

# Virgo-LIGO Data analysis activities at IP2I Lyon

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# The data-analysis group at IP2I

- 4 people (3 CNRS, 1 MDC UCBL) – ramping up
- Expertise in data analysis from HEP, detector characterization and R&D
- Officially joined the Virgo collaboration in November 2018 : very recent !



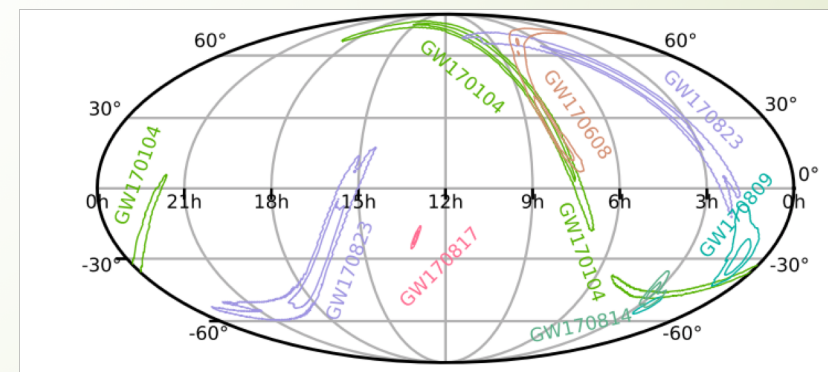
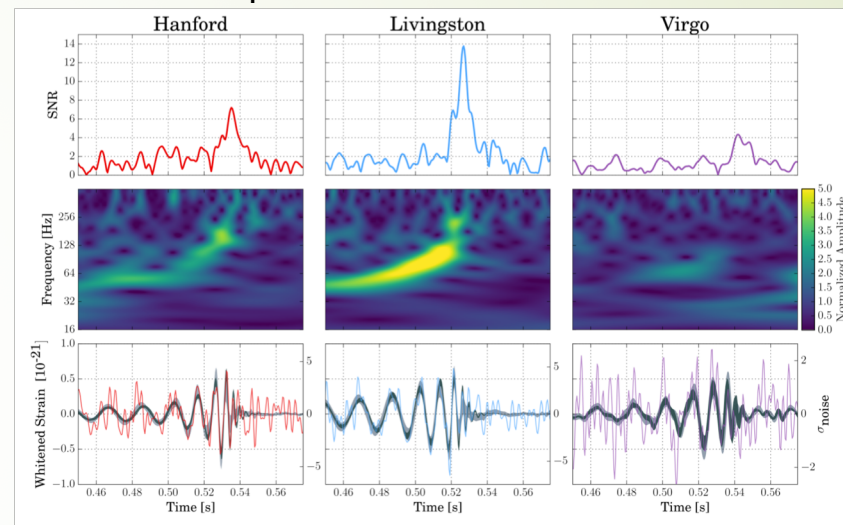
# The activities

- For O3 (observation run 2019-2020):
  - Analysis of Virgo-LIGO data searching for compact binary coalescences (in collaboration with LAPP, Urbino)
  - Participation to the characterization of the detector and monitoring of the quality of the data (in collaboration with EGO/LAL)
- Beyond O3 (>2020)
  - Review the interests on the data analysis side
  - Keep participating to detector characterization
  - Possible participation to the calibration of the Virgo detector response (common project with LMA, in collaboration with LAPP)

# Data analysis

- Search for **coalescence of compact binaries (CBC)**
- Already observed by LIGO-Virgo, expect more observations in O3 from the improved sensitivities
- Transient events ( $\sim 1$ - $\sim 100$  seconds)
- Use precise waveform predictions
- Perform matched filtering
- Waveform and duration can be quite different for different objects (BH, NS..)
- Coincidence of several detectors  $\rightarrow$  sky localization
- Can have EM counterpart (multi-messenger)

