

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

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**Nicolas Arnaud** ([narnaud@lal.in2p3.fr](mailto:narnaud@lal.in2p3.fr))

Laboratoire de l'Accélérateur Linéaire (CNRS/IN2P3 & Université Paris-Sud)

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

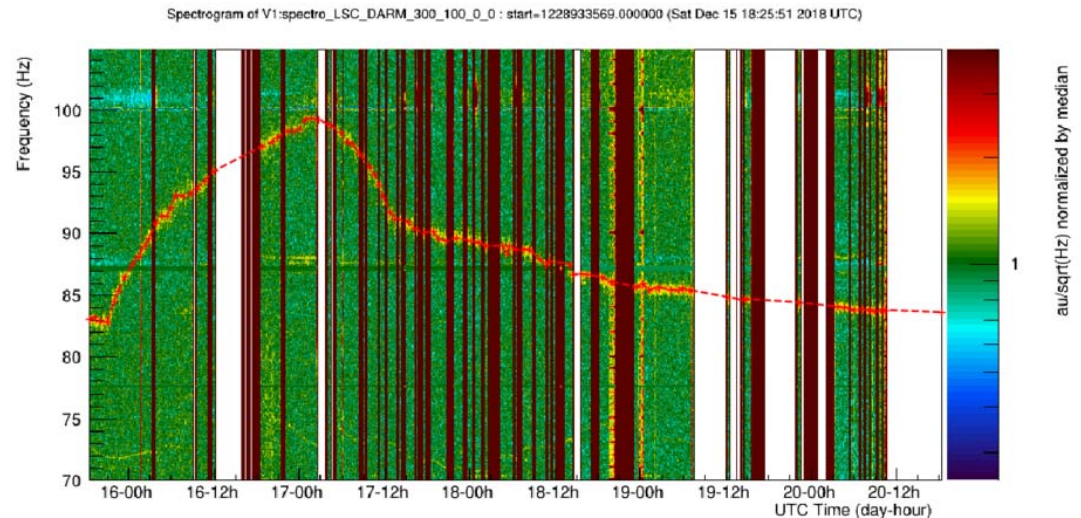
DMS		ITF Mode: Science (0d 3h 19m 50s)				ITF State: LOW_NOISE_3_SQZ (0d 3h 21m 39s)			
Injection	SIB1_IP	SIB1_BENCH	SIB1_BR	SIB1_Vert	SIB1_TE	SIB1_Guard	SIB1_Electr		
	MC_IP	MC_PAY	MC_BR	MC_Vert	MC_TE	MC_Guard	MC_Electr		
	Laser	LaserAmpli	LaserChiller	SL_TempController	RFc	LNFS	PC		
	MC_Power	PSTAB	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	DetectorSEnvironment	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	observers	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

