Air and Space this Week

Item of the Week

Clyde Tombaugh

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I admit, I'm not exactly the poetic type, but one particular turn of phrase has been a favorite of mine for years. It's in a beautiful sonnet written by John Keats, "On First Looking Into Chapman's Homer." The line is, "Then felt I like some watcher of the skies when a new planet swims into his ken;" What a feeling of discovery that would be!

Only four humans have ever had that pleasure. William Herschel knew he had discovered something when he first saw Uranus, but it was only some time later it was realized that his discovery was a new planet. Astronomers Galle and d'Arrest knew they were first to see a new planet, Neptune, and even though their excited observation was guided by a prediction from LeVerrier, they were the first to see it and know it was a planet in real time!

The fourth was Clyde Tombaugh, who was also guided by a prediction. Planet or dwarf planet, Pluto was an exciting and important discovery. This is Clyde's story.

THE DISCOVERY OF NEPTUNE

[This section and its references are from the Item of the Week, appearing on October 3, 2021]

Uranus was discovered by William Herschel in 1781. He was systematically counting stars in sections of the night sky, in part to help determine the structure of the Milky Way, so his finding Uranus was not exactly accidental, but it's not like he was specifically searching for a planet (as would be the case for Neptune and (dwarf) planet Pluto)).

Acceptance of Herschel's finding a planet of our Solar System did not come right away. The same was true of Herschel's choice for the name of the new object. The latter, "Georgium Sidus" or "George's Star," was Hershel's gesture of appreciation to King George III, his patron. It was simply ignored in favor of "Uranus" (Saturn's father), in keeping with the mythological gods and begats nomenclature. Careful additional observations and mathematical analysis, especially that of astronomer Johann Bode, would conclusively prove that Uranus was, in fact a planet, orbiting the Sun farther away than Saturn.

But that is not all careful observations and analysis showed. Working the math backwards showed and detailed analysis of astronomical records showed that Uranus had been spotted previously several times, but its non-star nature had not been recognized.

Continued careful tracking of Uranus showed that it deviated a slight amount from its predicted position, in a way that could not be mathematically duplicated if Uranus was out there by itself.

But what if there were another planet out there, beyond Uranus? Could it be responsible for the exact location of Uranus?

There was another planet farther out there, and, like Uranus, it had already been observed a number of times before but not recognized as a moving object, including once by John Herschel, William's son.

Alexis Bouvard had made and published position predictions for Uranus, and his observations of the deviations made him hypothesize, in print, that another planet, farther out, might be responsible. He also listed a few other possible causes.

Bouvard's observations and hypothesis sparked the imagination of two men, John Crouch Adams in England, and Urbain Le Verrier in France. Both made predictions about where a perturbing planet might be. Neither knew of the other or their interest in the same problem. Adams sent his to James Challis, the director of the Cambridge Observatory; Le Verrier sent his to the French Academy of Science. Either Challis sat on Adams' predictions, or the Astronomer Royal George Airy did, until word got to England of Le Verrier's prediction. The English began a systematic search in July, 1846, but Challis' star maps were not strictly up-to-date; he actually saw Neptune twice without knowing it.

Le Verrier had as much difficulty inspiring others to look for his predicted planet as Adams hed. Finally, Le Verrier sent his predictions to Johann Galle at the Berlin Observatory. Galle immediately jumped into action, along with his student Heinrich d'Arrest, who knew of a recently-prepared chart of the part of the sky in which Le Verrier's prediction lay.

Neptune was discovered after only ***one hour*** of searching. It was only 1° off from Le Verrier's predicted position. Adams had presented at least some predictive material up his chain first, but it was Le Verrier's more-complete predictions that actually led to the discovery. Credit of discovery was extremely important from a national pride perspective, and there has been much controversy ever since, in which both Adams and Le Verrier contributed little. Subsequent analysis and other factors suggest priority should go solely to Le Verrier, but for now, the credit is shared.

ENTER PERCIVAL LOWELL

Detailed tracking of the movement of the new planet began immediately after its discovery. Neptune, too, was found to deviate from its predicted path by a small, but measurable, amount. Might it be possible there was yet another planet farther out affecting Neptune's motion?

