

# Progress Report on ASO-S: 2022–2024\*

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**Abstract** The Advanced Space-based Solar Observatory (ASO-S) marked China's first comprehensive solar mission in space. Drawing upon the previous reports covering 2018–2020 and 2020–2022, we present here an update on the ASO-S made from 2022 to 2024. In August 2022, ASO-S completed its Phase D study and was successfully launched on October 9, 2022. The commissioning phase was carried out and concluded within the first nine months following the launch. The data and associated analysis software have been opened to the community and the research on the early ASO-S data has been well developed. We anticipate also the achievements in data research pertaining to ASO-S in the near future.

**Key words** Space astronomy, Solar physics, Spacecraft

**Classified index** P171

## 1 Introduction

As a part of the CNCOSPAR national report series, this is the third report dedicated to detailing the advancements of the ASO-S project. Our first report<sup>[1]</sup> provided an overview of ASO-S's history, the Phase-B study, and aspects of the Phase-C study. In our second report<sup>[2]</sup>, we elaborated on the later stages of the Phase-C study and portions of the Phase-D study. This report continues to document briefly the progress of ASO-S from 2022 to 2024, encompassing the conclusion of Phase-D, the launch, commissioning, and early observational research linked to ASO-S. For more detailed descriptions of the ASO-S, readers are encouraged to refer to references<sup>[3–7]</sup>.

## 2 Late Phase-D Study

The official Phase-D study ran from September 2021 to August 2022. The last report<sup>[2]</sup> outlined the progress of Phase D until March 2022. As per the plan, after the deli-

very of each of well-established subsystems, in May 2022 the integration of the entire system commenced smoothly. Subsequently, the final tests encompassing the environment, performance, communication, and so on were successfully conducted. By the end of August 2022, the mission successfully concluded its Phase-D study and was packaged, and ready for transportation to the launch site in Jiuquan, Gansu province. Shortly after, in early September 2022, ASO-S was safely flown to Jiuquan.

## 3 Launch and Commissioning Phase

After approximately one month of regular preparation and testing at the launch site, the ASO-S was successfully launched at 07:43 Beijing time on 9 October 2022. Following the launch, the ASO-S was given a Chinese nickname, Kuafu-1, named after a character in a well-known Chinese mythological story who pursued the Sun in an attempt to capture it. On November 23, 2022, the national media reported the first hard X-ray images of solar flares captured by HXI. Then, on 13 December

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2022, all the initial images obtained by FMG, HXI, and LST were collectively displayed in the national media. Gan *et al.*<sup>[7]</sup> described the final status of the mission just before the launch as well as the first light images obtained by ASO-S.

The commissioning lasted over 9 months, longer than anticipated. The performance of the platform and HXI exhibited an excellent correlation with the designed and expected outcomes. For the FMG and LST, although they fulfilled almost all requirements, the FMG exhibited a dark region in its full-disc image and a loss of functionality in one of the liquid crystal components; on the other hand, the LST displayed a light leakage in the SCI and had a spatial resolution lower than expected for both the SDI and WST. Addressing these issues and determining their root causes took considerable time.

By the end of July 2023, when the commissioning was officially completed, the final status of all three payloads was as follows: the FMG provided routinely longitudinal magnetic field data for the local region, with accuracy comparable to or even exceeding that of the HMI; the HXI offers currently unique solar hard X-ray images from Earth's perspective, ranking among the top in the world in image quality; the LST, for the first time, captured routinely Lyman-alpha images of the entire disc, extending to 2.5 solar radius.

The details related to the commissioning for the FMG, HXI, and LST can be found in the papers by Bai *et al.*<sup>[8]</sup>, Su *et al.*<sup>[9]</sup>, and Chen, *et al.*<sup>[10]</sup>, respectively. The latest status for Science Operation and Data Analysis Center (SODC) of ASO-S was presented by Huang *et al.*<sup>[11]</sup>.

