

# Virgo detector characterization activities during the O3 run from latency to gravitational-wave event validation

**Amaldi 13, Valencia – July 07, 2019**

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European Gravitational Observatory (Consortium, CNRS & INFN)

On behalf of the **Virgo Collaboration**

[VIR-0250A-19](#)



# Outline

- Introduction
- Highlights and challenges
- DetChar in the O3 run
- Conclusions

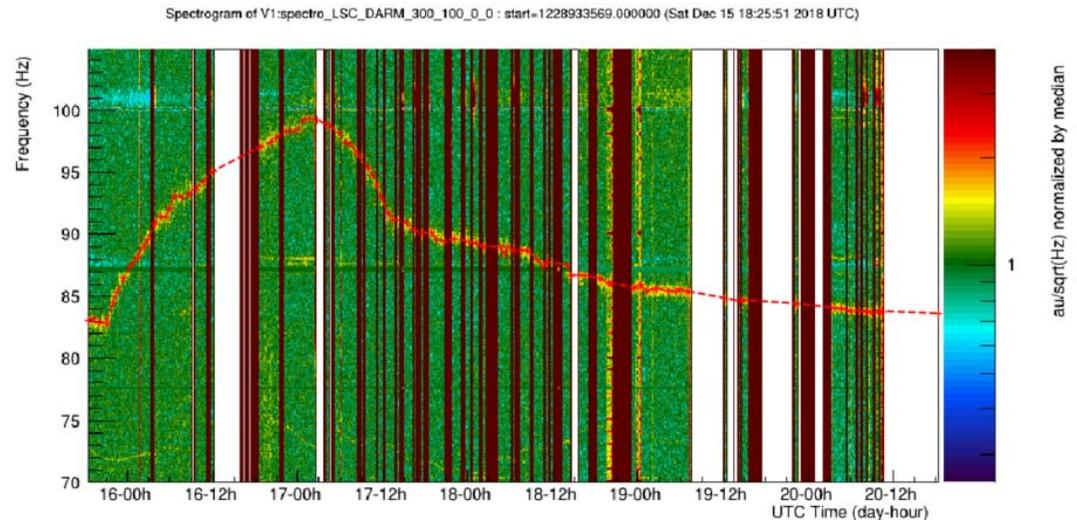
| DMS                |                    | ITF Mode: Science (0d 3h 19m 50s) |                |                   |                 | ITF State: LOW_NOISE_3_SQZ (0d 3h 21m 39s) |               |              |              |
|--------------------|--------------------|-----------------------------------|----------------|-------------------|-----------------|--|---------------|--------------|--------------|
| Injection          | SIB1_IP            | SIB1_BENCH                        | SIB1_BR        | SIB1_Vert         | SIB1_TE         | SIB1_Guard                                 | SIB1_Electr   |              |              |
|                    | MC_IP              | MC_PAY                            | MC_BR          | MC_Vert           | MC_TE           | MC_Guard                                   | MC_Electr     |              |              |
|                    | Laser              | LaserAmpli                        | LaserChiller   | SL_TempController | RFc             | LNFS                                       | PC            |              |              |
|                    | MC_Power           | PSTAB                             | IMC_AA         | IMC_AA_GALVO      | MC_F0_z         | BPC  | BPC_Electr    |              |              |
| Detection          | PD                 | QPD_B1p                           | QPD_B2         | QPD_B5            | OMC             | PicoDisable                                | Shutter       |              |              |
|                    | SDB1_IP            | SDB1_LC                           | SDB1_BR        | SDB1_Vert         | SDB1_TE         | SDB1_Guard                                 | SDB1_Electr   |              |              |
| ISC                | B2_8MHz_DPFI       | B4_56MHz_DPFI                     | DARM_UGF       | UNLOCK            | SSFS_UGF        | FmodErr                                    | GIPC          | EQ_Mode      |              |
|                    | B1p_DC             | B4_112MHz_MAG                     | B7_DC          | B8_DC             | LSC_rms         | ASC_rms                                    | 50Hz_FF       | ViolinModes  |              |
| Suspensions        | BS_IP              | BS_F7                             | BS_PAY         | BS_BR             | BS_Vert         | BS_TE                                      | BS_Guard      | BS_Electr    |              |
|                    | NI_IP              | NI_F7                             | NI_PAY         | NI_BR             | NI_Vert         | NI_TE                                      | NI_Guard      | NI_Electr    |              |
|                    | NE_IP              | NE_F7                             | NE_PAY         | NE_BR             | NE_Vert         | NE_TE                                      | NE_Guard      | NE_Electr    |              |
|                    | PR_IP              | PR_F7                             | PR_PAY         | PR_BR             | PR_Vert         | PR_TE                                      | PR_Guard      | PR_Electr    |              |
|                    | SR_IP              | SR_F7                             | SR_PAY         | SR_BR             | SR_Vert         | SR_TE                                      | SR_Guard      | SR_Electr    |              |
|                    | WI_IP              | WI_F7                             | WI_PAY         | WI_BR             | WI_Vert         | WI_TE                                      | WI_Guard      | WI_Electr    |              |
|                    | WE_IP              | WE_F7                             | WE_PAY         | WE_BR             | WE_Vert         | WE_TE                                      | WE_Guard      | WE_Electr    |              |
| Environment        | CB_Hall            | MC_Hall                           | TCS_zones      | NE_Hall           | WE_Hall         | WindActivity                               | Seismon       | BRMSMon      |              |
|                    | INJ_Area           | DET_Area                          | EE_Room        | DAQ_Room          | External        | DeadChannel                                | Lights        | SeaActivity  | WAB          |
| Infrastructures    | ACS_CB_Hall        | ACS_TCS_CHILROCK                  | ACS_TB         | ACS_DAO_Room      | ACS_EE_Room     | ACS_MC                                     | ACS_INJ       | ACS_DET      | ACS_NE       |
|                    | UPS_TB             | UPS_CB                            | UPS_MC         | UPS_NE            | UPS_WE          | FlatChannel                                | ExistChannel  | ACS_WE       | ACS_CB_CR    |
| SBE                | EIB_SBE            | SDB2_SBE                          | SDB2_LC        | SNEB_SBE          | SNEB_LC         | SWEB_SBE                                   | SWEB_LC       | SPRB_SBE     | SPRB_LC      |
| TCS                | NE_RH              |                                   | WE_RH          |                   | NI_CO2_Laser    |  | WI_CO2_Laser  |              | Chillers     |
| SQZ                | PLL                | Squeezer                          | SQZ_AA         |                   | SQZ_Shutter     |  | Cohe_CTRL     | SQZ_Inj      | Rack_TE      |
| Vacuum             | LargeValves        | Clean_Air                         | TubeStations   | TubePumps         | MiniTowers      | TurboLinks                                 | RemDryPMP     | VAC_SERVOS   |              |
|                    | Pressure           | CompressedAir                     | TowerServers   | TowerPumps        | CryoTrap        | O2_Sensors                                 | Tank          | HLS          |              |
| VPM                | DetectorSEnvironme | ControlRoom                       | Minitowers     | ISC               | Injection       | TCS  | Suspension    | Vacuum       | Metatron     |
|                    | DetectorMonitoring | DataCollection                    |                | Storage           |                 | DataAccess                                 |               | Automation   | DetChar      |
| DAQ-Computing      | Latency            | Disk                              | Timing         | Timing_rtpc       | Timing_dsp      | Fast_DAC                                   | ADCs_TE       | Daq_Boxes_TE |              |
|                    | DMS_machines       | DetOp_machines                    | olervers       | rtpcs             | CoilSwitchBoxes | INF_devices                                | ENV_devices   | VAC_devices  |              |
| Calib_Hrec         | CalINE             | CalWE                             | CalINJ         | CalBS             | CalPR           | PCalINE                                    | PCalWE        | HOFT         | NCAL         |
| ITFOnCall          | SoftwareAI         |                                   | TemperaturesAI |                   | InjectionAI     |  | UpsAI         |              | GeneratorAI  |
| DetChar-Ex.Trigger | Hrec_RANGE_BNS     |                                   | GraceDB_Alert  |                   | GRB_Alert       |  | KAMLAND_Alert |              | SNEWS_Alert  |
|                    |                    |                                   |                |                   |                 |  |               |              | STATE_VECTOR |

