

Run coordinator report

Nicolas Arnaud (nicolas.arnaud@ijclab.in2p3.fr)

Laboratoire de Physique des Deux Infinis Irène Joliot-Curie
(Université Paris-Saclay & CNRS/IN2P3)
European Gravitational Observatory

STAC @ EGO

Open session – May 28th, 2024

VIR-0448A-24



Outline

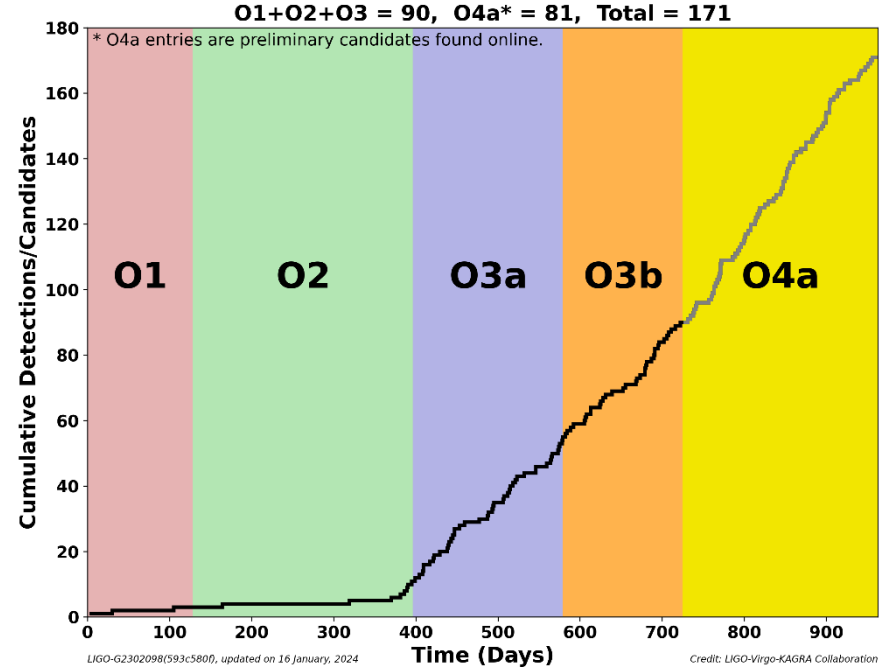
- From O4a to O4b
 - Preparing a 3-detector 10+ months joint data taking period
 - O4b Virgo performance
 - Individual detector
 - Inside the LVK network
 - Public alerts
 - Lessons learned since the beginning of O4b
 - Updates from working groups
 - Calibration, Computing, DetChar, Low-latency, Open data, Rapid Response Team
 - EGO operations team
 - Outlook
-
- Dual O4b coordination
 - Run coordinator
 - Commissioning coordinator

} Smooth management: regular interactions
and quick info transmission both ways

→ More / complementary info in Michal Was' talk, immediately following mine

O4a: 1-slide summary

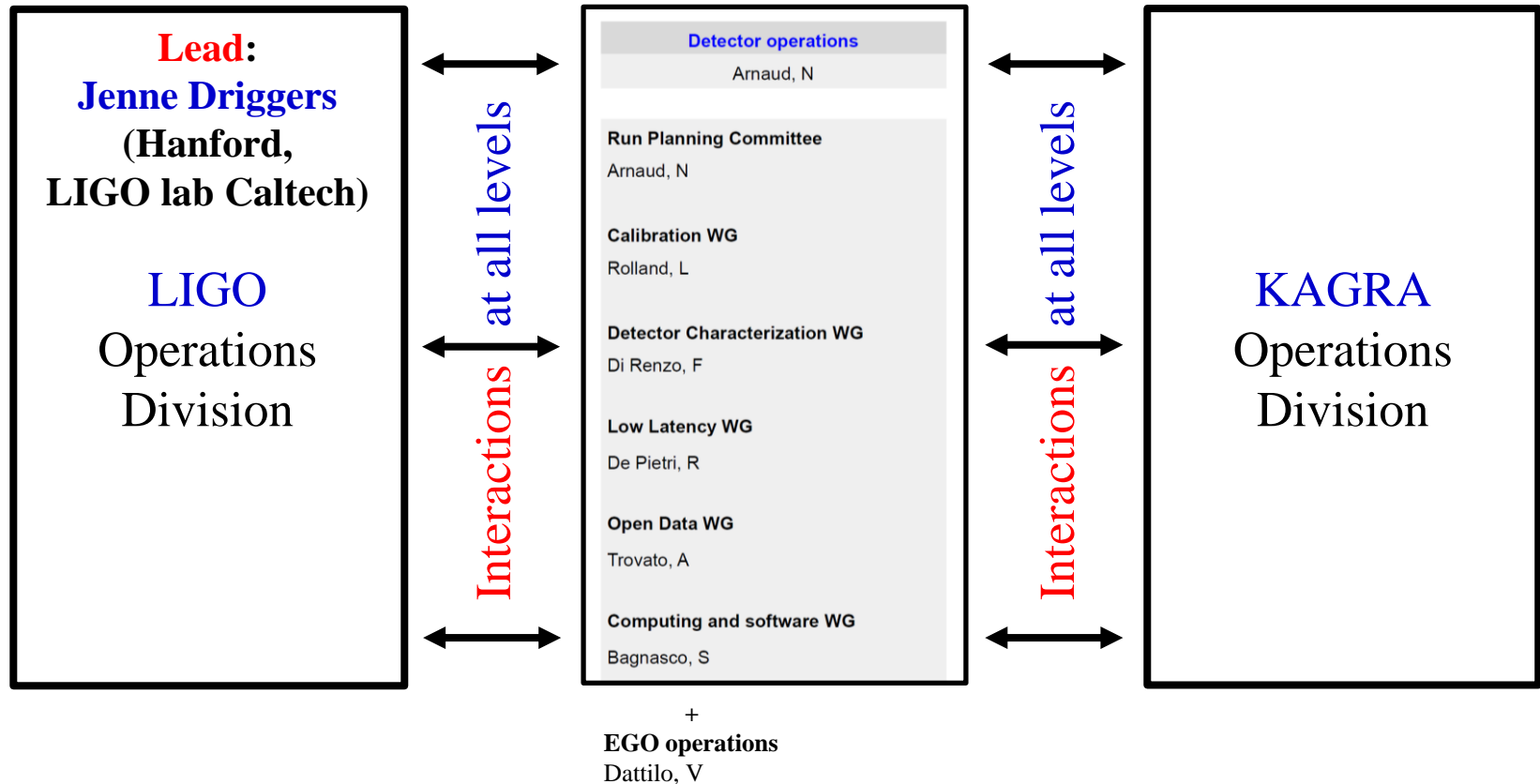
- O4a public alerts: **81**
 - 11 other triggers retracted
- Virgo not part of the run
 - No Virgo data by default
- But **Virgo could be nominally controlled at the time of a LIGO trigger**
 - Policy defined for the use of Virgo data, if requested by data analysts
 - ♦ **Relevant** for O4a offline analysis
- **Virgo contributions**
 - **Rapid Response Team (RRT)**: 1 8-hour shift / day in European TZ (~100% Virgo)
 - ♦ Smooth rota for Virgo
 - ♦ Groups who were not part of RRT during O4a are committed to in **O4b**
 - Computing
 - Low-latency alert infrastructure and analysis pipelines
 - O4a event validation – jointly with LIGO
 - And **data analysis working groups** of course!



Run coordination: from Virgo to LVK

Joint LVK Rapid-Response Team (RRT)

*Caveat: no such
formal organization
in Virgo Bylaws (yet)*



Run coordination: from Virgo to LVK

- Virgo run coordinator acts as **liaison to the (LK) Operations division(s)**
 - **4 site advocates**
 - LIGO Hanford: **Jenne Driggers**
 - KAGRA: **Takahiro Sawada**
 - LIGO Livingston: **Brian O'Reilly**
 - Virgo: **NA**
 - **3 lead site advocates**, each on duty 1/3rd of the time (alternating every other week)
 - **Jenne, Brian and NA** (+ backups from Virgo) – not **Takahiro**
 - **Rapid Response Team**
 - **3-tier system: Lv0 (on shift) → Lv1 (experts) → Lv2 (full team)**
 - **Coordination** shared by **geographical regions** [\leftrightarrow **by collaborations** in practice]
 - ♦ **Europe** (+ Africa): **Francesco DR** for **Virgo: 1/3rd of the time** since **O4a**
 - ♦ **Asia/Pacific: KAGRA**
 - ♦ **Americas: LIGO**
 - **LVK Organization**
 - **Weekly Operations meeting**
 - **Weekly site advocates meeting**
 - **Monthly joint coordinator meeting with RRT**
 - **Monthly joint coordinator meeting with data analysis and RRT**

}

[Open]

[Closed]
- Many **working group meetings**, **LVK mailing lists** and **chat channels**

Virgo O4b readiness

- 24/7 coverage in the control room
 - Crew of seven EGO operators – minimum of five needed for one such rota
 - On-call experts provided by Virgo subsystems and Virgo working groups
- Joint low-latency alert infrastructure and online pipelines ready
 - Three such pipelines with significant Virgo contributions
 - Infrastructure work personpower-limited
- Computing
 - All data transfers (from and to EGO) running fine
 - ♦ Virgo low-latency h(t) production and transfer critical: direct interface with LIGO
 - Production software frozen – limited improvements and developments as needed
- Improved calibration and h-reconstruction
 - Uncertainties reduced and better estimated, bias controlled
 - Better noise subtraction methods
 - Newtonian calibrators are complementing the photon calibrators
- Detector Characterization
 - Online data quality + Data Quality Report framework to vet low-latency events
 - Software tools and inputs from Virgo subsystems (channel lists)

O4b Planning

- Virgo to join O4b alongside LIGO from day 1 of this data-taking period
- O4b was scheduled to start on Wed. April 3rd
 - Delayed by a week: internet outage at LIGO Hanford on 05-07 April
→ O4b has started on Wed. April 10th at 1500 UTC
- Preceded by Engineering Run ER16
 - March 20th → April 10th (April 3rd originally)
→ Three weeks for final tuning
 - ♦ ↘ detector work (sensitivity + stability)
↗ data taking
 - ♦ Low-latency pipelines need time to shape their backgrounds
 - Automated public alerts enabled on Wed. April 3rd at 1500 UTC
 - RRT shifts restarted as well at the same time
 - ♦ Virgo TZ RRT planning well-covered for the first few months of O4b
- O4b to last at least 10 months
 - End date TBD, likely not earlier than mid-February 2025
→ Joint LVK discussion for a possible O4b extension of a few months

