Chapter 15
NICMOS Data Structures

In This Chapter...

This chapter is a guide to the structure of NICMOS data. The data file naming convention, formats, and organization are described, as are the file header keywords. The connection between the Phase II exposure logsheets and the data you receive is also explained, together with the paper products delivered.

15.1 NICMOS Data Files

STScI automatically processes and calibrates all NICMOS data and archives the data files resulting from pipeline processing in FITS format. If you have retrieved NICMOS files from the Archive (see Chapter 1), you will notice that their names look like this:

`*n3w2a1wqm*_cal.fits`

The first part of the file name (`n3w2a1wqm`) is the *rootname*, identifying the dataset to which the file belongs, the second (`cal`) is the *suffix*, identifying the type of data the file contains, and the third (`fits`) indicates that this is a FITS format file. Chapter 2 shows how to access the data contained in NICMOS FITS files; Appendix B explains how to decipher the rootnames of these files and explains why some of them are grouped into data *associations*. This section describes the different types of files that constitute a NICMOS dataset.

15.1.1 File Name Suffixes

Each file in a NICMOS dataset has a three-character suffix that uniquely identifies the file contents. Table 15.1 lists the file name suffixes for NICMOS and the corresponding file contents. The files that contain final calibrated data (which you will most likely use for analysis) are highlighted. This table lists *all* of the files that the pipeline *can* produce. For some observing strategies not all of the processing steps are performed and only a subset of these files will be produced by the pipeline. A brief explanation of the contents and origin of each file is given below.

- *Raw Science File* (`_raw`):
  This FITS file contains the raw image data received from the spacecraft. One file per exposure is created (a MULTIACCUM exposure is considered a single exposure irrespective of the number of samples specified).
- *Support File* (`_spt`):
  This FITS file contains supporting information about the observation, the spacecraft telemetry and engineering data from the instrument that was recorded at the time of the observation.
- *Association Table* (`_asn`):
  This file is a FITS binary table that contains the list of datasets making up an association.
- *Calibrated Science File* (`_cal`):
  This FITS file contains the calibrated science data for an *individual dataset*, and is produced by the pipeline calibration task **calnica** (see Chapter 16). The input to **calnica** are the `_raw` images. For a MULTIACCUM exposure, this file contains a single science image formed by combining the data from all samples.
- *Intermediate Multiaccum Science File* (`_ima`):
  This FITS file is also produced by the pipeline task **calnica** and contains the calibrated science data for all samples of a MULTIACCUM dataset before the process of combining the individual readouts into a single image has occured. This file is only produced for MULTIACCUM observations.
- *Mosaic Files* (`_mos`):
  These FITS files contain the composite target and, for chopped pattern sequences, background region images constructed by the pipeline task **calnicb** for an associated set of observations (see Chapter 16). The inputs to **calnicb** are the calibrated `_cal` images from **calnica**. Target images are co-added and background-subtracted. The value of the last character of the rootname is 0 for targets, and 1 to 8 for background images. These files are only produced for an associated set of observations.
- *Post-calibration Association Table* (`_asc`):
  This table is produced by the pipeline calibration task **calnicb,** and **is** the same as the association table _asn, with the addition of new columns which report the offsets between different images of the mosaic or chop pattern as calculated by the pipeline, and the background levels computed for each image. This file is only produced for an associated set of observations.

- *Trailer File*:
  This file contains a log of the pipeline calibration processing that was performed on individual datasets and mosaic products.
- *Processing Data Quality File* (`_pdq`):
  This FITS ASCII table provides quality information on the observation, mostly on pointing and guide star lock. Possible problems encountered, e.g., a loss of guide star lock or a guide star acquisition failure, are reported here.

Table 15.1: NICMOS File Name Suffixes

Suffix	File Contents
	Raw Data Files
`_raw`	Raw science data
`_spt`	Support file containing Standard Header Packet and Unique Data Log information
`_asn`	Association table
	Calibrated Data Files
`_cal`	Calibrated science data
`_ima`	Intermediate multiaccum calibrated science data
`_mos`	Mosaiced target or background images
`_asc`	Post-calibration association table
`_trl`	Trailer file
`_pdq`	Processing Data Quality file

15.1.2 Science Data Files

The `*_raw.fits`, `*_cal.fits`, `*_ima.fits`, and `*_mos.fits` files are all defined as *science data files*, as they contain the images of interest for scientific analysis.

File Contents and Organization

The data for an individual NICMOS science image consist of five arrays, each stored as a separate image extension in the FITS file. The five data arrays represent:

- The science (SCI) image from the detector.
- An error (ERR) array containing statistical uncertainties (in units of 1 σ) of the science data.
- An array of bit-encoded data quality (DQ) flags representing known status or problem conditions of the science data.

- An array containing the number of data samples (SAMP) that were used to compute each science image pixel value.
- An array containing the effective integration time (TIME) for each science image pixel.

A grouping of the five data arrays for one science image is known as an *image set* or *imset*.

A science data file can contain one or more imsets. For example, an individual NICMOS exposure obtained with the ACCUM mode will generate a `*_raw.fits` file with one imset; an individual MULTIACCUM exposure with *x* readouts will generate a `*_raw.fits` file (and, after calibration, a `*_ima.fits` file) containing $x + 1$ imsets, including the zeroth readout. The files `*_cal.fits` and `*_mos.fits` files always contain one imset.

In a MULTIACCUM exposure, the order of the imsets in the file is such that the result of the longest integration time (the last readout performed on-board) occurs ***first*** in the file (first imset), the one readout before the last is the seond imset, and so on; the zeroth readout is the last imset (i.e., the order is in the opposite sense from which they are obtained).

Although the five science, error, data quality, samples, and integration time arrays associated with each imset are stored in a single file, they are kept separate as five individual FITS image *extensions* within the file. The order of the images in the FITS files is listed in Table 15.2 and shown graphically in Figure 15.1 and Figure 15.2. The examples given in Table 15.2 and Figure 15.2 refer to a MULTIACCUM image (multiple imsets), while Figure 15.1 refers to ACCUM, BRIGHTOBJ and RAMP images (one imset, namely extensions 1 through 5). Each extension comes with its own header, and each FITS file contains, in addition, a *primary header* (primary header-data unit or HDU).

The only contents of the primary HDU are header keywords. There is no image data in the primary header. The keywords in the primary header are termed *global keywords* because they apply to the data in all of the file extensions. The organization and location of header keywords is explained in detail later in the chapter.

Table 15.2: NICMOS Science Data File Contents

Header-Data Unit	Extension Name	imset	Contents	Datatype
Primary (Extension 0)	(N/A)	(N/A)	Global keywords; no data.	(N/A)
Extension 1	SCI	1	Science image	raw: 16-bit int; calibrated: float
Extension 2	ERR	1	Error (sigma) image	float
Extension 3	DQ	1	Data Quality image	16-bit int
Extension 4	SAMP	1	Number of Samples image	16-bit int
Extension 5	TIME	1	Integration Time image	float
Extension 6	SCI	2	Science image	raw: 16-bit int; calibrated: float
Extension 7	ERR	2	Error (sigma) image	float
Extension 8	DQ	2	Data Quality image	16-bit int
Extension 9	SAMP	2	Number of Samples image	16-bit int
Extension 10	TIME	2	Integration Time image	float
.....	.....	...	....	.....

