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Looking for Discrete UV Absorption Features in the Early-Type Eclipsing Binaries μ^1 Scorpii and AO Cassiopeiae

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ABSTRACT. A search for discrete absorption components in the ultraviolet spectra of the early-type binaries μ^1 Scorpii and AO Cassiopeiae has been undertaken by analyzing material secured with the *International Ultraviolet Explorer* satellite during an exclusively assigned interval of nearly 50 hr. While the spectra of μ^1 Sco definitely do not show the presence of such lines, the spectra of AO Cas do confirm them and permit us to draw some conclusions about where they may be formed.

1. INTRODUCTION

Narrow features normally called discrete absorption components (DACs), as defined by Henrichs (1988), that appear in the ultraviolet spectra of early-type stars were noticed and called attention to by Morton (1976) in *Copernicus* spectra of the O9.5 Ve star ζ Ophiuchi (HD 149757). A similar feature had been observed earlier by Underhill (1975) in spectra of the B5 Ia star η Canis Majoris (HD 58350), and were interpreted as indicating the presence of a cloud moving away from the star at 235 km s^{-1}. The DACs are among the most striking features in the spectra of hot stars. DACs have since been reported on a number of O, B, and Be objects, whether single or double, and even in some early-type subdwarfs (see, for instance, Prinja & Howarth 1988; Massa et al. 1995; Kaper et al. 1997; and Prinja et al. 2002). A good recent review is given by Fullerton (2003). Nearly all detailed time-dependent studies of individual stars (about 25) were concerned with single stars. Regarding discrete lines in the spectra of close binaries, McCluskey & Kondo (1981) were the first to find "narrow absorption components" in the *International Ultraviolet Explorer* (*IUE*) spectra of AO Cassiopeiae, which were later reported and measured again by Sahade & Brandi (1991), together with those in the spectra of another close binary, namely HD 47129 (V640 Monocerotis; O8.5 V+…; $P = 14.4$ days). On the other hand, Howarth (1984) reported finding discrete lines in the spectra of the binary V861 Scorpii (HD 152667; B0.5 Iae+B2 V; $P = 7.8$ days). Gies & Wiggs (1991) analyzed essentially the same *IUE* data set for AO Cas as Sahade & Brandi did, but added Hα and He I data. By detailed modeling, they were able to separate the UV spectra from the two stars and found that the UV spectrum is dominated by the O9 III primary star, which is undermassive for its spectral type and close to filling its Roche lobe. They derived a mass ratio, secondary over primary, of 1.47 ± 0.08, in excellent agreement with the findings of Sahade & Brandi. Gies & Wiggs also concluded that the expected bow shock for the colliding winds never substantially occults the primary. The last paper was not concerned, however, with the DAC features in the stellar wind lines, which are clearly present.

Actually, discrete absorptions do make their appearance in all the resonance transitions that indicate mass loss in hot stars, namely in O VI $\lambda\lambda$1032, 1038, Si III λ1207, N V $\lambda\lambda$1239, 1243, Si IV $\lambda\lambda$1394, 1403, C IV $\lambda\lambda$1548, 1551, and Al III $\lambda\lambda$1855, 1863, and in the nonresonance lines of C III λ1176 and N IV λ1715, all of which, except those of O VI, are observed in material secured with the *IUE* satellite. These optical-depth enhancements are variable in intensity, velocity, and multiplicity, and the variations may occur rapidly, even on the order of hours. In most cases they are shifted to shorter wavelengths

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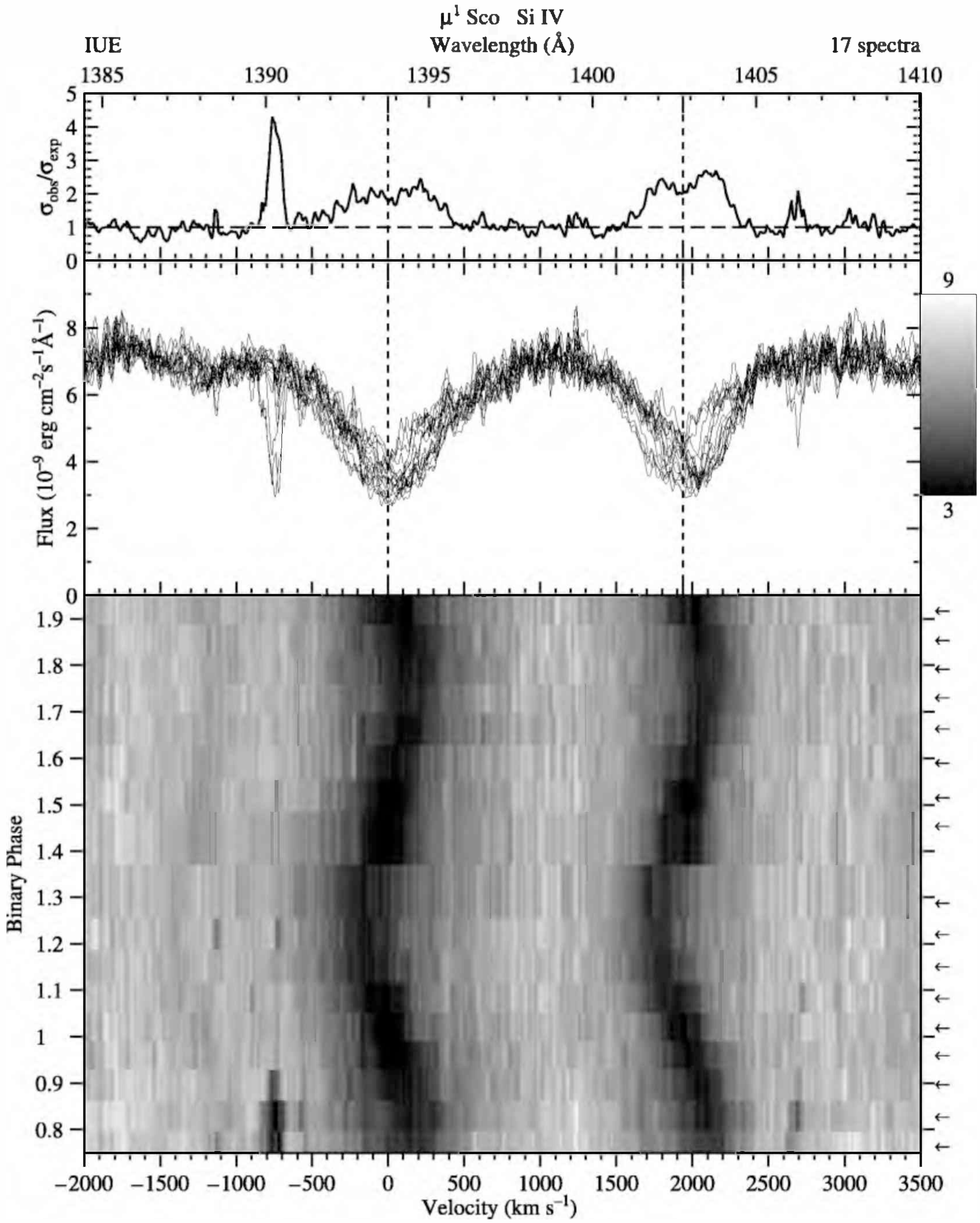

