

Third Generation Gravitational Wave Telescopes (3G)

**Takayuki TOMARU,
Gravitational Wave Science Project, NAOJ**

2. Science Goals

2nd Generation GW Telescopes

LIGO, Virgo, KAGRA



Astronomy

BH, NS, SN, Pulsar etc.



3rd Generation GW Telescopes

Einstein Telescope, Cosmic Explorer

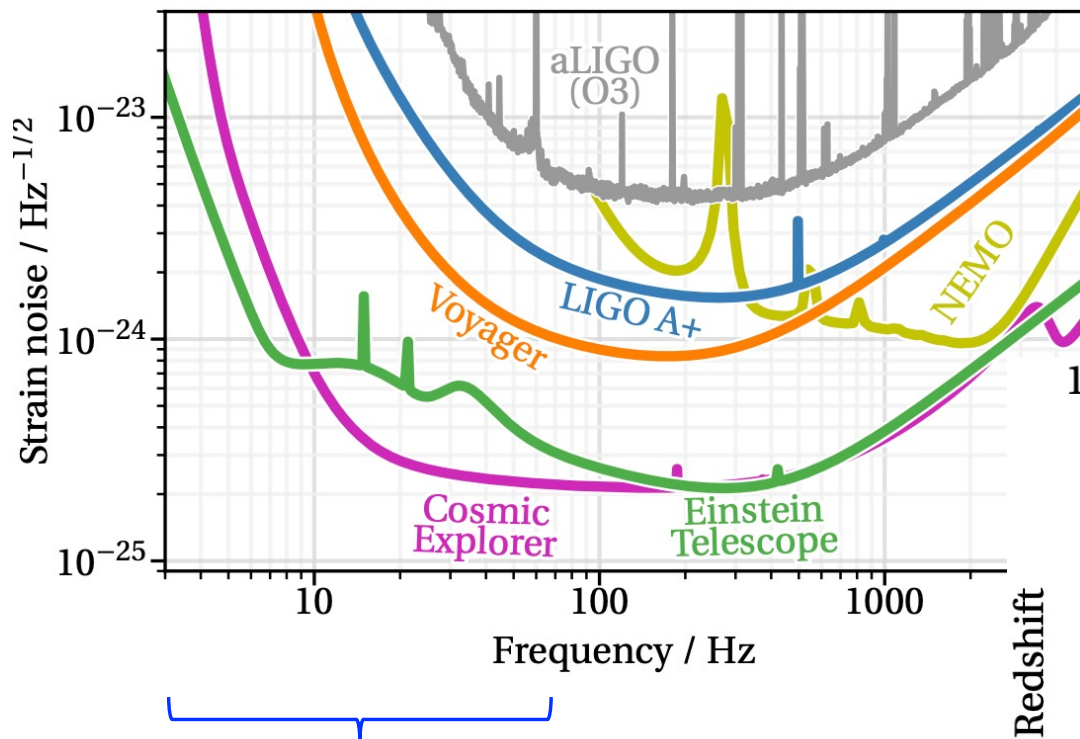


**Astronomy +
Cosmology**

- Sensitivity: $z > 50$, much far than optical telescopes
- Events: *BBH*: $z \sim 50$, 10^6 events/yr, *BNS*: $z \sim 2$, 10^5 events/yr

Statistical analysis is possible.

