Minor Contributions and Notes

CORRESPONDENCE CONCERNING THE CLASSIFICATION OF STELLAR SPECTRA[1]

At the meeting of the International Solar Union held at Mount Wilson in September 1910, part of the last session was devoted to the question whether the Union should not extend its activities to include general astrophysics, instead of limiting itself to solar physics. An interesting general discussion took place and resulted in a unanimous decision so to extend the scope of the Union. This important action was immediately followed by the appointment of a Committee on the Classification of Stellar Spectra.

At the present time there are in extensive use three distinct systems for classifying stellar spectra: (1) the Draper Classification, developed by the Harvard observers, in their systematic surveys of the heavens; (2) Miss Maury's Classification, also having its origin at this observatory in the course of similar work; and (3) Vogel's Second Classification, devised at Potsdam and extensively used in spectrographic observations at that observatory and many others. In addition, the classic types of Secchi, upon which Vogel's are based, are still in common use; and Lockyer's designations, as well as those of McClean, have been used in connection with important researches.

Astronomers and physicists have long recognized the desirability of doing away with the confusion that the use of so many distinct systems has entailed. The general feeling on this subject at the beginning of this century was well summarized in the paper[2] read by Professor Frost before the Section of Astrophysics of the International Congress of Arts and Sciences, held at St. Louis in September 1904. At that time, however, there was no international organization whose scope would properly have included questions of this character.

With the object of bringing out the opinions of astrophysicists on

[1] Edited by Frank Schlesinger, Secretary of the Committee on the Classification of Stellar Spectra of the International Union for Co-operation in Solar Research.

[2] "A Desideratum in Spectrology," *Astrophysical Journal*, **20**, 342, 1904. This paper also contains a brief bibliography of the subject of stellar classification according to their spectra.

this subject, the following self-explanatory letter was widely distributed shortly after the meeting at Mount Wilson:

Nov. 7, 1910

DEAR SIR: At the Fourth Conference of the International Union for Co-operation in Solar Research, the following gentlemen were appointed to serve as a "Committee on the Classification of Stellar Spectra": Messrs. Adams, Campbell, Frost, Hale, Hamy, Hartmann, Kapteyn, Newall, Pickering (*chairman*), Plaskett, Russell, Schlesinger (*secretary*), and Schwarzschild.

This committee met at Mount Wilson on September 2, immediately after the adjournment of the Conference itself. In accordance with power to add to their number, it was unanimously decided to ask Mr. Küstner to serve, and he was present at this meeting. Messrs. Hale and Campbell, who had already left the mountain, were the only absentees.

The chairman called upon each member in turn to express his views concerning the classification of stellar spectra and his opinion as to what the scope of the committee should be. A brief summary of this discussion follows:

Mr. Adams preferred the Draper Classification,[1] and thought that if the members of the committee themselves would use this classification exclusively, until say the next meeting of the Solar Union, it would go far toward establishing uniformity. Mr. Küstner preferred the Draper Classification and was using it exclusively. Mr. Hartmann thought that the Draper Classification was the best that had been proposed, but hoped that an effort would be made to retain the Roman numerals of Secchi, that have now become classic, and that the subdivisions be made as in the Draper system by the addition of Arabic numerals; thus, II, 3. Mr. Schwarzschild suggested that instead of the letters B, A, F, G, K, M, the numerals 0, 1, 2, 3, 4, and 5 might respectively be employed; thus A2 would become 1.2, etc. In this system the number denoting the type would be proportionate to the *color-index*. Mr. Russell suggested the advisability of substituting some method for *measuring* the type of spectrum for the *estimations* that are now employed, and asked whether this could not be applied to the Draper Classification. Mr. Plaskett preferred the Draper Classification, but said that as he believed uniformity to be the prime consideration he would gladly adopt whatever system could be agreed upon. Mr. Frost thought that the committee should make no recommendation at the present time but should first canvass the whole subject thoroughly; it appeared to him desirable to investigate the visual end of the spectrum in connection with the photographic before arriving at a definite conclusion. Mr. Schlesinger preferred the Draper Classification and had decided to use it

[1] This classification is described in the *Annals of Harvard College Observatory*, **56**, 66. The letters O, B, A, F, G, K, M, and N are used to designate the sequence of the spectra. Numerals from 1 to 9 after the letter denote intermediate spectra; thus, B_3 would be assigned to a spectrum between B and A, but more nearly resembling the former.

exclusively; he called attention to the desirability of making further distinction among the numerous spectra that are now classified as A without any modifying number; he thought that any attempt to establish a temporary uniformity now might prove an obstacle to the universal adoption of some more definite system later. Mr. Newall asked whether a spectrum might be intermediate between two letters in the Draper Classification that are not consecutive, as A5G. Mr. Pickering said in reply that such cases have not arisen in practice. Mr. Newall raised the question whether the committee should not consider the matter of stellar evolution. The members present seemed to be of the opinion that this was legitimately within the scope of the committee but that its immediate business should be the establishment of a uniform system for classification. Messrs. Russell, Hartmann, Kapteyn, and Schlesinger urged that no evolutionary basis for a classification be adopted at the present time; astrophysicists are not agreed as to the proper sequence from this point of view; if our ideas upon this matter should be modified in the near future (as seems very possible), then it would be necessary to modify or to abandon altogether any system of classification based upon these ideas. For similar reasons Mr. Russell asked that the use of such terms as "early" and "late," now so frequently used in describing spectra, be discontinued in favor of "white" and "red."

The secretary was directed to secure by correspondence as full an expression of opinion as possible, from the members of the committee and others, on the matters that had been discussed. The meeting then adjourned.

In accordance with this request, the following questions have been framed,[1] and you are asked to reply to them at length. In addition it is hoped that you will give your views in full upon any other points that may occur to you as being important in this connection.

(1) It will be noticed that, at the meeting reported above, there seemed to be a practically unanimous opinion that the Draper Classification is the most useful that has thus far been proposed. Do you concur in this opinion? If not, what system do you prefer?

(2) In any case, what objections to the Draper Classification have come to your notice and what modifications do you suggest?

(3) Do you think it would be wise for this committee to recommend at this time or in the near future any system of classification for universal adoption? If not, what additional observations or other work do you deem necessary before such recommendation should be made? Would you be willing to take part in this work?

[1] The general form that these questions should take was discussed at several informal meetings on the train coming east from the meeting at Pasadena. There were present at these meetings the chairman and the secretary of the committee, Mr. Russell, and (by invitation) Father Cortie.

(4) Do you think it desirable to include in the classification some symbol that would indicate the width of the lines, as was done by Miss Maury in *Annals of the Harvard College Observatory*, Vol. **28**?

(5) What other criteria for classification would you suggest?

Although it is not the intention of the committee to frame a formal report at once, it is desirable that your answers to some of these questions should be forthcoming very soon; this is particularly the case with the third question. May I therefore request that your reply be sent, if possible, so as to reach me not later than the end of this calendar year? If you can secure an expression of opinion from any other qualified astronomer, it will be very welcome.

Very respectfully yours,

FRANK SCHLESINGER
Secretary of the Committee

Replies to these questions were received from nearly all to whom they were addressed. With the approval of the chairman of this committee, and with that of the chairman of the Executive Committee of the Solar Union, these replies are reproduced herewith:

WALTER S. ADAMS

(1) I prefer the Draper Classification to any other which has been proposed as yet.

(2) It seems to me that in the Draper system of classification some rather valuable criteria are neglected. For example, in considering the gradual increase of intensity of the "metallic lines" in passing from type B through A to types F and G the metallic or solar lines are treated too much as though they were all affected alike. This, of course, is far from being the case. Lines enhanced in the spark, for instance, are among the first which appear in the A type and attain very great strength in such stars as α *Cygni*. They fall off steadily in intensity, however, in stars of the F, G, and K types, while, at the same time, many other groups of solar lines increase in intensity. I shall refer to this further in connection with question (5). I agree with Mr. Schlesinger that further distinction is needed among the spectra now classified as type A, and I am somewhat in doubt whether the range A to F is sufficient to include satisfactorily the vast number of stars which have this general type of spectra.

It appears to me doubtful whether it is advisable to increase the number of classes in the Draper Classification by "class R" referred to in Circular No. 145 of the Harvard College Observatory. Those of these stars observed at Mount Wilson, while showing marked differences from

the typical stars of classes N and O, particularly as regards the strength of the ultra-violet spectrum, could, I think, be assigned without serious difficulty to subclasses under these two letters.

(3) It does not seem to me desirable to recommend at present any system of classification for universal adoption. If observational material accumulates rapidly in the course of the next three years, the committee might possibly be ready to make some definitive proposals at the time of the next conference of the Solar Union. At present there is not sufficient material to warrant such a recommendation. The principal deficiency is the lack of spectra of stars taken with high dispersion and especially the dearth of material obtained in the less refrangible portions of the spectrum. It is unnecessary to say that the Mount Wilson Observatory will be most glad and most desirous to aid in every way possible in the collection of additional data.

(4) It seems to me most desirable to adopt in any definitive classification some symbol indicating the width of the spectral lines. At the same time, however, to add such a symbol to the Draper Classification at present would merely introduce confusion. Accordingly, I should favor the employment of the symbol only in connection with the material which is being collected with a view to use in a future classification.

(5) I have already referred to one point in this connection in question 2. Although astronomers and physicists are by no means agreed as to the interpretation of intensity changes among various lines as bearing on questions of temperature, I think there is little doubt that some special significance must be attached to the behavior of certain classes of lines, such as the enhanced lines, for example, in stellar spectra. Whether abnormal strength on the part of the enhanced lines indicates high temperature, or some particular condition in the radiating or absorbing gases analogous to that in the electric spark, we do not as yet know. We may hope, however, that this question will be definitively settled by physicists before very long, and, in the meantime, if we can accumulate data bearing on the behavior of this class of lines, we shall be in a position, as soon as the physical evidence is available, to make a considerable step forward, perhaps on the side of stellar evolution, but certainly from the point of view of classification.

The same reasoning holds true of numerous other classes of lines; for example, the lines of titanium, vanadium, scandium, and calcium, which are peculiarly strengthened in the spectrum of sun-spots and show a very similar behavior in stars of class K and M. Closely allied to these lines are the band lines of titanium oxide, magnesium hydride, and

calcium hydride, which are also present in the spectrum of sun-spots, and of which titanium oxide at least forms a prominent feature of stars of class M.

