On the Bench: QHY-10
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As many readers likely know, I’m the author of Nebulosity 3 — a program designed to let you capture and process DSO images from a wide range of cameras. One of the perks of doing this is that I get to see a lot of cameras. While some are only here for a few days while I make sure they’re well-supported, others get to stay awhile. Such is the case with the QHY10 I have here. While the camera is currently supported via the ASCOM driver, Bruce Morrell of AstroFactors (USA distributor for QHY) expressed an interest in having native support for the camera in the newly-release Nebulosity 3 under Windows and to explore options for Mac support (now in place!). With it not needing to get back on the FedEx truck ASAP, I’ve had a chance to put it on the bench and see just what this camera can do.

So, what is a QHY10? How many people out there want a nice big chip? How many like the convenience of one-shot color? Don’t want to spend two arms and a leg? Sure, DSLRs are one choice here, but what about cooling, temperature regulation, and 16-bit unadulterated output? This is where the QHY10 (and its cousins) step in and shine. The QHY10 is a 10 megapixel APS-C sized color camera capable of cooling to -45C below ambient and holding it there. It’s in a great form-factor and has some excellent specs, making it clearly worth consideration.

The QHY10 isn’t the only camera in QHY’s lineup that fits this niche. I did a review of the QHY8, the first in this series, back in 2008 for Astronomy Technology Today. It gave rise to the 8Pro, 8L, 10, and 12. Each of the newer cameras comes in a low-profile round case, ideal for setups like Starizona’s Hyperstar rigs. They’re also fully airproof and fully temperature regulated. The 8L uses a 6Mp Sony ICX413 sensor and the 8Pro uses an ICX 453 sensor, both with 7.8μ pixels. The QHY10 uses a 10Mp ICX493 sensor with 6.05μ pixels and the QHY12 bumps this up to a 12 Mp ICX613 sensor with 5.12μ pixels. The chips differ a bit in more than just the pixel count and size as well. The ICX453 in the 8Pro uses a “progressive” readout (all lines are read out in one pass, top to bottom). The other chips all use a two-frame readout process (odd and even lines). To mitigate interlacing effects when using short exposures (the second frame would still be exposing while the first is being read out, leading to different exposure times), two images are taken and only one “frame” is used from each. This way, they end up with the same exposure duration. Since these are not meant for planetary imaging, the fact that, for very short exposures, the odd and even lines come from different exposures some time apart is not a significant handicap. Price, of course, varies across the range as well, going from the 8L currently coming in at $1299 (USA, AstroFactors, May 2012) through the 10 ($2249), and on to the 12 ($2699).

Physical
The camera comes in two pieces and with a pair of cables. The main camera itself is a 63 mm black cylinder with an attractive gold band (it’s the same exact size of the obstruction on an 8” SCT), making it great for things like Hyperstar use. It’s 128 mm long, including the nose, which sports a standard T-thread and it weighs in at just under 400 g. The back holds a USB plug, an ST-4 guider output (should you ever consider using an APS-sized color camera as a guider!) and
a small round mini-DIN port that connects to the DC201 power control box. This small box contains the electronics to convert your 12V power source (it requires a solid 4A supply) into the various powers needed by the camera itself.

The camera head sports a sealed CCD chamber that is filled with dry air from the factory. Should humid air ever leak into the chamber to such an extent that dew begins to form on the CCD during use, you can dry the chamber yourself by removing a screw and replacing it with a small tube (provided) filled with silica gel. Cooling is provided by a TEC mounted to the CCD and exposed to a heatsink, whose fins can be seen about a third of the way up the camera. Inside the camera head is a small fan that keeps these fins cool and keeps the TEC effective. This fan, I should note, would never be described as “whisper quiet”, sounding more like some of our noisier mounts moving during full slew.

Finally, I should note that the back focus from the front of the T-threads to the image plane is approximately 20 mm. If needed, there is an optional adjuster for centering (±0.5 mm) and tilting (1 degree) the image plane that adds 3 mm of back-focus to this.

On the Bench
All this means little if the camera can’t put up good images. So, how does it do there? Well, if you give me an incredible camera and you give one of the imaging gods a mediocre camera, odds are the imaging god is going to produce a better image than I am. I don’t want to hurt someone’s view of a camera by saddling it with my skies and skills. Instead, I take the view that a camera should come as close as possible to perfectly reflecting the photons hitting it. If it adds anything of its own or takes anything away, we’ve got an artifact. If not, we’ve got a perfect camera. The nice thing is that we can figure out how close to a perfect piece of clear digitizing piece of glass it is by a series of bench tests.

So how good is it? It’s quite good. While this kind of money won’t buy you perfection, it seems it will get you nice and close – close enough that you’d never notice anything but excellent performance.

