SPECTRAL CLASSIFICATION OF RED VARIABLES ALONG THE GALACTIC EQUATOR

DONALD CAMERON AND J. J. NASSAU
Warner and Swasey Observatory, Case Institute of Technology
Received April 17, 1956

ABSTRACT

A catalogue is presented containing spectral classes, on the Case infrared system, for 723 red variable stars in a belt 12° in width, centered on the galactic equator, and extending from longitude 333° through zero to 201°. All known variables to the limiting photographic magnitude of 15.0 at maximum were selected. The statistical discussion is based on 541 M-type variables for which sufficiently reliable data are available The spectral distribution is shown in the form of histograms for the Mira, long-period, semiregular, and irregular types of variability. The first two groups show a spectral range between M2 and M10, while the two latter groups are strongly concentrated at M6 and M6.5, with none later than M7. Only 20 per cent of the M-type variables are earlier than M5 Frequency distributions in galactic longitude seem to indicate that the Mira and long-period types tend to concentrate along the local spiral arm, while the semiregular and irregular types form a disk distribution. However, these conclusions must be regarded as tentative. An examination of the period-spectrum relation does not show significant differences at different galactic latitudes However, the number of M variables in each subgroup is small. The galactic zone includes 110 carbon stars which are variable and 12 S-type stars The period-frequency distribution of the carbon stars shows that about one-third of them have periods betwen 360 and 440 days.

I. INTRODUCTION

A catalogue is given containing the spectral classification of 723 red variables with photographic magnitude 15.0 and brighter at maximum light, in a zone 12° in width centered at the galactic equator from longitude 333° through zero to 201°. It includes M, S, and carbon stars, as well as a few stars with peculiar spectra. The discussion is based principally on 541 M-type stars for which the data on spectrum, type of variability, and identity are known with reasonable certainty. The list of known red variables was prepared from the *General Catalogue of Variable Stars* (Kukarkin and Parenago 1948), the six supplements (Kukarkin *et al.* 1949–1954), and the *Catalogue of Stars Suspected of Being Variable* (Kukarkin *et al.* 1951).

II. THE DATA

The region was covered by three sets of overlapping plates, one centered at the galactic equator (central zone), the second at latitude $+4°$ (zone *a*), and the third at latitude $-4°$ (zone *b*). The total number of plates with ample overlaps to cover the region completely was 192. The infrared spectra were secured with the 4° objective prism with a basic exposure of 10 minutes. Most of the plates had two additional shorter exposures, to permit the classification of the brighter stars. The 1-N emulsion used with a Wratten No. 89 filter covered the near infrared region from λ 6800 to λ 8800.

All M stars were classified on the Case infrared system, as described by Nassau and van Albada (1949), and upon the revision and extension of this system for very late M's (M6.5–M10) given by Cameron and Nassau (1955).

The identification of the variables was made in the following manner. The co-ordinates of the stars were computed for the epoch of 1855 and then plotted on special *BD* charts which had been enlarged to the scale of our plates. In the majority of cases no difficulties were encountered, as simple superposition identified the stars with certainty. However, in regions crowded with M stars and in cases where exact coincidence was not attained, certain identification was not always possible. Doubtful cases are indicated in

Table 2 as described later. When all methods of identification failed, the star was omitted. The choice of the limiting magnitude, $m_{pg} = 15$, was made after preliminary studies showed that a fainter limit would yield spectra too faint for classification with certainty. This refers to both early and late M-type stars. Table 1 gives a summary of the number of all the variables observed in the survey according to type of variability and spectrum.

III. DESCRIPTION OF CATALOGUES

The arrangement of the variables in Table 2*a* is according to constellations, and the star designations follow the practice of the *General Catalogue of Variable Stars* (Kukarkin and Parenago 1948). Likewise, the type of variability (col. 2) and the spectral class (col. 3) were secured from the same catalogue and the seven supplements (Kukarkin *et al.* 1949–1955). The fourth column gives the Case spectral class, and the fifth column the date of observation. An asterisk (*) attached to the name of the variable refers to the notes at the end of Table 2*b*. A dagger (†) after the name of the star indicates that the identification is uncertain. A double dagger (‡) after the name of the star indicates that

TABLE 1

NUMBER OF VARIABLES CLASSIFIED

Spectrum	Mira	L P.	S.R.	Irreg.	Total
M	213	72	73	221	579
C	20	13	18	59	110
S	8	1	1	5	15
Total	241	86	92	285	704*

* Table 2 contains, in addition, 19 stars which, for various reasons, do not fit in Table 1, making the total 723 stars

additional spectral observations are given in Table 3. They were secured from other available plates of the same region taken on different dates. Table 2*b* gives spectral data of stars which are in the first part of the *Catalogue of Stars Suspected of Being Variable* (Kukarkin *et al.* 1951).

The detection of S stars in the near infrared is made from the presence of the lanthanum oxide bands at λ 7400 and λ 7900 and the highly reddened appearance of the spectrum. However, not all S stars show the lanthanum oxide bands in the infrared (Keenan 1954; Nassau *et al.* 1954). These featureless, but highly reddened, spectra cannot readily be distinguished from highly reddened M0 or M1 stars, particularly when the spectrum is overexposed. For spectra of this type in Tables 2 and 3, the symbol "S:" was adopted, which designates "possible S star" or "supergiant early M."

An examination of Table 2 reveals certain rather large discrepancies between the spectrum given in the *General Catalogue of Variable Stars* and the Case spectrum for some irregular and semiregular stars. For example, in the *General Catalogue of Variable Stars* the spectrum of AZ Cep, an irregular variable, is M6, while the Case spectrum for this star is M0. Since previous investigations (Joy 1942) have shown that variables of these two types do not, in general, vary more than 1 or 2 spectral subdivisions, a careful re-examination of all such cases was made. In a very few of these cases there was found to be some doubt as to the identification, but in most cases the existence of the discrepancy was confirmed. The differences referred to are much too large to be attributed to differences in the systems of classification.

TABLE 2a

SPECTRA OF RED VARIABLES IN THE GALACTIC ZONE

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
		AQUILA		
R Aql	M	M7e	M9	9 - 6-53
T	I?	M5	M5	7-20-54
RT*	M	M7e	M9p	7-20-54
SS	M		M6	7-20-54
UV	SR	N	C	7-20-54
UW	I	M0	M2:	9 - 2-54
XY	M		M8	7-20-54
AB	I?	M4	M5:	9-30-53
EM	M	M5	M7	7-20-54
EQ	LP		M5	7-22-54
ER*	M	Me	S	7-20-54
EU	M		M9	7-20-54
HP†	M		M6	9 -2 -54
KQ	SR	M1	M4	7-20-54
KT	LP		M5	7-20-54
KU	LP		M5	7-20-54
LO†	M		M0	7-20-54
LS	SR		M4	7-20-54
LU	SR	M4	M5	7-22-54
LX	LP		M9	7-22-54
MM	LP?		M8	7-22-54
MU	M		M4	7-22-54
MW	M?		M3	7-22-54
MX	LP		M9	7-22-54
V338	LP?	M5	M3	7-22-54
V353	I		M6	7-20-54
V373	I		M6.5	7-20-54
V446	SR	M1	M2	7-22-54
V449	I		M6.5	7-22-54
V451	I		M6	7-20-54
V455	M		M8	7-22-54
V462	I		M6.5	7-22-54
V473	I		M3:	7-20-54
V474	M		M6.5	7-20-54
V477	I	M6	M6.5	7-20-54
V482	I		M6	7-20-54
V483	I		M6	7-20-54
V486	I		M3	7-20-54
V637	M		M2	7-20-54
V642	I		M6	7-20-54
V806	M	M9	M6	9 -6 -53
V807	I?		M6.5	7-22-54
V812	LP		M7	7-20-54
V819	M		M9:	7-20-54
V830	I	M2	M5	7-22-54
V842	I	M7	M6	7-20-54
		AURIGA		
S Aur	LP	N	C	10-30-53
U ‡	M	M7e	M7:	11-16-54
W‡	M	M3e	M5	10-30-53
RU	M	M8e	M8	11-8 -54
SZ	M	M6e	M8	11-8 -54
		AURIGA (Cont'd)		
TV Aur	SR	S	S	11-7 - 54
TX	I?	N	C	10-30-53
UV	SR	Ne	C	10-30-53
UZ	I	M4	M4	10-30-53
AQ ‡	M	M7	M7	11-8 - 54
AU	M	Ne	C	11-7 - 54
AW	M		M9	11-7 - 54
AY	M	M4	M6.5	11-16-54
BB	SR	M3	M5	11-16-54
BG	LP		M7	11-8 - 54
BI	M		M6	11-8 - 54
BO	SR		M6	11-16-54
BP	I		M6.5	11-16-54
BQ	I		C	11-16-54
BR	I		C	11-16-54
BS	M		M9	11-16-54
BT	M		M8:	11-16-54
CM	I	N	C	11-8 - 54
DD	I		M6	11-8 - 54
DF	I		M6	11-8 - 54
DH	SR		M3	11-8 - 54
DI	I	N:	C	10-30-53
DL	I		M6	11-8 - 54
DM	M	M7	M7	10-30-53
DQ ‡	I	M5	M6	10-30-53
DR	SR		M6	10-30-53
DS	I	R or N	C	11-8 - 54
DV	SR	M5	M5	10-30-53
DZ	I		M6	11-8 - 54
EE	SR?	M7	M7	10-30-53
EF	I		C	11-8 - 54
EG	SR	M6	M7	10-30-53
EH	I		M6	11-8 - 54
EN	I?	M3	M6	10-30-53
EX* †	LP	M1	C	11 -8 - 54
EY	M		M6	12-17-52
EZ	I	M2	M6.5	12-17-52
FH	I		M6.5	12-17-52
FI* †	I	M1	M6.5	12-17-52
FL	I		M3	12-17-52
FQ	I		M3	11 -7 - 54
FT	I		M6.5	11-16-54
FU	I?	N	C	11-16-54
GH †	M		M10:	11-16-54
		CAMELOPARDALIS		
AG Cam	SR	M4	M3	10-30-53
		CANIS MAJOR		
W CMa	I	N	C	11-8 - 54
RS	I		M6.5	11-8 - 54
RV	I	M6	M6	11-16-54
SU	M		M6.5	1-1-55
SV	I		M4	1-1-55

