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Section A

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The Advanced Technology Solar Spectroscopic Imager —a novel experiment employing a transition-edge sensor to probe the soft X-ray solar corona

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Abstract

The Advanced Technology Solar Spectroscopic Imager (ATSSI) is a sounding rocket-borne experiment that will employ a Transition-Edge Sensor (TES) placed at the focus of a Wolter-I mirror to study large active region loops in the solar corona. The TES instrument will operate in the ~500–1500 eV EUV/soft X-ray bandpass, obtaining ~3 eV energy-resolved spectra at ~6.25 arcsec image resolution with a count rate of ~1000 photons/sec/pixel. Over a typical observation period of ~360 sec, we will raster scan over a 0.6 × 0.6 arcmin field of view to obtain a 6 × 6 pixel image containing true EUV/soft X-ray spectroheliograms of a solar active region. Using these observations, we can directly determine composition, electron density and thermal differential emission measure of large active region loops in order to constrain models of heating mechanisms and accurately measure the thermal morphology of these structures. In the current analysis, we present an initial instrument concept and discuss some of the mission science goals.

Keywords: Advanced Technology Solar Spectroscopic Images; Transition Edge Sensor; Solar active regions

1. Introduction

The Advanced Technology Solar Spectroscopic Imager (ATSSI) [1] is a sounding-rocket-borne observatory that will debut the use of a Transition-Edge Sensor (TES) and replicated grazing-incidence optic to measure the solar corona in the 500–1500 eV EUV/soft X-ray spectral range with ~3 eV resolution.

Obtaining high-energy spectral observations in conjunction with high spatial resolution imaging is imperative to understanding the temporal, spatial and thermal morphology of the solar atmosphere. Armed with highly resolved spectra at every imaged point, we will be able to further constrain models of coronal structures (e.g. small and large loops, funnels, bright points, spicules, etc.). Such highly detailed information regarding dynamics,

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magnetic morphology and elemental abundance will give us further clues toward understanding the complex nature of the sun. In the present analysis we briefly discuss the ATSSI instrument and present a representative active region solar spectrum we could expect to observe using a TES.

2. ATSSI system concept

The ATSSI will be built on the truss structure of the Multi-Spectral Solar Telescope Array (MSSTA) rocket payload, which has successfully flown three times [2]. ATSSI will fly a single TES pixel at the focus of a Wolter-I mirror. The TES instrument will be pointed at an active region on the sun, and, using the rocket's Attitude Control System, we will raster scan a 6×6 pixel image array. The dwell time of ~ 10 sec at each 6.25 arcsec pixel should be short enough to avoid distortion in the image caused by motion of small-scale coronal sources. (This deviates from the original concept of flying an 8×8 array, which has proven more complex and costly [1].)

The primary technical challenge of the mission will be to maintain the TES detector at its operating temperature of ~ 80 mK throughout the mission (particularly during launch). The cryostat will be an adiabatic demagnetization refrigerator (ADR), based on the one that was launched three times by McCammon et al. beginning in 1996 [3]. This system will be modified by introducing a combination of active and passive magnetic shielding in order to isolate the TES and SQUID amplifiers from the cryostat's strong magnetic field.

The detector itself will be a superconducting bilayer TES developed at NIST [4]. The detectors are fabricated as Mo/Cu bilayers on a Si_3N_4 membrane with a base Si substrate. Because of the steepness of the superconducting transition, the measurement of the photon energy is very accurate ($\Delta E \sim 3$ eV at 1.5 keV for ATSSI), resulting in a highly efficient, high-resolution detector. Although better energy resolution has been achieved (~ 2.0 eV [4]), we expect to suffer some degradation in resolution from pileup caused by the high solar flux.

In the present design, the Wolter telescope that feeds the detector will have an aperture of 125 mm and a focal length of 1820 mm. The geometrical collecting area is approximately 7 cm^2. The mandrels for the paraboloidal and hyperboloidal mirror sections will be precision diamond turned and flow-polished to the desired shape, and inspected for roughness and figure errors using optical interferometry and atomic force microscopy. The mirrors will then be constructed using a replication technique against the mandrels. Precisely controlled build-up of a rubidium shell results in a finished internal paraboloid and hyperboloid, each 100 mm long, with a grazing angle of 1° on each segment. Because the ATSSI uses a single-pixel detector, off-axis aberrations are not a significant concern.

It is important to keep out-of-band photons from reaching the detector, and to make sure that the count rate of in-band photons does not saturate the detector. The size and efficiency of the Wolter mirror are such that the unfiltered X-ray flux is several orders of magnitude higher than the detector is capable of counting. However, we have flexibility in filtering the flux and can use an assortment of different filter materials so that their absorption edges define a narrow energy window. The proposed filter stack uses a series of 5 filters, each consisting of a 4000 Å polyimide film with a 1500 Å aluminum coating on one side. The first filter will be placed at the telescope's entrance aperture to reject most of the visible and infrared light before it reaches the Wolter mirror shell, ensuring that the optic will not heat up and deform and that the filter will not be damaged by the concentrated solar flux. The rest of the filter stack will be placed between the optic and the detector. Those closest to the detector will need to be cooled in stages (e.g. 130, 30 and 2 K) in order to reduce infrared emission from the filters themselves. (In a separate analysis, we intend to more precisely determine the cooled filter stack and the impinging thermal load and infrared photon count rate.) The filters will be fabricated by Luxel Corp., who has built filters for the MSSTA missions, as well as TRACE and other extreme ultraviolet/soft X-ray observatories.

