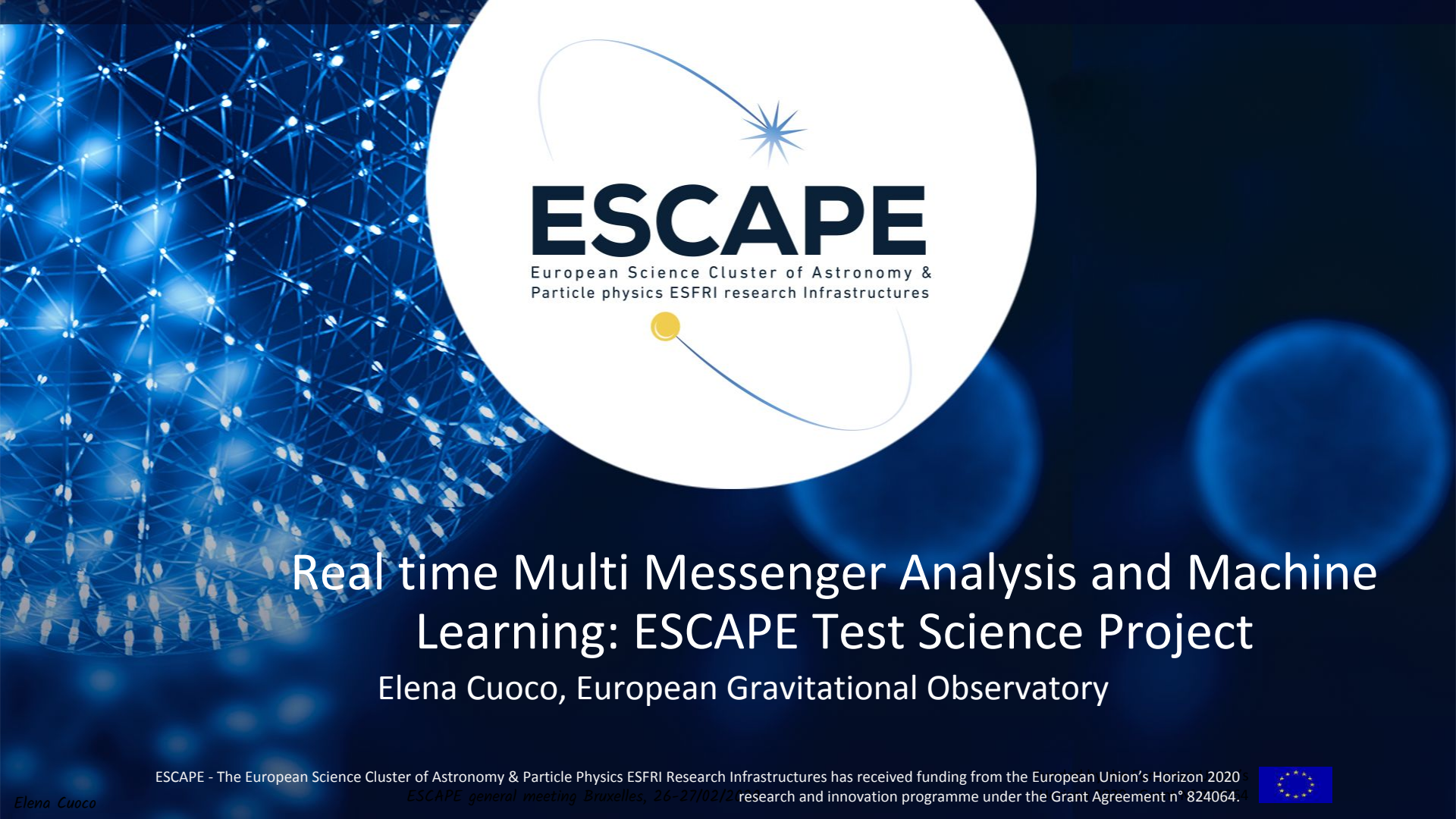
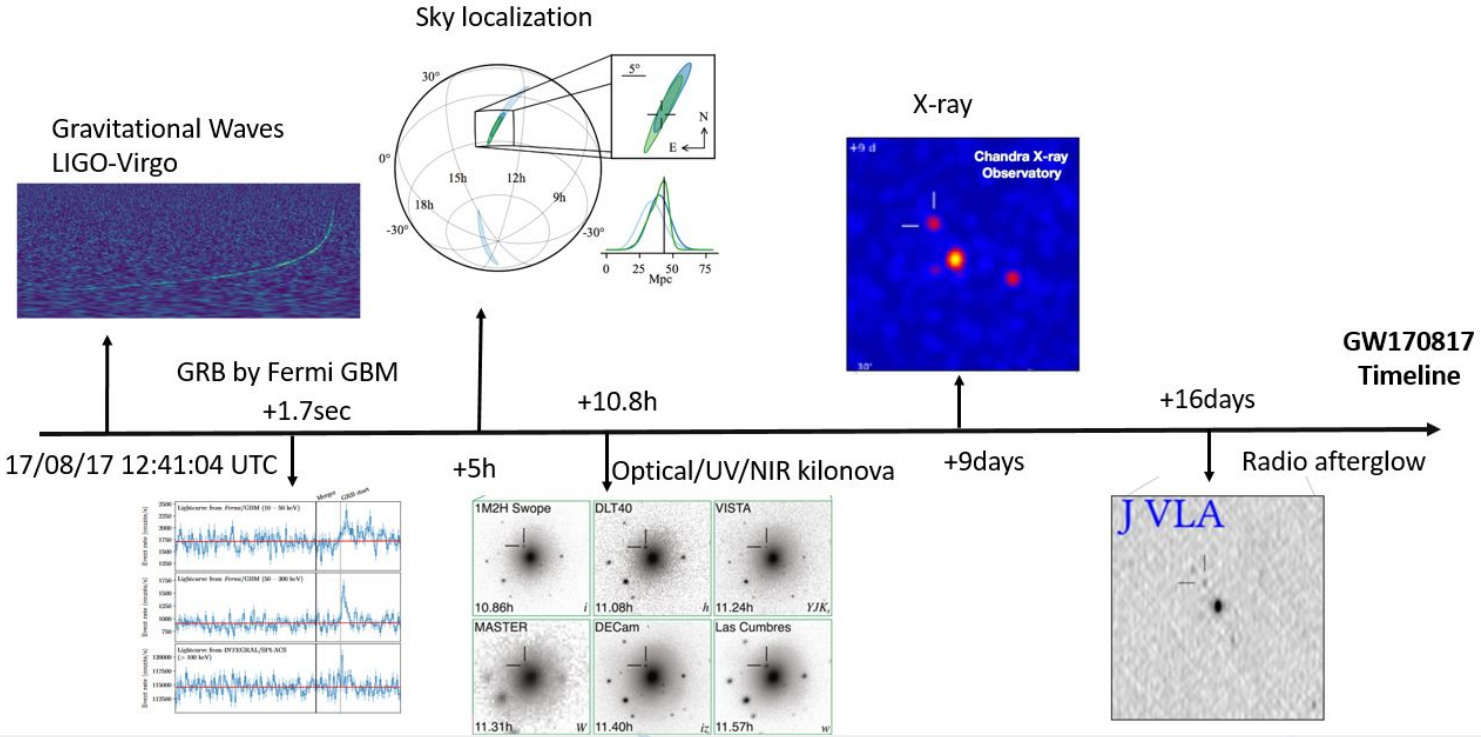


Real time Multi Messenger Analysis and Machine Learning: ESCAPE Test Science Project

Elena Cuoco, European Gravitational Observatory

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 the Grant Agreement n° 824064.

