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National Aeronautics and
Space Administration

**Scientific and Technical
Information Branch**

SPECTRAL CLASSIFICATION WITH THE INTERNATIONAL ULTRAVIOLET EXPLORER: AN ATLAS OF B-TYPE SPECTRA

by

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I. Introduction

A set of criteria for the spectral classification of B stars in the ultraviolet was published by Rountree & Sonneborn (1991, Paper I). In that paper it was shown that photospheric absorption lines in the 1200—1900A wavelength region can be used to classify the spectra of B-type dwarfs, subgiants, and giants on a two-dimensional system consistent with the optical MK system. The stellar wind lines are not used for classification on this system. Stars with peculiar wind lines are distinguished from "normal" stars, and are marked with the suffix "*w*." The observational material used in Paper I consisted of high-resolution spectra from the International Ultraviolet Explorer (IUE) archives, suitably resampled and displayed. Insofar as possible, the standard stars on which the ultraviolet classification was based were chosen from among the MK standards.

A number of representative spectra were shown in Paper I, in order to illustrate the classification method. But these spectral plots were reduced in scale by approximately 50%, and thus were not suitable for practical classification work. The purpose of the present Atlas is to make available a larger number of spectra at the scale used for classification. These spectra represent a dense matrix of standard stars, and also some interesting individual cases. Readers may use the figures in this Atlas to classify their own IUE spectra, after processing the data as described in Section II below. The recommended procedure for spectral classification with the Atlas is described in Section IV.

Although the Atlas should be useful as a guideline for ultraviolet spectral classification with instruments other than IUE, it should not be used for this purpose without reobserving the standard stars to make sure that there are no systematic effects.

II. Data Processing

The spectra comprising this Atlas were taken with the IUE short-wavelength prime (SWP) spectrograph in the high-dispersion mode. The extracted spectral data, produced by the standard processing provided by the IUE Project, were resampled to a resolution of 0.25A, normalized to a rough continuum level between 1150—1900A, and plotted on 11in. x 17in. paper on a laser printer. For details of the data reduction steps, see Walborn, Nichols-Bohlin, & Panek (1985) and Paper I. Our data processing procedures differ from those of the previous authors only in that the continuum normalization has been made autonomous rather than interactive and that the plots were produced on a laser printer rather than a CalComp plotter. The software needed to resample and normalize the spectra is available at the IUE Regional Data Analysis Facility at Goddard Space Flight Center. If the user does not have access to a laser printer that accommodates 11in. x 17in. paper, the spectral plots may be produced piecemeal on smaller paper, but the original scale (10A/cm) should be preserved. It is strongly recommended that any spectra last processed before the improved extraction software was put into production (1981 November) be reprocessed by the IUE Project before undertaking the resampling procedure.

III. Description of the Atlas

All the stars whose spectra are presented in this Atlas were drawn from the list in Table 2 of Paper I or from a second list of approximately 100 stars that were subsequently classified (without knowledge of their previous MK types) on the same ultraviolet system (Rountree & Sonneborn 1993, Paper II). In general, these are stars with visual magnitudes brighter than about 6.5, having normal MK types in the range B0—B8 III—V according to Rountree Lesh (1968), Hiltner, Garrison, & Schild (1969), or Morgan & Keenan (1973). A few supergiants were drawn from the work of Walborn & Nichols-Bohlin (1987).

The spectra are arranged in montages of four or five per two-page spread, or "plate." The wavelength scale is indicated by tick marks at 10A intervals above and below each spectrum, with numerical values of the wavelength in Angstroms shown at the bottom of the page. The crosses along the wavelength scales mark the echelle order splice points. The quantity plotted as a fine line at the top of each spectrum is the normalized data quality factor, which in these plots primarily indicates (by a downward spike) areas in which the data points may be contaminated by a camera reseau. The most important spectral lines, especially those used in classification, are identified along the top of each plate. The stars are identified to the left of their spectra. The spectral type given for each star is the *ultraviolet* spectral type; in most cases, this is identical with the optical MK type. In Parts 2 and 3 of the Atlas the rotational velocity from Uesugi & Fukuda (1982) or the date of observation is also given. Overall characteristics of the spectral type range covered by each plate are described in the text at the left of the spectra.

There are three parts to the Atlas. Part 1, Plates 1—14, contains sequences of spectra of standard stars for direct use in classification. Plates 1—7 show spectral-subtype (or temperature type) sequences for dwarf (class V), subgiant (class IV), and giant (class III) stars. Almost all of these stars are standards listed by Morgan & Keenan (1973) or by Rountree Lesh (1968). On the main sequence, where very fine subdivisions are possible, we provide some overlap between the groups of spectra on successive pages, so that the user will always be able to bracket the spectrum to be classified between two standards. Plates 8—14 present luminosity sequences at seven spectral subtypes. In these montages, some of the standards in classes III—V have been replaced with other stars whose spectra were judged to be equally representative of their type, so as to give as many examples as possible of normal ultraviolet spectra. The supergiants (class Ia) whose spectra appear here are the stars described by Walborn & Nichols-Bohlin (1987). These stars have not been classified on the ultraviolet system — the spectral types given are the optical MK types. The supergiant spectra are reproduced in this Atlas in order to show the full range of variation of certain spectral lines as a function of stellar luminosity.

Part 2 of the Atlas, Plates 15—20, illustrates the effect of rapid stellar rotation on the ultraviolet spectrum. Each plate in this section displays two pairs of spectra; each pair, closely matched in spectral type, consists of the spectrum of a slowly rotating star (*v sin i* usually <50 km/s) and the spectrum of a rapidly rotating star (*v sin i* usually >200 km/s). Although most of the rapid rotators are not standards, these illustrations should be helpful to the user who wishes to classify the spectrum of a broad-lined program star, since they show how these spectra are likely to differ from the narrow-lined standards.

Finally, spectra with anomalous stellar wind lines, primarily strong absorption lines of C IV λλ1548, 1550, Si IV λλ1393, 1402, and/or N V λλ1238, 1242, are illustrated in Part 3, Plates 21—26. These are stars whose ultraviolet spectral types have a "*w*" suffix in the classification of Rountree & Sonneborn (1991). As in Paper I, *italics* are used in the text accompanying Plates 21—26 to distinguish *ultraviolet* spectral types from optical MK types. The spectrum of at least one "normal" star of identical type is presented with each anomalous spectrum to show the good match in the photospheric absorption lines, which alone are used in classification. More detailed studies of some of these stars are referenced in the text opposite the spectrum in question.

IV. Use of the Atlas

After the user's program spectra have been processed as described in Section II, they may be classified by direct comparison with the spectra in this Atlas. As in the MK system, the ultraviolet classification system is defined by its standard stars, most of which are illustrated here. Therefore, a program star should be assigned the type of the standard star that it most closely resembles. It must be emphasized that the comparison should be made using *only* photospheric absorption lines. The N V, Si IV, and C IV lines should *not* be used in classification; they should be taken into account only in assigning the "*w*" suffix.

Table 1 lists the standard stars of the ultraviolet classification system, as well as the photospheric lines used as classification criteria. This is a slightly updated version of the similar table in Paper I.

In our experience, it is possible to assign a very accurate temperature type to a star from its ultraviolet spectrum, while luminosity class may be more difficult to identify accurately (see Paper II). Therefore, we recommend first locating the spectrum of a program star among the standards on the main sequence, and then going to the luminosity-effects plate at that spectral type to see if the star appears to be a subgiant or giant. If it does, its temperature type should be verified by locating the spectrum on the subgiant or giant sequence. Of course, this is an iterative procedure, since temperature type and luminosity class are not completely independent. Finally, the N V, Si IV, and C IV lines, if present, should be compared with the same lines in the standard spectrum to see whether the program star has an anomalous stellar wind. The behavior of the wind lines in the standard stars is described in the text accompanying the spectra in Part 1. It is also noted in *italics* in Table 1.

V. Conclusion

It is hoped that this Atlas will find extensive use in the classification of IUE high-resolution spectra, especially for stars that have not been observed in the visible region. Spectral types obtained by the procedures outlined here and in Paper I should be entirely consistent with MK spectral types. In principle, the same standards and criteria can be used for spectra obtained with a different ultraviolet spectrograph, but in that case the standards should be reobserved with the other instrument to avoid systematic effects.

References

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Walborn, N.R., & Nichols-Bohlin, J. 1987, Pub. Astr. Soc. Pac. 99, 40.
Walborn, N.R., Nichols-Bohlin, J., & Panek, J. 1985, *IUE Atlas of O-Type Spectra from 1200 to 1900A* (NASA Ref. Pub. 1155).

Table 1 - Ultraviolet Spectral Classification Criteria and Standard Stars

	V	IV	III
B0	υ Ori 1640A (He II) strong 1718A (N IV) strong 1748-51 (N III) marked *Si IV, C IV strong absorption*	HD 75821 Interpolate between V and III *Si IV, C IV absorption*	HD 48434 N III, N IV stronger 1854-61A (Al III) stronger 1247A (C III) stronger *N V, Si IV, C IV P Cyg profile*
B0.5	HD 36960, N III present He II, N IV moderate to strong C III strong *Si IV, C IV strong absorption*	λ Lep Interpolate between V and III *Si IV, C IV absorption*	1 Cas N IV, Al III stronger N III present but weak *Si IV, C IV absorption*
B1	ω^1 Sco, 42 Ori N IV weak to absent He II marked 1247A (C III) strong 1264A (Si II) present *Si IV strong, C IV wk. absorption*	α Vir Interpolate between V and III *Si IV, C IV absorption*	ο Per, σ Sco C III, He II, N IV stronger Si III 1300 multiplet stronger *Si IV, C IV absorption*
B1.5	HD 35299 1264A marked but <1247A He II weak *Si IV absorp., C IV wk. to absent*	λ Sco Interpolate between V and III *Si IV, C IV absorption*	12 Lac Si III, C III stronger *Si IV, C IV stronger*
B2	22 Sco 1264A (Si II) = 1247A (C III) 1310A (Si II) < 1300A (Si III) He II weak to absent *Si IV moderate, C IV absent*	γ Peg Si III, Al III, Fe III stronger than B2 V 1600-10A (Fe II) stronger *Si IV stronger, C IV absent*	π^4 Ori C III, Al III, Fe II, Fe III stronger than B2 IV *Si IV stronger, C IV present*
B2.5	σ Sgr 1264A (Si II) > 1247A (C III) 1310A (Si II) < 1300A (Si III) 1485A (Si II blend) present *Si IV absorption*	HD 32612 Interpolate between V and III *Si IV present, C IV absent*	π^2 Cyg Si II, Si III, C III, Fe II, Fe III Al III stronger *Si IV strong, C IV present*
B3	η UMa, η Aur 1264A (Si II) >> 1247A (C III) 1310A (Si II) ≥ 1300A (Si III) 1485A (Si II blend) marked *Si IV weak*	HD 134687, 126 Tau Interpolate between V and III *Si IV present, C IV absent*	HD 89890 Si II, Si III, C III, Al III, Fe III stronger *Si IV stronger, C IV present*
B4	HD 20809 1310A (Si II) ≥ 1300A (Si III) 1485A (Si II blend) prominent *Si IV weak to absent*	53 Per Si II, Si III, Al III stronger than B4 V *Si IV present, C IV absent*	No standard in program
B5	35 Eri, ρ Aur Si II dominates spectrum 1655A (C I), Fe II moderate 1670A (Al II), Al III strong *Si IV marginal to absent*	τ Her Si II, Si III, Al III stronger than B5 V *Si IV present, C IV absent*	δ Per, τ Ori Si II stronger than B5 IV *Si IV stronger, C IV absent*
B6	β Sex Similar to B5 V but Al III stronger Fe III weaker *Si IV absent*	19 Tau Interpolate between V and III *Si IV, C IV absent*	17 Tau Si II stronger *Si IV, C IV absent*
B7	α Leo Al II, C I prominent Al III weaker than B6 V Fe III absent	16 Tau Interpolate between V and III	η Tau Si II, Al II stronger than B7 V
B8	18 Tau Si II dominant Al II, C I prominent Al III, Fe III absent	No standard in program	27 Tau Si II, Al II stronger than B8 V

Part 1

Standard Stars

Main Sequence

B0 - B2

The earliest main-sequence B stars are characterized by lines of He II λ1640, N IV λ1718, and N III λλ1748,1751, which decrease smoothly from B0 to B1. C III λ1247 begins to weaken at B1, while the photospheric Si II lines λ1264 and λ1310 begin to increase in strength. The ratio λ1264/λ1247 is approximately unity at B2 V.

In these standard main-sequence stars, Si IV λλ1393, 1402 is mainly photospheric, and shows a marked decrease at B2. The stellar wind lines C IV λλ1548, 1550 are essentially absent by B2.

Plate 1a

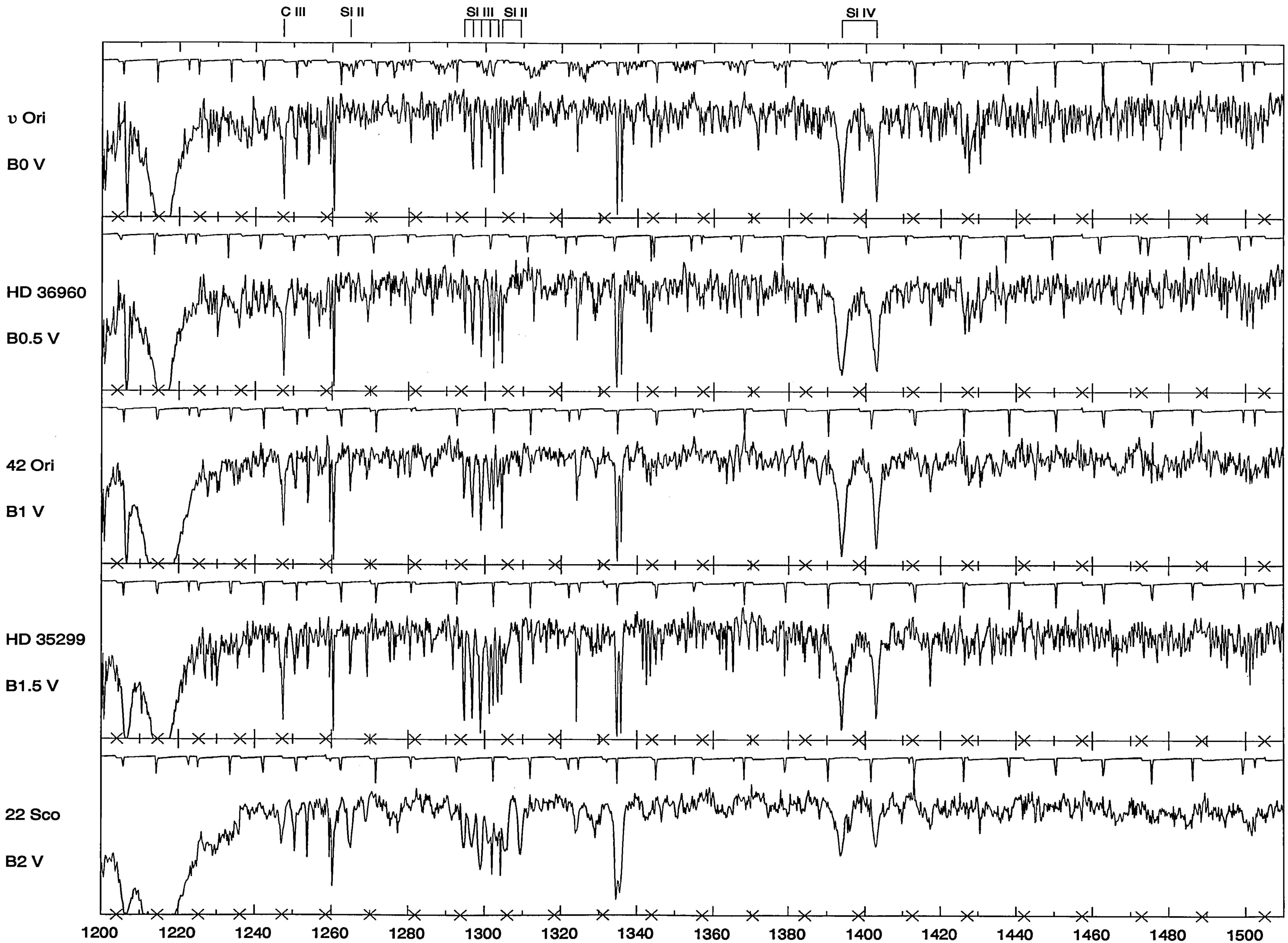
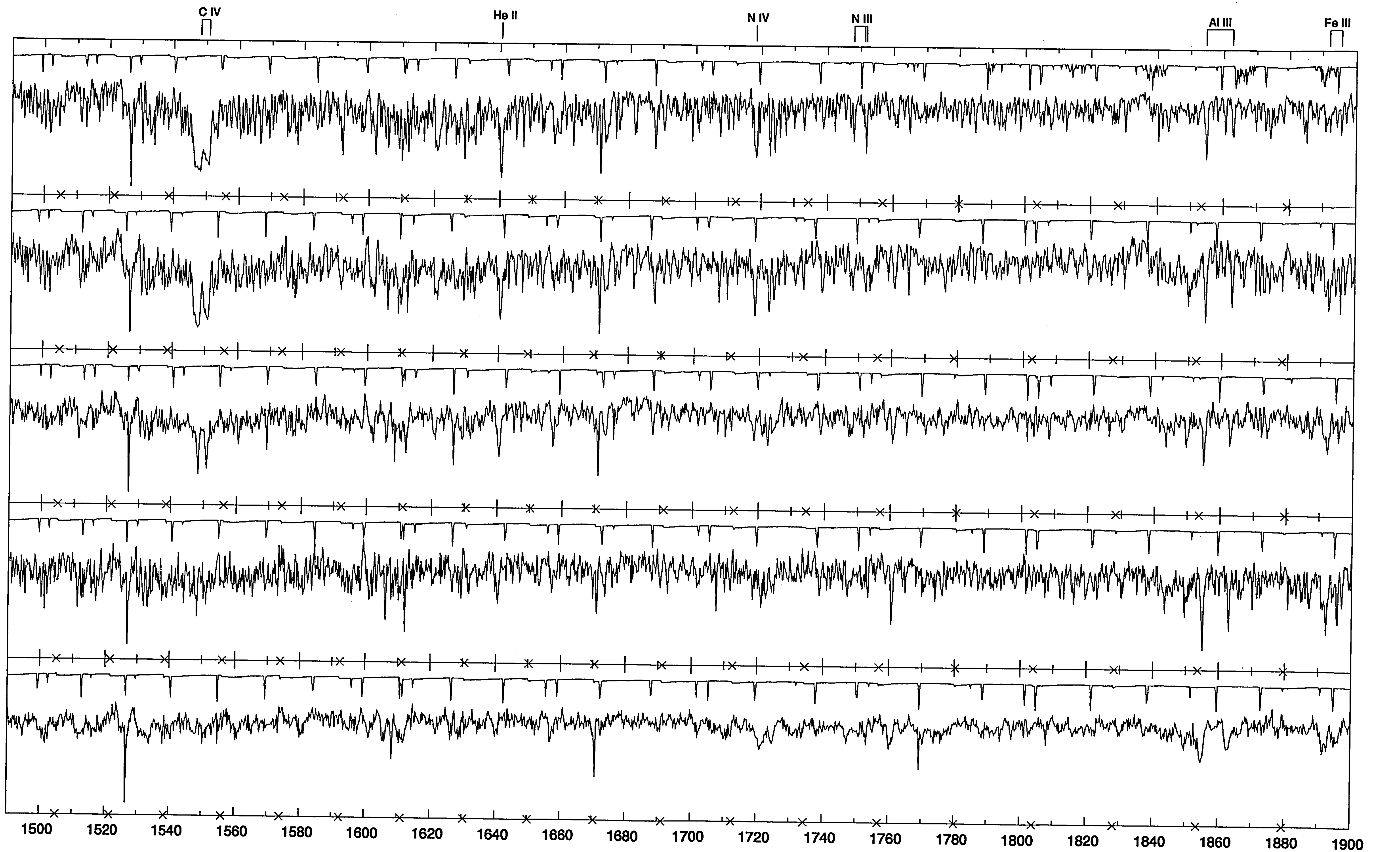


Plate 1b


C IV
He II
N IV
N III
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Main Sequence

B2 - B5

The ratio Si II λ1264/C III λ1247 increases monotonically from B2 to B5 on the main sequence, as does the ratio Si II λ1310/Si III λ1300. The photospheric Si II lines λ1485 and λ1533 also become prominent in this spectral type range.

Si IV λλ1393, 1402 decreases to marginal strength, while C IV λλ1548, 1550 is not normally present in main-sequence stars later than B2.

Plate 2a

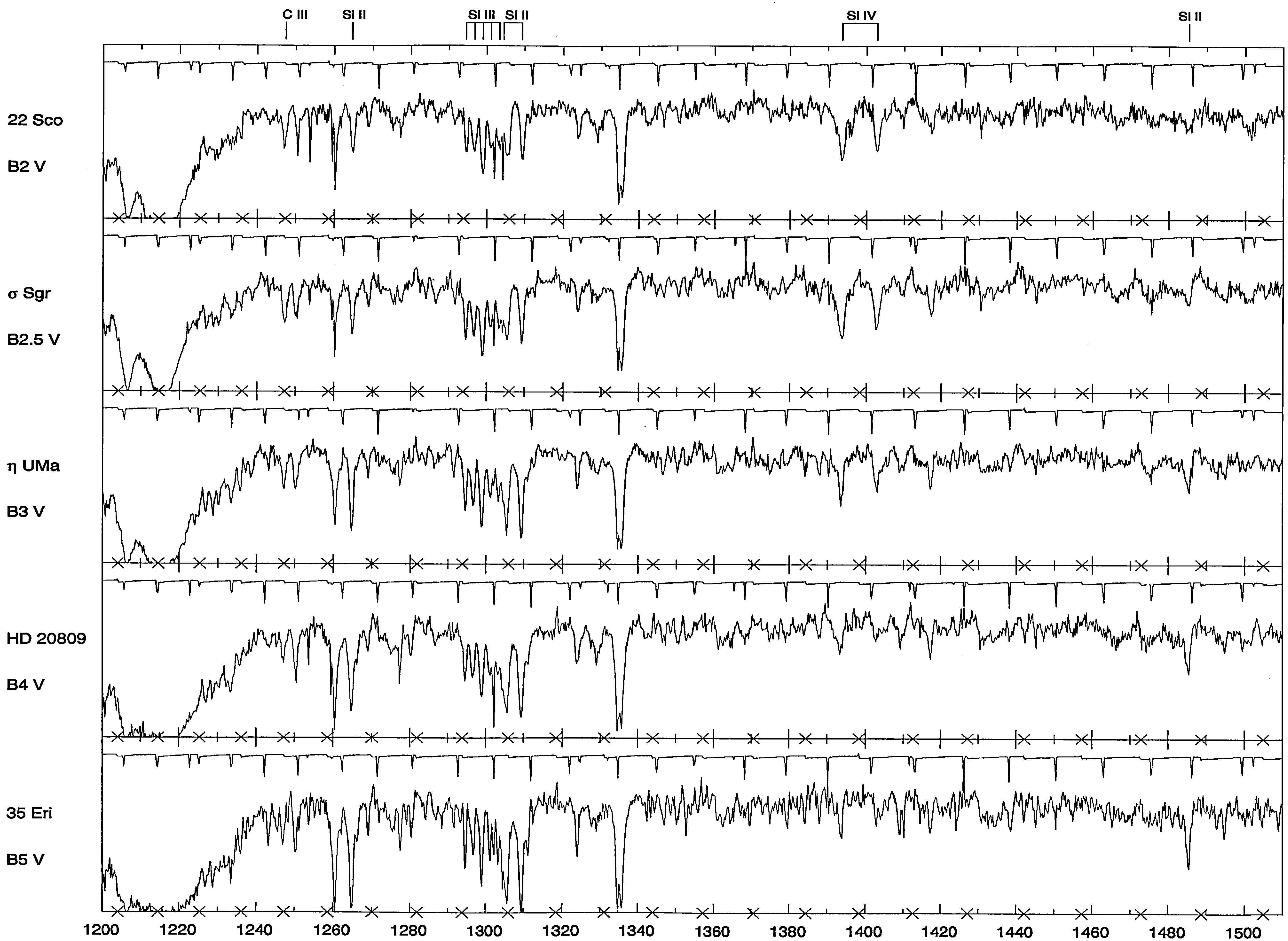


Plate 2b

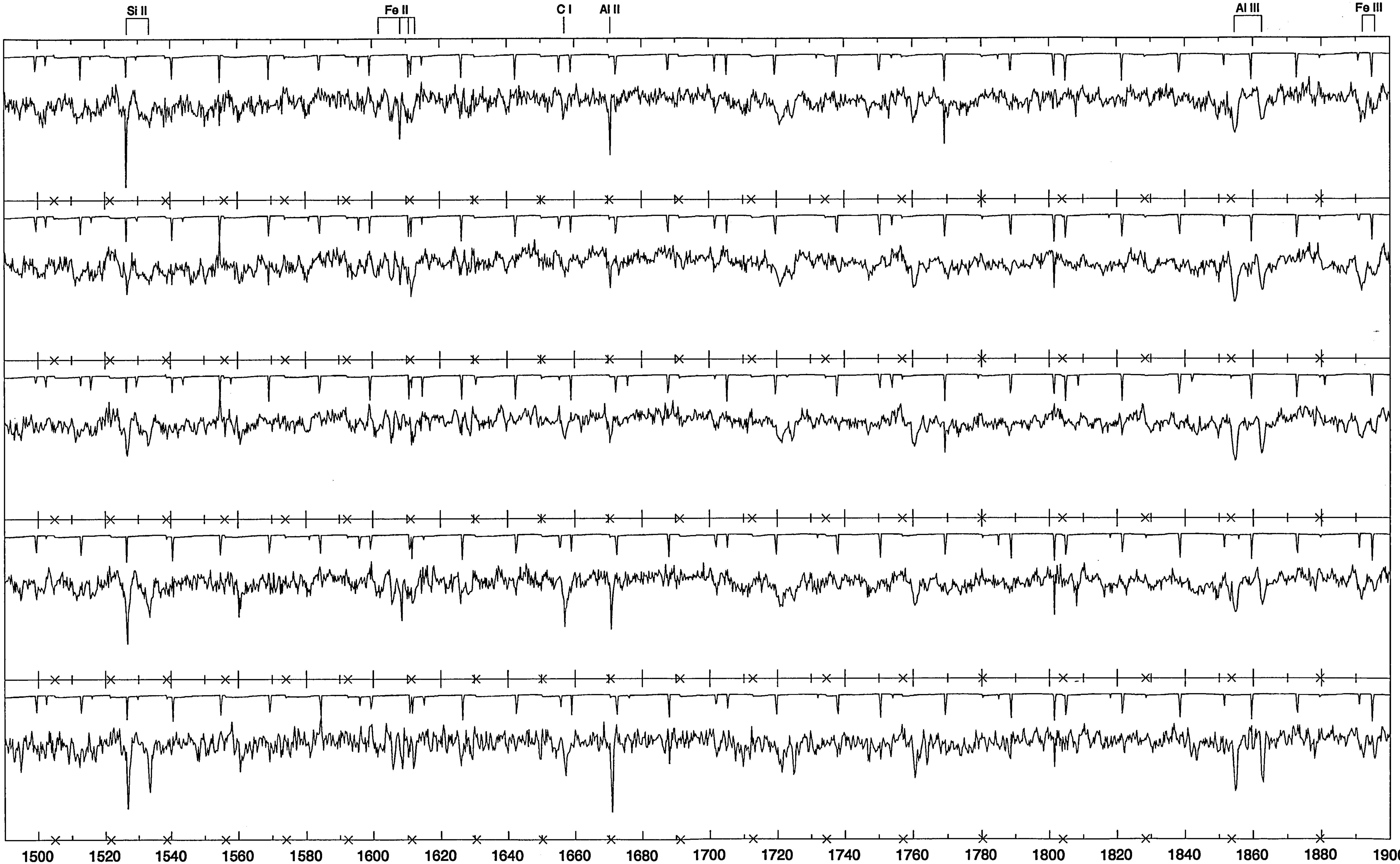

Si II
Fe II
C I
Al II
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Plate 3a

Main Sequence

B5 - B8

The lines of Si II dominate the stellar spectrum throughout this range of main-sequence types. Fe III λλ1892, 1896 weakens at types later than B5, while Al III λλ1854, 1861 reaches a maximum at B6.

