Prospects of KAGRA Observation in the Multi-messenger Era

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On behalf of the KAGRA collaboration

Mar 27, 2018

at ICEHAP, Chiba University

JGW-G1808116

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- Introduction
- Detector upgrades and Near Future Observation Prospects – LIGO and VIRGO
- KAGRA Status
- KAGRA's contribution on upcoming Observations
- Future Prospects of the Field

Introduction

- Gravitational wave astronomy has finally started 100 years after the Einstein prediction

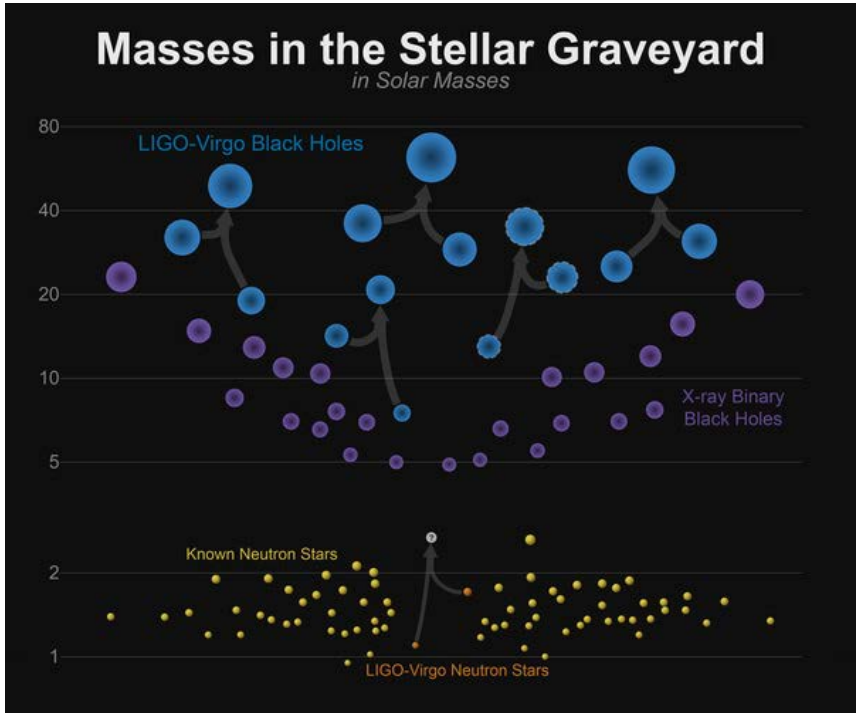
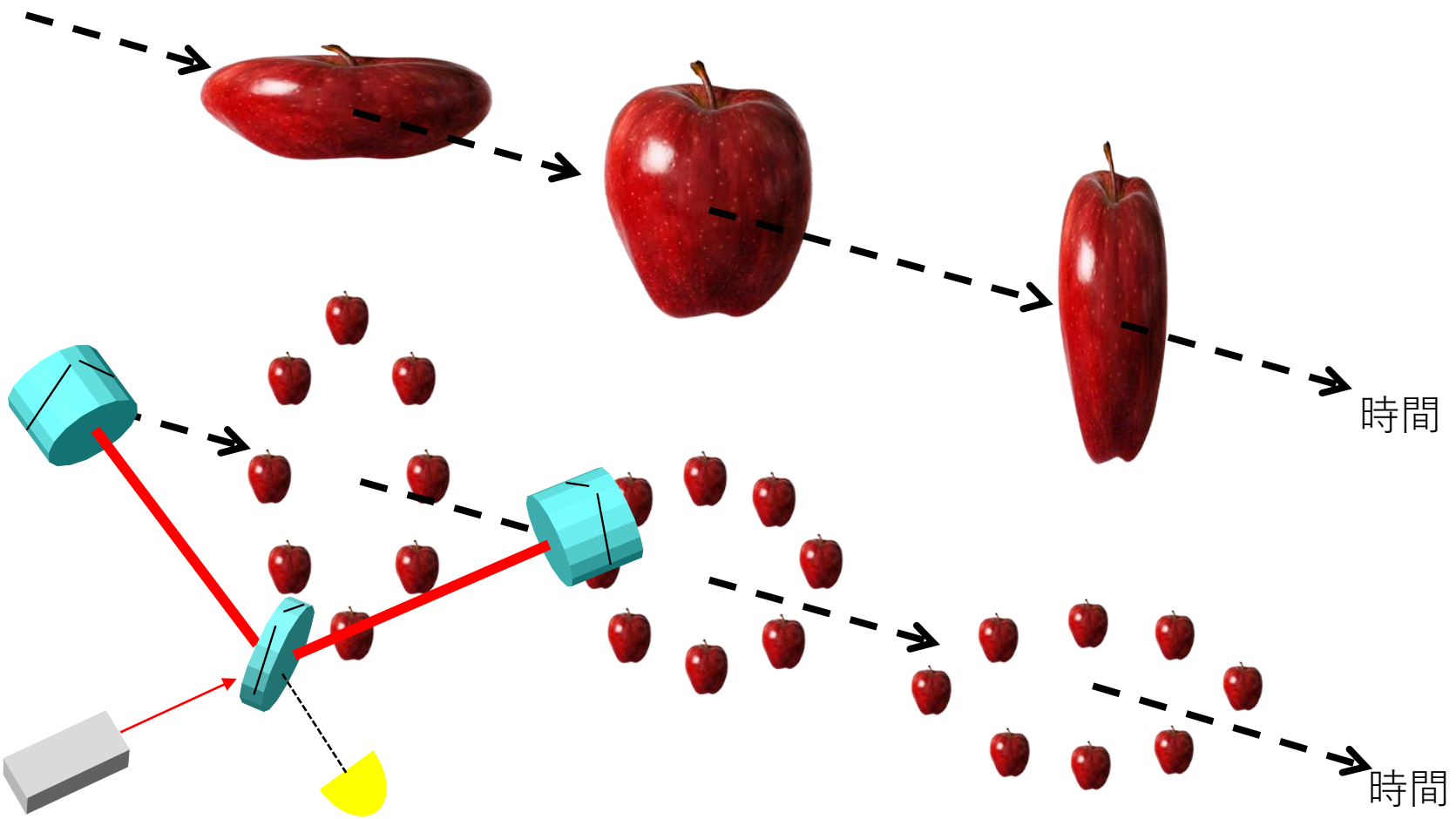


figure: LIGO Lab

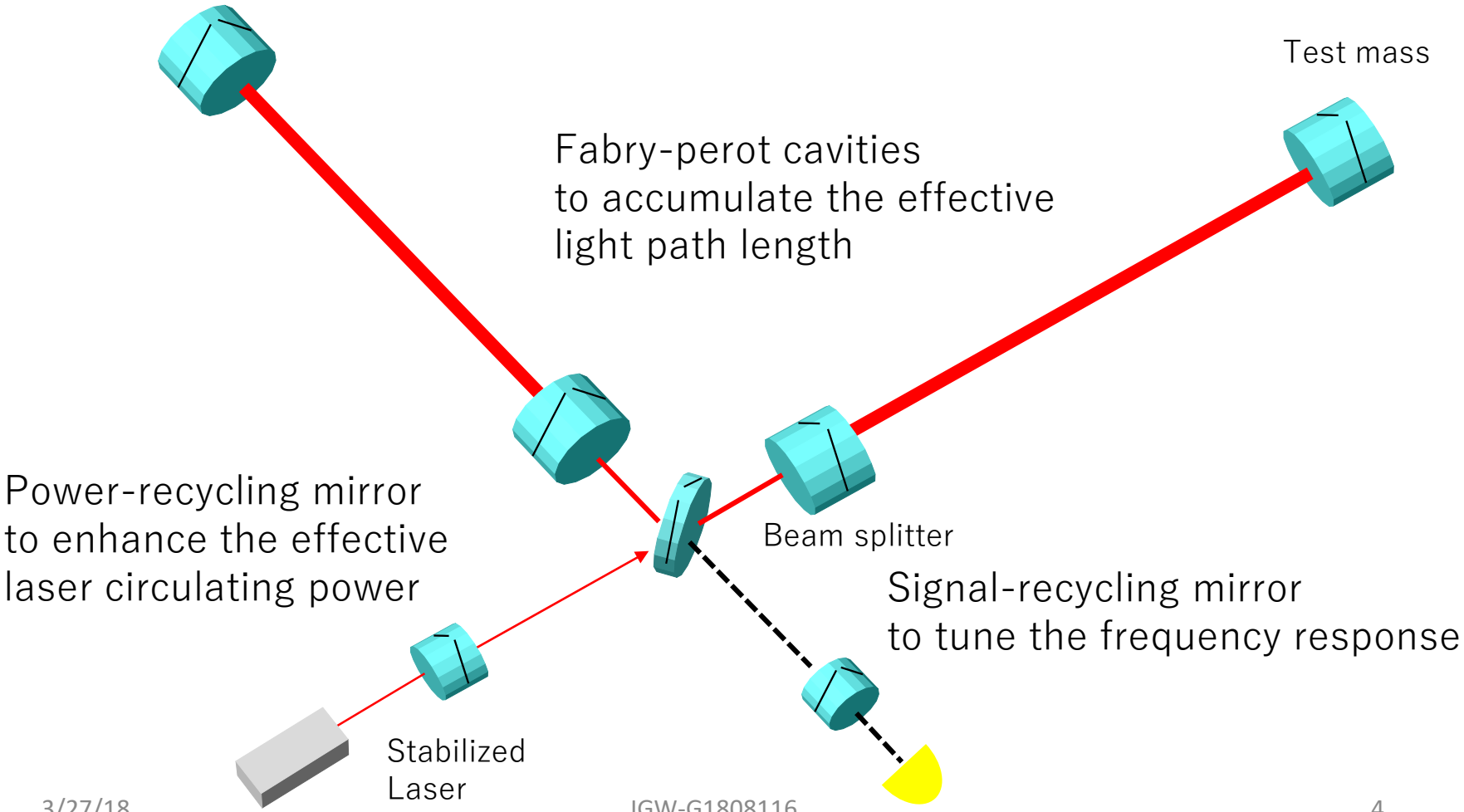
- LIGO's detection
  - The first detection GW150914
  - 2 BH-BH in Observation 1 (O1)
  - 3 BH-BH in O2
- LIGO-VIRGO detection
  - BH-BH
  - NS-NS – Multi-messenger Observation

