MAGNETIC FIELDS AND WINDS OF THE INTERMEDIATE HELIUM STARS

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ABSTRACT. The intermediate helium stars are exceedingly rare hot analogs of the classical Ap stars, and are the earliest type stars to possess observable global ordered magnetic fields. A recent discovery is the existence of stellar winds which have large scale magnetospheric structure embedded within them. The nature and geometry of the detected fields are summarized, and the modulation of the circumstellar material by the field is illustrated for two examples: the rapid rotator σ Ori E, and the slow rotator HD 184927. The complex variety of stellar wind phenomenology which may be encountered is displayed by a sample of ten helium strong stars. A few of these objects show Hα emission, and thus are the only known magnetic Be stars.

1. INTRODUCTION

This review is restricted to the intermediate helium stars (or helium strong stars) which occur in the region of the H-R diagram near B2V and show abnormally strong lines of neutral helium for that spectral type. Many of the helium strong stars are spectroscopic, photometric, and magnetic variables, with a single period common to all forms of variability. Thus these objects are hot analogs of the Ap stars. In the oblique rotator model for such stars, the magnetic/spectroscopic/ photometric period is identified as the stellar rotation period. The spectral morphology and photospheric parameters are reviewed by Walborn (1983), Bolton (1983), and Hunger (1986).

The surface gravities (and hence evolutionary status) of the helium strong stars remain somewhat controversial (cf. Walborn 1983); careful analysis of accurate observed profiles is required to investigate this question, and it is hoped that the work of Hunger (1986) and Odell (1986a) may help settle the issue. Intuitively, one expects that the helium strong, helium weak, and classical Ap stars form a unified sequence in temperature along the main sequence; for all three groups, surface abundance anomalies result from diffusive processes in the outer layers of a magnetic star. For the most luminous objects in this sequence, radiation pressure and mass loss also play an important role

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in determining the equilibrium atmospheric structure; the stellar winds and magnetic fields of the helium strong stars are described here.

Ultraviolet observations of three rapidly rotating magnetic helium strong stars in Orion (Shore and Adelman 1981) suggested the existence of weakly variable mass-losing stellar winds. An extensive program of contemporaneous UV and optical spectroscopy, and magnetic field measurements, was stimulated by this discovery. In 1982, the Helium-Rich Magnetic Emission-line Star Working Group (Hermes) was formed by P.K. Barker, C.T. Bolton, D.N. Brown, J.D. Landstreet, and S.N. Shore. Phase resolved observations have now been obtained for a variety of helium strong stars which provide a wide-ranging sample in rotation rate and magnetic field strength, in order to investigate the interaction of magnetic, rotational, and radiative forces in the winds from these stars. This review is based largely on work published or in progress by the Hermes Working Group.

2. MAGNETIC FIELDS

The processes affecting the profile observed when a spectral line is formed in the presence of a magnetic field have been reviewed by Landstreet (1980, 1982). Usually the existence of a global stellar magnetic field which has a line of sight component (a mean longitudinal field) is inferred from the presence of a characteristic "S-wave" circular polarization profile across the spectral line. The mean stellar surface field can be measured only for a very few sharp-lined stars with strong fields; it is important to realize that the ratio of surface to longitudinal field, and even the very detection of a longitudinal field, depend extremely strongly upon the field geometry and its orientation relative to the line of sight at the time of observation. Field detection becomes progressively more difficult for successively higher order multipole components, and present techniques cannot detect any locally strong but globally complex magnetic fields. If any such disordered fields should exist, indirect inferences based on, for example, the presence of gyroresonance radiation (Underhill 1984) might become practical in the future. The photon counting problem is severe for present optical techniques: a 100 gauss longitudinal field typically produces a peak circular polarization of only 0.005%.

Among the OB stars in general, several searches with null results (with errors ∿500 gauss) are reviewed by Borra, Landstreet, and Mestel (1982). An additional 31 stars ranging from O4 to B8 have been observed by Barker et al. (1981, 1985, 1987) again with null results (with errors ∿100 gauss). Apart from Rigel (Severny 1970) only the helium spectrum variables possess detectable fields within this spectral range.

The helium strong stars observed in the search for magnetic fields and/or stellar winds are listed in Table 1, where the information is drawn from Barker et al. (1982), Borra and Landstreet (1979), Landstreet and Borra (1978), Thompson and Landstreet (1985), Walborn

(1983), and references therein. For HD 37017 the table gives a revised period (Landstreet 1986) based on additional magnetic observations; Bolton (1986) has provided a revised period for HD 184927 from analysis of optical spectral features. Seven of the nine stars observed magnetically show positive detections, with maximum mean longitudinal field typically ∿1-3 kilogauss. When the field is variable, the strength varies sinusoidally (in all but one case) on the independently determined stellar rotation period. The sinusoidal variation implies a field which is predominantly dipolar in geometry; examples are shown in Figure 1. For a dipole, the ratio of surface to mean longitudinal field must exceed ∿2.4 even at the most favorable field orientation, so these stars commonly have true surface fields of ∿10 kilogauss.

