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OTTO STRUVE

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A Biographical Memoir by

KEVIN KRISCIUNAS

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Photo by Carl Bigelow, *Oakland Tribune*, Oakland, California

Otto Stussi

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August 12, 1897–April 6, 1963

BY KEVIN KRISCIUNAS

"WORK WAS THE MOTTO of the whole of life.... In a letter [we find] the following passage: ...The Struves cannot live happily without unceasing work, since from the earliest youth we have been persuaded that it is the most useful and best seasoning of human life."[1] Easily counted as one of the prominent astronomers of his century, Struve left a standard that many sought to emulate but few achieved.

The Struve I have just described is *not* the Otto Struve of this memoir, but his great-grandfather Wilhelm Struve (1793–1864). Yet the words apply equally well. The first of *seven* Struves in *five* generations to obtain a Ph.D. (or its equivalent) in astronomy,[2] in 1839 Wilhelm Struve founded Pulkovo Observatory near St. Petersburg, which has played a major role in positional astronomy ever since.[3] Wilhelm was one of the first three astronomers to measure the trigonometric parallax of a star—the final proof of Copernicanism. He published 272 works[4] and had eighteen children.[5]

Of the six Struves who pursued a career in astronomy,[6] four won the prestigious Gold Medal of the Royal Astronomical Society: great-grandfather Wilhelm in 1826, grandfather Otto Wilhelm in 1850, uncle Hermann in 1903, and our Otto in 1944. Such a level of recognition in astronomy

is unique, and the Struves must be counted with the Cassinis and Herschels as one of the most significant astronomical family dynasties.

One might also note that Otto Struve's great-uncle Carl was the Russian ambassador to Japan from 1874 to 1882, then ambassador to the United States in the 1880s.[7] His uncle Alfred was a noted geologist, and his uncle Wilhelm was president of the Imperial Geographical Society of Russia.[8]

EARLY YEARS

Otto Struve was born on August 12, 1897, on his family's estate in Kharkov, in the Ukraine, where his father Ludwig was director of the Kharkov University Observatory. In the Bancroft Library at the University of California, Berkeley, there are a few pictures relating to Struve's early years. One shows a corner of the house in which he was born, looking somewhat like Leo Tolstoy's house at Yasnaya Polyana. Another picture shows Otto's five-year-old brother in a sleigh hitched to a dog, with ten-year-old Otto and his seven-year-old sister standing behind. Yet another picture shows the three children, a nursemaid, the janitor, the son of the groundskeeper, and a cow.

Otto grew up as the eldest child in an upper-class Russian family whose relatives had ably served the Tsar and Russian science. Great-grandfather Wilhelm had fled Altona (near Hamburg) to escape being drafted into Napoleon's army and settled in Dorpat (now Tartu) in Estonia. The Struve heritage was thus as a family of Baltic German origin that lived and worked in the Russian Empire.[9] Otto was the first member of his family to attend Russian-speaking, not German-speaking, schools. His "first language" was equally German and Russian.[10]

At the time of the beginning of World War I, Otto graduated from the gymnasium in Kharkov and entered the univer-

sity there to study mathematics and astronomy. In 1916 he interrupted his studies and enlisted in the Russian Imperial Army. He became an artillery officer and served on the Turkish front.[11] After the Treaty of Brest-Litovsk (March 1918), which ended Russia's involvement in the war, Struve returned to the University of Kharkov, where he obtained his degree in 1919.

Russia was in turmoil. The Tsar had abdicated in March 1917, the Provisional Government was overthrown by the Bolsheviks in October–November of that year, and the country was embroiled in a civil war. Struve enlisted in the White Russian Army of General Anton Denikin in June 1919, a move he later called "the most self-sacrificing act of my life."[12] He adds: "I have no doubt that the time will come when the Russian people will recognize that patriotism was not the exclusive privilege of those who fought on the winning side." Struve was wounded in action in July 1919.[13] It was presumably during his army years that he contracted diphtheria, scarlet fever, typhoid fever, and rheumatic fever.

Very little information concerning Struve's activity in the Russian Civil War has come down to us. Apparently, once his horse was shot under him, and on another occasion he got a bullet through his sleeve.[14] For a while he was part of a cavalry unit that "would jump up and gallop off at a moment's notice whenever there was rumour that Trotsky was in the neighborhood. But they did not capture the leader of the opposition."[15]

This is not the place to discuss the Russian Civil War, but Struve was very much part of the dynamic events of the two stages of evacuation ahead of the Bolsheviks.[16,17] In March 1920 thousands of soldiers, women, and children were trying to get out of Novorossisk on the Black Sea. Roads to the port were blocked for miles. The route was

strewn with dead bodies, stripped naked and frozen. There were dead horses, mules, camels, abandoned guns, and vehicles. At the water's edge Cossacks shot their horses. Starving refugees tore the corpses apart for food. Struve was with a detachment of about 300 men. The families of several officers were with them. When it was learned that no women or children were to be allowed to board the ship, a ring of people was made, and the women donned men's uniforms. A commander of a White Army destroyer agreed to take 150 men. Otto Struve was to count off that half of the detachment and remain behind, but just then there was shell fire. The gangplank was unguarded and all 300 scrambled aboard. Seeing that the ship was listing, a British cruiser took on the 300 people and carried them to the Crimea.

General Denikin, leader of the Whites, was replaced by the inspirational General P. N. Wrangel.[18] But the Whites were on their last legs. Wrangel had commandeered enough ships and stockpiled sufficient fuel for the eventual evacuation from Russia altogether. In mid-November of 1920 a fleet of over 100 ships, carrying nearly 150,000 men, women, and children, left the Crimea for Turkey.[19] The Russian officers, Struve included, were sent to Gallipoli, where they were cared for by relief agencies. Struve eventually obtained permission to go to Constantinople to look for work.

During Struve's year and a half in Turkey, he ate at soup kitchens and worked at whatever jobs he could find. For some time he and other fellow Russian ex-officers worked as lumberjacks, sleeping six to a tent. One night during a severe thunderstorm, a tent nearby was hit by lightning and all of its occupants were killed.

Enter fate. Edwin Frost, director of Yerkes Observatory in Williams Bay, Wisconsin, had written to Struve. We read in Frost's autobiography that it was by mere chance that

his letter reached Struve. Struve was sitting on a park bench when another Russian ex-officer walked by. The other officer had opened the letter, hoping that it contained money. Instead, it was an offer of a job in America.[20]

Struve himself told this story many times, but under careful scrutiny the long arm of coincidence is much shorter. On December 25, 1920, the director of the Berlin-Babelsberg Observatory, Paul Guthnick, had written to Frost, relating the sad case of the Struve clan.[21] Hermann Struve, Guthnick's predecessor, had died on August 12. Ludwig Struve, having fled the war-torn Ukraine, had died in Simferopol on November 4. The younger of Otto's sisters had drowned, and Otto's brother had died of tuberculosis. Otto's mother had a position at the University of Simferopol. Another sister was with the mother, but it was impossible for Otto to communicate with them.[22] As Frost had been willing to try to obtain a position for Ludwig or Otto previously,[23] could Frost try again for the young Otto? Thus asked Guthnick.

