Introduction to Low-Cost Urban Deep Sky Photography: A Preliminary Exploration of Lightweight Narrowband Photography Solutions (2)

[Image] Narrowband monochrome image taken by the author using an M31Ha sensor, with an exposure time of approximately 2 hours. Location: Light pollution.

The city proper of Beijing is so heavily affected by the pandemic that it's causing headaches.

Equipment used: QHY268M astronomical camera, QHY5III462C guide camera + mini guide scope.

PoleMaster electronic polar mirror SkyRover60ED astronomical telescope, Aiton CEM25 equatorial mount.

Last time, we shared how to build a system from scratch that allows you to conduct deep-sky object surveys right at your doorstep, despite the light pollution.

This issue covers lightweight equipment solutions for shooting at a lower cost, as well as some precautions for the initial debugging process.

We will conduct hands-on practice and demonstrate some post-processing techniques.

This time we will introduce the process of shooting monochrome photos with a black and white camera and a single narrowband filter, without going into more complex procedures.

This includes content such as multi-narrowband color synthesis and color calibration. Due to space limitations, the following process will inevitably contain inaccuracies.

While there are areas for rigor and further optimization, our goal is to deliver in the simplest and easiest-to-implement way.

Everyone will go through all the necessary steps of deep-space photography, including shooting, preprocessing, and post-processing, and understand the basic principles involved.

And the details that cannot be ignored. As the old saying goes, for beginners starting from scratch, taking the picture is more important than taking a good one.

important.

Shooting of partial calibration frames (flat field)

In the last episode, we completed the basic equipment setup. Before the actual shooting, we still need one more thing.

A very important thing to do is to calibrate the captured frames. Manually calibrating image files is a key difference between astrophotography and solar photography.

Key characteristics and challenges of deep-sky photography. For beginners, the most important point...

It's crucial to recognize the importance of correctly capturing calibration frames, as they directly determine whether a deep-space photograph will be successful.

The available and final image quality limits. Calibration frames include dark, flat, and background.

(Bias). Some calibration frames can be taken indoors during the day. This was already discussed in issue 7 of this year's publication.

The previous article devoted a whole section to explaining the principles of calibration frames in detail; in this issue, we will only briefly describe their functions.

And shooting methods.

For the initial shoot, we need to capture a flat field during the day. This flat field is primarily used to counteract vignetting, lens elements, and...

Image defects caused by dust, scratches, etc. on the CMOS surface. We connected the camera to the computer, opened NINA,

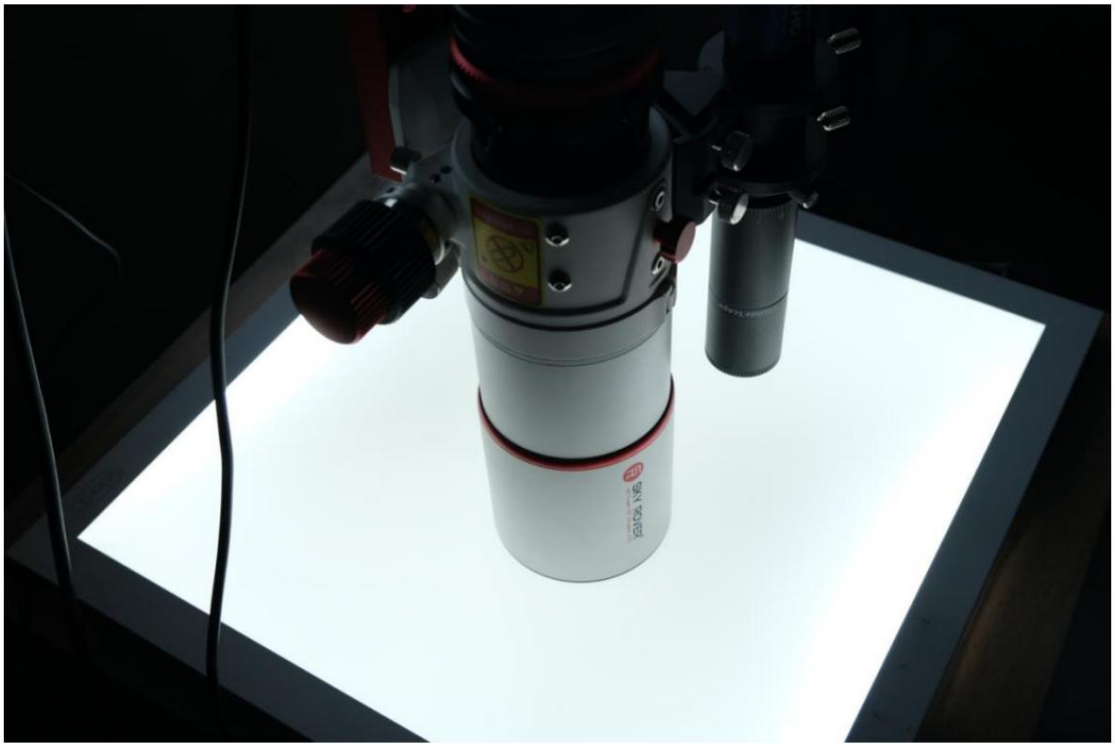
Activate the camera's cooling mode. For beginners, we'll use the same gain (similar to ISO on a DSLR) for our initial shots.

Shooting parameters such as offset can be left at their default values; no adjustments are necessary. We only need to control the exposure.

That's all. Then turn on the camera's cooling function. We can set the target temperature to 0 degrees Celsius to -10 degrees Celsius.

Between these settings, you can adjust the cooling level to a lower setting depending on the camera's cooling capacity. Throughout the rest of the process, including the actual filming, we...

Regardless of what you are shooting, you must keep the temperature, gain, and offset constant.



[Photo] Indoor shooting flat ground

For shooting flat areas, a uniform light panel can be used indoors, with the telescope vertically mounted on the panel.

During the shooting process, the telescope's focusing position needs to be as consistent as possible with the actual shooting position, which is something we emphasized in the last issue.

One reason for focusing at infinity during the day is to adjust the exposure time according to the situation, ensuring the brightness of the photo is within a certain range.

