Overview of Gravitational Wave Group in 2025

National Central University & Academia Sinica
Yuki Inoue on behalf of TW-LIGO instrumentation group and NCU-CMB group

CHiP GRAVITATIONAL WAVE

LSC

ASGRAF

2025/1/5 CHiP meeting

Taiwan-LIGO instrumentation group

National Central University
Yuki Inoue (PI)
Miftahul Ma'arif
Ta-Hun Yu
Hsiang-Yu Huang
Avani Patel
Kun-Yao Chang

Academia Sinica
Tsz-King Wong
Feng-Kai Lin
Daiki Tanabe
Vivek Kumar
Ting-Yi Liang

University of Philippine Diliman
Mario Organo

Senior Member
Chao Shiuh

NCU-CMB group (from 2025 April)

National Central University
Yuki Inoue
Masashi Hazumi

Calibration Analysis

Data analysis and pipeline development for Ongoing Observation

Core-Optics R&D

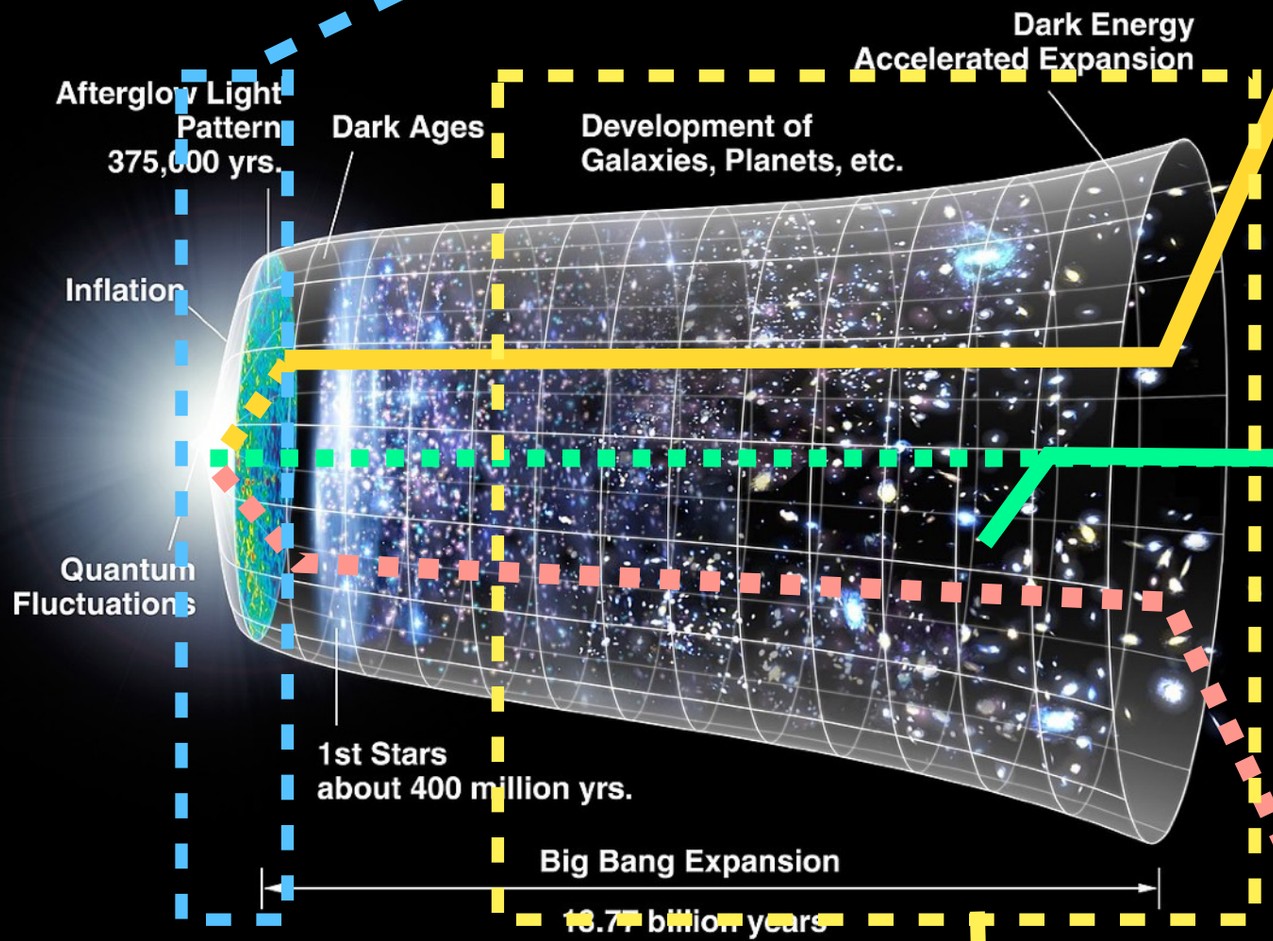
R&D for the new technology of GW with Taiwan semiconductor technology

