The discovery of gravitational waves (GWs) by the LIGO collaboration [1] in 2016 has provided a direct test on the prediction made by Albert Einstein a century ago based on his general theory of relativity [2]. It has caused a significant influence worldwide on the basic research in science.

Space-based GW detection has become the next interesting target for the further study on the gravitational universe as space-based GW detection would reach a wider range of gravitational radiation sources than the ground-based GW detection can [3]. After the LISA/eLISA strategic plan [4] on space-based GW detection was put forward in the 1990s, Chinese scientists also showed their interest and began to make proposals for space-based GW detection in the 2000s. Recently, the Chinese Academy of Sciences (CAS) has set up a strategic priority research program that includes the pre-study of space-based GW detection referred to as the 'Taiji Program in Space' [5].

GWs are expected to provide a new window to explore the evolution of early universe and the nature of gravity. Though space- and ground-based GW detectors adopt the same detecting principle of a Michelson interferometer, the required critical technology is quite different. Space-based GW detection needs to make use of gravitational reference sensors and a low-noise microthruster to implement drag-free performance as well as non-contacting discharging of test masses for free-flying test mass. It requires picometer optical assemblies for resolution ranging between the test masses and the spacecraft and high-stability monolithic precision ranging of test mass and spacecraft. The high-stability telescope, precision attitude control, a high-accuracy phase-meter and frequency stabilization are all needed for the precision ranging from spacecraft to spacecraft. To reach high thermomechanical stability, it is necessary to orbit the Sun.

The Taiji program is proposed to detect GWs with frequencies covering the range of 0.1 mHz to 1.0 Hz with higher sensitivity around 0.01–1 Hz than eLISA (see Table 1). The Taiji program proposes to use a triangle of three spacecrafts in orbit around the Sun (see Fig. 1). Laser beams are sent both ways between each pair of spacecrafts, and the differences in the phase changes between the transmitted and received laser beams at each spacecraft are measured. The preliminary design for the Taiji mission is based on 3-million-kilometer separations between the spacecrafts, and the expected launch date is about 2033. The purpose of the Taiji program is to study the most challenging issues concerning massive black holes, such as how the intermediate mass seed black holes were formed in the early universe, whether dark matter could form a black hole, how seed black hole grows into a large or extremely large black holes and what is the nature of gravity.

Gravity was the first recognized basic force in the universe, while its nature is not as clear as for the three other basic forces. Single gravitons are far from being observable, although GWs are thought to be composed of gravitons. Understanding the nature of gravity and the unification of all basic forces are the most challenging problems in basic sciences in the twenty-first century. Dark matter and dark energy observed via gravitational effects are regarded as two big ‘puzzling clouds’ in the twenty-first century in physics and astronomy. Solving those problems requires us to develop quantum gravity and build a unification theory for all basic forces. As the early universe was filled with elementary particles at very high energy and temperature, exploring the intrinsic correlation between the very small elementary particles and the extremely large universe has been regarded as the frontier of particle physics and cosmology in basic sciences.

The establishment of quantum gravity [6] is a necessity to understand the origin and evolution of the universe.

Table 1. Baseline design parameters of the Taiji preliminary mission proposal in comparison with the LISA/eLISA mission proposal.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Taiji Preliminary Mission</th>
<th>LISA</th>
<th>eLISA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm length (m)</td>
<td>3 x 10^9</td>
<td>5 x 10^9</td>
<td>1 x 10^9</td>
</tr>
<tr>
<td>1-way position noise budget (pm Hz^-1/2)</td>
<td>5 ~ 10</td>
<td>18 pm Hz^-1/2</td>
<td>11 pm Hz^-1/2</td>
</tr>
<tr>
<td>Laser power (W)</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Telescope diameter (cm)</td>
<td>~ 50</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>
This work was supported in part by the National Natural Science Foundation of China (11690022, 11475237 and 11121064), and by the Strategic Priority Research Program of the Chinese Academy of Sciences (XDB23030100), as well as the CAS Center for Excellence in Particle Physics (CCEPP).

Wen-Rui Hu\textsuperscript{1} and Yue-Liang Wu\textsuperscript{2,*}
\textsuperscript{1}Institute of Mechanics, Chinese Academy of Sciences, China
\textsuperscript{2}University of Chinese Academy of Sciences/Institute of Theoretical Physics, Chinese Academy of Sciences, China
\textsuperscript{*}Corresponding author.
E-mail: ylwu@ucas.ac.cn

**FUNDING**

Figure 1. Taiji spacecraft in orbit around the Sun.

**REFERENCES**

3. Reitze D. *Opening lecture: advanced LIGO and the dawn of gravitational astronomy* and *The next detectors for gravitational astronomy*, invited talks at KITPC program ‘The next detectors for gravitational wave astronomy’, April 6-May 8, 2015, Kavli Institute for Theoretical Physics China (KITPC), Chinese Academy of Sciences, China.