Around 2/3 is ideal. You can observe the curve of a single shot on the main control panel in NINA to determine the appropriate flat field.

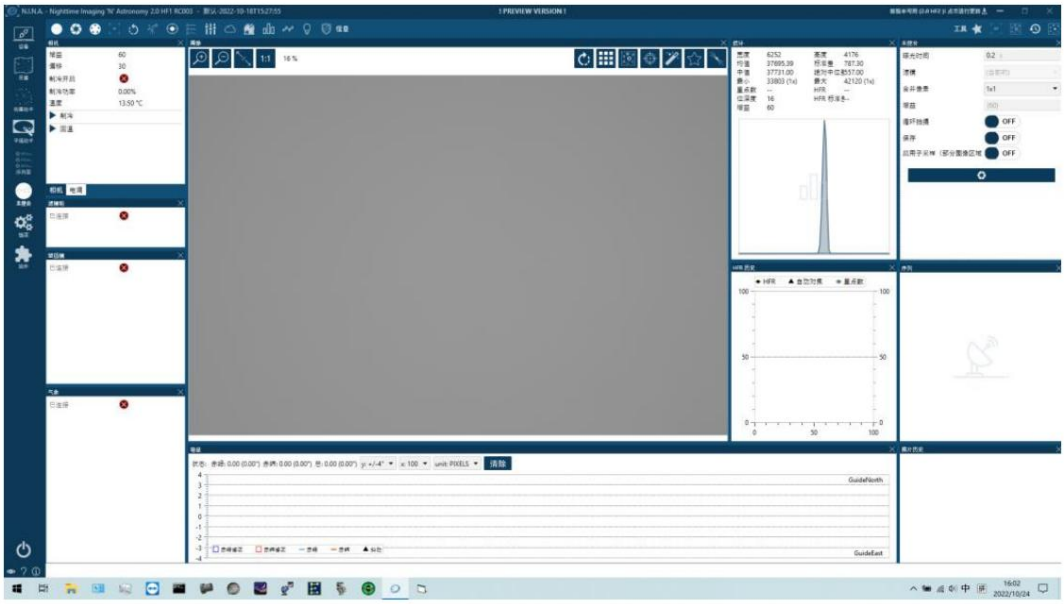
It's worthwhile. Take around 10-20 photos of a flat area; more if possible. A flat area can also be captured using afternoon light.

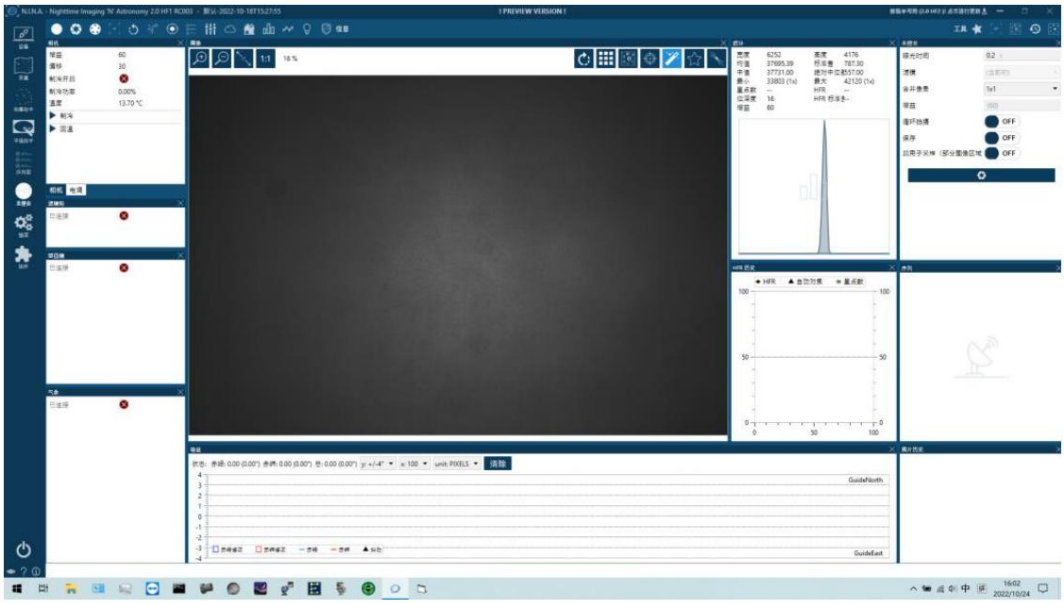
Shoot under even skylight. You can use NINA's flattening assistant to shoot under skylight; just follow the prompts.

Furthermore, strictly speaking, a flat field also requires shooting with a dark background, i.e., a dark flat field. According to the parameters of a flat field...

Shoot with the lens cap on, equivalent to the number of flat shots. We'll handle the remaining dark shots and biases during the actual shooting.

We'll talk about the on-site filming later, after the shoot is over.





[Image] The flat area appears to be a very uniform black field (above), however, if we stretch it a bit,

You'll find it's full of uneven imperfections (see image below). Therefore, flattening is used to remove them in the final image.

This imperfection is absolutely necessary.

Tips: Although flat-field mode can mitigate the impact of dust on the CMOS sensor surface on the image, I still strongly recommend using a flat-field mode.

