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Specification and Application of the MAMA Additive Image (MADDIM) to Track Charge Extraction

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J. R. Walsh, S. A. Baum, J. Rose, J. J. E. Hayes
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ABSTRACT

Incident photons extract charge from the channels of the Micro-Channel Plate of the STIS MAMA detectors. Continued exposure leads to a decrease in the gain and a subsequent drop in the detective quantum efficiency (DQE). Ground tests of MAMA tubes show that the rate of loss of DQE is dependent not only on the total amount of charge extracted, but also on the rate.

Plots are shown for the DQE loss v. exposure time for MAMA detectors and a fit to the data is used to derive the DQE loss in terms of detected rate. An archiving system has been set up to collect images from both the STIS MAMA detectors of the total number of detected counts and the DQE loss, the latter derived from the count rate. These files are referred to as MADDIM images and are designated with the suffix _oma. Collection of these data were begun in October 1997. The _oma files for each week are summed into a running total to produce the lifetime count and DQE loss images (designated by life_). Plots of the life_ images can be used to determine strategies for placement of spectra on the detector and could be used to adjust the pixel flat fields if substantial DQE loss has occurred, which is not the case in the 400 days so far monitored.

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1. Introduction

The two photon counting detectors in STIS are Multi-Anode Microchannel Arrays (MAMA) with 1024x1024 pixels. Although the spectral ranges differ—the NUV detector has a Cs_2Te photocathode for the 1650 to 3100 Å region whilst the FUV detector (1150 to 1700 Å) has a solar blind CsI photocathode—the detectors are similar (Timothy and Bybee, 1975). In common with all MAMA detectors, photons extract charge (liberate electrons) from the channels of the Micro-Channel Plate (MCP). The result of accumulated exposure with time is a decrease in the MCP gain as charge is extracted. In particular, exposure to high levels of illumination results in significant extraction of charge from the MCP. The result of a drop in electron gain is a shift of the pulse height distribution to lower gains. If the threshold for detection of events is kept fixed, then some real events will be lost leading to a decrease in the detective quantum efficiency (DQE). Globally this gain can be compensated by increasing the accelerating voltage on the input electrode of the MCP, up to specified limits. If however the charge extraction is not uniform across the whole MCP, due to higher levels of charge extraction in regions which have incurred high count rates over extended periods, local non-uniformities in DQE will result. Local loss of gain results in reduced sensitivity with concomitant effects on loss of signal in images and spectra. To guard against local and global reductions in the sensitivity a Bright Object Protection mechanism has been set in place (Clampin, 1996; Leitherer et al., 1996); count rate limits for local and global counts/sec are specified in the *STIS Instrument Handbook* (Baum et al., 1998).

Since the STIS MAMA detectors are a strictly limited resource, from the point of view of their longevity and their capability to deliver high quality science, careful housekeeping of the rate of charge extraction is essential to continued operation into the next millennium. In addition since MAMA flat fields cannot be taken very often as the required exposures are long and the lamp lifetime is limited, monitoring of the rate of charge extraction could provide incremental flat fields. Such flats would be particularly useful if higher count rates have been encountered in restricted regions of the detector as with spectra of emission line sources for example. This report describes the relation between DQE loss and illumination, as determined from ground calibration, and the procedures and their testing for generation and archiving of the MAMA ADDitive Image (MADDIM). Finally MADDIM data collected over a year is examined to assess the impact of charge extraction on lifetime and flat fields.

2. Ground Based Tests

The rate at which DQE decreases for the STIS MAMA detectors is dependent not simply on the total number of electrons extracted from the MCP but the rate at which they are extracted. During the ground-based laboratory tests of the MAMA detectors, the rate at which the DQE degrades as a function of accumulated illumination (i.e, count rate/s times exposure time) was measured. Figure 1 shows the measured points for tube STE6 (data from Danks 1996). Although this tube was not selected for flight it has a resitivity similar to the flight selected (NUV) tube STD6.

A least squares straight line best fit to log(accumulated exposure) against the log(recorded count rate), for count rates less than 1200 counts/sec/pixel yielded the following relation:

$$\text{Log (Texp (min.) to 1\% DQE loss)} = -2.39\ \text{Log(Cnts/s/pix)} + 10.48$$

The fit is shown as the continuous line in Figure 1. The mean deviation of the fit was slightly lower when including the eight points in Table 1 of Danks (1996), than if the average value for the three values of the number of minutes to a 1% DQE loss at 200 cnts/s/pixel was adopted. An example serves to show how to interpret this plot. If the MAMA detector is exposed for 100 minutes at a count rate of 700 counts/pixel/sec, then the loss in DQE at a pixel will be 1%. At a count rate of 1000 counts/pixel/sec, a loss of 1% DQE occurs in only 10 minutes. However there is a roll over in the linearity of the relation between detected counts and incident photons; this is illustrated in Figures 2 and 3 respectively (taken from Danks 1996) for the STE6 and STF1 MAMA tubes. Detected counts will never be recorded above ~300 counts/pixel/sec from the NUV-MAMA or above ~200 counts/pixel/sec for the FUV MAMA.

3. MAMA Lifetime Safekeeping

Two strategies are adopted to ensure that high count rates, which might cause global or local reduction in DQE, are avoided. One is a stringent Bright Object Protection (BOP) mechanism whereby all targets are vetted for brightness in the UV as far as this is possible Leitherer et al. (1996) describe in detail the observing policies to ensure BOP and Clampin (1996) the BOP hardware and software mechanisms. In addition before each MAMA exposure a short (0.3s) exposure in 4x4 (low res) binned pixels (256^2 image) is obtained and processed by the on-board software to check for any regions whose local count rate exceeds prescribed limits. Currently these limits are 200 counts/binned pixel/sec for the NUV-MAMA and 150 counts/binned pixel/sec for the FUV-MAMA. If any binned pixels with counts exceeding these limits are detected, the shutter is closed and the following exposure is aborted. This mechanism is called the Local Rate Check (LRC) and is described in Clampin (1996). The maximum allowed count rate is set by the Constraints and Restrictions Document (CARD) and is 500 counts/2x2 binned pixel/sec averaged over a period of 30s. Leitherer et. al (1996) has details.

The usually quoted lifetime count limit for a STIS MAMA pixel is 5×10^7 counts (Danks, 1996) although the exact number depends on the individual detector. Shown in Figure 1 (dashed line) is the limitation this count limit produces in the lifetime of the MAMA if exposed at a constant rate. Clearly this is not a likely situation given the differing dispersions, slit widths, brightness and spectral nature of the internal and external sources, but it implies that additional monitoring and protection mechanisms are required if a >5 year lifetime is to be retained at typical counts rates <=50 counts/pixel/sec. One adopted mechanism is shifting of the location of the nominal detector center so that for example the spectra of single objects or targets taken with a short slit will not all repeatedly occur on exactly the same region of the detector. The inherent non-repeatability of the MSM mechanism (Downes et al., 1997) will also introduce some additional “blurring” into the most exposed region of the detector. The frequency of shifts in the nominal detector center is once per month.

