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Time-Domain Studies with Astrosat

Invited talk

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Abstract. Astrosat is a multi-instrument orbiting observatory that was launched in 2015 by the Indian Space Research Organization (ISRO). The same field of view is observed simultaneously at wavelengths ranging from gamma ray to the optical blue. This talk described the observatory's performance, with emphasis on time-domain studies, and gave examples of results.

Keywords. Space vehicles, instrumentation: miscellaneous, ultraviolet: general, X-rays: general, methods: data analysis

1. Introduction

Astrosat is an astronomy satellite of the Indian Space Research Organization (ISRO). It was launched in 2015 September into a low-Earth orbit with an inclination of 6°, and with a designed minimum lifetime of 5 years. It is operating fully, and has a well-subscribed programme of investigations.

The observatory is ambitious and complex; it is comprised of four co-aligned instruments operating simultaneously, plus a scanning sky monitor that covers a hemisphere at a time. Built as a multi-wavelength facility, its instruments cover wavelengths from gamma rays to UV-blue. All the instruments operate simultaneously, subject to individual safety constraints, enabling multi-wavelength data to be obtained over a wide range of wavelengths. Astrosat is therefore a powerful and unique facility for time-domain studies.

Astrosat is a proposal-driven observatory. While most of the time is allocated to Indian-led proposals, time is set aside for Canada and for Leicester University, which are minor partners, and 20% is also reserved for internationally-led proposals. Proposal cycles last for a year, beginning each October; annual proposal calls are issued each January.

Both proposal entry and configuration of all the instruments is achieved through a web-based system. By default, all programmes receive data from all instruments. The data archive at the Indian Space Science Data Centre (ISSDC) is open once the one-year data proprietary period has expired. ISRO websites have full details of the instruments and operations. The website with much detailed information, including an instrument handbook, is https://www.issdc.gov.in/astro.html.

Fig. 1 shows a summary of the instrument specifications and performance; Fig. 2 shows the time-allocation plan. The following sections describe briefly the capabilities of the instruments for time-domain studies, and note some examples. Full details of the results can be found in papers in the astronomical literature. A list of Astrosat publications is maintained at www.isro.gov.in/sites/default/files/article-files/astrosat-0/astrosat-publications-030117.pdf.

	UVIT / OPT	SXT	LAXPC	CZTI	SSM
Optics	Twin Ritchey Chretian 2 mirror system.	Conical foil (~Wolter-I) mirrors	Collimator	2 - D coded mask	1- D coded mask
Bandwidth	1300-3200 Ang	0.3 - 8 keV	3 - 100 keV	10 - 100 keV	2 - 10 keV
Geometric Area (cm²)	1250	250	10800	1000	180
Effective Area (cm²)	60 (depends on filter)	125@0.5 keV 200@1-2 keV 25@6 keV	6000@5-30 keV	1000 (E>10keV)	~40 @ 2 keV 90 @ 5 keV (Xe gas)
Field of View	0.50° dia	0.35° (FWHM)	1° x 1°	17° x 17°	6° x 90°
Energy Resolution	5 – 90 nm - Spec R~100	2%@6keV	9%@22 keV	5% at 10 keV	19% @ 6 keV
Angular Resolution	0.9 – 1.3″	3 - 4 arcmin (HPD)	~(1-5) arcmin (in scan mode only)	8 arcmin	~10 arcmin
Time resolution	1.7 – 36 ms	2.6s, 0.3s,1ms	10 microsec	1 ms	1 ms

Figure 1. Summary of Astrosat instruments.

Instruments	PV Phase (6 months)[3]	Guaranteed Time (next 6 months)[4]	First Year Regular observations	Second year Regular observations	Third year Regular observations
X-ray Inst. Teams	67%	4 months	32.5%	20%	-
UVIT Teams	33%	2 months	17.5%	10%	-
Indian proposals	-	-	35%	45%	65%
International proposals	-	-	-	10%	20%
CSA Team[1]	-	-	5%	5%	5%
LU Team[2]	-	-	3%	3%	3%
TOO	-	-	5%	5%	5%
Calibration time	-	-	2%	2%	2%

Figure 2. Time allocation for Astrosat. Years beyond 3 are as year 3.

2. Overview of Instruments

2.1. *LAXPC*

The Large Area X-ray Proportional Counter (LAXPC) consists of three identical units that constitute a high-sensitivity, broad-energy band detector (3–80 Kev) with a high time-resolution of 10 microseconds. Fig. 3 shows its high effective area above 20Kev, compared to the Rossi X-ray Timing Explorer satellite (RXTE). LAXPC has become the workhorse instrument for timing studies of quasi-period oscillations (QPOs), spectral variability, and bursts in targets ranging from X-ray binaries to AGNs.

