Equipment

This is my piggyback setup: Canon 20Da mounted on an 8” LX200GPS using a Milburn piggyback mount. The LX200GPS is mounted to an AMF equatorial wedge. An STV autoguider, with e-finder, is mounted underneath the OTA, with a Losmandy PB-M8

Meade 8” LX200 GPS: I have a love/hate relationship with Meade. Meade is to be commended for their many innovations, which have made quality observing and astrophotography accessible to the average person. Meade is to be condemned for the erratic nature of their workmanship and apparent poor quality control. I will not bore the reader with all the details, except to note that my scope arrived with a broken tripod, stripped mounting screws, unmovable manual setting circles, and defective sensors. It took 3 months of repairs before I was able to use the scope.

I stuck with the LX200, because it is a fundamentally fine instrument, considering the price. Out of the box, the mount showed a periodic error of about 40 arc seconds, not great but good enough for normal and wide-angle camera lenses. After running the mount 12 hrs/day for a week, the error went down to about 30 arc seconds. With periodic error correction, I was able to reduce the error to about

15 arc seconds. Meade's PEC is unique in that it is permanently programmable; it is not necessary to retrain the drive each time out. I have also been pleased with the LX200's optics. Despite thousands of miles of travel, much through rough terrain, the scope has retained its collimation remarkably well. When mounted on a quality equatorial wedge and the standard Meade tripod, the 8" LX200 is quite sturdy, capable of consistent tracking for long exposures. When operating in the equatorial mode, the GPS serves only to enter the date/time; and that's necessary only for the go-to. I usually do not use go-to when doing wide-field piggyback work. Manual setting circles are sufficient to get me close; then I take a test shot and adjust my pointing as needed.

Equatorial Wedges: I began with the standard Meade equatorial wedge. It is very difficult to work with. Altitude is adjusted by a single screw, which pushes against a cavity in the underside of the wedge. As the altitude of the wedge changes, so does its tilt angle and contact point with the screw; the wedge often slips, undoing the adjustment. Azimuth adjustment is hindered by the lack of a smooth bearing with the tripod base. It is necessary to loosen and re-tighten the mounting bolt with each adjustment. Most annoying is the small altitude adjustment knob connected to the small screw, which requires strength to turn and is quite painful to the palm of the hand. Nevertheless, the standard Meade wedge works and, despite about 2 hrs spent on drift polar alignment, I have gotten good results with exposures up to 20 minutes.

A much better, and more costly, product is the ***AMF Equatorial Wedge*** by APT Astro (www.apastro.com) shown in the picture above. It is very sturdy and easy to mount on the tripod. Best of all, it is not necessary to loosen and tighten any bolts when making adjustments; just turn the knobs. Movement is much smoother than the Meade standard, permitting finer adjustments, and it's much easier on the hands. The downside: it costs about $650. Another alternative to consider is the ***Milburn Wedge*** (www.milburnwedge.com). I have used a Milburn Wedge owned by a friend and liked it a lot. I have been impressed by Ken Milburn's workmanship on other products. Note that his products are made to order and may take a few months to complete.

Piggyback Mounts: I began with the Meade piggyback mount. It is a rigid bracket secured in the mounting holes at the rear end of the OTA. Confined to this position, imaging with focal lengths of 50mm or shorter will pick obstruction from the front end of the OTA. The system permits no flexibility in orienting the camera. Also, I found the camera mounting screw a little short for my Nikon F3. Nevertheless, the mount was sufficient for 12 minute exposures, without any evidence of flexure.

The piggyback system made by the above mentioned Ken Milburn is the best I have seen. It consists of a Bogen 3025 tripod head on a dovetail rail running the length of the OTA. The tripod head and camera can be moved up and down the rail to avoid obstruction and, in some cases, to improve balance. The Bogen 3025 has three axes of movement, allowing for any orientation of the camera, including vertical shots. It is better than a ball head mount for vertical shots, because the three axes permit the camera's center of mass to be positioned more or less in line with the center of the OTA. I have been very pleased with this product. ***Losmandy*** also makes piggyback mounts (www.losmandy.com). The simplest system (PB-M8) consists of a rigid mount and a 3/4" wide dovetail rail. The mount may be moved up and down the rail, but there is no ability to change the camera orientation. I currently use this system to mount my STV on the underside of the OTA (see picture). Losmandy has piggyback mounts with rotational ability, but these require the larger dovetail plate.