As for the Ap stars, the period-v sin i relation permits an estimate of the inclination i of the rotation axis to the line of sight, provided one has a reasonable estimate of the stellar radius. An estimate of the obliquity β of the magnetic axis to the rotation axis then follows from the ratio of magnetic extrema. Given the small

TABLE 1

Magnetic Fields and Rotation of the Helium Strong Stars

HD	B_ℓ Extrema gauss	V sin i km s^{-1}	Period days	IUE Images*
36485	?	80	?	5
37017	-350/-2170	170	0.901190 ± 0.00005	24
37479	+3100/-2300	170	1.190811 ± 0.00001	30
37776	+2500/-2150	160	1.53869 ± 0.00007	30
58260	+2200/ ?	<30	?	7
60344	<490	<30	?	2
64740	+400/-800	160	1.33016 ± 0.00016	23
96446	-1400/ ?	<30	?	8
133518	<250	<30	?	3
184927	+2250/ 0	<17	9.52793 ± 0.00078	14

* *High dispersion SWP observations*

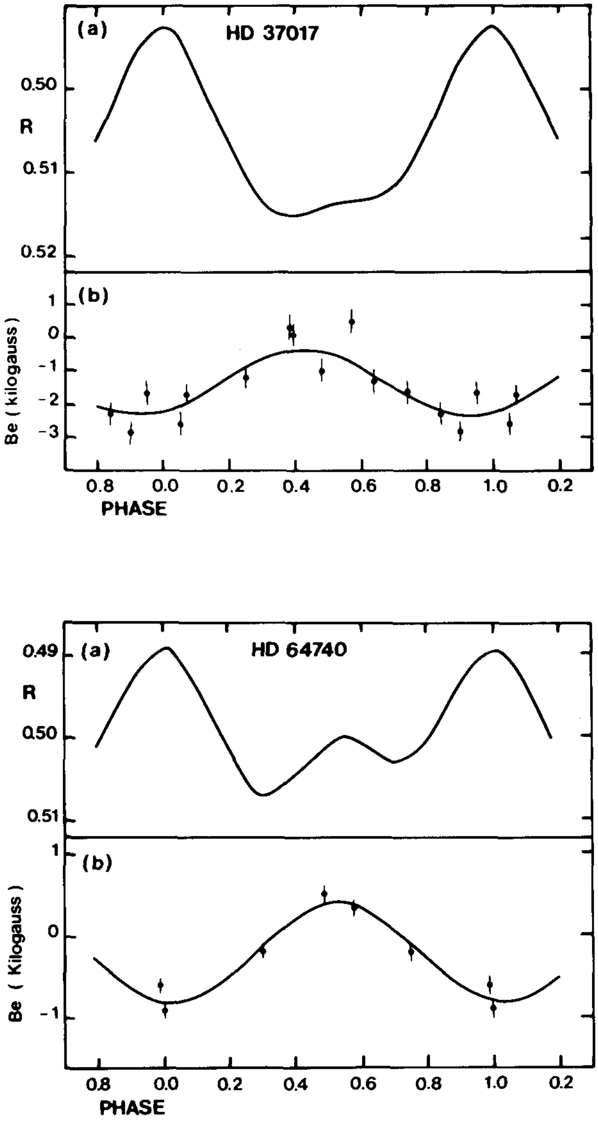

Figure 1. Typical sinusoidal variation of the mean longitudinal magnetic field on the stellar rotation period--indicating predominantly dipolar field geometry--for the helium strong stars HD 37017 (rotation period 0.90 day) and HD 64740 (rotation period 1.33 day). Also shown are the photometric helium line strength variations (a smaller value of the index R indicates stronger helium lines). Notice that the helium maxima occur at times of greatest exposure of the magnetic polar regions. From Borra and Landstreet 1979.

sample size, there is no clear indication of any preference for high or low obliquity among the helium strong stars. The stars HD 58260 and HD 96446 have apparently constant fields over many years; it is not known whether the magnetic and rotational axes are parallel, or the stars are simply viewed rotationally pole-on.

Figure 2 shows the unique non-sinusoidal magnetic field variation of HD 37776. This cannot result from a dipolar field distribution, and Thompson and Landstreet (1985) argued that for this object the quadrupolar field component is dominant--the first such case discovered. Interestingly, in HD 37776 both maximum and minimum helium line strength occur at phases when the mean longitudinal magnetic field is close to zero--quite unlike the stars with strong dipolar fields, for which helium maxima occur at or very near phases of magnetic extrema.

3. THE RAPID ROTATOR HD 37479 (σ Ori E)

This most extensively studied of the helium strong stars has come to be regarded as the prototype, even though every object in Table 1 is unique in some way. An analysis of optical and infrared behavior is

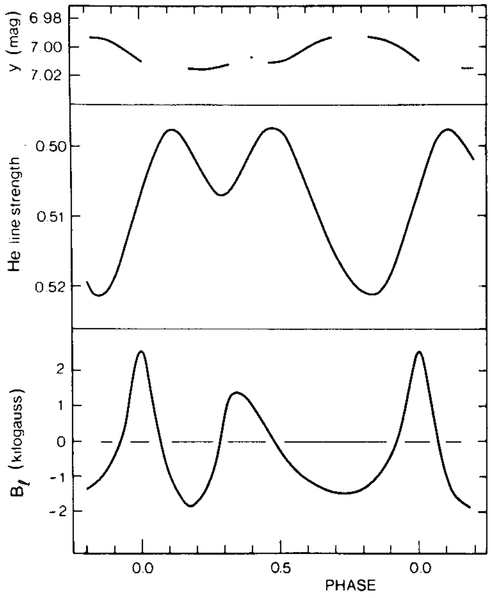

Figure 2. The unique mean longitudinal magnetic field variation of HD 37776 (rotation period 1.54 day), indicating a predominantly quadrupolar field geometry. The photometric helium line strength index and Strömgren y magnitude variations are also shown. In sharp contrast to the helium strong stars with dipolar fields, both maximum and minimum helium line strength occur at phases when the mean longitudinal magnetic field is close to zero. From Thompson and Landstreet 1985.

given by Groote and Hunger (1982), while magnetic observations are presented by Landstreet and Borra (1978). Possible interpretations of the data are discussed in both papers, which include the complete bibliography. Figure 3 summarizes the optical and magnetic variations on the stellar rotation period.

