Summary of Changes for GALEX Ops7 Pipeline

GALEX data released after February 2010 (and until the next major pipeline change), will be reduced with the new GALEX "Ops7.0.1" pipeline. One notable change will be the addition and deletion of several columns in the direct imaging merged catalog file (-xd-mcat.fits). There will also be a significant improvement in the quality of the data with a new set of calibrations. In particular, all magnitudes in both bands will be approximately 3% fainter due to a new calibration spectrum for LDS 749b.

There are no significant changes to the grism data products at this time. However, the new grism reductions will benefit from some of the new calibrations made for direct imaging (flat field, flux trend, and distortion corrections) as discussed below.

Direct Imaging Merged Catalog (-xd-mcat.fits) Changes

Deleted Header Cards

DYFCOR	Correction to Y detector direction (arcsec)
FUVTEMP	FUV temperature used for detector Y correction
DYF0	Detector Y correction function zeroth coeffecie
DYF1	Detector Y correction function first coeffecien

New Header Cards

PETAL	PETAL card value from -scst.fits file. 0 or 1.
BSC_X	Band Separation Correction in X(ra) (arcsec)
BSC_Y	Band Separation Correction in Y(dec)(arcsec)
BSC_E	Radial error in correction estimate (arcsec)

Fixed Header Cards

In previous pipeline these two values were a factor of 2.25 too small:

BQNBCKMD	BQ: Median of NUV background (pho/s/sq.arcmin)
BQFBCKMD	BQ: Median of FUV background (pho/s/sq.arcmin)

Deleted Table Columns

match_density	Matched sources per sq. deg. (rad<0.5)
nuv_unmatched_density	Un-matched NUV sources per sq.deg.(rad<0.5)
fuv_unmatched_density	Un-matched FUV sources per sq.deg.(rad<0.5)
reliability	Reliability of match.
objtype	0=galaxy,1=star,-1=unknown,etc.
quality	Quality flag (undefined)
adj_sep	Adj. separation after FUV Temp Corrctn(arcsec)
adj_fuv_det_y	Adjusted FUV detector y position (pixels)
NUV_FLUX_ISOCOR	Corrected isophotal flux
NUV_FLUXERR_ISOCOR	RMS error for corrected isophotal flux
NUV_MAG_ISOCOR	Corrected isophotal magnitude
NUV_MAGERR_ISOCOR	RMS error for corrected isophotal magnitude
NUV_FLUX_BEST	Best of FLUX_AUTO and FLUX_ISOCOR
NUV_FLUXERR_BEST	RMS error for BEST flux
NUV_MAG_BEST	Best of MAG_AUTO and MAG_ISOCOR
NUV_MAGERR_BEST	RMS error for MAG_BEST
NUV_ZPMAG	NUV zero point magnitude correction.
FUV_FLUX_ISOCOR	Corrected isophotal flux
FUV_FLUXERR_ISOCOR	RMS error for corrected isophotal flux
FUV_MAG_ISOCOR	Corrected isophotal magnitude
FUV_MAGERR_ISOCOR	RMS error for corrected isophotal magnitude
FUV_FLUX_BEST	Best of FLUX_AUTO and FLUX_ISOCOR
FUV_FLUXERR_BEST	RMS error for BEST flux
FUV_MAG_BEST	Best of MAG_AUTO and MAG_ISOCOR
FUV_MAGERR_BEST	RMS error for MAG_BEST
FUV_ZPMAG	FUV zero point magnitude correction.

Changed Columns

Both of these are now computed using SDSS/GALEX statistics:

nuv_poserr	NUV position error in arcseconds
fuv_poserr	FUV position error in arcseconds

Was:

nuv_cid3	Third candidate for NUV source (FUV ID)
fuv_cid3	Third candidate for FUV source (NUV ID)

Now:

nuv_cid3	Nearest unmatched FUV source within 7 arcsec (any S/N)
fuv_cid3	Nearest unmatched NUV source within 7 arcsec (any S/N)

