CCD OBSERVATIONS OF SHORT-PERIOD VARIABLES AT MIDDLEBURY COLLEGE

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Abstract

The Middlebury College Observatory is equipped with a 0.41-m reflecting telescope and a CCD imaging camera. Among the observational programs we have undertaken is the photometric study of short-period variable stars, especially δ Sct variables. There are many short-period ($P < 6^h$) variables with amplitudes of several hundredths of a magnitude or greater, which are ideal objects for study with CCDs on small telescopes, especially in educational settings.

1. CCD Cameras and Short-Period Variables

The advent of commercially available integrating CCD imaging cameras has opened up numerous possibilities for the possessors of telescopes of modest apertures who wish to perform meaningful astronomical research. In particular, the photometry of stars has become (even) more attractive, because the panoramic nature of the detector allows comparison stars to be recorded simultaneously with the program stars. Thus, useful results in differential photometry can be obtained even on nights not conventionally describable as "photometric" (uniform transparency). Of course, the great sensitivity is also a boon, as it allows a larger number of objects to be studied.

Eclipsing binaries are popular with amateur astronomers and small educational institutions; the results can be quite satisfying, as there are many systems which show deep eclipses and/or have frequent and/or rapid eclipses (such as Algols and W UMa systems). On the other hand, many of these systems have to be caught at just the right time, and the observation of a predictable eclipse is perhaps less likely to be of scientific interest (excepting certain cases, such as the timing of eclipses in studies of apsidal motion or period changes).

In this paper we encourage our colleagues to consider observations of short-period pulsating variables. Like the popular eclipsing binaries, the variations take place on short timescales, which makes it more likely that a single night's (or even a few hours') observations will bear useful results, which is especially convenient for educational settings. Furthermore, there are many short-period variables which are in need of observations, and the fact that, for many of these stars, the pulsations (and therefore light variations) have more than one strong frequency mode means that the results are not entirely predictable. Also, since pulsating variables are always "doing their thing," there is no need to worry about ephemerides, as is the case with most eclipsing variables. Finally, most of our knowledge of these pulsating variables is from observations in B or V, whereas CCDs have their peak responses in the red. Thus, almost any such observational results will be novel.

Well-known examples of pulsating variables are Cepheids and RR Lyr variables, whose pulsational periods range from many days down to a fraction of a day, and these objects are of course worthy of our attention. However, we will concentrate here on variables whose pulsational periods are just a few hours. These tend to be of spectral type A or F and are often referred to as "δ Scuti" variables, after the prototype of the class. The amplitudes of the variations are often as much as several tenths of a magnitude or more, though many have much smaller amplitudes. Because these stars are often found to be pulsating in more than one mode, the amplitudes are not necessarily constant.

Table 1. GCVS Stars (Period ≤ 0.25 day, Dec. ≥ -20°, ampl. ≥ 0.05 mag)

