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Introduction to the Solar Space Telescope

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Abstract. The design ofthe space solar telescope (SST) (phase B) has been completed. The manufacturing is under development. At the end of 2000, it will be assembled. The basic aspect will be introduced in this paper.

Key words. Space telescopes.

1. Introduction

The world wide development of solar space-based observations went through two steps in the spatial resolution: low resolution (sun as a star) in the 60s-70s, and medium resolution (1"—10") in the 80s-90S. The next step will be high spatial resolution (~ 0.1") in the beginning of 21st century. The solar magnetic fields provide the major incentive to work on solar physics, the small spatial scale of magnetically constrained structures and processes in the solar atmosphere provide the major incentive for high resolution solar telescopes (Rutten & Pamel 1993), the 3-dimensional (multi-wave bands and multi-layers) high resolution and continuous evolutions provide the major incentive for space-base large and synthetic solar telescopes.

In the research of the solar magnetic field, there are two very important aspects: one is the accurate measurement of the vector magnetic field (Wang 1994, 1999); the other is the character of the solar magnetic element (Wang *et al.* 1995). In the space solar telescope, these two aspects will be the most important contents that can probably help achieve a breakthrough in our understanding.

The space solar telescope has been proposed since 1992 (Ai 1993; Ai *et al.* 1993; Ai 1996; Ai 1998). The phase A (assessment study) was completed in 1995-1998 and the design (phase B) was basically completed in the past two years. Now the telescope is under development.

2. Scientific objectives

The main scientific objectives are to achieve a breakthrough in solar physics through coordinated, high resolution observations of transient and steady state solar hydrodynamic and magnetohydrodynamic processes, over 2-D polarized spectrum, UV, hard X-ray, soft X-ray, H_α image, and continuous time evolution. The practical contents of the scientific objectives are as follows: (1) Explore the 3-dimensional structure of the vector magnetic fields and the velocity fields with about 0.1"–0.15" spatial resolution by means of 2-D spectrometry. (2) Explore the fine structures of solar atmospheres, especially the heating of the chromosphere and the corona. (3) Study the energy build up, storage, triggering and release of solar flares. (4) Study the fine evolution of the solar active region, especially that of sunspots and prominences. (5) Study the various solar transient phenomena associated with solar terrestrial space environment. (6) Provide various parameters serving the purpose of forecasts of solar activity and associated calamities.

3. Basic parameters of the satellite

• Total weight	~ 2.0 ton
• Power	1200 W, 16 m^2 solar cell panel
• Orbit altitude	709 km, sun synchronous polar circular 6 am/6 pm nodal crossing
• Attitude	3 axis stabilized, pointing to solar disc
Pointing accuracy	±5″ (solar disc) ±40″ (ecliptic pole)
Control stability	±3″/s (solar disc) no constraint (ecliptic pole)
• Data recorder	6GB/day, (after data compression 5–10)
• Datastorage	4 GB
• Telemetry	down link rate: 30 Mb/s, X-waveband, 8200 MHz up link rate: 4KB/s, S-waveband, 1700 MHz
• Rocket	LM-4B
• Size	5 × 2 × $2m^3$
• Mission life	3 years
• Launch Date	2004

4. Payloads

4.1 *The main optical telescope (MOT)*

- 1 m diameter.
  Diffraction limit: ~ 0.1", FOV: 2.8' × 1.5'.
- 2-D real time polarization spectrograph for 2-D simulating Stokes parameter profile tunable wavelength range: 3900-7000 Å.
  Spectral resolution: Δλ ~ 0.075 Å (λ5300Å).
  8-channels: distributed in a spectral line or several spectral lines.
  Spectral distance between two close channels can be selected.
  Spectral distance: 1Δλ; 3Δλ; 5Δλ.
  Corresponding wavelength bandwidth: 0.80 Å; 2.40Å ; 4.Ö0Å.
  CCD: 8, 2048 pixels × 2048 pixels, 0.075"/pix.
- Accuracy of polarization analyzer: 2 × 10^{-4}.
- Wide band filter-graph: (3800-5500 Å; Δλ ~30Å).
  CCD: 1024 pixels x 1024 pixels, 0.05"/pix, exposure time: 10^{-4}s.
- Accuracy of correlation tracker: ~ ±0.01"; 80 Hz.

