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TAUVEX – An Ultraviolet Imager on the Indian GSAT-4 Satellite

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Abstract. The *TAUVEX* instrument consists of three imagers operating in several bands in the mid to near UV. We have proposed to fly *TAUVEX* as a secondary payload on the GSAT-4 mission to be launched in late 2004 and this proposal is currently under consideration by ISRO. The *TAUVEX* mission will consist of a series of scans over 1 degree wide bands in the sky which we will build up into a survey of the ultraviolet sky. The limiting magnitude in each of the three colours will be on the order of 19. We hope to make the data available to the Indian astronomical community soon after launch.

Keywords : Space Missions - UV; Sky Surveys - UV

1. Introduction

In collaboration with the Israeli *TAUVEX* team, we have proposed to fly an ultraviolet imager aboard the GSAT-4 satellite, to be launched by ISRO in late 2004. The *TAUVEX* payload consists of three UV imagers covering the wavelength region between 1400 Å and 3200 Å (for a full description see Brosch 1998). With moderate spatial resolution (7″) over a large field of view (54′), *TAUVEX* perfectly complements the Ultraviolet Imaging Telescope (UVIT - Pati & Rao 1998) aboard the ASTROSAT mission (scheduled for launch in late 2006) which has a much higher spatial resolution (1″) but with only half the FOV. On the other hand, *TAUVEX* is directly competetive with the recently launched GALEX mission (Burgarella et. al. 2003 and references therein) but, with its much longer mission life, will obtain superior coverage over the sky in three wavelength bands, compared with two for GALEX.

TAUVEX was one of the instruments scheduled for flight on the multiwavelength Spectrum-X Gamma mission of the Soviet Union's space program but was put on indefinite hold when the

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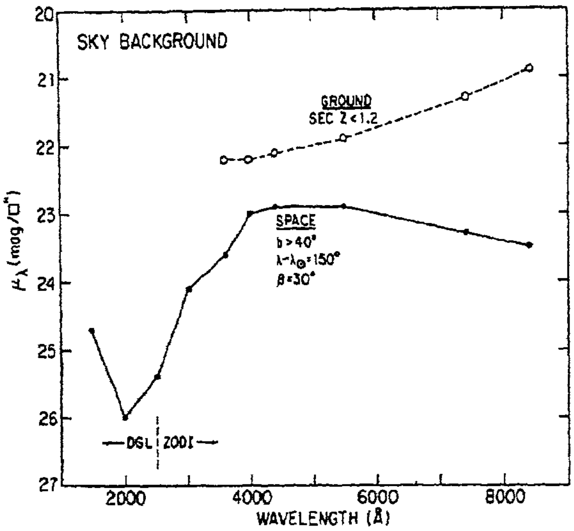

Figure 1. While the sky background at all wavelengths is much less in space (here shown for a low Earth orbit) than from the ground, we note that the sky background is particularly low in the UV. Thus the UV is the best spectral region to observe deep into the universe. Ths figure is reproduced from O'Connel 1982

Soviet Union broke up. *TAUVEX* is now in storage in an ultra-clean facility in El-Op, the Israeli aerospace company. Upon the chance for a secondary payload on what was then the (Indian geo-stationary satellite) GSAT-3 mission, I proposed, with N. Brosch (Tel Aviv University), *TAUVEX* as a perfect fit for the satellite and the short time available for payload development. Because of other factors, the *TAUVEX* payload was shifted to GSAT-4 and the proposal is now in the approval stage by both the Israeli and Indian space agencies.

We believe that we can obtain a unique science product with *TAUVEX* that will be widely used by Indian, Israeli, and international scientists and will complement both existing observatories such as UPSO at Nainital and IAO at Hanle and future missions such as ASTROSAT.

2. Science

The advantages of observing in the ultraviolet have been documented by O'Connell (1987); namely, that the sky background in this spectral regime is near zero allowing faint objects to be easily seen (Figure 1). Thus the ultraviolet is, much more than the visible, the best place to observe deep into the universe. Despite 40 years of observations from a series of rockets and spacecraft, the ultraviolet sky is still largely unknown. There has been no survey of the UV sky since the TD-1 satellite in the early 1970's, which had both low sensitivity and low spatial resolution. Pointed mode instruments such as the International Ultraviolet Explorer (IUE) and the

Hubble Space Telescope (HST) have yielded a wealth of data but have only observed objects discovered in other wavelength bands.