GW170817 detection and EM follow up



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Gravitational Waves & Multimessenger astronomy

- **Short GRB**
  Fermi GBM, INTEGRAL, Astrosat, IPN, Insight-HXMT, Swift, AGILE, CALET, H.E.S.S., HAWC, Konus-Wind
- **Gravitational waves (well-modeled)**
  Ligo/Virgo

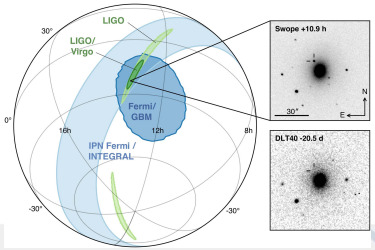
EARLY TRIGGERS (*sec to mins*)

- **X-Ray**
  Swift, MAXI/GSC, NuSTAR, Chandra, Integral
- **UV**
  Swift, HST
- **RADIO**
  ATCA, VLA, ASKAP, VLBA, GMRT, MWA, LOFAR, LWA, ALMA, OVRO, EVN, e-MERLIN, MeerKAT, Parkes, SRT, Effelsberg
- **IR**
  REM-ROS2, VISTA, Gemini-South, 2MASS, SPITZER, NTT, GROND, SOAR, NOT, ESO-VLT, Kanata Telescope, HST
- **Optical**
  Swope, DECam, DLT40, MASTER, VISTA, ESO-VLT + *others*

BROADBAND FOLLOW-UP (*hrs to days*)

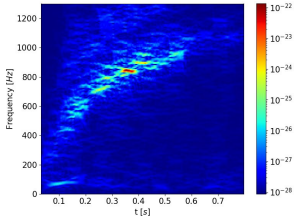
Binary Neutron Star Merger

- *Fast alert and sky Localization for follow-up study*
- *Better understanding of physical processes (e.g. heavy-element nucleosynthesis)*



Abbott et al. (2017)

- **Neutrinos**
  (prompt emission of ~ 90% of total CCSNe energy)
  IceCube, ANTARES, Pierre Auger Observatory
- **Gravitational waves**
  (prompt emission, unknown waveform, carry little energy)
  Ligo/Virgo



less et al. (2020)

- **E.M. emission** (delayed emission)

Core-Collapse Supernovae

- *Shed Light on explosion mechanism (neutrino-driven, MHD, acoustic)*
- *Information on physical characteristics of progenitor star (mass, rotation)*
- *Information on proto-neutron star*

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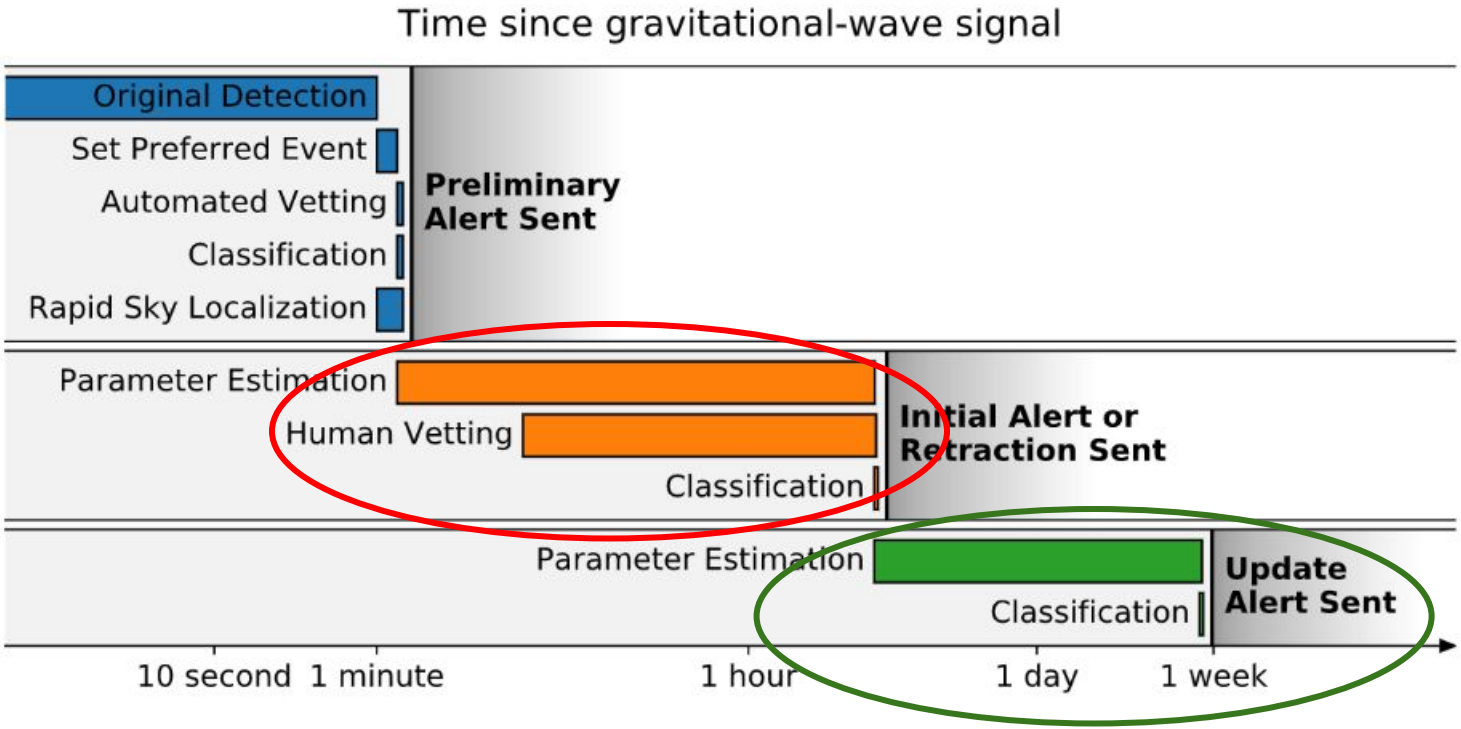
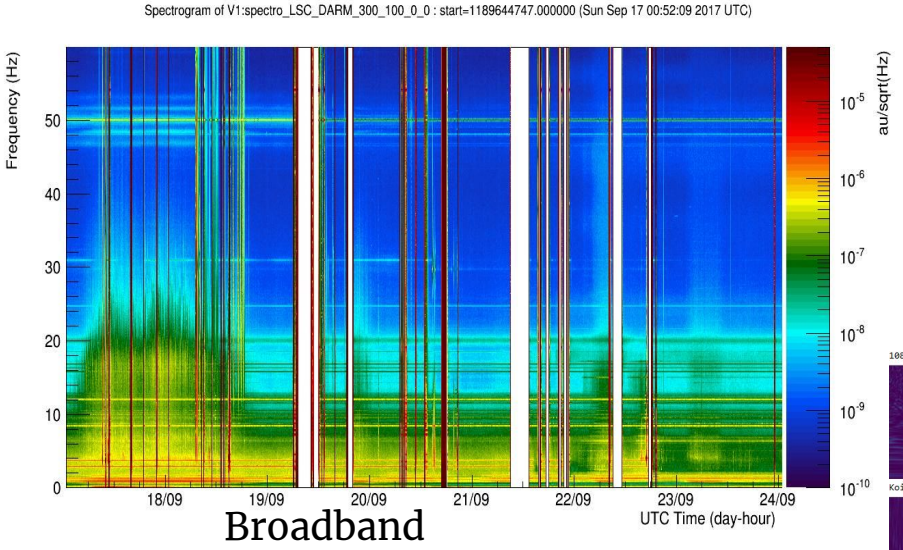
Gravitational Wave alert system