System Gain
The first thing I like to know about a camera is the system gain or transfer function. This is the number of electrons in every intensity unit (ADU or Analog Digital Unit) in the image. Using 5 pairs of flats at various intensities, I plotted the variance of the difference vs. the mean. The slope of a linear fit here gives us the system gain. With the camera’s software gain set at 0, this is 0.7 e-/ADU, confirming the specs listed by QHY. If we turn the software gain up to 32 (50%), the system gain becomes 0.35 e-/ADU.
Given this (and the camera’s ability to hit 65535 with enough light) we can estimate the full-well capacity to be roughly 46k e-.

**Dark Current, Stability, and Maximum Cooling**

Next up, is our dark current. Thermally generated electrons will make it into your CCD well and start to build up charge just like the photons from your DSO. Different chips do this differently and the temperature of the chip is, of course, a huge factor (typically, the dark current doubles for every 6C change). Using a range of exposures from 0-10 minutes, I estimated the dark current to be 1.1 ADU (or 0.64 e-) per minute when run at -10C. While I chose -10C to be consistent with my other reviews, even in very hot climates, the QHY10 will go lower than that. I confirmed QHY’s spec of being able to reach 45C below ambient, meaning that on even very warm summer nights, you can hit -15C or even -20C. If run down here, you’re looking at half this rate or even less. So, in a 10-minute exposure, you may have an average dark current of 3 electrons and an associated shot noise of 1.7 e-. With 5-minute exposures, you’re talking less than one electron worth of noise.

To determine how stable the regulation was, I set the camera up at room temperature, connected, and quickly began an hour-long series of one-minute exposures. From this, we can see not only how rapidly the camera reaches the set-point (here -10C), but also how stable it is. As you can see from the plot here, within five minutes, the camera had reached a stable point and had only moderate variation in the mean dark signal thereafter.

**Read Noise**

Every time you take an image you get the result of the actual photon flux and you also get a bit of randomness tossed in to keep life interesting. This random extra is the read noise (OK, you also get other bits of noise as well – see my articles on SNR here on Cloudy Nights). Of course, we want as little noise as possible to be added into our image.

Here, I took 100 bias frames and stacked them and then computed the standard deviation of the difference between each individual frame and the averaged frame (we care not about any fixed pattern in the image but in the variance across images). With the camera’s offset control set at 130, this led to a solid score of 8.2 e-. With the offset here, the bias signal is quite low (~240 ADU), and raising the offset dropped the read noise estimate to 7.1 e-, suggesting some of my prior score might be elevated as a result of quantization error (the rounding errors we get by forcing things into integers). It is also possible that the internal amplifier is simply a bit cleaner with a bit higher offset. Running with the gain elevated to 32, the read noise dropped a bit more down to 6.1 e-. While the noise is lower here, I would not recommend running the camera at this level as it halves the full-well capacity of the camera, cutting your dynamic range in half. Remember, even with a gain of 0, the camera runs at 0.7 e-/ADU and last time I checked, we
never recorded fractions of electrons. Running at the higher gain means it’s just about 3 ADU steps per electron.

The total amount of read noise is something certainly to consider, but the character of this read noise is, in my opinion, even more important. Just like when one thinks about guiding out a mount’s errors, you should concern yourself at least as much with the smoothness of the periodic error as with the total amount of periodic error, here you should concern yourself with the smoothness of the noise and not just its total amount.

We can look for fingerprints in the noise in several ways. The first, and simplest, is to just look at the average row and the average column to see if there are any fixed stripe-like patterns in the image.

Rather than just look at these averages, it’s usually best to look at a Fast Fourier Transform (FFT) of them, which decomposes this into the frequency components. It’s a much more effective means of picking out any patterns in the image. What we have above is an exceptionally clean response in the average row and average column. Whatever fingerprints are inside the read noise, they’re not vertical or horizontal!

Next, we turn to the 2D FFT of a single bias frame and of a read noise frame (average bias minus a single bias). A perfect camera in an ideal world will have a single bright dot in the center and that’s it. A perfect camera in this world would have a single bright dot in the center and a small amount of noise scattered in this image. The center point here means there is a “DC offset” in the image (the mean of the image is greater than zero). The image shows how much energy there is at different horizontal and vertical frequencies.

What we can see here is pretty close to ideal. You can pick out some horizontal bands in these FFT plots, but it’s not much. (Note, I use the same intensity scale here as I’ve used in reviews elsewhere.) Yes, I have seen better, but I’ve seen a lot worse as well. This is excellent performance and attests to clean electronics inside the camera.
Finally, we can look for issues by examining the histogram of the read noise (or the log of this). What we want is for the noise to be purely random. Deviations from this will show up as a difference between the blue noise (actual read noise frame) and the green line (random noise generated with the same mean and standard deviation) in the plot here. What we can see is that there is a small variation at the top end (more bright pixels than we would expect), but this is also excellent performance.

