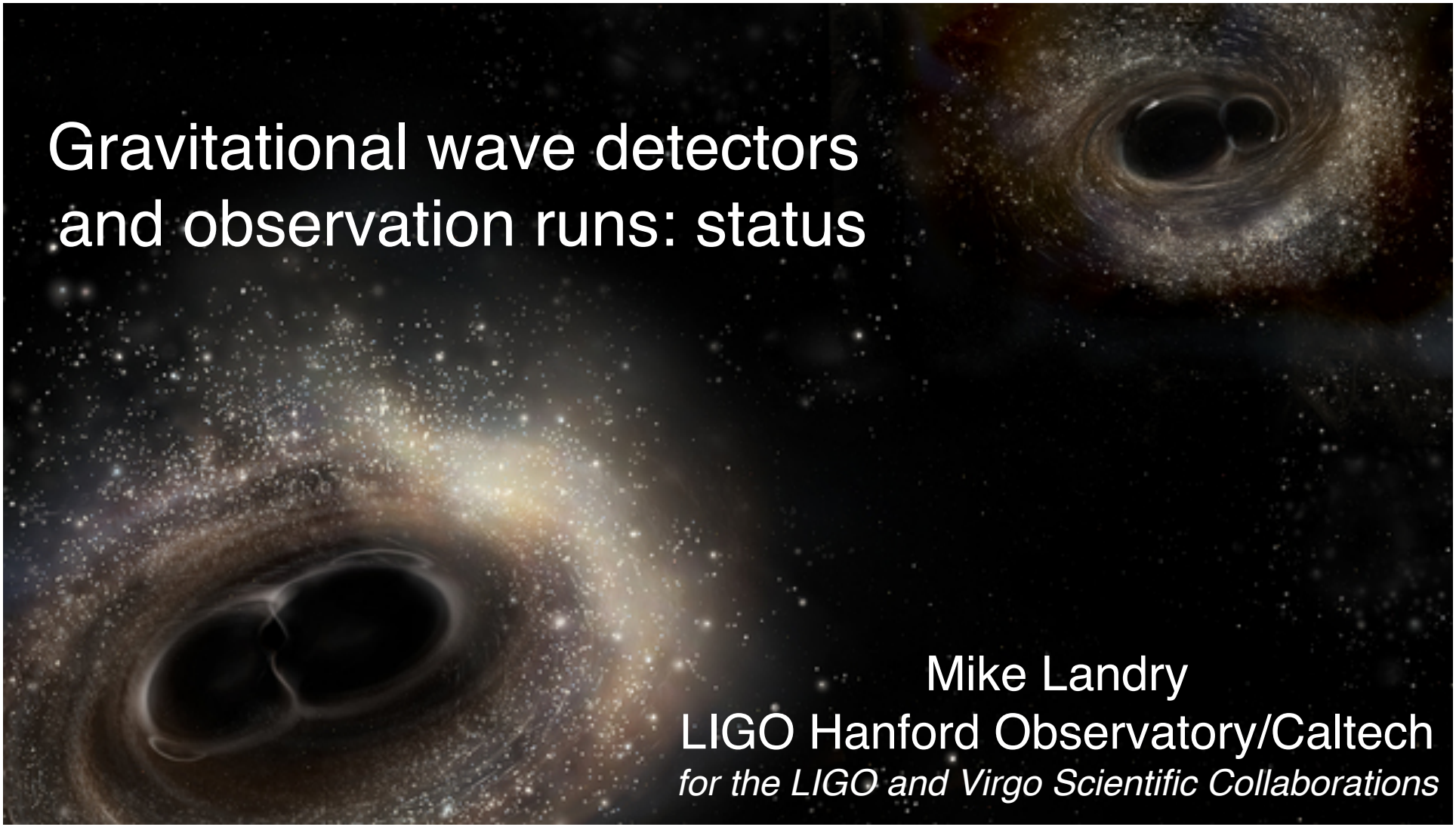
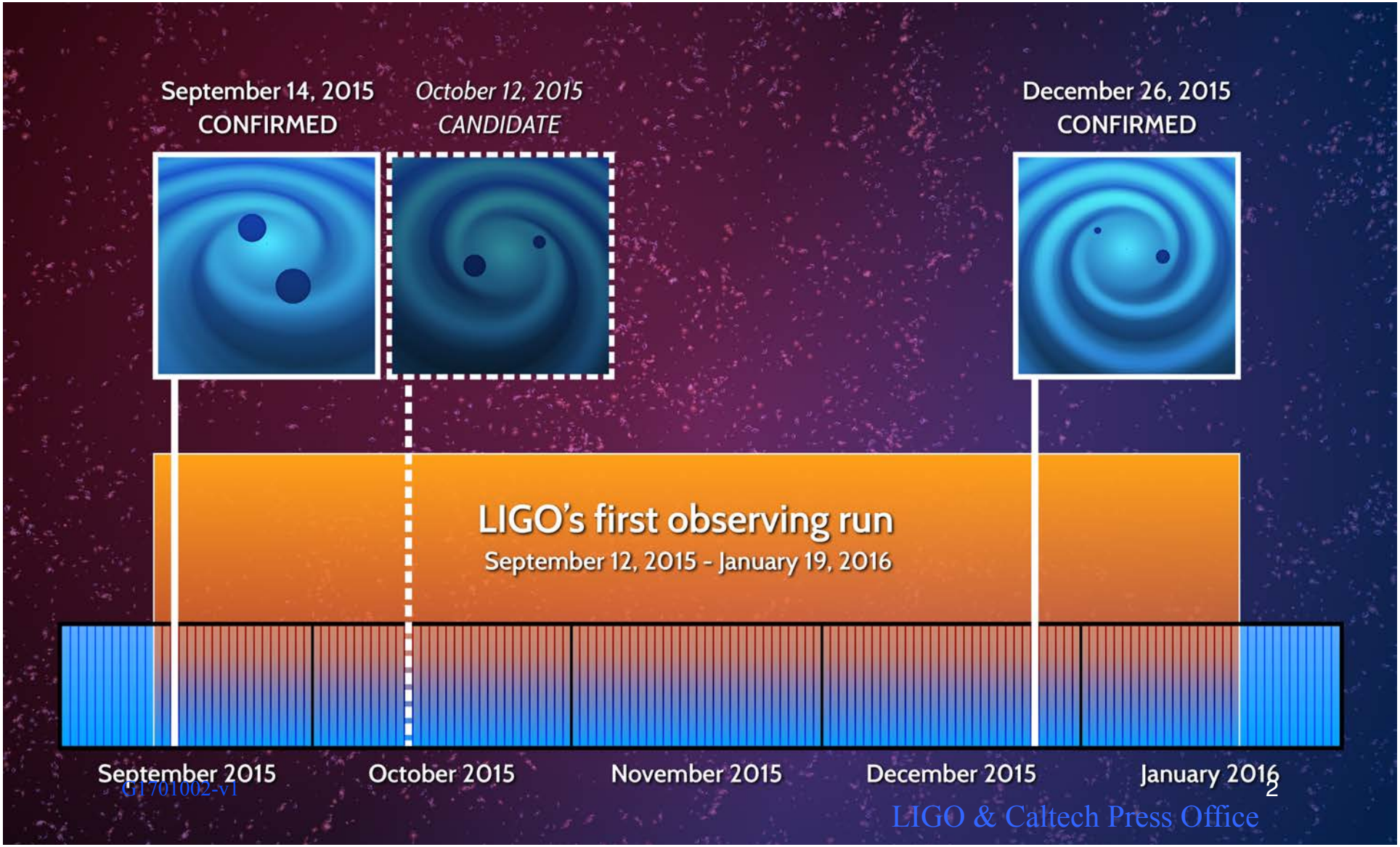


Gravitational wave detectors and observation runs: status

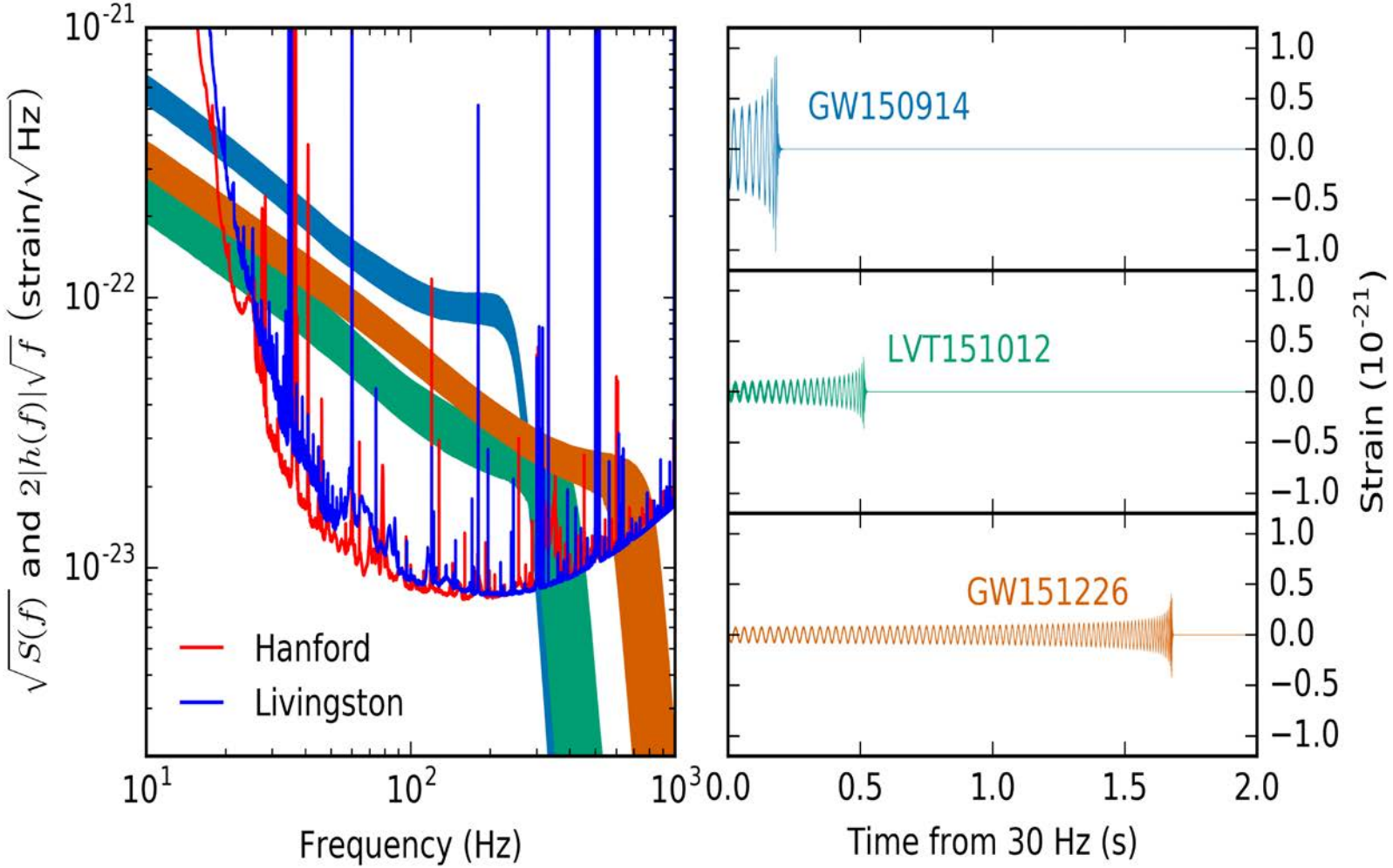
Mike Landry
LIGO Hanford Observatory/Caltech
for the LIGO and Virgo Scientific Collaborations

