

ACS Calibration Software

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Abstract. The current status of ACS calibration software is described, with emphasis on the correction of geometric distortion. Plans for the future are outlined, as are a variety of support utilities which we anticipate providing.

1. Overview

The Advanced Camera for Surveys (ACS) calibration pipeline has been processing science observations for about 6 months. From the outset the pipeline processing environment has supported On-The-Fly-Reprocessing, or OTFR. Indeed, for the majority of people, OTFR will be the most relevant mode of operation. Clearly, not everything is done by the pipeline, and often parameters need adjusting for specific data sets, so stand-alone use of the ACS software tools is also encouraged. A significant number of utilities are provided within the “pyraf” environment which also gives access to the normal suite of iraf/stdsdas software.

The initial pipeline processing of ACS data is accomplished with *calacs*, and the subsequent correction for geometric distortion and associated image combination is accomplished with *PyDrizzle*. The latter includes mapping the two 4096×2048 chips onto a single image.

Some of the calibration observations are obtained essentially contemporaneously with the data, in particular the daily darks which track the growth of hot pixels. These calibration observations require accumulation of data through a (partial) anneal cycle, processing and delivery to support the pipeline, hence there is an unavoidable delay before the best reference files are available for use. In addition there are occasional updates to calibration as new information becomes available, such as photometric measurements. Information on the appropriate reference files may be found on the ACS web page at STScI. Hence, in general both new observers and archival investigators should expect to use OTFR when they retrieve their data.

Below, the operations performed in the ACS calibration pipeline are described as well as some description of the ACS stand-alone software tool usage. We recognize that there is a need for improved cosmic ray rejection software, and we are actively working on this as well as on providing a number of additional support utilities.

2. ACS Pipeline Processing

At the time of writing, the current version of *calacs* is *4.1c*. This software performs basic standard image reductions. For the CCDs, it debiases, subtracts the dark frame, and flat-fields the data. Shutter shading and pre-flash can be corrected for. Known bad pixels and saturated data are flagged and if a CR-SPLIT has been specified, *calacs* will perform cosmic ray rejection. For the MAMA detectors a global linearity correction is applied. Finally, photometric keywords and image statistics are computed.

PyDrizzle 3.3d currently runs on the output products of *calacs*. *PyDrizzle* geometrically corrects the data and provides image combination if appropriate. The final *_drz* image is a single fits file containing three extensions. The first, SCI, is the (single) science image in

units of “count rate,” and the other two images are weight and context. The weight image provides the weight of the pixel as used by *drizzle* (see *drizzle* documentation elsewhere, Fruchter & Hook 2002) and the context image is a bitmap giving information on which images contributed to the output pixel.

The convention adopted for flat-fielding is that of “sky-flat”; hence the geometrical area of a pixel imprints itself on the flat-field, in addition to the photometric “sensitivity” of the pixel. *Drizzle* accounts for this effect and final output drz images are intended to be fully photometrically corrected. By contrast, if the flat-fielded images are analysed prior to geometric correction with *drizzle*, then allowance must be made explicitly for the pixel area. A utility to provide a pixel-area map is in test.

Adopting the OTFR philosophy above, calibrated ACS data are not archived: only the raw observations are archived.

Detailed descriptions of *calacs* may be found in the *ACS Instrument Handbook* (Pavlovsky et al. 2002), through the STScI ACS web site, and in a series of *Instrument Science Reports (ISRs)* for ACS, also available through the STScI ACS web pages. These include *ACS Instrument Science Reports* 99-03 (Hack 1999a), 99-04 (Mutchler et al. 1999a), 99-06 (Van Orsow et al. 1999), 99-08 (Hack 1999b), 99-09 (Mutchler et al. 1999b), 00-03 (Sparks et al. 2000), 01-10 (Sparks et al. 2001), and a new *Instrument Science Report* currently in review (Sparks et al. ISR 02-TBD). Detailed description of *PyDrizzle* may be found through the STScI web site, in particular <http://www.stsci.edu/hst/acs/analysis/drizzle>, with additional documentation in the *ACS Instrument Handbook* (Pavlovsky et al. 2002), the *ACS Data Handbook* (Mack et al. 2002), and Hack (2002), Hack et al. (2003).

