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Introduction to the Chinese Hα Solar Explorer (CHASE) Mission

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Abstract The Chinese Hα Solar Explorer (CHASE) mission, dubbed as "Xihe"—Goddess of the Sun, was launched on 14 October 2021 as the first solar space mission of China National Space Administration (CNSA). The CHASE mission aims to test an ultra-high precision and stability platform, and to acquire solar Hα Spectroscopic observations with high temporal and spectral resolutions. Since its launch, the in-orbit performance of the scientific payload—Hα Imaging Spectrograph (HIS) has been excellent. The first set of data has been calibrated and analyzed recently. The CHASE science data are expected to advance our understanding of the plasma dynamics in the solar lower atmosphere, and to investigate the Sun as a star for stellar physics.

Key words Space-based telescope, Solar physics, Solar activities

Classified index P35

1 Introduction

The Chinese Hα Solar Explorer (CHASE) mission was approved by China National Space Administration (CNSA) in June 2019. It was dubbed as "Xihe" in Chinese-Goddess of the Sun. At 18:51 on 14 October 2021 (China Standard Time), the CHASE was launched into a Sun-synchronous orbit with an average altitude of 517 km. The CHASE satellite has a weight of 508 kg and a size of 1210 mm × 1210 mm × 1330 mm. The life time of the CHASE mission is designed to be 3 years. The CHASE mission aims to test a new satellite platform with ultra-high precision and stability, and to perform solar Hα spectroscopic observations that are important for exploring the plasma dynamics in the solar lower atmosphere, namely the photosphere and chromosphere[1]. A topical issue on the CHASE mission was recently published to help users of CHASE data better understand its payload, technical parameters, observational modes, and data processing[2–7].

Since the first applications of spectrographs and filters in the earlier 20th century, the solar Hα observations have usually been obtained with ground-based telescopes[8–11], which suffer from seeing and weather effects of the Earth's atmosphere, and cannot provide all-day observations. The CHASE mission acquires, for the first time in space, solar Hα spectroscopic observations with very high spectral and temporal resolutions. Along with the X-ray and Extreme Ultraviolet Imager (X-EUVI) onboard the FY-3 E mission launched in July 2021[12], and the Advanced Space-based Solar Observatory (ASO-S) to be launched in the last quarter of 2022[13], the CHASE mission marks a milestone for Chinese solar observations to glide into the space age[14].

2 Science and Instrumentation

The primary goal of the CHASE mission is to investigate the plasma dynamics in the solar lower atmosphere,

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and to understand the physical mechanisms of solar eruptions. Specifically, the scientific objectives of the CHASE mission include: (i) formation, dynamics, and chirality of solar filaments; (ii) dynamics of solar activity in the photosphere and chromosphere; (iii) comparative studies of the solar and stellar physics. For more details, one may refer to Li *et al*.[3].

The scientific payload for the CHASE mission is the Hα Imaging Spectrograph (HIS), which has a weight of 54.9 kg and a size of 635 mm × 556 mm × 582 mm. It utilizes the ultra-high precision and stability platform to achieve solar Hα spectroscopic observations without requirement for a guide telescope or an imaging stabilization system. Fig.1 shows the schematic view of the CHASE satellite and the HIS instrument.

The CHASE/HIS has two observational modes: Raster Scanning Mode (RSM) and Continuum Imaging Mode (CIM). The RSM acquires solar spectroscopic observations in Hα (6559.7–6565.9 Å) and Fe I (6567.8–6570.6 Å) wavebands. The instrument spectral resolution or the spectral full width at half maximum (FWHM) is 0.072 Å, and the pixel spectral resolution is 0.024 Å. The RSM has three sub-modes: full-Sun scanning, region-of-interest scanning, and sit-stare spectroscopy. The first two have temporal resolutions of 30–60 s, and the last one has a temporal resolution less than 10 ms. The CIM acquires high-cadence (1 s) and full-Sun images at the continuum around 6689 Å with a FWHM of 13.4 Å. The CIM is designed to study the photospheric activities, and to test the stability of the satellite platform. More detailed instrument design and in-orbit performance are described by Liu *et al*.[6]. Table 1 summarizes the key technical parameters of CHASE/HIS.

3 In-orbit Observations

After the successful launch of the CHASE mission on 14 October 2021, it obtained the first-light images on 24 October 2021. Up to date, the CHASE/HIS operates well in-orbit as expected. Routine observations have started recently. The raw data are transmitted to three ground stations (Miyun, Kashi and Sanya) located in China, and then transferred to the Solar Science Data Center of Nanjing University (SSDC-NJU) through a dedicated internet access. The Level 1 science data and higher-level products are produced and released to community by SSDC-NJU. Detailed calibration procedures of CHASE data are described by Qiu *et al*. [4].

