

# DOLPHOT/NIRCAM User's Guide

version 2.0

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October 2022

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# 1 Introduction

This manual describes installation and use of the NIRCAM module for DOLPHOT. The NIRCAM module replaces the analytic PSF model with a lookup table computed using WebbPSF.

If you have any problems installing or using DOLPHOT or the provided utilities, please let me know.

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## 2 Installation

Installation of the NIRCAM module is done in addition to the regular DOLPHOT installation. See the DOLPHOT manual for installation instructions for DOLPHOT.

The NIRCAM module requires less than 1Mb for the sources and binaries, plus less than 1Mb per set of PSFs. Note that the PSFs are distributed separately, as you only need PSFs for the filters that you will actually be using.

The .tar.gz file for the NIRCAM module (as well as the PSFs) should be expanded from the same directory from which the DOLPHOT distribution was expanded.

### 2.1 Makefile

The Makefile is the same as the regular DOLPHOT installation, but includes several options used by the NIRCAM module. To enable the NIRCAM module, the three lines beginning with the NIRCAM definition should be uncommented.

No customization of the Makefile within the “nircam” subdirectory is needed.

After editing the makefile, you should be able to type “make” to compile DOLPHOT without any error or warning messages. Should you need to later recompile the programs, typing “make clean” will remove the original compilations to ensure that all programs get recompiled.

### 2.2 PSFs

You can either make your own PSFs or use the precomputed ones. Generally there is no need to generate your own, as precomputed PSFs are available for all filters. Instructions for computing PSFs are not currently available.

### 3 Preprocessing Steps

For the NIRCAM module to run correctly, data must be in the default format created by the STScI pipeline. Photometry is executed on the Stage 2 files (comparable to HST flt or flc images), while Stage 3 files (comparable to HST drz or drc) can be used as alignment reference images.

Because Stage 3 images produce suboptimal photometry (because of resampling of the images), support exists only for \_CFR and \_CAL datasets. DOLPHOT includes multiple-image support (including offset and rotation), so photometry can be run on multiple images of the same field, eliminating the primary purpose for photometering drizzled data.

This section takes you through the necessary steps (in order) for obtaining the best possible photometry from DOLPHOT.

#### 3.1 Create/Select Reference Images

If you have only one exposure per filter to photometer, and all images are taken at the same pointing, you can skip this step. Simply use your deepest image as the reference image in DOLPHOT.

It is possible that the NIRCAM reduction pipeline has already combined your images into a single Stage 3 \_I2D image per filter. If this is the case, you can also forgo any reprocessing, and use the deepest Stage 3 image as your reference frame.

Otherwise, there may be a need to generate a deep reference image in order to have sufficient depth and area coverage to align all images in your data set. Instructions on how to perform this are beyond the scope of this manual.

Once drizzling is complete, you may want to co-add the Stage 2 images taken at the same pointing using the DOLPHOT utility *imcombine*. (This can also improve cosmic ray rejection.) When you use *imcombine* for this purpose, make sure that the registration factor and sigma clipping are set sufficiently high that no additional cleaning is done, beyond the cleaning done by multidrizzle. It is also acceptable to photometer all of the Stage 2 images separately.

#### 3.2 *nircammask*: Convert to DOLPHOT Usable Format

```
nircammask <fits files>
```

```
nircammask -etctime <fits files>
```

*NIRCAMmask* takes as input FITS files in the format created by the STScI pipeline. Stage 2 processed images consist of a single 2048x2048 chip, while Stage 3 processed images may include multiple chips in the same filter, resampled into a common coordinate frame. Both Stage 2 and Stage 3 data also contain multiple extensions providing data quality, pixel area, and other data processed by *NIRCAMmask*.

The `-etctime` flag will cause *nircammask* to use the JWST ETC “start to end” calculation in place of the exposure time FITS keyword. This is recommended, though it is

suggested to run the ETC to confirm the value reported by *mirimask* matches the ETC output.

Before running *nircammask*, make sure you have backed up the original images, since *nircammask* will alter them!

A masked or saturated pixel is skipped by all other HSTphot routines - it is not used in sky determination, photometry, aperture corrections, etc.

All extensions other than SCI (the data extension) are deleted when writing the data back to disk. The output image will thus have only one extension.

### 3.3 *calcsky*: Calculate Sky for Image

`calcsky <fits base> < $r_{in}$ > < $r_{out}$ > <step> < $\sigma_{low}$ > < $\sigma_{high}$ >`

*Calcsky* is described in the DOLPHOT manual. Recommended parameters are as follows:

$$r_{in} = 10$$

$$r_{out} = 25$$

$step = 2$  for an accurate sky map, or  $step = -64$  for a quick one.

$$\sigma_{low} = 2.25$$

$$\sigma_{high} = 2.00$$

Since I always use non-zero FitSky settings in my photometry, the negative values of *step* are sufficient.