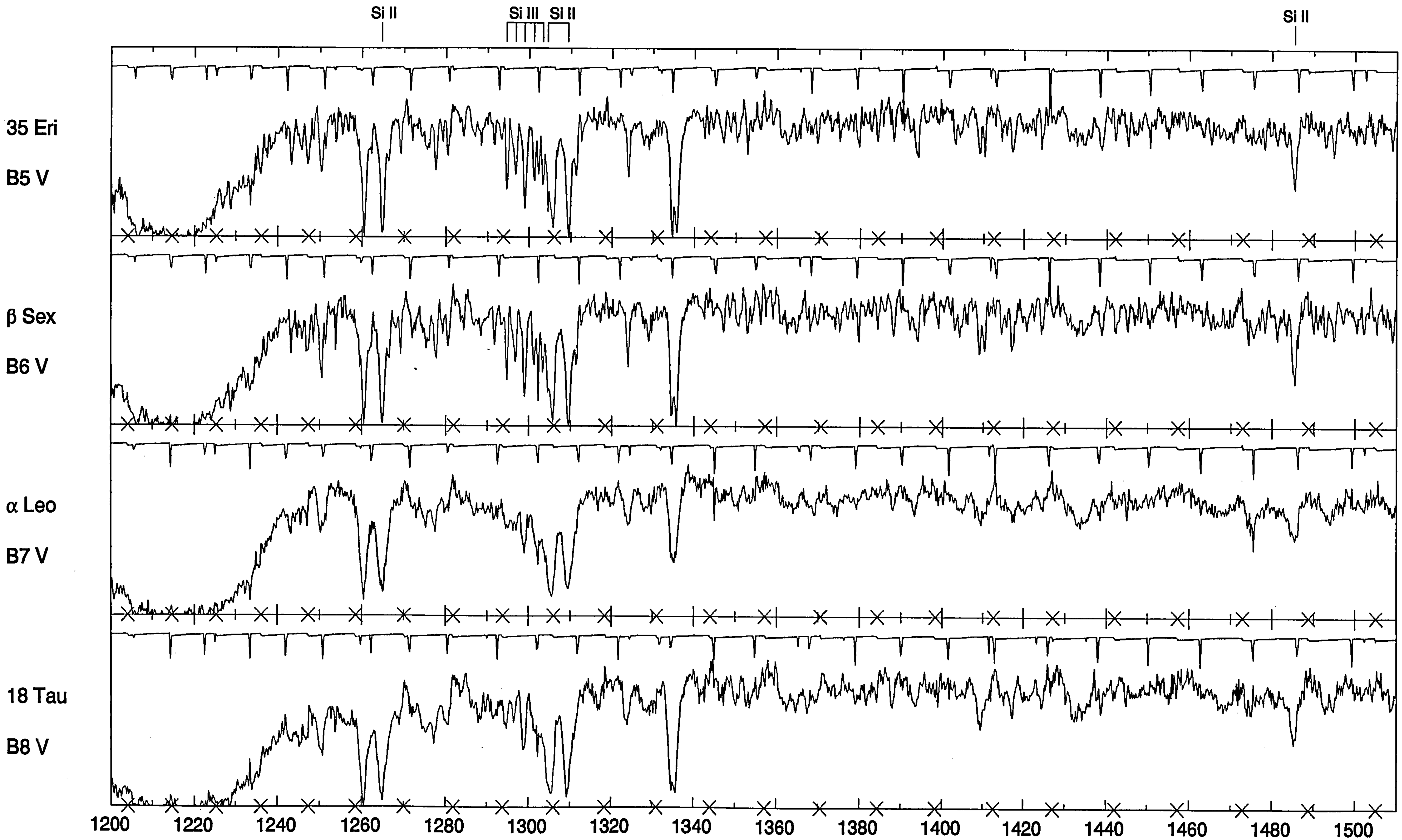
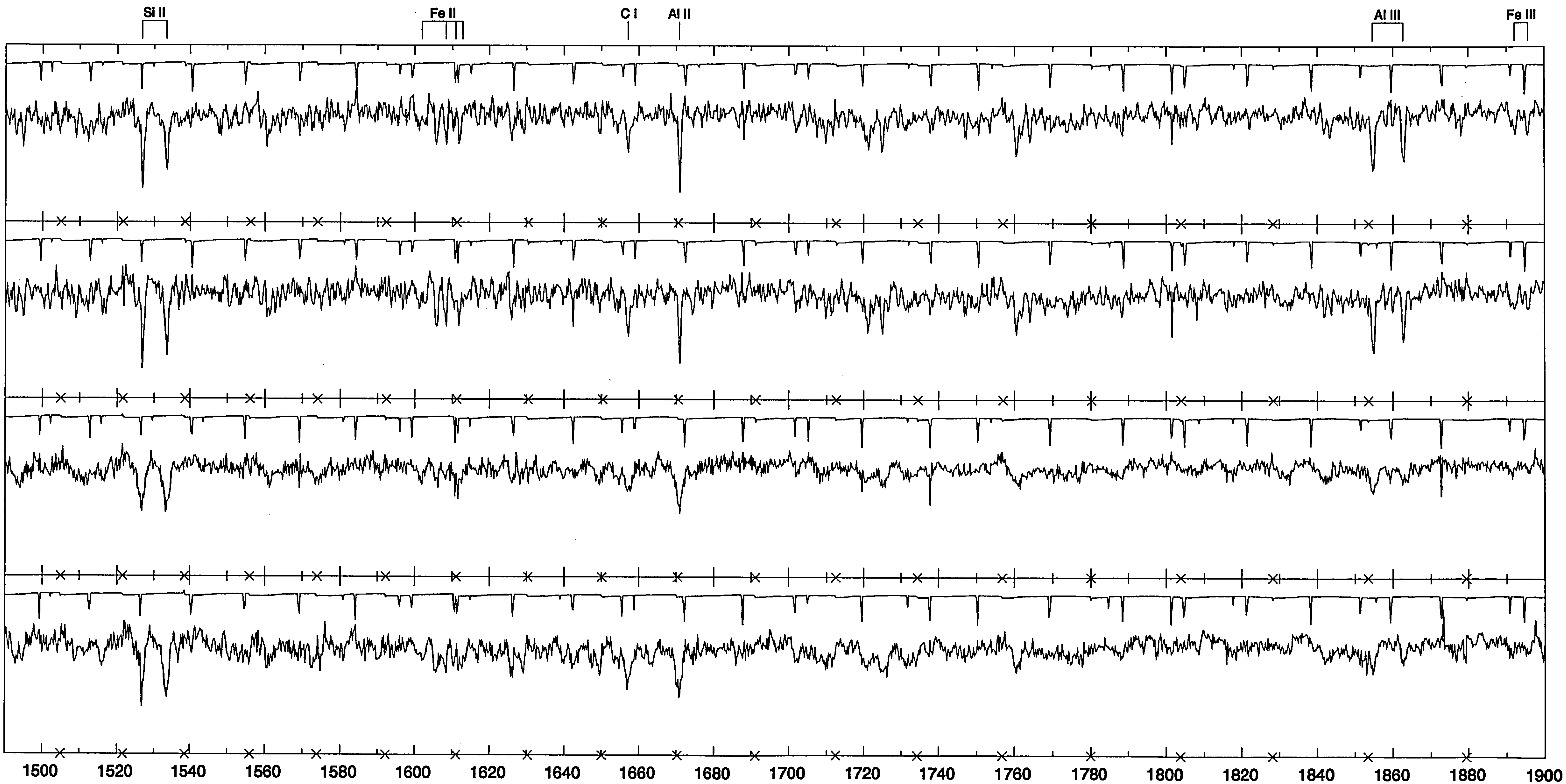


Plate 3b


Si II
Fe II
C I
Al II
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Subgiants

B0 - B2

In the subgiants, He II λ1640 remains prominent and C III λ1247 remains strong through B2. Spectral type is determined by the relative strength of the Si II photospheric lines. C IV λλ1548, 1550 can sometimes be seen as late as B2.

Plate 4a

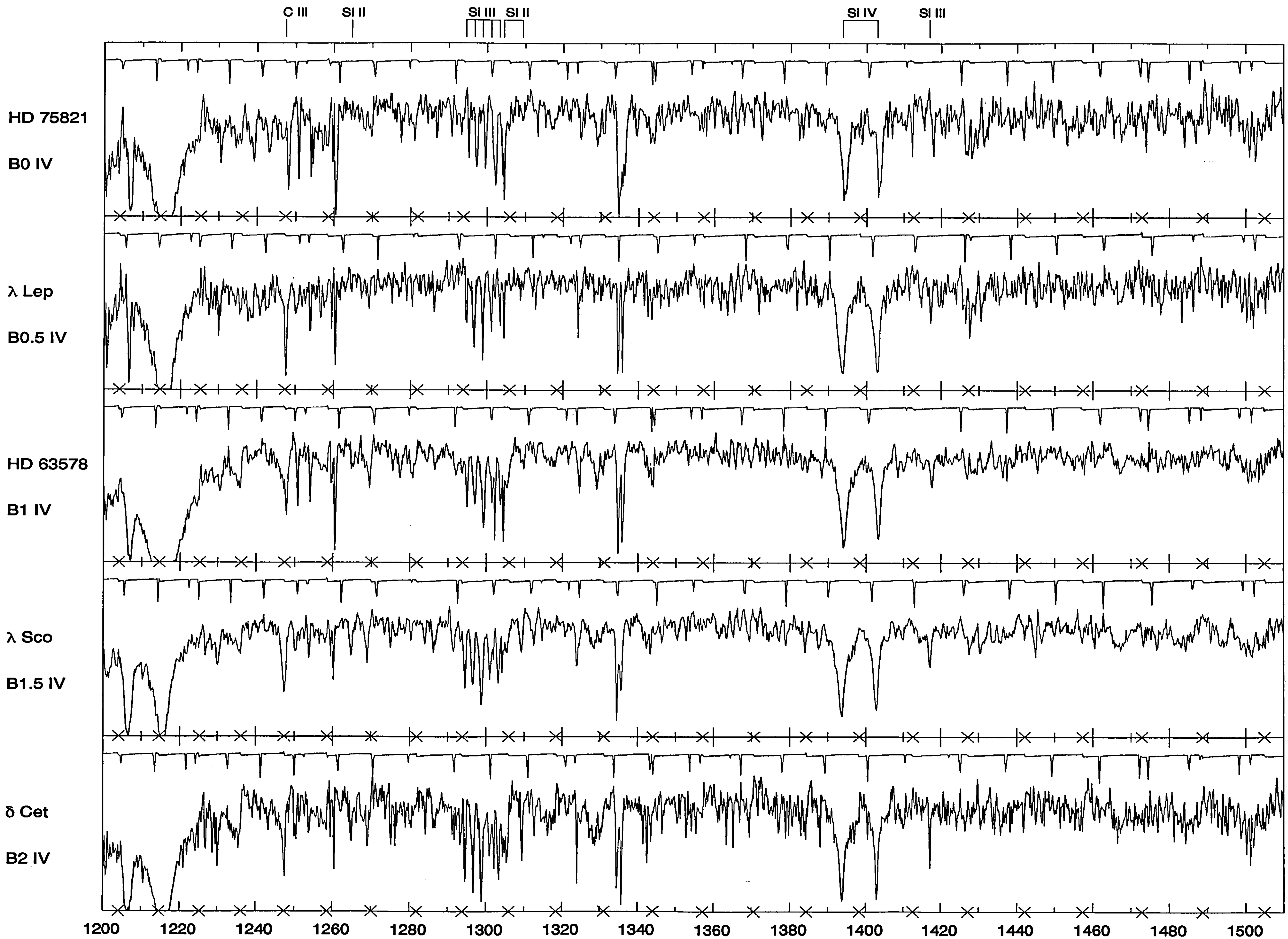
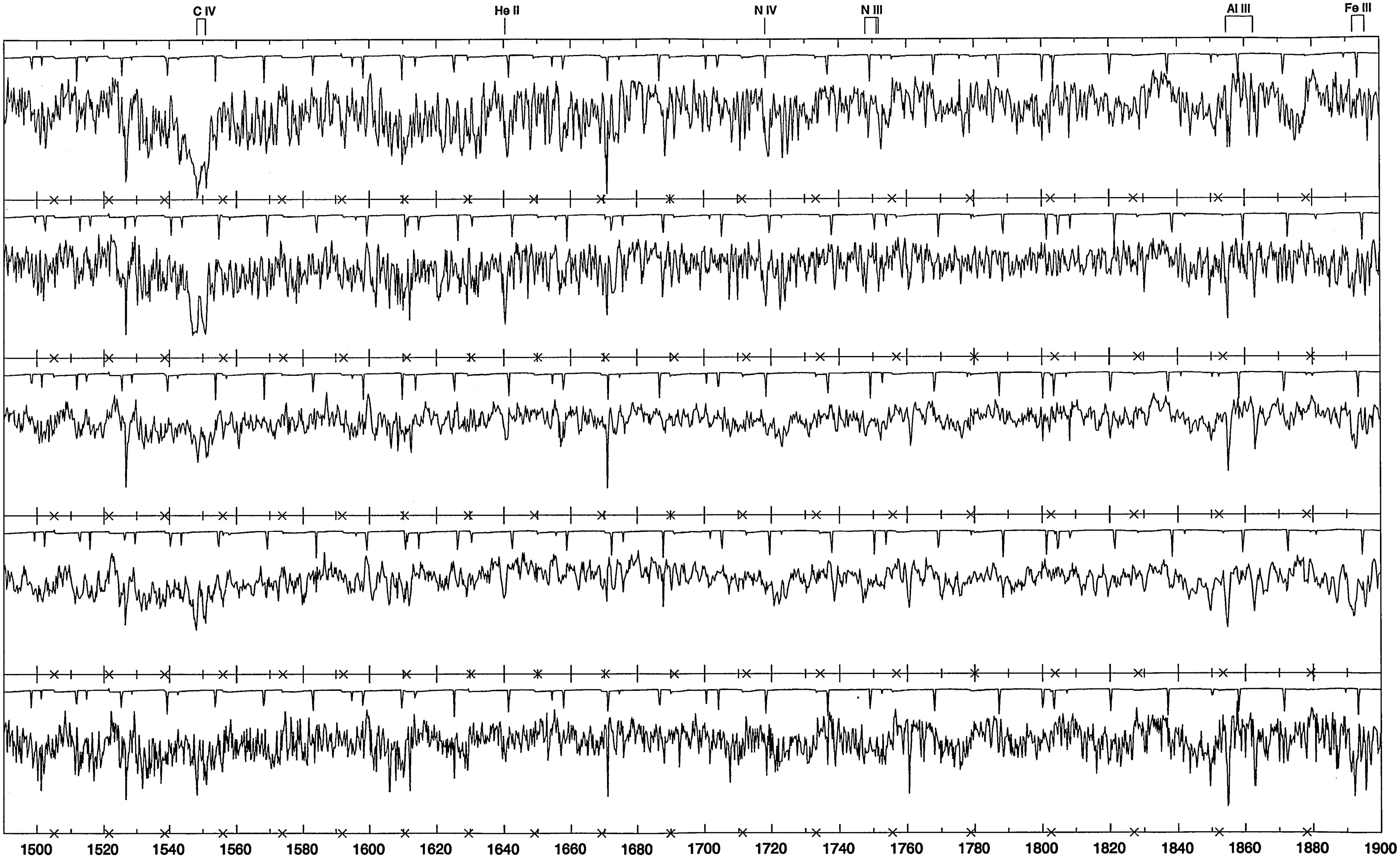


Plate 4b


C IV
He II
N IV
N III
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Subgiants

B2.5 - B7

The photospheric Si IV lines persist until type B5 in the subgiants. The relative strength of the Si II and Si III spectra makes a useful spectral type criterion.

Plate 5a

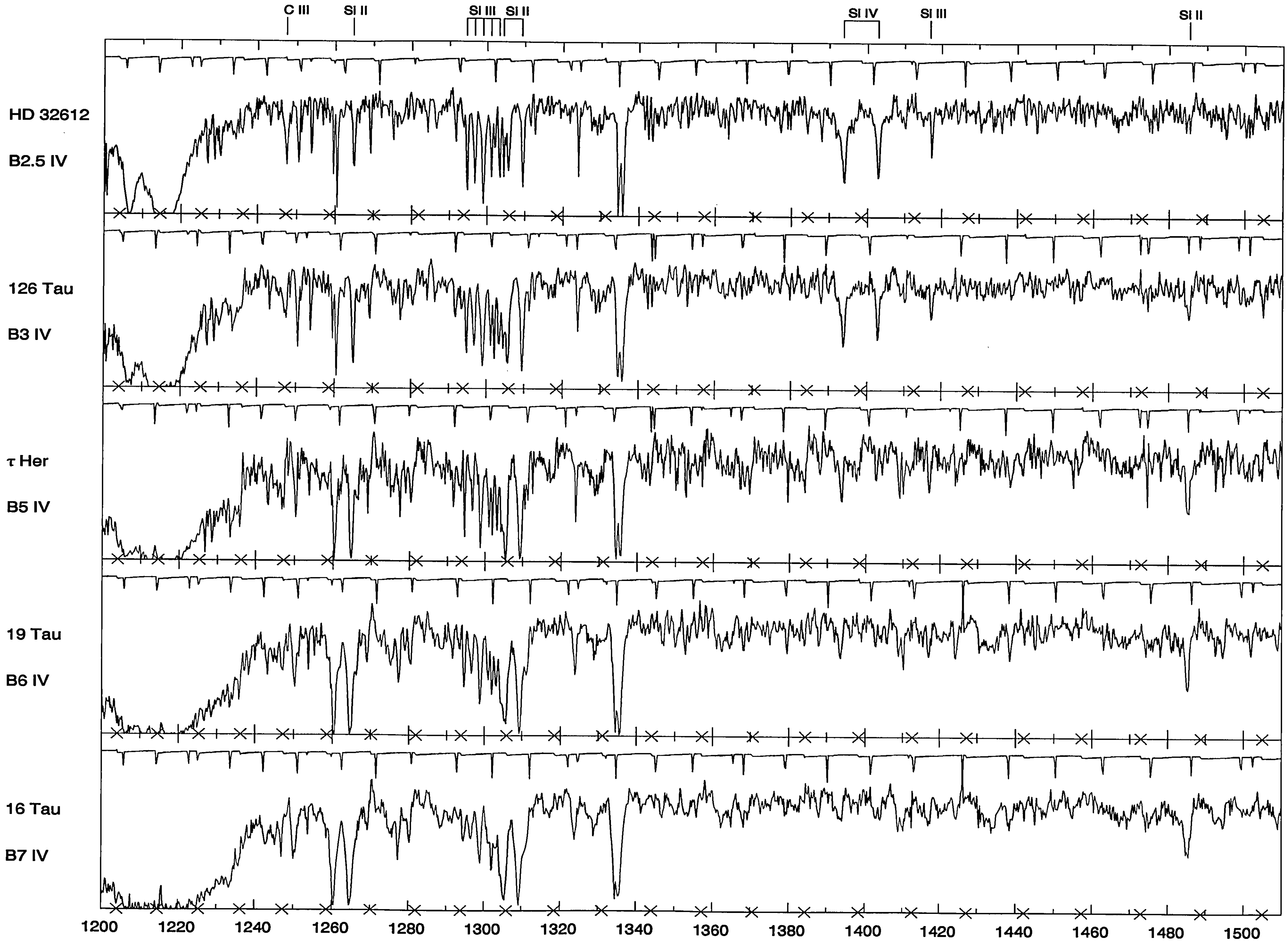
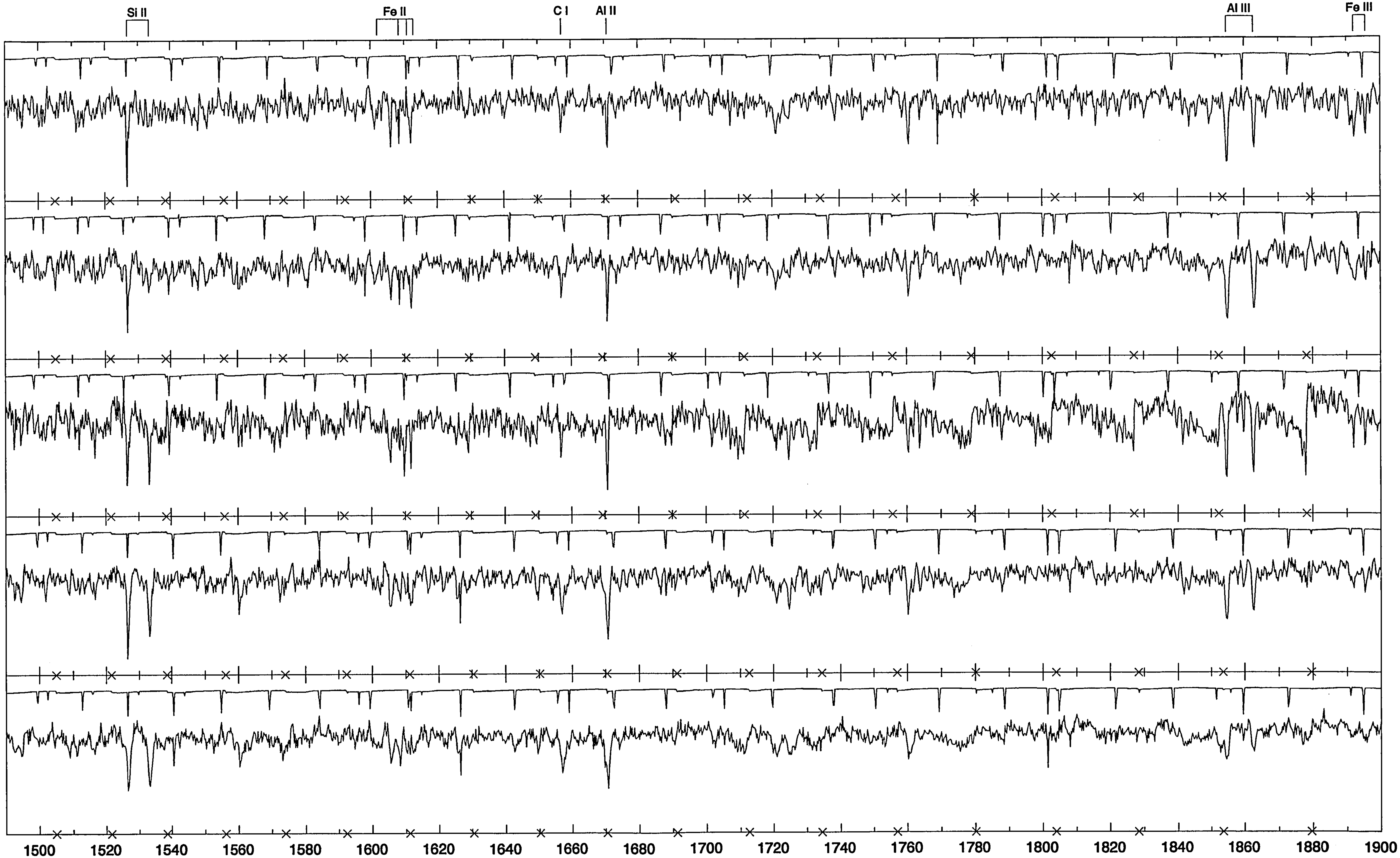


Plate 5b


Si II
Fe II
C I
Al II
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Giants

B0 - B2

In the giant stars He II λ1640 persists to B2, N IV λ1718 to B1, and N III λλ1748, 1751 to B0.5. Although C III λ1247 is stronger than on the main sequence, the ratio λ1264/λ1247 is still near unity at B2 III. Si IV λλ1393, 1402 and C IV λλ1548, 1550 exhibit P Cygni profiles at B0 III, and remain as strong absorption lines throughout this spectral type range.