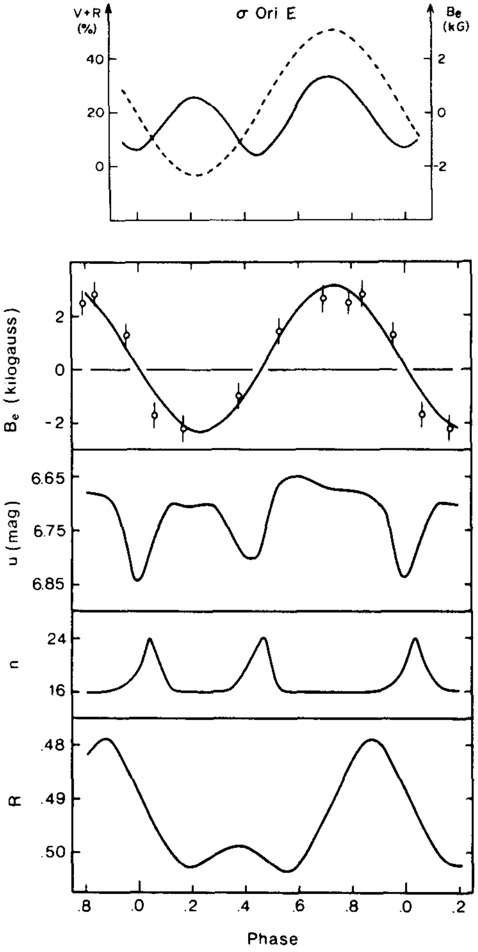

Figure 3. The best studied helium strong star HD 37479 (rotation period 1.19 day). The bottom panel (from Landstreet and Borra 1978) shows the variations in mean longitudinal magnetic field, photometric helium line strength index R, Strömgren u magnitude, and number n of the highest visible Balmer shell line. In the top panel (from Nakajima 1981) the solid line shows the corresponding variation of the Hα emission strength V+R (the sum of the red and violet emission peak intensities) expressed as a percentage of the local continuum level. The dashed line indicates the mean longitudinal magnetic field.

Figure 4 presents selected profiles of the C IV λλ1548, 50 resonance doublet observed with IUE; the rotational phases corresponding to those in Figure 3 are marked. The profiles are asymmetric, with a persistent shortward absorption extending to -600 km/s, indicating the existence of a stellar wind; however, there is no evidence for a fully developed P Cygni profile with longward emission above the continuum. As the star rotates, the absorption cores vary in depth by a factor of ∿2, but the variation is confined to wavelengths near line center: there is no detectable variation in the high velocity portion of the wind. Further, since it is not known whether all of the observed C IV arises in the wind--some contribution from photospheric C IV could be present--there is not even any unambiguous evidence for variability in the wind. Perhaps only the photospheric C IV, if any, varies as the star rotates. The nature and amplitude of the variations appear to be stable and repeatable during two epochs of observation separated by two years. The Si IV λλ1394, 1402 resonance doublet displays variability analogous to that in C IV, but of much lower amplitude because here the photospheric contribution certainly dominates. Detailed examination of other UV wavelength regions is in progress; Shore and Adelman (1981) found some evidence for variability in other species, especially C II λλ1334, 5.

HD 37479 is also a radio source: Drake et al. (1984) measured fluxes of ∿3.5 mJy at 6 cm and ∿3 mJy at 2 cm with the VLA. The spectral index of -0.1 suggests that a non-thermal mechanism such as gyroresonance emission is probably the source of radiation. As an aside, Drake et al. also detected a flux of 1.8 mJy at 2 cm from HD 37017, but HD 37776, HD 58260, and nine other Bp and Ap stars, were not detected, with 3σ upper limits of <0.5 mJy at 2 cm.

Groote and Hunger (1982) have developed the model shown in Figure 5 to interpret the available data (excluding UV observations). Here only the Hα and UV observations will be emphasized. HD 37479 shows weak double-peaked Hα emission which varies in strength and V/R ratio on the rotation period (Figure 3); thus, σ Ori E is a magnetic Be star. The highly ionized species such as C IV cannot arise from the same circumstellar regions as the Hα emission, so the (unsolved) problem is to determine the geometrical configuration of the stellar wind and the Hα emitting volume (as is the case for the classical Be stars).

First, Groote and Hunger have proposed the two clouds shown in Figure 5, to explain the variable Hα emission and Balmer shell absorption lines. However, high quality observations by Bolton (1985) show clearly that the V and R emission peaks rise and fall in intensity as the star rotates, but remain fixed in velocity at -500 and +500 km/s relative to line center, respectively. If the Hα emission region is trapped by, and forced to corotate with, the magnetic field, then this material must be at least two stellar radii above the photosphere to appear at this velocity. It is not obvious how to reconcile Groote and Hunger's model with these observations, but nevertheless there does appear to be some kind of trapped Hα magnetosphere within the wind. A similar situation exists for the Hα emission in HD 37017 (Odell 1986b).

Second, superposed on Figure 5 are the phases of maximum C IV absorption, obtained by Barker et al. (1986) from the entire IUE data

