TAUVEX AND ITS CONTRIBUTION TO TIME SERIES STUDIES

A multipurpose UV space telescope

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Abstract.
Although not designed specifically for the study of time-dependent phenomena, TAUVEX will provide unique observations of photometric variability in the ultraviolet (UV). I describe TAUVEX, which will operate together with the other scientific instruments on the carrier satellite, the Space Observatory Spectrum X-γ (SRG). I concentrate specifically on time-dependent observations, emphasizing the projected capabilities and limitations. I then describe a few objects in which the UV variability is interesting, and point out the advantage of simultaneous observations with the high-energy imaging telescopes on board the SRG observatory.

The Tel Aviv University Ultraviolet Explorer is the first space astronomy experiment constructed in Israel. It was selected in 1990 from a number of proposed experiments by the Israel Space Agency (ISA), and in 1991 it was adopted as one of the scientific instruments of the SRG spacecraft. Since its inception, TAUVEX aimed to fill the niche in the space astronomy research dealing with wide angle, reasonable angular resolution surveys of the UV sky.

The UV domain has been shown by O'Connell (1987) to be the region with the lowest diffuse sky background from low Earth orbit. Since the publication of O'Connell's paper new estimates have shown the UV sky background to be even lower (Murthy *et al.* 1996, Waller *et al.* 1996). As the detector technology for UV imaging can now provide essentially noiseless detectors, the sky background and the photon noise are the only noise sources against which a detection must be secured. This implies that reasonable photometry can be performed with even a modest size telescope, which could be affordable by a small country such as Israel.

The field of wide-angle reasonable-resolution surveys has been neglected since the TD-1 mission (Thompson *et al.* 1978, Boksenberg *et al.* 1978). Two instruments provided limited UV imaging capability: the Ultraviolet Imaging Telescope (UIT; Stecher *et al.* 1992) and the FOCA balloon-borne telescope (Milliard *et al.* 1992). Although the Hubble Space Telescope (HST) has UV imaging capability with the WFPC-2 and FOC instruments, and will have an enhanced imaging capability once the STIS instrument is installed and operates properly, this can accomodate only extremely small fields of view, and could hardly be classed as wide-field imaging.

TAUVEX was designed and built by El-Op, Electro-Optical Industries, Ltd. for Tel Aviv University and under the supervision and guidance of the TAUVEX scientific team, to compete successfully with both UIT and FOCA, and to provide interesting targets for HST follow-up. As a first national scientific payload, it was constructed using a conservative approach. This required extensive redundancy in most systems, with the first redundancy in having three independent telescopes, each 20 cm in diameter.

The Ritchey-Chrétien optical design provides images with 80% of the energy within 6-7", but the detectors degrade this to 9-11". The field of view is 54', and the detectors image this with 3" "electronic pixels". The detectors, manufactured by Delft Electronishe Producten (DEP), are of wedge-and-strip type, as used in the EUVE satellite and in the FAUST Shuttle-borne UV imager. These are photon-counting position-sensitive detectors, and the 2×10 bit address of each photon is decoded from the collected charge of the WSZ anode elements by a digital signal processor. Each detector is equipped with a four-position filter wheel. The filters cover the working range 1300 to 2800Å . To eliminate geocoronal and interplanetary Lyman α induced background, ~15 mm of warmed (to 25°C) CaF_2 are provided in the detector window, in the filters, and in the doublet corrector lenses.

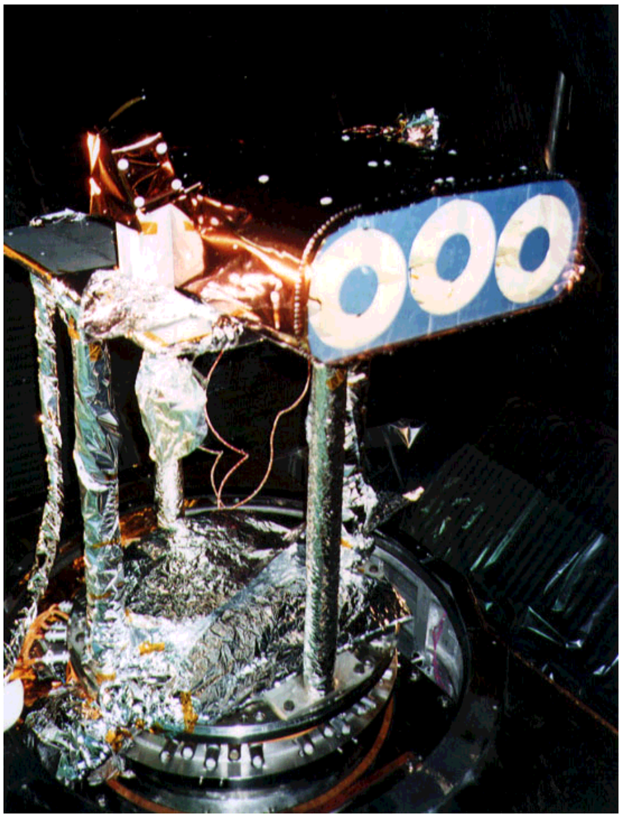

Figure 1. The TAUVEX thermal model is identical in external appearance to the flight model.

The platform on which TAUVEX will operate is not extremely stable. In order to conserve the original angular resolution, TAUVEX provides on-board tracking and motion compensation, while the photon events with corrected coordinates are collected in a doubly-redundant image buffer memory (IMEM). Typical observations last for one hour, after which the contents of the IMEM are transferred to a long-term storage medium (laptop hard disk) for eventual transmission to the ground station. The tracking corrections are transmitted to the SRG attitude and control system, and are available off-line to the other SRG scientific instruments.