Table 1. Parameters of the EUV images.

Telescope number	Wave length	Ion	$Log_{10}T$ (K)	Pixel size	Field of view	Focal length
1	12.9 nm	Fe XXI	7.0	0.25″	8.5′ × 8.5′	400
2	18.0 nm	Fe XI	6.1	0.25″	8.5′ × 8.5′	400
3	28.4 nm	Fe XV	6.3	2.5″	85′ × 85′	100
4	30.4 nm	He II	4.7	0.25″	8.5′ × 8.5′	400

4.2 *EUV imager for the solar telescope (EUT)*

The instruments consist of a bundle of four normal incidence astronomical telescopes with multi-layer coating: these coatings are reflecting selectively in narrow wavelength band passes, each a few per cent wide, covering EUV-lines of various Fe ions and the prominent He II 304Å line (see Table 1). Several bandpass filters centered on different lines, which are radiated at different known plasma temperatures, are necessary to cover the whole range of temperatures of the corona from its 'cool' base, the hottest spots in active regions to even hotter flares.

Table 2. Instruments parameters.

Name	MOT	WIS	HAT	EUV	SIRA
Weight	800 kg	30 kg	50 kg	131 kg	8 kg
Size	450 × Φ120+ 250 × 80 × 30	30 × 40 × 15	200 × Φ20	300 × Φ50	100
Power	600 W	20 W	40 W	30 W	49 W
Data rate	5 Mb/s 23 GB/day	1 Kb/s 25 MB/day	1 Mb/s 2 GB/day	6 Mb/s 6 GB/day	1.3 GB/day

4.3 *Wide band spectrometer (WIS)*

The overall detector characteristics are as follows:

- Soft-X-ray spectrometer (SXS)

Detector	gas proportional counter Xe + CO_2
Energy range	2-30 keV
Number of energy channels	64
Geometric area	5 cm^2
Time resolution	1 s
Energy resolution	20% at 5.9 keV (^{55}Fe)
Power consumption	5 W
Weight	4 kg
Amount of data	10 MB/day
FOV	8° × 8°

• Hard X-ray spectrometer (HXS)

Detector	Nal, ϕ7 .6 cm × 2.0 cm
Energy range	15–450 keV
Number of energy channels	32
Time resolution	1 s
Energy resolution	15% at 60 keV (^{241}Am)
Power consumption	5 W
Weight	6 kg
Amount of data	5 MB/day

• Gamma-ray spectrometer (GRS)

Detector	Nal, ϕ7.6 cm × 7.6 cm
Energy range	0.3–14MeV
Number of energy channels	256
Time resolution	4 s
Energy resolution	7% at 662 keV (^{137}Cs)
Power consumption	5 W
Weight	7 kg
Amount of data	10 MB/day

4.4 *H_a and white, light telescope* (*HAT*)

• Diameter: 12 cm
• Full disk by wedge prisms (FOV~ 1°)
• 0.5 Å (λ 6563 Å)
• White light: ~5500 Å
• 2 CCD: 2048 pixels × 2048 pixels, l"/pix

4.5 *Solar and interplanetary radio-spectrometry* (*SIRA*)

The SIRA-instrument shall determine the flux density and the degree of circular polarization of the solar radio emission in two orthogonal components. The chirp transform spectrometer will be designed with the following characteristics:

Frequency range	1 MHz to 60 MHz
Integration time	100 ms
Frequency resolution	$\Delta/f/f < 0.1$ but $\Delta f_{max} = 1$ MHz
Frequency range 1 MHz to 10 MHz	$\Delta f =$ 100 KHz
Frequency range 10 MHz to 60 MHz	$\Delta f =$ 1 MHz
Number of channels	2 × 160

Some parameters of the above mentioned instruments can be seen in Table 2.

5. Optical design of SST main telescope

The optical design of SST main telescope has been principally completed. As shown in Fig. 1, the present system consists of a F/3.5 paraboloid primary 1 m in diameter, a collimator of 5 lens and a F/39 imaging objective of 2 lenses.