A number of astronomers thought so. One of them would be Percival Lowell, but not just yet. Lowell was not particularly well-regarded by other astronomers, because he tended to take a pseudo-scientific approach to things, rather than follow scientific method rigorously. He decided what the situation was, then sought evidence to support that notion, rather than form hypotheses dispassionately.

Lowell's family was extremely wealthy, and like so many of his contemporaries, he received an excellent education in prep school then (of course) Harvard, and followed them up with a Grand Tour of Europe. His career was expected to involve the furtherance of the family fortune, and included an arranged marriage to a proper lady from a proper family (she was a sister-in-law of Teddy Roosevelt).

Black Sheep Percival would have none of that!

He rejected both the career path chosen for him and dumped his chosen-for-him bride to-be. He wanted no part of Boston high society and wanted to get away from it completely. A lecture he attended in 1882 about feudal Japan intrigued him, so off he went to the Far East. He would make several trips there over the next decade, and wrote four books about his observations and experiences.

Lowell was developing other academic interests, including astronomy, and he had taken a small telescope to Asia with him before. Departing the U.S. for his final trip to Japan, he delayed in San Fransisco in order to visit the Lick Observatory above San Jose and meet with famous astronomer E.E. Barnard. Then came one of those life-changing moments that we all experience.

Christmas, 1893, was the time. His aunt gave him a copy a book written by French astronomer and Mars expert, Camille Flammarion. The title (in English) was "The Planet Mars and Its Conditions of Habitability." It was a voluminous tome that contained a summary of astronomical thinking about the Red Planet, including the research and maps of Giovanni Schiaparelli. The gift was small, but …

Lowell was utterly thunderstruck (cue AC/DC, or better yet, Luca Stricagnoli)!

The idea that Mars might be inhabitable morphed into the conviction that it was. The maps of Schaparelli had a number of thin lines identified as "canali," which means "channels" in Schiaparelli's native Italian. A channel can be a naturally-occurring feature, but in most English usage, it is a waterway constructed by humans. But the two words are close, and a lot of people had the Suez Canal on their minds at that time, so "canals" they were to Lowell. And if they were made things, then there had to be Martians there to make them, at least in the past. Lowell imagined that what Schiaparelli saw and mapped were part of a Mars-wide irrigation system built to bring water from the polar regions to the parched equatorial zones, where the industrious Martians grew crops.

Lowell went to the Harvard College Observatory and met with William H. Pickering, an up-and-coming astronomer there who specialized in Mars study (he was also the nephew of Edward Charles Pickering, the HCO Director). Lowell's money talked, and WHP and his assistant, Andrew Douglass took a year-long leave of absence from HCO to accompany Lowell to the American Southwest to find a good site for an observatory Lowell would build so he could study Mars aggressively.

Time was of the essence. The nature of the orbits of Earth and Mars meant that Mars would be best observed when it was "in opposition" to the Sun (when the Sun, Earth, and Mars were in a straight line), and, because both orbits were a bit eccentric, the Earth-Mars distance at

opposition was not constant. Particularly favorable oppositions occur on a ~17-year cycle. [Mars' eccentricity was also the key for Johannes Kepler to be able to determine his first two "Laws of Planetary Motion," see the Item on Kepler here.] The next one of the favorable oppositions would occur in late 1894.

Lowell's team visited several candidate sites in early 1894, and decided that Flagstaff, Arizona Territory would work best from them. They then returned to Massachusetts to prepare for an observing expedition. Lowell borrowed an excellent 12-inch refractor from HCO and a new 18-inch refractor that was earmarked for an observatory in Philadelphia, and acquired a portable observatory structure that could be easily moved. Both telescopes had been made by the very famous Alvin Clark, the finest available. Off they went!

The team arrived in Flagstaff on May 28, 1894. Lowell would make several visits back to Boston soon thereafter (his mother was deathly ill), but WHP and Douglass used the borrowed telescopes to make a series of observations of Mars. They were having difficulty seeing the canali of Schiaparelli. Lowell joined them for the opposition period, and he, too, had trouble seeing linear features, at least at first. As any backyard astronomer knows, "seeing" depends on atmospheric turbulence, and typically there would be moments of really clear views followed by longer intervals of somewhat more blurry views. Lowell saw lines during those brief periods, and mapped them extensively.

