The Objects That Changed Astronomy

(And How to Observe Them)

-Brad Young, Astronomy Club of Tulsa

Part Three: Daguerre to Sputnik

The invention of photography (usually attributed to Daguerre) was not only a technological breakthrough for human civilization, but a powerful addition to the toolkit of astronomers. The human eye, though a miraculous organ, does not have the ability to gather photons over time like photography or imaging can. It also sees only a narrow band of the electromagnetic spectrum which we call visible light. Photography can integrate photons over time and "see" in different wavelengths above and below the frequencies available to our eyes.

Horsehead Nebula. Image by Author

New Tools Require New Thinking (Again)

"Young man, I am afraid you are wasting your time. If there were any more planets, they would have been found long before this" – as told to Clyde Tombaugh

The first astrophotograph was taken in 1840, of the moon. The usefulness of this method was seen immediately, but it took decades of improvements to the process to reach its full potential. Early adopters such as E.E. Barnard found the extent of known nebula (both bright and dark) throughout the sky increased dramatically using long exposures. Photographs also provided a record that could be checked against older images, leading to blinking methods for identifying planets and asteroids such as Pluto.

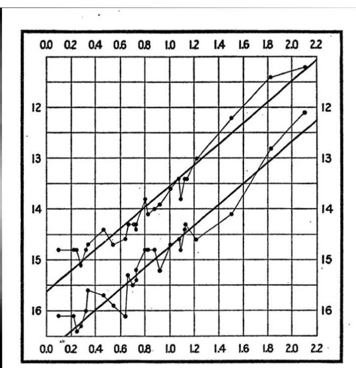

FIG. 2.

Brightness vs. Period Relationship

Photography also provided a much easier way of recording variable stars. The "standard candles" identified by Henrietta Leavitt (Cepheid variables) led to the *period-luminosity relationship* method of providing stellar and later galactic distances far beyond the reach of simple parallax.

Observing These Wonders

If you have imaging equipment or access to any of the remote imaging services, you can recreate the power that photography brought to astronomy. For instance, you may have struggled all your observing life to visually observe the Horsehead Nebula (Barnard 33) in Orion or spent hundreds on a H-beta filter. A 60 second exposure with no filter on a rental scope will give you an amazing view of the nebula to rival those seen in your astronomy books.

You can also use imaging to track variable stars, although many can also be tracked visually. There are many Cepheid variables that can be observed either way, and your observations used to calculate the distance to a star based on its period and apparent luminosity. Check the AAVSO website (American Association of Variable Star Observers) to understand how this is done.

Blinking images to search for asteroids or near-earth objects is still done via the various sky surveys such as Pan-STARRS and the Catalina Sky Survey. If you would like to be involved in this, you can request to be on a team via the IASC (International Asteroid Search Committee) and blink images provided to you by those surveys.

Imaging Relativity

"Spacetime tells matter how to move; matter tells spacetime how to curve." -John Archibald Wheeler

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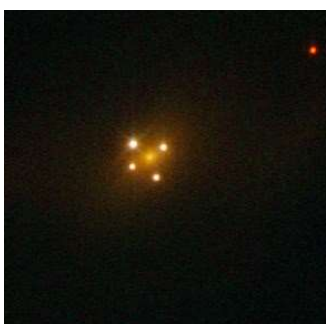
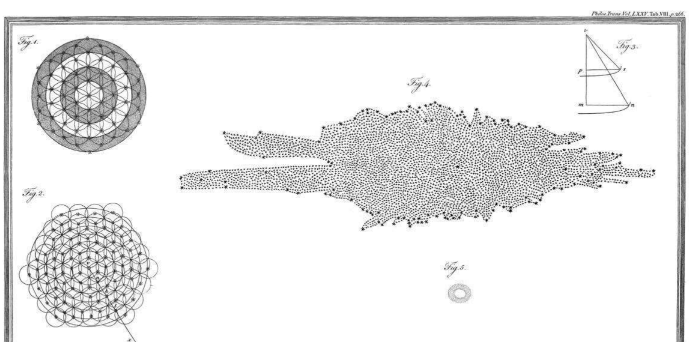
Another benefit of astrophotography was scale and adaptability. One of the effects of gravity predicted by Einstein's theory of relativity was that starlight passing near a massive object such as the sun would be bent by its gravity. This would seem to be a hard thing to prove, but at the 1919 solar eclipse, Sir Arthur Eddington took the famous photograph below that was used to prove the theory. Stars in the image (not visible at this scale) were compared to images of those same stars in Taurus without the sun in the field. The exact replication available using photography and very careful, precise measurement proved that the light from the stars near the sun had been displaced slightly by the gravity of the Sun during the eclipse.