TABLE 2a (Continued)
SPECTRA OF RED VARIABLES IN THE GALACTIC ZONE

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
		CANIS MAJOR (Cont'd.)		
TT CMa	M		S	11-8-54
BF	LP		M6.5	11-8-54
BV	I	N	C	11-8-54
CS	SR		M4	11-8-54
DI	M		M2	11-16-54
DK	M		S:	11-16-54
DM	M		M0:	11-16-54
DN	M		M9	1-1-55
DR	I		M5	11-8-54
DS	M		M4	11-8-54
DU	LP		M6.5	11-8-54
DX	I		M4	11-13-54
		CASSIOPEIA		
V Cas	M	M6e	M6	6-28-54
W*	M	Se	C	9-29-53
X	M	Ne	C	12-18-52
Z	M	M7e	M10	9-29-53
TY	M?		M6	9-29-53
TZ	I	cM2	M2:	6-29-54
UW	M	M5	M9:	9-29-53
UX	I?	R	C	9-29-53
VY‡	SR	M6	M6.5	6-29-54
WW	I	N	C	9-28-53
WX	I?		M0:	12-18-52
WY*	M	M3	Sp	9-29-53
WZ	SR	N	C	9-29-53
AA	I	M6	M6	9-28-53
AV†	M	N	C	6-29-54
BB	M		M8	6-29-54
BL	SR?	M6	M6	6-29-54
BO	I		M6	9-28-53
BQ	I		M6 5	9-28-53
BT	M	M8	M9	12-18-52
BX	SR?	M6	M5	12-18-52
CI	I		M6.5	9-28-53
CQ	I		M6 5	9-28-53
CU	SR	M6	M6	9-29-53
CX	SR		M6	9-28-53
DE	SR	M6	M6	9-28-53
DG	LP?		M6	9-29-53
DQ	I		M5	6-29-54
DR	I	M2	S:	6-29-54
DS	I	N	C	6-29-54
DX	M		C	6-29-54
DY	SR	M5	M6.5	9-29-53
EH	I	M4	M2:	6-29-54
EM	LP	M6	M6.5	6-29-54
EO	M	S	S	6-29-54

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
		CASSIOPEIA (Cont'd.)		
ER Cas	LP		M6	6-29-54
EZ‡	I		M6	6-29-54
FP	I		M6	9-29-53
FR	I	N	C	9-29-53
FX	LP		C	9-29-53
FZ	I		M6.5	9-29-53
GP	I	M3	M4	12-17-52
GQ	SR		M6	12-17-52
GS‡	I	M7	M6	12-17-52
GV	I	M4	M3	9-29-53
GW	I		C	9-29-53
HL	LP		C	9-28-53
HO	I	R	C	12-18-52
HS	I?		M3	12-18-52
HX	I		M3	9-28-53
II	M		M5	12-18-52
IM	SR	M5	M1	12-18-52
KN	I	M2	M1	9-29-53
KW	M		M6 5	9-1-54
		CEPHEUS		
W Cep	SR	Mep	M1	6-28-54
RW	I	cM0	M1:	6-28-54
ST	I	cM0	M2	6-28-54
TT*†	SR	M2	M6.5	9-1-54
TW	M	M0	M6.5	9-1-54
VX	M		M8	9-29-53
YY	M?	M6	M7	6-28-54
AB	M		M8	6-28-54
AC	M		M6.5:	6-28-54
AL	M		M6.5	6-28-54
AS	I	M4	M1:	6-28-54
AZ	I	M6	M0	9-1-54
BX	I		M5	9-29-53
BY	I	M3	M2	9-29-53
CD	I		M3	9-29-53
CH	SR	M3	M5	9-29-53
CI ‡	M		M5	9-29-53
CK	SR	M7	M7	9-29-53
CU	M	M6	M4	6-28-54
CV	SR	M3	M4	6-28-54
DG	I	N	C	9-1-54
		CYGNUS		
U Cyg	M	Ne	C	9-1-54
RR	SR	M3	M1:	10-30-53
RS	SR	Ne	C	6-29-54
RU	SR	M8e	M6.5:	6-24-54
RW	LP	cM3	M5	6-29-54
RY	I?	N	C	6-29-54
RZ	M	M7	M7	6-19-54
SX	M	M7e	M8	9-2-54
TT	SR	Ne	C	8-31-54
TY	M	M8	M6.5	7-22-54

TABLE 2a (Continued)
SPECTRA OF RED VARIABLES IN THE GALACTIC ZONE

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
		CYGNUS (Cont'd.)		
WX Cyg	M	Ne	C	6-29-54
YY	SR	N	C	9-2-54
AA*‡	SR	S	Mp	9-1-54
AD*‡	I	S	S:	9-2-54
AG	M	M6	M9:	9-1-54
AH	SR	M5	M6 5	9-1-54
AI ‡	I	M5	M6.5	9-2-54
AU	M	M6e	M7	6-29-54
AY	I	N	C	9-1-54
AZ*	I	cM2	M2	10-30-53
BC*	I	M4	M3:	6-29-54
BG‡	LP	M8e	M8	8-31-54
BH	M	M4	M5	9-2-54
BI ‡	I	M5	M3	6-29-54
BK	M		M9	9-5-54
BL	M		M6.5	9-5-54
BN	M	M4e	M4	9-5-54
BP	M		M5	9-5-54
BQ	M		M7	9-5-54
DG	M		M7	9-25-53
DH	M	M7	M6	6-19-54
DR	M	M3e	M7	9-2-54
DS	I	N	C	10-30-53
DV	M	M2	M2:	7-22-54
DW	M	M2	M6.5	7-22-54
EF	LP		M6.5	8-31-54
EH*†	M	M1	M6	9-10-53
EL†‡	M		M5	8-31-54
EO	M		M5	8-31-54
EQ	M	M5	M6.5	8-31-54
ER	LP		M8	8-20-53
ES	LP		M6.5	8-20-53
EV	M		M6.5	8-20-53
EW	SR		M6 5	8-20-53
FF*‡	M	M4e	S	9-2-54
FG	M		M9:	9-5-54
FH	LP		M5	7-22-54
FK	LP		M5	7-22-54
FM	M		M9	7-22-54
FN	M		M6	7-22-54
FQ	M		M9	8-31-54
FS	M		M6	8-31-54
FT	LP		M5	8-31-54
FV	LP		M3	9-10-53
FW	M		M7	8-31-55
FY	LP		M6	8-31-54
FZ	M		M9:	9-1-54
GN	SR	M5	M7	9-1-54
GU	M		M9	9-5-54
GY	I	M3	M7	9-5-54

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
		CYGNUS (Cont'd.)		
HI Cyg	LP		M5:	8-31-54
HR	M		M10	8-31-54
HV	SR	N	C	8-31-54
HW†	LP		M2	8-31-54
HX	M		M7	8-31-54
HY	LP		M7	9-10-53
HZ*†	M		M6	8-31-54
II	SR		M6 5	8-31-54
IK	SR		M5	8-31-54
IL	M		M9:	8-31-54
IN†	M		M6.5	8-31-54
IP	M		M10	8-31-54
IQ	M		C	8-31-54
IX	SR		M6.5	8-31-54
IZ	M	M7	M3	9-1-54
KL	M		C	8-20-53
KM	M	M4	M5	9-1-54
KO	M	M6	M6	6-29-54
KW	LP		M2	9-1-54
KZ	M	M8e	M9	6-29-54
LM	M		M6	9-2-54
LP	M		M8	9-5-54
LT	M		M7	9-5-54
LV	M		M7	9-5-54
LX*‡	M		S	9-5-54
LY	M		M5	9-5-54
LZ	M		M9:	9-5-54
MM	LP		M7	9-5-54
MQ	M	N	C	6-24-54
MV	I		M6	9-5-54
OQ	I		M7	9-1-54
PP	M	M7e	M6.5:	9-1-54
PR	I	M4	M6	9-1-54
PU	I	N	C	9-1-54
QZ	I	M3	M3	9-1-54
V338	M	M5e	M8	9-1-54
V341	M	M5e	M7	9-1-54
V342	LP		M7	9-1-54
V349	I		M4	10-30-53
V354‡	SR	M6	M5	9-2-54
V362	SR		M6.5	6-19-54
V375	LP		M6.5	9-2-54
V384	LP		M5	9-2-54
V397	I	M2	M7	9-2-54
V405‡	I	M6	M6.5	6-29-54
V408	I	M3	M6	6-19-54
V410	M		M8	9-5-54
V413	I	N	C	6-24-54
V415	LP		M6	9-1-54
V417	I		M6	9-1-54

