THE SEMIREGULAR VARIABLE STARS OF THE RV TAURI AND RELATED CLASSES

Alfred H. Joy
Mount Wilson and Palomar Observatories
Carnegie Institution of Washington
California Institute of Technology

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ABSTRACT

Observations.—A spectroscopic survey of the F, G, and K semiregular variables was based on Mount Wilson spectrograms of thirty-eight stars.

Physical characteristics.—Strong ionized lines indicate that many of the stars are as bright as, or brighter than, the long-period cepheids. The mean spectral type is about G0 at maximum and K0 at minimum light. Titanium oxide bands occur in twenty-one stars and are seen on spectra as early as G4. The mean radial-velocity range during a cycle is 36 km/sec, but irregularities are so great that mean velocity-curves are impossible. The relation of velocity changes to light-variations is similar to that of the cepheids. Hydrogen emission is present in twenty-five stars at times of increasing light. The G band of *CH* becomes stronger with decreasing light and later spectral type.

Subdivisions.—If the stars are divided according to radial velocity, the fast and slow groups are found to differ also in mean luminosity, spectral type, intensity of carbon bands, and distribution in the sky. The fast-moving group is undoubtedly of type II population, but the exact relationship of the slow group to Baade's populations is uncertain.

In order to investigate the spectroscopic characteristics of the semiregular variablet with intermediate spectral types and periods, thirty-eight stars have been observed as Mount Wilson with low dispersion. Nearly all the observable RV Tauri variables and most of the irregular variables of types F, G, and K have been included.

Among variable-star observers there is general agreement as to the standard behavior of RV Tauri variables, but, unfortunately, few stars meet all the requirements over any considerable length of time. The changes and irregularities are often most confusing. Cyclic variations are seldom repeated exactly, and the statistical use of suggested periods is unsatisfactory.

The strange fluctuations of light of these variables have been investigated by numerous observers. Particularly valuable results have been obtained from the Harvard photographs covering periods of time sufficiently long to show the extreme irregularities at different epochs.The painstaking work of Payne-Gaposchkin, Brenton, and Gaposchkin[1] giving light-curves for fourteen RV Tauri stars is most illuminating.

General data pertaining to the stars observed are in Table 1. The photographic magnitudes are mostly from Kukarkin and Parenago's *Catalogue of Variable Stars*. The classification according to Payne-Gaposchkin, Brenton, and Gaposchkin; Kukarkin and Parenago; and L. Rosino[2] ("RV" = RV Tauri class, "SR" = semiregular, "LP" = long period) is indicated in the eighth to the tenth columns. From observations of the light-changes, all three sources assign thirteen stars of the list to the RV Tauri class. Two place six other stars in this class, while for five stars the RV Tauri designation is from one only of these sources. The remaining thirteen stars are semiregular variables which are not recognized as RV Tauri stars, although in period, light-range, and spectroscopic characteristics they seem to be rather closely related to them. One star, AB Leonis (BD+20°2337), is the new variable whose light-changes were found by Miss D. Hoffleit[3] to be of the RV Tauri type.

[1] *Harvard Ann.*, Vol. **113**, No. 1, 1943.

[2] *Ap. J.*, **113**, 60, 1951.

[3] *Harvard Bull.*, No. 919, p. 11, 1949.

Five stars of the list—DF Cyg, SU Gem, U Mon, AI Sco, and RV Tau—have long-period light-variations of 690–2320 days superposed upon the short-period (50–90 days) light-curves. For U Mon, R. F. Sanford[4] discovered a variation of 40 km/sec in the γ velocity in a period of 2320 days, and the same period was later found by E. Loreta[5] in

TABLE 1

DATA CONCERNING VARIABLES OBSERVED

Star	Designation	l	b	m_{pg}		Period (Days)	Class			No. Plates
				Max.	Min.		Gap.	K. and P.	Rosino	
WY And..	233647	79°	−14°	9.5	10.6	109	....	SR	SR	10
BL Aqr....	2109*02*	17	−33	11.0	12.3	85	....	SR	....	8
TW Aql...	194613	20	− 8	10.6	12.7	96:	....	SR:	....	5
DY Aql...	1941*11*	357	−19	10.2	12.9	131	RV	RV	....	7
EZ Aql....	193408	14	− 8	12.4	14.6	39	RV	RV	RV	3
KK Aql...	194314	20	− 7	11.5	12.8	89	RV	SR	....	7
Z Aur.....	055353	127	+16	9.7	12.9	111	....	LP	....	9
AG Aur...	062047	135	+17	10.0	13.1	98	....	RV	SR	16
TW Cam..	041257	116	+ 6	10.4	11.5	86	....	RV	RV	6
RX Cap...	2009*13*	358	−26	11.6	13.7	68	RV	RV	RV	5
RU Cep...	010884	91	+22	9.3	10.4	109	....	SR	....	7
TZ Cep....	001973	88	+11	9.8	12.0	83	....	SR	....	6
AV Cyg...	191629	30	+ 6	11.2	13.0	90	RV	SR	....	7
DF Cyg...	194542	44	+ 8	10.8	15.2	50	RV	RV	RV	10
V360 Cyg..	210630	45	−12	10.8	13.3	63	RV	RV	RV	10
SS Gem...	060222	156	+ 3	9.2	10.7	89	RV	RV	RV	13
SU Gem...	060727	152	+ 6	10.7	13.2	50	....	RV	RV	5
SX Her....	160325	9	+45	9.0	11.1	103	....	SR	SR	21
UU Her...	163238	28	+41	8.5	10.6	71	RV	SR	SR	18
AC Her....	182621	18	+13	7.1	9.4	75	RV	RV	RV	73
AB Leo....	092720	179	+46	10.7	13.2	103	....	....	....	12
W LMi....	1039*26*	176	+63	11.3	14.5	117	....	LP	....	13
UW Lib...	1425*16*	303	+39	10.4	11.0	85	....	SR:	....	17
U Lup.....	1554*29*	313	+16	10.8	13.2	87	....	SR	....	7
U Mon....	0726*09*	194	+ 6	6.8	8.5	92	RV	RV	RV	68
TT Oph...	164403	349	+27	9.8	11.7	61	RV	RV	RV	14
TX Oph...	165905	352	+25	9.8	12.1	138:	RV	RV:	SR	11
UZ Oph...	171707	356	+22	10.5	13.1	87	RV	RV	RV	9
TX Per....	024136	116	−19	11.1	13.7	76	....	SR	....	10
S Sge......	200916	26	−11	9.0	11.5	71	RV	RV	RV	29
AR Sgr....	1853*23*	340	−14	9.6	11.5	88	RV	RV	....	8
AI Sco....	1749*33*	325	− 6	9.4	12.6	72	....	RV	RV	3
R Sct.....	1842*05*	355	− 3	6.5	9.6	144	RV	RV	RV	12
RV Tau...	044025	143	−11	9.8	13.3	79	RV	RV	RV	18
WW Tau..	035529	133	−16	9.9	12.9	125:	....	SR	....	6
SV UMa...	104055	119	+55	9.8	11.3	76	....	SR	SR	11
S Vul......	194427	31	0	10.1	11.4	69	RV	SR	....	18
V Vul.....	203226	37	− 9	9.0	11.0	76	RV	RV	RV	31

[4] *Mt. W. Contr.*, No. 465; *Ap. J.*, **77**, 120, 1933.

[5] *A.N.*, **267**, 399, 1938.

the light-variations. On account of insufficient spectroscopic observations, this important correlation between light and velocity measures has not been traced in other stars. These five stars have a short mean double period of 69 days, and their mean total light-range is over 3 mag. They are high-luminosity stars with mean galactic latitude of 7°. Emission is weak or absent.

SPECTROSCOPIC OBSERVATIONS

Our knowledge of the detailed spectroscopic behavior of the RV Tauri variables is based on the extensive studies of AC Herculis,[6] U Monocerotis,[4] R Sagittae,[7] and V Vulpeculae[8] by R. F. Sanford at Mount Wilson and of R Scuti[9] by D. B. McLaughlin at Michigan. Their observations cover the whole period of light-variations and indicate that the fundamental behavior is related to that of the cepheids. Under the most favorable circumstances the double period is clearly seen in spectrographic and radial-velocity changes,[10] as well as in the light-variations.