3. Dithering, Drizzling and PyDrizzle

There are two related issues that can be dealt with simultaneously using *drizzle*. The first is that ACS has significant internal geometrical distortion. Knowledge of the distortion is captured in the reference file “IDCTAB” which uses fourth-order polynomials. This distortion is implicit in the flat fields, since the flat-fielding convention we adopt is of sky-flats. *Drizzle* corrects for this distortion in a photometrically valid fashion.

The second issue is that the observing system for ACS (and other instruments) allows for “dithered” observations. That is, a sequence of exposures can be specified with the telescope pointing shifted slightly between observations. These small offsets serve to help eliminate bad pixels and hot pixels, span the gap between the chips, and improve pixel sampling somewhat. The same guide stars are used for a dither sequence, offering the necessary high accuracy in relative pointing for image combination. The data from a dither sequence are formally “associated” in the pipeline, and *drizzle* combines all the images in the association.

Larger regions may be covered using “mosaic” sequences, however these would not use the same guide stars and the resulting data do not form a formal “association” in the pipeline.

The *drizzle* software (Fruchter & Hook 2002) available in the *stsdas.dither* package combines multiple, offset images and corrects for geometric distortions. In order to implement *drizzle* for ACS (and for other instruments too) a python wrapper for *drizzle*, “*PyDrizzle*,” was written by Warren Hack. This interfaces to the core *drizzle* routine, and the two are maintained separately (*drizzle* by Hook and Fruchter). *PyDrizzle* provides a versatile and powerful but convenient interface to *drizzle*. It generally uses as its input an “association table” which simply provides a set of images for processing.

The initial implementation of *PyDrizzle* in the pipeline aims to be robust and conservative, by means of default parameter settings. It provides no sub-sampling nor iteration for cosmic ray rejection. It does however provide geometrical correction and photometric correction as well as putting into place the infrastructure required for our upgrade path.

For the case of CR-SPLIT observations, cosmic ray rejection is achieved in the usual way with *acsrej*. The initial implementation of *PyDrizzle* is described in detail in the *Instrument Science Report ACS 01-04* (Sparks, Hack & Hook 2001).

In stand-alone mode, access is provided to all parameters, so, for example, it is possible to correct, combine, rotate, position and subsample data with a one-line command. Also, in stand-alone mode it is possible to generate an association using data that were not originally associated at the proposal writing stage. This is a very powerful enhancement of analysis capability. The utility “*BuildAsn*,” available in *pyraf* and written as part of the *PyDrizzle* support effort, constructs an association table from any appropriate data set. Such a data set may be, for example, all archival observations of a particular galaxy taken at different times, pointings and orientations, but using the same filter and substantially overlapping. Positional misregistrations in image World Coordinate Systems are the norm under such circumstances, arising primarily from uncertainties in the guide star catalog. It is possible, however, to provide corrections in the association table, *PyDrizzle* will recognize these offsets and adjust the positional information appropriately.

4. Upgrade Path: MultiDrizzle

The only cosmic ray rejection currently provided is for the case where CR-SPLIT observations are acquired. However, the utilities available in the *stdas dither* package offer a much more powerful set of options, see Koekemoer et al. (2002a). A typical combination of such utilities is available in the script “*MultiDrizzle*”, developed by Anton Koekemoer, which uses capabilities that may be found in the *stdas dither* package, but which interfaces to *PyDrizzle* rather than *drizzle* directly (see Koekemoer 2002b). Specifically *MultiDrizzle* performs the following steps:

- sky subtract
- drizzle individual images separately
- tweak registration information (1)
- median combine the individually drizzled images
- “Blot” the result back to the original data sets
- identify cosmic rays on individual images *driz_cr*
- tweak registration information (2)
- drizzle the data again, combining into a single image

“*Blot*” is the reverse operation to *drizzle* and is available as part of *PyDrizzle* already. In order to process data in this way, it is necessary to run *calacs* with the flag *EXPSCORR* set to *PERFORM*. This then causes all individual images to be processed with *calacs* through to the flat-fielding stage. Currently, if the data are CR-SPLIT (also for some other modes) only the cosmic-ray-combined observations are processed. With *EXPSCORR* set, the initial basic processing does not need to be repeated. This is a significant advantage for external users who would otherwise need to download all relevant reference files as well as their data. The ability of the back-end system to handle the increase in data volume is currently being evaluated. If it is feasible, we will set this flag.

MultiDrizzle is available privately from Anton Koekemoer on a shared-risk best-effort basis and more information about it can be obtained from the *MultiDrizzle* website:

<http://www.stsci.edu/~koekemoer/multidrizzle>.

