

LVK and LHO status

Georgia Mansell

On behalf of LIGO lab and the entire LVK (!)



About me!

- Post doc at LIGO Hanford and MIT since 2018
- PhD at Australian National University in squeezed light
- Undergrad at Adelaide University

- My work focuses on gravitational-wave detector instrumentation
 - Commissioning the aLIGO detectors in the run up to observing runs

- This talk will have an instrumentation focus!!

Overview

- Recent collaboration publications
- Frequency dependent squeezing!
- Status of LIGO, Virgo, Kagra

LIGO-Virgo-Kagra collaboration overview

- New faces and farewells at LHO
- LHO site status
- Pre-O4 commissioning summary

LIGO Hanford observatory overview



Status of the LVK

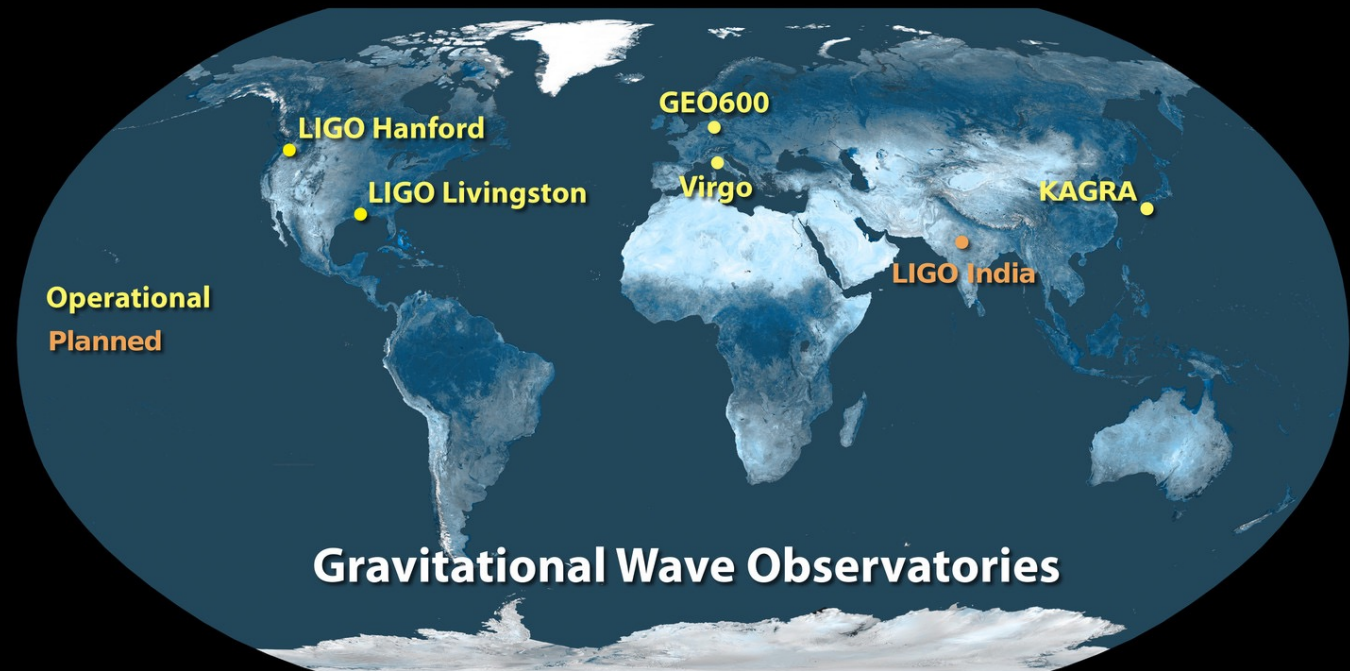
ETMY cleaning at Kagra – klog 17271

LVK update – recent publications

- Publication list with handy science summaries
<https://pnp.ligo.org/ppcomm/Papers.html>
- Today! NSBH announcement
 - Two NSBH events found in the O3 data
 - GW200105
 - Signal seen in 2 detectors, lower significance
 - $8.9 M_{\odot} + 1.9 M_{\odot}$
 - 900 million years ago!
 - GW200115
 - Triple detector discovery, high significance
 - $5.7 M_{\odot} + 1.5 M_{\odot}$
 - 1 billion years ago!

Status of LVK

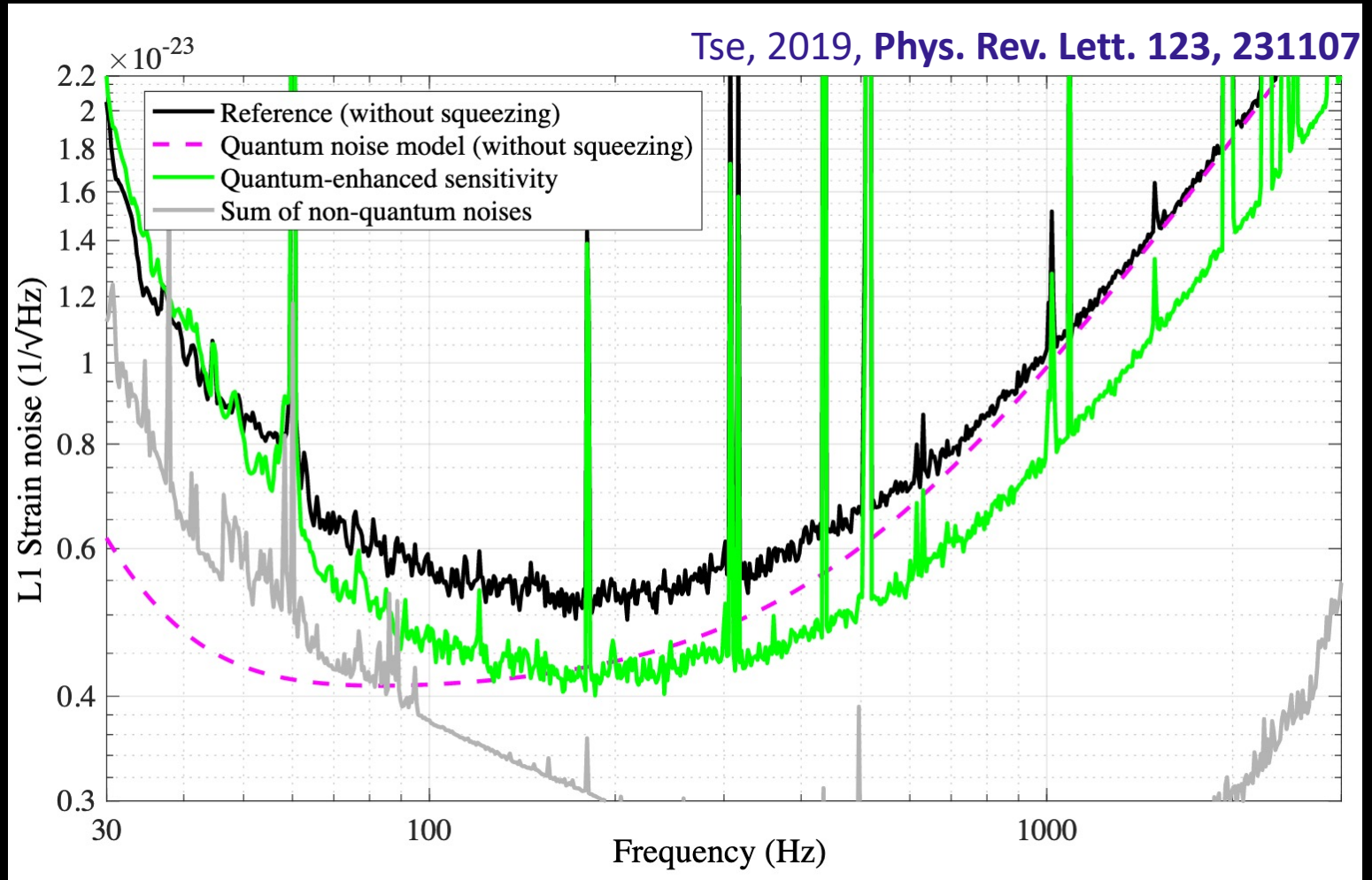
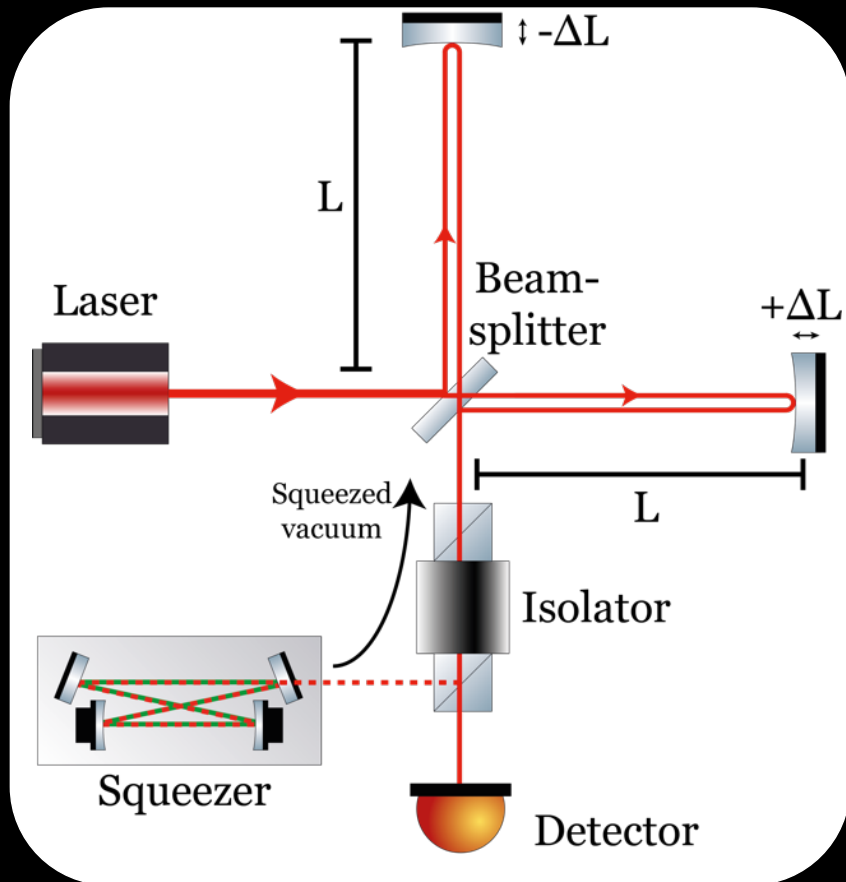
- Covid restrictions are lifting, and we're preparing for O4!
- O4 scheduled start date >July 2022
 - Aim: aLIGO 160 – 190 Mpc, AdV 90 – 120 Mpc, KAGRA 25 – 130 Mpc
- Frequency-dependent squeezing install at LIGO and Virgo sites
 - Major facility upgrade!
 - New optics
 - Elaborate additional controls
- Many many other upgrades at each site!