FIG. 1.—Variability in the 1990 *IUE* spectra of μ^1 Sco at the Si IV doublet. *Top axis*: wavelength; *bottom axis*: heliocentric velocity with respect to the primary member of the doublet. The doublet separation is indicated in the upper two panels. The middle panel shows an overplot of the profiles. The top panel shows the significance of the variability, expressed as the ratio of the observed to the expected variance of the flux. The lower panel is a gray-scale representation of the spectra as a function of the binary phase, with cuts as displayed along the middle panel. All spectral lines in this region are likely photospheric and clearly follow the binary motion. The sharp dark features around phase 0.8P are data artifacts due to improper ripple corrections, and should be ignored.

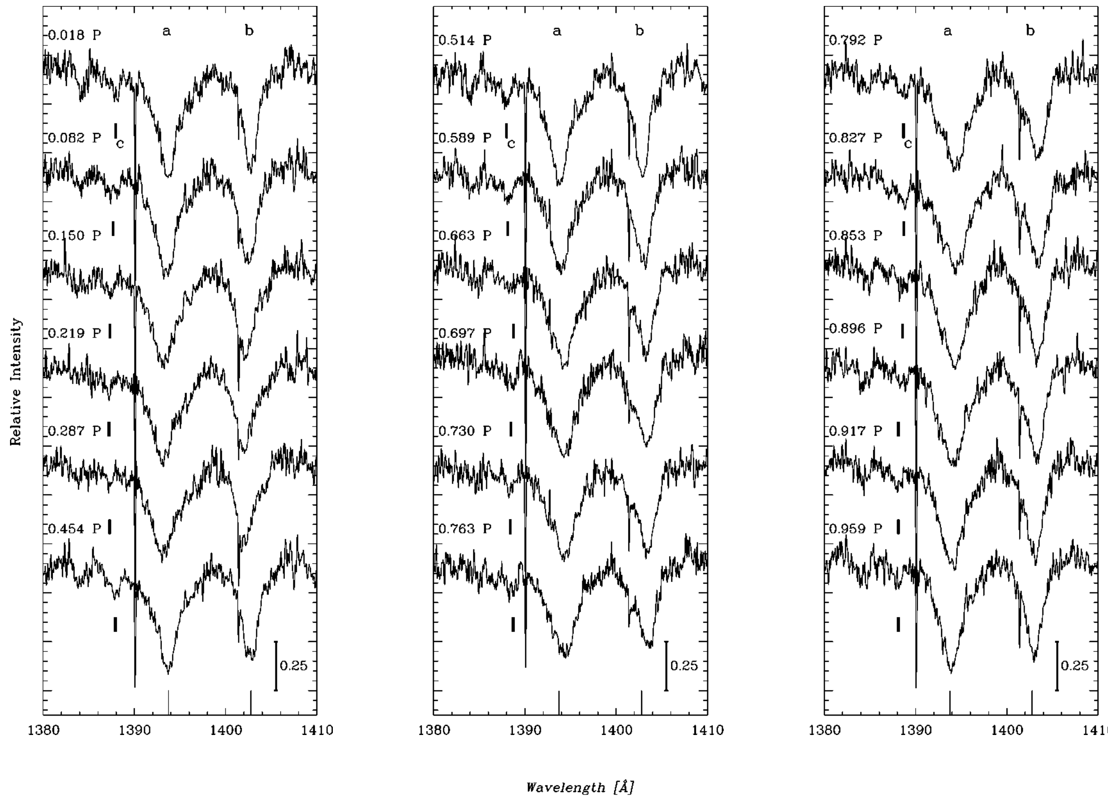

FIG. 2.—1990 *IUE* spectra of μ^1 Sco at the Si IV doublet. The long tick marks at the horizontal axis indicate the rest wavelength of the Si IV doublet. The long bar at the bottom right corner indicates the scale of the plots in units of the continuum intensity.

and move from lower to higher (negative) velocities. In the best-studied objects, in particular HD 24912 [ξ Per, O7.5 III(n)((f))], HD 66811 [ζ Pup, O4 I(n)f], HD 93843 [O5 III(f)], and HD 64760 [B0.5 Ib], there is a more-or-less well-defined recurrence timescale that is typically on the order of a few days to a week (i.e., comparable with the rotational period of the star). The time evolution of their shape and velocity can be explained by the hydrodynamical simulations by Cranmer & Owocki (1996), who showed that DACs can form in a perturbed wind arising from corotating interaction regions (CIRs), as originally proposed by Mullan (1984). In these simulations, the origin of the CIRs was not further specified. Nonradial pulsations (NRPs) and magnetic fields could also plausibly produce the necessary azimuthal asymmetry. Both explanations have been put forward; for instance, magnetic fields by Underhill & Fahey (1984), NRPs by Henrichs (1988), and perturbations of the wind by Howarth & Prinja (1989). The observational problems, however, are currently too difficult to demonstrate the existence of NRPs and/or (small) magnetic fields in these hot stars as the explanation of the recurrence timescale.

In the case of the binaries HD 47129 and AO Cas, Sahade & Brandi's (1991) conclusion was that the discrete features do not actually partake of the orbital motion. This gives an interesting modeling constraint on the minimum distance from the star of the material causing the optical-depth enhancements. Cranmer & Owocki's (1996) model indicates that these enhancements arise from a shallow velocity gradient, rather than from a local density enhancement, the distance of which would depend on the ratio of the rotational velocity of the surface and the stellar wind velocity. If this region is very close to the star, one would expect to see the reflected binary motion in the radial velocity of the features. If this area is crossed by the companion during its binary motion, one would expect to see significant disturbances with respect to the behavior of DACs in single stars. In order to try to advance in our understanding of the phenomenon, two early-type, relatively short-period eclipsing spectroscopic binaries, namely μ^1 Sco and AO Cas, were observed continuously with the *IUE* satellite in 1990 throughout an entire orbital cycle for μ^1 Sco and about 0.6 of a cycle for AO Cas. For both objects, we analyzed high-resolution (~0.2 Å) short-wavelength prime (SWP; 1150–1980 Å) images retrieved from the INES (*IUE* Newly Extracted Spectra) archive.

