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NEW VARIABLES ON THE EDGE OF THE NORTHERN MILKY WAY – PAPER 1: BeV1–30

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The new variable stars reported here have been found as part of a programme to discover and classify new variables using CCD observations of selected fields on the edge of the northern milky way (eg. Bernhard et al. 1997, Bernhard 1999). In this paper the details of the first group of stars resulting from this programme are given.

The observations were made using a 20-cm Schmidt-Cassegrain telescope and an unfiltered Starlight Xpress SX CCD camera. The CCD camera uses a Sony ICX027B chip which has a very broad response, peaking near 5500 Å, giving approximate V-band magnitudes, depending on the colour of the star. The frames are processed and analysed automatically. A mean dark frame is subtracted and the images are flat fielded. The reduction method has evolved from simple aperture photometry, used initially, to a variable aperture based on the signal in each pixel, and this has led to some improvement in the photometry. Further observations of some of the stars have been made by a number of collaborators using a variety of equipment, and these are detailed in the references to individual stars given later.

The observing programme is specifically designed for the detection and classification of short-period variables, and passes through distinct survey and follow-up phases. During the survey part of the programme several series of overlapping exposures are made systematically across sections of the sky. The same areas are re-observed between 5 and 10 times over one or two months. Ideally the observations are made in short runs of two or three consecutive days, at irregular intervals, but the usual observing constraints often disrupt this pattern. The survey exposures are 20 seconds long and typically provide useful photometry down to magnitude 13.5.

Survey images are analysed automatically and software is used to compare the magnitudes and identify likely variables. Stars with a variation of 0.2 mag on at least two images are considered as variable, plus those which show an obvious drop in brightness, ~ 0.5 mag on one image. A preliminary selection of the most likely short-period variables is made from the survey observations, on the basis of range and time scale of the variation, and colour. A period analysis on even this small number of observations may point towards a likely classification or period. Follow-up observations are made of all

the likely short-period variables with the apparently most tractable stars being given the highest priority. Further observations of the other variables are taken when possible. The apparently slowest variables with USNO-A2.0 (Monet et al. 1998) $b-r \sim 2$ or more are assumed to be red variables of some persuasion, and are not actively pursued.

During the follow-up phase each star is observed as continuously as possible. In general the exposure times are increased to 30 seconds to improve signal to noise, or tailored more specifically to the magnitudes of the variable and comparison stars. As these observations accumulate the likely nature of the variation becomes more clear and period analysis is performed. Once the period, or likely periods have been identified, further observations are timed to fill in the light curve or remove any ambiguities in the period.

The details of the positions and cross identifications of the Be variables are given in Table 1. The columns contain, 1; running Be number, 2; RA & Dec (2000) taken from the USNO-A2.0 catalogue, 3; the GSC number, 4; likely IRAS identification and 5; any other identification. The photometric data are given in Table 2. The columns are 1; running Be number, 2; the unfiltered CCD magnitude range based on the GSC comparison star magnitudes, 3; USNO-A2.0 r & $b-r$ magnitudes, 4; V and $B-V$ derived from Tycho-2, 5; the type of variation, 6; period, 7; reference. Additional comments, indicated by †, are given in notes to the table. All the red variables are identified as "SR", although it is recognised that they could be almost any type late-type variable, with the magnitude range possibly grossly under estimated.

