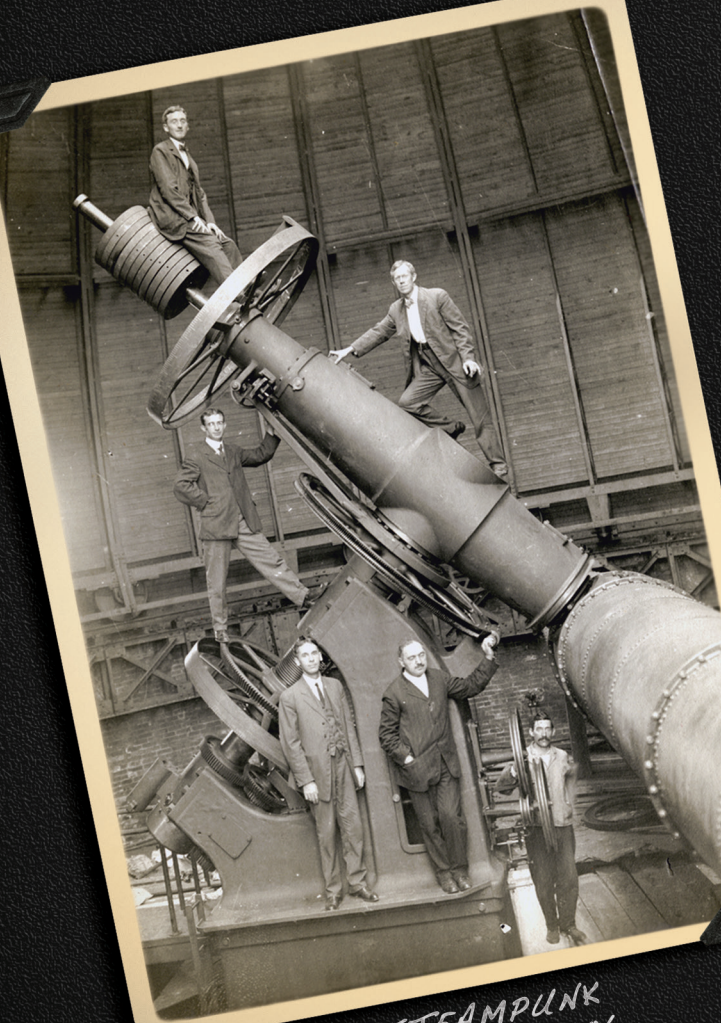




GRIFFITH OBSERVER

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STEAMPUNK
ASTRONOMY

From Ukiah to Yale: Frank Schlesinger and the Measurement of Stellar Positions

Dr. Joseph S. Tenn
Sonoma, California

SECOND PRIZE
JOAN AND ARNOLD SEIDEL
GRIFFITH OBSERVER SCIENCE WRITING CONTEST

Ukiah, once declared “the best small town in California,” is in Mendocino County, about 115 miles north of San Francisco. It’s part of California wine country and in territory that was still inhabited by the Pomo Indians when the Spanish arrived in the sixteenth century. California Indians fabricated exquisite baskets, and the Pomo baskets, artfully ornamented with vivid feathers, shell beads, and abalone pendants, are the most striking. Some of these Pomo baskets represent the structure of the cosmos in Pomo tradition. The Pomo, like everyone, monitored the seasonal behavior of the stars and recognized conspicuous asterisms, like the Pleiades and the Big Dipper. Despite Ukiah’s archaic affiliation with stars, few Californians also know that at one time Ukiah was the home of a telescope intended to pinpoint precisely the positions of stars.

This month, Dr. Joseph S. Tenn tells the story of an astronomer who began his career in Ukiah and subsequently spearheaded the acquisition of basic astronomical data on which the modern scientific understanding of the structure of the cosmos relies.

Dr. Tenn is a professional astronomer, a serious and disciplined historian of astronomy, and professor emeritus at Sonoma State University, which is about 69 miles south of Ukiah. He taught physics and astronomy at Sonoma State University from 1970 to 2009. In January, 2015, he also retired as secretary-treasurer of the Historical Astronomy Division of the American Astronomical Society, after eight years of service. He is an associate editor of the *Journal of Astronomical History and Heritage*, and he maintains a website dedicated to the astronomers awarded the Catherine Wolfe Bruce gold medal for a lifetime of outstanding research in astronomy, the highest award of the Astronomical Society of the Pacific: <http://phys-astro.sonoma.edu/BruceMedalists/>.

The pages of the *Griffith Observer* have been enriched before with articles by Dr. Tenn. All four of his previous contributions have won a prize in the magazine’s annual writing contest, and his tally includes

“The Rise and Fall of Astrophotography”
Honorable Mention
August, 1989

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Honorable Mention
November, 1987**

**“The Hugginses, the Drapers, and the Rise of Astrophysics”
Fourth Prize
October, 1986**

**“The Search for Solar Neutrinos”
Honorable Mention
August, 1976**

Six of Dr. Tenn’s students have also won a prize in the annual writing contest (two of them after graduating), and through them Dr. Tenn has further enhanced the content of the *Griffith Observer*.

This article on Frank Schlesinger spotlights a significant astronomer who is not a household name, like Copernicus or Hubble or Sagan or de Grasse Tyson, but whose lifetime of work buttresses the entire astronomical enterprise. Here Dr. Tenn has expanded a talk that he presented in October, 2014, in the “Tours of Earth & Sky” lecture series presented by the city of Ukiah in association with the restored Ukiah Latitude Observatory, built and operated by Frank Schlesinger.

