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PAUL WILLARD MERRILL

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A Biographical Memoir by

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ASTRONOMY, by its very nature, has always been pre-eminently an observational science. Progress in astronomy has come about in two ways: first, by the use of more and more powerful methods of observation and, second, by the application of improved physical theory in seeking to interpret the observations. Approximately one hundred years ago the pioneers in stellar spectroscopy began to lay the foundations of modern astrophysics by applying the spectroscope to the study of celestial bodies. Certainly during most of this period observation has led the way in the attack on the unknown. Even today, although theory has made enormous strides in the past thirty or forty years, observation continues to uncover phenomena which were unanticipated by the theorists and which are, in some instances, far from easy to account for.

The chosen field of the subject of this memoir was stellar spectroscopy, and his active career spanned the second half of the period since work was begun in that branch of astronomy. To some extent his professional life formed a link between the early pioneering times, when theoretical explanation of the observed phenomena was virtually nonexistent, and the present day. His own work was almost entirely observational, but he was always alert to see whether current theory could supply a reasonable account of his observations. His major contribution to astronomy is a very large body of carefully made, detailed material relating to the spectroscopic behavior of certain classes of stars. There is still no adequate physical theory to explain fully many of the phenomena described by Merrill, but he uncovered and exhibited the facts which will be basic to future theoretical development.

Paul Willard Merrill was born August 15, 1887, in Minneapolis, Minnesota. Has father was a Congregational minister who, in the course of his professional life, was required to move from one place to another from time to time. Young Merrill attended grammar school in Minneapolis; Silverton, Colorado; and several towns in California, and was graduated from the Santa Clara, California, high school in 1904. His father appears to have been something of a fundamentalist in outlook and to have been unsympathetic, if not actually antagonistic, to science in general. In spite of this lack of support for science at home, Merrill attended Stanford University, from which he was graduated in 1908 with a major in mathematics and a considerable interest in physics and astronomy. He did not study the latter subject in college but did a good deal of independent reading.

Following his graduation from Stanford, Merrill worked briefly for the Coast and Geodetic Survey in California. But his main interest clearly was more directed toward pure science and he shortly became a graduate student in the astronomy department at Berkeley and a Fellow of the Lick Observatory. Here he quickly became immersed in various studies in the general field of stellar spectroscopy under the guidance of several of the better known practitioners of the art of that time, especially W. W. Campbell, W. H. Wright, and J. H. Moore. In 1913 he was awarded the Ph.D. degree for a thesis dealing with B-type stars which have hydrogen emission lines in their spectra, and in the same year he was married to Ruth Currier of Cupertino, California, who, with a son, Donald, survives him.

Merrill next spent three years as an instructor at the University of Michigan, where he continued stellar spectroscopic investigations with the equipment available to him there. Then followed three years as a physicist at the National Bureau of Standards in Washington. This period included the time of United States involvement in the First World War, and Merrill worked on problems related to infrared photography and camera design and participated personally in pioneering experiments in aerial photography. In 1919 Merrill joined the staff of the Mount Wilson Observatory of the Carnegie Institution, where he remained active until the end of his life.

At that time work with the 100-inch telescope was just getting started. Since this was then, and for many years thereafter, the largest telescope in the world, a staff appointment at Mount Wilson was a wonderful opportunity for a young astronomer interested in observational astronomy. Besides the 100-inch and other equipment on the mountain, there was a youthful enthusiastic group of colleagues assembled by George Ellery Hale, and an active physics laboratory working on the solution of problems of immediate relevancy to the new science of astrophysics. Given his interests and these stimulating surroundings, it is no wonder that Paul Merrill set himself assiduously to work on the various facets of stellar spectroscopy nearest his heart.

The great majority of the stars are, in one sense, rather dull. That is to say, they are conformists; their spectra are normal and not differentiable from those of a good many similar stars. Moreover, they do not do anything; their spectra and their luminosities are constant, or so nearly constant that only the most refined and difficult observations could detect any variations. These are clearly objects in a happy state of equilibrium, content to go on radiating at the same old rate and in the same old way for very long periods of time. But, fortunately I think, not all stars are satisfied to conform to the quiet behavior pattern of the majority. The stellar population, like the human one, has its unorthodox members whose behavior distinguishes them from their brethren. Such stars form only a small fraction of the total number, but since virtually all of them are of high or moderately high luminosity they can be observed out to considerable distances and so a good sample is available for investigation.

