WFC3 DASH Reduction Pipeline* Development and Launch

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*https://github.com/spacetelescope/wfc3_dash

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I. Abstract

A new observing technique (DASH — drift and shift) has recently been developed for the Wide Field Camera 3 (WFC3) on the Hubble Space Telescope (HST) that allows wider areas to be surveyed more efficiently. This technique relies solely on HST's gyroscopes to point and guide the telescope. However, this outputs smeared images due to the intrinsic "drift" that occurs from relying solely on the gyros during an observation. The non-destructive readout mode of the WFC3/IR sensor allows most of the native HST resolution to be recovered for data taken using the DASH observing mode. This is accomplished by creating partial images from differences in the consecutive, non-destructive reads and realigning them ("shift"). Such reduction can be onerous and thus the HST user community could greatly benefit from a public reduction pipeline that can easily reduce DASH data. In this contribution, we present the DASH Reduction Pipeline: a set of tools for reducing WFC3/IR images taken under gyro control. The pipeline creates the partial images and aligns them, while also including options for creating mosaics, segmentation maps and association files. In addition, it allows users to customize how they run it based on the contents of the image. We provide extensive documentation and tutorials to guide users through the reduction process. Following the completion of the pipeline, this project will be available on the Space Telescope Science Institute (STScI) Github page for complete public access.

II. DASH Observing Mode

DASH is an HST observing mode originally developed to allow wider areas of the sky to be surveyed more efficiently. Wide field surveys with WFC3 are inefficient due to HST's natural lower limit to the exposure time of a single orbit. This minimum exposure time arises from overheads associated with guide star acquisition.

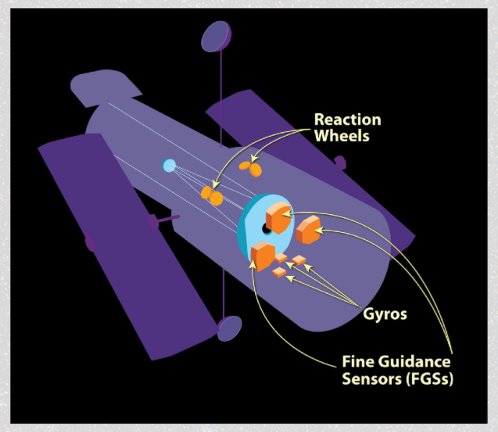
Overheads on WFC3

Action	Overhead Time
Guide-star acquisition	6 minutes
Total Exposure time	Up to 40 minutes
Buffer dump	5.8 minutes
Spacecraft maneuvers	Anywhere from 0.3 to 1 minute

WFC3 Instrument Handbook

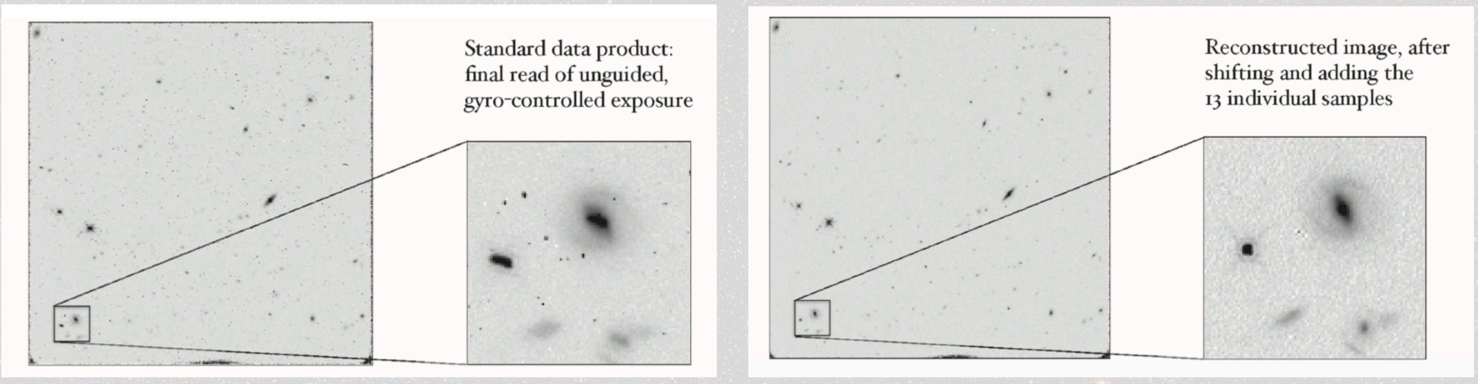
Keeping in mind WFC3's small field of view (4.6 $arcmin^2$), the inefficiency associated with wide surveys on WFC3 arises from the long exposure times and the small field of view.

The Fine Guidance Sensors (FGSs), 1 of the 5 sensors on HST, are responsible for acquiring a guide star during an observation. This process prevents drift that would otherwise occur if HST relied solely on the gyroscopes. The DASH technique is able to significantly reduce overhead times by no longer relying on the FGSs during an observation.Therefore, DASH is able to fit more than 2 pointings per orbit, compared to the 2 guide star acquisitions allowed per orbit when not using the DASH mode. However, this produces smeared output images when reduced through the standard pipeline. Therefore, a specific reduction pipeline is needed to reduce DASH data.



