HICKSON 50 AND THE QUESTION OF MAGNITUDE

by Michael A. Earl

I am always amazed at the amount of questions a single image can raise.

So here we were; Paul (Comision) and I, staring at an image of the Hickson 50 galaxy group that Paul's Omega observatory had taken just minutes earlier. We both remarked: "These objects couldn't possibly be as dim as this book is saying!" Paul was amazed that he could see them at all. He had been used to viewing 12th and 13th magnitude galaxies through the eyepiece, not spotting 19th and 20th magnitude objects with a CCD camera!

Hickson 50, the most challenging of the Hickson catalogue, is a group of five galaxies that form a small pentagon-like shape. The generally published (and accepted) magnitudes of the five galaxies (from brightest to dimmest) are 18.7, 18.9, 19.5, 19.6 and 20.0. According to some online accounts, some astronomers have claimed to have viewed the two brightest ones through the eyepiece using telescopes of at least 20-inches in aperture.

The Omega observatory saw all five of them using a single 20-second exposure. We were both shocked. When my CASTOR facility caught dwarf planet Eris in August 2005, it required 30 images of 20 seconds each (a total of 600 seconds) to even barely detect it above the background noise. Eris was magnitude 19.5 and was a point source. By this logic, the Hickson 50 galaxies should have appeared dimmer than Eris because their light is spread over a larger area.

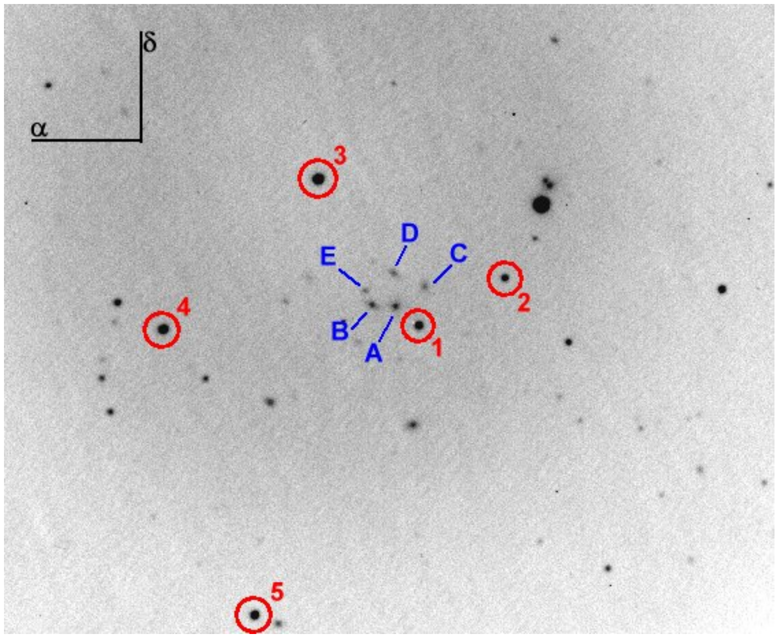

Figure 1: The Hickson 50 galaxy group as observed by the Omega observatory. The objects circled in red are the five reference stars used for photometric analysis. This is a negative crop of the original stacked image of effective exposure time of 10 minutes. Image by Paul G. Comision: 04:17 UTC May 29, 2008.

The Omega Observatory uses a 14-inch Meade LX-200 GPS telescope, an SBIG ST-10XME CCD camera and an f/6.3 focal reducer. My CASTOR system uses an 11-inch NexStar GPS and an SBIG 9XE CCD camera at prime focus. CASTOR also took an image of the Hickson 50 group and I found that all five galaxies can be seen easily with a single 20-second exposure.

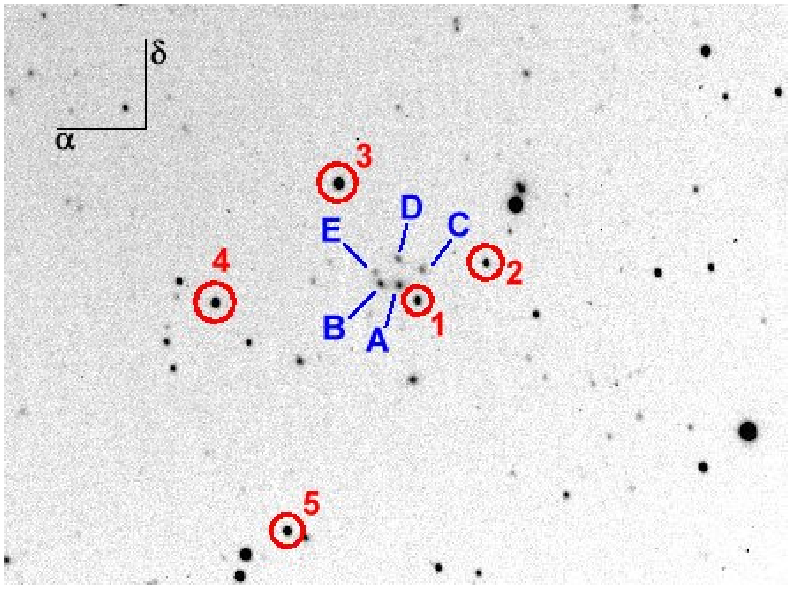

Figure 2: The Hickson 50 galaxy group as observed by CASTOR. The objects circled in red are the five reference stars used for photometric analysis. This is a negative crop of the original stacked image of effective exposure time of 10 minutes. Image by Michael A. Earl: 02:46 UTC May 25, 2008.

