Calibration and Interpretation of STIS Imaging Mode Fluxes

Introduction

While primarily a spectroscopic instrument, STIS also had a number of imaging modes, many of which provided unique capabilities, especially in the ultraviolet. However, most of the STIS imaging modes also had very wide, non-standard passbands, making the calibration and interpretation of STIS imaging data especially challenging. Here we describe the methods used to derive the adopted throughput curves, zero points, and aperture corrections for these modes and also estimate the remaining uncertainties in these quantities. The wide, non-standard passbands of STIS imaging modes also present special challenges when comparing to observations in other photometric systems. To aid in interpretation, we discuss the relationship between STIS magnitudes and colors and those of other common photometric system.

STIS Imaging Zero Points and Time Dependence.

The STIS instrument has 3 detectors, a CCD sensitive from ∼2000 to 10,300 Å, a Cs₂Te Multi-Ande Microchannel Array (MAMA) detector (1600 to 3100 Å) and a solar-blind CsI MAMA (1150 to 1700 Å). Sensitivities of these detectors have varied over time. For a given detector these changes depend on λ, but appear to be independent of the mode. So for imaging observations we will adopt the same time dependence that was determined for the 1st order spectroscopic modes (Stys et al. 2004, STIS ISR 2004-04). This leads to color dependent performance changes in the sensitivity with time. In Figure 1 we give examples of the predicted sensitivity changes for stars of different colors at 360 day intervals over the 7+ year operational life of STIS.

Determination of Absolute Throughputs

Since STIS is a spectrophotometer as well as an imaging instrument, the relative throughputs of different filters as a function of wavelength were easily determined by comparing filtered and unfiltered spectra of the same stars. To determine the wavelength dependent throughput of each detector’s unfiltered mode, a small number of stars with well measured SEDs and spanning a wide range of colors were observed. Deep images were taken in several filters to allow aperture corrections to be measured at large radii. The pre-launch estimates of the unfiltered mode throughputs vs. wavelength were then adjusted to match the observed count rates for each filter and target. For CCD imaging modes, the details of this calibration were presented in Proffitt 2004 (STIS ISR 2004-05). The unfiltered CCD throughput at long wavelengths had to be increased by up to 18% above prelaunch estimates. In addition, the subtraction of light into an extended red halo put up to 20% of the flux at distances from the image center >0.5". Wavelength dependent aperture corrections were also estimated using these data. For MAMA broadband clear, strontium fluoride, and quartz filters, existing standard stars were fit which provided unique capabilities, especially in the ultraviolet. However, most of the STIS imaging modes also had very wide, non-standard passbands, making the calibration and interpretation of STIS imaging data especially challenging. Here we describe the methods used to derive the adopted throughput curves, zero points, and aperture corrections for these modes and also estimate the remaining uncertainties in these quantities. The wide, non-standard passbands of STIS imaging modes also present special challenges when comparing to observations in other photometric systems. To aid in interpretation, we discuss the relationship between STIS magnitudes and colors and those of other common photometric system.

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If, for the Kurucz models considered above, we fit the STIS fluxes as a sum of the measured AB fluxes, we find the coefficients in Table 2.

The available detector/imaging filter combinations are summarized in Table 1 for a time near the beginning of STIS operations. The corresponding keywords in individual STIS image headers take into account the time dependent sensitivity changes, and contain values appropriate for the actual date of each observation.

<table>
<thead>
<tr>
<th>Detector</th>
<th>Filter Name</th>
<th>MJD</th>
<th>I1</th>
<th>I2</th>
<th>I3</th>
<th>I4</th>
<th>I5</th>
<th>I6</th>
<th>I7</th>
<th>I8</th>
</tr>
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<tbody>
<tr>
<td>50CCD</td>
<td>F28X50LP</td>
<td>7216.7495</td>
<td>1.639466e-19</td>
<td>1139.8442</td>
<td>25.863</td>
<td>25.264</td>
<td>0.071</td>
<td>0.019</td>
<td>0.002</td>
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</table>

Table 1: STIS Imaging Mode Zero Points on MJD 50552 (April 14, 1997)

The combined long wavelength filters of Guin type photometric systems, such as that used for the Sioane Digital Sky Survey (York et al., 2000), provide a better match to the F28X50LP filter throughput (right hand panel of Figure 2). While no ground based system can reach wavelengths as short as the unfiltered STIS CCD, the short-wavelength cutoff is close to the GALEX NUV band. This makes it possible to use SDSS photometry to robustly predict STIS CCD magnitudes. This may be useful to place STIS observations in the context of these broader surveys or to easily use synthetic colors calculated for these systems when interpreting STIS imaging observations.

Comparison of MAMA and GALEX Passbands

STIS has a variety of broadband UV imaging filters for use with the MAMAs. No particular combination of the available choices was adopted as a standard color, although the FUV SRF2 and NUV QTZ were the most commonly used combinations. However, the GALEX mission (Martin et al., 2005) will survey the entire sky in passbands similar to those available with STIS, and this suggests that the GALEX passbands may become such a "standard" vacuum UV color. In Figure 5 and Figure 6, we compare STIS MAMA and GALEX imaging passbands and colors. For unreddened stars, relatively tight transformations between these systems might be defined, but when extinction becomes substantial, the differences in wavelength cutoffs for these filters have large effects. Any attempts to cross-calibrate STIS and GALEX UV imaging magnitudes will have to pay close attention to the details of the SEDs.

Table 2: Coefficients to convert SDSS/Galex magnitudes to STIS 50CCD and F28X50LP AB magnitudes

<table>
<thead>
<tr>
<th>Target Color</th>
<th>Coefficients</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
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<tr>
<td>GALEX NUV</td>
<td>0.015</td>
</tr>
<tr>
<td>F28X50LP</td>
<td>0.025</td>
</tr>
</tbody>
</table>

References

Laidler et al., 2005, Synphot Data Users Guide (Baltimore, STScI)
Proffitt, C. R., 2004, STIS ISR 2004-08, (Baltimore, STScI)
Stys, D. J., Bohlin, R. C., & Goudfrooij, P. 2004, STIS ISR 2004-04 (Baltimore, STScI)

Figure 2: On the left, the throughput of the STIS CCD modes (red) is compared with the scaled throughput of the standard UBVRi′ system, and any transformation between STIS and other broadband photometric systems will depend strongly on the details of the SED Figure 3.

Figure 3: Relation between STIS 50CCD (left) and F28X50LP (right) magnitudes and Johnson V band as a function of color for a series of Kurucz main-sequence models, ranging in Teff from 50000 to 3500 K, and with a variety of metallicities and reddenings.

Figure 4: Relationship between STIS and Johnson colors for a variety of Kurucz main-sequence model sequences.

Figure 5: On the left, we compare the STIS FUV (red) and NUV (orange) MAMA passbands to those of GALEX (blue). The other panels show how broadband MAMA and GALEX magnitudes compare to the photometric models of a variety of metallicities and reddenings. We make these comparisons as a function of the STIS FUV SRF2 - STIS NUV QTZ ABMA color. The third panel of Figure 4 showed the relation between the color and Johnson V.

Figure 6: Comparison between STIS MAMA broadband magnitudes and GALEX magnitudes as a function of color for Kurucz models with a variety of metallicities and reddenings.