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Color Dependence of NICMOS Flatfields

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ABSTRACT

We report two methods for obtaining color dependent flat fields for NICMOS data. The first involves interpolation over wavelength, to obtain monochromatic flatfields. The second multiplies the instrumental response by a user-supplied source spectrum and weights existing narrowband flats by the result. Programs to produce both types of flatfields are described, along with the reference data necessary. We conclude with a discussion of how to make and apply these flatfields to correct data with large color differences within the image.

1. Introduction

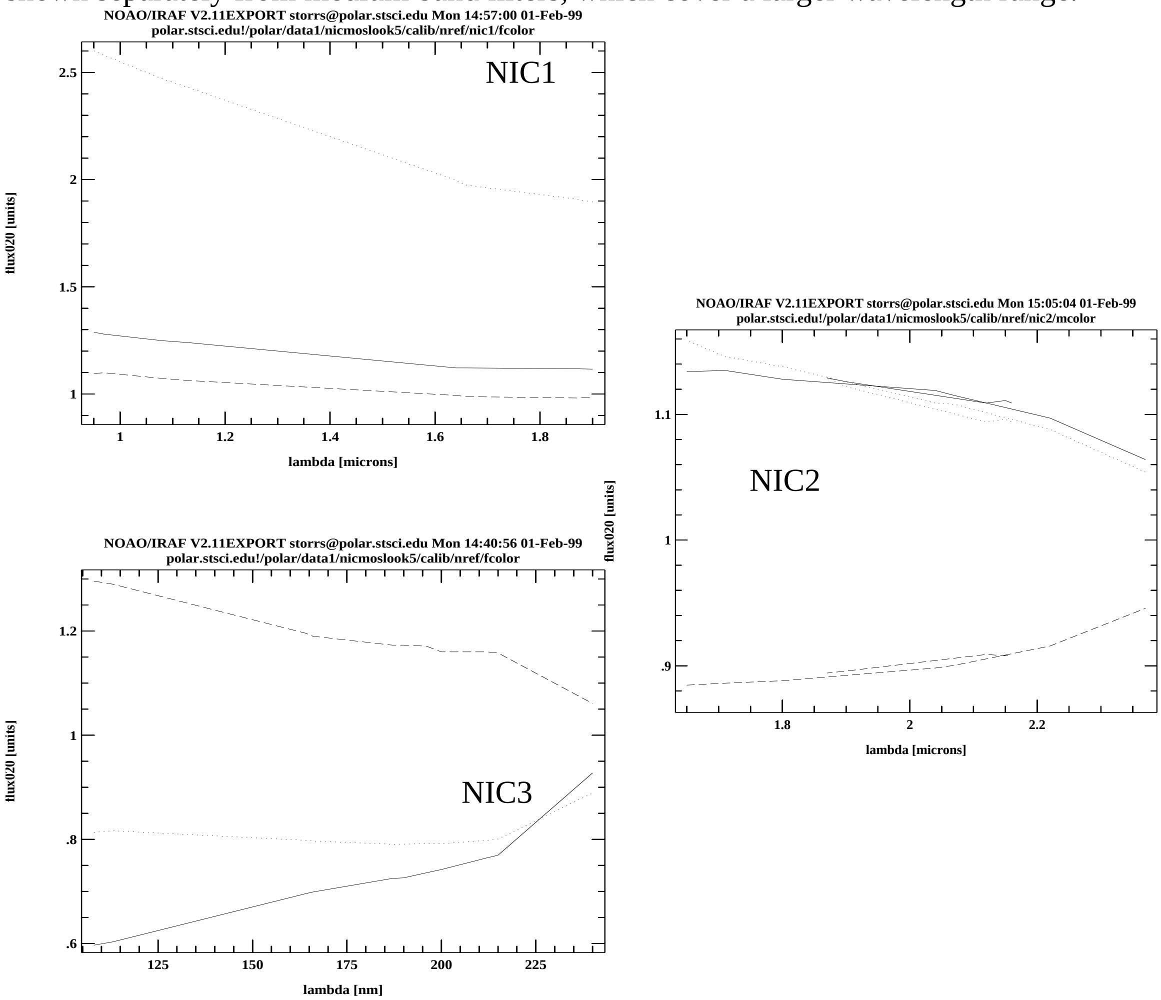
The pipeline flatfield data for NICMOS is made with the use of onboard flatfield lamps, which have an intrinsically blue color over most of the NICMOS sensitivity range. For example, although the mean wavelength of the F110W filter is 1.1035 μm, the pipeline flat for this filter is best matched by interpolation to a mean wavelength of 1.0 μm. The pipeline flats work well for most cases, but as described in Chapter 7 of the NICMOS Instrument Handbook, sources with extreme colors do exist, and broadband images of such sources may require special treatment.