L. Rosino[2] has recently estimated the spectral type and luminosity class of thirteen of the stars of Table 1. McLaughlin and Rosino have added greatly to the value of their spectrographic data by determining simultaneous light-curves.

Spectra of two of the variables of Table 1 obtained at Mount Wilson have already been described.[11] Data for the hitherto unpublished Mount Wilson observations are in Table 2, together with the spectrographic results for each plate. The photometric elements (mostly from the *Variable Star Catalogue* [1948], by Kukarkin and Parenago) used in computing the phases (fourth column) are in the notes following Table 3. The letters in the table indicate whether the phases are reckoned from maximum (M) or from minimum (m). In the last four columns are rough intensity estimates of the strongest emission lines, the titanium oxide bands, the general absorption effect of *CH* at the G band, and (M II) the relative strength of the lines of ionized metallic atoms as compared with those of neutral atoms. A dash is used to indicate that the photograph was not properly exposed to show the feature in question, but a zero indicates that the feature is not visible, even though the plate is competent to show it.

These observational results are summarized in Table 3, where the stars are separated into low- and high-velocity groups. In the last three columns are the mean or γ velocity, the approximate velocity range, and the residual velocity, assuming the usual solar motion of 20 km/sec.

The spectral types generally vary from about G0 somewhat before maximum light to about K0 near minimum. Near minimum light the titanium oxide bands appear in spectra which otherwise would be classed as G or K. The classification on the basis of the *TiO* bands is given in parentheses. This peculiar phenomenon, which was first noticed in R Sct,[11] seems to be characteristic of these stars and is especially outstanding among the members of group 2. In SV UMa an intensity of 4 in the titanium bands is observed on two spectrograms of types G5 and G8.

Rosino[2] has noted the presence of carbon bands in AC Her. On the Mount Wilson plates, as reported by Sanford,[6] the G band attains great strength as the light decreases to minimum. The λ 4215 *CN* band and the λ 4737 C_2 bands are faintly visible for a few days preceding minimum. Doubtless the total carbon absorption is responsible for a part of the loss of light. The small change in color index[1] at different phases indicates that the cyanogen absorption plays a minor role.

[6] *Mt. W. Contr.*, No. 424; *Ap. J.*, **73**, 364, 1931.

[7] *Mt. W. Contr.*, No. 481; *Ap. J.*, **79**, 81, 1934.

[8] *Mt. W. Contr.*, No. 481; *Ap. J.*, **79**, 82, 1934.

[9] *Pub. Obs. U. Michigan*, **7**, 57, 1938.

[10] D. B. McLaughlin, *Ap. J.*, **94**, 94, 1941.

[11] A. H. Joy. R Scuti, *Pub. A.S.P.*, **34**, 349, 1922; SX Herculis, *Mt. W. Contr.*, No. 443; *Ap. J.*, **75**, 127, 1932.

TABLE 2

SPECTROSCOPIC OBSERVATIONS OF RV TAURI AND SEMIREGULAR VARIABLES

Star	Plate	Date JD 24	Phase (Days)	Spectrum	Velocity (Km/Sec)	Disp. at $H\gamma$ (A/Mm)	Intensity			
							Em.	*TiO*	*CH*	M II
WY And	γ 19195	26993	M 108	G6	−176	70	0	0	2	1
	19262	7021	27	G8	−191	70	0	0	2	1
	C 6348	7431	2	—e	−192	35	4	0	—	—
	6351	7432	3	—e	−207	35	3	0	—	—
	γ 23000	9894	72	K2	−188	70	0	2	2	1
	23144	9932	1	G8e	−185	70	3	—	1	3
	Ce 3262	31038	19	—e	−197	20	1	—	—	—
	E 1455	1662	99	G2e	−179	70	3	0	1	2
	1492	1698	26	G3e	−197	70	1	0	1	2
	γ 27057	1724	52	K2	−198	70	0	3	1	2
					−191					
BL Aqr	γ 19769	27287	M 17	G4	+ 34	110	0	0	1	2
	C 7521	9826	6	G5	+ 46	110	0	0	2	2
	γ 22856	9857	37	G4	+ 36	70	0	0	2	2
	E 209	30209	49	K0	+ 52	110	0	1	3	1
	γ 23640	0220	60	G5	+ 39	110	0	1	2	2
	E 1441	1638	33	G8	+ 51	110	0	2	2	2
	1463	1665	60	G8	+ 55	70	0	2	2	2
	γ 27922	2053	23	G2	+ 47	110	0	0	1	2
					+ 45					
TW Aql	C 5156	27018	—	G5	+ 14	110	0	0	2	2
	γ 21862	9413	—	G6	+ 34	70	0	0	3	3
	22855	9857	—	G0	+ 35	70	0	0	0	3
	23639	30220	—	G4	+ 2	110	0	0	3	3
	E 268	0266	—	K0	+ 20	110	0	0	3	3
					+ 21					
DY Aql	C 7490	29766	m 109	K0	+ 3	110	0	3	2	1
	γ 22742	9804	15	G8	0	110	0	0	3	2
	C 7520	9826	37	K0	+ 30	110	0	2	3	2
	E 39	9896	107	—	—	110	0	2	—	—
	57	9913	124	G5e	+ 14	110	5	0	2	3
	146	30147	95	G6	+ 24	110	0	2	2	3
	259	0251	68	K0	+ 25	110	0	1	4	2
					+ 15					
EZ Aql	C 7348	29452	m 31	G5	—	110	0	0	2	2
	7351	9471	11	G8	+ 48	110	0	0	3	3
	7539	9853	7	K0	+ 49	110	0	0	2	3
					+ 48					
KK Aql	C 6168	27020	M 43	G6	−245	110	0	1	1	1
	6445	7611	13	—	−256	70	0	0	—	2
	γ 21160	8734	72	G2e	−280	110	4	0	1	2
	E 255	30250	80	G4	−231	110	0	0	2	2
	γ 27066	1727	49	G6	−246	110	0	2	1	2
	27703	1980	36	G4	−240	110	0	1	1	1
	27919	2052	19	G6	−262	110	0	0	0	1
					−252					

TABLE 2—*Continued*

STAR	PLATE	DATE JD 24	PHASE (DAYS)	SPECTRUM	VELOCITY (KM/SEC)	DISP. AT $H\gamma$ (A/MM)	INTENSITY			
							Em.	*TiO*	*CH*	M II
Z Aur........	γ 23030	29898	M 46	G4e	−155	70	5	0	2	1
	23163	9945	93	G6e	−187	110	4	0	2	2
	23339	30071	8	G2	−157	110	0	0	1	1
	E 258	0251	65	G2e	−152	110	3	0	1	1
	γ 23842	0302	5	G0e	−154	70	3	0	1	1
	23929	0334	37	G0	−160	110	0	0	1	1
	27176	1755	17	G5e	−157	110	5	1	1	1
	27503	1894	45	G4e	−168	110	4	2	1	1
	E 1688	1922	73	G3e	−170	110	2	0	2	2
					−165					
AG Aur......	C 4695	25305	M 30	G6	+182	70	0	0	1	2
	4717	5342	67	—	—	70	0	2	—	1
	4729	5344	69	—	+196	70	0	2	—	1
	5364	5956	92	G8e	+199	70	2	0	2	2
	5568	6256	97	G4e	+190	70	1	0	2	2
	5584	6267	10	G4e	+190	70	1	0	1	2
	5602	6283	26	G4	+192	70	0	1	1	1
	5624	6311	54	G8	+206	70	0	3	1	1
	5664	6340	83	G2e	+197	35	5	0	2	1
	5665	6340	83	G2e	+195	70	5	0	1	1
	V 94	6647	95	G5e	+195	35	2	0	2	2
	C 6347	7403	82	—	+201	35	4	—	—	—
	6349	7431	12	G4e	+186	70	4	0	1	2
	γ 27177	31756	12	G4e	+183	110	4	0	1	2
	27504	1894	53	K0	+189	110	0	1	2	1
	E 1689	1922	81	G8	+200	110	0	2	2	1
					+193					
TW Cam.....	γ 23137	29927	m 82	G8	− 69	110	0	0	0	3
	23197	9957	27	G8	− 44	110	0	0	1	3
	C 7642	9971	41	G5	− 51	70	0	0	1	3
	E 257	30250	63	G2	− 59	110	0	0	1	3
	γ 27171	1754	26	G3	− 61	70	0	0	0	3
	27971	2076	6	G4	− 40	110	0	0	1	3
					− 55					
RX Cap......	C 7515	29825	m 47	G3	−135	110	0	0	0	1
	γ 22848	9856	10	G0	−122	110	0	0	1	2
	23132	9927	13	G3	−148	110	0	0	1	2
	23509	30180	62	G2	−156	110	0	0	1	1
	26939	1696	15	G0	−135	110	0	0	0	2
					−135					
RU Cep......	γ 22107	29505	M 62	—	− 13	70	0	0	—	1
	22199	9560	7	—	− 18	70	0	0	—	2
	22415	9647	94	K0	− 4	70	0	1	1	2
	23027	9898	16	—	− 17	70	0	2	—	2
	23029	9898	16	K2	− 17	70	0	2	2	1
	27170	31754	11	K0	− 18	35	0	1	1	2
	27924	2053	91	G6	− 8	70	0	2	2	1
					− 12					
TZ Cep.......	γ 19188	26992	M 74	K0e	− 15	70	1	0	3	3
	21971	9450	42	G6	− 5	110	0	2	2	3

