CCDLAB – Manual

Graphical UVIT Data Pipeline

A guide for reducing Level 1 data from UVIT detector system onboard ASTROSAT to science ready images.

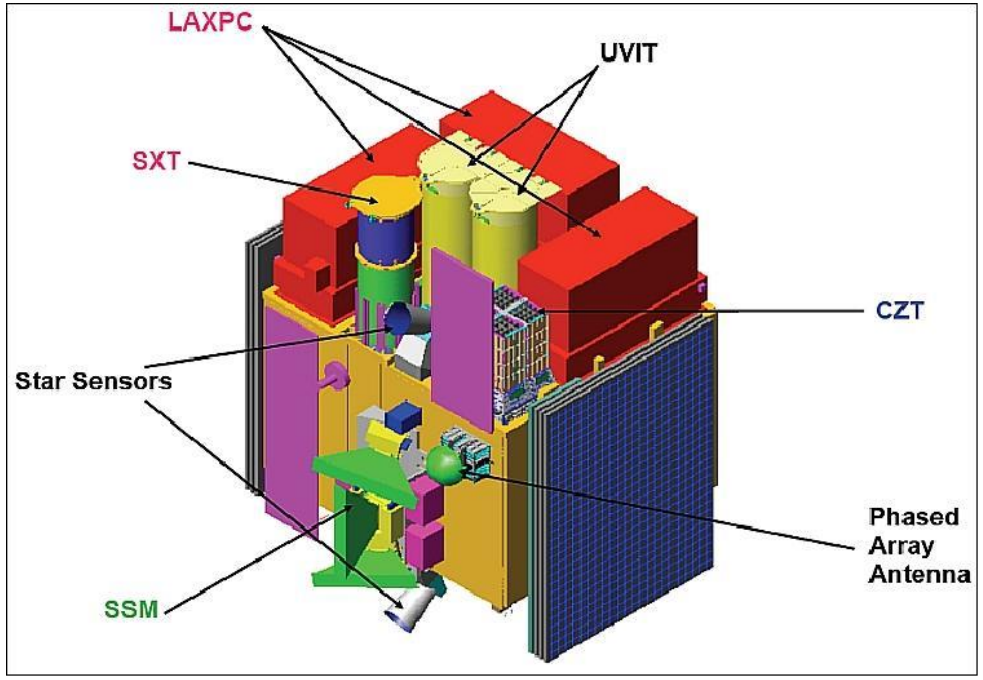
By

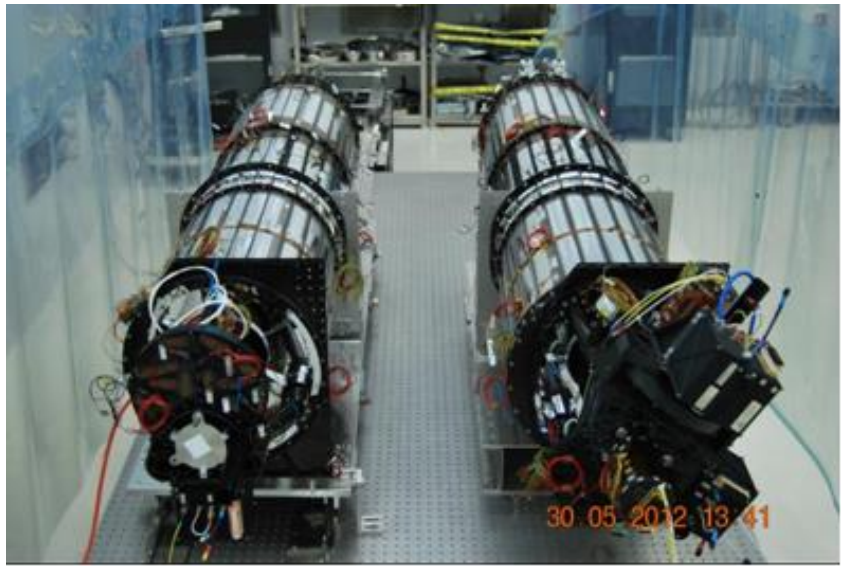
Vikrant Jadhav[1,2] and Jyoti Yadav[1],
[1]Indian Institute of Astrophysics, Bengaluru
[2]Indian institute of Science, Bengaluru

24-August-2020

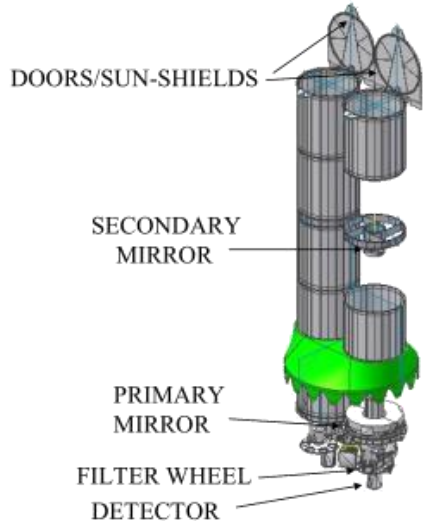
Content

0. Introduction to UVIT
1. Installation
2. Downloading and extracting Level 1 data
3. Digestion
4. Drift correction
5. Creating and merging images

