GALEX IMAGING MODE QUALITY ASSURANCE
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1. GENERAL DESCRIPTION OF IMAGING QA PROCESS

Quality assurance for GALEX imaging data products is performed in four ordered steps independently from the data processing pipeline.

- **Step 1**: Automated checks are performed and one of three possible QA grades (PASS, FAIL, or UNKNOWN) is established. The meaning of each QA grade is:

  PASS: Data has passed all automated QA checks and is recommended for inclusion in coadded products.

  FAIL: Data has failed some critical component of the automated QA checks and is NOT recommended for inclusion in coadded products. QA flags and analyst comments provide the details needed to asses why the data has failed the QA process.

  UNKNOWN: Automated QA checks are not able to determine the status of the data to a level that warrants a PASS or FAIL grade and is therefore not recommended for inclusion in coadded products. Further manual inspection is required to determine the final QA status.

- **Step 2**: Manual inspections by a QA analyst are performed. Manual inspections are designed to accomplish four things: 1) resolve the status of data which receives an UNKNOWN grade from the automated QA check, 2) provide comments about the data concerning artifacts or unusual features, 3) make suggestions for reprocessing in order to improve the data, and 4) confirm whether or not the data should be included in coadded products independent of the automated grade and coadd recommendation.

  Manual inspection by a QA analyst depends on two factors - the automated QA status and the type of data release involved. For all data releases (internal, public or guest investigator), any data which receives an UNKNOWN grade from the automated QA check will be manually inspected. However, **all** guest investigator data are manually inspected regardless of the automated QA grade.

- **Step 3**: Data is reprocessed as per the suggestions of a QA analyst. The automated QA and manual inspections (steps 1 and 2) are repeated for the reprocessed data.

- **Step 4**: A final automated QA check is performed which incorporates the analyst's comments and QA grade. The analyst's final QA grade from the manual inspection process will override the automated QA grade.

2. DESCRIPTION OF QA REPORT

The QA report provides a concise summary of the status of each visit and coadded product. A truncated example follows. The header of the report contains the report name, date and indicates if manual inspections were performed. The last line of the header is a list of report columns. The columns are ‘ | ’ delimited and are described below.

1. **eclipse** – Mission eclipse reference number for visits. Set to ‘MAIN’ for coadded products.
2. **field** – Target name with visit number and sub-visit number appended as appropriate.
3. **fexptime** – Recovered FUV exposure time (seconds). Set to −1 if the FUV intensity maps does not exist.
4. **nexptime** – Recovered NUV exposure time (seconds). Set to −1 if the NUV intensity maps does not exist.
5. **nhvnomn** – Time detectors are at nominal high voltage (maximum possible exptime, seconds).
6. **grelease** – Pipeline version.
7. **grade** – QA grade (PASS/FAIL/UNKNOWN).
8. **coadd** – Coadd status of visit (YES/NO). Set to NA for coadded products.
9. **flags** – String of QA flags (space separated).
10. **comments** – String of analyst comments (begins with #; space separated).

2.1. Example QA report

An example QA report (partial):

```
# QA REPORT: GI_VISITS
# Includes Manual Inspection
# Thu Mar 10 16:38:08 2005
# eclipse, field, fexptime, nexptime, nhvnomn, grelease, grade, coadd, flags, comments

8590 | [target]_0001      |  1588.00 |   1588.00 |   1601.00 | ops-v4_1-RC1 | PASS    | YES |  | #FUV_Hot_Pixel(1)

8697 | [target]_0001      |   529.00 |    529.00 |    541.00 | ops-v4_1-RC1 | FAIL    |  NO | ASTROMETRY_ROTATION  | #FUV_Hot_Pixel(2)

8312 | [target]_0001      |  1699.85 |   1699.85 |   1713.00 | ops-v4_1-RC1 | PASS    | YES | FUV_PSF_WARNING ASP_ERRSTDEV ASP_ERRDIFF OVERRIDE_UNK  | #ASP_Ok

8091 | [target]_0002      |  1511.00 |     -1.00 |   1516.00 | ops-v4_1-RC1 | FAIL    |  NO | FUV_PSF_BAD FUV_ONLY MISSING_PLATE_SOLUTION MISSING_ASP_STATS ...
... | #ASP_Bad_Image FUV_Hot_Pixel(2)
```

In the above example, eclipse 8590 passes all QA checks and is recommended for coadded products. No QA flags are set for this eclispe, but manual inspection notes a unmasked FUV hot spot.

Eclipse 8697, however, has failed the QA process and is not recommended for coadded products due to a rotation error in the astrometric solution (ASTROMETRY_ROTATION; § 3.1). Manual inspection of eclipse 8697 makes note of 2 unmasked hot spots. Althought the astrometry error excludes it from being inlcuded in any pipeline created coadded product, an end user of this data may feel confident using it once they correct the astrometry themselves.

Eclipse 8312 was flagged by the the automated QA checks for possible problems with the FUV PSF and aspect solution. Manual inspection concludes that the aspect solution is fine and resolves the UNKNOWN grade status to a PASS grade as indicated by the OVERRIDE_UNK flag.

Eclipse 8091 also fails the QA process and is an example of the worst case scenario; the data is unusable. There is only FUV imaging for this eclipse as indicated by the exposure times and QA flag (FUV_ONLY; § 3.5). FUV-only data do not have plate solutions (MISSING_PLATE_SOLUTION; § 3.1,3.8) because a proper aspect solution is not derived (MISSING_ASP_STATS; § 3.4). For this reason, eclipse 8091 and all FUV-only data will fail QA testing. FUV-only data may still be useful in some cases (§ 5). In the case of eclipse 8091, the automated QA flag which notes a bad PSF (FUV_PSF_BAD; § 3.3) suggests there is likely to be a problem with the image reconstruction. Unfortunately, the data is **not** useful as the comments from the manual inspection indicate that the aspect solution is poor enough that problems are easily detected in the image (ASP_Bad_Image; § 4).

