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Chinese Academy of Sciences' recent activities in boosting Chinese planetary science research

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Abstract: The Chinese Academy of Sciences and its affiliated institutes and universities, responding to ever-increasing needs of China's space explorations and exploitations in recent years, have taken a series of initiatives and conducted related activities to support Chinese planetary science research.

Keywords: Chinese Academy of Sciences; planetary science; space explorations and exploitations; capacity-building

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1. Introduction

Planetary science is a highly interdisciplinary field that focuses on studies of the fundamental characteristics of planets, moons, and comets in the inner and outer regions of the solar system, as well as on their formation and evolutionary processes (Shirley and Fairbridge, 1997). It aims to answer basic questions that have been asked for millennia: What is the nature of the universe? How do planets form and change? Is the destiny of humankind bound to Earth? Are we and our planet unique? (National Research Council, 2011). Planetary science is thus a globally-recognized frontier science that has the potential to yield fundamental new scientific knowledge and revolutionary discoveries.

During the past few decades, planetary science has undergone paradigm-changing revolutions as a consequence of the increasing number and sophistication of spacecraft operating throughout the solar system, which make it possible for *in situ* quantitative observations of planets and other solar system bodies that previously could be observed only remotely, by means of telescopes (Crawford, 2016). In this space age, planetary science develops synergistically with space technology to generate a wide range of scientific, technological, economic, political, and cultural benefits to humanity (ISECG, 2013). It has been demonstrated to serve as an engine of fundamental research and technology development, a driver of economic growth, and a generator of wealth (ISECG, 2013; Crawford, 2016; Wu J and Bonnet, 2017). This branch of specialized science also inspires the public and boosts national prestige (Wu J and Bonnet, 2017). In addition, the scientific output of planetary science has higher international visibility than that of other basic and applied sciences, and appeals particularly to the young. Wider access to the advances made by today's planetary science may inspire our youth to engage in fundamental sciences, such as physics and mathematics, and may thus indirectly enhance natural comprehensive strength.

China is well aware of this wide range of benefits and thus puts great emphasis on space exploration and exploitation programs. For example, China's 'Thirteenth Five-Year Plan', released in 2016, announced that planetary exploration is a national priority (Wei Y et al., 2018), and similarly, the 19th National Congress of the Chinese Communist Party held in 2017 has elevated deep space exploration to a key role in its national strategy.

As a result, China is emerging as the rising space power in the second round of deep space exploration (Qiu J, 2017a; Normile, 2016; Wei Y et al., 2018; Li CL et al., 2019). The four successful "Chang'E Project" satellite launches — and especially the latest "Chang'E-4" landing on the back of the moon for the first time — demonstrate China's strong space technology and engineering. In the near future, China has also planned a more eye-catching exploration program that focuses on the Moon, Mars, Jupiter, and asteroids, among other objectives (Wei Y et al., 2018; Li CL et al., 2019).

With successive implementation of deep space exploration programs and increasing discoveries of exoplanets, more samples and data are being obtained, which demand a quite rapid development of systematic planetary science. At the same time, planetary exploration has transcended its initial technology-focused stage and is now moving forward in the direction of a planetary science-oriented stage, in which planetary science will lead planetary exploration and act jointly with engineering and space technology to maximize scientific returns.

As the largest scientific organization in China, the Chinese Academy of Sciences (CAS) has been playing a key role in leading China's research, especially at the frontiers of the sciences. The Academy also serves as a 'locomotive' driving national innovation in science and technology (S&T), a 'think tank' that delivers con-

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sulting services for S&T development, and a 'big school' cultivating S&T research talent (American Association for the Advancement of Science, 2012).

As such, the activities of CAS and its affiliated institutes and universities in boosting planetary science reflect to a large degree the importance attached to this sector by Chinese government. We present here to the international scientific community a brief overview of what CAS has contributed to Chinese planetary science research over the past several years. Given the considerable extent of CAS activities, our report is necessarily illustrative rather than exhaustive.

