WHAT IS ASTROSAT ?

ASTROSAT is an unique space based observatory orbiting 650 km above the Earth. It can simultaneously observe several types of high-energy "light", coming from various exotic and mysterious objects in the universe.

ASTROSAT carries five different telescopes on board. These can collect incoming visible light, near and far ultraviolet rays, soft X-rays as well as hard X-rays - all at the same time ! It is the first dedicated Indian astronomy satellite, built by scientists and engineers from many institutes. It was launched by the ISRO PSLV-C30 rocket on 28 September, 2015.

WHAT WILL ASTROSAT SEE ?

NEARBY GALAXIES
The formation sites of the youngest and most massive stars in the universe

NEUTRON STARS
Behaviour of matter at extreme densities and magnetic fields

X-RAY BINARIES
The physics of a neutron star or a black hole sucking in gas from its neigbours

TRANSIENT SOURCES
The nature of enourmous stellar explosions that can outshine all other known sources

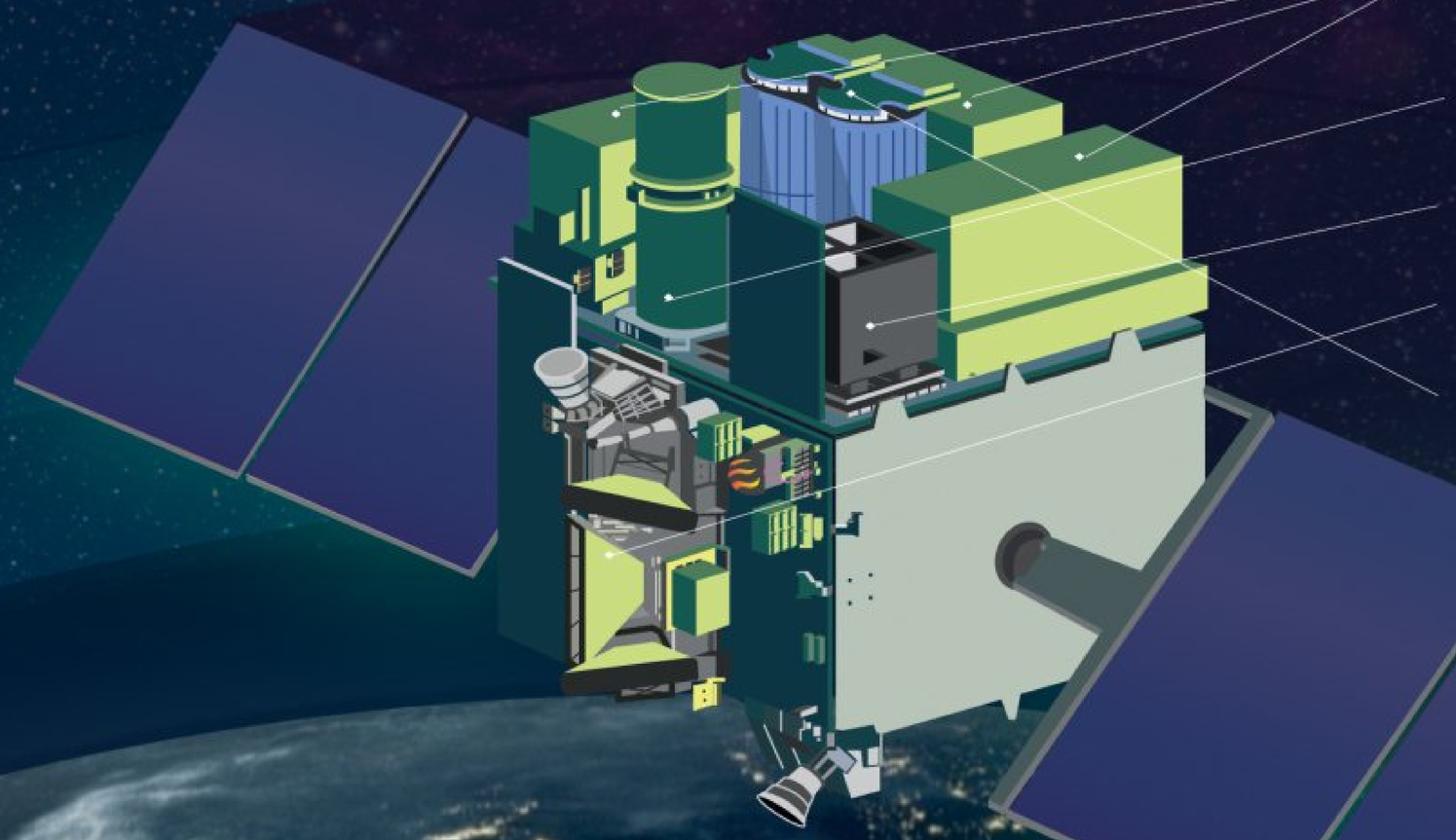
ASTROSAT will focus on some of the most energetic phenomena in the universe, by observing the ultraviolet and X-ray emission from celestial objects.

Our atmosphere absorbs high energy light. So, astronomers send out specialised telescopes like ASTROSAT into space to study these rays.

India's first Multiwavelength Space-based Observatory

ASTROSAT

The 5 telescopes of the ASTROSAT Observatory



1. Large Area X-ray Proportional Counter (LAXPC)
2. Soft X-ray Telecope (SXT)
3. Cadmium-Zinc-Telluride Imager (CZTI)
4. Scanning Sky Monitor (SSM)
5. Ultra Violet Imaging Telescope (UVIT)

Participating institutes

The Public Outreach & Education Committee of the Astronomical Society of India

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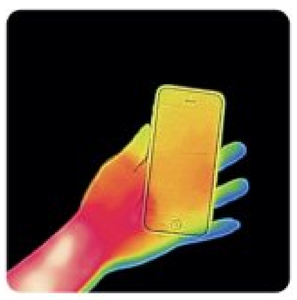
ASTROSAT: POSTER 1

DID YOU KNOW?

Some snakes and beetles can 'sense' infrared, whereas some birds, bees, shrimps, butterflies and reindeer can 'see' ultraviolet ! These and many other kinds of Light however are invisible to Human eyes.

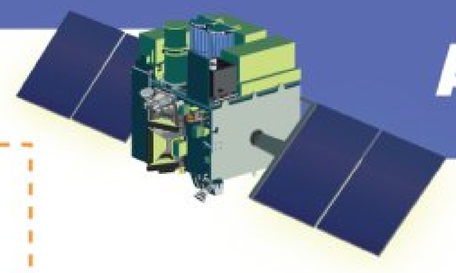


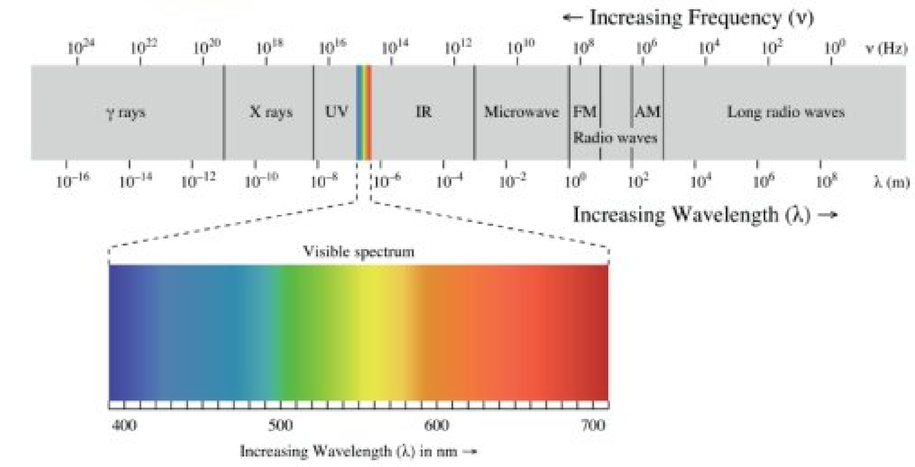
If our eyes could see more :
Clockwise from top left : Photographs in Infrared, visible, ultraviolet and X-ray light photographs of a person's hand holding a cellphone.

Credits : © Ideum - Maddy Minnis

Compare these pictures of the Andromeda Galaxy :

Left : As seen through a telescope
Middle : As shown by a telescope with lesser collecting area
Right : As would be seen at a lower resolution





Light is classified into wavebands such as gamma rays, X-rays, ultraviolet, visible, infrared, microwave and radio, in decreasing order of wavelength and energy. The range of wavelengths currently observed by our telescopes spans from 10 meter to 1/1000 nanometer !

To observe the universe in any waveband of light, astronomers use telescopes. Telescopes collect large amount of light, and focus it at a given point to obtain a bright magnified image of a part of the sky. Most telescopes have a surface (usually parabolic) which collects light and a detector at the focus which measures it. Astronomers want to build bigger and bigger telescopes for two reasons.

SEEING FAINTER

Larger telescopes collect more light. This enables them to image fainter objects, and thus detect dim objects near us and bright objects very far away. This is similar to how we can see dim objects in a cinema hall after a few minutes, when our eye pupil expands.

SEEING CLEARER

If the collecting surface is larger, the image will have finer details. This capability, called resolution, enables telescopes to distinguish between two objects very close together. Images from smaller telescopes will appear more blurred.

Original

Dimmer

Blurred

THE VISIBLE & INVISIBLE

IN HOW MANY WAYS CAN WE SEE?

Our natural curiosity to understand what is above us - the sun, the moon and the stars, led to the development of astronomy as a science. The distances, sizes and masses in astronomy are unimaginably huge. However, to understand the universe, we only have access to the light emitted by the objects in it.

Light is a transverse electromagnetic wave travelling at 300000 km per second, which is the maximum possible speed in our universe. Being a wave, light can be described by its wavelength (and equivalently, its frequency). Wavebands from radio to visible to x-rays and gamma rays are all just light waves, differing solely in their wavelength. Humans can only see in the narrow 'visible' range, and perceive different wavelengths within this waveband as colours.

