

# NICMOS Focus Data Reduction and Analysis Using Phase Retrieval

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## ABSTRACT

*This ISR documents the process of measuring NICMOS focus and is written as a tutorial that can be used by anyone wishing to learn focus data reduction and analysis using the phase retrieval technique.*

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## 1. Introduction

Procedure: The focus procedure is a multi-step process involving a number of software tools (XSTARVIEW, packages of IDL routines, IRAF tasks), working under UNIX and VMS/VAX. The procedure steps include:

- retrieval focus monitoring data (fits files) from the Archive
- careful examination and selection of stars for phase retrieval in each of the focus sweep frames obtained in a given visit of the focus monitoring proposal
- reduction of the selected star sub-images
- performing phase retrieval
- retrieving and analyzing engineering data for breathing corrections
- finding optimum solutions for focus values
- generating plots and tables used for decision making with regard to NICMOS operation.

Software: The focus procedure is based on the method of phase retrieval implemented in the form of a package of IDL routines written by John Krist. Analysis of stellar images used for phase retrieval may require application of IRAF tasks (display, imexam, imedit, minmax, etc.). Analysis of the phase retrieval results is accomplished using IDL codes written by A. Suchkov and partly by G. Galas. The software setup used for this tutorial has been tailored to the particular structure of the focus monitoring proposal 7901.

Data: For training purposes, we will use the focus sweep data from the NICMOS focus monitoring proposal 7901 obtained on May 25, 1998.

Training directory: This directory contains all of the necessary files that one will need while learning how to measure NICMOS focus from focus sweep data using phase retrieval. The directory pathname is: **/data/vera6/gala\_galas/fcs\_training**.

## 2. Creating Directories, Setting IDL, and Retrieving Data

At the end of this section you will have created:

- subdirectories to work with
- software to do focus
- image data files (**fits** files) from which to derive the focus.

**2.1.** Create on your disk in **/your\_dir\_pathname/** the following subdirectories:

**phase-retriev-pro**

**template.in**

**idl\_tr\_pro**

**idl\_tr\_pro/tab-dir**

**fcs25may-fits**

**fcs25may-hhh**

The last two directories will be referred to as **fits** directory and **hhh** directory, respectively.

Copy the files from the respective subdirectories in the training directory to your subdirectories. At the end of this part you will have in your **fits** directory data **fits** files and a program file **list7901.pro**. In your **hhh** directory you will find a program file **wfit.pro**

If you wish to analyze any other visit of the focus monitoring program 7901, copy **list7901.pro** to the **fits** directory for that visit. Similarly, copy **wfit.pro** to the **hhh** directory. Before retrieving **fits** files from the archive, make sure that you have about 420 Mb of free space on the disk where the **fits** files are to be placed.

**2.2.** Set the IDL library pathnames in your **~/setenv** file using as a template the line in the file **IDL\_setenv** in the training directory. Basically, you need to add to the STScI standard IDL library directories three more subdirectories:

**/data/your\_subdirectory\_path/phase-retriev-pro**

**/data/ your\_subdirectory\_path/idl\_tr\_pro**

`/usr/local/lib/idl/local/jhuapl/idlusr.`

### 3. Running Phase Retrieval and Getting Breathing Corrections

At the end of this section you will have the results of phase retrieval as well as focus breathing corrections.

#### 3.1. Running `list7901.pro`

```
cd /your_dir_pathname/fcs17apr-fits
```

Bring up IDL in this directory and run `list7901.pro`

```
IDL>.run list7901
```

This program is a modified version of the original John Krist procedure `list.pro`. This program is interactive and it will ask you for the pathname of the `template.in` directory. You will also be asked to enter the pathnames of the `hhh` directory and the directory containing the phase retrieval package. Be sure to include trailing slash, `'/'`, to complete the pathname.

After the run is over, exit IDL.

You will find that `list7901.pro` has created `nicmos?.txt` files in the `fits` directory. In the `hhh` directory, it has written down the focus sweep data files in the STSDAS format. The program has also generated three program files, `do1.pro`, `do2.pro`, and `do3.pro`, which have been written to the `hhh` directory.

Examine the output. For camera 2, delete the last line (exposure time 1.51) for coronographic image in the files `nicmos2.txt` and `do2.pro`.

#### 3.2. Running `wfit.pro`

Examine the focus sweep images to decide which star is the best for phase-retrieval. Sometimes you may need to edit the frame image before you can use it for phase retrieval; use the IRAF tasks `display`, `imexam`, or `imedit` to do that.

