Instrument Science Report NICMOS 99-003

NICMOS optical aberrations: coma and astigmatism

A. Suchkov, G. Galas
June 10, 1999

ABSTRACT

Coma and astigmatism of NICMOS cameras have been derived using phase retrieval analysis of the data from the NICMOS focus monitoring program. Analysis of these aberrations has revealed that y-coma in all three camera experienced a systematic change over the NICMOS lifetime in Cycles 7 and 7a. A similar variation has been found for x-astigmatism in camera 2. In camera 3, the x-astigmatism increased dramatically after the FOM had been given a y-tilt of 16 arcsec. X-coma and y-astigmatism in all cameras did not show substantial systematic variations over the same period of time. The results of this study should help to understand the origin of the NICMOS optics instability. They should also facilitate interpretation of possible changes in NICMOS cameras when they are back to operations after installation of the cryocooler in Cycle 10.

1. Introduction

NICMOS optical characteristics experienced noticeable variations since the start of the instrument orbital life in early 1997. These include not only the changing focus position (Burrows & Krist 1997; Suchkov, Bergeron, & Galas 1998) but also coma and astigmatism. A study of the latter aberrations may help to better interpret NICMOS data and understand processes responsible for camera optics instability. It will be useful when NICMOS comes back to life in Cycle 10, to quantify the changes in camera's optics which may occur during NICMOS inactive period.

In this report, we present the results of a study of NICMOS coma and astigmatism based on the data from the NICMOS focus monitoring program covering the period from June of 1997 through October of 1998.

2. The Data

During the NICMOS operations in Cycles 7 and 7*a* the focus in NICMOS cameras was monitored on a regular basis till the last days of NICMOS active life in January of 1999. The data for the monitoring program were obtained from observations of the stellar field of the open cluster NGC 3603 made at different focus positions which were controlled by the Pupil Alignment Mechanism (PAM). The amount of defocus at each of the PAM settings was derived using phase retrieval software developed by Krist & Burrows (1995) and Krist & Hook (1997). The details of the observations and analysis of the data used are described in Suchkov et al. (1998).

Along with focus position, the phase retrieval analysis of the stellar images of the focus monitoring program provided us with parameters characterizing *x*- and *y*-coma and *x*- and *y*-astigmatism for all cameras. For camera 2, *y*-astigmatism was set to a fixed value rather than found from PSF fitting as a part of the phase retrieval procedure. For the present study, we picked up the aberration parameters measured at PAM settings closest to the nominal PAM positions which are: 2.36 mm, 0.69 mm, and –9.5 mm for NIC1, NIC2, and NIC3 respectively.

3. Results

Coma and astigmatism in NICMOS cameras are generally small, producing the wavefront error typically less than 0.05 μm, that is ~5% of the wavelength at 1 μm. The mean values of coma and astigmatism along the detector's *x*- and *y*-coordinates, expressed in terms of the respective wavefront error, are given in Table 1. The means have been derived by averaging the results obtained from June of 1997 through October of 1998.