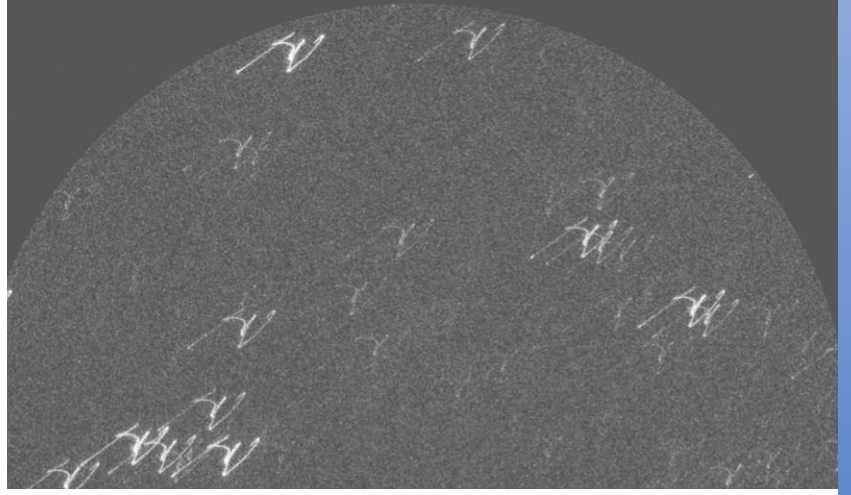




CONFIGURATION OF UVIT



Introduction to UVIT



- It is India's first UV telescope aboard ASTROSAT launched on 28 Sep 2015
- Field of view: 28’ Angular resolution: 1.5”—1.8"
- Simultaneous imaging in three channels: FUV (130–180 nm), NUV (180–300 nm), and VIS (320–530 nm)
- UVIT images are taken in photon counting mode.
- Onboard centroid algorithm notes the position of each event (ideally each photon)
- ASTROSAT is flown with an induced drift during UVIT imaging sessions with rate of 1 arcsecond per second (amplitude ~ 1’). Hence, drift correction is required.
- The integrated image before drift correction looks like the figure in top right.
- CCDLAB performs following corrections:
  - **Detector corrections**: Field distortion (due to fibre optic taper), centroiding bias, flat field
    - These corrections are done during the ‘Digestion’ process
  - **Satellite corrections**: Induced field drift, exposure array (due to the drift, edges of the image have different exposure time. Exposure array is used to normalise the photon counts in the full field of view)
  - **Rotation, transformation and combining images of different orbits**

1. Installation

- The version used here (2019) is available in the github repository. (https://github.com/jikrant3/CCDLAB)
- Alternatively, download a version from https://www.ucalgary.ca/uvit/ (this may or may not be the current version)
- Install *CCDLABsetup.msi* in Windows 7/8/8.1/10
- Keep *UVIT_CalDB* folder in *C:\ directory.*
- If needed, install VC++ redistributable package (*VC_redist.x64.exe*).
- Reference material: I recommend reading it to get the idea of how the program works

  CCDLAB: A Graphical User Interface FITS Image Data Reducer, Viewer, and Canadian UVIT Data Pipeline
  Postma, Joseph E. and Leahy, Denis, 2017, PASP, 129, 115002

2. Downloading and Extracting Level 1 data

2.1. Download '*level1*' file from https://astrobrowse.issdc.gov.in/astro_archive/archive/Home.jsp

2.2. The file name will be something like "*LEVL1AS1UVT20191227A07_062T01_9000003392_22977.zip*"

Meaning of the name:
LEVL1 = level 1 data
UVT = data from UVIT telescope
20191227 = Date of observation
A07_062T01 = Proposal cycle & target ID
A07_062T01_9000003392 = Observation ID
22977 = orbit number

2.3. Make sure to keep the *.gz/.zip* file in a separate folder.
(If there are any files in the same folder, they might get corrupted)

2.4. I recommend checking the digestion settings (3.2. and 3.3.) before extraction, because at the end of extraction the software provides an option for automatic digestion.

2.5. Unzip using `UVIT> Extract L1 gz or zip archives.`

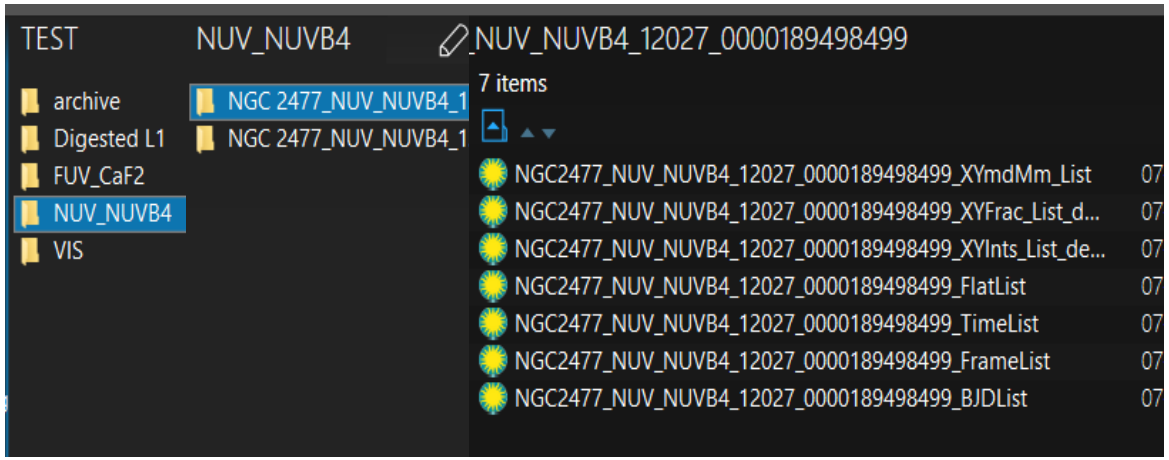
2.6. If you have already checked the digestion settings, select `yes` when asked to digest at the end of extraction. Otherwise, you can digest manually.