If an 11-inch aperture can see a limiting magnitude of 19.5 (Eris) using a CCD, you might think that a 14-inch aperture and CCD would see a limiting magnitude of 20, but there is much more to consider than just aperture size.

It is certainly true that Omega's aperture can gather about 1.6 times the amount of light CASTOR's aperture can gather. However, there are many other factors to consider when comparing the two systems.

The two facilities have different CCD cameras and therefore different pixel resolutions. The pixel resolution also affects how much light is collected over a specific period of time. The larger the individual pixels, the larger the amount of light will be collected in a specific length of time. CASTOR's pixel resolution is 1.562 arc-seconds, which is quite large. Omega's pixel resolution is 0.958 arc-seconds. This means that CASTOR's pixels gather 1.6 times the amount of light gathered by Omega's CCD pixels if using an identical exposure time. This negates Omega's telescope aperture advantage stated earlier. However, Omega's overall resolution is still better than CASTOR's.

Wait! There's more! The sensitivity of the two CCD cameras is different too! The maximum quantum efficiency of CASTOR's CCD camera is about 70%. This means that 70% of the light photons are detected. The maximum efficiency of the Omega CCD is about 90%. This is a difference of 1.3 times (0.3 magnitudes), which brings Omega back into the lead. Omega's limiting magnitude should only be slightly better than that of CASTOR's, if you exclude light pollution, camera noise, temperature, and humidity factors.

So, in a nutshell, both systems have an equally good chance of detecting the Hickson 50 group. Using Eris as the initial benchmark, the galaxies should still be very difficult to detect with Omega as well as CASTOR, yet they both saw the galaxies easily. Why?

I decided to conduct a photometric analysis based on the CCD images both CASTOR and Omega obtained. I stacked 50 images taken by CASTOR and another 50 taken by Omega. The resultant images were then analyzed to find out what the brightness of the Hickson 50 group was, as seen by the two facilities.

I will omit the intricate details of the photometric method I used, since it will make this article to long. I will instead save it for an upcoming article on my photometric analysis of the two novae in southern Ophiuchus.

In brief, I used five reference stars for the analysis. Many stars vary in brightness by several magnitudes. For example, the magnitude of Algol (Beta Persei) varies constantly, yet some references state the brightness as a single (constant) value, most likely the median of the brightness range. A variable cannot be trusted as a reference star, unless its specific light curve is known well. Using five stars ensures that the determined magnitudes of the Hickson 50 galaxies are consistent.

CCD cameras have differing sensitivities to different colours. Most CCD cameras are generally most sensitive in the visual (yellow) wavelengths and become less sensitive towards the red and the blue ends of the spectrum (see Figure 3). Therefore, a red (or blue) star will look dimmer than a yellow star, even if they are of the same apparent brightness! Using a red reference star to determine a yellow object's brightness might result in a brighter determined brightness (lower magnitude) than the true one.

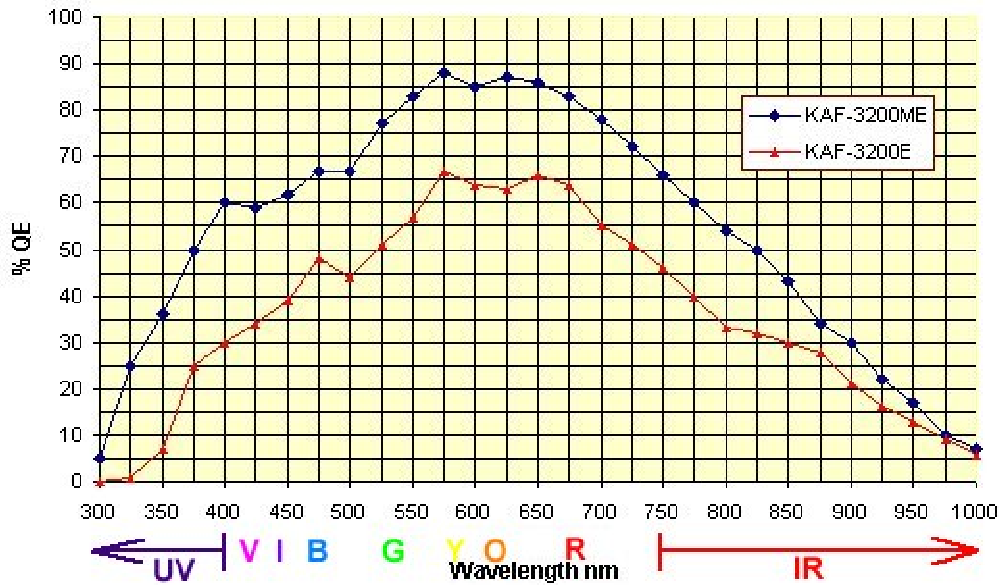

Figure 3: The spectral response (blue curve) of the Omega observatory ST-10XME CCD camera. Note that this CCD is most sensitive in the yellow-orange wavelengths and that it can detect both infra-red (IR) and ultra-violet (UV) wavelengths.