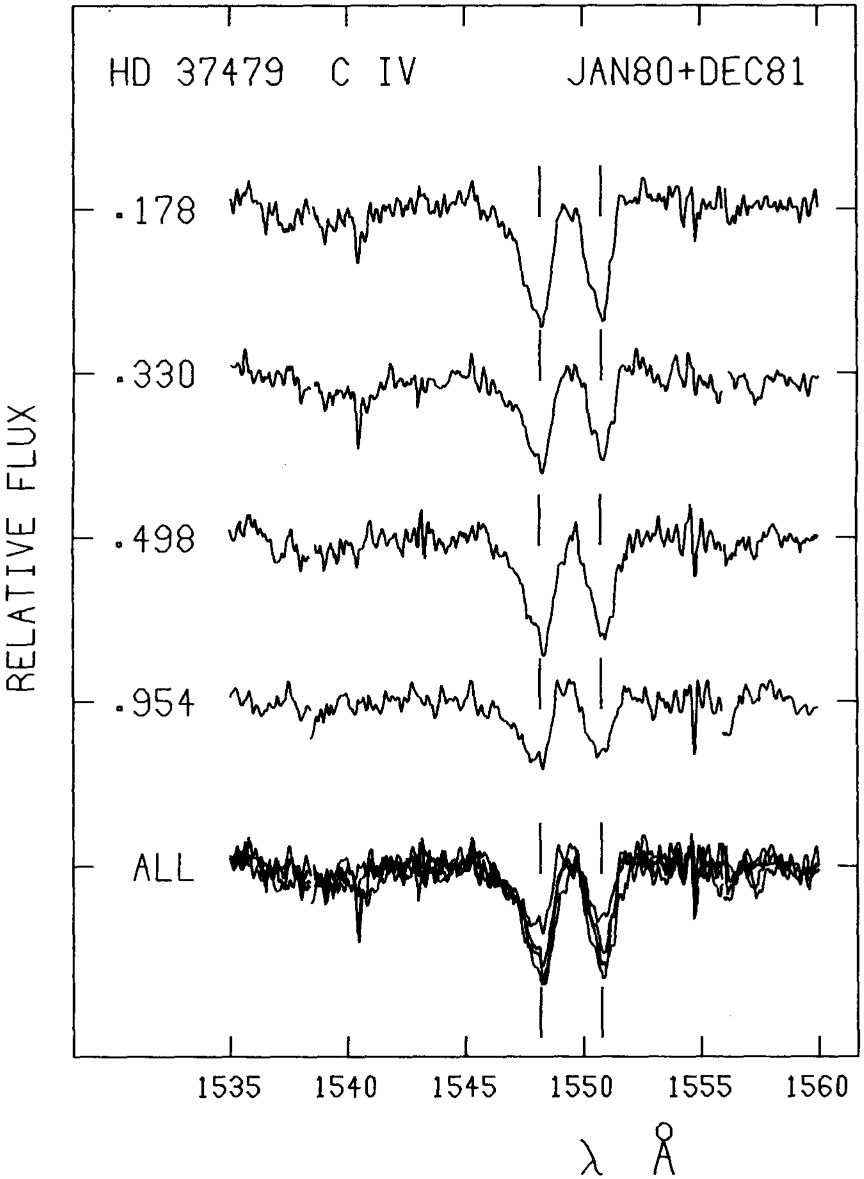

Figure 4. The asymmetric C IV resonance doublet in HD 37479, indicating the existence of a stellar wind. The vertical dashed lines mark the component rest wavelengths; the persistent shortward absorption extends to -600 km/s. Only a few representative profiles are shown, with the rotational phases (see Figure 3) marked; the four displayed phases are shown superposed at the bottom. The vertical spacing between horizontal tick marks for adjacent spectra equals the local continuum level. From Barker et al. 1986.

set (average spacing 0.05 in phase). One maximum coincides with maximum exposure of the negative magnetic pole. Thus one interpretation could be that the stellar wind emerges along the open field lines above this pole, and is thereby collimated into a jet or cone. However, the other C IV maximum is shifted by $\sim$0.2 in phase relative to the positive pole--and furthermore leads this pole in rotation! This cannot be realistic. In fact, examination of Figure 3 shows that both C IV maxima coincide with the phases of helium minima. While there is not yet any explanation for this, the photospheric C IV abundance could be related to the photospheric helium abundance, and be dependent upon the local surface temperature and gradient of magnetic field lines. This strengthens the suggestion that the C IV variation is possibly purely photospheric in origin, and hence that there is no evidence for stellar

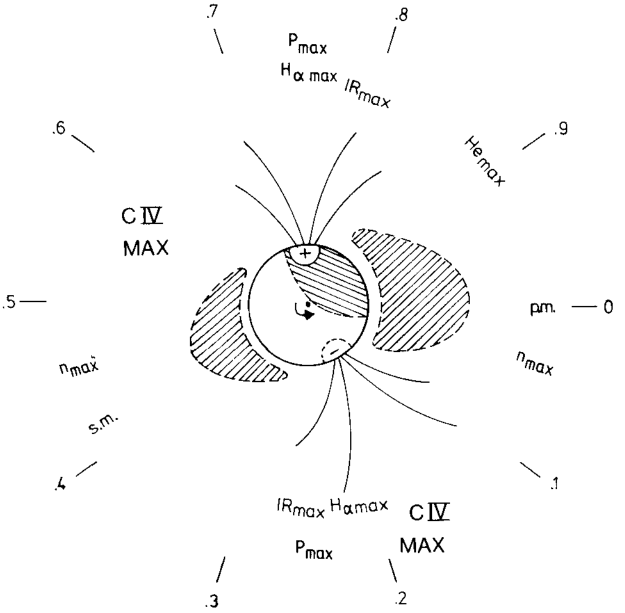

Figure 5. A perfect example of international non-collaboration. This model for σ Ori E (Groote and Hunger 1982) shows (viewed rotationally pole-on) the phases of maxima in Hα emission, IR emission, helium line strength, shell absorption, and linear polarization. The primary and secondary light curve minima are marked by p.m. and s.m. respectively. The projected orientation of the magnetic polar regions is also shown. The shaded region on the star marks the location of the helium strong spot, while the shaded circumstellar regions show the Hα emission clouds. Superposed on this diagram are the phases of maximum C IV absorption, obtained independently by Barker et al. 1986. These phases coincide with the times of helium minima, and do not correspond to the magnetic field phasing (see Figure 3).

wind variability in this star. Another explanation might be that the C IV ions are stratified in extended atmospheric lobes above the regions of minimum helium abundance, forming a superionized magnetosphere embedded within the general stellar wind. In this scenario, the magnetospheric density and geometry might be arranged so that, as observed, there is no detectable overt C IV emission at any phase.

