Present a possible observing scenario for the Advanced LIGO, Advanced Virgo, and KAGRA.

To be submitted to ‘Living Review of Relativity’.

* Draft is under review process in each collaboration.

Put at document servers:
- LIGO -- P1200087
- VIRGO -- VIR-0288A-12
- KAGRA -- JGW-P1706086-v1.

* Co-author list:
Alphabetical order using LIGO/VIRGO/KAGRA combined list. For KAGRA based on KAGRA2015.

Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO, Advanced Virgo and KAGRA

Abbott, B. P. et al. (LIGO Scientific Collaboration, Virgo Collaboration and KAGRA Collaboration)

January 20, 2017

Abstract

We present a possible observing scenario for the Advanced LIGO, Advanced Virgo and KAGRA gravitational-wave detectors over the next decade, with the intention of providing information to the astronomy community to facilitate planning for multi-messenger astronomy with gravitational waves. We determine the expected sensitivity of the network to transient gravitational-wave signals, and study the capability of the network to determine the sky location of the source. We report our findings for gravitational-wave transients, with particular focus on gravitational-wave signals from the inspiral of binary neutron star systems, which are considered the most promising for multi-messenger astronomy. The ability to localize the sources of the detected signals depends on the geographical distribution of the detectors and their relative sensitivity, and 90% credible regions can be as large as thousands of square degrees when only two sensitive detectors are operational. Determining the sky position of a significant fraction of detected signals to areas of $5 \text{ deg}^2$ to $20 \text{ deg}^2$ will require at least three detectors of sensitivity within a factor of $\sim 2$ of each other and with a broad frequency bandwidth. When KAGRA and the third LIGO detector in India reach design sensitivity, a significant fraction of gravitational-wave signals will be localized to a few square degrees by gravitational-wave observations alone.
It provides information to the astronomy community to facilitate planning (construction, commissioning, observation) for multi-messenger astronomy with gravitational waves.

‘The scenarios of detector sensitivity evolution and observing times given here represent our best estimates as of January 2017. They should not be considered as fixed or firm commitments.’
Revision of the Paper

• Updates:
  * O1 results and experience (BBH rate, …)
  * Best projections for future runs (O2, KAGRA, …)

• Writing team:
  * Cristopher Berry (Birmingham, UK), Brian O’Reilly (Caltech, USA), Massimiliano Razzano (Pisa, Italy), Masaki Ando (Tokyo, Japan)

• Reviewers:
  * LSC: Alan Weinstein, Ik Siong Heng, Lisa Barsotti
  * VIRGO: Andrea Vicerè, Frederique Marion
  * KAGRA: Kipp Cannon, Tomotada Akutsu
Current Status

• Most of review comments have been implemented.

• The manuscript is not finalized yet:
  - Updated calculations on rate, FAR,…
  - Details of Figures
  - Additional table for Range
e-mail exchanges every day and tele-cons.
KAGRA Descriptions

- KAGRA is included.

* **Fig.1 : Sensitivity curves**
  - Smoothed to comparable with those of LIGO and VIRGO.
  - Dates are rounded to 1-year precision.

* **Fig.2 : Observation plans**
  - Based on current bKAGRA plan up to 2020.3.
  - ‘Best Estimations’ after that.
Best-estimated sensitivity estimated by Somiya-san. (IRs for BNS, calculated with same code as LIGO)

*After Phase-2 (2018.4 - 2019.3)
  Full lock of cryogenic RSE
  No sensitivity goal

*After Phase-3 (2019.4-2020.3)
  1-yr commissioning after the first full operation.
  Best-estimated sensitivity for ‘20K low power x10’

*Best-estimated sensitivity for ‘20K high power x5’

*Best-estimated sensitivity for ‘20K high power x3’
Figure 2: Observation Plan

- **Phase 1**: Cryogenic (PR)MI, No sensitivity goal
- **Phase 2**: Cryogenic RSE, No sensitivity goal
- **Phase 3**: Cryogenic RSE, 1-yr commissioning after the first full operation

- **LIGO**:
  - O1
  - O2

- **Virgo**:

- **KAGRA**:

  - ~3-months (2020.1 - 3)
  - ~6-months (2021.1 - 6)

Design: From 2022.1-
So as to clarify the targets, we divide the bKAGRA into three phases.