Experimental Cosmology

Landscape of Gravitational wave stochastic background study with GW and CMB data

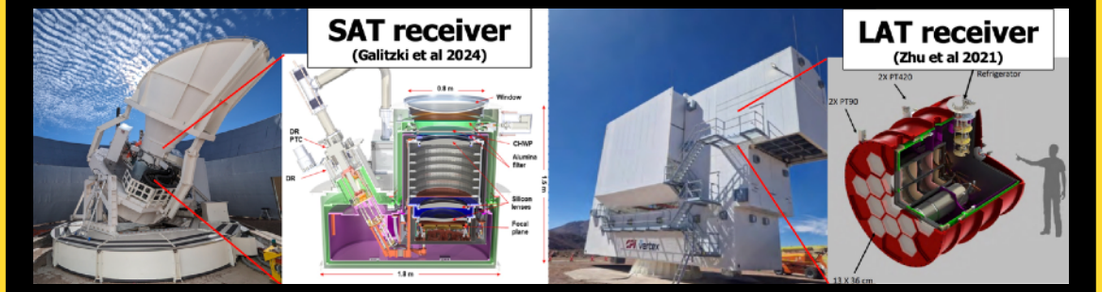
14 staffs and students join our group

Primordial Gravitational Wave



Astronomical Gravitational Wave

Simons Observatory

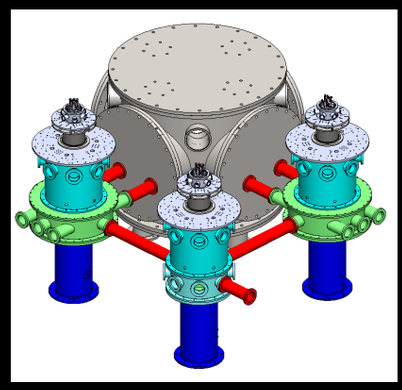


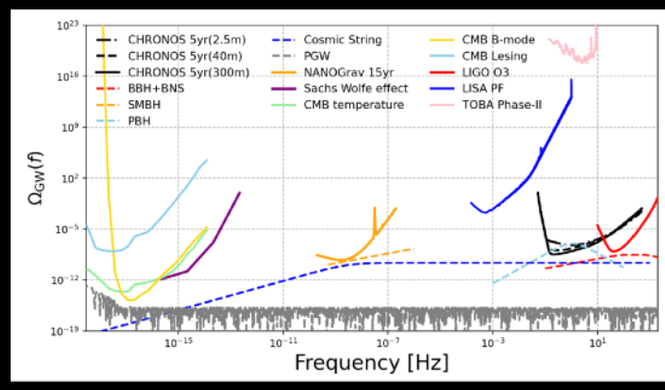
Science1 B-mode Detection
Science2 Cosmic Birefringence

LIGO-Virgo-KAGRA

Science3 Astronomical SGWB
Science4 Hubble constant

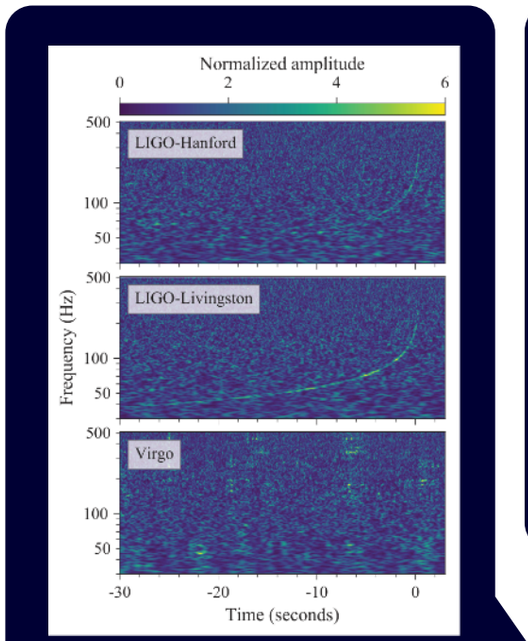
CHRONOS (New Probe)

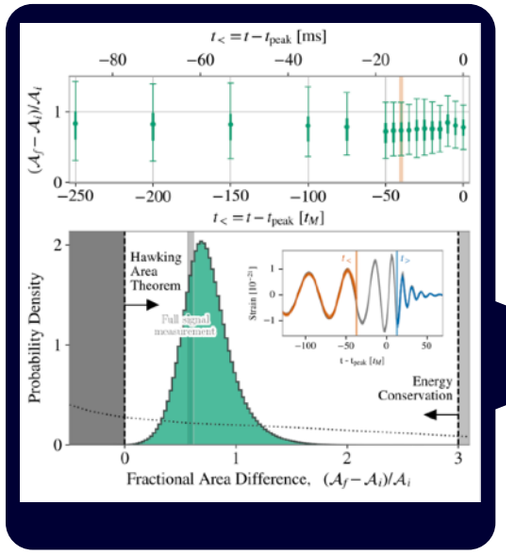




Science5 Sub-Hz GW

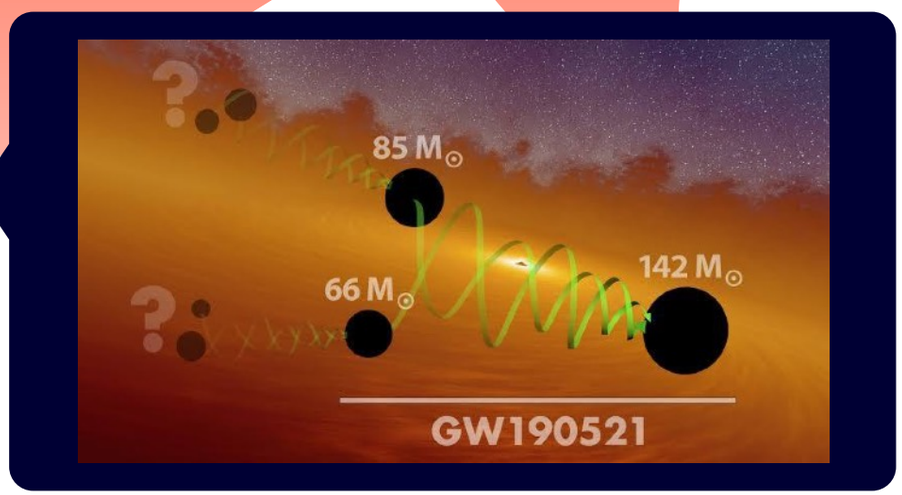
10 years anniversary



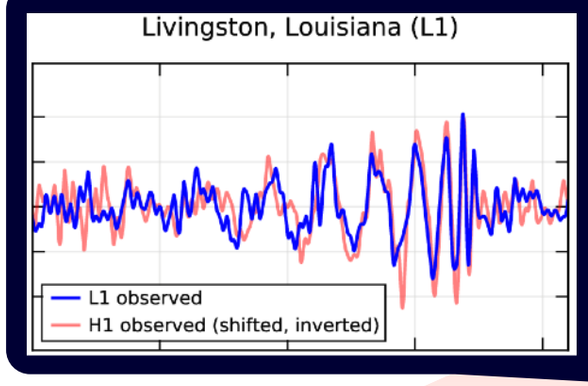


2025 Jan.14 Hawking's area law

2023 Nov.23 The largest Kerr black hole



2019 May. 21 IMBH



2017 Aug. 17 BNS

2015 Sep.14 The first detection

Before the great history of LIGO, there are discussion of quantum principle.

Introduction

10 years anniversary from the first detection of Gravitational wave

Main message of This talk!

OX = Observation X

Previous works

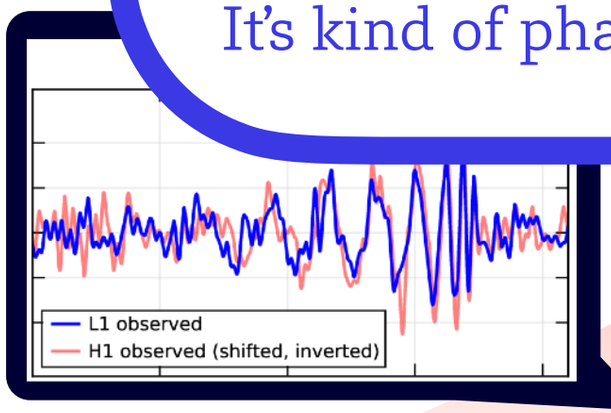
O1, O2, O3

The first detection era!

