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Statistics of categorized eclipsing binary systems. Lightcurve shapes, periods, and spectral types

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Summary. — We have examined the statistics of the lightcurve morphologies, eclipse depths, orbital periods, and spectral types of about 1000 eclipsing binary systems, after having attempted to subdivide these binaries into various basic evolutionary categories.
The applicability of statistical criteria, based on lightcurve morphologies and eclipse depths, for the categorization of eclipsing binaries has been found more limited than previously believed. In particular, EW-type lightcurves turn out to be good indicators of contact systems (though not conversely), while EA- and EB-type lightcurves have little physical significance. Moreover, our study reveals a strong deficit of short-period non-contact systems in the whole spectral range, together with an underabundance of early-type contact binaries (compared with the number of late-type contact pairs). Interestingly, the distribution of evolved Algol-type systems is shifted, on average, to periods longer than those of unevolved detached systems in the OB and early A spectral range (and to shorter periods in the F spectral range).

Key words : binary statistics — eclipsing binaries.

1. Introduction.

Statistical studies of the parameters of close binaries can yield valuable information on general aspects of their formation and evolutionary processes, provided a distinction between systems in very different evolutionary stages (e.g., evolved and unevolved binaries) is attempted (the study of very heterogeneous binary samples may lead to misleading results).

In the present paper, we shall investigate the implications of the relevant information expressed by the statistics of the most easily determined properties of eclipsing binaries (i.e., lightcurve morphology, depths of eclipses, orbital period, and spectral type). For this purpose, in order to overcome the limitations inherent in previous relevant statistical analyses [e.g., Budding (1981), who dealt with short-period systems alone ; Giuricin *et al.* (1983a)], in which only statistical considerations are used to outline distinctions between evolved and unevolved binaries, in section 2 we shall attempt to establish a subdivision of the catalogued eclipsing binaries into various basic evolutionary classes, by carefully inspecting the available photometric and spectroscopic properties of each binary. In section 3 we shall explore how these classes are related to the major lightcurve characteristics (lightcurve morphology and eclipse depths), whose applicability as criteria for a bulk categorization of binaries will be found to be limited. In section 4 we shall analyze separately the statistics of the orbital periods and spectral types of the various binary subsamples that we have constructed. The implications of our findings for general aspects of close binary formation and evolution will be briefly outlined.

2. Categorization of eclipsing binaries.

Through a survey of the catalogues of Kukarkin *et al.* (1969, 1971, 1974, 1976), Brancewicz and Dworak (1980), and Wood *et al.* (1980), supplemented by an inspection of the recent literature, we have gathered together the available data on the orbital periods, the primary's average spectral types, the types of lightcurve morphology (Algol-type EA, β Lyrae-type EB, W UMa-type EW, when available), and the depths of eclipses of the catalogued eclipsing (and ellipsoidal) binaries with periods $P \leq 50$ days, and apparent blue magnitudes $m \leq 12.5$ at maximum light. (More confidence has been placed in the last catalogue, whenever there are discordances). We have not considered the systems with unknown spectral classifications and the few eclipsing binaries having Wolf-Rayet and degenerate members.

Through a careful inspection of their photometric and spectroscopic properties, we have attempted to subdivide the binaries considered into the following basic categories, each of which is intended to group together systems with similar evolutionary characteristics.

i) Substantially unevolved detached systems with nearly main sequence components. We have included in this sample also a few binaries which are thought to be in a pre-main sequence evolutionary stage (i.e. BM Ori and the two BY Dra-type eclipsing variables SV Cam and YY Gem) and the short-period RS CVn-type stars RT And, WY Cnc, CG Cyg, UV Psc, and ER Vul, which are probably substantially unevolved. They are denoted as « d » pairs.

ii) Non-contact binaries which, in view of the pronounced overluminous and oversized properties of their cooler components (with respect to their masses or spectral types) are likely to have undergone (or to be undergoing) mass-exchange (together with mass ratio reversal) between the two members. [Obviously, classical semi-detached Algol binaries and Algols with undersized subgiant secondaries (i.e., sd-d systems) belong to this category.] They are hereafter referred to as « a » systems.

iii) Long-period RS CVn-type binaries (hereafter referred to as RS), which are thought to have evolved from the main sequence, with some accelerating effects due to mild mass transfer from the secondary (e.g., Popper and Ulrich, 1977).

iv) Contact systems (hereafter referred to as « c » systems) ; their lightcurves mostly display EW-type and EB-type shapes in the late- and early-type spectral ranges, respectively.

v) Evolved systems which may be a or c systems (their nature is unclear) ; they are hereafter referred to as « ac » systems. Fairly close binaries (with members of fairly unequal temperatures) for which it is difficult to discriminate between a contact or a typical semi-detached configuration (with lobe-filling cooler member) are included in this category.

vi) Non-contact systems which may be d or a systems (they are referred to as « da » systems).

vii) Systems (not included in the afore-mentioned categories) which have at least one member evolved well away from the main sequence (i.e., supergiant or late-type giant). Their evolutionary stage is generally unclear ; but if the secondary component is a main sequence star, they are likely to be in a prior-to-mass exchange stage. Also VV Cep-type stars belong to this category, whose members are referred to as VV systems.

In general, for a binary to be classified according to these categories, a lightcurve analysis — or at least a rough evaluation of the fractional radii of the two components and of the difference in temperature — must be available in the literature. However, also in a few cases in which these evaluations are not available, a categorization was permitted by consideration of indirect arguments (e.g., the presence of an appreciable orbital eccentricity generally points to an unevolved nature).

Table I lists the 1027 binaries (ordered by constellation) for which a categorization was given. A question mark denotes the cases of doubtful categorization. In these latter cases the interpretation of the available information is quite ambiguous so that our assignments are based on educated guesses. It is understood that in the other cases (by far the majority) there is generally sufficient information available to place a binary unambiguously into a given category, although a bit of personal judgement is often inevitably present (e.g., in the choice of the seemingly best photometric study for a given binary).

The observational material is inhomogeneous and sometimes of poor quality. In particular, we are aware that new photometric data — and new (sophisticated) lightcurve analyses for the closest pairs — could lead to a different classification for numerous systems for which only old visual and photographic observations are available. In our opinion, it is precisely this unavoidable fact (rather than uncertainties in the categorization itself) which constitutes the main limitation of this kind of statistical study. In any case, our task has been to attempt to establish the most accurate and extensive binary categorization based on current theoretical views on close binary evolution and on the present level of knowledge of the most accessible eclipsing binary parameters, aware as we are of the temporary nature of this level.

3. Lightcurve morphology and eclipse depths as criteria for binary categorization.

An inspection of the distributions of the major lightcurve characteristics (depths of eclipses and lightcurve morphology) of our binaries allows us to explore whether (and to what extent) they can provide good statistical criteria for a categorization of binaries having unsolved lightcurves. We shall focus our attention on the three most numerous categories (a, d, and c systems), since few systems (5 %) belong to the others.

