THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 79:481–505, 1992 April

KINEMATICS AND AGE OF RS CANUM VENATICORUM AND BY DRACONIS STARS

ZEKI EKER[1]
Ege University, Faculty of Science, Department of Astronomy, Bornova, Izmir, Turkey
Received 1990 July 20; accepted 1991 August 5

ABSTRACT

Space velocities of 146 chromospherically active binary stars have been calculated. Containing F–M spectral types on the main sequence together with G and K giants and subgiants, this very heterogeneous sample has been divided into groups in order to segregate stars which have similar kinematics and ages. After many trials for different criteria, the sample was divided into five groups: two groups for giants, two groups for main-sequence systems, and one group for main-sequence systems. Kinematics of subgiants implies a stellar age of ~2–3 Gyr. Young and old groups of giants and main-sequence systems could be characterized by a kinematical age of ~1 Gyr and >5 Gyr, respectively. These ages are estimated approximately according to space velocity distributions and dispersions in velocity space in each group. Inferred ages for the groups above agrees with circularization, rotation activity relation, and stellar evolution theories.

Subject headings: binaries: spectroscopic — celestial mechanics, stellar dynamics — stars: chromospheres

1. INTRODUCTION

Chromospheric activity among stars later than F has attracted much attention in recent decades. Enhanced emission cores in the Ca II resonance lines, H and K, and sometimes in the balmer Hα line are the primary indicators of this type of activity and are often accompanied by photometric variability. Accumulation of available data and comparison of common observational properties led Hall (1976) to define the class of RS CVn–type binaries. Soon after, Bopp & Fekel (1977) defined the class of BY Draconis–type stars.

Both group of stars show strong chromospheric activity and large spotted regions. RS CVn binaries can contain dwarf, subgiant, or giant components in the spectral range F–K, whereas the BY Dra stars are always dK or dM and may be single or binary. Recent reviews (Rodonò 1986; Linsky 1984; Charles 1983; Bopp 1983; Catalano 1983, 1986; Hall 1981; Baliunas & Vaughan 1985; Budding & Zeilik 1988) illustrate the various facets of stellar activity that may have some connection with magnetic processes in RS CVn–type and related objects. In order to determine the properties of such systems, many surveys in the northern hemisphere (Fekel, Moffett, & Henry 1986; Hall et al. 1986; Bopp 1984; Bopp et al. 1983; Morris & Mutel 1988; Busso et al. 1988; Budding & Zeilik 1987; Slee et al. 1987; Bopp, Africano, & Quigley 1986) and in the southern hemisphere (Collier, Evans, & Balona 1987; Balona 1987; Lloyd-Evans & Koen 1987; and Hearnshaw 1979) have been undertaken.

On the other hand, since some observational properties are shared between classes, a clear borderline differentiating RS CVn and BY Dra stars from other related systems such as FK Comae, W UMa, classical Algols, and flare stars does not exist. Moreover, as has been noted by Collier (1982), most of the short-period RS CVn systems should be classified as early-type BY Dra systems. Later, Fekel et al. (1986) expanded the definition of BY Dra stars to include F and G dwarfs as well. Strong chromospheric and coronal activity in these stars are generally attributed to the deep convection zone and the fast rotation that drives the dynamo mechanism (Majer et al. 1986; Stewart et al. 1988; Montesinos, Fernandez-Figueroa, & Castro 1987; Gilliland 1985; Baliunas & Vaughan 1985; Budding & Zeilik 1988). Binarity is important because mutual tidal effects between the components produce synchronism and hence drive fast rotation.

For the many reasons discussed above, isolating one class from the others is difficult and many objections can be raised about the question of classification. The recent Catalog of Chromospherically Active Binary Stars by Strassmeier et al. (1988, hereafter CCABS) contains RS CVn and BY Dra stars as well as similar systems not yet formally classified, although it excludes FK Comae stars, W UMa binaries, and classical Algols, which might be fundamentally different.

Popper (1980) made the remark that members within a class generally have a common evolutionary state. There has been much speculation about the evolutionary status of the RS CVn systems. The preponderance of mass ratios close to unity, the cool active component typically being a giant, and the hot component typically being close to the main sequence all appeared difficult to understand. Noting the similar activity and strong chromospheric emission in the T Tauri stars, Hall (1972), Catalano & Rodonò (1967), and Biermann & Hall (1976) claimed pre–main-sequence evolutionary status along with some exotic scenarios. However, indicators of youth such as the presence of lithium and close nebulosity have not been reported. Later, Popper & Ulrich (1977) argued that RS CVn stars have evolved off the main sequence in the same way as single stars, with perhaps mild mass exchange and probably mild mass loss as well. Working with mass ratios and eclipse probabilities, Morgan & Eggleton (1979) also supported the idea. However, the high rate of mass loss ($\sim 2 \times 10^{-9}\ M_\odot\ \mathrm{yr}^{-1}$) reported more recently by Mullan (1982) could not be maintained over the lifetime (~1 Gyr; Popper & Ulrich 1977) of these stars. Moreover, Blair et al. (1981) more recently sug-

[1] Currently at King Saud University, PO Box 2455, Riyadh 11451, Saudi Arabia.

gested that some of the RS CVn systems evolve into the symbiotic stars. Very recently, Demircan (1990) reviewed evolutionary status of RS CVn stars using absolute dimensions of 31 eclipsing binaries with reliable data.

The evolutionary status of the BY Dra stars is not as clearly defined in the literature. Because they are main-sequence dwarfs between spectral type F and M (Fekel et al. 1986), they are generally considered in the younger disk population; the RS CVn systems, on the other hand, have been placed in the old disk population (Eggen 1978). Stronger chromospheric emission in Ca II H and K and in Hα apparently contributes to the idea because emission-line dwarfs (dKe, dMe) have smaller peculiar velocities compared to normal dwarfs (dK, dM). That implies youth, according to the kinematics of Delhaye (1965) and Upgren (1988). Very recently, Soderblom (1990) assigned $\sim$1–2 Gyr kinematical age for BY Dra stars. However, the lack of old BY Dra stars seems puzzling, since these short-period binaries should be able to draw on orbital angular momentum to maintain rapid rotation well into old age.

In this study, the kinematics of chromospherically active binary stars, chosen mostly from CCABS, has been studied. Space velocities of 146 stars with complete kinematical input data (proper motion, radial velocity, and distance) have been recalculated. The sample is divided into subsamples in order to segregate stars with similar kinematical properties. From an intercomparison of these subsamples, kinematical ages of these systems are inferred from their velocity dispersions.

2. THE DATA

U, V, W are the velocity vectors of a star measured with respect to the Sun. Following the notation of Johnson & Soderblom (1987), the right-handed system has been used. Accordingly, the U component is directed toward the Galactic center ($l = 0°$, $b = 0°$); the V is measured in the direction of galactic rotation ($l = 90°$, $b = 0°$); and the W is directed toward the north Galactic pole ($b = 90$). Therefore, the space velocity S is defined as $S = (U^2 + V^2 + W^2)^{1/2}$. In computing the space motions (U, V, W), the method and the transformation matrices given by Johnson & Soderblom (1987) have been applied. The quantities needed for each star are celestial coordinates (α, δ), proper motion components (μ_α, μ_δ), radial velocity (V_r), and the distance from the Sun. These input data have been searched for every star in CCABS plus nine more. Nevertheless, only 146 stars of 177 have sufficient data to compute the space motions. Table 1 lists these stars with their basic input data.

The first column shows the CCABS number, and the second lists the common name for each star. Columns (3) and (4) give Galactic coordinates for equinox 1950 ($\alpha_{NGP} = 12^h\,49^m = 192^\circ\!.25$, $\delta_{NGP} = 27°$ and $\Theta_0 = 123°$ position angle). Columns (5), (6), (7), and (8) present proper motion components and uncertainties in the direction of α and δ, respectively, in arcsec per year. Columns (9) and (10) show the radial velocity of the mass center of the system and its uncertainty. Column (11) gives the distance in parsecs. Columns (12) and (13) display the trigonometric parallax and its uncertainty. Columns (14), (15), and (16) describe components of the distance of a star in rectangular coordinates such that X, Y, Z are measured toward Galactic center, Galactic rotation, and NGP, respectively. The last column indicates references to the source of the basic data. Reference numbers separated by semicolons relate to proper motions, radial velocities, and distances, respectively. If more than one reference number for a quantity is given, that means a weighted mean of this quantity has been entered. The two basic source catalogs for proper motions, SAO and AGK3, cannot be considered independent of each other, so proper motion averages from these two sources are not weighted. All uncertainties are translated to probable errors if they are different from the original reference in order to keep uniformity.

First, the 146 stars in Table 1 are arranged in three groups in order to investigate if the previously assigned classification type introduces any systematic differences in the kinematics. The first group contains RS CVn–type stars; the second group contains BY Dra–type stars; and the third group contains the stars not yet assigned a type and which are henceforth called "active."

A reliable space motion surely depends on accurate knowledge of the proper motion, radial velocity, and distance. Errors in radial velocity are to first order independent of the distance and can be determined relatively accurately. The average probable error in our sample is ± 1.0 km s^{-1}. These relatively close systems also have reliable proper motion measurements. Average probable errors are $\pm 0''\!.007$ yr^{-1} for both the α and δ components of proper motion. Unfortunately, only 48 systems of 146 have trigonometric parallaxes with usefully small errors. Accuracy of the distances of the other systems had to rely on other methods, usually spectroscopic. Since longer distances introduce extra complications to starlight-like interstellar reddening and absorption, uncertainties of the distances of these systems are adopted. For example, if a star is closer than 90 pc, it contains 15%; if it is farther than 200 pc, it contains 35%; and in between these limits, it contains 25% error in its distance.

These uncertainties were adopted because a crude estimate of the distance of a giant or a subgiant by spectroscopic parallax may contain 50% error which corresponds to about ± 1 mag error in the distance modulus. On the other hand, Drake, Simon, & Linsky (1989) adopted 20% error in the distance of RS CVn systems. Majer et al. (1986) estimated nearby systems to have 45% mean error at L_{bol} which means 15% probable error in the distance. Surely, more detailed study of a system may result in more accurate values such as that of Reglero, Gimenez, & Estela (1990) who derive a distance of 130 ± 10 pc for RS CVn from photometry. Also, Strassmeier & Fekel (1990) estimate the positions on the H-R diagram better than $\pm 2\, L_\odot$ for subgiants and giants by spectroscopy which leads to errors in the distance less than 10%. Concerning many qualitative studies on RS CVn and BY Dra stars, adopted uncertainties here should be considered as upper limits; actual probable errors could be smaller.

Propagation of the errors to space velocity components has also been computed by the method of Johnson & Soderblom (1987). The resulting uncertainties are modest (± 5 km s^{-1}) and small enough to be less than the velocity dispersions calculated. Computed space velocity components with respect to the Sun and propagated probable errors are listed in Table 2 together with other physical parameters of the systems which will be discussed later. Since all of the systems are relatively

TABLE 1

SPACE VELOCITY INPUT DATA AND SPACE DISTRIBUTION OF CHROMOSPHERICALLY ACTIVE BINARY STARS

Cat.No	Name	Galactic Coor. (degrees) L	B	Proper Motion (''/yr) Alpha	P.E.	Delta	P.E.	Radial Vel. (km/sec) Vo	P.E.	Dis. (pc)	Parallax ('')	P.E.	X (pc)	Y (pc)	Z (pc)	REFERENCES
	A - STARS DEFINED AS RS CVn TYPE															
1	33 Psc	93.7534	-65.9338	-0.0119	0.001	0.0940	0.001	-6.56	0.23	71			-1.9	28.9	-64.8	(108;64;93)
4	BD Cet	100.8685	-70.8638	0.0030	0.008	-0.0510	0.007	-4.8	0.2	71			-4.4	22.9	-67.1	(108;34;109)
5	13 Cet(A)	112.8854	-66.1473	0.4101	0.001	-0.0210	0.001	10.6	0.27	17.24	0.058	0.005	-2.7	6.4	-15.8	(108;89;79)
7	Zeta And	121.7383	-38.5939	-0.0970	0.004	-0.0770	0.004	-23.71	0.28	31.25	0.032	0.006	-12.8	20.8	-19.5	(108,68;54;79)
8	CF Tuc	302.7847	-42.4758	0.2458	0.008	0.0280	0.008	-0.4	0.81	54			21.6	-33.5	-36.5	(108;34;35)
13	CP-57 296	294.4857	-59.8879	0.0000	0.004	-0.0310	0.004	4	0.94	100			20.8	-45.7	-86.5	(108;34;35)
14	BD-0 210	139.3767	-61.1500	-0.1115	0.007	-0.2475	0.006	-82.8	1.21	60			-22.0	18.8	-52.6	(108,68;19;19)
15	AR Psc	136.5061	-54.6226	0.0966	0.006	0.2335	0.005	18	0.27	70			-29.4	27.9	-57.1	(108,68;42;109)
18	TZ Tri(A)	142.9761	-29.3982	-0.0528	0.004	-0.0720	0.004	-19.09	0.81	75			-52.2	39.3	-36.8	(108,68;63;88)
22	VY Ari	150.5789	-25.3835	0.2187	0.008	-0.1745	0.008	-2.8	0.35	21.74	0.046	0.011	-17.1	9.6	-9.3	(108,68;18;79)
24	LX Per	145.9916	-8.3051	0.0567	0.006	-0.0640	0.005	27.45	0.42	145			-118.9	80.3	-20.9	(108,68;49,102;92)
26	UX Ari	159.5477	-22.9116	0.0350	0.009	-0.1050	0.007	26.5	0.47	50			-43.2	16.1	-19.5	(108,68;28;92)
27	HR1099	184.9097	-41.5670	-0.0135	0.004	-0.1545	0.004	-15	0.2	35.71	0.028	0.005	-26.6	-2.3	-23.7	(108,68;41;79)
28	BD+25 580	163.3949	-23.5714	0.2464	0.008	-0.2795	0.007	-19.4	0.88	55			-48.3	14.4	-22.0	(108,68;29;109)
31	EI Eri	200.1708	-39.3785	0.0208	0.011	0.1310	0.010	17.6	0.27	75			-54.4	-20.0	-47.6	(108;42;42)
38	RZ Eri	208.0029	-33.1555	0.0162	0.012	-0.0060	0.012	37.6	1.41	105			-77.6	-41.3	-57.4	(108;30,102;93)
40	12 Cam	150.9516	10.8313	0.0093	0.005	-0.0300	0.005	0.58	0.3	134			-115.1	63.9	25.2	(108,68;4;88)
42	Alpha Aur	162.5842	4.5690	0.0992	0.004	-0.4270	0.004	29.48	0.05	13.16	0.076	0.004	-12.5	3.9	1.0	(108,68;106;70)
44	TW Lep	224.2455	-24.3233	0.0183	0.009	-0.0100	0.009	18	0.34	220			-143.6	-139.9	-90.6	(108;34;73)
45	BD+3 1007	201.3262	-13.7077	0.0250	0.007	-0.0005	0.006	27.1	0.27	164			-148.4	-57.9	-38.9	(108,68;34;109)
46	CD-28 2525	233.8704	-24.7126	0.0342	0.014	-0.0220	0.014	24	3	85			-45.5	-62.4	-35.5	(108;25;25)
48	CQ Aur	179.9260	4.6178	-0.0075	0.007	-0.0115	0.007	27	2	220			-219.3	0.3	17.7	(108,68;100;92)
51	CP-58 718	268.2798	-25.5631	0.0410	0.004	0.0470	0.004	10.4	0.27	60			-1.6	-54.1	-25.9	(108;34;35)
53	SV Cam	131.5703	26.5224	0.0478	0.007	-0.1475	0.007	-13	1.4	85			-50.5	56.9	38.0	(108,68;72;117)
57	AR Mon	220.3784	4.0981	0.0299	0.007	-0.0090	0.007	11.5	0.6	426			-320.8	-278.6	30.4	(108;99;93)
60	Sigma Gem	191.1867	23.2750	0.0680	0.004	-0.2385	0.004	45.8	0.37	58.82	0.017	0.006	-53.0	-10.5	23.2	(108,68;87;79)
61	54 Cam	160.3276	32.0471	-0.0314	0.004	-0.0605	0.005	24.8	0.7	38.46	0.026	0.016	-30.7	11.0	20.4	(108,68;65;79)
63	GK Hya	222.7025	23.0644	-0.0375	0.007	0.0065	0.007	35	2	220			-148.8	-137.3	86.2	(108,68;100;117)
65	RU Cnc	201.2791	33.1264	-0.0330	0.007	0.0100	0.007	2	2	190			-148.3	-57.7	103.8	(68;100;117)
66	RU Cnc	191.7650	35.6479	0.0058	0.006	-0.0150	0.007	12.2	0.81	395			-314.2	-65.4	230.2	(108,68;99;99)
67	TY Pyx	252.9156	11.8710	-0.0598	0.008	-0.0320	0.008	63.2	0.67	85			-24.4	-79.5	17.5	(108;5;93)
71	IL Hya	253.6868	18.7170	-0.0550	0.012	-0.0440	0.012	-8.5	0.34	263			-70.0	-239.1	84.4	(108;34;93)
72	CP-41 3888	268.7508	7.6083	-0.0861	0.008	0.0040	0.008	48.7	1.08	500			-10.8	-495.5	66.2	(108;34;109)
75	DM UMa	145.3587	51.3232	-0.0394	0.009	0.0005	0.008	-6.9	0.81	130			-66.8	46.2	101.5	(108,68;36;93)
76	Zeta UMa	195.0831	69.2514	-0.4321	0.001	-0.5910	0.001	-15.9	0.15	7.87	0.127	0.006	-2.7	-0.7	7.4	(108;15;79)
78	CD-38 7259	288.0548	21.3963	0.0175	0.007	-0.0360	0.007	7.8	0.6	62			17.9	-54.9	22.6	(108;34;35)
79	HR4492	295.5320	-3.5647	-0.0372	0.005	-0.0120	0.003	8	0.27	140			60.2	-126.1	-8.7	(108;34;35)
80	RW UMa	146.2345	61.8148	-0.0360	0.007	-0.0060	0.007	-21.09	1.49	150			-58.9	39.4	132.2	(68;110,100;117)
81	93 Leo	235.0070	73.9334	-0.1437	0.004	-0.0105	0.004	0.44	0.13	35.71	0.028	0.012	-5.7	-8.1	34.3	(108,68;11;79)
82	BD-8 3301	287.3162	52.6332	-0.0267	0.007	0.0090	0.007	-1.7	0.27	302			54.6	-175.0	240.0	(108;42;109)
83	HR4665	126.6648	44.3169	-0.0165	0.005	-0.0305	0.005	-45.29	0.07	130			-55.5	74.6	90.8	(108,68;22;93)
84	AS Dra	125.8334	43.7176	-0.4567	0.007	0.1750	0.008	-97.1	0.6	31.25	0.032	0.011	-13.2	18.3	21.6	(108,68;55;79)
85	BD+26 2347	226.2962	83.8818	-0.0148	0.007	-0.0135	0.006	-0.4	0.5	86			-6.3	-6.6	85.5	(108,68;81;48)
88	BD-4 3419	309.9586	57.8212	-0.0194	0.007	-0.0140	0.007	19	4	165			56.4	-67.4	139.7	(108;25;25)
89	RS CVn	99.2594	80.2948	-0.0591	0.008	0.0125	0.007	-14	1.35	21.74	0.046	0.013	-0.6	3.6	21.4	(108,68;101;79)
90	BD+39 2635	96.6812	76.6724	-0.0723	0.010	-0.0105	0.008	7.81	0.1	250			-6.7	57.2	243.3	(108,68;58;73)
91	HR5110	83.3261	76.4077	0.0846	0.004	-0.0155	0.004	6.43	0.16	52.63	0.019	0.006	1.4	12.3	51.2	(108,68;61;79)
93	CP-60 4913	309.1889	0.8649	0.0355	0.005	0.0160	0.005	91	0.6	80			50.5	-62.0	1.2	(108;34;35)
94	BH Vir	334.8538	57.0008	-0.0130	0.007	-0.0080	0.007	-28.7	4.5	166			81.8	-38.4	139.2	(68;1;109)
96	CP-59 5631	315.3029	-0.0296	-0.0999	0.005	-0.0400	0.005	16.9	0.54	63			44.8	-44.3	0.0	(108;34;35)
97	RV Lib	335.0994	38.2303	-0.0228	0.014	-0.0290	0.010	-28	2	270			192.4	-89.3	167.1	(108;100;92)
99	BD+26 2685	39.1140	56.2764	0.0208	0.007	-0.0130	0.006	-18.9	0.2	230			99.1	80.6	191.3	(108,68;42;73)
100	GX Lib	356.0202	40.1048	-0.0179	0.008	-0.1190	0.007	61.8	0.2	219			167.1	-11.6	141.1	(108;46;109)

