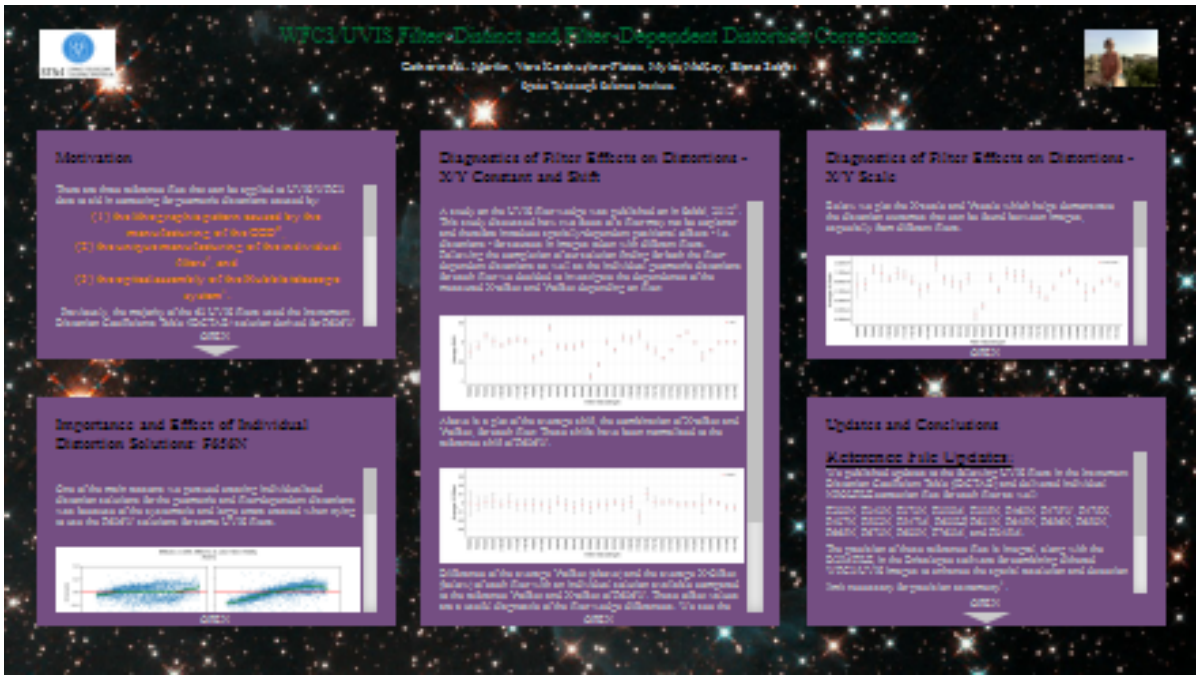
WFC3/UVIS Filter-Distinct and Filter-Dependent Distortion Corrections



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MOTIVATION

There are three reference files that can be applied to UVIS/WFC3 data to aid in correcting for geometric distortions caused by:

(1) the lithographic pattern caused by the manufacturing of the CCD[2],

(2) the unique manufacturing of the individual filters[4], and

(3) the optical assembly of the Hubble telescope system[1].

