Air and Space this Week

Item of the Week

A TALE OF TWO SCHMIDTS

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For many years in the 20th Century, one of the main hotbeds of astronomical research was the Palomar Observatory, home of a number of telescopes, including the famed 200" Hale Reflector and the 48" Schmidt camera. Obviously, one of the Schmidts referred to in the title of this Item is the guy who invented the Schmidt telescope design. The other Schmidt, recently passed, used the 200" to make an amazing discovery. This is their story.

INTRODUCTION

Let's start with a few words about telescope design. The basic idea is to gather light from a large area, focus it to a single point, and examine that point to enlarge the view. The telescope was invented over 400 years ago, but it was a rather simple thing; one lens gathered light from a distant object, and focused it to a point, where another lens enlarged the view. Two main problems were encountered right away: chromatic aberration and coma. The former is caused by the nature of refraction of light through a lens, just ask Roger Waters. Red light is refracted less than blue, so multicolored (white) light cannot be focused at a single point. The aberration is worse when the focal length of the lens is short, so in the mid-1600s astronomers had to use extremely long (and hard to manage) telescopes, some as long as a football field! Coma is caused when the focus of the image is not the same across the image; if it's in focus at the center of the image, it's out of focus near the edges, and vice-versa. Star images affected by coma look like little comets, hence the similarity of the word.

Mirrors reflect all visible wavelengths equally. One of Isaac Newton's many accomplishments was the development of a mirror-based telescope design still in use today. To work properly, the mirror has to be ground to a shallow parabolic shape; readily do-able but more complicated than making a mirror whose shape is a shallow spherical section. A small, plane mirror re-directs the converging image out of the tube (so one's head is not in the way).

Soon after Newton's design was made public, a French priest by the name of Laurent Cassegrain proposed that the flat mirror used by Newton be replaced by a mirror that reflects the converging image back down the telescope tube through a hole cut in the main mirror. This had the advantage of making the resulting telescope much shorter, and much easier to build and manage. The down side was that the secondary mirror couldn't be flat, rather, it had to be ground to a precise hyperboloid, another surface more difficult to create.

If only there was a way to make a Cassegrain-type design work where both primary and secondary had easier-to-make spheroidal surfaces …

BERNHARD WOLDEMAR SCHMIDT

Bernhard Schmidt was born on April 11, 1879 on the island of Nargen, Estonia, then a part of the Russian empire. Nargen is a small place, and most of its inhabitants at that time were either involved in fishing or piloting ships into the local harbor. Young Bernhard proved to be quite inventive; he build a camera out of a purchased lens and spare odds and ends and made pictures good enough for sale. He also was very interested in astronomy.

Alas, Bernhard was too interested in experimentation in things he shouldn't have. When he was 15, he lost a hand when the pipe bomb he built blew up prematurely. But that didn't stop or even slow his interest in photography and optics. He had youth jobs in retouching photographs, and even became skilled in drafting, in spite of having to use only one hand. At university, he acquired the ability to grind glass to the desired shape very proficiently, and the time he graduated, his mirrors were in demand for astronomical observatories.

Schmidt was based in Germany, and business boomed in the first decade of the 1900s. He made telescopic instruments of his own design, and with them took pictures that rivaled those of major professional observatories, all with one hand. Although he spoke German from birth, when WWI came, he was arrested as a Russian (Estonian) spy. He was interned for six months, and between the War and the economic conditions that followed, his business was kaput. He eventually ended up at the Hamburg Observatory in 1927, and participate in solar eclipse expeditions in that year and in 1929.

Inter-War astronomy was booming, with fundamental discoveries being made in both astronomy and astrophysics (*e.g.* here, here, and here). Many of the astronomical questions for which answers were sought needed a wide-field, high-resolution, view of the sky. The telescopes of the day that could deliver a wide-field view, regardless of design, were beset with coma; the image plane was curved, so across-image focus was imperfect.