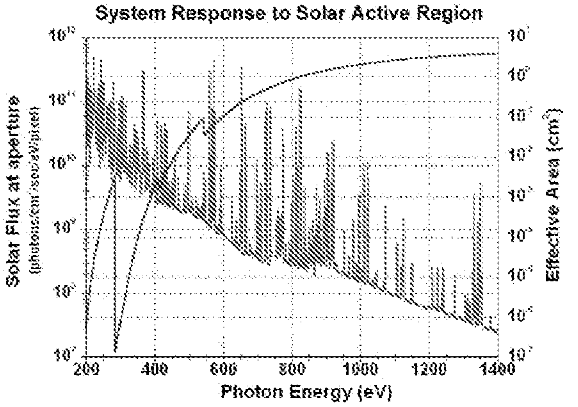

Fig. 1. Effective area (collecting area times efficiency) of the ATSSI telescope and filters, superimposed on a simulated spectrum from a solar active region at the aperture of the ATSSI.

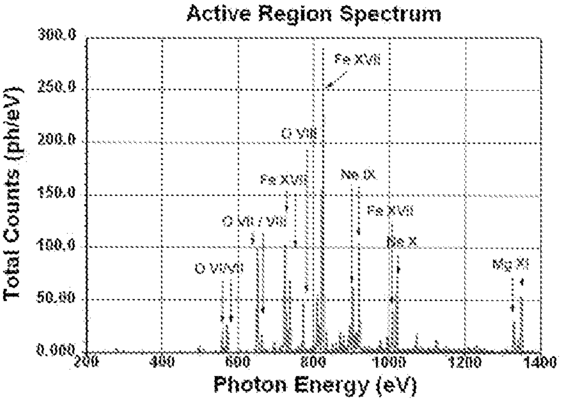

Fig. 2. Simulated result of a 10 sec, single pixel (~6.25 arcsec), observation of an active region by ATSSI.

Fig. 1 shows the effective area of the ATSSI instrument. Its response is dominated by the transmission of the filter stack, which strongly attenuates flux from EUV lines and continuum below 400 eV, as well as rejecting visible and infrared light. The mirror material and grazing angle were chosen so that throughput from the optic is essentially constant over the energy range of interest (500–1500 eV). The mirror reflectivity begins to drop very sharply at about 2500 eV, and defines the upper end of the ATSSI's energy window (solar active regions, however, do not emit strong lines beyond 1500 eV).

3. An active region in the X-ray

Superimposed on the throughput in Fig. 1 is the expected emission over the energy range of the ATSSI bandpass from a solar active region. It was calculated using the CHIANTI database [5]. The spectrum contains a continuum component that is strongest at low energies; at higher energies, it is characterized by strong, well-isolated emission lines from highly ionized iron, oxygen and other elements.

Fig. 2 contains the results of a simulation of what the ATSSI data might look like given the solar spectrum and instrument response of Fig. 1. Because the TES counts individual photons, the number of photons from a particular emission line which reach the detector was chosen based on Poisson statistics. The effect of the instrument's 3 eV resolution was simulated by assigning each photon to an energy bin chosen from a Gaussian distribution with FWHM of 3 eV. The continuum was also included in the simulation; however, few continuum photons contribute to the final spectrum.

A total of 16 emission lines are detected at a signal-to-noise ratio of at least 10 : 1. The energy resolution of the detector is not sufficient to detect Doppler shifts from any but the fastest plasma flows (~few hundred km/s). However, simply measuring fluxes in these lines provides a wealth of diagnostic information about the condition of the coronal plasma. The contribution functions for the lines in the ATSSI bandpass span the temperature range $T = 10^6$–10^7, thereby constraining the thermal differential emission measure over that range. This knowledge of the temperature and density distribution of material can be used to generate models of the structures responsible for this emission and to test theoretical coronal heating functions. Temperature-sensitive line ratios of O VII and Fe XVII can be measured as a further diagnostic tool. Hence, this observational technique will yield a wealth of important clues about the corona.

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References

[1] Wamba, et al., Proc. SPIE 4140 (2000) 384.
[2] Martinez-Galarce, et al., Opt. Eng. 39 (4) (2000) 1063.
[3] McCammon, et al., Astrophys. J. 576 (1) (2002) 188.
[4] Wollman, et al., Nucl. Instr. and Meth. 444 (1–2) (2000) 145.
[5] Young, et al., Astrophys. J. Suppl. Ser. 144 (2003) 135.