O1 events



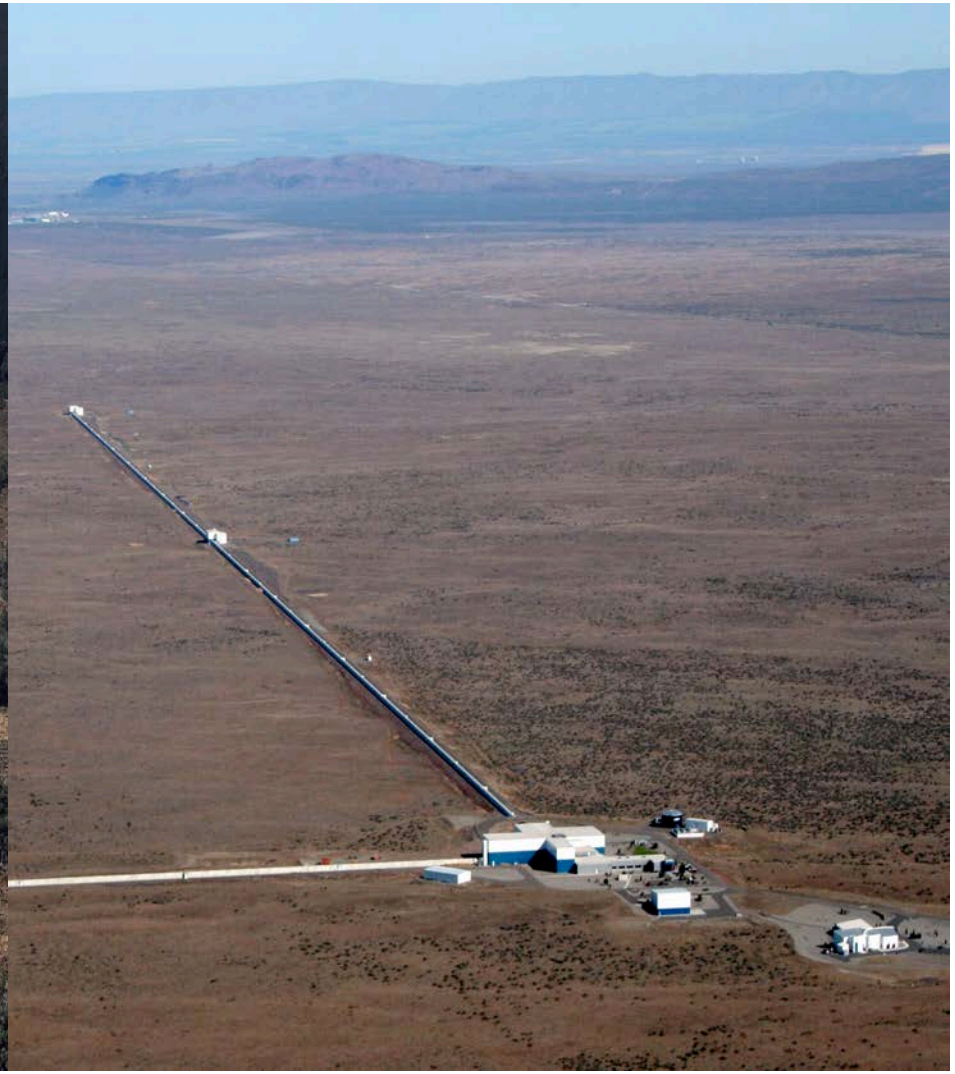
LIGO & Caltech Press Office

Comparing the three events

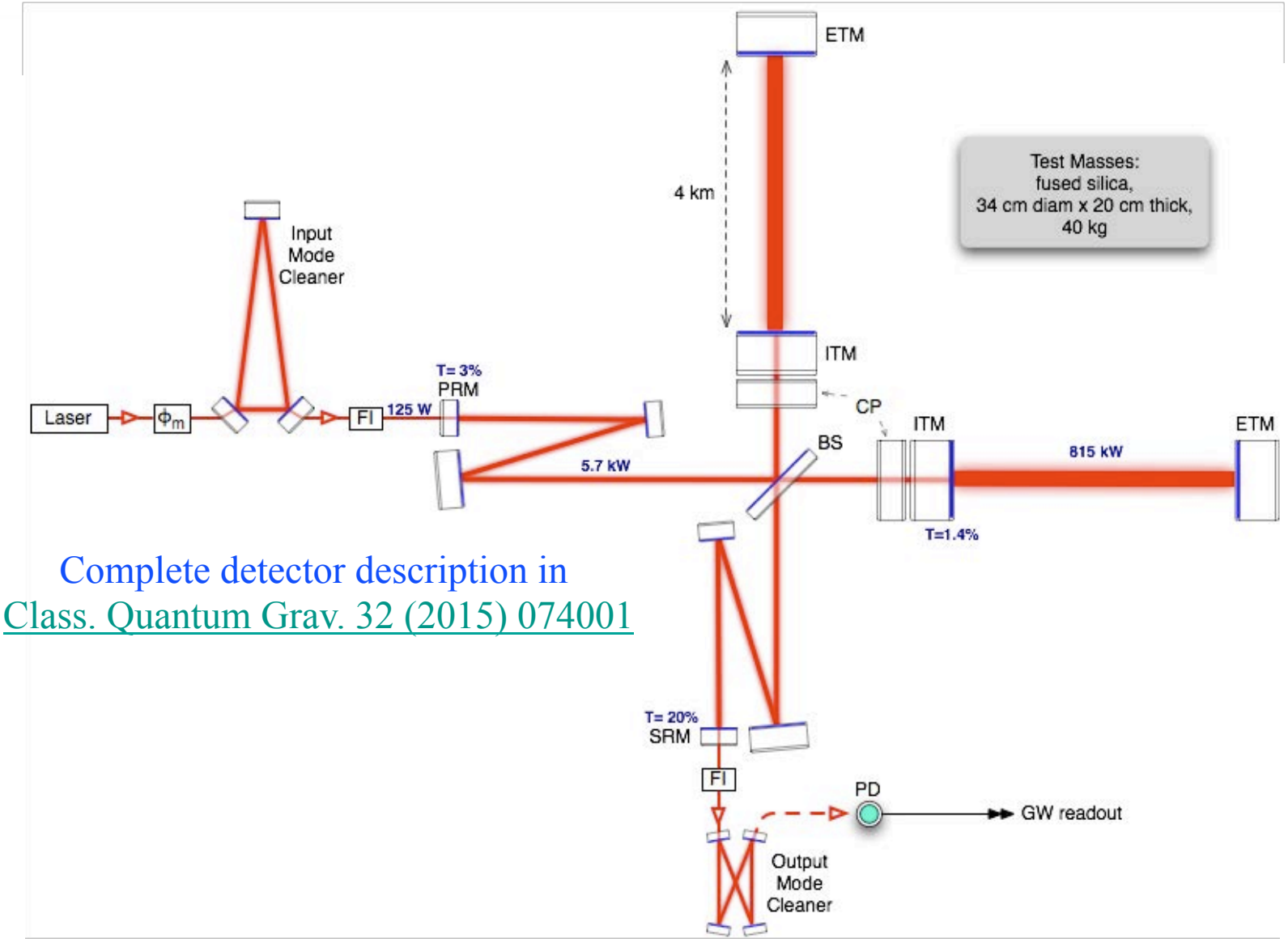


Phys. Rev. Lett. **116**, 241103, Phys. Rev. X 6, 041015 (2016)

LIGOs Livingston and Hanford



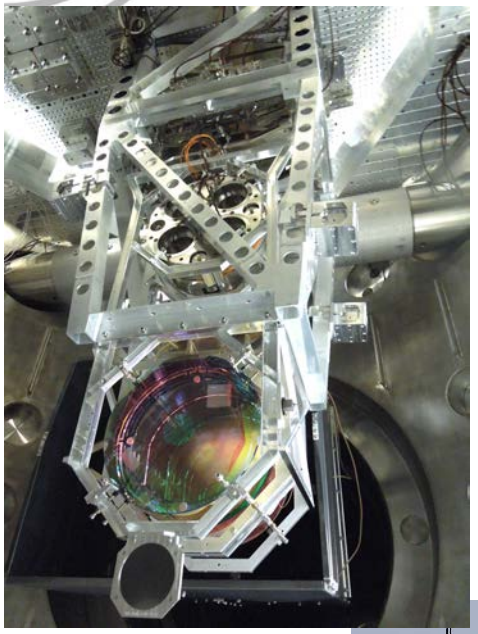
Optical configuration



Complete detector description in
Class. Quantum Grav. 32 (2015) 074001

Seismic Isolation

SUS designed and contributed by UK/GEO

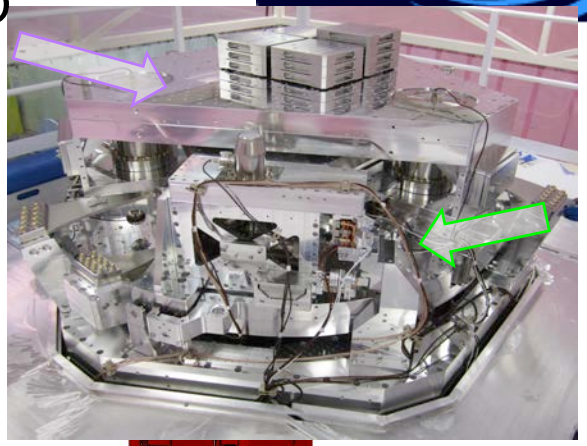


Ground Motion at 10 [Hz] ~ 10^{-9} [m/rtHz]

$$\Delta L = h\ L \sim 10^{-19}\ m / Hz^{1/2}$$

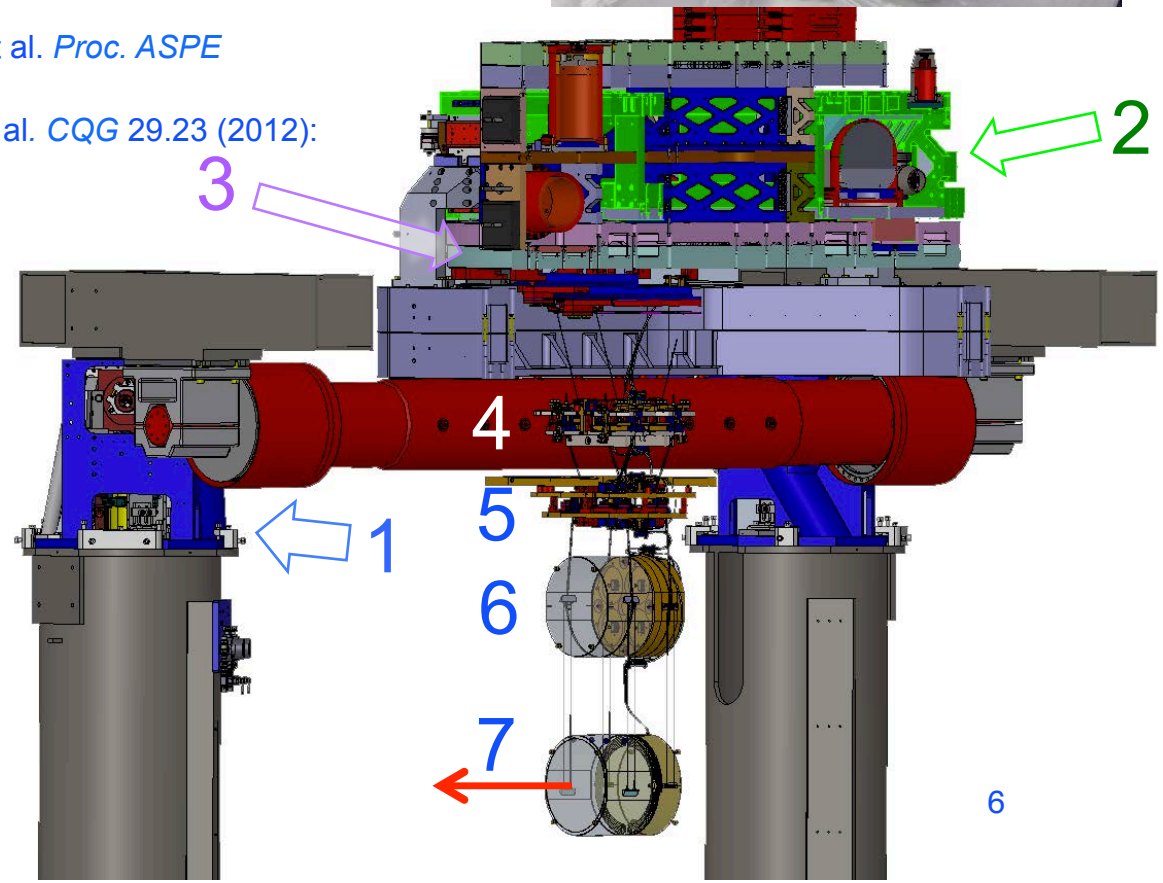
Need 10 orders of magnitude

Test masses are suspended from 7 stages of active and passive vibration isolation

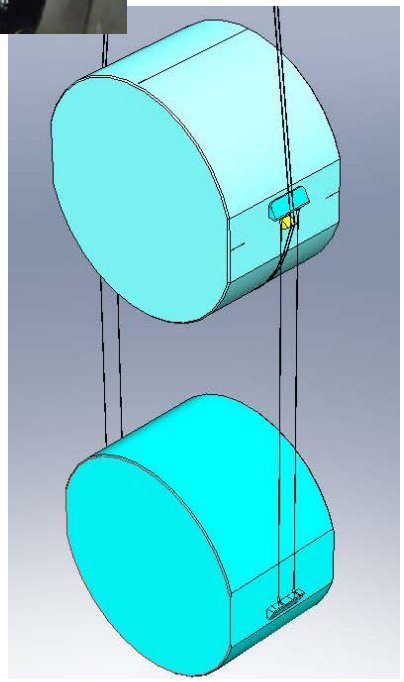


Matichard, F., et al. *Proc. ASPE* (2010)

Aston, S. M., et al. *CQG* 29.23 (2012): 235004.



