Program in space detection of gravitational wave in Chinese Academy of Sciences

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Abstract. On behalf of Space Gravitational Wave Detection Working Group in Chinese Academy of Sciences (CAS), ongoing development of gravitational wave detection in space in China has been presented in this talk. The preliminary mission design, primary science drivers, program for technological developments and the road-map will be described.

1. Space GW Detection mission design in China

A feasibility study of gravitational wave detection in space in China has been launched since 2008, meanwhile an investigation group in CAS for Space GW Detection was organized. In 2009 Space GW Detection was listed in "2050 Development Project" of CAS. The Space GW Detection Working Group in CAS was founded in 2012. It includes about ten institutions of CAS, Huazhong Univ. of Science and Technology, Dong Fang Hong satellite Co., and etc. Taiji [1,2] was proposed in 2015 and supported by CAS in 2016, who uses three Spacecrafts in a triangle that orbits the Sun. Tianqin [3] orbits the Earth was initiated by Zhongshan Univ. and supported by local government.

The road map of Space GW Detection in China could be summarized into three stages.

2016-2020: Technique Prototype developments and ground testing.

2021-2025: Technological developments and a pathfinder mission.

Two options are under consideration in this stage. One is gravity satellite mission which is similar to Grace-follow-on but with a laser interferometer as the primary ranging instrument. The other is to send two satellites into deep space (likely to be L1or L2). A 105 km long interferometer will be established between these two satellites. Apart from inertial sensor, single arm laser interferometry (telescope, pointing, metrology, ...etc) will be tested.

2026-2035: Implementation and launching of Chinese mission for GW detection in Space.

There is also a double track for mission development. One is to join eLISA or LISA. Chinese part likely to contribute over 20% with technical assemblies, such as Micro-Thruster, Telescope, Laser, Launcher, and others ... Another option is to develop an independent Chinese Mission with international collaboration.

For the latter one, we prefer the mission design of Taiji. From the sensitivity curve of the simulation, we may see that the most sensitive band of the design is around 0.01 Hz. Together with a slight improvement of the position noise, it enables an enhanced detection to light seed black holes [2]. This sensitivity curve will be the blueprint for our prototype development in the next five years.

