THE ASTROPHYSICAL JOURNAL, 243:576–582, 1981 January 15

89 HERCULIS: FURTHER MISDEMEANORS

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Received 1980 April 7; accepted 1980 July 16

ABSTRACT

BVRI and radial velocity observations of 89 Herculis covering the three seasons of 1977, 1978, and 1979 are presented. In the first season the star showed light and color curves reminiscent of a 68^d pulsation, but no simultaneous velocity curve exceeding 1 km s^{-1} amplitude. A well-developed light curve in 1978 abruptly gave way to low-amplitude fluctuations accompanied by larger changes in radial velocity. During 1979 no light curve was present, only random fluctuations, but there were signs of a velocity curve.

No adequate model to account for the observations has been found, although nonradial pulsation may offer the fewest difficulties. No effects on the colors as large as those predicted by Gillett, Hyland, and Stein from far-infrared data are found, but the star does show some excess in $(V-I)$. Radial velocities over almost 60 yr do not support the suggestion of Humphreys and Ney (1974) that 89 Herculis may have a binary companion.

The space motion of 89 Herculis is that of a typical high-velocity star headed radially outward through the Galaxy at $\sim$130 km s^{-1}, and a face-value application of the $P\sqrt{(\rho)}$ relation to the 68^d "pulsation" suggests a mass of only 1 or 2 solar masses. But how such a star could achieve normal Population I abundances (Searle, Sargent, and Jugaku) and have a well-determined $M_V = -6.8$—far more luminous than any other halo population star—remains unexplained.

Subject headings: stars: Cepheids — stars: individual — stars: supergiants — stars: variables

I. INTRODUCTION

89 Herculis (also designated V441 Her or HR 6685, $\alpha = 17^h51^m.4$, $\delta = +26°04'$ [1900]) is a fifth magnitude F2 Ia supergiant to which attention was drawn by Bidelman (1951) because it is one of very few such stars to be found well off the Galactic plane ($b = +23°.4$).

The problem of how so presumably young a star could be a kiloparsec or more off the plane led Abt (1960) to investigate its chemical composition. His conclusion that it is metal poor, however, was challenged by Searle, Sargent, and Jugaku (1963), whose analysis showed the star to have an entirely normal Population I abundance. These authors also concluded that the star could have reached its present position in the course of its expected lifetime of some 10^7 yr if it had left the plane with a *z*-velocity of about 100 km s^{-1}.

The location of 89 Her on the H-R diagram is known with uncommon precision. Its spectral type is definitive, it being an MKK standard, and its colors show it to be only slightly reddened, as is to be expected at that galactic latitude. Searle, Sargent, and Jugaku (1963) derived $M_V = -7.1 \pm 0.5$ from their spectroscopic analysis. Additionally, Osmer (1972) and Baker (1974) both calibrated the absolute magnitude from photoelectric measures of the O I λ7774 triplet, obtaining $M_V = -6.6$ and -6.68, respectively.

That 89 Her is slightly variable in radial velocity and in the structure of the Balmer lines was noted by Böhm-Vitense (1956), and at the same time Worley (1956) established it to be varying in brightness.

Sargent and Osmer (1969) showed that 89 Her undergoes mass loss and that, while the rate of mass loss is probably too low to affect the star's evolution, it does show several features difficult to explain, e.g., the high velocity of the material and the mechanism of the circumstellar line formation. Gillett, Hyland, and Stein (1970) discovered that the star shows a marked infrared excess in the 2–11 μm range, and their spectra in the 2.0–2.5 μm range revealed 89 Her to have an energy distribution closely resembling that of R CrB. Interpreting the excess as due to radiation from a circumstellar shell, Gillett *et al.* concluded that there should be optical effects of about half a magnitude at visible wavelengths. Humphreys and Ney (1974), however, suggested that for 89 Her and other similar stars it is more reasonable to interpret the infrared excess as arising from a luminous, very late M-star binary companion.

