A SEARCH FOR HELIUM SPECTRUM VARIABLES

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ABSTRACT. Helium spectrum variables, which show periodic variations in the strengths of their helium lines, form a very rare subgroup of the peculiar B-type stars. The amplitudes can be quite large, though smaller variations are more common, and the periods found so far are of the order of a week, ranging from one to ten days. In an attempt to discover new variables, twelve helium-peculiar OB-type stars were observed during a twenty-night run in May/June 1992 with the Helen Sawyer Hogg 60-cm telescope[1] of the University of Toronto Southern Observatory in Chile. Ninety-two spectra were taken of the twelve stars during this period. No gross helium-line variations, such as those seen in the prototype, HD 125823 (a Cen), were observed. Smaller variations are easily seen in one other known, small-amplitude spectrum variable. Attention is called to some of the program stars that show small amplitude variations significantly larger than the errors and that warrant further observation. Some of the stars exhibit variations of other lines, including hydrogen. Our data indicate that the period of a Cen is closer to 8.816 days than to 8.814 days, supporting a suggestion by Fahey (1984).

RÉSUMÉ. Les étoiles variables contenant de l'hélium démontrent de la variabilité périodique dans l'amplitude de leurs lignes spectrales et constituent un groupe très rare de variables particulières de type B. L'amplitude des variations peut être assez importante, quoique celles qui sont moins grandes sont plus communes et les périodes observées à date sont d'environ une semaine, avec une marge de variabilité d'un à dix jours. Dans le but de découvrir de nouvelles variables, douze étoiles particulières de type OB contenant de l'hélium ont été observées durant vingt nuits courrantes en mai et juin 1992, avec le télescope Helen Sawyer Hogg de 60 cm, de l'Observatoire du Sud de l'université de Toronto au Chili. Quatre-vingt douze observations du spectre des douze étoiles ont été faites durant cette période. Aucune variation importante des lignes spectrales n'a été observée, comme on en voit dans le prototype, HD 125823 (a Cen). Des variations plus attenuées ont clairement été observeés dans une autre variable reconnue pour la faible amplitude de ses lignes spectrales. Une attention doit donc être portée sur certaines étoiles au programme qui font preuve de petite amplitude, mais plus grande que celle des erreurs, et qui méritent de nouvelles observations. Certaines de ces étoiles présentent des variations dans d'autres lignes du spectre, y compris celles de l'hydrogène. Nos données indiquent que la période de l'étoile a Cen s'approche plutôt de 8.816 jours que de 8.814 jours, appuyant donc la suggestion de Fahey (1994). SEM

1. INTRODUCTION

Spectrum variables are good testing grounds for theories of stellar interiors, atmospheres, and evolution. Helium spectrum variables are especially interesting because the variability involves an element that is probably primordial and that is second in abundance only to hydrogen. They generally occur among the B stars and especially among the He-weak and He-strong stars, though some are also found among other classes of B-peculiar stars, such as the silicon Bp stars. (see Bolton 1983 for a review). Our sample is biased in favour of the discovery of new helium spectrum variables among the He-strong B-type stars, though we have included two O-type stars with helium peculiarities and three He-weak stars in the program.

In this search, we have targeted mainly members of the helium-strong subgroup, characterized by helium lines that are too strong for the MK spectral type as determined from the hydrogen and metal lines. In fact, the helium lines in the He-strong subgroup are much stronger than observed in any normal star and are classified as "peculiar" because they fall outside the normal range of observed helium-line strengths. Though the He-strong and He-weak stars are often described as "helium rich" or "helium poor," caution dictates that the classification should not imply an interpretation. Strong or weak helium lines may be a structural phenomenon and are not an unambiguous indicator of helium enrichment or deficiency. The helium-peculiar stars also exhibit very strong magnetic fields, comparable to those in the well-known magnetic A-type stars (Bohlender *et al.* 1987).

Some abundance analyses do find an excess of helium relative to hydrogen in the helium-strong stars, with typical values of N_H/N_{He} ~1. Effective temperatures are found to be about 20,000 K, consistent with a spectral type close to B2 V (Bohlender & Landstreet 1990; Hunger 1986a).

The first extreme helium star to be discovered was HD 124448 (Popper 1942), though it differs markedly from the others in the subgroup in that it displays no hydrogen lines at all. It is probably an evolved object, not related to the unevolved He-strong stars being discussed here. A better example of the subgroup is the well-known and intensely studied star σ Ori E, whose peculiarity was first described by Berger (1956) but whose variability was not noticed until much later (Walborn 1974). Descriptions are given by Bolton *et al.* (1986), Short & Bolton (1994) and Groote & Hunger (1997). There has been some controversy over the models for this star. HD 37017, also in the Orion Association, was studied extensively by Lester (1972).

The most dramatic helium spectrum variable known is HD 125823 (Norris 1968; note that this star is "a Centauri," not to be confused with α Centauri), which is included in our sample. It varies between the extremes of the helium-weak and helium-strong types. Since its discovery, fewer than a dozen of this particular type of helium variable star have been reported in the scientific literature (Hunger 1986a,b; Drilling & Hill 1986) and none varies as much as

[1] Dedicated on June 19, 1992 to Helen Sawyer Hogg in recognition of her distinguished research career and her long service to the University of Toronto.

a Cen. More systematic searches are needed in order to establish patterns.

The helium spectrum variations are periodic to a high degree. Typical periods are a few days, though periods up to 9-10 days have been observed (Underhill *et al.* 1975; Bond & Levato 1976). In addition to the helium lines, the metal lines may vary in strength, but usually only very slightly; if they do, the periods are invariably the same, though sometimes the phases are different. It is not unusual for the metals to vary in antiphase with helium.

