# THE UV RESONANCE LINES OF THREE HOT Ap STARS HD 133029, HD 175362 and HD 219749

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SUMMARY:

High resolution spectra of the Ap stars HD 133929, HD 175329 and HD 219749 have been obtained during two 16 hour shifts with the IUE satellite at Goddard Space Flight Center. Stellar wind, extended atmosphere in rigid corotation with the stellar surface and the influence of the strong magnetic field on the upper part of the atmosphere would explain the shape and the strength of the resonance lines. The resonance lines of HD 175362 in particular show very peculiar behavior. The necessary driving forces for the expanding envelope are not compatible with the diffusion theory of the Ap atmospheres.

## INTRODUCTION AND OBSERVATIONS:

HD 175362 belongs to the group of helium-weak stars building an extension of the Ap stars toward higher temperatures. The oblique-rotator model for the star has been published recently by Hensler, 1979. References to other investigations concerning HD 175362 can be found in his paper. Bonsack (1977) made a detailed study of HD 133029 yielding the following results: vsin i = 21 km/s, period of rotation of $2^d89$, $T_{eff}$ = 11375 K, B9p (log g = 4.0). Temperature estimates have been carried out by Adelman (preprint 1979). HD 219749 has probably a higher temperature but the same spectral type. The rotation period is $2^d60$.

Stimulated by the discovery of mass loss in the B9p star Alpha And (Rakos et al. 1979), the attempt was made to obtain high resolution observations in UV for other hot Ap stars. Very good high resolution short wavelength spectra of each star have been used for this investigation. IUE data reduction was carried out with the Tololo-Vienna interactive image processing system. According to the low value of v.sin i the spectral lines are in general narrow, but nevertheless there are very few lines without strong blends.

Highly ionized atoms Si IV, C IV, N V and N IV (Figure 1) are present showing strong absorption with extended blue wings and emission in the line cores. The emission features have velocities of expansion as high as 150 km/s. Much higher expansion velocity is connected with the broad absorption wings of this lines.

The Si IV doublet 1393.755 and 1402.769 is very strong in HD 175362. The first line shows strong reversal component in the core. From the blue edge of this emission the expansion velocity of 100 km/s and from the envelope absorption component 560 km/s can be derived. The second line seems to have even stronger blue-shifted (150 - 170 km/s) emission. Also a general expansion velocity of 500 km/s can be measured from the blue absorption line wing.

This doublet is very faint and blended by other lines in HD 133029. The C IV doublet 1548.195 and 1550.768 shows very similar behavior. The lines are less pronounced than the Si IV resonance doublet, 4 lines due to Fe III mask possible absorptions due to a wind or the emission components. At least the first line of C IV suggests an expansion velocity in the range of 600 km/s. The star HD 133029 and especially HD 219749 have visible C IV resonance doublets with certain blue-shifted wings.

The N V resonance doublet 1238.810 and 1242.800 in the spectrum of HD 175362 is very strong and the lines are broad. The first line has an undisplaced emission component and the blue-shifted absorption core at -170 km/s. The line wings are very broad allowing expansion velocities of more than 700 km/s. The second line of the doublet is unfortunately contaminated with a reseau mark. A strong emission is shifted bluewards slightly and broad line wings are present.

The spectrum of HD 133029 is underexposed at 1230Å. HD 219749 shows defintely very broad absorption and a terminal velocity of 500 km/s A probable emission can be allocated within the absosrption wing with an expansion velocity of -360 km/s.

Finally, in the spectrum of HD 175362 the N IV intercombination line from the ground state 1486.496 may be present as a very wide absorption feature completely on the blue side of the unshifted line position. The maximum of the expansion velocity derived from this feature approaches 1200 km/s. The same line is even sronger but less shallow in the other two stars. The low resolution spectra have pronounced absorption features in the same place. The presence of the emission features is uncertain.

The discussed lines demonstrate a hot expanding shell, stellar wind, and mass loss, an unexpected new characteristic of magnetic stars.

