COPERNICUS OBSERVATIONS OF

BETELGEUSE AND ANTARES

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*Guest Investigator with the Princeton University telescope on the Copernicus satellite, which is sponsored and operated by the National Aeronautics and Space Administration.

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ABSTRACT

Copernicus observations of the M-supergiants, α Ori and α Sco, are presented. The MgII h and k resonance lines are strongly in emission in both stars. The k line is highly asymmetric in both stars but the h line is symmetric. Upper limits for several other resonance lines are given for α Ori.

The possibility is explored that the k line asymmetry is caused by overlying resonance lines of MnI and FeI formed in the cool circumstellar gas shells around these stars. Observations of the MnI 4030-4033 Å lines are used to show that circumstellar shell absorption is too weak to explain the asymmetry. However, the overlying lines of MnI and FeI do appear to be responsible because selected FeI lines in the visible spectrum appear weakened by fluorescent emission driven by the MgII emission line. It is suggested that the absorption occurs in a cool turbulent region between the base of the circumstellar shell and the top of the chromosphere.

Subject headings: Circumstellar shells - emission-line stars - luminous stars - stars, individual

I. INTRODUCTION

Stellar chromospheres have long been inferred for the M-supergiants from the presence of CaII H and K in emission. In any study of these chromospheres it is important to obtain as much observational data as possible in order to accurately determine the physical structure. Since most of the expected species have resonance lines in the ultraviolet, we have used the NASA-Princeton satellite Copernicus (Rogerson et al., 1973a) to search for these lines in two M-supergiants, Betelgeuse (α Ori, M2Iab, m_V=0.8) and Antares (α Sco, M1Ib, m_V=1.1). Both stars are small amplitude variables; in addition, Antares has a B-type companion (B4V, m_V=6.6), at 3 arc-sec separation, which appears to be both the center of a nebula (5 arc-sec diameter, Stone and Struve, 1954) and a radio source (Hjellming and Wade, 1971).

The MgII h and k lines have previously been observed in α Ori by Kondo et al. (1972) who found a striking asymmetry in the k (2795 Å) component while the h component (2802 Å) was symmetric. These observations were confirmed by Kondo, Morgan and Modisette (1975). Observations of K-stars (Moos et al., 1974) have not revealed a difference between the h and k lines. In addition to observing the MgII h and k lines in α Ori, we have observed these lines in α Sco and have searched in the ultraviolet spectrum of α Ori for other possible chromospheric indicators. The MgII lines were observed strongly in emission in both stars and these observations and their possible interpretation are the main subject of this paper. None of the other lines we searched for in α Ori were detected.

From our null results, we have set upper limits upon the fluxes in these various lines as discussed in § II. These calculations are given in Table 2. In § II, we discuss our observations of the MgII lines, our calculation of the error limits of our observations and give various parameters calculated from the line profiles. We discuss possible interpretations of the asymmetry in the k line in § III and § IV.

II. OBSERVATIONS

Our observations of α Ori and α Sco MgII h and k are presented in Figures 1 and 2. These figures represent the averages of 12 scans for α Ori and of 30 scans for α Sco obtained with the V2 system. The resolution is 0.4 Å. The B star companion to α Sco may be expected to contribute up to 1000 counts/integration period in the 2800 Å region to the count rate obtained with Copernicus if the narrow (0.3 arc-sec) spectrometer slit were to include both stars. No positive evidence for this was seen in individual scans. However, some scans show a steep increase in count rate across the scan.

The noise estimate, σ, given in the figures and used subsequently in this paper is based upon two separate calculations. First, the estimated error in the background level is calculated by measuring the rms deviation of a series of points which appear to contain no significant stellar signal. Second, the standard $\sqrt{N}$ error is calculated and the two combined to give our estimated σ. This is not strictly valid since the errors are not independent. In addition, there are unknown errors arising from the different satellite orientations during the scanning. We feel that our formal error calculated as described above gives a fairly accurate picture of our relative uncertainties, but wish to stress that is is purely a formal one.

We collect in Table 1 various parameters calculated from our observations of MgII. In particular, we verify the striking asymmetry in the k line as contrasted with the symmetric h line. Assuming that the absolute response of the satellite remained constant from orbit 8330 (α Ori observations) to orbit 10730 (α Sco observations) (Snow, 1974), the observed MgII emission in α Sco is 80% that in α Ori. To estimate absolute fluxes, we must know the angular diameters of these two stars. The angular diameter of α Ori has been found to be wavelength dependent (Bonneau and Labeyrie, 1973). We use the observed value of 0".069 for 4220 Å, although this can at best be only a rough indicator of the value for the chromosphere. For α Sco, we use 0".042 (Gezari, Labeyrie and Stachnik, 1972). The satellite calibration corresponding to an efficiency of 0.64% at 2800 Å was provided by Snow (1974). This absolute determination of the chromospheric fluxes does not include a correction for interstellar and circumstellar reddening.

We note that our measured values for the widths of the h and k lines do not follow a Wilson-Bappu relationship. The absolute visual magnitudes for the two stars are M_V (α Ori)=-6 (Keenan and Morgan, 1951) and M_V (α Sco)=-5.2 (Stone and Struve, 1954) while the line widths are slightly larger in α Sco. The two stars do follow the CaII Wilson-Bappu relationship. We attribute this to the difficulty in measuring these widths from noisy data and to the possibility that the B star companion to α Sco contributes sufficient signal to distort the line profiles rather than to a breakdown of the Wilson-Bappu relationship.

The upper limits which we have been able to place upon the other chromospheric lines, Table 2, serve to eliminate extensive and/or hot regions surrounding this M-supergiant.

III. INTERPRETATIONS OF THE k LINE ASYMMETRY

The outstanding feature of the MgII lines is the contrast between the λ2795 and λ2802 lines; the former is strongly asymmetric and the latter is symmetric. The h and k lines are expected to be formed in a chromosphere; a static chromosphere would give rise to symmetric self-reversed line profiles. An explanation for the asymmetric k line might be provided by an extended, expanding chromosphere according to calculations by Kunasz and Hummer (1974; also Kunasz, 1973). Such chromospheres give rise to self-reversed lines with the intensity of the red peak greater than that of the blue peak. However, the regions of formation of the two MgII lines must surely overlap sufficiently that an expanding chromosphere cannot be modelled such that expansion effects appear in the k line (oscillator strength twice that of the h line) and not in the h line. The symmetry of the h line is most simply interpreted in terms of a stationary chromosphere and we have sought an alternative explanation for the asymmetric k line. The k line asymmetry has been seen in each of the three separate observations. This repeatability would suggest that it cannot be attributed to peculiar line formation conditions in a bright active region which happened to dominate the chromosphere at the time of observation.