On January 27, 1921, Frost wrote back to Guthnick to say he would do his best. There began months of sometimes daily activity on Frost's part to get Otto Struve to the United States. The famous job offer letter was sent by Frost on March 2, 1921,[24] and received by Otto Struve on April 27.[25] But Otto had already known that his situation was likely to change, as he had been in contact with Guthnick and his Aunt Eva in Berlin. On March 11, 1921, Struve wrote to Frost (in German) that he had heard of the job offer from Guthnick.[26] On April 12, Struve wrote a curious letter to Frost in English words but with entirely German syntax, in which he thanked Frost again in advance for the job offer.[27]

Struve took the letter to the YMCA to make sure it said what he thought it did. There he met a man named Areson,

who came from southern Wisconsin, knew Yerkes Observatory, and also knew Frost.

It is interesting to note what Frost said to others to strengthen the case for Otto Struve to enter the United States. To the president of the University of Chicago he wrote, "[Otto] is the son of the late professor of astronomy at Kharkov, and grandson and great-grandson of the two greatest astronomers of Russia, Otto and Wilhelm Struve. . . . I am perfectly willing to take him on his lineage."[28]

We regard Otto Struve as a first-class spectroscopist and astrophysicst. But in the letter of March 11, 1921, he says this to Frost:

> I feel it is my duty to confess openly that I am only marginally familiar with the area of astronomical spectral analysis and that I practically have never worked in that area. . . . Should this prove to be no hindrance to my appointment at Chicago [for the position of assistant for stellar spectroscopy], I would gladly answer your call.

Thus, Struve's training in astrophysics was almost entirely at the University of Chicago.

It took all spring and summer to arrange for Struve's visa and passage to the United States. He arrived in New York on October 7, 1921.[29] Three days later he arrived in Williams Bay,[30] wearing not the tattered Russian officer's uniform he had had on the ship, but an outfit he had bought at a flea market in New York, consisting of orange shoes, purple trousers, and a green jacket.[15,31]

YERKES YEARS

Struve was to spend the next twenty-nine years associated with Yerkes Observatory. He obtained his Ph.D. in December 1923 from the University of Chicago, with a dissertation on short-period spectroscopic binaries, and subsequently became instructor (1924), assistant professor (1927),

and associate professor (1930), and on July 1, 1932, he succeeded Frost as director. Struve became an American citizen in 1927.[13]

Otto's mother came by ship to the United States in early 1925. As Frost tells it:

> When I realized that her steamer would be crossing the line of totality of the eclipse of January 24, 1925, I prepared quite an elaborate document appointing her commissioner on the high seas of the Yerkes Observatory of the University of Chicago. I forwarded this to the chief officials of the steamship company in Hamburg and received from the commodore of the fleet the assurance that Madame Struve would have every opportunity to observe the eclipse. At the critical moment, with due ceremony, the captain escorted her to the bridge in spite of the fact that there was a snowstorm at the time.[32]

There is no account of the elder of Otto's sisters, who had been with Madame Struve in Simferopol. Presumably, she died between 1921 and 1925.[33]

Otto Struve married Mary Martha Lanning in May 1925. According to Chandrasekhar, it was her second marriage.[34] For three years prior to this, Mary had worked as a secretary at Yerkes. (Thus, she knew about observatory business.) "When [Mary] and Otto were first married they had such romantic feelings about their lives at Yerkes. . . . They skated on Lake Geneva in the wintertime while Otto sang Russian songs, very romantic songs to her."[35] At one point Otto and Mary almost adopted a four-year-old boy, but apparently Mary then decided against it. In the 1950s Struve lamented that the biggest disappointment in his life was not to have had a child (one would presume a son) to whom to pass on the Struve legacy.[36]

It is difficult to guess how the dynamics of Otto's marriage affected his scientific endeavors. Apparently, Mary enjoyed the status of being the wife of a famous observa-

tory director, and she would go to McDonald Observatory with Otto for months at a time, where she would help him with his data reduction tasks by copying down numbers that Otto called out while his eye was glued to a microscope eyepiece as part of reducing spectra.[37]

Otto, Mary, and Madame Struve (Otto's mother) formed a triumvirate. They lived together essentially the entire thirty-eight years of Otto and Mary's marriage. Both Otto's wife and mother survived him, but only by a few years.[38]

Otto Struve's first published paper, in Russian, concerned "Aid to Russian Scientists."[39] In the aftermath of the Russian Civil War, many people in Russia were starving. Frost, Struve, and George van Biesbroeck served as the Committee for Relief to Russian Astronomers.[40] Packages of food and clothing were sent to Russian astronomers in many cities. The funds came from astronomers and their families all across the United States.

Struve's scientific publications begin in 1923. The previous autumn the American Astronomical Society had met at Yerkes Observatory. Struve presented a paper on the spectroscopic binary 13γ Ursae Minoris, and the two-page abstract was published in *Popular Astronomy.* Struve's publication list grew at an average rate of twenty-two items per year, reaching a total of at least 907 items.[41] This places him near the top of astronomical productivity,[42] as measured by the total number of published items. (Thus, it is difficult to do justice to Struve's work in an article of this length.) About half of Struve's papers were what we call technical contributions. He published thirty-nine articles (and ten other items) in *Popular Astronomy* (1923–51), 154 in *Sky and Telescope* (1942–63), and eighty-three reviews of books and other astronomers' work. His popular articles kept many astronomers, both amateur and professional, abreast of the rapidly developing field of twentieth century astronomy and astrophysics.

Struve's most important work was published in several books and in the *Astrophysical Journal,* the premier research journal of astrophysics, which Struve edited from 1932 to 1947. According to my count, there were 223 such papers.

As a junior astronomer, Struve collaborated on projects with the more senior Yerkes astronomers. There were seven papers with G. van Biesbroeck containing positional measurements of asteroids (1923–28). With Frost and Storrs Barrett, he published "Radial Velocities of 368 Helium Stars" in 1926, and with the same coauthors, "Radial Velocities of 500 Stars of Spectral Class A" in 1929.[43] Such velocity data on stars allowed the determination of the sun's motion in the local portion of the galaxy. Also, the data bank of spectra with sufficient resolution to allow radial velocity measurements was also a data bank for Struve's subsequent work on the "peculiarities" of stellar spectra.

