Virgo commissioning: looking behind for lessons to the future

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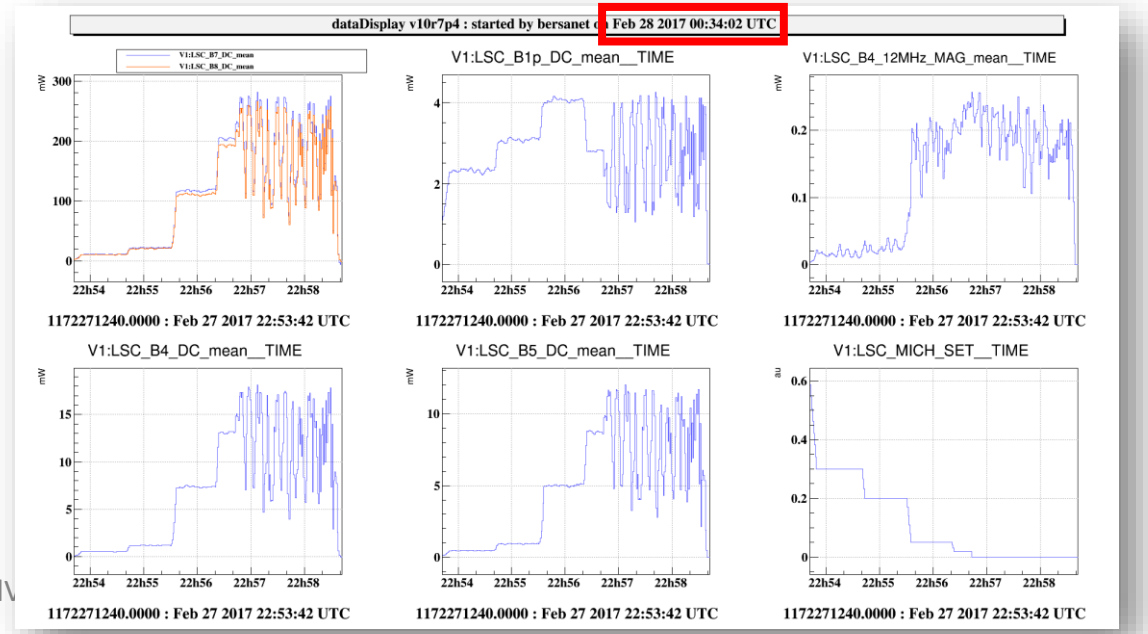
VIR-0530A-19

The early times

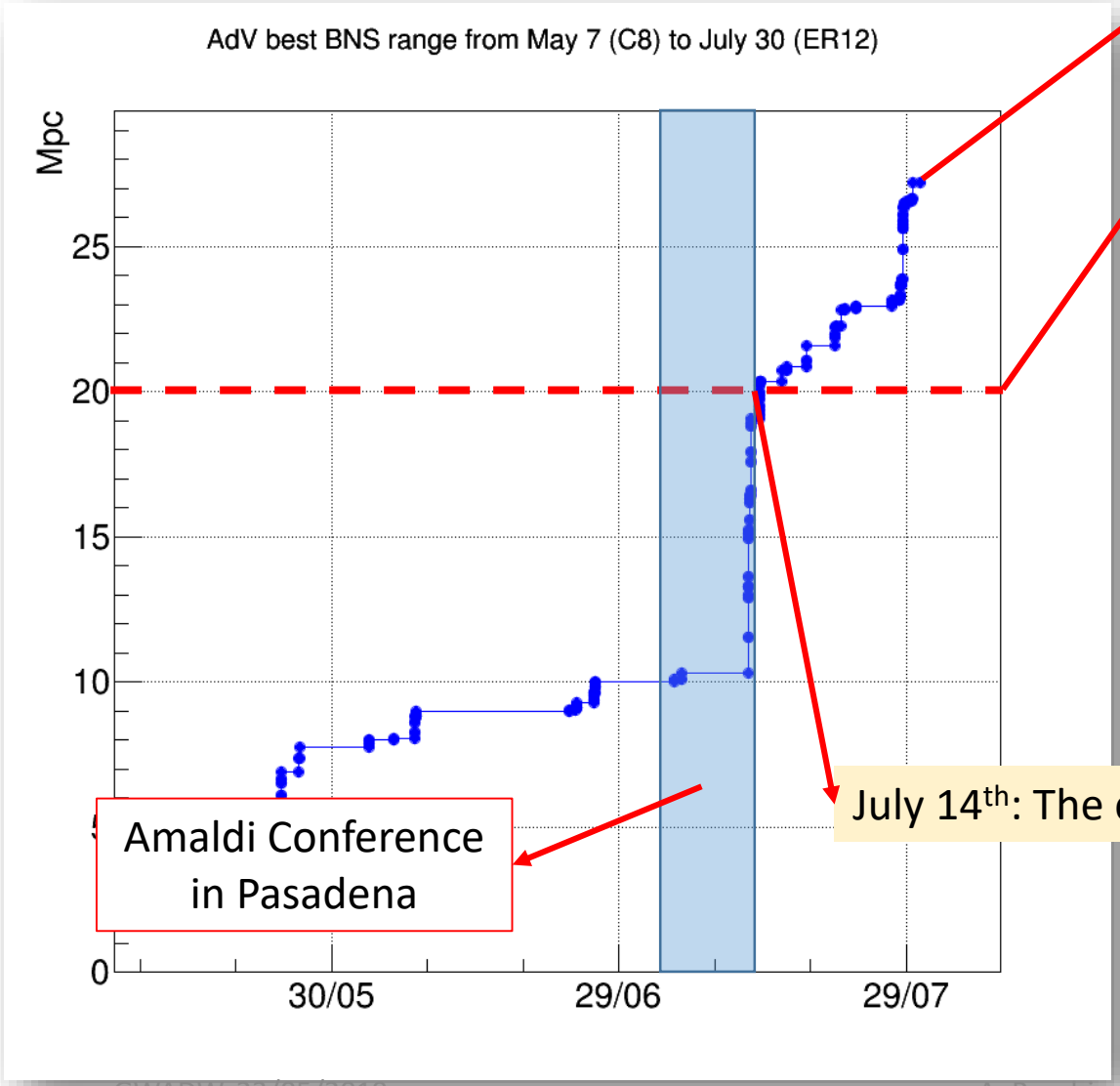
- The story begins at the end of February 2017 (appointed by the VSC);
- Situation was rather “exciting”:
  - Virgo not yet locking at dark fringe;
  - “Watchful” eyes from funding agencies;
  - LIGO O2 ending in summer 2017 (July-August);
- Promised the VSC that Virgo would be in observing mode by the 2017 Amaldi Conference (July);
- Inherited the huge work done by Bas.



