ALICE DATA RELEASE: A REVALUATION OF HST-NICMOS CORONAGRAPHIC IMAGES

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Document Version 1

ABSTRACT

The Hubble Space Telescope (HST) NICMOS instrument has been used from 1997 to 2008 to perform coronagraphic observations of about 400 targets. Most of them were part of surveys looking for substellar companions or resolved circumstellar disks to young nearby stars, making the NICMOS coronagraphic archive a valuable database for exoplanets and disks studies. As part of the Archival Legacy Investigations of Circumstellar Environments (ALICE) program, we have consistently re-processed a large fraction of the NICMOS coronagrahic archive using advanced PSF subtraction methods. We present here the high-level science products of these re-analyzed data, which we delivered back to the community through the Mikulski Archive for Space Telescopes (MAST) archive. We also present the first version of the HCI-FITS format (for High-Contrast Imaging FITS format), which we developed as a standard format for data exchange of imaging reduced science products. These re-analyzed product are openly available for population statistics studies, characterization of specific targets, or detected point source identification.

Keywords: methods: data analysis — techniques: image processing — catalogs

1. INTRODUCTION

The development of advanced post-processing techniques based on the use of a library of instrument point spread function (PSF) images to create a synthetic PSF that optimally subtracts the residual starlight from a target image has enabled significant progress in the direct imaging of extra-solar planets over the last decade. Previous PSF subtraction techniques, mainly consisting in one-to-one image subtraction either of a reference star or of an image of the science target itself with a different orientation of the field of view, were efficient at imaging debris disks in scattered light around young nearby stars, but mostly failed at reaching the contrast limits needed to detect faint exoplanets. Advanced post-processing algorithms based on the linear combination of PSF images (LOCI and its variants) or on Principal Component Analysis (PCA) can reach deeper contrast limits with ground-based observations, with PSF diversity obtained with the Angular Differential Imaging (ADI) or the Spectral Differential Imaging (SDI) observing strategies. They are also more efficient when using PSFs from many different stars (Reference star Differential Imaging, RDI), even when acquired with first-generation instruments on the Hubble Space Telescope (HST) and separated by large time intervals. This has been demonstrated by the re-discovery of HR 8799 planets (b,c, and d) in archival NICMOS data from 1998 (Lafrenière et al. 2009; Soummer et al. 2011).

These results made the community realize that a fraction of all previous results obtained with first-generation coronagraphic instruments might be outdated by the development of these advanced post-processing techniques.

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We started the ALICE project (Archival Legacy Investigations of Circumstellar Environments) with the goal to consistently reprocess the NICMOS coronagraphic archive with advanced post-processing methods. NICMOS was operating on-board HST for about 8 years between 1997 and 2008, and its mid-resolution channel NIC2 (pixel size 0.076") was equipped with a 0.3"-radius coronagraphic mask and a Lyot stop. About 400 stars were observed during the instrument operations, mostly in the two wide-band filters F110W and F160W as part of surveys looking for debris disks and planets around nearby stars. The ALICE pipeline assembles and aligns large PSF libraries from consistent subsamples of this database (acquired with identical filters and in the same NICMOS era), that are used to process each individual targets with the KLIP algorithm (Soummer et al. 2012a). This project has revealed new images of 9 debris disks previously undetected from the NICMOS data, among which 8 had never before been imaged in scattered light (Soummer et al. 2014; Choquet et al. 2016). In addition, we found a total of 452 point sources uncovered in the data (Choquet et al. 2015).

This data was processed and analyzed with the ALICE pipeline. A full description of the ALICE pipeline and its criteria for finding candidates can be found in (Choquet et al. 2014).

2. RELEASED DATASETS

2.1. *ALICE inputs*

The input data for the ALICE program come from the Legacy Archive PSF Library and Circumstellar Environments (LAPLACE) program[4] (HST program AR-11279, PI: G. Schneider; Schneider et al. 2010). This program delivered a homogeneous re-calibration of a large fraction of the raw NICMOS coronagraphic archive, optimized for imaging at separations close to the coronagraphic-mask inner working angle (radius of $0\farcs3$) using PSF subtrac-

[4] https://archive.stsci.edu/prepds/laplace

tion techniques. This re-calibration was performed using contemporary flat-field frames optimally matched to the location of the coronagraphic mask (as opposed to epochal flats), and using an improved bad-pixel correction. During the second era of NCIMOS operations (after replacement of its cooling system), dark calibration observations were obtained with less frequency than during the first era, and the LAPLACE program delivered two versions of re-calibrated images: one using observation-optimized dark frames when available, and one using synthetic model dark frames.

For consistency, the ALICE program re-analyzed all the non-polarimetric data from the LAPLACE program that were calibrated with contemporary flats for NICMOS Era 1[5], and with contemporary flats and observed dark frames for NICMOS Era 2[6], which represent 72% of the non-polarimetric NICMOS archival datasets. Furthermore, we also re-analyzed a few selected datasets that were not re-calibrated by LAPLACE program (from HST programs 7248, 10897, and 11155).

