The Objects That Changed Astronomy

(And How to Observe Them)

-Brad Young, Astronomy Club of Tulsa

Part Two: Galileo to Daguerre

As noted in the previous article, before 1600, humans made our most fundamental discoveries about how the universe works. But, as with any collection of ideas, some of them were wrong. Because people lacked some of the tools that modern scientists have, they arrived at conclusions that only new instruments, technology, and, most crucially, different thinking would correct. In astronomy, the most important invention is the telescope.

New Tools Require New Thinking

"Come with me now, pilgrim of the stars, for our time is upon us and our eyes
shall see the far country and the shining cities of Infinity which the wise men knew
in ages past, and shall know again in ages yet to be." — Robert Burnham Jr., Burnham's Celestial Handbook: An Observer's Guide to the Universe Beyond the Solar System, Volume 1: Andromeda Through Cetus

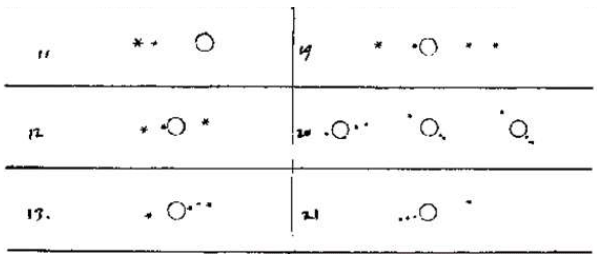
The invention of the telescope, coinciding with and integral to the Scientific Revolution, transformed astrologers and natural philosophers into astronomers. As the use of the instrument spread, the technology improved, with new and better eyepieces, lenses, and mirrors. Better views and careful observations provided data that needed explanations in a world that had not seen anything like these new objects and phenomenon. New scientific methods allowed us to build theories, ruin them, and rebuild them again.

Wabi-Sabi

Moving shadows; moonlight streams through the broken window

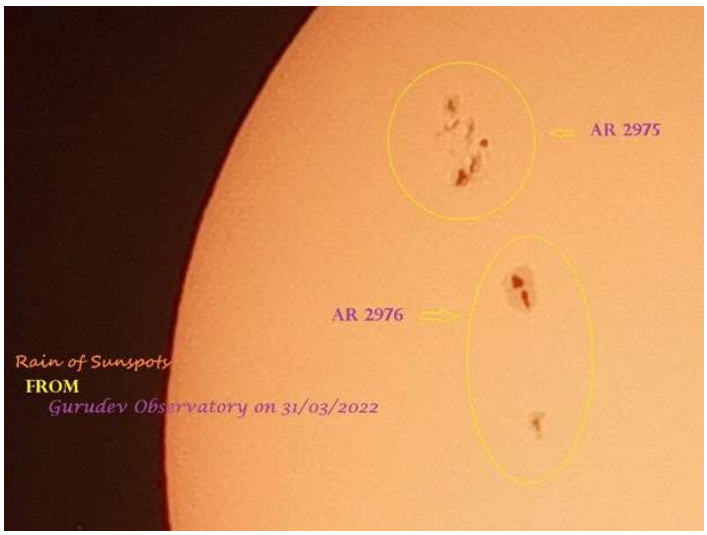
Japanese poem

As we all know, Galileo Galilei used the telescope to discover many things about the Solar System and the stars. Seeing the moons of Jupiter revolve around their planet, he argued that Copernicus was right about the Sun centered Solar System.



His report on the phases of Venus further supported Copernicus, showing it to be an inferior planet, orbiting the sun. Seeing sunspots on the Sun and detail in the markings on the moon, he posited that the heavenly bodies were not perfect immutable works but were instead part of a vibrant cosmos. Tracking the spots showed that the Sun rotated about its axis just like planets and moons do. In a way, it was these imperfections inspired astronomers to seek a better understanding of our universe. The Japanese have a philosophy of wabi-sabi, the view of finding beauty in the imperfection of nature.

These earliest telescopic sights are the same that inspire wonder at public star parties and outreach events. The rings of Saturn, the moons of Jupiter or the craters on the Moon through a telescope are sights no one should miss. For the sunspots and other solar phenomena, you can either project the sun's disc through a telescope onto a piece of cardboard or use a relatively cheap mylar filter to fit over the front of your telescope to see the disc in white light.