Although the mission plan is yet to be defined and will depend on science input from the general astronomical community, our baseline is to survey the entire sky over the 7 year mission lifetime combined with selected deep fields and observations of interesting targets. Our limiting magnitude will be on the order of 19 for the UV 3 band survey and 25 for the deep pointings. (Note that we quote magnitudes in Hayes & Latham 1975.) We will certainly detect more than 10^7 galaxies with 3-band photometry plus a comparable number of stars and, perhaps most excitingly, several million quasars. The sky is much different in the UV as opposed to the visible or any other wavelength and *TAUVEX* will afford us a new look at the universe.

3. Context

Because the Galaxy Explorer (GALEX) launched in April 2003 by NASA, has comparable properties, we must contrast our goals with theirs. The primary difference is that GALEX has chosen to sacrifice depth for an all-sky survey. With our longer mission life, we will obtain deeper observations over most of the sky and in three bands as opposed to the two of GALEX (1350–1800 Å; 1800–3000 Å). The GALEX sensitivity is on the order of 18th magnitude (after converting to the Hayes-Latham system we use) for the survey and 23rd magnitude for their deep survey over 100 square degrees. Our data will complement GALEX in those areas and will allow much more detailed testing of galactic and cosmological models. The Indian multiwavelength satellite ASTROSAT will also contain an ultraviolet imager but that will have a much smaller field of view and much higher spatial resolution. *TAUVEX* will be an ideal precursor to ASTROSAT in that areas selected on the basis of *TAUVEX* data can then be observed with much higher spatial resolution by UVIT.

4. Goals

Perhaps the most important science issue to be addressed by *TAUVEX* is simply that of a deep census of a large fraction of the sky. Immense numbers of new objects will be discovered which will then be followed up from ground-based observatories in India and Israel for identification and further classification.

Surprisingly the star formation rate at nearby epochs is not well known, because nearby galaxies are too large to observe with existing telescopes in space. With *TAUVEX* we will be able to survey galaxies to a redshift of 2.5 extending our models of galactic evolution to the present day. This has important consequences for our understanding of the history of the universe.

We will also obtain a measure of the diffuse galactic light over regions ranging from the Galactic plane to the poles. This is largely starlight scattered by interstellar dust about which little is known. Dust is important in many processes in our Galaxy and others, particularly in radiation transfer from starlight to the interstellar medium in which new stars are born.

Extragalactic light has long been the Holy Grail of diffuse studies but is hampered by Galactic light in most spectral regions. We will be observing the Galactic poles as part of our survey where we will be able to obtain the best observations of the extragalactic light. Through these observations we will be able to significantly constrain cosmological models.

5. Instrument

TAUVEX consists of two separate modules, which can be mounted separately but in proximity to each other. The optical module consists of three identical telescopes with wedge and strip anode detectors. The electronics module includes the associated electronics. The structure is made of aeronautical aluminium with a carbon composite for parts where thermal expansion is critical, such as the telescope metering structure. This allows for a large range in operating temperatures (20 to 50°C) with no further requirements on thermal gradients.

The optical module includes three identical, co-aligned and independent 20-cm Ritchey-Chretien telescopes. Each telescope has a field of view of 0.9 deg with a spatial resolution of about 7″ on the focal plane. The primary and secondary mirrors are both lightweighted zerodur coated with Al + MgF_2 with an effective reflectivity of better than 90% over the wavelength region of interest. In addition, two doublet lens pairs, made of CaF_2, correct the field of view for aberrations and serve as Lyman α blockers. A schematic of the telescope structure with the baffles is shown in Figure 2.

There are four filters per telescope offering 6 different UV bands for observation (Figure 3). In the standard mode for operation on GSAT-4, we plan to use one fixed filter per telescope to give effective bands of 1700 ± 250 Å, 2150 ± 210 Å, and 2530 ± 225 Å. The detectors are standard wedge and strip with a 25 mm CsTe photocathode. They use a 3 MCP chain to give a final spatial resolution of about 60 microns on the plate.

