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Space Solar Physics in China: 2020–2022*

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Abstract To follow up the last report two years ago, what happened from 2020 to 2022 deserves specially mentioning: CHASE was successfully launched on 14 October 2021; ASO-S will finish soon its Phase-D study and is scheduled for launch in October 2022; four solar mission candidates are being undertaken the engineering project evaluations; three solar mission proposals are being undertaken the background project evaluations; there are also quite a number of pre-study space solar physics projects getting either newly supported or finished. This paper describes in brief the status of all these related projects.

Key words Space astronomy, Solar physics mission

Classified index P35

1 Introduction

In order to see clearly the route of Chinese space solar physics, to read the series reports[1–10] is recommended, especially to read the last report[10] two years ago, so that one can better understand this report in the context of previous ones.

At first, Chinese H-alpha Solar Explorer (CHASE) was successfully launched on 14 October 2021. It was designed to spectrally image the whole Sun at lines of H-alpha (656.28 nm) and FeI (656.92 nm). A scheme of grating spectrometer plus scanning mirrors was used in its optical system. The first light and preliminary results look very nice and match well to the designed goals[11]. Another remarkable progress is the ultraviolet (19.5 nm) and soft X-ray (0.6–8.0 nm) images of the Sun, obtained by a payload on Fengyun-3E meteorological satellite, which was launched on 5 July 2021. The last most deserving of mention is ASO-S, the first Chinese comprehensive solar mission[12], which overcame a series of challenges in manufactures in a strict epidemic-control social environment. The final launch is scheduled in October 2022.

The detailed progress reports for CHASE, solar observations by Fengyun-3E and ASO-S can be found in Refs. [13–15], respectively. Following we therefore pay attention to other solar mission candidates which are now being undertaken the engineering evaluations, solar mission proposals which are being undertaken the background evaluations, and some pre-study space solar physics projects either newly supported or finished in the past two years.

2 Missions Under Engineering Evaluations

In the last report[10], a total of 4 finished pre-study projects and 9 undertaking pre-study projects were de-

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scribed. Among them, two years later, there are four (in fact five) which are confidently ready to compete for the engineering projects. They are as follows.

(1) Solar Polar-orbiter Observatory (SPO): led by National Astronomical Observatories, SPO aims at pursuing both origins of solar magnetic field and high-speed solar wind, as well as numerical modeling of the global heliosphere. The payloads include: magnetograph, white-light coronagraph, heliosphere imager, *in-situ* particle package, low-frequency radio spectrometer, and X-ray imager. The total weight of payloads is over 200 kg. The maximum inclination angle of the orbit is designed to be 81°, with a perihelion of 0.9 AU and aphelion of 1.15 AU. Therefore, SPO could be the first mission which observes the polar magnetic field in more details.

(2) Global Observation with three Spacecrafts around the Sun (GOSS): led by University of Science and Technology of China, GOSS aims at imaging the global Sun, by proposing to launch a group of three spacecraft into the Earth orbit around the Sun, separating each other by 120°. The primary scientific objectives are to study the origins of solar activity cycle, solar eruptions and extremely space weather events. The payloads include: full-disk vector magnetograph, solar ultraviolet imager, high-energy radiation detector, wide-field white-light coronagraph, and a group of in-situ particle and field detectors.

(3) Solar-Terrestrial Mission at L2: led by National Space Science Center, this project plans to launch a mission working at L2, making use of the natural shelter of the Earth (in fact only partially occulted) to observe the solar corona. The main payloads are an imaging spectroscopic polarimetric coronagraph (in tradition) plus in-situ plasma analyzer and in-situ magnetometer, in order to study the origins and propagations of CMEs and the solar wind.

(4) Solar or Solar-Terrestrial Observatory at L5: there are in fact two independent projects, one is Solar-Terrestrial Environment Monitor (STEM) led by National Space Science Center, and the other is Solar Observatory at L5 (SO-L5) led by Nanjing University. Both aim at making full use of L5 advantage and get a bird's view of the whole space from the Sun to the Earth and beyond. STEM pays more attention to the space weather domain while SO-L5 emphasizes more on solar physics. Both proposals are more or less similar in the payload deployments, including a couple of in-situ and remote-sensing instruments.

Above proposals (except SO-L5) joined the first-round meeting evaluations on 12 February 2022, organized by NSSC under the framework of CAS's Strategic Priority Program on Space Science. Projects 1, 2 and 3 seem to enter the next round evaluation, but it is obviously impossible to select all these three proposals to start the engineering phases finally. There will be fierce competition in the following steps. On the other hand, OS-L5 will try to pursue other channel, *i.e.*, to compete for support by Chinese National Space Administration, in late 2022. The OS-L5 team has some experience from this channel for the adoption of CHASE mission. In addition, as mentioned in the last report[10], there was a proposal called Space Weather Mission at L1, which belongs to the National Satellite Meteorological Center and is still waiting for the start of engineering phases. Anyway, currently we do not know which one could be ultimately successful or maybe none is selected, since within a limited financial budget competition with other domains are obviously unavoidable.