Frequency-dependent squeezing in a nutshell

Side note!
1/3

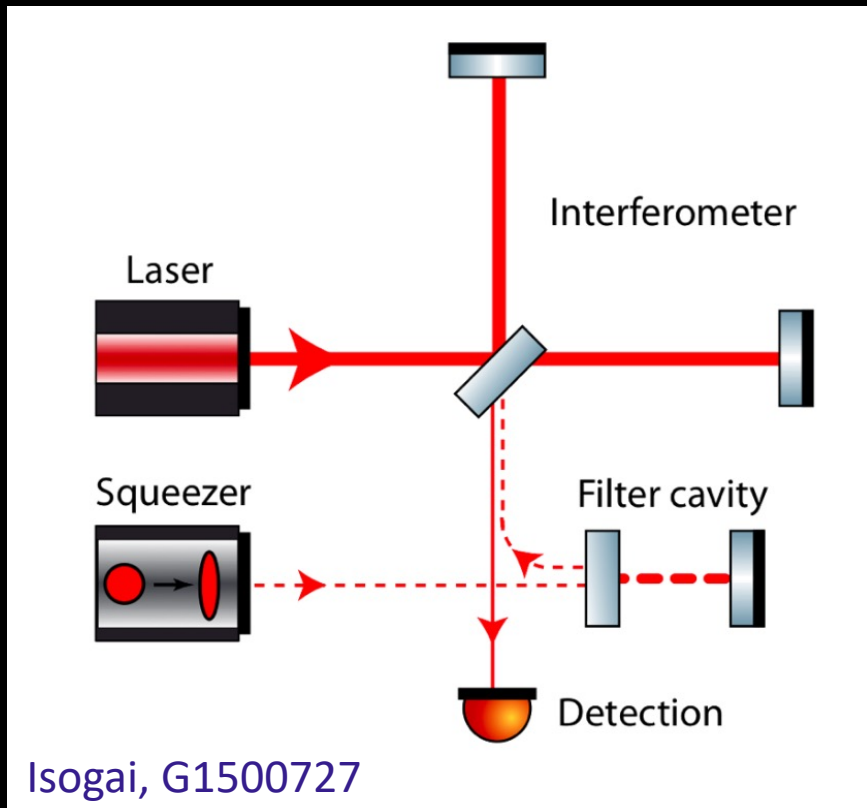
- In O3 both the LIGO and Virgo detectors injected squeezed light
- This made **quantum noise** better at high frequency and worse at low frequency



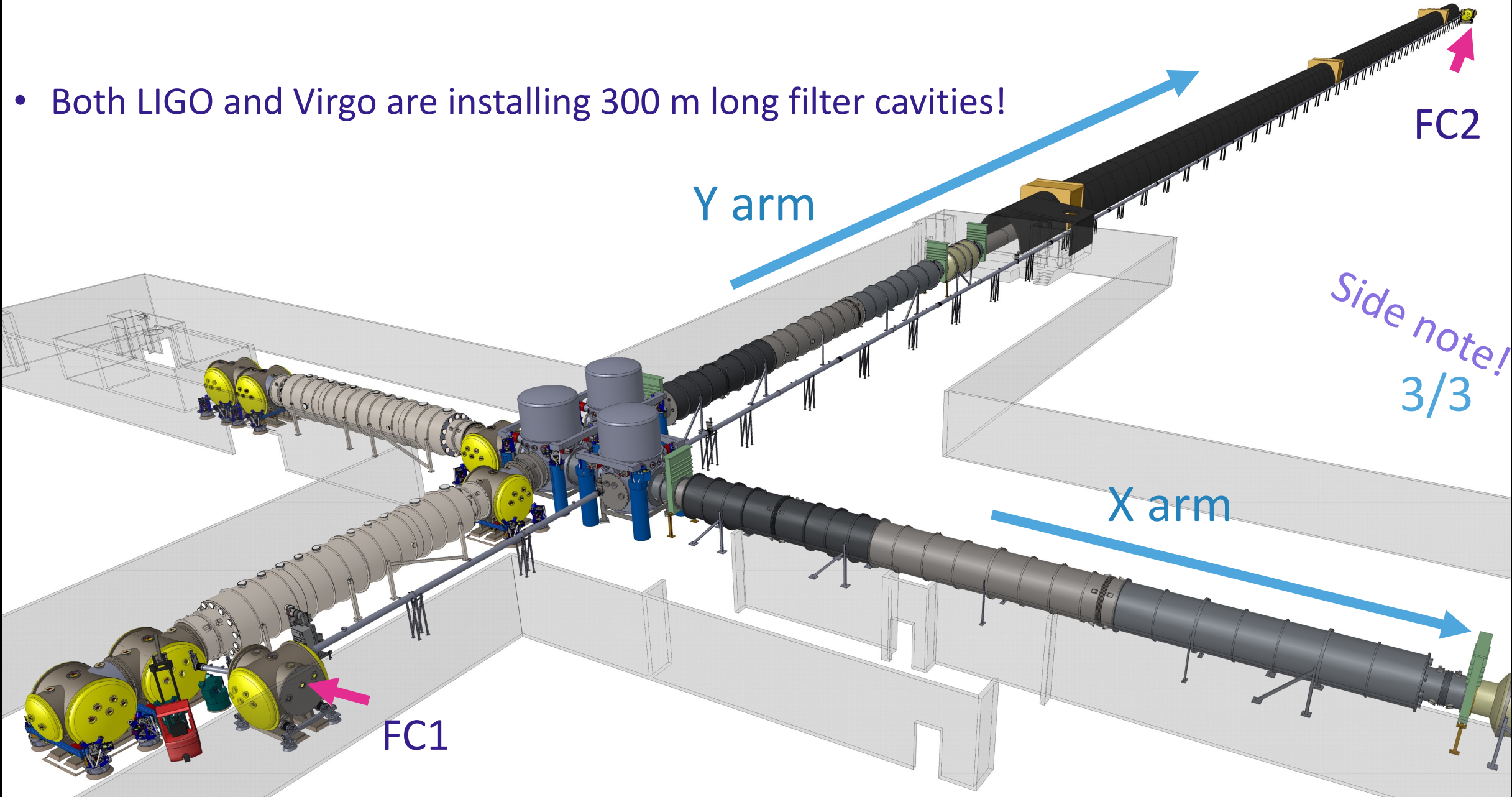
Frequency-dependent squeezing in a nutshell

