THE
ASTROPHYSICAL JOURNAL
AN INTERNATIONAL REVIEW OF SPECTROSCOPY
AND ASTRONOMICAL PHYSICS

VOLUME LVII MARCH 1923 NUMBER 2

REPORT OF THE COMMITTEE ON STELLAR CLASSIFICATION ADOPTED BY THE INTERNATIONAL ASTRONOMICAL UNION AT THE MEETING AT ROME, MAY 10, 1922[1]

The Committee[2] on Classification of Stellar Spectra finds its work greatly simplified by the fact that a definite plan of classification—the Harvard System—has already been adopted by international agreement, and has been used in extensive works, such as the *Henry Draper Catalogue*, which will be of value for a long time. Its duty, therefore, is not to make radical alterations in this system, such as changing the significance of the existing letters, or substituting numbers for them, but to suggest such modifications and extensions of the existing notation as may increase its usefulness to students of astrophysics.

a) With increasing knowledge of stellar spectra, it is desirable to have additional symbols which may be used to designate many of those characteristics which were formerly dismissed as "peculiarities." The new notation may in some cases appear complicated, but it should be remembered that its use is permissive, and not mandatory. The older notation remains complete in itself, and for many purposes is all that

[1] Reprinted, by permission, from *Transactions of the International Astronomical Union*, 1, 1922. London: Imperial College Bookstall, S.W. 7. Pp. 247+viii. Price, 15 shillings.

[2] The committee consisted of W. S. Adams, chairman, Miss Annie J. Cannon, Messrs. R. H. Curtiss, A. Fowler, A. de Gramont, M. Hamy, H. F. Newall, J. S. Plaskett, and H. N. Russell. Messrs. N. Bohr and M. N. Saha were added to the committee.

will be required, while the new makes it possible to compress into small compass information which would otherwise require voluminous notes.

b) The additional distinctions, like the original classification, are based on the line and band absorption and emission. The distribution of intensity on the continuous background is of great importance; but it is not considered, for three reasons: (1) It is already known that the correlation between the intensity distribution and the spectral class is so far from perfect that two practically independent symbols are required to express them. (2) All instruments record the line-spectrum in substantially the same fashion—barring the effects of different dispersion and resolving power. This is not the case for the intensity of the background, which may be influenced by such factors as absorption in the prisms. Great care is, therefore, necessary in interpreting the results obtained from spectrograms. (3) This distribution is intimately related to the color index and to the energy distribution in the spectrum. The problem involves spectroscopy, photometry, and the measurement of heat radiation.

c) It is evidently ultimately desirable that each spectral class should be precisely defined, both by verbal description and by means of standard stars. The present moment, however, does not appear opportune for doing more in this way than has already been done at Harvard. The exact relation of some of the more unusual classes of spectra remain to be investigated. Moreover, the recent application of the theory of ionization to stellar spectra promises a greater insight into the physical meaning of the spectral lines. There is good reason to believe that the relative intensities of lines emitted by the neutral atoms depend almost exclusively upon the temperature, while the intensities of enhanced lines, relative to those of the former groups, will vary also with the pressure or density of the star's atmosphere. It seems, therefore, desirable to postpone the *precise* definition of the characteristics of each spectral class until the relations of these two types of lines to the temperatures and absolute magnitudes of the star have been further considered.

I. GUIDING PRINCIPLES

a) The classification should describe the *spectra*, not the stars; that is, it should be based solely on what can be seen in the spectrum of a given star, when observed at a suitable time and with appropriate instruments.

b) The Draper Classification, or "Harvard System," which has already been adopted internationally, should be the basis on which any

further extensions should be built. Classification on other and different systems should be abandoned permanently.

c) Designations at present forming part of the Draper Classification should either be retained with the old meaning or abandoned entirely. No attempt should be made to retain the symbol but alter the meaning.

d) The capital letters, B, A, F, etc., *standing alone*, should be used to describe a spectrum only in those cases, when, on account of poor photographs or for other reasons, nothing more than the general character of the spectrum can be determined.

