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Progress of Strategic Priority Program on Space Science

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Abstract

The Strategic Priority Program on Space Science from 2011–2017 (hereafter referred to as SPP I), which officially went ahead in 2011, marks that a new chapter of Chinese space endeavor has been opened. The 4 satellites, Wukong/DAMPE, SJ-10, Mozi/QUESS and Insight/HXMT, has been achieving promising scientific results since their launch, e.g. Wukong directly detected a break in the teraelectronvolt cosmic-ray spectrum of electrons and positrons. To enable the sustainable development of China's space science endeavor, the Strategic Priority Program II on Space Science (hereafter referred to as SPP II) was officially approved in late 2017. SPP II includes 4 satellites——EP, ASO-S, SMILE and GECAM, Intensive Study of Future Space Science Missions, Advanced Research of Space Science Missions and Payloads, Space Science Mission Concept Research, and Data Analysis Research. Dedicated to exploring the unknown, the program is aiming to address scientific questions such as the origin and evolution of the universe and life, search for extraterrestrial life, and the impact of the Sun and the solar system on Earth and human development. Chinese space science community is committed to contributing to the progress of human civilization.

Key words

SPP on space science, Satellite, Science objectives

The official go-ahead of Strategic Priority Program I on Space Science (hereafter referred to as SPP I) in 2011, marks that a new chapter of Chinese space endeavor has been opened. Through both independent space science missions and international cooperation, SPP I has been achieving promising results, since the launch of four satellite, i.e. DArk Matter Particle Explorer (Wukong/DAMPE), Shijian-10 (SJ-10), QUantum Experiments at Space Scale (Mozi/QUESS) and Hard X-ray Modulation Telescope (Insight/HXMT). To enable the sustainable development of China's space science endeavor, SPP II on Space Science (hereafter referred to as SPP II) was officially approved in December 2017. SPP II include 4 satellites——Einstein Probe (EP), Advanced Space-borne Solar Observatory (ASO-S), Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) and Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor(GECAM), Intensive Study of Future Space Science Missions, Advanced Research of Space Science Missions and Payloads, Space Science Mission Concept Research, and Data Analysis Research. To explore the unknown, SPP II is addressing scientific questions such as the origin and evolution of the universe and life, search for extraterrestrial life, and the impact of the Sun and the solar system on Earth and human development.

1. SPP I Achieving Promising Scientific Results

1.1 Wukong/DAMPE

Wukong/DAMPE, which means understanding the space in Chinese, was launched on December 17, 2015 (see Figure 1 and 2). With the highest energy resolution, up to Jun. 2017, it directly detected a break in the teraelectronvolt cosmic-ray spectrum of electrons and positrons,

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and found the trace of the refined structure of energy spectrum at 1.4 TeV. Besides, it has detected 3.3 billion high-energy particles, mapping the whole sky three times. Its output has been published in *Astroparticle Physics* and *Nature*[1].

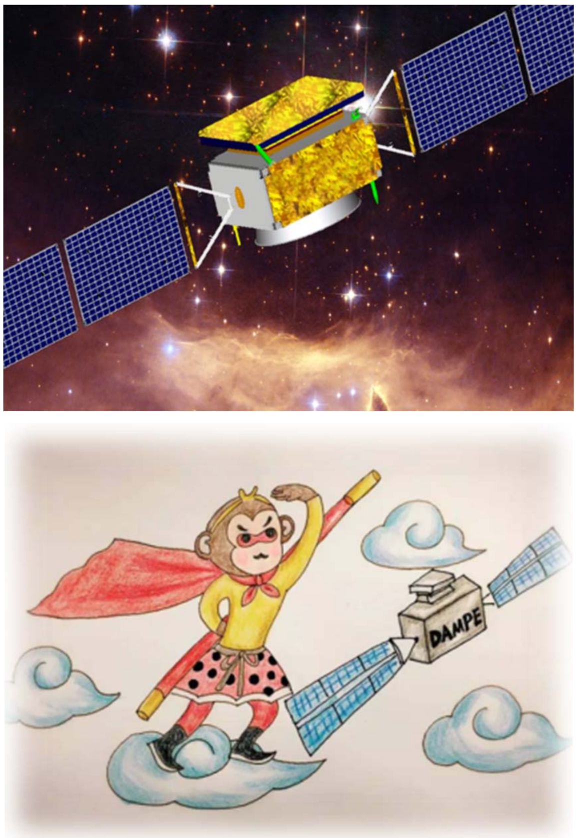

Fig. 1 Left: an artist's view of DAMPE satellite in orbit; right: the logo of Wukong from solicitation