First of all, let us assess to what extent the lightcurve morphology of a binary may reflect its general evolutionary stage. Table II gives the numbers of the a, d, c systems and of the other systems (including the binaries not categorized) having EA-, EB-, and EW-type lightcurves and falling within Log P (decimal logarithm of the period) bins of width 0.2. We have generally tabulated three numbers (if not zero), which are relative to the OB, A, and later spectral types, respectively (a systems are not present among the EW-type stars).

Clearly, almost all (more than 90 %) of the stars which exhibit W UMa lightcurves appear to be contact (c) systems. Those to which lightcurve synthesis computer models have been applied have been proved to be, in general, well-evolved or moderately evolved contact pairs, which have always been in contact or which have evolved into contact from initial semi-detached or detached configurations (e.g., Mochnacki, 1981, and references cited therein). Non-contact (detached) configurations have been found for a few EW binaries (mostly pairs of relatively long periods) ; the most compelling cases are the main sequence pair with nearly equal members WY Hya (Giuricin *et al.*, 1981) and the short-period RS CVn star ER Vul (Al-Naimy, 1981).

On the other hand, the EA and EB binaries form very heterogeneous classes of objects. Regarding the EB binaries, we remark that almost all categorized stars with $P \lesssim 0.6$ days and ~ 80 % of the OBA-type stars with $P \lesssim 0.8$ days are c systems. At longer P, we encounter numerous d systems ; in particular, for $P \gtrsim 1.2$ days, the d systems greatly dominate in the spectral range FGKM and are $\sim 1/3$ of the EB stars of spectral types OB, whereas, of the remaining fraction, the a systems greatly prevail over the c systems. The EA binaries are mainly composed of a and d systems (the former generally predominate) ; but in the short-period range also several c systems are observed as EA binaries.

We observe that the c systems, for which an EW-type lightcurve morphology is a good criterion of identification, fairly frequently also appear as EB or EA binaries, especially in the earliest spectral types (63 %, 53 %, 16 % and 25 %, 23 %, 10 % are observed as short-period EB and EA stars, respectively, in the spectral ranges OB, A, and FGKM). Among the a systems, EA stars prevail over EB stars, whose proportion strongly decreases as we go towards the latest spectral range (this holds especially for the long and medium period range). Similar considerations hold for the d systems. Some RS systems (generally EA stars) are also observed as EB stars.

In order to shed light on the usefulness of the eclipse depths as indicators of binary evolution characteristics, in table III we present the distributions of the a, d, c systems with respect to the depths of primary and secondary eclipses A_1 and A_2 (expressed in blue magnitudes rounded off to the first decimal figure) for three spectral intervals, OB, A and FGKM, respectively. Counts of stars with unknown A_2 are given in the first column.

There are very few binaries with very low A_1 and there is generally a larger fraction of low-amplitudes variables among the stars of early spectral types (low-amplitude binaries are hard to discover especially when they are faint). Apart from the fairly flat A_1-distribution of the OB-type c systems, both the shapes of the A_1-distributions of the d and c systems are characterized by a single broad maximum which falls in the range $A_1 = 0.4$-0.7 and by a real decrease towards higher A_1-values. Very few d and c systems (8 % and 7 %) have $A_1 \geq 1$ mag. Both d and c systems tend to be concentrated towards small differences in the depths of the two eclipses, $\Delta = A_1 - A_2$: 85 % of the d and c systems have $\Delta \leq 0.4$. This tendency is stronger for the late-type c systems, which display a W UMa-type lightcurve much more frequently than the early-type c systems do.

The majority — though not by much (59 %) — of the a systems is characterized by $A_1 \geq 1.0$ mag ; the percentage of a systems having lower A_1 is far from being negligible (it is 67 %, 29 %, and 46 % in the spectral ranges OB, A, and FGKM, respectively), at variance with what is generally held in the literature (Kraicheva *et al.,* 1981). Accordingly, we remark that also the subsample of EA binaries having $A_1 \leq 0.9$ mag contains a high fraction of a systems (i.e., 43 %, 33 %, and 26 % of the number of categorized binaries of spectral types OB, A, and FGKM) ; for the subsample of EB binaries having $A_1 \leq 0.9$ mag, the corresponding fractions are 40 %, 20 %, and 15 %, respectively. (For both subsamples, in the spectral range OB, the percentage of a systems is comparable to that of d systems). Large values of Δ are frequently encountered in the a systems, especially in the intermediate and late spectral types (66 %, 92 %, 90 % have $\Delta \geq 0.5$ in the spectral intervals OB, A, FGKM).

We recall that the eclipse depths of the EA and EB binaries have been generally used in the literature as a basis for a statistical distinction between the nearly main sequence (substantially) unevolved systems and the post-mass exchange evolved Algols. In particular, high-amplitude EA and EB variables (i.e., with $A_1 \gtrsim 1$ mag), have been generally classified as evolved systems. Then, for statistical studies of the properties of unevolved binaries, it has been customary to isolate a sample of unevolved systems by culling the low-amplitude ($A_1 \lesssim 1$ mag) EA and EB binaries from the catalogued objects (e.g., Webbink, 1976 ; Kraicheva *et al.,* 1981). Although this procedure reduces sample contamination by evolved objects, we have seen that the low-amplitude EA and EB binaries remain much more appreciably contaminated by evolved pairs than previously thought.

The major conclusions of this section can be summarized as follows. The EW-type lightcurve morphology appears to be a good indicator of contact systems ; but not conversely as only about half of them (only ~ 1/10 in the spectral range OB) are observed as EW variables (34 % and 16 % are detected as EB and EA stars, respectively). In the case of EA or EB-type lightcurve morphology, criteria such as $A_1 \geq 1.1$ mag or $A_1 \geq 1.0$ mag coupled with $\Delta > 0.4$ allow us to identify an extensive sample of a systems (the majority of them in the first case), where the proportion of interlopers is small (i.e., 11 % or 12 %, respectively). But the appreciable fraction of a systems having low-amplitude ($A_1 < 1.0$ mag) eclipses cannot be (on the basis of the photometric appearance alone) distinguished from d and c systems. In fact, samples of low-amplitude EA (and EB) binaries (with $A_1 \leq 0.9$ mag) are very heterogeneous ; since they comprise 30 % (25 %) and 45 % (29 %) of the a and d systems, respectively (the remaining fraction is mostly constituted of c systems) ; setting an additional constraint on Δ (e.g., $\Delta \leq 0.4$), we would just lessen a little the proportion of a systems to roughly 1/4 (for both EA and EB stars), enhancing that of d and c systems.