One of Struve's early and ongoing interests was interstellar calcium, whose presence was known from the absorption lines in the spectra of many stars.

It is now well known that most stellar atmospheres have about the same composition, but that the presence or absence of certain spectral lines is due to the pressure and temperature in these atmospheres. One of Struve's most important contributions to stellar spectroscopy involved the observed widths of spectral lines. These are affected by the abundances of the elements, broadening due to the rotation of the stars, and the effect of electric fields on the atoms (the Stark effect). The resulting widths (or dispersions) add quadratically:

$$\sigma^2_{observed} = \sigma^2_{abundance} + \sigma^2_{rotation} + \sigma^2_{Stark}$$

Struve noted in a 1929 paper that it was R. d'E. Atkinson who, in 1922, first considered Stark broadening in stellar spectra. Theoretical analyses by E. O. Hurlbert, H. N. Russell,

and J. Q. Stewart, and then M. Vasnecov, led to predictions of a measurable effect, a broadening of 1 Å for the sun, but 42 Å for α Lyrae, a much hotter star. Cecilia Payne had noted the Stark effect in actual spectra in 1925,[44] but it was Struve and C. T. Elvey (one of his two principal collaborators in the 1930s) who published the first proof. They investigated the widths of spectral lines in hot B and A stars and found that neutral atoms of low atomic weight show wider lines than the heavier atoms. They found that stars with narrow lines were more luminous than stars of the same spectral subdivision with broad lines, in agreement with theory. Theory stipulated, however, that hydrogen lines should increase in width due to Stark broadening from Hβ to Hε, and the observed increase was less than expected.

With the Russian astronomer G. A. Shajn, Struve showed, in 1929, that B- and A-type stars rotate much faster than the cooler G, K, and M stars. The hot stars can have equatorial rotation speeds in excess of 200 kilometers per second. By comparison, the sun's value is 2 kilometers per second. This led Struve to conjecture that rapidly rotating stars could fission into rapidly revolving close binaries, or perhaps rapidly revolving close binaries might fuse into rapidly rotating single stars.

Because stellar spectral lines contain information on abundance, rotation, and the Stark effect, one must try to separate their relative contributions. Struve states that the rotational dispersion can be separated statistically in short-period binaries. The dispersion due to abundance is best investigated in cooler stars (for which the Stark effect is small). Pinning down the Stark component involves a strong combination of theory and high dispersion observations of stars, something Struve specialized in.

A fourth contributing factor to the stellar spectral lines is turbulence in the stellar atmospheres. In 1934 Struve

and Elvey showed that stars such as 17 Leporis had lines with broad wings, attributable to turbulent motion on the order of 67 kilometers per second. This paper was an important contribution to the curve of growth method of spectral analysis (then only five years old), whereby the normalized line strengths (i.e., equivalent widths) are correlated with the abundances of the atoms present.

One of Struve's most important accomplishments was the organization of the construction of McDonald Observatory in west Texas. This has been described in some detail by Evans and Mulholland in their book *Big and Bright: A History of the McDonald Observatory*.[45] The funds for the observatory came from the estate of a wealthy Texas banker, W. J. McDonald (1844–1926), who left the bulk of his money ($800,000) to the University of Texas for the construction of an astronomical observatory. The will was contested by the banker's relatives, partially on the grounds that the desire to endow astronomy was a clear demonstration of insanity. The problem for the University of Texas was that it had the money but no astronomers. One of the chief testimonials to the usefulness of endowing an observatory came from E. B. Frost at Yerkes, and a thirty-year partnership between the University of Chicago and the University of Texas commenced in 1932, the year Struve became director. As Struve moved up the Yerkes ladder, he thus knew that at the top was the directorship of not one, but two, observatories.

Plans for the observatory called for a reflecting telescope of aperture 80 inches. (It turned out to be an 82-inch, and at the time of its dedication in 1939 was second in size only to the 100-inch at Mount Wilson.) It is situated at the 6,800-foot summit of Mount Locke in Jeff Davis County, a site likely to remain free from light pollution forever, given the desolation of west Texas and the observatory's remoteness from the nearest large city (160 miles).

Before the eighty-two inch telescope at McDonald was ready, important results had already been obtained at this new observing station for the Yerkes astronomers. Using a 150-foot nebular spectrograph set up on a hillside, Struve and his colleagues demonstrated that there are large areas of diffuse emission in the galaxy, showing lines of hydrogen and forbidden lines of ionized oxygen and nitrogen, which are characteristic of interstellar gas excited by ultraviolet light from hot stars. Today we call the ionized regions around hot stars Strömgren spheres, but Strömgren himself admits that it was Struve's observations in the late 1930s that stimulated his own theoretical work on questions relating to the interstellar medium.[46]

From 1932 onward Struve coauthored more papers with Pol Swings (1906–83) than with anyone else. Their prime occupation was spectroscopic studies of peculiar stars.

What constitutes a peculiar star? W. W. Morgan recalls: "[Struve] made the remark once that he never looked at the spectrum of a star, any star, where he didn't find something important to work on."[47] E. A. Milne adds: "[I]t is usually easy to recognize the characteristic Struve touch, the touch of one to whom the individual stars, with their individual peculiarities, were personal friends."[48]

To Struve, stars that had variable spectral lines were the most interesting, and the more complex those variations were, the better. Some of his favorites included unstable close binaries whose spectra were complicated by streams of gas, such as 27 Canis Majoris and β Lyrae. Struve contributed greatly to the study of the unusual binary ε Aurigae, an F-type supergiant that undergoes a two-year eclipse every 27.1 years. Struve participated in two observing campaigns on this object, in 1928–30 and 1955–57. Curiously, the absorption lines of the system are almost identical during the eclipse and out of the eclipse. In 1937, G. Kuiper,

B. Strömgren, and Struve concluded that the eclipsing body is a very tenuous mass of gas which is partly transparent to optical light.[49] Their model was criticized by others. Until recently, it could only be agreed upon that the eclipsing body was either a semitransparent shell or a flat, opaque disk that covers half of the surface of the primary. Recent data obtained with the International Ultraviolet Explorer allow us to update the Kuiper–Strömgren–Struve model: the eclipsing body is a star of temperature 10,000 Kelvin, about four times the size of the sun. Infrared data obtained during the 1982–84 eclipse show that the companion star is surrounded by a ring of dust of radius 10 Astronomical Units, with a temperature of 500 Kelvin.[50] There are still various uncertainties in modeling ε Aurigae, and it is to the credit of Kuiper, Strömgren, and Struve that they got the basics of the model correct from optical wavelength data only.