TABLE 1

CONSTANCY OF HR 6754 AND 87 HERCULIS

JD	$\Delta V_{6754\text{-}87}$	JD	$\Delta V_{6754\text{-}87}$
2,444,040.69 . . .	1.295	2,444,060.66	1.275
043.71	1.275	088.65	1.298:
049.67	1.285	116.60	1.293
050.69	1.275	117.58	1.285
051.68	1.282	134.56	1.287

A number of these conclusions will be reexamined in the light of data to be presented here.

My own interest in 89 Her stemmed from Worley's light curve. Although fragmentary, this shows a form not unlike that due to pulsation with a period of about 70 days. Perhaps coincidentally, a period-luminosity relation for classical Cepheids (Fernie 1967) predicts $M_V = -6.8$ for this period, which is just the absolute magnitude already known by other means. There was thus the tantalizing possibility that 89 Her is a Cepheid, but one which is located 0.3 mag in $(B-V)$ to the blue of the usual instability strip. On the other hand, the variability might be due to factors other than pulsation.

To investigate this, *UBVRI* photometry and radial velocities were obtained over three seasons during 1977, 1978, and 1979.

II. THE OBSERVATIONS

The *UBVRI* photometry was obtained with the system described elsewhere (Fernie 1974), using DDO 0.6 m and 0.5 m telescopes. It was done differentially throughout, using 87 Her as a comparison star. This was chosen because Worley (1956) had previously used it and had checked it for constancy; and it would make for easy comparison with Worley's results. However, although convenient in other ways, its spectral type of K2 III makes it less than ideal as a comparison star for 89 Her (F2 Ia), and two other stars, HR 6697 and HR 6754, were also tried. The constancy of the former was established by Percy, Baskerville, and Trevorrow (1979), and that of the latter by the results in Table 1. HR 6754 is a particularly good match to 89 Her in color, and it is recommended that future studies use it as the primary comparison star. However, for reasons of homogeneity, 87 Her has been used as the primary comparison star throughout this study. Absolute photometry for the three stars is given in Table 2, and the results for 89 Her are based on the assumption that the figures for 87 Her are exact.

TABLE 2

ABSOLUTE PHOTOMETRY OF COMPARISON STARS

Star	V	$U-V$	$B-V$	$V-R$	$V-I$
87 Her	5.074	2.185	1.143	0.846	1.399
HR 6697 . . .	6.305	0.860	0.659	0.537	0.865
HR 6754 . . .	6.373	0.322	0.304	0.303	0.449