Since the lifetime of the flat field lamps for both MAMA detectors (Deuterium for the NUV-MAMA and Krypton for the FUV-MAMA) is limited, deep flat fields cannot be taken often (see Shaw et. al 1998). Given that the accumulated DQE loss in 1 month, implied by Figure 1, could approach a few tenths of a percent for >=50 counts/pixel/sec exposure, then such changes in flat field will not be accessible by the yearly fielding campaign. Keeping a record of the total MAMA detector exposure (counts and count rates) will allow contemporaneous flat fields to be produced by comparison with the most recent flat. This can be seen as particularly important for the effects of small-scale features which have suffered from imaging of a bright point source or emission line. Inability to discriminate such features as flat field effects could lead to spurious detection of absorption lines in stellar spectra, for example. Additional advantages, beyond detailed tracking of the flat field behavior, to be gained from keeping a history of the in-orbit exposure of the MAMA detectors are:

- The position of the shifted detector center can be wisely chosen to ensure a region of low sensitivity does not form.
- Experience can be learned on the exact loss of DQE at higher count rates, perhaps allowing limited observations to count rates above 100 counts/pixel/sec for deep spectroscopy or imaging.
- Flat fielding can in principle be continued after the flat field lamps have died.
- Scheduled changes in detector voltage can be applied to compensate the loss of DQE and their effect carefully monitored.

4. Requirements for Creating MADDIM Images

In principle the creation and archiving of MADDIM (MAMA Additive Images) images would appear to be simple: take each MAMA image and sum it into a running mean image, daily, weekly or monthly, say; divide each image by its exposure time, apply equation 1 to determine the DQE loss and sum this with the other DQE loss images for that day, week etc.

Given the importance of continuous monitoring of the accumulated counts and the count rate per pixel (since higher count rates have a greater effect on charge extraction than lower count rates even if the accumulated total count is the same), it is necessary to archive both the sum and DQE MADDIM images for each individual exposure or over some time span (such as per day or several days). This ISR goes on to describe the detailed specifications for creating and archiving MADDIM images for both MAMA detectors. It was decided that MADDIM images be produced every day that there are STIS MAMA exposures giving a fine enough sampling of changes in DQE without a huge archival requirement of two extra 1024^2 images per exposure.

5. Creation of Daily MADDIMs

Generic Conversion produces image associations for each day on which there were MAMA data taken, one for each detector, and named as follows:

- `mama_nuv_yyyymmdd_oma.fits`
- `mama_fuv_yyyymmdd_oma.fits`

Each contains two images: one for the sum of all the counts for that day and the other for the DQE loss formed by calculating the count rates and applying equation 1. Both are 1024x1024 (lowres) pixel images. The third item of the name contains the date—year (yyyy), month (mm) and day (dd)—on which the file was written. For the sake of brevity, the two images will be referred to as `mama_nuv_date_sum` and `mama_nuv_date_dqe` for the NUV MAMA for example. The rules used by Generic Conversion in producing these files are as follows:

1. For day dd produce lowres (1024x1024) images for each of the exposures received on that day. In the case of Timetag data, collapse the time axis to produce an ACCUM image which is the sum of all counts received per pixel. If the data were taken in high res mode (2048x2048 pixels) block sum the data 2x2 pixels.

   Sum all the 1024x1024 images thus produced for that day into a single frame, the `mama_nuv_date_sum` image. A trailer file, with the same name as the MADDIM file with extension `tra`, is produced listing the names of all the images which went into forming the sum.

2. From each image produced as described in (1), convert to count rate by dividing each by the exact exposure time and apply equation 1 to convert each pixel to DQE loss. Sum all the DQE loss images for that day into a single image, the `mama_nuv_date_dqe` frame. The `mama_nuv_date_sum` and `mama_nuv_date_dqe` files have FITS headers and the headers are listed in Appendix 1. There are a number of keywords which are specific to MADDIM images and they refer to information about the date of the last exposure added to the MADDIM daily file, the time of start of the first file and the stop time of the last exposure included, the total integration time of all the exposures that day and the percentage of time using sub-arrays. Statistics on the mean, median maximum and minimum counts and DQE are also listed in the header. Both images are formed into a FITS association with the sum image as the first association and the DQE image as the second.

Figure 4 shows an example of a NUV MADDIM image and in Figure 5 a FUV MADDIM image is shown for a different date.

3. At approximately weekly intervals, but depending on the number of MAMA exposures, add the sum and DQE images to cumulative images of the sum and DQE respectively. These files have similar properties to the _oma files but are distinguished by the prefix *life_*, e.g.

life_nuv_19980705_oma.fits

The most recent file therefore provides the history of incident counts and DQE loss for each MAMA detector since collection of MADDIM images began.

6. Confirmation of the Procedure for MADDIM production

STIS NUV and FUV MADDIM images for the period 1997 October 06 to 11 were checked.

FUV

For FUV the following four daily sums were used:

- `mama_fuv_19971006_oma.fits`
- `mama_fuv_19971007_oma.fits`
- `mama_fuv_19971009_oma.fits`
- `mama_fuv_19971011_oma.fits`

All images were retrieved which were listed in the daily `.tra` files which were not proprietary for these days. The daily sums for `19971007` and `19971009` were checked and found to agree with that for the sum of the individual raw files. The calculation of the DQE loss was checked for the `19971009` data. The individual raw images were block summed to 1024x1024, divided by the exposure times and the formula applied:

DQE loss (%) = T(min) * 10**(-8.48 + 2.39*log10(cnts/s/pix))

The calculated values agree with those from the daily sum files. For example at pixel 498,686 (on an arc line) in the 2x2 block summed images:

- `o4bl12h2q` Raw 113 cnts, Rate 0.1704, DQE loss 5.329e-10
- `o4bl12h4q` Raw 584 cnts, Rate 1.747 DQE loss 7.002E-8
- Sum of two: DQE loss 7.055E-8. Value in `mama_fuv_19971009_oma.fits[2]` is 7.055E-8

NUV

For the NUV data over the same period, the following three daily sums were used:

- `mama_nuv_19971006_oma.fits`
- `mama_nuv_19971008_oma.fits`
- `mama_nuv_19971011_oma.fits`

Again all the images listed in the `.tra` files which were not proprietary were retrieved. For `19971011` the sum of the exposures on that day agrees with that in the daily`_oma` file. The calculation of the DQE loss for the `19971011` data was ratified with those in the daily sum files. For example at pixel 778,663 (on an arc line) in the 2x2 block summed images:

	Count	**Cnts/pix/s**	**DQE Loss (%)**
o4b111xdq	32	0.0677	4.187E-11
04b111xgq	40	0.738	1.447E-9
04b111xhq	54	1.061	3.234E-9
04b110yyg	2	0.0165	3.672E-13
04b110z1q	0	0	0
04b110z2q	2	0.0165	3.672E-13
04b117xjq	0	0	0
04b117xmq	0	0	0
04b117xnq	1	0.00910	8.036E-14
Sum of 9			4.723E-9

The value in `mama_fuv_19971009_oma.fits[2]` is 4.725E-9. This verified that the procedure is working as designed. In addition a check was made that there were no other MAMA images taken on these days which were missed by the procedure.