One of the most frequent and readily detectable stellar deviations is the occurrence in the spectrum of bright lines of hydrogen. These are sometimes accompanied by emission lines of other elements or by peculiarities in the absorption line spectrum. Moreover, these hydrogen emission lines are a pretty good indicator of the presence of an instability of some kind. For almost invariably a star with such lines will, if observed long enough, be seen to change in some fashion. Such changes range from the spectacular, roughly periodic, more or less repeatable variations of the long period variables to the slow and sometimes rather minor variations in the lines themselves as seen in some of the Be stars.

The foregoing remarks are intended as a brief background for what is clearly the central theme of Paul Merrill's researches in stellar spectroscopy. A unifying thread runs through his entire professional career from beginning (note the title of his thesis of 1913) to end. This can best be described as a great interest in, one might almost say a passionate enthusiasm for, the study of those stars whose spectra show deviations from the normal. Some of these objects put on performances which can only be described as weird and wonderful and which provide the astronomer with intricate and fascinating problems. But Merrill had a more far-reaching reason for his interest in the unorthodox stars. He believed that the processes which produce the peculiarities in their spectra are only exaggerations of the processes occurring in the atmospheres of normal stars. Thus, if an understanding of the peculiar stars could be attained, our attack on the general problems of all stellar atmospheres should thereby be facilitated. To a considerable extent this expectation has been fulfilled, although it must be acknowledged that many of the phenomena exhibited by the peculiar stars still lack a complete physical explanation.

Although Merrill's chief interest lay with the non-normal stars, his work did not deal with them exclusively. He found time also for other projects as well, sometimes quite extensive ones, but these were nearly all within the general area of celestial spectroscopy. His major researches of various kinds will be touched on later, but at this point a comment on the very lengthy bibliography attached to this memoir is in order. It is evident that a great many of the items listed there are brief notes concerning observations which Merrill considered significant or perhaps merely interesting. He firmly believed that the duty of the observer did not terminate with the collection or even with the measurement of spectrograms, but included the publication of all such results even though their significance might not be immediately apparent. In this view he was undoubtedly correct, for, while the retrieval problem in the ever-increasing proliferation of scientific literature is indeed formidable, it becomes incomparably worse when valuable information exists only in plate files, or in unpublished notes which will most likely be lost after the death of the individual who made them. Moreover, since so much of Merrill's work lay in the general area of peculiar stars, it was quite natural that he would come upon interesting deviations more frequently than would an observer who spent most of his time on problems of the more orthodox stars, and this fact, together with the viewpoint noted above, accounts for the very large number of items in the bibliography. Thus serendipity, a word which Merrill was fond of using, played a not insignificant role in his professional life.

I do not believe it is possible at the present time to give a meaningful order of importance to Merrill's major investigations. This could be done only, if at all, after enough time has elapsed to show what roles they play in the further development of astronomical progress. No significance, therefore, should be attached to the order in which they are touched upon here.

One of Merrill's major interests throughout his life was the study of the red stars and, in particular, those known as the long period variables. His earlier work on a selected few of these objects was hampered by the facts that most of them are rather faint and that the spectroscopic and telescopic equipment available to him was really inadequate to the task. The latter disadvantages were sufficiently reduced at Mount Wilson to enable him to start a long series of spectroscopic observations of these stars, about which relatively little was known at that time. He began by following as many of these objects through their cycles of variability as he could. The results of this work established the various correlations between the stellar brightness, radial velocities of the emission and absorption lines, intensities of the emission lines, and general spectral variations, which are now well known and which are basic to any understanding of the physical processes responsible for the observed variations.

In addition, the collected results on the radial velocities of the variables, together with their proper motions as determined by other observers, permitted the calculation of their space motions. This work, done in collaboration with G. Strömberg and R. E. Wilson, showed that the long period variables in general had space velocities considerably in excess of those found for the normal giants of similar absolute magnitude. Moreover, these space velocities turned out to be a function of the period of stellar variation, tending to decrease in general with increasing period, except that there appeared to be a rather pronounced maximum for periods around 200 days.

