INTERMEDIATE-TYPE SUPERGIANT VARIABLES: REQUEST FOR PHOTOELECTRIC OBSERVATIONS

JOHN R. PERCY
David Dunlap Observatory,
Department of Astronomy
Richmond Hill, Ontario, Canada L4C 4Y6 and
Erindale College,
University of Toronto,
Toronto, Ontario, Canada M5S 1A7

Abstract

This paper lists and describes a group of about 20 supergiant variables, with spectral types F, G, and K, ranges of $0^m.1$ to $1^m.0$, time scales of 40 to 300 days, and semi-regular light curves. Many of them lie outside the Cepheid instability strip and their relation (if any) to Cepheid and other variables is not clear. In order to understand the variations in these stars, it is necessary to observe them regularly throughout the observing season, preferably for several seasons. This would make a worthwhile project for an amateur photoelectric photometrist.

* * * * *

1. Introduction

The purpose of this paper is to call attention to a group of Cepheid-like variables with the following properties: spectral type F, G, or K, luminosity Class I (usually Ia), semi-regular light variations of $0^m.1$ or more with a "period" of tens or hundreds of days. For reasons which will be explained, the study of these stars would be a worthwhile project for amateur photoelectric photometrists. Many of the variables in this group have been known for years, but the existence and extent of the group, and its relation to supergiant variability in general, is only now becoming apparent.

The light variability of supergiants is now well established, both from photometric surveys and from studies of individual stars. The most recent and comprehensive reviews are by Maeder (1980a, b). Other important papers are by Appenzeller (1972), Maeder and Rufener (1972), Sterken (1977), Rufener, Maeder, and Burki (1978), Burki, Maeder, and Rufener (1978), and van Genderen (1980). According to these studies the amplitude of variability generally increases with luminosity. For the Ia supergiants, the amplitude increases from O type stars to the early B type stars, then decreases up to the F type stars. Here are found the Cepheid variables, with regular variability and (usually) large amplitude. For late type supergiants there is a strong increase in the amplitudes, which occurs at progressively earlier spectral type with increasing luminosity: at G type for class Ia and at M type for class II. The variability of the M supergiants (like Betelgeuse) is conspicuous and occurs on a time scale of hundreds of days. Extreme supergiants of all types (P Cyg, η Car, S Dor, and the Hubble-Sandage variables in M31 and M33) can vary appreciably, with amplitudes of a magnitude or more.

The cause of supergiant variability is not clear in all cases. The Cepheids are certainly pulsating and are doing so radially. The M supergiants are probably pulsating too, though convective motions may also be important. For other supergiants, Maeder (1980 a, b) concludes that "the period-luminosity-colour relation . . . is compatible with pulsation motions . . . and there are arguments favouring non-radial

oscillations." For the most extreme supergiants, secular (as opposed to periodic) effects may also be important.

It would be helpful, in order to understand the cause, to know whether the variability of supergiants is periodic, multi-periodic, semi-periodic, or non-periodic. This requires observations over several consecutive "periods" which, for these stars, means over several hundred days.

My own interest in these stars began with a search for small-amplitude and zero-amplitude stars in the Cepheid instability strip. Some of these were found and studied (Percy 1975; Percy et al. 1979); they tend to have short periods and regular light curves, like Polaris, for instance. A notable exception is HR 7308 (Percy and Evans, 1980), whose light curve changes slowly on a time scale of many months. The study of these short-period, small-amplitude Cepheids would be an interesting but generally uneventful project for amateur photometrists.

As well as the "true" small-amplitude Cepheids, however, there are also several Cepheid-like variables with small amplitudes and long periods. These tend to have irregular light curves and at least some of them lie outside the Cepheid instability strip. The study of these objects is especially important because true Cepheids, with long periods, are very rare in our Galaxy.

2. Individual Stars

Table 1 lists some probable and possible members of the group of Cepheid-like variables. Some, marked with an asterisk (*), are well established; the rest require further study. The comparison stars marked with an asterisk (*) are reasonably well tested for constancy; the rest should be tested against appropriate check stars. The Table does not include some suspected very-small-amplitude variables: HD 17971 and HD 18391 (Rufener, Maeder, and Burki 1978) and HD 96918 and HD 100261 (Stift 1979). Light curves of two of the stars in Table I are shown in Figures 1 and 2. Furthermore, Table 1 may contain some extraneous stars or may be incomplete. The stars in it form a very heterogeneous group. Some may be--or be related to--Cepheids, RV Tauri stars, yellow semi-regular variables, or even long-period variables. One of the reasons for studying these stars is to better understand their nature and their relationship to known classes of variables.

