Solar and Stellar Flares and their Effects on Planets
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The Lyman-α Solar Telescope (LST) for the ASO-S mission

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Abstract. The Lyman-α (Lyα) Solar Telescope (LST) is one of the payloads for the proposed Space-Borne Advanced Solar Observatory (ASO-S). LST consists of a Solar Disk Imager (SDI) with a field-of-view (FOV) of 1.2 $R_\odot$ ($R_\odot$ = solar radius), a Solar Corona Imager (SCI) with an FOV of 1.1 - 2.5 $R_\odot$, and a full-disk White-light Solar Telescope (WST) with the same FOV as the SDI, which also serves as the guiding telescope. The SCI is designed to work in the Lyα (121.6 nm) waveband and white-light (for polarization brightness observation), while the SDI will work in the Lyα waveband only. The WST works in both visible (for guide) and ultraviolet (for science) broadband. The LST will observe the Sun from disk-center up to 2.5 $R_\odot$ for both solar flares and coronal mass ejections with high tempo-spatial resolution

Keywords. solar flare, coronal mass ejection, coronagraph

1. Introduction

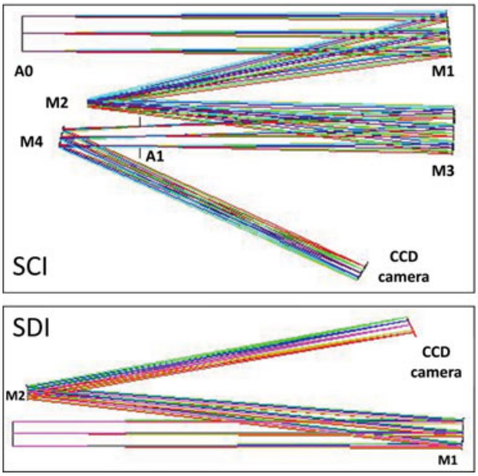
Solar flares and coronal mass ejections (CMEs) are the most energetic eruptions on the Sun and the primary drivers of disturbed (disastrous) space weather (Schwenn 2006). During flaring processes, particles (electrons, protons, neutrons, etc.) are accelerated to very high energy (Mev to GeV). After the initiation of CMEs, they are accelerated in a short time to high speed (up to more than 2000km/s) and may move towards the Earth with vast mass and numerous particles. When high energy particles and vast mass come close to the Earth, they will have great impact on the Earth's environment and subsequently on our daily life and the property in space.

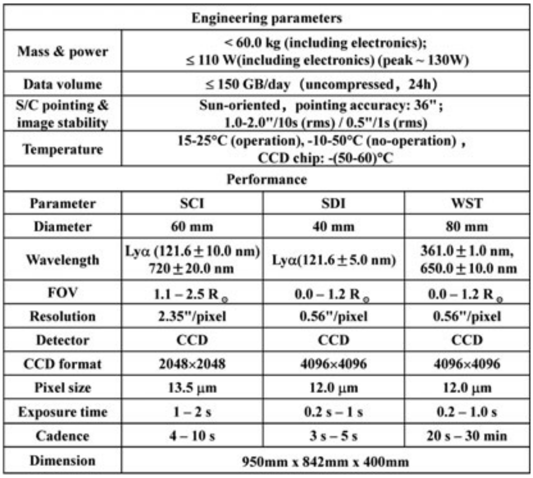
The neutral hydrogen Lyα line is the brightest EUV coronal line and very powerful in diagnosing structures of the solar atmosphere. As many proposed instruments, such as the Extreme Ultraviolet Imager (EUI) and the Multi Element Telescope for Imaging and Spectroscopy (METIS) on Solar Orbiter, the Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP) and the Lyman Alpha Spicule Observatory (LASSO), LST will observe the Sun in the Lyα line.

2. Scientific Objectives

The mission of the LST payload is to continuously monitor the Sun's activities and the source regions of space weather drivers, and to obtain high tempo-spatial resolution images of the Sun from the disk-center to 2.5$R_\odot$ in the Lyα waveband and white-light (for polarization brightness). Its scientific objectives are delineated as follows.