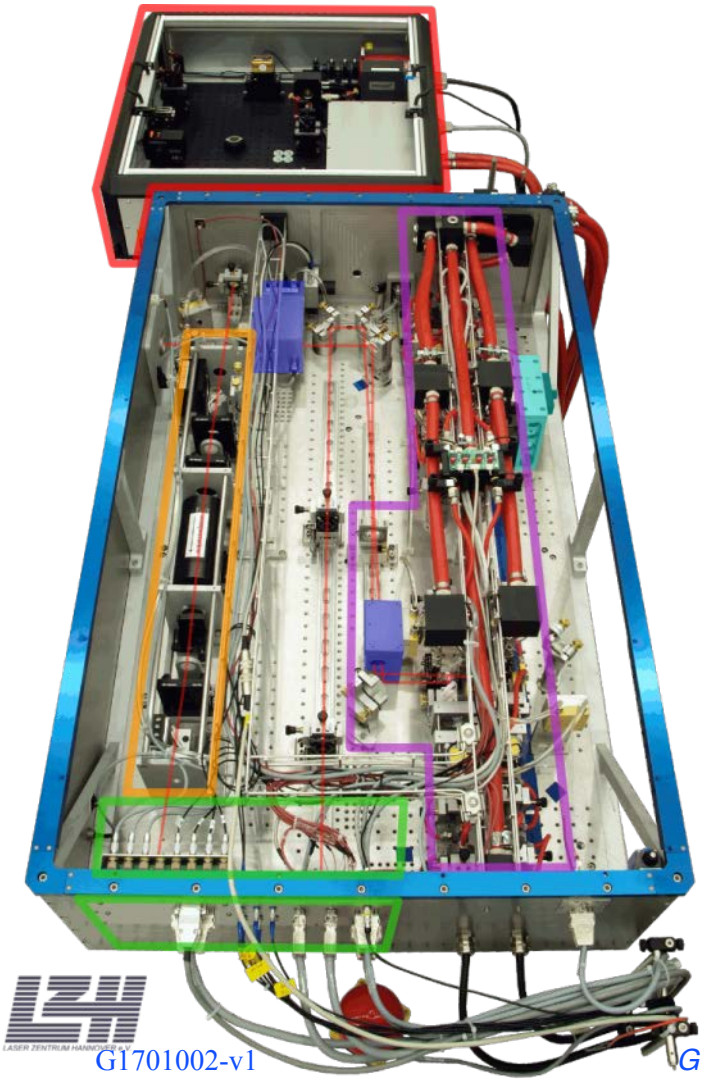
Last two stages are monolithic to improve Brownian noise

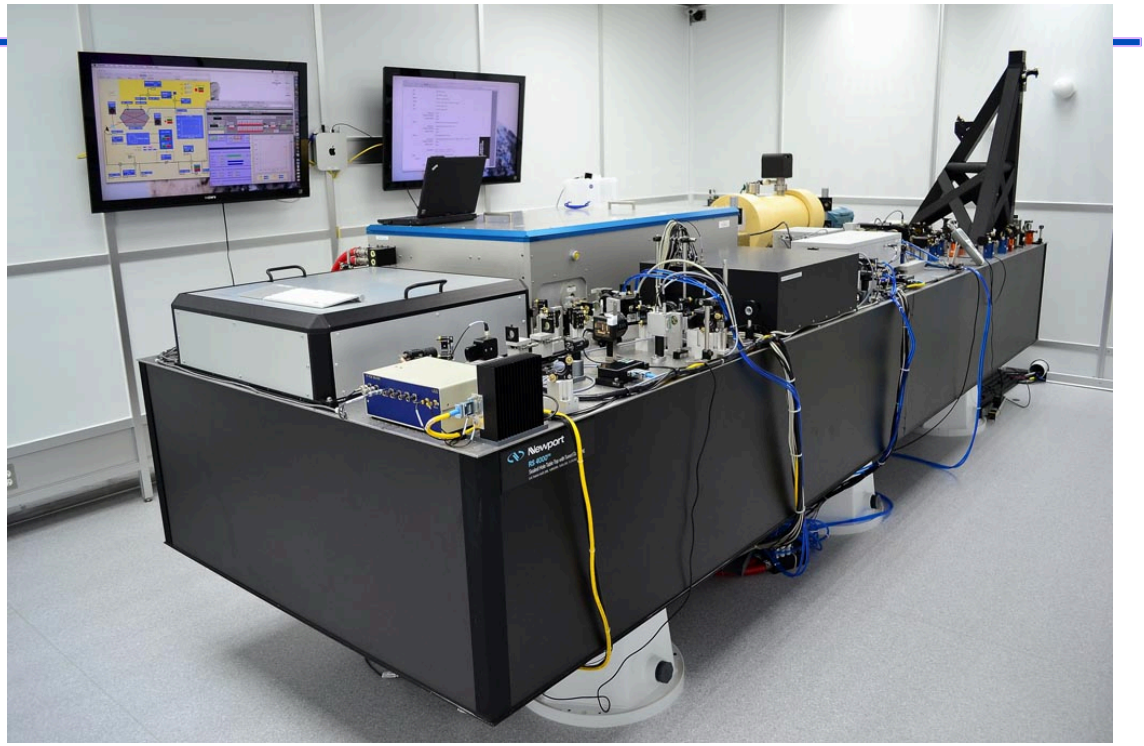


Cumming, A. V., et al. *CQG* 29.3 (2012): 035003.

200W Nd:YAG laser

Designed and contributed by Max Planck Albert Einstein Institute





- Stabilized in power and frequency – using techniques developed for time references
- Uses a monolithic master oscillator followed by injection-locked rod amplifier
- Delivers the required shot-noise limited fringe resolution

Post-O1 commissioning: *L1*

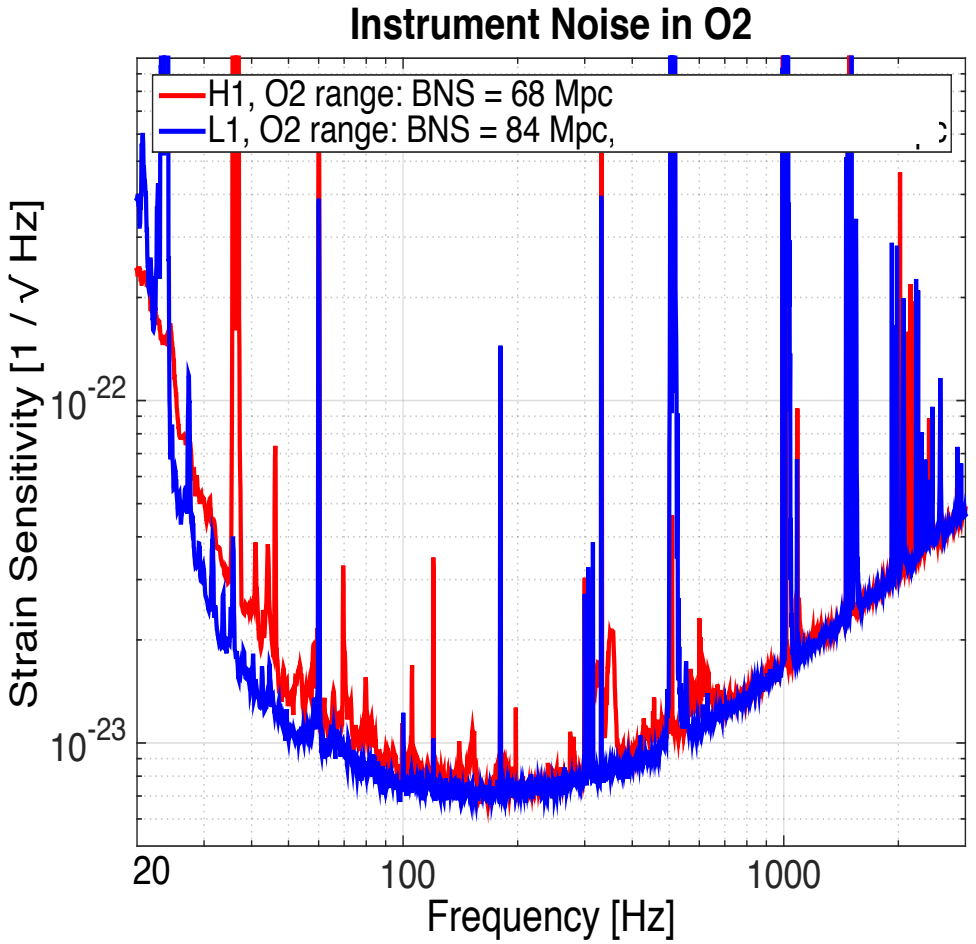
- Diagnosis and reduction of noise from scattered light off moving surfaces
  - » Several scattering sites identified in L1
  - » Compensation plate now “correctly” misaligned
  - » Scattering from photon calibrator periscope mirror identified, addressed in current vent (more on this later)
  - » Scattering and relative motion among one end station optics partially addressed
- Test-mass bounce/roll dampers, new photodiodes, new pre-mode cleaner, Faraday isolator, etc., in L1.
- Removed accidental noise from temperature sensor instrumentation in L1