SBIG STV: Possibly the best $2500 I have spent on this hobby. It is an integrated ccd camera, video cam, and autoguider. The camera and video are of mediocre quality, and the STV is used mostly as a stand-alone autoguider. It takes a few nights to get the hang of it, but the operation is quite intuitive, and the results can be amazing. Under good conditions, with prudent guide star selection, exposure time, and number of frames to average, I have gotten sustained sub-arc second tracking with my LX200. The STV has several extra features, including drive monitoring, which can assist in polar alignment (by measuring declination drift) and assess RA performance and the effect of PEC. For a guidescope, I use the e-finder. It is a 25mm achromatic lens at f/4. Only four inches long, it is light and requires no mounting rings or support. The ccd and e-finder fit comfortably on top or underneath the OTA. The STV comes with a monitor, so no separate computer is needed. My only complaint with SBIG is the owner's manual. The manual makes no mention of the "# of frames to average" parameter; it's not even shown on the menu diagram. One of the unique features of the STV is the ability to take and average multiple exposures before making a correction. The manual also fails to adequately describe the labeling of the four relays. The manual shows them as 1234, the STV shows just 1 for "on" or 0 for "off" in the four positions. I found this confusing. In general, the manual lacks a coherent discussion of autoguiding. It gives a good description of "auto" mode usage, but information needed for "manual" mode usage is scattered in different sections of the manual.

Cameras/Films: For film, I use the ***Nikon F3***. It has all the features necessary for long exposure photography, some helpful extras, and it's built like a tank. On the negative side, it's one of the heaviest 35mm film SLRs. Most of the films suitable for astrophotography have been discontinued by the manufacturers; I cannot recommend any current color print film. Fortunately**,** ***Kodak E200*** slide film is still available. It has excellent reciprocity, records good color saturation (especially red), and is not too grainy. Shooting at f/4, I find 30 minutes about the minimum exposure time. I have used Fuji Provia 400 a few times, but find it grainy and lacking the color richness of E200. Fuji Provia 100 looks promising, but the exposure times are brutal; I recently shot Sagittarius for 40 minutes, and it was not nearly enough.

Canon 20Da: An 8.2 magapixel DSLR, designed for astrophotography, the 20Da has everything, including a live focusing feature. It also has automatic dark frame noise reduction, but I don't use it because it would effectively double my exposure time, reducing the amount of imaging time. Instead, I take separate dark frames at the end of my sessions. While the darks certainly help, the 20Da seems to have very little noise, even at ISO 800. I had my 20Da modified by ***Hutech*** (www.hutech.com) with an IR filter which allows more deep red transmission. This decision was based, in part, on the ***Sky and Telescope*** review in November, 2005 (pp. 84-88). While the 20Da clearly shows a stronger red response than the 20D, I still found it a bit weak. As the unprocessed frame shows, the Hutech filter makes the entire image too red. This must be corrected with software, such as Photoshop, but it's not that difficult, and I'd rather have too much red data than too little. I am very pleased with my Hutech modified Canon 20Da. The advantages of DSLR over film are numerous. I like the feedback of the DSLR, so that I can immediately address problems like focus, elongated stars, and composition, rather than keeping my fingers crossed until the film is developed. The 20Da even displays a histogram to aid in setting the correct exposure.

Rental Equipment: For prime focus photography, I currently rely on equipment rented from the ***New Mexico Skies Guest Observatory*** (www.nmskies.com) and ***Rent-A-Scope*** (www.global-rent-a-scope.com). The ability to use high quality, permanently mounted, telescopes and cameras, on a rental basis, is especially appealing to me as an urban dweller. Once or twice a year, I travel to NM Skies. They have scopes ranging in size from 6" to 24," all equipped with ccd cameras. The scopes are attached to the highest quality mounts and are housed in clam shell domes. The systems are permanently aligned and have OPTEC TCF focusers. Instruction is provided on operation, which is done with PC software. I found the process quite user friendly. It is not necessary to stay in the dome. Once the exposure series is initiated, you can leave the dome and watch your images appear on computer in their comfortable library. NM Skies also has guest pads, with AC, where visitors may use their own equipment. Sometimes, I drive out with my equipment for wide-angle photography, to take advantage of the dark, transparent skies (~7.5 mag). Other times, I fly out and rent telescope systems which I could never afford to own or even handle. Virtually all the images on this site were shot on NM Skies property. Accommodations are very nice. Spacious and tastefully furnished apartments and cabins are available, with full kitchens and televisions. I have also visited the ***National Optical Astronomy Observatory***, located at Kitt Peak, near Tucson, AZ (www.naoa.edu). Unfortunately, my imaging was aborted when the Observatory shut down due to high winds. Their Advanced Observing Program offers much the same service as NM Skies. Their website suggests a growing emphasis on DSLR imaging (bravo!). I hope to try them again soon, hopefully with more cooperation from the weather.