TABLE 3

PHOTOMETRY OF 89 HERCULIS OVER THREE SEASONS

JD	V	$B-V$	$V-R$	$V-I$
1977				
2,443,309.609 . . .	5.391	0.367	0.291	0.451
3,312.625 . . .	5.378	0.351	0.296	0.439
3,315.615 . . .	5.374	0.318	0.295	0.445
3,316.616 . . .	5.363	0.332	0.276	0.425
3,318.607 . . .	5.370	0.348	0.279	0.428
3,326.642 . . .	5.401	0.339	0.298	0.442
3,327.608 . . .	5.414	0.345	0.299	0.458
3,334.594 . . .	5.453	0.364	0.325	0.477
3,335.621 . . .	5.458	0.365	0.318	0.483
3,415.526 . . .	5.472	0.390	0.330	0.478
3,420.525 . . .	5.449	0.381	0.323	0.471
3,434.494 . . .	5.419	0.382	0.327	0.475
3,437.482 . . .	5.405	0.377	0.319	0.472
3,452.487 . . .	5.357	0.345	0.305	0.420
1978				
2,443,650.724 . . .	5.449	0.353	. . .	. . .
3,658.637 . . .	5.496	0.381	. . .	. . .
3,663.673 . . .	5.484	0.380	. . .	. . .
3,665.627 . . .	5.475	0.373	. . .	. . .
3,669.668 . . .	5.469	0.360	. . .	. . .
3,673.646 . . .	5.457	0.359	. . .	. . .
3,679.659 . . .	5.418	0.315	. . .	. . .
3,682.677 . . .	5.390	0.317	. . .	. . .
3,684.662 . . .	5.385	0.308	. . .	. . .
3,688.650 . . .	5.362	0.295	. . .	. . .
3,700.626 . . .	5.380	0.322	. . .	. . .
3,701.665 . . .	5.385	0.324	. . .	. . .
3,704.656 . . .	5.422	0.317	. . .	. . .
3,706.715 . . .	5.427	0.331	0.342	0.468
3,707.668 . . .	5.430	0.324	. . .	. . .
3,725.623 . . .	5.430	0.394	. . .	. . .
3,729.605 . . .	5.431	0.393	. . .	. . .
3,738.683 . . .	5.425	0.391	0.308	0.471
3,741.654 . . .	5.471	0.324	0.369	0.584
3,742.582 . . .	5.464	0.329	0.373	0.578
3,752.551 . . .	5.403	0.386	0.306	0.488
3,753.560 . . .	5.442	0.335	. . .	. . .
3,774.551 . . .	5.423	0.339	0.350	0.513
3,777.510 . . .	5.418	0.373	0.317	0.476
1979				
2,443,998.752 . . .	5.459	0.326	0.297	0.464
4,010.815 . . .	5.413	0.344	0.385	0.470
4,011.737 . . .	5.443	0.337	0.337	0.481
4,024.714 . . .	5.500	0.355	0.309	0.516
4,036.670 . . .	5.457	0.369	0.350	0.534
4,037.708 . . .	5.464	0.379	0.341	0.515
4,040.691 . . .	5.423	0.370	0.311	0.457
4,043.708 . . .	5.471	0.340	0.349	0.518
4,049.675 . . .	5.455	0.337	0.333	0.488
4,050.690 . . .	5.452	0.349	0.316	0.510
4,051.684 . . .	5.455	0.351	0.323	0.524
4,060.656 . . .	5.421	0.318	0.312	0.486
4,088.646 . . .	5.502	0.352	0.350	0.511
4,116.597 . . .	5.498	0.334	0.345	0.511
4,117.578 . . .	5.499	0.349	0.349	0.536
4,128.566 . . .	5.493	0.354	0.350	0.504
4,134.562 . . .	5.476	0.343	0.343	0.532

The photometry of 89 Her is listed in Table 3. $(U-V)$ data were obtained, but are not published because of conflicting zero-point adjustments. The absence of multicolor data for much of 1978 was due to the regular photometer undergoing modifications at that time and being temporarily replaced by a blue-sensitive-only DC photometer. The general accuracy of the photometry can be judged from Table 1, where the standard deviation of a single observation is ± 0.007 mag. There is also good agreement with the entirely independent work of Percy, Baskerville, and Trevorrow (1979), done simultaneously elsewhere.

Radial velocities were obtained with the Cassegrain spectrograph of the DDO 1.9 m telescope, using dispersions of 8, 12, and 16 Å mm^{-1}. (All but three plates were 12 Å mm^{-1}.) The measurements were made on the DDO PDS microdensitometer and are listed in Table 4. Small corrections derived from IAU standard stars have been applied. Again unfortunately, the spectrograph was undergoing modifications throughout much of this period, and the overlap with the photometry is not as complete as one would wish.

Figure 1 shows the V magnitudes and radial velocities obtained during the 3 yr of observation. During the first season, the photometry seemed to show nothing unusual. Portions of three cycles were measured, and their interpretation as due to pulsation seemed quite straightforward. The period appeared to be in the range of 67 to 70 days, verifying Worley's (1956) results, and as Figure 2 shows, the colors varied much as expected. The relative amplitudes in the various filters are entirely typical of Cepheid behavior. It was decided to obtain further observations the following season mainly to refine the period.

Near the start of the 1978 season, however, it was realized that there was something severely wrong with this simple picture. First, the cycle then being observed was half a cycle out of phase with those of the previous season, implying a phase slippage of over a month in a 6 month period, which was far beyond the period uncertainties of the first season.