TABLE 2—*Continued*

Star	Plate	Date JD 24	Phase (Days)	Spectrum	Velocity (Km/Sec)	Disp. at $H\gamma$ (A/Mm)	Intensity			
							Em.	*TiO*	*CH*	M II
TZ Cep.......	γ 23028	29898	M 75	G8e	− 7	70	4	1	3	3
	23136	9927	21	K1	0	110	0	2	2	2
	23636	30219	64	K2e	+ 4	110	3	1	3	1
	27974	2077	13	K0	+ 6	110	0	0	0	1
					− 5					
AV Cyg......	γ 18899	26878	M 77	G4	− 28	70	0	0	3	1
	C 7305	9410	8	G3e	− 16	110	3	0	3	3
	7549	9855	4	G2e	− 30	110	3	0	3	2
	γ 23453	30151	31	G6	− 11	110	0	0	3	3
	E 1416	1600	45	G0e	− 32	110	1	0	2	2
	γ 26744	1633	78	G3	− 19	70	0	0	2	2
	C 7708	1958	44	G2e	− 28	110	2	0	3	2
					− 23					
DF Cyg......	γ 18070	26401	m 12	K0	− 5	110	0	0	2	3
	C 5751	6495	7	K2	+ 4	70	0	0	1	3
	5758	6516	28	G6	− 10	70	0	0	1	3
	5841	6606	18	K2	− 35	110	0	0	3	3
	7064	8702	23	K4	− 7	110	0	0	3	3
	7086	8731	2	K0	+ 8	110	0	0	1	3
	7100	8763	34	G6	− 9	110	0	0	2	2
	γ 21218	8793	14	G8	− 4	110	0	0	3	3
	21231	8821	42	G8	+ 7	110	0	0	4	3
	C 7193	9144	16	G5	− 16	110	0	0	3	3
					− 5					
V360 Cyg.....	C 7507	29806	m 57	F5	−260	110	0	0	0	1
	γ 22758	9824	11	F8e	−247	110	1	0	1	1
	C 7540	9853	40	G0	−238	110	0	0	0	1
	E 40	9896	20	G0e	−238	110	2	0	0	2
	313	30297	41	F8	−264	110	0	0	1	1
	1417	1600	16	F5	−258	110	0	0	0	1
	1433	1635	51	G0	−255	70	0	0	1	2
	γ 27056	1724	13	F8e	−240	110	1	0	0	1
	27173	1755	44	G0e	−264	110	1	0	0	1
	27920	2052	25	F5	−281	110	0	0	0	2
					−250					
SS Gem......	C 1677	23179	m 36	G5	+ 23	70	0	0	3	2
	3238	4249	35	—	+ 30	70	0	0	—	2
	3661	4539	57	G5	− 19	70	0	0	2	3
	4221	4984	55	G4	+ 9	70	0	0	3	2
	4560	5217	20	G8	− 17	70	0	0	4	2
	4740	5347	61	G4	− 14	70	0	0	—	2
	5610	6285	17	G5	− 14	35	0	0	3	2
	5630	6312	44	G2	− 19	70	0	0	1	3
	5647	6316	48	G0	− 15	70	0	0	2	2
	γ 17978	6322	54	G2	− 8	70	0	0	2	3
	C 5652	6338	70	G0	− 7	70	0	0	1	2
	5674	6342	74	G0	− 5	70	0	0	1	2
	γ 18035	6346	78	G2	− 23	70	0	0	1	2
					− 6					

TABLE 2—*Continued*

Star	Plate	Date JD 24	Phase (Days)	Spectrum	Velocity (Km/Sec)	Disp. at $H\gamma$ (A/Mm)	Intensity Em.	Intensity *TiO*	Intensity *CH*	Intensity M II
SU Gem......	γ 21440	29176	—	G2	+ 16	110	0	0	1	3
	23159	9944	—	G4	+ 2	70	0	0	1	2
	C 7661	30029	—	G2	− 7	110	0	0	2	3
	E 339	0324	—	F5	+ 7	110	0	0	0	2
	γ 26392	1463	—	G6	− 26	110	0	0	2	3
					− 2					
UU Her......	C 2742	23889	—	F5	−128	70	0	0	0	2
	2766	3916	—	F6	−142	70	0	0	0	2
	2796	3926	—	F8	−137	70	0	0	0	2
	3512	4417	—	F5	−121	70	0	0	0	2
	3980	4750	—	G0	−130	70	0	0	1	2
	4197	4956	—	F2	−132	70	0	0	0	2
	4224	4984	—	F5	−130	70	0	0	0	1
	4254	5011	—	F7	−127	70	0	0	0	2
	4285	5040	—	F4	−132	70	0	0	0	2
	4308	5048	—	G0	−139	70	0	0	0	1
	4370	5079	—	F6	−126	70	0	0	0	2
	5205	5777	—	F5	−131	70	0	0	0	2
	5234	5809	—	F6	−117	70	0	0	0	1
	5390	6018	—	F8	−141	70	0	0	0	2
	5415	6048	—	F8	−139	70	0	0	0	2
	5464	6135	—	F7	−144	35	0	0	0	2
	5740	6493	—	F7	−125	70	0	0	0	1
	5756	6516	—	F6	−125	70	0	0	0	1
					−131					
AB Leo.......	E 1681	31919	M 47	G0e	+208	110	4	0	1	2
	1690	1923	51	G0e	+188	110	5	0	1	1
	Ce 4231	1929	57	—e	+182	20	4	—	—	—
	γ 27603	1930	58	F6e	+166	70	3	0	0	1
	27651	1952	80	F5e	+163	70	3	0	0	1
	E 1707	1976	1	G3e	+194	110	1	0	1	1
	γ 27705	1981	6	G0	+172	110	0	0	1	1
	29272	2555	64	F8	—	110	0	0	1	1
	E 1951	2582	91	G0e	+180	110	5	0	1	2
	γ 29383	2611	17	F5e	+189	110	1	0	1	2
	E 1969	2636	42	G2e	+178	110	1	0	1	1
	γ 29524	2671	77	F5e	+182	110	6	0	0	1
					+182					
W LMi.......	C 7176	29379	M 101	—	—	110	3	1	0	—
	γ 21784	9380	102	K0e	—	70	3	1	2	1
	C 7664	30030	48	G4e	+ 57	110	10	2	1	1
	γ 23340	0071	90	G6e	+ 55	110	3	0	2	1
	E 87	0090	109	K0e	+ 94	110	2	1	3	1
	γ 23450	0151	53	G2e	+ 48	110	6	0	2	1
	24024	0397	64	G2e	+ 64	110	8	0	1	1
	E 422	0443	110	K0e	+ 96	110	3	1	3	1
	γ 26394	1464	76	G4e	+ 71	110	4	0	2	1
	E 1354	1546	41	G5e	+ 41	110	5	2	2	1
	1397	1568	63	G3e	+ 46	70	5	0	2	1
	1595	1844	104	K2e	—	110	0	3	2	1
	C 7715	1960	104	K0e	+ 90	110	1	2	1	1
					+ 66					