- In the following I will focus on the **Virgo Detector Characterization**, but the **equivalent group** exists in **LIGO** and is **extremely active**
  - We are **working together**: common **calls**, joint **projects**, **visitors**, etc.
  - We are also **working with KAGRA** to help them setting up their DetChar group

# **Detector Characterization (DetChar) in a nutshell**

# Detector Characterization: DetChar

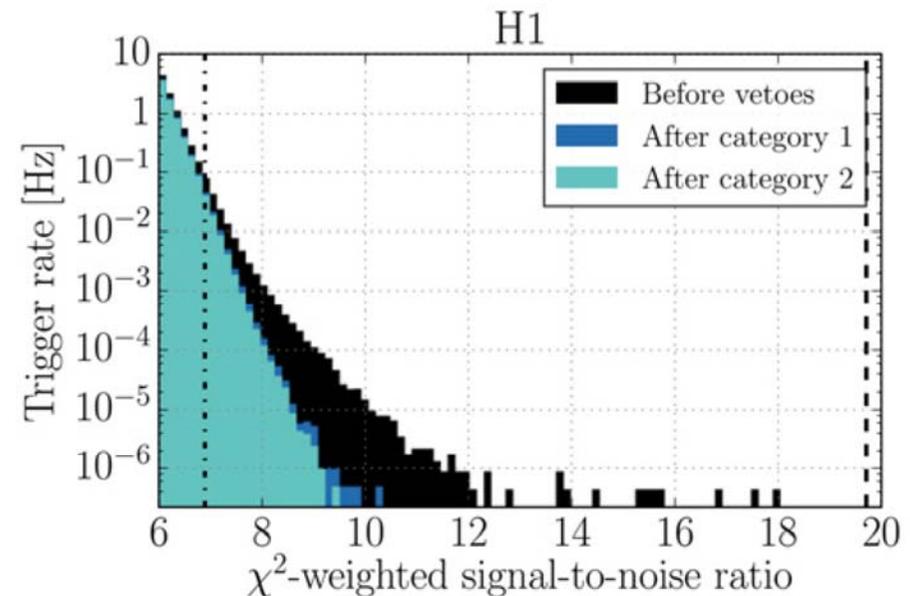
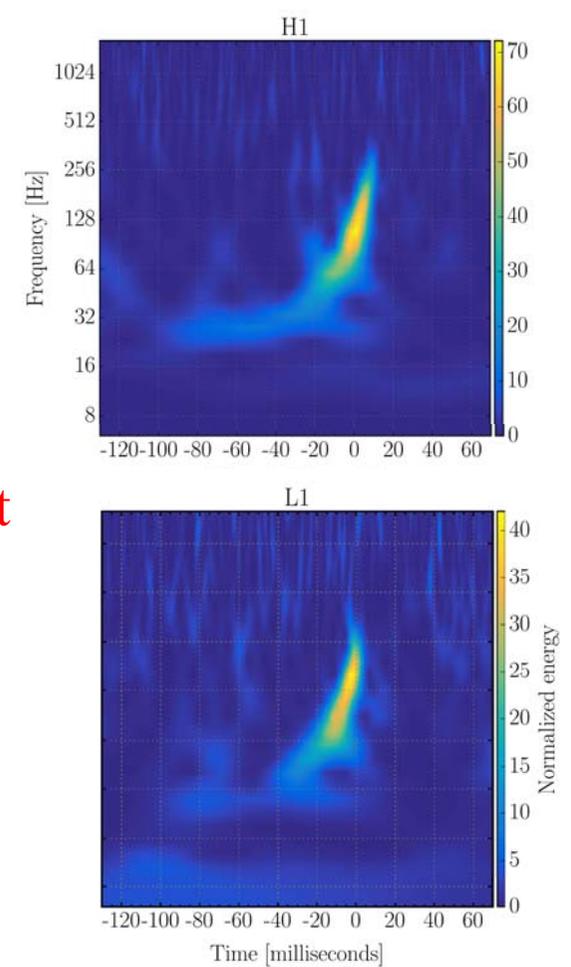
- **Detector monitoring**
- **Detector noise characterization**
  - **Transient and spectral**
  - **Noise evolution: it is not stationary!**
- **Several partners**
  - **Commissioning & noise hunting**
    - **Data quality analysis**
  - **Search groups**
    - **Data quality information**
    - **Veto**s: time and frequency domains
  - **DAQ / computing**
    - Access to **flags** and **veto**s for **online** and **offline** analysis
  - **Physics groups**
    - **Vet** gravitational-wave (GW) candidates
- **Virgo DetChar group**
  - About 5 FTE spread among O(20) people
  - **Weekly meeting attendance: 15-20 participants** on average



# Highlights and challenges

# GW150914

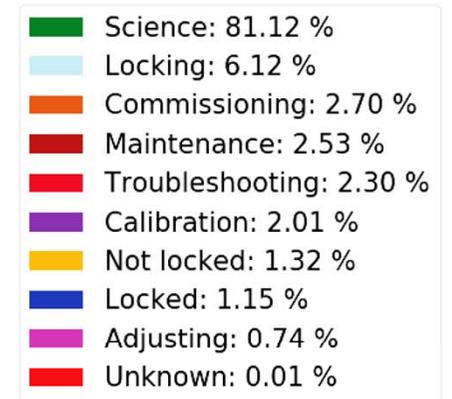
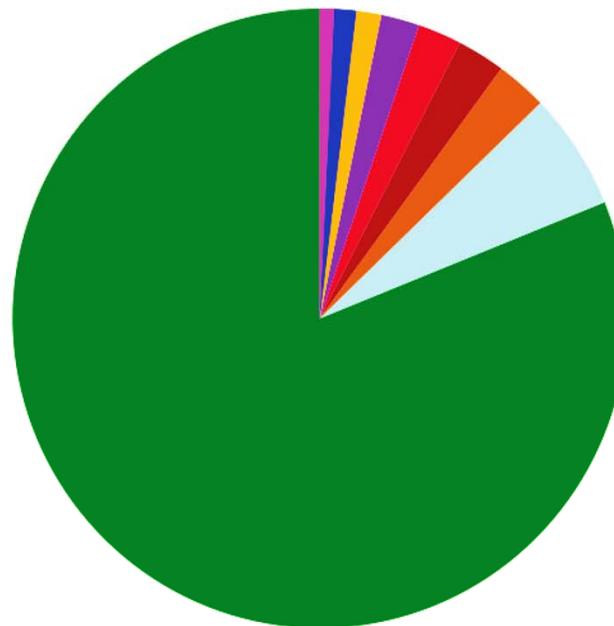
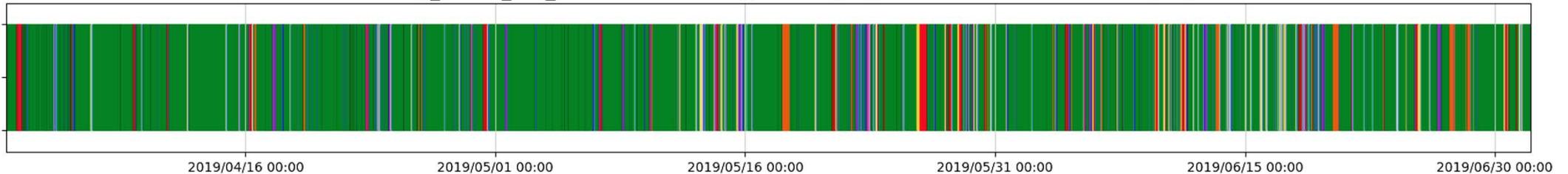
- **GW150914**: first direct detection of gravitational waves
  - **Data recorded**: September 15th, 2015
  - **Announcement**: February 11th, 2016
  - **5 month-work to acquire enough confidence that this event was a real binary black merger of astrophysical origin**
- **DetChar companion paper** to go along the announcement
  - **DetChar strategy**: identifying and mitigating noise sources
  - **Pipeline background studies**
  - **Extensive studies of the data around GW150914**
- Reference:  
[Class. Quantum Grav. 33 \(2016\) 134001](#)



