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FAST SPECTROSCOPIC VARIABILITY IN AP STARS I. HD 11503

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RESUMEN

Observaciones espectroscópicas de la estrella Ap HD 11503, tomadas en secuencias rápidas que cubren un tiempo mayor que el periodo deducido a partir de observaciones fotométricas, indican que algunas de las líneas varían en intervalos de tiempo del orden de horas. HD 11502, junto con HD 11503, constituyen el sistema binario ADS 1507. Se encontró que HD 11502 es una estrella normal que no pertenece a la clase Ap como había sido sugerido.

ABSTRACT

Recent spectroscopic observations obtained consecutively in a time greater than the proposed photometric short period of the Ap star HD 11503 indicate that the intensities of some lines vary in the same time span as the photometric period. In a similar study, it is found that HD 11502, which, along with HD 11503, constitutes the binary system ADS 1507 (γ Ari), does not belong to the Ap class as has been previously suggested.

Key words: **STARS-PECULIAR – SPECTROSCOPY – STARS-SPECTRUM VARIABILITY**

I. INTRODUCTION

It is well known that the Ap stars are characterized by low rotational velocities, the presence of intense magnetic fields of the order of 10^4 gauss and the anomalous abundances of specific elements such as Si, Cr, Mg, Fe, and Eu, among others.

The first variable characteristics observed after these stars were defined as a class were of a spectroscopic nature (Ludendorff 1906). Later, research in these stars was extended to photometric and magnetic studies and, in each, it was observed that the Ap stars present variations in a time range between 0.5 d and 200 d, with the most common variation being on the order of a few days (Ledoux and Renson 1966). Models were developed that tried to fit the observed characteristics and were aimed mainly at explaining and reproducing variations in photometry, spectroscopy, and/or in the intensity of the magnetic field in such relatively long periods of time.

Relations between spectroscopic, photometric and magnetic field variations were established and this feature was one of the most important criteria considered in discriminating between the physically different models (for example, the oblique rotator and the magnetic oscillator, which are among the most accepted models).

It has been known for a relatively long time, that these objects have photometric variations on the order of hours have been detected. For example, Bahner and Mavridis (1957) reported a period of half an hour for the star 21 Com. Later, Wood (1964, 1965, 1967) and Wood and Hollis (1971) found fast quasiperiodic variations in the intensities of the lines Hα, Hβ, and Hγ in about 50% of the stars that were observed. However, in further studies carried out by Breger (1974), the findings of Wood were not confirmed in the Ap stars 73 Dra and ϵ UMa.

Photometric searches for fast variations have been more fruitful. Such studies have given positive results after Percy (1973) started the search for rapid pulsations in some Ap stars; these studies were followed by those of Blanco, Catalano, and Stazzulla (1978), Weiss (1978) and Kurtz (1982). Up to now, two main groups of Ap stars with photometric variations seem to exist (Weiss 1983), namely: a) the group of high-overtone (K = 60) non-radial oblique pulsators established by Kurtz (1982) and, b) the group of low-overtone pulsators (fundamental and/or low overtone radial pulsators).

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TABLE 1

LOG OF SPECTROSCOPIC OBSERVATIONS OF HD 11502 AND HD 11503

Plate Number	Spect.	Disper. A/mm	Star	Date (1987)	Num. of Spectra	Observer
1BM 90	B&Ch	125	HD 11502	Jan 20	12	AQT
1BM 104	B&Ch	125	HD 11502	Jan 25	12	JHP, RP
1BM 111	B&Ch	125	HD 11503	Jan 29	12	AQT
1BM 204	B&Ch	125	HD 11503	Nov 04	12	OLC, AP
1BM 210	B&Ch	125	HD 11503	Nov 07	8	OLC
1BM 219	B&Ch	60	HD 11502	Nov 19	1	RP
			μ^3 Aqr		1	
			HD 11503		1	
MG 11	Mexigraph	67	HD 11502	Dec 03	1	JHP, RP
MG 12	Mexigraph	67	HD 11503	Dec 03	21	MAH, OLC

This group is less well-established and seems to be understood in terms of δ Scuti type pulsations.

With respect to the spectroscopic variations, the results have not been very rewarding. Rice, Wehlau, and Khokhova (1984) took a few spectra of θ Aur in rapid succession during several phases, but they could not detect any real variations. On the other hand, Polosukhina and Chuvaev (1975) have detected fast variations in the equivalent widths of Hα and Hβ of the order of 90 seconds in θ Aur. Nevertheless, since there seems to exist a correlation between the variation of the radial velocity, the luminosity and probably the spectrum in a fair number of variable stars (Preston 1971), it seems worthwhile to examine whether a variation in spectrum corresponds to variability in the photometry on the order of hours in order to fulfill Wolff's criteria (Wood 1975) for the confirmation of a period, i.e., periods obtained by two or more different techniques.

