Chapter 11

FGS Calibration

In This Chapter...

This chapter describes how FGS data are calibrated. Unlike the data from other HST instruments, FGS astrometry data are not calibrated automatically. Observers now require the assistance of the FGS team at STScI and the Space Telescope Astromety Team (STAT) at the University of Texas to process astrometry science data through the FGS pipeline. However, efforts are underway at STScI to provide IRAF/STSDAS tools that will enable observers to easily calibrate data using the current best set of calibration reference files and algorithms. These tools may eventually evolve into a fully automatic pipeline that generates and archives calibrated FGS astrometry data. Check STScI's FGS web pages for updates.

STScI acknowledges the contribution of the STAT in the design, development, and maintenance of the astrometry data processing pipeline. This pipeline has been in use since the beginning of the HST mission and has evolved into a robust and reliable tool that has processed more than 7,000 individual FGS astrometry observations.

11.1 The Visit

The current pipeline requires all data from a single visit to reside in a dedicated directory. The required files are the GEIS files for all three FGSs (`.a*h/.a*d`), the support schedule file (`.dmh`), and a pointer to the HST alignment point library. For example, if the FGS visit to be analyzed comprises five individual astrometry observations, then the directory containing the data to be calibrated should contain files shown in Table 11.1 (where PPP and SS are place holders for the actual program_ID and visit ID, respectively). There should be 35 files (5 observations, each with 7 files).

Table 11.1: GEIS Files in an FGS Dataset

File Name	Contents
fpppss01m.a1h	Header file, FGS1
fpppss01m.a1d	Data file, FGS1
fpppss01m.a2h	Header file, FGS 2
fpppss01m.a2d	Data file, FGS 2
fpppss01m.a3h	Header file, FGS 3
fpppss01m.a3d	Data file, FGS 3
fpppss01m.dmh	Support schedule for observation 01
...	...
fpppss05m.a1h	Header file for FGS 1
fpppss05m.a1d	Data file for FGS 1
fpppss05m.a2h	Header file for FGS 2
fpppss05m.a2d	Data file for FGS 2
fpppss05m.a3h	Header file for FGS 3
fpppss05m.a3d	Data file for FGS 3
fpppss05m.dmh	Support schedule for observation 05

11.2 Initial Data Processing

When all of the files pertaining to a given astrometry visit are present in a single directory, pipeline processing can begin. The initial round of data processing accomplishes several general tasks, regardless of whether the observations were gathered in POSITION mode or TRANSFER mode. The pipeline:

1. Reads the seven GEIS files belonging to each individual observation.
2. Identifies the FGS being used for astrometry and its observing mode.
3. Identifies potentially missing files.
4. Determines the status of the guiding FGSs, checking whether zero, one, or two guiding FGSs were actively maintaining the pointing of the telescope and whether they were guiding in CoarseTrack or FineLock.
5. Inspects the flags/status bits to determine whether the astrometry observation succeeded or failed, and in the case of a failure, to identify the reason for the failure.
6. Prepares output files with keywords whose values are either extracted from the input header files or computed from contents of the data files.

7. Assesses the data quality of successful observations, masking outliers, garbled telemetry, and telemetry dropouts. (Outliers are data that do not appear to be garbled but make no sense when viewed in the context of neighboring data points.)

11.3 POSITION Mode Pipeline

The pipeline usually calibrates POSITION mode data in two distinct stages. The first stage processes each single observation in a stand-alone fashion, ignoring the other observations belonging to the same HST visit. The second stage relates all the individual observations to one another so that an astrometric "plate" can be produced. Here we describe the sequence of events recorded during a POSITION mode observation and then the two stages of POSITION mode data calibration. See page 11-8 for a sample of POSITION mode pipeline output.

11.3.1 Position Mode Observations

In a typical POSITION mode observing program the astrometry FGS sequentially observes in Fine Lock *several* stars distributed about the pickle. Any temporal variability in the telescope pointing will contaminate the measured relative positions of these targets. Thus, the measured positions of all targets must be mapped onto a common, fixed coordinate system before an astrometric plate can be assembled.