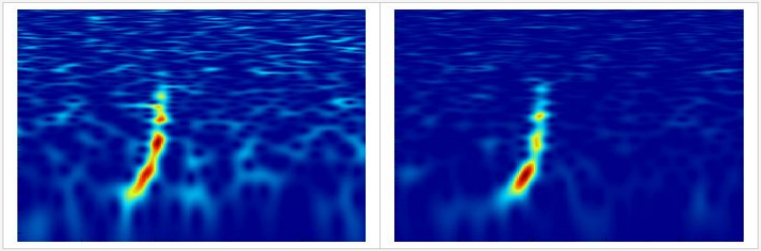


Detector Noise and Signals

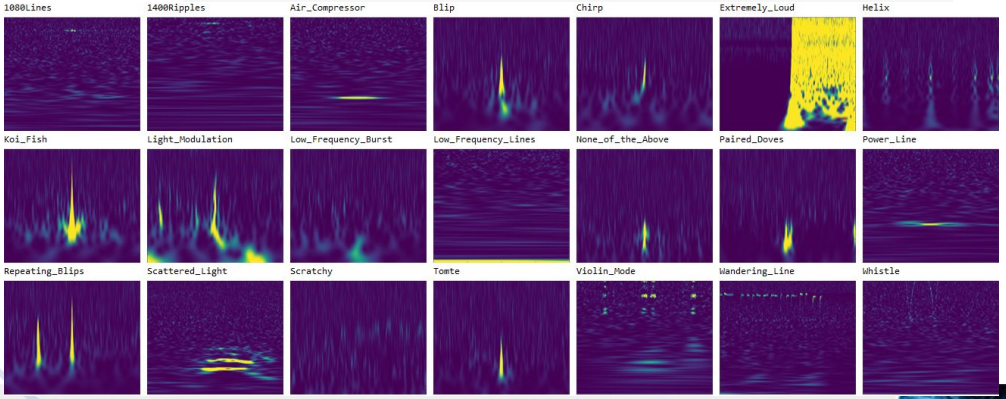


Broadband

Coherent WaveBurst was used in the first direct detection of gravitational waves (GW150914) by LIGO and is used in the ongoing analyses on LIGO and Virgo data.



Time-Frequency maps of GW150914: Livingston data (left), Hanford data (right)
First screenshot of GW150914 event



Glitches

Gravity Spy, Zevin et al (2017)
https://www.zooniverse.org/projects/zooniverse/gravity-spy

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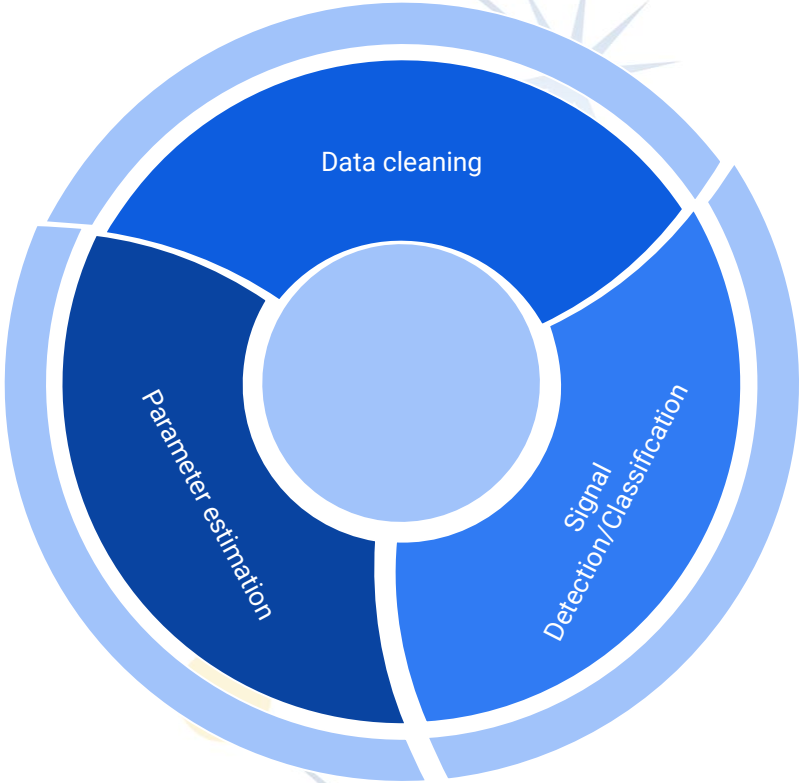
Machine Learning and real time analysis



Razzano M., Cuoco E. CQG-104381.R3
Iess, Cuoco, Morawski, Powell (2020)
Vajente et al. 10.1103/PhysRevD.101.042003
Deep Chatterjee, et al arXiv:1911.00116
Gabbard, Hunter et al. arXiv:1909.06296
....

