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ROBERT JULIUS TRUMPLER
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A Biographical Memoir by

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Robert J. Trumpler

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October 2, 1886–September 10, 1956

BY HAROLD F. WEAVER

ROBERT JULIUS TRUMPLER was born on October 2, 1886, in Zurich, Switzerland. He was the third child in a family of ten children. The Trumpler family, which traced its genealogy back to 1384, was well established and was active in business and manufacturing. A structured family life was regulated by a strict businessman father and was softened by a kind and loving mother. From a very early age the children were encouraged to be industrious, and they engaged in handicrafts that ranged from making puppets to embroidery. School was important and church was a significant activity. All these family characteristics were apparent throughout Trumpler's life.

CHILDHOOD AND EDUCATION

In a quite remarkable autobiographical sketch and self-analysis written before he finished the Gymnasium at age nineteen, Trumpler recounted some of his childhood memories and the succession of interests that occupied him up to that time. The document itself is an indicator of his character. The handwritten manuscript resembles a copper plate engraving. He was a perfectionist.

Growing up in a very large family (and having many cousins and relatives) made friends of secondary importance. Though he spoke of getting to know his fellow students at school, Trumpler had few close friends in his early years. He described himself as reserved, and often found it difficult to participate in a group conversation. He did well in school, but his classes seem not to have interested him, particularly in the earlier grades, since he had already learned to read and write at home. From summer excursions in the Swiss Alps with his father and two older brothers Trumpler gained a great love of nature, particularly the high mountains.

An important part of growing up in the Trumpler family was to decide what profession to enter after finishing school. The problem of deciding on a profession flows throughout Trumpler's account. As a quite small child he liked to do errands for the family and to learn about Zurich. He enjoyed getting to know the stores and the businesses of the city. He decided he would become a businessman. During an outbreak of smallpox in Zurich when school was dismissed, he substituted for an assistant in his father's office in order to learn more about his future profession, which seemed settled from early childhood. But as he grew older his interests began to change.

After the first years in the Gymnasium Trumpler began to formulate problems for himself—to educate himself, as he described it. He read extensively and explored art and literature, especially poetry. Eventually, he felt that he had too little imagination ever to write or to become a poet or an artist. However, photography gave him an artistic outlet that he enjoyed all his life. He developed a major and continuing interest in science and the scientific method. He could work in science by himself and the careful systematic development of data and evidence was much to his liking. Early on, he studied astronomy, but found that his knowledge of physics and mathematics was insufficient to get him deeply into the subject, and he did not have a telescope.

He became interested in biology and zoology. He described at length his intense interest in the dissection of a pigeon and his investigation of the internal organs and the detailed structure of the skeleton. Classes, he felt, interrupted these more interesting experiences.

At age seventeen Trumpler was confirmed in the church. He had gone to Sunday school regularly and had religious instruction at school. For a while after confirmation he seemed satisfied with what he had been taught, but he began to have doubts. He listened carefully to discussions, he said, and made his own observations of the world around him. He observed contradictions between what religion taught and what he observed. He believed what he himself observed; he became a skeptic. After much thought, he formulated three major questions that he would try to answer for himself:

Does God exist?
Does man have an immortal soul?
Does man have free will?

He finally equated God with the totality of physical laws that govern the universe. To the second question he could find no fully satisfactory answer. To the third question his answer was, he said, uncertain, but he was inclined to deny the existence of free will. He did, however, accept the moral teachings of Christianity as the rules to live by.

Trumpler's growing interest and joy in science made him question his early decision to go into business. He began to think about a career in science. He finally decided he was totally unsuited for business. He loved seclusion and thought, he wrote, not the constant contact with people that business required. He might become a science teacher in the Gymnasium, but again, his retiring nature would make it difficult or impossible to be a successful teacher. He tentatively decided that he would become a doctor. That would permit him to be involved in some science and would be a useful occupation. His parents argued against the plan. There were enough doctors, they said, and it would be difficult to find a practice. In the end, Trumpler gave up the idea. His paternal grandparents argued strongly that he should go into business and have science as a hobby. Trumpler respected his grandparents greatly and accepted their advice. On the last night of 1905 and in the first hour of 1906, Trumpler announced his decision to his parents. They were pleased. His father proposed that he should spend a year as an apprentice in a bank and that he then should study jurisprudence so that he could become a bank director. Trumpler noted that he hated jurisprudence, but he could console himself with some science.