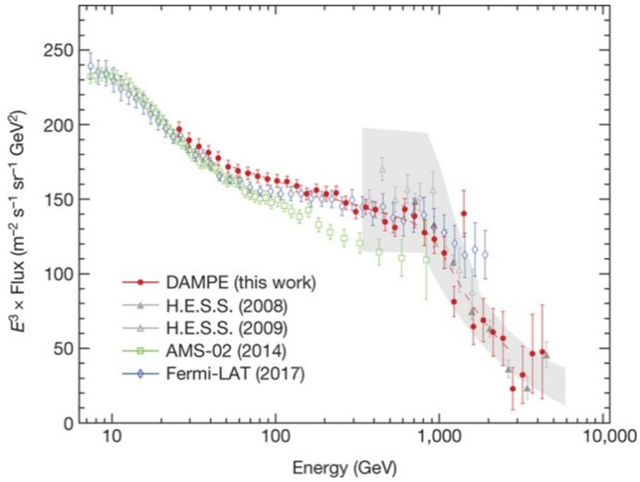

Fig. 2 Red dashed line: a smoothly broken power-law model that best fits the DAMPE data in the range 55 GeV to 2.63 TeV; AMS-0214 and Fermi-LAT16: direct measurements; H.E.S.S: indirect measurement

1.2 SJ-10

SJ-10 mission, which is a mission of 19 space micro-gravity experiments, was carried out from April 6—18, 2016. Mammal embryos developed in space for the first time and 15 experiments were carried out for the first time (see Figure 3 and 4).

1.3 Mozi/QUESS

Mozi/QUESS was launched on August 16, 2016. With the successful operation, satellite-to-ground quantum key distribution was accomplished for the first time; ground-to-satellite quantum teleportation was accomplished for

Fig. 3 Left: an artist's view of the SJ-10 satellite; right: the landing of the SJ-10 re-entry capsule

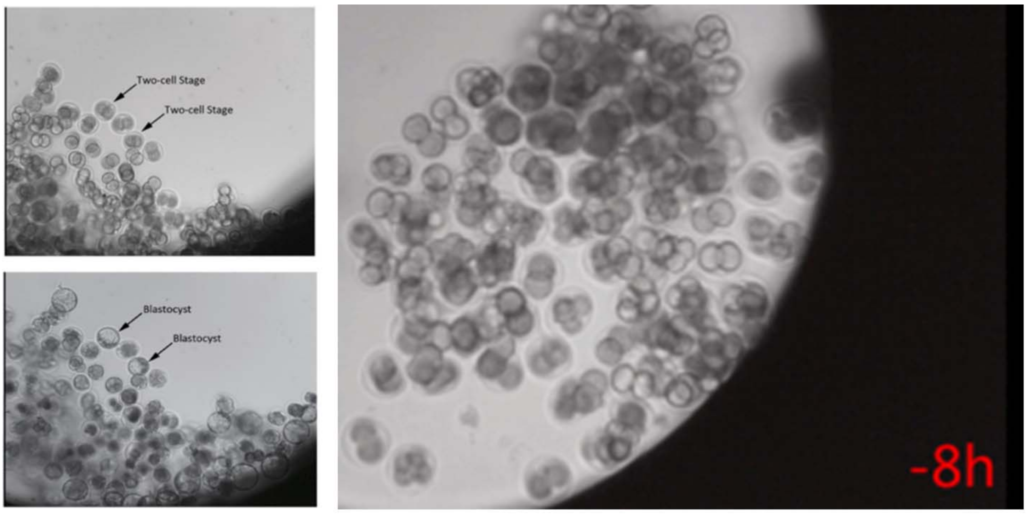

Fig. 4 Upper left: two-cell mouse embryos, four hours before launch; bottom left: mouse embryos that developed into blastocyst 80 hours after the launch

the first time, and satellite-ground and ground-satellite entanglement distribution over 1200 kilometers was accomplished for the first time (see Figure 5 and 6). Besides, intercontinental quantum communication was for the first time accomplished between China and Austria. Its output has been published in *Nature* and *Science*[2-4].