In conclusion, our study stresses that statistical criteria (based on lightcurve morphology, A_1, and Δ) for the categorization of eclipsing binaries have a much more limited range of applicability than previously believed. In this sense, Svechnikov *et al.*'s (1980) overoptimistic findings, which rely on a much smaller set of eclipsing binary data, appear to be unfounded. In particular, the Soviet authors stated that about 90 % of the eclipsing binaries can be reliably categorized on the basis of the three parameters A_1, Δ, and period P.

4. The period distributions.

The above remarks give us an indication of the nature of some uncategorized binaries. Hence, before proceeding with the separate analysis of the statistics of periods of our binaries (for various categories and spectral types), we have deemed it useful to subdivide the uncategorized binaries into the following three classes.

i) Low-amplitude ($A_1 < 1$ mag) binaries having EA or EB lightcurves or unknown lightcurve morphology (they form a very heterogeneous class of objects) ; they are hereafter denoted as E1.

ii) High-amplitude ($A_1 \geq 1$ mag) binaries having EA or EB lightcurves, hereafter denoted as E2 (they are very likely to be a systems).

iii) Binaries having EW lightcurves, hereafter denoted as E3 (they are very likely to be c systems).

Table IV shows the distribution of the primary's average spectral types of our binaries, grouped into various spectral intervals and categories. The counts of our binaries falling within Log P-bins of width 0.1 and having primaries in the spectral range O-B4 are shown in figure 1 ; various lines are used to designate different categories of binaries ; keeping in mind the above considerations, we have deemed it convenient to group together the a and E2 stars (designated by heavy solid lines) and the c and E3 stars (dotted lines) ; the d systems are denoted by dashed lines, whereas thin solid lines designate the other binaries. Analogous plots for the spectral ranges B5-9.5, A0-2, A3-9, F, and GKM are shown in figures 2 to 6.

Our efforts to distinguish between different categories of binaries allow us to highlight some important features of the period distribution, which could not be recognized in earlier (more simple) general statistical studies of eclipsing binaries.

The period statistics in question are burdened by geometrical and photometric selection effects : the former, which are related to the geometrical probability of detecting eclipses (which depends on the sum of the fractional radii of the two binary components) favour the discovery of contact and near-contact systems (e.g., Farinella and Paolicchi, 1978). The latter effects, depending on the apparent brightness of a binary, on the amplitude and shape of its lightcurve, favour the discovery of high-amplitude bright eclipsing variables ; thus, these effects make the a systems (having, on average, deeper eclipses) more easily discoverable than the d and c systems (for a given spectral and period interval) ; but they may be neglected in the inspection of the statistics of pairs belonging to the same category.

Taking into account the above remarks, from inspection of the figures we can draw the following major considerations. First of all, as regards the d systems, an extensive sample of which has been already discussed by Giuricin *et al.* (1983b), it is enough to say that we confirm the main features of the period and spectral type distributions of substantially unevolved detached systems : the absence of significant secondary maxima at $P \sim 9$ and ~ 35 days (mentioned in some earlier studies), their real decrease in frequency towards the short-period side (with respect to their apparent maximum which falls well above the critical periods corresponding to the transition from case A to case B mass transfer), the consequent deficit of short-period systems (in particular of those potentially undergoing case A mass transfer), the tendency of the lower envelope of the observed periods to show an increasing deviation from the critical periods for a ZAMS contact system in the latest spectral interval, and the existence of a secondary maximum of the spectral type distribution at the late F spectral types (in addition to the usual peak at the early A spectral types). We may add that, compared with Webbink's (1976) estimates — based on Allen's (1973) tabular data — of the percentages of observed main sequence stars down to the magnitude limit $m_v \sim 12$ (i.e., 0.1 %, 18 %, 52 %, 22 %, 6 %, 1.5 % for the O, B, A, F, G, KM spectral types, respectively), the OB-type d systems appear to be overabundant. As already discussed by Giuricin *et al.* (1983b), the rarity of very close binaries may be a good indicator that such binaries are rarely formed in the early spectral ranges, whilst in the late spectral range it may also be related to the occurrence of a very efficient process of angular momentum loss, which causes non-contact binaries to be rapidly brought into contact (Vilhu, 1982, and references cited therein). Thus, the low proportion of Algol binaries having undergone case A mass transfer (e.g., Giuricin and Mardirossian, 1981) appears to be a natural consequence of the paucity of unevolved progenitors with small enough periods.

Focusing our attention on the evolved binaries, we find that, compared with the proportion of d systems, there appears to be an overabundance of a systems of early- and intermediate-A spectral types (just where the photometric discovery probability of a systems appears to be particularly large), together with an underabundance of late F types (which seems to be physically more significant). As in the case of the d systems, in the OB and early A spectral interval the number of a (or a + E2) systems, which reaches the maximum around $P \sim 3 \div 4$ days and ~ 2.5 days in the spectral ranges OB and early A, respectively) tends to decrease intrinsically so much, as we go towards shorter periods, that the short-period tail ($P \lesssim 1.2$ days) is mostly populated by c systems. As one moves towards later A spectral types, this tendency is much less prominent and the period distribution of the a systems become broader. The increasing proportion of short-period ($P \gtrsim 1.2$ days) a systems gives rise, in the spectral range F, to another prominent peak at $P \sim 0.7$ days (besides that at $P \sim 2.5$ days). Multiple peaks are visible in the medium-period range for the a and d systems of mid- and late-A spectral types. It is of great interest that, in the spectral range OB and early A, the distribution of the a systems is shifted, on average, to longer periods than that of the d systems, whereas the opposite is observed in the F range. Since the d systems are the presumable progenitors of the a systems, this finding indicates that the fraction of angular momentum loss (involved in processes of tidal mass transfer) from a binary system is larger for lower-mass than for higher-mass systems ; this is in line with Popov's (1970) contention that the mass which leaves the binary takes away a specific angular momentum ~ 1.5 times and ~ 3 times larger than that of the original system in the high- and low-mass range, respectively.

Compared with the number of late-type c systems, our statistics demonstrate a large deficit of early-type contact binaries (and not only of early-type systems displaying W UMa-type lightcurves). The large frequency of the cool contact binaries can be regarded as evidence for the occurrence of a particularly efficient process of production of contact systems in the late spectral range (a scenario involving evolution from non-contact systems by angular momentum loss seems to be the most suitable production mechanism ; see e.g., Rahunen and Vilhu, 1982).

For consistency with the results coming from the period statistics of the d systems, it is required that the bulk of the OBA-type c systems are not born in contact, but have originated from initially detached systems, whose initial periods may have been slightly longer than the c systems have on average, if significant angular momentum losses are involved in the initiation of the (till now obscure) contact interaction process. However, even in this case, the roughly comparable frequency of short-period ($P \lesssim 1.2$ days) d and c systems appears to require a quite stable contact configuration, whose long survival is not easily explained by theoretical views on contact binary evolution (e.g., Webbink, 1980). Moreover, we note that, compared with the a systems, the c systems are encountered with greater frequency in the O and early B spectral range than in the late B and early A interval. This may mean that massive binaries can more easily emerge as contact systems (rather than as typical semi-detached Algol systems) from the phase of mass transfer which occurs when initially detached systems first interact tidally.