Gravitational-Waves

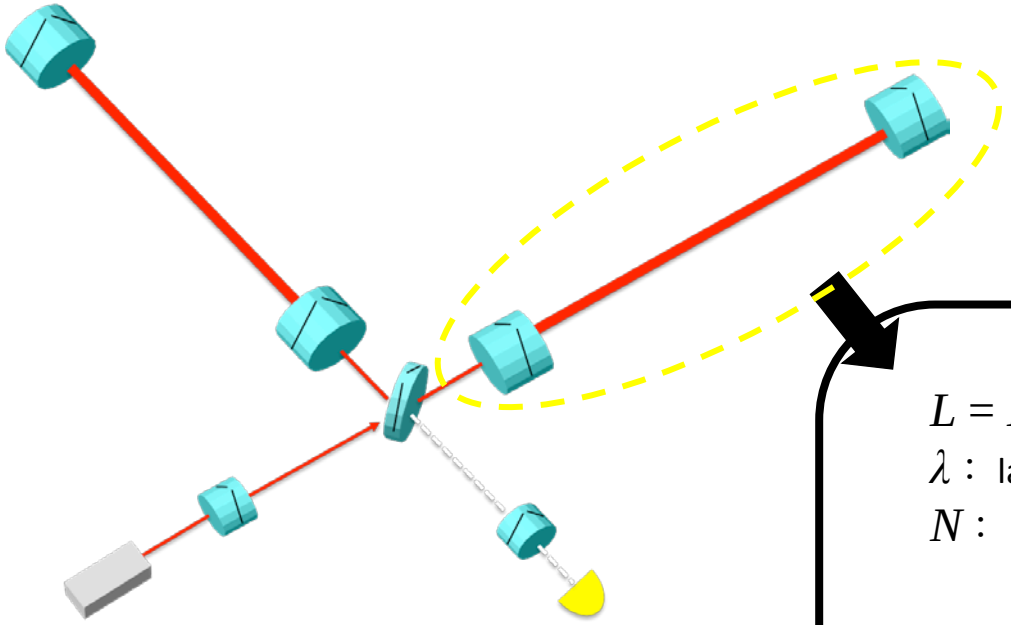


Overview of the Detectors

Test mass (mirror)
hung by a large suspension
to be isolated from seismic motions



Controlling the IFO

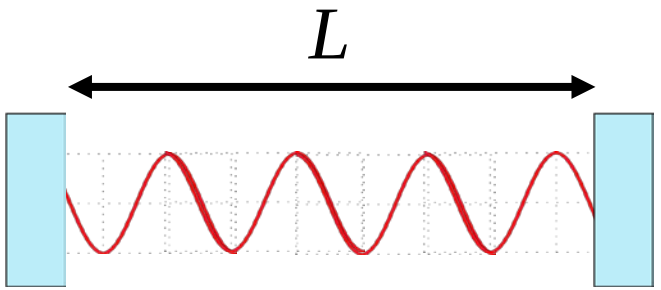


Lengths of optical cavities must be the integer multiple of the laser wave length

$L = N\lambda$

λ : laser wave length

N : Integer



aLIGO, VIRGO & KAGRA have 5 DoF to control

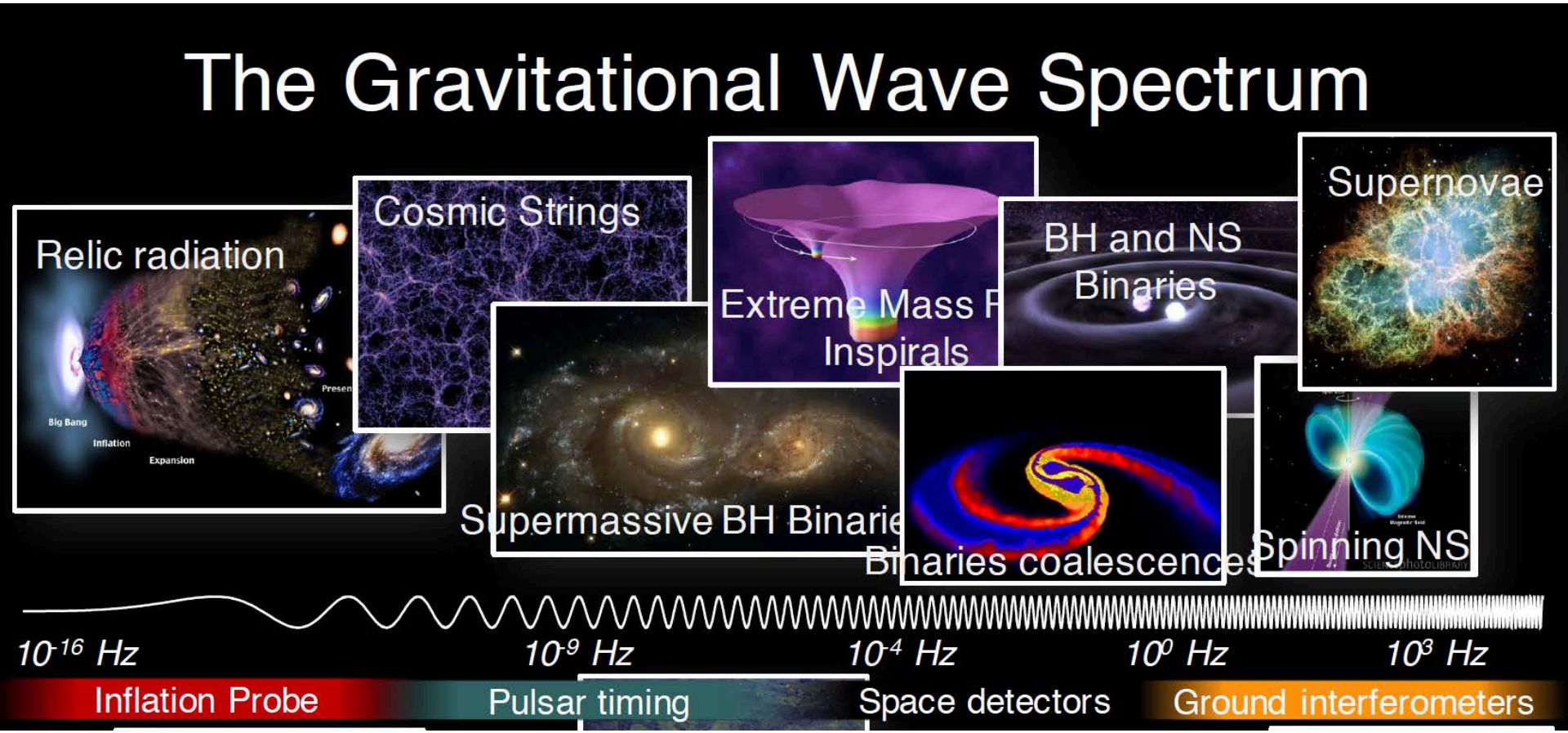
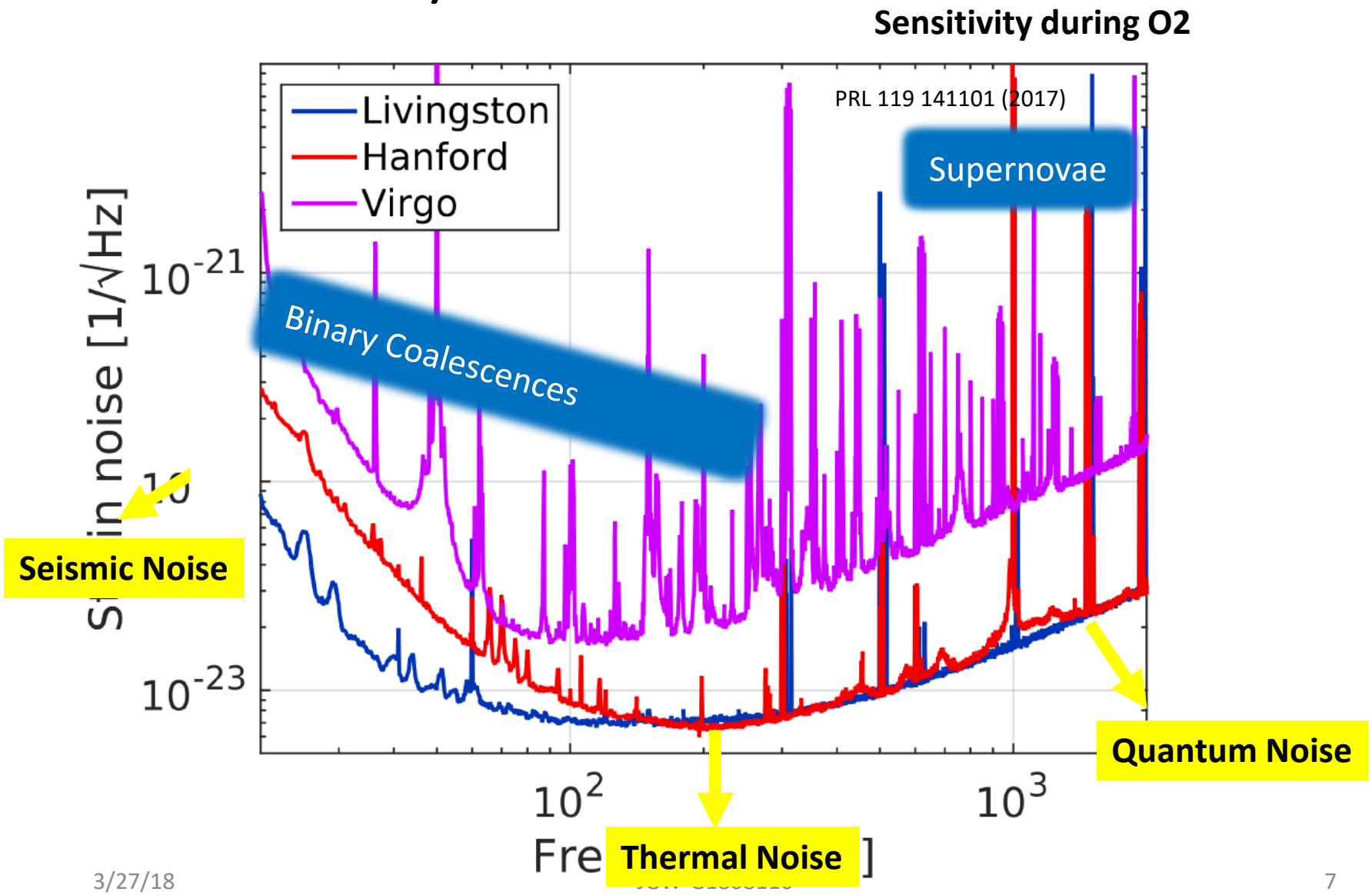


