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Combining NICMOS Parallel Observations

A. B. Schultz[1] and H. Bushouse

Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

Abstract. Two problems when working with NICMOS parallel observations are combining the images into mosaics and removing the telescope thermal background from the impacted filter images for wavelengths greater than 1.7 microns. We describe a useful technique to combine parallel observations into associations, which then allows for automated mosaicing and background removal using the NICMOS pipeline task **calnicb**. We demonstrate the technique using parallel NICMOS K-filter images of a region near the galactic center.

1. Introduction

The majority of NICMOS observations in the *HST* Archive are obtained in parallel to other instruments onboard *HST* and not pointed observations of specific targets obtained as part of a General Observer (GO) science program. Some of these parallel observations are *coordinated parallel* observations associated with the primary science observations, while others are *pure parallel* and are unrelated to the primary science observations. Many parallel observations have no proprietary period and are available to the general science community within a day or two of arrival on the ground.

In this report, we present a method to combine individual parallel observations into an association so that **calnicb** can be used in creating a mosaic of the images. And, we address the problem of removing the thermal background from observations obtained with the thermally impacted filters ($\lambda > 1.7$ μm).

2. The Data Set

As part of the Cycle 11 calibration program to determine the stability of the *HST*+NCS+NICMOS thermal background (program ID: 9269), NIC3 F222M filter observations are obtained in parallel to other *HST* instruments. It is this data set that we will use to demonstrate how to group parallel observations into associations. In particular, a star field near the galactic plane was observed with NIC3 in parallel to the prime STIS/CCD science observations of W-SGR (program ID: 9105), a binary Cepheid variable (HD164975).

Any targeted NICMOS F222M filter observation will need a background observation, preferably of equal exposure and of a blank field, to remove the thermal background of the telescope from the data. We will use exposures of a sparse field from the extended set of observations for program 9269, which were obtained close in time to the star field images, as the background data set. For this example, eight exposures each of the star field and the background will be used to produce a mosaic. Both data sets were calibrated using the standard STScI data pipeline program **calnica**. **Calnica** removes the instrumental signature from the individual exposures. The calibration steps for NICMOS data are described in

[1]Science Programs, Computer Sciences Corporation

the *NICMOS Instrument Handbook* (Malhotra et al. 2002) and in the *HST Data Handbook* (Mobasher et al. 2002).

In the *HST* ground system, a proposal exposure line that yields multiple exposures will automatically trigger the creation of an association for those exposures, including the creation of an association table that lists the names of all the individual exposures. The association table is then used as input to **calnicb**. Exposures obtained individually do not trigger the automatic creation of an association table, therefore it must be created by hand in order to process those data through **calnicb**. Note that not just any random collection of images can be processed with **calnicb**, as **calnicb** does not handle rotations amongst images, only simple x/y (RA/Dec) translational shifts. Any rotation between images must be removed before processing with **calnicb**.

2.1. Science Header Keywords

A few keywords in the headers of calibrated files (ipppssoot_cal.fits) need to be modified to enable **calnicb** processing of the parallel observations. If images are only to be stacked with no pattern, then only the NUMITER keyword needs to be modified to reflect the number of images to be stacked.

For the example discussed here (target and background), five keywords need to be modified. The keywords PATTERN1, P1_NPTS, PATTERN2, and P2_NPTS only need to be set in the header of the first image listed in the association table, as they are assumed to be constant in all images. The keywords PATTERN2 and P2_NPTS will most likely need to be added to the header as they are omitted for single exposures. The PATTERN2 and P2_NPTS keywords indicate that a secondary pattern was used; such as, a chop pattern. The PATTSTEP keyword will need to be set to a unique value in each image header.

The pattern type (PATTERN1 and PATTERN2) should be an accepted NICMOS pattern as defined in the Phase II instructions. For collections of images that contain both target and background exposures use one of the "CHOP" pattern types; such as, "NIC-ONE-CHOP". In the case for just target images, one of the dither pattern types; such as, "NIC-SPIRAL-DITH" will work. The PATTERN1 and PATTERN2 keywords are set to the same value.

The value of the P1_NPTS keyword needs to be the total number of pattern positions observed, while the P2_NPTS keyword value will depend upon the pattern selected. For this example, the NIC-ONE-CHOP pattern was selected as the target and background exposures will only be stacked. The P2_NPTS keyword needs to be set to a value of "2".

The PATTSTEP keyword must be set to a monotonically increasing number, starting with 1 for the first image in the pattern up through (P1_NPTS $\times$ P2_NPTS) for the last image. The necessary pattern keywords and their respective values are shown below.

```
> hedit n8c2f8pvq_cal.fits[0] P2_NPTS 2 add+
>imhead n8c2f8pvq_cal.fits[0] l+
...
              / PATTERN KEYWORDS

PATTERN1= 'NIC-ONE-CHOP'        / primary pattern type
P1_SHAPE= '                   ' / primary pattern shape
P1_PURPS= '                   ' / primary pattern purpose
P1_NPTS =                     8 / number of points in primary pattern
P1_PSPAC=              0.000000 / point spacing for primary pattern (arc-sec)
P1_LSPAC=              0.000000 / line spacing for primary pattern (arc-sec)
P1_ANGLE=              0.000000 / angle between sides of parallelogram patt (deg)
P1_FRAME= '          '          / coordinate frame of primary pattern
P1_ORINT=              0.000000 / orientation of pattern to coordinate frame (deg)
P1_CENTR= 'no      '            / center pattern relative to pointing (yes/no)
BKG_OFF = '   '                 / pattern offset method (SAM or FOM)
PATTSTEP=                     2 / position number of this point in the pattern
```

```
PATTERN2= 'NIC-ONE-CHOP'
P2_NPTS =                  2
```