The majority of the red giants, the M-type stars, are characterized by absorption bands of TiO in their spectra. But other red stars were long known in whose spectra bands of the molecule C_2 were prominent and those of TiO were missing. These are the R- and N-type objects. Still a fourth class among the red giants was established by Merrill. Following a suggestion by Baxandall, he found that the molecular bands in the spectra of these stars were due to ZrO. The space motions of these S-type objects as a function of period are very similar to those of the M-type stars.

Merrill studied extensively the similarities, and the equally important differences, between the various individuals representative of the different groups of long period variables, and also the similarities and differences between the groups themselves. All of this work was done in great detail and comprises a truly monumental mass of carefully compiled observational material. While many of the problems presented by these stars remain unsolved, Merrill's papers on them will long remain a gold mine of factual information for those who must eventually construct sound physical theories to account for their properties.

The preceding work was done with spectrographs yielding only modest dispersion. With the development of the coude spectrograph at Mount Wilson, Merrill made a number of extensive detailed investigations of selected objects. There is space here to mention only two of the important results. One is the proof that the strong hydrogen emission lines in the long period variables are produced in zones which actually lie below the reversing layers of the stars. The other is the discovery of technetium in S-type stars, a most surprising result, since no stable isotopes of this element are known.

At the time Merrill came to Mount Wilson only a modest number of early type stars with bright hydrogen lines were known, but he was already enthusiastic about the study of these objects. Shortly after assuming his new position at the Observatory he began a survey for the discovery of such stars which, with the aid of various collaborators, was extended over a period of about thirty years. This work was done with a refractor of 10-inch aperture provided with an objective prism. Since in these Be and Ae stars there is a fairly steep intensity decrement down the Balmer series, the most favorable line for discovery purposes is Hα. Accordingly, the 10-inch objective was specially figured to give the same focus at Hα and at the D-lines and to give a flat field throughout this wavelength region.

This effort resulted in the discovery of hundreds of hitherto unknown Be and Ae stars, and these findings, together with accounts of similar objects found elsewhere, were collected in a series of papers which also contained complete bibliographic material. A majority of the newly discovered emission-line stars were observed also with slit spectrographs for verification, and some of them proved to have spectra of such unusual and interesting characteristics that they were followed for long intervals by Merrill who described their behavior in numerous publications.

Besides the Be and Ae stars found in this survey, more than 500 miscellaneous bright-line objects were discovered and catalogued separately. Not much more is known about most of these stars, nearly all of which are rather faint, but it is virtually certain that among them are some which would well repay study with slit spectrographs. Also, a rather large number of emissions were discovered which have turned out to be due to faint planetary nebulae. The study of these was taken over by R. Minkowski, and they have proven to be very valuable in his own investigation of the planetaries.

The emission lines in the spectra of Be and Ae stars are produced in outer envelopes, unlike those of the long period variables. These envelopes sometimes become sufficiently thick to produce absorption lines, most commonly those of hydrogen, in the underlying continuous spectrum from the star. Such absorptions are usually sharp and deep, unlike those originating in the star's reversing layer, which are often wide and shallow. Objects which exhibit these features in their spectra are known as shell stars, and there is evidently a close connection between them and the emission-line stars. It is not surprising therefore that another by-product of Merrill's Hα survey was the discovery of a number of shell stars, several of which he investigated in detail over long intervals of time. These stars behave at times in most peculiar ways, and the underlying physics of the processes involved is anything but clear. Nevertheless, Merrill's work on these objects provides a very considerable body of observational material which must be of basic value to anyone interested in attempting a theoretical discussion of the phenomena of the shell stars.

Another field in which Paul Merrill made a substantial contribution was that of interstellar matter. So-called stationary lines of Ca II had been known in the spectra of certain early type stars since soon after the beginning of this century. These lines were so named because in the spectra of spectroscopic binaries, in which the stellar lines shifted back and forth periodically, the sharp Ca II lines remained fixed in position. In the 1920s it was suggested, notably by Eddington, that these absorption lines, and the similar stationary lines of Na I which had been found in the meantime, were produced in a general tenuous gaseous substratum filling the space between the stars. By 1930 this hypothesis was quite generally accepted, following the work of O. Struve, who showed that the intensities of the interstellar Ca II lines increased with the distances of the observed stars.