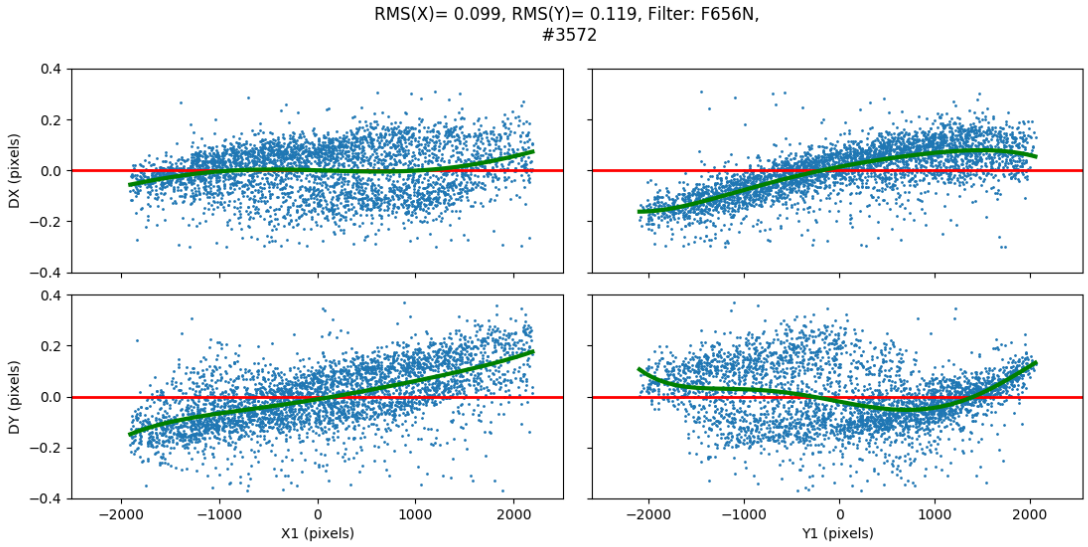
Previously, the majority of the 63 UVIS filters used the Instrument Distortion Coefficients Table (IDCTAB) solution derived for F606W in place of individual solutions to correct for the large scale distortions caused by the optical assembly.

14 UVIS filters were first updated and those individual solutions decreased astrometric errors to a level of 1.0 mas or 0.02 pixels[1]. As seen below in the residual plot example for F656N, some filters still had large residuals when using the F606W solution. Therefore, another 21 filters were updated. The 21 new geometric coefficient solutions and their 2D look-up tables (NPOLFILES) were solved for using observations of Omega Cen from calibration proposal 14393. The same solution methods were used as published in ISR 2009-33 (Kozhurina-Platais, V, et. al), ISR 2014-12 (Kozhurina-Platais, V) and these specific results will be published on in Martlin, et al (in prep).

Following the testing of these new geometric soluions for the additional 21 UVIS filters we investiagted differences in the coefficients of each individual solution, as seen in plots to the right. These coefficents all have a relation to an aspect of distortion, so studying their filter dependence is important and enlightening.

IMPORTANCE AND EFFECT OF INDIVIDUAL DISTORTION SOLUTIONS: F656N

One of the main reasons we persued creating individualized distortion solutions for the geometric and filter-dependent distortions was because of the systematic and large errors created when trying to use the F606W solutions for some UVIS filters.

