

NIC 2 Growth Curves

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September 13, 1999

ABSTRACT

The Encircled Energy for isolated stars has been analyzed for NIC 2 F110W, F160W and F165M to quantify both spatial and temporal variations in the growth curve. The typical variation observed is less than 4% at 3 pixels distance from the PSF peak for calibration data and up to 7% for science data, with one exception reaching 10% variation. Between 1.5 and 6.5 pixels, the Encircled Energy rises by about 12% in the F110W filter and by ~30% - 35% in the F160W and F165M filters. This value is consistent with information published in the NICMOS Instrument Handbook.

1. Introduction

One of the potential concerns with NICMOS data is the temporal and spatial variation of its image quality. In order to assess the stability of NICMOS images, we have undertaken an analysis of the Encircled Energy of isolated stars observed over a 2-year range and at different positions in the field of view. The observations were all in NIC2 using the filters F110W, F160W, and F165M.

2. The Data

There are 3 different sets of data investigated here: (1) calibration data of the NICMOS standard star P330E, (2) PSF stars from GO Programs 7826 & 7864, and (3) synthetic PSFs generated by TinyTim¹. The calibration data were chosen to address the questions of the temporal and spatial stability of the NIC2 PSF. The 7826 & 7864 observations were included as representative of science data. The synthetic PSFs were included for a comparison between predicted and observed image quality.

The samples are comprised of bright (count rate > 1500 counts/sec), isolated stars in sparse fields. Targets which could be affected by vignetting were not included. Targets which were contaminated by grot and targets which fell on the central, low-efficiency col-

1. TinyTim, Version 4.4, developed by John Krist and Richard Hook.

umn of the detector were not included. Targets with spoiler stars and targets which appeared to be possibly double were also excluded.

Calibration Dataset

A total of 497 observations were included in this dataset: 267 F110W, 51 F160W, and 180 F165M exposures. This dataset was chosen to investigate possibility of both temporal and spatial variations in the NIC2 PSF. The calibration dataset is summarized in Table 1. The positions in the field of view at which these data were obtained are illustrated in Figure 1; histograms of the dates of these observations are given in Figure 2 through Figure 4.

Table 1. Summary of Calibration Dataset

Filter	Prog.	# Obs.	Sampling	
			Temporal	Spatial
F110W	7693	222	No	Yes
F110W	7904	1	No	No
F110W	7902	31	Yes	Yes
F110W	7607	13	Yes	No
F160W	7607	18	Yes	No
F160W	7904	1	No	No
F160W	7902	32	Yes	Yes
F165M	7050	130	Yes	Yes
F165M	7034	40	No	Yes
F165M	7049	3	No	No
F165M	7152	3	No	No
F165M	7607	3	No	No
F165M	7691	1	No	No

Figure 1: Positions of Calibration Dataset Observations in Field of View.

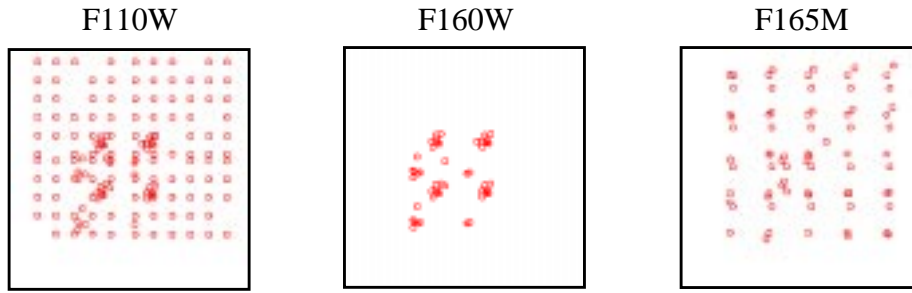


Figure 2: Calibration Dataset: Dates of Observations for F110W.