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TABLE I. — *List of categorized eclipsing binaries.*

ζ	And	VV
o	And	c?
RT	And	d
SY	And	a
TT	And	a
TW	And	a
UU	And	a
WW	And	a
WZ	And	c
XZ	And	a
AA	And	c?
AB	And	c
AD	And	d
AN	And	d
AP	And	d
BD	And	c
BL	And	c
BX	And	c
CD	And	da
CN	And	c
CO	And	a
CP	And	a
CZ	And	d
DS	And	c
S	Ant	c
Y	Ant	a
XX	Ant	d
DW	Aps	a
RY	Aqr	a
ST	Aqr	c
SU	Aqr	c
AO	Aqr	c
BW	Aqr	d
CD	Aqr	d
CX	Aqr	a
CZ	Aqr	a
DD	Aqr	c?
DV	Aqr	da
DX	Aqr	a?
DY	Aqr	d
EE	Aqr	c
EL	Aqr	c
σ	Aql	d
Y	Aql	c
XZ	Aql	a
YZ	Aql	a
FK	Aql	a
KO	Aql	a
KP	Aql	d
OO	Aql	c
QS	Aql	a
QY	Aql	a
V337	Aql	a
V342	Aql	a
V343	Aql	a
V346	Aql	a
V409	Aql	a?
V415	Aql	a?
V417	Aql	c
V599	Aql	c
V602	Aql	a
V609	Aql	d
V694	Aql	c
V724	Aql	d?
V804	Aql	c
V805	Aql	d
V822	Aql	a
V889	Aql	d
V1182	Aql	d
V1331	Aql	c
R	Ara	a
RW	Ara	a
UW	Ara	a
LP	Ara	a
LR	Ara	d
V535	Ara	c
V537	Ara	d?
V539	Ara	d
RR	Ari	VV
RS	Ari	a
RX	Ari	a
SS	Ari	c
SZ	Ari	d
β	Aur	d
RY	Aur	a
RZ	Aur	a
SX	Aur	a
TT	Aur	a
WW	Aur	d
ZZ	Aur	c
AH	Aur	c
AK	Aur	a
AM	Aur	a
AP	Aur	c
AR	Aur	d
BF	Aur	d
CG	Aur	d
CL	Aur	a
CQ	Aur	RS
EM	Aur	d
EO	Aur	d
EP	Aur	ac
FP	Aur	c?
GI	Aur	d
HL	Aur	a?
HP	Aur	d
HS	Aur	d
IM	Aur	a
IU	Aur	a
KU	Aur	d?
LY	Aur	c
i	Boo	c
SS	Boo	RS
SU	Boo	a
TU	Boo	c
TY	Boo	c
TZ	Boo	c
UW	Boo	d
VW	Boo	c
XY	Boo	c
ZZ	Boo	d
AC	Boo	c
AD	Boo	d?
BW	Boo	d
Y	Cam	a
SS	Cam	RS
SV	Cam	d
SZ	Cam	a
TU	Cam	d
XZ	Cam	a
AL	Cam	d
AN	Cam	a
AS	Cam	d
AT	Cam	d
AW	Cam	a
AY	Cam	d
AZ	Cam	d
S	Cnc	a
RU	Cnc	RS
RZ	Cnc	a
SW	Cnc	d
TU	Cnc	a
TX	Cnc	c
UZ	Cnc	a?
VY	Cnc	d
WW	Cnc	a
WX	Cnc	d
WY	Cnc	d
ZZ	Cnc	a
RS	CVn	RS
VZ	CVn	d
R	CMa	a
RT	CMa	a
SW	CMa	d
SX	CMa	a?
SZ	CMa	d
TZ	CMa	d
UW	CMa	c
CW	CMa	d
FF	CMa	c
FM	CMa	d
FZ	CMa	d
GZ	CMa	d
UZ	CMi	c?
XZ	CMi	c
YY	CMi	c
AG	CMi	d
δ	Cap	d
RW	Cap	a
TY	Cap	a
UW	Cap	d
AD	Cap	RS
X	Car	c
SS	Car	d
ST	Car	c?
SW	Car	a
CI	Car	a
CV	Car	a
DO	Car	a
DQ	Car	d
DV	Car	c
DW	Car	c
EM	Car	da
EX	Car	a
EZ	Car	c?
GG	Car	d?
GL	Car	d
GM	Car	d
GU	Car	a
GV	Car	d
GW	Car	c
HI	Car	a
HP	Car	d?
KQ	Car	a
PX	Car	ac
PZ	Car	a
QR	Car	d
QX	Car	d
QZ	Car	a
V348	Car	c?
RX	Cas	a
RZ	Cas	a
SX	Cas	a
TV	Cas	a
TW	Cas	a
TX	Cas	c
UU	Cas	d?
XX	Cas	d
YZ	Cas	d
ZZ	Cas	a
AB	Cas	a
AO	Cas	c
AQ	Cas	a
AR	Cas	d
BZ	Cas	a
CC	Cas	a
CW	Cas	c
DN	Cas	a
DO	Cas	c
DZ	Cas	a
GG	Cas	a
GT	Cas	a
IL	Cas	a
IR	Cas	a
IS	Cas	d
IT	Cas	d
IV	Cas	a
KR	Cas	a
LR	Cas	a
MN	Cas	d
OR	Cas	d?
OX	Cas	d
PV	Cas	d
QQ	Cas	a?
QX	Cas	d
V366	Cas	d
V368	Cas	d
V375	Cas	a?
V380	Cas	a
V396	Cas	a
V459	Cas	d
V486	Cas	ac
V523	Cas	c
RR	Cen	c
RZ	Cen	a?
SS	Cen	a
ST	Cen	d
SU	Cen	a
SV	Cen	c
SW	Cen	a
SY	Cen	a
SZ	Cen	d
VZ	Cen	a
BF	Cen	a
BH	Cen	c
IV	Cen	VV
KT	Cen	d
LP	Cen	a?
LT	Cen	d
LW	Cen	c
LZ	Cen	d
MN	Cen	a
MP	Cen	a
MQ	Cen	c?
MR	Cen	d