Post-O1 commissioning: *H1*

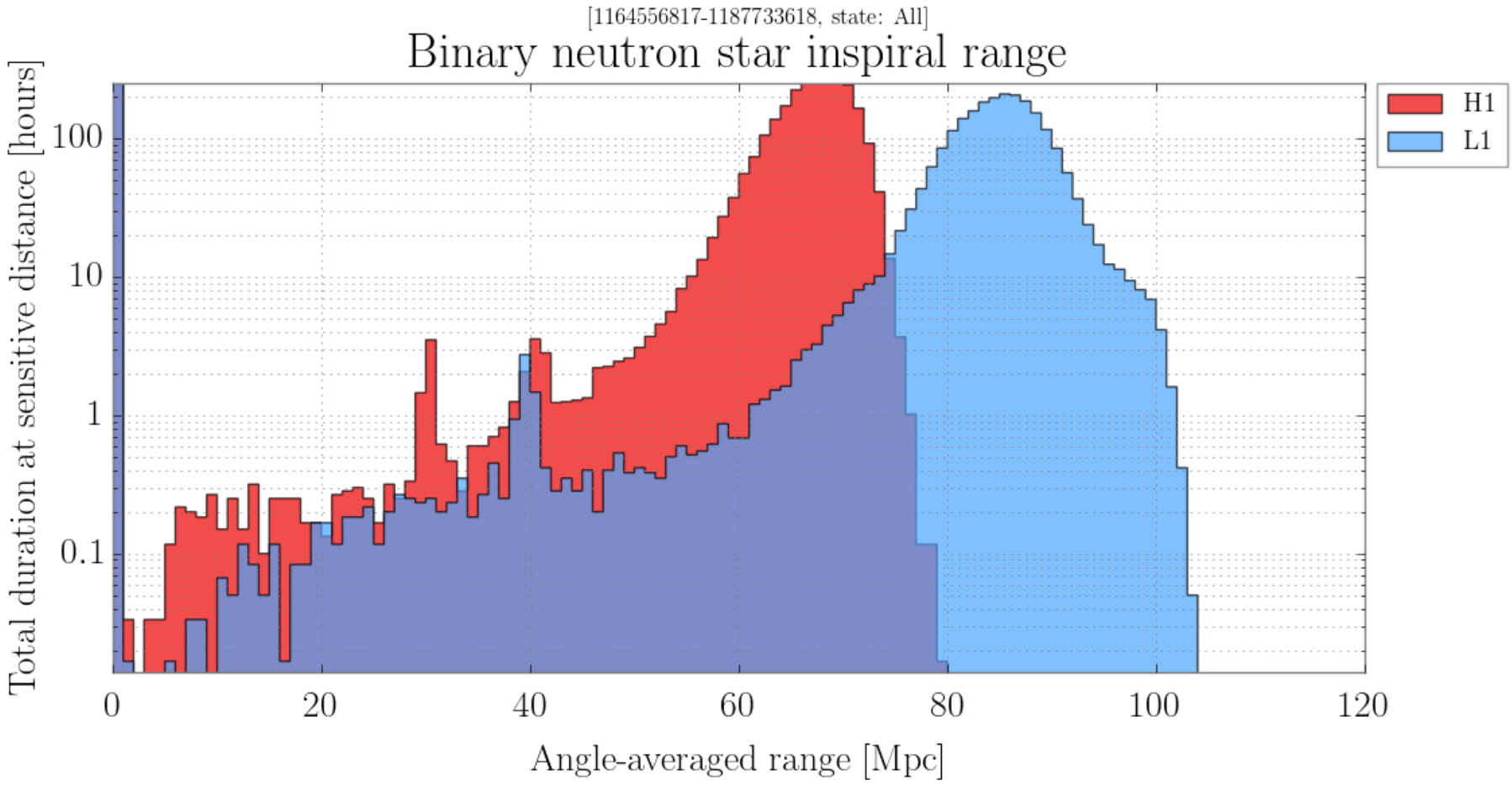
- High power stage (HPO) of H1 laser activated
  - » Required enhancements to angular controls
  - » Modified thermal compensation
  - » Development of techniques to reduce buildup of opto-mechanical parametric instabilities
  - » Study of beam jitter/geometry noise coupling to detector: excess beam jitter (both pointing and breathing mode) noted, plus excess coupling
- Beam rotation sensors (BRS)
  - » Tilt meters at both end stations allow for tilt-horizontal decoupling
  - » More robust interferometer operation in times of high microseism and winds at LHO

O2 observation run

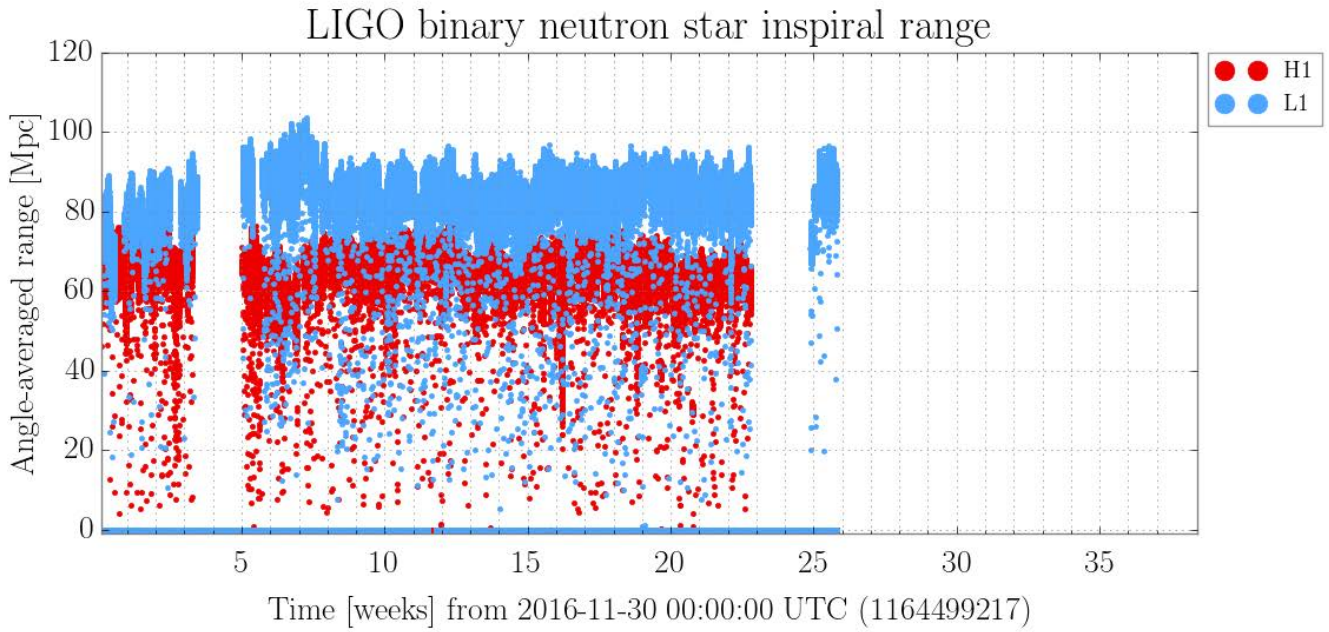
- The second Advanced LIGO run began on November 30, 2016 and is in progress. As of the current vent, approximately 75 days of Hanford-Livingston coincident science data have been collected, with two breaks (holiday season, current vent)
- Average reach of the LIGO network for binary merger events have been around 70 Mpc for 1.4+1.4 Msun, 300 Mpc for 10+10 Msun and 700 Mpc for 30+30 Msun mergers, with relative variations in time of the order of 10%.
- Approx. 45% of runtime has been coincident data (50% without recent vent downtime)
- *Six alerts sent to EM/ν partners*

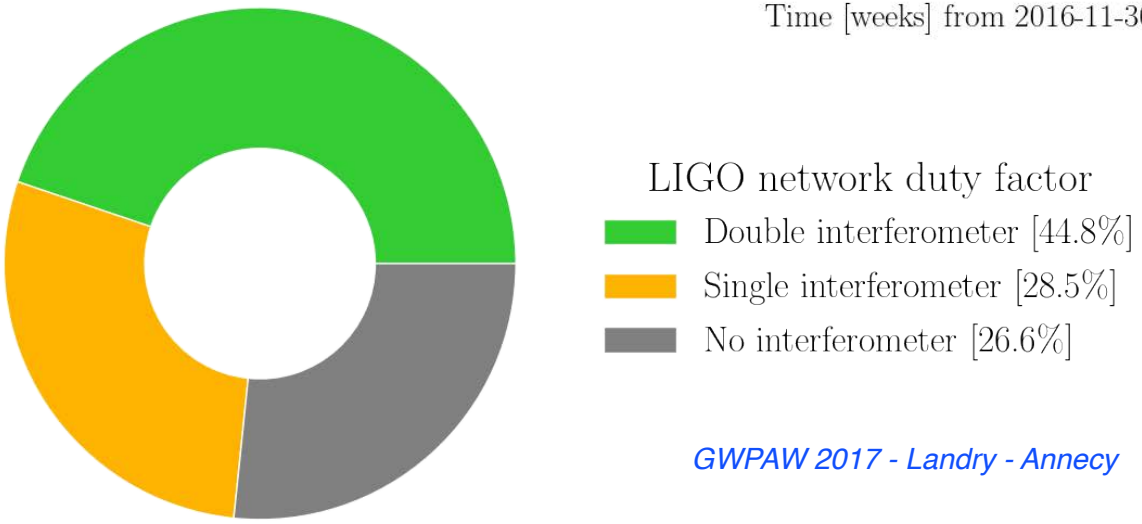


O2 Range

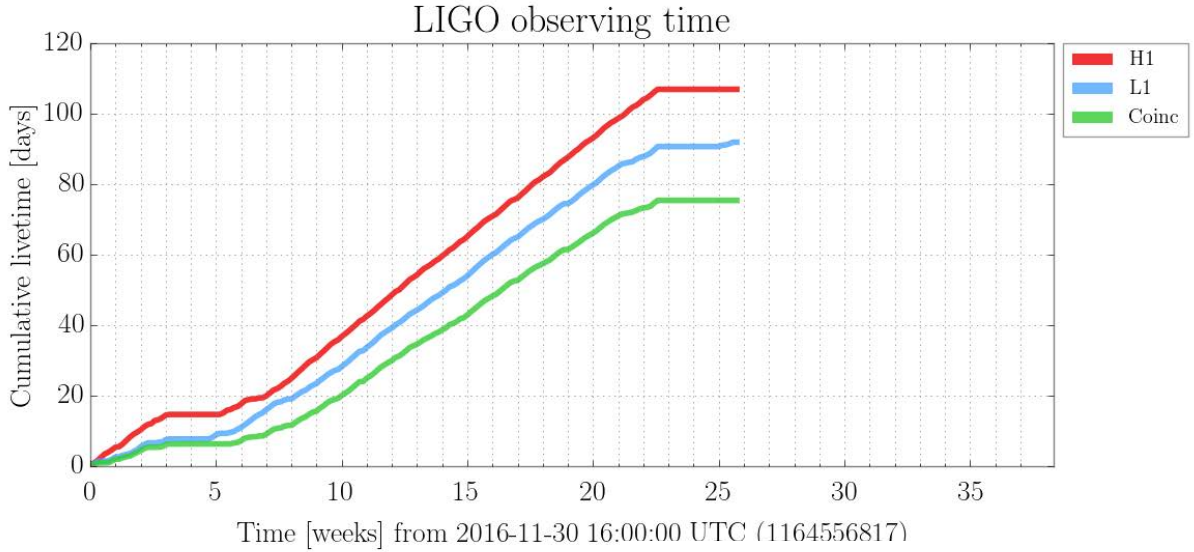

[1164556817-1187733618, state: All]
Binary neutron star inspiral range
Total duration at sensitive distance [hours]
100
10
1
0.1
0
20
40
60
80
100
120
Angle-averaged range [Mpc]
H1
L1