Note that running *calcsky* is currently mandatory, even if using FitSky settings of 3 or 4.

## 4 Running DOLPHOT

### 4.1 DOLPHOT Parameters

The NIRCAM module of DOLPHOT will be invoked whenever processing images that have been run through nircammask. When using the NIRCAM module, several parameters are disabled or have restricted ranges.

img\_aprad is set to 10 pixels

img\_RPSF and img\_RAper cannot exceed 24 pixels

Zero disabled (set to VEGAMAG zero points)

FPSF, SubPixel, img\_psfa, img\_psfb, img\_psfc disabled

EPSF, PSFsol, PSFStep disabled

MinS, MaxS, MaxE disabled

Recommended values for other parameters when running with `FitSky = 2` are as follows:

`PSFPhot = 1`

`PSFPhotIt = 2`

`Force1 = 0`

`img_apsky = 20 35`

`img_RAper = 5`

`img_RChi = 2.0`

`img_RSky = 15 35`

`img_RPSF = 15`

`SkipSky = 1`

`SkySig = 2.25`

`SecondPass = 5`

`SigFindMult = 0.85`

`MaxIT = 25`

`NoiseMult = 0.10`

`FSat = 0.999`

```
ApCor = 1
RCentroid = 2
PosStep = 0.25
RCombine = 1.5
SigPSF = 5.0
PSFres = 1
UseWCS = 2
```

Running with `FitSky = 2` is recommended in crowded fields. In this case, recommended parameter changes to the above are as follows:

```
img_RAper = 3
img_RSky2 = 4 10
```

If using `FitSky = 3`, the parameters are largely the same except that suggested `img_RAper` values are 8 pixels.

In some cases, blends or extended objects can hamper photometry of nearby stars. Setting `Force1 = 1` will solve this, but of course will also result in false detections of hot pixels and extended objects as single stars. So one may have to choose between a very clean but slightly incomplete CMD and a complete but contaminated one.

Finally, there are four new parameters that can be used:

```
FlagMask = 4
CombineChi = 0
InterpPSFlib = 1
NIRCAMvega = 1
```

`FlagMask` is a bitwise mask that determines what error flags will not be accepted when producing the combined photometry blocks for each filter. Note that error flag values of eight or more (when the “extreme case”) always cause the photometry to be ignored. A value of zero allows photometry with an error flag less than eight to be used. Adding one eliminates stars close to the chip edge, adding two eliminates stars with too many bad pixels, and adding four eliminates stars with saturated cores.

`CombineChi` also affects the combined photometry blocks. If set to zero (default), photometry will be combined weighted by  $1/\sigma^2$  to maximize signal to noise. If set to one, weights will be  $1/\sigma^2 \max(1, \chi^2)$  to reduce the impact of epochs with bad photometry. Note that using `CombineChi` of one will require tuning `NoiseMult` so that well measured stars have  $\chi = 1$  at all magnitudes (plots of chi vs. magnitude should show this). Note also that this will result in larger uncertainties for combined (but not individual



image) magnitudes and normalized count rates, as the individual image uncertainties are effectively multiplied by  $\chi$  when calculating combined magnitudes.

If InterpPSFlib is set to 0, the PSF library will use the nearest X,Y position where a precalculated PSF is available rather than interpolating. The impact is  $\approx 1\%$  on the PSF shape but some speed improvement.

If NIRCAMvega is set to 0, calibrated fluxes will be provided in units of Jy, and instrumental magnitudes in units of ABmag. Otherwise, when set to 1, Vega magnitudes are used and calibrated fluxes are scaled to for a zeroth magnitude source.

Note that the DOLPHOT/NIRCAM module does not have default distortion parameters included, but rather relies on the WCS information in the FITS file obtained from the JWST pipeline. Thus, `UseWCS = 2` is required when reducing NIRCAM data.

## 4.2 DOLPHOT Output

The DOLPHOT/NIRCAM output is virtually identical to the regular DOLPHOT output, with a few exceptions. First, if multiple images exist per filter, it will insert extra sets of photometry for each such filter (in order of wavelength) prior to the individual-image photometry. Following any combined-filter photometry are the single-image photometry blocks, in order that the images are provided in the parameter files.

Within the photometry blocks, there are also some differences. First is that calibrated instrumental magnitudes and transformed magnitudes are provided. Note that transformations are not yet supported, so the second magnitude is always 99.999 in the current DOLPHOT release. Also, a calibrated count rate and uncertainty is provided (effectively the instrumental magnitude and uncertainty expressed as a count rate).

As with all photometry, you will need to trim your detection list to eliminate objects classified as non-stellar, low signal-to-noise, or bad photometry quality. See the DOLPHOT manual for further discussion.