Plate 6a

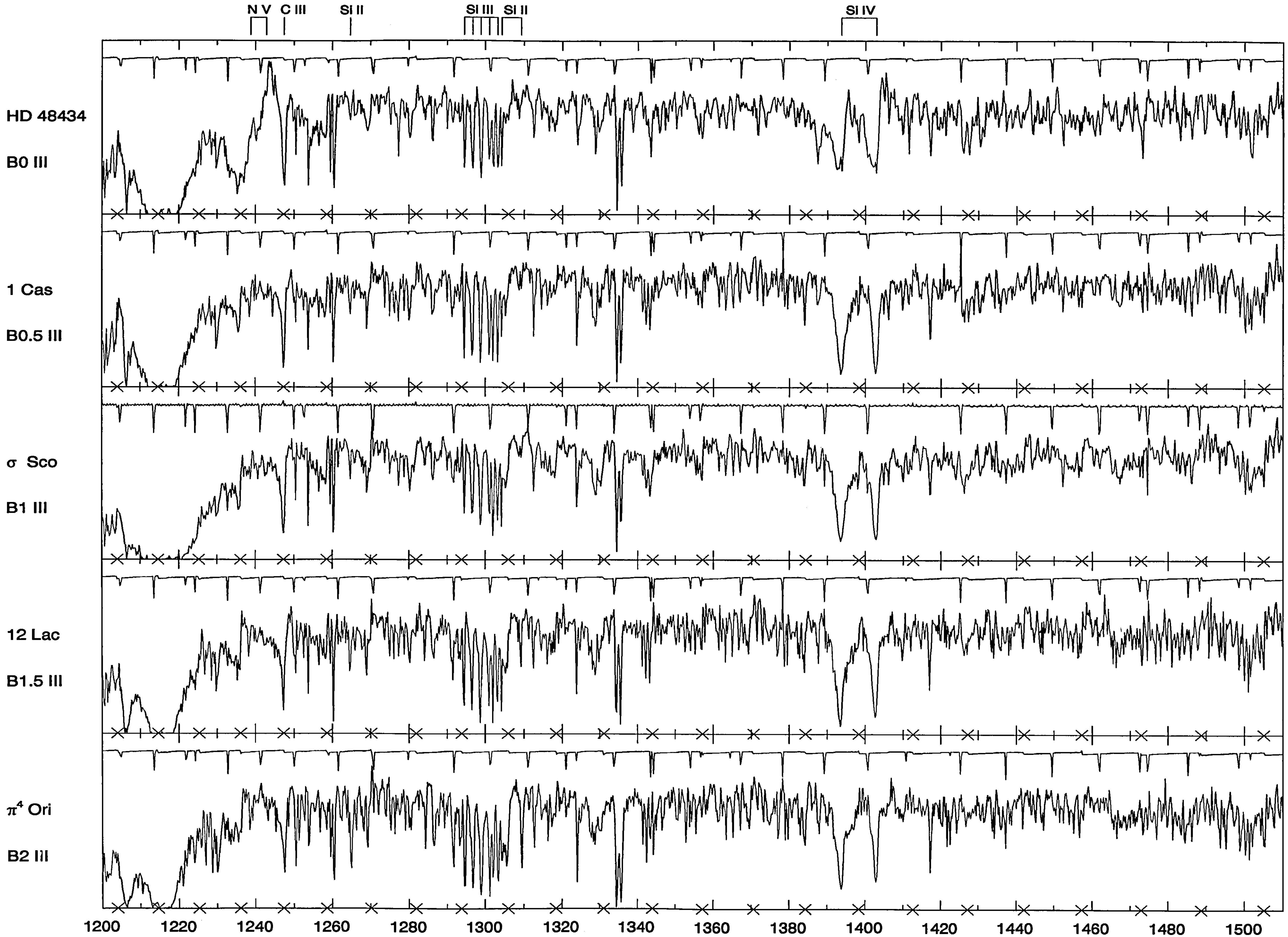
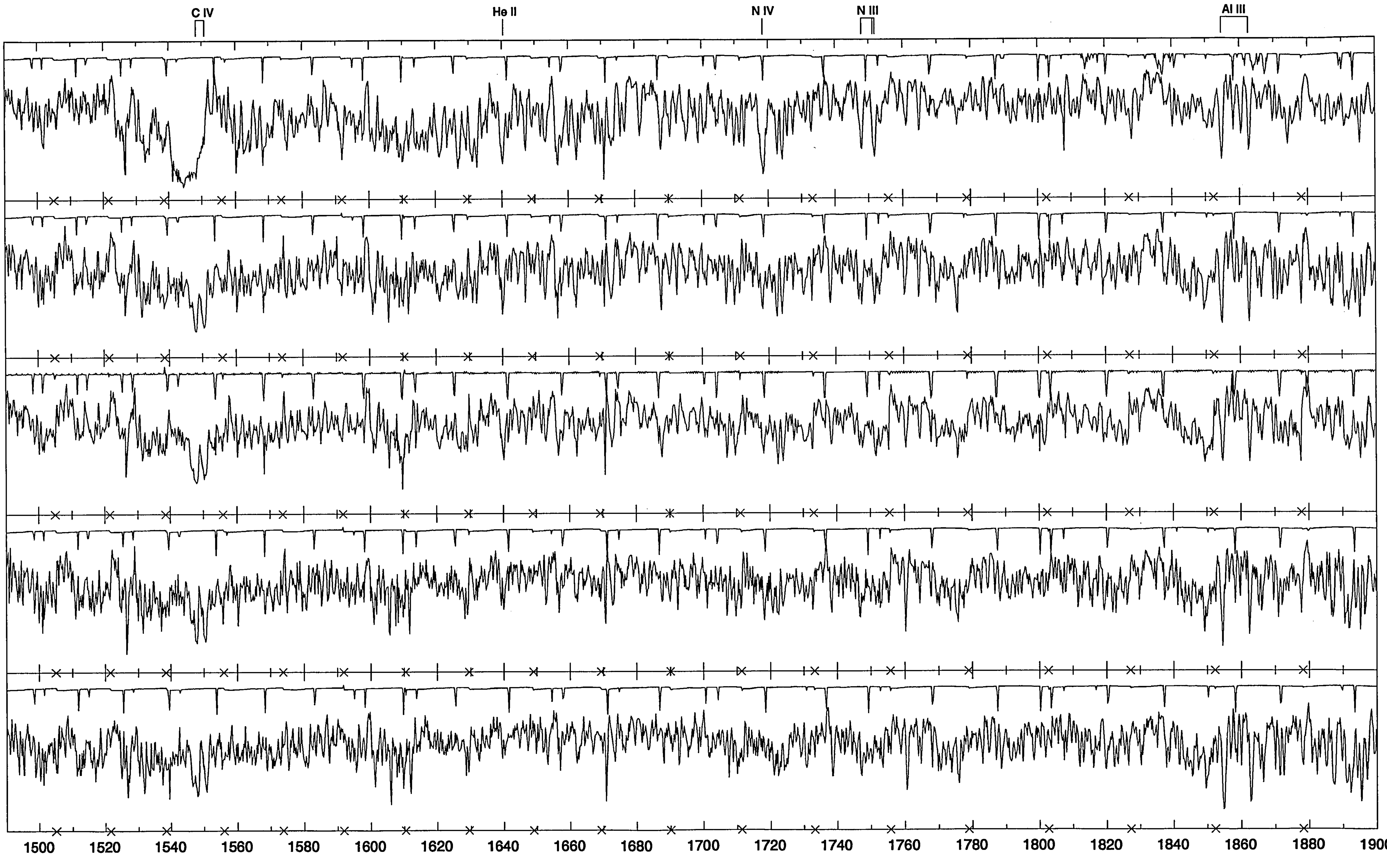


Plate 6b


C IV
He II
N IV
N III
Al III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Giants

B3 - B8

Si IV persists to B5 and C IV to B3 in normal giant stars, but the spectrum of stars in the B3—B8 range is still dominated by Si II lines.

Plate 7a

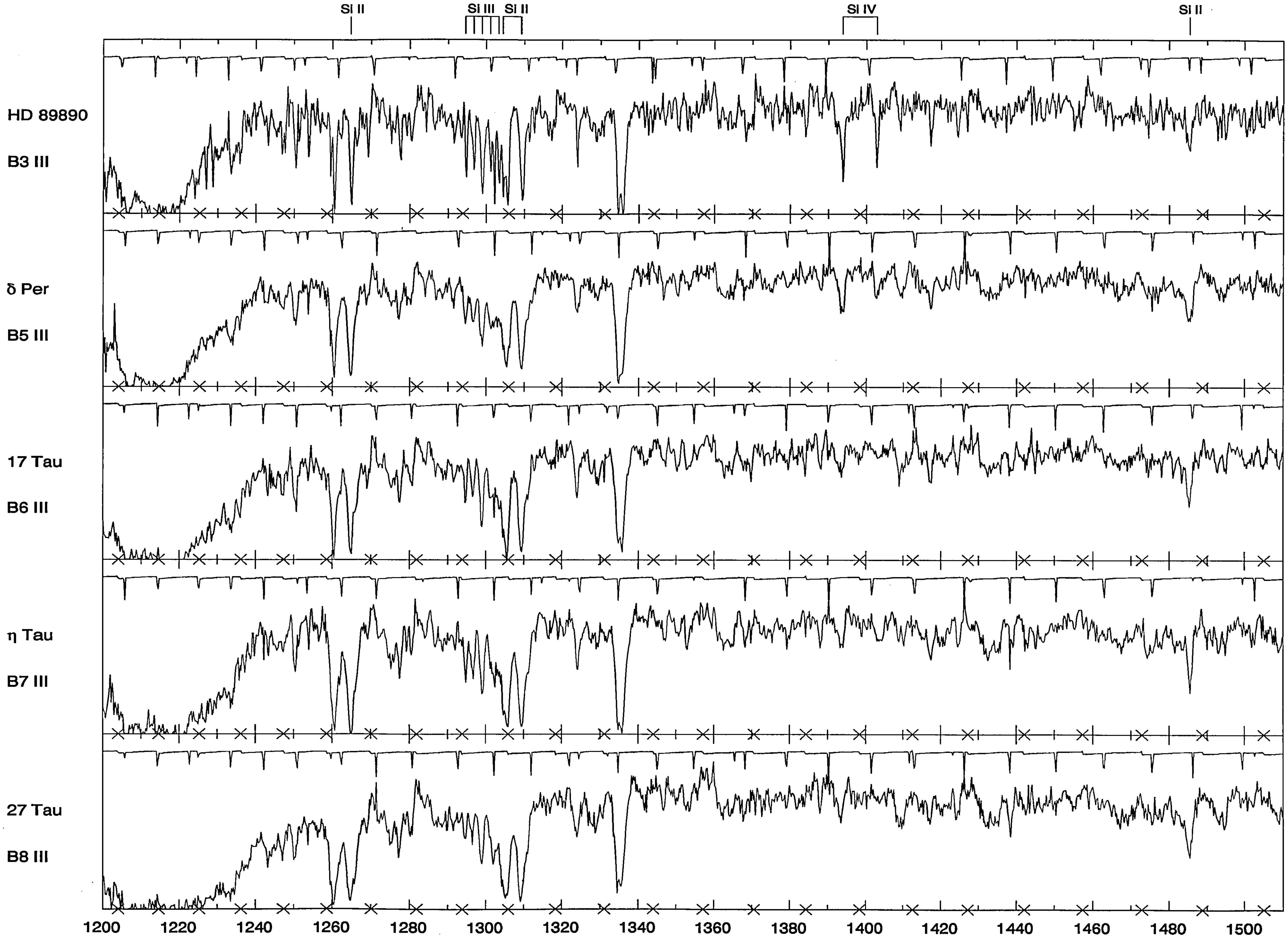


Plate 7b

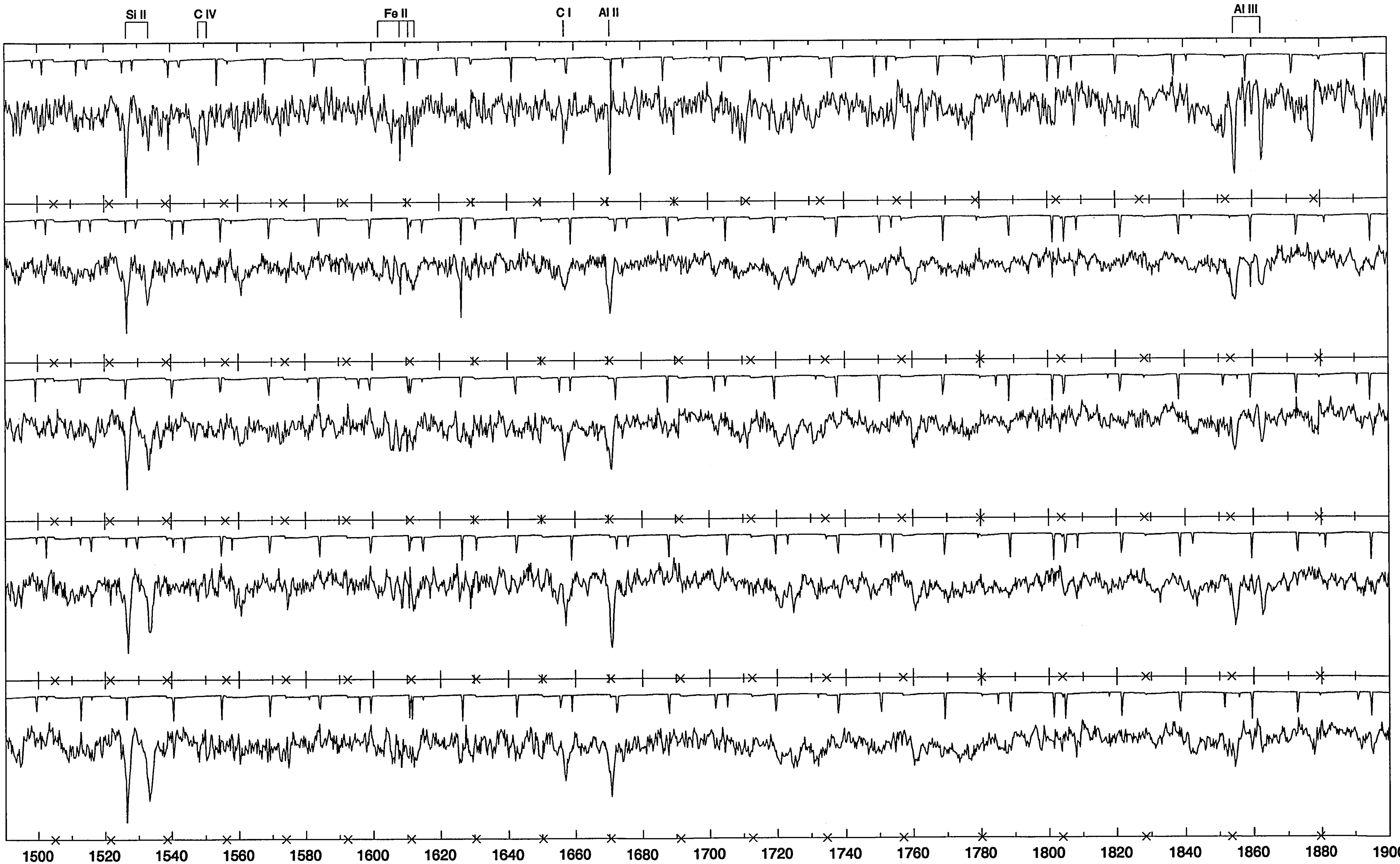

Si II
C IV
Fe II
C I
Al II
Al III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Plate 8a

Luminosity Effects
at B0

The indicated lines of C III, N IV, N III, and Al III all increase in going up the luminosity sequence from main sequence to giants. The wind lines of N V, Si IV, and C IV exhibit P Cygni profiles in giants and supergiants.

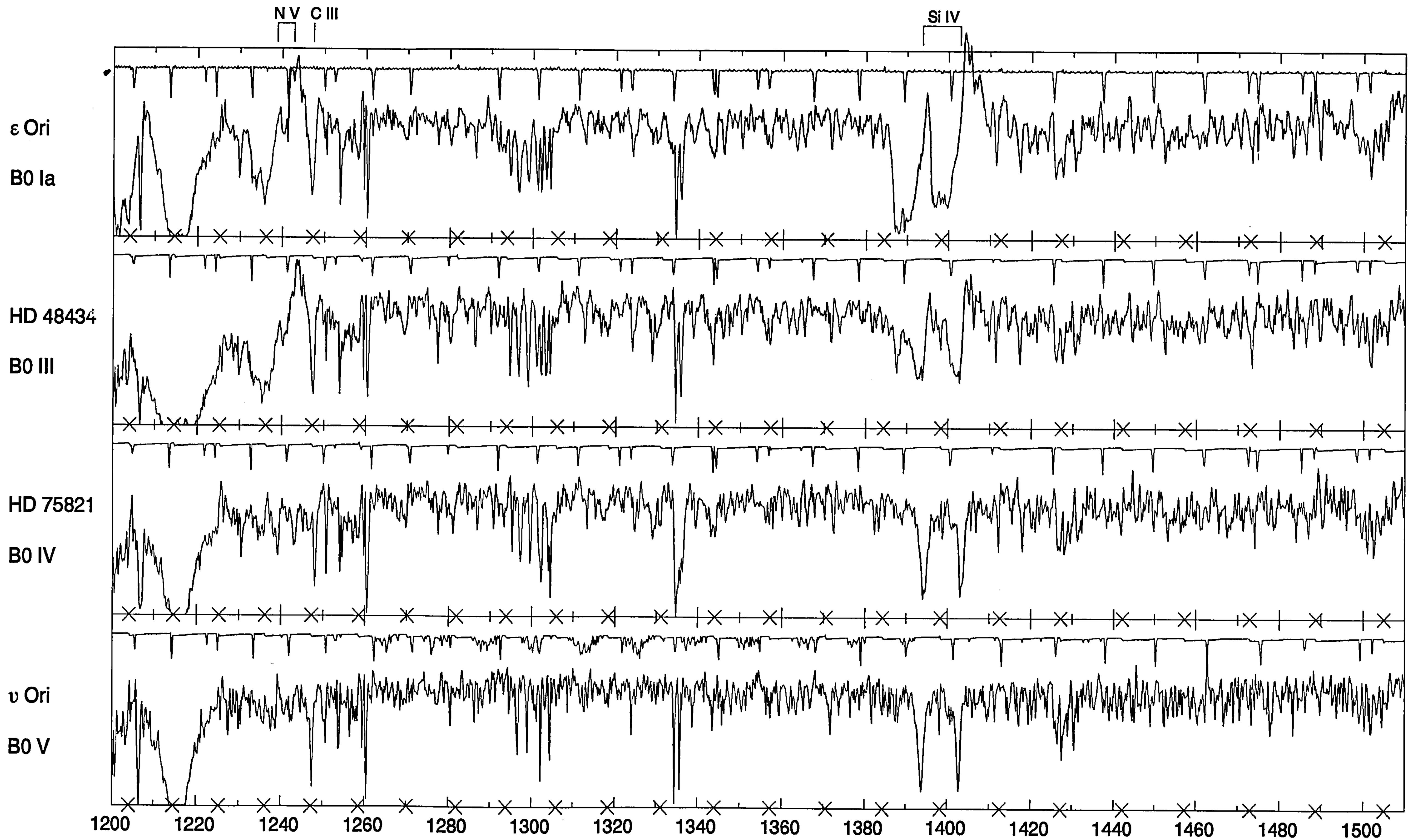


Plate 8b

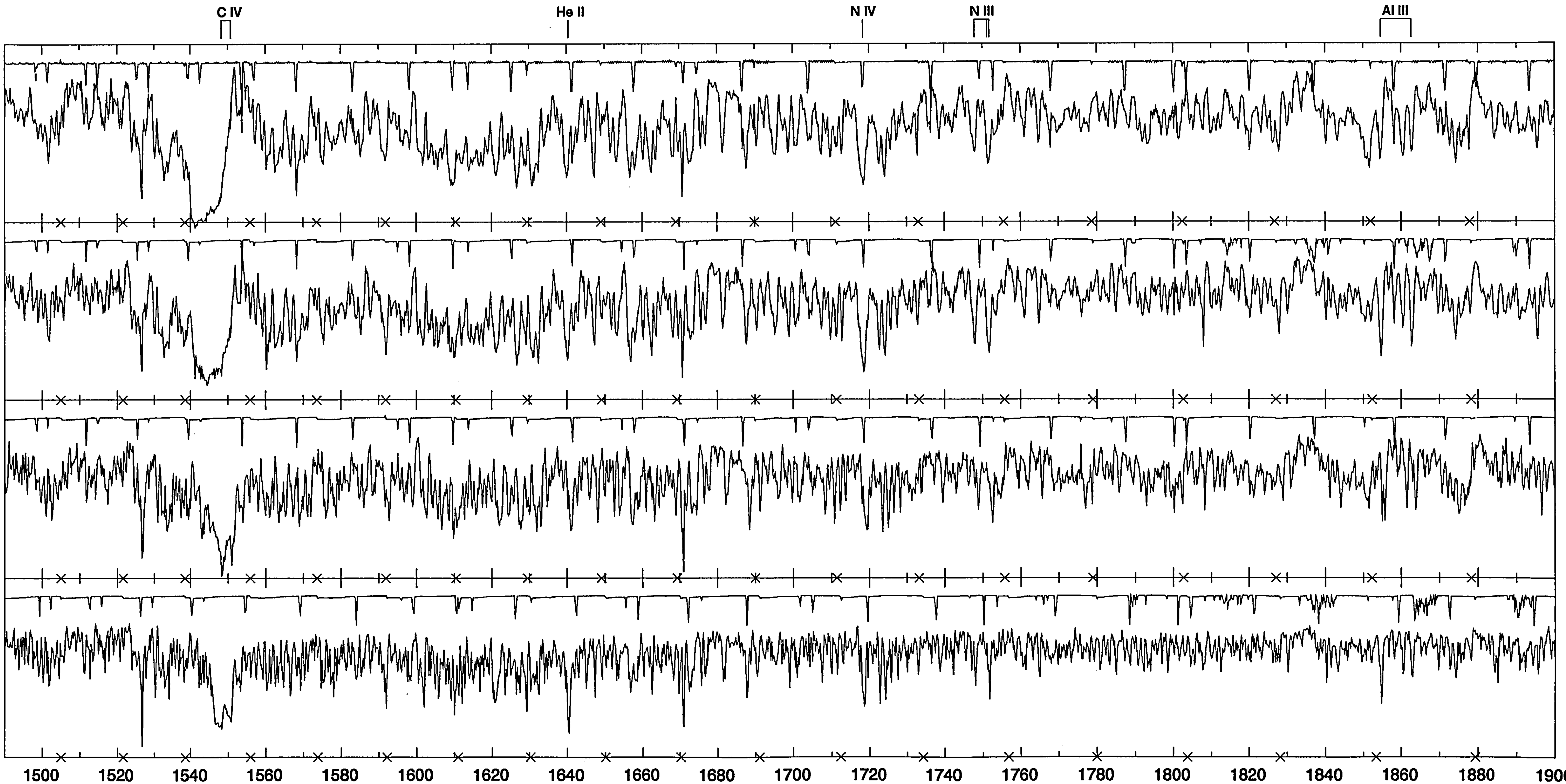

C IV
He II
N IV
N III
Al III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Plate 9a

Luminosity Effects
at B0.5

The C III, N IV, N III, and Al III lines are luminosity indicators. The stellar wind lines are in absorption, except in the supergiants.

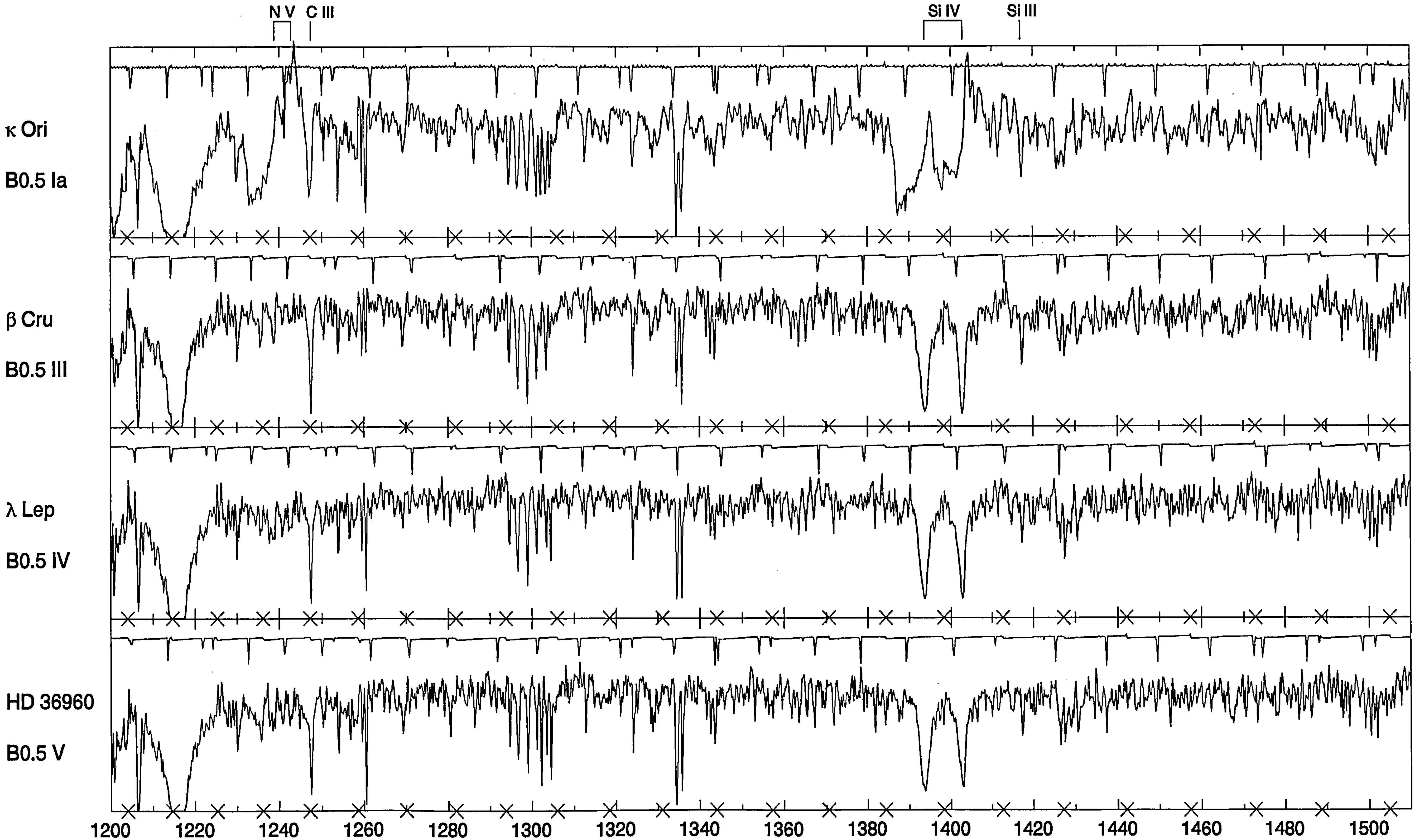


Plate 9b

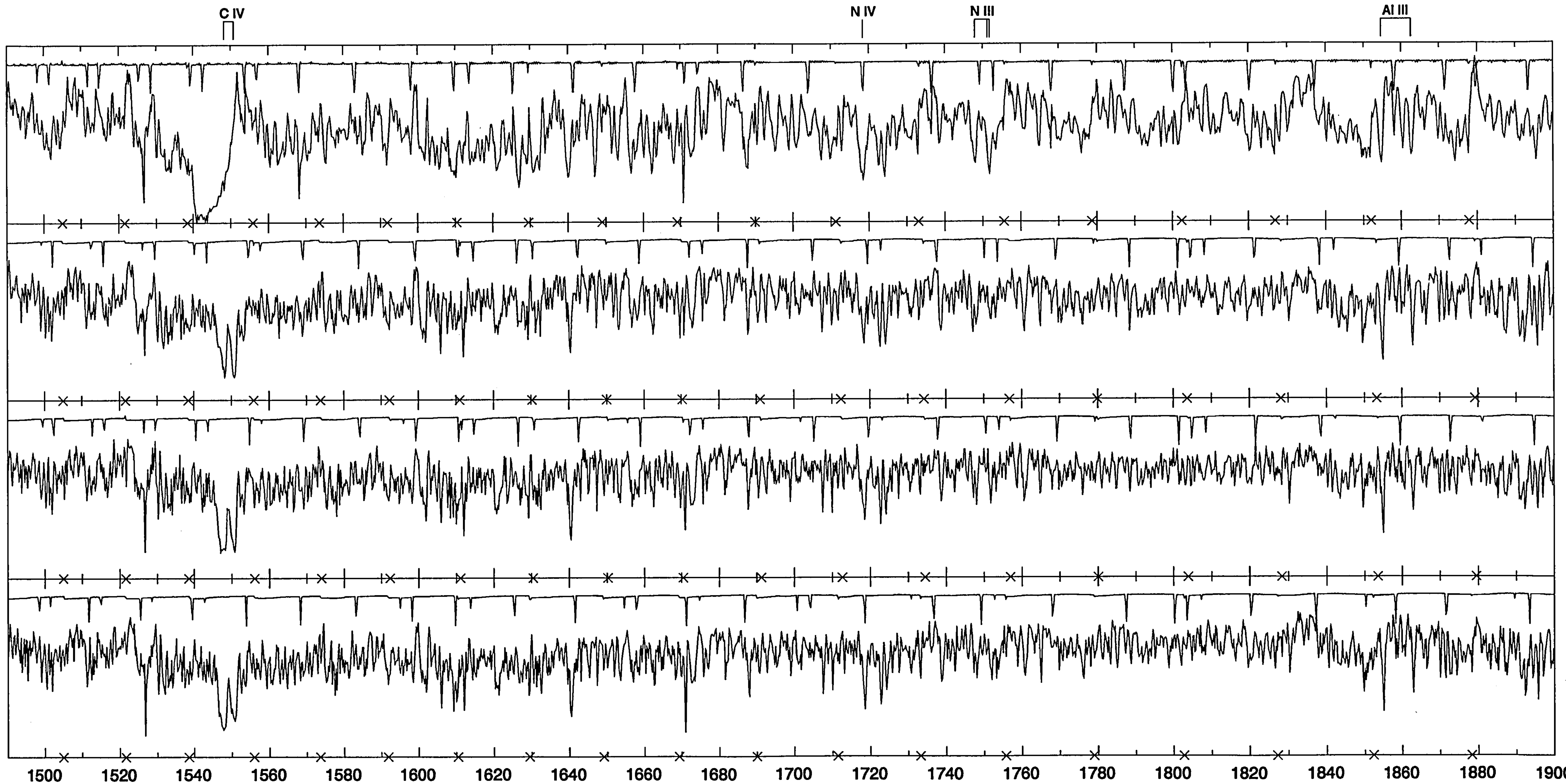

C IV
N IV
N III
Al III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Plate 10a

Luminosity Effects

at B1

The Si III multiplet at λλ1290-1300 is luminosity-sensitive in the B1—B3 spectral type range. C II, Si IV, C IV, and Al III exhibit P Cygni profiles in supergiants, but not in stars of luminosity class III—V.

