DECIGO: the Japanese Space Gravitational Wave Antenna

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DECIGO (DECI-hertz interferometer Gravitational wave Observatory) is the future Japanese space gravitational wave antenna with observation band around 0.1 Hz. It aims at detecting gravitational waves from various kinds of sources, with sufficient sensitivity to establish the gravitational wave astronomy. In the pre-conceptual design, DECIGO is formed by three drag-free spacecraft, 1000 km apart from one another. The relative displacements between proof masses housed in these spacecraft are measured by Fabry-Perot interferometers. We plan to launch DECIGO in 2024 after research and development phase, including two milestone missions (DECIGO pathfinder and Pre-DECIGO) for verification of required technologies.

Keywords: DECIGO, Gravitational waves, Astronomy, Space Mission

1. DECIGO

DECIGO (DECI-hertz interferometer Gravitational wave Observatory) is the future Japanese space gravitational wave (GW) antenna,[1] with observation frequency band of around 0.1 Hz (Fig. 1). This frequency band is the gap region between LISA (Laser Interferometer Space Antenna)[2] and terrestrial detectors such as Advanced LIGO[3] and LCGT (Large-scale Cryogenic Gravitational-wave Telescope).[4] In addition, this band opens the possibility to observe GWs from cosmological distance, because it is free from the confusion noises, irresolvable GW signals, from too many white dwarf binaries in our Galaxy.

Main targets of DECIGO are GWs from binary inspirals of compact binaries, and from the early universe. DECIGO will have sufficient sensitivity to observe GWs from distant (redshift of $z \sim 1$) neutron-star binaries which are a few months to 5 years before merger. By resolving GW signals emitted from many (about 3×10^5) binaries in this range, we will obtain information of mass distribution of neutron-stars, and thus, on the theory of the evolution of massive stars and on the equation of state of high-density matters. Moreover, observing distant binaries, which play

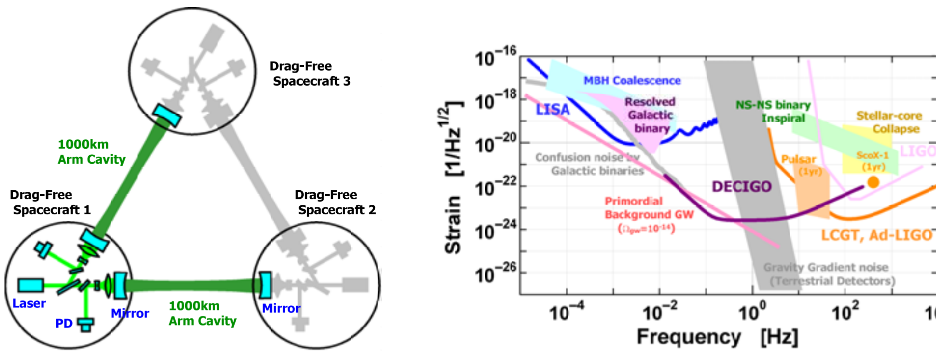

Fig. 1. Pre-conceptual design of DECIGO (left) and its design sensitivity (right).

as precise clocks, it will be possible to measure the acceleration of the expansion of the universe from their redshift change.[1] As for black-hole binaries, DECIGO will observe GWs from coalescences of intermediate-mass ($10^3 M_\odot$) black hole binaries, which could reveal the mechanism of the formation of super-massive black holes in the center of galaxies. The extremely good sensitivity of DECIGO would enable us to detect GWs from the very early universe, which could provide important information to understand the beginning of the universe.

2. Pre-conceptual design of DECIGO

In the pre-conceptual design, DECIGO is formed by three drag-free spacecraft, 1000 km apart from one another. Relative displacements of the proof masses (mirrors) inside the spacecraft are measured by Fabry-Perot interferometers (See Fig. 1). We adopted the Fabry-Perot configuration because it provides a better best sensitivity at 0.1 Hz band than an optical transponder configuration which is adopted by LISA. Although the Fabry-Perot configuration with shorter arm length has the larger acceleration noises by laser radiation-pressure noise and practical force fluctuations than transponder configuration with long arm length does, these noises would be still slightly lower than the confusion noise by Galactic binaries.

The distance between spacecraft (Fabry-Perot cavity arm length) was chosen to be 1000 km. This arm length was chosen so as to be short enough to avoid refraction losses of laser power, and to form Fabry-Perot cavities, and yet so as to be long enough to ensure the high sensitivity for GW signals. The mirrors forming the cavities, which works as proof masses in spacecraft, have a diameter of 1 m, with moderate reflectivity to realize the cavity finesse of 10. The mass of mirror (about 100 kg) was simply chosen to be the largest we could fabricate and handle. The laser source of DECIGO will have an effective power of 10 W with a wavelength of 532 nm. The orbit and constellation of DECIGO is to be determined, considering the gravity disturbances by the sun and planets, durability of the thruster fuels, solar power supply, and the required angle resolution for the GW source, and so on.

3. Milestone missions for DECIGO

Long and intensive development phase will be required in order to realize DECIGO. We plan to launch DECIGO in 2024 after design (a pre-conceptual design, a conceptual design, a preliminary design, and finally a final design) and prototype tests with the help of research and development with table top experiments. We also have two milestone missions, DECIGO pathfinder (DPF) and Pre-DECIGO, before the launch of DECIGO. DPF will be one small satellite consists of two proof mass mirrors, which form a short Fabry-Perot cavity. The cavity length is measured by a stabilized laser source, and the mirrors are kept in the satellite with a drag-free control. The target of DPF will the technical demonstrations: a drag free control, laser stabilization in space, precise measurement with Fabry-Perot cavity, and mirror clump system used at the launch of the satellite. In addition, since DPF will have a modest sensitivity for GW events, we expect some scientific results with continuous observation at the DECIGO frequency band. The objectives and a conceptual design of Pre-DECIGO will be determined during the research and development phase of DECIGO.

4. Conclusions

We have started a serious investigation to realize DECIGO by determining the pre-conceptual design. Although hard efforts will be required before its launch, DECIGO will provide fruitful scientific results by opening a new astronomy with gravitational waves.

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