Experience has shown that FGS astrometry is sensitive to HST body *jitter* and FGS *drift*. The jitter can be eliminated using the guide star data, whereas the drift is removed by applying a drift model derived from *check star* data. A *check star* is a target observed multiple times during the visit. Typically the observing strategy should involve at least two check stars, and they should be observed at least three times each.

The dataset for a given observation includes the Slew to the target, the Search, the CoarseTrack, the WalkDown, and the FineLock tracking, as well as guide star data over the same interval of time. These data provide information used by the pipeline algorithms to determine backgrounds, to locate the interferometric null, and ultimately, to pinpoint the position of the star relative to the other stars observed in the visit. These data can also be used for photometric studies.

The Slew portion of the observation is used to measure the background. During the slew the astrometer's photomultiplier tubes count the photons in the 5" IFOV, registering the background and serendipitous stars. These star spikes are removed in the pipeline's background averaging process, via a trimmed mean.

Upon completion of the slew, the FGS microprocessor assumes control and begins the acquisition of the target as described in "Target Acquisition and Tracking" on page 9-16. After the completion of CoarseTrack, the DataValid and TransferHold flags are set to 1. Then the FineLock acquistion begins and the DataValid flag returns to zero until tracking in FineLock begins and the DataValid flag is set once again (see Table 10.2). The FGS will continue to track its target in FineLock until the DF 224 computer terminates the activity and slews the IFOV to the next target in the sequence. This process repeats for each exposure until the end of the visit.

When the target is faint or the data are noisy, the onboard DIFF, SUM algorithm suffers from poor photon statistics and therefore might cause the FGS to mis-identify true interferometric null. The pipeline corrects for this problem using PMT data gathered during the slew, WalkDown, and FineLock tracking as described in step 5 below.

11.3.2 Processing Individual Observations

POSITION mode pipeline processing for each individual observation in the visit executes the following steps:

1. Inspection of the flags/status bits to locate the data fields recording:
   - The slew of the IFOV to the target's location.
   - The WalkDown to FineLock.
   - The FineLock tracking (FineLock/DataValid) of the target .
2. Computing the centroid of the IFOV, taken to be the median of the instantaneous *x,y* positions during the FineLock/DataValid interval, in the astrometer as well as the guide star positions in the guiding FGSs. Standard deviations about these centroids are also computed.
3. Updating the HST state vector, specified in the header files for the beginning of the observation, so that it is accurate for the temporal midpoint of the FineLock/DataValid interval.
4. Gathering photon statistics on:
   - PMT background during the slew to the target.
   - PMT data taken while the IFOV was still far (>0.1") from the null. (These data can be used to calculate SUM and DIFF values more accurate than those computed at the start of the WalkDown because they are based on up to 80 times more samples.)
   - PMT data taken while FGS was in FineLock/DataValid. (These data are averaged to compute the points on the S-curves of both axes which the FGS's microprocessor determined to be the true interferometric null. These values should be approximately the same as the DIFF, SUM computed by the FGS's microprocessor at the start of the WalkDown).
5. Applying the DIFF and SUM corrections to both axes of only the astrometry data to locate the true interferometric null. This algorithm determines the slope of the fine error signal near interferometric null as a function of position in the pickle, using a library of reference S-curves, the target magnitude, making use of the background data computed above, and the difference in the photomultiplier averages computed during the WalkDown and the FineLock/DataValid intervals (see Figure 9.12). This correction tends to

be small for bright stars ($V < 13.5$) but can be as large as 5 mas for faint ($V > 15$) stars.

6. Converting the raw telemetry encoder positions to instantaneous *x,y* detector coordinates using several parameters, such as the star selector lever arm lengths, and offset angles. The lever arm and offset angle are known to vary in time. They are monitored by an ongoing program called the Long Term Stability Monitor (LTSTAB) which executes multiple times a year. The values applied in the pipeline are determined by interpolation of the LTSTAB results.
7. Correcting the *x,y* centroids in the astrometer for Optical Field Angle Distortions (OFAD).
8. Correcting distortions in the astrometer arising from the pickoff mirror and aspheric mirror.
9. Removing differential velocity aberration from the *x,y* centroids using the updated HST state vector, a JPL Earth ephemeris, HST's V1 RA and DEC , the V3 roll, and the V2,V3 position of the alignment point. This correction is applied to both the astrometer FGS and the guide star FGSs.

