



ESCAPE

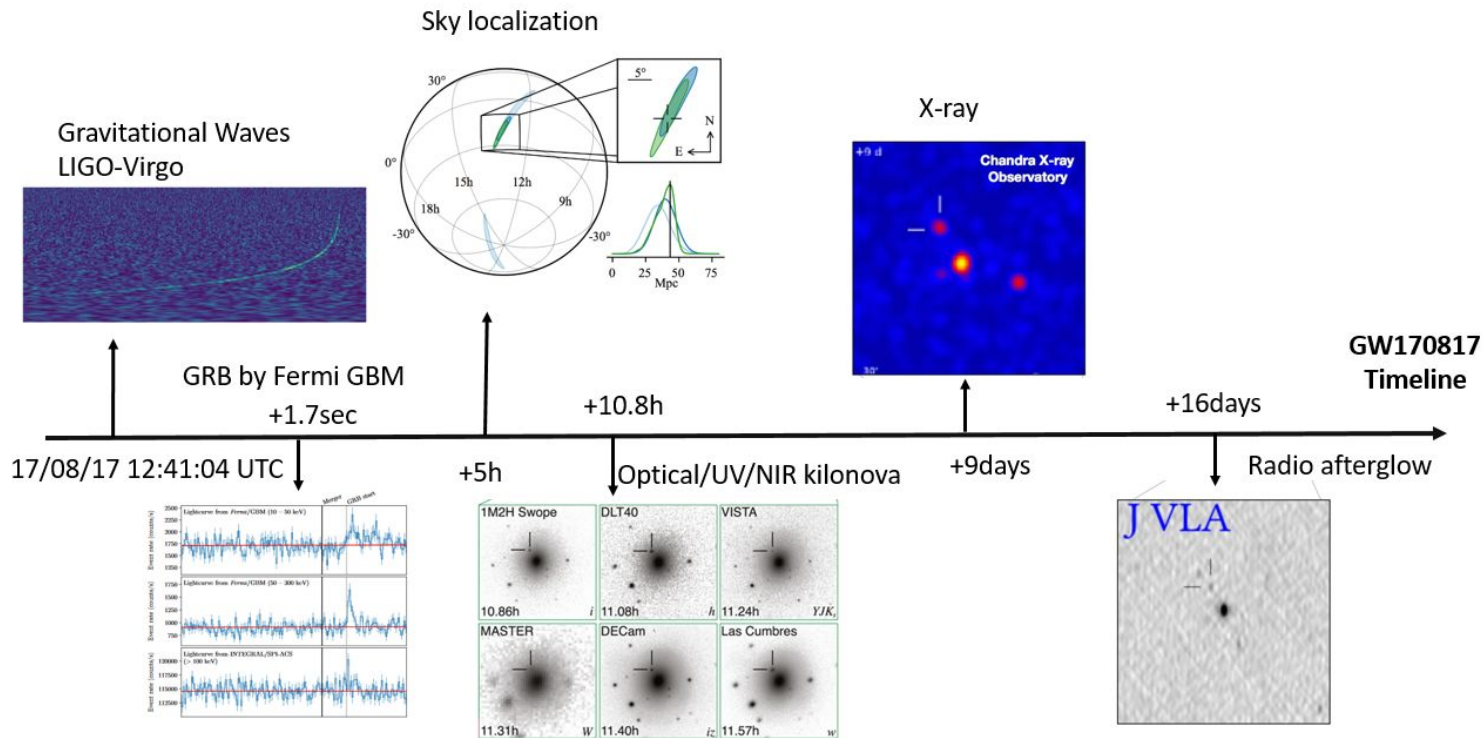
European Science Cluster of Astronomy &
Particle physics ESFRI research Infrastructures

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

Elena Cuoco, European Gravitational Observatory



GW170817 detection and EM follow up



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

- **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**

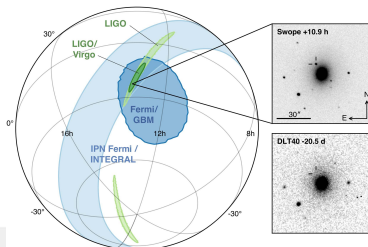
Swope, DECam, DLT40, MASTER, VISTA, ESO-VLT + *others*

EARLY
TRIGGERS
(sec to mins)

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)

ESCAPE general meeting Bruxelles, 26-27/02/2020

- **Neutrinos**

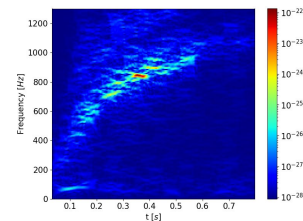
(prompt emission of ~ 90% of total CCSNe energy)

IceCube, ANTARES, Pierre Auger Observatory

- **Gravitational waves**

(prompt emission, unknown waveform, carry little energy)

Ligo/Virgo



less et al. (2020)