3. New Observations

In order to investigate the periodicity of these stars, observations must be made over several consecutive cycles: an interval of months to years, depending on the star. Such observations can be made at professional observatories, but only if telescopes are available to the observers throughout the season. This is not the case at national observatories (such as Kitt Peak) or at remote observatories (such as the University of Toronto's observatory on Las Campanas in Chile). Many amateur photoelectric photometrists, on the other hand, are able to make regular observations. A precision of $\pm 0^{m}.01$ is necessary but this is possible with care and with proper data reduction techniques (e.g., Hardie 1962; Welch 1979). In particular, standard comparison stars should be used and extinction and transformation coefficients should be carefully determined and used. Observations through one filter (Johnson V, for instance) would be sufficient for confirming the variability and for determining periodicity. Additional observations through a Johnson B filter would also be worthwhile in order to determine the (B-V) color curve. The most valuable observations are those obtained regularly (once every few days) by a single observer over a year or more. Sporadic observations are not useless, but they are more

difficult to combine with other observations.

I am willing to receive observations of these stars every year or two and to combine and analyze the observations from different observers. If sufficient and adequate observations are received, then these will be prepared for publication, with full credit being given to the observers.

It would also be helpful if a copy of all observations could be sent to the A.A.V.S.O. Headquarters to be filed there permanently. It is my hope that a permanent repository for amateur photoelectric observations could be maintained there (similar to the repository maintained by the I.A.U.). A list of the material added to the repository could be published in the J.A.A.V.S.O. each year.

Amateur photoelectric photometrists have shown, through their recent studies of RS CVn stars, for instance, that they can make important contributions to astronomical research. The study of these Cepheid-like variables would be yet another worthwhile project.

I thank Don Fernie, Russ Genet, Doug Hall, and Janet Mattei for their helpful comments. Doug Welch made most of the observations shown in Figures 1 and 2. The preparation of this paper was made possible, in part, by a grant from the Natural Sciences and Engineering Research Council of Canada.

REFERENCES

Alexander, J. B., Andrews, P. J., Catchpole, R. M., Feast, M. W., Evans, T. Lloyd, Menzies, J. W., Wisse, P. N. J., and Wisse, M. 1972, MNRAS, 158, 305.

Appenzeller, I. 1972, Publ. Ast. Soc. Japan, 24, 483.

Arellano Ferro, A. 1981, submitted to Publ. Astron. Soc. Pacific.

Burki, G., Maeder, A., and Rufener, F. 1978, Astron. Astrophys., 65, 363.

Dean, J. F. 1980, I.A.U. Inf. Bull. Var. Stars, No. 1796.

Ferni, J. D. 1975, Astron. J., 80, 458.

Ferni, J. D. 1980, Astrophys. J., in press.

Ferni, J. D. 1981, in preparation.

Fernie, J. D., Sherwood, V., and DuPuy, D. L. 1972, Astrophys. J., 172, 383.

Hardie, R. H. 1962, in Astronomical Techniques, ed. W. A. Hiltner (Chicago: Univ. Chicago Press), 178.

Huffer, C. M. 1932, Astrophys. J., 76, 1.

Larsson-Leander, G. 1958, Ark. f. Astron., 2, 283.

Larsson-Leander, G. 1961, Ark. f. Astron., 3, 17.

Maeder, A. 1980a, in Highlights of Astronomy, 5, ed. P. A. Wayman, in press (D. Reidel, Dordrecht).

Maeder, A. 1980b, Astron. Astrophys., in press.

Maeder, A. and Rufener, F. 1972, Astron. Astrophys., 20, 437.

Percy, J. R. 1975, I.A.U. Inf. Bull. Var. Stars, No. 983.

Percy, J. R., Baskerville, I., and Trevorrow, D. W. 1979, Publ. Astron. Soc. Pacific, 91, 368.

Percy, J. R. and Evans, N. R. 1980, Astron. J., in press.