NP	Cen	d
V344	Cen	a
V346	Cen	d
V348	Cen	a
V350	Cen	d?
V377	Cen	a
V379	Cen	a
V380	Cen	c
V402	Cen	d
V606	Cen	d
V621	Cen	a
V636	Cen	d
V646	Cen	a
V685	Cen	d
V701	Cen	c
V716	Cen	a?
V742	Cen	d
V745	Cen	a
V747	Cen	c
V752	Cen	c
V757	Cen	c
U	Cep	a
RS	Cep	a
SU	Cep	a?
VW	Cep	c
WX	Cep	d
WY	Cep	c
WZ	Cep	c
XX	Cep	a
XY	Cep	a
XZ	Cep	a
ZZ	Cep	d?
AH	Cep	d
AI	Cep	a
BB	Cep	a
CW	Cep	d
DH	Cep	d?
DN	Cep	d
DW	Cep	a
EG	Cep	c
EI	Cep	d
EK	Cep	d
EX	Cep	a
GK	Cep	c
GS	Cep	c
GT	Cep	a
GW	Cep	c
LZ	Cep	c?
NY	Cep	d?
NN	Cep	d
BD+57°2309		ac
RW	Cet	a
SS	Cet	a
TT	Cet	c
TU	Cet	VV
TV	Cet	d
TW	Cet	c
TX	Cet	c
TY	Cet	c
VV	Cet	c
VX	Cet	d
WY	Cet	d
WZ	Cet	a
XY	Cet	d
AA	Cet	d?
RS	Cha	d
RZ	Cha	d
YZ	Cha	d
T	Cir	a
AT	Cir	a
BF	Cir	a
RS	Col	c
RW	Com	c
RZ	Com	c
SS	Com	c
UX	Com	RS
ε	CrA	c
RW	CrA	a
TZ	CrA	a
UU	CrA	a
IS	CrA	a
α	CrB	d
U	CrB	a
RT	CrB	RS
RW	CrB	a
W	Crv	c
RV	Crv	c
SX	Crv	c
V	Crt	a
RS	Crt	c
RV	Crt	da
ZZ	Cru	a
AB	Cru	a
AE	Cru	a
AI	Cru	a?
Y	Cyg	d
SW	Cyg	a
SY	Cyg	a
UW	Cyg	a
UZ	Cyg	a
VW	Cyg	a
WW	Cyg	a
WZ	Cyg	c
ZZ	Cyg	a
AE	Cyg	a?
BR	Cyg	a
CG	Cyg	d
DK	Cyg	c
DL	Cyg	a
GG	Cyg	a
GM	Cyg	a
GO	Cyg	c
KR	Cyg	a
KU	Cyg	a
KV	Cyg	a
MR	Cyg	a
MY	Cyg	d
V345	Cyg	a
V346	Cyg	a
V366	Cyg	c
V367	Cyg	a
V371	Cyg	a
V380	Cyg	d
V382	Cyg	c
V387	Cyg	c
V388	Cyg	c
V401	Cyg	c
V442	Cyg	a
V448	Cyg	a
V453	Cyg	d
V455	Cyg	a
V456	Cyg	d?
V463	Cyg	a
V466	Cyg	d
V470	Cyg	d
V477	Cyg	d
V478	Cyg	d
V483	Cyg	d?
V498	Cyg	a
V505	Cyg	c?
V512	Cyg	a
V541	Cyg	d
V548	Cyg	a
V680	Cyg	a
V687	Cyg	a
V699	Cyg	a
V700	Cyg	c
V728	Cyg	a
V729	Cyg	c
V745	Cyg	d
V753	Cyg	c
V787	Cyg	a
V828	Cyg	d
V836	Cyg	c
V841	Cyg	c?
V891	Cyg	d
V909	Cyg	c?
V912	Cyg	a
V959	Cyg	a
V963	Cyg	c
V1011	Cyg	a
V1018	Cyg	d
V1034	Cyg	a
V1061	Cyg	d
V1068	Cyg	VV
V1073	Cyg	c
V1141	Cyg	c?
V1143	Cyg	d
V1305	Cyg	a?
V1425	Cyg	d
HR7551		VV
W	Del	a
RR	Del	a
TT	Del	a
TY	Del	a
YY	Del	a
AV	Del	a
BI	Del	a
BW	Del	d
BY	Del	d
DM	Del	c
FZ	Del	a
Z	Dra	a
RR	Dra	a
RX	Dra	d
RZ	Dra	a
SX	Dra	a
TW	Dra	a
TZ	Dra	a
UZ	Dra	d
WW	Dra	RS
AI	Dra	a
AR	Dra	a
AX	Dra	c
BF	Dra	da
BH	Dra	d
BS	Dra	d
BU	Dra	d
BV	Dra	c
BW	Dra	c
DE	Dra	d
BD+56°2190		d?
S	Equ	a
W	Equ	d
SV	Equ	c
RU	Eri	c
RY	Eri	a
RZ	Eri	RS
TZ	Eri	a
UX	Eri	c
VV	Eri	d
WX	Eri	a
YY	Eri	c
AO	Eri	a
AS	Eri	a
BC	Eri	c
BL	Eri	c
BQ	Eri	d
BW	Eri	c
BZ	Eri	d
CD	Eri	a
CO	Eri	a
CT	Eri	c
CW	Eri	d
SU	For	a
BD-36°01218		VV
RW	Gem	a
RX	Gem	a
RY	Gem	a
SV	Gem	a
SX	Gem	d
TX	Gem	a
WW	Gem	c
YY	Gem	d
AC	Gem	a?
AE	Gem	a
AF	Gem	a?
AL	Gem	a
AY	Gem	a
AZ	Gem	d
GW	Gem	a
GX	Gem	d
V	Gru	a
W	Gru	d
X	Gru	a
RU	Gru	d
RV	Gru	c
u	Her	a
θ	Her	VV
Z	Her	RS
RX	Her	d
SZ	Her	a
TT	Her	c
TU	Her	a
TX	Her	d
UX	Her	a
AD	Her	a
AK	Her	c
AW	Her	RS
BC	Her	a
BO	Her	a
CC	Her	a
CT	Her	a
DD	Her	a
DH	Her	a
DI	Her	d