Table 1. Mean and standard deviation of NICMOS aberrations

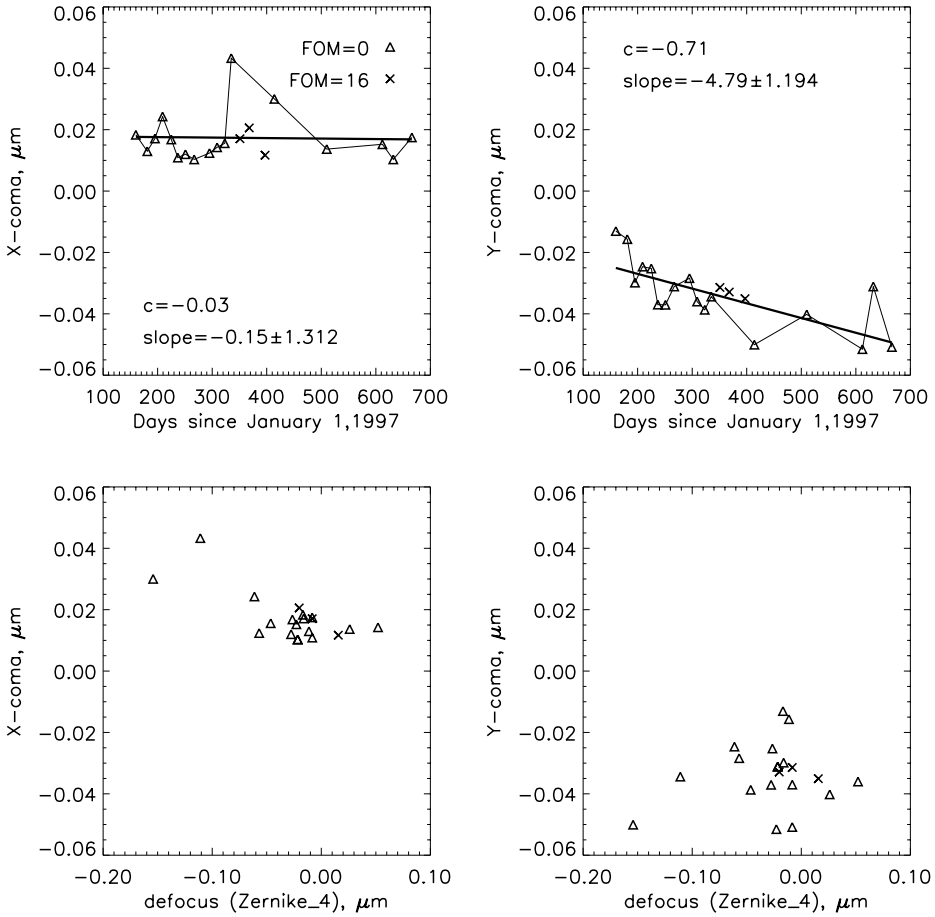
	NIC1	**NIC2**	**NIC3**	
	FOM=0"	FOM=0"	FOM=0"	FOM=16"
x-coma, μm	0.017 ± 0.008	0.018 ± 0.012	0.026 ± 0.006	0.030 ± 0.013
y-coma, μm	-0.034 ± 0.011	-0.028 ± 0.016	-0.040 ± 0.011	-0.058 ± 0.015
x-astigmatism, μm	0.002 ± 0.007	0.000 ± 0.009	0.003 ± 0.016	0.053 ± 0.023
y-astigmatism, μm	0.016 ± 0.012		0.027 ± 0.013	0.022 ± 0.014

With regard to the systematic behavior of NICMOS aberrations, we have found that there are almost no systematics in camera's astigmatism and *x*-coma, but *y*-coma in all three cameras had been gradually changing throughout the NICMOS lifetime in 1997—1998, and its value had nearly doubled by the end of this period. The same direction and

about the same amount of the change appears to be indicative of the same cause of that variation, possibly related to a continuing distortion in the instrument mechanical structure.

The history of all aberrations is shown in Figures 1 through 6. The straight thick line in the upper panels in these Figures, except for Figure 6, is a linear fit to the data points. The panels also give the correlation coefficient, *c*, and the slope of the fit (*slope* is in units of 10^{-5} μm day^{-1}). In the lower panels of Figures 1 to 6, the aberrations are plotted against defocus represented by Zernike coefficient *Zernike_4*. These diagrams show that aberrations basically do not correlate with defocus (except perhaps for *y*-coma in camera 2), which rules out the possibility that the observed regularities in aberration behavior stem somehow from the focus variations.