It would seem to me that in the estimation of the relative intensities of lines or groups of lines some reasonably constant standards should be employed. The hydrogen lines vary enormously in intensity between class A and class M, and the same is true of the line $\lambda 4227$ of calcium. I would suggest that possibly the strong arc lines of iron, which occur between $\lambda 4045$ and $\lambda 4415$, might be used for this purpose. These lines appear with considerable intensity in α *Canis Majoris* and change relatively less, I believe, in intensity than any other lines as we pass toward groups K and M.

A rough determination of the blueness or redness of a star may be most valuable in the construction of a system of classification. Could not such a determination of sufficient accuracy be obtained, when photographic plates of the same kind are employed, by measuring with the Hartmann microphotometer, or some similar instrument, the intensity of the continuous spectrum at a few selected points? Such measures could be made very rapidly, and, while of course they would not serve as a basis of temperature determinations for the stars, they would be most important in anything like an empirical classification. I need only refer in this connection again to certain stars of Harvard class R. These appear to have a spectrum in all respects identical with the stars of class N, except that they are relatively much more intense in the blue and violet regions of the spectrum. Actual measures of intensity would be very valuable in the classification of these objects.

MOUNT WILSON
December 7, 1910

SEBASTIAN ALBRECHT

When the circular letter of November 7 in regard to the work of the Committee on the Classification of the Stellar Spectra reached me I was working on a paper entitled "A Quantitative Method for Determining the Stellar Spectral Types of the Brighter Stars."[1] The paper is based on the variation of the wave-lengths of some of the spectrum lines of stars, which variation is progressive with the spectral type in the Draper Classification. It is the inverse of the problem for which I published a preliminary paper in the *Astrophysical Journal* (**24**, 333, 1906) and in the Lick Bulletins.

[1] *Astrophysical Journal*, **33**, 130, 1911.

I was therefore especially interested in the circular letter; I think the idea of a committee for this problem a good one. The Draper Classification is, in my opinion, the best one available at present, and I agree with Mr. Adams' suggestion that if this classification were generally used by astronomers it would tend toward establishing uniformity. The curves accompanying my paper show that the Draper Classification represents fairly approximately the actual consecutive steps between types. In my opinion, the greatest need for improvement in the classification is for the O and B types, though here my method does not promise to yield as satisfactory results as in the types A to Mb. My present paper is for types F to Mb, though I am extending it to the A types. I have also done some work along this line for the B types of spectra. For the present, at least, this method has the limitation of not being applicable to faint stars. For the bright stars I believe it will be possible to obtain a considerable accuracy.

It is my plan to make a thorough study of this problem, and accordingly a request is being sent to several observatories for the loan of a suitable series of spectrograms.

In reply to question (3) I should think it best to wait before any system of classification be recommended for universal adoption.

CÓRDOBA, ARGENTINA
December 26, 1910

W. W. CAMPBELL

(1) The Harvard College Observatory classification of stellar spectra, which makes use of the distinguishing letters O, B, A, F, G, K, M, and N, is, in my opinion, the most useful system that has thus far been proposed. We have been using it almost exclusively for many years, both on Mount Hamilton and in the work of the D. O. Mills Expedition to the southern hemisphere.

(2) Any slight objections on my part to the Harvard classification are due to the errors which exist in assignments of types to individual stars, and do not pertain to the system itself. The numerous errors in assignments contained in earlier Harvard volumes appear to have been eliminated from the data as published in *Annals H.C.O.*, Vol. 50. The few existing errors are probably due in most cases to poor atmospheric conditions when the objective spectrograms were obtained, and in other cases to over-exposure or under-exposure of the individual spectra.

(3) I think we should not recommend at this time, and perhaps at no future time, any system of classification for universal adoption; but we should aim for a convenient system in harmony with all existing knowledge of spectra. We can scarcely hope to obtain a system so perfect at the epoch of publication that the years immediately following would not suggest modifications, at least in detail. It would seem that the question of "universal adoption" would almost take care of itself, or at least depend upon the success of our efforts.

I should like "to take part in this work," but just what I shall be able to do, either personally or through the assignment of duties to members of the Lick Observatory staff, can hardly be made clear until the ideas of the committee have taken more definite form. Stellar spectrograms in the possession of the Lick Observatory may be considered as available for the purposes of the committee in so far as they seem to apply to the problem.

(4) I think it would be desirable to arrange that the system of classification could be utilized to indicate the widths of the lines in individual stellar spectra.

(5) Before improvements on the existing Harvard classification are attempted, the committee should, in my opinion, arrange to obtain spectrograms of representative stars in the green, yellow, orange, and red. It is now easy to render commercial dry plates sensitive to exposures in these regions. It has been found from researches on the sun, on stars containing bright lines, and on stars containing both bright and dark lines, that the $H\alpha$ hydrogen line is frequently differentiated in characteristics from the hydrogen lines in the blue and violet regions. Again, the sodium D_1 and D_2 lines and the helium D_3 line can hardly fail to show significant variations from one spectral type to another. There is no doubt that the H and K calcium lines are important guides to classification. It is not impossible that $H\alpha$, D_1, D_2, and D_3, and many other lines, one or all, may be equally important.

The Lick Observatory has relatively very few photographs covering the visual regions of stellar spectra, and this is probably true of other observatories. I should advocate that the first work of the committee consist in making arrangements to secure a large number of representative stellar spectrograms covering the green, yellow, orange, and red regions.

LICK OBSERVATORY
January 31, 1911

ANNIE J. CANNON

(1) The Draper Classification, as described in Harvard *Annals*, **28**, Part II, and abridged in Vol. **56**, No. 4, seems to me the most useful thus far proposed. I have studied in detail the photographic spectra of about 4300 stars, situated from the North to the South Pole, and I find that the sequence in the order Oe, B, A, F, G, K, M, with intermediate subdivisions, is satisfactory for classifying all the observed spectra except peculiar objects.

(2) As suggested by Dr. Hertzsprung, the principal divisions heretofore designated by B, A, etc., should be called Bo, Ao, etc. This has been done in a new catalogue of the spectra of about 1660 southern stars I have recently completed, which is now nearly all in print.

Instead of Ma, Mb, and Mc, numerals should have been continued for the M stars. Ma should be called Mo; Mb, M5; and Mc might be designated by another letter, as there is as much difference between spectra of classes Ma and Mc as between Ko and Ma.

The subdivisions described in Harvard *Annals*, **28** and **56**, represent, as nearly as I could make them at the time of writing, the progressive changes in the spectra. But in the light of today's knowledge, some of the intervals do not seem to be exactly true. For instance, A5 should, I think, be called A8, as it is nearer to Fo than to Ao. A3 should be called A5. However, I have always tried to conform to the adopted intervals, so that the same letters should mean as nearly as possible the same in the different catalogues containing spectra of my classification.

(3) Not at the present time. The Harvard classification is based primarily upon the portion of the spectrum from λ 3889 to λ 4922. Other portions should be studied. I have examined the portion from $H\beta$ to D_3 for six stars of Class B and found very little that helped in the classification except the absence or presence of $H\beta'$, λ 5413. For stars of Classes G and K, it seems to me this portion should be studied to determine what relation the varying intensities of the numerous metallic lines have to the progressive changes in the spectra.

Spectra taken with the slit spectroscope should be studied with reference to their adaptation to the Harvard classification. I have made a preliminary study of the spectra of 20 stars, photographed with the slit spectroscope at the Yerkes Observatory, and of 49 at the Lick Observatory. After a little study of these spectrograms, I tried the experiment of classifying, according to the Draper notation, each of them having the dispersion of one prism. The name of the star was

concealed, and no comparison was made with objective-prism plates. It was found that the class assigned to these spectra was the same as that already adopted here, or differed by only one subdivision. Some changes appeared in the relative intensities of a few lines, which must be carefully studied. I think it is very important that all these differences should be investigated, so that we may be sure we are dealing with realities, before any definite, universal system is adopted.

(4) Yes. We must be very careful, however, to distinguish between real and apparent width. This can perhaps be done to greatest advantage with slit spectroscope photographs. The spectra classed as divisions *c* and *ac* by Miss Maury are rare and peculiar objects; for of 4800 stars whose spectra have been studied here in detail, only about 90 have been placed in those divisions. It appears from a comparison of some of the spectra of division *c* and other spectra, taken with the slit spectroscope, that the difference is more in the peculiar intensity of numerous strongly marked lines than in the real width of the lines.

(5) Peculiar spectra should be investigated. I find groups of stars in classes Ao to Go in which lines due to certain elements are strong, as, for instance, the silicon lines λ 4128.5 and λ 4131.4, or the strontium lines λ 4077.9 and λ 4215.7.

The position in the sequence of stars from Bo to B8, having also bright hydrogen lines, should be studied.

HARVARD COLLEGE OBSERVATORY
February 6, 1911

A. L. CORTIE

(1) There is no doubt, I think, that the Draper Classification is most useful, but at the same time I think that Secchi's should be retained as expressing the broad classes of the stellar spectra, i.e., stars with few lines, stars with many lines, and stars with banded spectra. It has also the advantage that one can visualize at once mentally a star of type I, II, III or IV.

(2) Not so in the Draper system of classification, especially when the numbers are appended to the letters. One does not form easily a mental picture of the difference, say, between a B3 and a B4 star. In Sir Norman Lockyer's system of classification generic names are given to classes of spectra founded upon some typical star in the class. It seems possible that a system could be devised that would retain the advantages of Secchi's, the Draper, and Lockyer's nomenclatures. In the discussion at Mount Wilson, Professor Hartmann suggested that

both Secchi's numerals and Pickering's letters should be employed; thus, IIG5. If now a typical star of this particular variety were named after this combination a visual picture of the spectrum would force itself on the observer's mind. This system, too, would be truly philosophical. We should have class II, Genus G, Species 5, and the name in brackets of an individual star.

(3) I think it would be well to recommend some scheme for universal adoption in the near future, which would only require secondary modifications with further progress of observation. Secchi's numerals will always remain, and from the general consensus of opinion at Mount Wilson, so too will the Draper letters. But the numbers following the letters may have to be altered with the progress of observation. It is well to devise a system in which the skeleton will be permanent. I should personally be willing to take part with Father Sidgreaves in any observations required for elucidating any system of classification proposed by the committee.

(4) I do not think it would be advisable to include in the classification any symbol to indicate the width of the lines; certainly not yet. It would make a system of classification too complicated.