Figure 15.1: Data Format for ACCUM, RAMP, BRIGHTOBJ and ACQ Modes

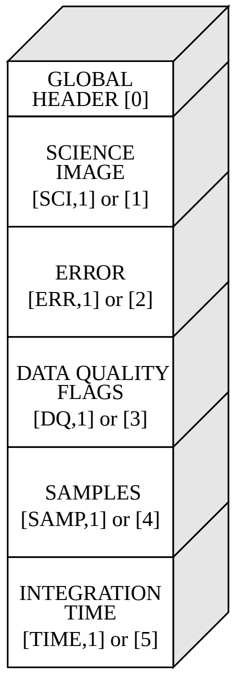
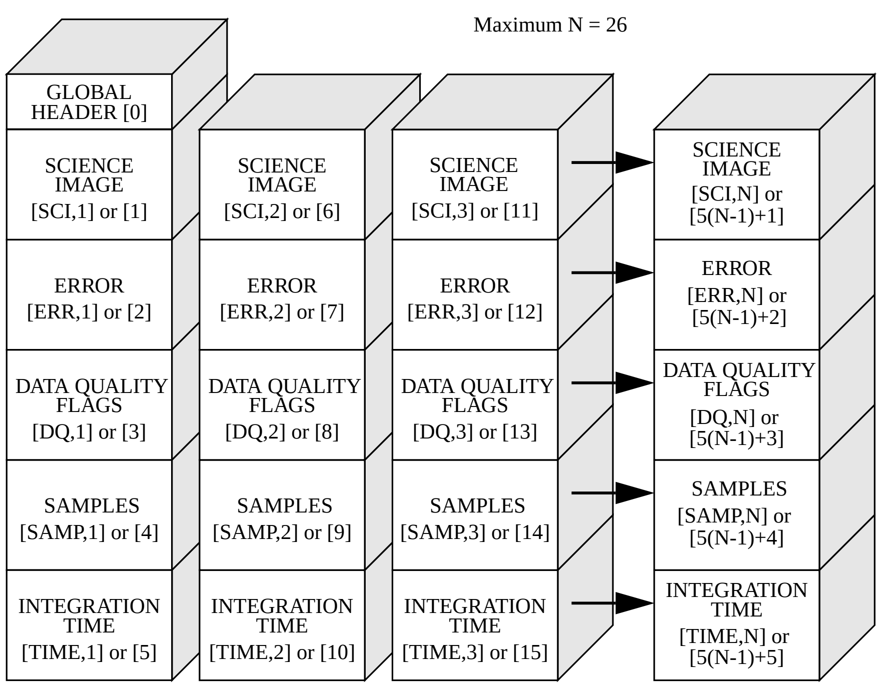


Figure 15.2: MULTIACCUM Mode Data Format



The following sections explain the contents and origin of each of the five image arrays in each imset in more detail.

Science Image

This image contains the data from the detector readout. In ACCUM, RAMP, and BRIGHTOBJ modes the image received from the instrument is the result of subtracting the initial from the final readouts of the exposure. In MULTIACCUM mode the images received are the raw (unsubtracted) data corresponding to each detector readout. In this case the subtraction of the zeroth read is done in the ground calibration pipeline task **calnica** (see Chapter 16). In raw datasets the science array is an integer (16-bit) image in units of DNs (counts). In calibrated datasets it is a floating-point image in units of DNs per second (count rates).

Error Image

The error image is a floating-point array containing the statistical uncertainty associated with each corresponding science image pixel. For all observing modes except RAMP, this image is computed in the ground calibration pipeline task **calnica** as a combination of detector read noise and Poisson noise in the accumulated science image counts (see Chapter 16) and is expressed in terms of 1σ uncertainties. In RAMP mode the instrument computes the variance for each pixel value from the intermediate readouts and returns the variance image to the ground where it is stored in the raw science data file (`*_raw.fits`). In this case the ground calibration pipeline simply converts the variance values in the raw data file to standard deviations.

Data Quality Image

This integer (unsigned 16-bit) array contains bit-encoded data quality flags indicating various status and problem conditions associated with corresponding pixels in the science image. Because the flag values are bit-encoded, a total of 16 simultaneous conditions can be associated with each pixel. Table 15.3 lists the flag values and their meanings.

Number of Samples Image

The SAMP image is an integer (16-bit) array containing the total number of data samples that were used to compute the corresponding pixel values in the science image. For RAMP mode observations this information is computed by the instrument and sent to the ground to be recorded in the raw data file (`*_raw.fits`). For ACCUM and BRIGHTOBJ modes, the number of samples contributing to each pixel is set to a value of 1 in the raw data file. For MULTIACCUM mode the sample values in the raw and intermediate data files are set to the number of readouts that contributed to the corresponding science image. Because the number of samples in the raw images for MULTIACCUM, ACCUM and BRIGHTOBJ modes have one number for all pixels of an imset, the array is usually not created (to save on data volume), and the value of the sample is stored in the header keyword PIXVALUE in the SAMP image extension (see Table 15.6 below).

In MULTIACCUM calibrated data files (`*_cal.fits`) the SAMP array contains the total number of valid samples used to compute the final science image pixel value, by combining the data from all the readouts and rejecting

Table 15.3: NICMOS Data Flag Values

Flag Value	Bit Setting[a]	Flag Meaning
0	0000 0000 0000 0000	No known problems
1	0000 0000 0000 000**1**	Reed-Solomon decoding error in telemetry
2	0000 0000 0000 00**1**0	Poor or uncertain Linearity correction
4	0000 0000 0000 0**1**00	Poor or uncertain Dark correction
8	0000 0000 0000 **1**000	Poor or uncertain Flat Field correction
16	0000 0000 000**1** 0000	Poor Background subtraction
32	0000 0000 00**1**0 0000	Defective (hot or cold) pixel
64	0000 0000 0**1**00 0000	Saturated pixel
128	0000 0000 **1**000 0000	Missing data in telemetry
256	0000 000**1** 0000 0000	Bad pixel determined by calibration
512	0000 00**1**0 0000 0000	Pixel contains Cosmic Ray
1024	0000 0**1**00 0000 0000	Pixel contains source
2048	0000 **1**000 0000 0000	(unassigned)
4096	000**1** 0000 0000 0000	User flag
8192	00**1**0 0000 0000 0000	User flag
16384	0**1**00 0000 0000 0000	Reserved

a. Most significant bit is at left.

cosmic ray hits and saturated pixels. In this case the sample array may have different values at different pixel locations (less or equal to the total number of samples in the MULTIACCUM sequence), depending on how many valid samples there are at each location.

