Manual stacking with Stellina

V 1.1.1, by Capitaine Nautilus

Introduction

"Manual stacking" is the process of taking the individual images captured by Stellina and stacking them yourself in a specialised application. This is automatically done by Stellina on the fly and generates the JPEG and TIFF images obtained in Stellinapp. This document is not a full-fledged tutorial but rather a *modus operandi*, a series of steps that will help you on your way. I know that it is difficult to find how to do it but once you know the tricks, it is easy. If you want to have a deeper understanding of the processes, I invite you to read DeepSkyStacker's documentation.

Stacking does not produce any ready-to-see image. The TIFF you get will be mostly black. You will need to "develop" it in an image processing software (like Affinity Photo, Photoshop or Pixinsight). This document will not cover this part as there are already many tutorials explaining this, e.g. the tutorial for processing Stellina's TIFF on Vaonis website.

This document is aimed at Stellina's users. Stellina is an automated astrophotography station that collects, stacks and processes images of the deep sky. All along this document, I shall use Stellina terminology. However, this document could probably be useful for all kinds of systems that capture raw images of the sky.

English is not my first language so I apologize in advance for any mistake or awkwardness in my style. I decided to use this language so that it would be readable by a maximum of Stellina users.

Why do it manually?

Manual stacking adds quite a bit of hurdle to the process of getting a picture out of Stellina. Why bother? Here are, for me, the main reasons, by decreasing order of importance:

1. It allows you to collect data over several nights, thus reaching a much higher number of images.
2. It produces images in full resolution (6MP) instead of half, and in 32 bits instead of 16 (TIFF) or 8 (JPEG)
3. You have total control about which images you stack. Stellina does an incredible job of rejecting bad images… but it also accepts some that you might want to remove.
4. You are no longer faced with the dilemma of restarting or not a capture when Stellina warns you that the temperature has dropped by more than 3°C. Just refocus and restart the capture, and you'll stack both sessions together. I never wait until Stellina warns me. As soon as I see the temperature dropping by one degree or more, I refocus.
5. You can leave Stellina to collect data all night long while you are sleeping. It will close itself automatically when the sky becomes too clear at dawn and the images will be waiting for you on the USB key.

Hardware and software needed

Mandatory

- Stellina, or another telescope with a sensor that captures images.
- An USB key of at least 32 GB to collect those images
- A computer running Windows to process the images. You need a lot of RAM, of processing power (having several processors will help a lot) and of hard disk capacity.
- An application to stack the images. There are several. Here we shall use DeepSkyStacker, from now on named **DSS**. This application is free. It runs on Windows only.
- Time. Selecting the images takes time. Stacking them takes time (although you don't need to be present). Developing the resulting TIFF takes time. Each picture is the result of a lot of work, typically several hours.

Optional

- An application that can read big files without crashing, like Notepad++. I use it to read the header of the FITS.

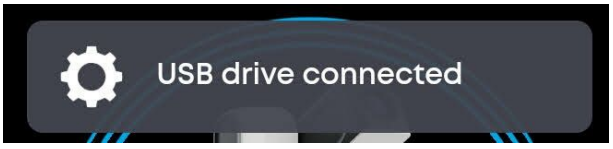
- Python to automatise the FITS selection process.

Some terminology

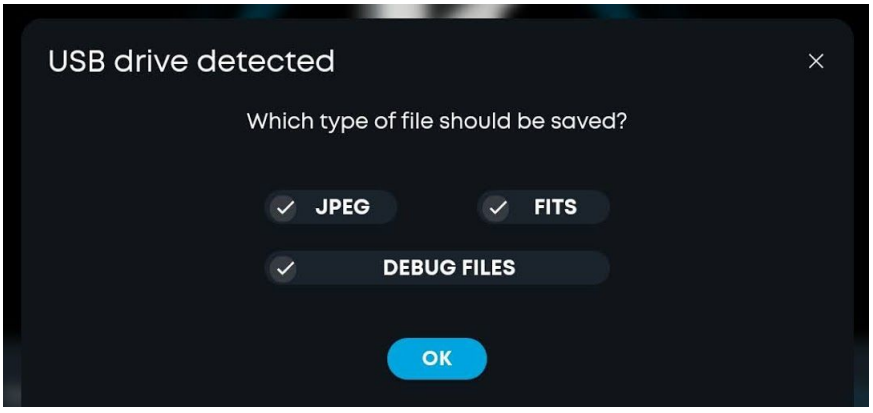
- **FITS**: format of the brute images collected by Stellina, the ones you are going to stack. Often used to represent the images themselves.
- **Light frames**: images containing the data you want to see and stack. In Stellina, they are in the FITS format
- **Dark frames**: images without any exterior signal. They only contain sensor noise. They look like black images with random coloured pixels. Using darks is optional. It allows removing sensor noise from the final image, thus improving its quality. Dark frames are specific to the sensor, you can't use the dark frames from another Stellina.
- **Flat, bias, offset frames**: As we can't (yet?) collect those images with Stellina, we won't discuss them. They are other ways to purify the signal from the sky.
- **File list**: List of light and dark images, saved for reuse in DSS.
- **Registering**: image analysis that prepares your lights and darks for selection and stacking. You only need to register each FITS once.
- **Stacking**: mathematical process that combines lights to increase the signal-to-noise ratio, thus producing a better image of dark objects.
- **Bayer pattern**: Red-green-blue pattern of the matrix filter used to produce colour images from sensors that can only measure the intensity of light. Stellina only uses two Bayer patterns: "BGGR" and "RGGB".

