9-1987

Chromospherically Active Stars. III. HD 26337 = EI Eri: an RS CVn Candidate for the Doppler-Imaging Technique

Francis C. Fekel
Vanderbilt University

Robert Quigley
Western Washington University

Kim Gillies
Kitt Peak National Observatory

John L. Africano
Kitt Peak National Observatory

Recommended Citation
Fekel, F.C.; Quigley, R.; Gillies, K.; Africano, J.L. "Chromospherically Active Stars. III. HD 26337 = EI Eri: an RS CVn Candidate for the Doppler-Imaging Technique" Astronomical Journal v.94, p.726 (1987)

CHROMOSPHERICALLY ACTIVE STARS. III. HD 26337 = EI ERI: AN RS CVn CANDIDATE FOR THE DOPPLER-IMAGING TECHNIQUE

Francis C. Fekel[a),b)]
Dyer Observatory, Vanderbilt University, Nashville, Tennessee 37235
and
McDonald Observatory, University of Texas at Austin, Austin, Texas 78712

Robert Quigley[a)]
Department of Physics and Astronomy, Western Washington University, Bellingham, Washington 98225

Kim Gillies and John L. Africano
Kitt Peak National Observatory, National Optical Astronomy Observatories,[c)] P. O. Box 26732, Tucson, Arizona 85726-6732
Received 31 March 1987; revised 2 June 1987

ABSTRACT

The variable star HD 26337 = EI Eri is a chromospherically active G5 IV single-lined spectroscopic binary with a period of 1.94722 days. It has moderate strength Ca II H and K emission and strong ultraviolet emission features, while Hα is a weak absorption feature that is variable in strength. The inclination of the system is $46^\circ \pm 12^\circ$, and the unseen secondary is most likely a late K or early M dwarf. The $v \sin i$ of the primary is 50 ± 3 km s^{-1}, resulting in a minimum radius of $1.9 \pm 0.1\ R_\odot$. When compared with the Roche lobe radius, this minimum radius indicates that the primary is close to filling its Roche lobe. This results in a strong constraint on the mass ratio with $\mathscr{M}_1/\mathscr{M}_2 \geqslant 2.6$ and a mass for the primary of at least $1.4\mathscr{M}_\odot$. We estimate a distance to the system of 75 pc, indicating that a useful trigonometric parallax could be obtained. HD 26337 has a moderate lithium abundance $\log n(\mathrm{Li}) = 1.75$–$2.0$. It is suggested that many chromospherically active stars may still have moderate lithium abundances because they have evolved from late A or early F type main-sequence stars. Such a star would not deplete its surface lithium abundance while on the main sequence, and would evolve rapidly across the H-R gap while its convection zone develops and begins to deplete lithium.

I. INTRODUCTION

Bidelman and MacConnell (1973) detected Ca II H and K emission in HD 26337 = EI Eri ($\alpha = 4^h04^m8$, $\delta = -08^\circ10'$, 1900) and classified it as G5 IV. Fekel *et al.* (1982) identified it as a single-lined RS CVn binary and determined a preliminary orbital period of 2.04 days. They found that the star had a V amplitude of 0.19 mag and a period of 2.038 days. Photometric observations of Bopp *et al.* (1983) indicated a slightly longer period of 2.049 days. Fekel, Moffett, and Henry (1986) reported that the 2.04 day period is an alias of the correct period, which is slightly less than two days. In this paper we present spectroscopic observations supporting this result and discuss other properties of this RS CVn system.

II. OBSERVATIONS AND REDUCTIONS

The high-dispersion ground-based spectroscopic observations were obtained at McDonald and Kitt Peak National Observatory with a variety of solid-state detectors (Table I). All observations included the wavelength range 6390–6455 Å, while the ones obtained with the McDonald 2.1 m telescope also included the Hα line. Each radial velocity (Table II) was determined relative to one of the following International Astronomical Union (IAU) velocity standards, β Gem, α Ari, 10 Tau, or ι Psc. Their assumed radial velocities are 3.3, -14.3, 27.9, and 5.3 km s^{-1}, respectively (Pearce 1955). Details of the cross-correlation reduction procedure have been given by Fekel, Bopp, and Lacy (1978).