There are also more sophisticated filters available to observe in hydrogen alpha and other wavelengths that may bring out other details. As always ***never look at the sun directly*** and always use approved equipment and methods when looking at the sun in any telescope.

New Ocean of Discovery

Then felt I like some watcher of the skies when a new planet swims into his ken;

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Or like stout Cortez when with eagle eyes he
star'd at the Pacific—and all his men
Look'd at each other with a wild surmise— silent,
upon a peak in Darien.

"On First Looking into Chapman's Homer"
by John Keats

The telescope also opened a vast ocean of discovery of objects never seen by human eyes. More comets were discovered, and Edmund Halley proved that one, later named for him, returned every 76 years, the first time the previously terrifying objects became tamed and predictable. Charles Messier made his list of fuzzy deep sky objects that were stationary, so he wouldn't confuse them with comets. His list of "rejects" represents some of the most enticing objects to view in a small telescope. William Herschel also observed thousands of nebulae, clusters, etc., and produced the first deep sky catalog of the entire sky with his sister Caroline's able assistance.

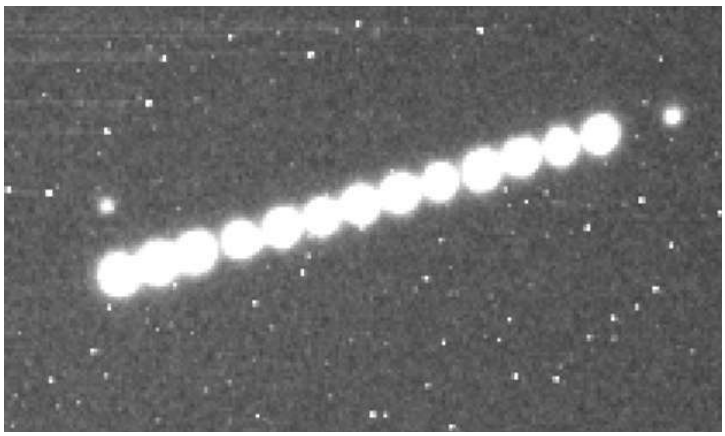
Telescopes of modest to enormous size will show all these objects in varying degrees of clarity and detail. But the most amazing thing discovered in the telescopic age was that there are other planets in our solar system. William Herschel was appointed Court Astronomer and given the money to build his large telescopes because he found the unexpected, a planet beyond the orbit of Saturn. His proof of the planetary nature of Uranus was indeed an epochal discovery, equal in magnitude to Balboa's discovery of the hitherto unimagined Pacific Ocean (Keats had the wrong conquistador).

Throughout human history, it was known that there were five planets other than Earth, and this was considered the final answer. Later review of records as far back as Galileo and perhaps even Hipparchus showed that Uranus had been seen by others before and even given a catalog number (34 Tauris). But Herschel provided scientific proof through diligent observation, and after his discovery came those of Piazzi and others who found dozens of asteroids. The search for what turned out to be the asteroid belt centered on a distance predicted by Bode, who noticed a periodicity in the location of the planets from the sun.

Later, inconsistencies in Uranus' orbit led to the discovery of Neptune by Le Verrier, Galle, and Adams, all using math and visual telescopes. You can easily

		Mean Distance from Sun in AU (Earth = 1AU)	Mean Distance from Sun by Bode's Law: ($a = 0.4 + 0.3[2^n]$)
	n	a	
Mercury	-∞	0.39	0.4
Venus	0	0.72	0.7
Earth	1	1.00	1.0
Mars	2	1.52	1.6
????	3		2.8
Jupiter	4	5.20	5.2
Saturn	5	9.54	10.0
Uranus	6	19.18	19.6

repeat these astounding discoveries with binoculars or a small telescope. Uranus, Neptune, and several of the brighter asteroids are visible at some point in the year around their opposition. Check your local astronomy magazine, website, or software to find when they are easily visible. Be sure and bring a chart with you as the only way to identify a planet or asteroid is either noting a star that shouldn't be there or sketching the star field over a few nights to see which one moved.