Side note!
2/3

- For O4 we want broadband improvement – frequency dependent squeezing
- To achieve this, we need to reflect our squeezed beam off a high-finesse optical cavity before sending it into the interferometer



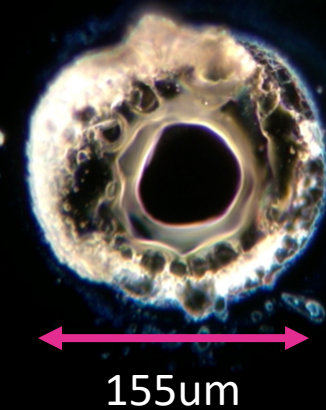
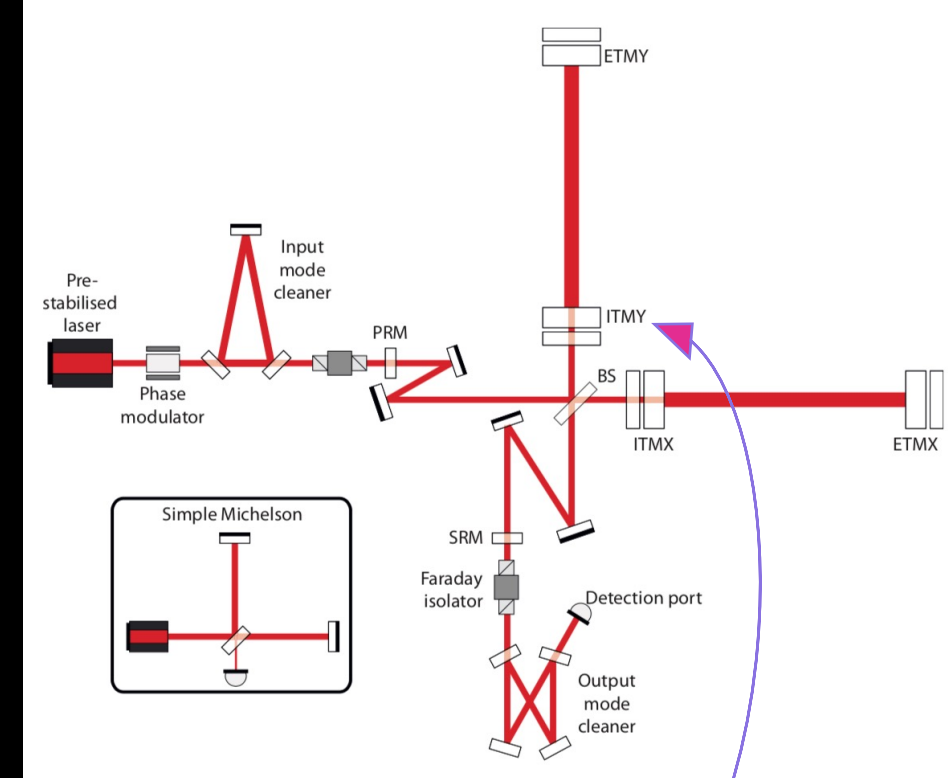
- Both LIGO and Virgo are installing 300 m long filter cavities!



Side note!
3/3

Status of LIGO

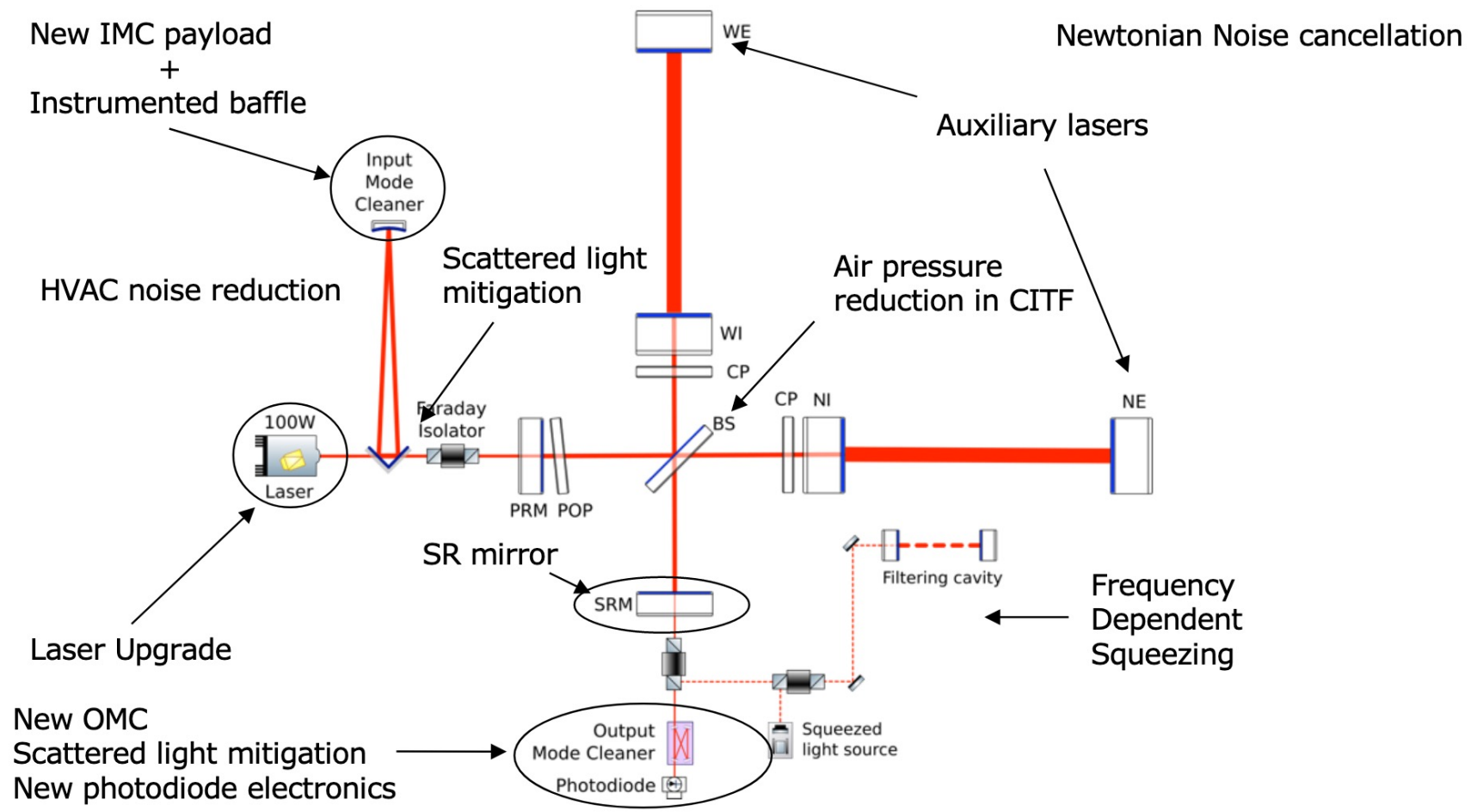
- O4 sensitivity improvement plans
 - Improved stray light control (important $<200\text{Hz}$)
 - New higher power laser amplifier
 - Point absorber-free test masses
- A+ project (O5, maybe ready by O4?)
 - High efficiency Faraday isolators
 - Adaptive mode matching at anti-symmetric port
 - Frequency-dependent squeezing!