2. Activities in Boosting Chinese Planetary Science Research

2.1 Cultivation of Planetary Science as a First-level Scientific Discipline

An essential pre-requisite to a successful and sustainable planetary science research and deep-space exploration program is the building of various indigenous capacities, particularly human resources. This is especially relevant for China, having decided that space exploration and exploitation will be long-term and sustainable national scientific enterprises. Efforts to accomplish such capacity-building must be entrusted to the nation's high-level comprehensive universities and finest institutions. Top priority is to establish an appropriate disciplinary level for planetary science, and to construct well-designed corresponding educational systems.

The planetary science discipline and corresponding educational system in the United States (US) have been well established since as early as the 1970s (Tatarewicz, 1990; Cruikshank and Chamberlain, 1999; Ruley, 2013). For example, by the mid-1970s ten US universities had begun to grant PhDs in planetary science, and the total number of cultivated researchers had reached several hundred (Tatarewicz, 1990). Such construction of a distinct specialized discipline has played a very important role in establishing the US as the leading country of the world in planetary science, space technology, and related applications (Tatarewicz, 1990; Ruley, 2013).

In contrast, there has been no clear notion of planetary science as a separate scientific discipline in China. Especially, no doctors' degree-conferring entity (among universities or research institutes) for the planetary science discipline has been officially authorized. China has nearly 1300 universities that can grant bachelors' degrees, and about 500 of them can grant doctoral degree, but none of them can grant a degree in planetary science. Planetary science education is still scattered on the interdisciplinary edges of traditional disciplines such as Earth science and Astronomy (Wan WX et al., 2019). As a result, no systematically well-designed courses, curriculum, and research programs trimmed specifically to educate potential professional personnel in planetary science have been developed. Such lack, or slow development, of the planetary science discipline has seriously limited China's potential to become a country with robust capability for deep space exploration and exploitation, or even endangered the very survival of planetary science as a specialty available to Chinese scientists.

In China, the officially authorized establishment of a scientific discipline, especially a first-level one, usually confers legitimacy, which in turn tends to bring an increase in public visibility and thus stakeholders' support, including increased financial support, especially from national-level funding, and cultivates the needed talent pool. Traditionally, the Academic Degrees Committee of the State Council (ADCSC) has been responsible for authorizing new degree awarding powers (DAPs). On April 19, 2018, the ADCSC reformed the authorization policy, granting autonomous DAPs to twenty universities. UCAS is one of the universities to receive this new autonomy.

Such a granting of DAPs to UCAS was based primarily on the University's educational capacities and recent performances. In particular, UCAS had developed a series of conditions, capacities, and advantages that met the strict standards for being authorized the power to confer degrees in the specialized discipline of planetary science.

First, planetary science education meets the national strategy needs, as indicated in the introduction section. Second, planetary science is highly interdisciplinary in nature, involving the important interdisciplinary "Big science" specialties of Earth Science and Astronomy, but also such basic sciences such as physics, chemistry, biology, and mathematics. Planetary science education will cover all of these disciplines, thus providing all courses needed to prepare students for work in planetary science. This comprehensive, integrative approach is in accordance with the high emphasis by ADCSC on establishment of the newly-emerged interdisciplinary field as a first-level scientific discipline. At the same time, UCAS has developed a sound and complete interdisciplinary educational system in two planetary-science related divisions, i.e. the College of Earth and Planetary Sciences (CEPS) and the School of Astronomy and Space Science. Third, UCAS is the largest undergraduate university in China which has more than 45000 undergraduate applicants annually; this applicant volume fully meets the criterion that an institution may award a degree in a first-level discipline only if it has sufficient applicants from whom to select qualified candidates. Fourth, UCAS's cherished educational philosophy of integration of scientific research with first degree level education helps to cultivate professional talent. Under such a system, high-level researchers in various CAS institutes can serve as part-time teachers, providing students with hands-on practical knowledge and research opportunities by putting classroom know-how into practice. In combination with full-time resident university-based educators, this approach strengthens educational capacities. Such a unique educational system helps cultivate talent, which is very much in accordance with ultimate aims of ADCSC. This program was established in accordance with the goal of promoting a combination of science research and basic education to foster innovative talent.