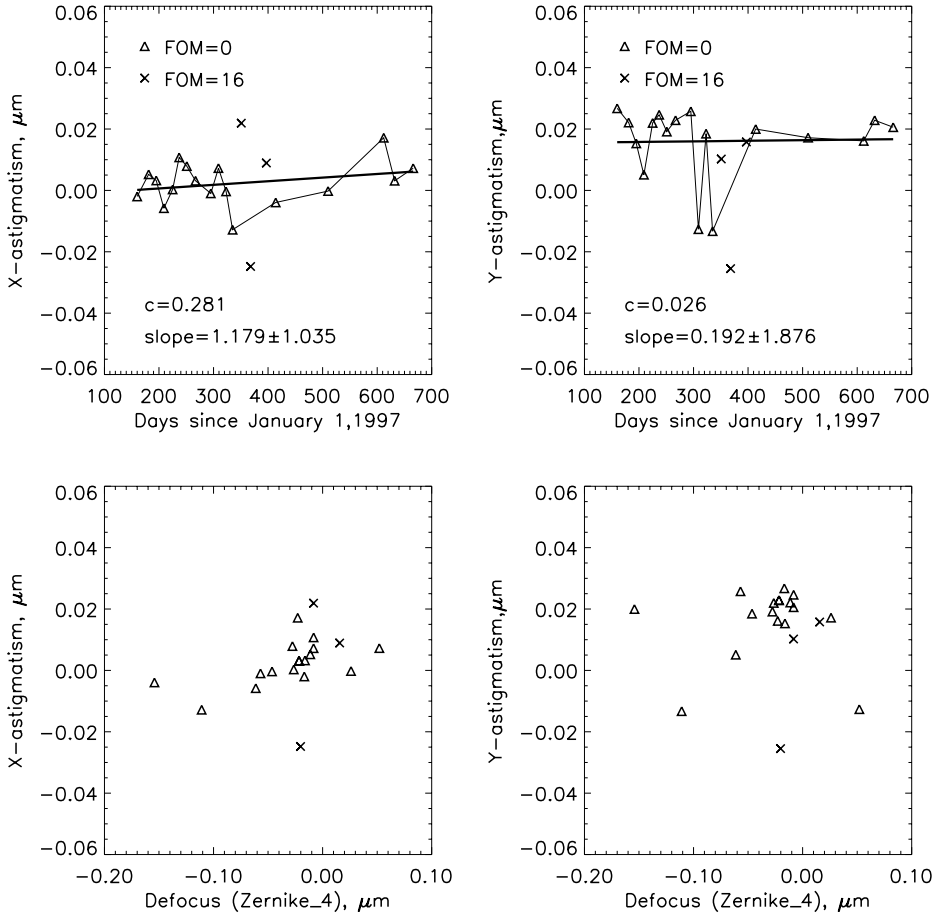
Figure 1: Coma in camera 1 (filter F095N).



While *x*-coma in camera 1 (Figure 1) does not show any long term regular behavior, *y*-coma had certainly been downtrending throughout the entire NICMOS lifetime, as suggested by a rather large correlation coefficient and the slope which is non-zero well

beyond errors. By the end of 1998 the value of *y*-coma had nearly doubled as compared to what it was at the beginning of the NICMOS operations.