The hydrogen absorption lines, however, do not vary in HD 125823 (a Cen). While there are a few reported cases of mild Balmer-line strength variations (Walborn 1982; Barker 1986), most of the stars have not been known to show strongly variable hydrogen-line absorption strengths. HD 125823 (a Cen), whose helium lines vary from stronger than normal to almost zero in an 8.8 day period, shows no variation in the Balmer lines. Photometric variations are small or non-existent, consisting of at most a few hundredths of a magnitude in the *U* and *B* bands (Pedersen 1979). A few of the stars show variable Hα emission (Bolton 1983; Bohlender 1994).

All known helium spectrum variables follow a period-$v \sin i$ relation (Hunger 1986a). It implies that they are oblique rotators, an idea attributed to Guthnik & Prager (1918) and developed by Deutsch (1958), who applied it to the Ap stars. Problems regarding the non-detection of radial velocity changes in some of the stronger lines have since been addressed and have been attributed to saturation of the line cores (Landstreet & Borra 1978; Hunger 1986a).

The magnetic fields of these stars are also important to our understanding of the oblique-rotator model for helium line variability. All of the known helium-strong and helium-weak spectrum variables have detectable magnetic fields (Bohlender *et al.* 1987; Bohlender 1994; Borra *et al.* 1983). Their fields are variable, with the same periods as their photometric and spectroscopic fluctuations.

The main problem facing the oblique rotator model is how to create and maintain the regions of differing composition in the star. It has been known for some time that helium can settle out of a sufficiently stable stellar atmosphere under the right conditions (Michaud 1970). At first glance, that would appear to allow only the possibility of stars developing helium-poor atmospheres, with the helium diffusing inward towards the core. However, ionized helium diffuses 100-1000 times more slowly than its neutral counterpart under the conditions expected in an early-type star's atmosphere. It follows that the inward rate of diffusion decreases with radius, because of increasing ionization, which can result in the creation of a helium-rich layer with a helium-poor region above it (Bolton 1983). If a radiatively driven stellar wind were introduced, the downward diffusion would then be taking place in an upwardly moving reference frame. That could allow the helium reversing layer to occur higher in the star's atmosphere than might otherwise be possible, its radius being dictated by the balance between the rates of diffusion and mass-loss (Osmer & Peterson, 1974). If the He-enriched or depleted layers were to exist near optical depth ~1, they would affect the helium line strength and mislead attempts at abundance analysis.

Computer models have indicated that helium separation can occur in the atmospheres of hot stars in such a manner (Vauclair 1975, 1991). However, the mass loss rates required are ten or more times higher than would be expected from models for the winds of such stars (Lucy & Solomon 1970). The expected winds would sweep the reversing layer out into space. The key to the dilemma is the magnetic field.

A magnetic field will exert a retarding force on a charged particle moving perpendicularly to it. Thus, the magnetic field provides a mechanism by which the stellar wind might be slowed to the point where the helium reversing layer could be retained (Shore 1993). If we were to assume a simple dipolar geometry for the field, the maximum non-radial component of the magnetic field would occur at the magnetic equator, and the reversing layer would have its minimum astrocentric distance there. The magnetic field would become increasingly radial with increasing magnetic latitude, allowing the stellar wind to flow more freely and the reversing layer to rise progressively. It would result in what would appear to be (and are) differing chemical compositions at different latitudes, as the reversing layer would reside at different radii and hence different optical depths. Such compositional variations would have the appearance of bands or caps. More complicated field geometries could result in the presence of more localized spots, for which some evidence exists (Bohlender & Landstreet 1990; Groote & Hunger 1997).

As the star rotates, the different areas will be swept across the visible face of the star. That produces the observed variations in the helium lines and explains their periodicity. The variability of the metallic lines can be explained by a similar diffusion process, or perhaps simply as a symptom of the helium segregation. The helium enrichment or depletion of different regions may change the temperature structure of the atmosphere, and so might affect temperature-sensitive lines in principle; in practice it is probably not very sensitive to changes in helium abundance (Bohlender private communication). They should demonstrate the same periodicity as the other variations, which is in accordance with observations.

The purpose of this survey is to enlarge the sample of known helium spectrum variables. In the theoretical interpretation there are many free parameters involving the magnetic field, the star, and the geometry, thus allowing a wide range of behaviour. A good statistical look at the phenomenon requires a relatively large sample, which does not yet exist. Though relatively rare, OB-type stars are visible at large distances, thus yielding a large accessible population of potential helium spectrum variables. In addition, the characteristic of being helium strong (easily detectable in classification surveys) or helium weak gives criteria by which to choose candidates for closer inspection. These two factors give us the tools necessary to expand efficiently the sample of known helium spectrum variables. We report below the results of one observing run.

2. Observations and Reductions

The observations were carried out between May 24 and June 12, 1992, with the Helen Sawyer Hogg 60-cm telescope of the University of Toronto Southern Observatory on Cerro Las Campanas in north-central Chile. The Garrison classification spectrograph was used with a glycol-cooled PM512 CCD (Photometrics, Inc.), which is coated with MetaChrome II for improved blue response. A new first-order grating was used in the wavelength interval 4100–4500Å with a resolution of 1.7 Å per 2 pixels. Signal-to-noise ratios of a few hundred are achieved by widening the spectra up to 30 pixels

Table I
The Target Stars

HD No.	Hbg No.	MK type	V	B-V	U-B	Notes
66765	120	B2 V	6.60	−0.14	−0.76	2SB, sl. He-strong, var
117357	828	B0.5 IIIne	9.07	0.20	−0.69	var H emiss., He absorp.
133518	928	B2 Vp	6.30	−0.06	−0.72	He-strong
135038	945	B8 III (p?)	8.37	0.01	−0.39	He-weak?
147880	1138	B5: III (p?)	8.63	0.04	−0.39	He-weak?
149257	1173	B2 Vp	8.46	−0.01	−0.77	He-strong
150136	1188	O5 III (f)	5.54	0.20	−0.76	He "washed out," SB?
164769	1539	B2 IVp	9.23	−0.04	−0.79	He-strong
165207	1551	B2 Vp	8.25	−0.10	−0.76	He-strong
168785	1623	B2 Vp	8.51	0.04	−0.73	He-strong
168941	1624	O9.5 IIp	9.34	0.07	−0.87	He II 4686 too strong
172854	1650	B3 IIIp	7.69	0.23	−0.30	He-weak

for most of the program stars. The standard procedure is for at least three successive ten-minute frames to be taken of each object, to aid in the detection of cosmic rays. The three frames are then added to make one "exposure." The signal-to-noise ratio per pixel is generally 40-80; after co-adding and binning, the overall signal-to-noise is generally between 100-500.

