Data Acquisition with Agile

1 Initial setup a day before your observing time

As the Agile data acquisition software is not integrated in to TUI, an observer will have to copy images over in real time on their own. In this section, I will describe the first step to take towards automating such a process and saving yourself a lot of time and effort. However please note that the steps given in this section and the next are optional and entirely at your discretion.

1. Let us suppose that you intend to copy images acquired using Agile on to your linux computer Compy. If you do not already have ssh-keys on Compy, then please execute the following command to generate them:

   ssh-keygen -t dsa -b 1024

   You will be asked whether the key should be saved as the file id_dsa in the sub-directory .ssh in your home directory. Please press Enter to continue, and you will then be asked to choose a passphrase. I strongly recommend not typing empty at this point. Please choose a passphrase (typically longer than a regular password) and enter it again when prompted.

2. Please type the following line on Compy. If you saved the file id_dsa.pub in an alternative location in step 1, then you would enter that path instead in the command below.

   ssh agile@newton.apo.nmsu.edu ”umask 077; cat >> .ssh/authorized_keys” < ~/.ssh/id_dsa.pub

   Please note the quotation marks above are double quotes. This step will ask you for the password of the user agile on newton. If you do not have this password, please call the Observatory and ask the observing specialist to disclose the password to you.

3. Find out what shell you are running on Compy by typing the command “echo $SHELL”. If you are running tcsh, then please type “ssh-agent”. If you are running a bash shell, please type “exec ssh-agent bash”.

4. Next please type the command “ssh-add” on Compy. You will now be required to enter the passphrase you chose in step 1. At this point, if you attempt to ssh from Compy to newton or scp a file from newton to Compy (running the scp command on Compy), you will no longer need to enter a password.

5. Please log on to newton as user agile and then type

   ssh name@Compy.xy.edu ”umask 077; cat >> .ssh/authorized_keys” < ~/.ssh/id_dsa.pub

   where name is your username on Compy and you will probably need the complete address for Compy. This step will require your password on Compy.

6. Please type the command “exec ssh-agent bash” followed by the command “ssh-add” on newton as user agile. You will now be required to enter a passphrase that you must obtain by calling the Observatory. After this point, you will be able to scp a file from newton to Compy without a password, running the scp command on newton. This is the reciprocal arrangement of that described in steps 1 through 4.

7. Similarly, please log on to newton as user agile and then log on to the data acquisition computer nimble as the user ccd. Please obtain both passwords from the observing specialists. Next please type on nimble:

   ssh name@Compy.xy.edu ”umask 077; cat >> .ssh/authorized_keys” < ~/.ssh/id_dsa.pub

8. Please type the word “ssh-agent” followed by the word “ssh-add” on nimble. You will now need to enter the passphrase for user ccd on nimble, which you can obtain from the observing specialists. At this point, you will be able to log on to Compy from nimble without needing a password.

   You do not have to go through this initial setup each time you observe; it has to be carried out once. The next time you observe you will only have to run through steps 3, 4, 6 and 8.

2 Setting up scripts for real time data transfer

The scripts that you will choose to run to copy images in real time depend on the exposure time you chose. Agile observers have so far shown a dichotomy and I can sub-divide them into two categories: hares and turtles. :-) A hare observer is one who will be running the instrument at exposure times of 5 s or shorter, and a turtle observer is one who will run the instrument at exposure times longer than 5 s.

A hare observer will be writing their data to the local disk nimble:/archive. Hence they will have to run a script on nimble to copy every twentieth image to nimble:/export/images/agile_data (NFS mounted disk) for the observing specialists to monitor the focus. Additionally, they will have to copy every twentieth image to their own computer to ensure that the data are satisfactory. A turtle observer can choose to write the data directly to the NFS mounted disk nimble:/export/images/agile_data and copy every single image to their own computer. Please note that you can create directories and write images to the NFS mounted disk /export/images/agile_data as user ccd on nimble, but you cannot write to this disk as user agile on newton as the access from newton is read-only.

