WFC3 and IR Flat Fields


Abstract
The WFC3 flat field program for both the UVIS and IR channels consists of ground-flat, sky-flat and Earth-flat fields. Creation of the WFC3 flat fields starts with the ground-flat (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 ∼0.1% peak-to-peak for the IR and ∼0.25% 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 residuals in C2D0 and the WFC3 pipeline, we are, in parallel, executing both a sky-flat and an Earth-flat 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 structure. L-flat corrections are then derived from stellar L-flats and sky-flat programs to remove the remaining low-frequency structure and are described in the UVIS Flats and IR Flats sections.

UVIS Flats
The stellar L-flat is based on multiple differenced 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 ambiguity (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 ∼0.4%. The uncertainty in photometry due to the flat field correction has an rms of ∼0.2% 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 3x3 grid does not adequately model the ‘sharp’ diagonal edges of the flare apparent in the ground flats, and for this reason, the feature should be removed prior to solving for the low-frequency residuals.

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

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.

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 world 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 differenced 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.