The mass loss is also confirmed by the other resonance lines of Si III and Si II. The Si III 1206.510 line is strong and broad in HD 175362 with an extended blue wind and the maximum expansion velocity of 600 km/s. The Si II (3) 1309.274 line is not a resonance line, but it originates from the fine structure level of the ground term. Such lines tend to behave like resonance transitions in the lower density part of stellar atmosphere, where neither the photon flux nor the particle density is high enough to populate the excited levels. The line is strong broad and symmetrical in the spectrum of HD 175362. The Doppler velocity of ± 340 km/s can be derived from the profile. The resonance line of the same multiplet 1304.369 is unfortunately on the edge of the detector field and therefore of very low quality. The 1309.274 line is also strong and broad in HD 219749 and HD 133029. In the spectrum of HD 175362 the second Si II resonance line at 1526.719 shows a narrow interstellar feature in the core, which has very broad, shallow, and symmetric wings. The photospheric Si II line of the same multiplet (UV 2) 1533.445 is visible but fainter by a factor of two. According to their gf values the intensities should be reversed. The same situation also holds for the resonance line Si II 1260.418 and the fine structure level line 1264.737.

HD 133029 and HD 219749 have very strong 1526.719 and 1533.445 lines. The first line has strong blue wings, showing a terminal velocity in the range of -500 km/s.

Also the resonance lines of Si II 1190.418 and 1193.284 in the spectrum of HD 175362 are remarkable. The first line seems to show core reversal and emission in the blue and red wings with a very moderate velocity of ±120 km/s. The second line is stronger and probably symmetric, it is unfortunately on the edge of the detector field.

The doublet Ti III 1295.897 and 1298.706 in the spectrum of HD 175362 contains broad, rather symmetric lines with emission in the cores of both lines. Likewise, S II and C II resonance lines confirm the expansion velocity in the order of 600 km/s in HD 175362. S II 1250.500 is very strong line, somewhat disturbed by the reseau mark on the detector. It is also present in HD 219749 with a similar velocity distribution. The doublet C II 1334.515 and 1335.703 is one of the strongest absorption features (except Lyman Alpha) in the spectrum of HD 175362. The asymmetry in the blue wing is strongly indicated.

C II lines are also visible in the other two stars. The first line of the doublet in HD 219749 has a blue shift of -70 km/s and a wide shallow blue wing with the terminal velocity of -400 km/s. HD 133029 has also an extended blue wing of the unshifted 1334.515 line with the same velocity distribution.

The resonance lines of neutral atoms are very narrow, as opposed to the broad features produced by ions. A very good example in HD 175362 is N I at 1199.55. The line is very similar to two other lines; N I 1200.218 and 1200.707. The same is true for O I 1355.605 and Cl I 1379.528 in all three stars.

## DISCUSSION OF THE RESULTS:

Stellar wind and mass loss in the atmosphere of a peculiar magnetic star is an unexpected phenomenon. It poses a serious problem for the explanation of abundance anomalies by diffusion. The whole stellar atmosphere would not be quiet enough for diffusion processes to operate, even if the expanding envelope is restricted to the outermost regions of the stellar atmosphere. The second question concerns the driving forces for the expanding envelope. Also the reason for the measured abundance anomalies located at the opposite magnetic poles should be explained.

First, discussion should be pointed to the question of the stellar luminosity class. HD 175362 is classifed as B8p IV according to its visual spectrum. According to the Snow-Jenkins Catalogue (1977), Si III 1206.510 is not visible in B8 III stars. It is strong in the spectrum type earlier than B5 III or B4 V, but also in B8 Ia. This line is strong in HD 175362 and at least suggests an unusual character of the upper part of the atmosphere. Supergiant structure is also supported by the energy distribution in the low dispersion spectrum. The Ultraviolet Bright-Star Spectrophotometric Catalogue (ESA SR 27) has been used for comparison. HD 175362 has a similar spectrum as the stars HD 34085 B8 Ia, HD 202850 B9Iab, and HD 212593 B9 I. Also the presence of C II multiplet no. 11 at 1323.9 of photospheric origin suggests the supergiant structure. These lines are missing in the spectra of the main sequence stars of type B8 V, but they are quite strong for spectrum type B8 Ia. The same is true for the multiplet no. 4 of C III around 1176Å - as a comparison see Beta Orionis A B8 Ia (Snow-Jenkins, 1977). Two other stars, HD 133029 and HD 219749 are "standard" Ap stars without any strong indication for giant structure, except for stellar wind.

Besides the recent detection of a magnetic field in Canopus (F0 Ib), Rakos et al. (1976), the present results confirm that strong magnetic fields in stars are widely independent of the stellar type and, therefore fossil in origin.