All QA flags are summarized in Table 1 and discussed in detail in § 3. Analyst comments from manual inspections are summarized in Table 2 and discussed in § 4. The combination of QA flags and comments will provide the reason(s) data have failed the QA process and help evaluate its usefulness for purposes other than pipeline coaddition.

2.1.1. Summary Tables of QA Report Flags and Comments

Table 1. Summary of QA Flags

§	FLAG	MEANING	CONDITION	GRADE
3.1	ASTROMETRY_SHIFT	astrometry error	shift distance $> 1.5''$	FAIL
3.1	ASTROMETRY_ROTATION	astrometry error	absolute rotation $> 0.04°$	FAIL
3.2	HV_LOW	detector high volatage below nominal	eclipse 643 to 749	FAIL
3.3	NUV_PSF_BAD	likely NUV PSF problem	FWHM(A)/FWHM(B) > 1.2 or fitFWHM $\geq 8''$	UNKNOWN
3.3	NUV_PSF_WARNING	possible NUV PSF problem	FWHM(A)/FWHM(B) ≤ 1.2 and fitFWHM $> 5.7''$	N/A
3.3	FUV_PSF_BAD	likely FUV PSF problem	FWHM(A)/FWHM(B) > 1.13 or fitFWHM $\geq 8''$	UNKNOWN
3.3	FUV_PSF_WARNING	possible NUV PSF problem	FWHM(A)/FWHM(B) ≤ 1.13 and fitFWHM$>5.7''$	N/A
3.4	ASP_ERRSTDEV	possible bad aspect solution	err[RA/DEC]_stdev > 15	UNKNOWN
3.4	ASP_ERRDIFF	possible bad aspect solution	err[RA/DEC]max-err[RA/DEC]min $> 50''$	UNKNOWN
3.5	NO_DATA	no intensity maps with exposure time	f/nexptime $\leq$ 0s	FAIL
3.5	NUV_ONLY	no FUV intensity maps with exposure time	fexptime $\leq$ 0s and nexptime $>$ 0s	N/A
3.5	FUV_ONLY	no NUV intensity maps with exposure time	nexptime $\leq$ 0s and fexptime $>$ 0s	N/A
3.5	TIME_BELOW_MIN	recovered exptime below minimium	0s $<$ f/nexptime $\leq$ 10s	FAIL
3.5	TIME_RECOVERY_LOW	recovered exptime less than 80%	f/nrecovertime $\leq$ 80%	N/A
3.6	GRELEASE_LOW	pipeline version less than minimum	GRELEASE $<$ expected	FAIL
3.7	BLOB_RATIO_HI	FUV window charging likely strong	hiq_blob_cr/blob_cr > 0.2	UNKNOWN
3.7	BLOB_RATIO_MEDIUM	FUV window charging likely moderate	$0.1 <$ hiq_blob_cr/blob_cr < 0.2	N/A
3.7	BLOB_RATIO_LOW	FUV window charging likely weak	$0.013 <$ hiq_blob_cr/blob_cr < 0.1	N/A
3.8	MISSING_NUV_INT	missing NUV intensity map	no X-nd-int.fits* file	FAIL
3.8	MISSING_FUV_INT	missing FUV intensity map	no X-fd-int.fits* file	FAIL
3.8	MISSING_NUV_RRHR	missing NUV high-res response map	no X-nd-rrhr.fist* file	FAIL
3.8	MISSING_FUV_RRHR	missing FUV high-res response map	no X-fd-rrhr.fits* file	FAIL
3.8	MISSING_NUV_SKYBG	missing NUV background map	no X-nd-skybg.fits* file	FAIL
3.8	MISSING_FUV_SKYBG	missing FUV background map	no X-fd-skybg.fits* file	FAIL
3.8	MISSING_NUV_PSFSTATS	missing NUV PSF estimates	no X-nd-psf_stats.txt file	FAIL
3.8	MISSING_FUV_PSFSTATS	missing FUV PSF estimates	no X-fd-psf_stats.txt file	FAIL
3.8	MISSING_PLATE_SOLUTION	missing plate solution	no X-nd-cat_mch_rtastar_stats.txt file	FAIL
3.8	MISSING_MCAT	missing merged band source catalog	no X-xd-mcat.fits file	FAIL
3.8	MISSING_COLOR_JPEG	missing QA jpeg images	no X-xd-int_2color.jpg file	FAIL
3.8	MISSING_ASP_STATS	missing aspect solution error estimates	no X-asp_stats.txt file	FAIL
3.8	NUV_INT_NOT_COMPRESSED	NUV intensity map not compressed	no X-nd-int.fits.gz file	UNKNOWN
3.8	FUV_INT_NOT_COMPRESSED	FUV intensity map not compressed	no X-fd-int.fits.gz file	UNKNOWN
3.9	MISSING_VISIT_NUV_#	approved NUV visit missing from coadd	visit coadd status YES and not included	FAIL
3.9	MISSING_VISIT_FUV_#	approved FUV visit missing from coadd	visit coadd status YES and not included	FAIL
3.9	BAD_VISIT_FUV_#	unapproved NUV visit included in coadd	visit coadd status NO and included	FAIL
3.9	BAD_VISIT_FUV_#	unapproved FUV visit included in coadd	visit coadd status NO and included	FAIL
3.9	TIME_LOSS_NUV	NUV exptime less than sum of approved visits	coadd NUV exptime $<$ expected	FAIL