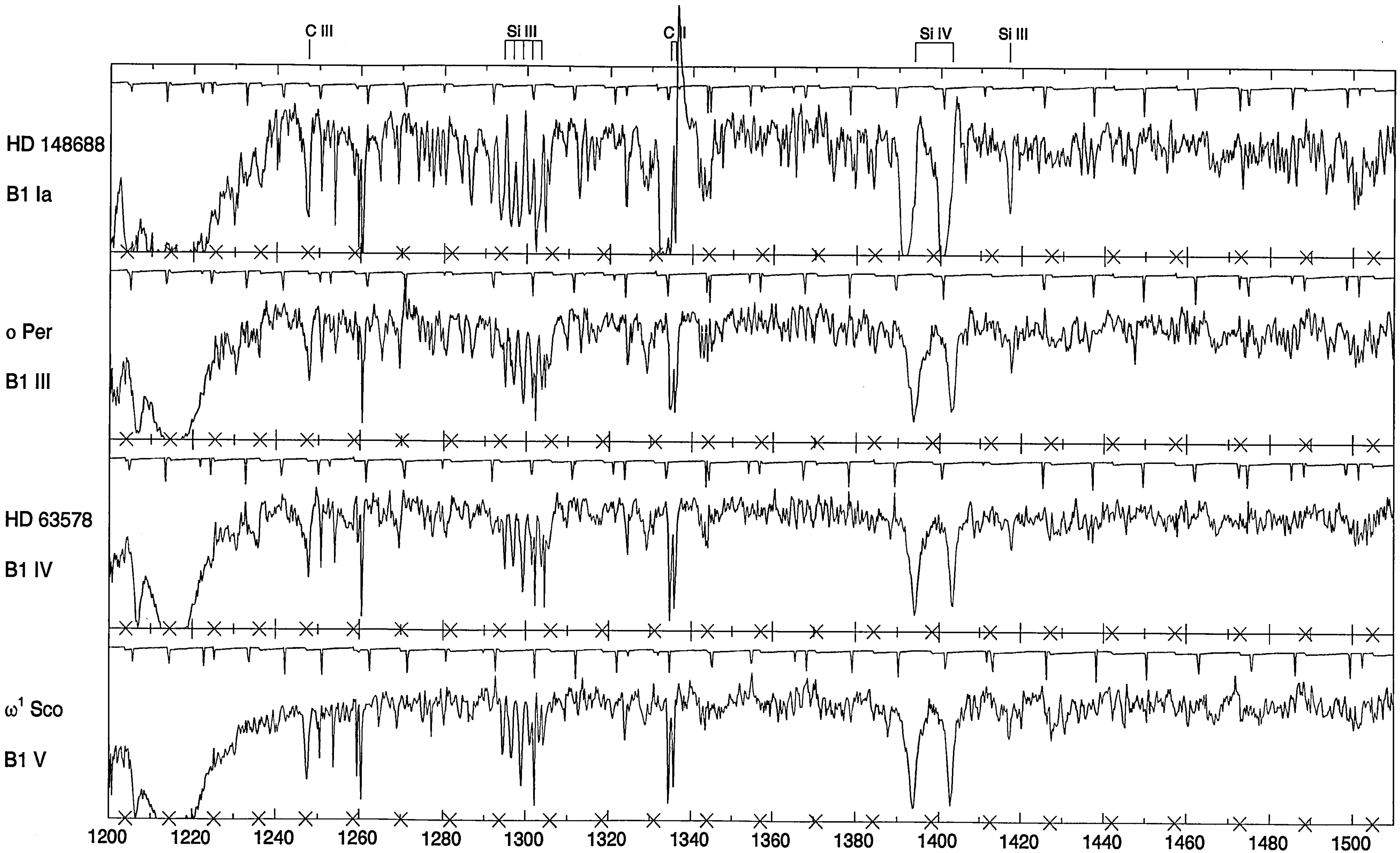
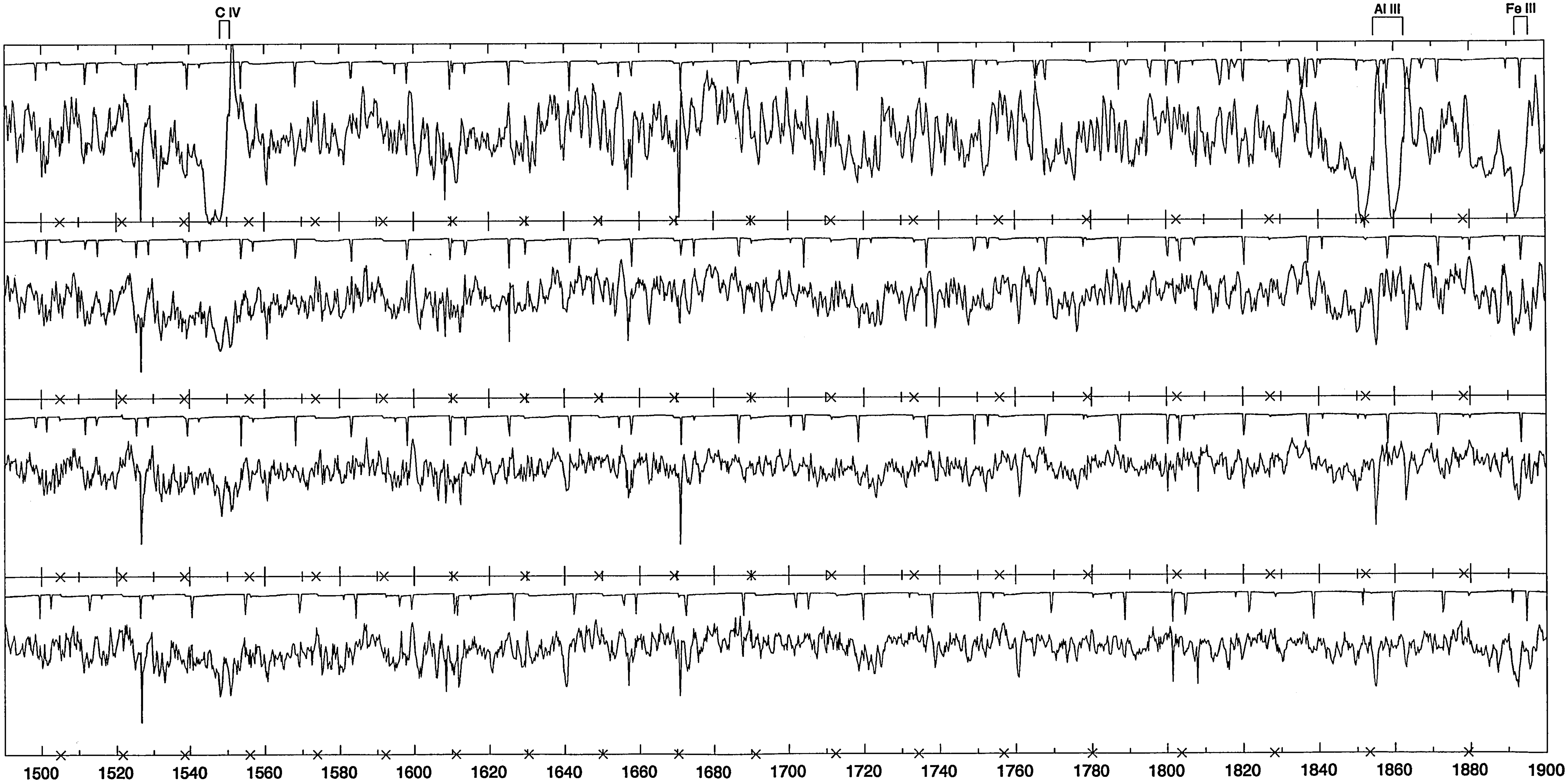


Plate 10b


C IV
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Luminosity Effects

at B2

Lines of C III, Si III, Fe II, and Fe III are luminosity indicators for main-sequence, subgiants, and giant stars at spectral type B2. C II, Si IV, C IV, and Al III exhibit P Cygni profiles in supergiants.

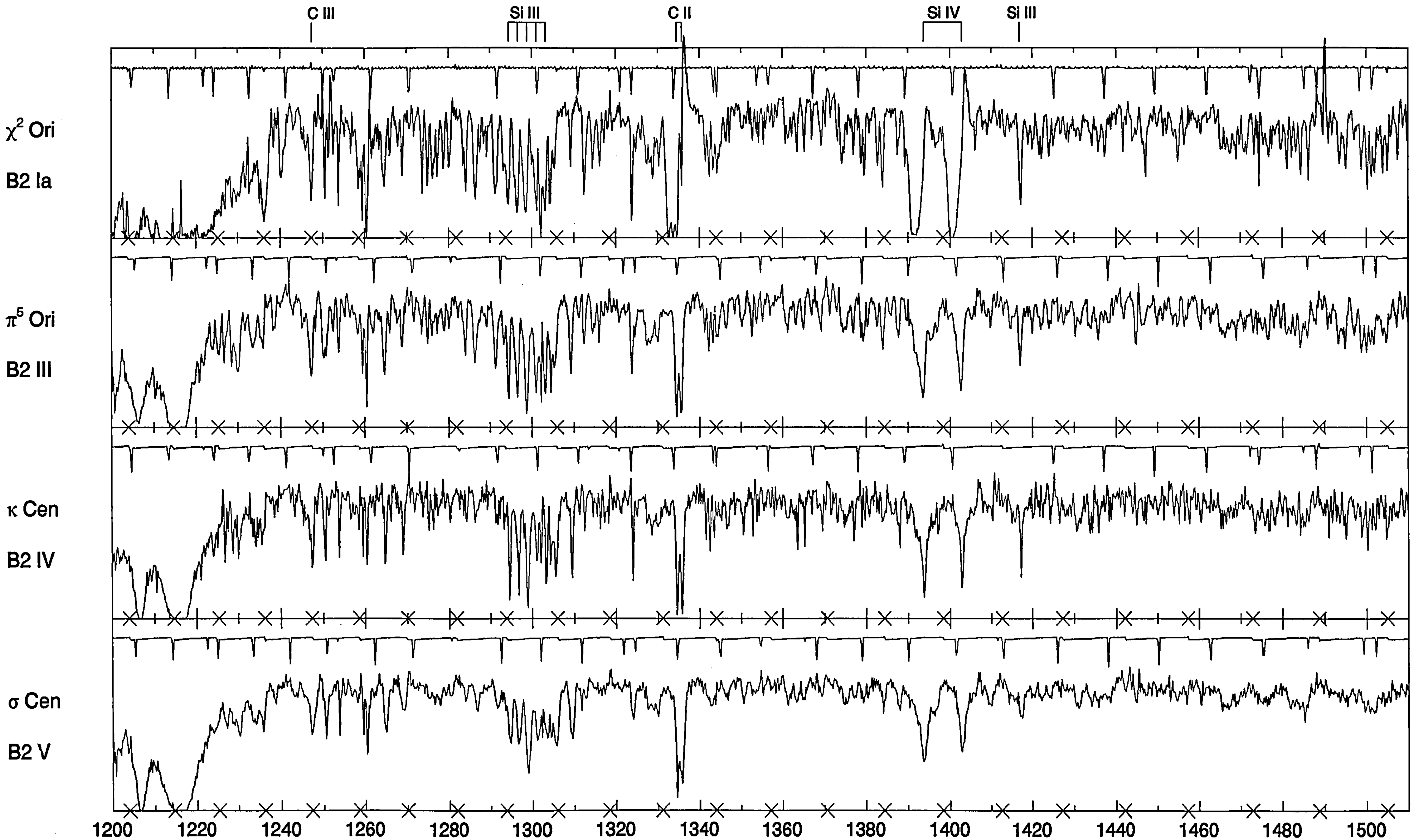


Plate 11b

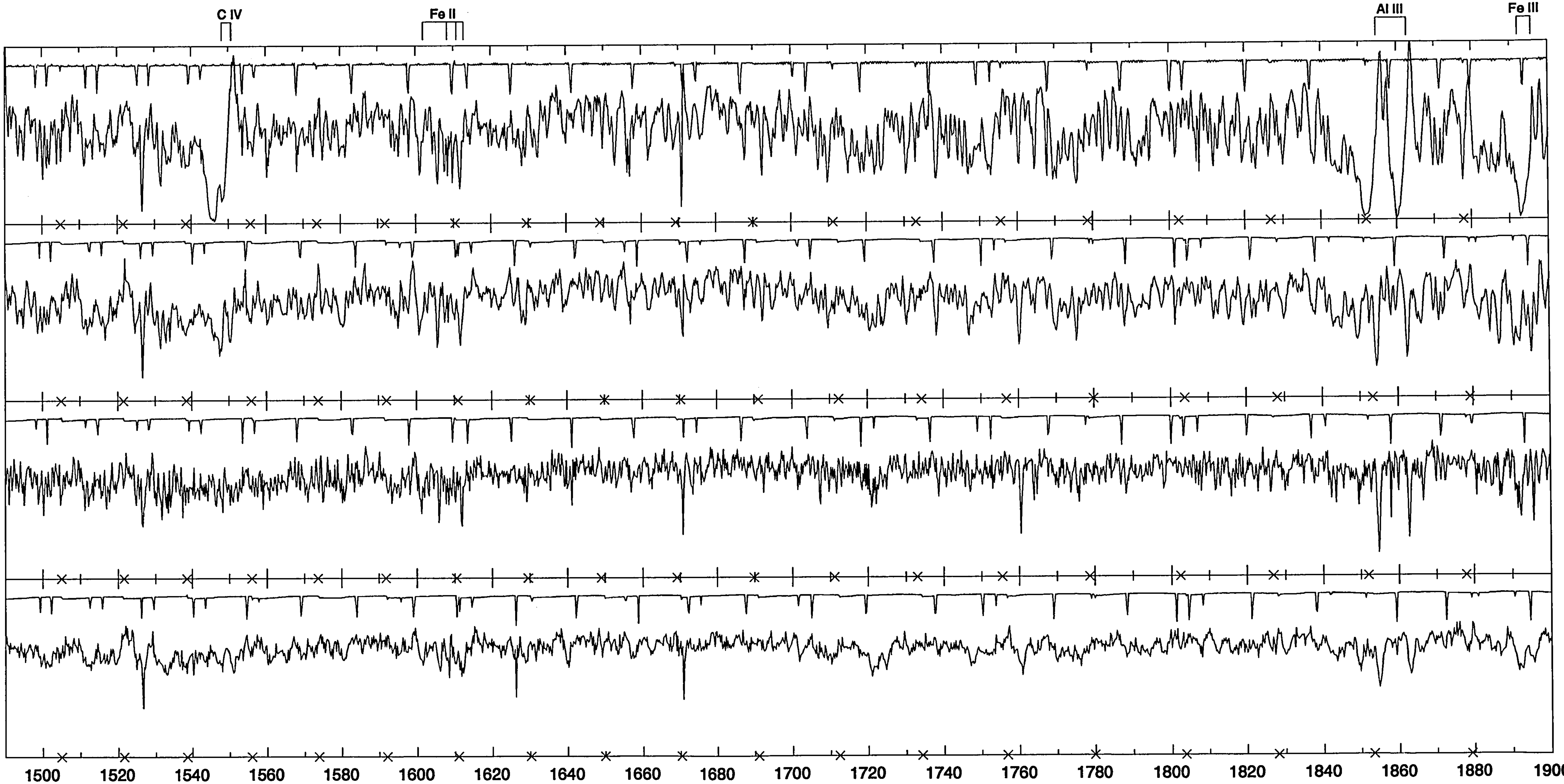

C IV
Fe II
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Plate 12a

Luminosity Effects
at B2.5

The principal luminosity indicators at spectral type B2.5 remain the lines of C III, Si III, Fe II, and Fe III. The Si II blend at λ1485 makes its first appearance at this spectral type. The supergiant wind features of C II, Si IV, C IV, and Al III are weaker than at B2.

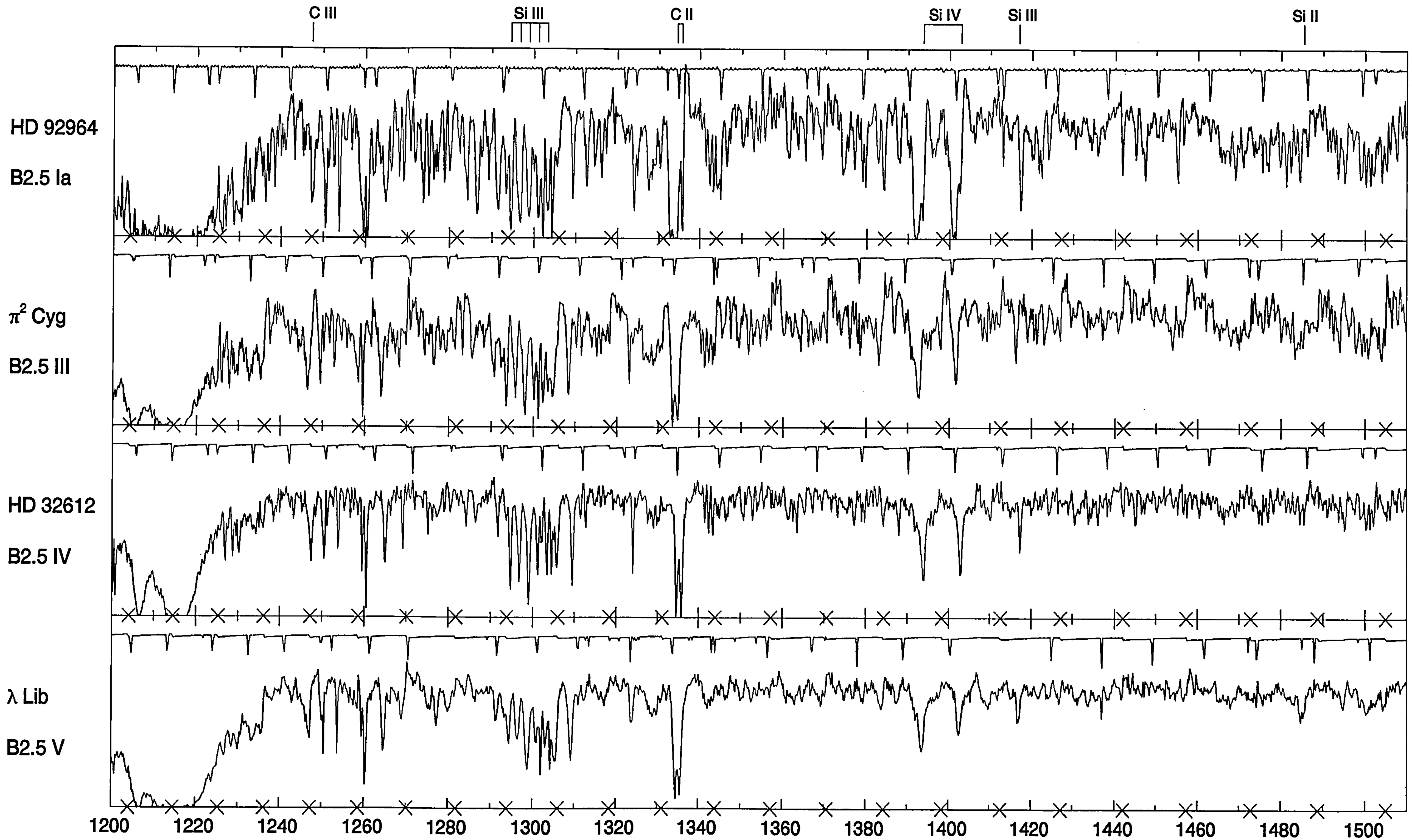
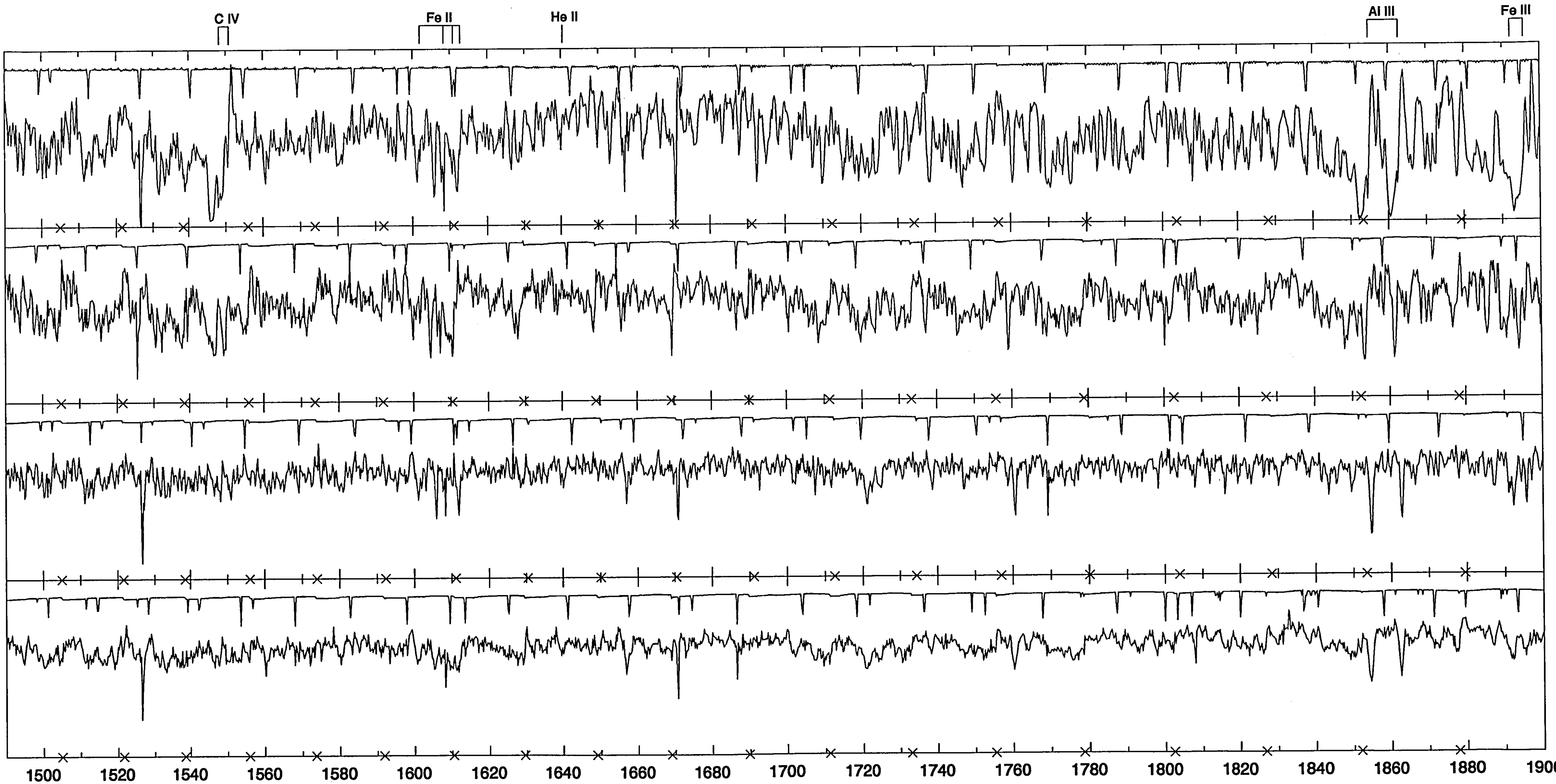


Plate 12b


C IV
Fe II
He II
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Luminosity Effects
at B3

Lines of C III, Si III, Fe II, and Fe III remain luminosity-sensitive at type B3, but show less variation than at earlier types. The most prominent wind feature in B3 supergiants is C IV λλ1548, 1550.