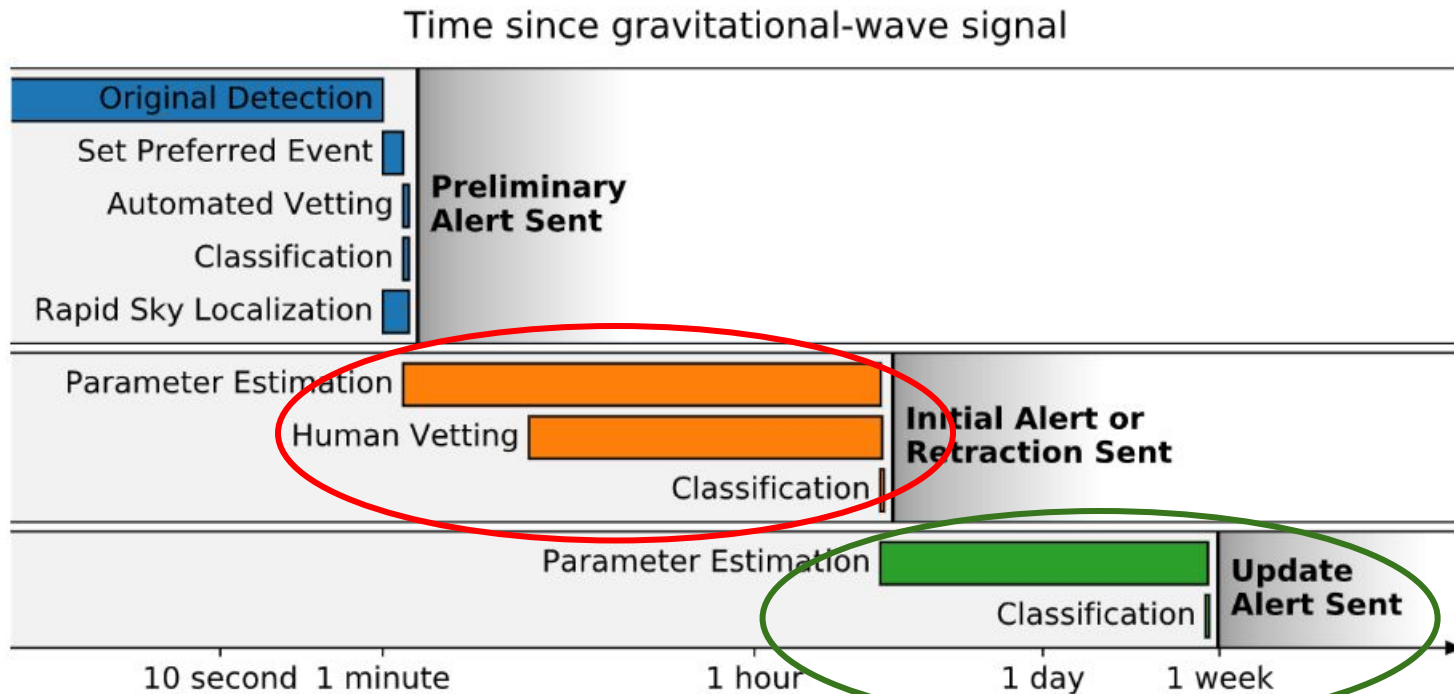
- **E.M. emission** (delayed emission)

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*

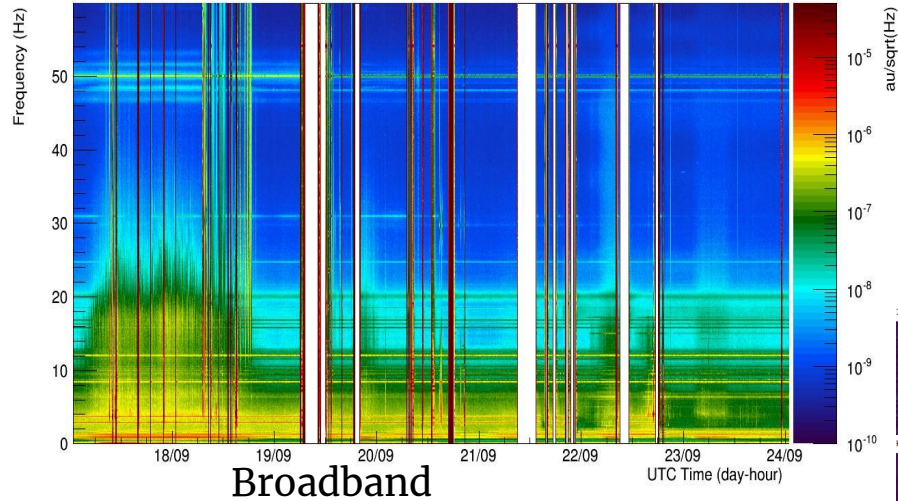


Gravitational Wave alert system



Detector Noise and Signals

Spectrogram of V1:spectro_LSC_DARM_300_100_0_0 : start=1189644747.000000 (Sun Sep 17 00:52:09 2017 UTC)

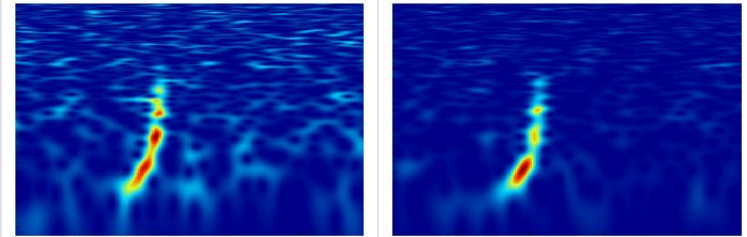


Glitches

Gravity Spy, Zevin et al (2017)

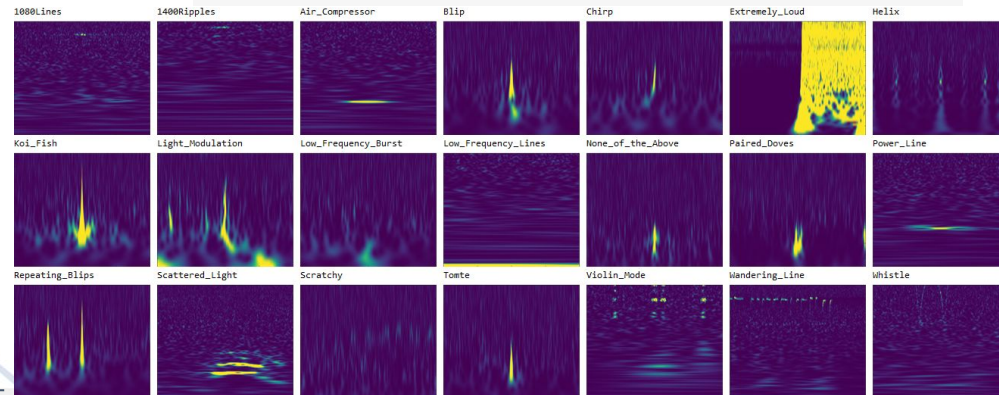
<https://www.zooniverse.org/projects/zooniverse/gravity-spy>

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.