New Table Columns

ib_poserr	Interband position error in arcseconds
nuv_scq_mdn	NUV median Q within 40 arcsec of source
nuv_scq_p05	NUV 5th percentile Q: 40 arcssec of source
nuv_scq_p95	NUV 95th percentile Q: 40 arcssec of source
fuv_scq_mdn	FUV median Q within 40 arcsec of source
fuv_scq_p05	FUV 5th percentile Q: 40 arcssec of source
fuv_scq_p95	FUV 95th percentile Q: 40 arcssec of source
fuv_ncat_flags	FUV_FLAGS from -fd-ncat.fits
fuv_ncat_mag	FUV calibrated magnitude from -fd-ncat.fits
fuv_ncat_magerr	Error for nuv_fcat_mag
fuv_ncat_s2n	Signal to noise for fuv_ncat_flux
nuv_fcat_mag	NUV calibrated magnitude from -nd-fcat.fits
nuv_fcat_magerr	Error for nuv_fcat_mag
nuv_fcat_s2n	Signal to noise for nuv_fcat_flux
fuv_ncat_fwhm_image	FUV FWHM_IMAGE value from -fd-ncat.fits (px)

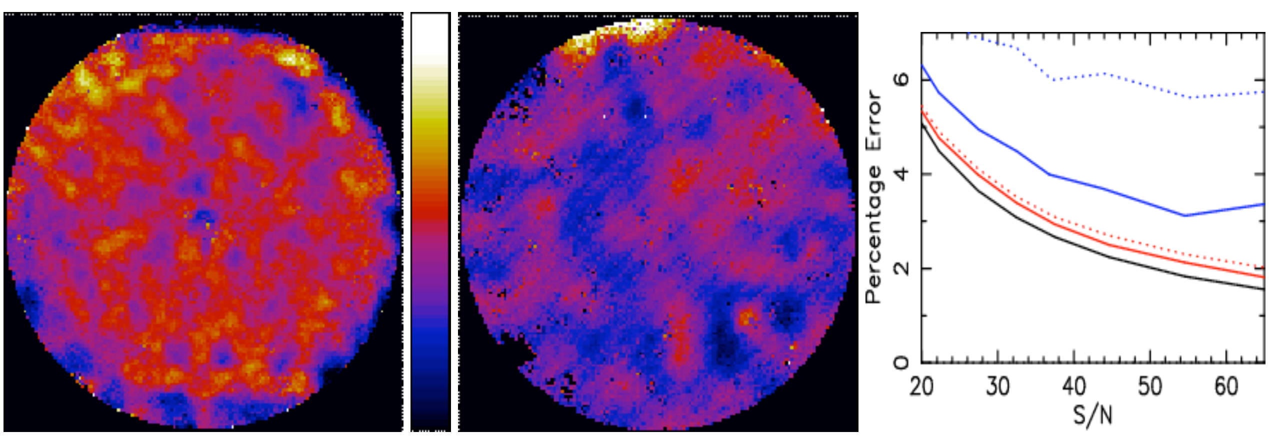
fuv_ncat_fwhm_world	FUV FWHM_WORLD value from -fd-ncat.fits (deg)
fuv_ncat_flux_radius_1	FUV FLUX_RADIUS #1 (-fd-ncat)(px)[0.20]
fuv_ncat_flux_radius_2	FUV FLUX_RADIUS #2 (-fd-ncat)(px)[0.50]
fuv_ncat_flux_radius_3	FUV FLUX_RADIUS #3 (-fd-ncat)(px)[0.80]
fuv_ncat_flux_radius_4	FUV FLUX_RADIUS #4 (-fd-ncat)(px)[0.90]
fuv_ncat_flux_radius_5	FUV FLUX_RADIUS #5 (-fd-ncat)(px)[0.95]
fuv_ncat_flux_aper_1	FUV FLUX_APER #1 (-fd-ncat)(cnt/sec)[2. px]
fuv_ncat_flux_aper_2	FUV FLUX_APER #2 (-fd-ncat)(cnt/sec)[3. px]
fuv_ncat_flux_aper_3	FUV FLUX_APER #3 (-fd-ncat)(cnt/sec)[5. px]
fuv_ncat_flux_aper_4	FUV FLUX_APER #4 (-fd-ncat)(cnt/sec)[8. px]
fuv_ncat_flux_aper_5	FUV FLUX_APER #5 (-fd-ncat)(cnt/sec)[12. px]
fuv_ncat_flux_aper_6	FUV FLUX_APER #6 (-fd-ncat)(cnt/sec)[17. px]
fuv_ncat_flux_aper_7	FUV FLUX_APER #7 (-fd-ncat)(cnt/sec)[23. px]
fuv_ncat_fluxerr_aper_1	error for fuv_ncat_flux_aper_1
fuv_ncat_fluxerr_aper_2	error for fuv_ncat_flux_aper_2
fuv_ncat_fluxerr_aper_3	error for fuv_ncat_flux_aper_3
fuv_ncat_fluxerr_aper_4	error for fuv_ncat_flux_aper_4
fuv_ncat_fluxerr_aper_5	error for fuv_ncat_flux_aper_5
fuv_ncat_fluxerr_aper_6	error for fuv_ncat_flux_aper_6
fuv_ncat_fluxerr_aper_7	error for fuv_ncat_flux_aper_7
fuv_ncat_mag_aper_1	FUV MAG_APER #1 (-fd-ncat)(raw mag)[2. px]
fuv_ncat_mag_aper_2	FUV MAG_APER #2 (-fd-ncat)(raw mag)[3. px]
fuv_ncat_mag_aper_3	FUV MAG_APER #3 (-fd-ncat)(raw mag)[5. px]
fuv_ncat_mag_aper_4	FUV MAG_APER #4 (-fd-ncat)(raw mag)[8. px]
fuv_ncat_mag_aper_5	FUV MAG_APER #5 (-fd-ncat)(raw mag)[12. px]
fuv_ncat_mag_aper_6	FUV MAG_APER #6 (-fd-ncat)(raw mag)[17. px]
fuv_ncat_mag_aper_7	FUV MAG_APER #7 (-fd-ncat)(raw mag)[23. px]
fuv_ncat_magerr_aper_1	error for fuv_ncat_mag_aper_1