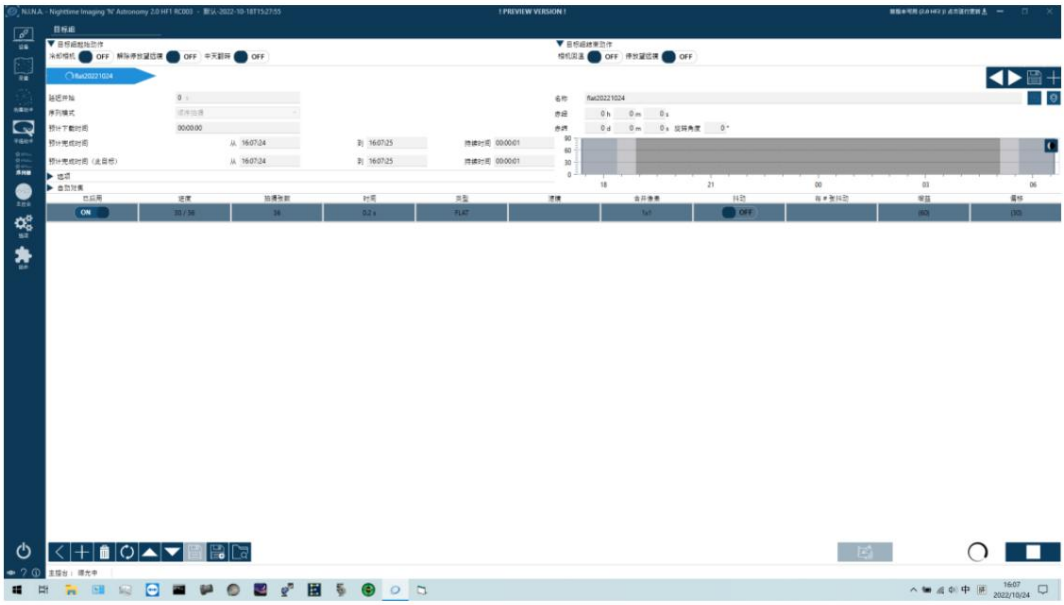
Before shooting, be sure to clean the surface of the CMOS sensor, as dust near the CMOS sensor can affect the image.

It's extremely large and likely to move during filming, which would ruin the flat ground we worked so hard to film during the day.

Actually, the best time to shoot a field-level image is immediately after the actual shooting is finished, using a field-leveling board (specifically for telescopes).

(Lens cap with light plate), but we do not have such equipment, so it is best to ensure the equipment is clean.

While cleaning, the site was also filmed during the daytime on the day of the official filming.



[Image] In NINA, we can go to Sequencer - Create Sequence, and then label the corresponding calibration frame type.

(Dark, Flat, Bias) – simply select the number of shots and parameters to group them for shooting; it's very convenient. This is how you save them.

The data will be named in a corresponding format for easy identification and management. I recommend using all bright frames and calibration frames.

All were filmed in sequence.

After completing the shooting plan and all the above preparations, we can begin the formal night shooting.

Installation equipment

Place the device on a level surface, facing north (approximately north using your phone's compass), and adjust it.

The polar axis (elevation axis) of the equatorial mount is aligned so that its scale points approximately to the local latitude. Then, based on our white...

The counterweight marks on the equatorial mount are used to adjust the position of the weights and the imaging equipment, ensuring that the counterweights on the right ascension and declination axes of the equatorial mount are level.

Balance. Finally, return the equatorial mount to its initial zero position, power on all devices, and connect it to the computer. This way, we can...

The next step is to perform polar axis calibration.

[Image] The shooting environment on the day of the demonstration sample. It's easy to see that the light pollution was really severe.

Precision polar axis

Precise polar alignment is the most critical step in our equatorial mount calibration, directly determining the quality of our long exposures.

Fortunately, with an electronic polar microscope, the process of precisely aligning the polar axis is very simple; you just need to follow the prompts in the software.

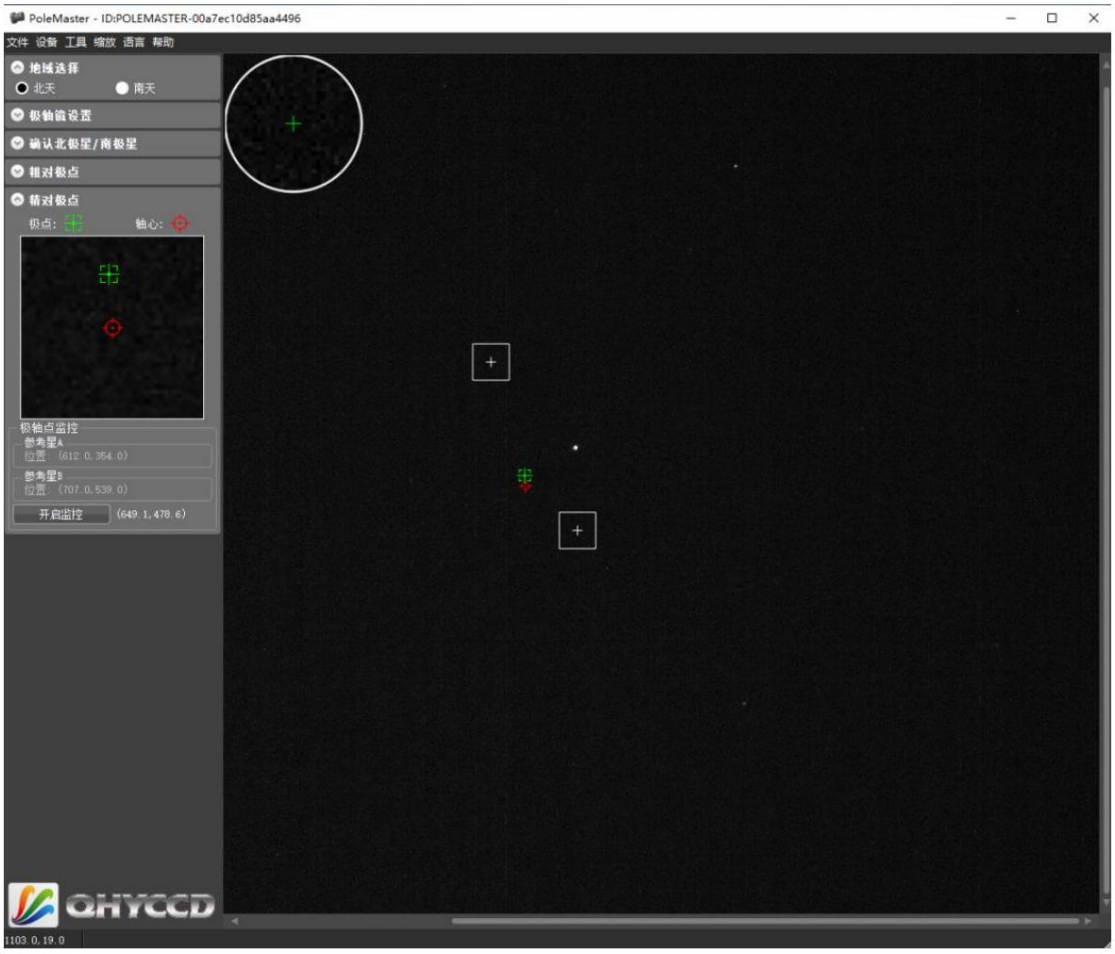
Simply follow the instructions step by step.