3. Science Objectives

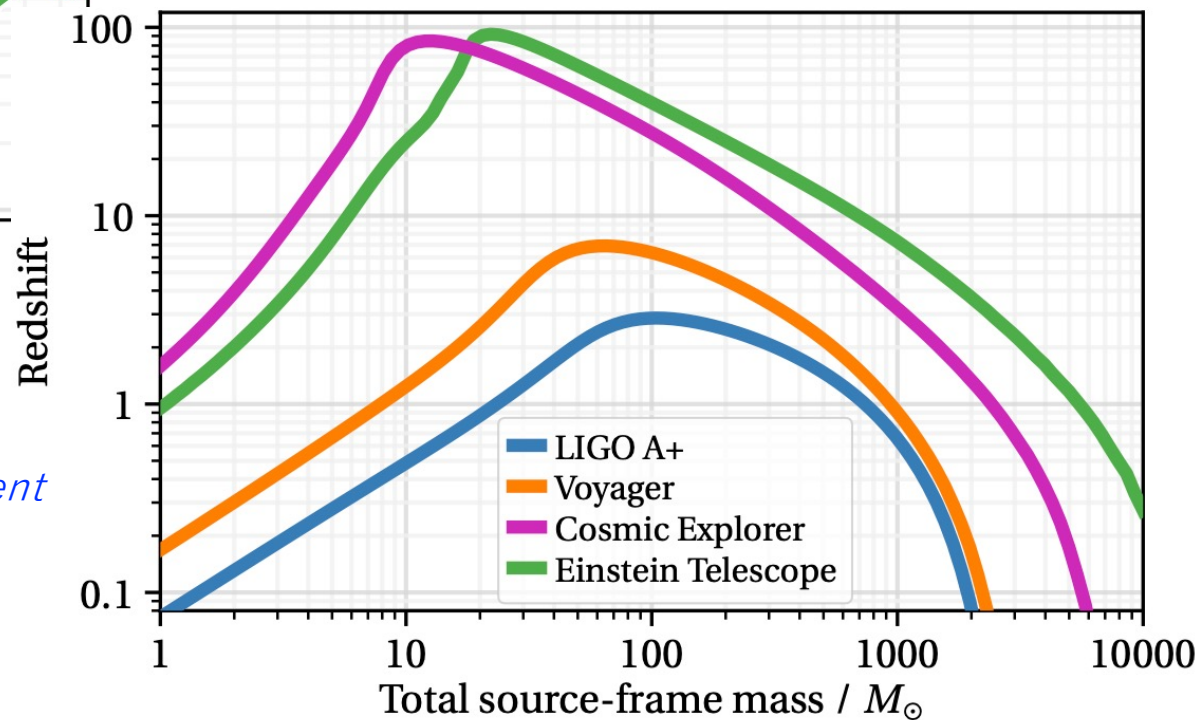


<https://cosmicexplorer.org/sensitivity.html>

Thanks to good low-frequency sensitivity, 30% of 200 Mpc BNS events can be detected with sufficient S/N 1-6 hours before the merger.



