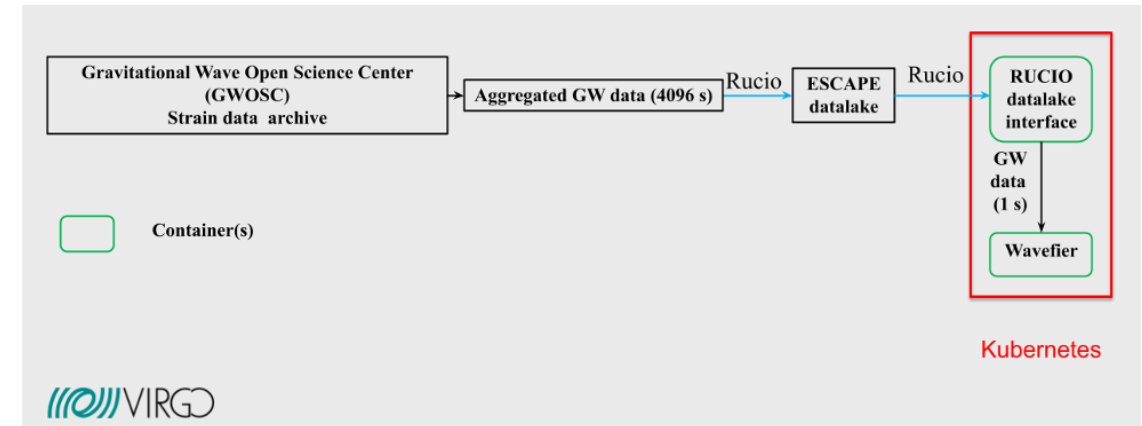
Keywords: Machine Learning, Big Data, Apache Kafka, Gravitational Waves

Grants: European Commission, ASTERICS - Astronomy ESFRI and Research Infrastructure Cluster (653477)

License (for files): MIT License

Test Case: ESCAPE Datalake

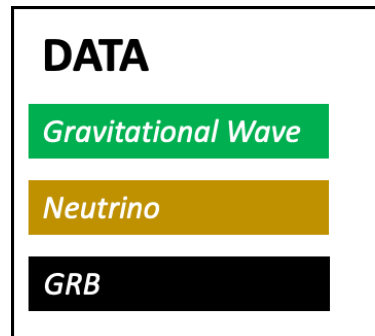
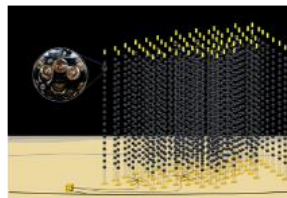
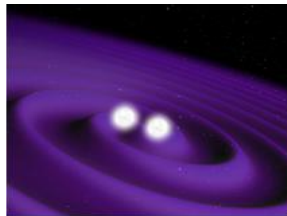
- Gravitational Wave Open Science Center data
- Successfully attached to ESCAPE datalake
- Gravitational wave specific implementation
- CNAF cloud (region Tier1) on shared Virgo **Kubernetes** cluster.
- Astrophysical signal triggers sent to Influx DB and plotted through Grafana dashboard



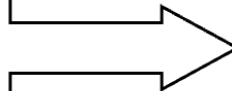
On-going Test Case: Multi-messenger Data

Different Data Formats

- Gravitational waves (.gwf)
- Gamma ray bursts (.fits)
- Neutrino (.fits)

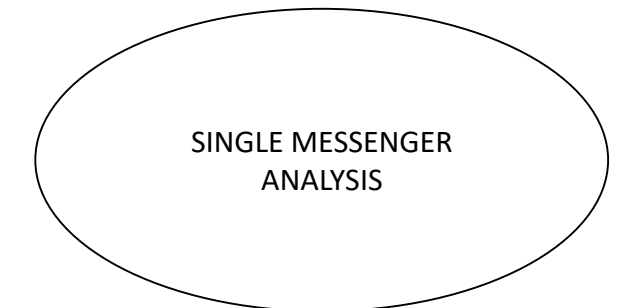
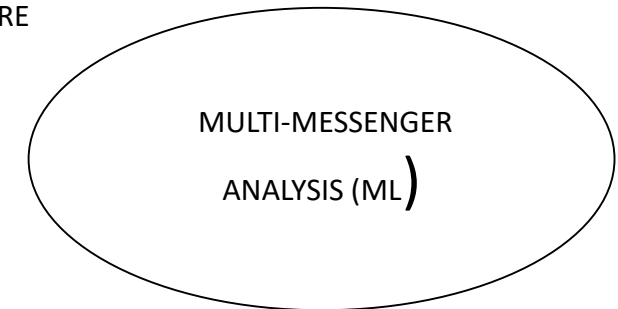
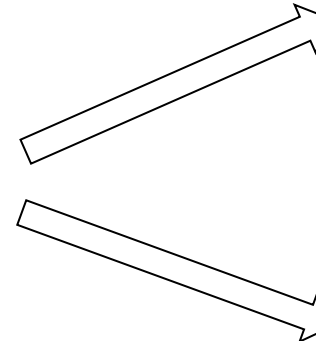
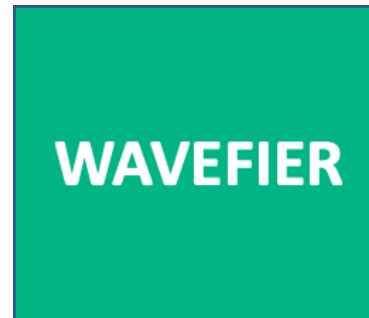


Kafka stream



Separate Analysis Pipelines

- Wavelet Detection Filter (GW) —> integration in ESCAPE VRE
- Analysis pipeline for Gamma ray
- Neutrino pipeline
- MM pipeline



Collaboration of Astronomical Communities





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Measuring the dark Matter environments of black hole binaries with Gravitational Waves

Alessandro Parisi (Scuola Normale Superiore and University of Amsterdam)

supervisors: E.Cuoco and G.Bertone

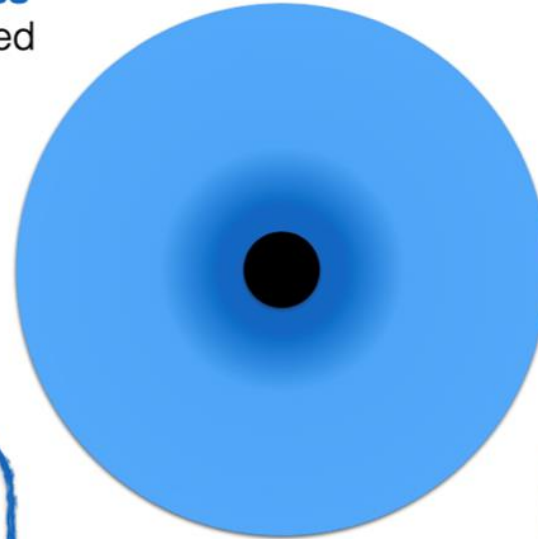
In collaboration with: G.Bertone, P.Cole, A.Coogan, B.Kavanagh,
D.Gaggero, E.Cuoco, A.Iess



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Dark Matter Spikes

Consider now a cold **DM 'spike' or 'dress'** around the central BH (not to be confused with ultralight boson clouds).



Study the following benchmarks:

$$\begin{aligned} m_1 &= 1M_{\odot} \\ m_2 &= 10^{-2} - 10^{-4}M_{\odot} \\ \rho_{\text{DM}} &= \rho_6 \left(\frac{10^{-6} \text{ pc}}{r} \right)^{\gamma_{\text{sp}}} \end{aligned}$$

Astrophysical scenario

$$\gamma_{\text{sp}} = 7/3 \approx 2.3333 \dots$$

$$\rho_6 \approx 5.45 \times 10^{15} M_{\odot} \text{ pc}^{-3}$$

...depending on a number of environmental factors...

[[astro-ph/9906391](#), [astro-ph/0509565](#),
[1305.2619](#), ...]

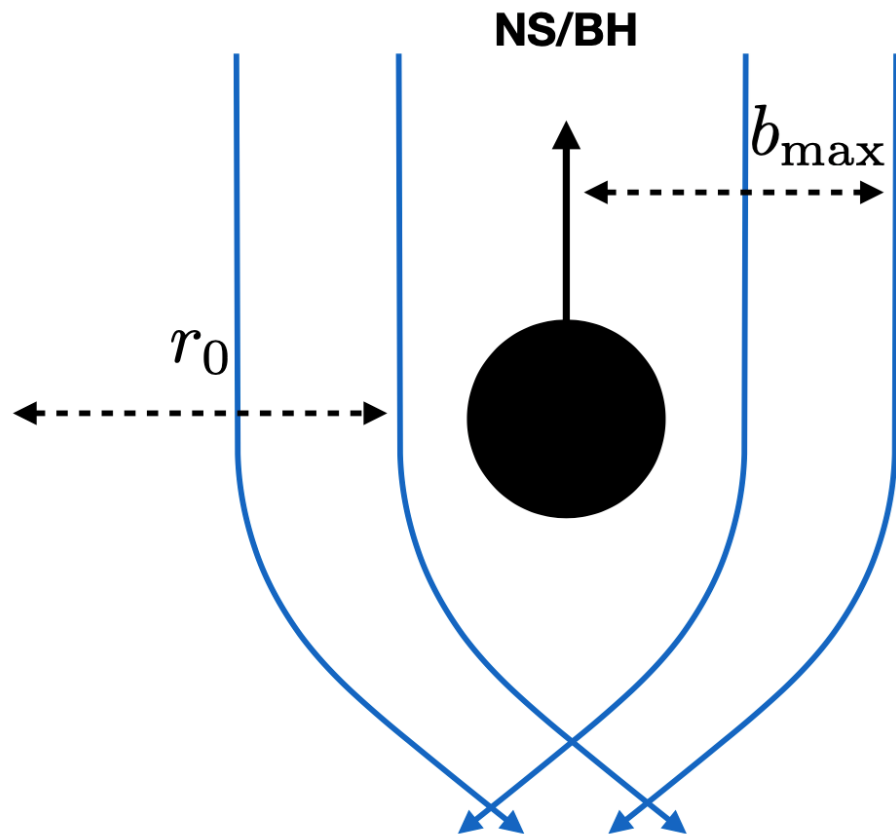
PBH scenario

$$\gamma_{\text{sp}} = 9/4 \approx 2.25$$

$$\rho_6 \approx 5.35 \times 10^{15} M_{\odot} \text{ pc}^{-3}$$

[[Bertschinger \(1985\)](#), [astro-ph/0608642](#),
[1901.08528](#), ...]

Dynamical Friction



$$\frac{dE_{\text{orb}}}{dt} = -\frac{dE_{\text{GW}}}{dt} - \frac{dE_{\text{DF}}}{dt}.$$

$$\frac{dE_{\text{GW}}}{dt} = \frac{32G^4 M(m_1 m_2)^2}{5(c r_2)^5}. \quad \frac{dE_{\text{DF}}}{dt} = 4\pi (G m_2)^2 \rho_{\text{DM}}(r_2) \xi(v) v^{-1} \log \Lambda.$$