TABLE 2—*Continued*

Star	Plate	Date JD 24	Phase (Days)	Spectrum	Velocity (Km/Sec)	Disp. at $H\gamma$ (A/Mm)	Intensity Em.	TiO	CH	M II
UW Lib......	γ 22735	29803	—	G7e	+155	70	0	0	1	1
	22756	9824	—	G8	+186	110	0	1	1	1
	C 7538	9853	—	G6e	+164	110	4	0	1	2
	γ 23341	30071	—	G4	+146	110	0	1	2	1
	E 106	0119	—	G7e	+169	110	2	2	2	2
	151	0149	—	G2e	+194	110	1	0	2	2
	γ 23510	0181	—	G8	+155	110	0	1	1	1
	24025	0398	—	K0	+142	110	0	0	2	2
	24054	0423	—	G6	+176	110	0	2	2	1
	E 423	0443	—	G7e	+179	110	4	3	2	2
	442	0471	—	G6e	+136	110	2	0	2	1
	1396	1567	—	G4e	+161	70	2	0	1	2
	γ 26612	1595	—	G6e	+169	110	1	1	1	1
	26742	1633	—	G5e	+171	70	1	0	1	2
	27642	1948	—	G8e	+174	110	2	0	2	2
	C 7707	1958	—	G6e	+146	110	1	0	2	2
	γ 27706	1981	—	G8	+145	110	0	0	2	1
					+163					
U Lup........	C 7485	29765	—	K0	−134	110	0	2	2	1
	7502	9806	—	—	—	110	0	1	—	1
	E 93	30091	—	G6e	−134	110	2	0	2	1
	107	0119	—	K0e	−141	110	1	0	2	1
	171	0178	—	K0	−124	110	0	2	2	1
	1428	1634	—	G2	−109	110	0	0	2	2
	C 7716	1960	—	G6e	−141	110	4	0	2	1
					−130					
TT Oph......	γ 6870	21711	m 13	G4e	− 64	70	1	0	2	2
	C 340	2414	43	G6e	− 43	35	2	0	3	3
	386	2443	12	—	—	35	3	0	—	—
	441	2473	42	G5e	− 41	35	1	0	—	3
	476	2483	52	K0	− 62	35	0	0	3	3
	504	2507	15	G4e	− 53	70	2	0	3	3
	1075	2866	8	G8	− 49	35	0	0	3	2
	1114	2882	24	G5	− 58	70	0	0	2	3
	1218	2918	59	K0	− 57	35	0	0	3	3
	1265	2940	20	G6	− 67	70	0	0	2	3
	1367	2970	50	G8	− 81	70	0	0	2	3
	1640	3136	33	K0	− 39	70	0	0	3	2
	2297	3592	0	G8	− 34	70	0	0	3	3
	3881	4715	24	G7	− 61	70	0	0	2	3
					− 50					
TX Oph......	C 4225	24984	—	G2e	−157	70	1	0	1	3
	4251	5010	—	G0	−166	70	0	0	0	3
	4399	5129	—	G2	−172	70	0	0	1	3
	4739	5346	—	G3	−170	70	0	0	1	3
	4928	5458	—	G6e	−158	70	1	0	1	3
	5227	5786	—	G4e	−161	70	1	0	1	2
	5435	6078	—	G0e	−155	70	1	0	1	2
	γ 24129	30484	—	F8	−165	110	0	0	0	3
	24151	0504	—	G3	−178	110	0	0	—	3
	26613	1595	—	G6	−164	110	0	0	1	2
	E 1683	1919	—	F5e	−177	110	1	0	0	2
					−165					

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TABLE 2—*Continued*

Star	Plate	Date JD 24	Phase (Days)	Spectrum	Velocity (Km/Sec)	Disp. at $H\gamma$ (A/Mm)	Intensity			
							Em.	*TiO*	*CH*	M II
UZ Oph......	C 4899	25439	m 24	G6e	− 99	70	1	0	2	3
	5149	5688	11	G6	− 58	70	0	0	2	3
	5460	6133	19	G4e	− 99	70	1	0	0	2
	γ 21968	9450	15	G5e	− 80	70	2	0	1	2
	23345	30087	41	G4	− 87	110	0	0	2	2
	23637	0220	86	G8	− 76	110	0	2	2	2
	E 443	0471	75	G2	−120	110	0	0	3	2
	γ 24130	0484	1	G8	− 90	110	0	1	2	2
	E 1415	1600	68	G2e	− 92	110	2	0	2	2
					− 85					
TX Per.......	γ 19263	27021	M 6	K2	− 15	70	0	1	4	2
	22109	9506	48	G7	− 7	110	0	0	3	2
	C 7432	9646	36	K0e	+ 7	110	1	2	2	1
	E 43	9896	58	K0	− 6	110	0	1	2	2
	54	9912	74	—	—	70	0	2	—	2
	261	30251	31	G8e	+ 22	110	2	1	4	2
	1493	1698	28	K2	− 6	70	0	3	1	2
	γ 27174	1755	9	G6	− 13	110	0	1	3	2
	27251	1786	40	G5	+ 21	110	0	0	2	1
	E 1762	2082	31	G6e	− 2	110	3	1	2	1
					0					
AR Sgr.......	C 4995	25518	m 31	G6	−101	70	0	0	1	2
	5487	6164	62	G2	−101	70	0	0	1	1
	5557	6242	52	F8	− 90	70	1	0	0	1
	E 50	9912	31	G0	−101	70	0	0	0	2
	γ 23508	30180	36	G0	−108	70	0	0	1	2
	23634	0219	75	G2	−102	110	0	0	1	2
	26616	1596	46	G3e	−105	70	2	0	0	1
	E 1430	1634	84	F5e	− 88	70	1	0	1	1
					−100					
AI Sco........	C 6261	27254	—	K2	− 3	110	0	0	1	3
	6268	7256	—	G0	− 40	110	0	0	2	—
	E 274	30267	—	G5	− 8	110	0	0	2	2
					− 15					
RV Tau......	C 4511	25183	m 63	K1	+ 46	70	0	0	4	3
	5150	5690	19	G4	+ 39	70	0	0	2	3
	5329	5875	48	K0e	+ 34	70	1	0	3	2
	5617	6310	11	G8e	+ 48	70	2	0	1	3
	5658	6339	40	G8	+ 44	70	0	1	3	2
	5702	6431	53	G5e	+ 33	70	1	0	3	2
	5843	6606	71	G8	+ 41	70	0	0	3	3
	γ 19122	6964	36	G5	+ 32	70	0	0	2	1
	19199	6993	65	G4	+ 18	70	0	0	3	3
	C 6173	7020	13	G5e	+ 33	70	1	0	2	3
	E 47	9897	61	G6	+ 39	110	0	0	2	3
	279	30267	38	G6	+ 28	110	0	1	4	3
	1498	1710	66	G4	+ 25	110	0	0	2	3
	γ 27059	1724	1	G6	+ 41	70	0	0	3	2
	E 1524	1744	21	G4	+ 22	110	0	0	2	2
	γ 27175	1755	32	G6	+ 5	110	0	0	3	2