Two ultraviolet spectroscopic observations were obtained with the short-wavelength-primary (SWP) camera of the *International Ultraviolet Explorer* (*IUE*) satellite. These two observations, SWP 25280 and SWP 25291, were obtained on UT dates 20 February 1985 and 21 February 1985 with exposure times of 150 and 120 min, respectively. Both observations cover a wavelength region from 1200 to 2000 Å and were obtained through the large aperature, which has a resolution of about 6 Å. The observations were absolutely calibrated with standard computer software routines at the Regional Data Analysis Facility of the Goddard Space Flight Center.

TABLE I. Telescope-detector combinations.

Telescope	Detector	Dispersion (Å mm^{-1})	Resolution (Å)	Wavelength range (Å)	Source code
McDonald 2.7 m	Reticon	4.4	0.36	110	MR1
McDonald 2.1 m	Reticon	9.5	0.42 or 0.56	235	MR2
Kitt Peak coudé feed	RCA CCD	4.2	0.30	65	KR
Kitt Peak coudé feed	Texas Instruments CCD	7.6	0.23	90	KT

[a)] Visiting Astronomer, Kitt Peak National Observatory, National Optical Astronomy Observatories, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.
[b)] Guest Observer with the *International Ultraviolet Explorer* satellite.
[c)] Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

 0004-6256/87/030726-05$00.90

TABLE II. Radial velocities of HD 26337.

HJD 2440000 +	Phase	V (km s^{-1})	O − C (km s^{-1})	Source	Standard
4179.903	0.083	43.1	1.9	MR1	10 Tau
4180.916	0.603	− 3.7	0.4	MR2	β Gem
4181.857	0.086	41.0	0.1	MR2	α Ari
4182.814	0.578	− 8.6	− 2.2	MR2	α Ari
4473.973	0.104	38.1	− 1.2	MR1	10 Tau
4475.963	0.126	35.6	− 1.2	MR1	10 Tau
4478.955	0.662	4.3	1.0	MR2	α Ari
4507.885	0.519	− 9.2	0.2		
4627.626	0.013	44.5	− 0.2	MR1	β Gem
5356.702	0.432	− 6.3	0.9	KR	β Gem
5357.670	0.929	42.0	− 0.2	KR	β Gem
5358.679	0.447	− 10.2	− 2.1	KR	α Ari
5359.745	0.995	47.8	3.0	KR	α Ari
5360.716	0.494	− 7.0	2.6	KR	β Gem
5361.702	0.000	41.3	− 3.5	KR	β Gem
5594.999	0.810	28.1	0.4	KT	β Ari
5596.022	0.336	3.2	− 0.5	KT	β Gem
5596.963	0.819	27.7	− 1.3	KT	β Gem
5599.008	0.869	36.2	0.1	KT	10 Tau
5717.791	0.870	34.7	− 1.6	KT	10 Tau
5718.764	0.370	1.9	2.9	KT	β Gem
5719.768	0.886	39.9	1.8	KT	β Gem
5720.740	0.385	− 3.8	− 1.0	KT	10 Tau
5721.727	0.892	40.7	1.9	KT	β Gem
5941.958	0.992	45.0	0.2	KT	ι Psc
5971.996	0.418	− 6.9	− 0.8	KT	α Ari
6076.766	0.223	22.2	0.0	KT	α Ari

III. ORBIT

Our 26 observations obtained at McDonald and Kitt Peak National Observatory from 1979 to 1985, plus one photographic observation obtained at Kitt Peak by Bopp (1980), were used to determine the orbital elements. The period-finding program of Deeming (Bopp *et al.* 1970) identified two possible periods close to two days. On the basis of a limited data set, Fekel *et al.* (1982) preferred the period of 2.04 days. Analysis of the complete data set, however, indicates that a period of 1.95 days is the correct one. We computed spectroscopic orbits with both periods and found that the velocity residuals were smaller for the shorter period. Collier Cameron, Lloyd Evans, and Balona (1987) claim the same period from an independent set of spectroscopic observations. Our combined data confirm that the 1.95 day period is the correct one and that the 2.04 day period is an alias (Lloyd Evans 1985).