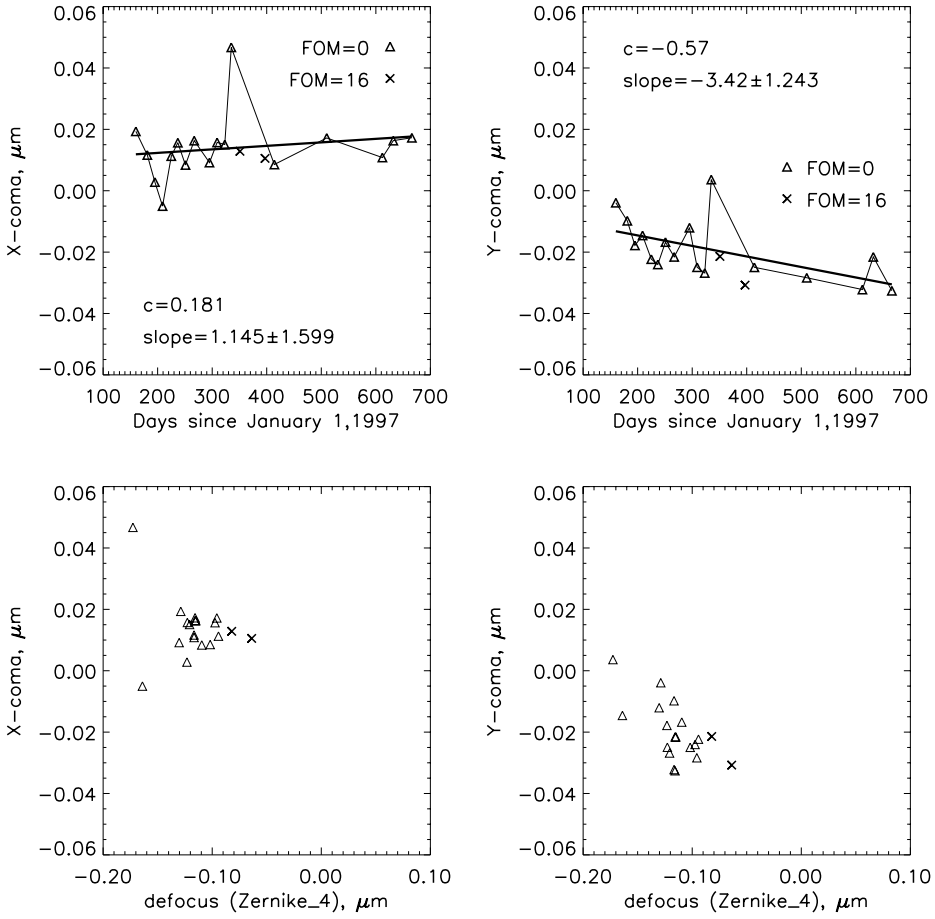
Figure 2: Astigmatism in camera 1 (filter F095N).



Astigmatism in camera 1 had been close to zero most of the NICMOS lifetime, with no signature of any long term systematics during this period.

The properties of coma in camera 2 (Figure 3) are essentially the same as in camera 1. There is a marginal evidence that *y*-coma correlates with defocus, suggesting that the variations in both characteristics have a common cause.

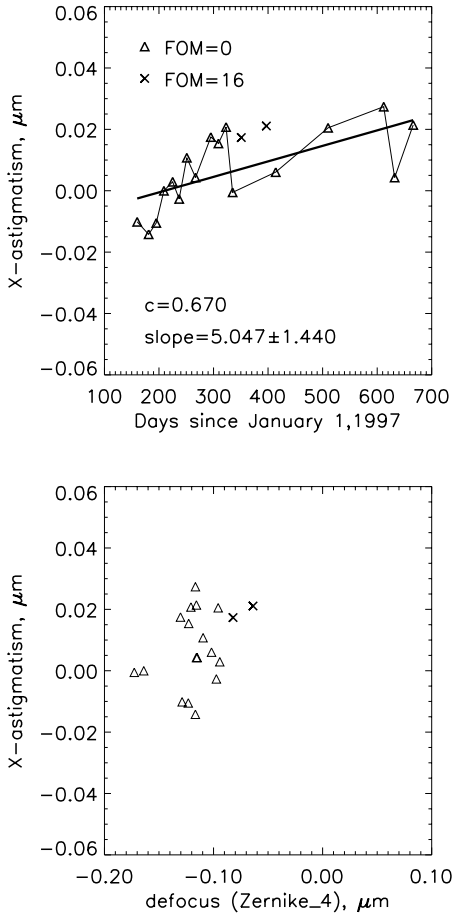
Figure 3: Coma in camera 2 (filter F110W).



X-astigmatism in camera 2 (Figure 4) remained within ±0.02 μm since the beginning of NICMOS observations. An interesting thing about it is, however, a steady uptrend which persisted through the end of the NICMOS active life. In this respect camera 2 turns out to be different from camera 1.