3 Missions under Background Project Evaluations

Among the pre-study projects described in the last report[10], besides above 5 projects which are being undertaken the engineering evaluations, there are still three projects which were recently submitted to apply for a background project, *i.e.*, an intensive study for clarifying some major scientific questions and making the project technically more feasible. Background study is in principle a necessary stage within the framework of CAS's Strategic Priority Program on Space Science if the project would like to go further into the engineering phases. These three projects are as follows.

(1) Close Observation on Solar Eruptions (COSE): led by Yunnan Astronomical Observatory, COSE aims at measuring the magnetic reconnection region directly and exploring the current sheet which results in solar flares and CMEs, with a group of instruments for ener-

getic particles, ambient plasma, electric field, magnetic field, EUV imagers, and so on. The closest distance from the Sun is designed to be 3 to 5 solar radius. To measure *in-situ* current sheet in such a close distance is really a great challenge both in technology and science, and needs a series of extensive studies to prove its feasibility.

(2) Solar and Stellar Coronal Explorer: led by Peking University, this project aims at combining both observations of the solar CMEs and the stellar CMEs on a single platform, comparing the difference of the solar CMEs from the stellar CMEs, and understanding the essence of CMEs. The proposed payloads include solar EUV spectrometer, solar EUV spectral coronagraph, stellar EUV spectrometer, stellar EUV telescope, and some other remote-sensing and in-situ instruments. This proposal is based on the pre-study project of Solar Transition region Observation and Research Mission (STORM, January 2018 to December 2019), but the revision is obvious and needs to be further studied.

(3) Formation-flying High Energy Solar Observatory: led by Purple Mountain Observatory, this project plans to launch two spacecraft separated about 100 meters. The front one is equipped with the focused grazing telescope, while the rear one is the detector, so as to get unprecedentedly high spatial resolution in solar hard X-ray imaging. Besides the focused grazing X-ray telescope, the updated project related to the original pre-study one includes also two other instruments, extremely high-spatial-resolved EUV and soft X-ray telescopes, and a solar gamma-ray imager. The extension of the instruments and the spacecraft itself need to be thoroughly investigated, so as to prove its advantage and feasibility.

At the moment, above three proposals are still awaiting to be evaluated in the soon-coming new round background project competitions. It is hard to say the results. Even one is selected, two to three years are needed to carry on. After background stage even if it could go smoothly into the engineering phases, other four to five years are necessary. So, for these background candidate projects the earliest date into the orbit would be around 2030.

4 Pre-study Projects: Newly-Supported

During 2020–2022, there are a set of newly funded pre-study projects. Some have gotten further supports due to their good behaviors in the first term of pre-studies, others are new proposals. We mention only part of them as follows.

(1) On key technologies of solar coronagraph in EV/EUV: it focuses on the design of raster with high resolution, suppress of stray light, detector with large dynamic range, and numerical discriminator of space and wavelength. Outcomes of the project could be applied to future missions.

(2) On key technologies of solar imaging at 46.5 nm: it focuses on the fabrication of a multi-filmed reflector, the property of CMOS under vacuum environment, and so on. Achievements of the project will serve directly the background candidate of Solar and Stellar Coronal Explorer or other missions.

(3) On heliosphere imager: it focuses on the design of a comprehensive heliosphere imager, stray-light model of optical system, fabrication of a prototype model, and the data processing method. Achievements of the project seem to have a wide application in future missions.

(4) High Resolution Solar Soft X-ray Telescope: it aims at proposing a novel scheme to realize a high resolution solar soft X-ray telescope.

5 Conclusions

We have seen from the above that in the past two years from 2020 to 2022 quite a lot of progress has been made, especially the zero-breakthrough of the first Chinese solar spacecraft CHASE was launched on 14 October 2021, and before the end of 2022 the first Chinese comprehensive solar mission ASO-S will also be launched. The researches based on the data from both CHASE and ASO-S will be used to promote substantially the progress of solar physics. Besides, there are five solar mission proposals which are now being undertaken the engineering evaluations, and three other solar mission proposals which have been submitted for the new round

competitions of background projects. Optimistically, after the successful launch of ASO-S, we might expect one or two new solar missions which could get a green light either for engineering phases or for background stages, so that we solar community could make sustainable development.

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