A common image processing technique for images that don't flat well is to use flats taken through filters of different (but nearby) color. We have expanded on this technique for NICMOS observations, by producing two routines and associated calibration files, to produce linear combinations of existing flatfields. The first technique involves fitting the color response of the narrowband flatfields to produce two images, one for the slope of the pixel response and one for the intercept. The program (see appendix A) then multiplies the slope image by the input wavelength and adds the intercept image. The second technique makes a weighted average of flatfields for a given camera. If the spectrum of the object is known, the observer can then make a flatfield weighted by the spectrum and the response of the camera and filter. The data can either be reprocessed using either of these flats, or the calibrated data can be selectively multiplied by the ratio of the flat to the pipeline flat.

2. Color dependence of NICMOS pixels

Each pixel of each camera has a different response to different wavelengths of light. This is illustrated in Figure 1, where the value of the narrowband pipeline flatfields is shown as a function of wavelength for all three cameras. Three pixels for each camera are shown. It is noticeable that pixels with a weaker response (i.e., flatfield values >1) tend to have increasing sensitivity with wavelength (their flatfield values tend toward 1 at longer wavelengths) while more sensitive pixels (with flatfield values <1) tend be less sensitive at longer wavelengths. This is in keeping with the observation in Chapter 7 of the NICMOS Instrument Handbook, that the flatfield variations tend to decrease in magnitude, with increasing wavelength (see Figure 7.3 there).

Figure 1: Color dependence of flatfield for pixels (20,20)(solid line), (120,120)(dotted line), and (220,220)(dashed line). Note that for NIC2, data from narrowband filters is shown separately from medium band filters, which cover a larger wavelength range.



It is noticeable in Figure 1 (as well as in Figure 7.6 of the Handbook) that over most of the wavelength range, the color response is linear. Only at the reddest wavelengths does the response differ significantly from linear. Thus to produce monochromatic flats we used a linear least-squares fit to the narrowband flatfields for each camera, to determine the wavelength dependence of each pixel. For cameras 2 and 3, we did not include the longest wavelength filter flats in our fitting, because of the rapid change in response there. The narrowband filters in camera 2 only cover a small part (1.87 to 2.16 μm) of the wavelength range covered by the other filters, so the medium band filters were used in the fit as well. Figure 1b. shows the narrowband trend separately from the medium band trend, although both were used in the final fitting.

Note that camera 2 has predominantly red filters-- creating an "interpolated flat" in the 1 μm region actually requires extrapolation, and errors in the linear fit to the data can lead to large uncertainties in the result. We do not recommend the use of interpolated flats for NIC2 observations in the 1 μm region. A similar caveat is necessary for very red wavelengths in NIC3-- for observations much beyond about 2.1 μm monochromatic flatfields will be extrapolated rather than interpolated, and the results will be uncertain.