Status of Virgo



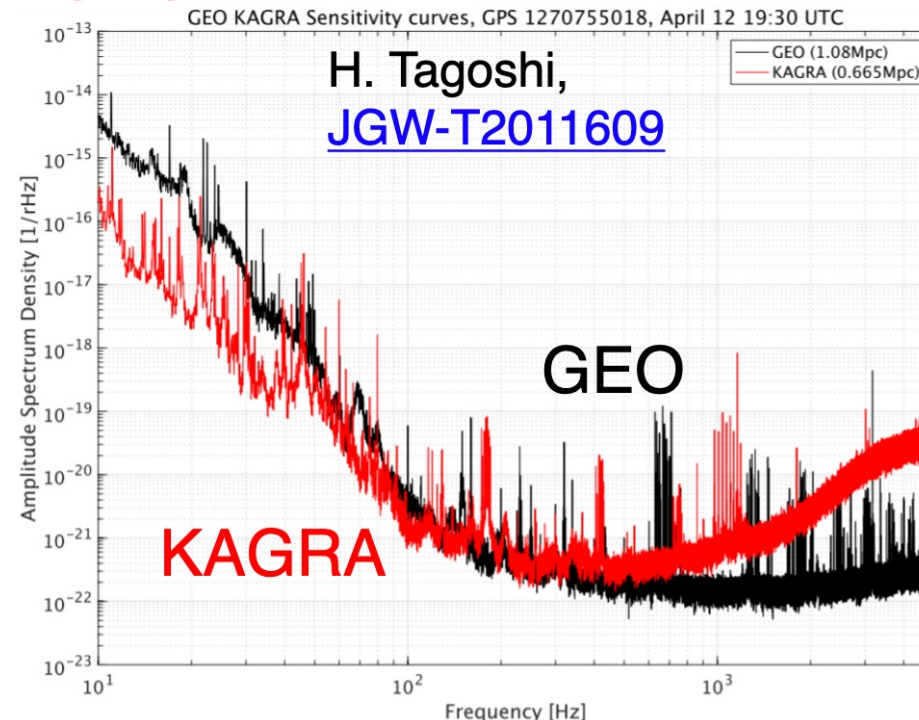
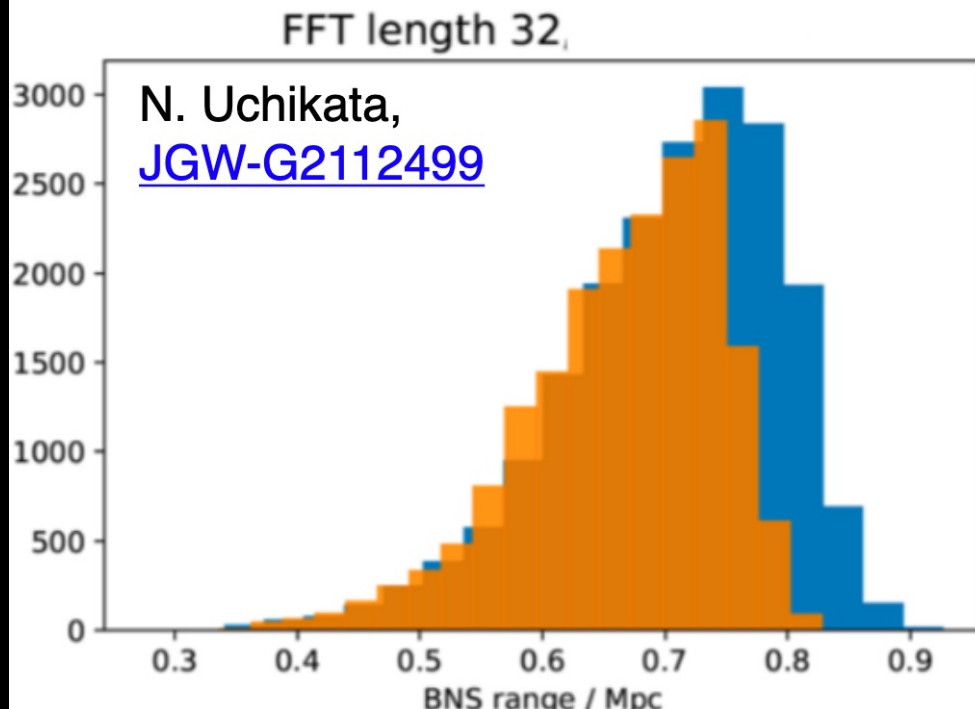
AdV+ Phase I





Status of KAGRA

- **O3GK** observing run on April 7-21, 2020 with GEO
- Detector sensitivity was **~ 0.7 Mpc** (~ 1 Mpc at best)
We originally planned to reach 8-25 Mpc for O3
- Detector configuration was **power-recycled FPMI**
We originally planned to operate with dual recycling
- Focus of this talk: ***What do we prepare for O4?***



Status of LHO



Photo: Chandra Romel

Who's who at LHO

New faces 😊

- Cory Grimmer – Site safety
- Nidhi Patel – Operator
- Craig Cahillane – Postdoc
- Mitchell Robinson - Instrument Assembly Technician

- Aurora Shaffer (c/o TJ Shaffer)
- Neal Grabeel (c/o Sheila Dwyer)



Cory Grimmer



Craig Cahillane



Nidhi Patel

Who's who at LHO

Some departures ☹️

- Hugh Radkins (seismic engineer) retired
- Jeff Bartlett (operator) retired
- Niko Lecoeuche (operator) now at UBC



Site status – it's complicated!

Reconnecting...