2.2. *ALICE outputs*

The outputs of the ALICE program – and delivered data described through this document – all come from the input data detailed above. Non-reprocessed data may have been so for three reasons: (1) not part of the LAPLACE inputs described above, (2) bad acquisition images not centered on the coronagraphic mask, (3) sub-pixel alignment failure within a PSF library. The complete list of NICMOS coronagraphic programs (non-polarimetric data) is detailed in Table 8. The table also reports the number of targets per HST program that have been partly or entirely re-processed as part of the ALICE program. The complete list of re-processed images for each HST program, target, and filter set can be accessed on the MAST archive. Details on how these data were re-analysed (field-of-view, alignment procedure, PSF subtraction and analysis methods) are described in Choquet et al. (2014).

NICMOS data from 401 targets were used as input for the ALICE program, some observed in multiple HST programs (451 different target observations) and/or with multiple filters (590 different datasets). The number of input images that were re-analyzed by the ALICE program amounts to a total of 4879 images (83% of them were acquired with the F110W or F160W filters). Reprocessed data are delivered for 494 datasets out of the 590 input ones (56 of them were entirely composed of bad acquisition images, 40 of them could not be properly aligned within a PSF library). The majority of these datasets were acquired with the F110W or F160W filters (408 datasets). This amounts to a total of 3955 reprocessed images (86% in F110W or F160W), delivered back to the community.

2.3. *Note on the reprocessing efficiency*

The different NICMOS filters were unequally used during its coronagraphic operations. While the F110W and F160W were commonly used both for surveys and for specific-object characterizations, the other wide-band filters and all the medium-band and narrow-band filters were exclusively used for characterization of known circumstellar objects.

Table 1
ALICE reference PSF Libraries

Filter	Era 1 # images[a]	# PSF[b]	Era 2 # images[a]	# PSF[b]
F110W	144	54	1854	809
F160W	824	360	1248	655
F165M	42	16	49	19
F171M	36	16	66	6
F180M	98	46	69	14
F187N	5	0	9	6
F187W	3	0	0	0
F190N	5	0	18	0
F204M	4	4	74	19
F205W	11	0	0	0
F207M	174	76	0	0
F212N	28	10	0	0
F215N	28	10	18	0
F222M	15	0	52	7
F237M	5	5	0	0

[a] Number of images used as input of the ALICE program.
[b] Number of images used as references for PSF subtraction.

The PSF libraries assembled by the ALICE pipeline are thus much larger in the F110W and F160W filters than in the other filters. Furthermore, as ALICE's reprocessing is based on Multi-Reference star Differential Imaging (MRDI) and excludes images with detected circumstellar material from the reference PSF libraries (except in "planet mode", which includes images of the science target acquired in a different orientation of the spacecraft, when available, Choquet et al. 2014), the medium- and narrow-band filter data were reprocessed with PSF libraries of very small sizes (see Table 1). ALICE's reprocessing for these datasets is not expected to much improve upon classical PSF subtraction techniques. The real added value from the ALICE program mostly concerns NICMOS data acquired with the F110W and F160W filters.

3. RELEASED PRODUCTS

For each dataset re-processed by the ALICE program, we provide three kind of outputs: 1) a high-level science FITS file, gathering all the high-contrast imaging metrics in a standard format for the combined data at the target level. This is the main output product of the ALICE program and should be used for detection purposes. 2) A folder with FITS files for each reprocessed image of the dataset, gathering the material needed to perform forward modeling of an astrophysical signal. These should be used for characterisation of signals detected in the main high-level science product. 3) A folder with preview PDF files of the main outputs of the dataset.

3.1. *Definition of dataset*

We refer to a *dataset* as the set of images acquired with the same filter element, as part of the same HST program, and under the same target identifier (HST `TARGNAME` keyword). Datasets are thus composed of an homogeneous group of images as designed by the PI of the program. A dataset may combine images acquired

[5] https://archive.stsci.edu/missions/hlsp/laplace/dd1/LAPL/NICMOS-LAPL-DD1/LAPL_DATA/contemp_flats/repaired/*_clc_*.fits
[6] https://archive.stsci.edu/missions/hlsp/laplace/dd2/LAPL/NICMOS-LAPL-DD2/LAPL_DATA_DD2/comtemp_flats-DD2/*_o_clc_*.fits

Table 2
Structure of the HCI-FITS files

Label	Type	Dimensions	Description
DATA_INFORMATION	BINTABLE	$N_{im} \times 12$	Characteristics of each image
REDUCED_DATA	IMAGE	$N_{im} \times N_x \times N_y$	Reduced data products
SNR_MAP	IMAGE	$N_{im} \times N_x \times N_y$	SNR maps
SENSITIVITY_MAP	IMAGE	$N_{im} \times N_x \times N_y$	2D detection limits
DETECTION_LIMIT	BINTABLE	$N_{im} \times 2 \times N_\rho$	Radial detection limits
SOURCE_DETECTION [optional]	BINTABLE	$N_{source} \times 20 \times N_{im}$	Detected point sources characteristics

with different spacecraft orientations, with different exposure times, and different epochs. We assume that any potential astrophysical source remains unchanged in all the images of a dataset when combining them in the main ALICE science FITS file.