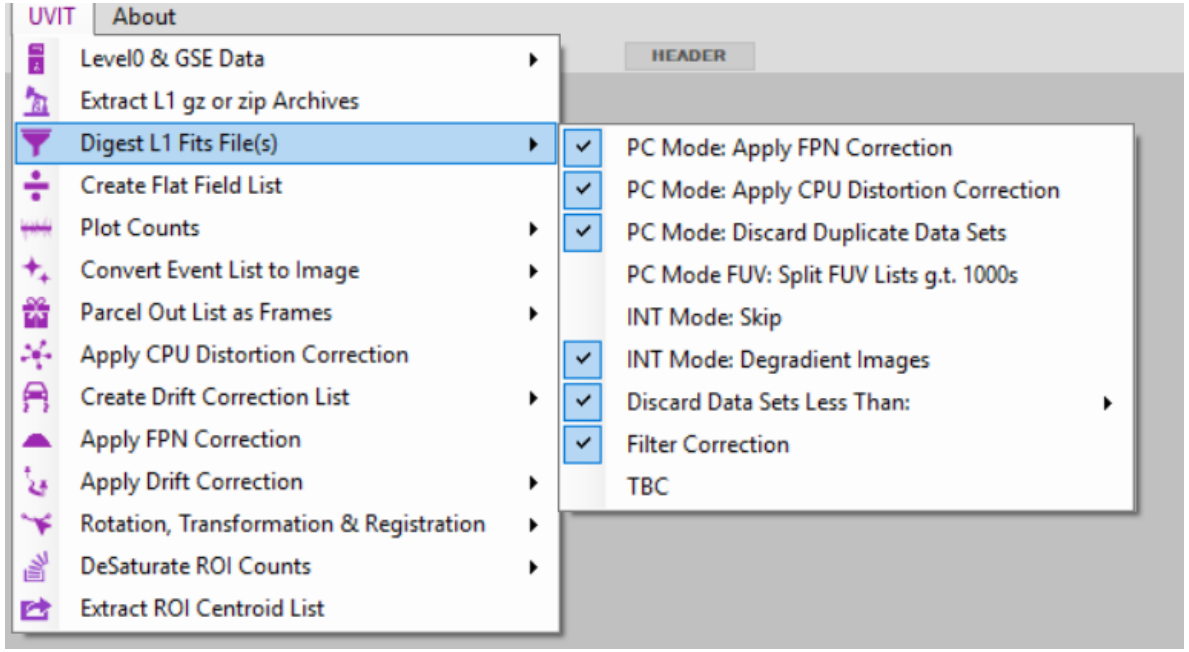
2.7. One can manually extract the *.zip* file.
Then copy all the *level1, .lbt* and *.tct* files at some same folder.
Manual digestion should be performed in the same folder.

3. Digestion

3.1. The digestion options are given in `UVIT>Digest:`

`PC mode: Apply FPN correction:` --
`PC mode: Apply CPU distortion correction:` --
`PC mode: Discard duplicate data set:` There are multiple data dumps from the satellite. Some data may be duplicated. This setting allows to remove such data.
`PC mode FUV: Split FVU lists g.t. 1000s:` --
`INT Mode: skip:` --
`INT Mode Degradient Images:` --
`Discard Data Sets Less Than:` 20 sec or less observation'bright object detection' are ignored.
`Filter Correction:` --
`TBC:` There was an issue in a clock onboard ASTROSAT (in December 2018). This made the clock go in cycles. Use this function to correct the observations affected by this issue.





3.2. If the observations were done before December 2018:

- Digest using `UVIT > Digest L1`. Keep setting as shown in the image at top right.
- Select all (FUV and NUV) "*level1*" files from the master folder and digest them.

3.3. If the observations were done after December 2018:

- Turn on `UVIT>Digest>TBC`. Keep rest of the settings similar to 4.2.1.

3.4. After Digestion you will have files categorized based on Filters and Orbits. As shown in image at bottom left

- Take note of *_xyints* and *_timelist* files

4. Drift correction

- There are two primary methods to do drift correction
  - SELF: Drift is corrected by integrating the counts in an image for some time (e.g. 2 sec) and, aligning and staking all such frames. The drift correction is limited by the bright stars in the image and the stacking time. Longer stacking time will lead to larger PSF.
  - VIS: Uses the VIS channel provided in the observation. The drift is corrected by tracking a few bright stars (there will be more bright stars in visible compared to UV).
  - Combination of SELF and VIS: See section 4.3.
- I prefer using VIS method over SELF method. So, first try drift correction using VIS and if it fails (not satisfactory), try SELF.
- Advance users (or stuck-with-bad-images-ones) can try the combination of VIS and SELF

4.1. SELF Drift correction

- The images will be drift corrected using bright stars in the respective filters.

