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New opportunities for Indian space astronomy

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1. Introduction

I intend to talk about the new opportunities in space astronomy which are becoming available in India, primarily through the initiatives taken by ISRO and several astronomers over the past several years. I decided to talk about this because opportunities which are now becoming available to the Indian astronomers represent a quantum jump from the past, and provide us with means to do space astronomy at a much more intensive level as compared to what has been possible so far. The future of space astronomy in our country would depend on how we exploit the present situation; a successful use of the opportunity by the astronomers, would encourage ISRO to provide greater support for space astronomy in the future. After giving a brief history of space astronomy in India, I talk about ASTROSAT (with special emphasis on UltraViolet Imaging Telescope, on which I am presently working) and about using it, and conclude by emphasizing the importance of making the best use of this opportunity by Indian astronomers.

2. History of space astronomy in India

Let me give a very brief history of non-ground based astronomy in India. More than 50 years ago, balloon-borne experiments were started at TIFR, Mumbai to study cosmic rays, and these continued fairly vigorously up to about 1970. While the facility to launch experiments on stratospheric balloons from Hyderabad was being used to study cosmic-rays, it was little used for other astronomy till the year 1968 (see Tata Institute of Fundamental Research 1945-1970). But, after 1968 this facility was extensively used by PRL and TIFR for hard X-ray and far-infra-red astronomies. During the years 1969-82, astronomers at ISAC, PRL, and TIFR used the sounding rockets for X-ray astronomy. Beginning with Aryabhatta (the first Indian satellite), astronomers from ISAC, PRL,

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and TIFR have used many Indian satellites to launch instruments for X-ray/gamma-ray/solar astronomy. Through an Indo-Israel collaboration, ISRO is to launch TAUVEX (an ultraviolet telescope from Israel) on one of its satellites, and Indian astronomers would be able to use it for observations. While some of these programmes have given very important results, and have generated a lot of experience in instrumentation for space astronomy, they were not large projects and each of these only involved a small number of astronomers from the country. On the other hand, as we shall see below, ASTROSAT is a large project with several instruments for simultaneous observations in many bands, and it promises to offer Indian astronomers a unique facility for multi-wavelength astronomy for many years.

3. ASTROSAT

ASTROSAT would be the first Indian satellite fully devoted to astronomy, and it is designed to observe in multi-wavelengths, from visible range to hard X-rays. There is a set of five co-aligned telescopes on it:

- Cadmium-Zinc-Telluride array with coded mask, to image in 10-100 keV range,
- Large Area Xenon-filled Proportional Counters with collimators, to observe in 3-100 keV range,
- Scanning Sky Monitor, to image in 2-10 keV range, to study transient sources,
- Soft X-ray Imaging Telescope, to image in 0.3-8 keV range with a resolution of $3'$,
- UltraViolet Imaging Telescope, to image in 130 - 550 nm with a resolution of $2''$. (see Astrosat Project Report, 2003).

This large set of instruments, provides a unique capability of making simultaneous observations in many bands and providing new insights into emission mechanisms and variability of X-ray sources, e.g. active galactic nuclei and X-ray binaries. In addition, the wide angle images provided by UltraViolet Imaging Telescope (UVIT), with an angular resolution which is ~ 3 factor better than that of images from GALEX mission of NASA, would give morphology of UV sources to unprecedented distances in the Universe. The satellite would be placed in a near-equatorial orbit and is expected to operate for 5 years. A brief description of UVIT is presented below to give an idea of what kind of effort is involved in realising goals of ASTROSAT.

3.1 UVIT

This instrument is designed to make simultaneous images, over a field of $\sim 30'$ diameter, in three channels: 130-180 nm (FUV), 180-300 nm (NUV), and 350-550 nm (VIS); each of the three channels has a set of filters for selecting a band. The images are made by a set of two Cassegrain telescopes each of 375 mm aperture; one of the telescopes is used for FUV channel, and the other is used for NUV and VIS channels. Intensified imaging detectors are used to get a sensitivity of 20 mag in FUV in 15 minutes of exposure. The most challenging goals are the high spatial resolution, and a high throughput in FUV.

The spatial resolution is affected by: optics, detectors, and pointing/tracking of the satellite. Surface-figure of the mirrors required for FUV is ~ 4 times better than what is required for VIS, and the optics is being done by LEOS, ISRO, Bangalore. The detectors are required to have a spatial resolution $\sim 1''$, i.e. ~ 4000 effective pixels on a diameter or an rms error < 10 microns on the position of each detected photon. In order to meet this requirement, detectors are being made through an Indo-Canadian (ISRO/CSA) collaboration, and high resolution intensifiers for these are being developed by Photek, UK. Any long exposure images are blurred by drift in pointing of the satellite, and this effect can only be eliminated by taking a large number of short (< 1 s) exposures and co-adding these with appropriate shifts. As the number of photons collected over a 1 s exposure in FUV/NUV channels is small, the "appropriate" shift is estimated by an inter-comparision of short exposure images from VIS channel; a successful implementation of this process requires that relative alignment of the two telescopes does not vary by $>1''$ through any orbit, even though temperature variations are expected to occur as the satellite passes from bright side to dark side of the orbit.

While all the optics has to be clean, the requirements of cleanliness are much more demanding in ultraviolet channels as compared to the visible channel; the absorption cross sections of organic materials are so high in FUV that monomolecular layers can lead to significant absorption. This calls for special control and monitoring procedures to avoid any contamination at all stages of work on ground, from fabrication of the parts to launch of the satellite, as well as in the orbit. The net transmission of optics in FUV is also significantly affected by scattering on the surfaces due to micro-roughness, e.g. a micro-roughness of 15 Å rms on a mirror only leads to a loss of $\sim 0.05\%$ light at a wavelength of 5500 Å, but the loss increases to $\sim 1\%$ at a wavelength of 1500 Å. Thus, all the optical surfaces in FUV telescopes are required to have a very low micro-roughness. In order to meet these challenging requirements on cleanliness and smoothness of the optical surfaces, a special purpose clean laboratory is being established at IIA.