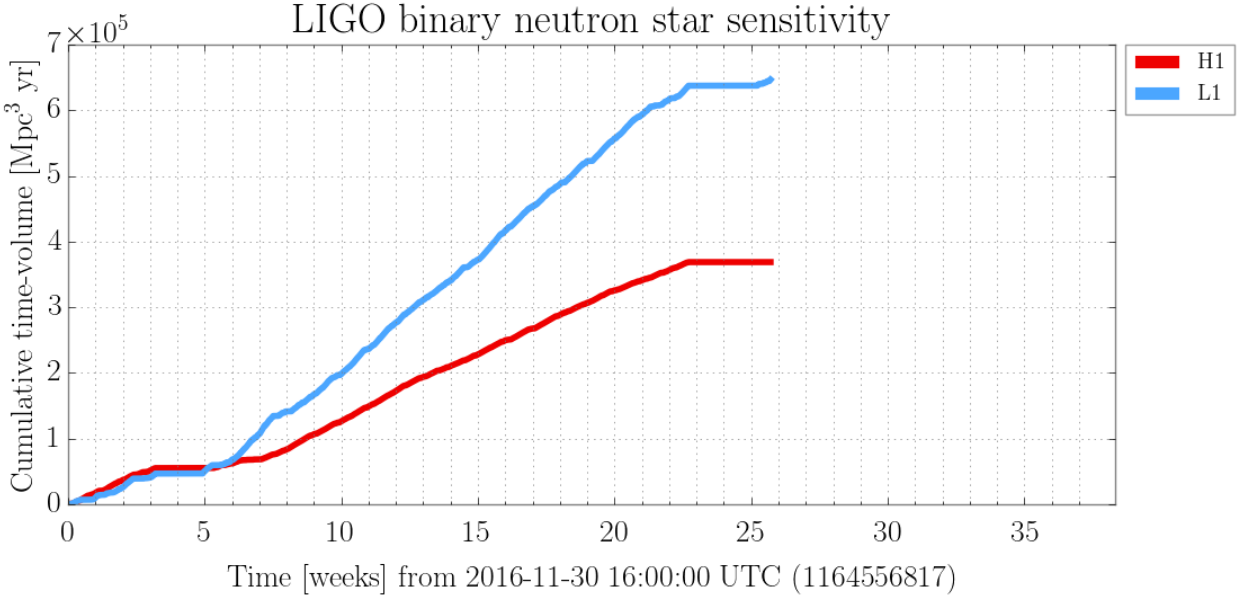
O2 Segments and duty factor





O2 Volume

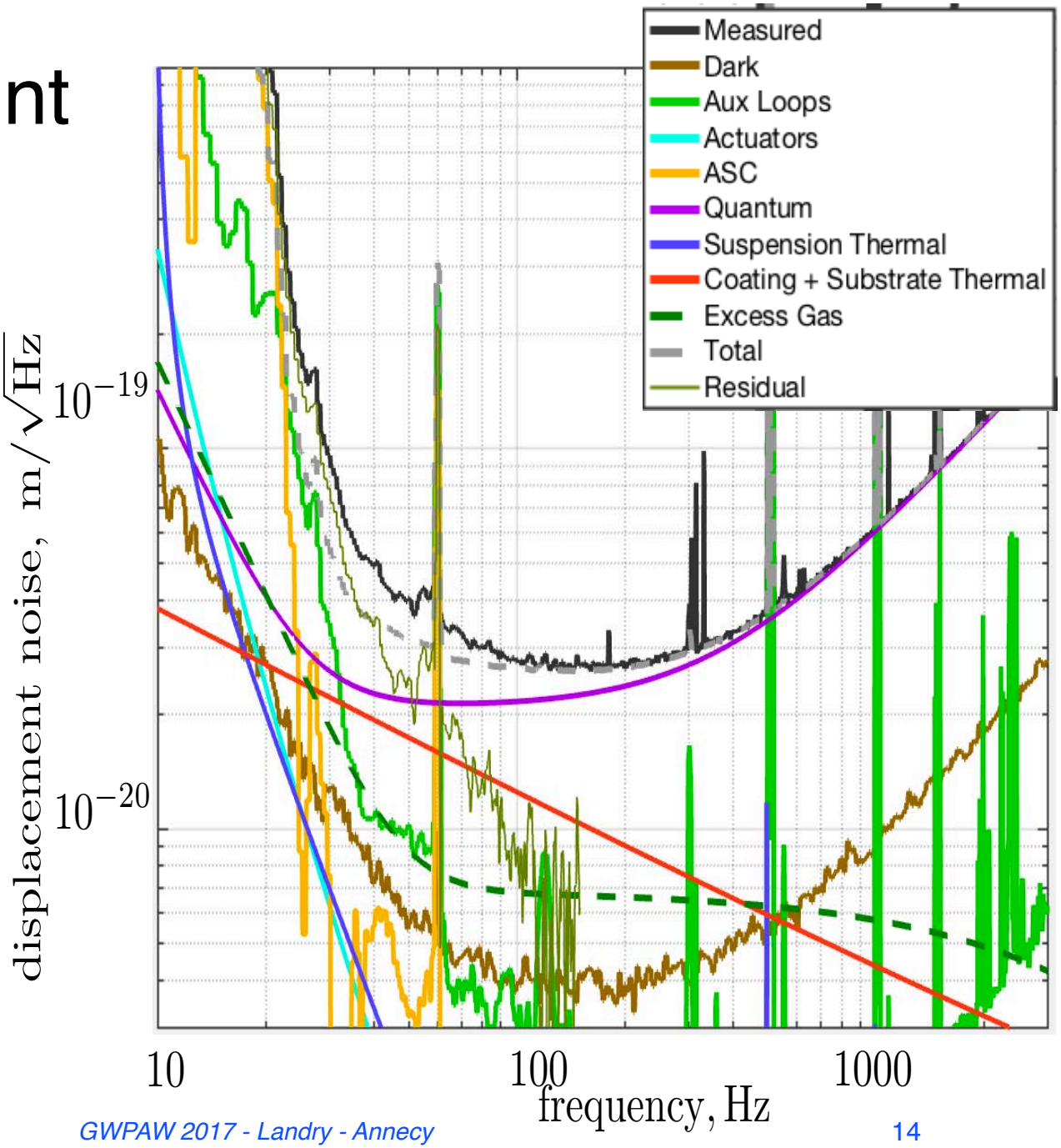




G1701002-v1

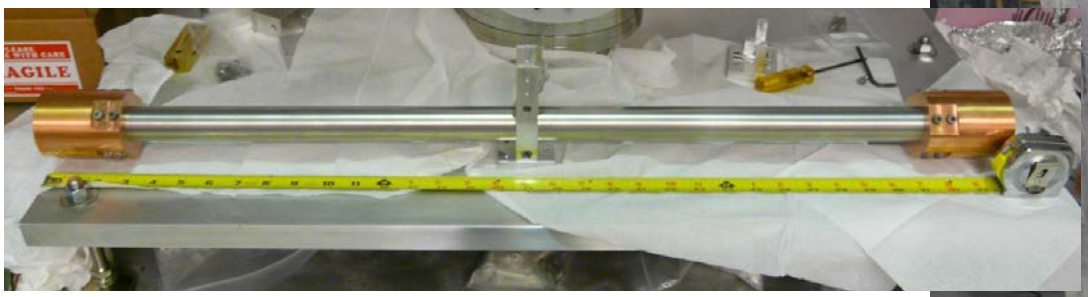
Displacement noise – L1

- Noise model of high-range data segment in Livingston detector
- Tracks shot noise at high frequencies
- Tracks servo-induced noise at low frequencies.
- Slight excess 30-100 Hz, attributed to light scattering from moving surfaces.

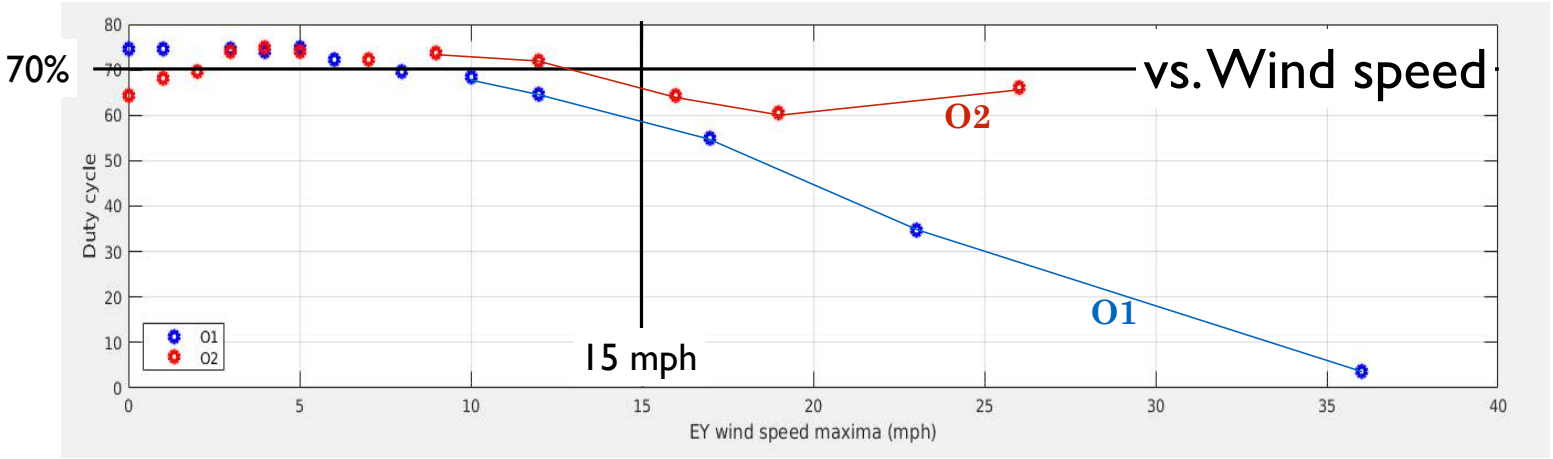


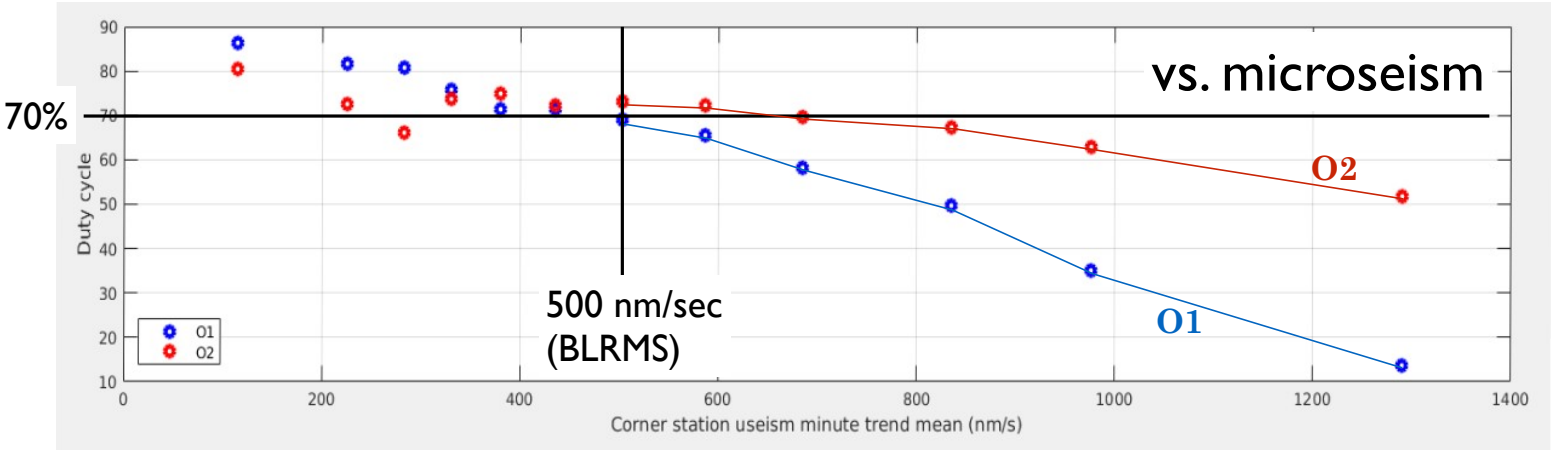
BRS – Beam rotation sensor

- Mitigation of tilt-horizontal coupling required for good low-f detector performance
- BRSs installed in both LHO endstations, plus prototype cornerstation version: U. Washington