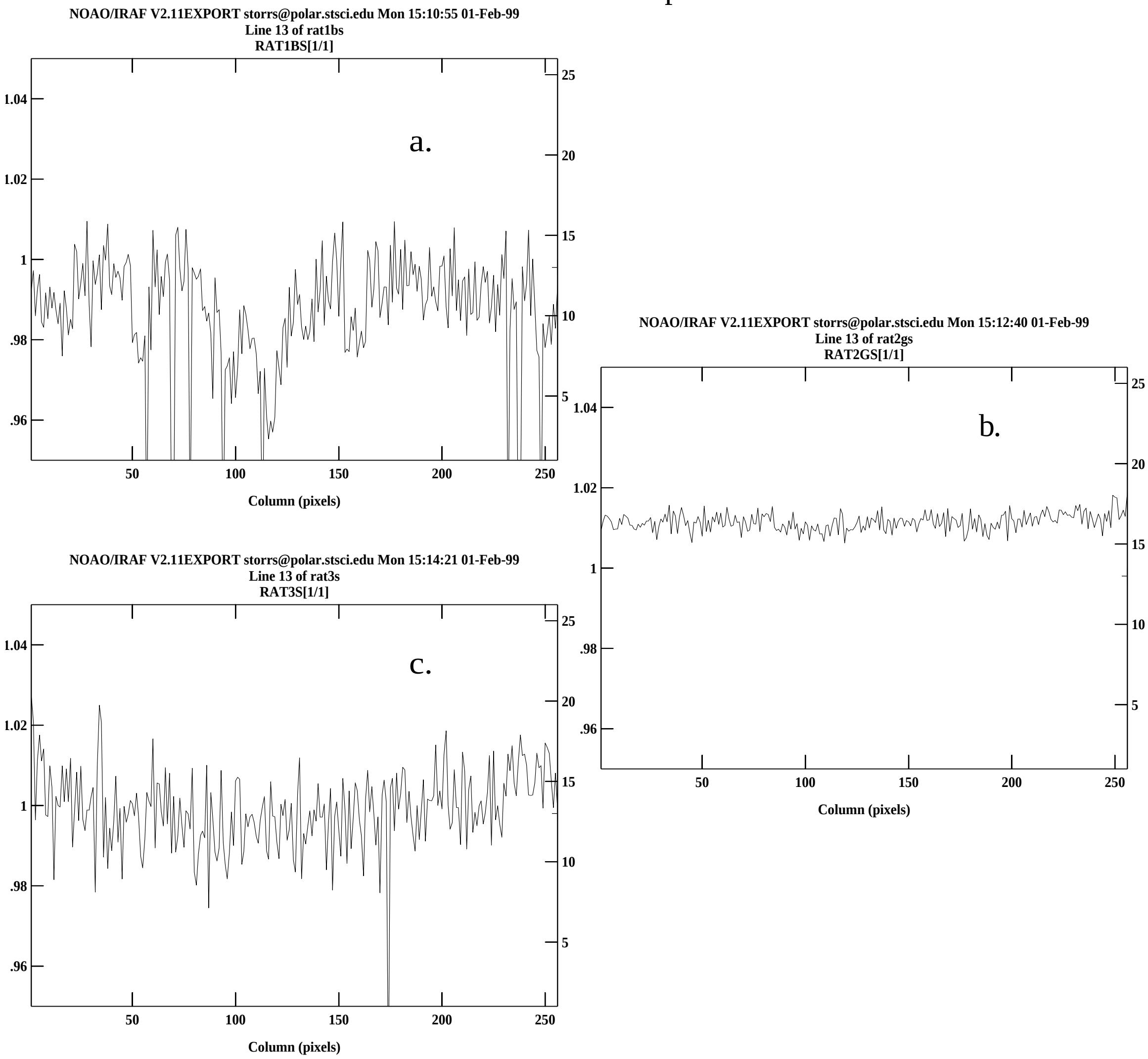
3. Creation of interpolated flatfields

The linear least squares fitting of the flatfields was performed as described in Bevington (1969). For camera 1, eight flats were used: F095N, F097N, F108N, F113N, F164N, F166N, F187N, and F190N. For camera 2, eleven flats were used: F165M, F171M, F180M, F187N, F190N, F204M, F207M, F212N, F215N, F216N, and F222M. For camera 3, ten flats were used: F108N, F113N, F164N, F166N, F187N, F190N, F196N, F200N, F212N, and F215N. The camera 2 F237M flat, and the camera 3 F240M flat were not included in the linear fit due to their non-linear response (see discussion above) but are included in Figure 1.

The linear least-squares fit resulted in two images for each camera: one for the zero-wavelength intercept of the linear fit, and one for the slope. A given wavelength (in microns) is multiplied by the slope image and the intercept image is added to it to get an interpolated flatfield. An STSDAS script to do this is described in Appendix A. It should be emphasized that this works best if the flatfield is interpolated-- the wavelength desired should lie within the wavelength range of the flats used in the fit. Otherwise, errors in the fitting may lead to erroneous flatfields. Observers with objects at extremes of the wavelength region may wish to perform a higher-order fit to the flatfield response.

Figure 2 shows a comparison between the F110W pipeline flatfields (F160W for NIC2) and interpolated flats created with this process. For cameras 1 and 3, the best fitting interpolated flats were made at a wavelength of 1.0 μm, significantly shorter than the mean wavelength of the F110W filter. For camera 2, the best fitting interpolated flat was made at a wavelength of 1.54 μm, only slightly shorter than the mean wavelength for the F160W filter (1.5931 μm). This is because the intrinsically blue spectrum of the flatfield lamp (T = 2800 ˚K has a peak wavelength of 1.03 μm) gets less pronounced at longer wavelengths, farther along the Rayleigh-Jeans tail of the spectrum.