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A prototype for Real time analysis: Wavefier

Real time Gravitational Wave transient signal classifier

Key Objectives

- *Setup a prototype for a **real time** pipeline for the detection of transient signals and their **automatic** classification*
- *Best practice for **software management***
- *Test different software architecture solutions to prototype a **scalable** pipeline for **big data** analysis in GW context.*
- ***Interoperability** and access to data and services*
- ***ICT services** supporting research infrastructures*
- *Use of **data in network** infrastructures and services*

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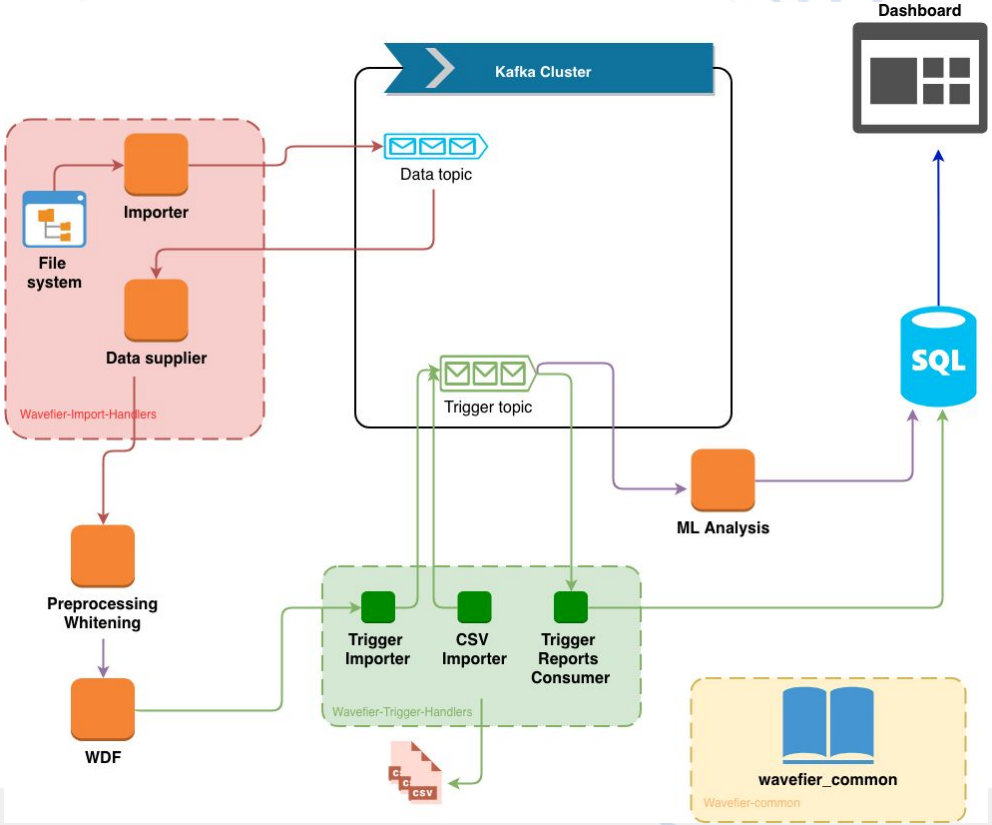
Wavefier/offline Architecture



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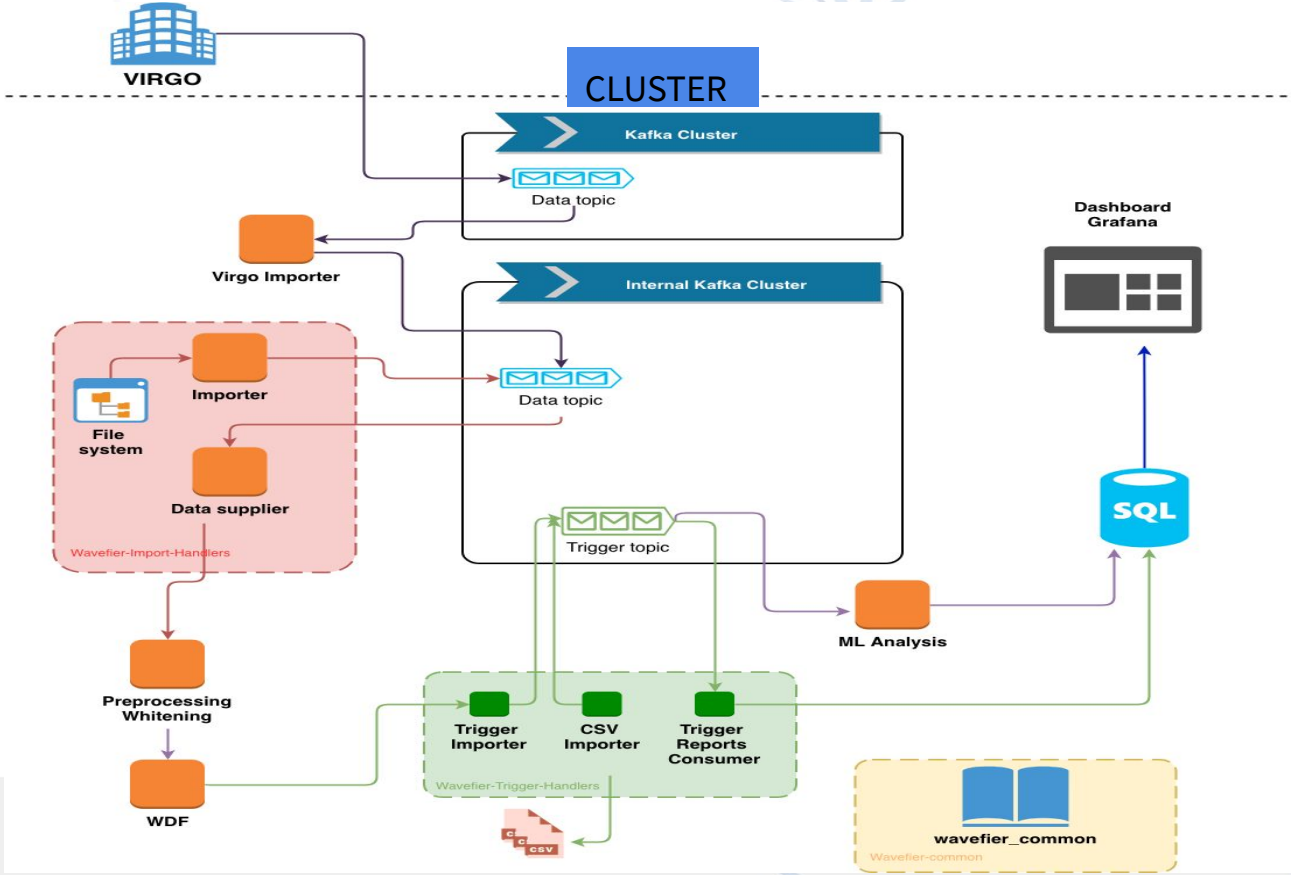
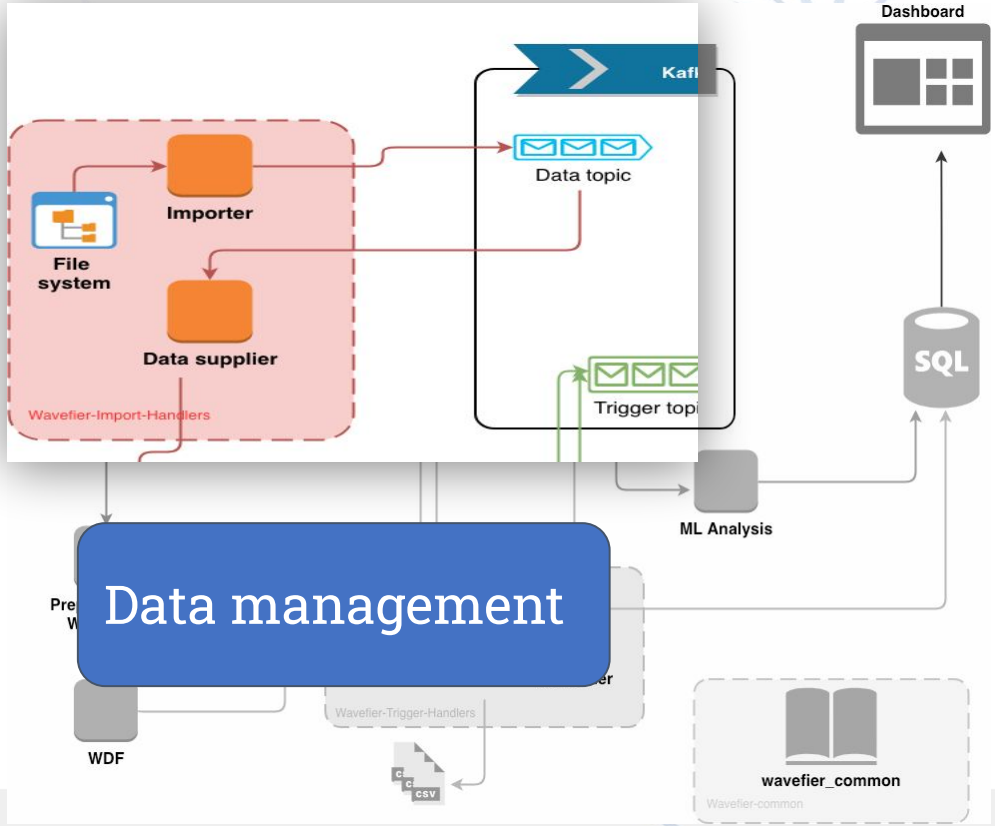
Wavefier/online Architecture