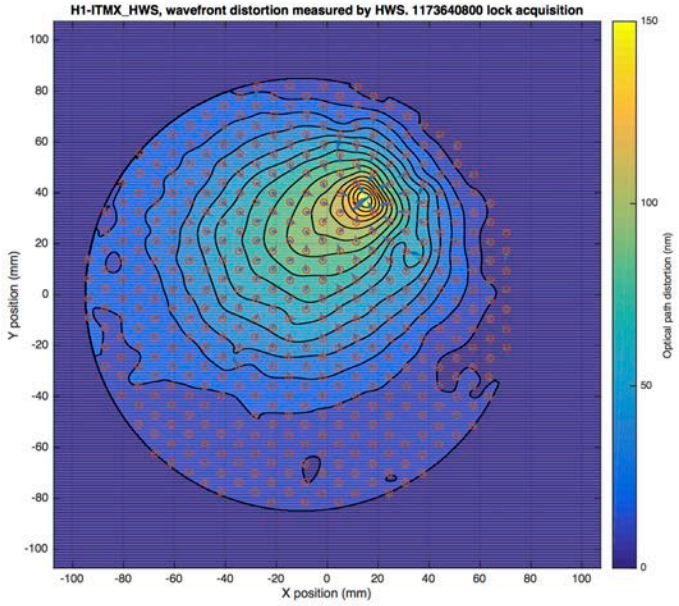


BRS impact at LHO

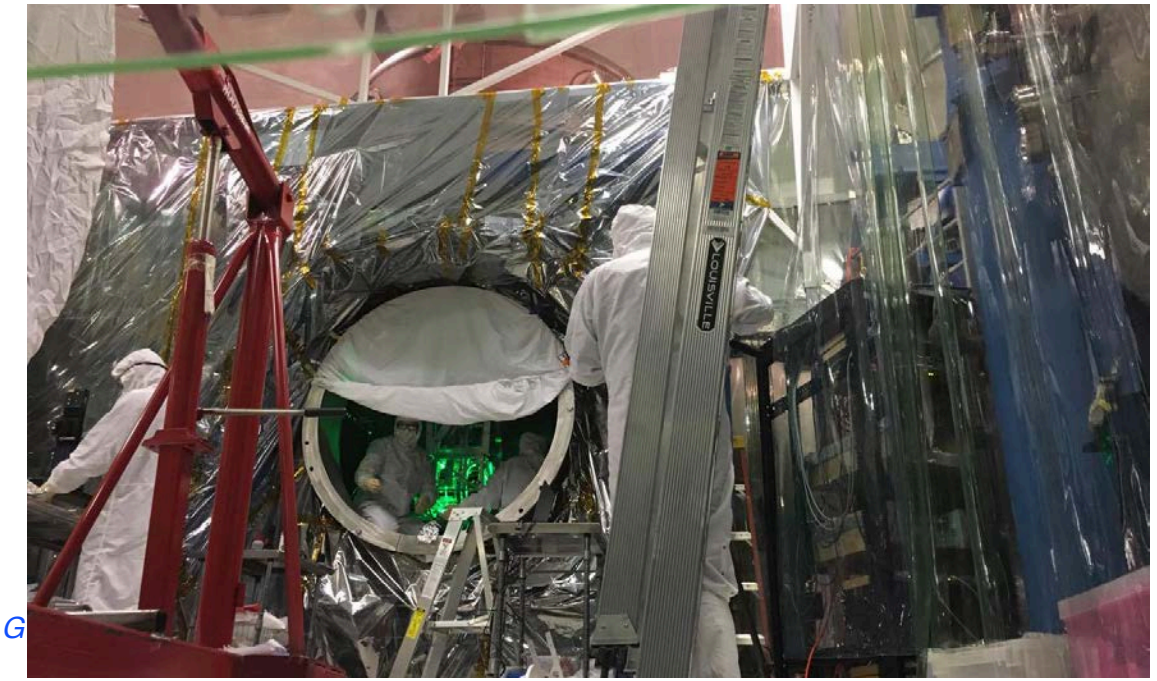




H1 ITMX contamination



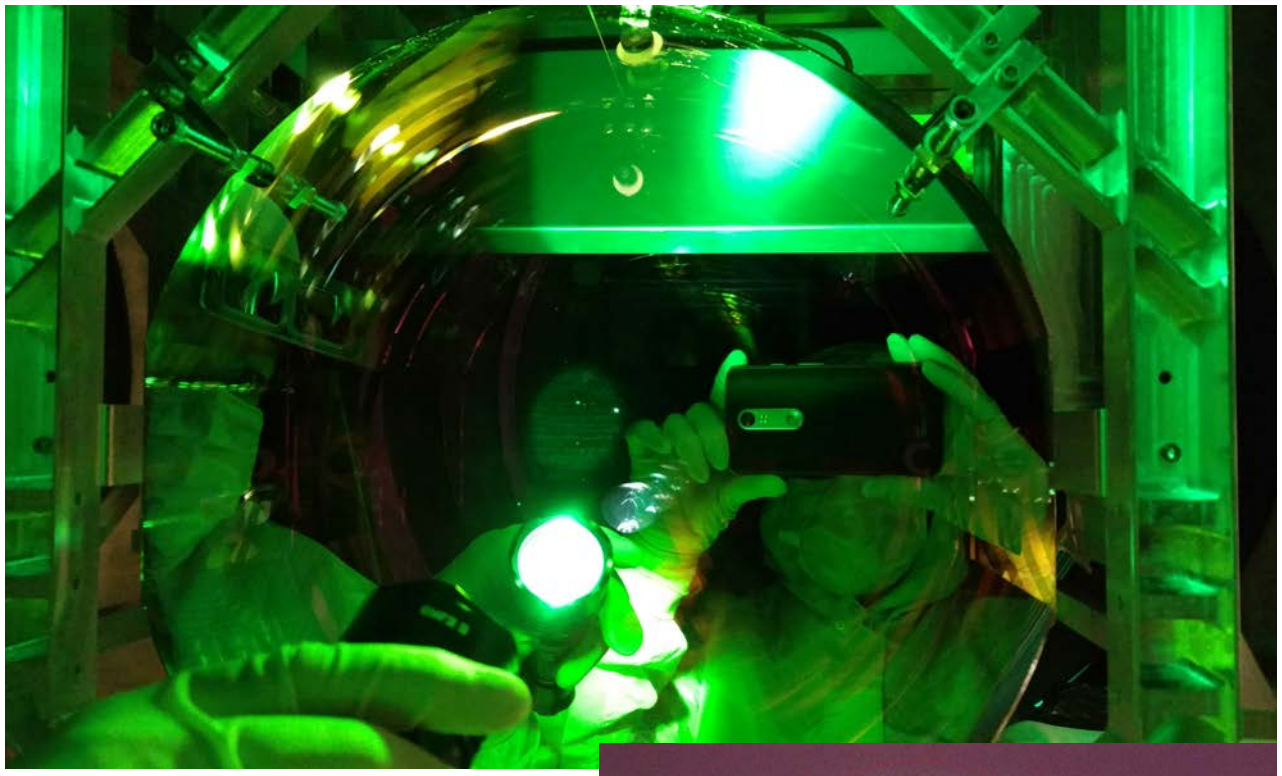
- Hartmann wavefront sensor images show point absorber on ITMX
- Possible mechanism for beam jitter coupling
- Elected to vent H1 vertex

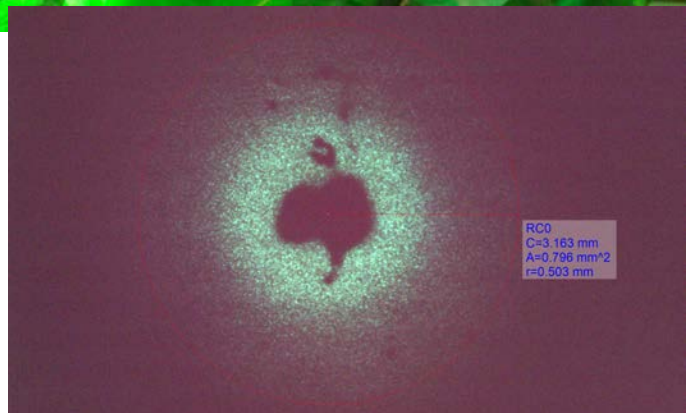


- One-day vertex vent requires ~2 week pumpdown before lifting gatevalves
- Additional work: Hartmann y-path, baffle damping

Cornerstation vent at LHO

- Inspection did not yield obvious contamination at the site indicated by Hartmann analyses
- Found evidence of contamination sites on ITMX, origin not completely clear
- Test-cleaned at limb of optic, FirstContact cleaned HR surface
- *Gatevalves opened last week, relocked and find point absorber still present*





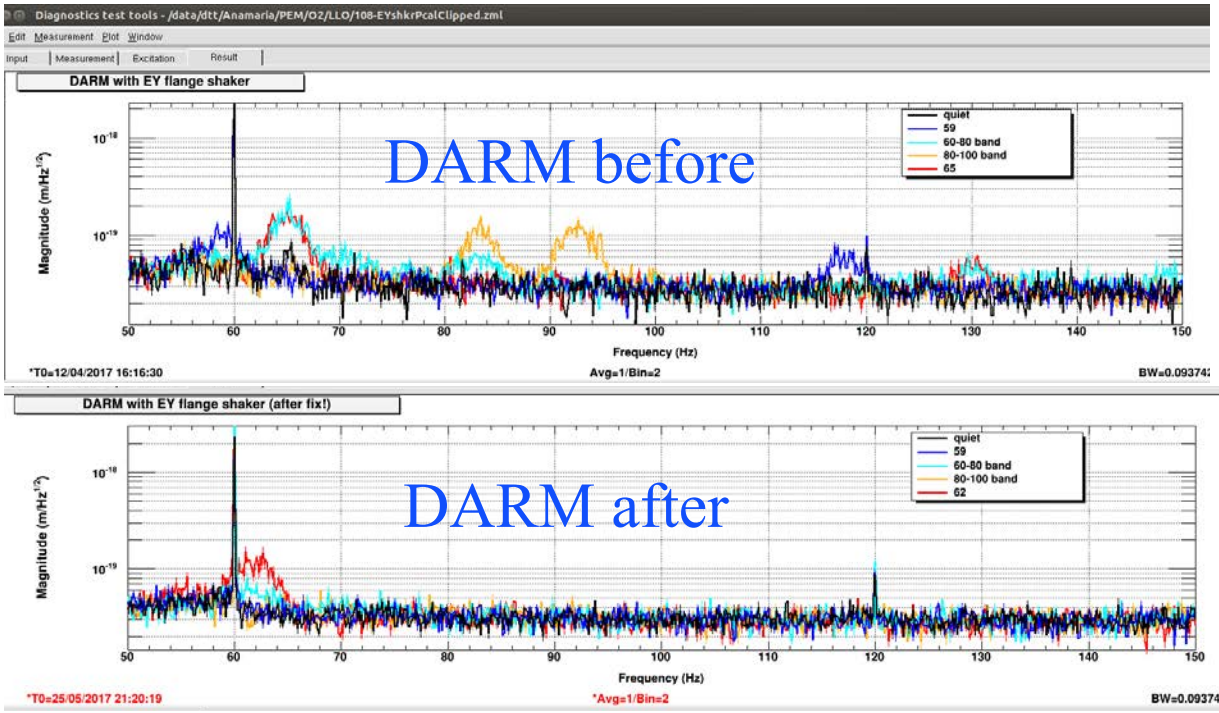
Hanford DOE May 9th event

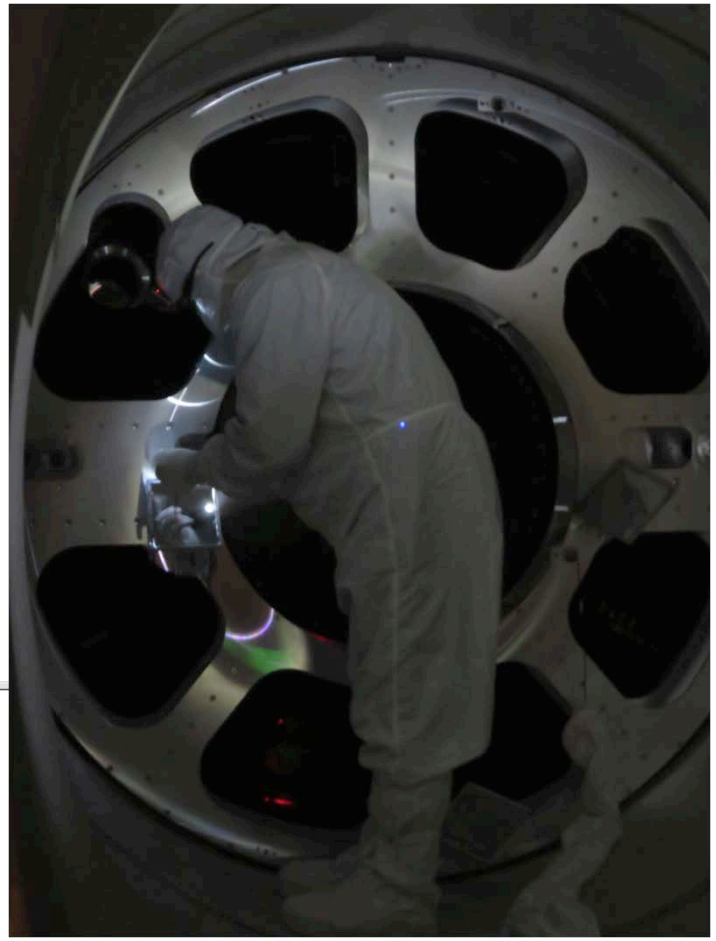
- There are to be 269 calendar days in O2: we vented for 1 day
- The only day (ever) we've been asked to shelter-in-place at LHO was May 9, the same day as our single-day vent of O2

- 20' cave-in of a train tunnel at the DOE Purex Facility12 miles east of the H1 vertex
- No airborne contamination detected
- Breach filled with 50 truckloads of clean soil