In the present work, we focus on every absorption feature, other than those that originate in the stellar photosphere(s), that appears in the Si IV and C IV spectral profiles of the two objects, and we discuss their properties.

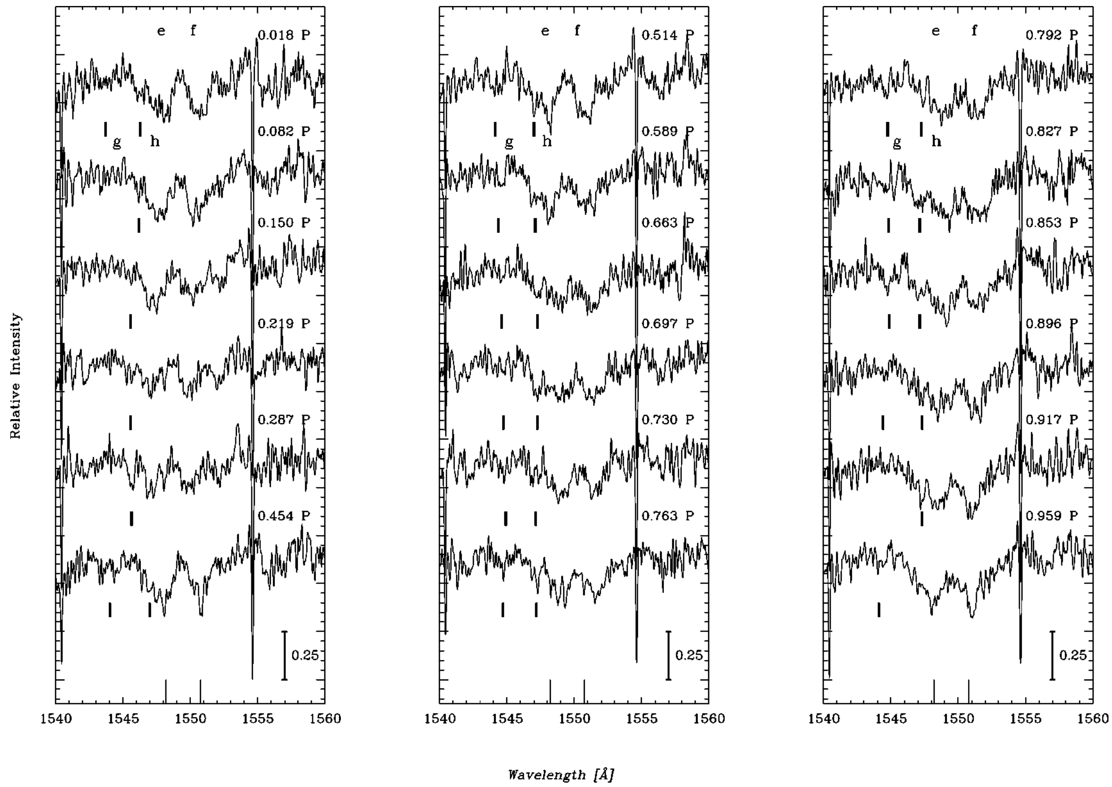

FIG. 3.—1990 *IUE* spectra of μ^1 Sco at the C IV doublet. The long tick marks at the horizontal axis indicate the rest wavelength of the C IV doublet. The long bar at the bottom right corner indicates the scale of the plots in units of the continuum intensity.

2. μ^1 SCORPII

We first consider μ^1 Sco (HR 6247 = HD 151890 = BS 6247 = GC 22677; $\alpha = 16^h48^m29^s$, $\delta = -37°57'.8$ [B1950.0]; 2.94–3.22 *V* mag; B1.5 V + B6.5 V; $P = 1.5$ days). We have analyzed a series of 18 spectra, secured in 1990 July, that cover just one orbital cycle. The material for the star has been measured for radial velocity not only for any possible discrete absorption is concerned, but also for the features that reflect the orbital motion. Just to make sure that our radial velocity measurements are not affected by any systematic errors, we have compared our radial velocities of the two members of the system with those of Stickland et al. (1996), and we have found that the two sets of measurements are in very good agreement. All radial velocities are heliocentric and were obtained by Gaussian profile fitting.

In order to quantify the variability we are looking for, we have calculated the ratio of the observed to the expected variance of the flux ($\sigma_{obs}/\sigma_{exp}$) as a function of wavelength and have displayed this quantity in Figure 1, along with an overplot of the spectra. Before calculating the observed variances, we normalized the stellar fluxes by scaling each spectrum with a different factor. We did not apply a shift in radial velocity, in order to bring out the orbital velocity variations, as characterized by the M-shaped temporal variance displayed in the upper panel. To calculate the expected variance, we used a noise model as derived for high-resolution *IUE* spectra by Henrichs et al. (1994). The function that gives the signal-to-noise ratio as a function of the flux f is $A \tan h(f/B)$, which for the spectra of μ^1 Sco yields best-fit values of $A = 17.4 \pm 0.2$ and $B = (3.8 \pm 0.1) \times 10^{-9}$ ergs cm^{-2} s^{-1} Å^{-1}, with a reduced $\chi^2 = 0.88$. This fit was determined from all available data points in the spectra, excluding the known regions of échelle order overlap and of stellar wind features around the transitions listed in § 1.

Figure 1 shows a gray-scale representation of the development of the spectra as a function of binary phase, the phases having been computed with an origin at JD 2,432,001.0475 and a period of 1.44626876 days (taken from the Supplemento ad Annuario Cracoviense; Danilekiewicz-Krosniak & Kurpinska-Winiarska 2002). Figures 2 and 3 show our set of individual spectra of the object for Si IV and C IV, respectively, in order of phase. All the plotted spectra have been normalized to the continuum intensity. In Figures 2 and 3 we use the labels *a*, *b*, *e*, and *f* to indicate the Si IV and C IV photospheric features measured for orbital motion. On first visual inspection, no evidence for DACs can be seen in the gray-scale figure. The sharp dark features around phase 0.8*P* in Figure 1 are data artifacts due to improper ripple corrections, and are ignored.