Percy, J. R. and Welch, D. L. 1981, submitted to Publ. Astron. Soc. Pacific.

Rufener, F., Maeder, A., and Burki, G. 1978, Astron. Astrophys. Suppl., 31, 179.

Sterken, C. 1977, Astron. Astrophys., 57, 361.

Stift, M. J. 1979, Astron. Astrophys., 80, 134.

Van Genderen, A. M. 1979, Astron. Astrophys. Suppl., 38, 381.

Van Genderen, A. M. 1980, Astron. Astrophys., 88, 77.

Welch, D. L. 1979, J. Roy. Astron. Soc. Canada, 73, 370.

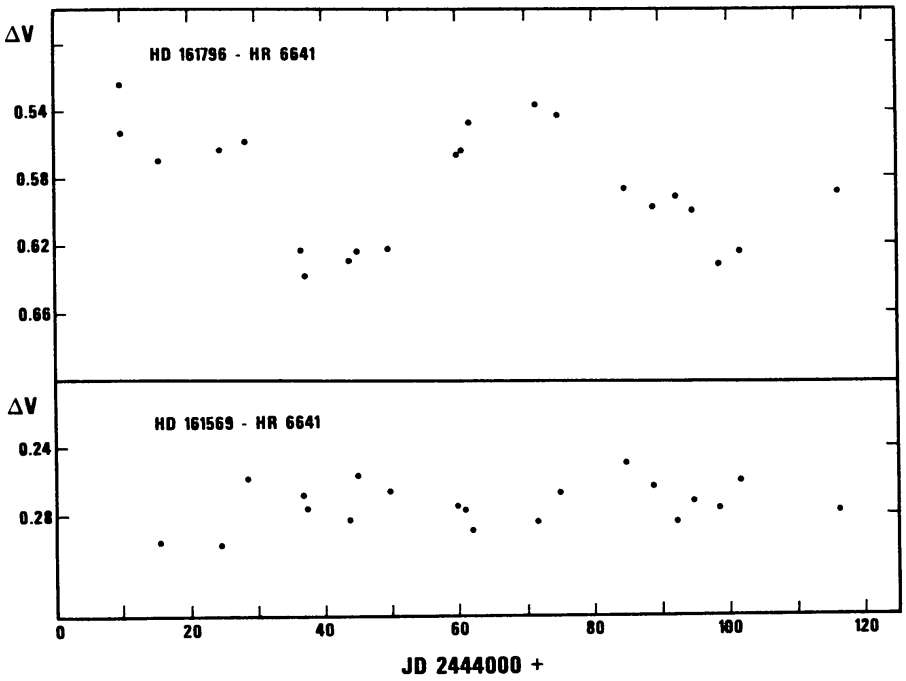

Figure 1. The light variability of HD 161796, in yellow light, in 1979, relative to HR 6641 (Percy and Welch 1981).

