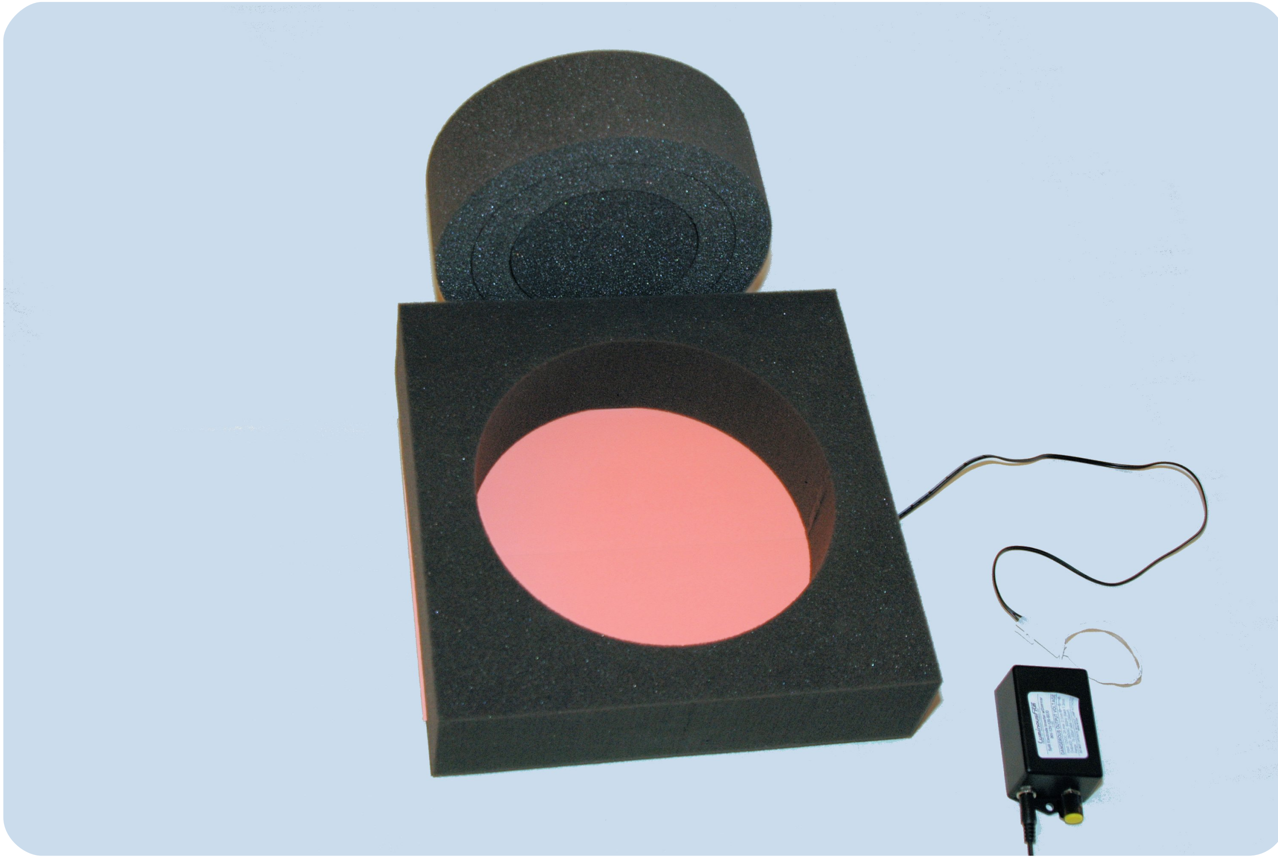


# A Lite ELPH for Flat-fielding a CCD Camera

I must confess up front that much of what will be described below started as a potential commercial venture about six months ago. As such the final product which I intended to call the "Lite ELPH" is a reasonably refined assemblage of off-the-shelf parts and one optional custom made item. There is nothing particularly brilliant about its implementation. In a large sense it is a consolidation of many ideas bantered about on many astronomy-based websites and therefore wholly unpatentable. Nonetheless, completion of this project was an educational adventure into cost containment and free-market forces which I found nearly as interesting as its actual design. In the end, the projected cost even with steep volume discounts for individual components did not offer any significant advantage over similar products presently on the market. This account is therefore offered free of charge to anyone who prefers to build rather than buy. I therefore assume no responsibility for any trouble you may get into with your significant other or injuries sustained from improper handling of this high voltage electrical device. Also, I have absolutely no personal, commercial or financial ties to any of the vendors which are mentioned in this article.

The collection of proper CCD flat-fields represents one of the more challenging tasks in lowering the noise floor necessary to extract the last bit of detail out of an image. Flats are intended to capture the fixed noise signature which may include out of focus artifacts from dust aka "donuts", imperfections on the CCD matrix, and any other uneven illumination such as that caused by optical vignetting. Any change to the optical train, including filters, orientation or cleanliness will require the collection of new flats. Ideally, not unlike taking bias and dark frames, this should be a highly controlled process but for many amateur astrophotographers this goal falls short for a variety of reasons. The narrow window of opportunity at dawn or dusk is rarely long enough particularly if one needs to collect twilight flats and flat darks from multiple filters. Skylight flats which require averaging dozens of images simply take too long. Some folks swear by them, but in my hands, daytime "T-shirt" flats never achieve the level of uniformity expected from flats. Another option includes the construction of a home-made light box featuring a diffused indirect incandescent or white LED light source. Most examples I've seen employ a complicated array of diffusers or lights, are bulky, not particularly portable, and often only address the needs of a single telescope. By comparison, designing a light weight box around an electroluminescent panel (ELP) greatly simplifies the design parameters. A single device can easily cover all apertures between 3 and 8" which is fortuitous since this likely represents the largest market segment for amateur astronomers. As such, most of the assembly details described below focuses on telescopes in this size range but is scalable to the many different sizes commercially available (A2-A6).