Part of HST's Pointing Control System (NASA. nasa.gov)

For a more detailed description of DASH, reference Momcheva et. al., 2016.

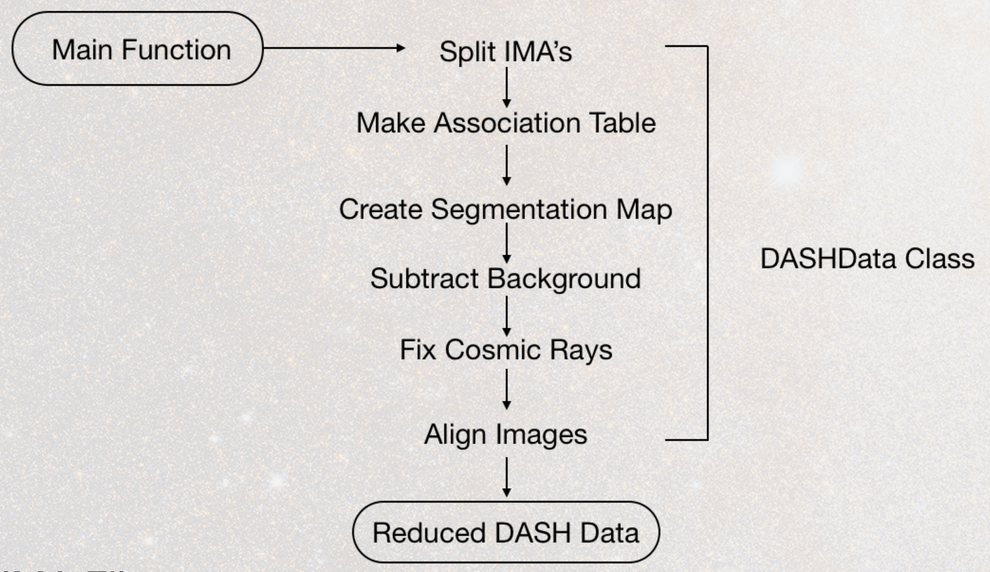


DASH image before (left) and after (right) being run through a similar DASH pipeline (Momcheva et. al., 2016)

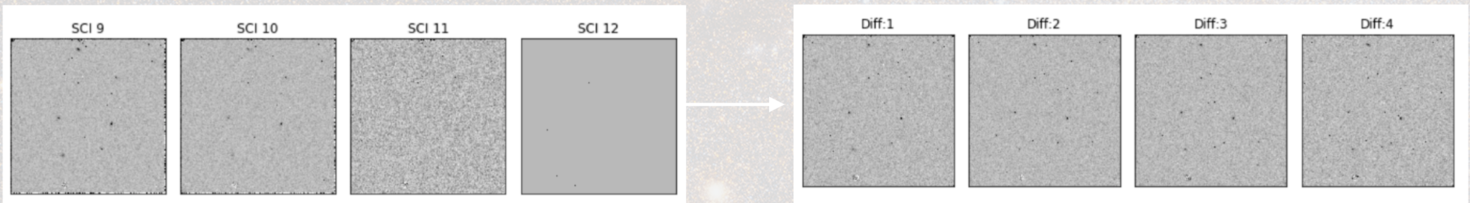
III. Motivation

The purpose of this project is to successfully develop and implement a generalized DASH pipeline to ease the process of reducing DASH data. The pipeline should be customizable, able to be changed according to the users scientific goals, while also allowing for easy mosaic creation. Additionally, the pipeline will include a Jupyter Notebook tutorial that walks the user from data download to finished product ready for science analysis. The goal is to have the final product available for public use on STScI's official Github page.

IV. DASH Pipeline



Splitting the IMA File:
- First step of reduction process
- Takes difference of each extension of the IMA file



FLT vs. IMA:
- Both outputs of calwf3 pipeline
- FLT - single IR calibrated exposure (smeared for DASH data; 1 science extension)
- IMA - calibrated intermediate IR multiaccum image (multiple science extensions corresponding to non-destructive readouts)

Make Association Table:
- Makes a new association table for the reads extracted from a given IMA

Create Segmentation Map:
- Creates segmentation map (from original FLT file) that is used in background subtraction and to fix cosmic rays
- Uses photutils to detect sources and create source list
- Also option to create segmentation map from difference files

Subtract Background:
- Performs median background subtraction for each individual difference file

Fix Cosmic Rays:
- Uses L.A.Cosmic (van Dokkum, P. G., et. al. 2001) to locate cosmic rays, then removes them within the boundaries of objects, as defined by the segmentation map