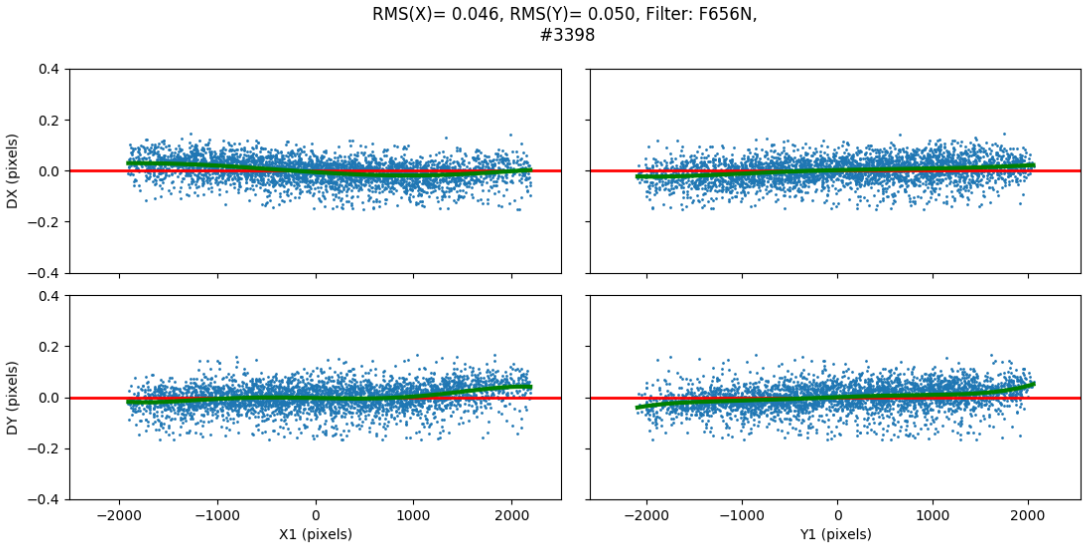


Above we plot the TweakReg solution residuals from matching a F656N UVIS image of Omega Cen to a F606W image using the F606W geometric solutions for both filters, as previously done.

Our main tests to ensure our individual filter solutions improved our corrections were completed with TweakReg which uses ***_flc.fits** files as input then finds *X* and *Y* positions in each image. From there, TweakReg uses the distortion reference files such as our updated geometric and new filter-dependent solutions provided by the file headers under IDCTAB and NPOLFILE to correct the multiple sets of *X* and *Y* positions.

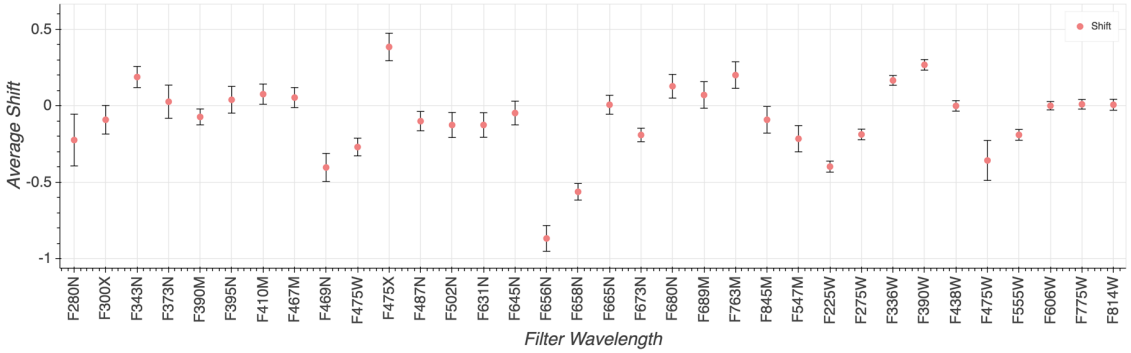
One metric of checking our new calibrations is to compare the residuals from *X* and *Y* position corrections between two images before and after individualized solutions are applied. Below we have a set of tests where we use an image of Omega Cen taken in F606W and a seocnd image taken of Omega Cen with the same pointing and orientation but using F656N. For the first plot of residuals we ran TweakReg with the F606W IDCTAB solution on both images. For the second plot, we ran TweakReg a seperate time with the F606Wsolutions only on the F606W image and the F656N image on the F656N image.

Below we plot the TweakReg solution residuals for the same F656N and F606W match using the new filter specific solutions.