Despite overall poor weather, observations were obtained on thirteen nights, which were fairly well spaced over the twenty-night interval. It allowed measurements to be taken over more than one period for stars with longer cycles, and also allowed adequate phase coverage for any stars with periods close to an integral number of days.

The program stars were chosen from a survey of southern OB stars by Garrison, Hiltner & Schild (1977; hereinafter GHS). Heidelberg (Hbg) numbers are from Klare & Szeidl (1966). The GHS survey has a limiting magnitude of about 10 in *V*, and provides the MK classifications for the stars observed. GHS include comments on stars with peculiar spectra, including those with abnormal helium line strengths. Photometry for the stars is found in Schild *et al.* (1983; hereinafter SGH).

The comments in GHS were used for selecting our candidates. Seven stars noted to have strong helium lines were chosen as primary candidates. Five other stars having either weak helium lines or other helium spectral peculiarities were chosen as secondary candidates. The stars chosen are in the range $5.5 < V < 9.4$ and are listed in Table I.

Spectra of thirty-nine standard stars were observed, ranging from late O to early A; each was taken at least once during the run. Three primary standards were taken nightly. Also observed as variability standards were the known helium spectrum variables HR 3089, HR 7129 and a Centauri. The subset of standards actually used is listed in Table II.

The spectra were reduced with IRAF 2.9.1, running on a Sun 3/160. From the 900+ frames taken (including reference and calibration frames), 241 finished spectra were produced. All of the stellar exposures consisted of three frames and most are widened by 30 pixels. They were co-added and reduced to one dimension.

The exposures for each object were then stacked to allow visual inspection for large-scale variations. The stacked and difference (from the mean) spectra for the known variables are shown in figures 1ab–3ab. The difference spectra for two of the primary standards are shown in figure 4ab to illustrate the confidence level for constant spectra of good quality. Stacked and difference spectra for the program stars are shown in figures 5ab–12ab. For a few of the candidates only one or two spectra were obtained and no differences were visible, so they are excluded from the series of illustrations. A few of the spectra were in the range 3850–4250 Å, and are not illustrated here. Note that the stacked spectra are not necessarily taken on consecutive nights, so a periodic change in line strength might not appear obvious in the plots; in the first instance we were searching for any changes that occurred. Follow-up observations of the most interesting cases will be necessary to ascertain periods.

3. Discussion

3 (a). Known Helium Spectrum Variables

HD 125823 (a Centauri, figure 1ab) shows dramatic variability in the strengths of all the neutral helium lines in the wavelength region covered, notably 4121, 4144, 4168, 4387, and 4471Å. The Julian dates in figure 1ab are those on which the observations were made. The helium-line strengths at maximum are stronger than in normal stars at B2 V, the peak of helium-line visibility, but they approach invisibility at minimum. However, the Balmer lines show no significant changes. Most of the other strong lines, notably Si II 4128–30 Å, show no changes. Mg II 4481Å may vary slightly. Curiously, however, the Fe II line at 4233Å is faintly present and appears to vary slightly in antiphase compared with helium. The line is not visible in normal early B stars and usually begins to appear only at about spectral type B8. It is not clear if the changes in profile of C II 4267Å are real, though the reductions have been checked several times and no sources of error were found that could lead to the effect. The line has strong non-LTE effects and is known to be unreliable as a temperature indicator (Hamilton & Garrison 1995).

There has been some disagreement (on the order of a few hundredths of a day) about the period of a Centauri's helium variability. The measured values seem to be increasing slowly with time (Fahey 1984). Such a trend of slowly increasing period is supported by our results. In figure 1 it is clear that the maximum of the helium lines does not occur at zero phase (JD2440083.5 + 8.814, or JD2448782.918) as given by Norris (1971). Our data are more consistent with a period of 8.816 days (JD2448776.076).

The reported variability of HR 3089 (Bohlender & Landstreet 1990) for the helium lines is not very obvious in our data (figure 2ab). C II 4267Å and Mg II 4481Å are easily visible and essentially constant. The blend at 4415-17Å, which may be due to O II, is relatively strong and non-variable. Si II 4128–30 Å is marginally visible. Besides the strong helium lines, however, the spectrum is quite peculiar. There appears to be a strong, non-variable feature at 4072–6 Å, which is possibly O II, but that is usually seen in stars earlier than B1 or above the main sequence at B2. There is also a line at 4444 Å, which may be O II or N II. As HR 3089 is the hottest well-established helium-strong star, the appearance of O II is perhaps not so surprising. A further comprehensive study of high-resolution, high S/N spectra of the star would be very informative.

HR 7129 (figure 3ab), also a known helium spectrum variable, exhibits a clear helium line variation, though it is considerably less dramatic than in HD 125823. The He I lines 4144, 4387, and 4471

Table II
The Standard and Comparison Stars

Spectral Type	Luminosity Class V	IV	III	Ib
B1	ω^1 Sco		σ Sco	
B2	22 Sco β Sco C[a]	μ^2 Sco υ Sco	β Lup	
B3	η Hya			
B5	κ Hya[a]	γ Cir	ι Aql	67 Oph
B6	β Sex			
B7	α Leo	δ^1 Tel	HR 6460	
B8	HD 142315		ω Car[a]	
B9	HD 141774	α Del	γ Lyr	
B9.5	ω^2 Aqr			
A0	109 Vir γ Oph		HD 142805	
B2-8p var	a Cen[a]			
He-var	HR 3089[a] HR 7129[a]			
He-weak	HR 5988			
Silicon	HD 147890			
Si-4200	HD 142884			
Manganese	HR 6003			

[a] Nightly standards and known variables.