With this criteria in mind, it was decided to carry out a search for rapid variation in the spectrum of a few Ap stars with reported or suspected short period photometric variability on the order of hours. The star HD 11503 (BD+18 243 = HR 546 = γ Ari S) was selected from among several possibilities from an extensive list kindly provided by Weiss (1984) since it has shown fast photometric variability with a period of 2.5 h (Rakosch and Fiedler 1978).

II. OBSERVATIONS

The observations were carried out at the Observatorio Astronómico Nacional in Tonantzintla, Puebla with the 1-m telescope. Two spectrographs were used with 103aO Kodak plates. Initially, a Boller and Chivens spectrograph with a dispersion of 125 A/mm and later of 60 A/mm both centered at Hγ was utilized (plates 1BM). A second spectrograph, Mexigraph, designed by R.F. Garrison was later used, with a dispersion of 67 A/mm centered also at Hγ (plates MG). Table 1 summarizes all the observations.

With the B&Ch spectrograph several series of spectra of HD 11503 were obtained, one series on each plate (Figures 1 to 4 – Plates); each spectrum had the same exposure time. Since homogeneity is of vital importance if line strength differences are to be appreciated, it was decided to record the whole series of spectra on the same plate; consequently, 15 minute intervals were allowed between consecutive spectra, giving a high density coverage along the reported photometric period. In addition, a comparison spectrum of He-Ar was exposed and, finally, a spectrum of an early A type star was recorded on the same plate for comparison purposes.

A new series of spectra with a more extended time baseline covering a time span twice the reported photometric period of the star HD 11503 was obtained with the Mexigraph on December 3, 1987 (MG 12 plate, Figure 5 – Plate). The whole sample of spectra was obtained on a single plate; an exposure time of three minutes to each spectrum was given with a separation of 15 minutes between successive ones. A comparison spectrum of Ar was exposed on the same plate.

The star HD 11502, which along with HD 11503 constitutes the binary system ADS 1507, was also observed in the same way since there were indications that it might also be an Ap star (Babcock 1958). Consequently, it was observed with the B&Ch spectrograph on the following dates: January 19/20, January 25, and November 19, 1987. On the first date, a series of twelve spectra, was obtained, each one with two minutes exposure and a time separation between consecutive spectra of fifteen minutes. Similar exposure and separation times were used for the second plate, a series of seven spectra, at the end of which an A0V star (BS

2034) was also registered. Only one spectrum of HD 11502 was obtained on the most recent date along with HD 11503 and an A0 reference star (μ^3 Aqr, Figure 4). With the Mexigraph, only one spectrum of this star was obtained on Dec 3, 1987 and is shown in Figure 5 (plate MG 13).

III. DISCUSSION

In the past there have been controversial results with respect to the membership of the star HD 11502 to the Ap category. Maitzen *et al.* (1978) stated that HD 11502 and HD 11503 together form the visual binary system ADS 1507 with a separation of 7".9. They also emphasized doubts about the peculiarity of each member of the system since, as they pointed out, the Henry Drapper catalogue does not give separate classification (only A0p for both), while in the Bright Star Catalogue (1964), HD 11502 is assigned a spectral class of A Si, whereas B9 is given for HD 11503. In the catalogue of Berthaud and Floquet (1974) only HD 11503 is listed as a peculiar A type star and Babcock (1958) describes both as A0p stars. Deutsch (1947) also pointed out that HD 11502 is not an Ap star. More recently, Maitzen (1976) has shown that HD 11502 is not an Ap star either, with no rotational variability shown. Later Maitzen *et al.* (1978) with a scanner and conventional photometry found that only HD 11503 is peculiar and that it is slightly brighter in all colors than HD 11502.

The results of the present paper unquestionably support the findings of Maitzen *et al.* (1978). Neither one of the obtained spectra of HD 11502 show any indication of belonging to the Ap class (Figures 4 and 5). No indications of variability of any kind are shown, neither on the order of hours as in HD 11503 nor on the order of days which could have also been detected since both series were obtained several days apart.

On the other hand, HD 11503 presents a completely different spectrum. With respect to its membership in the "peculiar" class, the spectra show, beyond any doubt, that it belongs to the Si-Cr-Eu Ap class (Catalano and Renson 1974), as can be seen from the Si II 4128-31 and Sr II 4078 wavelengths.

