



How to run QACITS for the Vortex Coronagraph at NIRC2 on Keck II

A Quick User Manual

Keck Adaptive Optics Note 1105

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How to run QACITS

Quick user manual

Description

The complete QACITS procedure consists of 3 steps that can be run separately or all in a row:

1) **Calibration sequence:** to acquire an off-axis PSF image and its associated sky image, and also a sky image associated with the science/optimization images.

2) **Optimization sequence:** to center the star and close the loop on QACITS with acquisition settings allowing faster acquisitions (reduced integration time and coad number, as well as sub-framed images). This loop stops as soon as the tip-tilt estimations are stable (by default, there should be 2 consecutive estimations smaller than $0.1 \lambda/D$). If this criterion is not met, the loop will stop after a maximum of 10 iterations.

3) **Science acquisition sequence:** to run QACITS in closed loop while acquiring data with the desired acquisition settings.

Calling sequences

Typical inputs:

n_sci : Number of acquisitions requested for the science sequence
tint_sci : Integration time for the science acquisitions
coad_sci : Coadd number for the science acquisitions
data_dir : Path name of the directory where the data are saved (string)
object_name : Name of the object, as written in the fits file (string)
tint_opti : Integration time for the optimization acquisitions
coad_opti : Coadd number for the optimization acquisitions
/do_calib : Force the calibration sequence

Getting starting

Open an IDL terminal (right click and in the IDL menu, click on IDL 8.1)

In the IDL console, go to the qacits directory:

```
IDL> cd, 'qacits/'
```

1) To run a calibration sequence:

```
IDL> run_qacits_calib, tint_sci, coad_sci, data_dir=data_dir
```

Note that the star should be roughly centered onto the vortex at the beginning of the sequence (not precisely, a 10 pixel range should be fine).

2) To run an optimization sequence:

```
IDL> run_qacits_opti, tint_sci, coad_sci, data_dir=data_dir, object_name=object_name
```

If you do not provide the object name, a frame will be acquired (1 coad and shortest possible integration time to minimize the time needed for the acquisition) to retrieve it from the fits file header. It is recommended to provide the object name to skip this step (be careful, it is case sensitive).

There are additional optional keywords that you can use:

```
IDL> run_qacits_opti, tint_sci, coad_sci, data_dir=data_dir, object_name=object_name,  
tint_opti=tint_opti, coad_opti=coad_opti, /do_calib
```

The optimization sequence is acquired with default values, that can be changed using the tint_opti, coad_opti and subc_opti keywords, in particular if the target is faint.

Default values are: tint_opti=0.2s and coad_opti=10.

The keyword /do_calib will force the calibration sequence to be called. If /do_calib is not set and if calibration files already exist for this target, they will be used and the calibration sequence will be automatically skipped. If they do not exist, the calibration sequence will be run automatically (no need to put /do_calib in the inputs).

A calibration sequence should better be called again if observations on a target are longer than 1h, to refresh the sky image and off-axis PSF.

3) To run a science acquisition sequence:

```
IDL> run_qacits_sci, n_sci, tint_sci, coad_sci, data_dir=data_dir,  
object_name=object_name
```

As in the case of the optimization sequence, the calibration sequence can be forced using the /do_calib keyword:

```
IDL> run_qacits_sci, n_sci, tint_sci, coad_sci, data_dir=data_dir,  
object_name=object_name, /do_calib
```

4) To run a complete sequence: calib+opti+sci

```
IDL> run_qacits_nirc2, n_sci, tint_sci, coad_sci, data_dir=data_dir,  
object_name=object_name
```

Warning: the calibration sequence will be skipped if a calibration sequence with the same star name has already been taken during the night. The calibration sequence can be forced by using the /do_calib keyword:

```
IDL> run_qacits_nirc2, n_sci, tint_sci, coad_sci, data_dir=data_dir,  
object_name=object_name, /do_calib
```

The integration time and number of coad for the optimization sequence can be set using the optional keywords:

```
IDL> run_qacits_nirc2, n_sci, tint_sci, coad_sci, data_dir=data_dir,  
object_name=object_name, tint_opti=tint_opti, coad_opti=coad_opti
```

Display windows

Two small windows will appear at the top of the screen showing the off-axis PSF and a circular pattern corresponding to the light emitted by the center of the vortex mask. If the star is not inside the window on the left, the sequence will most probably crash, and you will need to recenter the star on the vortex manually before starting the sequence again.

During the QACITS loop (optimization or science), several windows will appear and be refreshed at every iteration:

- *left*: the sub-image (sky subtracted) used by the QACITS estimator. The inner circle (radius of $2 \lambda/D$) of the image is highlighted by 30%.

- *middle*: the current estimation of tip-tilt (there are 2 different estimators: the blue vector corresponds to the estimator based on the inner part of the image, while the red one corresponds to the estimator based on the outer part of the image. The green dashed vector is the one that is currently used by QACITS – usually the red one).
- *right*: all estimations of tip-tilt. The current one is drawn in white.
- *bottom right*: estimation of the null depth (ratio of the flux integrated over the central disk (radius of $2 \lambda/D$) of the coronagraphic image and off-axis PSF).

Important notes

- The optimization/science loops can be stopped before the completion of all iterations by typing 'n' when the following message is prompted (for less than 1 sec!!!):

```
Apply correction and continue QACITS? [y/n]>
```

If the full script has been launched (run_qacits_nirc2), beware that stopping the optimization sequence will not stop the science sequence.

- If the observed target is faint, the integration time and coad for the optimization sequence should be increased in order to make the optimization more efficient, even though it will take more time.
- If the observed target is very bright ($R_{\text{mag}} < 6$?), the off-axis PSF might be saturated. In this case, the integration time for the off-axis PSF might be reduced by decreasing the size of the sub-frame. Currently, this parameter can be tuned in the qacits_nirc2_params.pro routine. To open the file:

```
IDL> spawn, 'gedit qacits_nirc2_params.pro &'
```

At line 99, the variable subc_psf can be changed to a lower value (default: 256), typically 128. Save the file, reset the IDL compiler (IDL>.res command) and run the calib sequence again.

- In case the optimization sequence does not converge and oscillate:
 - first, check that the off-axis PSF is not saturated (this has the effect of artificially increasing the gain of the correction loop).
 - the instability could be due to a currently imperfect off-load procedure of the dtcloffsets. In this case, we recommend:
 - stopping the loop
 - off-loading the dtcloffsets by typing in the nirc2 terminal:

```
modify -s ao dtclxoffset=0 dtclyoffset=0
```

- manually recenter the star using px, py or pxy commands, or the mov command in the nirc2 terminal.
 - run the optimization sequence again.
- A log file is automatically generated when acquisitions are taken by the QACITS routines (acquisitions taken using the goi command in the nirc2 terminal are not logged). This file is named as [UT-date]_nirc2_qacits.log and can be found in the folder log of the QACITS folder. The different columns, delimited by semi-colon are:
 - the acquisition number of the file
 - the UT time
 - the name of the object

- the acquisition type (sci/opt/acq/skp/psf/sky)
- the integration time
- the number of coadds
- the dtclxoffset status (if relevant)
- the dtclyoffset status (if relevant)
- the estimated tiptilt in x (if relevant)
- the estimated tiptilt in y (if relevant)
- the estimation of the null depth (if relevant)