Hygiea every 20 min 12Apr 2022 by author

Note that in May 2022, both Uranus and Neptune are near the sun. Hygiea, an asteroid, is in Virgo, but you'll need a 4-inch telescope.

The Messier objects provide a great introduction to the deep sky objects observable by modest visual telescopes. Messier's first item (M1), the Crab Nebula in Taurus, is a supernova remnant and it is easy to see how Messier confused it with a comet. Other catalogs, such as Herschel, Caldwell, and books by Rev. Webb, Burnham, and many others will point out the famous, the strange, and the beautiful objects first seen by the pioneers in telescopic astronomy. *In May 2022, M1 is up right after dark but will be hard to see by mid-May. But there are dozens of Messier objects well placed this month.*

The Survey Era

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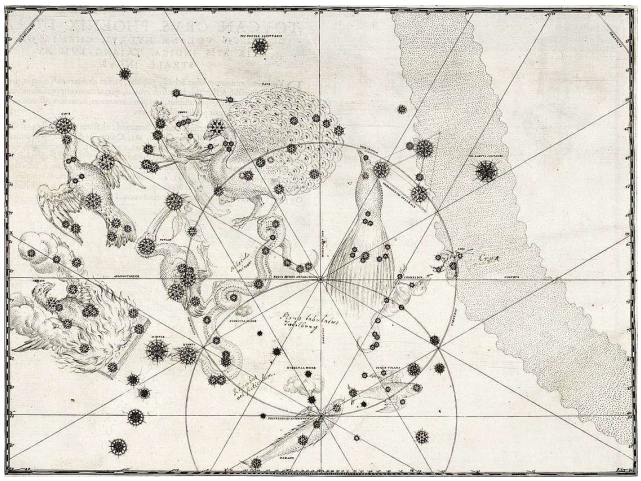
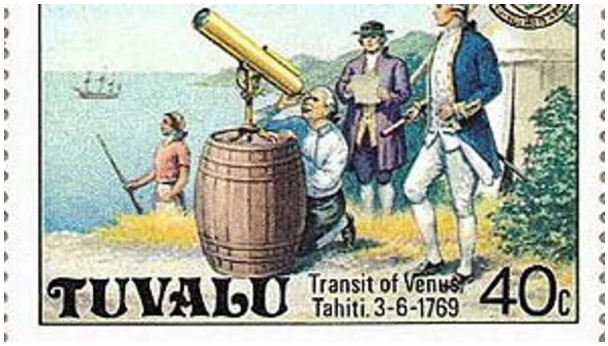
I propose to take such a survey of the Universe that the mind may be able really to receive and to perceive an individual impression.

"Eureka: A Prose Poem", by Edgar Allen Poe



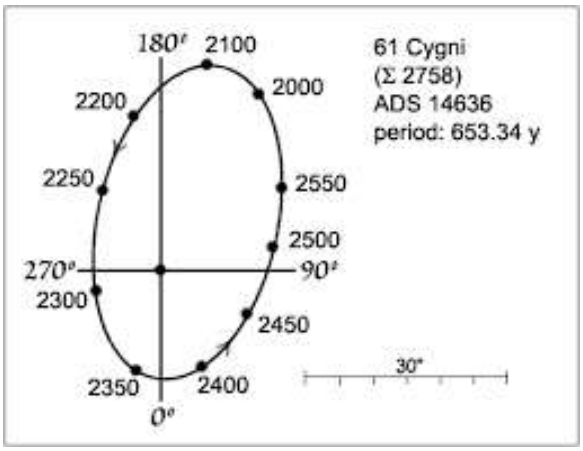
The Age of Discovery opened the southern sky to European eyes, as Halley, John Herschel, and especially Lacaille voyaged to the southern hemisphere and charted the stars and objects seen there. New constellations were devised, although the native peoples there had long had their own star stories. The invention of the micrometer and better achromatic lenses allowed for splitting and measuring double stars. Many of these were seen to be actual pairs, orbiting each other exactly as Newton and Kepler predicted, following the same rules of gravity and elliptical orbital motion devised for objects in our Solar System.