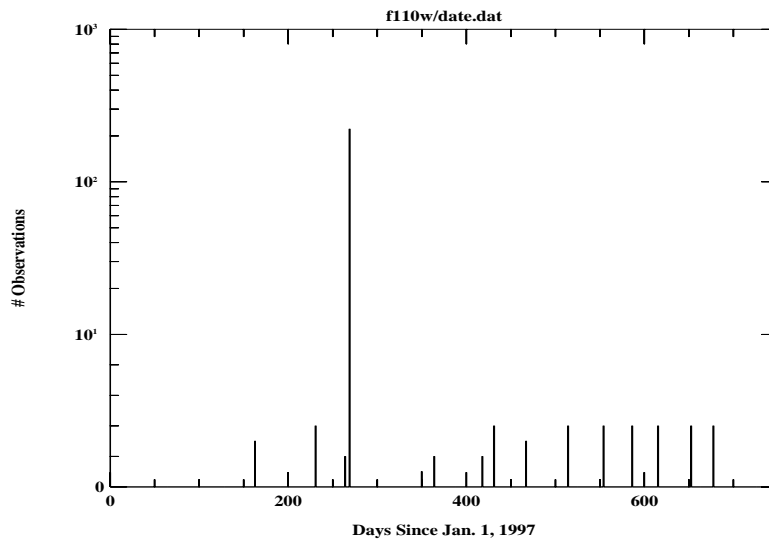


Figure 3: Calibration Dataset: Dates of Observations for F160W.

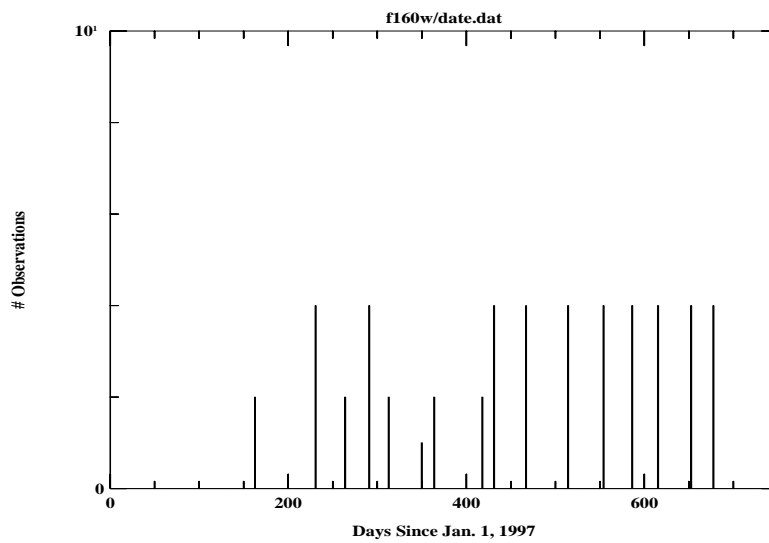
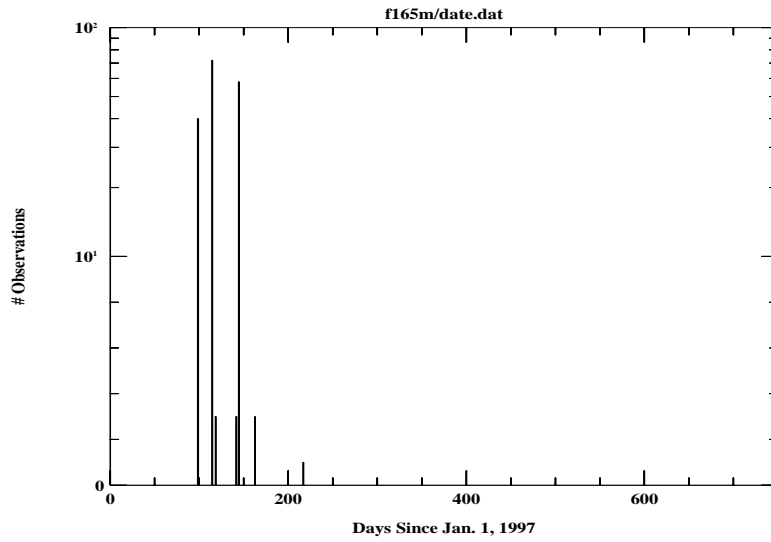


Figure 4: Calibration Dataset: Dates of Observations for F165M.



Science Dataset

One hundred and twenty-two observations from programs 7826 and 7864 were included in the science dataset; these data are summarized in Table 2. The positions of the observations in the field of view are given in Figure 5 and the dates of observation are shown in Figure 6 through Figure 8.

Table 2. Summary of Science Dataset

Filter	Prog.	# Obs.	Sampling	
			Temporal	Spatial
F110W	7826	41	Yes	Yes
F160W	7826	43	Yes	Yes
F160W	7864	14	Yes	Yes
F165M	7864	24	Yes	Yes

Figure 5: Positions of Science Dataset Observations in Field of View.