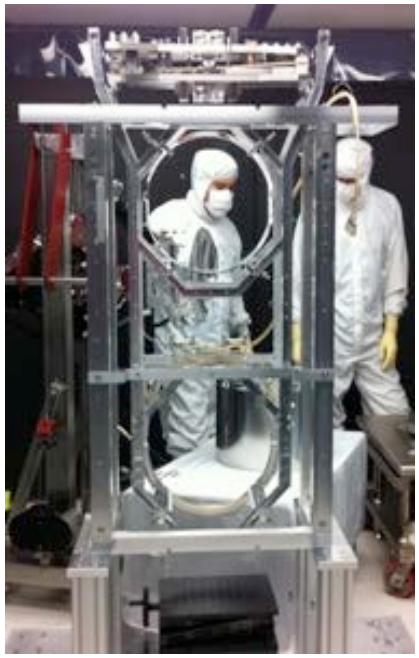
Figure: M Evans

Sensitivity Curve



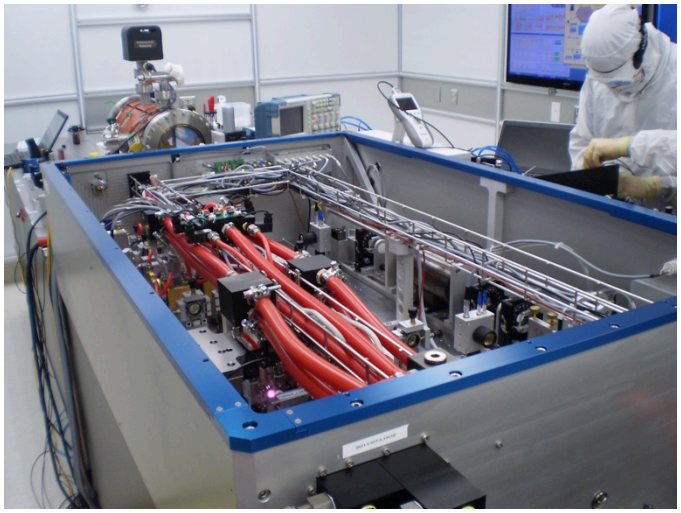
Detectors with State-of-Art Technologies