Modisette, Nichols and Kondo (1973), exploring a suggestion by Herbig, proposed that the asymmetry be attributed to absorption by an overlying FeI resonance line (2795.006 Å, a $^5D_4$ - z $^3G°_4$, multiplet UV3). By assuming an optically thin chromosphere, Gaussian line profiles and neglecting any other overlying lines, they were able to calculate the required strength in the FeI line to produce the observed asymmetry. Their overlying FeI line has a very large half-width of ~ 3 Å, greater than that of the MgII lines, and an equivalent width of 2500 mÅ. The location of the absorbing FeI layer was not discussed.

We propose a different approach. The M-supergiants are known to possess substantial circumstellar shells (Deutsch, 1956 and Weymann, 1962). We use the observed properties of these circumstellar shells to estimate the amount of absorption expected. This will be done without reference to the observed MgII lines.

Our search for coincident atomic and molecular lines (see also Gahm, 1974 and Greve, 1974) showed that a MnI resonance transition (a $^6S_{5/2}$-y $^6P°_{7/2}$ multiplet UV1) at 2794.817 Å would also contribute to the absorption in the k line. There are many other lines within the required wavelength interval but to obtain the large column density required to produce a strong absorption line in the cool circumstellar shell, we are concerned only with absorptions out of levels with very small energies ($\lesssim$ 0.1 eV). Both the FeI and the MnI transitions arise from their respective ground states. The only additional line in this region is a zirconium transition at 2795.14 Å but due to the low cosmic abundance of zirconium (Zr/Fe ~ 3 x 10^{-5}), the relatively high lower state energy (0.07 eV) and the small oscillator strength (Kurucz [1974] gives gf=4.8×10^{-2}) any effect of this line will be quite small. We center our attention upon the FeI 2795.006 Å and the MnI 2794.817 Å lines.

Another FeI line from multiplet UV falls at 2803.169 Å within the long wavelength peak of the h line. At an excitation temperature T ~ 1000°K the optical depth in this line is 9% that of the FeI 2795 line according to calculated oscillator strengths (Kurucz, 1974). If FeI absorption is important in the interpretation of the MgII lines, this line at 2803 Å will reduce any expansion asymmetry in the h line. This line would have a considerable influence on the profile according to the modelling by Modisette _et al_. but they overlooked this possibility.

The MnI absolute oscillator strength, gf=3.70, was adopted (Ostrovsky and Penkin, 1957; Bell _et al_. 1959). The MnI line is broadened by hyperfine structure (hfs) splitting. The a^6S ground state has a negligible splitting. We estimated the hfs splitting of the $y\ ^6P°_{7/2}$ state from Rottmann (1958). The 2795 Å line is composed of 6 hfs components with a total width of 0.017 Å or 1.8 km s^{-1}; the 3 strongest components representing 60 percent of the total line strength span only 0.9 km s^{-1}. Since our adopted Doppler velocity parameter for the shell is v_D = 4 km s^{-1}, we can neglect the hfs splitting. This MnI line is a strong resonance transition. With oscillator strengths from Blackwell and Collins (1972), we calculate that the probability of a reemission at 2795 Å following absorption is 0.987; the MnI photons must scatter many times before they can escape the shell in a longer wavelength transition for which the shell is optically thin.

The FeI line is a weak intercombination transition. Kurucz has calculated an oscillator strength (gf = .000410) from intermediate coupling line strengths and a radial integral obtained using Thomas-Fermi-Dirac wavefunctions. Comparison of these calculations with experimental results (see, for example, Blackwell et al., 1975) shows good agreement. However, the largest discrepancies are anticipated for the weak intercombination transitions; a factor of two uncertainty is probably an upper limit.

Our observations (see below) provide a direct measure of the column density of neutral Mn in the shell. We adopt the reasonable assumption that the degree of ionization for Mn and Fe is similar. We estimate that the optical depths at the line centers are τ(MnI) $\sim 220\ \tau$ (FeI). The large difference in the cosmic abundances, N(Fe)/N(Mn) ~ 73, is offset by the oscillator strength ratio. We assume a kinetic temperature of 1000°K and calculate the partition function of the neutral iron to be 16. Although the FeI transition is weak, it is an efficient route for ultraviolet photons to be converted to visible photons which can escape directly from the shell; the probability of a return emission at 2795 Å is only 0.40%.

Two properties of the observed circumstellar shell are particularly important. Weymann (1962) calculated that the minimum shell radius for α Ori was about 16 stellar radii, based on the assumption of plane-parallel geometry. Our reanalysis (Bernat and Lambert, 1975) confirms this value for α Ori, and we find a shell radius for α Sco of about 4 stellar radii. Hence, the shell must be treated assuming spherical not plane-parallel geometry and, for α Ori, any occultation effects by the star are minimal and the net equivalent width of a pure scattering line will be zero; i.e. if the photons absorbed in a strong resonance transition are not converted to others for which the shell is optically thin, we shall see no overlying absorption provided that the observations refer to the entire shell. For α Sco, occultation of the far side of the shell by the stellar surface will increase the net equivalent width. Secondly, Weymann derived a Doppler velocity of about 4 km/sec for the α Ori shell, a value we find also for the KI 7699 Å line. Absorption by the shell is limited to a few Doppler widths from line center or about 0.12 Å at 2800 Å.

III. THE COOL CIRCUMSTELLAR SHELL

Two direct methods of establishing the effects of the circumstellar shell suggest themselves. The most direct would be the observation at high resolution of the region around 2795 Å. Since the shell lines would be quite sharp, this requires an instrumental resolution of better than 0.1 Å, which is possible with Copernicus. We intend to undertake this observation as soon as possible.

A second possibility involves the observation of shell lines which arise from the same lower level as the ultraviolet lines. In particular, we have observed the MnI lines 4030.755 Å ($a\ ^6S_{5/2} - z\ ^6P^\circ_{6/2}$, multiplet 2) and 4033.074 Å ($a\ ^6S_{5/2} - z\ ^6P^\circ_{5/2}$, multiplet 2); which have oscillator strengths 0.099 and 0.069 that of the MnI 2795 Å line. Each of these line is also composed of six hfs components with a total splitting of .05 Å and .04 Å. The most intense components are separated by less than half this amount and we again neglect the hyperfine structure. Our observational data consists of 0.07 Å resolution scans obtained with the Tull (1972) coude' scanner for α Ori and 3 Å/mm plates for α Sco. To model the 4030 Å, 4033 Å and 2795 Å profiles, we have used a modification of Kunasz and Hummer's technique for solving the radiative transfer equation in an expanding, spherical atmosphere (Kunasz and Hummer, 1974; Kunasz, 1973). Our modification (Bernat, 1975) replaces the hollow core with an opaque, emitting core; i.e., the radiation emerging from the stellar core would be the chromospheric MgII k line in the case of the 2795 Å line and the photospheric MnI line in the case of the 4030 and 4033 Å lines.