Participating institutes

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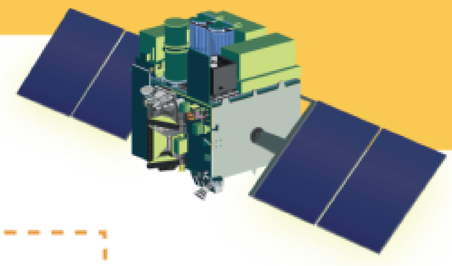
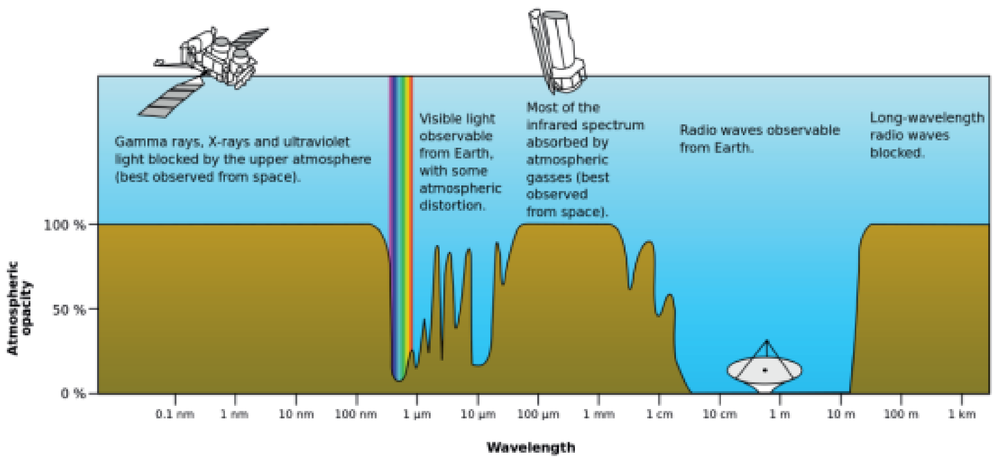
ASTROSAT: POSTER 2



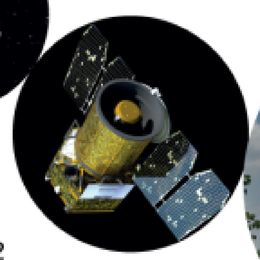
Our atmosphere is a protective blanket for life on earth. However, it does so by absorbing all the incoming X-rays and ultraviolet and most of the infrared and microwave radiation from space. Hence, to observe these wavebands, we need to put our telescopes outside the Earth's atmosphere.



Our atmosphere is opaque to various light wavelengths :
Except for the visible, near infrared and radio telescopes, all other telescopes need to be outside the Earth's atmosphere.

Astronomers need to build telescopes to observe in all these wavebands. However, the energies and the nature of interaction of light with matter are very different for each waveband. Hence, the telescopes and technology behind the detectors are also very different for each waveband.

1



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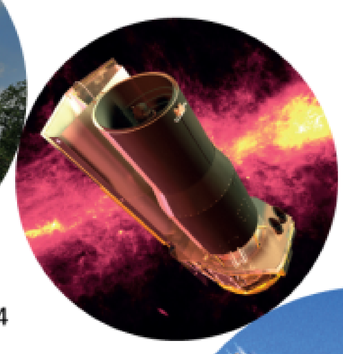


4

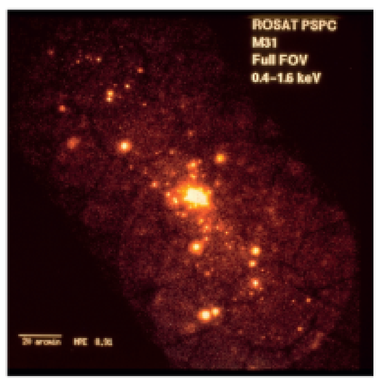
5

Some examples of astronomical telescopes

1. Chandra, an X-ray telescope in space
2. GALEX, an ultraviolet telescope in space
3. Vainu Bappu Telescope, Tamilnadu, a visible range telescope
4. Spitzer, an infrared telescope in space
5. Giant Metrewave Radio Telescope, Maharashtra

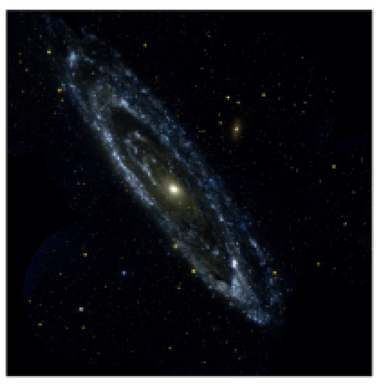
A galaxy, like our own Milky Way, consists of stars, gas, dust and planets, along with magnetic fields and cosmic rays. Each panel below is a picture of our nearest neighbour, the Andromeda Galaxy, in different wavebands of light. Listed under each image are the objects that emit in those wavelengths.

X-Ray



Hot gas, white dwarfs, neutron stars, stellar black holes, central active galactic nucleus

Ultraviolet

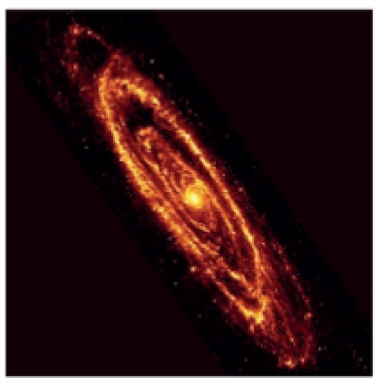


White dwarfs, very hot young stars, central active galactic nucleus

Visible

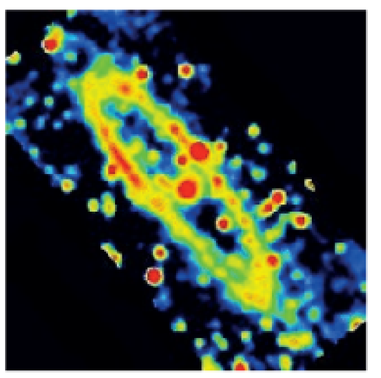
Stars, gas around young hot stars, planetary nebulae, novae

Infrared



Dust, cold stars, planets, star forming regions

Radio



Cold gas, pulsars, molecules, supernova remnants

Images Courtesy: NASA/JPL-Caltech

UNIVERSE REVEALED

A MULTI-WAVELENGTH VIEW

Celestial objects emit light in almost all wavebands, and the physical processes responsible for each waveband are different from each other. Hence, to understand an object in its entirety, astronomers need to observe it in all these wavebands. For example, the visible light from the Sun is from its surface, and tells us about the 6000 K temperature photosphere and its sunspots. X-ray emission is from the million degree hot atmosphere of the Sun, whereas the radio emission is from a region outside the photosphere and is sensitive to solar flares. We need all of this information to understand the Sun.

The background image is of the supernova remnant Cassiopeia A. The infrared emission is coloured red, visible emission is orange and the X-ray emission is blue and green.

Participating institutes

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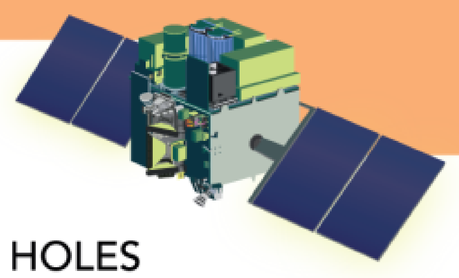
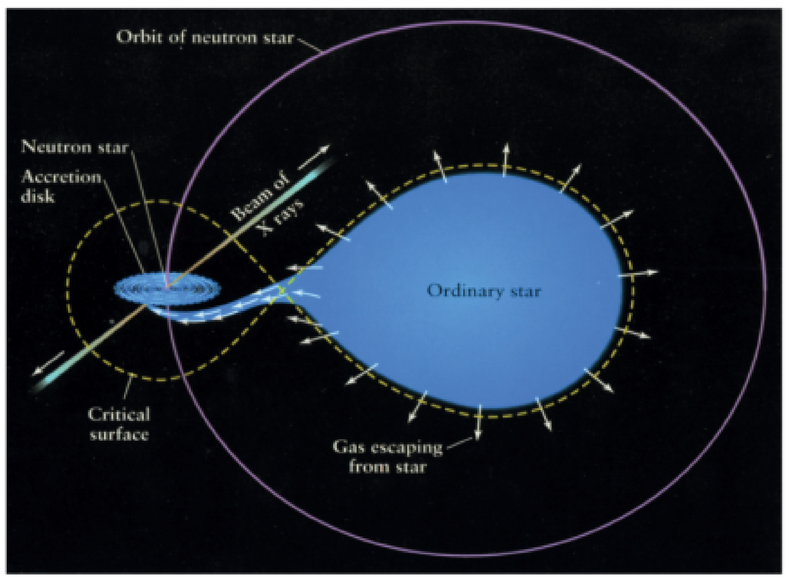


NEUTRON STARS

Neutron stars weigh about as much as our Sun, but are around 12 km in size, so that a teaspoon of its matter would weigh 2 trillion tons ! Though mainly made of neutrons, a small fraction is composed of matter which is yet unknown to us. Neutron stars are the only laboratory in the universe where we can study matter at such high densities.