Collecting images

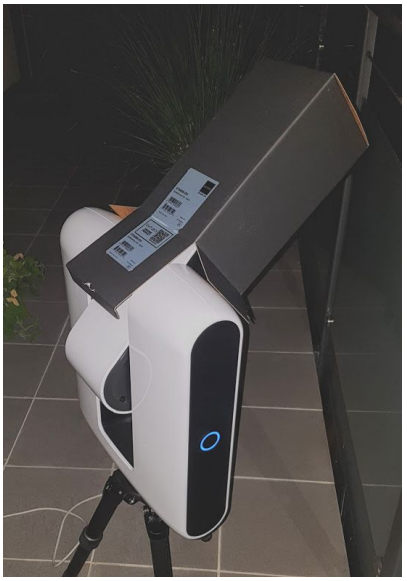
Before powering up Stellina, plug your USB drive in the telescope. Switch it on, connect Stellinapp. If the USB drive is recognized, you should get this dialog box:



Tap on it and ensure that all the boxes are checked, like this:



Debug files are optional. If you want to use my Python script for FITS selection, you'll need them. Otherwise, you can leave it unchecked.



Collecting Light frames

Proceed with your capture as you would normally.

Once finished, close Stellina, unplug it, and carry the USB drive to your computer.

Taking Dark frames

Taking dark frames is optional. You may ignore this section for your first tries.

After about 30 to 45 minutes of capture, place a dark object over Stellina's arm to block all light from reaching its sensor. The cardboard box of Stellina's Gitzo tripod fits perfectly (see picture). Leave it like that for 5 to 10 minutes. You can then continue with your capture normally. The FITS collected during that period will be your darks.

You only need to do that about once per season, as darks depend only on external temperature (as long as you cannot change gain and exposure time in Stellina). However, you will need to get darks for RGGB and BGGR Bayer patterns. So you must repeat that operation on two objects which you know what pattern they use. That can be a bit tricky…

Importing FITS into DSS

First, copy the FITS from your USB key to your harddrive. The files you need are in the folders that contain "capture" in their name. Each time you start a new capture or do a refocus you get a new folder. For instance:

K:\stellina-a8f7dc\309\2020-07-04_22-26-20-observation-IC59\22-27-40-capture-initial

K:\stellina-a8f7dc\311\2020-07-06_23-59-11-observation-C9\00-05-55-capture-adjust-framing

K:\stellina-a8f7dc\311\2020-07-06_23-59-11-observation-C9\00-10-31-capture-adjust-focus

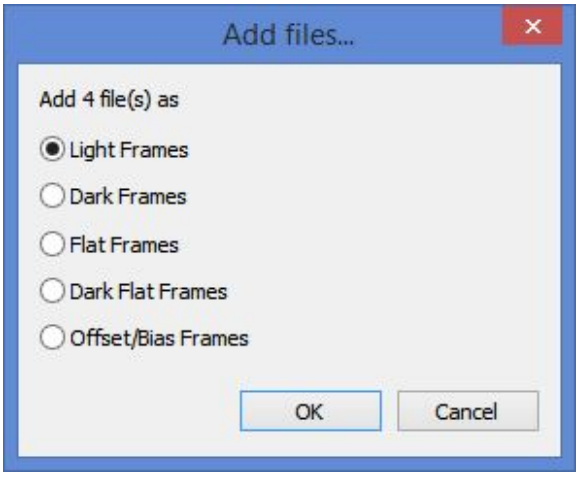
You may ignore the other folders.

Copy all the files in those "capture" folders to your hard disk. The files you'll need for the stacking are the *.fits. You'll also find the JPEG and TIFF there (if you chose to save them) but you will not need them for the stacking. Those are ALL the images captured by Stellina. Some were bad (because of a cloud, bad tracking or whatever reason) and Stellina did not use them for its automatic stacking. The FITS that were stacked have a corresponding JPEG (same number).

Your dark frames, if you took any, are among those that were not used.

A way to automatise this process is to use the Python script I uploaded on Stellina's Facebook.

Now, open DSS, then drag and drop all the *.fits images into it. Do NOT use the "Open picture files" as this can only upload up to 500 files at a time. Dragging and dropping ensures you use all your FITS. After some time, DSS asks you what type of frames those are. Select "Light frames":

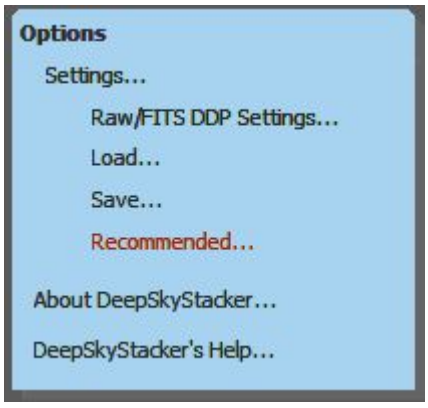


You need now to know which is the Bayer pattern of those FITS. If you used my Python script, the Bayer pattern will be indicated in the name of each FITS. If not, you must open one of the FITS in Notepad++. The first part of that file is called the header and contains information about the capture. Look for "BAYERPAT=" and you'll see what pattern is used:

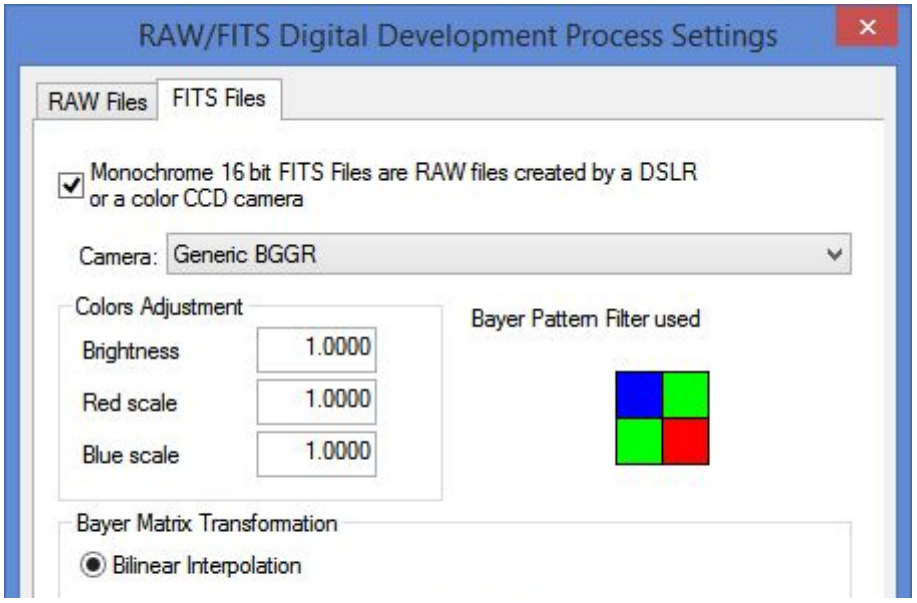
```
SIMPLE  =                    T / Standard FITS                                  BITPIX  =
16 / # bits/pixel                                NAXIS   =                    2 /
Dimensions                                  NAXIS1  =                 3072 / Picture
width                                NAXIS2  =                 2080 / Picture
height                               EXTEND  =                    T / Extensions are
permitted                       BZERO   =                32768 / offset data range to that of unsigned
short    BSCALE  =                    1 / default scaling factor                     DATE-OBS=
'2020-07-07T00:10:44' / Capture time (UTC)                        INSTRUME= 'stellina-a8f7dc'    /
STELLINA by Vaonis                           BAYERPAT= 'RGGB    '           / Bayer
pattern                                EXPOSURE=                10000 / [ms] Total Exposure
Time                         GAIN    =                  200 / Sensor gain
OFFSET  =                    200 / Camera brightness parameter                  TEMP    =
29.1 / [C] Sensor temperature                PIXSZ   =                  2.4 / [um] Pixel
size                              FOCAL   =                  400 / [mm] Focal
length                            WB_B    =                   77 / White balance
(blue)                         WB_R    =                64 / White balance
(red)                          COMMENT STELLINA by
Vaonis
END
```

In my case, most of the time it is BGGR, possibly because I'm mostly taking eastward and southward pictures. When an object is close to the zenith, its pattern switches to "RGGB". Usually however, the same pattern is used for all the FITS of a session. DSS will warn you if the pattern changes among the FITS.

In DSS, in the "Options" panel on the left, click on "Raw/FITS DDP Settings":



Select the "FITS" tab and set it as in this screenshot:



Just make sure that you set "Generic BGGR" or "Generic RGGB", depending on what you found in the FITS header. Then click on "Apply".

At that point, I like to save the file list. Click on "Save the file list…" (uuuh) and place that file in the same folder as your FITS. Give it a sensible name, as this one will be used for your final TIFF.

Warnings

You cannot stack FITS having different Bayer patterns. You must stack them separately, and then stack together the two resulting images.

Similarly, you cannot stack FITS of different sizes. Normally it's not a problem as Stellina produces only one type of images… except sometimes when we change version of the firmware, as between v16 and v17.

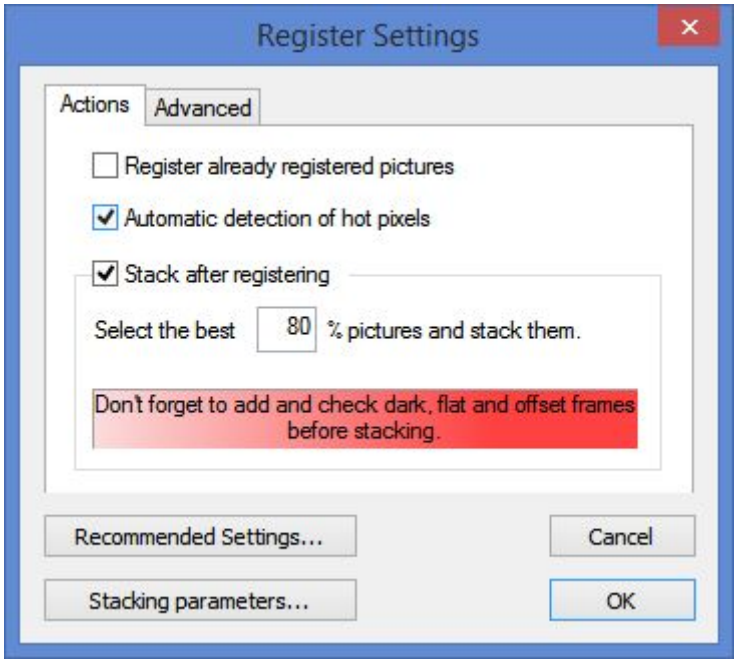
If you are sure that all light frames, dark frames and FITS options are correctly to the same Bayer pattern but DSS still complains that they do not, that's a bug. Save the File List, close the DSS, reopen it and load the File List. Everything should work now.