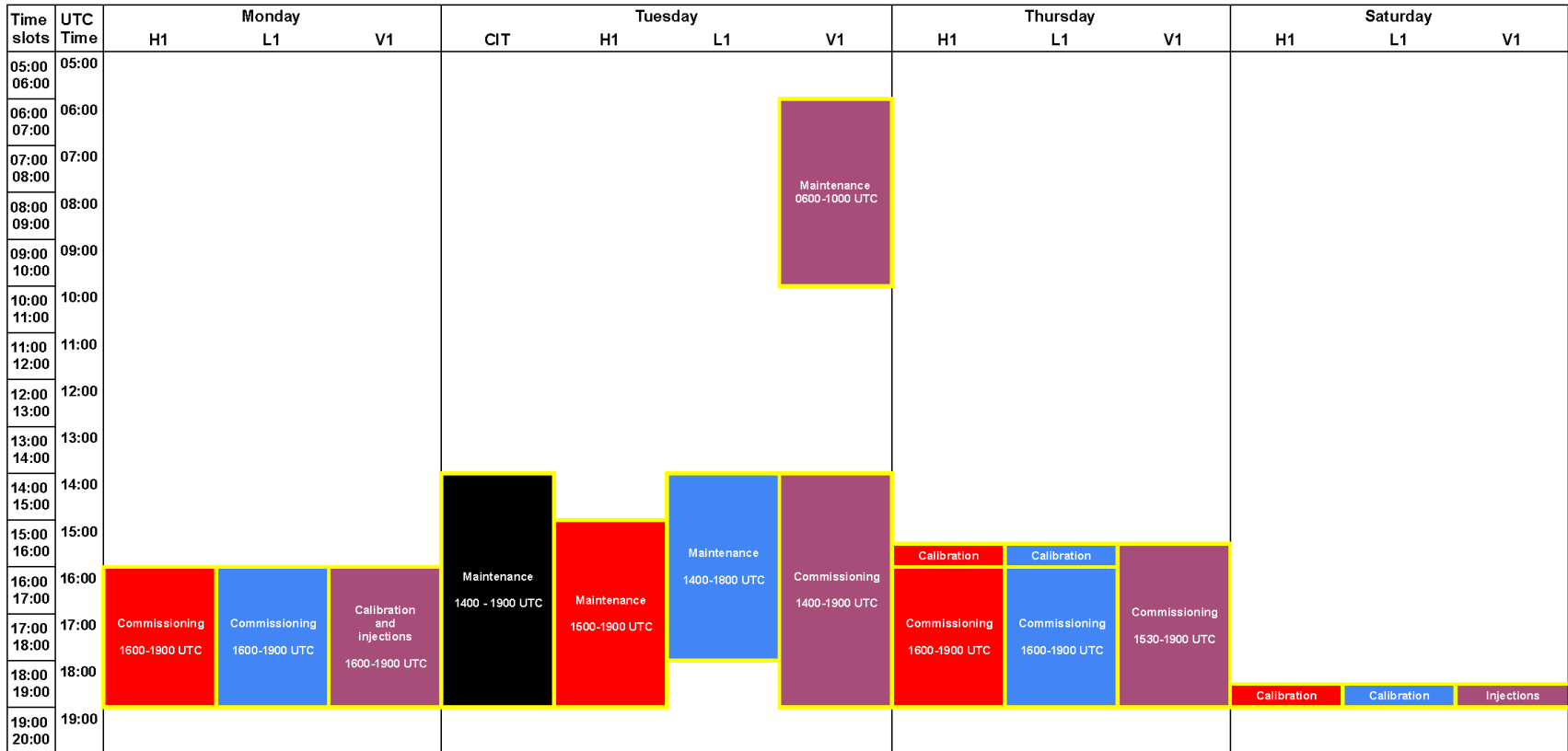
Use of Virgo data

- Virgo data not to be used for triggering in low latency during O4b
 - Sensitivity ratio limits the improvement provided by a third detector
 - 50% more computing resources needed to go from 2 to 3 detectors
- Virgo data will be used in low latency for sky localization of the potential source
 - Using a third detector can significantly reduce the size of the skymaps
 - Virgo data are vet in low latency exactly like the LIGO data
 - ♦ Dedicated Virgo framework ready and fully operational
- O4b overall strategy: maximize 3-detector uptime
 - Requires more, continuous, coordination at the LVK level
 - ♦ In particular, align known, weekly recurring, downtimes – see next slide

LVK planning

CIT
Hanford
Livingston
Virgo

- Downtimes aligned as much as possible among the three detectors
- Priority: 3-detector data taking



Downtimes / week

- **Maintenance:** 4 hours (2.4%)
- **Commissioning:** 8.5 hours max. (5.1%)
- **Calibration:** 3 hours max. (1.8%)
- **Injections:** 0.5 hour max. (0.3%)

→ Up to 10% of duty cycle

EGO operations team

- New member added to the **operators team**
 - **Team of 7 people** needed for a long run
 - Series of **training sessions** organized **for operators**
 - Held by **subsystem and working group experts**
- **Slides and recordings** available on



<https://scientists.virgo-gw.eu/DetectorOperations/trainingssessionsschedule.htm>

- **3 shifts / day** (7:00-15:00, 15:00-23:00 and 23:00-07:00)
7 days / week

→ **Full 24/7 coverage in control room**

- **Support** to experts to configure and tune the **Detector Monitoring System**

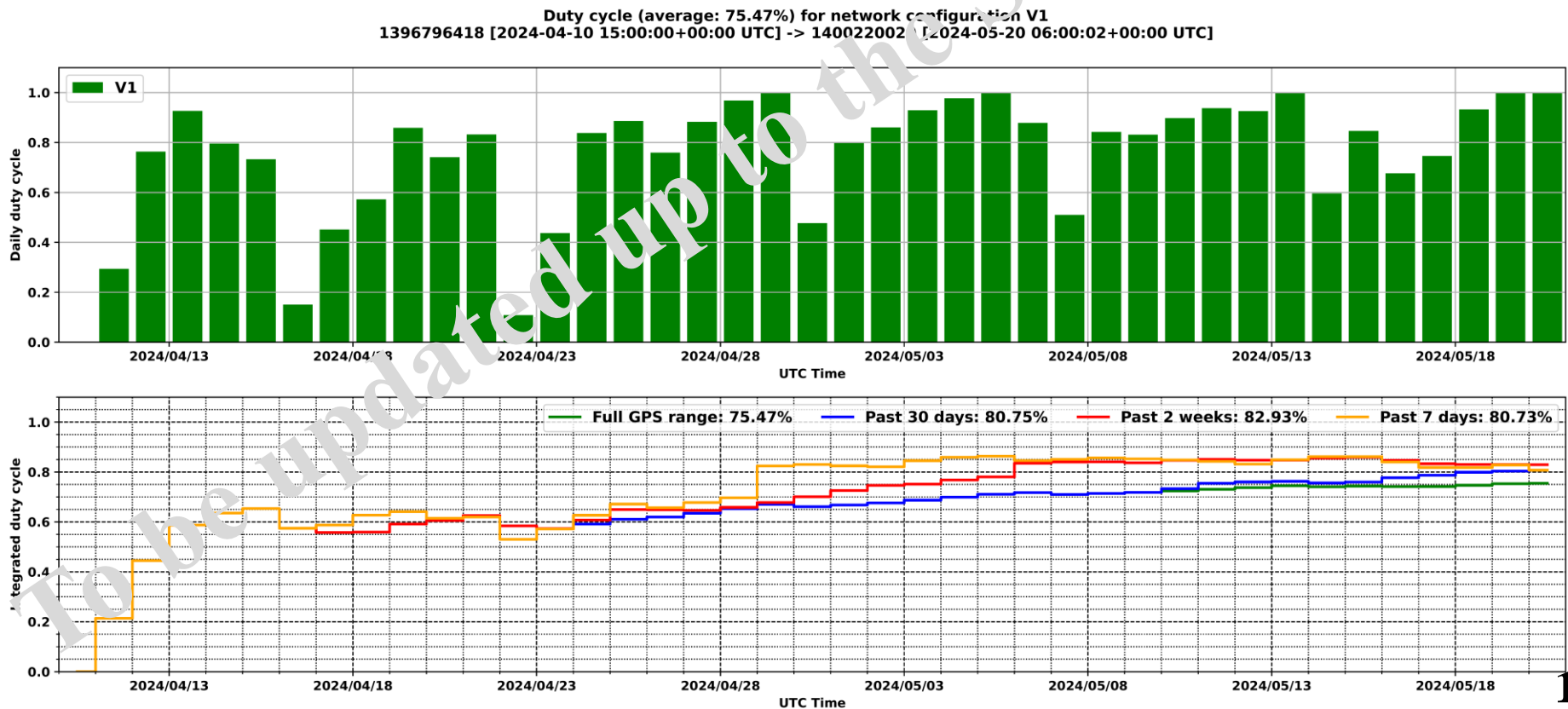
- Re-defined / updated **access rules** to the **technical/experimental areas**