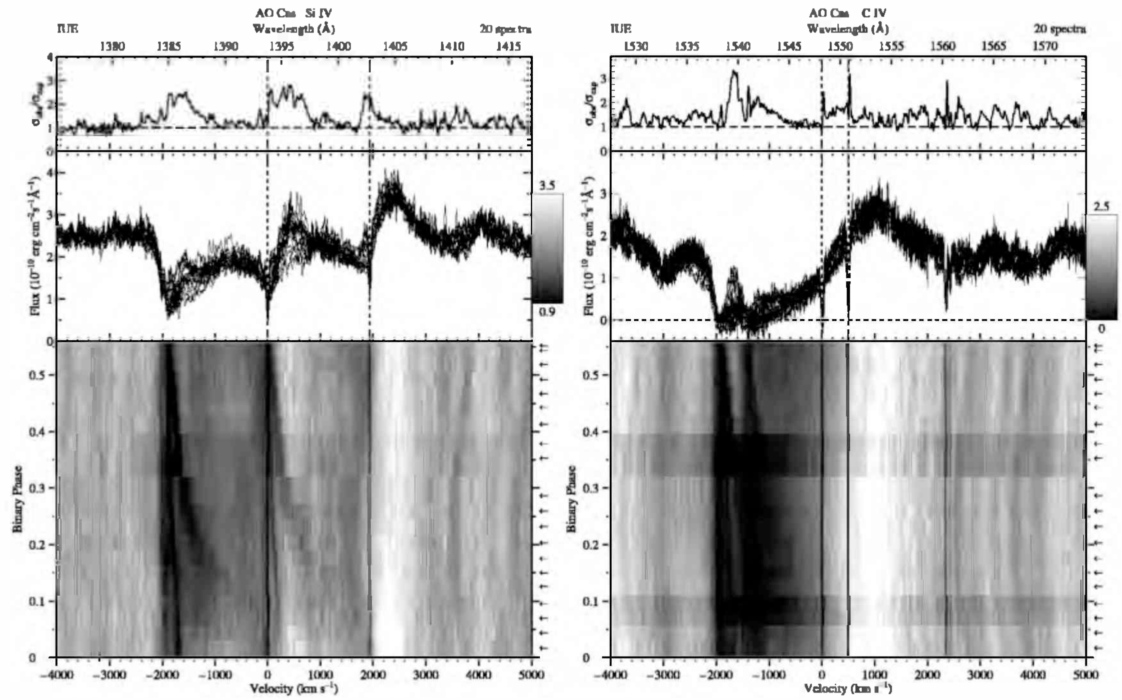

FIG. 4.—Variability in the 1990 *IUE* spectra of AO Cas at the doublets of Si IV (*left*) and C IV (*right*). Axes and panels are similar to those in Fig. 1. The features in this spectral region that clearly follow the binary motion (only half a period is displayed) are the photospheric absorption lines and the emission in the C IV. The Si IV emission and the DACs are not partaking of this motion, which should be considered as clear observational evidence that the DACs (and probably also the Si IV emission) are formed much farther outward than the C IV emission line forming region.

On examining the spectra of μ^1 Sco carefully, we found in both Si IV and C IV some features that are fainter and appear toward shorter wavelengths than the features measured for the orbital motion; we have labeled them *c* for Si IV λ1394 and *g* and *h* for C IV λλ1548, 1551. The ultraviolet line identifications for τ Sco produced by Rogerson & Ewell (1985) suggest that those features could actually be identified as arising from Si III λ1387.948 + Si III λ1388.011, Fe III λ1544.025 + Fe III λ1544.068, and Fe IV λ1546.400 + Fe III λ1546.551 for components *c*, *g*, and *h*, respectively. Such a conclusion appears to be correct, because the velocity curves that result coincide with the one yielded by the atmospheric Si IV and C IV features.

Regarding what we would call discrete components, we should note that we find no evidence of their presence in our spectra of μ^1 Sco.

3. AO CASSIOPEIAE

As for AO Cas (HR 65 = HD 1337 = BD +50°46′ = GC 46; $\alpha = 0^h15^m03^s$, $\delta = 59°09\overset{'}{.}3$ [B1950.0]; 6.07–6.24 *V* mag; O9.5 III + O8 V; Bagnuolo & Gies 1991; $P = 3.5$ days), the material that has been analyzed does not cover a complete orbital cycle, but the actual coverage in time is sufficient to suggest some conclusions, particularly if we also take into account the results reported in the already mentioned papers by Bagnuolo & Gies (1991), Gies & Wiggs (1991), and Sahade & Brandi (1991), in which the orbital period had actually been covered, but only through observations spread over quite a long interval of time. The phases of the different observations considered in this paper were computed by using the figures given in Kholopov's (1987) catalog, namely JD 2,432,191.189 for the origin and 3.523487 days for the value of the period.

Figure 4 shows, in a fashion similar to Figure 1 for both the Si IV and C IV resonance lines, an overplot of the available spectra (arbitrarily normalized to their averaged flux in two separate broad wavelength bands outside the stellar wind lines), along with the significance of the variability and a gray-scale plot as a function of binary phase. In the case of Figure 4, we did not apply radial velocity shifts to the individual spectra, a fact that gives as a result the clearly visible curved progression of the photospheric lines (see also below). For the calculation of the variances, we used the same procedure as in § 2, but with best-fit parameters $A = 21.3 \pm 0.8$ and $B = (2.8 \pm 0.2) \times 10^{-10}$ ergs cm^{-2} s^{-1} Å^{-1} and a reduced $\chi^2 = 0.64$.