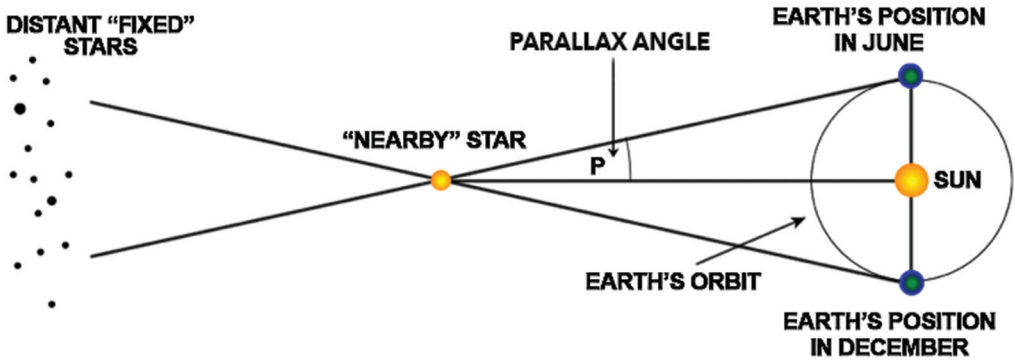
—ECK

HOW FAR AWAY is that star? The question is asked at many a public viewing night at any observatory. The question is important. Those who have seriously pondered the cosmos have often asked how the stars are arranged and what our position is. In short, where are we? In addition, neither the size nor the luminosity of a star can be determined without knowing its distance.

Measuring stellar distances is hard to do. In the sixteenth century Nicolaus Copernicus determined the relative distances of the planets from the sun. He found that Mercury, Venus, Mars, Jupiter, and Saturn are approximately 0.4, 0.7, 1.5, 5.2, and 9.2 times as far from the sun as earth, but he didn’t know the scale. Generations of astronomers finally got approximate values for the sun-earth distance (the *astronomical unit*), but the stars

are much farther away. Measuring their distances was difficult.

Those who accepted Copernicus’s claim that the earth is orbiting the sun realized that either the stars are all at the same distance, like points on a planetarium ceiling, or that the nearby stars should show a parallax as the earth changes position. The parallax (angle p) is half the angle through which a nearby star appears to move in six months. For large distances the star’s distance is inversely proportional to its parallax. If the angle is as small as one arcsecond (1/3600 of a degree), then geometry tells us that the star’s distance is 206,265 times the earth-sun distance. Astronomers call the distance at which a star’s *parallax* is one second of arc one *parsec* and measure the distances to the stars and beyond in parsecs. (Some prefer light-years. One parsec equals 3.26 light-years.)



Parallax is the angle p . It is half the angular displacement of a “nearby” star with respect to the far-more-distant background stars measured from opposite sides of the earth’s orbit. (courtesy Las Cumbres Observatory Global Telescope Network)

Sixty-six years after Copernicus’s publication, the recently-invented telescope was turned on the sky. The early telescopes were difficult to use. Measurements were difficult, but they got better. It took more than two centuries of telescope improvement before the first parallax shift was detected and measured. In the late 1830s three astronomers, in three different countries, looking at three different stars, all succeeded at about the same time. The largest parallax measured was just $\frac{3}{4}$ of an arcsecond. This implied a distance for alpha Centauri of 1.3 parsecs, or some 270,000 astronomical units. On a scale in which the

distance from the earth to the sun is one foot, the next star is 51 miles away.

Now we know that the distances between the stars are large, but we still need to measure them if we are to determine how the stars are arranged in space.

By the year 1871, only a handful of stellar distances had been measured, and the accuracy of the measurements was poor. That was the year that Prussia, having conquered much of central Europe and humiliated France, proclaimed itself the German Empire. And that was the year that Frank Schlesinger was born in New York City. Both of his parents had immi-

FRONT COVER

Steampunk Astronomy

The precision required for astrometric astronomy encouraged the development of large refractor telescopes in the nineteenth and early twentieth centuries. These heavy-metal instruments, with their monumentally long, ribbed, and bolted tubes, their tall, industrial mounts, and their high domes, created the iconic image of a telescope in popular culture. Frank Schlesinger, standing on the pier of the Thaw 30-inch refractor with a hand on a ring, and the astronomers of Allegheny Observatory take telescopic liberties during construction of this impressive refractor. This must be one of the most fetching images ever taken of a telescope, and it announces here Dr. Joe S. Tenn’s prizewinning Joan and Arnold Seidel *Griffith Observer* Science Writing Contest article, “From Ukiah to Yale,” in this issue. (courtesy Hayden Memorial Library, Citrus College, Schlesinger Collection)



Yerkes Observatory provides an elegant setting in 1898 for a portrait of its well-dressed staff. Frank Schlesinger is fourth from right. George Ellery Hale is seated on the balustrade, above Schlesinger and just to the left. (University of Chicago Photographic Archive, apf6-01291r, Special Collections Research Center, University of Chicago Library)



Frank Schlesinger moved to California and built and operated the Ukiah Latitude Observatory. Here, around 1900, Schlesinger appears in front of the complete facility. (City of Ukiah)

grated as children from Silesia, then ruled by Prussia and called *Schlesien* in German. The name *Schlesinger*, pronounced shley' zing er, and rhyming with zinger, means a native of Schlesien. Schlesinger accepted that Americans usually pronounce it Shless' in jer and rhyme it with messenger. He was the youngest of seven, and his father died, leaving little money, when the boy was nine.