## Technology from the 1960s

ELP technology has been around for at least five decades and most commonly used to backlight instrument panels or displays for a broad range of products (e.g. watches, automobile dashboards, nightlights, ad signs). Not all ELPs are created equally so that the selection process deserves special attention. I'll leave it up to the reader to Google the product specifications on ELPs, but in a nutshell it is important to make sure that the output spectrum is as broad as possible between 400-700nm. This is particularly important to ensure sufficient output signal for those folks using narrow band filters. At least one ELP (FLATLITE®) would appear to meet this requirement based upon

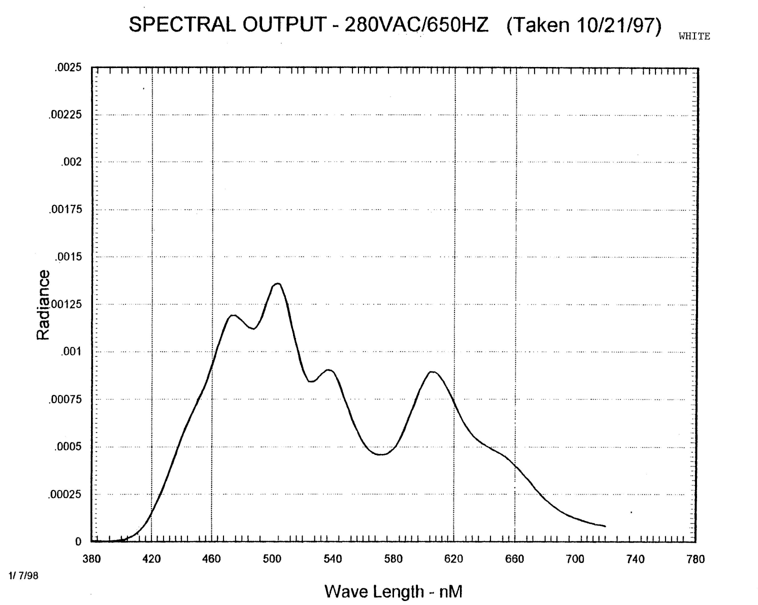
## Caveats:

The "UnderOak Observer" is published advertisement free using Scribus (v1.3.3.14). Its intent is both entertainment and informational. Every reasonable effort is made to verify facts and avoid personal bias, however, the reader bears full responsibility for actually listening to what I have to say.

## Cover Page Art:

van den Bergh 93 reflection and emission nebula in Canis Major. Color was rendered using Registar after synthesizing green from red and blue images downloaded with the DSS Plate Finder (http://archive.stsci.edu/cgi-bin/dss_plate_finder).

Editor: Kevin B. Alton
Writer: Kevin B. Alton



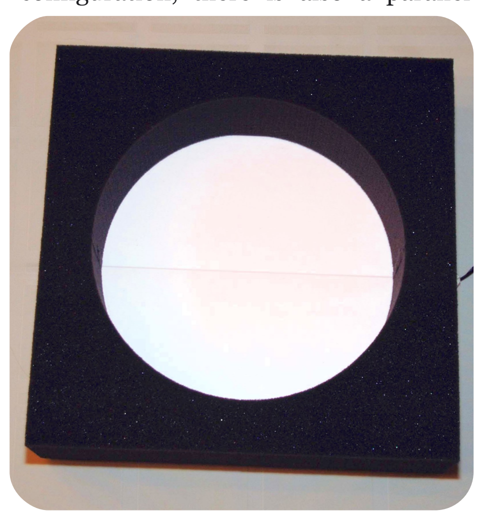

Above (Fig. 2)
Spectral output from FLATLITE© split-electrode ELP

Bottom right (Fig. 3)
Illuminated split-electrode ELP shown seam

their published spectrum (http://www.e-lite.com). More about this later on when the spectral output from two different ELP lamps collected under real world conditions will be revealed. This particular spectrum (Fig. 2) comes from a 9”×12” split-electrode panel (pink off – white on) purchased from Knema, LLC (http://www.luminousfilm.com/category/Electroluminescent-Panel-+-Inverter-24). There is, however, a seam down the middle of the panel (Fig. 3) which is clearly visible but interestingly does not appear in any clear or photometric B, V or $I_C$ filter flats taken (n=20) with an SBIG ST402-ME camera.

