E. C. PICKERING IN THE HISTORY OF VARIABLE STAR ASTRONOMY

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E. C. Pickering (1846-1919) in 1911 was the prime founder of the AAVSO. It is fitting that we pay him tribute in this first issue of the Journal of this Association.

Appointed Director of Harvard College Observatory in 1876, his first innovation was the introduction of precise stellar photometry as one of the major fields for research and development at the observatory. He devised and built numerous types of photometers. The results he obtained with his meridian photometer are still widely used and are the basis of many visual magnitude sequences. This was later followed by his and Henrietta Leavitt's important work on the determination of photographic sequences at regular intervals over the whole sky, from pole to pole. From his plans for the systematic photography of the heavens there materialized the world's greatest impetus to the discovery and analysis of new variable stars. In 1877 scarcely 200 variable stars were known; by 1915 over 4500 were catalogued of which three-quarters had been discovered on Harvard plates alone. Probably no other individual since Argelander had stimulated so much interest in our special field of astronomy.

As a physicist, Pickering was keenly interested in the physical properties of the stars, and his observational programs had as a clear goal the attainment of sufficient observational data to permit eventual clarification of these physical properties. The nature of variable stars at that time was not at all well understood. Even Algol-type variables (of which only five were then recognized) were not yet necessarily accepted as being eclipsing binaries (1). How very great the advancement of knowledge has been in the intervening years is evident from the following quotation from the 1880 version of an elementary text book, Elements of Astronomy written by Sir Norman Lockyer (2), the most eminent astrophysicist of the Pickering era:

> The cause of this change of brightness in variable stars is one of the most puzzling questions in the whole domain of Astronomy. Three theories have been advanced:-
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> 1. That the variable revolves in its axis; that its surface is not equally luminous in all parts; and hence it appears more or less bright, according to the part that is presented toward us.
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> 2. That the variable is accompanied by non-luminous planets, which in the course of their revolution get between us and the variable, and thus eclipse the latter either in whole or in part.
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> 3. The most recent theory is that of Balfour Stewart, deduced from his researches on the Sun, which is doubtless a variable star. He has found that the approach of a planet to our Sun increases its brightness, especially in that part which is nearest the planet. Hence he supposes that the variable has a large planet revolving round it at a small distance; that the part of the star which is nearest the planet will then be more luminous than that which is more remote, and, as the planet revolves, an

appearance of variation, with a period equal to that of the planet's revolution, will be presented to the observer.

If we suppose the planet to have a very elliptical orbit, then for a long time it will be at a great distance from its primary, while for a comparatively short time it will be very near. We should, therefore, expect a long period of darkness, and a comparatively short one of intense light - precisely what we have in temporary stars.

Compare and contrast these remarks with Pickering's own thoughts at about the same time (3). He had classified the variables into five categories:

Type I. Temporary stars.
Type II. Long period variables.
Type III. Stars undergoing slight changes according to laws as yet unknown (Examples: alpha Orionis, alpha Cassiopeiae).
Type IV. Short period variables or stars whose light is continually varying with great regularity in a period not exceeding a few days (Examples: beta Lyrae, delta Cephei).
Type V. Algol type stars.

Pickering commented that "probably different causes act in the case of the different classes." (3) For the first class one might assume "that by a collision, or by the liberation and ignition of a vast amount of hydrogen, the star was suddenly heated to incandescence, and gradually lost its light by cooling." (3) The rapidly fading emission lines of hydrogen observed in the spectrum of Nova Cygni 1876 seemed to support this view. While others expressed the opinion that the rapidity of the cooling would imply a small star only a few miles (sic.) in diameter, to him it appeared more probable, especially in view of the star's negligible parallax, that only the surface of a large star was involved, the heat being lost quickly by radiation and conduction.