Frank was a bright boy, and his family managed to get him through high school and into the City College of New York, the famous free college that had been founded in 1847 as the Free Academy of New York. When he graduated in 1890, there was no money for graduate school, which he wanted to attend, and so he took a job as a surveyor and also taught mathematics at a night school.

After four years of surveying, much of it laying out streets for the growing city of New York, Schlesinger was admitted as a part-time graduate student in astronomy



Prior to the appointment in Ukiah, Schlesinger went to school in New York and also helped survey the city's streets. This vintage picture of the view up Broadway from Dey Street, taken not long after Schlesinger left for California, includes St. Paul's Chapel, the smaller building with red columns. The church is still there. (New York City, 1900, Detroit Publishing Co., no. 53573, courtesy Library of Congress)



Horses kept the wheels of commerce turning in Ukiah at the turn of the twentieth century, when the Ukiah Latitude Observatory began operation. (courtesy Robert J. Lee Photographic Collection of the Mendocino County Historical Society, original photograph donated by Dr. P. Poulos)

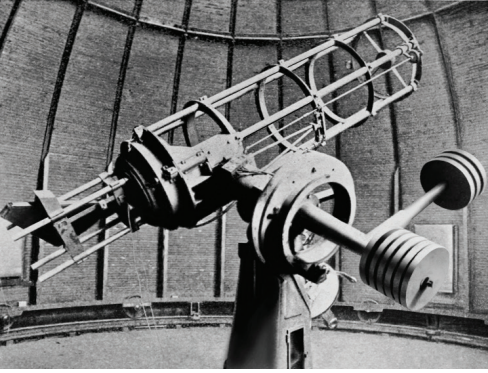
at Columbia University. He kept his day job but gave up the night-school teaching. Two years later he was awarded a fellowship which allowed him to become a full-time student, and in 1898 he received a Ph.D., one of the first 33 in astronomy awarded in the United States. For his thesis research he carefully measured photographic plates given to the university a few years earlier by Lewis Rutherford, one of the wealthy amateurs who were pioneering the “new astronomy” of spectroscopy and photography while professional astronomers continued to devote their resources to measuring positions and motions in the sky and computing orbits. This was not surprising, for most professionals were employed by national observatories that produced atlases for celestial navigation. Even astronomers in universities were suspicious of the new technologies often called *astro-physics*.

The summer of 1898 saw the young astronomer working as a volunteer at the recently built Yerkes Observatory, the home of the world’s largest refractor, with a lens

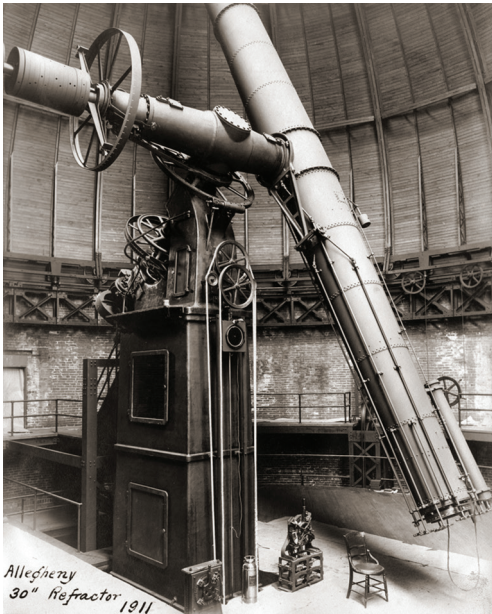
of 40 inches (1 m). It had been built by George Ellery Hale, who was only three years older than Schlesinger but far ahead of him in his career. Hale, raised in wealth in Chicago, was always in a hurry, and he was an expert at talking wealthy individuals into funding his projects. The Yerkes refractor was the first of four world’s largest telescopes he would start. Schlesinger conducted some notable experiments in which photography was used to measure stellar positions and thus parallaxes.

Hale was impressed by Schlesinger’s creativity and skill, but there were no funds to hire the young man. He went back to Columbia for the fall. And then he got a job offer—in Ukiah, California.

During Schlesinger’s adolescence astronomers had become disturbed by the discovery that the earth’s axis moves around a bit. This is not either of the big, well-understood motions of precession and nutation but a tiny, erratic shift due mostly to changes inside the earth. The position of the celestial pole, directly above the earth’s



The Keeler Memorial Reflector, a 30-inch cassegrain, at Pittsburgh's Allegheny Observatory is named for the observatory's second director, James Edward Keeler. The telescope, shown here as it appeared in 1912, became operational in 1906, before construction on the observatory was finished. (*Popular Science Monthly*, volume 81, (1912) page 409)