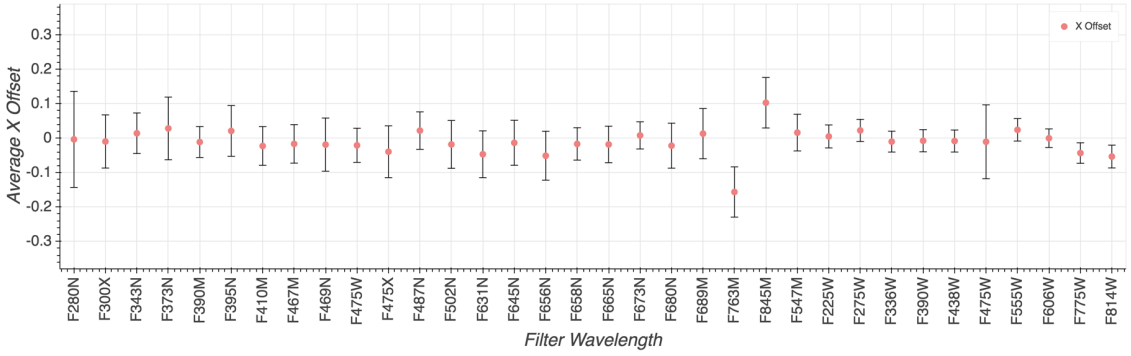


DIAGNOSTICS OF FILTER EFFECTS ON DISTORTIONS - X/Y CONSTANT AND SHIFT

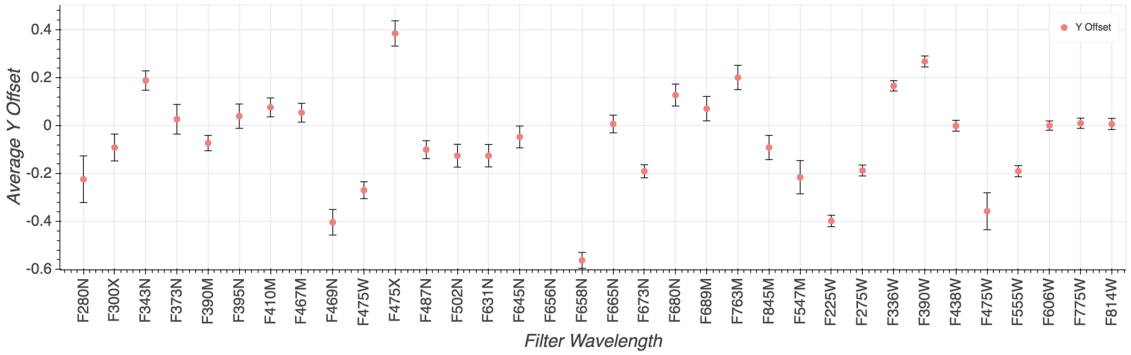
A study on the UVIS filter wedge was published on in Sabbi, 2012[4]. This study discussed how two faces of a filter may not be coplanar and therefore introduce spatially-dependent positional offsets - i.e. distortions - for sources in images taken with different filters. Following the completion of our solution finding for both the filter-dependent distortions as well as the individual geometric distortions for each filter we decided to investigate the dependence of the measured X-offset and Y-offset depending on filter.



Above is a plot of the average shift, the combination of X-offset and Y-offset, for each filter. These shifts have been normalized to the reference shift of F606W.

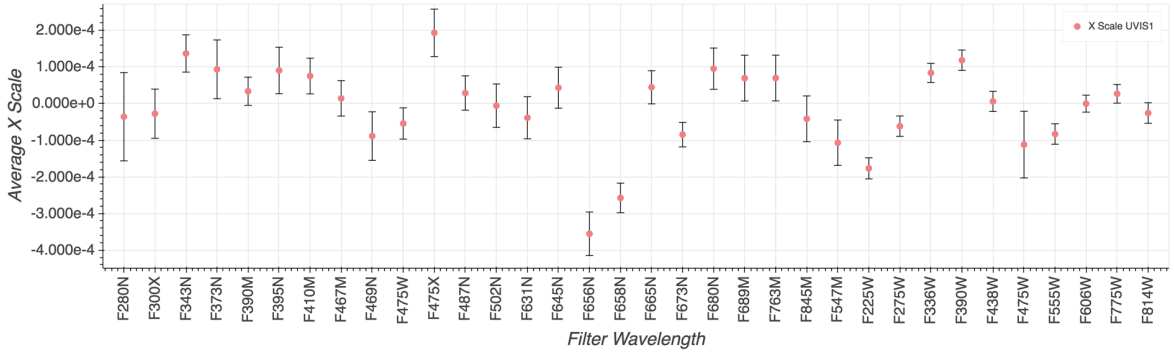


Difference of the average Y-offset (above) and the average X-Offset (below) of each filter with an individual solution available compared to the reference Y-offset and X-offset of F606W. These offset values are a useful diagnostic of the filter wedge differences. We see the expected variation through increasing central filter wavelengths.