The PoleMaster electronic polar mirror can only function properly if it can identify Polaris within the image, however...

We don't need to worry about not being able to see Polaris with the naked eye in situations with severe light pollution, as long as we are on...

Following the correct operating procedure, Polaris is highly likely to be the brightest star in the electronic polariscope image. Polar calibration.

Once you get it right, the rest of the steps will go very smoothly.



[Image] PoleMaster software at work. Simply follow the on-screen instructions throughout the process.

Single preview and simple composition

After aligning the polar axis, we can take a 5-second exposure on the control panel to check if the star points are accurate.

Ensure the focus is correct. If we've already made adjustments during the day, we basically only need to fine-tune the telescope here.

Make slight adjustments to the shaft and repeat the test a few times.

Search for targets and compose a picture

NINA's "Composition Assistant" offers very convenient features for finding subjects and composing shots. Enter what you want to photograph.

For a target, such as the M31, clicking "Load Image" will display its outline and its current position in the image.

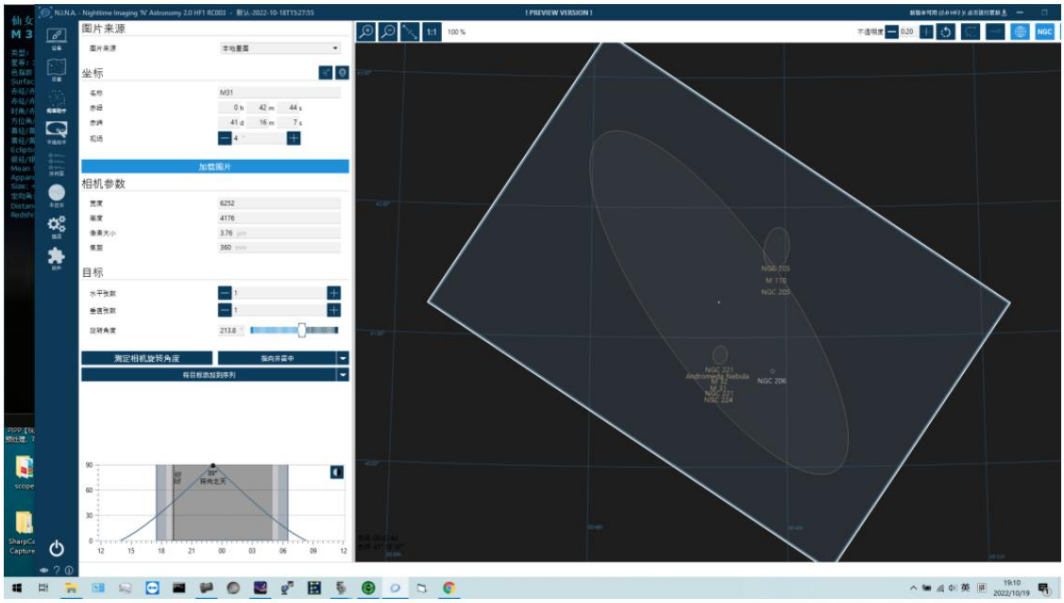
Approximate location. Then click "Point and Center" to move the device to the target.

Next, we need to click "Measure Camera Rotation Angle," and the system will analyze the current angle of the image.

You can compose the shot by manually rotating the camera. Most star telescopes have a mechanism for manual rotation (i.e.,

(CAA), rotate it to adjust the composition to our desired state. Be careful to move gently, and avoid making any group...

The component underwent a significant displacement.



Start guiding

Why is star guiding necessary? Without star guiding, our first long exposure might be normal, but...

By the second and third images, the star points started to appear as trailing lines. Guiding the star system involves using the equatorial mount after it has already moved to the target.

The equatorial mount is continuously made minor adjustments to maintain tracking stability. In the PHD guiding software, most of...

The camera manufacturer has already entered the settings; we need to fill in the remaining parameters, such as the telescope's focal length.

Leave the rest as default. Then click on a bright star in your field of view and click "Start Star Guide".

[Image] PhD software at work

Determine the exposure duration

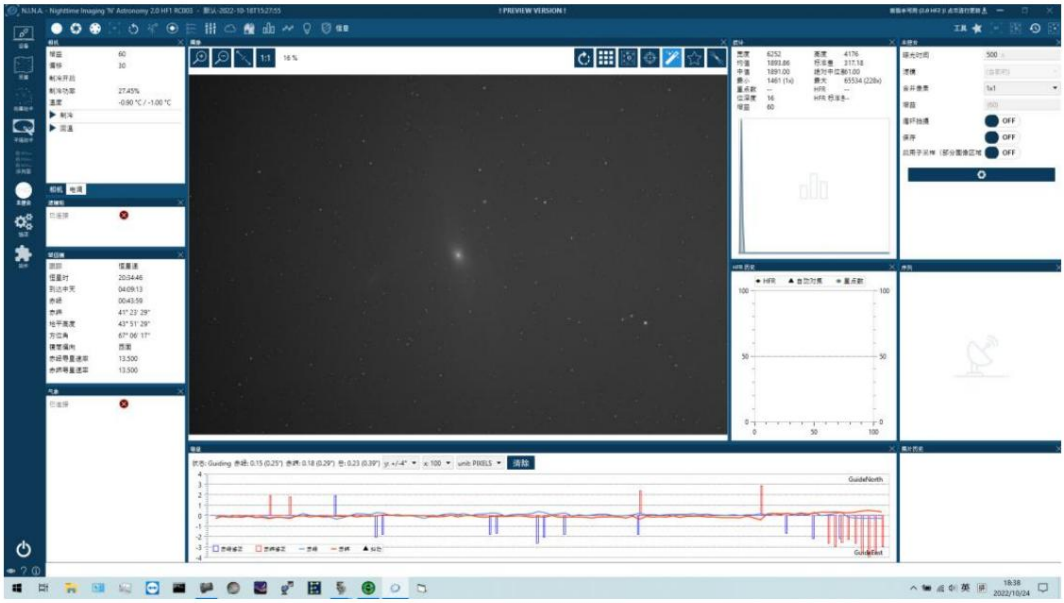
Let's not rush. First, let's take a single exposure to see the effect. We need to take several shots.