Beginning at the end of the year 2018, UCAS and one of its important collaborators, the Institute of Geology and Geophysics (IGG), took this opportunity and conducted a number of activities to evaluate the DAPs for the planetary science and to cultivate it as a first level discipline.

On December 4, 2018, IGG organized and convened a meeting to evaluate the qualifications of a new unit that could be authorized an autonomous awarding degree power and capacities of establishing planetary science as the first-level discipline in UCAS. Twenty-five evaluating committees from twenty planetary science related research entities (among which eight entities are affiliated with, and 12 entities are external to, CAS) unanimously agreed and supported the proposal that UCAS take the lead in establishing planetary science as a first-level discipline. Based on the discipline-constructing experience of western universities, especially America and Europe, a structure for a Chinese planetary science discipline and its sub-discipline layout, as shown the Table 1, was constructed (Wu FY et al., 2019).

Table 1. The structure and layout for planetary science as a first-level discipline (Wu FY et al., 2019)

First-level discipline	Secondary-level discipline	Research directions
Planetary science	Planetary physics	Planetary space physics
		Planetary atmospheric physics
		Planetary solid physics
		Planetary probe technology
	Planetary geology	Planetary lithosphere science
		Planetary environmental science
		Planetary resource science
		Astrobiology
	Planetary chemistry	Planetary material science
		Planetary chronology
		Isotopic planetary chemistry

On December 25, 2018, the Earth science degree committees of UCA assessed and passed the proposed plan to cultivate planetary science as a first-level discipline. On January 6, 2019, in the 11th meeting of the fourth Academic Degree Committee of the Chinese Academy of Sciences, this proposal was formally approved.

Subsequently, on February 21, 2019, for public dissemination and wider discussions in the academic sphere, a seminar was held to talk about publishing a special issue on the journal "Bulletin of Chinese Academy of Sciences (BCAS)", one of the core media of the national science think tank. As a result, BCAS organized and published six papers under the theme of "Planetary Science: New Discipline, New Dream". Together, these papers systematically introduce the plan to advance planetary science research, the characterizes of the planetary science discipline, its current status, the experience and progress of the planetary science discipline in western countries, especially in the United States and Europe, and the necessity, urgency, and strategy to establish planetary science as a separate discipline in China (Hui HJ and Qin LP, 2019; Li XY et al., 2019; Rong ZJ et al., 2019; Wu FY et al., 2019; Wan WX et al., 2019; Wei Y and Zhu RX, 2019).

2.2 Formation of the Chinese Planetary Science Union

For centuries, natural science was primarily a private activity, pursued primarily by fortunate individuals. In the 19th century, technologies emerged from scientific discoveries; accumulating knowledge of the regularities in nature began to be exploited in new ways for human benefit. "Big science", however, is a worldwide phenomenon that dates primarily from the 1940s. It has been made possible by strong governmental and corporate investment in scientific research and education. That investment increased dramatically when the development of radar, computers, and nuclear energy demonstrated the enormous power of scientific knowledge to affect daily life, not to mention political and economic relationships among nations.

Cooperative alliances between and among existing research and educational institutions proved highly effective in this new era. Influential examples in the United States were the establishment of the Ivy League and the Universities Space Research Association (USRA).

USRA was founded on March 12, 1969 as a fledgling consortium of forty-nine universities (https://www.usra.edu/) in response to urgent needs to analyze samples of lunar rock and soil collected by Apollo astronauts and an anticipated increased need for a wide variety of space science research and education. At that time, NASA was experiencing a serious lack of human resources specializing in space sciences; NASA "looked around for …… people to do the science and found nobody." (Burrows, 1990; Burns, 2010). James Webb (1906–1992), then the second NASA Administrator, regarded the universities as the principal vehicles for building a "Space Age America"(https://www.usra.edu/), and proposed to bring together the best minds in academe. Since then the USRA has evolved into a big coalition with 110 university members; it was reported that in 2017 individuals from more than 488 universities were directly involved in USRA activities (https://www.usra.edu/). The role of the USRA has evolved to providing a mechanism through which universities can cooperate effectively with one another, with the government, and with other organizations to further space science and technology and to promote space-related education, including public outreach (Coleman and Hussein, 2000).