7. History of MAMA Exposure as Revealed by MADDIM Images

On-orbit production of the MADDIM _oma images only began from 6 October 1997, i.e. five months after the beginning of MAMA use after installation of STIS aboard HST. Thus the foreseen application of MADDIM images as monitoring the total counts detected, and the absolute loss in DQE, is not possible. Ideally such monitoring should have been instituted from first turn-on of the MAMA. For the purposes of MADDIM production, the fiducial point must be taken as 6 October 1997. From the beginning of February 1998, routine production of the life_ files began. This process was only begun at the beginning of February 1998 so the frequency of summing prior to that date is lower (about once per month). It should be noted that the name of the life_ files (and also the _oma files) reflects the date the file was written, not the first or last date for which the sum was performed. The keywords FIRSTDAY and LASTDAY give the first and last days respectively of the data files used in adding to the last MADDIM files. In the case of the life_ files, these keywords reflect the period over which MADDIM images were summed before adding to the last life_ file. Thus the latest life_ image provides the cumulative counts (association 1) and DQE loss (association 2) since 6 October 1997.

Statistics of the cumulative counts and the mean and maximum DQE loss for all the life_ files were made and the results are plotted in Figures 6 and 7 (data to 26 October 1998). Figure 6a shows the cumulative counts (per pixel) and mean cumulative DQE loss (% per pixel) for the FUV MAMA and the same for the NUV MAMA in Figure 6b. Since the count rate may be higher in small regions, such as for spectra, then the maximum DQE loss is the figure of most interest; this is plotted in Figure 7 for both FUV and NUV MAMA detectors.

A high count in one observation does not necessarily reflect a high DQE loss, but this is generally the case. For example for the NUV MAMA there is a large jump in DQE loss (see Figures 6b and 7 for MJD) between 20 and 25 August corresponding to an E230H spectrum of the star HD 124897. The profile of an Mg II line had peak count rate of 20.1 counts/pix/s for 3833s, producing a decrease in DQE of 0.00119% at pixel (398,198). This level of exposure causes a negligible change in the flat field response - only if consistently high exposure is maintained at the same place on the detector will a significant change in the flat field become noticeable. Given that the accuracy of the pixel-to-pixel flats is about 1% for the low resolution (1024x1024 pix) mode, then up to 1000 exposures at the 20 cnts/s level would be required to produce a measurable change in the flat field.

The plots in Figure 6 show the expected behavior of a steady rise in cumulative counts and DQE loss with time, although there are some steps in this growth. At the present rate it would take about 1000 yrs of STIS use to produce a 1% change in DQE. However the high priority of NICMOS observations in 1997-8 has meant that STIS utilization was relatively low and the trend shown in Figures 6 and 7 can be expected to steepen in 1999.

Plots such as Figures 6 and 7 provide a very useful quick look assessment of the cumulative exposure of the STIS MAMA detectors and should be produced on a routine basis - such as once per month. If a high count rate event is seen, then the _oma files can be examined to determine the nature and extent of the high count rate event. Examination of the archive for the dates covered by the _oma file will pinpoint exposures responsible for the raised DQE loss. If it becomes apparent that for example the first order (G140L and G230L) spectra, which occur on a similar area of the detector, are giving rise to a more extended region of DQE loss then it may become necessary to modify the settings for such observations.

8. Figures

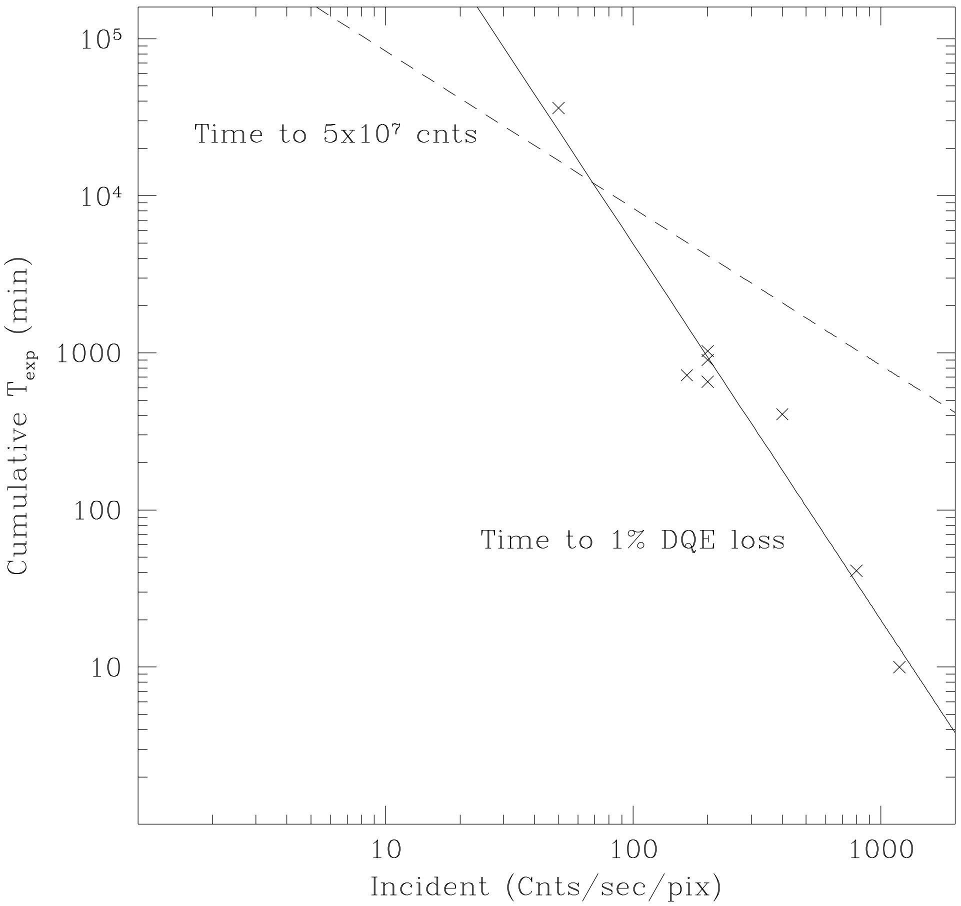

Figure 1: The relationship between the cumulative exposure time (minutes) and the incident count rate on the MAMA detector per pixel per second is plotted in two cases. The bold line shows a fit to the data of Danks (1996), given by the crosses, for the cumulated time required to produce a 1% loss in DQE at a given count rate. The dashed line shows the time in which a pixel would reach the MAMA lifetime value of $5\mathrm{x}10^7$ counts per pixel at a given constant count rate.