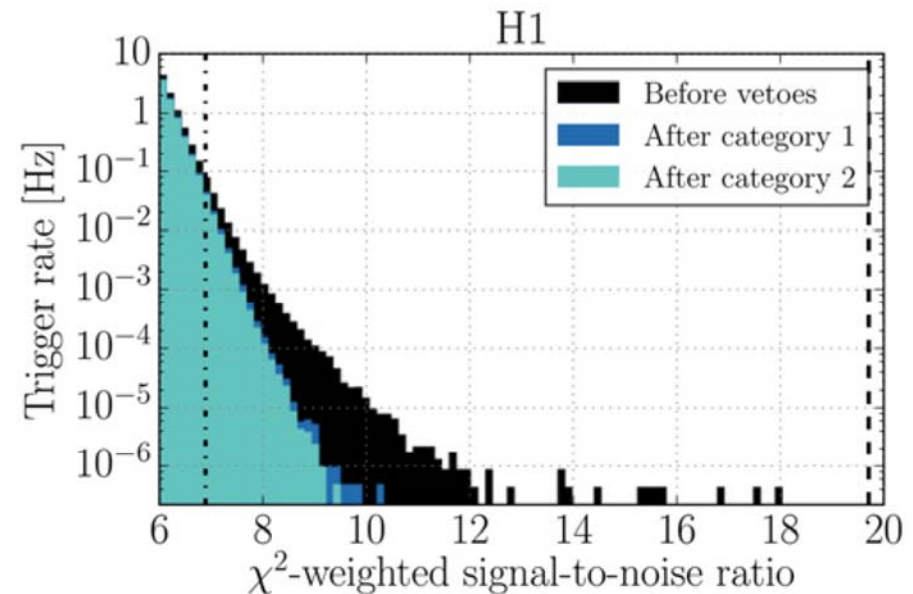
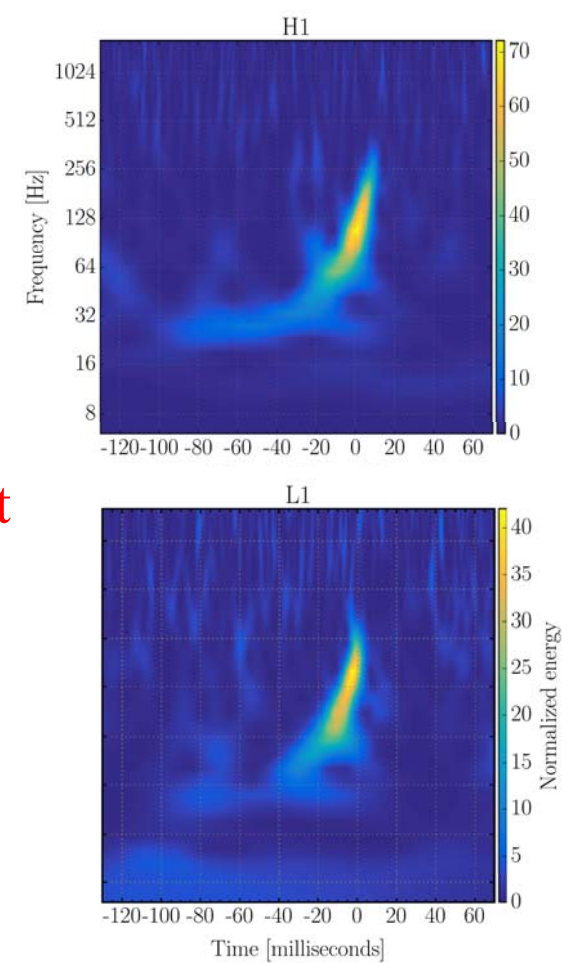
- **Detector monitoring**
- **Detector noise characterization**
  - **Transient and spectral**
  - **Noise evolution: it is not stationary!**
- **Several partners**
  - **Commissioning & noise hunting**
    - **Data quality analysis**
  - **Search groups**
    - **Data quality information**
    - **Veto**s: 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

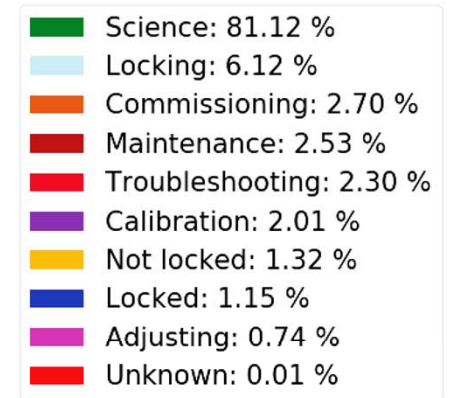
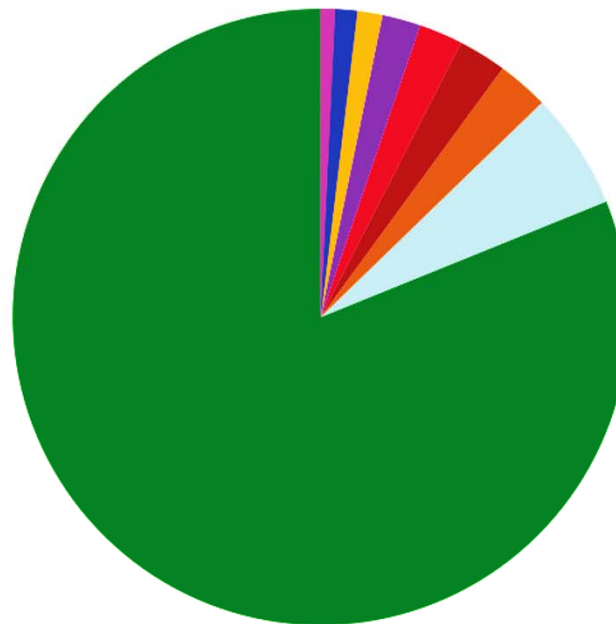
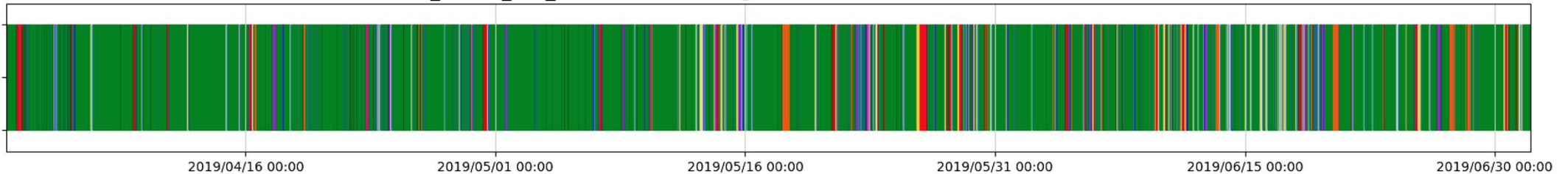
- **GW150914**: first direct detection of gravitational waves
  - **Data recorded**: September 15th, 2015
  - **Announcement**: February 11th, 2016→ 5 month-work to acquire enough confidence that this event was a real binary black merger of astrophysical origin
- **DetChar companion paper** to go along 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**