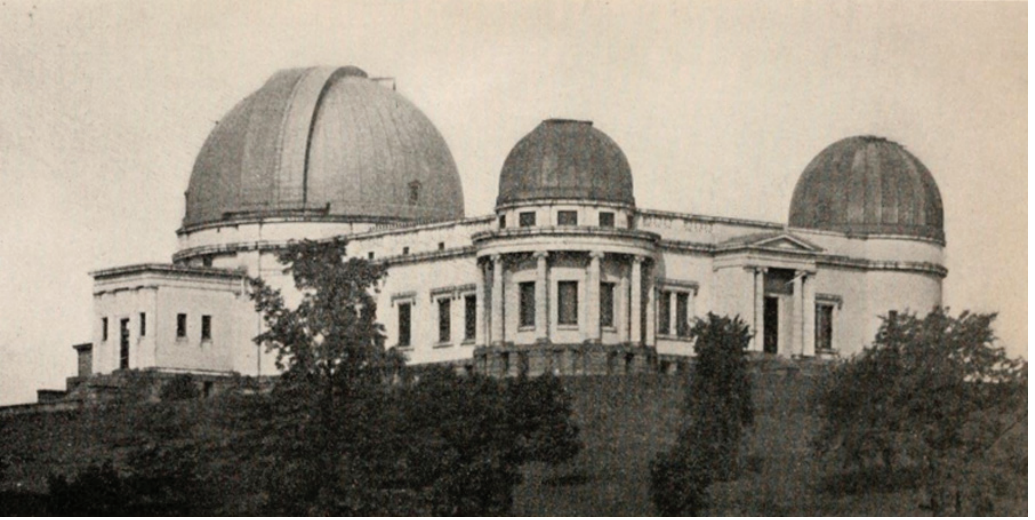


The Thaw Memorial Refractor was completed in 1912. This photograph was taken in 1911, before the 30-inch lens was installed. An instrument intended for visual use, the 30-inch telescope was redirected to photographic astrometry. (courtesy Hayden Memorial Library, Citrus College, Schlesinger Collection)

axis, can shift by a tenth of an arcsecond or so. That, in turn, shifts the latitude of every point on the planet. Astronomers measuring positions needed to know their latitudes precisely, and so this shift had to be measured. A Berlin conference in 1885 led to the decision to establish the International Latitude Service. Several telescopes at the same latitude around the world would measure precise positions of the same stars on a regular basis. Initially there were to have been four International Latitude Observatories—in Mizusawa, Japan; Carloforte, Italy; Gaithersburg, Maryland; and Ukiah, California, all very close to $39^{\circ}8'$ north. Almost immediately the Russian Empire offered to provide a fifth, at Chardzhou (now Turkmenabat) in central Asia (The original site is now in Türkmenistan, near the border of Uzbekistan.), and the astronomers at the Cincinnati Observatory pointed out that they happened to be at the same latitude and offered to join the network. Thus there were originally six, but this number varied over the years. The central Asian site moved more than once, and Cincinnati dropped out after 16 years.

Schlesinger, age 28, arrived in Ukiah early in 1899. His first job was supervision of the construction of the observatory and set-up of the 0.1-m (4-inch) telescope, which had been made for the purpose in Berlin along with identical instruments for Mizusawa, Chardzhou, and Carloforte. Once he got the telescope operational, he measured the positions of the same few stars night after night, under the overall direction of Hisashi Kimura, head of the project and director of the latitude observatory in Japan from 1899 to 1941.

Schlesinger had lived his entire life in New York City, which had 3.4 million people in the 1900 census. Now he was in



Three domes and Classical Revival architecture made an instant landmark out of the new Allegheny Observatory in 1912. (*Popular Science Monthly*, volume 81, (1912) page 410)

Ukiah, population 1,850, and he was the only professional astronomer in the vicinity. Once he had his observatory up and running, the routine measurements did not take much time. What was there to do?

In 1900, Schlesinger married 23-year-old Ukiah resident Eva Hirsch, and in 1901 his only child, future planetarium director F. Wagner Schlesinger, was born. Frank made frequent trips to Berkeley, 185 km (115 miles) away, where Armin O. Leuschner had started a graduate program in astronomy, and to the Lick Observatory, where there were several astronomers with whom he could exchange ideas.

Schlesinger presented a paper at the first meeting of what is now called the American Astronomical Society, in 1899, suggesting improvements in the determination of parallax and describing some innovations he had made during his summer at Yerkes. He pointed out that there were fewer than 30 stars with parallaxes known to within 0.05 arcsec but that a single observer (Who do

you think he had in mind?) could increase this number by 200 in just three or four years by using his improved methods and a big refractor. And he applied for jobs elsewhere.



The Allegheny Observatory still commands the hill in Pittsburgh's Riverview Park and is part of the University of Pittsburgh, eight miles away. At this time, the Observatory was under renovation. (photograph E.C. Krupp, 24 May 2010)



Astronomers convened in August, 1912, at the new Allegheny Observatory for the 14th Meeting of the American Astronomical Society. Frank Schlesinger is circled. John Brashear, with a beard, is to the right and slightly forward. Brashear was a patron of the observatory and built many telescopes, for which he is well known today. Dr. Edward C. Pickering stands to the right of Brashear. Pickering was the Director of Harvard College Observatory and at the time of this photograph President of the American Astronomical Society. Annie Jump Cannon, the celebrated classifier of stellar spectra is the second woman to the right of Pickering. (American Institute of Physics Emilio Segre Visual Archives)

In 1902, Hale obtained a grant from philanthropist Andrew Carnegie specifically to support Schlesinger's measurement of stellar distances with photography at Yerkes. The following spring the Schlesingers were on their way to Wisconsin.

Schlesinger and astronomer Edward E. Barnard conducted a test. They used the same telescope (the 40-inch) and measured the positions of the same stars. Barnard observed visually with a micrometer at the telescope, and Schlesinger observed photographically, with plates taken earlier by George Willis Ritchey. The result was amazing. Schlesinger's probable errors were only one-third as large as Barnard's, and he

required only one one-hundredth as much time. Within a few years most astronomers switched to photographic methods for obtaining stellar positions. Barnard is known today as the pioneer of wide-field photography of the Milky Way (along with Max Wolf at Heidelberg).