4.1.1 `UVIT>Create Drift Correction List>From PC mode List`

4.1.2 Select *_XYInts* from all filters. Start with `Stacking Time = 2 sec`. (The final image will be better with lower stacking time. But depends upon the bright stars in the respective filters)

4.1.3 It will create *_XYInts_deDrift* files.

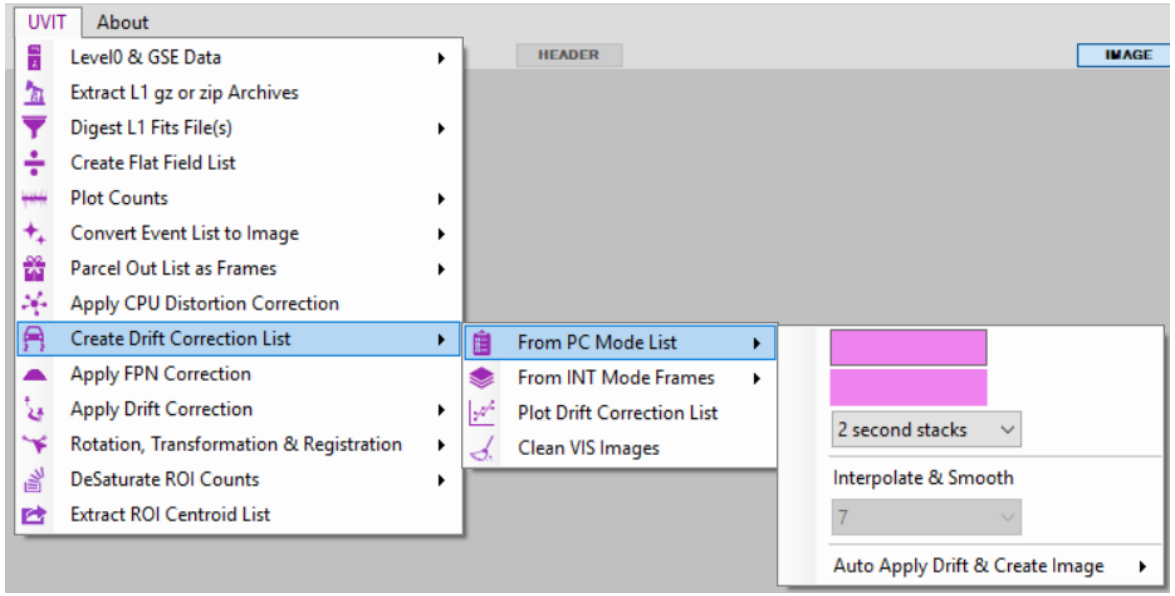
4.1.4. If some images are not drift corrected:

4.1.4.1. Increase the `stacking time` gradually (3, 4, 5 ,7… sec) and try (ideally 5 sec should be the maximum stacking time, but you can increase the stacking time on your own discretion)

4.1.4.2. Repeat `UVIT>Create Drift Correction List>From PC mode List`.

4.1.4.3. Use the original *_XYints* files here.

4.1.4.4. And it will replace the old *_Xyints_deDrift* files



4.2. VIS Drift correction

4.2.1. Look and clean VIS images

4.2.1.1. The different folders in *VIS* signify different orbits.

4.2.1.2. Open all (In case if slow PC, some lower and random number of images can be opened) *VIS* images in one folder/orbit.

- Check other folders. (Not entirely necessary but better to check all VIS folders).

4.2.1.3. Use ‘scan’ feature in CCDLAB (with time 0.0) to look for artefacts and overall drift.

4.2.1.4. If *VIS* images look ok, proceed to next step (4.2.2).

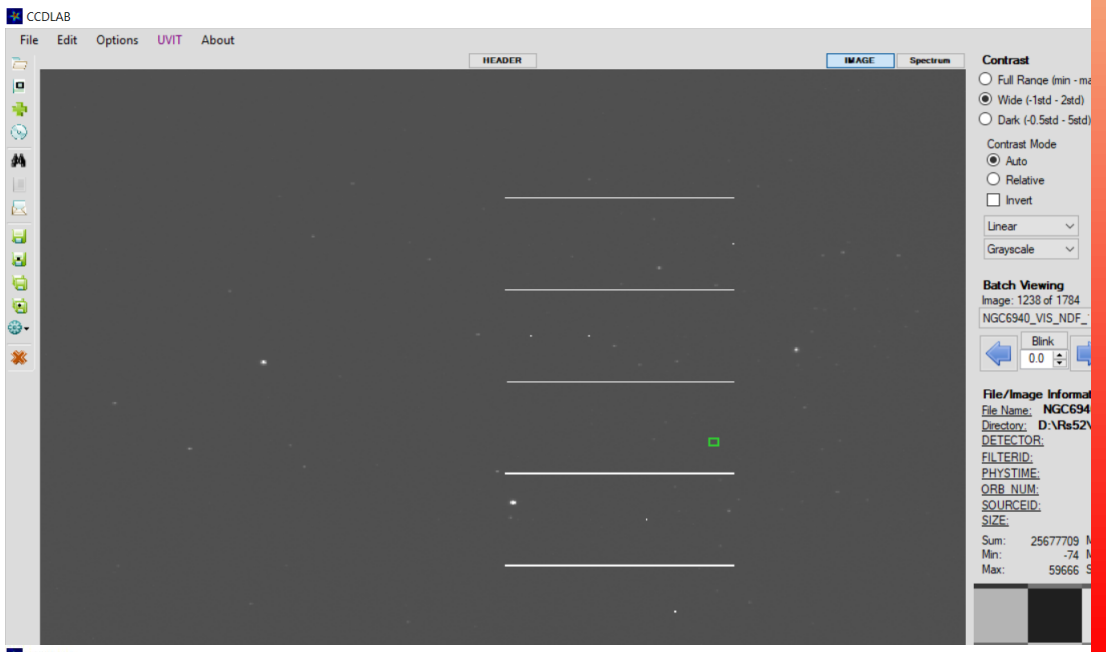
4.2.1.5. If there are artefacts as shown in top figure