2.1 Instructions for turtle observers

When acquiring data at exposure times in excess of 5 s, it should be safe to write the data directly to the NFS mounted disk /export/images/agile_data on nimble. This disk is cross-mounted on newton and jeppe, and the data will be readily accessible to the observing specialist. Writing a full frame unbinned image directly to /export/images/agile_data usually takes a quarter of a second, but can sometimes be as slow as a few seconds. Writing data over the network is dependent on the network speed; should you feel that the data acquisition has slowed down, please stop the program right away and start writing the data to the local disk /archive.

1. Please let the observing specialist know the sub-directory in /export/images/agile_data, where you are writing the images as user ccd on nimble, so as to allow him/her to continue monitoring focus.

2. Since you have already set up the ssh-agent as in section 1, you should now be able to copy images from newton to Compy without needing a password.
3. If you type the command “/Users/agile/Agile-software/Agile_data_scp.scr”, you will see the usage statement below on how to use this script to copy images from newton to Compy in real time.

   Usage: Agile_data_scp.scr dir_from user@hostname dir_to run_name file_seq_number file_size naptime step

   The first command line argument is the directory from where you wish to copy the data, the second argument is your user name@Compy (exactly the same as your choice in step 5 of section 1), and the third argument is the directory on Compy where you wish to place the data (you must have write permission for this directory). The next argument is the root name of the images. For example, if the images are object1.00001.fits, object1.00002.fits, and so on, then the root name is simply “object1”. Suppose you have just started acquiring the data and naturally wish to copy all your images, then you would choose the file_seq_number to be 1. However if you stopped the script and wanted to restart from object1.00219.fits, then you would choose the file_seq_number to be 219. Using the command “ls -l” on newton, please determine the size of your images and include it as the sixth argument. This real-time script will only copy those images that match this file size, and thus protect you against getting images that have only been half-written. You could choose the naptime to be equal to the exposure time or a second or two shorter to account for the transfer time between newton and Compy. If you wished to copy every image in real time, then the last argument would be 1.
4. Please also feel free to copy this script /Users/agile/Agile-software/Agile_data_scp.scr and customize it to your needs, so that you would have to give fewer arguments. Please call your custom copy by a different name and do not over-write the original script.
5. Please plan on trying out this script when you acquire dark frames prior to your telescope time. Even if you are observing during the second half of the night, you can request the observing specialist to set you up for darks or biases before your allocated time.
6. When you acquire biases or flats or any other images at short exposures, please plan on writing the data to nimble:/archive directly.

2.2 Instructions for hare observers

When acquiring data at exposure times equal to or shorter than 5 s, please plan on writing the data to the local disk /archive on nimble. Writing a full frame unbinned image to the local disk should take less than 0.02 s. There are two possible ways in which hare observers could transfer every tenth or twentieth image to the NFS mounted disk /export/images/agile_data, and to their own computer.

A. The conservative method of achieving the above would be to use the script Agile_data_cp.scr to copy every twentieth image from the local disk nimble:/archive to the NFS mounted disk nimble:/export/images/agile_data. Additionally, you would run the script Agile_data_scp.scr on newton to copy the images to Compy to help ensure that the data meets your requirements.

A1. If you simply type Agile_data_cp.scr on nimble, you will see the following usage statement:

Usage: Agile_data_cp.scr dir_from dir_to run_name file_seq_number file_size naptime step

The first command line argument is the directory from where you wish to copy the data, the second argument is the directory where you wish to place the data. For example, you may be copying images from the directory /archive/nov07/SDSS0745/ to the directory /export/images/agile_data/nov07/SDSS0745. The next argument is the root name of the images. For example, if the images are object1.00001.fits, object1.00002.fits, and so on, then the root name is simply "object1". Suppose you have just started acquiring the data, then you would choose the file_seq_number to be 1. However if you stopped the script and wanted to restart from object1.00220.fits, then you would choose the file_seq_number to be 220. Using the command "ls -l", please determine the size of your images and include it as the sixth argument. This real-time script will only copy those images that match this file size, and thus protect you against getting images that have only been half-written. You could choose the naptime to be equal to the exposure time or a second shorter. When acquiring sub-second exposures, you may want to copy every twentieth image over. When using exposure times of a few seconds, you could copy every tenth or every fifth image over. Accordingly, the step size would be 20 for sub-second exposures and ten or five for relatively longer exposures.