For the couch potatoes like me, Rent-A-Scope may be the answer. You can operate telescope/imaging systems from home, via the internet. Rent-A-Scope has five systems housed in a roll-off dome at New Mexico Skies Observatory; they also have two systems in Australia and one in Israel. Their slogan is: "Where the Sun Never Rises." Scopes range from the Takahashi Sky 90 to the 300mm Takahashi Mewlon. All are on Paramounts and are equipped with SBIG ccd cameras. Focusing rarely needs to adjusted, thanks to the OPTEC focusers. The imaging process is even easier than the NM Skies system; a video demo on their website will confirm this. Very little is required in the way of experience or knowledge. The biggest challenge is downloading and processing the images. Unlike NM Skies, where calibrated FIT files on CD are presented upon departure, RAS images must be downloaded in zip format, via FTP. Calibration files must also be downloaded and applied to the images using software, such as MAXIM DL. It's a little time consuming, but not that difficult. In general, I have been very pleased with the quality of my RAS images. I highly recommend their service for the beginner and the experienced.

Techniques

Polar Alignment: In my opinion, polar alignment is the single most important task under the control of the user. With accurate alignment, one can eliminate declination drift and field rotation, which allows for quality unguided exposures using short focal length optics. When guiding is desired, it can be done solely in Right Ascension, eliminating backlash in declination, which plagues many mounts. Most commercial mounts have rough polar alignment routines built into their software. Michael Covington describes a rough polar alignment process, applicable to any telescope, in his classic "Astrophotography for the Amateur." However, to achieve optimal alignment, it is necessary to improve on the rough alignment with a method like "declination drift." With perfect polar alignment, stars will not drift at all in declination. So, the task is to adjust the mount in altitude and azimuth until there is no declination drift for an acceptable period of time (e.g., 5 minutes). A high power reticle eyepiece is recommended to view the star's drift. The drift alignment process is discussed in many sources, and I will not repeat it here. Instead, I refer the reader to an article by Bruce Johnston at www.members.aol.com/ccdastro/drift-align.htm. It is the most elegant and clearly written description I have seen. I also recommend the brief article written by Chuck Vaughn in the April, 2003 issue of S&T (p. 133). Mr. Vaughn describes the process using "up/down" and "left/right" movement of the star as seen through the telescope. I take this handy reference with me whenever I go out to image. I offer the following suggestions: 1) level your tripod as best as possible before beginning polar alignment. While perfect leveling is not ultimately necessary, it makes the drift alignment much easier. That's because adjustments in altitude can change the azimuth pointing and vice versa, when the tripod is not level. This requires several iterations of altitude and azimuth adjustments; a level tripod will reduce the required number of iterations; 2) when viewing a star near the east or west horizon for altitude alignment, it is necessary to reposition yourself and contort your head a little, so that declination movement is up/down and azimuth movement is left/right. Otherwise, star drift will be at an angle as seen in the eyepiece, making it difficult to tell if the drift is in dec. or RA. Before monitoring drift, move the telescope in dec and RA and rotate the eyepiece as necessary, so that the star moves up/down when moving the scope in dec.; 3) defocus the star a little, to make it larger and easier to detect drift; 4) be patient – it can take over an hour to eliminate drift, even for experienced users. But it is well worth the effort. Drift alignment may be expedited by using an autoguider, such as the STV. The STV has a drive monitor feature, where RA and dec drift is measured without any guiding corrections; the drift is displayed on a graph. The mount is adjusted in alt and az until any slope on the declination axis is eliminated. The autoguider can measure fainter stars than the eye and detect drift sooner, speeding up the process.