O4

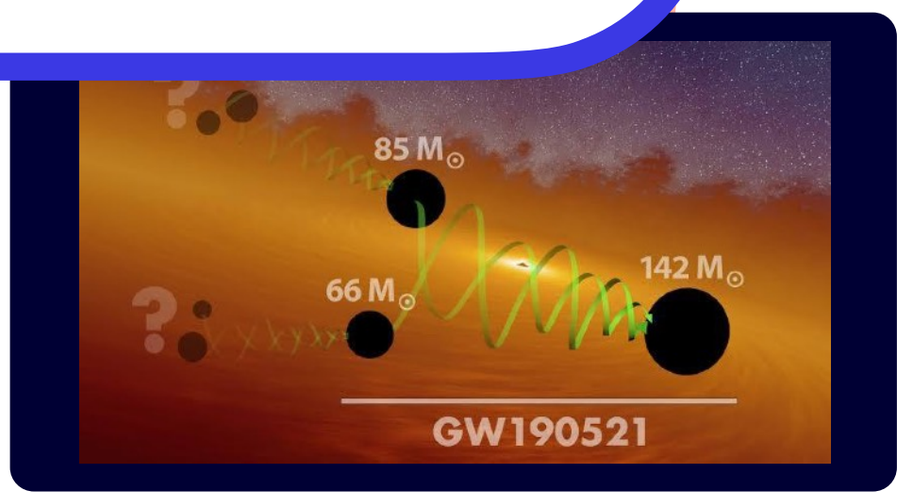
The statistical evaluation era!

It's kind of phase transition to new era of astronomical GW observation!



2017 Aug. 17 BNS

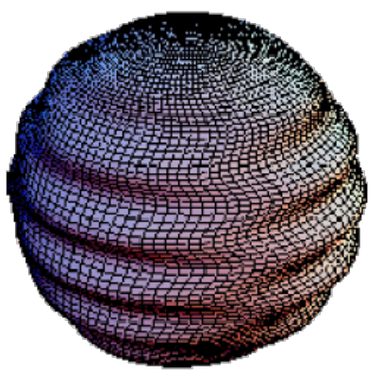
2015 Sep.14 The first detection



What’s next discovery?