1956ApJ...124..346C

TABLE 2a (Continued)
SPECTRA OF RED VARIABLES IN THE GALACTIC ZONE

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
CYGNUS (Cont'd.)				
V420 Cyg	I		M2	9-1-54
V421	M		M8	9-1-54
V422	M	M6	M4	6-29-54
V423* †	LP		M6	9-1-54
V424	I		M6	9-1-54
V427	SR		M3	9-1-54
V430	I?	M4	M3	6-29-54
V431	I		M6.5	9-1-54
V432	I	R	C	6-29-54
V433	LP		M6 5	6-29-54
V434	M		M5	6-29-54
V436	LP		C	6-29-54
V440	I		M3	6-29-54
V441	LP	M5	M4:	9-2-54
V446	LP	M5	M6.5	9-2-54
V449 ‡	I	M3	M3:	8-31-54
V452	M		M7	9-1-54
V467	SR	N	C:	8-20-53
V487	SR	M3	M6:	8-20-53
V489	I	Mc	M6.5	9-2-54
V497	M		M8	9-1-54
V506	M		M7	9-1-54
V515	LP		M6	10-30-53
V527	I	M7	M6.5	9-2-54
V551 ‡	M		M6	9-2-54
V557	M	M7	M9	8-20-53
V562	M		M6.5	9-2-54
V573	M	R	C	6-19-54
V575	SR	S	S	6-19-54
V579	I	M5	M6	9-2-54
V582	I	M4	M4	6-19-54
V590	I	M5	M6	9-5-54
V591	I	M2	M1	9-5-54
V592	LP		M7	9-5-54
V594	I		M6	9-2-54
V595	I		M5	9-5-54
V597	M		M6.5:	9-2-54
V600	M		M6	9-5-54
V606	SR		M5	9-5-54
V612	I		M6.5	9-5-54
V615	M		M6	6-28-54
V617	I		M5	9-5-54
V619	I		M6.5	9-5-54
V622	I		M5	9-5-54
V623	I		M6.5	9-5-54
V624	I	N	C	9-5-54
V626	I	M0	M6	9-5-54
V627	LP		M5	9-5-54
V629	I	M4	M6	9-5-54
V634	I		M4	9-5-54
CYGNUS (Cont'd.)				
V637 Cyg	M		C	9-5-54
V643	LP		M6	9-5-54
V644 †	LP		C	9-5-54
V649	I		M6	9-5-54
V653	LP		M6.5	9-5-54
V655	M		M7	9-5-54
V656	LP		M6.5	9-5-54
V662	M		M6:	9-5-54
V674	I		C	9-5-54
V682	I		M6	9-5-54
V685	I		M6	9-5-54
V701	I		C	9-2-54
V707	SR		M4	9-5-54
V717	I	M2	M2	8-20-53
V718*	SR	M3	M5	8-20-53
V722 ‡	I		M6.5	8-20-53
V723	I		M6	8-20-53
V727	M		M7	9-2-54
χ* ‡	M	Mpe	M10	8-31-54
GEMINI				
TU Gem	I	N	C	11-16-54
UU	M		M9	11-13-54
AB	I	N	C	12-26-54
AP	I		M6.5	11-13-54
AQ	I	M6	M6.5	11-13-54
AR	LP		M6	11-13-54
AS	I		M6	11-13-54
AT	SR		M6	12-26-54
BF	LP		M6	11-16-54
BI	I	M3	M6.5	11-16-54
BL	I	M4	M6	11-13-54
BV	I		M4	11-16-54
BX	I		M5:	11-16-54
BY*	I		M5p	11-16-54
BZ	I		M2	11-16-54
CC	SR	M3	M6.5	12-26-54
CF	I		S	12-26-54
CG	LP		M6.5	11-16-54
CL	LP	M3	M6.5	12-26-54
CN	LP		M7	12-26-54
CR	I	N	C	11-13-54
DH	SR	N	C	11-13-54
DO	M		M5	11-7-54
DY*	SR	M	M5	11-13-54
EE	M		M6	11-13-54
EK	LP		M7:	11-16-54
EP	SR?		M6.5	11-13-54
EV	I		C	12-26-54
FK	I	M7	M6.5	12-26-54
HERCULES				
NN Her	I		M5	7-20-54

TABLE 2a (Continued)
SPECTRA OF RED VARIABLES IN THE GALACTIC ZONE

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
LACERTA				
SV Lac	M		M7	9-1-54
TV	I	N	C	9-1-54
TX	I	R	C	9-1-54
TY	M		M8:	9-1-54
UU	M		M5:	9-1-54
UZ	M		M9:	9-1-54
VW	M		M9	9-1-54
WW	LP		M5:	9-1-54
WY	I?		M6.5	9-1-54
WZ	LP	M6	M6	6-28-54
XY	SR		M4	9-1-54
YY	I?		M6	9-1-54
YZ	LP		M7	9-1-54
AA	I		M6.5	9-1-54
AB	SR?		M6	9-1-54
AD	SR		M6	9-1-54
AF	I?		M5	9-1-54
AL	I		M6 5	9-1-54
AM	M		M5	9-1-54
AN	M?		M9	9-1-54
AO	M		C	9-1-54
AP	M		M9:	9-5-54
AS	M		M2	9-5-54
BX*	M		M10	6-28-54
CT	I	R	C	9-5-54
CU	I?		M6	9-1-54
CV	I		M5	9-1-54
CW	I		M0:	6-28-54
DM	M		M7	9-1-54
DS	M		M6	9-1-54
DU †	M		M2	9-1-54
DV	I	N	C	6-28-54
LYRA				
S Lyr* ‡	M	Me	S	7-22-54
X	I	M0	M2	7-22-54
BW	I		M2	7-22-54
MONOCEROS				
V Mon	M	M5e	M8	11-13-54
W	I	N	C	12-17-52
X	SR	M3e	M5	12-17-52
RV	SR	N	C	11-13-54
RY	LP	N	C	12-17-52
RZ	M		M6	12-26-54
ST	M		M6.5	12-26-54
SW	SR	M5	M6	11-8-54
SY	M	M6e	M7	11-13-54
TT	M	M5e	M7	11-13-54
WY	I		M6	11-16-54
AF	M	M7	M7	12-17-52
AH	M		M7	11-13-54
AK	M		M5	11-13-54
AL	M		M3	11-13-54
MONOCEROS (Cont'd.)				
AM Mon	M		M10	11-13-54
AP	I		M3	12-17-52
AZ	M		M9	11-13-54
BF	M		M6	12-26-54
BG	LP	N	C	11-13-54
BK	M		M4	11-13-54
BN	SR	N	C	11-8-54
BR	I		M5:	11-13-54
BU	LP		M3:	11-13-54
BY	SR		M6	11-8-54
CD	M		M6.5	11-8-54
CG	M	N	C	11-13-54
CL	M	Ne	C	11-13-54
CN	M		M7	11-8-54
CO †	LP	N	C	11-13-54
CQ	I	M6	M6	11-8-54
CR	I		C	11-13-54
CT	I		M6	11-8-54
CY* †	I	M7	M5	11-8-54
DE	I	N	C	11-8-54
DF	I	N	C	11-8-54
DG	I		M2	11-8-54
DI	I	M2	M6	11-13-54
DM	I		M6.5	11-13-54
DS	LP		M6	11-16-54
DX	I		M2	11-8-54
EF	I		M7	11-16-54
EG	I	M6	M6	11-8-54
EL	I	M6	M5	11-8-54
EM	LP	R:	C	12-17-52
EN	I		M2	11-8-54
EO	I	M6	M5	11-8-54
ER	M		M9:	12-17-52
EU	I	N	C	11-8-54
EX	I		M5	12-17-52
FF	I		M3	11-13-54
FL	I		M4	11-8-54
FM	I		M5	11-8-54
FO	I		M4	11-13-54
FR	I		M6	11-13-54
FU*	SR	S	S:	11-13-54
FX	M		M6.5	12-26-54
GN	M		M9:	11-8-54
GS †	M		M9:	11-16-54
GT	LP		M5	11-8-54
GW	M		M7	11-16-54
GX	M		M9	12-26-54
GY	I	N	C	11-8-54
HN	M		M9:	12-17-52
HW	M		M10:	11-8-54