As the director of the Yerkes and McDonald Observatories, Struve was both dedicated and demanding. He was invariably the first one to arrive in the morning, and he spent many evenings at the office.[51] After an evening staff meeting he might go off to the forty-inch and observe all night.[52] That he could be considered a twenty-four-hour-a-day astronomer was almost true.[53] "He had only one interest and one concern, namely, that astronomy should be developed and pushed to the maximum that was possible."[54] "On one theme alone he was completely inflexible, that a scientist should think first of science and only third or fourth of himself."[55]

Because of Struve's duties and observational interests there was insufficient time for him to be very involved with teaching, at least while he was at Yerkes. Chandrasekhar recalls that Struve's frequent trips to Texas caused him to miss up to two-thirds of his lectures. No one was assigned to teach

them in Struve's stead; students were given some plate to measure and analyze in his absence.[56] Still, when it came to Ph.D. qualifying exams, Struve had a great interest in a high level of achievement. W. H. McCrea recalls that he was astonished to see how exacting Struve's standards were. He would not "lower the hurdle" but would give the student "the fullest possible opportunity to surmount it."[57] We can characterize Struve's attitude toward his colleagues and students thus: "It was unforgivable in his eyes for anyone to fall short of full commitment."[52]

In spite of Struve's successes in building McDonald and pushing astrophysics ahead, a case could be made that his greatest accomplishment was making the Yerkes Observatory staff the brain trust it was in the 1930s and 1940s. Elvey we have already mentioned. W. W. Morgan finished his Ph.D. under Struve in 1931[58] and recalls, "His [Struve's] influence was far and away the most important in my formative years as an astronomer. He had an intense enthusiasm that he translated to me, and was the sound basis on which I was able to build."[59] In the summer of 1936 Gerard Kuiper was hired, and also Bengt Strömgren (later Yerkes director, 1950–57). In 1937 S. Chandrasekhar, the brilliant mathematical astrophysicist, was hired. Other notables who were staff members include Jesse Greenstein, W. A. Hiltner, and Gerhard Herzberg. There were many visitors, such as Swings, Jan Oort, M. G. J. Minnaert, H. C. van de Hulst, and Albrecht Unsöld.

Struve worried about appearances, rank, and position. During the Depression he was concerned about hiring foreign astronomers when many Americans were out of work. When the wife of his deputy George van Biesbroeck wrote a letter to Belgium which was excerpted in a popular astronomy magazine and noted how Yerkes was being run by "the two Europeans," Struve was particularly angry.[60] That

is how Morgan, who was born in America, replaced van Biesbroeck as deputy.

Not all these luminaries stayed at Yerkes forever. Strömgren returned to Denmark after only a year and a half, though later (1947–48) he was a visiting professor.[61] World War II threatened to take all the staff away for war work. (Elvey went and never came back.) The very existence of the observatory was threatened. Subscriptions to the *Astrophysical Journal* declined, and the number of issues sent abroad was reduced, because of censorship, to a trickle. Struve did his best to keep things together and founded the Yerkes Optical Bureau, which did wartime optical designs.[62]

One of Struve's most progressive ideas from the war years was the proposal to organize a scientific consortium, which would run McDonald Observatory and even build a new telescope, a Schmidt camera with a seventy-two-inch spherical mirror and a fifty-inch corrector. If the consortium were to be organized, its member universities could provide their respective astronomers access to first-class telescopes at a first-class site.[63] While nothing came of the idea at the time, the 1950s saw the establishment of the Association of Universities for Research in Astronomy (AURA), which runs Kitt Peak National Observatory. Otto Struve served on the original organizing committee for building KPNO.[64]

After the war, science worldwide underwent a major phase of expansion that has continued until today. The University of Chicago hired many new famous faculty and made them Distinguished Service Professors: Marshall Stone (mathematics), Enrico Fermi (physics), Harold Urey (chemistry), and Gustav Rossby (meteorology). But President Robert M. Hutchins had overlooked upgrading Struve's rank. Chandrasekhar sensed Struve's disappointment and went to Hutchins to suggest making Struve a Distinguished Service Professor. According to Chandrasekhar's later memory,

Hutchins said, "I can kick myself for not thinking of it. I'm ashamed that I never thought of it. Thank you, Chandra, for telling me." Struve became a Distinguished Service Professor within a month.[65]

The years 1947–50 were a stress-filled time for Struve and Yerkes, and this was due in part to a miscalculation by Struve. Struve's ideal was George Ellery Hale (1868–1938), the founder of Yerkes Observatory, then of Mount Wilson Observatory.[66] Hale can be seen looking over Struve's shoulder in the photograph accompanying this article. Chandrasekhar recalls, "[Struve] imitated his life, I think even consciously. . . . [H]e wanted very much to be treated the way Hale was treated in the latter part of his life. It was his great disappointment to him that he felt he was not so treated."[67]

In 1947 Struve became chairman of the astronomy department, and Kuiper became observatory director. Apparently Struve expected Kuiper to seek his approval on all major observatory matters. Kuiper, who had a mind of his own, could not function in this manner, and developed an ulcer.[68] Struve's junior colleagues were renowned in their own right and Struve "perhaps felt a little as a masterful conductor might whose choir all wanted to be soloists."[69]

In 1949 Struve wrote to his wife that he felt he was being squeezed out of Yerkes by Chandrasekhar and Kuiper.[70] Archival material shows that there were a lot of bitter feelings about the situation at Yerkes at that time, but in reality astronomy *always* came first with Struve, and Struve's estimate of a person's contributions to astronomy was the most important part of Struve's relationship with that person. For example, Struve was responsible for Chandrasekhar being nominated as the Russell lecturer of the American Astronomical Society for 1949. Struve nominated Chandrasekhar as his successor as president of the AAS (a post Struve held from 1946–49). Also, on the first occasion

that Struve participated in the selection of a Bruce Medalist, the award was made to Chandrasekhar in 1952. Chandrasekhar told me in 1987, "I am concerned with the prevalent misunderstanding that Struve and I did not continue with the warmest personal relations during the later years at Yerkes or after his departure to Berkeley and elsewhere."[71]

Kuiper recalls this period as follows:

> [Struve] was often overworked, suffered from insomnia which caused him sometimes to be in somewhat of a daze following two or three hours of sleep. . . . In time he decided on a complete change, accepting a professorship at the University of California in 1950. To his former Yerkes associates and friends, Struve appeared a different man after he had moved to Berkeley. . . . He seemed casual and even somewhat light-hearted about his new duties and involvements, although he took his scientific observing programs, now carried out at the Mt. Wilson Observatory as a guest investigator, as seriously as ever.[10]

POST-YERKES YEARS

At Berkeley, Struve was chairman of the astronomy department and director of the Leuschner Observatory. There he devoted much more time to graduate students than was ever possible at Yerkes. He worked closely with postdoctoral fellow Su-Shu Huang, Argentinian astronomer-in-exile Jorge Sahade, and assistant Velta Zebergs.