The profiles of the underlying photospheric MnI lines were estimated; calculations based upon a model photosphere cannot be considered reliable for these strong lines. The profile estimation was facilitated by a lower resolution scan ($\Delta\lambda \sim 0.15$ Å) covering about 15 Å and centered on the MnI triplet (4030, 4033, 4034 Å). The weakest line at 4034 Å clearly shows the deepest "photospheric" core suggesting that shell reemission is filling in these cores with the greatest effect on the strongest 4030 Å line. In Figure 3, we show predicted shell profiles for α Ori. Since seeing conditions at the time of observation were poor, we assume that the observed profiles represent an integration over the shell and star. Details of the line profile fitting will be given elsewhere (Bernat, 1975). We note that the depth of the narrow displaced core is primarily a monitor of the optical depth and the height and extent of the redward reemission is a measure of the shell diameter. These parameters were adjusted to obtain the fit to the stronger 4030 Å line. Then, the 4033 Å line was predicted from the relative oscillator strengths without further parameter adjustment. This profile fitting for α Ori gives an optical depth $\tau(4030) \sim 1.2$ or a column density $N(\mathrm{MnI}) \sim 1.5 \times 10^{13}\ \mathrm{cm}^{-2}$. A similar analysis of the photographic profiles for α Sco suggests $\tau(4030) \sim 0.3$ or $N(\mathrm{MnI}) \sim 3.8 \times 10^{12}\ \mathrm{cm}^{-2}$. We calculate shell optical depths for the 2795 MnI line center: $\tau(2795) = 8.4$ (α Ori) and $= 2.1$ (α Sco). For the FeI 2795 Å line center, we estimate $\tau = .04$ (α Ori) and $= .01$ (α Sco).

Our interpretation of the MnI core profiles as a composite absorption-emission feature (a P Cygni profile) produced by the circumstellar shell differs substantially from an earlier interpretation by Adams (1956). He identified two absorption components: the violet displaced shell component and a red displaced broad component which originated in the stellar photosphere. Here, we suggest that this second component be given an alternative interpretation as a blend of shell emission concentrated near the photospheric velocity and the broad underlying photospheric line (see Figure 3). Our interpretation will explain the correlations noted by Adams. For example, the intensity of the emission component (or, equivalently, the strength of the red absorption component) will vary with the photospheric velocity. The intensity will be a minimum when the photosphere shell velocity difference is a minimum and the shell sees the deep core of photospheric line. As the velocity difference increases, the shell can scatter a greater intensity of light from the line wings and the emission intensity increases. A more detailed discussion of Adams' correlations will be presented elsewhere (Bernat, 1975).

With the shell column densities and the respective probabilities for reemission at 2795 Å, we have calculated the line profiles of the 2795 Å FeI and MnI lines. Figure 5 shows the MnI profiles when the observations refer to the entire shell. Our theoretical profile are quite similar to the shell profile derived from the KI 7699 Å resonance line by Goldberg et al. (1975). The net (absorption minus the redward reemission) equivalent width for the MnI line is small: W_λ = 32 and 13 mÅ for α Ori and α Sco respectively. Since the Copernicus spectrometer slit width corresponds to only 0.3 arc-sec (a small fraction of the predicted and observed shell diameter for α Ori, Bernat and Lambert, 1975), the observations cannot include all the reemission. Reemission would have been scattered along the slit. Our calculated maximum equivalent width refers to the absorption core without the reemission and is 84 and 40 mÅ for α Ori and α Sco respectively. The equivalent widths of the FeI line are less than 1 mÅ in both shells. These computed shell absorption lines are insufficient to explain the observed asymmetry in the MgII k line (see Figure 5). The discrepancy is especially marked for α Sco; the asymmetry is perhaps stronger than for α Ori but the circumstellar shell is much less evident in all the resonance lines (CaI 4216 Å, CaII H and K, MnI 4030 etc.).

The shell will also scatter photons in the MgII h and k lines. The resultant profiles will look similar to those given in Figure 4 for the MnI lines, although the optical depth in the MgII lines will be much larger and the conversion probability will be zero. Thus, part of the h_3 and k_3 minima will be due to photons scattered by the shell but with our resolution we are unable to separate the shell's effects from the "normal" minima. At the very large optical depths in the MgII lines, the effect of the shell would be similar for the h and k lines, i.e., we would not be able to produce the observed different profiles.

We have also investigated the effects of interstellar absorption on the MgII k line profile. Clearly, if the interstellar medium were to absorb the k-line wing producing the observed asymmetry, the h line should also be asymmetric. In addition, Hobbs' (1969) observations of NaI in stars near α Sco and α Ori show velocities relative to the star in the -18 to +9 km/sec range. In our observations, any interstellar MgII absorption would not be resolved from the "normal" h_3 and k_3 central reversals.

To ascribe the large asymmetry observed to interstellar MnI 2795 Å would require that interstellar absorption be detectable in the MnI 4030 Å line. There is no evidence for interstellar absorption in the MnI 4030 Å line in either α Ori and α Sco. We may also calculate the expected interstellar equivalent widths in the following manner. Boksenberg et al. (1972) derive a column density N(MgI) $\sim 3 \times 10^{12}$ cm^{-2} for several stars in Orion; Rogerson et al. (1973b) derive N(MgI) $\leq 7 \times 10^{10}$ for two stars in Scorpio. By allowing for the distance differences between the various stars and for the Mn to Mg abundance ratio of ~ 300 and assuming N(MnI)/N(MgI) ~ N(Mn)/N(Mg), we derive N(MnI) $\sim 10^{10}$ cm^{-2} and N(MnI) 10^{8} cm^{-2} (α Sco) or equivalent widths W_λ(α Ori) ~ 3 mÅ and W_λ(α Sco) ~ 0.03 mÅ. Thus, we conclude that interstellar absorption will have an entirely negligible effect on our observed MgII profiles. At much higher resolution, it may be possible to detect interstellar MgII absorption in the cores of the h and k lines.

IV. FeI FLUORESCING TRANSITIONS

If the MnI and FeI transitions are responsible for the k line asymmetry, we can expect to observe fluorescing MnI and FeI emission lines in the visual.

The MnI line has a small (1.3%) branching ratio with the 5341.065 Å (a $^6D_{9/2}$ - y $^6P°_{7/2}$, multiplet 4) line most likely (0.81%). The large number of scatterings required to convert a Mn photon enhance the probability that the photon will not be converted at all (for example, the ultraviolet photons might be extinguished on dust grains within the shell). In addition, the relevant visual Mn lines are blended making unambiguous determination of any emission difficult. The FeI line is an intercombination transition with a 59% probability of emission in the 4307.91 Å (a $^3F°_3$ - a $^3G_4$, multiplet 42) line. Fluorescence in FeI and MnI in long-period variables through wavelength coincidences with the MgII h and k lines was first discussed by Thackeray (1937).

Tracings of 3 members of multiplet 42 in α Ori from a 3 Å/mm plate are shown in figure 5. The 4272 and 4326 Å lines should be unaffected by the fluorescence in the 4307 Å line. The gf-values are in the ratio 0.74 (4326 Å): 0.83 (4307 Å): 1.0 (4272 Å) and, at photospheric temperatures, the small differences in excitation potential may be ignored. Clearly, the 4307 Å line is weaker than expected and we attribute this to filling in of the line by the emission arising from absorption in the 2795 Å intercombination transition. Another line at 4202 Å is similarly affected. This observation was first made by Spitzer (1939) who drew attention to the possibility of fluorescence. Our photographic spectra for α Sco show a similar but weaker effect. We assume that the α Ori and α Sco observations approximate averages over the star and the entire shell.