TABLE 2a (Continued)
SPECTRA OF RED VARIABLES IN THE GALACTIC ZONE

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
		MONOCEROS (Cont'd.)		
IN † Mon	I	M4	M3	12-26-54
IT	I		C	12-26-54
KN	I		S:	11-8-54
KO	I		M6	11-8-54
KP	I		M2	11-8-54
KQ	I		C	11-8-54
		OPHIUCHUS		
X Oph	M	M6e	M9	7-20-54
TY	I	N	C	7-20-54
WY	I	M5	M6	7-20-54
BI	M	M3e	M5	7-20-54
BK	M	M6e	M9	7-20-54
V498	I		M4	7-20-54
V604	M		M5	7-20-54
V623	I		M6.5	7-20-54
V635	M		M5:	7-20-54
V639	M		M5:	7-20-54
V644	M		M4	7-20-54
V647 †	M		M9:	7-20-54
V649	I		M6.5	7-20-54
V652 †	M		M1	7-20-54
V654 †	I		M1:	7-20-54
V655	M		M8	7-20-54
V658	M		M5:	7-20-54
V659 †	M		M7:	7-20-54
V663	I		M3	7-20-54
V667	I		M6	7-20-54
V668	M		M5p	7-20-54
V669	SR		M6.5	7-20-54
V670	I		M6	7-20-54
V673	M		M7	7-20-54
V675	M		M6	7-20-54
V678	LP		M1	7-20-54
V679*	I	S	S	7-20-54
V835	I		M6	6-28-54
V851	SR	M4	M6	7-20-54
		ORION		
U Ori	M	M8e	M9	11-7-54
RR	M	M5e	M8	11-7-54
BL	I	N	C	11-13-54
BQ	SR	M5	M6 5	11-7-54
DD	I?	M6	M6.5	12-17-52
DP	I?	M6	M6.5	1-1-55
DQ	LP	M3	M6.5	11-16-54
DR	I	M4	M6 5	1-1-55
DS	I		M6.5	1-1-55
DT	M		M10	11-16-54
		ORION (Cont'd.)		
DU Ori	I	M3	M1:	11-13-54
DV* ‡	I		M2p	1-1-55
EE	I		M4	11-16-54
EI	I?		C	12-17-52
EL	SR		M3:	11-13-54
EM	LP		M6:	11-13-54
EN	I		M5	12-17-52
EO	I		M6.5	12-17-52
GK	LP	N	C	11-13-54
GL	SR		C	11-16-54
QU	I		M6	11-7-54
QW* †	I		M3	11-7-54
QX	M		M6.5	11-16-54
QZ	LP		M6 5	11-16-54
V337 †	I		M5	11-7-54
V340	LP	M0	M4	11-16-54
V342	LP		M6.5	11-7-54
V382	M		M9:	12-26-54
		PERSEUS		
S Per	SR	cM3e	M4	9-28-53
W ‡	SR	M8	M5	12-17-52
RS	I?	cM4	M4	9-28-53
SU	SR	cM3	M3:	9-28-53
SW ‡	SR	M5	M5	10-30-53
SY	LP	Ne	C	12-17-52
TY*	M		M6	9-28-53
UU	I	M5	M4	12-17-52
XX	I?	M4	M3	9-28-53
YZ ‡	I	cM2	M2	9-28-53
AD	I	cM2	M2	9-28-53
AO	I		M6	10-30-53
AP ‡	M	M7	M6.5	12-17-52
AQ	M		M7	10-30-53
AT	I	R	C	12-17-52
AU	M		M6.5	12-17-52
AV	I	N	C	12-17-52
BI	I	R	C	10-30-53
BK	I	R	C	12-17-52
BL	SR		M6.5	10-30-53
BT	I		C	9-28-53
BU	SR	cM4	M4	9-28-53
BX †	I		M6:	9-28-53
CN * †	M	M0	C	9-28-53
CT	I		M6	9-28-53

TABLE 2a (Continued)
SPECTRA OF RED VARIABLES IN THE GALACTIC ZONE

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
PERSEUS (Cont'd.)				
CZ Per	I		M4	9-28-53
DI †	M		M9:	9-28-53
DP	I		M6 5	9-28-53
DQ	I		M6.5	9-28-53
DY	SR		C	9-28-53
EE	I		M6.5	9-28-53
ER	SR	M8	M6.5	9-28-53
EW †	I		C:	9-28-53
EY	I		M4	10-30-53
FI	M		M7	10-30-53
FL	I	N	C	10-30-53
FN	I		M6.5	10-30-53
FP	I		M3	10-30-53
FR	I	N	C	12-17-52
FS	LP		M6	12-17-52
FT	I		M6	10-30-53
FU	M		M9:	12-17-52
FV ‡	I	M6	M6.5	12-17-52
FZ	I	cM1	M2	9-28-53
GH	SR	M6	M6	12-17-52
GL	M		M6	11-7-54
GM	M	N	C	11-7-54
GN	I		M6.5	11-7-54
GO	I	M4	M4	11-7-54
GR	M		M9:	11-7-54
GS *	M		Sp	11-7-54
GU	I		M4	11-7-54
GV	I		M6	11-7-54
GZ	LP		M9	11-7-54
HL †	I		M6	11-7-54
HN	LP		C	11-7-54
HO	I	M7	M6 5	11-7-54
HR	I	M3	M6	12-17-52
HT	SR	M5	M7	10-30-53
HX	I		S	10-30-53
IO	I	M4	M3	12-17-52
PUPPIS				
TZ Pup	M		M7	11-13-54
UU	M		M3	11-13-54
UV	SR		M5	11-13-54
BF	I		C	11-13-54
EE	M		M1	11-13-54
EI	I		M6.5	11-8-54
FV	I		M6	11-8-54
FX	LP		M6	11-8-54
FY	I		M6.5	11-8-54
FZ	I		M6.5	11-8-54
GG †	I	S5,6	M0::	11-8-54
GM	I		M6	11-8-54
GN	I		C	11-8-54
GQ	SR		M6	11-8-54
SAGITTA				
T ‡ Sge	I	M4	M6.5:	9-30-53
W	M	M4e	M6.5	10-2-53
Z †	I		M3:	7-22-54
TT	M		M6	7-22-54
UV	LP		M1	7-22-54
VV	I		M6.5	7-22-54
WX	M		M6	7-22-54
XZ	I		M3	7-22-54
AA	I		M6	7-22-54
AB	M		M8	7-22-54
AF	M		M5	7-22-54
AG	LP		M6	7-22-54
DD	SR	M3	M6	7-22-54
SAGITTARIUS				
SS Sgr	SR	R	C	6-28-54
SZ	SR	N	C	6-28-54
UZ	M		M6	6-24-54
VV	M	Me	M8	6-24-54
VX	SR	M4e	M4	6-27-54
AK	M	M5e	M9	6-28-54
FK	M		M9:	6-28-54
V746	M		M9:	6-24-54
V764	M	Me	M4	6-24-54
SCUTUM				
S Sct	SR	N	C	7-2-54
T	SR	N	C	7-2-54
RV	?	R	C	6-28-54
RX	I	N	C	7-2-54
TX †‡	LP		M6.5	6-28-54
VW ‡	M		M4	6-14-54
WW	M		M6.5	7-2-54
AA	M		M6	7-2-54
AB	M		M2	7-2-54
AI	M		C	7-2-54
AX	M		M3	7-2-54
BC	LP		M5	7-2-54
BP †	I?	M3	M4p	6-14-54
CG	M		M8	7-2-54
FR	I	M3	M2	6-24-54
SERPENS				
BE Ser	M		M5	6-28-54
BP	I		M6	7-20-54
BR	M		M5	7-20-54
BW	M		C	7-20-54
BX	I		M6	9-3-53
BY ‡	I	M6	M6	9-3-53
CZ	I	M3	M6.5	6-24-54
DE * †	M		M9	7-20-54

TABLE 2a (Concluded)
SPECTRA OF RED VARIABLES IN THE GALACTIC ZONE

Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations	Star	Type of Variable	Spec Class GCVS	Spec Class Case	Date of Observations
		TAURUS					TAURUS (Cont'd.)		
Y Tau	SR	N	C	11-8-54	EE Tau	I		M4	11-8-54
Z	M		M7	11-8-54	EG	I		M5	11-8-54
RU	M	M0	M6.5	11-8-54	EH	I	M3	M3	11-8-54
TU	I	N	C	11-7-54	EI*	LP		S	11-8-54
VZ	?		M4	11-8-54	EK	LP		M6.5	11-8-54
AB	LP	M5	M6.5	11-7-54	EL †	I	M0	M6.5	11-16-54
AT	I		M6	11-7-54	ER	I	N	C	11-8-54
AW	M		M9:	11-7-54					
AX	SR		M6.5	11-7-54			VULPECULA		
AY	I		M5	11-7-54	W Vul	LP	M5	M6	9-2-54
					RW	M		M6.5	7-22-54
AZ	I	M8	M7	11-16-54	SS	M		M3	7-22-54
BB *	I	M0	S:	11-7-54	XY	M		M6.5	7-22-54
BC	I		M6	11-7-54	YY ‡	M		M8	7-22-54
BD	I		M3	11-7-54	YZ	M	M6	M8	9-10-53
BE	SR?		M4	11-7-54	AA	M		M9:	9-10-53
					AG	M		M6	9-10-53
BF	SR		M6	11-16-54	AR	I	N	C	8-20-53
BM *			M3p	11-16-54	CE*	I	S	S	8-20-53
CO	I		M5	11-16-54					
CP	I	N	C	11-8-54	CG	I?	N	C	7-22-54
CS	I		M5	11-7-54	CH	M		M5	9-2-54
					CN	M		M5	7-22-54
					CO	I		C	7-22-54
DU	I		M3:	11-8-54	DE	M		M8	7-22-54
DW	LP		M7	11-8-54					
DX	I	M5	M3:	11-8-54	DI	I		M6.5	7-22-54
DY	I	M2	M5	11-8-54	DK	LP	M6	M6.5	7-22-54
DZ	I		M6	11-8-54	DL	LP		M6	7-22-54

TABLE 2b
SPECTRA OF RED SUSPECTED VARIABLES IN THE GALACTIC ZONES

Star	Type of Variable	Spec Class Case	Date of Observations	Star	Type of Variable	Spec Class Case	Date of Observations
82	I	M6.5	9-29-53	1042	M	M6:	11-13-54
124	I	M2	12-18-52	1085	I?	M6	11-13-54
304	I	M6.5	10-30-53	4006	I	C	6-28-54
411	SR	M5	7-20-54	4614	I?	M5	6-19-54
601	LP	M7	11-7-54	4786	LP	C	7-22-54
				4847	I	M5	7-22-54
709	I?	C	1-1-55	4856	LP	M7	7-22-54
712	I?	M6:	11-13-54	4921 *	LP	M8	9-1-54
728	I?	C	12-17-52	4970	I	M6	9-1-54
893	M	M6.5	4-1-55	5067 †	I	M3	6-29-54
				5286 *	M	M5	9-1-54
912	LP	M6.5	1-1-55	5454	I	M6.5	9-1-54
933	LP	M9:	11-16-54	5482 ‡	LP	M6	9-1-54
943	LP	M6.5	11-13-54	5501	LP ?	M6	6-28-54
985	LP?	M6.5	11-13-54	5654 *	LP	M6p	9-1-54
1023 *	LP	M4	11-13-54	5675 †	SR?	M5	9-1-54
				5783	I?	M4:	6-29-54