Nominal operation of the geostationary GSAT-4 satellite requires that the platform be pointed to a single location on the Earth's surface. Thus, unlike most astronomical missions where the satellite itself is responsible for target acquisition, we require an independent pointing mechanism to be built by the ISRO Satellite Applications Centre (ISAC) as a modification of that used for the Solar Orbiting X-ray Spectrometer (SOXS) payload on GSAT-2. The general mission plan is to scan a strip of the sky at a constant declination and then, once per day, shift by 0.1 deg to scan a new declination. Thus, over the mission lifetime, a redundant map of the entire sky will be built up. Where warrented by demands from the science community, specific targets can be observed, within the constraints of operating as a secondary payload on a geosynchronous mission.

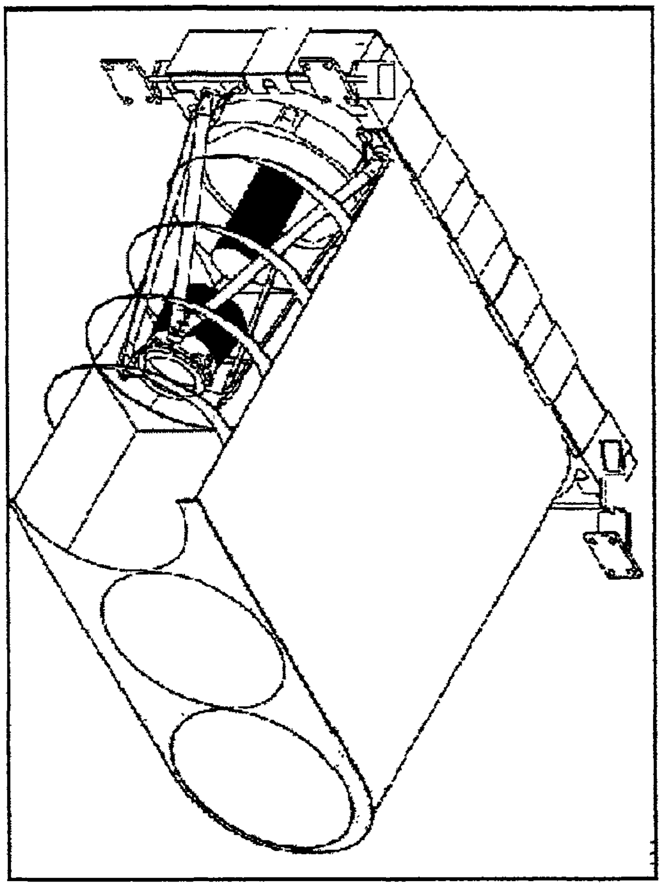

Figure 2. A schematic of the *TAUVEX* optical module structure is shown. One of the telescopes is cut away to show the bafffles and mirrors.

6. Status

We have had several technical discussions with ISRO and El-Op (who are responsible for the *TAUVEX* instrument) which have been very positive. We are now (May 1, 2003) awaiting final decisions on the acceptance of the payload by the Israeli Space Agency and subsequent to that by ISRO. The launch of the GSAT-4 mission is scheduled for late 2004 and so it is critical that these decisions are made as soon as possible.

Once accepted for GSAT-4, we welcome input and help from the Indian astronomical community. As a major space project, considerable work is needed on every aspect from science

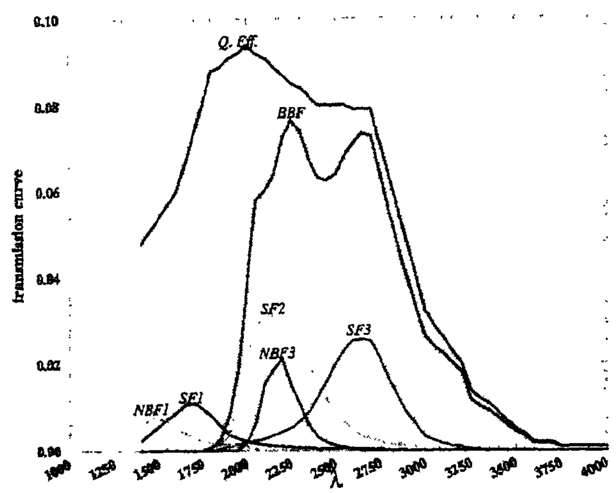

Figure 3. The spectral ranges of the *TAUVEX* filters are shown here. For nominal operation on GSAT-4, we will only use a single filter for each of the three imagers but will maintain the capability to change filters should it be desired on programmatic or scientific grounds.

issues to mission planning and data analysis. More information about the project can be found at http://www.iiap.ernet.in/tauvex/tauvex.html or from murthy@iiap.ernet.in.

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