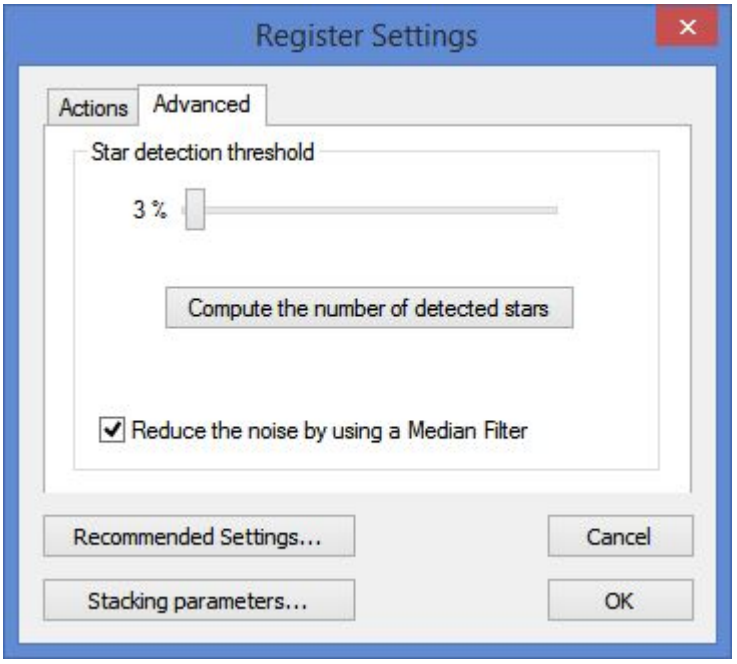
Registering and stacking in one step

This is the "quick" and dirty way: you'll let DSS choose alone which FITS are good and which are not.

Click on "Chek all", so that all light frames are checked.

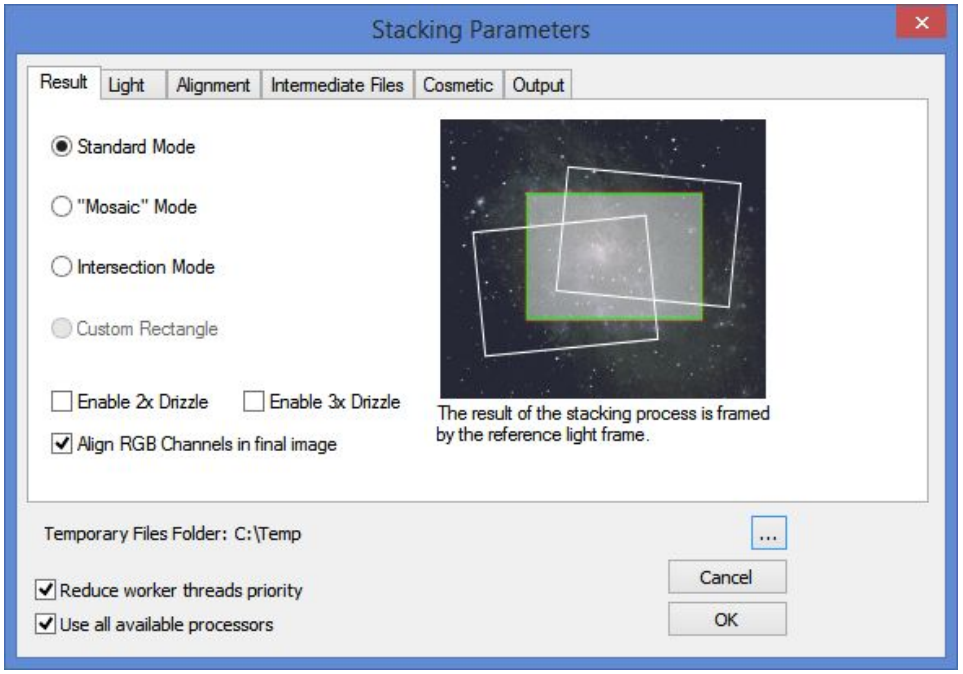
Click on “Register checked pictures” (in red).