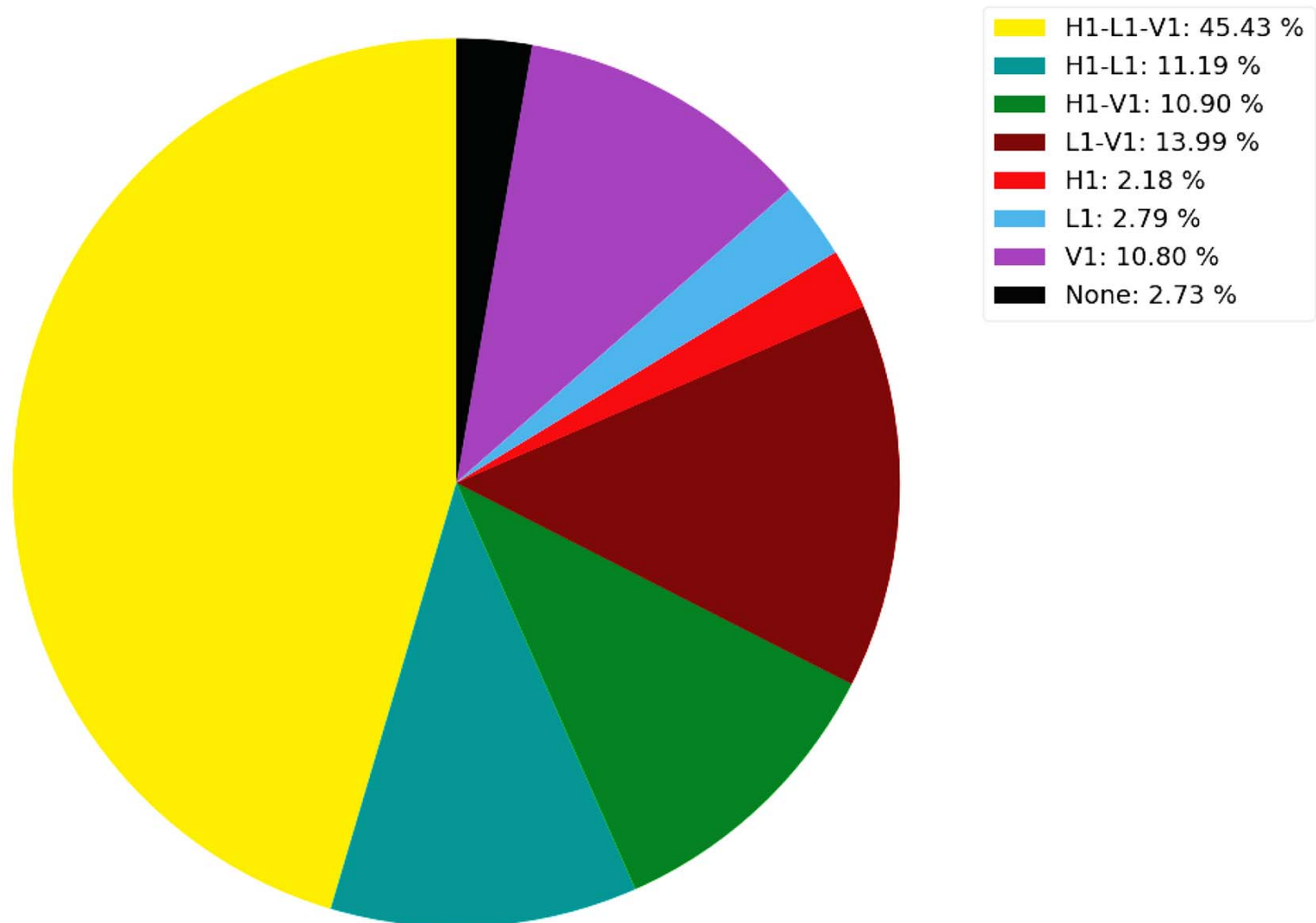
Status of channel V1:DQ\_META\_ITF\_Mode -- time range: 2019/04/01 15:00:00 UTC -> 2019/07/02 03:30:02 UTC