In the mosaic images (`*_mos.fits`), the data in the SAMP array indicate the number of samples that were used from overlapping images to compute the final science image pixel value.

Integration Time Image

The TIME image is a floating-point array containing the effective integration time associated with each corresponding science image pixel value. These data are always computed in the ground calibration pipeline for recording in the raw data file. For ACCUM and BRIGHTOBJ mode observations each pixel has the same time value. For MULTIACCUM observations each pixel for a given readout has the same time value in the raw and intermediate data. Therefore, the same data-volume-saving technique is used in these cases: the array is not created and the value of the time is stored in the header keyword PIXVALUE in the TIME image extension (see Table 15.6 below). For RAMP mode observations the integration time for each pixel is computed from the exposure time per sample and the total number of samples contributing to each pixel; a TIME array is thus returned to the ground.

In MULTIACCUM calibrated data files (`*_cal.fits`) the TIME array contains the combined exposure time of all the readouts that were used to compute the final science image pixel value, after rejection of cosmic ray and saturated pixels from the intermediate data. As in the case of the SAMP array, the TIME array can have different values at different pixel locations, depending on how many valid samples compose the final science image in each pixel.

In mosaic images (`*_mos.fits`), the TIME array values indicate the total effective exposure time for all the data that were used to compute the final science image pixel values.

15.1.3 Auxiliary Data Files

The `*_spt.fits`, `*_trl.fits`, `*_pdq.fits`, the `*_asn.fits`, and the `*_asc.fits` files are termed *auxiliary data files*. They contain supporting information on the observation, such as spacecraft telemetry and engineering data, assessment of the quality of the observation, calibration information, and information on the associations present in the observations.

Association Tables

The *association tables*, `*_asn.fits` and `*_asc.fits`, are FITS binary tables which are created when a particular observation generates an association of datasets (see "Associations" on page B-4). In particular, the `*_asn.fits` table is generated by OPUS, and contains the list of datasets which make up the association (e.g., from a dither or chop pattern). The `*_asn.fits` tables are the inputs to the pipeline **calnicb**, which creates the mosaiced or background subtracted images (`*_mos.fits` files) from the input datasets. All the datasets must have been processed through the basic pipeline data reduction (**calnica**) before being processed through **calnicb**. In addition to the output science image(s), **calnicb** produces another associations table (`*_asc.fits`), which has the same content as the `*_asn.fits` table, along with additional information on the offsets used by the pipeline for reconstructing the science image. For mosaics (dither patterns), there is only one final image produced, with file name `*0_mos.fits`. For chop patterns, in addition to the background-subtracted image of the target (`*0_mos.fits`), an image for each background position will be produced; the file names of these background images are `*1_mos.fits`, `*2_mos.fits`,..., `*8_mos.fits` (A maximum of eight independent background positions is obtainable with the NICMOS patterns, see the *NICMOS Instrument Handbook* for details).

Support File

The support files `*_spt.fits` contain information about the observation and engineering data from the instrument that was recorded at the time of the observation. A support file can have multiple extensions within the same file; in the case of a MULTIACCUM observation there will be one extension for each readout (i.e., each imset) in the science data file. Each extension in the support file holds an integer (16-bit) image.

Trailer File

The trailer files *_trl.fits contain information on the calibration steps executed by the pipelines and diagnostics issued during the calibration.

Processing Data Quality File

The processing data quality files (*_pdq.fits) contain general information summarizing the observation, a data quality assessment section, and a summary on the pointing and guide star lock. They state whether problems were encountered during the observations, and, in case they were, describe the nature of the problem. There is one *_pdq.fits file produced for each dataset, and, in case of associations, one *_pdq file for each NICMOS product (i.e., each *_mos.fits file).

15.2 Header Keywords

Both the primary header and the headers of each image extension in a science data file contain *keywords*. The keywords store a wide range of information about the observations themselves (e.g., observing mode, integration time, filters or grisms), the processing of the data by the OPUS pipeline (e.g., calibration steps performed and reference files used), and the properties of the data themselves (e.g., number of image extensions, dimensions and data type of each image, coordinate system information, flux units, and image statistics).

The primary header carries global keywords which are applicable to all extensions; the modification of a keyword in the primary header has the effect of changing the value seen by all extensions. In addition to the common keywords, the extension headers carry extension-specific keywords, which contain information relevant to the image in a particular extension. For example, observation parameters, calibration switches and reference file names are contained in the primary header. Exposure time and coordinate information, on the other hand, is contained in the header of each image extension because this information could vary from one group of extensions to another.

Table 15.4 below lists most of the keywords in the primary header of the *science data files*; the observer may find many of them useful. A complete description of the keywords can be found at the following WWW page:

http://archive.stsci.edu/keyword

Table 15.5 lists some of the relevant keywords that are specific to image extensions; they appear in the extension headers, but not in the primary header:

In the SCI image extensions, additional keywords describing the data quality are present. They give the number of pixels which have a flag different from zero in the DQ extension, and a suite of statistical information (mean, standard

Table 15.4: Science Data File Primary Header Keywords

Keyword Name	Meaning
	Image Keywords
NEXTEND	Number of extensions in the file (up to 130 for MULTIACCUM).
FILENAME	Name of the file
FITSDATE	Date on which the FITS file was generated
FILETYPE	Type of data: SCI - Science Data File SPT - Support File ASN_TABLE - Association Table
TELESCOP	HST
INSTRUME	Instrument used (NICMOS)
EQUINOX	Equinox of the celestial coordinate system (J2000.0 for HST observations)
	Data Description Keywords
ROOTNAME	Rootname (IPPPSSOOT) of the dataset
IMAGETYP	Image type EXT = external image FLAT = flatfield image DARK = dark image
PARALLEL	Indicates if the observation was taken in parallel
PRIMESI	Primary Instrument used for the observation
	Target Information
TARGNAME	Proposer's target name
RA_TARG	Right Ascension of the target (degrees, J2000)
DEC_TARG	Declination of the target (degrees, J2000)
	Proposal Information
PROPOSID	Proposal's identification number
LINENUM	Exposure's logsheet linenumber, from the Phase 2 proposal
	Exposure Information
ORIENTAT	Position angle of the image y axis (degrees East of North)
FGSLOCK	Commanded FGS lock (FINE, COARSE, GYROS, UNKNOWN)
DATE-OBS	UT date of start of the observation (dd/mm/yy)
TIME-OBS	UT time of start of the observation (hh:mm:ss)
EXPSTART	Exposure start time (Modified Julian Date)
EXPEND	Exposure end time (Modified Julian Date)
EXPTIME	Total integration time (sec)

Table 15.4: Science Data File Primary Header Keywords (Continued)