(5) No other criteria but those already mentioned.

STONYHURST, ENGLAND
November 27, 1910

HEBER D. CURTIS

I am firmly of the opinion that no benefit could be derived by introducing any new system of classification of stellar spectra; we have too many systems at present. Any attempt to classify spectra on an evolutionary basis would, in my opinion, be most unwise at present, and would lead to further confusion in the future. I consider the Draper Classification to possess ample elasticity to allow for any expansion which may become necessary in the future. I would therefore answer the questions propounded as follows:

(1) I consider the Draper Classification the most useful that has thus far been proposed.

(2) As far as its present use by astrophysicists is concerned, I would suggest no modifications. It is quite possible that the need may arise, with the progress of spectrographic surveys with higher dispersions, to increase the number of subdivisions in the various classes of the Draper System. Such new subclasses, if needed, should be added with considerable conservatism, and their adoption should be in the hands of some central body, such as the present committee.

(3) I believe the Draper System possesses sufficient elasticity to allow for any probable future development, and thoroughly approve its immediate adoption as a standard system.

(4) I do not consider advisable the present adoption of any added symbol to indicate the width of the lines. The number of binaries showing the spectra of both components is increasing rapidly, and for such stars "wide" and "narrow" lines will recur at regular epochs. Moreover, lines classified as "narrow" in low-dispersion surveys might frequently be "wide" and unusable with higher dispersion.

LICK OBSERVATORY
November 17, 1910

R. H. CURTISS

(1) I concur in the opinion of the committee.

(2) One objection to the Draper system, which I am not inclined to urge, is that the notation is arbitrary. The original order has been disturbed and now the classification does not rest upon any suggestive scheme. Again I am not sure that the spectra now known as peculiar or composite or both will fall in with the Draper system, though they will probably yield to classification.

(3) I believe that a uniform system even if temporary should be recommended by the committee for universal adoption. Work could then be prosecuted with the object of proving such a system. Especial attention should be given to missing links, to abrupt changes between successive divisions, and to spectra vaguely known as peculiar.

(4) I think a symbol indicating the character of the lines should be used.

(5) If the wave-lengths of the lines of a spectrum are variable I think that fact should be denoted by a symbol attached to the classification letter.

ANN ARBOR
January 3, 1911

H. LUDENDORFF AND G. EBERHARD

Auf die in dem Brief vom 7ten November enthaltenen Fragen geben wir gemeinschaftlich die folgenden Antworten:

(1) Wir sind der Ansicht, dass die Draper-Klassifikation die zweckmässigste unter den bisher aufgestellten Klassifikationen ist.

(2) Gegen sie haben wir im Wesentlichen nur den Einwand, dass die Reihenfolge der Buchstaben O, B, A, F, ... wenig schön ist. Trotzdem würden wir dafür sein, diese Buchstaben beizubehalten, da

die Einführung neuer Buchstaben und Zahlen nur die Verwirrung vergrössern würde.

(3) Wir würden es für zweckmässig halten, wenn die Draper-Klassifikation *vorläufig* zur allgemeinen Anwendung empfohlen würde. Im übrigen schliessen wir uns aber der Meinung von Professor Frost an, dass namentlich erst noch das visuelle Ende der Spektra näher untersucht werden muss, bevor man entscheiden kann, ob die Draper-Klassifikation als definitiv angesehen werden kann.

(4) Es wäre sehr wünschenswert, wenn der Charakter der Linien durch irgendwelche Symbole gekennzeichnet würde. Es wird aber nicht leicht sein, zu einer befriedigenden Lösung dieser Frage zu gelangen, da in denselben Spektren Linien verschiedenen Charakters auftreten können, und da bei Anwendung verschiedener Dispersionen die Linien desselben Spektrums sehr verschieden beurteilt werden können. Ein Beispiel für die letztere Tatsache bietet der Stern η *Aquilae*, den Miss Maury zu der "Division *ac*" (Spektra mit ziemlich scharfen Linien) rechnet, während Wright von den Spektrallinien dieses Sternes sagt: "They have the general characteristics of breadth and haziness, which tend to make them objectionable for purposes of accurate measurement."

Um die allgemeine Einführung und richtige Anwendung der Draper-Klassifikation zu erleichtern, wäre es ratsam, wenn das Komité eine Liste von Normalsternen für die einzelnen Klassen veröffentlichte, und damit zugleich eine Tabelle, welche die Umwandlung der Bezeichnungen von Miss Maury, Vogel, u.s.w., in die der Draper-Klassifikation ermöglicht.

POTSDAM
Dezember 14, 1910

WILLIAMINA P. FLEMING

Having discussed the questions of classification and notation fully with Professor E. C. Pickering before his answers were sent, and having acquiesced in his statements therein, there seems very little left for me to add in detail, except what has come to me through direct, and partly recent, observations.

(1) The Draper Classification seems that best adapted for use in the study of stellar spectra, at the present time.

(2) For spectra of classes M to R, the present nomenclature seems altogether inadequate to provide for the numerous classes into which these may be subdivided, especially those of classes M, N, and R.

(3) Not at this time, nor in the near future, so far as I can judge from my own experience in classifying spectra of faint stars, obtained with

photographic doublets and using small prisms. The objective-prism plates received here recently from Mr. J. A. Parkhurst, for classification of spectra, show the faint stars with such wonderfully good definition that, from them, many differences may be obtained with certainty, which might be seen only imperfectly on our photographs here. Such, also, was the case with a photograph from which I classified the spectra of a number of stars for Professor Schwarzschild, although on his plate the definition was not good in the region between $H\beta$ and $H\gamma$.

(4) Any peculiarity in the appearance of the lines, for which no provision has been made in the Draper Classification now in use, should be indicated in some way, in order to avoid the necessity for writing notes or remarks on them.

(5) My work at the present time on "Peculiar Spectra," especially those of classes M, N, and R, seems to indicate that, in assigning any new notation, if such should be done before this work is completed in detail, scope for interpolation between spectra so designated should be allowed. Class M has already been divided into four subclasses, Ma, Mb, Mc, and Md, and it has been found necessary to further subdivide the last of these, class Md, into eleven, Md to Md 10, with one (Md 1.5) inserted even after this work was supposed to be covered. Further, the material is now available here for connecting classes N and R, and even class R might be subdivided if better photographs with larger dispersion were available.

HARVARD COLLEGE OBSERVATORY
January 3, 1911

EDWIN B. FROST

The opportunity seems particularly favorable for an examination of the whole question, *ab initio*, as if no system of classification had ever been proposed; for the organization of the Solar Union is representative of so many and widespread scientific societies that if a formal "international classification" should be proposed by the committee and then be thoroughly discussed and amended, and finally adopted by the Union at some meeting, six, nine, or more years hence, it would seem that its universal adoption ought to be assured.

In urging this thorough sort of consideration of the matter, I am not depreciating the insight and labor of those who have proposed the earlier or the later classifications: on the contrary, the acumen shown in their discriminations seems to me to be remarkable, and the later additions to and modifications of the earlier work have represented actual and

important differences in spectra. But it seems to me clear that none has adequate elasticity in providing subdivisions, or groups, for future studies made with improved apparatus and higher dispersion, and covering a greater extent of spectrum.

An examination and discussion of the possible bases of a classification would appear to be a natural preliminary to the investigations of the committee. Among these would be considered the physical differences in stars as indicated by the continuous spectrum—the wave-length of its maximum of intensity, and its extension to the ultra-violet, etc.—the condition of the star's atmosphere, as indicated by the character of its lines, whether of emission or absorption, broad or narrow, diffusely or sharply bounded. A knowledge of how their character corresponds to different kinds of electrical excitation, or how their wave-lengths vary in different spectral types, may lead to a diagnosis of the conditions of pressure in the star. Information as to the level in which the lines originate will be very useful here.

At the start the question arises: How far should a classification be made a chemical one? Obviously to a considerable extent, as this affords a very natural basis of discrimination. The presence of the lines of helium in a stellar spectrum, for instance, is most distinctive. But we shall not construe the lack of the lines of a substance necessarily to imply the absence of that element. Much valuable experimentation could be made in physical and chemical laboratories on the mutual compatibility of the different elements and compounds. Very little work has yet been undertaken in this direction.

Doubtless all agree in understanding by a chemical discrimination that the particular star is in that phase of development where the conditions favor the spectral predominance of certain elements, which may have been obscure in previous phases, and may vanish in later phases. May not this ultimately be reduced largely to a matter of temperature? It is certainly significant that the recent visual determinations of stellar temperatures by the spectrophotometer methods, by Wilsing and Scheiner, should so closely follow the commonly accepted sequence of spectral types; whether or not the absolute temperatures are correct is not material here, so long as the relative effective temperatures are reliable.

It is desirable that both branches of the temperature-curve should be recognized, in so far as their validity can be established, in any new classification, particularly for the red stars. One cannot help feeling that Sir Norman Lockyer must be right, to some considerable extent,

in his contentions on this point, even if the evidence he has thus far presented may not be entirely convincing.

The suggestions on this topic by Professor H. N. Russell in his paper at the meeting of the Astronomical Society at Harvard last summer may require careful consideration in this connection.[1] If it can be proven that of two red stars having very similar spectra one is on the rising branch and the other on the descending branch of a temperature-curve, then the classification ought to show it. If other collateral facts enable us to discriminate *where the spectra themselves do not*, it ought to be indicated; and it should not be difficult to devise symbols for the purpose. It would be safe to expect, if the conditions were real, that in the future differences in the spectra would be recognized which we do not at present realize.

The symbols adopted ought to give all the information which could be conveyed without becoming too complicated: if possible the predominant chemical elements; the nature of the lines, distinguishing between sharp and diffuse lines,[2] and indicating the presence of bright lines, if any.

Serious consideration ought to be given to whether any analogies could be adopted from the classification of natural history, as sub-kingdom, class, order, family, genus. For many astrometrical studies only the broadest distinctions are needed, as of the four types of Secchi. These might, for instance, correspond to the "class" in the sense used in natural history. It certainly would be advantageous to consider families and genera of spectra, as a minute study will in my opinion reveal numerous cases where the sequence of spectra (not thereby implying any theory of stellar evolution) has a choice of collateral branches to follow before the next group is reached. To adapt the terms, in so far as they were not letters or numerals, to universal use, it might be advantageous to employ the Latin.

