WFC3 UVIS and IR Flat Fields

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Abstract

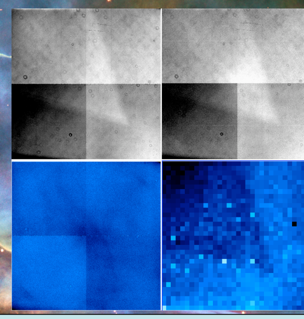
The WFC3 flat field program for both the UVIS and IR channels consists of ground flats, sky flats and Earth flats. Creation of the WFC3 flats starts with the ground flats (pixel-to-pixel variation) which are combined with on-orbit observations of stellar fields (low frequency modulation) to produce the so-called LP-flats. The ground flat field accuracy is ~ +/-2.0% peak-to-peak for the IR and ~ +/-2.5% in the UVIS. Assessment of the flats is done by identifying the peak-to-peak and rms variations. As we continue to refine these flats and test them for inclusion in CDBS and the WFC3 pipeline we are, in parallel, executing both a sky flats and an Earth flats program to use as secondary confirmation of the flat field program. In addition, internal flats are used to monitor flat field stability.

WFC3 Flat Fields

Variations in detector properties, such as the pixel thickness and non-uniform doping can cause differences in the pixel-to-pixel response of the detector that affect the accuracy of astronomical data. Additional wavelength-dependent low-order structures are introduced by the system illumination pattern and variations in the filter response. These variations are usually removed by normalizing the astronomical data to a uniform illumination of the detector with light passing through the entire optical path of the telescope. This process is commonly called flat fielding, and as a result the collected flux of a source should not depend on its position on the detector.

During the spring of 2008 WFC3 carried out thermal vacuum testing (TV3) which included obtaining ground based flat fields to be used for the reduction of all WFC3 on-orbit data. These ground flats include both the high frequency pixel-to-pixel (P-flat) and low frequency (L-flat) structures.

After WFC3 was installed on Hubble in Servicing Mission 4 (SM4), tests performed during the Servicing Mission Observatory Verification (SMOV) indicated that the ground-based flat fields do not fully remove the low-frequency structures. L-flat corrections are then derived from stellar L-flats and sky flats programs to remove the remaining low-frequency structure and are described in the UVIS Flats and IR Flats sections.



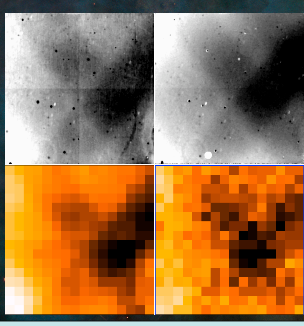
Panel 1 = Ground flat
Panel 2 = Earth flat (not flat fielded)
Panel 3 = Earth flat divided by ground flat - shows true low-frequency residuals inflight after removing the 'flare' feature
Panel 4 = Stellar L-flat***(dark blue indicates that the photometry will be too faint when using the ground flat, light blue indicates that it will be too bright.)

UVIS Flats

The stellar L-flat is based on multiple dithered exposures of Omega Centauri at various roll angles and has been modeled using the same matrix solution algorithm developed for ACS (van der Marel, ACS ISR 2003-10). The solution is presented as a 32x32 grid which is later resampled and smoothed to correct the flat fields obtained on the ground. The photometric residuals indicate a wedge-shaped 'flare' approximately 1% above the background which is the same amplitude (but in the inverse sense) as the flare in the ground flats. The rms of the stellar L-flat is 0.8%, with a peak-to-peak of +/- 2.5%. The uncertainty in photometry due to the flat field correction has an rms of <0.7% over the whole detector.

The flare is likely also present in the stellar photometry at a very low level, but local background subtraction removes it from the low-frequency residual image. The flare is not a true variation in the detector QE, and it should be removed prior to solving for low-frequency residuals. A 32x32 grid does not adequately model the 'sharp' diagonal edges of the flare apparent in the ground flats, and for this reason, this feature should be removed prior to solving for the low-frequency residuals.

We are working currently on methods of separating the additive term of the ghost reflections from the (multiplicative) flat fields.