The flux absorbed by the FeI 2795.006 Å line may be estimated from the observed fluorescence at 4306 Å. The emission was estimated using the 4272 Å line as the undistorted photospheric line profile and converted to an absolute flux using spectrum scans (Faÿ and Honeycutt, 1972; Faÿ and Johnson, 1973). We estimate that flux of about 1600 ergs cm^{-2} s^{-1} at 2795 Å is needed to account for the fluorescence in α Ori.

The k line asymmetry in α Ori corresponds to a flux deficiency of 3000 ergs cm^{-2} s^{-1} at the stellar surface. An optically thick FeI 2795 Å line with a large Doppler width ($v_D \sim 10$ km s^{-1}) would account for about 50% of this deficiency or a flux of 1500 ergs cm^{-2} s^{-1}. This flux is in good agreement with the estimate based upon the observed fluorescence. A similar conclusion holds for α Sco. These calculations suggest that the overlying FeI and MnI lines are responsible for a major part of the observed k line asymmetry. As shown in § 3, the circumstellar shell is <u>not</u> responsible for the fluorescence and an alternative site must be found.

The FeI line at 2803 Å overlying the MgII h line appears not to produce fluorescence in the appropriate visible lines. Since the optical depth in this line is about 10% that of the 2795 Å line, the latter can have a substantial optical depth ($\tau \sim 5$) and provide an asymmetric k line. The non-appearance of fluorescence via the 2803 Å line does exclude very large optical depths ($\tau \sim 50$) in the 2795 Å line. There remains the possibility that the 2803 Å line may be marginally affecting the h line and that the intrinsic chromospheric MgII profiles are both asymmetric in the sense predicted by an expanding chromosphere.

V. CONCLUSIONS

The observed weakening by fluorescence of the FeI 4307 Å line is good evidence that the MnI and FeI resonance transitions overlying the MgII k line profile are responsible for the strong asymmetry of this line in α Ori and α Sco. However, our quantitative study shows that the absorption provided by the cool circumstellar shells is insufficient to provide the observed asymmetry. The discrepancy is especially marked for α Sco for which the circumstellar shell is very tenuous.

One possible location for an additional cool layer would be the top of the chromosphere. The chromospheric temperature must peak and fall to the low kinetic temperature of the shell. The shell is distinguishable because it is expanding relative to the photosphere at about 10 km s^{-1}; i.e. the narrow shell absorption cores are displaced to the violet relative to the broader photospheric lines. If the top of the chromosphere were turbulent and approximately stationary relative to the photosphere, its effect on the absorption cores could go unnoticed. Of course, it would symmetrically broaden and deepen the cores of the photospheric lines but their profiles cannot be predicted with sufficient precision to detect this additional absorption. Boesgaard and Magnan (1975) discuss the ultraviolet FeII emission lines and propose that they are produced by infalling gas about 1.5 stellar radii above the surface. This chromospheric gas is presumably also responsible for the MgII emission whose formation we have not discussed. These authors suggest that the chromosphere may contain large scale inhomogenieties of hot and cool gas. The FeI fluorescence must occur in the cool gas. If the excitation temperature is moderately high, excited lines may also affect the MgII line profiles. Further observational evidence for this chromospheric structure is needed.

In this study, we have not given serious consideration to alternative explanations of the k line asymmetry (e.g. an expanding chromosphere). A test of our suggestion that the asymmetry is the result of overlying MnI and FeI resonance transitions will be possible when high resolution scans of the k line are obtained; the MnI and FeI lines should show up as deep absorption features within the MgII profile. High resolution scans should also be made of the h line in order to assess the contribution from the 2803 Å FeI line. These scans will also enable a better assessment to be made of the symmetry of the chromospheric MgII profiles.

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REFERENCES

Adams, W. S. 1956, Ap. J., 123, 189.

Bell, G. D., Davis, M. H., King, R. B., and Routly, P. M. 1959, Ap. J., 129, 437.

Bernat, A. P. 1975, in preparation.

Bernat, A. P., and Lambert, D. L. 1975, in preparation.

Blackwell, D. E., and Collins, B. S. 1972, M.N.R.A.S., 157, 255.

Blackwell, D. E., Ibbetson, P. A., and Petford, A. D. 1975, M.N.R.A.S., 171, 195.

Boesgaard, A. M., and Magnan, C. 1975, Ap. J., in press.

Boksenberg, A., Kirkham, B., Towlson, W. A., Venis, T. E., Bates, B., Courts, G. R., and Carson, P. P. D. 1972, Nature Phys. Sci., 240, 127.

Bonneau, O., and Labeyrie, A. 1973, Ap. J., 181, 61.

Deutsch, A. J. 1956, Ap. J., 123, 210.

Fay, T. D., and Honeycutt, K. 1972, A. J., 77, 29.

Fay, T. D., and Johnson, H. R. 197[illegible], Ap. J., 181, 851.

Gehm, G. F. 1974, Astron. Astrophys. Suppl., 18, 259.

Gezari, D. Y., Labeyrie, A., and Stachnik, R. V. 1972, Ap. J., 178, L71.

Goldberg, L., Ramsey, L., Testerman, L., and Carbon, D. 1975, Ap. J., in press.

Greve, A. 1974, Astron. Astrophys., 36, 135.

Hobbs, L. M. 1969, Ap. J., 158, 461.

Keenan, P. C. and Morgan, W. W. 1951, Astrophysics, J. A. Hynek, ed., New York: McGraw-Hill Book Co.

Kondo, Y., Giuli, R. T., Modisette, J. L., and Rydgren, A. E. 1972, Ap. J., 176, 153.

Kondo, Y., Morgan, T. H., and Modisette, J. L. 1975, Ap. J. (Letters), 196, L125.

Kunasz, P. G. 1973, unpublished Ph.D. thesis, University of Colorado.

Kunasz, P. B., and Hummer, D. G. 1974, M.N.R.A.S., 166, 57.

Kurucz, R. L. 1974, SAO Special Reports #359 and 360.

Modisette, J. L., Nichols, R. E., and Kondo, Y. 1973, Ap. J., 186, 219.

Moos, H. W., Linsky, J. L., Henry, R. C., and McClintock, W. 1974, Ap. J. (Letters), 188, L93.

Ostrovsky, Y. I., and Penkin, N. P. 1957, Optics and Spectrosc., 3, 193.

Rogerson, J. B., Spitzer, L., Drake, J. F., Dressler, K., Jenkins, E.B., Morton, D. C., and York, D. G. 1973a, Ap. J. (Letters), 181, L97.

Rogerson, J. B., York, D. G., Drake, J. F., Jenkins, E. B., Morton, D. C. and Spitzer, L., 1973b, Ap. J. (Letters), 181, L110.