4. THE SLOW ROTATOR HD 184927

This recently discovered helium strong star was studied optically by Levato and Malaroda (1979) and references therein. A magnetic field was found by Barker et al. (1982); the variations in strength of the field and optical features are shown in Figure 6. The lines of He I vary in phase with the magnetic field, but lines of H, Si III, and N II vary in antiphase; thus there is a helium rich region near the positive magnetic pole.

The observations of C IV in Figure 7 provide a dramatic contrast to those of σ Ori E. The doublet is highly variable on the stellar rotation period. When the positive magnetic pole is closest to the subsolar point, each component of the doublet displays strong longward emission, whereas when the magnetic field is close to zero, C IV is strongly in absorption. Exactly as for HD 37479, maximum C IV absorption coincides with the phase of helium minimum. The steep shortward edge to the longward emission occurs essentially at the rest wavelength. At all phases, there is an extended shortward absorption which reaches -600 km/s from line center, and reveals the presence of a stellar wind. Exactly as for HD 37479, this extended shortward absorption does not vary as the star rotates. The Si IV doublet shows very asymmetric profiles rising steeply on the longward side, with an extended shortward absorption. Again, the amplitude of variations is much less than at C IV because of the dominant photospheric contribution. Other UV wavelength regions have not yet been examined for variability.

Interpretation of these observations is less complete than for σ Ori E. As argued for that star, there may be some photospheric (or atmospheric lobe) contribution to C IV, explaining the coincident C IV absorption maximum and helium minimum. The high velocity wind far from the star does not vary. The C IV seen in emission must be circumstellar in origin, but its greatest strength occurs at low velocity, and when the positive magnetic pole is closest to the line of sight. It is not easy to see whether the C IV emission arises in the wind close to the star, or perhaps in a magnetosphere trapped by horizontal field lines. In any case, the C IV emission modulation shows that the wind/magnetosphere is strongly controlled by the field. Further, the amplitude of the modulation implies that a significant portion of the C IV emitting material is highly compact and close to the star.

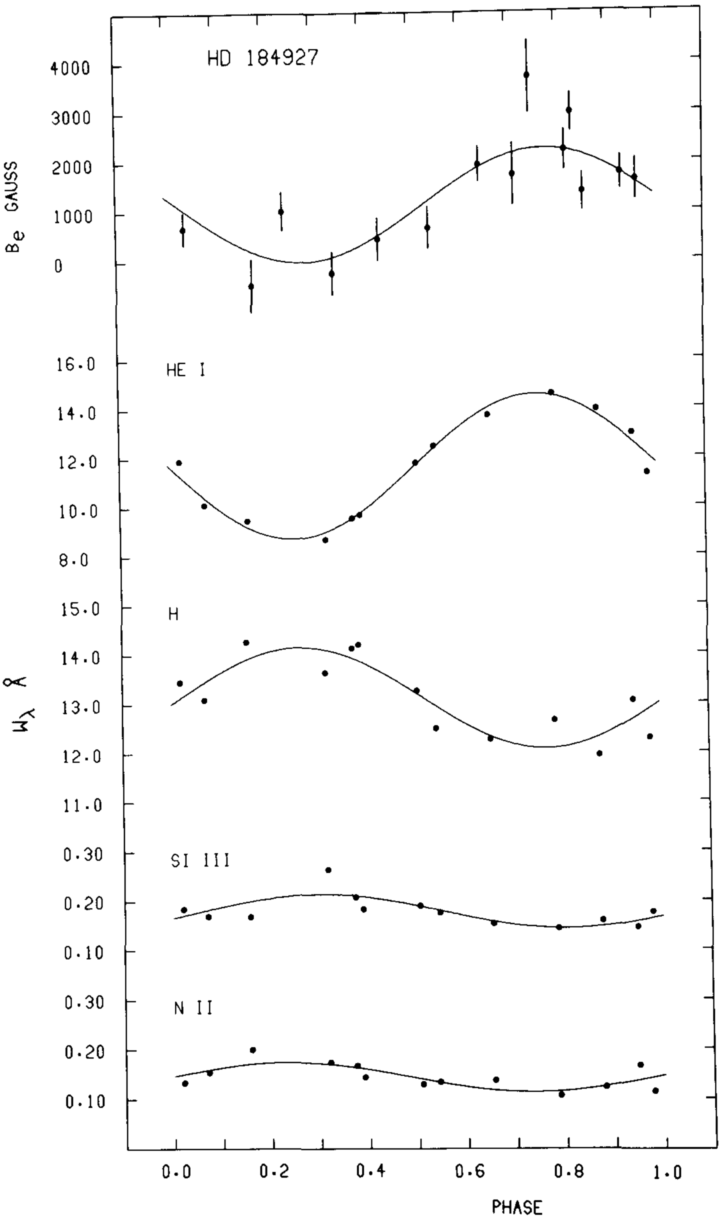

Figure 6. The mean longitudinal magnetic field and equivalent widths of optical features in the slow rotator HD 184927, phased on the ephemeris JD 2,444,796.0 + 9.536E. The smooth curves show least-squares sine wave fits to the data. From Barker et al. 1982.