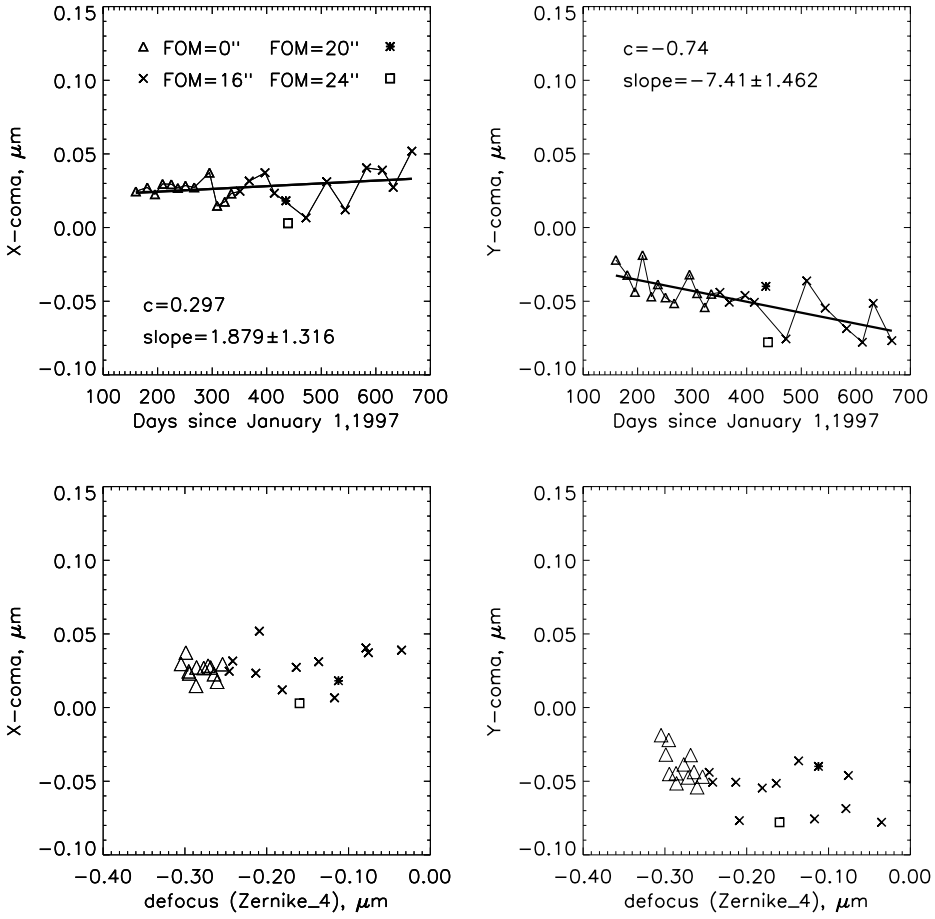
Coma in camera 3 (Figure 5) shows basically the same features as in the other two cameras, but the values of *y*-coma are a bit larger. If persists, the downtrend seen in the upper right panel may drive *y*-coma well beyond a 0.1 μm level when NICMOS begins to operate with the cryocooler.

Figure 4: Astigmatism in camera 2 (filter F110W; *y*-astigmatism not measured).



Most dramatic changes happened to astigmatism in camera 3. Its *x*-component increased by about a factor of 5 and became more unstable after the nominal Field Offset Mirror (FOM) *y*-tilt had been changed from 0 to 16 arcsec in December of 1997 in order to reduce significant vignetting in this camera. The magnitude of the effect was quite substantial, which is clearly seen in Figure 6. The tilted FOM also resulted in better focus in camera 3 (smaller defocus values in the lower panels of Figure 1). Therefore it looked like one could improve the degraded focus of camera 3 by tilting the FOM by a larger amount. However, it was found that the astigmatism above the level corresponding to the FOM tilt of 16 arcsec leads to an uncomfortably large PSF degradation. At the same time, a designated calibration program conducted in March of 1998 showed that larger FOM tilts, while driving *x*-astigmatism rapidly up, do not result in further improvements in camera's focus position (see the asterisk and the square in Figure 6). So it was decided to leave the FOM *y*-tilt at 16 arcsec.

