ASTROPHYSICS

Taiji-1 Paves Way for Space Detection of Gravitational Waves

The early morning of August 31st witnessed the successful launching of a satellite for experiments under microgravity from Jiuquan Satellite Launching Center in northwestern China. Named “*Taiji*-1”, this satellite marks the first mission under the Phase-II of the Strategic Priority Program on Space Science (SPPSS-II) sponsored by the Chinese Academy of Sciences (CAS). As confirmed by the National Space Science Center (NSSC), CAS in late September, the experiments aboard are so far in smooth operation, and the satellite in proper status with all test results reported normal.

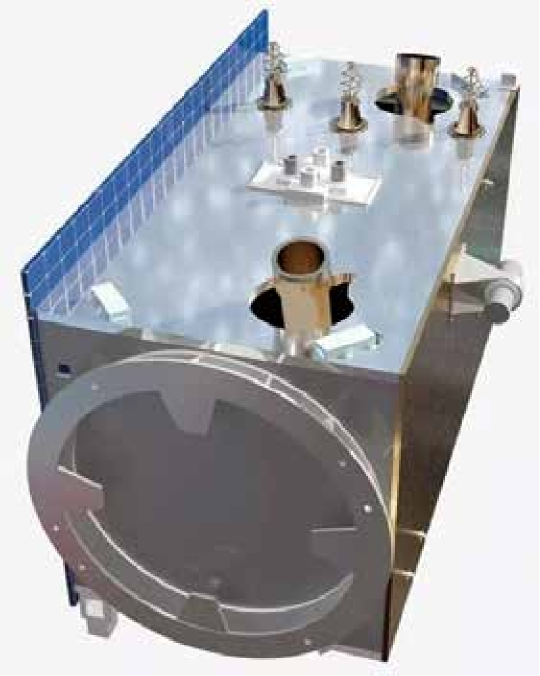
This announces the successful completion of the satellite’s first stage of in-orbit tests, as well as the first step on a journey to detect gravitational waves (GWs) from space.

Taiji-1, the first experiment satellite of China for space detection of gravitational waves (GWs), got its name from *Taiji* Program, a space GW detector proposed by CAS. Comprising of three satellites, the detector is designed to form an equilateral triangle orbiting the Sun 18 to 22 degrees ahead of the Earth, with each side (baseline) spanning a distance of 3.0 million km.

Scheduled to fly in around 2033, the conception of the GW detector can be traced back to 2008, when the Academy took the lead in China to explore the feasibility of detecting GWs from space. The following years saw it develop into a three-stage layout and roadmap, with its first stage featuring one satellite as a pathfinder, followed by a double-satellite and a trio-satellite stage. In August 2018, the single-satellite project for *Taiji* Program was officially adopted by SPPSS-II, taking the first step toward implementing the program.

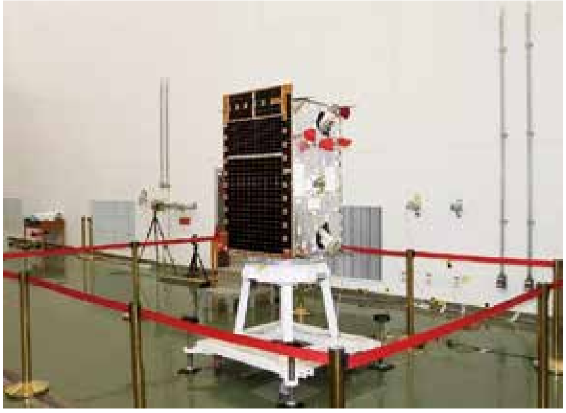
It took the satellite development team, consisting of experts from the CAS Innovation Academy for Microsatellites, only one year to develop and build the satellite.

As indicated by the first results from the in-orbit tests and data analysis of *Taiji*-1, the interferometer aboard has achieved a measuring precision of hundred picometer level, making it able to discern a distance as small as the diameter of an atom. Besides, the gravitational reference sensor aboard is now able to detect fluctuations in Earth gravity as trivial as trillionths of the gravitational acceleration; and the resolution of its micro-thruster can tune its impulses less than one μN a time. The success lays a firm foundation for future detection of GWs in space.



Model of *Taiji*-1, the first experiment satellite for space detection of gravitational waves.