Each EL panel is imbedded in a plastic laminate but for the most part, these light sources are not designed for continual use outside and should be stored away from direct sunlight (UV is damaging), excessive heat, and moisture. Outdoor and UV resistant laminates are available as custom ordered items but at considerable added cost. Lamp brightness is dependent on the input voltage and frequency. Most of the ELPs suitable for flat-fielding require the purchase of a DC power supply and a DC/AC inverter. They both must be carefully matched to the ELP surface area to provide optimal illumination and lamp lifetime. The inverter can produce very high voltage (50-350 VAC) with an applied frequency between 50 Hz to 3 KHz so that care must be taken in handling these devices. A 12 VDC@1 amp wall-wart power supply and a dimmable 100 VAC@ 600 Hz split electrode inverter were purchased as a bundled package with the 9”×12” ELP described above for less than the price of individual components. Dimmable inverters are a good investment since there is a significant advantage in being able to adjust the amount of light needed to obtain 30-50% of the full-well capacity of a CCD camera over an appropriate period of time.

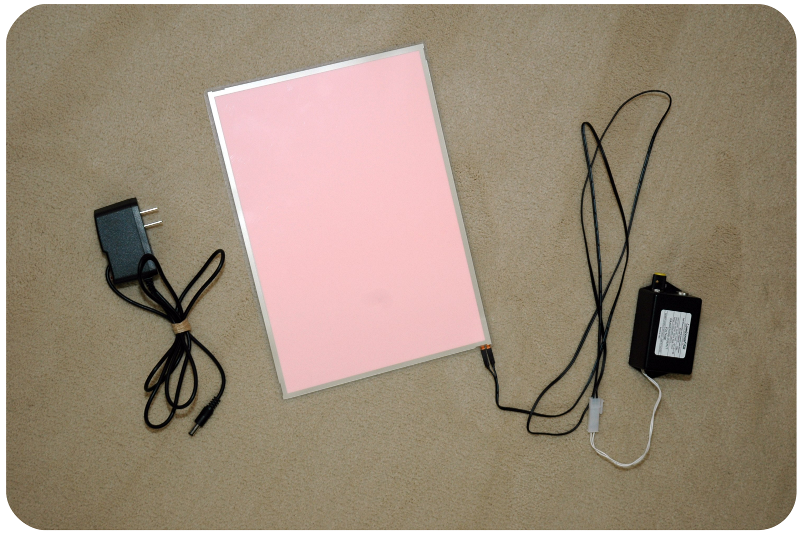
For those concerned about the seam visible with the split-electrode configuration, there is also a parallel



electrode electroluminescent lamp (Fig. 3) which is generally available in many of the same sizes (A2 to A6). Please note that these dimensions do not necessary correspond to the illuminated portion of the panel. Unfortunately, for instance, an A4 sized panel which is nominally 11.7×8.3 inches does not provide a large enough illuminated surface (~11.25×7.88”) to entirely fill up the image field from an 8” telescope. An A3-sized ELP would accommodate up to 11” whereas an A2-sized panel will fully illuminate a 16” telescope. It is possible to get custom sizes but the cost will escalate significantly unless you plan on ordering a large number for a group or club. Larger panels can be cut to size (http://www.luminousfilm.com/tech/fabrication-sheet-se-.pdf) however this is not a job for the faint-hearted since each cut edge must be resealed to prevent moisture invasion or a short-circuit.

## OK, let's build this thing

Enough said about the ELP light source and onto actually constructing a light box to take flat-field images. EL panels are too thin (~0.02”) and flimsy to be used without additional support. A good solution to this problem is to sandwich an ELP between two appropriately sized sheets of acrylic plastic. Clear or frosted Plexiglass (aka Lucite and Perspex) can be purchased at your local Home Depot or Lowes; however, the internet offers a greater variety in sizes, colors and thicknesses. There are many vendor choices but eStreetPlastics

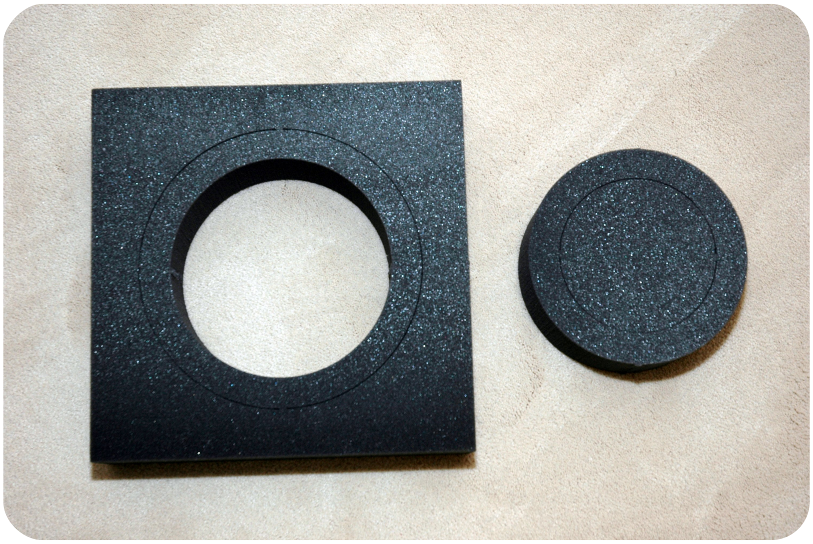


Above (Fig. 3)
Size A4 parallel electrode ELP with 12V DC power supply and inverter