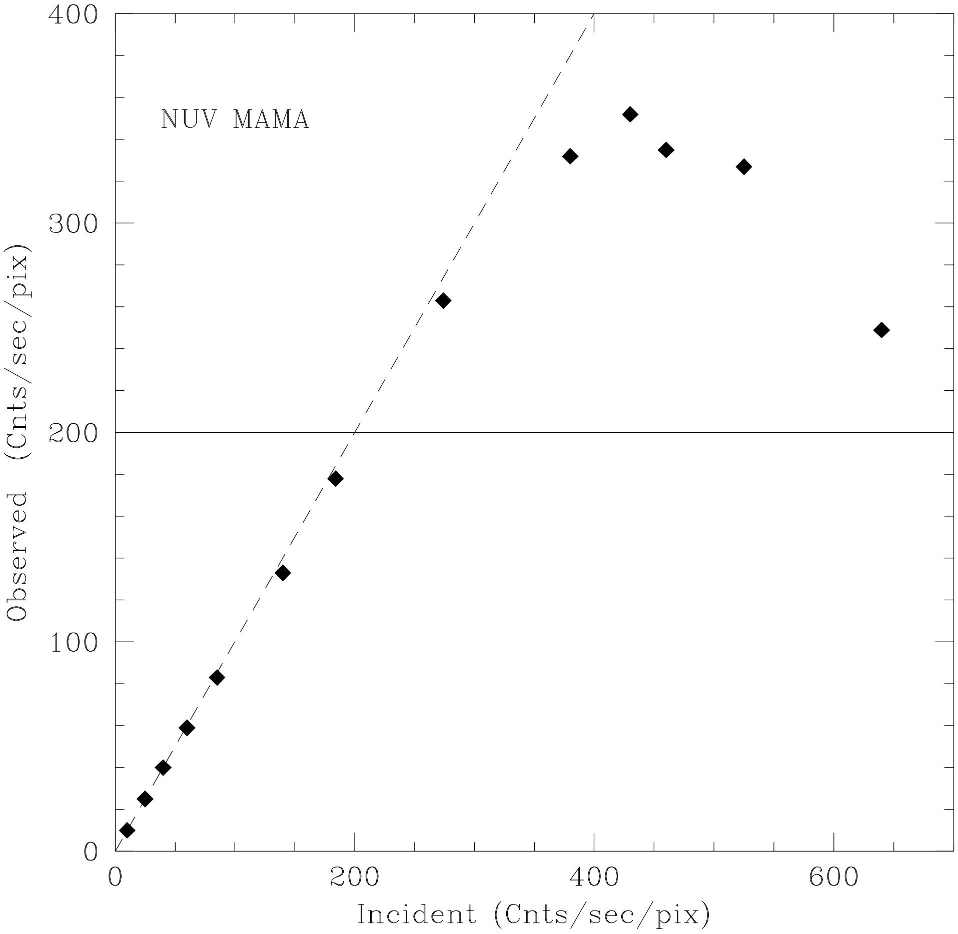

Figure 2: The Local Dynamic Range, expressed in terms of detected count rate against incident count rate, is shown for MAMA tube STE6 (NUV - Band II - MAMA). The Local Rate Check Monitor cut-off, which causes the STIS shutter to be closed, is indicated by the horizontal line. The dotted line shows the linear relation between observed and incident counts.

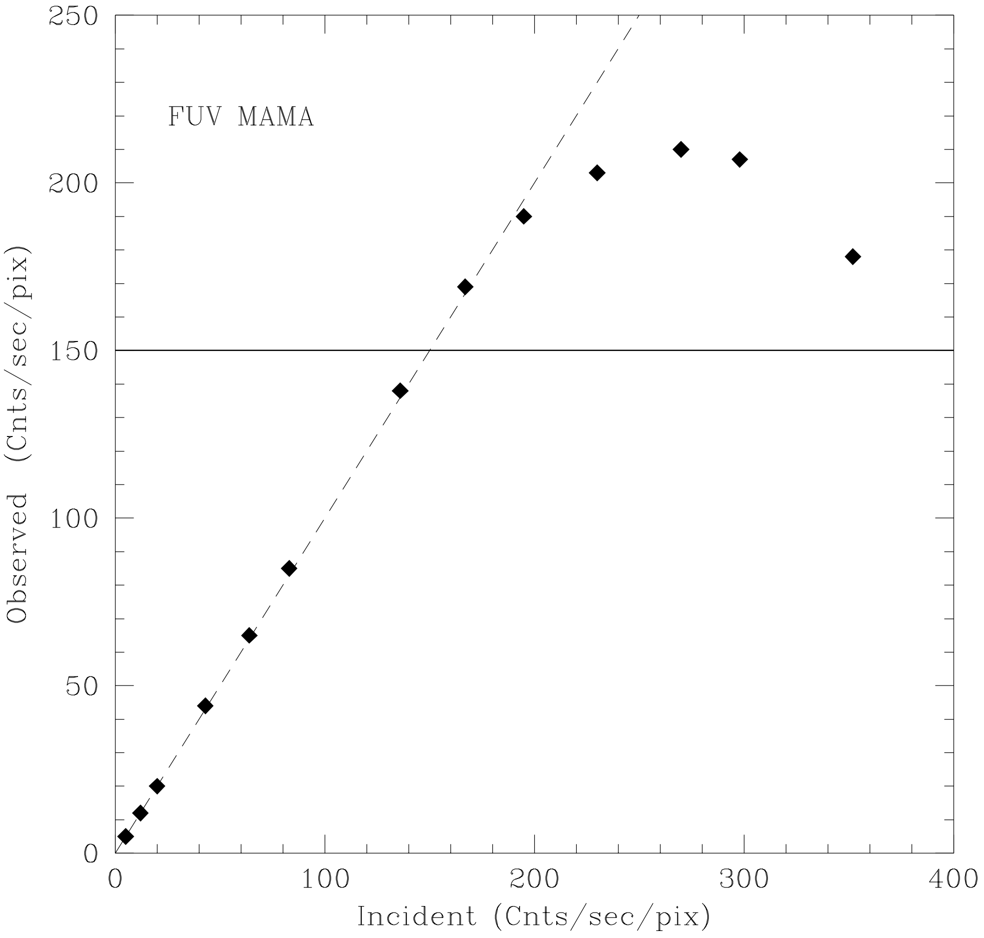

Figure 3: The Local Dynamic Range is shown as in Figure 2, but for MAMA tube STF1 (FUV - Band I - MAMA).

