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HIGH GALACTIC LATITUDE CATACLYSMIC VARIABLES

STEVE B. HOWELL
Planetary Science Institute, Tucson

AND

PAULA SZKODY
Department of Astronomy, University of Washington
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ABSTRACT

We have isolated a sample of stars which are either known or are good candidates for being halo cataclysmic variables. This sample consists of 84 stars of which 57 are dwarf novae (two of these are probable DQ Her systems), 12 are nova-like stars, seven are AM Her objects, and eight are classical novae. Periodicities are known for 27 of the systems. If these stars are indeed halo members, then their distances range from 350 pc to 8 kpc and they represent objects that should be significantly older than their disk counterparts. If they do not represent true halo members, then they are intrinsically very faint systems ($M_v > +10$). Comparing the gross properties of this sample to those for the disk cataclysmic variables, we find that below the period gap, the mean outburst amplitude for the halo dwarf novae is 3 mag greater than for the disk dwarf novae. For systems with periods ≤ 4 hr, the halo cataclysmic variables have a higher percentage of systems below the period gap than the disk cataclysmic variables. The implications of these findings are discussed, as well as possible sample biases and selection effects.

Subject headings: high-latitude objects — stars: binaries — stars: dwarf novae — stars: novae

I. INTRODUCTION

Cataclysmic variables (CVs) are close binaries in which a mass-losing secondary (a late main-sequence dwarf) is in orbit with a white dwarf primary. Typical dimensions for these systems are of the order of a solar diameter, and accordingly they have periods that are very short; a little over 1 hr to about 15 hr. Periods in the range of 2–3 hr are uncommon, and this interval has been termed the CV period gap. A comprehensive review of these systems and discussion of the period gap is given in Patterson (1984).

The material that is lost from the secondary usually accumulates in a disk around the primary with eventual accretion onto its surface. This transfer of material to the disk can be responsible for flickering (random low-level variations of order 0.1–1.0 mag), and periodic variations due to viewing the hot spot created at the stream/disk interface. An increase in the transfer rate of material from the secondary to the disk, or a disk instability leading to increased transfer of material through the disk, is thought to be the cause of the usual 2–5 mag outbursts observed in the dwarf novae type of CVs (see reviews by Smak 1984 and Wade and Ward 1985). All dwarf novae with periods below the period gap show, at times, enhanced outbursts called superoutbursts. During the superoutbursts, there are photometric humps present at a period a few percent longer than the orbital period. These stars belong to a subgroup of CVs known as the SU Ursae Majoris stars (reviewed by Warner 1985). Current work on the cause of the superoutburst phenomenon (Whitehurst 1988); involves the tidal stress in an eccentric accretion disk.

Some CV primaries have significant magnetic fields (100,000 to a few million gauss) which cause the inner disk to be disrupted and this material to be funneled along field lines to accrete at the magnetic poles of the white dwarf. As the white dwarf spins (with a period shorter than the orbital period), the accretion column beam sweeps around the disk and creates a pulse that can be observed in the optical. Sometimes the beat period between the primary spin period and the orbital period (or its harmonics) are seen. If the magnetic field is larger than ~20 MG, the entire accretion process is governed by the field lines, no disk forms, and the spin period of the white dwarf is synchronized with the orbital period. The first of these magnetic CVs are a subgroup called DQ Herculis stars (see Warner 1985) while the second type (with no disk) are called AM Herculis stars (see Lamb 1985).

Howell (1982) showed that of the 426 known variables designated as N (all types), Nl, UG, and Z Cam in the third edition of the General Catalogue of Variable Stars (Kurkarkin 1969, hereafter GCVS), only 60 (14%) of them were above 30° Galactic latitude. In his review, Patterson (1984) listed all the CVs (known at that time), with measured orbital periods. His list contained 113 stars of which only nine (8%) are possible Galactic halo objects. Even recent large surveys such as the PG survey (Green, Schmidt, and Liebert 1986) go only as faint as $B \sim 16.5$ and thus (for an assumed CV M_v of 7.5) hardly reach into the Galactic halo. Bond and Tifft (1974) and Bond (1978) presented spectroscopy of over 100 high-latitude blue variables from the GCVS, yet only two of them are faint enough to be possible halo members. These four examples show that the study of CVs has been severely limited to those systems that reside in the plane of the galaxy. The main reason for this bias is that in general, any system in the halo is much fainter due to its large distance, and therefore detailed studies of properties such as orbital periods would require large amounts of time on the largest telescopes.