TABLE 1—*Continued*

Cat.No	Name	Galactic Coor. (degrees) L	B	Proper Motion (''/yr) Alpha	P.E.	Delta	P.E.	Radial Vel. (km/sec) Vo	P.E.	Dis. (pc)	Parallax ('')	P.E.	X (pc)	Y (pc)	Z (pc)	REFERENCES
101 -	CP-62 4482	319.6261	-5.3328	-0.0678	0.005	-0.0590	0.005	-8.6	0.81	54			41.0	-34.8	-5.0	(108;34;35)
103 -	RT CrB	46.6762	53.4456	0.0150	0.007	0.0050	0.007	-3	2	360			147.1	156.0	289.2	(68;100;117)
107 -	Sigma CrB	54.6686	46.1376	-0.2749	0.001	-0.0800	0.001	-11.94	0.43	21.28	0.047	0.006	8.5	12.0	15.3	(108;111,6;79)
109 -	WW Dra	90.8600	39.4539	0.0168	0.007	-0.0615	0.005	-29	1.35	180			-2.1	139.0	114.4	(108,68;102;93)
110 -	Epsilon UMi	114.9964	31.0487	0.0073	0.004	0.0060	0.004	-10.57	0.27	71.43			-25.9	55.5	36.8	(108,68;33;79)
111 -	V792 Her	75.4075	36.3859	-0.0059	0.013	-0.0250	0.008	12.8	0.2	75			15.2	58.4	44.5	(108,68;42;93)
112 -	V824 Ara	324.9009	-16.2967	-0.0112	0.007	-0.1340	0.005	2.31	0.28	30			23.6	-16.6	-8.4	(108;14;35)
113 -	HR6469	64.6888	33.5834	0.0122	0.005	-0.0675	0.004	-2.8	0.05	50	0.020	0.006	17.8	37.7	27.7	(108,68;42;79)
114 -	CD-33 12122	354.2937	0.1923	-0.0087	0.014	0.0170	0.014	-25.3	0.94	400			398.0	-39.8	1.3	(108;85;85)
115 -	29 Dra	105.4921	31.3528	-0.0688	0.005	0.0365	0.004	-11	2	87.9			-20.1	72.3	45.7	(108,68;42;44)
117 -	Z Her	40.8678	18.4909	-0.0276	0.007	0.0775	0.007	-45.95	0.25	85			61.0	52.7	27.0	(108,68;101;117)
118 -	MM Her	47.7804	21.1073	0.0015	0.005	-0.0340	0.005	-51.5	0.67	190			119.1	131.3	68.4	(108,68;102;92)
119 -	V772 Her	47.7575	19.2978	-0.0350	0.006	-0.0580	0.006	-22.82	0.13	41.67	0.024	0.001	26.4	29.1	13.8	(108,68;12;12)
122 -	V815 Her	56.1834	21.7560	0.1145	0.007	-0.0275	0.006	-13.4	0.54	31			16.0	23.9	11.5	(108,68;94;73)
125 -	AW Her	46.6749	13.7705	-0.0170	0.007	0.0000	0.007	-43	2	315			209.9	222.6	75.0	(68;100;117)
127 -	o Dra	89.3066	23.1363	0.0693	0.004	0.0290	0.004	-19.53	0.21	67			0.7	61.6	26.3	(108,68;121;73)
131 -	V478 Lyr	61.8502	10.1244	0.1121	0.007	0.1110	0.006	-20.2	0.1	26			12.1	22.6	4.6	(108,68;42;73)
132 -	HR7275	82.9813	18.7344	-0.1117	0.006	-0.0570	0.005	5.18	0.25	48			5.6	45.1	15.4	(108,68;123;93)
134 -	BD-20 5516	17.5096	-15.8961	-0.0028	0.005	-0.0940	0.007	-13.4	0.2	31			28.4	9.0	-8.5	(108;34;35)
136 -	HR7428	87.5128	16.8741	-0.0094	0.006	-0.0120	0.005	-5.2	2	302			12.5	288.7	87.7	(108,68;103;31)
137 -	V1764 Cyg	62.6803	3.3752	0.0058	0.007	-0.0145	0.006	-22.30	0.20	340			155.8	301.6	20.0	(108,68;23,42;73)
140 -	V4091 Sgr	23.6123	-24.5716	0.0256	0.014	-0.0090	0.010	-29.9	0.27	340			283.3	123.9	-141.4	(108;34;109)
141 -	BD-21 5735	23.2942	-30.6104	0.0280	0.014	-0.0140	0.010	-21.9	0.54	99			78.3	33.7	-50.4	(108;34;93)
144 -	ER Vul	73.3412	-12.3050	0.0937	0.007	0.0100	0.006	-25.06	0.52	45			12.6	42.1	-9.6	(108,68;96,91;117)
149 -	BD-14 6070	39.2555	-42.1283	0.0160	0.005	0.0080	0.005	-27	0.34	93			53.4	43.6	-62.4	(108;34;73)
151 -	42 Cap	39.5589	-43.9690	-0.1221	0.002	-0.3040	0.002	-1.3	0.27	34.48	0.029	0.007	19.1	15.8	-23.9	(108;3;79)
	Delta Cap	37.6042	-46.0085	0.2620	0.001	-0.2940	0.001	-0.2	0.47	15.38	0.065	0.006	8.5	6.5	-11.1	(108;9;9)
153 -	RT Lac	93.4060	-9.0264	0.0570	0.013	0.0265	0.009	-53.6	0.54	43.48	0.023	0.008	-2.6	42.9	-6.8	(108,68;75;79)
154 -	HK Lac	95.9221	-6.7173	0.0627	0.006	0.0405	0.005	-23.6	0.2	150			-15.4	148.2	-17.5	(108,68;53;117)
155 -	AR Lac	95.5573	-8.3024	-0.0377	0.006	0.0500	0.006	-33.19	1.86	40			-3.8	39.4	-5.8	(108,68;118,104;118)
157 -	V350 Lac	100.6135	-7.2922	-0.0278	0.009	-0.0365	0.009	5.356	0.21	69			-12.6	67.3	-8.8	(108,68;95;93)
159 -	IM Peg	86.3646	-37.4841	-0.0236	0.005	-0.0285	0.005	-12.84	0.34	50			2.5	39.6	-30.4	(108,68;62;88)
163 -	RT And	108.0579	-6.9252	-0.0020	0.007	-0.0070	0.007	20	3	95			-29.2	89.7	-11.5	(68;97;117)
164 -	SZ Psc	80.6662	-51.9638	-0.0030	0.006	0.0410	0.005	11.34	0.67	100			10.0	60.8	-78.8	(108;78,102;93)
165 -	EZ Peg	97.5864	-32.4574	-0.0704	0.001	0.0088	0.000	-27.24	0.12	83.33	0.012	0.002	-9.3	69.7	-44.7	(108,68,113;57;113)
166 -	Lamda And	109.9027	-14.5305	0.1550	0.004	-0.4140	0.004	6.84	0.12	23.26	0.043	0.006	-7.7	21.2	-5.8	(108,68;116;79)
167 -	BD+27 4588	104.2241	-32.0011	0.3079	0.008	0.2380	0.007	-2.05	0.4	25			-5.2	20.6	-13.2	(108,68;76;109)
168 -	II Peg	108.2246	-32.6225	0.5874	0.007	0.0395	0.006	-18.1	0.6	29.41	0.034	0.005	-7.7	23.5	-15.9	(108,68;114;79)
	B - BY DRACONIS STARS															
6 -	FF And	120.9524	-27.2912	0.2500	0.007	0.9000	0.007	-0.47	0.6	23.81	0.042	0.005	-10.9	18.1	-10.9	(51;21;51)
20 -	CC Eri	258.4740	-63.4168	0.0572	0.014	-0.3010	0.014	41.94	1.5	13.16	0.076	0.013	-1.2	-5.8	-11.8	(108;39;79)
36 -	V833 Tau	172.5131	-13.3589	0.2225	0.001	-0.1374	0.001	35.3	5	16.75	0.060	0.004	-16.2	2.1	-3.9	(108,68,24;66;24)
50 -	OU Gem	193.4090	3.0923	-0.1236	0.006	-0.1790	0.007	-8.4	0.1	12.35	0.081	0.012	-12.0	-2.9	0.7	(108,68;59;79)
58 -	YY Gem	187.4623	22.4814	-0.2030	0.005	-0.1100	0.006	7.82	1.69	13.70	0.073	0.002	-12.6	-1.6	5.2	(108,68;17;82)
70 -	BD+40 2197	182.0397	45.2777	-0.3489	0.007	-0.3725	0.007	-3.2	1.16	28.57	0.035	0.005	-20.1	-0.7	20.3	(108,68;8;79)
73 -	DH Leo	206.8651	51.5333	-0.2345	0.007	-0.0430	0.007	14.94	0.21	32.26	0.031	0.006	-17.9	-9.1	25.3	(108,68;7,16;79)
74 -	BD-11 2916	258.4081	38.9841	0.1352	0.011	-0.2550	0.009	1.2	0.1	34.48	0.029	0.012	-5.4	-26.3	21.7	(108;42;79)
106 -	BD+25 3003	41.8053	48.2558	-0.0757	0.007	-0.1240	0.006	-4.45	0.09	30			14.9	13.3	22.4	(108,68;56;56)
108 -	CM Dra	86.5462	40.9067	-1.1110	0.001	1.1752	0.001	-118.6	0.54	14.49	0.069	0.005	0.7	10.9	9.5	(51,24;83;83)
126 -	BY Dra	80.5603	23.5827	0.1816	0.007	-0.3170	0.005	-25.35	0.09	15.63	0.064	0.008	2.3	14.1	6.3	(108,68;86;115)
129 -	V775 Her	54.5849	9.5815	0.1273	0.005	-0.2865	0.005	10.31	0.04	24.39	0.041	0.005	13.9	19.6	4.1	(108,68;77;79)
139 -	HR7578	17.1795	-23.9125	-0.1329	0.003	-0.4120	0.003	-5.1	0.13	14.93	0.067	0.007	13.0	4.0	-6.0	(108;43;79)

TABLE 1—*Continued*

Cat.No	Name	Galactic Coor. (degrees) L	B	Proper Motion (''/yr) Alpha	P.E.	Delta	P.E.	Radial Vel. (km/sec) Vo	P.E.	Dis. (pc)	Parallax ('')	P.E.	X (pc)	Y (pc)	Z (pc)	REFERENCES
143 -	V1396 Cyg	82.4362	-3.9495	0.6200	0.007	-0.2600	0.007	-30.7	0.4	17.24	0.058	0.003	2.3	17.1	-1.2	(51;45;84)
148 -	BD-0 4234	54.2199	-34.9256	0.4240	0.017	0.0015	0.017	-109.6	0.4	50	0.020	0.008	24.0	33.3	-28.8	(108,68;98;98)
158 -	FK Aqr	37.8182	-59.0676	0.4555	0.014	-0.0560	0.010	-8.7	0.46	7.7			3.1	2.4	-6.6	(108;71;71)
162 -	KZ And	105.9020	-11.5289	0.1532	0.006	0.0050	0.008	-6.85	0.4	23			-6.2	21.7	-4.8	(108,68;20;109)
C -	ACTIVE BINARIES															
2 -	BD+45 4408	114.6384	-16.3180	0.8773	0.007	-0.1270	0.006	-9	10	11.11	0.090	0.005	-4.4	9.7	-3.1	(108;2;79)
3 -	5 Cet	98.3442	-63.2365	0.0060	0.002	-0.0040	0.002	1.11	1.33	140			-9.1	62.4	-125.0	(108;32;73)
9 -	Eta And	124.6464	-39.4342	-0.0357	0.004	-0.0385	0.004	-10.33	0.68	111.11	0.009	0.005	-48.8	70.6	-70.6	(108,68;52;74)
10 -	BD+25 161	126.4459	-36.1979	-0.0122	0.007	-0.0145	0.006	-20	10	55			-26.4	35.7	-32.5	(108,68;67;109)
11 -	AY Cet	137.7486	-64.6444	-0.1079	0.002	-0.0590	0.002	-30.32	0.08	66.67	0.015	0.005	-21.1	19.2	-60.2	(108;107,42;74)
16 -	CD-24 751	201.9642	-77.1655	0.1709	0.012	0.0860	0.012	3.4	0.34	100			-20.6	-8.3	-97.5	(108;34;109)
17 -	BD+34 363	139.1067	-24.9973	-0.0581	0.008	-0.0130	0.007	-27.4	0.67	77			-52.8	45.7	-32.5	(108,68;42;73)
21 -	CD-38 899	244.7192	-64.1763	0.1003	0.005	-0.0770	0.005	19.3	0.47	35			-6.5	-13.8	-31.5	(108;34;109)
23 -	BD-05 592	185.9639	-50.3929	0.0194	0.006	0.0160	0.006	13.7	0.4	146			-92.6	-9.7	-112.5	(108;34;109)
29 -	V471 Tau	172.4795	-27.9387	0.1020	0.001	-0.0081	0.000	37.78	0.75	58.82	0.017	0.002	-51.5	6.8	-27.6	(24,113;120,119;113)
30 -	CP-52 497	261.7780	-45.8005	0.1463	0.005	-0.2190	0.005	70.2	0.47	32			-3.2	-22.1	-22.9	(108;34;109)
33 -	BD+16 577	177.6204	-23.3561	0.1061	0.006	-0.0215	0.006	37.1	0.2	44.44	0.023	0.001	-40.8	1.7	-17.6	(108,68;90;38)
34 -	BD+17 703	176.6091	-22.4320	0.1171	0.006	-0.0375	0.006	38	0.2	46.51	0.022	0.001	-42.9	2.5	-17.7	(108,68;10;38)
35 -	BD+36 903	164.4995	-7.7564	0.0053	0.006	-0.0655	0.005	5.8	0.27	50			-47.7	13.2	-6.7	(108,68;42;73)
37 -	3 Cam	153.3211	4.2613	0.0040	0.005	-0.0080	0.004	-40.47	0.81	85			-75.7	38.1	6.3	(108,68;27;73)
39 -	BD+24 692	176.1788	-12.6754	0.0956	0.006	-0.0555	0.006	41.1	0.24	42.02	0.024	0.001	-40.9	2.7	-9.2	(108,68;60;38)
41 -	CP-77 196	289.2953	-31.9157	-0.0274	0.008	0.0100	0.008	-2.8	0.54	82			23.0	-65.7	-43.4	(108;34;73)
43 -	HR1908	194.3339	-11.0237	0.0591	0.007	-0.0060	0.006	-119	4	160			-152.2	-38.9	-30.6	(108,68;13;73)
49 -	CP-54 973	262.6546	-27.9415	-0.0070	0.009	0.0150	0.007	49	0.27	110			-12.4	-96.4	-51.5	(108;34;73)
55 -	Gl 268	178.9430	19.9155	-0.4696	0.007	-0.9500	0.007	37.9	0.34	5.92	0.169	0.007	-5.6	0.1	2.0	(51;112;79)
59 -	CD-44 3573	257.8220	-11.5301	-0.0457	0.008	-0.0130	0.009	1.6	0.34	190			-39.3	-182.0	-38.0	(108;34;109)
62 -	BD-06 2585	230.6686	17.1278	-0.1057	0.008	-0.0290	0.008	27.8	0.27	95			-57.5	-70.2	28.0	(108;34;109)
64 -	HR3385	254.8179	3.1401	-0.0148	0.007	-0.0010	0.007	8.9	0.4	135			-35.3	-130.1	7.4	(108;34;109)
86 -	BD+25 2511	239.7685	84.4535	-0.0291	0.007	-0.0280	0.006	0	10	55			-2.7	-4.6	54.7	(108,68;37;109)
92 -	CD-32 9477	313.5289	28.4711	-0.0063	0.014	-0.0140	0.014	9.2	0.2	760			460.1	-484.4	362.3	(108;34;109)
95 -	4 UMi	117.6722	38.7796	-0.0311	0.004	0.0290	0.004	5.97	0.07	100			-36.2	69.0	62.6	(108,68;105,122;74)
120 -	ADS11060C	47.7575	19.2978	-0.0350	0.006	-0.0580	0.006	-22.8	0.13	41.67	0.024	0.001	26.4	29.1	13.8	(108,68;12;12)
121 -	CD-48 12280	345.0610	-13.0610	0.0150	0.011	0.0510	0.008	5	0.4	170			160.0	-42.7	-38.4	(108;34;73)
128 -	nu Sgr	12.9054	-10.8899	0.1024	0.002	-0.0260	0.002	-107	3	29.41	0.034	0.010	28.2	6.5	-5.6	(108;28;79)
130 -	Tau Sgr	9.3378	-15.3680	-0.0531	0.001	-0.2490	0.001	44.7	4	26.32	0.038	0.009	25.0	4.1	-7.0	(108;80;79)
133 -	HR7333	31.3934	-8.9310	0.1120	0.002	0.0480	0.002	-18	0.19	37.04	0.027	0.005	31.2	19.1	-5.7	(108;50;79)
135 -	CP-41 9096	357.7278	-23.9156	0.0329	0.008	-0.0070	0.008	-39.3	0.27	417			380.9	-15.1	-169.0	(108;34;109)
138 -	BD-6 5221	32.9713	-13.4710	0.0149	0.008	-0.0200	0.008	-21.4	0.2	209			170.5	110.6	-48.7	(108;42;109)
145 -	CD-31 18145	14.4101	-43.0111	-0.0884	0.014	-0.0910	0.014	49.1	1	265			187.7	48.2	-180.8	(108;34;109)
146 -	BD+10 4514	62.5469	-25.5096	0.0021	0.007	-0.0490	0.006	5.91	1.15	43.10	0.023	0.001	17.9	34.5	-18.6	(108,68;40;69)
156 -	BD+29 4645	88.5588	-22.3995	-0.0146	0.007	-0.0025	0.006	20	9	80			1.9	73.9	-30.5	(108,68;67;109)
160 -	BD-1 4364	73.0344	-51.9335	0.0500	0.008	0.0280	0.010	-21.6	3	260			46.8	153.3	-204.7	(108,68;47;73)
161 -	CD-34 15853	10.6301	-65.2665	-0.0435	0.014	-0.1320	0.014	31.5	3.7	46			18.9	3.6	-41.8	(108;34;73)

NOTE.—See text for the errors of distances which do not have parallax measurement.