Table 1—Continued

§	FLAG	MEANING	CONDITION	GRADE
3.9	TIME_LOSS_FUV	FUV exptime less than sum of approved visits	coadd FUV exptime $<$ expected	FAIL
3.9	TIME_GAIN_NUV	NUV exptime greater than sum of approved visits	coadd NUV exptime $>$ expected	FAIL
3.9	TIME_GAIN_FUV	FUV exptime greater than sum of approved visits	coadd FUV exptime $>$ expected	FAIL
3.9	NO_VISIT_CHK	visit quality not checked for coadd product	none	N/A
3.10	OVERRIDE_FAIL	FAIL grade overridden by analyst	none	?
3.10	OVERRIDE_PASS	PASS grade overridden by analyst	none	?
3.10	OVERRIDE_UNK	UNKNOWN grade overridden by analyst	none	?
3.10	OVERRIDE_COADD_Y	coadd YES status overridden by analyst	none	N/A
3.10	OVERRIDE_COADD_N	coadd NO status overridden by analyst	none	N/A

Note. — X = field (i.e. target/visit/sub-visit)

Table 2. Standardized QA Analyst Comments

§	COMMENT	MEANING	GRADE
3.4	ASP_Ok	Aspect solution appears good	PASS
3.4	ASP_Bad_Plot	Aspect solution appears bad from boresite plot	FAIL
3.4	ASP_Bad_Image	Aspect problems obvious in image	FAIL
3.7	Blob	FUV window charging is visible	N/A
4	Transit(N)	Satellite(?) trail is visible	N/A
4	Transit_Asteroid(N)	Asteroid(?) trail is visible	N/A
4	NUV_Hot_Pixel(N)	Unmasked NUV detector hotspot	N/A
4	FUV_Hot_Pixel(N)	Unmasked FUV detector hotspot	N/A
6	Reprocessed_No_Dphot	Reprocessed with out *deltaphot* refinement	N/A
6	Reprocessed(T1..TN)	Reprocessed and time interval limited	N/A

Note. — (N) indicates quantity or position. (T) indicates time interval.

2.2. Using Data That Fails QA Testing

2.2.1. Correctable Data

Data with a failing QA grade may still be of use if the reasons are **limited** to astrometry related problems. Astrometry rotation errors are the most common reason for data to fail the QA process. The user of the imaging data can correct the astrometry and feel confident that the data is fine. If it is part of a multiply visited target, the corrected data can be included in a user built coadd. Even those without plate solutions (MISSING_PLATE_SOLUTION) could be fine.

2.2.2. Uncorrectable Data

The only time that data can, unequivocally, not be used for scientific analysis is if the problems are uncorrectable outside of enhancements to the GALEX direct imaging pipeline. This situation is limited to confirmed image aspect solution errors or cases of sub-nominal detector high voltage operation. Confirmed aspect solution errors will have either ASP_Bad_Plot or ASP_Bad_Image in the QA report comments. The HV_LOW flag will be set in the QA report in the event of sub-nominal detector high voltage.

3. AUTOMATED QA DESCRIPTION

The following describes the specific checks performed by the automated QA and the meaning of all flags. Not all files mentioned are available as part of public or guest investigator data releases. To shorten file name descriptions the field name (target/visit/sub-visit) portion is represented as 'X'.

For a single observations, the automated QA checks that the data are within acceptable limits of astrometry, detector high voltage settings, point spread function, aspect solution, exposure time, pipeline version, FUV window charging (blob), and that requisite files are present.

For coadded products, the automated QA checks that the data are within acceptable limits for astrometry, point spread function, exposure time, pipeline version, and that the requisite files are present. Additionally, coadd-specific checks confirm that the product includes all visits and only visits that have been deemed acceptabled for coadding, each visit is built with the appropriate pipeline version, and the exposure time is consistent with the sum of the exposure time of the visits approved for coaddition.

3.1. Astrometry (qachkastrom)

Plate solutions are computed independently of the astrometric solution in order to test the quality of the astrometry. This is done by matching pipeline source catalog objects to stars selected from a subset of the ACT, SAO, and USNOA star catalogs. A minimum of 6 stars within a match radius of $4''$ are required to compute the plate solution. Therefore, if our astrometry is off by more that $4''$ no plate solution is generated and the data will receive a FAIL QA grade with the PLATE_SOLUTION_MISSING flag set. The data, however, may be fine other than the astrometric error.

If a plate solution has been successfully derived (X-nd-cat_mch_rtastar_stats.txt), the shift and rotation are evaluated. If the offset from the combined x/yshift is greater than $1.5''$ (1 pixel) the flag ASTROMETRY_SHIFT is set. If the absolute rotation angle is greater than $0.04°$ (corresponding to an offset of 1 pixel at $0.6°$ from center) the flag ASTROMETRY_ROTATION is set. Either condition is sufficient to generate a FAIL grade. Rotation is the most common reason for a visit to receive a FAIL grade.

At present, because plate solutions are only computed for observations which include NUV imaging, all FUV-only data will default to a FAIL grade. However, no specific astrometry flag is set. See comments on FUV-only data (§ 5).

3.2. Detector High Voltage (qachkhv)

During an early phase of the mission several observations (eclipses 643 to 749) were performed with the high voltage of the detectors set below the nominal operating level. Proper use of this data would require special and unique calibration which is unlikely to occur in the foreseeable future. Visits with eclipse numbers that fall in the range of 643 to 749 set the flag HV_LOW and is sufficient to generate a FAIL grade. This is not directly applicable to coadded data products.

3.3. Point Spread Function (qachkpsf)

Although the GALEX PSF is neither Gaussian nor uniform, an attempt is made to estimate the FWHM of point sources in a way that catches many PSF-related problems.

In theory, because the same aspect solution is applied to both the NUV and FUV (obtained simultaneously), if the PSF in one band is within acceptable limits the other should also be within limits. Nonetheless, for QA purposes, the PSF in both bands are inspected because PSF measurement is sensitive to background estimates and crowding.

The estimators are derived from the pipeline X-[f/n]d-psf_stats.txt output. Specifically, the average value for fitFWHM and the moments FWHM(A) and FWHM(B) for a limited sample of likely point sources within the central 1200 pixel radius at all detector position angles are inspected.