The positions of the lines in the spectrum of HD 11503 were calibrated on the plates by means of the He-Ar comparison spectrum. The positions of the comparison lines as well as of the problem lines were determined using a measuring microscope of the Instituto Nacional de Astrofísica, Optica y Electrónica shop. The relation between the position and the wavelength was obtained by a least squares fit of a straight line with a correlation coefficient of 0.9999 and the resulting uncertainty in the wavelength of about 1 A. The main source of line identifications in this study is Moore (1972) and the MIT Tables (Harrison 1962). The results are presented in Figures 1 to 5. As previously stated, the spectra of each series have the same exposure time and the same photographic processing conditions; therefore, the variations shown in each plate can be assumed to be due to intrinsic variations in the spectrum of the star rather than to photographic effects.

As in spectral classification, some lines should be assumed as standards, i.e., lines that can be considered as constant throughout the plate. Although no studies have been carried out with the purpose of detecting fast spectroscopic variations in HD 11503, there are studies in other stars that indicate that the hydrogen lines, as well as the Mg II 4481 line, can be considered as constants in 73 Dra on short time scales (Breger 1974, Bonsack and Markowitz 1967).

After obtaining the spectra of the 1BM 111 plate (Figure 1), it was found that some lines presented indications of fast spectroscopic variability, particularly in the variation of λ4063 with respect to λ4078. This fact encouraged the acquisition of the other plates in which these changes were always detectable (Figures 2 and 3). One more spectrum of both stars, HD 11502 and HD 11503, was obtained at a higher dispersion of 60 A/mm (Figure 4).

When the Mexigraph became available, we had the opportunity to obtain better spectrograms (i.e., a larger number of wider spectra of greater dimensions on the same plate than the ones on the 1BM plates). On the MG 12 plate (Figure 5) at 67 A/mm, the lines are better defined as is evident from the separation of the Si II 4028 and Si II 4031 lines. A careful inspection of the spectra showed several changes in the intensities of some lines. Each variable line has been compared to a line that appears to be constant with respect to the previously defined standard lines. The following pairs of lines have been compared: λ4063 with respect to λ4078, λ4188 to Cr II λ4172 and finally, λ4489 to Mg II λ4481. Line λ4078 is a blend of the lines of Cr II 4077.50 and Sr II 4077.714, whereas the line at λ4063 A was left unidentified by Deutsch (1947). This line can be related to Fe I 4063.286 corresponding to multiplet number 698 of Moore (1972). The most conspicuous variation is presented by the pair 4063/4078.

Some quantitative measurements of the relative intensities of the most conspicuous pair was done using Deutsch's (1947) second criterion, namely:

$$\lambda 4063/\lambda 4078 = \begin{cases} 0 \text{ if } 4063 << 4078 \\ 3 \text{ if } 4063 = 4078 \\ 6 \text{ if } 4063 >> 4078 \end{cases}$$

The uncertainties in each measurement can be

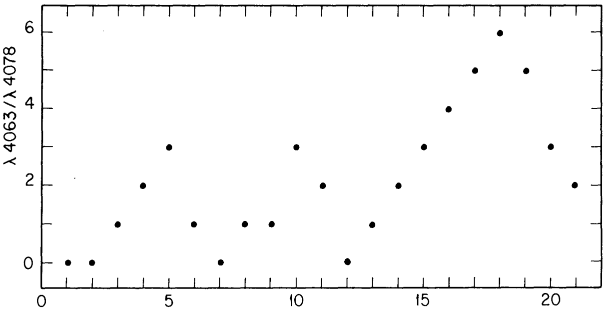

Fig. 6. Intensity variations of the ratio $\lambda4063/\lambda4078$ measured from the plate MG 12 of HD 11503. The criteria followed was that of Deutsch (1947).