In reply to the specific inquiries of the secretary of the committee, I will say:

(1) Under present conditions the Draper Classification seems to be the best one for provisional use until some action shall be taken by the Solar Union regarding an "international classification."

(2) (*a*) Some of the objections originally urged against the early form of the Draper Classification have been met by dropping the use of

[1] *Science*, **32**, 883, 1910.

[2] As was done by Miss Maury in her classification, which has many points of remarkable excellence.

certain letters, such as C, D, E, and H, which depended in part upon instrumental adjustments, and did not represent real differences in the stellar spectra. But this rectification has brought with it the serious disadvantage of discontinuity, and lack of logical sequence. This is of small consequence to us who have in a sense grown up with the photographic classifications. But we must have in mind our colleagues in other branches of science, the physicists, chemists, mathematicians, and geologists. To them a system having the order P, O, B, A, F, G, K, M, N, R surely could not carry any definite impression of a logical sequence of spectra. We must also remember the difficulties of our friends who are each year trying to teach to hundreds of students the main points of difference in stars as indicated by their spectra.

(*b*) The Draper Classification is essentially based upon plates taken with low dispersion. No one can have more admiration than I for the skill and discrimination of Professor E. C. Pickering, Mrs. Fleming, Miss Maury, and Miss Cannon in their work on the classifications successively evolved at Harvard; but there are in many respects very marked differences between small-scale objective-prism plates and large-scale spectrograms obtained with slit-spectrographs. Some of the distinctive features on the small scale are lost on the large scale. If only one scale were available, probably the low dispersion would be the one to choose for purposes of broad classification; but any system is incomplete which does not depend upon plates taken with both the low and high dispersion.

(*c*) The Draper Classification lacks subgroups at certain points. This applies particularly to type A. Under both A and A2 are necessarily included many spectra which with high dispersion are quite widely different. Further, the addition of the letter "p," for peculiar, as Ap, Bp, while doubtless necessary in the Draper Classification, cannot be permanently justified. It stands for the avoidance of an assignment. In an international study and investigation, there ought to be subdivisions enough to provide for all peculiar groups, families, or genera. One hundred groups might possibly satisfy present requirements, but the system ought to be elastic enough to provide for an indefinite number, 1000 or more.

(*d*) It seems inappropriate to discuss at this time any modifications of the Draper Classification. With his habitual courteous consideration for the views of others, Director Pickering might adopt those of the suggestions made with some unanimity, and then we should have still another classification to add to the present confusion. If the result

of the present preliminary inquiry should be favorable to the general use of the Draper system until international action is taken, it would surely be desirable to use that system as it is incorporated in the *Harvard Revision* (*Annals*, **50**, 1908), in Miss Cannon's valuable study of 1477 stars (*Annals*, **56**, 1910), and in Mrs. Fleming's forthcoming memoir on stars with peculiar spectra.

(3) I think it would be exceedingly unwise "for this committee to recommend at this time or in the near future any system of classification for universal adoption." The duty of this committee, as it seems to me, is to report to the Solar Union at its meeting in 1913, making such recommendations as it may agree upon prior to that meeting. Perhaps by 1916 the committee might have time to carry out the necessary investigations so that proposals could be made to the Union regarding an international classification.

Special and minute studies should be made of the different varieties of spectra, with the use of plates covering all the spectrum photographable, with both low and high dispersion. Perhaps the varieties of the different types would be assigned to different observers for their special investigation. Relations to stellar temperatures as derived from spectral photometric measurements and from those made with the heterochrome photometer should be examined. Work should be done in physical and chemical laboratories on the spectra of mixed gases and the suppression of spectra in such mixtures; on the relative shifts of different kinds of lines under different conditions. The physicists or chemists ought to submit hydrogen to every possible variation of laboratory conditions with a view to producing the lines discovered by Professor Pickering in ζ *Puppis* and in certain other stars. A general attack on the problem of the spectral lines not yet found on the earth might lead to new information regarding nebulum.

I should be willing to take part in the work, particularly in utilizing our collection of some four thousand spectrograms obtained with the Bruce spectrograph.

(4) As already stated, I should certainly regard it as desirable that the nature (width, sharpness, etc.) of the lines should be indicated in the classification.

(5) I have suggested above several criteria, and it would unduly protract this already over-long communication to propose others at this time.

THE YERKES OBSERVATORY
February 16, 1911

M. HAMY

Comme les autres membres du comité chargé de s'occuper de la question, je pense que la Classification de Draper répond assez bien aux besoins de l'astronomie. Je lui reproche cependant de ne pas parler assez à l'esprit. Les notations employées pour désigner les différents genres de spectres ont la mérite d'être brèves; mais je préférerais des dénominations rapellant un peu ce qui caractérise chacun des spectres. Je pense, par ailleurs, qu'il serait très utile, dès maintenant, de s'entendre au sujet de l'adoption universelle d'un système de classification, quel qu'il soit; et pour ma part, je le répéte, j'adopterais volontiers celui de Draper. Toutefois, dans mon esprit, cette adoption ne saurait que provisoire. Le jour, en effet, ou l'on sera en possession de données certaines sur la température des étoiles, j'estime qu'il faudra laisser de côté l'empirisme et classer les spectres stellaires en se fondant sur les températures de ces astres, ainsi que Lockyer a voulu le faire en partant de considérations theoriques.

Au cas où le système de Draper serait adopté, je suis d'avis de rejeter l'emploi de symboles complémentaires destinés à fournir des indications sur l'aspect des raies, non que cette indication soit inutile, mais parce que je suis concerné de la complication. Un instrument perfectionné mais de maniement complexe rend souvent moins de service qu'un autre plus rudimentaire qui a pour lui l'avantage de la simplicité.

PARIS
Novembre 19, 1910

J. HARTMANN

(1) Als *vorläufiges* System ist das Draper System das beste, wenn es auf genauere Bezeichnung des Spektraltypus ankommt. In *sehr* vielen Fällen ist es jedoch gar nicht nötig und in noch viel mehr Fällen überhaupt gar nicht *möglich* einen Stern genau in eine der Draper-Abteilungen einzuordnen. Ich halte es daher für das *erste* Erfordernis einer allgemein brauchbaren Einteilung, dass sie zunächst alle Sterntypen in ganz wenige *grosse* Gruppen einteilt, die sich stets, auch bei schwachen Sternen leicht unterscheiden lassen. Jede Klassifikation, die sofort alle Sterne in zu viele verschiedene Gruppen einteilt, ist nicht nur zu schwerfällig, sondern überhaupt unbrauchbar. Historisch zeigt sich dies auch darin, dass alle Benutzer anderer Klassifikationen nebenher immer noch die Bezeichnungen Secchis I, II Typus benutzen.

Ich meine also dass man als *oberste* Einteilung die Secchi'schen Typen beibehalten soll—jeder kennt sie und jeder benutzt sie heute.

(2) Als zweite Grundregel schlage ich vor: Es soll nicht eine Klassification der Sterne oder ihres physikalischen Zustandes, sondern eine rein äusserliche Klassifikation der Spektra sein. Es kommt nur darauf an, dass jedes Spektrum durch ein Symbol möglichst kurz und genau charakterisiert wird, ohne dass durch das Symbol irgend etwas über den physikalischen Zustand des Sterns gesagt werden soll. Diese Verknüpfung des Symbols mit bestimmten physikalischen Begriffen ist erst Gegenstand besonderer Untersuchungen, die im Laufe der Zeit zu ganz verschiedenen Resultaten führen können; solche verschiedene Folgerungen sollen aber keinen Einfluss auf das Symbol und die Klassifikation haben.

(3) Es empfiehlt sich nicht, zu schnell ein neues Bezeichnungssystem aufzustellen. Am besten wird es sein, vorläufig die kombinierte Bezeichnung Secchi+Draper zu benutzen, also etwa IB5.

(4) Für die wichtigste Aufgabe halte ich zuerst die Aufstellung von "Repräsentanten." Man soll alle vollkommen identischen Spektra verschiedener Sterne zusammenordnen und aus jeder solchen Gruppe den hellsten Stern, dessen Spektrum am leichtesten zu erhalten und genauer zu untersuchen ist, als Repräsentanten der Gruppe betrachten. Ich schlage vor, diesen Teil der Arbeit zunächst in Angriff zu nehmen und die Debatte über die Repräsentanten zu eröffnen. Erst wenn die Repräsentanten festgestellt sind, wird man nur diese zu klassifizieren haben. Bis zur Annahme definitiver Symbole wird es sich empfehlen, zur Charakterisierung eines Spektrums den Repräsentanten des betreffenden Spektraltypus zu nennen.

(5) Ueber die Kriterien, nach denen die Klassifikation erfolgen soll, wird man besser erst beraten, wenn die Frage der Repräsentanten vollkommen erledigt ist. Es handelt sich dann nur um die Ersetzung des Sternnamens des Repräsentanten durch das Symbol.

So viel es meine Zeit und meine Hülfsmittel hier zulassen, will ich gern meine Mitarbeit zur Verfügung stellen.

GÖTTINGEN
Februar 7, 1911

EJNAR HERTZSPRUNG

The spectral classification of stars should be made so that the designation of spectrum is connected in a simple way with other physical properties. If only one sequence of designations is used, as in the *D.C.*, the spectrum should be connected linearly with the color-index, m (*photogr.*) $-m$(*vis.*). Now the *D.C.* Classification nearly fulfils this condition, as the increase in color-index is about $0^m.4$ for each spectral class. I should

recommend that the *D.C.* Classification be modified so that the relation between the spectrum and mean color-index will be exactly linear. The modification needed will not be greater than the systematic differences now existing between the different Harvard Catalogues (the spectrum F in *D.C.* is generally called F5 or F8 by Miss Cannon) joined together in the *H.R.*

To distinguish the rough classification of the *D.C.* from the later more precise ones in the same system, I use Ao (A zero) for simple A, etc.

Great care should be taken to get the spectral classification independent of the brightness of the stars.

An imperfection in the present use of the *D.C.* scale is the inequality of the tenth-divisions. Certain tenths, as 5 and 2, are much more numerous than others, as 7, 4, and 6. It would perhaps be practicable to make a continuous scale of spectra exactly corresponding to the color-index scale and with the aid of an arrangement like that of the Hartmann microphotometer to determine the scale-reading corresponding to the spectrum examined.