(http://www.estreetplastics.com/) probably has one of the best selections of sizes and colors. Since my largest telescope has 8” of aperture, the stock 12”×12”×1/8” sheets were perfectly suited to my needs. Compared to frosted Plexiglass, white Plexiglass with the same thickness (1/8”) was very effective at attenuating (10% vs 70%) the lamp output. Interestingly, frosted Plexiglass was not much different than a clear acrylic sheet. Functionally it probably doesn’t matter, but I chose black for the bottom piece of the sandwich based largely on esthetic preference. The next consideration is how to fasten the pieces together. I shied away from directly gluing them together since there was concern regarding compatibility with Plexiglass and potential seepage into the laminate protecting the EL panel. One viable option would be to drill holes in the Plexiglass at a number of strategically located positions outside the ELP perimeter and fasten the sandwich using appropriately sized nylon

### Raison d'être...

This marks the first of what I hope to be many issues of the "UnderOak Observer" published on a quarterly basis. Although this inaugural issue is also focused on a do-it-yourself project I've called the "Lite ELPH", I expect that most issues will be heavily oriented towards the photometric research on variable stars and minor planets that is regularly conducted from UnderOak, my backyard observatory. The organization of each Research Article will follow a format similar to that expected in peer reviewed papers. However, in contrast to rigid formalism there will be a generous supply of sidebar comments or tips which will hopefully clarify new concepts and encourage other amateur astronomers to consider participating in this exciting research.



Above (Fig. 4)
Charcoal black foam block with pre-cut concentric circles to accommodate different aperture telescopes

screws and nuts (e.g. ¼-20 and 3/8" length). Non metallic fasteners are probably a better choice since they are not electrically conductive and shouldn't scratch any surface they may inadvertently contact. Another alternative is to seal the periphery using rubber or Neoprene U shaped edge trim (1/4" opening) such as those available at McMaster's (http://www.mcmaster.com/#trim-molding/=c8dkwf). FWIW, U-shaped door edge trim available at your local auto parts store is unfortunately not wide enough to accommodate two 1/8" acrylic sheets.

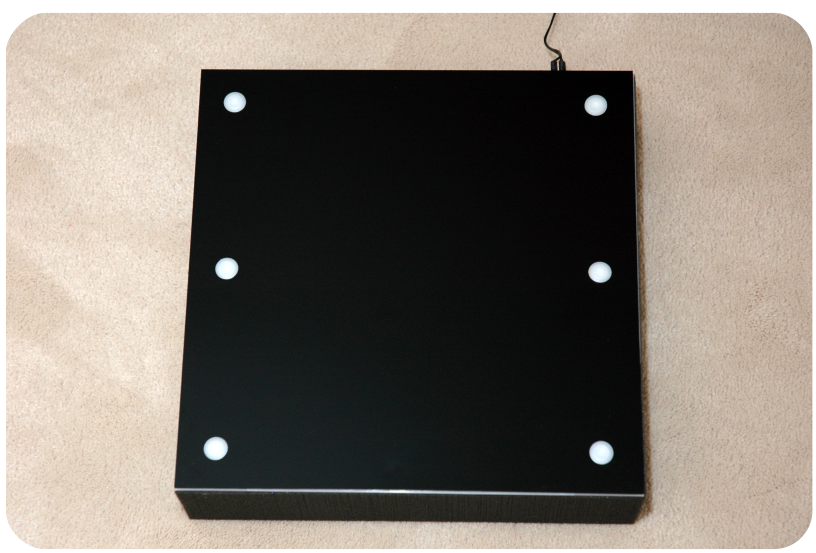
For many folks, assembly can stop at this point since the device is ready to mount on the wall or position directly on top of an optical tube. Conversely, the more elegant design I had in mind from the beginning of this project included a foam shroud pre-cut with concentric circles (5, 7 and 9") which would accommodate most telescopes with 4", 6" or 8" of aperture (Fig. 4). I reasoned that without a shroud, the user would have to position the telescope perfectly level pointing upwards rather than being able to fit it in any orientation. Furthermore, since not all telescopes necessarily have a flush flat surface to balance a flat panel, a shroud could provide more flexibility and security. The overall size of the charcoal foam (firm) custom ordered from Foam N' More, Inc. (http://www.foamforyou.com/) was 12"×12"×3". The three concentric circles are not cut fully around; each features two narrow tabs in a staggered configuration which can be easily sliced away with a knife or scissors. This pick-and-cut approach affords additional rigidity should the user only be interested fitting a single telescope. Since I have already paid the setup charge to have these foam blocks fabricated, anyone interested in obtaining the exact same item should be able to purchase them without incurring that initial fee. Check with the folks at Foam N' More before ordering anything since I am making some assumptions in this regard. Perhaps the cleverest contribution made to the overall design of this shrouded light-box involves the use of snap-in panel fasteners (aka ChristmasTree™ clips) to lock the Plexiglass-ELP sandwich together and to provide multiple posts (Fig. 5) onto which the foam can be secured with a little dab of glue. Most on-line vendors will only sell these fasteners in bulk amounts (>1000). Happily, a selection of these panel fasteners is available in smaller quantities from Non Ferrous Fastener, Inc.. Although the prototype shown to the right employs six single head ITWFastex clips received as a gift, the 1/4"×1.5" black clips which are sold