There are several interesting conclusions to be drawn from Figure 4. The emission in Si IV and C IV behaves differently as a function of binary phase. The noticeable curvature in the trend of the velocity shift in the C IV emission parallel to the photospheric absorption lines shows that the region where the

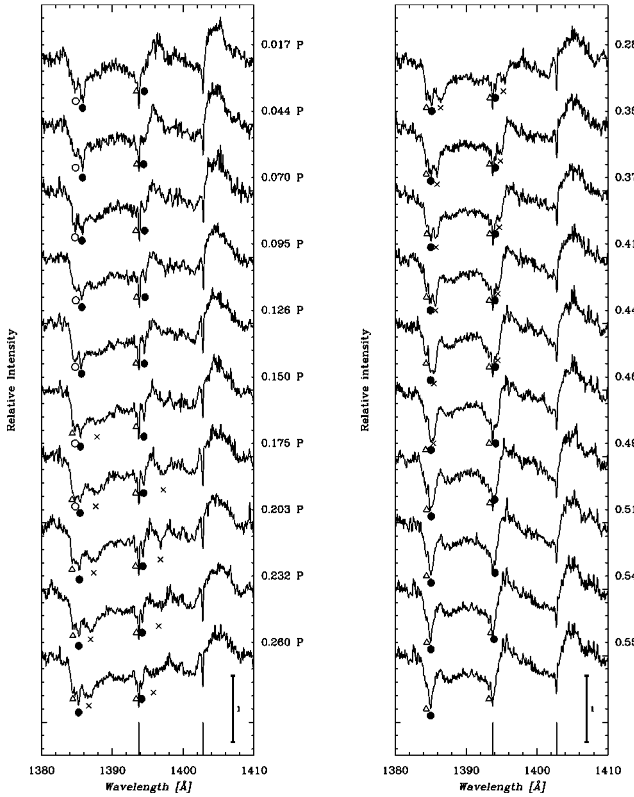

FIG. 5.—1990 *IUE* spectra of AO Cas at the Si IV doublet. The different symbols represent the corresponding components listed in Table 1: triangles = component *a*, open circles = *b*, filled circles = *c*, and crosses = *d*. The long tick marks at the horizontal axis indicate the rest wavelength of the Si IV doublet. The long bar at the bottom right corner indicates the unit of intensity.

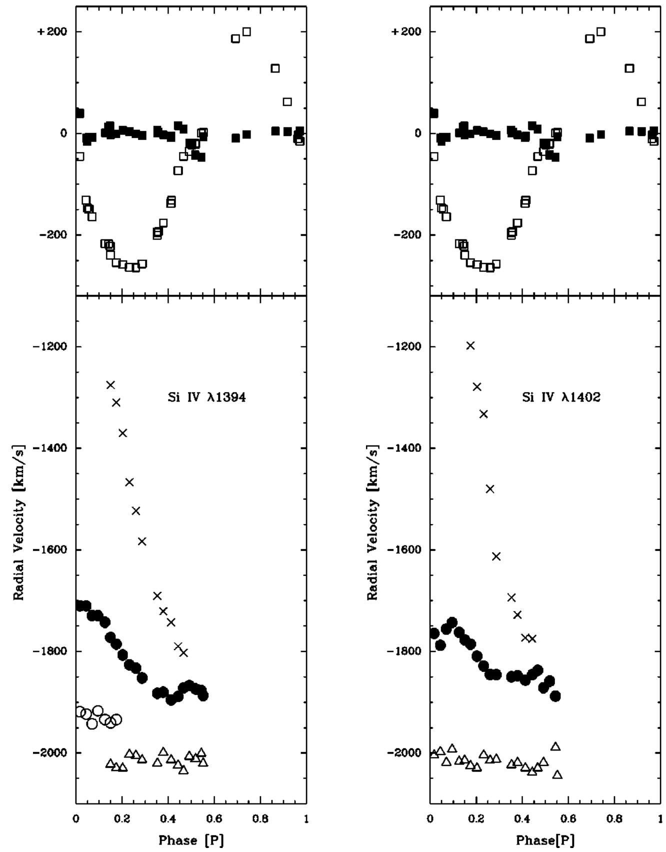

FIG. 6.—*Top*: Photospheric radial velocity curve for the primary component (*open squares*) and the secondary component (*filled squares*) of AO Cas. *Bottom*: Radial velocities of the measured features at Si IV in AO Cas. The different symbols represent the corresponding components listed in Table 1: triangles = component *a*, open circles = *b*, filled circles = *c*, and crosses = *d*.

emission is formed must be very close to the star, at least much closer than where the DACs are formed. Interestingly, the emission in the Si IV line hardly varies, most likely signifying that the radial extent of the Si IV emitting region is much larger than the C IV emitting region, a conclusion that had also been reached by Gies & Wiggs (1991). This will put important constraints on the ionization conditions in a radiatively driven stellar wind. Let us add that since Gies & Wiggs (1991) find that the inclination of the system is 61°, the structure that creates the DACs should extend a substantial distance above the orbital and equatorial plane of the primary. However, according to Dessart (2004), even then, Cranmer & Owocki's (1996) results are essentially valid.

Figure 5 shows the individual spectra of AO Cas we had at our disposal for this investigation, and Figure 6 gives the plots of the radial velocity measurements listed in Table 1. The radial velocities of the components were derived by considering the minimum pixel position on the line centers in the case of narrow features, and by Gaussian profile fitting in the case of broader ones.

On examining the spectra plotted in Figure 5, we find four different components, the weakest and bluest of which are designated as "component *a*." Between phases 0.017*P* and 0.126*P*, we distinguish two narrow features arising from Si IV 1394, which we have designated as components *b* and *c*. Figure 5 shows that component *c* gradually shifts toward component *b* and eventually merges with it near phase 0.150*P*. For phases 0.150*P* and 0.175*P*, it becomes difficult to distinguish between both components, but we tried to measure them separately by taking into account the two peaks that are still observed. From phase 0.203*P* on, only one peak is observed, and the measured velocity is assigned to component *c*. Component *b* of Si IV λ1403 is too badly blended with the interstellar medium feature, and as a consequence, it has not been measured and does not appear in Table 1. In addition, the λ1403 line is affected by the P Cygni profile of the λ1394 component, and this adds to the conclusion that the measurements of Si IV λ1403's narrow components would not be reliable. From phase 0.150*P* on, we distinguish another feature, designated as component *d*, that starts as a broad line, gradually shifts toward more negative