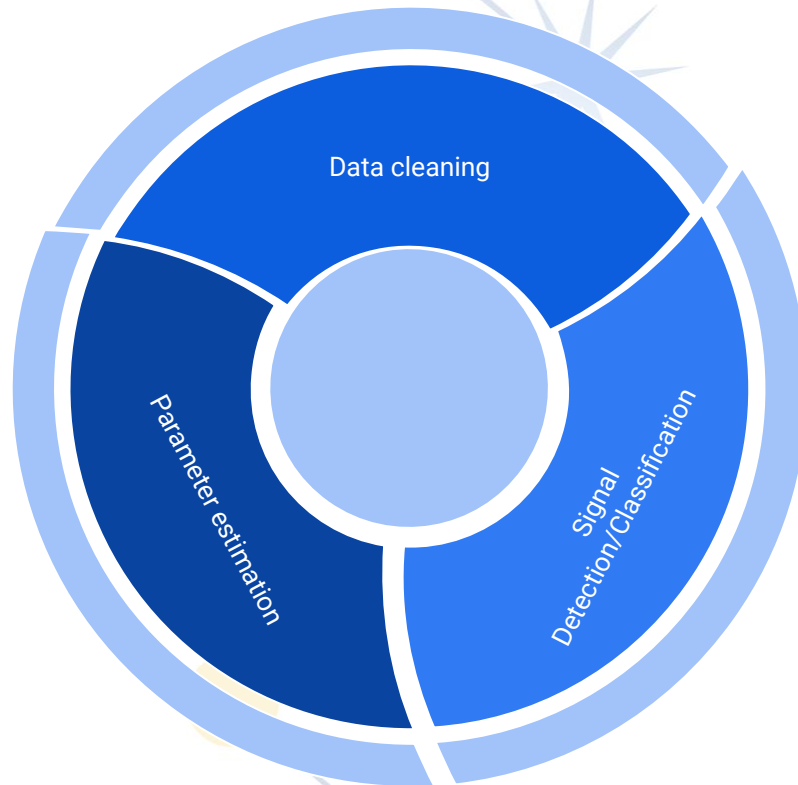


Time-Frequency maps of GW150914: Livingston data (left), Hanford data (right)

[First screenshot of GW150914 event](#)



Machine Learning and real time analysis



Razzano M., Cuoco E. CQG-104381.R3
less, Cuoco, Morawski, Powell (2020)
Vajente et al. [10.1103/PhysRevD.101.042003](https://arxiv.org/abs/10.1103/PhysRevD.101.042003)
[Deep Chatterjee](https://arxiv.org/abs/1911.00116), et al [arXiv:1911.00116](https://arxiv.org/abs/1911.00116)
[Gabbard, Hunter](https://arxiv.org/abs/1909.06296) et al. [arXiv:1909.06296](https://arxiv.org/abs/1909.06296)

....