fuv_ncat_magerr_aper_2	error for fuv_ncat_mag_aper_2
fuv_ncat_magerr_aper_3	error for fuv_ncat_mag_aper_3
fuv_ncat_magerr_aper_4	error for fuv_ncat_mag_aper_4
fuv_ncat_magerr_aper_5	error for fuv_ncat_mag_aper_5
fuv_ncat_magerr_aper_6	error for fuv_ncat_mag_aper_6
fuv_ncat_magerr_aper_7	error for fuv_ncat_mag_aper_7
fuv_ra_adj	FUV adjusted RA in degrees
fuv_dec_adj	FUV adjusted DEC in degrees
sep_img	Separation on images (with no adjustment)
match_reliability	Reliability of match (based on source density)

Calibration Changes

Flat Field

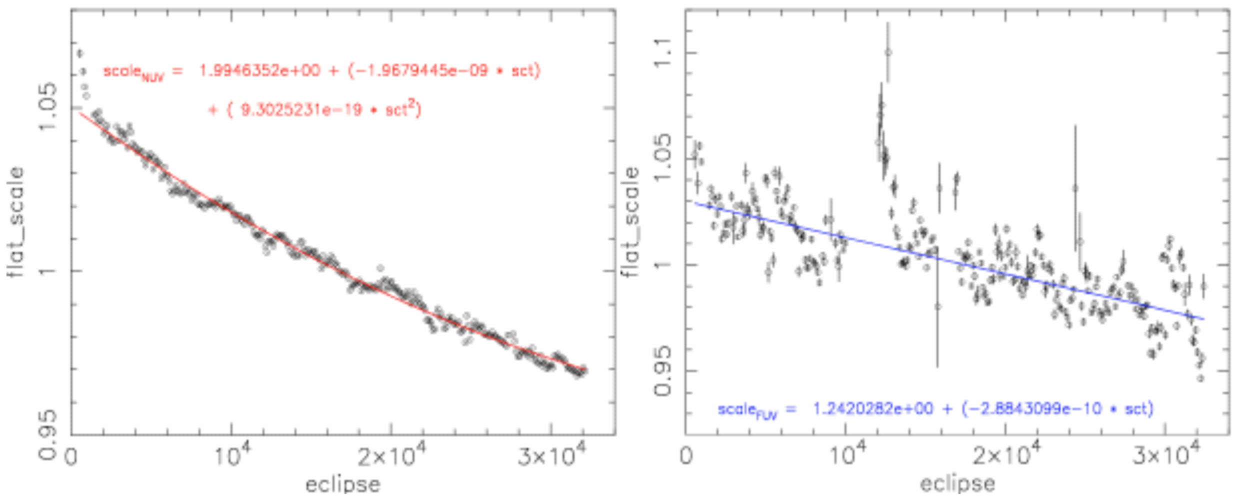
New, more precise flat field (detector response) maps were created using the relative flux between detections of millions of objects observed throughout the mission. The maximum range of adjustments relative to the prior (ops6) flat field are approzimately +/-5% for the NUV and +/-25% for the FUV. The RMS correction was about 1%(NUV) and 3%(FUV). The following images show the relative corrections to previous flat field for NUV(left) and FUV(right). Range is 0.5 to 0.95 for NUV and 0.3 to 1.0 for FUV.