1.4 Insight/HXMT

Insight/HXMT was launched on June 15, 2017. It successfully monitored the entire GW170817 along with other satellites and observatory around the world, such

Fig. 5 Left: an artist's view of Mozi/QUESS satellite; right: the logo of the satellite

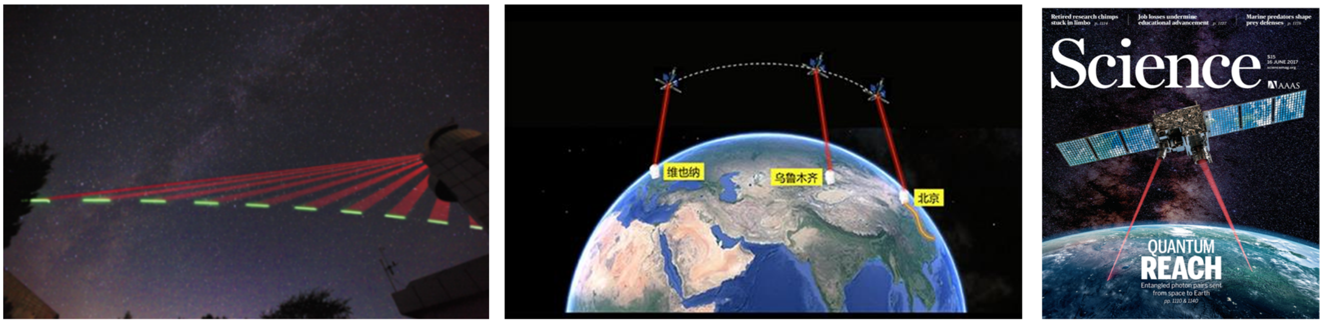

Fig. 6 Left: quantum key distribution and teleportation; middle: intercontinental quantum communication between China and Austria; right: the cover of *Science* journal in June 16, 2017

as XXXX, the localization area and especially the optical counterpart (SSS17a/AT2017gfo) with very large collection area (~1000 cm^2) and microsecond time resolution in 0.2–5 MeV(see Figure 7 and 8). Its output has been published in journals like *Astrophysical Journal Letters* and *Science China*.

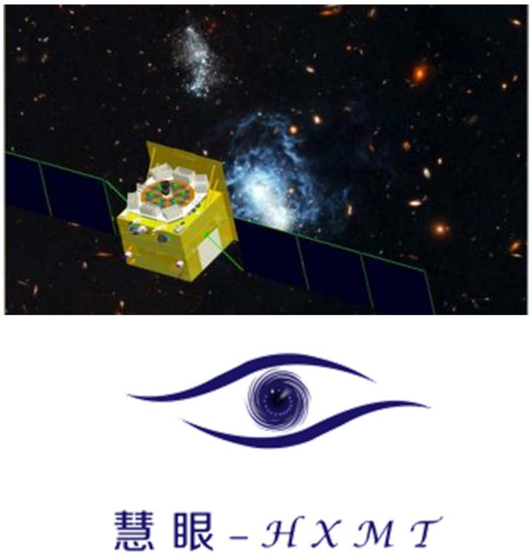

Fig. 7 Left: an artist's view of Insight/HXMT in orbit; right: the logo of the satellite

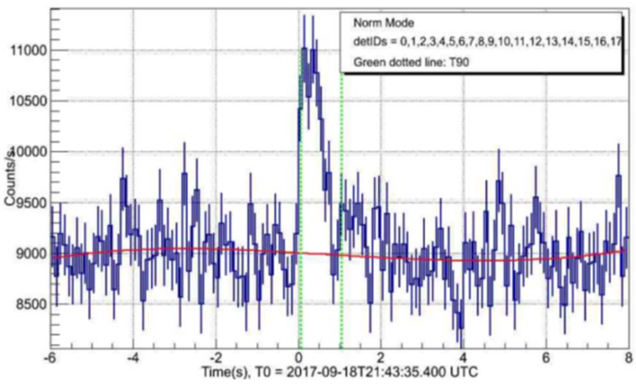

Fig .8 Monitoring of the entire GW170817 localization area

SPP I has passed the final review and was closed in November 2017.