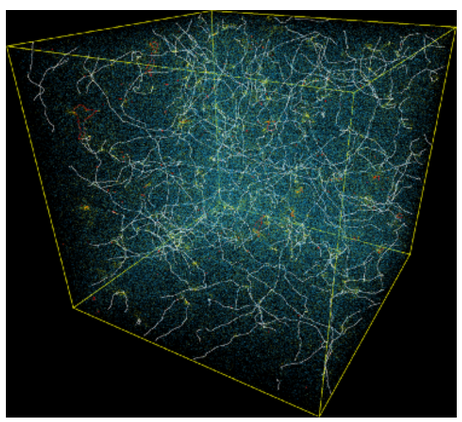
Stochastic background source

Primordial



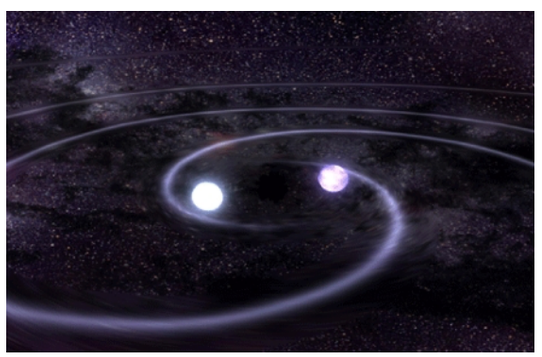
- Initial fluctuation
- Inflation

Phase transition



- Cosmic string

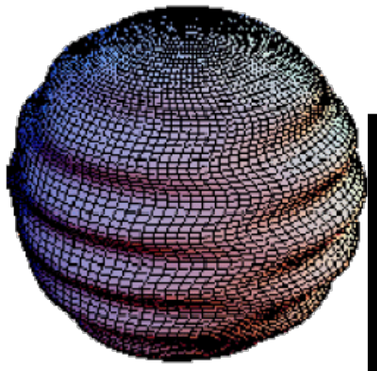
Astronomical



- BBH and BNS

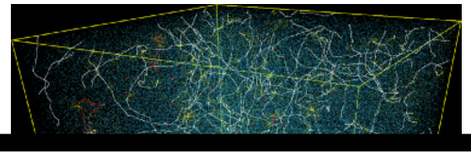
Stochastic background source

Primordial

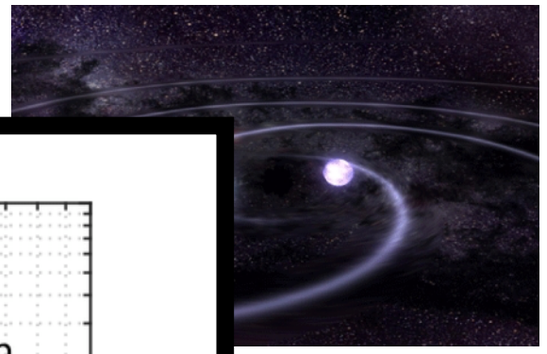


- Initial fluctu
- Inflation

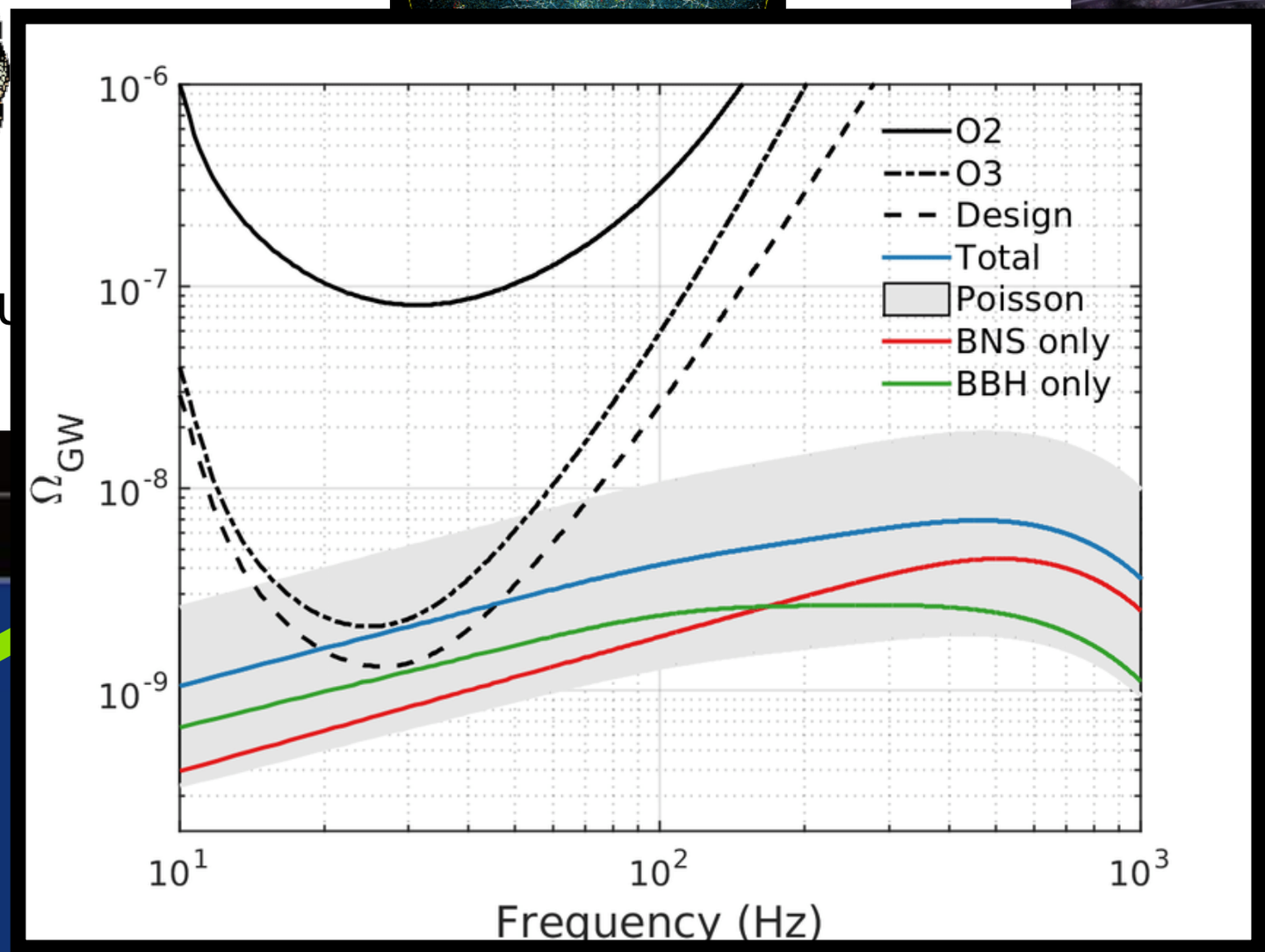
Phase transition



Astronomical



and BNS



CHRONOS 5yr(2.5m)
CHRONOS 5yr(40m)
CHRONOS 5yr(300m)
BBH+BNS
SMBH
PBH
Cosmic String
PGW
NANOGrav 15yr
Sachs Wolfe effect
CMB temperature
CMB B-mode
CMB Lesing
LIGO O3
LISA PF
TOBA Phase-II

$\Omega_{GW}(f)$

10^{23} 10^{16} 10^{9} 10^{2} 10^{-5} 10^{-12} 10^{-19}

10^{-15} 10^{-11} 10^{-7} 10^{-3} 10^{1}

Frequency [Hz]

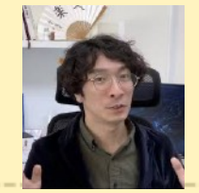
M.Hazumi
Simons Observatory

T.Okumura
Large Scale Structure

K.W.Ng
Puler Timing Array/ Cosmology

U.L.Pen

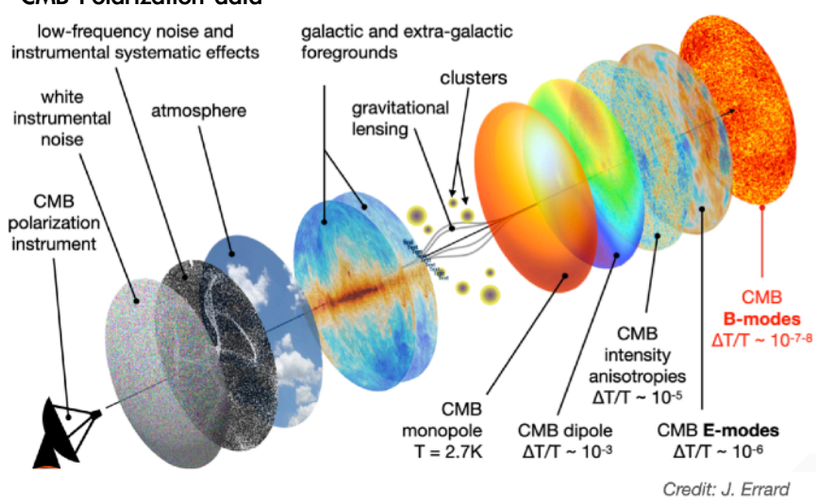
M.Onglao
Taiwanese GW detector



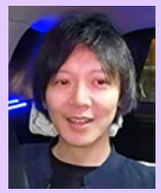
Y.Inoue
GW interferometer

Data

CMB Polarization data



Y.K.Chiang
Correlation analysis



K.Umetsu
SZ effect

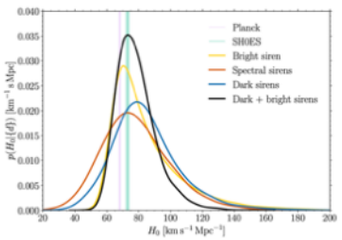
G.C.Liu
CMB and GW

C.H.Shen
QFT

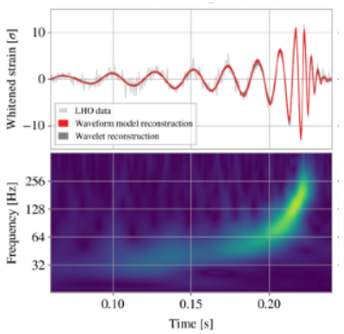
M.Sasaki
Cosmology

Data

Hubble constant



Black hole and Neutron star



New team for Stochastic background

陽明交通大学
S.I. Tam

IPMU
M.Takada

Subaru PFS

淡江大学
G.C.Liu

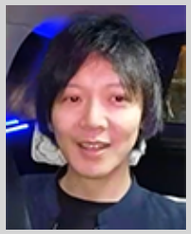
Princeton

Max Planck institute
E.Komatsu

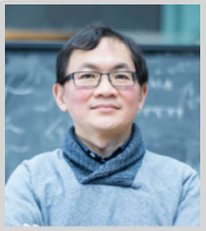
MoU

ASIAA
Observational Cosmology and Astrophysics


Teppei Okumura(PI)