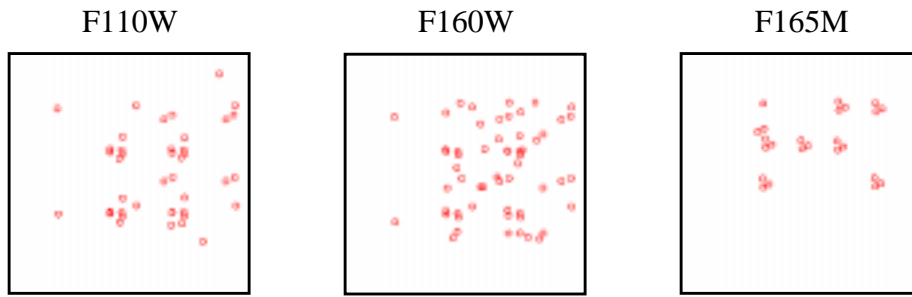


Figure 6: Science Dataset: Dates of Observation for NIC2 F110W.

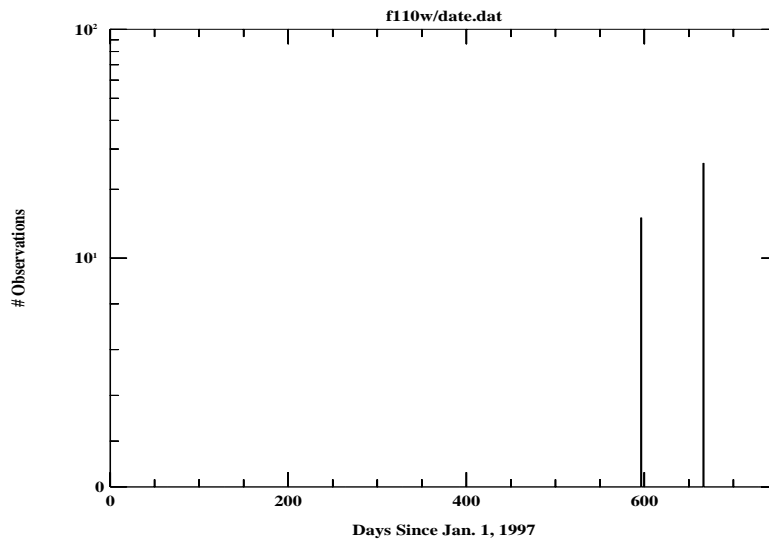


Figure 7: Science Dataset: Dates of Observation for NIC2 F160W.

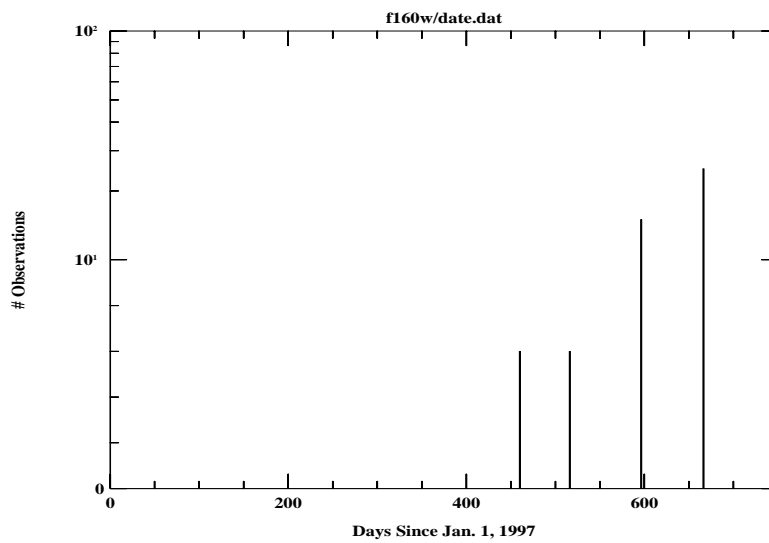
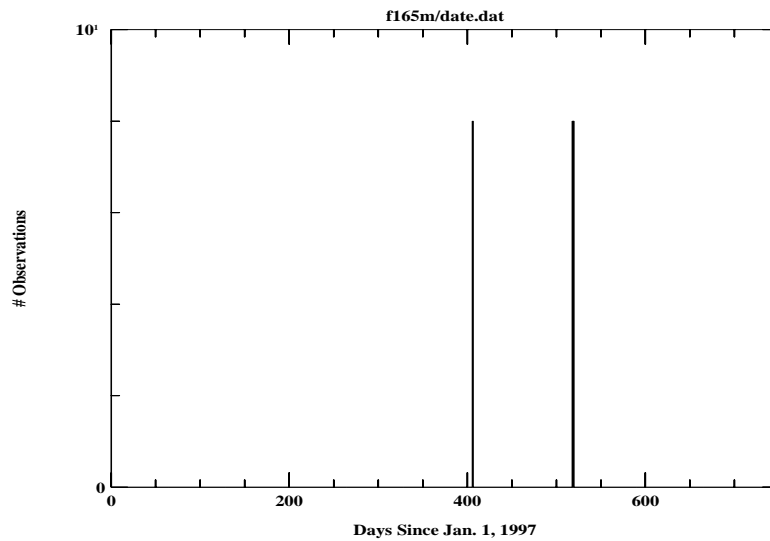


