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Recent News and Status of the KAGRA Gravitational Wave Telescope

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First Detection of GW

- Advanced LIGO detectors
- binary black hole mergers GW150914 36Msun & 29Msun GW151226 14Msun & 7.5Msun





Where Do BBHs Came From?

- masses were heavier than expected
- usual stars can only be ~10Msun BHs
- still under discussion
 - primordial BHs?
 - from first stars?
 - from globular clusters?
 - etc.....





https://www.ligo.caltech.edu/

Sky Location

- sky location with 2 detectors has limitations within ~ hundreds of square-degrees (size of the full moon: 0.5 deg²)
- need 3 or more detectors to localize better

LVT151012

GW150914

GW151226

4

Global Network of GW Detectors

 upgrade/construction around the world

GEO-HF operation)

Advanced Virgo (construction)

LIGO-India (approved)

Advanced LIGO (preparing for O2)



KAGRA (construction)

KAGRA

東京大学

- Large-scale Cryogenic Gravitational Wave Telescope (Nickname: KAGRA)
- constructed underground in Japan
- 60+ institutes, 200+ collaborators

OF TOYAMA

degli Studi

del Sannio

project started in 2010



Takaaki Kajita

IHS

and many

more...

PI:

KORE

Mathematical Sciences | South

Where's KAGRA?

• Kamioka mine, Gifu, Japan



Facilities Around Kamioka

3 km L-shaped tunnel under Mt. Ikenoyama

XMASS(dark matter) CLIO KamLAND(neutrino) (GW) X tunnel(3 km) Super-Kamiokande

KAGRA

(neutrino)

Gooale 牧発電所

Route 41

tunne

ffice

東茂住郵便局一

©2016 Google、DigitalGlobe、Cnes/Spot Image、地図データ©2016 ZENRIN maps.google.co.jp フィードバックの送信 3D

高幡山 丛

津島神社 🖬

大滝 🙃

KAGRAトンネル

- 3 km vacuum pipe for each arm (~ 1e-7 Pa)
- laser beam go back and forth





Working Underground is Tough

 helmet, work clothes, rubber boots, oximeter, electric bicycles, etc



Why Underground?

- seismic motion of mirrors will be noise source
- seismic noise underground is roughly 2 orders of plot by A. Shoda, JGW-G1605219 magnitude NS $\mathbf{H}_{\mathbf{Z}}$ 10⁻⁶ smaller WE Displacement [m/v 10^{-7} seismic 10^{-8} motion 10^{-9} 10^{-10} KAGRA 10^{-11} (Kamioka) 10^{-12}

ler

 10^{-1}

 10^{0}

Frequency [Hz]

 10^{1}

 10^{2}

11

Laser

Suspensions for Seismic Isolation

suspend mirrors to reduce seismic noise



Vibration Isolation System

• 7-stage pendulum super attenuators



Room Temperature Suspension





Thermal Noise

- Brownian motion of atoms creates thermal noise
- cool down mirrors to 20 K to reduce thermal noise



Cryostat

developed cryocoolers with ultra-low vibration



TOSHIBA Leading Innovation >>>



cryocooler

Displacment meter for ch1

> Displacment meter for ch2 柏で実験中の冷凍機ユニット⁶

Inside the Cryostat



Optical Baffles

- for absorbing stray light and 300 K thermal radiation
- nickel-phosphorus-tungsten (NiPW) black coating

T. Akutsu+, Optical Materials Express 6, 1613 (2016)





Sapphire Mirror

sapphire has high Q-value

- HR loss < 45 ppm
- absorption
 < 50 ppm/cm
- figure error
 < 0.5 nm rms

$$\delta x_{
m thermal} \propto \sqrt{rac{T}{\zeta}}$$

E. Hirose+, Phys. Rev. D 89, 062003 (2014)

22 cm dia.



Clean Environment

• ISO class 1 super clean booth



Recent News

- Nov 2015: inauguration of initial phase facility
- Mar-Apr 2016: First test runs with simplified 3-km Michelson configuration



http://kyodonews.net/news/ 2016/03/25/54510

First Test Runs

- 3-km room temperature Michelson interferometer
- March 25 31 and April 11 25



Duty Factor

• 85.2 % for March run, 90.4 % for April run



Sensitivity

not good, but the very first result for KAGRA **MICH NoiseBudget** 10⁻⁵ Measured 10⁻⁶ Sum seismic notse 10⁻⁷ Acoustic noise displacement [m/rtHz] 10⁻¹⁰ 10⁻¹⁰ 10⁻¹⁰ 10⁻¹¹ 10⁻¹² 10⁻¹³ 10⁻¹⁴ Actuator noise 10⁻⁸ Frequency noise Intensity noise OUSTIC 10⁻⁹ Seismic noise Sensor noise Shot noise ADC noise 10⁻¹⁶ 10¹ 10³ 10^{0} 10⁻¹ 10² 10^{4} frequency [Hz] plot by T. Shimoda, M. Nakano

Test Run Results

- gained experience on 3-km interferometer operation
- observation shift and data transfer/management worked as expected
- plot by K. Hayama, A. Araya et al. acquired environmental K1:LSC-MICH OUT 80 measured with data at KAGRA site ey-ex 3-km Michelson 60 displacement[um] e.g. tidal length change of 40 3-km arms 20 -20 prediction using GOTIC2 model 3 (tidal effect from the Moon and the Sun) 0 from 9:00JST 25 Mar, [day] time 2016

Data Transfer and Management

- real time transfer to ICRR Kashiwa and Osaka City Univ.
 - (~3 sec latency,~ 200 MB/sec)
- delayed mirroring at Academia SINICA, Taiwan and KISTI, Daejeon
- 7.5 TB in total



KAGRA Roadmap



Recent Progress on Cryogenics

- cryogenic suspensions under development
- cryostat assembly on-going





photos from JGW-G1605315

Summary

- KAGRA is under construction at Kamioka, Japan
- Key features: underground and cryogenic
- First test runs with room temperature 3-km Michelson interferometer successfully completed on March 2016
- Cryogenic test run expected on March 2018
- Observation runs expected on ~ 2019