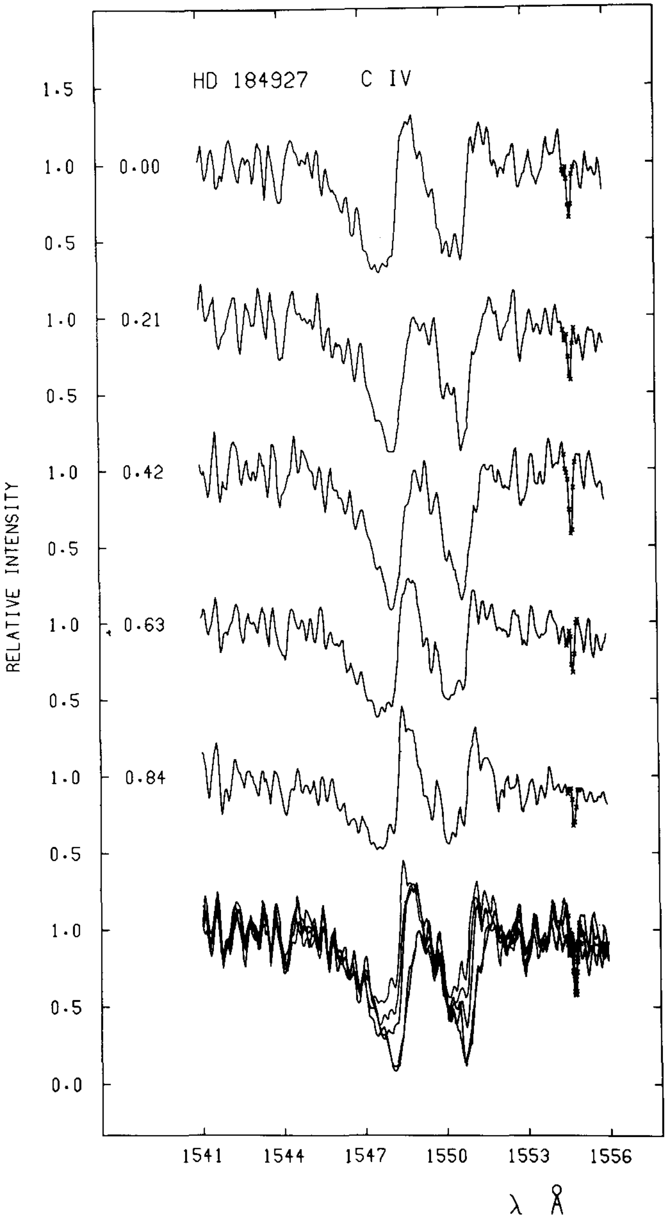

Figure 7. The top five profiles show the C IV resonance doublet in HD 184927 at the marked rotational phases; the same five spectra are superposed at the bottom. From Barker et al. 1982.

5. STELLAR WIND PHENOMENOLOGY

Figures 8 and 9 display the characteristic range of variation in C IV for nine of the stars listed in Table 1. HD 120640 in Figure 9 is now known not to be helium strong. HD 36485 profiles are not shown, but in fact are not much different from those for HD 120640, and are not variable. There may not even be any C IV present: the three sharp absorptions near the C IV doublet rest wavelengths probably result from Fe III (the same three features are seen in HD 58260 and HD 96446 superposed on the C IV emission). The variety in the C IV profile shape and in the amplitude of any variability for this sample of stars is overwhelming, if not dismaying. The most common feature is the presence of extended shortward absorption wings, indicating mass loss in a stellar wind, for those stars with C IV absorption.

The only cases of dominant C IV emission occur for stars in which the line of sight to the observer roughly corresponds to the magnetic axis: that is, at the maximum field phase of HD 184927, and also for HD 58260 and HD 96446, both of which have large and apparently constant fields. The lack of magnetic and spectral variations in HD 58260 and HD 96446 may arise either from their being viewed rotationally pole-on, or from intrinsic slow rotation; HD 184927 is a known slow rotator. These three stars are similar in that the C IV emission has a pronounced asymmetry, which is not true of the C IV emission in HD 64740, the star with next strongest emission. Walborn (1974) has reported weak broad emission wings to Hα in the rapid rotators HD 37017, HD 37479, and HD 64740--but not in HD 58260 or HD 96446. The present spectroscopic data show little or no Hα emission in HD 184927. Thus one arrives at the first taxonomic conclusion regarding this sample of helium strong stars: the strongest and most asymmetric C IV emission occurs in the stars which are either intrinsically the slowest rotators, or which are observed pole-on, whereas Hα emission is strongest in the most rapid rotators. The lack of significant Hα emission in HD 37776 may be related to the unique quadrupolar field geometry for this star.

A comparison of these C IV profiles with the stellar wind profiles seen in OB and Be stars in general is intriguing. The superionized resonance doublets in luminous OB stars typically display a broad absorption trough (with or without longward emission) which often has superposed narrow absorption components shifted to shortward wavelengths within the trough. Among Be stars there is sometimes no trough, only the shifted narrow components (SNCs). These features can show minor irregular variations in the luminous OB stars, and dramatic irregular variations in the Be stars, but not in normal low luminosity B stars; the present observational status is reviewed by Henrichs (1984, 1986). The origin of the SNCs is not understood for any of these stars, but it has been suggested that they may result from ejection of discrete "blobs" of material into the ambient stellar wind (which produces the general trough). The blobs in turn may result from fluctuations in the mode and amplitude of non-radial pulsation (recently discovered for many of these stars). The relevant points here are: first, there do not appear to be any irregular fluctuations in the wind