A subdivision or second co-ordinate of spectral classification may in the future be connected with the absolute brightness of the stars. At the present time this can be done only in a very imperfect way, as we have still no spectral equivalent of the great difference in absolute brightness between such stars as *α Boötis* and *70 Ophiuchi* or *α Tauri* and *61 Cygni*, which are in pairs ranked in the same spectral class and subdivision (XVa, remark 184, and XVIa). For the "earlier" spectral types we have the valuable subdivisions *c* and *ac* of Miss Maury, which spectral distinctions are criteria of great absolute brightness. Using the *D.C.* classification the *c* and *ac* properties should at least be indicated by the letter *p* (peculiar), which has occasionally been omitted, for example from the very peculiar star *α Cygni*.

Therefore, with the above-mentioned modifications, I recommend at present the use of the *D.C.* classification. As the most important problem now I consider the exploration of the connection between absolute brightness and spectrum. The recent discovery of star-streams among the *Orion* stars by Kapteyn and Eddington holds out a prospect of getting the absolute brightness of such stars, the parallaxes of which are not directly measurable.

Accordingly I imagine for the future a spectral classification in two co-ordinates, the one giving the normal color-index and the other the normal absolute brightness corresponding to the spectrum observed.

POTSDAM
December 2, 1910

S. S. HOUGH

I concur in the general opinion put forward that the Draper Classification is the most useful that has thus far been used, and the most convenient one at the present time on which to base any system for general adoption.

The chief objection to the Draper system to my mind is to be found in its nomenclature rather than in its actual classification. While the essential feature of the system is the existence of a more or less regular sequence between the various types, the symbols by which the leading types are denoted follow one another in an apparently arbitrary manner, having no relationship to the order in which the types occur in this sequence. I would suggest that if any system is to be proposed for universal adoption, the Draper sequence should be utilized, but the various classes should be designated by a sequence of symbols following either a strictly numerical or a strictly alphabetical order. The former is doubtless open to objection on the grounds that it suggests quantitative relationships between some characteristic properties which differentiate the classes.

The chief objection to the latter is the departure from existing practice which has already in some measure become established. To avoid confusion with existing notation the principal types might be indicated by letters of the Greek alphabet. Arabic letters attached could then serve for the further subdivision of types and numerals for interpolation between types as in the Harvard notation.

Such a scheme would have the advantage that the committee would be in a position to decide the number of typical classes without reference to the existing classification, except so far as that the same sequence would be involved, and to give a precise definition of the characteristics peculiar to each class by reference to a particular typical star.

While the system should be made as elastic as possible to provide for typical deviations from the leading types selected, I think a too minute classification at present neither necessary nor desirable. What is required is a notation which should be suggestive in character and the significance of which should be absolutely free from ambiguity.

This I would consider the most far-reaching step which could with advantage be taken at the present time. It is not improbable that the early future may indicate some natural system of classification founded on a physical or chemical basis rather than a purely optical one. Any system previously introduced would almost certainly have to give way to a new one founded on such considerations. Until this stage is reached,

any modification of the Harvard system, which on the whole seems to meet the practical requirements of an empirical classification, appears to me undesirable except in the direction I have indicated.

CAPE OF GOOD HOPE
December 20, 1910

F. KÜSTNER

Bei unserer jetzigen Kentniss der Sternspectren erscheint es mir zur Zeit nicht möglich an die Stelle der Draper Classification eine besserer zu setzen.

Ich empfehle deshalb, diese Classification vorläufig und so lange, bis die Fortschritte der Beobachtung von selbst eine Aenderung verlangen werden, beizubehalten; und auch an ihrer Art der Bezeichnung nichts wesentliches zu ändern, da dies nur zu Verwirrung führen würde.

Für dringend notwendig halte ich es, das rothe Ende des Spectrums bei möglichst vielen Sternen photographisch genauer zu untersuchen.

BONN
Dezember 19, 1910

H. C. LORD

There is one aspect of the classification of stellar spectra that I have had some experience with, and have found a great deficiency in the existing catalogues in this respect. My trouble can best be shown by an example. Suppose I wished to measure the velocity of a certain star, the first thing that I would want to know is what its spectrum looks like. I turn to the Draper catalogue and find it classed as B_3; I then find a description of B_3, but at best such a description falls far short of a good enlargement of a typical spectrum of class B_3. It would seem to me, therefore, of the utmost importance that whatever classification is adopted, it should be accompanied with a photographic catalogue of typical stellar spectra, so that if one finds a star of type B_3 he can turn to a picture and see what B_3 looks like and not have to depend upon a description by someone else.

My second trouble is closely akin to the above. Suppose two stars, A and B, are photographed at Harvard with their greatest resolving power and A is found to have broad hydrogen lines and nothing more, while B is found to have the hydrogen lines narrower than A, though still broad, and in addition a number of very fine other lines. Now it can be easily shown from the principles of physical optics that if star B were to be photographed with a spectroscope of much smaller resolving

power, the resulting photograph would show very broad hydrogen lines and nothing else. It would seem to me, therefore, that the above-mentioned catalogue should contain photographic enlargements of spectra taken with different instruments covering as wide a range of resolving power as possible. Then any observer, knowing his own instrument, could tell at a glance about what to expect from spectrograms of a star classed as of a given type.

To answer your questions:

(1) I agree.

(2) Lack of photographic catalogue of typical spectra as explained above.

(3) (*a*) I think now is as good a time as any.

(*b*) Additional observations as outlined above should be made but they had better be made after the adoption of the classification than before.

(4) No. Pictures are better.

EMERSON MCMILLIN OBSERVATORY
January 9, 1911

J. LUNT

(1) It seems necessary to distinguish the several classifications emanating from the Harvard College Observatory at different times by quoting the year of publication. The name Harvard Classification seems to me preferable to Draper Classification and I would distinguish the following:

"Harvard Classification 1890."
"Harvard Classification 1897."
"Harvard Classification 1901."
"Harvard Classification 1909."

As further modifications are almost certain to be introduced in the future this would provide a short reference title for each classification. Although the 1909 Classification is based on and closely follows the 1901 Classification, there are differences of more or less importance; e.g., in the former classification we find the abbreviation of the symbols of the classes, the different choice of typical stars, the inclusion of Class N, the absence of reference to other classes (P and Q).

The 1897 Classification contains classes C and L, which are not so named in the later ones but still are used in recent work.

I concur in the opinion that the Harvard (or Draper) Classification 1909 should be the *basis* of a system for universal adoption, it being

understood that modifications in detail would be made as our knowledge of differences of stellar spectra became more complete.

In details, however, I think none of the published Harvard classifications is perfect and that even the latest should be modified in certain ways before being put forward for universal acceptance.

(2) The symbols for the subdivisions of the classes should be uniform throughout. Having started with Oa, Ob, Oc, Od, Oe, I think it would be an advantage to continue Ba, Bb, Bc, Bd, Be, uniformly with classes O and M, instead of using numerals which have a decimal meaning. This decimal division is unsuited for the subdivision of *all* the class intervals and there are great practical difficulties in deciding whether a given spectrum is 8 or 9 tenths of the interval between two types.

There should be only *one* typical star for each class and that one the brightest example of its class. The 1901 and 1909 classifications between them sometimes give three typical stars, which introduces confusion. Let each class symbol refer to one star only.

α *Boötis* as type star for class K is preferable to ϵ *Scorpii*.

α *Orionis* as type star for class Ma is preferable to γ *Hydri*.

Wherever possible I would refer to stellar types (except in tables) by naming the type star, e.g., *Sirius* type, *Canopus* type, *Procyon* type, *Aldebaran* type, using the noun as an adjective.

I agree with Mr. Schlesinger that a further subdivision of class A is necessary.

Spectra might with advantage be further differentiated in subgroups having additional suffixes to present symbols such as Ba, Baa, Baaa, or Ba, Ba^2, Ba^3. This would be a convenient way of including new typical stars which differ appreciably from the nearest type star. Where a bright-line star has the same composition as a dark-line star, I would class it with the dark-line star and add β to the suffix, e.g., $Ba^2\beta$. The suffix W might also be used to indicate spectra with wide diffuse lines.

In the 1901 Classification ϵ *Canis Majoris* and β *Crucis* are classed as B1A under type star β *Centauri*. I consider that the first-named star should be used as a type star as the best example of a star showing oxygen lines. In the 1897 Classification *R Leonis* is classed as XXa under type star o *Ceti*, although its spectrum is very different. The nature of composite spectra should be indicated by bracketed symbols.

(3) I think it would be wise for the committee to recommend, not at present but in the near future, a slightly modified and improved classification based on the Harvard 1909 Classification, on the understanding that it is always open to revision by a standing committee

deliberating yearly; and as a preliminary step I should be in favor of printing the classification—with whatever modifications are, in the immediate future, approved by the committee—as a separate circular containing a fuller description of each typical star, including wavelengths and origins (where known) of its distinctive lines, and a photograph of its spectrum marked in such a way as to call attention to its distinguishing features. The photographs should be as far as possible on the same scale. This would give a working basis for the full discussion of the question. Very few observatories possess photographs of all the star spectra used as types in the Harvard Classification. In many cases objective-prism photographs are alone available, but wherever possible photographs taken with a slit spectroscope should be reproduced. This seems to me the first step toward a full discussion of the subject by all who are interested in it.

(4) I agree with Miss Maury in placing in separate subgroups spectra in which (*a*) all lines are exceedingly narrow and sharp and (*b*) all lines wide and hazy. The symbol for the latter I would suggest should contain *wd*—wide diffuse, and for the former *ns* or *nf*—narrow and strong or narrow and faint.

(5) The fundamental criterion for classification should be a chemical one. Wherever a new group of lines appears as we pass from simple hydrogen stars, a new symbol should be employed. Spectra in general need to be still further differentiated into subgroups and varieties by adding to existing symbols in the way I have suggested.

The Roman numerals of Secchi should in my opinion be discarded entirely as no longer adequate. Their retention would only add confusion and complicate the Harvard notation unnecessarily.

At the present time I think that an evolutionary basis of classification is premature, but the terms "early" and "late" are so convenient and so frequently used that I would continue to use them in preference to "white" and "red" (which have a more restricted meaning), even though they may ultimately have to be abandoned.