Second, the first season's radial velocities had been reduced, with the surprising result that although small fluctuations in velocity were apparent, there was no

TABLE 4

Radial Velocities of 89 Herculis

JD 2,440,000+	RV km s^{-1}	s.e. km s^{-1}
1971		
1047.833......	−25.5	0.7
1047.899......	−27.4	0.7
1058.816......	−23.4	0.5
1977		
3310.632......	−26.7	0.7
3317.657......	−30.9	0.7
3338.609......	−27.8	0.9
3345.597......	−28.8	0.9
3352.625......	−29.6	0.8
3387.664......	−26.7	2.4
1978		
3569.928......	−31.6	0.8
3571.896......	−30.8	0.9
3580.824......	−31.9	0.7
3585.895......	−34.1	1.4
3587.819......	−35.9	0.8
3592.929......	−31.1	0.9
3597.923......	−32.0	0.6
3604.561......	−31.5	0.6
3607.600......	−29.9	0.6
3616.877......	−27.0	0.6
3626.532......	−26.4	0.9
3627.533......	−26.0	0.6
3631.670......	−25.9	0.6
3632.589......	−26.8	0.5
3633.551......	−26.3	0.6
3659.830......	−26.6[a]	...
3679.797......	−23.7[a]	...
3742.573......	−28.1	0.8
3780.518......	−34.5	0.6
3790.504......	−31.8	0.4
3812.469......	−30.0	1.1
3818.469......	−33.6	1.5
1979		
3951.940......	−25.2	0.6
3952.872......	−29.3	0.5
3971.909......	−25.9	0.5
3974.831......	−25.0	0.5
3981.774......	−22.5	0.5
3995.757......	−23.2	0.8
3998.878......	−19.9	0.7
4001.876......	−20.6	0.5
4002.715......	−24.1	0.8
4010.850......	−26.1	0.5
4015.841......	−25.8	0.6
4030.635......	−30.5	0.6
4038.603......	−25.9	0.5
4044.861......	−22.2	0.4
4049.624......	−23.1	0.5
4053.652......	−28.8	0.7
4057.737......	−26.6	0.5
4086.580......	−29.2	0.5
4092.564......	−26.7	0.5
4136.522......	−30.4	0.6
4143.496......	−29.6	0.5

[a] Dominion Astrophysical Observatory results courtesy Alan Batten, private communication.