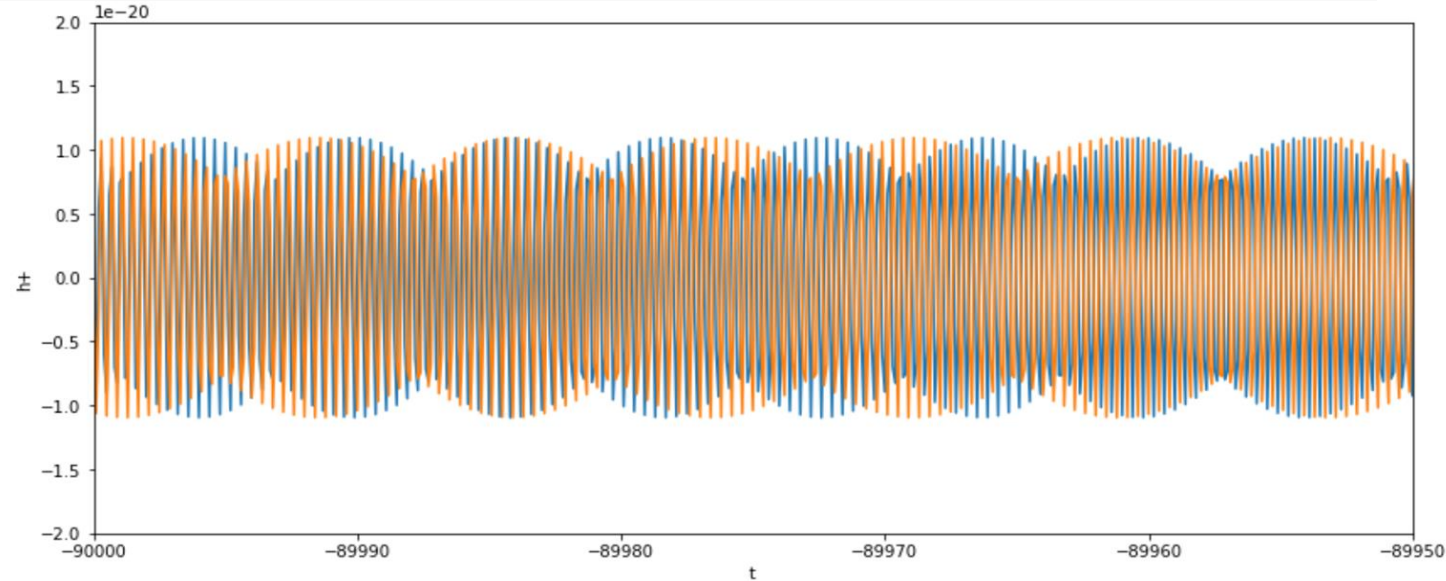
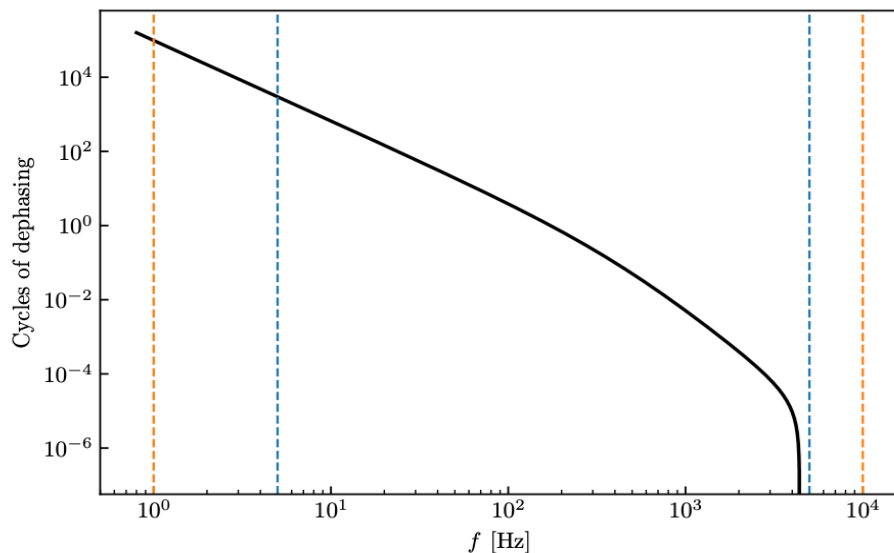
$$\dot{r}_2 = -\frac{64G^3 M m_1 m_2}{5c^5 (r_2)^3} - \frac{8\pi G^{1/2} m_2 \rho_{\text{sp}} \xi \log \Lambda r_{\text{sp}}^{\gamma_{\text{sp}}}}{\sqrt{M} m_1 r_2^{\gamma_{\text{sp}} - 5/2}}$$

$$h_+(t) = \frac{4G_N \mu}{c^4 D_L} \frac{1 + \cos^2 i}{2} (\omega r_2)^2 \cos[2\Phi_{\text{orb}}(t) + 2\phi],$$

$$h_{\times}(t) = \frac{4G_N \mu}{c^4 D_L} \cos i (\omega r_2)^2 \sin[2\Phi_{\text{orb}}(t) + 2\phi],$$

#EDIT WAVEFORM PARAMETERS BELOW:

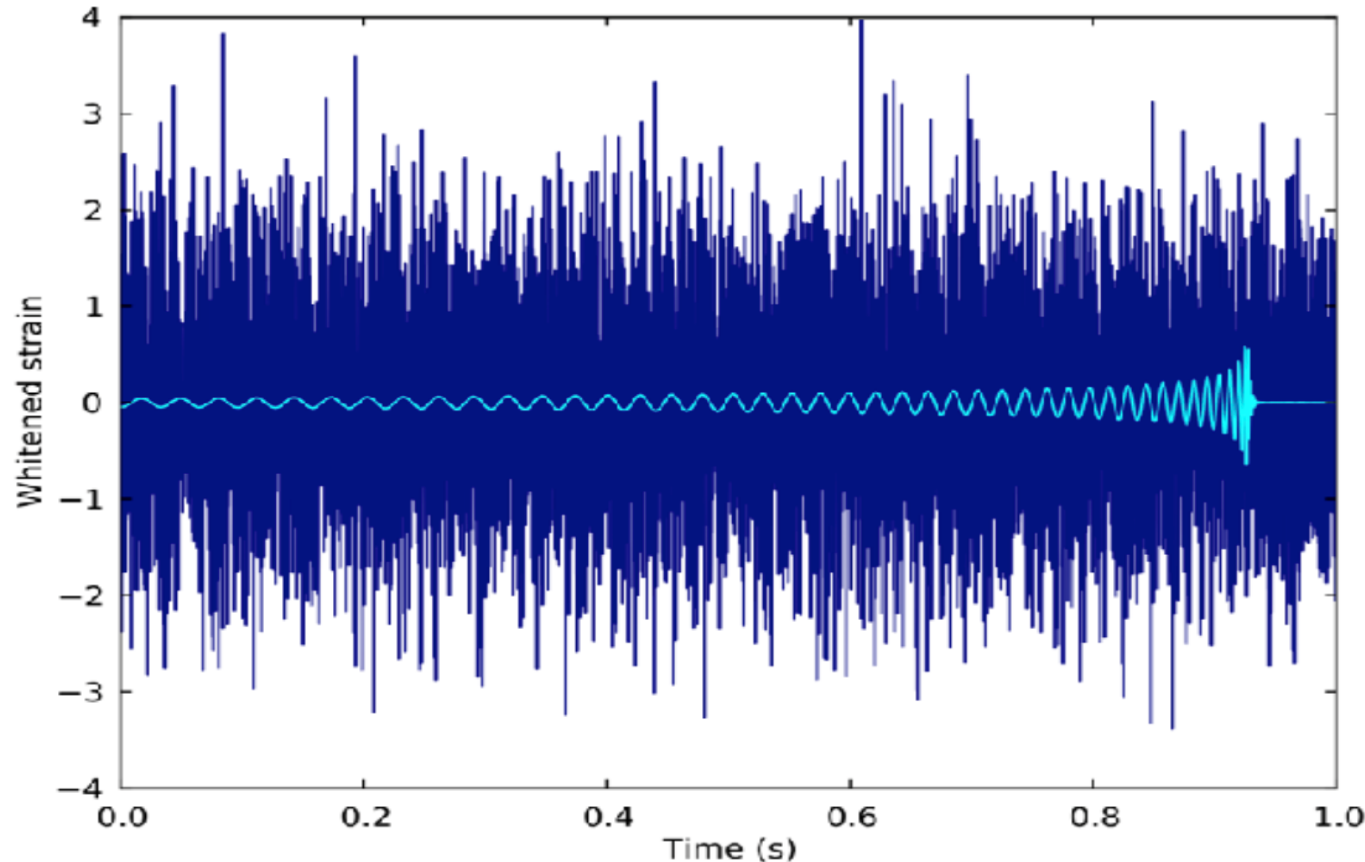
```
#-----
m_1      = 1.0      # [MSun]
m_2      = 0.001    # [MSun]
t_obs    = 1*DAY     # Duration of the waveform
t_end    = -0.0*YR   # End time of the waveform
f_samp   = 200      # Sampling frequency [Hz]
d_l      = 100000    # Luminosity distance [pc]
iota     = 0.0      # Inclination angle [rad]
phi_c    = 0.0      # Phase at coalescence [rad]
```



$$N_{\text{cycles}}(t_{\text{max}}, t_{\text{min}}) = \int_{t_{\text{min}}}^{t_{\text{max}}} f_{\text{gw}}(t) dt = \int_{f_{\text{min}}}^{f_{\text{max}}} df_{\text{gw}} \frac{f_{\text{gw}}}{\dot{f}_{\text{gw}}}$$

$$\Delta N_{\text{cycles}} = N_{\text{cycles}}^{\text{vac}}(f_{\text{max}}, f_{\text{min}}) - N_{\text{cycles}}^{\text{DM}}(f_{\text{max}}, f_{\text{min}})$$

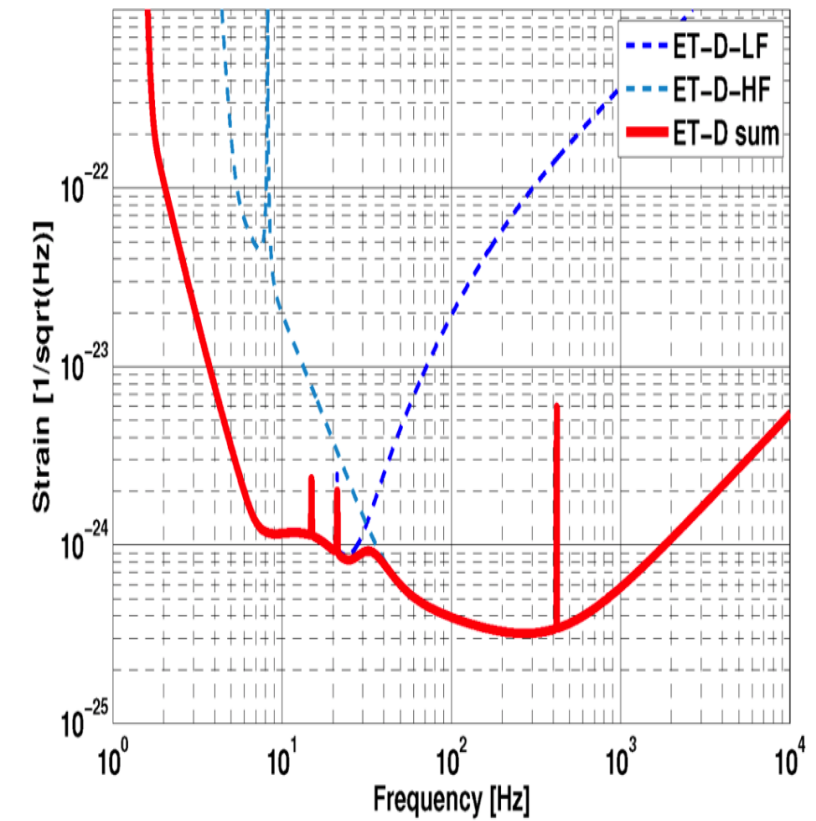
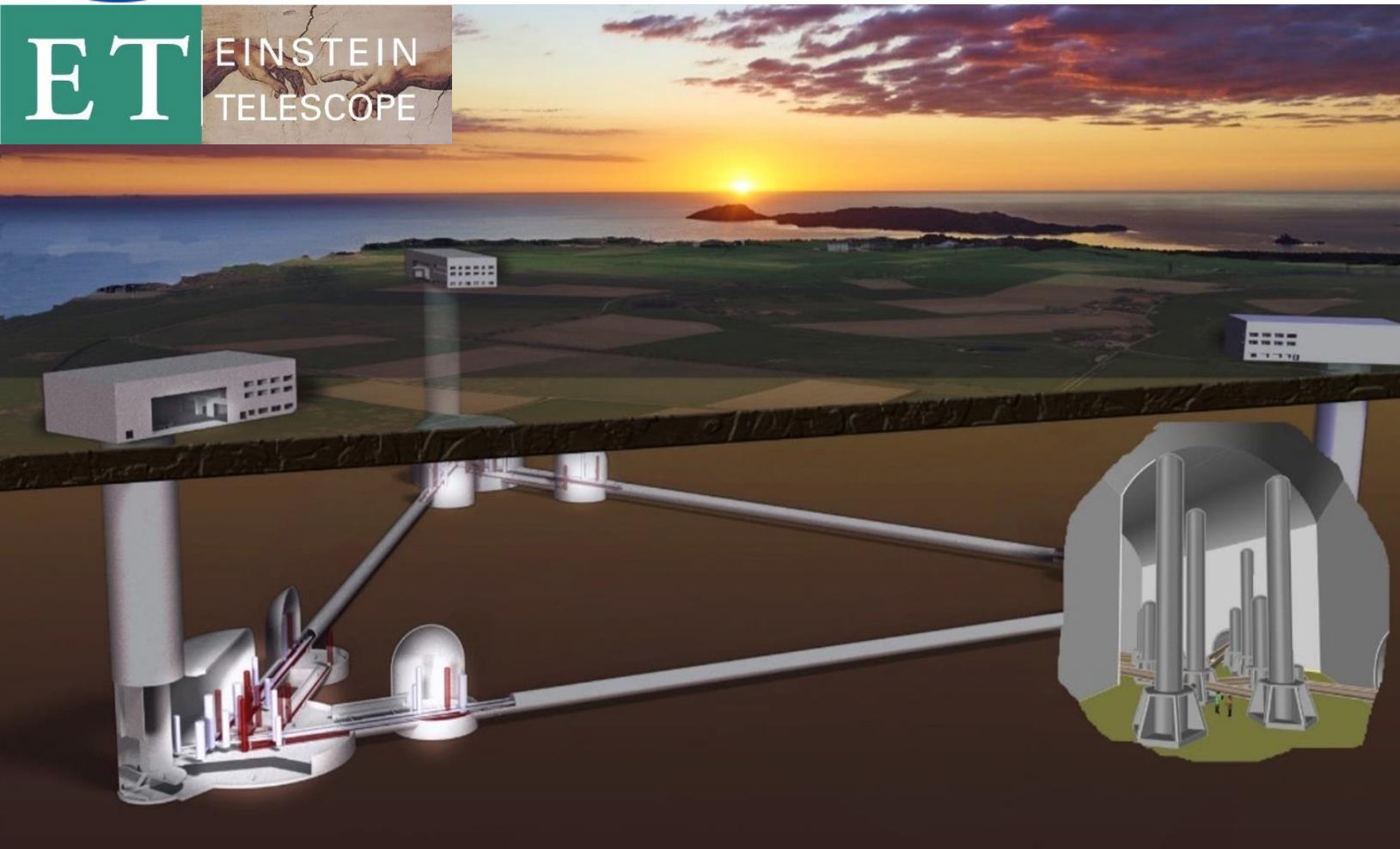
Matched Filtering