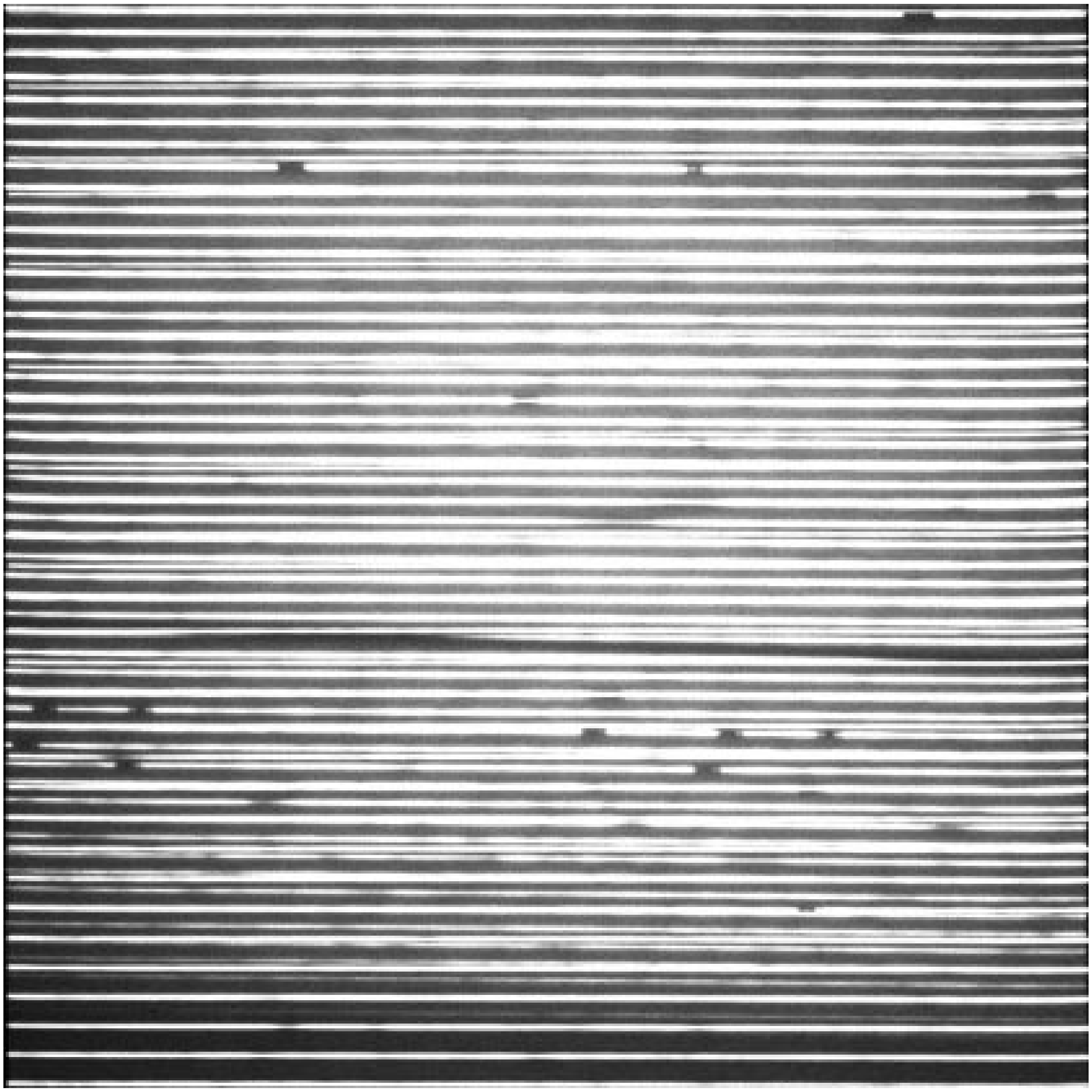

Figure 4: A FUV MAMA MADDIM cumulative count image is shown for observations on 7 January 1998. The peak count is 1278 and the mean 153.

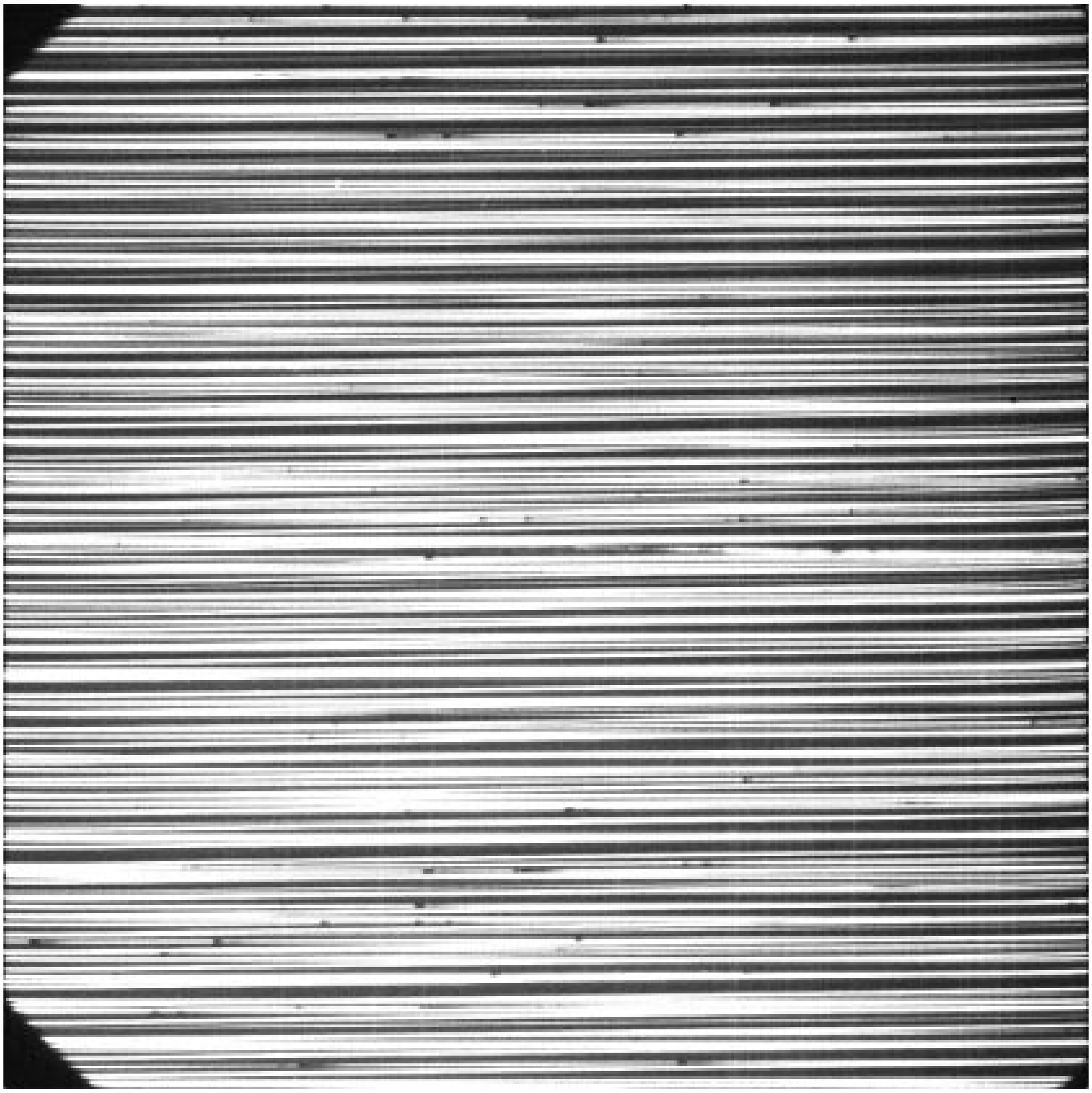

Figure 5: As Figure 4 but shown for the NUV MAMA for the observations on 6 December 1997. The peak count is 1278 and the mean is 153.

