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OF

EDWIN BRANT FROST

1866–1935

BY

OTTO STRUVE

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Edwin B. Frost

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As I write this memoir of the life of Edwin Brant Frost I am deeply conscious of the fact that the most characteristic feature of his life's work was the international scope of his scientific interests. Mr. Frost was one of the most outstanding representatives of a large group of American scientists who recognized no narrow national barriers in science. Throughout his long and distinguished career he worked for international cooperation in astronomy—his chosen field—and many of the recognized achievements of international meetings and committees owe their success, directly or indirectly, to his efforts.

The disturbing political events of the past few years and months tend only to strengthen our realization of the enormous value of Frost's efforts. Since the beginning of the world war conditions have not been conducive to the development of true international cooperation. There are now fewer men in science, who, like Frost, had an opportunity to study in Europe. Likewise, there have been fewer foreign students in America. Regulations of foreign governments concerning the exportation of currency and political restrictions have, for many years, prevented the normal exchange of fellows, traveling students, and visiting scientists. Even the exchange of books and periodicals is becoming increasingly difficult because of monetary restrictions or because of rapid fluctuations in the foreign exchange.

When Professor George E. Hale organized the *Astrophysical Journal* in 1895, he added to the name of the new periodical the subtitle: *An International Review of Spectroscopy and Astronomical Physics.* In a plan of publication formulated in Berlin it was decided "that five associate editors be chosen to represent Germany, Great Britain, France, Italy and Sweden on the editorial staff, for it was felt from the first that unless the *Journal* were made truly international in character it could not be a success." The original board of editors consisted of

Hale and Keeler. Frost, Ames, Campbell, Crew, and Wadsworth acted as assistant editors. Cornu, Dunér, Huggins, Tacchini, Vogel, Hastings, Michelson, Pickering, Rowland, and C. A. Young were the associate editors. After he was made acting editor in 1902, together with Hale, Frost continued the international policy outlined by the latter, and to this day the *Astrophysical Journal* includes in its list of collaborating editors a group of five distinguished astronomers and physicists of other countries.

When, during the war, Professor Elis Strömgren organized at Copenhagen his international bureau of astronomical information between the belligerent countries, Frost whole-heartedly supported it. When after the end of the great war German and Austrian observatories were unable to pay the subscription price for the *Astrophysical Journal,* Frost devised a plan whereby the *Journal* was sent to them free, payment being deferred until economic conditions in central Europe would improve.

Having learned of the distressing conditions in famine-stricken Russia, Frost organized in the spring of 1922 an informal committee (with the cooperation of Professor Van Biesbroeck and the writer) for the relief of Russian astronomers. This committee collected the considerable sum of $2,556.12 among American astronomers and friends of science, and disbursed the entire amount to the suffering astronomers in Russia, mostly in the form of Mr. Hoover's ARA food packages. Although some efforts had been made earlier to help the astronomers at Pulkovo, the immediate stimulus for the formation of Frost's committee came through a letter to him from the distinguished director (now deceased) of an eastern observatory in Russia. This letter begins as follows: "The severe conditions of famine which now prevail in Russia compel me as director to appeal to you for help for the staff of the observatory . . . " Touching are some of the replies acknowledging the receipt of the packages: "We Russian astronomers during many years have been separated from the whole civilized world, but now we feel our bonds renewed with the men of learning and the progress of universal science." It was indeed a satisfaction for Mr. Frost to learn that a ten-dollar food package had carried two persons through a month.