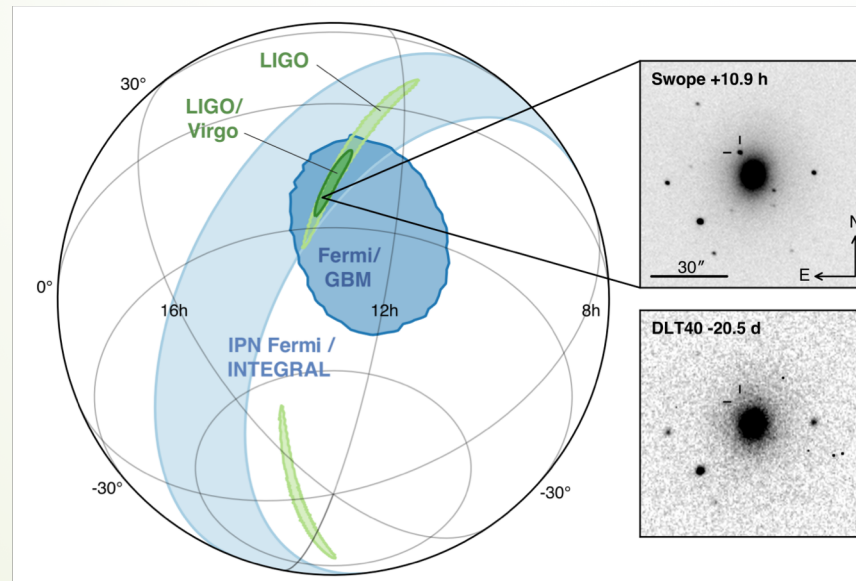
Example event GW170814





# Data analysis (CBC)

- All analyses run on the LIGO and Virgo data together
- Analyses running « **online** » for alerts
  - Fast, efficient and reliable
  - Three pipelines during O2 (2016-2017), **of which one Virgo: MBTA (LAPP, Urbino)**
  - Multi-messenger astronomy



## Example event GW170817

- GW signal (NS coalescence)
- Shortly followed by a  $\gamma$ -ray burst



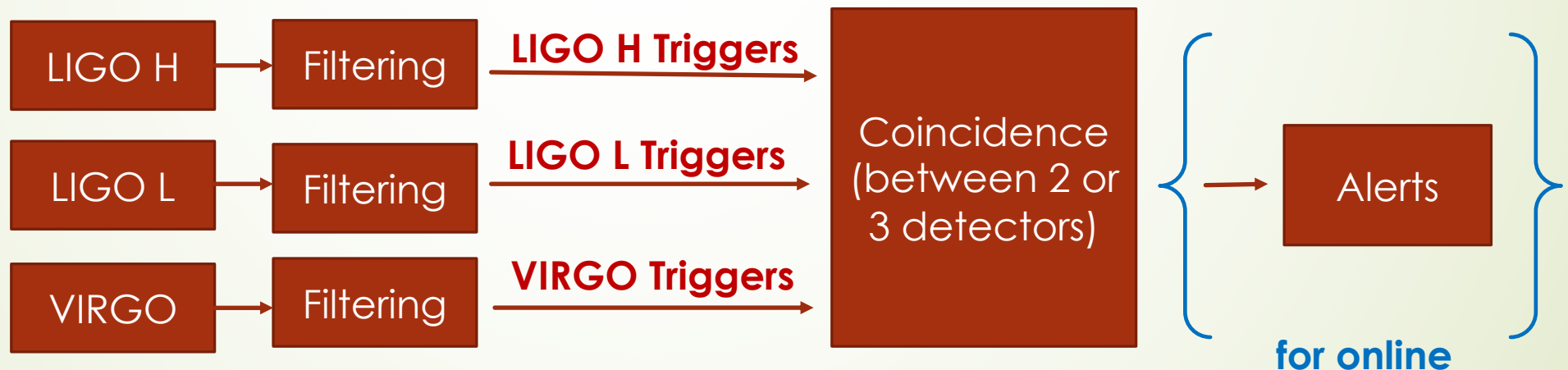
# Data analysis (CBC)

- Analyses running « **offline** » for publications
  - Use of the official final calibration
  - Refined monitoring of efficiency and fake rate
  - Precise determination of the parameters
  - Only two pipelines during O2 (both LIGO)
- **Our aim: take the MBTA pipeline offline**
  - Participate to the O3 data taking and observations
  - Building on existing and robust bases, facing the new challenges of offline, hopefully exploiting the proximity of the CC IN2P3
- In all cases: crucial to understand and control the background
  - Signal-based vetoes, gating, data quality from detector information...