Figure 8: Science Dataset: Dates of Observation for NIC2 F165M.



Synthetic Dataset

For completeness, a comparison of observed and predicted NIC2 PSFs is included in this report. Synthetic PSFs were obtained from TinyTim by Megan Sosey at wavelengths of 1.10, 1.60, and 1.65 μm . The PSFs were not subsampled and were generated using the default weighting scheme for polychromatic PSFs provided with the TinyTim software.

3. Data Reductions

The centroids of the stars were obtained using the `cl.images.tv.imexamine` task. Aperture photometry (`noao.digiphot.apphot.phot`) was then performed on the stars based on these centroids. The photometry aperture was set to 10 pixels and the sky measurements were taken from an annulus between 10 and 15 pixels from the centroid. The task `sts-das.hst_calib.ctools.pprof` was used to construct the Encircled Energy curves shown in Section 4 below.

4. Results

Calibration Dataset

The Encircled Energy curves for the calibration dataset are given in Figure 9 through Figure 11. Table 3 lists the pertinent information and statistics for the EE measurements. The maximum range of temporal and spatial variation observed in EEs in the calibration dataset is 4% with the largest variation observed at the shortest wavelengths probably due to slight PSF undersampling (see last column of Table 3).

Figure 9: Calibration Dataset: Growth Curves for NIC2 F110W

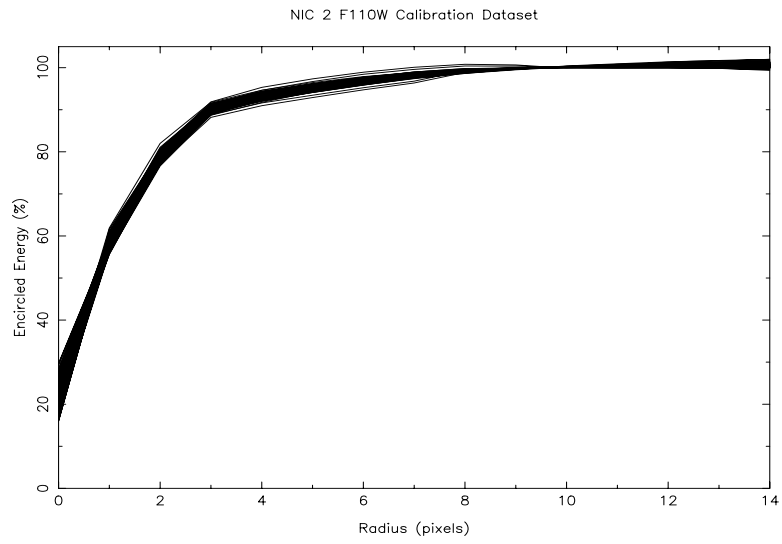


Figure 10: Calibration Dataset: Growth Curves for NIC2 F160W

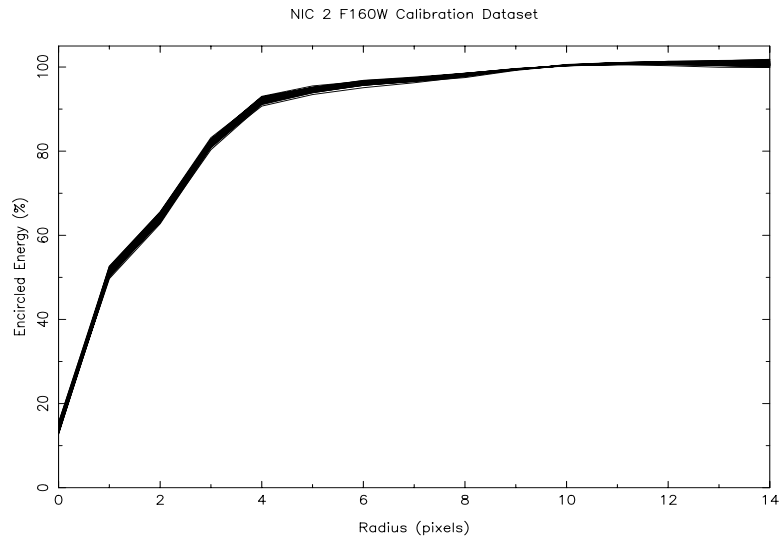


Figure 11: Calibration Dataset: Growth Curves for NIC2 F165M

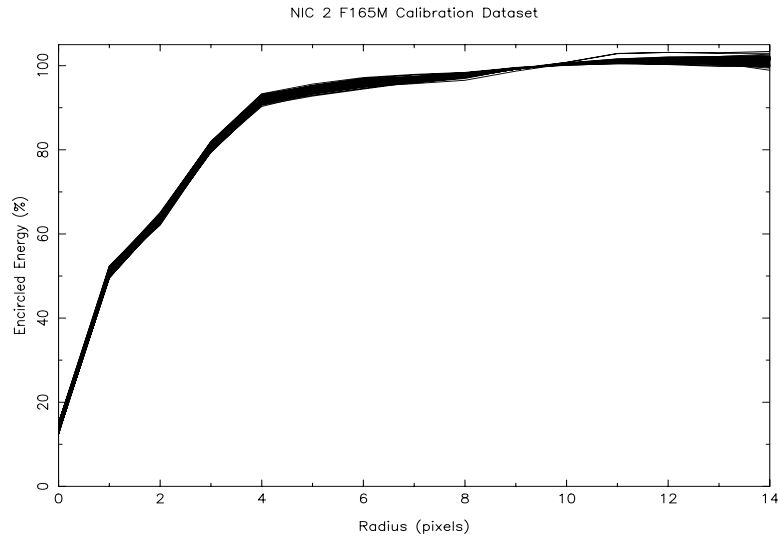


Table 3. Encircled Energy Statistics for the Calibration Dataset

Filter	Prog. ID	Radius (Pixels)	# Data	Mean EE (%)	SD	Var.	Min EE (%)	Max EE (%)	Min - Max (%)
F110W	7693	3	222	90.24	0.61	0.37	88.19	91.87	3.68
F110W	7904	3	1	90.15	---	---	---	---	---
F110W	7902	3	31	89.82	0.47	0.22	88.92	90.76	1.83
F110W	7607	3	13	90.66	0.53	0.29	89.68	91.76	2.08
F110W	All	3	267	90.21	0.61	0.37	88.19	91.87	3.68
F110W	7693	6	222	96.86	0.45	0.20	94.73	98.93	4.20
F110W	7904	6	1	96.96	---	---	---	---	---
F110W	7902	6	31	96.78	0.25	0.06	96.08	97.19	1.11
F110W	7607	6	13	97.01	0.41	0.17	96.33	97.89	1.55
F110W	All	6	267	96.86	0.43	0.18	94.73	98.93	4.20
F160W	7607	3	18	82.28	0.55	0.30	81.23	83.21	1.98
F160W	7904	3	1	81.58	---	---	---	---	---
F160W	7902	3	32	81.69	0.49	0.24	80.34	82.49	2.15
F160W	All	3	51	81.89	0.58	0.33	80.34	83.21	2.87
F160W	7607	6	18	96.11	0.38	0.15	95.09	96.64	1.55
F160W	7904	6	1	95.75	---	---	---	---	---
F160W	7902	6	32	96.20	0.33	0.11	95.64	96.84	1.21
F160W	All	6	51	96.16	0.35	0.12	95.09	96.84	1.75