A few targets have several datasets with the same filter element, in different HST programs (despite HST policies not to re-observe a target in the same mode), or within the same program (target re-observed after a failed acquisition).

3.2. *The HCI-FITS file*

The main science output of the ALICE program is a multi-extension FITS file (Pence et al. 2010) that gathers all the high-level information about the re-processed dataset.

In an effort to facilitate high-level data exchange and to make exoplanet population statistical analyses easy, we developed a specific format for these data, and we propose that it becomes a standard for reduced products of high-contrast imaging data. We describe below the main choices we made for the Version 1 of this format, a provide a detailed description of its content. We hereafter call this format the HCI-FITS file, for High-Contrast Imaging FITS file. It is inspired from the OI-FITS format, which is the standard for calibrated data exchange from optical interferometers (Pauls et al. 2004, 2005).

A single FITS file— To enable high-level science analyses of high-contrast imaging data, several products are mandatory (e.g. the reduced image, detection limits, source detections). In order to prevent information loss when exchanging data, all the information must be gathered in a single file. The FITS file format offers the structure needed to achieve that, through the use of extensions. Extensions may contain different types of data, including images (`IMAGE` extension type) which is appropriate for the reduced images, sensitivity and SNR maps, and multi-dimension tables (`BINTABLE` extension type) which is appropriate for radial detection limits, characteristics of potentially detected sources, or general characteristics of the reduced products. Moreover, having a single file as reduced product makes databases more convenient to both implement and use.

A flexible standard— We developed HCI-FITS format to be compatible with any type of dataset, regardless of the instrument, or observing mode, or processing method used to obtain the final reduced products. It can be used for both ground-based of space observation, for coronagraphic and saturated imaging, for broadband imaging, integral-field spectroscopy, and polarimetric imaging. Depending on the observer/analyst's choice to present the reduced data, a HCI-FITS file may contain products for either a single image or an image cube. For example, this format supports all options between combining all reduced images from an IFS in one broadband image and keeping each reduced image separated in a spectral cube, while tracking specific image characteristics in all cases.

Structure of the HCI-FITS format— We identified five main products that are necessary for a high-level use of reduced HCI data: The reduced images, the SNR maps, the sensitivity maps (or "noise" maps), the radial detection limits (or "contrast curves"), and the characteristics of any detected point sources. The HCI-FITS format is thus composed of 6 extensions, one for each of these products, plus one which tracks the main characteristics of each image provided in the file. The extensions may appear in any order in the FITS file, but must have mandatory `EXTNAME` values to enable compatibility between files. The structure of the HCI-FIST format is provided in Table 2. The SOURCE_DETECTION extension is optional but must respect the specified format if present. This structure is not exclusive and may include additional data in other extensions (e.g. intermediate products such as the instrument PSF image). Reading software or codes should not presume the presence of such additional extensions.

The mandatory products enable analyses such as detection limit comparisons and astrophysical signal comparisons, but does not enable precise characterization of unreported signal. Such characterisation requires a forward modeling process (Lagrange et al. 2010; Milli et al. 2012; Soummer et al. 2012b; Pueyo 2016) for which intermediate products are needed (instrument PSF image, raw data, eigen-images of the PSF library). Such detailed characterization is out of the scope of the HCI-FITS format use.

The DATA_INFORMATION extension is critical to identify the characteristics of each reduced image in the file. It is the extension that make this format compatible with any collection of high-contrast images. It is a `BINTABLE` extension that must be composed of 12 fields that track the orientation, polarisation state, epoch, and spectral information of the images. It must have as many rows as images provided in the file, and if several images are provided, the order must be the same in the DATA_INFORMATION table as in the image cubes. We present in Table 3 the structure of this table.

The DETECTION_LIMIT extension is also `BINTABLE` and reports the radial point source detection limits for each image present in the file. It must be composed of two mandatory fields reporting the separation from the star and the corresponding detection limit. The header

Table 3
DATA_INFORMATION extension

Label	Type[a]	Description
Image_Number	I	Index of the image in the cube
Orientation	D	Sky-orientation of the image vertical axis
Combined_rotation_angle	D	Parallactic angle combined in the image
Number_of_Exposures	I	Number of exposures combined in the image
Exposure_Time	D	Total exposure time combined in the image
Observation_Start	D	Mod. Julian Date at the start of the exposure
Observation_End	D	Mod. Julian Date at the end of the exposure
UT_Midpoint_Date_of_Observation	A	UT date at the image mid-point
UT_Midpoint_Time_of_Observation	A	UT time at the image mid-point
Wavelength	D	Effective wavelength of the image
Bandwidth	D	Effective bandwidth of the image
Polarization	A	Polarization state of the image

[a] L = logical (8 bit), I = integer (16 bit), E = real (32 bit), D = double (64 bit), A = character string (160 bit)

Table 4
DETECTION_LIMIT extension

Label	Type[a]	Description
Radius	D (N_{im})	Radial separation from the star
Detection_Limit	D (N_{im})	Point source detection limit

[a] L = logical (8 bit), I = integer (16 bit), E = real (32 bit), D = double (64 bit), A = character string (160 bit)

of this extension must indicate the confidence level of the detection limit using the mandatory `NSIGMA` keyword. The structure of this extension is presented in Table 4.