Rottman, H. R. 1958, Z. Phys., 153, 158.

Snow, T. P. 1974, Private communication.

Spitzer, L. 1939, Ap. J., 90, 494.

Stone, C. N., and Struve, O. 1954, P.A.S.P., 66, 257.

Thackeray, A. D. 1937, Ap. J., 86, 499.

Tull, R. G. 1972, Proceedings ESO/CERN Conference on Auxiliary Instrumentation for Large Telescopes, Geneva, p. 259.

Weymann, R. 1962, Ap. J., 136, 844.

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TABLE 1.

The MgII h and k lines in α Ori and α Sco

	α Ori			α Sco		
	h	k_v	k_r	h	k_v	k_r
Line Counts/14 sec	11420	3975	6970	9230	2700	6350
	±500	±350	±350	±300	±210	±270
Observed Flux (ph. cm^{-2} s^{-1})	43.7	15.2	26.7	35.4	10.3	24.3
Stellar surface flux (10^3 erg cm^{-2} s^{-1})	11.1	3.85	6.8	24.2	7.1	16.7
Full width at base of line (Å)	3.6	3.8		4.6	4.0	

TABLE 2

Upper Limits to Line Flux from α Ori

Line	Counts and σ per 14 secs.	Copernicus efficiency (%)	3σ Upper Limit to obs. line flux (ph cm^{-2} s^{-1})	3σ Upper Limit to stellar surface line flux (10^3 erg cm^{-2} s^{-1}
CII 1037Å	-3.9 ± 1.4	0.14	0.07	0.05
CIII 977Å	-2.5 ± 1.2	<0.025	0.35	0.25
NII 1085Å	-2.5 ± 1.1	0.23	0.04	0.03
OI 1302Å	21.3 ± 0.8	0.025	0.23	0.13
FeI 2380Å	3032 ± 118	0.63	1.4	0.43
FeI 2395Å	3133 ± 111	0.63	1.3	0.38
FeII 1145Å	-2.2 ± 1.7	0.19	0.07	0.05
CO 1085Å	-2.5 ± 1.1	0.23	0.04	0.03

NOTES TO TABLE 2

1. The count rate refers to the mean background rate outside the expected position of the line. The predicted background count rate has been subtracted for lines below 1200 Å.
2. The Copernicus efficiency figures are from Snow (1974).
3. The CO observation includes the part of the (0,0) band of the Hopfield-Birge ($C^1\Sigma^+ - X^1\Sigma^+$) system.

FIGURE CAPTIONS

Fig. 1 - Copernicus scan of the MgII doublet in Betelgeuse. The background level (dashed line) is attributable to noise events and does not represent the stellar continuum. Positions of the MnI and FeI resonance transitions discussed in the text are shown above the spectrum.

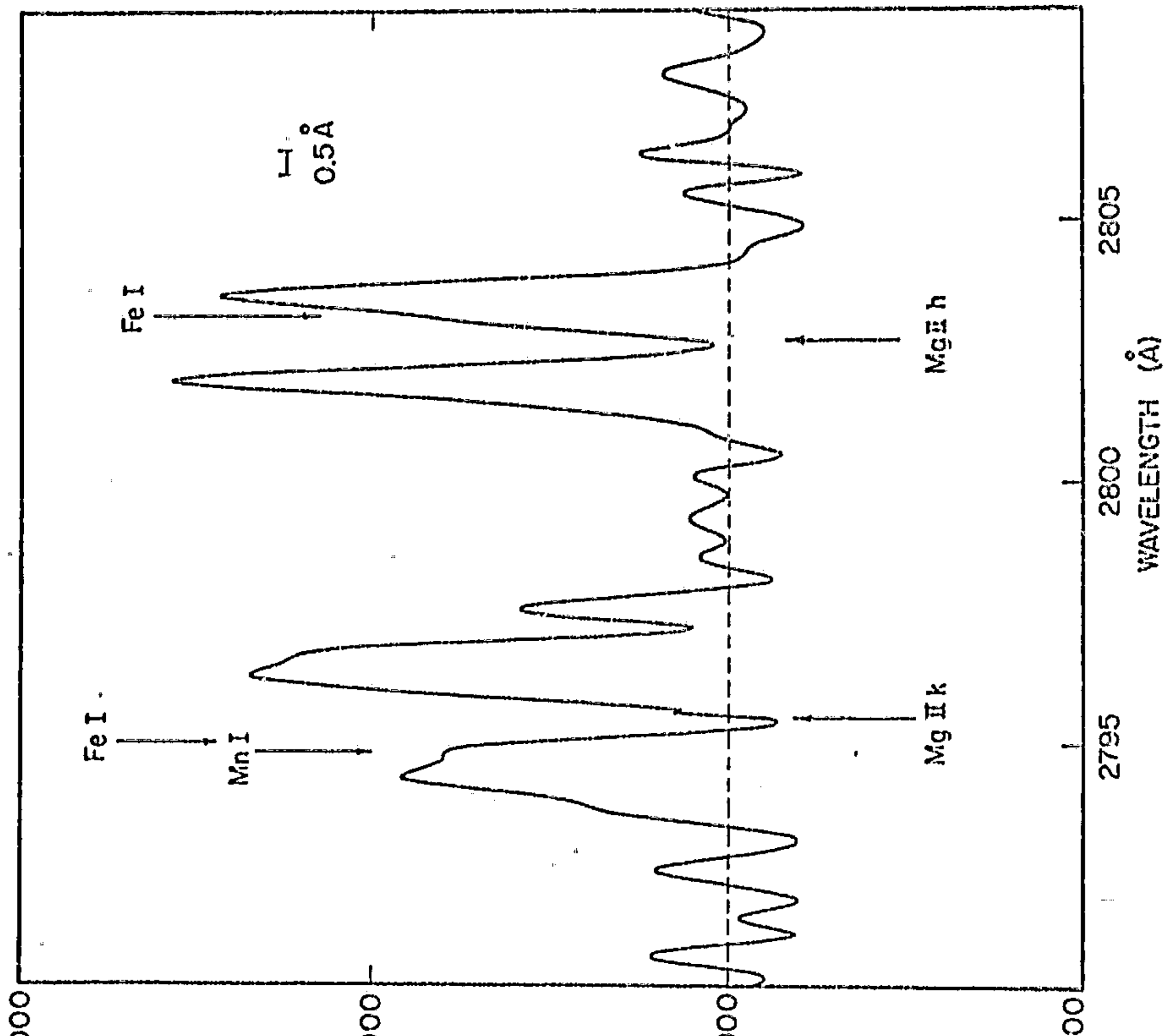
Fig. 2 - Copernicus scan of the MgII doublet in Antares.

Fig. 3 - The cores of MnI resonance lines in α Ori at (a) 4030.8Å and (b) 4033.1Å. The interpolated core of the photospheric line is shown by the dashed line. The predicted shell absorption core with redward emission is shown by the solid line. The intensity scales for the two lines are not identical.