In the months following the opposition, Lowell developed his ideas about Mars, its inhabitants, and their engineering prowess. He took his ideas both to the astronomical community, and to the general public. Most of the astronomers snorted with derision, but the public ate it up.

Lowell published several articles in *Popular Astronomy* in the year following the opposition. In them, he laid out his thoughts about Mars and its canals. Lick Observatory's E.E. Barnard, whose famously-acute vision was augmented by a Clark refractor much larger than Lowell's, observed at the same time, under better seeing conditions, and saw only a mottled surface.

Long story short, Lowell was fooled by a quirk of the eye-brain combination – when one looks at a spotted object at the limit of the eye's resolution, the brain tends to play "connect the dots." One perceived lines when they were not really there. Schiaparelli had mapped "canali," but as better telescopes came on line, astronomers did not see the lines. Lowell had created a whole set of speculations (not even real hypotheses) about their creation. Many were expecting to find constructed canals on Mars up until the *Mariner 9* spacecraft flew by Mars over 50 years ago.

Lowell appreciated how well his ideas inspired the public, but he smarted from the criticisms of his ideas and research methods from Barnard and the other established professionals. He bought an even larger Clark refractor (24"), one of the finest telescopes of that type ever made, and took it along with Douglass and two assistants (WHP had gone back to HCO by this time) to Mexico City to observe the next Mars opposition, which would be almost as good as the one in late 1894. Lowell arrived late in Mexico, and although his assistants had made a number of observations, Lowell himself resorted to making observations of Mercury and Venus.

Venus was already known for its featureless appearance, thought (correctly) to be due to an extensive, permanent cloud cover. But Lowell didn't see that, his drawings of Venus displayed a black-and-white spoke-like feature Lowell claimed was naturally-occurring linear outcrops of bare rock protruding from the venusian sands.

The reaction of the astronomical community was much less kind this time around, and Lowell was not just criticized, he was being laughed at. Some of the astronomers took to calling Lowell's Venus markings "canals."

Lowell grew up in a very privileged environment; he was not used to hearing "no" and he certainly wasn't used to getting laughed at. The humiliation proved too much, and he suffered a nervous breakdown that kept him out of action astronomically for several years.

His recovery was slow. He was not only nursing his mental health, he was nursing some grudges. He returned to Flagstaff in 1901, and immediately fired Douglass, who openly thought that Lowell's canals on Mars and Venus were mere illusions. He wanted academic vindication. And he hoped to get it with new observations of Venus, this time with a state-of-the-art spectrograph (see here for more on astronomical spectroscopy).

Lowell had made a promise earlier to one of his former assistants, now a professor at Indiana University, to hire a recent IU grad named Vesto Melvin Slipher at least temporarily. Lowell did, and set him to work with the new spectrograph. Slipher made detailed observations of Venus for several months, but could not confirm Lowell's observation of spoke-like features. He did, however, discover that the rotational period of Venus was very long, likely as long as the venusian year. It isn't, but that was still an important conclusion, but not notable enough to salvage Lowell's astronomical reputation. What to do?

"Lowell wanted desperately to improve his credibility among other astronomers. So, Lowell thought, if he could predict the location of a ninth planet, "Planet X," and then find it, it would surely improve his status." [DPC and WS quoting Tombaugh, page 99]

Slipher remained at Lowell Observatory for the next 53 years!

Just as he had been inspired by Schiaparelli and his lineated map, Lowell was also intrigued by how Adams and Le Verrier were able to predict a position for Neptune based solely on the observed slight deviation in Uranus' motion from its predicted path.

The mathematical techniques used by Adams and Le Verrier, and by William H. Pickering, who was shaping up to be a rival of Lowell's quest for Planet X, were complex. Even using "Thacher's Cylindrical Slide Rule" a rudimentary analog computer, there was difficulty in coming up with a good prediction. The calculations required a starting assumption on the size, distance, and orbit of the as yet undiscovered planet, and it was a "garbage in-garbage out" situation. None of the calculated spots were working out. Lowell tied off his thinking about Neptune and Planet X with the September 1915 publication, "Memoirs on a Trans-Neptunian Planet."