Filter	Prog. ID	Radius (Pixels)	# Data	Mean EE (%)	SD	Var.	Min EE (%)	Max EE (%)	Min - Max (%)
F165M	7050	3	130	80.21	0.30	0.09	79.39	80.85	1.47
F165M	7034	3	40	80.78	0.69	0.47	79.65	82.01	2.35
F165M	7049	3	3	80.11	0.40	0.16	79.83	80.57	0.73
F165M	7152	3	3	80.50	0.36	0.13	80.22	80.90	0.68
F165M	7607	3	3	80.18	0.46	0.22	79.90	80.72	0.82
F165M	7691	3	1	80.01	---	---	---	---	---
F165M	All	3	180	80.34	0.48	0.23	79.39	82.01	2.62
F165M	7050	6	130	95.50	0.13	0.02	95.14	95.97	0.83
F165M	7034	6	40	95.88	0.63	0.39	94.44	97.17	2.73
F165M	7049	6	3	95.55	0.13	0.02	95.41	95.68	0.26
F165M	7152	6	3	95.36	0.08	0.01	95.28	95.44	0.16
F165M	7607	6	3	95.58	0.15	0.02	95.47	95.75	0.28
F165M	7691	6	1	95.93	---	---	---	---	---
F165M	All	6	180	95.59	0.35	0.12	94.44	97.17	2.73

Science Dataset

The EE curves derived from the science data are shown in Figure 12 through Figure 14, and summarized in Table 4. The largest variations are observed for program 7826, which observes the Baade window. Although sparsely populated, stars in this region of the sky cannot be technically defined as “isolated”. Program 7864, instead, contains “bona-fide” isolated stars selected from the Guide Star Catalog. Hence the smaller differences observed for the stars in 7864 relative to 7826. In particular, the former shows maximum variances of order 2% at 3 and 6 pixels distance from the PSF peak in the F165M filter (last column of Table 4).