→ VIR-0282A-24

#	DMS	ITF Mode: Prepare_science (old ch 44m 1s)										ITF State: LOCKING_CARM_NULL_3F (old ch 15s)					UTC: 2024-05-20 19:11:48										
Injection	ML		SL		PMC		LaserAmpli			LaserChiller			RFC		LNFS												
	SLC_Ba_MC_Temp		MC_Power		PSTAB		IMC_AA		IMC_AA_GALVO		MC_F0_2		BPC		BPC_Electr												
Detection	PD		PD_RF		QPD_B1p		QPD_B2		QPD_B4		QPD_B5		QPD_RFC		OMC		PicoDisable		Shutter								
ISC	PR_parking/SR_parking		DCP		Etalon		Unlock		UGF		B1p		B4		B7		B8		LSC_rms		ASC_rms		DPH1		ViolinMo		
ALS	NE_ALS_Laser					NE_ALS_ARM					WE_ALS_Laser					WE_ALS_ARM					CEB_ALS_Laser						
Suspensions	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														
	SDB1_IP		SDB1_IC		SDB1_BR		SDB1_Vert		SDB1_TE		SDB1_Guard		SDB1_Electr														
	BS_IP		BS_F7		BS_PAY		BS_BR		BS_Vert		BS_TE		BS_Guard		BS_Electr		BS_TestMass										
	NI_IP		NI_F7		NI_PAY		NI_BR		NI_Vert		NI_TE		NI_Guard		NI_Electr		NI_TestMass										
	NE_IP		NE_F7		NE_PAY		NE_BR		NE_Vert		NE_TE		NE_Guard		NE_Electr		NE_TestMass										
	PR_IP		PR_F7		PR_PAY		PR_BR		PR_Vert		PR_TE		PR_Guard		PR_Electr		PR_TestMass										
	SR_IP		SR_F7		SR_PAY		SR_BR		SR_Vert		SR_TE		SR_Guard		SR_Electr		SR_TestMass										
	WI_IP		WI_F7		WI_PAY		WI_BR		WI_Vert		WI_TE		WI_Guard		WI_Electr		WI_TestMass										
	WE_IP		WE_F7		WE_PAY		WE_BR		WE_Vert		WE_TE		WE_Guard		WE_Electr		WE_TestMass										
Environment	CB_Hall		MC_Hall		TCS_zones		NE_Hall		WE_Hall		WindActivity		Seismon		BRMSMon		QNR		TE_alarmed								
	INJ_Area		DET_Area		EE_Room		DAQ_Room		MeteoStations		DeadChannel		FlatChannel_ENV		Lights		SeaActivity										
Infrastructures	ACS_CB_Hall		ACS_TCS_CHII		ACS_TB		ACS_DAQ_Roo		ACS_FF_Room		ACS_MC		ACS_INJ		ACS_DET		ACS_NE		ACS_WAB		ACS_FCIM						
	UPS_TB		UPS_CB		UPS_MC		UPS_NE		UPS_WE		IPS		FlatChannel		ExistChann		Sensors		ACS_WE		ACS_CB_Cf		ACS_COB		ACS_FCIM		PyHVAC
SBE	EIB		SIB2_SBE		SIB2_IC		SPRB_SBE		SPRB_IC		SDB2_SBE		SDB2_IC		SNEB_SBE		SNEB_IC		SWEB_SBE		SWEB_IC						
	SQB1_SBE		SQB1_IC		SQB2_SBE		SQB2_IC		FCIM_SBE		FCIM_IC		FCIM_SBE		FCIM_IC												
TCS	NE_RH		WE_RH		SR_RH		NI_CO2_Laser		WI_CO2_Laser		NI_AUX_Laser		WI_AUX_Laser		Chrocc_SR		Chrocc_PR		Chillers		TCS_Electr						
QNR	LFC		AFC		QNR_GALVO		QNR_ACTUATORS		QNR_SQZ		PLLs		SQZ_INJ														
Vacuum	LargeValves		Clean_Air		TubeStations		TubePumps		MiniTowers		Turbolinks		SQZ		RemDryPMP		VAC_SERVOS		Tiltmeter								
	Pressure		CompressedAir		TowerServers		TowerPumps		CryoTrap		O2_Sensors		Tank		HLS		Vacuum_LAB										
VPM	Detector/Senviroi		ControlRoom		Minitowers		ISC		Squeezer		Injection		TCS		Suspension		Vacuum		Metatron								
	Detector/Monitori		NewtonNoise		DataCollection		Storage		DataAccess		Automation		DetChar		Calibration		LLDataProd										
DAQ-Computing	Latency		Disk		Timing		Timing_rtpc		Timing_dsp		Fast_DAC		ADCS_TE		Daq_Boxes_TE												
	Domains		DMS_machines		observers		rtpcs		CollSwitchBoxes		INF_devices		ENV_devices		VAC_devices		TCS_devices										
Calib_Hrec	CalNorth		CalWest		CalBS		CalPR		CalSR		PcalNorth		PcalWest		HOFT		HOFT_Bias		NCAL		CalINJ		NoiseInjectio				
DetChar-Ex.Trigger	Hrec_RANGE_BNS					GRB_Alert					SN_Alert																

O4b Virgo status

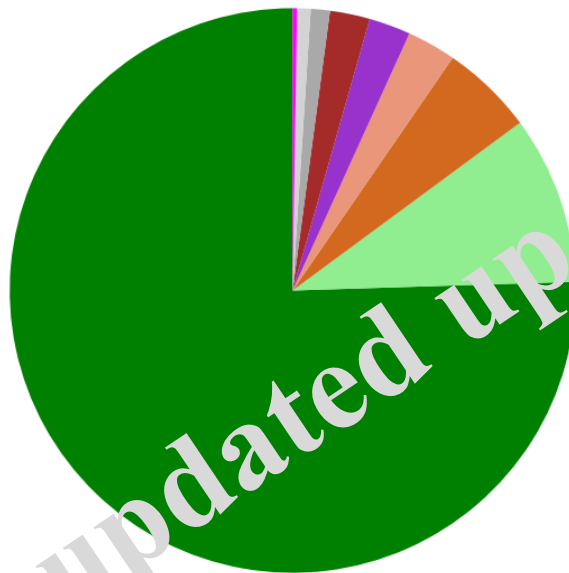
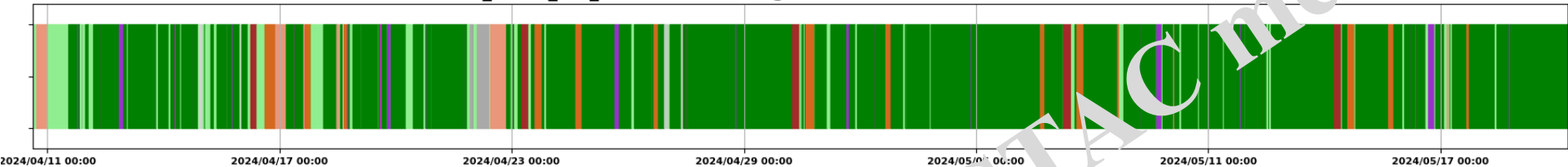
- **Rough start** with a handful of new (and unrelated) hardware problems
 - First two weeks: duty cycle ~60%
 - **All fixed**
- Since then (**five more weeks**): **duty cycle much higher** and still growing in average
 - **No hardware problem**, **continuous monitoring of transient issues**, good weather



O4b Virgo status

- Duty cycle summary

Status of channel V1:DQ_META_ITF_Mode -- time range: 2024/04/10 15:00:00 UTC -> 2024/05/20 06:55:31 UTC



Science:	75.50 %
Prepare science:	9.63 %
Commissioning:	5.29 %
Troubleshooting:	2.80 %
Calibration:	2.38 %
Maintenance:	2.28 %
Bad weather:	1.09 %
Earthquake:	0.77 %
Adjusting:	0.25 %
Unknown:	0.00 %

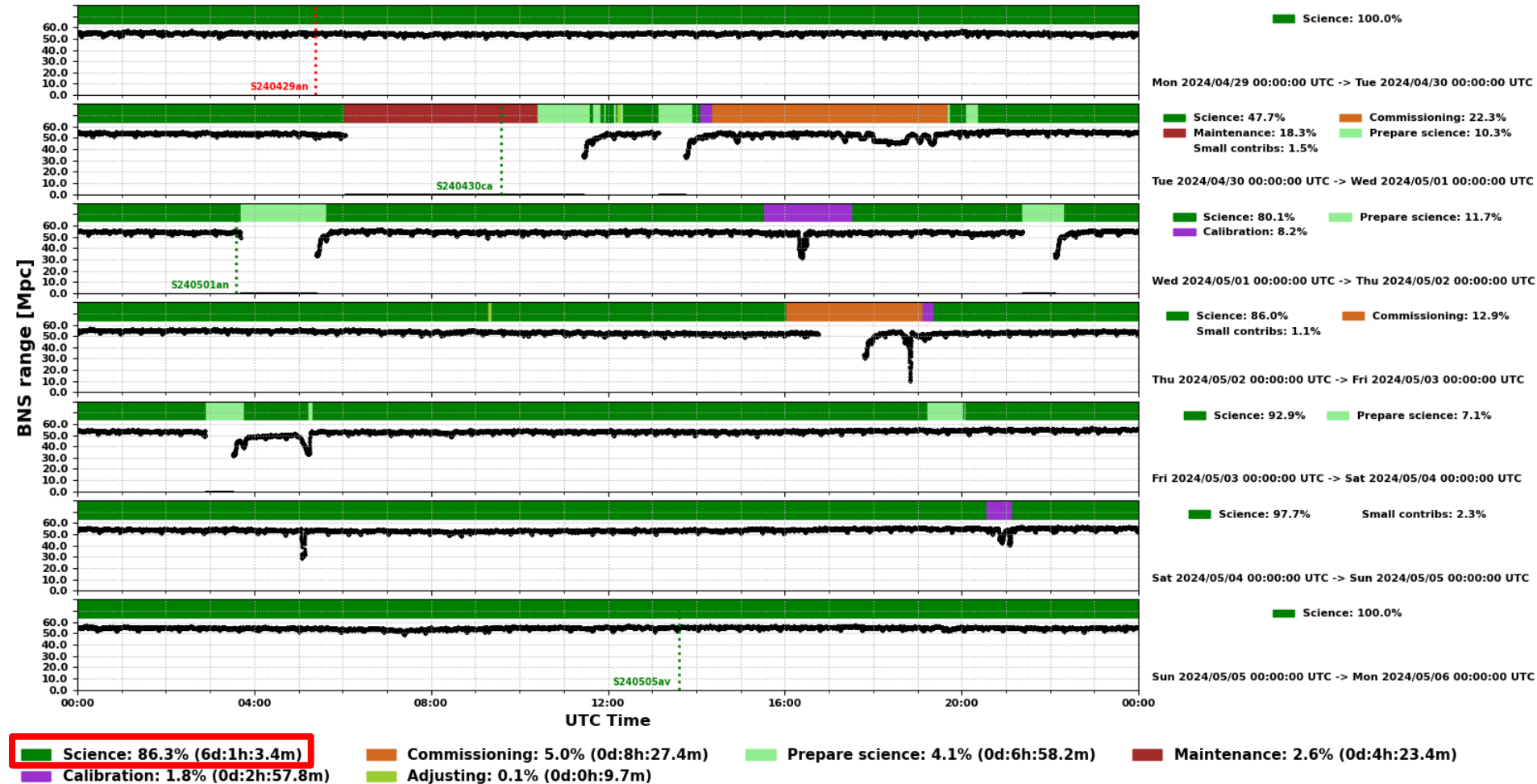
→ Updated list of detector “modes”: improving our automated monitoring