CAPE OF GOOD HOPE
December 14, 1910

ANTONIA C. MAURY

(1) The Draper Classification appears to me to express satisfactorily the most detailed information in regard to the largest number of stars. As a somewhat different classification was proposed by me and published in *Harvard Annals*, **28**, Part I, I may say that the latter represented an

attempt to discover and exhibit the natural sequence of type as revealed in high-dispersion spectra of bright northern stars; and that, as this sequence showed continuous transformation by barely perceptible changes or gradations, the groups into which it was divided were necessarily somewhat arbitrary. The twenty groups named by successive Roman numerals, into which the series consisting of stars of Secchi's I, II, and III types and of those of *Orion* and helium type was divided, were based mainly on least readily definable differences. As these groups, with a few exceptions, have been represented in the Draper nomenclature, and as the Draper symbols, when placed in order O, B, A, F, G, K, M, with their appended arabic numerals, express the sequence presented in *Harvard Annals*, **28**, Part I, the change of symbol does not seem of moment.

(2) However, it does seem to me important that in a final classification this sequence, which shows in so very marked and wonderful a way the gradual transformation of spectral type, and must in some manner express the law of stellar evolution, should be represented either by numerals in natural sequence or by letters in alphabetical order. If this be not done, the attempt to grasp in thought the evolutionary changes and fix in memory the places of individual stars becomes bewildering.

As, however, main divisions of type clearly exist, it would seem well to represent these by letters, adding arabic numerals for intermediate stages, as has been done in the Draper system. But why could not the Draper letters be rearranged in alphabetical order for a final nomenclature?

Moreover, might not the classic numerals of Secchi be retained to represent, as they actually do with the exception of the helium stars, the great fundamental types? The alphabetic groups would then be subdivisions under them.

(3) It seems to me to be of supreme importance that the system to be finally and universally adopted should be *evolutionary*. The main difficulty at present in the way of this would seem to be our ignorance as to the place in the sequence of the groups of rare stars, as the bright-line stars of V type newly discovered at Harvard, as well as *Novae* and others.

We cannot but recognize, however, the gradual transformation of type from stars of Draper class B, through A, F, G, K, M, i.e., from the *Orion* or helium type through Secchi's types I, II, and III. This is shown in an unmistakable manner in the Harvard photographs of high disper-

sion, discussed in *Harvard Annals*, **28**, Parts I and II. And the transition from Secchi's type III to type IV (Draper M to N) was proved by photographs taken at the Yerkes Observatory.

Since, then, the vast majority of stars evidently fall in this sequence, there would seem to be little doubt that it represents the main outlines of stellar evolution.

The transition from O to B, that is, from "V type" bright-line stars to the helium type, was also well shown by Miss Cannon in the case of stars discussed in *Harvard Annals*, **28**, Part II. Yet the scarcity of stars of this kind raises a doubt whether they represent a universal phase of evolution or merely an occasional one. The same may be said of other rare types. Obviously, however, this small sprinkling of peculiar stars should hardly stand in the way of the evolutionary classification of the main body of stars.

As to the question whether the order O, B, A, F, G, K, M, N should be reversed, the evidence seems to me almost conclusive against this. For, if we reverse the order, we should have to assume either that cooling stars change from red through yellow and white to blue, instead of pursuing the opposite course, or else that such stars, as, for example, the sun, are growing hotter instead of cooler, which seems unlikely. The high light-intensity in the ultra-violet of B and A stars and the gradual falling off of light in this region and later in the blue, with advance toward Secchi's types III and IV, seem clear proofs of loss of energy by radiation.

Again, the vast atmospheres of hydrogen and helium of B and A stars, when contrasted with the heavier metallic atmospheres of solar and third-type stars, seem clear evidence of an early stage of condensation; while the banded spectra of stars of type IV, indicative of still heavier vapors, scarcely permit us to doubt that they are the most advanced in condensation of all. The fact also that nearly all *Algol*-variables are helium or B stars is necessarily accepted as evidence of light weight in the latter. So that, were we to reverse the commonly accepted order, we should have to assume that the solar and even the deep-red stars with fluted spectra are growing not only hotter but also rarer, which seems out of the question.

Finally the overwhelming predominance of helium or B stars in great nebulous regions as those of *Orion* and the *Pleiades* seems to prove irresistibly that the helium stars are in an early stage of formation from the nebulae.

These considerations strongly suggest the conclusion that the order

of the sequence from O to N is altogether unlikely to be reversed by further study and investigation.

(4) In regard to stars classed by me as series *b* and *c*, parallel to the normal series, I would say that the distinctions recorded were, in the majority of cases, unmistakable, and readily evident to anyone familiar with the photographs. The *b* variation consisted in unusual width and haziness of lines and did not affect their relative intensity, so that it would appear to call for some purely physical explanation, as, for example, rapid rotation.

The parallel series *c*, on the other hand, showed special lines of enhanced intensity as well as great sharpness in all the lines, and narrowness noticeable especially in lines of hydrogen and helium. In such stars as *α Cygni* and *β Orionis* these peculiarities were very striking. They must indicate important differences of constitution in these stars, which seem to pursue a line of evolution that, through a portion at least of its course, deviates from the normal. The study made by Dr. E. Hertzsprung (see *Astronomische Nachrichten*, **179**, 373, 1909; and articles by the same observer, "Zur Strahlung der Sterne" in *Zeitschrift für wissenschaftliche Photographie*, **3**, 429, 1905; **5**, 86, 1907) led him to the conclusion that these stars are bodies at great distance and of supernormal light-energy.

In *Harvard Annals*, **56**, No. IV, pp. 113, 114, Miss A. J. Cannon gives a list of stars showing enhanced silicon lines, and another list of those in which λ 4077.9, believed to be due to strontium, is unusually dominant. These classes of stars, like the *c*-stars, form collateral series, all such variations, however, ceasing as Secchi's type III is approached.

It would seem that these, and any other parallel series possible to trace, should in a final classification of spectral groups be clearly distinguished, since a study of their variant lines would seem likely to prove extremely suggestive in investigations as to the real nature of stellar evolution.

HASTINGS-ON-HUDSON, N.Y.
January 1, 1911

J. A. PARKHURST

(1) I have used the Draper Classification in classifying over a thousand spectra taken with the Zeiss objective-prism and doublet, the spectra having a dispersion of 2.34 mm between $H\beta$ and $H\epsilon$. The color-curve of the doublet is flat from $H\gamma$ well out into the ultra-violet, the focus for $H\beta$ being slightly longer; so that the region from $H\beta$ to

the ultra-violet was available for the classification. Though the scale of the spectra is very small, the resolution on good plates is somewhat better than the engraving in *Harvard Annals*, **64**, for the types A to G, but rather poorer than the engraving for types K to M. For classification of spectra between B and M on this small scale the Draper system seems to me to be satisfactory. It is much more useful to me than Secchi's would be, and it would be practically impossible for me to use Vogel's system, since his criteria are mostly invisible on this scale.

The Draper system seems to be substantially complete within the limits mentioned, for I have found no spectra which fall without the sequence. Another reason for my liking this system is that the curve connecting the "color-index" and the spectral type is very nearly a straight line, when the distances between the letters A, F, G, K are platted equal.

(2) As a sort of a modification of the system I would suggest a little more definite statement of the criteria so that fractions of a division between types F, G, and K could be measured with a precision comparable with the fractions between A and F. It is possible to measure the width of the Fraunhofer K line, as compared with $H\delta$ and $H\epsilon$, and so determine the classification between A and F. It would seem possible to use the solar G group and the calcium 4227 line in a similar way, to get a numerical measure of the classification between F, G, and K. It would probably be necessary to measure also the opacity of the continuous spectrum, as a check on the measures of width of lines.

(3) It seems to me that the visual and the ultra-violet portions of the spectrum should be taken into account in fixing upon a plan to recommend for universal adoption. I expect to do some work on the visual region soon.

YERKES OBSERVATORY
January 5, 1911

EDWARD C. PICKERING

(1) The daily use of the Draper Classification of stellar spectra for more than twenty years has satisfied me that it is very convenient for a large portion of the stars. Also, that for the principal classes of spectra it is a natural system, and that while the names may be changed, the principal subdivisions must be retained, permanently. In the sequence B, A, F, G, K, M, the letters A and B might be interchanged. But A is a great group including half the stars in the sky, while B appears to represent a few very large, distant objects occurring in certain regions only.

(2) See also (4). The most important modifications to be recommended are to extend the classification. Thus, the classes Ma, Mb, Mc, and Md differ from each other more than classes G and K or K and M. These subdivisions had not been discovered when the letters were assigned. The divisions of Md also differ widely. In some, Hγ is ten times as bright as Hδ; in others, Hδ is ten times as bright as Hγ. If new letters should be assigned to the fundamental types (which is not advisable) separate letters should be assigned to Ma, Mb, and Mc, and Md should be further subdivided. The present notation does not lend itself well to peculiar spectra, like those of nebulae, novae, and stars of classes O and R.

(3) It would not be wise for this committee to recommend a system of classification until the laws of evolution of stars are fairly established. In order that the class of spectra should be measured instead of estimated, as proposed by Professor Russell, it would perhaps only be necessary to measure accurately the intensity of different portions of the spectrum. I hope to undertake this work, but the errors introduced by such measurements would probably be larger than those in classifying the spectra. The reverse would probably be the case if the intensity of the photographs was measured mechanically by means of a bolometer, radiometer, or other similar instrument. Approximate results could also be obtained by comparing the photographic and photometric magnitudes. This is the most practical method for very faint stars. The last of these methods is in use here, and the first method will probably be tried. I should be glad to do my share of any investigations that would aid the work of the committee.

Photographs of many stellar spectra have been taken here with isochromatic plates, but the yellow portions have not proved of much use in classifying the spectra.

By the courtesy of two members of the committee, fifty excellent photographs of stellar spectra taken with the slit spectrographs of the Yerkes and Lick Observatories have been sent here for examination. A careful study is now being made of them.

(4) Yes. With an objective-prism, increased width of lines is not easily distinguished from change in focus of the telescope. With a slit spectroscope, the comparison spectrum shows that a widening cannot be due to this cause. The width of two lines compared with their distance apart could in some cases be well estimated or measured.

HARVARD COLLEGE OBSERVATORY
November 21, 1910

J. S. PLASKETT

(1) The Draper Classification is the most useful scheme hitherto proposed, but it is possible that it might be improved upon in some respects.

