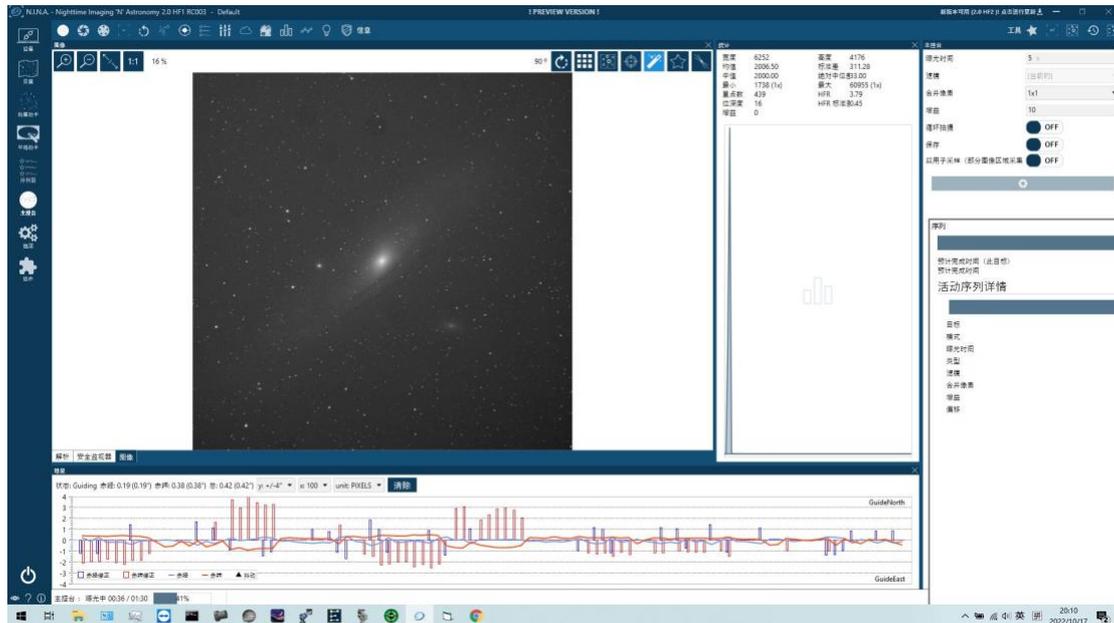


Introduction to Low-Cost Urban Deep Sky Photography: A Preliminary Exploration of Lightweight Narrowband Photography Solutions (1)



90 -second single shot of the M 31 Andromeda Galaxy taken from below our apartment building in a light-polluted neighborhood . Next, we'll start from scratch, building and debugging our equipment step by step, to achieve our goal of completing deep-sky photography right at our doorstep.

amateur astronomers in cities, especially large cities filled with skyscrapers , deep-sky photography is actually quite difficult. In addition to the fast pace of life and the lack of time for long-term photography activities, severe light pollution in cities is also a major obstacle that discourages aspiring astronomers.

Astronomy enthusiasts I know in big cities often have two choices: one is to entrust all their equipment to a civilian observatory in a town or suburb with less light pollution and remotely control it from home; the other is to take their equipment to the suburbs for shooting when they have time. However, the former often means high annual maintenance costs, which is not friendly to beginners with limited financial resources; while the latter also has considerable hidden costs, such as needing to own a car or rent one, and wasting a lot of time on the road.

This is one of the main reasons why deep-sky photography has such a high barrier to entry . But are these challenges truly insurmountable? Are urban and deep-sky photography inherently contradictory? In this article, I would like to share some of my thoughts and insights on how to solve these problems.

The proposed solution in this article is suitable for enthusiasts who possess the following qualities and ideas:

- I had no prior experience with deep-sky photography, but I already possessed the technical foundation for using a DSLR camera and a certain amount of photographic knowledge .
- I possess good patience and the courage to try and fail ;
- My budget for purchasing deep-sky photography equipment is limited. (But I should prepare at least 10,000 yuan. Although it's still expensive, it should be acceptable considering that professional mirrorless systems can easily cost tens of thousands of yuan.)
- I don't own a car, or I don't want to go to the suburbs on my days off, since I'm already exhausted from working.
- I enjoy the process of deep-sky photography more than the perfect result. (After all, the image quality from areas with severe light pollution can hardly compare to that from dark areas.)

With these ideas in mind, we can then begin our equipment setup process:

First, we must control the weight and size of the entire equipment set. If your balcony offers good shooting conditions, the total weight of the equipment can be adjusted accordingly. Otherwise, just carrying the equipment up and down stairs is already a huge hassle. Our goal is to keep the total weight of all equipment under 10kg as much as possible. This weight is still not light for the average mirrorless camera user, but keep in mind that a standard deep-sky photography set weighs around 20-30kg. 10kg is almost the limit for lightweight design; any lower and some components will inevitably be unusable.