# Global 3-detector running

- Individual detector **duty cycle**: example of **Virgo**

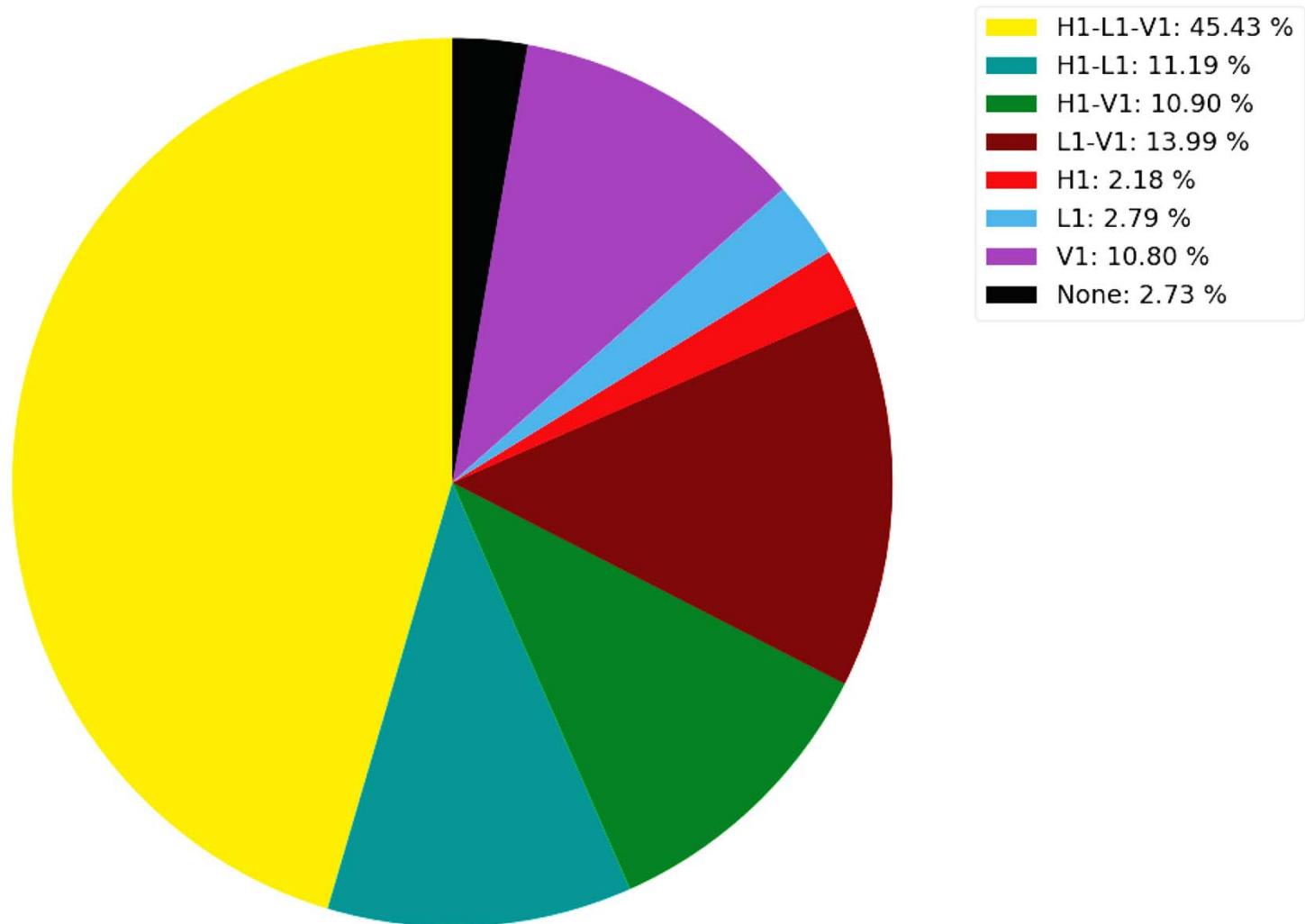
Status of channel V1:DQ\_META\_ITF\_Mode -- time range: 2019/04/01 15:00:00 UTC -> 2019/07/02 03:30:02 UTC



# Global 3-detector running

- Network duty cycle

plot\_HLV\_science\_segments: Number of detectors online  
2019-04-01 15:00:00+00:00 UTC -> 2019-07-02 02:07:03+00:00 UTC -- segments: DMT-ANALYSIS\_READY (H1-L1), SCIENCE (V1)



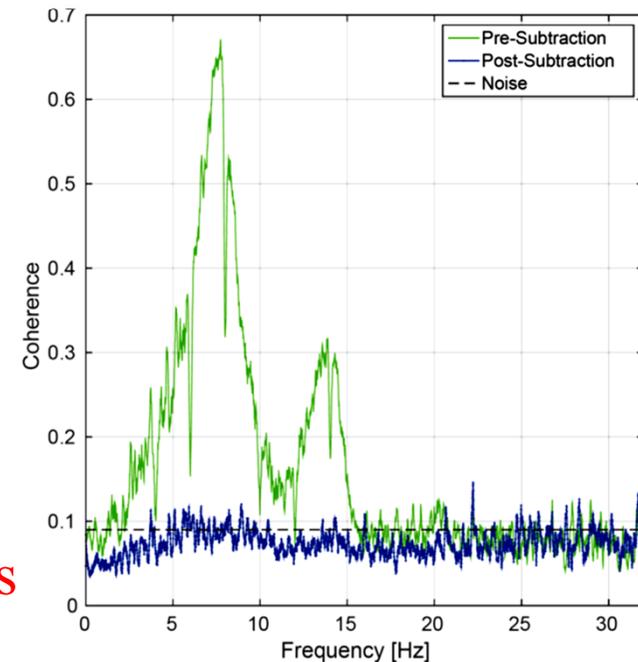
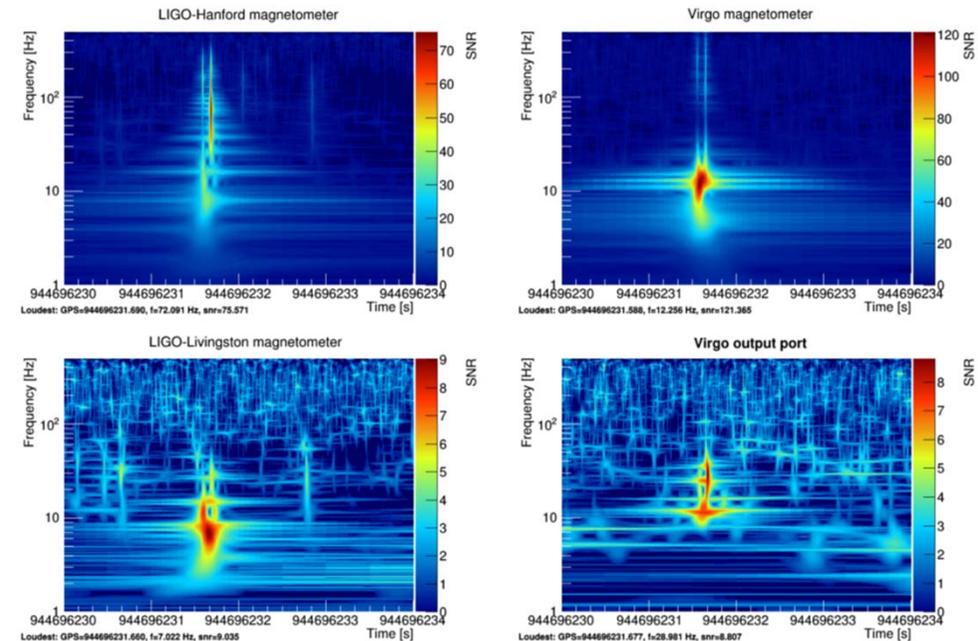
# Schumann resonances