During the 1950s Struve devoted a great deal of energy to the study of β Canis Majoris (or β Cephei) stars, a field "which he was thought to have discovered, has since been brought to fruition, and progress in it has been gratifying."[72] There are only about two dozen of these stars known, perhaps due to the small fraction of time massive stars are found in one portion of the Hertzsprung–Russell Diagram. These stars are all of spectral type B0 to B3 and are giants, subgiants, or bright giants (luminosity class II to IV). They

exhibit light and spectral variations on time scales of hours and show multiple periods in their light curves. Their behavior is attributed to pulsations regulated by a combination of the mass and rotational speed.

Having served as a vice president of the International Astronomical Union from 1946 to 1952, Struve was honored with election to its presidency in 1952 at the Rome assembly. The Korean War had caused the cancellation of the IAU meeting scheduled for Leningrad in 1951. Viktor Ambartsumian, spokesman for the Soviet delegation, had expressed official displeasure regarding the cancellation of the Leningrad meeting. It fell to Struve to reassure the Russians that a meeting would take place in the Soviet Union soon. Struve's comments were made to the assembly in Russian and electrified the audience.

In 1955 the IAU met in Dublin. Struve's opening address, reprinted in the October 1955 issue of *Sky and Telescope*, was full of anecdotes and was not of the serious tone one usually associates with him. Struve reminded his listeners that the purpose of the IAU was to pursue international cooperation whenever necessary or useful, as opposed to whenever possible. He related his own perspective that astronomy research requires the participation of all civilized nations, that the most important tools of astronomy were the astronomers. (Thus, training is paramount.) He quoted de Sitter that "astronomy is the most beneficial of the sciences for serving the ideal aims of mankind." He said that the IAU should advise various national committees regarding their scientific priorities, but added, "As a believer in evolution rather than revolution, I do not advocate sudden changes."

In 1958 the IAU meeting was held in Moscow, but Struve did not attend. A couple of years previously he had received a copy of a book that dealt with astronomy at the University of Kharkov (Struve's alma mater) from 1805 to

1955. Struve noted that the book was devoid of a great amount of political propaganda. However, he found out that the Library of Congress had a previous version of the book that contained derogatory remarks about him. The copy that had been sent to Struve had had four pages removed, with others pasted in as replacements. This involved changes to the first appendix, the index, the table of contents, and even the errata slip.[73]

The undoctored version discusses Otto's father, Ludwig, then says:

> His son Otto Struve, having been instructed in his own time at Kharkov University, [and] having betrayed his native land [*izmenniv Rodine*], went abroad and settled in the USA. Over the course of a long time he was in the service of the American imperialists in the capacity of director of the Yerkes Observatory, near Chicago.[74]

In the book Struve was also taken to task for his article "Freedom of Thought in Astronomy," published in 1935.

Struve was not amused that his activities were called "traitorous," and did not want to be subjected to any further attacks in Moscow.

In 1956 Struve suffered a fall while observing. Broken bones kept him from being at the University of Pennsylvania to receive an honorary degree in June of that year. About 1958 he contracted hepatitis, and its aftermath was cirrhosis of the liver, the eventual cause of his death.[75]

While Struve's published papers still dealt with optical stellar spectroscopy, he also became convinced of the importance of developing radio astronomy, which he pushed at Berkeley. In 1959 he took a new job as the first director of the National Radio Astronomy Observatory in Green Bank, West Virginia, in part because he was on the search committee for a director, and the committee could not

find anyone to accept the position.[76] Struve lent prestige to NRAO at that time, and he served as a mentor because of the astronomical research tradition he represented. Some feel he was not the right person for the job, and it was a disappointment to all that the construction of the 140-foot telescope, well under way at the time of Struve's arrival, was slowed beyond expectations. Still, Struve's prestige lent credence to the proposal for the 300-foot transit telescope, which recently finished twenty-five years of service,[77] and Struve was supportive of Frank Drake's Project Ozma, the first search for extraterrestrial life.

After two and one-quarter years as the director of NRAO, Struve decided to resign. He wrote to I. I. Rabi, the president of Associated Universities, Inc., which managed NRAO, that he had insufficient time for his research, and that all the meetings "leave me in a state of continuous fatigue which is the cause of other health problems."[78]

Struve's final positions were as a visiting professor of astronomy at Caltech and, simultaneously, a visiting staff member at the Institute for Advanced Study at Princeton. He died on April 6, 1963, in Berkeley, California, and his remains were cremated.

We list below Struve's academic awards and honorary degrees.

1944 Gold Medal, Royal Astronomical Society
1948 Bruce Gold Medal, Astronomical Society of the Pacific
1950 Draper Medal, National Academy of Sciences
1950 Decoration: Chevalier, Order of the Crown, Belgium
1954 Rittenhouse Medal
1954 Janssen Medaille, Société Astronomique de France
1955 Medaille Jules César Janssen, French Academy of Sciences
1955 G. Bruce Blair Award, Astronomical Society of the Pacific

Honorary doctorates:

1939 Sc.D., Case School of Applied Sciences
1946 Sc.D., University of Copenhagen
1948 Sc.D., University of Liège
1951 Doctor Honoris Causa, National University of Mexico
1956 Sc.D., University of Pennsylvania
1960 Sc.D., Wesleyan University
1960 Dr.Phil., Kiel University
1960 Doctor Honoria, National University, La Plata
1961 Doctor of Laws, University of California

CONCLUDING REMARKS

According to Struve's own hand, when he was in his early fifties he was six feet tall, weighed 192 pounds, had grey hair and grey eyes. (I mention this because of some recollections that Struve was of *very* great size, which in fact was not all *that* great.) It has been said by a number of independent sources that he was walleyed because of spending too much time squinting into a microscope eyepiece measuring spectra, which ruined his binocular vision. His physical appearance and demeanor were such that people were intimidated by him, although he did not try to be intimidating.

Others speak of his European formality. In 1963 Struve sent a copy of *Astronomy of the 20th Century* to Morgan, which was inscribed, "To Bill Morgan." This was the only time Struve had ever called him by his first name. Yet with astronomers such as Bart Bok, Cecilia Payne-Gaposchkin, Sergei Gaposchkin, Bengt Strömgren, Nicholas Bobrovnikoff, and others, his letters began with greetings, "Dear Bart," Dear Cecilia," etc. Letters to his wife start simply, "Dearest" and end "Love, Otto."