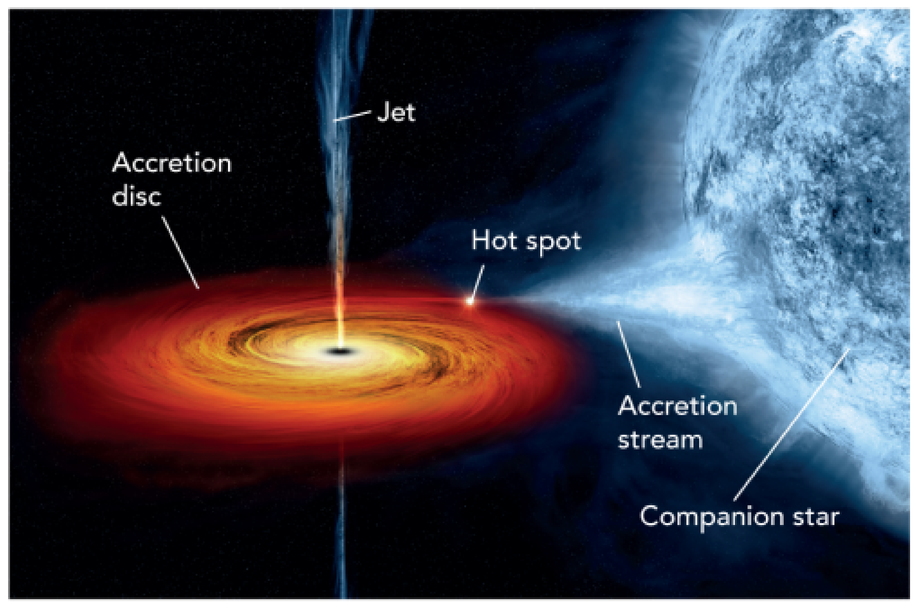


A neutron star accreting matter from its normal com panion star (aritist's impression)

A neutron star in a binary system pulls in matter from its companion star due to gravity, which then ignites. ASTROSAT will measure this brightening across all wavebands and resolve the question of the nature of ultradense matter itself.

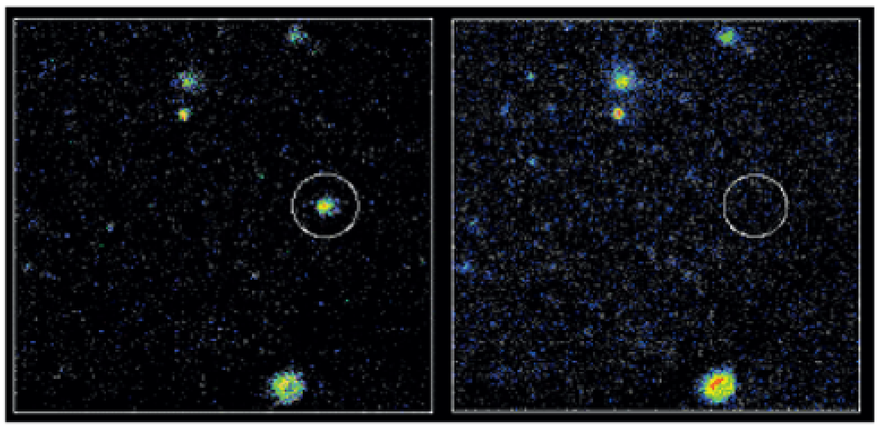
BLACK HOLES

Very massive stars (more than 15 to 20 times the Sun's mass), when they exhaust their nuclear fuel, collapse into black holes. Matter that is attracted by its gravity spirals into the black hole through a flat disk, slowly losing angular momentum. This accretion disk is very hot and emits visible, ultraviolet and X-rays, and also produces two perpendicular jets of relativistic matter. The structure of this accretion disk and the origin of these jets are still unknown.



Artist impression of a black hole in a binary, with its accretion disk and jets

As it moves inwards in the accretion disk, the gas gets hotter and emits progressively in visible, ultraviolet and X-rays. ASTROSAT will study how light from these wavebands varies on small timescales and answer questions about the structure of such disks, the associated jets, and even what happens extremely close to the black hole itself. Likewise, ASTROSAT will also be used to study much larger disks and jets around supermassive black holes (with masses millions or billions times the Sun) that are known to exist in the centres of distant galaxies.



A recurring transient X-ray source in the Andromeda galaxy, discovered by the ROSAT satellite X-ray telescope

TRANSIENT SOURCES

Unlike the radio or the visible sky, the high energy sky is extremely variable. Bright new unknown sources suddenly appear, only to fade away. Phenomenal explosions called Gamma Ray Bursts, the last few moments of massive dying stars, regularly dominate the images of the high energy light coming from various portions of the sky. In addition, there are many transient sources whose nature is still a mystery !

ASTROSAT will continuously monitor the sky to look for such transient sources, and when detected, can study them with its array of telescopes as well as alert other telescopes around the world.

THE ASTROSAT SKY

WHAT CAN WE LEARN?

The celestial objects that we can see in UV and X-rays are exotic, unfamiliar and much more energetic that those we see in the visible wavelengths. For an object to be bright in the ultraviolet, the gas that emits the light needs to be as hot as tens of thousands of Kelvin, and for X-rays to be emitted, it can have a temperature of millions of Kelvin. Such conditions are typically found in very hot stars, hot gas, white dwarfs, neutron stars, black holes and active galactic nuclei.

ASTROSAT can observe simultaneously over a large range of wavebands. This unique capability ative examples are described above.enables ASTROSAT to answer some of the fundamental questions about the universe. Representative examples are described above.

Participating Institutes

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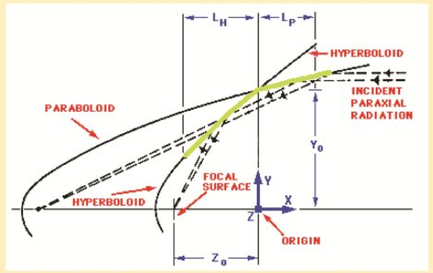
Soft X-ray Telescope (SXT) onboard AstroSat

X-RAY TELESCOPE

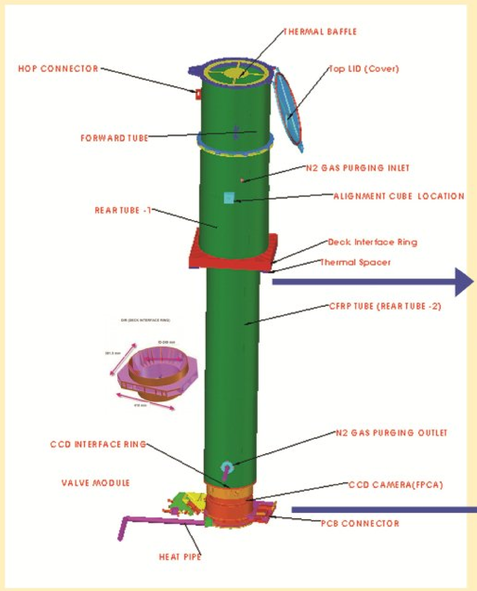
Telescopes make clear images of cosmic objects by collecting large amount of light using mirrors, and by focusing them on an imager. In case of X-rays, the reflections from the mirrors have to be in very small (grazing) angles. So the geometry of an X-ray telescope is quite different from that of a telescope which works in visible light. One such geometry is the Wolter-I geometry (shown on the right), in which X-rays are reflected twice, first by a paraboloid mirror, and then by a hyperboloid mirror, before being focused. Usually many nested mirror shells are used to increase the collecting area. The surface quality of the mirrors is required to have low roughness of a few Angstroms to avoid scattering. The SXT uses thin foil mirrors with smooth gold surface of 10 Å smoothness replicated from a smooth glass surface. Forty shells each having 4 segments are nested in Wolter-I geometry.

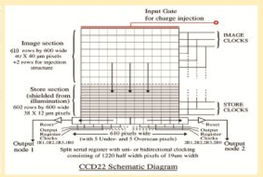


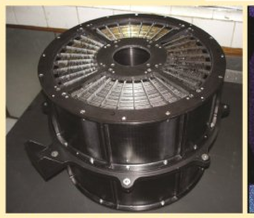
The principle of the Wolter-I optics using ray diagram.

WHY SOFT X-RAY TELESCOPE (SXT) ON AstroSat ?

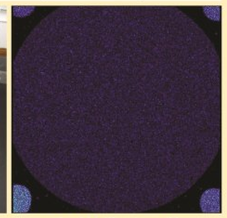
SXT will be important for several scientific goals mentioned (top right). It is the first Indian X-ray focussing telescope, which will mark a major Indian technology advancement. An assembly of all the gold covered mirrors is shown below. All major components of SXT and the entire electronics have been built and assembled at the Tata Institute of Fundamental Research (TIFR) at Mumbai, India, except the focal plane camera with a cooled charge-coupled device (CCD) provided by the University of Leicester, U.K.



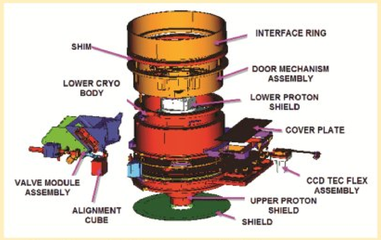




Assembled mirrors made at TIFR.

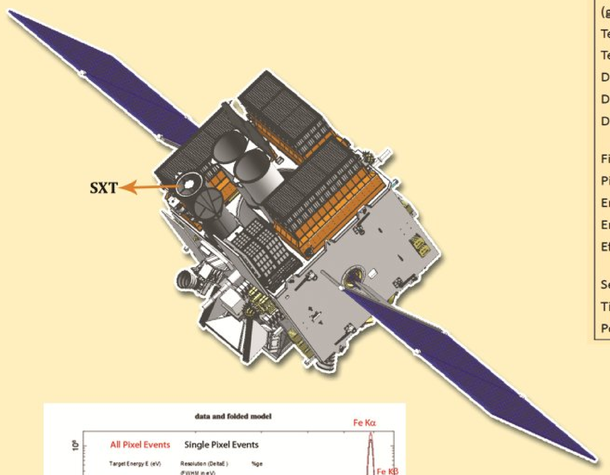


The CCD illuminated by 5 internal calibration sources.



Focal Plane CCD Camera Assembly & its components.