50/bag would appear to be equivalent (http://www.non-ferrousfastener.com/products.php?cat=267&pg=2). Plexiglas is brittle so that care must be taken while drilling the holes, otherwise it will chip or scratch. If one is available, a drill press operated at slow speed produces a very clean hole. Each sheet comes with a removable adhesive mask which was not taken off until drilling was completed. To ensure a proper match both sheets were taped together, drilled first with a small bit (1/8") after which the bit size was increased to match the final dimension recommended for the fastener. Following removal of the protective masking and thoroughly cleaning the Plexiglass components, the EL lamp was centered and then taped along the two long edges onto the black panel. Before fully assembling, holes (1.5" inches deep) were gently drilled into the foam using one of the Plexiglass sheets as a template. This greatly facilitated alignment of the foam with the posts exposed after the panel fasteners were pushed through the Plexiglass-ELP sandwich. A dollop of Barge all purpose cement was squeezed into each hole in the foam block and the posts carefully aligned before fully inserting them into the pre-formed holes. After turning the device foam-side up and making minor lateral adjustments to ensure the foam and Plexiglass-ELP sandwich were properly mated, the glued light-box was allowed to set overnight. The finished product, as seen from the bottom (Fig. 6) has been dubbed the "Lite ELPH" which is an acronym for Lite-weight ElectroLuminescent Panel Housing.

Testing was performed to compare the output spectra and luminosity recorded using the split electrode and parallel electrode ELPs previously described. Since the A4 parallel electrode ELP is not large enough to fully illuminate either of my 8" catadioptrics (Celestron or Vixen), the 5" diameter cutout on the foam shroud was selected for use

Above (Fig. 5)
Face-up view of Plexiglass-ELP sandwich showing posts from 1.3" panel fasteners

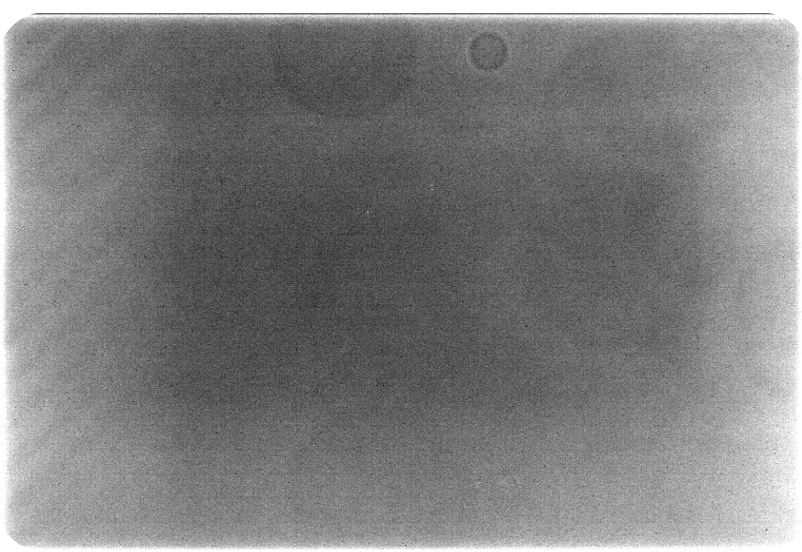
Below (Fig. 6)
Bottom-side view of the Lite ELPH



Top right (Fig. 7)
Indoor Setup for Flat-fielding Televue NP101

Bottom (Fig. 8)
NP101 Master flat from average of 20 images

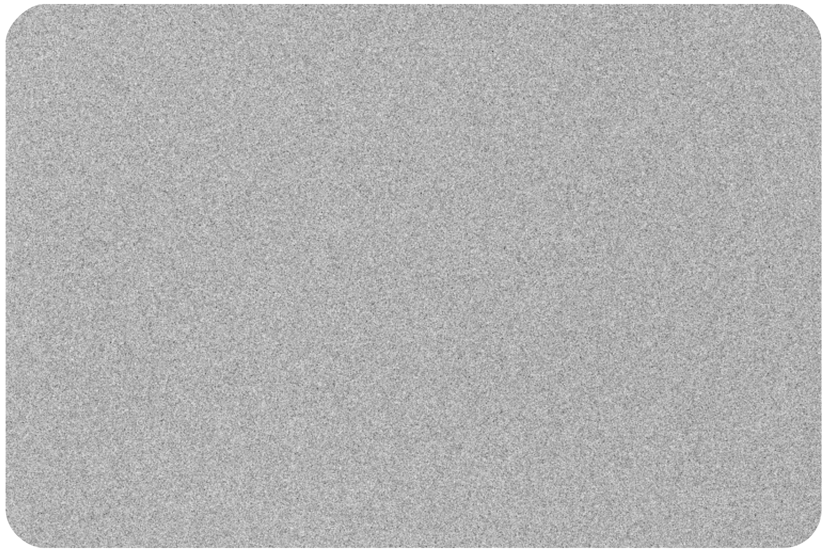
with a Televue NP101 refractor which nominally has 4” of aperture. As above, the same CCD camera (ST-402 ME) was used for flat fielding but this time in the comfort of my home office (Fig. 7). To thoroughly address whether the seam on the split-electrode lamp affects flat fielding, the following strategy suggested in part by Peter Kalajian from Alnatik Astrosystems (Sky and Telescope, March 2011) was employed. Twenty flats, dark-flats, and bias frames were taken after which the ELPH was rotated 90° and another series of 20 identical flats and dark flats were collected. All images were processed using the advanced calibration protocol in AIP4Win (v2.3.1). The first set was calibrated using the master flat (Fig. 8) generated from the second set of images and resulted in a highly uniform image consistent with excellent flat-field correction (Fig. 9). The resulting histogram (Fig. 10) was highly symmetrical (skew = 0.00431) and aside from three spurious pixels outside of 3σ deviations, the mean pixel value (11778.36) was within



±0.468%. It would appear that since the seam in the split electrode lamp is so far out of focus, it is not detected in either flat. Flat fielding with the A4 parallel electrode revealed similar uniformity (±0.511%).