The ratio of FWHM(A)/FWHM(B) is a good indicator of how elongated the PSF is. While large values of fitFWHM are also indicative of problems with image construction. The following empirically derived conditions find the vast majority of problematic fields independent of aspect solution (the source of PSF quality) checks.

For NUV images: If FWHM(A)/FWHM(B) > 1.2 or fitFWHM $\geq 8''$ then the flag NUV_PSF_BAD is set. If FWHM(A)/FWHM(B) ≤ 1.2 and fitFWHM $> 5.7''$ then the flag NUV_PSF_WARNING is set.

For FUV images: If FWHM(A)/FWHM(B) > 1.13 or fitFWHM $\geq 8''$ then the flag FUV_PSF_BAD is set. If FWHM(A)/FWHM(B) ≤ 1.13 and fitFWHM $> 5.7''$ then the flag FUV_PSF_WARNING is set.

Because the central 1200 pixel radius is also the likely location of pointed observations of large galaxies, the afore mentioned issue of background levels and crowding can cause spuriously large PSF measurements especially in the FUV (i.e. M31). Therefore, if the NUV PSF is within acceptable limits but the FUV PSF fails, the FUV PSF flag is changed to a warning. PSF_BAD is not sufficient to generate a FAIL grade. If no other critical flag is set it will generate an UNKNOWN grade. A PSF_WARNING has no effect on the QA grade.

3.4. Aspect Solution (qachkasp)

GALEX executes a spiral dither pattern of order 1 arcminute during observations. One of the more challenging tasks preformed by the pipeline is to create images from the raw time and detector position tagged photons lists. The accuracy of the aspect solution derived from the spacecraft reported pointing information is often not accurate enough to generate images with the desired PSF quality and astrometric solution. The pipeline component *deltaphot* attempts to refine our pointing knowledge. The basic function is to locate known stellar sources in the field of view, track the true dither pattern, and generate accurate aspect and astrometric solutions.

Deltaphot is robust and performs optimally for the vast majority of observations, however, difficulty can arise when the spacecraft's pointing knowledge error exceeds expected tolerances of spacecraft motion, position or roll. If *deltaphot* is unable to accurately track the stellar sources (looses lock), that portion of time is rejected and the recovered exposure time is reduced. The limiting case occurs when *deltaphot* is unable to match any stars and no aspect solution is possible. The ability to compensate for these effects is the primary factor in producing instrument limited PSFs, recovering the full exposure time and accurate astrometry.

At present, NUV data is required for *deltaphot* to operate because of the low success rate of matching stellar catalogs to FUV images. That is, optical stellar catalogs are much more likely to be NUV sources than FUV sources. For this reason, FUV-only observations rely on the spacecraft reported position for aspect and astrometric solutions. Hence, image reconstruction aspect problems are difficult to detect in an automated fashion and one must rely on PSF checks and manual visual inspection to asses quality.

The automated QA aspect checks are designed to flag observations where *deltaphot* has made an erroneous aspect solution. Problems can range from the subtle - tracking errors that increase the PSF or false stellar source matches that lead to incorrect astrometry; to the dramatic - oscillating lock between multiple stars (due to drifting) resulting in images with duplicate, offset sources. See Figure 1 for an example of a successful aspect solution and Figure 2 for an example of a aspect solution with errors.

WARNING: Egregious errors of oscillating lock are obvious when inspecting images only if the duration of the oscillation is long. If the duration of the oscillation is short, only the brightest point sources will have offset duplicates and the problem may not be obvious from manual inspection of a single image. Since guest investigators will obtain all program data regardless of quality assessment, they must take QA aspect flags seriously and examine images with great care before using the data. A QA analyst has provided their opinion in the comments section of the QA report about any field with aspect warning flags set. Nonetheless, GIs should examine all images, whether flagged with aspect warnings or not, before using the data. Despite best efforts, data with errors may escape detection.

Using the *deltaphot* pipeline statistics file (X-asp_stats.txt), the automated QA will flag aspect solutions where the difference between the *deltaphot* solution and spacecraft reported solution is large enough to likely cause problems for *deltaphot*. Specifically, two conditions are considered. 1) If the difference between the minimum and maximum offset between the *deltaphot* and spacecraft reported RA (errx) or DEC (erry) exceeds $50''$ the flag ASP_ERRDIFF is set. 2) If the standard deviation of the offset between the *deltaphot* and spacecraft reported RA (errx) or DEC (erry) exceeds $15''$ the flag ASP_ERRSTDEV is set.

As this check will flag probable but not certain *deltaphot* related errors, either condition will prevent a PASS grade but not cause a FAIL. If no other critical flags are set the resulting grade will be UNKNOWN and manual inspection is required.

Due to the wide functionality of the *deltaphot* program, aspect, PSF and astrometry errors often occur simultaneously but not always. For example, the PSF and astrometry may be fine if the initial pointing was accurate and only a brief oscillating lock occurs. QA testing all three captures most problems.

Aspect solutions are applicable to visit level data only. The QA process excludes any visit with aspect solution problems from coadded products.