# 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)





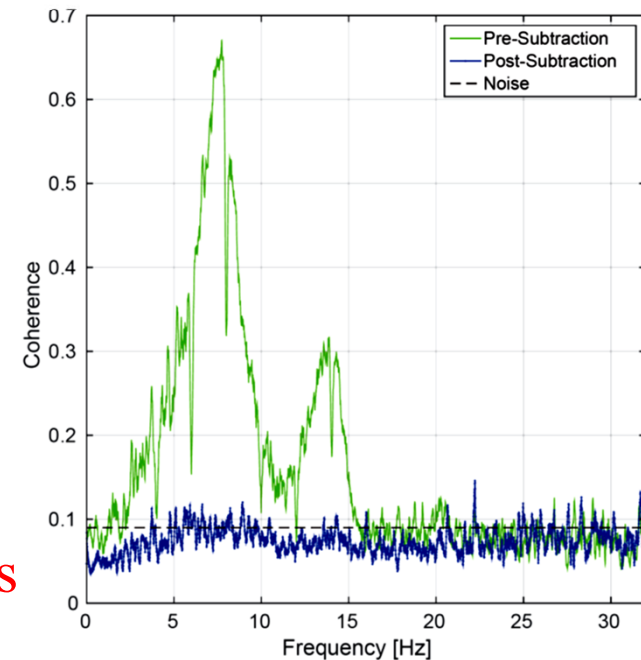
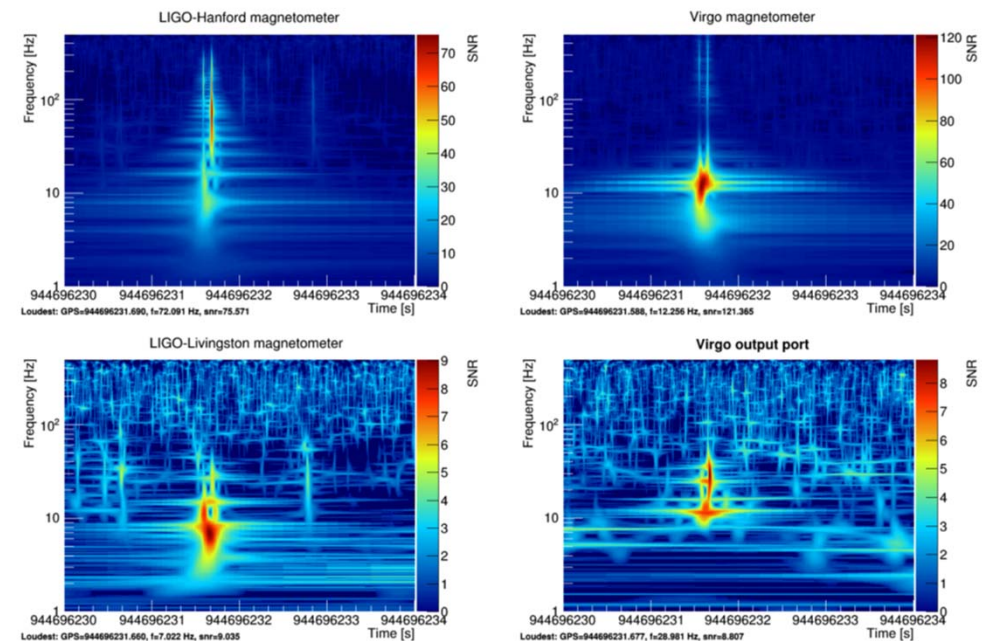
# Schumann resonances

- 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.