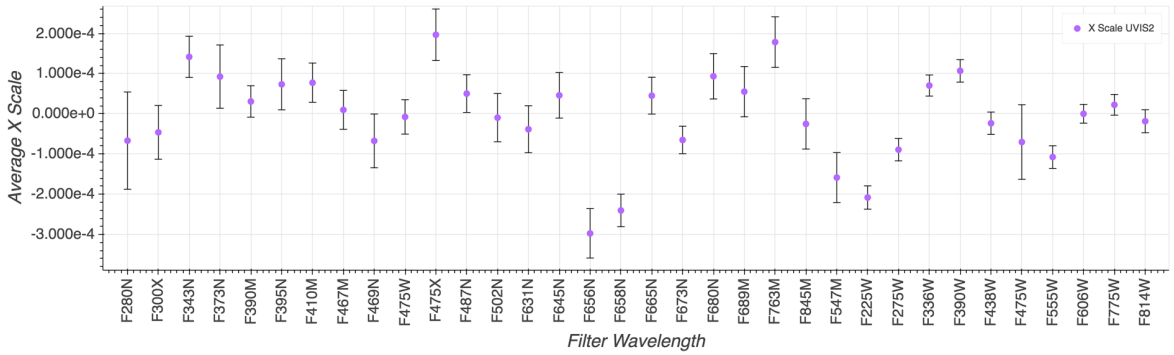

Y Offset
Average Y Offset
0.4
0.2
0
-0.2
-0.4
-0.6
F280N
F300X
F343N
F373N
F390M
F395N
F410M
F467M
F469N
F475W
F475X
F487N
F502N
F631N
F645N
F656N
F658N
F665N
F673N
F680N
F689M
F763M
F845M
F547M
F225W
F275W
F336W
F390W
F438W
F475W
F555W
F606W
F775W
F814W
Filter Wavelength

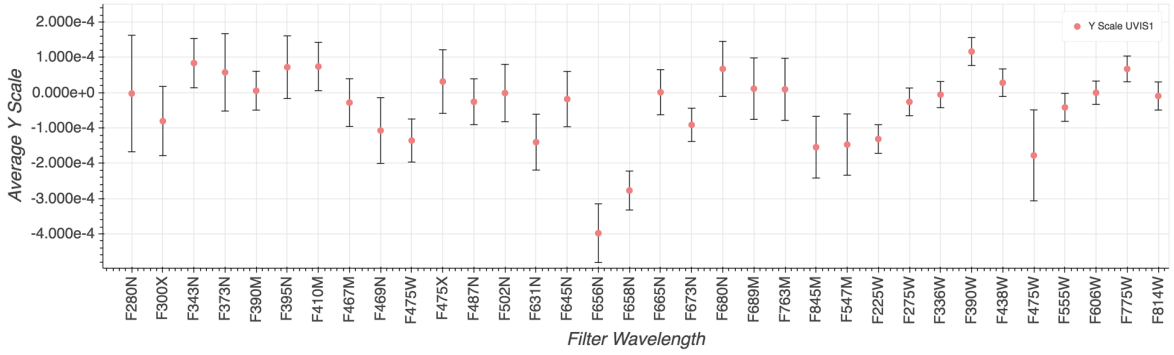
DIAGNOSTICS OF FILTER EFFECTS ON DISTORTIONS - X/Y SCALE

Below we plot the X-scale and Y-scale which helps demonstrate the distortion extremes that can be found between images, especially from different filters.