Plate 13a

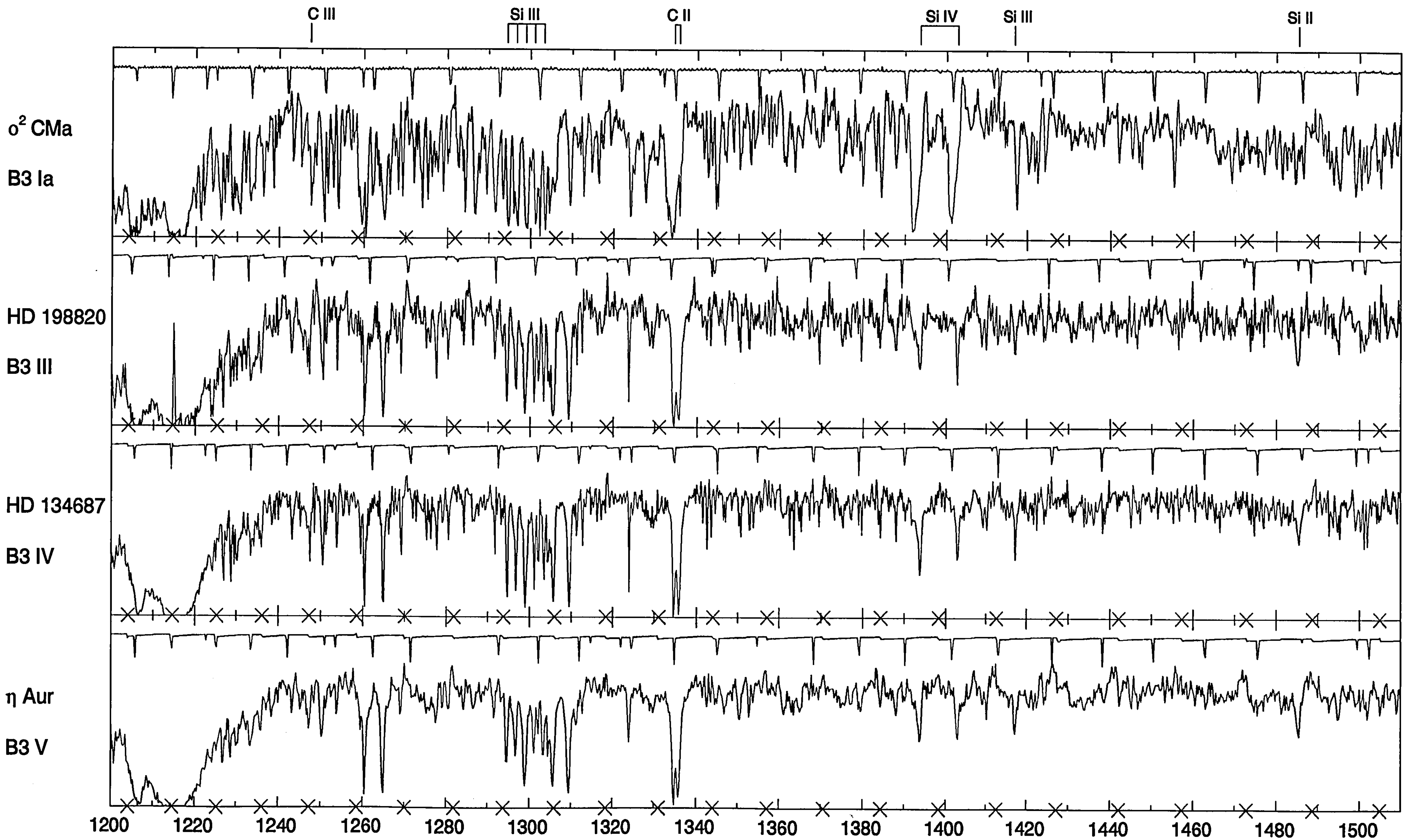
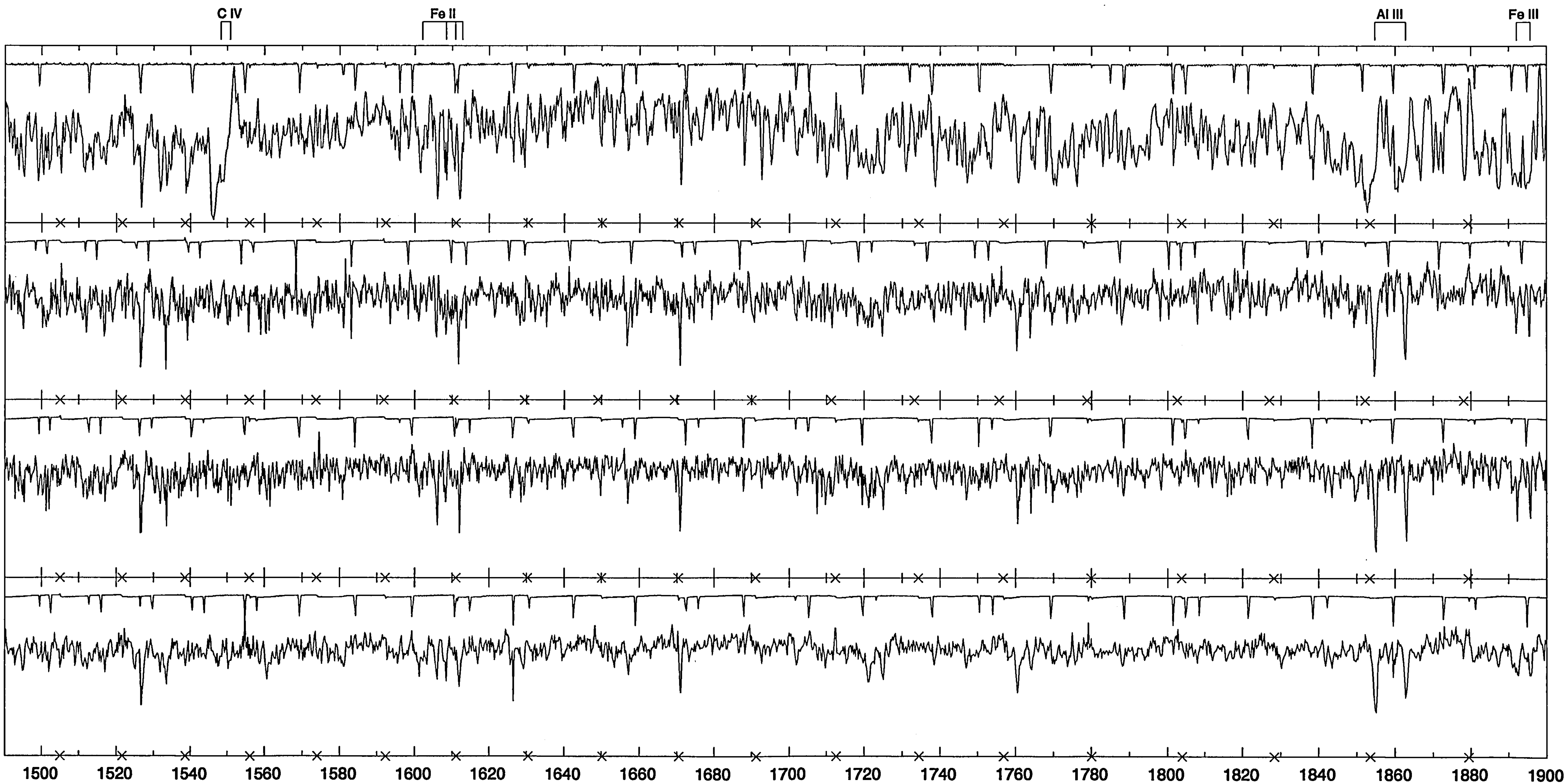


Plate 13b


C IV
Fe II
Al III
Fe III
1500
1520
1540
1560
1580
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1620
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1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Plate 14a

Luminosity Effects

at B5

Lines of Si II, Si III and Al III are luminosity indicators for classes III, IV, and V. In the supergiants, the wind lines of C II, Si IV, C IV, and Al III are in absorption.

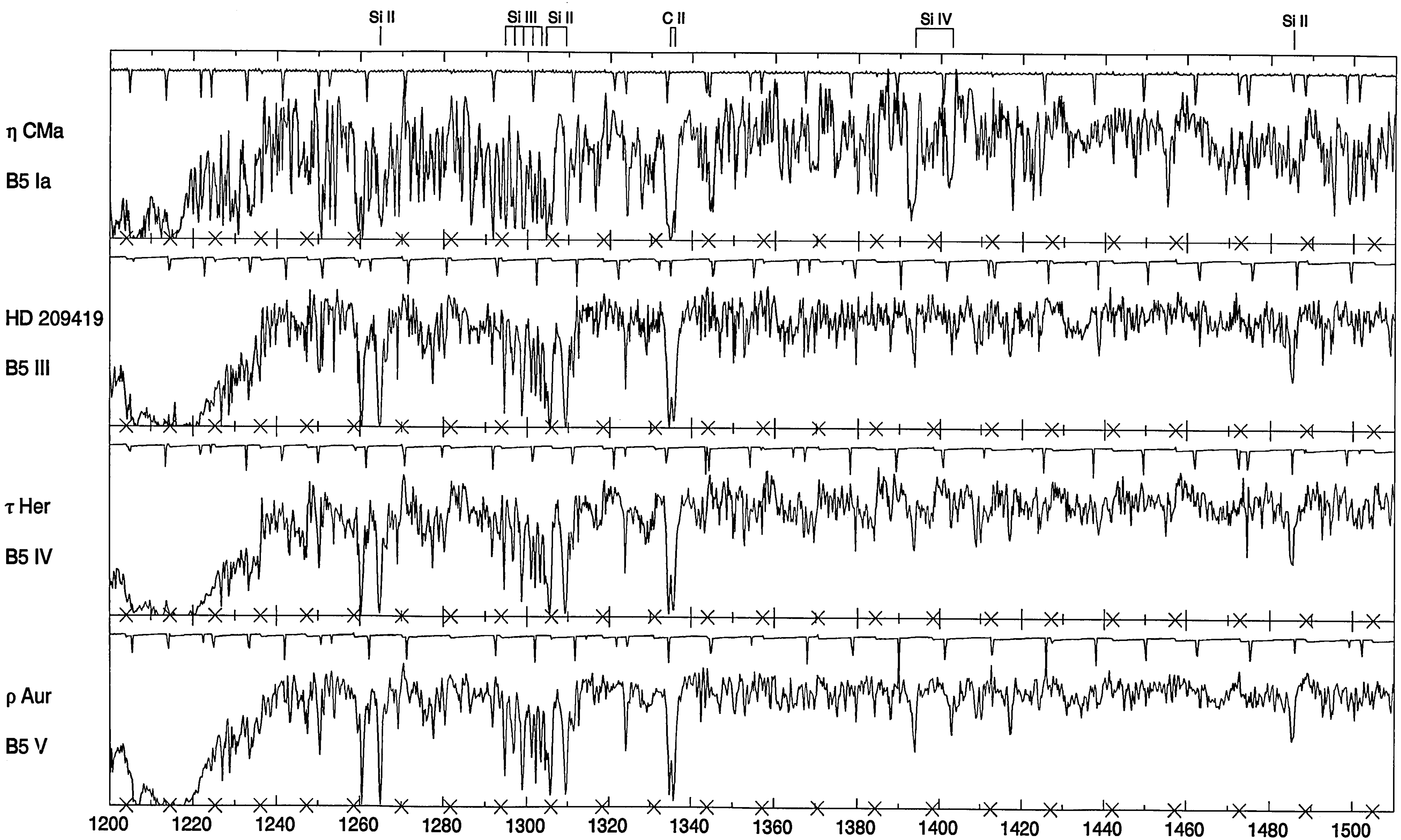
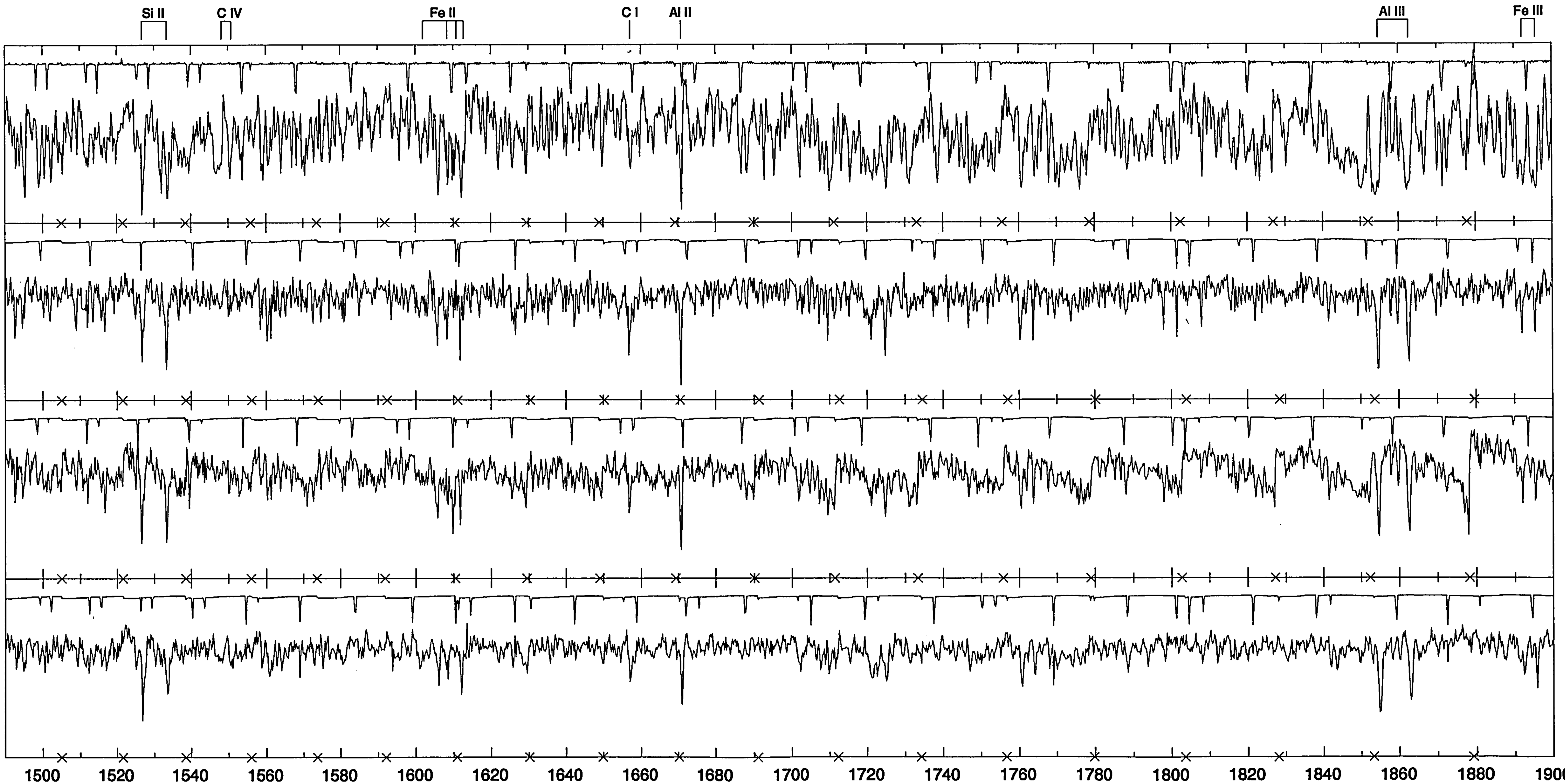


Plate 14b


Si II
C IV
Fe II
C I
Al II
Al III
Fe III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Part 2

Effects of Stellar Rotation

Rotation Effects

at B0.5

With the exception of Si IV and C IV, all the marked spectral lines in these stars are photospheric. They are broader and shallower in the rapid rotators HD 135160 and δ Sco than in the slow rotators HD 36960 and λ Lep. Both width and depth must be taken into account in estimating the strength of these lines for classification purposes.

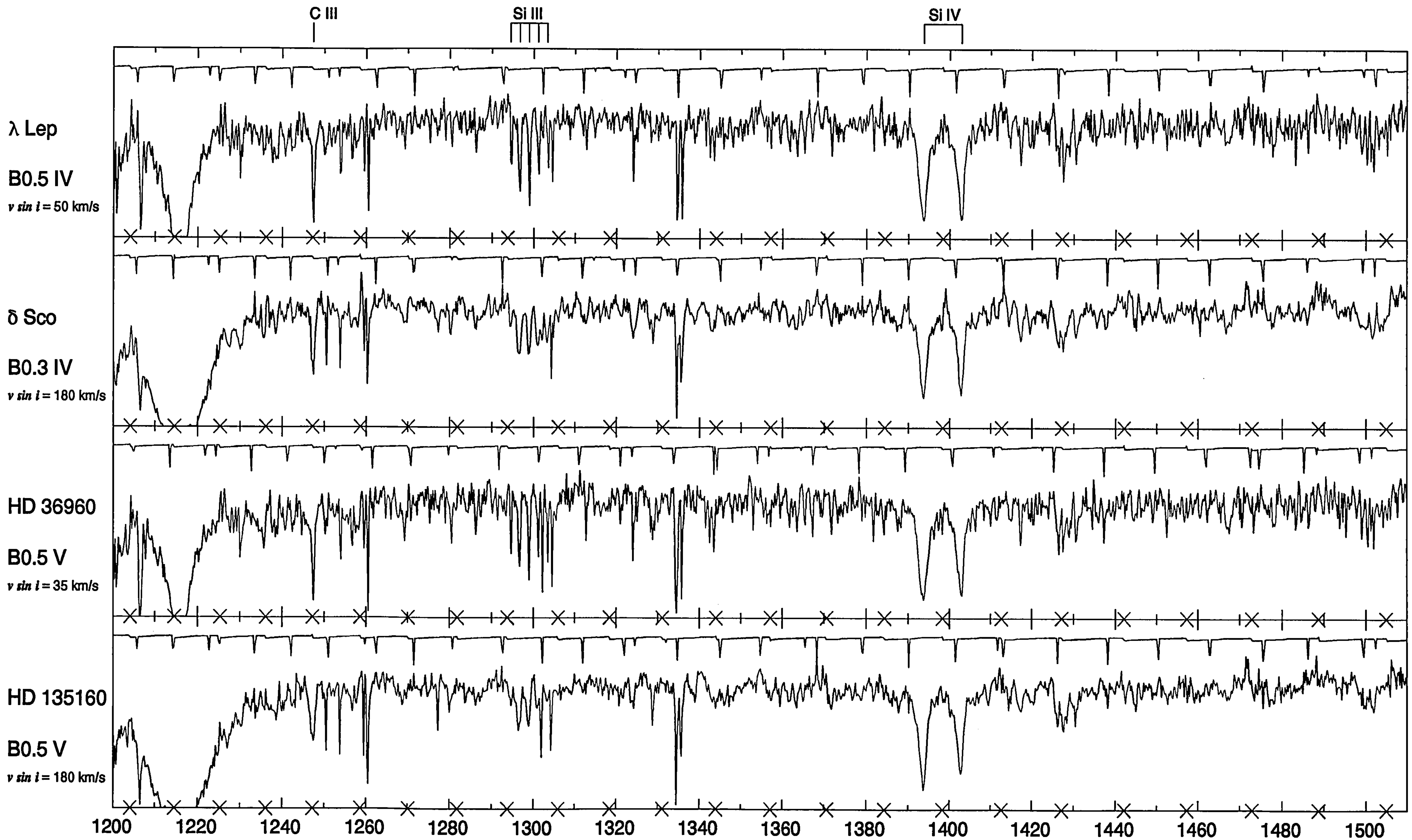


Plate 15b

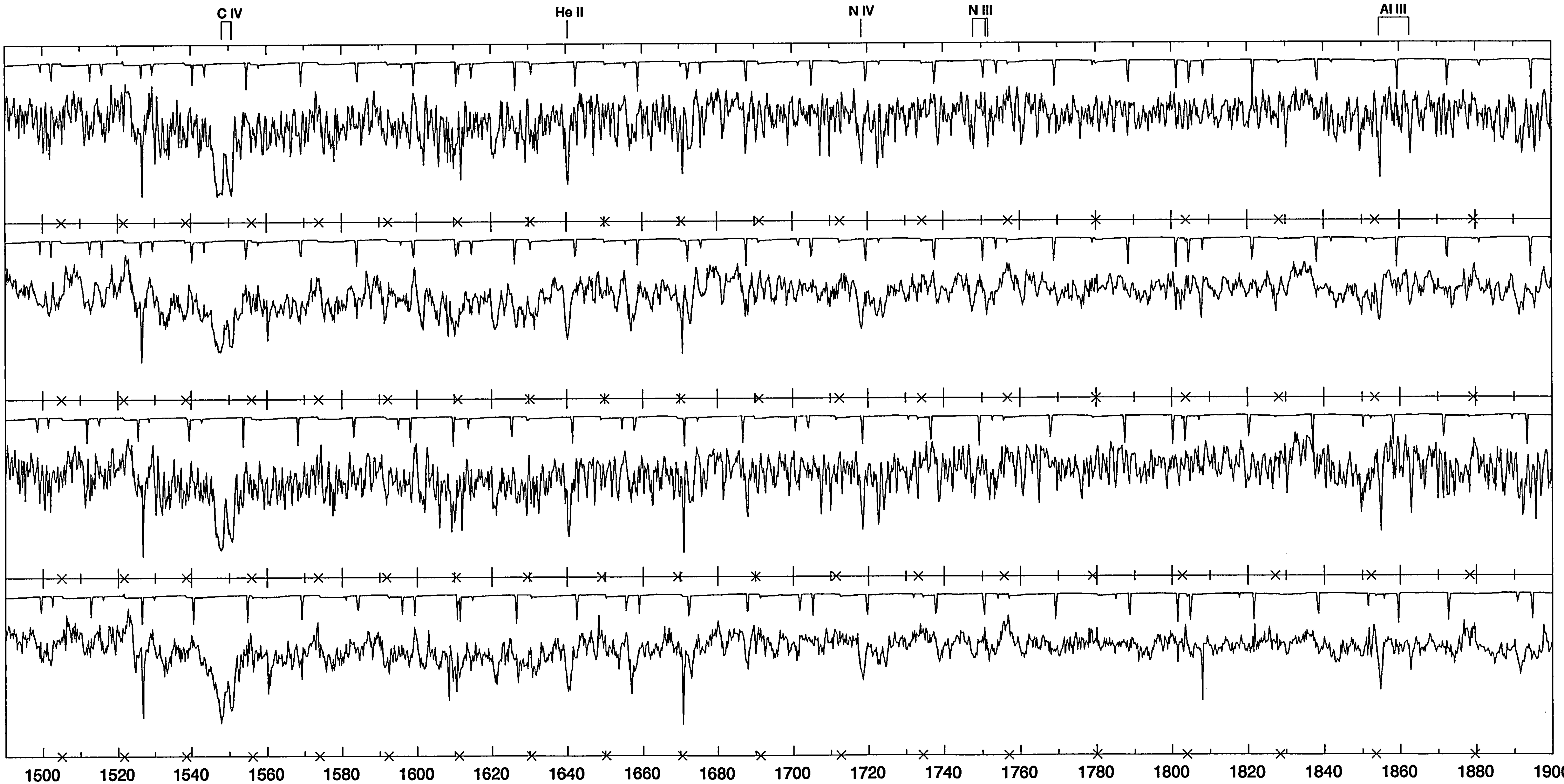

C IV
He II
N IV
N III
Al III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

Plate 16a

Rotation Effects

B1 - B1.5 Main Sequence

Unlike the photospheric and stellar wind lines, the interstellar lines are unaffected by rotation. They are easily picked out in the stellar spectra of rapid rotators HD 154445 and HD 37303 by their very sharp profiles. Some lines, e.g. Si II λ1526, have both stellar ind interstellar components.