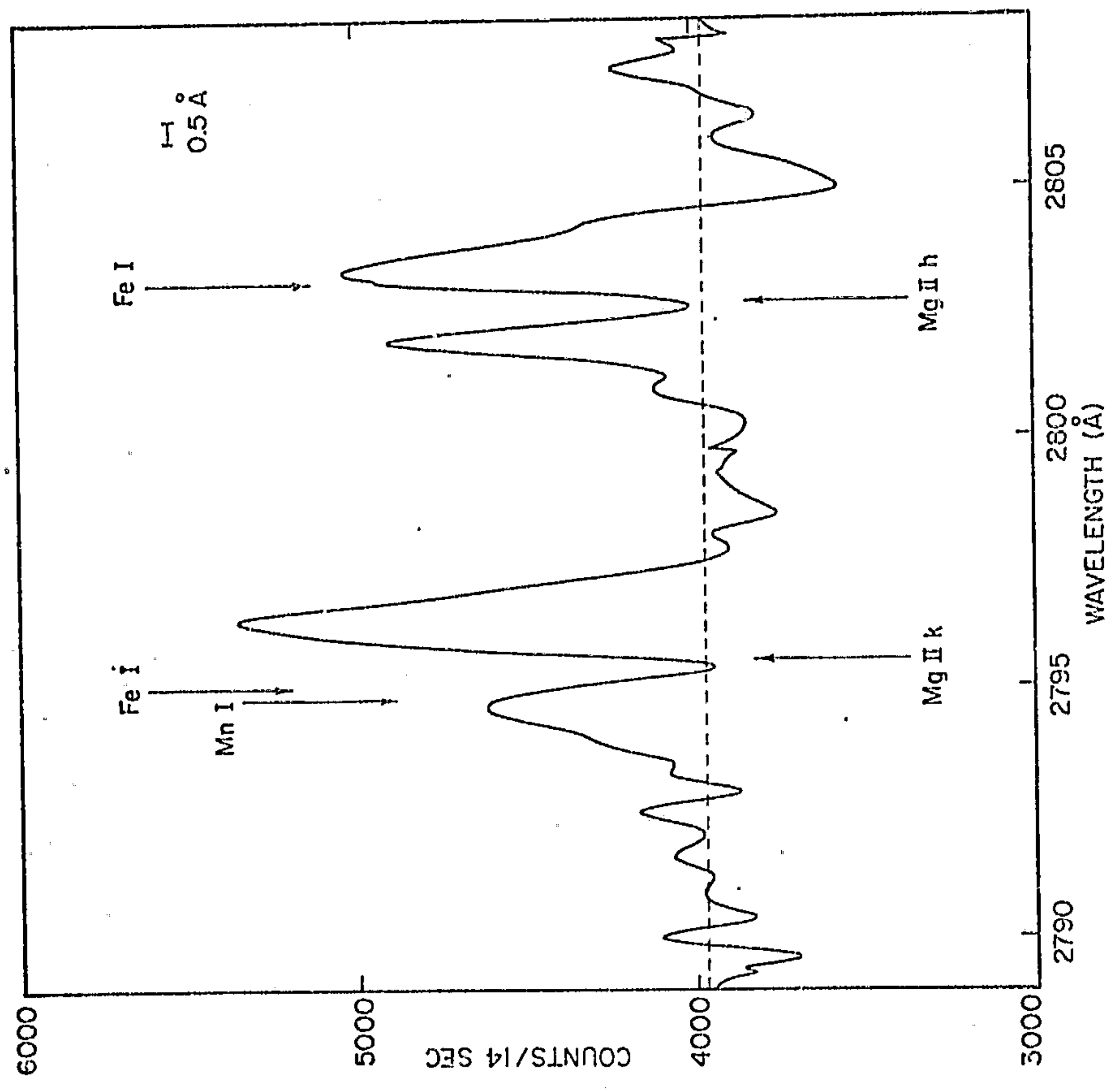
Fig. 4 - Predicted profiles for the MnI 2795Å line formed in the circumstellar shells of α Ori and α Sco.

Fig. 5 - MgII K line profiles for α Ori and α Sco showing the <u>maximum</u> effect of the overlying circumstellar MnI 2795Å line. The dashed line shows the observed profile (solid line) after correction for the MnI line.

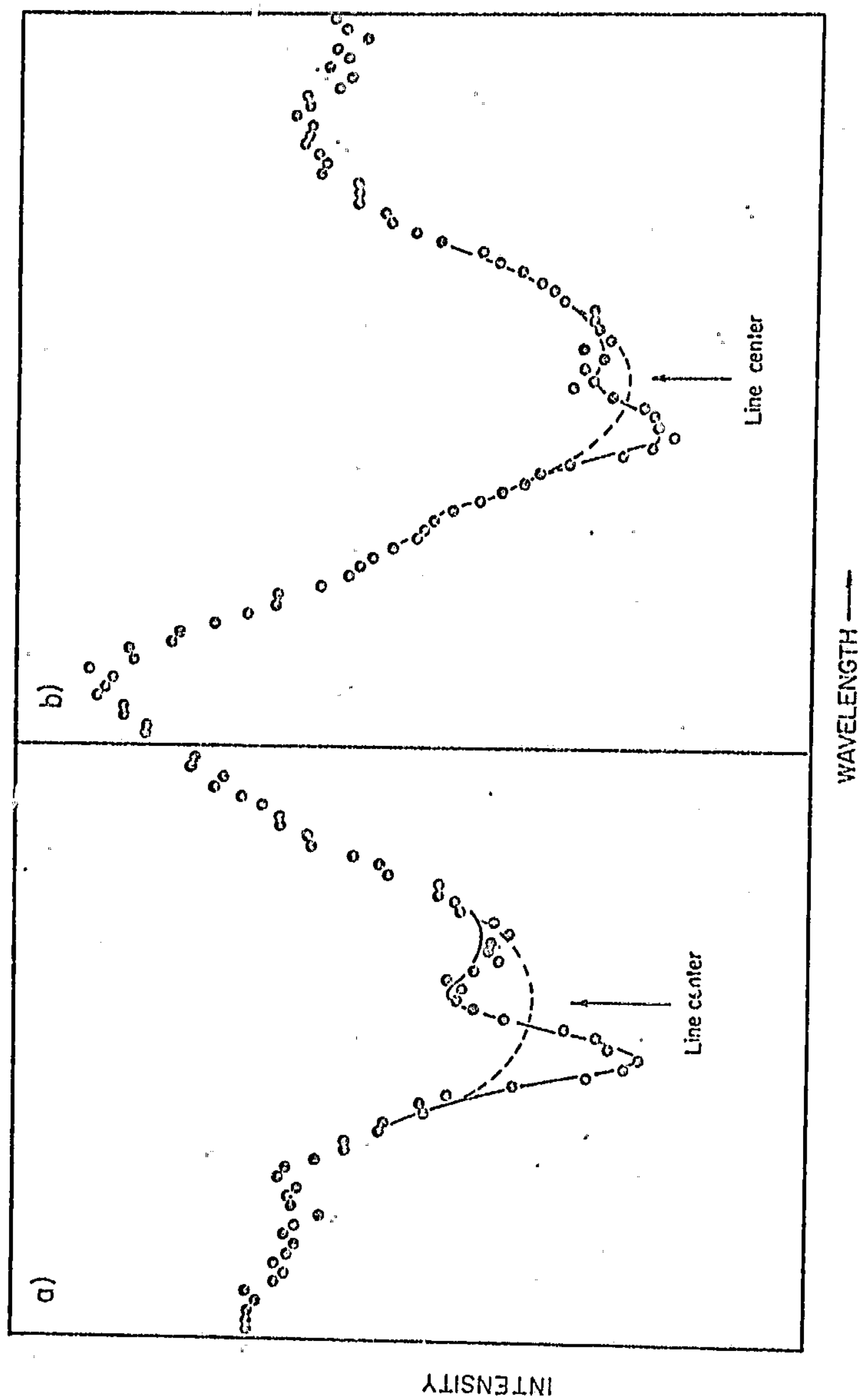
Fig. 6 - The α Ori photospheric spectrum near the FeI lines at 4272, 4307, and 5326Å. The local continuum for these three lines is at the top of the figure. The CoI line in the left hand panel shows a narrow displaced core arising in the circumstellar shell.