**Star Test**
A final spot to look for errors in the camera is to see how well it behaves when imaging stars. Our stars are brutal on electronics as you must go from very dark (near the floor) to saturated signals and back again often in just a few pixels. This requires a lot of bandwidth and well-damped circuits. Rather than do this on actual stars, I use a Hubble Optics 5-star artificial star and an SLR lens for this so that the conditions can be controlled.

Raw images showed no signs of any issues when run at the standard speed, in the high speed, or in the binned standard-speed images. It is only when one goes to binned, high-speed images that one can see issues (dark vertical bars off of the bottoms of saturated stars). As this kind of mode is only used for framing, this is not a flaw in the camera to be concerned about. Any actual binned images (which would turn this into a mono camera) would be done with the normal download speed mode.
Rather than show this as raw images, I’m showing surface plots here. On the left is an image showing a frame taken at 1x1 with low gain, showing the full range of the data. You can see that the stars profiles go smoothly into the background with no hint of any undershoot. On the right is an image taken with full gain and stretching both the “black point” (the bottom of the image) and the “white point” (the top of the image) to look in detail for any deviation. You can see a bit of noise of course and you can see the edge of the Hubble Optic’s round surface, but there is no hint of any dark “ears” to the stars’ profiles (which would show up as dips below the surface). So, stretch the image all you like and you won’t start to see artifacts on the edges of the stars. Over-sharpen and of course you will, but that won’t be the fault of the camera!

Software

The camera is supplied with EzCAP, a basic Windows-based capture program for all of the QHY cameras. You can frame, focus, and capture series of images with ease. It’s not geared towards any image processing, but it will get you going out of the box. In addition, QHY supplies ASCOM camera drivers that will make the camera compatible with most Windows-based capture applications.

One thing that I did find a bit strange about the image in both EzCAP and in the ASCOM driver (ASCOM driver tested in Nebulosity v3) is that the image comes out in a non-canonical orientation. As you can see here in this shot of a business card, it is not only in a portrait layout (vertical rather than horizontal), but text is mirror-imaged. This was taken with an SLR lens attached and many of us will need to mirror-image in any case (based on the optics ahead of the sensor), but the vertical orientation is strange when one considers our monitors are wider than they are tall. In addition, the EzCAP and ASCOM interfaces by default leave the optical black in place. Most users will want to select “Active area only” in the ASCOM Properties page to remove this on the fly.
Since I found this odd, I did the mirror-about-the-diagonal flip (or rotate 90 degrees and then mirror) needed to make it canonically-oriented when using the native driver in Nebulosity 3 (the dark band below the image here is just extra screen space and not part of the actual image). A tool in Nebulosity lets you apply this in batch to images should you need to convert between the two formats.

Conclusions
This is a really nice camera. I’ve been using a mono cam with a filter wheel (a QSI 540) for a number of years and have many great things to say about that setup. That said, I’ve been looking for a nice one-shot color camera to add to the mix as that route has its plusses as well. With my mono cam on my 4” f/4 Borg and a one-shot color on an 8” SCT with a Hyperstar running side by side, I’d have a formidable setup that would let me get line filter and RGB data at the same time. Even with just one scope going, there is a lot to say for the ease of RGB work with a one-shot color sensor.

The QHY10 gives you the size of a typical DSLR sensor, but in a package that gives you a full 16-bits worth of data (vs. 12 or 14 bits), regulated cooling (down to -45C below ambient), very clean electronics, and comes in a package that won’t tax your focuser and is well-suited for Hyperstar imaging. What’s not to like? It’s a great camera and comes in at a significant savings compared to its competition. What’s more, it’s certainly got a leg up in several departments when compared with the popular KAF-8300C. The pixels are a bit bigger (6.05 vs. 5.4 μm) and yet it packs in almost 2 million more pixels on its bigger chip (23.6 x 15.8 mm vs. 19.96 x 13.52 mm). Each pixel holds more electrons too giving it a greater dynamic range (~4 dB more). In fact, it fits the bill so well, I’m seriously contemplating keeping it and adding it to my arsenal.

Is there anything not to like? The only things I would really change on the camera had I a magic wand would be the noise level and the power draw. Its bench performance was excellent. Sure, a few of the tests showed things that could be a hair better, but only a hair (or even a split hair). There’s nothing there that raises any kind of concern for me. But, the fan is pretty loud and while -45C from ambient is admirable, I wish it had a setting that would drop the maximum temperature differential and, in so doing, drop the maximum current needed and the fan noise. Or, of course, we could keep the maximum cooling and still have both of these!

My guess is, neither of these are deal-breakers for the vast majority of potential customers. That leaves you with a well-cooled, low-noise, great-performing, large-chip, 10Mp camera in a nice form-factor.