Possible follow-up observations

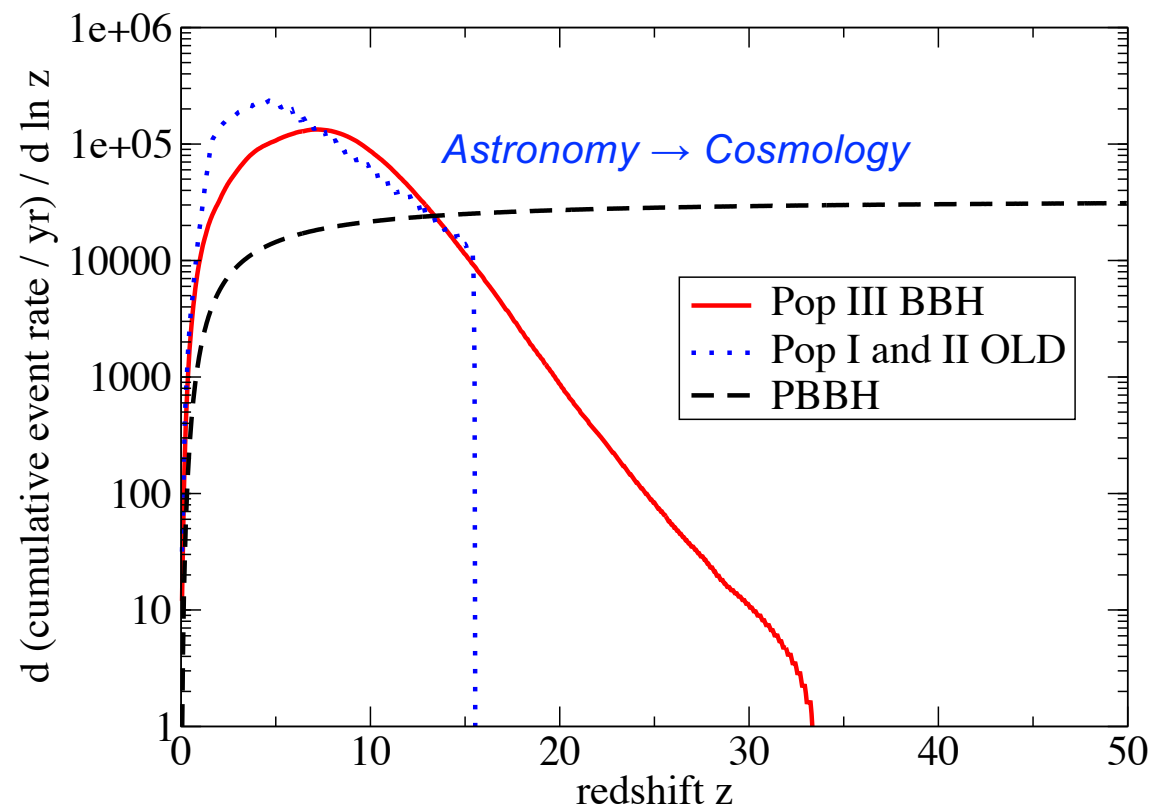


3. Science Objectives

Scenario Selection

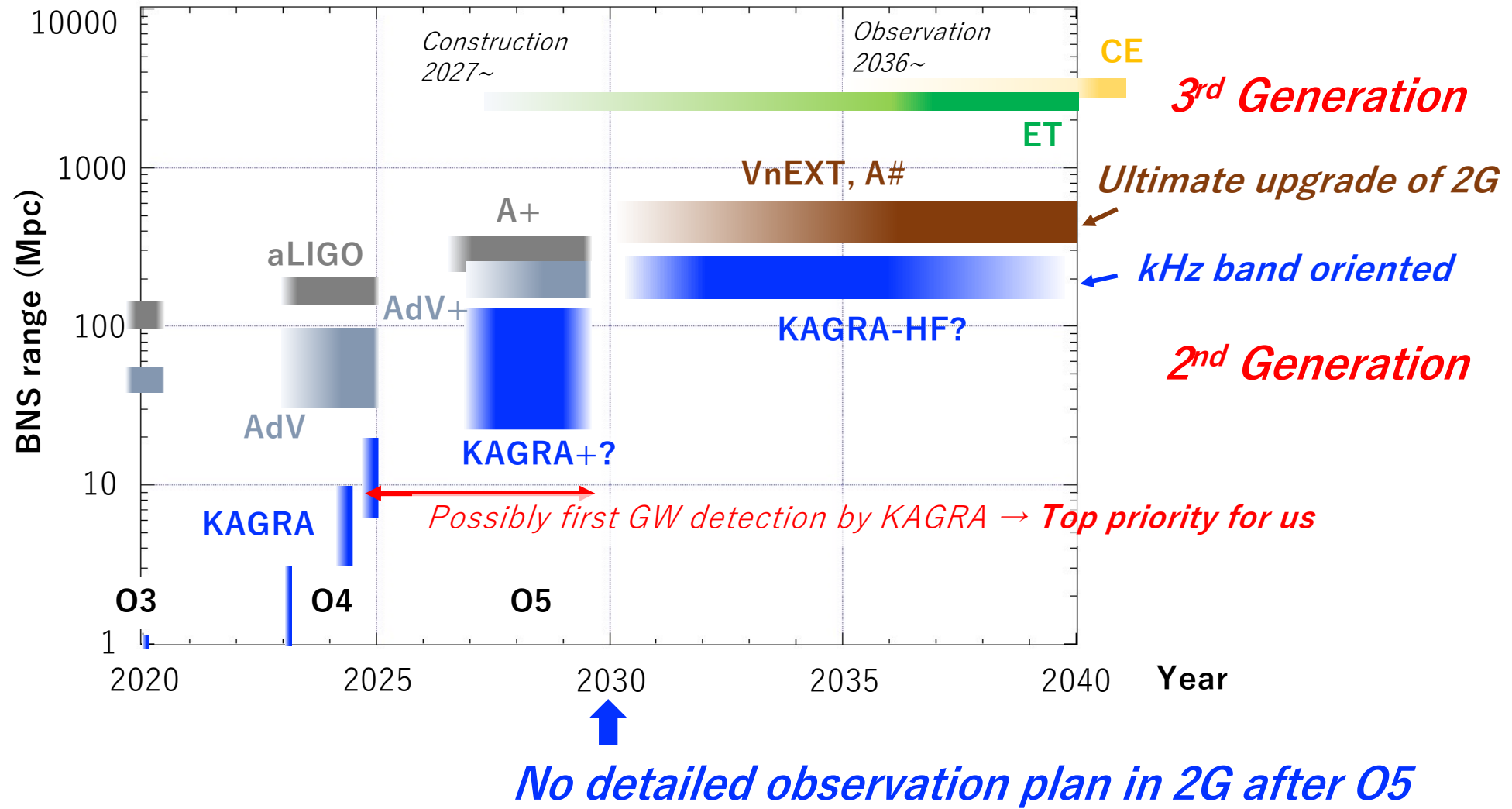
- Standard stars (POP I) ?
or POP II ?
 - Our universe is too young to generate so many LVK BBH?
- POP III ?
 - Kinugawa et al. predict that binary merger of dozens-solar-mass BBHs can be observed present day.
- Primordial BBH ?
 - Quantum fluctuation at the cosmic inflation era can generate many BBHs