an Union's
N° 824064

Architecture



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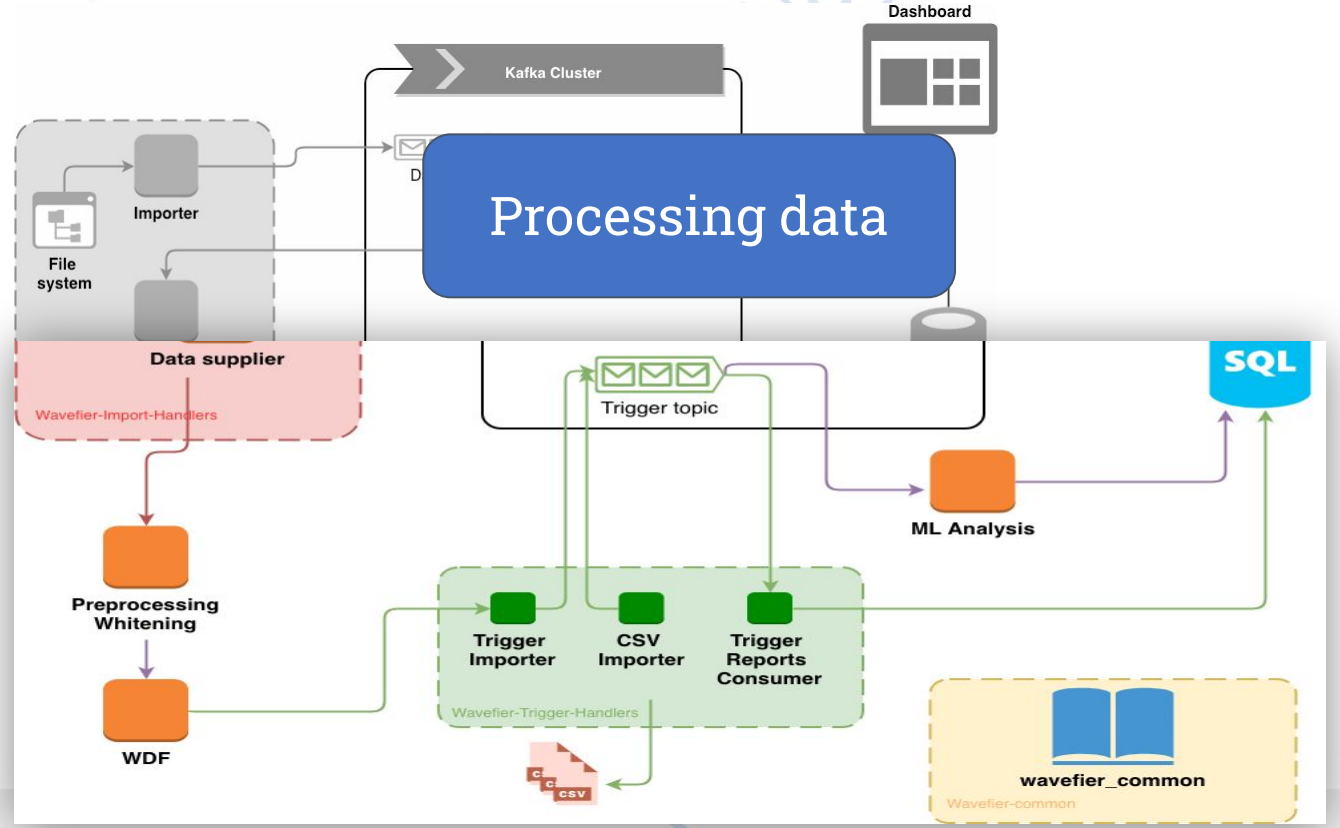
Architecture



