Aligning HST Images to Gaia: a Faster Mosaicking Workflow

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Abstract
We present a fully programmatic workflow for aligning HST images using the high-quality astrometry provided by Gaia Data Release 1. Code provided in a Jupyter Notebook ([https://github.com/spacetelescope/gaia_alignment](https://github.com/spacetelescope/gaia_alignment)) works through this procedure, including parsing the data to determine the query area parameters, querying Gaia for the coordinate catalog, and using the catalog with TweakReg as a reference catalog. This workflow greatly simplifies the normally time-consuming process of aligning HST images, especially those taken as part of mosaics.

Introduction
Gaia Data Release 1 (DR1) provides high-accuracy positions for over one billion stars with a median positional error approximately 2.4 milliarcseconds (Gaia Collaboration et al. 2016), smaller than one tenth of any HST imaging instrument pixel. The catalogs derived from DR1 can be used as a reference for aligning HST images to within very small positional errors, which allows for the images to be combined easily with software such as AstroDrizzle. Moreso, by providing accurate catalogs covering large areas, using the Gaia catalogs streamlines the procedure of creating HST mosaics. Without catalogs as accurate as those provided by Gaia mosaicking is often done by aligning images relatively to each other using sources in the overlapping regions of pairs of images. Since the overlap between mosaic tiles is small this is often a difficult process which can require many iterations. The use of the Gaia catalogs greatly simplifies this process, often only requiring one pass for alignments of many mosaic tiles taken in many filters.
A Jupyter notebook has been written providing an example path through this process, with many of the procedures written in functions that could be applied in other codes. The notebook is available as part of a github repository.

Caveats

While this method does greatly reduce the effort necessary to align data, especially large mosaics, there are a small number of issues that may make this workflow less efficient or accurate for various datasets.

Photometric Ranges

Gaia DR1 provides a broad, white-light $G$ band magnitude for all sources recorded (Jordi et al. 2010). In general, almost all of the stars measured by Gaia are $G < 21$. Naturally, the fainter stars recorded in the Gaia catalogs have higher positional uncertainties than the brighter ones. However, these low-uncertainty, bright stars often saturate the detectors of HST imagers, especially when wide band filters are used with longer exposure times, rendering them useless for alignment. However, preliminary testing on various datasets shows the larger positional uncertainties on the fainter stars do not affect the alignment solution much (a more thorough analysis of this will be presented in a future ISR).

Source Densities

Although Gaia has mapped positions of > $10^9$ sources, the density of sources across the sky is naturally not uniform, so some regions of the sky have very few sources in the Gaia catalogs. Therefore, sparse fields may not align well enough with this methodology. Since HST images can detect fainter sources than Gaia, in some cases, aligning to other HST images may provide better relative astrometry than Gaia, as the increased number of sources increases the quality of the fit. For fields with many sources this is significant enough to only affect science where accurate astrometry is highest priority (also presented in a future ISR).

Proper Motions

Except for a small subset of sources, Gaia DR1 does not contain proper motion measurements (DR2 will). As when working with any source catalog, the proper motions of sources can reduce the quality of the alignment if the epoch of the catalog and data are very different.

References


Figure 1: DSS imagery of the target, LMC-N44 used in the example notebook (only a small subset of the data is used for brevity). The HST observation footprints are overlaid as boxes, and the circles are the Gaia sources in the same field. Code to create figures such as this are included in the notebook.
Figure 2: The full HST/WFC3 mosaic of the target, LMC-N44, used in the example notebook. The alignment methodology presented in the notebook greatly decreases the time and levels of user input necessary to create mosaics such as this.