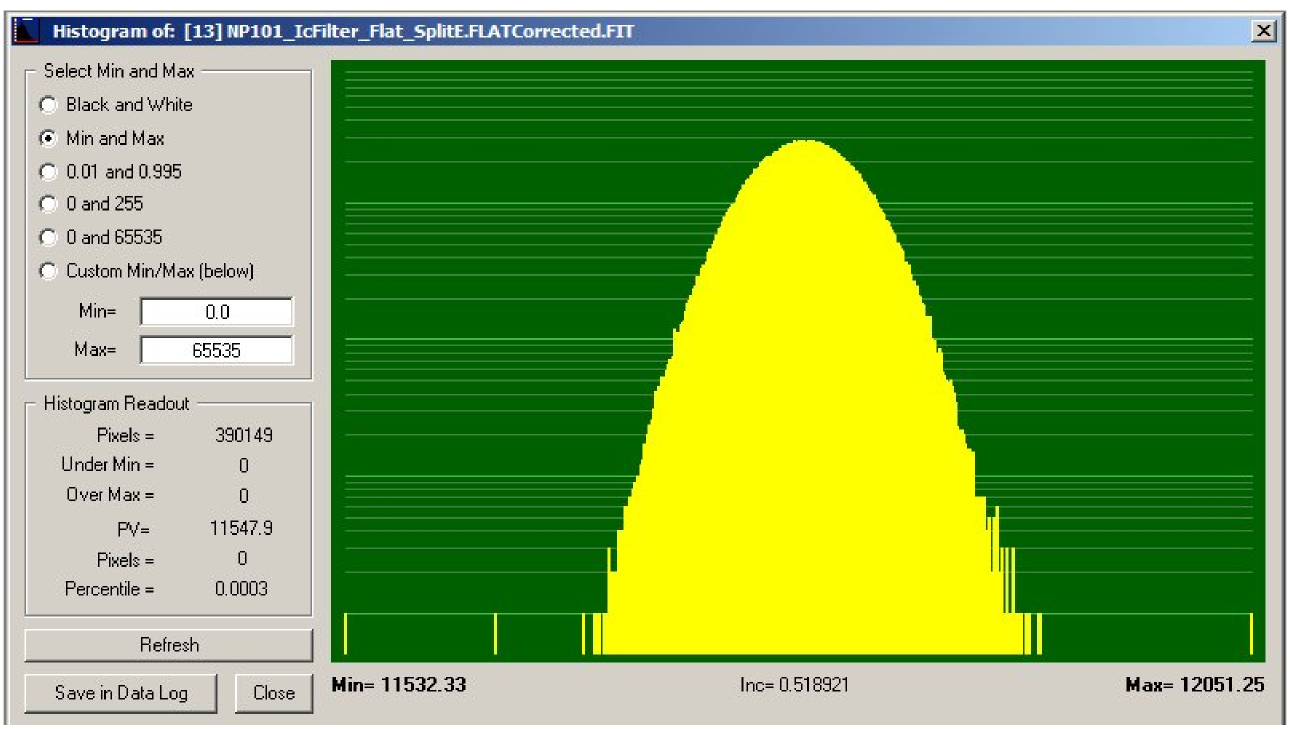
Narrow-band (<12 nm) filters presently used to image deep-sky objects are a testament to the improved sensitivity of digital cameras and increasing sophistication of today’s amateur astrophotographer. The most common filters (Hα, Hβ, OIII, NII, and SII) which are centered at 656.3, 486.1, 500.7, 658.4 and 672.4 nm, respectively, can be expected to greatly attenuate light output from the EL lamp. As can be seen in Figs. 12 and 13 this may be problematic for wavelengths longer than 650 nm (6500 Å). However, at least in the case of a Lumicon 48 mm Halpha Night Sky filter which is actually a cutoff filter (50%) below 640 nm and transmission filter (90%) above 650 nm, there were plenty of photons reaching the CCD camera. Unfortunately I do not have a bonafide narrow-band filter to test but expect that the exposure times will have to be significantly increased over those which typically work for standard RGB or photometric B, V, R and $I_c$ filters.