NOTES TO TABLE 2*a*

RT Aql —Anomalous type; no λ 8300.
ER —No λ 7400 or λ 7900 bands on this plate, but a plate taken on 6-19-47 shows strong absorption at λ 7400 and λ 7900.
EX Aur —Identity uncertain; faint, early M near the C star may be EX.
FI —Identity uncertain; M2, *BD* star nearby.
W Cas —Appears to be a C star on Case plate taken on 9-29-53; was classified as S1e by Miss Davis (1934) and Se by Merrill (1940); Keenan (1954) lists it among "Stars with Spectra Related to Type S" and notes that "infrared CN bands and Swan bands of C2 were observed by Bidelman at Yerkes and by Keenan at Perkins (1950)."
WY —Strong absorption band at λ 7900; broad absorption from λ 7900 to λ 8400; the plate was taken 56 days after minimum light.
TT Cep —Very faint spectrum nearby—possible early M, may be TT Cep.
AA Cyg —Classified S7, 5 and S7.5, 6 by Keenan (1954); is known to have both M and S characteristics.
AD —Spectrum greatly overexposed; classed S5, 8 by Keenan (1954).
AZ —Tapered spectrum.
BC —Tapered spectrum.
EH —Identity uncertain; another M nearby.
FF —The spectrum is clearly that of an S star on three different infrared plates; this is in disagreement with M4e, which is listed in the *General Catalogue of Variable Stars* and was probably taken from the Dearborn survey (Lee and Bartlett 1944), M4, and Miss Cannon (1934), Me.
HZ Cyg —Identity uncertain; two late M stars close together.
LX —Has λ 8500 absorption band, in addition to strong λ 7400 and λ 7900
V423 —Identity uncertain, two late M stars nearby.
V718 —Tapered spectrum.
χ —Classed S7, 1e; S9, 1e; and S10, 1e by Keenan (1954).
BY Gem —Spectrum has appearance of an M5, but with λ 7900 absorption band.
DY —Classed S8, 5 by Keenan (1954).
BX Lac —This is the latest-appearing M10 we have observed.
S Lyr —Plate taken on 7-22-54 shows weak λ 7900 and reddening; plate taken on 5-2-55 (see Table 3) shows strong absorption at λ 7900 and λ 7400.
CY Mon —Identity uncertain; an M6.5 nearby.
FU —Keenan (1954) lists this among "Stars with Spectra Related to Type S."
V679 Oph—Classed S4.5, 8 by Keenan (1954); blue plate taken on 7-14-49 shows faint C-star spectrum.
DV Ori —Several emission features between λ 7900 and λ 8500.
QW —Identity uncertain; and M6 nearby.
TY Per —Possible emission near λ 8800.
CN —There is no M star nearby; however, an M0 of $M_{pg} = 13.2$ at max would probably be beyond the plate limit.
GS —Very broad and intense absorption band at λ 7900.
DE Ser —Identity uncertain; an M5 nearby.
BB Tau —No distinct absorption features, strong taper, possible S star on 4° plate; on 2° plate it appears to have carbon features; may be similar to W Cas (see note) which has both carbon and S-star features.
BM Tau —Listed as short period; not yet sufficiently investigated in *General Catalogue of Variable Stars;* absorption or emission near λ 7400.
EI —Strong absorption at λ 7400 and λ 7900; typical S-star spectrum.
CE Vul —Spectrum is greatly overexposed, but it shows the λ 7400 and λ 7900 absorption bands.

NOTES TO TABLE 2*b*

1023 —NO Mon in seventh supplement to *General Catalogue of Variable Stars.*
4921 —V738 Cyg in seventh supplement to *General Catalogue of Variable Stars.*
5826 —V750 Cyg in seventh supplement to *General Catalogue of Variable Stars.*
5654 —λ 7900 absorption present.

TABLE 3
ADDITIONAL SPECTRAL OBSERVATIONS OF RED VARIABLES

Star	Case Spec Class	Date of Observations	Star	Case Spec Class	Date of Observations
U Aur	M9	2-4-55	V551 Cyg	M4	8-20-53
	M9	2-24-55	V722	M6	9-2-54
W	M6.5	11-8-54	χ	M7	5-11-53
AQ	M6 5	10-30-53		M7	6-2-53
DQ *	M6p	11-8-54		M9	7-25-53
VY Cas	M6.5	8-29-54	χ	M10	8-20-53
EZ	M5	9-29-53		M9	9-8-53
GS	M6.5	11-1-54		M7	6-19-54
CI Cep	M6	6-29-54		M7	7-22-54
AA Cyg	M2p	6-19-54		M10	10-24-54
AA	Mp	7-21-55	S Lyr*	S	5-2-55
AD	S:	7-22-54	DV Ori	M1	11-16-54
AI	M6	7-22-54	W Per	M2	8-29-54
	M6	8-20-55		M2	11-1-54
BG	M7	7-22-54		M4	1-12-55
BG	M8	10-24-54	SW Per	M6.5	11-7-54
BI	M3	9-3-53	YZ	M1	12-17-52
EL	M4:	9-10-53	AP	M8	10-30-53
FF *	S	9-29-53	FV	M6	10-30-53
LX	S	8-20-55	T Sge	M6 5	8-20-53
V354	M4	10-30-53	TX Sct †	M6:	6-14-54
V405	M6.5	10-24-54	VW	M6	7-2-54
V449	M3	8-20-53	BY Ser	M6 5	7-20-54
	M3	7-22-54	YY Vul	M5	8-20-53
	M2	9-2-54	5482	M5	6-28-54

Notes: DQ Aur - absorption at λ8300 and several regions longwards of λ8400
FF Cyg - Very faint and narrow absorption band at λ8300.
S Lyr - See note at end of Table 2.

IV. TYPES OF VARIABILITY AND THEIR SPECTRAL DISTRIBUTION

Of the M-type variables given in Table 2*a*, 541 have the necessary data for study of their spectral distribution. Although much work has been done in this field, it was felt that such a study might prove useful for the following reasons:

a) The spectra of at least two-thirds of these variables were previously unknown. Thus the present data greatly strengthen spectral-distribution studies.

b) All spectra were secured with the same instrument and dispersion, and the system of classification is uniform.

c) The fact that the variables under consideration are confined within the same region (6° on each side of the galactic equator) as the general survey of late M's whose distribution is also under study here (Nassau *et al.* 1956) enables us to make comparisons between the two studies.

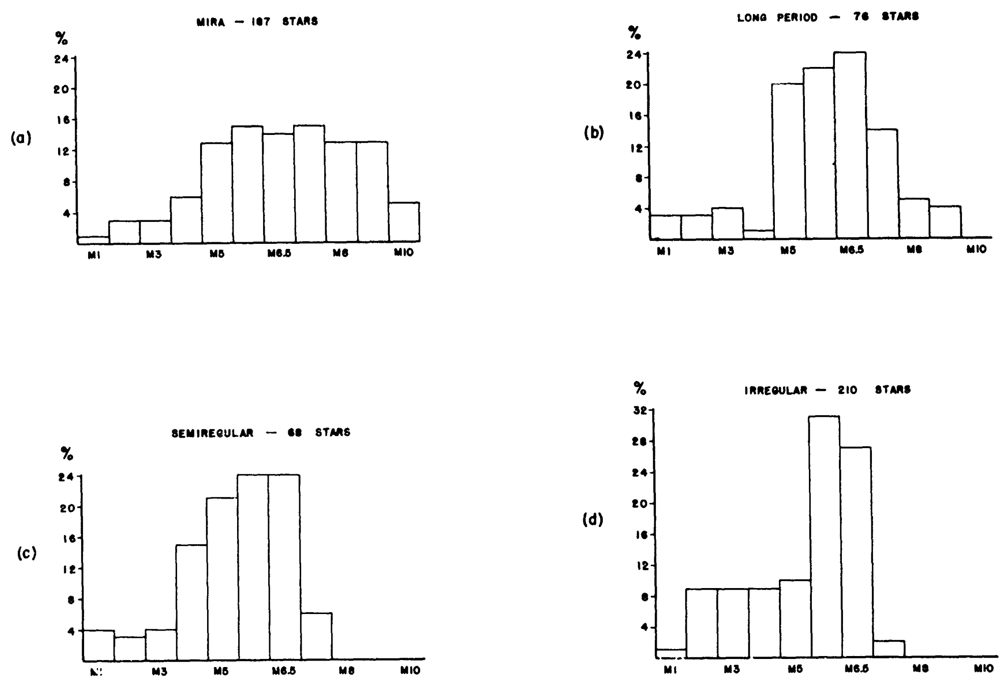

FIG. 1 —Frequency distribution of M variable stars. *a*, Mira type; *b*, long period; *c*, semiregular; *d*, irregular

d) The limiting magnitude of the stars in the survey is the same.

e) Although the observed spectral classes do not refer to the time of maximum light, the relatively large number of stars provides means for estimating the range of spectral variability of the different types.

The division into types of variability given in the *General Catalogue of Variable Stars* is being followed. The Mira type includes those variables of long period with regular periodicity and amplitudes of variation greater than 2.5 mag. They generally show emission lines during certain phases. The long-period type is similar to the Mira variables except for the amplitude, which is less than 2.5 mag. The semiregular type has large irregularities in the period and small amplitudes. The irregular type shows no periodicity and has small amplitudes. Figure 1 shows the spectral distribution of the 541 variables of Table 2 according to these types, and Table 4 gives their distribution in the three galactic zones. Only those variables whose type of variability and Case spectra are definitely known are included in the statistics. No marked differences between the three zones were observed when separate figures were compared. However, the number of stars in each of the zones was too small for a definite conclusion. The principal feature of the figure and table may be summarized as follows:

1. No marked asymmetry in the number of stars of the different types of variables is present between zones *a* and *b*. The somewhat larger number of irregular variables in zone *b* is attributable partly to the supergiants in the h and χ Persei clusters which are in this zone.