3. The Association Table

An association table (i.e., ipppssoot_asn.fits) is stored in a FITS file, in a FITS binary table extension. It contains a list of the members in the association, relevant information on the exposures (target or background), and the name of the output product (ipppssoot_mos.fits). For example, the association table n626s4020_asn.fits displayed below contains three rows, consisting of the names of the two exposures and the output product name.

```
        > tread n626s4020_asn.fits
Column       1              2            3
Label  ___MEMNAME____ ___MEMTYPE____ MEMPRSNT
     1 N626S4DCQ      EXP-TARG       yes
     2 N626S4DFQ      EXP-TARG       yes
     3 N626S4020      PROD-TARG      yes
```

The easiest way to create an association table for non-association exposures is to copy an existing table and use the ttools package task **tedit** to edit the table entries. The task **tedit** allows the user to add or delete rows and to edit individual row entries. There should be a row for each exposure and a row for the output product. For the following example, there are eight rows for the target and background images and two rows for output products.

```
        > tedit n8c2f8010_asn.fits
Column       1              2            3
Label  ___MEMNAME____ ___MEMTYPE____ MEMPRSNT
     1 N8C2F8PVQ      EXP-TARG       yes
     2 N8C2F8PWQ      EXP-TARG       yes
     3 N8C2F8PXQ      EXP-TARG       yes
     4 N8C2F8PYQ      EXP-TARG       yes
     5 N8C2F8PZQ      EXP-TARG       yes
     6 N8C2F8Q1Q      EXP-TARG       yes
     7 N8C2F8Q4Q      EXP-TARG       yes
     8 N8C2F8Q5Q      EXP-TARG       yes
     9 N8C2GLE8Q      EXP-BCK1       yes
    10 N8C2GLE9Q      EXP-BCK1       yes
    11 N8C2GLEAQ      EXP-BCK1       yes
    12 N8C2GLEBQ      EXP-BCK1       yes
    13 N8C2GLEEQ      EXP-BCK1       yes
    14 N8C2GLEFQ      EXP-BCK1       yes
    15 N8C2GLEIQ      EXP-BCK1       yes
    16 N8C2GLEJQ      EXP-BCK1       yes
    17 N8C2F8010      PROD-TARG      yes
    18 N8C2F8011      PROD-BCK1      yes
```

Calnicb will create separate output products for the star field and the background, stacking and averaging the images since no dithering was performed. **Calnicb** also performs background subtraction and source identification on the images in the association.

```
> calnicb n8c2f8010_asn.fits
```

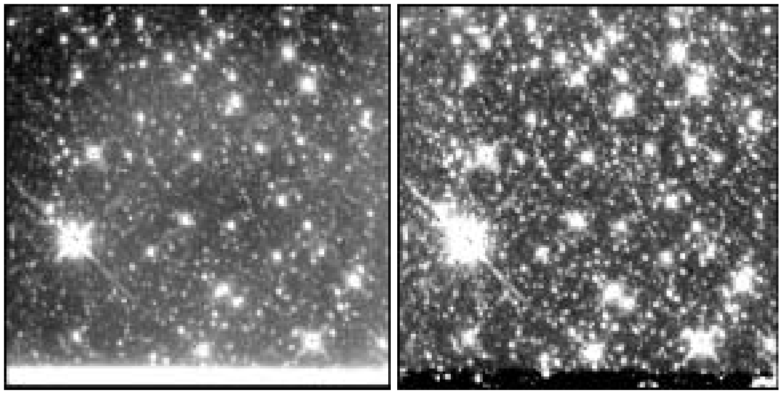

Figure 1. NIC3 F222M filter parallel imaging of the galactic plane, (left) the calibrated star field image and (right) the star field with the thermal background subtracted. In practice, the field stars in the background images should be removed before the subtraction. The total integration time was $(8 \times 128 =)1,024$ seconds. The band along the bottom of the images, about $\sim$ 15–20 rows wide, is due to vignetting by the FDA mask.

For this example, the resulting background sky image contained a few point sources which were removed by median filtering before subtracting it from the star field image. The mstools package task **msarith** was used to perform the subtraction in order to properly propagate the data quality and error arrays of the multi-IMSET files.

```
> msarith n8c2f8010_mos.fits - n8c2f8011_mos.fits starfield_bck
```

4. Discussion

The combined F222M filter image and the same image with the background subtracted are presented in Figure 1. The parallel NICMOS images revealed a couple of dozen bright stars in front of a densely packed background of faint stars, thus demonstrating the usefulness of the above technique to combine parallel observations into a single association.

References

Malhotra, S., et al. 2002, "Near Infrared Camera and Multi-Object Spectrometer Instrument Handbook," Version 5.0, October 2002 (Baltimore: STScI)

Mobasher, B., et al. 2002, "*HST* Data Handbook for NICMOS," Version 5.0, January 2002 (Baltimore: STScI)