Similarly B–A, K–M may denote spectra which lie somewhere between the classes mentioned when more precise specifications cannot be made.

e) In cases of great uncertainty, Secchi's types may be employed. These may be characterized briefly as follows:

		Harvard Types
Type I.	Predominant hydrogen lines	Oe, B, A, F, F_5
Type II.	Prominent metallic lines	F8, G, K, K_5
Type III.	Titanium oxide bands	M
Type IV.	Carbon bands	N, R
Type V.	Bright Wolf-Rayet lines	Oa, Ob, Oc, Od

It is not recommended that this grouping be used in statistical work on account of the extreme heterogeneity of Type I. Stars of spectra Oe to B_5 should, in any case, be separated from the other stars of Type I.

f) The decimal system of classification (G_2, etc.) should be used in all cases in which it is established that a continuous spectral sequence exists. Such combinations will hereafter be called the "main symbol."

g) The present notation by means of small letters appended to the capital letter (as Oa) should be retained in cases in which it has not been clearly established that a continuous and unique sequence exists.

h) The terms "early" and "late" are very convenient. It is well, however, to emphasize that they denote positions early or late in the spectral sequence O—B—A—F—G—K—M, without any necessary connection whatever with an early or late stage of physical evolution. The terms "hotter" and "cooler," "whiter" or "redder" sometimes cover the same characteristics, but describe the star rather than the spectrum.

i) Composite spectra should be denoted by the sign + connecting the two superposed types (as K_0+B_9), or by two separate lines as is done in the *Henry Draper Catalogue*. The latter is convenient for purposes of tabulation.

j) The spectra of variable stars should normally be recorded as at maximum brightness. When the spectrum varies continuously, as in Cepheid variables, it may be recorded, for example, as F_7 to G_4; when discontinuously as in eclipsing variables, like a composite spectrum, e.g., Ao+K or $\left\{\begin{matrix}\text{Ao}\\ \text{K}\end{matrix}\right.$

k) Additional notation should be devised to describe as many as may be convenient of those spectral characteristics which are known to be common to any considerable number of stars. Such notations should be simple to print, and convey as much information as may be practicable in a small compass.

II. SPECIFIC EXAMPLES OF THESE RULES

I.*c*. Although the evidence of color index suggests strongly that what is now called K_5 is really much nearer to M than to K, it is inadmissible to change the designation of this type to K8. The meaning of the symbols in the existing catalogues must be preserved.

Again, the notation Md has been found to include cases in which the "underlying spectrum" is not of Class M at all. This symbol may, therefore, advantageously be dropped.

I.*f*. and *g*. (i) Although the evidence is strong that Oe and Oe_5 represent spectra immediately preceding Bo, the spectral sequence in Classes Oa to Od is not yet certainly worked out. Hence it seems desirable to retain for the present the existing notation for all these classes.

(ii) Again, Ma, Mb, and Mc clearly form a sequence, running on continuously from K_5. It is suggested that they be called in future Mo, M_3, and M8, the second interval on the decimal classification being taken wider than the other, because it appears to correspond to a greater difference in the spectra.

(iii) Similarly, Na and Nb may be called in future No and N_3. The relations of the very red stars called Nc by Miss Cannon are not yet clear enough to justify giving their spectra a decimal notation.

Spectra intermediate between K and R (should such occur) will have to be called K_5R.

(iv) The question of the notation for the spectra of gaseous nebulae should be deferred until further investigations have been made. Attention should be called, however, to the strong desirability of classifying the spectra of the nebula and the nucleus separately whenever possible.

III. NEW SPECTRAL CLASSES

a) Novae

It seems very desirable to have some less cumbersome description than at present of the successive stages through which the spectrum of a Nova ordinarily passes. The letter Q has been used for spectra of this type (*Harvard Annals*, **28**) and should be retained. In view of the uncertainties of progression in sequence, the differences between various novae and the intermingling of spectral characteristics, the decimal notation cannot at present be used. The following quite provisional system of notation is suggested, not for immediate use, but as a basis of discussion, in the anticipation that it will be revised and improved in the future. The use of the letter "e" to indicate the presence of bright lines in other classes of spectra precludes its use in this connection. Bright bands due to hydrogen appear always to be present, except in Class Qz, and are not referred to specifically.