Table 1: Positions and Identifications for BeV1–30

No.	RA (2000) Dec	GSC	IRAS	Other
BeV1	19 53 40.2 +09 23 50	1062-0033		V1490 Aql
BeV2	20 11 44.6 +08 55 17			V1492 Aql/A2.0 0975.18231027
BeV3	14 51 17.1 −11 09 43	5582-0545		
BeV4	05 52 27.9 +06 20 53	0128-1121	05497+0620	CSS 170
BeV5	06 20 40.0 +06 16 08	0144-1300	06179+0617	
BeV6	18 04 57.5 +08 57 38	1008-0332	F18025+0857	V2501 Oph
BeV7	18 09 57.3 +08 50 25	1009-0766		
BeV8	19 46 25.0 +08 45 12	1057-1309		
BeV9	07 11 52.6 +04 04 05	0171-2059		
BeV10	18 32 06.9 +08 07 13	1024-2911	18297+0804	
BeV11	18 35 06.1 +08 14 28			A2.0 0975.12232581
BeV12	18 19 46.8 +08 00 24	1010-0732		
BeV13	06 18 56.2 +04 09 20	0140-1831		
BeV14	16 24 49.7 +08 04 15	0959-1397		
BeV15	16 51 29.9 +06 22 27	0396-1710		
BeV16	18 07 29.2 +06 22 36		18050+0622	A2.0 0900.11650430
BeV17	19 24 36.4 +06 31 28	0477-3880		
BeV18	19 37 11.8 +06 28 10	0490-4680		
BeV19	19 43 40.3 +10 39 07			A2.0 0975.16187403
BeV20	19 39 30.6 +10 43 14	1060-2412		
BeV21	19 54 12.7 +10 39 29	1062-2668		
BeV22	19 49 15.2 +10 35 42	1062-1819		
BeV23	20 09 36.2 +10 39 09	1076-1805		
BeV24	20 18 13.7 +10 37 55	1078-0852	F20158+1028	
BeV25	21 10 21.1 +10 36 01	1108-0961	21079+1023	
BeV26	21 04 22.4 +10 28 29	1108-2511	F21019+1016	
BeV27	20 03 00.6 +10 34 56	1076-1332		
BeV28	21 28 30.2 +10 45 23	1123-1704		
BeV29	22 01 40.7 +10 37 19	1139-0011		
BeV30	23 32 32.6 +10 33 21	1172-1452		

Table 2: Photometric data for BeV1–30

No.	Range	r	$b-r$	V	$B-V$	Type	Period (d)	Reference
BeV1	10.5–11.0	10.9	0.4	11.00	0.45	EA	1.6160	IBVS No. 4540
BeV2	12.6–13.6	13.3	2.3			SR	~ 60	vsnet-obs 17668
BeV3	11.6–11.9	11.8	0.7	11.18	0.62	EA?	1.0672 ?	vsnet-obs 15317
BeV4	11.7–12.2	11.6	2.5			SR	189†	vsnet-obs 15402
BeV5	11.6–12.1	11.8	1.8			SR		vsnet-obs 15840
BeV6	11.7–12.0	11.5	2.5			SR	~ 41	vsnet-obs 17997
BeV7	11.6–12.1	11.1	1.6	11.59	0.51	EA	2.16347†	IBVS No. 4685
BeV8	11.7–12.2	11.6	1.4	11.82	0.38	†	†	IBVS No. 4685
BeV9	11.4–11.9	11.4	0.6	12.19	−0.15	EA?		vsnet-obs 20089
BeV10	12.1–12.5	11.8	3.0			SR	> 40	vsnet-obs 21154
BeV11	12.2–12.4	11.7	3.1			SR		vsnet-obs 21220
BeV12	11.5–11.8	11.7	0.7	11.75	0.62	?		vsnet-obs 21457
BeV13	12.1–12.8	12.0	0.7			EA	1.1496	IBVS No. 4797
BeV14	12.6–13.6	12.3	0.7			RRa	0.6446	IBVS No. 4797
BeV15	12.7–13.4	12.6	0.6			RRa	0.7789	IBVS No. 4797
BeV16	12.8–13.1	12.0	3.2			SR		vsnet-obs 23743
BeV17	12.3–12.7	12.1	1.5			EW?	0.73254 ?	vsnet-obs 23759
BeV18	12.8–13.1	12.4	1.1			?		vsnet-obs 23790
BeV19	12.4–12.7	12.4	2.6			SR		vsnet-obs 23834
BeV20	12.7–13.0	12.7	1.8			SR		vsnet-obs 23842
BeV21	12.2–12.5	12.4	2.8			SR		vsnet-obs 23861
BeV22	12.1–12.4	12.4	3.0			SR		vsnet-obs 23893
BeV23	12.6–13.0	12.8	2.5			SR		vsnet-obs 23916
BeV24	11.6–11.9	11.8	3.0			SR		vsnet-obs 23936
BeV25	12.3–12.8	12.4	3.1			SR		vsnet-obs 23949
BeV26	12.1–12.6	11.7	2.7			SR		vsnet-obs 24086
BeV27	11.5–11.9	11.4	1.3			EA?	0.7789 ?	vsnet-obs 24169
BeV28	12.7–13.2	12.7	0.3			EW?	0.5579 ?	vsnet-obs 24187
BeV29	12.5–13.5	12.5	0.5			EA?		vsnet-obs 24334
BeV30	12.1–12.4	12.3	0.9			?		vsnet-obs 24340