Final orbital elements (Table III) were computed with the differential-corrections program of Barker, Evans, and Laing (1967). The formal solution of the spectroscopic orbit gave a value for the eccentricity of 0.008 ± 0.020, so in accordance with the precepts of Lucy and Sweeney (1971), an $e = 0$ solution has been adopted. The observed radial velocities and the computed radial-velocity curve are plotted in Fig. 1. Because of its large projected rotational velocity of 50 km s^{-1} (Fig. 2) and line asymmetries due to spots, the standard error of an observation of unit weight for HD 26337 is 1.6 km s^{-1}, which is about twice the value found for orbital solutions of narrowlined stars.

TABLE III. Orbital elements.

$P = 1.94722 \pm 0.00003$ (m. e.) days
$T_0 = 2446074.384$ HJD
$\gamma = 17.6 \pm 0.4$ km s^{-1}
$K_1 = 27.2 \pm 0.6$ km s^{-1}
$e = 0.0$ (assumed)
$a_1 \sin i = 7.29 \pm 0.16 \times 10^5$ km
$f(m) = 0.0041 \pm 0.00027\ \mathcal{M}_\odot$
Standard error of an observation of unit weight = 1.6 km s^{-1}

IV. ACTIVE-CHROMOSPHERE CHARACTERISTICS

The Ca II H and K emission in this late-type star was first noted by Bidelman and MacConnell (1973). This was confirmed by Fekel (1980), who found it to be moderate in strength, class C on Hearnshaw's (1979) qualitative emission scale.

In most RS CVn binaries, Hα is an absorption feature, although it is typically weaker, that is, has a smaller equivalent width, than in similar stars that are not chromospherically active (Smith and Bopp 1982). Figure 11 of Fekel, Moffett, and Henry (1986) shows that the Hα absorption line of HD 26337 is quite weak. Four additional Hα observations indicate that it is also quite variable in strength, with equivalent widths ranging from 0.3 to 1.1 Å. For comparison, the inactive star μ Her A, which is also classified as G5 IV, has an Hα equivalent width of 2.4 Å. The Hα line of HD 26337 deserves extensive monitoring to determine whether the variations correlate with the spot period, as has been found at times for the very active systems HR 1099 = V711 Tau (Bopp and Talcott 1978) and UX Ari (Nations and Ramsey 1980).

Bopp *et al.* (1983) obtained a low-resolution long-wavelength ultraviolet spectrum of HD 26337. They detected the Mg II blend at 2800 Å as an emission feature and computed a surface flux of 3.3×10^6 ergs cm^{-2} s^{-1} for it.

Baliunas, Blair, and Guinan (1983) obtained ultraviolet long-wavelength spectra of HD 26337 on four days between December 1982 and March 1983. Their preliminary analysis of these spectra indicated that the emission from Mg II $h + k$ was moderately strong and variable.

One of our two short-wavelength (SWP) ultraviolet spectra is shown in Fig. 3. Ultraviolet emission features typical of chromospherically active stars are noted. Table IV gives the

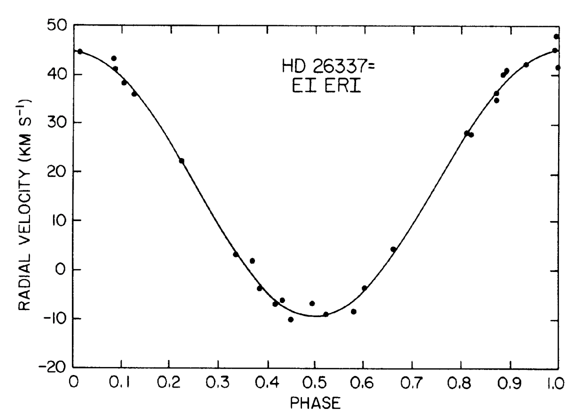

FIG. 1. Observations and computed radial-velocity curve of HD 26337 = EI Eri. Phase is computed from T_0, the time of maximum positive velocity.