In the `hhh` directory, enter IDL and run `wfit`:

```
IDL> wfit, nicmos=1
```

```
IDL> wfit, nicmos=2
```

```
IDL> wfit, nicmos=3
```

Follow directions in the IDL window as you run `wfit` (see quoted expressions below). For the image filename in the WFIT window, include `_cal`.

In the widget panel **Edit PSF**, define the extracted size of the box for the selected star. It is supposed to be an odd number, typically ranging from 15 pixels for well focused

images to 25 pixels for images far out of focus. Press the right button to exit intensity transformation widget “To exit, press the right button”.

Choose an isolated star which is bright enough to provide a good PSF.

“Place cursor over star and press the left button to select.” “Mark the corners of a box defining the background”. To do that, click the left button in an empty field at two points separated by about 20 to 30 pixels; this would mark upper corners of the box. Check the value of the background, it is supposed to be almost the same for the entire focus sweep.

Centering the image: “Place cursor over the center of star and press a button.”

Cut out a box of about 5 pixels in the corners of the PSF by pressing and dragging the middle button. This removes part of the diffraction spikes, which reduces errors in phase retrieval results. Exit the star window, exit the frame window, exit the widget. You have an option to re-edit image.

The main output from wfit is the **\*.dat** files in the **hhh** directory.

Check these files to make sure you used the same star (approximately the same *xy* coordinates). The same star across all the frames is implied by the focus centering procedure which reduces focus value to the center of the detector. Exit IDL.

The best way to quickly learn how to run **wfit.pro** is one-on-one tutoring. Email for help to: **galas@stsci.edu**.

### **3.3. Running do?.pro.**

In the **hhh** directory, at the UNIX prompt run:

```
idl dol.pro
```

The main output is the files **\*.xli** in the **hhh** directory (along with some other files written to the same directory).

### **3.4. Running show\_dat.pro**

Enter IDL and run:

```
IDL> show_dat
```

You’ll be asked to enter the **hhh** directory pathname. For the **hhh** training directory you will enter **/your\_directory\_path/fcs25may-hhh/**.

The procedure will concatenate the files **\*.xli** and **\*.dat** and will create IDL variables which will be stored in the files **zernike?.idl**.

### **3.5. Updating input files**

Update the file **d1.tab** in your **idl\_tr\_pro/tab-dir** directory and the file **f\_input.pro** in the **idl\_tr\_pro**.

To update **dl.tab** just follow the previous line of the table. Do the same for the **f\_input.pro**. The last line in the training **f\_input.pro** is:

```
18: begin &date_obs='April 17, 1998' &dt_o='17apr' &dd=472. &spl=[0,0,0] &end
```

You need to know *dd* - day since January 1, 1997. For *spl*, leave all numbers in brackets as zeros.

For example, for May 25, 1998, you will have to add the next line:

```
19: begin &date_obs='May 25, 1998' &dt_o='25may' &dd=510. &spl=[0,0,0] &end
```

This input will be used as you run **fpam\_plot.pro**, visit = visit.

Visit is the line number (in this case, 19) plus 1, i.e., 19+1=20.

### **3.6. Getting breathing corrections**

This subsection is based on instructions supplied by John Krist. You need a VMS account on STOSC to have an access to engineering data used for computing focus breathing corrections. Once you have the account, login to the VMS machine FABRY.

On your machine, enter:

```
xhost fabry
```

Then rlogin to FABRY:

Once in FABRY (STOSC), copy to the current directory the file **mkout.pro** from the **idl\_tr\_pro** directory, leaving the same filename (i.e., **mkout.pro**). Then enter:

```
set display/create/node=your_machine_name.stsci.edu/  
trans=tcPIP
```

Example:

```
STOSC> set display/create/node=gnomon.stsci.edu/  
trans=tcPIP
```

Bring up IDL. At the IDL prompt enter:

```
IDL>.run disk$claret:[elee]omsatplot
```

From “file” menu, choose “save set file”, then “breathing”.

Choose a start time 2 hours before the first observation, choose the end time 1 hour after the last exposure (use **nicmos?.txt** files to find out the start time and the end time of the observation). Then press RETURN twice.

From “plot” menu choose “single”, choose “SM” for “Y parameters”, push DONE.

Examine the plot. Push PRINT to make a printout (default 3c17lps\_post), make the window alive, use the Return (not EXIT of the widget).