We have isolated a sample of 84 high Galactic latitude CVs in order to determine their properties and compare them to the known properties of those in the Galactic disk. Most of the sample stars are extremely faint suggesting that they are indeed members of the Galactic halo and may represent a distinct population of CVs. If these stars are really Population II CVs, then one would expect them to be of a very old uniform age, contain low-Z material, and contain a large proportion of short-period systems. If they are simply intrinsically faint, nearby systems, then the accepted values of CV space densities and lifetimes may need to be altered. This latter possibility may prove to be even more interesting than the first. We shall use the term "halo CV" to refer to the stars in question here.

In this paper, we present the results of the *first* comprehensive study of a large sample (84) of probable halo cataclysmic variables. Of the 27 periods known to date for this sample, 11 (40%) have been determined recently by our group. Specific details for these stars have been published elsewhere (see Howell *et al.* 1988; Howell and Szkody 1988; Howell *et al.* 1990; Szkody *et al.* 1989). Our purpose here is to compare the gross properties of the halo CVs with those known for the larger group of well-studied disk CVs. Section II states the sample selection criteria, while § III discusses the global properties we have found for these stars. Section IV discusses how these stars relate to their relatives in the disk and what conclusions can be drawn from the available data.

II. SAMPLE SELECTION

The initial sample selection was done via a computer search using the facilities of the National Space Science Data Center (NSSDC) at the NASA/Goddard Space Flight Center. The software used to extract the data was kindly provided by L. Brotzman. Two search tactics were employed, mostly as a means of cross-checking the resulting lists so as to achieve a high level of completeness. The first method was to search for objects with Galactic latitudes of greater than $\pm 40°$ *and* a listed amplitude range of greater than 1.9. (This criteria resulted in searched RA values from about 9^h to 17^h). This initial list of 168 stars were mostly type M (Miras) or of type SR (semiregular variables). The second method was a complete search of the GCVS for *all* objects with types of N* (* = any additional designation), UG*, Z Cam*, and a listed magnitude range of greater than 1.9. This list contained 461 objects. Searches of each list for CV candidate stars were made and then correlated in order to form a sample.

The above search criteria were not by themselves sufficient to place a star into our sample; the star also had to be a probable member of the galactic halo. We assumed that the absolute magnitude of our sample was the same as the mean values determined for CVs and novae at quiescence ($M_v = 7.5$ and 4.5, respectively; see Wade and Ward 1987), and we chose the Galactic disk/halo boundary at approximately 350 pc z-distance. Patterson (1984) showed that the scale height of CVs with known distances was only 190 pc, and Allen (1976) gives the mean z-distance for Population II stars as starting at 400 pc above the plane. Therefore, our choice of a minimum z-distance seems a good one. The minimum magnitude listed for any given object had to place it at a z-distance of greater than 350 pc, as well as meeting the above conditions, in order to be included in the final list. By using the condition of assigning an M_v to a star, even low Galactic latitude objects could become part of the sample if they were faint enough. Due to the fact that reddening can be responsible for faintness as latitude decreases, we allowed no objects with latitudes of less than 30° in the sample. It turned out that very few stars (less than 10%) were marginal cases for inclusion into the list using any of the above criteria. Additional stars from the literature (e.g., the PG list of CV candidates; Green *et al.* 1982), preprints, and the new fourth edition of the GCVS (Kholopov *et al.* 1985) have since been added.

It should be pointed out that the four previously known AM Her stars that are part of this sample had their distances estimated based on their minimum magnitude and an M_V of 7.5. Warner (1987) states that "estimates of their $\dot{M}_2$ place them among the DN [in M_V] at minimum light." Al Cam and AH Eri, which are probable magnetic systems (DQ Hers) have been treated as DN in terms of an assigned M_V. They have shown multiple outbursts and are thus DN as well as possibly DQ Hers, presumably like EX Hya. For the nova-like systems, Warner (1987) showed that their M_V should be nearer to 4.5 than 7.5. We initially picked these using M_V of 7.5, as many of these objects (like the PG objects) are not well studied, and the NL assignment may be incorrect. Since our objective was to isolate stars well outside the disk, we feel that this choice was very conservative. Thus, if we have an error in the sample for the NL systems, it is in the direction of definite inclusion as a probable halo member.

Many selection effects are undoubtedly a part of our sample. Using stars from the GCVS means, by its very nature, that the contributed variables come from varied sources. The attendant biases, selection criteria, and possible cataloging errors are retained in our sample. Our observations have favored the determination of periods of 4 hr or less due mostly to observational constraints of time and our desire to obtain data on a large number of stars. We generally would observe a new star for 2–4 hr, do a quick-look analysis, and then reobserve the object if it showed any indication of a periodic nature. We determined a modulation was real if it was seen in at least two independent light curves. About 70% of our observed systems showed a repeatable photometric variation (see Howell and Szkody 1988 for a discussion of the period finding techniques used and Howell *et al.* 1990 for summary statistics of our observational program).