Keiich Umetsu(Co-PI)


Yi-Kuan Chiang (Co-PI)


Ue-Li Pen


King-Wang Ng

Estimated Parameter

Theoretical prediction

NTU/LeCosPA
Quantum Field Theory


Chia-Hsien Shen(Co-PI)


Misao Sasaki

成功大学
I.N Chiu

Plan to join for SZ effect and Collation science

Combined Data analysis

Provide Released data

Theoretical prediction

中華民國重力学会

collaboration member

Simons Observatory

J. Dunkley (Princeton)
S. Staggs(Princeton)
B. Keating(UCSD)
A. Lee(UC Berkley)

NCU
Data analysis and Experiment for GW and CMB


Yuki Inoue (Co-PI)


Masashi Hazumi


Mario Onglao

collaboration member

IGWN/LIGO

A.Markoshan(Stanford U.)
R.Adohikari (Caltech U.)
J.Betzwieser (LIGO Livingston)
E.Goetz (British Columbia U.)
L.Sun (National Australia U.)

MoU

University of Philippines , Diliman

ASIOP
H.Wong

CHiP
C.M.Kuo(NCU)

collaboration

KEK
Y.Chinone (KEK/QUP)
M.Hasegawa (KEK/QUP)
T.Kanayama (KEK)

A lot of Achievements on 2025

- LIGO O4-a data release and publications -> Daiki Tanabe
- CHRONOS paper release -> Mario Onglao
- LIGO remote control room in CHiP -> Hsiang-Yu Huang
- Coating study -> Vivek Kumar & Ting-Yi Liang

Recent papers

CHRONOS: Cryogenic sub-Hz cROss torsion bar detector with quantum NOn-demolition Speed meter

Yuki Inoue,[1,2,3,4,*] Hsiang-Chieh Hsu,[3] Hsiang-Yu Huang,[1,2] M.Afif Ismail,[1,2,3] Vvek Kumar,[3,5] Miftahul Ma'arif,[1,2] Avani Patel,[1,2] Daiki Tanabe,[3,2,4] Henry Tsz-King Wong,[3,2] and Ta-Chun Yu[1,2]

[1]*Department of Physics,National Central University, Taoyuan, Taiwan*
[2]*Center for High Energy and High Field (CHiP), National Central University, Taoyuan, Taiwan*
[3]*Institute of Physics, Academia Sinica, Taipei, Taiwan*
[4]*Institute of Particle and Nuclear Studies, High Energy Acceleration Research Organization (KEK), Tsukuba, Japan*
[5]*Department of Physics, Institute of Applied Sciences and Humanities, GLA University, Mathura 281406, India.*
(Dated: October 25, 2025)

Optical design and sensitivity optimization of Cryogenic sub-Hz cROss torsion bar detector with quantum NOn-demolition Speed meter (CHRONOS)

Yuki Inoue,[1,2,3,4,*] Daiki Tanabe,[3,2,4] M.Afif Ismail,[1,2,3] Vivek Kumar,[3,5] Mario Juvenal S Onglao III,[6,2] and Ta-Chun Yu[1,2]

[1]*Department of Physics,National Central University, Taoyuan, Taiwan*
[2]*Center for High Energy and High Field (CHiP), National Central University, Taoyuan, Taiwan*
[3]*Institute of Physics, Academia Sinica, Taipei, Taiwan*
[4]*Institute of Particle and Nuclear Studies, High Energy Acceleration Research Organization (KEK), Tsukuba, Japan*
[5]*Department of Physics, Institute of Applied Sciences and Humanities, GLA University, Mathura 281406, India.*
[6]*National Institute of Physics, University of the Philippines - Diliman, Quezon City 1101, Philippines*
(Dated: October 25, 2025)

Torque cancellation effect of Intensity noise for Cryogenic sub-Hz cROss torsion bar detector with quantum NOn-demolition Speed meter (CHRONOS)

Daiki Tanabe[a,b,d†], **Yuki Inoue**[c,d,a,b‡], **Vivek Kumar**[e,a], **Miftahul Ma'arif**[c,d], **Ta-Chun Yu**[c,d]
[a]Institute of Physics, Academia Sinica, Nangang, Taipei, 015011, Taiwan
[b]Institute of Particle and Nuclear Studies (IPNS), High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305-0801, Japan
[c]Physics Department, National Central University, Taoyuan 32001, Taiwan
[d]Center for High Energy and High Field Physics, National Central University, Taoyuan 32001, Taiwan
[e]Department of Physics, Institute of Applied Sciences and Humanities, GLA University, Mathura 281406, India

CHRONOS

Main project paper

Y.Inoue et. al.
arXiv: 2509.23172
Submitted to PRL. Under reviewing.

Optical feasibility paper

Y.Inoue and D.Tanabe et. al.
arXiv: 2510.24780
Submitted to PRD.

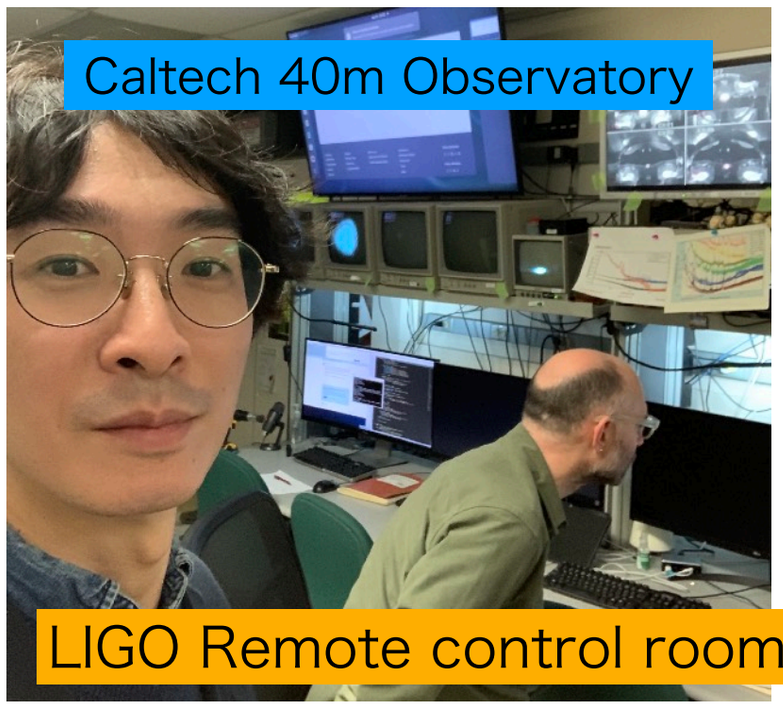
Intensity noise paper

D.Tanabe and Y.Inoue et. al.
arXiv: 2510.24779
Submitted to PRD.