In a 1945 biographical memoir of Schlesinger, noted astronomer Dirk Brouwer wrote,

The results of Schlesinger's work at the Yerkes Observatory were epoch-making, the accuracy of his determinations of stellar distances far exceeding that of previous measurements by others. His procedure has since been used so univer-

*sally that it is difficult to realize that it was so completely developed by a young astronomer in such a short time.*¹

Hale, having extracted much more funding from Carnegie, left Yerkes in 1904 to found the Mount Wilson Observatory in southern California. He wanted to put Schlesinger on the Mount Wilson payroll but keep him at Yerkes, where the long-focus refractor was superior for parallax measurements, but before this could happen, the young man got a better offer.

In 1905, at age 34, Schlesinger became director of the Allegheny Observatory in Pittsburgh. It was a big step up.

Opened in 1861 by local businessmen and donated six years later to what is now



Frank Schlesinger was Vice President of the American Astronomical Society when he appeared in the February, 1914, issue of *Popular Science Monthly* (volume 84, page 199).

the University of Pittsburgh, the original Allegheny Observatory became a major research institution under Samuel Langley and James Edward Keeler. It suffered, however, from a poor site, and its instruments were soon outstripped by others. By 1905, funds had been raised and a new observatory, located away from the city lights and smoke, was under construction. It was to have two major telescopes, a reflector and a refractor, each 30 inches (.76 m) in diameter.

The Keeler Memorial reflector was ready for use shortly after Schlesinger arrived, while the Thaw refractor was at an early stage of construction. He took advantage of the reflector to turn spectroscopist for a few years. Not averse to the new astronomy, he made important observations of spectroscopic binaries, the stars most useful for determining stellar masses, and he established some of their orbits.

When the first lenses ground for the refractor had to be rejected, Schlesinger consulted astronomers worldwide, and obtaining their support, he convinced the powers at Allegheny to allow conversion of the telescope's design to that of a photographic instrument. Having the short rays to which the photographic emulsion was most sensitive focused on the plate reduced the exposure time his photographs required.

As soon as the refractor was completed, in 1914, Schlesinger turned the reflector and spectroscopic work over to his staff and returned to his first love, astrometry. He would devote the rest of his career to measuring and cataloguing positions in the sky. In the words of his collaborator Ida Barney,

He used the photographic place as it had not been used before in astronomy, and made it yield results of the greatest

Year	Type	Stars	Authors
1924, '35	Parallaxes	9404	FS+, FS & LFJ
1930, '40	Bright Star Catalogues	9096	FS, FS & LFJ
1925-43	Zone Catalogues (12): Positions & Proper Motions	92,329	FS, IMB+

Frank Schlesinger compiled several fundamental star catalogues, which provide essential information on parallax, position, brightness, and relative motion for a robust number of stars. Other astronomers depended on these catalogues for decades. Authorship by Frank Schlesinger and his collaborators, Louise F. Jenkins and Ida M. Barney, is indicated by their initials, "FS," "LFJ," and "IMB." (courtesy Dr. Joseph Tenn)

*precision by considering in his reductions all sources of error.*²

In a short time Schlesinger became a major figure in American astronomy. His 1911-1912 series of publications, which presented his precise measurements of parallaxes at Yerkes, had enormous impact, and he produced many more at Allegheny. He attended what was probably the world's greatest gathering of leading astronomers to that time, hosted by Hale at Mount Wilson in 1910 to establish the International Union for Co-operation in Solar Research and show off the new 60-inch (1.5 m) reflector, Hale's second world's-largest telescope.

Speaking on "The Responsibilities of an Observatory Staff" at the dedication of the new Allegheny Observatory while hosting the American Astronomical Society (AAS) meeting in 1912, Schlesinger said that he would have liked to place this inscription above the door,

*Abandon hope of making discoveries,
all who enter here.*³

Schlesinger was not interested in the kind of flashy discoveries that made news, such as a new comet, nova, or moon of Jupiter. He wanted to gather data that would be useful to later generations, especially precise stellar positions that would allow determination of the stars' motions across the sky (*proper motions*). Meanwhile, the big observatories on the West Coast—Lick, Mount Wilson, and, from 1918, the Dominion Astrophysical Observatory in Victoria—would use spectroscopy to measure the component of motion along the line of sight.

A portrait taken in 1914 shows the 43-year-old observatory director and AAS vice president looking rather satisfied. He had come a long way from Ukiah.

World War I brought disruption to astronomy as to everything else. The Yale University Observatory, which had seen little activity since the retirement of its last director in 1910, shut down completely. At Allegheny, Schlesinger resigned as head of the University of Pittsburgh graduate school and offered his services to the government. He served in 1918 with the Signal Corps, in charge of airplane instruments.

In 1919, he became the president of the AAS at age 48. There would be no younger one until 1960, and that year he represented American astronomers at the first meeting of the International Astronomical Union. He also began negotiations for what would be his ultimate professional position.

On April 1, 1920, Frank Schlesinger assumed the directorship of the Yale Observatory. Some wondered why he took it. Yale's equipment was far inferior to that at Allegheny, and practically nothing had been done at Yale in a decade. But Yale had money. Its endowments produced one of the largest incomes of American observatories, and it was willing to build a major new telescope.