The plot shows the average total percentage error in flux vs. Poisson computed S/N. The black line is the Possion error. The red line is NUV, blue is FUV. The dotted lines are the Ops6 pipeline and the solid lines are the Ops7 pipeline. The improvement in flux accuracy for any given source will depend on detection location. However, on average, the flux error due to non-Poissonian causes has been reduced from 1.2% in ops6 to 0.8% in ops7 for NUV, and 5.5% to 2.5% for FUV.

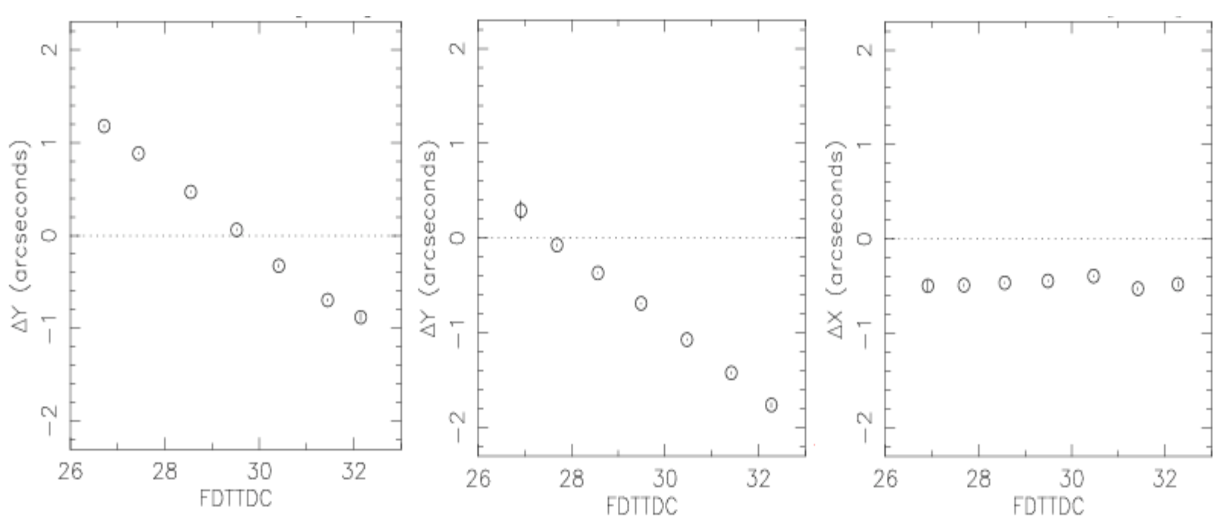
Flux Trend with Time

By combining the relative flux over time of many objects, the decrease in detector response over the 6+ year mission has been more precisely calibrated. Relative to ops6, an adjustment of 1% in NUV and 5% in FUV (over a 6 year timespan) has been applied to the ops7 data. The total decrease in sensitivity over the first 6 years of the mission is now 8% for NUV and 6% for FUV. The following plot shows the relative scale factor applied to the response image (flat field) vs. time for the first 6 years of the mission.



FUV to NUV Position Correction

The position separation between NUV and FUV was found to be strong function of electronics temperature (FDTTDC) in the detector Y direction (range of correction is +/-1 arcsecond). A trend in the offset of this function with time was also found (range of +/- 0.5 arcseconds over the first 6 years). The following plots show the dependence with temperature in the Y detector direction (left and middle). The slope remains the same over time, although the offset of the function varies with eclipse number (left plot is near eclipse 13750, right is near 26250). The X offset also varies with time (right plot is near 26250) but not with temperature.