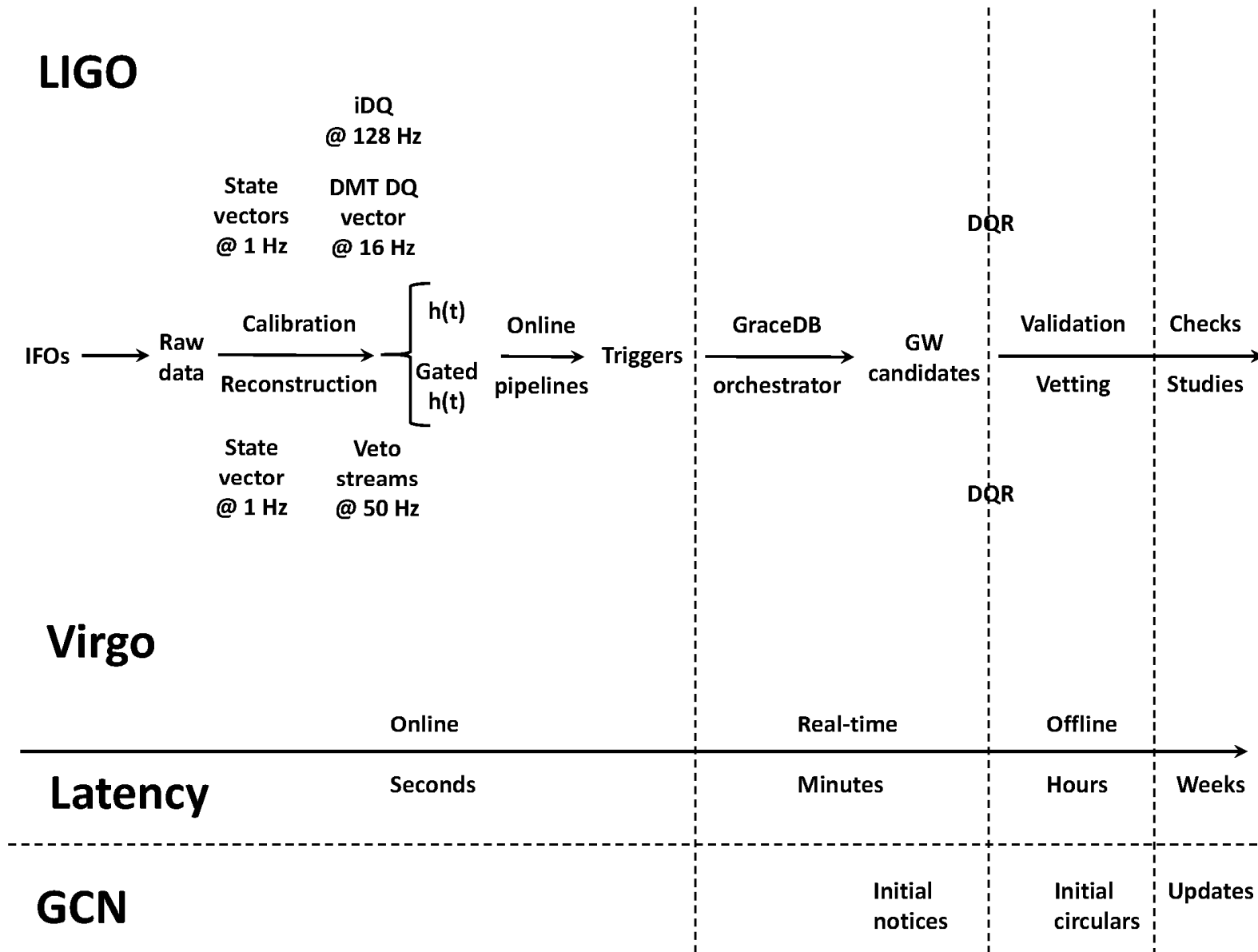
# Open data releases

- [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

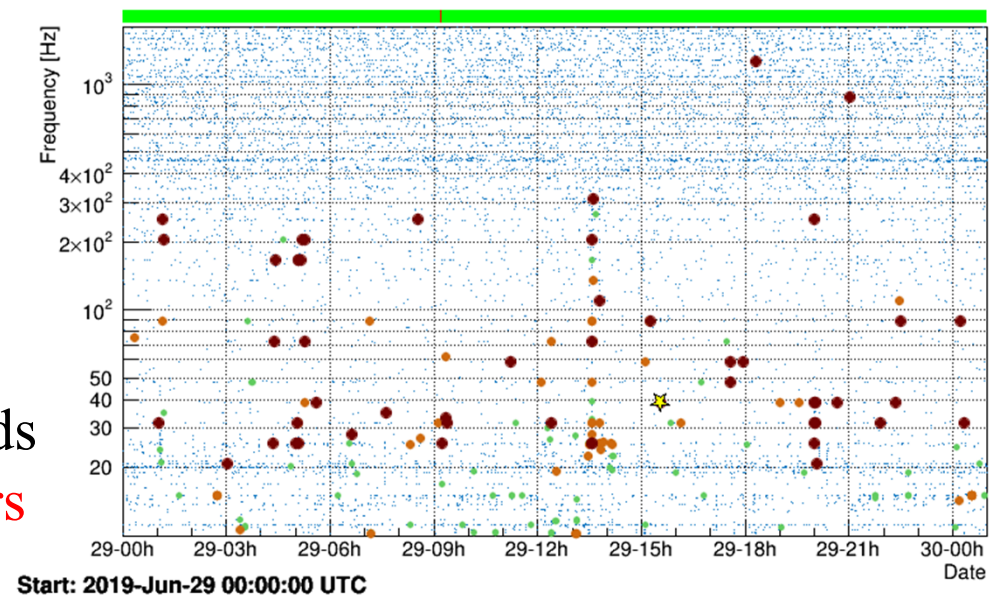
# Glitches

- **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](#)

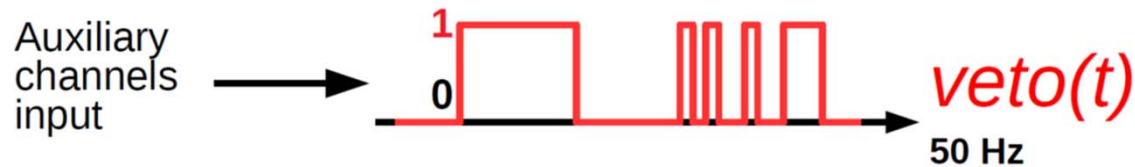
- Two main channels
  - **$h(t)$**