Table 1 lists the 84 stars known to date which we consider to be probable Galactic halo CVs. Figure 1 shows plots of the minimum and maximum magnitude for the sample stars as well as their Galactic longitude and latitude, while Table 2 gives the sample breakdown by variable type. Warner (1987) showed that for CVs, the system inclination plays an important role in its M_V value. Even though the mean M_V of the NL and N classes is 4.5 and that for the DN is 7.5, the ranges are quite large: $M_V = 2$–7 for NL and N and $M_V = 5$–11 for DN. In Table 3, we have calculated the *minimum* z-distance (using $\pm 40°$ Galactic latitude which is our sample cutoff) that the sample stars would have for the M_V ranges given above. If we then assume that *as many as* one-half of the systems are inclined so as to have the lowest values of M_V, we find that *at most* only ~ 20 systems from our sample would be less than the 350 pc limit. In fact, only about one-half of our stars are near the 40° cutoff, so that realistically the number of possible sample members below a z-distance of 350 pc is more likely to be *at most* ~ 8.

III. RESULTS

For cataclysmic variables as a class, knowledge of the orbital period is of fundamental importance. Therefore, a major part of our ongoing program on these stars is the determination of the orbital periods. Table 4 presents the list of the 27 stars from the sample for which periods have been determined by our study or by others. Note that AL Com and AH Eri (Howell and Szkody 1988; Szkody *et al.* 1989) both show periods that are less than the ~ 72 minute minimum period predicted for a CV by Nelson, Chau, and Rosenblum (1985). It is likely that

TABLE 1

PROBABLE HALO CATACLYSMIC VARIABLES AND CANDIDATES[a]