I'm not sure you're going to be able to replicate this famous use of imaging yourself, but it stands as one of the best early uses of photography to prove a fundamental theory about our universe. If you have a very large scope or highly sophisticated imaging setup, there are other examples, such as gravitational lensing. An Einstein Cross, such as Huchra's Lens, also pictured below (by Hubble Space Telescope), is a famous example. Four images of the same distant quasar (plus one in the center, too dim to see) appear in the middle of the foreground galaxy due to strong gravitational lensing.



Island Universes

One thing you can admire every clear night are the galaxies in the universe, either the one that we inhabit or all the other ones in the sky. Before photography, these nebulous patches were thought to be clouds of gas within our own, singular Galaxy. William Herschel famously sketched our Milky Way as a flattened disc based on his visual observations:



In the 20th century, Hubble, Friedmann, and Lemaitre used general relativity and spectrography to show that these nebulae were other galaxies and were receding away from us in all directions. The spectrum of all but the nearest galaxies shifted to the red end of the spectrum, an example of the Doppler effect. This was a fundamental change in the way the universe was understood; we were no longer alone as a single galaxy, but one in a universe of millions of galaxies, all racing away from each other. These discoveries led to the Big Bang theory of the formation of the universe.

If you have a spectrograph available, you can replicate this discovery yourself. Barring this, just go out and admire our Milky Way or another galaxy some night either visually or with imaging and realize that it's been barely a century since we first understood what these islands of other stars were.

Image by Author

To determine the distance to other galaxies, supernovae are imaged and typified as either Type I or II. The light curve determined by observation identifies the type, and the apparent brightness can be used to approximate distance. This allowed Hubble and others to note that the further from Earth a galaxy was, the faster it was receding from us – now known as Hubble's Law

$v = H \times D$

or recessional velocity of a galaxy from us is proportional to its distance from us. The constant H (Hubble's Constant) is a measure of the "expansion factor" of the universe. This constant has been highly controversial as it determines whether the universe is "open" (will expand forever) or "closed" (will ultimately crash back into a Big Crunch).

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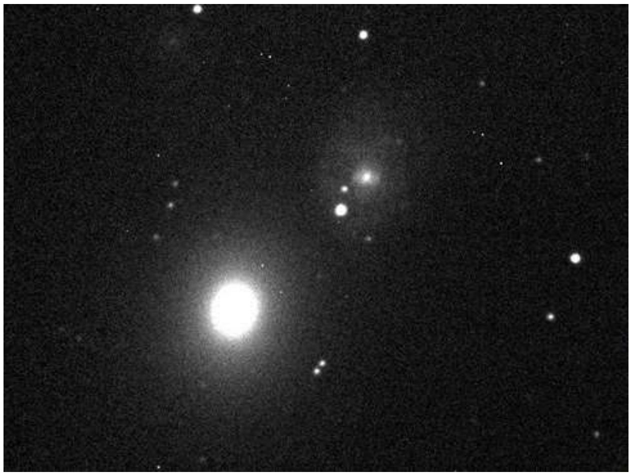
Observing Extragalactic Supernovae

You can approximate the distance to a galaxy by observing extragalactic supernovae, such as SN2022hrs in NGC 4647. This galaxy happens to appear to be next to Messier 60, a bright galaxy in Virgo. See my article on it to find its location. Once the light curve is complete, astronomers will use the data reported to AAVSO to review their current distance (63 million light years away) listed for NGC 4647.



SN 2022hrs *Image by Author*

Check sites such as Latest Supernova to find opportunities to image or visually observe these amazing sights. Until we finally have one here again in the Milky Way, these are the supernovae we can see.

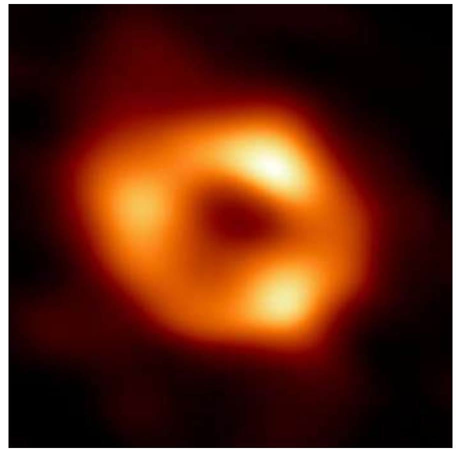
Radio and Other Wavelengths

"Decide yourself if radio's gonna stay - reason it could polish up the gray" "Radio Free Europe" by R.E.M.