$z > 15$ observation is required



*T. Nakamura, Prog. Theor. Exp. Phys. 2015,
arXiv:1607.00897v2 [astro-ph.HE]*

4. Science Investigations



4. Science Investigations –*NAOJ-GWSP's contributions*

*Our basic plan is to contribute **with know-how** rather than budget.*

Our advantages

- **Cryogenics**
- **Underground experience**
- **Quantum Optics Technology**
- **VIS technologies**

- **KAGRA's features are key to 3G, and it is expected that its experience will be applied to 3G.**
- **NAOJ-GWSP has these know-hows.**

ET

ET adopts cryogenic mirrors and underground site.
ET strongly encourages us to contribute.

CE

CE is constructed at the ground Surface.
In phase 2, CE can introduce cryogenic mirrors.

NAOJ-GWSP will be the core of the ET-Japan/CT-Japan group.

4. Science Investigations –*NAOJ-GWSP's contributions*

4.1 Science Investigations until 2033

-2028 *ET: Design & R&D phase*

KAGRA: O5 commissioning & Observation phase → *Our top priority*

We make **small contributions** to ET on common researches and site studies with KAGRA, where possible.

← *We can receive human power support from ET to KAGRA*

2028-2033 *ET: Construction phase*

KAGRA: KAGRA-HF upgrade? →

- *SRM replace*
- *Squeezer installation*

- Participate in construction work in Europe to the extent possible
- Responsible for small-scale hardware production and testing

Cryogenic device, Crystalline mirror & suspension, gravitometer etc...

4. Science Investigations –*NAOJ-GWSP's contributions*

4.2 Science Investigations beyond 2034

Observation phase

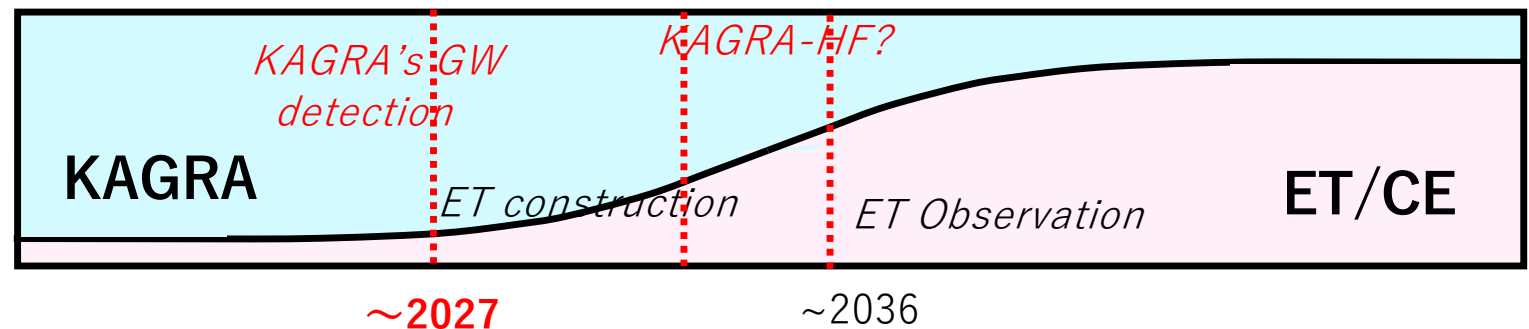
- Contribution to operation, management and upgrade *with budget*
- Asian Data Center for ET/CE
 - *Tire-1 level storage*
 - *GRID computing & CPU*
- Multi-messenger Astronomy
 - New dedicated follow-up telescope?