A2. Please do not attempt to copy more than one image at a time under any circumstances. Also, do not copy over images very frequently as you may cause the data acquisition program to slow down or crash. The code is not yet threaded, and therefore vulnerable to your activities on nimble. Please understand that Agile is conceptually different from other instruments because the camera operation is dictated by the timing pulses. The data acquisition software must keep up or crash and die.

A3. Similar to step 3 for turtle observers, please also run Agile_data_scp.scr to copy images from newton to Compy with a step size identical to what you chose above.

B. You could also choose to run a single script as user ccd on nimble called Agile_data_remote.scr to perform both tasks of copying every tenth or twentieth image to /export/images/agile_data and also to scp that image to Compy.

B1. If you type Agile_data_remote.scr on nimble, you will see the following usage statement:

Usage: Agile_data_scp.scr dir_from local_dir_to user@hostname remote_dir_to run_name file_seq_number file_size naptime step

The first command line argument is the directory from where you wish to copy the data, the second argument is the directory on nimble where you wish to place the data. For example, you may be copying images from the directory /archive/nov07/SDSS0745/ to /export/images/agile_data/nov07/SDSS0745. The third argument is your user name@Compy (exactly the same as your choice in step 7 of section 1), and the fourth argument is the directory on Compy where you wish to place the data (you must have write permission for this directory). The next argument is the root name of the images. For example, if the images are object1.00001.fits, object1.00002.fits, and so on, then the root name is simply “object1”. Suppose you have just started acquiring the data, then you would choose the file_seq_number to be 1. However if you stopped the script and wanted to restart from object1.00220.fits, then you would choose the file_seq_number to be 220. Using the command “ls -l”, please determine the size of your images and include it as the seventh argument. This real-time script will only copy those images that match this file size, and thus protect you against getting images that have only been half-written. You could choose the naptime to be equal to the exposure time or a second or so shorter to account for the transfer time between nimble and Compy. The step size would be 20 for sub-second exposures and ten or five for relatively longer exposures.

B2. Please do not attempt to copy more than one image at a time under any circumstances. Also, do not copy over images very frequently as you may cause the data acquisition program to slow down or crash.

3 Generic instructions for acquiring images

1. Please ssh to the data acquisition computer nimble with the username ccd using the command *ssh -X ccd@nimble.apo.nmsu.edu*. If you are not on site, you will have to first log on to newton and from there on to nimble.

2. Please type *pvparam* after you log on to nimble. This should allow you to see if the computer can talk to the CCD camera. This action will also initiate the cooling of the CCD if the camera has been turned on recently. The CCD cools to -40 C in about five minutes, and you should probably wait for ten minutes to be conservative before acquiring data. You do not have to worry about the output, as long as it does not resemble a series of error codes. If it does, please let the observing specialist know and refer to the trouble shooting guide on the wiki pages to discern a course of action.

3. The data acquisition program *aacq* on nimble is completely independent of telescope control. To acquire images of an object, please use TUI to slew the telescope to that object. Please type *aacq*, and you will see a usage statement.
   Usage: aacq N exptime directory image_name
   where N is the number of images you want to acquire,
   exptime is the exposure duration in seconds,
   directory is the full path for where you want to store the data (100 char max),
   and image_name will decide the names of the images (20 char max; no spaces),
   The images will be named image_name.00001.fits, image_name.00002.fits and so on.

   You can also display images during acquisition by adding an optional yes
   at the end of the command line.

   For example, you could type *aacq 10 2 /export/images/agile_data/may07/ engtst1*
   Please ensure that the directory you want to write the images to is actually present, otherwise you will get an inscrutable error message.

4. Once you give the relevant arguments, the program will guide you through various choices for the binning and windowing values, and also ask you for your preference of CCD gain. The program will then ask you to specify various keywords to include in the FITS headers. If you don't want to type this for each sequence of exposures, a short cut I use is to create a profile. For example, the command you would then use is
   aacq 100 20 /export/images/agile_data/may07/ AG0006 < /home/ccd/profile,
   where /home/ccd/profile could look like the following:

   2 2
   0 511
   0 511
   medium
   SDSS1610-0102
   16:10:33.63
   -01:02:23.3
   2000
   BG40
   ASM
   APO
   3.5m
   Agile

   The first line gives the x & y binning, the next two lines specify the windowing along x & y respectively, and the fourth line gives the choice of CCD gain from among the values: high, medium or low. All subsequent values are added as keywords to the FITS headers. These include the object name, the sixth, seventh, and eighth lines give the RA, DEC, and EPOCH values for the object, the ninth line gives the filter information, the tenth line gives the name of the observer, the eleventh line gives the name of the observatory, the twelfth line gives the size of the telescope, and the thirteenth line gives the name of the instrument.