Though not specifically tied to astrophotography and imaging, understanding that there were other wavelengths of light that could be studied led to other useful tools. Radio astronomy has proven to be essential to understanding how objects such as pulsars (neutron stars spinning and pulsing light in our direction) work. The background radiation left over from the Big Bang was discovered in the microwave region of the spectrum. Unfortunately, some of the wavelengths of light are blocked by our atmosphere and their use would have to wait for space-based observatories (see next article). On the other hand, I think it's okay that ultraviolet light from the sun is not allowed at full power directly to our skin.

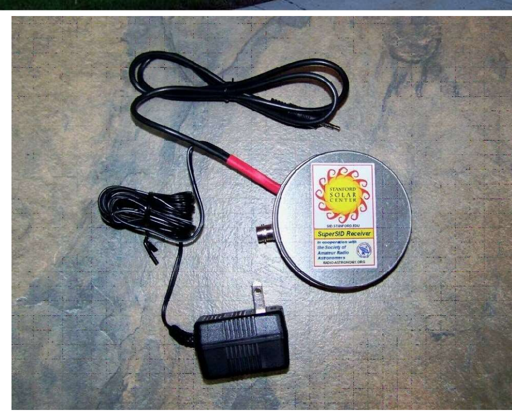
Radio astronomers keep making news, even during the writing of this article. To quote Wikipedia:

> On May 12, 2022, astronomers, using the Event Horizon Telescope, released a photograph of Sagittarius A* produced using data from radio observations in April 2017, confirming the object to be a black hole. This is the second confirmed image of a black hole, after Messier 87's supermassive black hole in 2019.



Sagittarius A the black hole at center of Milky Way*

Radio astronomy is available to amateurs via DIY setups that can be put together with a little effort and expense. Examples include the SuperSID receiver (left) to monitor solar activity, and the Radio Jove setup (antennae on right, separate receiver) to monitor storms on Jupiter.



With special permission, you can even use radio scopes remotely, such as the 20-meter Green Bank radio scope. I observed many objects using that setup a few years ago, including this record of radio source 3C123.

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But one thing you can observe with no expense at all is the background radiation discussed above. Just turn your old (analog) TV to a station that doesn't broadcast and look at the snow on the screen. A few of those pixels are lit up by the microwave radiation left over from the beginning of the universe!

A Picture is Worth a Thousand…Hours of Processing?

"I got a Nikon camera; I love to take a photograph"- *"Kodachrome"* by Paul Simon

"Dreamy" Jupiter drawn by Trouvelot, 1880's

"Official" Jupiter image released by NASA et al, 2017

Astrophotography and later digital imaging have changed both the professional and amateur astronomical communities in enormous ways. Professional astronomy now relies exclusively on the use of imaging. The availability of the entire electromagnetic spectrum has made investigating our universe much easier and has provided the basis for our current astrophysical theories.

Amateur astronomy has also been changed by photography but has not entirely switched over to imaging only. Hopefully, the visceral experience of visual observing will survive, and imaging will be synergistic, not supplanting eyes at a telescope.

The next article, Part Four, will complete this survey of the objects that changed astronomy by looking at the Space Age, and all the unparalleled discoveries made possible by space-based observatories and probes.

Credits:

- Wikipedia
- NASA
- Leavitt, Henrietta S; Pickering, Edward C "Periods of 25 Variable Stars in the Small Magellanic Cloud" Harvard College Observatory Circular, vol. 173, Public Domain, retrieved May 12, 2022, at https://commons.wikimedia.org/w/index.php?curid=34747012
- https://www.aavso.org/cosmic-distance-ladder
- http://iasc.cosmosearch.org/
- http://www.warrenastro.org/was/newsletter/WASP-2022-05.pdf
- https://www.rochesterastronomy.org/supernova.html
- EHT Collaboration - Astronomers reveal first image of the black hole at the heart of our galaxy (Image link), CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=117932040
- https://www.gb.nrao.edu/20m/peak/3C123/Skynet_57458_3C123_17889_18894.htm
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