We have confidence to lead gravitational-wave science: an interview with Yueliang Wu

By Hepeng Jia

Yueliang Wu, chief scientist of Taiji Program, is a well-known theoretical physicist and the Vice-President of the University of Chinese Academy of Sciences (UCAS). Taiji Program, initially proposed in 2008, is one of China’s ambitious plans to observe gravitational waves. Obtaining his Ph.D. at the Institute of Theoretical Physics (ITP) under the Chinese Academy of Sciences (CAS) in 1987, Wu had been working at Dortmund University and Mainz University in Germany and Carnegie-Mellon University and the Ohio-State University in the USA. In 1996, he joined the ITP and became its director in 2007. He has also served as the Director of the Kavli Institute for Theoretical Physics China at the CAS since 2006. In 2007, he was elected as a CAS member.

Wu’s research is focused on elementary particle physics, quantum field theory, symmetry principle and cosmophysics. In recent years, he has been proposing a gravitational quantum field theory as a new approach to reconciling the general theory of relativity and quantum mechanics. The most fundamental unanswered question of the general theory of relativity is how general relativity can be reconciled with the laws of quantum physics to produce a complete and self-consistent theory of quantum gravity. To extend the general relativity to realize the reconciliation, Wu suggested a basic gravitational field be needed in the future model.

Since 2012, he, together with Wenrui Hu, has been working as Taiji Program’s chief scientist and promoting nationwide gravitational-wave research. National Science Review (NSR) spoke with Wu about the future of gravitational-wave research, the development of China’s nationwide gravitational-wave studies and particularly the progress of Taiji Program.

NSR: Can you briefly outline the importance of gravitational-wave research? Why were the worldwide scientists so excited when LIGO (Advanced Laser Interferometer Gravitational-Wave Observatory) announced the first detection of the wave in February 2016?

Wu: One hundred years ago, [Albert] Einstein predicted gravitational waves as part of his general theory of relativity. Until LIGO’s detection, gravitational waves had been the last predictions of general theory of relativity that was not experimentally confirmed. So, the detection of gravitational waves completely proved the correctness of general theory of relativity.

But it is not just about the theory. It offers a new way for us to understand the world and the universe. Because of their long-distance travel, gravitational waves are very weak, but on the other side of the coin is the waves help us to observe the far deep universe better than our current technologies. After experiencing big inflation, our universe consists of 95%’s dark energy and dark matter. Mastering gravitational-wave detection, measurement and analysis, we will have a greater chance to study the formation and development of universe that we have known little.

Gravitational-wave detection itself is very important. Think about the situation of electromagnetic waves! After [Heinrich] Hertz conclusively proved the existence of the electromagnetic waves in experiment in 1888, the electromagnetic waves at different bands have been detected and widely applied in our life. In the future, gravitational wave might have the wide applications, benefiting our life. The gravitational-wave research is just beginning, and China has every reason to master it.
**INTERVIEW**

**NSR:** Then what are its exact benefits to Chinese science?

**Wu:** The gravitational-wave research is the most frontier basic research. Its future measurement could be at the scale of picometer (1/10000 of nanometer). It covers physics, photonics, astronomy, cosmology, precision measurement, navigation technology, material science and space engineering. Actively engaging gravitational-wave research can make us reach or keep leaderships in these fields. Although LIGO has detected gravitational wave twice, confirming its existence, the wave’s own characteristics are unclear. Thus, Chinese scientists should work together with their international colleagues to explore these unknown aspects.

Although the detection of gravitational wave conclusively proves Einstein’s general theory of relativity, its significance is far beyond that. The general theory of relativity is after all a classic theory, and gravitational-wave research can bring many new understandings and discoveries of unknown universe, such as probing the formation of super massive black holes and bringing clues to unify general relativity and quantum theory. In this regard, Chinese scientists’ research has made progress paralleling their international counterparts. Stepping ahead with gravitational-wave research can strengthen our advantages.

Of course, as in other mega science projects, advancing such a frontier study agenda can promote China’s high-technology, engineering and equipment development. All these can be spilled over to industries to fuel our social and economic progress.

In addition to basic research itself, actively engaging gravitational-wave research will bring us an intellectual overhaul in science policy and management. Let’s take the example of LIGO. Before the first detection of gravitational wave in 2015, scientists had been working there for 40 years, and the funding agencies had supported for that length of time. It indicates that our five-year plan style cannot meet the demands of the current frontier basic research. We need 10-year or 15-year plan for the major basic research projects.

**NSR:** Then what are Chinese scientists’ plans for gravitational-wave studies? You are the chief scientist of Taiji Program, but how about other projects?

**Wu:** The Taiji Program can trace back to 2008, which was proposed at a Xiangshan Science Conference (small-scale top academic workshop series aimed at discussing and debating crucial aspects of Chinese science), though there wasn’t the name at that time. It is a space gravitational-wave detection project, planning to launch three satellites to form a triangle in orbit around the Sun. With the distance of 3 million kilometers between each other, detectors in the Taiji satellites will be able to access to a wide range of low and medium frequencies of the wave. We plan to launch the Taiji satellites in around 2033.

Compared with LIGO and other Earth-based detectors, the space detection can effectively avoid noises and signal pollutions in the Earth as well as meet the high thermomechanical stability, obtaining more accurate gravitational wave with wider low and medium frequencies. In addition, LIGO and other Earth-based detection projects have been deployed for 40 years. Compared with them, we do not have competitive advantages [in developing Earth-based detection projects].