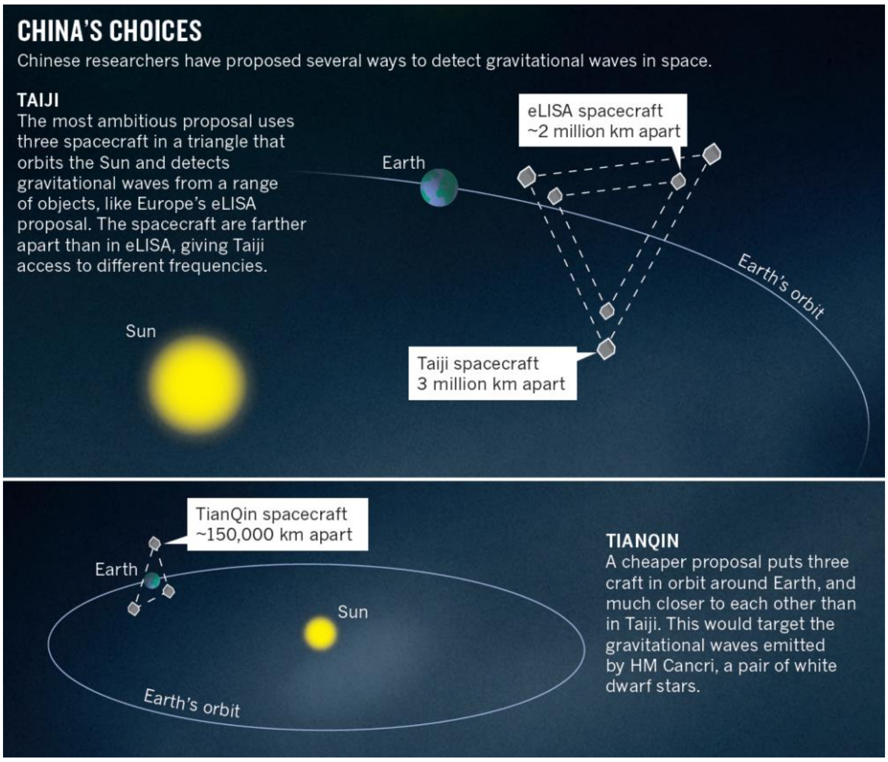

Fig.1 The programme design of Taiji and Tianqin missions

As we may see from the figures [2,4], the Taiji mission will be able to probe light seeded black holes at the earlier epoch and this will be important in our understanding of the structural formation of our Universe. Event rate estimates of MBH mergers at earlier cosmological epoch and Cosmological MBH merger simulation based on Monte Carlo realization of EPS formalism, Equal mass light seed black hole (PopIII remnants) seeding, Semi-analytical dynamics —prolonged and chaotic accretion models, coalescence spin and recoil determination: numerical relativity fitting formula, etc. Taiji mission is going to be an integral part of high redshift astronomy in China, complementary to the Infrared and radio astronomy.

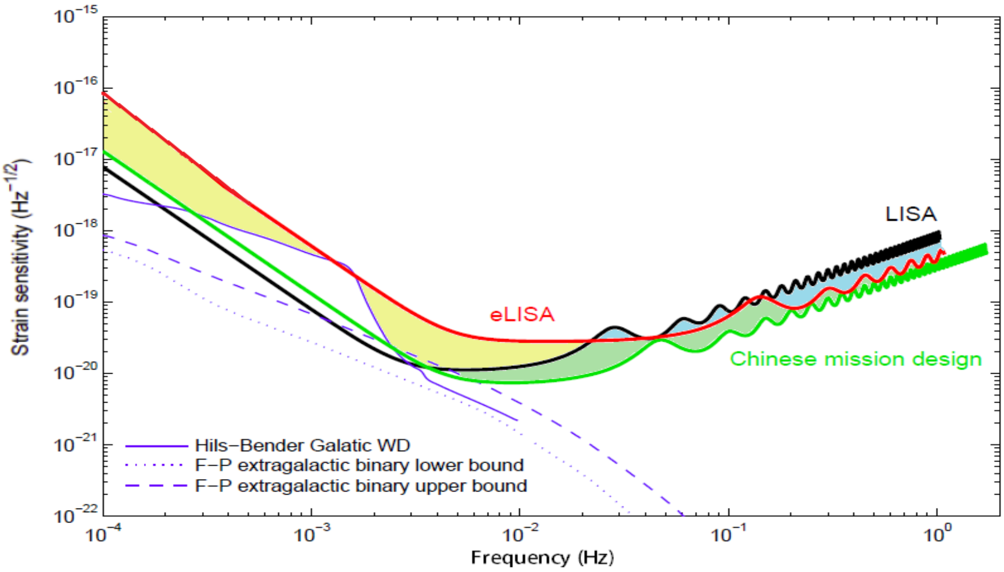

Fig.2 The sensitivity design of the Chinese space gravitational wave detection project

Table 1 Baseline design parameters

Armlength (m)	Telescope diameter (m)	Laser power (W)	1-way position noise ($\frac{\mathrm{pm}}{\sqrt{\mathrm{Hz}}}$)	Acceleration noise ($\frac{\mathrm{m\ s^{-2}}}{\sqrt{\mathrm{Hz}}}$)
3×10^9 (Chinese mission option)	0.46	2	8	$3\times10^{-15}(>0.1\mathrm{mHz})$
1×10^9 (eLISA)	0.2	2	11	$5\times10^{-15}(>0.1\mathrm{mHz})$
5×10^9 (LISA)	0.4	2	18	$3\times10^{-15}(>0.1\mathrm{mHz})$