Keyword Name	Meaning
	Instrument Configuration Information
CAMERA	NICMOS camera used in the observation (1, 2, or 3)
PRIMECAM	NICMOS Prime Camera during the observation (for internal parallels)
FOCUS	In-focus camera for this observation
APERTURE	Aperture used in the observation (NICi, NICi-FIX, NIC2-CORON)
OBSMODE	Observing mode (MULTIACCUM, ACCUM,...)
FILTER	Filter or grism used
NUMITER	Number of iterations in the exposure
NREAD	Number of ACCUM initial and final readouts
NSAMP	Number of MULTIACCUM or RAMP samples
SAMP_SEQ	MULTIACCUM exposure time sequence name
PATT_OFF	Pattern offset method (SAM, SAM-NO-REACQ, etc.)
PATTERN	Pattern type
PFRAME	Reference frame of pattern (DETECTOR, SKY)
PORIENT	Pattern orientation on the sky relative to North-to-East (degrees)
NUMPOS	Number of positions in the pattern
DITHSIZE	Size of the dither steps (arcseconds)
CHOPSIZE	Size of the chop steps (arcseconds)
PATT_POS	Position number of the exposure in the pattern sequence
FOMXPOS	X offset of the Camera FOV using NICMOS FOM (arcsec)
FOMYPOS	Y offset of the Camera FOV using NICMOS FOM (arcsec)
NFXTILTP	FOM X-tilt position (arcsec)
NFYTILTP	FOM Y-tilt position (arcsec)
NPXTILTP	PAM X-tilt position (arcsec)
NPYTILTP	PAM Y-tilt position (arcsec)
NPFOCUSP	PAM focus position (deg)
READOUT	Detector array readout rate (FAST, SLOW)
SAMPZERO	Sample time of MULTIACCUM zeroth read (sec)
ADCGAIN	Analog-digital conversion gain (electrons/DN)
	Photometry Keywords
PHOTMODE	Combination of <INSTRUME>+<CAMERA>+<FILTER>

Table 15.4: Science Data File Primary Header Keywords (Continued)

Keyword Name	Meaning
PHOTFLAM	Inverse sensitivity (erg/cm^2/angstrom/DN)
PHOTFNU	Inverse sensitivity (Jy*sec/DN)
PHOTZPT	ST magnitude system zero point
PHOTPLAM	Pivot wavelength of the photmode (Angstrom)
PHOTBW	Root Mean Square bandwidth of the photmode (Angstrom)
	Calnica Calibration Reference Files (inputs to calnica)
MASKFILE	Static data quality file
NOISFILE	Detector read noise file
NLINFILE	Detector non-linearity file
DARKFILE	Dark current file
FLATFILE	Flat field file
PHOTTAB	Photometric calibration table
BACKTAB	Background model parameters table
	Calnica Calibration Reference File Pedigree (outputs from calnica)
MASKPDGR	Static data quality file pedigree (values: GROUND dd/mm/yyyy - for reference files originated from Thermal Vacuum data; INFLIGHT dd/mm/yyyy - for reference files originated from on-orbit calibration observations)
NOISPDGR	Detector read noise file pedigree (values: GROUND dd/mm/yyyy; INFLIGHT dd/mm/yyyy)
NLINPDGR	Detector non-linearity file pedigree (values: GROUND dd/mm/yyyy; INFLIGHT dd/mm/yyyy)
DARKPDGR	Dark current file pedigree (values: GROUND dd/mm/yyyy; INFLIGHT dd/mm/yyyy; and MODEL dd/mm/yyyy for the synthetic darks, see next Chapter)
FLATPDGR	Flat field file pedigree (values: GROUND dd/mm/yyyy; INFLIGHT dd/mm/yyyy)
PHOTPDGR	Photometric calibration table pedigree (values: GROUND dd/mm/yyyy; INFLIGHT dd/mm/yyyy)
BACKPDGR	Background model parameters table pedigree (values: GROUND dd/mm/yyyy; INFLIGHT dd/mm/yyyy)
	Calnica Calibration Switches (allowed values: PERFORM, OMIT)
BIASCORR	Correct wrapped pixel values
ZSIGCORR	MULTIACCUM zero read signal correction
ZOFFCORR	Subtract MULTIACCUM zero read
MASKCORR	Data quality initialization (DQ array)
NOISCALC	Calculate statistical errors (ERR array)

Table 15.4: Science Data File Primary Header Keywords (Continued)

Keyword Name	Meaning
NLINCORR	Correct for detectors non-linearities
DARKCORR	Dark correction
FLATCORR	Flat-field correction
UNITCORR	Convert to count rate
PHOTCALC	Populate photometry keywords
CRIDCALC	Identify cosmic ray hits (update of DQ arrays in `*_ima.fits` output of calnica for MULTIACCUM)
BACKCALC	Calculate background estimates
WARNCALC	Generate user warnings
Calnica Calibration Indicators (output from calnica; values: PERFORMED, SKIPPED, OMITTED)	
BIASDONE	Correct wrapped pixel values
ZSIGDONE	MULTIACCUM zero read signal correction
ZOFFDONE	Subtract MULTIACCUM zero read
MASKDONE	Data quality initialization (DQ array)
NOISDONE	Calculate statistical errors (ERR array)
NLINDONE	Correct for detectors non-linearities
DARKDONE	Dark correction
FLATDONE	Flat-field correction
UNITDONE	Convert to count rate
PHOTDONE	Populate photometry keywords
CRIDDONE	Identify cosmic ray hits (update of DQ arrays in *_ima.fits output of calnica for MULTIACCUM)

Table 15.4: Science Data File Primary Header Keywords (Continued)

Keyword Name	Meaning
BACKDONE	Calculate background estimates
WARNDONE	Generate user warnings
	Calibration Status
CALSTAGE	State of the calibration (values: CALNICA, CALNICB, UNCALIBRATED)
CAL_VER	Version number of the CALNIC code
	Calnicb Calibration Information
ILLMCORR	Subtraction of background illumination pattern reference image (input values: PERFORM, OMIT)
ILLMDONE	Subtraction of background illumination pattern reference image (output values: PERFOMED, SKIPPED, OMITTED)
ILLMFILE	Background illumination pattern reference image filename
ILLMPDGR	Background illumination pattern file pedigree
MEAN_BKG	Mean background level (DN/sec), computed by calnicb
	Association Keywords
ASN_ID	Association rootname
ASN_TAB	Name of the association table
ASN_MTYP	Role of the dataset in the association (e.g., targe, ; first background, second background, etc.; allowed values: EXP_TARG, EXP_BCKn, PROD_TARG, PROD_BCKn, where EXP=input exposure, PROD=output image, TARG=target, BCK=background, n=1-8)

deviation, minimum and maximum of good pixels in the entire detector and per quadrant) on the image.

Keywords giving the data on the ephemeris and engineering data on the status of the telescope and of the instrument during the observations are reported in the support file, `*_spt.fits`. Table 15.6 describes some of the relevant keywords from this file.

