Planning

- Pick large bright subjects when you are first starting out in deep-sky astrophotography.
- Choose a focal length that will frame the deep-sky object well.
- Decide how you want to frame the object in a planetarium program or star chart before you go out.
- Research a guidestar before you go out.
- Shoot when the object is high in the sky and transiting the meridian.
- Shoot from the darkest location you can.
- Shoot deep-sky objects on nights of good atmospheric transparency.
- Make sure batteries are fully charged before going out.

Equipment Setup

- Setup the scope, collimate, align finder.
- Balance the scope with all of the equipment in place.
- Shoot twilight flat-field frames if necessary (make sure scope is focused on infinity).
- Polar align.
- Perform drive adjustments such as periodic error training and backlash compensation.
- Set up anti-dewers.
- Attach all electrical devices to power supply.
- Hook up camera to computer.

Camera Settings

- Set Program Mode to Manual Exposure or Bulb.
- Set Drive to Single Shot.
- Set ISO to 400, 800 or 1,600 based on object brightness.
- Turn Image Review Off.
- Turn Auto-focus Off.
- Set White Balance to Daylight for non-modified camera
- For a modified camera, use a custom white balance set with a gray card shot in sunshine on a clear day at noon.
- Set File Format to Raw (or Raw + JPEG).
- Set Optical Resolution to the highest (native) setting.
- Turn Long-exposure noise reduction Off if you are planning on shooting separate dark frames, Turn On if you are not.
- Turn off in-camera sharpening if you are shooting JPEGs at a high ISO.
- Set contrast and color saturation to normal if shooting JPEGs.
- Set color space to sRGB normally or Adobe RGB if extremely knowledgeable about color spaces.
- Turn off flash.
- Turn off Lens Peripheral Illumination Correction.
- Turn off Auto Lighting Optimizer.
- Turn off High-ISO Noise Reduction.
- Set exposure to Bulb.
- Put Compact Flash Card in camera.
- Use a remote release to open the shutter, or self-timer if you don't have one.
- Mirror lockup is not necessary for long-exposure astrophotography with a decent mount. Use for high-resolution planetary work.

Drift Polar Aligning

- On the Meridian correction for the mount's altitude, if the star drifts South, the mount is too far East.
- On the Eastern Horizon correction for the mount's azimuth, if the star drifts South, the mount is too Low.
- Mnemonic: S-E-L. (South, East, Low)
- If you monitor a star at high power (225X) and it doesn't drift in either direction, north or south, off the cross hair for 5 minutes, for both the altitude and azimuth adjustments, you are accurately polar aligned. Ignore any East-West Drift.

Focusing

- Software assisted metric focusing is the most accurate method of focusing.
- Live-View video is the easiest method of focusing. Remember for Live View:
 - Use manual exposure and manual focus.
 - Use ISO 1600, bulb shutter-speed, and the lens' widest aperture.
 - Use a *bright* star or planet to focus on.
 - Eyeball the focus through the viewfinder to get close to focus before you try to use Live View.
 - Zoom in to 10x to focus.
- A Bahtinov mask can work well for focusing point sources, but can't be used on extended objects. You can, however, just focus on a star and then move the scope to a planet or the Moon.
- If you don't have a Live View or a computer, just take a test exposure of a star through a Bahtinov mask and examine the image on the LCD on back of camera at high magnification.
- Autofocus can work if the optical system is fast enough and the star is bright enough and located exactly on the autofocus spot.
- Be aware that many auto-focus camera lenses will focus past infinity.
- Knife-edge focusers like the Stiletto and Mitsuboshi can be accurate and easy to use if you are familiar with knife-edge focusing.
- At an absolute minimum, use the additional magnification found in a right-angle finder to focus a star, and then double check it by taking an exposure and examining the star at high magnification on the camera's LCD. Tweak the focus a little bit on each side of the best apparent focus to see if you can improve it. Adjust the exposure so the stars are not saturated and over-exposed.
- The worst way to focus is by eye alone through the viewfinder without any additional magnification.
- Once you have achieved focus, lock the focuser down. If it is a lens, tape it down. Be careful that the focus does not change in the process of locking it down.
- Refocus periodically during the night especially if the temperature is changing.

Target Acquisition and Framing

- Locate the object and frame it correctly.
- Move the scope if necessary to find a focus star.
- Focus the scope and lock down the focus.
- Move the scope back to the object if necessary.
- Shoot test exposures to determine the correct exposure and double check the framing.