## 4 Research Organisation and Early Results

The scientific organization is a crucial component of the ASO-S project. Alongside the work surrounding SDOC and the release of the first ASO-S images to the public, on 11-12 April 2023, an international tutorial on ASO-S data was conducted online. Over 400 participants from 25 countries attended this meeting. During the event, Dr. Weiqun Gan, the Principal Investigator of the mission, presented the status of all three payloads in orbit and addressed relevant scientific issues such as data release and limitations, data policy, the ASO-S Guest

Investigator Program (AGIP), and the ASO-S special issue on Solar Physics. Additionally, three payload data scientists, Drs. Yang Su, Li Feng, and Suo Liu (representing Jiangtao Su), demonstrated the data and software for HXI, LST, and FMG, respectively. A half-day practice session with a Q&A segment completed the tutorial in a closed loop. Since 1 April 2023, the entire data set from HXI, the local longitudinal magnetic field data from FMG, and the data of SDI and WST from LST have been freely accessible to the research community.

To encourage users to utilize ASO-S data, enhance scientific output, and foster closer international collaboration, the ASO-S team has launched the ASO-S Guest Investigator Program (AGIP) to the global solar community\*. Additionally, the first announcement was issued in international community media in April 2023. As of April 2024, approximately 11 proposals have been received, with 8 being approved. Successful applicants have visited or will visit, the Solar Data Operation Center (SDOC) at Purple Mountain Observatory since October 2023 for several months to conduct independent or collaborative research based on or related to ASO-S data. The program's effectiveness has been evaluated and has proven to be positive. The AGIP is expected to remain available at least until the end of 2025.

To foster analysis of ASO-S data among researchers, a joint science assembly between ASO-S and CHASE was successfully held in October 2023. Over 200 domestic participants attended the event, and approximately 100 oral presentations were made, covering topics related to ASO-S, CHASE, or both. Some of these talks were later submitted to a special issue on Solar Physics, entitled "ASO-S Mission: Inflight Performance and its Early Results", which opened in February 2023. By the deadline of 15 March 2024, a total of 31 papers had been submitted to the special issue. As of 30 April 2024, about 10 papers have been published or accepted, while the remaining are still under review. Additionally, over ten other papers related to ASO-S data have been submitted to other journals, which are either published or under review. Among these early results, beyond calibration and orbital testing, we can see some noteworthy findings, like the work on the WLFs observed by the WST of LST<sup>[12]</sup>, together with the hard X-ray observations by the HXI. This work, marked by

\* [http://aso-s.pmo.ac.cn/english/science/asos\\_gip.jsp](http://aso-s.pmo.ac.cn/english/science/asos_gip.jsp)

the editor's choice, revealed that WLFs are not as rare as previously thought, with about 25% of solar flares exhibiting enhanced continuum emission at 360 nm. Another significant study focuses on hard X-ray imaging of slipping reconnection and Quasi-Periodic Pulsations (QPP) in a solar flare<sup>[13]</sup>, which sheds light on a new QPP mechanism that is associated with energetic electrons accelerated by quasi-periodic energy release from slipping reconnection process with periodic magnetic flux input. Gan *et al.*<sup>[14]</sup> comprehensively summarized all of the early achievements of ASO-S.

In order to better organize research based on ASO-S data, several national research projects have been granted funding, as highlighted in this report. These grants include funding from the Strategic Priority Research Program of the Chinese Academy of Sciences, the National Key R&D Program of China, and the National Natural Science Foundation of China. Although these research grants do not exclusively support work related to ASO-S, they indeed provide significant support for research involving ASO-S observations.

## 5 Conclusions

As China's first comprehensive solar-dedicated spacecraft, ASO-S is currently operating smoothly in orbit. Approximately 500 GB of primary data is processed daily at SDOC and transformed into high-level data, enabling users to download events of interest from the mission's homepage. Although the data from the SCI of LST have not yet been opened to the community, both the ultraviolet (Lyman-alpha) and visible light waveband observations sometimes capture excellent observations of CMEs. However, personalized processing is required, which hinders the public release of this data. For the FMG, the vector magnetic field can be obtained by rotating the platform, which can be performed in the user mode. The close cooperation with the science team members is obviously beneficial for making full use of the data from ASO-S. We sincerely hope that more and more colleagues will become interested in the ASO-S mission and utilize its data, ensuring that the scientific objectives of ASO-S are fully realized.

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