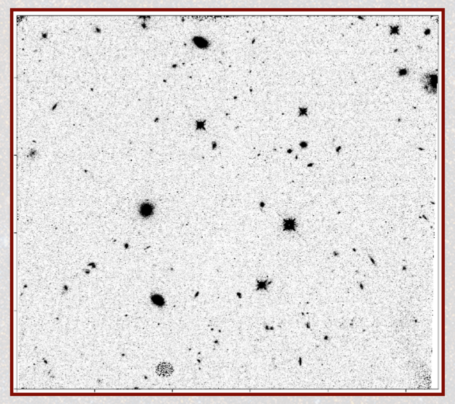
Align Images:
- Aligns new FLT's (difference images) to a catalog or themselves
- Aligns WCS's
- Drizzles images together

Main Function:
- Runs entire pipeline in order
- Has option to create mosaics

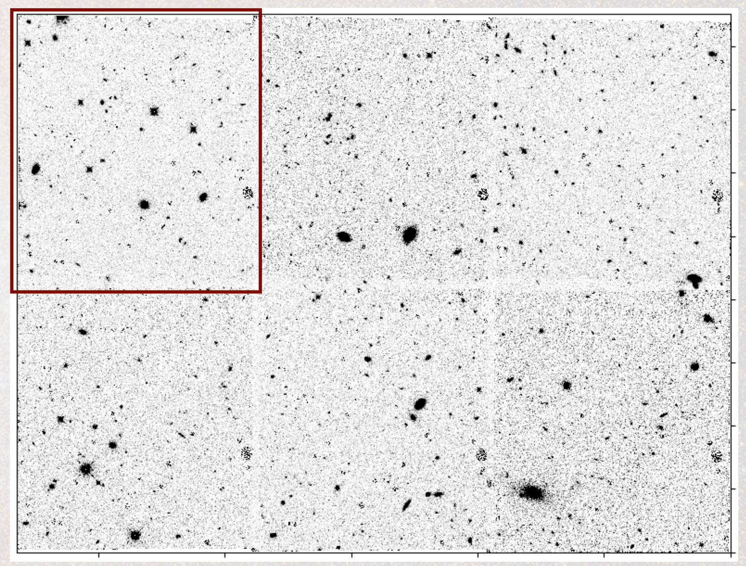
V. Jupyter Notebook Tutorial

An important aspect of this project was the inclusion of a Jupyter Notebook tutorial that walks the user from data downloads to calibrated data ready for science analysis.

The Jupyter Notebook tutorial currently uses the first DASH proposal (GO 14144, PI: van Dokkum) and outputs reduced images. Multiple IMA files can be combined to create mosaics.



Output image from DASH Jupyter Notebook tutorial for proposal GO 14144 (PI: van Dokkum)



Output mosaic from DASH Jupyter Notebook tutorial for proposal GO 14144 (PI: van Dokkum)

Segmentation map from DASH Jupyter Notebook tutorial for proposal GO 14144 (PI: van Dokkum)

The notebook is currently in the process of being expanded into a set of three different notebooks: 1) One that breaks down the IMA file, 2) one that aligns different IMA files to a catalog, and 3) one that aligns different IMA files to a single mosaic.

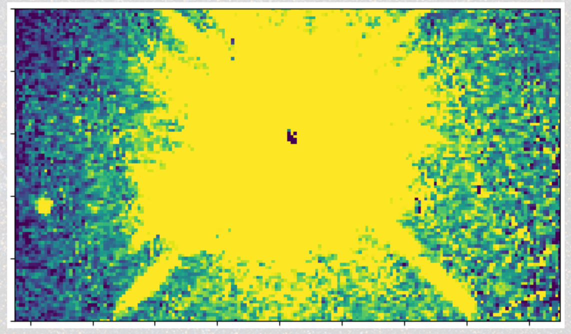
1)
1. Imports
2. Introduction
3. Downloading Relevant Data
4. Running DASH
   a) Creating DashData object
   b) Create diff files
   c) Create association tables
   e) Subtract background from new FLT's
   f) Fix cosmic rays

2)
   g) Align reads to each other
   h) Align reads to catalog
   i) Align reads to each other, then to gaia catalog

3)
5. Creating Mosaic

VI. Troubleshooting & Updating Pipeline

Following the reduction process, some bright objects contain dark regions in their centers. This is most likely due to either over-saturation or subtraction errors somewhere in the pipeline.



Example of dark spot in center of bright object following DASH reduction pipeline (proposal GO 14624)

Future projects include:
- Adding more customization options
- Updating the notebooks & documentation
- Writing additional wrappers and setup scripts

The DASH pipeline and updates are available at:
https://github.com/spacetelescope/wfc3_dash

VII. Acknowledgements

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VIII. References

Dressel, L., 2019. "Wide Field Camera 3 Instrument Handbook, Version 12.0" (Baltimore: STScI)
Momcheva I., van Dokkum, P. G., van der Wel, A., et. al. 2016, ApJL
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van Dokkum, P. G., et.al. 2001, arXiv: https://arxiv.org/pdf/astro-ph/0108003