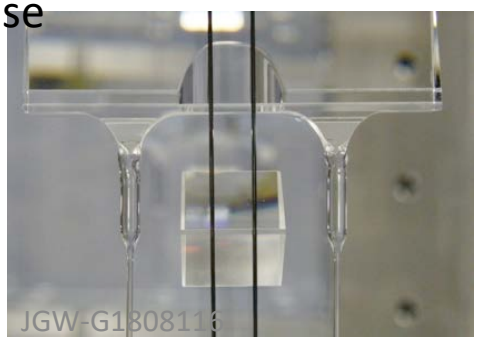
Seismic Noise

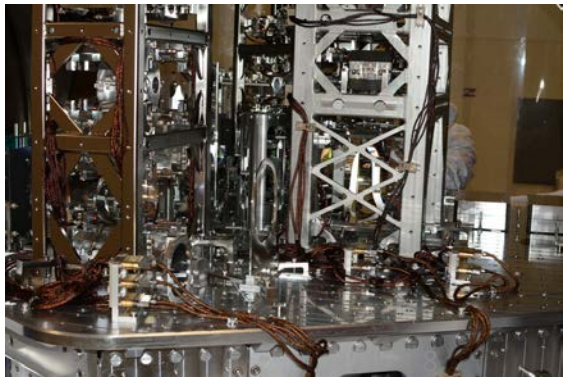


Thermal Noise

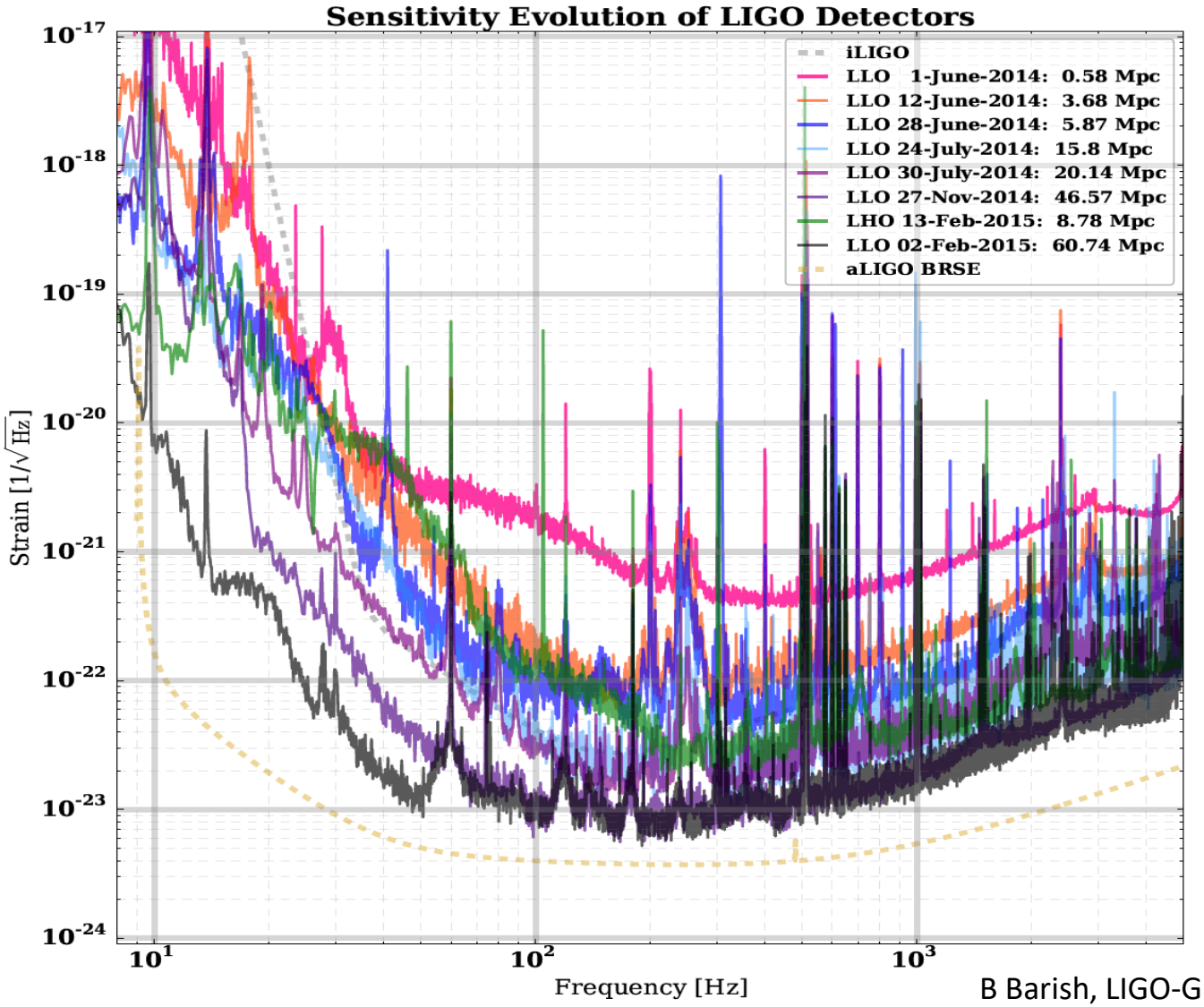
Quantum Noise





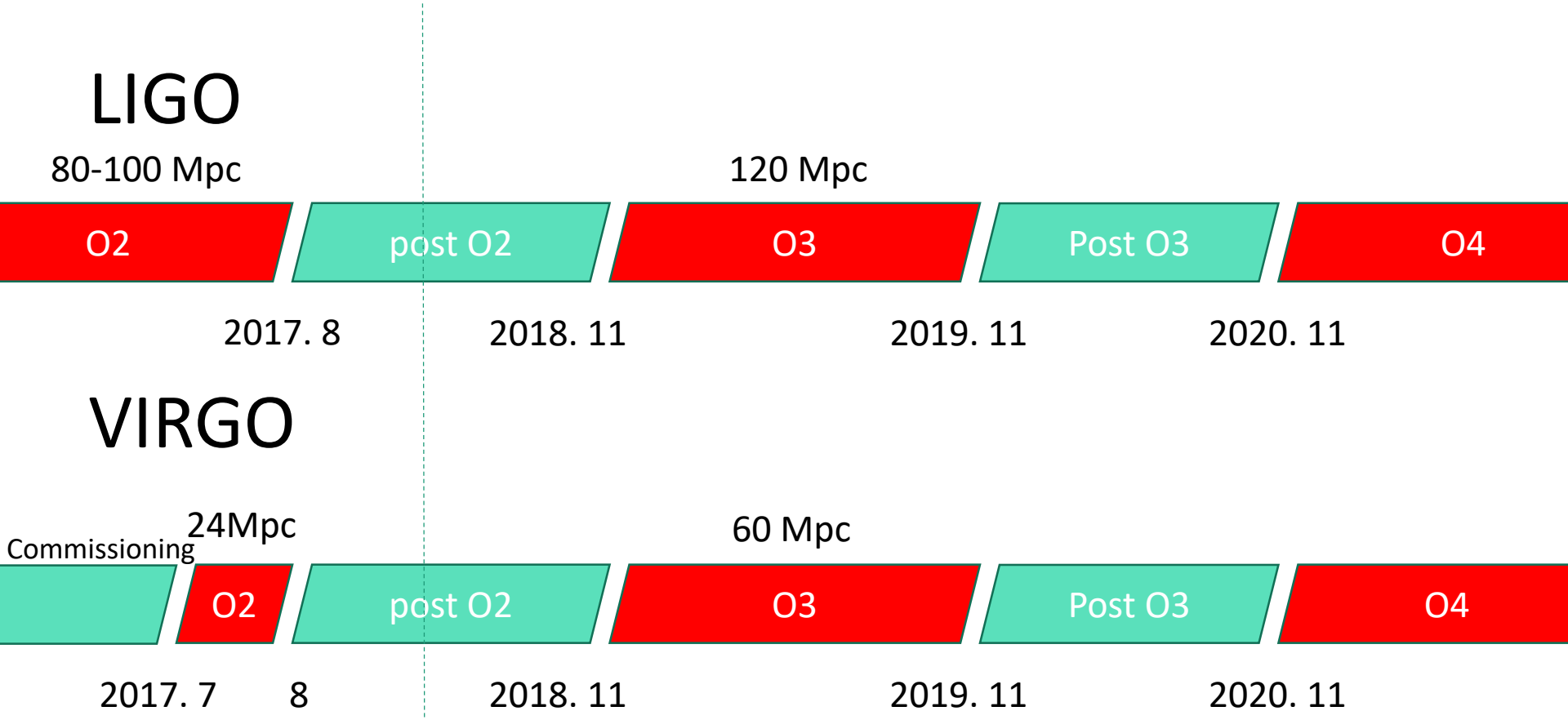


Figures: H Yamamoto



B Barish, LIGO-G1600214

L-V Observation Plan



Upgrades towards O3

LIGO

- Power up to 50W
- Squeezing input
  - 40% reduction of shot noise
- Optic swap
- Stray light control
- Vacuum System repair

Upgrades towards O3

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- Power up to 50W
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- Vacuum System repair