SCHEMATIC OF AstroSat WITH SXT ONBOARD



MAIN SCIENCE GOALS OF SXT

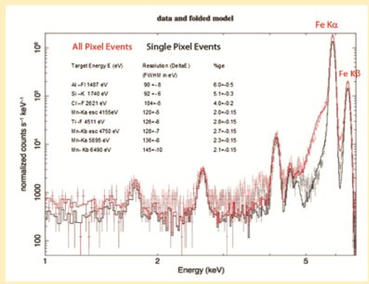
1. Studying matter in extreme conditions, and testing fundamental laws of physics, e.g., law of gravitation by observing neutron stars and black holes.
2. Carrying out spectroscopy of hot thin plasmas in galaxies, clusters of galaxies, nuclei of active galaxies, quasars, supernova remnants and stellar coronae.
3. Studying the physics of shocks and accretion disks, coronae, photo ionized regions and their density, temperature, ionization degree, and elemental abundances.
4. Studying low energy absorption and the nature of absorbers, for example, whether these are cold (neutral) or warm (ionized).
5. Studying soft X-ray excesses due to a blackbody emission in active galactic nuclei, and in binary X-ray pulsars in conjunction with other higher energy X-ray instruments.
6. Carrying out spatially resolved spectroscopy of supernova remnants and clusters of galaxies.

Characteristics of SXT

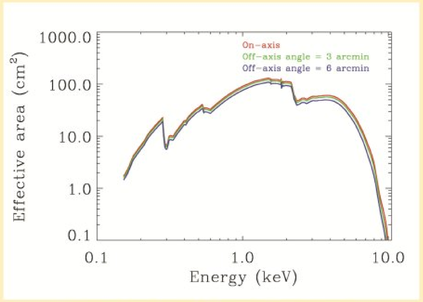
Telescope:	2.0 m focal length
(grazing incidence – conical approximations to Wolter I type)	
Telescope Mirrors:	Conical shells
Telescope PSF:	< 3 arcmins (HEW)
Detector:	e2V CCD-22 (Cooled < -80° C)
Detector Format:	600 x 600 pixels (40 microns size)
Detector Readout Modes:	Photon Counting (PC), Fast Window (FW), Photon Counting Window (PCW), CAL, BIAS.
Field of View:	41.3 x 41.3 arcmin
Pixel Scale:	4.13 arcsec/pixel
Energy range:	0.3 - 8.0 keV
Energy Resolution:	145 eV @ 5.9 keV
Effective Area:	128 cm^2 @ 1.5 keV 22 cm^2 @ 6.0 keV
Sensitivity:	10^{-13} ergs cm^{-2} s^{-1} (5σ, 20000 s)
Time Resolution:	2.4 s (PC mode), 278 ms (FW mode, 150 x 150 centered pixel)
Position Accuracy:	0.5 arcmin

SXT Mirror specifications

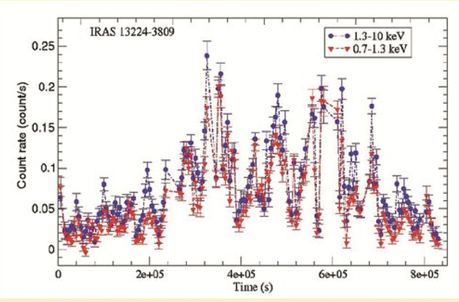
Telescope Length:	2465 mm
(Telescope + camera + baffle + door)	
Top Envelope Diameter:	386 mm
(Max at Middle flange)	
Focal Length:	2000 mm
Maximum radius of foils:	130 mm
Minimum radius of foils:	65 mm
Reflector Length:	100 mm
Reflector thickness:	0.2 mm (Al)
+ Epoxy (50-60 microns) + gold 1500 Å	
Minimum reflector spacing:	0.5 mm
Number of nested shells of foils:	40x8=320



X-ray spectrum of Fe^{55} radioactive calibration source onboard the camera.



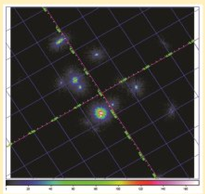
Effective area of SXT (Mirrors + CCD camera).



SXT will study the variability of accreting Supermassive Black Holes as shown above for a Seyfert Galaxy IRAS 13224-3809.

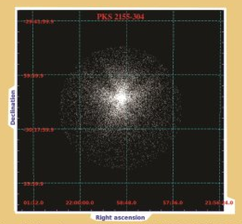
SCIENTIFIC CAPABILITIES OF SXT

1. Nearly 1000 times better sensitivity over non-focussing instruments of similar areas making over 10000 sources detectable
2. Separation of confusing sources
3. Arc-min imaging
4. Spatially resolved spectroscopy
5. Variability studies
6. Medium energy resolution X-ray spectroscopy (the best on AstroSat)

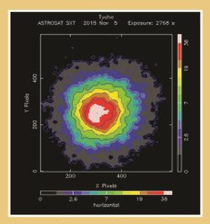


A simulation for 100 sec observation with SXT of the galactic center using sources from the INTEGRAL reference catalog with arbitrary strengths (summing up to 1 Crab).

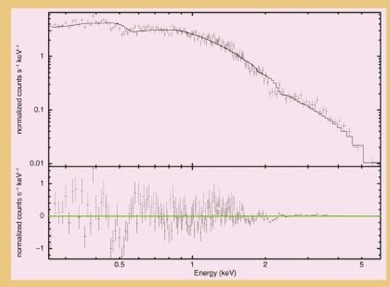
On-orbit performance ...

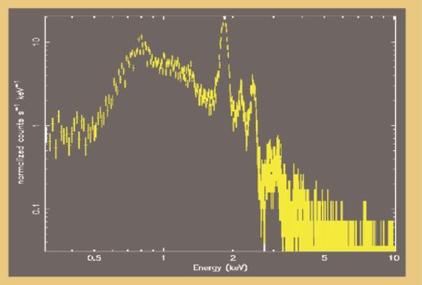


First light observations of PKS 2155-304, a blazar at redshift of 0.116 with exposure time ~2300 sec observed on Oct 26, 2015.



X-ray image of Super Nova Remnant, Tycho SN with exposure time ~ 2700 sec.





Soft X-ray spectra of PKS 2155-304 (left) and a Supernova Remnant Tycho (right). Emission lines from fully ionised Mg, Si, S, Ar, Ca can be seen in the spectrum of Tycho SN.

TIFR/UoL/ISRO

astrosat_sxt@tifr.res.in

Large Area X-ray Proportional Counters (LAXPC) onboard AstroSat

LAXPC is one of the payloads onboard AstroSat for timing and spectroscopy of the X-ray sky in the 3-80 keV energy bands.

LAXPC SPECIFICATION

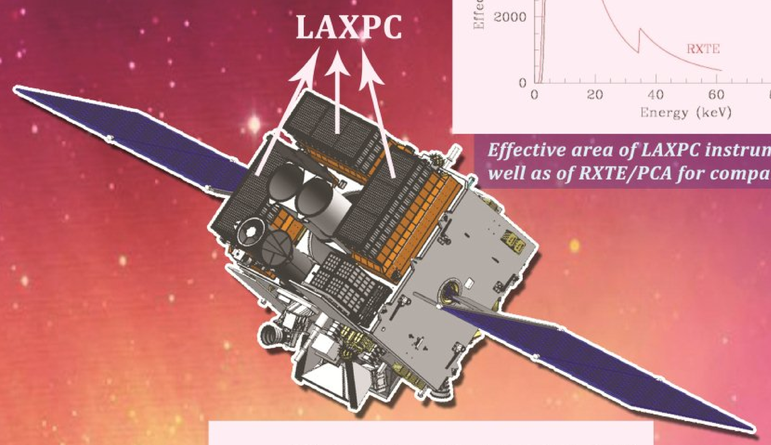
Detectors	:	Three co-aligned large area proportional counters
Gas mixture	:	90% Xenon +10% CH_4
Energy range	:	3 - 80 keV
Effective area	:	6000 cm^2 @ 5-20 keV
Field of View	:	0.9^0 x 0.9^0 defined by collimator
Energy resolution	:	10 - 12 % @ 22 - 60 keV
Angular resolution	:	~ 1-5 arc-min (Scan mode)
Time resolution	:	10 μs
Sensitivity	:	0.1 mCrab (3σ, 1000 sec)

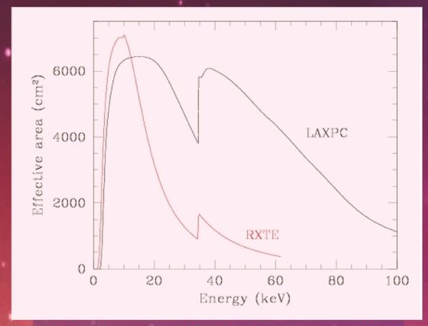
MODES OF OPERATION

Broad Band (BB) counting data:
Records count rate in various energy bands with selectable time bin.

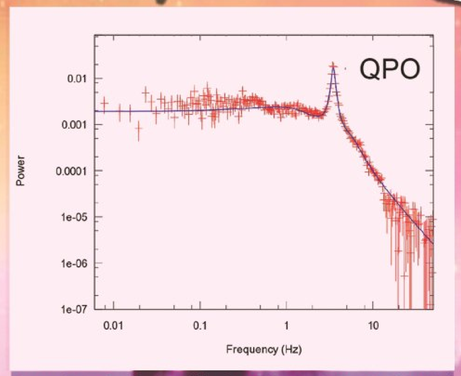
Event Mode:
Records arrival time of events with an accuracy of 10 μs.

Fast Counter Mode:
Records counts in four energy channels (only from top layer of each LAXPC).