- Added ones: “Prepare Science” (goal: take data), “Bad weather” and “Earthquake”
- Detector states not specific of a given mode have been removed
 - “Locking”, “Locked”: not informative about what the current mode is

Best 7 days in O4b so far

- Monday April 29th → Sunday May 5th

Weekly summary plot: 2024/04/29 00:00:00 UTC -> 2024/05/06 00:00:00 UTC -- S-events: 3 ADVOK, 1 ADVNO



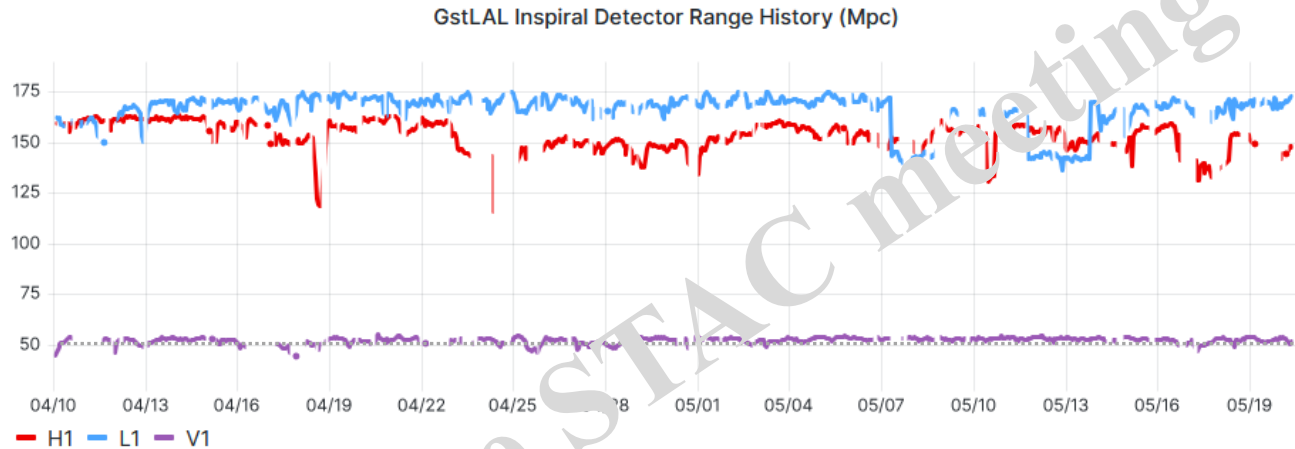
O4b Virgo status

- **BNS range**

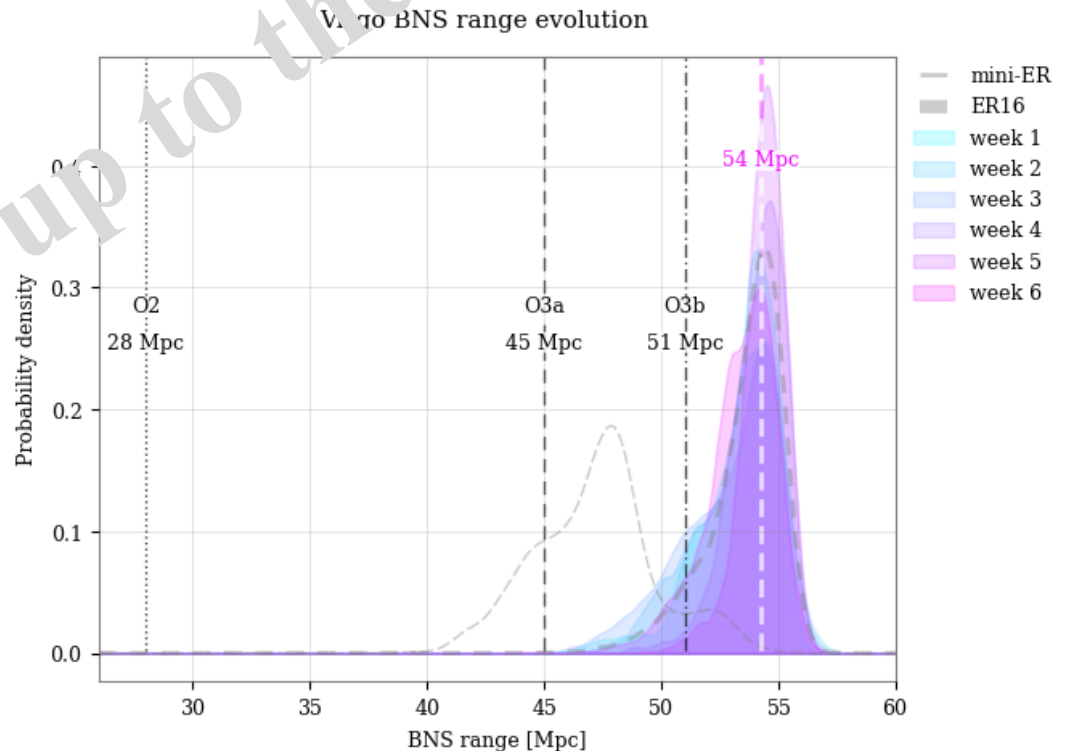
- Data from the new version of gwistat:

<https://online.lgw.org>

[Public website]

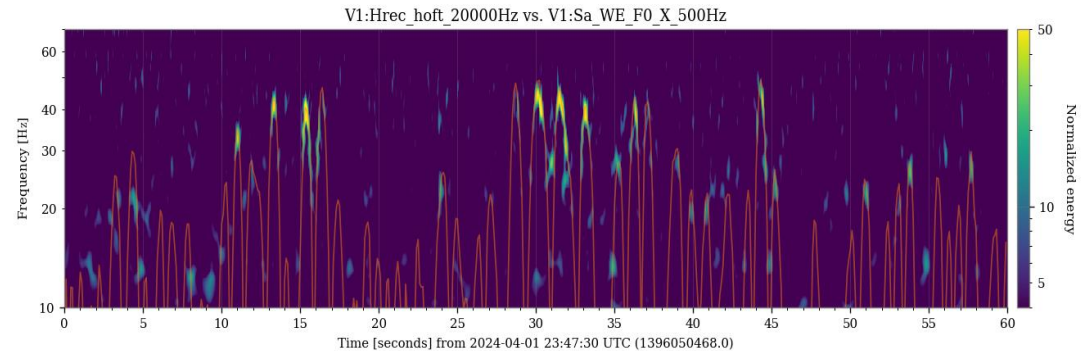
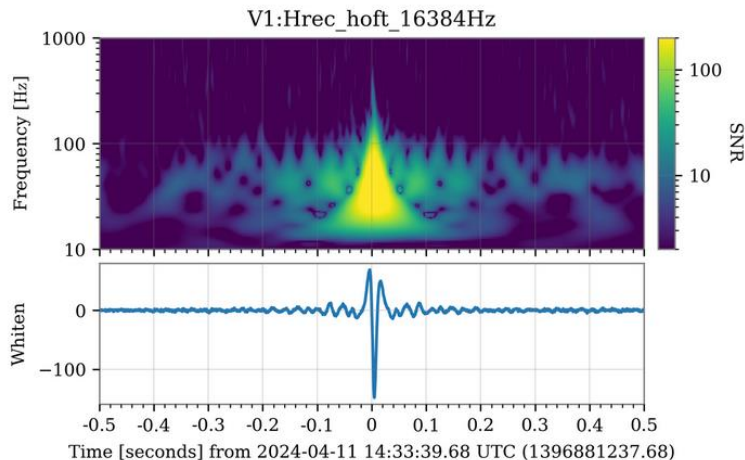
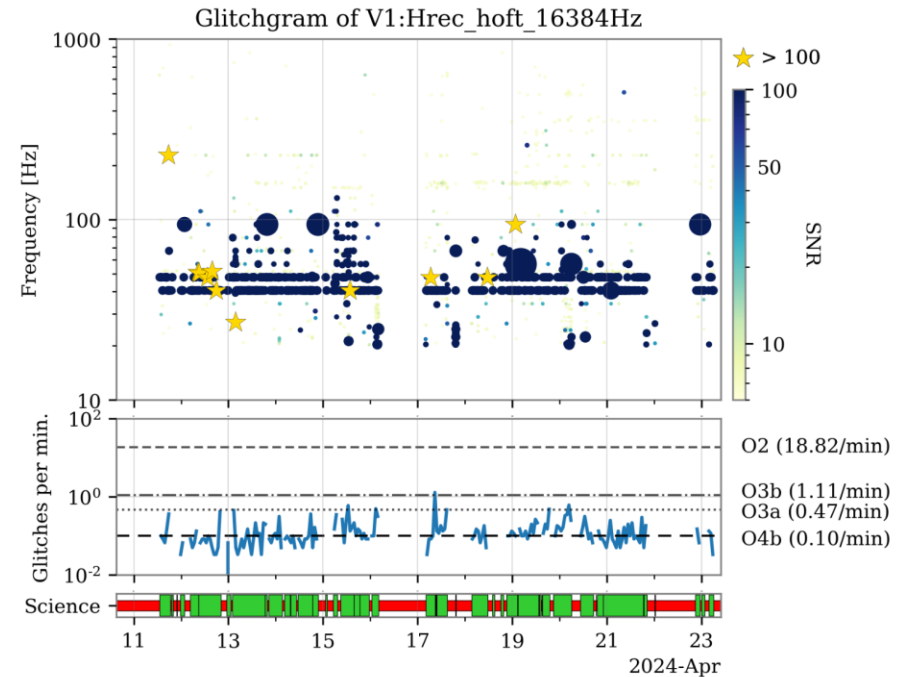


→ Virgo range quite stable between 50 and 55 Mpc



Data quality: transient noises (“glitches”)

- **Reduced glitch rate** compared to O3
→ **0.10/minute** vs **1.11/minute**
- Only two known families of glitches
 - **25-minute glitches**
 - ◆ Impacted Virgo data for a recent event
→ Investigations to continue via a **dedicated taskforce**, now that the start of O4b is behind us
 - **Scattered light**
→ **Only during bad weather**



Data quality: spectral lines

- Spectral lines identification
 - Inputs from different, complementary tools
- O4b Catalog in progress

Channels

Check here to show only subset channels. Showing all channels.