Image and Support Frames - Flat Field Frames - Shoot in raw file format.

- Shoot first if you are doing twilight flats after sunset.
- Use an evenly illuminated light source.
 - Light Box
 - Double white T-Shirt in front of the lens or scope
 - Twilight sky opposite the Sun
 - Large evenly illuminated flat sheet or foam-core board
 - Focus the camera or telescope on infinity.
- Use a low ISO.
- Expose on manual at the camera's suggested meter reading and expose to midhistogram, or shoot on autoexposure with aperture value mode.
- For camera lenses shoot at the same f/stop you will use for the light frames.
- Shoot with all components of the optical system the same as for the light frames: filters, Barlows, telecompressors, adapters, etc.
- For twilight flats, shoot with the telescope drive off.
- Shoot at least 16 frames total.
- Do not change the orientation of the camera to the telescope tube when you aim the scope at the object to shoot the light frames.
- If your flat-field frames are longer than 1 second at high ambient temperatures, you may need to shoot darks at the same ISO, temp and exposure as the flats, as well as bias frames for your flats.

Image and Support Frames - **Light Frames** -Shoot in raw file format.

- Locate object and frame. Don't change focus or camera orientation to the scope tube from settings used above for flat-field frames if you have shot, or plan to shoot, flat-field frames.
- Move the scope slightly between exposures or groups of exposures if you want to dither.
- Shoot with in-camera noise reduction turned off if you are planning to calibrate with dark frames. Shoot with in-camera noise reduction turned on if you are not going to use separate dark frames and are shooting at high ambient temperatures.
- Shoot as many exposures as possible of the deep-sky object.
- Determine the correct exposure by examining the histogram.

Image and Support Frames - Dark Frames - Shoot in raw file format.

- Turn off in-camera noise reduction.
- Cover all openings. No light should be able to enter the camera. This includes the viewfinder eyepiece.
- Shoot a minimum of 9 or 16 dark frames at the same ISO, exposure and temperature as the light frames. More darks is better.
- If you want to create a scalable master dark frame for use with different exposure times, make sure to shoot bias frames at the same temp and ISO, and make the exposure length of the dark frames longer than the longest light frame you want to use it with.

Image and Support Frames - **Bias Frames** -Shoot in raw file format.

- Cover all openings including the camera eyepiece.
- Shoot 9 or 16 frames at the shortest exposure the camera can make.
- Use same temperature and ISO as Light frames.

Guiding and Tracking

- First achieve accurate polar alignment.
- Take some time exposures of various lengths... 30 seconds, 1 minute, 2 minutes, 4 minutes, and 8 minutes, and then examine the stars in the image at high magnification. This will tell you how long you can expose without guiding for the accuracy of your right ascension gears.
- Short focal-length lenses piggy-backed on top of a correctly polar aligned equatorial mounting usually don't need to be guided at all. Longer focal-length telephoto lenses and telescopes usually do need to be guided.
- For visual manual guiding while shooting at long focal lengths, use a cross-hair eyepiece magnification at least 10x that of the imaging scope. Divide the focal length of the imaging scope by 50 to get imaging magnification of the imaging scope. Divide the focal length of the guidescope by the focal length of the guiding eyepiece to get the magnification of the guiding setup.
- Adjust the focus of the cross hairs of the guiding eyepiece first before putting it in the scope.
- Guide on a star that is in focus.
- Calculate the guiding tolerance necessary for the focal length of the imaging scope or lens.

ISO and Exposure

- For unguided exposures, expose as long as the mount's tracking allows with no trailing.
- Expose long enough to get the object detail out of the noise that is generated in the camera. A good aim point is for the sky background to be at least 20 to 40 percent of the way from the left side to the right of the histogram. The length of exposure necessary to reach this point will depend on how dark your observing site is.
- At high ambient temperatures, take shorter exposures at higher ISOs. As the temperature drops, you can take longer exposures at lower ISOs. You will need more total short sub-exposures at higher temperatures.
- Take as many sub-exposure frames as you can and average them together in software.

File Formats, Downloading, Archiving

- Shoot raw file format in the camera.
- Make sure your camera's memory card has enough space to store all of the files you will shoot.
- Download the files from your memory card with a USB2 compact flash card reader to your home computer.
- Always archive your original files before you work on them. They should be archived to a permanent optical storage medium like a CD-R or DVD. If originals are stored on a hard drive, and the drive goes bad or catastrophe strikes, you will lose all of your hours of hard work if they are not backed up to another source.
- If you shoot JPEG originals, always archive them separately, and then work on them as TIFF files when you process them. Save your works-in-progress, and final images as TIFF files because TIFF is a lossless file format. Opening a JPEG and re-saving it as a JPEG will lose data.