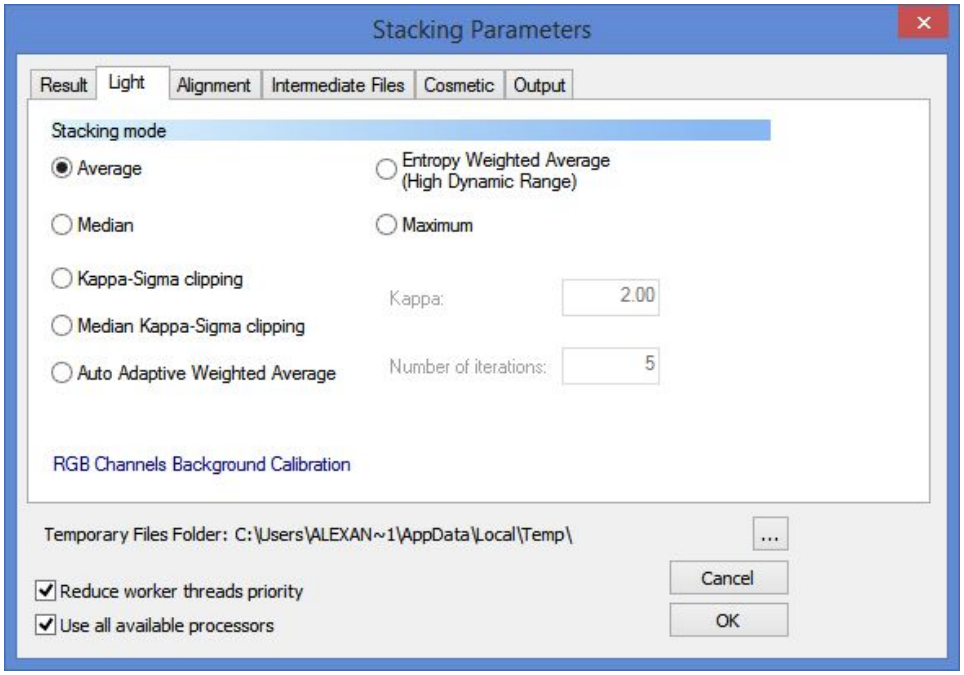


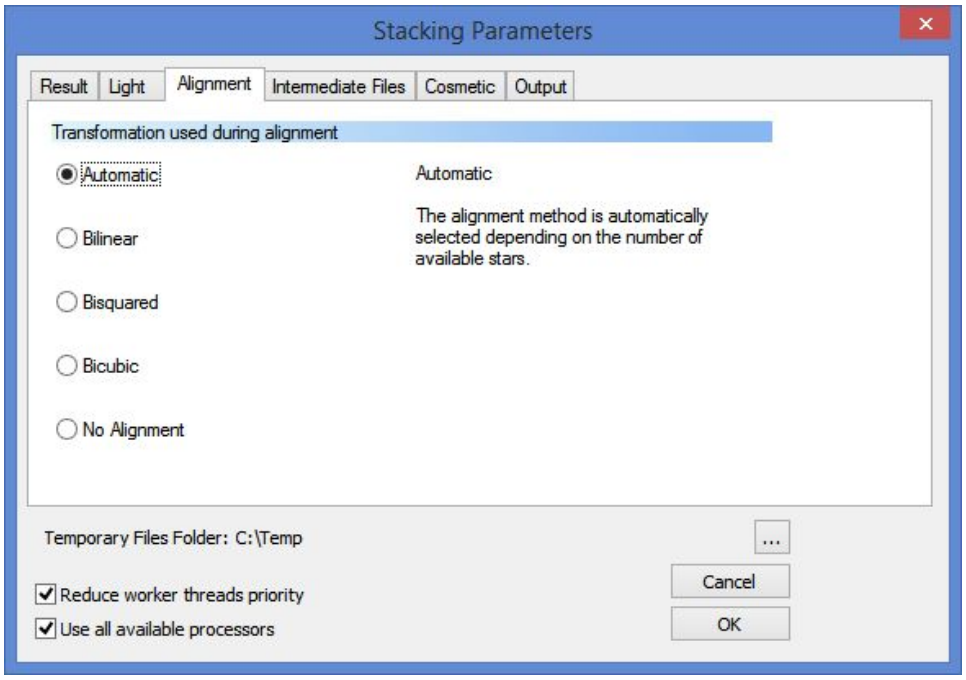


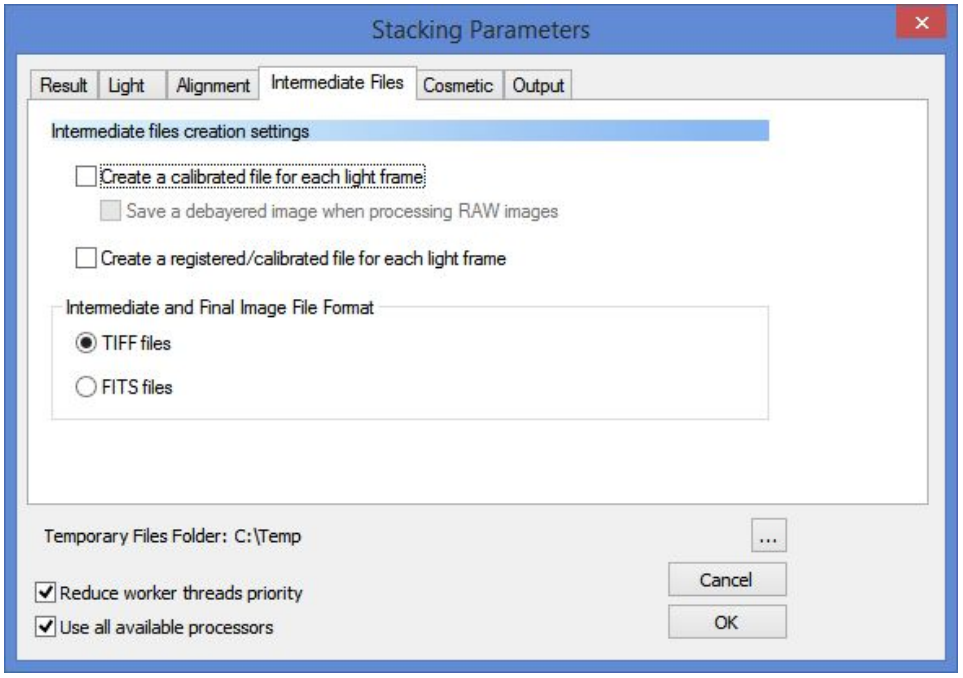
Set the dialog box like this. You’ll have to play with the “star detection threshold” a bit. Set it to 3% and click on “Compute the number of detected stars”. If should get between 30 and 70 stars. If you get less, decrease the threshold. If you get more, increase it.