How it went

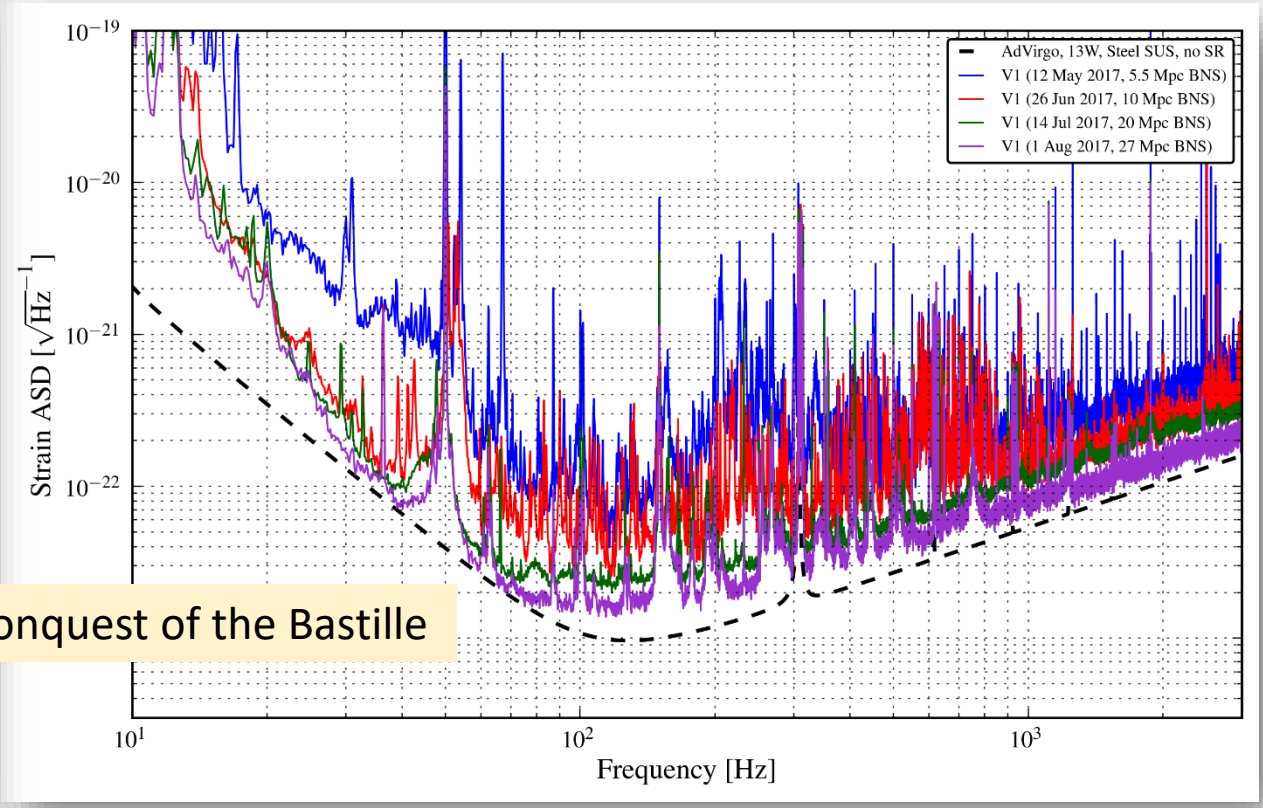
Virgo joins O2

Threshold to join O2 (from the Obs. Scenario)