The calibration flow of RSM data involves several steps including the dark-field and flat-field correction, slit image curvature corrections, wavelength and intensity calibration, and coordinate transformation. Fig.2 shows an example of the raw RSM spectrum (a) and the calibrated Level 1 spectrum (b). It can be found that the digital offsets, slit image curvature, bright and dark stripes due to irregularities of the slit, and non-uniform responses on the detector, *etc*., are removed. The calibrated RSM Level 1 spectrum shows clearly three spectral lines, and the features of solar limb darkening, scanning of an active region and a sunspot. The calibrated spectral profiles and its comparison with the BASS2000 ground-based spectra are shown in Fig.3. Both emission intensities are calibrated by using the continuum intensity at around 6500 Å given by Ref. [15].

For a full-Sun scanning, over 4600 steps are needed, which takes only about 46 s. One single step produces a spectrum as shown in Fig.2. Taking one specific

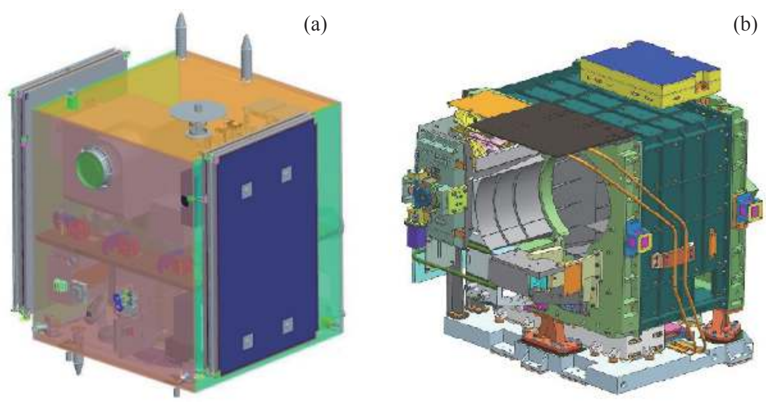

Fig. 1 Schematic view of the CHASE satellite (a) and the HIS instrument (b)

wavelength along the slit from every step, we can splice an image at this wavelength. Fig.4 shows an example of the full-Sun image at Hα center (6562.8 Å) produced by a scanning sequence at 06:01:05–06:01:52 UT on 22 December 2021. It has to be noticed that a scanning sequence produces 376 solar images at different wavelengths.

Table 1 Key parameters of CHASE/HIS

Parameter	Value
Primary aperture	180 mm
Effective focal length	1820 mm
Field of view	40′×40′
RSM	
Passbands	6559.7–6565.9 Å 6567.8–6570.6 Å
Instrument FWHM	0.072 Å
Pixel spectral resolution	0.024 Å
Pixel spatial resolution	0.52″
Scanning time	30–60 s
Exposure time	<10 ms
Quantization (ADC)	12 bit
CIM	
Center wavelength	6689 Å
Passband FWHM	13.4 Å
Pixel spatial resolution	0.52″
Exposure time	<5 ms
Frame rate	1 s
Quantization (ADC)	10 bit

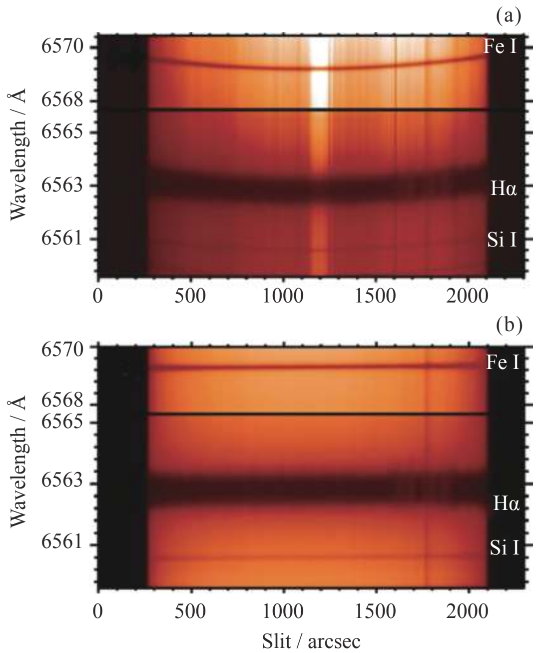

Fig. 2 Raw RSM spectrum observed at 06:01:27 UT on 22 December 2021, and the calibrated Level 1 RSM spectrum

The RSM of CHASE obtains precise Fe I and Hα spectral profiles for every pixel on the full solar disk or in the region of interest, that are able to derive simultaneously the photospheric and chromospheric Dopplergrams. Fig.5 shows an example of the chromospheric Dopplergram derived by using the full-Sun Hα spectral profiles. The accuracy of velocity field is estimated to be better than 0.06 km·s^{-1}. The blue and red arrows indicate the *y*-axis of the detector and the solar north pole. The differential rotation from poles to the equator and the complex velocity distributions are clearly distinguished.