Schmidt then had a brainstorm. He could build a telescope of the Cassegrainian configuration, and counter its coma and astigmatism while using easier-to-make spherical mirrors by mounting the secondary mirror on an aspheric lens of low curvature. The lens would support the secondary, eliminating its metal supports that caused slight image degradation. The only remaining issue was spherical aberration; the focal plane was curved, not flat. Schmidt created an ingenious way to grind the lens, by taking a flat piece of glass, pulling a partial vacuum on one side of the piece, causing it to deflect, then grinding the other side flat. When the vacuum was released, the plate went back to its normal shape, with a flat side (where the vacuum was) and a slightly-curved ground side. The flat plate was on the outside, which helped protect it.

This was an amazing leap of imagination, and has led to a number of other catadioptric (mirror/lens combinations) in later times. The lens he added to the system is today known as a "Schmidt corrector plate!"

The spherical aberration of the Schmidt system was countered the same way as the grinding of the lens. If the telescope was going to be used for photography only, then a film holder whose curvature was established by making a pattern blank curved by a partial vacuum on one side. The results were phenomenal, a very wide field of view with very few aberrations.

Alas, Schmidt did not profit from his invention. Economic conditions as the Depression built kept him in near-poverty the rest of his life. He built one "Schmidt camera" and upgraded two existing telescope's optics, but little professional accomplishments followed. He fell ill on a trip to Leiden in the Netherlands (an amazing hotbed of astronomy at the time), and died of a lung infection upon his return to Hamburg, on December 1, 1935.

Astronomer Walter Baade had traveled with Schmidt on the 1929 eclipse expedition. He became an advocate of the Schmidt design. Under his encouragement, an 18" camera was produced in 1936, and it worked very well. Most famously, a 48" Schmidt camera was built for the Palomar Observatory. Along with the famed 200" Hale telescope, the 48" gave Palomar a phenomenal "one-two punch!"

MAARTAN SCHMIDT

Maarten Schmidt was born on December 28, 1929, in Groningen, The Netherlands. He grew up there and attended the University of Groningen, graduating in 1949, and stayed for his master's degree the following year. He then went to Leiden University, an afore-mentioned hotbed of astronomical research (see above and also here), where he studied under Jan Oort. He received his Ph.D. in Astronomy in 1956. He was awarded a Carnegie Fellowship after that, and then in 1959, he went to work for Cal Tech. His initial work was on the relationship between interstellar gases and star forming in them, resulting in what is now known as "Schmidt's Law." After that, he began using the 200" Hale telescope at Palomar to look at spectra of unusual sources of radio-wavelength emissions. He was able to obtain a good spectrum from one of the odd sources, known as 3C 272. It had been known for some time, but Schmidt's spectrum was the first one good enough for some spectral lines to be seen well. At first the lines were not at wavelengths known to produce them, but Schmidt, in a burst of Schmidtian insight Bernhard would have appreciated, realized that they were common lines uncommonly red-shifted. Such red shifts implied immense distances, yet 3C 273 was quite bright in the telescope, implying that this thing was *incredibly* luminous, as much as an entire galaxy!

Schmidt called 3C 273 a "quasi-stellar object," shortened to *quasar*. Other quasars were soon discovered.

This was an amazing discovery, both in the professional community and with the general public. He made the cover of *Time* magazine on March 11, 1966. Other professional honors followed, including membership in the National Academy of Science (1980), the Bruce Medal (1992), the inaugural Kavili Prize (2008), and many more.

Schmidt had an excellent research career, and also held important posts in academic management.

Maarten had met his wife, Cornelia, at a party hosted by Jan Oort in 1955. They remained married until Schmidt's death on September 17, 2022, at his home in Fresno. He was 92.

PALOMAR'S 48" SCHMIDT CAMERA

Construction of a Schmidt camera of large size (48" corrector plate and a 72" main mirror) was begun at Palomar Observatory in 1939. WWII delayed its completion until 1948. It initially used curved glass photographic plates, but it went several upgrades over its still-active lifetime, becoming the host telescope of the Zwicky Transient Facility now of comet-detecting fame in 2017. A major upgrade in 2000-2001 replaced the original Schmidt corrector plate with one with less chromatic aberration and converted from glass plates to a curved CCD camera, which in turn has been upgraded several times since. It is now fully automated and controlled remotely.

The first CCD camera for the 48" Schmidt was the Near-Earth Asteroid Tracking camera (NEAT). From 2003-7, its CCD camera was upgraded and became was the home instrument for the Quasar Equatorial Survey Team (QUEST). The camera was upgraded again in 2017, using a design specific to the 48", when it became the host for the ZTF.