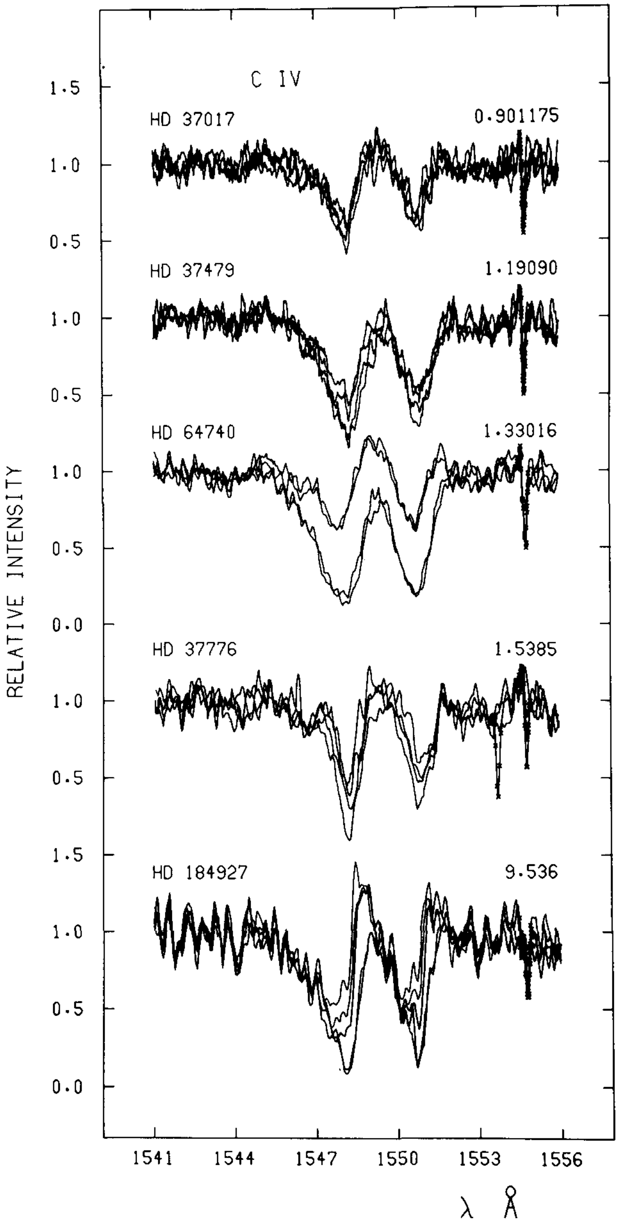

Figure 8. Here and in Figure 9, IUE spectra are superposed to show the characteristic variation of C IV in the helium strong stars. This figure shows the stars with known photometric period; the period in days is marked for each object. From Barker et al. 1982.

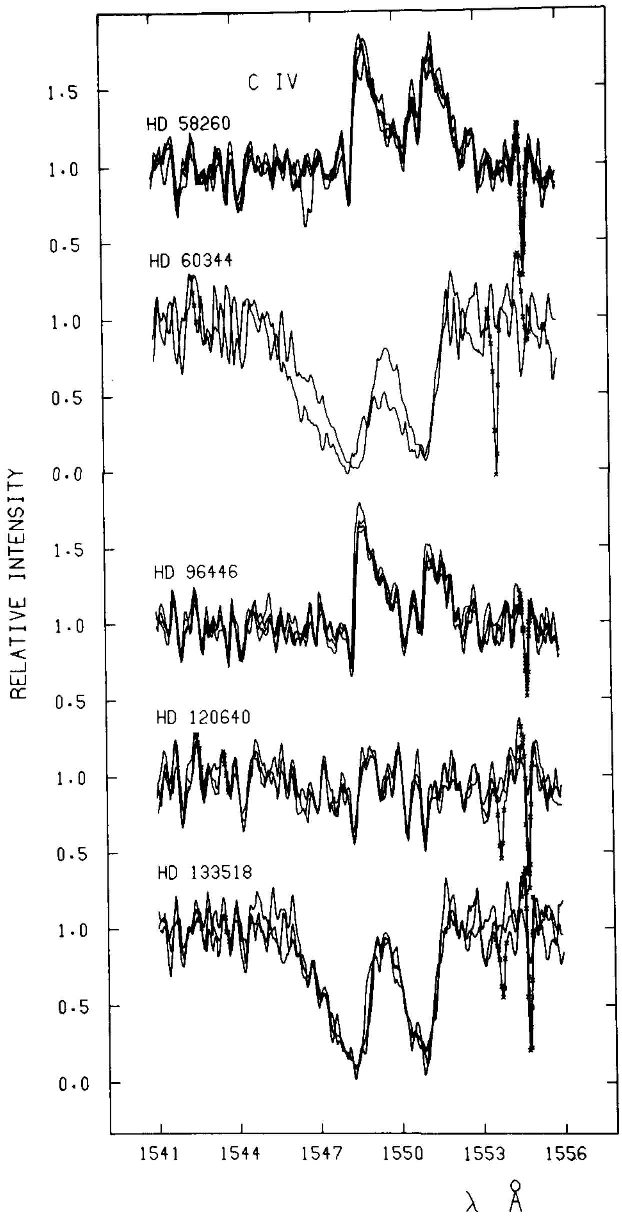

Figure 9. As in Figure 8, for the stars of unknown rotation period. HD 120640 is now known not to be a helium strong star, while HD 36485 (recently discovered as helium strong) is described in the text. From Barker et al. 1982.

profiles of helium strong (or helium weak) stars; second, no helium peculiar star has ever been observed with SNCs present; third, non-radial pulsation has not yet been observed among the helium peculiar stars (but has anyone looked?).

If future work confirms these points, the different phenomenological behavior for helium peculiar vs. OB and Be stars might be explained by supposing that a strong global magnetic field acts to suppress non-radial pulsation, and hence the ejection of blobs and production of irregular profile variability and SNCs. Or, perhaps the helium peculiar stars have quiescent winds simply because they are nothing but normal main sequence B stars that happen to have magnetic fields.