All this time, Lowell was spending time observing Mars during oppositions, and publishing several books about Mars and Martians that were immensely popular with the public. By 1916,

his health was failing, but he still made speaking engagements in Toronto and California, before returning home to Flagstaff, where he continued to observe up to the very end. He died there on November 12, 1916.

INTERREGNUM

Percival Lowell had died, but the Lowell Observatory lived on. However, Lowell's widow caused a LOT of financial and managerial grief in the ensuing decade, with the result that the nest egg Lowell left for the Observatory was diminished by half. For the next 15 years, the Observatory limped along, with only three astronomers on staff. Lowell's work on Planet X was left untouched as there were no funds to support it. But the Observatory's management and financial woes began to lessen in the late 1920s, and they were finally able to start upgrading their telescopes and other supporting infrastructure.

Lowell's aforementioned rival in the search for Planet X, William Henry Pickering, should not be confused with William Hayward Pickering, a New Zealand-born rocket scientist who headed the Jet Propulsion Laboratory for 22 years! Our story's WHP was at Harvard, and he was very active in making a number of predictions for the position of Planet X, assisted ably by Elizabeth WIlliams. Most astronomers paid them little mind, because they knew of the many assumptions that had to be made for the calculations.

The improving situation of Lowell Observatory, and WHP's continued publication of Planet X position predictions spurred the astronomy team at Lowell to circle back to the issue of Planet X. It would not have had much time to move from the positions predicted by Lowell. But the search, with 1920s technology would be laborious, likely long, and potentially unrewarding. They needed an observing assistant who wouldn't flinch at those conditions…

CLYDE TOMBAUGH

Clyde William Tombaugh was born on a farm near Streator, Illinois on February 4, 1906. He would be the first of six children. His growing family moved to a farm near Burdett, Kansas, where they suffered a major economic calamity when a severe hailstorm destroyed an entire year's crops. But being poor and the oldest son on a hardscrabble farm did not diminish young Clyde's interest in astronomy. His father had bought him a simple telescope before the hailstorm, good enough to pique his interest but not allowing him to see the Moon and planets as well as he wanted to. So he began building his own telescopes from scratch and drawing what he saw. Jupiter's atmosphere was showing more turbulence than usual at that time, and Clyde was so proud of his drawings of Jupiter (and Mars, too) that he sent them to Lowell Observatory, because so many observations of Mars had been made there but a few years before.

The Lowell astronomers were looking for a dedicated observer, and reasonably-decent drawings show up from a poor farmer's son, used to hard work, and smitten by astronomy. Hmmmmmm. Of course they offered him a job! He would conduct the tedious search for Planet X; his not having a college degree did not matter.

Tombaugh arrived in Flagstaff in January, 1929. His primary task would be to search for Planet X, but as the "new guy" he'd also have a lot of support work to do, especially until the new telescope he'd be using in the search arrived and was up and running. Clyde shoveled coal, maintained equipment (most farm boys of that era were really good at "field engineering!"), and gave public tours of the facility.

The new telescope was only one of the tools critical to Tombaugh's search. It would produce large photographs of selected spots of the sky (no digital imaging here – the photographs were chemical emulsions on glass plates). The tactic would be to then take a photograph of the exact same place and compare the two. Stars would not have moved during the time between shots, but any asteroid, comet, ***or new planet*** would have. Lowell astronomer V.M. Slipher acquired a machine that would hold both negatives and have an optical system that would allow them to be compared – the operator would see first one, then the other at their control. Seeing motion attracts the eye, making the identification of a moving object relatively easy. The problem was that there was a LOT of sky to cover, and Planet X was likely to be quite faint. Slipher also had to devise a way to use suction to gently warp the large image negative plates the new telescope produced so the device could keep the entire negative in sharp focus.

Slipher's device was called, fittingly, a "blink comparator," invented in 1904 by Carl Pulfrich at Zeiss AG. It was extraordinary useful for looking for movement in two pictures of the same scene, AND it was also extraordinarily useful for detecting changes not in position, but rather in brightness, making it a boon in finding variable stars. A device similar to the Lowell Observatory's was used by Harvard astronomer Henrietta Leavitt to find Cepheid variables in the Andromeda Galaxy (see here).