The new Director insisted that the telescope be build not in Connecticut but in the southern hemisphere. By this time more than half a dozen observatories were measuring stellar positions in the United States and Europe, and they were all following Schlesinger's methods. The southern sky had barely been touched. Even before taking over at Yale he started seeking a southern location and commissioned site testing in three countries. Towns in New Zealand competed for his attention, but he accepted an excellent offer from the University of Witwatersrand in Johannesburg, South Africa. It included free land, housing, and office space.

The 26-inch (0.66-m) lenses were ground by the Brashear company's expert optician J.B. McDowell, his last project. The mounting was made relatively cheaply by the engineering department at Yale, and Schlesinger designed it with economy and efficiency in mind. The narrow sliding-roof observatory allowed observations only very near the meridian, where atmospheric distortion is smallest. In December, 1924, Schlesinger sailed for South Africa with the lenses as his closely-watched personal baggage. Other telescope parts followed on a later ship.

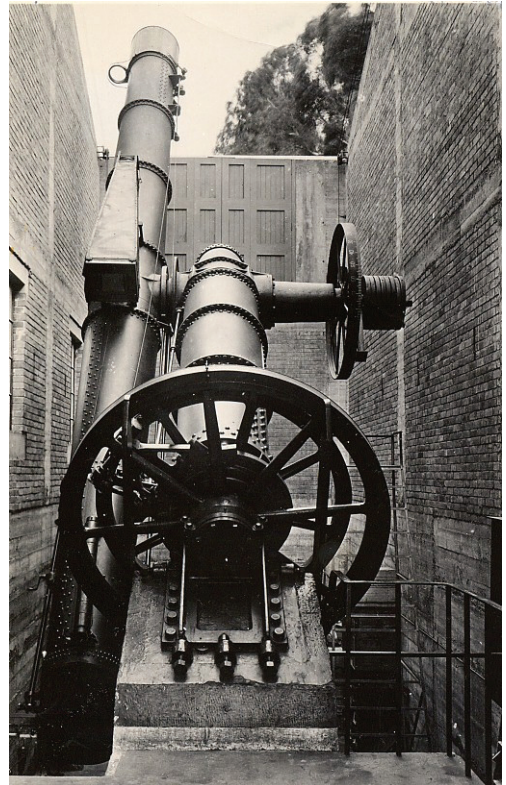
He arrived in Johannesburg in February, 1925, chose the site, supervised the construction of the observatory, and was ready for its dedication by June. The Prince of Wales happened to be visiting South Africa and was persuaded to speak at the dedication. (This was the future Edward VIII, who would reign for less than a year in 1936 before abdicating.)

Schlesinger hired experienced parallax observer Harold Alden to manage the Yale Southern Station and returned to New Haven to devote most his time to supervising measurement of the steady stream of

plates shipped from South Africa and to making catalogues.

He was eminently successful. The number of stars with measured parallaxes rose from tens to thousands during Schlesinger's directorship at the Allegheny and Yale Observatories, and a great many were due to him. As Dorrit Hoffleit wrote in 1949,

To Schlesinger probably more than to any one other individual we owe tribute for the large increase in the numbers and quality of trigonometric paral-



By June, 1925, Schlesinger's 26-inch refractor was ready for southern skies at the Yale Southern Station in Johannesburg, South Africa. (Yale Astronomy Department Archives)



Louise Freeland Jenkins worked with Frank Schlesinger at Yale and edited the third edition of the *Yale Bright Star Catalogue*. Between 1921 and 1932 she taught school in Japan. A decade after her return to the U.S., she co-edited the *Astronomical Journal*. (Yale Astronomy Department Archives, 1930s photograph)



Ida M. Barney assembled astrometric data for 150,000 stars at Yale University, where she earned a Ph.D. in astronomy. (Yale Astronomy Department Archives, 1930s photograph)

*lax determinations within the past fifty years.*⁴

Astronomers have made catalogues since the time of the Babylonians. Early catalogues show very rough positions of stars and their brightnesses. Schlesinger produced catalogues of positions, parallaxes, proper motions, and more.

An astronomical catalogue makes dull reading, since it consists of page after page of tables of numbers. Yet it is valuable to astronomers attempting to make models of everything from the size and shape of the Galaxy to the evolution of a star. Schlesinger's first parallax catalogue, published in 1924 with the assistance of Margaretta Palmer (1862-1924) and Alice Pond, was a compilation of 1870 stars,

with observations made at many observatories. Palmer, who had worked at Yale since 1889, was the first woman to earn a Ph.D. in astronomy in an American university, at Yale in 1894, and she was the only employee of the Yale Observatory who had been there since before Schlesinger arrived. Tragically, she died in an automobile accident shortly after the catalogue was finished.

Schlesinger's main coauthors were Louise F. Jenkins and Ida M. Barney. Jenkins (1888-1970), who had an M.A. in astronomy from Mt. Holyoke College, worked for Schlesinger at both the Allegheny and Yale observatories. She taught at Mount Holyoke and in missionary schools in Japan in between. Barney (1886-1982) earned a doctorate in math-

ematics at Yale in 1911 and continued the zone catalogues long after Schlesinger's death. She ultimately brought out more than a dozen on her own.