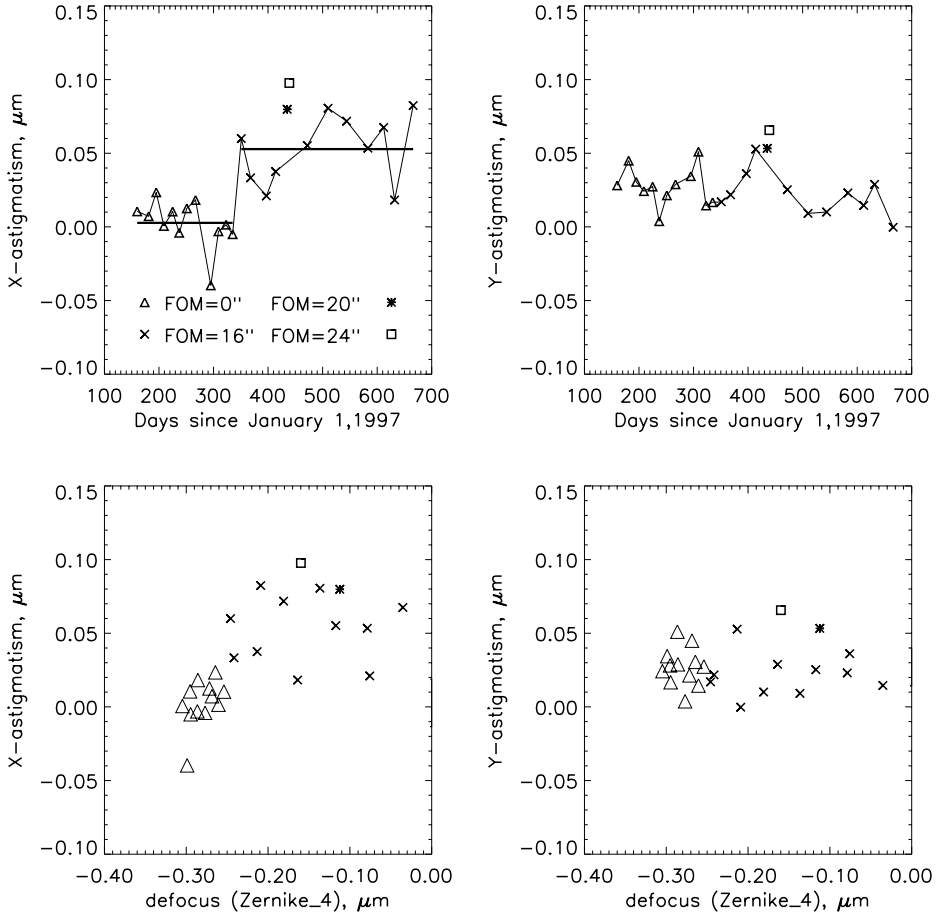
Figure 5: Coma in camera 3 (filter F108N).



4. Recommendations

- In view of the persistent downtrend in y-coma, which is apparently indicative of ongoing relaxation in the NICMOS mechanical structure, it would be desirable to check NICMOS coma during the SMOV after the Servicing Mission 3b in order to assess the respective changes which may occur in the instrument during the NICMOS inactive period, i.e. from the end-of-life time till the installation of the cryocooler.
- Another reason to check both coma and astigmatism during the SMOV is that NICMOS with the crycooler will have higher operating temperatures, which may adversely impact its optics and increase aberrations.
- Given a significant PSF degradation caused by *x*-astigmatism in camera 3, it is desirable to more accurately quantify this degradation. This can be accomplished using *TinyTim* modeling for the range of astigmatism values found in this study (i.e., up to ~0.1 μm). This not only should help to better interpret the existing NICMOS data but also will provide a background for adequate response should astigmatism get worse after the Servicing Mission 3b.

Figure 6: Astigmatism in camera 3 (filter F108N). The straight lines represent the mean *x*-astigmatism at two different FOM settings, 0 arcsec and 16 arcsec (FOM *y*-tilt



5. References

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Krist, J. E. & Burrows, C.J. 1995, Applied Optics, 34, 4951.

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