The most important discovery of this period was the fundamental scale of the nearby universe. The relative distances between the sun and planets were known, but it took the careful, scientific method (proposed by Halley) of timing the Transit of Venus in 1769 to provide the scale. Until ocean voyages and harsh overland travel could be mastered, we could not cover the great distances needed to make the needed observations. Jeremiah Horrocks first observed the Transit in 1639 but had no other reports to provide the needed data.



Once the actual distance was known from the Earth to the Sun (the astronomical unit AU), all distances in the solar system could be calculated. Later, Friedrich Bessel used stellar parallax, the change in position of the stars over the course of six months (the extent of Earth's orbit), to provide distances to stars in our region of the Milky Way.

Double and multiple stars can be seen with a telescope, and you can even track their orbital motion, though many take years to show movement. There are many beautiful double stars, but you might visit 61 Cygnus later in the summer. Not only is it possible to split it with mounted 10 x 50 binoculars (though a small scope helps), it is also the star that Bessel used stellar parallax to determine the distance of the 61 Cygnus system from Earth.



61 Cygni Orbital Motion

A trip to the tropics or Southern Hemisphere will open a fantastic sky journey also, with the southern constellations and magnificent deep sky objects available you can never see from up north. Hopefully, you just observed one of the Venus transits, as they will not repeat this century. However, Mercury also transits the sun, either in May or November. We will have to wait until 2032 for the next one.

Other Light

"What's the frequency Kenneth?"
Spoken to newsman Dan Rather by his assailants; inspired a song by R.E.M.

Rainbows had been known since recorded history began, and prisms and the splitting of light into its constituent colors were studied by Newton, However, the true beginnings of spectroscopy and studying the entire electromagnetic spectrum began in 1800 with William Herschel. Herschel measured the temperature of each color and noticed there was a large increase beyond the red end of the spectrum, what we now call infrared light.

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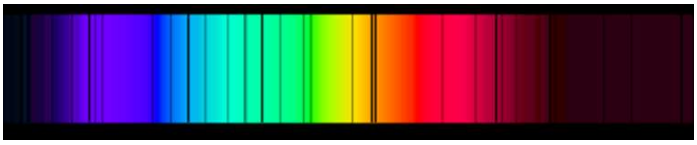

In 1814, Frauenhofer built the first spectrometer and identified dark (absorption) lines in the solar spectrum, which were later named in his honor. He matched these with known chemical elements and provided a way to determine what stars are made of. Helium, 10% of the visible matter in the universe, was found in the solar spectrum decades before it was identified on Earth.

Spectroscopy is indeed a powerful tool. We were beginning to understand that there were other ways to study our universe, using new technology. This would expand enormously in the next 200 years, as we will see in later articles. Doing your own spectroscopy is more difficult than the other telescopic work discussed above. It requires a diffraction grating and is used, in modern times, with imaging equipment. So, we will need to move into astrophotography, and later, astroimaging. The next article will discuss how we invented those, and how you can use the tools to rediscover the objects that changed astronomy.

You can, however, note the color of stars and from that understand their temperature and other characteristics. Annie Jump Cannon invented the stellar classification system by color, using letters to differentiate the classes. A common mnemonic for the system is "Oh, Be A Fine Girl Kiss Me". O stars are very hot and blue, and each class gets cooler through white, yellow, orange, and finally red (M). A small telescope or binoculars will help draw out the color, and you can also spot colors in double stars, which may both be the same shade or very different.

Your Friend the Telescope

Learning how to use a telescope can be a daunting task, but it is well worth the effort. There are many more things to see, and the objects you admire with your eyes often have wonderful detail and deeper beauty through a scope. Man's grasp of the universe has been increased exponentially by the telescope, and your enjoyment of astronomy can be too. Peering through a telescope is a joy shared by many people, and you can join that community if you like. Attending a star party or outreach event is always a treat, and the wonder observing the planets and stars ignites in children of all ages is amazing. It all began 400 years ago and has been a cornerstone of the Scientific Revolution that has changed human history. Whether a meters wide world class scope or a cheap refractor from a big box store, optical aid has made the universe wider, and our understanding of it deeper.

"Love looks through a telescope; envy, through a microscope."

Josh Billings

Sources and links:

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