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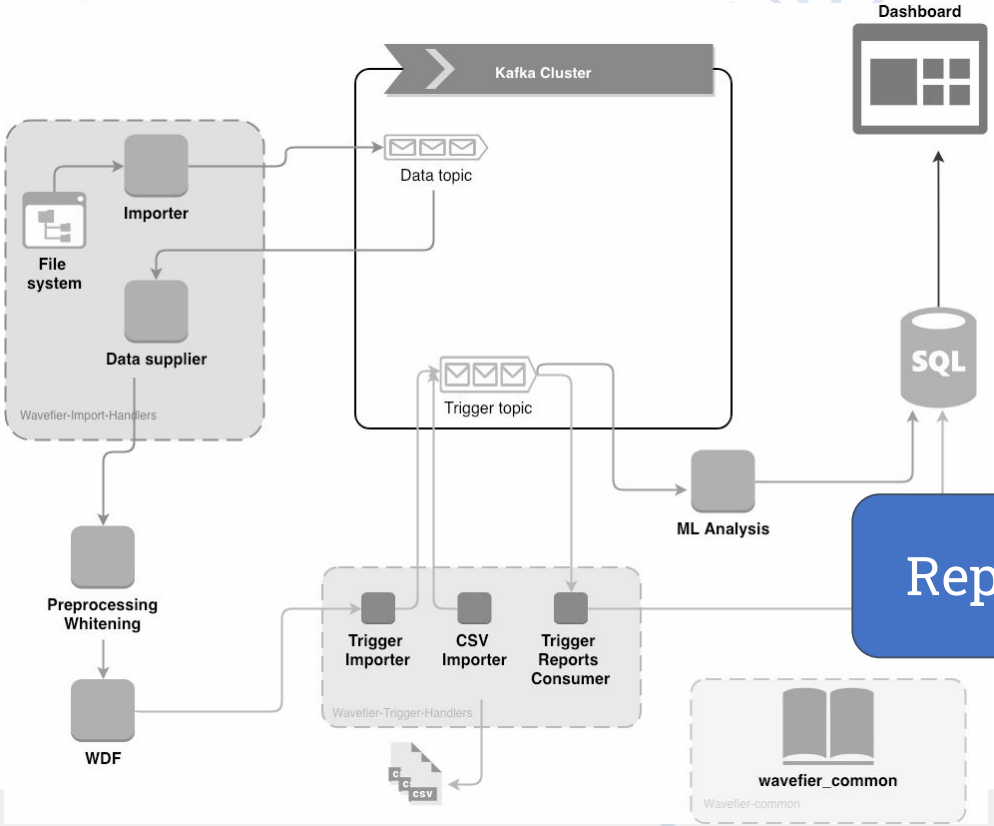
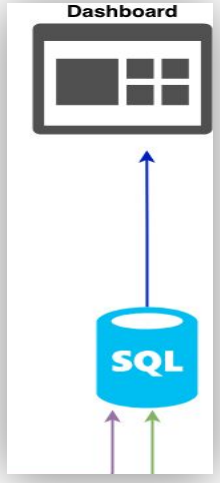
Architecture





Reporting management

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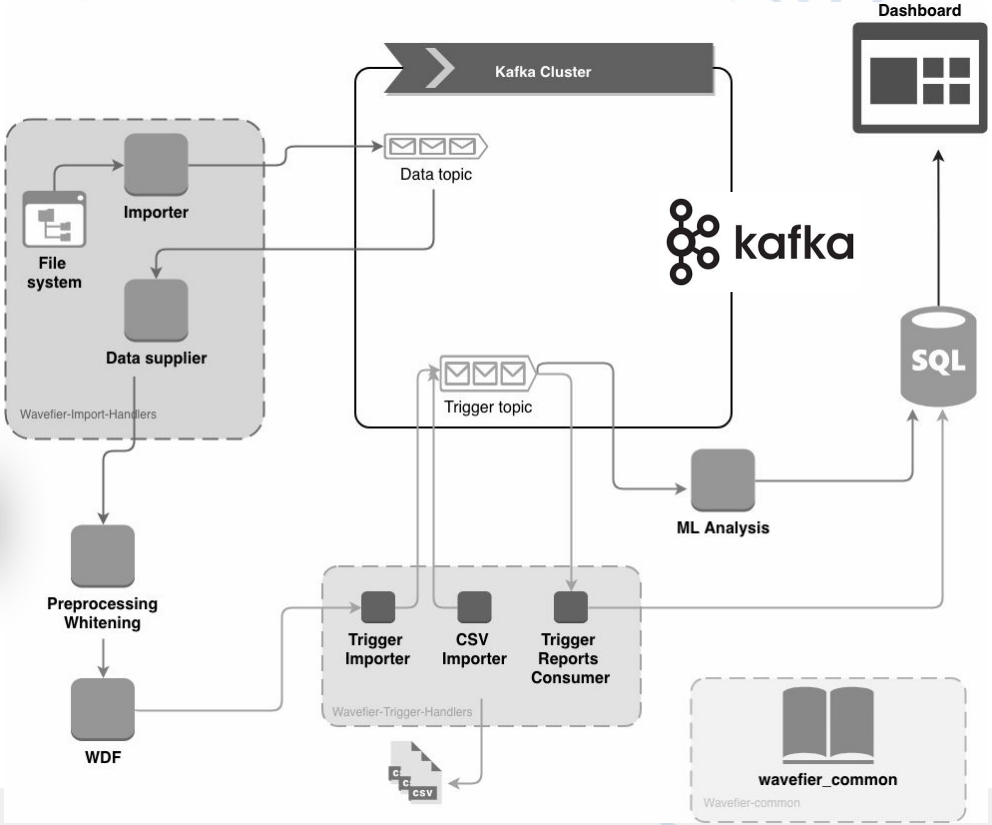
Software library and tools



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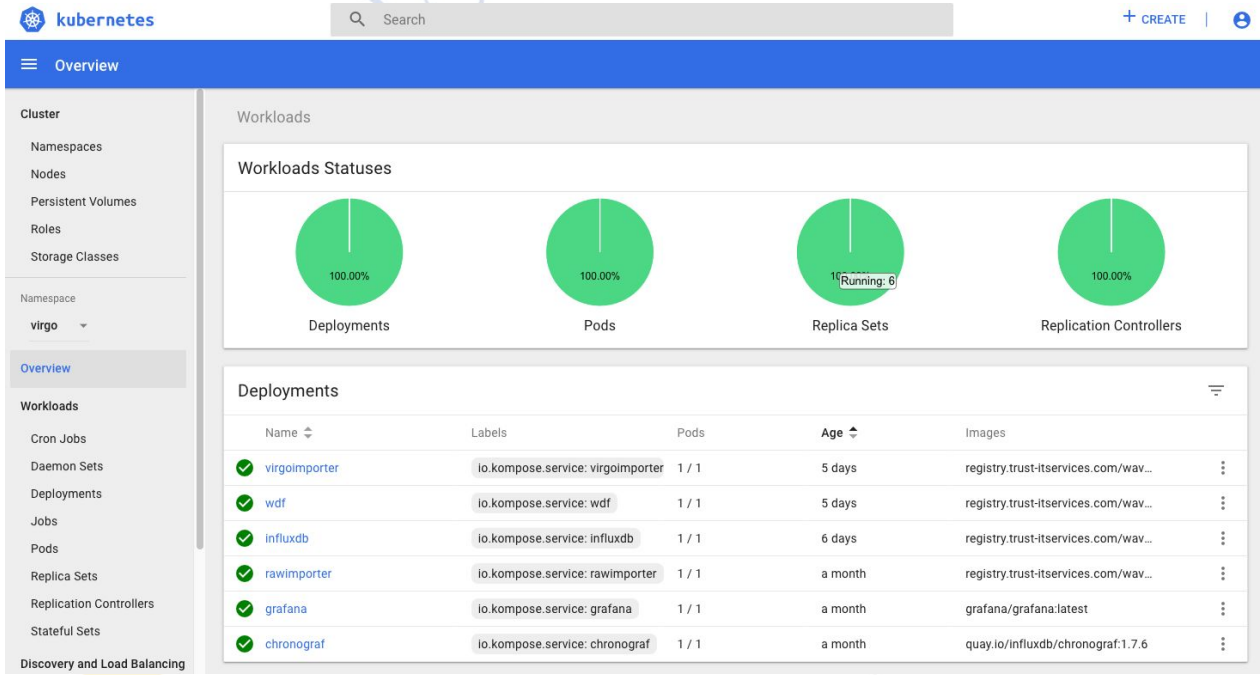
Working on Cloud cluster