(2) The principal objection to the Draper Classification occurring to me is that the designations of the different types of spectra do not of themselves suggest anything in regard to the character of the spectra, and are in this respect arbitrary and unsatisfactory. It is true that familiarity with and use of the Draper system soon diminishes the weight of this objection, but for those using or referring to it occasionally, a system of nomenclature which would at once suggest the type of spectrum designated would be a decided advantage, and I would suggest that the committee consider the possibility of such a modification. Would it be possible to combine the simplicity and the universally known features of Secchi's nomenclature with the more complete, systematic, and consecutive division of the spectral types in the Draper Classification? There is, of course, the objection that one would have a tendency to associate the order of the numerals therein used with the order of stellar development, and this, considering the present state of our knowledge of stellar evolution, would be inadvisable. A similar objection may be urged to the designations of the Draper subdivisions in that they are always used in one order, thus always A4F never F6A, tacitly assuming that stars develop from the A to the F types, and not, as may be possible, from F to A.

(3) In my opinion, the question in all its bearings should be discussed as fully as possible by correspondence, so that at the next meeting of the Solar Union at Bonn in 1913, the committee may be prepared to recommend some scheme of spectral classification for universal adoption. It does not seem to me advisable to formulate any system before that date, as it can only be put into satisfactory shape after personal meetings and discussions among the members, and such meetings will not likely be possible until the next Solar Conference. On the other hand, the only thing that would justify a longer delay than that necessary for a full consideration of the question would be the chance of obtaining, in the near future, some more positive knowledge of the order and process of stellar evolution than we at present possess. The probability of a final solution of that problem is not, in my opinion, sufficiently great to justify a long postponement of the advantages that will undoubtedly accrue from the adoption of some uniform system of spectral classification.

It seems to me desirable before a definite classification is adopted that some work be done on the red end of stellar spectra up to and including $H\alpha$. It is possible that very valuable criteria for the division and distinction of the various types may be obtained from the behavior of some of the lines, such as the sodium D, the helium D_3, and the magnesium b, between $H\alpha$ and $H\beta$. It would be necessary to obtain, with a reasonably high dispersion, not less than 50 Å per mm, photographs of the red end of the spectrum of representative stars of the different spectral subdivisions, before it could be determined whether any modifications of existing divisions would be required. Such work and any further work that might develop I would be willing to take part in.

(4) It seems to me to be essential, or at least very desirable, in any complete system of classification, to introduce some method of representing the width of the lines. It is undoubtedly true that there is frequently much greater difference in the appearance of two stars of the same type, one with wide and one with narrow lines, than between two stars, each with narrow lines, of types one or more subdivisions apart. It may not be necessary to introduce a separate symbol to represent the character of the lines. If we consider all spectra with sharp or moderately sharp lines as normal, and represent them in the ordinary way, then spectra with diffuse lines might be differentiated from the normal by the use of the same distinguishing letters and figures but in different type, e.g., sloping or italic.

OTTAWA
January 26, 1911

HENRY NORRIS RUSSELL

(1) Yes.

(2) None, except some details of notation referred to later.

(3) It seems to be generally admitted that the classes O, B, A, F, G, K, M, N correspond in a general way to the principal types of stellar spectra. If the same unanimity of opinion on this point that was in evidence at Mount Wilson should appear on more extended correspondence, I think the committee might recommend at once that they be generally adopted in preference to other existing systems.

The detailed classification, however, demands a careful study of the minor differences among spectra and also of the most convenient notation for expressing them, and this will take some time, and require a good deal of discussion.

The most important observational work seems to me to be the study

of the yellow and green regions of the spectrum. This is obviously *necessary* before any definite classification can be attempted.

Next to this comes the study of plates taken with slit spectroscopes with reference to the width of the lines, etc. I believe this is already under way.

I would add the suggestion that a comparative study should be made of the spectra of stars of very different total luminosity but the same spectral class (Hertzsprung's "giant" and "dwarf" stars). If any definite and constant *spectroscopic* differences exist, they will be of value in classification.

(4) Hertzsprung's work (see *Astronomische Nachrichten*, **179**, 373, 1909) shows conclusively that the fineness of the spectral lines is of great astrophysical importance. The object of the study suggested in the last paragraph would be largely to find the analogous difference among the redder stars. Such differences should be certainly taken into account in a satisfactory classification.

(5) In my opinion, the classification should be based exclusively on a study of the spectra, i.e., of the *line and band absorption*, without reference to color, intrinsic brightness, and the like, much less to theoretical considerations. External considerations should be admitted only (1) in the search for differences, *perceptible in the spectra themselves*, which might otherwise escape notice; (2) in determining which of numerous small differences are entitled to specific rank.

For example, I find while studying the relations of mass, brightness, etc., among the fainter stars, that those of type K seem less homogeneous than the others, and this suggests the desirability of closer definition of its limits, especially toward type M. Here the visual region will doubtless be of great importance.

The Draper Classification seems to me all the better because the letters are not in alphabetical order. This helps to keep the novice from thinking that it is based on some theory of evolution. The decimal notation for those finer differences which are of the nature of gradations between the types is admirable. It should be *reserved for this purpose*. If the types of spectra now denoted by Md1 to Md9 are not stages in a gradation from Md to something else, some other notation should be devised for them.

The use of small Roman letters a, b, c . . . . for other subdivisions of a type not in the nature of a transition toward the next seems also to be excellent. I would suggest for discussion the use of some definite letter (perhaps *l*) to denote the presence of bright lines. Other letters

might be used for other frequently occurring peculiarities, leaving *p* (which is now rather overworked) for the more exceptional cases, to be explained in footnotes; and, in rougher classification, as a general indication of abnormality. The width of the spectral lines might be denoted by Greek letters (e.g., α narrow, β medium, γ broad). The letters *a*, *b*, *c*, used by Miss Maury, are pre-empted for types O and M.

Absence of a given sign should in general denote *deficiency of information* about the characteristic in question; e.g., a spectrum between B9 and A1 should be called A0 (as suggested by Professor Pickering), leaving A (without affix) as a general rough designation for spectra not nearer B or F. Similarly, every case where the width of the lines is known (whether it is normal or not) should have a Greek letter.

The symbols denoting peculiarities of spectrum would of course be exceptions to this rule. It might perhaps be desirable to devise some notation for a moderately rough classification by half-classes, as say F+ for a spectrum nearer to F5 than to F or to G, reserving F5 for spectra definitely classified as not F4 or F6.

In defining the exact limits of the broader classes, e.g., whether B8 and B9 should be counted as B or A, extraneous data, such as the average proper motion, may in my opinion be used to advantage; and the same may be said of the assignment of those decimal subdivisions now practically disused, e.g., K3, K7, K8, K9. The subclasses of type K in particular may need revision with the aid of the visual region of the spectrum, and here observations of colors may be of use.

When agreement on the details of classification is reached, a series of type stars should be chosen, preferably several for each subdivision, and these should be taken as its permanent definition.

PRINCETON UNIVERSITY OBSERVATORY
December 31, 1910

J. SCHEINER

Zu dem Vorschlage, eine allgemein einzuführende Classificirung der Sternspectra aufzustellen, und der Anfrage ob hierzu die Draper Classification für geeignet gehalten wird, möchte ich folgendes bemerken.

Eine solche Classification muss eine so gute sein, dass sie nach unseren jetzigen Kenntnissen nicht verbesserungsdürftig ist. Sie muss mnemotechnisch einfach sein, und ganz bestimmte Grundgedanken müssen in ihr zum Ausdruck kommen.

(1) Die Draper Classification erfüllt beide Bedingungen nicht; sie ist nicht einfach, und die beiden Grundprincipien der Eintheilung,

Breite der Linien und das Auftreten bestimmter Elemente, wird nicht klar auseinander gehalten. Die Argumente, die Buchstaben A, B, etc., befinden sich nicht einmal in den richtigen Reihenfolge. Wenn sie sich den jetzigen Kenntnissen auch besser anschliesst als die 2te Vogel'sche Classificirung, so ist letztere dafür bequemer und einfacher; aber auch sie wäre nicht ohne wesentliche Aenderungen einzuführen. Ich kann mich daher dem Vorschlage, die Draper Classification allgemein einzuführen, nicht anschliessen.

(2) Einen bestimmten Vorschlag zu einer neuen Eintheilung oder gar den Entwurf zu einer solchen möchte ich nicht machen, da ich mit den neuesten Untersuchungen, welche die spectralen Erscheinungen mit anderen Factoren (Eigenbewegung, Parallax, etc.) in Verbindung bringen, nicht genügend vertraut bin. Es scheint mir aber so, als wenn auch diese Dinge in einer neu aufzustellenden Eintheilung eventuell zu berücksichtigen wären, wenn gleich vorher noch manches zu untersuchen sein dürfte.

(3) Ich halte den jetzigen Zeitpunkt, wo sich gerade neuere Untersuchungen eröffnen, *nicht* für die geplante allgemeine Einführung irgend eine Classification für geeignet. Es dürfte überhaupt verfehlt sein, hierbei eine Abstimmung vorzunehmen und eine Majoritätsbeschluss herbei zu führen. Vielmehr müsste eine aus zahlreichen Mitgliedern bestehende Specialkommission eingesetzt werden, die nach sorgfältigen Berathungen ein Votum nur dann abgeben dürfte, wenn sie sich über einen Vorschlag nahezu einstimmig einigt. Stellt sich eine solche Einigung als unmöglich heraus, so wäre das ein Zeichen dafür, dass überhaupt der Versuch der Einführung einer Classification der Sternspectra verfrüht ist und vorläufig der Zukunft überlassen bleiben muss.

POTSDAM
Dezember 1910

FRANK SCHLESINGER

(1) I concur in the general opinion as to the usefulness of the Draper Classification; it has been in exclusive use at the Allegheny Observatory for some time.

(2) This classification has responded well, and still does so, to the immediate needs of astronomers. Whatever objections I have to this system (except for one or two of minor importance) are concerned with the question as to its adoption as a permanent and universal classification. These objections are: First, that it deals with only the photographic region of stellar spectra. It appears probable, from the some-

what casual explorations that have been made in other regions, that the photographic portion of the spectrum is richer in practical criteria for classification than any other; but it can hardly be doubted that a thorough study of the visual portion would be well rewarded from this point of view, as well as from the more general and more important ones presented by the question of stellar evolution.