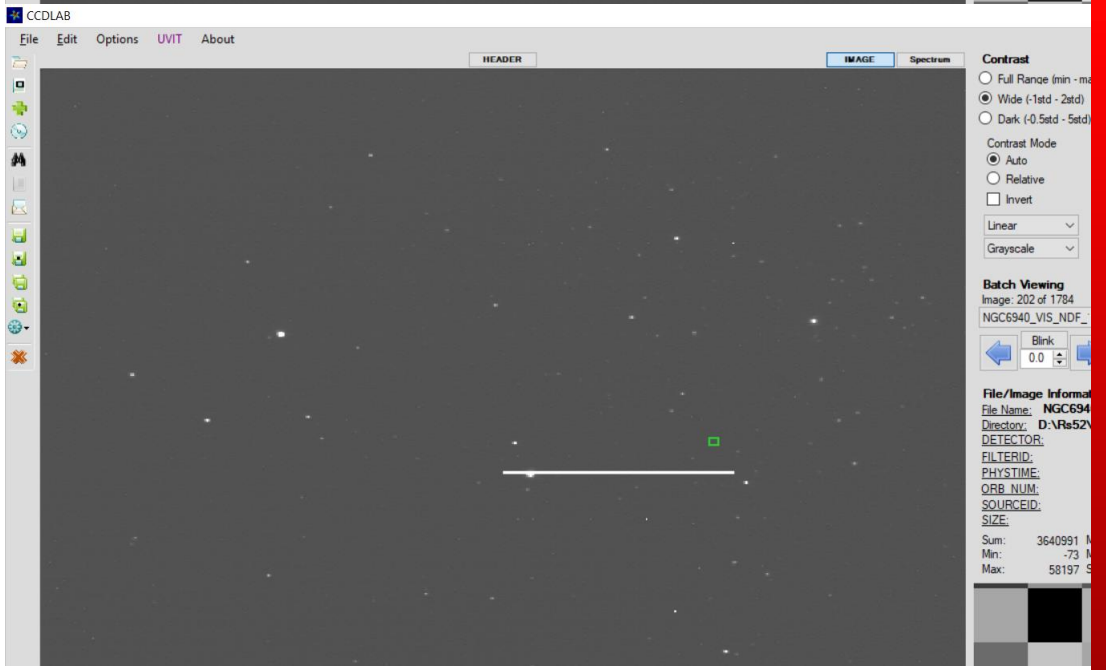
- Use `UVIT>Create Drift Correction List>Clean VIS Images` to clean VIS master folder.
- Check VIS folder again for artefacts, it should be ‘cleaner’ now.

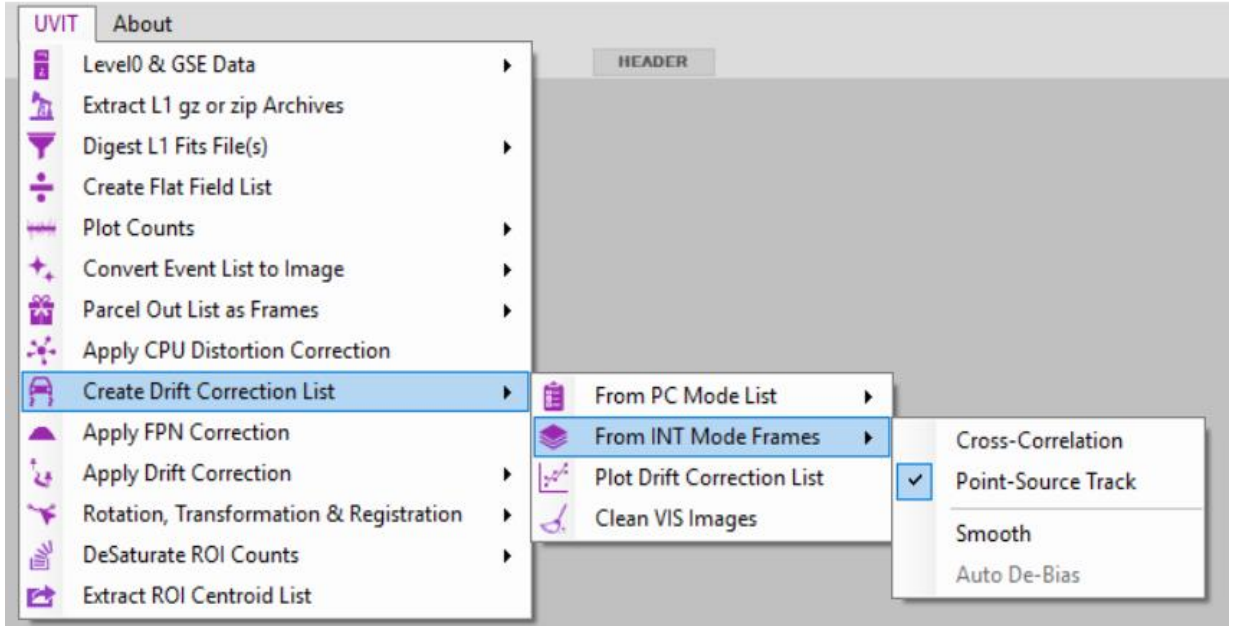
4.2.1.6. If there are still some small artefacts (e.g. bottom figure), the VIS images are good enough. You can go forward to next step (3.2).