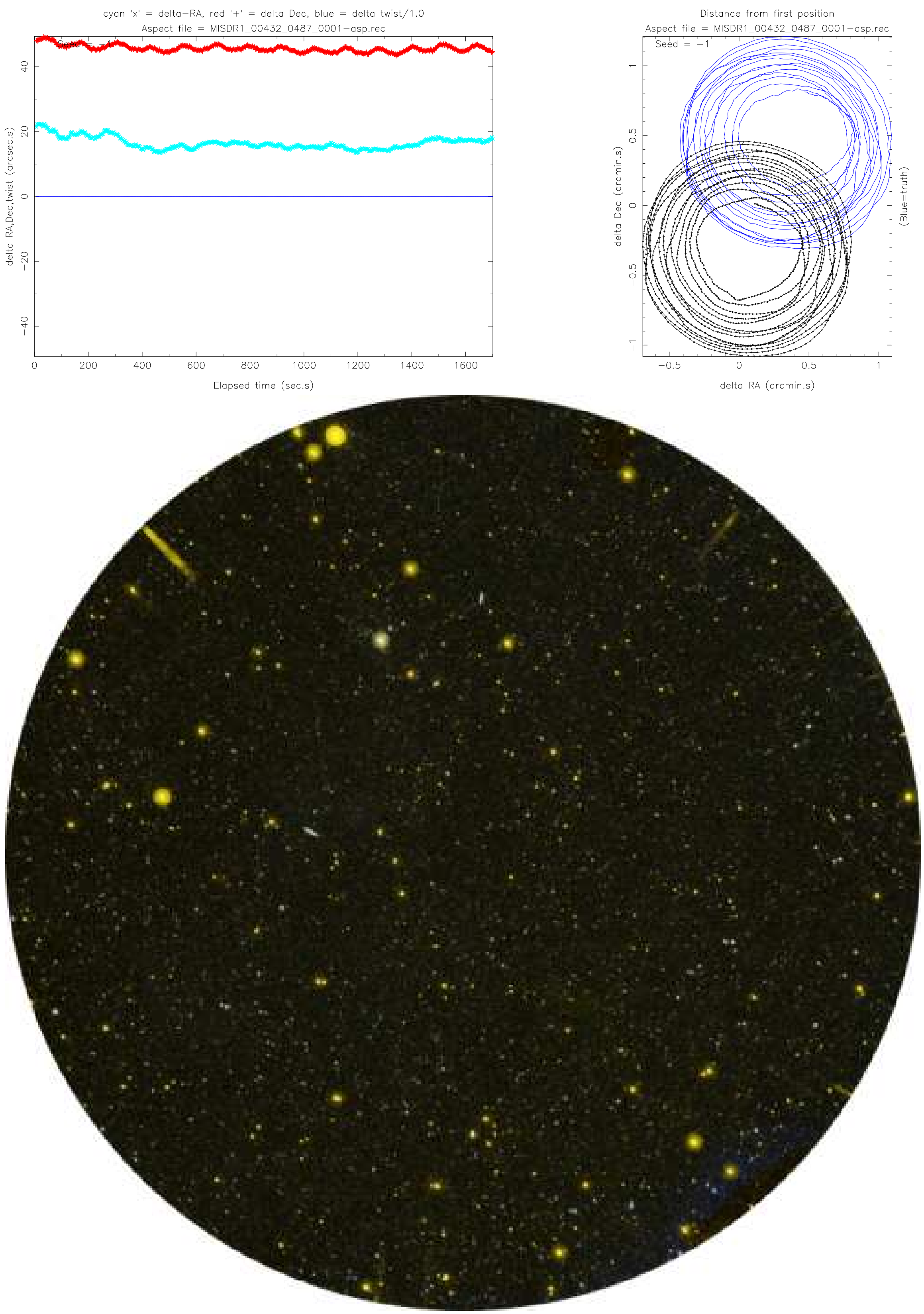

Fig. 1.— Example of a high quality aspect solution. The two panels at top are the boresite plots. The top left plot shows the RA and DEC offset from the reported spacecraft position as a function of time. The top right plot shows the true dither pattern relative to the spacecraft reported pattern. The resonstructed image data (as a composite of FUV and NUV) is in the bottom panel.