  - **DARM**
- **Analysis window**
  - **Gating + windowing** applied on both ends
  - Only **central part** used to produce **triggers**
  - **Overlap** between analysis windows

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

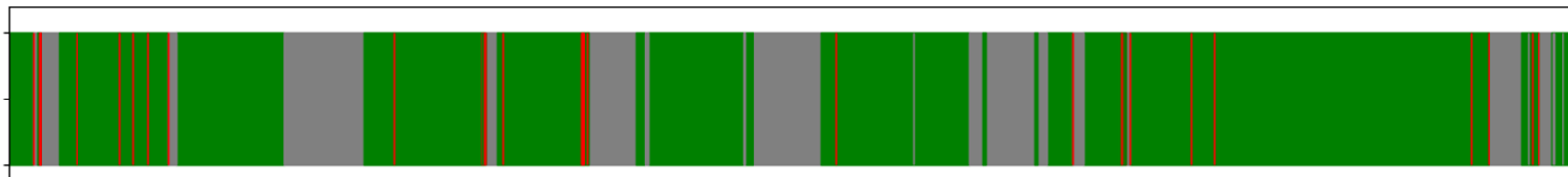
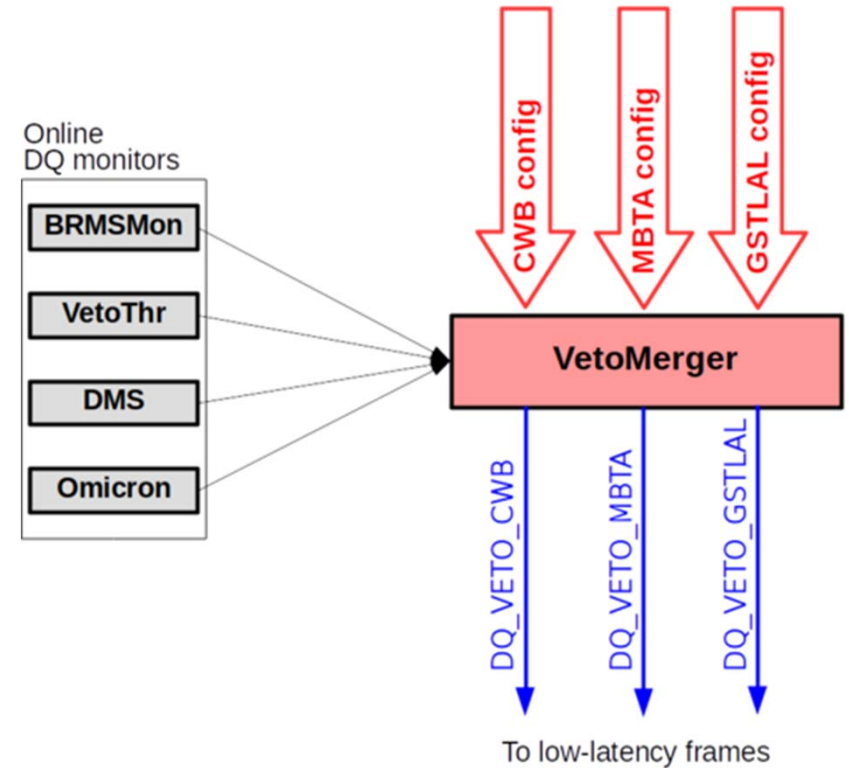