It is reasonable to suppose a rigid corotation of closed magnetic lines of force within a distance of a few stellar diameters from the stellar surface. At larger distances the lines remain open, as do the magnetic lines of the solar magnetic sector structure in the neighborhood of our planet (see figure 2). The ionized atoms will be forced and accelerated along these lines, spinning with the frequency $\omega$ and semidiameter according the magnetic field $B$, charge q, and the mass m of the ion.

$$r = \frac{m\,c\,v_t}{q\,B} \qquad w = \frac{q\,B}{m\,c}$$

The resulting speed $v_t$ depends on the distance from the stellar surface and the efficiency of the rigid rotation and the corresponding centrifugal forces. For $R_\star = 6\ R$ , and the period of rotation of $3^d67$, the equatorial rotational velocity will be 83 km/s. In a distance of only 7 $R_\star$ the velocity of 600 km/s could be achieved.

In general, the $v_t$ is given by the following equation

$$v_t = \frac{2 \pi R \;\; R_*}{P \; 86400 \; R}$$

(P is the rotational period in days, usually known for Ap stars.) The escape velocity $v_e$ is given by

$$v_e = 617.7 \; (M_*/M \quad)^{1/2} \; / \; (R_*/R \quad)^{1/2} \;\; \text{km/s}$$

For the condition $v_t = v_e$ we can get the "escape radius" $R_e$

$$R_e/R \quad = (12.2 \; P)^{2/3} \;\; (M_*/M \quad)^{1/3}.$$

For HD 175362 and the assumption $M_* = 3$ M we get the following result:

$$R_e = 18 \; R \quad \text{and} \; v_e = 252 \; \text{km/s}.$$

For a larger stellar diameter, according to the proposed spectral type, this velocity can be produced within the extended stellar atmosphere. Ions with high spinning speeds in the line of sight over the stellar surface, accelerated along the magnetic line of force by rigid corotation of the atmosphere, would explain broad symmetric absorptions in the wings of the resonance lines and the absence of such broad features for neutral atoms.

Finally, instead of diffusion, some kind of magnetohydrodynamic separation process should be investigated. In general, the magnetic field and its direction, systematic motion of the gas in the deeper region of the stellar interior, the atomic mass and the charge set the path for the motion of each ion - similar to the mass spectrograph principle. As soon as the specific ions are guided to the surface of the star, the abundance anomaly is formed. Slight changes in the stellar structure may result in the large abundance anomalies. From this point of view the magnetic stars are a permanent challenge for the theorist.