	A	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM
3	RED = tentative																			
4		JUNE 21	JUNE 28	JULY 5	JULY 12	JULY 19	JULY 26	AUG 2	AUG 9	AUG 16	AUG 23	AUG 30	SEPT 6	SEPT 13	SEPT 20	SEPT 27	OCT 4	OCT 11	OCT 18	OCT 25
20	People Out	TJ out ~June 18-June25	Chandra out June 28-July6	Rahul out	Kyle out few days	Chandra out few days														
21	DOORS				HAM 3 DOORS OFF HAM7 DOORS OFF	HAM & DOORS/ ARM ON	HAM5 DOORS OFF HAM4 DOORS OFF	HAM7 ARM OFF, W DOOR ON, S DOOR OFF	HAM6 DOORS OFF	BSC DOORS ON	HAM4 DOORS ON		HAM5 DOORS ON VENT EX	PUMP CORNER minus H6 H7	PUMP EX VENT EY	PUMP EY				
22																				
23	CDS/EE	CDS A+ SUS install			Install New CDS Fileservers	Test File servers		IO Chassis arrive	Upgrade End station IO Chassis	Upgrade corner station IO Chassis	Upgrade corner station IO Chassis	Upgrade corner station IO Chassis	Upgrade corner station IO Chassis							
25	DET/OPS/COMM			Install FC1 into HSTS SUS near H3		Kit TMS Baffle												COMMISS START?	ETMs arrive onsite	BONDING LLO ETMs
28								Las Haz on/off	Need PSL beam (or NPRO) ~200mW				Finished PSL IFO beam align check?							
29	BSC 9 10												EX charge meter in-situ reset	End vents ? - TMS Baffles, cryobaff	End vents ? - TMS Baffles	End HWS work?				
30	HAM7	Install new CR	Install new CR Dirty H7 Cabling	Install new CR Dirty H7 Cabling	Doors OFF, Arm On	Install HPDS ZM2 and 5 and ISC paths	Install OPO, cable, suspend	Door on/off	Con't Commission OPO/Squeezer beam alignment (Lee/Dhruva)	Con't Commission OPO/Squeezer beam alignment (Lee/Dhruva)	align OPO to HAM5->7	Con't OPO commiss	Con't Cable/Test ZM 5, 4, 2 install FC1 HSTS baffle	con't HAM7 alignment lay Table baffles	Install HDDS ZM1 and ZM3, cable, test MM to FC1, etc (Lee/Dhruva)	Align HDS ZM1 ZM2 ZM3, HDS baffles latest	SQZ table work (Lee/Dhruva)	Align HDS ZM1 ZM2 ZM3	ISI rebalance	Install Nozzle Baffles
32	HAM5	Install new CR	Install new CR	Install new CR	(OFI arrives to lab from UF1 ?)	Lab OFI work, kit DCPD path/posts, etc	Deinstall OFI table to chamberside, fix other HAM5 FRSES	Swap TT to HSDS ZM6	Slide OFI structure new location, Reinstall OFI, suspend, test	OFI, align into HAM6 (MC flashes, coaligned with SQZ beam), lay DCPD path	OFI, align into HAM6 (MC flashes, coaligned with SQZ beam), lay DCPD path	Con't Reinstall OFI, install shroud, recheck alignment	New table baffle/ SRM baffle/ ZM6 baffle	Clean SRM/SR3, ISI Rebal, Nozzle baffle, Close up						
34	HAM6	Install new CR	Install new CR	Install new CR				Open +X door	Alignment checks of beams into HAM6	Alignment checks of beams into HAM6		Translate OM1 position, fix alignment path	OMC Scans	Possible HTDS OM2 install Install DCPD	Alignment of HAM6	ISI rebalance				
36	HAM 3 4				Install HAM3 Baffles, HAM3 GS13 Fix	HAM3 ISI rebalance		HAM4 HWS Pico Mtr Install MCT Baffle add-on	HWS Align X and Y	Close up	Roll table back up to chamber	Cable in-air pico Work HWS in-air upgrade, realignment								Work HWS in-air upgrade, realignment
38	BSC 1 2 3	Fix TCSX	Clean ITMX Mod BS Gold Baff FRS 9601	Nozzle Baffle install at both X/Y Manifold	CPBx dampers 14602 GV inspection at spool?	CPBy dampers 14602 GV5 seal replacement	Unclamp/ clean ITMs and BS Close	BSC3 E VP rebuild	Roll TCS table back up to chamber	Work TCSX Periscope, table alignment										Fire up TCS Lasers

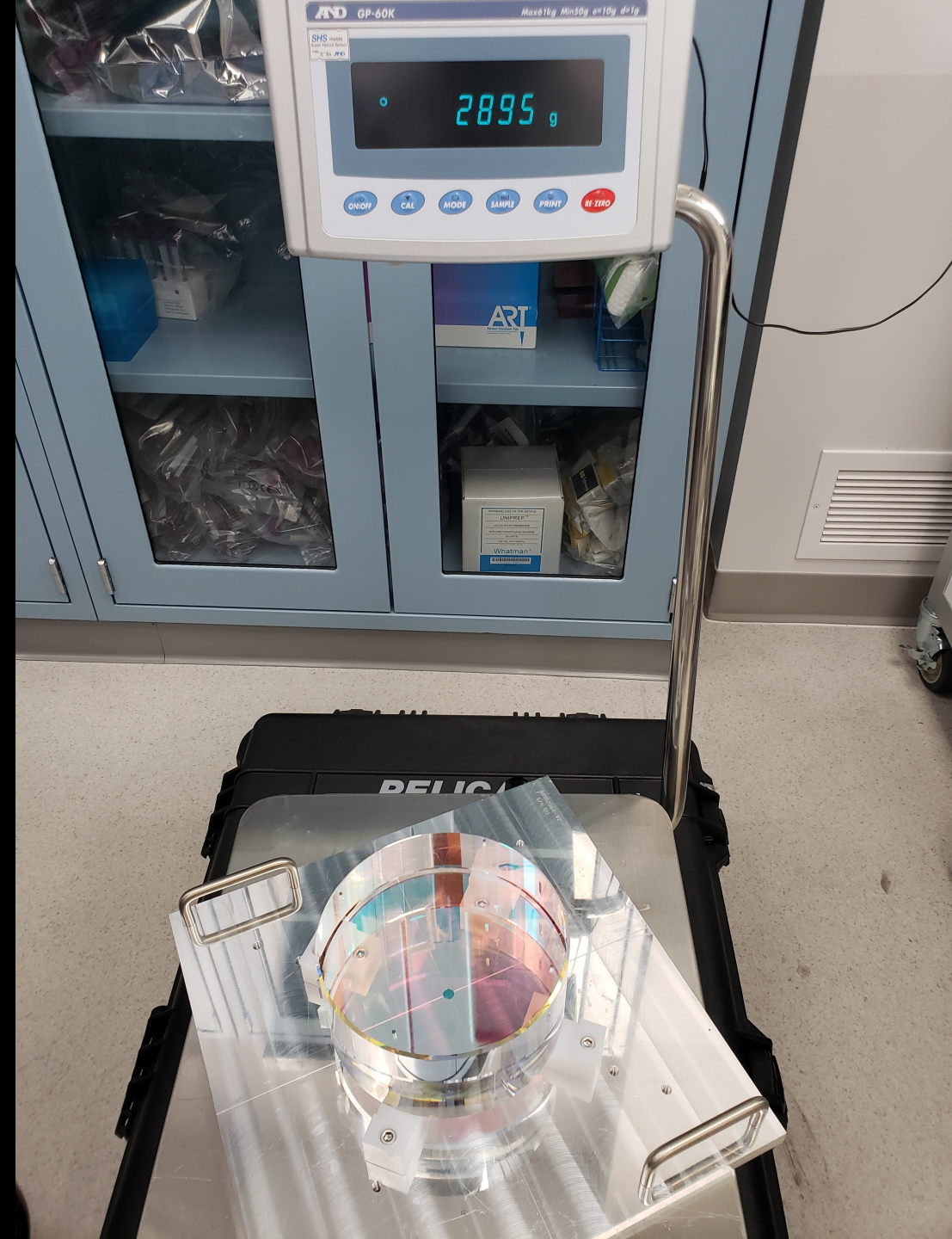
Site status (1/3)

- LIGO exploration center (LExC) is under construction
 - New outreach center at Hanford – see discussion led by Amber at 4pm!