China's talent reserve in space sciences is certainly much better than that of America almost 50 years ago when USRA was created. At present, China has many universities with divisions, departments, or laboratories engaged in planetary-science-related research (Table 2). At the start of the second surge of space explorations and exploitations, China needs to make full use of the current human resources available, especially from these universities. Drawing on the history and experience of the USRA, the Chinese Planetary Science Union (CPSU) was established on 2 July 2019, jointly sponsored by twenty-seven prestigious universities (Table 2) including UCAS, Peking University, Tsinghua University, University of Hong Kong, and Macau University of Science and Technology. The main purpose of CPSU is to promote China's planetary science education and scientific research and strengthen the integration of Chinese planetary scientists into the international community.

Each university has strengths in planetary-science-related disciplines; however, none of the sponsoring institutions has systematically-designed and well-developed and all-covering sub-discip-

Table 2. Memberships of Chinese Planetary Science Union and their research units related to planetary sciences

No.	University name	Education or research departments name
1	University of Chinese Academy of Sciences	• College of Earth and Planetary Sciences • School of Astronomy and Space Science
2	University of Science and Technology of China	• Department of Geophysics and Planetary Science and Technology • Department of Astronomy • Center for Excellence in Comparative Planetology
3	SUN YAT-SEN University	• Planetary Environmental and Astrobiological Research Laboratory • School of Physics and Astronomy • School of Earth and Engineering
4	China University of Geosciences(Wuhan)	• Planetary Science Institute • School of Earth Sciences, China University of Geosciences • Institution of Geophysics & Geomatics
5	Peking University	• Planetary and Space Science Research Center • School of Earth and Space Sciences • Department of Astronomy, School of Physics
6	Macau University of Science and Technology	• State Key Laboratory of Lunar and Planetary Sciences
7	Shandong University (Weihai)	• Planetary Science Research Center
8	Harbin Institute of Technology (Shenzhen)	• Planetary science laboratory
9	Nanjing University	• Department of Earth and Planetary Sciences • School of Astronomy and Space Science • School of Earth Sciences and Engineering
10	Guilin University of Technology	• Meteorite Planetary Science Research Center • School of Earth Sciences
11	Beihang University	• School of Astronautics • School of Space and Environment • School of Physics
12	Nanjing University of Information Science & Technology	• School of Earth Sciences and Engineering • School of Geographic Science
13	South University of Science and Technology of China	• Department of Mechanics and Aerospace Engineering • Department of Earth and Space Sciences
14	Wuhan University	• State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing • School of Geodesy and Geomatics
15	Tsinghua University	• Department of Astronomy • Department of Physics
16	Beijing Normal University	• Astronomy Department • Center for Relativity and Gravitation
17	China University of Geosciences(Beijing)	• School of Earth Sciences and Resources • School of Geophysics and Information Technology
18	Tongji University	• The School of Aerospace Engineering and Applied Mechanics
19	Luoyang Normal University	• Institute of Space Physics
20	South-Central University for Nationalities	• College of Resources and Environmental Science
21	Nanjing University of Aeronautics and Astronautics	• College of Astronautics
22	North China Electric Power University	• School of Mathematics and Physics
23	Nanchang University	• Institute of Space Science and Technology
24	The University of Hong Kong	• Space Laboratory • School of Geosciences and Info-physics
25	Chongqing University	• College of Aerospace Engineering
26	Jilin University	• College of Mechanical and Aerospace Engineering
27	Zhejiang University	• School of Aeronautics and Astronautics • School of Earth Sciences

lines. Therefore the formation of such a university alliance is intended to achieve a partnership within the university community that will make full use of each institution's particular research and educational strengths. The alliance serves as a platform for sharing knowledge of deep space exploration and planetary science research, promoting collaborative planetary-science related research among its members, and make greater contributions to the development of space science and technology.

