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Long-Term and Short-Term Variations of NICMOS Foci

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Abstract. We present the results of the NICMOS focus monitoring program and discuss long-term focus variations due to ongoing deformation processes within NICMOS, short-term variations due to HST "breathing" effects, and focus spatial variations across NICMOS fields of view.

1. Introduction

The NICMOS cameras were designed to share a common focus whose position can be adjusted using the Pupil Alignment Mechanism, or PAM. PAM's main part is an adjustable mirror which can be moved within ± 10 mm about its zero position, thus allowing fine tuning of the actual location of the focus. It was hoped that, whatever changes to the HST optical path may happen, the focus could always be brought back to the position of the detectors. Unfortunately, the unforeseen deformation of the NICMOS dewar has caused large mechanical distortions within NICMOS, which resulted in loss of a common focus for the three cameras. Worst of all, the camera 3 detector was pushed way out of the range within which the PAM can adjust the focus position. Soon after the Servicing Mission, this detector required a PAM position of about -17 mm to be in focus, which was far beyond the reach of the PAM (see Burrows 1997 for more extensive discussion of the issue).

The ongoing deformation processes in NICMOS keep changing the location of the detectors with respect to the PAM zero position. This necessitates checking the NICMOS camera foci on a regular basis so as to ensure timely adjustments of PAM nominal settings if required. To this end a special focus monitoring program observes biweekly a stellar field of the open cluster NGC 3603, and the data are analyzed to retrieve the current focus position.

2. Long-term Focus Variations

The results of long-term focus monitoring as of September 8 are presented in Figure 1. The abscissa is the day of observation (day number starting January 1, 1997). The ordinate gives the position that the PAM should have to get the focus at the location of the detector (implied PAM position, often referred to as focus position in the PAM space). It is obtained using three different techniques based on phase retrieval, encircled energy, and plate scale measurements, respectively. Phase retrieval provides absolute value for the focus position. The method was developed by Krist & Burrows (1995) and expanded lately by Krist & Hook (1997b) to incorporate the NICMOS cameras. Encircled energy and plate scale provide independent focus measurements, which allows double-checking phase retrieval results.

Inspection of Figure 1 suggests that the detector positions have been pretty stable over the last three months except perhaps for the point at day 224, August 12. A slight difference between phase retrieval and encircled energy results, especially noticeable for NIC2, is