A prototype for Real time analysis: Wavefier

Real time Gravitational Wave transient signal classifier

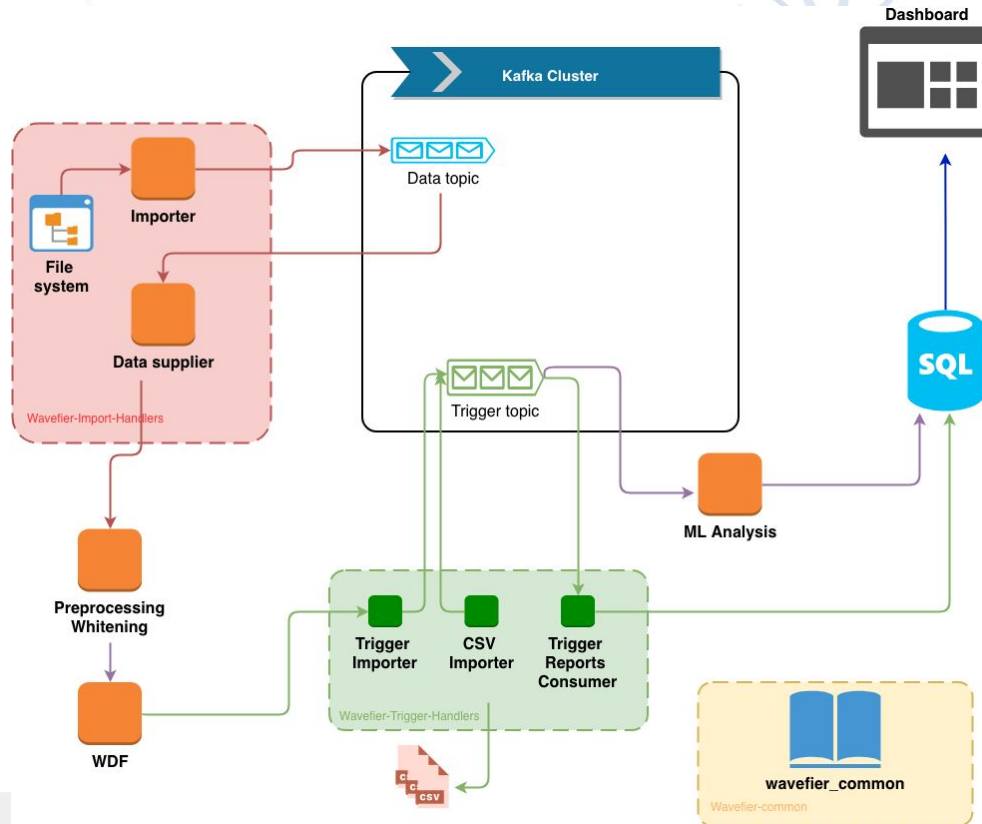
Key Objectives

- ⊙ *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*

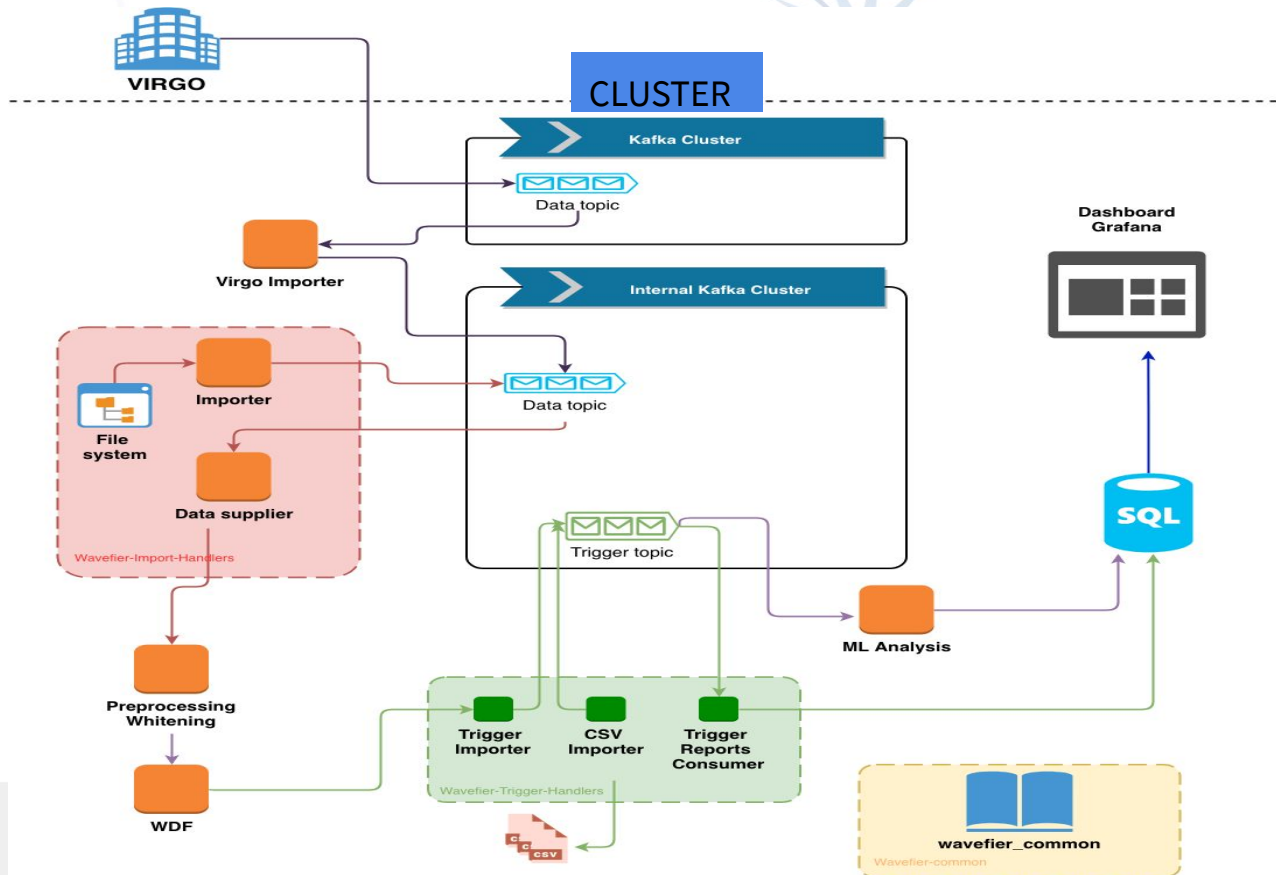
The screenshot shows a presentation slide for the Wavefier project. At the top left is the Wavefier logo with the text 'Real time Gravitational Wave transient signal classifier'. Below this, the text reads 'Wavefier: a prototype for a real time transient signal classifier'. The slide features several logos: LAPP (Laboratoire d'Astrophysique de Provence), CNRS (Centre National de la Recherche Scientifique), IN2P3 (Institut National de Physique Nucléaire), EGO (European Gravitational Observatory), and Trust-IT Services (Communicating ICT to markets). The Asterics logo is also present, with the text 'Astronomy 2020 & Research Infrastructures Cluster'. At the bottom, it states 'H2020-Astronomy ESFRI and Research Infrastructure Cluster (Grant Agreement number: 653477)' and 'H2020-ASTERICS project brings together for the first time scientists and communities from astronomy, astrophysics, particle astrophysics & big data. http://www.asterics2020.eu'.