The pipeline produces output files that log these corrections, the associated standard deviations about the centroids, and the photometry averages from the four PMTs.

At this point no further processing on the individual observations are possible. The next step is to combine the measurements of the individual targets to correct for POSITION-mode jitter and FGS drift.

11.3.3 Assembling the Visit

The goal of this segment of the pipeline is to map all of the positional measurements of the individual targets onto a fixed but arbitrary coordinate system. It involves POSITION mode *de-jittering* and application of the DRIFT correction.

POSITION Mode De-jittering

The pipeline accounts for spacecraft jitter during the visit by establishing a fixed but arbitrary reference frame determined by the *x,y* centroids of the guide stars within the guiding FGSs. The HST pointing control system uses the position of the dominant guide star to fix HST's translational position and that of the roll guide star to fix HST's orientation. The output products of the pipeline processing of the individual observations include the *x,y* centroids of the guide star positions evaluated over the same time interval as the astrometer centroids. During the course of the visit any change in the *x,y* centroids of the dominant guide star within its FGS is interpreted to be HST translational jitter and is removed from the both the astrometer and the guide star maintaining HST roll. Next, any motion of the roll guide star with respect to the dominant guide star perpendicular to the line between them is interpreted as uncompensated roll of HST about the dominant guide star. The pipline then removes this roll from the astrometry data. Typically the size of the de-jittering correction is less than a millisecond of arc when averaged over the visit but can be as large as 3–5 mas for any given observation, such as when HST transits from night into day.

De-jittering is not performed at a 40 Hz rate because that would introduce noise into the dataset. Instead the time-averaged centroids of the guide stars are computed for the same time interval that the astrometer was in FineLock/DataValid. The positions of the guide stars in the first exposure, corrected for differential velocity aberration, define the reference frame for the remainder of the visit. So, for example, if the dominant guide star x,y centroids measured during the Nth astrometry observation differed from those in the first observation by (dx,dy) = (1 mas,1 mas), then the appropriate conversion to dV2,dV3 is applied to the roll star and the astrometer's local x,y centroids. This procedure creates a fixed but arbitrary coordinate system for the entire visit.

POSITION Mode Drift Correction

After the FGS data have been de-jittered, there will remain an apparent motion of those astrometry targets which have been observed more than once within the observing sequence. These check stars provide the data required for the next and potentially large correction. The drift correction model assumes that the astrometer is a rigid body which both translates and rotates in the HST focal plane during the course of the visit and corrects the measured positions of the stars in the visit for contamination by this motion.

The time-tagged positions of the check stars are used to generate a model for this drift, and the time-tagged positions of all the stars in the visit are adjusted by application of the model. Three separate models can be applied:

- ***Linear***: Translation only, no rotation.
- ***Quadratic***: Translation only, no rotation.
- ***Quadratic and roll***: Translation and rotation.

The choice of model depends upon the number of check stars available and the number of times each is observed. Clearly if there is only one check star in the visit the rotation model cannot be applied. Also, if check stars are not observed frequently enough (three times or more), the quadratic models might not be reliable. The pipeline applies all three models, providing three sets of corrected centroids. It is the responsibility of the GO to decide which set is best. The output of the fitting program includes fit residuals and χ^2.

The size of the drift correction is typically 6 to 12 mas under two-FGS guidance. The amount of drift appears to be related to the intensity of the bright Earth projected down the V1 boresight during target occultations. This intensity, and hence check star drift (generally), is highest for targets in HST’s orbital plane and lowest for those at high inclination.

When only one FGS is used for guiding, the telescope is not roll-constrained. Under such circumstances the check stars can reveal very large motions, up to 60 or 70 mas over the course of the orbit. Nevertheless, this drift can be successfully removed from the astrometry data, provided the proposal contained an adequate check star scenario. For example, the overlay of the plates from two separate POSITION mode visits, each measuring some 20 stars in an astrometric field distributed throughout the pickle yielded an rms residual of about 1 mas, even though one of the visits had one-FGS guiding and check-star drifts on the order of 30 mas.