- **Phase-1**: Operation of a 3km cryogenic Michelson interferometer (-2018.3).
- **Phase-2**: Operation with full configuration: cryogenic RSE IFO (2018.4 – 2019 1Q??)
- **Phase-3**: Commissioning and Observation run (2019 2Q ??-)

The 3rd KAGRA International Workshop (May 21st, 2017, Academia Sinica, Taipei, Taiwan)
Top-down Constraint

• Promise to the government:
  Operation of the KAGRA cryogenic interferometer by the end of FY2017 (2018.3).
  - Constraint for Phase-1 goal.

• Positive Interpretation:
  - Cryogenic operation is an indispensable step for KAGRA. We will realize it anyway.
  - Almost no delay on schedule because of this constraint, by minimizing the additional tasks only for this step.
Plan for bKAGRA Phase-1

- Operate 3-km Cryogenic Michelson Interferometer.
  - Most of the parts are the bKAGRA final ones:
    - Full configuration for ETMs.
    - Most of Upper stream parts than BS.
  - Some simplifications from full bKAGRA:
    - No ITMs.
    - Power-recycling will be possible, but optional.
    - Low-power laser, No Green-lock system.
    - Simplified output optics:
      No SRM??, No OMC, Fixed BRT.
bKAGRA Phase-1

- PRMI with 3 km arms.
- Cryogenic End Test Masses suspended full config. (Type-A VIS +Cryo-payload)
- Final VIS for PRC, BS,….
- Low laser power.

**Type-Bp System for PRM, PR2/3**
- Final Config.
- Room temp., 300K
- Power Recycling implementation is TBD

**Type-B System for BS, SR2/3**
- Final config.
- Room temp., 300K
- No SRM

**Full-system Cryogenic Sapphire ETMs**
- Cryogenic test masses Sapphire, 20K
- Cryogenic Payload
- Type-A VIS
# Plan for bKAGRA Phase-1

The 3rd KAGRA International Workshop (May 21st, 2017, Academia Sinica, Taipei, Taiwan)

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## Vibration Isolation
- VIS Prep.
- VIS Inst.
- Type-A (ETM X/Y)
- Type-B (BS, SR2/3)
- Type-Bp (PRM, PR2/3)

## Cryogenic
- Cryostat
- Cooling test
- CRYp Assemble + Evaluation
- CRYp Inst.
- Cool Down

## Sapphire Test Mass
- Polish + Coating
- Sapphire ETMs
- Sapphire ITMs

## Interferometer
- iKAGRA
- Interferometer Commissioning
- 20K-300K PRMI (Sapphire)
- 20K PRMI (Sapphire)
bKAGRA Phase-2
- RSE with 3 km arms.
- Cryogenic Test Masses
  suspended full config.
  (Type-A VIS +Cryo-payload)
- Final VIS for PRC, BS,….
- Low laser power.

**Type-Bp System**
for PRM, PR2/3
- Final Config.
- Room temp., 300K
- Power Recycling
  implementation is TBD

**Full-system Cryogenic Sapphire ETMs**
- Cryogenic test masses
  Sapphire, 20K
- Cryogenic Payload
- Type-A VIS

**Type-B System**
for BS, SR2/3
- Final config.
- Room temp., 300K
- No SRM
Plan for bKAGRA Phase-2/3

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Plan for bKAGRA Phase-3

- Commissioning and Observation runs.
  * Hard to make plans for interferometer sensitivity.
    Rough estimation:
    ~1 year (2020.3) for 60Mpc (O1 level).
    ~2 years (2021.3) for (near) final sensitivity.

  * Sensitivity improvement timeline depends strongly on the preparations, subsystem-level performance checks, and experiences.

Very preliminary (No consensus yet)
In aLIGO it took ~8 month to achieve 60Mpc. 

Sensitivity improvement progress will strongly depends on preparations and experiences.