Notes:
BeV4: $P = 189$ days Lloyd (2000) and Takamizawa (2000), S star
BeV7: Revised ephemeris 2451243.46 + 2.16347×E
BeV8: Colour suggests a δ Scuti with $P = 0.1726$ or 0.2087 days, with 0.3453 and 0.4175 days less likely

The magnitude ranges of the variables are given with respect to the approximate V-band GSC magnitudes of the comparison stars. For stars of intermediate colour these values are probably close to the V magnitude, but for the red variables there is an increasingly large colour equation, and the values are probably more representative of the r magnitude.

Discrimination between the short-period and the SR variables is made principally on the time scale of the variation but with some guidance from the $b-r$ colour. The distribution of $b-r$ for this sample is shown in Figure 1, and while the two groups are easily identified there is little clear air between them. It is possible that some of the short-period variables contain late-type stars, but photometric errors and time differences between the b and r plates will conspire to reduce the separation.

The initial announcements about these stars, which contain the survey data and some preliminary analysis, were made electronically (Bernhard 1998–1999) and are available on the VSnet at `http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/` as given in Table 2. More detailed observations and analysis are available for BeV1 (Bernhard et al. 1997), BeV7 & 8 (Lloyd & Bernhard 1999) and BeV13, 14 & 15 (Lloyd et al. 1999).

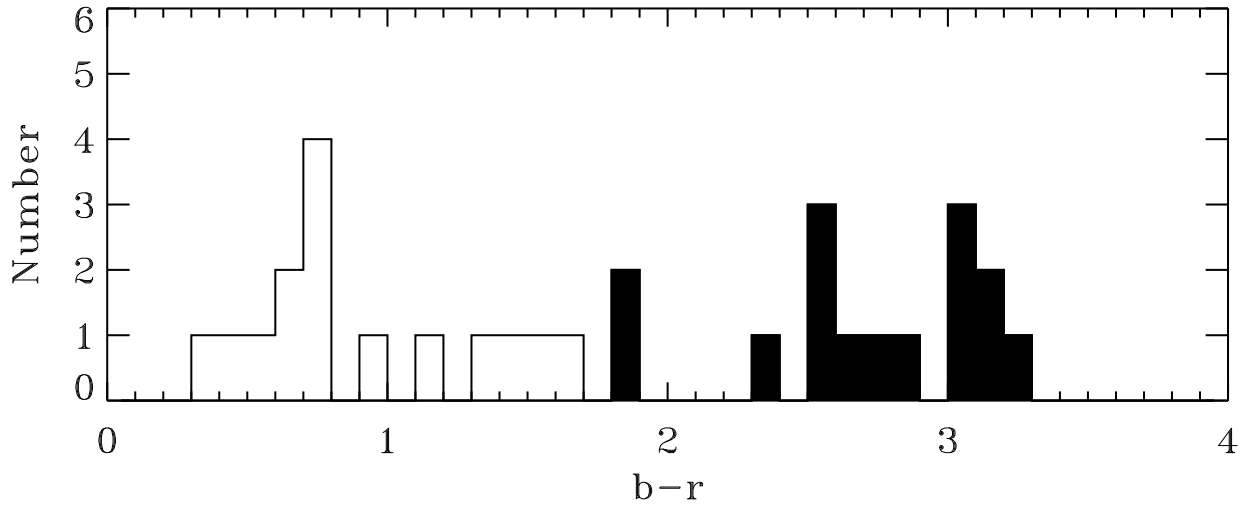

Figure 1. The distribution of $b - r$ for the stars in Table 2 with the assumed SR variables shaded.

Although the programme is aimed at the detection of short-period variables it is clear from Table 2 that many of the variables are late-type stars. Exactly half (15) of the stars in this sample are designated SR, and of the remaining stars three are confirmed eclipsing binaries with a further six possibilities, two are confirmed RR Lyrae variables, and the remaining four stars are unclassified short-period variables.

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