TABLE I *(continued)*.

DK	Her	da
EF	Her	d
FN	Her	d
GU	Her	d
HS	Her	d
LT	Her	a
LV	Her	d?
MM	Her	RS
MT	Her	c
MX	Her	a
PW	Her	RS
V338	Her	a
V342	Her	a
V359	Her	d
V450	Her	d?
V600	Her	c?
V624	Her	d
TU	Hor	d
χ^2	Hya	d
RX	Hya	a
SX	Hya	a
SY	Hya	a
TT	Hya	a
TY	Hya	a
VW	Hya	a
VY	Hya	a
VZ	Hya	d
WY	Hya	d
AI	Hya	d
AV	Hya	c
DE	Hya	a
DF	Hya	c
DI	Hya	c?
EU	Hya	a
EZ	Hya	c
FG	Hya	c
GK	Hya	RS
HS	Hya	d
RS	Ind	c?
RY	Ind	c?
SU	Ind	a
RT	Lac	RS
RW	Lac	d
SS	Lac	d
SW	Lac	c
TW	Lac	a
UW	Lac	a?
VX	Lac	d
VY	Lac	a?
AR	Lac	RS
AU	Lac	a
AW	Lac	d?
CM	Lac	d
CN	Lac	a?
CO	Lac	d
CS	Lac	a
CY	Lac	a
DG	Lac	a
EK	Lac	d
GX	Lac	da
V345	Lac	d
V350	Lac	RS?
Y	Leo	a
RT	Leo	a
TX	Leo	d
UU	Leo	a
UV	Leo	d
UX	Leo	d
UZ	Leo	c
VZ	Leo	a
WY	Leo	d
WZ	Leo	a
XX	Leo	a
XY	Leo	c
XZ	Leo	c
AG	Leo	d
AL	Leo	d
AM	Leo	c
AP	Leo	c
HD82191		d
T	LMi	a
RT	LMi	c
V	Lep	c
Z	Lep	c?
RR	Lep	c
RS	Lep	a
δ	Lib	a
RV	Lib	RS
SS	Lib	a
VZ	Lib	c
EI	Lib	d
ES	Lib	c
HD136905		RS
DT	Lup	a
FT	Lup	c
GG	Lup	d?
HD134518		d
RR	Lyn	d
RZ	Lyn	a
SW	Lyn	c
SX	Lyn	a
TU	Lyn	VV
UU	Lyn	c?
VV	Lyn	c
β	Lyr	a
RV	Lyr	a
TT	Lyr	a
TZ	Lyr	c
UZ	Lyr	a
EW	Lyr	a
FL	Lyr	d
PY	Lyr	c
TY	Men	c
TZ	Men	d
UX	Men	d
VY	Mic	a
RU	Mon	d
RW	Mon	a
TU	Mon	a
UX	Mon	a
VV	Mon	RS
AO	Mon	d
AQ	Mon	a
AR	Mon	a
AS	Mon	a
AT	Mon	d
AU	Mon	a
AV	Mon	a
AW	Mon	a
BB	Mon	c
BO	Mon	a
DD	Mon	c
EP	Mon	d
FS	Mon	a
FV	Mon	a
FW	Mon	a
HI	Mon	d
HO	Mon	a
HY	Mon	d
IL	Mon	d?
IM	Mon	d
MX	Mon	c?
V380	Mon	d
V448	Mon	d?
V450	Mon	d?
V521	Mon	d?
HD47732		c?
TU	Mus	c
TV	Mus	c
VV	Mus	a?
AY	Mus	d
CX	Mus	a?
Z	Nor	a
RR	Nor	a
GM	Nor	d
IT	Nor	c
UZ	Oct	c
U	Oph	d
RV	Oph	a
SW	Oph	a
SZ	Oph	a
UU	Oph	a
WZ	Oph	d
V391	Oph	a
V451	Oph	d
V456	Oph	da
V501	Oph	c
V502	Oph	c
V506	Oph	d
V508	Oph	c
V535	Oph	a
V566	Oph	c
V735	Oph	a
V839	Oph	c
V846	Oph	d
V1010	Oph	c
δ	Ori	d
η	Ori	a
ψ	Ori	d
Z	Ori	a
VV	Ori	d
BM	Ori	d
CP	Ori	a
CQ	Ori	d?
DN	Ori	a
EQ	Ori	a
ER	Ori	c
ET	Ori	ac
EW	Ori	d
EY	Ori	a
FF	Ori	a
FH	Ori	a
FI	Ori	d
FK	Ori	a
FL	Ori	a
FM	Ori	a
FO	Ori	d
FR	Ori	a?
FT	Ori	d
GG	Ori	d
V392	Ori	a?
V530	Ori	a?
V536	Ori	d
V642	Ori	d
V647	Ori	d
V648	Ori	d
HD38735		d?
BI	Pav	a
KZ	Pav	a
MV	Pav	c
U	Peg	c
TY	Peg	a
UX	Peg	a
AQ	Peg	a
AT	Peg	a
AW	Peg	a
BB	Peg	c
BG	Peg	a
BK	Peg	d
BN	Peg	d
BO	Peg	d?
BX	Peg	c
DF	Peg	a
DI	Peg	a
DK	Peg	a
DM	Peg	a
DO	Peg	a
DV	Peg	d
EE	Peg	d
EH	Peg	a
GH	Peg	a
b	Per	a?
β	Per	a
Z	Per	a
RT	Per	a
RV	Per	a
RW	Per	a
RY	Per	a
ST	Per	a
WY	Per	a
XZ	Per	a
AB	Per	a
AG	Per	d
AY	Per	a
BO	Per	a
DM	Per	a
EX	Per	d
IK	Per	c
IQ	Per	d
IT	Per	a
IU	Per	d
IW	Per	d
IZ	Per	a
KW	Per	ac
LX	Per	RS
V436	Per	d
ζ	Phe	d
AE	Phe	c
AI	Phe	VV
δ	Pic	d
X	Pic	a
RV	Pic	a
Y	Psc	a
RV	Psc	c?
SU	Psc	a
SX	Psc	ac
SZ	Psc	RS
UU	Psc	d
UV	Psc	d
UW	Psc	d
RW	Psa	c
2	Pup B	d
V	Pup	a
RR	Pup	a
SW	Pup	a
TY	Pup	c
UZ	Pup	c
VY	Pup	a
XY	Pup	a
XZ	Pup	a
YY	Pup	d
ZZ	Pup	a
AA	Pup	a
AU	Pup	c
AV	Pup	c
KV	Pup	a
KX	Pup	d
MQ	Pup	a
NO	Pup	d
BD-20°2538		d
RZ	Pyx	c
TT	Pyx	a?
TY	Pyx	RS
U	Sge	a
SY	Sge	a?
UZ	Sge	a
CW	Sge	a?
DE	Sge	a
DM	Sge	d
EL	Sge	c
G	Sgr	d
RS	Sgr	a?
SX	Sgr	a
WX	Sgr	a
WY	Sgr	a
XY	Sgr	a
XZ	Sgr	a
YY	Sgr	d
ZZ	Sgr	a
BN	Sgr	a
BQ	Sgr	a
DV	Sgr	a
EG	Sgr	a
V354	Sgr	a
V356	Sgr	a
V505	Sgr	a
V523	Sgr	d
V524	Sgr	a
V525	Sgr	c
V526	Sgr	d
V779	Sgr	c
V1647	Sgr	d
V2283	Sgr	d
V2349	Sgr	a
V2509	Sgr	c
V2617	Sgr	c?
V3792	Sgr	d
HR 7464		d
μ^1	Sco	a
AL	Sco	a
FV	Sco	d
V393	Sco	a
V453	Sco	a
V474	Sco	d
V490	Sco	d
V496	Sco	d?
V499	Sco	d
V565	Sco	d
V590	Sco	a
V594	Sco	a
V604	Sco	d
V607	Sco	a
V616	Sco	d
V626	Sco	d?
V634	Sco	d?
V638	Sco	d
V700	Sco	a
V701	Sco	c
V760	Sco	d
V764	Sco	d
V906	Sco	d
BD-32°12935		c?
RT	Sct	c
VV	Sct	d
AL	Sct	d
U	Sct	a
W	Sct	a
RS	Sct	a?
RY	Sct	c?
RZ	Sct	a
AC	Sct	a
CT	Sct	a
CW	Sct	d?
ER	Sct	d
V	Ser	a
W	Ser	a
RS	Ser	c
AK	Ser	a
AO	Ser	a
AQ	Ser	d
AS	Ser	c
AU	Ser	c
BI	Ser	d
CC	Ser	c
CQ	Ser	a
CX	Ser	a
EG	Ser	d
Y	Sex	c
λ	Tau	a
RW	Tau	a
RZ	Tau	c
SV	Tau	a
TY	Tau	d
WY	Tau	c
AC	Tau	a
AH	Tau	c
AM	Tau	a
AN	Tau	d
AQ	Tau	a
BN	Tau	a
BV	Tau	a
CD	Tau	d
CF	Tau	a
CT	Tau	c
CU	Tau	c?
EN	Tau	d
EQ	Tau	c
ET	Tau	a
EW	Tau	d?
GR	Tau	c?
GW	Tau	d?
HU	Tau	a
V711	Tau	RS
RV	Tel	a
HO	Tel	d
V	Tri	a
X	Tri	a
RS	Tri	d
RU	Tri	VV
RV	Tri	a?
RR	Tra	c?
EP	Tra	d
EQ	Tra	a
V	Tuc	a
AN	Tuc	a
AQ	Tuc	c
BD-75°00026		RS
W	UMa	c
RW	UMa	RS
TX	UMa	a
TY	UMa	c
VV	UMa	a
XY	UMa	RS?
XZ	UMa	a
ZZ	UMa	d
AA	UMa	c
AC	UMa	a?
AF	UMa	a
AW	UMa	c
BH	UMa	c
ε	UMi	RS
W	UMi	a
RS	UMi	RS
RT	UMi	a
RU	UMi	c
S	Vel	a
RR	Vel	a
RV	Vel	a
RX	Vel	a
TT	Vel	a
ZZ	Vel	a
AC	Vel	d
AO	Vel	d?
AS	Vel	a
AY	Vel	a?
BC	Vel	d
BU	Vel	c
CV	Vel	d
CW	Vel	a
DN	Vel	a
DX	Vel	d
DZ	Vel	a
EO	Vel	d
EQ	Vel	a
FU	Vel	a
α	Vir	d
UW	Vir	a
UY	Vir	d
VV	Vir	c
AG	Vir	c
AH	Vir	c
AW	Vir	c
AX	Vir	c
AZ	Vir	c
BD	Vir	a
BF	Vir	a?
BH	Vir	d
CG	Vir	d
CX	Vir	d
DL	Vir	a
DM	Vir	d
W	Vol	a?
Z	Vul	a
RR	Vul	a
RS	Vul	a
XZ	Vul	a?
AB	Vul	d
AT	Vul	a
AW	Vul	c
AX	Vul	d
AY	Vul	a
AZ	Vul	a?
BE	Vul	a
BO	Vul	a
BP	Vul	a
BQ	Vul	d?
BS	Vul	c
BT	Vul	d
BU	Vul	a
CD	Vul	a
DR	Vul	d
EQ	Vul	d
ER	Vul	d
EV	Vul	a?
EY	Vul	a
FR	Vul	a