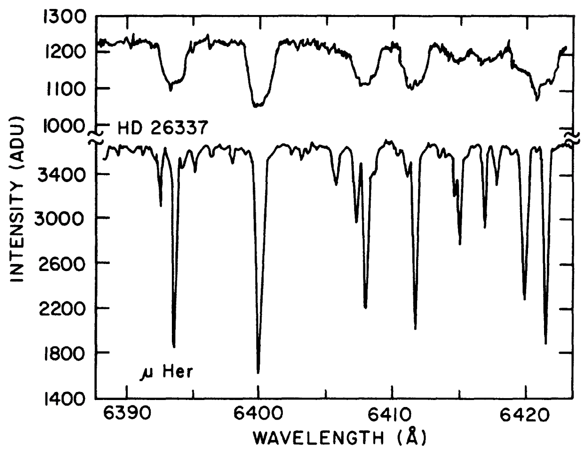

FIG. 2. Portion of a CCD observation of HD 26337 compared with that of μ Her A. The line broadening of HD 26337 is quite evident.

emission-feature identifications and the measured observed fluxes for both SWP spectra. A line-by-line comparison of the measured fluxes of the two spectra indicates quite similar values, so little can be said about possible emission flux variability. Thus, these fluxes were averaged and converted to surface fluxes following the procedure of Linsky *et al.* (1979). Since the $V-R$ color of active stars appears to have a color excess relative to inactive ones (Fekel, Moffett, and Henry 1986), we used the surface brightness-$(B-V)$ color relation of Barnes, Evans, and Moffett (1978) and the observed value of $B-V=0.68$ (Fekel, Moffett, and Henry 1986). This results in a visual surface brightness consistent with the $V-R$ color of the G5 IV star μ Her A. Compared with the results of Stickland and Williams (1983) for HR 1099 and UX Ari (listed in Table IV), the surface fluxes of HD 26337 are quite similar, with the fluxes of HD 26337 being greater than either system for some of the lines.

Simon and Fekel (1987) included HD 26337 in their examination of the dependence of ultraviolet chromospheric emission upon rotation among late-type stars. Their Fig. 3 shows that the normalized C IV flux and line surface flux of HD 26337 are appropriate for its rotation period when compared with other active-chromosphere stars.

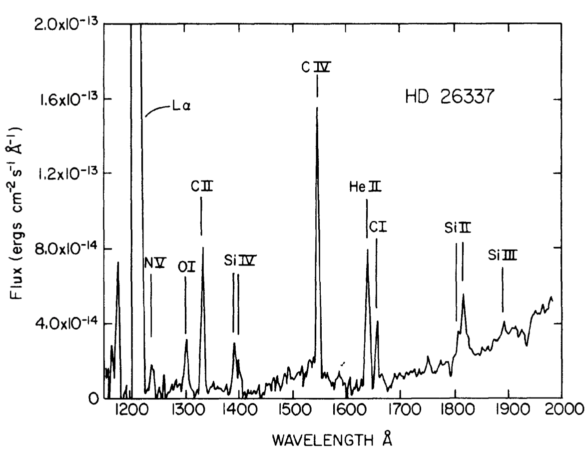

FIG. 3. *IUE* low-resolution short-wavelength observation, SWP 25291, of HD 26337 with the emission lines identified.

The ultraviolet continuum of the G5 IV star is quite evident in Fig. 3. There is no evidence for a hot continuum from a second star.

V. DISCUSSION

Although HD 26337 is certainly an RS CVn binary, it is not one of the classical double-lined eclipsing systems as defined by Hall in 1976. Like II Peg and GX Lib = HD 136905, the system is single lined and has a mass ratio substantially different from unity.

Bidelman and MacConnell (1973) classified the star as G5 IV from objective-prism plates, while Harlan (1974) classified it as G2 IV–V. Recently, Abt (1986) obtained spectrograms of a number of stars, most of which were suggested to be weak-lined dwarfs from their photometric indices. He classified HD 26337 as a weak-lined G5 V.

If HD 26337 is weak lined as a result of a deficiency of metals, this would indicate that it is relatively old. However, there appears to be an alternate explanation for the line strengths. Olsen (1984) noted in his photometric study of G and K dwarfs that RS CVn binaries often resemble metal-deficient dwarfs in their Strömgren photometric indices. Figure 4 shows a portion of a CCD observation of HD 26337. Its spectrum is compared with that of μ Her A, whose spectral lines have been broadened to 50 km s^{-1}. It is obvious that the lines of HD 26337 are substantially weaker, supporting the findings of Olsen (1984) and Abt (1986). This phenomenon was first seen in HR 1099 (Fekel 1983). These line asymmetries and the line weakening are caused by a lack of flux from cooler spots relative to the photosphere in these types of stars (Vogt and Penrod 1983) rather than metal deficiencies.