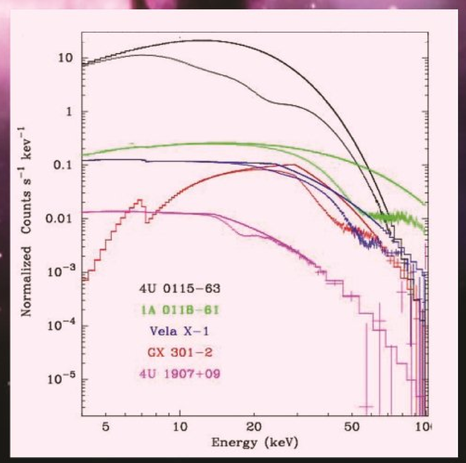




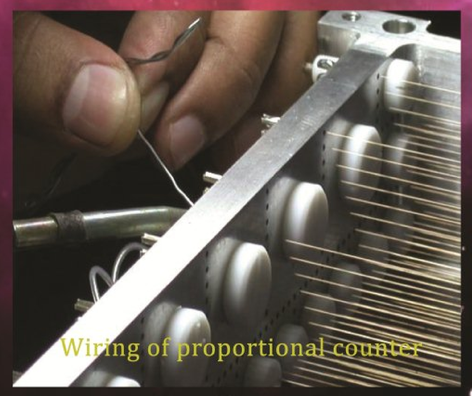
Effective area of LAXPC instrument as well as of RXTE/PCA for comparison.



Quasi-Periodic Oscillations from GRS 1915+105.



Simulated cyclotron lines for various X-ray sources.

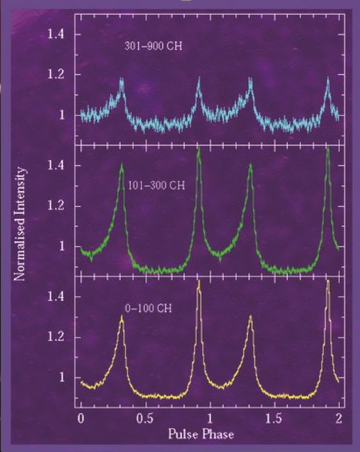


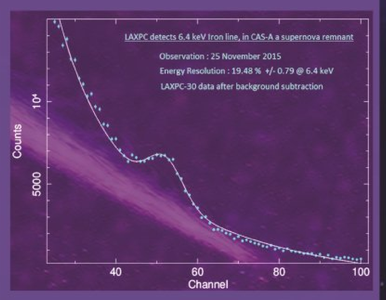
Wiring of proportional counter

MAIN SCIENCE GOALS OF LAXPC

* Study of fast periodic and quasi-periodic variabilities in X-ray binaries to probe the enviornment at in immediate vicinity of compact objects.
* Study of thermonuclear flash on the surface of Neutron star.
* Measurement of Neutron star magnetic fields using Cyclotron features.
* Characterisation of the broad band X-ray spectra of Galactic and extraglactic Black Hole sources.
* Possible glitches and non-linear pulse period evolution of Anomalous X-ray Pulsars (AXPs) and Soft Gamma Repeaters (SGRs).
* Quasi-periodic & aperiodic variations of Active Galactic Nuclei (AGNs) and comparison of temporal properties of AGNs with their galactic analogues, the Black Hole Candidates.

On-orbit performance ...





Folded lightcurve of Crab Nebula combining all the three proportional counters in different energy bands (left). The observed spectrum of Cas A with Fe-line profile (top).

TIFR/RRI/ISRO

laxpc@tifr.res.in

CADMIUM-ZINC-TELLURIDE IMAGER (CZTI) ONBOARD ASTROSAT

Main Characteristics

The Cadmium-Zinc-Telluride Imager (CZTI) is one of the four X-ray instruments onboard AstroSat. CZTI equipped with a Coded Aperture Mask has the following salient features:

- High stopping power, low thermal noise & room temperature operation,
- Excellent energy and spatial resolution,
- Low background,
- Unmatched broadband (0.3 - 100 keV) capability when CZTI is combined with two other instruments SXT and LAXPC onboard AstroSat.

CZTI Characteristics

Area	976 cm^2 (geometric)
	480 cm^2 (effective)
Pixels	16384 (64 modules of 256 pixels each)
Pixel size	2.46 mm x 2.46 mm (5 mm thick)
Imaging method	Coded Aperture Mask
Field of View	4.6° x 4.6° (15 – 100 keV)
	17° x 17° (@ 150 keV)
Angular resolution	8 arc-min
Energy resolution	~ 6% @ 100 keV
Time resolution	20μs
Energy range	15 - 100 keV
	Up to 1 MeV (Photometric)
Sensitivity	0.5 mCrab (5σ, 10000 sec)
Memory	50 Mbytes per orbit

Main Scientific Goals

- Hard X-ray Imaging & Spectroscopy of bright X-ray sources.
- Cyclotron line profiles of highly magnetized neutron stars in X-ray binaries.
- Spectral curvature associated with Compton reflection & thermal Comptonization in Black Hole X-ray Binaries and Active Galactic Nuclei.
- Study of Cosmic diffuse X-ray background.
- Hard X-ray emission from Gamma-Ray Bursts (GRBs).

INTRODUCTION

Cadmium-Zinc-Telluride Imager onboard AstroSat provides the crucial hard X-ray data for wide band X-ray spectroscopic observations of X-ray binaries, AGNs and other bright X-ray sources. Background suppression using a veto detector, background measurement using a Coded Aperture Mask, continuous calibration using an alpha-tagged X-ray source are some of the features of this payload. Time tagged individual photon data on a continuous basis provides an excellent opportunity to understand and correct the systematic errors in the spectral data.

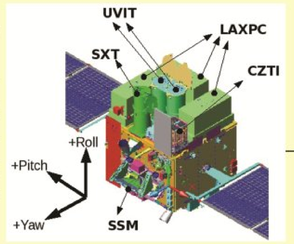


Figure 1. Schematic model of AstroSat. CZTI is mounted co-aligned with LAXPC, UVIT and SXT payloads. Above 100 keV, CZTI behaves as a hard X-ray all sky monitor (using a partial coding technique) to provide data simultaneous to the SSM.

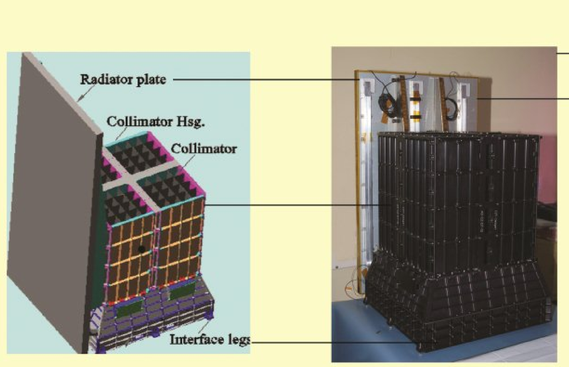


Figure 2. (Left) 3D Model of CZTI design without the CAM (see Figures 3 and 4). (Right) A fabricated model of CZTI payload.

DETECTORS

The detection area of CZTI is achieved using a mosaic of 64 CZT modules of size 4 cm x 4 cm, arranged in four identical and independent quadrants. The four quadrants are surrounded by passive shield and a collimator. Active shield in the form of a scintillator detector (veto detector) is used to further reduce the background. Coded aperture Mask (CAM) along with a collimator is used to obtain moderate imaging so that background rates can be measured and multiple X-ray objects in the Field of View could be distinguished. An alpha-tagged detector is used to calibrate the energy response of the main detector in flight. The detectors are maintained in the temperature range of 0 - 15 °C using a specially designed passive cooling and active heating technique.

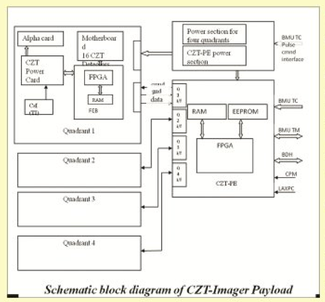


Figure 5. A schematic block diagram of the CZTI payload. The Detector package, shown on the left, includes four identical and independent quadrants and it stores individual event data and has only digital communication with the electronics package (shown on the right). The Processing Electronics (PE) contains a FPGA with an embedded processor and it has a built-in cold redundancy. All satellite communications are handled by PE.

CODED APERTURE MASK

Design and principle of coded mask imaging:

- CZTI will use a Coded Mask for imaging at E < 100 keV.
- Shift of the shadow of the mask on the detector will be used to derive source location.
- CZTI Mask consists of a pattern of holes in a 0.5 mm thick Tantalum sheet.
- Each 4 cm x 4 cm detector module has its own 256-element Mask, located 48 cm above the detector plane.
- Mask patterns designed using pseudo-noise Hadamard array to minimize side lobe levels. Transparency is 50% (equal no. of closed and open elements).

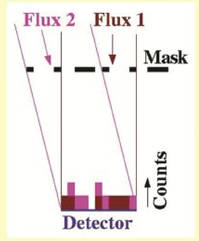


Figure 3. Coded Mask Imaging Principle: The detector detects a combined shadow of multiple sources shining through the mask at different angles. Modeling the observed shadow as a linear combination of multiple shadows recovers the location and strength of the individual sources.

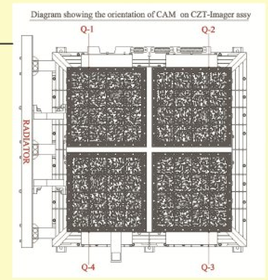


Figure 4. Design of mask pattern of the four quadrants. Alignment correct to 0.1 mm is achieved using mechanical positioning. Adequate inter-module and inter-quadrant gaps are provided to minimize the blocking of detectors.

- Mask pattern replicated for each quadrant, but with progressive 90-deg rotations.
- Image reconstruction will use cross-correlation of detected shadow pattern with the mask pattern, followed by shadow fitting.
- Light curves and Spectra may be derived using a Mask-Weighted Binning technique.