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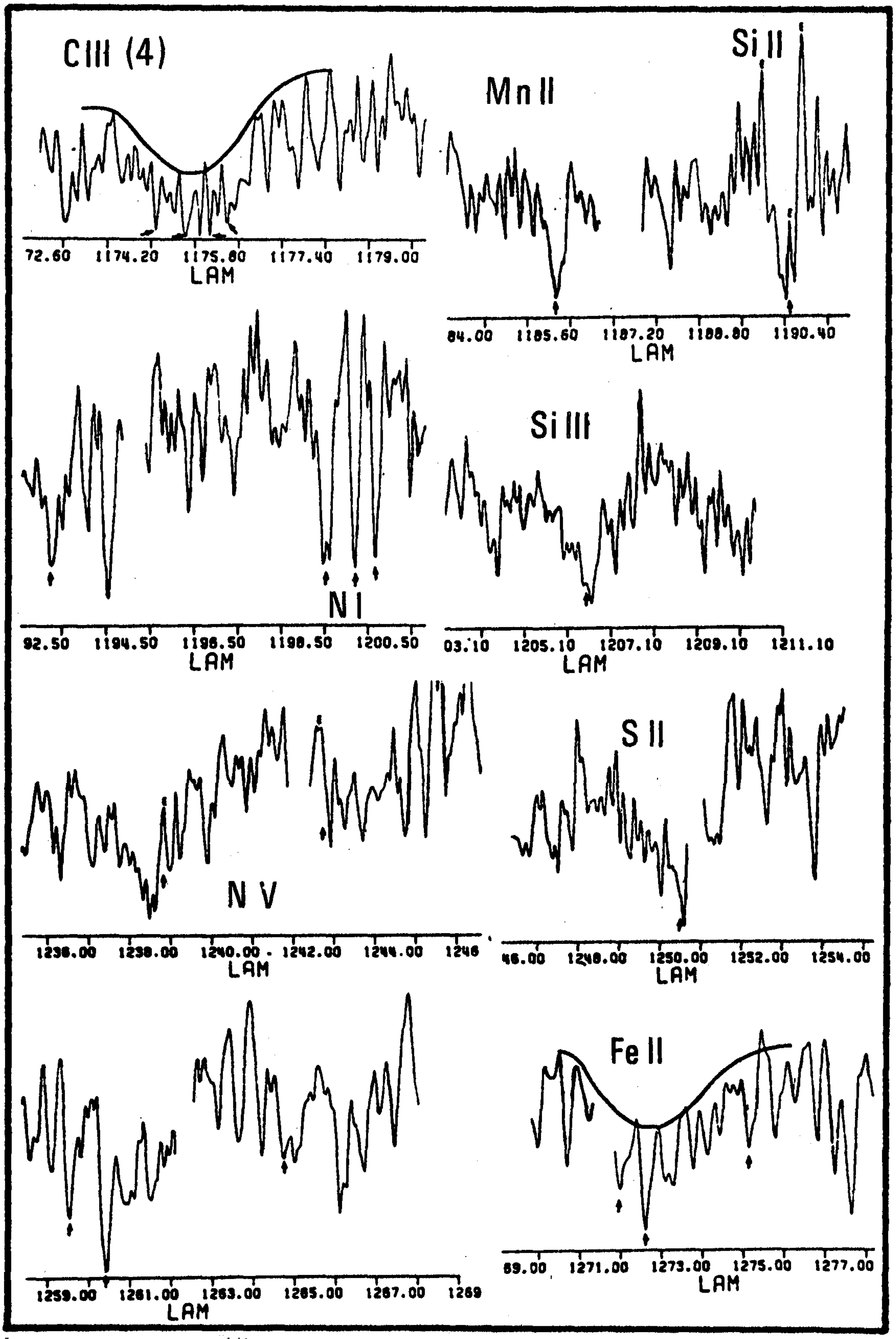



Figure 1. The UV resonance lines in the spectrum of HD 175362.