Since the system is not double lined, it is more difficult to determine properties of the system such as the inclination and the nature of the secondary. Yet some limits can be determined. Most of the masses of the active star in RS CVn binaries range from 1.2 to 1.8 $\mathscr{M}_\odot$ (Popper 1980). Combining the value of the mass function (Table IV) with each assumed primary mass, we determine the corresponding minimum value of the secondary mass, which occurs when $i=90°$. The estimated upper limit for the mass of the secondary is about 1.0–1.3 $\mathscr{M}_\odot$, depending on the mass and assumed luminosity of the primary, and is based on our experience of detecting the secondaries of other RS CVn binaries in the 6430 Å wavelength region. This upper limit for the secondary mass results in a lower limit for the inclination. Table V gives the results of such calculations. Column 1 is the assumed primary mass. Column 2 is the secondary mass that results if $i=90°$. Column 3 is the resulting mass ratio. Column 4 is the assumed upper limit to the mass of the secondary, while column 5 is the inclination resulting from that assumed upper limit. Thus, the lower limit for the inclination of the system is 34°. Column 6 lists the computed minimum Roche lobe radius of the primary. Fekel, Moffett, and Henry (1986) determined $v \sin i = 50 \pm 3$ km s^{-1}. This value, combined with the photometric rotation period of 1.95 days (Hall *et al.* 1987), gives a minimum radius $R \sin i = 1.9 \pm 0.1\ R_\odot$ indicating that the star is definitely a subgiant rather than a dwarf. Since there appears to be no photometric evidence of eclipses, $R_1 + R_2 < a \cos i$, where R_1 and R_2 are the radii of the primary and secondary, respectively, and a is the semimajor axis of the relative orbit. From the mass ratios in Table V, the maximum value of $a \sin i = 4.08\ R_\odot$ and the upper limit to the inclination is 58°.

TABLE IV. Ultraviolet emission-line fluxes (erg cm^{-2} s^{-1}).

		Observed flux $\times 10^{-14}$		Average surface flux $\times 10^{-4}$		
Ion	(Å)	SWP 25280	SWP 25291	HD 26337	UX Ari	HR 1099
N V	1240	16.5	13.0	20.6	30.9	9.1
O I	1305	21.2	19.5	28.4	63.1	30.2
C II	1335	52.9	47.0	69.8	33.9	45.7
Si IV	1400	30.0	28.9	41.1	17.4	20.4
C IV	1550	87.9	92.4	127.3	52.5	69.2
He II	1640	36.3	44.5	56.4	30.2	30.2
C I	1657	24.3	16.8	28.7	—	—
Si II	1808,1817	22.2	30.7	14.0	33.9	30.2
Si III	1892	3.9	3.7	5.3	—	—

As the mass ratio $\mathscr{M}_1/\mathscr{M}_2$ decreases, the maximum inclination also decreases. Thus, the inclination of the system is $46° \pm 12°$.

Since each mass ratio in Table V corresponds to the smallest possible secondary mass for the postulated primary mass, the mass ratio given is a maximum value. The mean Roche lobe radius times sin i computed from these mass ratios ranges from 1.9 to 1.7 $R_\odot$. There is no photometric or spectroscopic evidence for mass transfer in the system. Since the observed value of $R \sin i = 1.9 \pm 0.1\ R_\odot$, the system must have a large mass ratio of at least 2.6 if the primary does not fill its Roche lobe. This constrains the mass of the primary to be at least $1.4\mathscr{M}_\odot$. From the value of the mass ratio, the secondary is probably a late K or early M dwarf since no evidence for a hot white dwarf companion is seen in the ultraviolet.

Such a moderate mass, as opposed to a mass of 1.1 or 1.2 $\mathscr{M}_\odot$, is also suggested by its lithium abundance. From a Kitt Peak TI CCD observation of the lithium region, the equivalent width of the lithium line is 0.036 Å. Assuming an effective temperature of 5700 K, similar to that assumed for some G subgiants by Pallavicini, Cerruti-Sola, and Duncan (1987), their curve of growth for lithium results in an abundance of log $n(\text{Li}) = 2.0$. Even if the equivalent width is reduced to 0.025 Å to account for possible blends, the abundance is still log $n(\text{Li}) = 1.75$.