Trumpler graduated from the Gymnasium first in his class and became an apprentice at a bank in Zurich. Within a year the mismatch between banking and his interests became unbearable. With parental approval he left the bank and in 1906 entered the University of Zurich to study astronomy, physics, and mathematics. He had found his life interest. He began to participate in student activities at the university. He joined the Academic Alpine Club of Zurich and with friends from the club climbed many of the highest peaks of the Swiss Alps. During a week-long trip on skis through the glacier region of the Berner Oberland, Trumpler and friends from the Alpine Club made one of the first winter attempts to climb some of the high peaks.

In 1908 Trumpler transferred to Gottingen, where he studied with some of the leading scientists of the time—Klein, Hilbert, Voigt, Schwarzschild—and completed a Ph.D. degree magna cum laude in 1910 under the direction of Professor J. Ambronn. His thesis involved experiments in the photographic recording of the meridian transits of stars. He remained at Gottingen as an assistant until he joined the Swiss Geodetic Commission in 1911.

At a meeting of the Astronomische Gesellschaft in Hamburg in 1913 Trumpler took the opportunity to meet many of the leading American astronomers. With Frank Schlesinger he discussed a plan he had developed to determine the proper motions of the Pleiades. He had become interested in that cluster when he observed it in the course of his thesis work at Gottingen. Schlesinger was interested in the plan and thought it was feasible.

War interrupted Trumpler's work at the Geodetic Commission. In 1914 he was called up for military duty as a first lieutenant in the Swiss Army. In 1915 Schlesinger invited Trumpler to become an assistant at the Allegheny Observatory. Fortunately, Trumpler received a leave of absence from the army with permission to leave Switzerland to accept the position at Allegheny. He arrived in the United States in May 1915. In the summer of 1916 he returned to Switzerland for his marriage to Augusta de la Harpe. Together with his bride, Trumpler returned to the United States, crossing the Atlantic in a military convoy.

Trumpler was invited to the Lick Observatory as a Martin Kellogg fellow in 1919 and was appointed assistant astronomer in 1920. With a position in a major American observatory, Trumpler decided that his future was in the United States. He became a naturalized citizen in 1921.

SCIENTIFIC WORK

The bulk of Trumpler's scientific work falls into two categories: (1) positional astronomy, or (2) the study of star clusters and the Milky Way. His earliest work was all in positional astronomy, his thesis field. His first paper, published in 1910, related to the determination of the latitude of Gottingen; his work with the Swiss Geodetic Survey consisted of the accurate determination of longitudes of the Swiss observatories. At the Allegheny Observatory Trumpler published the parallaxes of 23 stars and the proper motion of Nova Aquila.

He was also very actively at work on topics that fell in the second category. In 1915 he published a paper on the relative motions of the Pleiades and in 1920 a second one on the constitution of that cluster. Perhaps his most significant work at Allegheny, a forerunner of things to come, was a study of the classification of star clusters.

Trumpler's approach to the study of a phenomenon or class of objects was to gather all available data (including his own observations) and compile a very detailed catalog that he could then use to show the relationships of various features of the objects or phenomenon. His creation of the extensive catalog of star clusters, on which he spent many years, was an outgrowth of the early work at Allegheny. It provided the basis for the most important papers he published during his years at Mt. Hamilton.

At Lick, Director W. W. Campbell recognized Trumpler as an exceedingly accurate and skillful observer and chose him as his collaborator for the 1922 Lick-Crocker Eclipse Expedition to Wallal, Australia. The expedition's principal objective was to measure the deflection of light at the limb of the Sun in order to test Einstein's theory of the deflection of light in a gravitational field. Eddington had measured the deflection at the 1919 eclipse as 1.61 +/- 0.3 seconds of arc, a value determined from five stars measured on each of two plates. Campbell wanted a much stronger test of the effect.