Amaldi Conference in Pasadena

July 14th: The conquest of the Bastille



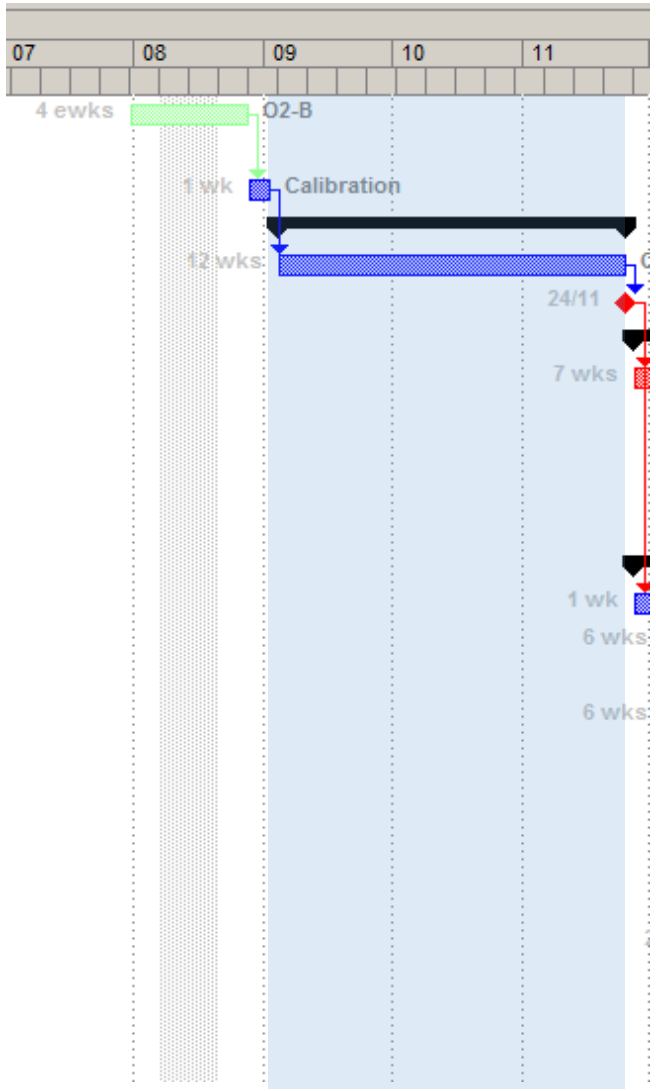
Getting info from the rush

- The very quick and dirt run to join O2 was a success;
- Nevertheless, some things could have been done differently (maybe with a different result…);
- Despite the very limited amount of time for commissioning, never managed to run the ITF on **a 24/7 basis** (even if afternoon shifts often ending early in the morning and some shifts in the weekend) due to **lack of person power**;
- We were pushing to meet several **milestones** (OMC locking, AA, DC readout…), without a **long term plan**.

- What we should not forget:
  1. Person power **must not** be a limiting factor for the commissioning efficiency;
  2. Commissioning works much better if you have **a (flexible) plan**. See next slides…

Commissioning after O2

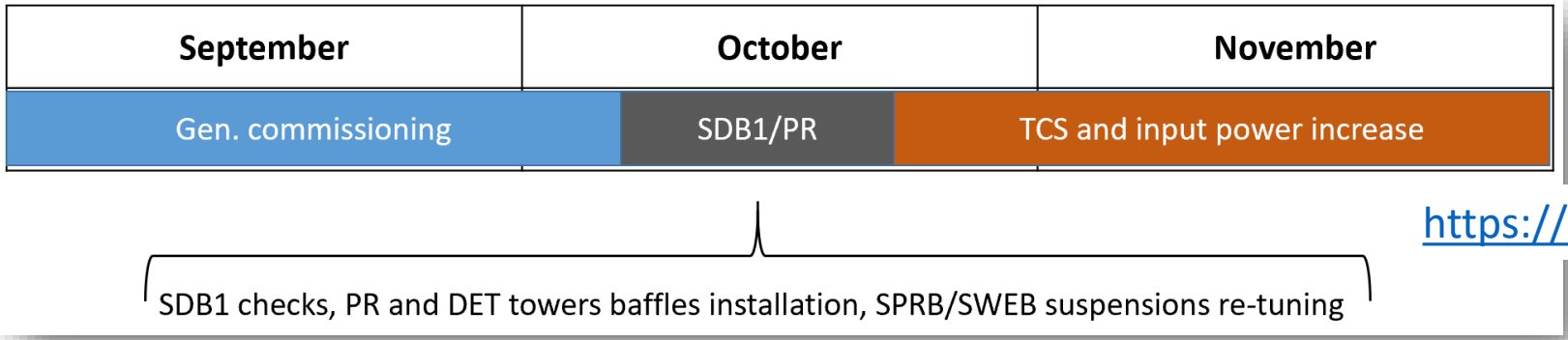
- With Detector Management negotiated 3 months of commissioning before installing invasive upgrades (monolithic suspensions, high power laser, squeezer);
- Window of opportunity to improve the ITF configuration:
  - Perform activities left behind due to the beginning of the science run (for instance, the linear alignment);
- TCS commissioning:
  - Prepare for input power increase;
  - ITM etalon tuning;
  - Optimize contrast defect;
- Some (well known) villains:
  - SDB1 scattered light;
  - B4 ghost beam;
  - glitches;
  - 50 Hz line;
- Increase input power to 25 W.