Guiding: With declination drift eliminated by good polar alignment, the next task is to reduce movement in Right Ascension, which is caused by periodic error in the mount. If your scope has periodic error correction, use it. The left and right arrow keys on the keypad are used to keep the star centered in the reticle eyepiece throughout the mount's PE cycle (usually 4-8 minutes). The telescope software remembers your corrections and replays them through the duration of the night's operation (Meade's PEC replays the correction every time you activate the scope, unless the training data is erased or overwritten). With PEC, it may be possible to image unguided with focal lengths up to about 150mm. For longer focal lengths, active guiding may be necessary to avoid elongated star images. Having PEC engaged makes manual guiding much easier; in fact, I cannot imagine manual guiding without PEC. Manual guiding simply involves using the keypad arrow keys to keep the guide star centered in a reticle eyepiece throughout the exposure. When doing piggyback photography, the telescope may be used as the guidescope; a 9mm reticle, with a 2000mm focal length scope gives a magnification of about 200, which is ideal. When imaging prime focus, an off-axis guider or separate guidescope is needed. I offer the following thoughts on manual guiding: 1) if available with your mount, reduce the guiding rate, to avoid over correcting (30-50% sidereal works best for me); 2) dim the intensity of the reticle; if it's too bright, the guide star may be obscured by the reticle crosshairs; 3) guide in RA only to avoid declination backlash. This requires accurate polar alignment as described above.

Autoguiding: Manual guiding is not a very pleasant experience; it is tough on the body, eyes, and mind. If you decide to pursue astrophotography, you will probably want an autoguider, which is a ccd camera that takes snap shots of a guide star, measures movement of the star from its centroid position, and sends commands to the mount to correct the movement. I use the STV from Santa Barbara Instruments Group. As you can tell from the above comments, I find the STV a remarkable and indispensable instrument, capable of sub-arc second tracking. While I find it user friendly, it takes a few nights of practice to become comfortable with its many features. With the autoguider, I can sit back and relax during the entire imaging session, without remaining glued to the eyepiece. Before the STV can guide, it must be calibrated; the autoguider measures the telescope movement in all four directions to determine the amount of correction needed when guiding. However, my LX200 declination has so much backlash, the STV is unable to calibrate in dec. No problem – with the STV I can calibrate and guide in RA only. With accurate polar alignment, this is sufficient. With the STV, I suggest using the e-finder as a guidescope when imaging with short focal lengths (e.g., under 600mm). It's light, compact, inexpensive, and has given me and others good results.

Image Processing:

Film: Nearly all film astrophotos can benefit from digital enhancement, using image editing software, such as Photoshop or Paint Shop Pro. Typically, the background needs to be darkened and the midtones brightened. The biggest challenge may be obtaining a good scan of the negative or slide. Despite extensive research, I have not found any commercial entity in Chicagoland capable of scanning astro negatives/slides. Typically data is "clipped" from the shadow or highlight end (or both) of the histogram. Since I don't shoot much film anymore, I have not invested in my own scanner; instead, I send my slides/negatives to Tony Hallas (www.astrophoto.com). He produces a good scan to CD for a very reasonable price. His scans fill out the histogram, but leave enough room at both ends for additional contrast adjustments. With a good scan, contrast, color saturation, and color balance can easily be improved using "levels" and "curves" in Photoshop. Photoshop is a massive program, with a steep learning curve. However, 90% of the work is done with just two functions, levels and curves. The process is greatly simplified by Jerry Lodgriguss, in his CD book, "Photoshop for Astrophotographers." He provides a straightforward, step-by-step example using a wide-angle Milky Way image captured on color print film. Sophisticated processes, such as layers and masks, are discussed, but the simple functions of levels, curves, and sharpening are sufficient to greatly enhance most images.