Qa Absorption spectrum of faint lines. Bright bands inconspicuous.

Qb Absorption spectrum of stronger lines, mainly enhanced metallic, many of which are double. Bright bands stronger.

Qc Absorption spectrum of enhanced lines, oxygen, nitrogen, helium and associated elements. Bright lines of all of these elements.

Qu Broad nebulous emission bands near 3480, 4515, and 4640A, accompanied at times by one at 4379A. The spectrum appears usually to occur in conjunction with other typical forms which it may modify through the extinction of some of their characteristic radiations, particularly 3445 and 4686A.

Qx Bright bands due to enhanced lines, oxygen, nitrogen, and helium. Absorption lines faint.

Qy Bright nebular bands in addition to preceding.

Qz Bright nebular bands. Weak Wolf-Rayet bands.

The stage in which Wolf-Rayet bands are strong in addition to the nebular bands may be indicated by Qz5O. (Capital letter O.)

Combinations of any of these spectra may be indicated by combinations of the letters. Thus Qbc would indicate that spectrum Qb was more prominent than Qc, and Qcb would show the reverse.

b) A New Class of Red Stars

Miss Cannon has found that a number of long-period variables and some other red stars, such as π_1 Gruis, R Cygni, and R Andromedae, have underlying spectra which are similar to one another, but do not

resemble Class M, and Dr. Merrill has shown from slit spectrograms that they do not resemble Classes R or N. Their spectrum in the region λ 4500 to λ 4700 is of a most complicated nature, and appears to consist of both absorption and emission lines, with absorption bands present at about λ 4650 and λ 6470. Most of the stars belonging to this type are long-period variables, and show bright hydrogen lines. The type may represent a third branch of the main spectral sequence, cognate with the K5-M and R-N branches. The letter S is suggested for this type.

IV. NOTATION FOR PECULIARITIES

a) Characteristics Connected with Absolute Magnitude

When observations of sufficient delicacy have been made, the spectroscopic absolute magnitude, upon the Mount Wilson system, provides a detailed description of these peculiarities. The more conspicuous differences, however, which can be detected upon inspection by an observer once familiar with them, suffice to divide the spectra into three groups. These may be denoted by small letters placed before the main symbol. They are defined as follows:

1. *Very Bright Stars*

All lines normally are narrow and sharp. In spectra later than Ao, the hydrogen lines are abnormally strong for the general spectral type. So also are the enhanced lines. λ 4227 *Ca* is abnormally weak compared with Hγ or λ 4215 *Sr*+.[1]

This set of characteristics, which is very conspicuous, is shown by Miss Maury's "c-stars," by the Cepheid variables, the stars called "pseudo-Cepheids" by Adams and Joy, and by practically all other stars of exceptionally great luminosity including some cases, like ζ[1] Scorpii and β Orionis, of type B.

It is suggested that these be denoted by the prefix *c* and be called "c-stars," leaving the term Cepheids for variables.

2. *Bright Stars*

In these spectra the enhanced lines are fairly strong. λ 4227 has a moderate intensity for the spectral type. The low-temperature lines, such as λλ 4435 *Ca*, and 4454 *Ca*, are relatively weak. The hydrogen lines are strong.

In class F, λλ 4077 *Sr*+, 4215 *Sr*+, 4290 *Ti*+ are strong.

[1] The sign "+" following a chemical symbol indicates that the line in question is an enhanced line, originating in ionized (positively charged) atoms.

In classes G, K, and M, λλ 4077 and 4215 are strong.

These are ordinary giant stars, and their spectra may be denoted by the prefix *g*.

3. *Faint Stars*

In these spectra λ 4227 is strong for the class, and λλ 4435, 4454 *Ca* and 4535 *Ti* are strong. The enhanced lines are weak.

In Class F, λλ 4077, 4215 and 4290 are weak.

In Class M, λ 4607 *Sr* is relatively strong, the hydrogen lines are weak.