For stars of his Type II variations analogous to, but more pronounced than those of sunspots might be operative. A popular view which might apply to his Type IV was that the variations were "due to the revolutions of the star upon its axis when the different portions are of unequal brightness," (3) or, if the revolving star were not spherical, "in revolving it exposed a disc of varying area." (3)

To account for the Algol type stars he proceeded to a masterly analysis of the observations, disposing of older theories of a volcanic eruption, a collision, a system of sunspots, inter-position of a cloud of meteorites, and finally proving that the eclipsing body must be of stellar and not planetary dimensions. Not only did he derive the orbit, but he also noted a change in Algol's period, "the observed times of minima of Algol seem to show that its period has undergone a dimunition during the last century. Such a change is easily explained on the theory of a second satellite. The disturbance caused by the third body, or by a resisting medium, might sensibly vary the period from year to year. The law of this change is not yet known..." (3) Already in 1783 Goodricke had noted the periodicity of Algol and correctly surmised that it could be accounted for by the interposition of a large body revolving around Algol. Pickering, however, by his orbit determination, is the first to have given positive proof.

In his discussion of short period variable stars (4), Pickering made the discovery of their concentration toward the galactic plane, a distribution not shared by the Algol stars. Most remarkably from our modern standpoint, in his list of 25 short period variables (in which beta Lyrae was included) he noted that just two, W Virginis and u Herculis, (the latter a beta Lyrae type), failed to conform to the distribution of the others. Here was the first clue to the discovery of Population II! In this paper on the short period variables Pickering also mentions in passing a theory not applicable to short period stars which might, he thought, account for his Type II long period variables, namely, variation "due to the absorbtion of a rotating mass of gas." This he felt was supported by the banded features in the spectra of the long period variables. Sufficient data for positively testing the theory were, however, still unavailable.

I had frequently heard mentioned that Pickering neglected theoretical astrophysics in preference to purely observational astronomy. Obviously his discussion of Algol, for example, demonstrates that he had the theoretical problems so well in mind that he realized that the ultimate solution of the theoretical problems would have to depend heavily upon observational evidence. Hence, Harvard under his regime specialized in the accumulation of data. In the field of variable stars, long histories of the light variations were deemed of higher priority than interpretation based on insufficient facts. Moreover, Pickering was an administrator who realized the value of segregating tasks according to the abilities and available time of his associates. Some observations of tremendous value to the professional could equally well be carried out by enthusiastic amateurs. Already in 1882 he published A Plan for Securing Observations of Variable Stars (5). Here he deplored that "Many such persons spend evening after evening at their telescopes without obtaining results of any permanent value.... Most commonly the observer has no special plan and spends many hours without result, while the same time might have been employed with equal pleasure to himself and results of great value collected." He also added "Much valuable assistance might be rendered by a class whose aid in such work has usually been overlooked. Many ladies are interested in astronomy and own telescopes, but with two or three noteworthy exceptions their contributions to science have been almost nothing."

Referring to his five types of variables, Pickering evaluated the relative feasibility of turning various aspects of the work over to the amateurs, reserving other aspects to the more experienced, and still others to the professional. In regard to his Type I stars (the novae) he commented that they occur so infrequently "that the apparent discovery of one is to be received with utmost caution." (5). Yet, if one is really found the discovery should immediately be announced by telegram to the Harvard Observatory.

Nearly three-fourths of the known variables belonged to his second type (the long period variables), and they were the ones most strongly recommended to the amateur, who should observe such stars once or twice a month and report the observations in monthly formal reports. He described methods for observation and included a questionnaire for any persons who might be interested in participating. (6)

On January 27, 1883, this pamphlet was followed by his First Circular of Instructions for Observers of Variable Stars, (6) a considerable number of individuals having signified their intention of joining in the proposed work. For several years thereafter (1884-1887) an annual summary of their observations was published in the Proceedings of the American Academy of Arts and Sciences, in much the same form that AAVSO observations have been reported over the past sixty years. The earliest years of Pickering's Directorship were thus keenly devoted (among other matters) to plans for visual observations of variable stars, culminating, after some lapses in the amateur work, with the founding of the AAVSO in 1911. The history from there on is well described by R. Newton Mayall (7). From its beginning until his retirement in 1949, Leon Campbell was in charge of the visual observations and their reduction.