2. The central zone has fewer Mira-type and long-period variables than the other two zones. This is probably due to the combined effect of absolute magnitude and interstellar absorption rather than to selection. The number of semiregular and irregular variables is practically the same in the three zones if the h and χ supergiants are excluded.

3. The distribution of Mira and long-period variables covers all the M subclasses, being greatest from M5 through M7 or M8.

4. The distribution of semiregular and irregular M variables covers all M subclasses through M6.5 but ends abruptly at M7. There are no semiregular or irregular variables later than M7 and only nine that late.

TABLE 4

DISTRIBUTION OF M VARIABLES IN THE THREE ZONES

Type	Zone *a*	Central Zone	Zone *b*	All Zones
Mira	75	47	65	187
Long period	28	18	30	76
Semiregular	21	26	21	68
Irregular	65	62	83	210
Total	189	153	199	541

5. The irregular variables are concentrated at classes M6 and M6.5.

6. Twenty per cent of the M variables are earlier than M5.

The published material for Me variables by Merrill (1941) and for the irregular M variables by Joy (1942) provides means for comparison with our data. In this case the stars are not confined to the galactic belt, and the given spectra usually refer to the time of maximum light. Merrill's distribution (Fig. 2, *a*) of Me variables is much sharper than ours (Fig. 1, *a*) and the percentage of later-type stars much smaller than ours. This is as should be expected. For the irregular variables, Joy's distribution (Fig. 2, *b*) shows that the concentration occurs at M5 and M6 instead of at M6 and M6.5, as in our case (Fig. 1, *d*). Here a small difference between the Mount Wilson and Case systems of classification may exist, although the difference may be due, at least in part, to the fact that our spectra do not refer to the time of maximum light.

V. DISTRIBUTION OF THE M VARIABLES IN GALACTIC LONGITUDE

That selection effects are present and may influence the longitude distribution of the variables is well known. Nevertheless, not all aspects of the distribution can be attributed to selection alone, as will be shown in the following discussion. Figure 3, *a*, *b*, *c*, and *d*, shows the longitude distribution of the M variables according to type of variability. The similarity of Figure 3, *a* and *b*, suggests that they can be combined to form one group.

It is our understanding[1] that a second edition of the *General Catalogue of Variable Stars* will incorporate these two groups into one. Also the irregular variables will be grouped with the semiregulars. Figure 3, *c* and *d*, indicates that their distributions also are not dissimilar. A grouping of each of the two types of variability is shown in Figure 3, *e* and *f*, which show striking dissimilarities. The Mira-plus-long-period-variable group (Fig. 3, *f*) shows a marked maximum in the neighborhood of longitude 35° and a possible indication of a second maximum 180° from it, suggesting a grouping of these stars along the local spiral arm. Omitting the interval between $l = 333°$ to $l = 3°$, since this region is influenced to a great degree by broad obscuration, the semiregular plus irregular variable group (Fig. 3, *e*) shows a uniform distribution throughout.

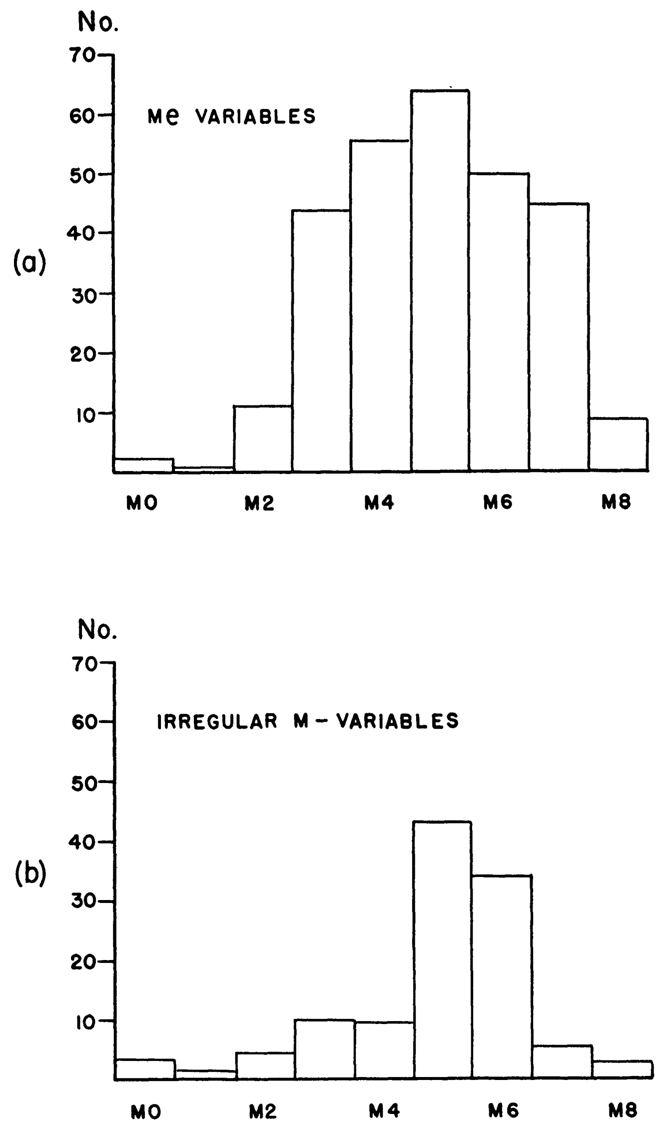

FIG. 2 —Frequency distribution of M variable stars according to Merrill and Joy. *a*, Me variable stars (Merrill); *b*, irregular M variable stars (Joy). (These figures have been replotted in the form of histograms from the original data of Merrill and Joy for comparison with Fig. 1, *a* and *d*)

[1] This was stated by Kukarkin at the meeting of Commission 29, Dublin, 1955.

In Figure 4 the longitude distribution is shown for three different spectral groups: *a*, M0–M4; *b*, M5–M6.5; and *c*, M7–M10. Since the early M variables are predominantly irregular and semiregular, it is not surprising that Figures 4, *a*, and 3, *e*, are somewhat similar. Also Figures 4, *c*, and 3, *f*, are similar, since the M7–M10 variables are largely Mira or long period. In fact, of the 113 M7–M10 variables classified in this study, Table 5 shows that 92 per cent are Mira or long period. It is noteworthy that the distribution of the M7–M10 Mira variables also suggests a grouping of these stars along the local spiral arm. This is in agreement with Baade's (1951) suggestion that the Mira variables are intermediate between populations I and II and that the late-M Mira variables are population I. Unfortunately, the number of early-M Mira type is too small to yield a definite conclusion.

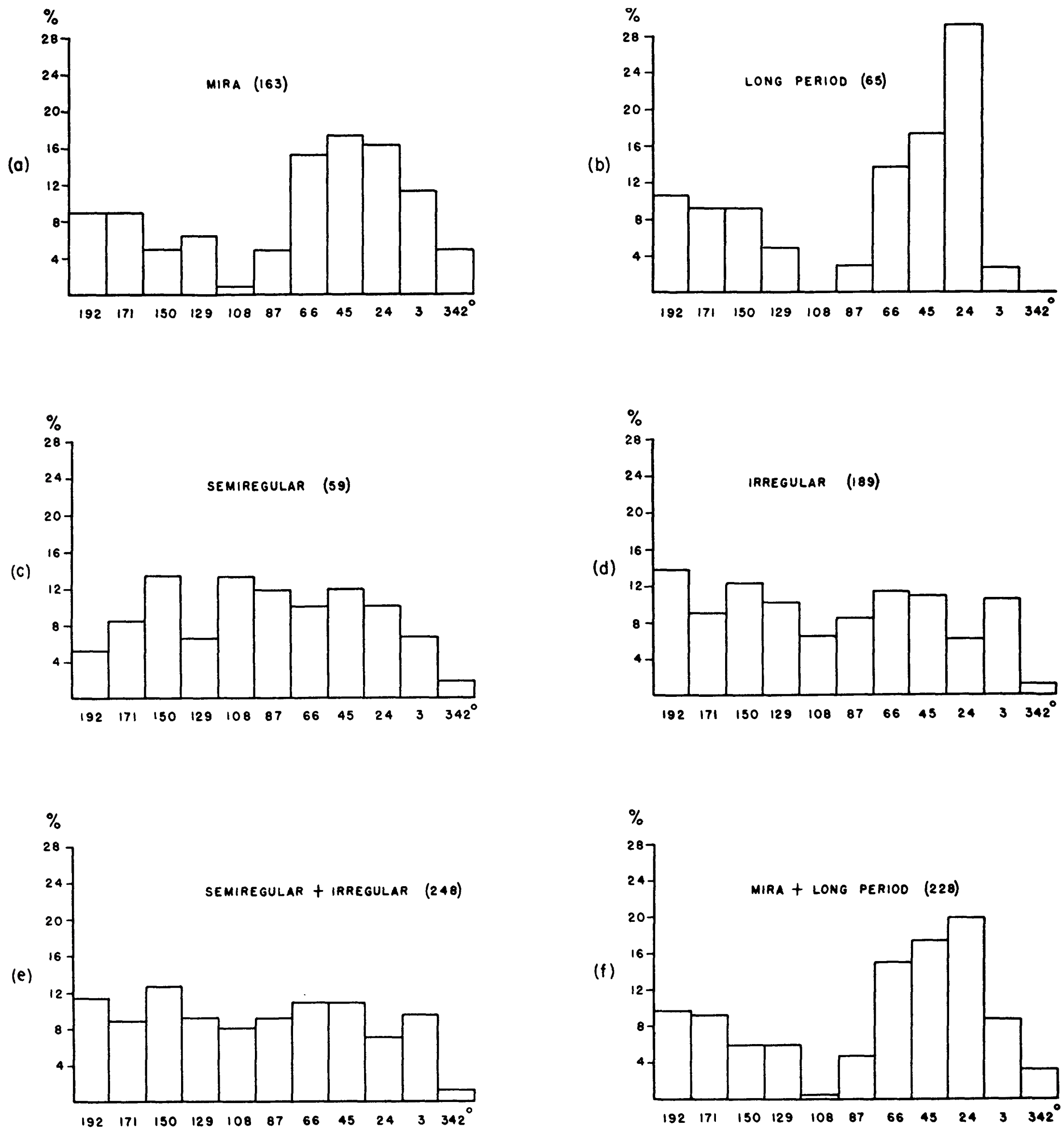

FIG. 3—Frequency distribution of the M variable stars in galactic longitude. *a*, Mira type; *b*, long period; *c*, semiregular; *d*, irregular; *e*, semiregular plus irregular types; *f*, Mira plus long-period types. Galactic longitude is plotted as abscissa, and the total number of stars is given in parentheses after the type of variability.