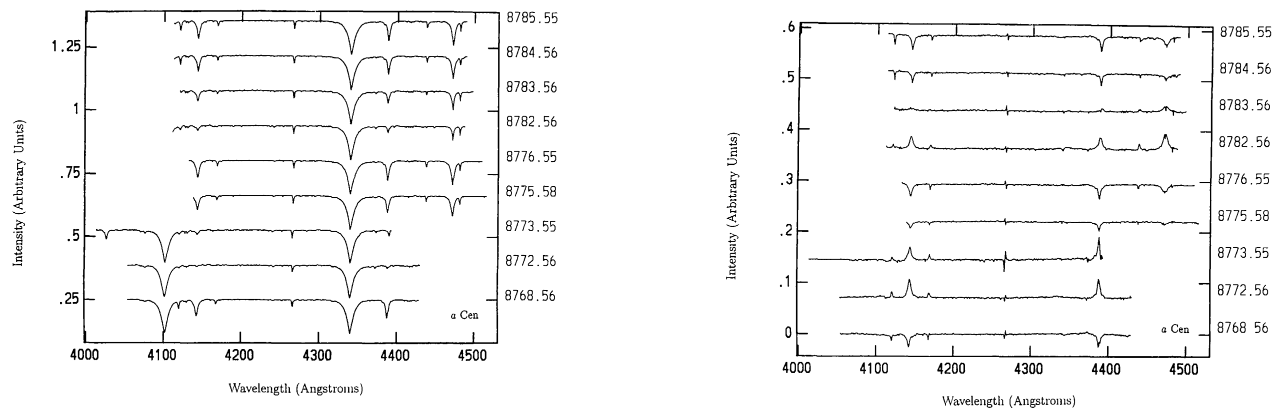

Fig. 1ab — a Centauri = HD 125823 (B2-B9 IIIp). Zero phase is JD2448782.918 for a period of 8.814 days or JD2448776.076 for a period of 8.816 days. In this and following figures the difference spectra are on the right.

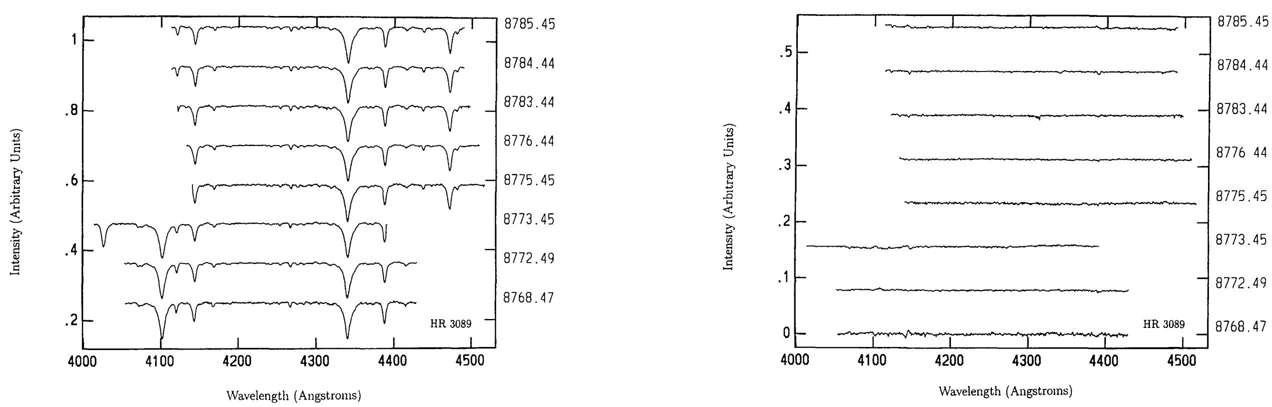

Fig. 2ab — HR 3089 (B2 III). Zero phase is JD2448775.573 for a period of 1.33026 days (Bohlender & Landstreet 1990).

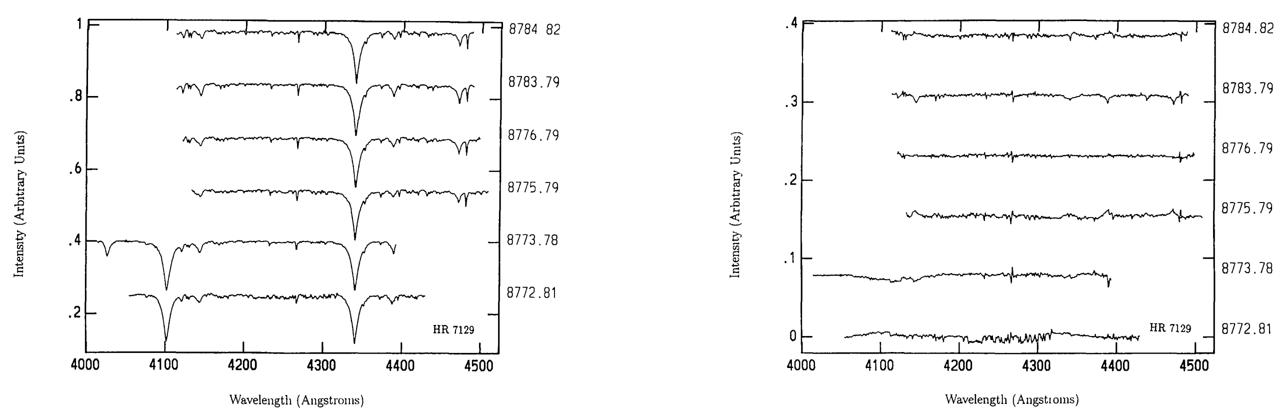

Fig. 3ab — HR 7129 (B8 IV). Zero phase is JD2448774.15 for a period of 3.67 days (Wolff & Wolff 1976).