- **To explore the relationship between CMEs and eruptive prominences and solar flares.** This relationship has been long in debate and so far inconclusive. Statistical studies show that there exists clear association between flares and CMEs (e.g., Wang & Zhang 2007), and the association rate increases with the energy of events (Yashiro & Gopalswamy 2009). LST will image the solar disk and the inner corona





Engineering parameters			
Mass & power	< 60.0 kg (including electronics); ≤ 110 W(including electronics) (peak ~ 130W)		
Data volume	≤ 150 GB/day (uncompressed, 24h)		
S/C pointing & image stability	Sun-oriented, pointing accuracy: 36"; 1.0-2.0"/10s (rms) / 0.5"/1s (rms)		
Temperature	15-25°C (operation), -10-50°C (no-operation), CCD chip: -(50-60)°C		
Performance			
Parameter	SCI	SDI	WST
Diameter	60 mm	40 mm	80 mm
Wavelength	Lyα (121.6 ± 10.0 nm) 720 ± 20.0 nm	Lyα(121.6 ± 5.0 nm)	361.0 ± 1.0 nm, 650.0 ± 10.0 nm
FOV	$1.1 - 2.5\ R_{\odot}$	$0.0 - 1.2\ R_{\odot}$	$0.0 - 1.2\ R_{\odot}$
Resolution	2.35"/pixel	0.56"/pixel	0.56"/pixel
Detector	CCD	CCD	CCD
CCD format	2048×2048	4096×4096	4096×4096
Pixel size	13.5 μm	12.0 μm	12.0 μm
Exposure time	1 – 2 s	0.2 s – 1 s	0.2 – 1.0 s
Cadence	4 – 10 s	3 s – 5 s	20 s – 30 min
Dimension	950mm x 842mm x 400mm		

Figure 1. Optical configuration of the SCI (upper left) and SDI (lower left), and the specifications of the LST instrument.

simultaneously in the same waveband and therefore is quite suitable for conducting such a study.

- **To study the triggering mechanisms, physical parameters and evolutions of solar flares and CMEs.** Even though past studies have narrowed down the possible CME initiation models to two main classes: those in which the pre-eruptive current-carrying magnetic field structures are sheared arcades (e.g., Antiochos *et al.* 1999) and those in which they are flux ropes (e.g., Amari *et al.* 2014), we are still far way from the conclusion. It is still a challenges to understand the triggering and energy accumulating mechanisms of these events in the low solar corona.
- **To investigate the acceleration mechanisms of CMEs in the inner corona and their kinetic behaviors.** Once started, CMEs often show quick expansion and acceleration, which is linked to both the rising phase of the soft X-ray flare (Zhang *et al.* 2001) and the particle acceleration (Berkebile-Stoiser *et al.* 2012). LST will provide the full-coverage data of the solar disk and the inner corona to address these scientific questions.
- **To determine the source regions of CMEs and their physical property.** Both solar flares and CME take place in the very low layer of the solar atmosphere. The physical conditions of the source regions of flares and CMEs on the disk determine, in some degree, their behavior and characteristics. LST together with the Full-disk vector Magnetograph (FMG) payload on the ASO-S will easily locate the source regions and the observation data are quite suitable for their property study.

3. Instrumentation

I give here the composition, up-to-date designs, specifications and key technical issues of the LST instrument in the following subsections, respectively.

3.1. *Composition & Current Designs*

The LST is composed of a Solar Disk Imager (SDI), a Solar Corona Imager (SCI) and a full-disk White-light Solar Telescope (WST). This combination can well address the above-mentioned scientific objectives. Please refer to Figure 1 (right) for details of the instrument specifications.

The SCI is an inner-occulted Lyot-type reflective coronagraph. Its optical design is shown in Figure 1 (upper left). For SDI, two mirrors are used to image the Sun on the focal plan (Figure 1, lower left). A partial transmission filter is used to split the incident light of the WST and subsequently feed the guiding and polarization brightness channels. We do not show here the optical layout of the WST to save space.

3.2. *Key technical issues*

The most important two issues for the LST development (especially for the SCI) are stray-light control and image stability. Conjugate design, baffles, light-trap and super-polished mirror are used to realize the required stray-light level. Of all the stray-light sources, scattering from the main mirror is most significant stray-light source. To achieve the required stray-light, the required RMS surface roughness for the main is about 0.1 - 0.2 nm, which is of challenge but possible. Cleanroom needs also to be used to minimize the contributions of dusts and particles during the developing processes.

The WST also serves as the guiding telescope and produces a white-light image of the solar disk on the focal plan, where four Photo Multiplier Tubes (PMTs) are placed to detect the solar limb and provide the guiding signal via some processing unit. After processing and calculation, the signal is used to drive the PZTs behind the main mirror to stabilize the image. Experiments demonstrate that this can well achieve the designed stability.

Other key issues include the fast readout of large format CCD camera with low noise, low temperature maintenance of the CCD chip, and accurate control of the PZTs, etc.

4. Summary

The ASO-S and its proposed payloads including LST are now under phase B study and is proposed to be launched around the next solar maximum. According to the design and outlined scientific objectives, LST will open a new window (Lyα) to observe the Sun continuously from disk center up to 2.5$R_\odot$ without gap with high tempo-spatial resolution, and contribute to the study of solar flares, CME initiation, evolution and kinetics, of the relation between flares, prominence eruptions and CMEs, and of the interface region between the corona and the chromosphere, etc.

Acknowledgements

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