TABLE 1
Radial Velocity Measurements of AO Cas

SWP Image	Phase (P)	Photospheric Velocities[a] V_1	Photospheric Velocities[a] V_2	Si IV λ1394 *a*	Si IV λ1394 *b*	Si IV λ1394 *c*	Si IV λ1394 *d*	Si IV λ1403 *a*	Si IV λ1403 *c*	Si IV λ1403 *d*
39329	0.017	−45.6	39.3	...	−1919	−1710	...	−2004	−1764	...
39331	0.044	−131.7	−8.9	...	−1923	−1710	...	−1997	−1788	...
39333	0.070	−164.2	−7.6	...	−1943	−1730	...	−2019	−1756	...
39335	0.095	...	...	...	−1895	−1730	...	−1993	−1743	...
39337	0.126	−217.3	0.6	...	−1934	−1742	...	−2017	−1762	...
39339	0.150	−240.0	−2.3	−2020	−1940	−1773	−1275	−2015	−1777	...
39341	0.175	−254.3	−1.2	−2029	−1934	−1785	−1310	−2025	−1786	−1198
39343	0.203	−258.2	5.5	−2030	...	−1807	−1370	−2030	−1809	−1279
39345	0.232	−263.7	3.6	−2003	...	−1826	−1467	−2004	−1809	−1332
39347	0.260	−264.1	−0.5	−2005	...	−1833	−1523	−2015	−1829	−1480
39349	0.287	−257.1	−4.0	−2014	...	−1852	−1583	−2012	−1846	−1613
39354	0.353	−200.1	1.7	−2020	...	−1882	−1691	−2023	−1846	−1694
39356	0.379	−176.2	−2.6	−1999	...	−1880	−1721	−2019	−1848	−1728
39358	0.413	−137.9	−8.2	−2014	...	−1895	−1742	−2030	−1856	−1773
39360	0.443	−73.0	15.2	−2024	...	−1889	−1790	−2038	−1846	−1775
39362	0.467	−45.2	7.9	−2035	...	−1872	−1803	−2030	−1837	...
39364	0.492	−35.7	−19.8	−2007	...	−1867	...	−2019	−1871	...
39366	0.519	−21.1	−43.7	−2011	...	−1874	...	...	−1858	...
39368	0.544	10.7	−46.9	−2001	...	−1877	...	−1989	−1888	...
39369	0.552	62.1	−6.6	−2020	...	−1887	...	−2045	...	...

Note.—Photospheric radial velocities and radial velocities (in km s^{-1}) of the narrow absorption components (*a*–*d*) of the Si IV doublet in AO Cas.
[a] Data taken from Stickland (1997).

velocities and becomes narrower, eventually merging with component *b* at phase 0.519*P*.

In regard to the measured radial velocities of the components plotted in Figure 6, there are two distinct discrete components (*a* and *b*) that are undoubtedly present and appear approximately stationary. The features that coincide rather well with those in Table 5, columns (9) and (10), of Sahade & Brandi (1991) suggest velocities of about −2020 and −1930 km s^{-1}, respectively, in fairly good agreement with the velocities derived from the earlier material, and thus implying that at least in the case of AO Cas, the behavior of these two discrete features could have been rather constant with time.

In addition, we find that component *c*, which accelerates to more negative velocities between phases 0*P* and 0.3*P* and then merges with stationary component *b*, displays a rather constant velocity from phase 0.3*P* on.

Finally, component *d* appears to behave differently from the other nonstationary component, in the sense that it starts as a broad line and becomes narrower and stronger as it shifts toward shorter wavelengths, eventually merging with the stationary component. The overall behavior of this feature throughout the observed interval of time appears to be similar to the ones reported by Prinja & Howarth (1988) in 68 Cyg and by Henrichs et al. (1994) in ξ Per, both O7 III stars.

Summarizing our results, we can say that the so-called discrete components, when connected with close binary systems, do still yield a constant velocity, and therefore they must originate in layers that do not partake of the orbital motion and where the influence of the system's gravitational field is not already noticeably felt. The last statement must be true for the discrete lines that yield a constant velocity throughout the orbital period of the binary. However, in AO Cas we find two nonstationary components, *c* and *d*, that accelerate to more negative velocities and merge with the stationary ones. In particular, component d behaves similar to other DACs found in O stars and may partly be connected with the star's expanding atmosphere.

It is interesting to compare previous spectra of AO Cas in the region of Si IV, which were taken at randomly different epochs and cover about a full orbital cycle (see Fig. 7). If DACs arise from a fixed spot at the photosphere of the primary star (which is likely corotating with the binary orbit), they are expected to keep phase over many orbits. This is not observed in Figure 7, implying that in all likelihood, the origin of the DACs is not attached to the same spot over a period of 10 yr. However, the comparison between Figures 7 and 4 is not too strong, as archival data are rather sparse in the first half of the orbital cycle.

On the other hand, from the comparison between archival spectra of AO Cas in the region of Si IV at about 1400 Å, taken in different epochs but at about the same phases as the new ones (see Fig. 8), one would say that they seem to display about the same pattern, but with different relative intensities