In his autobiography "An Astronomer's Life" Mr. Frost has given an excellent account of his life. He was born on July 14, 1866, at Brattleboro, Vermont, the descendant of one Edmund Frost, who was born about 1600 in England, and came to America in 1635 in order "to escape the more savage oppression of England." Edwin Brant's father—Carlton Pennington Frost—was a professor and dean of the medical school at Dartmouth College. Edwin Brant Frost spent many years of his early life at Hanover. In 1882—about a month before his sixteenth birthday—he passed the entrance examinations at Dartmouth College. In his senior year he became interested in astronomy. Professor C. A. Young had moved to Princeton in 1877, but Frost knew him and his family quite intimately and Fred, the younger son of Professor Young, had been Edwin Brant's chief playmate. In August, 1885, a nova appeared in the great spiral nebula of Andromeda. It was then believed that "we might be observing the sudden transformation of the nebula into a star along the lines of the theory of Laplace." Frost was greatly interested in the new phenomenon and chose it as the topic of his senior class oration. He graduated in 1886, with a speech on the influence of astronomy upon literature.

After graduation, Frost enrolled as a post-graduate in the department of chemistry, and almost at once was appointed assistant under Professor Bartlett. For a short time he taught school at Hancock, New Hampshire. Early in 1887 he accepted an invitation from Professor C. A. Young and went to Princeton to take a practical course in astronomy, being a guest in the Young household. In the fall of 1887, Frost was appointed instructor in physics and astronomy at Dartmouth College. He was then only 21 years old. In the summer of 1888 he assisted Professor Young in reading the proofs of the latter's textbook on *General Astronomy*. This excellent book made a great impression upon the young astronomer. With his brilliant memory he was able to retain until his death an almost photographic mental record of nearly every page! Even after total blindness had prevented him from consulting this book, he could unerringly point out the page and paragraph when he wanted someone to read a particular passage to him.

In 1890 Frost took leave of absence from Dartmouth and went first to England where, among others, he met Sir William and Lady Huggins. At Greenwich he met the chief assistant, H. H. Turner—later Savilian Professor of Astronomy at Oxford—who remained one of his life-long friends. After a short stay at Strassbourg, where he attended lectures by Kohlrausch, Wiener, Becker and others, and where he became acquainted with other graduate students and assistants: Peter Lebedeff of Russia, H. Kobold (now in Kiel), J. Halm (later astronomer at the Cape of Good Hope), Frost went to Potsdam to work under Vogel. In 1891 he was appointed assistant at Potsdam under Scheiner and Vogel. Nova Aurigae provided much excitement that year, and Vogel assigned to Frost the task of observing its spectrum. It was through this somewhat accidental occurrence that Frost embarked upon the study of stellar spectra, which later became his special field of research.

Scheiner had just published an important new book on the *"Spectral Analyse der Gestirne,"* and Frost decided to translate it into English. This translation, containing many additions and revisions by the translator, was printed by Ginn and Company in 1898. It remained the standard textbook of astrophysics in the English language for almost twenty years.

In the autumn of 1892 Frost returned to Dartmouth College as assistant professor of astronomy. In the same year he met Dr. George E. Hale at the Rochester meeting of the American Association for the Advancement of Science. It was at this meeting that Hale learned from Alvan G. Clark that two excellent 40-inch discs cast by Mantois of Paris were being offered for sale. Frost probably did not then realize that he would be custodian of these discs for more than a quarter of a century.

In 1897 Frost attended the conference of astronomers held in connection with the dedication of the Yerkes Observatory at Williams Bay, Wisconsin. The following April Professor Hale invited him to become professor of astrophysics at the Yerkes Observatory of the University of Chicago.

When Hale organized the famous expedition from the Yerkes Observatory to Pasadena, which formed the beginning of the Mount Wilson Observatory, Frost remained at Williams Bay as acting director. In 1905, upon Dr. Hale's resignation, he was appointed director—a position which he held until his retirement in 1932.