- Inputs: all data quality flags available online
- One stream per pipeline
  - ◆ Pipeline-specific configurations

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

...

$\longrightarrow$  Being tested on live data



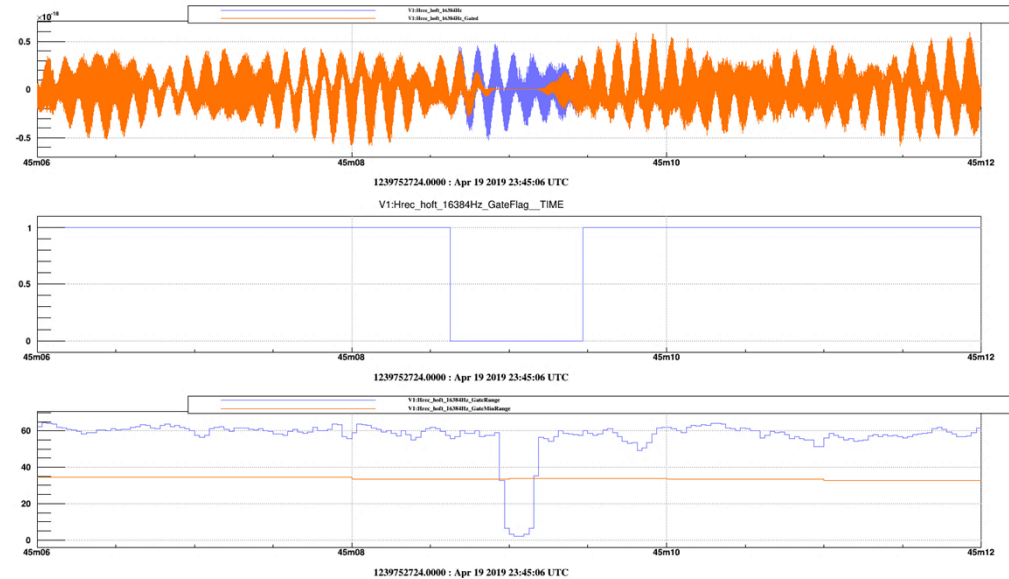
Not in Science:  
24.231% [1d:16h:42m:28s]  
 In Science, no veto:  
75.756% [5d:7h:16m:11s]  
 In Science, veto:  
0.013% [0d:0h:1m:21s]