REFERENCES TO TABLE 1

1 Abt,H.A.(1965) Publ.Astron.Soc.Pacific,77,367.
2 Abt,H.A.(1970) Astrophys.J.Suppl.,19,387.
3 Abt,H.A.,and Levy,S.G.(1976) Astrophys.J.Suppl.,30,273.
4 Abt,H.A.,Dukes,R.J.,and Weaver.W.B.(1969) Astrophys.J.,157,717.
5 Andersen,J.,and Popper,D.M.(1975) Astron.Astrophys.,39,131.
6 Bakos,G.A.(1984) Astron.J.,89,1741.
7 Barden,S.C.(1984) Astron.J.,89,683.
8 Barden,S.C.,and Nations,H.L.(1986) in Cool Stars Stellar Systems, and the Sun,ed.M.Zeilik and D.M.Gibson(Springer)P.262.
9 Batten,A.H.(1961) Publ.Dom.Ap.Obs.,11,395.
10 Batten,A.H.,and Wallerstein,G.(1973) Publ.Dom.Ap.Obs.,14,135.
11 Batten,A.H.,Fisher,W.A.,Fletcher,A.M.,and Hill,G.(1983) Publ.Astron.Soc.Pacific,95,768.
12 Batten,A.H.,Morbey,C.L.,Fekel,F.C.,and Tomkin,J.(1979) Publ.Astron.Soc.Pacific,91,304.
13 Beavers,W.I.,and Eitter,J.J.(1986) Astrophys.J.Suppl.,62,147.
14 Bennett,W.W.,Evans,D.S.,and Laing,J.D.(1962) Royal.Obs.Bull,No.61.
15 Berman,L.(1931) Lick Obs.Bull.,15,109.
16 Bolton,C.T.,Aslan,Z.,Kamper,K.W.,and Lyons,R.W.(1981) Astron.J.,86,1267.
17 Bopp,B.W.(1974) Astrophys.J.,193,389.
18 Bopp,B.W.(1987) private Communications
19 Bopp,B.W.,Ake,T.B.,Goodrich,B.D.,Africano,J.L.,Noah,P.V.,Meredith,R.J.,Palmer,L.H.,and Quigley,R.(1985) Astrophys.J.,297,691.
20 Bopp,B.W.,and Fekel,F.C.(1975) Publ.Astron.Soc.Pacific,87,891.
21 Bopp,B.W.,and Fekel,F.C.(1977) Publ.Astron.Soc.Pacific,89,65.
22 Bopp,B.W.,Fekel,F.C.,Griffin,R.F.,Beavers,W.I.,Gunn,J.E.,and Edwards,D.(1979) Astron.J.,84,1763.
23 Bopp,B.W.,Fekel,F.C.,Hall,D.S.,Henry,G.W.,Noah,P.V.,Africano,J.,Wilkerson,M.S.,and Beavers,W.I.(1982) Astron.J.,87,1035.
24 Borgman,E.R.,and Lippincott,S.L.(1983) Astron.J.,88,120.
25 Buckley,D.A.J.,Tuohy,I.R.,Remillard,R.A.,Bradth,H.V.,and Schwartz,D.A.(1987) Astrophys.J.,315,273.
26 Campbell,W.W.,and Moore,J.A.(1928) Publ.Lick Obs.,16,276.
27 Cannon,J.B.(1918) Publ.Dom.Ap.Obs.,4,175.
28 Carlos,R.C.,and Popper,D.M.(1971) Publ.Asron.Soc.Pacific,83,504.
29 Carquillat,J.M.,Nadal,R.,Ginested,N.,and Pedoussaut,A.(1979) Astron.Astrophys.,74,113.
30 Cesco,C.U.,and Sahade,J.(1945) Astrophys.J.,101,370.
31 Charles,P.A.(1983) in IAU Colloq.71,Activity in Red Dwarf Stars,ed.M.Rodono and P.Byrne(Dordrecht:Reidel)p.415.
32 Christie,W.H.(1933) Astrophys.J.,77,310.
33 Climenhaga,J.L.,McKellar,A.,and Petrie,R.M.(1951) Dom.Ap.Obs.Vic.,8,401.
34 Collier,A.C.(1987) private communications.
35 Collier,A.C.,Haynes,R.F.,Slee,O.B.,Wright,A.E.,and Hillier,D.J.(1982) M.N.R.A.S.,200,869.
36 Crampton,D.,Dobias,J.,and Margan,B.(1979) Astrophys.J.,234,993.
37 Eggen,O.J.(1978) Inf.Bull.Var.Stars,No.1426.
38 Eggen,O.J.(1984) Astron.J.,89,1358.
39 Evans,D.S.(1959) M.N.R.A.S.,119,526.
40 Fekel,F.C.(1981) Astrophys.J.,248,670.
41 Fekel,F.C.(1983) Astrophys.J.,268,274.
42 Fekel,F.C.(1988) private communications.
43 Fekel,F.C.,and Beavers,W.F.(1983) Astrophys.J.,267,682.
44 Fekel,F.C.,and Simon,T.(1985) Astron.J.,90,812.
45 Fekel,F.C.,Bopp,B.W.,and Lacy,C.H.(1978) Astron.J.,83,1445.
46 Fekel,F.C.,Hall,D.S.,Africano,J.L.,Gillies,K.,Quigley,R.,and Fried,R.E.(1985) Astron.J.,90,2581.
47 Fekel,F.C.,Moffett,T.J.,and Henry,G.W.(1986) Astrophys.J.Suppl.,60,551.
48 Fernandez-Figueroa,M.J.,Montesinos,B.,de Castro,E.,Rego,M.,Gimenez,A.,and Reglero,V.(1986) Astron.Astrophys.,169,219.
49 FitzGerald,M.P.(1974) J.R.A.S.Can.,68,23.
50 Franklin,K.L.(1952) Astrophys.J.,116,383.
51 Gliese,W.(1969) Catalog of Nearby Stars,Veroff des ARI-Heidelberg Nr.22(Karlsruhe:Braun).
52 Gordon,K.C.(1946) Astrophys.J.,103,13.
53 Gorza,W.L.,and Heard,J.F.(1971) Publ.David Dunlap Obs.,3,no:4.
54 Gratton,L.(1950) Astrophys.J.,111,31.
55 Greenstein,J.L.,Hack,M.,and Struve,O.(1957) Astrophys.J.,126,281.
56 Griffin,R.F.(1978) Observatory,98,257.
57 Griffin,R.F.(1985) Observatory,105,81.
58 Griffin,R.F.(1987) private communications.
59 Griffin,R.F.,and Emerson,B.(1975) Observatory,95,23.
60 Griffin,R.F.,and Gunn,J.E.(1978) Astron.J.,83,1114.
61 Harper,W.A.(1953) Astrophys.J.,118,262.
62 Harper,W.E.(1920) Publ.Dom.Ap.Obs.,1,203.
63 Harper,W.E.(1921) Publ.Dom.Ap.Obs.,2,179.
64 Harper,W.E.(1926) Publ.Dom.Ap.Obs.,3,341.

65 Harper,W.E.(1949) Publ.Dom.Ap.Obs.,7,149.
66 Hartmann,L.,Bopp,B.W.,Dussault,M.,Noah,P.V.,and Klimke,A.(1981) Astrophys.J.,249,662.
67 Heard,J.F.(1956) Publ.David Dunlap Obs.,2,107.
68 Heckmann,O.,Dieckvoss,W.(ed),Kox,H.,Guenther,A.,and Brosterhus,E.(1975) AGK 3,Vol.1-8,(Hamburg-Bergedorf).
69 Heintz,W.D.(1969) Astron.Astrophys.,2,169.
70 Heintz,W.D.(1975) Astrophys.J.,195,411.
71 Herbig,G.H.,and Moorhead,J.M.(1965) Astrophys.J.,141,649.
72 Hiltner,W.A.(1953) Asrophys.J.,118,262.
73 Hirshfeld,A.,and Sinnott,R.W.(1982) Sky Catalog 2000,Vol.1.
74 Hoffleit,D.1982,The Bright Star Catalog(4th ed.;New Haven:Yale University Press).
75 Huenemoerder,D.P.,and Barden,S.C.(1986) Astron.J.,91,583.
76 Imbert,M.(1969) Astron.Astrophys.,3,272.
77 Imbert,M.(1979) Astron.Astrophys.Suppl.,38,401.
78 Jakate,S.,Bakos,G.A.,Fernie,J.D.,and Heard,J.F.(1976) Astron.J.,81,250.
79 Jenkins,L.F.(1963) in General Catslogue of Trigonometric Parallaxes,Yale Uni.Obs.
80 Jones,H.S.(1928) Ann.Cape.Obs.,10,no:8,p120
81 Kraft,R.P.(1965) Astrophys.J.,142,681.
82 Kron,G.E.(1952) Astrophys,J.,115,301.
83 Lacy,C.H.(1977) Astrophys.J.,218,444.
84 Lippincott,S.L.(1975) Astron.J.,80,831.
85 Lloyd-Evans,T.,Balona,L.A.,And Fekel,F.C.(1987) M.N.R.A.S.,226,813.
86 Luck,P.B.,and Mayor,M.(1980) Astron.Astrophys.,92,182.
87 Luyten,W.J.(1936) Astrophys.J.,84,85.
88 Majer,P.,Schmith,J.H.M.M.,Golub,L.,Harnden,F.R.,and Rosner,R.(1986) Astrophys,J.,300,360.
89 Mayor,M.,and Mazeh,T.(1987) Astron.Astrophys.,171,157.
90 McClure,R.(1982) Astrophys.J.,254,606.
91 McLean,B.J.(1982) M.N.R.A.S.,201,421.
92 Montle,R.E.(1973) Masters Thesis,Vanderbilt Univ.Nashville,TN,p.36.
93 Mutel,R.L.,and Lestrade,J.F.(1985) Astron.J.,90,493.
94 Nadal,R.,Pedoussaut,A.,Ginested,N.,and Carquillat,M.(1974) Astron.Astrophys.,37,191.
95 Northcott,R.J.(1947) Publ.David Dunlap Obs.,1,369.
96 Northcott,R.J.,and Bakos,G.A.(1967) Astron.J.,72,89.
97 Payne-Gaposchkin,C.(1946) Astrophys,J.,103,291.
98 Petterson,R.C.,Willmarth,D.W.,Carney,B.W.,and Chaffee,F.H.Jr.(1980) Astrophys.J.,239,948.
99 Popper,D.M.(1976) Astrophys.J.,208,142.
100 Popper,D.M.(1987) private communications
101 Popper,D.M.(1988) Astron.J.,95,1242.
102 Popper,D.M.(1988) Astron.J.,96,1040.
103 Sanford,R.F.(1925) Astrophys.J.,61,326.
104 Sanford,R.F.(1951) Astrophys.J.,113,299.
105 Scarfe,C.D.(1971) Publ.Astron.Soc.Pacific,83,807.
106 Shen,L.Z.,Beavers,W.I.,Eitter,J.J.,and Salzer,J.J.(1985) Astron.J.,90,1502.
107 Simon,T.,Fekel,F.C.,and Gibson,D.M.(1985) Astrophys.J.,295,153.
108 Smithsonian Astrophysical Observatory Star Catalog,(Washington: Smitsonian Institute),1966.
109 Strassmeier,K.G.,Hall,D.S.,Zeilik,M.,Nelson,E.,Eker,Z.,and Fekel,F.C.(1988) Astron.Astrophys.Suppl.,72,291.
110 Struve,O.(1945) Astrophys.J.,102,74.
111 Tanner,R.W.(1949) Publ.David Dunlap Obs.,1,471.
112 Tomkin,J.,and Pettersen,B.R.(1986) Astron.J.,92,1424.
113 Vilkki,E.U.,Welty,D.E.,and Cudworth,K.M.(1986) Astron.J.,92,869.
114 Vogt,S.S.(1981) Astrophys.J.,247,975.
115 Vogt,S.S.,and Fekel,F.C.(1979) Astrophys.J.,234,458.
116 Walker,E.C.(1944) J.R.A.S.Can.,38,249.
117 Walter,F.M.,Cash,W.,Charles,P.A.,and Bowyer,C.S.(1980) Astrophys.J.,236,212.
118 Walter,F.M.,Neff,J.E.,Gibson,D.M.,Linsky,J.L.,Rodono,M.,Gary,D.E.,and Butler,C.J.(1987) Astron.Astropys.,186,241.
119 Young,A.(1976) Astrophys.J.,205,182.
120 Young,A.,and Nelson,B.(1972) Astrophys.J.,173,653.
121 Young,R.K.(1920) Publ.Dom.Ap.Obs.,1,263.
122 Young,R.K.(1927) Publ.Dom.Ap.Obs.,4,27.
123 Young,R.K.(1944) J.R.A.S.Can.,38,366.

TABLE 2

SPACE VELOCITIES WITH RESPECT TO THE SUN AND SOME PHYSICAL PARAMETERS

No	Cat.No	Name		U	p.e.	V	p.e.	W	p.e.	Specral type		Period (days)	e	Mc/Mh ($M_\odot$)	Mc ($M_\odot$)	f(M) ($M_\odot$)	Rc/Rh ($R_\odot$)
		SYSTEMS CONTAINING WHITE DWARF															
1	115 -	29 Dra	+	-15.0	3.0	-27.1	3.4	16.1	3.8	WD/K0-2III	SB1	39		/0.5			>5/0.012
2	11 -	AY Cet	x	45.9	12.3	-2.9	2.0	16.3	3.7	WD/G5III	SB1	56.82	0.04	2.09/0.55			6.8/0.012
3	29 -	V471 Tau	x	-44.7	1.7	-15.8	2.8	-1.4	2.2	WD/K2V	SB1	0.52	0.0	0.8:/0.6			>0.6/0.012
4	121 -	CD-48 12280	x	18.3	3.9	38.2	12.2	6.4	8.3	WD/G8III	SB1	>600					
		GIANTS (high velocity)															
5	1 -	33 Psc	+	-12.5	1.8	24.2	4.0	18.3	1.9	K0III	SB1	72.93	0.27			0.03	13 *
6	7 -	Zeta And	+	25.3	3.1	-13.9	0.6	6.1	1.7	K1II	SB1	17.77	0.0	0.6473	2.7	0.033	12.6/0.7
7	45 -	BD+3 1007	+	-23.2	2.1	-19.5	5.5	9.8	6.6	F:/K1III	SB1	53.58	0.03			0.09	>11
8	60 -	Sigma Gem	+	-29.3	4.2	-75.9	24.0	14.1	1.8	K1III	SB1	19.60	0.0			0.0814	14.7 *
9	71 -	IL Hya	+	-5.6	15.3	-17.2	10.8	-85.7	32.3	K1III	SB1	12.91	0.05			0.073	>6
10	72 -	CP-41 3888	+	-146.8	58.6	-61.9	5.6	-122.1	48.9	K2IIIp	SB1	52.27	0.13			0.048	14.4 *
11	90 -	BD+39 2635	+	-62.6	24.1	-58.4	23.5	20.1	5.0	K1III	SB1	20.27	0.0			0.035	>6
12	99 -	BD+26 2685	+	11.9	10.0	-1.3	7.1	-29.6	6.5	K1III	SB1	18.67	0.066			0.02	>16
13	100 -	GX Lib	+	87.5	15.0	-108.3	37.3	-16.2	20.6	[G-KV]/K1III	SB1	11.13	0.0			0.066	>7
14	127 -	o Dra	+	-16.3	2.5	-10.4	1.2	-25.0	2.8	G9III	SB1	138.42	0.114			0.183	11.3 *
15	132 -	HR7275	+	19.7	3.3	-3.8	1.4	19.8	3.0	K1IV-III	SB1	28.59	0.04			0.194	>8
16	136 -	HR7428	+	13.7	10.7	-7.5	3.2	3.5	8.0	A0V/K2III-II	SB1	108.57	0.05			0.121	30 *
17	137 -	V1764 Cyg	+	-3.2	10.4	-26.8	5.3	-20.9	13.0	K1III	SB1	40.14	0.0			0.29	>22
18	140 -	V4091 Sgr	+	-45.5	13.1	-17.6	15.5	-27.3	23.7	K0III	SB1	16.89	0.04			0.045	>6
19	149 -	BD-14 6070	+	-23.1	2.3	-10.3	2.0	14.5	1.8	K1III	SB1	49.14	0.08			0.05	>13
20	159 -	IM Peg	+	6.6	1.7	-12.3	0.8	5.8	1.0	K2III-II	SB1	24.65	0.0			0.0937	>12
21	43 -	HR1908	x	114.1	4.1	1.8	8.4	58.2	10.1	K4III	SB1						25.2 *
22	49 -	CP-54 973	x	-11.2	4.0	-40.7	2.3	-25.1	4.1	F/G8-K0III	SB1	106.78	0.309			0.265	6 *
23	59 -	CD-44 3573	x	-2.3	7.8	8.7	3.3	-41.4	12.6	K1III	SB1	11.76	0.01			0.066	12.7 *
24	92 -	CD-32 9477	x	9.2	40.8	-45.8	41.6	-35.2	47.1	K2IIIp	SB1	22.74	0.0			0.0075	14.4 *
25	128 -	nu Sgr	x	-105.9	3.0	-21.5	1.0	6.0	4.2	K3III	SB1						6.5 *
26	130 -	Tau Sgr	x	45.9	3.9	-24.1	7.4	-17.8	1.8	K1III	SB1						9.6 *
27	135 -	CP-41 9096	x	-62.2	11.4	5.6	16.1	-44.7	25.8	K2-3III	SB1	45.18	0.0			0.17	16.5 *
28	145 -	CD-31 18145	x	125.9	34.7	-103.9	42.9	32.5	26.5	K1IIIp	SB1	63.09	0.521			0.013	12.7 *
29	160 -	BD-1 4364	x	-77.2	26.5	-5.4	10.3	6.8	8.2	K0III	SB1						13.8 *
30	18 -	TZ Tri(A)	+	29.5	2.9	-11.9	1.4	-17.2	4.2	G5III/G5III	SB2	14.73	0.04	0.9913	>1.10		
31	44 -	TW Lep	+	-0.6	7.4	-26.7	9.2	5.2	9.9	F6IV/K2III	SB2	28.34	0.05				>9/
32	57 -	AR Mon	+	29.8	14.8	-37.3	15.8	45.5	21.6	G8III/K2-3III	SB2	21.21	0.0	0.2991	0.8		14.2/10.8
33	66 -	RZ CnC	+	0.5	7.9	-29.1	15.9	10.7	9.9	K1III/K3-4III	SB2	21.64	0.0	0.1700	0.54		12.2/10.2
34	83 -	HR4665	+	13.5	3.0	-43.1	5.0	-19.8	3.6	K1III/K1III	SB2	64.44	0.0	0.9810	>1.43		>13/>13
35	111 -	V792 Her	+	9.5	3.2	6.6	2.7	9.1	3.6	F2IV/K0III	SB2	27.54	0.0	1.0417	1.46		12.28/2.58
36	114 -	CD-33 12122	+	-22.5	2.9	18.1	27.5	31.5	29.1	F2IV/K1III	SB2	30.97	0.0	1.0104	1.7		~14/~5.5
		GIANTS (low velocity)															
37	4 -	BD Cet	+	7.4	2.9	-15.9	3.2	-0.9	1.2	K1III	SB1	35.10	0.04			0.11	>10
38	40 -	12 Cam	+	-12.3	3.0	-15.0	4.8	-6.3	3.3	K0III	SB1	80.17	0.35			0.0801	12.4 *
39	79 -	HR4492	+	-13.2	5.9	-16.0	2.6	-14.9	4.3	A0/K2-4III	SB1	61.36	0.0			0.0123	28.5 *
40	82 -	BD-8 3301	+	-35.1	17.2	-8.8	9.3	0.6	6.5	K0III	SB1	10.39	0.02			0.11	>5
41	110 -	Epsilon Umi	+	1.1	1.2	-7.0	0.8	-8.1	1.1	A8-F0V/G5III	SB1	39.48	0.04	2.1538	2.8	0.1273	12/1.7
42	113 -	HR6469	+	13.2	4.6	-6.0	1.4	-6.1	1.7	{F2V/[G0V]?}G5IV	SB1	2018	0.68				>10
43	134 -	BD-20 5516	+	-10.0	0.5	-16.7	2.2	-1.3	1.1	K1III	SB1	13.05	0.0			0.00083	>9
44	141 -	BD-21 5735	+	-24.3	4.1	-12.3	4.6	-1.4	6.2	K2III	SB1	23.21	0.05			0.061	>10
45	154 -	HK Lac	+	-53.9	13.7	-29.1	1.6	-0.4	3.8	F1V/K0III	SB1	24.43	0.01			0.105	11.4 *
46	157 -	V350 Lac	+	11.2	3.6	7.2	0.7	-6.2	3.0	K2III	SB1	17.76	0.02			0.12	>11
47	3 -	5 Cet	x	-3.8	1.4	-3.3	1.6	-2.8	1.4	~F/K1III	SB1	96.41	0.12			0.1317	~50