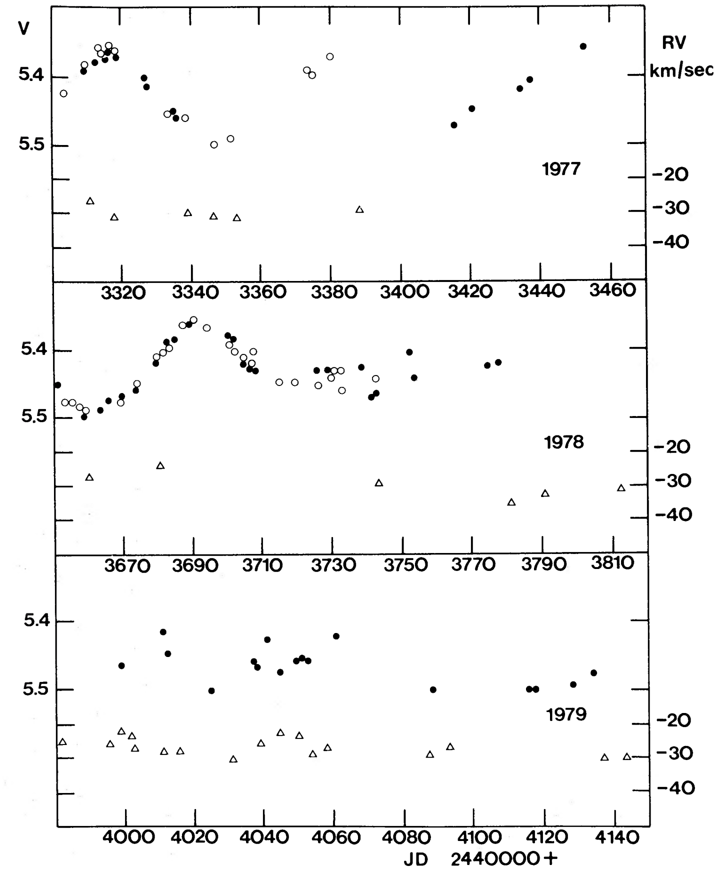

FIG. 1.—V magnitudes (*circles*) and radial velocities (*triangles*) of 89 Her over three seasons. Only those velocity data overlapping the photometry are shown. Filled circles represent DDO photometry, open circles that of Percy, Baskerville, and Trevorrow (1979).

sign of a velocity curve corresponding to the light curve. In the well-defined first cycle of 1977, the radial velocity at maximum light was -30.9 ± 0.7 km s^{-1}, while at minimum light it was -29.6 ± 0.8 km s^{-1}. From the well-known correlation between light amplitude and velocity amplitude for Cepheids, a velocity amplitude of over 8 km s^{-1} would have been expected. (In fact, the ratio $\Delta(RV)/\Delta m$ increases from right to left across the H-R diagram; so since 89 Her is blueward of the Cepheids, one might expect an even larger velocity amplitude).

Third, the pulsation mass derived from the $P\sqrt{(\rho)} = Q$ relation is peculiar. Since the spectral type and absolute magnitude of the star are so well known, one may deduce a radius of $130 \pm 15\ R_\odot$. Then with $P = 68^d$ and Q between 0.04 and 0.06, one obtains masses between 0.7 and 1.7 $\mathfrak{M}_\odot$. An observational P-R-$\mathfrak{M}$ relation (Fernie 1965) gives $\mathfrak{M} = 2.9\ \mathfrak{M}_\odot$, while a theoretical one (Stobie 1969) yields 2.1 $\mathfrak{M}_\odot$. Yet if 89 Her is a normal supergiant, one would expect a mass of about 20 $\mathfrak{M}_\odot$, depending on which crossing of the Hertzsprung gap is involved. Note that any assumption of overtone pulsation worsens the discrepancy and that the present rate of mass loss is far too small to account for it. Neither is it appropriate to think of 89 Her as some kind of Population II Cepheid; they are even further removed from it in the H-R diagram than are the classical Cepheids and of much lower luminosity. Their P-L relation (Demers and Harris 1974) predicts $M_V = -3.0$; the observed value is -6.8.

The fourth indicator that something was amiss can be seen from Figure 2. The declining portion of the light curve is steeper than the rising portion, which is just the opposite of almost any other pulsating variable. Also, maximum light is unusually peaked.

Further surprises soon appeared during the 1978 season, as the center panel of Figure 1 shows. A well-defined cycle was underway at the start, although again the two radial velocities during this period do not show the expected velocity curve (their difference is marginal, and in any case in the opposite sense to that expected). But during the declining part of the light curve the cycle suddenly collapsed into a random kind of "fluttering" that persisted for the remainder of the season. This is only on the order of hundredths of a magnitude, but is taken to be real since it is at about

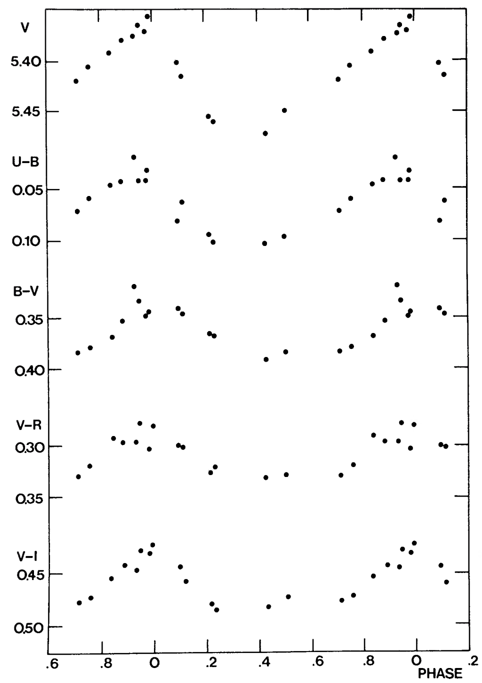

FIG. 2.—Light and color curves of 89 Her during the 1977 season. Phasing has been done with 68^d period.