In the night of December 15, 1915, Frost lost the use of his right eye. He writes in his autobiography: ". . . I was working alone at the forty-inch telescope, photographing the spectrum of a rather faint star, by name 20 Persei. I had difficulty in seeing the divisions of the circle and in guiding after I had brought the star into proper position upon the slit of the spectroscope. I carried on the exposure until an assistant arrived and then found that vision in the right eye was greatly reduced. I had my own fear of what was the trouble, because my mother had suffered from a detached retina. My fears were unfortunately well founded." Frost retained the use of his left eye and was able to read with it. In 1921 he lost the use of this second eye. I clearly remember how, on October 10, of that year, Mr. Frost met me at the station in Williams Bay when I arrived from Constantinople. With Professor Van Biesbroeck to help him overcome the restrictions of his vision (due then mostly to nearsightedness in the remaining eye) he drove his own car to the Observatory, where he introduced me to my duties as his assistant. A few nights later I was observing at the forty-inch refractor, and forgot to mark the spectrograms for identification. The next morning Mr. Frost came to my office and offered to help me identify the stars from their spectra. I lined them up for him in the Hartmann spectrocomparator, but, to his surprise, he could not see the lines. It was found later that a hemorrhage had occurred in the good eye; and a rapidly forming cataract—which never ripened and thus could not be removed—soon completely extinguished his vision.

The tragedy of a great astronomer becoming blind cannot adequately be described. Mr. Frost gave an example to everyone who knew him of courage and cheerfulness. He adjusted himself to his lack of vision, and continued, for eleven years, to direct the Yerkes Observatory and to edit the *Astrophysical*

Journal. One of his biographers fittingly wrote of him: "This cruel malady—and what could be harsher than blindness to an astronomer?—deafness to a musician perhaps—brought out such magnificent traits of character and aroused in those who saw him go about his ways in cheerful mien, such quick sympathy and profound admiration that the influence of his dark years upon his fellow-men was perhaps even greater than those devoted actively to research." Probably no other scientist has ever been admired and loved so much by those who knew him or knew of him. Children used to gather around him and hear his stories about the stars, or the birds which he could imitate to perfection, or the trees which he had planted in the park surrounding the Observatory. Grown-up people of all classes of life listened reverently to him when, on a Saturday afternoon, he explained to them the operation of the great telescope. At the opening of the Century of Progress Exposition in Chicago in 1933, when the light of Arcturus was used to turn on the illumination of the Fair grounds on the shore of Lake Michigan, Mr. Frost gave the principal address which was heard by many thousands of visitors in Chicago and by millions of listeners over the radio. A well-known astronomer dedicated to him a large volume of astronomical research, in the following words:

"TO
EDWIN BRANT FROST
MY FIRST TEACHER OF ASTRONOMY
THIS VOLUME
IS GRATEFULLY INSCRIBED
IN THAT NIGHT INTO WHICH HE HAS FOLLOWED
GREAT GALILEO MAY HE STILL SEE WITH THE
EYES OF HIS DEVOTED AND REVERING STUDENTS."

Frost's astronomical work began in 1889 at the Shattuck Observatory of Dartmouth College. He observed sun spots, comets, occultations, and in 1891 he computed the orbit of Comet 1890 IV (Zona). In 1892 he published an important paper on the thermal absorption in the solar atmosphere, which was inspired by H. C. Vogel at the Potsdam Observatory. In later years Frost retained his interest for solar investigations: he was an ardent observer of the flash spectrum during solar eclipses. At the eclipse of May 28, 1900, he obtained a series of excellent exposures of the flash spectrum and his measurements of the wave-lengths and identifications of the lines were among the best at that time, and formed the basis for later work by other observers.

The great majority of Frost's scientific contributions deal with the spectra of the stars and, in particular, with the determination of their motions in the line of sight.

The original equipment of the Yerkes 40-inch refractor included a stellar spectrograph designed by Professor Keeler of the Allegheny Observatory and constructed by Mr. Brashear of Pittsburgh. This instrument was described by Professor Hale and Mr. Ellerman, and was used by them to great advantage for a study of the spectra of very red stars. However, the mechanical parts were not sufficiently stable and free of flexure to permit its use for the determination of radial velocities. Accordingly, Frost decided to build a new modern spectograph intended primarily for radial-velocity work. In 1899 Miss Catherine W. Bruce made a gift to the Yerkes Observatory of $2300 for the new instrument, and in January, 1902, Frost was able to publish in the *Astrophysical Journal* a complete description of the Bruce spectrograph, together with some preliminary measurements of stellar motions.