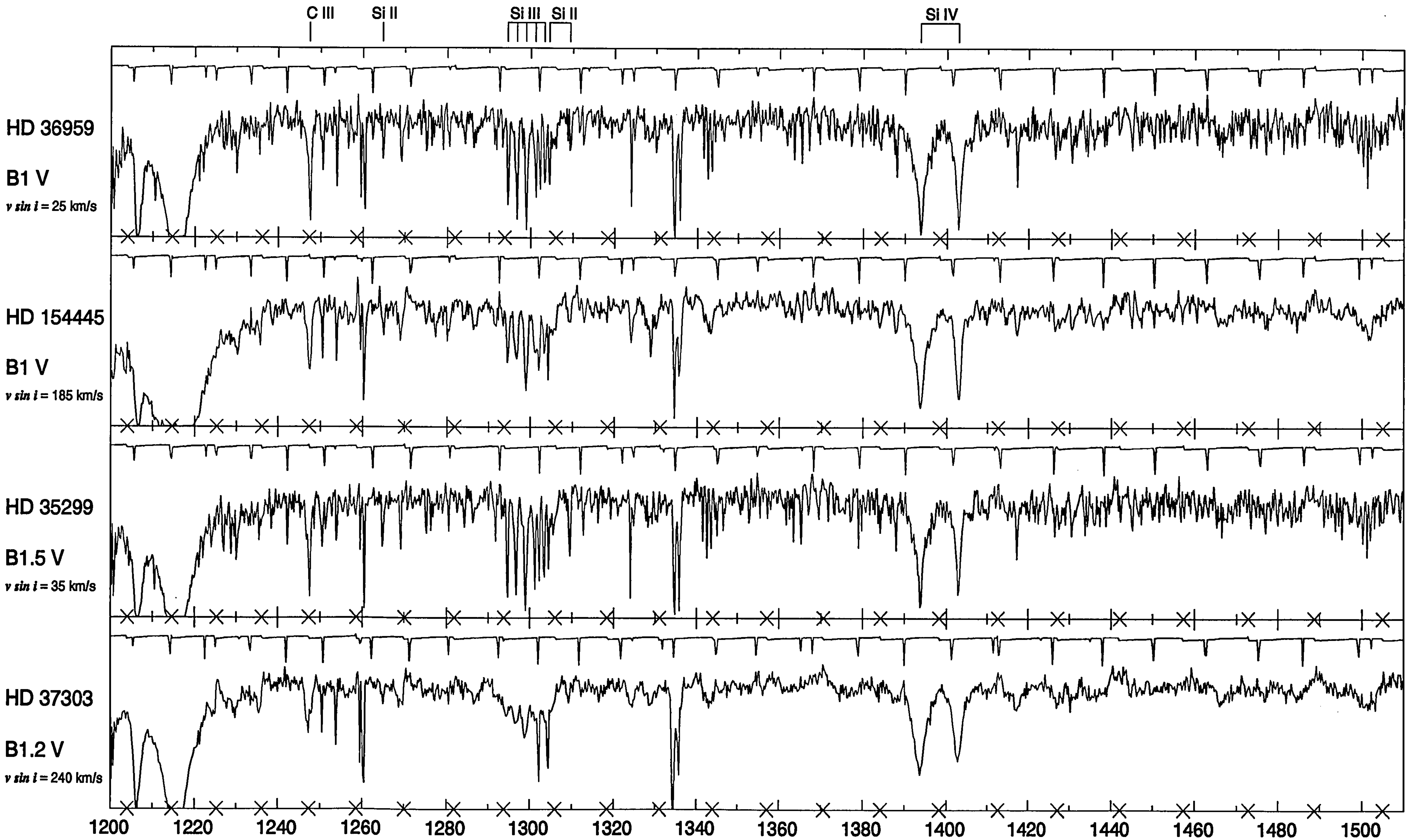


Plate 16b

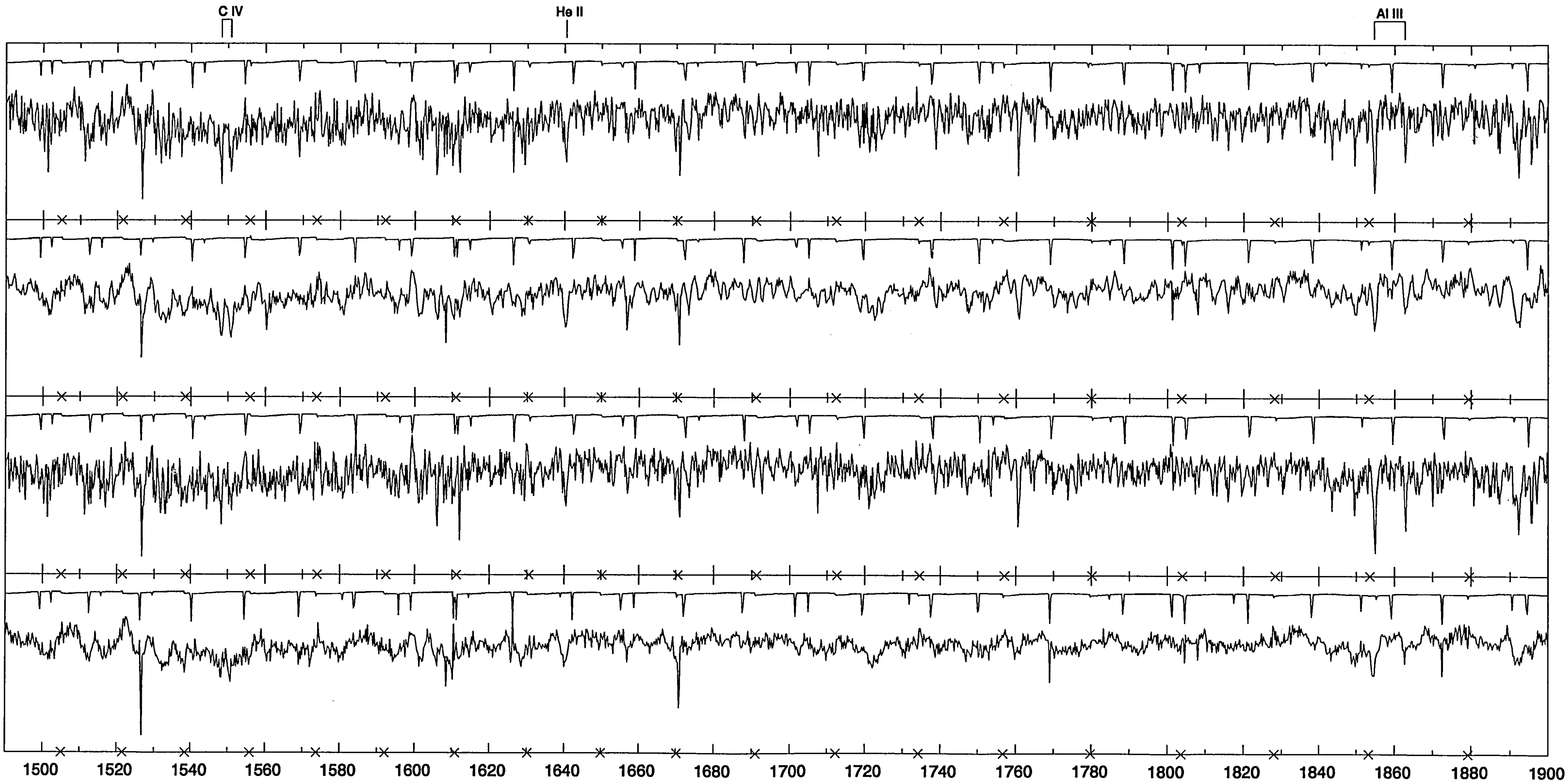
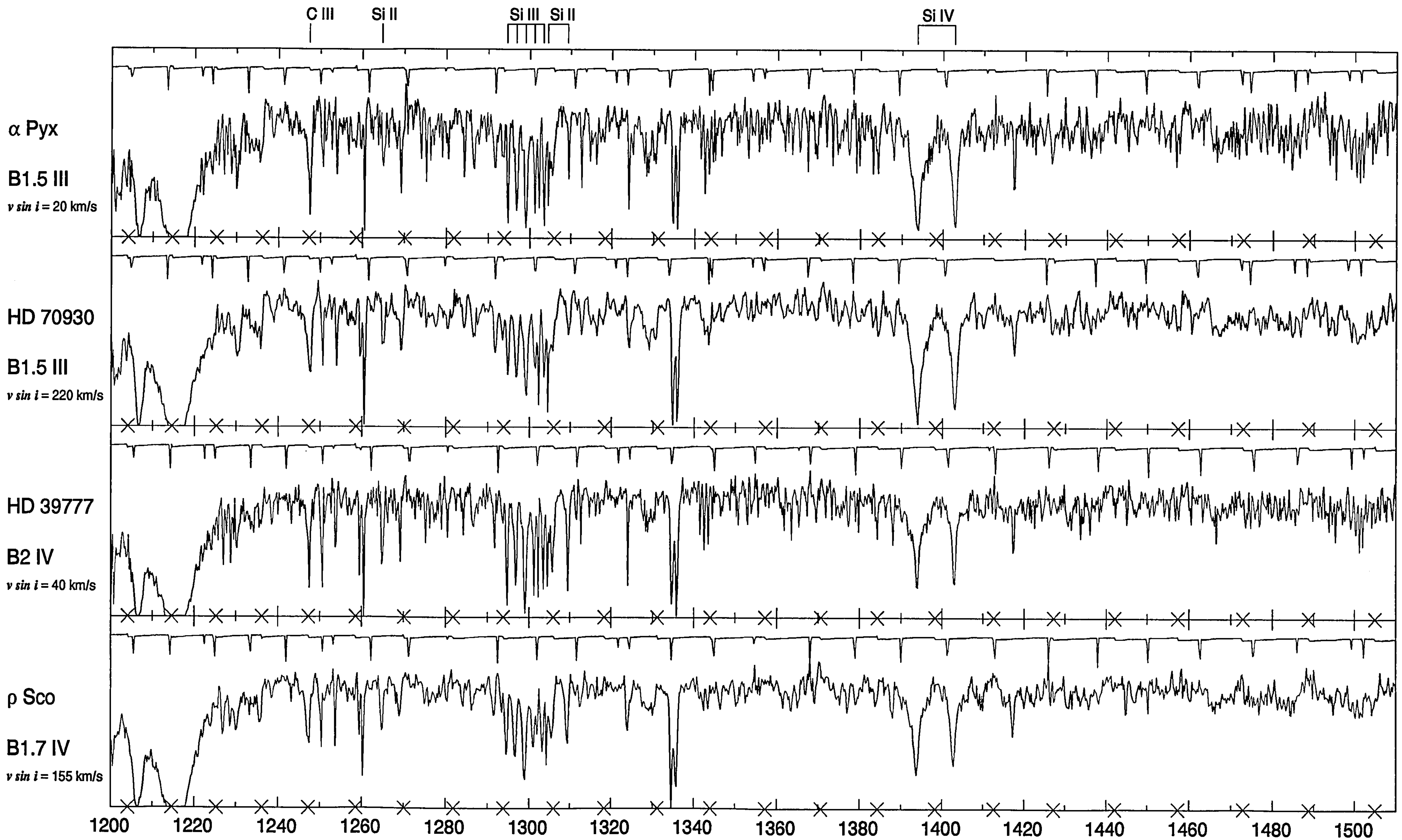

C IV
He II
Al III
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880
1900

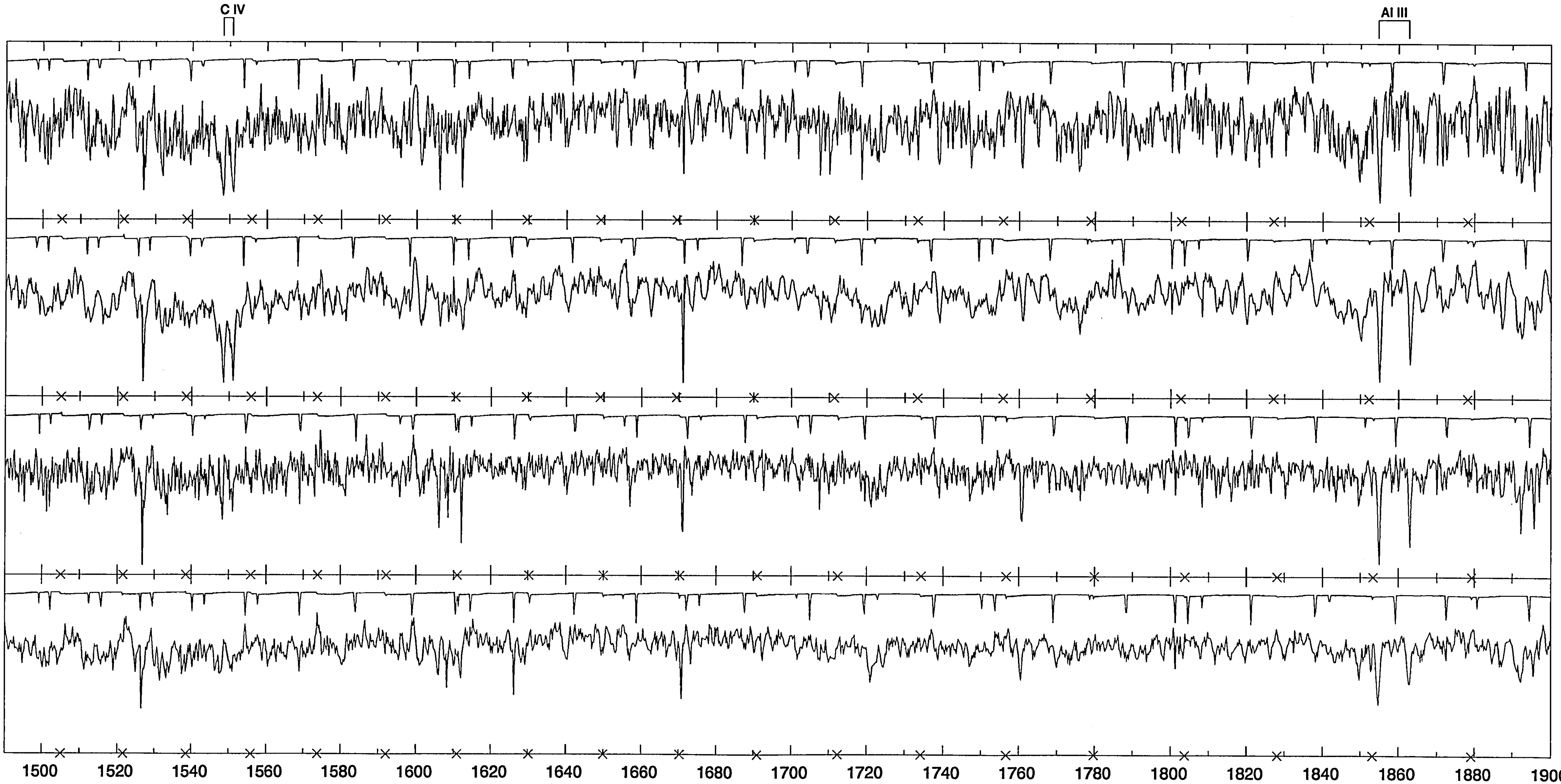
Plate 17a

Rotation Effects

B1.5 - B2 Giants and Subgiants

Rotation effects tend to be less pronounced for stars above the main sequence, but they can produce apparent differences in the signal-to-noise ratio (S/N). Note that the instrumental S/N is about 30 for all the digital plots in this Atlas.




C IV
Al III
1500
1520
1540
1560
1580
1600
1620
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1880
1900

Rotation Effects

B2.5 - B3 Subgiants

Line broadening can pose a less severe problem for the classification of the mid-B stars, where the stellar wind is weak and the photospheric Si II lines are not yet saturated. For example, HD 150745, with a *v sin i* of 285 km/s, is one of the fastest rotators in this program, yet its spectrum is quite comparable to that of the moderate rotator δ Ori B.

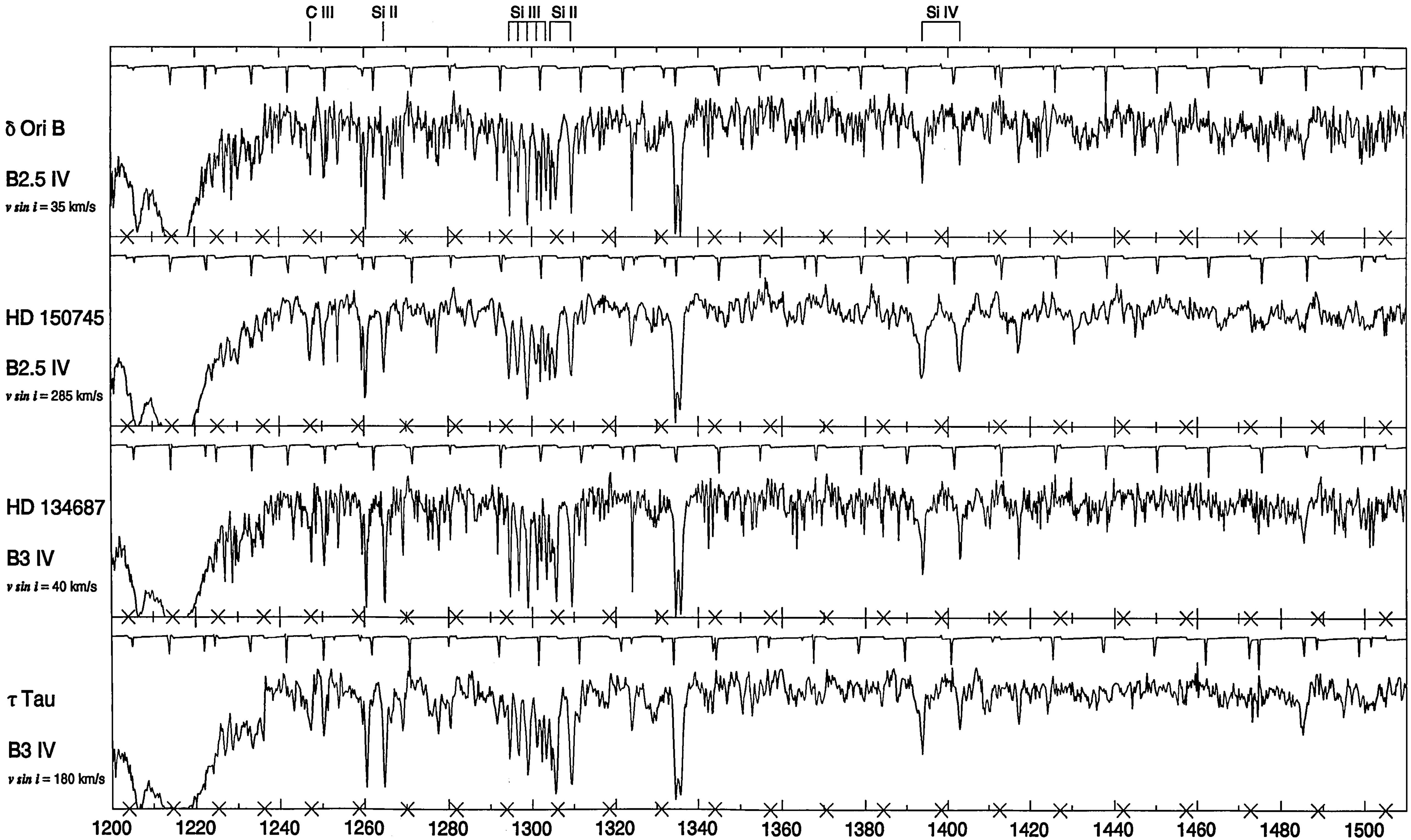
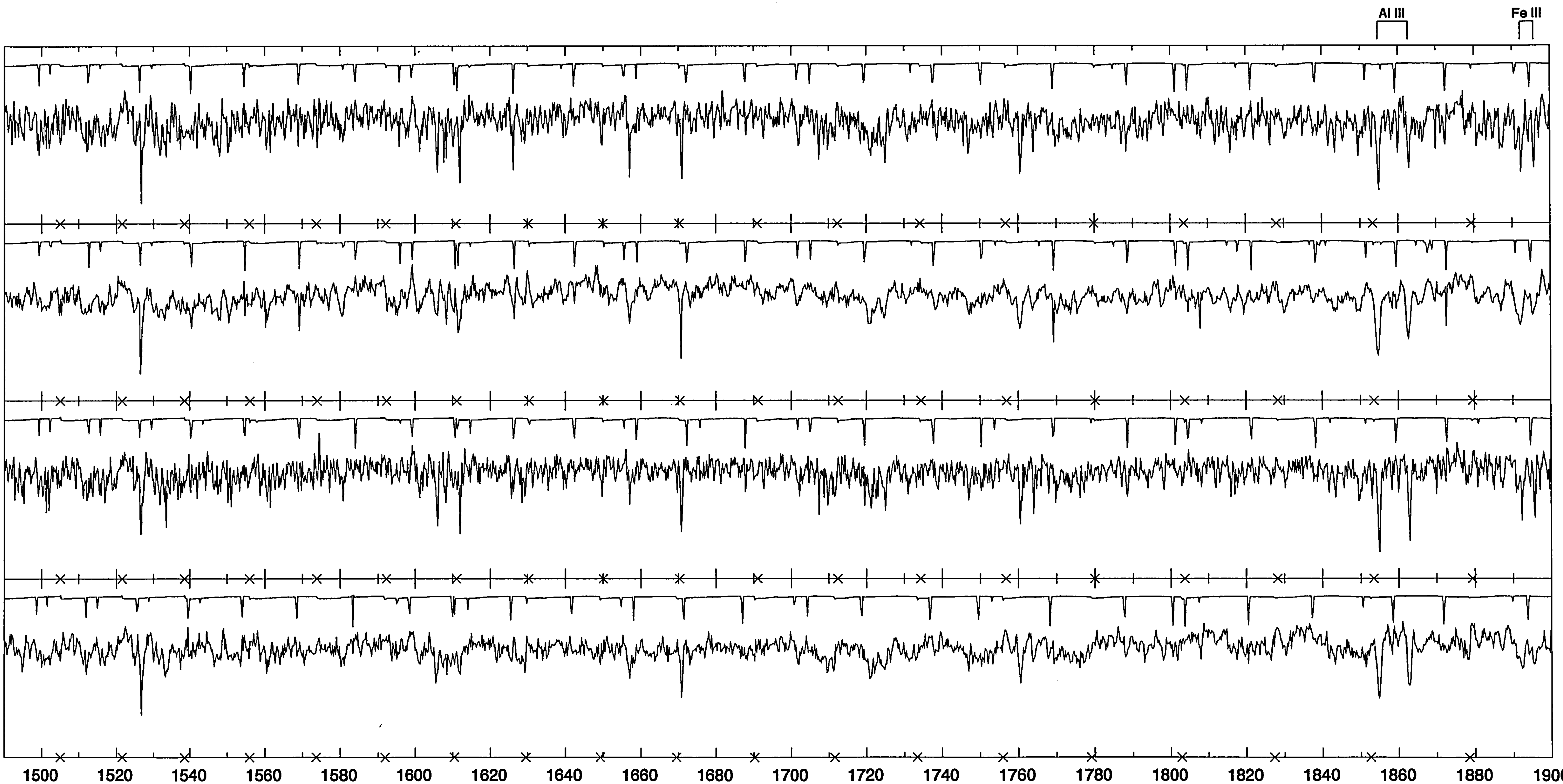


Plate 18b


Al III
Fe III
1500
1520
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1620
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Plate 19a

Rotation Effects

B5 - B6 Giants and Subgiants

The spectrum of the late B stars is dominated by lines of Si II, whose relative strength is the principal classification criterion. In order to ensure that both depth and width of the lines are accurately taken into account, it is useful to have both broad-lined and narrow- lined standard spectra.

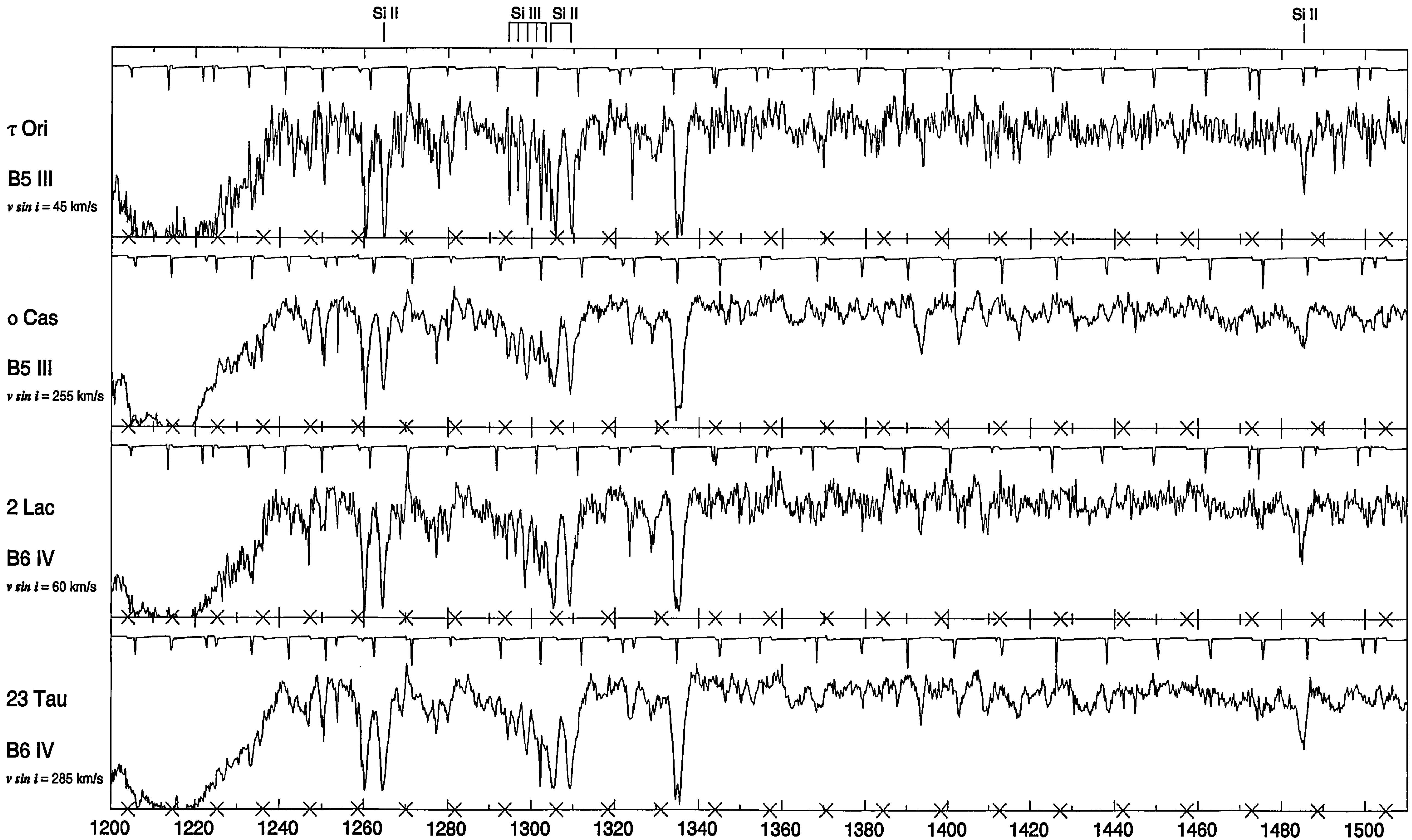
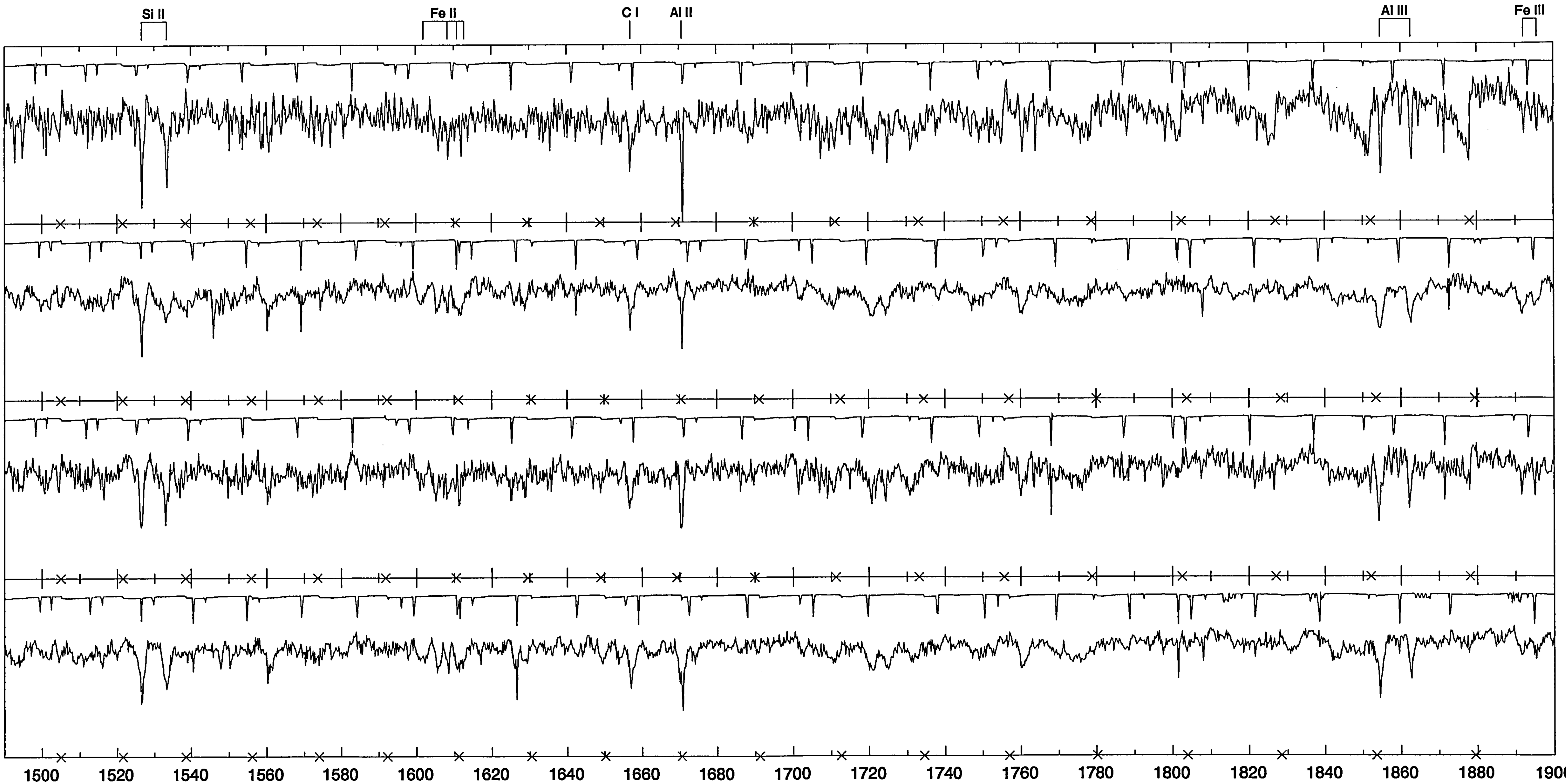


Plate 19b


Si II
Fe II
C I
Al II
Al III
Fe III
1500
1520
1540
1560
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1640
1660
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1700
1720
1740
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1780
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1880
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Plate 20a

Rotation Effects

B6 - B7 Giants

Many of the late B giant standards, including 16 Tau, 17 Tau, and η Tau, are members of the Pleiades cluster. This cluster is a particularly good source of broad-lined standards, although narrow-lined stars are found there also.