The Data Analysis chapter (Chapter 13) discusses the techniques of plate overlays and determinations of parallax and proper motion.

11.4 TRANSFER Mode Pipeline

11.4.1 TRANSFER Mode Dataset

The dataset for a TRANSFER Mode observation includes all of the acquisition phases described in “Target Acquisition and Tracking” on page 9-16, as well as the transfer scans described in “Transfer Scans” on page 9-21. Each TRANSFER mode observation consists of a number of scans specified in the original proposal. Simultaneous guide star data cover the entire observation.

Automatic pipeline processing of TRANSFER mode data is limited to locating each scan in the astrometer’s data file, editing out bad data arising from garbled telemetry, and determining the median position and standard deviations of the guide stars within the guiding FGSs during each scan.

The pipeline generates three ASCII files for every scan, one for each FGS. Each file contains the 40 Hz raw star selector A,B encoder values and the photon counts/25msec of the four PMTs. The guide star data are provided for (optional) de-jittering of the astrometer’s IFOV. Each of these files begins with a small header containing keywords whose values pertain globally to the observation or specifically to the scan, such as the filter used or the universal time at the start of the scan. The HST state vector is also included.

11.4.2 Mapping TRANSFER Mode to POSITION Mode

Planned upgrades to the TRANSFER mode pipeline to support the mapping of the TRANSFER mode results onto POSITION mode plates, along with POSITION mode observations made in the same visit, include the following steps:

1. Differential velocity aberration correction to the astrometer and the guide stars. This step requires access to the definitive HST orbit file because the HST state vector evolves considerably over the course of the TRANSFER mode observation, which can be up to 40 minutes long.
2. Computation of guide star *x*,*y* centroids to establish the fiducial position for the dominant guide star.
3. Translational de-jittering of the astrometer IFOV at 40 Hz.
4. Location of the individual scans in the observation.

5. Cross-correlating, shifting, binning, and co-adding the individual scans.
6. Polynomial curve fitting to the co-added scans. The residual of each scan to this fit is evaluated to locate individual scans which might be contaminated by HST jitter. (Step 3 would not remove a recentering event in which the guider was not tracking its guide star during some extreme HST jitter crises). Such scans are identified and disqualified, and steps 5 and 6 are iteratively repeated until no further disqualifications occur.
7. Time tagging and recording the shifts determined from the cross-correlation. These data are used to generate a drift model for the TRANSFER mode data when the observation is in a visit with POSITION mode observations.
8. Generation of output files that log the corrections made, identify the scans which have been disqualified, specify the polynomial coefficients of the fit, and present the drift model and guide star centroids and standard deviations. This step also includes creation of individual scan files which contain the star selector A,B values and the counts from the four PMTs for each scan. These files have names such as `F42N0102M.`*n*`S`*m* where *n* = 1,2,3 to identify the FGS and *m*=1,2,3,... to specify the scan number.

11.4.3 Limitations of the TRANSFER Mode Pipeline

The pipeline cannot carry out further processing of TRANSFER mode data because the header and data files made available to the pipeline do not contain sufficient information. For example, the header files do not specify if the observation is of a single calibration reference star, or of a binary system, or an extended object, each of which needs different additional processing. The B-V color of the target needs to be specified for the analysis of observations of binary stars or extended objects so that the appropriate single star reference S-curve can be retrieved from the calibration library. These activities will be discussed in Chapter 13.

Observers should consult the STScI FGS web pages for updates to the status of the pipeline upgrades.