15.3 Working with NICMOS Files

The quickest way to learn how each observation was performed is to use the **iminfo** task in the STSDAS **toolbox.headers** package to look at the headers of the science data. The output from **iminfo** summarizes on one screen the relevant information about an observation (Table 15.7) and the instrument configuration

Table 15.5: Image Extension Header Keywords in Science Data Files

Keyword Name	Meaning
	Data Description Keywords
EXTNAME	Name of the extension in an imset of the data file (SCI, ERR, DQ, SAMP, TIME)
EXTVER	Extension version; integer number to uniquely identify an IMSET in a science data file. A MULTIACCUM file can contain up to 26 IMSETs, i.e. up to EXTVER=26.
INHERIT	Switch to allow the image extension header to inherit the primary header keywords. Allowed values: T=TRUE, F=FALSE.
DATAMIN	Minimum pixel value
DATAMAX	Maximum pixel value
BUNIT	Brightness units; allowed values: COUNTS, COUNTS/S.
PIXVALUE	When ALL pixels in an image extension have the same value (e.g., the SAMP and TIME arrays in the *_ima.fits file from a MULTIACCUM exposure or the ERR, DQ, SAMP and TIME arrays in the *_raw.fits files from a MULTIACCUM, ACCUM or BRIGHTOBJ exposure) the pixel array of that extension is not generated, and the PIXVALUE keyword is instead populated with the common value of the pixels.
	World Coordinate System of Image
CRPIX1	x-coordinate of image's reference pixel
CRPIX2	y-coordinate of image's reference pixel
CRVAL1	RA of reference pixel (degrees)
CRVAL2	DEC of reference pixel (degrees)
CD1_1	Partial derivative of RA with respect to x
CD1_2	Partial derivative of RA with respect to y
CD2_1	Partial derivative of Dec with respect to x
CD2_2	Partial derivative of Dec with respect to y
	Readout Parameters
SAMPNUM	Sample number of the MULTIACCUM sequence
SAMPTIME	Total integration time (sec)
DELTATIM	Integration time of the sample (sec)
ROUTTIME	UT time of array readout (MJD)

Table 15.6: NICMOS Primary Header Keywords in the Support Files

Keyword Name	Meaning
PA_V3	Position angle of the V3 axis of HST (degrees)
RA_V1	RA of the V1 axis of HST (degrees in J2000)
DEC_V1	DEC of the V1 axis of HST (degrees in J2000)
RA_SUN	RA of the Sun (degrees in J2000)
DEC_SUN	DEC of the Sun (degrees in J2000)
RA_MOON	RA of the Moon (degrees in J2000)
DEC_MOON	DEC of the Moon (degrees in J2000)

during the observations (Table 15.8), by reading and reporting the value of the appropriate keywords.

Table 15.7: Observation Information in iminfo Listing

Field Descriptor	Header Keyword Source
Rootname	ROOTNAME
Instrument	INSTRUME
Target Name	TARGNAME
Program	ROOTNAME (positions 2–4)
Observation set	ROOTNAME (positions 5–6)
Observation	ROOTNAME (positions 7–8)
File Type	FILETYPE
Obs Date	DATE-OBS or FPKTTIME
Proposal ID	PROPOSID
Exposure ID	PEP_EXPO
Right Ascension	CRVAL1
Declination	CRVAL2
Equinox	EQUINOX

The entire suite of keywords from any header can be listed with the IRAF task **imheader**. Given that NICMOS data files contain multiple extensions, the number of the desired extension must always be specified. For example, to list the primary header content of a calibrated image, you type

```
cl> imheader n0g70106t_cal.fits[0] long+ | page
```

where [0] identifies the primary header. To list the header of the *second* science image in a MULTIACCUM sequence (the sixth extension):

Table 15.8: NICMOS-Specific Information in iminfo Listing

Field Descriptor	Header Keyword Source
Image type	IMAGETYP
Number of extensions	NEXTEND
Camera number	CAMERA
Aperture	APERTURE
Filter name	FILTER
Observation Mode	OBSMODE
Number of initial/final reads	NREAD (ACCUM)
Number of intermediate samples	NSAMP (MULTIACCUM or RAMP)
MULTIACCUM sequence	SAMP_SEQ
Exposure time (sec)	EXPTIME
Readout speed	READOUT
Association ID	ASN_ID
Number of Iterations	NUMITER
Calibration steps done	Switches whose values are set to “PERFORMED”. Switches are: ZOFFDONE, MASKDONE, BIASDONE, NOISDONE, DARKDONE, NLINDONE, FLATDONE, UNITDONE, PHOTDONE, CRIDDONE, BACKDONE, WARNDONE

```
cl> imheader n0g70106t_cal.fits[6] long+ | page
```

An example of a header listing is shown in Figure 15.3 below.

Figure 15.3: Long imheader

```
n3uy01onm_cal.fits[0][1][short]: n3uy01onm_raw.fits
    No bad pixels, min=0., max=0. (old)
    Line storage mode, physdim [0], length of user area 6642 s.u.
    Created Sun 22:41:40 06-Jul-97, Last modified Sun 22:41:40 06-Jul-97
    Pixel file 'n3uy01onm_cal.fits' [NO PIXEL FILE]
    ORIGIN  = 'STScI-STSDAS Fits Kernel 20Aug96b' / FITS file originator
    FITSDATE= '21/04/97  '          / Date FITS file was generated
    IRAF-TLM= '18:08:26 (20/04/1997)' / Time of last modification
    OBJECT  = 'n3uy01onm_raw.fits' / Name of the object observed
    NEXTEND =                    5 / Number of standard extensions
    DATE    = '19/04/97           ' / date this file was written (dd/mm/yy)
    FILENAME= 'N3UY010NM_RAW.FITS' / name of file
    FILETYPE= 'SCI                ' / type of data found in data file

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

                  / DATA DESCRIPTION KEYWORDS

    ROOTNAME= 'N3UY010NM          ' / rootname of the observation set
    IMAGETYP= 'SCIENCE            ' / type of exposure identifier
    PARALLEL= 'NO                 ' / indicates if observation taken in parallel
    PRIMESI = 'NICMOS             ' / instrument designated as prime

                  / TARGET INFORMATION

    TARGNAME= 'IC5063             ' / proposer's target name
    RA_TARG =       313.009716667 / right ascension of the target (deg) (J2000)
    DEC_TARG=      -57.0686083333 / declination of the target (deg) (J2000)

                  / PROPOSAL INFORMATION

    PROPOSID=                 7119 / PEP proposal identifier
    PEP_EXPO= '01-010#002         ' / PEP exposure identifier including sequence
    LINENUM = '1.010              ' / PEP proposal line number
    PR_INV_L= 'Calzetti           ' / last name of principal investigator
    PR_INV_F= 'Daniela            ' / first name of principal investigator
    PR_INV_M= '                   ' / middle initial of principal investigator

                  / EXPOSURE INFORMATION

STDIN-line 42-file 1 of 1
```

Chapter 2 describes in detail how to work with FITS file extensions. Here we will recap the essentials. In order to simplify access to NICMOS FITS image extensions, each extension header contains the two keywords: `EXTNAME` (extension name) and `EXTVER` (extension version number). The `EXTNAME` keyword identifies the nature of the extension (SCI, ERR, DQ, SAMP, TIME, see Table 15.7). The `EXTVER` keyword contains an integer value which is used to uniquely identify a particular imset (quintuple of image extensions). For example, the five image extensions (single imset) contained in the science data file for an ACCUM, RAMP, or BRIGHT OBJECT observation will all usually be assigned an `EXTVER` value of 1 because there will only be one group of extensions in the file. In a MULTIACCUM science data file, each group of extensions associated with a given readout will have a unique `EXTVER` value, running from 1 up to the total number of readouts in that particular file.

