Bull. Astr. Soc. India (2003) 31, 249–255

Ultra Violet Imaging Telescope (UVIT) – Science*

N. Kameswara Rao
Indian Institute of Astrophysics, Bangalore

Abstract. Some of the significant areas of astronomy that would be persued by UVIT, one of the payloads on the proposed Indian multiwavelength astronomy satellite ASTROSAT, is described. Some of the considerations and uniqueness of the system are high lighted. UVIT aims to provide flux calibrated images of the sky at a spatial resolution of about a second of arc in the wavelength range 1250 to 3200Å along with optical bands.

1. Introduction

ASTROSAT, the first Indian multiwavelength astronomy satellite, is proposed as a mission of IRS - class that would be placed into a near earth (~ 600 km s^{-1}) orbit with an inclination of ~ 15 degrees. The four major instruments on board would cover UV (1250 – 3200Å), optical, soft (0.3 – 8 keV), hard (2 – 80 keV) X-ray regimes. The UV and optical imaging would be carried out by UVIT. All the payloads would be aligned to point at the same part of the sky at any time.

UVIT aims to provide flux calibrated images of the sky at a spatial resolution of about a second of arc in three main channels FUV, NUV and visible simultaneously with 0.5 degree field of view. The wavelength range of 1250 – 3200 Å and 4000 – 8000Å would be covered through the use of broad and narrow band filters. In the expected mission life of 5 years UVIT would image all the 4π steradians of the sky either in a scanned survey mode or in a stare mode. Despite 40 years of UV observations from variety of rockets and space craft, the UV sky is largely unknown. Low sky background in UV wavelengths (e.g. 26 mag/arc sec^2 at 2000 Å) enables even small aperture telescopes to observe faint sources by integrating longer. The last UV all-sky survey was done by TD -1 mission in 1972 to a magnitude limit of 9th. It did not include a single galaxy or QSO. The first deep survey of the sky is expected to be performed by the mission GALEX (Martin 1998), due to be launched some time in 2003, with a spatial resolution of 5 – 10 arc seconds. The instruments on the Hubble Space Telescope provide images of small regions (< 1′) of the sky at high spatial resolution (<0.″1) Neither GALEX nor HST are well suited to address some of the important problems in modern astronomy e.g. the star formation rate at low redshifts.

**This presentation is on behalf of UVIT team

UVIT fills a unique but critical niche in observational UV astronomy with high resolution imaging (~ 1″) of large regions. The HST UV camera fields are 50 times smaller in diameter while the spatial resolution is 10 times higher, resulting in comparable limiting magnitudes for galaxies (extended objects). By the time UVIT is launched in 2006, GALEX would have been up for over 2 years or more. UVIT would thus be able to take advantage of the GALEX data base with better resolution. UVIT has the additional advantage of simultaneous visible imagery at comparable spatial resolution to UV along with X-ray observations.

1.1 Saha and Beginings of UV Astronomy

About eighty years back H. Oberth pointed out the advantages of observations from space, namely the availability of the entire electromagnetic spectrum for observations of sources as well as observations free of the earth's atmospheric blurring effects. As Savage (1999) comments 'At that time, no professional astronomer took these ideas seriously. Over subsequent 20 years the only other published speculations about observatories in space appear in the science fiction literature'. However one astrophysicist who emphasized the importance of UV astronomy way back in 1937 is Megh Nath Saha. In a lecture given at Harvard Observatory, published in Harvard Observatory Bulletins, 905, 1937, he states 'But access even to these limited regions (i.e 2000Å – 3200Å) will result in invaluable additions to our knowledge for they will afford information about the behavior of the resonance lines of most of the elements which occur in the Fraunhofer spectrum and thus ease our way for the final solution of the mysteries of solar physics: e.g. we expect to get, a) about L alpha λ1216 of H, b) about λ1640, λ1215 of He^+, c) about existence or otherwise of the Li continuum at about λ2300, d) about the resonance lines of elements from Be to O ..., e) As regards Mg we shall obtain much desired information about the resonance lines of Mg and Mg^+ which are just beyond λ2900, f) the same is true of resonance lines of Al to S, g) We hope to also obtain very valuable information regarding transitional elements particularly Fe^+.

The above short account will indicate how much we should gain from a Statosphere observatory.'

It would be nice to see UVIT as an attempt to ful-fill Saha's vision of a space observatory for UV astronomy as part of Indian Multi Wavelength astronomy satellite ASTROSAT.