Detail is reported by Prof.Mario Onglao's report

International Collaborations

New device are developed!



LIGO Remote control room in Taiwan!

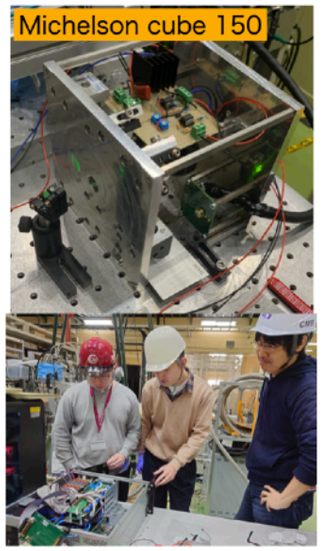
MoU b/w CHiP and UoP Diliman!

Achieved ultra low loss coating!

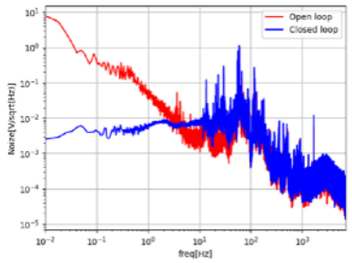
Michelson Alignment Cube 150
Collaboration with QUP/KEK

Last year report

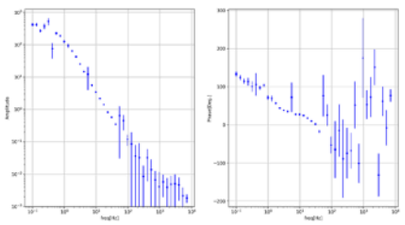
Collaboration with QUP/KEK