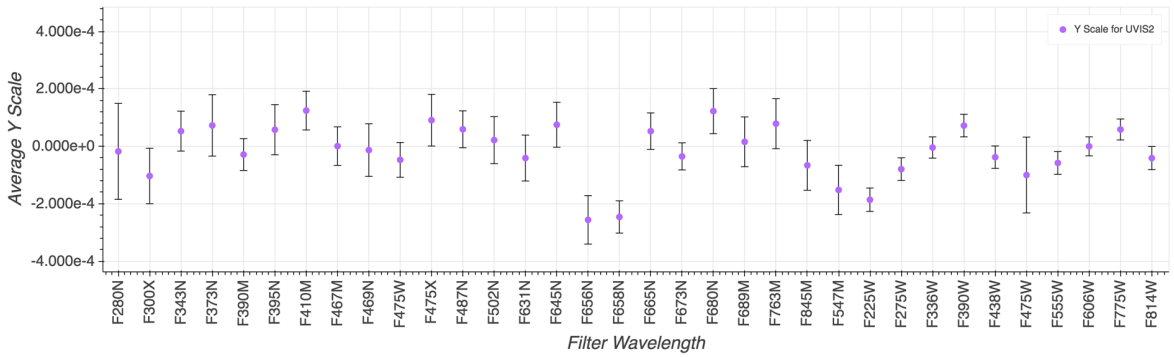


Difference of the average X-scale of UVIS1 (above) and UVIS2 (below) of each now calibrated filter compared to the reference X-Scale of F606W. We see the expected variation through increasing central filter wavelengths. These scales are a measurement of the relative plate scale and the plotted value shows how each individual filter differs from the reference relative plate scale.





Difference of the average Y-scale of UVIS1 (above) and UVIS2 (below) of each now calibrated filter compared to the reference X-Scale of F606W. We see the expected variation through increasing central filter wavelengths. These scales are a measurement of the relative plate scale and the plotted value shows how each individual filter differs from the reference relative plate scale.



UPDATES AND CONCLUSIONS

Reference File Updates:

We published updates to the following UVIS filters in the Instrument Distortion Coefficient Table (IDCTAB) and delivered individual NPOLFILE correction files for each filter as well:

F280N, F343N, F373N, F390M, F395N, F469N, F475W, F475X, F487N, F502N, F547M, F600LP, F631N, F645N, F656N, F658N, F665N, F673N, F680N, F763M, and F845M.

The precision of these reference files is integral, along with the D2IMFILE, in the Drizzlepac software for combining dithered WFC3/UVIS images to enhance the spatial resolution and detection limit necessary for precision astrometry[1].

Conclusions:

We can see throughout this study that there are substantial differences between the various coefficients important to precise astrometry and coordinate system transformations which depends heavily on the UVIS filter used. Our updates will allow for more precise solutions for creating drizzled products and allow for greater precision in astrometry work.

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ABSTRACT

The *WFC3/UVIS* filter wheel contains 63 filters that cover a large range of wavelengths from near ultraviolet to the near infrared. Previously, analysis was completed on the 14 most used *UVIS* filters to calibrate geometric distortions. These distortions are due to a combination of the optical assembly of HST as well as the variabilities in the composition of individual filters. We report recent updates to reference files that aid in correcting for these distortions of an additional 21 *UVIS* filters. They were created following a calibration of the large-scale optical distortions and fine-scale filter-dependent distortions. Furthermore, we present results on a study into a selection of unique polynomial coefficient terms from all solved filters which allows us to better investigate the filter-dependent patterns across a large range of wavelengths.

These updates will provide important enhancements for *HST/WFC3* users as they allow more accurate alignment of images across the range of *UVIS* filters.

REFERENCES

1. Kozhurina-Platais, V. “Astrometric Correction for WFC3/UVIS Filter-Dependent Component of Distortion”. ISR 2014-12.

2. Kozhurina-Platais, V, et al. “Astrometric Correction for WFC3/UVIS Lithographic-Mask Pattern”. ISR 2013-14

3. Kozhurina-Platais, V., et al. “WFC3 SMOV Proposal 11444 – UVIS Geometric Distortion Calibration.”. ISR 2009-33.

4. Sabbi, E. “UVIS Filter Wedge Check”. ISR 2012-001.