LAB TESTS & SIMULATIONS

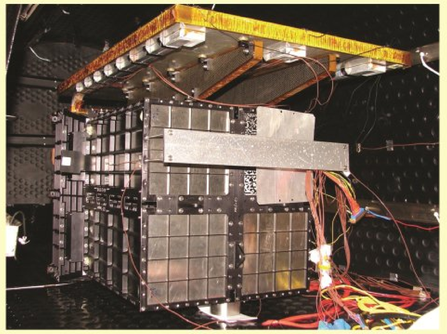


Figure 6. Thermovac test of the Qualification Model of CZTI. In this model only one quadrant was active. The temperature distribution at extreme temperatures were found to be as per the design.

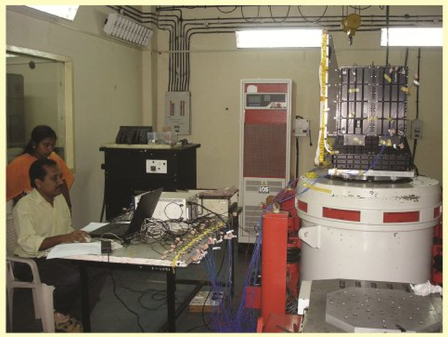


Figure 7. Vibration test of the Qualification Model of CZTI. The CAM holding, CZT module fixture and other mechanical designs were validated in this test.

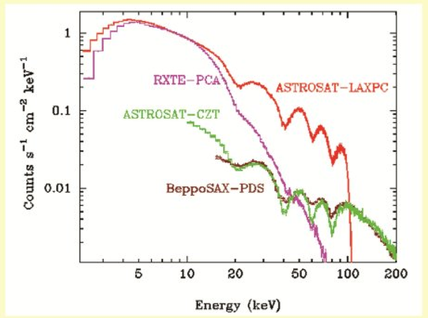


Figure 8. Simulated 10 ksec observations of a hard X-ray pulsar spectrum. The cyclotron lines are nicely resolved by CZTI .

On-orbit performance ...

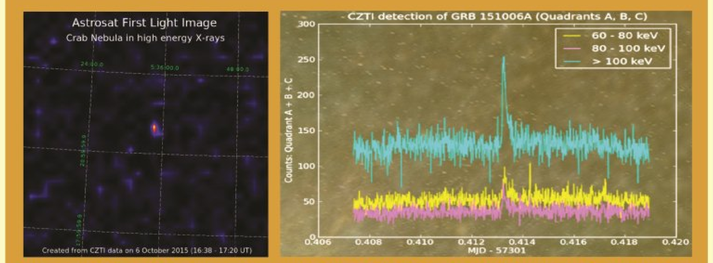


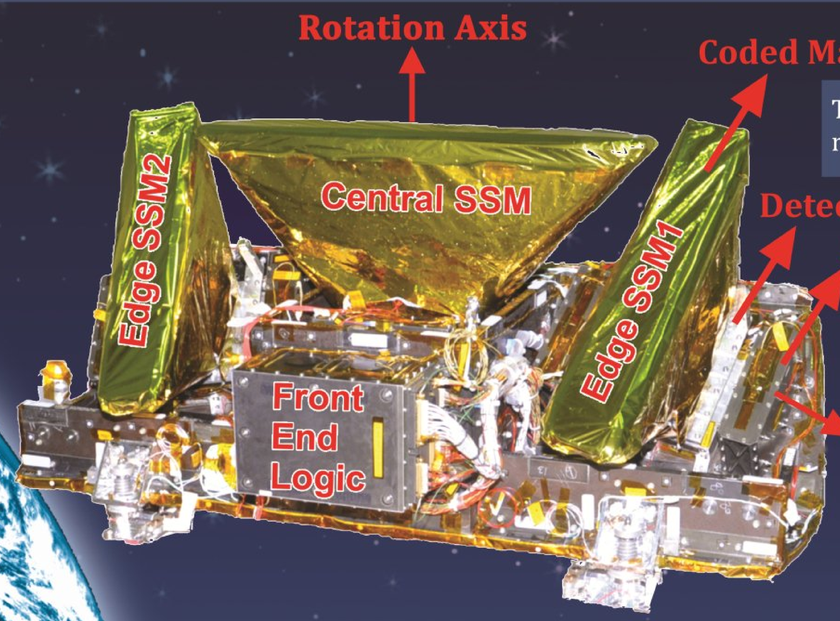
Image of Crab Nebula as observed by CZTI (left) and lightcurve of Gamma Ray Burst GRB 151006A (right).

czti@tifr.res.in

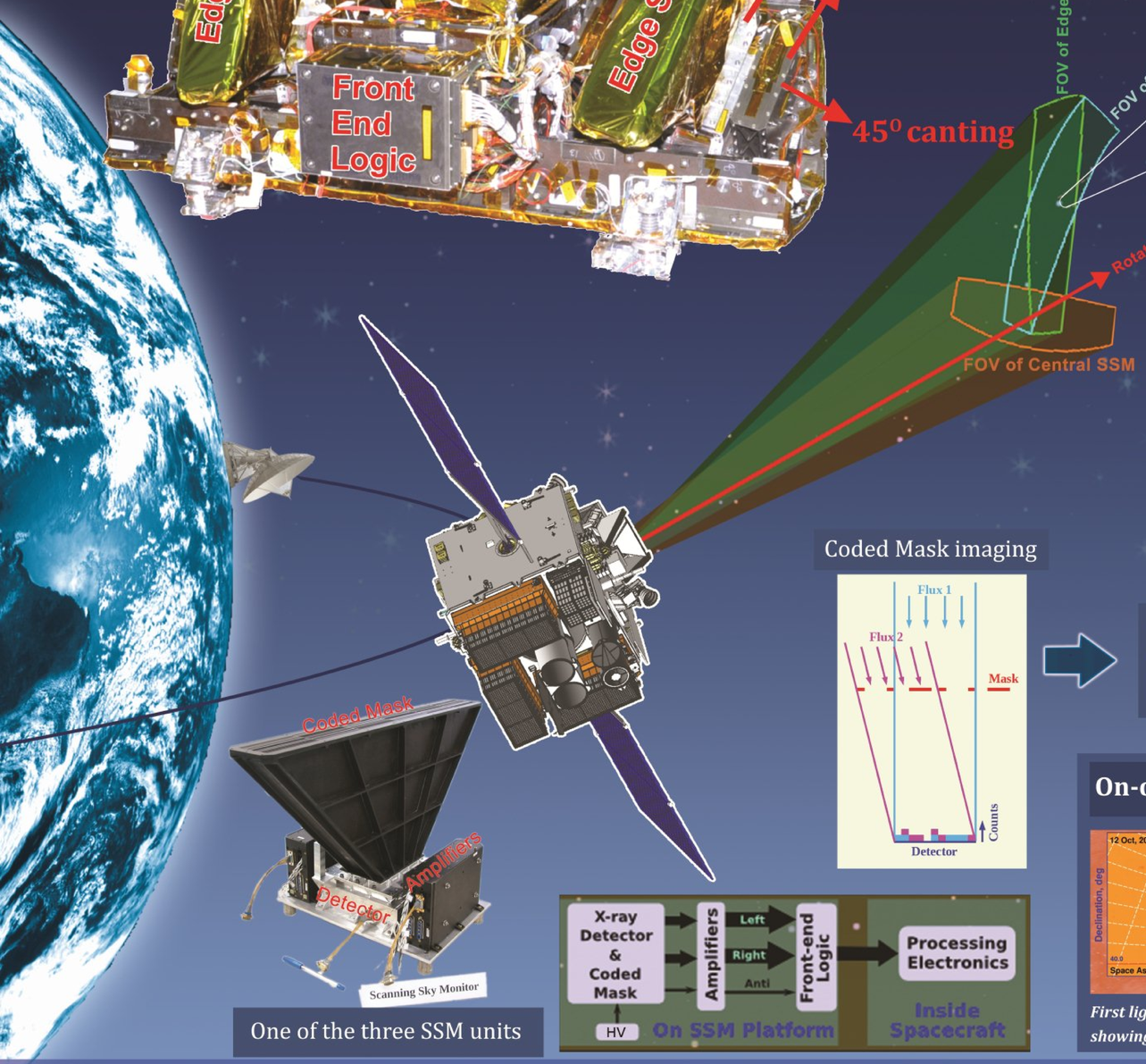
Scanning Sky Monitor (SSM) onboard AstroSat

To detect and locate X-ray transients

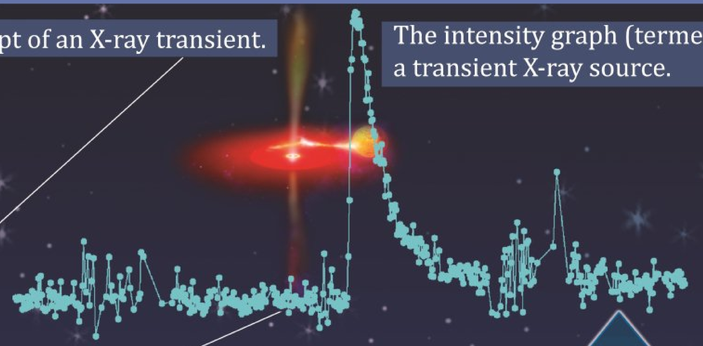
SSM is one of the X-ray payloads onboard AstroSat to detect and locate transient X-ray sources in the X-ray band of 2.5 to 10 keV.



Three SSM Flight Units assembled on the rotation platform.

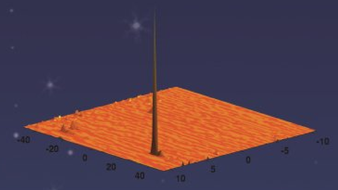


Artist's concept of an X-ray transient.