Trumpler approached the project in his usual thorough and detailed way. The two eclipse cameras (of focal lengths 5 feet and 15 feet) were set up on Mt. Hamilton in the form they would be used at the eclipse and were thoroughly tested on the stars. Their field errors were carefully examined. A method of differential measurement of stellar images was devised and the apparatus necessary for its use was constructed. The literature on the derivation of the deflection of light at the limb of the Sun was researched and some errors in the earliest discussions were corrected. Four months before the eclipse the cameras were set up in Tahiti just as they were to be set up and used in Australia. Photographs of the eclipse field of stars were taken with telescope pointings as nearly as possible identical to those that would exist at the time of the eclipse. These formed the standards against which the stars photographed during the eclipse would be measured. The eclipse expedition was a complete success. Ten plates were obtained. Depending on the camera, approximately 70 or 140 stars were measured on each plate. The final result determined for the deflection of light at the limb of the Sun was 1.75 +/- 0.09 seconds of arc. This was taken as strong confirmation of the Einstein theory, which predicted 1.75 seconds of arc.

In 1925 Trumpler used the catalog of star clusters he was developing to write a paper entitled “Spectral Types in Open Clusters.” It presented data from the HR diagrams for 52 clusters. Trumpler found that there were two types of clusters. Type 1 contained no giant stars and had a main sequence in which the spectral types might extend from spectral type O or B down the main sequence as far as the observations went. Type 2 contained red giant stars and had no stars earlier than A or F on the main sequence. No cluster was found that contained both O or early B stars and red giants. Nowadays, the explanation of the two cluster types is immediately evident: they are the result of stellar evolution. In 1925 these observations were challenging. Trumpler surmised that the difference of the cluster types was caused by a difference in the mass distribution among the stars when the cluster was formed, but it was not possible for him to reach a satisfactory solution to the puzzle with the then current idea that small-mass stars evolved more rapidly than large-mass stars.

In 1930 Trumpler published "Preliminary Results on Distances, Dimensions, and Distribution of Open Star Clusters." It was an extraordinary paper and represented an immense amount of labor. HR diagrams determined for 100 clusters were used to infer distances that were then used to derive linear diameters for the clusters in the sample. The diameters covered a wide range from 2.3 to 21 parsecs. Next the clusters were classified according to central concentration, range of brightness of stars, and richness of the cluster, and their linear diameters were re-discussed. The expectation was that clusters of the same classification would have the same linear diameter. They did not; distant clusters of any one type seemed to have diameters larger than nearby clusters of the same type. Exhaustive analysis of the data for possible causes of this discrepancy left Trumpler with only two possibilities: clusters did increase in size with distance (a situation that is not physically reasonable) or the distances determined from the HR diagrams were wrong because of absorption of light in the Milky Way. Trumpler showed that on average the absorption is 0.67 (photographic) magnitudes per kiloparsec and that the absorption is selective, since distant stars appeared redder than nearby stars of the same spectral type. Finally, he showed that the absorbing material is concentrated primarily in a thin layer in the galactic plane.

Trumpler then went on to present his catalog of 334 clusters for which he computed distances from their diameters. These 334 objects were used to determine the space distribution of the clusters and to determine the plane of the galaxy. But, from that point on the broader conclusions about the galactic system reached from these data went badly astray. Though Trumpler had discovered interstellar absorption, he did not at the beginning clearly perceive its overpowering influence on observations of distant objects. In 1930 ideas about the size and nature of the galaxy, especially its size, were at a very early stage of development. At that time Trumpler believed that the 334 open clusters he was investigating defined the galaxy, the Milky Way system. According to his analysis, the system was at most 10,000 parsecs in diameter; the Sun was roughly near its center. Earlier investigators had proposed very different models of the galaxy. In 1918 Shapley first delineated the quasi-spherical system of globular clusters and identified the center of the globular cluster system with the center of the galaxy at a distance of 16,000 parsecs from the Sun. In 1927 Lindblad and in 1928 Oort explained the systematics of stellar motions as arising from rotation of the galaxy around a center located at a distance of 10,000 parsecs in the direction of the center of the system of globular clusters. It was a time of great confusion.