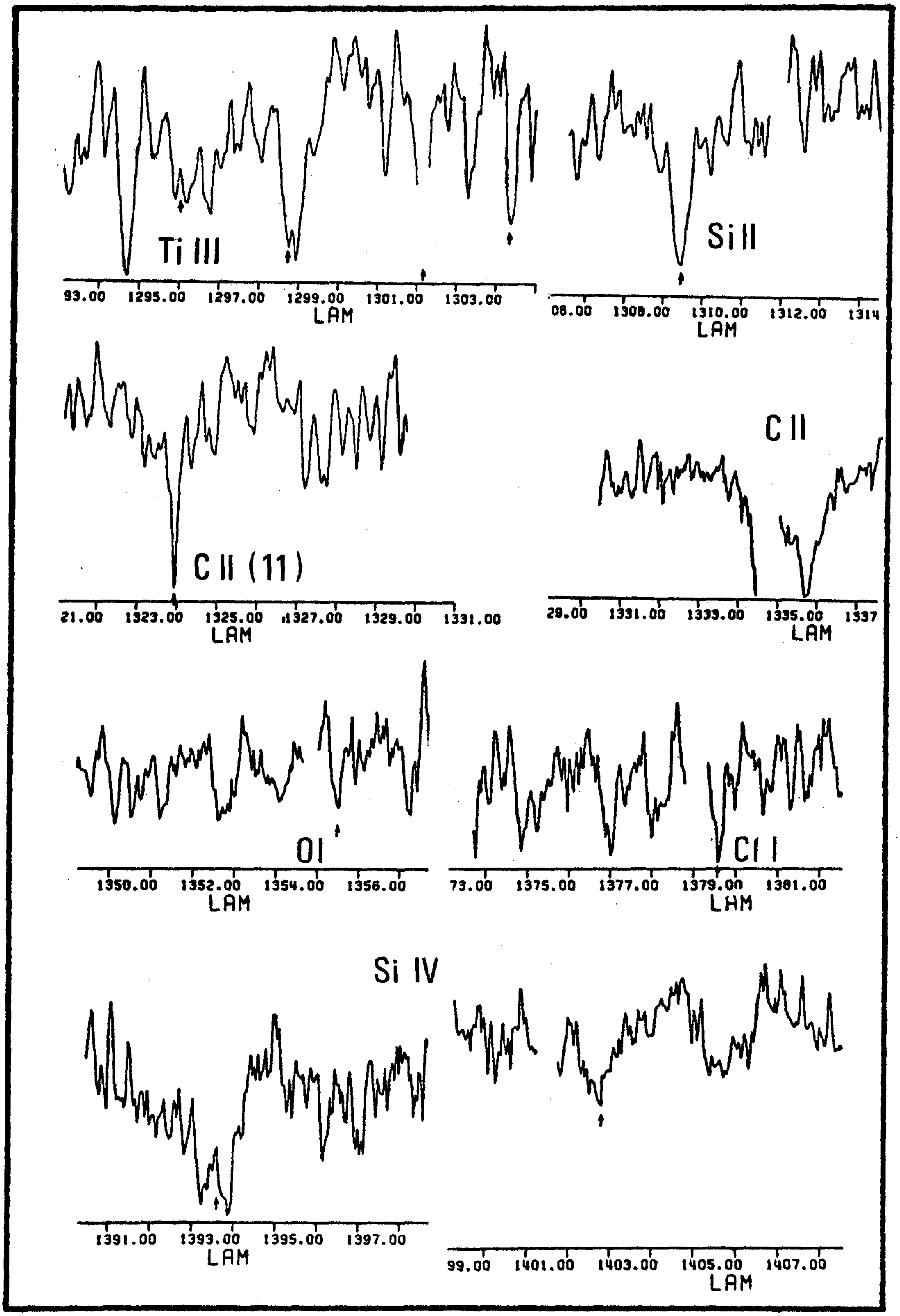
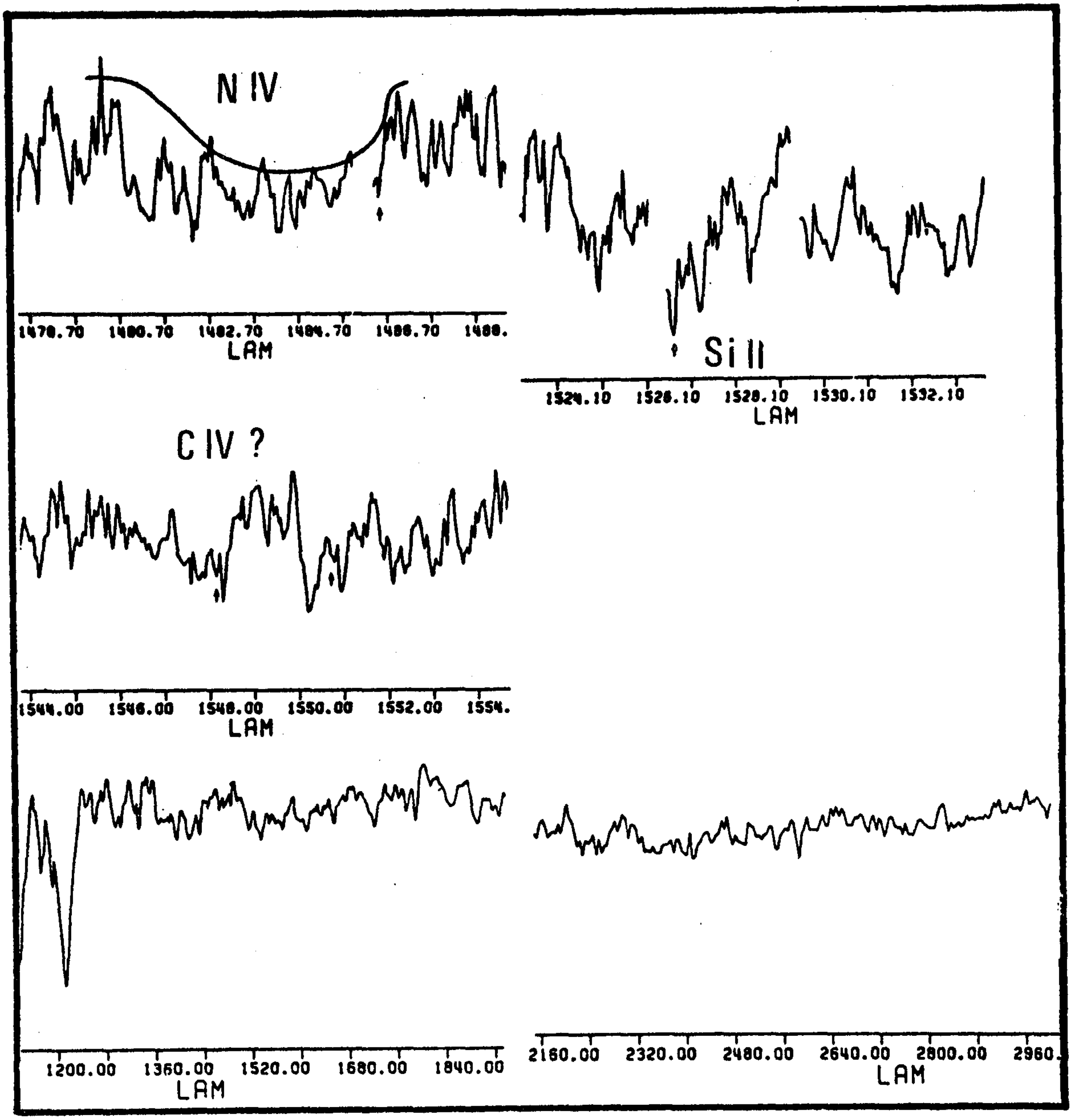