For a single frame, maximize the exposure time while maintaining the ellipse of the star points. If a narrowband filter is used...

When shooting with an M31 lens, try to ensure that the exposure time for each shot is over 300 seconds; however, there's no need to worry too much.

With precise polar alignment, achieving a long exposure of around 500 seconds is not difficult.

If the emission nebula has clear details under Ha conditions, a single shot of around 200 seconds can produce good results.



[Image] A 500-second preview of a single image using the Ha narrowband filter, clearly showing the core features of the M31. If only...

Using a black and white camera with a cutoff filter (single L channel), a similar effect can be achieved in about 90 seconds, but the environment is not ideal.

That would involve more light pollution.

Shooting sequence

The final image in deep-space photography is created by stacking multiple long-exposure single images; this is what we need to do.

The reason for shooting in sequence. Return to NINA's composition assistant interface, click "Add Target to Sequence" -- "Simple"

A "single sequencer" can generate a sequence of the current target. This is the boundary of the flat-field sequence we captured earlier.

Next, set the exposure time and number of shots as previously determined, then click the start button in the lower right corner.

You can then begin taking a set of photos. Because we lack components such as an electric focuser and filter wheel, we only...

You need to select "ON" for "Center Target" and "Automatically Open Guide Stars", and turn off all others.

Shooting in dark and Bias

After the sequence is finished shooting, don't pack up yet, we still have two very important sets of calibration frames to shoot.

Dark fields and bias are primarily used to counteract background noise and thermal noise introduced by long exposures. Dark fields require a telescope lens...

Cover the camera with the shutter to ensure exposure in complete darkness. The exposure time in the dark needs to be the same as during the actual shooting.

Our single-image exposure times are consistent; if a single image at night has a 200-second exposure, then a single image in dark conditions must also have a 200-second exposure.

200 seconds; take about 10-20 shots in dark conditions, or more if possible. The lens should also be covered for the bias.

Cover the exposure, but use the shortest exposure time achievable by the camera. Take as many shots as possible, even 30-50.

I don't mind having too many, since each one is only a short time anyway.

[Image] Parameter settings for Dark and Bias

Actually, after the first shoot, we didn't need to shoot the subsequent dark scenes on location. Our first shoot...

The photographer wasn't yet certain about the exposure time for each individual shot, which is why they were shooting in darkness at the very end. Once we know...

You can adjust your exposure time and then go home to shoot in dark conditions after packing up your equipment. We can also shoot during the day...

Multiple dark scenes with the same exposure time are used to build a personal dark scene library for future use. **Bias, however, does not...**

However, due to its inherent principles, it is necessary to film on-site as much as possible after the filming process has ended.

Congratulations! We've completed all the pre-production shooting procedures here! You can pack up and go home to rest for a while.

La.

Post-processing

Due to space limitations, we will only introduce the most critical steps in Pixinsight astrophotography processing here.

And corresponding beginner-level tools.

Tips: ASCOM, PHD, NINA, and PoleMaster, which we used previously, are all free software.

However, the post-processing software PixInsight is a paid service. If it's your first time shooting, you can choose a trial version on their official website.

Filtering materials

Before preprocessing, we need to check our bright frames (i.e., single images of deep-sky objects).

Remove low-quality images, such as those that are out of focus or have streaks, to ensure the quality of each subsequent image being overlaid.

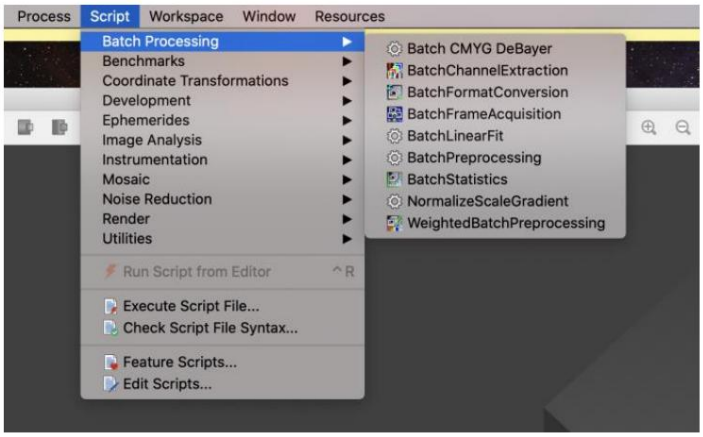
The quality of a single frame.

Preprocessing

Preprocessing refers to the process by which post-production software aligns and overlays all the bright frames and calibration frames we captured previously.

The process of adding and calibrating. And in Pi, we have a script that's perfect for beginners: click on the menu bar...

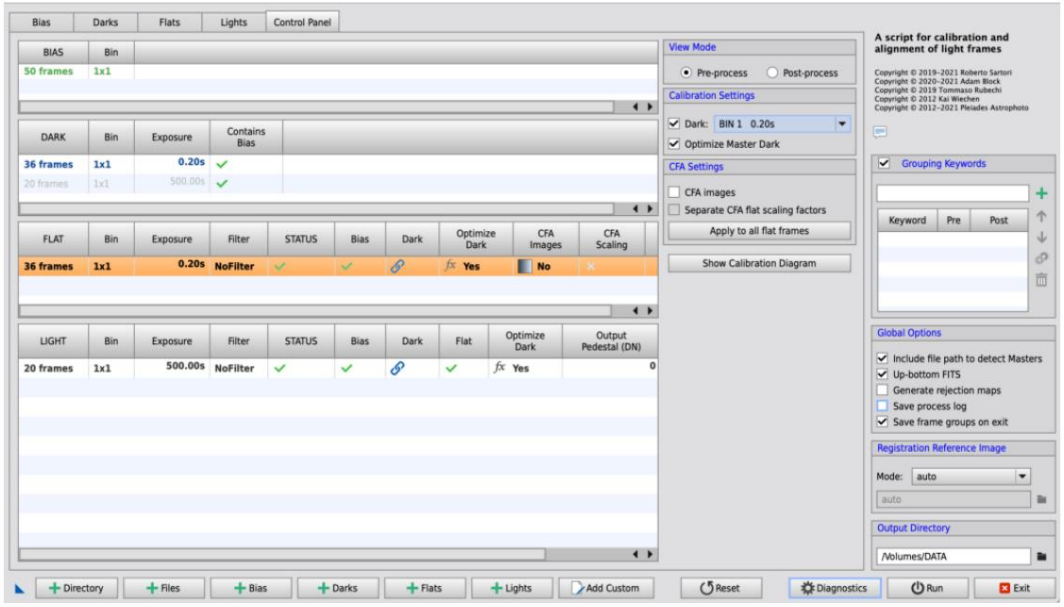
You can call it by going to Script -- Batch Processing -- WeightedBatchProcessing.



