Research in Astronomy and Astrophysics

PAPER

Chinese Hα Solar Explorer (CHASE) – a complementary space mission to the ASO-S

To cite this article: Chuan Li *et al* 2019 *Res. Astron. Astrophys.* **19** 165

RAA 2019 Vol. **19** No. **11**, 165(5pp) doi: 10.1088/1674–4527/19/11/165

http://www.raa-journal.org *http://iopscience.iop.org/raa*

Research in Astronomy and Astrophysics

Chinese Hα Solar Explorer (CHASE) – a complementary space mission to the ASO-S

Chuan Li[1,2], Cheng Fang[1,2], Zhen Li[1,2], Ming-De Ding[1,2], Peng-Fei Chen[1,2], Zhe Chen[3], Liang-Kui Lin[4], Chang-Zheng Chen[3], Chang-Ya Chen[4], Hong-Jiang Tao[3], Wei You[4], Qi Hao[1,2], Yu Dai[1,2], Xin Cheng[1,2], Yang Guo[1,2], Jie Hong[1,2], Min-Jie An[4], Wei-Qiang Cheng[5], Jian-Xin Chen[5], Wei Wang[4] and Wei Zhang[4]

[1] School of Astronomy and Space Science, Nanjing University, Nanjing 210023, China; *lic@nju.edu.cn*
[2] Key Laboratory for Modern Astronomy and Astrophysics (Nanjing University), Ministry of Education, Nanjing 210023, China
[3] Changchun Institute of Optics, Fine Mechanics and Physics, Changchun 130033, China
[4] Shanghai Institute of Satellite Engineering, Shanghai 201109, China
[5] Shanghai Academy of Spaceflight Technology, Shanghai 201109, China

Received 2019 June 28; accepted 2019 July 2

Abstract The Chinese Hα Solar Explorer (CHASE) is designed to test a newly developed satellite platform and conduct solar observations. The scientific payload of the satellite is an Hα imaging spectrograph (HIS), which can, for the first time, acquire full-disk spectroscopic solar observations in the Hα waveband. This paper briefly introduces CHASE/HIS including its scientific objectives, technical parameters, scientific application system, etc. The CHASE mission is scheduled to launch in 2021. It will complement the observations by on-orbit solar spacecraft (such as SDO, IRIS, STEREO and PSP), as well as future solar missions of the Solar Orbiter and Advanced Space-based Solar Observatory (ASO-S).

Key words: instrumentation: spectrographs — Sun: atmosphere — Sun: activity

1 INTRODUCTION

The Sun is a unique star, which can be observed with high spatial and spectral resolution. It acts as a window through which astronomers can better understand other stars and the universe. Observations of and research on solar activity constitute one of the most important branches in astrophysics and space science. Since the launch of the first Orbiting Solar Observatory (OSO) in 1962, more than 70 solar spacecraft have been launched (Gan et al. 2012). China's first officially approved solar spacecraft is the Advanced Space-based Solar Observatory (ASO-S). It is scheduled to launch in 2021 or 2022, depending on progress (Gan et al. 2019). It is worth noting that there is another opportunity for solar space observation in China, namely, the recent development of a test satellite for solar observation and platform experimentation (Chen 2018).

The Chinese Hα Solar Explorer (CHASE) was jointly proposed by Nanjing University, the Shanghai Academy of Spaceflight Technology and the Changchun Institute of Optics, Fine Mechanics and Physics. CHASE passed the project review in May 2018, and was officially approved by the China National Space Administration (CNSA) in June 2019. It is scheduled to launch in 2021, and will conduct observations till the maximum of solar cycle 25. CHASE is based on a newly developed satellite platform with exceptional pointing accuracy and stability. The excellent performance of this platform facilitates solar spectroscopic observations.

2 SCIENTIFIC OBJECTIVES

The scientific payload of CHASE is an Hα imaging spectrograph (HIS) that can, for the first time, acquire full-disk spectroscopic solar observations in the Hα waveband (line center at 6562.81 Å). Compared to ground-based Hα telescopes, the advantages of HIS include: (1) no seeing effect arising from the Earth's atmosphere; (2) no contamination resulting from molecular spectral lines (e.g., water molecule spectral lines at Hα wings as displayed in Fig. 1); and (3) all-day and all-weather solar observations.