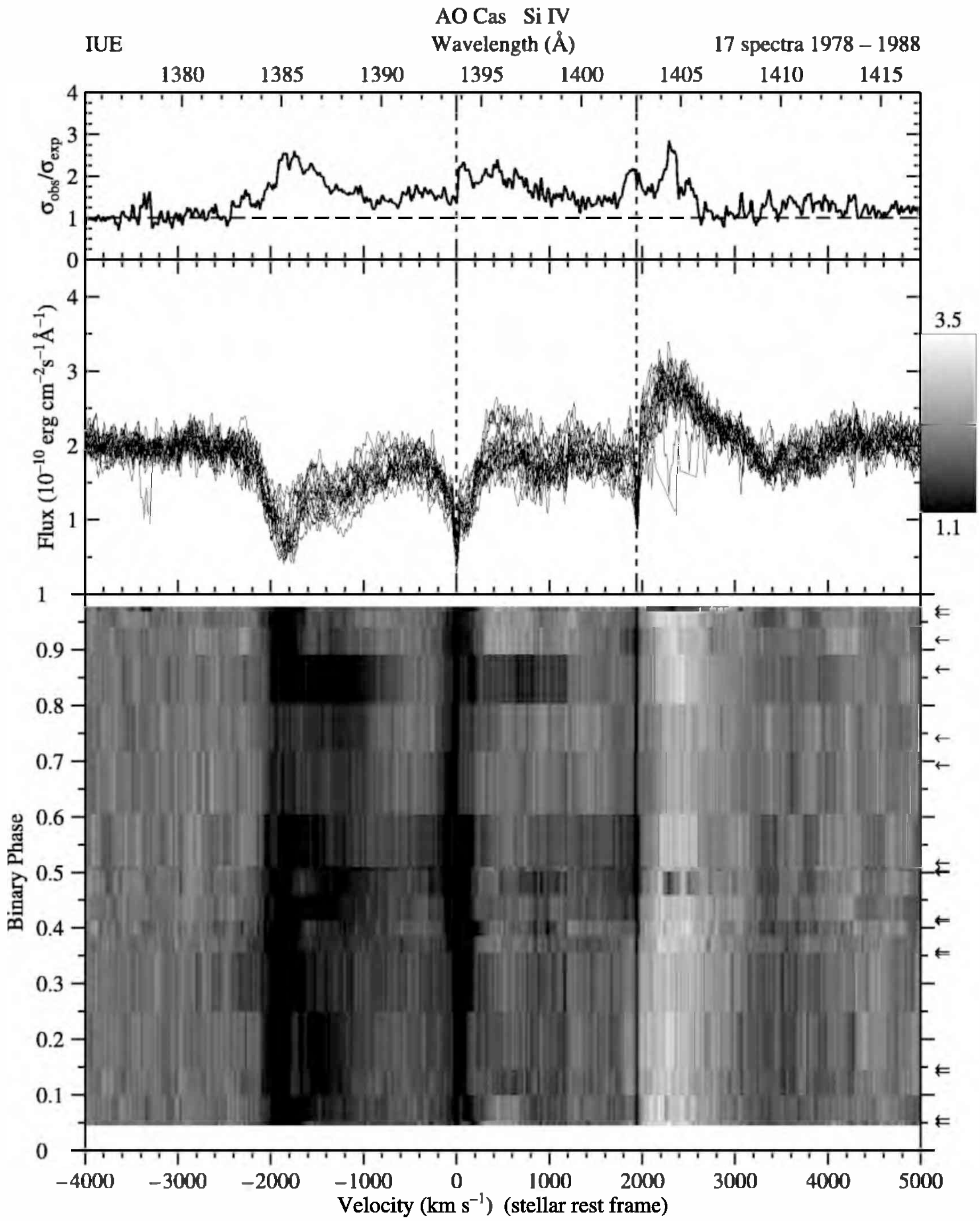

FIG. 7.—Variability in the 1978–1988 *IUE* spectra of AO Cas at the doublets of Si IV, as analyzed by Sahade & Brandi (1991) and Gies & Wiggs (1991), taken prior to the spectra considered in the current paper. Axes and panels are similar to those in Fig. 1. If DACs arise from a certain spot at the photosphere of the primary star (which is likely corotating with the binary orbit), they are expected to keep phase over many orbits. The fact that this is not observed implies that it is likely that the origin of DACs is not attached to the same spot over a period of 10 yr.

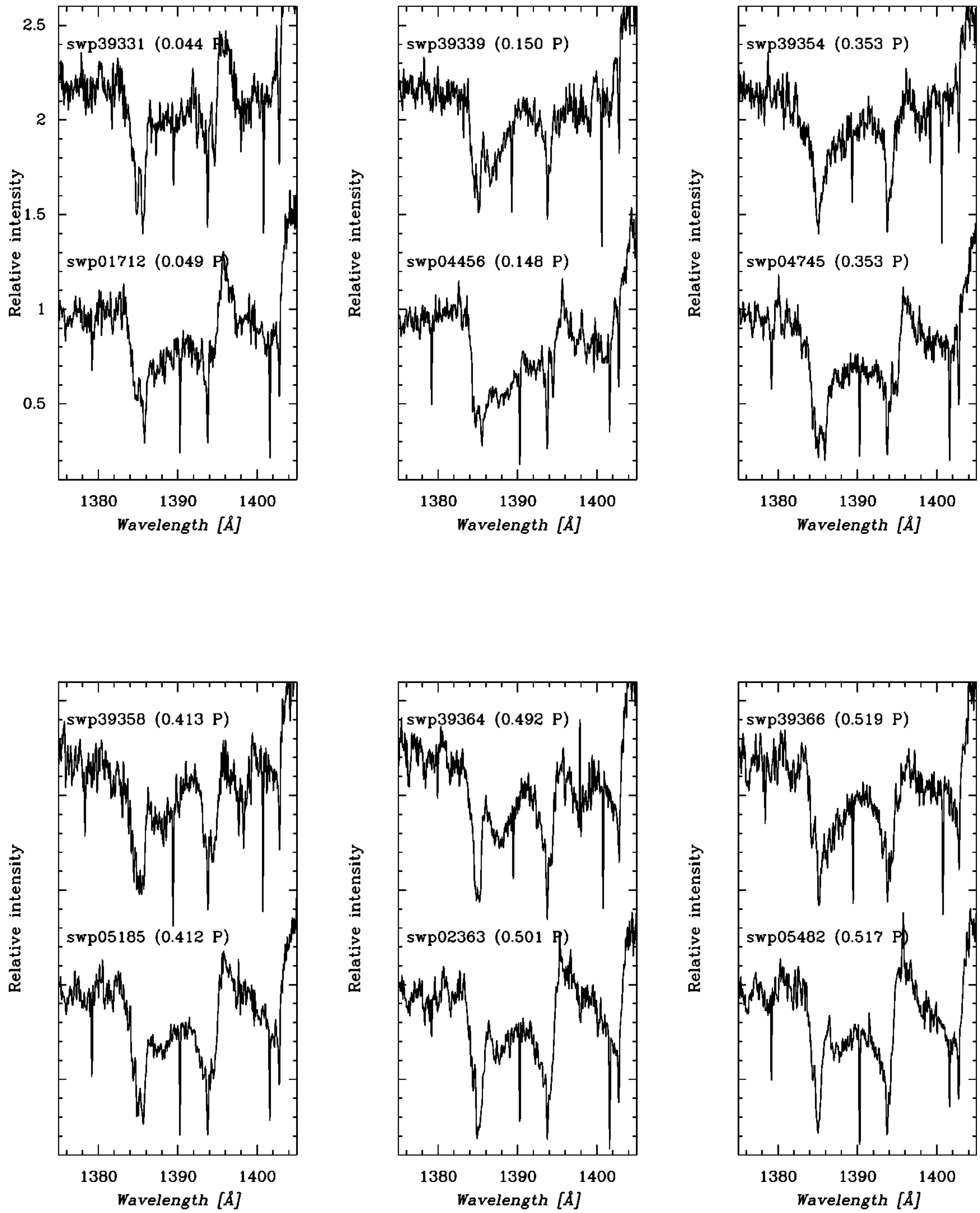

FIG. 8.—Comparison of Si IV discrete components observed in *IUE* spectra of AO Cas from 1991 and in the interval 1978–1988 at the same phases.

of the components. This may support the idea that the DACs are in some way related to the orbital phase; unfortunately, the available evidence is not strong enough to make sure.