Struve was a very, very serious person, but not one hundred percent so. The brief obituary of Struve by Chandrasekhar in the *Astrophysical Journal*[79] is accompanied by a picture of

Struve laughing. Chandrasekhar chose that picture on purpose. In a 1941 article on interstellar matter, Struve recalls something said by Eddington: people talk a lot about interstellar dust and gas, though they do not know much about it. This is like the man who refuses to sleep in a supposedly haunted room and says, "I do not *believe* in ghosts, but I am *afraid* of them."

What is Struve's legacy? It is not really that things have been named after him, like asteroid 2227 Struve,[80] or the eighty-two-inch telescope at McDonald, named in his honor in 1966.[81] One Festschrift was published in 1966,[82] and another in 1973.[83] In 1970 a collection of ten of his best papers was published with then-modern updates by experts in each subspecialty.[84] If we focus on Hearnshaw's book *The Analysis of Starlight*, the three most mentioned names are those of Struve, W. S. Adams, and H. C. Vogel.

In addition to the founding of observatories, the Struve family legacy involves the observation of double stars. Otto's great-grandfather and grandfather observed the positions of double stars. Otto observed them spectroscopically. Otto Struve was one of the first to study the processes of mass transfer between hot stars and their companions. "The fact is that mass transfer in interacting binaries is behind all the work now going on in such objects as novae, recurrent novae, and by generalization to more massive objects to the infall of material into white dwarfs, into black holes, etc."[85] Struve and other pioneers in this field gave us "information that was not merely gravitational but also entered the region of atomic physics."

Another whole field that this touches on therefore is the nature of the spectroscopic peculiarities of matter in rapid motion at relatively low densities travelling from one star to another. Furthermore, in cases where mass is lost to an individual star alone or in a binary expanding shells

occur which are recognizable by spectroscopic peculiarities due to the dilution of radiation. Struve and Wurm were among the first to compute the effect of dilution of the radiation field on the spectroscopic evidence. The idea of non-local thermodynamic equilibrium (non-LTE) now dominates solar envelope astrophysics, theory and observation, and became a useful tool for the recognition of stellar winds before observations from space and the ultraviolet made them directly observable. Similarly, the phenomenon he calls large scale turbulence which affects the curves of growth of disturbed stars is connected with the heating of the outermost envelope or the wind itself, so that the characteristic temperature inversion, with the chromosphere hotter than the reversing layer and the corona hotter than either seems to be a general characteristic of dilute gases in rapid motion.[86]

Struve's contributions to the growth of American astrophysics cannot easily be overestimated. He had a hand in the renaissance at Yerkes and the establishment of McDonald Observatory, Kitt Peak National Observatory, and the National Radio Astronomy Observatory. He built the Yerkes brain trust of the 1930s and 1940s and provided visiting European astronomers with scientific opportunities unattainable in Europe. Struve was one of the founders of modern consortium research. He also helped hold the International Astronomical Union together in the politically charged 1950s.

Struve was exceptionally dedicated to astronomy and worked very hard, many would say too hard, to advance it. His legacy is the influence he had on his colleagues and associates worldwide, personally and in print. His life and his dedication were exemplary, one might say even legendary.

THIS MEMOIR COULD NOT have been written without input from people who knew Otto Struve, particularly S. Chandrasekhar, W. W. Morgan, Sarah Kuiper Lansberg, and Jesse and Naomi Greenstein. An earlier draft of this

paper was read by a number of interested parties, among them A. Batten, D. Osterbrock, D. DeVorkin, J. Sweitzer, B. T. Lynds, V. Zebergs, I. Biermann, L. Sisson, and G. Herbig. The last mentioned made useful suggestions for the selected bibliography. Invaluable material was obtained from the Bancroft Library (University of California, Berkeley), the Yerkes Observatory archives, and the Gerard Kuiper archives at the University of Arizona.

NOTES

1. Otto Wilhelm Struve, *Zur Erinnerung an den Vater den Geschwistern dargebracht* (Karlsruhe, 1895):9. Unpublished 87-page translation by Alan Batten.

2. Alan H. Batten, "The Struves of Pulkovo—A Family of Astronomers," *Journal of the Royal Astronomical Society of Canada*, 71 (October 1977):345–72. See also Alan H. Batten, *Resolute and Undertaking Characters: The Lives of Wilhelm and Otto Struve* (Dordrecht: Reidel, 1988), and the series of articles about the Struves by Z. N. Sokolovskaya in the *Dictionary of Scientific Biography*.

3. Kevin Krisciunas, *Astronomical Centers of the World* (Cambridge: Cambridge University, 1988):chapter 5, and references therein.

4. Z. N. Novokshanova (Sokolovskaia), *Vasilii IAkovlevich Struve* (Moscow: Izdatel'stvo "Nauka," 1964):249–73.

5. O. W. Struve, note 1, pp. 29–30, 56.

6. Otto Struve's cousin Georg (1886–1933) was an astronomer in Germany whose son Wilfried (1914-) obtained a Ph.D. in astronomy in 1939, but after World War II became an acoustical engineer.

7. Otto Wilhelm Struve to Simon Newcomb, 13/1 January 1882, Newcomb Archives at the Library of Congress. There are eleven letters of Carl Struve to Newcomb and his wife in this archive.

8. Otto Struve, "Abridged Record of Family Traits," National Academy of Sciences, Washington, D.C. 1954?.

9. On one of Otto's immigration applications to the United States in 1921 he lists his nationality as Estonian. He may have feared that American officials would not give him a visa if they thought all Russians were Communists. Edwin B. Frost to Henry de Bach, July

26, 1921, Yerkes Observatory Archives. Also, Struve Archives at Bancroft Library, ID number 67/135, identity papers.

10. Gerard P. Kuiper to T. G. Cowling, August 7, 1963, Kuiper Archives, University of Arizona.

11. Lieutenant Struve is pictured on p. 5 of James S. Sweitzer, "A Most Exceptional Star: The Life of Otto Struve," *Griffith Observer*, 51 (September 1987):3–11.

12. Otto Struve, "Footnote to History," *Science*, 129 (1959):60.

13. Otto Struve, Autobiographical Materials, Bancroft Library, ID number 67/135.

14. T. G. Cowling, "Otto Struve 1897–1963," *Biographical Memoirs of the Fellows of the Royal Society*, 10 (1964):283–304, p. 284.