VI. PER CENT OF VARIABLES AMONG STARS OF SPECTRAL CLASSES M7–M10

The distribution of the M7–M10 stars is of particular interest, as will become apparent in the following section. These stars, which show the vanadium oxide absorption bands at λ 7400 and λ 7900, are among the coolest stars observed, and our experience with them has given us reason to believe that a large percentage, if not all, of them are variable. In fact, Nassau and Blanco (1954) have stated: "In a hundred or more cases examined, the presence of the VO bands indicates variability, usually of the Mira type or long-period variable." In addition, a limited study has been made covering an area of about 2 square degree in Cygnus (R.A. = 19^h55^m; dec. = 36°8, epoch 1855) in which

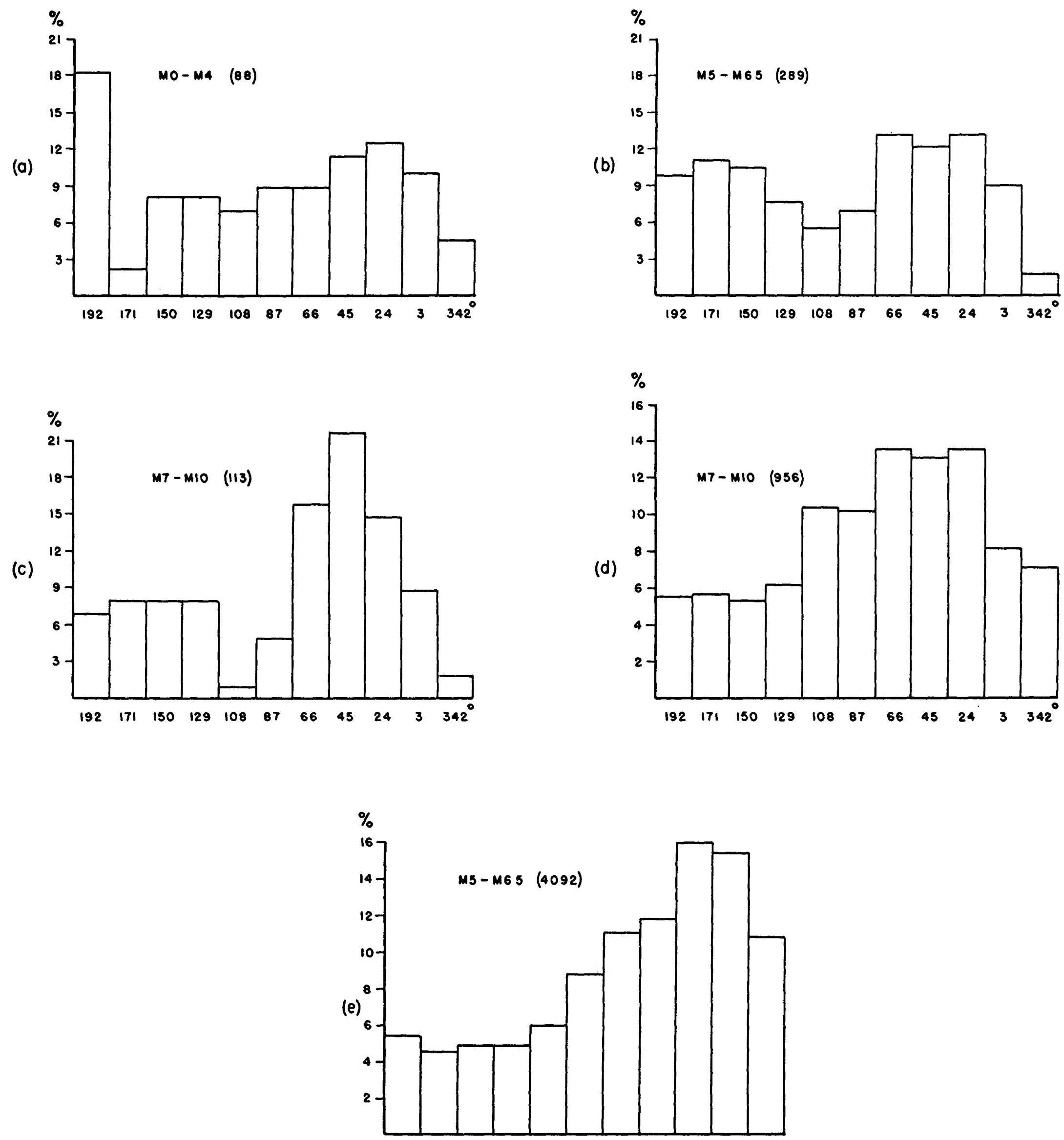

FIG 4.—Comparison of the frequency distributions of the M variable stars and late M stars. *a*, M0–M4 variable stars; *b*, M5–M6.5 variable stars; *c*, M7–M10 variable stars; *d*, M7–M10 stars; *e*, M5–M6.5 stars. Galactic longitude is plotted as abscissa, and the total number of stars is given in parentheses after the spectral group.

all stars of class M5 and later were examined for variability. The area contained 73 such stars.

The results of this survey (Table 6) show that 56 per cent of the stars in the spectral range M7–M10 are definitely variable, and if those strongly suspected of variability are included, this figure increases to 76 per cent. While these results must necessarily be considered provisional, nevertheless they indicate that a majority of the stars of these spectral classes are variable. Additional evidence for the variability of M stars is furnished by Stebbins and Huffer (1930), who, using photoelectric photometry, found that 30 out of 32 stars of spectral classes M4, M5, and M6 varied by more than a tenth of a magnitude.

TABLE 5

M7–M10 VARIABLE STARS

Type	No.	Per Cent	Type	No.	Per Cent
Mira .	86	76	Semiregular .	4	4
Long period . .	18	16	Irregular	5	4

TABLE 6

VARIABLES AMONG STARS OF SPECTRAL CLASSES M7–M10

Variability	Total	At Least One Spectrum M7–M10	All Spectra between M7 and M10
Definite . .	30	24	5
Strongly suspected	11	9	1
Suspected... . .	20	10	0
Non-variables .	12	0	0
Total	73	43	6

VII. COMPARISON OF DISTRIBUTIONS OF VARIABLES AND LATE M STARS IN LONGITUDE

In this section a comparison is given of the distribution in longitude of the variables in the galactic belt of 12° width and all stars of classes M7–M10 for the same region. The latter distribution is from unpublished material by Nassau, Blanco, and Cameron. Figure 4, *c*, shows the distribution of the M7–M10 variables. Figure 4, *d*, shows the distribution of all stars of spectral classes M7–M10 in zones *a* and *b* (Nassau *et al.* 1956). Since the majority of these stars should be variable and of the same type as the known variables given previously, their distribution should be the same. The lack of agreement in Figure 4, *c* and *d*, may be due to the following or to their combined effect: (*a*) the galactic distribution of the variables is influenced by selection; (*b*) a systematic difference may exist between the M7–M10 groupings for the two surveys; it is also known that the two surveys were not carried out to the same limiting magnitude; (*c*) an appreciable number of M7–M10 stars may not be Mira-type or long-period variables.

With regard to the first possibility, it appears that the minimum at $l = 108°$ shown in the distribution of the Mira and long-period variable group in Figure 3, *f*, cannot be attributed to selection, because the Mira variables, which constitute the largest part of this group, have large amplitudes of variation and would be discovered more easily than the much smaller-amplitude semiregular and irregular variable stars of Figure 3, *e*.

The second possibility has been given very serious consideration for several reasons. First, the distribution of M7–M10 stars, shown in Figure 4, *d*, which is taken from the Nassau, Blanco, and Cameron (1956) paper, is based on classification from 2° spectral plates, while the distribution of the M7–M10 variables, Figure 4, *c*, is based on 4° spectral plates. Thus both a difference in the limiting magnitudes of the two surveys which is known to exist and a systematic difference in the limiting spectral class, M7, could exist. The importance of the latter becomes evident if one recalls that the irregular and semiregular variables show a large concentration at M6.5 and then drop off to practically zero at M7. Thus a slight systematic shift of the spectral limit at M7 toward M6.5 would include a large number of irregular and semiregular variables in the M7–M10 group, which might alter the appearance of the distribution.

Because of these considerations, an independent check of the distribution of the M7–M10 and M5–M6.5 stars shown in Figure 4, *d* and *e*, was made. This time the 4° plates were used—the same plates as were used for the classification of the variables. Two regions were chosen for the check: one around $l = 108°$, the minimum of the variable-star distribution (Fig. 4, *c*), and the other around $l = 40°$, the maximum in the distribution. Both authors examined the plates for these two regions independently, selecting all stars M5 and later and classifying them. The results of this check indicate no significant difference from the original distribution of M7–M10 stars. It seems possible, therefore, that the difference in the two distributions (Fig. 4, *c* and *d*) may be attributed to the differences in the limiting magnitudes. The latter, dealing with fainter stars, may be reaching stars in the Perseus arm.