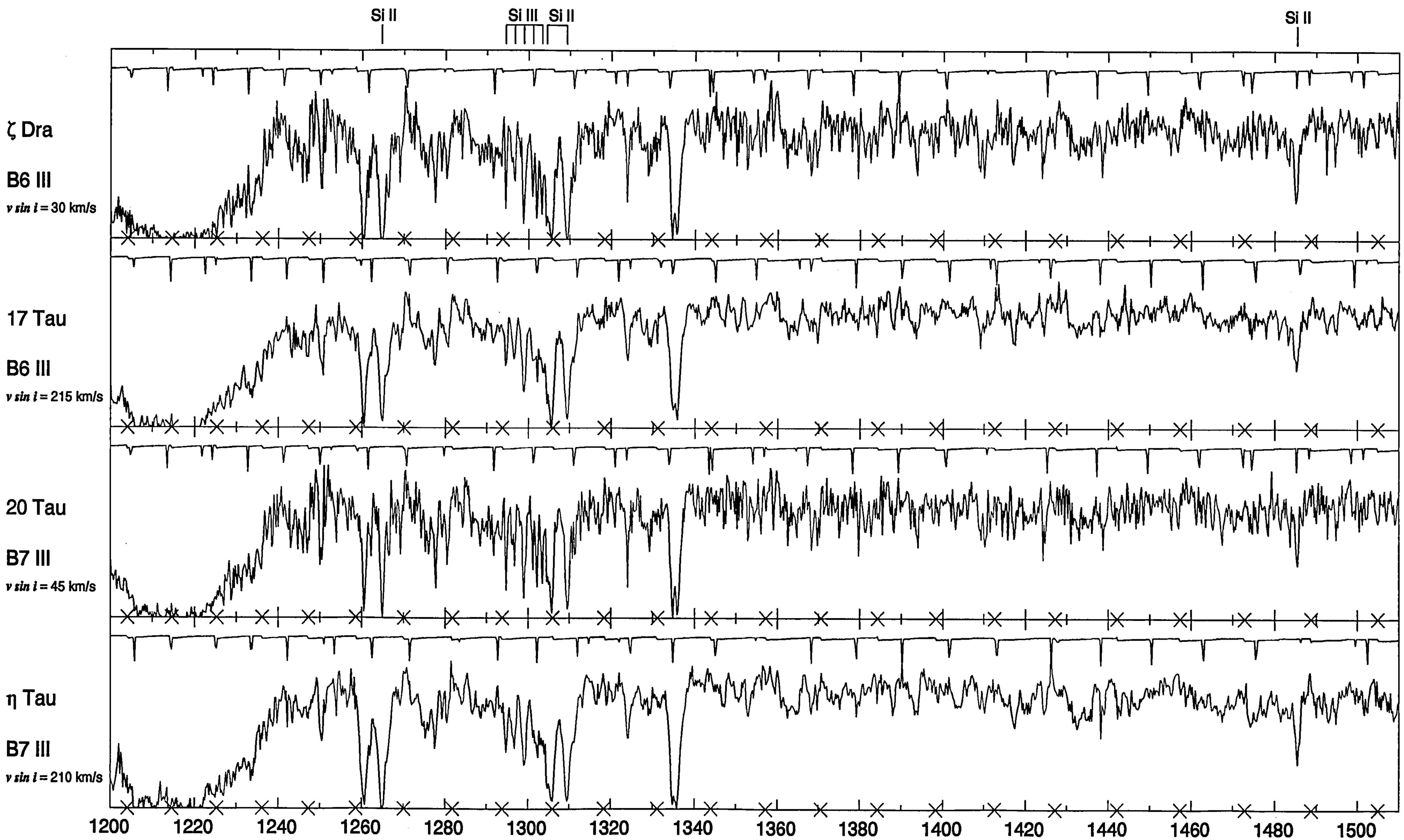
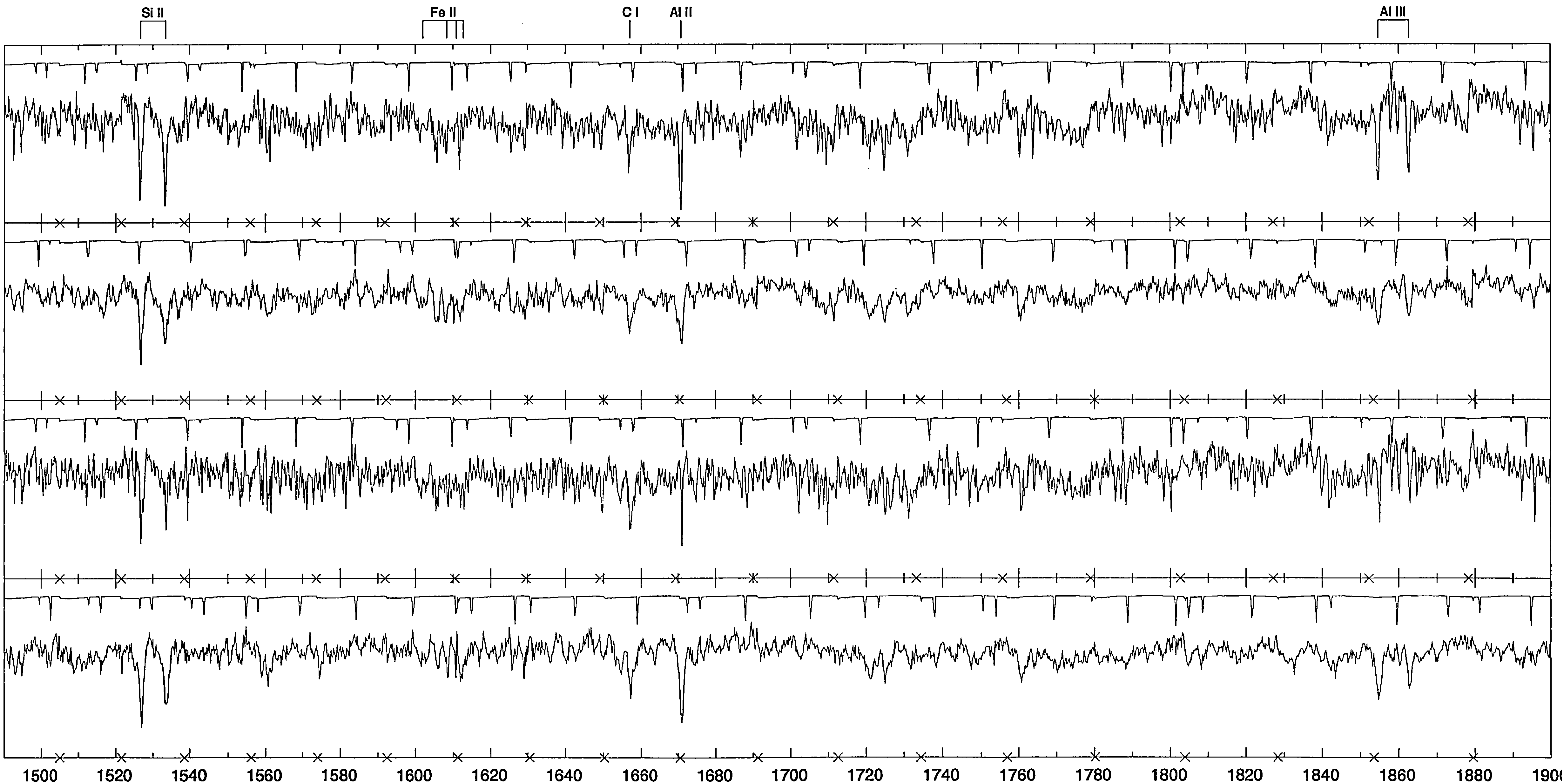


Plate 20b


Si II
Fe II
C I
Al II
Al III
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Part 3

Stellar Wind Effects

Stellar Wind Effects

at B0 - B0.5

Both υ Ori and τ Sco are MK standards for type B0 V. In the ultraviolet, however, τ Sco exhibits greatly enhanced lines of N V, Si IV, and C IV. We use υ Ori as the standard for ultraviolet classification at *B0 V*, while τ Sco is designated *B0 Vw*, indicating that the stellar wind lines appear to be "abnormal" in comparison with the standard. The two spectra of τ Sco presented here were taken over three years apart; there is no indication of long-term variability in the stellar wind, but variations on a shorter time scale cannot be ruled out. Walborn, Nichols-Bohlin, & Panek (1985) also describe the enhanced stellar wind features of τ Sco, which they classify as B0.2 V.

Although it is a β Cephei variable, β Cru has a normal optical MK type of B0.5 III and a normal ultraviolet spectrum. In contrast, HD 53974, whose optical type is also B0.5 III (Rountree Lesh 1968), was given the ultraviolet classification of *B0.5 IIIw* by Rountree & Sonneborn (1991), who cited its broad stellar wind lines and especially the P Cygni profiles of N V and C IV.

Plate 21a

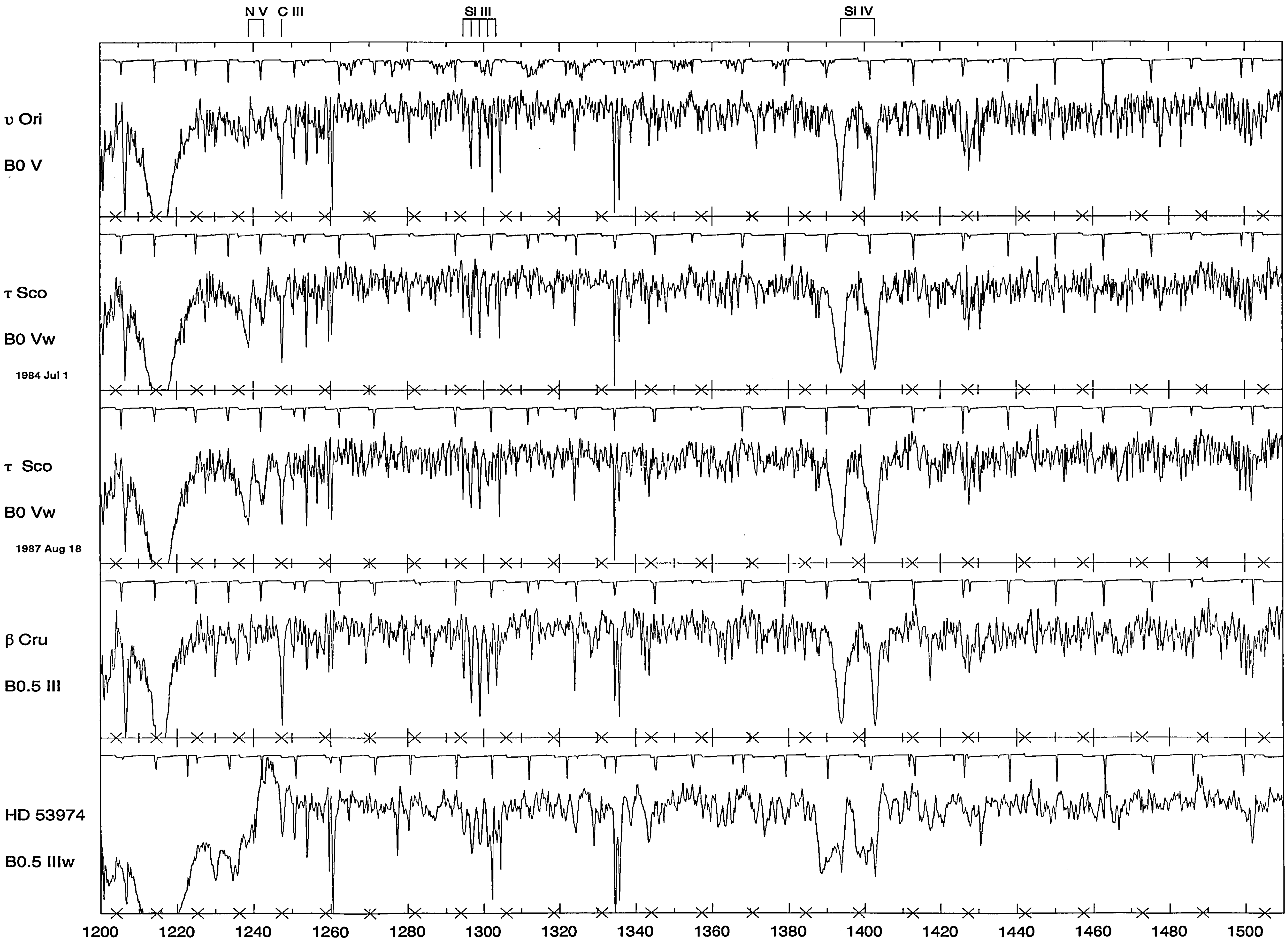
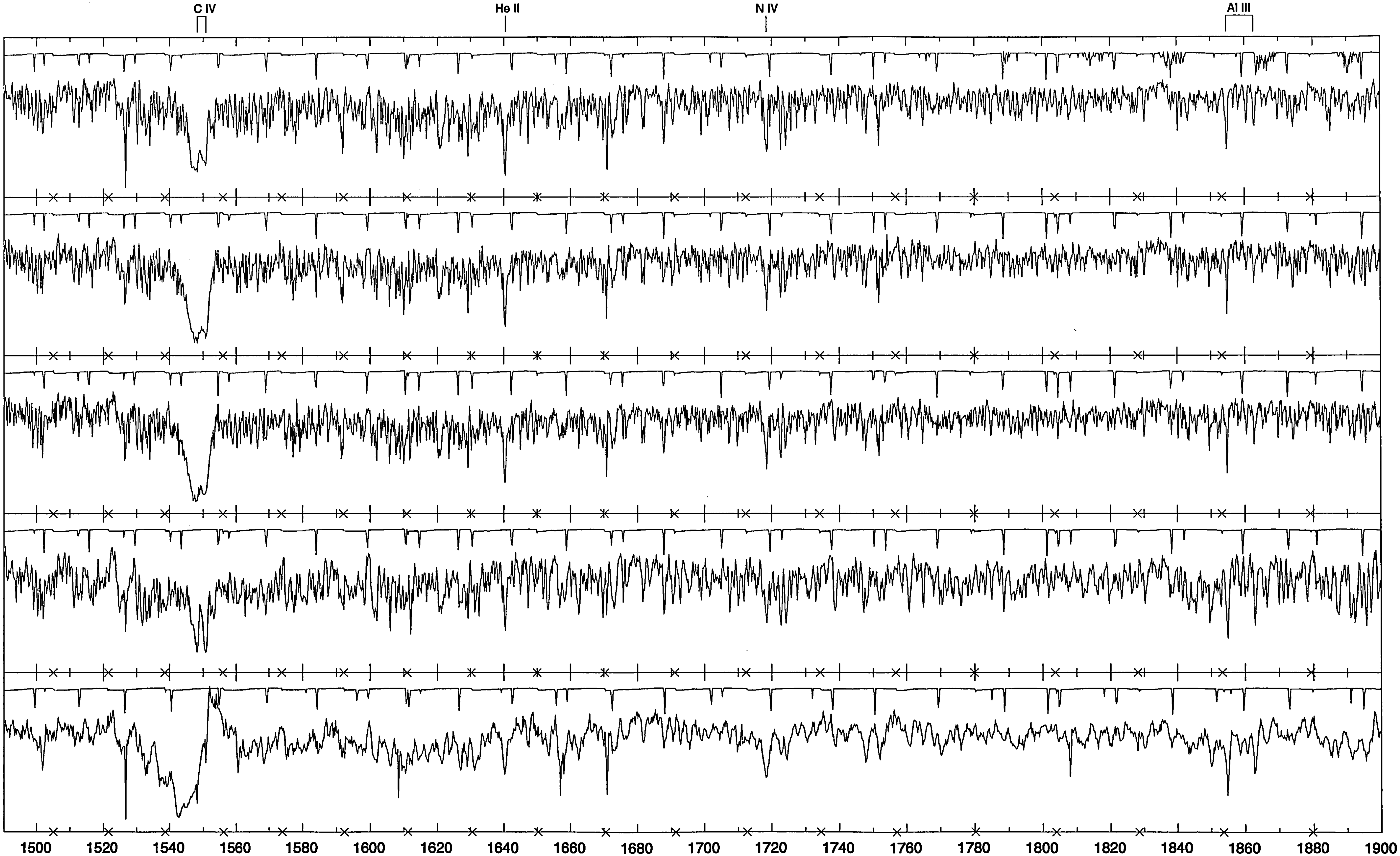


Plate 21b


C IV
He II
N IV
Al III
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Stellar Wind Effects

at B1

The MK standard for B1 III is o Per; σ Sco is a β Cephei variable and a spectroscopic binary, but at classification dispersion both its optical and its ultraviolet spectra are normal for B1 III. However, ξ^1 CMa, another β Cephei variable, is classified *B1 IIIw* because of the P Cygni profiles of the N V and C IV lines, and the weakness of the Si IV absorption lines. Rountree and Sonneborn (1991) cite evidence for a variable stellar wind in this star.

Grady, Bjorkman, and Snow (1987) describe 2 Vul as a Be star with a variable wind and a partially resolved discrete absorption component. In the example displayed here, the C IV doublet is greatly enhanced in comparison with the normal spectrum of HD 63578. The latter star is a rapid rotator ($v \sin i = 200$ km/s).

Plate 22a

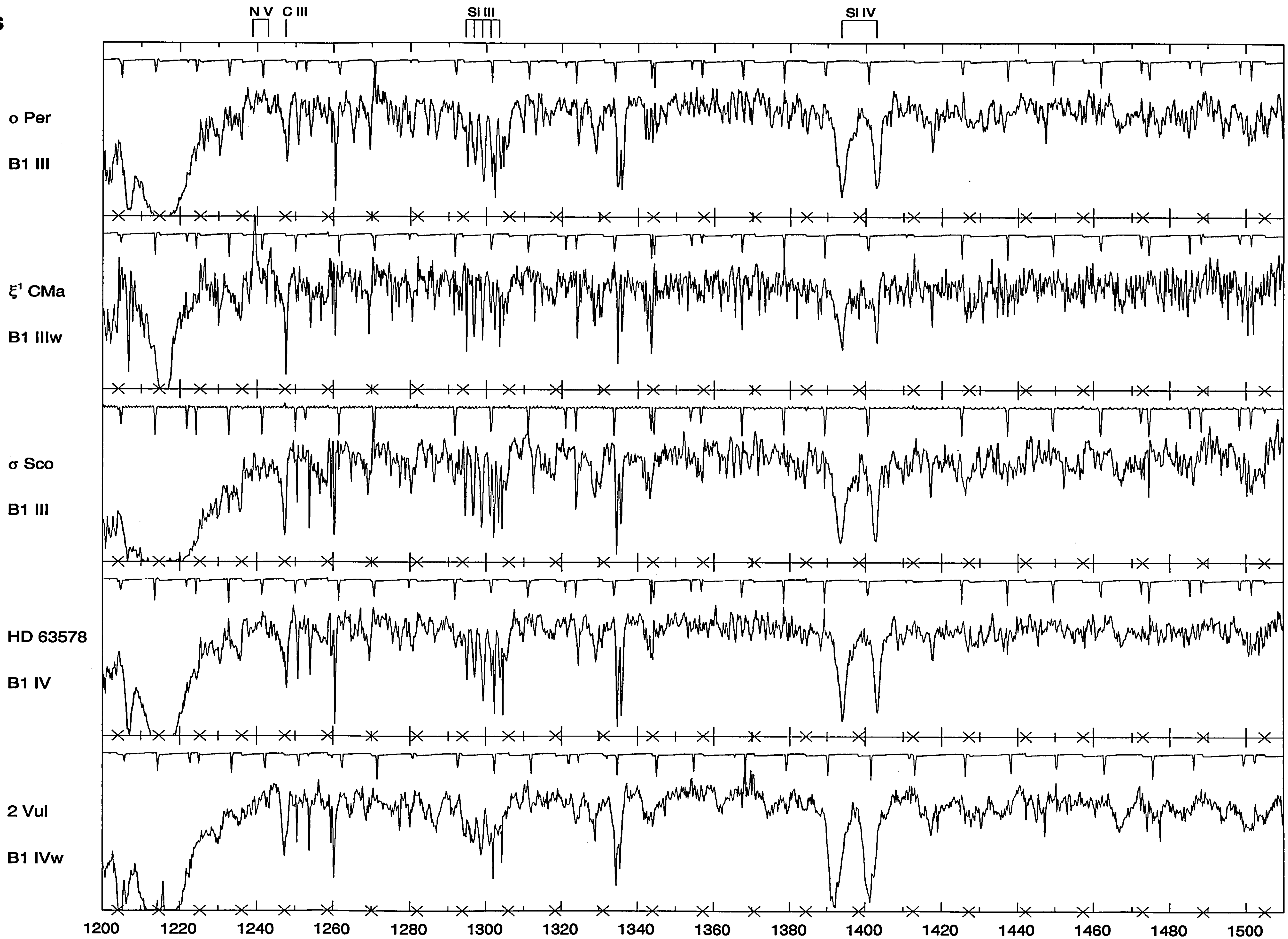
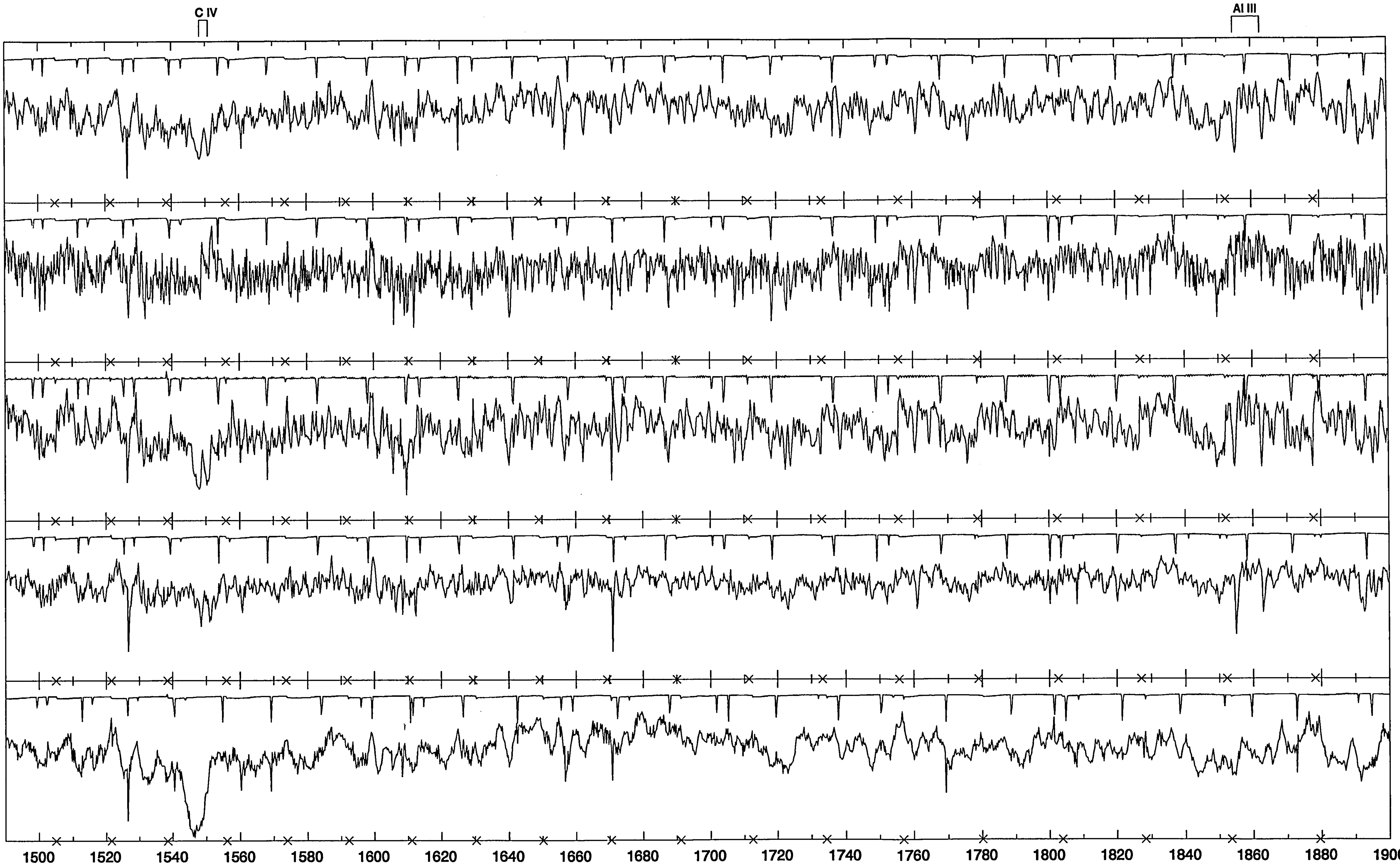


Plate 22b


C IV
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1880
1900

Stellar Wind Effects

at B1.5

HD 85871 and HD 166596 have anomalously strong C IV lines, in comparison with the normal *B1.5 III* spectrum of HD 70930. The Si IV lines have peculiar profiles, in addition to enhanced line strength.

The C IV lines, normally absent at *B1.5 V*, are prominent in the spectrum of 19 Mon. Grady, Bjorkman, & Snow (1987) describe this star as having a variable stellar wind. Emission at Hα is cited by Irvine (1975) and Hirata & Asada (1976).

Plate 23a

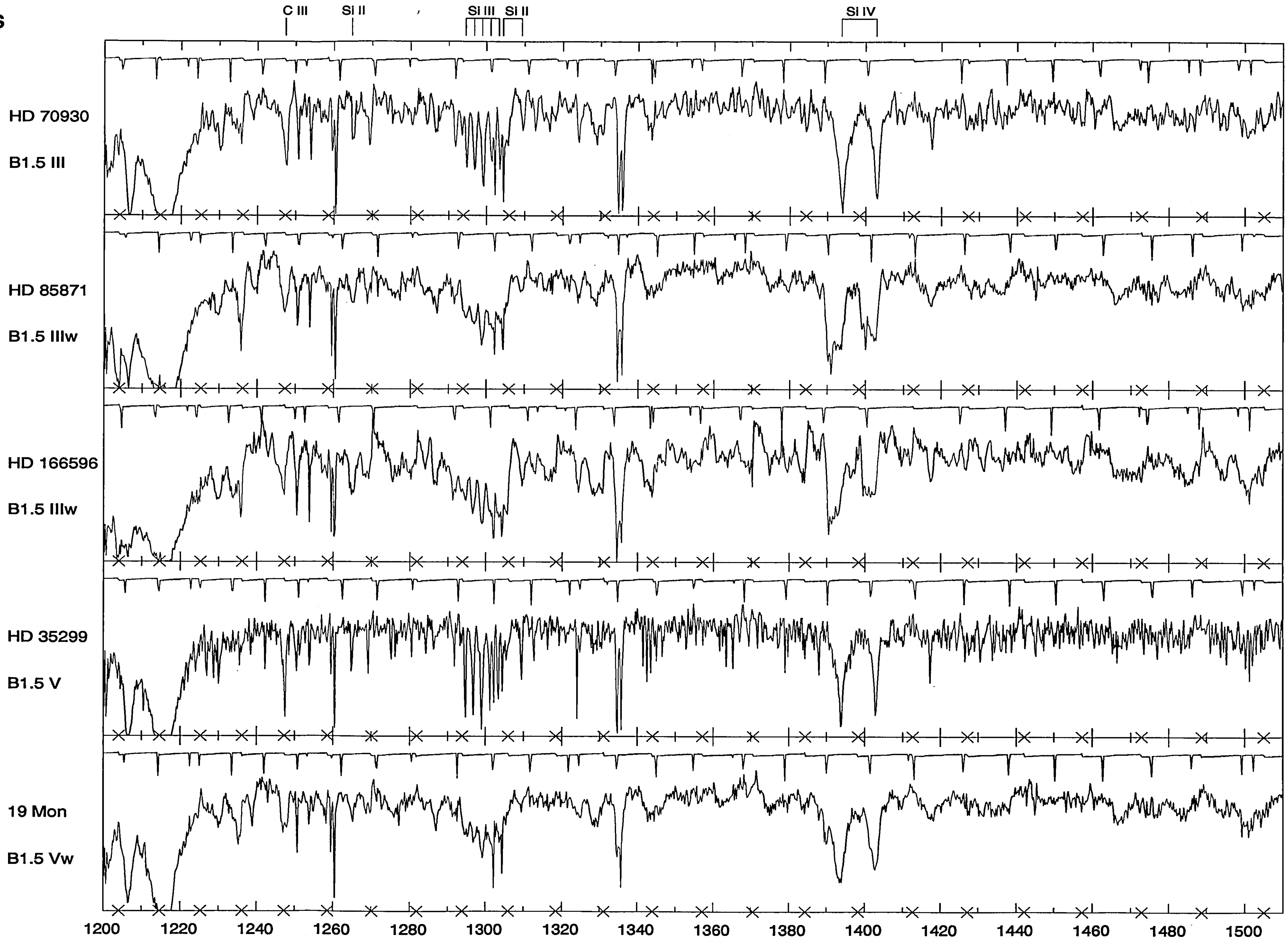
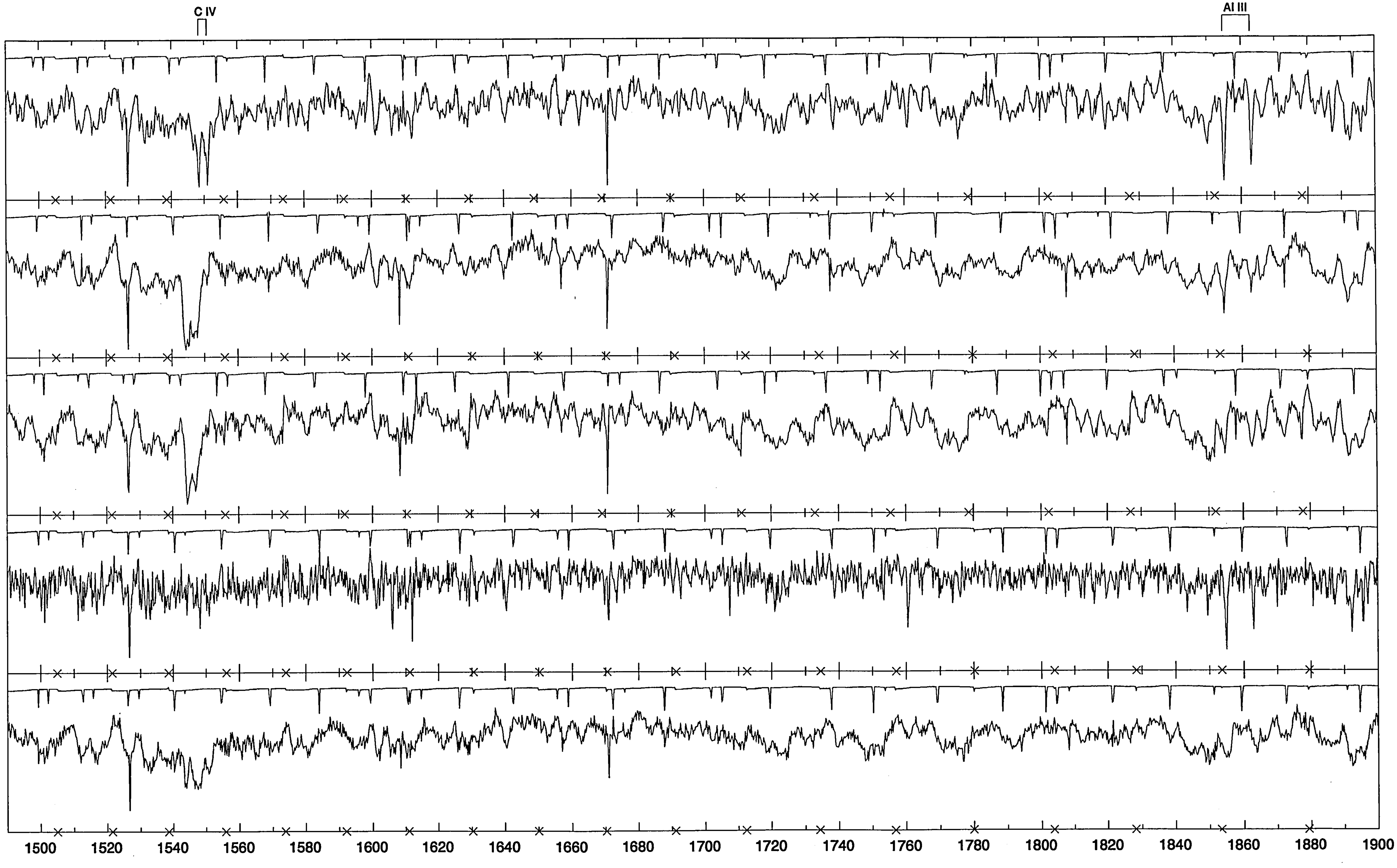


Plate 23b


C IV
Al III
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1780
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Stellar Wind Effects

B2 Dwarfs

The ultraviolet spectrum of 13 Sco is normal for a rapidly rotating B2 V star (*v sin i* = 225 km/s). In particular, the C IV lines are vanishingly weak. The other B2 dwarfs depicted here exhibit different degrees of C IV enhancement. The choppiness of the spectra of HD 57150 and HD 161056, due to a poor echelle ripple correction in the data processing, makes precise classification difficult.