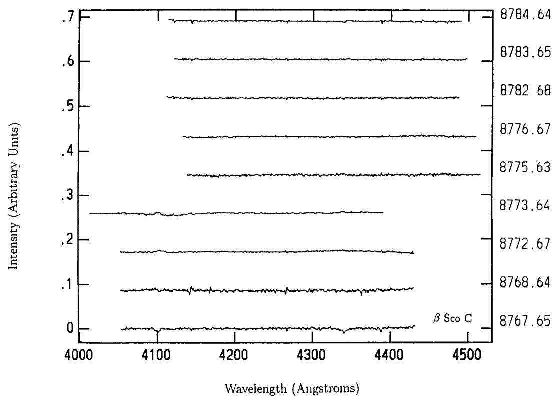

Fig. 4A — β Scorpii C = HD 144218, standard B2 V star.

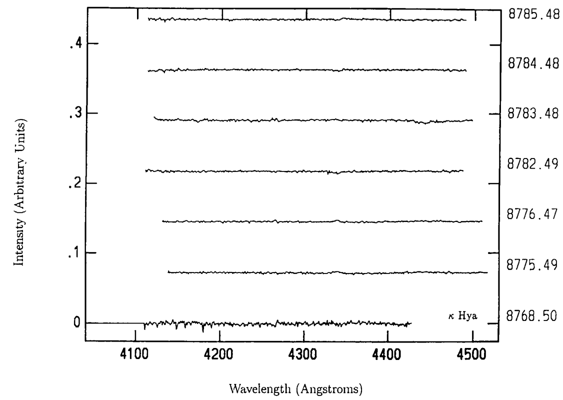

Fig. 4B — κ Hydrae = HD 83754, standard B5 V star.

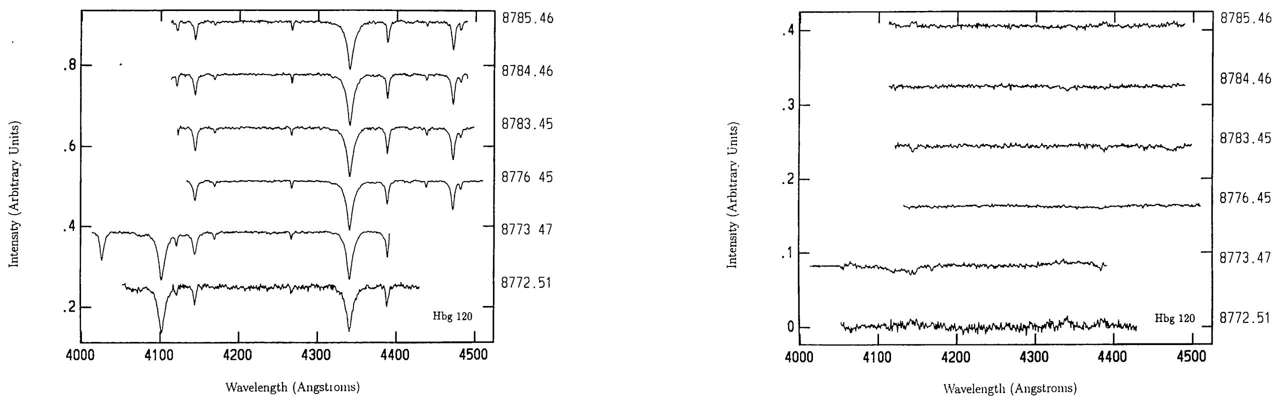

Fig. 5AB — Hbg 120 = HD 66765, B2 V (two-line spectroscopic binary; helium slightly enhanced).

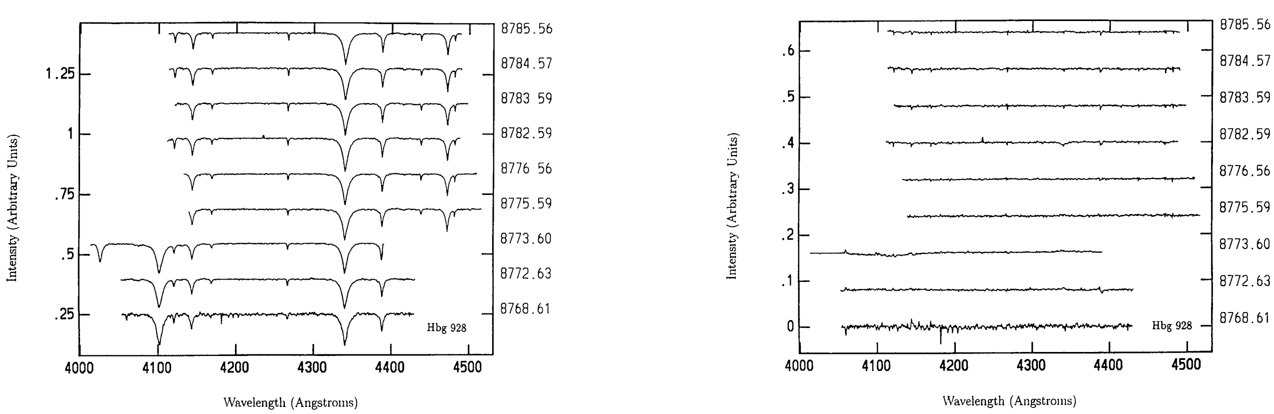

Fig. 6AB — Hbg 928 = HD 133518, B2 Vp (helium-strong star).