2. Key technology development

Some key techniques have been developed for this mission in recent years. Experiments on frequency locking of Nd:YAG lasers have been performed in Wuhan, Institute of Physics and Mathematics, CAS. The primary solution to the laser source is to develop an on-satellite frequency and intensity stabilized Nd:YAG laser that covers a 5-year space mission. The laser consists pump laser diodes and a monolithic non-planer ring oscillator (NPRO), being capable of delivering more than 2 W optical power at 1064 nm without additional gain stage. The frequency noise of the pre-stabilized laser will be on the order of 10 Hz/√Hz at Fourier frequency of 10 mHz. We are also looking into the possibilities of a fiber laser system that is promising in terms of reliability and simplicity. Currently, the frequency pre-stabilization system has been developed based on a 10-cm ultra-stable space-borne optical reference cavity. In addition, vibration tests have been performed for several vital components and a radiation test is scheduled in order to evaluate the susceptibility of the pump laser and the NPRO to the proton beam. In the future we will further investigate the Nd:YAG approach, focusing on its output power, lifetime, and space qualification. Laser interferometers with 10 pm/√Hz have been developed in Institute of Mechanics, CAS [5] and Huazhong Univ. of Sci. and Tech. [6] with the aid of AEI on how to simulate and build the experimental interferometer to achieve the required sensitivity of the mission. Accelerometer development is mainly in Huazhong Univ. of Sci. and Tech. and Lanzhou Institute of Physics, CAST, and the flight mode reaches 10 ng/√Hz. The telescope is another key element of Interferometric Ranging System (IRS). Each optical assembly in each Spacecraft(SC) includes a telescope pointing towards a far SC. The aim of the telescope is: (1) it gathers the light coming from the far SC(~100 pW) and (2) it expands and collimates the small outgoing beam(~1 W) and send it to the far SC. Due to the very demanding noise requirements, crucial stability must be taken in the design and validation of the telescope not to degrade the IRS performance. For instance, any fluctuation in the distance and angle between the primary and secondary mirrors of the telescope will translate directly into phase noise in the IRS. This fact implies that the path-length noise in the telescope must be less than 1 pm/√Hz in the LISA band and M1-M2 divergence angle must be less than 1 nrad/√Hz. All SiC telescope (stop diameter: 200mm) was designed and analyzed and the simulation result of stability of all-SiC telescope can reach less than 10 pm/√Hz according to the environment of the mission orbit. Space gravitational wave detection also requires low noise (0.1 μN/√Hz), long life (about 5 years) micro propulsion system. To meet this target, we need to study the mechanism, the principle prototype and the integration scheme of micro propulsion system. The working mechanisms of field emission electric thruster and radio frequency ion micro thruster were studied by National Microgravity Laboratory, Institute of mechanics, CAS, and the principle prototypes were developed. Further optimization is under research. In addition, other parts of the micro propulsion system, such as the power processing unit, the propellant supply unit and neutralizer etc. will be entrusted to the companies who have relevant qualifications. We will work with Lanzhou Institute of Space Physics CAST, and Beijing Institute of Control Engineering on the micro propulsion system integration, engineering transformation and system testing. In order to reduce the disturbance applied on the inertial reference caused by non- conservative forces, the statically and stable satellite platform need to be studied, including technology of statically and stable satellite platform system

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design, inertial measurement sensors, drag free control algorithm, micro thruster , highly stable structure and precision temperature control technology. Major research institutions in China including DFH Satellite Co Ltd, Shanghai Engineering Center of Small Satellite, CAS, China Academy of space technology (CAST), CAS (Institute of mechanics etc.), Sun Yat-sen University (SYSU), Huazhong University of Science and Technology (HUST) etc. Launch Vehicle Technology is established in China as an escaped orbit launch service for the mission. ChangZheng-5(CZ-5) rocket will launch the main part of Chinese space station load of 25 tons in about 2020, and it is able to launch 3 satellites orbiting the Sun with a Load of 5.7 tons.

3. Some international activities

Chinese mission of Space gravitational wave detection in space will open for collaboration with international society, especially with ESA scientists. Chinese mission can develop and work with eLISA for collaboration and data comparison. With international collaboration we can employ more techniques in same models and types for high efficiency and low cost. Here we propose several international scientific activities to push on the collaboration.

- International Symposium on Gravitational Waves, (ISGW2017) Beijing, May 25-29, 2017
- Taiji Union for Gravitational Wave Detection in Space is set up and all researchers and scientists all over the world are welcome.
- Joint Albert Einstein Institute for Radio Astronomy and Gravitational Physics between Max Planck Society and Chinese Academy of Sciences to be discussed in MPG-CAS Meeting to be held in Bonn, Germany in March, 2017.
- Chinese pathfinder would be launched in 10 years to test key technology for GWD in Space, International collaboration is welcome.
- Joint research proposal to be submitted to the DFG and National Science Foundation, China after the Sino-German meeting in 2017.

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