The third optional `BINTABLE` extension reports the characteristics of the point sources detected in the data. For each source it must indicates its astrometry, photometry, and SNR in each image provided in the file.

Specifics of the ALICE HCI-FITS files— For the specific case of ALICE, the HCI-FITS files always contain the reduced data for each combined-roll and for the combination of all images, so the ALICE products present cubes of $N_{im} = N_{roll} + 1$, where N_{roll} is the number of spacecraft orientation used to observe the target.

As the ALICE data were reprocessed using the PCA-based KLIP algorithm using large PSF libraries, we provide in the REDUCED_DATA header some specific keywords describing the reduction parameters we used for the dataset (See Table 5).

The images in the SENSITIVITY_MAP extension are computed from the temporal variance of the residual speckle field through the PSF library. To do so, we reprocessed the reference images from the PSF library with the same parameters as the science images, and rotated-combined groups of them with the same numbers, weights, and angles as for the science combined images. We then compute covariance matrix of these combined reference images, convolve it with a $1\lambda/D$ aperture, and compute its square-root to estimate the temporal speckle noise map per resolution element. The images in the SNR_MAP extension are computed by convolving the reduced images from the REDUCED_DATA extension with the same aperture, and dividing it with the images from the SENSITIVITY_MAP. The tables provided in the DETECTION_LIMIT extension are the radial averages of the images in the SENSITIVITY_MAP extension, computed in 2-pixel wide annuli. They are

Table 5
ALICE keywords in the HCI-FITS file extension headers

Keyword	Type[a]	Description
	REDUCED_DATA	
EXTNAME	A	Extension name
BUNIT	A	Brightness units
REDALGO	A	Reduction algorithm
REDSTRAT[b]	A	Strategy to build the PSF library
EXCLANG	E	Exclusion angle for ADI strategy (deg)
TKL	I	Num. of subtracted KL-modes w. KLIP
NPSFLIBR	I	Number of images in the PSF library
	SNR_MAP	
EXTNAME	A	Extension name
BUNIT	A	Brightness units
NOISEMET	A	Method used for the detection limit
APERTRAD	D	Aperture radius (pix)
SPATSCAL	A	Spatial unit
	SENSITIVITY_MAP	
EXTNAME	A	Extension name
BUNIT	A	Brightness units
NOISEMET	A	Method used for the detection limit
NSIGMA	I	Detection limit confidence level (sigma)
APERTRAD	D	Aperture radius (pix)
SPATSCAL	A	Spatial unit
	DETECTION_LIMIT	
EXTNAME	A	Extension name
NOISEMET	A	Method used for the detection limit
NSIGMA	I	Detection limit confidence level (sigma)
APERTRAD	D	Aperture radius (pix)
SPATSCAL	A	Spatial unit

[a] L = logical (8 bit), I = integer (16 bit), E = real (32 bit), D = double (64 bit), A = character string (160 bit)
[b] Two values may be found in ALICE-generated HCI-FITS files: "RDI" when all images of the target have been excluded from the PSF library, or "ADI+RDI" when the the PSF library also includes images of the target acquired at a complementary orientation of the spacecraft, respecting the EXCLANG exclusion angle.

normalized by the stellar flux converted to count/s (keyword `STARFLUX` in the primary header) to give a measure of the point source detection limit in terms of contrast to the star. We provide in the header of these three extensions keywords describing the parameters used to compute these metrics (see Table 5).

The characteristics of the detected sources in extension SOURCE_DETECTION are computed from a match-filter process with a synthetic NICMOS PSF, computed for the corresponding filter element with the TinyTIM software package (Krist et al. 2011). The source astrometry is determined with the position that maximizes

Table 6
SOURCE_DETECTION extension

Label	Type[a]	Description
Candidate	I	Index of the detected source
SNR	D (N_{im})	SNR of the source
dRA	D (N_{im})	Relative R.A. from the star
err_dRA	D (N_{im})	Uncertainty on the dRA
dDEC	D (N_{im})	Relative Declination from the star
err_dDEC	D (N_{im})	Uncertainty on the dDEC
Sep	D (N_{im})	Separation from the star
err_Sep	D (N_{im})	Uncertainty on the separation
PA	D (N_{im})	Position Angle (east of north)
err_PA	D (N_{im})	Uncertainty on the PA
Flux_cs	D (N_{im})	Photometry in count/s
err_Flux_cs	D (N_{im})	Uncertainty on Flux_cs
Flux_mag	D (N_{im})	Photometry in magnitude
err_Flux_mag	D (N_{im})	Uncertainty on Flux_mag
Flux_Jy	D (N_{im})	Photometry in Jy
err_Flux_Jy	D (N_{im})	Uncertainty on Flux_Jy
Flux_erg	D (N_{im})	Photometry in erg/cm2/s/A
err_Flux_erg	D (N_{im})	Uncertainty on Flux_erg
Contrast	D (N_{im})	Contrast from the star
err_Contrast	D (N_{im})	Uncertainty on the Contrast

