Critical Design Review (CDR)
Of
ULTRA VIOLET IMAGING TELESCOPE (UVIT)
(June 17th -18th 2011, ISAC, Bengaluru)

PV Phase Calibration in Orbit

UVIT-CDR-00-012

Indian Institute of Astrophysics
Bangalore-560034

UVIT-CDR-00-012

PV Phase Calibrations in Orbit

Annapurni Subramaniam
03 June 2011

The calibration plan describes the overall goals of the in-flight calibration and outlines a set of calibration tasks. A calibration task is the configuration, observation and analysis required to calibrate a specific aspect of the instrument. The primary goal of this calibration is to ensure that the scientific quantities obtained from the UVIT instrument conforms to the requirements set forth by the instrument document. This also needs to fulfill the requirements set forward by the science projects.

UVIT-in flight calibration is designed to allow automated processing of UVIT data by the pipeline with the goal of producing a calibrated set of images and spectra which can be used for quantitative data analysis in order to achieve the scientific objectives. The activities listed in this document pertain to three types of calibrations. Photometric calibration is a measurement of broadband source-independent flux. Calibration will yield a conversion of a measured count rate into a broadband flux and the conversion of ratios of count rates into broadband colours. The spectroscopic calibration consists of estimation of wavelength coverage, wavelength and flux calibrations. Astrometric calibration is the measurement of the relation between a point on the detector based on the image created by the telescopes and the absolute position in the sky.

The performance verification (PV) phase of the UVIT is of approximately, two month duration. The photometric calibration tasks along with the other calibration will be performed in this time. The in-flight calibration tasks will be performed during the PV phase and repeated at regular intervals to monitor the performance of the system as well as to improve the already estimated parameters. Hence, some of the calibration activities or tasks will be repeated at regular intervals. As per the recommendations of the monitoring team, certain calibration tasks may be included while planning the observing cycles also.

The in-flight photometric, spectroscopic and astrometric calibration tasks of the UVIT during the PV phase and across the mission is summarised. Various tasks have been identified along with the list of standard stars. Approximate time required to perform these tasks are also listed. These are preliminary estimates, these will be improved with the help of the ground calibration.

The following table summarises various calibration tasks planned to be taken up during the PV phase:

1. Photometric zero-point (FUV, NUV, VISUAL)
2. Secondary photometric calibration (FUV, NUV, VISUAL)
3. Flux calibration of the grism
4. Dispersion and wavelength calibration of the grism
5. Astrometric positional calibrations
6. Astrometric angular separation estimations
7. Linearity of response and bright star limits

8. PSF estimations
9. Timing calibrations
10. Estimation of background

Details of various calibrations:

1. Photometric calibration:

Absolute spectrophotometric and photometric calibration is a high priority for targetted observations and will comprise roughly ¾ of the observations. Since UVIT has a large number of filters, the photometric calibration task can be quite time-consuming. Hence it is highly recommended that as far as possible, same set of targets and images should be used for multiple calibration purposes.
For example, the zero-point observation tasks should be combined with the PSF calibration. Approximately ¼ of the time may be required for spectroscopic and astrometric calibration and other specialised calibration activities. Detector dark measurements are particularly useful for monitoring the health of the detector system and will be performed regularly, this can be measured during the non-observing time of the orbit. The scattered light as well as estimation of the background at the entry and exit of the allowed UVIT observing window will also be estimated.

UV spectrophotometric standards have been collected from the previous missions, including the HST standards on the WD scale. These standards stars will be used for inflight calibrations. The expected count rates for these standards are estimated based on the ground calibration values of the filter-detector bandpass profile and effective aperture. First order estimates are provided and will be improved once final tables are available. Detailed calibration procedures are provided in the inflight document.

The photometric calibrations will be done in the photon counting mode for the FUV and NUV detectors. The calibrations for three sizes of windows will also be performed. The calibrations in the integrated mode will be done for the visual channel. The photometric calibrations will also address the issue of spatial variation by taking standard star images in 9 positions in the detector. This will be used to estimate the low frequency variation of the sensitivity across the detector.