Another problem I have found in photometry is infra-red radiation. The stars of spectral type “M” (reddish) can emit enormous amounts of infra-red radiation. Why is infra-red radiation a problem? Grab your digital camera and point your TV remote at it. Push any of the buttons on the remote and look at the camera’s preview screen. You should notice that when you push any button of the remote, the camera can see the light coming out of the remote’s infra-red emitter. The CCD camera can detect infra-red radiation from the stars and can fool you into believing that the star is much brighter than advertised. If you use the published magnitude value of such a reference star, your photometry might show a dimmer value (higher magnitude) than the true one because of this infra-red bias.

In actuality, I have found online that the published magnitudes of the Hickson 50 group are their Blue (B) magnitudes, which differ significantly from their unfiltered magnitudes. Nevertheless, the published values can convince astronomers that the galaxies are much fainter than they actually are, especially if this fact is omitted! Are the published values wrong? I say no, because the published values were derived using a method that was different than the ones used by Omega and CASTOR.

There is one more wrinkle in this maze called photometry. Can you actually trust your star catalogue? The brightness of every star in a catalogue is based on the detector (and filters) used to capture it!

Let’s look at a favorite star catalogue of many; the USNO A2.0. This catalogue is based on several (film) sky surveys (Palomar in the northern sky, the Science Research Council and the European Southern Observatory in southern sky). The USNO A2.0 is entirely based from the Earth’s surface. The image plates scanned for this catalogue were the red (R) and blue (B), neither of which are in the visual (V). So, the magnitudes quoted for the USNO A2.0 stars might be biased towards the red or to the blue. More importantly, what benchmarks did they use in the original Palomar survey conducted in 1953? What wavelengths of red and blue were predominately detected? Did they use filters, or did they use red (and blue) sensitive plates?

Of course, you have to trust something to even get started! However, I did use several catalogues including the USNO A2.0, the Hubble Guide Star Catalogue (GSC) and the newer USNO CCD Astrograph Catalogue (UCAC) to compare their specific magnitudes for the five reference stars chosen. I found that for the chosen reference stars, the magnitudes determined with USNO A2.0 stars were at least 1 magnitude fainter than the GSC and UCAC values. Since the USNO A2.0 was the “odd man out”, I decided not to use the USNO A2.0 for any future photometric analysis. I will still use it for astrometric analyses however!

So, the final question becomes: how bright are the Hickson 50 components as viewed with Omega and CASTOR? After a careful photometric analysis of both CASTOR and Omega images, I have determined the following magnitudes, with the values in parentheses being the original published values:

Hickson A:	17.0 (18.7)
Hickson B:	17.2 (18.9)
Hickson C:	17.8 (19.5)
Hickson D:	17.8 (19.6)
Hickson E:	18.2 (20.0)

It is amazing the difference a few magnitudes can make! For a CCD camera, these are duck soup if using an aperture of at least 8 inches and a minimum exposure time of 20 seconds. These determined (unfiltered) magnitudes are about 6 times (about two magnitudes) brighter than their published (Blue) values. The above values are the result of averaging the results of Omega and CASTOR, which differed by only 0.3 magnitudes for each of the five galaxies.

Photometry is extremely challenging for those who want to the see the truth. Just like everything else, it all comes down to where to start and what to trust. As in life, “trust” is also a relative term!

Again, are the published values of the Hickson 50 group wrong? I like to think that the values are misleading at most, but certainly not wrong. If I used a blue filter to image Hickson 50, I would find that the galaxies would not be detected or at least extremely faint. However, the published values should be clarified to illuminate the fact that they are the Blue magnitudes and not the Visual.

If you obtain images of Hickson 50 with your equipment, will your photometric analysis give similar results, or will the Omega-CASTOR values be "wrong" as well?

When you start questioning published values, whatever they are, you begin a journey into discovery that can lead you in all kinds of strange places. You find that the magnitude scale has always been one of comparisons and not absolutes. When we learn the magnitude scale, we learn to gauge the brightness of a new object with respect to reference objects we have already viewed. The brightness of the reference objects themselves were determined by comparing them with other reference objects, etc. With today's CCD cameras, we can get a better feel of just how bright objects are, but there are still many factors to take into consideration. This is not likely to change soon.

Just think: a single 20-second exposure caused all this!