The third possibility leads to the conclusion that a considerable number of non-variables exists among stars of classes M7–M10, since hardly any irregular and semiregular variables are found in this spectral range. This seems less likely. However, red stars with very small amplitudes of variability may exist, which, under the prevailing methods of discovery, are considered non-variable. These stars do not, in general, come to the attention of the spectroscopists.

It is apparent that no definite conclusions are possible. However, the material available seems to indicate that the Mira and long-period variable group tends to show concentration along the local spiral arm and that the irregular and semiregular group shows a tendency for disk distribution.

VIII. PERIOD-SPECTRUM RELATION

The relation between period and spectrum for each of the types of variability was examined, with the idea of possible differences at different galactic latitudes. No such differences were found, although the number of stars in each subgroup was small. The period-spectrum distribution for all the stars in each group is given in Figure 5, *a*, *b*, and *c*. A few stars with periods greater than 700 days are omitted. For the Mira type (Fig. 5, *a*) the greatest concentration of stars is between 280 and 400 days and between spectral classes M6–M7, inclusive. The well-known trend of period with spectrum is evident; short periods correspond to early spectra, and long periods to late spectra. The long-period variables (Fig. 5, *b*) show a concentration in the period interval of 160–200 days and the spectral classes M6 and M6.5. The strong grouping of the semiregular variables (Fig. 5, *c*) between M5 and M6.5 has been pointed out. Here a similarly strong grouping between the period interval of 80 to 160 days is also present. Relatively few stars are outside this interval.

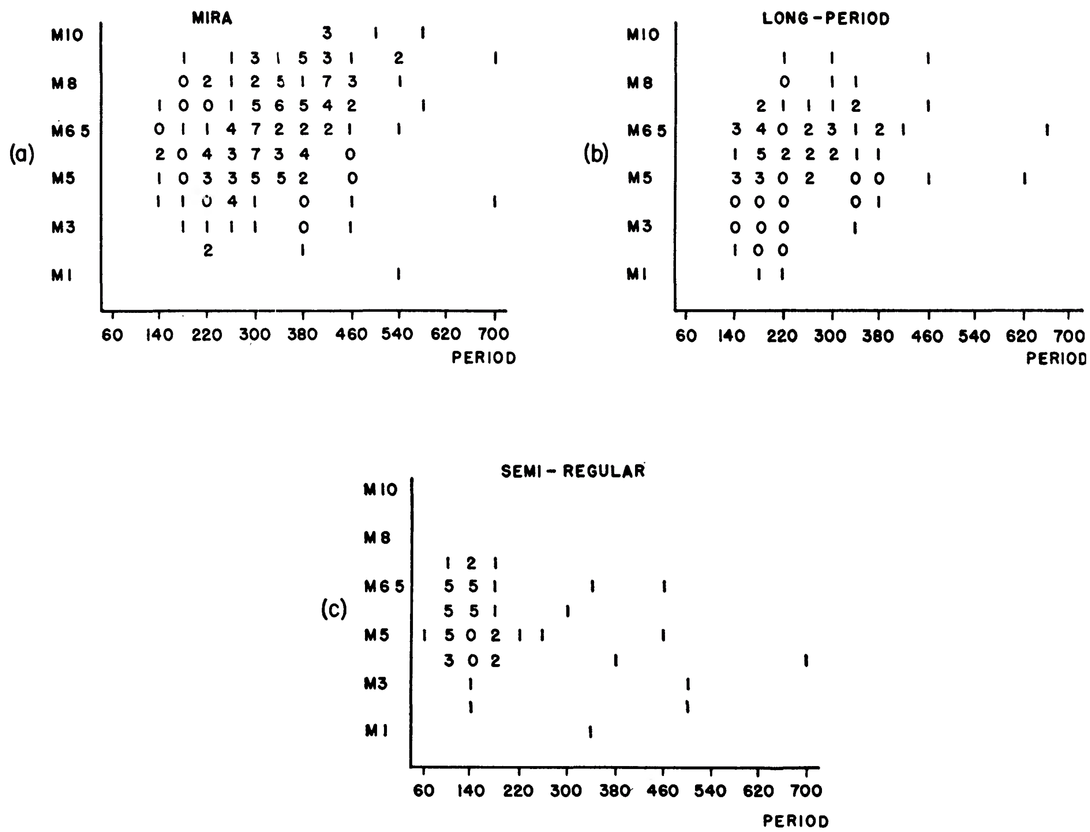

FIG. 5.—Period-spectrum relation. *a*, Mira type; *b*, long period; *c*, semiregular

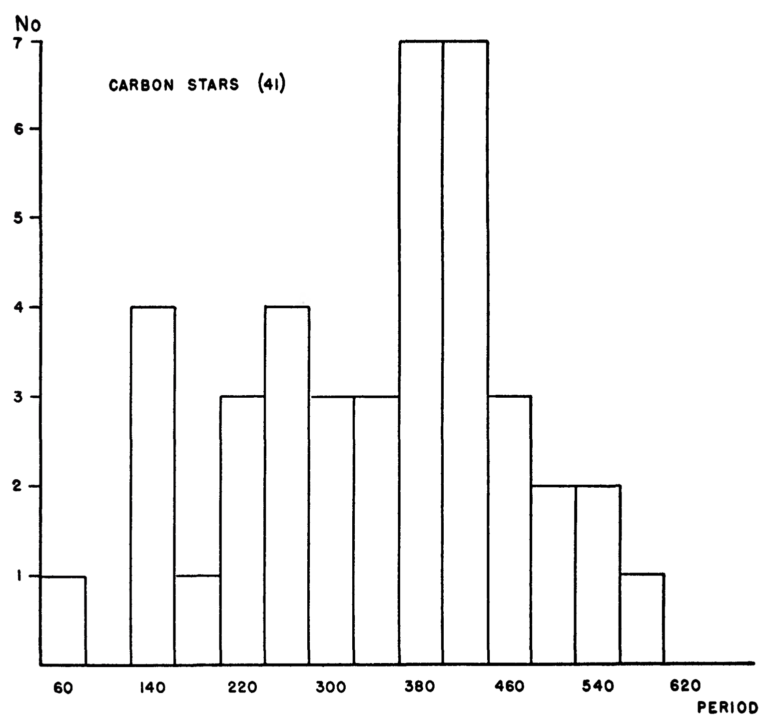

FIG. 6.—Period-frequency distribution of carbon variable stars (Mira, long-period, and semiregular types of variability are included).

IX. CARBON STARS

In the galactic zone there are 110 carbon stars which are known to be variable. Of these, 18 are Mira type, 9 are long-period variables, and 14 are semiregular. The period-frequency distribution for all these stars is given in Figure 6, which shows a maximum at about 420 days. The corresponding maximum for the M variables occurs about 100 days earlier.

Note added in proof.—The following carbon stars should be added in Table 2*a:* V478 Aqu, V Cyg, LW Cyg, GI Per, CZ Mon, V429 Cyg, V577 Cyg, DU Cas, LS Cas.

To Table 2*b* add the suspected variables 4376, 4712, 4995. Also add two S-type stars V633 Cyg and the suspected variable 4665, and the M0 star BU Gem.

REFERENCES

Baade, W. 1951, *Pub. Obs. U. Michigan*, **10**, 7.
Bidelman, W. P. 1950, *Ap. J.*, **112**, 219.
Cameron, D. M., and Nassau, J. J. 1955, *Ap. J.*, **122**, 177.
Cannon, A. J. 1934, *Harvard Bull.*, No. 897.
Davis, D. N. 1934, *Pub. A.S.P.*, **46**, 267.
Joy, A. H. 1942, *Ap. J.*, **96**, 344.
Keenan, P. C. 1950, *A.J.*, **55**, 172.
———. 1954, *Ap. J.*, **120**, 484.
Kukarkin, B. V., and Parenago, P. P. 1948, *General Catalogue of Variable Stars* (Moscow: Academy of Sciences, U.S.S.R.).
———. 1949–1951, First, second, and third supplements to the *General Catalogue of Variable Stars* (Moscow: Academy of Sciences, U.S.S.R).
Kukarkin, B. V., Parenago, P. P., Efremov, U. E., and Kolorov, P. N. 1953–1955, fourth, fifth, sixth, and seventh supplements to the *General Catalogue of Variable Stars* (Moscow: Academy of Sciences, U.S.S.R.).
———. 1951, *Catalogue of Stars Suspected of Being Variable* (Moscow: Academy of Sciences, U.S.S.R.).
Lee, O. J., and Bartlett, T. J. 1944, *Ann. Dearborn Obs.*, Vol. **5**, Part 1B.
Merrill, P. W. 1940, The Spectra of Long-Period Variable Stars (Chicago: University of Chicago Press).
Merrill, P. W. 1941, *Ap. J.*, **94**, 171.
Nassau, J. J., and Albada, B. G. van. 1949, *Ap. J.*, **109**, 391.
Nassau, J. J., and Blanco, V. M. 1954, *Ap. J.*, **120**, 468.
Nassau, J. J., Blanco, V. M., and Cameron, D. M. 1956, *Ap. J.*, Vol. **124** (November).
Nassau, J. J., Blanco, V. M., and Morgan, W. W. 1954, *Ap. J.*, **120**, 478.
Stebbins, J., and Huffer, C. M. 1930, *Pub. Washburn Obs.*, **15**, Part 3, 139.