11.5 POSITION Mode Pipeline Output

The following example illustrates the current format of the output from the POSITION mode pipeline, which gives the key information needed for data analysis. Enhancements of this format are under development.

```
!
 !     CALFGS:    VERSION 2.0
 !     date of calibration processing -> 18-FEB-97  15:44:29
 !
 !
 OBSERVATION_ID = F3FV0602M           !
 OBSERVING_MODE = POSITION            !
```

```
TARGET_ID      = 6920_975           !
STAR_ID        =     0              !
MAGNITUDE      =  12.85             !
PRA            =   92.22249166667   ! degrees, predicted target position
PDEC           =   24.38458055556   ! degrees, predicted target position
!
RAV1           =   92.28756740940   ! degrees ... Spacecraft pointing data
DECV1          =   24.58115491606   ! degrees
ROLLV3         =   87.69312835639   ! degrees
X_POS          =  6255.850861       ! Km ....... Spacecraft orbital position
Y_POS          =  2940.146717       ! Km
Z_POS          =  -937.186147       ! Km
X_VEL          =    -3.271298       ! Km/sec ... Spacecraft orbital velocity
Y_VEL          =     5.872820       ! Km/sec
Z_VEL          =    -3.460530       ! Km/sec
OBS_TIME       = 1997 031 12:47:46  ! UT at (X,Y,Z,Vx,Vy,Vz)
!
ASTROMETER_FGS = 3                  ! ID of astrometer FGS
FILTER         = F583W              ! ASTROMETER FGS FILTER
DISTORTION     = PERFORM            ! status: PERFORM, OMITT, or COMPLETED
LATERAL_COLOR  = PERFORM            !
WEDGE          = PERFORM            !
ABERRATION     = PERFORM            !
!
! *** POSITION from encoder values (-2=FGS data corrupted or not available)
!                    (FL)       (FL)       (FL)
X_AVE          =  -201.3386  -161.9243   191.5194    ! asec, FGS=1,2,3
Y_AVE          =   795.5815   643.5501   716.0092    ! asec, FGS=1,2,3
X_X_AVE        =     0.0020     0.0021     0.0028    ! asec, FGS=1,2,3
Y_Y_AVE        =     0.0023     0.0017     0.0026    ! asec, FGS=1,2,3
X_Y_COR        =  1.611E-01  1.513E-01  1.034E-01    ! asec, FGS=1,2,3
X_Y_COV        =  7.395E-07  5.304E-07  7.656E-07    ! asec, FGS=1,2,3
!
X_MEDIAN       =  -201.3386  -161.9242   191.5194    ! asec, FGS=1,2,3
Y_MEDIAN       =   795.5815   643.5503   716.0091    ! asec, FGS=1,2,3
X_MAD          =     0.0016     0.0016     0.0021    ! asec, FGS=1,2,3
Y_MAD          =     0.0018     0.0014     0.0021    ! asec, FGS=1,2,3
!
! *** positions valid only after DISTORTION & ABERRATION corrections ***
!
X_CORRECTED    =  -201.3161  -161.8805   191.4970    ! asec, FGS=1,2,3
Y_CORRECTED    =   795.5054   643.5306   716.0089    ! asec, FGS=1,2,3
X_X_CORRECTED  =     0.0020     0.0021     0.0028    ! asec, FGS=1,2,3
Y_Y_CORRECTED  =     0.0023     0.0017     0.0026    ! asec, FGS=1,2,3
!
RA             =    -1.0000    -1.0000    -1.0000    ! deg FGS=1,2,3
DEC            =    -1.0000    -1.0000    -1.0000    ! deg FGS=1,2,3
!
EXPOSURE_TIME  =  4.06500E+01       ! seconds of FINELOCK DATA (POSITION MODE)
NPIXELS        =  1627              ! # samples used from FINELOCK interval
!
!
!
! ........................................................................... !
!
!    PCS ALIGNMENT PARAMETERS FOR DIFFERENTIAL VELOCITY DE-ABBERATION
!
VELAB_SI       = FGS
VELAB_FGS      =  3
X_VELAB        = -253.72
Y_VELAB        =  712.47
!
DOM_GS_FGS     =  2
!
```