Star	Type	R.A. (1950)	Decl. (1950)	l	b	Magnitude Minimum	Maximum	Δ	References
CV Aqr	UG	$21^h18^m58^s$	−14°31′	36°6	−39°7	16.6	12.4	4.2	
EG Aqr	UG	23 22 9	−8 35	71.7	−62.3	18.5	14	4.5	
EH Aqr	UG	23 31 29	−23 7	42.5	−72.0	21	17.5	3.5	1
VY Aqr	UG	21 9 28	−9 2	41.6	−35.2	17.5	8	9.5	
VZ Aqr	UG	21 27 48	−3 12	50.6	−36.3	17.2	11.3	5.9	
AB Boo	N:	14 4 43	20 59	16.7	71.6	22	4.5	17.5	
T Boo	N:	14 11 46	19 18	14.3	69.4	18.5	9.7	8.8	
TT Boo	UG	1 55 5	40 56	68.8	60.7	19.6	12.7	6.9	2
UZ Boo	UG	14 41 42	22 13	27.8	64.0	20.5	11.5	9	2
WW Cet	UG	0 8 52	−11 46	90.0	−71.8	16.8	9.3	7.5	
WX Cet	UG	1 14 38	−18 12	157.0	−79.1	18	9.5	8.5	1
XX Cet	NL	2 20 20	−19 46	197.9	−67.8	19.7	18	1.7	1
AK Cnc	UG	8 52 35	11 30	216.7	32.6	17	13	4	3
AR Cnc	UG	9 19 6	31 18	194.9	44.5	19.0	15.3	3.7	3
CC Cnc	UG	8 33 24	21 32	203.7	32.2	17.6	13.1	4.5	3
DE Cnc	UG	8 32 33	19 5	205.3	31.4	18	14.6	3.4	
AL Com[c]	UG(DQ)	12 29 54	14 37	282.9	76.5	22	13	9	1, 2
FU Com	UG	12 28 24	27 41	211.8	85.4	21	19.5	1.5	3
FY Com	UG	12 46 54	27 41	181.6	89.5	21	19.5	1.5	3
GO Com	UG	12 54 11	26 53	9.1	88.7	20	13.1	6.9	3
RY Dor	N	5 14 56	−66 51	277.2	−34.2	18	12.4	5.6	
YY Dra[c]	UG	11 40 45	71 59	130.3	44.4	16.5	12.9	3.6	4, 5
CP Dra	UG	10 11 25	73 41	136.3	39.4	20	15.1	4.9	
DM Dra	UG	15 33 0	59 57	94.1	47.2	20.7	15.5	5.2	3
AH Eri	UG(DQ)	4 18 4	−13 29	208.3	−39.0	18.5	13.5	5	1
CP Eri	UG	3 8 8	−9 56	191.7	−52.9	19.2	16.7	2.5	1
XZ Eri	UG	4 9 10	−15 32	209.4	−42.3	17.5	14.6	2.9	
SZ For	UG	3 39 13	−26 46	222.1	−52.3	20.8	18.2	2.6	
UZ For[c]	AM	3 33 20	−25 54	220	−53.0	18.5	17	1.5	6
V544 Her	UG	16 35 39	8 43	25.0	33.5	20	14.5	5.5	3
V589 Her	UG	16 19 54	19 29	35.6	41.3	17.5	14.1	3.4	3
V592 Her	NS	16 28 42	21 24	38.8	40.0	20	12.3	7.7	
V610 Her[d]	UG	16 41 33	22 37	41.5	37.6	16.8	16.2	0.6	
V611 Her[d]	UG	16 41 33	20 4	38.5	36.7	16.4	15.4	1.0	
RU Hor	UG	2 45 1	−63 48	283.9	−49.1	17.5	13.9	3.6	
TT Ind[d]	UG	20 29 46	−56 44	341.0	−36.3	16.5	14	2.5	
T Leo	UG	11 35 53	3 39	263.5	60.5	15.7	10	5.7	
X Leo	UG	9 48 21	12 7	223.7	45.1	16.5	11.1	5.4	2
DO Leo[c]	NL	10 38 11	15 27	230.0	57.4	17	16	1.0	4
DP Leo[c]	AM	11 14 38	18 14	245.0	76.0	19.5	17.5	2.0	
RZ Leo	UG	11 34 49	2 6	264.8	59.1	19.2	11.5	7.7	2
U Leo	N	10 21 23	14 15	226.3	53.2	17.3	9.5	7.8	
RU LMi	UG	9 59 24	34 8	191.8	53.2	19.5	13.8	5.7	3
ST LMi[c]	AM	11 2 59	25 22	212.0	68.0	16.4	15	1.4	
LU Men	UG	4 43 40	−76 42	289.4	−33.7	17	11.4	5.6	
AO Oct	UG	20 59 25	−75 33	317.8	−34.4	21	13.5	7.5	
BE Oct	UG	23 58 5	−77 36	306.5	−39.5	17.5	15.4	2.1	
V699 Oph	UG	16 22 36	−4 34	9.7	29.4	18.5	13.8	4.7	3
V794 Sco	UG	16 8 20	−9 43	2.6	29.1	17.3	16	1.3	
LX Ser[c]	NL	15 35 44	19 2	29.8	51.0	17.4	13.3	4.1	
MR Ser[c]	AM	15 50 33	19 5	33.0	47.7	17	14.9	2.1	4, 7
X Ser	NB	16 16 41	−2 22	10.8	31.9	18.3	9	9.3	3
V2276 Sgr	UG	20 22 52	−43 50	356.9	−35.0	16.7	14.3	2.4	
KK Tel	UG	20 24 54	−52 28	346.3	−35.8	19.7	13.5	6.2	
VW Tuc	UG	0 18 5	−74 10	305.9	−43.1	16.5	15.4	1.1	
VZ Tuc	NA	0 32 7	−73 33	304.7	−43.8	18	11.4	6.6	
SW UMa	UG	8 32 59	53 39	164.8	37.0	17.0	9.5	7.5	2, 8
AN UMa	AM	11 1 36	45 19	165.1	62.2	20.2	14.9	5.3	
BC UMa	UG	11 49 39	49 31	146.3	65.1	18.3	10.9	7.4	3
BZ UMa[c]	UG	8 49 53	58 0	159.0	38.8	17.8	10.5	7.3	
CE UMa	UG	11 13 30	29 38	201.3	68.9	21	15.5	5.5	
CH UMa[c]	UG	10 3 9	67 47	142.9	42.7	16	10.6	5.4	5
CI UMa	UG	10 14 7	72 12	137.6	40.5	17.5	13.8	3.7	3
CY UMa	UG	10 54 2	49 57	159.4	58.6	17	11.9	5.1	
DI UMa	UG	9 8 53	51 2	167.5	42.7	17	15	2.0	
DR UMa	NL	13 57 0	55 58	104.5	58.9	18.2	17.5	0.7	
DV UMa[c]	UG	9 43 26	+45 0	174.0	45.0	19.3	14	5.3	9
RW UMi	NA	16 49 48	77 7	109.6	33.2	21	6	15.0	1
TW Vir	UG	11 42 48	−4 9	273.6	54.6	16.4	11.2	5.2	2