4.2.1.7. If there are large artefacts after cleaning, do not use VIS for drift correction.

4.2.1.8. After this step, I recommend restarting CCDLAB.







4.2.2. Creating Drift Correction list

4.2.2.1. `UVIT>Create Drift Correction List> From INT mode Frames.`

4.2.2.2. Select VIS master folder.

4.2.2.3. Select at least 2 bright sources

- Even 'saturated looking' points can be selected
- You have to select these manually for each orbit
- Use LEFT-CLICK to select stars and RIGHT-CLICK to proceed to next orbit.

4.2.2.4. It will create *.drift* files in each *VIS* folder corresponding to their drift.

4.2.2.5. You can check the drift correction plots using `UVIT> Create Drift Correction List>plot Drift Correction List` (doesn't work all the time)

4.2.2.6. If the graphs of drift correction are smooth, proceed to next step (4.2.3.). And you can skip section 4.3.

4.2.2.7. If the graphs have sharp edges/discontinuities (as shown in next page 4.3.), do the finer corrections mentioned in sec 4.3.

4.2.3. Applying Drift Correction

4.2.3.1. Do this separately for NUV and FUV

4.2.3.2. `UVIT>Apply Drift Correction>Consolidate NUV or VIS drift series and Apply to NUV or FUV.`

4.2.3.3. Select all *.drift* files from *VIS* folder (search '*drift' in *VIS* folder)

4.2.3.4. Select *_timelist* files from NUV and FUV Separately (Search '*NUV*time' in *Master* folder)

4.2.3.5. It will create new files with suffix *_deDrift* corresponding to previous files.

4.3. Combination of SELF and VIS

This step is only recommended if VIS *.drift* is showing peaks or discontinuities. (Or sometimes if the stellar PSFs are not circularly symmetric.)

4.3.1. To recheck *.drift* files: `UVIT>Create Drift Correction List>Plot Drift Correction List`

4.3.2. In case of graph like figure (a), recheck the observation date and turn on `TBC` while digesting

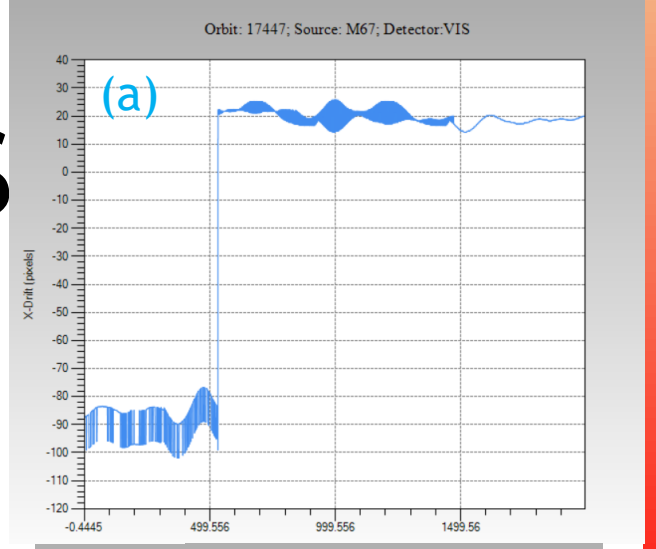
4.3.3. In case of graphs are like (b) or images are like (c, each star has a double→ problem in traking), you need to make finer corrections mentioned in this section.

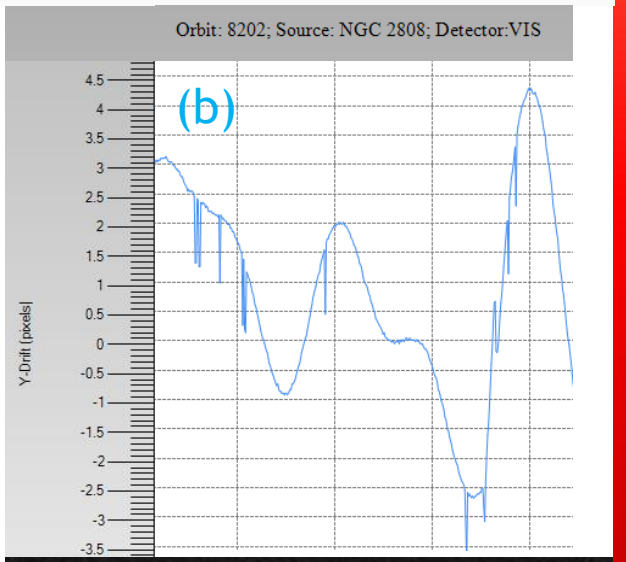
4.3.4. You need to do these corrections only in the folders/orbits which show such problems (b/c)

