

## NCS NICMOS Focus and Coma Analysis

E. W. Roye

*Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, Maryland, 21218*

A. B. Schultz

*Science Programs, Computer Sciences Corporation and the Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, Maryland, 21218*

**Abstract.** After the installation of the NICMOS Cooling System (NCS), the NICMOS focus was measured and found to be comparable to that observed in Cycle 7. The NIC1 and NIC2 foci have both moved about 1 mm (in PAM space) in the negative direction since Cycle 7, and the NIC3 focus has moved fractions of a mm (in PAM space) in the positive direction since Cycle 7, bringing it closer to focus than it was during that time. New optimal focus values were uplinked to *HST* on May 8, 2002, and subsequent NICMOS focus monitoring data have revealed that the focus has remained relatively stable. In addition, coma measurements have been made for all three cameras. A tilt grid was executed for NIC1 on May 10, 2002 revealing a significant amount of coma. New settings for NIC1 optimal PAM tilt were uplinked to *HST* on May 16, 2002. The correction successfully alleviated the observed NIC1 coma. NIC2 and NIC3 tilt grids executed on June 9, 2002. Smaller amounts of coma were observed in these two cameras. New settings for NIC2 optimal PAM tilt were uplinked to *HST* on September 29, 2002, successfully alleviating all coma. No update was required for NIC3.

### 1. Introduction

The NICMOS Pupil Alignment Mechanism (PAM) is used to adjust the focus of the NICMOS cameras. By moving the PAM back and forth along its axis, the focus can be measured and adjusted. The focus data consist of a series of images in and out of focus passing through best focus. The best focus can be subsequently determined from these data. The PAM is also used to take out misalignments between the *HST* exit pupil and the NICMOS entrance pupil. As the PAM is tilted, the relayed *HST* exit pupil image is translated relative to an internal NICMOS pupil at the Field Offset Mechanism (FOM). The FOM also carries the *HST* spherical aberration correction in its surface figure, so any misalignment between the aberrated *HST* pupil and the FOM produces a wavefront error. This error shows up as a pseudo-derivative of the spherical aberration, i.e., a field-independent coma that varies linearly with the misalignment of the pupil. The PAM is tilted to correct for such misalignment. The amount of tilt is measured in steps where one step is about  $7.8''$ . (PAM movement can only be adjusted by an integer number of steps.) Measurement of coma is hence accomplished via a set of data called a “tilt grid,” in which a series of images are taken at a variety of PAM tilt positions around the default position. The tilt position at which coma is minimized can be derived from this dataset.

## 2. Observations

The southern open star cluster NGC 3603, also observed for the Cycle 7 focus monitor and tilt grid programs, was observed for all the focus sweeps (program IDs: 8977, 9323, and 9637) and tilt grids (program IDs: 8977, 9323, and 9637). The focus sweeps in NIC1 and NIC2 consisted of a series of 17 MULTIACCUM images obtained over a range of  $\pm 8$  mm of PAM travel in 1 mm increments. For NIC3, the focus sweep was conducted at PAM settings of  $-0.5$  mm to  $-9.5$  mm of motion, and consisted of only ten MULTIACCUM images. The NIC1 tilt grid observations consisted of a 9 point grid surrounding the then-current default position, with one MULTIACCUM observation taken at each of the 9 grid points. The data spanned the range of  $[-4,0,4]$  in both the  $x$  and  $y$  directions. The NIC2 tilt grid consisted of a 13 point grid, with one MULTIACCUM observation taken at each position. The inner nine points comprised a  $3 \times 3 \pm 4$  step tilt grid, and the outer four points comprised a  $2 \times 2 \pm 8$  step tilt grid.

The data were re-calibrated off line with calnica using model-generated, color-dependent flats and specially made NCS darks along with all the other standard reference files.

## 3. Focus Monitor Results

The first NCS focus sweep was executed for all three cameras on May 3, 2002. Phase retrieval and encircled energy methods were used to measure the best focus position. The independent results agreed favorably with one another. Adjustments to the PAM positions were implemented on May 9, 2002 for NIC1 and NIC2 (PAM1 and PAM2). No focus adjustments were implemented for NIC3 (PAM3) or for the NIC2 coronagraphic focus (PAMC).