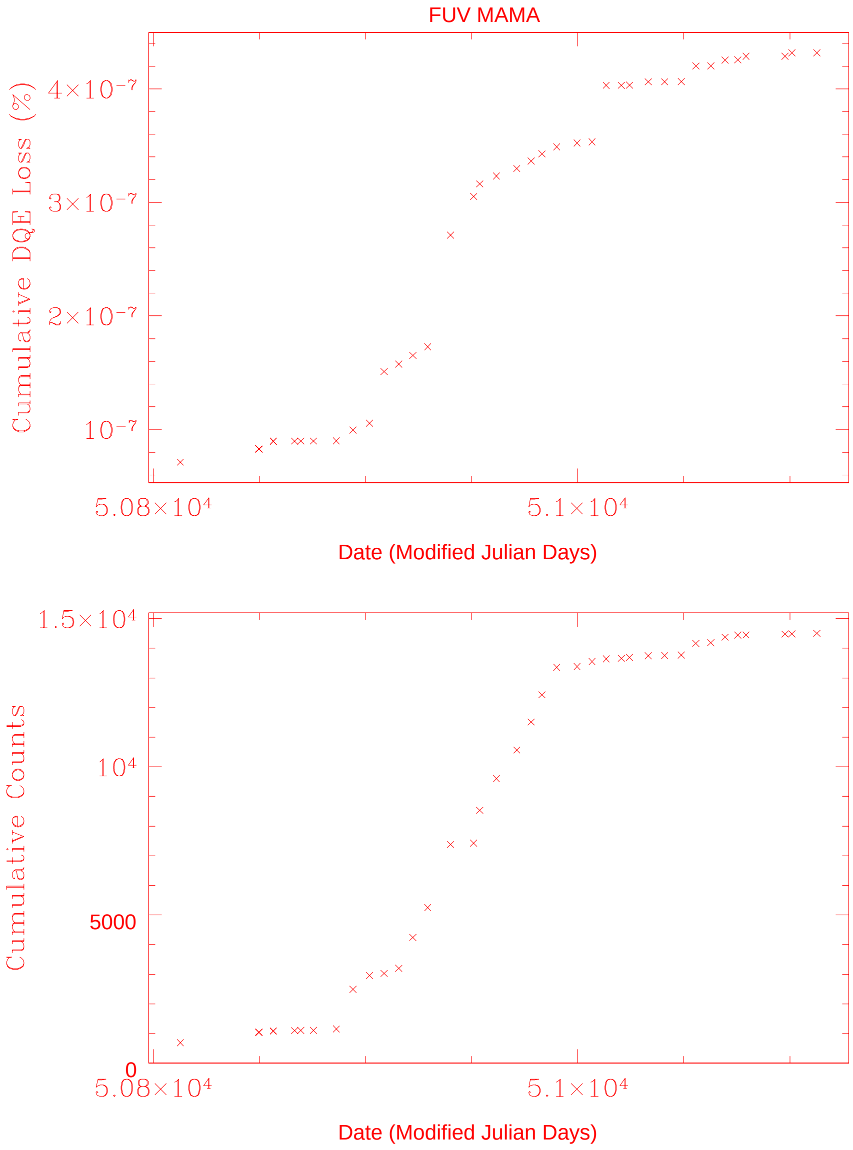

Figure 6: (a) The mean cumulative counts (per pixel) and the mean cumulative DQE loss (% per pixel) are shown for the FUV MAMA for all MADDIM data from 06 October 1997 to 26 October 1998.

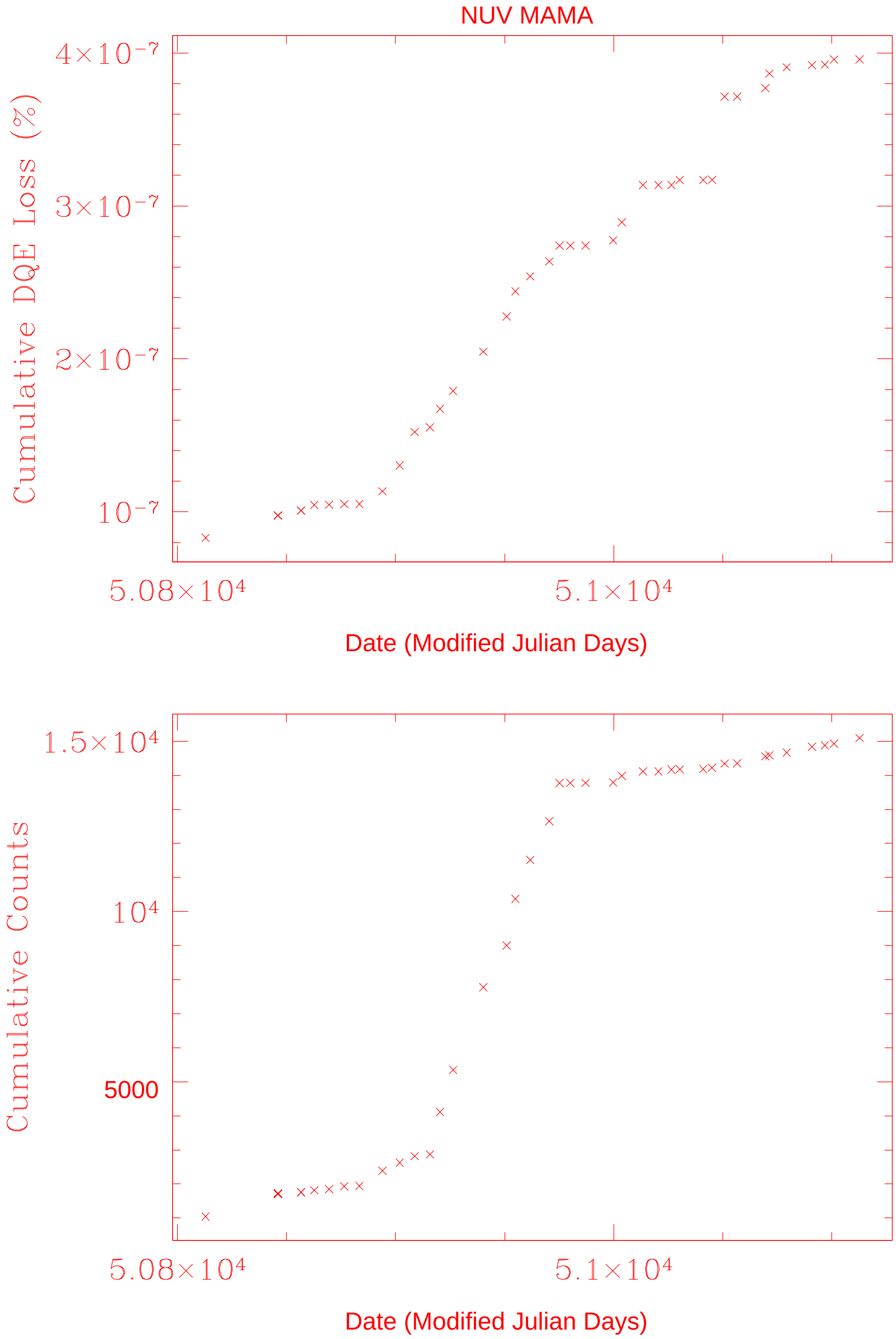

FIGURE 6b: As Figure 6a but shown for the NUV MAMA.