These spectra may be denoted by the prefix *d* (dwarf stars).

For spectra earlier than Bo these differences disappear, so far as is known, all the stars being bright. The difference between ordinary giant and dwarf stars does not become prominent until spectra later than Fo are reached. The prefix *c*, therefore, will not at present be used with spectra earlier than Bo, or *g* and *d* with spectra earlier than Fo.

In the selection of standard or typical spectra, it is recommended that the fundamental types shall be giant stars, preferably of absolute magnitude about o or +1 (except in Class B, where they must necessarily be brighter). Stars showing either the c-star or dwarf characteristics should be selected as auxiliary standards.

There is additional reason for this, because in the classification of the spectra of dwarf stars developed at Mount Wilson, the decimal subdivisions are of much less unequal value than in the Harvard classification for giant stars. A dwarf K5 is much more nearly midway between Ko and Mo than a giant K5. It may be remarked incidentally that in plotting the physical data, it is well to plot K2 and K5 for giant stars as if they were K5 and K8, respectively. This should not, however, be done in the case of the dwarfs.

b) Width of Lines

Exceptionally narrow lines usually appear to be associated with the "c" peculiarity, and are already accounted for. Spectra showing all the lines unusually wide or diffuse on good plates may be denoted by "n," following Rowland's designation for diffuse (nebulous) lines in the solar spectrum. Similarly the letter "s" may be used to qualify spectra in which the lines are sharp, but in which the "c" characteristics (such as abnormally strong hydrogen and enhanced lines) are not present.

c) Double Lines

Spectra in which the lines are double rather than reversed belong to spectroscopic binaries with both components bright. In such cases the notation for composite spectra should be used.

The spectra of spectroscopic binaries in which only one component is visible present, as such, no peculiarity. Variable radial velocity cannot be detected by mere inspection of a single spectrum. They should not receive any special notation.

d) Stationary Lines

On the other hand so-called "stationary" (H) and (K) lines (so far found only in types O and B) are recognizable by their appearance, being very much sharper than the other lines in the spectrum. The symbol "k" suggesting the (K) line is proposed for this class of stars. The same symbol may be used to describe spectra in which the (D) lines and possibly others show the same characteristics. To illustrate, δ Orionis would be designated Bonk.

e) Bright Lines

It is suggested that spectra showing bright lines be denoted by the letter "e" (emission), except in classes where bright lines are normally present (as in O, P, and Q).[1]

In certain classes, most of the bright line stars have fairly definite characteristics, and may be considered as forming a recognized group. In these spectral classes, a spectrum which has emission lines differing considerably from those of the recognized group may be denoted by "ep." Cases in which the bright lines are conspicuously "reversed" (with a dark center) may be denoted by "er." These recognized groups are as follows:

1. *Classes A and B*

The hydrogen series may be thought of as composed of the normal Class B absorption lines, increasing in strength from Hα toward the violet, each having superposed upon it, in a nearly symmetrical position, one of a series of bright lines which decrease in strength from Hα toward the violet. Frequently in the hydrogen series (with a one-prism slit-spectrograph) one or more of the lines Hβ to Hϵ will show *both* emission and absorption components, the lines toward the violet showing no emission, and those toward the red showing no absorption; but in some cases Hα is the only distinct emission line. The emission lines often are double, and in some cases may appear as bright edges to a well-defined absorption line. Fainter emission lines (enhanced metallic) may or may not be present.

[1] The notation Pe, already in use, is still admissible, as it denotes a type of bright line spectrum.

Slight lack of symmetry of the combined bright and dark hydrogen lines need not require the suffix "p."

If desired, the letters a, β, etc., may be appended to indicate which is the last visible bright line of the hydrogen series.

In certain stars, such as P Cygni, the lines consist of a bright emission line with an absorption line bounding it on the violet side. These spectra may be denoted by "eq," the "q" recalling their similarity to certain stages of the spectra of Novae.