15. Sarah Kuiper Lansberg, "Stories told by or about Dr. Otto Struve," unpublished notes, 1963?.

16. F. D. M. (only author's initials given), "New Honors for Dr. Struve, the Wisconsin Astronomer Who Once Was Russia's Man without a Country," *Milwaukee Journal*, May 9, 1937. Obtained from Yerkes Observatory Archives.

17. Richard Luckett, *The White Generals: An Account of the White Movement and the Russian Civil War* (New York: Viking, 1971):349–54, 381–84.

18. By coincidence, a student and colleague of Wilhelm Struve was Wilhelm Wrangel, who became a Russian admiral. See Joseph Ashbrook, "The Crucial Years of Wilhelm Struve," *Sky and Telescope*, 25 (June 1963):326–27. Peter Wrangel was a descendent of Wilhelm Wrangel.

19. Luckett, note 17, p. 384.

20. Edwin Bryant Frost, *An Astronomer's Life* (Boston and New York: Houghton Mifflin, 1933):255–56.

21. Paul Guthnick to Edwin B. Frost, December 25, 1920, Yerkes Observatory Archives. Original in German.

22. Eva Struve to Edwin B. Frost, April 11, 1921, Yerkes Observatory Archives.

23. Edwin B. Frost, "A Family of Astronomers. Hermann Struve, 1854–1920; Ludwig Struve, 1858–1920," *Popular Astronomy*, 29 (1921):536–41, p. 539.

According to Gleb Struve (Otto's second cousin), Peter Struve (Gleb's father) may have played a role in putting Otto in touch with Frost. Peter Struve was an advisor to Generals Denikin and

Wrangel and traveled back and forth from Berlin to southern Russia during the Civil War (letter of Alan Batten to K. Krisciunas, July 27, 1988). He was also a prolific writer on economic and political matters. See two-volume biography by Richard Pipes, *Struve: Liberal on the Left (1870–1905)* and *Struve: Liberal on the Right (1905–1944)* (Harvard University Press, 1970 and 1980). Peter Struve's collected works, numbering 663 items, were published in a fifteen-volume edition in 1970 by University Microfilms.

24. Edwin B. Frost to Otto Struve, March 2, 1921, Bancroft Library, ID number 67/135. A copy exists in the Yerkes Observatory Archives.

25. Otto Struve to Edwin B. Frost, April 28, 1921, Yerkes Observatory Archives.

26. Otto Struve to Edwin B. Frost, March 11, 1921, Yerkes Observatory Archives. Original in German.

27. Otto Struve to Edwin B. Frost, April 12, 1921, Yerkes Observatory Archives.

28. Edwin B. Frost to Harry Pratt Judson, April 14, 1921, Yerkes Observatory Archives.

29. Edwin B. Frost, note 23, pp. 540–41.

30. Edwin B. Frost to Alexander Kaznakoff, October 10, 1921, Yerkes Observatory Archives.

31. Cowling, note 14, p. 285. According to Cowling, who is probably basing his version on notes from Mary Struve, Otto arrived in Wisconsin wearing a green hat, blue coat, brown trousers, and tan shoes. In any case, he must have been quite a sight!

32. Edwin B. Frost, note 20, p. 256.

33. There is some confusion as to the number of Otto's sisters. Did he have one or two? In Guthnick's letter to Frost, note 21 above, it states, "eine jüngere Schwester vor den Augen des Vaters und eines Bruders beim Baden ertrunken," meaning "a younger sister [of Otto] drowned right within view of [her] father and brother." This could mean "a sister younger than Otto" or "the younger of Otto's two sisters." Given that the drowning was known to Guthnick, it must have been known to Eva Struve in Berlin (Otto's aunt). Another sister must have existed, for in the letter of Eva Struve to Frost (note 22), dated April 11, 1921, it says, "My nephew's mother and sister are at Simferopol in Crimea." Also, in Sokolovskaya's article on Ludwig Struve in the *Dictionary of Scientific Biography*, she

refers to a six-year-old sister of Otto dying in 1919, and refers to Otto's brother Werner and another sister.

34. S. Chandrasekhar, interview by Kevin Krisciunas, October 6, 1987, American Institute of Physics, Oral History Project, p. 20.

35. Naomi Greenstein, "Reminiscences of Otto and Mary Struve," cassette tape monologue of January 21, 1988, as suggested by a list of questions prepared by Kevin Krisciunas. American Institute of Physics, Oral History Project.

36. Letter of Donald E. Osterbrock to Kevin Krisciunas, July 9, 1988. Osterbrock attributes this to Su-Shu Huang, who worked with Struve in Berkeley.

37. Interview of Paul and Helen Jose, Fort Davis, Texas, January 15, 1988, by Kevin Krisciunas and James Sweitzer. The Joses did graduate work in astronomy at the University of Michigan in the early 1930s. Paul Jose worked at McDonald Observatory in the late 1940s and the 1950s. They still own the Struves' incredibly long dining room table and eleven of the original twelve chairs, which Mary and Otto Struve had at House A at the observatory. More on Paul Jose is to be found in Evans and Mulholland's book (note 45).

38. Otto's mother died on October 1, 1964, at the age of ninety. Mary Struve was discovered to have died on August 5, 1966. The estimated date of death was July 19. The cause of her (natural) death could not be determined. (Death certificates obtained from the Alameda County, California, recorder.) I am told by a number of sources that after World War II Mary Struve was very much a recluse.

39. *Dernières Nouvelles* (Paris), No. 614, 1922, in Russian.

40. Materials pertaining to the Astronomers Relief Committee were obtained from the Yerkes Observatory Archives.

41. The most complete published list is by A. Unsöld in *Mitteilungen der Astronomischen Gesellschaft* (1963, pp. 5–22), which lists 444 papers and abstracts, with references to data published in Harvard Cards, and observatory reports. However, in the Bancroft Library at Berkeley there is Struve's own list compiled in early 1962, which is 876 items long. We must subtract two from that list because they are errata, and four more because they are the second halves of articles published in *Sky and Telescope.* But we must add three books, twenty-one items in Unsöld's list, one from *Popular Astronomy*, and twelve articles from *Sky and Telescope* (May 1962 to April 1963),

hence the number 907. About 8 percent of these are abstracts and observatory reports.

42. The most prolific astronomer, according to the number of published items, was Ernst Öpik (1893–1985), who published 1,094 items. Letter of John McFarland, librarian at Armagh Observatory, to K. Krisciunas, February 27, 1986.

43. Full references to Struve's published work are included in the selected bibliography at the end of this memoir.

44. Cecilia Payne-Gaposchkin, *An Autobiography and Other Recollections*, ed. Katherine Haramundanis. (Cambridge: Cambridge University Press, 1984):169.