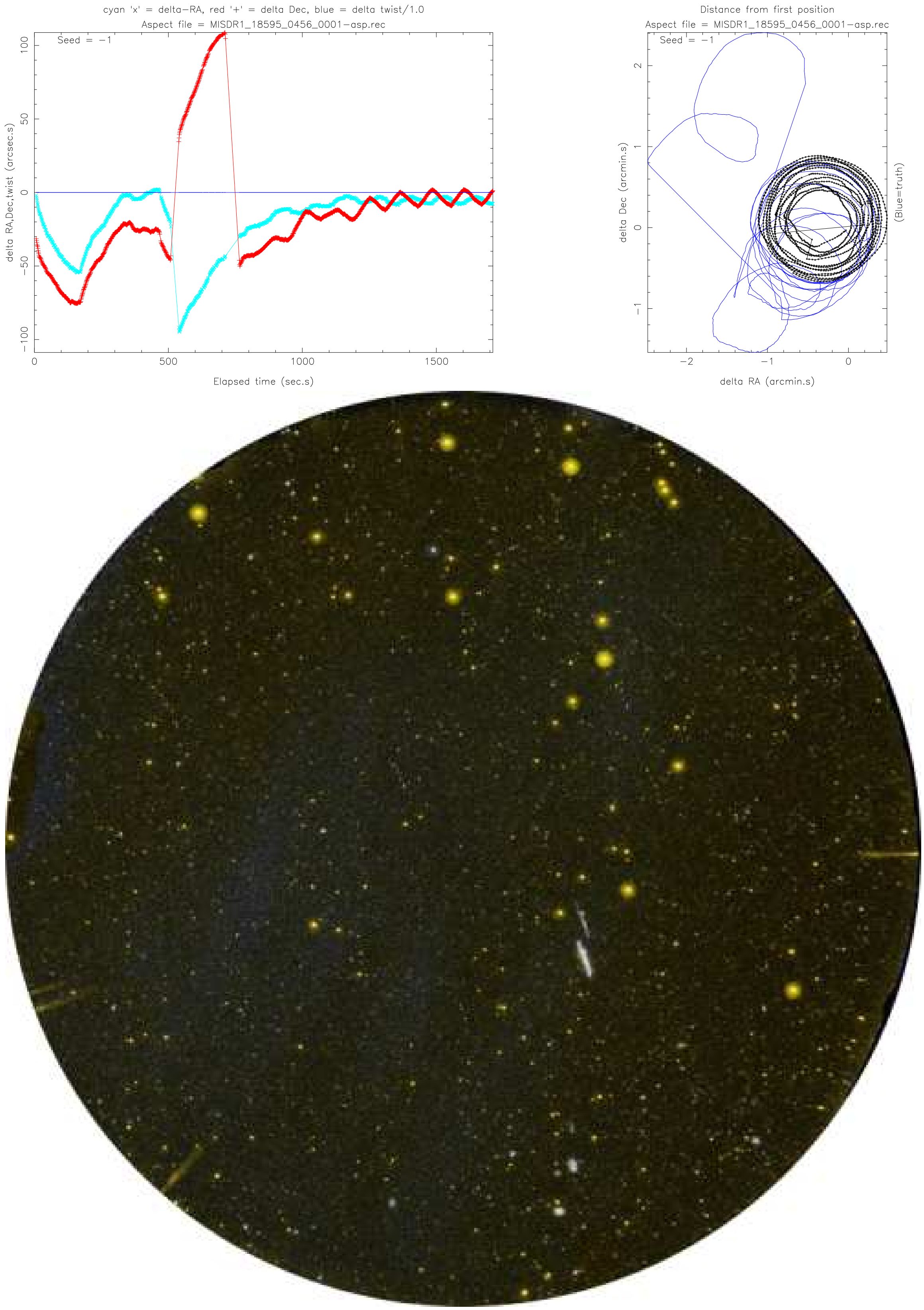

Fig. 2.— Example of a poor quality aspect solution. Panels are the same as in Fig 1. Duplications due to oscillation lock by *deltaphot* are obvious in this case. When the duration of the aspect solution error is short problems can be very subtle.

3.5. Exposure Time (qachkexprel)

The exposure times recorded in the headers of the end product intensity maps (X-[f/n]d-int.fit) are inspected. If the FUV and NUV exposure times are zero or can not be retrieved a NO_DATA flag is set. If the FUV or NUV exposure times are zero or can not be retrieved a NUV_ONLY or FUV_ONLY flag is set respectively. These flags are independent of the planned observation type and detector operating status. Automated QA does not verify if the observation was planned as F/NUV-only. A NO_DATA flag will generate a FAIL grade.

If the exposure time for either band is $0 < \text{exptime} \leq 10$ seconds the flag TIME_BELOW_MIN is set and a FAIL grade is generated. Such low exposure times suggest *deltaphot* related problems.

The warning flag TIME_RECOVERY_LOW is set when the recovered exposure time is less than 80% of the time the detector was operating at the nominal high voltage setting (the maximum possible exposure time). When the recovered exposure time falls below this level *deltaphot* has likely had some difficulty computing the aspect solution. It does not mean that there are any problems with time it has recovered - just that more than 20% of the observation time was not recoverable.

3.6. Pipeline Version (qachkexprel)

The GALEX data processing pipeline is prone to rapid improvements. Therefore the automated QA checks that the pipeline version under which the data product was built is at the level designated for the specific release or higher. The version is read from the header of the intensity maps. If the pipeline version is lower than expected the GRELEASE_LOW flag is set and the QA grade is set to FAIL.

3.7. FUV Window Charging/Blob (qachkblob)

For reasons that are still not fully understood, a small area on the edge of the FUV detector window can accumulate charge anomalously. As the charge builds up, field emission can trigger the FUV microchannel plate directly beneath it. When the charge is strong, the field emission can be detected above the background levels in FUV images. This is commonly referred to as the blob. The blob is rigorously tracked in every observation by comparing the detector high pulse height count rate to total count rate in the affected region. It behaves in a reasonably predictable manner. Space weather events, however, can cause rapid changes. When the count rate from the blob begins to exceed manageable background levels the FUV detector is turned off and the window is allowed to discharge.

Automated QA queries the mission operations trending database for the blob tracking values. If the ratio of high pulse height count rate to total count rate (hiq_blob_cr/blob_cr) in the region is ≥ 0.2 the BLOB_RATIO_HI flag is set and the blob is likely to be easily visible in the FUV data. If the ratio is between 0.1 and 0.2 the BLOB_RATIO_MEDIUM flag is set and the blob may be detectable depending on the background levels in the FOV. If the ratio is between 0.013 and 0.1 the BLOB_RATIO_LOW flag is set, however it is unlikely to be easily distinguishable from the background.

Only the BLOB_RATIO_HI flag is sufficient to prevent a PASS grade (remain UNKNOWN). Figure 3 is an example of strong blob presence. Manual inspection by a QA analyst will determine if the data is acceptable for PASS.

3.8. Requisite Files (qachkfiles)

Automated QA checks for the existence of four band-specific and four band-independent critical files in the pipeline directory. Other than a flag for a missing plate solution, most missing file issues are resolved by reprocessing and are unlikely to be seen for data made available to guest investigators or the public.

Flags for all missing files are suppressed if the NO_DATA flag is set. Flags for FUV or NUV band-specific files are suppressed if the NUV_ONLY or FUV_ONLY flags are set respectively.

The following band-specific files must exist: intensity maps (X-[f/n]d-int.fit*), high resolution response maps (X-[f/n]d-rrhr.fit*), background maps (X-[f/n]d-skybg.fit*), and PSF measurements (X-[f/n]d-psf_stats.txt). Non-existence will set the MISSING_[F/N]NUV_INT, MISSING_[F/N]UV_RRHR, MISSING_[F/N]UV_SKYBG, and MISSING_[F/N]UV_PSFSTATS flags respectively. Any of these flags is sufficient to generate a FAIL QA grade.

The intensity maps must also be compressed otherwise the [F/N]UV_INT_NOT_COMPRESSED flag is set and a QA grade of UNKNOWN will persist.

