Status of KAGRA -construction, commissioning and data distribution toward the first operation in 2015-

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KAGRA is a laser interferometric gravitational wave detector under construction in the Kamioka-mine, Japan. The excavation of the tunnel was completed on March 2014. We are installing the peripherals in 2015: vacuum system, cryostat, vibration isolation system, laser, optics, digital control system and data acquisition, etc.

KAGRA will have a the first operation at room temperature mirror planned in the end of 2015, which is called as iKAGRA. iKAGRA is not only a first observation of KAGRA, but also an end-to-end test of the whole KAGRA system including data analysis.

Keywords: KAGRA; Gravitational Waves; Laser Interferometric Detector for Gravitational Waves

1. Introduction

The gravitational wave is an important prediction by Einstein with his 'Theory of General Relativity' in 1916. We humankind have been trying to detect the gravitational waves. However, according to the very weakly coupling constant of gravity interaction, the direct detection of the gravitational wave has not been achieved yet in the summer of 2015. In the hundred years memorial of the born of General Relativity, some large experiments is getting highly potential of the detection. Advanced LIGO [1], Advanced Virgo [2] will upgraded from their initial configuration, and will achieve the 100 Mpc detection range for the gravitational wave from neutron star binary soon. KAGRA [3 4] is also large laser interferometric gravitational wave detector. It is now under construction, and is planning to have a first operation in December 2015.

The gravitational wave is a propagation of the distortion $h_{\mu\nu}$ of the space-time. We can derive the wave equation from the perturbation of Einstein equation of General Relativity. The mass motion which has change of the quadruple moment $I_{\mu\nu}$ will be a source of gravitational wave radiation. The amplitude of the gravitational wave is $h \sim \frac{2G}{Rc^4}\ddot{I_{\mu\nu}}$ where R is a distance from the source, c is a speed of light. Since the coupling constant of the gravitation G is weak, it is hard to prepare the artificial size sources for the measurement.

The main target of current ground-based gravitational wave detectors are massive and compact astoronomical objects, e.g. stellar-core collapse at supernovae, coalescence of binary compact stars as neutron stars and/or black holes, pulsars, etc. These compact objects are produced or connected with high energy phenomenon with strong gravity field. In this mean, the detection of the gravitational waves are not only as the confirmation of the General Relativity, but also will be a probe for such a drastic astronomical objects.

However, even in the case of neutron star binary coalescence at 100 Mpc away, the strain amplitude is roughly $h \sim 10^{-24}$ To measure this incredible small amplitude, km-scale ground-based laser interferometers are under upgrade/construction.

2. KAGRA

2.1. *overview*

KAGRA is a laser interferometric gravitational wave detector under construction in the Kamioka-mine, Japan. The KAGRA interferometer is a 3km base-line Fabry-Perot-Michelson, which is placed inside the tunnel under the mountain to reduce the seismic disturbances and to achieve stable environment. KAGRA also employs cryogenic mirrors with sapphire substrate to reduce the thermal noise.

KAGRA design sensitivity is shown in Figure 1.

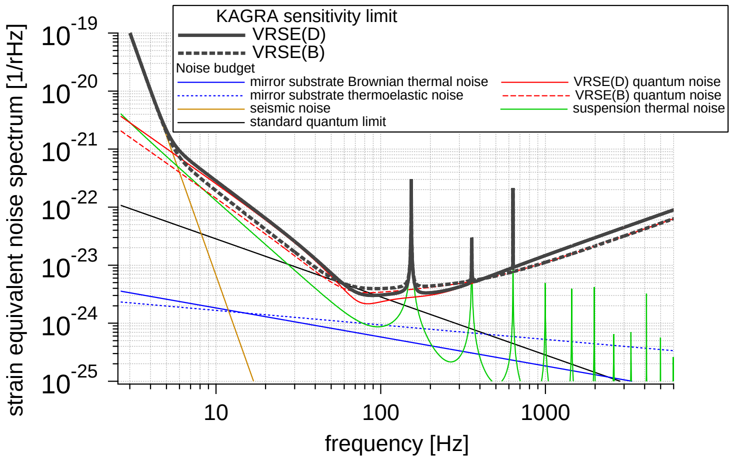

Fig. 1. Official Design Sensitivity of KAGRA [5]

This sensitivity curve can be derived from the 'detection range' of the gravitational waves for certain sources : compact binaries. For most promising source neutron star binary coalescence, KAGRA will have a detection range of 176 Mpc for whole sky average, and maximum reach of 280 Mpc. Figure 2 displays maximum reach of detection range as a function of the mass.

The important milestones of KAGRA operation are planned.

iKAGRA , which means 'initial' KAGRA. Test mass mirrors will be in room temperature, and the interferometer configuration is simple Michelson type. Cryostat chambers are placed at KAGRA site already, but it will not op-

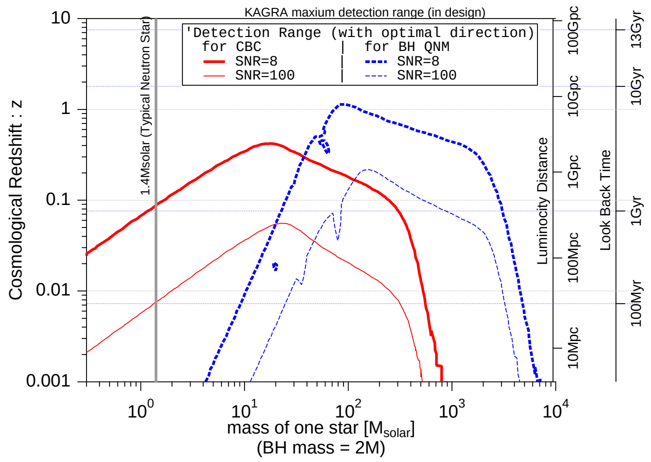

Fig. 2. KAGRA's maximum reach of detection range of Gravitational Wave sources. red line : compact binaries, blue line : quasi-normal mode of black hole formed by binary coalescence with 3% mass energy, Kerr parameter 0.9.[6]

erate in iKAGRA. However, iKAGRA requires the whole system operation from laser to the data analysis pipeline. This is KAGRA's first operation with its end-to-end system. iKAGRA operation is planned as December 2015.