Most of Schlesinger's coworkers were highly educated women who never married and who dedicated their lives to their work in astronomy. Schlesinger, born and raised in the nineteenth century, was very much a man of his time, with attitudes that would be unacceptable today. As early as 1901, near the beginning of his career, he wrote in a letter,

I am thoroughly in favor of employing women as measurers and computers and I think their services might well be extended to other departments. Not only are women available at smaller salaries than are men, but for routine work they have important advantages. Men are more likely to grow impatient after the novelty of the work has worn off and would be harder to retain for the reason.⁵

There is no evidence that his attitude ever changed. He became, along with Harvard College Observatory Director Harlow Shapley and Princeton Observatory Director Henry Norris Russell, one of the most influential people in American astronomy. In a 1977 interview, astronomer Peter van de Kamp stated,

They were sometimes referred to as "the Generals." They ran astronomy, in a way. Their opinion was very important; when it came to appointments and that sort of thing, they were consulted.⁶

Schlesinger started a group called "The Neighbors," which consisted of astronomers in the northeastern United States. They met about four times a year for a weekend,



By 1937, Frank Schlesinger had completed a term as President of the International Astronomical Union and was known to astronomers worldwide. (Yale Astronomy Department Archives, photograph by Harris & Ewing, Washington, D.C.)

usually at Yale, to talk informally about astronomy. Today we would say they were networking. He refused to allow women to attend, even though a few, notably Cecilia Payne-Gaposchkin, were highly respected astronomers.

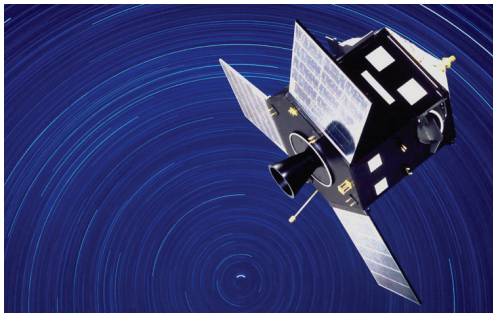
Many honors and offices came to Schlesinger. In the late 1920s, he received medals from the French Academy of Sciences, the Royal Astronomical Society of London, and the Astronomical Society of the Pacific. He served as president of the International Astronomical Union from 1932 to 1935. His formal portrait in 1937 shows him as a distinguished elder statesman of astronomy.

In poor health during his last five years, Schlesinger retired in 1941 and moved to

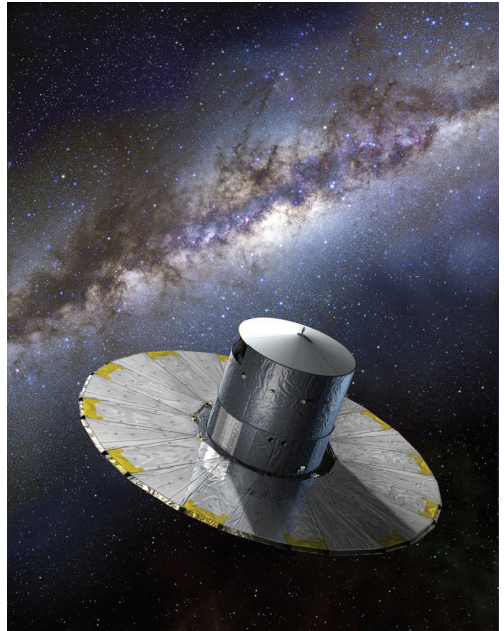
his summer home in Lyme, Connecticut. He died two years later at 72.

Schlesinger's work continued. New editions of the three types of catalogues kept coming out of Yale. Produced by Barney, Jenkins, Dorrit Hoffleit, Carlos Jaschek, William van Altena, and others, they continued to appear until 1995. Ultimately the Yale Zone catalogues contained information about more than 227,000 stars, primarily proper motions of the stars in each zone, determined by combining the Yale observations with much earlier ones in the *Astronomical Gesellschaft Catalogue*, while the 5th edition of the *Bright Star Catalogue*, published in 1995, had standard errors as small as 0.01 arcsecond.

Then astrometry got off the ground. In 1989, the European Space Agency (ESA), after many years of preparation, launched *Hipparcos*, a satellite which could measure stellar positions with unprecedented precision thanks to the absence of atmosphere to distort the light of the stars. The



Hipparcos, an astrometric satellite lifted by the European Space Agency into orbit on 8 August 1989, measured parallaxes with more precision than ever before for 118,218 stars. It continued to operate until 1993, and the *Hipparcos Catalogue* was published in 1997. The name "Hipparcos" is an acronym for "High precision parallax collecting satellite" but also acknowledges the ancient Greek astronomer Hipparchus, who is one of six famous astronomers on the Griffith Observatory Astronomers Monument. (illustration © ESA)



The *Hipparcos* mission was followed by *Gaia*, a European Space Agency satellite designed to assemble a detailed and precise three-dimensional catalogue of one billion astronomical objects. It was launched on 19 December 2013 and reached the stable L₂ Lagrange point, almost a million miles from earth, on 8 January 2014. Observations are now underway and scheduled for completion in 2018. (illustration © ESA-D. Ducros)

spacecraft, although it did not go into its planned orbit, took data for four years, and then the astronomers from 14 countries spent another four years analyzing those data. The wait was worth it. In 1997, ESA released the *Hipparcos Catalogue*, containing 118,218 stars, with their parallaxes measured to within 0.001 arcsecond. ESA later published the *Tycho Catalogue* of more than one million stars with parallaxes to slightly lesser precision. These latter stars were observed with the satellite attitude detectors, designed for spacecraft operation and only added to the program well after the design of the mission began. A second

version, *Tycho 2*, extended the catalog to more than 2.5 million stars.