Choose “exit” in the main window with the plot, the prompt IDL> will appear in the window where rlogin fabry is done,

Stay in IDL. Run:

```
IDL> .run mkout
```

You will be prompted to enter the date in the specified format.

Exit IDL.

Stay in STOSC. FTP to your machine:

Example:

```
STOSC> ftp your_machine_name
```

Once the FTP connection is established, cd to your fits directory. Example:

```
YOUR_MACHINE_NAME.STSCI.EDU> cd /your_pathname/fcs25may-fits
```

Put your data file, leave the filename unchanged (**data.out**).

```
Example: VERA.STSCI.EDU> put data.out
```

Quit FTP, logout STOSC.

In the **fits** directory, get into IDL and run:

```
get_breathing, 'nicmos1.txt'
```

Do the same for nicmos2 and nicmos3. This creates files **nicmos1.out**, etc.

You are done.

## 4. Analysis of the Phase Retrieval Results

At the end of this section you will have plots for Z4, the NICMOS focus history plot and the NICMOS focus history table.

**4.1.** In the directory **idl\_tr\_pro** enter IDL and run **fpam\_plot.pro**. Before running, make sure that the parameters are set correctly:

- If breathing is unavailable, then set: `breath=0`, otherwise set `breath=9`.
- Visit is the visit number as defined in the file **f\_input.pro** plus 1.

At the IDL prompt enter:

```
IDL> fpam_plot, breath=breath, visit=visit
```

For example, for the observation of May 25, 1998, run:

```
fpam_plot, breath=9, visit=20
```

The output is a set of plots for Z4, focus in PAM space (not centered), and breathing corrections. Examine the output.

The output for the centered focus is a line of focus values which will be written to the file **fcnt25may\_bre9\_o5.tab**. The file is stored in the directory **hhh**. The first number in the file is the day since 1/01/97, the rest of the numbers are the foci for the three cameras accompanied by the focus error. IDL prints the filename on the screen. In the filename, **\*bre9** stands for optimized breathing corrections, **\*bre0** stands for breathing corrections not applied, and **\*o5** tells you that five focus values measured around best focus have been rejected.

**4.2.** Append the line from the file **fcs25may-hhh/fcnt25may\_bre9\_o5.tab** generated by **fpam\_plot** to the file **idl\_tr\_pro/tab-dir/hist1\_fcs\_cenbre9\_o5.tab** which contains the results from the previous visits of the focus monitoring program.

**4.3.** If you analyze visits subsequent to the one of May 25, 1998 (used for current training), you will have to update the files **enc\_eddnew.tab** and **plate\_23new.tab** in the **tab-dir** directory using focus results based on measurements of encircled energy and plate scale.

**4.4.** From the **idl\_tr\_pro** directory, run **f\_plot.pro**:

```
IDL> f_plot
```

The routine will ask for the last date of observation. Enter May 25, 1998. This date will show up in the title of the plot. Then it will ask to enter the pathname of the focus table directory, the filename of the focus table from phase retrieval (i.e., **hist1\_fcs\_cenbre9\_o5.tab**), the filename of the focus table from encircled energy (i.e., **enc\_eddnew.tab**), and the filename of the focus table from plate scale (i.e., **plate\_23new.tab**). The output file, **fcs\_history.ps**, generated by **f\_plot.pro**, is usually circulated as an official NICMOS group focus update release.

**4.5.** Once breathing corrections and centering are done and the file **hist1\_fcs\_cenbre9\_o5.tab** in the directory **tab-dir** is updated, run the procedure:

```
IDL> fhistory_tab
```

The output is a table of focus values stored in the file **tab-dir/fhistory9.tab**. This table is delivered for circulation along with the focus history plot as an official focus update release.

## 5. Acknowledgments

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for her comments as she reviewed the document. Comments made by A.Suchkov were very helpful in improving this document.

## **6. List of Relevant Publications**

Suchkov, A. & Galas, G. 1998, NICMOS ISR 98-005. “NICMOS Focus Field Variations (FFV) and Focus Centering”.

Suchkov, A., Bergeron, L., & Galas, G. 1997, NICMOS ISR 98-004, 1998. “NICMOS Focus Monitoring”

Storrs, A., Suchkov, A., Bergeron, L., & Galas, G. 1997, Bull. AAS, 1997, 29, 1225. “NICMOS Foci”.

Suchkov, A., Bergeron, L., & Galas, G. 1997, The 1997 HST Calibration Workshop, eds. S.Casertano et al., p. 308. “Long Term and Short Term Variations of NICMOS Foci”.