The Bruce spectrograph remained Frost's principal instrument, and with it he accumulated an enormous amount of material on the spectra of the hottest stars, spectroscopic binaries, novae and variable stars. It is of interest in this connection that the Bruce spectrograph has for over thirty-five years been the principal spectrographic instrument of the Yerkes Observatory. Without major changes it has served two generations of astronomers, and even today it continues to produce results which are equal to those obtained elsewhere. With a short-focus camera designed by Dr. G. W. Moffitt and with one of the original prisms made of Mantois glass, recently refigured by Bausch and Lomb, we are able to photograph the spectra of stars of the eleventh photographic magnitude in a few hours, with a dispersion of about 120 A/mm. at λ 4500. The definition given by the single prism is excellent: with a longer camera it has recorded a vast number of spectral lines never before observed with any instrument.

Incidentally, the old Brashear spectrograph of the 40-inch telescope was transferred by Frost to the 12-inch refractor, where it was used for many years in the observation of prominences. A few years ago it was again used for stellar work by Messrs. Elvey and Keenan, who obtained with it the total intensities of Hα in several stars. Quite recently this old spectrograph, equipped with a single prism and with a new short camera, has again been transferred to the 40-inch, where Dr. G. P. Kuiper uses it for the classification of the spectra of stars as faint as magnitude 13.

Frost's first work with the Bruce spectrograph dealt with the motions of the helium stars. These stars had been somewhat neglected by other observers, partly because their lines are often ill-defined and partly because the laboratory wave-lengths of many of the lines were not adequately known. In collaboration with Dr. W. S. Adams, Frost overcame these difficulties and in 1904 there appeared in the *Publications of the Yerkes Observatory* a paper, under joint authorship, on the "Radial Velocities of Twenty Stars having Spectra of the Orion Type." A careful investigation of the systematic errors of the instrument preceded the work, and the precision obtained for the twenty stars was very gratifying. Although the number of stars was not sufficient to make a solution for the solar motion, "the distribution of positive and negative velocities shows clearly the direction of the motion of the sun in space." The mean motions of the helium stars were found to be surprisingly small, only 7.0 km/sec as the mean of the twenty radial velocities corrected for solar motion. It was already known that the average velocities of the cooler stars were considerably larger. Thus, Frost and Adams brought out the significant fact that the average motions of the stars were not the same for all spectral types. This result has been of fundamental importance in all later investigations concerning the dynamics of the stellar system.

But the most significant result was stated by the authors in the following short sentence: ". . . if the sign be regarded, the mean becomes +4.6 km/sec." In other words, after the component of the solar motion had been subtracted from the measured velocities, the mean velocity with regard to the sign was not zero or close to zero, but was of the same order of magnitude as the mean velocity taken without regard to sign. The authors had thus, for the first time, recorded the famous K-effect in the motions of the helium stars, which, literally interpreted, means that the system of B-type stars, as a whole, expands with a velocity of 4.6 km/sec.

In 1910 Frost, in collaboration with J. C. Kapteyn, returned to the question of the mean motion of the helium stars. After having discussed the solar motion from the large amount of radial velocity material collected by Frost, the authors remark: ". . . meanwhile our numbers bring out a somewhat unexpected fact, namely that the velocity of the sun relative to the stars near the apex is found to be very different from that relative to the stars near the antapex. To show this more clearly, a separate solution was made for the stars for which $\lambda < 90°$ and for which $\lambda > 90°$. We thus find:

Near apex $v = -18.38 \pm 1.40$ km, from 32 stars
Near antapex $v = -28.38 \pm 1.36$ km, from 29 stars
Simple mean $v = -23.38$ km, from 61 stars

The difference is very considerable and cannot well be attributed to accidental error alone."