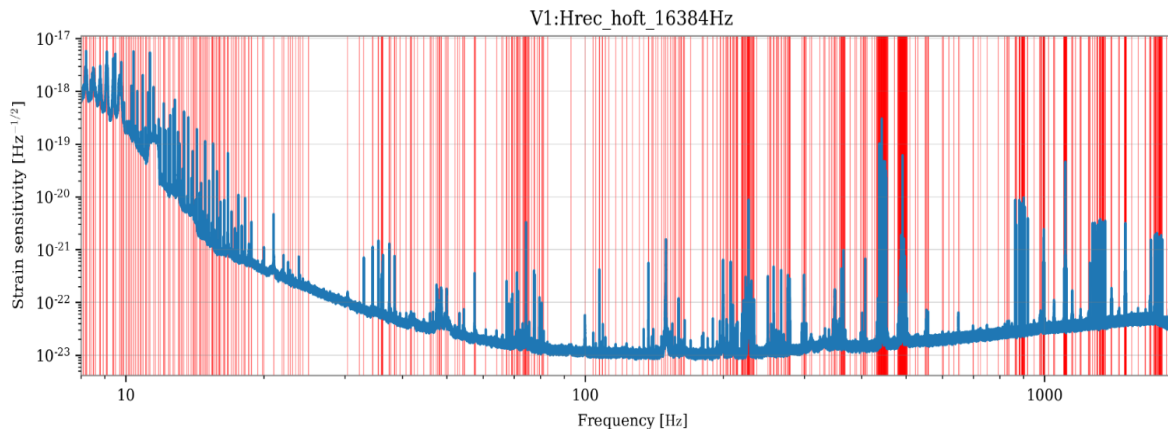
⚠ 'Hidden' channels are those that have been seen in the O4b within the last 30 days.
 ⚠ Filters are case-sensitive. The '*' (asterisk) can be used as a wildcard, while '-' (underscore) characters must be escaped (\) to prevent them being used as wildcards.

Currently showing: 0:000 (of 88143 channels)

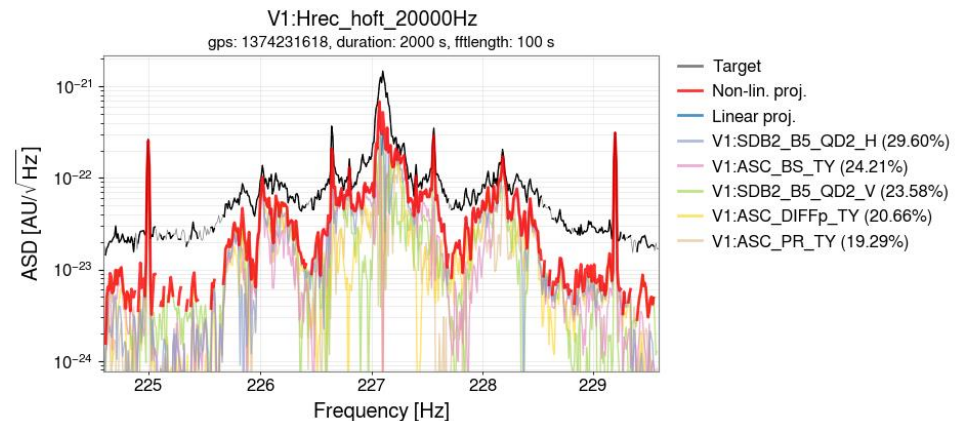
Channel list filter

Clear Filter Channels

Channel name	Sample rate	Units	CPS		Description	History
			First seen	Last seen		
V1:Sa_B5_Qd2_Ch000000	1	COUNTS	130074910	1120834790	00: Ring suspension lower containing the beam-splitter wire	
V1:Sa_B5_Qd2_g_0000	10000		130074910	1120834790	00: Ring suspension lower containing the beam-splitter wire	



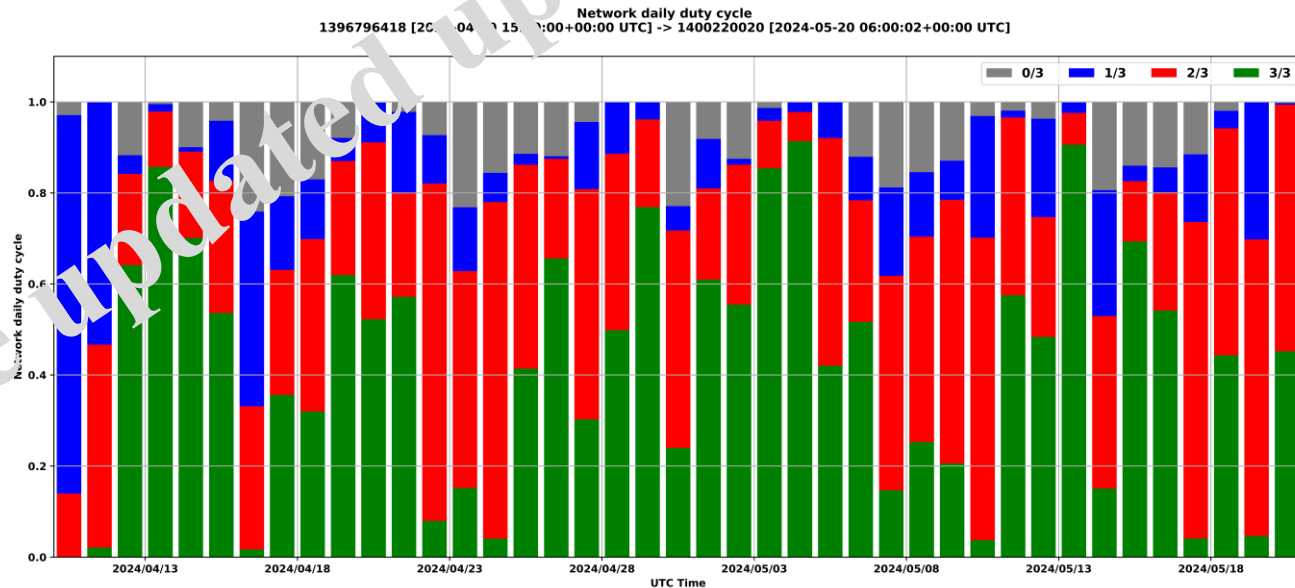
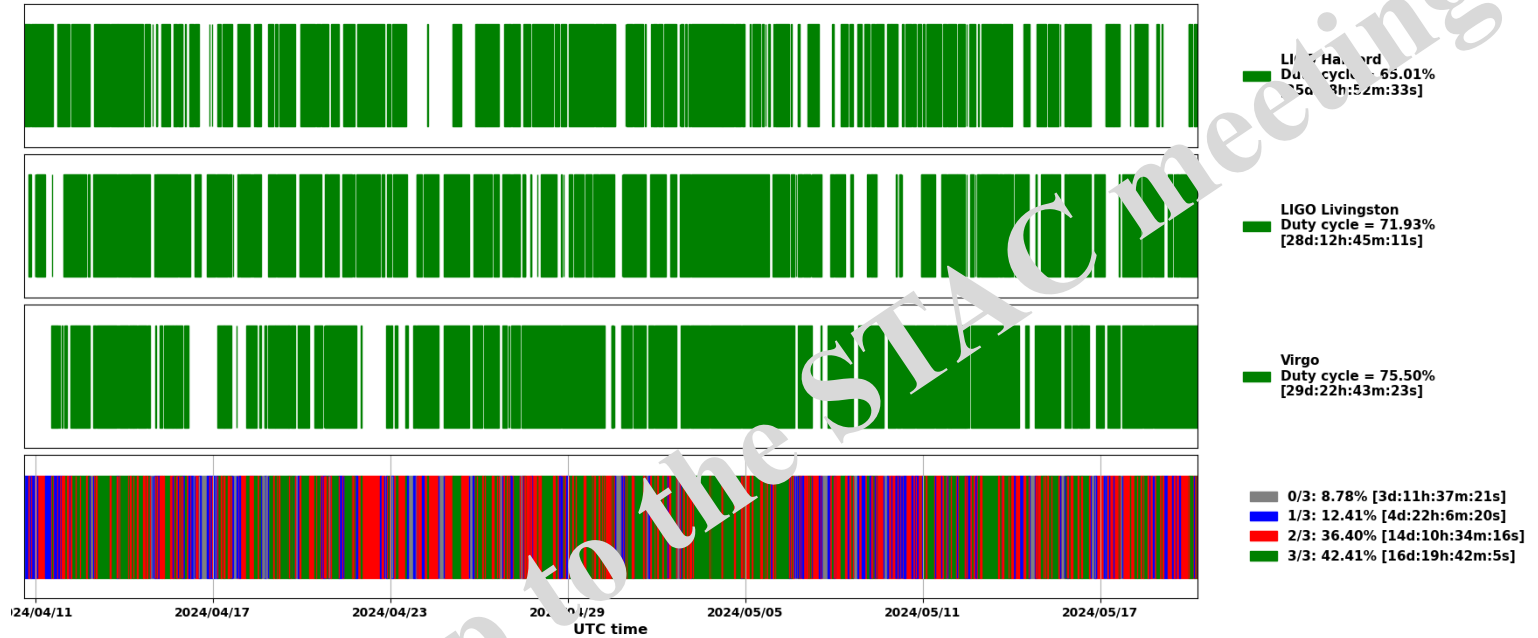
- Characterization of bilinear noise
 - Sidebands



O4b LVK network

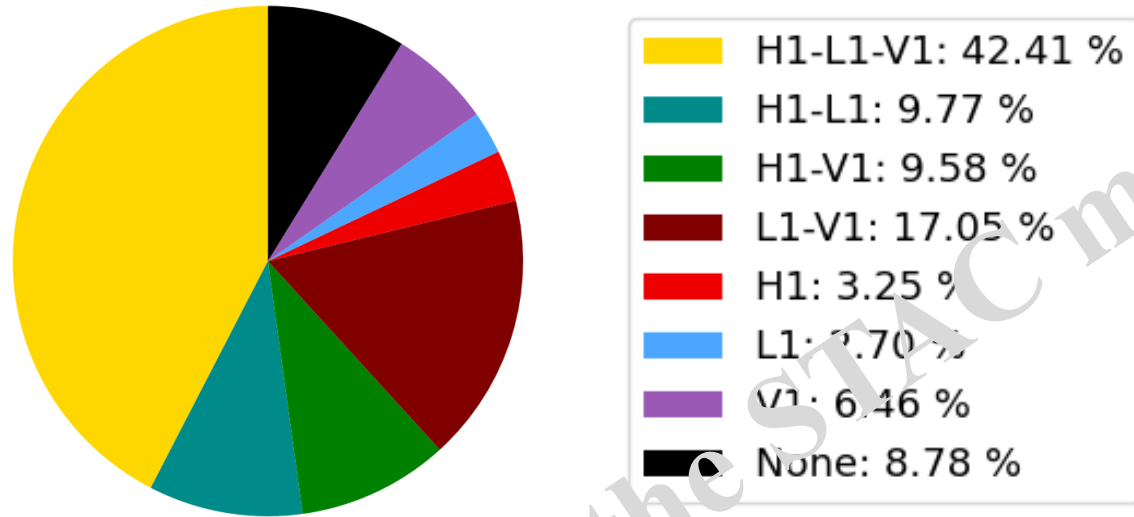
H1-L1-V1 network: 2024-04-10 15:00:00+00:00 UTC -> 2024-05-20 07:00:02+00:00 UTC -- science segments