the 10 σ level. Evidently some such interlude as this could account for the apparent phase slippage between 1977 and 1978.

Finally, in the 1979 season, as Figure 1 again shows, there was no well-defined cycle at all, the fluttering persisting all season. But now—perversely—there is a hint in portions of the velocity data of a curve with the expected 8 km s^{-1} amplitude. Note the overall decline in light through the season, accompanied by an overall decline in radial velocity.

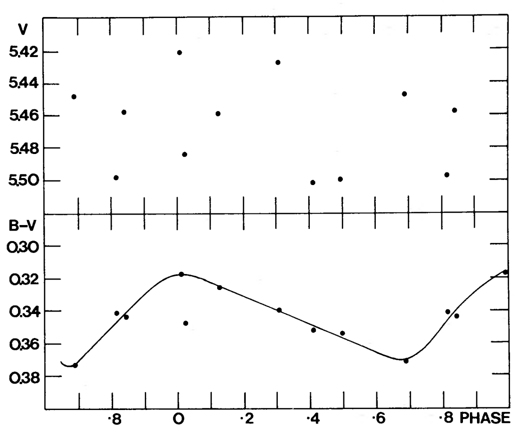

FIG. 3.—V and $B-V$ photometry of 89 Her during 1979, phased with a 68^d period. Normal points have been used, and the one scattered point in the lower panel is the last observation of the season.

A final surprise lay in the $(B-V)$ data for 1979. To improve precision, I have clumped closely spaced observations into normal points and phased them on a 68^d period. The results are shown in Figure 3. In the upper panel the V data show only a random scatter, but in the lower panel there is a quite well-defined curve for the $(B-V)$ data, the sole scattered point comprising the very last observation of the season. Evidently, there was a smooth but small variation in temperature whose effect on the light was swamped by some other phenomenon.

III. DISCUSSION

No simple explanation of these somewhat bizarre observations is obvious. One can immediately rule out any geometric model, which would have to invoke either some binary phenomenon or rotation. Although during the first season of photometry some notions of a binary explanation were entertained, that seems firmly ruled out by the radial velocities and the erratic behavior of the light variation.

Neither does any kind of rotating spotted-star model look promising. For a 130 $R_\odot$ star to rotate in 68^d requires an equatorial velocity of 97 km s^{-1}, and there is no suggestion of any such velocity in the spectral line widths. In fact, Sargent and Osmer (1969) estimated a Doppler-velocity parameter for the lines of 9 km s^{-1}, noting that this is a measure of the sum total of thermal motions, rotation, microturbulence, and macroturbulence. If one invokes a sin i projection factor to reconcile the 9 and 97 figures, the aspect must be within 5° of pole-on, and then any spottiness would be ineffective.

It therefore seems that one must turn to some form of pulsation. Ordinary radial pulsation would appear to be ruled out by the radial velocities. Even if multimode excitation is present, it is not clear that the velocities could be identical at the extremes of light variation. Also, it is noteworthy how abruptly a cycle can be switched off: Note in the center panel of Figure 1 how the declining light curve is suddenly converted to constancy to within 0.02 or 0.03 mag for the next month or so.

The so-called fluttering, of course, may be no more than the usual well-known instability of luminous supergiants at the level of a few hundredths of a magnitude and a few km s^{-1}. Such changes are consistent when interpreted as due to small changes in radius. What is unsettling is the lack of a luminosity change phased to the temperature change implied by Figure 3. The amplitude of 0.05 mag in $(B-V)$ would have been expected to produce a V light curve of over 0.1 mag amplitude, whereas there are only random fluctuations in V of no more than 0.08 mag.