FGS / 11

FGS / 11

```
! ...................................................................... !
!
!                       GUIDE STAR / ASTROMETER TRACKING
!
!                   FGS1              FGS2              FGS3
!
!                GUIDE STAR        GUIDE STAR        ASTROMETER
!                 FINE LOCK         FINE LOCK         FINE LOCK
!
! ...................................................................... !
!
!            PHOTOMETRY: average counts/25 msec over exposure interval
!
!                     GUIDE STAR      GUIDE STAR      ASTROMETER
!                        FGS1            FGS2            FGS3
!
PMTSUM         =      831.6524       5843.9882        649.6138
PMTXA          =      187.9005       1355.9204        160.2842
PMTXB          =      175.9104       1254.1306        167.2680
PMTYA          =      235.8850       1742.8638        165.0006
PMTYB          =      231.9565       1491.0734        157.0609
!
PMTXA_BCK_MED  =     4.00  ! astrometer bckgrnd MEDIAN of PMTXA (-1=NA)
PMTXB_BCK_MED  =     5.00  ! astrometer bckgrnd MEDIAN of PMTXB (-1=NA)
PMTYA_BCK_MED  =     4.00  ! astrometer bckgrnd MEDIAN of PMTYA (-1=NA)
PMTYB_BCK_MED  =     4.00  ! astrometer bckgrnd MEDIAN of PMTYB (-1=NA)
!
PMTXA_BCK_AVE  =     3.98  ! astrometer bckgrnd AVERAGE of PMTXA (-1=NA)
PMTXB_BCK_AVE  =     4.71  ! astrometer bckgrnd AVERAGE of PMTXB (-1=NA)
PMTYA_BCK_AVE  =     4.69  ! astrometer bckgrnd AVERAGE of PMTYA (-1=NA)
PMTYB_BCK_AVE  =     4.10  ! astrometer bckgrnd AVERAGE of PMTYB (-1=NA)
!
PMTXA_BCK_MAD  =     2.77  ! astrometer bckgrnd MAD of PMTXA (-1=NA)
PMTXB_BCK_MAD  =     3.26  ! astrometer bckgrnd MAD of PMTXB (-1=NA)
PMTYA_BCK_MAD  =     3.38  ! astrometer bckgrnd MAD of PMTYA (-1=NA)
PMTYB_BCK_MAD  =     3.02  ! astrometer bckgrnd MAD of PMTYB (-1=NA)
!
PMTXA_BCK_SIG  =     1.40  ! astrometer bckgrnd S.D. of PMTXA (-1=NA)
PMTXB_BCK_SIG  =     1.73  ! astrometer bckgrnd S.D. of PMTXB (-1=NA)
PMTYA_BCK_SIG  =     1.73  ! astrometer bckgrnd S.D. of PMTYA (-1=NA)
PMTYB_BCK_SIG  =     1.48  ! astrometer bckgrnd S.D. of PMTYB (-1=NA)
!
PMTXA_BCK_TMIN =     2.00  ! astrometer bckgrnd trimed MIN for PMTXA (-1=NA)
PMTXB_BCK_TMIN =     2.00  ! astrometer bckgrnd trimed MIN for PMTXB (-1=NA)
PMTYA_BCK_TMIN =     2.00  ! astrometer bckgrnd trimed MIN for PMTYA (-1=NA)
PMTYB_BCK_TMIN =     2.00  ! astrometer bckgrnd trimed MIN for PMTYB (-1=NA)
!
PMTXA_BCK_TMAX =     7.00  ! astrometer bckgrnd trimed MAX for PMTXA (-1=NA)
PMTXB_BCK_TMAX =     8.00  ! astrometer bckgrnd trimed MAX for PMTXB (-1=NA)
PMTYA_BCK_TMAX =     8.00  ! astrometer bckgrnd trimed MAX for PMTYA (-1=NA)
PMTYB_BCK_TMAX =     7.00  ! astrometer bckgrnd trimed MAX for PMTYB (-1=NA)
!
SAMPLES_BCKGD  =     1006  ! no. of samples used to compute background
!
PMTXA_WD_MED   =   165.50  ! astrometer walkdown MED for PMTXA (-1=NA)
PMTXB_WD_MED   =   164.00  ! astrometer walkdown MED for PMTXB (-1=NA)
PMTYA_WD_MED   =   164.00  ! astrometer walkdown MED for PMTYA (-1=NA)
PMTYB_WD_MED   =   160.00  ! astrometer walkdown MED for PMTYB (-1=NA)
!
PMTXA_WD_AVE   =   165.43  ! astrometer walkdown AVE for PMTXA (-1=NA)
PMTXB_WD_AVE   =   163.68  ! astrometer walkdown AVE for PMTXB (-1=NA)
PMTYA_WD_AVE   =   165.38  ! astrometer walkdown AVE for PMTYA (-1=NA)