One decade later, in a paper presented at the dedication of the McDonald Observatory and published in 1940 with the title “Galactic Star Clusters,” Trumpler showed how star clusters could be used in the solution of a variety of galactic problems. In one section of the paper, he analyzed the visibility of galactic star clusters of representative types located in the plane of the galaxy at different distances from the Sun. Interstellar absorption was assumed to be present. He demonstrated that at distances of 5,000 parsecs from the Sun even the brightest and most favorable galactic clusters would have been missed in all the observational surveys that had been made up to that time, and fainter clusters would be undetectable at distances of 2,000 parsecs or less.

Trumpler then acknowledged that all 334 clusters he had studied in the 1930 paper were located within a few kiloparsecs from the Sun; they did not outline the galaxy. One may note from the drawing in Trumpler's paper that, by 1940, the accepted distance to the center of the galaxy was settling down at 10,000 parsecs and its location was in the direction to the center of the system of globular clusters.

In a 1935 paper entitled "Observational Evidence of a Relativity Red Shift in Class O Stars" Trumpler analyzed seven clusters that contained O-type stars for systematic differences in radial velocity between their O stars and stars of later types. The O stars all showed positive residual velocities. The average red shift (absolute value) was 10.1 km/s. As a confirming test of such a red shift, Trumpler determined the solar motion from O-type stars. Any red shift present should show as a K-term. The K-term found from 69 stars was +6 km/s. The measured red shifts in the clusters were used to infer the masses of the O stars. Trumpler determined distances to the clusters from their HR diagrams and used measured magnitudes of the O stars along with standard bolometric corrections and temperature scales to compute their radii. He calculated individual O star masses that ranged from 75 to 340 times the mass of the Sun. These results for the "Trumpler Stars," as these O stars were called in the literature, were and still are controversial. Stellar masses that are 100 or more times the mass of the Sun are incompatible with modern ideas of stellar formation and instability. That there is a gravitational red shift present in the O stars is certain, but the shift measured by Trumpler is excessive by a factor of at least three and possibly more. The source of the large values and the inferred masses is unknown and presents a continuing problem in need of a solution. A variety of data, not only from the clusters but from other sources as well, indicate that an additional as yet unknown effect is very likely present in the clusters or the O stars.

As early as 1924 Trumpler started to measure radial velocities for a selection of open clusters. Originally, it seems that these were simply to supply statistical information for his extensive catalog of clusters. As time went on, it became apparent that radial velocities were useful for the solution of many problems and the program became the observational focus of Trumpler's scientific career. Radial velocities can, for example, provide a means of separating cluster members from non-members as in Trumpler's 1938 investigation of the star cluster in Coma Berenices. This study is an excellent example of the huge effort required to produce the information Trumpler would have liked for each cluster: its position, distance, proper motion, and radial velocity, along with a complete list of cluster members and a full set of observable properties for each member. These data, in turn, could be used to provide a picture of the fundamental physical properties of the cluster: its motion in space, its linear size, the space and velocity distributions of the cluster members as a function of mass or luminosity, etc. Trumpler would have liked to establish all these functions for many nearby clusters.

During the period from 1940 to his retirement in 1951, Trumpler was fully occupied by teaching and working on his extensive program of radial velocities. He did continue to observe spectra with the 36-inch telescope and he gave various public lectures and participated in a few symposia, but he produced no important papers on clusters; it was a period of data gathering. Unfortunately, even though he continued to work on the radial velocity program after retirement, he did not live to complete the task he had set for himself. It was an overwhelming project for one individual, and would have been a very large task even for a group. His plan to use the information in a major study of galactic rotation was never realized. Some data from the radial velocity program in manuscript form have been supplied to individual investigators; it is hoped that all the data can be made generally available.

Trumpler undertook two projects at the Lick Observatory well afield of his major work on clusters. One, at the request of the Solar Parallax Commission of the International Astronomical Union, involved observations of Eros at the opposition of 1931 as part of the international campaign to measure the solar parallax. The other was a program of the Lick Observatory to observe Mars at the opposition of 1924.