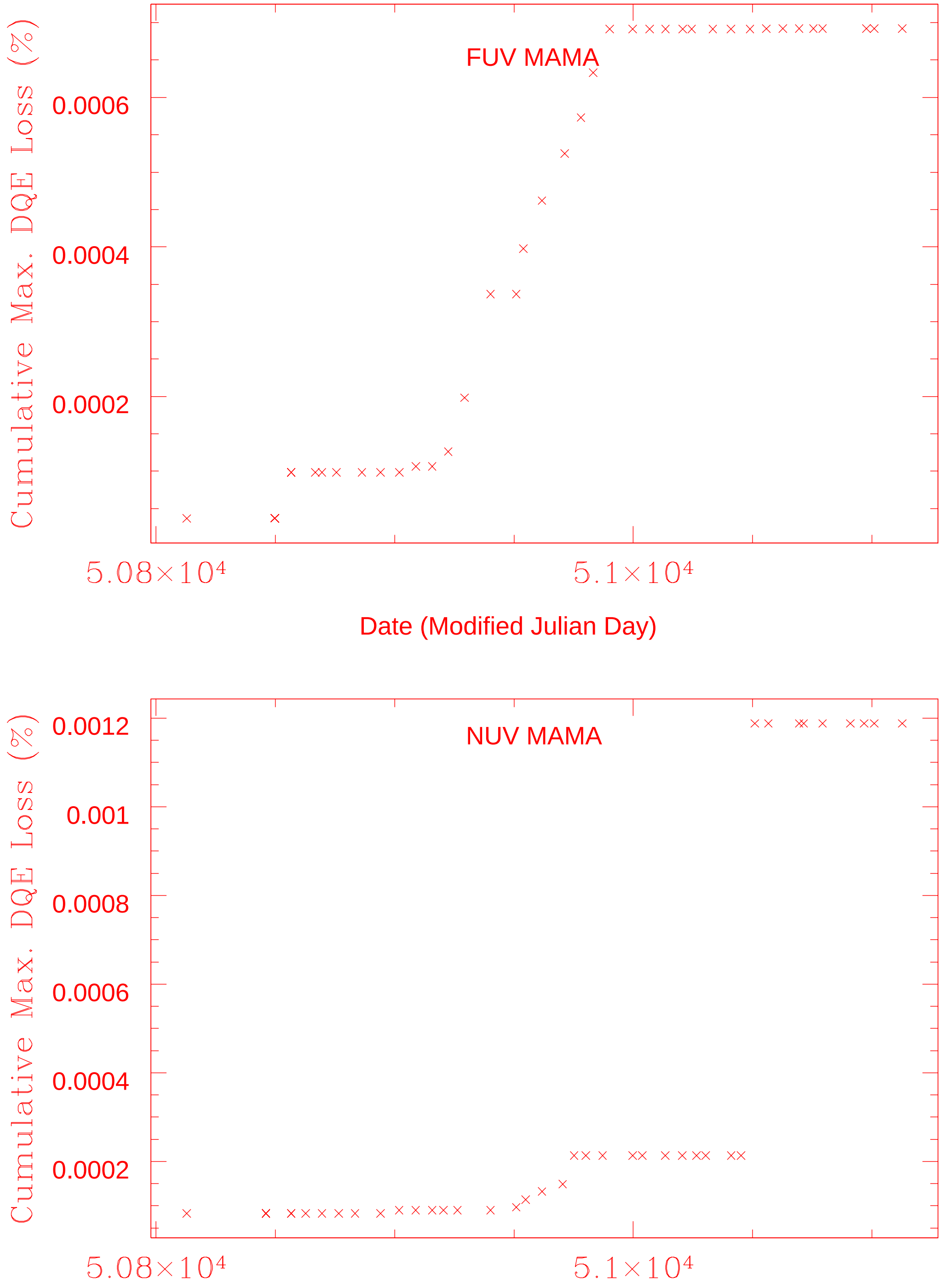

Figure 7: The maximum DQE loss (% per pixel) suffered by the FUV and NUV MAMA's as a function of time over the interval 6 October 1997 to 26 October 1998 is shown.

9. References

- Baum, S. A., et al., 1998, STIS Instrument Handbook, Version 2.0
- Clampin, M., 1996. Bright object protection mechanisms for STIS. STIS ISR 96-031
- Danks, T., 1996. Bright Object Protection Review Response. Report GSFC-STIS-MAMA-003
- Downes, R., Hartig, G., Plait, P., 1997. Mode Selection Mechanism Repeatability STIS-ISR 97-06
- Leitherer, C., Baum, S., Clampin, M., 1996. STIS Bright Object Protection Observing Policies for the MAMA Detectors STIS-ISR 96-028
- Shaw, R. A., Kaiser, M. E., Ferguson, H. C., 1998. MAMA Flat-Field Status and Plans. STIS ISR 98-015
- Timothy, J., Bybee, R., 1975, Review of Scientific Instruments, 4-6, 1615

10. Appendix

NUV-MAMA MADDIM file - Headers

Association Header

```
mama_nuv_19971011_oma.fits[0][1][short]:
No bad pixels, min=0., max=0. (old)
Line storage mode, physdim [0], length of user area 1539 s.u.
Created Thu 18:24:10 08-Jan-98, Last modified Thu 18:24:10 08-Jan-98
Pixel file "mama_nuv_19971011_oma.fits" [NO PIXEL FILE]
EXTEND  =                    T / File may contain standard extensions
NEXTEND =                    2 / Number of standard extensions
GROUPS  =                    F / image is in group format
DATE    = '12/12/97          ' / date this file was written (dd/mm/yy)
FILENAME= 'mama_nuv_19971011_oma.fits' / name of file
FILETYPE= 'ACC               ' / type of data found in data file

TELESCOP= 'HST               ' / telescope used to acquire data
INSTRUME= 'STIS              ' / identifier for instrument used to acquire data
EQUINOX =               2000.0 / equinox of celestial coord. system

              / SCIENCE INSTRUMENT CONFIGURATION

DETECTOR= 'NUV-MAMA          ' / detector in use: NUV-MAMA, FUV-MAMA, or CCD

              / SUMMARY TYPE

SUMTYPE = 'DAILY             ' / type of grand MAMA summary

              / SUMMARY INFORMATION

FIRSTDAY= '11/10/97          ' / date of first exposure added (dd/mm/yy)
LASTDAY = '11/10/97          ' / date of last exposure added (dd/mm/yy)
START_TM=   5.073211433521E+04 / start time of first exposure added (MJD)
END_TIME=   5.073226503322E+04 / stop time of last exposure added (MJD)
TOTTIME =          1546.500122 / total integration time of all exposures
TOTSUBT =             0.000000 / % of total integration time using subarrays

              / STATISTICS

MEANCNTS=            24.921277 / mean counts
MEDCNTS =            14.000000 / median counts
MINCNTS =             0.000000 / minimum counts
MAXCNTS =          2561.000000 / maximum counts
MEANDQEL=             0.000000 / mean quantum efficiency loss
MINDQEL =             0.000000 / minimum quantum efficiency loss
MAXDQEL =             0.000003 / maximum quantum efficiency loss
```