2. UVIT Configuration

UVIT consists of two indipendent 38 cm telescopes, one dedicated to FUV (1250 – 2000Å) and the other to NUV (2000 – 3200 A) and visible channels. The NUV and visible channels are seperated by a dichroic mirror that reflects NUV and transmits visible. These channels are further divided in wavelength bands by use of filters. Each channel has wheels consisting of 8 filters of 50mm diameter. The detectors are photon counting CCDs with CsI, CsTe, and S20 photocathodes for FUV, NUV and visible channels, respectively. The field of view is 0.5 degrees with a spatial resolution of 1 to 1.5 arc second resolution. The sensitivity is expected to be better than 4 sigma detection for a star of 21 mag. in 1000 sec with 500 Å filter in FUV. A time resolution of a sec and photometric stability of 5% and accuracy of about 10% is proposed. Both scan mode and stare mode of observing is envisaged. A life time of 5 years is expected.

3. Science Drivers and Objectives

UVIT would measure the flux of celestial sources in various UV bands providing spectral energy distributions and variability of point sources, morphology of extended sources complemented by observations simultaneously in selected optical bands. The science objectives of UVIT are broad based extending from solar system objects to galaxy clusters. Some of the major scientific topics that are important to UVIT mission are outlined below.

- Multiwavelength study of X-ray sources
- Solar activity in Stars
- Auroral Emissions from Planets
- Hot Stars
- White Dwarfs - (in Clusters)
- Cataclysmic Variables and X-ray binaries
- Pulsating Hot Stars
- High mass stars and Luminous blue variables
- Dust Extinction Studies
- Imaging the Emission Nebulae and Supernova Remnants
- Hot stars in nearby galaxies
- Quasars and Active Galactic Nuclei
- UV morphology of Galaxies
- Deep Surveys and Rate of Star formation
- UV Sky Surveys

Some of these topics are elaborated below.

3.1 Solar activity in Stars

One of the major unknowns about solar activity is the cause of 11 year sunspot cycle, the variation of UV emission as the Sun ages. These are the least understood phenomenon in other stars. They are important in other stars. They are important in the context of Sun's past and future. It is now known that other solar type stars do show periodic or semiperiodic variations of chromospheric emissions - cycles of years to days. These variations are linked to stellar rotation and magnetic activity cycles. UV region is ideally suited to study these phenomenon since the stellar continuum is weak. The NUV region contains the Mg II resonance lines at 2800 A, which has been established as good indicator of chromospheric activity. The FUV region contains lines of C IV, He II, Si IV etc. that reflect the behaviour of transition region (chromospheric to coronal). In view of the studies of stellar coronae proposed by the X-ray payloads on ASTROSAT, it is important to study the emissions from transition and chromospheric region as well. The 1350 – 1750 Å region is important (covered by BaF_2 and CsI detector cutoff). UV photometry can be used to study the rotation period - activity relation, the Maunder minima in various stars. The behaviour with age, metalicity, and binary nature would be very valuable. The large field of view of UVIT would be essential to study stars in clusters. The UV photometry of young stars (eg. T Tauris) in which the surface fluxes of the chromospheric lines are 1000 times stronger would enable to study stars in various Galactic clusters of different ages. [In a 30 minute integration one would be able to reach V ~ 12th in the FUV 400Å band with a S/N of 4. The Mg II lines can be observable to V ~ 16]. Monitoring of these emissions for few years would require good photometric calibrations and stability.

3.2 White Dwarfs - (in clusters)

White dwarfs are the hot end products of stellar evolution of intermediate mass stars and can be observed most easily in UV. UV images of globular clusters provide the best means of determining the low mass hot stars, the various subclass of white dwarfs, subdwarfs and blue horizontal branch stars. The UVIT's resolution is needed to study these crowded fields to identify.The morphology of the distribution of hot stars is important in the cluster evolution studies.The UV colour - magnitude diagrams would be important addition to the stellar evolution studies.

3.3 High mass stars and luminous blue variables

These are the most luminous stars in the UV and are rare enough to minimize problems with confusion and background. They normally occur in associations and clusters where UVIT's spatial resolution is of special importance. These are useful for extragalactic distance determinations. UVIT would be able to reach Virgo cluster of galaxies. The variabilty of the Wolf-Rayet and OB stars, especially, the ones in binary systems would be utmost important to arrive at the fundamental properties of these stars including dust production.

3.4 Dust Extinction Studies

The hot stars are also used as background sources to estimate the interstellar extinction and its wavelength dependence. The interstellar dust extinction is higher in the UV region relative to visible, thus more sensitive for detection in UV. The shape of the interstellar reddening curve is fairly uniform and well characterized for the diffuse interstellar medium. The prominent feature in the reddening curve is the $\lambda 2000$ absorption feature. The amount of reddening is estimated by straightening the dip of the λ2000 feature. From the intrinsic colours estimated from the knowledge of spectral types and observed UV colours the amount of extinction can be estimated. UVIT with its capability of observing hot stars to 21st magnitude (or fainter) with a large field of view would provide more sensitive means of mapping the dust distribution in many parts of the galaxy.