Naively, one might think that we can only make confident detections when $|h(t)| > |n(t)|$
However, the **majority of signals are expected to be $|h(t)| \ll |n(t)|$**

Therefore, we need a method to detect signals from noise-dominated data
If we know the possible forms of $h(t)$, we can “filter” out things that are non-signal-like

Einstein Telescope



Develop a catalog of waveforms for different luminosity distances and masses

Luminosity distance $d = 10\text{kpc}, 20\text{kpc}, 30\text{kpc}, 40\text{kpc}, 50\text{kpc}, 60\text{kpc}, 100\text{kpc}$

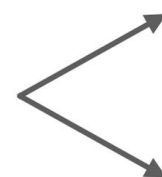
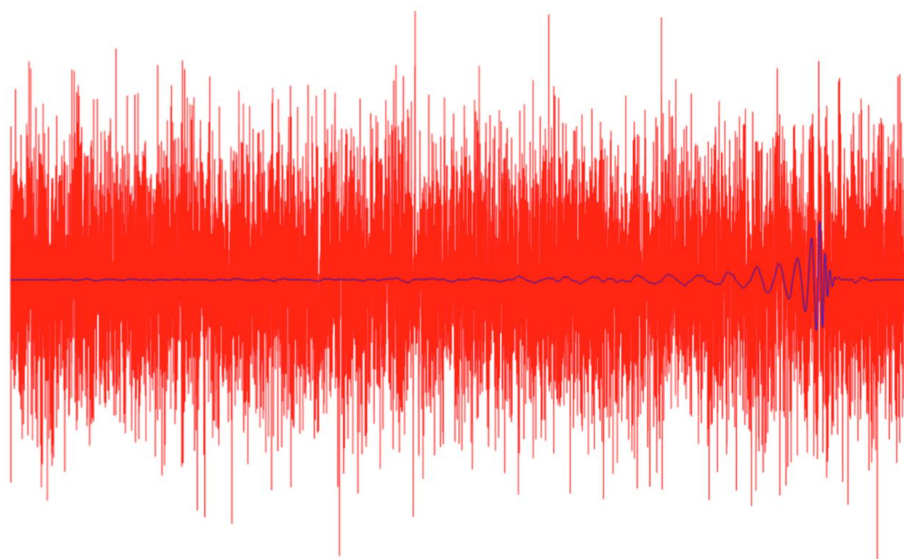
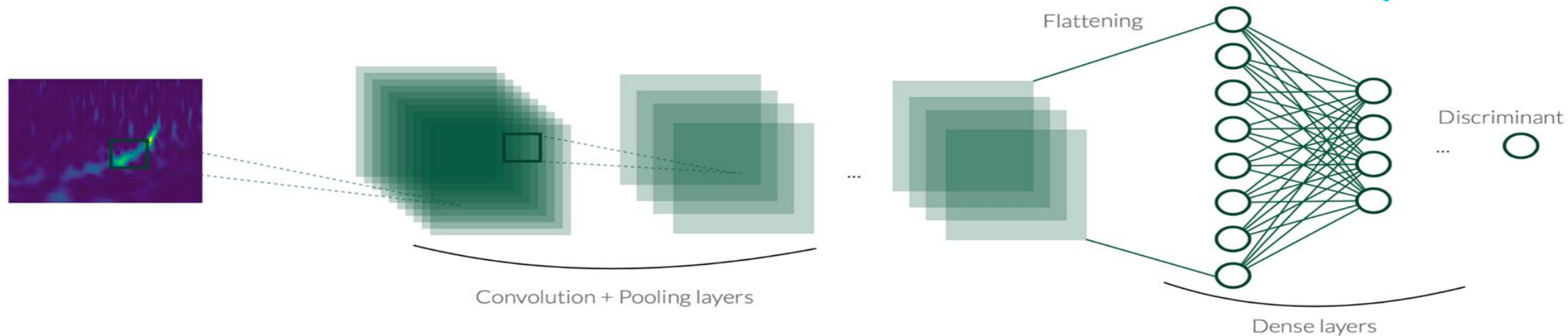
Mass $m_1 = 1M_{\odot} \quad m_2 = 10^{-2} - 10^{-4}M_{\odot} \quad \Delta m_2 = 0.001M_{\odot}$

Antenna Sensitivity 100 different directions

We have 11400 GW for the vacuum and 11400 GW with dark matter +802 GW at 100kpc

Total: 22800 waveform +802

Machine Learning for classification



Vacuum

Dark Matter

This projects acknowledges the computational resources and support provided by the following institutions: Scuola Normale Superiore



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KM3NeT Instrument Response Function for point-source analysis



Mikhail Smirnov
supervisor: Kay Graf



Friedrich-Alexander-Universität
Erlangen-Nürnberg



ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS



ESCAPE - The European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructures has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 824064.

Motivation

- Adopt the most common problem of neutrino astrophysics for open science
- Provide an effective tool, which can extract IRF information from KM3NeT simulation data
- Flexibility in operation and user-defined IRF interface
- Compatibility with other astrophysical analysis, like CTA which is based on `gammapy`
- Easy installation procedure (preferred `pip install` package)
- Different options for output (fits, histograms, tables, GADF)

Overview of the KM3NeT detector

KM3NeT (cubic kilometer neutrino telescope) [J.Phys. G43 \(2016\) 084001](#)

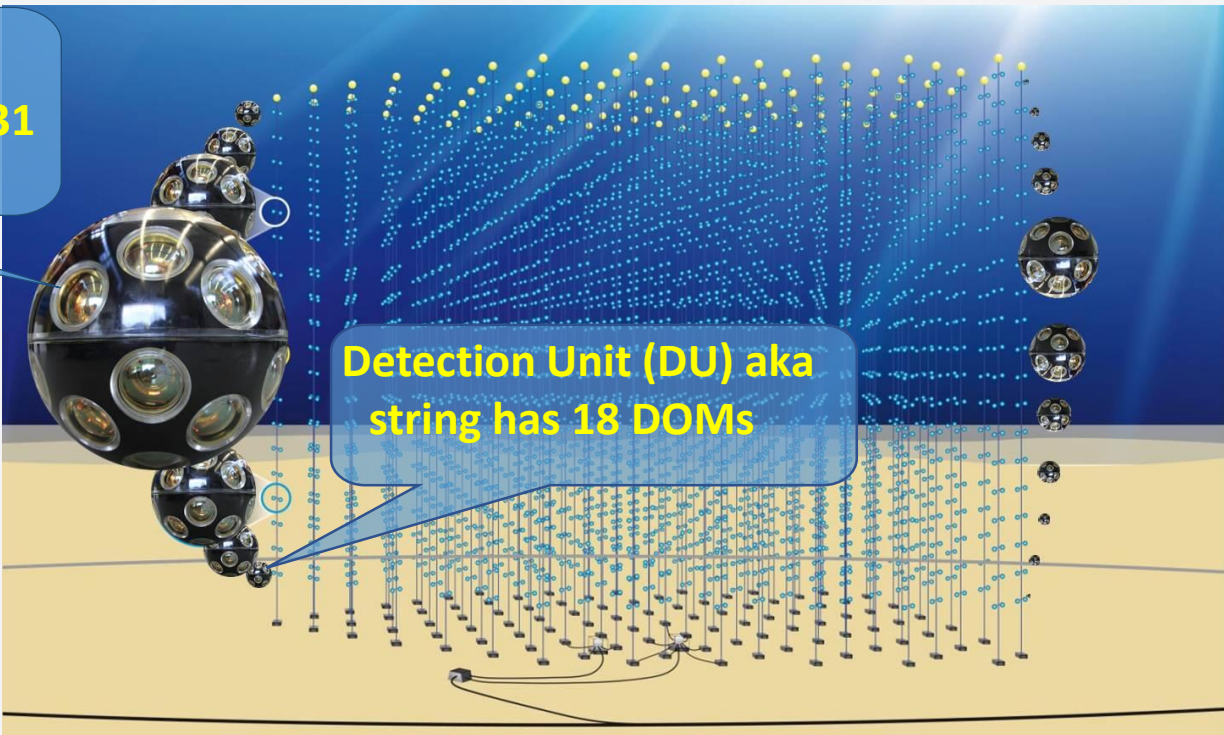
KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss)
discovery and observation of HE cosmic neutrino sources
($E_\nu \sim \text{GeV-PeV}$) high energy neutrinos
Depth – 3500 m – offshore Sicily (Italy)

KM3NeT/ORCA (Oscillation Research with Cosmics in the Abyss)
determination of the neutrino mass hierarchy
($E_\nu \sim \text{MeV - GeV}$) low energy neutrinos
Depth – 2500 m – offshore Toulon (France)



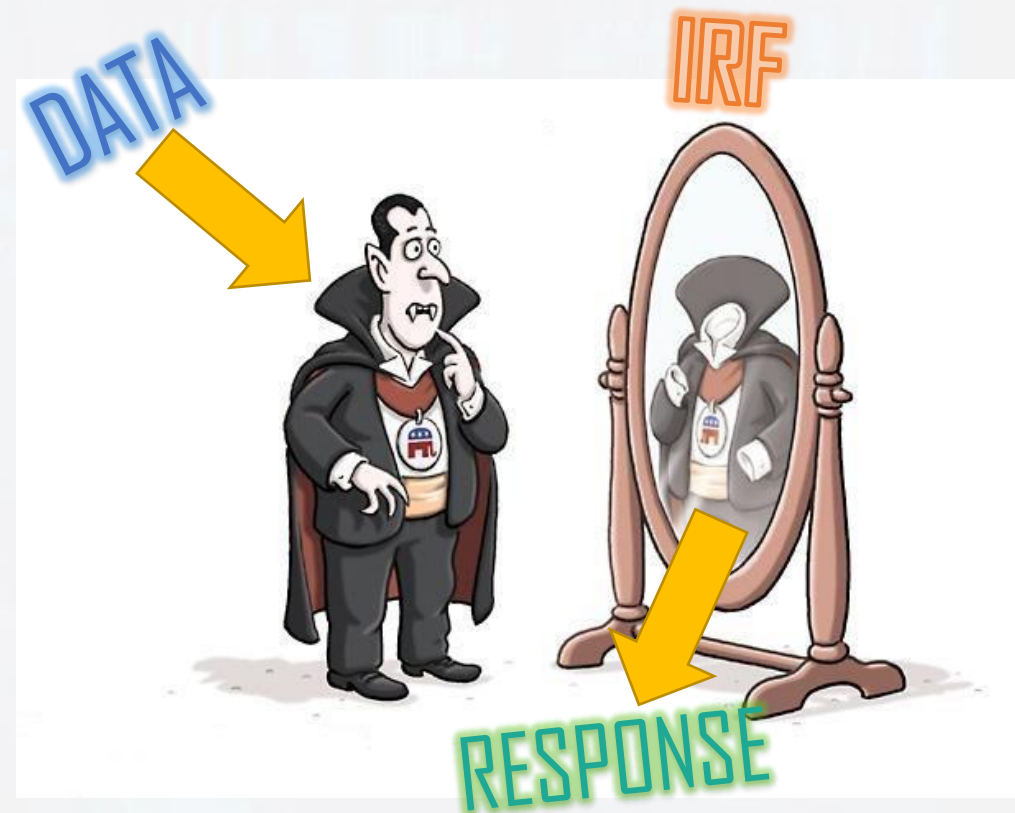
Parameter	ARCA	ORCA
DU distance	90 m	20 m
DOM spacing	36 m	9 m
DU height	~ 800 m	~ 200 m
Instrumented mass	2*500 Mton	7 Mton
Amount of DUs	115*2	115

Digital Optical Module (DOM) 31 of 3" PMTs



What is IRF in KM3NeT?