4.3 Threshold Science

- ET construction must be started.
- *Make NAOJ-GWSP RU*

Planned Contributions

Within GWSP scale



7. Current Status

(1) ET

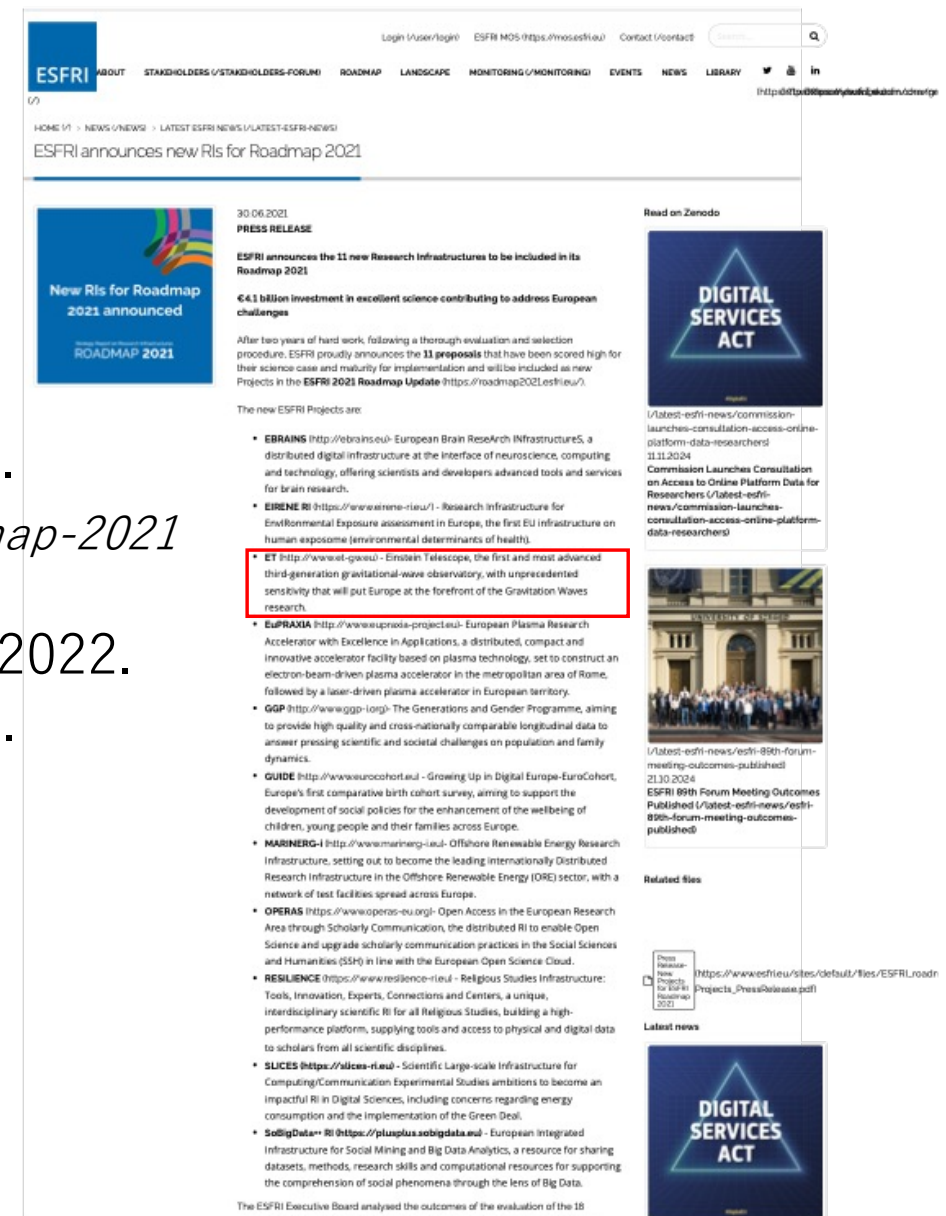
- ET was featured in the European Strategy Forum on Research Infrastructures ([ESFRI](https://www.esfri.eu/)) Roadmap 2021.

<https://www.esfri.eu/latest-esfri-news/new-ris-roadmap-2021>

- ET Collaboration has been launched in 2022.
- [91 research units](#) are authorized (2024).
- Site Studies are on going.

Candidate locations:

- Sardinia (*Italy*)
 - Maastricht (*Euregio Maas-Rijn*)
 - Lausitz (*Germany*)
- Fundamental design is on going.



7. Current Status: R&Ds

- KAGRA and ET have signed a LoI.
- Perugia-NAOJ-ICRR also signed a LoI.

- Italy**
- SarGrav research facility is being built on a former mine site in Sardinia. ~30ME.
 - Italian government funded 50 ME in 2022 for technology development and site study expenses.
 - Italian government seems to be positive to fund half of ET construction cost.

- Netherlands**
- ET pathfinder research facility under construction in the suburbs of Maastricht, a candidate site ~30ME.
 - In April 2022, the Dutch government announced that if ET is built on the Dutch site, the Dutch government will pay about half of the construction cost, 0.9 BE

- Germany**
- ET in the German RI National Roadmap Prioritization Process
 - 50ME/yr, total **1BE** is requested.