Panel 1 = Sky flat
Panel 2 = Earth flat (not flat fielded)
Panel 3 = 16 x16 binned sky flat
Panel 4 = Stellar L-flat (dark red indicates that the photometry will be too faint when using the ground flat, light red indicates that it will be too bright

IR Flats

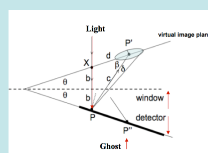
New IR flat fields have been created from a combination of the existing ground-based flat fields (LP-flats) and a new low-frequency correction (L-flat) from sky flats. To create the sky flat, a large number of long exposure science images were combined after masking out sources for multiple filters. Investigating the wavelength dependence of the sky images showed no significant deviation between filters with a variation of less than 1%. Therefore, a single gray sky L-flat correction was calculated and applied to all filters. In total over 2000 images were combined, all with exposure times >300s.

The stellar L-flats are derived from independent measurements of the star cluster Omega Centauri in different broad-band filters. They are in agreement with the results from the sky flat correction for both the spatial features and the amplitude of the L-flat corrections, as well as the lack of a significant dependence on wavelength. In addition, in L-flats obtained from observations of the moonlit Earth, both the shape and amplitude of the low-frequency structures are strikingly similar to the sky flat as well as the stellar L-flat.

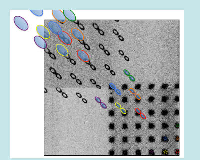
The uncertainty in photometry due to the flat field correction has, over the whole detector, an rms of <0.7%, with a maximum peak-to-peak range of -2.0/+1.9%. The uncertainty will be larger at the detector edge. The corresponding uncertainty in photometry due to flat fielding therefore typically has an rms of <0.01 mag (and 0.02 mag at the detector edge). In addition, the uncertainty in the wavelength dependence of the sky flat correction should also be less than 0.01 mag. The excellent agreement between these three independent tests verifies that the new flat fields are appropriate both for observations of sparse fields and for targets which uniformly illuminate the detector.

UVIS Flare

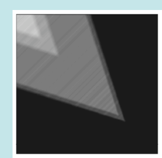
Flat fields obtained during TV3 ground testing and from images of the moonlit Earth show a flare-shaped feature. This flare is a result of ghost reflections caused by light reflected from the detector, returning to the detector chamber's window, and then back to the detector.



•The incident beam expands with angle delta to form a defocused ellipsis at P'
•The same pattern will appear on the detector at P" as a ghost



•Ground image with a grid of sources in the D quadrant at lower right generates ghost ellipses in a flare to the upper left. Black indicates real data.
•Colored and shaded ellipses are introduced to guide the eye between sources and ghosts.



•A geometric model of the surface brightness of 4 ghost reflections
•Generated from 4 defocused ellipses created from the reflections between the 2 glass windows of the chamber

New LP-flat Reference Files

New IR flat fields were ingested into CDBS on December 7, 2010 at 10.31pm. Data retrieved after this date are processed using the new reference files. WFC3 users interested in applying these new IR flat fields can either re-retrieve the data from the archive or re-run the standard calibration pipeline CALWF3 on the raw IR data.

New UVIS flats will be available in CDBS in the coming months. Much progress has been made in understanding the in-flight photometric residuals, and the new moonlit Earth flats will be instrumental in removing the flare prior to fitting the low-frequency residuals in detector response.

Glossary

LP-flat - detector response correction image, including both pixel-to-pixel sensitivity and low-frequency modulations

Ground flat - LP-flat obtained from uniform illumination via the CASTLE stimulus during TV3 Ground tests

Sky flat - LP-flat obtained from many co-added observations of sparse fields with sources masked out

Earth flat - LP-flat obtained from observations of the bright Earth limb (may be sunlit or moonlit)

L-flat - low-frequency correction to detector sensitivity, due to differences in-flight versus ground calibration computed in one of three ways: 'Sky flat / Ground flat', 'Earth flat / Ground flat', or from dithered observations of stars (see below)

Stellar L-flat - L-flat derived by moving stars to different regions on the detector and measuring changes in response.

Internal flat – flat fields obtained with the internal calibration subsystem. These flats are used to monitor for flat field changes as well as assess the health of the instrument and are not used in the calibration pipeline.

For more on WFC3 at this conference, see posters in Session 254.

For further information

http://www.stsci.edu/hst/wfc3