Shore & Brown (1990) reported C IV and Si IV line variations in HD 37017. Balmer line emission in HD 57150 and HD 72067 has been described by Slettebak (1982).

Plate 24a

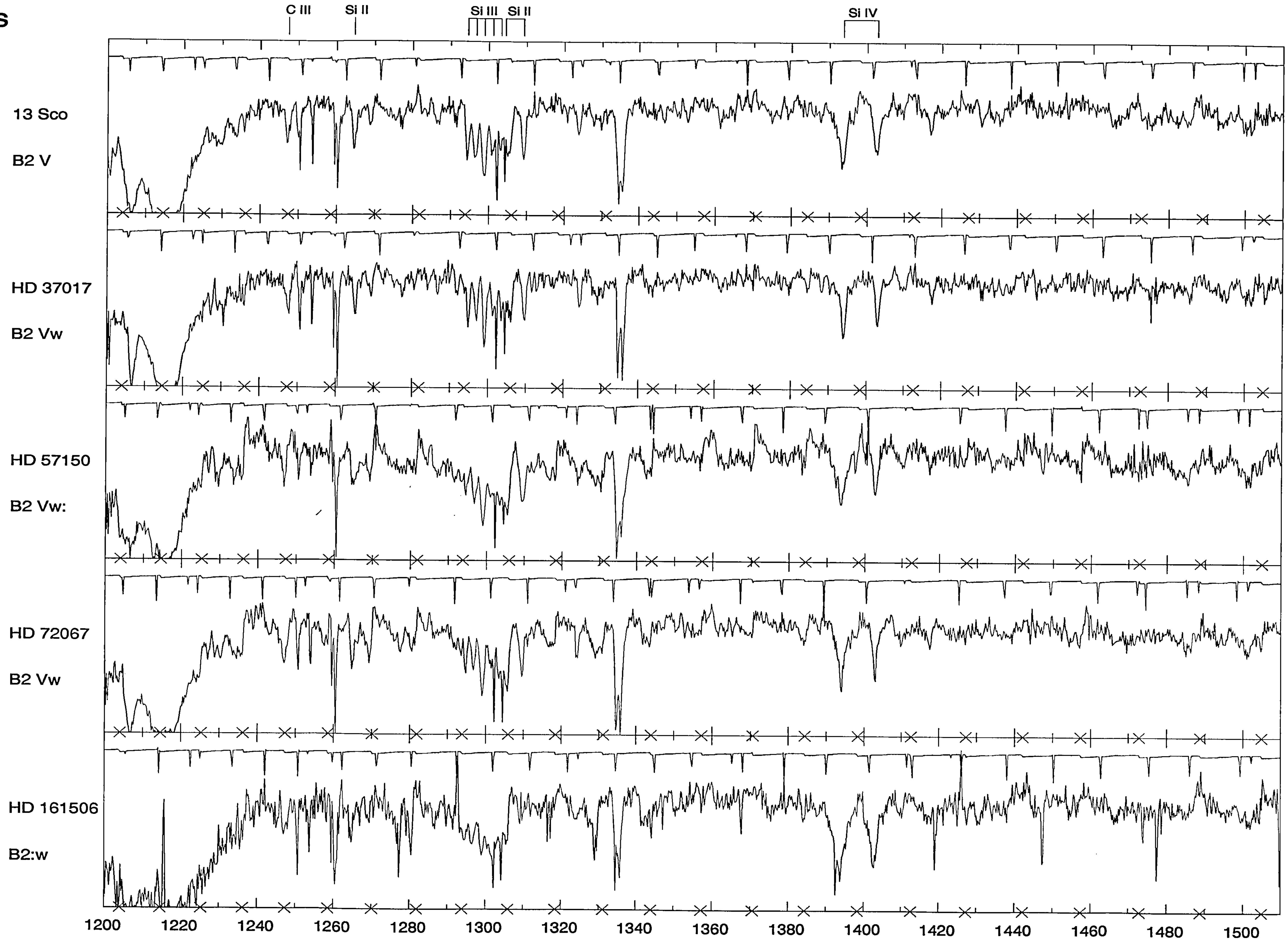
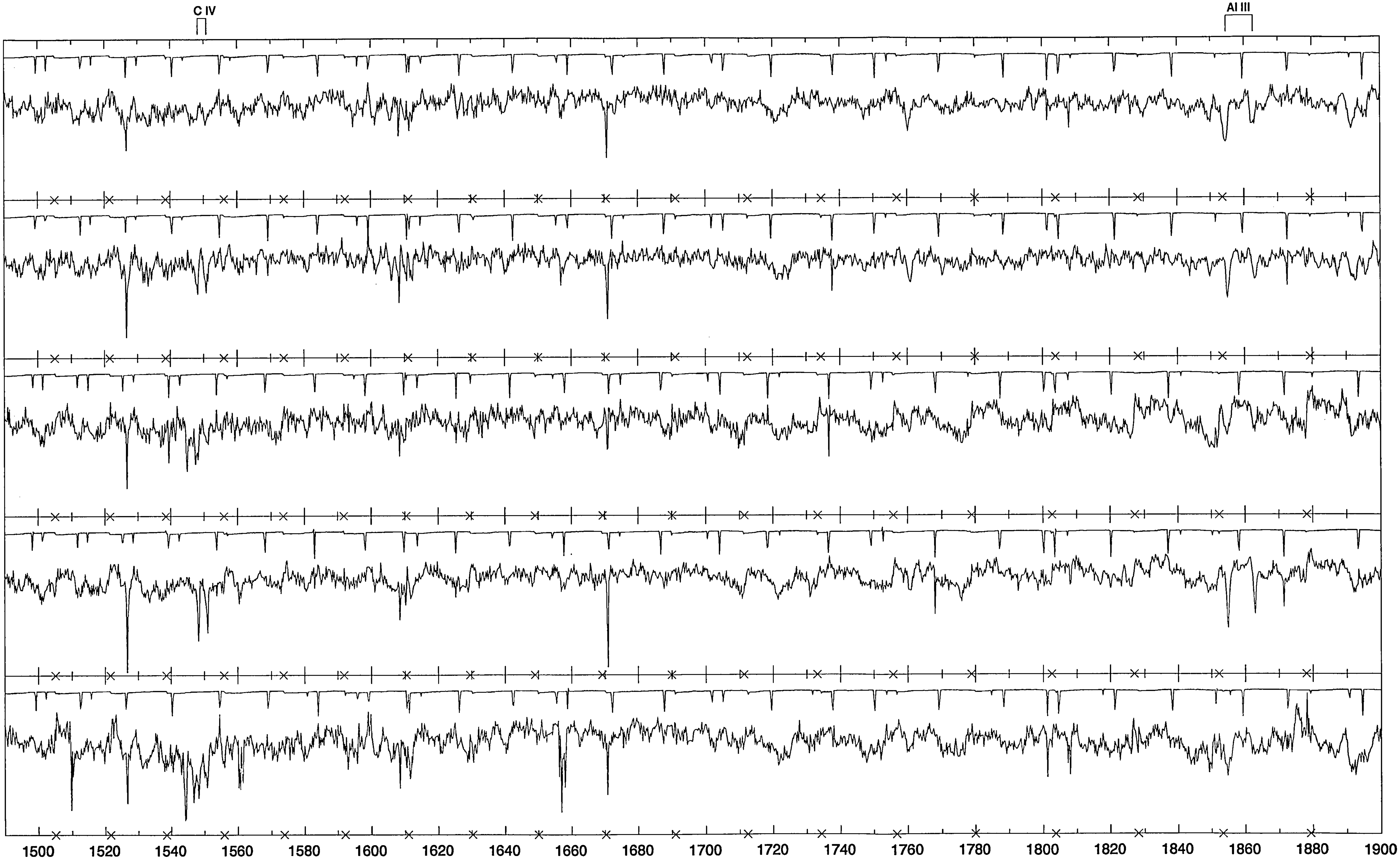


Plate 24b


C IV
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Stellar Wind Effects

The B2 Subgiant ζ Cas

The β Cephei variable δ Cet has a normal ultraviolet spectrum for a B2 V slow rotator ($v \sin i$ = 10 km/s). The N V lines are absent, Si IV lines are moderately strong, and C IV is very weak. In ζ Cas, which is not a β Cephei variable, the wind lines are all enhanced and are variable in strength. This variation is especially remarkable in the C IV lines. Sonneborn, Garhart, and Grady (1987) set an upper limit of several months for the time scale of the wind variability in this star.

HD 163472 (*B2 IVw*) has an ultraviolet spectrum very similar to ζ Cas. Its potential variability has not been studied.

Plate 25a

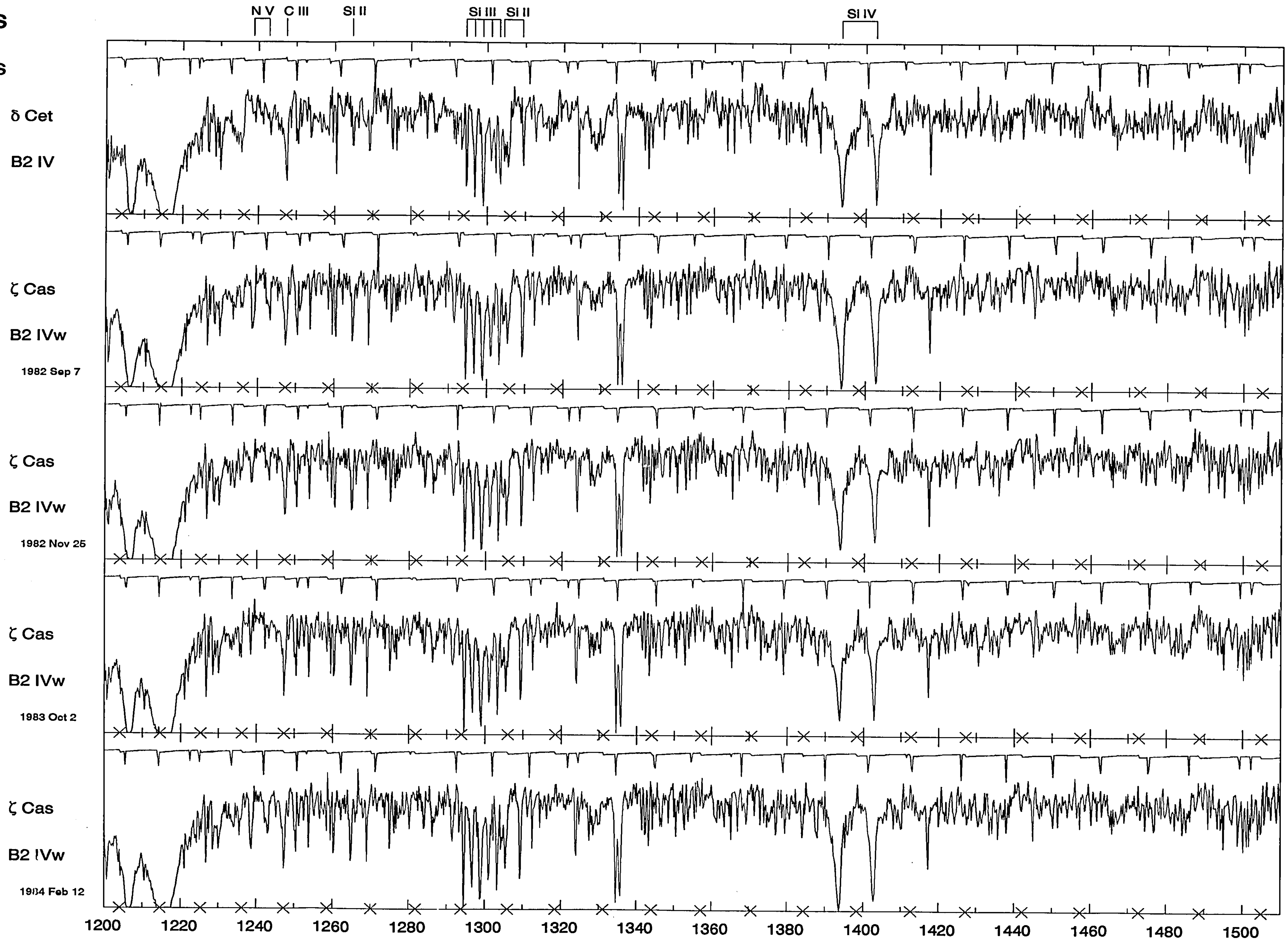
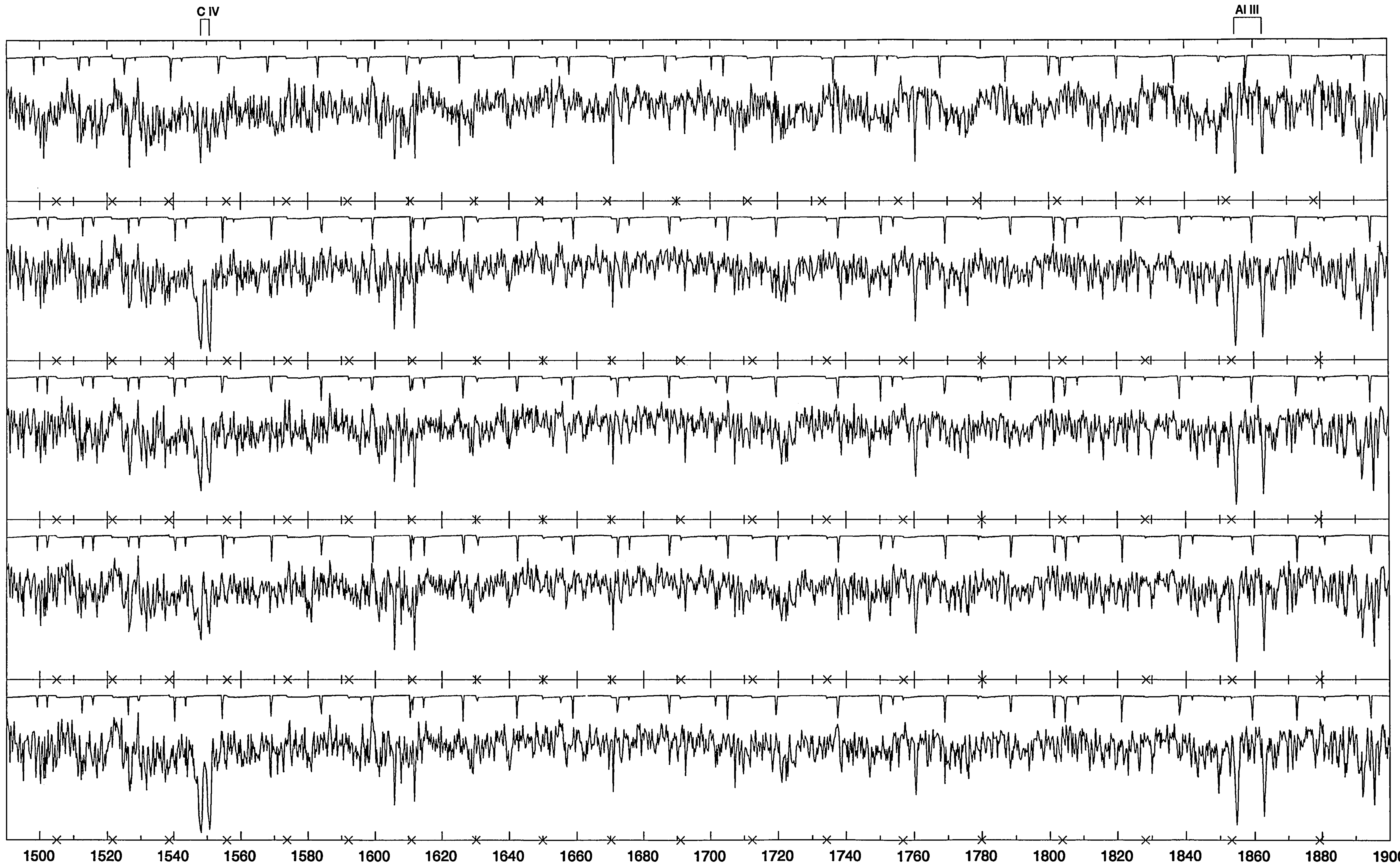


Plate 25b


C IV
Al III
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1760
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Stellar Wind Effects

Mid-B Dwarfs

HD 192685 is essentially identical with the B2.5 V standard σ Sgr, except for the abnormal profiles of the Si IV lines and the abnormal strength of the C IV doublet. In HD 72356, all the stellar wind lines are enhenced in comparison with the B4 V standard HD 20809.

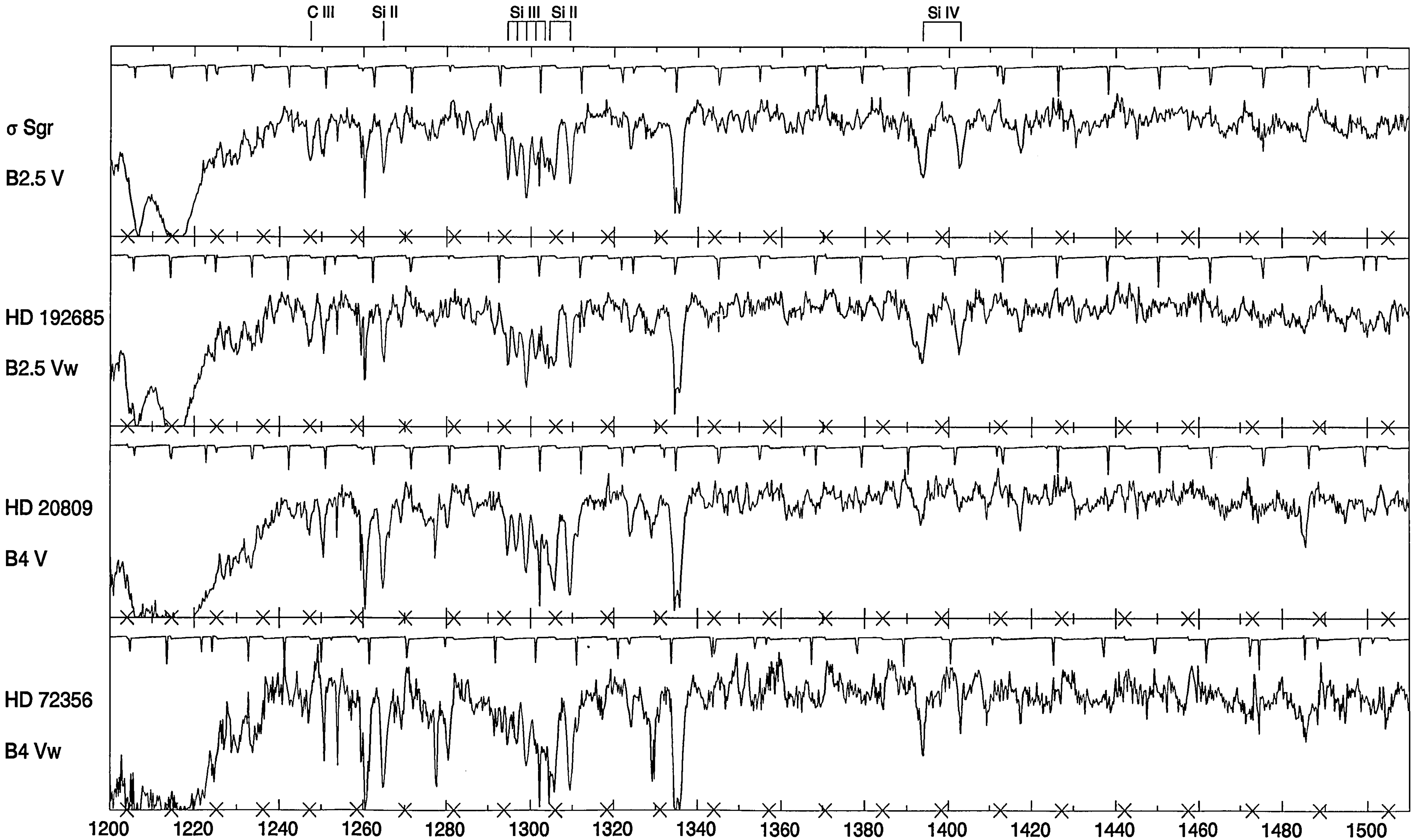
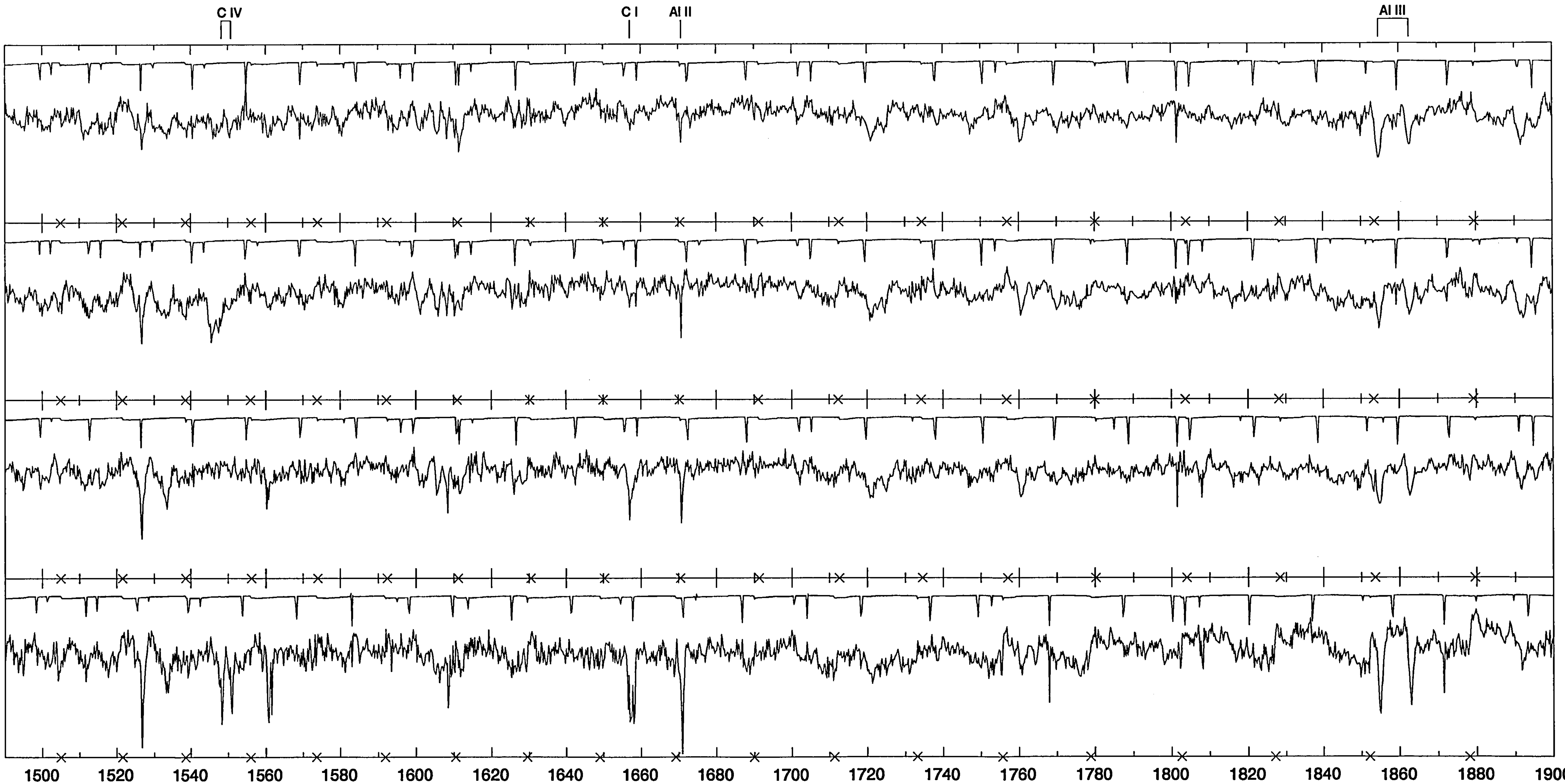


Plate 26b


C IV
C I
Al II
Al III
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1520
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1560
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13. ABSTRACT *(Maximum 200 words)*

New criteria for the spectral classification of B stars in the ultraviolet show that photospheric absorption lines in the 1200-1900A wavelength region can be used to classify the spectra of B-type dwarfs, subgiants, and giants on a two-dimensional system consistent with the optical MK system. This atlas illustrates a large number of such spectra at the scale used for classification. These spectra provide a dense matrix of standard stars, and also show the effects of rapid stellar rotation and stellar winds on the spectra and their classification. The observational material consists of high-dispersion spectra from the International Ultraviolet Explorer archives, resampled to a resolution of 0.25A, uniformly normalized, and plotted at 10A/cm. The atlas displays such spectra for about 100 stars, arranged in spectral-type, luminosity, and rotational velocity sequences. The atlas should be useful for the classification of other IUE high-dispersion spectra, especially for stars that have not been observed in the optical.

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