3.2 Observations with UVIT

One of the principal aims of ASTROSAT is to carry out multi band observations on X-ray sources, and UVIT would observe these sources in FUV, NUV, and VIS bands with an angular resolution of $< 2''$.

In addition to the observations on X-ray objects, the two ultraviolet channels of UVIT are very well suited to study a large variety of objects, e.g. variable stars, hot stars in Galactic clusters, binaries and hot stars in Globular clusters, white dwarfs, nebulae, distribution of hot stars and star forming regions in galaxies, properties and distribution of dust in galaxies, duration and sites of star formation in interacting galaxies. Let me give a few examples of the results obtained from some of the past UV-missions. In NGC 7023, scattering by the dust was seen to be more forward directed in UV than in the visible (Witt et al. 1992); UV bright evolved stars were resolved in galactic globular clusters and studied for their colours (Landsman et al. 1992); a survey of the IUE spectra of blazars showed that the magnitude of UV variability is correlated with UV luminosity and optical polarisation, supporting the view that jet is the source of UV rather than accretion disk (Edelson 1992); the UV emission in M33 was seen to be far more extensive than H alpha emission, showing that UV emission is more powerful of the two as tracer of star formation (Thilker et al. 2005); good correlation was seen between H-alpha and UV emissions in the halo of M82, suggesting that dust is carried with the outflowing gas (Hoopes et al. 2005); evidence of short but delayed bursts of star formation was seen in the tidal tails of NGC4438 (Boselli et al. 2005).

Except one result on blazars, all the results quoted above are from the imaging missions: the Ultraviolet Imaging Telescope (UIT) (see Stecher et al. 1997 for a description of UIT) and the Galaxy Evolution Explorer (GALEX) (see Martin et al. 2005, and Morrissey et al., 2005 for a description of GALEX). The spatial resolution of UVIT is expected to be better by a factor of 3 compared to GALEX/UIT, and it is expected to have a sensitivity similar to GALEX. Thus, for the same level of details, UVIT can observe to ~ 3 times more distant as compared to GALEX. This comparision and the rich variety of recent results obtained with GALEX demonstrates the potentialities of UVIT for extragalactic astronomy. Further, a high sensitivity and a high spatial resolution of UVIT make it a powerful instrument for Galactic astronomy too.

4. Using ASTROSAT

In the above section a lot has been said about the kind of observations which can be made with UVIT, and without going into any details it can be said that a large variety of interesting observations can be made by ASTROSAT, simultaneously in many bands spanning the range from visible to hard X-rays. However, it also needs to be said that the possibilities for observations would be limited by many factors, e.g. basic configuration and details of the hardware, tests and calibrations done on the components and the instruments, protocols used to carry out observations, our capacity to predict behaviour of the instruments and the radiation environment in the orbit, etc.; some of these factors affect quality of the results, and the others affect efficiency of observations. Perhaps a few examples relevant to UVIT could make it clear: a) while any calibrations done on ground would lead to a saving in the time spent on in-orbit calibrations, it is almost impossible to determine distortions on pixel to pixel and other small scales in the orbit, and unless these are done on ground quality of the images would be less than the best possible; b) a less reflecting coating on the baffles would enhance sensitivity in fields near bright sources;

c) inclusion of grisms/gratings would provide a possibility of low-resolution spectroscopy on selected targets.

It might be asked why all the possible calibrations and tests would not be done on ground, and why the best possible and most comprehensive hardware would not be used in the payloads? While all that is required to obtain the minimal goals would certainly be done, any further value-addition would depend on how much of total resources, in particular human resources, are available on the project. At present only a small number of astronomers are seriously involved in this project, and it is clear that in order to make the value-addition a much larger involvement of Indian astronomers is required to push possible improvements/modifications.

As of now a relatively small number of astronomers are actively involved in ASTROSAT, while the potential of this observatory is such that a much larger number of astronomers can use it for very interesting observations. It is possible that most of the potential users take the view that they would get involved when the satellite is in orbit and is commissioned, and when its actual performance is evident. However, that might be too late as very little influence can be exercised on the payloads once the satellite is in orbit, and unlike for a ground based observatory there is very little scope for improvements/changes after the launch. Therefore, if you want to observe with ASTROSAT please do get involved in it in a hurry.

5. Conclusion

I told you about some of the features of ASTROSAT, and have tried to convince you that it provides unique opportunities in space astronomy to Indian astronomers. It is a great opportunity, not only because of the possibility of making simultaneous observations in many bands spanning from hard X-rays to visible, but also because it is the first attempt by India to enter space astronomy in a major way. The effort required to make this a success is very different from what we have done in the past, and it calls for collaborations between individual astronomers and between institutions on a scale much larger than that done in the past in our country. In particular, the project involves a long drawn effort over years before the observations are possible, and there is always some risk of minor/major failure. Given the long drawn effort and the risks involved, interest of individuals in the project can only be sustained by a hope of large yields at a later time, and to that extent any involvement at this stage has to be an act of faith in success of the project. It also appears that a large project in space astronomy can only be undertaken like this, and if we are so far not used to this approach we should seriously think about adopting it. The support provided by ISRO to this project demonstrates their intention to provide means to Indian astronomers for doing space astronomy in a big way. A successful completion of this project would certainly open more opportunities to us for space astronomy. Therefore, I urge you all to seriously consider grabbing this historic opportunity.

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