Technically, HIS can obtain two-dimensional (2D) spectral lines for the whole solar disk using the raster scanning mode in less than one minute, and then hundreds of images at different Hα and Fe I wavelengths can be reconstructed. At each wavelength, a 2D image reveals information from a specific layer of the solar atmosphere, as shown in Figure 1, which is an example of spectroscopic observation recorded locally by the 1-meter New Vacuum Solar Telescope (NVST) operated by Yunnan Observatories (Liu et al. 2014). HIS will enable solar physicists to reconsider the importance of spectral lines in the lower solar atmosphere. The scientific objectives of CHASE/HIS are as follows:

1. The Hα spectroscopic and imaging observations provide precursor information on solar activity in the photosphere and chromosphere, and help to understand the dynamics and trigger mechanisms of solar eruptions.

The emergence of solar active regions (ARs) usually appears as arch filament systems observed at the Hα center, and sunspots and faculae at the Hα wings (Zwaan 1985). Therefore, Hα spectroscopic and imaging observations can clearly demonstrate the evolution of solar ARs. On the other hand, Hα is the strongest spectral line that responds sensitively to solar activity in the chromosphere. Therefore, Hα spectroscopic and imaging observations can precisely reveal the structures, evolutions and dynamic processes associated with solar flares, and further provide effective diagnoses of particle precipitation, thermal conduction and magnetic reconnection. Figure 2 displays the bidirectional outflows of flare magnetic reconnection derived from the Hα line profiles (Hong et al. 2016). Furthermore, the Hα spectroscopic and imaging observations can be applied to investigate solar wave phenomena, e.g., Moreton waves (Moreton & Ramsey 1960), precursors of coronal mass ejections (CMEs), e.g., filament oscillations (Chen et al. 2008), etc.

2. The Hα spectroscopic and imaging observations reveal the fine structures and evolutions of filaments, and their relations with solar eruptions.

Filaments, appearing as prominences on the solar limb, are one of the most important structures on the Sun. Hα is the best spectral line for filament observations. Figure 3 shows the full-disk Hα line center image observed by the Optical and Near-infrared Solar Eruption Tracer (ONSET), which is managed by Nanjing University (Fang et al. 2013). The elongated dark structures are filaments. The Hα space observation can record the processes of filament formation, evolution and eruption, and aid in understanding their relation with solar flares and CMEs. Furthermore, the study of filaments is a key issue in solar physics due to the fact that the fine structure of a filament corresponds to the magnetic topology of a flux rope (Zirin 1972; Wang et al. 1997; Ouyang et al. 2017), and that the chirality of a filament is an important tool to diagnose magnetic fields in the chromosphere and corona (Chen et al. 2014; Casini et al. 2017).

Table 1 Technical Parameters of the Raster Scanning Mode

Items	Parameters
Wavebands	Hα: 6562.8 $\pm$ 2.5 Å Fe I: 6569.2 $\pm$ 0.8 Å
Field of view	$40' \times 40'$
Aperture	180 mm
Focal length	1820 mm
Spatial resolution	$1''$
Pixel resolution	$0.5''$
Instrument FWHM	0.14 Å
Pixel spectral resolution	0.05 Å
Full-disk scanning time	60 s
Quantization (ADC)	12 bit

Table 2 Technical Parameters of the Continuum Imaging Mode

Items	Parameters
Waveband	6535 – 6545 Å
Field of view	$40' \times 40'$
Aperture	180 mm
Focal length	1820 mm
Spatial resolution	$1''$
Pixel resolution	$0.5''$
Quantization (ADC)	10 bit
Frame rate	1 fps

3. The Hα spectroscopic and imaging observations facilitate study of the dynamics of solar activity in the lower atmosphere.

How energy is transported to the lower atmosphere in white-light flares, via non-thermal electrons or Alfvén waves, is an unsolved question in solar physics (Ding et al. 1999). One way to investigate this question is to examine whether periodic shifts or regular broadening of the Hα line profiles exists. Ellerman bombs are another prominent type of solar activity in the lower atmosphere. The Hα spectroscopic and imaging observations are able to confirm whether thermal or non-thermal energy dissipation plays the key role in producing Ellerman bombs (Fang et al. 2006). Furthermore, the Hα spectroscopic and imaging observations can yield full-disk Doppler velocity maps with a high cadence (less than 1 minute), which are critical to the study of helioseismology, magnetohydrodynamic (MHD) waves, etc.