Noise measurement



Transfer function measurement



Install to NCU observatory

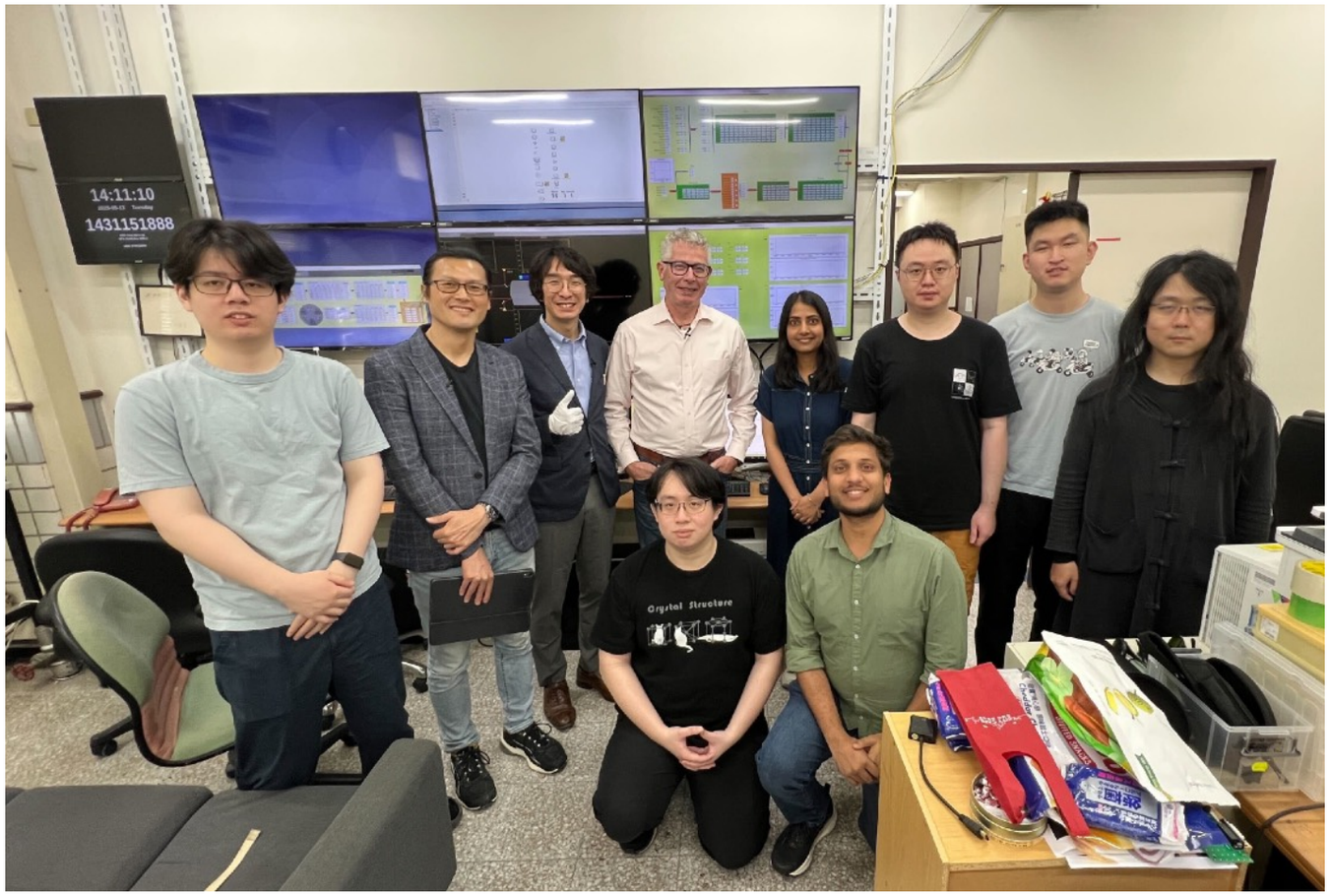
2026~

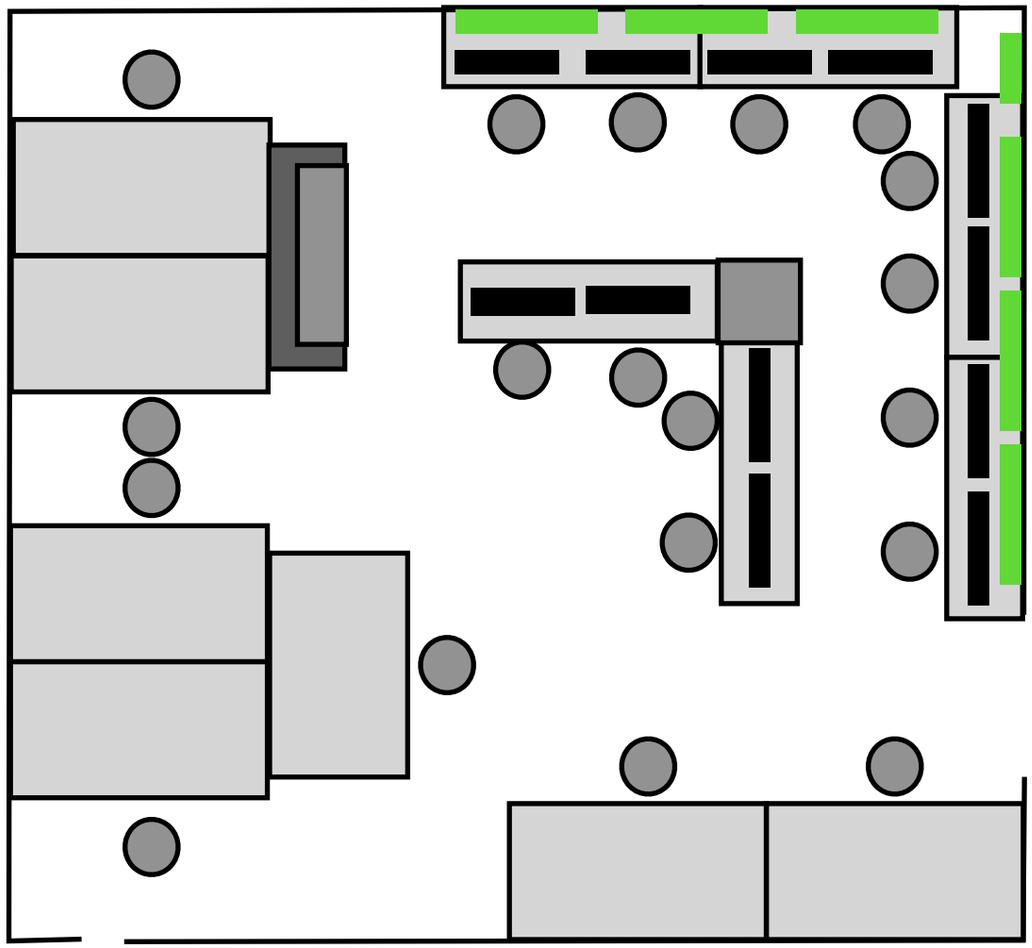
MAC100

iPad size

iPhone size

LIGO Remote control room in NCU

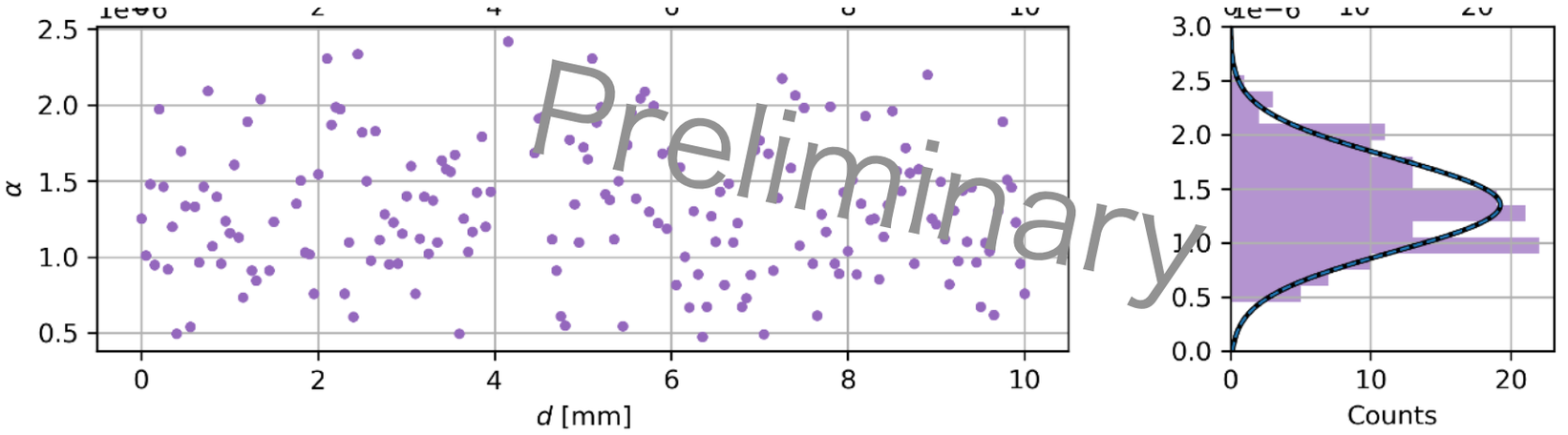




- Host institute: NCU CHiP
- Control LIGO Livingston and Hanford observatory
- Demonstration test is reported by Hsiang-Yu's presentation