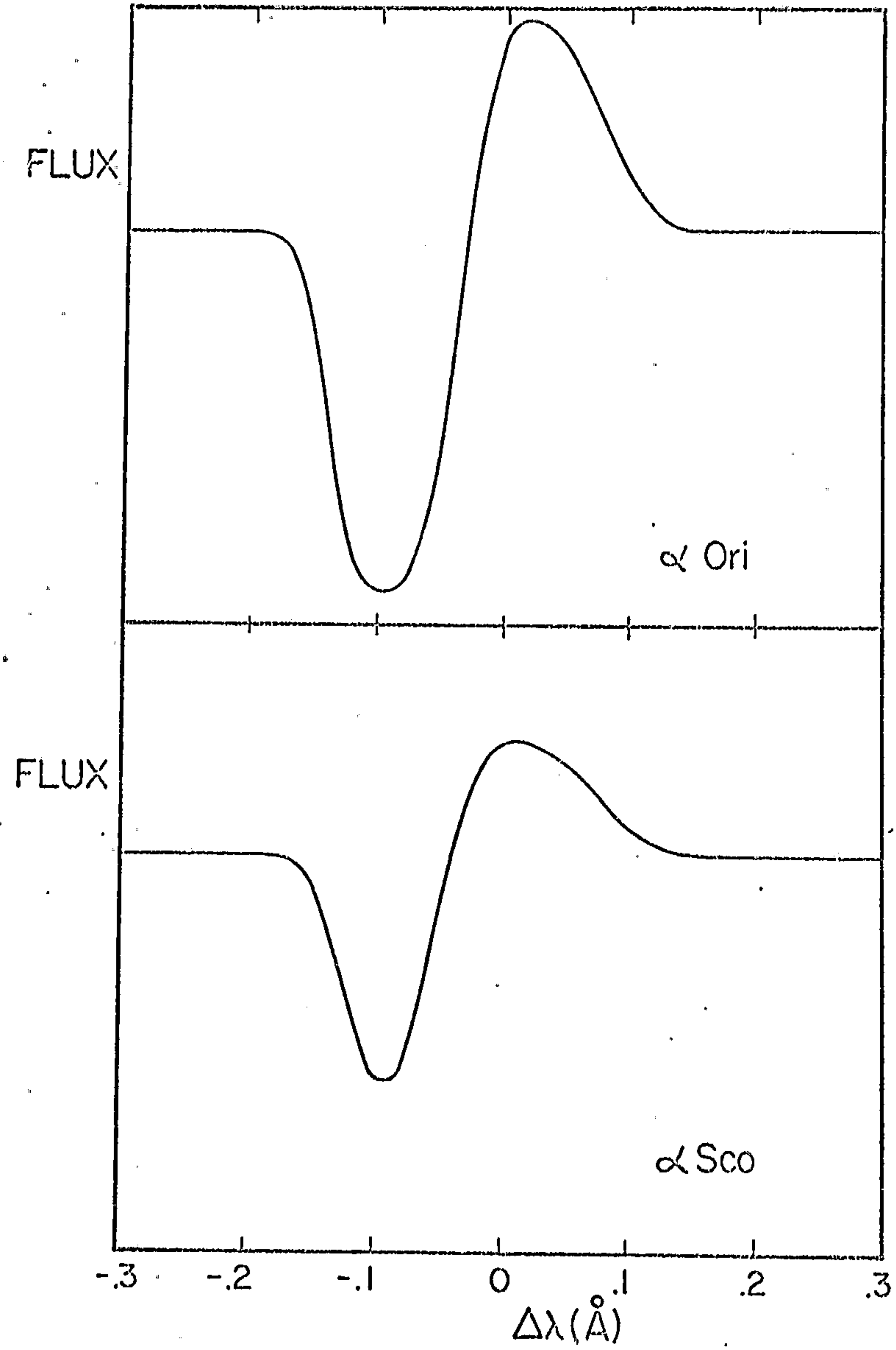


COUNTS/14 SEC
6000
5000
4000
3500
WAVELENGTH (Å)
2795
2800
2805
Fe I
Mn I
Mg II k
Fe I
Mg II h
0.5 Å

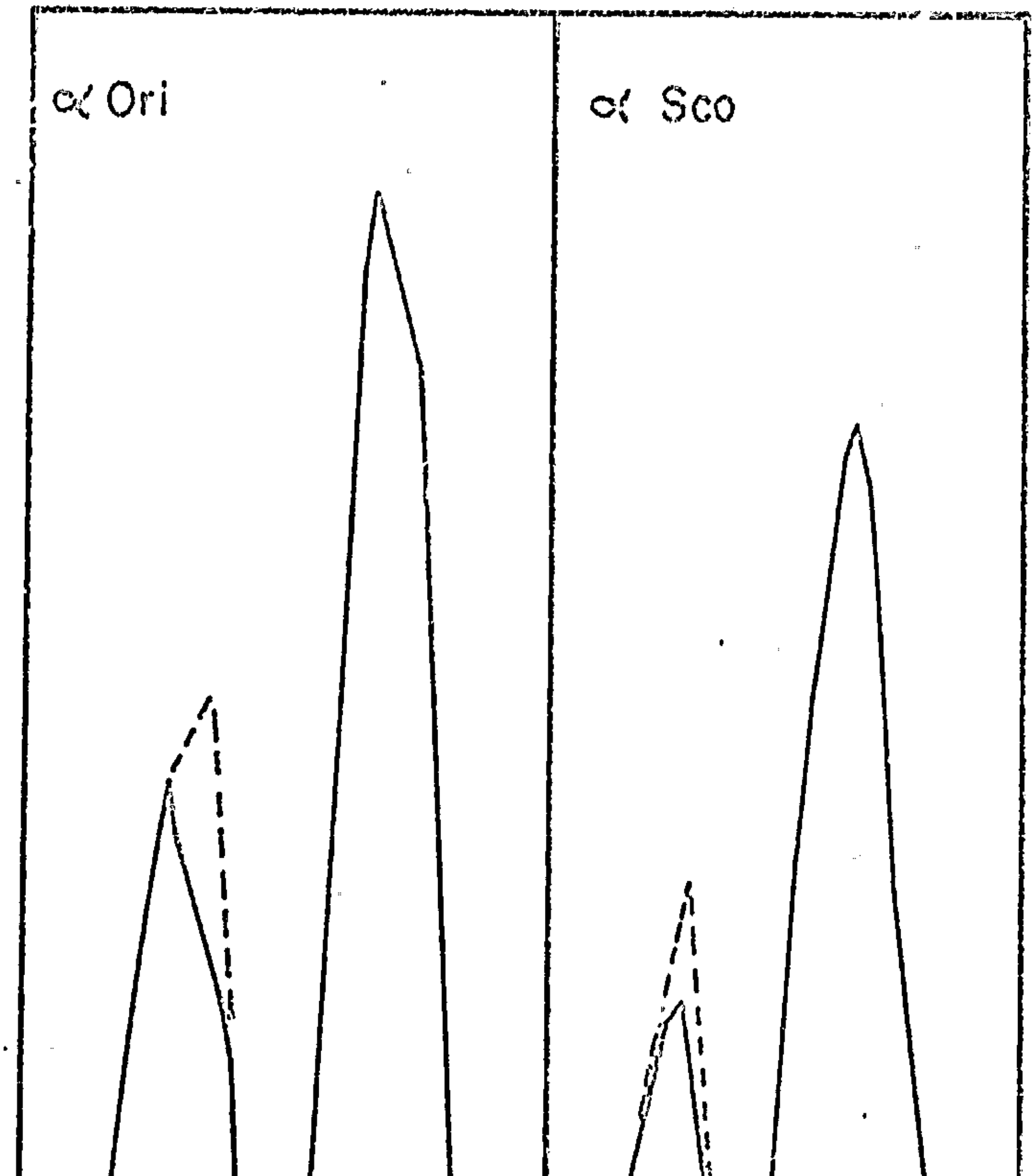


COUNTS/14 SEC
6000
5000
4000
3000
WAVELENGTH (Å)
2790
2795
2800
2805
0.5 Å
Fe I
Mn I
Fe I