To list the header of the *second* science image in a MULTIACCUM sequence, in addition to the command line above, one can give:

```
cl> imheader n0g70106t_cal.fits[sci,2] long+ | page
```

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In general, to access a particular image extension, append the name and version number of the desired extension in square brackets to the end of the file name. The `EXTNAME` value is specified first, then the `EXTVER` value, separated by a comma. Indeed, the use of the keywords EXTNAME and EXTVER is not limited to the task **imheader,** but can be used in all IRAF tasks.

The primary header data unit in a NICMOS FITS file does not contain the `EXTNAME` or `EXTVER` keywords. The absolute extension number 0 (zero) refers to the primary header.

If a calibration keyword needs to be changed, the IRAF/STSDAS **chcalpar** task can be used. For instance, to modify the flatfield calibration from PERFORM to OMIT in a given data file, the following command can be given:

```
cl> chcalpar n0g70106t_raw.fits
```

The pset list appropriate for the image will appear, and the calibration keyword can be modified. The operation performed with **chcalpar** can be equivalently performed (although in a more cumbersome way) with the general IRAF task **hedit**; in this case, the extension [0] of the primary header must be explicitly specified:

```
cl> hedit n0g70106t_raw.fits[0] flatcorr OMIT
```

Do not try to edit a keyword in an extension header unless you are certain that the keyword does not reside in the primary header. (See “Header Keywords and Inheritance” on page 2-6).

Image sections can be specified in the case of NICMOS data with the same syntax as all IRAF images. For example, to specify a pixel range from 101 to 200 in the *x* direction and all pixels (denoted by an asterisk) in the *y* direction from the second error image in a file, the complete file name specification would be `n0g70106t_cal.fits[err,2][101:200,*]`.

If you use both extension and image section syntax together, the extension name or number must come first enclosed in one set of brackets, and the image section specification in a second set of brackets.

15.4 From the Phase II Proposal to Your Data

The connection between the Exposure Logsheet that each observer fills out during the Phase II proposal process and the datasets and associations that the observer receives once the observations are executed can be better understood through some examples.

The first example shows an exposure logsheet entry that will generate only one dataset:

```
Exposure_Number: 1
Target_Name: HDF
Config: NIC2
Opmode: MULTIACCUM
Aperture: NIC2
Sp_Element: F160W
Optional_Parameters: SAMP-SEQ=STEP256,NSAMP=12
NUMBER_of_Iterations: 1
Time_Per_Exposure: DEF
Special_Requirements: POS TARG 0.5, 0.5
```

The science data file in the dataset will contain 13 imsets (corresponding to the MULTIACCUM NSAMP=12 parameter), and some of the header keywords will be filled with the relevant information from the target and exposure logsheets of the Phase II (e.g., the keywords TARGNAME, RA_TARG, DEC_TARG,....).

The next example shows an exposure logsheet entry that will generate both multiple datasets and an association:

```
Exposure_Number: 1
Target_Name: HDF
Config: NIC2
Opmode: MULTIACCUM
Aperture: NIC2
Sp_Element: F160W
Optional_Parameters:PATTERN=SPIRAL-DITH-CHOP,NUM-POS=8,
DITH-SIZE=1.5,CHOP-SIZE=0.75,SAMP-SEQ=STEP256,NSAMP=12
Number_of_Iterations: 1
Time_Per_Exposure: DEF
Special_Requirements:
```

In this observation, eight datasets (one for each position of the pattern) and one association will be created. The pipeline products will include the eight reduced datasets, one mosaic of the background-subtracted target, and one mosaic of the background.

An association will be generated also in the case below:

```
Exposure_Number: 1
Target_Name: HDF
Config: NIC2
Opmode: MULTIACCUM
Aperture: NIC2
Sp_Element: F160W
Optional_Parameters: SAMP-SEQ=STEP256,NSAMP=12
NUMBER_of_Iterations: 3
```

```
Time_Per_Exposure: DEF
Special_Requirements:
```

The number of iterations is 3, implying that three datasets will be generated from this exposure logsheet, plus an association table containing the three datasets. The collection of multiple iterations into an association is a new feature introduced by the NICMOS and STIS pipelines. In our specific example, The co-added image from the three iterations will be one of the products of the pipeline.

15.5 Paper Products

After the data from an observation have been received and processed through the STScI pipeline, hardcopy products (*paper products*) are generated which summarize the data obtained. The paper products are sent to the observer together with the data to provide a first look at the observations and their quality. Here we briefly describe the NICMOS paper products.

Paper products typically summarize the set of exposures that constitute a visit in the Phase II proposal. The set of exposures can be either individual datasets or associations. Paper products are produced by accessing the appropriate keywords in the dataset headers or in the association tables.

A given page of the NICMOS paper products falls into one of two categories: visit-level page or exposure-level page. The content of the pages is as follows:

Visit-Level Pages

- ***Cover Page***: contains the proposal ID, the visit number, the PI's last name, and the proposal title.
- ***Explanatory Notes***: a set of notes explaining the information contained in the paper products.
- ***Target List***: a table listing the targets of the observations being summarized (Figure 15.4).
- ***Observation Summary***: a table summarizing the proposal information for each exposure in the present set, including processing and data quality flags (Figure 15.4).
- ***Optional Parameters***: a table listing the optional parameters, other than the Pattern related parameters, used in the observations (Figure 15.4).
- ***Observing Pattern Strategy***: a table listing the observing pattern used for each exposure in the set (Figure 15.5).

Exposure-level Pages

- ***Exposure Plots***: a graphical representation of the data contained in each exposure, including the final calibrated science image and, in case of associations, successive pages containing a cartoon of the observing pattern plus the on-target and background individual images (Figure 15.6, Figure 15.7, and Figure 15.8).
- ***Data Quality Summary***: a summary of the spacecraft performance, pipeline processing status, and calibration data quality for each exposure.
- ***Calibration Reference File Summary***: a summary of the calibration processing switches and reference files used to process each exposure (Figure 15.9).