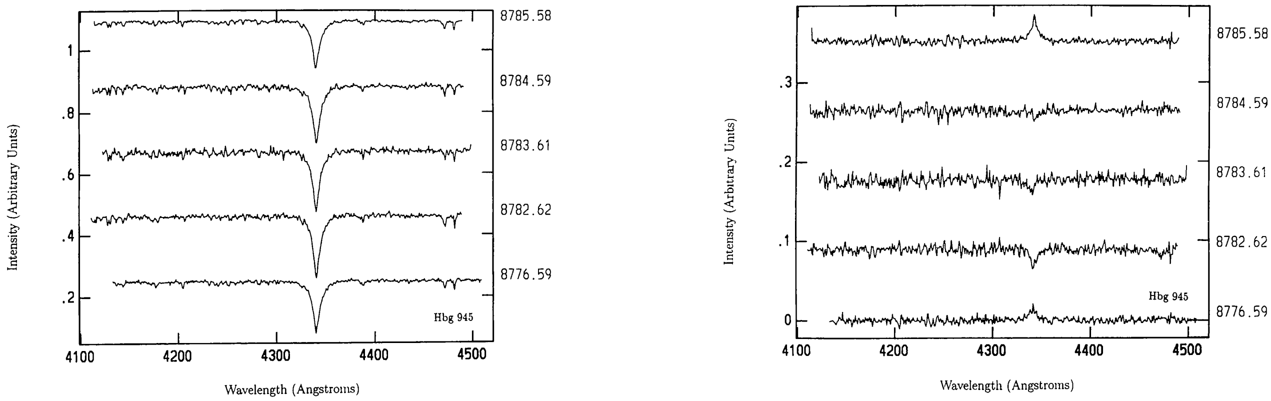

Fig. 7ab — Hbg 945 = HD 135038, B8 III (p?) (hydrogen profiles are peculiar, as in weak-helium star).

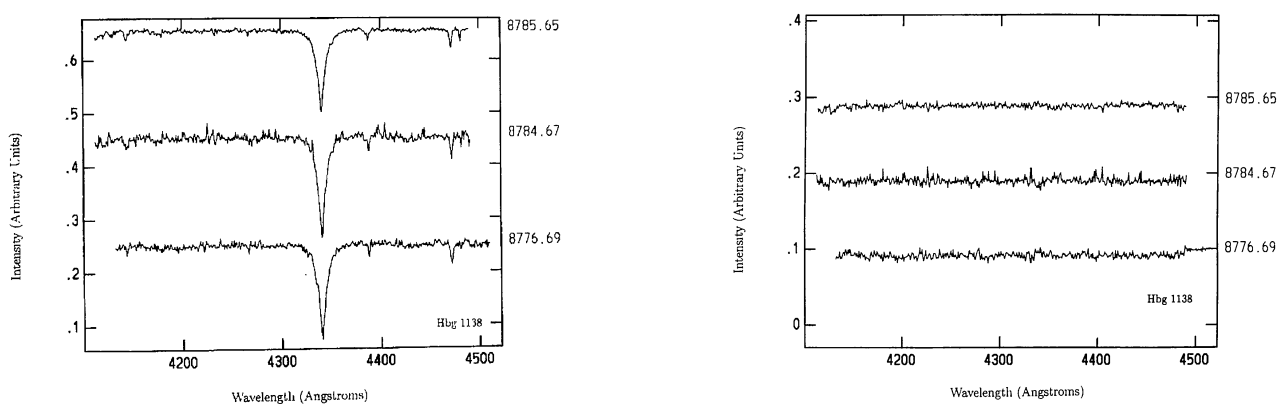

Fig. 8ab — Hbg 1138 = HD 147880, B5 III (p?) (silicon, magnesium weak, hydrogen profiles are somewhat peculiar, marginal helium-weak star).

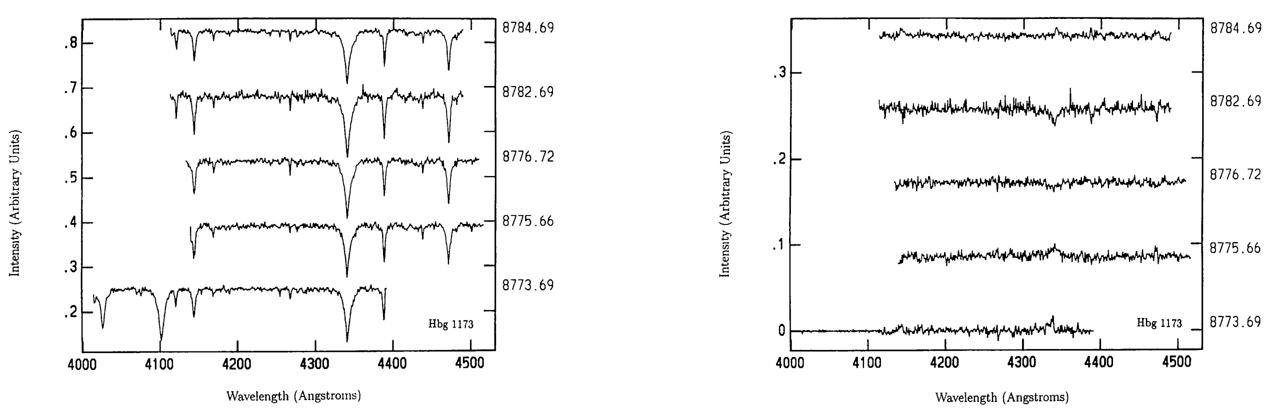

Fig. 9ab — Hbg 1173 = HD 149257, B2 Vp (helium-strong star).

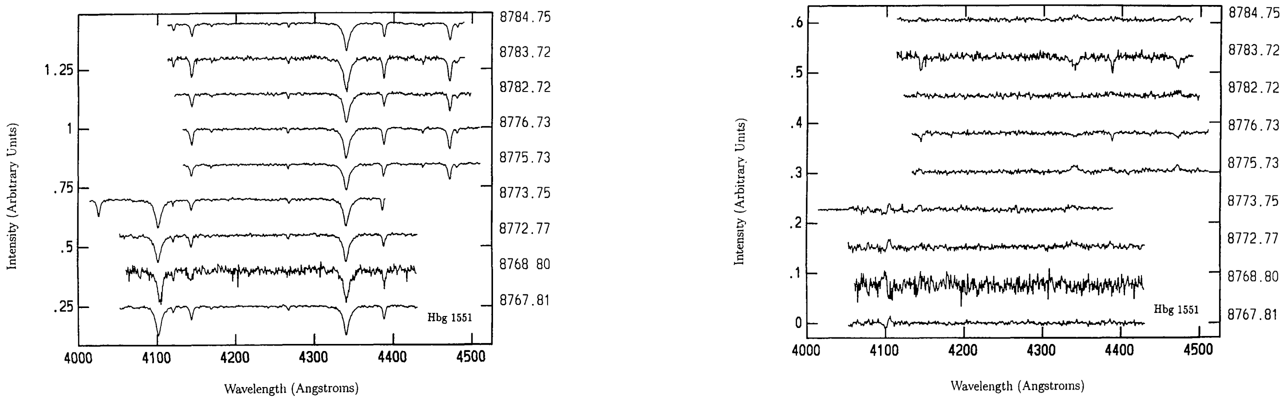

Fig. 10AB — Hbg 1551 = HD 165207, B2 Vp (helium-strong star).