2. SPP II Officially Approved and Aiming to Explore the Unknown

2.1 Einstein Probe (EP)

Time-domain astronomy is one of five areas in which major discoveries are highly expected.

EP will help address some fundamental questions in astronomy by monitoring & exploring cosmic high-energy transients, with its science objectives: (1) demography, origin, and evolution of black hole population; (2) how gravitational waves are produced, and their effects? (3) life cycle of the first generation of stars, re-ionization; (4) how supernovae explode?

EP is planned to launch in late 2022 (see Figure 9).

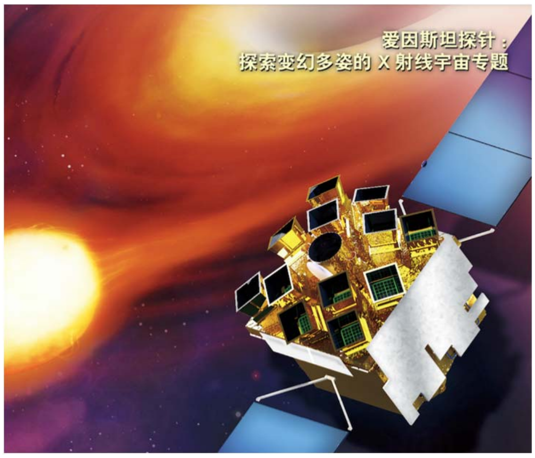

Fig.9 Artist's view of EP satellite in orbit

2.2 Advanced Space-borne Solar Observatory (ASO-S)

The science objective of ASO-S is to study solar magnetic field, solar flares, CMEs, their physical formations, mutual interactions, and close connections: (1) relationship between solar magnetic field and solar flares; (2) relationship between solar magnetic field and CMEs; (3) relationship between solar flares and CMEs.

ASO-S is planned to launch around 2022 (see Figure 10).

2.3 Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE)

SMILE is an ESA-CAS joint science mission, expected to carry out global imaging of the interaction between solar wind and magnetosphere for the first time. It is a new milestone of geospace exploration, enabling the great leaps from the local to the global detection.

Its science objectives are to (1) determine when and where transient and steady magnetopause reconnection dominates; (2) define the substorm cycle, including timing and flux transfer amplitudes; (3) define the development of CME-driven storms, including whether they are sequences of substorms.

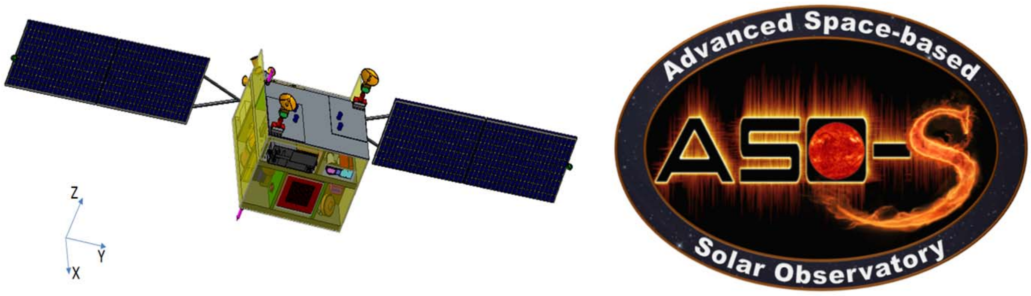

Fig. 10 An artist's view of ASO-S satellite in orbit

SMILE is planned to launch around 2022 (see Figure 11).

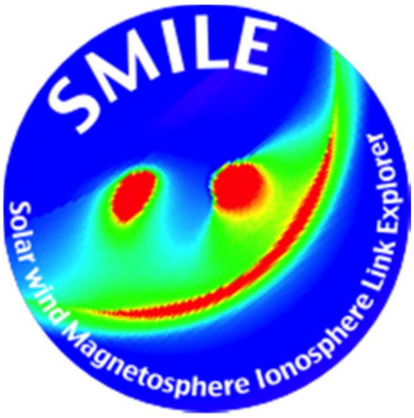

Fig. 11 SMILE mission's logo

2.4 Gravitational Wave high-energy Electromagnetic Counterpart All-sky Monitor(GECAM)

The first detection of both the GW and EM marks the multi-messenger GW era. As a leading mission based on innovations, the core science of GECAM is GW ElectroMagnetic counterpart (GWEM).