In conclusion, the spectrum of AO Cas displays at least two discrete components that have probably been present during a very long interval of time. As for the question of additional components that may form closer to the star or to the system, if we are dealing with a binary system, we still require more information even to be able to advance an acceptable, reasonable suggestion. Let us only add that because binaries with periods that are not too long require relatively little observing time, future efforts should concentrate primarily on objects such as AO Cas, which hold the promise of being better suited to provide an answer to the questions involved.

4. CONCLUSIONS SUGGESTED BY THE PRESENT WORK

The first suggestion that comes from the present work is that discrete absorptions, at least those that yield rather constant velocity throughout, arise in material that is being lost by the appropriate star and that is located far enough away to be uncoupled from the binary motion of the underlying star. The typical separation between the two stars in the AO Cassiopeiae system is somewhere between 2.5 and 3 times the primary stellar radius (Sahade & Brandi 1991). If the region where the DACs arise were only a few stellar radii distant from the star, we would expect, at least in the CIR model of Cranmer & Owocki (1996), that the DACs would follow the radial velocity of the star or be significantly disturbed by the binary companion. Since neither of these motions are observed, we conclude that the high-velocity DACs may be produced outside the orbital radius of the companion; i.e., certainly more than 5 stellar radii of the primary star. These considerations could be taken as boundary conditions for a detailed model in which both companions should be taken into account. Similar arguments can be put forward concerning radial extent of the C IV emitting region, which is likely formed much closer than the orbital separation. The Si IV emitting region is likely more spread out. This conclusion with respect to the location of the region where the discrete lines do form in AO Cas appears to be at variance with the working hypothesis in the case of single stars for which the DACs do seem to arise close to or at the stellar surface, a conclusion derived from the observation of time series that suggest a strong correlation with the stellar rotation rate (Henrichs et al. 1988; Prinja 1988; and Fullerton 2003) and that is also the basis for the currently favored CIR model for the origin of the DACs (Cranmer & Owocki 1996). In the case of the binary AO Cas, the behavior of the DACs that yield constant velocities throughout the orbital cycle (see, e.g., Figs. 4 and 7) do seem to be yielding somewhat different mean velocity values at different times, but nevertheless they do always seem to originate outside the strict gravitational domain of the two members of the stellar system. This would again seem to support the strong suspicion that the origin of the DACs is not at a localized fixed position, but rather, is a sort of a transient phenomenon.

A second question that arises is why those discrete lines make their appearance in the spectra and why they are limited to very early spectral types. The reason is probably related to the higher density of the wind in early-type stars, particularly in emission-line objects. Now, the two features in AO Cas (components *a* and *b*) that do yield a constant velocity throughout the entire orbital cycle seem to have displayed no changes over a time interval of a good number of years, and as a consequence, their behavior appears to be different than what has been generally observed in single stars. The question then arises whether we are actually dealing with different types of phenomena. Only more observations and/or a better understanding of what is happening could then give us the answer.

In short, the present work has shown that: (1) no discrete components are displayed by the spectrum of μ^1 Sco, in agreement with the conclusions from previous work that those features are normally not present in every early-type main-sequence objects; (2) in the case of AO Cas, what we have labeled as discrete lines *a* and *b* suggest no intensity and/or velocity variations with time, and the question then arises as to whether we are dealing here with a phenomenon different from in single stars, for which intensity and/or velocity variations are the rule, or whether the behavior of such lines is different in the case of binary systems; and (3) to understand the nature of the features labeled *c* and *d* in the case of AO Cas, which we have described and also measured, we actually need more observational material that would completely cover at least one complete orbital cycle.

We finish this paper by stressing the fact that it would be highly desirable to undertake a new, more complete series of observations whenever a new UV observatory, such as the *World Space Observatory/Ultraviolet* (*WSO/UV*), is placed in orbit, to check and to ascertain the suggestions that seem to come out of the present material, and to answer the questions that remain open. We would also hope that the assignment of observing time in future space observatories will take into consideration the problems one is dealing with, rather than just assigning a set number of hours/days to each approved request.

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REFERENCES

Bagnuolo, W. G., & Gies, D. R. 1991, ApJ, 376, 266
Cranmer, S. R., & Owocki, S. A. 1996, ApJ, 462, 469
Danilekiewicz-Krosniak, E., & Kurpinska-Winiarska, M. 2002, Supplemento ad Annuario Cracoviense 74 (Krakow: Krakow Obs.), 21
Dessart, L. 2004, A&A, 423, 693
Fullerton, A. W. 2003, in ASP Conf. Ser. 305, Magnetic Fields in O, B, and A Stars, ed. L. A. Balona, H. F. Henrichs, & R. Medupe (San Francisco: ASP), 333
Gies, D. R., & Wiggs, M. S. 1991, ApJ, 375, 321
Henrichs, H. 1988, in O Stars and Wolf-Rayet Stars, ed. S. Jordan & R. Thomas (NASA SP-497; Washington: NASA), 199

Henrichs, H. F., Kaper, L., & Nichols, J. S. 1994, A&A, 285, 565
Henrichs, H. F., Kaper, L., & Zwarthoed, G. A. A. 1988, in Proc. Celebratory Symp., A Decade of UV Astronomy with *IUE* (ESA SP-281; Noordwijk: ESA), 2, 145
Howarth, I. D. 1984, MNRAS, 206, 625
Howarth, I. D., & Prinja, R. K. 1989, ApJS, 69, 527
Kaper, L., Henrichs, H. F., & Fullerton, A. W. 1997, A&A, 327, 281
Kholopov, P. N., ed. 1987, General Catalogue of Variable Stars, vol. 3 (4th ed.; Moscow: Nauka), 216
Massa, D., et al. 1995, ApJ, 452, 842
McCluskey, G., & Kondo, Y. 1981, ApJ, 246, 464
Morton, D. C. 1976, ApJ, 203, 386
Mullan, D. J. 1984, ApJ, 283, 303
Prinja, R. K. 1988, MNRAS, 231, 21
Prinja, R. K., & Howarth, I. D. 1988, MNRAS, 233, 133
Prinja, R. K., Massa, D., & Fullerton, A. W. 2002, A&A, 388, 587
Rogerson, J. B., & Ewell, M. W. 1985, ApJS, 58, 265
Sahade, J., & Brandi, E. 1991, ApJ, 379, 706
Stickland, D. J. 1997, Observatory, 117, 37
Stickland, D. J., Sahade, J., & Henrichs, H. F. 1996, Observatory, 116, 85
Underhill, A. B 1975, ApJ, 199, 691
Underhill, A. B., & Fahey, R. P. 1984, ApJ, 280, 712