TABLE II.

EA binaries.

Log P	a	d	c	others
1.5–1.7	1 1 2			1 5
1.3–1.5	6 4			3
1.1–1.3	2 7	2 2		1 2
0.9–1.1	6 15 4	6 5 4		1 8
0.7–0.9	8 25 7	10 3 4		2 3 7
0.5–0.7	33 33 8	9 25 18	2	2 8 9
0.3–0.5	21 64 20	9 25 16		2 13 2
0.1–0.3	10 46 13	12 25 10	1 1	4 7 2
−0.1–0.1	4 23 7	1 12 13	4 4 3	3 7 4
−0.3– −0.1	7 9	1 6	1 9 4	2 6
−0.5– −0.3			1 4	2

EB binaries.

Log P	a	d	c	others
1.5–1.7	1			
1.3–1.5				
1.1–1.3	2			1
0.9–1.1	3	1 1		1
0.7–0.9	4	1 1	2	1 1 2
0.5–0.7	3	2 1	2	2 2
0.3–0.5	11 1	9 5	1	2 1
0.1–0.3	10 2	14 6 3	6	5 4 2
−0.1–0.1	4 8 4	3 6 7	4 15 2	2 5
−0.3—0.1	6 5	1 2	5 20 10	2 4 2
−0.5—0.3			6	1 1

EW binaries.

Log P	d	c	others
0.1–0.3			1
−0.1–0.1	2 1	3 2	1 2
−0.3—0.1	1 4	3 8 13	2 1 1
−0.5—0.3		1 5 57	2 5
−0.7—0.5		10	3

TABLE III.

Depth of the eclipses of the « a » systems.

A2 / A1		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0.1			3 1						
0.2	1		1	1					
0.3	2 1 1		6	1	1				
0.4	1 1		2	1 1	1 1 1				
0.5	2 2 1	1	1 1 2	5 2	2	2			
0.6	4 1 1	1 1	1 4 6	4 1 1	2 2	2	2 1		
0.7	1 9 2	1 1	3 4 3	4 2 2	2	2	1		
0.8	1 5 5		1 9 3	2 4	1 1	3 1			
0.9	2 1		5 4 1	2 4	2 1	3 2 2	1	1 1	
1.0	3 2 4	1 2	2 8	1 1 1	2 2	1		1	
1.1	7	1	3 4 2	1 1 2		1 2	1		
1.2	1 4 2	2	2 7	2 2		1			1
1.3	4	1	2 9	2 1	1				1
1.4	2 1		2 4		1 1				
1.5	1 8 1	1 1	1 1 2		1 1				
1.6	1		6	2	1		1		
1.7	4	1	1 1						
1.8	3 1		2		1				
1.9	3 2		1						
2.0	5 1		3	2		1			
≥2.1	2 28 7	2 9 2	8 27 3	3 1	1				

Depth of the eclipses of the « c » systems.

A1 / A2		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	≥1.1
0.0	1	1											
0.1	2		2										
0.2	1		1	1 3									
0.3	1			1 1	4 1 6								
0.4	1 1		1 2	1	1 2	1 12							
0.5	1 4		1 1	2	2 4	1 1 8	1 5 10						
0.6			1 1	2 7 1	1 1 3	2	2 4 6	3 9					
0.7	1	1		4	3 2		1 2	1 6	2 6				
0.8	1		1 1	2 2	2 2	1		2	1 4	1			
0.9	1		1	1	4	1		2 1	1	1 1			
1.0	1					1				1			
1.1			2					1			3	1	
1.2				1									
1.3									1				1
1.4	1									1			
1.5	1												
≥1.6	1		1										

Depth of the eclipses of the « d » systems.