Pallavicini, Cerruti-Sola, and Duncan (1987) suggest that the lithium abundance in RS CVn binaries may be enhanced because the starspots on these stars have cooler temperatures and therefore a lower degree of ionization of lithium in the spots. Instead, we suggest that most chromospherically active stars showing moderate or strong lithium features may have evolved from late A or early F main-sequence stars. Such stars would not deplete surface lithium abundances while on the main sequence because of the lack of a convection zone. Compared with lower-mass stars having convection zones, they would evolve relatively rapidly through the Hertzsprung gap and would not have time to completely deplete their surface lithium abundance.

If the star has evolved from an early F dwarf and now has an absolute visual magnitude between 2.5 and 3.0, its parallax is between 0\".012 and 0\".015. Thus, trigonometric-parallax observations of this star would be of use for placing further constraints on the mass of the primary from evolutionary tracks.

The star has been noted as a candidate for Doppler imaging (Fekel 1983; Bopp *et al.* 1983; Vogt and Penrod 1983), a technique for obtaining resolved images of rapidly rotating late-type spotted stars. Recently, Vogt, Penrod, and Hatzes (1987) have discussed criteria for the selection of such stars. From their experience they suggest a signal-to-noise ratio of at least 100 per resolution element, although they typically aim for 400 per resolution element, a resolution $\lambda/\Delta\lambda$ of at least 40 000 or 0.16 Å at 6430 Å, a rotational-axis inclination of 20° to 70° for the star and a $v \sin i$ value between 20 and 100. The combination of high signal-to-noise ratio and high dispersion requires that the star be reasonably bright. Although over one magnitude fainter than HR 1099, HD 26337, with a V magnitude of 7.11 (Fekel, Moffett, and Henry 1986), is still relatively bright. With a $v \sin i = 50$ km s^{-1} and $i = 46° \pm 12°$ its projected rotational velocity and inclination are also within the required limits. Since there is no evidence of secondary absorption lines, blending problems are less severe than in a double-lined system.

There are several possible problems. First, HD 26337 has a right ascension similar to HR 1099 and UX Ari, two other Doppler-imaging candidates. Thus, it might be difficult to

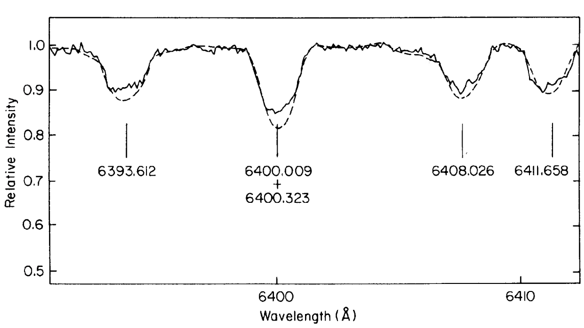

FIG. 4. Portion of an observed spectrum of HD 26337 (solid line) compared with a spectrum of μ Her A that has been broadened to 50 km s^{-1} (dashed line). The lines of HD 26337 are obviously weaker and asymmetric.

TABLE V. Mass and inclination limits.

$\mathscr{M}_1$ ($\mathscr{M}_\odot$)	$\mathscr{M}_2(i=90°)$ ($\mathscr{M}_\odot$)	$\mathscr{M}_1/\mathscr{M}_2$	$\mathscr{M}_2(u)$	i (°)	$R_L \sin i$
1.8	0.62	2.90	1.3	34	1.91
1.6	0.57	2.81	1.2	34	1.87
1.4	0.53	2.64	1.1	35	1.77
1.2	0.48	2.50	1.0	35	1.68

obtain high-signal-to-noise observations of all three on the same night. A more serious problem is that the period is short and close to two days. Thus, exposure times are limited because of velocity smearing, and it takes about 40 days to observe a phase cycle unless it is observed at quite different hour angles during the night. The most serious problem is that the spots appear to be changing rapidly. Hall *et al.* (1987) note that both the amplitude of the variation and the photometric period change from year to year. In addition, the light curve changes, at least in amplitude, from month to month. These results indicate that the spots have been evolving rather rapidly, and intensive sets of observations over a one to two month timescale will be necessary to resolve this spot evolution. Despite these difficulties, HD 26337 is one of about a half-dozen known stars for which Doppler imaging can be used.