Sum Header

```
mama_nuv_19971011_oma.fits[1][1024,1024][real]:
No bad pixels, min=0., max=0. (old)
Line storage mode, physdim [1024,1024], length of user area 2714 s.u.
Created Thu 18:24:10 08-Jan-98, Last modified Thu 18:24:10 08-Jan-98
Pixel file "mama_nuv_19971011_oma.fits" [ok]
EXTEND  =                    T / File may contain standard extensions
NEXTEND =                    2 / Number of standard extensions
GROUPS  =                    F / image is in group format
FILENAME= ’mama_nuv_19971011_oma.fits’ / name of file
FILETYPE= ’ACC               ’ / type of data found in data file

TELESCOP= ’HST               ’ / telescope used to acquire data
INSTRUME= ’STIS              ’ / identifier for instrument used to acquire data
EQUINOX =               2000.0 / equinox of celestial coord. system

              / SCIENCE INSTRUMENT CONFIGURATION

DETECTOR= ’NUV-MAMA          ’ / detector in use: NUV-MAMA, FUV-MAMA, or CCD

              / SUMMARY TYPE

SUMTYPE = ’DAILY             ’ / type of grand MAMA summary

              / SUMMARY INFORMATION

FIRSTDAY= ’11/10/97          ’ / date of first exposure added (dd/mm/yy)
LASTDAY = ’11/10/97          ’ / date of last exposure added (dd/mm/yy)
START_TM=   5.073211433521E+04 / start time of first exposure added (MJD)
END_TIME=   5.073226503322E+04 / stop time of last exposure added (MJD)
TOTTIME =          1546.500122 / total integration time of all exposures
TOTSUBT =             0.000000 / % of total integration time using subarrays

              / STATISTICS

MEANCNTS=            24.921277 / mean counts
MEDCNTS =            14.000000 / median counts
MINCNTS =             0.000000 / minimum counts
MAXCNTS =          2561.000000 / maximum counts
MEANDQEL=             0.000000 / mean quantum efficiency loss
MINDQEL =             0.000000 / minimum quantum efficiency loss
MAXDQEL =             0.000003 / maximum quantum efficiency loss
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
INHERIT =                    T / inherit the primary header
EXTNAME = ’SUM               ’ / extension name
EXTVER  =                    1 / extension version number
ROOTNAME= ’O4BL10Z2Q         ’ / rootname of the observation set
EXPNAME = ’N19971011         ’ / 9 character exposure identifier
BUNIT   = ’COUNTS            ’ / brightness units

/ World Coordinate System and Related Parameters

CRPIX1  =                  1.0 / x-coordinate of reference pixel
CRPIX2  =                  1.0 / y-coordinate of reference pixel
CRVAL1  =                  1.0 / first axis value at reference pixel
CRVAL2  =                  1.0 / second axis value at reference pixel
CTYPE1  = ’PIXEL             ’ / the coordinate type for the first axis
CTYPE2  = ’PIXEL             ’ / the coordinate type for the second axis
CD1_1   =                  1.0 / partial of first axis coordinate w.r.t. x
CD1_2   =                  0.0 / partial of first axis coordinate w.r.t. y
CD2_1   =                  0.0 / partial of second axis coordinate w.r.t. x
CD2_2   =                  1.0 / partial of second axis coordinate w.r.t. y
LTV1    =                  0.0 / offset in X to subsection start
LTV2    =                  0.0 / offset in Y to subsection start
LTM1_1  =                  1.0 / reciprocal of sampling rate in X
LTM2_2  =                  1.0 / reciprocal of sampling rate in Y
RA_APER =   0.000000000000E+00 / RA of reference aperture center
DEC_APER=   0.000000000000E+00 / Declination of reference aperture center
PA_APER =   0.000000000000E+00 / Position Angle of reference aperture center
```

DQE Header

```
mama_nuv_19971011_oma.fits[2][1024,1024][real]:
No bad pixels, min=0., max=0. (old)
Line storage mode, physdim [1024,1024], length of user area 2673 s.u.
Created Thu 18:24:10 08-Jan-98, Last modified Thu 18:24:10 08-Jan-98
Pixel file "mama_nuv_19971011_oma.fits" [ok]
EXTEND  =                    T / File may contain standard extensions
NEXTEND =                    2 / Number of standard extensions
GROUPS  =                    F / image is in group format
FILENAME= 'mama_nuv_19971011_oma.fits' / name of file
FILETYPE= 'ACC               ' / type of data found in data file

TELESCOP= 'HST               ' / telescope used to acquire data
INSTRUME= 'STIS              ' / identifier for instrument used to acquire data
EQUINOX =               2000.0 / equinox of celestial coord. system

              / SCIENCE INSTRUMENT CONFIGURATION

DETECTOR= 'NUV-MAMA          ' / detector in use: NUV-MAMA, FUV-MAMA, or CCD

              / SUMMARY TYPE

SUMTYPE = 'DAILY             ' / type of grand MAMA summary

              / SUMMARY INFORMATION

FIRSTDAY= '11/10/97          ' / date of first exposure added (dd/mm/yy)
LASTDAY = '11/10/97          ' / date of last exposure added (dd/mm/yy)
START_TM=   5.073211433521E+04 / start time of first exposure added (MJD)
END_TIME=   5.073226503322E+04 / stop time of last exposure added (MJD)
TOTTIME =          1546.500122 / total integration time of all exposures
TOTSUBT =             0.000000 / % of total integration time using subarrays

              / STATISTICS

MEANCNTS=            24.921277 / mean counts
MEDCNTS =            14.000000 / median counts
MINCNTS =             0.000000 / minimum counts
MAXCNTS =          2561.000000 / maximum counts
MEANDQEL=             0.000000 / mean quantum efficiency loss
MINDQEL =             0.000000 / minimum quantum efficiency loss
MAXDQEL =             0.000003 / maximum quantum efficiency loss
PCOUNT  =                    0 / number of group parameters
GCOUNT  =                    1 / number of groups
INHERIT =                    T / inherit the primary header
EXTNAME = 'DQE               ' / extension name
EXTVER  =                    1 / extension version number
ROOTNAME= 'O4BL10Z2Q         ' / rootname of the observation set
EXPNAME = 'N19971011         ' / 9 character exposure identifier

/ World Coordinate System and Related Parameters

CRPIX1  =                  1.0 / x-coordinate of reference pixel
CRPIX2  =                  1.0 / y-coordinate of reference pixel
CRVAL1  =                  1.0 / first axis value at reference pixel
CRVAL2  =                  1.0 / second axis value at reference pixel
CTYPE1  = 'PIXEL             ' / the coordinate type for the first axis
CTYPE2  = 'PIXEL             ' / the coordinate type for the second axis
CD1_1   =                  1.0 / partial of first axis coordinate w.r.t. x
CD1_2   =                  0.0 / partial of first axis coordinate w.r.t. y
CD2_1   =                  0.0 / partial of second axis coordinate w.r.t. x
CD2_2   =                  1.0 / partial of second axis coordinate w.r.t. y
LTV1    =                  0.0 / offset in X to subsection start
LTV2    =                  0.0 / offset in Y to subsection start
LTM1_1  =                  1.0 / reciprocal of sampling rate in X
LTM2_2  =                  1.0 / reciprocal of sampling rate in Y
RA_APER =   0.000000000000E+00 / RA of reference aperture center
DEC_APER=   0.000000000000E+00 / Declination of reference aperture center
PA_APER =   0.000000000000E+00 / Position Angle of reference aperture center
```