- Duty cycle

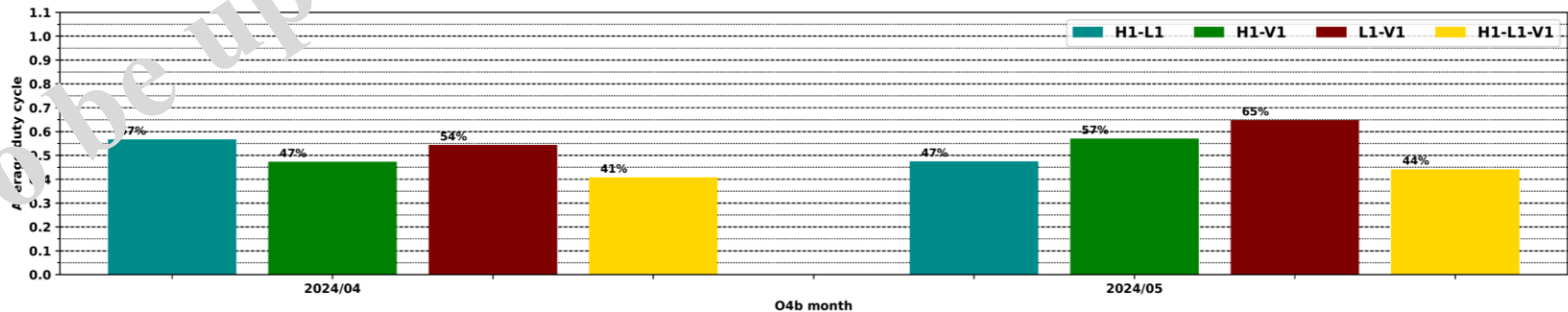
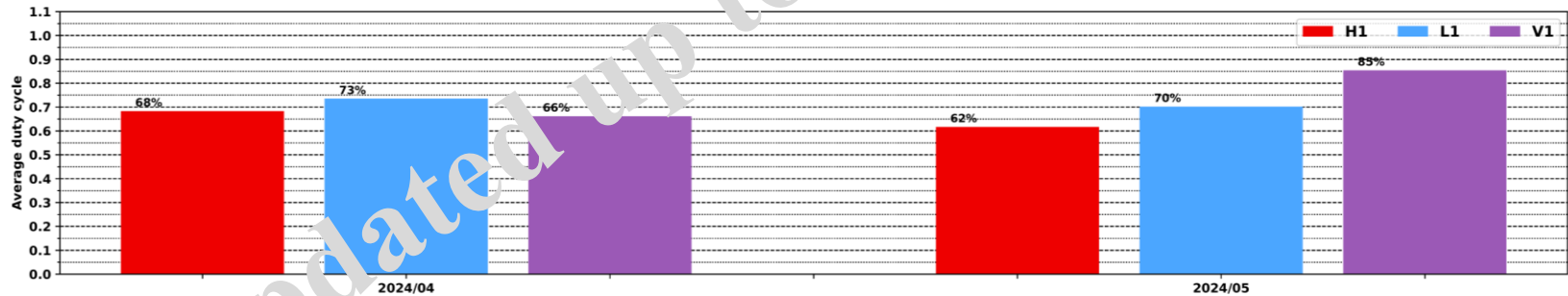


O4b LVK network

- Duty cycle

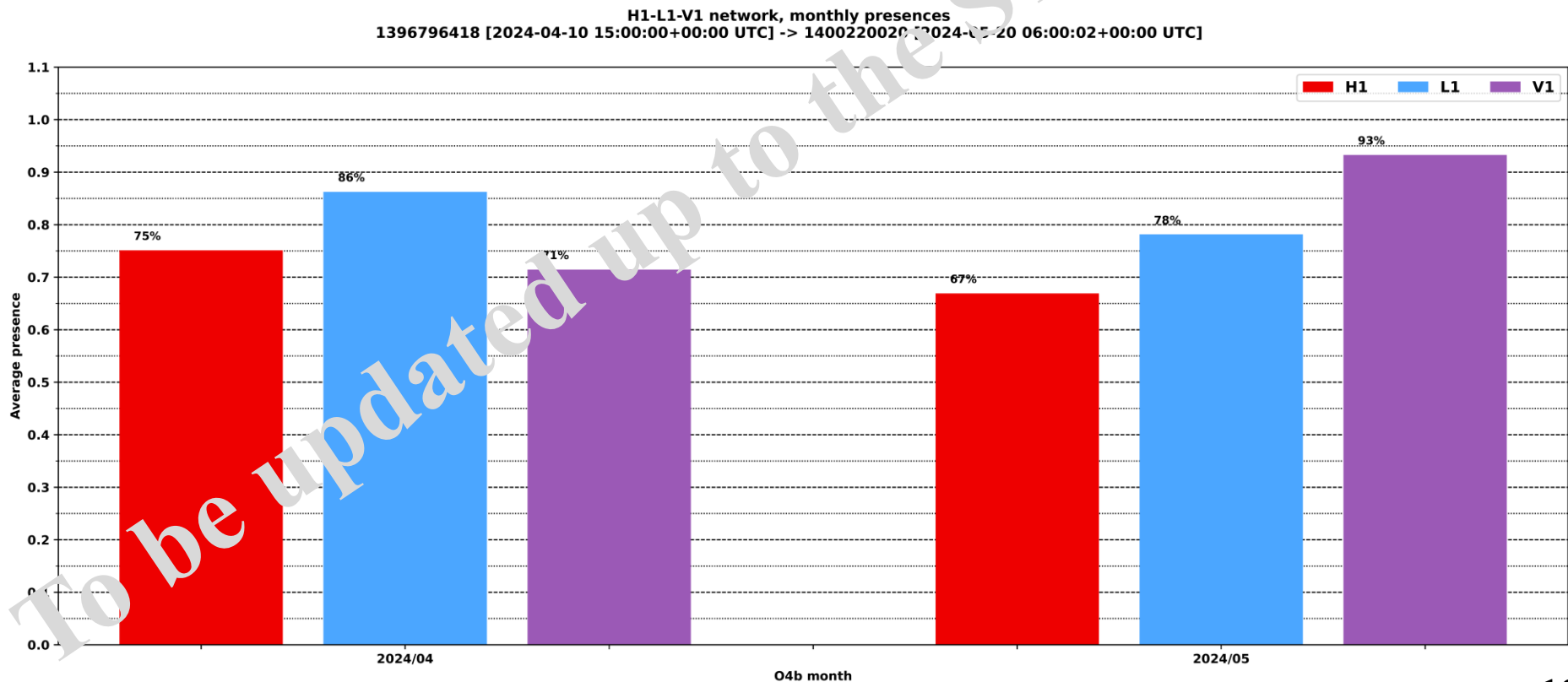


Monthly duty cycles
1396796418 [2024-04-10 15:00:00+00:00 UTC] - 1400220020 [2024-05-20 06:00:02+00:00 UTC]



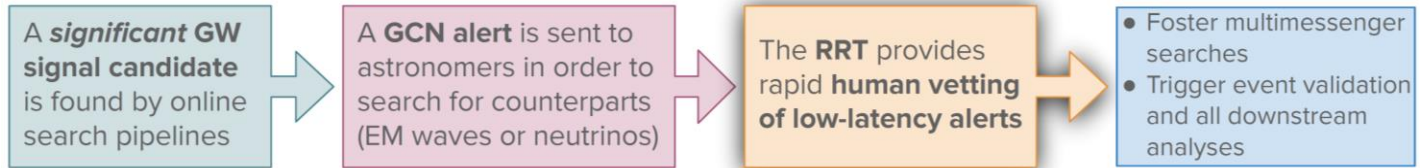
O4b LVK network

- “Presence” of a detector
 - (3-instrument duty cycle) / (2-instrument network w/o that detector duty cycle)
 - The higher the better
 - Reflects both the (good) performance of that detector and the (bad) performance of the other two instruments