TABLE 1—*Continued*

Star	Type	R.A. (1950	Decl. (1950)	*l*	*b*	Magnitude Minimum	Magnitude Maximum	Δ	References
PG 0134+070	NL	1 34 18	7 1	141.0	−53.9	15.8	...	...	1, 4
PG 0244+104	NL	2 44 55	10 23	161.0	−42.9	15.8	...	...	4
PG 0818+513[d]	NL	8 18 53	51 15	168.0	34.8	15.5	...	...	4
PG 0917+342[d]	NL	9 17 8	34 9	183.0	44.5	15.1	...	...	4
PG 0948+344	NL	9 48 52	34 21	175.0	51.0	16.8	14.4	2.4	4
PG 1341−079	UG	13 41 0	−7 59	325.0	52.4	15.8	13	2.8	3, 4
PG 1550+131	NL	15 50 33	13 3	24.0	45.3	16.0	...	...	4
PG 2240+193[d]	NL	22 40 1	19 16	88.0	−33.8	15.7	...	...	4
2138−453[c]	UG	21 38 11	−45 18	358	−47.0	20.4	...	...	10
V1	AM	21 34 45	−43 55	0.0	−45.0	20.72	17.87	2.9	11
V5	UG	21 25 23	−42 45	0.0	−45.0	19.6	18.3	1.3	11
V6	UG	21 25 56	−42 42	0.0	−45.0	18.53	16.47	2.1	11
CBS 31	NL	10 51 46	30 23	200	45.0	16.0	...	...	12
CW 1045+525	UG	10 45 0	52 30	158	57.0	16.5	...	...	12
EXO 0234−5232	AM	2 34 32	−52 32	273	−58.0	20.1	18.8	1.3	13

[a] All data are from the GCVS, except the magnitude data if a reference is given.
[b] If no reference is given, the GCVS is the source of the original reference.
[c] Other names: AL Com = Rosino's star; YY Dra = DO Dra = PG 1140+719; DO Leo = PG 1038+155; DP Leo = 1E 1114+18; UZ For = EXO 033319−2554.2; ST LMi = CW 1103+254; LX Ser = Stepanian's object; MR Ser = PG 1550+191; BZ UMa = PG 0849+580; CH UMa = PG 1003+678; DV UMa = US 943; 2138−453 = UK survey object.
[d] Marginal halo object, *z* slightly < 350 pc.

References.—(1) Szkody *et al.* 1989; (2) Howell and Szkody 1988; (3) Howell *et al.* 1990; (4) Green *et al.* 1982; (5) Thorstensen 1986; (6) Beuermann, Thomas, and Schwope 1987; (7) Szkody 1988; (8) Shafter *et al.* 1986; (9) Howell *et al.* 1988; (10) Hawkins and Véron 1987; (11) Hawkins 1983; (12) Wagner *et al.* 1988; (13) Beuermann *et al.* 1987.

these observed periods are not orbital in nature but indicate membership in one of the magnetic subclasses of CVs. Thus, we know orbital periods for 25 (30%) of the 84 sample members.

Figure 2 shows period histograms for the halo stars from Table 4 except AL Com and AH Eri and for a set of disk CVs taken from Patterson (1984). In an effort to compare more equally CV types in Figure 2, we did not use a total of 17 related systems from Patterson's list; 14 of type DD, XR, or V471 and three systems with periods of >10 hr. To compensate for our observational bias toward periods <4 hr (since ~70% of our systems showed repeatable variations, we feel that below 4 hr we are about 70% complete in our period determinations), we compare only the number of systems of each kind below this period value. For the halo objects, this represents a sample of 21 systems, and for the disk stars, it is a sample of 49 systems.

While both sets of objects seem to have a preference for periods in the 1.5–2 hr range, the halo CVs appear to have a higher percentage of systems below the gap (16/21 = 76%) in comparison to the disk CVs (28/49 = 57%). In addition, there is a difference in the fraction of systems between 3 and 3.5 hr (1/21 = 5% for halo CVs vs. 13/49 = 27% for the disk CVs).

Outburst amplitude histograms are presented in Figure 3. The disk stars plotted are again from Patterson and include