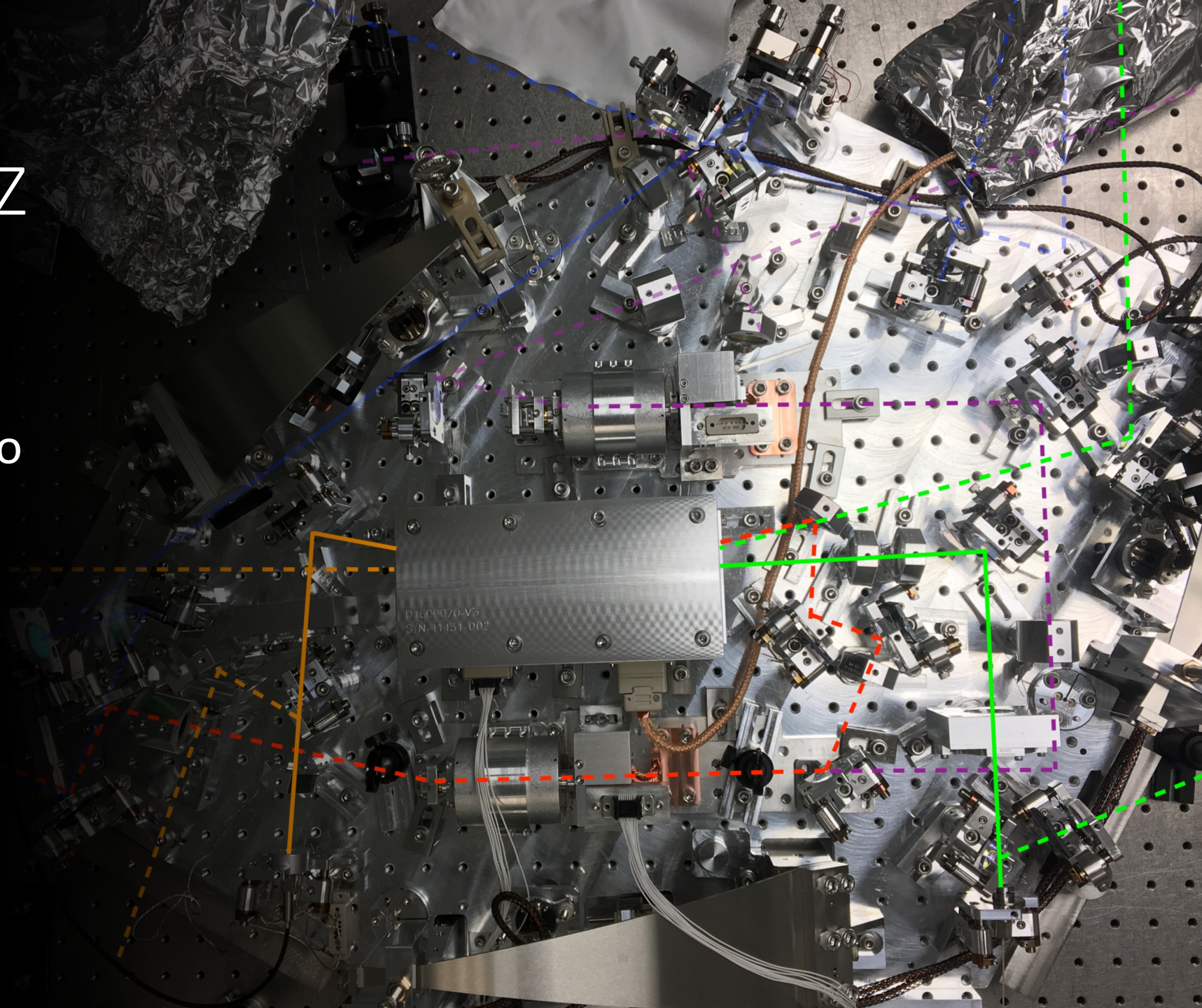
Site status - SQZ

- Frequency-dependent squeezing
 - Massive facilities undertaking!
 - Two new HAMs to hold filter cavity optics
 - New FC “end station” – the HAM shack
 - New 300 m beam tube
- Anticipate install of squeezer, FC optics in August– October 2021



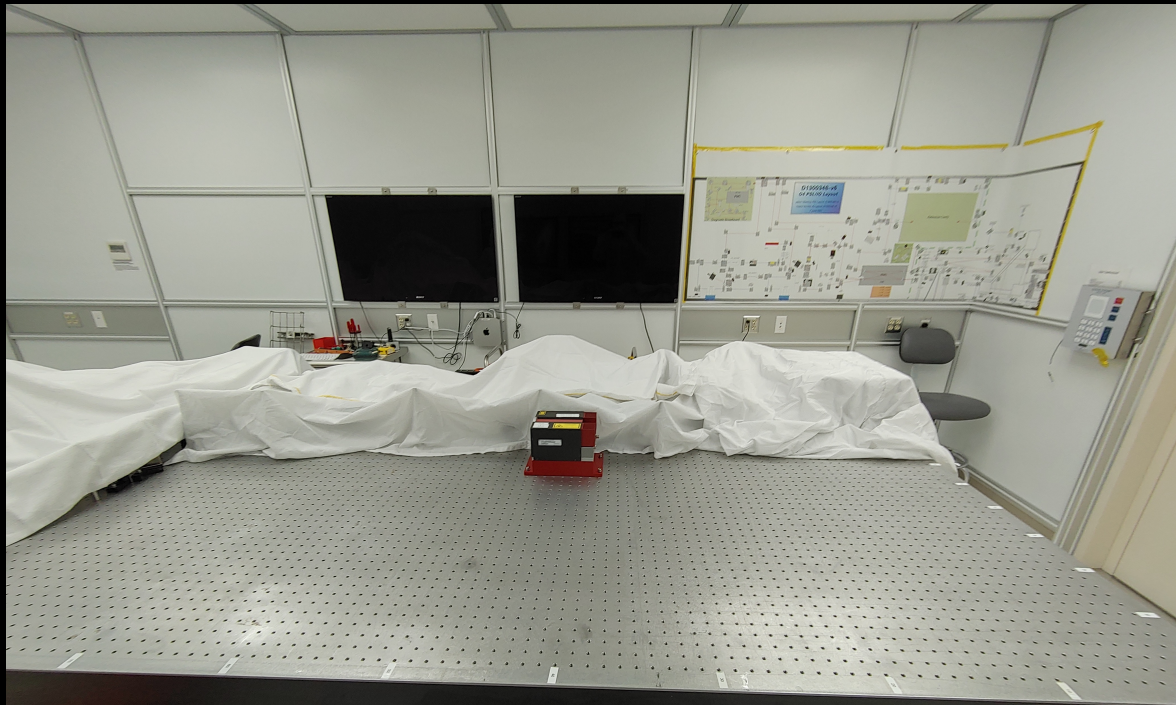
Site status - SQZ

- New paths on the squeezer platform to route beam to and from filter cavity

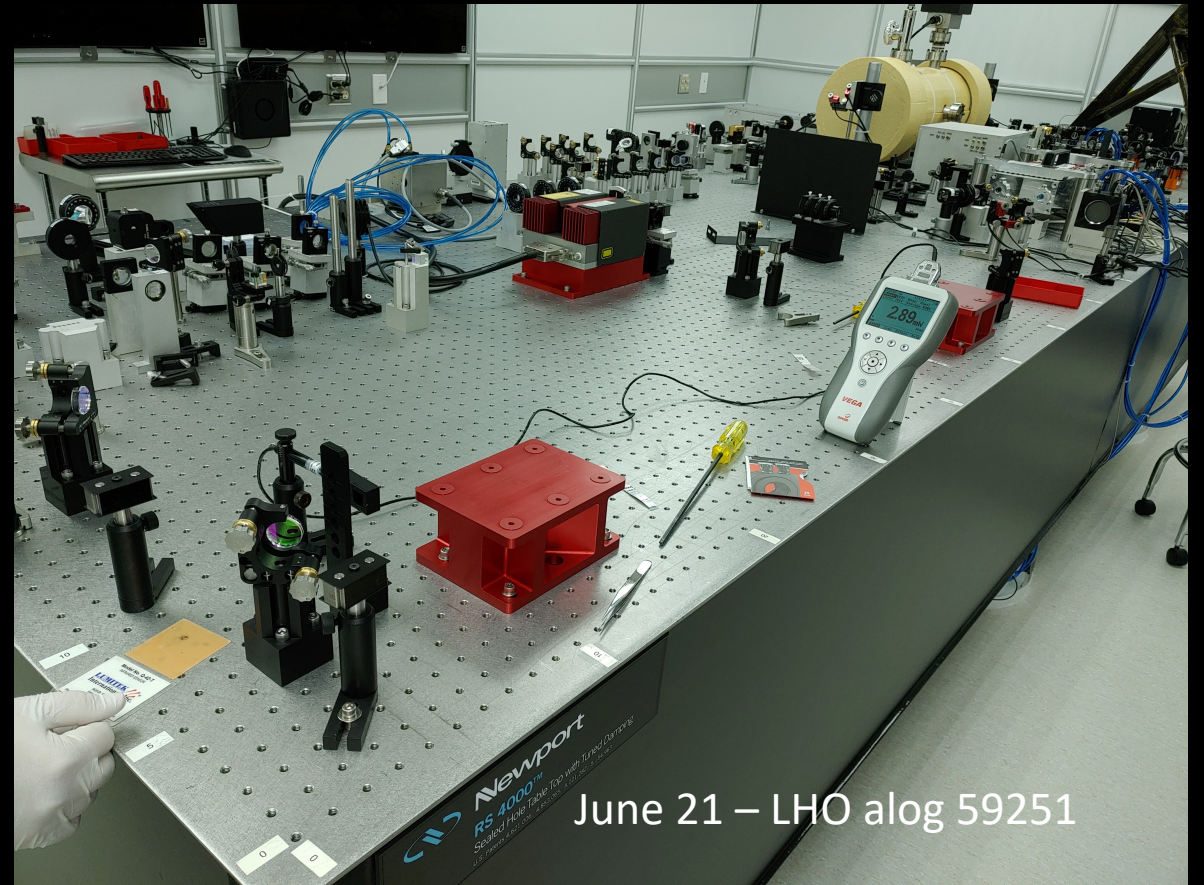


Site status - PSL

- New amplifier = more power out of the pre-stabilized laser
- Visual progress! Complete table re-alignment