The GW is a type of matter wave originated from radical motion and change in mass and energy. As early as about 100 years ago, Albert Einstein predicted its existence based on his theory of general gravity. Not until 2015, however, did humankind first directly detect this space-time oscillation from the Earth ground – LIGO (Laser Interferometer Gravitational-wave Observatory) eventually succeeded in picking up the weak, vague signals from the merger of binary black holes, after decades of efforts. Since then, human beings not only can “see” the cosmos via electromagnetic waves, but also “hear” its voices by virtue of GWs – this revolutionary


The satellite *Taiji*-1.

experiment has invited one more "messenger" to tell the story of the cosmos.

GWs of different frequencies give clues about various astrophysical processes occurring in different stages of cosmic evolution. The GWs detected from space fall in the mid- and low-frequency bands of the spectrum. Such space-time ripples are set off by more massive celestials compared to those of higher frequencies as detectable from the Earth ground. Free from the complexity of noise on the ground, space-based GW detectors might be able to capture weaker signals and find out more distant sources of them. This will help us reveal much enriched astrophysical phenomena and better understand how our universe works.

Signals of GWs are extremely weak, however. This poses a great challenge on space detection of them and pushes it to the limits of existing human technologies for precise measurement and control. *Taiji*-1 has meant to test the feasibility of existing key technologies and verify their in-orbit implementation.

Under the framework of SPPSS-II, CAS plans to fly a series of missions for various science goals, including the Gravitational Wave Electromagnetic Counterpart All-sky Monitor (GECAM), the Advanced Space-borne Solar Observatory (ASO-S), the Einstein Probe (EP) and the Solar wind Magnetosphere Ionosphere Link Explorer (SMILE). They are set to detect electromagnetic signals from GW sources, black holes, and fluctuations in solar activities, aimed at understanding the mechanisms underlying solar activities and the origin and evolution of the universe. All the above missions are to be launched by 2023.

(By SONG Jianlan)

PLANT SCIENCE

Plants Have a Knack for Balanced Diets

Nutritionists like to recommend people to take a balanced diet to stay healthy. This seems a simple task at a first glance, but it could be really hard to stick for long. However, this could be indeed a simple task for plants. Because plants are sort of born nutritionists, having a knack for balanced diets. They are equipped with built-in sensors and signaling networks that together enable the plant host to monitor soil nutrients in real time and uptake those in a balanced manner to suffice optimal growth and yield.

In a recent study published in *Nature Plants* (doi: 10.1038/s41477-019-0384-1), scientists from the CAS Institute of Genetics and Developmental Biology found that NRT1.1B, a nitrate sensor in rice (*Oryza sativa* L.), also controls the uptake of phosphate from the soil to achieve a coordinated nutrient utilization. The study shows that nitrate perception strengthens the binding of NRT1.1B with SPX4, a phosphate signaling repressor that acts to inhibit the utilization of phosphate. The enhanced binding promotes the degradation of SPX4, and subsequently activates the phosphate-responsive genes that act to improve phosphate utilization. Interestingly, many nitrate-responsive genes are also under the control of SPX4. So, these two nutrient signaling pathways are intertwined and coordinated.

"This work represents a breakthrough in the field of nutrient signaling and beyond regarding the novel and highly intertwined organization of these two nutrient signaling pathways," highlighted by a commentary in the same issue of *Nature Plants*, "it also raises an exciting question: how often is this mode of coordination happens in other signaling pathways?"

This signaling coordination explains for how plants uptake different nutrients in a balanced way, which may find use in creating the smart crops for a more sustainable agriculture. After all, the crops would feed the world better if the soil feed them more properly at the first place.

(By YAN Fusheng)

Rooting from Leaf Explants – What Happens Within the First Two Hours Matters

Many plants can regenerate a new, complete plant from a cut twig or a detached leaf. But its underlying mechanism related to wound signaling remained elusive until a recent report appeared in *Nature Plants* (doi: 10.1038/s41477-019-0408-x). By studying the rooting from leaf explants, leaf taken from the plant and grown in an artificial medium, scientists from the CAS Center for Excellence in Molecular Plant Sciences/Shanghai Institute of Plant Physiology and Ecology (SIPPE) illustrated that a serial of molecular events happening within the first 2 h are critical for the plant regeneration and rooting.