- Global electromagnetic resonances of the **Earth-ionosphere ‘waveguide’**
  - Extremely low-frequency
  - Generated and excited by lightning
  - **Magnetic fields coherent over global distances**

→ Potential issue for stochastic background searches

- Use data from a **network of magnetometers**
  - At **GW detector locations**
  - At **other sites** (magnetically quiet)
- Compute **correlations**
- **Remove** them using **Wiener filtering techniques**

- References: [Class. Quantum Grav. 33 \(2016\) 224003](#)  
[Class. Quantum Grav. 34 \(2017\) 074002](#)  
[Phys. Rev. D 97, 102007 \(2018\)](#)



[\[arXiv:1606.01011\]](#)

[\[arXiv:1612.01102\]](#)

[\[arXiv:1802.00885\]](#)

# Observation run 3

- **April 1<sup>st</sup> 2019**: start of Observation run 3
  - **One year of global network data taking**
  - **Three detectors initially**: LIGO Hanford, LIGO Livingston, Virgo
    - ◆ **KAGRA should join the network during O3**
    - **4-detector configuration for the first time!**

| UID                       | Labels   | t_start           | t_0               | t_end             | FAR (Hz)  | Created                 |
|---------------------------|--|-------------------|-------------------|-------------------|-----------|-------------------------|
| <a href="#">S190701ah</a> | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1246048403.576563 | 1246048404.577637 | 1246048405.814941 | 1.916e-08 | 2019-07-01 20:33:24 UTC |
| <a href="#">S190630ag</a> | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1245955942.175325 | 1245955943.179550 | 1245955944.183184 | 1.435e-13 | 2019-06-30 18:52:28 UTC |
| <a href="#">S190602aq</a> | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1243533584.081266 | 1243533585.089355 | 1243533586.346191 | 1.901e-09 | 2019-06-02 17:59:51 UTC |
| <a href="#">S190524q</a>  | ADVNO SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT          | 1242708743.678669 | 1242708744.678669 | 1242708746.133301 | 6.971e-09 | 2019-05-24 04:52:30 UTC |
| <a href="#">S190521r</a>  | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1242459856.453418 | 1242459857.460739 | 1242459858.642090 | 3.168e-10 | 2019-05-21 07:44:22 UTC |
| <a href="#">S190521g</a>  | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1242442966.447266 | 1242442967.606934 | 1242442968.888184 | 3.801e-09 | 2019-05-21 03:02:49 UTC |
| <a href="#">S190519bj</a> | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1242315361.378873 | 1242315362.655762 | 1242315363.676270 | 5.702e-09 | 2019-05-19 15:36:04 UTC |
| <a href="#">S190518bb</a> | ADVNO SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT          | 1242242376.474609 | 1242242377.474609 | 1242242380.922655 | 1.004e-08 | 2019-05-18 19:19:39 UTC |
| <a href="#">S190517h</a>  | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1242107478.819517 | 1242107479.994141 | 1242107480.994141 | 2.373e-09 | 2019-05-17 05:51:23 UTC |
| <a href="#">S190513bm</a> | ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT          | 1241816085.736106 | 1241816086.869141 | 1241816087.869141 | 3.734e-13 | 2019-05-13 20:54:48 UTC |
| <a href="#">S190512at</a> | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1241719651.411441 | 1241719652.416286 | 1241719653.518066 | 1.901e-09 | 2019-05-12 18:07:42 UTC |
| <a href="#">S190510g</a>  | ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT          | 1241492396.291636 | 1241492397.291636 | 1241492398.293185 | 8.834e-09 | 2019-05-10 03:00:03 UTC |
| <a href="#">S190503bf</a> | ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT          | 1240944861.288574 | 1240944862.412598 | 1240944863.422852 | 1.636e-09 | 2019-05-03 18:54:26 UTC |
| <a href="#">S190426c</a>  | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1240327332.331668 | 1240327333.348145 | 1240327334.353516 | 1.947e-08 | 2019-04-26 15:22:15 UTC |
| <a href="#">S190425z</a>  | ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK                          | 1240215502.011549 | 1240215503.011549 | 1240215504.018242 | 4.538e-13 | 2019-04-25 08:18:26 UTC |
| <a href="#">S190421ar</a> | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1239917953.250977 | 1239917954.409180 | 1239917955.409180 | 1.489e-08 | 2019-04-21 21:39:16 UTC |
| <a href="#">S190412m</a>  | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1239082261.146717 | 1239082262.222168 | 1239082263.229492 | 1.683e-27 | 2019-04-12 05:31:03 UTC |
| <a href="#">S190408an</a> | PE_READY ADVOK SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK GCN_PRELIM_SENT | 1238782699.268296 | 1238782700.287958 | 1238782701.359863 | 2.811e-18 | 2019-04-08 18:18:27 UTC |
| <a href="#">S190405ar</a> | ADVNO SKYMAP_READY EMBRIGHT_READY PASTRO_READY DQOK                          | 1238515307.863646 | 1238515308.863646 | 1238515309.863646 | 2.141e-04 | 2019-04-05 16:01:56 UTC |

- **Open public alerts**
  - **Lowest possible latency**
  - **Preceed vetting in most cases**
    - Possible **retractions** at a later stage
    - ◆ **Automate** tasks as much as possible
      - More events: compact binary coalescences (black holes, neutron stars), etc.