This peculiar phenomenon of expansion of the system of helium stars has been the subject of many later investigations, and even today it has only been partly explained. Kapteyn and Frost were aware that "a constant error, depending on instrumental and personal influences and on errors in the assumed wave-lengths of the lines both in the star spectrum and in the comparison spectrum such that the positive velocities would result too great, might of course explain the difference." To test this possible explanation Frost devoted much time and energy to the determination of the wave-lengths and to the elimination of systematic errors in radial velocities. But the

K-effect persisted. It is of historic interest that Kapteyn and Frost concluded that "the most plausible [explanation] would seem to be that either the stars near the apex, or those near the antapex, or both, belong in unequal numbers to the two great star-streams." A somewhat similar explanation, in terms of systematic motions among the brighter helium stars, was recently proposed by Paskett and Pearce, at Victoria.

The final radial velocity results obtained at the Yerkes Observatory were published by Frost, Barrett and Struve in the *Astrophysical Journal,* 64, 1, 1926, and in the *Publications of the Yerkes Observatory,* Volume VII, Part 1, 1929. The former contains the velocities of 368 B-type stars and the latter those of 500 A-type stars.

One of the earliest results of Frost's work on radial velocities was the discovery of a surprising number of new spectroscopic binaries. The pages of the *Astrophysical Journal* were virtually swamped with announcements of new binaries. Their number grew so rapidly that Frost was, at times, concerned over the question whether enough stars of constant velocity would be left to provide sufficient material for a study of the motions of the system of helium stars. He and his associates, therefore, began the laborious task of determining the orbits of some of these binaries.

On May 14, 1902, Frost made an important discovery, although at the time he himself probably did not realize how deeply it would affect our knowledge of the stars. On that particular night he took two spectrograms of the bright B-type star β Cephei. During the winter of 1901-1902 he had measured eleven spectrograms of this star and had found it to possess a variable velocity. He states in his first announcement concerning β Cephei: "We had assumed from the first plates that the period would be rather long, but a suspicion to the contrary led me to take two plates on the night of May 14, and during the interval of five and one-half hours the velocity changed 14 km, or nearly half of the whole range so far observed." Such rapid variations in radial velocity were quite unheard of in 1902, and Frost diligently continued his observations. Four years later he announced that the period is $4^h 34^m 11^s$, and that the velocity curve is nearly symmetrical, with a range of 34 km/sec. The shortest period of any spectroscopic binary previously known was 1.45 days in the case of μ Scorpii and *V* Puppis. Frost noticed that the radius of the orbit of β Cephei, computed from the velocity curve, would be inconceivably small—only 45,000 kms—and he suggested that the binary hypothesis could only be true if the inclination of the orbit were close to 0°. He says: ". . . if the radius of the orbit of the brighter star is assumed for the moment to be the same as that found by Vogel for Algol (1.6 million kms), then the inclination of the plane would lack only about 1½° of 90°; and the observed projected velocity would have to be increased nearly forty-fold, yielding an actual velocity of over 600 km/sec."

β Cephei was not then known to vary in light, and this was believed to support the hypothesis of a small inclination. Frost was therefore immensely interested when, in 1913, Guthnick announced that the light of β Cephei varies with an amplitude of 0.05 magnitude, the period of this variation being identical with that found by Frost. However, the light curve did not resemble those of ordinary eclipsing variables. Furthermore, it seemed inconceivable that the small range in radial velocity could at all be reconciled with an eclipse. The problem of β Cephei remained unsolved for many years.