Public alerts

- **Low-latency alert workflow**

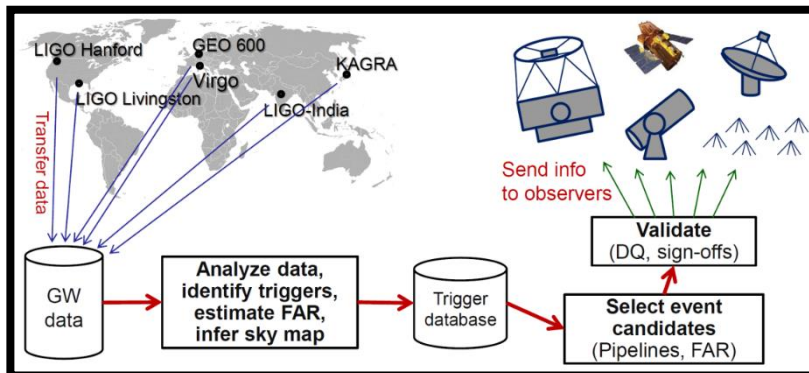
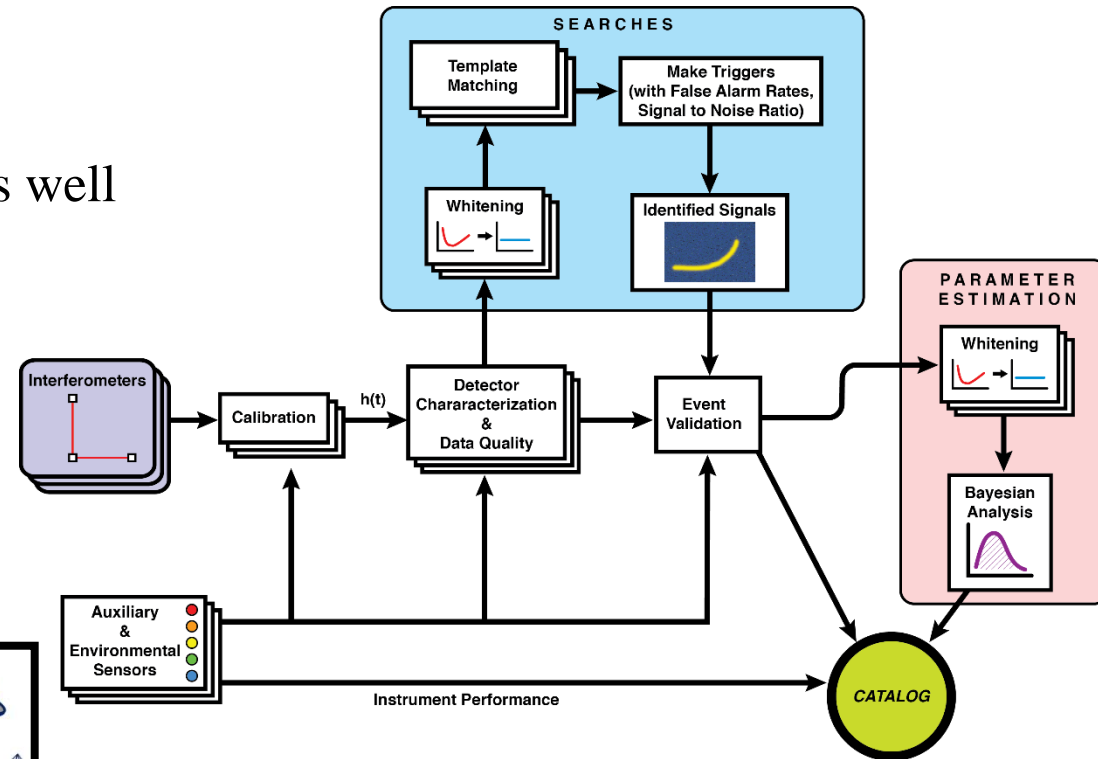


- **LVK data analysis framework**

- Applies mostly to low latency as well

- **From detectors to alerts**

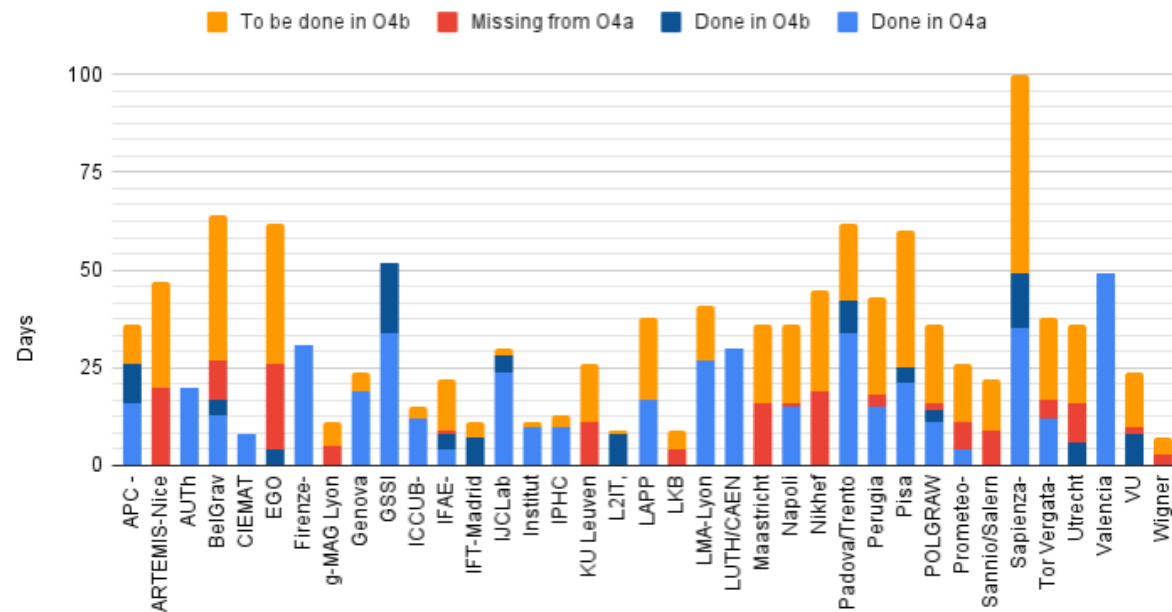
[Old plot]



Rapid Response Team (RRT)

- Solid infrastructure and excellent overall performance
 - Relying on group contributions for shift coverage and mentorship of colleagues
- 93 individuals from 22 Virgo groups participated in O4a
 - 70% are Early Career Researchers: PhD and Postdocs
- 161 people on the O4b rota
 - 26 institutions
 - Significant increase coinciding with Virgo being part of the run

O4a: May 24, 2023 - Jan 16, 2024 (237 days). O4b: Apr 10, 2024 - Feb 28, 2025 (324 days)



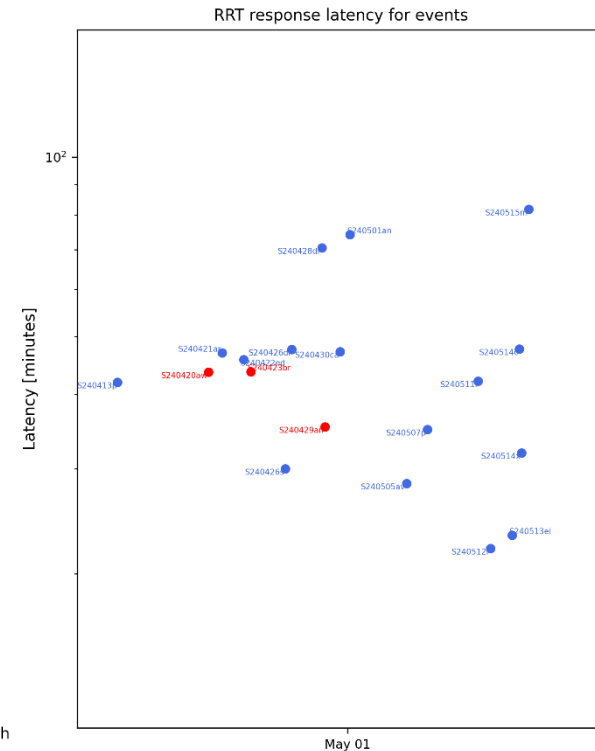
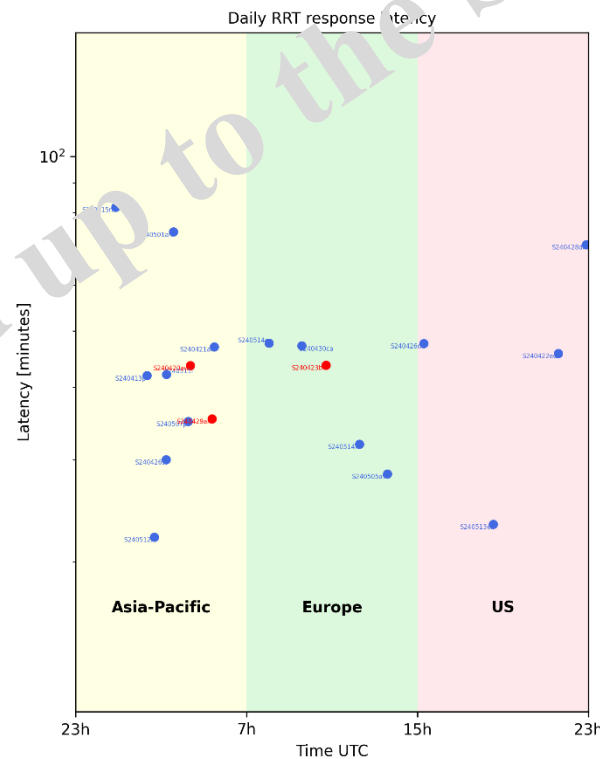
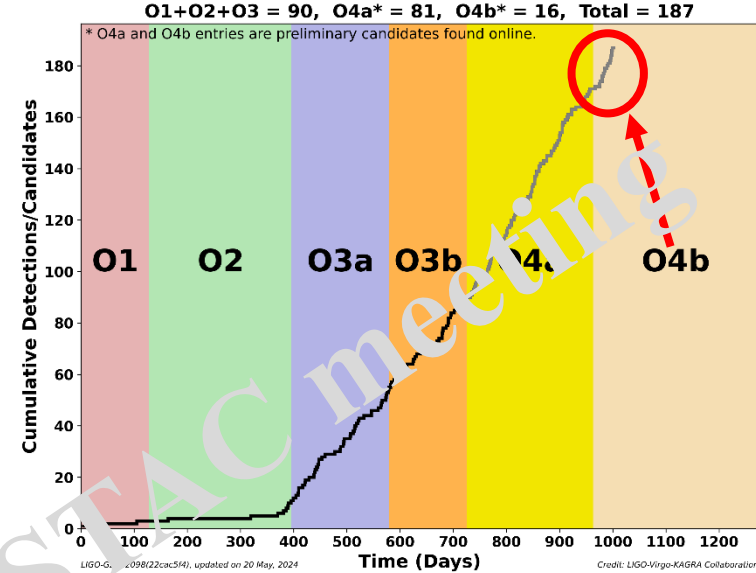
Updated: May 24, 2024

Public alerts

- **O4b significant** detection candidates: **16**
 - 19 [total] – 3 [retracted]