Figure 12: Science Dataset: Growth Curves for NIC2 F110W

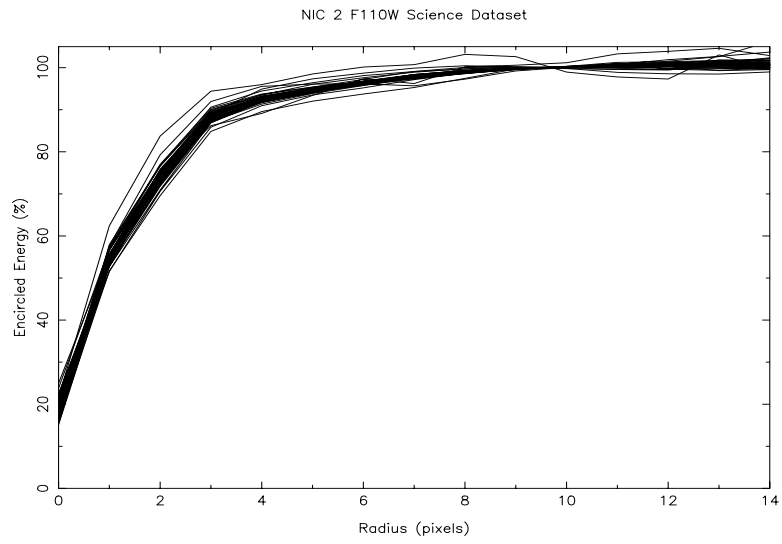


Figure 13: Science Dataset: Growth Curves for NIC2 F160W

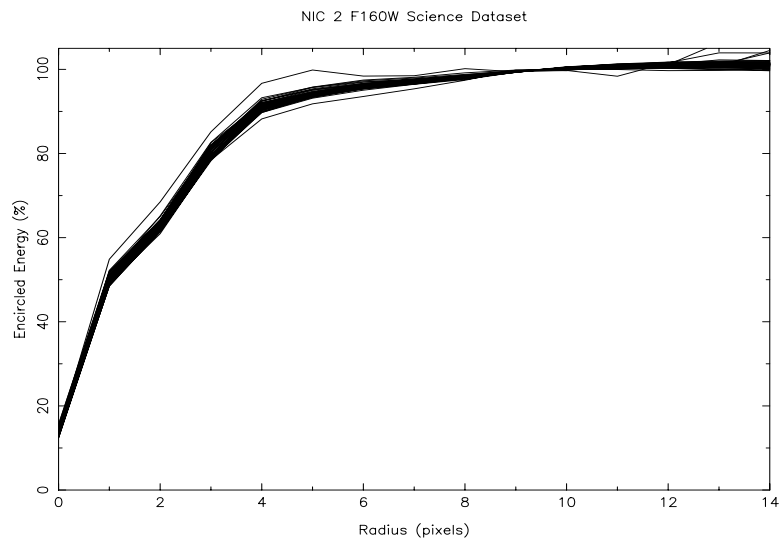


Figure 14: Science Dataset: Growth Curves for NIC2 F165M

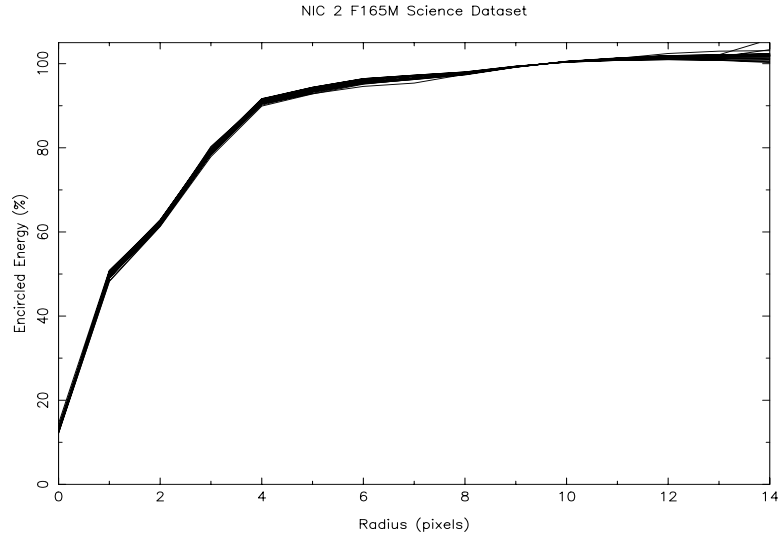


Table 4. Encircled Energy Statistics for Science Dataset

Filter	Prog. ID	Radius (Pixels)	# Data	Mean EE (%)	SD	Var.	Min EE (%)	Max EE (%)	Min - Max (%)
F110W	7826	3	41	88.49	1.64	2.70	84.85	94.42	9.57
F110W	7826	6	41	96.52	0.95	0.91	93.73	100.15	6.42
F160W	7826	3	43	80.07	1.36	1.84	78.25	85.15	6.90
F160W	7864	3	14	81.53	0.54	0.29	80.28	82.57	2.29
F160W	All	3	57	80.43	1.36	1.85	78.25	85.15	6.90
F160W	7826	6	43	95.96	0.73	0.54	93.55	98.40	4.85
F160W	7864	6	14	96.04	0.36	0.13	95.37	96.64	1.26
F160W	All	6	57	95.98	0.66	0.43	93.55	98.40	4.85
F165M	7864	3	24	79.17	0.58	0.33	77.91	80.30	2.39
F165M	7864	6	24	95.65	0.44	0.19	94.59	96.46	1.86

Synthetic Dataset

The EE curves for the synthetic dataset are shown in Figure 15 and the EE measurements comparing the three datasets are summarized in Table 5.