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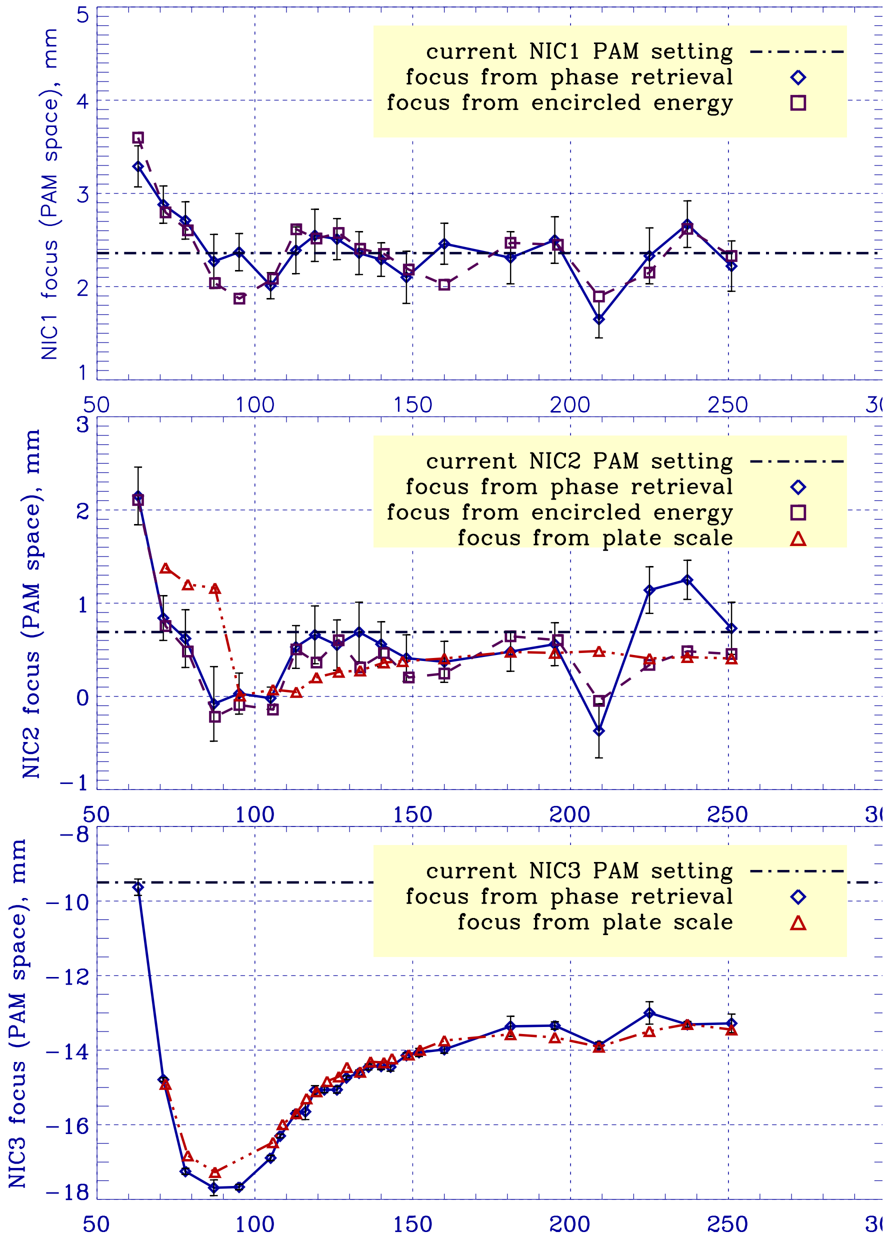

Figure 1. NICMOS focus history (as of September 8, 1997)

mainly due to the fact that the former were corrected for focus spatial variations across the camera field of view (see below) whereas the phase retrieval results were not.

3. Focus Variations on an Orbital Time Scale

Alongside with long-term focus variations displayed in Figure 1 there are short-term variations which potentially may impact photometry. They occur on the HST orbital time scale and are caused by changing HST thermal conditions as the spacecraft moves from night to