# Multi-Band Template Analysis

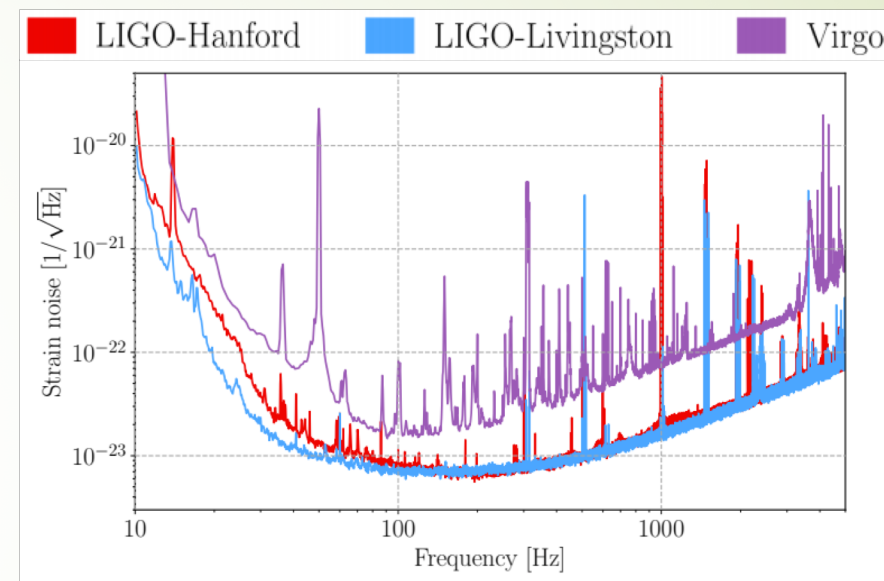
- Matched filtering to extract the GW signal from the data
- Splits the matched filters across two (or more) frequency bands
- Bands chosen so to ~equally share the signal-to-noise ratio (SNR)
- Reduce computational costs
- Loose negligible SNR wrt single-band analyses

## DATA



# Data quality and characterization of the detector

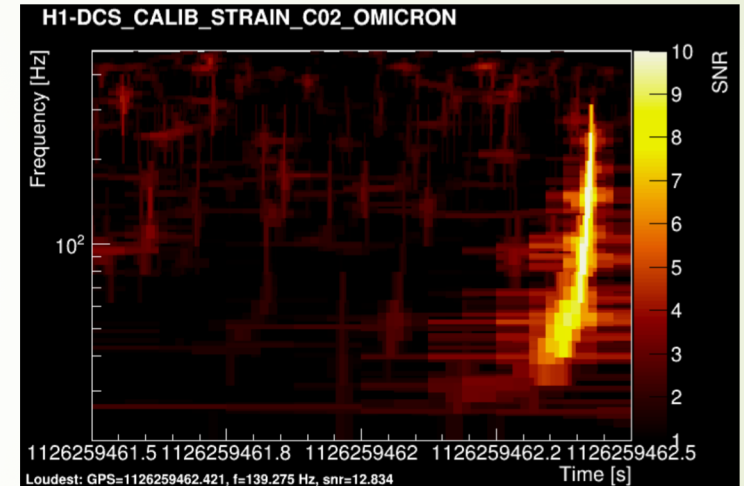
- Noise investigation
  - Noise events, noise coupling in the detector, feedback to commissioning group
- Detector monitoring
  - Generate flags to track the general status of the detector, define scientific run data-quality requisites..
- Data quality input for analyses (online and offline)
  - Provide data quality input to assess a GW detection, vetoes for transient searches, track noise spectral lines for continuous searches...





# Data quality and characterization of the detector

- Correlate with weather/seismic conditions, human disturbance
  - Correlate with operations
  - Correlate with (unusual) activity on-site
  - Study periodicity
  - ...
  - A real detective job!
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- Considered a general-interest task within Virgo: all groups have to contribute!



# Summary

- New group at IP2I joining the existing Virgo activities
- Mainly dedicated to LIGO-Virgo data analysis
- Aim : participate to O3 (2019-2020) for CBC searches
- Implication in detector characterization
- Plans for after O3 to be determined...

# Backup



# Data analysis in LIGO-Virgo

- Different type of searches for GW signals
- Transient sources
  - Coalescences of compact binaries (known waveform assumed)
  - Generic GW bursts (poorly modeled)
- Persistent sources
  - Continuous waves (from pulsars..)
  - Stochastic (relic GW from early evolution of the Universe)