Building a planning

- **Already during O2**, a query was made to the SSMs for shifts requests;
- Priorities have been assigned to the requested tasks, based on:
  - Impact on sensitivity;
  - Impact on ITF operation;
  - Necessity as predecessors for other high-impact tasks;

SS		Priority		# of shifts	shift leader	activity	expected outcome	predecessor	required ITF status
ENV		B2		3,0	I. Fiori	Switch off tests	evaluate the critical equipments		ITF in low noise
ENV		B2		3,0	I. Fiori	Acoustic noise injection	evaluate the acoustic noise		ITF in low noise
ISC		B2		0,2	M. Mantovani	further reduction of the 6MHz mod index	Lower the beat between the 8MHz and the 6MHz, possible noise improvement		ITF in low noise
ISC		B2		2,0	M. Mantovani	Use the 6MHz for SSFS and MICH	improve the auxilary signals SNR	PD saturation evaluation	ITF in low noise
ISC		B3		0,5	M. Mantovani	SSFS optical TF	evaluate the needed control filter for the target ugf (20kHz)	electronics equipment	ITF in final configuration
ISC		B1		0,5	M. Mantovani	MICH offset instead of DARM offset	it should, from simulation, reduce the common noise coupling in DARM		ITF in low noise
ISC		B1		1,0	M. Mantovani	56MHz modulation index increase	improve the SNR for ausiliary dof (SSFS, MICH)	PHD saturation problem solved	ITF in low noise
ISC		B1		3,0	M. Mantovani	Completion of the alignment for the arm cavities	Improve the stability of the ITF and accuracy		ITF in low noise



https://wiki.virgo-gw.eu/Commissioning/Post-O2

…and it worked

- (Almost) **all tasks** completed **in time!**
- **Advanced** (flexible – see next slides) **planning** is really an essential part of the commissioning activities.

	Sub system	shift allocation	Priority	Earliest start	Duration (shifts)	Reference person	Commissioning action	
6	ENV		B1		1,0	I. Fiori/ R. Gouaty	repeat the picomotors tests	✓
7	DET		B1	28/08/2017	0,5	R. Gouaty	Part 2: Do a low noise 3 lock, but with OMC1 only locked, to check that the structures at few hundred Hz and few kHz are already present	✓
8	DET		B1		9,0	R. Gouaty	Open the tower. Block the bench and measure the resonances of the mounts with accelerometers, investigate for stray beams with laser …	✓
9	ENV	Night	B1		0,5	I. Fiori	PR ghost	✓
10	ENV	**4 Sept**	B1		4,0	F.Nocera	50Hz line investigation (stepper motors WE, WI, RH NE ….)	✓
11	ISC	**4 Sept**	B1		0,5	M. Mantovani	MICH offset instead of DARM offset	✓
12	ISC	**4 Sept**	B1		1,0	M. Mantovani	56MHz modulation index increase	✓
13	ISC	**4 Sept**	B1		3,0	M. Mantovani	Completion of the alignment for the arm cavities	✓
14	DET		B1	28/08/2017	0,5	R. Gouaty	SDB1 noise investigations: Part 1: Inject noise into OMC PZT at 5-20kHz to identify OMC mechanical resonances and to measure down-conversion (check how it depends on the dither amplitude).	✓
15	DET		B1	05/09/2017	1,0	R. Gouaty	Adjust some preamplifiers for 25W of input power on control photodiodes	✓