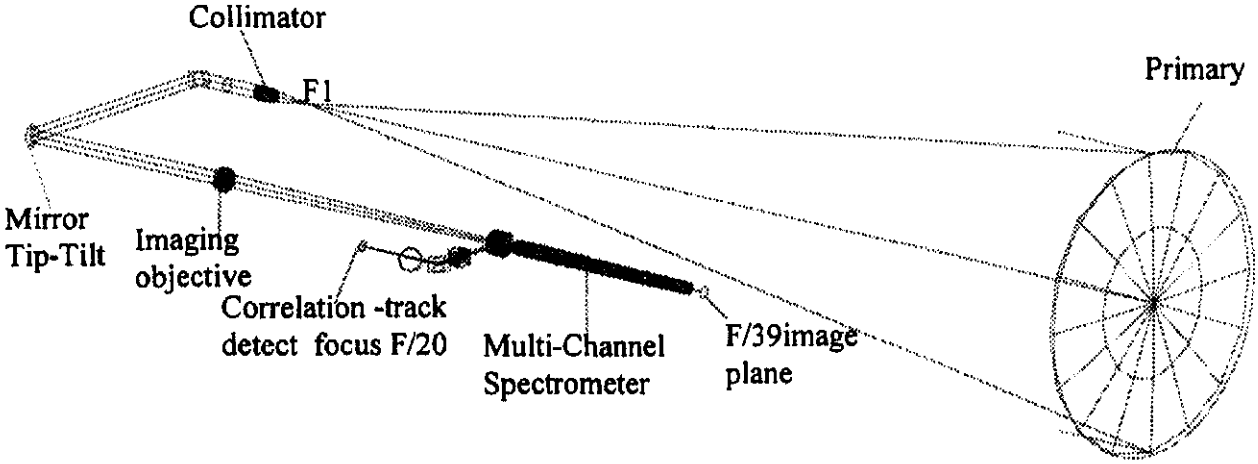

Figure 1. Optical system of SST main telescope.

• Parameters and specifications:

Telescope clear aperture	ϕ985 mm with stop at the primary
Center obstruction	17% in diameter
System focal length	38500 mm at 633 nm
Field of view	2.8′ × 1.5′
Detector CCD size	2048 × 1024 with 0.014 mm × 0.014 mm/pix
Operating wavelength	Any wavelength within 393–656 nm spectral ranges with a band width of 2nm

• Optical performance: The calculated PSF results for the main telescope are shown in Table 3 and Fig. 2. The results demonstrate that the designed system image quality is very close to the diffraction limit (S.R. > 0.85), on any working wavelength and over a field of view of 1.6′ in diameter. With such optical image quality, it will be possible to realize its required spatial resolution of 0.15″ at wavelength 600 nm.

• Alignment tolerances studies: The alignment tolerances given in Table 4 correspond to the displacement and tilt that introduce in the system a spatial resolution degradation of 0.08″.

Table 3. Strehl ratio values obtained by calculation at F/39 focal plane for SST main telescope.

Wavelength	393.3 nm	422.6 nm	517.8 nm	524.9 nm	532.4 nm	587.6 nm	656.3 nm
S.R.(0.0)	0.948	0.998	0.989	0.988	0.988	0.986	0.989
S.R.(0.707)	0.913	0.985	0.952	0.950	0.948	0.952	0.965
S.R.(1.0)	0.850	0.950	0.931	0.935	0.938	0.952	0.966

Assembly, integration and optical test configuration has been defined and will be carried out in Beijing Astronomical Observatory. It consists of a vibration isolation stand onto which the main telescope and all necessary test equipment may be installed. Auto-collimation method is chosen for testing telescope output wavefront errors introduced by either misalignment between the primary and lens collimator, or