We made test on cloud, thanks to GARR support, using kubernetes and dockers



Thanks to EGO IT department, now we are making tests with Singularity at EGO computing center

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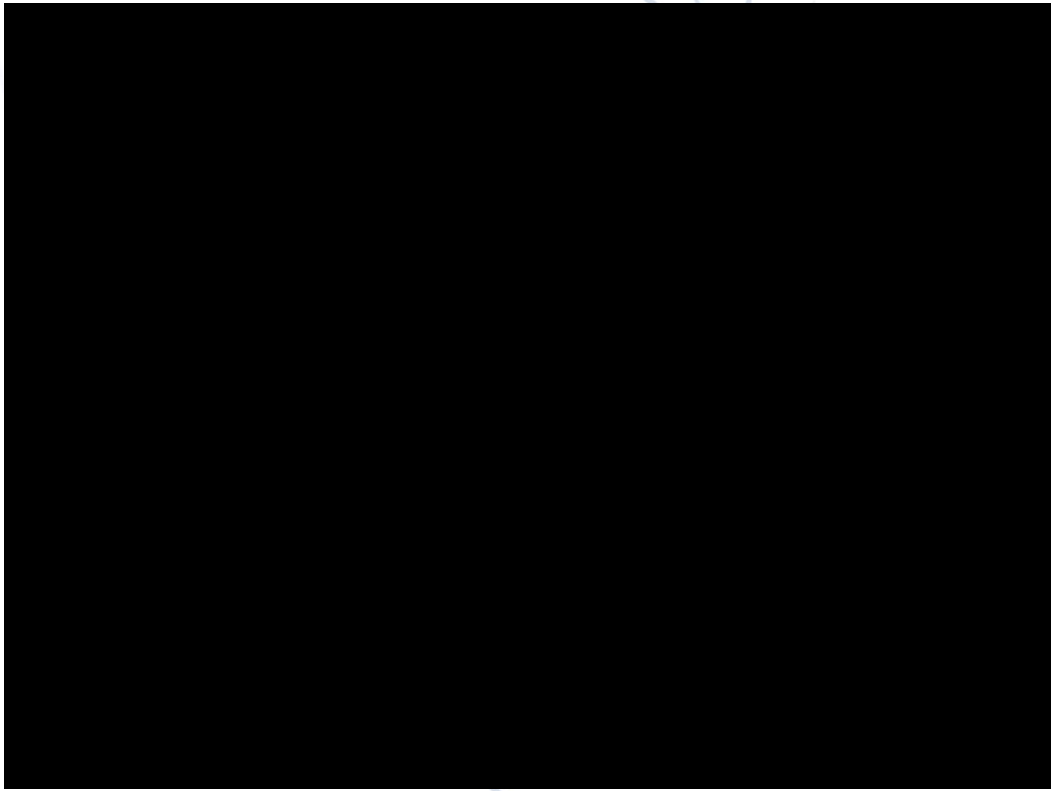
Wavefier at work



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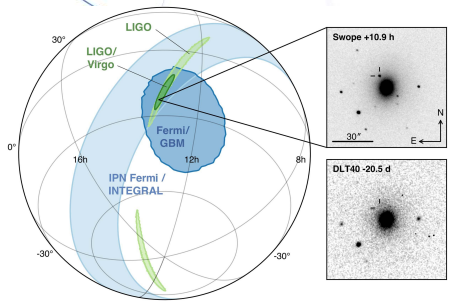
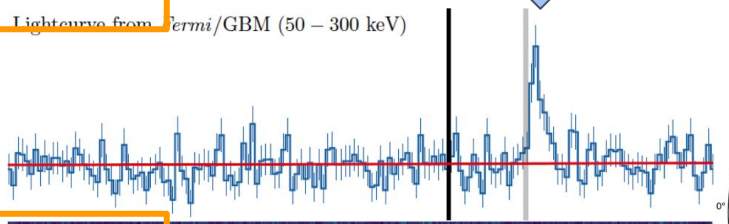
Multi-probe real time analysis

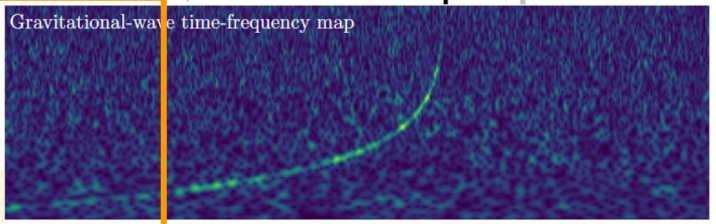


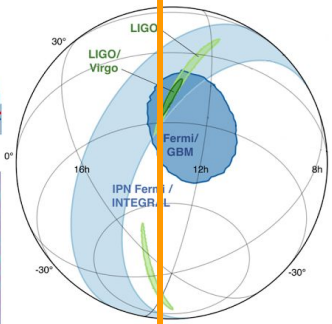
Can we extract information analyzing the heterogeneous data?