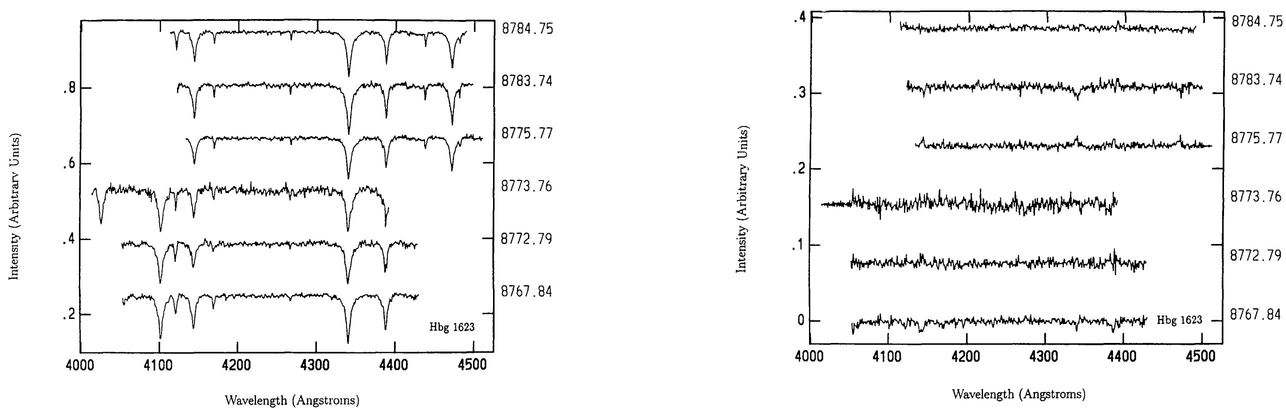

Fig. 11AB — Hbg 1623 = HD 168785, B2 Vp (helium-strong star).

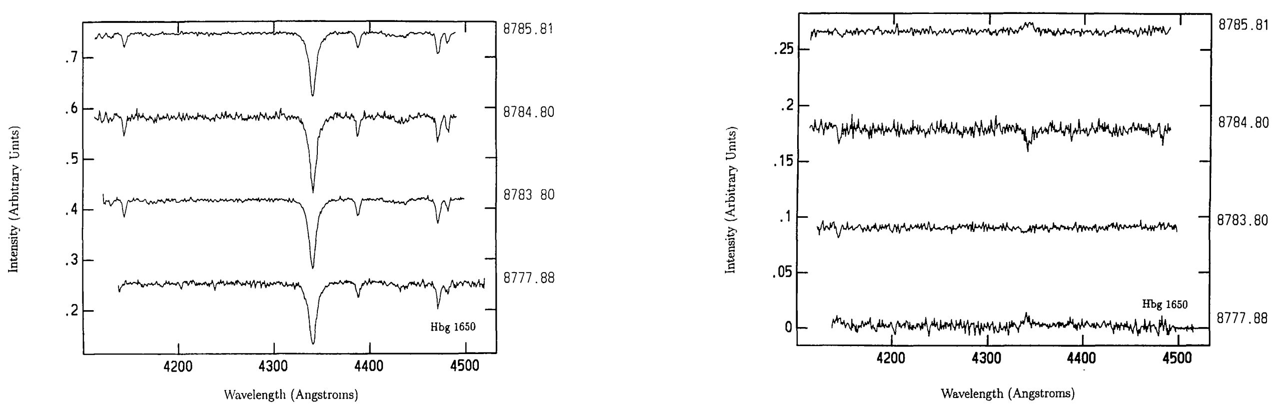

Fig. 12AB — Hbg 1650 = HD 172854, B3 IIIp (helium lines are weak for the rest of the spectrum).

Å lines vary unmistakably, and their maxima seem to coincide well with zero phase. The blend Si II 4128–30Å and an O II line at 4370 Å seem to vary in antiphase with the helium lines. The C II 4267 Å line has been reported to vary (Wolff & Wolff 1976). In our data there is a possible line shift or profile variation, as described above for a Cen (HD 125823), but no apparent variation in line strength. As in a Cen, the hydrogen lines and Mg II 4481 Å appear to be constant in strength, with a possible line profile shift. Other discernable, but apparently non-variable, lines are Fe II 4233 Å (which varies in a Cen), and the O II blend at 4415-7Å.

3 (b) Nightly Standards and the Question of Errors

Three of the non-variable standards (β Sco C, B2 V; κ Hya, B5 V; and ω Car, B8 IIIn) were taken nightly and can be used to estimate the true errors introduced by the reduction process. Differences in the flats used in the first stages of reduction, as well as the effects of the rectification process and the dispersion correction, could lead to apparent variations in the spectra. Figure 4ab is an illustration of the difference spectra for β Sco C and κ Hya.

The only visible difference is in the amount of noise present in each of the exposures. That is most likely a consequence of differences in signal-to-noise ratio (S/N) in the raw data, because varying sky conditions and exposure times translate into different S/N for each night. Except for the S/N differences, the spectra appear to be very uniform, so it is likely that any night-to-night processing artefacts will be comparatively small. The shift in profile of C II 4267 Å is slightly visible in the spectrogram of β Sco C, indicating that it may be an artefact of the reduction process, though we could not find any obvious errors.