2. *Classes M, N, R, and S*

In all these the bright lines are usually of the type associated with long-period variability. The hydrogen lines are bright and narrow, with no absorption components visible. In Class M, Hγ is usually bright and conspicuous, while Hδ is still stronger. Hϵ is absent or extremely weak, Hβ and Ha are weak or absent, except when the underlying spectrum is of an early division of Class M, or possibly a late one of Class K, in which case Hβ, Hγ, and Hδ may have approximately equal intensities. Weaker bright lines, especially at $\lambda\lambda$ 3905, 4138, 4178, and 4202, are not unusual. In stars of Class S, which show bright hydrogen lines, Hβ is much stronger than Hγ or Hδ, though Hγ is usually conspicuous.

As these differences in the intensity of the hydrogen lines appear to be closely correlated with the underlying spectrum, no additional notation to describe them appears to be called for at present.

Consideration of a notation for the spectra of long-period variables near minimum should be deferred till they have been more fully investigated. It is already known that in o Ceti at least, the spectrum at minimum is very different from that at maximum, or from any other known spectrum.

3. *Classes F, G, and K*

Bright line spectra are here so rare that no characteristic group can be recognized. The mere addition of the suffix "e" may serve for the few known cases, which are far from similar to one another.

f) Variable Spectra

In certain cases the spectrum of a star varies. Although this is a peculiarity of the star and not of the spectrum, it is obviously desirable to refer to it in catalogues of spectra. This may be done either by giving the limiting types between which the spectrum varies, as for example, cF5–cG2, or simply by annexing the letter "v" to the spectral designa-

tion. The symbol "ev" will denote variability in emission lines such as has been observed in many B-type stars. In such cases, as in those in which the letter "p" is used, details should be given in notes.

g) Other Peculiarities

The letter "p" should be used to denote miscellaneous peculiarities, not sufficiently frequent or important to justify individual designations. It may be suggested that this should be understood to qualify the symbol immediately preceding. Thus B2pe would denote a star of Class B2, with peculiarities in the absorption spectrum, and emission lines of the normal type, while B2ep would denote a star with peculiar emission lines.

Similarly, A2pn would denote a peculiar A2 spectrum in which all the lines were wide; A2np one in which the lines were widened in some peculiar fashion.

The same principle may be extended to other symbols. Thus F8ne would denote an F8 spectrum with all lines wide, and with bright lines; F8en, one in which the dark lines were normal, but the bright lines abnormally wide.

V. NOTATION OF INDIVIDUAL LINES

a) The Fraunhofer letters for certain lines are so well established that it does not seem desirable to abandon them. Following a suggestion of the Committee on Notations, these lines should be denoted by letters in brackets or parentheses. Those symbols which it is proposed to preserve are (A), (a), (B), (α), (D), (b), (G), (H), and (K). It is worthy of note that each of these with the exception of the last two, denotes a group of lines having a common origin. Since the lines of the (E) group do not all belong to the same element, there is no reason for retaining this symbol.

For the hydrogen lines, the notation Hα, Hβ, etc., should be adopted.

d) In giving the origin of a line, the chemical symbol of the element should be printed in italics, as recommended by the Committee on Notations. When the line is known to originate in an ionized atom, or shows other strong evidence of being an enhanced line, the chemical symbol should be followed by the sign +, in accordance with the usage now prevailing among physicists. Thus λ 4571 *Mg*, λ 4481 *Mg*+, λ 4045 *Fe*, λ 4233 *Fe*+.

The symbols "pq" are used to indicate peculiarities of a character suggestive of the spectrum of Novae.

The exclamation symbol "!" may be used as a modifier to indicate very marked degree in a phenomenon. Thus "e !" means that the

emission lines are exceptionally strong; "p !" that the peculiarities are remarkable.

Examination of the notes to Miss Cannon's classification of spectra in *Harvard Annals*, **28, 56,** and **93,** shows that the proposed notation will cover almost all the peculiarities which occur at all frequently, with certain exceptions. The most notable of these are spectra of Class A showing unusual strength of the silicon lines λλ 4128, 4131 (as in α Doradus), or of the strontium line λ 4077 (as in δ Normae). An examination of the proper motions indicates that stars showing these peculiarities are distinctly brighter than the average; but further study will be required before it can be determined with certainty whether these characteristics are associated with the "c" or "g" characters, or are independent of these, and to what degree they are connected with one another.