- IRF is a property of a neutrino telescope
- It contains information about the physical characteristics of the detector, such as angular resolution, energy resolution, effective area or volume of the detector
- It allows to quickly estimate the background
- It is based on [gammapy](#) for cross-experiment use
- In [gammapy](#) the IRF consists of 4 parts:
 - Effective area
 - Energy dispersion
 - Point spread function
 - Background

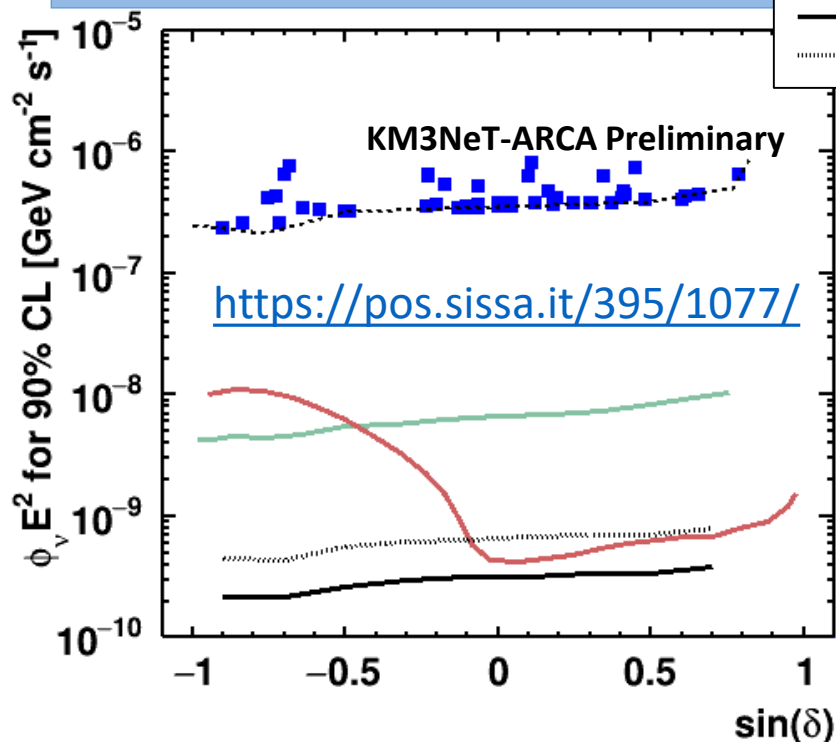


Scientific outcome – analysis of distant source

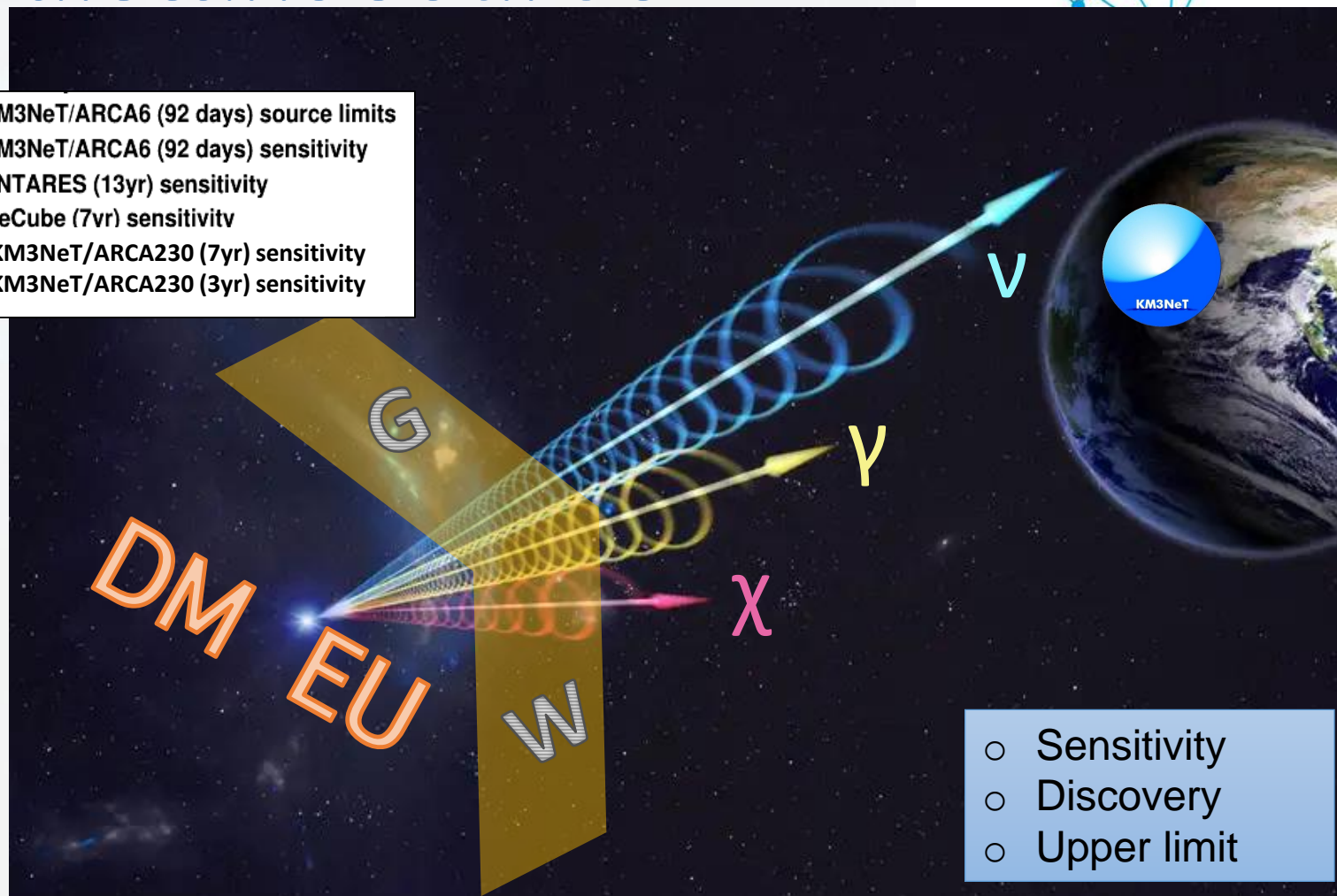
Neutrino source types:

- **Point-like**
- Diffuse
- Extended

Follows to power law $\sim A \cdot E^{-\alpha}$



- KM3NeT/ARCA6 (92 days) source limits
- KM3NeT/ARCA6 (92 days) sensitivity
- ANTARES (13yr) sensitivity
- IceCube (7yr) sensitivity
- KM3NeT/ARCA230 (7yr) sensitivity
- KM3NeT/ARCA230 (3yr) sensitivity



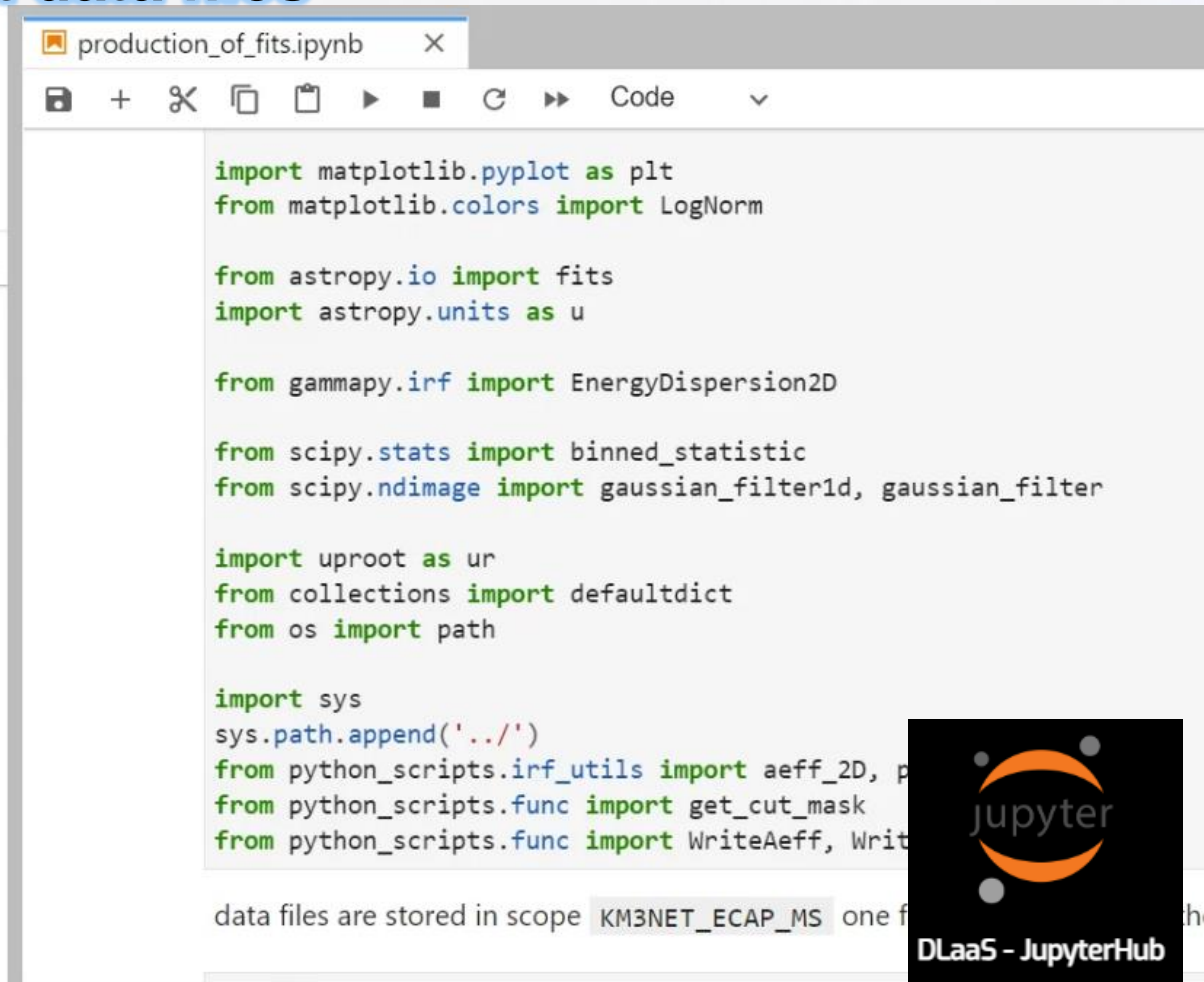
- Sensitivity
- Discovery
- Upper limit

search for a neutrino excess from 46 candidate sources 92 days of data taking: May 2021 --> Sep 2021