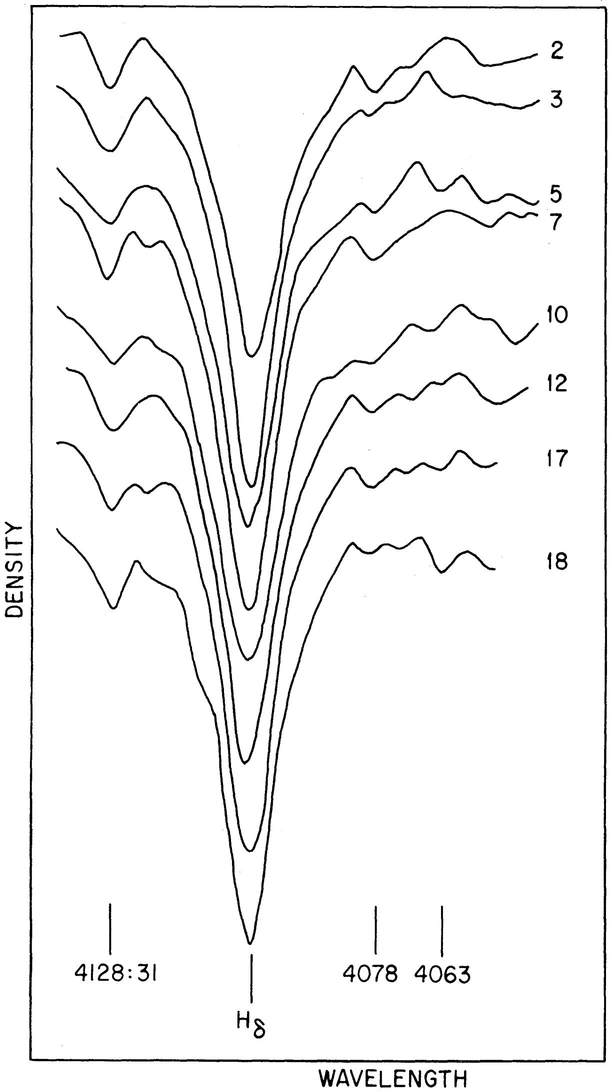

Fig. 7. Microdensitometric traces of HD 11503 from the plate MG 12. It demonstrates the fast variation of $\lambda4063$ with respect to $\lambda4078$. The number indicates the corresponding spectrum shown in Figure 5.

TABLE 2

INTENSITY VARIATIONS IN HD 11503 OF THE LINE $\lambda4063$ WITH RESPECT TO $\lambda4078$ IN DEC. 3, 1987 ACCORDING TO DEUTSCH'S CRITERIA

Num.	U.T.	Int.	Num.	U.T.	Int.
1	2:27	0	11	4:54	2
2	2:38	0	12	5:09	0
3	2:53	1	13	5:24	1
4	3:08	2	14	5:33	2
5	3:23	3	15	5:54	3
6	3:38	1	16	6:09	4
7	3:53	0	17	6:24	5
8	4:09	1	18	6:38	6
9	4:24	1	19	6:55	5
10	4:38	3	20	7:10	3
	...	...	21	7:25	2

expected to be one unit in this scale as Arellano-Ferro and Garrison (1979) have demonstrated. The values obtained following the aforementioned criterion have been summarized in Table 2 and are presented schematically in Figure 6.

In order to support our claim of such variations, some microdensitometric tracings were obtained with the PDS machine of the INAOE, on the MG 12 plate of the Mexigraph. They are the average of five scannings with a 25 × 25 micron window, and they were later processed at the PDP 11 computer of the INAOE; a smoothing subroutine (Hayden 1987) was applied. The final microdensitometric scans, Figure 7, unquestionably support the fast variation of $\lambda4063$ with respect to $\lambda4078$. These changes are also shown photographically in Figure 8, where it is seen that the variations are on the order of 45 minutes; although from these data a precise period cannot be inferred.

The results presented here support the photometric results of Rakosch and Fiedler (1978), who also determined photometric variations on the order of hours. An interesting problem to tackle in the future would be the explanation of the mechanism that produces such relatively fast spectroscopic variations. Weiss (1978) has questioned the short photometric period of variation of HD 11503 that was reported by Rakosch (1963) and Rakosch and Fiedler (1978). In later photometric observations of the same star, he was unable to detect any variability and, consequently, speculated that the comparison star, HD 11326, used in the differential photometric studies by Rakosch could be variable. Nevertheless, he proposed a period of rotation of 2.6098 d for HD 11503 as Deutsch had previously determined. However, the comparison star (HD 11326) taken in the study of Rakosch has an spectral type of K2III which cannot be a short period pulsator.

One possible explanation that could reconcile both findings would be the existence of erratic behaviour of some properties in a few Ap stars as has been reported by Hack and Struve (1971) and in the recent study of Kreidl *et al.* (1990), on 21 Com they were unable to prove photometrically the short period variation that were reported earlier, and they proposed that the variations are not periodic but produced by spots on the surface of a rotating star.

In any case, the results obtained in the present research are new, but not unexpected. As in the case of photometric variability, which has been known for decades, new results have been obtained when new techniques of observation are utilized. For example, the low amplitude-short period variability found in the δ Scuti and marginal Am stars was not determined until the advent of differential photometry. Analogously new results in spectroscopic variability in Ap stars have been determined when different methods of data acquisition have been used.