[a] L = logical (8 bit), I = integer (16 bit), E = real (32 bit), D = double (64 bit), A = character string (160 bit)

the cross-correlation between the reduced images and the normalized synthetic PSF. The photometry of the source is retrieved with the maximum value of the cross-correlation, subtracted from the local background level, corrected from post-processing over-subtraction with analytical forward modeling (Soummer et al. 2012b), and corrected from correlation losses between the synthetic and the real PSF by using photometric calibration data acquired on calibration white dwarfs. The contrast is computed by normalizing the photometry by the stellar flux converted in count/s (keyword `STARFLUX` in the primary header). Table 6 provides a description of the SOURCE_DETECTION extension.

The primary header of the ALICE HCI-FITS files is described in Table 9 of Appendix B. It gathers a selection of keywords useful at a science level, and come from the raw HST FITS header, LAPLACE program added keywords, and from our work.

3.3. *Data image products*

In addition to the main HCI-FITS file which provides science metrics for the combined products of a dataset, we also provide a "Products" folder gathering intermediate products for each image in the dataset. These files are complementary to the combined HCI-FITS products. While the purpose of main HCI-FITS file is to provide high-level science metrics to quantify the detection limits and detected sources in the dataset, the data image products are useful for diagnostic and astrophysical signal forward modeling.

For each data image, we provide a multi-extension FITS file gathering the products described in Table 7. Unlike the main HCI-FITS file, these products are specific to ALICE and their format is not compatible with all type of high-contrast science products.

The REDUCED_IMAGE extension provides the reduced image computed by the ALICE pipeline using the KLIP algorithm. The image is not derotated and is presented with the same field orientation as the raw NICMOS image. The star is centered on pixel (41, 41) with pixel (1,1) at the bottom-left of the image. The header of the extension provides detailed information on the reduction parameters used to compute the image (see Table 10).

The RAW_IMAGE extension provides the raw NICMOS image calibrated by the LAPLACE program. The LAPLACE image has been cropped to a smaller field of view (80 × 80 pixels) and the star centered on pixel (41, 41). The header of the extension lists the keywords provided in the raw HST file, as well as the position of the star center in the full NICMOS field of view (See Table 10).

The REDUCTION_ZONE extension provides a binary image of the reduction zone (pixels with 0 value were excluded from the reduction). In most case the reduction zone correspond to the full image except for a central mask of a few pixels radius. The parameters used to define the reduction zone are provided in the extension header (see Table 10).

The EIGEN_IMAGES extension provides the cube of the first principal components of the PSF library used for the PSF subtraction, truncated at the number of components actually used to reduce the data. This cube can be used to analytically compute the impact of the PSF subtraction process on an astrophysical source using forward modeling.

The REF_FILE_NAMES extension provides a table with the file-name of the NICMOS images composing the PSF library used to reduce the image. The table also provides the position of the star center in these reference images in the full NICMOS field of view, around which they have been aligned and cropped to 80 × 80 pixels.

3.4. *Preview Folder*

Finally, we also deliver for each dataset a "Preview" folder that contains PDF and CSV files of the content of each extension of the main HCI-FITS file. The PSF files show images of each frame of the REDUCED_DATA extension (one version with the point source detections circled and one version without), of the first frame (North-combined frame) of the SNR_MAP extension and of the DETECTION_LIMIT extension. The CSV files show all the data contained in each BINTABLE extension (DATA_INFORMATION, DETECTION_LIMIT, SOURCE_DETECTION).

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Table 7
Structure of the exposure-level Science Product FITS files

Label	Type	Dimensions	Description
REDUCED_IMAGE	IMAGE	$N_x \times N_y$	Reduced data image
RAW_IMAGE	IMAGE	$N_x \times N_y$	Calibrated raw data image
REDUCTION_ZONE	IMAGE	$N_x \times N_y$	Reduction zone
EIGEN_IMAGES	IMAGE	$N_x \times N_y \times N_{kl}$	Cube of eigen-images used for KLIP subtraction
REF_FILE_NAMES	BINTABLE	$N_{ref} \times 5$	List of the reference image filenames

Facilities: HST-NICMOS.

APPENDIX

A. THE NICMOS CORONAGRAPHIC ARCHIVE

We report in Table 8 the comprehensive list of HST programs that used the coronagraphic mode of the NICMOS instrument for non-polarimetric observations. We also report the number of target observed per program, as well as the number of these which have been recalibrated as part of the LAPLACE program, and reanalyzed as part of the ALICE program.