TABLE 1. Preliminary List of Long-Period Cepheid-Like Variables

	HD	HR	Name	R.A. (1900)	Dec.	V	B-V	Sp. T.	Remarks and References
V*	31964	1605	E Aur	$04^h\ 54^m.8$	$+43^\circ\ 40'$	2.99	+0.54	F0 Ia	Period about 100^d; range $0^m.2$. System is also an
C*	34411	1729	λ Aur	05 12.1	+40 01	4.85	+0.62	G0 V	enigmatic eclipsing variable. Ref.: Huffer (1932);
C*	32655	1644		04 59.7	+43 02	6.16	+0.42	F2IIp?	Larsson-Leander (1958, 1961).
V	62058	2974	R Pup	07 37.0	-31 26	6.61	+1.17	G0 Ia	Open cluster member. Once thought to vary by $0^m.6$;
C*	61409	2942		07 34.1	-35 03	6.59	+1.14	K0	subsequent observations showed no variation. Recent
C	63077	3018		07 41.8	-33 59	5.36	+0.60	G0 V	results vary by $0^m.06$ in 27^d. Ref.: Stift (1979).
V	90772	4110		10 23.7	-57 08	4.66	+0.50	F0 Ia	Period probably greater than 40^d; range $0^m.1$.
C	89569	4061		10 15.0	-55 37	5.80	+0.48	dF7	Variability recently discovered; further observations
C	91324	4134		10 27.5	-53 12	4.88	+0.50	dF7	are needed. Ref.: Arellano Ferro (1981).
V*	101947	4511	V810 Cen	11 38.8	-61 56	5.05	+0.81	G0 Ia:	Period about 125^d; range $0^m.1$ to $0^m.2$; irregular with
C*	102350	4522		11 41.7	-60 37	4.10	+0.90	G3 III	unequal minima. Member of Stock 14. Has a close
C*	101021	4475		11 32.4	-60 44	5.14	+1.13	K1 III	blue companion. Ref.: Van Genderen (1980).
V	112374	4912		12 51.1	-25 55	6.76		cF6	Period about 65^d?; range about $0^m.3$. Variability
C	111786	4881		12 46.6	-26 12	6.13	+0.24	A0	recently discovered; further observations are
C	111295	4860		12 43.1	-27 03	5.66	+0.96	G5	needed. Ref.: Arellano Ferro (1981).
V*	119796	5171	V766 Cen	13 40.2	-62 05	6.23	+1.84	G8 Ia	Time scale greater than 1000^d; range exceeds 1^m.
C	118261	5113		13 30.4	-61 11	5.62	+0.50	dF5	Ref.: Dean (1980); van Genderen (1979); some
C	118520	5124		13 32.3	-57 07	6.04		K0	similarity to HR 8752.
V*	141527	5880	R CrB	15 44.5	+28 28	5.9	+0.60	F8 I	Prototype R CrB variable. Also varies with
C*	141352			15 43.7	+28 46	7.45	+0.44	F2	period about 40^d to 45^d; range $0^m.1$ to $0^m.2$ but
C*	140913			15 41.1	+28 47	8.08	+0.54	G0 V	irregular. Ref.: Fernie et al. (1972); Fernie (1981).
V	155603	6392		17 07.5	-39 39	6.48	+2.26	G5 Ia	Period very long?; range about $0^m.1$; irregular?
C	155974	6405		17 09.7	-35 38	6.11	+0.48	dF7	Ref.: Dean (1980).
C	157060	6454		17 15.9	-35 49	6.43	+0.55	dF9	
V*	159378		Tr27-102	17 32.6	-33 24	8.39	+1.94	G0 Ia	Period about 80^d; range $0^m.1$; irregular. Probable
C*	158528			17 24.7	-33 17	8.38	+0.25	A5	member of Trumpler 27; may have a blue companion.
C*	161612			17 41.4	-33 58	7.21		G5	Ref.: Van Genderen (1980).
V*	161796			17 42.5	+50 05	7.27		F3 Ib+	Period about 45^d to 60^d in different seasons;
C*	162132	6641		17 44.5	+47 39	6.28		A0	range about $0^m.1$. Refs.: Fernie (1981); Percy
C*	161569			17 41.2	+45 05	6.61		B9	and Welch (1981).

V*	163506	6685	89 Her	17	51.4	+26	04	5.47	+0.35	F2 Ia	Period about 67^d; range $0^m.3$; irregular.
C*	165373	6754		18	00.5	+23	56	6.37	+0.30	F0	Refs.: Percy et al. (1979); Fernie (1980).
C*	163840	6697		17	53.1	+24	01	6.31	+0.66	G0	
V	165782		AX Sgr	18	02.3	-18	34	7.40	+2.03	G8 Ia	Period about 350^d?; range $0^m.8$?. Member of
C*	166052			18	06.7	-18	52	7.62	+0.12		association Sgr OB4? Variations small and/or irregular (Fernie, 1975).
V*	177300		BL Tel	18	58.9	-51	34	7.33	+0.52	F5 I	Period about 65^d; range $0^m.1$. Star is also an
C*	177171	7213	ρ Tel	18	58.4	-52	29	5.15	+0.53	dF8	eclipsing variable, period 778^d, with an M type
C	176557			18	55.8	-50	28	7.18	+1.46	K2	companion. Ref.: Van Genderen (1980).
V*	180093	7296	RY Sgr	19	10.0	-33	42	6.1		Fp	R CrB variable. Also varies with period of $38^d.6$
C	181321	7330		19	14.9	-35	10	6.47	+0.63	dG2	and range about $0^m.5$. Alexander et al. (1972).
C*	179576			19	08.0	-32	36	8.22	+0.98	K0	
V*	217476	8752	V509 Cas	22	55.9	+56	25	4.99	+1.29	G0 Ia	Time scale of a year or more; range $0^m.3$ or more.
C*	216174	8688		22	45.7	+55	22	5.45		K1 III	Star is very luminous, spectroscopically active
C*	219134	8832		23	08.5	+56	37	5.57	+1.01	K3 V	and a radio source. Ref.: Percy and Welch (1981).
V*	224014	9045	ρ Cas	23	49.4	+56	57	4.4	+1.05	F8 Iap	Period about 320^d; range about $0^m.3$; irregular.
C*	223173	9010		23	42.1	+56	54	5.64		K3 II	Refs.: Fernie et al. (1972); Percy and Welch (1981).
C*	223165	9008	5 J Cas	23	42.2	+58	06	4.94		K1 III	