PMTYB_WD_AVE   =   159.98  ! astrometer walkdown AVE for PMTYB (-1=NA)
!
```

```
PMTXA_WD_MAD   =    11.19  ! astrometer walkdown MAD for PMTXA (-1=NA)
PMTXB_WD_MAD   =    11.63  ! astrometer walkdown MAD for PMTXB (-1=NA)
PMTYA_WD_MAD   =    11.98  ! astrometer walkdown MAD for PMTYA (-1=NA)
PMTYB_WD_MAD   =    10.75  ! astrometer walkdown MAD for PMTYB (-1=NA)
!
PMTXA_WD_SIG   =    13.89  ! astrometer walkdown S.D. for PMTXA (-1=NA)
PMTXB_WD_SIG   =    14.48  ! astrometer walkdown S.D. for PMTXB (-1=NA)
PMTYA_WD_SIG   =    14.85  ! astrometer walkdown S.D. for PMTYA (-1=NA)
PMTYB_WD_SIG   =    13.11  ! astrometer walkdown S.D. for PMTYB (-1=NA)
!
NSAMPLES_X     =       376 ! X AXIS: #SAMPLES USED TO COMPUTE WD PMT DIFF/SUM
X_FL_DIFF/SUM  =   -0.0219 ! X PMT DIFF/SUM FROM FLDV INTERVAL (-1=NA)
X_WD_DIFF/SUM  =    0.0055 ! X PMT DIFF/SUM FROM WALKDOWN INTERVAL (-1=NA)
K1X_UPGREN69   =    0.0301 ! REF X AXIS S-CURVE INVERSE SLOPE OF UPGREN69
X_DIFF         = -0.000824 ! X CENTROID SHIFT (ARCS), ADD TO X_MEDIAN (-1=NA)
!
NSAMPLES_Y     =       241 ! Y AXIS: #SAMPLES USED TO COMPUTE WD PMT DIFF/SUM
Y_FL_DIFF/SUM  =    0.0253 ! Y PMT DIFF/SUM FROM FLDV INTERVAL (-1=NA)
Y_WD_DIFF/SUM  =    0.0171 ! Y PMT DIFF/SUM FROM WALKDOWN INTERVAL (-1=NA)
K1Y_UPGREN69   =    0.0151 ! REF Y AXIS S-CURVE INVERSE SLOPE OF UPGREN69
Y_DIFF         =  0.000125 ! Y CENTROID SHIFT (ARCS), ADD TO Y_MEDIAN (-1=NA)
!
! ........................................................................... !
!
!                          COARSE TRACK coordinates
!
!                  GUIDE STAR      GUIDE STAR      ASTROMETER
!                     FGS1            FGS2            FGS3
!
CT_X          =    -124.846         -69.454         191.867   ! X, arc seconds
CT_Y          =     705.588         720.397         716.168   ! Y, arc seconds
!
! ........................................................................... !
!
!     raw, STAR SELECTOR values mean and median over measured interval
!     (-2=mean, median not computed), (FL) = finelock, (CT) = COARSE TRACK
!
!                  GUIDE STAR      GUIDE STAR      ASTROMETER
!                   FGS1 (FL)       FGS2 (FL)       FGS3 (FL)
!
SS_A_AVERAGE  =          0               0               0    ! “THETA A”
SS_B_AVERAGE  =          0               0               0    ! “THETA B”
SS_A_MEDIAN   =     499751          376375          258989    ! “THETA A”
SS_B_MEDIAN   =     713495          830629          616509    ! “THETA B”
SPCR1         =     768442          734328          518064    ! “CT THETA A”
SPCR2         =    1560040         1479462         1232352    ! “CT THETA B”
!
!
! ........................................................................... !
!
!                     Star Selector to X,Y conversion parameters
!
!                           FGS1              FGS2              FGS3
!
SS_A_dev_angle       =  6.885174200      6.759527300      6.852572700
SS_B_dev_angle       =  6.862490000      6.772780000      6.857440000
SS_A_offset          = -0.049323366      0.568665570     -0.627579600
SS_B_offset          =  0.000000000      0.000000000      0.000000000
magnification        = 57.219718800     57.236389900     57.043404000
!
```

FGS / 11