Figure 15.4: Target List, Observation Summary, and Optional Parameters

Visit: 001 **Proposal: 7119** *NICMOS*

Target List

Target Name	R.A. (J2000)	Dec. (J2000)	Description
IC5063	20:52:02.30	-57:04:07.0	GALAXY;SEYFERT;QUASAR;INTERACTING G

Observation List

Visit-Exp#	Rootname	Target Name	Camera Used/Frame	Operating Mode	Spectral Element	Observing Pattern	Exposure Time per Iteration (sec)	Number Iterations	Quality Flags Obs	Proc	Cal
1.030	N3UY01030	IC5063	2/2	MULTIACCUM	F222M	ONE-CHOP	127.962	1	○	○	●

Quality flags: ○ = OK ● = Not OK Blank = Unknown or file missing

Observation List-Optional Parameters

Visit-Exp#	Rootname	Target Name	Camera Used	Operating Mode	Optional Parameters
1.030	N3UY01030	IC5063	2	MULTIACCUM	SAMP-SEQ=STEP256 NSAMP=10 OFFSET=SAM-NO-GYRO

Figure 15.5: Observing Pattern Strategy

Visit: 001 **Proposal: 7119** *NICMOS*

Observing Pattern Strategy

Visit-Exp#	Rootname	Target Name	Camera Used	Operating Mode	Pattern Name	Pattern Orient (degrees)	Number Positions	Dither Size (")	Chop Size (")
1.020	N3UY01020	IC5063	2	MULTIACCUM	ONE-CHOP	0.00	2	0.00	119.88

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Figure 15.6: Individual Exposures