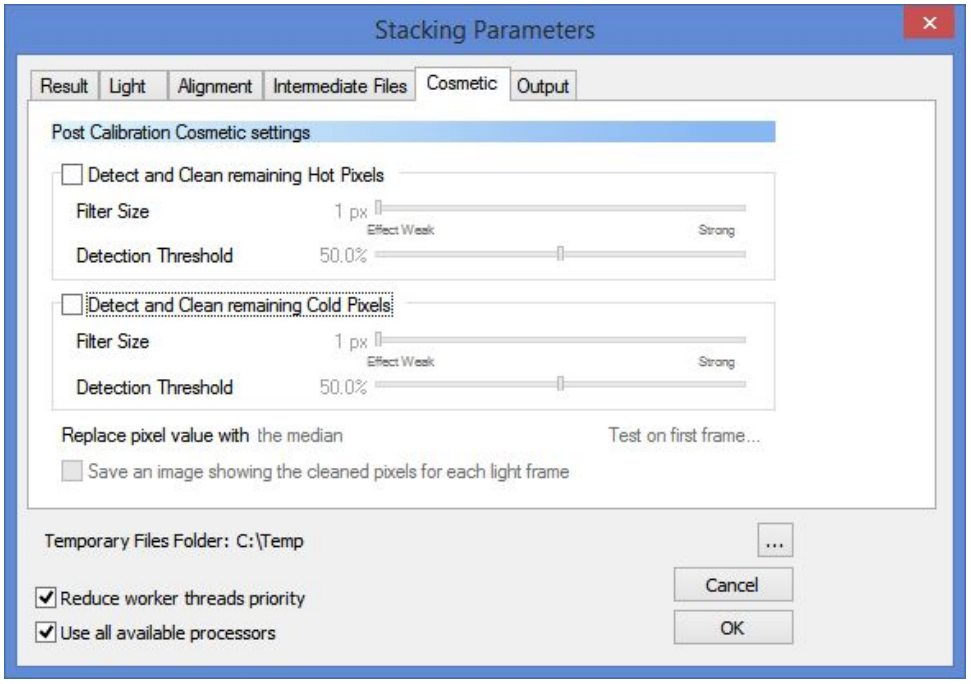
Then, click on “Stacking parameters”. This is very important and what may make your stacking fail or succeed. Copy the following parameters:

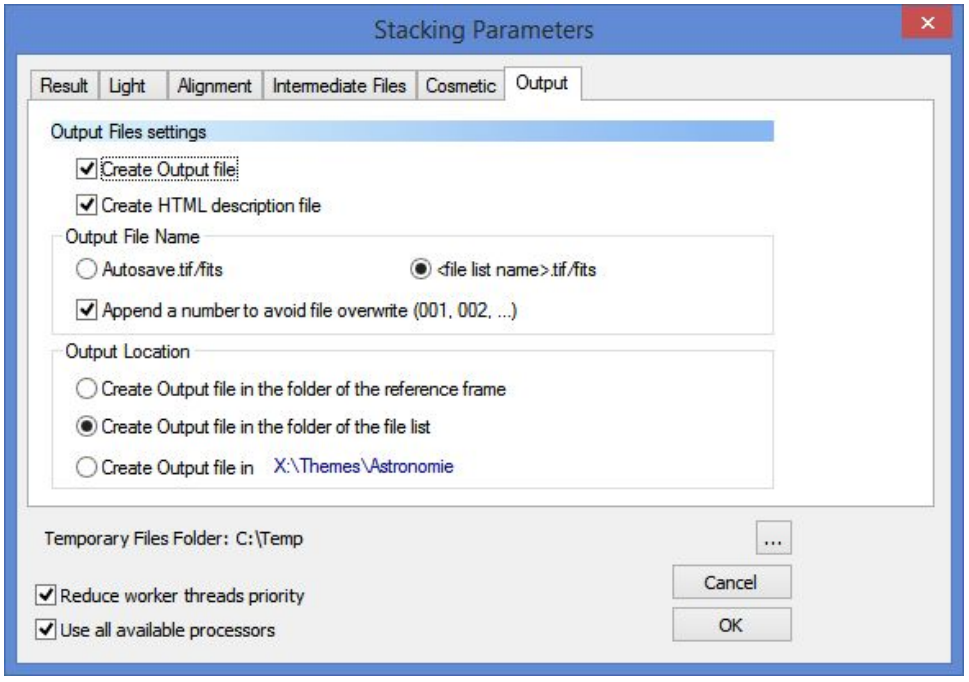



Stacking Parameters
Result
Light
Alignment
Intermediate Files
Cosmetic
Output
Stacking mode
Average
Entropy Weighted Average (High Dynamic Range)
Median
Maximum
Kappa-Sigma clipping
Kappa:
2.00
Median Kappa-Sigma clipping
Auto Adaptive Weighted Average
Number of iterations:
5
RGB Channels Background Calibration
Temporary Files Folder: C:\Users\ALEXAN~1\AppData\Local\Temp\
...
Reduce worker threads priority
Use all available processors
Cancel
OK


Stacking Parameters
Result
Light
Alignment
Intermediate Files
Cosmetic
Output
Transformation used during alignment
Automatic
Bilinear
Bisquared
Bicubic
No Alignment
Automatic
The alignment method is automatically selected depending on the number of available stars.
Temporary Files Folder: C:\Temp
...
Reduce worker threads priority
Use all available processors
Cancel
OK


Stacking Parameters
Result
Light
Alignment
Intermediate Files
Cosmetic
Output
Intermediate files creation settings
Create a calibrated file for each light frame
Save a debayered image when processing RAW images
Create a registered/calibrated file for each light frame
Intermediate and Final Image File Format
TIFF files
FITS files
Temporary Files Folder: C:\Temp
...
Reduce worker threads priority
Use all available processors
Cancel
OK





Once all set, click on OK, and again on OK.