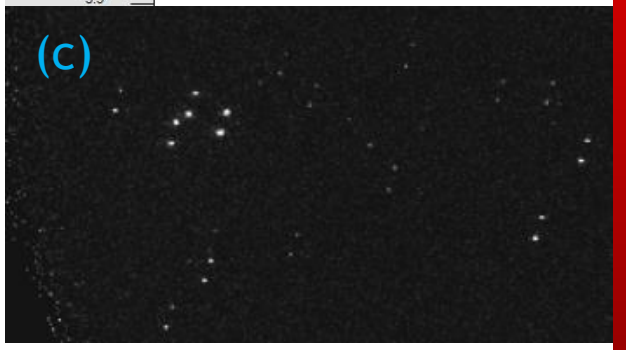
4.3.5. Lets say the *UV folder* is: *NGC_752_FUV_CaF2_22977_0000288276584*
The corresponding *VIS folder* is closest to 0000288276584 e.g. NGC_752_FUV_CaF2_22977_0000288276584

4.3.6. `UVIT>Creat Drift Correction List> From PC mode list`

- 4.3.6.1. Keep `stacking time` 30 or 20 or 10 sec.
- 4.3.6.2. Select *_XYInts_deDrift* in whichever filter and orbit had the problem
- 4.3.6.3. It will create *_Xyints_deDrift_deDrift* files which will be used for final analysis







4.4. Checking PSF

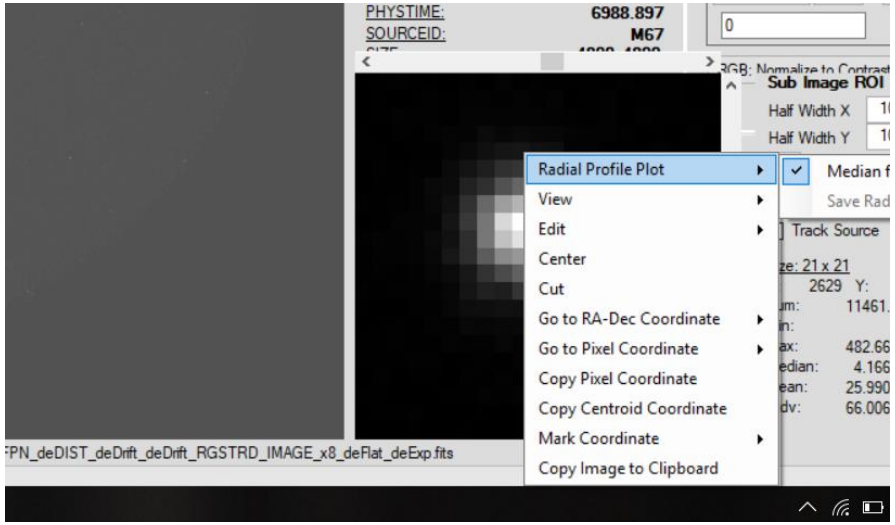
4.4.1. After the drift correction you can check the profile of the stars using CCDLAB

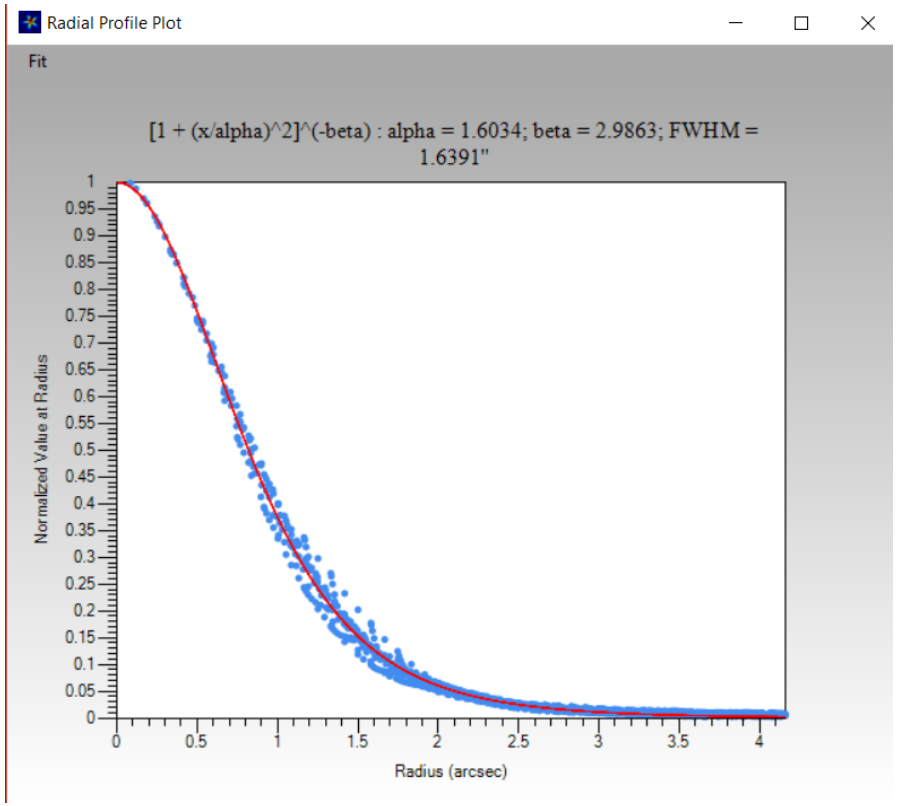
4.4.2. Right click on a star in the smaller `window>Radial Profile Plot`