Many discoveries related to the shape of the Milky Way and the motions of the stars within it have been made with *Hipparcos* data. For example, the positions and motions are so good that they can be propagated back in time to 1900. They yield more precise positions for the reference stars used by Schlesinger and others in the old latitude observatories. The old observations were then collected and reinterpreted with these data by Czech astronomers, and now much more is known about the tiny wobble of the earth's axis.

Are the astrometrists satisfied? No, there is always more to be done. A new astromet-

ric satellite, *Gaia*, was launched by ESA on December 13, 2013. By now there are 21 countries, including Canada, which is an associated member, in the collaboration. *Gaia*, which is planned to operate for five years, is at an orbit point called L₂, 1.5 million kilometers (930 thousand miles) from earth in the direction away from the sun. Its billion-pixel camera is surveying more than a billion stars and expected to determine their positions some 50 times more precisely than *Hipparcos*. This will enable the construction of an accurate three-dimensional map of our Galaxy. Frank Schlesinger would be pleased.

Acknowledgements

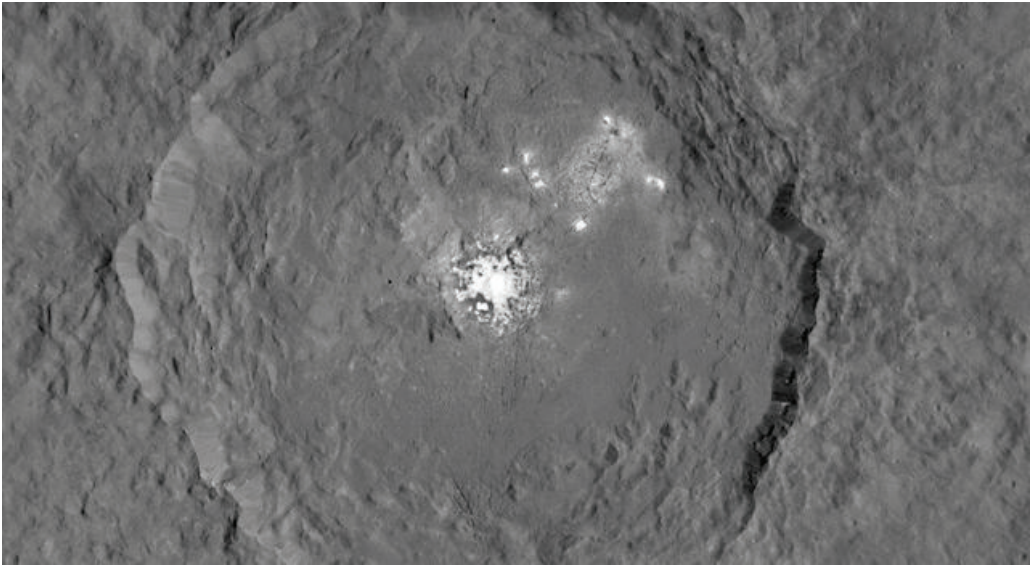
The author is grateful to those who helped obtain images: Martin Bradley (City of Ukiah), Lanette Granger (Citrus College), and William van Altena and Kim Monocchi (Yale University). Professor van Altena also read an early version of this paper and made helpful suggestions. This research has made use of NASA's Astrophysics Data System Bibliographic Services.

Notes

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Occator crater on the dwarf planet Ceres is named for one of 12 divine assistants of Ceres, the Roman goddess of cultivation, fertility, and grain. Occator means "he who harrows." Occator was responsible, then, for leveling the ploughed field and breaking up clods of soil. Whatever harrowed this crater did a pretty spotty job. The composition of the white spots is still under investigation. (composite image, Dawn spacecraft, NASA/JP:L-Calteck/UCLA/MPS/DLR/IDA)

Spotting Occator Crater

Occator Crater, in which the mysterious white spot on dwarf planet Ceres resides, has now been observed from an altitude of 915 miles by NASA's *Dawn* spacecraft. Details as small as 450 feet, about three times better than *Dawn*'s efforts in June, have been revealed. The crater is 57 miles wide and 2½ miles deep, and new pictures confirm the enigmatic white spot inside the crater is actually a complex of

spots. The brightest is near the crater's center, about where one might expect a central peak, and is about seven miles across. The spot, however, also seems to be nearly level with the crater floor. A fainter, elongated spot is northeast of the central spot, about midway to the rim, and has about the same area. Other tiny spots are scattered around it. The *Dawn* team at Jet Propulsion Laboratory has not yet announced what the white material may be.

BACK COVER

Astronomy at the Confluence of the Ohio and Allegheny

This month, in "From Ukiah to Yale," Dr. Joseph S. Tenn tells the story of astronomer Frank Schlesinger, who pioneered the use of photography in positional astronomy. Schlesinger was the Director of the Allegheny Observatory, in Pittsburgh, from 1903 to 1920. The Allegheny Observatory was founded in 1859 but was replaced by a new observatory building that was constructed during Schlesinger's tenure and completed in 1912. The Allegheny Observatory is primarily a research observatory, but it continues to offer public tours that are offered from April through October on Thursday or Friday. James Keeler, the second Director of the Allegheny Observatory (1891-1898) is acknowledged on the entablature of the wing off the main dome. (photograph E.C. Krupp)

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