Figure 1. cont.

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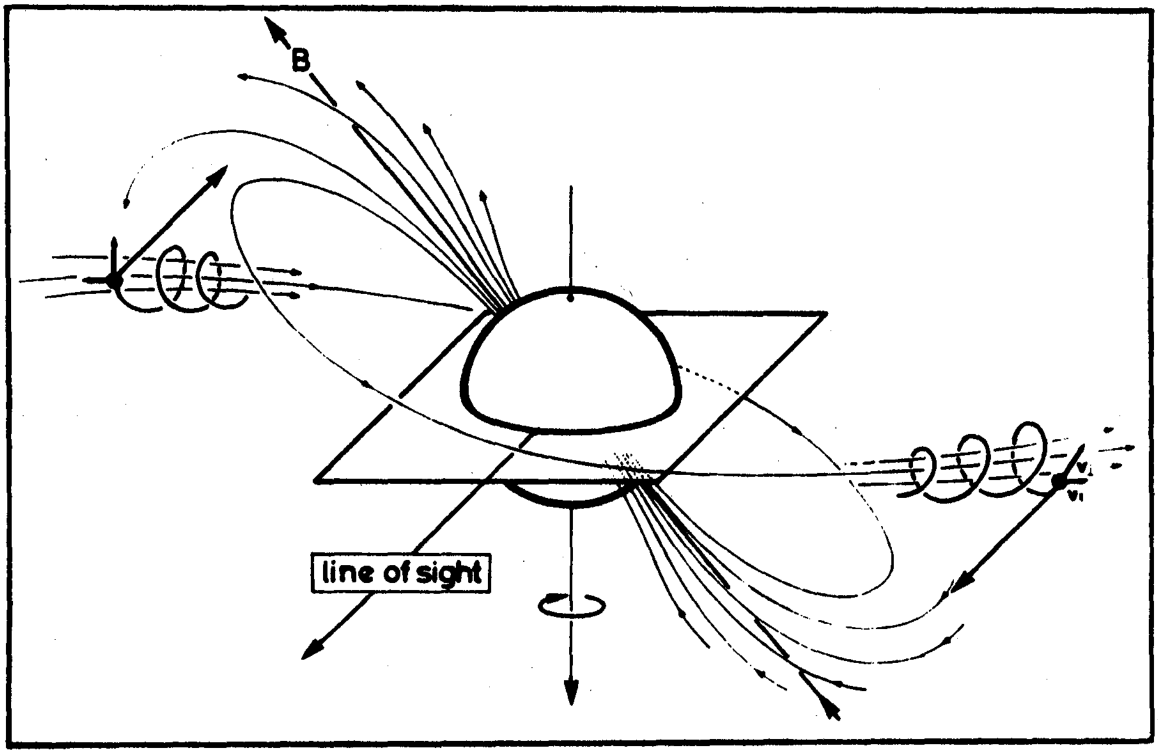


Figure 2. Spinning ions in the line of sight over the stellar surface.