Endstation/HAM1 vent at LLO

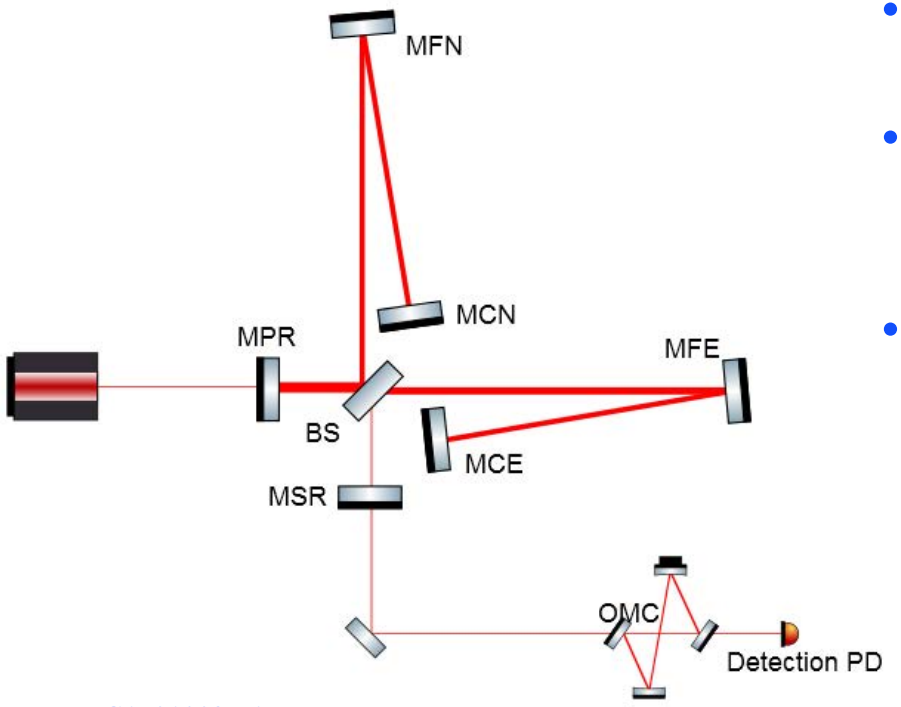
- Vented L1 EY station and removed camera transport mirrors
- Scattered light peaks mitgated





GEO Astrowatch

- *Don't miss a large, "nearby" GW event*
- Current GEO 600 instrument science aspects require a working detector: bring GEO back to data taking mode over nights and weekend



- Since end of O1: Astrowatch + instrument science
- No significant reduction of experimental work during O2 → we aim for a duty cycle of >70%.
- *Astrowatch will continue past O2*

Note: a 2nd ~2week downtime is planned for the 2nd half of 2017 to fix MSR suspension OSEMs.

GEO Research

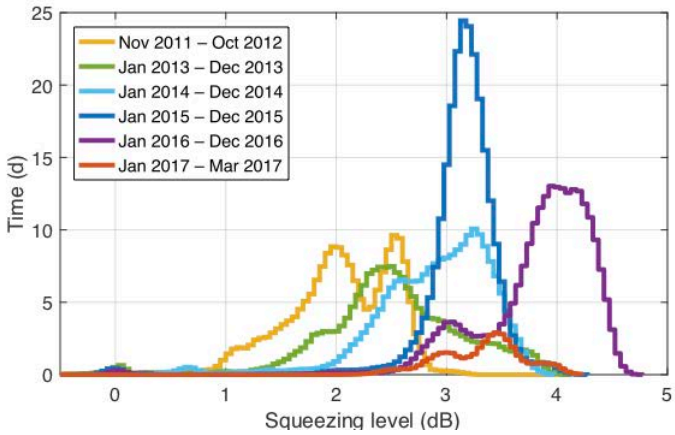
- Squeezing
  - injection loss: new faraday optimization, HOM scattering reduction
  - 4.4dB highest observed squeezing level
- **Beam Splitter Thermal Compensation & power up**

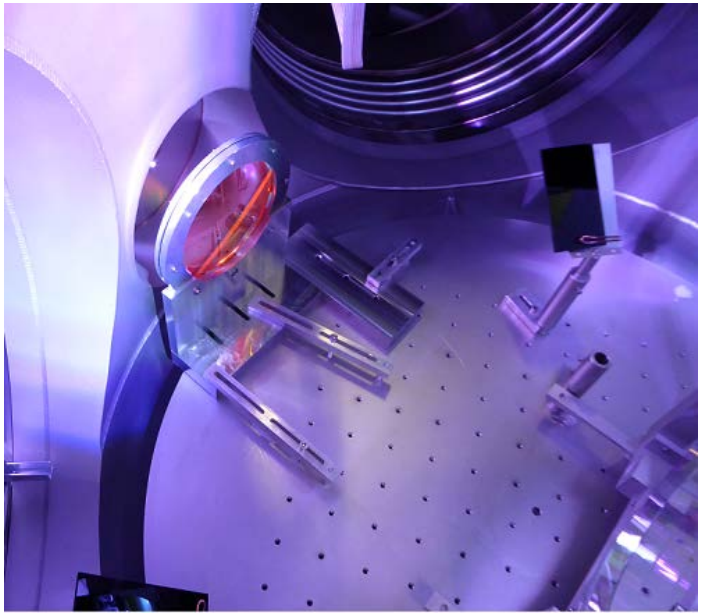
- heater array imaged on the beam splitter

- imaging lens recently installed (in-vacuum)

Else:

- Output Mode Cleaner AA (MDWS)
- Polarization Effects (from IFO)
- Noise at medium frequencies
- Optical AC Coupling
- Bilinear Noise Couplings with Signal Recycling





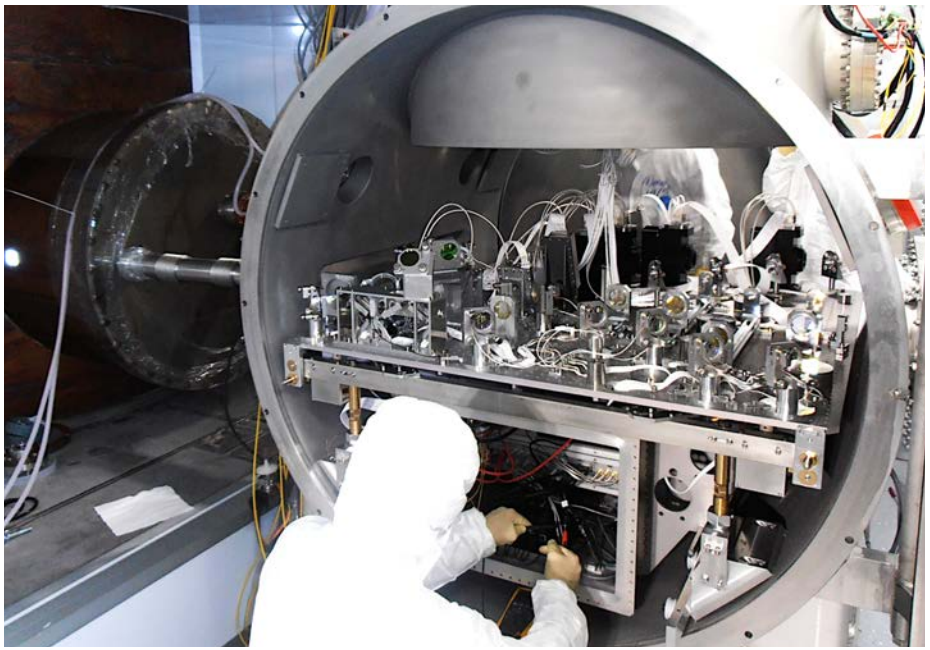
ADVANCED VIRGO

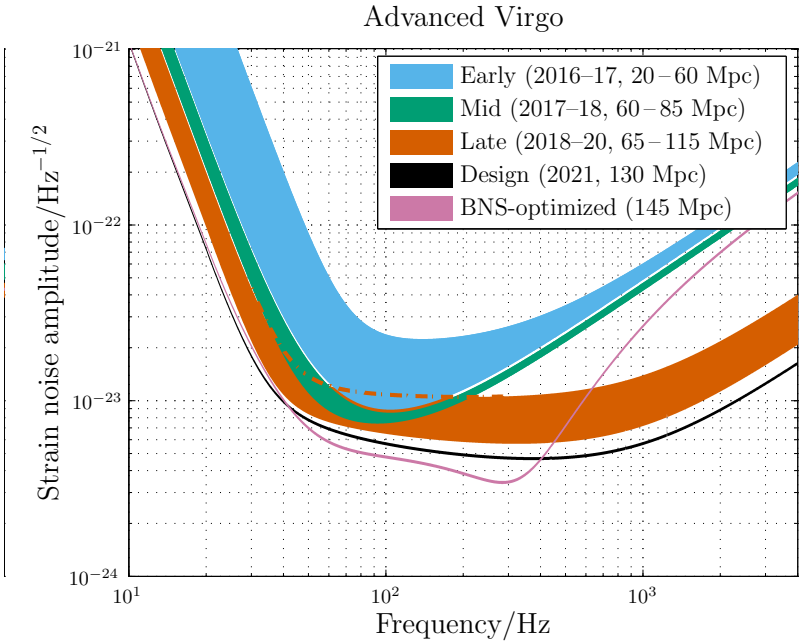
6 EU countries
20 labs, ~250 authors

APC Paris
ARTEMIS Nice
EGO Cascina
INFN Firenze-Urbino
INFN Genova
INFN Napoli
INFN Perugia
INFN Pisa
INFN Roma La Sapienza
INFN Roma Tor Vergata
INFN Trento-Padova
LAL Orsay – ESPCI Paris
LAPP Annecy
LKB Paris
LMA Lyon
NIKHEF Amsterdam
POLGRAW(Poland)
RADBOUD Uni. Nijmegen
RMKI Budapest
University of Valencia

Virgo status

- Advanced Virgo operating with stable lock on dark fringe
- >85% duty cycle in recent commissioning run
- Sensitivity steadily improving

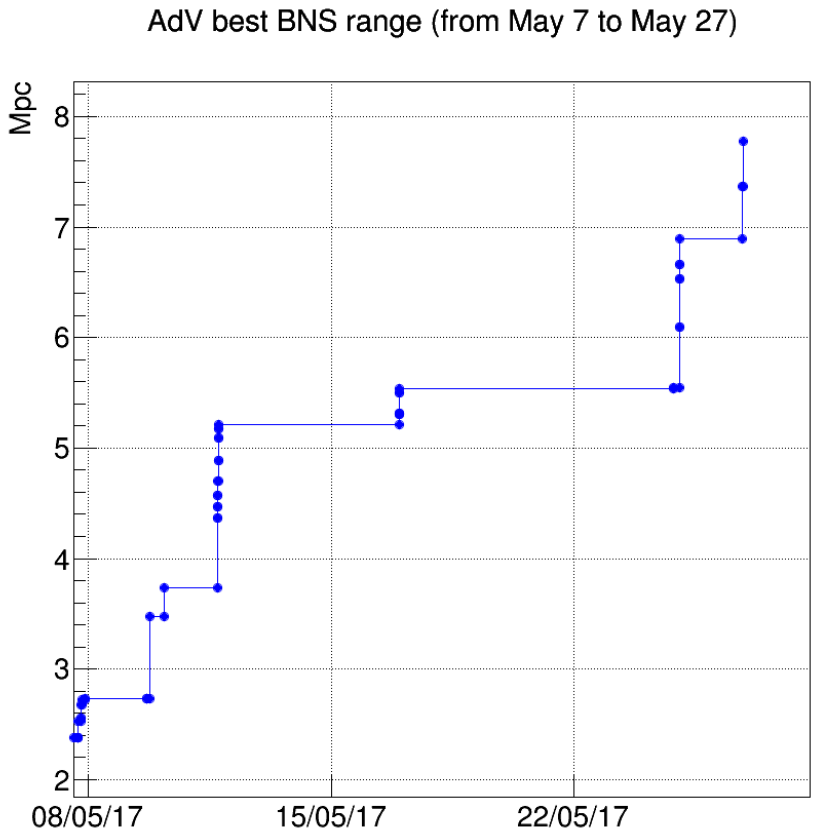




N. Leroy, A. Rocchi

Virgo pathway to O2

- Path to join O2 includes:
  - » Improve power recycling cavity (PRC) stability with thermal compensation (TCS)
  - » Suspend the detection bench (includes output photodiodes)
  - » Employ low noise actuation
  - » Make use of noise subtraction techniques
  - » Initiate weekend engineering/ science runs
  - » Increase interferometer input power from 13W to 25W
  - » Noise hunting!