STScI personnel are also actively working on a trimmed down, robust version of the script to provide much of the *MultiDrizzle* functionality. We anticipate offering a script that does not attempt image registration initially, although as noted above, users may provide such information themselves and insert it into the association table that drives the processing.

5. Support Utilities

A variety of support utilities have been requested for assisting with ACS analysis efforts. The following list provides examples of requests that are in hand, and which will be implemented as resources permit:

- velocity aberration correction to geometry
- coordinate conversion utilities, detector xy to sky, vice versa, raw xy to corrected xy, vice versa.
- pixel area map
- exposure time image

Input on additional tools is welcome. Our current planning may be found in a new ACS *Instrument Science Report* by Sparks, Hack, Hook and Koekemoer (2002), which includes description of new tools to help with other forms of data such as ramp filter observations. Note, however, that the software will be developed on a priority basis including maintenance of basic existing capabilities, so this should be regarded as a “wish-list.” Finally, ST-ECF has undertaken to provide software support for analysis of ACS grism data, using the “aXe” package.

6. Conclusions

Currently, ACS data are processed through the calibration pipeline, *calacs*, to provide basic image reductions, and then with *PyDrizzle* to provide geometric distortion correction and image combination. In stand-alone mode, *PyDrizzle* offers a wide variety of additional functionality, as compared to the default parameter settings adopted in the pipeline environment. A particularly powerful enhancement is the capacity to develop new “associations” and process a group of overlapping images into a single, combined image. Ways are being explored to improve the cosmic ray rejection strategy for dithered data. As resources permit, additional new utilities are being brought online to enhance the scientific utility of ACS observations.

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References

- Fruchter, A. S. & Hook, R. N. 2002, *PASP*, 114, 144
- Hack, W. J. 1999a, “CALACS Operation and Implementation,” *Instrument Science Report ACS 99-03* (Baltimore: STScI)
- Hack, W. J. 1999b, “CALACS reference files,” *Instrument Science Report ACS 99-08* (Baltimore: STScI)

- Hack, W. J. 2002, in ASP Conf. Ser., Vol. 281, *Astronomical Data Analysis Software and Systems XI*, ed. D. A. Bohlender, D. Durand, & T. H. Handley (San Francisco: ASP), 197
- Hack, W. J., Busko, I., & Jedrzejewski, R. 2003, “New STScI Data Analysis Applications,” *ADASS XII Proceedings*
- Koekemoer, A. M., et al. 2002a, *HST Dither Handbook*, Version 2.0 (Baltimore: STScI)
- Koekemoer, A. M., Fruchter, A. S., Hook, R., & Hack, W., 2002b, *MultiDrizzle: An Integrated Pyraf Script for Registering, Cleaning and Combining Dithered Images*, this volume, 337
- Mack, J., et al. 2002, in *HST ACS Data Handbook*, version 1.0, ed. B. Mobasher (Baltimore: STScI)
- Mutchler, M., Jedrzejewski, R., & Cox, C. 1999a, “ACS calibration pipeline testing: basic image reduction,” *Instrument Science Report ACS 99-04* (Baltimore: STScI)
- Mutchler, M., Hack, W., Jedrzejewski, R., & Van Orsow, D. 1999b, “ACS calibration pipeline testing: cosmic ray rejection,” *Instrument Science Report ACS 99-09* (Baltimore: STScI)
- Pavlovsky, C., et al. 2002 *ACS Instrument Handbook*, version 3.0, (Baltimore: STScI)
- Sparks, W. B., Jedrzejewski, R., Clampin, M., & Bohlin, R. C. 2000, “Software tools for ACS: Geometrical Issues and Overall Software Tool Development,” *Instrument Science Report ACS 00-03* (Baltimore: STScI)
- Sparks, W. B., Hack, W. J., & Hook, R. N. 2001, “Initial Implementation Strategy for Drizzle with ACS,” *Instrument Science Report ACS 01-04* (Baltimore: STScI)
- Sparks, W. B., Hack, W. J., Hook, R. N., & Koekemoer, A. 2002, “ACS Software Tool Development,” *Instrument Science Report ACS 02-TBD* (Baltimore: STScI)
- Van Orsow, D., Mutchler, M., Hack, W., & Jedrzejewski, R., 1999, “ACS calibration pipeline testing: error propagation,” *Instrument Science Report ACS 99-06* (Baltimore: STScI)