Secondly, we should try to keep the total cost of equipment as low as possible, but we must also use resources wisely. In my opinion, for a beginner, the most important thing is to familiarize yourself with the shooting process and basic principles. Assembling a usable set of equipment that can produce successful images is sufficient. Upgrading equipment can wait until you are certain you have the interest and ability for deep-sky photography. Blindly pursuing "perfect from the start" can lead to significant financial losses. At the same time, we cannot use substandard, low-quality products, as this will severely impact the success rate of your shots.

Small-aperture refracting ED mirror

The pursuit of portability and lightweight design dictates that we need to choose **small to medium-diameter refracting mirrors as the primary mirror** . This is because the weight and cost of astronomical equipment increase exponentially; increasing the mirror's diameter and weight not only means increased weight and cost for the mirror itself, but also necessitates a heavier and more expensive equatorial mount, which is clearly uneconomical. For photographic telescopes, ED (extra-polarized) lenses are essential, effectively reducing dispersion compared to aneutralizing lenses. Of course, if the budget allows, APO (extra-polarized) lenses offer an even better experience. I used the Sky Rover 60ED + field plan corrector kit, which is almost the lowest-priced ED lens

on the market and is extremely compact and portable. If the budget allows, you can also consider the Sky Rover 70SA, a higher-spec APO-level telescope that eliminates the need for a separate field plan corrector. For beginners, small APO lenses like the 70SA already far exceed their needs; higher-spec lenses often mean greater weight and a heavier equatorial mount, making them cumbersome to use.



[Image] Sky Rover 60ED

Tips: The focal length of a small-aperture refracting telescope is similar to that of a super telephoto lens (300mm or more) for a DSLR camera, but why do we choose an astronomical telescope instead of a super telephoto lens for deep-sky photography?

We can think of astronomical telescopes as super-telephoto lenses optimized for (and only for) targets at infinity. Because the optimization is done in only one place, the cost can be significantly reduced. Super-telephoto lenses for mirrorless or DSLR cameras need to consider imaging performance across various focusing distances, often resulting in weaker optimization at infinity, and high-quality super-telephoto lenses are extremely expensive. However, if you already own such an expensive lens, I believe there's no need to buy a separate astronomical telescope. Even today, there are still many masters of deep-sky photography who insist on using DSLR lenses as their primary lenses.

Lightweight equatorial mount

Good news: Now that we've chosen a lightweight and portable small-aperture refractor as our primary mirror, we can opt for a lightweight and inexpensive equatorial mount! Here are a few lightweight equatorial mounts that I highly recommend, all of which should meet our needs.

Explore Scientific iEXOS -100 . This is a very standard, lightweight equatorial mount currently on the market, and it excels in all aspects.

The Aiton Cem-25P is heavier than the previous model, and this equatorial mount is now discontinued. However, if you can get it for a low price on the second-hand market, it's still a very good value.

The Xinda Az- GT i is a top choice for many enthusiasts seeking lightweight equipment. However, since it is essentially a theodolite, additional accessories need to be purchased, attachments modified, and the structure strengthened to transform it into a reliable equatorial mount. In short, it requires some tinkering.



[Image] Explore Scientific iEXOS -100 and Xinda Az- GT i (right). The GTi itself has a relatively simple structure and requires some additional third-party components for reinforcement. The author equipped it with Xinda's original latitude mount, RB's red and blue dovetail groove, and polar axis lens holder. The iEXOS -100 can use official accessories.

Ha narrow band filter

Why is a filter placed so prominently? Because in cities with severe light pollution, narrowband filters are the ideal choice for combating light pollution. Our current light pollution mainly comes from sodium lamps, mercury fluorescent lamps, and LED lights used extensively for outdoor lighting. Their light emission is not concentrated across a specific spectrum. Furthermore, the spectra of deep-sky objects , such as the well-known nebulae (primarily H, S, O), are not in the same spectral range as these light sources. Therefore, we can use narrowband filters to "filter out" light pollution and "filter out" light from celestial bodies.

If you have three filters—Ha, O3, and SII (commonly known as three narrowband filters)—you can create classic "Hubble color" images. It's important to note that narrowband photography isn't entirely suitable for celestial objects like galaxies. However, in situations with severe light pollution and difficult post-processing, using a single Ha filter to photograph galaxies can still be a compromise. In our brief demonstration below, we'll use a monochrome astronomical camera with a single Ha filter to produce a monochrome image.

Tip: Incandescent lamps emit almost the entire visible light spectrum, making it nearly impossible to eliminate their influence with filters. Fortunately, incandescent lamps are now rarely seen.

Astronomical Cryo Camera

We chose a camera with cooling capabilities specifically designed for deep-sky photography, not only because cooling and temperature control effectively manage thermal noise during long exposures in deep-sky photography, but also because professional astronomical cameras often come in both monochrome and color versions, and we needed a monochrome camera to work with narrowband filters for this project.



[Image] QHY 533 M Astronomical Camera

Of course, we can also use a color astronomical camera with a light pollution filter or a DSLR camera with a light pollution filter, but these two methods are not as simple and effective as using a black and white camera with a narrowband filter in cities with severe light pollution.