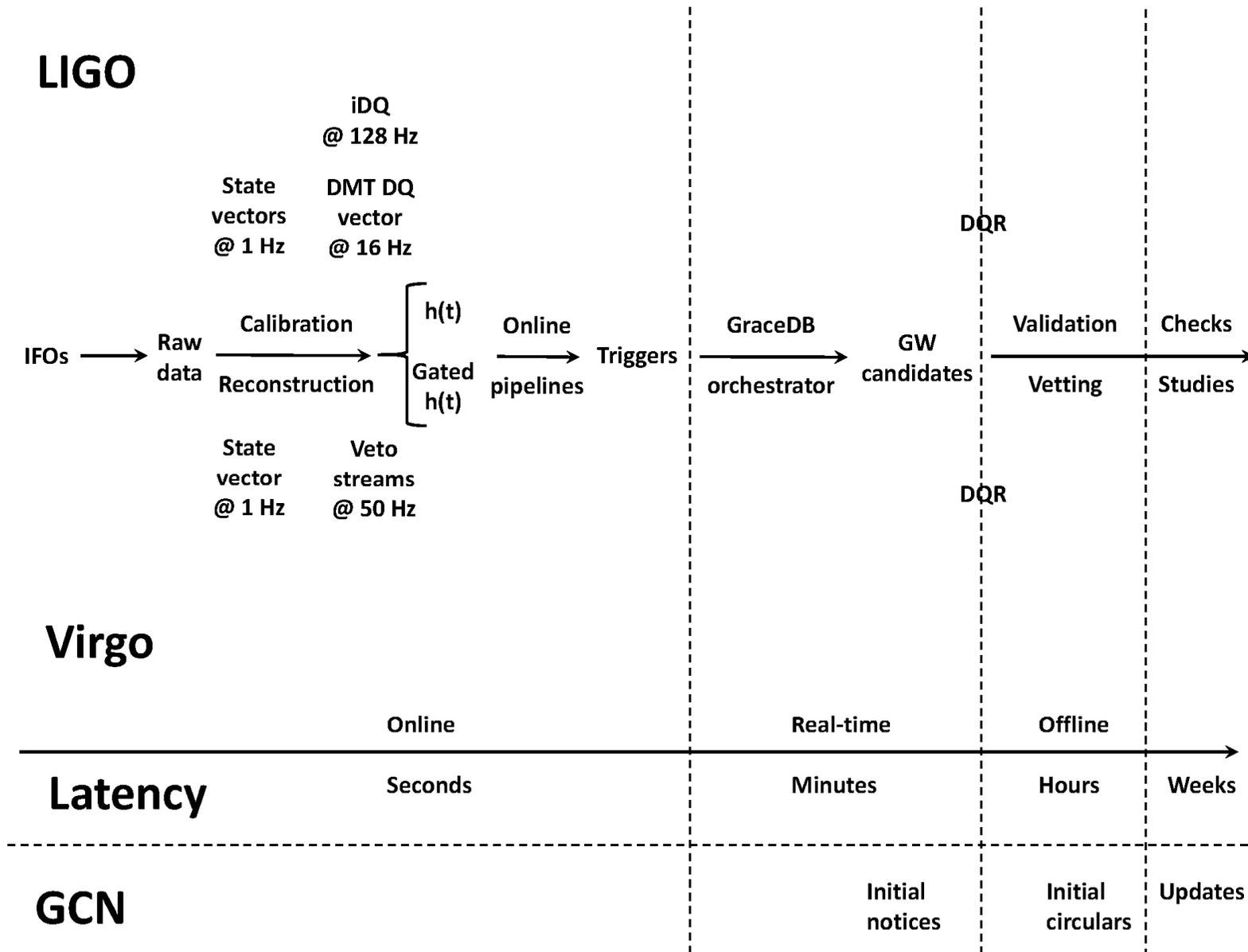
# Open data releases

- [Gravitational Wave Open Science Center](#)
- Data public around each event when published
- Current policy: given dataset published 18 months after data taking is over
  - Tough schedule for the LIGO and Virgo collaborations
    - ◆ (Re)processings, analysis, validation, publication
    - O2 data to be released in a couple of weeks
- [Tens of projects already based on LIGO-Virgo open data](#)
  - At all scientific levels, art & science, etc.
- Goal: users should be able to reproduce LIGO-Virgo results
  - Document everything
    - For scientific consistency and with future open data releases in mind

# **Virgo DetChar in the O3 era**

# Dataflow

- From the **detectors**, to the **offline validation** of **online events**



# State Vector

- **Live interferometer status**
  - 1 Hz channel
  - Bit structure
- Bits 0-1: science data taking
- **Bit 10: online data quality assessment**
  - **1 ⇔ Data OK**
  - **0 ⇔ Data is bad**
  - Inputs: **saturation flags**
    - ◆ Output port photodiodes
    - ◆ Suspension coil drivers
    - ◆ DARM (differential Fabry-Perot arm length) glitch rate
- **Constant monitoring of the SCIENCE segments**
  - State Vector should match information from the Virgo automated control system
- **Bit 10 is only flagging a very small fraction of the data**

**0: h(t) was successfully computed**

**1: science mode button is pushed**

2: observation ready

3: h(t) was produced by the calibration pipeline

4: calibration filters settled in

5: No stochastic HW injections

6: No CBC HW injection

7: No burst HW injection

8: No HW injections for detector characterization

9: No continuous wave HW injection

**10: good data quality (CAT1 type)**

11: interferometer is locked

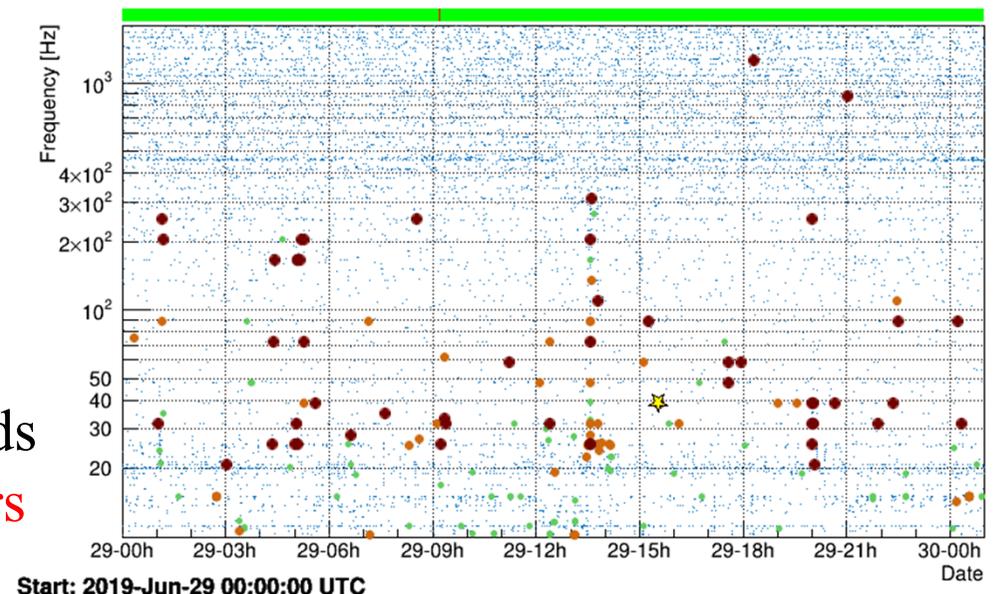
# Glitches

- **Omicron** tool
  - **400 channels** processed **online**
  - **3,000 channels** reprocessed **offline**
  - Based on the **Q-transform**:  
overcomplete basis of **sinusoidal Gaussian** functions
    - ◆ Glitches defined by  
{time, frequency, SNR}

→ Reference: [public Virgo note](#)

- Two main channels
  - **$h(t)$**
  - **DARM**
- **Analysis window**
  - **Gating + windowing** applied on both ends
  - Only **central part** used to produce **triggers**
  - **Overlap** between analysis windows

| BRMSMoniSM    | TFMoni                | NonStatMoni           | SpectroMoni           | BRMSMon               | BRMSMonHrec           |
|---------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| SegOnline     |                       |                       |                       |                       |                       |
| FdOmRaw1      |                       | Om_parameters_1024_00 |                       | Om_parameters_1024_01 |                       |
|               | Om_parameters_1024_02 |                       | Om_parameters_1024_03 |                       | Om_parameters_1024_04 |
|               | Om_parameters_2048_00 |                       | Om_parameters_2048_01 |                       | Om_parameters_2048_02 |
|               | Om_parameters_2048_03 |                       | Om_parameters_2048_04 |                       | Om_parameters_2048_05 |
|               | Om_parameters_2048_06 |                       | Om_parameters_2048_07 |                       | Om_parameters_2048_08 |
|               | Om_parameters_2048_09 |                       | Om_parameters_2048_10 |                       | Om_parameters_2048_11 |
|               | Om_parameters_2048_12 |                       | Om_parameters_2048_13 |                       | Om_parameters_2048_14 |
|               | Om_parameters_2048_15 |                       | Om_parameters_2048_16 |                       | Om_parameters_2048_17 |
|               | Om_parameters_2048_18 |                       | Om_parameters_2048_19 |                       |                       |
| FdOmRaw2      | OmRawBroadCast        | Om_parameters_2048_20 |                       | Om_parameters_2048_21 |                       |
|               | Om_parameters_2048_22 |                       | Om_parameters_2048_23 |                       | Om_parameters_2048_24 |
|               | Om_parameters_2048_25 |                       | Om_parameters_2048_26 |                       | Om_parameters_2048_27 |
|               | Om_parameters_2048_28 |                       | Om_parameters_2048_29 |                       | Om_parameters_2048_30 |
|               | Om_parameters_2048_31 |                       | Om_parameters_2048_32 |                       | Om_parameters_2048_33 |
|               | Om_parameters_2048_34 |                       | Om_parameters_2048_35 |                       | Om_parameters_2048_36 |
|               | Om_parameters_2048_37 |                       | Om_parameters_2048_38 |                       | Om_parameters_2048_39 |
|               | Om_parameters_2048_40 |                       | Om_parameters_2048_41 |                       | Om_parameters_2048_42 |
|               | Om_parameters_512_00  |                       | Om_parameters_main_00 |                       | Om_parameters_main_01 |
|               | Om_parameters_main_02 |                       |                       |                       |                       |
|               | Om_parameters_hoft    |                       |                       |                       |                       |
| VetoThr       |                       | Om_veto_00            |                       | VetoMerger            |                       |
| Ivalert_virgo |                       |                       |                       |                       |                       |