In the early 1930s Merrill enlisted the collaboration of several colleagues at Mount Wilson and embarked on an extensive study of the interstellar Ca II and Na I lines in the spectra of several hundred B-type stars. This effort involved the measurement of both the displacements (radial velocities) and the intensities of the lines, the latter being measured by the methods of photographic photometry. In the case of the sodium lines especially, the strengths of both members of the doublet could be measured, and the systematic variation of the doublet ratio with intensity was an item of particular value in the theoretical interpretation of the results. Upon completion, this investigation provided by far the largest and most complete body of information on the interstellar lines, and it has been utilized in several subsequent researches by various individuals.

Since the Mount Wilson interstellar work mentioned above was carried out with rather modest dispersion (25–30 A/mm), it largely missed what has turned out to be one of the most useful developments in this field. This is the resolving of the interstellar lines into several components, which can be accomplished only through the use of higher dispersion. On the other hand, the lower dispersion was probably an advantage in facilitating the discovery of several hitherto unknown interstellar absorption features. These are more or less diffuse lines, or symmetrical bands, one of which occurs in the photographic region and the others in the yellow and red parts of the spectrum. It is strongly suspected that these absorption features are associated with the grains or dust in space which produce the phenomenon of interstellar reddening of starlight. The precise identification of the molecules responsible for them is still unknown, however.

Merrill did pioneering work in extending the observable part of the spectrum into the red and infrared. While at the Bureau of Standards he experimented with sensitizing plates for these wavelengths by the use of dicyanin. Later, at Mount Wilson, after such red and infrared sensitive plates became available through commercial channels, he did considerable observing with grating spectrographs of the long wavelength portions of stellar spectra. He was the first to observe stellar spectra with relatively high dispersion in the near infrared.

Paul Merrill was a wonderful colleague. His enthusiasm was infectious, and he was willing and able to talk informatively at length at any time about astronomical matters. Younger staff members could, and did, learn a great deal from him in such conversations. Moreover, he was very generous in inviting others to participate in his current investigations and in giving them a full share of both responsibility and credit.

Merrill was a lifelong rock-ribbed Republican and made no effort to conceal his distaste for certain political personalities on the American scene. Political discussion with him was enjoyable, however, since it was never acrimonious and was always maintained on a gentlemanly level. Neither party would make the slightest dent in the other's convictions, but at the end both would agree that the discussion had been good fun. At one point Merrill actually embarked on a political career although, fortunately for astronomy, it was of short duration. In 1930–1931 he served as one of the Directors of the City of Pasadena.

Merrill's retirement in September 1952 was something of a joke among his associates. Except for bringing an end to his years of observing on Mount Wilson, his retirement had no other discernible effect, and he continued to spend fully as long hours in his office each day as he had before. In fact, this is merely an example of the enthusiasm and interest in his work which characterized his whole life. Although he had suffered severely from arthritis for many years, he never allowed his disability to hinder him in the pursuit of his profession.

Paul Merrill died unexpectedly, following an operation, on July 19, 1961. Although it may be trite to say that his death is a severe loss, both to his science and to his friends, it is indeed true. His influence on the development of astronomy in the first half of the twentieth century has been considerable, and the large volume of valuable data he accumulated forms an enduring monument to his skill and enthusiasm.

KEY TO ABBREVIATIONS

Astron. Soc. Pac. Leaflet = Astronomical Society of the Pacific, Leaflet
Astrophys. J. = Astrophysical Journal
Bull. Natl. Bur. Standards = Bulletin of the National Bureau of Standards
J. Roy. Astron. Soc. Canada = Journal of the Royal Astronomical Society of Canada
Lick Obs. Bull. = Lick Observatory Bulletins
Monthly Notices Roy. Astron. Soc. = Monthly Notices of the Royal Astronomical Society
Mt. Wilson Contrib. = Mt. Wilson Contributions
Mt. Wilson and Palomar Obs. Rept. = Mt. Wilson and Palomar Observatories Report
Phys. Rev. = Physical Review
Popular Astron. = Popular Astronomy
Publ. Am. Astron. Soc. = Publications of the American Astronomical Society
Publ. Astron. Obs. Univ. Mich. = Publications of the Astronomical Observatory of the University of Michigan
Publ. Astron. Soc. Pac. = Publications of the Astronomical Society of the Pacific
Sci. Monthly = Scientific Monthly
Sci. Papers Natl. Bur. Standards = Scientific Papers of the National Bureau of Standards
Trans. Internatl. Astron. Union = Transactions of the International Astronomical Union

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