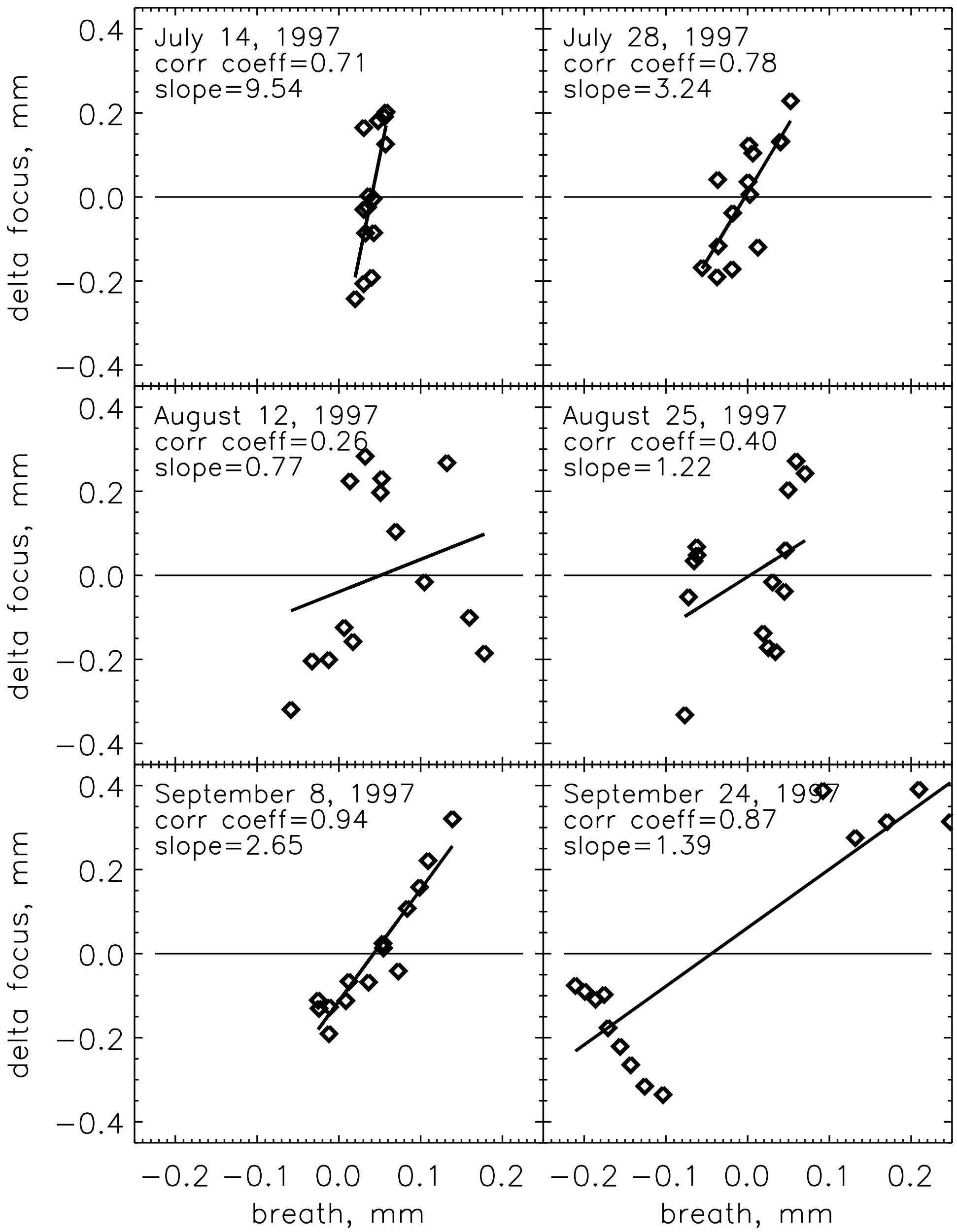

Figure 2. Correlation between focus position and breathing for NICMOS 1 data from six different data sets. The focus is measured relative to the mean value determined by each of the data sets. Both focus and the breathing parameter are given in mm in PAM space. The Figure illustrates that although in some cases focus follows the telescope temperature variations pretty much as expected from the current breathing model, the cases with low correlation coefficient and the correlation slope different from 1 indicate that the model is far from being ideal.

day and back to night. The resulting effect is known as "breathing" (see Suchkov & Casertano 1997 for the details of this effect and its impact on photometry). The NICMOS focus monitoring data provide a unique data set to quantify focus breathing and assess its impact on photometry. In Figure 2 we display the correlation between the measured focus position for camera 1 and a "breathing" parameter derived from telescope temperature data. There is no doubt that in some cases focus follows the telescope temperature variations.