TABLE 2—*Continued*

Star	Plate	Date JD 24	Phase (Days)	Spectrum	Velocity (Km/Sec)	Disp. at $H\gamma$ (A/Mm)	Intensity Em.	Intensity *TiO*	Intensity *CH*	Intensity M II
RV Tau......	γ 27347	31831	m 29	G5	+ 25	70	0	0	3	3
	E 1908	2496	66	G4e	+ 24	110	1	0	3	2
					+ 35					
WW Tau.....	γ 22473	29678	—	G5	− 99	110	0	0	2	2
	E 48	9897	—	G4e	−113	110	5	2	1	2
	γ 23161	9945	—	K2	−102	110	0	3	2	1
	23196	9957	—	K0	−109	110	0	3	1	2
	E 284	30268	—	K0	−109	110	0	—	1	2
	γ 27068	1727	—	G4e	−120	110	2	1	2	2
					−110					
SV UMa......	C 4667	25278	—	G5e	− 80	70	6	0	1	2
	4738	5346	—	G4e	− 86	70	3	0	2	3
	4761	5353	—	G5e	—	70	1	0	1	2
	4764	5362	—	G6	− 99	70	0	0	1	2
	4804	5380	—	G8	−101	70	0	1	3	3
	4822	5394	—	G5	− 97	70	0	4	2	3
	4841	5410	—	G8	− 85	70	0	4	—	2
	4850	5422	—	G6	− 90	70	0	3	3	2
	5148	5688	—	G8	− 90	70	0	1	2	2
	5164	5723	—	G2e	− 85	70	1	0	2	1
	5393	6018	—	G3	−101	70	0	0	2	3
					− 90					
S Vul.........	C 2937	24377	M 56	G6•	− 14	70	0	0	1	2
	3950	4744	28	G6	+ 1	70	0	0	1	2
	4400	5129	35	K2	+ 10	70	0	1	4	3
	4983	5515	14	K0	− 5	70	0	0	3	3
	5180	5751	47	K0	− 1	70	0	0	3	3
	5211	5779	7	G0	− 13	70	0	0	1	2
	5237	5809	37	G8	+ 6	70	0	0	3	2
	γ 16781	5836	64	G4	− 10	70	0	0	2	2
	17544	6154	44	G6	− 3	70	0	0	3	2
	17545	6155	45	G6	− 3	70	0	0	—	2
	17576	6169	59	G4	− 2	70	0	0	1	3
	C 5556	6241	62	G2	− 9	70	0	0	—	2
	γ 17855	6285	39	K0	+ 4	70	0	0	3	2
	C 5615	6310	63	G6	− 5	70	0	0	1	3
	5801	6554	37	G8	+ 8	70	0	0	2	2
	5819	6580	63	G5	− 4	70	0	0	1	3
	5846	6607	22	G6	− 13	70	0	0	2	3
	6046	6879	23	G4	− 6	70	0	0	1	3
					− 2					

TABLE 3

SUMMARY OF SPECTROSCOPIC RESULTS

STAR	SPECTRUM (ATOMIC LINES *TiO*)	MAX. EMISSION INT.	*CH* G BAND INT.	MAX. M II INT.	VELOCITY Meas. (Km/Sec)	Range (Km/Sec)	Resid. (Km/Sec)
	Group 1: Velocities < 70 Km/Sec						
BL Aqr	G2 –K0 (M2)	0	1–3	2	+ 45	20	+ 57
TW Aql	G0 –K0	0	0–3	3	+ 21	35	+ 39
DY Aql	G5e–K0 (M3)	5	1–3	3	+ 15	30	+ 29
EZ Aql	G5 –K0	0	2–3	3	+ 48	—	+ 66
TW Cam	G2 –G8	0	0–1	3	– 55	30	– 56
RU Cep	G6 –K2 (M2)	0	1–2	2	– 12	15	– 3
TZ Cep	G6 –K2e (M2)	4	0–3	3	– 5	20	+ 4
AV Cyg	G0e–G6	3	2–3	3	– 23	20	– 4
DF Cyg	G5 –K4	0	1–4	3	– 5	45	+ 13
SS Gem	G0 –G8	0	0–4	3	– 6	55	– 19
SU Gem	F5 –G6	0	0–2	3	– 2	40	– 13
SX Her	G3e–K0 (M3)	8	0–3	2	+ 20	15	+ 38
AC Her	F1 –K4e	4	0–4	3	– 30	60	– 10
U Mon	F8e–K2 (M2)	5	1–4	3	+ 35	45	+ 17
TT Oph	G2e–K0	3	2–3	3	– 50	45	– 33
UZ Oph	G2e–G8 (M2)	2	1–3	3	– 85	70	– 67
TX Per	G5e–K2 (M3)	3	1–4	2	0	40	– 3
R Sge	G2 –K0	0	1–4	3	+ 10	40	+ 27
AI Sco	G0 –K2	0	1–2	3	– 15	35	– 6
R Sct	G5e–K2 (M3)	3	2–3	3	+ 40	35	+ 56
RV Tau	G4e–K1 (M1)	2	1–4	3	+ 35	45	+ 24
S Vul	G0 –K2 (M1)	0	1–4	3	– 2	25	+ 17
V Vul	G4 –K3 (M2)	1	1–4	3	– 15	40	+ 2
	Group 2: Velocities > 70 Km/Sec						
WY And	G2e–K2 (M3)	4	1–2	3	–191	55	–183
KK Aql	G2e–G6 (M2)	4	1–2	2	–252	50	–234
Z Aur	G0e–G6e (M1)	5	1–2	2	–165	35	–167
AG Aur	G2e–K0 (M3)	5	1–2	2	+193	25	+188
RX Cap	G0 –G3	0	0–1	2	–135	35	–123
V360 Cyg	F5 –G0e	2	0–1	2	–250	45	–235
UU Her	F2 –G0	0	0–1	2	–131	25	–114
AB Leo	F5e–G3e	6	0–1	2	+182	50	+175
W LMi	G2e–K2e (M3)	10	1–3	1	+ 66	55	+ 70
UW Lib	G2e–K0 (M3)	4	1–2	2	+163	60	+176
U Lup	G2 –K0e (M2)	4	2–2	2	–130	30	–122
TX Oph	F5e–G6e	1	0–1	3	–165	20	–147
AR Sgr	F5e–G6	2	0–1	2	–100	10	– 88
WW Tau	G4e–K2 (M3)	5	1–2	2	–110	20	–119
SV UMa	G2e–G8 (M4)	6	1–3	3	– 90	20	– 86

NOTES TO TABLES 2 AND 3

WY And — Max. = JD 2428408.9 + $108^{d}8E$. On plates C 6348, C 6351, and Ce 3262 the stellar D1 and D2 sodium lines are well separated by velocity from the interstellar lines. Ce 3262 was taken and measured by R. F. Sanford. On this plate the $H\alpha$ emission is symmetrically divided by a strong, deep absorption line.

BL Aqr — Max. = JD 2430160 + $85^{d}E$.

TW Aql — P = 96? days. Sharp lines.

DY Aql — Min. = JD 2428344 + $131^{d}42E$.

NOTES TO TABLES 2 AND 3—*Continued*

EZ Aql — Min. = JD 2428611.05 + 38ᵈ61*E*. Extensive light-observations by Taylor and Olivier (*Pub. Obs. U. Pennsylvania*, Vol. **6**, Part 5, 1941). The spectrum is much like that of DF Cyg.

KK Aql — Max. = JD 2428308.4 + 88ᵈ7*E*.

Z Aur — Max. = JD 2432072 + 110ᵈ96*E*.

AG Aur — Max. = JD 2425766.5 + 98ᵈ26*E* (*Schneller*, 1939).

TW Cam — Min. = JD 2428647 + 85ᵈ6*E*.

RX Cap — Min. = JD 2420741.4 + 67ᵈ95*E*. Only maximum phase was observed.

RU Cep — Max. = JD 2430649 + 109ᵈ5*E*. Observed by P. C. Keenan, M0 III (*Ap. J.*, **95**, 462, 1942). The Mount Wilson observations are poorly distributed and do not cover the minimum phases.

TZ Cep — Max. = JD 2425840 + 83ᵈ0*E*.

AV Cyg — Max. = JD 2430659 + 89ᵈ7*E*. Except for λ 4077 and λ 4215 *Sr* II, the lines are weak.

DF Cyg — Min. = JD 2414883.5 + 49ᵈ808*E*. The spectrograms were all obtained at the brighter phases of the long-period variation of 782 days. The remarkable light-variations of this star were discovered and extensively observed by Miss M. Harwood (*Harvard Ann.*, **105**, 521, 1937).

V360 Cyg — Min. = JD 2426967 + 63ᵈ26*E*. The emission lines are double, with shortward component stronger; separation 160 km/sec. The absorption lines are weak.