The calibration procedures for CIM data include the dark-field and flat-field correction, and the transformation to the heliographic coordinates. Fig.6 displays the Level 1 CIM image observed at 02:02:40 UT on 25 November 2021.

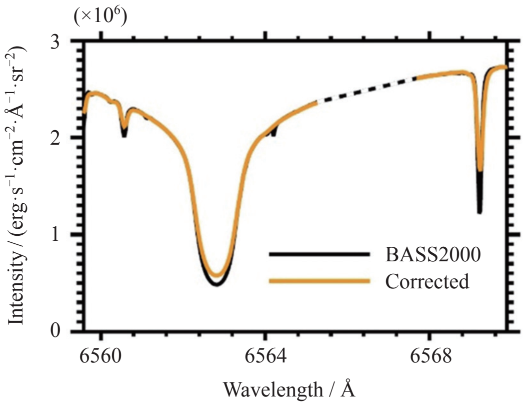

Fig. 3 Comparison between the calibrated spectral profiles and the ones from BASS2000

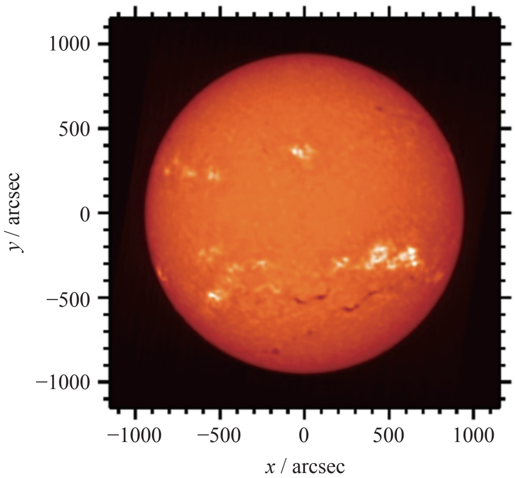

Fig. 4 Full-Sun spectroscopic image at the Hα center of 6562.8 Å

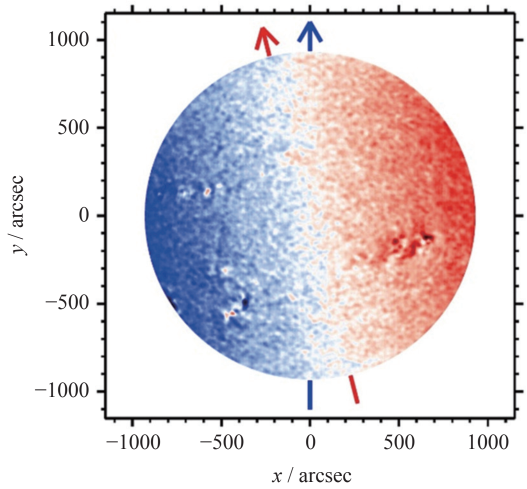

Fig. 5 Higher-level product: the full-Sun chromospheric Dopplergram

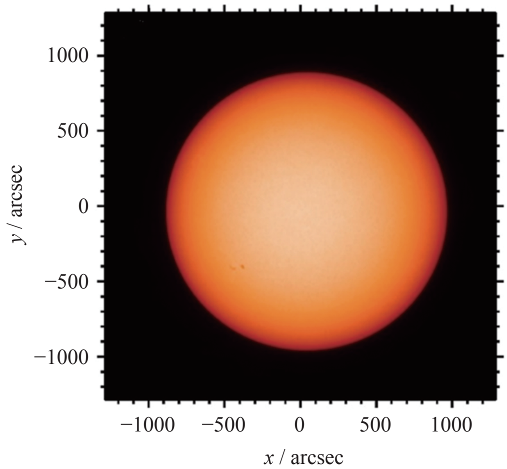

Fig. 6 Calibrated CIM photospheric image

4 Summary

Up to date, the in-orbit performance of the CHASE mission has been excellent. The first set of data has obtained and calibrated. The FITS formatted Level 1 science data are released to public through the website at SSDC-NJU*. The CHASE data are expected to advance our understanding of the plasma dynamics in the solar atmosphere, and to investigate the Sun as a star for stellar physics.

*https://ssdc.nju.edu.cn

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