Figure 2: Ratio of pipeline flat to interpolated flat: a., NIC1 F110W, b., NIC2 F160W, c., NIC3 F110W. Note variations on the order of a few percent or less.

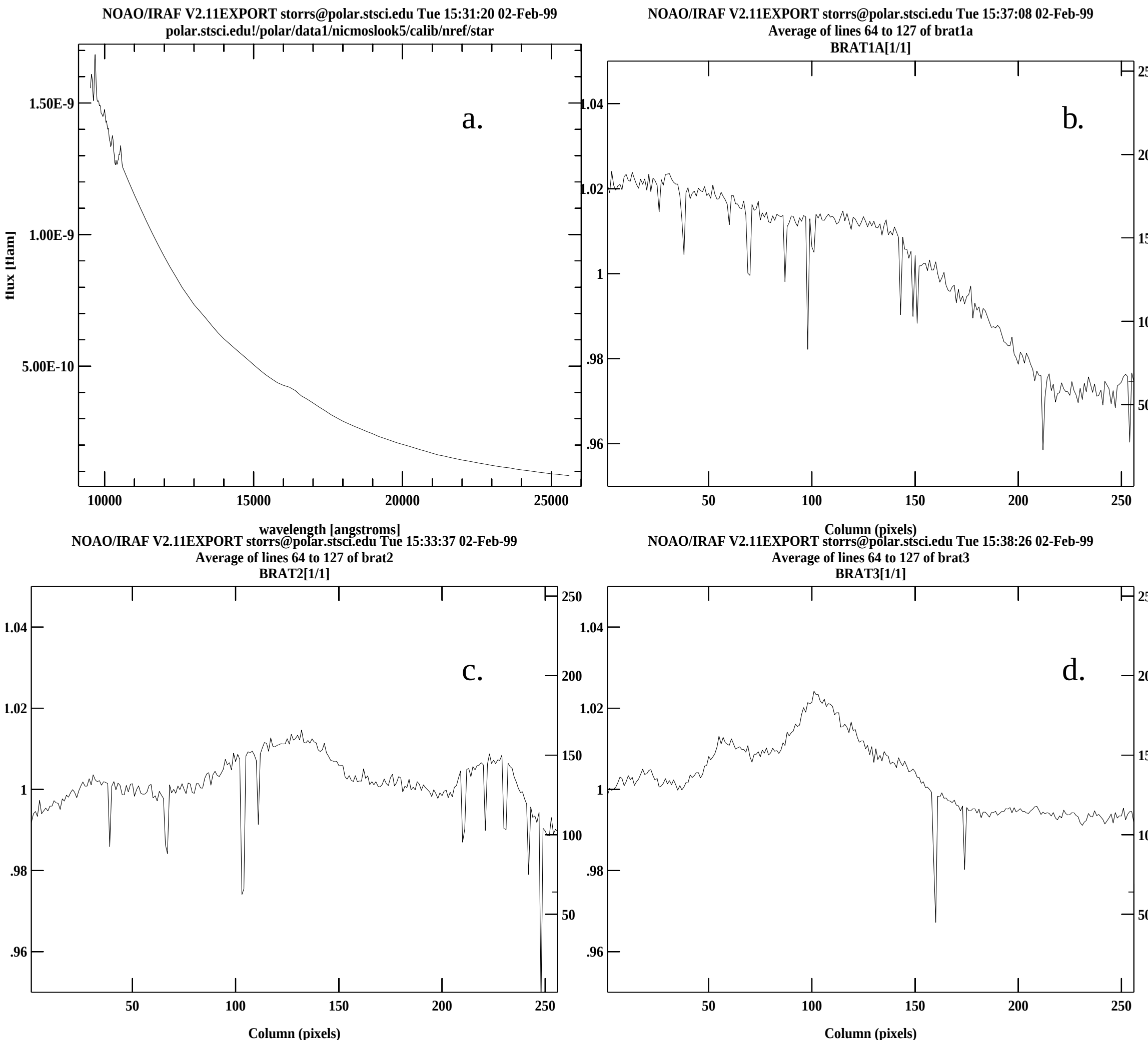


4. Creation of polychromatic flatfields

If the spectrum of the object is known, then a color dependent flatfield can be produced from the weighted sum of the narrowband flats in the bandpass used for the observation. Appendix B describes a program that will accept as input the camera, filter, and a file containing the desired spectrum. The program uses the **stsdas.synphot** task to multiply the source spectrum by the camera and filter response, and then determines the relative response in each narrowband (and for camera 2, medium band) filter. The pipeline flat for that filter is multiplied by the normalized response and the result summed. As with the monochromatic flats, this process produces a flatfield that can either be used to recalibrate the entire image, or ratioed to the pipeline flat used for the image and applied to selected regions of the image. A process similar to this (implemented using IDL) was successful in reducing some of the Hubble Deep Field data.

