Image Processing of ST2000XM Images with Small Focal Length

Part1 – CCDSTACK Workflow (Release 1.2)

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1. CALIBRATION WITH CCDSTACK

1.1. Requirements for darks

The dark current of SBIG cameras cannot be neglected. So, a dark subtraction is very important. The dark current of my ST2000XM camera mutates very slowly. This is the reason, why I use dark frames with an age of up to 2 months. I shoot darks only in astronomical unusable nights. The observing time in clear nights is too precious!

The darks are created with exactly the same adjustments as used for the light frames:

- Same binning
- Same chip temperature
- Same exposure time

The number of dark frames should be equal or higher than the number of light frames.

1.2. Master darks

The first step of the calibration process is the creation of the master darks using CCDSTACK:

- Process -> Calibrate -> Make Master dark.
  - Combine Settings: Clip min/max Mean
  - With adjustment 2/2

1.3. Requirements for the flats

To reach very deep images, a high quality flat is absolutely necessary. If you let your camera at your optics without doing any rotations or other movements, then it is not necessary to shoot each night a new flat. I have used flats, which were older than one month, without any problems. A careful inspection of the position of the dust particles is very important, if you use old flats.

Basically, I create a separate master flat for each used filter. All flats are shot in 1x1 binning, even if the colours of the object are captured in 2x2 binning. The average ADU value should reach 35 to 50% of the saturation value. This means for the ST2000XM: Saturation = 62.000 -> average between 22,000 and 31,000.

The exposure time should not be too short (possible disturbance through shutter) and not too long (for fast creation of flats). Exposure times between 0.4 and 5 s are useful for my equipment.

Because of these short exposure times it is not necessary to shoot flat darks with exactly the same exposure time as the exposure time of the flat, but a master bias subtraction or a master dark with a standard exposure time of 2 s is adequate.

20 to 30 flat frames are captured for each filter. 50 dark frames with an exposure time of 2 s are used for the master flat dark.

I use two methods for the creation of the flats. Both methods lead to similar results:

- **Sky flat:** The evening sky is captured opposite to the sun in a height of 45° to 60°. The telescope is moved during capturing of the flat frames to get a movement of the stars from one exposure to the next exposure. The filter sequence is: Halpha / R / G / B / Clear. The exposure time has to be changed continuously to reach approximately 50% of the saturation level.
- **Monitor flat:** A white cloth is clamped over the dew cap of the refractor. The telescope points directly towards a monitor, which shows a pure white image. The distance

between the monitor and the front lens of the refractor is approximately 30 cm. This setup leads to similar flats as with the sky flat method.

1.4. Master flats

The first step is to create the master flat dark. This can be done in the same way as in chapter 1.2 described.

The master flat can be created with CCDSTACK in the following way:

- Process->Calibrate->Make Master Flat
- The request ‘dark/bias subtract each flat frame’ should be answered with ‘Yes’ and then you should choose the master flat dark, which had been created in the previous step.
- Combine Settings: Sigma reject Mean / normalize = auto / sigma multiplier = 2 / iterations limit = 1

1.5. Calibrating of the light frames

- File -> Remove All Images
- File -> Open -> Open all light frames through one filter
- Process -> Calibrate -> Calibrate
- Calibration Settings:
  - Dark subtraction: Choose appropriate master dark and set adaption = none
  - Flat Field: Choose appropriate master flat and **do not** activate ‘subtract bias’
  - Apply to All
- Adjust Display: activate DDP / activate Apply to All / Click Autoscale.
- File -> Save data -> All

2. REGISTRATION WITH CCDSTACK

The further procedure depends on the desired resolution of the finished image:

- original resolution
- double resolution with drizzle method

2.1. Registration with original resolution

2.1.1. Luminance registration

At first, the luminance frames are registered. The reference image should be an image, which shows very good stars and which is in the middle of the dither area. I prefer a step size of 1 pixel for luminance dithering (square with 5x5 pixel -> 25 positions).

If you are sure that there is no hint of rotation between the single frames (which is very seldom the case), then you can choose FFT using the option 'Shift Only' and you will get a very good registration. If rotation is necessary, then FFT can only be used for prealignment. An exact registration can only be reached with a following ‚Star Snap'. I prefer to choose 5 stars for 'Star Snap': one star in each of the four image corners and the last chosen star in the image centre (=rotation centre). The selected stars should be bright, but not saturated. After clicking 'Align All' you should make a carefully inspection of the registration via blinking of the images. If single images are not optimally aligned, then it often helps, if you do a manual prealignment of the problematic image or if you choose other stars.

If you are happy with the registration, then you have to resample the images. This can be done with Apply->Cosine for strongly undersampled images like mine or with Apply->Bicubic Bspline for better sampled images.