When a leaf is cut from *Arabidopsis thaliana* (a small flowering mustard plant), a fresh wound will be formed. At the same time, a plant hormone jasmonate (JA) surges during the first 10 minutes within the detached leaf, and peaks at around the 30th min, drops afterwards and disappears at around 4 h. This pulse of JA production sort of mimics an up-and-down wave. During the surging part of the JA wave, the increasing JA level promotes the production of auxin, another plant hormone that helps with plant growth and rooting. However, too much JA could reverse the effect to the opposite and inhibit plant growth and rooting. After 2 h, the JA wave slacks and the decreasing of JA allows a continuous accumulation of auxin afterwards, which finally acts to promote rooting from the detached leaf. This newly-identified signaling pathway shall help scientists find new angles to improve many widely-used plant regeneration techniques, such as grafting, cuttage and tissue cultures.

(By YAN Fusheng)

DRUG DEVELOPMENT

New Anti-HIV Drug Candidate Thioraviroc Approved for Clinical Study

On May 5, 2019, Thioraviroc, a new anti-HIV drug candidate that binds to CCR5 (one of the key co-recepetors for HIV infection), received a clinical trial permission issued by the National Medical Products Administration (NMPA), formerly known as the China Food and Drug Administration (CFDA).

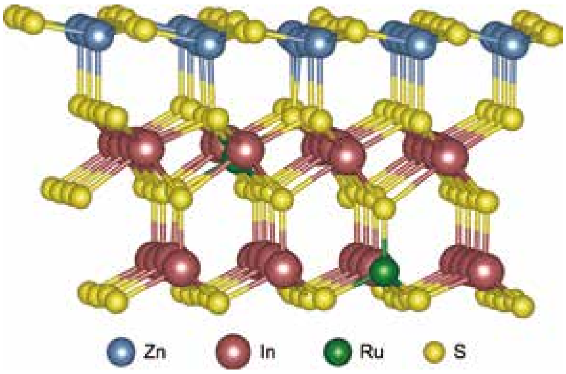
Thioraviroc was jointly developed by scientists from the CAS Shanghai Institute of Materia Medica (SIMM) and the CAS Kunming Institute of Zoology (KIZ). To develop this new drug candidate, several research teams converged their efforts and specialties, covering computer-aided drug design, efficient synthesis of these new drug structures, illustrating how they bound to CCR5 and testing their anti-HIV activities. The preclinical tests showed that Thioraviroc reprsented a promising drug candidate with good pharmacokinetic profiles and good safety in rats and dogs. More importantly, compared with the only anti-HIV drug Maraviro available on market since 2007 that also acts as CCR5 antagonist, Thioraviroc proved itself a better antagonist against CCR5 and showed either improved or equivalent anti-HIV potency against various HIV strains, clinical strains and resistant strains. Scientists are currently preparing Thioraviroc for the Phase I clinical study.

(By YAN Fusheng)

GREEN CHEMISTRY

Harvest Light to Yield Diesel-Fuel Precursors and Hydrogen

Harvesting light to split water into hydrogen (H_2) and converting biomass to fuels or value-added chemicals are two hot pursuits in the field of green chemistry. Most efforts are focused on one topic or the other. In a recent study published in *Nature Energy* (doi: 10.1038/s41560-019-0403-5), Dr. WANG Feng's group from the CAS Dalian Institute of Chemical Physics (DICP) reported a method for producing both diesel-fuel precursors and hydrogen from biomass-derived starting materials.



When illuminated by visible light, this catalyst converts biomass-derived compounds to diesel-fuel precursors and hydrogen. (Credit: Dr. WANG Feng, DICP)

Using biomass in this fashion is attractive as it is the largest and the only sustainable carbon source whose use will not further mess up with our atmosphere by adding up the CO_2 concentration like the fossil fuels did. More importantly, by coupling the production of two kinds of fuels with one catalyst, the Ru-doped $ZnIn_2S_4$, they solve a pending problem in photocatalytic H_2 production. Conventionally, scientists use semiconductors as catalysts to produce the photoexcited electrons that then reduce protons in water to form hydrogen. This process also generates excited holes, or positive-charge carriers that may corrode the catalyst and reduce its efficacy gradually. One way out is by adding sacrificial reagents to quench these damaging charges. However, the use of sacrificial reagents could cause two new concerns: the generation of by-products that cause safety concern and wasting the oxidizing power of the excited holes for nothing value-added. So, it is of rational urge and practically value to make use of both excited electrons and holes and herein Dr. WANG's group shows us a good example of how to make it happen by channeling these two kinds of powers for producing two kinds of fuels.

(By YAN Fusheng)