5. Once the sequence of exposures is started, you could end it prematurely with cntl-c, and the newly modified program will be able to shut down the camera safely. No other steps are required. However there is still a point at the very beginning when the software is establishing communication with the camera, where a cntl-c will result in a complete loss of communication with the camera. I have now included a boldface warning statement informing you not to type cntl-c at that point. Should you ever manage to do so, you will have to regenerate the device /dev/rspiusb0 using the commands "rmdevrsp" to delete the corrupted device and then execute "mkdevrsp" to create a new one. You will also have to unload and reload the drivers using the commands "rmrsp" and "inrsp" respectively. None of these commands require the root password anymore, or any other password for that matter.

9. To acquire bias or dark frames when the instrument is not mounted on the NA2 port, ensure that the dark slide is in. To acquire bias or dark frames when the instrument is mounted on the NA2 port, ensure that either the dark slide is in or the port iris is closed. Then to acquire bias frames please type
   aacq 100 0 /archive/may07/calib/ Bmay16 < /home/ccd/profileB,
   where profileB may look like:

2 2
0 511
0 511
medium
bias
00:00:00.00
00:00:00.0
0000
BG40
ASM
APO
3.5m
Agile

To acquire a hundred 30 s dark frames, you would simply type
aacq 100 30 /archive/may07/calib/ Dmay16-30 < /home/ccd/profileD,
where profileD could be similar to profileB in every respect except for the word *dark* instead of *bias*.

10. Please do not display images during data acquisition when acquiring data remotely from Washington or elsewhere. But you could do so if you were on site at APO and if you were acquiring data for exposures longer than 10s or so, depending on the network speed at the time. It would however be better if you chose to get the images from nimble or newton and then display them on your own computer.

11. When acquiring data at short sub-second exposures, the most conservative approach for reliable timing would be to leave nimble alone. Our data acquisition program is not threaded code at the moment, and hence it is vulnerable to your activities on nimble.

4 Calibration Frames with Agile

4.1 Bias Frames

The bias merely refers to a positive electronic offset that is added to all pixels of the CCD image to prevent loss of low level data. This step is carried out within the electronics controller just prior to digitization. A high bias value is not harmful, but a low bias value may cause the loss of low level data. Should the bias drop to extremely low values of 20 to 30 counts for 2x2 binning, please request the observing specialist to power down the camera and increase the bias offset.

A bias frame is typically acquired as an image with a zero second exposure. It contains the dark current accrued during the readout time, apart from the bias offset. Note that for Agile, the bias value depends on the choice of binning. The observer will now be able to use an overscan strip to subtract the correct amount of bias from each image, and be largely immune to fluctuations in the bias. Since the readout for Agile is extremely fast, it takes only 46 s to acquire a hundred bias frames. An observer could generate a master bias frame from the set of hundred biases, and then simply store just the master frame, deleting the rest to save disk space.

4.2 Dark Frames

The Agile CCD is cooled to -40 C and we measure a dark current of 6.8 counts/s for each unbinned pixel. This instrument is meant to be used with short exposures, and hence we can get away with cooling the CCD to -40 C, relatively warm compared to other instruments. The dark current with nxn binning should be n^2 times 6.8 counts/s per binned pixel. Dark frames are typically acquired using the same exposure time as the images they are meant to be subtracted from. Dark frames can be acquired prior to the allocated telescope time or right after as the instrument need not be mounted at the telescope to acquire bias or dark frames.

4.3 Dome Flats or Sky Flats

There is no special arrangement to acquire flats with Agile; it is essentially the same as with all other instruments. When acquiring flats with a short exposure time, please plan on writing the data to the local disk nimble:/archive directly. As the data acquisition program runs, you will notice that for each acquired image, the program prints out the value of the center pixel. This number is an instantaneous indication of the counts in the flat that you can use to adjust the exposure time. You should of course copy a few images over and verify explicitly that you are indeed getting the counts you desire.

