Beyond Silicon: Astronomy with an InGaAs Array

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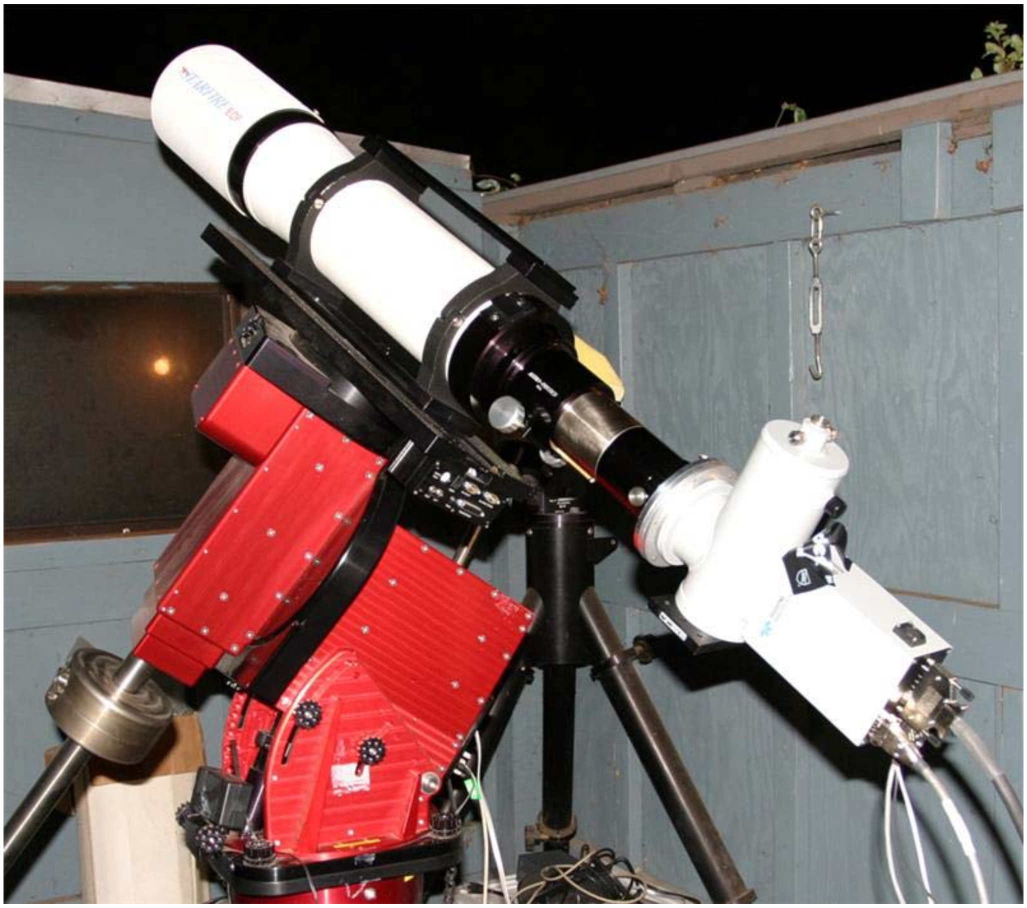
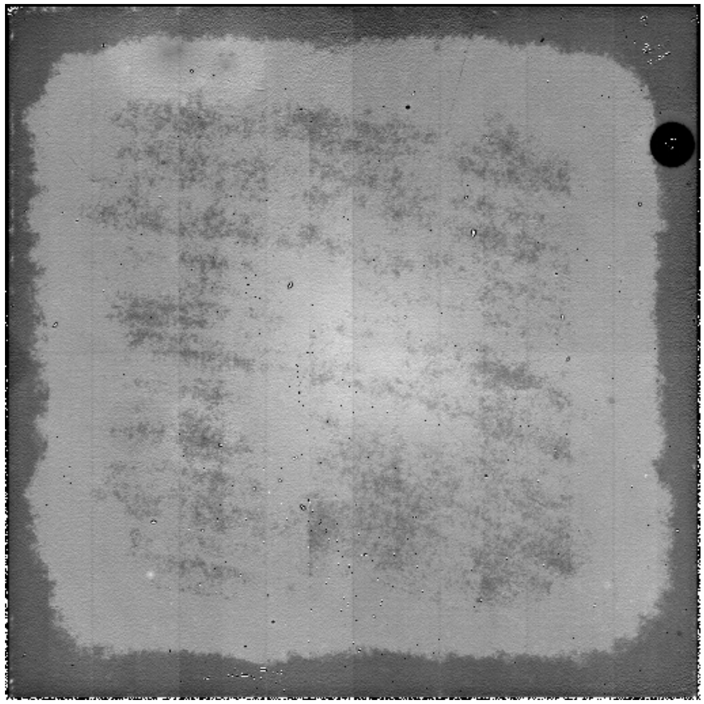
I recently had a chance to evaluate an Indium Gallium Arsenide (InGaAs) detector array for astronomy. Silicon CCDs are sensitive to light with wavelengths from 350 to 950 nm, and this InGaAs array was sensitive from 900 to 1500 nm wavelength. I had no idea what celestial objects looked like at these wavelengths, nor experience with such detectors, so this was a new experience for me. Michael MacDougal, Vice President of Aerius Photonics (www.aeriusphotonics.com), brought up a liquid nitrogen cooled 1024x1024 array with 18 micron square pixels to try out in my backyard roll-off roof observatory. I borrowed a 130 mm F/6 Astrophysics refractor to use with the camera, and we set it up on my Paramount. Below you can see the detector dewar hanging off the back of the scope. I think we set a record for the most expensive camera ever suspended with a single setscrew!