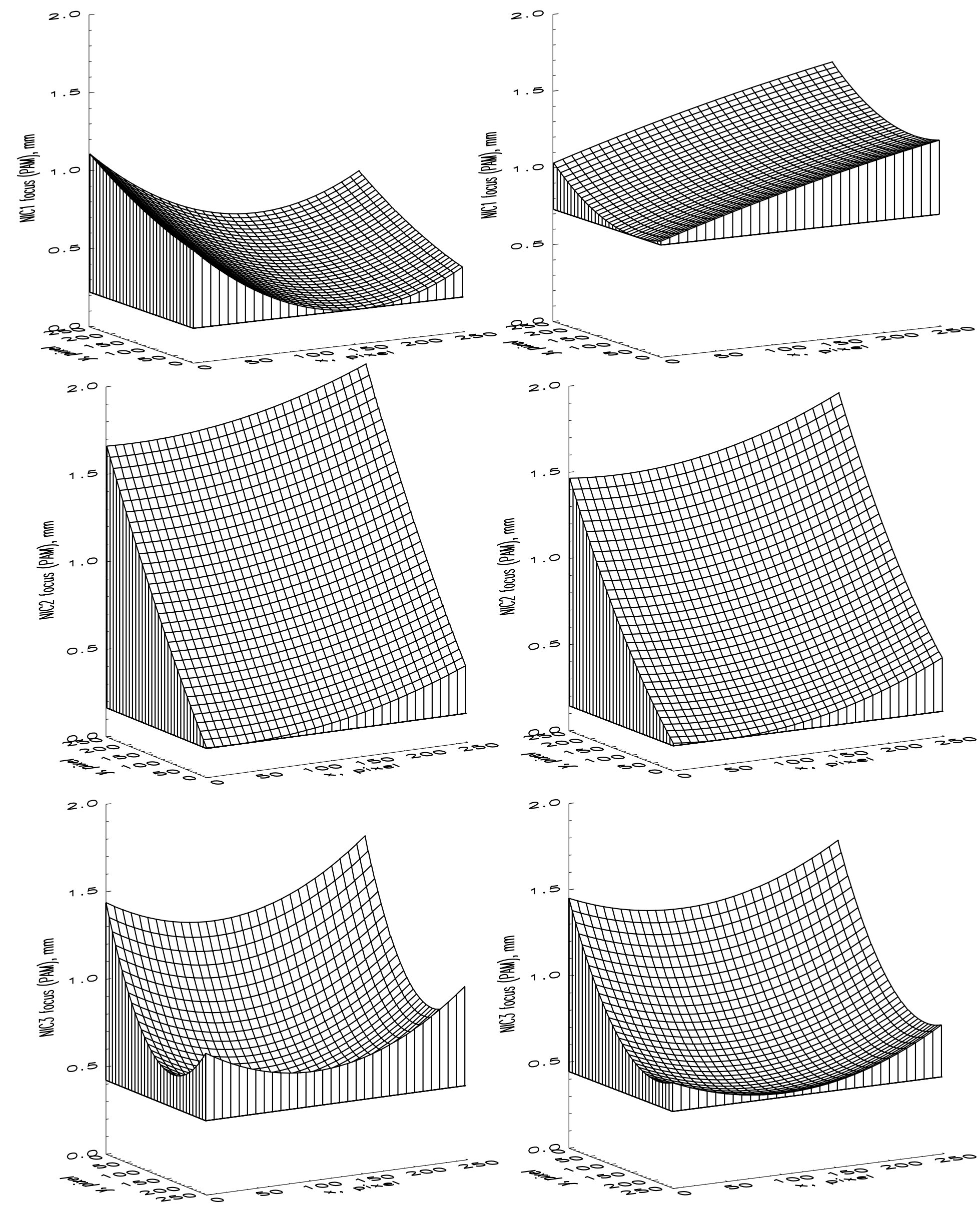

Figure 3. Focus variations across the field of view of NIC1 (top), NIC2 (middle), and NIC3 (bottom) from two different data sets taken at the same epoch for each of the cameras. The two sets are given to illustrate the level of statistical significance for geometrical pattern of focus variations. The differences between the patterns from paired data sets are within statistical errors.

However, in other cases the correlation coefficient is low and the slope of the correlation is far from being 1, suggesting that the breathing model which converts temperature variations to focus change is not ideal. This makes the application of breathing corrections to focus data a tricky task. Fortunately, the magnitude of breathing is typically smaller than ± 0.2 mm and actual focus variations are smaller than ± 0.5 mm (in PAM space) over the orbital period. Thus breathing may probably be important only for high-precision, small-aperture photometry, especially in cases when the detector is out of the best focus position.

4. Focus Variations Across the Detectors' Field of View

Along with temporal variations, the NICMOS foci have been found to vary spatially across the detectors' field of view. The effect is not so large as to be of prime concern for photometry. However, observers doing high-precision photometry may want to keep it in mind to better assess the accuracy of their photometry and to be able to correct for this effect if necessary.