Frost clearly understood that in order to explain the apparent contradictions in β Cephei, more observational material on other stars was required, and he started systematic observations for the detection of other similar objects. Every star known to have a variable radial velocity, for which no period had been found, was placed on the observing program and long series of spectrograms were obtained on a few single nights. Most of these cases yielded only constant velocities, but a small number of stars were gradually discovered which seemed to resemble β Cephei. Other observatories added to the list, and by 1921 the number was sufficient for a preliminary discussion. This discussion Mr. Frost assigned to me, a few weeks after my arrival at the Yerkes Observatory. For spectroscopic binaries of types O, B and A, the amplitude of the velocity curve increases, on the average, rapidly with decreasing period, in accordance with Kepler's third law. But this increase continues only until a period of about 1.3 days is reached. For still shorter periods the amplitude again decreases. This can mean only one thing: β Cephei and all similar stars are not true binaries. They resemble more closely the Cepheid variables, but differ from them by the small amplitude of their light variations. Many representatives of this group display irregularities in their light curves as well as in their velocity curves. The entire group has often been designated as the β Canis Majoris stars, and Henroteau, who, I believe, first introduced this term, counted β Cephei among them. The name is, however, historically incorrect, and scientifically misleading. β Cephei was, without doubt, the first and most typical representative of the mysterious group of quasi-Cepheids of early type and of very short period. While irregularities are present both in its velocity curve and light curve, it promises to give valuable results to the observer who can combine photoelectric observations of the light with accurate measurements of the radial velocity. We know surprisingly little concerning these stars, and Frost's work on β Cephei will become increasingly appreciated as we begin to unravel their secrets.

In 1917 Frost started a long series of observations of the peculiar spectroscopic binary and eclipsing variable ε Aurigae. Its period had been found by Ludendorff to be 27 years, and it was important to determine the spectrographic orbit as well as to elucidate some very strange phenomena reported by the Potsdam observers during the eclipse of 1902. This work was continued by the present writer and by Elvey, and the results of the Yerkes Observatory investigations were published by Frost, Struve and Elvey in the *Publications of the Yerkes Observatory*, Volume 7, Part 2, 1932. The spectrographic observations made during the eclipse revealed an unsymmetrical broadening of the lines towards the red during the partial phase preceding total eclipse and towards the violet following total eclipse. The authors interpreted this phenomenon as being produced by the absorption within the rotating outer layers of the eclipsing star. Almost simultaneously Guthnick advanced the same hypothesis in the case of ζ Aurigae. These two stars have given the first indication of the existence in certain super-giants of tenuous atmospheres (or reversing layers) extending to heights of more than one astronomical unit. In most ordinary stars the height of the reversing layer is of the order of a few hundred kilometers. The complete interpretation of the system of ε Aurigae was not possible in 1932, and there remained a serious discrepancy between the evidence furnished by the velocity curve and that furnished by the light curve. The latter suggests that the eclipse of the bright F star is total. Consequently, at constant minimum we should observe the spectrum of the eclipsing star alone. Yet, the spectral lines at minimum are, with very few exceptions, stronger replicas of the normal F-star lines. On the other hand, at maximum separation of lines, around 1925, only the normal F star was visible; the other set of lines was completely absent. Recent progress in the study of ζ Aurigae and VV Cephei has paved the way for the explanation of this apparent paradox. It is expected that the riddle of ε Aurigae will soon be solved—thus bringing to a conclusion a series of investigations inaugurated by Frost twenty years ago.

From the beginning of his work with the Bruce spectrograph Mr. Frost was interested in the problem of systematic errors in radial velocities; his efforts, over a period of thirty years, have profoundly influenced the methods of radial-velocity observers. In 1902 he sent a circular letter to some of the world's leading observatories inviting them to cooperate in the observation of a selected list of ten "fundamental velocity stars." As Frost remarked, "the history of progress in other fundamental measurements would suggest that systematic differences between the results at different observatories are likely to become more apparent as the accuracy of the determinations increases." The observations of planets or of the moon give, of course, an excellent check for each individual observatory, but since the latter have extended surfaces they illuminate the slit of the spectrograph uniformly. Stars which are more nearly point sources must be "guided" on the slit. Lack of exact centering of the star image on the slit caused, for example, by atmospheric dispersion or by optical defects in the guiding system, introduce a troublesome systematic error which is not present in planetary observations. Furthermore it is important to have the test objects well distributed over the sky so that observations can be made at all times. This would not always be true in the case of planets.