There were two phases to the plan for Mars: (1) a color survey of the planet made photographically with filters and matched photographic emulsions at the Crossley reflector and (2) combined photographic and visual observations made with the 36-inch refractor in the relatively small wavelength range (yellow and red) in which it could be used effectively. W. H. Wright made the color survey and Trumpler carried out the photographic-visual survey. He made about 1,700 photographs of Mars directly at the focus of the 36-inch refractor during the 1924 opposition. He analyzed some 150 of these taken at moments of best seeing. They provided determinations of the diameter and polar flattening of Mars, the heights of the visible atmosphere in yellow and red light, and the position of the planet's north pole. Trumpler then went on to determine the areographic longitudes and latitudes of 228 markings on the planet. Each marking was measured on from 3 to 17 photographs. From these positions a map of Mars was drawn and analyzed. In his discussion of the map Trumpler always described the so-called canals as a network and pointed out that though they were generally drawn as uniform, they were, in fact, quite irregular. He concluded that they were natural features in the topography of Mars. The bright areas that appeared for short periods he suggested were snow or frost. When he compared his maps of the dark areas with those of earlier observers there seemed to be changes in extent in latitude of some features. He thought that, if this were the case, the most likely explanation was that the dark areas represented vegetation that varied in coverage from year to year.

When Trumpler's chart is compared with a modern map made from *Viking* photographs, there is a remarkable similarity, particularly in the delineation of dark areas. One can readily see that the network, as Trumpler called it, is made up of edges of craters, areas between adjacent craters, and small spots that happen to be approximately in line, all natural features in the landscape.

LIFE ON MT. HAMILTON AND AT BERKELEY

As he correctly described himself in his early autobiographical sketch, Trumpler was slightly reserved, but he was broadly intellectual, a person with many interests. Augusta Trumpler shared his many intellectual interests, but was much more outgoing. While at Pittsburgh at the Allegheny Observatory, they found and joined the Unitarian Church, which fitted well with the philosophical views developed by Trumpler when he was a young student. Activities of the Unitarian Church formed an important part of their lives.

The Trumplers' first daughter was born while they were in Pittsburgh. Coming to the isolation of Mt. Hamilton with a small child must have been a daunting experience. For the first year they had rooms in the dormitory and took their meals at the boarding house. Eventually, they did move into an observatory house, the first of many different ones they occupied until one was built specifically for them in 1928.

Today the isolation of Mt. Hamilton during the first quarter of the century is hard to imagine. It was a small community of 40 to 50 people—the families of the five or six astronomers plus those of the staff that maintained the instruments and houses plus the observatory secretary, graduate students, assistants, and the school teacher who taught in the one-room Mt. Hamilton school. In the 1920s cars were not the commonplace items they are today. For many residents of Mt. Hamilton, the Trumplers among them, communication with the outside world was by the stage, which six days each week made the 25-mile trip between San Jose and the observatory, bringing the mail as well as food and supplies and carrying passengers. A trip to San Jose was an event that required careful planning and at least an overnight stay.

The family of an astronomer on Mt. Hamilton had an unusual life. Each astronomer normally worked one, two, or more nights a week at the telescope and then slept during daylight hours. Children had to learn to play quiet games; dogs were not allowed on the mountain. Social events were infrequent. Occasionally there were movies in the schoolhouse. The families took turns renting the films. Saturday was Visitors' Night, a special occasion when the children could "go up top" to see all the visitors who came from San Jose and the Bay Area to look through the 36-inch telescope. There were some sports on the mountain. There was a tennis court and hiking was popular. A dam on Isabel Creek some 5 miles from the observatory provided swimming on hot summer days. In summer there were graduate students from Berkeley and sometimes visiting astronomers. All would join the residents of the mountain at the post office at noon when the stage arrived from San Jose. The astronomer who served as postmaster would deliver the mail, and the custodian would set out for each family the supplies just brought up.