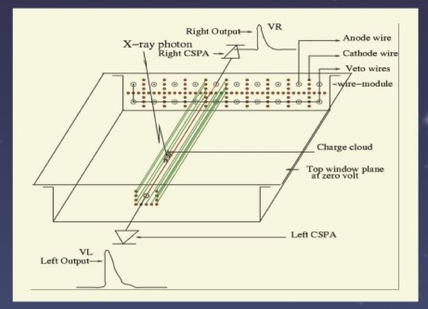
The intensity graph (termed light curve) for a transient X-ray source.

The shadow of the mask is processed to generate the X-ray sky image.



A simulated sky plane image.

Position Sensitive Proportional Counter



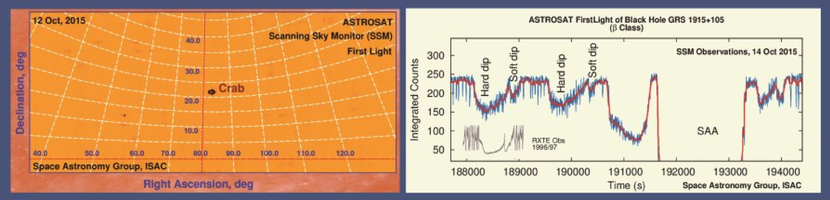
Each X-ray photon is converted into charge by the detector which is further processed by the electronics.

Coded Mask imaging

X-ray photons from a celestial source cast the shadow of the coded mask on the detector plane.

One of the three SSM units

On-orbit performance ...



First light observation of Crab Nebula (left) and observation of Galactic Black Hole GRS 1915+105, showing β class variability (right).

SSM Specification Table

Parameters	Specification
Energy Range	2.5 keV - 10 keV
Detector	One-dimensional position-sensitive gas-filled proportional counter
Gas mixture	25% Xe + 75% P-10 (P-10 is 90% Argon + 10% Methane)
Gas pressure	800 torr
Diameter of anode	25 micron
Active length of anode	60 mm
Type of anode wires	Carbon-coated Quartz
Cell Size	12 mm square
Entrance Window	50 micron thick Aluminized Mylar (Al thickness is 1000 Å)
Detector operating voltage	~1500 Volt
Unit Slit size of coded mask	0.95 mm
Energy resolution	~25% at 6 keV
Position Resolution	~1.5mm (FWHM)
Angular resolution	10' – 13' in the coding direction, 2.5° across
Time resolution	0.1 ms
Sensitivity (600s, 3 sigma, 2.5-10 keV)	*~25 milliCrab for SSM1 & 2* *~28 milliCrab for SSM3*
Field of View (FOV) FWZM	Central SSM: 22.1° x 100° Edge SSMs: 26.8° x 100°
Payload Weight	65.5 kg
Payload Power	~49 W
Effective area (for all three SSM cameras)	*~11 cm² @ 2.5 keV* *~51 cm² @ 5 keV*
Memory Required (for all three SSM cameras)	200 Mbyte per orbit
Event Rate	Nominal 400 c s⁻¹, max 5,000 c s⁻¹; electronics designed for 50,000 c s⁻¹

Credits: Artist's impression of GRS1915+105, CfA; ASM lightcurve of SWIFT J1753.5-0127

ISRO/IUCAA

ssm@isac.gov.in

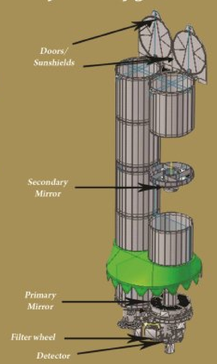
Ultra-Violet Imaging Telescope (UVIT) onboard AstroSat

AstroSat is India's first full-fledged astronomy satellite capable of observing simultaneously from optical to hard X-rays. It carries five payloads – the Ultra-Violet Imaging Telescope (UVIT) sensitive in the optical/UV bands and four other payloads sensitive in the soft/hard X-ray bands.

UVIT PAYLOAD

- Two telescopes for simultaneous imaging in three channels, Far Ultra-Violet (FUV) 130-180 nm, Near Ultra-Violet (NUV) 200-300 nm,Visible (VIS) 320-550 nm
- Intensified CMOS detectors for photon counting
- Optical diameter of the primary mirrors: 375 mm
- Plate-scale: ~ 0.023 mm/arc-sec
- Partial fields for temporal resolution of few ms
- Spacecraft drift corrected by shift-add of short exposures
- Multiple filters to select bands in each channel
- Gratings for slitless spectroscopy in FUV & NUV

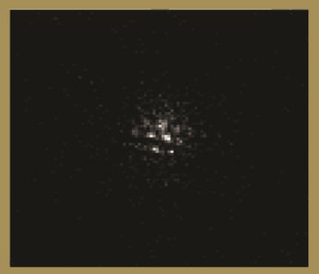
UVIT Payload Configuration



FACT SHEET

	FUV	NUV	VIS
Detector	Intensified CMOS	Intensified CMOS	Intensified CMOS
Operation mode	Photon counting/Integration	Photon counting/Integration	Integration
Telescope Optics	RC (2 mirrors)	RC (2 mirrors)	RC (2 mirrors)
Bandwidth	130-180 nm	200-300 nm	320-550 nm
Geom. Area (cm^2)	1250	1250	1250
Effective area	11 cm^2 at peak	50 cm^2 at peak	50 cm^2 at peak
Field of View	28 arcmin	28 arcmin	28 arcmin
Spectral Resolution (FWHM)	< 500A (depends on filter)	< 500 (depends on filter)	< 500 (depends on filter)
Spatial Resolution	< 1.7 arc-sec	< 1.7 arc-sec	~ 2.2 arc-sec
Time Resolutin	2.0 ms	2.0 ms	2.0 ms
Sensitivity	20th magnitude (5σ) in 160 s	--	--
Photometric accuracy	10%	10%	10%

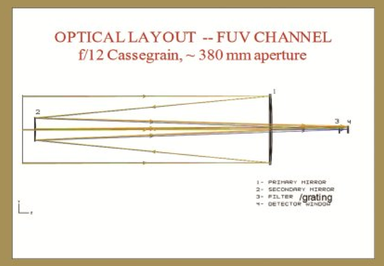
UVIT EM IN THERMOVAC

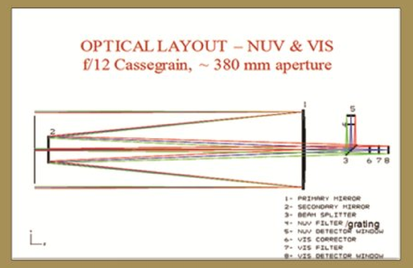


PSF of FUV telescope as obtained by collimator beam @ 150 nm FWHM ~ 1.5 arc-seconds.

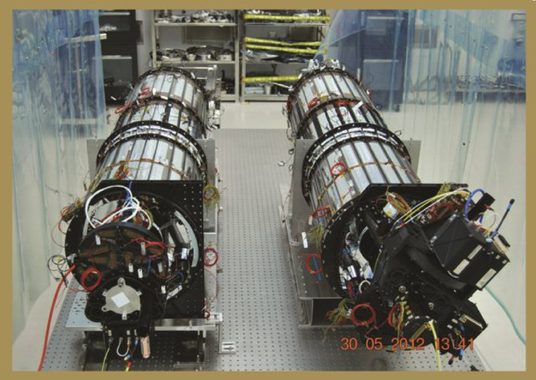
TELESCOPE OPTICS

UVIT consists of two telescopes, one for FUV and the other for NUV+VIS. Each telescope is an Ritchey-Chretien configuration and consists of two hyperbolic mirrors. The primary mirror has an aperture of 375 mm and the effective focal length is 4750 mm. In the NUV+VIS telescope, a dichroic beam splitter is used for spectral division of the beam in NUV (reflection) and VIS (transmission), thus forming the two channels NUV and VIS.

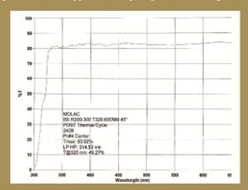




UVIT FLIGHT MODEL ON OPTICAL BENCH



Reflection efficiency of beam splitter

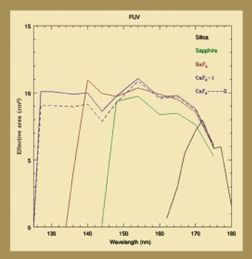


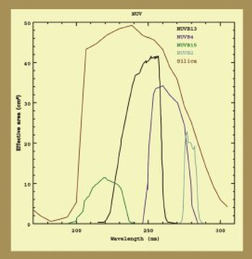
Transmission of beam splitter

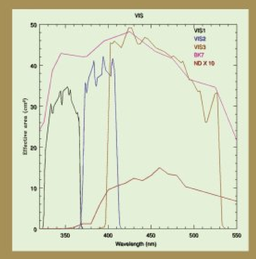
FILTERS & GRATINGS

All the three channels carry a filter wheel with a number of filters. FUV and NUV also carry gratings for low resolution spectra. The gratings have spectral resolution of about 100 and peak transmission of about 20%.

Filter characteristics







DETECTORS

All the three detectors for the three channels are intensified CMOS imagers with an aperture of 40 mm. Their construction and electronics are identical except for the photo-cathode and window material.