The number of discoveries made with the 48" are legion, see here for more info.

Samuel Oschin was a wealthy LA-area entrepreneur and philanthropist who made his initial fortune in WWII manufacturing tools and airplane parts for the War effort, and even more money after the War in the manufacture of furniture, air conditioners, and real estate. He had an interest in astronomy, and contributed significantly to the Palomar Observatory. The 48" Schmidt camera there was renamed the Samuel Oschin Telescope in 1987, in recognition of his support.

THE 200" HALE TELESCOPE

The 200" Hale Telescope at Palomar Observatory had an interesting creation (and its mirror was poured in my home town!) and a storied history. I will devote a future Item of the Week to it in the near future.

3C 273

Strong radio sources were detected prior to 1963, but nobody could find a visible light object to correspond to their locations. Detailed observations during a lunar occultation (Things in Front of Other Things!) over one such source in Virgo helped out the astronomers. The radio noise disappeared at the same time a normal-looking star did. It was the source, a stellar object. As related, Maarten's analysis of the spectrum of that visible light object determined it was deeply red-shifted, indicating a distance of a staggering two billion light-years. Yet it was bright enough in the visible spectrum to be seen easily (magnitude +12.3), and it was producing large amounts of detectable radio energy. To be so bright so far away meant that 3C 273 must be almost unbelievably powerful!

More strangely, further detailed observation showed the energy coming from 3C 273 changed slightly over time, its light curve showing variations of several periods. Short periods. Shorter than the time it would take for light to traverse on object the size a quasar was thought to have to be to produce so much energy. Such variations showed that a quasar was not only super bright, it was unexpectedly tiny, too.

We know today that quasars are almost certainly an example of "active" galactic nuclei, where black holes with a mass more than a billion times that of our Sun are pulling in large amounts of material around them, the energy of the infall manifesting as huge amounts of energy across the EM spectrum.

The American Association of Variable Star Observers (AAVSO) has a 40-year history of 3C 273 observations. They were also involved in work with Harlan Smith analyzing photographic plates held at Harvard College Observatory to extend the 3C 273 light curve 80 years prior to its identification as a quasar. AAVSO has an interesting site about 3C 273 here: https://www.aavso.org/vsots_3c273

QUASARS AND TECHNOLOGY

OK, the actual connection between Bernhard and Maarten was only the fact that the Palomar Observatory had the 48" camera designed by Bernhard and the 200" Hale Telescope Maarten used to discover the nature of quasars. But the point is, I think, well taken that when both are together, they are an example of the interrelationship between astronomical inquiry and the technology that enables us to gain enough knowledge to pose questions for the next-generation technology to help us understand (sorry for the Pythonesque turn there).

The 48" is itself a case in point. It imaging system in the early days was very primitive by today's standards, while its wide-angle capability remained essentially remained the same over time. As more advanced CCD imagers were installed in the 48", old questions were resolved and enough new information was acquired to allow the formation of new hypotheses and other questions.

The 200" is similar in the sense that the nature of the astronomical inquiry changed over time in tandem with the prevailing imaging technology. Other telescopes, on Earth or Earth orbit, have allowed astronomers to have a deeper understanding of quasars, but the earlier configuration and instrumentation of the 200" allowed Maarten to make the breakthrough discovery.

NOTE: Somewhere in the dustbin of my memory, I vaguely recall that the discovery of 3C 273 and its unusual nature was the subject of, or at least mentioned in, a musical piece in the late 1960s. I was thinking it might have been the Byrds or CSNY, but a check of the discography says otherwise. I have searched the Internet for possible confirmation, and I can usually come up with some obscure connections, but this time I've had no luck. If any of you out there knows of this, *please* drop me a note about it.

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Maarten Schmidt

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Maarten Schmidt and has former post-Doc, Donald Lynden-Bell, were awarded the inaugural Kavili Prize for their work on quasars (an impressive professional honor, which by the way, carried a $1M prize! Schmidt was asked to write a piece about their work for the Kavili folks, see: https://www.kavliprize.org/maarten-schmidt-autobiography

AAVSO: https://www.aavso.org/vsots_3c273

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The 48" Schmidt Camera

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