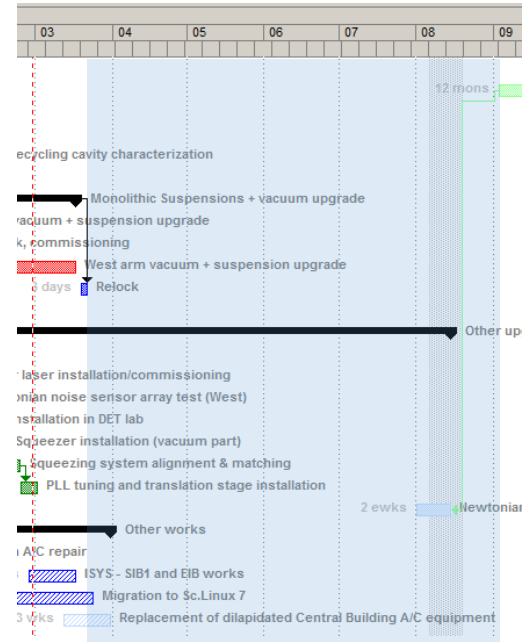
Upgrades and commissioning for O3

- Interrupt installation of upgrades for **three weeks**;
- Objectives:
  - Check lock acquisition;
  - Calibration;
  - Look for new noise sources;
- Things went very smooth: two weeks to recover the ITF and get a decent sensitivity;
- Info used in building the commissioning planning for O3!

Rough plan for O3

- Commissioning starting mid March 2018: ITF recovery (**2-3 weeks**);
- Target: O3 planned to start in **fall 2018**;
- General plan up to June, priority to problem solving activities

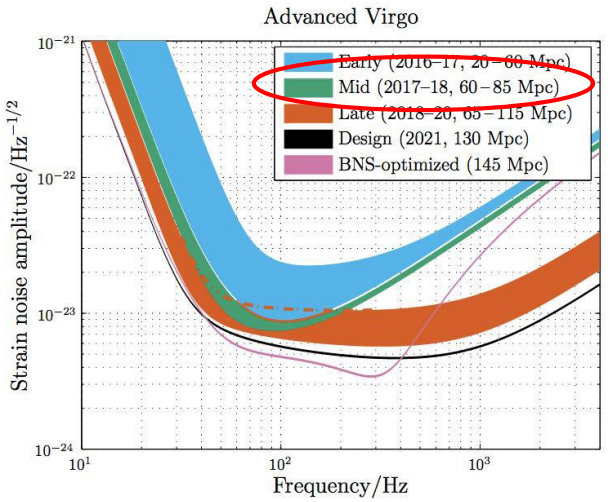
March		April	May	June
	Recovery + calibration	Improve detector configuration, re-measure noise couplings, Optical Characterization	Input power increase, mitigate parametric instabilities, TCS	Commissioning of squeezing



- Plan on the Wiki:

(https://wiki.virgo-gw.eu/Commissioning/CommissioningForO3);

- Something did not really go as planned…



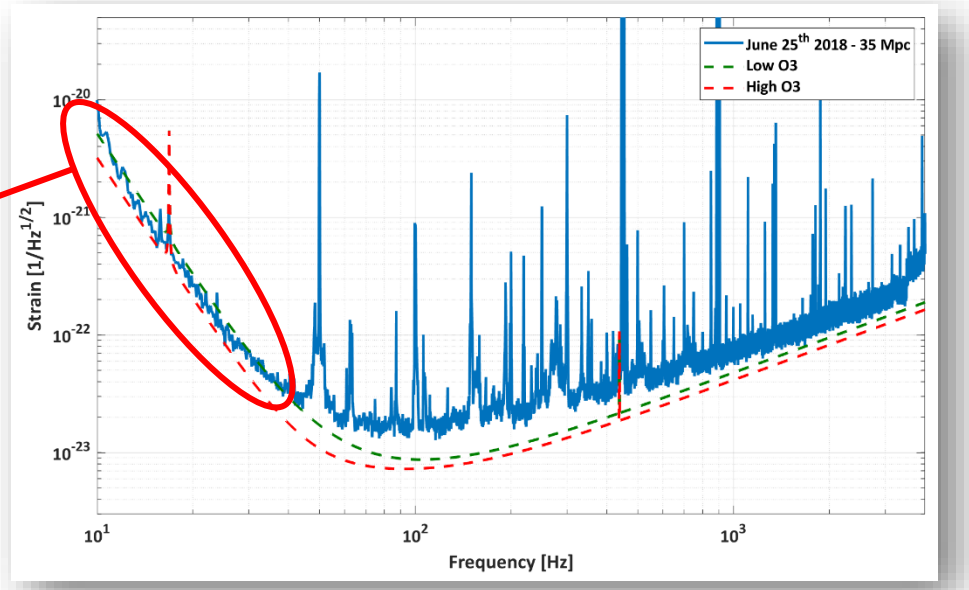
Commissioning requires flexibility…

- ITF recovery (planned **2-3 weeks**) actually took **6 weeks**;

March	April	May	June
	Recovery + calibration	Improve detector configuration, re-measure noise couplings, Optical Characterization	Input power increase, mitigate parametric instabilities, TCS	Commissioning of squeezing

- All activities pushed forward by more than **a month** (out of 7);
- Anyway, towards the end of June (@ 12 W input power), BNS range had improved wrt O2: from **27 Mpc to 35 Mpc**.