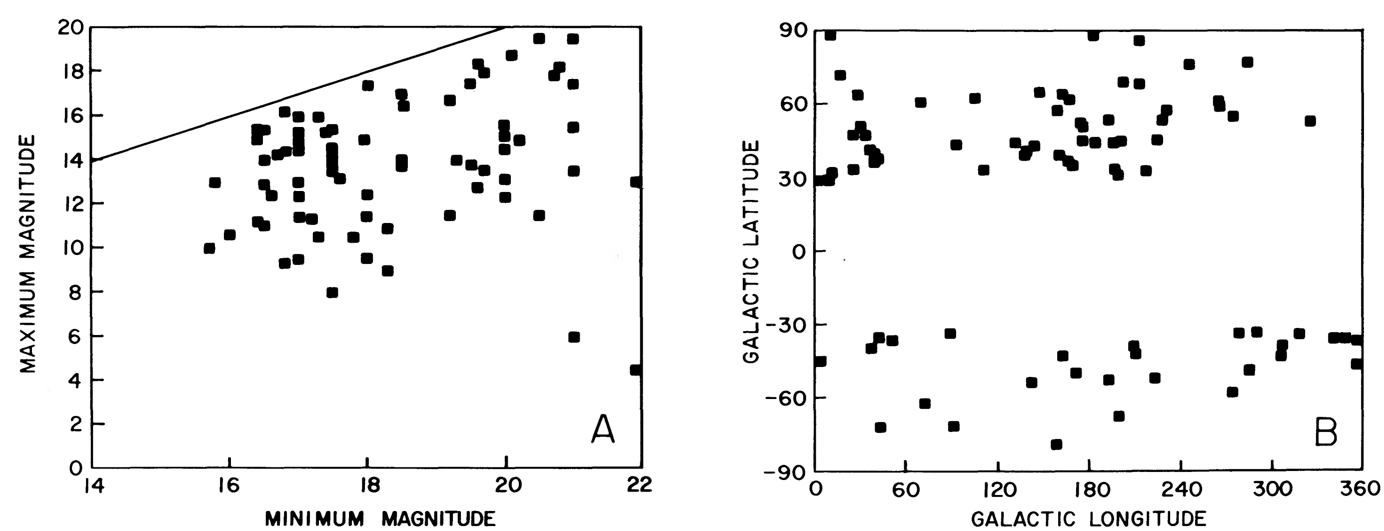

Fig. 1.—(*a*) The minimum and maximum recorded magnitude for all the stars in the sample taken from Table 1. The line shows the locus of points for which minimum and maximum magnitudes are equal. (*b*) The sample distribution in Galactic longitude and latitude (see Table 1).

TABLE 2

BREAKDOWN OF SAMPLE BY TYPE

Type	Number
UG	57
NL	12
N	8
AM	7

only those which were designated as dwarf novae. They appear to be normally distributed about a mean of $\Delta m = 4.1 \pm 1.3$. Figure 3 also shows all the dwarf novae listed in Table 1. Their distribution is much broader and has a mean of $\Delta m = 4.7 \pm 2.4$. χ^2 tests reveal that the disk and halo stars are distributed normally (95% and 99.5% confidence levels, respectively), but, at the 80% confidence level, they are *not* members of the *same* distribution function. We cannot rule out the possibility that the halo distribution is multimodal.

Figure 4 shows the relation between orbital period and outburst amplitude. The disk stars are all of Patterson's UG stars with known orbital periods, while the halo stars are the UG objects listed in Table 3 excluding AL Com and AH Eri. The number of halo systems with orbital periods below the period gap is only about half as many as for the disk systems, but it can clearly be seen that the mean outburst amplitude range for the two groups are different. The disk stars have $\overline{\Delta m} = 4.3 \pm 1.4$ ($\overline{\Delta m} = 4.1 \pm 1.1$ if the large-amplitude possibly odd disk system [WZ Sge; see Gilliland, Kemper, and Suntzeff 1986] is not used) while for the halo stars $\overline{\Delta m} = 6.9 \pm 1.7$. Above the gap, it also appears that the mean halo outburst amplitude may be larger for the halo stars, but there are too few data to be statistically certain.

TABLE 3

MINIMUM z DISTANCE FROM M_V RANGE

A. DWARF NOVAE + AM HERCULIS SYSTEMS

MAGNITUDE AT MINIMUM (mag) ($\pm$0.5)	NUMBER OF STARS	MINIMUM z DISTANCE (pc) [$b = \pm 40°$] $M_v = 5$	7.5	11
15.5	2	1058	334	66
16.5	13	1676	530	106
17.5	16	2656	840	168
18.5	8	4210	1331	265
19.5	9	6672	2110	421
20.5	10	10575	3344	667
21.5	5	16761	53001	1058
22.5	1	26563	84001	1676

B. NOVA-LIKE + NOVAE SYSTEMS

MAGNITUDE AT MINIMUM (mag) ($\pm$0.5)	NUMBER OF STARS	MINIMUM z DISTANCE (pc) [$b = \pm 40°$] $M_v = 2$	4.5	7
15.5	5	4210	1331	421
16.5	3	5572	2110	667
17.5	3	10575	3344	1058
18.5	5	16761	5300	1676
19.5	1	26563	8400	2656
20.5	1	42100	13313	4210
21.5	1	66724	21100	8672
22.5	1	105750	33441	10575

TABLE 4

SYSTEMS WITH KNOWN PERIODS

STAR	PERIOD Hours	Minutes	REFERENCES
AL Com	0.7	42	1, 2
AH Eri	0.7	42	2
SW UMa	1.4	82	1, 3
T Leo	1.4	85	4
CBS 31	1.5	90	5
DP Leo	1.5	90	6
VY Aqr[a]	1.6	96	7
RZ Leo	1.7	102	1
BZ UMa	1.8	107	8
V1	1.8	109	9
TT Boo	1.9	111	1
MR Ser	1.9	113	10
AN UMa	1.9	114	11
ST LMi	1.9	114	6
EXO 0234−5232	1.9	115	12
RW UMi	2.0	117	1
DV UMa	2.1	124	13
UZ For	2.1	127	14
TU Men	2.8	170	15
U Leo[b]	3.2	193/385	16
LX Ser	3.8	228	17
X Leo	3.9	237	1, 18
YY Dra	4.0	240	20
WW Cet	4.2	253	19
TW Vir	4.4	262	1, 4
PG 0134+070	5.2	313	2
CH UMa	8.3	496	21

[a] Superhump period is between 93 and 99.5 minutes.