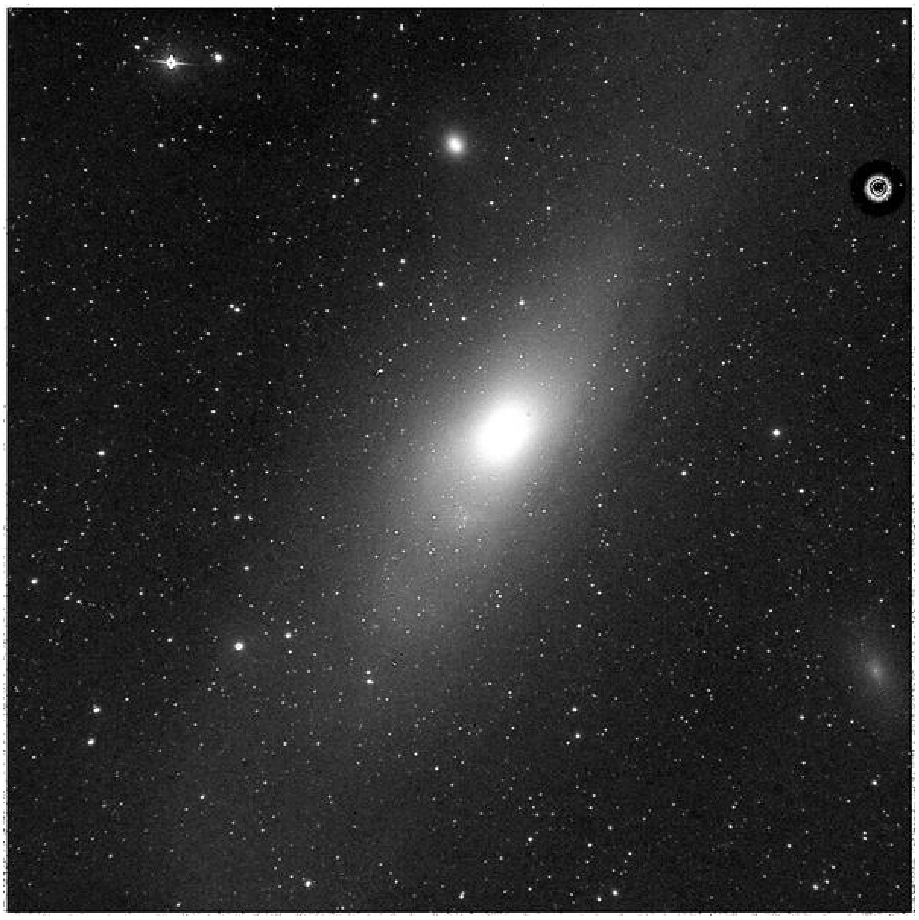


The first interesting piece of information we found out is that sky backgrounds are much higher in this wavelength band. Based on actual measurement the sky background is 3 times higher than that measured with an unfiltered ST-10XME, after accounting for pixel size. The second point of major difference with silicon CCDs is that the device nonuniformity is much greater than silicon. A flat field frame is shown below where the contrast has been scaled to be about half of the full scale values.

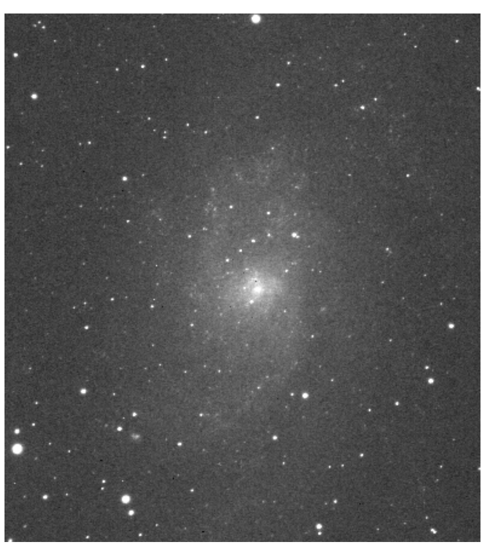


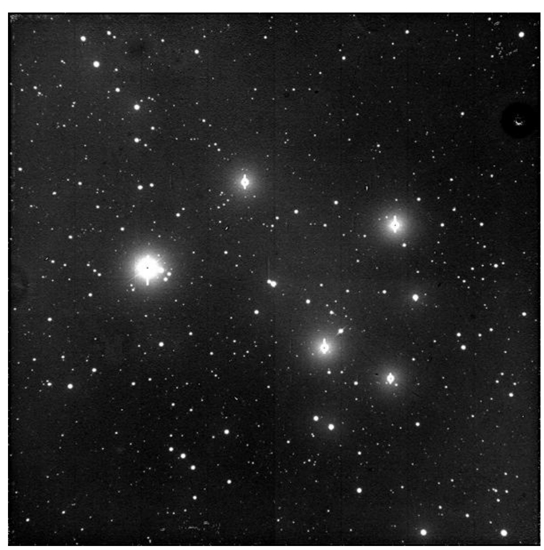
In general, InGaAs arrays are more challenging to build than silicon CCDs. Silicon's greater uniformity is due to the greater maturity of that imaging technology since tons of money was poured into its development over the years. Aerius Photonics specializes in low-noise large InGaAs arrays both at room temperature and cryogenic temperatures. The way these arrays are constructed starts with a 1024 x 1024 array of photodetectors being defined on the InGaAs material (the light sensing portion), and then indium bumps are applied to each pixel. The InGaAs detector array is then turned over and mated with a silicon CMOS readout that acts as a multiplexer for the data. The black circle in Figure Two is a region where there is a detector defect. The device is a "back side illuminated" photodetector, and so it generally has a 100% fill factor. The "frame" around the image is an edge effect specific to the readout chip used. My measured performance for this array is that its read noise was in the neighborhood of 10 electrons rms per pixel, assuming that the signal we saw at high light levels was limited by photon noise. With the high sky background our exposures are limited to 20 seconds. All images in this article are single 20 second exposures.

The first object we imaged was the Andromeda Galaxy, M31. We had to catch it early in the evening so we didn't have to image too high in the sky, and have liquid nitrogen spill from the dewar. The galaxy is shown with DDP processing.