The most attractive—or least unattractive—interpretation of the observations may be one of nonradial pulsation. Preliminary theoretical investigations of this for supergiants have already been published by Lucy (1976) and Dziembowski (1977). Both investigated models appropriate to α Cyg (A2 Ia), and both concluded that while macro- and microturbulence may be accounted for by high-mode nonradial instabilities, more regular variability is not to be expected. However, to what extent this conclusion would apply to a star of later spectral type like 89 Her is uncertain, and Dziembowski further states that "in this case our oscillation code is unreliable because, depending on the mode, 20–30% of the excitation energy comes from the atmosphere."

Osaki (1971) investigated nonradial pulsation as an explanation for the β Cep phenomenon, and this idea has been developed and applied with considerable success by Buta and Smith (1979) to the B4.5 V star 53 Per. However, it would seem that the signature of nonradial pulsation in these cases is asymmetric and variable line profiles. Inspection of PDS microdensitometer tracings of four plates of 89 Her taken at various phases do not show anything of this nature, and neither do Searle, Sargent, and Jugaku (1963)—who made a much more detailed spectroscopic examination of the star—comment on any such effect, apart, of course, from lines indicative of the mass loss. On the other hand, 89 Her is far from being a β Cep star; in particular it lacks the high rotation of B-stars, which can interact with nonradial pulsation.

In summary, it seems that the case for 89 Her being a nonradial pulsator remains inconclusive, although what evidence there is does not appear promising.

IV. COMMENTS ON EARLIER CONCLUSIONS

Table 5 lists the mean magnitude and colors of 89 Her, obtained by simply averaging all the data in Table 3. Standard errors of the means are all less than 0.01 mag. Table 5 also compares these to the intrinsic colors of an F2 Ia star given by Johnson (1966) which give E, the excess of the individual indices, and E_{B-V}, their equivalent excess in $(B-V)$. Evidently the color excess of 89 Her is small, of order 0.1 mag or less. There is also a small excess in $(V-I)$, which is not surprising in

TABLE 5

AVERAGE PHOTOMETRIC PARAMETERS OF 89 HERCULIS

Parameter	V	$B-V$	$V-R$	$V-I$
89 Her......	5.44	+0.35	+0.33	+0.49
F2 Ia.......	...	+0.25	+0.26	+0.47
E..........	...	+0.10	+0.07	+0.02
E_{B-V}.......	...	+0.10	+0.09	+0.01

view of the excess at longer infrared wavelengths (Gillett, Hyland, and Stein 1970). There is no support, however, for the suggestion by the latter that the circumstellar shell should produce effects of order half a magnitude in the visible.

Neither do the data offer any support to the alternate explanation of the infrared excess being due to a luminous late-type binary companion (Humphreys and Ney 1974). Not only has the radial velocity shown no significant systemic variation over the past 3 yr, but it is consistent with data obtained in 1971 (see Table 4), with the velocities found nearly 25 yr ago by Böhm-Vitense (1956), and even with five velocities obtained at Lick between 1920 and 1926 (Campbell and Moore 1928). If 89 Her is a binary, it must be one of extremely long period.

Finally, attention is drawn to the space motion of 89 Her. Searle, Sargent, and Jugaku (1963) concluded that the star could have reached its present position a kiloparsec off the Galactic plane if its initial z-velocity was about 100 km s^{-1}. They did not, however, consider the star's actual space velocity, possibly making the reasonable guess that the proper motion of a star more than 2 kpc away is not likely to be known with any useful precision. 89 Her, however, happens to be an FK4 star, and its proper motion is therefore known much more accurately than is often the case. Also, with its seemingly well-known absolute magnitude and low reddening, its distance is more than usually reliable too. It may, therefore, be worth making at least a rough estimate of its space velocity.