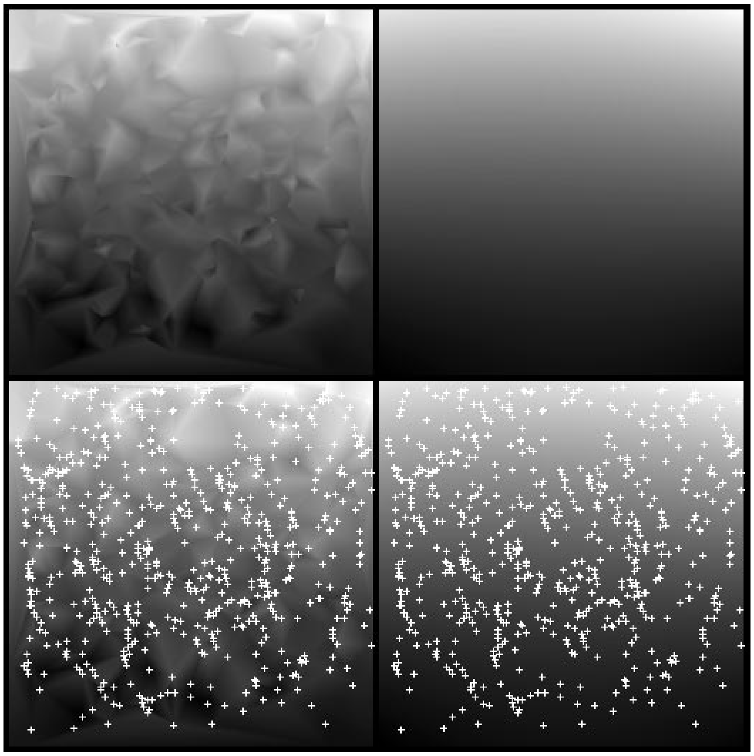

Figure 4. Grey scale presentation of the tilt in NIC2 obtained from encircled energy measurements. Upper left is triangle interpolation between all 630 encircled energy points in NIC2 through day 251, all normalized to 0 PAM at the center and included in the fit. The upper right is a smooth surface fit to the interpolated data. The lower 2 images are the same as above, but with the 630 measurement points overplotted as crosses.

To quantify focus positional dependence in all three cameras, we used focus measurements from phase retrieval for all suitable stars in a set of different frames. Thus we were able to restore the two-dimensional geometry of focus variations from different sets of independent data. In each case the focus values were fitted using multiple quadratic regression in x and y. The result of the fit for two different data sets is shown in Figure 3. In all panels, the fitting surface has been plotted in the same scale to allow straightforward comparison of the amount of focus deviations from the focal plane for all detectors. The focus position is measured in millimeters of the PAM space, with an arbitrary zero chosen so as to ensure better viewing.

The results for camera 2 show the largest range of focus variation, about 1.5 mm. Consistent results from different frames have been shown also by camera 3, with a more complicated focus abberation pattern and a smaller range of peak-to-peak focus variations. Camera 1 has the smallest field of view and thus provides us with smaller number of stars to derive the focus. As a consequence, statistical uncertainties as obtained for individual frames are in that case larger, with any systematics in focus variations being not much different from statistical errors. These results are consistent with earlier results obtained by John Krist from different data sets (unpublished).

The results from phase retrieval have been found to be consistent with independent focus measurements from encircled energy. Figure 4 gives a grey scale representation of the focus variation across the NIC2 field of view which has been obtained from encircled energy measurements for 630 stellar images in the focus monitoring data. One can see that both Figure 3 and Figure 4 are suggestive of the same top-to-bottom geometry of focus variation across the NIC2 detector field of view, with peak-to-peak focus difference of about 1.5 mm (in PAM space).

In an independent study, Krist & Hook (1997a) have estimated the impact of spatial focus variations on aperture photometry for all three cameras. They have incorporated the focus positional dependence into the *Tiny Tim* software, so the observers can now use *Tiny Tim* to simulate the corresponding NICMOS PSFs variations across the detectors' field of view.

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