DSLR/one-shot color ccd: DSLRs and ccds record light differently from film and require more extensive processing. Most imagers shoot multiple exposures of 5-10 minutes and stack them to improve the signal-to-noise ratio. The SNR can also be improved by applying dark frames (exposures at the same ISO and exposure time as the light frames, with the lens covered). Special software, other than Photoshop, is required for these tasks. I have used ***Images Plus*** for my DSLR images. It will convert the RAW images to color, apply dark frames, and stack the individual frames. While it does a good job, I find the Images Plus routine awkward and not very intuitive. I intend to try ***MAXIM DL*** for these tasks. Based on my experience with MAXIM DL for ccd processing, I suspect it may be easier than Images Plus for DSLR processing. With the individual frames calibrated and stacked, the image may be enhanced for contrast and color saturation/balance. The DSLR can output a JPEG image, where the camera software sets white and black points. My Canon produces nice JPEG images, but most astrophotographers prefer to shoot in the RAW mode and manually set the white and black points in Photoshop. When an unprocessed 16 bit image is opened in Photoshop, it is very dark, often showing just the brightest stars. That's because the chip records some 65,000 brightness levels, while Photoshop can display only 256 levels on a computer monitor. The result is most of the data is compressed into a very small area at the dark end of the histogram. It is necessary to use a combination of levels and curves to brighten the image and maximize the color. The process is often called "contrast stretching," where the data is stretched, or spread out, to fill up a much larger portion of the histogram. This is more art than science and requires practice and experimentation. Often I spend an hour or more on an image to get the desired contrast and color. I highly recommend the DSLR processing tutorial by Steve Cannistra at www.starrywonders.com. He provides a sequence of steps and typical levels and curves adjustments to get the most out of your images. I have just ordered Jerry Lodriguss' new book, "A Guide to Astrophotography with DSLR Cameras" (www.astropix.com). While I have not yet read the book, I have seen many of Jerry's suggestions in his messages on various Yahoo discussion groups. If his previous book is any indication, the new one promises to be a winner. One-shot color ccds, like the ***SBIG ST-2000XCM***, function similarly to the DSLR and employ similar processing techniques. I have used ***CCDSOFT/CCDOPS*** to repair bad pixels and stack individual frames taken with the ST-2000XCM. MAXIM DL also appears up to the task. DSLR and single-shot ccd technologies are similar in that the imaging chip is covered with a color matrix filter, so that each pixel ends up with just red, green or blue data. When converted to color, data between neighboring pixels is interpolated to produce a realistic color image. Because of the interpolation, most processes, such as alignment, deconvolution, and histogram adjustments must be performed after color conversion; if done prior to conversion the color will be destroyed. Once calibrated, color converted, aligned, and stacked, DSLR and one-shot ccd images may be processed in Photoshop using very similar techniques.

CCD LRGB Processing: Without a filter array covering the imaging chip, the only way to get color from a ccd is to expose the chip separately through red, green, and blue filters. In contrast to the DSLR and single-shot ccd, each pixel has its appropriate amount of red, green and blue data by the end of the imaging sequence. There is no need to interpolate data between neighboring pixels to get a color picture. Instead, three separate frames are processed and combined into RGB color. Typically, the color exposures are shot at lower resolution and higher sensitivity, and a separate, luminance frame is added from a series of full resolution, unfiltered exposures. MAXIM DL easily combines the channels and performs a contrast stretch to produce the RGB or LRGB image. Many astrophotographers, like myself, feel that full advantage of the LRGB imaging technique is realized by separately processing the luminance and color frames in Photoshop. Because resolution in the color exposures was sacrificed for increased sensitivity, the color data is processed for ideal color saturation and balance (using mostly linear histogram adjustments). The luminance frame, obtained from full resolution exposures, is processed for ideal detail and sharpness (using mostly nonlinear adjustments, including complex S curves). When combined, the image incorporates the best features of both. I generally follow the steps outlined by Ron Wodaski in "The New CCD Astronomy." Often, addition of the luminance frame drains color from the image. In that case, I employ Rob Gendler's double luminance layering technique (www.robgendlerastrotopics.com). It's very simple and usually restores the color saturation, while retaining detail.

For several of my images, I applied highlight masks while increasing contrast in Photoshop. The process is clearly outlined by Jerry Lodriguss and illustrates the power of Photoshop. The highlight mask is a used to brighten midtones, while preventing bloated stars, burned out galactic cores, etc.

I highly recommend a good noise/grain reduction program. I use ***Neat Image*** or ***Noise Ninja***, whichever works best on the particular image. Both are user friendly and have the effect of making faint signal smoother, while enhancing detail. On some images, brightness is increased by a full photographic stop or more.

<u>Comment</u>: Based on my experience, colors are noticeably richer when captured on a monochromatic camera, using filters, than with single-shot color technology. Perhaps that's because of the need for interpolation by the DSLR or one-shot ccd. Perhaps it's sensitivity; color data cannot be binned to increase sensitivity in these cameras. Further, exposure time is effectively split between the three colors when using the matrix filter; by contrast, all exposure time with the mono camera is devoted solely to red, green, or blue. DSLR astrophotographers seem to be trending to longer total and sub exposure times to improve color response (see Chuck Vaughn in S&T, November, 2006, pp. 97-102).