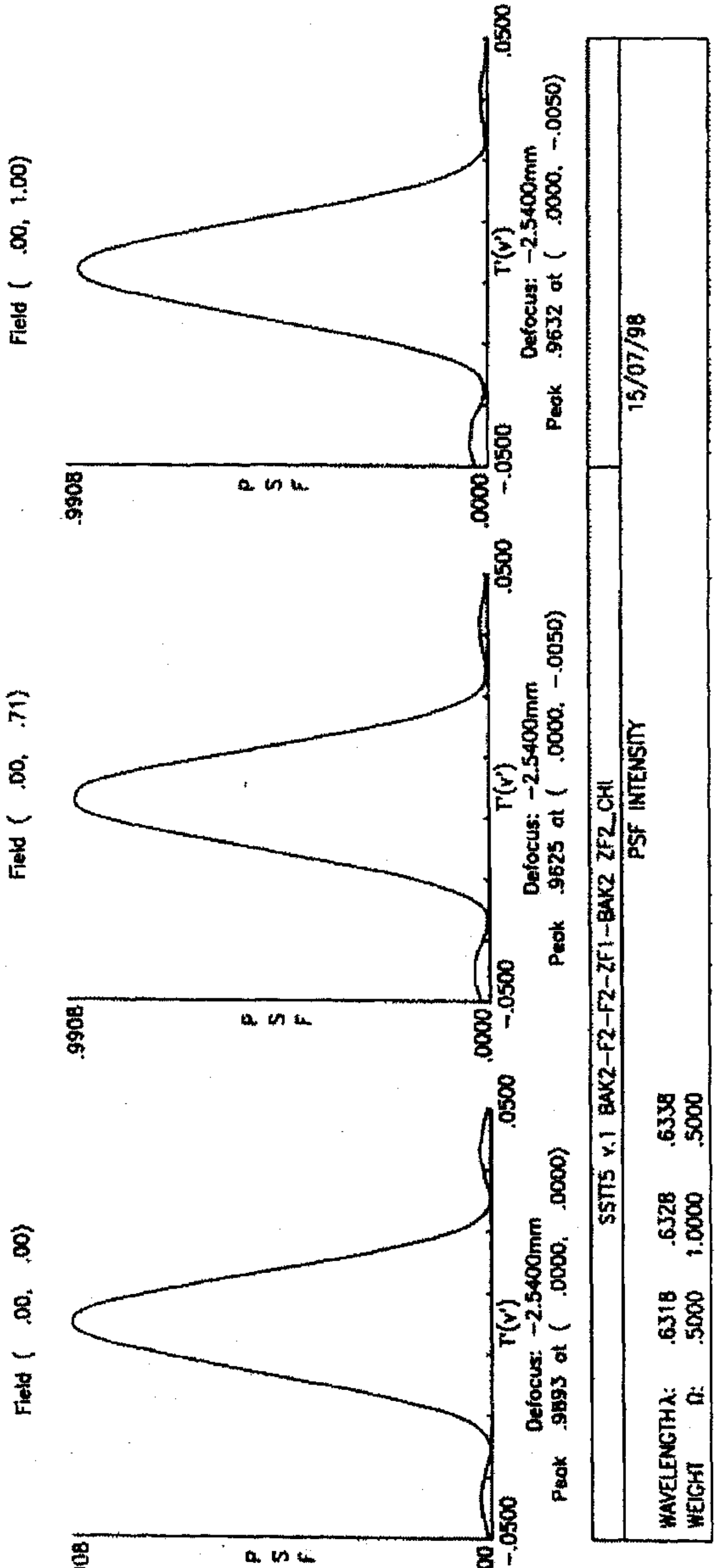

Figure 2. Calculated PSF at 633nm and with a field of view 3.24′ in diameter for SST main telescope.

Table 4. Alignment tolerance for SST main telescope.

	Tilt	Decentre	Defocus
Primary	4″	0.04 mm	
Collimator	1′	0.04 mm	0.04 mm
Imaging objective	2′	0.2 mm	0.1 mm

the primary surface distortion. In order to characterize wavefront of the telescope operating in full lm aperture, a plane mirror with the same diameter as the primary of surface quality λ /60(rms) will be used as reflector in the auto-collimation test optics. The gravity load effect and solar thermo effect simulation for primary after their integration on ground, has been also studied.

1 m paraboloid primary and 1 m flat reflect has been manufactured. Zerodur is chosen as mirror glass and both mirrors need to be polished to a surface accuracy of λ/60(rms).

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