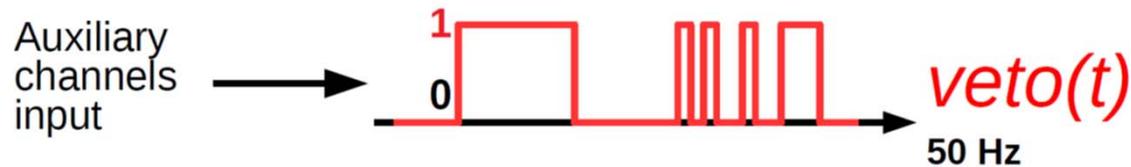


# Veto streams

- Goal: **reject online triggers likely due to glitches**

- 50 Hz channels

- Veto flags: 1  $\Leftrightarrow$  veto      0  $\Leftrightarrow$  pass



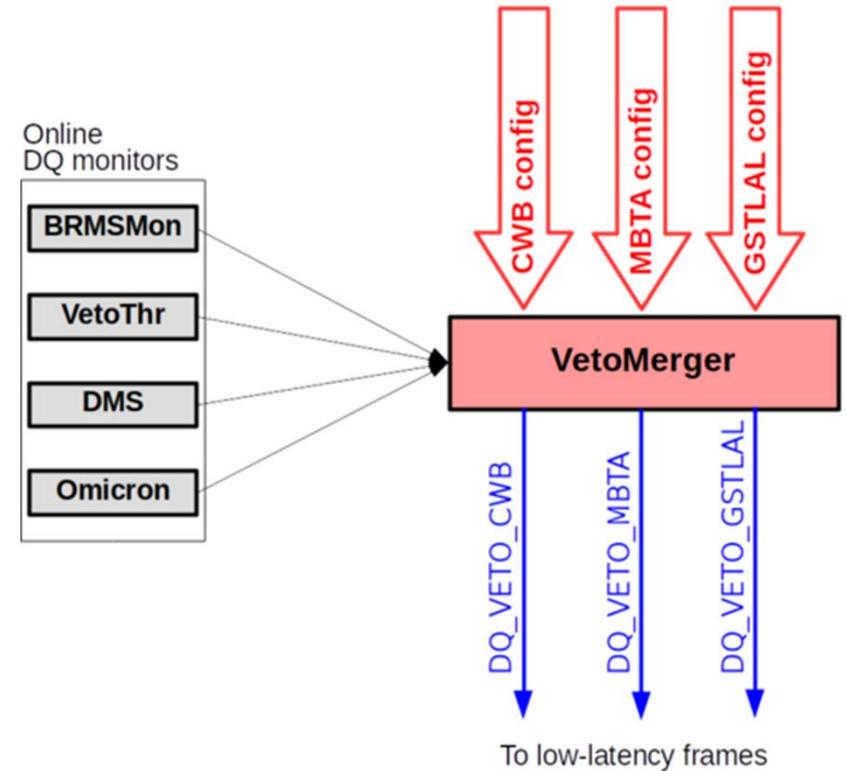
- Inputs: all data quality flags available online

- One stream per pipeline

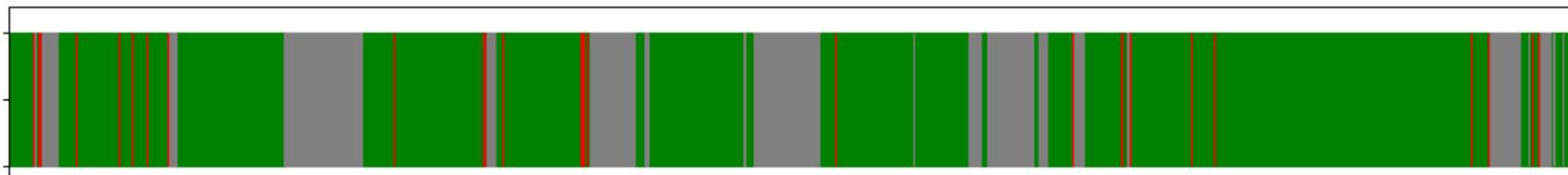
- ◆ Pipeline-specific configurations

*Burst*      V1:DQ\_VETO\_CWB  
*CBC*      { V1:DQ\_VETO\_GSTLAL  
               V1:DQ\_VETO\_MBTA  
               V1:DQ\_VETO\_PYCBC

...



Being tested on live data

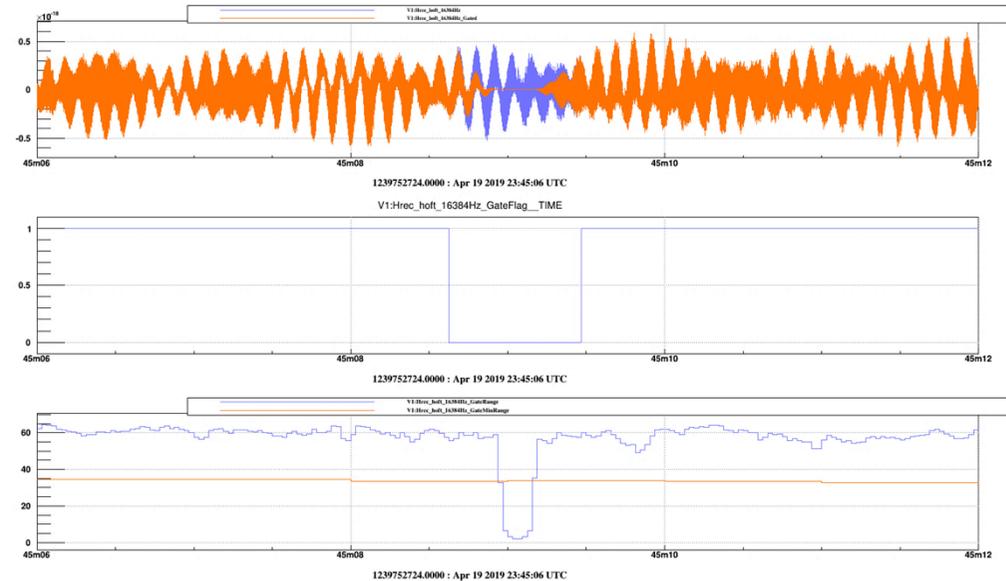


Not in Science:  
24.231% [1d:16h:42m:28s]  
 In Science, no veto:  
75.756% [5d:7h:16m:11s]  
 In Science, veto:  
0.013% [0d:0h:1m:21s]