Key Specifications

* Window

- 5mm thick MgF_2 for FUV, 5mm thick Silica for NUV and VIS
- 3:1 fibre-taper to transmit light from phosphor screen of 40 mm to CMOS imager (Star-250)

* Quatum Efficiency: 5% at peak in FUV, 11% at peak in NUV/VIS

Operation

* Photon Counting Mode (FUV and NUV only)

- Frame rate: 29 frame/s for full field, and 640 frame/s for the smallest field of 5.5' x 5.5'
- detection of individual photons
- Time-tagged events, high time resolution ~5 ms
- Spatial Resolution: 0.9'' for FUV & NUV, 1.3'' for VIS

* Integration Mode (all channels)

- Signal resulting from multiple photons are integrated for a specified exposure time.
- Spatial resolution ~5 arc-sec (FWHM)

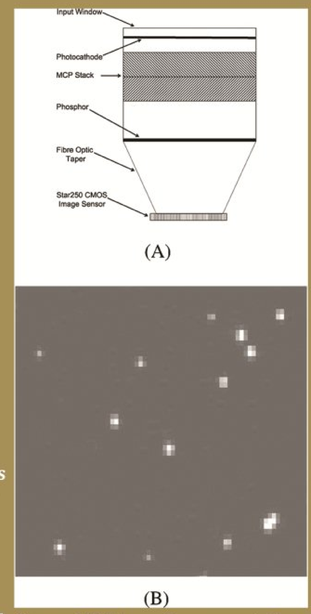


Figure: (A) Schematic representation of a CMOS Imager used in UVIT. (B) Section of CMOS data frame containing some photon events, recorded in a laboratory experiment.

SCIENCE WITH UVIT

- Simultaneous observations of active galactic nuclei, X-ray binaries etc. in Ultra-violet bands.
- Ultra-violet fast timing (sub-second) study of accreting compact objects.
- Photometric and Spectral study of large class of objects such as,
  - *Young objects and UV-sources in Galactic star forming regions*
  - *Exotic stars in globular & open clusters in the Galaxy*
  - *AGBs and WDs in the Galaxy*
  - *Novae and cataclysmic variables in the Galaxy*
  - *RR Lyrae, sub dwarfs, and metal poor stars in the Galactic halo*
  - *Star formation in nearby galaxies*
  - *Star formation in interacting galaxies*
  - *Star-formation history of the universe*

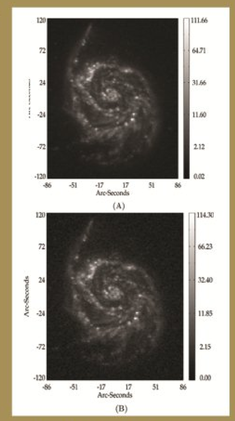
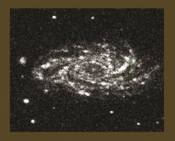


Figure: Input (A) and simulated UVIT image (B) of M51 galaxy. The GALEX UV image of M51 was used as the input image after applying necessary corrections such that the same galaxy is being observed by UVIT at a distance three times the actual distance.

On-orbit performance ...



UVIT-NUV image of a spiral galaxy NGC 2336 (left). Same source as observed by Galex (top).

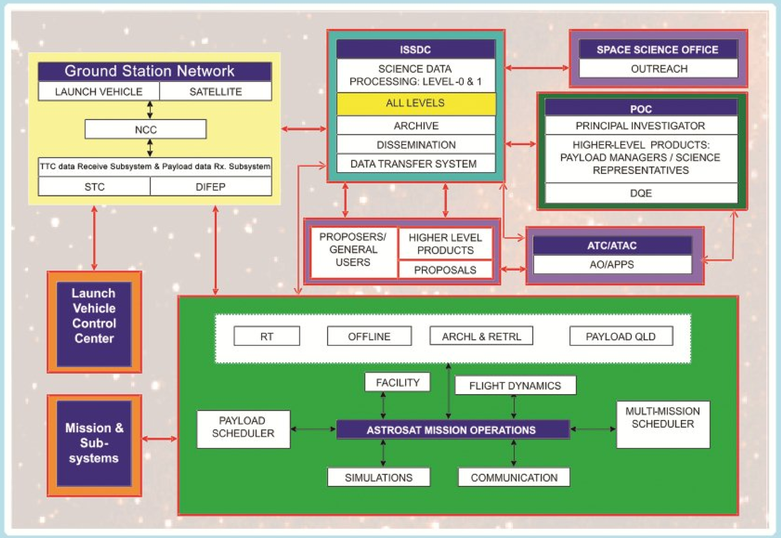
IIA/IUCAA/CSA/TIFR/ISRO

uvit@iiap.res.in

AstroSat Ground Segment

INTRODUCTION:

AstroSat is an exclusive Astronomy Mission by Indian Space Research Organisation (ISRO), configured to observe the celestial sources in multi-wavelength, simultaneously. The satellite weighing about ~1513 kg will be orbiting at an altitude of 650 km, with an inclination of 6^0. Four of the instruments, Ultra-Violet Imaging Telescope (UVIT: Far UV – 130-180 nm, Near UV – 200-300 nm, Visible – 320-550 nm), Large Area X-ray Proportional Counters (LAXPC: 3-80 keV), Soft X-ray Telescope (SXT: 0.3-8 keV), and Cadmium-Zinc-Telluride Imager (CZTI: 15-100 keV) are co-aligned for simultaneous observation. The fifth instrument, Scanning Sky Monitor (SSM: 2.5-10 keV) is positioned normal to the co-aligned axis scouting for X-ray flares and for monitoring X-ray sources.



OVERVIEW OF GROUND ELEMENTS:

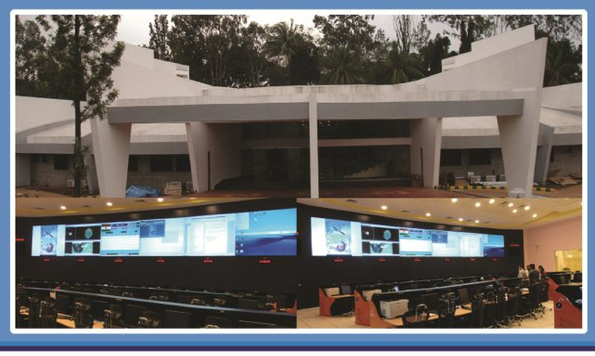
ISRO Telemetry Tracking and Command Network (ISTRAC) is bestowed with the responsibility of providing the ground support for all the phases of this mission. AstroSat Ground Segment comprises TTC and Payload data reception stations, Satellite Control center, Indian Space Science Date Center and Payload Operation centers (POCs). AstroSat TTC & Payload Ground Station, along with the Indian Space Science Data Center (ISSDC) is collocated in the Indian Deep Space Network (IDSN) Complex, Baylalu. All these four operational areas are intimately connected through communication links. In addition to the above, there is an arrangement for the pre-processing and approval of the received request for the satellite time that streamlines the sequence of observations to be carried out considering the merit, exigency of the proposals and the constraints posed by the satellite and the geometry. These ground systems function in unison towards fulfilling the mission objectives.

TTC & PAYLOAD DATA RECEPTION CENTRE/STATION:

AstroSat Antenna is dedicated for AstroSat TTC & Payload operations. The station is tailored to meet the mission requirements in conjunction with the onboard RF systems. A standby payload station is also made available at SCC, Bangalore. For the purpose of improved visibility and extended TTC operations, rest of ISTRAC S-Band Network will be utilized. The ground station transfers the TTC data to the control center and the exclusive payload data reception stations transmits instrument wise de-multiplexed data to Science Data Center, after due conditioning.

MISSION OPERATIONS COMPLEX (MOX):

Satellite control center comprises computers, technical facilities, Mission control & Mission analysis area and dedicated mission control area. At the Satellite Control Center, the satellite health is monitored, tele-commands uplinked towards payload operations and configuration changes onboard, attitude determination, orbit determination, visibility generation, scheduling and archival of all TTC data sets. The timetabling for various source observations and operating various instruments is approved by a separate committee identified for this purpose. This center houses all necessary and approved mission operation software and analysis tools. The pre-launch simulations are also organized from this center. ISTRAC communication network comprising both terrestrial and satellite links, provides real time voice / data / fax connectivity for all the ground elements, inclusive of launcher agency.



PAYLOAD OPERATION PLANNING:

The first six months after the launch is dedicated for performance verification, followed by guaranteed time phase of another six months. AstroSat observations are basically proposal-driven and Announcement of Opportunity (AO) comes in to effect, a year after the launch, but not for SSM. AstroSat Operations Portal handles the reception of proposals, processing, source finalization and sequencing of the same, considering the satellite constraints, geometry, merit / exigency of the proposals.

AstroSat Proposal Processing System (APPS) accepts all the proposals in to its proposal data base and takes up further processing based on the predetermined criteria. It is also interfaced with other planning tools such as Astroviewer and Exposure Time Calculator, along with details of the instruments mode, constraints etc. The source selection and finalization shall be carried out by the AstroSat Time Allocation Committee (ATAC - Members are drawn from science and technical areas), assisted by the peer reviewing mechanism that assess all the proposals on their scientific merit and feasibility, and taking into account the comments of the AstroSat Technical Committee (ATC) on the proposals. Approval of proposals will be based on the scientific merit & feasibility and will be made by ATAC & ATC . The approved proposals shall be passed on to Payload Programming System for the generation of time-lined command sequence output to be uplinked to the satellite.

ISSDC & POCs:

The Indian Space Science Data Center (ISSDC) is bequeathed with the responsibility of governing the ingest, Quick look Display (QLD), processing (for level-0/1), archival (all levels, along with the auxiliary data) and dissemination of payload data. It also receives and archives the higher level products generated by POCs/Guest Observers. ISSDC also supports scientists with payload and instrument health monitoring Facilities, in addition to serving as an alternate control center.

Payload Operation Centers (POCs) are the instrument wise focal points. They monitor the health of the instruments, coordinates the instrument related operations, plan periodic calibrations and higher level data processing. They receive the processed data from ISSDC and return higher level products generated at their end for archival and dissemination to general public after lock-in period.

MISSION OPERATIONS:

Thus, end-to-end mission activities, involving, payload operation proposal reception & processing, command generation and uplink, payload operations, satellite orbit and attitude maintenance, payload data reception and processing, dissemination and archival activities are carried out by the unified ground segment. Above all, the ground segment is responsible for the up-keeping of this space asset that provides a conducive environment for the instrument operations, inclusive of the desired orbit and attitude. It also serves the mandate given towards training and public outreach.