As a result of Frost's continuous efforts a large mass of data on the standard velocity stars has been accumulated at various observatories. In 1925 the International Astronomical Union appointed a sub-committee of the commission on radial velocities for the selection of a new list of standard velocity stars. Frost was the chairman of this committee. The final list published in the *Transactions of the International Astronomical Union,* Vol. III, 1928, contains 28 stars in both hemispheres; this list includes most of Frost's original standard stars. The adopted standard velocities are based upon several thousand individual observations made at twelve observatories. They are, to date, the most precise set of radial velocities known. The probable error for each star is of the order of $\pm$ 0.1 km/sec.

The final results of the Yerkes observations of standard velocity stars were used for the derivation of a set of stellar wave-lengths for use with dispersions of around 10 A/mm at λ 4500. These were published as a "List of Recommended Wave-lengths for Three-Prism Dispersion" in the *Transactions of the International Astronomical Union,* Vol. V, 1935.

After his appointment as director of the Yerkes Observatory, Mr. Frost was obliged to devote a large part of his time to administrative duties. But he took a keen interest in the work of his associates. Of the original staff, after Hale, Ellerman, Adams, Ritchey and Pease had gone to Mount Wilson, Burnham, Barnard and Barrett remained permanently with Frost at Yerkes. Schlesinger soon left to become the director of the Allegheny Observatory. Fox remained until 1909 when he was appointed director of the Dearborn Observatory. Of Mr. Frost's later associates we must mention Mitchell, Slocum, Lee, Van Biesbroeck and Ross. Mr. Frost was especially fortunate in having with him as scientific secretary of the Observatory a close friend and loyal collaborator—Professor Storrs B. Barrett.

Mr. Frost had many honors. The University of Cambridge, England, conferred upon him the honorary degree of D. Sc. in 1912. He also had a D. Sc. from Dartmouth in 1911. He was elected a member of the National Academy of Sciences in 1908; of the American Philosophical Society in 1909; of the American Academy of Arts and Sciences in 1913; of the Washington Academy of Sciences in 1915. He was made a foreign associate of the Royal Astronomical Society in 1908. He held honorary memberships in the Societa degli Spettroscopisti Italiani; the Astronomical Society of Mexico, the Royal Astronomical Society of Canada, and the Russian Astronomical Society.

He was married in 1896 to Miss Mary E. Hazard of Boston. His family life was a happy one, and he has set a monument to it in his book "An Astronomer's Life," which is dedicated to Mrs. Frost. Touching are the pages in which he describes her faithful help in preparing the manuscript for the book, in assisting him with his lectures and in smoothing over the many difficulties which came to him with his blindness. Three children survive him: Miss Katharine Brant Frost is in business in Chicago; Mr. Frederick H. Frost, a paleobotanist, is assistant superintendent of the Warren Paper Company in Portland, Maine; and Mr. Benjamin DuBois Frost is a business man in New York City.

Mr. Frost died on May 14, 1935, after an operation at Billings Hospital of the University of Chicago.

BIBLIOGRAPHY OF

EDWIN BRANT FROST

List of Abbreviations

A. and Ap. = Astronomy and Astrophysics.
A.J. = Astronomical Journal.
A.N. = Astronomische Nachrichten.
Ap.J. = Astrophysical Journal.
J.Can.R.A.S. = Journal of the Royal Astronomical Society of Canada.
Mem. Nat. Ac. Sc. = Memoirs of the National Academy of Sciences.
Mem. Spettr. It. = Memorie della Societa degli Spettroscopisti Italiani.
N.S. = New Series.
P.A. = Popular Astronomy.
Proc. A.A.A.S. = Proceedings of the American Association for the Advancement of Science.
Proc. Am. Phil. Soc. = Proceedings of the American Philosophical Society.
Proc. Nat. Ac. Sc. = Proceedings of the National Academy of Sciences.
Publ. = Publication.
Publ. Am. Astr. Soc. = Publications of the American Astronomical Society.
Publ. A.S.P. = Publications of the Astronomical Society of the Pacific.
Publ. As. and Ap. Soc. Am. = Publications Astronomical and Astrophysical Society of America.
Sid. Mess. = Sidereal Messenger.

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