We thank Dr. Y. Kondo and the staff of the *IUE* observatory for their help in the acquisition and reduction of ultraviolet spectra. We thank Drs. L. Balona and T. Lloyd Evans for access to their data in advance of publication. We thank Dr. S. Vogt for several helpful conversations. The comments of the referee are appreciated. This research has been supported in part by NASA grant 5-397 to F. Fekel.

REFERENCES

Abt, H. A. (1986) Astrophys. J. **309**, 260.
Baliunas, S. L., Blair, W. P., and Guinan, E. F. (1983). Inf. Bull. Var. Stars No. 2323.
Barker, E. S., Evans, D. S., and Laing, J. D. (1967). R. Obs. Bull. No. 130.
Barnes, T. G., Evans, D. S., and Moffett, T. J. (1978). Mon. Not. R. Astron. Soc. **183**, 285.
Bidelman, W. P., and MacConnell, D. J. (1973). Astron. J. **78**, 687.
Bopp, B. W. (1980). Private communication.
Bopp, B. W., Africano, J. L., Stencel, R. E., Noah, P. V., and Klimke, A. (1983). Astrophys. J. **275**, 691.
Bopp, B. W., Evans, D. S., Laing, J. D., and Deeming, T. J. (1970). Mon. Not. R. Astron. Soc. **147**, 355.
Bopp, B. W., and Talcott, J. C. (1978). Astron. J. 83, 1517.
Collier Cameron, A., Lloyd Evans, T., and Balona, L. (1987). Mon. Not. R. Astron. Soc. (submitted).
Fekel, F. C. (1980). In *Cool Stars, Stellar Systems and the Sun*, edited by A. K. Dupree, SAO Spec. Rep. No. 389, (Smithsonian Astrophysical Observatory, Cambridge, MA), p. 133.
Fekel, F. C., Bopp, B. W., and Lacy, C. H. (1978). Astron. J. **83**, 1445.
Fekel, F. C., Hall, D. S., Henry, G. W., Landis, H. J., and Renner, T. R. (1982). Inf. Bull. Var. Stars No. 2110.
Fekel, F. C., Moffett, T. J., and Henry, G. W. (1986). Astrophys. J. Suppl. **60**, 551.
Hall, D. S., Osborn, S. A. G., Seufert, E. R., Boyd, L. J., Genet, R. M., and Fried, R. E. (1987). Astron. J. **94**, 723.
Harlan, E. A. (1974). Astron. J. **79**, 682.
Hearnshaw, J. B. (1979). In *Changing Trends in Variable Star Research*, IAU Colloquium No. 46, edited by F. M. Bateson, J. Smak, and I. H. Urch (University of Waikato, Hamilton, New Zealand), p. 371.
Linsky, J. L., Worden, S. P., McClintock, W., and Robertson, R. M. (1979). Astrophys. J. Suppl. **41**, 47.
Lloyd Evans, T. (1985). Private communication.
Lucy, L. B., and Sweeney, M. A. (1971). Astron. J. **76**, 544.
Nations, H. L., and Ramsey, L. W. (1980). Astron. J. **85**, 1086.
Olsen, E. H. (1984). Astron. Astrophys. Suppl. **57**, 443.
Pallavicini, R., Cerruti-Sola, M., and Duncan, D. K. (1987). Astron. Astrophys. (in press).
Pearce, J. A. (1955). Trans. IAU **9**, 441.
Popper, D. M. (1980). Annu. Rev. Astron. Astrophys. **18**, 115.
Simon, T., and Fekel, F. C. (1987). Astrophys. J. **316**, 434.
Smith, S. E., and Bopp, B. W. (1982). Astrophys. Lett. **22**, 127.
Stickland, D. J., and Williams, D. (1983). Observatory **103**, 58.
Vogt, S. S., and Penrod, G. D. (1983). Publ. Astron. Soc. Pac. **95**, 565.
Vogt, S. S., Penrod, G. D., and Hatzes, A. P. (1987). Astrophys. J. (submitted).