[b] Need confirmation as a CV.

REFERENCES.—(1) Howell and Szkody 1988; (2) Szkody *et al.* 1989; (3) Shafter *et al.* 1986; (4) Shafter 1983; (5) Wagner *et al.* 1990; (6) Szkody *et al.* 1985; (7) H. E. Bond 1986; private communication; (8) Szkody and Feinswog 1988; (9) Tuohy *et al.* 1988; (10) Wilson *et al.* 1986; (11) Schmidt *et al.* 1986; (12) Beuermann *et al.* 1987; (13) Howell *et al.* 1988; (14) Beuermann, Thomas, and Schwope 1987; (15) Stolz and Schoembs 1984; (16) Downes and Szkody 1989; (17) Schwarzenberg-Czerny 1984; (18) Shafter and Harkness 1986; (19) Thorstensen and Freed 1985; (20) Mateo *et al.* 1990; (21) Thorstensen 1986.

IV. DISCUSSION

Two possibilities exist for interpreting of the stars in our sample. They could be bona fide members of the Galactic halo, as we suspect, in which case some of them are extremely far away (up to 8 kpc!) or they could be intrinsically very faint systems (i.e., $M_v > 7.5$). In the former case, the halo CVs should be all of uniform age and older than their disk counterparts, should have formed under different initial conditions than the disk stars, and should consist of low-Z material. A different metal content could have an effect on the outburst amplitude, time scale, and duration of these systems (see Cannizzo, Shafter, and Wheeler 1988 and references therein). If the latter is true, then these stars would have $M_v > +10$, very different from that of the accepted numbers of +4.5 and +7.5 for classical and dwarf novae respectively (Kraft and Luyten 1965; Wade and Ward 1987). In this case, our estimate of space densities and lifetimes for CVs would need to be altered. The need for distance determination is thus critical in understanding these objects.

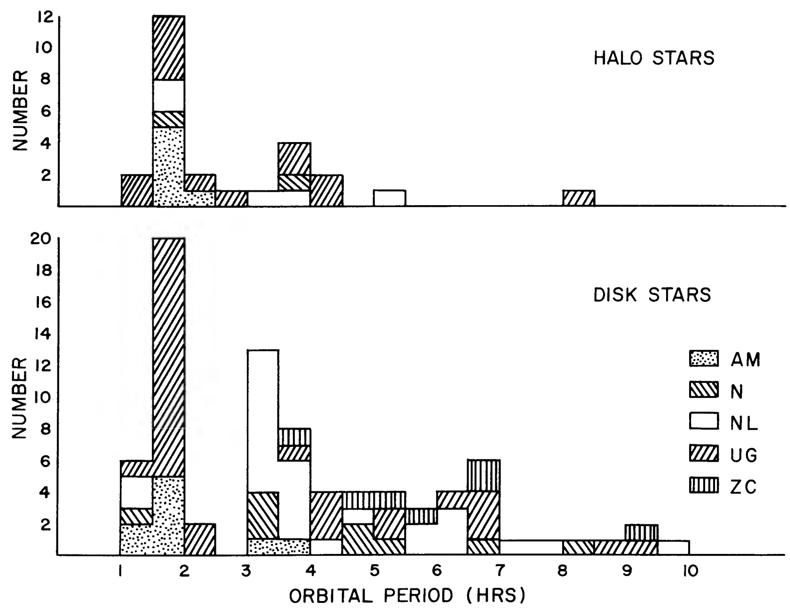

FIG. 2.—Orbital period histograms for the halo stars listed in Table 3 (does not include AL Com and AH Eri), and a sample of disk CVs taken from Patterson (1984) (see text).

We have seen (Fig. 2) that the halo systems seem to show a perference for orbital periods below the period gap. If these stars are indeed older than the disk systems, one would expect them to consist of shorter orbital periods as speculated in evolutionary models (Paczyński and Sienkiewicz 1983; Spruit and Ritter 1983; Hameury *et al.* 1988).