Trumpler became interested in gardening and undertook the development of a garden at a natural spring on the east side of Mt. Hamilton about a mile from the road. During World War I the site had been used by some of the astronomers to grow vegetables, but it was later abandoned. The development undertaken by the Trumplers and their five children was a weekend activity that lasted for many years. After reclaiming the older space and enlarging it, they rebuilt a high fence around the garden to keep out the deer. They built a small cabin and picnic area next to the garden; the lumber for the structure was carried to the site piece by piece. There was a small swimming pool and play area (called Monkey's Paradise) for the children. With picks and shovels the family dug out and made a road that finally allowed them to drive to the garden. In this extensive work they were often helped by summer graduate students from Berkeley, who enjoyed the exercise as well as the hospitality of the Trumpler family. Though the cabin and the area are again falling into decay, the residents of the mountain still speak of Trumpler's Garden.

An arrangement between the Lick Observatory and the Berkeley Department of Astronomy made it possible for periodic exchanges of personnel to occur. An astronomer from Lick would spend a semester teaching at Berkeley; a professor from Berkeley would spend a semester doing research at Lick. The Trumplers got to know several families from Berkeley and found that they shared many interests. Trumpler exchanged with Berkeley in 1924 and 1930. The family enjoyed being in a university town and Trumpler found that he enjoyed teaching, and was successful at it in spite of his much earlier doubts.

With five children, the Trumplers were facing an important problem. The one-room school on Mt. Hamilton went through only the eighth grade. One by one the children would have to leave the mountain to continue their education. In 1935 when two children were living away from home, Trumpler arranged to continue as a Lick astronomer but with residence in Berkeley, where the family would again be united. Trumpler commuted to Lick to use the 36-inch telescope during the school year and the family returned to their house on Mt. Hamilton during the summer.

At Berkeley, Trumpler had an office in the Department of Astronomy where he carried on his research and writing. Occasionally he would give some specialized classes in galactic structure. He found that he enjoyed teaching and working with the graduate students. In 1938 he transferred permanently to the Berkeley campus as professor of astronomy, but he retained the house at Mt. Hamilton where the family spent the summers and Trumpler observed with the 36-inch telescope.

Trumpler was a very successful teacher. Periodically, he gave the introductory course for non-majors, as did all the faculty members. He expanded and modernized the upper division course in practical astronomy, a field in which he had worked throughout his career: setting up and testing instruments, measuring photographic plates, etc. He also developed a graduate course in statistical astronomy (galactic structure), which all the graduate students took. It was Trumpler's specialty and was very popular with the students. Many chose him as their thesis adviser.

In the summer of 1939 Trumpler had an accident at the 36-inch telescope that had an important unforeseen consequence. Trumpler was alone at the telescope and for the first observation of the night needed to reverse the instrument from one side of the pier to the other. This operation is performed slowly from a platform near the top of the mount by locking the telescope and turning two wheels that slowly move it to the desired location. The operation can also be performed quickly from the floor by holding the telescope at the eye end and swinging it around by hand. The instrument is very heavy and, once moving, has a great deal of momentum. At the critical moment when the instrument is just moving over the pier around the polar axis, the operator must move the telescope around its second axis or else the eye end of the telescope will move directly into the floor, potentially damaging the telescope and the equipment mounted on it. Trumpler missed the moment to swing the telescope around the second axis and it started to go into the floor. He was partially under the telescope desperately trying to get the clamp to stop the motion when the telescope struck him on the knee, driving his heel into the floor. His heel was crushed. The telescope was undamaged, but the experience was painful for Trumpler, who spent a long period of time with his leg in a full cast.

During recuperation, when Trumpler was learning to walk normally again, the doctor advised him to do a good deal of walking in sand. The Trumplers started spending time at Santa Cruz and Rio del Mar, where they would walk on the beach. On one occasion, when they were returning their house key to the rental agent, they learned that a house on the cliff overlooking the beach at Rio del Mar had just been put up for sale at a very favorable price because the owner was fearful that the Japanese were about to attack. (They had attacked Pearl Harbor a few days earlier.) The Trumplers looked at the house and bought it on the spot. It became a home that they very much enjoyed and to which they retired.

