AstroDrizzle: More than a New MultiDrizzle

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AstroDrizzle is new software for aligning and drizzling Hubble Space Telescope images. It is a substantial improvement on the current MultiDrizzle with a particular enhancement on the handling of astrometry. This software is part of the new STSDAS package DrizzlePac, a suite of tasks that will replace the STSDAS Dither package. This package allows the user to do a lot more than simply combine their HST images with high photometric and astrometric fidelity. We present examples based on HST images that show how the tasks in this package now provide a new paradigm for working with the world coordinate system of these images, for aligning the images and for combining them with AstroDrizzle to produce the best possible HST science. The details of the combined images generated by AstroDrizzle are also discussed to illustrate how the provenance of the final product now gets maintained.

Our Ideology

- Astrometry should be like any other calibration
- Separate reference files should no longer be needed after using them to calibrate the data
- All astrometric information should be in the image header

Our Goals

- The best available geometric distortion information should be incorporated into the HST image headers
- A user should be able to easily align an image and update its WCS to match another image or catalog
- Users should be able to easily exchange astrometric solutions with each other and/or the archive

A Whole New Environment

Meeting these goals resulted in the development of the new **DrizzlePac** package, a Python package which contains many tasks including:

✓**AstroDrizzle** (the replacement for MultiDrizzle)

- combines images using the input image headers containing the full geometric distortion model as part of the WCS
- Image headers get updated to include distortion information using a unique combination of FITS conventions and standards.

The remaining tasks in the **DrizzlePac** package provide a complete implementation of this new standard including:

✓updates headers to follow the new FITS conventions,

✓interpreting the WCS using the distortion model for coordinate transformations,

✓aligning images using the full WCS information, and

✓extracting a full WCS with distortion for sharing.

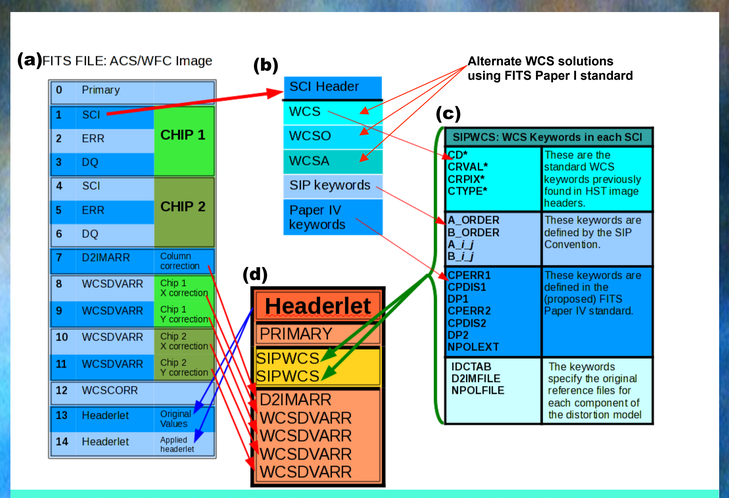

Figure 1: Description of the full WCS, distortion included, and the headerlet. The keywords associated with each WCS are listed in Table (c), while the full set of extensions that make up a headerlet are shown in Table (d).

The "New, Complete" WCS

AstroDrizzle relies on the WCS information to align and combine images without requiring any additional external reference information. This required development of the means to record distortion solutions in the WCS. The ACS distortion model, the most complex distortion model for any HST image, required the combination of :

- **SIP convention**: used for the polynomial distortion coefficients,
- **FITS Paper IV**: Paper IV lookup tables get used for the optional non-polynomial distortion terms as well as the 1-D column corrections .
- **FITS Paper I**: alternate WCS nomenclature allows AstroDrizzle and other DrizzlePac tasks to keep track of multiple WCS solutions which share the same distortion model

Figure 1 illustrates the keywords that now appear in calibrated HST image headers after being updated by AstroDrizzle to fold in the distortion reference information into the WCS. The new distortion extensions rely on original calibration reference files named *NPOLFILE (non-polynomial distortion file) and D2IMFILE (detector-to-image correction)* to replace the DGEOFILE reference file.