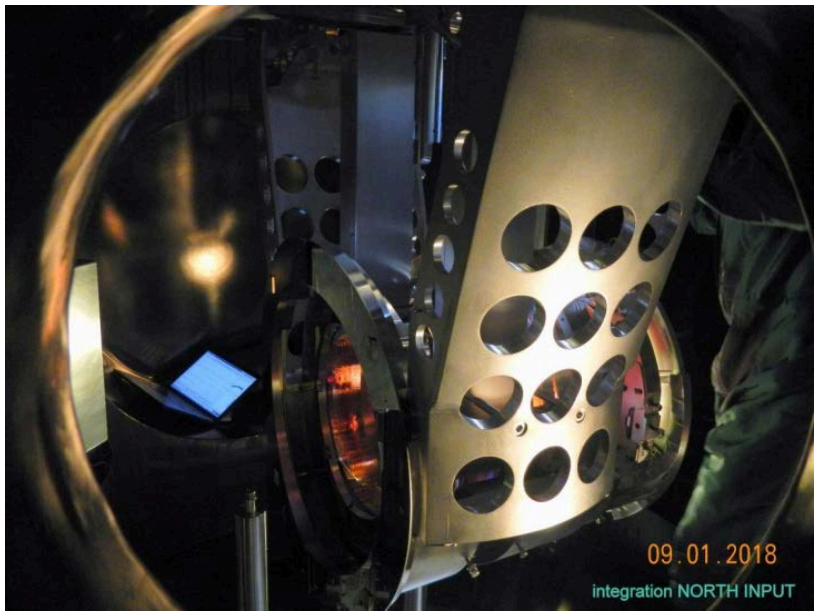
Barsotti, LIGO-G1800598

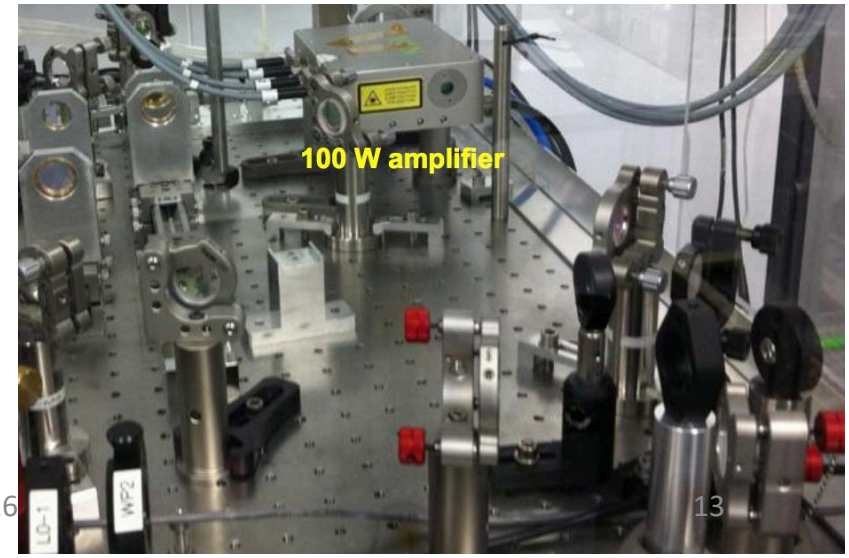
Target 3dB Squeezing

Upgrades towards O3

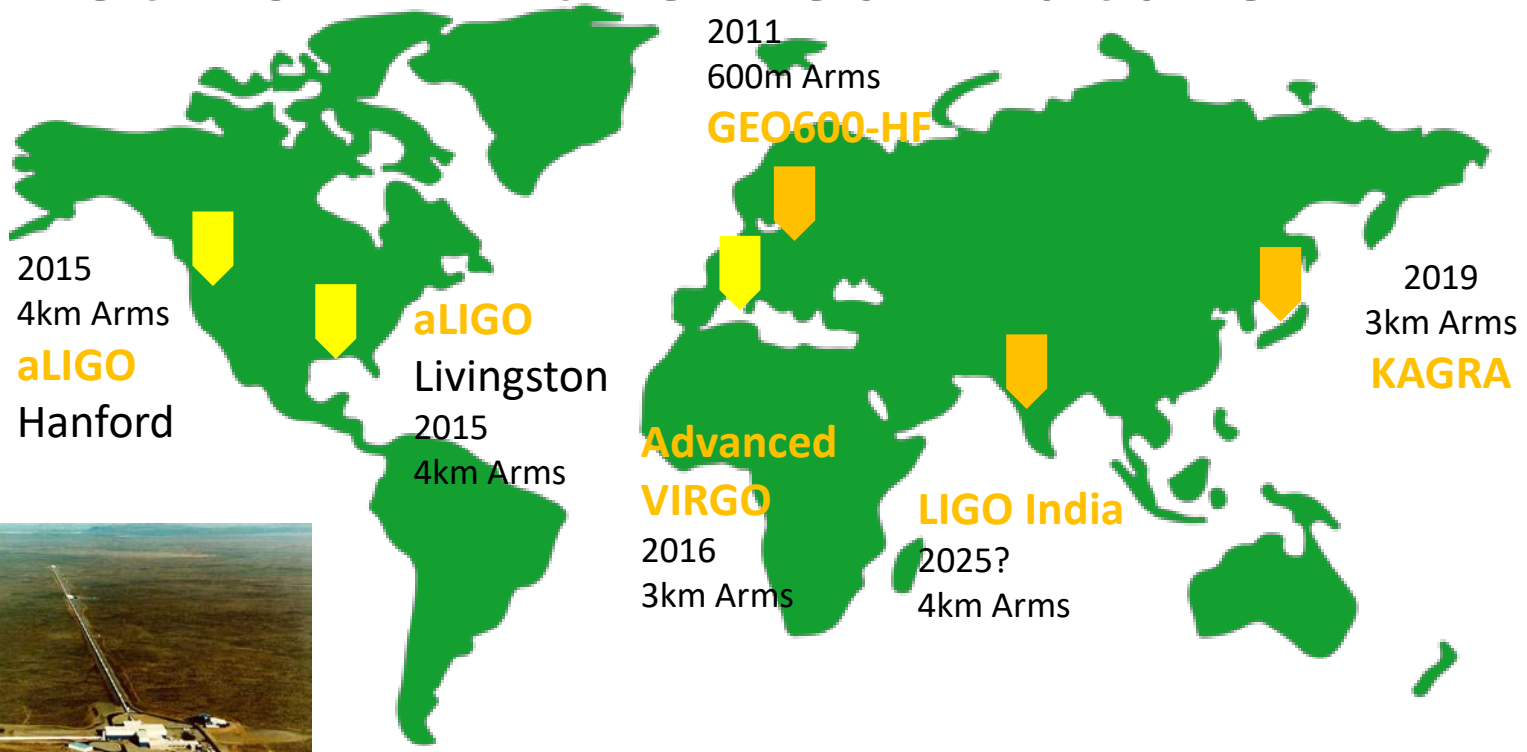
VIRGO

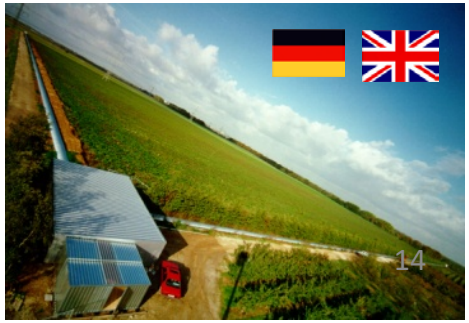
- Monolithic suspension
- vacuum system upgrade & cleaning
- Laser High power amp (100W) installed
- squeezer being installed
- Newtonian noise subtraction





International Observation Network in the near Future





KAGRA

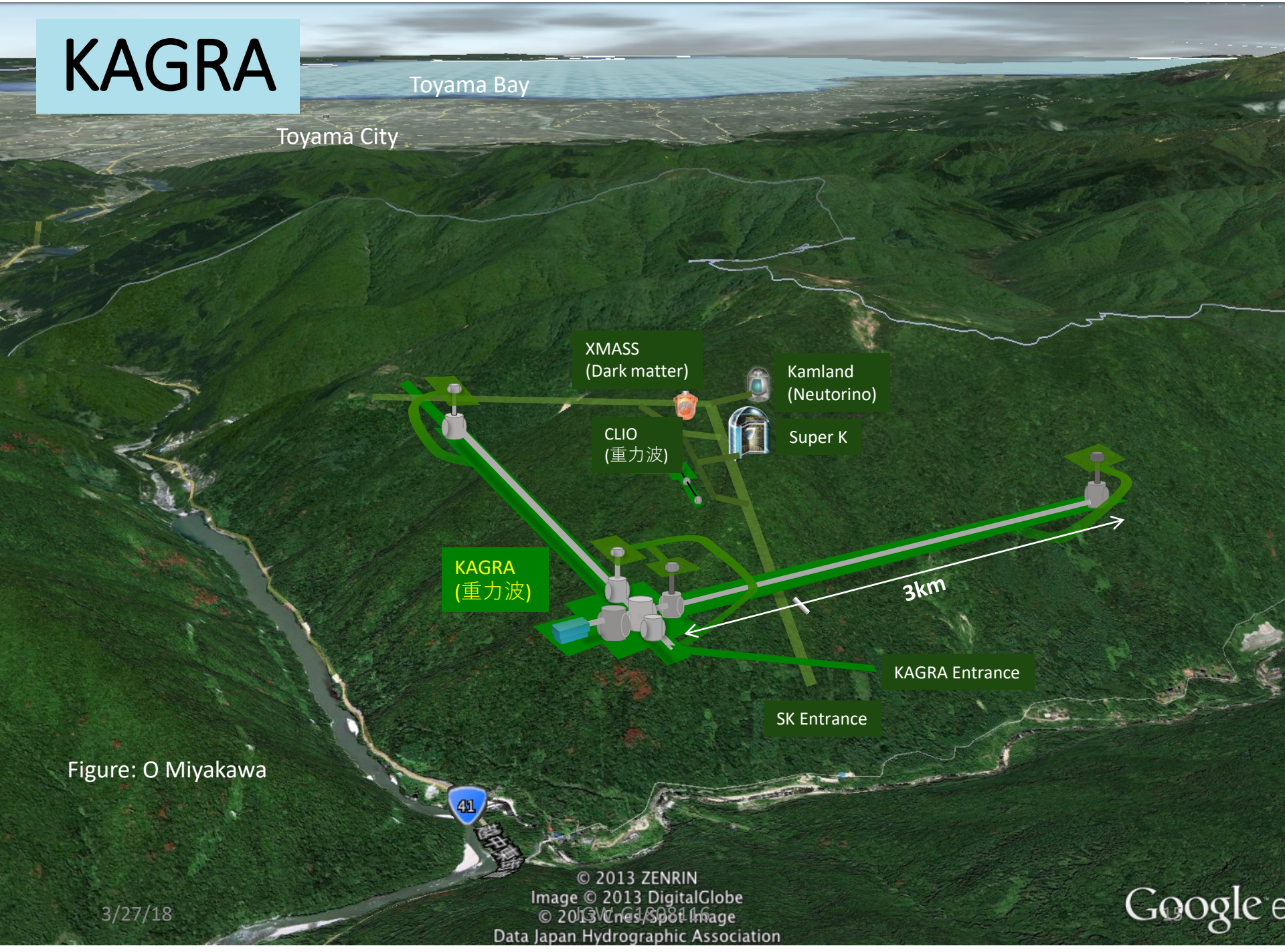
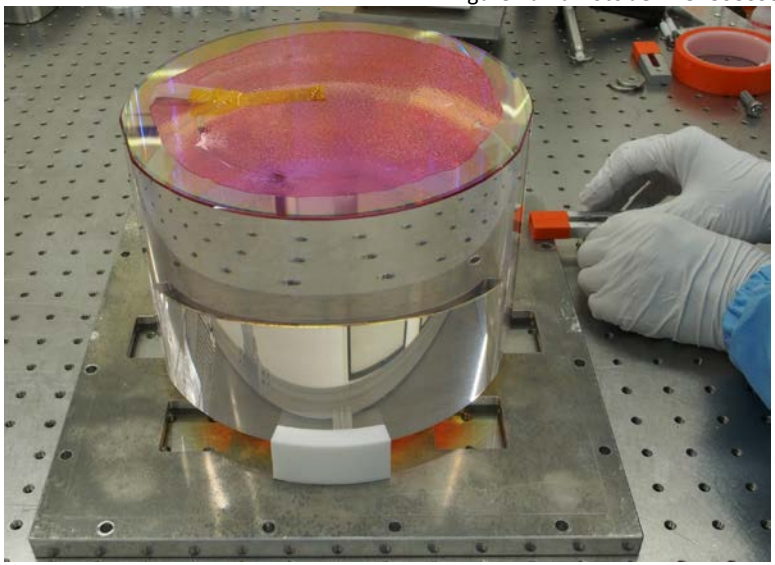
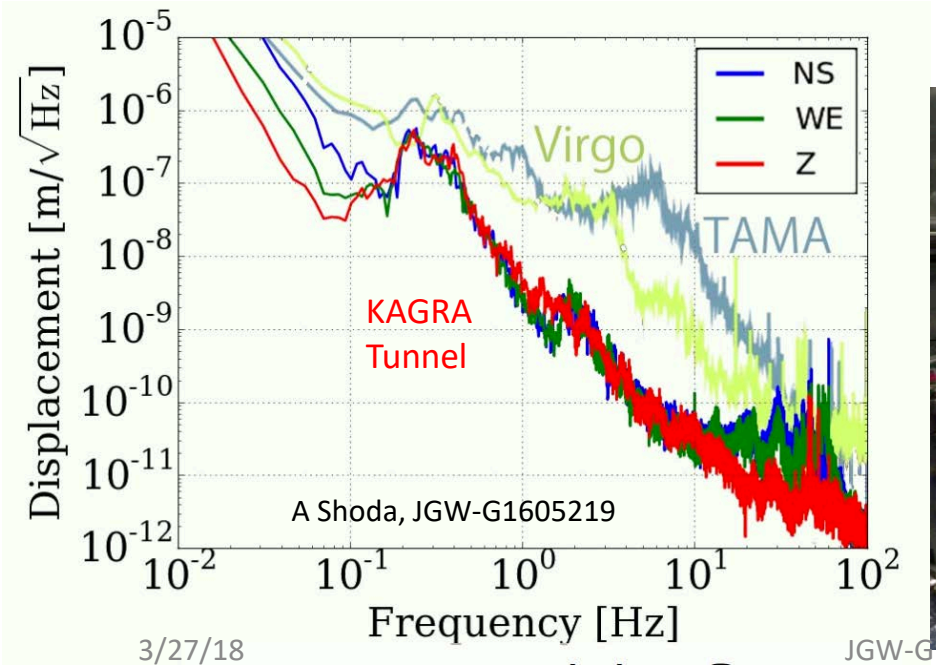


Figure: O Miyakawa

Underground and Cryogenic

Figure:Yamamoto JGW-G1808095



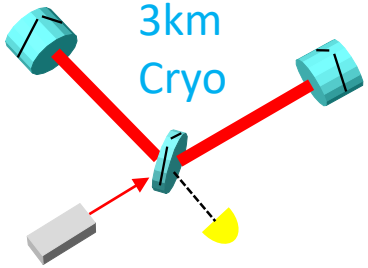


KAGRA Status

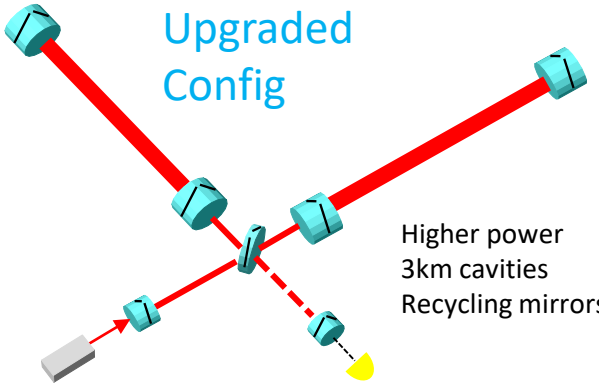
Engineering run

Phase-1 | Phase-2 | O3 | Phase-3

2018. 5 | 2019. ? | ?