3 (c) Program Stars

The previously unexamined program stars are illustrated in figures 5ab -12ab. Most of the spectra were taken in the 4100–4500 Å region, so that is the only region shown. None of the new candidates shows dramatic changes in the helium lines, such as those in a Cen, though we were hoping to find some. Several show small helium-line variations, indicating that further study is warranted. A few show definite hydrogen or other line variations. To avoid problems resulting from small artificial night-to-night changes tied to the rectification process in IRAF, we consider mainly periodic changes in line ratios. That minimizes the processing "noise." Some lines in some stars are marginally variable. When combined with other line information, the results are strengthened in some cases and rendered inconclusive in others.

Hbg 120 (HD 66765, figure 5ab) seems to have a definitely variable line at He I 4144 Å. The other He I lines at 4121, 4168, 4387 and 4471 Å appear to be marginally variable, all with the same phase, thus supporting the reality of the helium variations. The effect is too systematic to be spurious. GHS list note that the star is a two-line spectroscopic binary. Further investigation is warranted.

Hbg 828 (HD 117357, not illustrated) is faint and heavily reddened. The diffuse interstellar absorption band at 4430 Å is prominent. The star was observed on only two nights and the resulting spectra have relatively low S/N per pixel. Only a few strong lines of hydrogen and helium are discernable, so any apparent variations are probably not real. GHS note that this B0.5 IIIne star has variable emission and 4471 Å absorption.

Hbg 928 (HD 133518, figure 6ab) is a strong helium star that may show marginal helium-line variations. The May 26 spectrogram (JD 2448768.61) is much noisier than others because of poor sky conditions. Its raw S/N per pixel is only about 30–40, whereas the others are consistently above 100. The helium lines, though very strong, do not seem to show gross variations. A few of the lines, namely 4144 and 4387 Å, seem to vary slightly and should be investigated at higher resolution. The Fe II line, 4233 Å, pops up in emission, but only in one spectrogram (8782.59). It is not a cosmic ray and is well above the noise level, so its presence is an interesting puzzle. Bohlender *et al.* (1987) find no evidence for a magnetic field in the star. Pedersen & Thomsen (1977) find no evidence for variability in the He 4026A line. If the star is truly variable, it would be the first case of known spectrum variability in a non-magnetic, helium-peculiar star.

Hbg 945 (HD 135038, figure 7ab) is a weak-helium star, as noted in GHS. The hydrogen line at Hγ is strikingly variable. More complete coverage, both photometric and spectroscopic, would be fruitful. On the other hand, the helium lines are so weak that small variations would be difficult to detect. The S/N is relatively low, but it is clear that there are no gross variations in the helium lines, such as those in HD 125823. The 4471/4481 Å line ratio seems constant within the noise limits, though small variations are not ruled out. Si II 4128–30 Å seems constant.

Hbg 1138 (HD 147880, figure 8ab) is a tantalizing case. GHS note that it has weak silicon and magnesium lines as well as peculiar hydrogen-line profiles and is probably a weak-helium star. Unfortunately, the star was observed on only three nights. The helium lines, especially 4144 Å, may be variable, but more spectra are needed to confirm this.

Hbg 1173, Hbg 1551, and Hbg 1623 (HD 149257, HD 165207, and HD 168785; figures 9ab–11ab) are all helium-strong stars. All have very strong helium lines, with Mg II 4481 Å visible. Significant variations are visible in the hydrogen and helium lines, though nothing as striking as in a Cen is apparent. Hydrogen varies in phase with helium. Follow-up observations are recommended.

Hbg 1188 (HD 150136, not illustrated) is classified as an O5 III(f) star and was included in the sample because GHS noted that the helium lines were peculiar in appearance ("washed out"). The most prominent lines besides Hγ are He II 4200 Å and He I 4471 Å. The diffuse interstellar feature at 4430 Å is one of the strongest features in the spectrum. Only two spectra were obtained, but no gross variations are visible.

Hbg 1539 (HD 164769, not illustrated) has only two exposures, the second being of much lower signal-to-noise ratio than the first. The helium lines are unusually strong, but no gross variations of the helium or other strong lines are visible. GHS note that Ca II is present and broad (as in some shell stars).

Hbg 1624 (HD 168941, not illustrated) was observed only once. It is an O star with helium peculiarities. The peculiarities reported in GHS (very strong He II 4686 Å) are confirmed.

Hbg 1650 (HD 172854, figure 12) is a another good candidate for further investigation of helium variability, though the data here are not complete enough or of high enough quality to unambiguously establish helium-line variability. GHS list the star as having weak helium lines for the rest of the spectrum. The hydrogen lines, however, vary significantly. The equivalent width ratios of He I 4387 Å to Hγ and He I 4471 Å to Mg II 4481 Å show some evidence of variation, but are inconclusive. Curiously, C II 4267 Å is much weaker than in most of the other stars in the sample, whereas it should be at its peak strength.

4. Conclusions

We conclude that four of the stars show small helium variations, two show marginal helium variations, and two show strong hydrogen variations, but further study is needed to confirm the variations and to determine periods. None of the twelve new target stars in our survey undergo the gross variations in helium or metal lines observed in the classical strong-to-weak helium variable, a Cen. Unfortunately, our study was hampered by bad weather. From the eye estimates and equivalent width ratios, a reasonable estimate of the nominal confidence level for the well-observed sequences is about 10% for the strong lines. Indeed, we can see such changes in two of the three known helium variables, but none are visible in the standards, so the small variations observed in many of the survey stars are real. For the poorly observed stars, all we can say is that they do not appear to vary wildly at the times of the few observations.

For smaller scale variations, there are several cases where further investigation is warranted. The helium-peculiar stars are in general not very well understood, so higher resolution and higher S/N studies would produce interesting results in any case. With better data the application of Fourier transform or other mathematical techniques could reveal quantitatively the extent of small variations or variations in the weaker lines.

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