B. ALICE HCI-FITS FILE PRIMARY HEADER

In the primary header of the HCI-FITS file, we selected keywords from the raw HST data keywords, and calibrated LAPLACE keywords that may be useful for a high-level science analysis of these data. We also added useful keywords specific to our work. The list of keyword present on the ALICE HCI-FITS file is presented in Table 9.

C. DATA IMAGE FITS FILE HEADERS

In Table we describe the header of the Data image FITS file provided in the "Products" folder. Most of the keywords in the primary header come from the raw NICMOS FITS file primary header, and we only describe here the keywords that we modified or added. Similarly, the RAW_IMAGE extension header corresponds to the SCI extension header in the raw NICMOS file, and we describe her the added keywords.

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Table 8
Non-polarimetric NICMOS coronagraphic programs

Prog.	Cy.	Type	LAPL[a]	ALICE[b]	PI	Title
				ERA 1		
7038	7	SM2/NIC	0/3	0/3	G. Schneider	NICMOS Target Acquisition Test
7052	7	SM2/NIC	0/1	0/1	G. Schneider	NICMOS Coronographic Performance Verification
7157	7	SM2/NIC	0/1	0/1	G. Schneider	NICMOS Optimum Coronagraphic Focus Determinaton
7179	7	GTO/NIC	1/1	0/1	B. Smith	Search for Volcanic Activity on Encleadus
7220	7	GTO/NIC	4/5	4/5	R. Weymann	Imaging of Quasar Host Galaxies
7221	7	GTO/NIC	3/3	0/3	J. Hill	Imaging of Quasar Absorber Systems
7226	7	GTO/NIC	44/44	39/44	E. Becklin	Search for Massive Jupiters
7227	7	GTO/NIC	29/29	28/29	G. Schneider	A Search for Low Mass/Sub-Luminous Companions to M-Stars
7233	7	GTO/NIC	18/23	17/23	B. Smith	Dust Disks around Main Sequence Stars
7248	7	GTO/NIC	0/1	1/1	B. Smith	Spectroscopy and Polarimetry of the Beta Pictoris
7329	7	SNAP	20/20	0/20	M. Malkan	The Nature of the Damped LyAlpha Absorbers – A New Study of Young Galaxies
7418	7	GO	3/3	3/3	D. Padgett	NICMOS Imaging of Young Stellar Object Circumstellar Nebulosity
7441	7	GO	0/6	0/6	M. Brown	A Search for Zodiacal Dust around Bright Nearby Stars
7808	7	ENG/NIC	1/1	1/1	G. Schneider	NICMOS Coronagraphic Hole Location Test
7828	7	GO	0/1	0/1	J. Hollis	Detection of the Infrared Jet in the R Aquarii Binary System
7829	7	GO	6/6	5/6	C. Johns-Krull	Mapping H_2 Emission Around T Tauri Stars
7834	7	GO	7/7	6/7	R. Rebolo	A Search for Giant Planets Around Very Young Nearby Late-type Dwarfs
7835	7	GO	8/14	7/14	E. Rosenthal	A Search for Superplanets Embedded in Beta Pic&Vega-like Circumstellar Disks
7857	7	GO	7/8	7/8	A.-M. Lagrange	Investigating the missing link between disks around Pre Main Sequence and Main Sequence stars
7897	7	SNAP	20/20	17/20	M. Clampin	Probing planetary formation around main- sequence stars: A snapshot survey
7924	7	ENG/NIC	1/1	1/1	G. Schneider	NICMOS Coronagraphic Hole Location Re-Test
8079	7	CAL/NIC	2/2	2/2	A. Schultz	Mapping the Light Scatter in the NICMOS Coronagraphic Hole {PSF Recovery Orbits}