3km
Cryo



Upgraded
Config

Higher power
3km cavities
Recycling mirrors?

Noise Hunting
Further Upgrades

LIGO & VIRGO

120 Mpc

O2 | post O2 | O3 | Post O3 | O4

60 Mpc

Design
Sensitivities

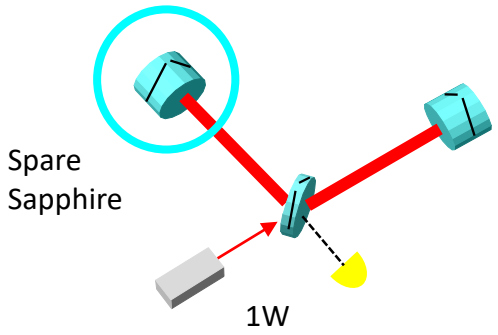
O2 | post O2 | O3 | Post O3 | O4

2017. 8 | 9 | 2018. 11 | 2019. 11 | 2020. 11

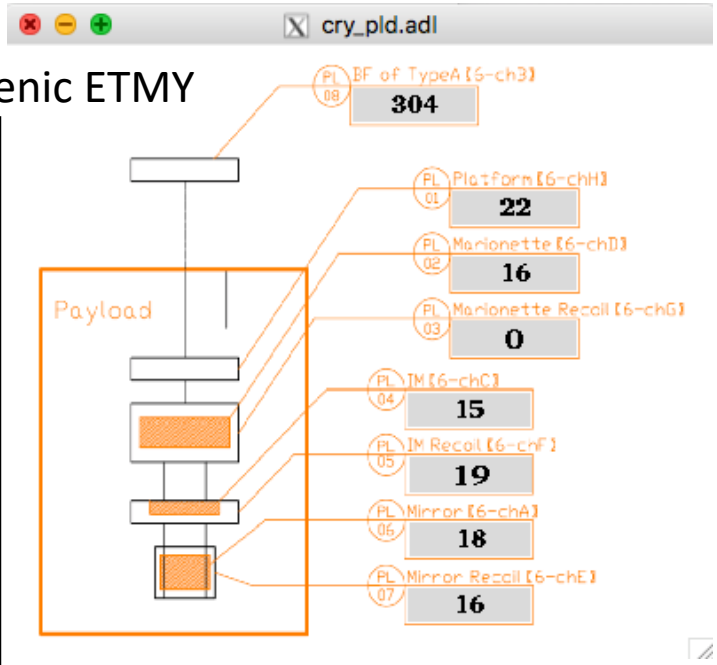
Detectors Status

BS (type B)

PR2 (type Bp)

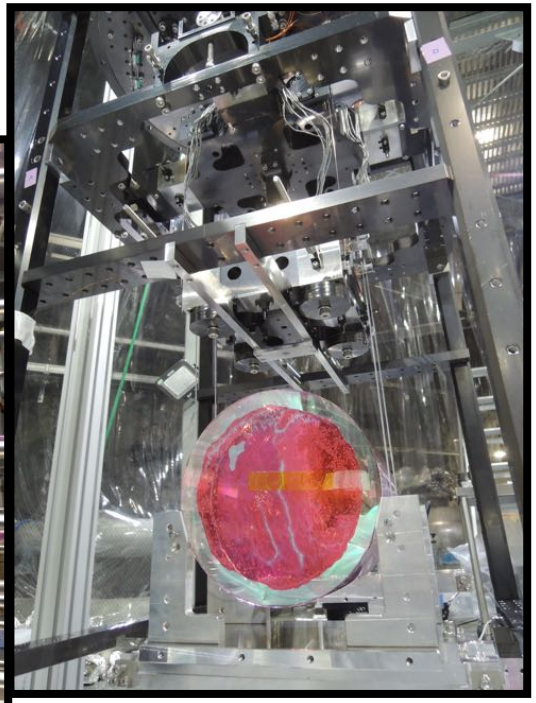


Cryogenic ETMY



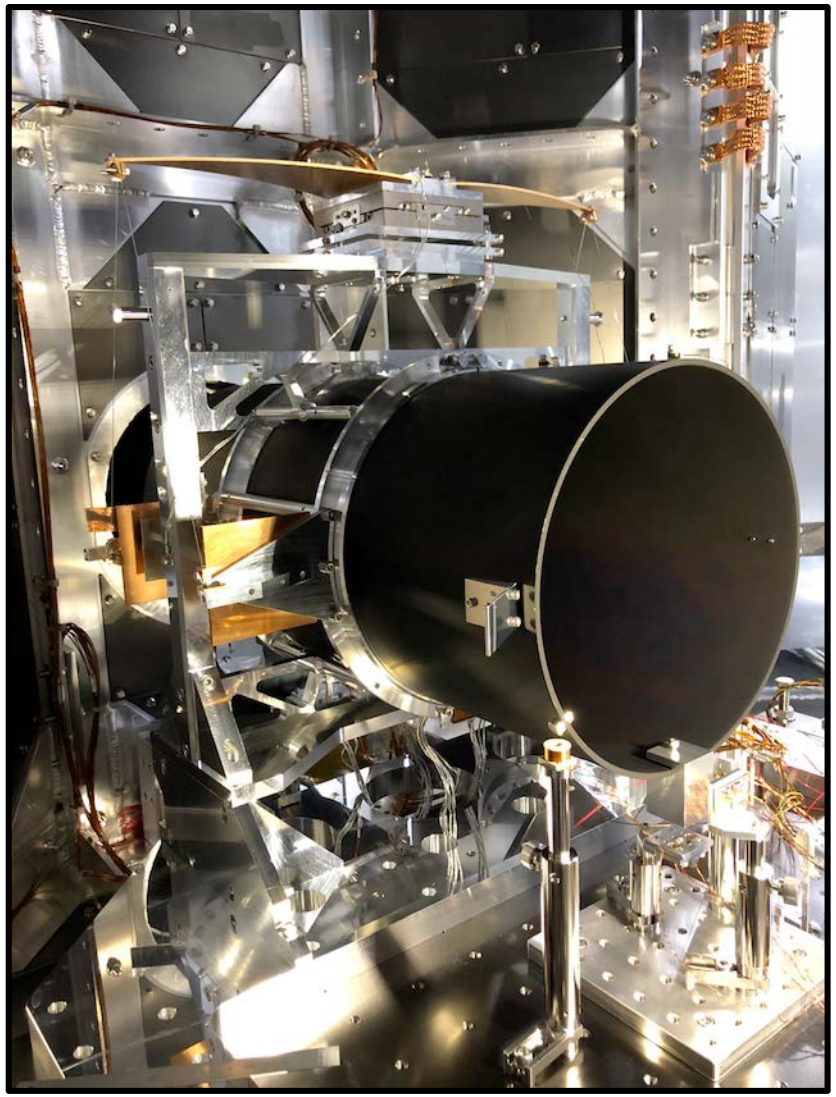
Cryo-payload
with a sapphire hung

EY (type A)