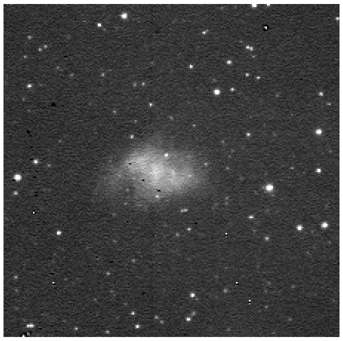


The outer reaches of the galaxy seem fainter in the near infrared. From there we moved onto M33 and then M45 (Pleiades). Once again, the general look was similar to unfiltered silicon CCD images.

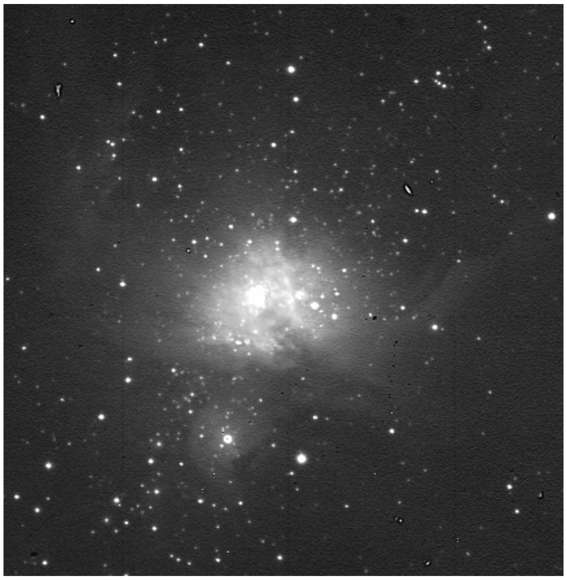


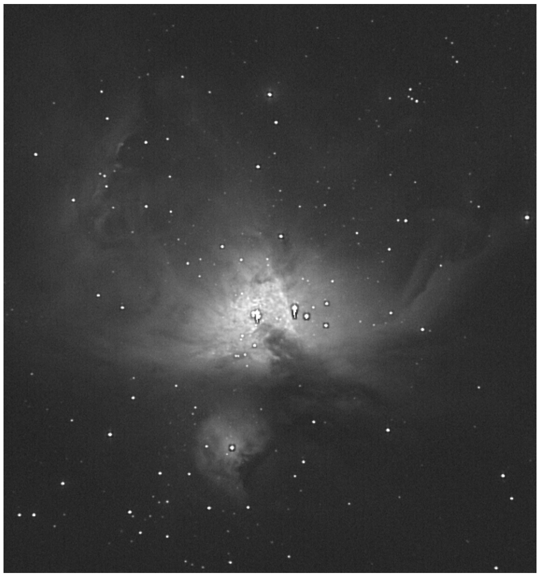


I don't believe the glow around the bright stars in the Pleiades image is real since other objects had glows around the stars. We are using a telescope way beyond its design wavelengths, so the coatings are doing unknown things. I was quite impressed that the images were as sharp as they were! From there we moved onto M1 (the Crab Nebula). A cropped portion of the frame is shown.



This is interesting since there is no Hydrogen Alpha light 656 nm light being detected here - the detector is blind to it. This is all continuum radiation. We ended our evening by imaging M42, the Orion Nebula. Below I have posted a picture taken both with the InGaAs array (left) and an ST-3200 (right). The major difference between the two images is that the InGaAs array shows up the open cluster behind the nebulosity clearly. The light from these stars cannot penetrate the dust of the nebula except at longer wavelengths.





At the end of the evening I concluded that the detector array's sensitivity was excellent, and the noise so low that quality astronomical imaging was readily achievable. SBIG and Aerius Photonics will continue to explore bringing InGaAs technology down to a cost range where small colleges and advanced amateurs can utilize this wavelength range to produce new views of celestial objects, to probe through the dust to the stars beyond!