Electronic polar mirror

Using narrowband filters has a drawback: because the amount of light entering the camera per unit time is reduced, the exposure time naturally needs to be longer compared to conventional photography. This places higher demands on the accuracy of our equatorial mount. This is where an electronic polarimeter, capable of precise and

efficient polar alignment, becomes necessary. While there are devices and algorithms on the market that use a primary mirror for polar alignment, the primary mirror is not actually positioned on the polar axis, resulting in some conic aberration. Therefore, using an electronic polarimeter is still more accurate.



Mini guide mirror + guide camera

In the era of high-sensitivity, small-pixel cameras, the reduction in pixel size and increase in pixel density of guide cameras mean that telescopes with very long focal lengths are no longer needed to effectively detect the movement of stars. Furthermore, with increased sensitivity, large-aperture telescopes are no longer necessary. In particular, the shorter focal lengths result in a larger field of view, allowing for the guidance of more bright stars. Therefore, an entry-level guide camera and a mini guide scope are sufficient to meet our guiding needs.







[Image] My demonstration equipment: Aiton CEM -25 P equatorial mount, Skyrover 60 ED primary mirror, QHY 268 M astronomical camera, QHY 5 III 462 C guide camera + Mini guide scope, PoleMaster electronic polar mirror. The QHY 268 M is relatively expensive, but we can easily replace it with the 5 33 M or other entry-level black and white astronomical cameras, thus making it easier to keep the overall budget below 10,000 yuan while still maintaining satisfactory performance.

Laptop or industrial PC

A home laptop will suffice. We don't have high requirements for computer specifications during filming, but it needs to have at least one USB 3.0 or higher transfer rate interface.

Other optional accessories

Small outdoor power supply: If your planned shooting location lacks power, then a reliable outdoor power supply will be necessary. Currently, with market development, there are now outdoor power supplies specifically designed for astrophotography equipment.

[Image] Southern Astronomy Outdoor Astronomical Power Supply

Active USB Hub: Data transfer issues are often overlooked by astrophotography enthusiasts, yet they are frequently the culprit behind failed shots. Typically, we need four USB outputs: guide, main camera, equatorial mount, and electronic polar mirror. However, most laptops may not have enough spare USB ports, necessitating a multi-port docking station (Hub). However, multi-port setups often lead to insufficient USB power, causing USB read problems (usually the main camera with high read volumes will experience signal abnormalities). Therefore, an active USB power supply is crucial. This is where hubs become important. They also help to keep our cabling neat and organized.

Electric focuser: Since we are not operating remotely, we can choose not to use it to save on budget.

Off-axis guide (OAG): In my opinion, mini guide scopes are easier to adjust and use than OAGs for beginners, so I do not recommend them here.

Commercially available astronomical computers or industrial PCs specifically designed for deep-sky photography are an option to consider, but in reality, your laptop can perform all the tasks of these professional computers and is more flexible. If we need to save costs, why not use that few thousand dollars of budget on the more important primary telescope?

Preparation before shooting

Connect and debug the device

Because our shooting time at night is very limited, and setting up in the dark without any preparation would be very troublesome, we need to complete as many parts as possible during the daytime. What we need to do includes:

Install the necessary device drivers and software according to the instructions from all parties. The software required for this example includes: ASCOM device management platform, NINA imaging software, PHD guiding software, and PoleMaster electronic polar guide software .



Connect and power on all products to confirm they are functioning correctly. This step is crucial for beginners, effectively preventing a chaotic and disorganized situation on-site. Also, remember to bring all necessary cables with you.

Pre-focus the primary telescope and main camera, as well as the guide telescope and guide camera. Since focusing at night can only be done on bright stars or the moon, which is relatively troublesome, it's best to perform infinity focusing during the day. Point the telescope at a distant building or mountain, rotate the telescope's focusing mechanism until the image is sharp, and then remember the corresponding focusing position. This will make accurately focusing on stars at night much easier.

Arrangement Plan

Before shooting, determine the time and location. Generally, choose a flat area with a wide field of view where you can see Polaris, making it easier to accurately align with the polar axis. Even with narrowband filters, try to avoid light pollution, especially strong point light sources (like streetlights). Also, try to avoid shooting during moonrise and the waxing moon, as the moon itself contributes to light pollution for deep-sky photography.

Here, we recommend using the free software Stellarium (virtual planetarium). By entering your location and time into the software, it can display the rising and setting of the moon at your location within a certain time period , as well as the position of the celestial body you want to photograph.



As you can see from this , considering various external conditions, the number of days suitable for deep-sky photography is actually quite limited . And so far, we haven't even considered the wind issue. Wind not only affects seeing, but excessive wind can also cause the telescope and tripod to sway, which severely interferes with the equipment's automatic tracking. Unfortunately, in places like Beijing, where I live, almost every sunny day is windy. In such cases, we can only improvise, placing stones or bricks from the roadside on the equatorial mount's support platform to try and ensure its stability.

With these preparations complete, we can now move on to the practical application.

(To be continued)