Integration with ESCAPE services

Example of IRF production from dst data files

- common gamma analysis tools
- production_of_fits.ipynb

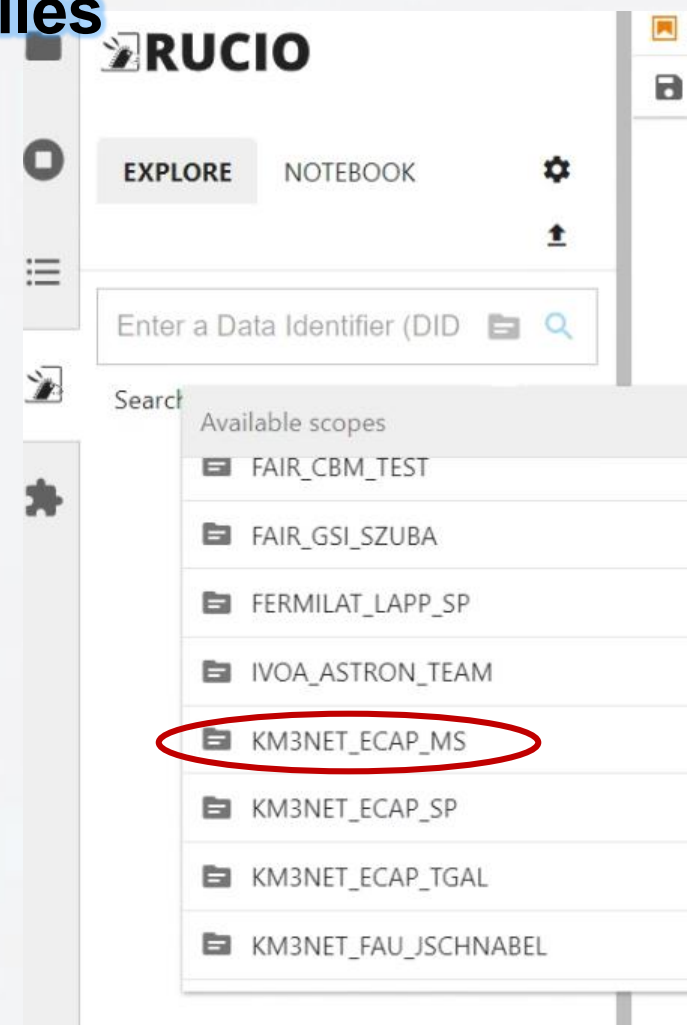


Integration with ESCAPE services

Example of IRF production from dst data files

<https://gitlab.in2p3.fr/escape2020/virtual-environment/irf-from-km3net>

- common gamma analysis tools
- production_of_fits.ipynb
- choose scope in RUCIO



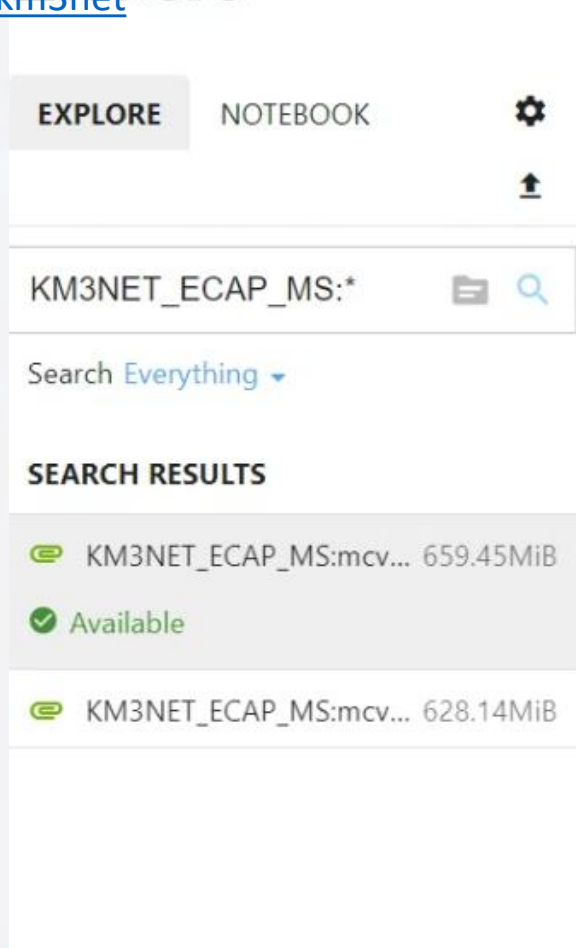
Integration with ESCAPE services

Example of IRF production from dst data files

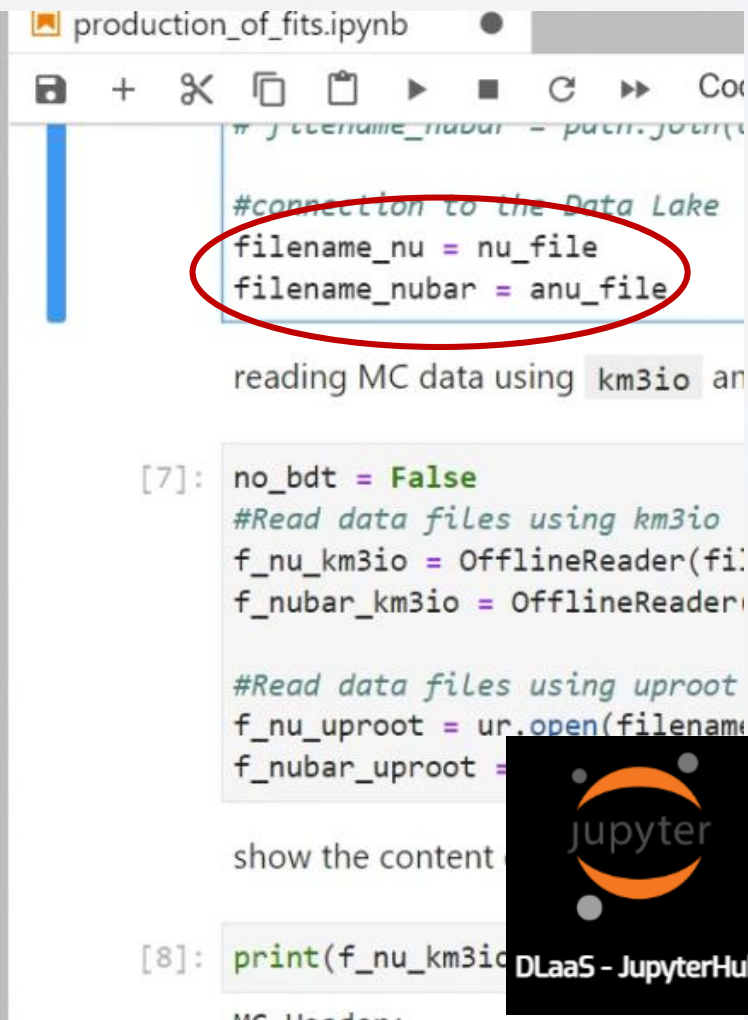
<https://gitlab.in2p3.fr/escape2020/virtual-environment/irf-from-km3net>

- common gamma analysis tools
- production_of_fits.ipynb
- choose scope in RUCIO
- attach data files into notebook

RUCIO



The RUCIO interface shows a search for 'KM3NET_ECAP_MS:*'. The search results list two files: 'KM3NET_ECAP_MS:mcv...' (659.45MiB) and 'KM3NET_ECAP_MS:mcv...' (628.14MiB). Both files are marked as 'Available'.



The Jupyter Notebook interface shows the code for IRF production. The code includes a connection to the Data Lake, reading MC data using km3io, and printing the content of the files. The code is as follows:

```
#connection to the Data Lake
filename_nu = nu_file
filename_nubar = anu_file

reading MC data using km3io and

[7]: no_bdt = False
#Read data files using km3io
f_nu_km3io = OfflineReader(fi
f_nubar_km3io = OfflineReader

#Read data files using uproot
f_nu_uproot = ur.open(filename
f_nubar_uproot =

show the content

[8]: print(f_nu_km3io
MC Header:
```

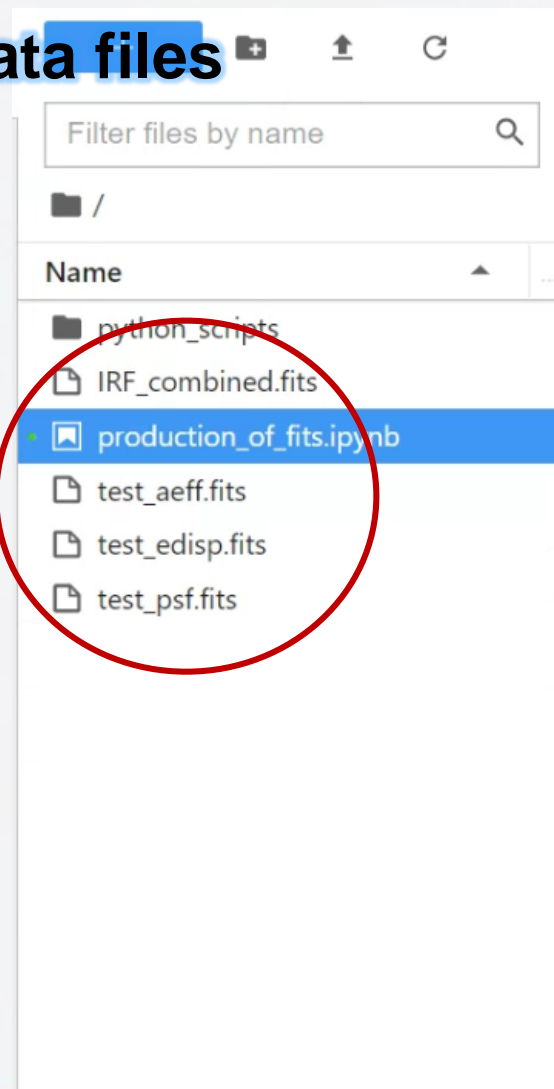

Integration with ESCAPE services

Example of IRF production from dst data files

<https://gitlab.in2p3.fr/escape2020/virtual-environment/irf-from-km3net>

- common gamma analysis tools
- production_of_fits.ipynb
- choose scope in RUCIO
- attach data files into notebook
- run notebook

using km3irf
package



Integration with ESCAPE services

Example of IRF production from dst data files

<https://gitlab.in2p3.fr/escape2020/virtual-environment/irf-from-km3net>

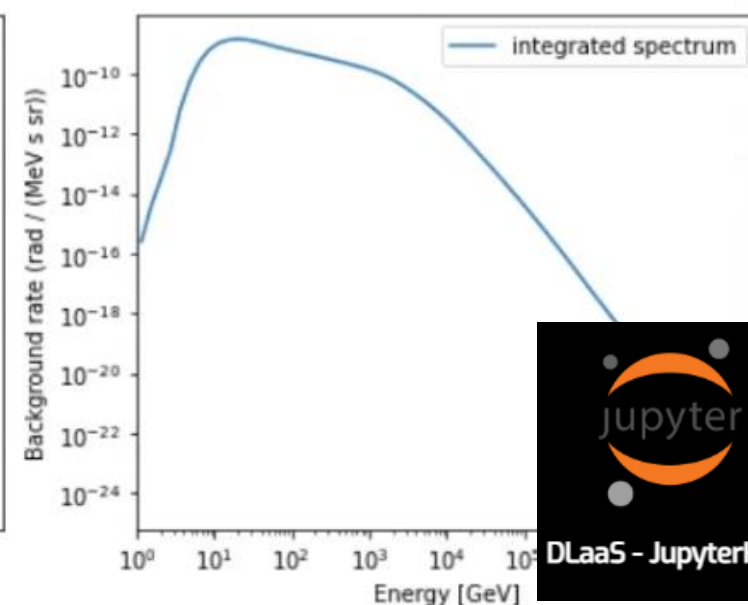
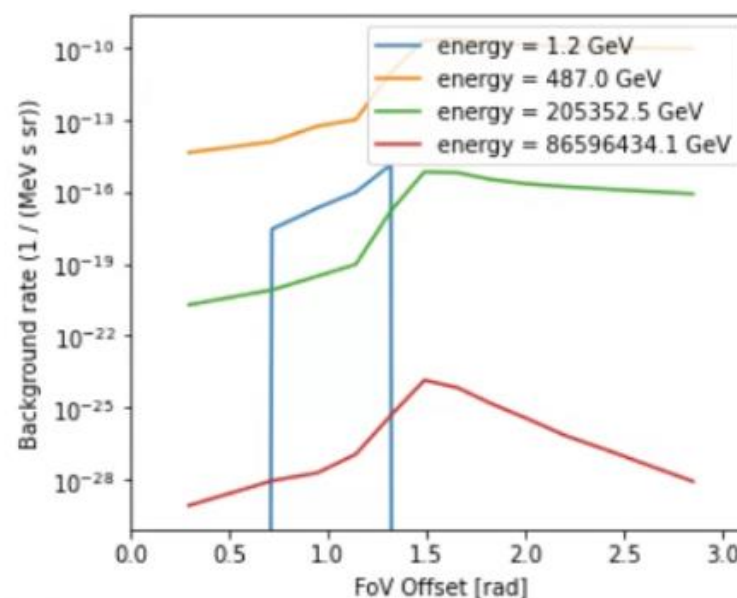
- common gamma analysis tools
- production_of_fits.ipynb
- choose scope in RUCIO
- attach data files into notebook
- run notebook
- investigate results

```
[34]: from gammapy.irf import load_irf_dict_from_file

[35]: merged_irf = load_irf_dict_from_file("./IRF_combined.fits")
merged_irf.keys()

[35]: dict_keys(['aeff', 'psf', 'edisp', 'bkg'])

[36]: merged_irf['bkg'].peek()
```



Integration with ESCAPE services

Example of IRF production from dst data files

<https://gitlab.in2p3.fr/escape2020/virtual-environment/irf-from-km3net>

- common gamma analysis tools
- production_of_fits.ipynb
- choose scope in RUCIO
- attach data files into notebook
- run notebook
- investigate results
- content of combined IRF
- reproducibility and re-use

```
[37]: for name in merged_irf.keys():
      print(merged_irf[name])
```