2.2. *CZTI*

The Cadmium Zinc Telluride Imager (CZTI) is a four-component coded mask instrument for high-energy imaging up to 100Kev, and monitoring for higher energies. It enables Compton spectroscopy and polarimetry, has on-board calibration, and has good background measurement and rejection capabilities. Typical results include the hard pulse profile of the Crab, and detections of Gamma-Ray Bursts.

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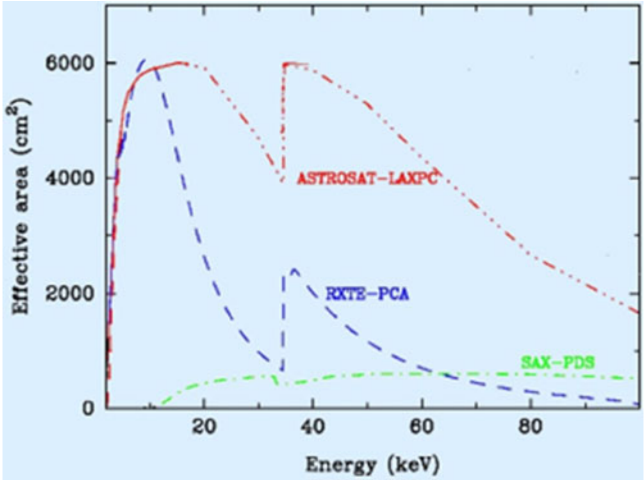

Figure 3. LAXPC collecting area compared to other facilities.

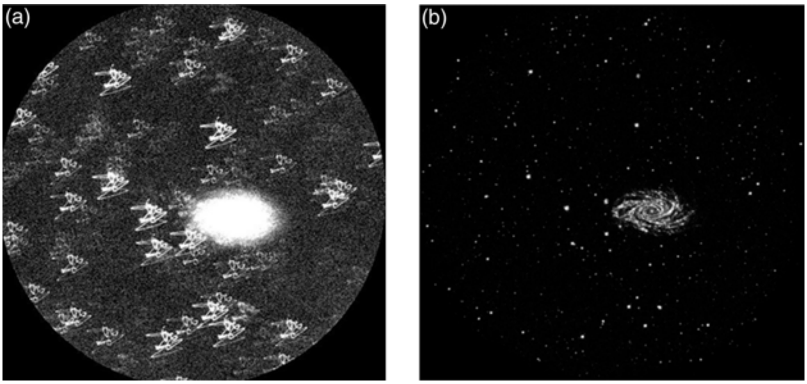

Figure 4. Left panel (a): UVIT image without drift correction. Right panel (b): UVIT image with drift correction.

2.3. *SXT*

The Soft X-ray Telescope (SXT) is a grazing-incidence foil telescope with good performance and energy resolution from 0.2–7 Kev; it uses a CCD detector. Time-resolution down to 1 millisecond is available. Some examples of results include spectra of the blazar Parkes 2155-304 and flares on Proxima Centauri. Data from SXT and CZTI have also been coordinated to produce light-curves of the high-mass X-ray binary Cyg X-3.

2.4. *UVIT*

The UVIT telescopes offer a wide field of view in three wavebands simultaneously, each with a set of filters or gratings, and with resolution at the arcsecond-level. The full-field time-resolution is 30 milliseconds, but it can be 20 times faster for sub-field observations. The UVIT instrument capability supports a wide range of science topics, as well as the ability to monitor changes at both X-ray and UV-optical wavelengths.

The high spatial resolution of UVIT is achieved by correcting for spacecraft drift when assembling the science images from individual photon-event centroids. The drift over an observing window can amount to several arcminutes, as shown in Fig. 4a.

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Examples of time-variable objects over a range of time-scales include the first UV RR Lyr light-curves in the globular cluster NGC 1851, AGN UV flux changes in both lines and continuum, and the UV pulse profile for the Crab pulsar.

2.5. *SSM*

The Scanning Sky Monitor (SSM) covers half the sky at a time, depending on the Astrosat roll angle, by scanning three one-dimensional detectors angled at 120°. Its field centre is orthogonal to the boresight of the other instruments. As well as spotting new variables, the SSM monitors the flux from known variables such as X-ray pulsars, and can be folded to provide phased light-curves.

Acknowledgements

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