This entire WCS, complete with distortion information, can be extracted as a single entity: the 'headerlet'. The headerlet can then be applied to copies of that original image to update them with the WCS solution stored in the headerlet. This allows the user to manage and track the entire WCS, distortion included, for every image.

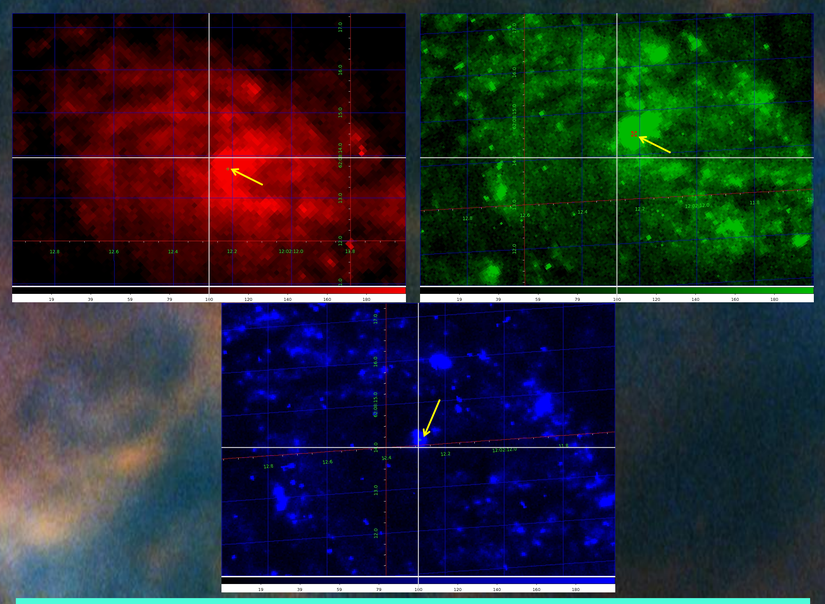

Figure 2: Close-up of core of NGC4041 from single exposures taken using WFPC2 F814W (red), ACS/WFC F658N (green), and WFC3/UVIS F336W (blue). These image sections show the exact same area on the sky based on the WCS information in the WFC3/UVIS image header. The same feature in the core has been marked by a '+' symbol at the tip of each yellow arrow in each image. All images have been linearly scaled from -1 to 200.

EXAMPLE:

The tasks in the DrizzlePac package were used to compute the astrometric errors found when trying to align WFC3/UVIS, ACS/WFC and WFPC2 images of NGC4041; specifically,

- **WFC3/UVIS**: ibgt19iuq, ibg19ivq, ibgt19iyq
- **ACS/WFC**: j8mx61itq, j8mx61ivq
- **WFPC2**: u6eaf805r, u6eaf806r

Figure 2 illustrates the original alignment of these images based on the WCS information provided in the image headers delivered by the HST archive.

Processing Steps:

1. Use 'astrodrizzle' to create a drizzled image for each instrument.
   - This relies on very good HST alignment within a single visit to generate an image for each instrument with many of the cosmic-rays removed.
2. Use 'tweakreg' to update the WCS information of the ACS and WFPC2 drizzled image to align with the WFC3/UVIS drizzled product.
3. Apply the new WCS alignment for the ACS and WFPC2 images to the original calibrated (_flt.fits and _c0m.fits) files using 'tweakback'
4. Use 'astrodrizzle' to create a new drizzled image for each instrument that is co-aligned to the WCS solution of the WFC3/UVIS data.

Figure 3 illustrates the results of aligning the newly updated calibrated (_flt.fits and _c0m.fits) images.

Figure 3: Composite image based on WFC3/UVIS F336W (blue), ACS/WFC F658N (green) and WFPC2 F814W (red) observations of NGC4041 taken at 3 different visits. The WFC3 image was created using 'astrodrizzle', and the other instrument's images were updated using DrizzlePac tasks to align with the WFC3 drizzled image. The updated WFPC2 and ACS images were then combined using 'astrodrizzle' to create the co-aligned drizzle products (one for each instrument) that was overlaid in DS9 to create this composite image. The WFPC2 image was not dithered resulting in the edges of each chip being evident to the North and West of the core in this composite.