2. Spectroscopic calibrations:

The spectroscopic mode of operation in UVIT is using gratings. These gratings are mounted in the filter wheels and result in spectra for each object in the FOV. In order to achieve the projected science, these spectra need to be calibrated.
The spectroscopic calibration requirements can be broadly classified as:

1. Estimation of the location and extent of spectra in the image plane,
2. Estimation of the shift of the zeroeth order image with respect to the position of the object in the image plane,
3. Estimation of curvature within the length of the spectra,
4. Wavelength and dispersion calibration,
5. Flux calibration.

All the above are required to be performed in both FUV and NUV channels. Some of these could be carried out simultaneously in both channels and some will be performed separately. All the above estimations also need to be performed as a function of location in the detector. The above estimations are required to be performed in the ground and its variation as a function of position on the detector needs to be estimated. Thus variation in the estimated grid should be the basic pointer towards the in-

flight grid spacing requirement. It is felt that a five point grid should be adequate to estimate the positional variation of the above parameters. Thus, the above calibrations are required to be performed during the PV phase.

3. Astrometric calibrations:

The astrometric calibrations can be classified as

1. Absolute astrometric calibration: Estimation of offset between the measured and actual position on the sky.
2. Relative calibration: Estimation of variation in angular separations/ image scale as a function of position on the detector
3. Estimation of positioning error for detected sources (termed as error circle)

The first task can be achieved by observing astrometric standard stars at various locations in the sky. These observations will be used to estimate the offset between the measured positions and the actual position of the object. An average of this over the various pointings will give the error circle. The second task can be achieved by observing fields with multiple standard stars within the field. The number of locations needed to be measured on the detector can be 6/9 point observations. One could also use suitable star clusters with astrometrically calibrated stars. The final grid with angular size variation will be estimated by convolving the ground and in-flight calibrations.
Details of observation and targets are being worked out. (Firoza probably has the details)

3. PSF estimations:
The in-orbit psf estimation will use the images taken during the photometric calibrations. The positional dependance as well as the psf in various filters will be estimated.

4. Timing – A suitable source with known timing will be observed to calibrate the time between the pulses using suitable pulsars. This will also be done in combination with the other payloads for cross-calibration of timing.

5. Background estimation: The background can be of two types. There may be some light during the entry and exit of the allowed UVIT observing window of each orbit. This background may change depending on the location of Sun. Therefore, the first images taken during the entry and exit of each orbit will be used to estimate the background counts as a function of the Sun and Moon angle. This is the first type and will be estimated during the pv phase using the calibration data.
The second type is the scattered light due to the presence of a bright background or a nearby bright star. A few observations with bright targets and various separation from the field of view will be used to estimate the change in the background flux as a function of the proximity of a bright object. Plans to identify bright background is still in the planning.

6. Bright object detection: This is a safety feature for protecting the detector by ramping down the voltage when a bright source appears in the field. This will be tested by observing faint source for long integration time.

UVIT – PV phase calibration Summary:

The in-flight photometric, spectroscopic and astrometric calibration tasks of the UVIT during the PV phase and across the mission is summarised. Various tasks have been identified along with the list of standard stars. Approximate time required to perform these tasks are also listed. These are preliminary estimates, these will be improved with the help of the on going ground calibration.

The following table summarises various calibration tasks and the time involved ***during the PV phase***:

Task	***Exposure time***	***Number of orbits "*" = once/week others ~ once/month***
Photometric zero-point (FUV and NUV):	388 min	16 orbits*
Photometric zero-point (FUV):	116 min	6 orbits*
Photometric zero-point (VIS):	71 min	2 orbits*
Secondary photometric cal. (FUV, NUV):	103 min	3 orbits*
Secondary photometric cal. (FUV):	51 min	1.5 orbits*
Secondary photometric cal. (VIS):	38 min	1.1 orbits*
Flux calibration of grism:	108 min	3.1 orbits*
Wavelength calibration of grism:	90 min	2.5 orbits
Astrometric position calibration:	100 min	2.8 orbits
Astrometric angular separation:	40 min	1.2 orbits
Bright star and linearity checks:	35 min	1 orbit
Background estimation:	35 min	1 orbit
Timing calibration:	35 min	1 orbit
PSF estimation:	35 min	1 orbit