TABLE 2—*Continued*

No	Cat.No	Name		U	p.e.	V	p.e.	W	p.e.	Specral type		Period (days)	e	Mc/Mh ($M_\odot$)	Mc ($M_\odot$)	f(M) ($M_\odot$)	Rc/Rh ($R_\odot$)
48	23 -	BD-05 592	x	-21.8	4.7	-1.2	4.2	0.5	3.9	G8IV-III	SB1	48.26	0.10			0.024	>8
49	37 -	3 Cam	x	33.5	1.1	-20.8	1.7	-4.0	1.8	KOIII	SB1	121.00	0.02			0.282	12.8 *
50	64 -	HR3385	x	-4.1	4.6	-7.5	1.3	-7.5	4.9	KOIII	SB1	45.13	0.0			0.0048	11 *
51	95 -	4 Umi	x	-22.7	5.0	-0.7	1.8	-1.7	1.9	K3III	SB1	605.80	0.14			0.124	25.2 *
52	138 -	BD-6 5221	x	-18.5	4.7	-24.3	8.0	-16.5	10.8	sdB/KOIV-III	SB1	20.66	0.10			0.0047	>7.5
53	38 -	RZ Eri	+	-26.7	4.2	-21.4	5.7	-15.6	5.1	Am/KOIV	SB2	39.28	0.36	0.9412	>1.7		12.6/3.7
54	42 -	Alpha Aur	+	-36.5	0.4	-15.0	1.3	-8.1	0.6	G1III/KOIII	SB2	104.02	0.0	1.1801	3.31		12.7/7.8
55	48 -	CQ Aur	+	-28.0	2.1	-5.5	7.4	-10.5	8.3	G2/KO	SB2	10.62		1.2424	2.0		8.7/1.9
56	9 -	Eta And	x	25.3	12.7	-6.8	1.9	-9.5	9.1	G8IV-III/G8IV-III	SB2	115.71	0.01	0.9040	>0.306		
		SUBGIANTS															
57	31 -	EI Eri	+	-42.4	5.2	24.1	5.6	11.3	4.5	G5IV	SB1	1.95	0.0			0.00408	>1.9
58	51 -	CP-58 718	+	-10.0	2.0	-15.1	1.0	8.2	2.2	K1IV-IIIp	SB1	13.64	0.05			0.0059	2.24 *
59	75 -	DM Uma	+	-18.4	7.0	-8.8	4.9	-16.0	4.2	KO-1IV-III	SB1	7.49	0.0:			0.016	~4
60	88 -	BD-4 3419	+	0.7	5.9	-24.5	6.9	11.2	4.7	K2IV-III	SB1	>20					4.93 *
61	93 -	CP-60 4913	+	70.2	2.2	-61.6	1.8	4.7	1.8	K2IV-III	SB1	11.99	0.0			0.0012	2.9 *
62	96 -	CP-59 5631	+	-9.5	3.6	-35.0	3.6	0.3	1.4	K1IV	SB1	6.00	0.0			0.025	1.5 *
63	151 -	42 Cap	+	31.7	7.9	-43.0	10.2	-0.8	0.5	G2IV	SB1	13.17	0.18			0.016	2.84 *
64		Delta Cap	+	-7.5	0.7	-21.3	2.0	-17.8	1.7	F1IV-III/K1IV	SB1					0.037	3.2 *
65	166 -	Lamda And	+	-1.5	0.4	-6.3	1.8	-48.8	6.6	G8IV-III	SB1	20.52	0.04			0.000611	4.4 *
66	168 -	II Peg	+	-69.7	10.9	-47.7	4.9	-3.5	2.1	K2-3V-IV	SB1	6.72	0.0			0.035	2.2
67	16 -	CD-24 751	x	-87.0	22.3	-18.7	7.4	16.5	5.1	KOIV	SB1	15.05	0.39			0.013	>4
68	17 -	BD+34 363	x	33.4	3.2	-4.8	2.9	1.7	2.8	G5IV	SB1	23.90					2.2 *
69	35 -	BD+36 903	x	-7.9	0.6	-10.4	2.2	-10.3	2.0	K1III	SB1	21.30	0.05			0.0565	3.8 *
70	41 -	CP-77 196	x	-1.6	3.0	7.6	2.1	-8.1	3.1	K1IIIp	SB1	19.31	0.0			0.11	4 *
71	62 -	BD-06 2585	x	-34.6	5.7	-22.3	2.5	-37.1	11.8	K1IV	SB1	16.54	0.31			0.0021	>5
72	133 -	HR7333	x	-26.0	1.9	3.5	2.4	-10.8	2.5	G8IV-III	SB1	266.54	0.83			0.128	3.8 *
73	156 -	BD+29 4645	x	3.7	2.7	19.3	8.4	-5.4	4.1	F/G5IV	SB1						
74	8 -	CF Tuc	+	-54.6	8.5	-30.4	4.9	-4.4	1.8	GOV/K4IV	SB2	2.80	0.0	1.1205	1.205		3.32/1.67
75	13 -	CP-57 296	+	10.3	2.8	-11.7	3.0	3.7	2.2	G6-8IV-IIIe	SB2	0.66	0.0	0.7975		0.0056	4 *
76	15 -	AR Psc	+	-67.5	9.1	42.6	5.6	33.1	7.2	/G8IV	SB2	14.30	0.19	0.7712	>0.14		>1.5/
77	24 -	LX Per	+	-53.8	7.7	-32.1	12.4	-21.3	5.8	GOIV/KOIV	SB2	8.04	0.0	1.0135	1.32		2.8/1.6
78	26 -	UX Ari	+	-25.4	1.2	-13.5	3.8	-24.0	2.7	G5V/KOIV	SB2	6.44		1.1228	>0.71		0.93/3
79	27 -	HR1099	+	24.8	2.5	-16.9	3.3	-3.6	2.5	G5IV/K1IV	SB2	2.84	0.0	1.2491	1.4		3.9/1.3
80	61 -	54 Cam	+	-26.7	4.2	-1.9	5.7	8.0	3.2	F9IV/G5IV	SB2	11.08	0.107	0.9790	1.61		2.64/3.14
81	63 -	GK Hya	+	-46.0	10.6	-11.1	6.9	-14.8	12.1	F8/G8IV	SB2	3.59		1.0879	>1.3		3/1.4
82	65 -	RU CnC	+	-19.5	6.3	11.7	6.5	-20.2	7.4	F5IV/K1IV	SB2	10.17	0.0	1.0141	1.5		5/1.9
83	67 -	TY Pyx	+	-23.1	3.3	-62.6	1.4	-13.2	5.1	G5IV/G5IV	SB2	3.20	0.0	0.9867	1.2		1.68/1.59
84	78 -	CD-38 7259	+	12.2	2.5	-7.5	1.1	-5.2	2.4	G5V/K1IV	SB2	11.71	0.055	1.0209	0.29		
85	80 -	RW UMa	+	-13.9	6.9	-19.3	5.8	-23.9	2.9	F8IV/K1IV	SB2	7.33	0.0	0.9750	1.45		3.17/1.25
86	81 -	93 Leo	+	-20.3	8.8	-11.8	5.1	-5.7	2.6	A6:V/G5IV-III	SB2	71.69	0.0	1.1380	>1.02		5.9/1.7
87	89 -	RS CVn	+	-5.4	1.8	-4.8	1.1	-13.5	1.3	F6IV/G8IV	SB2	4.80	0.0	1.0431	1.4		4.1/1.88
88	91 -	HR5110	+	18.7	6.0	11.4	3.3	3.3	1.0	F2IV/K2IV	SB2	2.61	0.0	0.5415	0.8		2.85/3.10
89	97 -	RV Lib	+	-26.2	12.7	-36.0	21.5	-31.3	12.4	G5IV/K3IV	SB2	10.72		0.1786	>0.4		
90	101 -	CP-62 4482	+	-20.6	2.5	-11.9	2.8	-2.1	1.3	K2IV/K2IV	SB2	49.43	0.516	1.0074		2.89	
91	103 -	RT CrB	+	-0.1	10.6	20.2	12.9	-16.9	8.6	G0/KO-2	SB2	5.12		1.0482	>1.34		2.6/2.6
92	109 -	WW Dra	+	51.2	14.4	-21.1	3.8	-19.0	4.5	G2IV/KOIV	SB2	4.63	0.0	0.9778	>1.4		3.9/2.3
93	112 -	V824 Ara	+	-9.5	1.8	-13.8	2.0	-9.2	1.5	G5IV/KOIV-V	SB2	1.68	0.0	0.9340	>0.459		
94	117 -	Z Her	+	-55.4	3.7	-15.5	2.9	7.2	4.2	F4V-IV/KOIV	SB2	3.99	0.0	0.8968	1.1		2.60/1.69
95	118 -	MM Her	+	-11.8	6.9	-51.5	5.1	-30.4	5.2	G2IV/G8IV	SB2	7.96	0.04	1.0241	1.27		2.83/1.58
96	125 -	AW Her	+	-30.3	7.7	-42.7	8.2	12.2	12.5	G0/K1IV	SB2	8.80		0.9863	>1.4		3.00/1.12
97	153 -	RT Lac	+	-10.5	5.0	-54.0	0.8	5.7	2.4	G9IV/K1IV	SB2	5.07	0.0	2.1413	1.66		3.4/4.2
98	155 -	AR Lac	+	2.3	1.2	-30.9	1.9	16.5	2.1	G2IV/KOIV	SB2	1.98	0.0	1.0043	>1.3		3.1/1.8
99	164 -	SZ Psc	+	-8.6	3.4	21.3	4.1	1.2	3.0	F8IV/K1IV	SB2	3.97	0.04	1.3558	>1.6		5.08/1.38
100	165 -	EZ Peg	+	23.8	4.3	-11.7	2.1	27.2	2.4	G5V-IV/KOIV:	SB2	11.66	0.0	1.0083	>0.071		

TABLE 2—*Continued*

No	Cat.No	Name		U	p.e.	V	p.e.	W	p.e.	Specral type		Period (days)	e	Mc/Mh ($M_\odot$)	Mc ($M_\odot$)	f(M) ($M_\odot$)	Rc/Rh ($R_\odot$)
		MAIN SQUENCE (high velocity)															
101	53 -	SV Cam	+	-36.8	6.9	-52.8	7.0	3.4	3.0	G2-3V/K4V	SB1	0.59	0.0	0.7000	0.7		0.7/1.2
102	76 -	Zeta Uma	+	-0.7	0.3	-24.7	1.2	-19.7	0.3	G5V	SB1	3.98	0.0			0.0000517	0.78 *
103	122 -	V815 Her	+	-5.6	0.9	-4.0	1.2	-20.9	2.6	G5V/[M1-2V]	SB1	1.81	0.029			0.0306	0.93
104	10 -	BD+25 161	x	12.5	5.1	-13.0	6.6	8.6	6.1	G2V	SB1						1.03 *
105	30 -	CP-52 497	x	16.5	3.5	-73.5	3.8	-29.4	3.2	K1Vp	SB1	2.56	0.04			0.052	0.7 *
106	161 -	CD-34 15853	x	29.8	4.1	-22.2	4.8	-23.0	3.7	G5Vp	SB1	1.64	0.0			0.054	0.9 *
107	129 -	V775 Her	*	27.1	2.7	-1.6	1.2	-25.6	3.4	K0V/[K5-M2V]	SB1	2.88	0.003			0.0362	0.7 *
108	14 -	BD-0 210	+	89.0	9.0	-59.4	5.3	35.8	5.7	G5V:/G5V:	SB2	0.52	0.0	0.9158	>0.8		~0.9/~0.9
109	28 -	BD+25 580	+	-5.0	3.5	-98.5	14.2	-6.0	2.8	G2V/KV	SB2	1.93	0.035	0.6239	0.72		>.07/>1
110	84 -	AS Dra	+	-24.9	22.6	-73.4	5.8	-93.2	9.0	G4V/G9V	SB2	5.41	0.07	0.9600	>0.706		
111	94 -	BH Vir	+	-17.7	5.2	-4.9	5.9	-24.5	4.7	F8V-IV/G2V	SB2	0.82	0.0	1.0193	0.9		1.15/1.05
112	107 -	Sigma CrB	+	-7.5	0.4	-28.8	2.8	10.0	2.4	F6V/G0V	SB2	1.14	0.022	0.9702	1.12		1.21/1.22
113	167 -	BD+27 4588	+	-44.3	6.7	-4.7	0.8	13.7	2.0	G5V/KV	SB2	6.20	0.02	0.6770	>0.27		
114	6 -	FF And	*	-51.5	6.1	22.6	2.8	89.5	10.6	dM1e/dM1e	SB2	2.17	0.0	0.9704	0.54		
115	20 -	CC Eri	*	8.3	2.2	-32.2	2.6	-31.9	1.7	K7Ve/	SB2	1.56	0.046	0.5153	~0.24		/~0.7
116	70 -	BD+40 2197	*	-29.5	4.7	-51.5	7.4	-35.5	4.9	K2V/[dK]	SB2	3.80	0.0	0.9696	~0.74		
117	108 -	CM Dra	*	-103.4	7.1	-120.7	2.3	-34.9	3.1	M4Ve/M4Ve	SB2	1.27	0.0	0.8739	0.207		0.235/0.252
118	143 -	V1396 Cyg	*	-22.2	1.1	-31.6	0.4	-49.9	2.7	dM3e	SB2	3.28	0.04	0.6906	>0.125		
119	148 -	BD-0 4234	*	-127.1	29.7	-78.4	3.7	-5.3	27.4	K3Ve/K7Ve	SB2	3.76	0.0	0.8045	0.55		~0.45/~0.55
		MAIN SQUENCE (low velocity)															
120	22 -	VY Ari	+	-10.1	2.9	-26.9	6.2	-3.3	1.3	G9V	SB1	13.20	0.085			0.042	0.99 *
121	131 -	V478 Lyr	+	-25.6	2.4	-7.9	1.5	-9.9	1.3	G8V/[dK-dM]	SB1	2.13	0.0			0.0118	>0.9
122	119 -	V772 Her	+	-5.8	1.0	-25.5	0.9	-5.7	1.1	{G0V/[M1V]}G5V	SB1	0.88	0.045	0.5673	0.59	0.0754	0.6/1.0:
123	46 -	CD-28 2525	+	-3.4	5.0	-28.4	4.6	-0.8	5.3	G1V	SB1						1.12
124	5 -	13 Cet(A)	+	-29.6	2.4	-14.6	1.6	-12.5	0.3	{F7V/}G4V	SB1	2.08	0.0			0.0189	1.47 *
125	2 -	BD+45 4408	x	-35.0	4.5	-30.1	8.8	-12.0	2.9	dK6	SB1						0.5 *
126	36 -	V833 Tau	*	-38.1	4.8	-14.9	1.5	-2.0	1.2	dKVe	SB1	1.90					0.6 *
127	85 -	BD+26 2347	+	-2.2	2.8	-7.7	2.8	-1.2	0.6	F8V/F8V	SB2	0.96	0.0	0.9643	0.82		1.1/1.1
128	163 -	RT And	+	-6.4	3.1	19.4	3.0	-5.0	3.1	F8V/G5V	SB2	0.63	0.09	0.6463	0.99		0.97/1.1
129	144 -	ER Vul	+	-22.8	2.6	-22.2	0.7	-8.2	2.5	G0V/G5V	SB2	0.70	0.02	0.9277	0.98		1.23/1.23
130	55 -	Gl 268	x	-43.3	0.5	-19.8	0.9	-7.2	0.9	dM5e/dM5e	SB2	10.43	0.34	0.8317	>0.159		
131	120 -	ADS11060C	x	-5.8	1.0	-25.4	0.9	-5.7	1.1	K7:V	SB2	>=5					
132	33 -	BD+16 577	x	-40.3	0.6	-16.2	1.4	-1.9	1.2	G6V/K6V	SB2	5.51	0.0	0.7138	0.776		
133	39 -	BD+24 692	x	-43.2	0.4	-17.5	1.5	-1.2	1.2	K3V/K3V	SB2	11.93	0.511	0.9501	>0.75		~0.8/~0.8
134	21 -	CD-38 899	x	-3.9	0.8	-26.7	3.0	-8.9	1.4	G5-8V/[G]	SB2	0.95	0.0	0.8134			
135	86 -	BD+25 2511	x	-2.7	1.9	-10.1	2.4	-1.0	10.0	G9V	SB2						
136	34 -	BD+17 703	x	-41.8	0.6	-20.6	1.7	-1.6	1.4	G4V/G8V	SB2	75.65	0.22	0.8807	>0.99		
137	146 -	BD+10 4514	x	7.1	1.4	-1.4	1.2	-8.4	1.4	{F9V/G0V}GIV	SB3	3.97	0.013	0.9580	>0.50		
138	50 -	OU Gem	*	9.0	0.2	-3.8	1.0	-11.7	1.7	K3V/K5V	SB2	6.99	0.15	0.8445	>0.59		
139	139 -	HR7578	*	3.9	0.9	-30.9	3.1	0.7	0.2	K2-3V/K2-3V	SB2	46.82	0.692	1.0021	>0.85		>0.8/>0.8
140	162 -	KZ And	*	-13.4	2.3	-11.8	0.9	-4.5	1.2	dK2/dK2	SB2	3.03	0.034	0.9494	>0.41		/>0.74
141	106 -	BD+25 3003	*	6.9	1.6	-19.9	2.8	1.0	0.9	K2V/K6V	SB2	9.01	0.0	0.8256	>0.71		
142	126 -	BY Dra	*	16.1	2.6	-18.6	0.6	-27.6	2.2	K4V/K7.5V	SB2	5.98	0.307	0.8911	0.44		/1.2-1.4
143	158 -	FK Aqr	*	-16.8	2.0	-8.7	1.0	-1.0	1.3	dM2e/dM3e	SB2	4.08	0.01	0.8055	>0.22		
144	58 -	YY Gem	*	-12.4	1.6	-4.0	0.4	-10.7	0.8	dM1e/dM1e	SB2	0.81	0.0	0.9235	0.57		/0.62
145	74 -	BD-11 2916	*	40.9	16.8	-20.8	8.3	-13.3	6.0	K3-4V/K3-4V	SB2	6.87	0.014	0.9948	>0.545		>0.8/>0.8
146	73 -	DH Leo	*	-34.4	5.2	-15.2	2.4	-11.0	4.4	{K2V/K5V}K5V	SB3	1.07	0.0	0.6750	0.58		[0.67/0.97]

nearby, the first order correction for galactic differential rotation described in Mihalas & Binney (1981) has been applied to the space motions (U, V, W), although its effects are negligible for the majority of the systems.

Figure 1 shows a rather uniform distribution in galactic coordinates, as expected, considering the nearness of these systems. This may also be understood by realizing that all systems are well contained in the galactic disk in the solar neighborhood. Figure 2 displays the distribution of U and V components of space velocity of all of the systems together.

3. KINEMATICS AND AGE

The relationship between stellar kinematics and age has been studied by von Hoerner (1960) using the theory of Spitzer & Schwarzschild (1953) that velocity dispersion results from the accumulation effect of encounters between stars and other stars and gas complexes. Empirical evidence in the form of tables showing changes in kinematical properties for stars of different age groups has been summarized by Blaauw (1965), Delhaye (1965), Eggen (1971), and Mihalas & Binney (1981). Velocity dispersion, defining velocity ellipsoids in velocity space, progressively and clearly increases toward the later spectral types up to mid-F. The situation for the lower main sequence is less clear because these stars have lifetimes as long as or longer than, the age of our Galaxy and hence comprise a random mixture ranging from very young to very old stars. This effect must be considered when segregating stars according to age group.

Our sample appears very heterogeneous as it contains stars from F to M on the main sequence together with G and K giants. Moreover, the orbital periods of the binaries in the sample range from a fraction of a day to more than 100 days. Regarding the binary evolution (Plavec 1968; Thomas 1977), different period ranges may represent different evolutionary paths, so their lifetimes may differ. Nevertheless, classification with respect to activity, such as RS CVn and BY Dra, may well represent different kinematical status.