In the past for each star only one or at the most two spectra per night were obtained and thus, spectroscopic variations on the order of days were established. Consequently, it has been assumed that the Ap stars have a periodic behaviour on the order of days. This has been the case with HD 11503 which, after the analysis by Deutsch (1947), was assigned a period of 2.607 days and almost all the studies carried out after his work have assumed this period. However, upon analizing Deutsch's data, it seems difficult to establish unequivocally and categorically such a period since these data consist mainly of two groups separated by more than one year. Each set consists of few data points, of one or at the most two spectra on each night; and the nights are very seldom close enough to establish a 2.607 d period. The first set of data of fourteen points, one of which, HJD 2431784 is separated by fifty two days from the rest of the set which consists of only thirteen points in 187 days. Even dividing the whole set into two natural subsets, each one is constituted by five points in eleven days and another of six points in fifteen days, hardly enough to unquestionably predict a 2.607 d period or to discard or detect a possible fast spectroscopic variation. Nevertheless, it has to be recognized that his phase diagram looks remarkably adequate for his data and period.

Another set of data that could throw some light on the time length of the variability is that of van Genderen (1971) who carried out photometric studies of twelve magnetic variable stars, among them HD 11503. Considering his 12 points in 57 days, it is impossible to determine or reject from these data alone a time variation determination on the order of hours.

The spectroscopic variations found in the present paper are consistent with the photometric variations of Rakosch and Fiedler (1978). Of course, since the period of rotation of HD 11503 is assumed to be 2.607 d, the variations shown in the present paper are not explained by considering rotation alone. Vogh, Penrod, and Hatzes (1986) and Hatzes, Penrod, and Vogt (1989) have shown the existence of a spot pattern that is fixed to the surface of the star. Thus, any spectroscopic or light variation on the order of two and a half days is due to its rotation, but the short period variations that are currently presented might be due to some flare-like activity that is taking place in the atmosphere of the star. Further spectroscopic studies at higher resolution both in wavelength and time are desirable but, at any rate, we have shown that fast variations in specific lines exist in some of the Ap stars.

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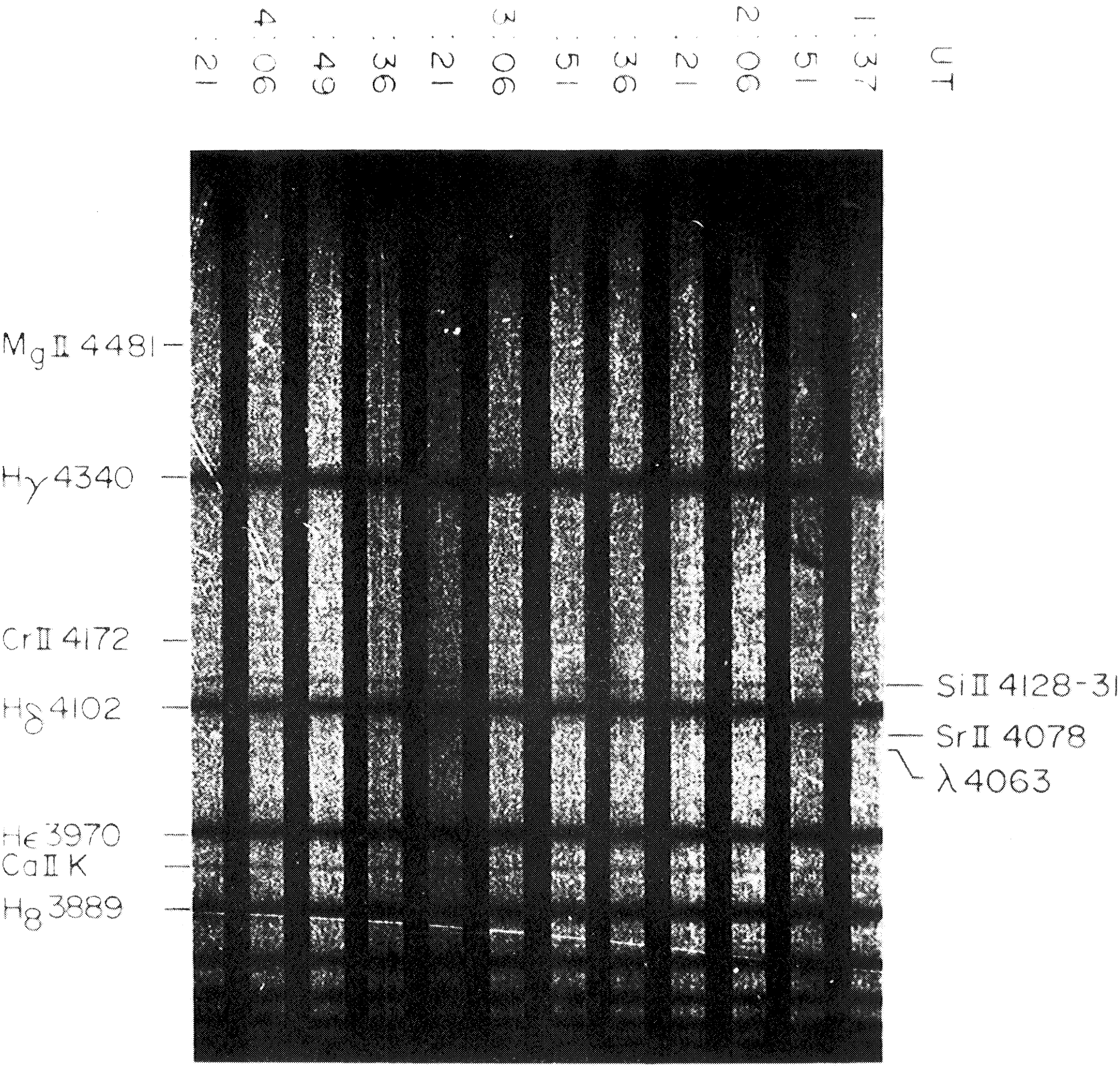