SS Gem — Min. = JD 2430020 + 89ᵈ31*E*.

SU Gem — *P* = 50.12 days, with an additional long-period variation of 689.6 days. The absorption lines show large changes in intensity.

SX Her — The spectroscopic behavior of this star resembles that of the Mira stars in some particulars. Hydrogen emission occurs for about 30 days before and after maximum light. *TiO* bands attain considerable strength at minimum light.

UU Her — Alternating periods of 90.40 and 71.06 days have been found. The G band is usually absent. Spectral changes and velocity variations are small and uncertain. The star is unlike other stars of the group. The mean of the Mount Wilson and McCormick trigonometric parallaxes is 0″010. The observations were made at the times when the period of 90 days prevailed.

AC Her — Sanford (*Mt. W. Contr.*, No. 424; *Ap. J.*, **73**, 364, 1931) found that during increasing light the hydrogen lines have emission edges. The velocity-curve shows a double maximum corresponding to the double minimum of the light-curve. The spectral type at maximum is earlier than that of any other star in the list and has a large range (F1–K4), although no *TiO* bands appear. The G band shows remarkable changes with phase. L. Rosino (*Ap. J.*, **113**, 60, 1951) calls attention to the strength of the carbon bands during decreasing light and classifies the star as Rp at this phase.

AB Leo = BD+20°2337 — Max. = JD 2428880 + 103ᵈ2*E*. A. Vyssotsky found emission lines of hydrogen in objective-prism spectra of this star. From Harvard plates Miss Hoffleit discovered light-changes which resemble those of the semiregular or RV Tauri variables. She determined the elements used here. The light-curve seldom shows alternating bright and faint minima, but the period seems to hold, even though the epoch may shift. At times the light-fluctuations become irregular and of small range. The bright lines are strong and persistent, showing slow decrement shortward, but the type is too early to permit *TiO* bands. The star is evidently one of the semiregular variables of high velocity and moderate luminosity.

Plate Ce 4231 was taken by R. F. Sanford. On this plate the emission at $H\alpha$ is symmetrically divided by a narrow central reversal. In general, the absorption lines are sharp, and the spectrum resembles that of UU Her, but, on the plates showing the earliest estimated spectral type, the lines seem weak, although no certain veiling effect is observable.

W LMi — Max. = JD 2428303 + 117ᵈ2*E*. The light-changes and period are poorly determined. The range of light-variation is large. The hydrogen emission lines are strong and persistent, but the enhanced lines are weak. This star should certainly be placed among the high-velocity stars.

UW Lib — *P* = 84.73 days. No epoch. This period does not seem to satisfy the velocity and spectral variations. Small light-range.

U Lup — The period is variable between 75 and 95 days, according to D. J. K. O'Connell (*Harvard Bull.*, No. 893, 1933).

U Mon — Sanford (*Mt. W. Contr.*, No. 465; *Ap. J.*, **77**, 120, 1933) found that the velocity-curve shows a double minimum, corresponding to the double maximum of the light-curve. Hydrogen emission and *TiO* bands were observed.

TT Oph — Min. = JD 2428723 + 61ᵈ08*E*. This star, which was at first thought to be an eclipsing binary, is one of the best examples of the RV Tauri type of variation. The light-

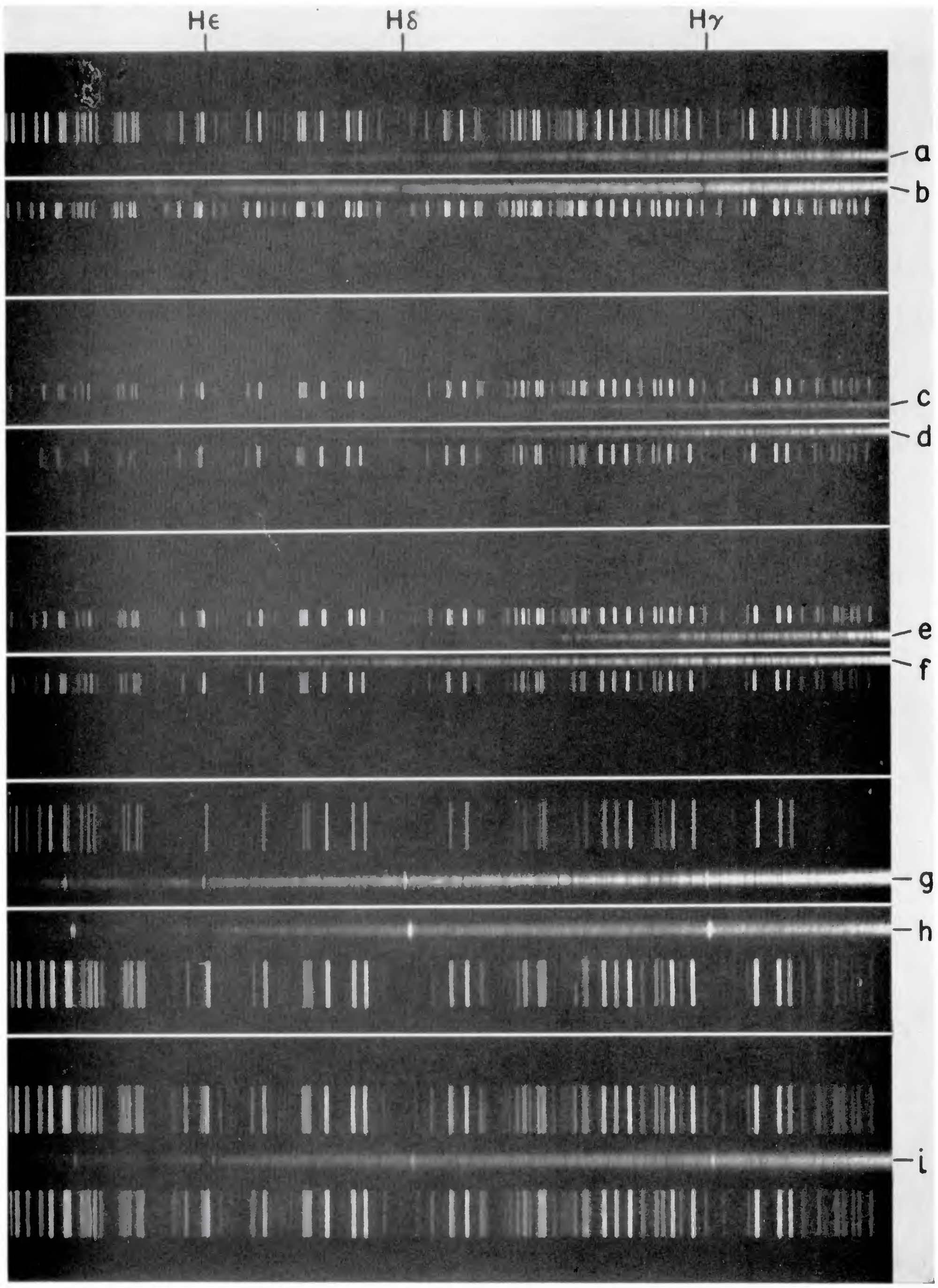

FIG. 1.—Spectra of semiregular variables. *a*, K2 (M3), TX Persei; *b*, F4, UU Herculis; *c*, G5 (M4), SV Ursae Majoris, strong titanium bands on G5 spectrum; *d*, G8e, RV Tauri, *CH* weak; *e*, KO, RV Tauri, *CH* strong; *f*, G6, TW Camelopardalis, ionized metallic lines strong; *g*, G2e, WY Andromedae, ionized metallic lines weak, slow decrement of bright lines, *Hε* weakened; *h*, G5e (M2), W Leonis Minoris, all absorption lines weak, *Hε* absent; *i*, G0e, AB Leonis, lines weak.