3 TECHNICAL PARAMETERS

CHASE/HIS is onboard a newly developed satellite platform with an excellent pointing accuracy ($< 5 \times 10^{-4}$ deg) and very high stability ($< 5 \times 10^{-5}$ deg s^{-1}). The excellent performance of the platform ensures solar spectroscopic observations by CHASE/HIS. CHASE will be launched into a Sun-synchronous orbit with an average altitude of ∼517 km. The orbital period is ∼94.7 min. Due

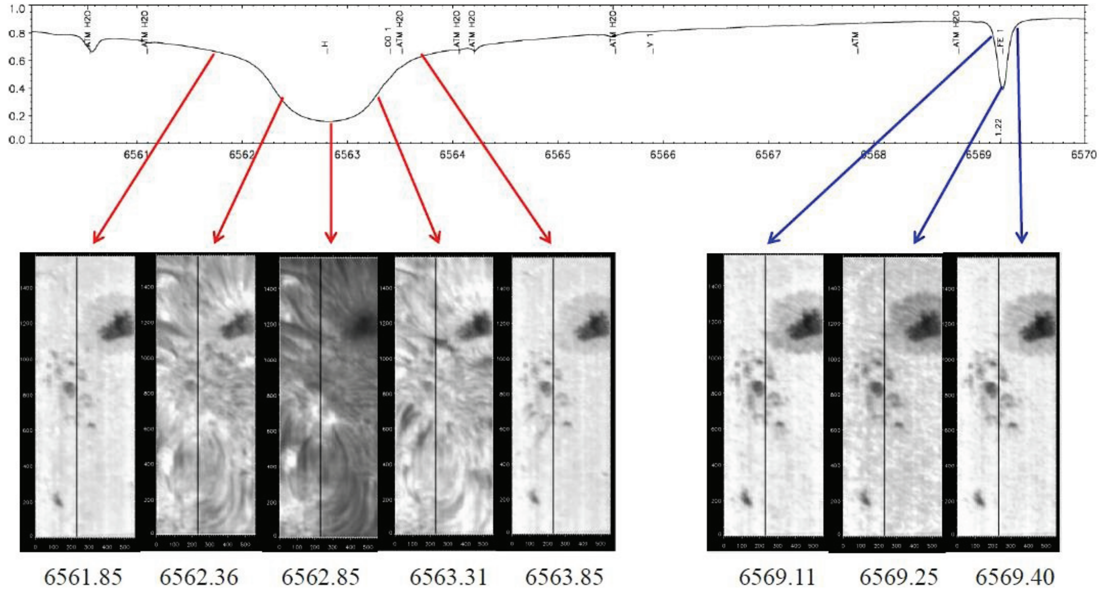

Fig. 1 Solar Hα spectral images obtained from the NVST, operated by Yunnan Observatories .