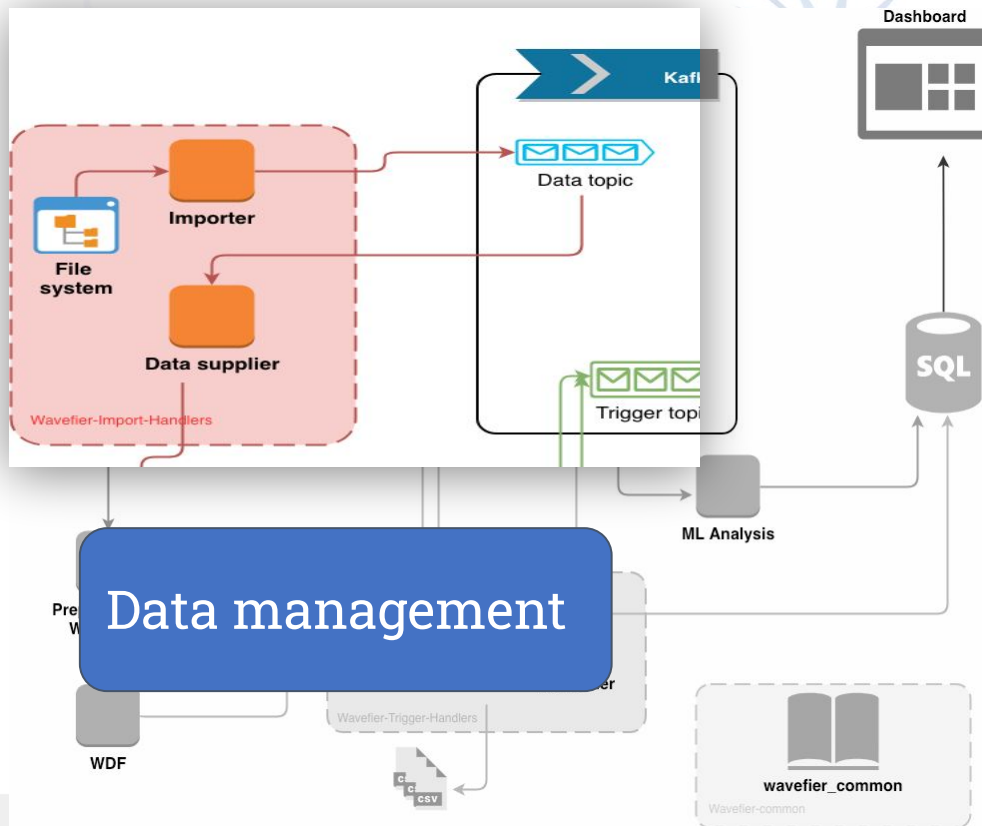
Wavefier/offline Architecture



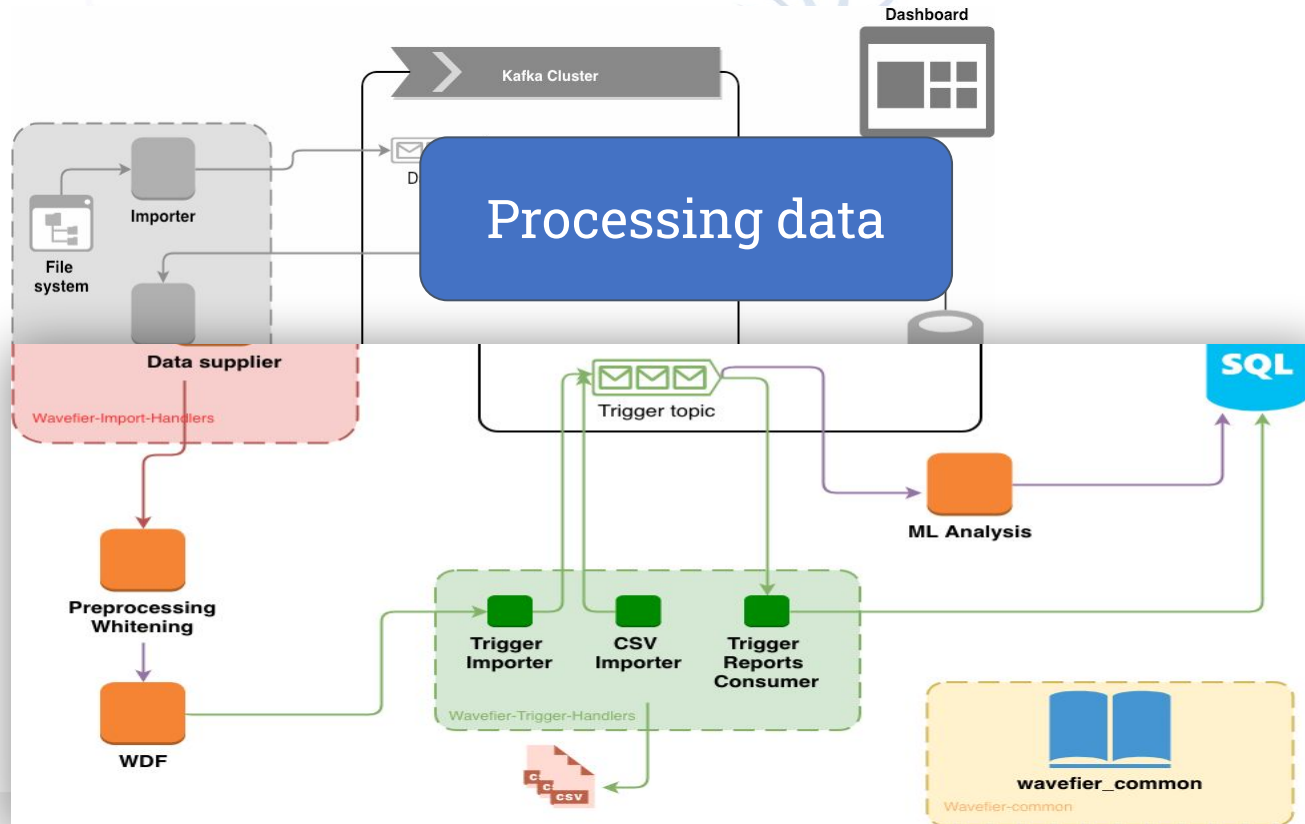
Wavefier/online Architecture



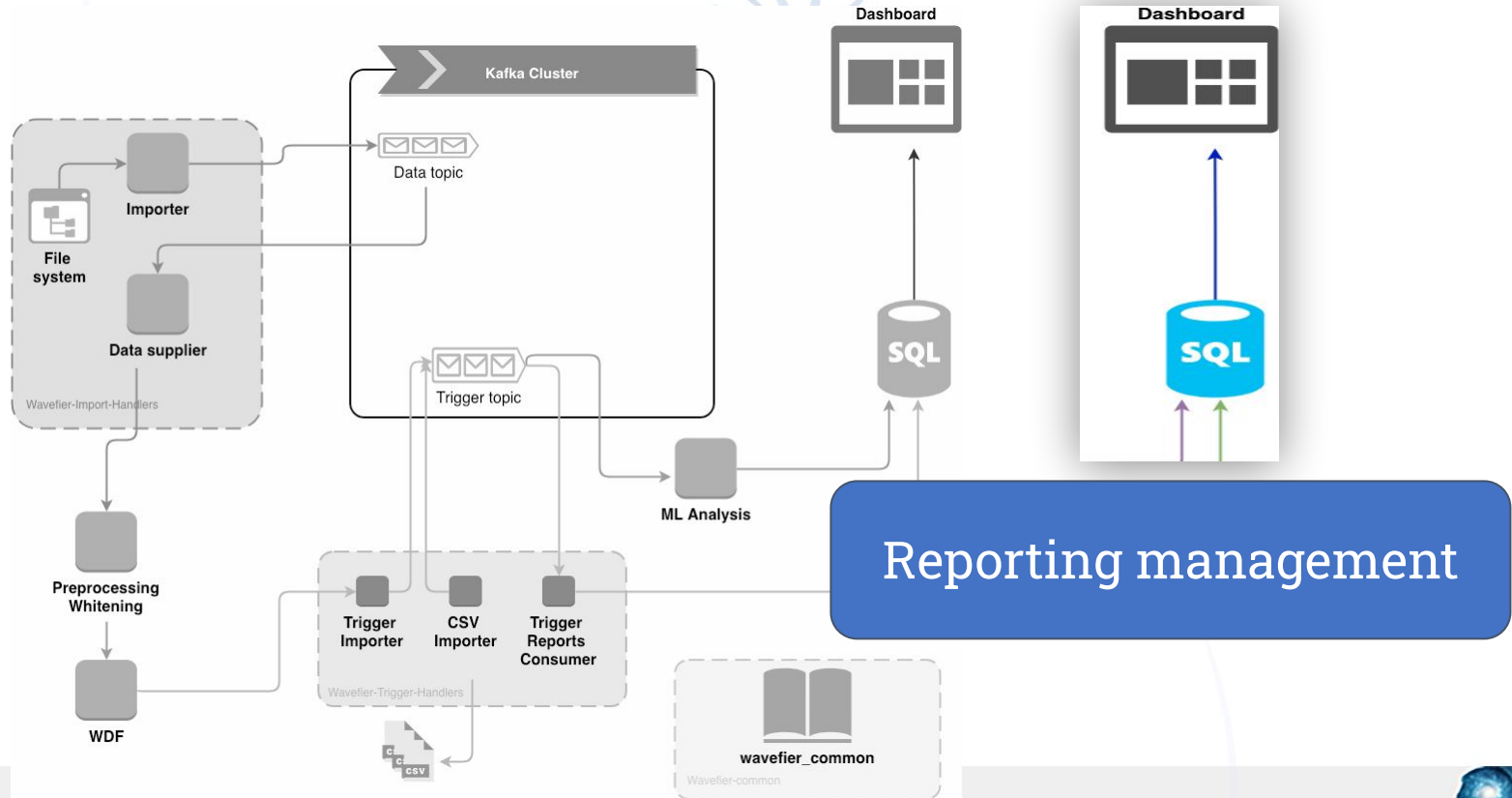
Architecture



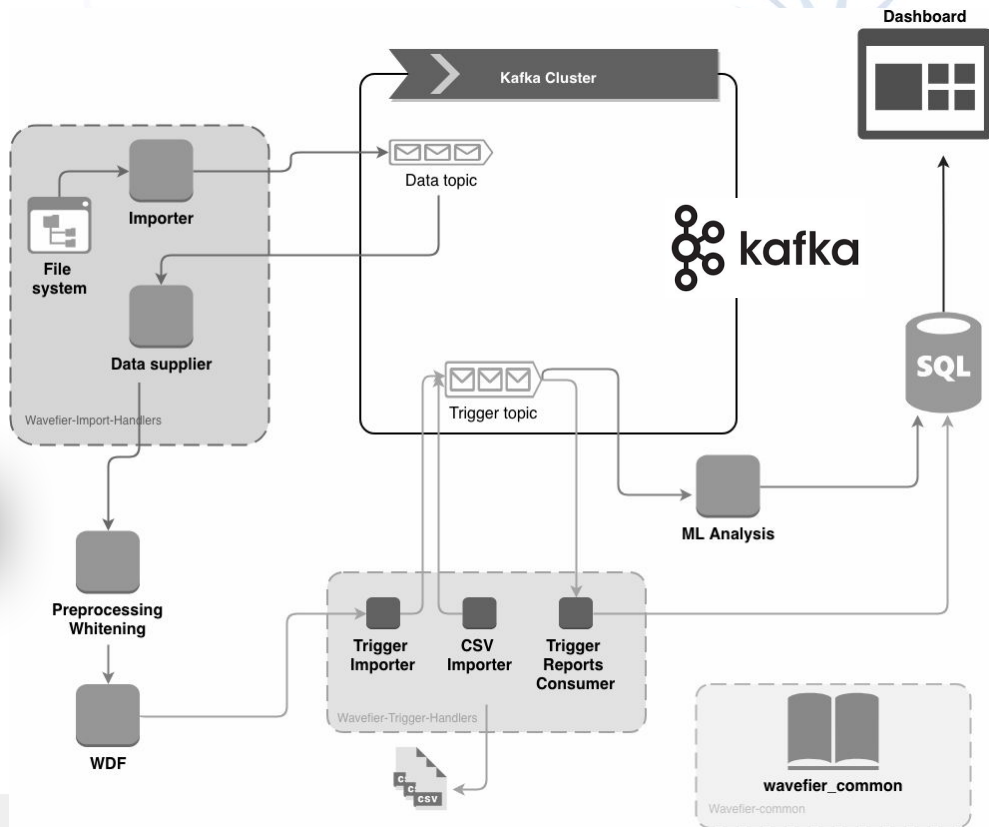