Distribution of space velocities of the total sample in a U, V diagram is shown in Figure 2. Figure 3 divides the sample according to activity classes (groups in Table 1). Although the crowding of stars around LSR is more pronounced in the RS CVn group, low- and high-velocity stars exist in all three groups. RS CVn and active systems could be considered alike kinematically. However, it is not possible to say much about BY Dra stars since their numbers are so few. Elimination of a few high-velocity stars would represent a different picture; nevertheless, this is not possible since space velocities are well defined among these nearby late-type main-sequence systems. It will be shown that BY Dra systems and their main-sequence counterparts in the other groups (RS CVn and active) exhibit similar kinematical behavior.

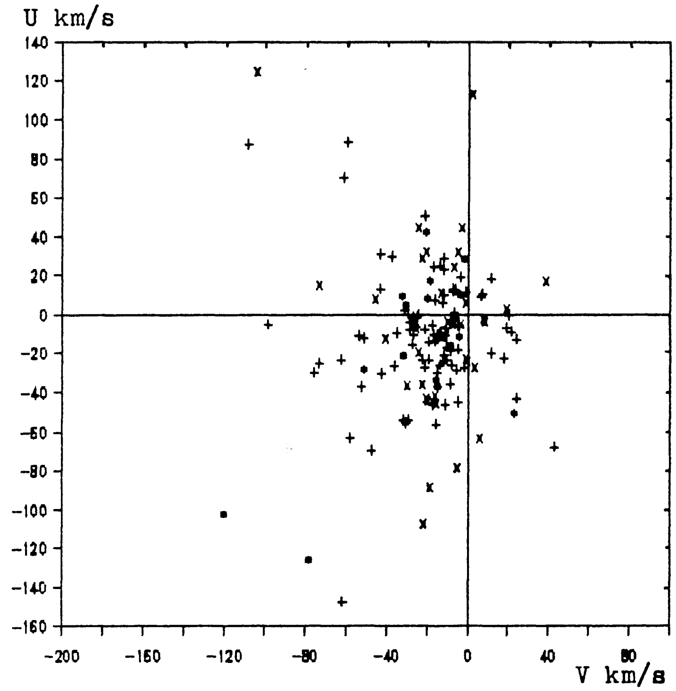


FIG. 2.—Space velocity distributions of the sample in u, v diagram. *The velocities are with respect to the Sun. The position of the LSR is marked with a circle.* Symbols for the stars are the same as in Fig. 1.

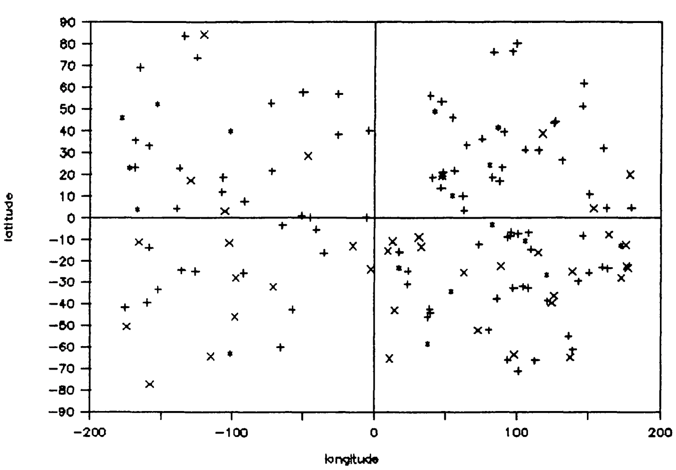


FIG. 1.—Distribution of the sample stars in Galactic coordinates. RS CVn stars: plus signs; BY Dra stars: asterisks; and active systems: crosses.

Figure 4 presents the total sample in different orbital period (P_o) ranges. From top to bottom: $P_o < 2$, $2 < P_o < 14$, and $P_o < 14$ days which are the ranges used by Hall (1976) in his original definition of RS CVn binaries. No significant difference was found among these groups either.

Possibly, a sensible approach for identifying similar age groups is to segregate stars according to luminosity class because degree of evolution might bring kinematical difference. According to the spectral classification recorded in CCABS, basic groups were established. First, systems with one or both components of luminosity class III are called giants. There are only two systems with luminosity class II. They are also included in giants. Then, systems with one or both components of the class IV symbol are called subgiants. The rest are called main-sequence. Four of the systems containing a white dwarf (29 Dra, AY Cet, V471 Tau, CD −48°12280) were not included in these groups. Any ambiguity was resolved on the basis of the radii or absolute magnitudes.

A U, V diagram of white dwarf containing systems is displayed in Figure 5. Because their number is insufficient, no further investigations are attempted for this group.

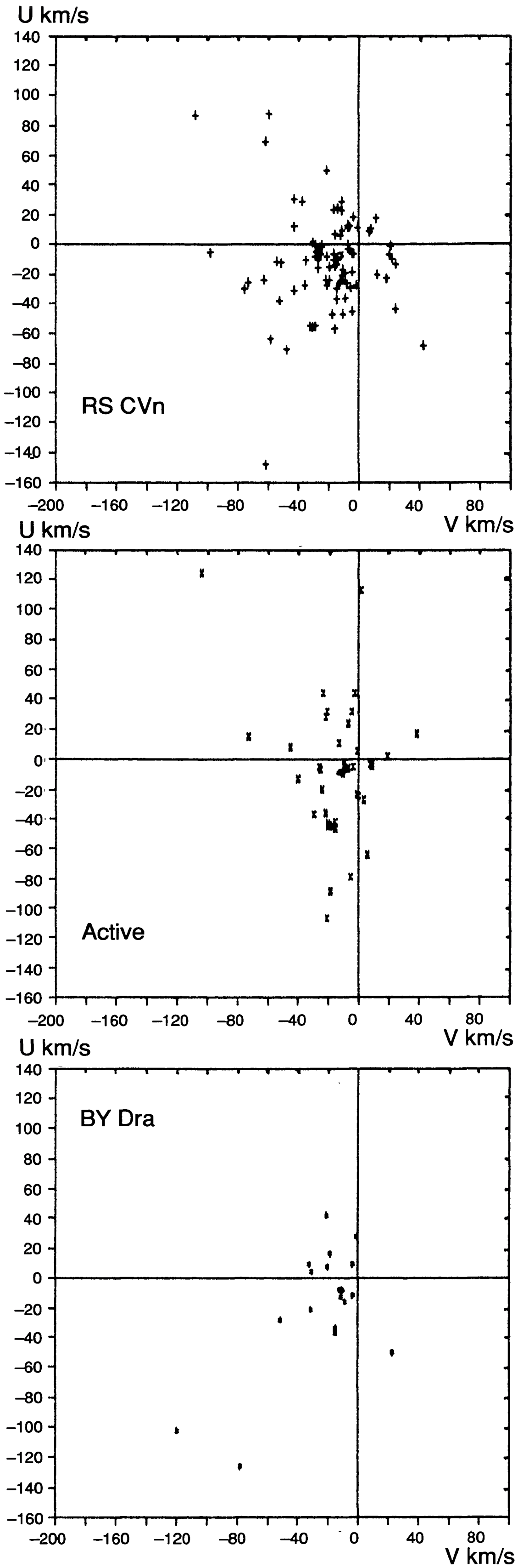


FIG. 3.—Comparison of the U, V diagrams for the groups according to activity class. *The name of each group appears in each box.* The symbols and the presentation are the same as Fig. 2.

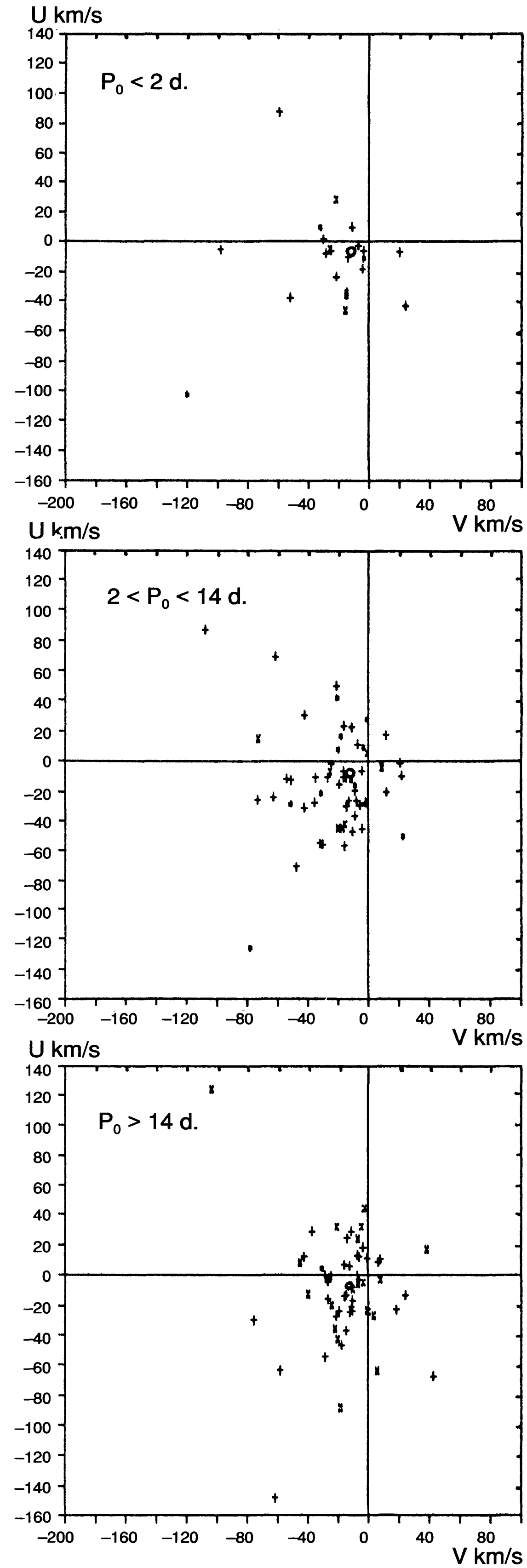


FIG. 4.—Comparison of the U, V diagrams for the groups according to orbital period ranges. The symbols and the presentation are the same as Fig. 3.

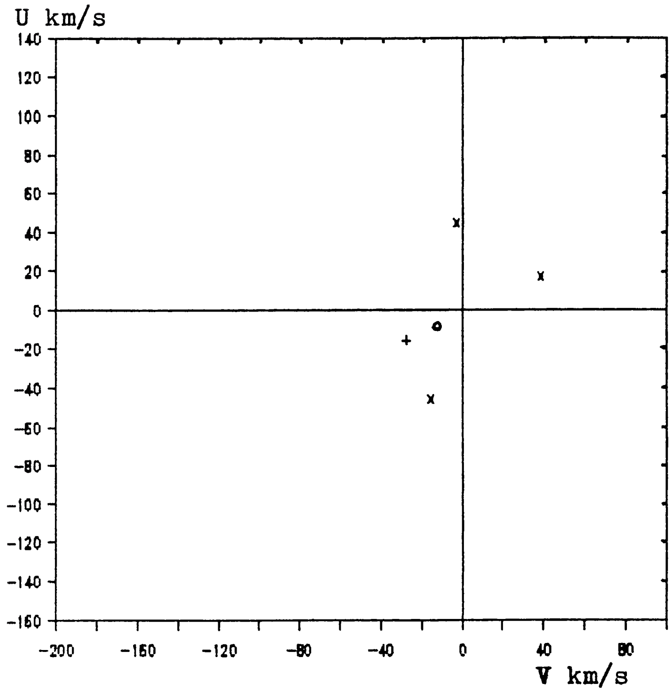


FIG. 5.—Appearance of the systems containing a white dwarf on the U, V diagram. The symbols and the presentation are the same as Fig. 3.

A U, V diagram intercomparing the groups according to luminosity class is presented in Figure 6. At a first glance, all three groups look alike. However, notice the concentration of low-velocity stars around LSR and the outstanding appearance of high-velocity stars in main sequence and giants. On the contrary, subgiants show a rather smooth distribution; also, dispersions of high-velocity stars are not as large as the other two groups. On the other hand, it is not possible to conclude that more evolved systems are more dispersed according to overall appearance of the groups. Further investigations are needed to search subgroups which are more homogeneous in stellar ages. Therefore, this grouping is kept essential for further segregation; that is, separating criteria will be applied to these three groups separately.

A more interesting situation emerged when each group was divided between single- and double-lined systems. Figure 7 compares single-lined systems (SB1) to double- or multiple-lined systems (SB2), with giants on the top, subgiants in the middle, and main-sequence systems on the bottom. SB1 giants clearly have larger dispersions than SB2 giants. On the contrary, SB2 systems appear more scattered among main-sequence stars. For subgiants, distribution could be considered the same for SB1 and SB2 systems. Greater dispersion implies greater age; therefore, SB1 giants appear older than SB2 giants, and the opposite could be suggested for main-sequence systems.

This unexpected situation needs some explanation. It is possible that for giants some of the systems might contain white dwarfs as their unseen companions which are of a higher evolutionary state and which have greater stellar ages. The large brightness difference between a giant star and a white dwarf prevents detection of the white dwarf. White dwarf companions have been discovered for four systems already (Fig. 5).

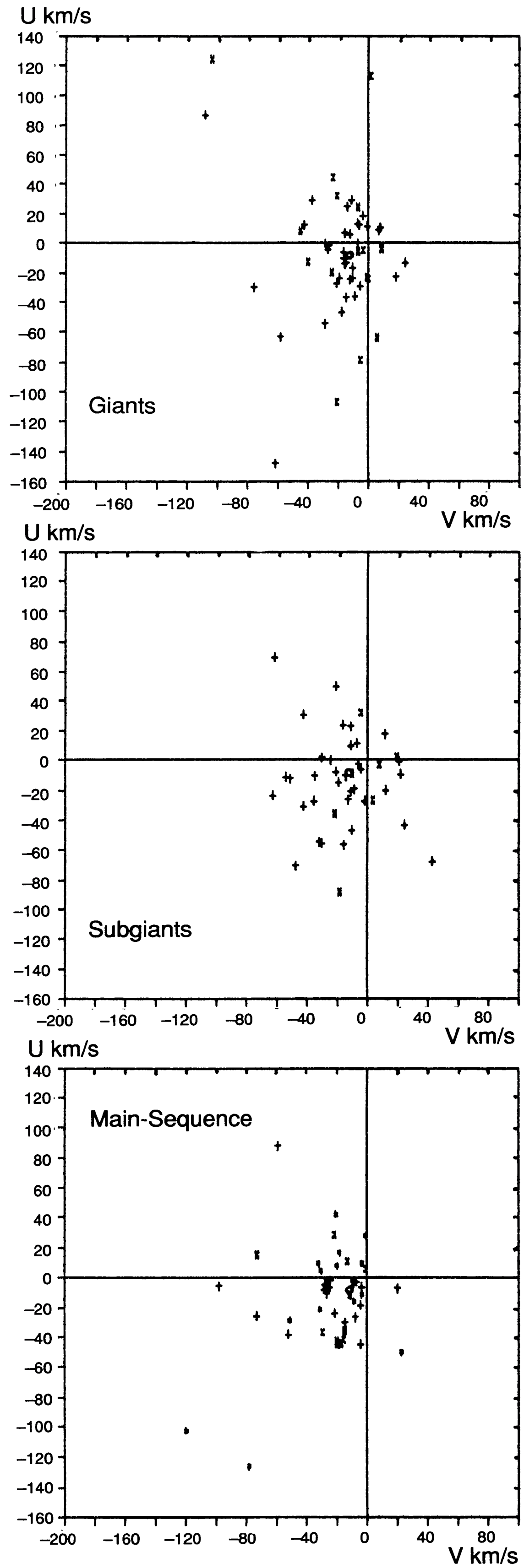


FIG. 6.—Comparison of the U, V diagrams for the groups according to luminosity class. The symbols and the presentation are the same as Fig. 3.

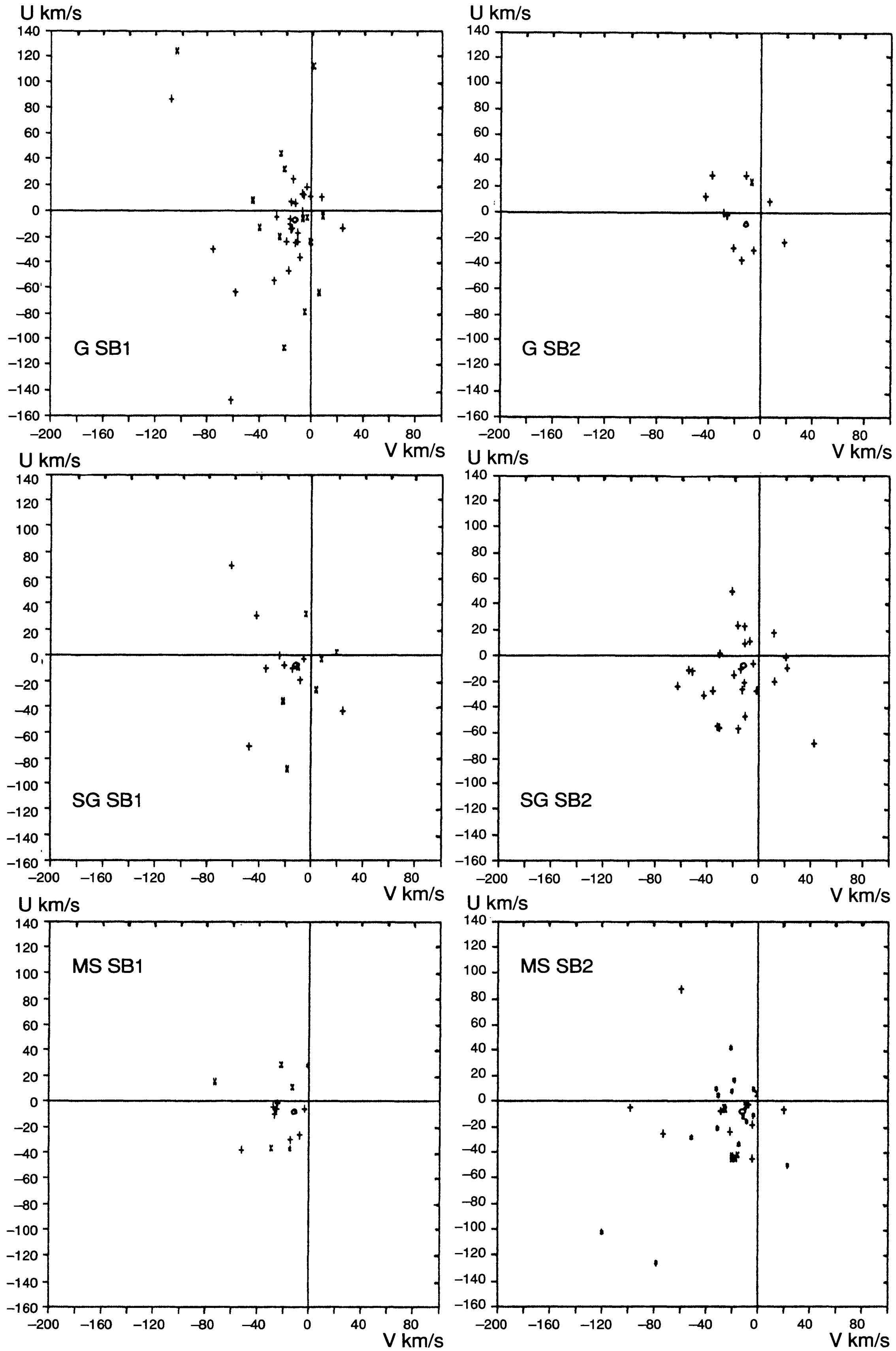


FIG. 7.—Comparison of the single-lined (SB1) and double- or multiple-lined (SB2) systems on the U, V diagram. The symbols and the presentation are the same as Fig. 3. The groups are labeled as follows: G, giants; SG, subgiants; MS, main-sequence.

This fact suggests that similar companions might exist for other systems, but they have not yet been discovered.