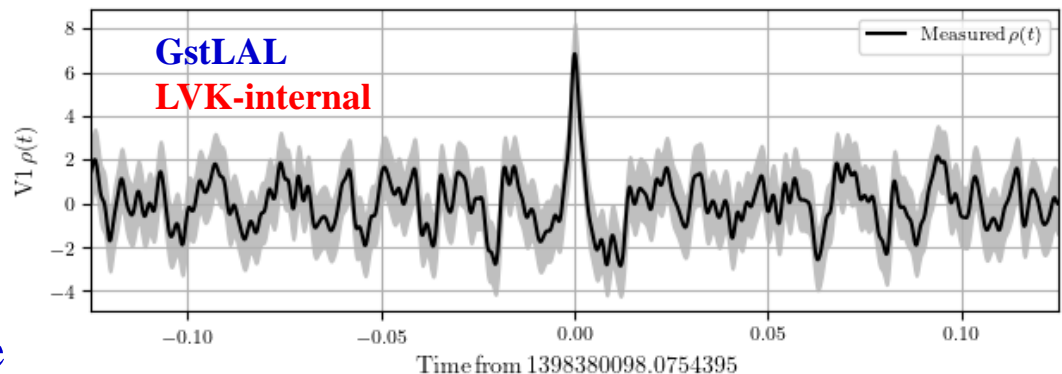
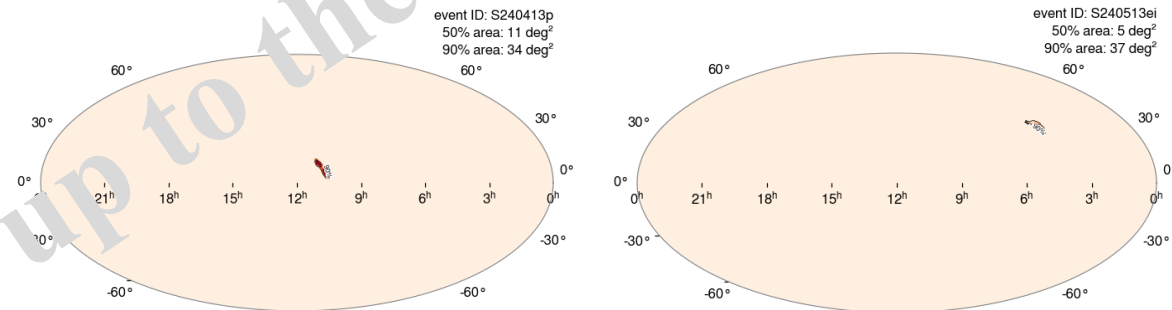
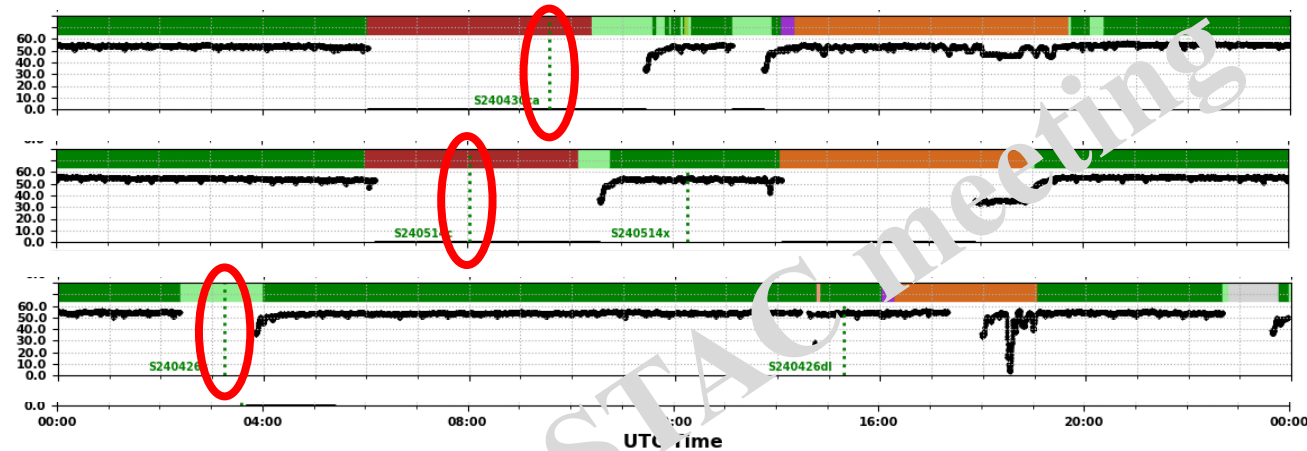
→ <https://gracedb.ligo.org/superevents/public/O4b>

- **Rapid Response Team (RRT)**
 - **Good** alert processing and vetting by **level-0 RRT (Lv0) shifters**
 - A bit slow sometimes
 - **Good level-1 expert (Lv1) coverage**
 - **Virgo Lv0 shifters** schedule filled until August included
 - **Good response from Virgo groups overall**



Public alerts

- 13/16 (81%) with Virgo
 - 2 during maintenance
 - 1 while relocking in between two Science segments
- Skymaps benefit from the addition of Virgo data to the LIGO trigger
 - S240413p high-profile due to its good localization
→ S240511i and S240513ei well-localized as well
- S240428dr
 - Trigger: Hanford-single
 - ◆ Livingston down
 - Virgo SNR: 6.9
→ A record for Virgo if event confirmed offline



Public alerts

- **Good Data Quality Report (DQR) performance** overall
 - Tool used to **vet data quality** for **all event candidates** – in particular in **low latency**
→ **No problem** with **data availability** at EGO, nor **data transfer** in low latency
- **Two problems** identified since the beginning of O4b
 - **Mitigation** in place: **very quickly**
 - **Proper fix taking time**: requires **code writing**, **testing** and **update to production**
 - **Need to protect from an online pipeline misbehaving and sending many alerts** passing the DQR triggering cuts in a short amount of time
 - **Filesystem stress at EGO** may have lead to **one control loss**:
data not flowing properly internally
 - ♦ Currently, **each alert is processed independently from all the others**
 - ♦ LIGO not willing to address that problem in the common part of the framework
 - To be **done at the Virgo DQR level**
 - LVK code used to **transfer DQR results to the central CIT location** to be improved, to **avoid interference between DQRs running in parallel on the same event**
 - **1 occurrence**: prevented transfers from EGO to CIT during **10 minutes**
 - ♦ **No impact on the DQR running at EGO**, only on the results transfer
 - ♦ **Code fixed**, to be included in a future production release of the framework

To watch out: lessons learned so far

- **Low-latency $h(t)$ reconstruction** at **EGO** for online gravitational-wave searches
 - Need to **provide $h(t)$ frames** in a **timely way even when the detector is down**
→ **Direct** (thus **sensitive**) **interface with LIGO** through the **low-latency pipelines**
 - **Monitor latency + study its fluctuations + mitigate/fix their causes**
 - **Check low-latency $h(t)$ frames** when leaving the DAQ
→ **Fix their contents** (by putting down all bits of the state vector) if needed
 - **Enforce rules** to act on that (and other) **critical part(s)** of the **Virgo** framework
 - ◆ **Any work** should be **announced** and **cleared**
by **control room / coordinators** **before it may start**
 - ◆ **Use test** systems/dataflows **to not interfere** with production Hrec
 - ◆ **Once the activity is completed, monitor the system**
until back to nominal Science data taking
- **Follow-up on errors** done while **steering Virgo**
 - **Update documentation, improve procedure, implement protections**, etc.
- **Complexity** of the **low-latency system**
→ **Difficulties** to **implement changes coherently**

Computing update

- **Low latency data distribution**
 - Up and running in production mode using jointly developed l1dd library
 - Spikes in latency in low latency Virgo data are being addressed
 - Virgo frames missing strain data solution being tested into the offline End-to-End Archival data replay setup
- **Raw data transfer**
 - Data are **flowing** into the dedicated O4b directories at CNAF and CCIN2P3 with **good performances**. Common efforts to **reduce the raw data flux** have helped in achieving the result
- **Bulk data distribution**
 - Prepared **OSDF/CVMFS** Louvain origin infrastructure **working as expected** and **transitioned successfully to Rucio technology** for aggregated h(t) data transfer
 - After dedicated tests with the **Calibration group**, ready to support the **Analysis Ready files** (for offline analyses) **transfer**, using the same infrastructure
- **Low Latency pipelines**
 - **MBTA** and **cWB** are **running nominally** and **contributing to events discovery**
- **CVMFS-based file network system at EGO** to **improve performance**

DetChar group status update

- **Organization**: a solid infrastructure inherited from O3 plus some novelties
 - Weekly meeting
 - Wiki pages
 - Two, recently started, gitlab projects
 - ♦ Tasks: monitor ongoing activities and ping DetChar intervention
 - Foster interactions among Data Analysis and Commissioning groups
 - ♦ Help for newcomers: request assistance from experts or discuss common issues
- **Composition**
 - Based on Virgo Member Database – does not necessarily reflect reality (worse!?)
 - 27 members, for a total of 7.25 SVAC
 - 0.27 SVAC/person – 0.47 in Data Analysis, 0.24 in post-O5 R&D
 - 17 different institutions : 1.6 people/institution
 - Reduced knowledge transfer and limited mentoring possibilities
- **O4b core activities**
 - Continue the support to Commissioning and detector Operations
 - ♦ Monitoring and investigation of known issues
 - ♦ Prompt investigation of new noise sources
 - Data-quality products for low-latency and offline searches – including final dataset
 - Event validation – jointly with LIGO (and KAGRA)

Other news

- Live operator report from ongoing shift now available on the logbook

- Temporary solution for now
→ Work in progress towards a more permanent one

Virgo Runs (O4b)	
irace	- 8:09 Tuesday 07 May 2024 (64186) % 📄
Operator Report - Morning shift	
<u>DRAFT - REPORT IN PROGRESS - will be finalized at the end of the shift</u>	
Upon arrival, I found the ITF locked and in SCIENCE mode.	
At 6:05 UTC I set the MAINTENANCE mode.	

- Calibration and Hrec approved by Virgo review committee for O4b
 - Following provisional sign-off for ER16

- Rhys Poulton (EGO) replacing Duncan MacLeod (LIGO) as chair of the Software Control Change Board (SCCB)
 - Rhys and Duncan swapping their positions in the SCCB
 - Need to follow up closely the possible evolution of the SCCB
 - ♦ “Friction” (sic) added to the system with the goal of limiting mistakes
 - ♦ Tendency to make the SCCB procedure more invasive, more complex and compulsory for any software change
 - Need to find (and keep) a balance between efficiency and burden

- 7th GWOSC workshop took place mid-April

- <https://gwosc.org/odw/odw2024> + Lessons learnt: <https://dcc.ligo.org/G2401025>

Outlook

- Virgo started O4b on time and is committed to be part of the whole data taking period
 - Discussions have started about a possible extension of the run
 - May impact the schedule of tests to be done on a stable O4b-optimized detector
 - Excellent duty cycle so far
 - Virgo Science data available for most low-latency alerts
 - Improve sky localization
 - Optimized LVK / run + commissioning planning to maximize 3-detector uptime
 - ♦ “Drawback”: no detector observing up to ~10% of the time
 - Focus on monitoring performance and improving things where possible
 - All run-related working groups performing well
 - Personpower remains limited but some balance has been found
 - Focus on critical areas
 - Priorities driven by issues identified and investigations done during the run
- We’ll see what Summer and Fall bring us, but Spring doesn’t look bad so far!