Fig. 1. Spectroscopic observations of HD 11503 on January 29, 1987 obtained with a dispersion of 125 A/mm centered at Hγ.

O. LOPEZ-CRUZ ET AL. (See page 249)

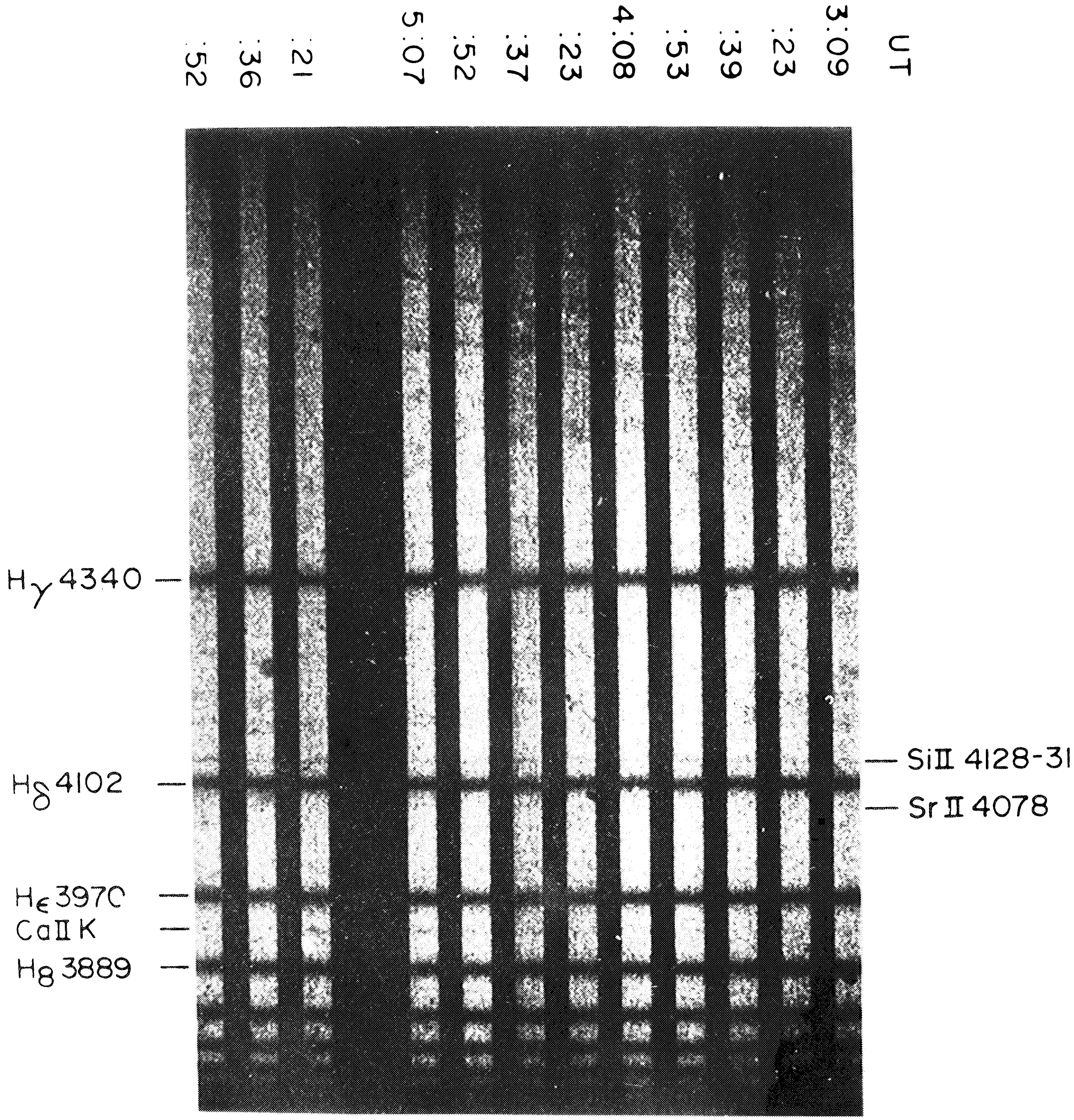

Fig. 2. Spectroscopic observations of HD 11503 on November 4, 1987 