June 9 – LHO alog 59172



June 21 – LHO alog 59251

Site status – going in chamber

- Many other vacuum incursions in the works!
- Replaced ITMY in December 2020
- Installing new stray-light baffles
- Upgrading thermal compensation system
- Moving the squeezer to a fresh HAM
- New output Faraday isolator install



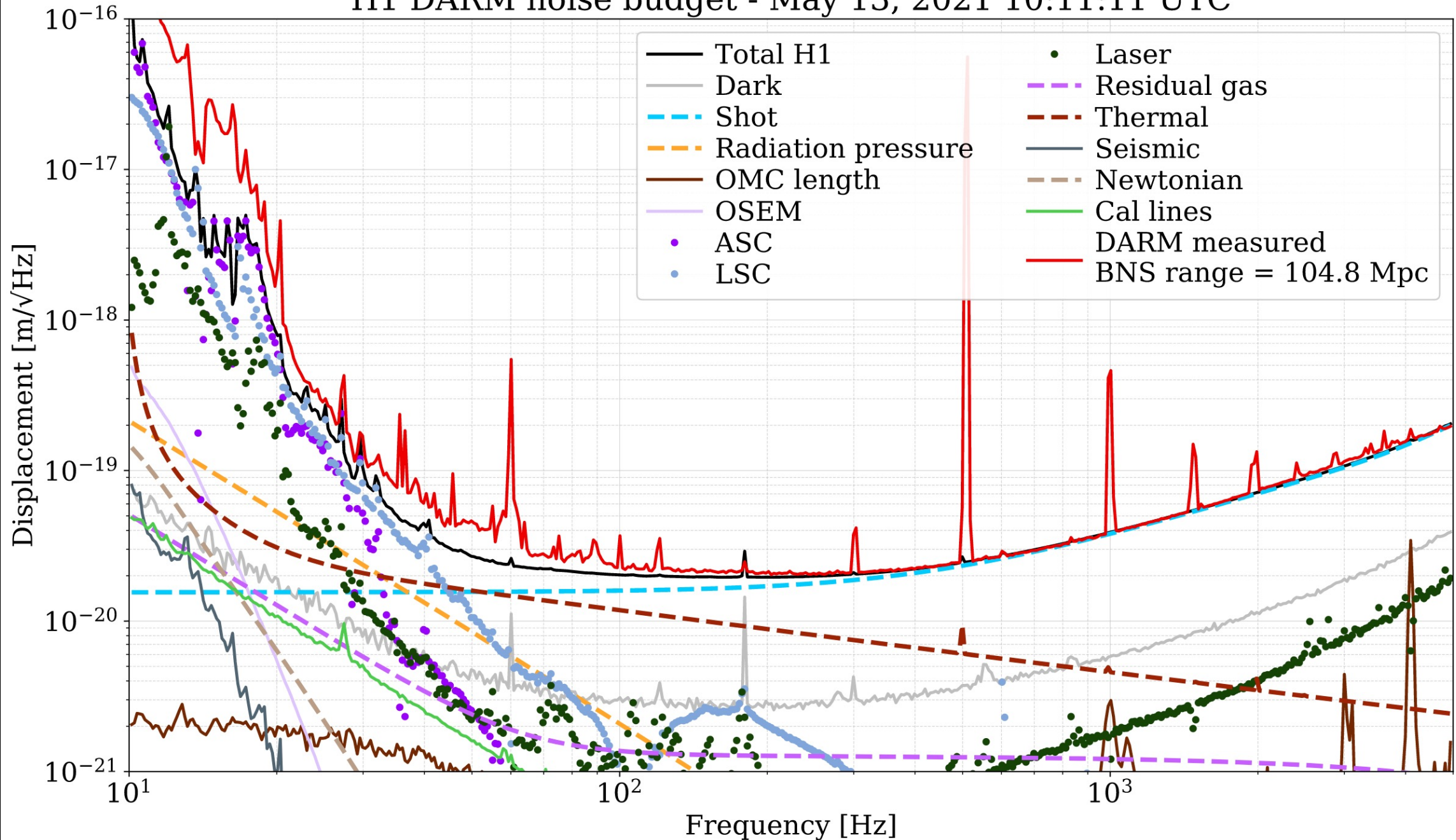
Travis Sadecki and Sebastien Biscans with new ITMY

Pre-O4 mini commissioning period

- In March/April 2021 we had a commissioning period*
- Good news: new ITMY has no significant point absorbers!
 - Reduced scatter coupling
 - Angular controls became more stable and reasonable
 - Powering up was easier! Reached 47W requested from PSL
- Bad news: mystery noise (20-80Hz band) was consistent with O3

*vacuum envelope pumped down, commissioners “get” the interferometer, we work on acquiring lock and reaching low-noise configuration