Meanwhile photographic investigation of variable stars was developing rapidly, primarily under Pickering's leadership and despite the caustic scepticism of some confirmed visual observers reluctant to face change. He devised numerous techniques for the photographic discovery of variable stars. The most productive was the positive-negative method, whereby a negative was superposed over a positive from another plate taken at a different time with the same telescope. Multiple images on a single plate were also used for variables of very short period, although such plates were more useful in the analysis of short period light curves than for new discoveries. Objective prism plates, showing short dispersion spectra of multitudes of stars also yielded their crop of variable stars, particularly novae and long period variables, stars whose spectral characteristics immediately ear-marked them as variables.

In 1881 the two stars of shortest period listed by Pickering (4) were R Muscae (0.89 day) and T TrA (1.0 day), both discovered by Gould in 1871. Recent catalogues now list the first as having a period of 7.5 days, and the second as non-variable. The next shortest periods in his list were slightly over two days. The discovery in globular clusters of variables having periods on the order of half a day or less was therefore as exciting as pulsars are today. In 1889, upon examining plates taken by E. S. King at Wilson's Peak, California, (where King was site-testing to find a suitable high altitude station for Harvard Observatory), Pickering discovered the first cluster type (now called RR Lyrae type) variable in the cluster M3. Bailey soon found two others in 47 Tucanae, and in 1893 Pickering and Mrs. Fleming found one each in omega Centauri. Fascinated, Bailey then made the study of globular clusters, particularly omega Centauri, his life's work, finding over 500 and determining the periods of several hundred variables.

To Henrietta Leavitt Pickering delegated two immense and important tasks. She did the bulk of the work of determining photographic magnitude sequences, in many cases with the help of Mount Wilson plates going as faint as magnitude 20. She was also assigned the task of examining the plates on the Magellanic Clouds for variable stars. There she found Cepheid variables in unprecedented numbers (over 2000). Her discovery in the Magellanic Clouds of the period-luminosity relation is a well known story, which ultimately revolutionized the determination of galactic and extra-galactic distances.

Mrs. Wilhelmina P. Fleming became the expert on finding variable stars by means of their spectra. In 1884 Pickering first discovered bright lines in the spectrum of Mira. Mrs. Fleming soon noted that a combination of bright hydrogen lines with dark absorption bands signified long period variables. Novae were also readily detected by their unusual emission spectra. Mrs. Fleming found five! Jealousy even arose between her and the observers in the southern station in Arequipa, Peru, who examined the plates they had taken before shipping them to Cambridge, thereby depriving her of the most spectacular discoveries while she must needs search meticulously for the less glamorous objects the southern observers might have missed in their necessarily more cursory survey. (8)

In the Harvard Alumni Bulletin for March 15, 1915, "J.D.M." paid tribute to Pickering, stating, "There is no such thing as jealousy among astronomers: on the contrary the greatest cooperation prevails. Professor Pickering, the Director of the Harvard Observatory, has done much to extend and increase this agreeable and valuable relation." Alas, astronomers are just as human as other mortals. In 1894, after Pickering had published a catalogue of the magnitudes of over 20,000 stars, a former colleague and cataloguer of variable stars discovered that out of some hundred variable stars contained in the catalogue, 15 of the faintest had been misidentified. What malignment thereafter appeared in Boston's normally dignified newspaper, the Transcript! The severity of the attack was attributed to the "animus" of the former colleague.(9)

In the life of every administrator petty but temporarily disturbing incidents do occur. The errors under Pickering's regime were trivial indeed in contrast to his vast accomplishments. The photometric researches he initiated and the observations started by himself and delegated to able assistants clearly altered the trends of modern astronomy. They spanned the wide breach between the older, mainly astrometric programs dependent on meridian circles, and the new astrophysical concepts. Dr. Annie J. Cannon (10) described Pickering as warm-hearted, eager to help young astronomers, cordial, with optimism and faith in humanity. "One of his greatest pleasures in later days was the harmonius cooperation with other astronomers, both at home and abroad." If Pickering had done nothing else than accumulate the Harvard plate collection simply for others to use, he would merit the immortal acclaim of all variable star observers. This and the founding of the AAVSO are incomparable legacies to variable star astronomy by a man who accomplished a great many other things besides.

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