Since the first focus sweep there have been five subsequent sweeps: June 5, July 22, August 26, October 15, and October 28. The focus is relatively stable and fairly consistent with Cycle 7 and 7N measurements. However both the NIC1 and NIC2 foci have moved slightly in the negative direction (bringing them closer to 0 mm in PAM space). The NIC3 focus has moved slightly in the positive direction since Cycle 7. This is very fortunate, as it has brought NIC3 closer to focus than it was for the duration of Cycle 7. However, since the optimal NIC3 focus is still slightly beyond the range of motion of the PAM, no adjustment was required for the NIC3 focus position. See Figure 1 for a plot of the NCS focus history compared with the focus histories for Cycles 7 and 7N.

Slight variations in the measured focus positions are due to periodic variations in the *HST* optics, also known as telescope breathing. The present data are not corrected for breathing due to the lack of a robust model. The breathing model that was implemented during Cycles 7 and 7N no longer applies to the NCS data. For more detailed information, see Schultz et al. (2002).

## 4. Coma Analysis Results

### 4.1. Serendipitous Data Analysis

During the filter wheel test portion of the SM3b SMOV, serendipitous first light images were taken with NIC1 and NIC2. These images revealed some coma in both cameras. A coarse, temporary adjustment was made and uplinked to *HST* on May 9, 2002 to help diminish the coma in both NIC1 and NIC2.

### 4.2. NIC1 Coma Analysis

A nine point tilt grid for NIC1 executed on May 10, 2002. Four analyses of the data were performed using two independent methods. The first coma-analysis method utilized phase retrieval to measure the  $X$ - and  $Y$ -coma values at each of the tilt grid positions. These