The Smithsonian Star Catalog gives the components of proper motion as $\mu_\alpha = +0''.003$, $\mu_\delta = +0''.007$, each with a standard deviation of $\pm 0''.001$. These translate into $\mu_l = +0''.008$, $\mu_b = 0''.000$. While these do not contradict the suggestion of Searle, Sargent, and Jugaku (1963), it is somewhat disconcerting that *all* the present motion should appear parallel to, rather than transverse to, the plane.

Adopting a radial velocity of -27 km s^{-1}, and correcting for standard solar motion and galactic rotation, I find the velocity components of 89 Her relative to the LSR to be $\dot{X}$ (toward the Galactic center) = -130 km s^{-1}, $\dot{Y}$ (toward $l = 90°$) = $+20$ km s^{-1}, $\dot{Z}$ (toward $b = +90°$) = -20 km s^{-1}. This corresponds to a space velocity of 130 km s^{-1} directed toward $l = 171°$, $b = -7°$. In short, 89 Her appears to be a typical high-velocity star on an orbit directed radially outward through the Galaxy, and this conclusion is not changed substantially even by errors several times the formal ones in the proper motions.

It therefore seems to me quite unlikely that 89 Her is an ordinary Population I star that happened to be fired vertically off the plane soon after birth through some slingshot effect such as the catastrophic disruption of a binary system. Rather, it appears to be a halo star traveling on a galactic orbit typical of such stars, which in turn must mean that its apparent youth of 10^7 yr is illusory. But if it is a low-mass star (perhaps about 2 $\mathfrak{M}_\odot$ as the pulsation at first seemed to suggest), then how did it manage to achieve a luminosity that grossly exceeds that of almost any other Population II object?

Evidently the mystery of 89 Her remains to be unraveled.

V. SUMMARY

1. 89 Her at times shows light and color variations reminiscent of pulsation. These, however, can disappear abruptly and are replaced by erratic random fluctuations ("fluttering") on a characteristic scale of 0.05 mag.

2. The light curves are not accompanied by velocity curves, as would be expected for radial pulsation. In one well-observed cycle the radial velocity remained constant to within the measuring error of 0.8 km s^{-1} at maximum and at minimum light, whereas radial pulsation would have led to the expectation of a change of 8 km s^{-1}. Nevertheless, the radial velocities do show erratic changes of about this order on time scales of weeks.

3. Geometric effects such as rotation are unable to explain the observations.

4. Nonradial pulsation may offer an explanation, although existing theoretical investigations do not predict it, and there is no sign of asymmetry in the spectral lines apart from that due to mass loss.

5. The colors of 89 Her show it to be only slightly reddened by about 0.1 mag, and that it has an IR excess. No effects as large as those predicted by Gillett, Hyland, and Stein (1970) on the basis of a circumstellar shell are observed.

6. Radial velocities spanning almost 60 yr offer no support to the suggestion of Humphreys and Ney (1974) that 89 Her is a binary.

7. The space motion of 89 Her indicates a highly eccentric galactic orbit, with the star headed radially outward through the Galaxy at 130 km s^{-1}. There is almost no component of velocity transverse to the Galactic plane. This makes it seem more probable that 89 Her is a halo-type object, rather than a normal Population I supergiant expelled from the plane near birth by some slingshot effect. On the other hand, if it is in fact an old, low-mass star, one is at a loss in explaining how it might masquerade as a normal supergiant, in particular how it might achieve $M_V = -6.8$, which is much more luminous than other Population II stars.

I am much indebted to several people for help in this investigation. Nancy Evans obtained a significant amount of the radial velocity data and provided fruitful discussions, as did John Percy. Alan Batten kindly obtained two plates for me at the Dominion Astrophysical Observatory during the time our own spectrograph was out of commission. Jim deRoux obtained some of the photometry for me and did much of the data reduction, while Ron Lyons made available his expertise on the PDS microdensitometer. This work was supported in part through an operating grant from the Natural Sciences and Engineering Research Council of Canada.

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