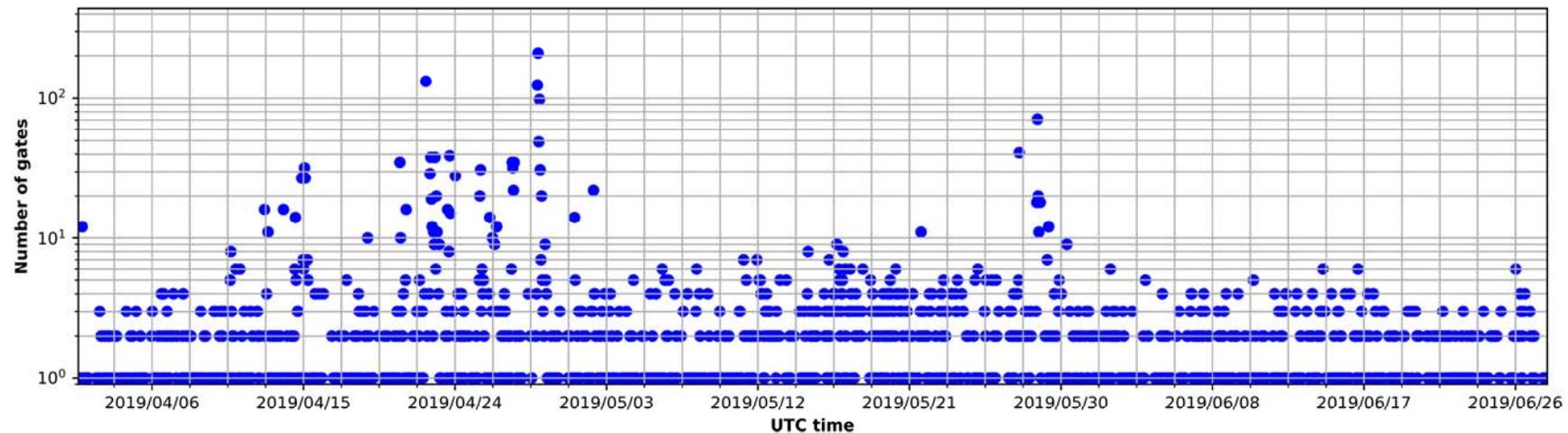
DQ\_VETO\_PYCBC

# Gated $h(t)$

- Goal: getting round of extremely loud glitches, while keeping the pipelines running
  - Glitches pollute PSD estimation
  - Gate out data instead of interrupting the data analysis
- In Virgo, based on MBTA internal gating
  - Triggered by significant downwards excursions of the BNS range

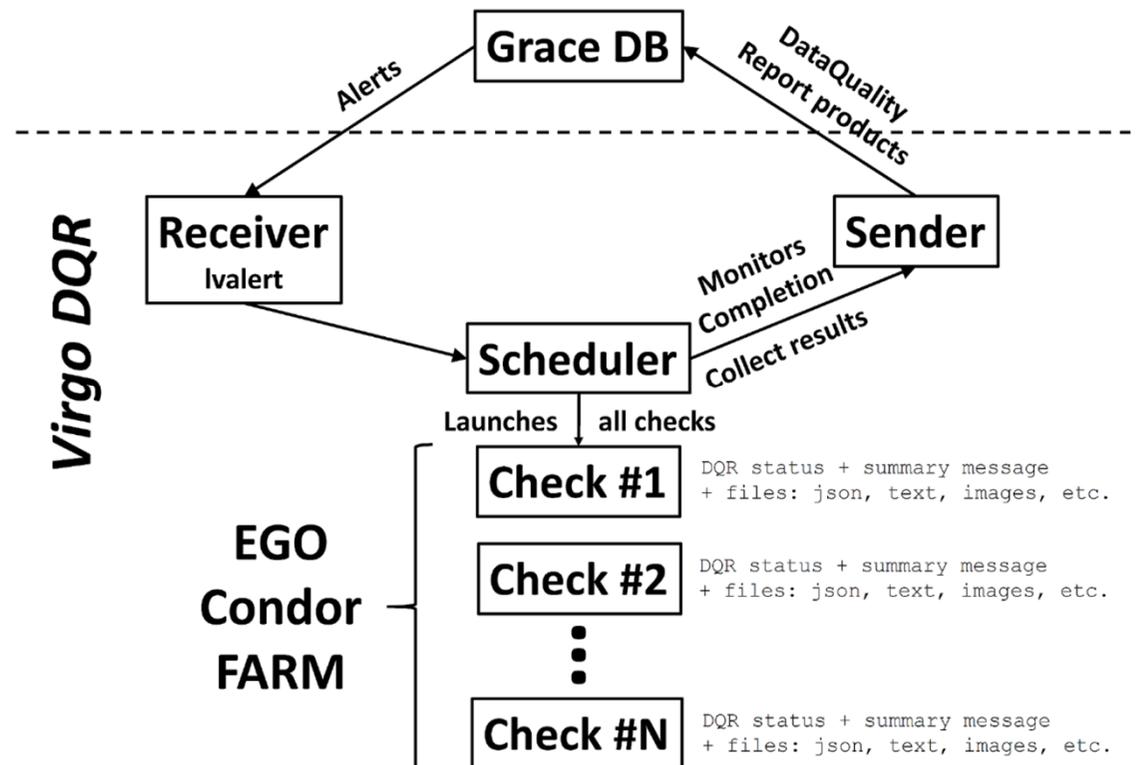


→ Promising to help identifying hopefully short but quite pathological data segments



# Data quality reports

- **Data Quality Report (DQR)**
  - Triggered by each (online) GW trigger
  - Runs various analysis on the available data: from basic to complex
    - ◆ Detector status, environment status, noise analysis, more expert plots, etc.
  - Each task reports a status
    - Helps final decision: keep or reject event
  - Runs independently on data from all three detectors
    - Virgo flavour of the DQR
      - ◆ Results gathered and linked back to the event that triggered the DQR
- **Fully automated**
  - 4,000+ DQRs since O3 began
  - Actual response now depends on significance
  - Extremely reliable framework



# DQR workflow example: S190630ag

- One of the recent LIGO-Virgo triggers

- Public information: <https://gracedb.ligo.org/superevents/S190630ag/view>

- **Timeline** (EGO local time)

- Event t0 20:52:05
- S-event creation in GraceDB 20:52:28
- Virgo DQR triggered by GraceDB 20:52:35
- Virgo DQR generation 20:57:40
- Virgo DQR processing 20:58:00
- Key information available 21:03:56
- 21:13:42
- Virgo DQR processing completed 21:50:23

← 300 s  
configurable  
latency  
[Conservative]

→ LIGO-Virgo internal monitoring of that task

| Log Entry Created         | Submitter     | Comment                                   |
|---------------------------|---------------|---|
| Jun 30, 2019 19:50:24 UTC | Virgo Detchar | Condor DAG is done: monitoring has ended. |
| Jun 30, 2019 18:58:03 UTC | Virgo Detchar | Condor DAG is running.                    |
| Jun 30, 2019 18:57:59 UTC | Virgo Detchar | Virgo DQR being initialized.              |
| Jun 30, 2019 18:57:58 UTC | Virgo Detchar | Condor DAG successfully generated.        |

# Offline data quality

- Goals
  - Final data quality assessment for the new detections
  - Final dataset for offline analysis
- Basic container: time segments
  - SCIENCE segments
  - Primary data quality vetoes: segments during which the data are definitely bad
    - ◆ Using online-computed flags
    - ◆ Adding flags for offline-identified issues
  - Additional, optional, data quality flags
    - ◆ Available to optimize the cuts of each analysis
  - Flags keeping track of changes in the interferometer configuration with SCIENCE segments
    - Action not causing the loss of the detector control nor visible in the data
      - ◆ Example: switching on/off some correction
- Framework in its final stages
  - First segment lists available to analysts
  - Plan is to update them regularly, following the data taking progress

# Spectral lines

- **Noise Frequency Event Miner: NoEMi**
  - Monitoring and identification of spectral noise lines
  - **Major rewriting for O3: “quicker, smaller, lighter, easier”**

The screenshot shows the NoEMi web application interface. It features two main sections: 'Persistence lines' and 'Critical ratio lines'. Both sections have a table of data and a 'Download this list of lines' button. A red circle highlights the download button in the 'Persistence lines' section, with a red arrow pointing to a browser window that displays the downloaded data as a text file.