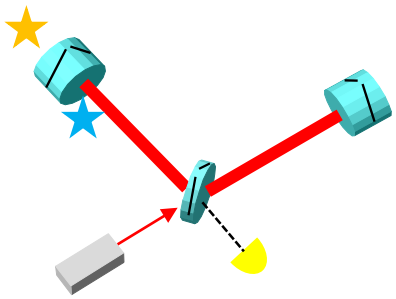


Figures: KAGRA VIS & CRY team

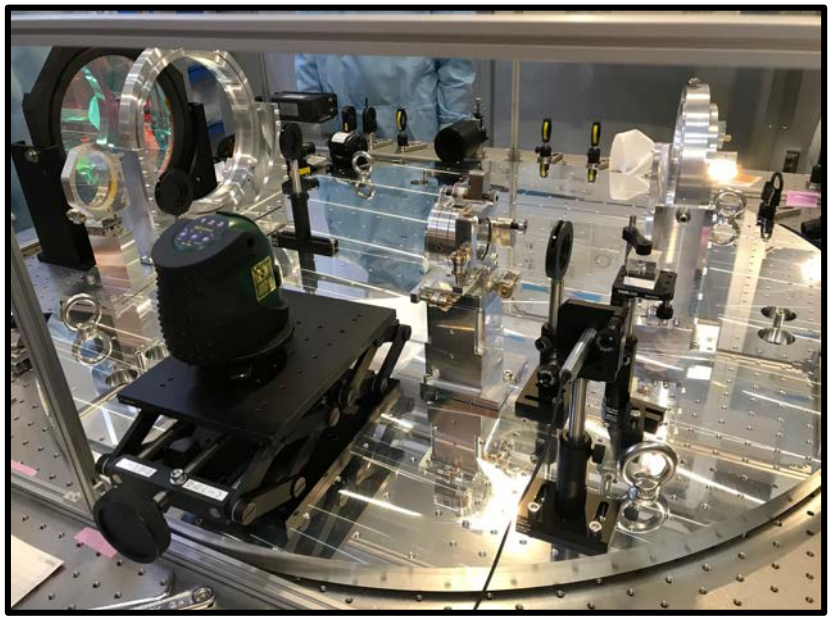
Detectors Status



★Wide Angle Baffle



Figures: KAGRA AOS team

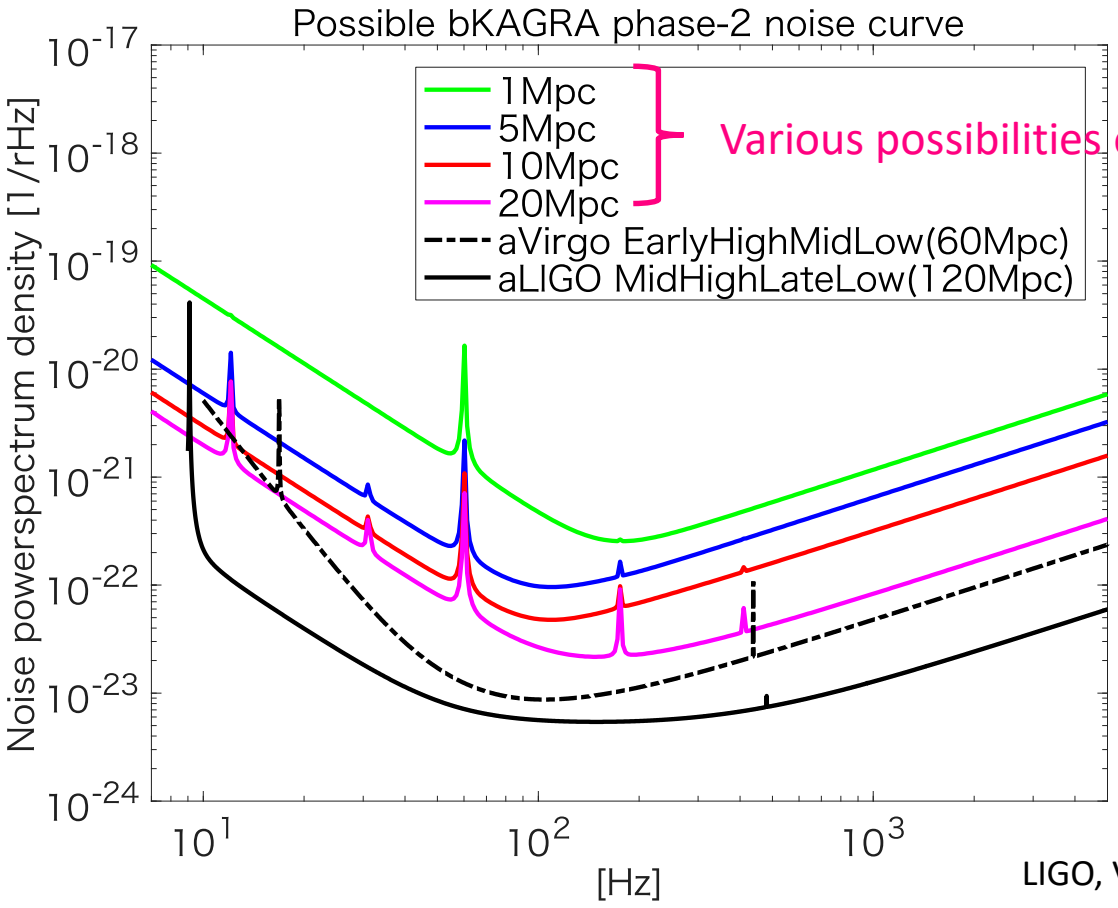


★Transmitting port detection bench

Sensitivity Threshold for O3

- Tagoshi, JGW-G1808094

Considering various BNS range of KAGRA



KAGRA(1Mpc)
KAGRA(5Mpc)
KAGRA(10Mpc)
KAGRA(20Mpc)
Virgo(60Mpc)
LIGO(120Mpc)

JGW-T1707556
JGW-T1707569
JGW-T1808031
LIGO, Virgo: taken from arXiv:1304.0670

Improvement for Source localization (preliminary)

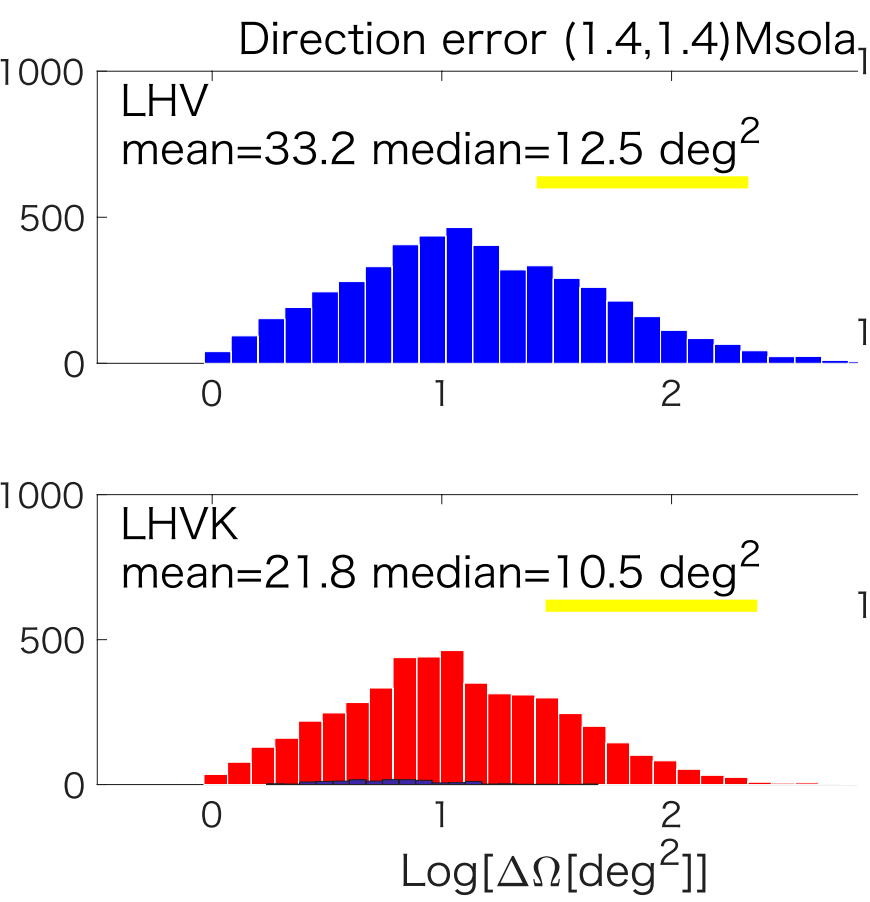
- Tagoshi, JGW-G1808094

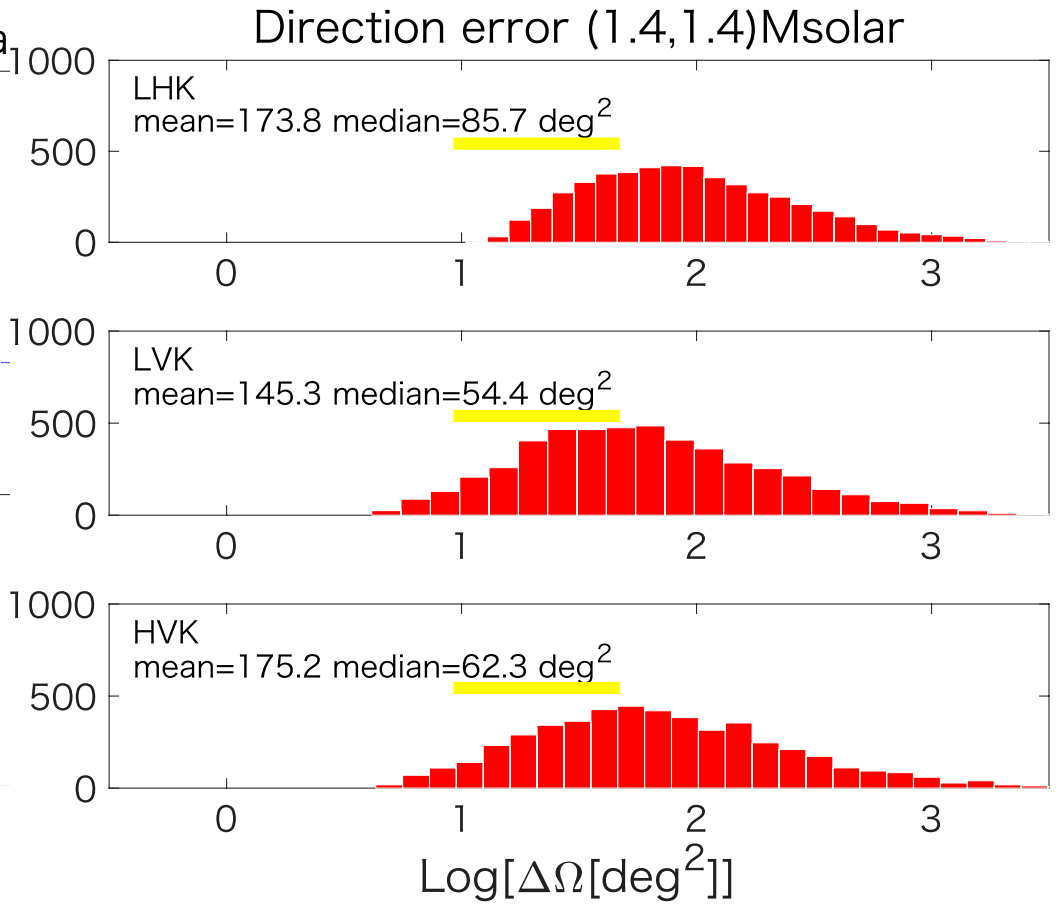
An example case study:

- BNS range (average observable distance with SNR=8):
  - KAGRA: 10Mpc
  - LIGO: 120Mpc
  - Virgo: 60Mpc
- Source:
  - BNS (1.4, 1.4) Msolar at 40Mpc
  - Uniform distribution for sky location, inclination, polarization
  - 5000 realizations
- Method :
  - Fisher matrix, Simple TaylorF2 waveform

Improvement for Source localization (preliminary)

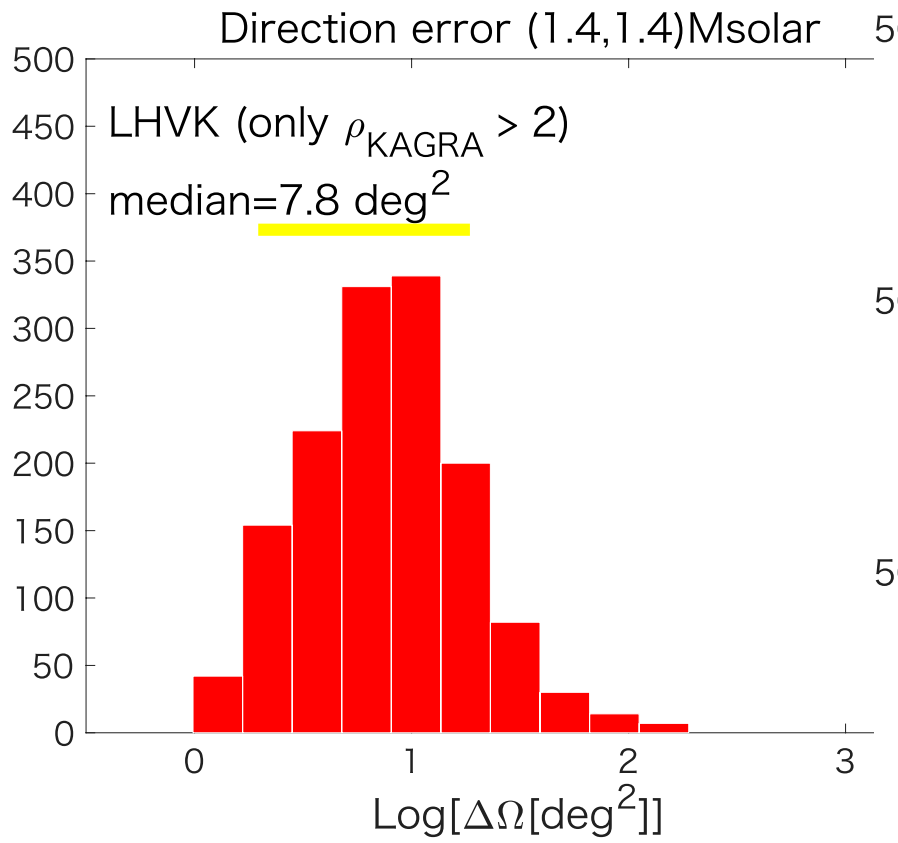
- Tagoshi, JGW-G1808094

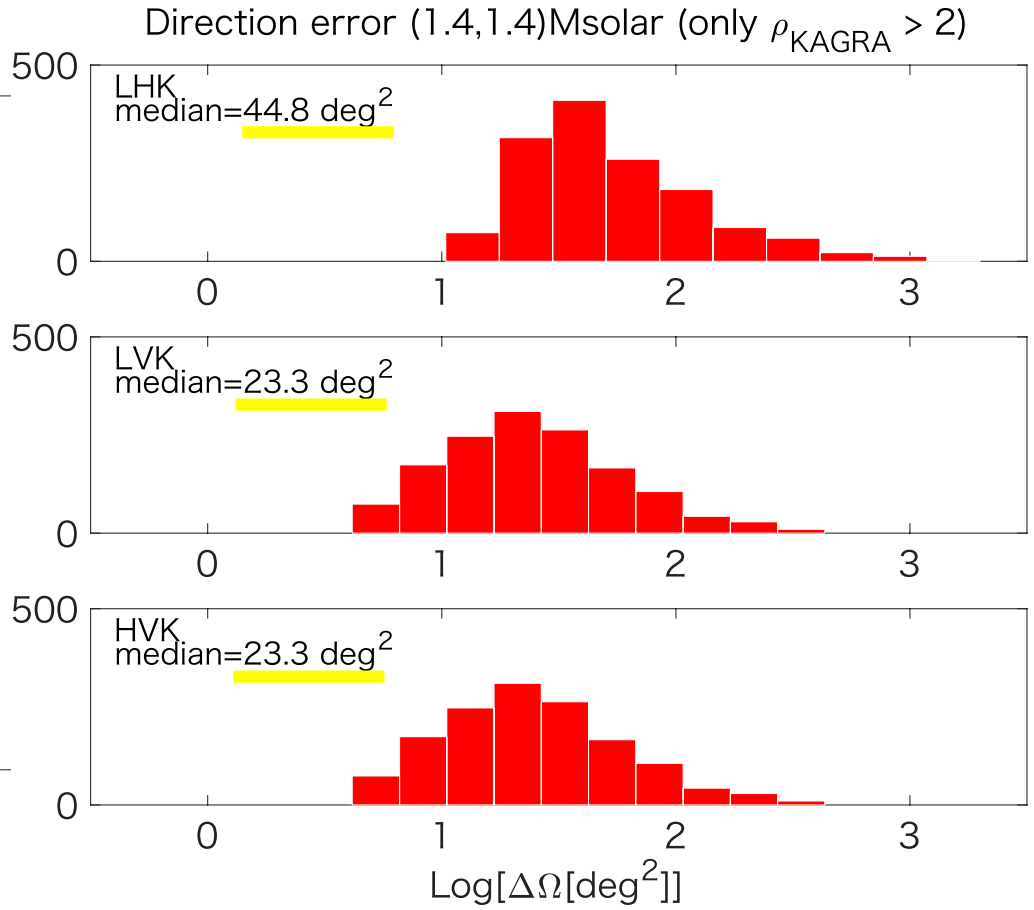




Improvement for Source localization (preliminary)

- Tagoshi, JGW-G1808094





GW170817 case: ΔΩ ~ 30 deg^2

Sky Localization Accuracy

- Tagoshi, JGW-G1808094

Baysian parameter estimation simulation

Source:

BNS (1.4, 1.4) Msolar at 40Mpc

Inclination = 30 deg

BNS range of detectors:

LIGO: 120Mpc, Virgo: 60Mpc , KAGRA: 10Mpc

Detectors	HL	HLV	HLK	HVK	LVK	HLVK
90% ΔΩ [deg^2]	66.4	14.0	32.5	15.7	27.6	10.1

Injected SNR 19.4 (H), 26.2 (L), 2.7 (V), 3.5 (K)

Detectors	HL	HLV	HLK	HVK	LVK	HLVK
90% ΔΩ [deg^2]	100	30.2	50.3	308.3	35.4	19.1

Summary

- KAGRA will perform test operation with cryogenic Michelson configuration in April (phase-1)
- Upgrade to the Full-configuration Cryogenic Interferometer will follow
- KAGRA will try to join O3
- Evaluation of sensitivity threshold to join O3 has started among KAGRA Joint efforts with LIGO and Virgo are starting soon

We are working very hard to join the next LIGO and Virgo observation

- from Tagoshi, JGW-G1707454-v3

Future: With Full KAGRA Sensitivity

NS-NS@180Mpc (95%CI)

(1.4,1.4)Msun	LHV	LHVK
median of δΩ [Deg^2]	30.25	9.5

L:LIGO-Livingston
H:LIGO-Hanford
V: Virgo
K: KAGRA
I: LIGO-India

J.Veitch et al., PRD85, 104045 (2012)
(Bayesian inference)
See also Rodriguez et al. 1309.3273

direction, inclination, polarization angle are given randomly

BH-NS@200Mpc

(10,1.4)Msun	LHV	LHVK	LHVKI
median of δΩ [Deg^2]	21.5	8.44	4.86

Tagoshi, Mishra, Arun, Pai, PRD90, 024053 (2014) , Fisher matrix

Further Future Outlook

Next Generation:
- LIGO Voyager (silicon cryogenic)

Future Ideas:
- Cosmic Explorer (US, 40km, cryogenic…etc)
- Einstein Telescope (EU, 10km) … or identical detectors?