2.3 Establishment of CAS's Research Platforms

CAS's research platforms mainly refer here to those CAS key laboratories and research centers. They are important bases for CAS to organize to concentrate on its research advantages in high-level basic and applied basic research, gather and train outstanding scientists, and carry out high-level academic exchanges. During the past few years, the CAS Key Laboratory of Planetary Sciences, the CAS Key Laboratory of Earth and Planetary Physics, and the CAS Center for Excellence in Comparative Planetology have been established, marking an important endeavor by the CAS to strengthen its high-level research in the planetary science discipline. The main task of these entities is to carry out innovative research on the frontiers of planetary science.

The CAS Key Laboratory of Planetary Sciences was jointly established in 2013 by CAS's Shanghai Astronomical Observatory and CAS's Purple Mountain Observatory (http://english.shao.cas.cn/ns/es/index_2.html) in order to make full use of these institutions' strengths in astronomical research as applied to the study of planetary science. The laboratory strives to become an important special platform for international leading-edge basic planetary science research, undertaking the major tasks of conducting deep-space exploration and cultivating high-caliber research talent. Its research directions include measuring and determining the orbits of planetary probes, ground based and deep-space explorations of minor planets, internal structures and dynamics of planets, chemistry of planetary meteorites, and formation and evolution of planetary systems.

The CAS Key Laboratory of Earth and Planetary Physics was established in 2014, hosted by the IGG (http://www.epp.ac.cn/). The IGG has become one of the most important and well known geoscience research institutions in China; it is the result of a merger in 1999 of the CAS Institute of Geology with the CAS Institute of Geophysics, followed in 2004 by the further incorporation of the Ionosphere Research Room of the Wuhan Institute of Physics and Mathematics. As is indicated by its former titles and this integrating process, IGG research is rooted mainly in Earth science and has now expanded to include research on planetary physics and comparative planetology.

The CAS Center for Excellence in Comparative Planetology is housed in the University of Science and Technology of China (USTC), Chinese Academy of Science, having been created recently (in 2019) by merger of three entities, i.e. CAS's Institute of Geochemistry, CAS's Purple Mountain Observatory, and resources of Nanjing University external to CAS. USTC has the School of Earth and Space Sciences, established in 2001, which inherited the famous Division of Earth and Space Sciences established as early as 1979. The School now consists of the Department of Geophysics and Space Sciences and the Department of Geochemistry and Environmental Sciences. Space physics and geochemistry are its key disciplines; solid state geophysics is its second important discipline.

Nanjing University is one of the top ten universities in China and is well known for its long history of Earth science research. In 2018 it established the Department of Earth and Planetary Sciences. CAS's Institute of Geochemistry hosted the Center for Lunar and Planetary Sciences (CLPS), which was established as early as 2005. Its research programs in planetary science, cosmochemistry, selenology, and meteorites are well known. As an important research group, CLPS has been engaged in designing and conducted scientific explorations in the series of "Chang'E" lunar missions.

The establishment of CAS's Center for Excellence in Comparative Planetology endeavors to integrate and make full use of each research advantage, gathering human resources within and outside the CAS in order to establish a new model for research activities. Such a model is thought conducive to maximization of major scientific outputs in addressing the cross-discipline frontier issues of comparative planetology.

2.4 Establishment of the Journal *Earth and Planetary Physics*

A disciplinary journal is an important platform both for professional exchanges in academia and for knowledge dissemination to the public. Its establishment is thus deemed to be one of the most clear-cut features that mark a consolidating scientific discipline (Strick, 2004).

In recent years, both the quantity and the quality of research papers on Earth and planet physics, especially with the advent of a second surge of the space age, has led to the emergence of several important research themes in the discipline of planetary science; however, internationally peer-reviewed periodicals are still lacking in China. In 2017, the Chinese Geophysical Society (CGS) in cooperation with the CAS's IGG and Science Press, founded the journal Earth and Planetary Physics (EPP). To increase its international visibility, EPP is hosted by the American Geophysical Union in cooperation with the American publisher Wiley (Wan WX, 2017).