				ERA 2		
8979	10	SM3/NIC	1/1	1/1	G. Schneider	NICMOS Optimum Coronagraphic Focus Determinaton
8983	10	SM3/NIC	2/2	2/2	G. Schneider	NICMOS Mode-2 Target Acquisition Test
8984	10	SM3/NIC	1/1	1/1	G. Schneider	NICMOS Coronagraphic Performance Assessment
9693	11	CAL/NIC	2/3	1/3	G. Schneider	NICMOS Coronagraphic Performance Assessment
9834	12	GO	7/7	6/7	J. Debes	Finding Planets in the Stellar Graveyard: A Faint Companion Search of White Dwarfs with NICMOS
9845	12	GO/DD	1/1	1/1	M. Liu	NICMOS Confirmation of a Young Planetary-Mass Companion
10147	13	GO	0/2	0/2	M. Endl	Detecting the elusive low mass companion around epsilon Indi
10167	13	GO	8/8	7/8	A. Weinberger	Imaging of Ices in Circumstellar Disks
10176	13	GO	111/111	108/111	I. Song	Coronagraphic Survey for Giant Planets Around Nearby Young Stars
10177	13	GO	56/56	54/56	G. Schneider	Solar Systems In Formation: A NICMOS Coronagraphic Survey of Protoplanetary and Debris Disks
10228	13	GO	2/2	2/2	P. Kalas	Multi-color HST imaging of the GJ 803 debris disk
10244	13	GO	2/2	2/2	M. Wyatt	Coronagraphic imaging of Eta Corvus: a newly discovered debris disk at 18 pc
10448	13	GO	1/1	1/1	A. Schultz	NICMOS 2-gyro Coronagraphic Performance Assessment
10464	14	ENG/NIC	1/1	1/1	A. Schultz	NICMOS 2-gyro Coronagraphic Performance Assessment
10487	14	GO	11/11	9/11	D. Ardila	A Search for Debris Disks in the Coeval Beta Pictoris Moving Group
10527	14	GO	23/23	22/23	D. Hines	Imaging Scattered Light from Debris Disks Discovered by the Spitzer Space Telescope Around 20 Sun-like Stars
10540	14	GO	10/10	9/10	A. Weinberger	Imaging Nearby Dusty Disks
10560	14	GO	1/1	1/1	J. Debes	Confirming Planetary Candidates in the Stellar Graveyard with NICMOS
10599	14	GO	4/4	4/4	P. Kalas	Multi-color imaging of two 1 Gyr old debris disks within 20 pc of the Sun: Astrophysical mirrors of our Kuiper Belt
10847	15	GO	0/1	0/1	D. Hines	Coronagraphic Polarimetry of HST-Resolved Debris Disks
10849	15	GO	23/23	23/23	S. Metchev	Imaging Scattered Light from Debris Disks Discovered by the Spitzer Space Telescope around 21 Sun-like Stars
10852	15	GO	3/6	2/6	G. Schneider	Coronagraphic Polarimetry with NICMOS: Dust grain evolution in T Tauri stars
10854	15	GO	0/6	0/6	K. Stapelfeldt	Coronagraphic Imaging of Bright New Spitzer Debris Disks II.
10857	15	GO	0/4	0/4	A. Weinberger	Are Organics Common in Outer Planetary Systems?
10896	15	GO	0/1	0/1	P. Kalas	An Efficient ACS Coronagraphic Survey for Debris Disks around Nearby Stars
10897	15	GO	0/2	1/2	J.-F. Lestrade	Coronagraphic imaging of the submillimeter debris disk of a 200Myr old M-dwarf
11148	16	GO	0/3	0/3	J. Debes	High Contrast Imaging of Dusty White Dwarfs
11155	16	GO	0/8	5/8	M. Perrin	Dust Grain Evolution in Herbig Ae Stars: NICMOS Coronagraphic Imaging and Polarimetry
11157	16	GO	0/26	0/26	J. Rhee	NICMOS Imaging Survey of Dusty Debris Around Nearby Stars Across the Stellar Mass Spectrum