bKAGRA , which means 'baseline' KAGRA. This is nominal configuration of KAGRA with cryogenic temperature mirror. The interferometer configuration will be Fabry-Perot-Michelson with power and signal recycling. Thus, we will realize not only cryogenic mirrors and suspensions, but also advanced optics from iKAGRA to bKAGRA. bKAGRA is planned as starting late 2017 or early 2018.

2.2. *Construction Status of KAGRA*

The excavation of the tunnel was completed on March 2014. We are installing the peripherals in 2015: vacuum system, cryostat, vibration isolation system, laser, optics, digital control system and data acquisition, etc.

Photographs in Fig.3(a)(b) show the recent progress of KAGRA. Photographs (a) and (b) were taken at almost same position of KAGRA tunnel, from the center corner toward the X- and Y-arm. These photographs show the typical progress of KAGRA site in these 8 months.

2.3. *Data Distribution Plan*

At the iKAGRA operation, we also plan to implement KAGRA data system that include the data transfer between the detector site and remote storages. To real-

Fig. 3. Photograph from the center corner toward the X- and Y-arm. (a) is taken on October 28th 2014, (b) is taken on July 6th 2015.

ize a low latency event search in KAGRA, the data transfer and distribution are important role of iKAGRA operation.

Fig. 4 displays overview of KAGRA data flow : i.e. transfer and distribution of data.

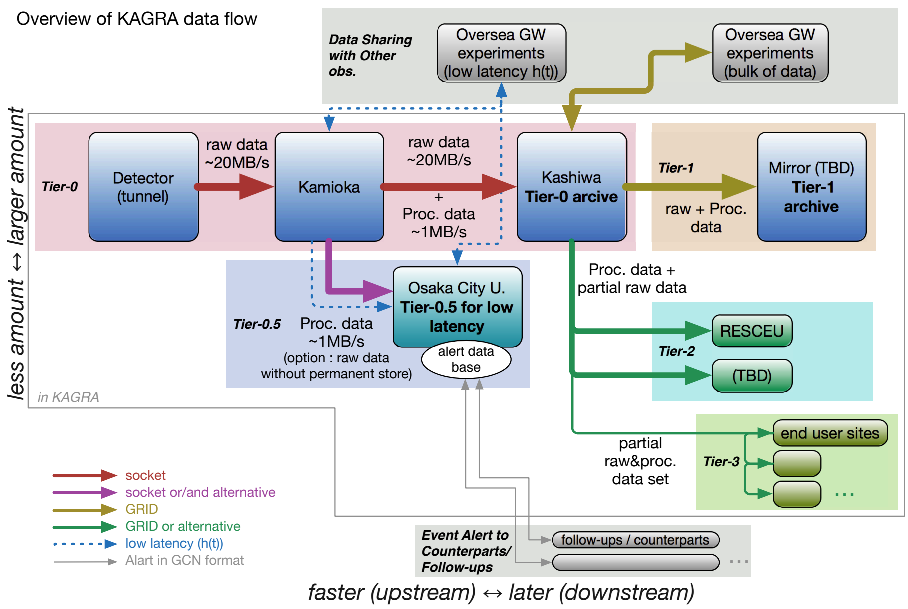

Fig. 4. KAGRA data transfer and distribution

KAGRA data derived from digital control system are written in frame formatted data files. Data files will be transferred to the data server in surface building of Kamioka, via optical fiber for data transfer exclusive use. Rate of raw data is about

20MB/s ($\sim$ 630 TB/year). In surface building at Kamioka 'Analysis building', temporary storage system with 200 TiB lustre file system. 'Lustre' system is parallel distributed file storage which consists of meta-data servers and object storage servers to achieve the redundancy and high reliability. The temporary storage system is not only a safety spool of network transfer but also quick access storage for on-site studies. Raw data files and pre-process data that include calibration or off-line detector characterization will be sent to Kashiwa main storage. In iKAGRA, the storage of Kashiwa is 100 TiB system, but it will be upgraded as Peta-Byte class in bKAGRA era.

Another important path of data distribution is from Kamioka to Osaka. The cluster system at Osaka City University will execute event search pipeline for the low latency searches of compact binary coalescence and burst gravitational waves.

3. Summary and Acknowledgement

KAGRA construction progresses rapidly in 2014-2015. Its first operation iKAGRA is planned to be held at December 2015. We hope to achieve this important milestone of KAGRA.

KAGRA work was supported by MEXT, Leading-edge Research Infrastructure Program, JSPS Grant-in-Aid for Specially Promoted Research 26000005, and JSPS Core-to-Core Program, A. Advanced Research Networks.

The work of the low latency GW data analysis was supported by MEXT Grant-in-Aid for Scientific Research on Innovative Areas "New Developments in Astrophysics Through Multi-Messenger Observations of Gravitational Wave Sources" (Grant Number 24103005).

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