Var	*RA (1950)*	*Dec*	*type*	*Vmax*	*Vmin / ampl.*	*Per.(d)*	*Sp. type*
CC And	00 41 03	+42 00.5	DSCT	9.18	9.46	0.1249	F3IV-V
DK And	23 26 15	+50 16.	RR:	12.5	13.1	0.2437	
BS Aqr	23 46 12	-08 25.4	DSCT	9.13	9.65	0.1978	A8-F3
CK Aqr	20 58 18	-11 15.6	DSCT	12.9	13.8	0.1241	
V802 Aql	18 56 18	-03 05.4	DSCT	13.4	14.3	0.1338	
V879 Aql	18 47 37	+10 54.2	DSCT	13.1	14.8	0.1190	
UW Ari	03 04 36	+17 41.3	BCEP	6.10	0.13	0.1528	B1.5V
VW Ari	02 24 04	+10 20.5	SXPHE:	6.64	6.76	0.149	F0IV
V356 Aur	05 39 17	+28 58.6	DSCT	8.01	8.12	0.1892	F4IIIP
YZ Boo	15 22 12	+37 02.6	DSCT	10.30	10.80	0.1041	A6-F1
VZ Cnc	08 38 10	+10 00.2	DSCT	7.18	7.91	0.1784	A7III-F2III
BT Cnc	08 36 50	+19 57.4	DSCTC	6.66	0.06	0.1023	F0III
AD CMi	07 50 12	+01 43.7	DSCT	9.21	9.51	0.1230	F0III-F3III
GM Com	12 09 53	+27 39.5	DSCTC	8.06	8.14	0.208	F5V
XX Cyg	20 02 17	+58 48.7	SXPHE	11.28	12.13	0.1349	A5
V798 Cyg	19 36 09	+30 47.7	DSCT:	12.4	12.8	0.1948	
CN Dra	19 46 41	+68 18.8	DSCTC	6.29	0.09	0.100	F0III
DL Eri	03 54 14	-09 53.7	DSCTC	6.15	0.09	0.1559	F1V
KV Gem	06 44 20	+15 46.6	RRC:	12.4	12.9	0.2185	
LR Gem	06 12 14	+22 19.1	BCEP	9.01	9.12	0.2389	B0IV
DY Her	16 28 57	+12 06.8	DSCT	10.15	10.66	0.1486	A7III-F4III
IT Her	18 43 44	+25 17.1	RRC	12.9	13.3	0.2260	
LS Her	15 59 49	+17 37.2	RRC	10.79	11.12	0.2308	A5
VX Hya	09 43 21	-11 46.6	DSCT:	10.21	10.96	0.2234	F2IB-F8
SZ Lyn	08 06 06	+44 37.2	DSCT	9.08	9.72	0.1205	A7-F2
TV Lyn	07 29 50	+47 54.7	RRC	11.24	11.66	0.2407	A6
V588 Mon	06 36 21	+09 43.9	DSCTC	9.66	9.72	0.11	A7III-IV
V589 Mon	06 36 43	+09 45.1	DSCTC	10.27	0.05	0.124	F2III
V5670Oph	17 55 54	+01 06.4	DSCT	11.07	11.43	0.1495	A7-F3
BP Peg	21 31 00	+22 31.3	DSCT(B)	11.69	12.28	0.1095	A0
KP Per	03 29 13	+44 41.2	BCEP	6.37	0.14	0.2018	B2IV
KV Per	01 55 13	+57 12.0	RRC	13.8	14.3	0.2491	
VY Psc	01 43 52	+17 09.8	DSCTC	6.54	6.59	0.2	A7III
V854 Sco	16 10 32	-09 46.4	DSCT	13.0	13.4	0.1024	
V369 Sct	18 48 36	-06 24.8	DSCT	9.14	9.43	0.223	F8III
CW Ser	15 50 41	+06 14.3	DSCT	11.59	12.06	0.1892	A/F
DK Vir	13 13 51	-01 07.6	DSCTC	6.67	6.72	0.1192	F0IV
BW Vul	20 52 15	+28 19.9	BCEP	6.52	0.24	0.2010	B1III-B2IIIEAV
LT Vul	19 01 34	+21 11.6	DSCT	6.52	6.62	0.1090	F2III

The information in Table 1 was drawn from a machine-readable version of the *General Catalogue of Variable Stars* (Kholopov *et al.* 1985)(GCVS), and lists several known variables with periods less than 0.25 day, amplitudes 0.05 magnitude or greater, and positions north of declination -20° . Due to space limitations, we have omitted from the list dozens of others which fit the stated criteria. Many additional GCVS stars have reported amplitudes of magnitude 0.02-0.04, and undoubtedly some of them occasionally show greater variation (just as some in the Table 1 may occasionally show smaller variations). The attributed type of variability is predominantly δ Sct, though some of these may be misidentifications. In any case, there is a plentiful supply of rapidly varying stars which are worth observing.

2. The Middlebury College Observatory

Middlebury College (in Middlebury, Vermont) operates an observatory equipped with several telescopes which are used for public viewing, introductory and advanced astronomy courses, senior thesis projects, and research. The centerpiece instrument is a computer-controlled DFM 0.41-meter aperture Cassegrain reflector. The primary detector is a Photometrics thermoelectrically-cooled CCD camera (formerly a PM512 chip, now a Thomson TH7895B chip) and is primarily used in imaging. A photoelectric photometer is also available. The primary instruments include a set of broad-band filters (BVRI, matched to those of our colleagues in the Keck Northeast Astronomy Consortium in order to facilitate collaborative photometry projects) and a stellar spectrograph. The telescope has also been used in conjunction with a bench-mounted, high-resolution spectrometer by means of an optical fiber feed.