EffectiveAreaTable2D

```
-----
axes   : ['energy_true', 'offset']
shape  : (48, 12)
ndim   : 2
unit   : m2
dtype  : >f8
```

PSF3D

```
-----
axes   : ['energy_true', 'offset', 'rad']
shape  : (24, 6, 111)
ndim   : 3
unit   : 1 / sr
dtype  : >f8
```

EnergyDispersion2D

```
-----
axes   : ['energy_true', 'migra', 'offset']
shape  : (24, 56, 6)
ndim   : 3
unit   :
dtype  : >f8
```

Background2D

```
-----
axes   : ['energy', 'offset']
shape  : (64, 12)
ndim   : 2
unit   : 1 / (MeV s sr)
dtype  : >f8
```




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Extreme Universe VRE-DEMO: Searching for FRB persistent radio source counterpart in dwarf galaxies using LOFAR

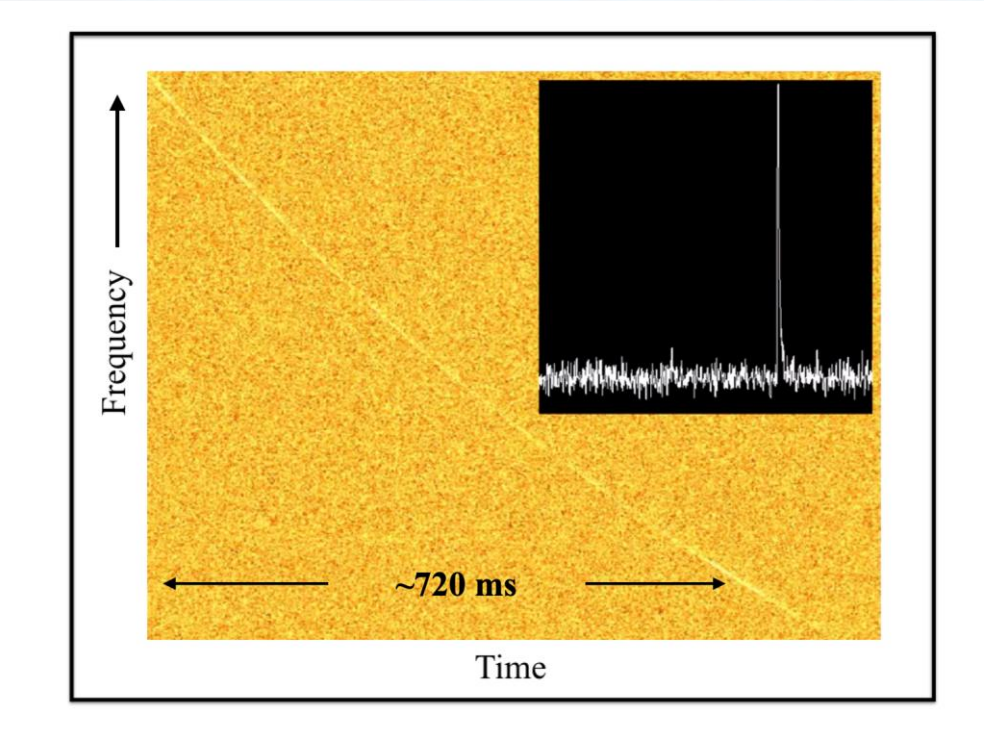
Dany Vohl (UvA/ASTRON)
Harish Vedantham (ASTRON)
Jason Hessels (UvA/ASTRON)



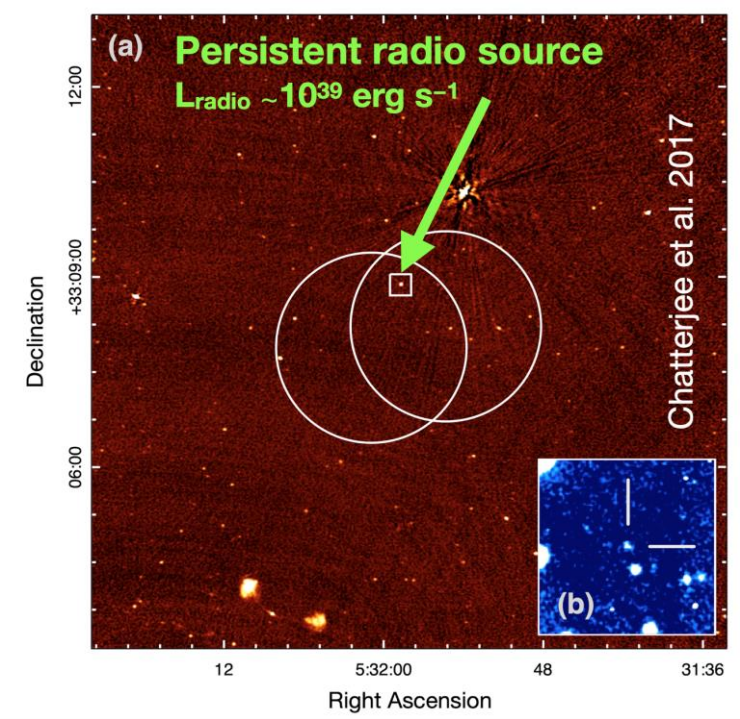
ESCAPE - The European Science Cluster of Astronomy & Particle Physics ESFRI Research Infrastructures has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 824064.

- ❑ Current research interest in dwarf galaxies ($M_{\odot} < 10^{9.5}$)
 - ❑ May host **intermediate-mass black holes** (IMBH)
 - ❑ Predicted, possibly detectable as compact radio source
 - ❑ Metal poor, can host superluminous supernovae
- ❑ Two repeating **fast radio burst** (FRB)
 - ❑ Localised to dwarf galaxies
 - ❑ Co-located to **persistent radio source** (PRS): energetic plerion?
- ❑ Can we find IMBH or PRS in deep radio surveys?