3.5 Emission Nebulae and Supernova remnants

The emission nebulae, the H II regions and Planetary nebulae, radiate in strong emission lines caused by the photoionization of the gas by the central hot star. The ionization structure across the nebulae can be mapped by imaging the nebulae in the dominant emission lines (preferably the same element in various stages of ionization). In the UV region lines of carbon occurs in different stages of ionization - C IV λ1550, C III λ1909, CII λ2326 etc. (no prominent lines of carbon occur in the optical region). Some PNs display gradients of nucleosynthetically processed material (e.g. carbon) close to the star (e.g. Abell 30, Abell 78). The high angular resolution mapping in the emission lines would bring out the inhomogeneities of these elemental distributions. PNs being generally smaller in angular extent do need high angular resolutions. The shocked high temperature gas in supernova remnants is dominantly seen in lines of C IV. Mapping such remnants in C IV lines would complement X-ray studies in estimating the ionization structure. The surface brightness to which extent UVIT would be able to map would depend on the C IV filter characteristics.

3.6 UV Morphology of Galaxies

Nearby Galaxies

UVIT is ideally suited to a complete survey of hot stars in nearest galaxies (e.g. LMC, SMC). They contain large population of young hot stars which have never been fully catalogued or imaged in UV. With its higher angular resolution and wider field it would be ideal source to study current star-formation activity by the presence of massive hot stars. The major local group galaxies have sizes from $\sim$ 0.5 to several degrees. Most of them can be covered in a single exposure of UVIT field. Out of 20 members only 8 have sizes above 0.5 degrees. These images can even be used to study interstellar extinction in the galaxies. Study of hot eclipsing binaries (complemented by spectroscopy) would estabilsh distance scale using purely geometrical techniques.

Galaxies are multicomponent systems and the UV probes different components than does the optical. The UV morphology of even normal galaxies would look different from the optical. Rest frame UV images of nearby field galaxies will provide opportunity to compare the structures and spectral energy distributions of galaxies at the present epoch with those of younger high redshift ($z > 0.5$) observed in the rest frame in the optical region.

Deep Surveys and Rate of Star formation

Deep survey similar to Hubble Deep Field (long exposures) would provide information on UV flux from distant galaxies and UV background light.

Lyman-break galaxies

Recent studies of star formation history of the universe which can now be roughly traced from $z = 0$ show an apparent peak between $z \sim 1$ and 2 that declines to $z \sim 4$. The redshift data are identifying galaxies from photometry by locating the strong spectral break at the Lyman limit at 912 Å (in the rest frame). UVIT would be able to cover $0.5 < z < 2$. In the range $0.5 < z < 1.3$, the Lyman - break objects discovered can be compared directly to the star formation rate deduced from conventional redshift surveys. This will allow for the first time, an emperical calibration of the completeness of the Lyman break technique. The range $1.3 < z < 2$ is difficult to probe with ground based spectroscopy (optical wavelengths) since all important emission lines have been red shifted to near infrared. In recent years, with the availability of sensitive detectors in near infrared, this difficulty is eased considerably. Thus UVIT would provide by far the best estimates of star formation rate in this key redshift range.

3.7 UV Sky Survey

Sky survey to a magnitude limit of 21 is planned for the first 6 to 8 months of the mission. It is expected to cover about 10000 sq. degrees of the sky primarily in two UV bands. It would be first time the UV sky would be mapped with comparable resolutions to the ground based surveys where the source confusion would be minimal. This would provide unbiased census of various UV sources.

4. Summary

In summary, the scientific goals of UVIT are well defined, achievable and significant. The instrument would not duplicate the capabilities of available or planned missions. At present, there is only one planned mission that resembles UVIT - that is GALEX. The spatial resolution of GALEX would be 5 to 10 times poorer. Many of the programmes listed above, would not be possible with significntly poorer resolutions than proposed for UVIT. UVIT not only would complement GALEX but goes much further in allowing more detailed studies.

It is only hoped quick and positive decisions would be taken soon to realise this exciting mission. Already enormous amount of effort and time have been lost due to lack of haste in giving a go ahead to the project .

Acknowledgements

I would like to thank my colleagues on the UVIT team Jayant Murthy, Ashok Pati, Ajoy Saxena, Raghavendra Prasad, Gangadhara, Shyam Tondon and others for the ongoing fruitful collaboration. I am also thankful to ASTROSAT team members for their encouragement