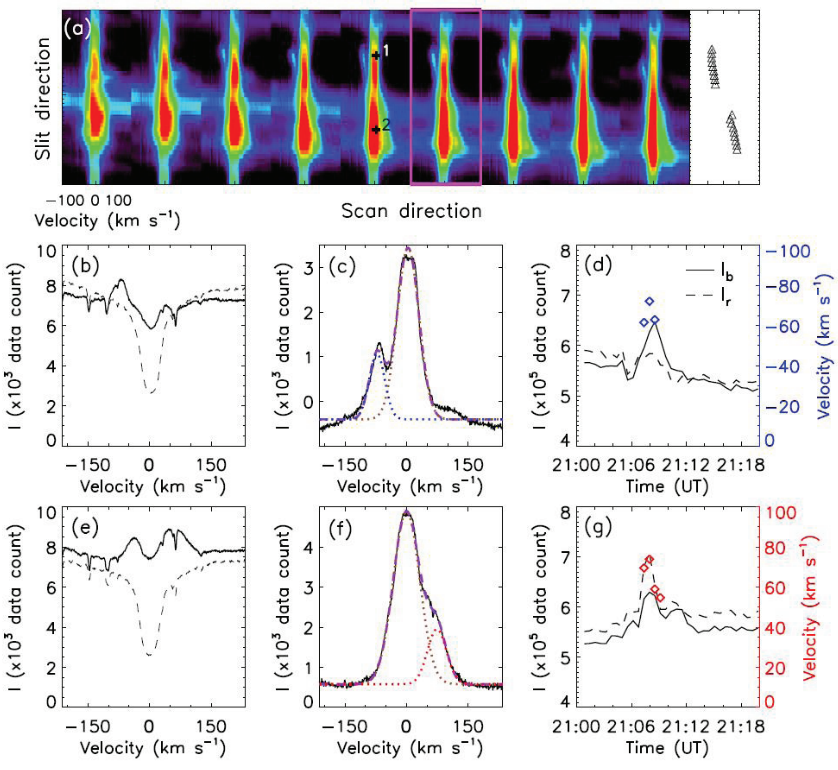

Fig. 2 Hα line profiles and bidirectional outflows in a flare AR (adapted from Hong et al. 2016).

to limited space o the satellite platform, CHASE/HIS is designed to have a weight of ∼40 kg and a volume of ∼489×480×517 mm. A detailed design of CHASE/HIS will be provided in a forthcoming paper. Figure 4 shows illustrative diagrams of CHASE and the satellite platform.

CHASE/HIS has two solar observation modes: full-disk raster scanning mode and full-disk continuum imaging mode. The raster scanning mode is developed based on the excellent pointing accuracy and stability of the satellite platform. As a result, it no longer needs a guiding telescope or image stabilization instrument. The raster scanning mode consists of two spectral lines: Hα (6562.8 ± 2.5 Å) and Fe I (6569.2 ± 0.8 Å). The latter is useful because it is a pure photospheric line and can be employed for spectral calibration. The raster scanning mode can obtain full-disk spectroscopic data in less than 60 s, or local-area

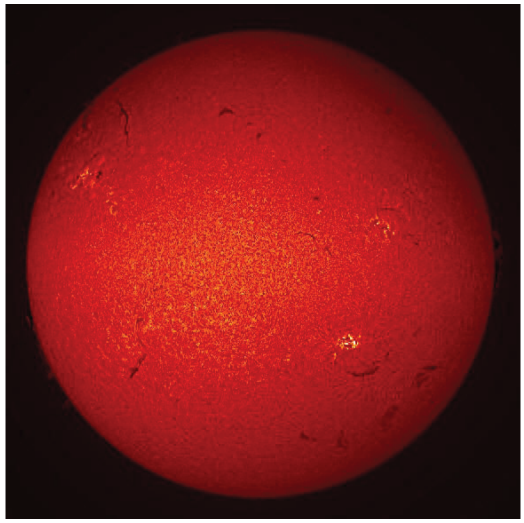

Fig. 3 Full-disk Hα line center image observed by ONSET, which is managed by Nanjing University.

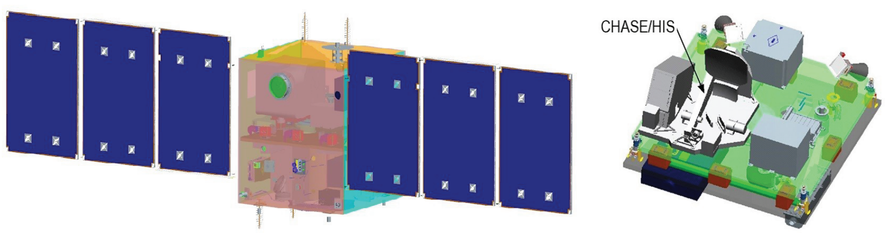

Fig. 4 Illustrative diagrams of CHASE and the satellite platform.

spectroscopic data in 30 – 60 s. The continuum imaging mode is available at the waveband 6535 – 6545 Å, which is not contaminated by any other spectral lines. The continuum imaging mode can also be applied to verify the pointing accuracy and stability of the satellite platform. Brief descriptions of the technical parameters for the two modes are provided in Tables 1 and 2, respectively.