Recommended Exposures for Deep-Sky Objects

• Based on the darkness of the observing site, a latest generation low-noise camera, reasonably high elevation of the object in the sky.

| ISO \ F# | 2.8 | 4 | 5.6 | 8 |
|----------|--------|--------|--------|--------|
| 400 | 15 sec | 30 sec | 1 min | 2 min |
| 800 | 8 sec | 15 sec | 30 sec | 1 min |
| 1600 | 4 sec | 8 sec | 15 sec | 30 sec |

Light-polluted suburban observing site (Naked Eye Limiting Magnitude = 3.5)

Moderately Dark Observing Site (Naked Eye Limiting Magnitude = 6)

| ISO \ F# | 2.8 | 4 | 5.6 | 8 |
|----------|---------|---------|---------|------------------------|
| 400 | 2.5 min | 5 min | 10 min | 20 min <mark>NR</mark> |
| 800 | 75 sec | 2.5 min | 5 min | 10 min |
| 1600 | 37 sec | 75 sec | 2.5 min | 5 min |

Very Dark Observing Site (Naked Eye Limiting Magnitude > 7)

| ISO \ F# | 2.8 | 4 | 5.6 | 8 |
|----------|---------|--------|------------------------|------------------------|
| 400 | 6 min | 12 min | 24 min <mark>NR</mark> | 48 min <mark>NR</mark> |
| 800 | 3 min | 6 min | 12 min | 24 min <mark>NR</mark> |
| 1600 | 1.5 min | 3 min | 6 min | 12 min |

Notes

- NR = Not Recommended.
- These times should be considered starting points only. Take test exposures and examine the histogram to determine the correct exposure for your observing site.
- Images shot at temperatures higher than about 32F (0C) should have dark frames subtracted from them.
- Exposures with an IDAS LPS or Astronomik CLS filter should go 2x to 3x longer than the times listed above.
- The chart may be expanded for other f/stops by direct extrapolation from the values given above.

Recommended Number of Exposures

- From an urban or suburban observing site with light pollution, your exposures will be short so you will need to shoot a lot of sub-exposures to get enough signal-to-noise ratio in your images. For bright objects like M27, you may need to shoot 90 sub-exposures at 1 minute each at ISO 800 at f/8.
- For faint deep-sky objects try for a total exposure time of 1 to 4 hours, depending on how dark your observing site is.
- The total number of sub-exposures needed will be determined by the length of an individual sub exposure and the total desired exposure time. If you can shoot 5 minute exposures (for a given combination of ISO, F/stop and sky brightness), and you want 2 hours of total exposure time, then you will need 24 sub-exposures.
- The longer the total exposure, the more photons the camera records, and the higher the resulting signal-to-noise ratio in the final image.

Recommended Methods of Controlling In-Camera Heat

- Turn off the LCD image display after a shot is taken.
- Use a fast compact flash card or write the files directly to a computer.
- Use an external power source instead of the in-camera battery.
- In warm ambient temperatures (above 40F), use a fan to blow air onto the camera during exposures.
- Do not wrap the camera in cold packs to try to lower the internal temperature.
- Do not pause between frames to try to let the camera cool off.
- Shoot continuously and record as many photons as possible.

Using a Remote Interval Timer to Automate Image Capture for Bulb Exposures

Longer than 30 Seconds

- Set the camera to single shot mode.
- Turn off autofocus on the lens or camera if using a camera lens.
- Set the exposure mode to bulb on the camera.
- Set the total number of exposures desired on the timer.
- Set the Interval time between exposures to 10 seconds on the timer to give the camera time to download the raw file to the in-camera memory card or to the computer. For older cameras with a USB 1 connection, this time may need to be increased.
- Set the Exposure time on the timer to desired exposure.
- Start the exposure sequence by pressing START on the timer.
- To use the mirror lock up, put the camera in self-timer mode and set the mirror lockup with the camera controls. Then program the remote interval timers as normal but add the length of the camera's self-timer time to the exposure time. The remote interval timer will then signal the camera to start the process and the mirror will lock up, the self timer will count down, and the shutter will open.