Older appearance of SB1 giants could be explained by the same simple scenario, but a similar explanation cannot be given for main-sequence systems. Yet, the opposite appearance makes SB1 systems look younger. Looking at main-sequence systems (see Fig. 7), one can notice that almost all of the BY Dra stars appear as SB2. Since BY Dra stars have spectral types K0 or later, the overall appearance of SB2 systems could be shifted to later spectral types with respect to SB1 systems. To investigate this, spectral types of both groups are compared. Figure 8 shows the number distribution of primaries by spectral types. A primary is defined here as the hottest component if the system is a SB2. The figure shows that SB2 systems represent later spectral types. Later spectral types imply older ages on the main sequence; therefore, SB1 systems might appear younger. A narrower spectral range of giants and subgiants should not bring such a complexity.

Since a large range of spectral type (F–M) exists for main-sequence stars, it may be a good idea to divide them into two groups and then investigate if later spectral types actually represent older ages in the present sample. Therefore, the main-sequence systems were divided into a group with components K0 or later and systems having at least one component earlier than K0. The former group is called late main-sequence

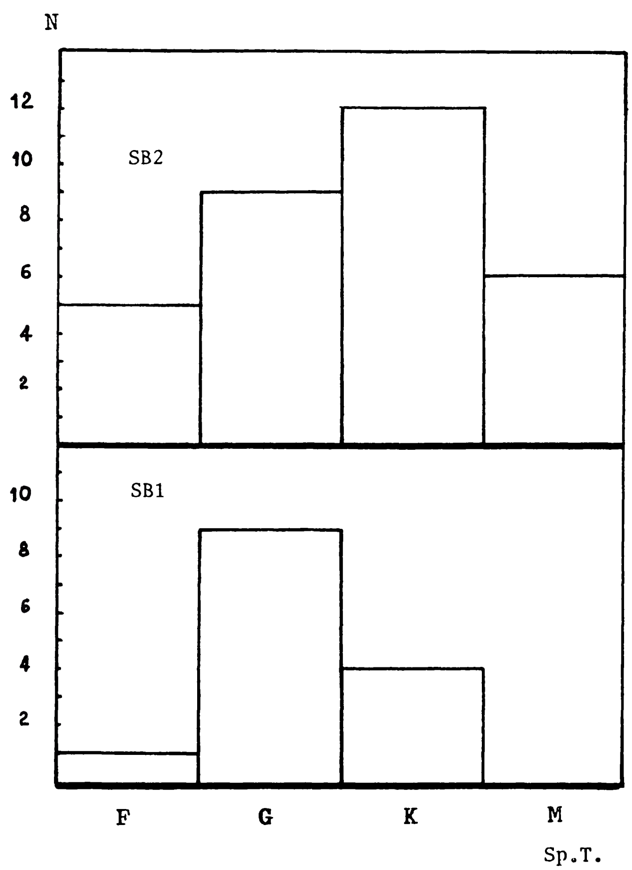


FIG. 8.—Number distribution of primaries by spectral types for the systems on the main sequence. A primary is defined as a hotter component for SB2 systems.

(LMSE) and the latter early main-sequence (EMSE). The definition of BY Dra systems that places all of them in LMSE along with five other active systems. The other groups contain the RS CVn–type and active systems.

The top two boxes of Figure 9 compare space velocity distributions on the U, V diagram for the EMSE and LMSE groups. Unfortunately, the older appearance of later spectral types cannot be confirmed here. Basically, there is no apparent kinematical difference between them. The two boxes in the bottom compare SB1 and SB2 systems in the EMSE group. Ignoring three stars (AS Dra, BD −0°210, BD +25°580) with higher velocities, the distributions of SB1 and SB2 systems appear the same. Such comparison in LMSE is of no significance since only four SB1 systems exist in this group. The older appearance of SB2 systems in Figure 7 must be the false result of small number statistics. On the other hand, the number of SB1 systems is less for later spectral types, which is natural since low intrinsic brightness of a primary allows detection of a secondary more easily.

One known method of distinguishing a younger population from older ones in the galactic disk is to investigate the distribution in the direction perpendicular to the galactic plane (Z) and the space velocity component in the same direction (w, with respect to LSR). Sixty-nine percent of the stars in the sample have distances $d < 100$ pc, and 85% of the systems are contained in $Z = \pm 100$ pc. Also, the sample is strongly influenced by selection effects. For example, there are no BY Dra stars beyond 50 pc, and there is only one main-sequence system beyond 100 pc from the Sun. The values of Z would be small and of doubtful significance to reflect stellar ages for the groups here, since scale heights of even the youngest objects in the disk are of the order of 50–100 pc. Therefore, only space velocity component w is adopted as a criterion for differentiating stellar ages in groups according to luminosity class. Figure 10 shows the number distributions of these groups in w. Again, notice the smoother distribution of subgiants. The other two groups appear more irregular and have larger high-velocity tails. High- and low-velocity stars of each group have been separated according to an arbitrary choice ($|w| = 10$ km s^{-1}). Their U, V diagrams are intercompared in Figure 11. The left-hand boxes contain high-velocity stars ($|w| > 10$ km s^{-1}), and the right-hand boxes contain low-velocity stars ($|w| \leqq 10$ km s^{-1}); from top to bottom, the boxes present giants, subgiants, and main-sequence stars. Low-velocity stars are expected to be mostly young, but they may contain the low-velocity tail of some older stars. For example: BD −0°4234, a BY Dra star having low $|w|$, actually could be considered a high-velocity star according to other velocity components (−127, −78.4, −5). On the other hand, this star is known to be metal-deficient (Peterson et al. 1980). Moreover, BD +25°580, an RS CVn star, has a very high-velocity component (−5, −98.5, −5.9). Therefore, these two stars are included in the box of high-velocity stars together with BY Dra itself. The reason for this will be given when orbital eccentricities are discussed. Giants and subgiants did not have such cases.

Figure 11 clearly shows that low-velocity stars are much younger than high-velocity stars for giants and main-sequence systems. High- and low-velocity subgiants do not show much difference. Their distributions could be considered about the same.

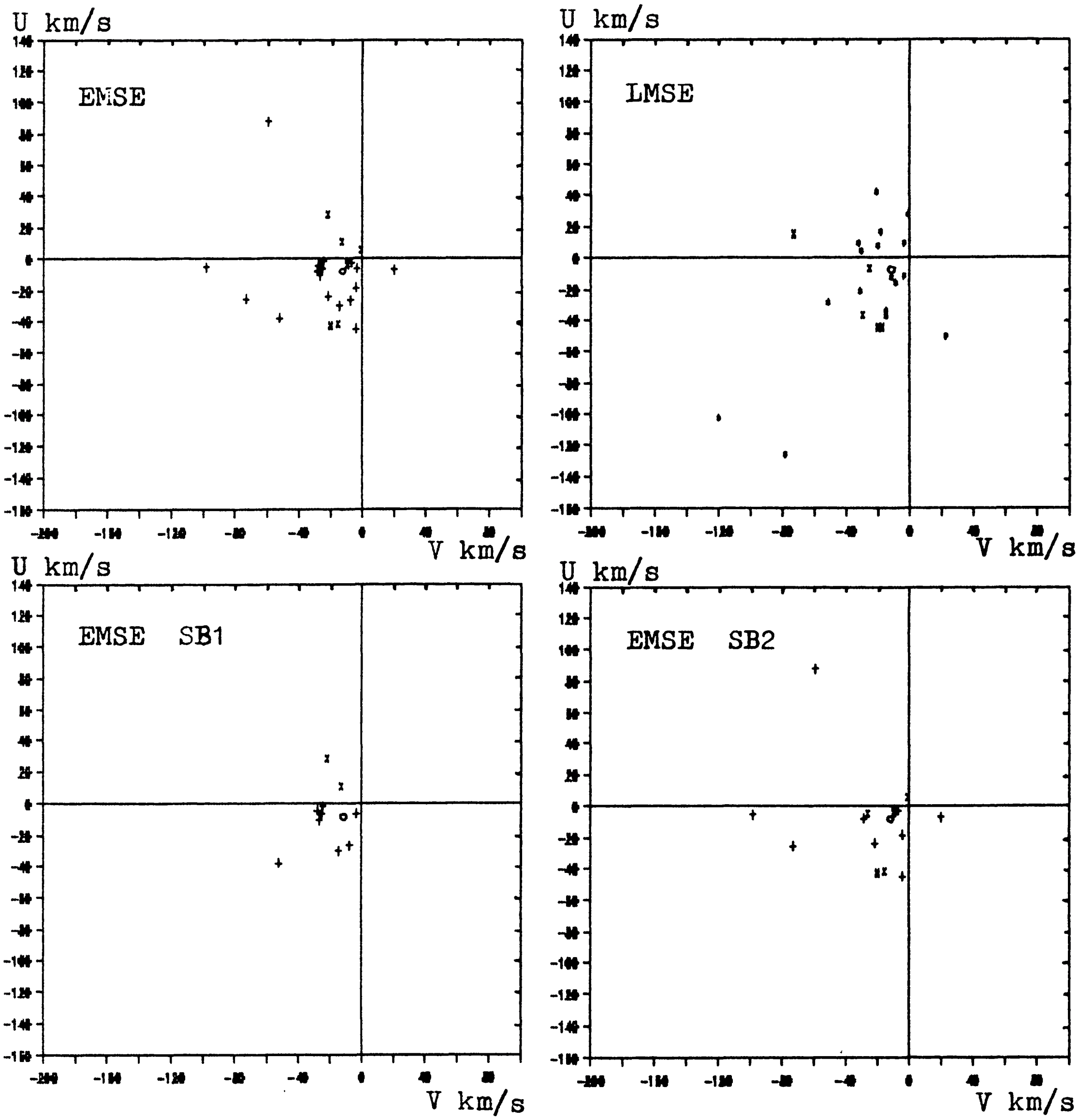


FIG. 9.—Comparison of main-sequence systems for different criteria. The symbols and the presentation are the same as Fig. 3. The systems are labeled as follows: EMSE, systems containing a component earlier than K0 spectral type; LMSE, systems with spectral types K0 or later. The lower two boxes compare SB1 and SB2 systems in group EMSE. Since there are only four SB1 system in the group LMSE, no comparison is shown.

Vertex deviation of velocity ellipsoid is another characteristics of young stars. Low-velocity K giants ($|w| < 10$ km s^{-1}) have been shown to have vertex deviation similar to A0–A3 stars (Vyssotsky 1951). Vertex deviation exists also for dwarf stars from F to M spectral types, but only for small relative speeds with respect to LSR (Delhaye 1965; Mihalas & Binney 1981). Although the number of stars is not high, a slight vertex deviation of the velocity ellipsoid is noticeable for the low-velocity giants and main-sequence stars in Figure 11. No deviation was recognizable in any of the other groups up to this point.

Consequently, giants and main-sequence systems can be divided into two groups, but subgiants can be considered as a single group kinematically. These groups and their stars are listed in Table 2. This table also gives components of space motions with respect to the Sun, their propagated errors, spectral type, binarity, orbital period and eccentricity, mass ratio of cool to hot components, mass of cool component, mass function (if SB1) and radii of components of each star. All of the groups, including the ones used in the segregation process, are summarized in Table 3 with their kinematical quantities such as averages of the velocity components and dispersions. Average velocities are the straight means of the velocities with respect to the Sun, as was done in the U, V diagrams. However, velocity dispersions are computed as root mean square velocities with respect to the LSR. The position of the LSR in velocity space has been determined by subtracting the space motion of the Sun with respect to the LSR. That is given in Mihalas & Binney (1981) as $U = 9.2$, $V = 12$, $W = 6.9$ km s^{-1}. These averaged quantities, including $\langle s^2 \rangle^{1/2}$ (s is a space motion of a

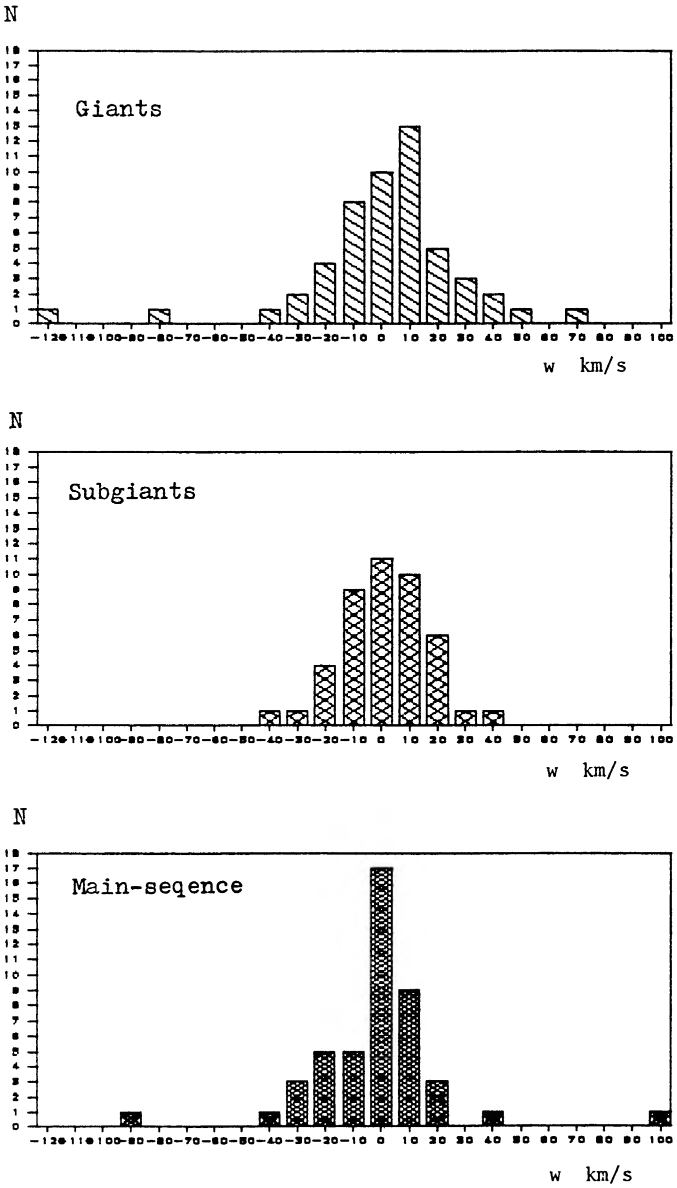


FIG. 10.—Number distribution in w space velocity component (with respect to the LSR) for the groups of giants, subgiants, and main-sequence systems. The data have been binned for ± 5 km s^{-1}.

star with respect to the LSR), are related to stellar ages using Table 4-18 in Mihalas & Binney (1981). These approximate ages are recorded in the last column of Table 3 for the groups which are similar in age or kinematical properties.

Calculating the dispersions with respect to the LSR instead of the average motions of the groups in Table 3 may appear as an error in the determination of the ages. However, in a steady state galaxy, the average of the space motions will reflect the Sun's peculiar velocity with respect to the LSR in the directions radially from the galactic center and perpendicular to the galactic plane. Therefore calculating dispersions in these directions using LSR values from Mihalas & Binney (1981) does not introduce any systematic errors. We cannot do the same for the direction in the galactic rotation, since aging effects cause some group of stars to lag systematically behind the LSR, so that dispersions in this direction appear artificially larger.

First of all, since the groups contain a small numbers of stars, one is forced to calculate dispersions with respect to the LSR in order to minimize random errors. On the other hand, the main purpose of the table is to compare kinematical quantities among groups, and the dispersions with respect to the LSR are sufficient for this aim. Besides, the ages are rough estimates made by comparing those kinematical quantities to the ones given in Table 4-18 in Mihalas & Binney (1981). Therefore, even more accurate values would make only a negligible difference in the determined ages. For example, as a result of smaller values for $\langle v^2 \rangle^{1/2}$, the dispersions with respect to velocity average would have been (47.58, 37.29, 37.16) instead of (46.72, 45.62, 36.61) for the oldest group in Table 3. It is clear that these new values would not change the age of the group significantly. Besides, $\langle V \rangle$ instead of $\langle v^2 \rangle^{1/2}$ is relevant in Table 4-18 in Mihalas & Binney (1981).

4. CORRELATION WITH PHYSICAL QUANTITIES

4.1. *Orbital Period, Mass, and Radius*

It is of interest to see how physical quantities such as mass, radius, mass ratio, spectral class, orbital period, and eccentricity are related to kinematical properties and age. Since the total sample is very heterogeneous, a search for such relations would be meaningless or fruitless unless done properly. For example, attempts to explore the influence of orbital period on kinematical features did not reveal any significant differences. As shown in Figure 4 and Table 3, kinematical features of stars in different orbital period ranges do not differ from each other. However, orbital periods are dramatically different among the groups in Table 2. The longest periods occur among the giants, and the shortest among the main-sequence stars. Straight averages of orbital periods are 56.51 days for giants, 13.35 days for subgiants, and 3.55 days for main-sequence systems. In computing these numbers, systems with periods exceptionally long compared to others in their groups were excluded. These are a giant HR 6469 with $P_o = 2018$, a subgiant HR 7333 with $P_o = 266.544$, and two dwarfs BD + 17°703 and HR 7578 with orbital periods 75.648 and 46.817 days, respectively.

The relationship between velocity space and orbital period was also investigated by examining the stars within each group in Figure 11 and Table 2 separately. However, the only relation found was among the main-sequence systems when they were segregated according to age. Even excluding BD +17°703 and HR 7578, the younger main-sequence systems have 4.43 days for an average orbital period, still about twice the 2.52 day average orbital period for the old main-sequence systems. One can get a similar impression for high- and low-velocity giants which have average orbital periods of 40.85 and 79.57 (excluding HR 6469) days, respectively (see Table 4). But, this larger appearance is caused by 4 UMi ($P_o = 605^{\mathrm{d}}.8$). Eliminating it makes average orbital periods 40.85 and 50.34 days for high- and low-velocity stars, respectively. But, notice that the stars with extremely large orbital periods appear in the younger groups of giants and main-sequence systems.

Dwarf K and M stars showing Hα or Ca II emission are considered young (Delhaye 1965; Upgren 1988). Their emission is attributed to the rapid rotation associated with their

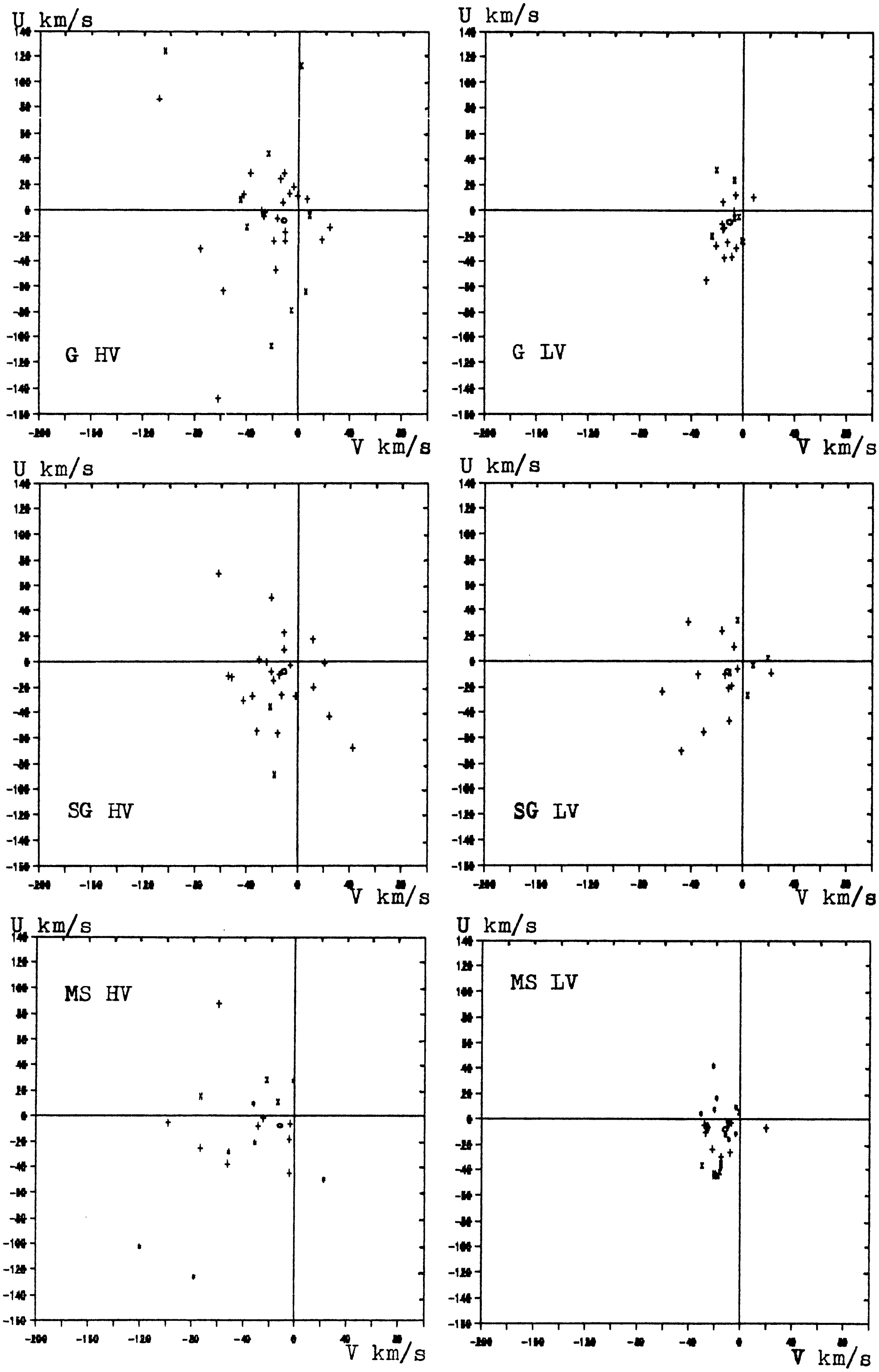


FIG. 11.—Comparison of high- (HV, $|w| > 10$ km s^{-1}) and low-velocity (LV, $|w| < 10$ km s^{-1}) stars. The symbols and the presentation are the same as Fig. 3. The groups are labeled as follows: G, giants; SG, subgiants; MS, main-sequence systems.