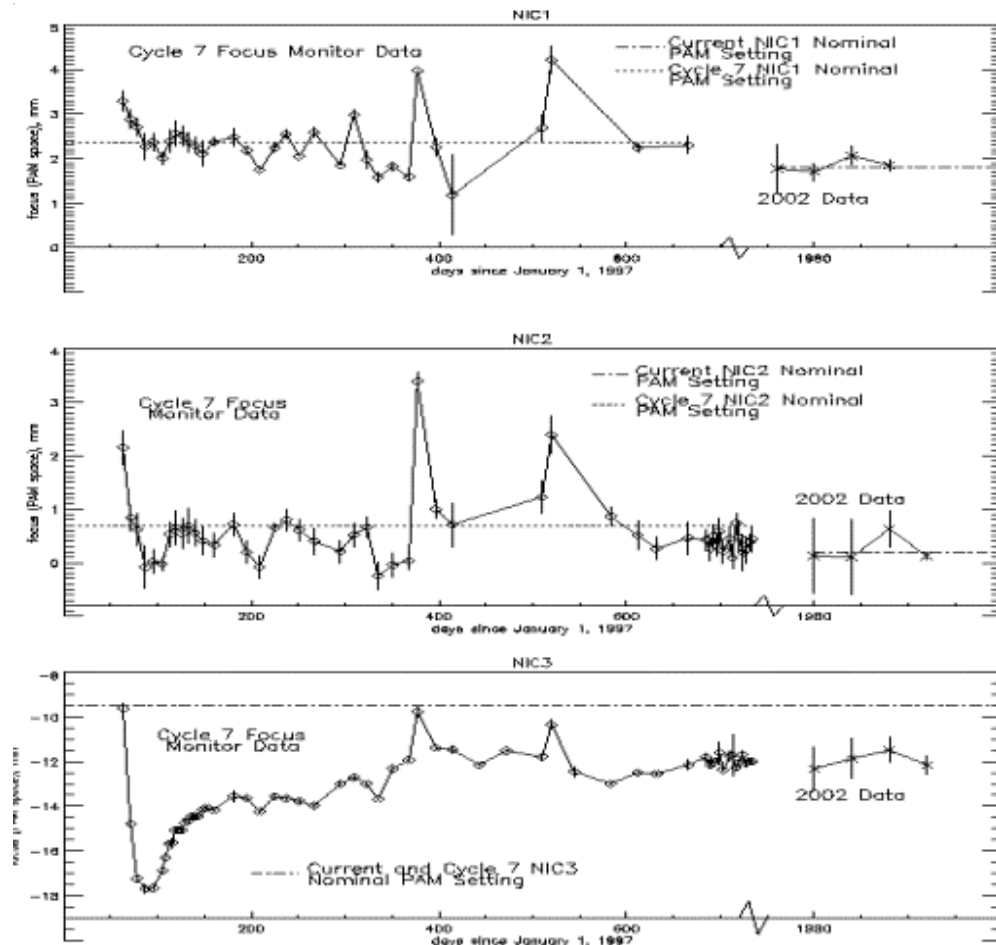


Figure 1. NCS NICMOS focus history results compared to Cycles 7 and 7N. The  $x$ -axis represents the number of days since January 1, 1997 and  $y$ -axis represents the position of the PAM in mm.

values were then fit to a model and the position at which coma is nulled was extracted from the model. Three separate analyses of the tilt grid were performed using this method. A fourth analysis utilized an independent method in which composite PSFs were created by combining the same nine stars from each of the tilt grid images. Interpolated and extrapolated model PSFs were then built in order to find the optimal grid position at which flux was most symmetrically distributed and coma amplitude minimized. All results agreed well. A recommendation for the final position of (+16, +14) was made and uplinked to *HST* on May 16, 2002. NIC1 coma was successfully removed. Figure 2 shows the NIC1 PSF before and after the final tilt correction. For more detailed information, see Roye & Krist (2002).

#### 4.3. NIC2 Coma Analysis

A thirteen point tilt grid for NIC2 executed on July 9, 2002. Two separate models were built based on the measured phase retrieval  $X$ - and  $Y$ -coma values at each of the grid points. The results agreed well, and a recommendation for the final position of (+15, +10) was made and uplinked to *HST* on September 30, 2002. NIC2 coma was successfully eliminated.

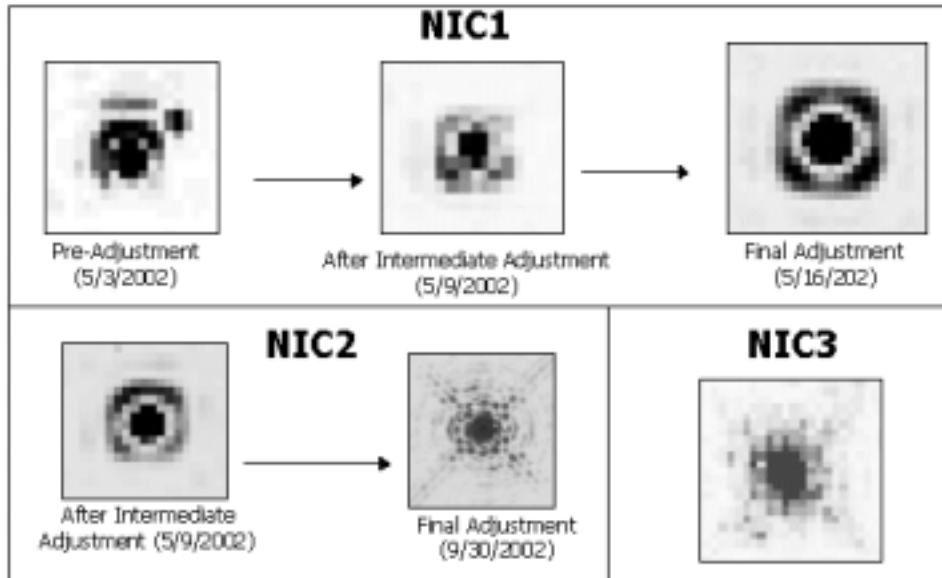


Figure 2. NIC1 and NIC2 PSFs before and after PAM tilt correction for coma. NIC3 PSF is shown for comparison.

Figure 2 shows the NIC2 PSF before and after the final tilt adjustment. For more detailed information, see Rove et al. (2002).

## References

- Roye, E. W., et al. 2002, "SM3B Coma Measurement" *Technical Instrument Report* NICMOS 2002-002 (Baltimore: STScI)
- Roye, E. W. & Krist, J. 2002, "NIC2 Coma Measurement" *Technical Instrument Report* NICMOS 2002-005 (Baltimore: STScI)
- Schultz, A. B., et al. 2002, "SM3B Focus Check" *Technical Instrument Report* NICMOS 2002-001 (Baltimore: STScI)