NOTES TO TABLES 2 AND 3—*Continued*

	minima are usually well defined and of nearly equal depth. Emission lines of hydrogen appear during increasing light and reach greatest intensity 2 days before maximum light. The velocity-curve shows definite correlation with the light-curve. No *TiO* bands have been observed. The enhanced lines are strong.
TX Oph	$P = 138?$ days. The range in velocity and spectral type is small. The enhanced lines are strong and indicate the highest luminosity of the high-velocity stars.
UZ Oph	Min. = JD 2422531.84 + 87ᵈ39*E*. This star may belong to the high-velocity group.
TX Per	Max. = JD 2428466 + 76ᵈ3*E*.
R Sge	Sanford found (*Mt. W. Contr.*, No. 481; *Ap. J.*, **79**, 81, 1934) that the radial velocities show little correlation with the light-curve, but D. B. McLaughlin (*Ap. J.*, **94**, 94, 1941) discovered that, by omitting velocities obtained when light-variations were irregular, a reasonable correlation could be determined. No *TiO* bands or emission lines were found. The G band strengthens at minimum light.
AR Sgr	Min. = JD 2426103 + 87ᵈ87*E* (*Harvard Ann.*, **113**, 39, 1943). Observed minimum.
AI Sco	$P = 71.78$ days, with superposed period of 960 days.
R Sct	The appearance of *TiO* bands at spectral type G9 was noted (*Pub. A.S.P.*, **34**, 349, 1922) in 1922. This fine example of RV Tauri variation has been thoroughly studied by D. B. McLaughlin (*Pub. Obs. U. Michigan*, **7**, 57, 1938).
RV Tau	Min. = JD 2429290 + 78ᵈ6*E* (*Harvard Ann.*, **113**, 49, 1943). Observed minimum. A superposed period of 1227 days has been suggested. The G band and the enhanced lines are strong, but the emission lines and *TiO* bands are weak and rarely seen.
WW Tau	The period varies from 113 to 138 days. The velocity range is small, but there is considerable variation in spectral type.
SV UMa	$P = 76$ days. The light-variations are quite irregular, and the period is variable. The star was spectroscopically observed in 1930 by R. O. Redman (*M.N.*, **92**, 116, 1931) at Victoria. A series of seventeen spectrograms covering more than a cycle failed to show, at that time, the strong emission lines of hydrogen and the *TiO* bands observed later at Mount Wilson. A McDonald spectrogram in 1941 by P. C. Keenan was classified as K3p: I*a* (*Ap. J.*, **95**, 463, 1942) with weak lines.
S Vul	Max. = JD 2423671.7 + 67ᵈ77*E* (*Schneller*, 1939). The period is variable. Velocity and spectral variations are small, but the strength of the G band shows large fluctuations with phase. The spectrum resembles that of cepheids of intermediate period.
V Vul	Sanford (*Mt. W. Contr.*, No. 481; *Ap. J.*, **79**, 82, 1934) reported weak *TiO* bands but no emission.

The *CH* absorption is an outstanding feature of the stars of group 1, reaching its greatest strength at the times of later spectral type. At other phases the band becomes weak or disappears. In group 2, *CH* seldom attains great intensity. In all the stars, marked changes in the bands take place in a few days' time. The λ 4215 *CN* band has also been found for a short period preceding minimum in the luminous stars DF Cyg, SS Gem, U Mon, RV Tau, and SV UMa.

Emission lines of hydrogen occur, especially at times of increasing light, in a majority of the stars of both groups. The bright lines are stronger and more persistent in group 2. The decrement toward the violet is usually gradual. The bright hydrogen line $H\epsilon$ is often greatly reduced in intensity by the absorption of the H line of calcium (Fig. 1, *g*, *h*, and *i*).

With further observation, hydrogen emission or titanium bands may yet be found at favorable phases in some of the stars in which these features were not observed.

The irregular behavior of the stars makes it impossible to draw useful velocity-curves from scattered observations. The mean measured velocity range of 36 km/sec is somewhat less than that of the most luminous cepheids, but this may be due to periods of inactivity which occur from time to time among the semiregular variables. The mean velocity range is the same for both groups of Table 3.

In studies of variable stars the period of variation has usually been an important factor in the discussion. This parameter has rendered little help with the irregular stars discussed in this paper. Various correlations with period have been tried, but they have not seemed significant.

SUBGROUPS

Since the stars of the present list were included largely on the basis of their spectral characteristics, considerable study was given to their spectroscopic behavior, in order to detect the presence of physically defined subgroups. Such an analysis points to a division (Table 3 and Fig. 3) into high- and low-velocity groups as the most natural and fruitful means of bringing together the stars of like physical characteristics. Only five stars of the list have residual velocities between 57 and 114 km/sec, and none are found between 70 and 86 km/sec. A value of 70 km/sec was set as the lower limit of the velocities of group 2. It is near the minimum frequency of velocities and corresponds well with the values used by Oort and others in separating stars of low and high velocity. If the maximum strength of the ionized lines (fifth column of Table 3) or that of the G band (fourth column) had been taken as criteria, the grouping would have been practically the same,

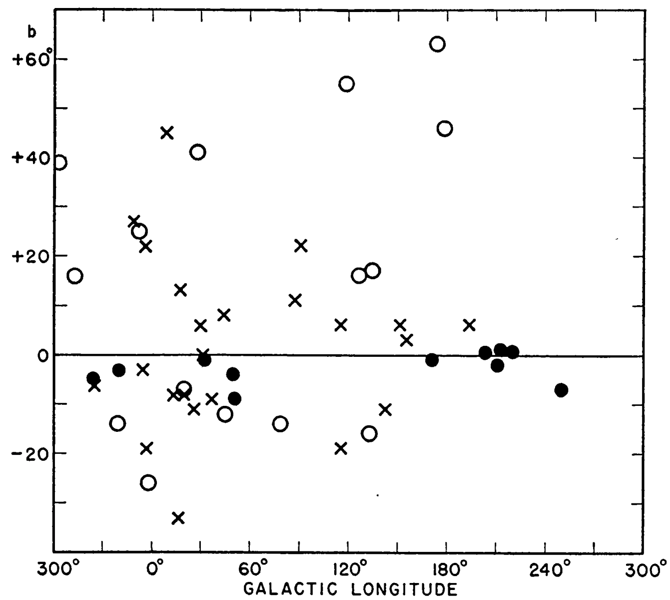

FIG. 2.—Galactic latitude and longitude of semiregular variables. Circles are high-velocity stars (Group 1); crosses, low-velocity stars (Group 2); and filled circles, cepheids with period > 20 days.

except that it might have been necessary to place TW Cam in group 2 with the high-velocity stars.

The evidence for two physical groups among these semiregular variables is strong in several respects: (1) The mean galactic latitudes of groups 1 and 2 (13° and 27°) indicate a difference in distribution (Fig. 2), although in neither group is the concentration toward the galactic equator as marked as in the δ Cephei variables, for which the average distance from the equator is less than 5°. (2) Mean proper motions determined by R. E. Wilson are 0.″018 for thirteen stars of group 1 and 0.″035 for seven stars of group 2. Since these values are, respectively, two and three times the mean proper motions of cepheids with periods greater than 20 days, it seems unlikely that either group has close kinetic relationship with the long-period cepheids. (3) Mean residual radial velocities (Table 3) without regard to sign: group 1, 28 km/sec; group 2, 154 km/sec. (4) A plot of radial velocities according to galactic longitude (Fig. 3) shows a distinct difference in the distribution of velocities in the two groups. The high velocities of group 2 are widely separated from those of group 1. A solar-motion solution for group 2 from the radial velocities indicates a group motion of 263 km/sec in nearly the same direction as that of RR Lyrae stars[12] and the high-velocity R-type stars.[13] The smaller velocities of group 1, unlike those of the δ Cephei stars, show little galactic-rotation effect. (5) The average spectral type of group 2 is slightly earlier than that of group 1: at maximum F9 for group 2, G2 for group 1; at minimum G7 and K0, respectively. (6) The ionized lines of metals are distinctly stronger in group 1, and the absorption spectrum is more clearly defined, indicating higher luminosity. (7) The G band (*CH*) reaches greater intensity in group 1, but this may be, in part, due to the effect of later spectral type in the low-velocity stars. (8) Emission lines of hydrogen are often found in both groups at certain phases but occur more frequently and in greater strength among the high-velocity stars (eleven of twenty-three stars in group 1; thirteen of fifteen stars in group 2). (9) The double period with two unequal minima of light, typical of the more regular RV Tauri stars, seldom occurs in group 2.