4 SCIENTIFIC APPLICATION SYSTEM

The scientific application system of CHASE is responsible for monitoring the in-orbit operation of HIS, receiving and managing downstream data, scientific processing of the raw data, release of the scientific data and software, etc.

According to the receiving capability of the antenna and data rate of CHASE/HIS, $\sim$4.2 Tb of storage space is needed every day to store the raw and processed data. Therefore, at least 4.6 Pb of storage space is required considering the 3-year lifetime of CHASE. In order to manage the large amount of data, we use a scalable horizontal storage structure. Scientific processing of the raw data includes radiation and wavelength calibration, flat field and dark field corrections, spectral line curvature correction, and splicing of images that result from raster scanning. The processed scientific data are then released in a standard format for the solar community.

5 SUMMARY

CHASE will be the first Hα space telescope that can acquire full-disk spectroscopic solar observations. The scientific objectives of CHASE are to study solar activity in the lower solar atmosphere and provide critical data for space weather forecasting. The technical objectives of CHASE are to verify the pointing accuracy and stability of the satellite platform.

CHASE will be launched in 2021, close to the time when ASO-S will also be launched. CHASE is an excellent complementary space mission to ASO-S because (1) the CHASE/HIS Hα observations and ASO-S/LAT Lyα observations can reveal the dynamics of solar activity from the photosphere up to the transition region; and (2) the CHASE/HIS spectroscopic observations, ASO-S/HXI hard X-ray observations and ASO-S/FMG magnetic diagnosis provide complementary tools for studying the physical processes of solar activity. Combining CHASE data, the in-orbit observations from SDO, IRIS, STEREO, PSP, etc., and those of future solar missions like Solar Orbiter, ASO-S, etc., will greatly enhance research in solar physics, in particular helping to reveal the nature of solar activity.

Acknowledgements We would like to thank the staff and administrators of NVST of Yunnan Observatories and ONSET of Nanjing University for providing observational data. We also thank Prof. Jingxiu Wang and Prof. Weiqun Gan for their helpful comments and suggestions. This work was funded by the "Integration of Space and Ground Based Instruments" project of the China National Space Administration and the National Natural Science Foundation of China (Grant Nos. 11673012, 11533005 and 11733003).

References

Casini, R., White, S. M., & Judge, P. G. 2017, Space Sci. Rev., 210, 145
Chen, P. F., Innes, D. E., & Solanki, S. K. 2008, A&A, 484, 487
Chen, P. F., Harra, L. K., & Fang, C. 2014, ApJ, 784, 50
Chen, P. F. 2018, Science China: Physics, Mechanics & Astronomy, 61, 109631
Ding, M. D., Fang, C., & Yun, H. S. 1999, ApJ, 512, 454
Fang, C., Tang, Y. H., Xu, Z., Ding, M. D., & Chen, P. F. 2006, ApJ, 643, 1325
Fang, C., Chen, P.-F., Li, Z., et al. 2013, RAA (Research in Astronomy and Astrophysics), 13, 1509
Gan, W., Huang, Y., & Yan, Y. 2012, Scientia Sinica: Physica, Mechanica & Astronomica, 42, 1274
Gan, W. Q., Yan, Y. H. & Huang, Y. 2019, Scintia Sinica: Physica, Mechanica & Astronomica (in Chinese), 49, 059602
Hong, J., Ding, M. D., Li, Y., et al. 2016, ApJ, 820, L17
Liu, Z., Xu, J., Gu, B.-Z., et al. 2014, RAA (Research in Astronomy and Astrophysics), 14, 705
Moreton, G. E., & Ramsey, H. E. 1960, PASP, 72, 357
Ouyang, Y., Zhou, Y. H., Chen, P. F., & Fang, C. 2017, ApJ, 835, 94
Wang, J., Shi, Z., Yang, X., & Zirin, H. 1997, in Astronomical Society of the Pacific Conference Series, 118, 1st Advances in Solar Physics Euroconference, Advances in Physics of Sunspots, eds. B. Schmieder, J. C. del Toro Iniesta, & M. Vazquez, 116
Zirin, H. 1972, Sol. Phys., 22, 34
Zwaan, C. 1985, Sol. Phys., 100, 397