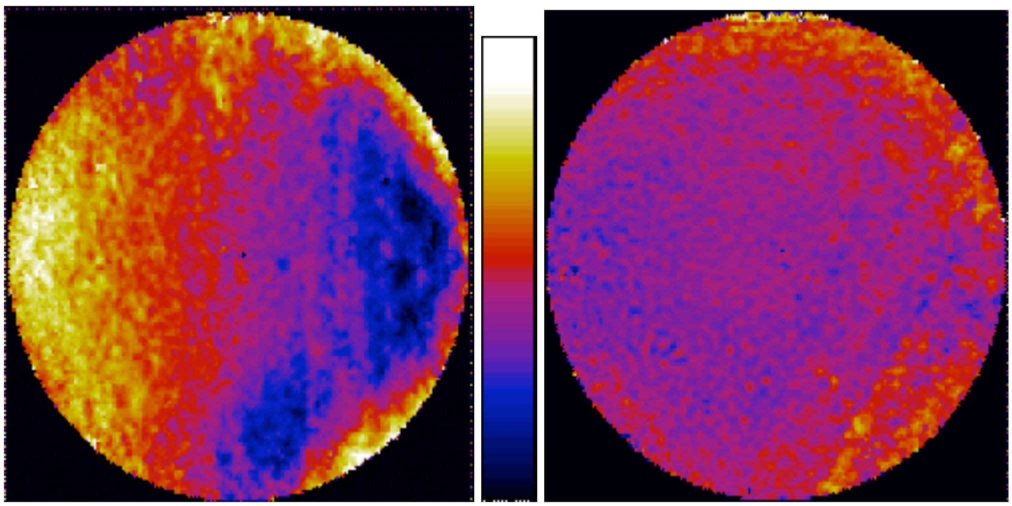



```
dx = x_coef_0[t]  ;   dy = y_coef_0[t] - ( 0.3597 * (FDTTDC - 29.) )
```

This correction is applied to the photon positions to better align the NUV and FUV images. However, even after this correction, a misalignment on the order of 0.2 arcseconds often still occurs between NUV and FUV. A further correction is computed from the source catalogs of each exposure and the adjusted FUV source position appears as the new MCAT columns 'fuv_ra_adj' and 'fuv_dec_adj'.

Distortion Corrections

Using a catalog of 55 million SDSS sources, approximately 7 million matches were made with GALEX NUV source detections (about 850,000 with FUV). These matches were used to construct distortion maps (photon position corrections in the X and Y direction as a function of detector position). The following images show the NUV corrections in the X detector direction(left) and the Y detector direction(right). The range is -1.0 (black) to +1.0 (white) arcseconds.



These distortion maps are a strong function of the separation of the detector STIM photons, so separate maps were created for different ranges of STIM separations. In the new ops7 pipeline, photon positions are adjusted according to these maps. The maximum correction in these maps is +/- 1 arcsecond, with a typical (RMS) correction of about 0.15 arcseconds. Since the positional error is still dominated by other causes, on average, the improvement in the NUV positional error is only reduced from 0.35 arcseconds (in Ops6) to 0.32 arcseconds (in Ops7). For FUV, the error is reduced from 0.48 arcseconds (in Ops6) to 0.34 arcseconds (in Ops7), although this is mainly due to the improvement in the NUV to FUV alignment.

Magnitude Zero-Point Adjustment

We used new measurements of the standard star LDS 749b to calibrate the GALEX magnitude scale. We used large aperture extractions (105 arcsecond radius), which has about 7% more flux relative to the default GALEX catalog magnitude (MAG_AUTO) due to the light in the wings of the PSF. To minimize saturation effects, we used only measurements with large pulse height (Q > 15).

To apply this calibration, the flat fields are scaled in such a way to make the average LDS 749b large aperture magnitude at high Q match the computed AB magnitude from the CALSPEC (www.stsci.edu/hst/observatory /cdbs/calspec.html) calibration spectrum using the GALEX effective area response, applying the following equations (flux is in photons per second):

```
NUV_mag = -2.5 * log10(flux) + 20.08   ;    FUV_mag = -2.5 * log10(flux) + 18.82
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In the new calibration, the new GALEX NUV fluxes (in Ops7) are 3.9% fainter (+0.043 magnitudes) as compared the Ops6 reductions. The FUV fluxes are 3.0% fainter (+0.033 magnitudes). Most of this adjustment is due to a new LDS 749b calibration spectrum from CALSPEC, which is now 3.0% fainter in NUV and 2.6% fainter in FUV relative to LDS 749b data used in the Ops6 calibration. The remaining difference in the new pipeline is due to new flat field and flux trend calibrations.

The following plots show the relative flux variation with Q at different magnitudes. All curves are scaled to 1.0 at the highest Q value. LDS 749b is closest to the black curve in the NUV plot and red curve in FUV. Although the FUV calibration is not significantly effected by saturation, we estimate the NUV calibration still has about a 1% saturation effect (implying that unsaturated sources may still be about 1% too bright in the NUV catalog).