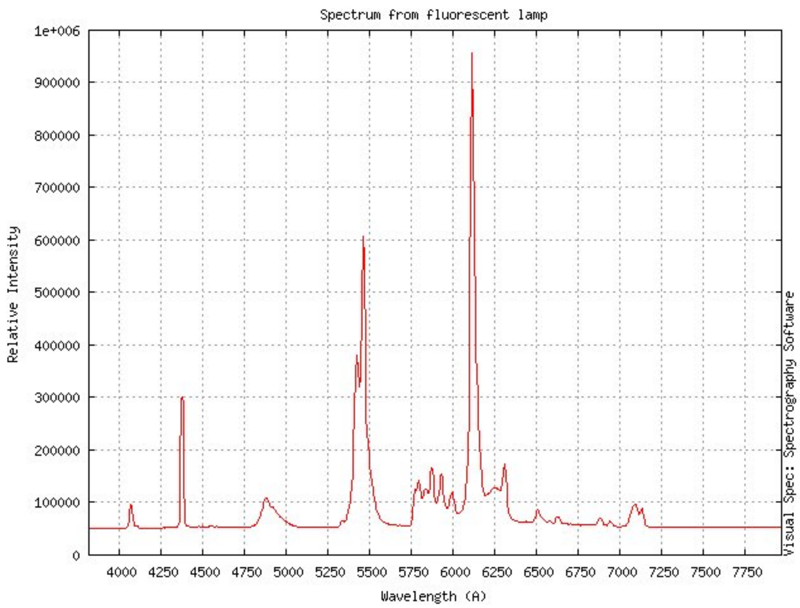
Despite the split-electrode lamp reference spectrum which was provided by the manufacturer (Fig. 2), I was not satisfied that the spectral output from the split- or parallel-electrodes had been adequately characterized under real-world conditions faced by the typical amateur astrophotographer. An SBIG Deep Sky Spectrograph (DSS 7) mated with the ST-402 ME camera proved to be invaluable for conducting a series of spectroscopic investigations. The DSS 7 is a moderate resolution (16 Å) instrument designed to separate and focus wavelengths between 4000 and 8000 Å across the CCD array. A two point calibration (Visual Spec v3.8.8) was used to standardize spectra using the Hg (5465 Å) and $Eu^{+3}$ (6116 Å) emission lines from a compact fluorescent lamp (Fig. 11).



Above (Fig. 9)
Flat-field corrected "flat" image after rotating position of ELPH by 90°

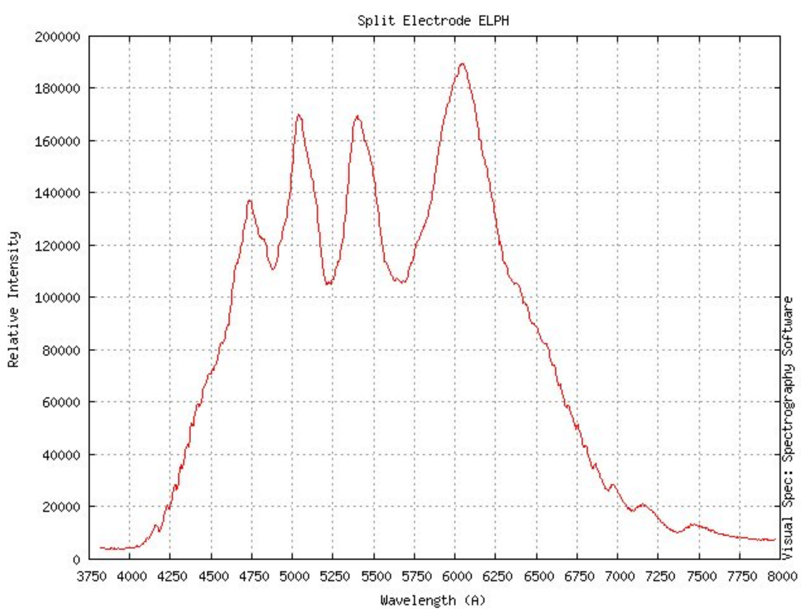
Below (Fig. 10)
Histogram from flat-fielded "flat" showing symmetrical distribution of pixel values from split-electrode lamp






Above (Fig. 11)
Reference spectrum from compact fluorescent lamp

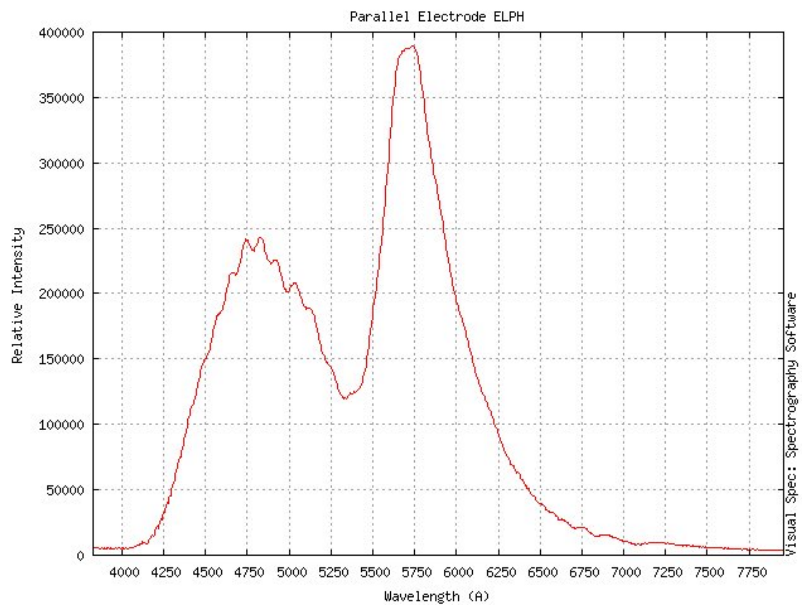
Below (Fig. 12)
Spectrum from split-electrode lamp




The results from the split-electrode and parallel-electrode ELPs are shown in Figs. 12 and 13, respectively. Significant differences between these two lamps were observed which in retrospect is not surprising since the chemical recipe each supplier uses for producing these panels is highly proprietary. The split-electrode spectrum (Fig. 1) provided by the manufacturer (http://www.e-lite.com) proved to be quite different possibly due to the higher operating voltage (280VAC) or major change in the lamp formulation since 1997 when the spectrum was taken.