obtained with a dispersion of 125 A/mm centered at Hγ.

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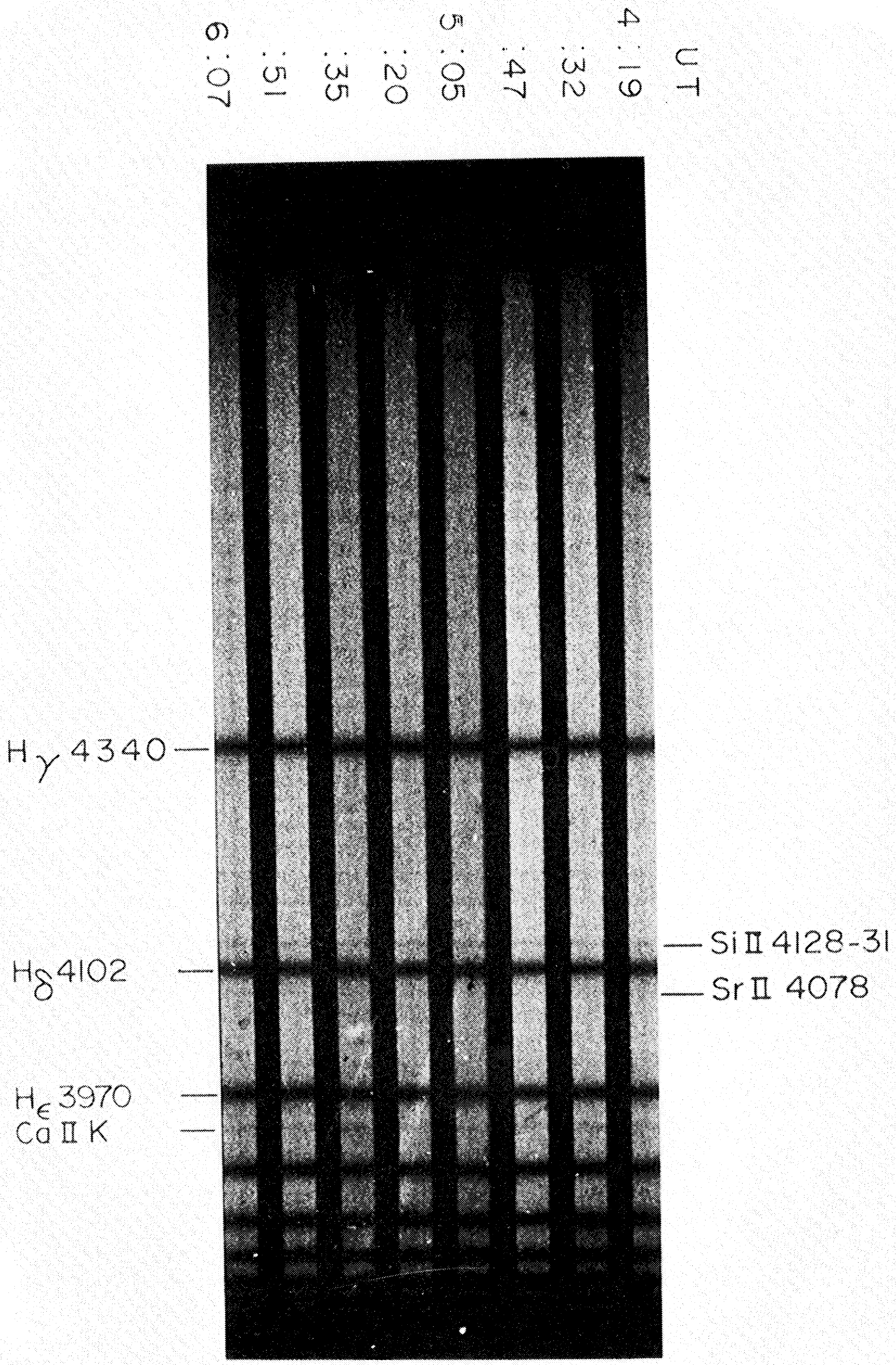

Fig. 3. Spectroscopic observations of HD 11503 on November 7, 1987 obtained with a dispersion of 125 A/mm centered at Hγ.