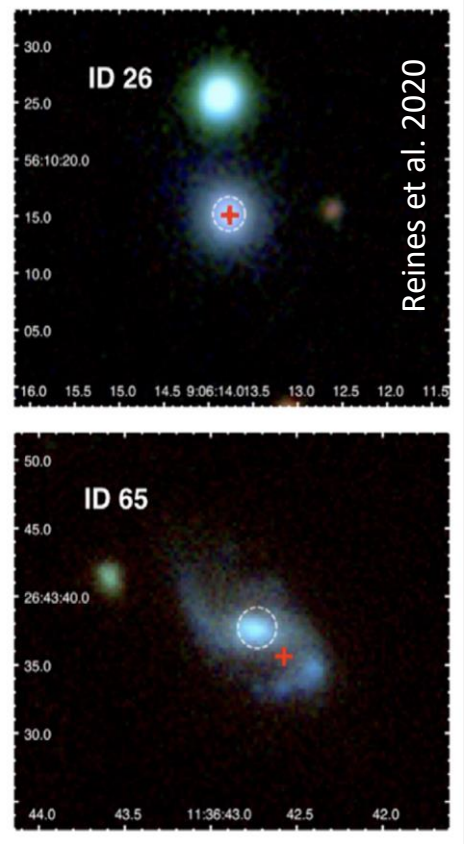
Fast Radio Bursts



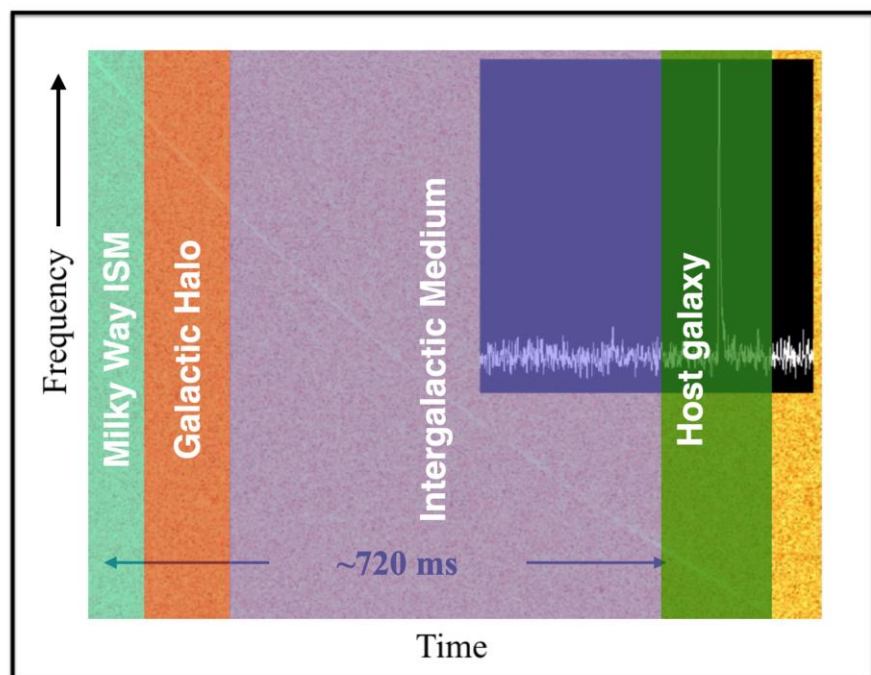
PRS



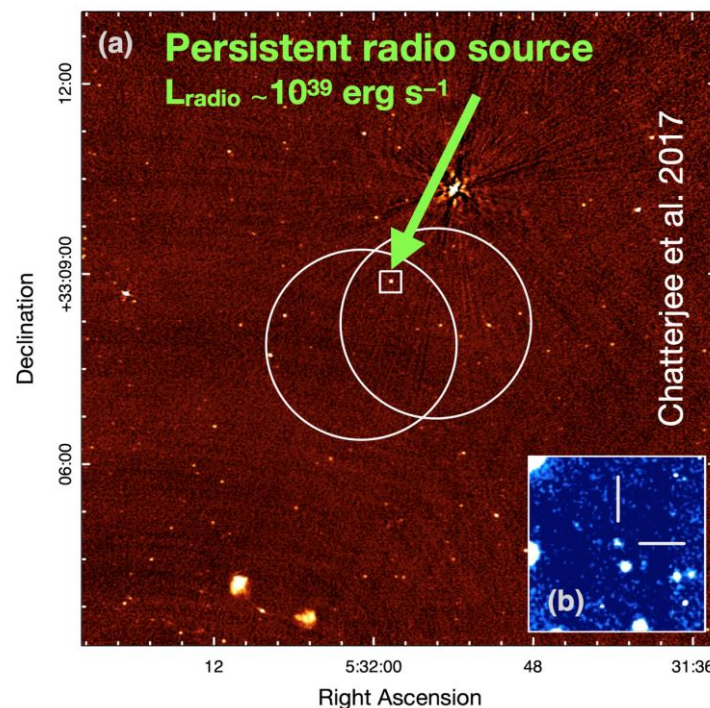
IMBH



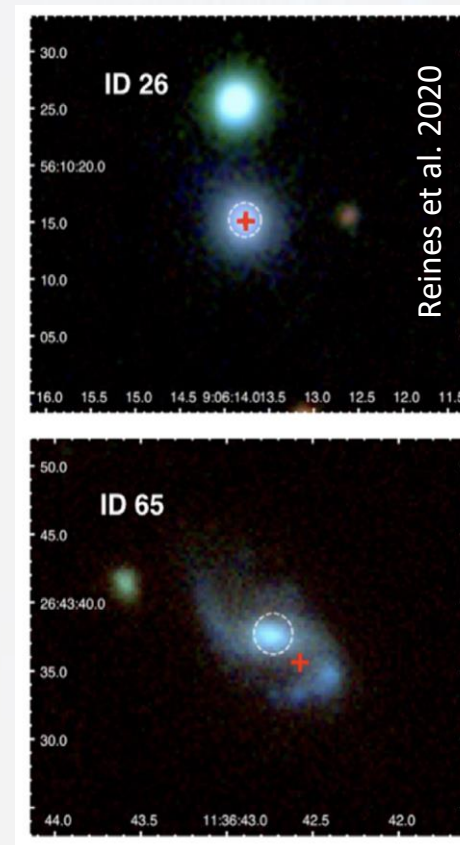
Fast Radio Bursts



PRS

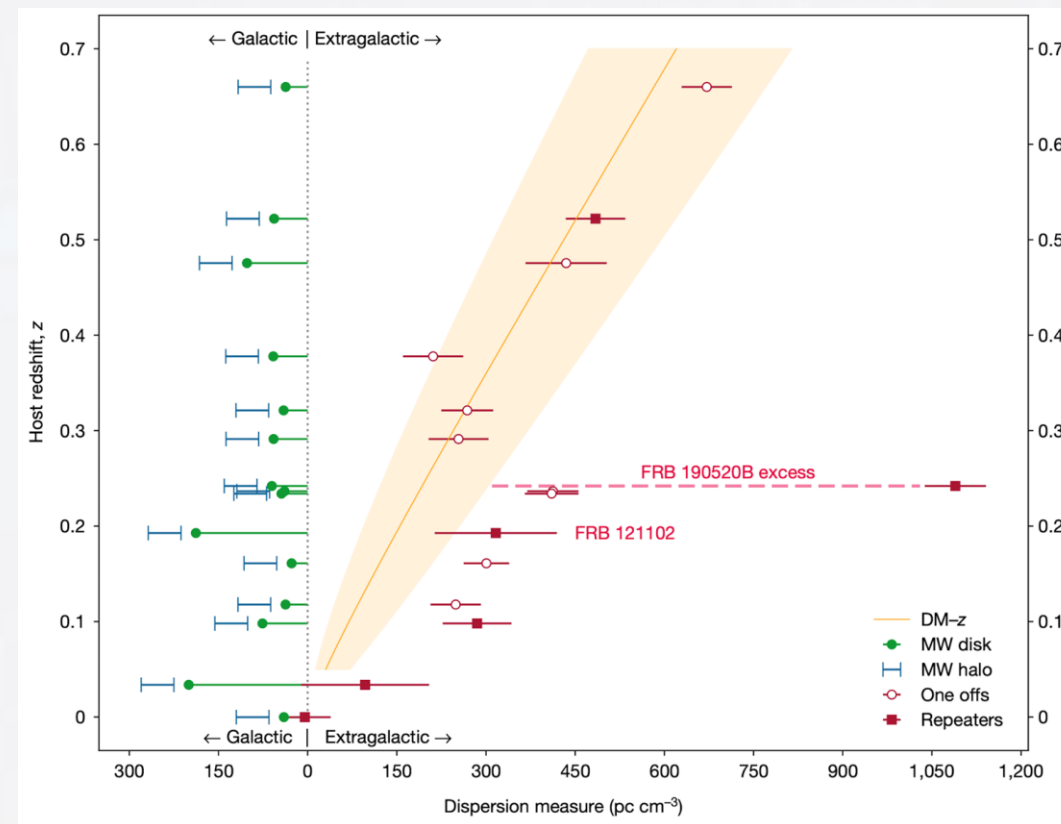
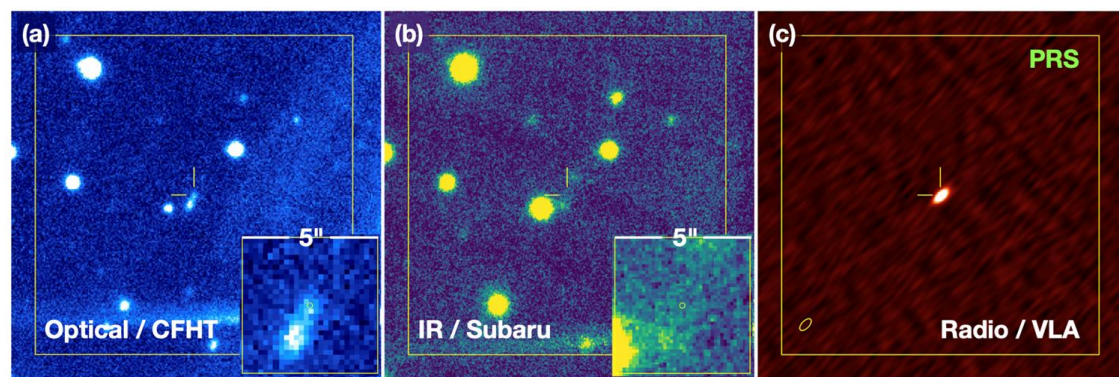


IMBH



Only the 2nd known repeating FRB co-located to PRS

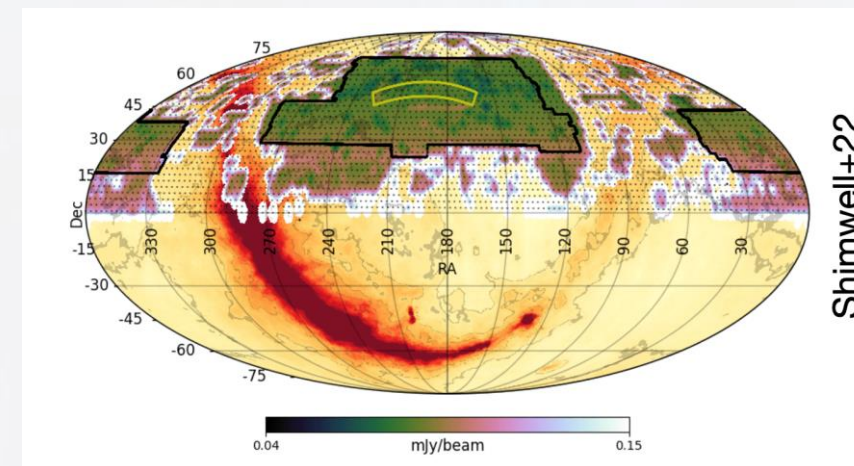
- Star forming dwarf host galaxy (Niu et al. 2022)



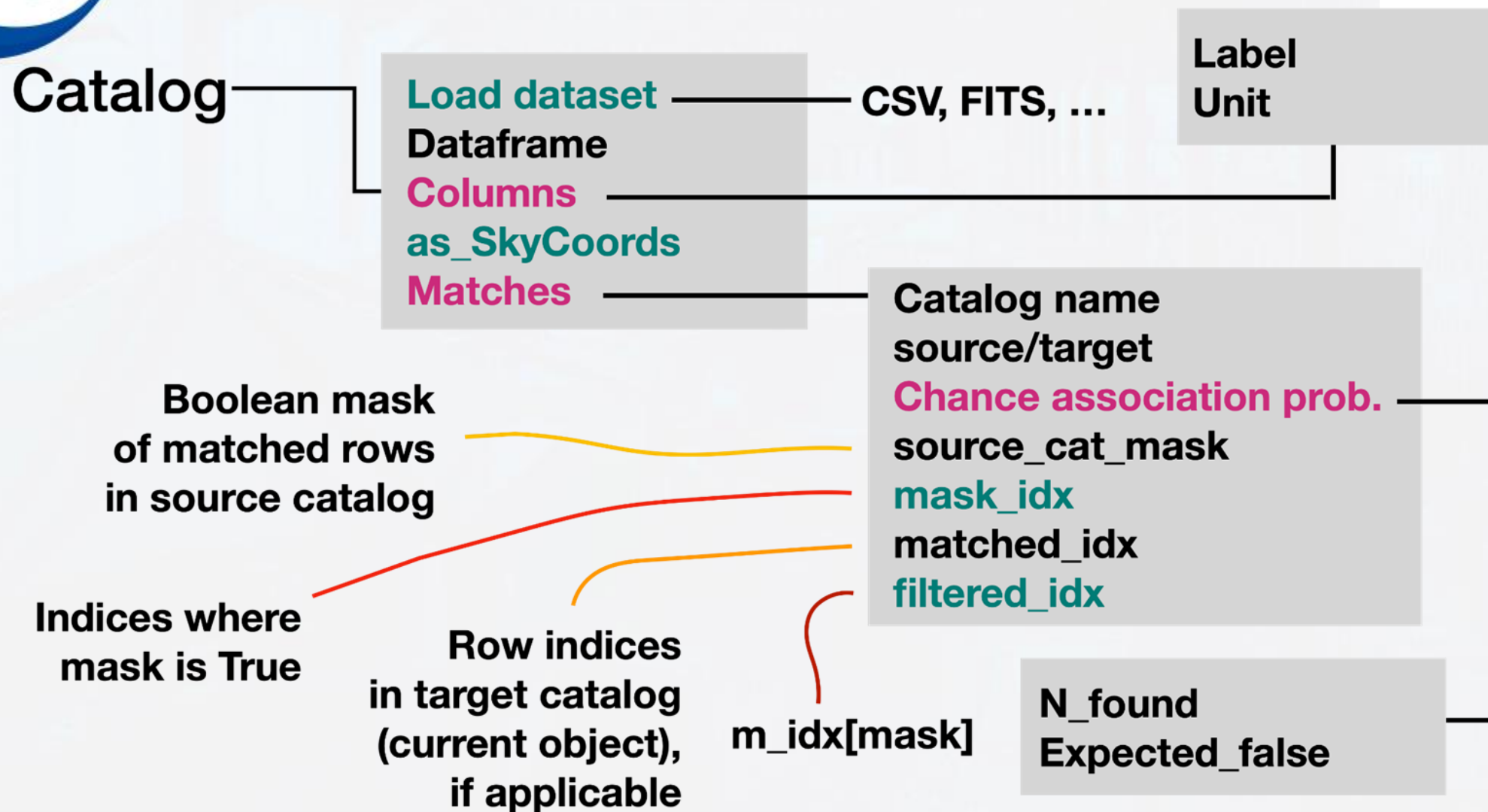
Law et al. 2022: *“Given that FRBs occur with a high volumetric rate (comparable to that of core-collapse supernovae [...]) and that PRS are luminous, it may be that PRS constitute a significant new class of extragalactic radio source.”*

What are we looking for?

- ❑ **We aim to increase known IMBH and/or PRS sample**
- ❑ Search for **Over-luminous compact radio sources (OCRs)** in **Dwarf galaxies**
- ❑ **RADIO:** LoTSS 2nd data release (Shimwell et al. 2022; 144 MHz)
 - ❑ > 4 million radio sources over $\sim 5500 \text{ deg}^2$ covered
 - ❑ $0''.2$ astrometric accuracy (comparable to optical surveys)
- ❑ **OPTICAL:** Census of the local Universe (CLU; Cook et al. 2019)
 - ❑ 270 000 sources over 3π of the sky; $z < 0.0471$
 - ❑ Spans dwarf galaxies to larger spirals
 - ❑ Provides various physical properties: e.g.
 - ❑ *Stellar mass, Star Formation Rate (SFR)*

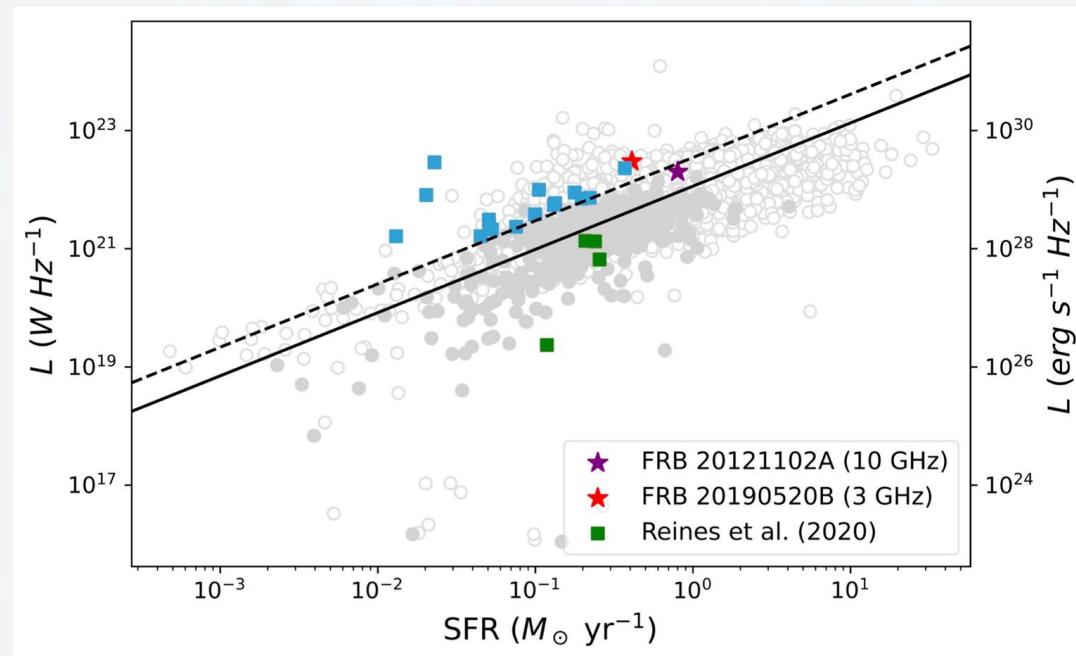


MATCHMAKER (python package)