Mg II k
Mg II h

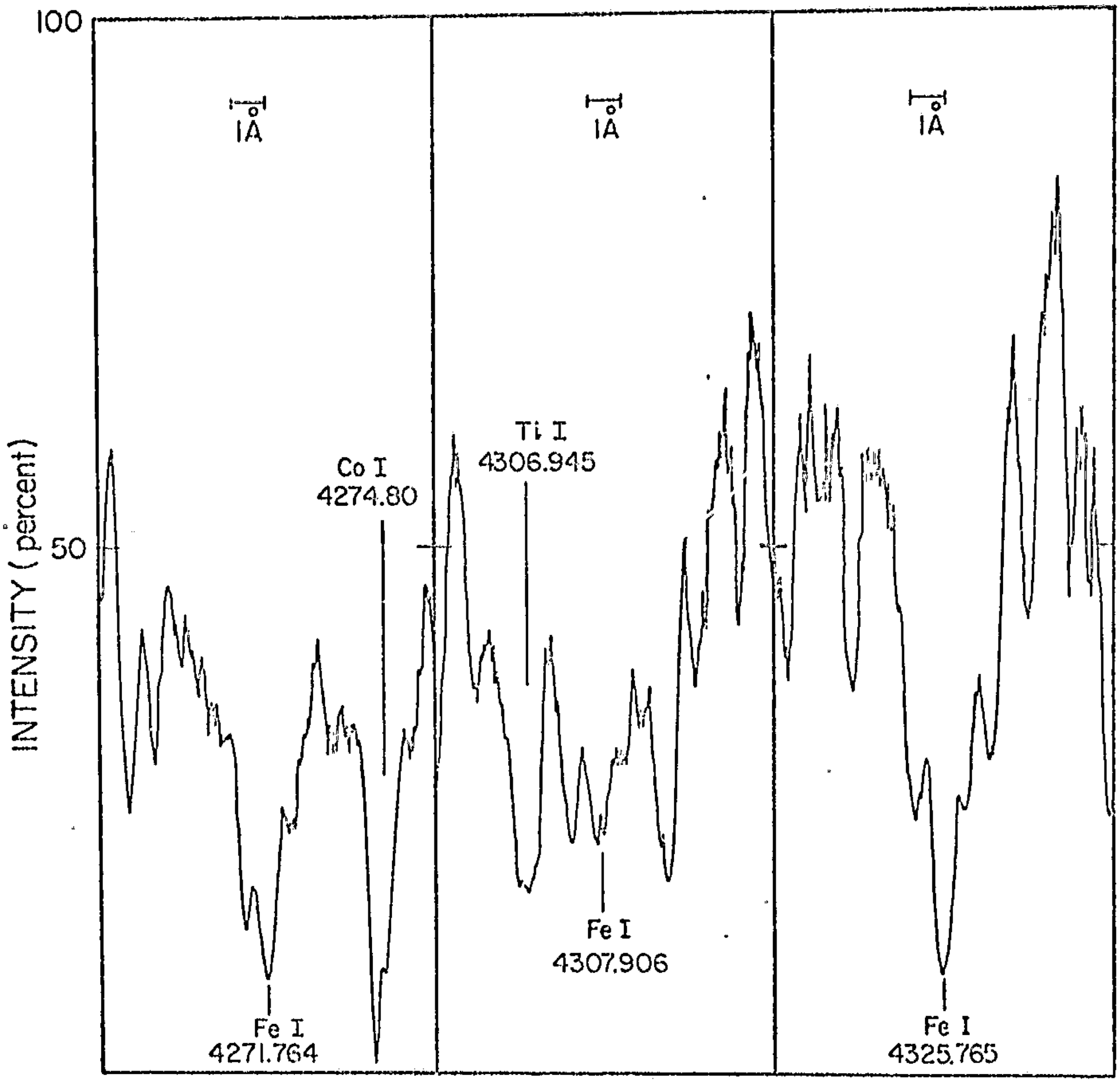

a)
b)
Line center
Line center
WAVELENGTH
INTENSITY



FLUX
α Ori
FLUX
α Sco
-.3
-.2
-.1
0
.1
.2
.3
Δλ(Å)



α Ori
α Sco



100
50
INTENSITY (percent)
1Å
1Å
1Å
Co I
4274.80
Ti I
4306.945
Fe I
4271.764
Fe I
4307.906
Fe I
4325.765