**Persistence lines**

| Channel           | Frequency range           | Frequency peak      | CR   |
|-------------------|---------------------------|---------------------|------|
| V1:ENV_NEB_SEIS_V | 13.449664422-13.48971873  | <u>13.46015485</u>  | 0.85 |
| V1:ENV_NEB_MIC    | 13.45631192-13.46584864   | <u>13.45988819</u>  | 0.26 |
| V1:LSC_DARM       | 14.998305498-15.001285728 | <u>15.000093636</u> | 0.54 |

**Critical ratio lines**

| Channel        | Frequency range           | Frequency peak     | CR    |
|----------------|---------------------------|--------------------|-------|
| V1:LSC_DARM    | 10.141126644-10.156027794 | <u>10.14470292</u> | 0.098 |
| V1:ENV_NEB_MIC | 17.08980224-17.14702256   | <u>17.14583047</u> | 0.098 |
| V1:ENV_NEB_MIC | 17.16013555-17.18159317   | <u>17.17920899</u> | 0.048 |

**Downloaded data (from browser window):**

```
# delta f presence persistency CR log10(ampli)
13.460154836 0.04 0.853658536585366 12.8340074137931 -15.9702990054678
13.45988819 0.01 0.269230769230769 4.150555454545456 -5.93696255070324
15.000093636 0.0549019607843137 5.040123333333333 -16.9948150147071
15.79819923 0.1 87.148426 -15.2003438489571
16.29887787 0.01 1 76.47257375 -15.6359007066969
16.798960464 0.01 1 113.77806 -15.2825156186016
24.171821204 0.04 0.682926829268293 10.6205084210526 -16.867228860491
24.16604848 0.03 0.336538461538462 5.277445833333333 -8.49434368345189
24.847965648 0.01 0.196078431372549 4.33728714285714 -18.7025193434592
24.90395219 0.03 0.701923076923077 10.850773 -7.11128357261239
24.91950162 0.03 0.597560975609756 9.28589857142857 -17.4322977316556
24.999957378 0.01 0.92156862745098 7.51945230769231 -18.5764880487681
26.9531549 0.03 0.317307692307692 5.18532034482759 -6.29067185111829
26.954641936 0.02 0.195121951219512 4.919400833333333 -17.9161753013488
27.999856896 0.0137254901960784 4.071825 -19.6684885523134
32.999490744 0.0176470588235294 4.543532222222222 -20.3261167868454
33.69680803 0.06 0.586538461538462 10.7191124324324 -4.4990019747027
33.699024464 0.05 0.560975609756098 7.85484205882353 -15.8624372408208
33.999655932 0.0156862745098039 4.043815 -20.3067842595806
34.497950388 0.01 1 128.662761538462 -17.6231199815662
34.840080792 0.0117647058823529 4.016341666666667 -19.723523222314
34.845445206 0.0117647058823529 3.937993333333333 -20.0430883967073
34.99982112 0.01 0.92156862745098 10.04851 -19.5699543842792
35.999986308 0.0529411764705882 4.95905571428571 -20.1391308890312
36.173808494 0.02 0.170731707317073 7.57620636363636 -18.1815370989937
36.498280764 0.01 1 200.66157 -17.6026841073804
37.499041998 0.01 1 139.4042166666667 -17.8473343048773
40.419565142 0.06 0.451219512195122 8.192295 -16.7205795473955
40.38443293 0.04 0.278846153846154 6.30791269230769 -6.33262794775944
44.649109332 0.05 0.231707317073171 5.796655833333333 -18.1014832177143
44.86082496 0.03 0.158536585365854 4.666578888888889 -18.8107292635448
44.999684862 0.01 0.647058823529412 5.0640175 -20.4650436231899
45.192703512 0.04 0.158536585365854 4.688927777777778 -18.0513904762211
45.53887174 0.004 0.24390243902439 4.91826692307692 -17.4083963625983
47.46314298 0.0137254901960784 3.8879 -20.3586134135161
47.813618028 0.01 0.431372549019608 4.429703333333333 -19.9157330014043
47.885878888 0.04 0.207317073170732 6.51311571428571 -17.6285506278204
47.89350828 0.0121951219512195 4.551604444444444 -17.5892978858986
47.90781339 0.01 0.121951219512195 4.604891 -17.6850091610523
47.909720738 0.0109756097560976 4.580808888888889 -17.9336089465976
```

# Spectral lines

- **Lines Database**
  - Collect all information about lines found in the data
    - Many new functionalities added for O3

Lines DB

10.4 534.3 1058.2 1582.1 2106.0 2629.9 3153.8 3677.7 4201.6 4725.5 5249.4 5773.3 6297.2 6821.1 7345.0 7868.9 8392.8 8916.7 9440.6 9964.3

Frequency (Hz)

Click on a line frequency to view additional associated information.

| Frequency (Hz)        | Tags               | Width (Hz)             | Stationarity | Notes   | Line source     |            |
|-----------------------|--------------------|------------------------|--------------|---|-----------------|------------|
| <a href="#">10.53</a> | <a href="#">O2</a> | 0.1                    | Stationary   | CAL noise line49<br>Observed in O2                            | Calibration     |            |
| <a href="#">12.5</a>  | <a href="#">O2</a> | 0.1                    | Stationary   | CALnoise PR_MIR_perline0<br>Observed in O2                    | Calibration     |            |
| <a href="#">16.3</a>  | <a href="#">O2</a> | 0.1                    | Stationary   | CALnoise BS_MAR_permline0<br>Observed in O2                   | Calibration     |            |
| ID                    | Type               | Locations              |              | Recording devices   | Added by        | Date added |
| 66                    |                    | Central Building (CEB) |              | Magnetometer  | hemming         | 02-08-2017 |
| <a href="#">18.6</a>  | <a href="#">O2</a> | 0.1                    | Stationary   | Observed in O2  | Air conditioner |            |
| <a href="#">20</a>    | <a href="#">O2</a> | 1                      | Stationary   | Mechanical mode of External Injection Bench<br>Observed in O2 | Mechanical mode |            |
| <a href="#">24.6</a>  | <a href="#">O2</a> | 0                      | Stationary   | DAQ room air conditioner (elog 38709).<br>Seen in O2.         | Air conditioner |            |
| <a href="#">29.2</a>  | <a href="#">O2</a> | 0.1                    | Stationary   | Eliminated 25/7/17  | Vacuum pump     |            |
| <a href="#">29.68</a> | <a href="#">O2</a> | 0.5                    | Stationary   | Excited with white z shaking of SDB1 (elog 38625)             | Mechanical      |            |

# DetChar shifts

- **Supplement DetChar experts**
    - Nominally 2 shifters / week, from a maintenance period to the next one
    - Collaboration-wide service task
      - ◆ Contribution proportional to the number of Virgo authors in a given group
  - **Main tasks**
    - Data quality monitoring
    - Rapid Response Team for online triggers
- Effective since pre-O3 commissioning last Fall
- Positive experience overall
    - ◆ **Training** and **documentation** are keys to the success of such initiatives

*Virgo DQR documentation:*

Introduction

Checks

FAQ

Instructions for  
shifters and RRT

For experts

*LIGO DQR documentation:*

Introduction

# Conclusions

# Outlook

→ When writing that slide...

- 3 months into O3
  - 74+ days of SCIENCE data
  - 4,000+ DQRs processed
  - 16 open public alerts
  - 57 DetChar shifts
  - ~20 people involved in regular DetChar activities
- Work (always) in progress!
- ~Quarter of the expected data taking completed
  - Offline work
  - Next campaign of upgrades: Advanced Virgo Plus