Figure 15: NIC2 Growth Curves for Synthetic Dataset

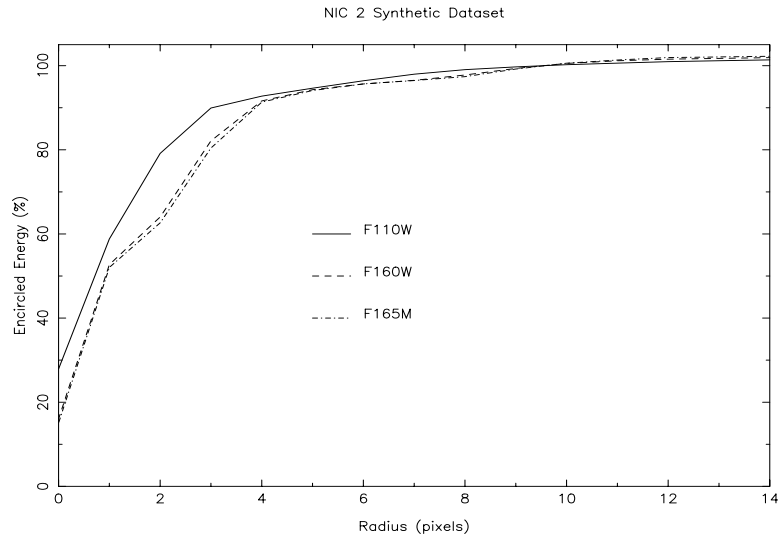


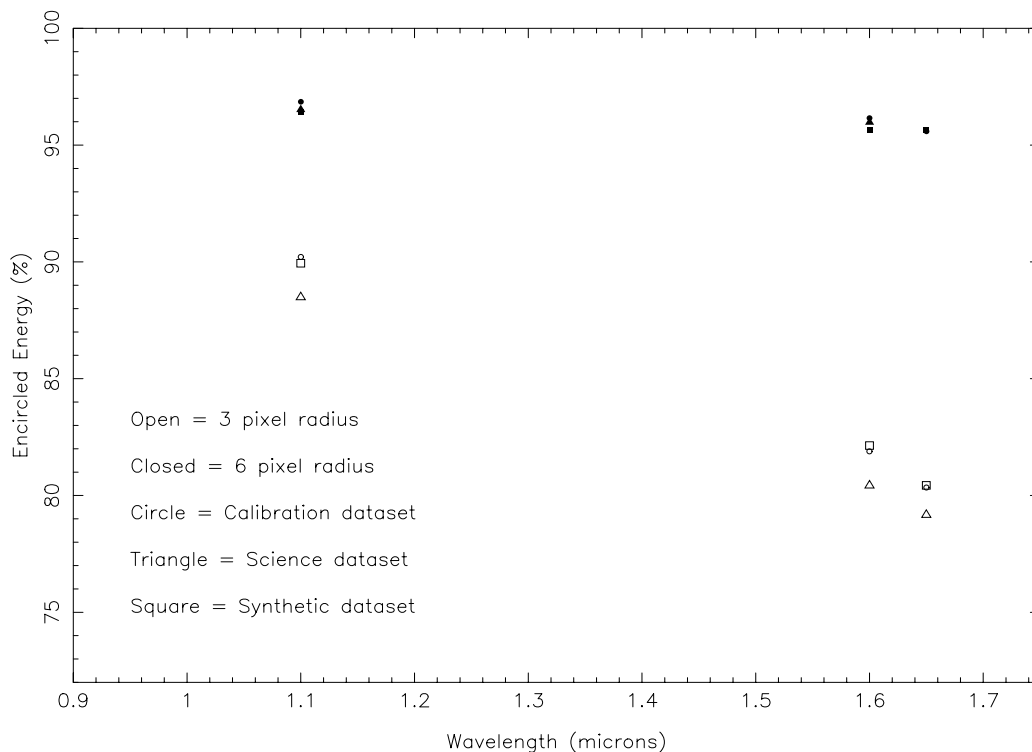
Table 5. Encircled Energies for the Synthetic Dataset

Wavelength (μm)	Radius (Pixels)	Synthetic EE (%)	Calibration Mean EE (%)	Science Mean EE (%)
1.10	3	89.94	90.21	88.49
1.60	3	82.14	81.89	80.343
1.65	3	80.43	80.34	79.17
1.10	6	96.41	96.86	96.52
1.60	6	95.66	96.16	95.98
1.65	6	95.66	95.59	95.65

5. Conclusion

A comparison between the EEs for the synthetic dataset and the mean EEs for the calibration and science datasets are given in Figure 16. At a radius of 3 pixels, the science dataset has EE measures systematically lower than both the calibration and synthetic datasets by approximately 1.5%. However, this trend is not evident at a radius of 6 pixels.

Figure 16: Comparison of Predicted and Observed Encircled Energies



As shown in Table 6, the mean Δ EEs between radii of 1.5 and 6.5 pixels is 12% to 35% with the largest variation associated with the reddest filter. A 35% increase in EE corresponds to an equivalent magnitude difference of approximately 0.33 mag, consistent with information published in the NICMOS Instrument Handbook.

Table 6. Δ EE Between Radii of 1.5 and 6.5 Pixels for the Calibration & Science Datasets

Calibration Dataset				Science Dataset			
Filter	# Data	Mean Δ EE (%)	σ	Filter	# Data	Mean Δ EE (%)	σ
F110W	267	11.92	0.83	F110W	41	14.91	2.07
F160W	51	29.79	0.97	F160W	57	32.26	1.87
F165M	180	32.45	0.65	F165M	24	34.59	1.07

In conclusion, the NICMOS NIC2 PSF appears relatively constant in time and detector position, with maximum variations of \sim 4% or less in EE at a distance 3 pixels from the PSF peak when measured in well-exposed, isolated stars.