[a] Number of targets in the program with at least one image re-calibrated by the LAPLACE program.
[b] Number of targets in the program with at least one image re-processed by the ALICE program.

Table 9
Primary header of the HCI-FITS file for ALICE products

Keyword	Type[a]	Description	Reference
File Information)			
FILETYPE	A	Type of data found in the file	This work
ORIGIN	A	FITS file originator	FITS standard
DATE	A	Date this file was written (yyy-mm-dd)	FITS standard
FITS File Structure			
DATATYPE	A	Data type	This work
NEXTEND	I	Number of extensions	This work
EXT[k]NAME	A	Name of Extension [k]	This work
EXT[k]TYPE	A	Type of Extension [k]	This work
Data Structure and Description			
FRAMFORM	A	Structure of each frame	This work
FRAMENUM	I	Number of frames in the dataset	This work
FRAME[k]	A	Description of frame [k]	This work
Program and Instrument Information			
TELESCOP	A	Telescope used to acquire data	HST keyword
INSTRUME	A	Identifier for instrument used to acquire data	HST keyword
PROPOSID	I	PEP proposal identifier	HST keyword
PR_INV_L	A	Last name of principal investigator	HST keyword
PR_INV_F	A	First name of principal investigator	HST keyword
CAMERA	I	Camera in use (1, 2, or 3)	HST keyword
FOCUS	A	In-focus camera for this observation	HST keyword
APERTURE	A	Aperture in use	HST keyword
FILTER	A	Filter wheel element in beam during observation	HST keyword
Target Information			
TARGNAME	A	Proposer's target name	HST keyword
ALTNAME[k][b]	A	Alternative name #[k] of the target	SIMBAD
EQUINOX	I	Equinox of celestial coord. system	HST keyword
RA_TARG	D	RA of target (deg) (J2000)	SIMBAD
DEC_TARG	D	Declination of target (deg) (J2000)	SIMBAD
SC_EMAJ	D	Sky coord. error ellipse major axis	SIMBAD
SC_EMIN	D	Sky coord. error ellipse minor axis	SIMBAD
SC_EPA	D	Sky coord. error ellipse position angle	SIMBAD
SC_BIB	A	Sky coord. bibliography code	SIMBAD
PARALLAX[c]	D	Parallax for target found (mas)	SIMBAD
PAR_ERR[c]	D	Parallax mean error	SIMBAD
PAR_BIB[c]	A	Parallax bibliography code	SIMBAD
PROPRA[c]	D	Proper motion (RA) of target (mas/yr)	SIMBAD
PROPDEC[c]	D	Proper motion (Dec) of target (mas/yr)	SIMBAD
PM_EMAJ[c]	D	Proper motion error ellipse major axis	SIMBAD
PM_EMIN[c]	D	Proper motion error ellipse minor axis	SIMBAD
PM_EPA[c]	D	Proper motion error ellipse position angle	SIMBAD
PM_BIB[c]	A	Proper motion bibliography code	SIMBAD
Information on other astrophysical sources			
CANDNUM	I	Number of point source detections	This work
DISKDET	L	Disk detected in this dataset	This work
Photometric Information			
ADCGAIN	D	Analog-digital conversion gain (electron/DN)	HST keyword
STARFLUX	D	Star flux computed from synphot (count/s)	This work
J_2MASS	D	Target J band magnitude (2MASS catalog)	LAPLACE keyword
JE_2MASS	D	2MASS J magnitude uncertainty	LAPLACE keyword
H_2MASS	D	Target H band magnitude (2MASS catalog)	LAPLACE keyword
HE_2MASS	D	2MASS H magnitude uncertainty	LAPLACE keyword
K_2MASS	D	Target K band magnitude (2MASS catalog)	LAPLACE keyword
KE_2MASS	D	2MASS K magnitude uncertainty	LAPLACE keyword
F160W_EF	L	K band SED flux density excess flag (Y,N)	LAPLACE keyword
F160W_JY	D	Filterband target flux density estimate (Jy)	LAPLACE keyword
PHOTMODE	A	LAPLACE keyword	
PHOTFLAM	D	Inverse sensitivity (ergs/cm**2/Angstrom/DN)	HST keyword
PHOTFNU	D	Inverse sensitivity (JY*sec/DN)	HST keyword
PHOTZPT	D	ST magnitude system zero point (mag)	HST keyword
PHOTPLAM	D	Pivot wavelength of the photmode (Angstrom)	HST keyword
PHOTBW	D	RMS bandwidth of the photmode (Angstrom)	HST keyword
Astrometric Information			
PIXSCALE	D	Pixel scale (arcsec)	

[a] L = logical (8 bit), I = integer (16 bit), E = real (32 bit), D = double (64 bit), A = character string (160 bit)
[b] For this dataset delivery, we only provide ALTNAME1 – the resolved SIMBAD name.
[c] When the information is available.

Table 10
Header of the Data image FITS file

Keyword	Type[a]	Description
Added/edited keywords in the Primary Header		
FILETYPE	A	Type of data found in data file
ORIGIN	A	FITS file originator
DATE	A	Date this file was written (yyyy-mm-dd)
DATATYPE	A	Data type
NEXTEND	I	Number of standard extensions
EXT[k]NAME	A	Name of Extension [k]
EXT[k]TYPE	A	Type of Extension [k]
FRAMFORM	A	Structure of the frame
ALTNAME1	A	Simbad name for target
PIXSCALX	E	Pixel scale in X direction
PIXSCALY	E	Pixel scale in Y direction
Keywords in the REDUCED_IMAGE extension header		
EXTNAME	A	Extension name
BUNIT	A	Brightness units
REDALGO	A	Reduction algorithm
REDSTRAT	A	Strategy to build the PSF library
EXCLANG	E	Exclusion angle for ADI-type strategy (deg)
TKL	I	Number of eigenimages used for KLIP-type subtraction
NPSFLIBR	I	Number of images in the PSF library
STARCENX	E	Star center X position in the full NICMOS frame (pix)
STARCENY	E	Star center Y position in the full NICMOS frame (pix)
Added/edited keywords in the RAW_IMAGE extension header		
EXTNAME	A	Extension name
STARCENX	E	Star center X position in the full NICMOS frame (pix)
STARCENY	E	Star center Y position in the full NICMOS frame (pix)
Keywords in the REDUCTION_ZONE extension header		
EXTNAME	A	Extension name
BUNIT	A	Brightness units
ZONECPA	I	Zone center PA to North (deg)
ZONEDPA	I	Zone delta PA (deg)
ZONERIN	I	Zone inner radius (pix)
ZONEROU	I	Zone outer radius (pix)
Keywords in the EIGEN_IMAGES extension header		
EXTNAME	A	Extension name
REDALGO	A	Reduction algorithm
REDSTRAT	A	Strategy to build the PSF library
EXCLANG	E	Exclusion angle for ADI-type strategy (deg)
NPSFLIBR	I	Number of images in the PSF library

[a] L = logical (8 bit), I = integer (16 bit), E = real (32 bit), D = double (64 bit), A = character string (160 bit)