The CCD camera is, of course, under the control of a computer, in this case a Mac IIci. The telescope pointing and tracking are admirably controlled by an Apple IIe computer; as originally delivered, however, all commands had to be entered at the keyboard. Much of the CCD observing protocol (such as entering filenames and exposure durations) also required the use of a keyboard. As our observatory has no warm room, and Vermont winters can make for uncomfortable observing, it was considered desirable to be able to observe without removing one's mittens. This was accomplished by a combination of (1) recoding the telescope drive's software user interface to accept commands over a serial line, (2) programming the Mac IIci to send the slew commands to the Apple IIe over the serial line, and (3) implementing Macintosh keystroke macros to allow ASCII characters to be entered by (mouse-controlled) cursor motions. The most difficult of these three tasks would have been (2), were it not for the fact that the Macintosh application HyperCard and its programming language HyperTalk make programming the Mac quite easy, even for serial communications. The fact that HyperCard lends itself so readily to construction of databases such as lists of astronomical objects was also a great advantage.

With these improvements, Middlebury senior thesis students showed that it was possible to obtain dozens of CCD images over a several-hour period at temperatures down to 8° F, without suffering the slightest trace of frostbite.

The various lab exercises and research projects Middlebury College students and faculty have undertaken with this equipment include broad-band photometry of stars, extragalactic SNe, QSOs, and asteroids, and high-resolution spectroscopy of the sun. Included among these projects has been some preliminary work in the study of short-period variables, in which we have demonstrated the appropriateness of this class of variable star as objects of study for small telescopes equipped with CCD cameras. The entire project, from selection of targets through obtaining the observations to producing the light curve after data reduction in sophisticated image-processing environments (such as IRAF), is well within the ability of undergraduate students.

3. Preliminary Results: R Light Curve of RV Ari

In the winter of 1991, the authors obtained a total of over 300 CCD images of short-period variables. Figure 1 shows the preliminary light curve for one of them, RV Ari (V≈12), observed through a broad bandpass (2000 Angstroms wide, centered at 7500 Angstrom) filter. This star, according to the GCVS, has a maximum V magnitude of 11.85, an amplitude of variation in V of approximately 0.4 magnitude, and a period of 0.093 day. Our results essentially confirm that period, but we were surprised to find a much larger amplitude (about 1 magnitude!). A subsequent search of the literature provided other references which also reported variations of up to approximately 1 magnitude (Spinrad 1959).

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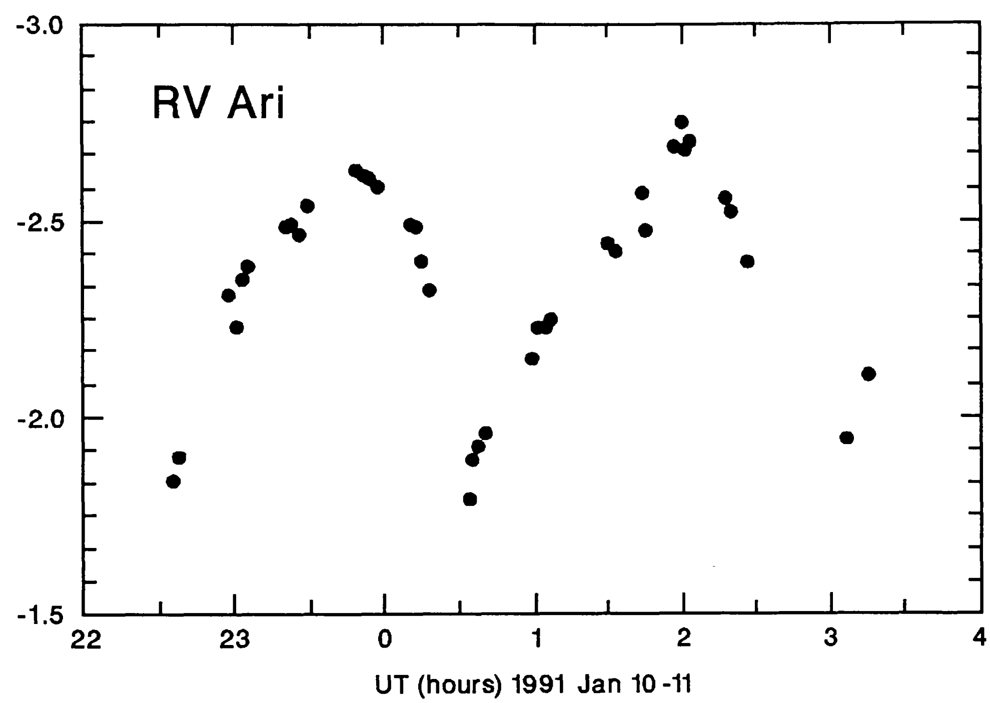

Figure 1. The differential light curve of RV Ari with respect to a comparison star in the same field of view as the variable, in red light (see text for description of filter). The observations are from the night of 1991 Jan 10-11.