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Constructing and Reducing Sets of HST Observations Using Accurate Spacecraft Pointing Information

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Abstract. The implementation of "On-The-Fly" Re-Calibration at the ST-ECF and CADC goes some way towards alleviating the problem of obtaining good and timely calibration of HST exposures. However, the data access paradigm is still to consider each exposure individually, re-calibrate them and offer the results to users, who subsequently process the data further.

We describe here techniques to automatically group together HST WFPC2 exposures for cosmic ray removal, co-addition and combination into mosaics with minimal resolution loss. We show that the execution of these tasks has been made essentially automatic.

The ST-ECF archive now offers the possibility to select *"associations"* of datasets and the automatically combined final products. A further spin off of this project is that more reliable pointing information for all exposures is provided.

1. Introduction

In 1995 the ST–ECF introduced, along with the CADC, the re-calibration on-the-fly (OTF) of archived HST exposures. By making use of the best current calibration software and reference files, OTF guarantees that archive users always retrieve from ST–ECF and CADC archives the current best products (i.e., calibrated data).

Pushing the concept further, ST–ECF and CADC are working in the direction of providing the astronomers with an *active* archive system, able to relieve the astronomers of time consuming and boring tasks, therefore increasing the productivity of archive researchers. In this framework the ST–ECF embarked upon a project aimed at building associations of WFPC2 exposures, recovering the otherwise lost information of which observation strategy (e.g., CR-SPLIT, dithering) a WFPC2 proposer decided to employ.

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When looking at an association the archive users immediately see what the shifts between all the exposures were without having to compute them manually. Upon request the archive system can produce a cosmic ray-free mosaic out of the association. Indeed a reliable automatic pipeline has been put in place.

All this is possible thanks to the reliable HST pointing information provided by the jitter files which are a product of the Observatory Monitoring System software at STScI.

2. Jitter Files as a Source of Reliable Pointing Information

After some tests it was clear that:

- the world coordinate system (WCS) keywords available in the header of the exposure FITS files are unreliable. For example, cases where two exposures with identical WCS keywords were found to be clearly shifted.
- Cross correlation to compute shifts among exposures cannot be easily automated, since not all the exposures have enough features or a good signal to noise ratio, and because of the presence of cosmic rays.

Since October 20th 1994 the Observatory Monitoring System subsection of the HST pipeline (STScI) has generated the so called jitter files. Jitter files are normally used to monitor the telescope pointing stability and the trends in the telescope and instrument performance as the orbital environment changes. By correlating the HST Mission Schedule and the time-tagged engineering telemetry data stream downloaded from HST it is possible to reconstruct with great accuracy the pointing sequence of any given scientific observation.

Since the initial production of jitter files, different formats have been adopted. The current format jitter files contain:

- a table of pointing and environment measurements, *e.g.,* right ascension, declination, magnetometer readouts, etc., sampled every 3 seconds.
- a 2D histogram showing the number of times HST was pointing in each element of a 64x64 grid with each pixel 2 milliarcsec in size.

2.1. Jitter Pointing Accuracy

Due to relative errors in Guide Stars coordinates (about 0.3 to 0.4 arcsec), the Fine Guide Stars alignment uncertainty (up to 50 milli-arcseconds [mas]), thermal breathing of the telescope (around 15 mas) and other minor effects, the absolute accuracy in the pointing ranges between 0.5 and 2 seconds of arc. On the other hand the relative accuracy is better than 10 mas within the same HST visit, that is, if the telescope didn't have to re-acquire a guide star during the sequence of observations.

Problems arise if the observation is taken in parallel mode. While the velocity aberration is corrected for the primary instrument, the differential velocity aberration causes the secondary instrument aperture to experience a drift on the sky. The effect can be as high as 50 mas for a full orbit observation, depending on the relative position on the focal plane of the primary and secondary instruments.

3. WFPC2 Associations: Computing the Shifts

Shifts among exposures can hence be computed with good accuracy using the jitter information in the case when all the observations were made during the same visit and WFPC2 was the primary instrument. The procedure consists of:

- Computing the right ascension, declination and roll angle averages and standard deviations from the jitter table, along with some telemetry keywords.
- Assigning a jitter quality flag to each exposure depending on the telemetry keywords and on the standard deviations. The flag can assume the value:
  - 'P' for exposures with small standard deviations and no suspect keyword values,
  - 'G' for exposures with not so small standard deviations or with bad keyword values like GUIDEACT not equal to 'FINE LOCK' etc.
  - 'B' for exposures with missing jitter information or with standard deviations too high or having the SLEWING flag on, etc.
- Grouping together all the 'P' and 'G' exposures
  - taken within the same HST visit
  - in the same filter
  - by the same PI
  - where the distance between each pair is less than 25 PC pixels
  - and the difference between the roll angle of two exposures cannot account for a shift bigger than a tenth of a PC pixel on the full image.
- Computing the shifts Δx and Δy in PC pixels
- Identifying those exposures in the association which are well registered within a tenth of a PC pixel and placing them in sub groups for cosmic ray removal.

4. WFPC2 Association Pipeline

Once we can compute the shifts we may recover the observation strategy (CR-SPLIT, POS-TARG) adopted by a PI. By making use of the computed shifts and rejecting all the exposures not flagged as 'P' (see above), it is possible to run an automatic pipeline which provides not only on-the-fly re-calibrated observations but also offers cosmic ray-free images from all the exposures found to be well aligned within the association.

The overall mosaic of the association can also be requested. In this case the 'drizzle' software (Hook & Fruchter, 1997) is used to build the mosaic of all the cosmic ray-free images preserving photometry, minimising loss of resolution (for sub-pixel shifts) and correcting for geometric distortion using the polynomial model of Trauger et al.

We plan to use a simpler, less CPU demanding, 'shift-and-add' technique for those associations where the shifts are simple integer numbers of pixels.

5. Conclusions

The great reliability of the jitter information has allowed the ST–ECF to:

- Reconstruct the WFPC2 PI's observation strategy (CR-SPLIT, POS-TARG)
- Build associations of WFPC2 exposures
- Compute the shifts among exposures within an association
- Build an automatic pipeline able to clean cosmic rays from aligned exposures and to co-add them with shift-and-add or drizzle techniques.

The ST–ECF archive users can now concentrate on their science while the bulk work of re-calibration, removal of cosmic rays, co-addition of WFPC2 frames is taken care of by the ST–ECF archive system.

The same system will be installed at the Canadian Astronomy Data Centre (CADC).

More information and access to the associations can be found at the following URLs: `http://archive.eso.org/archive/hst/wfpc2_asn/` (ST–ECF) and `http://cadcwww.dao.nrc.ca/` (CADC).

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