GECAM aims for the great opportunity in GW research around 2020 (see Figure 12).

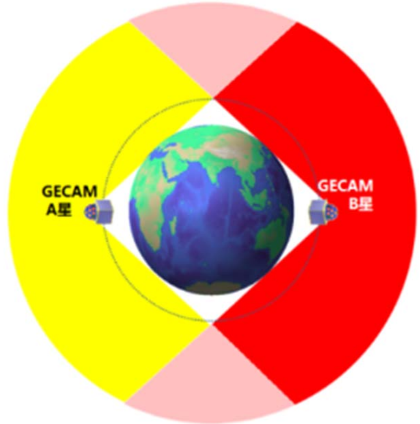

Fig. 12 An artist's view of GECAM mission in orbit

2.5 Intensive Study of Future Space Science Missions

The Intensive Study of Future Space Science Missions aims to carry out intensive studies of the selected future science missions including their scientific objectives, their payload definitions, and related key technologies.

The missions include Taiji Program, enhanced X-ray Timing and Polarimetry mission (eXTP), Small Bodies Sample Return Mission, Ultra-long Wavelength Astronomical Observation Array, Mid-to-high Orbit Quantum Satellite, Magnetosphere-Ionosphere-Thermosphere (MIT) Coupling Constellation Mission, and Water Cycle Observation Satellite (WCOM). Among the 7 missions, Taiji Program, eXTP, Small Bodies Sample Return Mission, Ultra-long Wavelength Astronomical Observation Array, and Mid-to-high Orbit Quantum Satellite entered into intensive study phase in late 2017 and early 2018. MIT and WCOM are currently under enhanced study in the frame of intensive study missions.

The main scientific goal of Taiji Program is to observe gravitational wave from mergence of binary black holes or great massive celestial bodies and so on. It adopts a "Three-step" strategy, *i.e*. technology development, technology test & pre-study of GWD, and then fully exploring the gravitational universe.

eXTP will conduct unprecedented research on singularity (black hole), stars (neutron star or quark star) and extremes (gravity, density, magnetism). It will offer for the first time the most complete diagnostics of compact sources: excellent spectral, timing and polarimetry sensitivity on a single payload.

Small Bodies Sample Return Mission will address two key scientific questions: (1) the formation of the solar system; (2) the formation of planets in the inner solar system. Another major scientific question is “the accumulation of planetesimal”.

Ultra-long Wavelength Astronomical Observation Array aims to make a high angular resolution map for the whole sky, as well as taking a high precision measurement of the global spectrum, and observe radio activity of the Sun and planets. The mission will open up a new window for astronomical observations at the lower end of the electromagnetic spectrum, and obtain vital information on the astronomical sources at the ultra-long wavelength band, such as the flux, spectrum, and spatial distribution of low frequency radio sources.

Mid-to-high Orbit Quantum Satellite plans to develop an all daytime quantum key distribution payload to realize quantum light modulation, 10,000-kilometers link establishment, and real-time quantum key extraction. This project plans to develop a space time-frequency laser transmission payload to achieve a sub-pico-second quantum real-time frequency transmission. It also plans to make Bose-Einstein condensate on the satellite platform to realize <100pK quantum gas and an ultra-cold atomic quantum interferometer.

MIT is targeting the coupling processes of the Earth’s magnetosphere-ionosphere- thermosphere system. The mission’s science objectives focus on the acceleration mechanism and the origin of upflow ions and other related scientific questions (see Figure 13).