H1 DARM noise budget - May 13, 2021 10:11:11 UTC

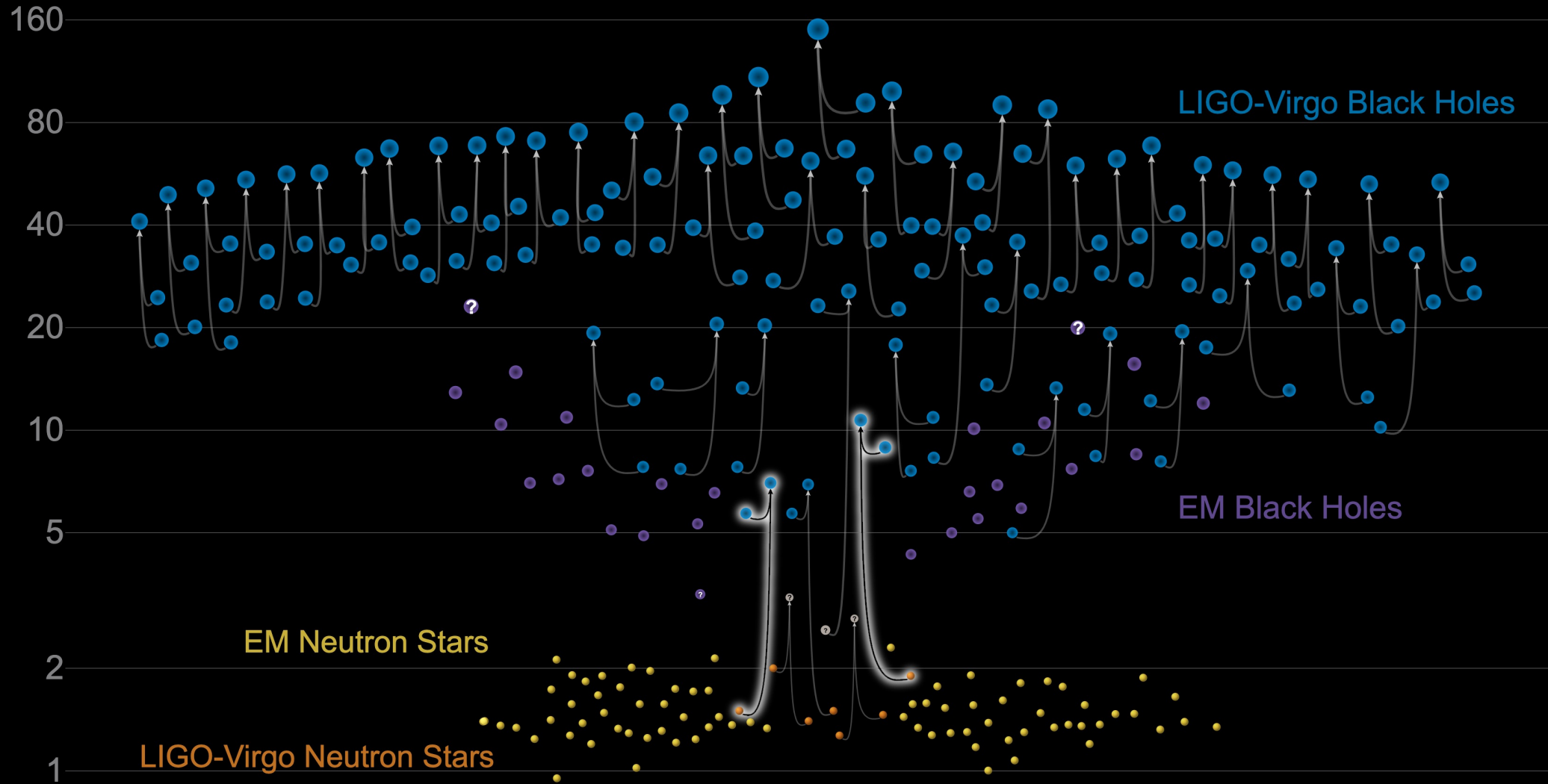


Conclusion

- All hands on deck as we push towards O4 (and O5!)
- Ambitious target sensitivity (160-190 Mpc for aLIGO), but we have some ideas of how to get there
- Exciting upgrades to many systems
- Expect more BBHs, BNSs, NSBHs in 2022!

Masses in the Stellar Graveyard

in Solar Masses



GWTC-2 plot v1.0

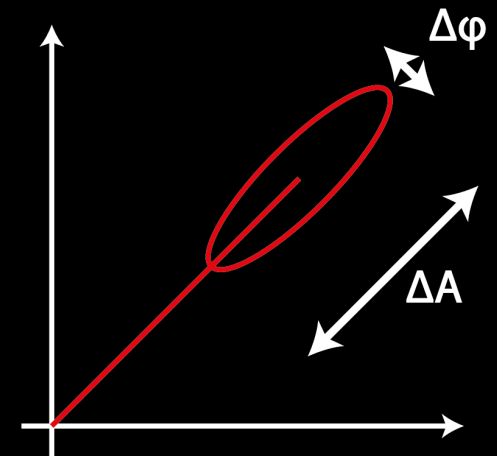
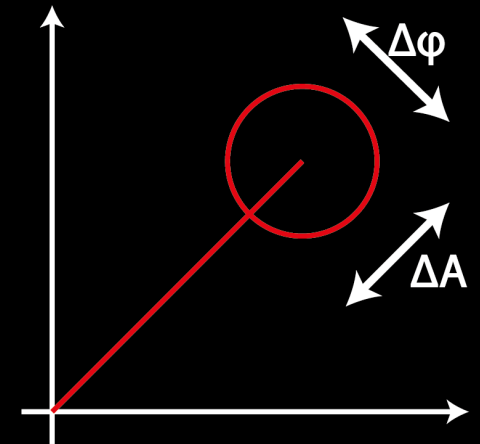
LIGO-Virgo | Frank Elavsky, Aaron Geller | Northwestern

Frequency-dependent squeezing in a nutshell

- Shot noise is caused by the quantum nature of light
- Heisenberg uncertainty principle relates the amplitude and phase uncertainty

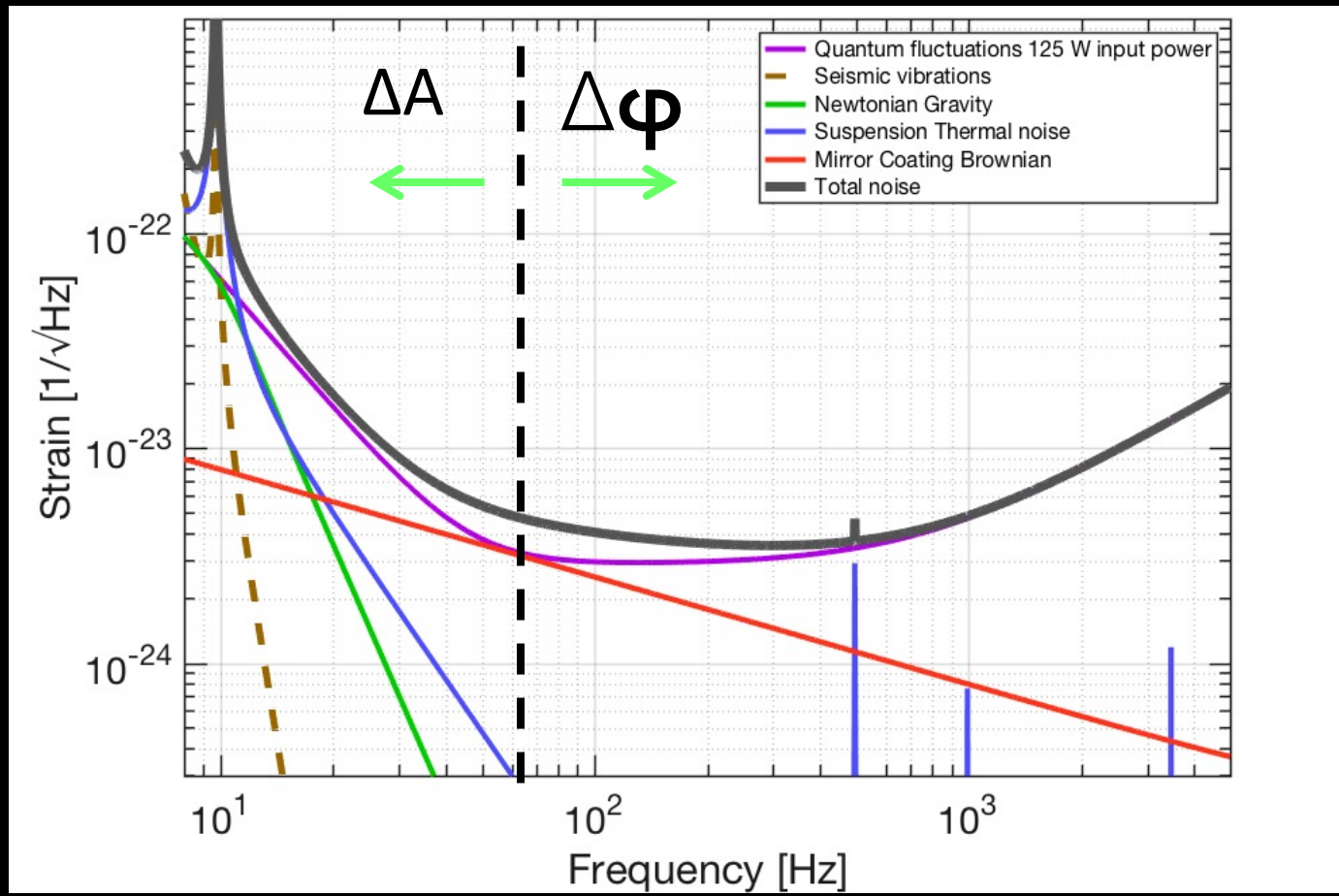
$$\Delta A \Delta \phi \geq 1$$

- Squeezing is reducing the noise in one quadrature at the expense of the other
- Squeezing is produced in a nonlinear crystal



Frequency-dependent squeezing in a nutshell

- Shot noise is associated with phase quadrature
- Radiation pressure noise is associated with amplitude quadrature



Frequency-dependent squeezing in a nutshell

- In O3 we injected phase squeezing only – improved shot noise but made radiation pressure noise worse!