TABLE 3

AGE-RELATED STATISTICS

DATA	# of Stars	Velocity Avarages (km/s)						Dispersions (km/s)							AGE $\times 10^9$ y.
		⟨U⟩	⟨p.e⟩	⟨V⟩	⟨p.e⟩	⟨W⟩	⟨p.e⟩	$\langle u^2\rangle^{1/2}$	s.d.	$\langle v^2\rangle^{1/2}$	s.d.	$\langle w^2\rangle^{1/2}$	s.d.	$\langle s^2\rangle^{1/2}$	
All Stars	146	-10.49	6.2	-19.57	5.5	-6.52	5.7	37.43	3.1	26.95	2.2	23.40	1.9	51.72	~5
RS CVn	91	-10.64	6.2	-20.25	5.7	-6.07	5.6	31.98	3.4	26.50	2.8	23.87	2.5	47.90	
BY Dra	17	-19.79	5.4	-26.00	2.5	-10.22	4.6	43.55	10.9	34.79	8.7	29.12	7.3	62.89	
Active	38	-5.96	6.6	-15.07	6.2	-5.94	6.7	45.67	7.5	23.82	3.9	18.98	3.1	54.89	
0<Po<2 d.	22	-11.77	3.4	-25.84	3.5	-5.62	2.6	34.27	7.5	35.28	7.7	15.84	3.4	51.67	
2<Po<14 d.	56	-12.23	6.0	-22.45	4.8	-10.73	5.0	34.44	4.6	27.76	3.7	24.81	3.3	50.72	
14<Po d.	58	-9.17	7.6	-15.50	6.7	-4.35	7.6	36.84	4.9	23.99	3.2	24.50	3.2	50.33	
Cont. WD.	4	1.14	5.2	-1.89	5.1	9.35	4.5	35.68	20.6	26.68	15.4	17.85	10.3	47.99	
G	52	-6.28	8.7	-19.15	8.2	-6.37	9.2	44.64	6.3	26.45	3.7	27.91	3.9	58.92	
SG	44	-12.78	5.5	-15.24	4.7	-5.58	4.1	31.10	4.7	23.22	3.5	16.33	2.5	42.11	~2-3
MS	46	-14.05	4.2	-25.73	3.2	-8.99	3.4	34.03	5.1	30.60	4.6	23.98	3.6	51.67	
G SB1	41	-7.82	9.6	-20.09	8.1	-8.60	9.2	48.59	7.7	28.31	4.5	29.30	4.6	63.41	
G SB2	11	-0.57	5.6	-15.65	8.5	1.94	9.5	24.90	7.9	17.92	5.7	21.96	6.9	37.73	
SG SB1	17	-10.37	5.0	-15.59	4.1	-6.17	3.6	35.97	9.0	22.53	5.6	16.53	4.1	45.55	
SG SB2	27	-14.30	5.8	-15.02	5.1	-5.20	4.5	27.60	5.4	23.65	4.6	16.21	3.2	39.80	
MS SB1	14	-7.49	3.3	-24.29	3.6	-10.91	2.5	22.44	6.2	22.23	6.2	11.83	3.3	33.73	
SM SB2	32	-16.92	4.6	-26.36	2.9	-8.14	3.8	38.01	6.8	33.61	6.0	27.67	5.0	57.79	
EMSE	24	-8.29	3.8	-23.97	3.6	-7.67	3.1	26.92	5.6	27.47	5.7	21.87	4.6	44.24	
EMSE SB1	10	-7.54	3.1	-22.00	3.6	-8.39	2.5	18.89	6.3	16.40	5.5	10.30	3.4	27.05	
EMSE SB2	14	-8.83	4.4	-27.37	3.7	-7.16	3.4	31.42	8.7	33.18	9.2	27.28	7.6	53.22	
LMSE	22	-20.33	4.6	-27.65	2.6	-10.41	3.8	40.39	8.8	33.69	7.4	26.10	5.7	58.72	
MS HV	19	-15.42	6.4	-39.64	4.2	-12.57	5.2	46.72	11.0	45.62	10.8	36.61	8.6	74.86	>5
MS LV	27	-13.09	2.7	-15.94	2.4	-6.46	2.1	20.91	4.1	11.43	2.2	6.06	1.2	24.59	~1
SG HV	25	-13.88	6.2	-16.08	5.4	-4.88	5.0	34.26	6.7	24.65	5.0	21.15	4.3	47.21	
SG LV	19	-11.35	4.6	-14.15	3.9	-6.50	3.0	26.39	6.2	21.20	5.0	5.37	1.3	34.27	
G HV	32	-3.35	11.1	-24.05	11.2	-6.58	12.5	54.34	9.8	33.01	5.9	35.33	6.3	72.74	>5
G LV	20	-10.97	4.9	-11.30	3.3	-6.02	4.0	21.36	4.9	8.74	2.0	5.29	1.2	23.68	~1
GHVX2	25	-6.68	12.6	-25.85	11.2	-11.02	12.7	60.09	12.3	35.49	7.2	37.27	7.6	79.12	>5
GLVI2	27	-5.92	5.2	-12.94	5.3	-2.06	6.0	22.24	4.4	13.47	2.6	14.62	2.9	29.83	~1-2
GHVX2R	25	-4.28		-17.16		-4.65		47.96		22.97		24		58.34	~5

NOTE.—Velocity averages are with respect to the Sun. Dispersions are with respect to LSR. G: giants; SG: subgiants; MS: main squence; EMSE: main-squence stars containing a component earlier than K0. LMSE: main-squence stars components K0 or later. SB1 or SB2: spectroscopic binary single- or double-lined. HV: with high velocity; LV: low velocity (see text).

youth. By the time magnetic braking and loss of angular momentum has slowed the star's rotation rate, it has lost its activity as well. If the star is a member of a close binary system, its rotation will not slow down below a certain value, because of tidal synchronization. Since the rotation-activity relation (Baliunas & Vaughan 1985; Budding & Zeilik 1988) is generally accepted, a rapidly rotating star in a binary must also keep its activity at a certain level as long as it rotates rapidly. In short-period systems, the synchronous rotation rate is higher and the synchronization time scale itself is quicker. This enables them to keep their activity for such a long time. By contrast, younger systems on the main-sequence group have longer orbital periods. They are active simply because they are still young. Synchronous rotation cannot be achieved for the systems with very long periods, or, if achieved, would be too slow to keep the system in an active state. That is why systems of very long period are missing among the high-velocity (old) systems in our sample. It should be remembered that our sample contains active stars only.

The average of the other physical parameters are summarized in Table 4. The largest value of the mass and the radius in a system were used to calculate these average quantities. The mass function is for SB1 systems only. Some of the radii of SB1 systems are estimated with one Stefan-Boltzmann law and bolometric corrections from Johnson (1966) if they are not given in CCABS. Those are marked with asterisks in Table 2. As

TABLE 4

QUANTITY AVERAGES

Data	P_o[a] (days)	Mass[b] ($M_\odot$)	$f(M_\odot)$[c]	Radius[b] ($R_\odot$)
Giants (G)	56.51	2.24	0.091	13.10
Subgiants (SG)	11.35	1.16	0.032	3.36
Main-sequence (MS)	3.55	0.74	0.036	0.90
MS HV (old)	2.52	0.70	0.035	0.86
MS LV (young)	4.43	0.77	0.037	0.94
G HV (old)	40.86	2.25	0.094	12.7
G LV (young)	79.57	2.22	0.096	14.1

[a] Excludes exceptionally large values.
[b] Largest value in a system was used.
[c] For SB1 systems only.

shown in Table 4, the stars in an advanced evolutionary state are larger and more massive as expected. But the younger main-sequence group does not show smaller values compared to the old main-sequence group, probably because the former group contains stars in earlier spectral types which are expected to be heavier and larger. The values could be considered alike for high- and low-velocity giants.

4.2. *Eccentricity*

Distribution of orbital eccentricities could be another clue to distinguish younger systems in the sample since tidal interactions between components of a binary circularize the original orbit over time. According to Mathieu & Mazeh (1988), the circularization time scale for late-type stars is proportional to the orbital period of the binary to the power 16/3. They also suggest that if circularization of short-period binaries takes place when the stars are on the main sequence, different transition periods are expected for samples of different ages. This transition period is called the cutoff period. Orbits with periods less than the cutoff period could be claimed to be circular. An observed cutoff period can be used, therefore, as an age indicator for an open cluster. On the other hand, a completely different mechanism, using a power law of 49/12, for the circularization of short-period binaries were also suggested recently (Tassoul 1988; Zahn & Bouchet 1989). This new theory is claimed to be more efficient. Zahn & Bouchet (1989) also argued that for binary systems with masses ranging from 0.5 to 1.25 $M_\odot$, most of the circularization occurs at the pre–main-sequence phase. The subsequent decrease in eccentricity on the main sequence is negligible. Consequently, the cutoff period is independent of the age of the sample.

The space velocity distribution (U, V) of binaries with nearly circular orbits ($e \leqq 0.04$) and binaries with eccentric orbits ($e > 0.04$) of the total sample is compared in Figure 12. If Mathieu & Mazeh (1988) are right, one is more likely to find high eccentricities among the orbits of young stars. Of course, one should never forget that circularization is strongly related to orbital period. The younger appearance of stars with high eccentricity is clear in Figure 12 if the four stars with high velocities are ignored. Making this comparison for the selected orbital period ranges does not change the general picture. Actually, eccentric stars with longer periods concentrate more closely near the LSR. But, it should be noted that the four stars which are ignored also appear in this group. The older appearance and high eccentricity of those stars could be attributed to their longer periods ($P_o > 14^d$). The group with $P_o < 2^d$ is not displayed in Figure 12 because all orbits are circularized, so no comparison can be made for this group.

On the other hand, the appearance of Figure 12 might not be conclusive because different kinds of stars exist in each group regarding to luminosity class, evolutionary state, and different ranges of mass which are outside Zahn & Bouchet (1989)'s argument. Therefore distribution of eccentric stars among the groups in Table 2 should represent better picture.

The general appearance is that stars with circular or nearly circular ($e \leqq 0.04$) orbits exist in every group. However, all of the eccentric orbits ($e > 0.04$) belong to the stars in the low-velocity main-sequence group (younger group) except three stars: CC Eri, AS Dra, and BY Dra. CC Eri could be ignored since its eccentricity is at the border of selection limit (e = 0.046). AS Dra could also be ignored since its e (0.07) is not significantly large. Besides, space velocity (−25, −73, −93) of this star implies that it is old. But, why does BY Dra appear in the old group with a high e (0.307) despite its short period ($P_o = 5.98^d$). Apparently, its high-velocity tail of (w) distribution (the opposite case of BD −0°4234 and BD +25°580) misplaces it. Otherwise, a circular orbit is expected regarding the inferred age of the high-velocity group. That is why, although its W space velocity component is out of the selection range, it is placed among the low-velocity stars.

A similar comparison is not available for subgiants since they are considered kinematically one group. However, giants display a different scenario than main-sequence systems. Both groups of the giants share stars with eccentric orbits ($e > 0.04$) which have almost the same ratio. Seven of 19 in the low-velocity group and nine of 28 in the high-velocity group have eccentric orbits. Although this is not a surprise, the circularization time scale is expected to be much larger than the age of the systems due to their long orbital periods. But it remains a puzzle to explain the existence of circular orbits among them. A possible explanation is given by Mazeh et al. (1990), such as long-period circular binaries might reflect the original distribution of eccentricities of the samples. Simply, their formation mechanism could be responsible. Alternatively, some of the long-period circular orbits could have been circularized when an unseen secondary star, presumably now a white dwarf, went through the giant phase.

4.3. *Mass Ratio*

The distribution of mass ratios among the groups in Table 2 shows interesting characteristics. Lucy & Ricco (1979) argued that SB2 binaries have a mass ratio distribution that peaks at q = 0.97 and that this peak is a clue to the formation mechanism for short-period binaries. The distribution of mass ratios is shown here in Figure 13 for giants, subgiants, main-sequence systems, and EMSE and LMSE groups. The data have been grouped in intervals of 0.1. The peak at q = 0.97 is clearly shown for main-sequence and EMSE groups. But the peak appears at the $0.8 < q < 0.9$ range for LMSE group. Since these systems are still on the main sequence, the distribution func-

1992ApJS...79..481E

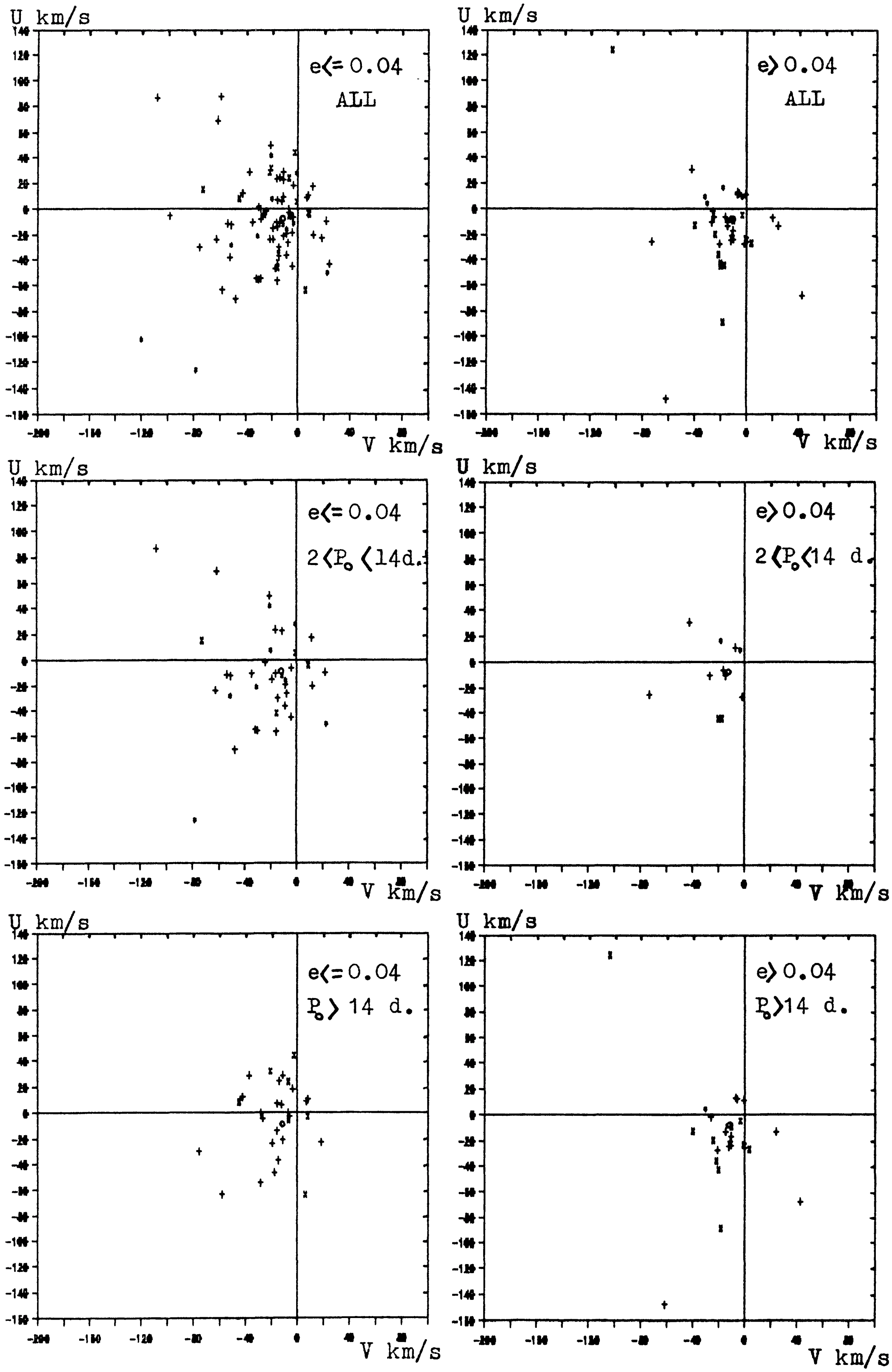


FIG. 12.—Comparison of the stars with circular or nearly circular ($e \leq 0.04$) orbits and the stars with eccentric ($e > 0.04$) orbits in left and right boxes, respectively. From top to bottom, the total sample (ALL), $2 < P_o < 14$ days, $P_o > 14$ days. The symbols and the presentation are the same as Figure 3.

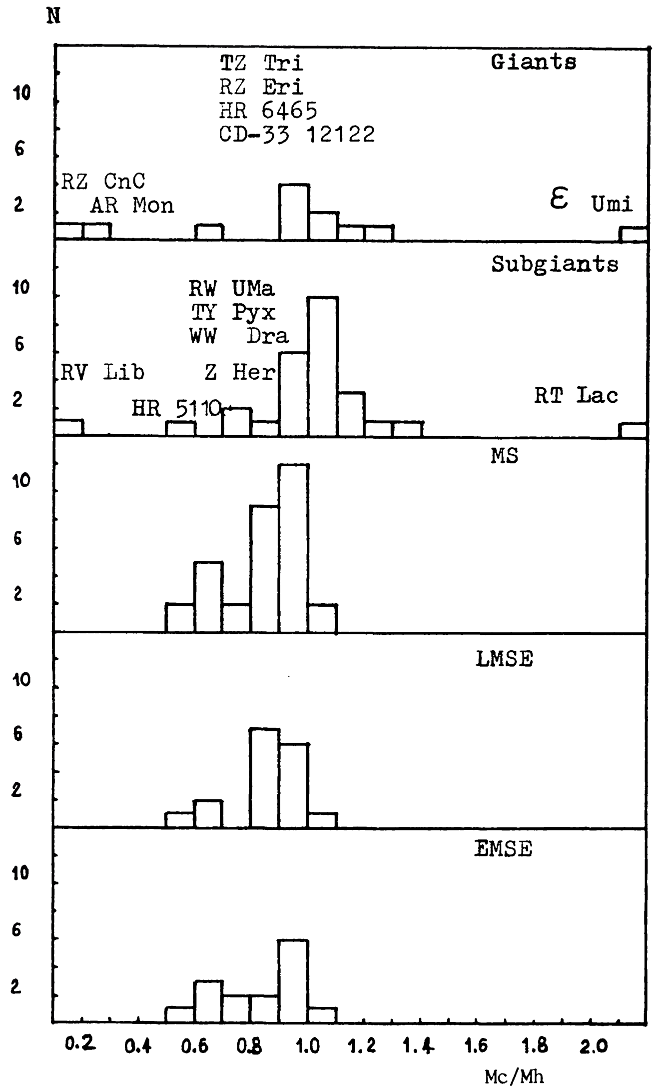


FIG. 13.—The mass ratio distribution of different groups. The mass ratios are in the sense of $q = M_c/M_h$.

tion should not be affected by evolutionary effects. If we take mass ratios as $q = M_c/M_h$ (c = cool, h = hot), then all mass ratios are less than 1 except for one system which could be attributed to a measuring error (Lucy & Ricco 1979). Fekel et al. (1988) did not find a sharp peak among the BY Dra stars, and our more extensive data confirm this finding.