Some comparisons between polychromatic flats and pipeline F160W flats are shown in figure 3. The first panel shows the spectrum used to generate the flats, a typical late-F main sequence star. The next three panels are comparisons of flats for an object with this spectrum, observed through the F160W filter in each camera, to the pipeline broadband flat. The deviation is typically only a few percent, which is expected given the relatively flat spectrum in the region around 1.6 μm.

Figure 3: Comparison of polychromatic and pipeline flats. a., the input spectrum (a late-F V star), b., ratio of pipeline F160W to polychromatic flat in camera 1, c., ratio of pipeline F160W to polychromatic flat in camera 2, d., ratio of pipeline F160W to polychromatic flat in camera 3.



5. Conclusions

Observers of fields of objects with extreme colors should reprocess their data along the lines described in Chapter 7 of the NICMOS Instrument Handbook. If they have data on the crude colors of the objects (e.g. narrowband filter images at longer and shorter wavelengths than the broadband image) these may be used to create a color map. Color dependent flat fields, made in either manner described above, can be ratioed to the pipeline flat and the broadband image multiplied by the various ratio flats depending on the color of the objects. If no a priori color information is available, the observer may wish to make several interpolated flats, and multiply the broadband image by the ratio of these flats to the pipeline flat, to see which does the best job of minimizing structure that looks like the flatfield. Failing all this, the observer may want to get in touch with their contact scientist to try to determine how best to analyze their data.

Which method is chosen depends on the signal-to-noise desired. The monochromatic flats combine information from all narrowband flats (save the reddest) and some medium band flats (for NIC2) and thus should have a much better (factor of three) SNR than any individual flat. In addition, the calibration files for this method (the slope image and the intercept image, for each camera) are small, and can be used by a variety of systems (e.g. IDL) to produce a good flat. The polychromatic system requires STSDAS, although there is an IDL implementation that works at STScI. Either implementation requires the suite of narrow and medium-band flatfields, which may be a problem for observers with limited disk space. Also, the SNR depends on the linear combination of only a few flats, leading to an increase of a factor of two or so.

Calibration files and IRAF scripts are available from the NICMOS web page. Follow the “Instruments” link on http://www.stsci.edu and click on “NICMOS”. Look under the “Calibration” category. After downloading the desired script (and reference data if necessary) install it from within IRAF by typing “task interflat = interflat.cl” for the monochromatic program, and “task bandflat = bandflat.cl” for the polychromatic program. Either script can be easily altered by the user to fit your needs. For example, each script does a great deal of work to produce a multigroup FITS file similar to the pipeline flats. If the observer just needs the flatfield (and not the error, DQ, etc. images) much of the scripts can be commented out. For example, the “interflat.cl” script doesn’t use the pipeline reference files except to make the multigroup headers and error files. If those sections of the script are deleted (and the output line appropriately revised) the observer will need only the slope and intercept images for the desired camera to generate monochromatic flat fields.

6. References

Bevington, P.R. (1969): Data Reduction and Error Analysis for the Physical Sciences, McGraw-Hill Publishing Co., New York, p. 104

7. Appendix A

The script “interflat.cl” is an IRAF/STSDAS script that will accept the NICMOS camera number (1, 2, or 3), the desired wavelength for the interpolated flat (in microns), and the name of the output file. It will do the linear interpolation by multiplying the slopeN file by the wavelength and adding the interceptN file to that product, where N is the camera number. These files will be available from the STScI NICMOS web site, or from your CS.

8. Appendix B

The script “bandflat.cl” is an IRAF/STSDAS script that will take an input spectrum and camera and filter, and produce an average of narrowband flats weighted by the expected contribution of the source. Note that stsdas and synphot must be implemented, and the NICMOS flatfields stored in a directory with IRAF alias nref$ and the pipeline flatfield filenames must be as in the calibration database. The script will be available from the STScI NICMOS web site, or from your CS.