Already compliant with O3 requirement



What happened afterwards

- Following the **revised** commissioning plan, ITF input power increased **to 25 W**;
  - Already tested in **fall 2017** → straightforward, no locking issue, smooth TCS tuning…

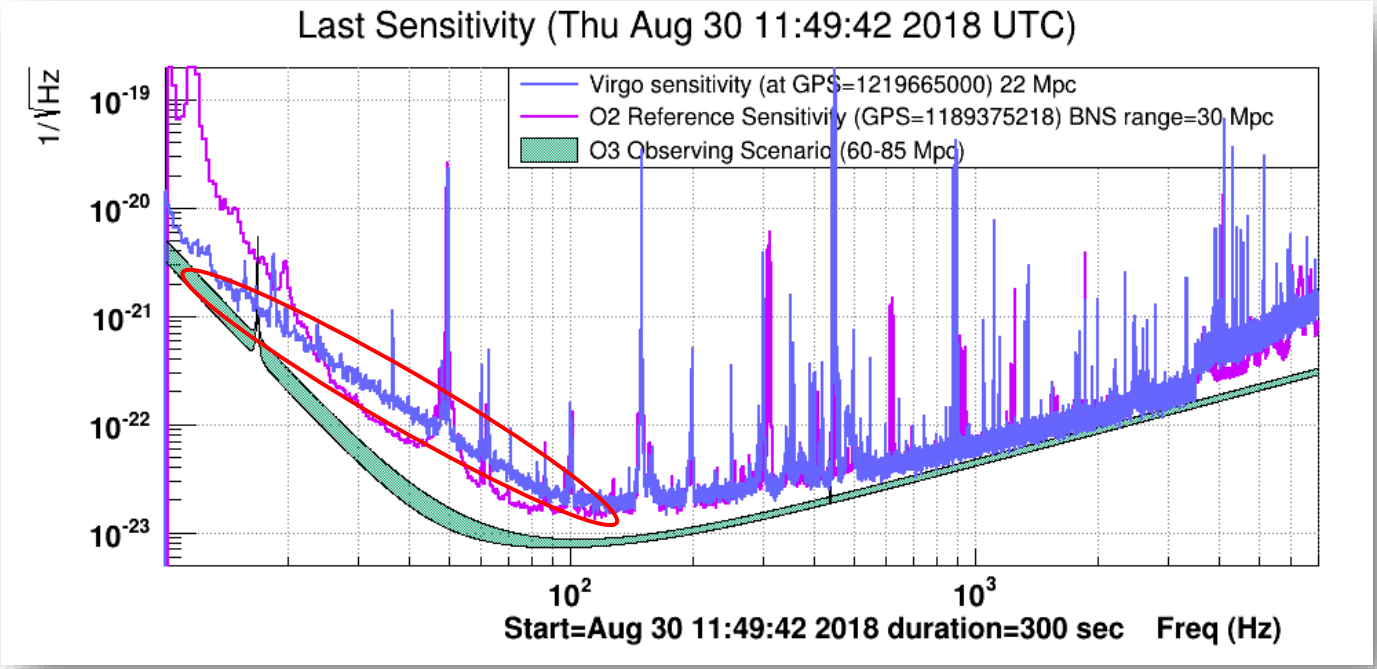
What happened afterwards

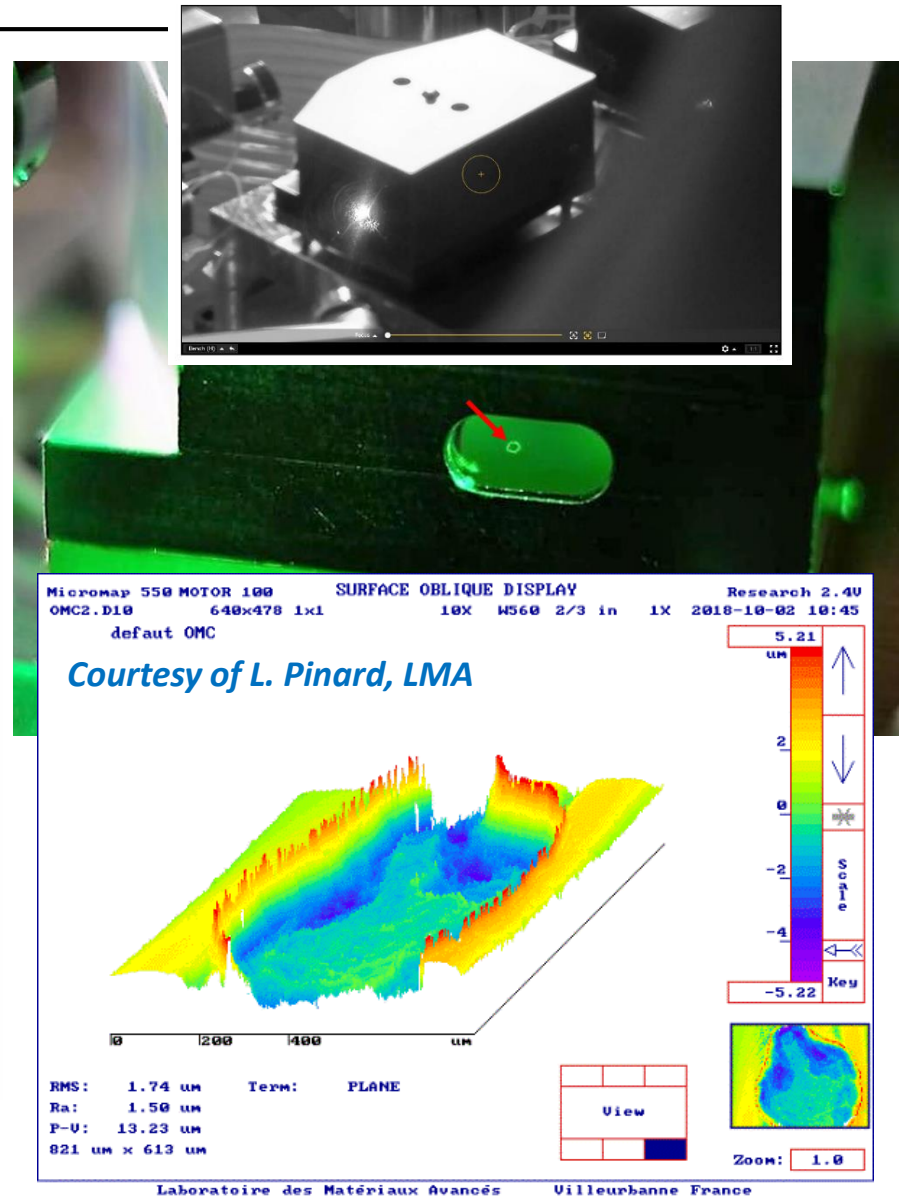
- Following the **revised** commissioning plan, ITF input power increased **to 25 W**;
  - Already tested in **fall 2017** → straightforward, no locking issue, smooth TCS tuning…
- But the ITF was different now:
  - PDs/electronics saturation appeared in many impacting locations;
  - TCS alignment/tuning took much longer than in fall 2017;
  - DET tower venting for stray light mitigation was planned after a couple of weeks;
  - Faced the failure of the laser amplifier power unit;
- ITF (partially) recovered low noise operation only at the **end of August** 2018;

- Things to remember for the future:
  1. Your advanced planning need to include **flexibility**: issues happen;
  2. Even if a task went smooth once (recovery or TCS tuning), there is **no guarantee** it will always be the case;
  3. Never plan a possibly impacting activity **right before** a shutdown…

Waking up with a new “friend”

- Summer 2018 was difficult and with very low duty cycle;
- **New mystery noise** appeared at low frequency;