The appearance of the distribution changes as we look at more evolved systems. One star in an RS CVn system evolves off the main sequence as a single star, but perhaps with a little mass exchange and/or mass loss (Popper & Ulrich 1977). According to this statement, the more massive component has evolved and become the cool component. Therefore, the expected peak must be placed in the q = 1.0–1.1 interval. Such a peak appears for the subgiant group but not for the giant group. This peak is much sharper than the one for the main-sequence groups if the $q < 1$ part is ignored. The absence of a peak for the giants could be explained if those systems are not considered short-period systems and if Lucy & Ricco (1979) are right.

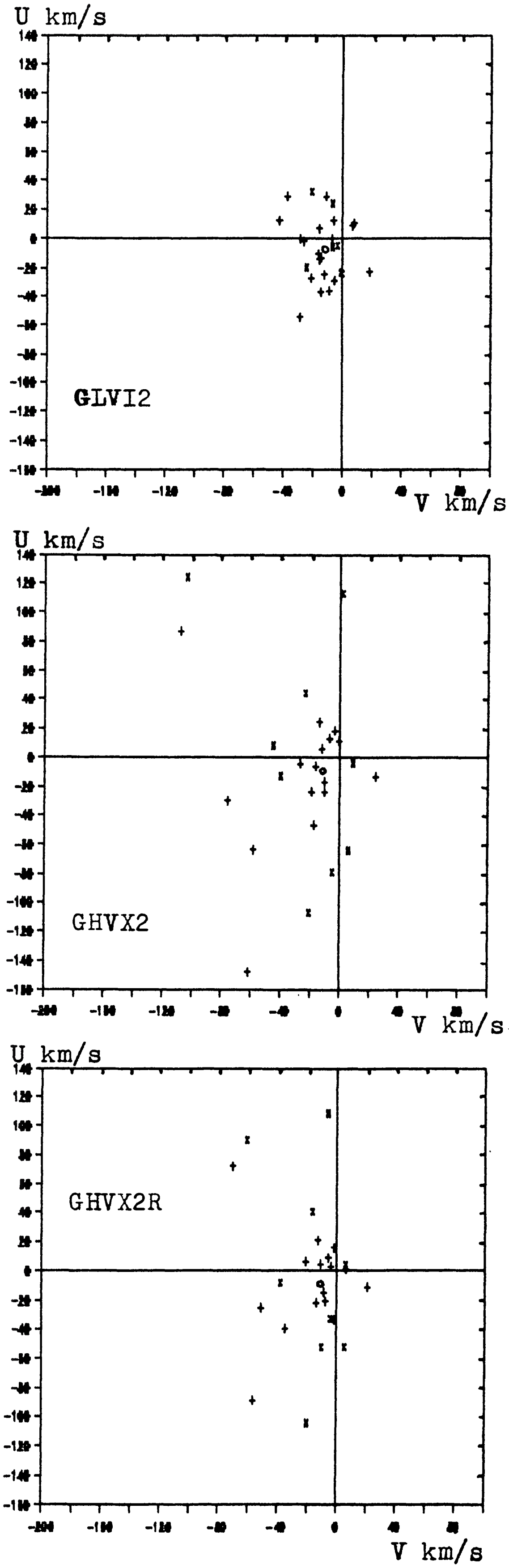
Systems having mass ratios very far from unity appear to involve Roche lobe filling or other problems regarding the observations or the evolutionary status. For example, ϵ UMi (q = 2.15) is not a double-lined spectroscopic binary. The mass ratio given here is from the photometric solutions of this long-period eclipsing system by Hinderer (1957). RT Lac is a very peculiar system in which apparently one component filled its Roche Lobe, but disagreement exists about mass flow from the cool component to the hot component or vice versa (Milone 1976, 1977; Eaton & Hall 1979; Huenemoerder 1985; Huenemoerder & Barden 1986). On the smaller end of the mass ratio distribution, RZ Cnc and AR Mon among the giants and RV Lib and HR 5110 among the subgiants are suggested as systems in which the less massive cool component fills its Roche lobe (Hall & Kreiner 1980; Montesinos, Gimenez, & Fernandez-Figueroa 1988; Eker 1987). Most of the other systems having a less massive cool component are far from Roche lobe filling, but abnormal evolution is suggested in the sense that either the more massive star has the smaller radius or components have equal masses but their radii are greatly different (Montesinos et al. 1988; Popper & Ulrich 1977). To explain the configuration of these systems, mass transfer or loss similar to that suggested by Popper & Ulrich (1977) is required. Most of the systems showing normal evolution appear in the $q > 1$ region of our distribution. Since distribution changes direction from main-sequence to evolved systems, it is possible that some systems may still have the cooler component less massive. Given all the preceding reasons, the distribution of mass ratio $q = M_c/M_h$ resembles a Gaussian shape for evolved systems.

5. CONCLUSIONS

Kinematics of 146 chromospherically active binaries were investigated. Since the sample is very heterogeneous, the stars are segregated into groups best representing stars with similar ages and kinematical properties. In the process, U, V diagrams of various groups were carefully examined, and their kinematical quantities are listed in Table 3. Stellar ages implied by stellar space motions are recorded in the last column of this table for only those groups that make sense with regard to similar age and kinematical properties.

According to present data, stars as young as young disk population (~1 Gyr) and older than intermediate disk population (>5 Gyr) exist in the sample. The stars having these upper and lower age limits happen to be on the main sequence. Close binaries are able to draw angular momentum from the orbit to maintain rapid rotation well into old age. Therefore, the existence of old stars among these main-sequence systems is expected. Soderblom (1990) used a limited sample containing 32 BY Dra systems to study their kinematics. Ignoring five deviant stars in the velocity distribution permitted him to assign ~1–2 Gyr kinematical age. The actual number of BY Dra stars is 17 if the original definition by Bopp & Fekel (1977) is considered. Including all the stars in his list, the sample here contains 46 main-sequence systems (about 50% more) which is statistically more relevant and makes possible the segregations of stars into two different age groups.

According to Iben (1967), it takes 7 Gyr for a 1 $M_\odot$ star to deplete its hydrogen in the core. If 2 Gyr of overall contraction



time is included, the main-sequence lifetime of a 1 $M_{\odot}$ star becomes 9 Gyr. Because the main-sequence lifetime is much longer for less massive stars, all stars in our old main sequence group have spectral types later than G2 except two BH Vir and σ^2 CrB. However, listed masses of BH Vir are less than 1 $M_{\odot}$. σ^2 CrB have masses just slightly higher than 1 $M_{\odot}$, which means main-sequence lifetime could still be bigger than inferred age. On the other hand, broader ranges of masses and earlier spectral types exist among the young main-sequence group, which is consistent with the suggested age.

Subgiants appear to be slightly younger than intermediate disk population stars with ages of ~2–3 Gyr. Previously, kinematical stellar ages of the same order were suggested for main-sequence and RS CVn–type stars (Wielen 1974), and this was regarded as a serious argument against post–main-sequence evolution for these systems (Biermann & Hall 1976; Montle 1973). It takes 2.4 Gyr for a 1.5 $M_{\odot}$ star to reach the giant branch on the H-R diagram (Iben 1967) if mass loss does not occur. Recently a mass-loss rate as high as $\sim 2 \times 10^{-9}\ M_{\odot}\ \mathrm{yr}^{-1}$ has been suggested for chromospherically active stars by Mullan (1982). If it is assumed that a significant amount of mass ($\sim 0.2\ M_{\odot}$) was lost during the active star's lifetime, the system must have evolved off the main sequence with a higher mass than it has now. Therefore, the ~2–3 Gyr ages seem to agree well with the stellar masses listed here for subgiants.

Kinematics of giants also permits two different age groups. Distribution on *U*, *V* diagram and dispersions of low-velocity giants display similar kinematic features and same age (~1 Gyr) as the young main-sequence group. On the other hand, SB2 giants clearly appear younger than SB1 giants (Fig. 7). Therefore, one could prefer to include all SB2 systems in the younger group. Such a group is formed and named as GLVI2. The other high-velocity group from which all SB2 binaries are excluded is called GHVX2. *U*, *V* diagrams of these groups are shown in Figure 14. They are also added to Table 3. The average motions changed and dispersions increased a little for both groups with respect to previous grouping. Now, the young group of giants represent a kinematical age of ~1–2 Gyr. High-velocity group of giants in both cases appear older than intermediate disk population stars (>5 Gyr).

The SB1 systems appear older. That is a rather remarkable result if their inferred age is true. Their older appearance could be attributed to the possible existence of some white dwarfs as unseen companions. If such systems are present, they would certainly influence the motion statistics and cause the age of the group to be raised. Unfortunately, the present data are not sufficient to account for this influence.

On the other hand, the large scatter in the *U*, *V* diagram may be caused by using longer distances than true distances. Since errors in the distance directly influence tangential velocity, the space motion could be mistaken and *U*, *V*, *W* components might appear too large. Indeed, all of the groups among giants which display large dispersions contain stars with large uncer-

FIG. 14.—High- and low-velocity giants when all of the SB2 systems are included in the low-velocity group. The symbols and the presentation are the same as Fig. 3. Groups are labeled as follows: GLVI2 for low-velocity group which includes all SB2; GHVX2 for high-velocity group which excludes all SB2; GHVX2R for group GHVX2, but velocities are corrected for possible overestimation.

tainties, while their countergroups show reasonable uncertainties. This can be seen by comparing averages of propagated errors (Table 3) for the groups: G SB1 to G SB2; GHV to GLV and GHVX2 to GLVI2. Notice that the largest uncertainties are in group GHVX2. Therefore, it is possible that the distances of these systems are overestimated.

The effect of overestimated distance on a space velocity could be corrected by reducing the components of the velocity for the amounts of propagated errors. Such a reduction is applied to the stars in GHVX2, and the resulting U, V diagram is displayed in Figure 14 for comparison. This group of new data is called GHVX2R and also added to Table 3.

The group GHVX2 becomes as old as intermediate disk population stars ($\sim$5 Gyr) after correcting for possible overestimated distances. However, the group still appears older than GLVI2. But notice the five stars (ν^2 Sgr, GX Lib, HR 1908, CP $-41°3888$, CD $+31°18145$) in GHVX2R which stand out from the rest. If they are excluded (and they certainly would be excluded if they had white dwarf companions), then both groups will be kinematically indifferentiable. Accordingly, all giants could be considered as a single group having a kinematical age about $\sim$2 Gyr. Future research is required to improve the distances or investigate the existence of white dwarfs.

Popper (1980) remarks that members of classes generally have a common evolutionary state. That is apparently not true for RS CVn–type binaries, which contain very young main-sequence systems together with evolved giants, nor for the BY Dra stars, which contain very young and very old systems also. If age is not relevant to their definitions, Collier's (1982) note and the suggestion of Fekel et al. (1986) about some early-type RS CVn systems being early-type BY Dra stars becomes meaningless. It could be suggested that all main-sequence RS CVn type stars should be considered BY Dra–type stars, because the only difference in definition is that BY Dra stars have spectral types later than K while the rest of their features are in common. If age is relevant and the definition of a BY Dra star requires youth, then some of currently defined BY Dra stars would be excluded.

This research was supported by TUBITAK (Turkish Scientific and Technical Council). I would like to thank Zeki Aslan for his useful suggestions and Necdet Gudur for his help on accomplishing this project. My sincere thanks to D. S. Hall for careful proofreading and instructive criticism of the text. I am deeply indebted to the anonymous referee who brought to my attention very important points regarding the structure and the exposition of the present paper.

REFERENCES

Baliunas, S. L., & Vaughan, A. H. 1985, ARA&A, 23, 379
Balona, L. A. 1987, South Africa Astron. Obs. Circ., No. 11, 1
Biermann, P., & Hall, D. S. 1976, in IAU Symp. 73, The Structure and Evolution of Close Binary Systems, ed. P. Eggleton, S. Mitton, & J. Whelan (Dordrecht: Reidel), 303
Blaauw, A. 1965, in Stars and Stellar Systems, 5, Galactic Structure, ed. A. Blaauw and M. Schmidt (Chicago: Univ. of Chicago Press), 444
Blair, W. P., Stencel, R. E., Shaviv, G., & Feibelman, W. A. 1981, A&A, 99, 73
Bopp, B. W. 1983, in IAU Colloq. 71, Activity in Red Dwarf Stars, ed. P. B. Byrne & M. Rodonò (Dordrecht: Reidel), 343
———. 1984, ApJS, 54, 387
Bopp, B. W., Africano, J. L., Stencel, R. E., Noah, P. V., & Klimke, A. 1983, ApJ, 275, 691
Bopp, B. W., Africano, J., & Quigley, R. 1986, AJ, 92, 1409
Bopp, B. W., & Fekel, F. C. 1977, AJ, 82, 490
Budding, E., & Zeilik, M. 1987, ApJ, 219, 827
———. 1988, Ap&SS, 143, 393
Busso, M., Scaltriti, F., Persi, P., Ferrari-Toniolo, M., & Origlia, L. 1988, MNRAS, 234, 445
Catalano, S. 1983, in IAU Colloq. 71, Activity in Red Dwarf Stars, ed. P. B. Byrne & M. Rodonò (Dordrecht: Reidel), 363
———. 1986, in Flares, Solar and Stellar, ed. P. M. Gondhalekar (RAL workshop 86-085), 105
Catalano, S., & Rodonò, M. 1967. Mem. Soc. Astron. Ital., 38, 395
Charles, P. A. 1983, in IAU Colloq. 71, Activity in Red Dwarf Stars, ed. P. B. Byrne & M. Rodonò (Dordrecht: Reidel), 415
Collier, A. C. 1982, Ph.D. thesis, University of Canterbury, New Zealand
Collier, A. C., Evans, L. T., & Balona, L. A. 1987, private communication
Delhaye, J. 1965, in Stars and Stellar Systems, 5, Galactic Structure, ed. A. Blaauw & M. Schmidt (Chicago: Univ. of Chicago Press), 61
Demircan, O. 1990, in Active Close Binaries, ed. C. Ibanoglu (Dordrecht: Kluwer), 431
Drake, S. A., Simon, T., & Linsky, J. L. 1989, ApJS, 71, 905
Eaton, J. A., & Hall, D. S. 1979, ApJ, 227, 907
———. 1971, PASP, 83, 251
———. 1978. Inf. Bull. Var. Stars, 1426
Eker, Z. 1987, MNRAS, 228, 869
Fekel, F. C., Gillies, K., Africano, J., & Quigley, R. 1988, AJ, 96, 1426
Fekel, F. C., Moffett, T. J., & Henry, G. W. 1986, ApJS, 60, 551
Gilliland, R. L. 1985, ApJ, 299, 286
Hall, D. S. 1972, PASP, 84, 323
———. 1976, in Multiple Periodic Variable Stars, ed. W. S. Fitch (Dordrecht: Reidel), 287
———. 1981, in Solar Phenomena in Stars and Stellar Systems, ed. R. M. Bonnet & A. K. Dupree (Dordrecht: Reidel), 431
Hall, D. S., Fekel, F. C., Boyd, L. J., & Genet, R. M. 1986, in Cool Stars, Stellar Systems and the Sun, ed. M. Zeilik & D. M. Gibson (Heidelberg: Springer), 64
Hall, D. S., & Kreiner, J. M. 1980, Acta. Astr., 30, 387
Hearnshaw, J. B. 1979, in IAU Colloq. 46, Changing Trends in Variable Star Research, ed. F. M. Bateson, J. Smak, & I. H. Urch (Hamilton: Univ. of Waikato), 371
Hinderer, F. 1957, Astron. Nachr., 284, 1
Huenemoerder, D. P. 1985, AJ, 90, 499
Huenemoerder, D. P., & Barden, S. C. 1986, AJ, 91, 583
Iben, I. 1967, ARA&A, 5, 571
Johnson, D. R. H., & Soderblom, D. R. 1987, AJ, 93, 864
Johnson, H. L. 1966, ARA&A, 4, 193
Linsky, J. L. 1984, in Cool Stars, Stellar Systems, and the Sun, ed. S. Baliunas & L. Hartmann (Heidelberg: Springer), 244
Lloyd-Evans, T., & Koen, M. C. J. 1987. South Africa Astron. Obs. Circ., 11, 21
Lucy, L. B., & Ricco, E. 1979, AJ, 84, 401
Majer, P., Schmitt, J. H. M. M., Golub, L., Harnden, F. R., & Rosner, R. 1986, ApJ, 300, 360
Mathieu, R. D., & Mazeh, T. 1988, ApJ, 326, 256
Mazeh, T., Latham, D. W., Mathieu, R. D., & Carney, B. W. 1990, in Active Close Binaries, ed. C. Ibanoglu (Dordrecht: Kluwer), 145
Mihalas, D., & Binney, J. 1981, Galactic Astronomy (2d ed.; San Francisco: W. H. Freeman and Company)
Milone, E. F. 1976, ApJS, 31, 93
———. 1977, AJ, 82, 992
Montesinos, B., Fernandez-Figueroa, M. J., & Castro, E. 1987, MNRAS, 229, 627
Montesinos, B., Gimenez, A., & Fernandez-Figueroa, M. J. 1988, MNRAS, 232, 361
Montle, R. E. 1973, M.A. thesis, Vanderbilt University
Morgan, J. G., & Eggleton, P. P. 1979, MNRAS, 187, 661
Morris, D. H., & Mutel, R. L. 1988, AJ, 95, 204

Mullan, D. J. 1982, A&A, 108, 279
Peterson, R. C., Wilmarth, D. W., Carney, B. W., & Chaffee, F. H. 1980. ApJ, 239, 928
Plavec, M. 1968, Adv. Astron. Astrophys., 6, 201
Popper, D. M. 1980, in IAU Symp. 88, Close Binary Stars, Observations and Interpretations, ed. M. J. Plavec, D. M. Popper, & R. K. Ulrich (Dordrecht: Reidel), 387
Popper, D. M., & Ulrich, R. K. 1977, ApJ, 212, L131
Reglero, V., Gimenez, A., & Estela, A. 1990, A&A, 231, 375
Rodonò, M. 1986, Highlights Astron., 7, 429
Slee, O. B., Nelson, G. J., Stewart, R. J., Wright, A. E., Innis, J. L., Ryan, S. G., & Vaughan, A. E. 1987, MNRAS, 229, 659
Soderblom, D. R. 1990, AJ, 100, 204
Spitzer, L., & Schwarzschild, M. 1953, ApJ, 118, 106
Stewart, R. T., Innis, J. L., Slee, O. B., Nelson, G. J., & Wright, A. E. 1988, AJ, 96, 371
Strassmeier, K. G., & Fekel, F. C. 1990, A&A, 230, 389
Strassmeier, K. G., Hall, D. S., Zeilik, M., Nelson, E., Eker, Z., & Fekel, F. C. 1988, A&AS, 72, 291 (CCABS)
Tassoul, J. L. 1988, ApJ, 324, L71
Thomas, H. S. 1977, ARA&A, 15, 127
Upgren, A. R. 1988, PASP, 100, 251
von Hoerner, S. 1960, Mitt. Astr. Rechen. Inst., Heidelberg, Ser. A, 13
Vyssotsky, A. N. 1951, AJ, 56, 62
Wielen, R. 1974, Highlights Astron., 3, 395
Zahn, J.-P., & Bouchet, L. 1989, A&A, 223, 112