The registered single frames should be saved in a separate directory (e.g. align_lum).

2.1.2. RGB registration

The registration of the RGB images is very similar to the registration of the luminance frames. At first, the same luminance image, which has been used as reference for luminance registration, should be opened. Then all RGB images are opened. If the RGB images are binned 2x2, then these images are automatically resized to the size of the luminance frame.

Afterwards, you can use the same procedure as for the luminance registration. If the RGB images are 2x2 binned, then it is sometimes better to choose brighter reference stars, which can also run into saturation a little bit.

The registered RGB images should be saved in a separate directory (e.g. align_rgb)

2.2. Drizzle

Drizzle works best, if you use a not whole-numbered step size for dithering (e.g. 0.5 pixel) and if you capture many single frames for an optimal S/N ratio. The colours should be captured with 1x1 binning.

At first, all luminance frames are resized by a factor of 2. This can be done optimally with:

- Edit->Transform->Resize->Specify Scale
- Magnify = 2
- Interpolation = Nearest Neighbor

Afterwards, you can do the registration of the luminance and the colour frames in the same way as described in chapter 2.1 (original resolution). There is one difference: You should use the interpolation method ‘Nearest Neighbor’ instead of ‘Cosine’ for drizzled images.

3. COMBINING WITH CCDSTACK

3.1. Normalize

The data reject functions are very powerful tools of CCDSTACK. These functions need very well normalized images for optimal results.

The normalization can be done with:

- Stack -> Normalize -> Auto

Typically, it is not necessary to select an area. After the normalization an information window, which shows the scale factors of each image, appears. All factors should lie in the range between 0.7 and 1.3. Otherwise, the normalization process did not work optimally or it is a hint, that the single frames were captured under strongly changing conditions. (Maybe bad images should be removed.)

If you are sure that all images were captured under excellent transparency and that there was only a variation of the sky background (e.g. moon rise), then there is also the possibility to weight all images with the same factor and to compensate the varying sky background by subtracting an offset:

- Stack->Normalize->Control->Offset
- Select a big area of the image with sky background

The selection of the reference image for luminance normalization is uncritical, but the reference images for RGB should be chosen carefully: The RGB reference frames need very good transparency and the highest possible height of the object for minimum influence by extinction.

If you use a filter wheel, then it is a good idea to switch continuously between the filters R, G and B. Afterwards, you should choose three consecutive R, G and B images, which were captured at high elevation and during excellent transparency. This procedure is the basis for an easy to achieve colour balance.

Finally, the quality of the normalization can be checked easily:

- Adjust display -> Activate ‘Apply to all’
- Blink the single frames -> All Images should show a similar brightness.

3.2. Data rejection and combining

Data rejection means that single pixels in single images are excluded from the combining process. This concept allows the elimination of satellites, tracks of air planes, cosmics and hot/dark pixels, which occur only in single images.

Provided that the normalization worked well, then the data rejection in CCDSTACK is very easy. The help of CCDSTACK suggests Poisson Sigma Reject, but I prefer STD Sigma Reject, when at least 6 frames are available. The following adjustments work often very well:

- Stack -> Data Reject -> Procedures
    - STD Sigma Reject
        - Top image %: Do **not** activate, but input the factor manually.
            - Typical factor for 6 frames: 1.8
            - Typical factor for 20 frames: 2.2
        - No iteration limit
        - Activate ‘Clear before apply’
        - Apply to all

The rejected pixels are shown in red colour. So, the process can be easily checked and the factor can be modified if necessary.
When the rejection is okay, then the combining of the single images is done via mean:

- Stack->Combine-> Mean

4. RGB AND LUMINANCE EXPORT

4.1. RGB factors

The pdf document www.astrophoton.com/tips/color_balance.pdf describes the determination of the RGB factors. A correction of extinction is very important for a low object height. For calculation of the extinction you should choose the object height of the same frame, which had been used for normalization.

If you know the RGB factors, then the multiplication can easily be done with CCDSTACK:

- Process->PixelMath->Multiply by

4.2. RGB creation

- Color->Create
  - Luminance: None
  - Filter factor: = ratio of single exposure times (e.g: If your single exposure times are R=600s/G=300s/B=300s, then you have to input R=2/G=1/B=1).
  - Set Background: Select neutral background area
  - Apply

4.3. DDP

DDP should be used fort the RGB image and for the luminance image. A very good starting point is the standard CCDSTACK DDP:

Activate DDP in the ‘Adjust Display Window’ and click on Autoscale. The background should be decreased a little bit.

If you are happy with your settings, then the image can be saved as 16 bit scaled tif, which can be easily imported in Photoshop.