Tombaugh was diligent, and success was not long in coming. He began his search on April 6, 1929, and less than one year later, on February 18, 1930, he found THE blink. Continued observations showed it had a planetary-type orbit, out past Neptune!

OK, now you've discovered a new planet. What next?

Well, the Disney people were impressed, and named the newly-created Micky's dog for the new planet later that year. Walt swore to the end the connection was not true, but it was; a retired illustrator confirmed what everyone knew anyway, Walt or no Walt. Every planet should have a Disney creation for engaging students!

As for Clyde, he went back to school (while maintaining his Lowell affiliation). He earned a B.S. and M.S. in Astronomy from the University of Kansas in 1936 and 1938, respectively. He served his country in WWII by teaching navigation to Navy personnel at Northern Arizona University. In the meantime, he was discovering hundreds of asteroids with the blink comparator. He then worked at the White Sands Missile Range in the early 1950s and then moved over to the New Mexico State University in Las Cruces until his retirement in 1973. *He died on **January 17, 1997**, twenty-five years ago this year.*

Honors came down upon Clyde like rain, starting with the Royal Astronomical Society's Jackson-Gwilt Medal in 1931. He was inducted into the International Space Hall of Fame in 1980, had an

asteroid named after him (1604 Tombaugh), and the area of Pluto that looks like a heart was named "Tombaugh Regio" in his honor. Some of his ashes were aboard the *New Horizons* spacecraft, so, in a way, Clyde not only saw it first, he got there before any of us did!

As a boy, I wrote him a fan letter just before he retired, and he was kind enough to send me a personal response. This is yet another reminder to all of us in the Space exploration public engagement biz that even a little gesture like a letter, or an autograph like Al Bean's, can make a big difference in a young person's education and career path!

PLUTO TODAY

New Horizons data and other observations and modeling are showing today's astronomers that Pluto and its Kuiper Belt colleagues are an important part of understanding the origin and evolution of our Solar System. One of the things we have learned from the study of the outer Solar System is that planetary orbits are not static, but evolve over time. Similarly, astronomical nomenclature evolves, too, as is natural, expected, and proper in response to new observations and data becoming available. Whether there are eight or many of these things called planets is far less important that what we can learn from them!

And learn from them we did. Pluto, Charon, Pluto's other moons, and the Kuiper Belt bodies discovered to date are reshaping our view of Solar System formation and evolution. The New Horizons mission was the topic of an Item last year (here); the results from the New Horizons mission will be the subject of a future Item.

CODAS

The Lowell Observatory generously loaned the actual blink comparator that Tombaugh used to discover Pluto to the Smithsonian National Air and Space Museum in 2015, in time for the fly-by of Pluto by the *New Horizons* spacecraft. What a wonderful display it made! We had a test article for *New Horizons* suspended from the ceiling in the former Exploring the Planets gallery, with the blink comparator underneath, with a video showing the blinking Tombaugh would have seen that fateful day, eighty-five years after the Pluto fly-by. BTW: NASM also had a blink comparator for brightness on display in the former Explore the Universe gallery. Many thanks to the good folks at Lowell, and to Dave DeVorkin and the NASM folks involved in the loan/display; it was the kind of exhibit that makes NASM such a special place!

Amazingly, *New Horizon*'s fly-by of Pluto, our first good look at that object, occurred **50 years to the day after** the *Mariner 4* fly-by of Mars, our first good look at that object! Mission PI Alan Stern used that fact to good effect in public presentations about the fly-by! Somewhere Robert Farquhar must be smiling at that "coincidence!"

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Lowell Observatory, in Flagstaff, Arizona, has a library of interesting and informative videos for those interested in Astronomy, and even a set of Science Challenges for Kids. Check them out at: https://lowell.edu/discover/image-video-library.

Discovery of Neptune

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Enter Percival Lowell

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Frank K. Edmondson was an assistant to Tombaugh. NASM's David DeVorkin is an expert on astronomy history; see the oral history he conducted with FKE here: https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4588-1

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Pluto Today

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