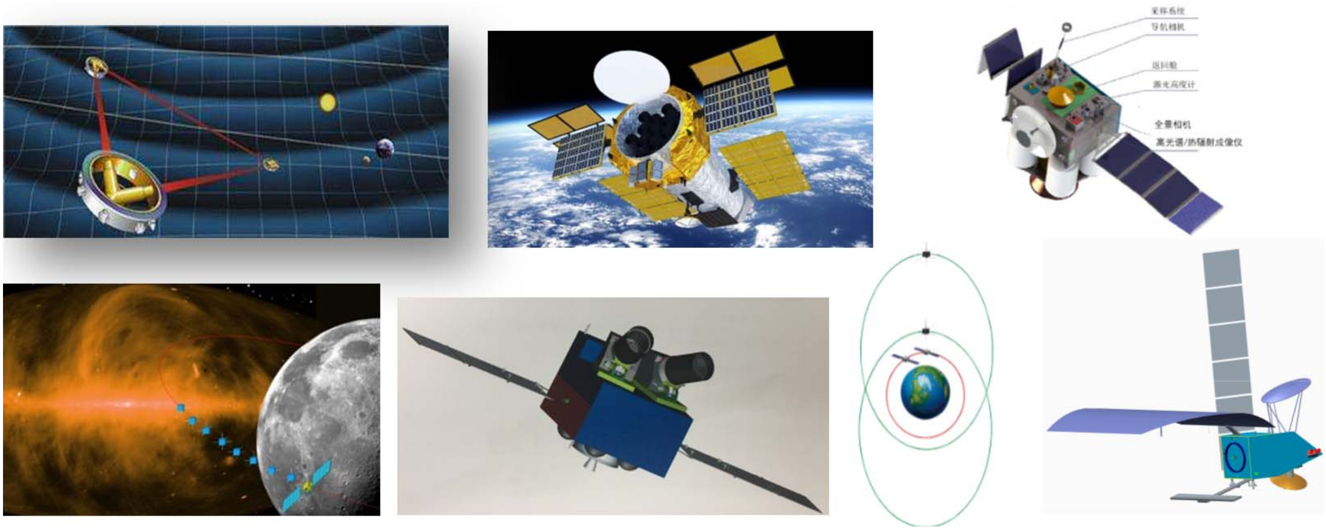

Fig. 13 Illustration of Taiji Program, eXTP, Small Bodies Sample Return Mission, Ultra-long Wavelength Astronomical Observation Array, Mid-to-high Orbit Quantum Satellite, MIT, and WCOM mission(from upper left to bottom right)

WCOM is to better understand the status and process of the Earth's water cycle system under the global change environment, by simultaneous and fast measurement of a set of water cycle key parameters (soil moisture, ocean salinity, ocean surface evaporation, snow water equivalent, frozen/thaw, atmospheric vapor…)

2.6 Advanced Research of Space Science Missions and Payloads

The Advanced Research of Space Science Missions and Payloads is targeted for the advanced research on key technologies for future space science satellites by planning a cluster of research subjects, including innovative concepts of space science missions, key technologies of payloads, ground calibrations as well as short-time flight demonstrations.

The project includes nearly 60 research subjects in total and will lay a solid foundation for China’s future space science missions.

2.7 Space Science Mission Concept Research

Space Science Mission Concept Research, the new project in SPP II, aims to foster innovative space science mission concepts, as an input to the above-mentioned advanced research missions and intensive study missions, laying a solid foundation for the sustainable development of space science. Up to 80 concept proposals are sponsored.

2.8 Data Analysis Research

Apart from the 4 satellites, intensive study missions, advanced research missions, and mission concept research, last but not least, data analysis research is also sponsored in SPP II, to support the science output of the 4 satellites in SPP I.

3. Conclusion

For space science, China is still a newcomer. There are several challenging issues that we need to face and to solve in a better way still in order to maintain the current positive development situation. These issues are but not limited to (1) reassuring the continuation of the government budget for space science, (2) encouraging great number of proposals focusing on the frontiers of fundamental breakthroughs, (3) selecting process and criteria for good proposals, (4) responsibility of science team during the engineering development phase, (5) evaluation of the output of each mission operated, *etc*. For these, there are also some preliminary findings [5, 6].

Honored as a "jewel" in the crown of space exploration, space science is an inter-discipline frontier, nurturing major scientific and technological breakthroughs, closely related to human's survival and development. China's space science entered into a new stage since the implementation of SPP I, which now is producing promising discoveries. The ongoing implementation of the SPP II will enable the sustainable development of China's space science endeavor, advance China's economic and social interest and make a contribution to the progress of human civilization.

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