45. David S. Evans and J. Derral Mulholland, *Big and Bright: A History of the McDonald Observatory* (Austin: University of Texas Press, 1986).

46. Bengt Strömgren, interview by Lillian Hoddeson and Gordon Baym, May 6 and 13, 1976, American Institute of Physics, Oral History Project, pp. 26, 46.

47. W. W. Morgan, interview by David DeVorkin, August 8–9, 1978, American Institute of Physics, Oral History Project, p. 13.

48. E. A. Milne, "On the Award of the Gold Medal to Professor Otto Struve, Director of the Yerkes and McDonald Observatories," *Monthly Notices of the Royal Astronomical Society*, 194 (1944):112–20, p. 117. One is reminded of the twentieth century Indian mathematician Ramanujan, for whom "every positive integer was one of his personal friends." See James R. Newman, "Srinivasa Ramanujan," in *The World of Mathematics*, ed. James R. Newman (New York: Simon and Schuster, 1956):368–376, p. 375.

49. Otto Struve and Velta Zebergs, *Astronomy of the 20th Century* (New York and London: Macmillan, 1962):305–12.

50. Margherita Hack, "Epsilon Aurigae," *Scientific American* (October 1984):89–105. See also *1982–1984 Eclipse of Epsilon Aurigae*, ed. Robert E. Stencel (Washington, D.C.: NASA, 1985), NASA Conference Publication 2384.

51. Chandrasekhar interview, 1987, note 34, p. 9.

52. G. H. Herbig, "Introduction: A Personal and Scientific Appreciation of Otto Struve," in *Spectroscopic Astrophysics: An Assessment of the Contributions of Otto Struve*, ed. G. H. Herbig. (Berkeley and Los Angeles: University of California Press, 1970):1–3, p. 2.

53. W. W. Morgan, interview by Kevin Krisciunas, October 7, 1987.

54. S. Chandrasekhar, interview by Spencer Weart, May 17–18, 1977, American Institute of Physics, Oral History Project, p. 70.

55. Jesse Greenstein, "Otto Struve," cassette tape monologue [July] 1988, American Institute of Physics, Oral History Project, p. 6.

56. Chandrasekhar interview, 1987, note 34, pp. 14–15.

57. W. H. McCrea, "Clustering of Astronomers," *Annual Review of Astronomy and Astrophysics,* 25 (1987):1–22, p. 13.

58. J. B. Hearnshaw, *The Analysis of Starlight: One Hundred and Fifty Years of Astronomical Spectroscopy* (Cambridge: Cambridge University Press, 1986):337.

59. Morgan interview, 1978, note 47, p. 13.

60. Evans and Mulholland, note 45, p. 31. See also *Ciel et Terre* (1934):97–100 and (1935):170.

61. Struve had wanted Strömgren to come for three years, but they agreed that it would be half that. It was agreed from the start to be a temporary appointment. Strömgren interview, 1976, note 46, pp. 29, 48.

62. David H. DeVorkin, "The Maintenance of a Scientific Institution: Otto Struve, the Yerkes Observatory, and Its Optical Bureau during the Second World War," *Minerva* 18 (Winter 1980):595–623.

63. Otto Struve, "Cooperation in Astronomy," *Scientific Monthly* 50 (1940):142–47; DeVorkin, note 62, pp. 603–4; Evans and Mulholland, note 45, pp. 98–100.

64. Leo Goldberg, "The Founding of Kitt Peak," *Sky and Telescope,* 65 (March 1983):228-32.

65. Chandrasekhar interview, 1987, note 34, p. 25.

66. After his success in building the 100-inch telescope at Mount Wilson, Hale gave up the directorship in 1922. W. S. Adams succeeded him in this role, but as the person in charge of operations. Hale continued on as "honorary director in charge of policy." See Helen Wright, *Explorer of the University: A Biography of George Ellery Hale* (New York: E. P. Dutton, 1966):345.

67. Chandrasekhar interview, 1977, note 54, p. 71.

68. Sarah Kuiper Lansberg, interview by Kevin Krisciunas, January 16, 1988.

69. Cowling, note 14, p. 292.

70. Otto Struve to Mary Struve, January 5, 1949, Bancroft Library.

71. Chandrasekhar interview, 1987, note 34, p. 26.

72. A. van Hoof, "The Beta Canis Majoris Stars," in Herbig, note 52, pp. 343–63, 361.

73. Ruth S. Freitag to Kevin Krisciunas, February 23, 1988.

74. A. I. Slastenov, *Astronomy at the University of Khar'kov over 150 Years* (in Russian) (Khar'kov: Khar'kovskogo gosudarstvennogo universiteta imeni A. M. Gor'kogo, 1955):64–66, p. 64. See also Vladimir Kourganoff, "Otto Struve: Scientist and Humanist," *Sky and Telescope,* 75 (April 1988):379-81; and Kevin Krisciunas, "More About Otto Struve," *Sky and Telescope* 76 (September 1988):229–30.

Let us consider the grammatical structure of the first sentence of the quote ". . . having betrayed his native land, he went abroad and settled in the USA." Given the temporal ordering of these three clauses, "having betrayed his native land" came before his emigration, and so it must refer to Struve's activity as an officer in the White Russian Army. (I thank Prof. Kourganoff for his help in clarifying the original Russian.)

75. Death certificate obtained from Alameda County, California, recorder.

76. Beverly T. Lynds, interview by Kevin Krisciunas, August 12, 1988.

77. David S. Heeschen, letter to K. Krisciunas, August 12, 1988. The 300-foot transit telescope at NRAO met its demise on November 15, 1988. See Gerrit L. Verschuur, "Reminiscences of the 300-Foot," *Sky and Telescope,* 77 (March 1989):252–53.

78. Otto Struve to I. I. Rabi, October 31, 1961, Bancroft Library.

79. S. Chandrasekhar, "Otto Struve. 1897–1963," *Astrophysical Journal,* 139 (February 15, 1964):423.

80. *Sky and Telescope,* 68 (October 1984):312.

81. Bart J. Bok, "Otto Struve Memorial Symposium," *Sky and Telescope,* 32 (August 1966):68–71.

82. M. Hack, ed., *Modern Astrophysics: A Memorial to Otto Struve* (Paris: Gauthier-Villars, and New York: Gordon and Breach, 1967).

83. A. H. Batten, ed., *Extended Atmospheres and Circumstellar Matter in Spectroscopic Binary Systems* (Dordrecht: D. Reidel, 1973). IAU Symposium 51 (Struve Memorial Symposium).

84. See G. H. Gerbig, ed., note 52.

85. J. Greenstein, note 55, p. 4.

86. J. Greenstein, note 55, pp. 4–5.

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