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But we also have planned ground-based Ali Project, also led by CAS, aiming to explore gravitational waves from the Big Bang itself by measuring the polarization patterns of the cosmic microwave background (CMB) radiation. It will be installed in Ali Observatory of CAS National Astronomical Observatory of China in Tibet. Tibet’s thin atmosphere, low level of water vapor and clean environment can dramatically reduce the interference with CMB radiation detection. Ali Project will be headed by Xinmin Zhang of CAS Institute of High-Energy Physics.

Another project is to detect gravitational-wave signal using pulsar timing array. The pulsar timing array gravitational-wave detection project (abbreviated below as pulsar timing project), headed by Kejia Li of Peking University, will fully utilize the newly completed FAST (Five-hundred-meter Aperture Spherical radio Telescope, the world’s largest filled-aperture radio telescope) to grasp changes in pulse arrival time of electromagnetic waves caused by gravitational wave’s ripple effect in space-time. Analysing the signals will enable us to not only detect gravitational waves but also measure the effect of gravitational waves.

Besides Taiji, another space gravitational-wave detection scheme proposed by Chinese scientists is Tianqin Project initiated by Jun Luo, president of Sun Yat-sen University. Like Taiji, Tianqin will launch three satellites, but they will be stationed in the Earth orbit, which Luo believes to have lower technical difficulties. Tianqin has different targeted sources of gravitational waves and frequencies for detection from those by Taiji.

**NSR:** How about their budget and funding situation? Despite rapid growth of China’s research and development (R&D) expenditure, basic research remains, accounting for as little as 5% of the total R&D expenditure. Do you worry that the state cannot provide enough funding? After all, there are concerns that spending too heavily in certain scientific directions will reduce funding and resources allotted to other basic research fields.

**Wu:** Taiji Program proposes a budget of about 15 billion yuan (about US$2.2 billion) over 20 years. Distributed to every year, it will be translated to about 700 million yuan (about US$102 million) each year on average. We should say the amount is reasonable. Funding for each stage will be pre-conditioned by the success at its earlier stage and with the economic growth, money spent in later phases will account for a fewer portion.

If the state decides to support the program, it will not reduce supports for other scientific research, because once the policy support is finalized, it will take the form of special fund, not snatching a share from regular basic research budget.
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Ali, pulsar timing and Tianqin all have their own reasonable budget. Currently, the preparatory research of Taiji, Ali and pulsar timing projects is mainly supported by CAS strategic priority research programs (Category B) and National Natural Science Foundation of China (NSFC). We expect the state will offer substantial supports for gravitational-wave research.

NSR: Then will there be competition among these gravitational-wave projects? How to deal with the competition?

Wu: As mentioned above, Taiji, Ali and pulsar timing projects each have their specific scientific goals. Ali project’s goal can be described as short-term, because it has already had good conditions. Then pulsar timing and Taiji can be said as middle-term and long-term projects. It is very reasonable for Ali to get a bigger part [of funding] because of its relatively more mature conditions.

The relationship among Ali, pulsar timing and Taiji is collaborative rather than competitive because of their different scientific targets, implementation stage and observation/measurement targets. Scientists and engineers can freely move between these different projects.

NSR: Then how have the Chinese science community been prepared for implementing these gravitational-wave detection projects?

Wu: Although China has not developed major gravitational-wave detection equipment like LIGO before, individual scientific research on gravitational wave has been done at many scientific institutions. We have closely followed international advances in this area. Since the above mentioned 2008 Xiaangshan Science Conference, three such high-profile meetings have been held and studies have been strategically arranged long before the 2016 announcement of gravitational-wave detection.

One important aspect to mention is our collaboration with the European Space Agency (ESA) to develop its eLISA space gravitational-wave detection project starting in 2012. ESA initially suggested we contribute 20% of funding to the project but we insisted on developing technologies and instrument accounting for 20% of the whole project. This has paved a very good technological foundation for developing Taiji and other projects.

Now studies on all key technologies related to gravitational-wave detection have been carried out across CAS institutes and at some universities. For example, we have developed our own optical telescope technologies used for the wave detection; satellite development and manufacturing at CAS Shanghai Engineering Center for Microsatellites is rather mature; scientists at CAS have developed high-accuracy angle instrument meeting the requirement to detect gravitational wave. China last year also launched the small satellite on microgravity measurement. The satellite, developed by CAS scientists under Hu, has set a very good foundation for space-based gravitational-wave detection.

It is true that China’s laser interferometer system started late, but we are catching up. CAS Institute of Mechanics has developed a version of space laser interferometer that only lags the requirement of gravitational-wave detection for about one order of magnitude.

NSR: You mentioned the collaboration with ESA. How about China’s international collaboration in gravitational-wave studies?

Wu: From the very beginning, China’s gravitational-wave studies have been actively engaging international collaboration. In each of the past five years, we have bilateral meeting focused on gravitational-wave studies with Germany. While collaborating with ESA to jointly develop its eLISA, we also proposed our own Taiji. We have kept on the principle of walking on two legs (meaning do not give up both options). Taiji has more ambitious goal. The distance between eLISA satellites is 2 million kilometers while ours is 3 million, covering more frequencies. eLISA has designed a two-way interference to save cost, while Taiji’s goal is six-way interference, which means signals between any two of the three satellites can be used to detect gravitational wave. Thus, it can provide a cross check for the gravitational-wave signals. Meanwhile, it allows to measure the polarization of gravitational waves and might also enable us to probe the nature of dark energy. We are always open to international colleagues and our advances are warmly welcomed by them. In the future, we will form Taiji Alliance to further lead international efforts on gravitational-wave studies.

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