NOTES: V denotes the variable star; V* denotes a well-established variable star. C denotes the comparison or check star; C* denotes a comparison or check star whose constancy has been reasonably well established. References given are the most recent (usually); additional references can be found therein, or in the Bibliographic Star Index.

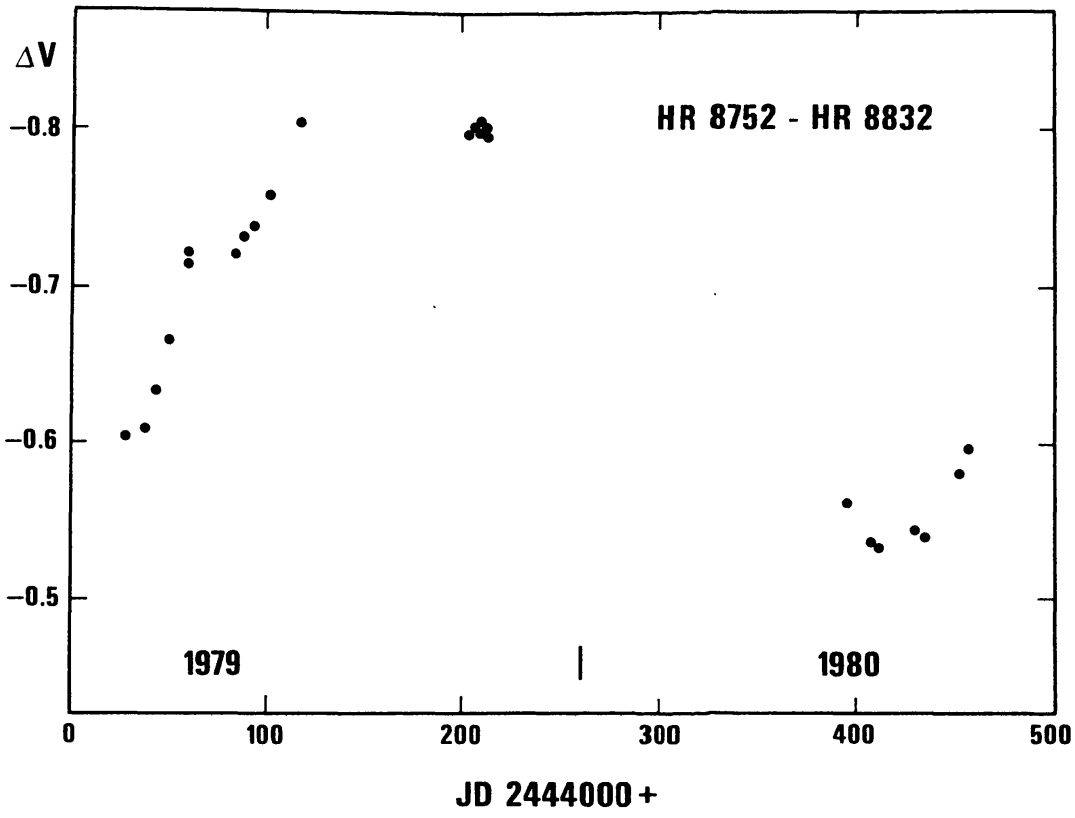

Figure 2. The light variability of HR 8572, in yellow light, in 1979 and 1980, relative to HR 8832 (Percy and Welch 1981).