Pending such study, they may still be called Aop, A2p, etc., the question of a notation for their peculiarities being postponed.

Some of the more difficult objects, such as η Carinae and SS Cygni have been classified on a provisional basis to show the capabilities of the method.

VI. EXAMPLES OF THE PROPOSED NOTATION

c-Stars		*Giants*		*Dwarfs*	
ε	Canis Majoris... cB1	γ	Velorum..... Oap	α	Canis Minoris... dF5
β	Orionis..... cB8	ζ	Puppis..... Od	β	Virginis..... dF8
η	Leonis..... cAo	29	Can. Maj..... Oe		The Sun..... dGo
α	Carinae..... cFo	ι	Orionis..... Oe5	μ	Herculis..... dG5
α	Persei..... cF5	ε	Orionis..... Bo	70	Ophiuchi Br.... dKo
α	Ursae Minoris... cF8	γ	Orionis..... B2	70	Ophiuchi Ft.... dK4
ζ	Geminorum..... cGo	α	Gruis..... B5	61_1	Cygni..... dK8
5	Lacertae (Boss 5804)..... cK2	α	Lyrae..... Ao		Lal. 21185..... dM3
α	Scorpii..... cMo	β	Leonis..... A5		Barnard's Star.. dMo
		θ	Scorpii..... gFo		
		ε	Ceti..... gF5		
		τ	Persei..... gG1		
		η	Piscium..... gG5		
		α	Boötis..... gKo		
		α	Tauri..... gK5		
		δ	Virginis..... gMo		
		β	Pegasi..... gM3		
		45	Arietis..... gM8		
		B.D.	+42°2811..... Ro		
			−3°1685..... R5		
		19	Piscium..... No		
			+67°350..... N2		
		VX	Andromedae... Nc		

Nova Type

Qa	Nova Aquilae 1918	June 8–9
Qb	Nova Aquilae	June 10–13
Qc	Nova Aquilae	June 14–20
Qx	Nova Aquilae	June 21–July 1
Qy	Nova Aquilae	July 1, 1918–Oct., 1919
Qz	Nova Aquilae	1920–21
QzO	Nova Geminorum	February, 1914

Red Stars

π_1 Gruis	S
R Cygni	Se
R Geminorum	Se
R Andromedae	Se

Wide and Double Lines

δ Orionis	Bonk
α Eridani	B5n
α Leonis	B8n
α Aquilae	A5n
δ Geminorum	A7n

S Antliae	A6n, A6n	or A6n+A6n
W Urs. Maj.	dF8n, dF8n	or dF8n+dF8n
β Scorpii	B1k, B1	or B1k+B1
μ Scorpii	B3, B3	or B3+B3
β Aurigae	Ao, Ao	or Ao+Ao
α Aurigae	gGo, F5	or gGo+F5
V Puppis	B1, B3	or B1+B3
o Leonis	cF5, A	or cF5+A
U Sagittae	B8, gG2	or B8+gG2

Bright Lines

γ Cassiopeiae	Boe
η Tauri	B5eα
β Lyrae	cB8+B2nep
P Cygni	B4eq
α Cygni	cA2eα
RT Serpentis	cFoe
RZ Ophiuchi	cF8e
W Virginis	cF7e
σ Geminorum	gK1e
T Tauri	gG5e
Comp. α Gemin.	dMo+dMoe
T Aquarii	M1e
o Ceti (max.)	M6e
o Ceti (min.)	Mvep !
R Leonis	M8e
T Coronae Bor.	M5epn
R Aquarii	M6e+P
28 Tauri (Pleione)	B8ev
ϕ Persei	Bpevr
+11°4673	Beqpv
η Carinae	Qp !
SS Cygni maximum	B8n !q
SS Cygni minimum	Opq
R Cor. Bor.	cF5ep
H.D. 42474	gMoep !