The following band-independent files must exist: aspect solution status file (X-asp_stats.txt), plate solution (X-*-cat_mch_rtastar_stats.txt), merged band source catalog (X-xd-mcat.fits), and jpeg image of the data (X-xd-int_2color.jpg). Non-existence will set the MISSING_ASP_STATS, MISSING_PLATE_SOLUTION, MISSING_MCAT, and MISSING_COLOR_JPEG flags respectively. Any of these flags is sufficient to generate a FAIL QA grade.

Note that aspect solutions are not applicable to coadded data.

3.9. Coadds/Mains (qachkmainvis)

Once the visit level data has been through the automated QA/manual inspection iterative process, coadds (mains) are built for those targets with multiple visits.

Fig. 3.— Example of strong FUV window charging (the blob). This image is a NUV (red) and FUV (blue) color composite. In standard North-up East-left projected data, the blob can appear anywhere along the detector edge depending on the spacecraft roll angle. In this particular case the BLOB_RATIO_HI flag is set.

The same automated QA checks are performed on coadded data products as are done for single visits except the non-applicable checks for sub-nominal high voltage settings, blob presence, and aspect solution issues which are only possible to perform at the visit level.

In addition to the visit level checks, coadd specific checks confirm that the product includes all visits and only visits with an approved QA coadd status, each visit is built with the appropriate pipeline version, and the exposure time is consistent with the sum of the exposure time of the visits with an approved QA coadd status.

These checks are accomplished by comparing the expected visits eclipse numbers, exposure times and pipeline versions in the final visit QA report for a given target to the visit eclipse numbers, visit pipeline version and total exposure time in the header of the coadd intensity maps.

If an approved visit is missing from a coadd a MISSING_VISIT_[F/N]UV_# flag is set where # is the visit number. If a unapproved visit is included in the coadd a BAD_VISIT_[F/N]UV_# flag is set. A MISSING_VISIT or BAD_VISIT flag will generate a FAIL QA grade.

If the exposure time of the coadd is greater or less than the total expected from the approved visits then a TIME_GAIN_[F/N]UV or TIME_LOSS_[F/N]UV flag is set respectively. A TIME_GAIN or TIME_LOSS flag will generate a FAIL QA grade.

It is possible to perform automated QA on coadded data without prior knowledge of the QA grade of the constituent visits. In this case a NO_VISIT_CHK flag is set.

3.10. Grades and Analyst Overrides (qachkstat)

A FAIL grade will result from any of the following flags: ASTROMETRY_SHIFT, ASTROMETRY_ROTATION, TIME_BELOW_MIN, MISSING_ASP_STATS, HV_LOW, MISSING_[file], GRELEASE_LOW or NO_DATA. For coadded data a FAIL will also occur if a TIME_LOSS_[F/N]UV, TIME_GAIN_[F/N]UV, MISSING_VISIT_# or BAD_VISIT_# flag is set.

Provided none of the above strict FAIL flags are set, an UNKNOWN grade will persist if a ASP_X, BLOB_RATIO_HI, NUV_PSF_BAD, FUV_PSF_BAD or [F/N]UV_INT_NOT_COMPRESSED flag is set.

If none of the strict FAIL or UNKNOWN persisting flags are set then the automated QA grade will be PASS.

Manual inspection by a QA analyst is needed to resolve an UNKNOWN grade. An analyst can also override any automated QA grade. When this happens a OVERRIDE_[PASS/FAIL/UNK] flag is set depending on whether the automated QA grade was PASS, FAIL or UNKNOWN.

4. MANUAL INSPECTION DESCRIPTION

When a analyst manually inspects visit level data, the reason is most likely to resolve an UNKNOWN QA grade due to the inability of the automated QA checks to determine if the aspect solution is good.

The analyst will check the aspect solution by inspecting the boresite tracking plot for discontinuities and/or irregular motion and by inspecting the fits and/or jpeg representations of the image data for signs of poor aspect solutions (blurring, streaking, duplication etc.). This is typically sufficient to determine if the aspect solution is good or bad. If multiple visits for a given target are available the images will be compared. This is a very simple way to detect even very subtle aspect errors. The analyst may also inspect low resolution time-series "movies" of the data to watch the FOV movement/dither over the course of the observation if needed.

If the aspect solution is deemed good the standardized comment ASP_Ok is added and the grade is set to PASS. If the boresite plot shows irregular motion the comment ASP_Bad_Plot is added and the grade is set to FAIL. If the aspect solution problems are severe enough to be detected with a visual inspection of the image, the comment ASP_Bad_Image is added and the grade is set to FAIL.

In addition to resolving an UNKNOWN QA grade, an analyst may provide comments about the presence of FUV window charging, note transiting objects in the FOV, and note unmasked detector hot spots. Table 2 summarizes the standardized analyst comments. Free form comments may also appear. Analysts do not provide comments about detector window and dichroic reflections.

Analysts can change the QA grade for any visit. Analysts may also change the coadd status of any visit independently from the grade. Typically, if a visit has a PASS QA grade the coadd status is YES. However, there may be other reason for excluding visits from coadded products. Deep fields, for example, may exclude a visit with transiting sources or unmasked detector hot spots as the effect on total exposure time is small.

5. COMMENTS ON FUV-ONLY DATA

FUV-only observations must be treated differently than standard 2-band or NUV-only imaging observations. As described in § 3.4, the pointing refinement software *deltaphot* requires NUV band imaging. Therefore, FUV-only data rely solely on the often inaccurate spacecraft provided position information for aspect and astrometry solutions. Because *deltaphot* does not run on FUV-only data, no stellar sources are matched and a plate solution is not generated. Automated QA tests are limited in their ability to evaluate FUV-only data.

All FUV-only data will receive a FAIL QA grade due to the lack of a plate solution. A user of this data is required to confirm and, if needed, correct the astrometry. There is a low probability of the pipeline generated astrometry being correct.