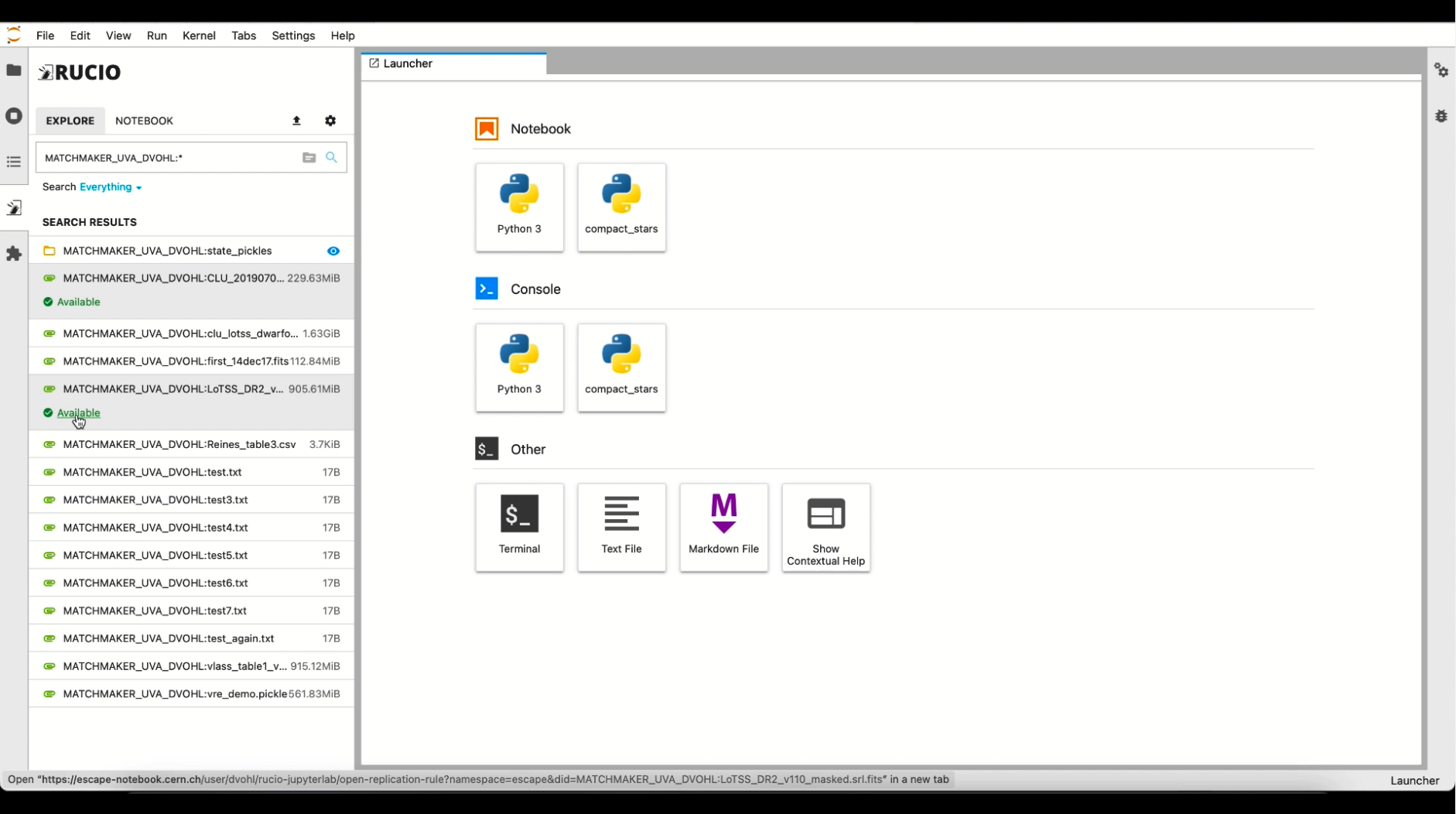
Demo: search for OCRs

1. RUCIO & Code
2. Cross-matching
3. Candidates selection
4. Query VO (SDSS, NED, ASTRON, ...)
5. Composite cutout images



Special thanks to Yan Grange, Enrique Garcia, Elena Gazzarrini & Alba Vendrell Moya

Demo: search for OCRs



The screenshot shows the RUCIO web interface. On the left, a sidebar contains a search bar with the query 'MATCHMAKER_UVA_DVOHL:*'. Below the search bar, a list of search results is displayed, including file names and sizes. The file 'MATCHMAKER_UVA_DVOHL:LoTSS_DR2_v110_masked.srl.fits' is highlighted. The main area of the interface shows a 'Launcher' section with buttons for 'Notebook', 'Console', and 'Other'. The 'Notebook' section includes buttons for 'Python 3' and 'compact_stars'. The 'Console' section includes buttons for 'Python 3' and 'compact_stars'. The 'Other' section includes buttons for 'Terminal', 'Text File', 'Markdown File', and 'Show Contextual Help'.

The logo for ESCAPE (European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures) is located in the top left corner. It features a stylized blue starburst above the word "ESCAPE" in large, bold, dark blue capital letters. Below "ESCAPE" is the full name in smaller text. The logo is set against a white circular background with a blue border.

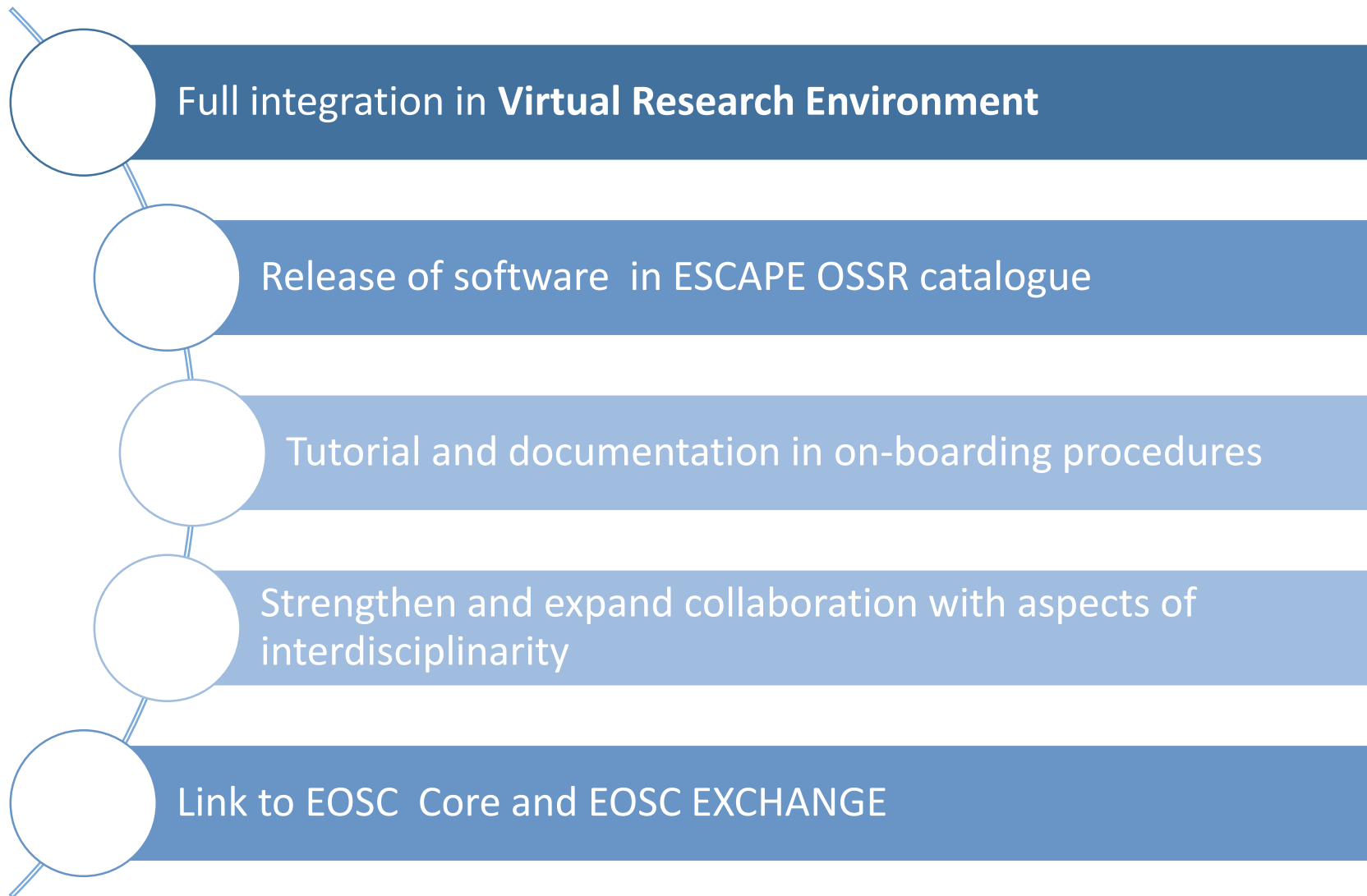
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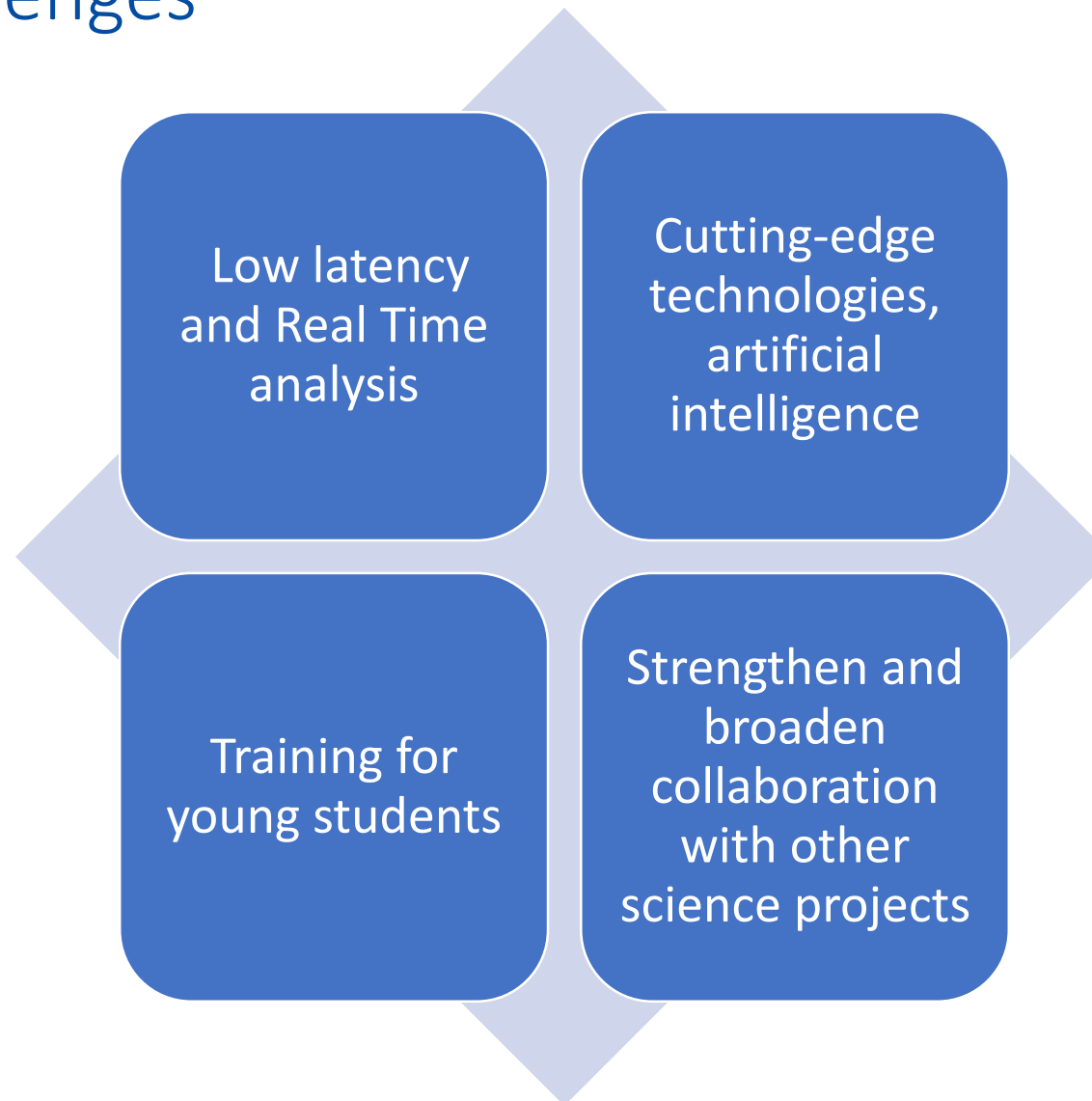


Consolidation and open challenges

Consolidation: what's next?



Open challenges



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Thank you for your attention