6. HELIUM WEAK STARS

Only slightly out of place at this Colloquium, these stars seem to be intermediate objects between the helium strong and Ap stars: helium weak stars are generally analogous to the Ap stars in regard to spectrum variations and presence of magnetic fields, and occur on the main sequence at spectral types between those of helium strong and Ap stars. Brown, Shore, and Sonneborn (1985) discovered weakly asymmetric C IV absorption in HD 21699, which varies on the magnetic and rotational period. This was interpreted as evidence for collimated jets emerging from above the magnetic poles. Interestingly, the only helium weak stars to show this behavior are the "sn" stars HD 21699, α Scl, and 36 Lyn (with sharp hydrogen and metallic lines but broad diffuse helium lines), in a survey conducted by Shore and Brown (1986). In this pleasing sequence from early B to A type stars, the Ap stars themselves presumably lack the C IV morphology shown by the helium peculiar stars only because they are insufficiently luminous to possess radiatively driven winds--although they may possess corotating magnetically driven winds (Rakos 1981).

7. FUTURE DIRECTIONS

In summary, the helium strong stars have winds and magnetospheres whose structure is modulated by the global stellar magnetic field. Despite the complex phenomenology, one might hope that the varietal sample available will ultimately permit elucidation of the interacting effects due to rotation rate, magnetic geometry, radiative and diffusive forces, and stellar orientation.

Some aspects of these factors have been addressed theoretically. The role of diffusion is reviewed by Bolton (1983) and Michaud (1986). Nakajima (1981) developed a model for the Hα emission in which circumstellar gas--constrained to move only along the field lines--is trapped in a corotating magnetosphere whose inner and outer boundaries are determined by the balance between centrifugal and gravitational forces. This qualitatively predicts that the rapid rotators should have stronger Hα emission than the slow rotators, as observed, but the model does not include radiative forces. Peterson and Theys (1981) considered the extension above the photosphere of early B star atmospheres with strong horizontal magnetic fields. Limber (1974), Saito (1974), and Nerney (1980) constructed wind models driven entirely by magnetically enforced corotation. Shore (1978) attempted to model the balance between radiative and diffusive forces in magnetic B stars. Barker (1982) and Friend and MacGregor (1984) constructed magnetic wind models incorporating the effects of line radiation pressure.

Unfortunately, no model yet includes the effects of all the forces known or suspected to be influential among the helium strong stars. Not only must all these forces be treated simultaneously, but in addition, fully three-dimensional models must eventually be sought if one hopes to approach the complex realities of Figures 8 and 9. Such calculations have not yet been attempted. Progress will be slow, but--based on the present qualitative intuitive physical scenario outlined here--one hopes it will be substantial.

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DISCUSSION

BALASUBRAMANIAM: In measuring the magnetic fields, what criteria do you use to eliminate lines that are temperature sensitive?

BARKER: None. For the early B stars, one is limited to lines of helium and hydrogen. The hydrogen lines are stronger and steeper, and produce a stronger polarization signal; generally only H_β is observed. In any case, there is no evidence for any coronal or prominence-like fine structure in these stars.

BALASUBRAMANIAM: Again: are the magnetic fields derived from two different lines?

BARKER: Only one line is observed in each star because the photon counting problem is unbelievably severe, it takes half a night on the 3.6 meter telescope to observe one star at one line.

ODELL: Is it possible to get incorrect field measurements if the line profile is varying with a timescale of 1 day?

BARKER: Yes, very easily, unless one uses a large enough telescope that the entire sequence of polarization observations can be completed in a time much less than the rotation period. This of course is true whether or not the observed profile has any weak emission component.

HUNGER: The R-index of Pedersen, if really not O.K. can only get messed up because the filter in between λ 4009 Å and λ 4020 Å does not measure the true continuum, because these two He I lines may overlap.

MICHAUD: Is the same phasing between He and H observed for all He rich stars and, is it the same for the He weak stars?

BARKER: As shown in Figure 1, the helium strong stars with dipolar fields have helium maxima when the magnetic poles are closest to the subsolar point. The phasing is different for HD 37776 with its quadrupolar field. For the helium weak star 3 Sco, the phasing is also different even though this does have a dipolar field.

HUNGER: As to the anti-correlation of CIV and H_α emission, HD 60344 has a low mass (1.3 $M_\odot$), and hence may belong to the low mass subgroup if that really exists. HD 133518 is probably not He-rich.

BARKER: I believe Walborn in his classification paper did still include HD 133518.

LIEBERT: I may be committing an unpardonable sin: The unwritten rule whenever a talk on magnetic stars is presented, is never to ask basic questions, like where does the magnetic field come from. Since the Orion OB group is close and relatively easy to study, why is σ Ori E so unique? The more global question to Dr. Hunger what fraction of B stars relly have He strong magnetic behaviour?

HUNGER: Roughly one third.

GARRISON: There is an interesting, tight cluster of about 12 stars surrounding σ Ori E. It includes also a helium-weak star and a mild Ap star. The main sequence is very tight, about the width of the line drawn, according to some unpublished MK work I did on it. If you plot the He-weak star according to its color, it falls about 0.7 magnitude below the main sequence, whereas its spectrum is cooler and above the main sequence - the truth is probably somewhere in between.

HILL: This question is for Dr. Garrison. In this small cluster containing the Orion complex, do you find any other stars with the same T_{eff} as σ Ori E but not with its peculiarities?

BARKER: Not exactly the same, but there are stars bracketing it on the main sequence.

GURM: Are there any X-ray studies from these objects?

BARKER: It has been suggested (Groote, Kaufmann, and Hunger, Astron. & Astrophys., 1978, 63, L9) that HD 64740 may be coincident with the X-ray SOURCE 4U 0750-49. I do not believe that any helium strong star has ever been deliberately observed at X-ray wavelength.

GURM: There seems to be coronal behaviour as there is a strong collimated wind from the magnetic pole. It forces us to think that there is a sun like phenomenon. However, differences could arise because some dust may be present.

BARKER: Many helium strong stars show IR excesses, but for HD 37479, Groote and Hunger argued that emission from dust is unlikely.