## 5 PSF Utility Reference

The following programs are utilities included with the NIRCAM module. Since there is little need for computing custom PSFs, no documentation is provided – use at your own risk!

### 5.1 *nircammakepsf*: Compute PSF for Filter

```
nircammakepsf <filter>
```

### 5.2 *nircamshowpsf*: Display PSF for Filter

```
nircamshowpsf <filter> <chip> <X/1024> <Y/1024> <dX> <dY> <<flags>>
```

## 6 Recipe for NIRCAM Photometry

Assuming that an appropriate reference image exists, the recipe for generating photometry is reasonably simple.

1. Run nircammask on all NIRCAM images
2. Run calsky on each image to generate \*.sky.fits files
3. Run dolphot

## 7 Changes to DOLPHOT/NIRCAM

October 16, 2022 release

1. Initial release
2. Only the filters used in our ERS program have been incorporated.
3. Caveat: zero points are not yet implemented. Photometry is output with a zero point of 1 DN/second.
4. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
5. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used.
6. Not yet tested: combined short+long wavelength photometry, comparison of observational to synthetic CMDs, and PSF time variability

October 23, 2022 release

1. VEGAMAG zero points have been implemented, but only work correctly if using the latest MJy/sr photometry calibrations
2. Only the filters used in our ERS program have been incorporated.
3. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
4. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used.
5. Not yet tested: combined short+long wavelength photometry, comparison of observational to synthetic CMDs, and PSF time variability

October 27, 2022 release

1. All NIRCAM filters have been implemented (zero points and PSFs), though only those used by our ERS program have been fully tested.
2. Caveat: VEGAMAG zero points only work correctly if using the latest MJy/sr photometry calibrations in the pipeline reduction
3. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
4. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used.

5. Not yet tested: combined short+long wavelength photometry, comparison of observational to synthetic CMDs, and PSF time variability

November 13, 2022 release

1. Updated PSFs and encircled energy corrections for F200W and longer wavelength filters
2. Caveat: VEGAMAG zero points only work correctly if using the latest MJy/sr photometry calibrations in the pipeline reduction
3. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
4. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used.
5. Not yet tested: comparison of observational to synthetic CMDs and impact from PSF time variability

November 30, 2022 release

1. Added PSFs and zero points for F150W2 and F322W2
2. Caveat: VEGAMAG zero points only work correctly if using the latest MJy/sr photometry calibrations in the pipeline reduction
3. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
4. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used.
5. Not yet tested: comparison of observational to synthetic CMDs and impact from PSF time variability

December 3, 2022 release

1. Added ability to select between flux and magnitude outputs in Vega mag vs. Jy using the NIRCAMvega parameter.
2. Caveat: VEGAMAG zero points only work correctly if using the latest MJy/sr photometry calibrations in the pipeline reduction
3. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
4. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used.

5. Not yet tested: comparison of observational to synthetic CMDs and impact from PSF time variability

March 19, 2023 release

1. Added ability to deal with NaN values now used by JWST pipeline to flag bad pixels
2. Caveat: VEGAMAG zero points only work correctly if using the latest MJy/sr photometry calibrations in the pipeline reduction
3. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
4. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used.
5. Not yet tested: impact from PSF time variability

April 6, 2023 release

1. Corrected errors in PSF library that impacted PSF variability across chips. Note users will need to re-download PSFs.
2. Caveat: VEGAMAG zero points only work correctly if using the latest MJy/sr photometry calibrations in the pipeline reduction
3. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
4. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used.
5. Not yet tested: impact from PSF time variability

October 11, 2023 release

1. Updated VEGAMAG zero points to match new recommendation of adopting the Sirius-Vega based calibration system
2. Caveat: VEGAMAG zero points only work correctly if using the latest MJy/sr photometry calibrations in the pipeline reduction
3. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
4. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used
5. Not yet tested: impact from PSF time variability

December 2, 2023 release

1. -etctime flag added to nircammask to set DOLPHOT exposure time consistently with JWST ETC.
2. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
3. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used
4. Not yet tested: impact from PSF time variability

December 21 2023 release

1. Subarray support added
2. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
3. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used
4. Not yet tested: impact from PSF time variability

February 4, 2024 release

1. Updated all PSF libraries to include higher PSF spatial sampling as well as the current WebbPSF (1.2.1), which matches empirical PSFs significantly better. Note that all PSFs need to be downloaded due to the change in format.
2. Caveat: Data Quality processing not implemented for Stage 2 images. Stage 2 pixels with SCI values of exactly zero are masked as bad pixels.
3. Caveat: All alignment and calibration data are obtained from the FITS headers; the ASDF data are not used
4. Not yet tested: impact from PSF time variability