We simply need to drag our dark field, flat field, background, and bright field into the corresponding Dark field folders as required.

Flat, Bias, and Light (dark flat fields should also be placed in Dark; the system will automatically match them to flat fields and then set them)

Set the output file path and click Run.



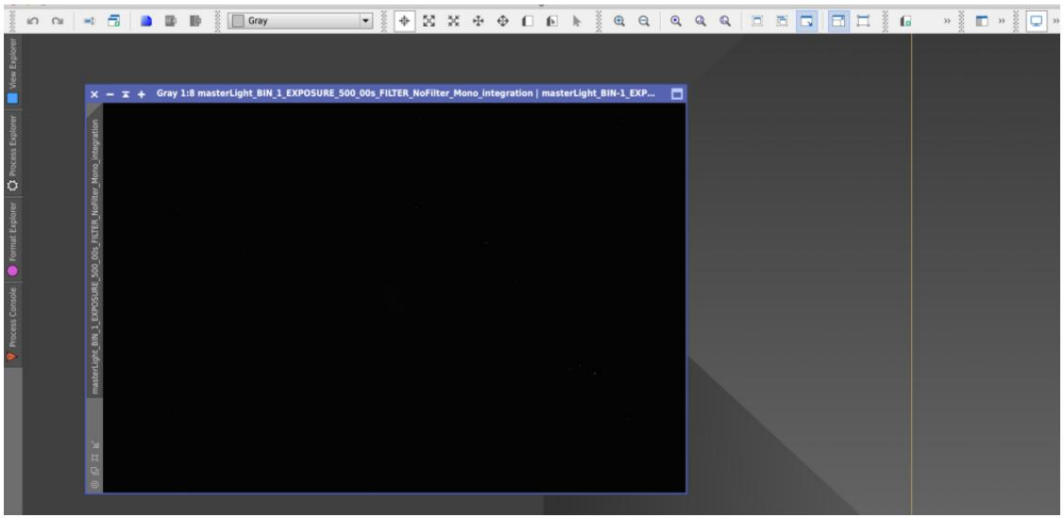
wait

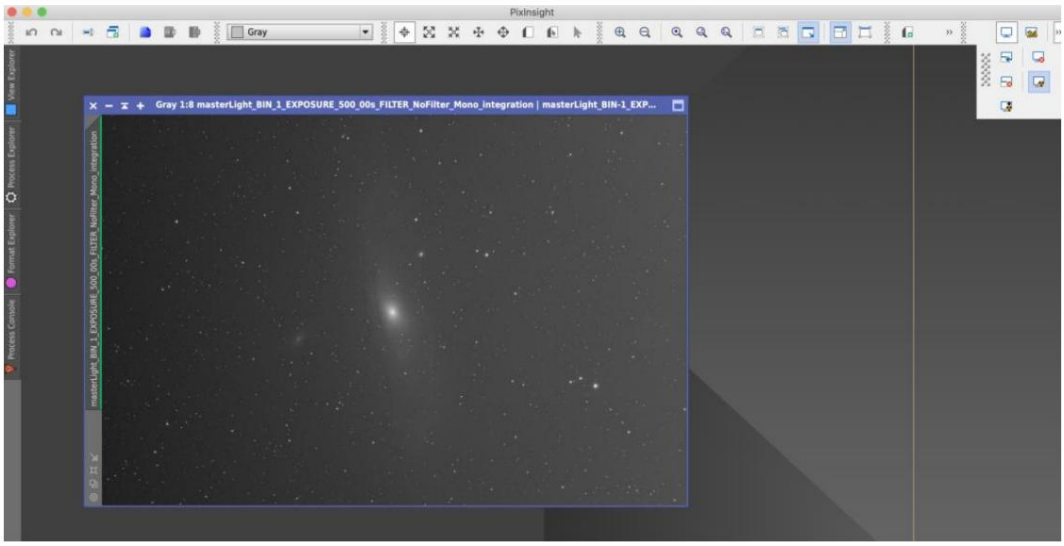
After about ten minutes, the system will generate an automatically overlaid and calibrated bright frame, positioned as we set.

In the output directory, in the "master" folder, there is a file named "masterLight_……_.xisf". Open it.

We'll see a dark image in the Pi. Don't worry, click the icon in the toolbar above.

With a button that looks like a nuclear bomb (automatic stretching), we can preview the processed image.





As you can see, the superimposed image is much smoother and has significantly more detail than the original photo. However, this...

The photo is noticeably darker on the left and brighter on the right. Therefore, we need to proceed with the next important post-processing step for PI.

Tips: Although we used a script this time, for rigorous preprocessing, I strongly recommend using other methods as much as possible.

The best results can only be achieved by operating it manually.

DBEÿDynamicBackgroundExtractionÿ

DBE is specifically designed to handle uneven backgrounds. Click "Process Explorer" in the left sidebar, then double-click...

DynamicBackgroundExtraction allows you to call the DBE program. Then we add anchor points to the background.