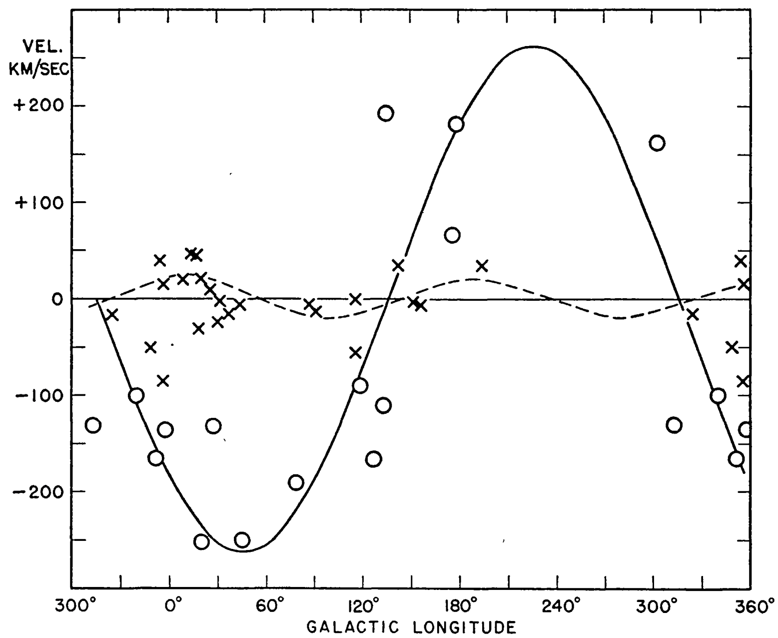

FIG. 3.—Radial velocity and galactic longitude of semiregular variables. Circles are high-velocity stars (Group 1); crosses, low-velocity stars (Group 2). The solid curve shows the radial velocity of Group 2 with reference to the sun; the dashed curve is the theoretical galactic rotation effect having a maximum of 25 km/sec.

The stars of group 2 are doubtless of type II population and might be expected to resemble those of groups 4 and 5 of the globular clusters.[14] This similarity prevails with regard to luminosity, period, and the occasional appearance of emission lines in our group 2 as compared with group 5 of the clusters. On the other hand, in the clusters the mean range of light-variation is smaller, 0.8 mag. compared to 2.2 mag. Also, in the clusters the G band is stronger and the spectral type somewhat later, although the *TiO* bands apparently are less frequent.

High-luminosity variables such as those of group 4 in the clusters seem to be few or absent among the high-velocity stars of the galaxy. Perhaps TX Oph may be an exception. Several of the low-velocity stars of our group 1 are similar to those of group 4 in the

[12] J. H. Oort, *B.A.N.*, **8**, 337, 1939; O. Struve, *Pub. A.S.P.*, **62**, 217, 1950.

[13] N. W. McLeod, *Ap. J.*, **105**, 390, 1947.

[14] A. H. Joy, *Ap. J.*, **110**, 105, 1949.

clusters, except that the group 1 stars are later in spectral type and have strong G bands, while *CH* in group 4 of the clusters is weak or absent.

From these considerations it seems evident that these semiregular variables may well comprise two groups based on distribution, motions, luminosity, or the intensity of the G band of *CH*. The relationship of these two groups to the variables of the δ Cephei class, on the one hand, and to the red M-type variables, on the other, is yet uncertain. Group 2 definitely should be included in population II, but the place of group 1 is not clear. Since the peculiar motions of group 1, which includes many of the best-known RV Tauri variables, such as U Mon, R Sct, and V Vul, are large as compared with the long-period cepheids but yet are much smaller than is generally found for type II stars, and their galactic latitude agrees with neither, it seems best, at present, to consider these stars as an anomalous group of population I stars. Possibly they may be related to the widely scattered giant K stars whose rapid velocities were first found by W. W. Campbell.

Most of the stars of group 2 are irregular variables which cannot meet the rigid requirements usually set up for the RV Tauri class. TX Oph and RX Cap have most of the RV Tauri characteristics and may correspond to the RV Tauri group in the clusters.

ABSOLUTE MAGNITUDE AND DISTANCE

On account of the great distances, trigonometric parallaxes of these stars are few and unreliable. Spectroscopic estimates of the visual absolute magnitude have been published for SX Her[11] (−1.5) and U Mon[15] (−2.0), and comparisons with the spectra of cepheids of the same spectral type indicate clearly that the luminosity of the brightest stars is as high as, or perhaps higher than, that of any of the cepheids. This conclusion is confirmed by the distances determined from the strength of the interstellar lines of sodium[16] in three of the less luminous stars (WY And, AG Aur, and UU Her), from which absolute magnitudes brighter than −2.2 may be deduced. In the globular clusters the absolute photographic magnitudes of the RV Tauri and semiregular groups are −3.0 and −1.5, respectively. Using the proper motions of sixteen stars (eleven belonging to these groups), P. P. Parenago[17] found a mean absolute visual magnitude of −0.4, but this value is of low weight on account of the small proper motions (mean about 0$''$.02) involved.

Rosino[2] has classified eleven of the stars (eight of group 1 and three of group 2) and assigned the luminosity class I*a* or I*b*, indicating visual absolute magnitudes as high as −4 or −5 according to the Yerkes system.

While none of these methods of determining absolute magnitude are precise, they indicate that the RV Tauri and related stars are among the most highly luminous stars and that they are comparable with the cepheids of similar spectra and periods of from 20 to 40 days for which Shapley's period-luminosity curve gives photographic absolute magnitudes as bright as −3.0.

Judging by the strength of their ionized lines, many of the stars of group 1 appear to be somewhat more luminous than the brightest cepheids. Absolute photographic magnitudes −3.0 for group 1 and −1.5 for group 2 seem to be reasonable mean values.

Neglecting space absorption, the distances of the stars of group 1, as determined from this value of the absolute magnitude and their median apparent magnitudes, average about 7 kpc. Since only twelve stars of this group are within 10° of the galactic equator, large corrections to their apparent magnitudes on account of interstellar absorption are probably limited to a few stars of the group. Some of the stars, such as BL Aql, SX Her, TT Oph, and UZ Oph are distant 2.5–5 kpc from the galactic plane. With these assumptions, the mean distance of the stars of group 2 is about 4 kpc.

[15] W. S. Adams *et al.*, *Mt. W. Contr.*, No. 511; *Ap. J.*, **81**, 225, 1935.

[16] A. H. Joy, *Pub. A.S.P.*, **46**, 51, 1934.

[17] *A.J.U.S.S.R.*, **11**, 95, 1934.

CONCLUSIONS

As a result of spectroscopic observations it is evident that the semiregular variables with pseudo-periods between 39 and 144 days and spectral types F, G, and K do not form a homogeneous group. In motion, luminosity, and spectral behavior no standard pattern is rigorously followed. The RV Tauri stars, well known to observers of variable stars for their irregular light-changes, are the accepted models for the group, but wide deviations in the behavior and characteristics of the individual stars are present.

On the basis of velocity, of absolute magnitude as determined by the strength of the ionized lines, and of the maximum intensity of the G band (*CH*), the thirty-eight stars observed may be separated into two groups, group 1 having velocities less than 70 km/sec, brighter absolute magnitudes, and greater maximum intensities of the G band. Within these two groups marked differences among the stars are found.

The stars of group 2 evidently belong to the type II population and correspond closely with the semiregular variables of the globular clusters. In luminosity and in radial-velocity variations the members of group 1 are similar to the long-period cepheids, but they are more scattered with reference to the plane of the galaxy and fail to show clearly the effect of galactic rotation. Also, these stars frequently have hydrogen emission and titanium oxide bands which have not been found in the cepheids. The place of the group 1 stars with reference to Baade's population types is not yet clear.

The veiling and absorption effects of titanium and carbon bands must contribute toward dimming the light of the semiregular stars at certain phases. On the other hand, increases in light may be, in part, due to flare effects, which are accompanied by hydrogen emission and a marked diminution in the visibility of the absorption spectrum at times in many of the stars. Such outbursts must be quite different in size and duration from those encountered in the faint dwarfs of extremely low temperatures.