Trumpler often spoke about writing a book based on his course in statistical astronomy. In 1951, the year he retired, he and a former student who was then on the staff of the Lick Observatory completed the book. *Statistical Astronomy* was published by the University of California Press in 1953 and was reprinted by Dover in 1962. It was Trumpler's last publication.

The Trumplers retired to Rio del Mar where he continued to work on his radial velocity data and to develop the large garden he so much enjoyed. They were founding members of the Unitarian Universalist Society in which they were very active. Trumpler's health began to fail rapidly after being diagnosed with leukemia. He died unexpectedly on September 10, 1956, after a few days in the hospital.

Trumpler was a member of the International Astronomical Union and many astronomical societies. He had been a councilor of the American Astronomical Society and twice was president of the Astronomical Society of the Pacific (1932 and 1949). He was elected to the National Academy of Sciences in 1932 and was a fellow of the American Academy of Arts and Sciences. To honor him as an outstanding teacher who guided many students through their theses, the Astronomical Society of the Pacific established the Trumpler Prize for the most outstanding Ph.D. thesis of the year; it has been given annually since 1974.

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SELECTED BIBLIOGRAPHY

1915

The relative proper motions of the Pleiades. *Astron. Nachr.* 200:217-30.

1920

A study of the Pleiades cluster. *Publ. Astron. Soc. Pac.* 32:43-49.

1921

Physical members of the Pleiades group. *Lick Obs. Bull.* 10:110-19.

1922

Comparison and classification of star clusters. *Publ. Allegheny Obs.* 6:45-74.

1923

With W. W. Campbell. Observations of the deflection of light in passing through the Sun's gravitational field during the total solar eclipse of September 21, 1922. *Publ. Astron. Soc. Pac.* 35:158-63.

Historical note on the problem of light deflection in the Sun's gravitational field. *Publ. Astron. Soc. Pac.* 35:185-88.

1924

A method for differential measurement of stellar photographs. *Publ. Astron. Soc. Pac.* 36:9-14.

Preliminary results on the Einstein test from observations with the five-foot camera. *Publ. Astron. Soc. Pac.* 36:221-34.

Visual and photographic observations of Mars. *Publ. Astron. Soc. Pac.* 36:263-69.

1925

Spectral types in open clusters. *Publ. Astron. Soc. Pac.* 37:307-18.

The cluster M11. *Lick Obs. Bull.* 12:10-16.

1927

Visual and photographic observations of Mars made at the opposition of 1926. *Publ. Astron. Soc. Pac.* 39:103-11.

Observations of Mars at the opposition of 1924. *Lick Obs. Bull.* 13:19-45.

1928

Final results on the light deflection in the Sun's gravitational field from observations made at the total eclipse of September 21, 1922. *Publ. Astron. Soc. Pac.* 40:130-34.

1929

The relativity deflection of light. *Publ. Astron. Soc. Pac.* 41:23-34.

1930

Preliminary results on distances, dimensions, and distribution of open star clusters. *Lick Obs. Bull.* 14:154-88.

Absorption of light in the galactic system. *Publ. Astron. Soc. Pac.* 42:214-27.

Spectrophotometric measures of interstellar absorption. *Publ. Astron. Soc. Pac.* 42:267-74.

1932

The deflection of light in the Sun's gravitational field. *Publ. Astron. Soc. Pac.* 44:167-73. *Science* 75:538-40. *Z. Astrophys.* 4:208-20.

1935

The constitution of the star cluster in Coma Berenices. *Publ. Astron. Soc. Pac.* 47:219.

Observational evidence of a relativity red shift in class O stars. *Publ. Astron. Soc. Pac.* 47:244-56.

1937

With F. J. Neubauer, P. H. Hutchings, C. E. Smith, and K. P. Kaster. Observations of Eros made at the Lick Observatory during the opposition of 1931 with a preliminary determination of the solar parallax. *Lick Obs. Bull.* 18:93-107.

1938

The star cluster in Coma Berenices. *Lick Obs. Bull.* 18:167-95.

1940

Galactic star clusters. *Astrophys. J.* 91:186-201.

1953

With H. F. Weaver. *Statistical Astronomy*. Berkeley and Los Angeles: University of California Press.