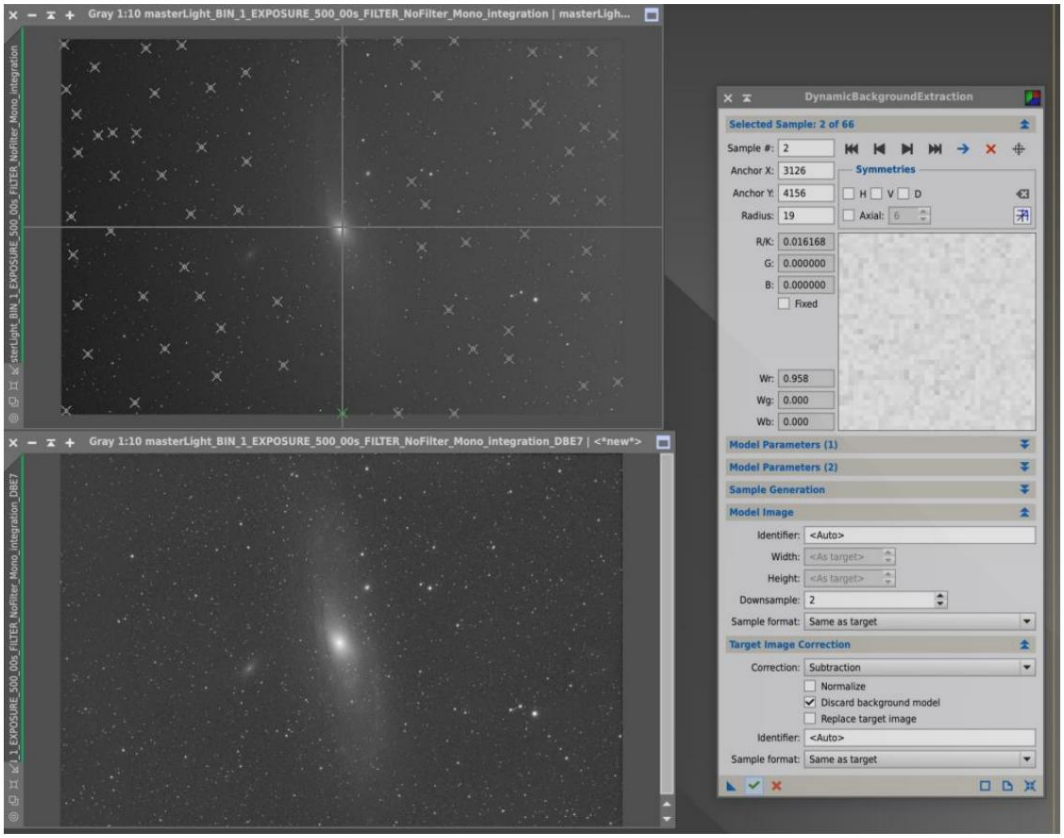
Distribute the reference points evenly across the background; 50-60 points are sufficient. Avoid including star-shaped dots and...

Do not click on non-background areas, and also avoid clicking around the galaxy; otherwise, the area around the galaxy will appear larger than the background after processing.

Darker and more difficult to handle. Most options in the DBE menu can be left at their default settings for now; only the "Target" setting needs adjustment.

The options below "Image Correction" are listed. In the Correction options, select "Subtraction," and then...

Select the first two items below selectively, and finally click the checkmark at the bottom.



As you can see, the processed image not only has a more uniform background, but also reveals more detail in the galaxies. However...

We'll then notice that the image has become much noisier. So, we'll proceed with noise reduction.

MureDenoise

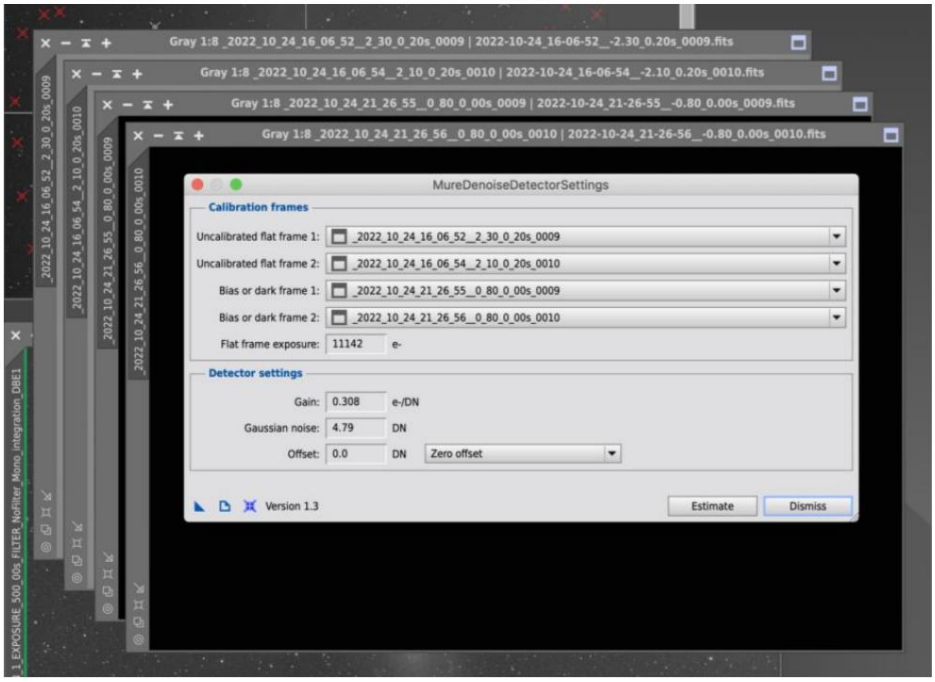
MureDenoise is a noise reduction tool that Pi has focused on updating in recent years. Unlike other noise reduction tools,

MD is relatively simple to use and suitable for beginners, requiring only two main steps:

Measurement: Drag two uncalibrated flat field images, two dark field images, or background images into the workspace, then click Script-

In the NoiseReduction-MureDenoiseSetting section, drag in the previously selected flat and base values, and click Estimate.

The system will then automatically generate two data points: Gain and Gaussian noise.