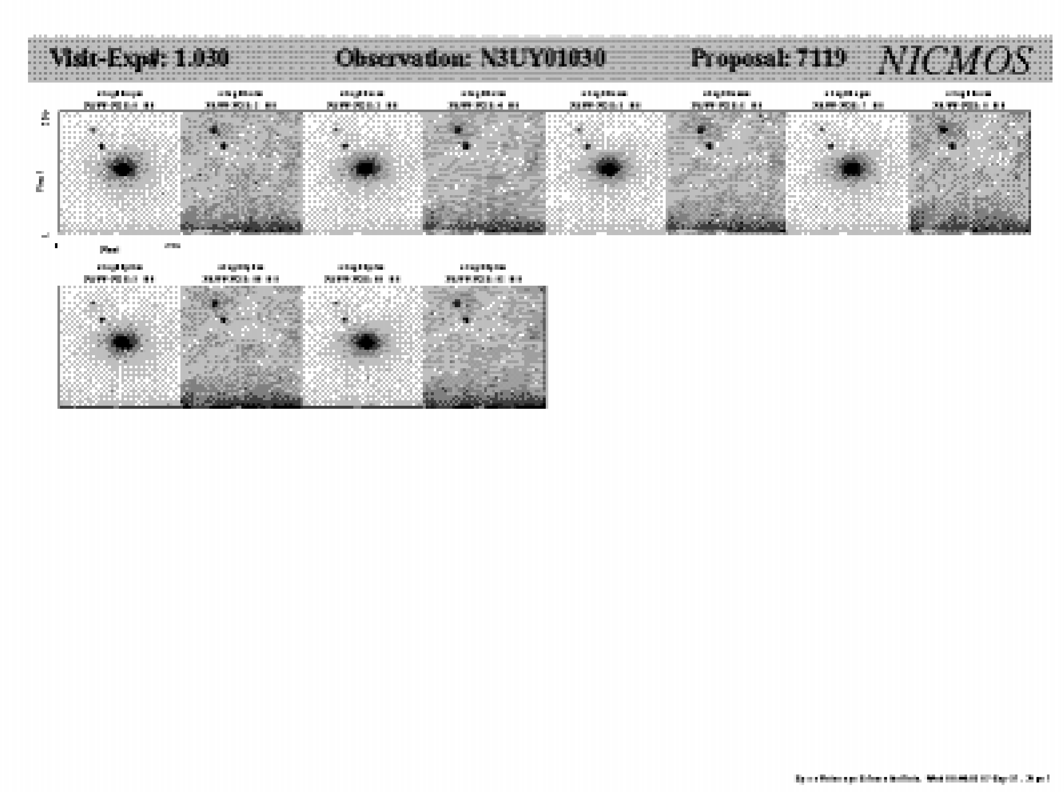


Figure 15.7: Calibrated Science Image

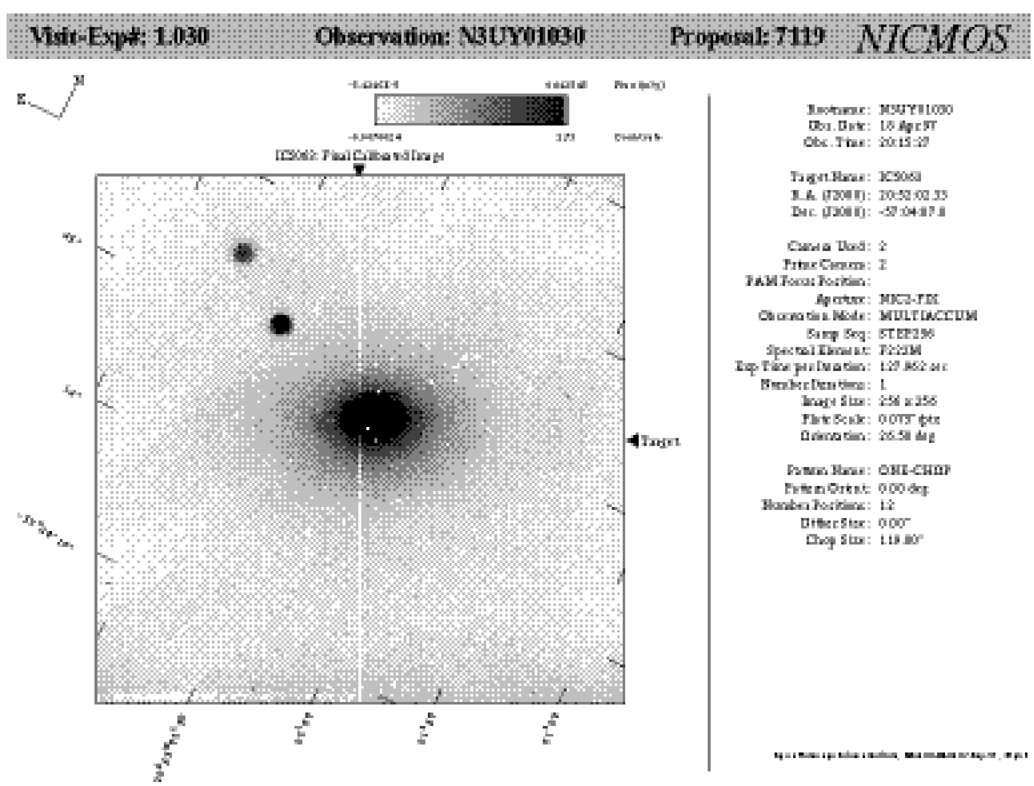


Figure 15.8: On-Target/Background Individual Images

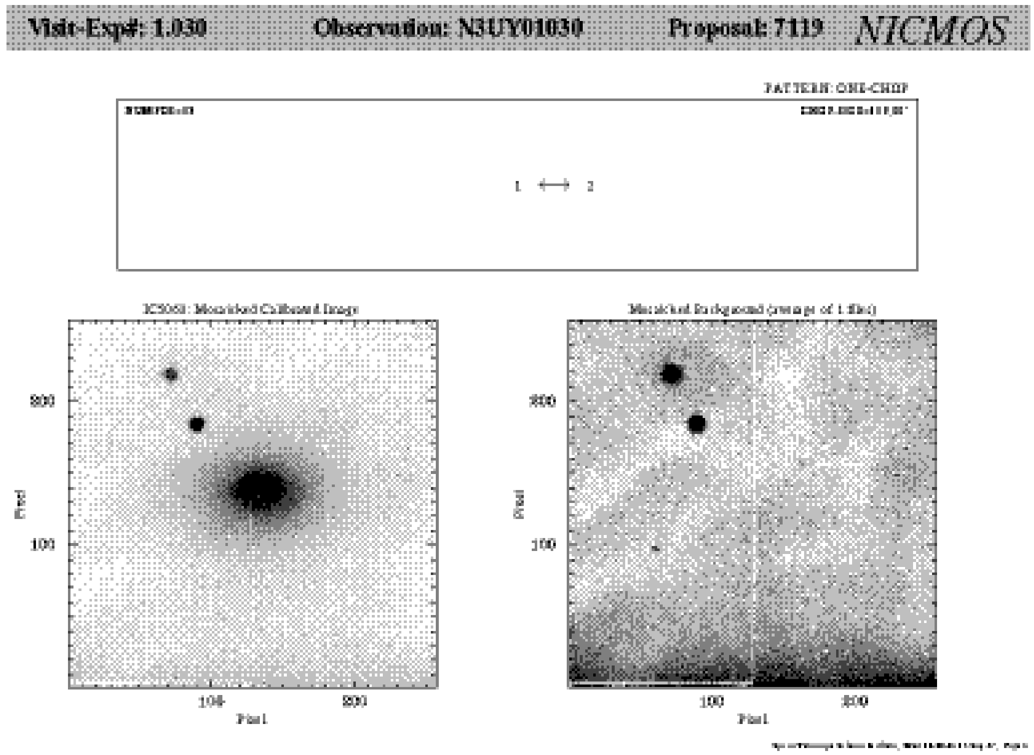
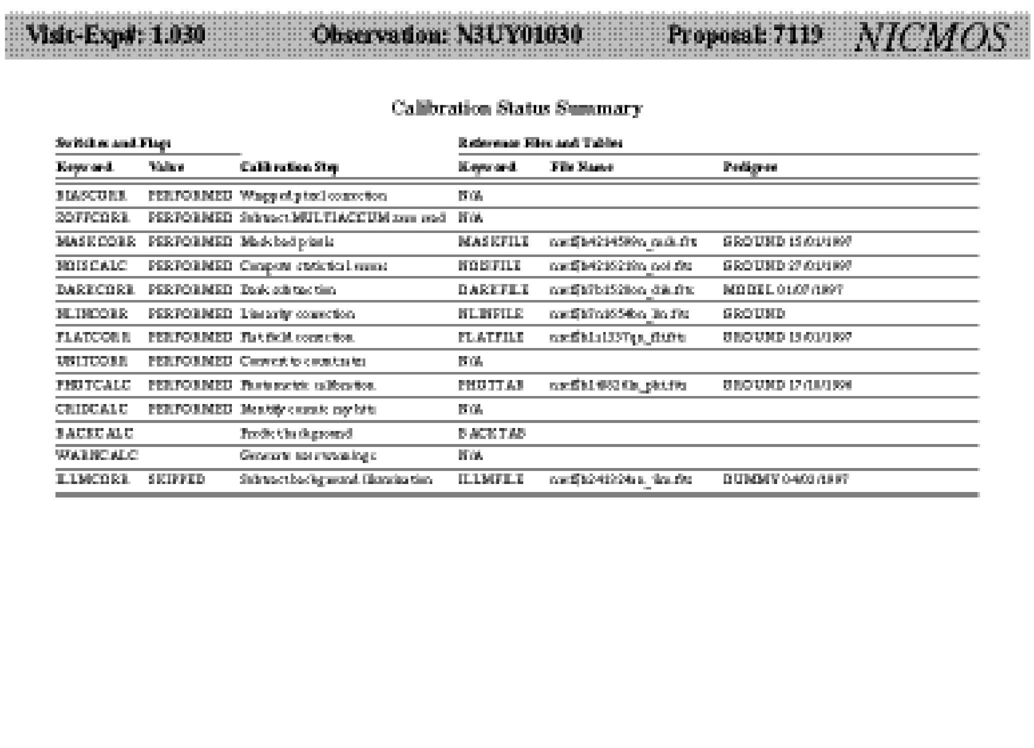


Figure 15.9: Calibration Status Summary



Visit-Exp#: 1.030 Observation: N3UY01030 Proposal: 7119 NICMOS

Calibration Status Summary

Switches and Flags			Reference Files and Tables		
Keyword	Value	Calibration Step	Keyword	File Name	Pedigree
BIASCORR	PERFORMED	Wrapped pixel correction	N/A		
ZOFFCORR	PERFORMED	Subtract MULTIACCUM zero read	N/A		
MASKCORR	PERFORMED	Mask bad pixels	MASKFILE	nref$h4214598n_mask.fits	GROUND 15/01/1997
NOISCALC	PERFORMED	Compute statistical errors	NOISFILE	nref$h4216521tn_noi.fits	GROUND 27/01/1997
DARKCORR	PERFORMED	Dark subtraction	DARKFILE	nref$h7b1528on_drk.fits	MODEL 01/07/1997
NLINCORR	PERFORMED	Linearity correction	NLINFILE	nref$h7a16546n_lin.fits	GROUND
FLATCORR	PERFORMED	Flat field correction	FLATFILE	nref$h1a1337qn_flt.fits	GROUND 15/01/1997
UNITCORR	PERFORMED	Convert to countrates	N/A		
PHOTCALC	PERFORMED	Photometric calibration	PHOTTAB	nref$[illegible]_pht.fits	GROUND 17/10/1996
CRIDCALC	PERFORMED	Identify cosmic ray hits	N/A		
BACKCALC		Predict background	BACKTAB		
WARNCALC		Generate user warnings	N/A		
ILLMCORR	SKIPPED	Subtract background illumination	ILLMFILE	nref$h2410224n_ilm.fits	DUMMY 04/03/1997

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