ALIGN

Alignment of HST images requires calibration of the distortion model to less than 0.1 pixels and accurate positions of sources within each image. HST calibrations for ACS and WFC3 remove distortions with residuals which has an RMS of <<0.1 pixels, often close to 0.01 pixels. The DrizzlePac package includes the following tasks:

✓**Pixtosky, skytopix and pixtopix**: perform coordinate transformations based on the full distortion model included in each HST image header

✓**Tweakreg**: computes the offset between images using point source finding and catalog matching and applies that offset directly to the image header's WCS keywords.

✓**Tweakback**: applies WCS solution recorded in drizzled image header (after being updated by 'tweakreg') to distorted input files (*e.g.*, _flt.fits or _c0m.fits) used to create the drizzled image.

These tasks rely on the STWCS package to provide a simple interface to the entire WCS for all HST instruments and to support all the coordinate transformations.

COMBINE

AstroDrizzle now replaces MultiDrizzle as the primary task for correcting distortion and removing cosmic-rays in HST images. AstroDrizzle differences and improvements include that it:

- like the rest of the DrizzlePac package, was implemented using Python and C.
- uses WCSLIB to perform astrometric computations through the PyWCS and STWCS packages to transform pixel coordinates to the sky then to an output tangent plane.
- corrects a number of bugs which still remain in MultiDrizzle; bugs such as,
  - ✓ not correctly applying the distortion to binned data,
  - ✓ introducing astrometric errors when rotating the final drizzled image, and
  - ✓ not "dropping" as many pixels from the final output image.
- uses Python's multiprocessing module to speed up the single drizzle and cosmic-ray identification steps (more steps will use parallel processing later)
- can be used either interactively using the newer, smarter TEAL GUI interface or it can be run interactively or from Python tasks using Python syntax
- relies on configObj files (.cfg/.cfgspc) files to keep track of parameter values for use with TEAL. These files can be written out or loaded into TEAL to run all the DrizzlePac tasks.
- can be run on all Python-supported platforms: Linux (RHEL5/6), Mac OS X (Leopard/Snow Leopard/Lion), and even Windows.

SHARE

A lot of effort can often go into getting proper alignment of images so that they can be combined correctly to obtain clean images for study. The DrizzlePac supports the use of headerlets as a means of recording and sharing the WCS solution from a user's or group's well-aligned set of images.

Tasks for working with headerlets include:

- ***Creating headerlets***: write_headerlet, archive_headerlet, extract_headerlet
- ***Applying headerlets***: apply_headerlet, attach_headerlet
- ***Managing headerlets***: headerlet_summary, restore_headerlet, delete_headerlet

The small size of a headerlet, typically less than 100kb, and full FITS compliance allows them to be easily shared. Keywords in the headerlet PRIMARY header provide information on what image it applies to as well as any information on what this specific WCS solution , such as the image or astrometric catalog/field that was used to derive this WCS solution, the RMS of the fit, and the author of the headerlet. Multiple headerlets can be derived for and applied to any image, each with its own astrometric solution.

Current Status

The DrizzlePac package has been installed in the pipeline for use on ACS and WFC3 images as of June 6, 2012. It can be downloaded as part of the IRAFX beta release (updated weekly) from:

http://stsdas.stsci.edu/irafx

A full public release of the entire STScI_Python package containing DrizzlePac will be made available for download by mid-July 2012.

The DrizzlePac Handbook along with examples of how to use AstroDrizzle (complete with data and config files) and much more can be found on the DrizzlePac homepage at:

http://drizzlepac.stsci.edu/

Future Development

A lot of testing went into the development of this entire package, however, there can always be improvements. This package's role in operational pipeline processing means that there will be a continued effort to improve this software, fixing bugs as they are noted, and making it easier for people to use. Anyone using this software can report bugs or problems using this software to:

help@stci.edu

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