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CAS Embraces Era of Multi-messenger Astronomy with Successful Launching of "*Huairou*-1" Twin Satellite

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Named "*Huairou*-1", a small pair of micro-satellites quietly embarked on a ground-breaking journey. The twin was thrown into the sky at 4:14 am (GMT +8) of December 10, 2020 from the Xichang Satellite Launch Center in Northwest China, and successfully entered the preset orbit. As the first flight of the Phase-II of the CAS-sponsored Strategic Priority Program on Space Science (SPPSS-II), this twin probe marks the first ever space-based equipment of China for the search of electromagnetic (EM) counterparts of gravitational wave (GW) sources. By monitoring and detecting high-energy X-ray and gamma-ray signals, it will capture EM profiles of drastic astronomical events – like the merging of two black holes or neutron stars – that potentially stir up gravitational waves, the ripples in the space-time continuum.

"*Huairou*-1" is a mission set for an SPPSS-II project called "the Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor

An artistic illustration of GECAM (By courtesy of GECAM team)

(GECAM)". Aimed at searching for high-energy EM counterparts of gravitational wave events, the successful launch of this mission blows the horn for the era of multi-messenger astronomy.

The landmark detection by LIGO and VIRGO of a special GW source in August 2017 has changed the game of astronomy. Different from other known GW sources, this merging of two neutron stars, labelled GW20170817 after the date of its discovery, gave off visible light aside from GW signals, making it possible for conventional observational equipment to join the GW party. Tens of optical telescopes, ground- or space-based, successfully caught the EM profile of this spectacular astronomical event. The enriched data from this unprecedented global synchronized observation has offered astronomers a great opportunity to understand this spectacular merging process from different perspectives, and make a more thorough inquiry into the underlying physical laws. For the first time, humankind got the message from the universe simultaneously via two different "messengers", namely the EM and GW signals. This has since raised the veil of the era of multi-messenger astronomy, where humankind can not only "hear" but also "see" the universe.

The bright prospects of multi-messenger observations have greatly raised the expectation of scientists for improved understanding of our universe, and GECAM arrives just timely to take advantage of this rare luxury. In 2016, even one year previous to the detection of GW20170817, CAS scientists proposed the project with foresight of the updated demands for EM observation performance in the wake of the upgrading of LIGO and VIRGO. It was soon approved by CAS in late 2018, and will perform all-sky monitoring to detect high-energy EM counterparts of gravitational wave events, mainly X-rays and gamma-rays, termed "Gravitational Wave Gamma-Ray Bursts (GWGRB)" for short.

The mission focuses on high-energy X-ray and gamma-ray signals, which are understood to herald the signals of other wavebands and might provide follow-up observations with important clues about the location of the GW source. Such fleeting high-energy radiations only sustain for a very short while, hence all-sky monitoring of excellent sensitivity will play a key role in the detection and observation of GW events.

The mission comprises of two micro-satellites orbiting at an altitude of 600 km above the Earth. The two share the same orbital plane, but operate in reverse phase, therefore always staying opposite to each other on either side of the Earth. This orbit design will allow them to completely cover the whole sky to overcome the shadow of the Earth in their fields of view.

As the first scientific satellite flown after the inauguration of the Space Science Laboratory of the National Comprehensive Science Center in Huairou, suburban Beijing, the GECAM twin satellite is now named "*Huairou*-1" by CAS and the Beijing Municipal Government. It is expected to discover an unprecedentedly exhaustive collection of GWGRBs, plus new-type high-energy radiations emitted by merging events between neutron stars and black holes. It is also expected to make a big difference in detecting potential high-energy radiations from fast radio bursts of extragalactic origins, ultralong and ultra-soft gamma-ray bursts, and magnetar bursts. These discoveries will greatly help us unravel the formation and evolution of compact celestial bodies, like black holes and neutron stars; and better understand their merging. On top of these, GECAM will also observe high-energy radiations occurring between the Sun and the Earth, including the solar flares, terrestrial gamma-ray flashes and terrestrial electron beams, and investigate their underlying physics.

The launch of "*Huairou*-1" also unveils a new stage of CAS's space science explorations. Under the framework of SPPSS-II, a total of four satellites will be launched by 2025, including the Einstein Probe (EP), a mission aimed at detecting transients in the X-ray universe; the Advanced Space-based Solar Observatory (ASO-S), a space-based astronomical observatory for solar physics; the Solar wind Magnetosphere Ionosphere Link Explorer (SMILE), a joint project in cooperation with the European Space Agency focusing on the interaction between the solar wind and the Earth's magnetosphere; and GECAM, a mission to search for high-energy EM counterparts of gravitational wave events. With these new missions, CAS is set to look closely into the origin and evolution of our cosmos, and also solar-terrestrial physics.