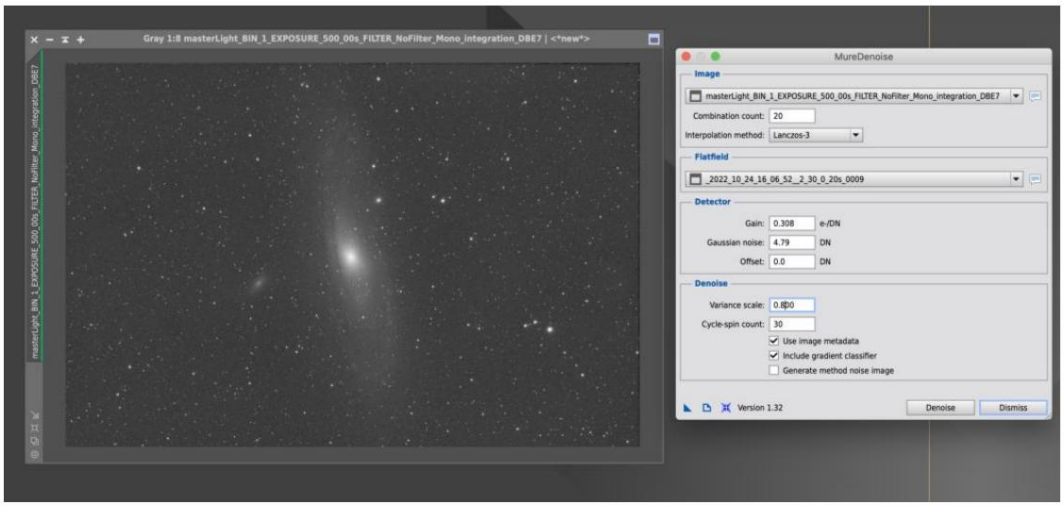


Execution: Click on MureDenoise above the previously selected option in the menu bar, and enter the Gain and...

The value of Gaussian noise. In the Denoise option, I recommend a variance scale of 0.3-0.8.

Between (if the original image has very little noise, this number should be as small as possible), Cycle-spin count is between 20 and

Between 30. Click Denoise:



This gives us an image with significantly reduced noise. MureDenoise can be executed repeatedly.

Alternatively, we can continue using tools such as MultiscaleMedianTransform (MMT) to proceed.

Noise reduction or sharpening can be performed, and the two can be combined. However, be careful not to overdo the noise reduction, as this can easily backfire.

system.

Tips: Any post-processing noise reduction will result in image degradation. The most effective way to reduce noise is to perform noise reduction as much as possible during the initial preparation.

Longer exposure times allow for more data acquisition and improved signal-to-noise ratio. Therefore, post-processing noise reduction cannot be relied upon entirely.

Function.

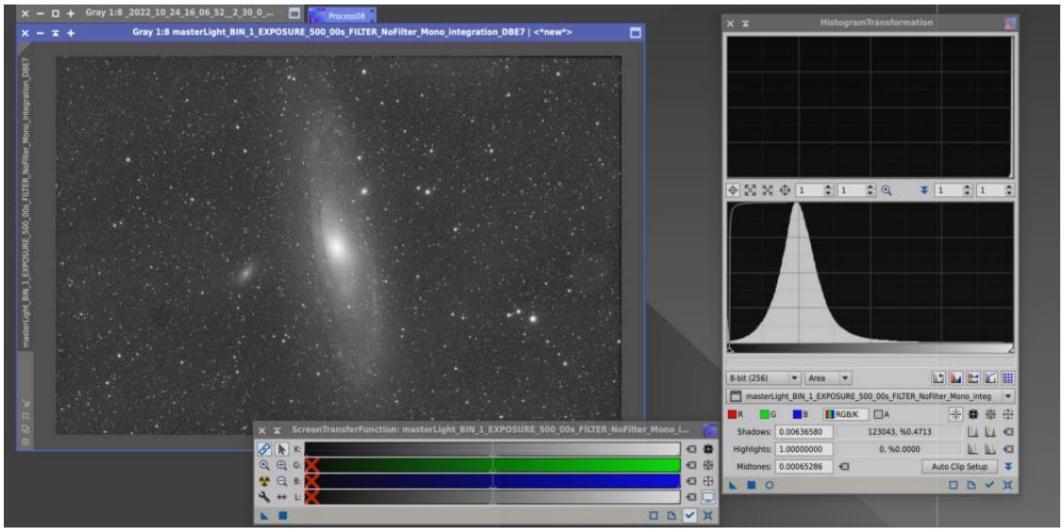
Histogram conversion

Our previous processing was all done in a linear environment, yes, that's the original, dark image.

We've only opened a preview. To obtain the final image suitable for human visual observation, we need to...

This involves transforming a linear function into a nonlinear one. This requires us to use the ScreenTransferFunction (STF) and...

The HistogramTransformation (HT) tool.



First

Open STF, click the Auto Stretch button, then click the small triangle in the lower left corner and drag it into HT;

Then drag the small triangle from HT into the image. After this process, we'll find that even if we turn off...

The preview screen won't be completely black anymore even with automatic stretching disabled. Next, we can continue adjusting it in HTF.

Use a curve to determine the general color tone of the image; then you can output the final image.

Finally, we can choose to continue with some stylization in Photoshop, such as cropping, color correction, etc.

Add watermarks, etc., and you can generate your final photo.

Tip: When adjusting colors, be careful not to set the background to completely black, as the cosmic background light will have some brightness.

A completely black background is not scientifically sound. For monochrome photographs, a dark gray background close to black is preferable.

summary

So far, we have achieved our initial goal: to achieve the lowest possible cost and the lightest possible weight.

The equipment allows for deep-space photography without the need to travel far to escape light pollution; it can be used in areas near home. (Author)

The sample images shown only have a narrowband exposure of about 2.5 hours. Readers who can achieve longer exposures than the author will be encouraged to explore this further.

With better exposure (which is easy) or better shooting conditions than mine (which is even easier), it can be easily achieved.

Better results than the sample.

NINA and Pixingsight are both complex and powerful astrophotography software, but we only used them this time.

This is just the tip of the iceberg. However, the overall process still revolves around our preliminary preparations and calibrations.

Shooting - Preprocessing - Background Processing - White Balance (not covered in this example) - Noise Reduction & Sharpening - Non-linear Transformation - Stylization

The process involves several key steps. More advanced deep-sky photography techniques are left for aspiring astrophotographers to explore on their own.

Sola.