- The day after a high power flash at the dark port during an unlock burned the first surface of the OMC.





The low frequency noise

- Since there were no clues about the origin, decided to involve the whole collaboration;
- Dedicated meeting:
  - Very large attendance: almost **60 people** connected + those (**~40**) here on site (**large** fraction of the **Collaboration**);
  - Very fruitful discussion and outcome: list tests to shed some light;
- Dedicated Wiki page (https://wiki.virgo-gw.eu/Commissioning/OneOverFCube);
- Several hints (suggestions from A. Vicerè and G. Cagnoli) pointed to test masses being charged + unknown source of common noise;

eZuce recording of the special meeting held on October 22nd, 2018 - link

Recap by D. Bersanetti on the TDS - VIR-0695A-18

- Spotted on August 3rd, after C10 - #42323
- Modelled as 1/f2.5 - VIR-0671A-18
- Affecting sensitivity in the frequency range 20-100 Hz - #42847
- Change in amplitude over time to-be-confirmed - VIR-0671A-18
- Date of appeareance uncertain, sometime between June 29th and July 24th - #42956
- Link to an old (2016) aLIGO Livingstone Logbook entry - #28751
- Link to A. Viceré slides on Pink Noise - VIR-0738A-18
- Link to F. Sorrentino slide on charging issue at LIGO - VIR-0741A-18
- Rey Weiss Ion Generator: ion_generator_for_LIGO.pdf
- Minutes of the special session at the November Virgo Week: minutes_v1.pdf (Thanks Nicolas Arnaud)