The large range in Δm observed for UG outbursts in the halo systems (see Fig. 3) is of interest. It may be an indication of a metallicity difference affecting the disk instability or superoutburst mechanisms. It appears (Fig. 4), that the short-period halo systems have a much larger outburst amplitude. The correct distance determination (from detection and spectral typing of the secondary, for example) of the eight halo systems below the period gap will determine if the quiescent disk magnitudes are fainter than for the disk CVs, possibly implying lower mass transfer rates. Some clues to the mass transfer rate can come from compilations of the outburst recurrence time scales (currently unknown for the poorly studied faint systems) and from the amplitudes of hot spot modulations, which are generally larger in low mass transfer systems. Alternatively, observing only large amplitudes for the halo stars could be merely a selection effect. It is possible that as we go to fainter apparent magnitudes, we only discover the dwarf novae with large outburst amplitudes, i.e., easily detectable. Figure 3 certainly shows that low-amplitude halo CVs seem to exist. As in the case with most of our sample stars, very little information is known, and the small-amplitude systems seen in Figure 3 may represent simply orbital modulations and not true dwarf novae outbursts at all. Note, however, the lack of an appreciable number of large-amplitude disk systems that one might expect detected and cataloged if they do indeed exist.

V. CONCLUSION

We have presented the initial results of our study of a sample of halo cataclysmic variables which appear to have some differences from their well-studied counterparts lying in the Galactic disk. These differences include larger outburst amplitudes and shorter orbital periods. Our observational program is continuing with further orbital period determinations, spectroscopic observations of those systems showing abnormal spot or pulse

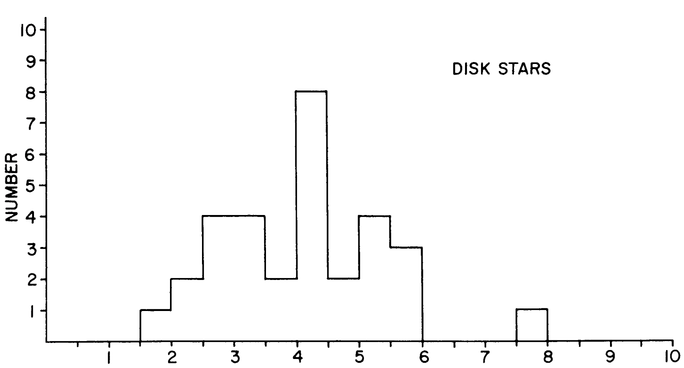

FIG. 3*a*

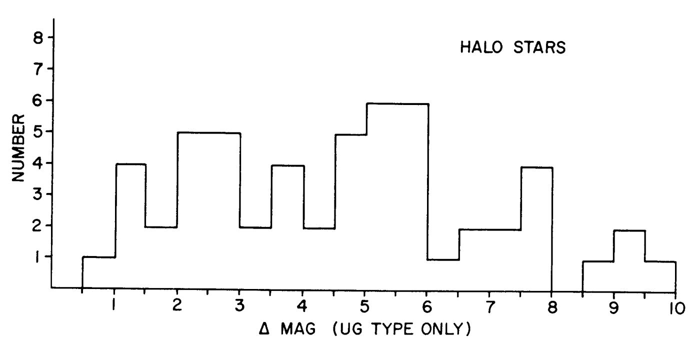

FIG. 3*b*

FIG. 3.—Outburst amplitude histograms for UG stars only from Table 1 and the Patterson (1984) sample used (see text)

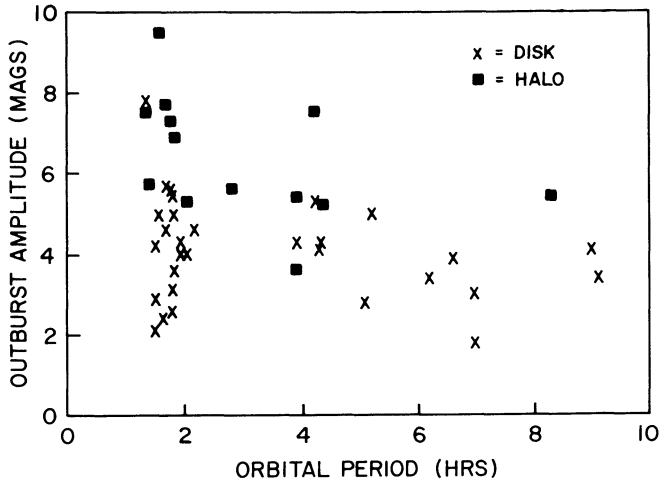

FIG. 4.—The relation between orbital period and outburst amplitude for the stars in Fig. 3 with known periods. The halo systems with periods below the period gap have an outburst amplitude of ~ 3 mag greater than the disk systems.

modulations, and distance determinations based on secondary typing. We encourage other observers to aid in the database collection for the halo CVs. In this way, a better understanding of the statistical differences of the halo and disk CVs may be determined through available data on a large number of objects.

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STEVE B. HOWELL: Planetary Science Institute, 2421 East 6th Street, Tucson, AZ 85719

PAULA SZKODY: Department of Astronomy, University of Washington, Seattle, WA 98195