Architecture



Architecture



Software library and tools



 **Grafana**

 **influxdb**

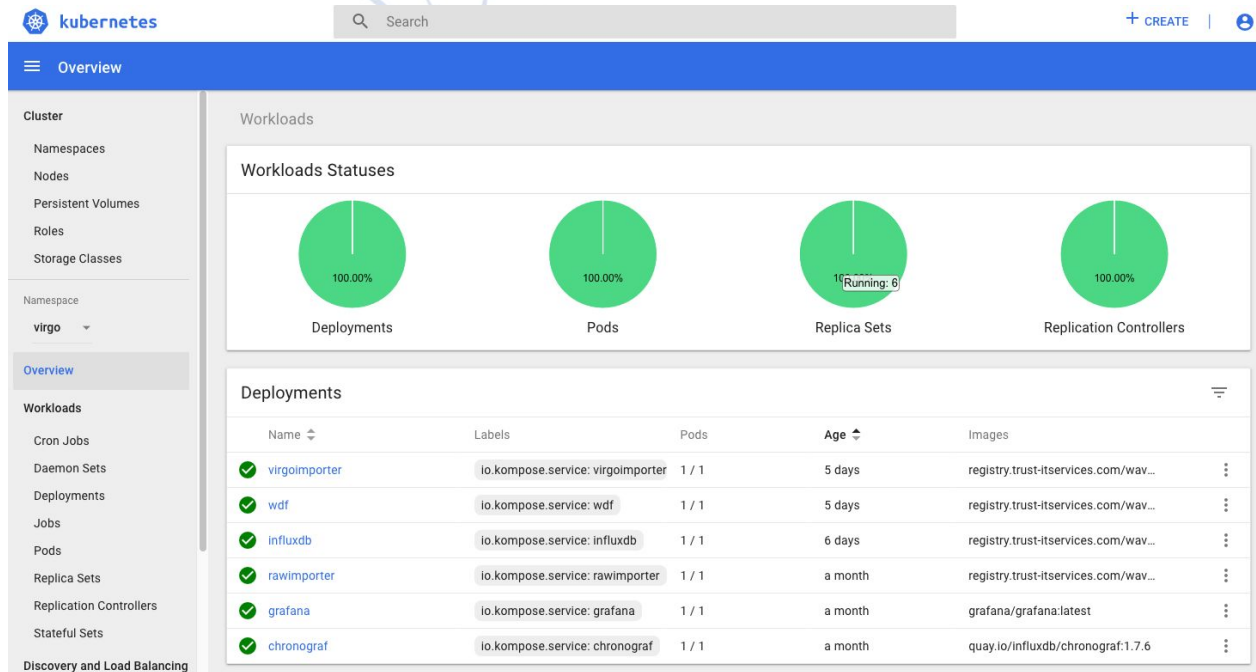
 **TensorFlow**

 **python™**



Working on Cloud cluster

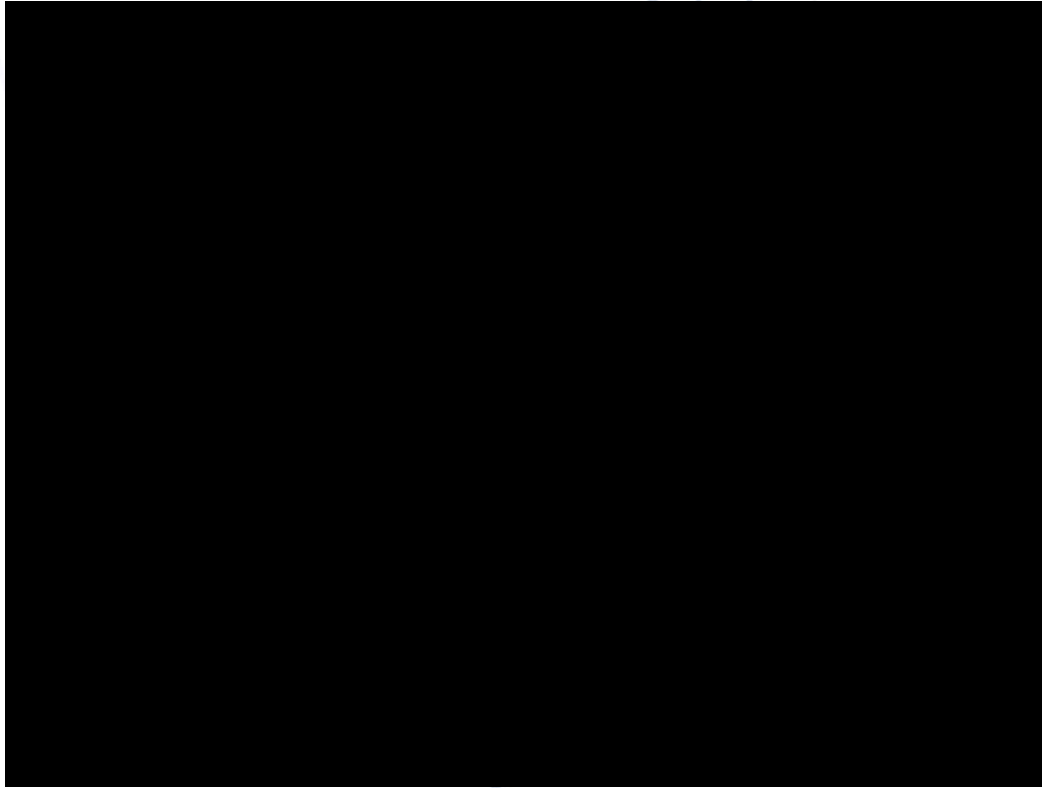
We made test on cloud, thanks to GARR support, using kubernetes and dockers



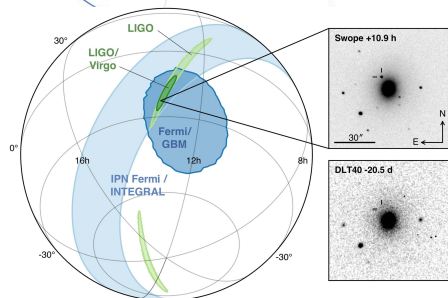
Thanks to EGO IT department, now we are making tests with Singularity at EGO computing center