To cater to the increasing trend of planetary science research, the contents of EPP are not limited to the traditional geophysical domain, but will also include studies of the composition and evolution of various planets and satellites of the solar system as well as studies of planets outside the solar system. EPP will focus its attention primarily on areas such as solid-Earth geophysics, atmospheric physics, space physics, and planetary sciences. It commits itself to provide a high-quality academic communication platform for geophysical and planetary sciences research.

The founding of EPP is an epoch-making event for Chinese Earth science. EPP aspires to first-class international standards. EPP has been born at the right time and will certainly make important contributions to the state's key research strategy by providing a top-class academic communication platform (Wan WX, 2017). The new-born EPP depends on the support of the Earth and planetary research community, and serves researchers in international academic exchange. It is expected that in the not distant future EPP will join the ranks of first-class international periodicals of Earth science, and become a new flagship journal of Chinese Earth science (Wan WX, 2017).

2.5 Establishment of CGS's Planetary Physics Section

A well-organized academic or professional society not only marks consolidation of a scientific discipline (Strick, 2004) but is also an important network or platform for promotion of a science discipline in academic and public circles.

American geophysical scientists are well aware this. As early as 1962, during the then fledgling stage of planetary science, they created a Planetary Sciences Section as a sub-organization within the American Geophysical Union (Tatarewicz, 1990). In contrast, until recently no planetary science sub-organization had been established within China's counterpart, the Chinese Geophysical Society (CGS).

Founded as early as in 1947, the CGS is a first-level society of the China Association for Science and Technology (CAST). With a formal enrollment of 18419 members, according to official statistics at the end of December 2017, the CGS is one of CAST's largest and most influential societies.

Now the situation has changed. In 2017, at its seventieth anniversary, the CGS created a planetary physics section, the first academic society dedicated to planetary physics in China. This activity signals a new stage in which conventional planetary physics research, marked by individual and scattered studies, is being transformed into a comprehensive, systematic, and in-depth research program organized under the flag of geophysics (Wan WX, 2017).

CGS has expanded its scope from traditional geophysics to include the study of planetary physics. The aims of the planetary physics section are to address the needs of rapid development of interdisciplinary planetary science. CGS's planetary physics section creates an innovative exchange and collaboration network and platform for its members, which will play a very important role in bringing together scientists from diverse backgrounds, communicating scientific knowledge, overcoming disciplinary boundaries, and further consolidating and promoting planetary science research by sponsoring well-organized workshops, conferences, seminars, and public outreach.

2.6 Launch and Implementation of Strategic Priority Space Science Program

For any natural science discipline to grow into a thriving intellectual pursuit depends critically on sustainable financial support. In the case of planetary science, lack of private enterprise interest and financial inputs makes state funding especially crucial to progress in this field.

Traditionally, space exploration and exploitation have been focused primarily on space technology and space applications; almost no effort has been devoted to basic space science. Space activities have been technology- or engineering-led rather than science-driven, geared primarily towards practical or political needs such as military security concerns, technological prowess demonstrations, and national prestige inspiration (Biever, 2016; Wu J and Bonnet, 2017). During the period of frequent space activities from 2002 to 2011, almost no space science satellite related projects were launched (Qiu J, 2017b). And before 2011, among the more than 100 satellites sent into space, only Double Star had a dedicated science mission (Xin H, 2011).

This situation has changed profoundly as a result of two groundbreaking initiatives conducted by CAS and its affiliated National Space Science Center. The first was that in 2011 the CAS took space science under its wing from the China National Space Administration (Xin H, 2011).

The second was the successful application of the CAS's National Space Science Center to create a Strategic Priority Program on Space Science. The Strategic Priority Programs, including the one in space science, were put forward by the CAS based on its systemic 2015 roadmap for strategic science and technology research and development. As a core component of the CAS Innovation 2020 Program, the strategic priority programs are designed to allow the academy to achieve major innovative breakthroughs and form advantageous research clusters. Two types of research projects are identified, types A and B. Type A programs focus on addressing advanced technologies and key S & T issues related to public welfare and interests, promoting technological change and the formation and development of emerging industries, serving China's economic and socially sustainable development.