When acquiring skyflats at dusk, please wait till the counts in a one second exposure are about 35000 counts/pixel. At that point, please initiate a series of 200 one second exposures. There are high chances that you will obtain more than a hundred good skyflats with this method. Possibly even all two hundred skyflats may meet your signal-to-noise requirements. Similarly to acquire a large number of good skyflats at dawn, please initiate a series of 200 one second exposures when the counts of a one second image reach about 8000 counts/pixel. When acquiring these skyflats, please ensure that the telescope is not tracking and that the stars are reasonably focused.

5 Choosing CCD gain

The photons incident on a CCD are converted into electrons due to the photoelectric effect. The CCD gain effectively decides how many counts or ADU (Analog to Digital Units) we get for the accrued electrons. It should be chosen so that the counts from the objects of interest are within the linear range of the CCD, and utilize the dynamic range fully. Please refer to the instrument characterization document for exact values of gain; I have only quoted approximate values for the examples below.

Suppose a bright star observer was getting 50000 counts/pixel at the peak of the stellar profile in a one second exposure at the default setting of medium gain $\sim$2. Should this observer switch the CCD gain to low $\sim$1, he/she will now derive about 25000 counts at the peak pixel during the one second exposure. This lower value is well within the linear regime of the CCD, and allows the observer to continue acquiring data at the same exposure time. This observer could also choose to expose the CCD for 0.5 s instead to reduce the counts, but would end up increasing the effect of read noise in his/her data as he/she would be reading out twice in a second instead of once a second with the low gain setting.

Similarly, suppose another observer was acquiring 10000 counts/pixel at the peak pixel of his/her star. This observer could either increase the exposure time by two or simply increase the gain from medium $\sim$2 to high $\sim$4. Perhaps increasing the exposure time may cause this observer to lose time resolution if he/she was studying variable phenomena. The observer could thus use the CCD gain to his/her advantage to get a higher count rate, utilizing the dynamic range well, and without decreasing the effective time resolution.

On the other hand, consider an observer with a faint target and relatively bright comparison stars. This observer could switch the CCD gain to high, but perhaps such an action would bring the bright comparison stars in the nonlinear regime of the CCD or close to saturation even. The observer could switch to low CCD gain as in the first example, but that could bring his/her target star of interest to very low counts. It would be better for such an observer to stay with the default choice of medium gain, so as to get reasonable counts for both the faint target star and the brighter comparison stars.

6 Choice of Read Rate

The Agile CCD camera is capable of two read rates: the default fast read rate of 1 MHz and the slow read rate of 100 KHz. The fast read rate yields an observer high time resolution, while the slow read rate yields lower read noise. The data acquisition program will determine the readout time at 100 KHz for a full frame for the binning selected by the observer. Should this value be smaller than the chosen exposure time, the program will automatically switch to the slow read rate of 100 KHz for lower read noise. However if the exposure time is smaller than the readout time at 100 KHz, then the program will stay with the default fast read rate of 1 MHz. For example, suppose an observer chooses 2x2 binning to acquire data. The readout time for a 2x2 binned full frame is about 3.1 s at the read rate of 100 KHz. Should the observer choose an exposure time longer than or equal to 3.2 s[1], the program will switch to the slow read rate of 100 KHz. Else it will stay with the default fast read rate of 1 MHz provided the exposure time is at least 0.5 s long.

The read noise is about 9.2 ē RMS at 1 MHz, and 3.9 ē RMS at 100 KHz. We expect that faint stars observed in dark or grey conditions should be dominated by read noise. This feature of the CCD camera should thus allow us to improve the signal-to-noise for faint stars especially. Should the observer want to force the CCD camera to read out at the fast rate of 1 MHz, then he/she could add the flag FORCE-FAST-MODE as the last command line argument given to the data acquisition program. However the observer should not do so without good reason.

[1]We require that the exposure time be 0.1 s longer than the readout time at 100 KHz to conservatively account for the jitter in readout time. Note that the jitter in readout is irrelevant in the context of timing precision as Agile has a frame transfer CCD.