Wavefier at work



Multi-probe real time analysis

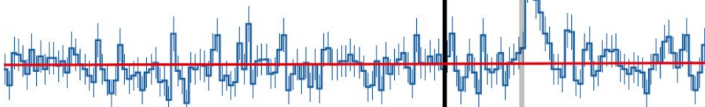


*Can we extract information
analyzing the heterogeneous
data?*

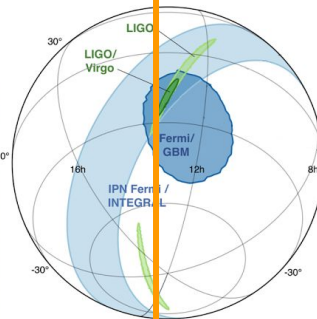
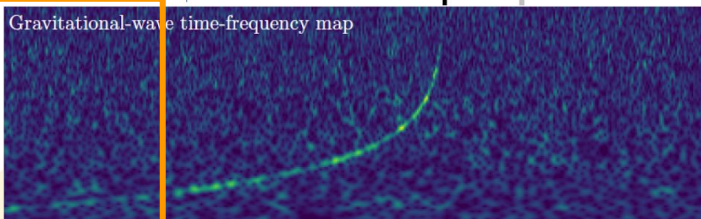
GW event

Lightcurve from Fermi/GBM (50 – 300 keV)

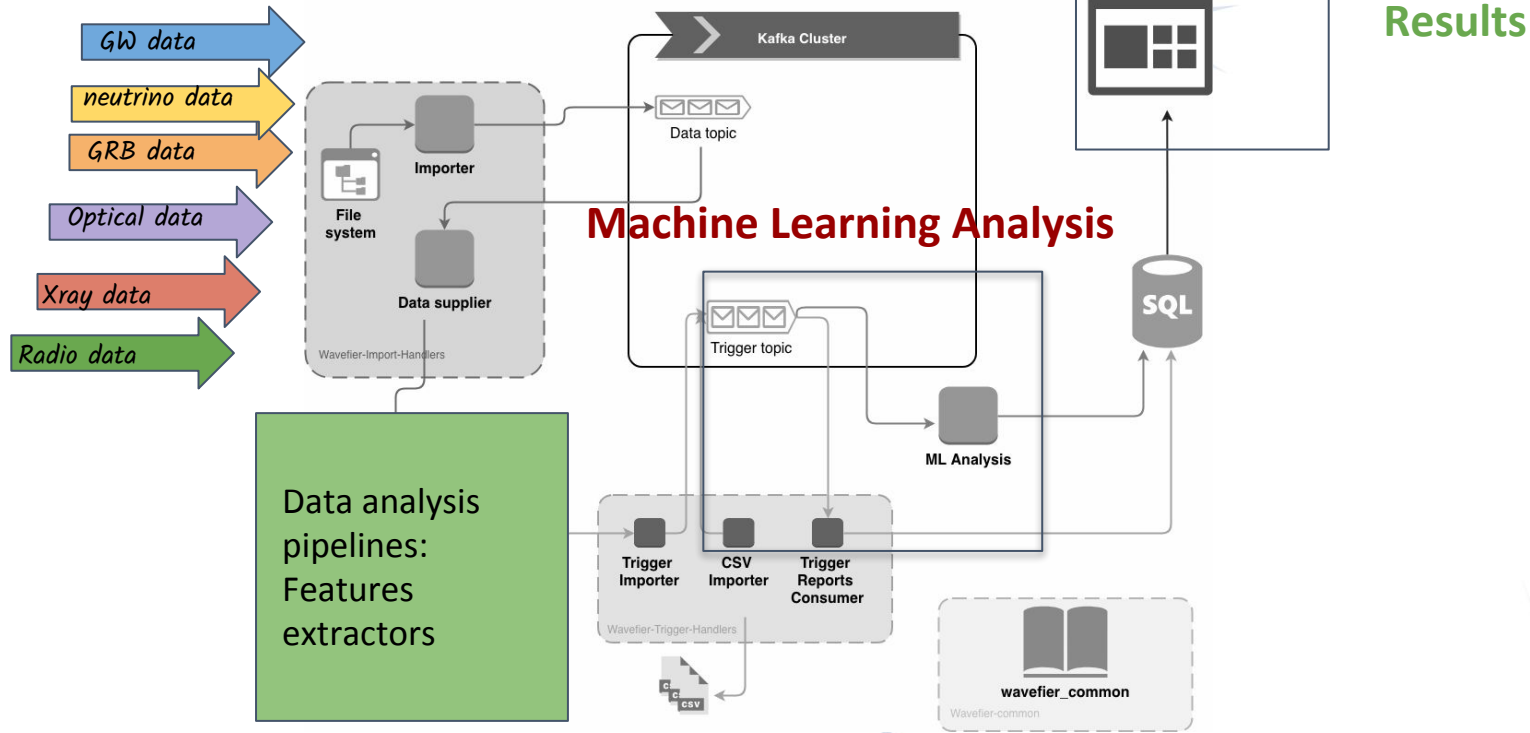
Short GRB event



Gravitational-wave time-frequency map



MMA in ESCAPE framework



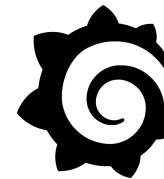
Data server



Kafka cluster



Dashboard



ESCAPE
OSSR

Open-source Scientific Software
and Service Repository

FAIR



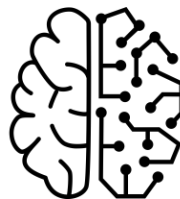
ESCAPE
DIOS

Data Infrastructure
for Open Science



ESCAPE
VO

Virtual
Observatory



WDF + Machine Learning



Database



ESCAPE
SAP

Science Analysis
Platform



ESCAPE
CS

Citizen
Science



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