Tests proposed during the meeting

- change SR position;
- switch off/unplug RH power supplies -→ **DONE**;
- switch off TCS in vacuum motors -→ **DONE**;
- switch off temperature probes in the towers; -→ **DONE**;
- switch on/off SDB1 picomotor driver -→ **DONE** ;
- put bad offset for BS alignment -→ **PARTLY (TX) DONE**;
- mistune FmodErr;
- look for correlation between CMRF and 1/f3, through SSFS line -→ **PARTLY DONE** ;
- change mirror position wrt F7 -→ **PARTLY (NE) DONE**;
- tappings tests on the vacuum links;
- switch off calibration lines for dithering;
- inject noise lines from different locations in the ITF to check for nonlinearities;
  - injected power noise line at the level of the perturb input of the PSTAB rampeauto -→ **DONE** ;
  - SSFS low frequency noise injections -→ **DONE**;
- inject actuation noise on BS/PR and IMC;
- direct measurement of SUSP boards with Spectrum Analizer -→ **DONE** ;
- quality factors of test masses;
- switch off test of penning vacuum sensors -→ **DONE**;

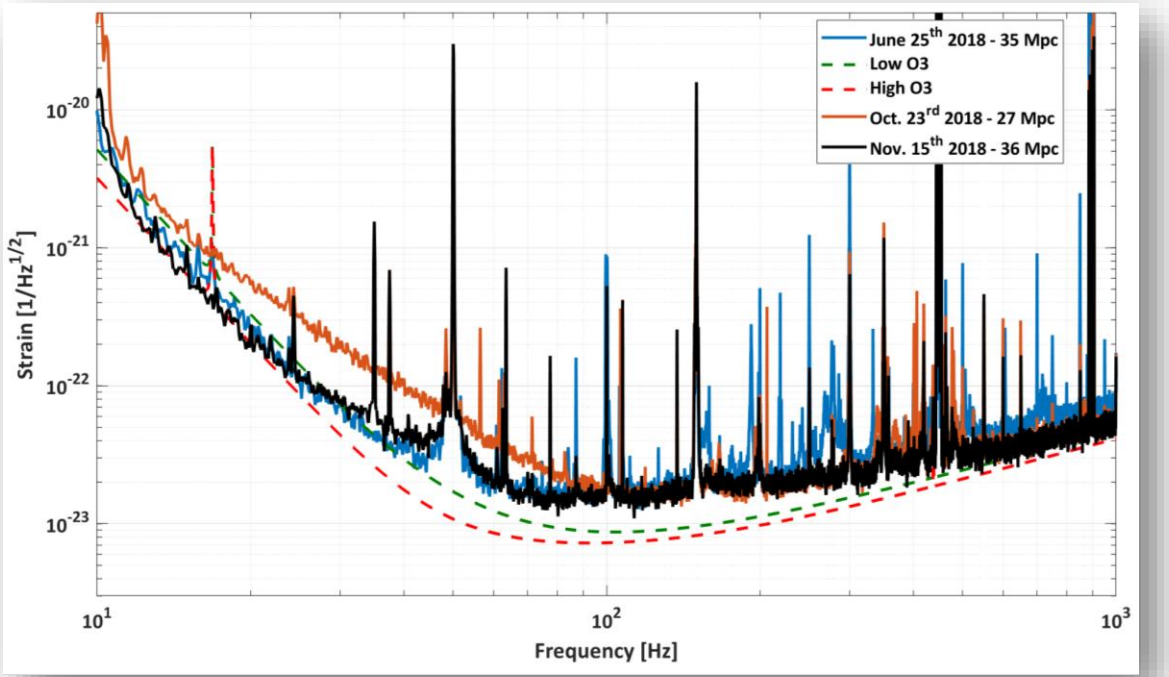
Tests done so far

- Suspensions and actuators - #42893 - #42910 - #43249 - #43286
- B1p_DC Switched back to Audio/DC Blend - #42898 - #42899 - #42956 - #42995
- New Filter Implementation in Acl - #42903 - #42951 - #43040
- Switch-Off Test of TCS DAS Actuators - #42916 - #42953
- Modulation Amplitude of the 56 MHz Sideband - #42986 - #42998

The low frequency noise

- Putting all the information together allowed to identify and solve the issue:
  - Mirrors (at least the ETMs) are charged;
  - Excess common mode noise in coil drivers;
- Low frequency noise **identified** and **solved**:
  - With the good ITF duty cycle, solution came **in three weeks**;
- Sensitivity started to improve again;

- Our collaborations are huge:
  - **Extremely useful** expertise hides in **the labs**;
  - CTRL rooms must be **open** to the outside world.



Conclusions

- Commissioning (sensitivity) progresses happen in jumps;
- Efficiency is made of several ingredients (non exhaustive list):
  - **Person power** – not necessarily on site;
  - **Ahead planning** – that will be updated in time;
  - **Flexibility** – issues or new needs must be considered on the fly.
- Collaborations are incredibly rich reservoirs of knowledge!
- One last point:
  - Commissioning teams should meet more often;
  - Last workshop was in 2017 in KAGRA;
  - What about a workshop at every LVC meeting?

In the end, everything will be fine,

If not, it means it is not the end yet.