The FITS will first be registered. DSS computes a quality score for each of them, keeps the best 80% and then stacks them. The whole process can take a while, depending on how many FITS you have.

In the end, you'll get a TIFF file with the same name as your File list and in the same folder. (it might be called "autosave" if you did not set a file list name.)

Registering, selecting and stacking in three steps.

Registration

There is not much difference with the previous section, except that you have more control over every step. Just make sure that the "Stack after registering box is unchecked" before clicking OK.

Selection

Once the registration process is complete, you must now select the light frames yourself. Only the frames that are checked will be used for the stacking. But first you must be able to see something, which is not usually the case upfront.

Click on “Score” to sort the light frames by score and move to the last on in the table (with the highest score). Select it.

Light Frames:31 - Dark Frames: 0 - Flat Frames:0 - Dark Flat Frames: 0 - Offset/Bias Frames: 0

Path	File	T..	Score	dX	dY	Angle	Date/Time	Size	CFA	D.	I...	ISO/Gain	Expo...	...	FWHM	Sky Backg...	#Stars
X:\Them...	M20_bggr_rnd0.450927_img-0111.fits	L..	396.63	NC	NC	NC	29/06/2020 22:07:38	3072 x 2080	Yes	G.	F...	200	10 s	...	6.34	1.84 %	83
X:\Them...	M20_bggr_rnd0.443788_img-0074.fits	L..	404.76	NC	NC	NC	29/06/2020 21:59:49	3072 x 2080	Yes	G.	F...	200	10 s	...	6.37	1.85 %	85
X:\Them...	M20_bggr_rnd0.464215_img-0017.fits	L..	408.10	NC	NC	NC	29/06/2020 21:47:27	3072 x 2080	Yes	G.	F...	200	10 s	...	6.20	1.92 %	84
X:\Them...	M20_bggr_rnd0.438847_img-0015.fits	L..	413.30	NC	NC	NC	29/06/2020 21:47:03	3072 x 2080	Yes	G.	F...	200	10 s	...	6.39	1.92 %	88
X:\Them...	M20_bggr_rnd0.440706_img-0157.fits	L..	426.18	NC	NC	NC	29/06/2020 22:17:35	3072 x 2080	Yes	G.	F...	200	10 s	...	6.24	1.77 %	87
X:\Them...	M20_bggr_rnd0.446173_img-0012.fits	L..	428.33	NC	NC	NC	29/06/2020 21:46:31	3072 x 2080	Yes	G.	F...	200	10 s	...	6.21	1.92 %	88
X:\Them...	M20_bggr_rnd0.454999_img-0194.fits	L..	431.11	NC	NC	NC	29/06/2020 22:25:22	3072 x 2080	Yes	G.	F...	200	10 s	...	6.14	1.73 %	86
X:\Them...	M20_bggr_rnd0.453600_img-0148.fits	L..	436.49	NC	NC	NC	29/06/2020 22:15:47	3072 x 2080	Yes	G.	F...	200	10 s	...	6.14	1.77 %	88
X:\Them...	M20_bggr_rnd0.460082_img-0150.fits	L..	455.43	NC	NC	NC	29/06/2020 22:16:08	3072 x 2080	Yes	G.	F...	200	10 s	...	6.05	1.77 %	90
X:\Them...	M20_bggr_rnd0.460613_img-0226.fits	L..	458.13	NC	NC	NC	29/06/2020 22:32:18	3072 x 2080	Yes	G.	F...	200	10 s	...	5.92	1.71 %	90

Main Group | Group 1

Above the table you’ll see the FITS… mostly black. On the upper right of the window, look for this widget:

Move the grey triangle (and maybe the others too) until you can see better. Often, the object is barely visible but you must be able to see most stars. That’s how you are going to judge the quality of each frame.

By selecting each frame and waiting for one second, you can see that image. You then decide if you want to keep it or reject it (check it or uncheck it). That’s a long and fastidious process. I never look at all of them, only those that are more likely to be bad images.

Sort by score and look at the frames with scores below 200 or 100. Uncheck the bad ones.