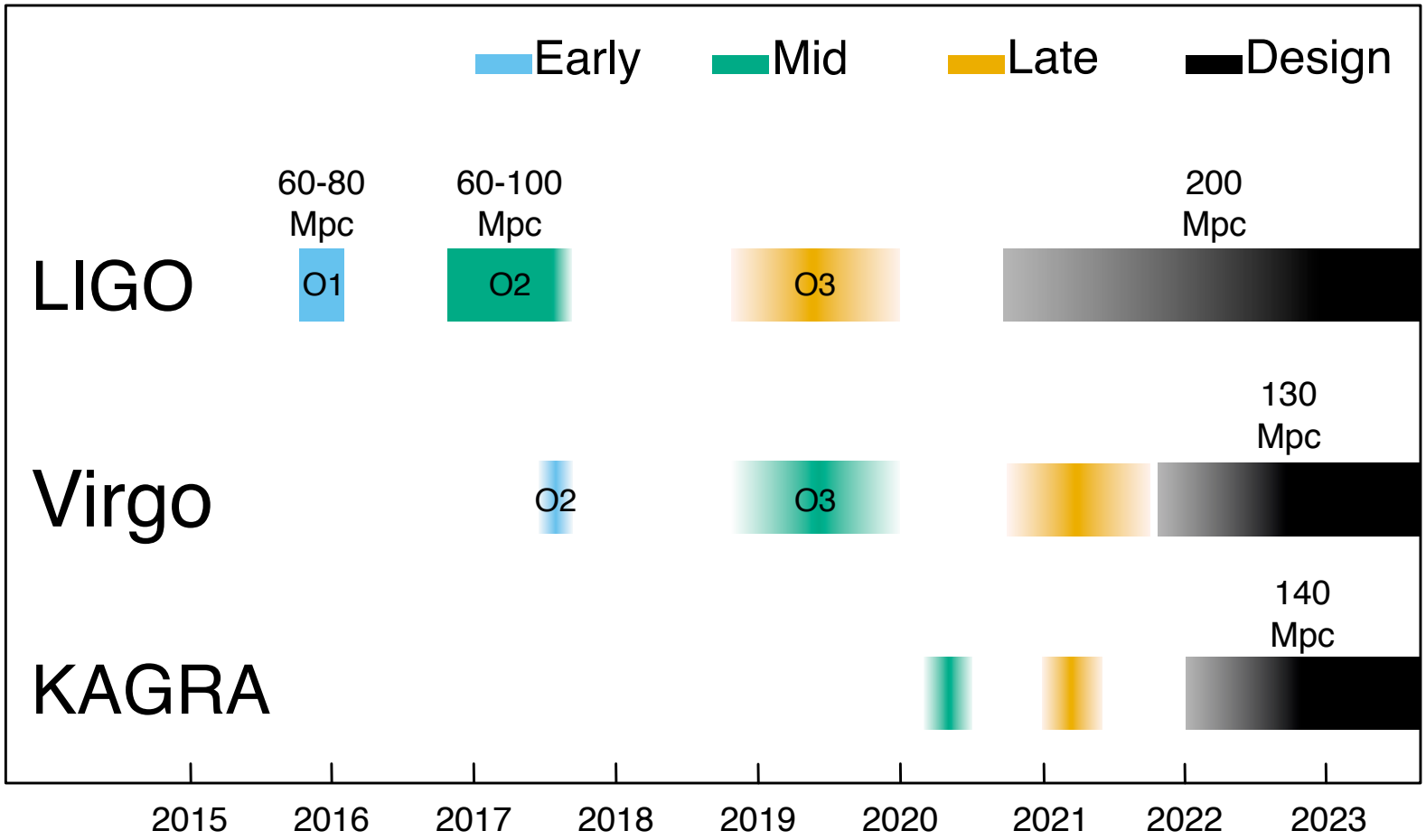


Virgo post-O2 work

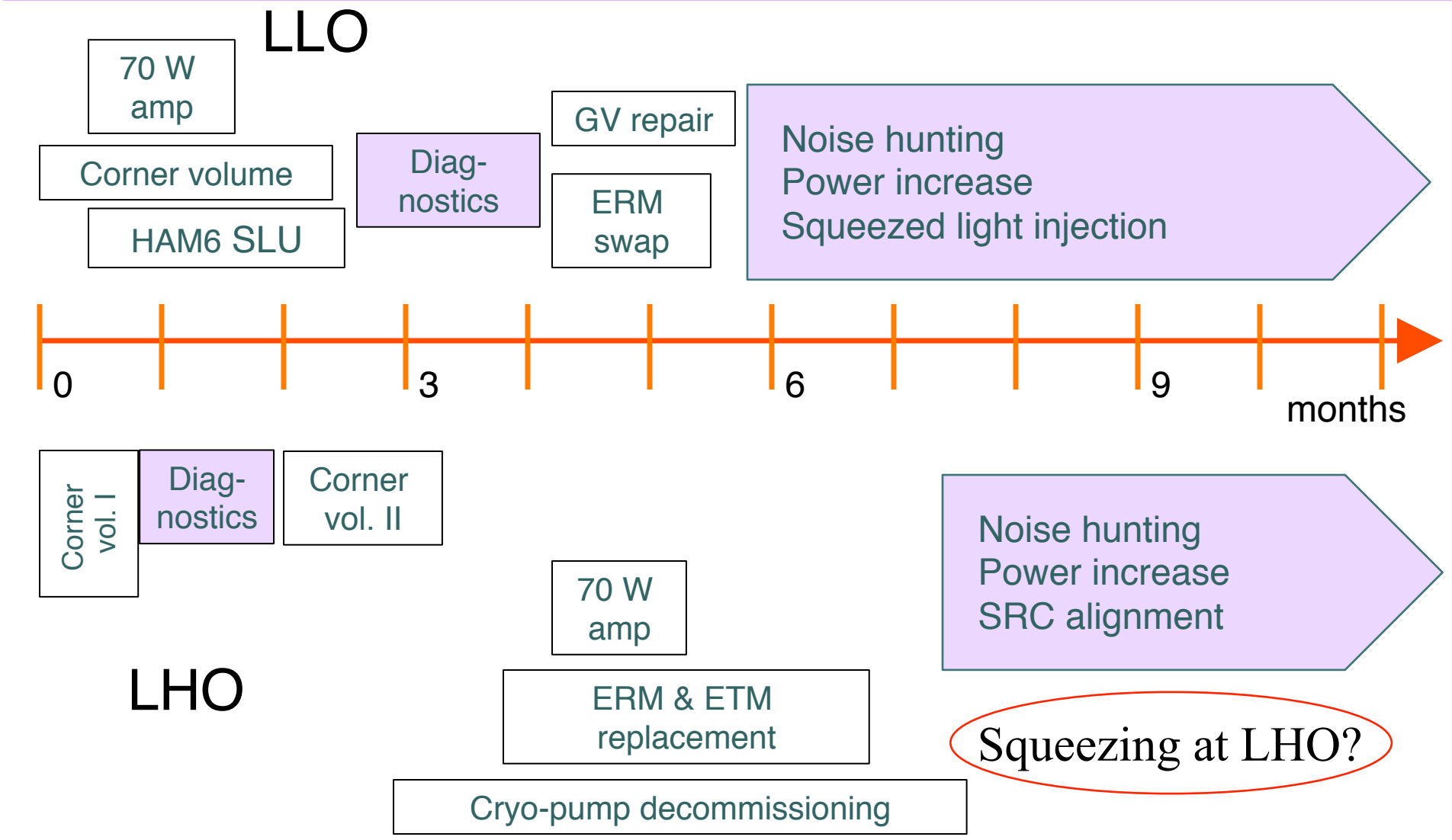
- Window of opportunity to increase stability and sensitivity
- Minimize interferometer downtime due to installations
- Prioritize with respect to sensitivity gain/impact on commissioning
- Upgrades being considered
  - » Monolithic suspension
  - » GEO squeezer
  - » High-power laser
  - » Signal recycling mirror (requires auxiliary lasers for locking)

} These are the priority items

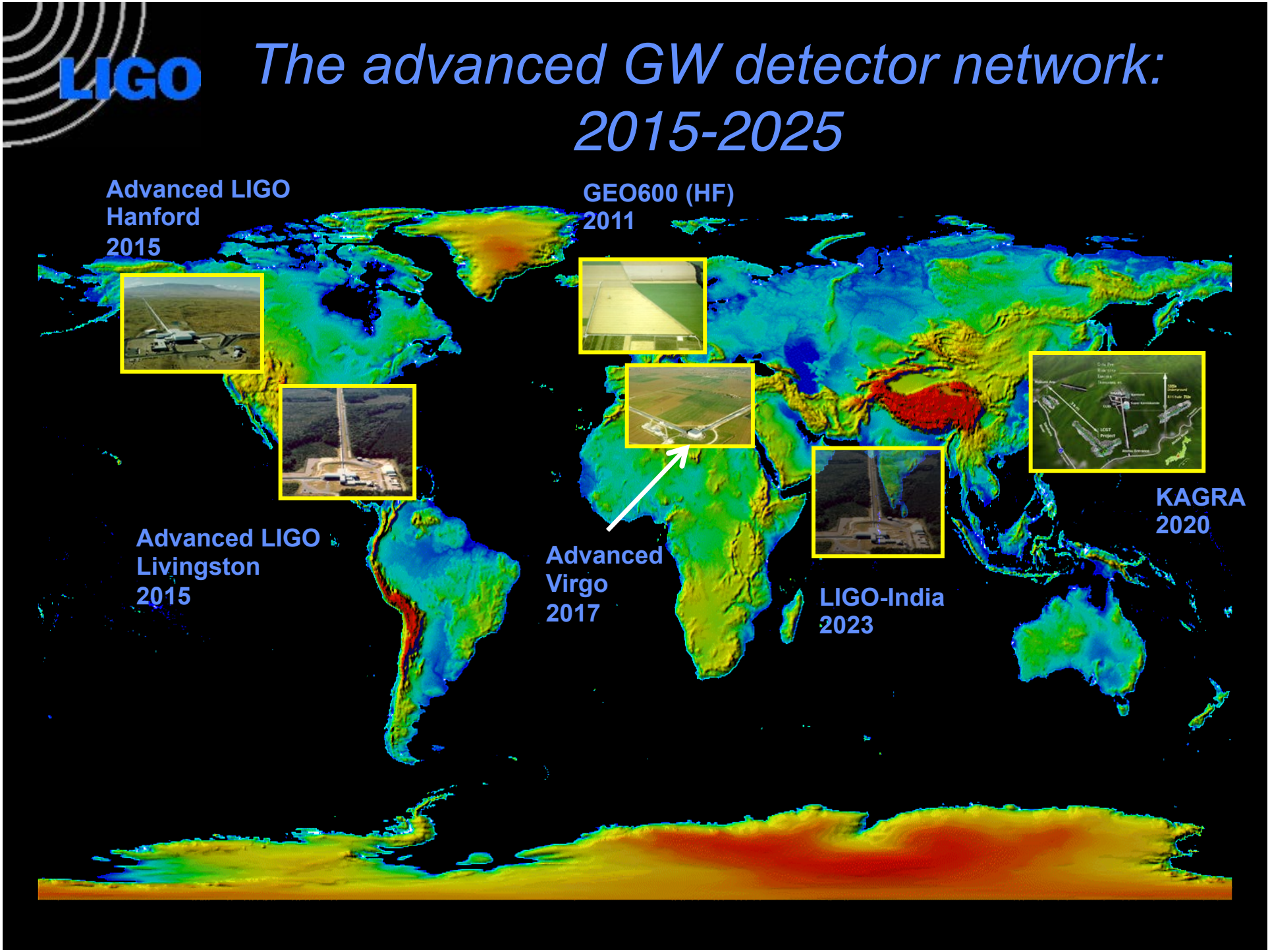
Observing scenario



Post-O2 commissioning



The advanced GW detector network: 2015-2025



LIGO Scientific Collaboration