As both an initiator and organizer, CAS's National Space Science Center gained continuous big national funding supports from two consecutive Strategy Priority Program on Space Science (Stage I, 2011–2017, and Stage II, 2018–2022). In these two programs, planetary science has been assigned a very important role in designing projects, identifying project objectives, and specifying research contents.

In the first, planetary scientists led and worked together with engineers and technology developers to design the program. In the second, the general objectives of two programs were focused more scientifically than technologically, dedicated to deepen humanity's understanding of the universe and our planet Earth, seeking new discoveries and new breakthroughs in space science (Wu J et al., 2016). In the third, planetary science-related research accounts for a large proportion of its programs, and were at least co-equal with the technology, engineering and possible technology applications (Wu J and Wang C, 2018).

Such strong national fund support and increased focus on basic science has resulted in significant scientific results, as was expected. For example, the data collected by space science satellites in the first stage of the Strategic Priority Program on Space Science such as Dark Matter Particle Explorer, Quantum Experiments at Space Scale, Hard X-Ray Modulation Telescope, ShiJian-10 Recoverable Satellite, etc., have facilitated notable ground-breaking scientific achievements (DAMPE Collaboration, 2017; Yin J et al., 2017; Liao SK et al., 2017; Ren JG et al., 2017).

Over the next five years, the on-going second stage of the Strategic Priority Program on Space Science will include the launch of four more space science satellites, which will include the Einstein Probe (EP), the Advanced Space-based Solar Observatory (ASO-S), and the ESA-CAS Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE) (Wu J and Wang C, 2018). These probes are expected to facilitate significant original scientific results about time-domain high-energy astrophysics, the relationship between the solar magnetic field and solar eruptions, interactions between the solar wind and the magnetosphere, and detection of gravitational wave electromagnetic counterpart from gamma-ray bursts (Wu J and Wang C, 2018).

Overall, in terms of support and funding, the Strategic Priority Space Science Program is currently among the most ambitious projects of the Chinese Academy of Sciences. The first stage of the five-year Strategic Priority Program on Space Science provided $510 million from 2011–2017 for the development of four science satellites and related scientific researches . An additional $730 million has been allocated to the CAS for space science over the next five years (2018–2022) (Qiu J, 2017a). Although the overall funds appear smallish as compared to NASA's contemporaneous $19.3 billion budget (Normile, 2016), the budget of the Strategic Priority Space Science Program has been the biggest ever invested in a non-military Chinese space program. In addition, from its start in 2011 to the present, the CAS has initiated and implemented twenty type A Strategic Priority Research Programs, among which the space science programs account for two, highlighting the importance attached to space science by CAS and the Chinese government.

The Strategic Priority Research Program on Space Science thus represents the coming of age of China's space science efforts (Qiu J, 2017b). This project also marks a turning point in the history of space science missions, in which planetary science begins to lead deep space exploration and acts synergistically with various advanced technologies to produce science breakthroughs.

3. Summary

CAS and its institutes and universities have conducted a series of activities and initiatives to strengthen Chinese planetary science research and to promote the public visibility of this important scientific specialization. Some of these activities are kinds of capacity-building, such as establishment of planetary science research centers or CAS's key laboratories, and formation of the Chinese Planetary Science Union. Other activities have been strategic, such as the launch of that Strategic Priority Space Science Program, while still others involve discipline consolidation, such as cultivating Planetary Science to be a first-level scientific discipline, establishing the Earth and Planetary Physics Journal, and creating CGS's planetary physics section. These activities have generated science breakthroughs, accelerated the pace of science technology development, cultivated scientific domains of expertise, and transformed space missions from technically-focused to more science-led. Overall, these accomplishments have promoted the development of Chinese planetary science. In the future, CAS and its component and cooperating entities must — and will — continue to play leading roles in Chinese planetary exploration and exploitation.

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