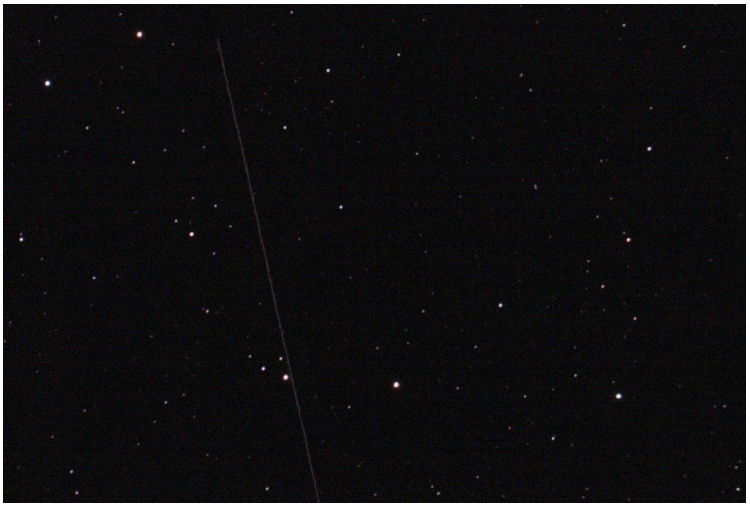
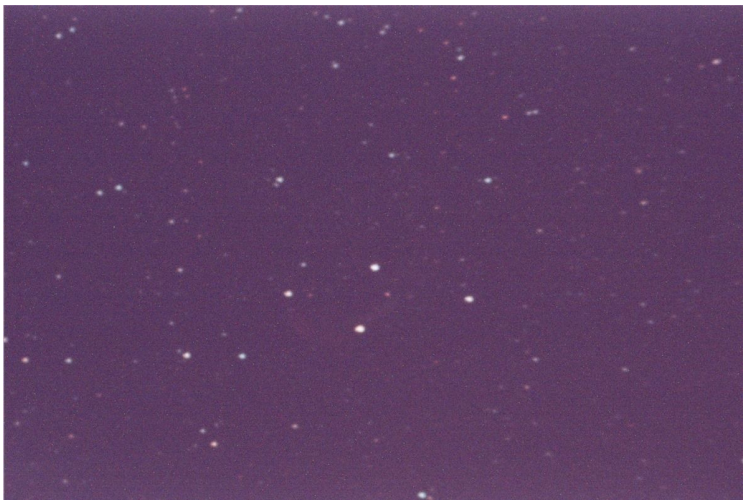
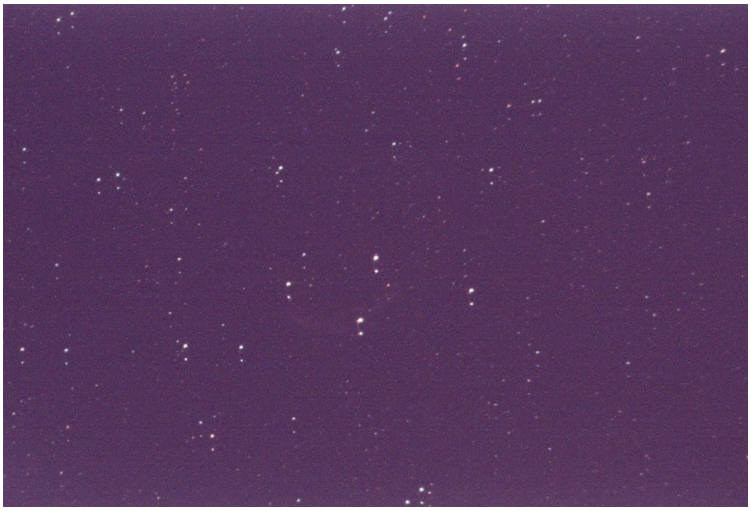
Sort by FWHM (star thickness), and look at the frames with values above 6. That’s where you’ll find badly focused stars or failed tracking. In particular if you ignored Stellina’s temperature warning.

Sort by Sky background and look at the extreme values. Usually, if you have more than 1.5% of sky, it was too clear, or cloudy. Low values may have other problems.

Sort by #Stars (number of detected stars) and look at the extreme values. A high number of stars might means that there were vibrations and the stars appear twice.

Here is a good frame:

And here are examples of bad frames:


You might also want to click on “Compute offsets” and then sort by dX, dY and Angle. This is in particular true if your are working from a balcony, where vibrations are more prone to happen. The vibrated frames will be more easily detected by sorting by those, as well as by #Stars.

I know, it’s heartbreaking to uncheck all those frames… but I have found that it’s better to have a few high-quality frames than many bad ones. Blurry stars and clear skies are particularly bad, and difficult to correct in post-treatment.

Don’t be too anxious about the satellite tracks or the vibration patterns. The kappa-sigma algorithm is quite good at taking care of those problems. It is more helpless with clear frames and blurry stars.

Once you are happy with your selection, save the File List again.

Stacking

Click on “Stack checked pictures” (in red), then on “Stacking parameters”. You can then set the parameters as shown in the previous section.

Drizzling

If you are working with a small object, you may try the “Drizzle” modes. This will lengthen the stacking time but you’ll have a higher resolution in the end. That resolution is not “cheated” but uses the fact that the images are not perfectly aligned. So, one point in the sky can “land” halfway between two pixels. Drizzle uses that to double (or even triple) the resolution.

But before doing the drizzle, it is advised to select a smaller area from the frames to decrease the computation time. You do that by clicking on this icon:

And then drawing a red rectangle around the area of interest.

Do not expect miracles though. I found drizzle 2x more useful than 3x.

Developing the TIFF

The resulting TIFF will be disappointingly dark. You need to develop it in your favourite photography application, in most of the same way you develop Stellina's TIFF. However, the TIFF generated by DSS are 32 bits instead of 16 bits. Most Photoshop's tools only work in 16 bits, so you'll have to convert the TIFF in 16 bits first. This can be done in Photoshop. By contrast, Affinity works well in 32 bits and you can keep this depth all along. If you want to use Topaz Denoise, you'll also have to convert to 16 bits beforehand. This can be done from Affinity's Document menu.

Conclusion

There would be a lot more to say… But I hope this will be enough to let you get a first image. Then, the best way to progress is to experiment… and read DSS documentation.

One more advice: for your first attempt, take an easy target, like a large and bright nebula (M16, M8, M42). If you can see something on the FITS, it will be easier later. If you have FITS from M42, start with those, as you'll then be able to continue with Vaonis' TIFF development tutorial on the same object.