More serious and difficult is evaluating the quality of the aspect solution. If it is obvious there are problems with the image reconstruction from a simple inspection of the image, it will be noted by an analyst in the comments as ASP_Bad_Image. More worrisome are the subtle aspect errors discussed in § 3.4. PSF QA tests may provide a clue about potential problems. If the FUV_PSF_BAD flag is set, there is likely significant aspect solution errors. If the FUV_PSF_WARNING flag is set and the field is not crowded then one should also use caution.

It is recommended that FUV-only data be compared to optical imaging. For example, compare visit data to digitized Palomar Observatory Sky Survey plates. Be wary of any point sources that do not have optical counterparts (at single visit depth). In particular, look for offset duplication of the brightest FUV point sources.

6. COMMENTS ON GUEST INVESTIGATOR REPROCESSING

6.1. Repairing Minor Aspect Solution Errors

For data that has aspect solution errors limited to discrete time intervals (§ 3.4), we have attempted to repair the data by excluding the offending portions of the observation. The visits for which this has been done are commented with 'Reprocessed(T1...TN)' in the QA report. Where data outside the intervals T1...TN are excluded.

6.2. Repairing Major Aspect Solution Failures

As described in § 3.4, the limiting case of aspect solution error is the lack of solution due to the inability of *deltaphot* to match any NUV stellar point sources despite the existence of NUV data. For guest investigator data, when this occurs, we have attempted to recover the data by reprocessing it using the same method employed for processing FUV-only data (§ 5). That is, by relying solely on the less accurate spacecraft reported position information for aspect and astrometry solutions.

Like FUV-only data, these visits will receive a FAIL QA grade because of the lack of aspect solution error estimates and lack of plate solution. In addition, these visits will have 'Reprocessed_No_Dphot' in the QA report comments.

All warning and suggestions relevant to FUV-only data described in § 5 are relevant to data reprocessed without *deltaphot*.

A. GLOSSARY

AIS All-sky Imaging Survey [EXPTIME=100 s]

All-sky survey tile A tile composed of multiple, separate dithered pointings, called legs, occurring within a single eclipse.

CPS Counts per second.

DIS Deep Imaging Survey [EXPTIME=30,000 s]

Dither A controlled motion of the satellite to move the telescope boresight in a tight, slow spiral pattern that moves outward to 1.5 diameter across the sky.

Eclipse Time interval during which the Sun is occulted by the Earth during a particular orbit of the spacecraft, typically 1800-2000 sec in length. All GALEX observations occur while GALEX is in eclipse. One target is observed per eclipse. The data acquired during an eclipse is sometimes referred to as an eclipse.

EXPTIME Nominal exposure time in seconds at each location in a GALEX survey.

FUV Far Ultraviolet detector

GALEX Galaxy Evolution Explorer

Leg A single, dithered pointing within an all-sky survey tile.

MCP Microchannel Plate, the high-voltage electron-multiplier array that is the basis for the GALEX detectors.

MIS Medium-Imaging Survey [EXPTIME=1500 s]

NGS Nearby Galaxy Survey [EXPTIME=1500 s]

NUV Near Ultraviolet detector

Observation The acquisition of photon data from a region of the sky during a single orbital night (eclipse).

Pointing Generic term referring to the location on the sky of a single, dithered GALEX field of view. A single tile or a target may consist of one or more pointings.

Primary Tile A tile whose center coincides with a non-AIS target center or whose legs coincide with all-sky survey leg centers. Thus a target can be roughly described as a primary tile plus an optical wheel setting.

PSF Point Spread Function, the distribution of light in an image of an unresolved object

Region A pre-defined area on the sky where one or more targets (see list below) are clustered. A region is used for planning purposes.

SC Spacecraft

Secondary Tile A tile with no single target counterpart, i.e., a secondary tile's photon data will come from multiple targets. Note that no data from secondary tiles exist in the GR1 release.

Sub-visit A sequential count of legs detected and processed by the pipeline (see leg and all-sky survey tile). If all data for an AIS tile reach ground and are processed normally, the sub-visit number will correspond to the leg number, but if there are data gaps or the processing is aberrant in some way, legs may be missing (or possibly split in two), but sub-visit numbering will always be sequential. (Note the rough correspondence between visit vs. eclipse, and sub-visit vs. leg.)

Survey A type of observation designed to study the sky at given depth (exposure time), with a given sky coverage and location, and in Imaging, Grism, or Opaque GROW mode. (See Survey Summary in the GR1 documentation.)

Target An area of sky observed by GALEX together with the spacecraft-motion and instrument commands used for that observation. Note that because the commanded spacecraft motion can be complex, a target can have a complex shape. In particular, All-sky Imaging Survey (AIS) targets are composed of several separate pointings, which may or may not overlap. Also note that the same geometric part of the sky (see Primary Tile) may be observed in both direct and grism modes, making two targets. A target can be roughly described as a primary tile plus an optical wheel setting. Targets may overlap one another. Most targets will consist of a single, roughly-circular, 1.25 degree diameter GALEX field of view, or, for AIS targets, a series of overlapping fields of view.

Tile An area of sky for which the pipeline has generated (or will generate) an image using GALEX photon data. A tile may have an arbitrary shape (see Target), but in general will comprise one or more images with north in the +Y direction. (See Primary Tile, and Secondary_Tile.) Most tiles will consist of a single, roughly-circular, 1.25 degree diameter GALEX field of view, or, for AIS tiles, a series of overlapping fields of view.

Visit The planned sequential repeat count of an observation from a single eclipse of a single target. For example, if 10 widely-separated eclipses are allocated for observing a particular target, the visits will numbered 1 through 10. Note that since not all planned observations are made successfully, and some data may not reach ground, some visits may be missing from a sequence. See also sub-visit.

VisitData Processed data from a single visit

WCS World Coordinate System (FITS CRVAL1,CDELT2,CROTA2,etc.)