A1 \ A2	-	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	≥1.1
0.0		2											
0.1		1 2	4 1 1										
0.2	1 2		5 7 1	3 2 1									
0.3	1 2	1	1 1	1 1	8 1								
0.4	6 3		1 2	4 2	3 2 1	6 7 2							
0.5	1 6 5	1	1 1	1 2 3	1 1 2	1 7 3	6 6 6						
0.6	7 2		2 1 1	1 1	1 1	5 2	6 2 3	5 5 1					
0.7	1 5 2	1	2 1 2	1 4 2	1 1 2	1 2	3 3	6 1 2	1 3 3				
0.8	1 3		3	1 3 2		1	2	1	1 3	3 2 2			
0.9	1 3		1		1 1	1	1 1 1	2	1				
1.0	4 3		2	1				1	1			1	
1.1					1					1			
1.2	1												
1.3	2 2		1										
1.4													
1.5	2												
≥1.6													1

TABLE IV. — *The number of binaries for various spectral classifications and categories.*

Sp. types	a	d	c	da	ac	RS	VV	E1	E2	E3
O	5	4	9							
B0–4	38	35	11	1	2		1	10		2
B5–9.5	78	50	18	1			1	19	8	1
A0–2	144	73	25	1	2			38	10	1
A3–5	78	26	25	1		1		8	2	1
A6–9	27	25	16					3	1	1
F0–4	32	29	33	1	1	2	1	7	2	1
F5–9	29	43	42	3	1	6		5	4	4
G0–4	15	13	22		1	8	3	4		1
G5–9	3	3	10			9	1			4
KM	3	3	4			4	4		1	2

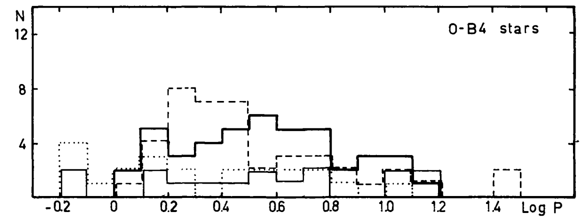

FIGURE 1. — Counts (N) of the eclipsing binaries having primaries in the spectral range O-B4, for various categories; the counts of the a and E2, d, c and E3 systems are designated by heavy solid lines, dashed lines, and dotted lines, respectively; thin solid lines designate the other binaries; bins of 0.1 width in Log P (decimal logarithm of the orbital period, expressed in days).

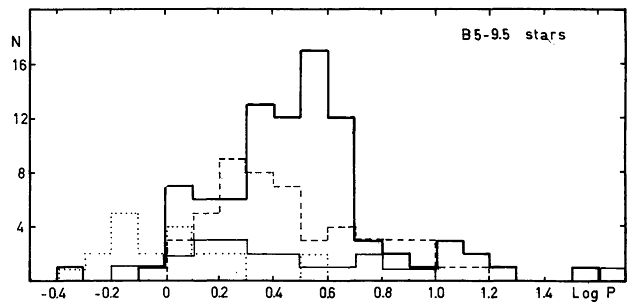

FIGURE 2. — The same as in figure 1, but for the spectral range B5-9.5.

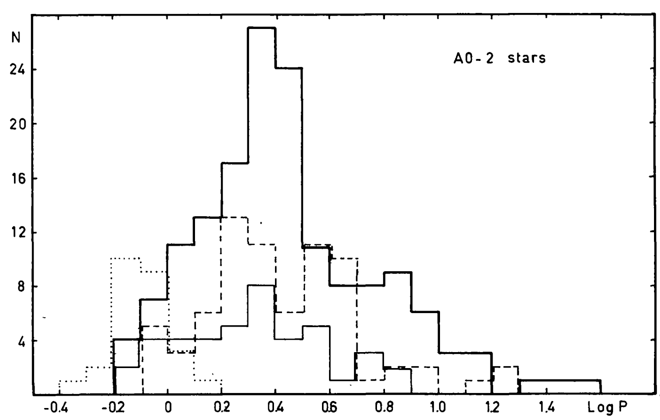

FIGURE 3. — The same as in figure 1, but for the spectral range A0-2.

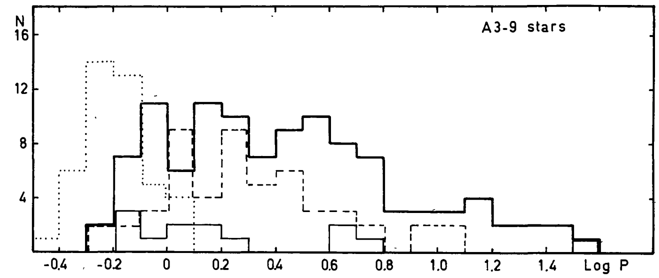

FIGURE 4. — The same as in figure 1, but for the spectral range A3-9.

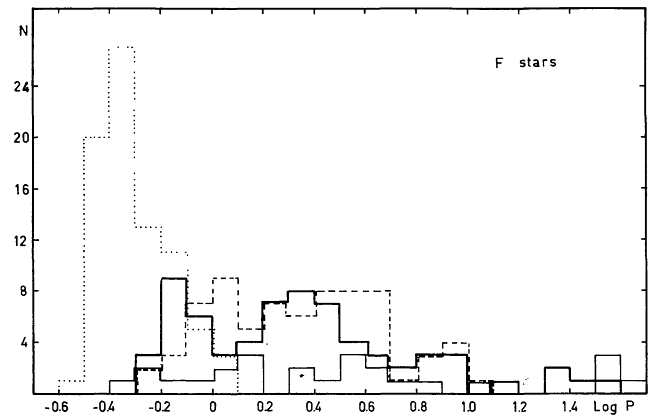

FIGURE 5. — The same as in figure 1, but for the spectral range F.

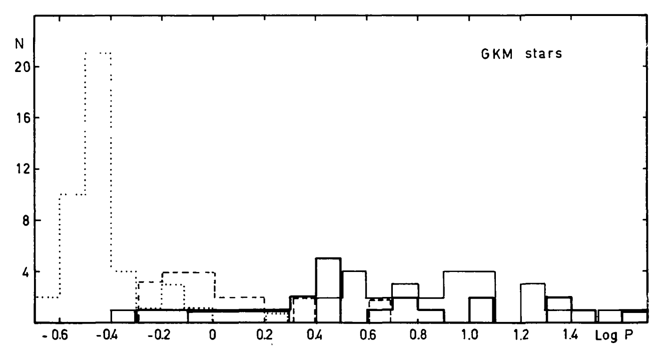

FIGURE 6. — The same as in figure 1, but for the spectral range GKM.