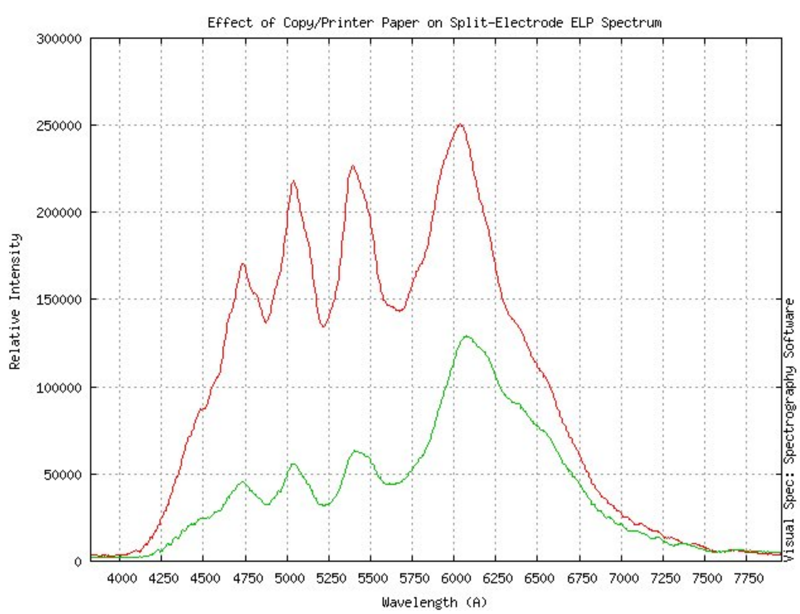
In the same regard, the reader should also be cautioned that only one type of each ELP was tested making any conclusions about batch to batch uniformity or similar products from other suppliers impossible. Nonetheless, both panels produced plenty of flux for standard color and photometric filters in the blue (4000-5000 Å) and green (4750-5750 Å) wavelength regions. Exposure times for photometric B and V flats were less than 1.5 sec at the dimmest lamp setting. Even with the foam shroud, a white paper diffuser can be easily slipped in between the foam and working side of the lamp to further attenuate the output so that longer (>2 sec) exposure times are possible. As shown in Fig. 14, a single 8.5×11" sheet of Staples multipurpose paper (96 bright/20 lb) was tested using the DSS-7 spectrophotometer. There was ~50% reduction in total output but disproportionate losses were fairly obvious below 5500 Å. White Plexiglass did not exhibit this differential effect but appeared to reduce the signal equally across the measured wavelengths. Color and photometric R filters generally allow transmission in a range between 6000 and 7000 Å so that a CCD detector would also not suffer from lack of photons. Additionally, my guess is that flat fielding with narrow-band Hβ (4861 Å) or OIII (5007 Å) filters will not require excessive exposure times. Above 6500 Å, however, the relative output of light from both lamps is low, particularly with the parallel electrode panel (Fig. 13). This is consistent with the longer exposure time (4 sec) at full intensity necessary to achieve 50% full well capacity with an $I_C$ photometric filter. The practical importance of this dissimilarity suggests that much longer exposure times will be necessary to get flats from narrow-band Hα (6563 Å), NII (6584 Å) and SII filters (6724 Å). All things considered for telescopes 8” and smaller, the 9”×12” split-electrode panel (pink off – white on) sourced from Knema, LLC is a good choice. The larger sized (A3 and A2) panels appear to be the parallel electrode type but were not tested during this assessment.

In summary, it is hoped that this article on the construction of a simple electroluminescent light box for flat-fielding will encourage others to do the same. Granted, I only looked at two of the many ELPs that are commercially available. The ready to use 9”×12” split-electrode EL panel is large enough to illuminate up to 8” of aperture and costs around $160 including a dimmable inverter, power supply, two 12”×12”×1/8” Plexiglass sheets, and fasteners. Similarly, an A3 sized panel good up to 11” will set you back ~$210 with dimmable inverter, power supply, two custom cut (16.75”×16.75” ×1/8”) Plexiglass sheets and fasteners. Domestically (USA), cheaper alternatives may be




Above (Fig. 13)
Spectrum from parallel-electrode lamp

Below (Fig. 14)
Differential absorption of light (green curve) produced by the insertion of a white sheet of paper



found at the ElectroLuminescence, Inc. (http://e-luminates.com/osc3/product_info.php?cPath=27&products_id=93) or Glow Hut (http://glowhut.com/el-strip--el-panel.html) websites but they have a smaller selection of panel sizes and inverters. Irrespective of the vendor, this relatively modest expenditure in an era of multi-thousand dollar cameras, mounts, and telescopes is arguably one of the best investments you can make if you are interested in simplifying the process of collecting flats and improving image quality. Don't hesitate to e-mail me through my observatory website (http://www.underoakobservatory.com) if you have any further questions.

Lunar image (3 sec exposure) taken with Nikon D70 through Televue NP101 at UnderOak Observatory. The starry field separately rendered is precisely superimposed onto the moon's location near mid-eclipse (3:20 am EST) on December 21, 2010.