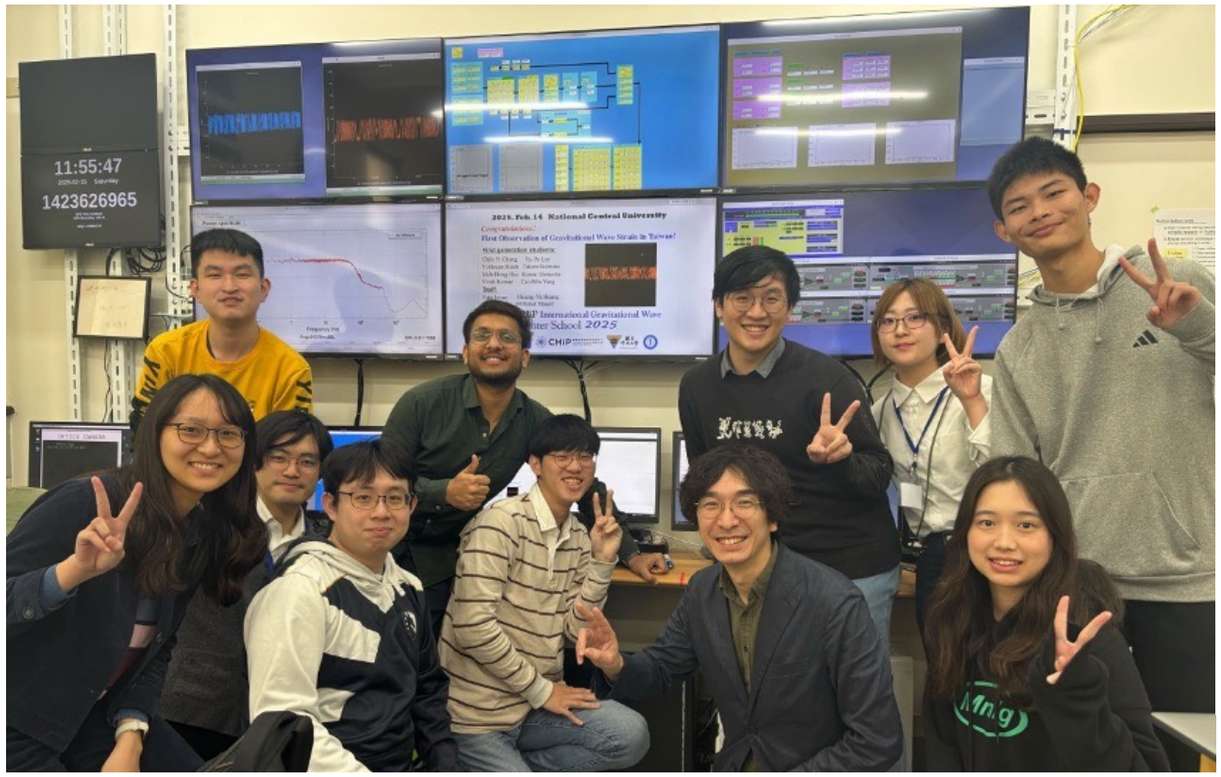
LPCVD coating (aSi, SiN,SiON)

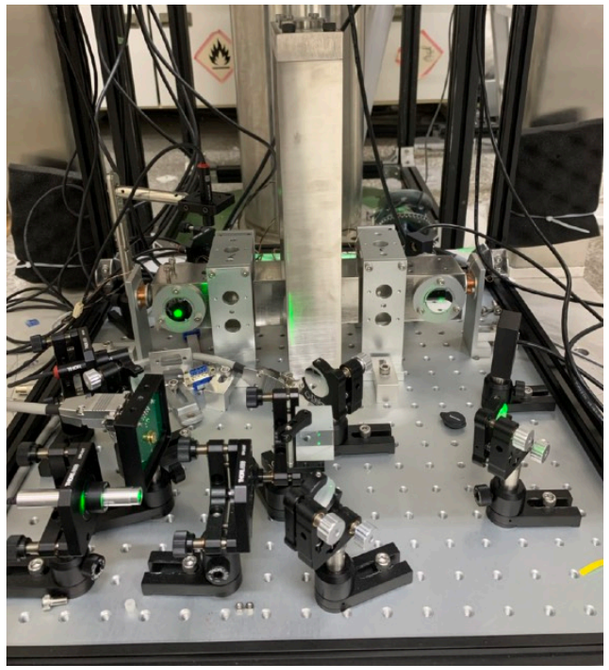
Ultra low optical loss coating is demonstrated!!

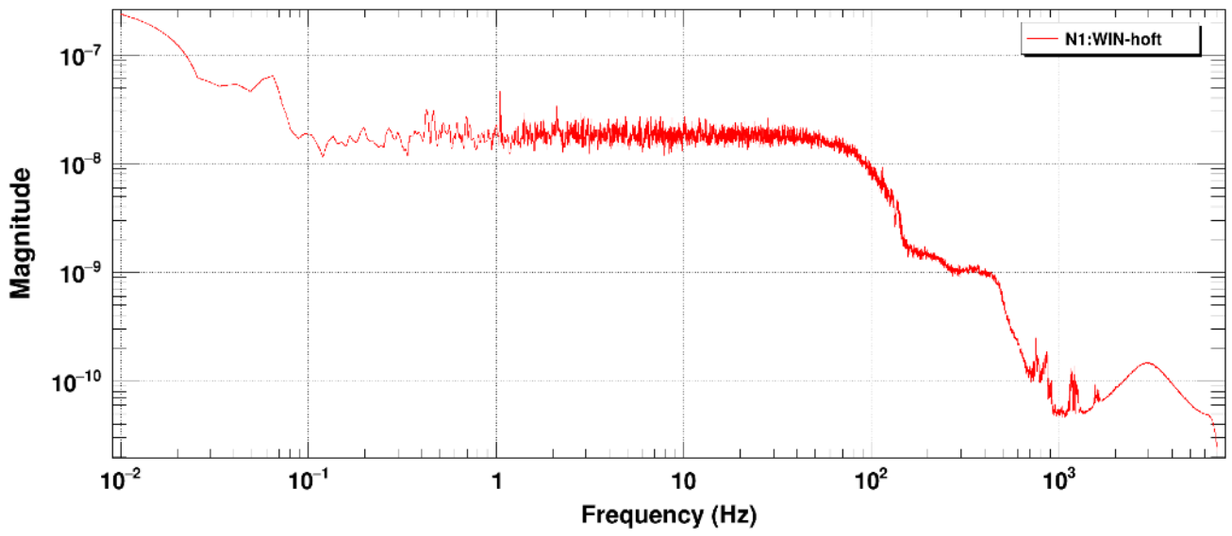


- Collaboration works between Stanford and NCU
- Improvement of Uniformity of material property
- Understanding of Band gap is necessary
- LIGO optical loss: 5 ppm

Winter school and Summer school







We organized CHiP International GW summer/winter school!

In the school, we tried to reconstruct h(t) signal from interferometer response.

Summary

- Observation 4 is successfully finished. We are focusing on O5 study. Both Dr.Daiki Tanabe and Dr.Avani Patel are playing significant roles for next LIGO.

- Development and characterization of new coating are ongoing. We achieved ultra low optical loss coating.

- CHRONOS R&D is ongoing.

- Michelson Cube 150 was developed.

- We will focus on Stochastic Background study as NEXT.