DQ\_VETO\_PYCBC

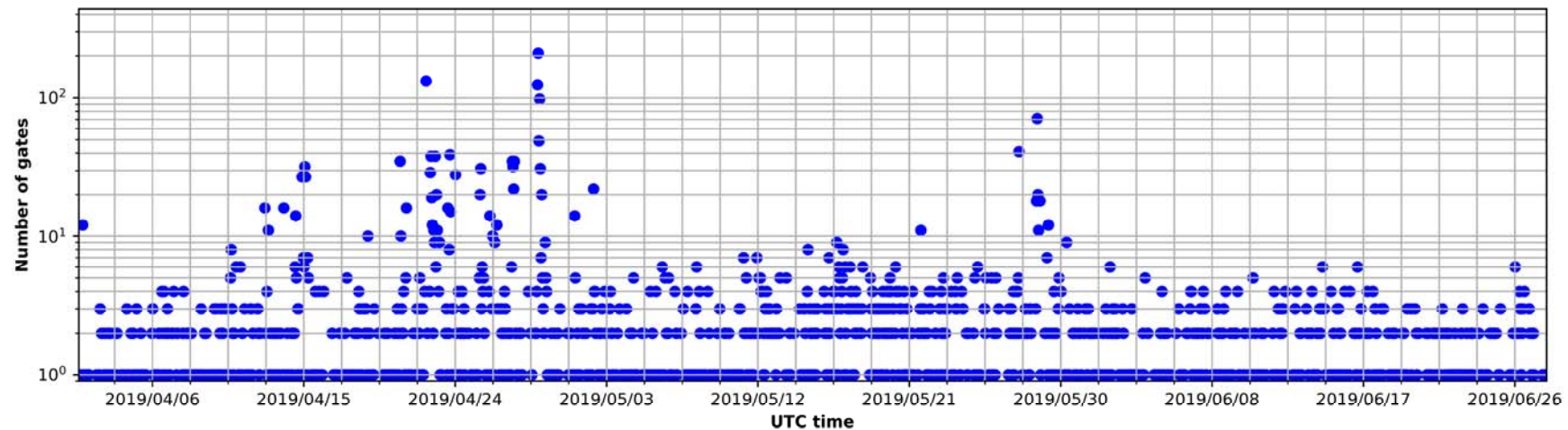


# Gated $h(t)$

- 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

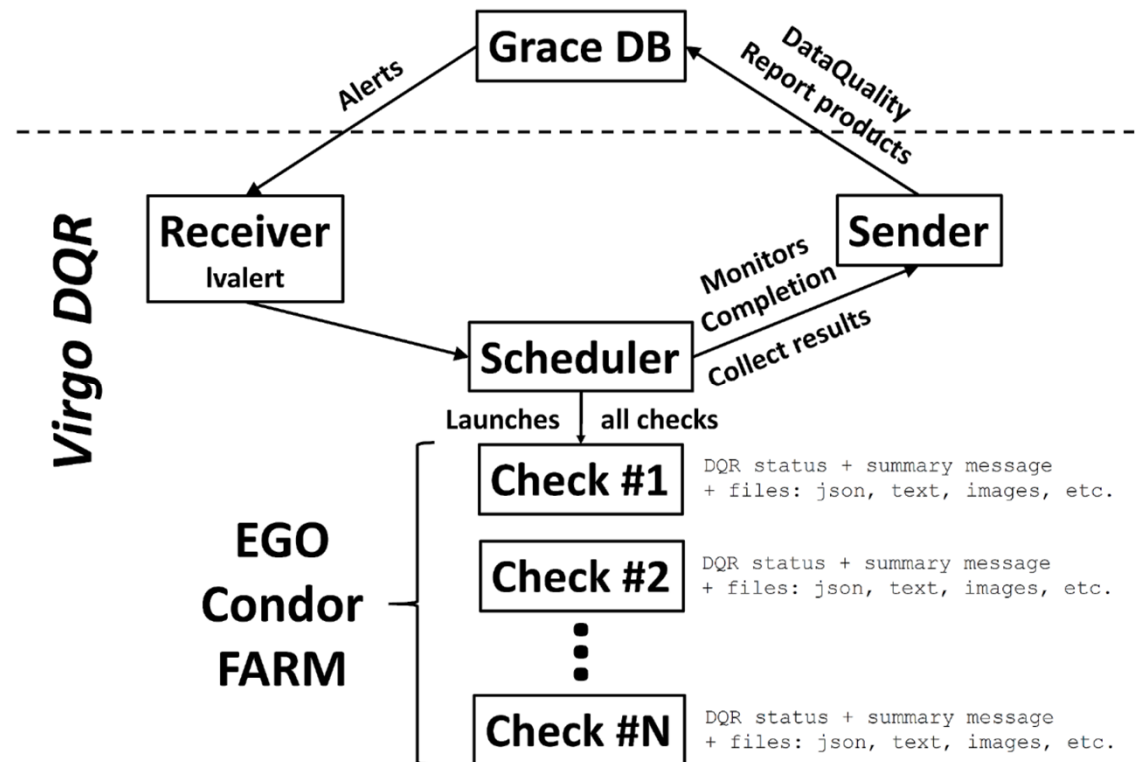


→ Promising to help identifying hopefully short but quite pathological data segments



# 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 0.05 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 Observed in O2	Calibration	
<a href="#">12.5</a>	<a href="#">O2</a>	0.1	Stationary	CALnoise PR_MIR_perline0 Observed in O2	Calibration	
<a href="#">16.3</a>	<a href="#">O2</a>	0.1	Stationary	CALnoise BS_MAR_permline0 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 Observed in O2	Mechanical mode	
<a href="#">24.6</a>	<a href="#">O2</a>	0	Stationary	DAQ room air conditioner (elog 38709). 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