4.4.3. Use '`Fit`' in the Radial Profile Plot to get FWHM and overall intensity distribution.

4.4.4. If the FWMH is good (<2.0") and radial symmetry is present, you can proceed to merge images.

4.4.5. Otherwise tweak some settings in drift correction process like stacking time and redo the drift correction for problematic files/filters/orbits only. (It will replace previous *_deDrift* files so create a backup, if you want to compare with previous results)





5. Creating and merging Images

5.1. Creating Images to view in the interim:

5.1.1. `UVIT>Convert Event List to Image`

5.1.2. Select *_XYInts_deDrift* files in all (FUV and NUV) folders.

5.1.3. The images are created as *_deDrift_IMAGE*

5.2. Rotating NUV Images: (if you have NUV data)

5.2.1. NUV images are physically rotated and mirrored due to the sensor's physical placement.

5.2.2. `UVIT>Rotation, Transformation & Registration>Transform NUV to FUV Frame`

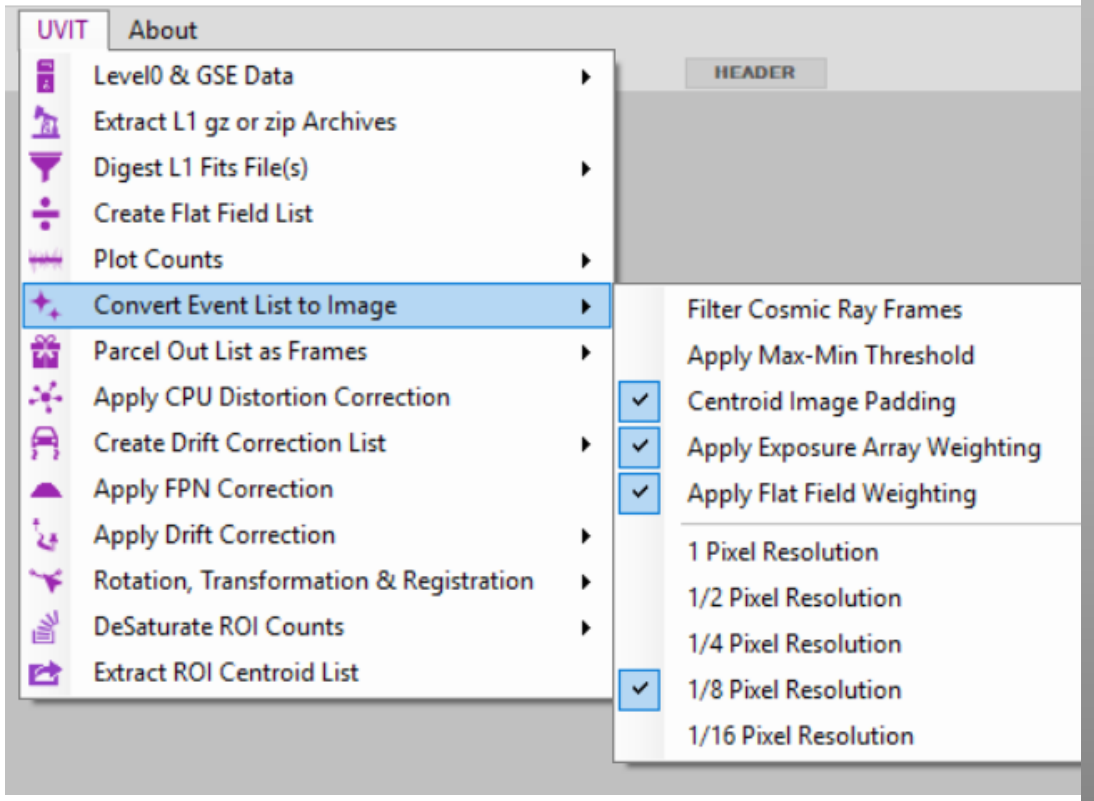
5.2.3. Select final *_XYInts_deDrift* (or *deDrift_deDrift* if created) files in all NUV folders.

5.2.4. It will creat *_XYInts_deDrift_FSRG* files which will be used for further process

5.3. Selecting stars or registration/alignment

5.3.1. Add FUV images along with transformed NUV images using `File>Add file(s)`

5.3.2. Visually select at least 3 bright & unsaturated stars common in FUV and NUV for next step (5.4.)



Creating and merging Images

5.4. Registering/aligning all images in XY coordinates:

5.4.1. `UVIT>Rotation, Transformation & Registration>General registration`

- Typically, `Registration Image resolution = 4` = ¼ pixel

5.4.2. Select final *_XYInts_deDrift* files from all FUV and NUV filters.

5.4.3. Select at least 3 bright and unsaturated stars using LEFT-CLICK and use RIGHT-CLICK to go to next image.

5.4.4. Slight adjustments in translation and rotation are needed in all subsequent images

- Translation: Drag one of the green square
- Rotation: The first point you clicked will be set as origin. Use any other point to rotate the green squares

5.4.5. After all images are registered, *_XYInts_deDrift_RGSTRD* files are created.

5.5. Merging registers images

5.5.1. `UVIT>Rotation, Transformation & Registration>Merge Centroid Lists`

- Go to folder corresponding to a filter
- Select *_XYInts_deDrift_RGSTRD* files in all subfolder in the same filter

5.5.2. Repeat the process for all filters

5.6. The final science ready file will have name like:
NGC7789_NUV_NUVB13___MASTER___deFPN_deDIST_deDrift_FSRG_RGSTRD_IMAGE_x8_deFlat_deExp.fits

Thanks