For a fast photometry option, we used a modified "tracking" routine. This allows the definition (by ground command) of one square region in two of the telescopes, or two such windows in one telescope, in which objects of interest for fast photometry are located. The routine sums the photon events in the window(s) and outputs the total count every integration time to two fast photometry vectors, which are part of the data package collected during the observation.

The shortest integration time is determined by the charge replenishment of the MCPs in the detector. This limits the system to 10 msec shortest integration time. The longest integration time equals the exposure time (typically one hour). In order to perform consistent photometry, only one time base is used in SRG, which originates from a temperature-stabilized crystal oscillator on-board SRG, which is checked periodically against a master clock at the ground station (Moscow time). The TAUVEX time base is synchronized every second to this SRG time signal.

As a conclusion, TAUVEX is able to provide time resolved photometry for a single object in two UV bands, or two objects in one UV band, with time resolution of 10 msec or longer for as long as SRG points to the target. This is done simultaneously with the other SRG instruments, providing coverage from $\sim$4 eV to 100 keV.

Among the interesting observations which could be performed with TAUVEX on SRG one cannot count, unfortunately, a two-color UV light curve of the Crab pulsar. The Crab PSR has been observed with the HST High Speed Photometer by Percival *et al.* (1993). The HST HSP collected only 1.5 UV photons per pulse period, on average. This scales to $\sim 10^{-2}$ photon events per 33 msec period for TAUVEX, assuming the same quantum efficiency of detectors, and is unfortunately too low for the periodicity to be detected by TAUVEX. There are, fortunately, other targets which are interesting and **brighter**, where significant variability at UV wavelengths has already been detected. I shall review a few examples below, not attempting to cover the field in any systematic or complete fashion.

In the extragalactic field, variability observations by TAUVEX are restricted to the brighter AGNs of the BL Lac flavor. Relatively strong brightness changes have been observed in these sources, but not with as fast a sampling as TAUVEX will be able to observe. As an example, the BL Lac object PKS 2155-304 shows strong variations in the UV, which correlate with X-ray and optical light fluxes (Edelson *et al.* 1995). The object is bright enough to use integration times as fast as a few minutes, but the analysis by Edelson *et al.* is limited by the IUE response to $\sim$one hour. An added bonus is the possibility of simultaneous high and low energy X-ray observations of the object with SODART, JET-X, F-UVITA and MART.

Among stars, I mention in particular the predicted possibility to detect asteroseismologic pulsations from subdwars (Charpinet *et al.* 1996). The subdwarf B stars are believed to be $\sim$0.5 $M_{\odot}$ objects with very small H envelopes, which cannot evolve after core He exhaustion to the asymptotic giant branch. Their effective temperature stays higher than 20,000K throughout their core-burning stage. Only one observation of variability of such a star (Feige 108; Bergeron *et al.* 1984) has apparently been reported. The periods predicted by the models of Charpinet *et al.* (1996) indicate pulsation periods from tens to hundreds of seconds; these are easily measured with TAUVEX. Finally, we identified a region where such stars are relatively abundant. An analysis of a UV image obtained by the FAUST telescope in the direction of Coma revealed a number of possible hot subdwarfs brighter than m_{UV}=12 (Brosch *et al.* 1997), probably members of the Mel 111 open cluster, for which integration times of $\sim$10 sec should be sufficient for variability studies.

The field of flare stars has hardly been studied in the UV. One interesting observation, from the astrophysical station ASTRON, has been reported by Burnasheva *et al.* (1989). The observations were performed in three spectral bands with the ASTRON UV telescope, and simultaneous observations were done from the Crimean Astrophysical Observatory 1.25 m telescope. Such observations may serve as prototypes for correlated space and ground observations with TAUVEX and WiseObs, with different UV bands on TAUVEX and higher quantum efficiency detectors at WiseObs. Such correlated observations may clarify the mechanism of flaring and its energy budget.

In the area of periodic variability much work has been done on cataclysmic variables with IUE and lately with the HST. The FOS on HST allowed fast spectroscopy of V795 Her (Rosen *et al.* 1996), which showed that variability of emission lines is not exhibited by the UV continuum. The 71 sec oscillation in DQ Her was studied by Robinson *et al.* (1996); the amplitude at 2180Å apparently changes from orbit to orbit (P=4^h 39^m). Even the spin of the white dwarf in YY Dra could be detected at 1420-1525Å by Haswell & Patterson (1996). All these objects could be observed by TAUVEX, with the additional advantage of long, uninterrupted observations in the elongated orbit.

Apart for the opportunity to perform extended, multi-band, photometric observations in the UV, the operation of TAUVEX on board the SRG observatory offers the unique possibility of simultaneous variability coverage from 100 keV to $\sim$100 eV (overlapping), with additional UV coverage by F-UVITA and TAUVEX, from $\sim$18 eV to $\sim$4 eV. We expect to obtain simultaneous ground-based observations from the WiseObs for those targets which will be observable at night and will be high enough in the sky for the latitude of WiseObs. The contribution of TAUVEX, and the SRG platform from which it will operate, promises to be one of the more fruitful in the study of time-dependent astrophysical phenomena.

More information on TAUVEX, including many pictures of the different models, can be found inthe TAUVEX home page at the URL: **http://www.tau.ac.il/ benny/TAUVEX/**.

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