GW event

Short GRB event







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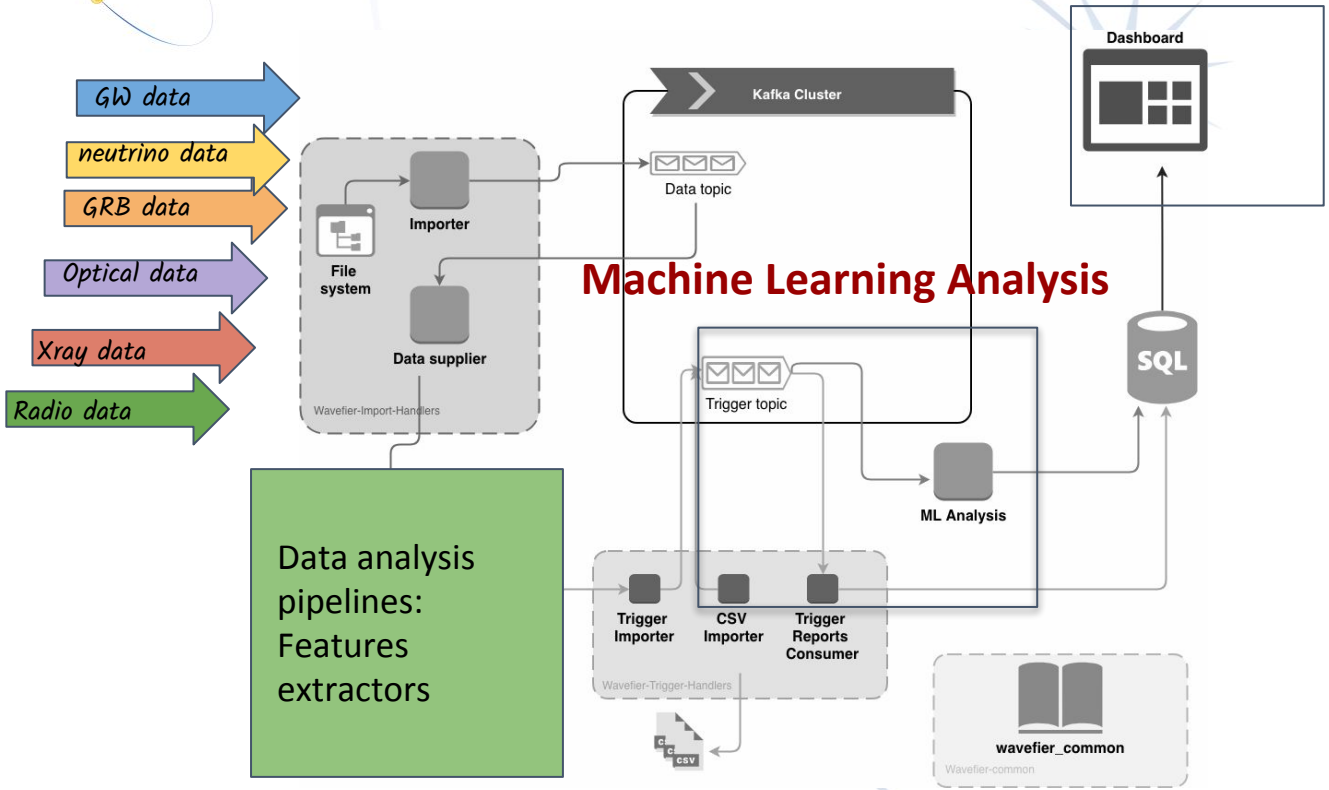
MMA in ESCAPE framework



Results

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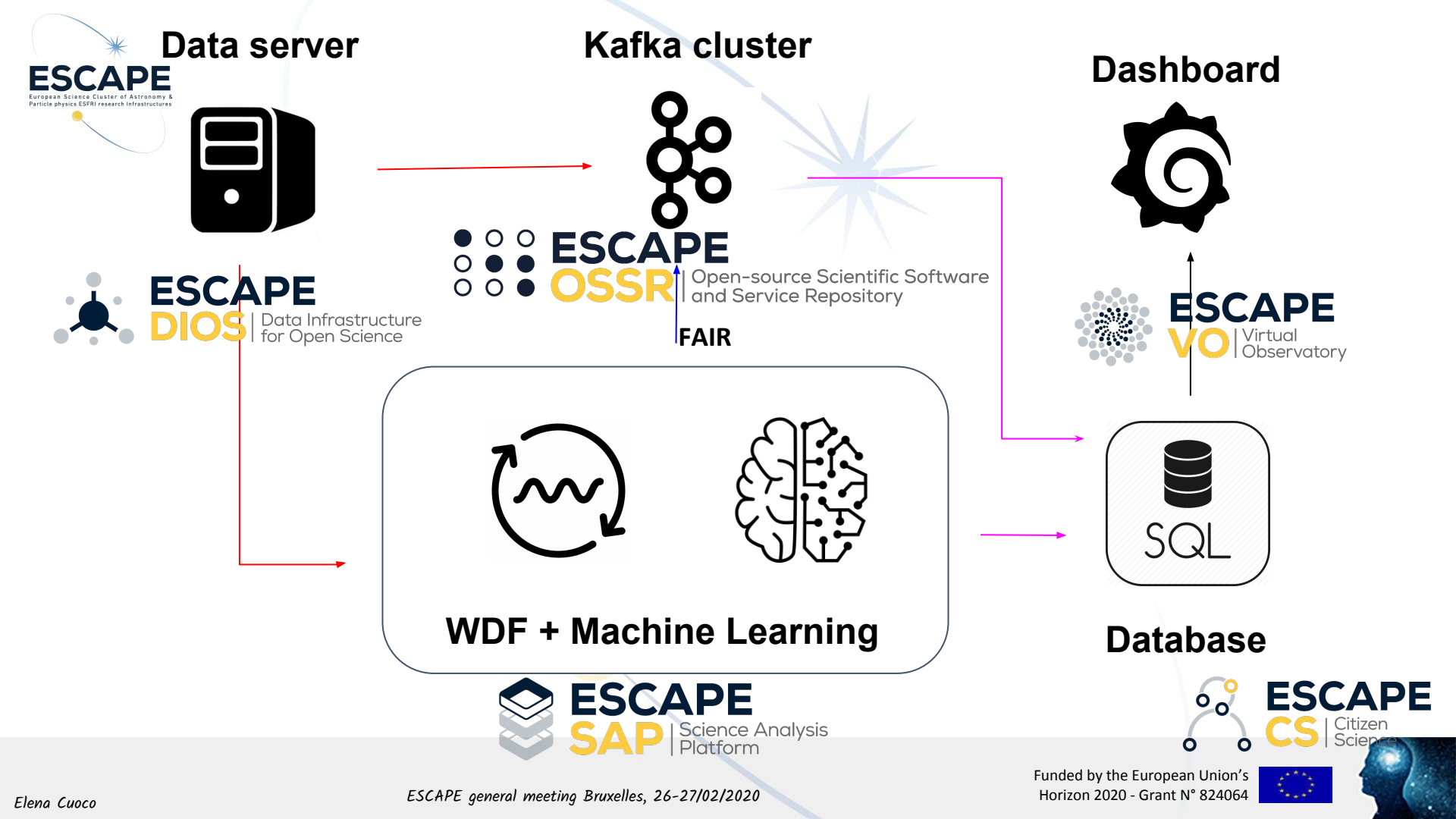

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MMA real time Proposal

Innovative workflows in WP3

Consider this Test Science Project as project of the group

Data

Open or simulated data

Analysis

Machine/Deep Learning Classifier

Multi probe Analysis to prepare common analysis for future Facilities

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