A second objection is that the observational material from which the Draper Classification was made is restricted in still another way; the plates were obtained by means of objective-prisms attached to telescopes that were not guided by hand. As a result, they do not show some important details that are well brought out in other photographs, especially those obtained by means of a slit spectrograph. This probably accounts, among other things, for the wide diversity of spectra that have been classified as A. Thus *Sirius*, α *Coronae*, and θ *Aquilae* are assigned to this one class, although they show considerable differences on plates taken with slit spectrographs.

A third objection to the universal adoption of this classification as a permanent one is that it neglects certain important criteria; to mention only the two of these that seem to me to be of greater importance than the others, we have the progressive changes in the form of the intensity-curve in the continuous spectrum as we go from one type to the next and the progressive changes with type in the wave-lengths of certain lines.

(3) I do not think that this committee can profitably recommend at this time any system of classification for permanent adoption. Nor do I believe that it will be possible to do this to advantage in the near future. Much observational work will be necessary in order to establish a system on so firm a basis as to render improbable a revision within a few years after it is set up. The general character of this observational work should be to *co-ordinate* the more important criteria, and the various regions of the spectrum, into a consistent whole. But I am opposed to considering in this connection (classification) any other facts than those revealed in the spectra themselves. If we do not draw the line here, we shall soon become involved in a piece of work that is almost coextensive with sidereal astronomy itself, and which is in fact inseparable from the question of stellar evolution.

I would suggest the following investigations as being the most profitable that this committee could undertake or encourage at the present time: first, the continuation and extension of the work of Parkhurst and Jordan, King and others, on the relation of star colors to spectral type; that is, the determination of the *color-index*, or difference

between photographic and visual magnitudes. These investigations have already shown that the color-index varies directly with the type in the Draper Classification, when the latter are arranged in the order O, B, A, F, G, K, M. It remains to invert this problem and to see whether the spectrum can be correctly classified from a knowledge of the color-index; or, in other words, whether any two stars that are of the same spectral type according to the Draper criteria always have precisely the same color-index. If not, the specific reasons for this should be ascertained. Such investigations are especially valuable, since they would seem to afford the possibility of determining the spectral type by quantitative methods. The same remark applies to Albrecht's recent work, in which the spectral type is co-ordinated with progressive changes in wave-length. This method of classifying spectra quantitatively is more laborious than by means of the color-index, and cannot be applied to as faint stars; but it should, in my opinion, be vigorously prosecuted.

Finally, as Professor Frost has urged, the visual portion of the spectrum should be carefully studied before any permanent system of classification can be adopted. For this purpose, it would greatly facilitate matters if the whole extent of the spectrum from λ 3600 to λ 6800 could be photographed on one plate. This has recently been made possible through the manufacture of plates that are almost equally sensitive to this whole range of spectrum. A reflecting telescope and a grating spectrograph would also be essential for this purpose. If circumstances warrant, the Allegheny Observatory is prepared to install such a spectrograph, to be used in connection with the Keeler Memorial Reflector.

(4) Symbols denoting the widths of lines would be very convenient. These symbols should be assigned from a study of slit spectrograms, and care should be taken that the spectra are of normal density. I regard this matter of specifying the width of lines as being of minor importance as compared with other questions that the committee is considering.

ALLEGHENY OBSERVATORY
February 1911

K. SCHWARZSCHILD

(1) Die Draperklassifikation ist nach meiner Meinung die beste zur Zeit existierende.

(2) Der Hauptvorwurf gegen das Drapersystem ist die unglückliche Wahl der Buchstaben für die Spektraltypen. Wenn das System jetzt neu einzuführen wäre, würde ich den Vorschlag machen, die Buchstaben

überhaupt durch Zahlen zu ersetzen, und zwar 0 statt B, 1 statt A, 2 statt F, 3 statt G, 4 statt K, 5 statt M zu schreiben und die Zwischenstufen durch Dezimalen mit eventuell mehreren Stellen auszudrücken. Statt der Draperbezeichnung A2 würde ich also 1, 2 schreiben; die Zahl 1, 25 würde ein Spektrum in der Mitte zwischen den Drapertypen A2 und A3 bezeichnen. Bei dieser Bezeichnungsweise würde die den Spektraltypus angebende Zahl mit 0.4 multipliziert sehr nahe den Farbenindex ergeben.

(3) Ich halte es *nicht* für richtig, in nächster Zeit ein System zur allgemeinen Annahme zu empfehlen. Schon die bisherige Diskussion hat dem Drapersystem zu weiterer Verbreitung geholfen und es wird ganz von selbst in den nächsten Jahren die herrschende Stellung einnehmen. Doch ist das Studium der Sternspektren zu sehr im Fluss, als dass man jetzt abschliessende Bestimmungen treffen könnte.

Ueber die Zukunftsprojekte möchte ich folgendes sagen. Es ist das Verdienst vor allem der Harvard Sternwarte, nachgewiesen zu haben, dass die Sternspektren sich in eine Serie einordnen lassen, in der die Elemente sich nach einer festen Reihenfolge ablösen. An der Spitze steht das Helium, dann folgt der Wasserstoff, darauf Calcium, schliesslich Titan und Eisen, bis sehr zahlreiche Elemente und Banden auftreten. Es ist dies nebenbei bemerkt dieselbe Reihenfolge der Elemente, die man beim Eindringen in die Sonnenatmosphäre antrifft. Diese Gesetzmässigkeit steht fest für die kräftigen Linien, die in Spektren geringerer Dispersion sichtbar sind. Sehr wenig untersucht ist bisher das Verhalten der feineren Linien, die auf den Spektrogrammen grösserer Dispersion hervortreten. Es ist möglich, dass diese sich nicht mehr in eine Serie einordnen lassen—Frost und Adams finden z. B. für die Orion-Sterne aus den feinen Linien zwei Parallelserien. Vielleicht liegen die Verhältnisse in Wirklichkeit noch komplizierter. Die Draperklassifikation stellt die Spektra dar als Funktion einer Variabeln, die man als "Entwicklungsstadium" bezeichnen kann. Bei Miss Maury tritt bereits als zweite Variabel die Linienbreite hinzu, die nach den Untersuchungen von Hertzsprung ein physikalisch sehr wichtiges Kriterium ist. Es ist sehr wohl möglich, dass man noch mehr Variabler bedarf, um alle feinen Variationen der Spektra darzustellen. Ich möchte aber vermuten, dass die Anzahl der Variabeln begrenzt ist und vielleicht die Zahl 3 nicht überschreitet. Ich glaube nämlich nicht gern, dass die Verteilung der Elemente auf den Sternen zufällig ist, vielmehr möchte ich annehmen, dass die Mischung der Substanz der Sterne aus den chemischen Elementen überall die gleiche oder höchstens

eine vom Alter der Sterne gesetzmässig abhängige ist. Ist letztere Voraussetzung aber richtig, so kann das Spektrum eines Sterns schliesslich von nichts anderem mehr als seiner Masse, seinem Alter und seiner Temperatur (seinem Energiegehalt) abhängen.

Das Programm, das sich hieraus ergibt und das vor einem internationalen Beschluss über eine Klassifikation der Spektraltypen durchgeführt sein sollte, ist: die Klassifikation der Spektraltypen in der von der Harvard-Sternwarte inaugurierten Weise nochmals unter Berücksichtigung von Spektren grosser Dispersion vorzunehmen. Das Potsdamer Observatorium würde hierzu nicht viel beitragen können, da die aufgenommenen Spektra sich auf eine verhältnismässig kleine Zahl von Sternen beziehen. Die meisten Observatorien, die Sterne von veränderlicher Radialgeschwindigkeit verfolgen, werden in ähnlicher Lage sein. Vielleicht würde die Herstellung einer internationalen Sammlung möglichst guter Diapositive von möglichst vielen Sternspektren, wie sie für Radialgeschwindigkeiten gebraucht werden, das beste Mittel sein, um rasch zu dem nötigen Material zu gelangen.

POTSDAM
Dezember 16, 1910

WALTER SIDGREAVES

(1) Yes, as a preliminary working step.

(2) Only that I personally prefer *stellar names* as Altairian, etc., to numbers and letters.

(3) I hesitate much as to this. We are still in want of some indication in the life of a star of declining age, and distinction between heat effect and electrical effect.

(4) Yes, especially of the hydrogen, helium, magnesium, and calcium lines.

My preference for names in place of numbers and letters will be best understood by the remark that a stellar name is a picture of the spectrum to any stellar spectroscopist. Subdivisions or intermediaries can be expressed by steps 1, 2, 3, etc., toward the next name of the list.

STONYHURST COLLEGE, ENGLAND
December 1910

V. M. SLIPHER

(1) Yes.

(2) Would it not be advantageous, in the long run, to have the letters denoting the spectral sequence arranged alphabetically, by using A in place of O, and call in C or D to take the place now held by A?

(3) If there is a general agreement among spectroscopists on a uniform system of classification I see no reason why its recommendation for adoption should be postponed, except it be for acquiring corroborative knowledge of unexplored parts of the spectrum, such as the region from λ 4900 to λ 6900. Co-operative work should supply these needed facts at an early date. A few years ago I made spectrograms of this region of certain typical stars, and I could probably arrange to carry the work farther and with higher dispersion.

(4) A symbol to indicate the width of the lines should prove to be useful, as for certain studies such knowledge is almost indispensable, and moreover the cause of the abnormal width needs investigation.

(5) In the classification should not the relative intensities of different regions of the continuous spectrum from type to type be carefully considered?

LOWELL OBSERVATORY
January 5, 1911

J. WILSING

Zu Gunsten der Einführung der dem Draper Katalog zu Grunde liegenden Klassification der Sternspectra spricht die bereits bestehende Geneigtheit zahlreicher Fachgenossen für diese Einteilung. Die notwendige Aenderung der Buchstaben hat nur formale Bedeutung.

Da indessen der praktische Wert jeder einzuführenden Klassification von der Homogenität abhängen würde, so wären zuvor auf jeder beteiligten Sternwarte bestimmte characteristische Normalspectra aufzunehmen, wie eine Anzahl solcher Spectra bereits in *Harvard Annals*, **56**, bezeichnet worden sind. Auf Grund der Vergleichung der von den verschiedenen Beobachtern angefertigten Originalnegative würde die Stellung dieser Spectra in der Klassification festzusetzen sein und als Richtschnur sie die weiteren Bestimmungen dienen können. Dabei würde sich auch ergeben, ob die Einführung noch weiterer Kennzeichen notwendig und möglich ist, ohne die Homogenität zu gefährden.

POTSDAM
Dezember 13, 1910