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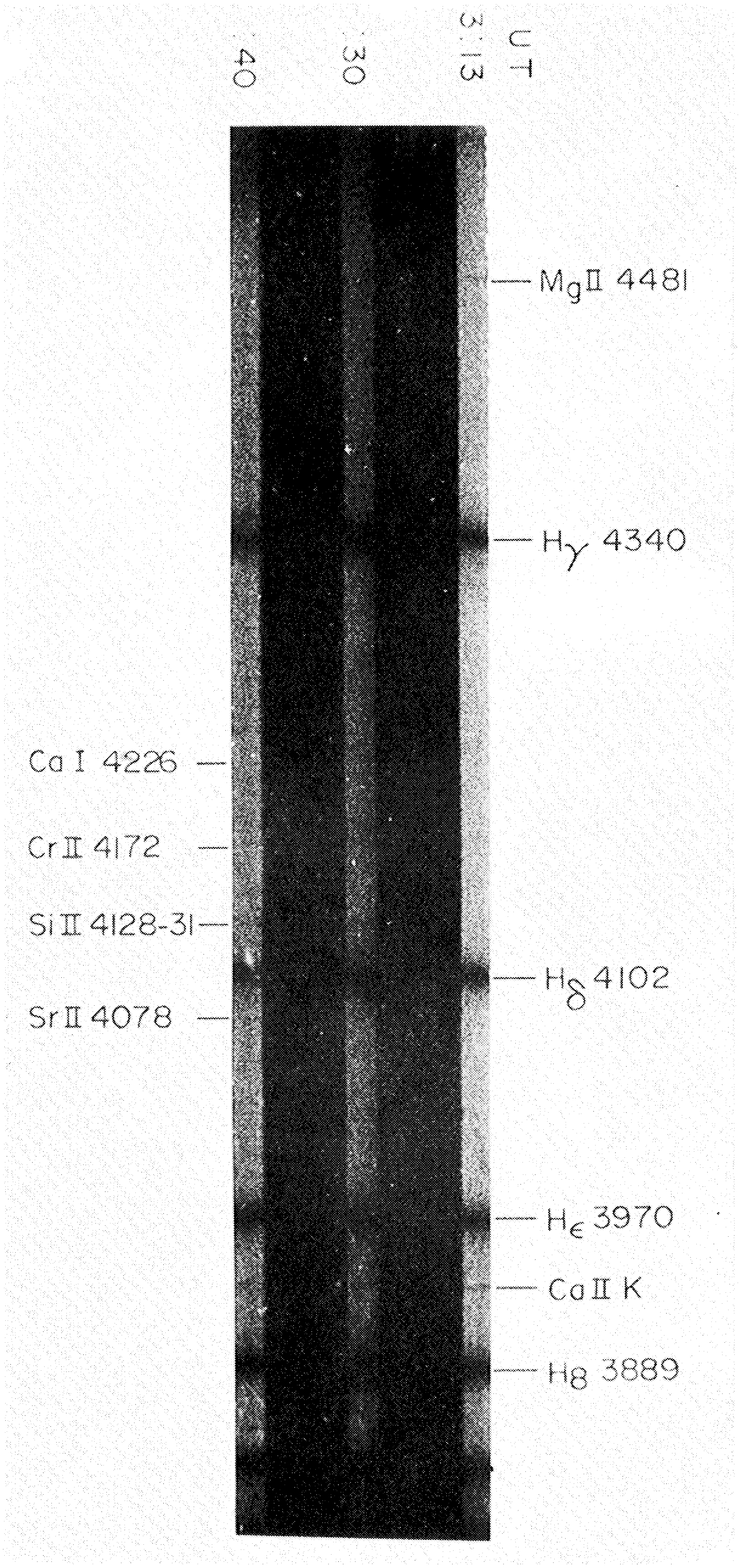

Fig. 4. Spectroscopic observations of HD 11502, μ^3 Aqr and HD 11503 on November 19, 1987 obtained with a dispersion of 60 A/mm centered at Hγ.

O. LOPEZ-CRUZ ET AL. (See page 249)

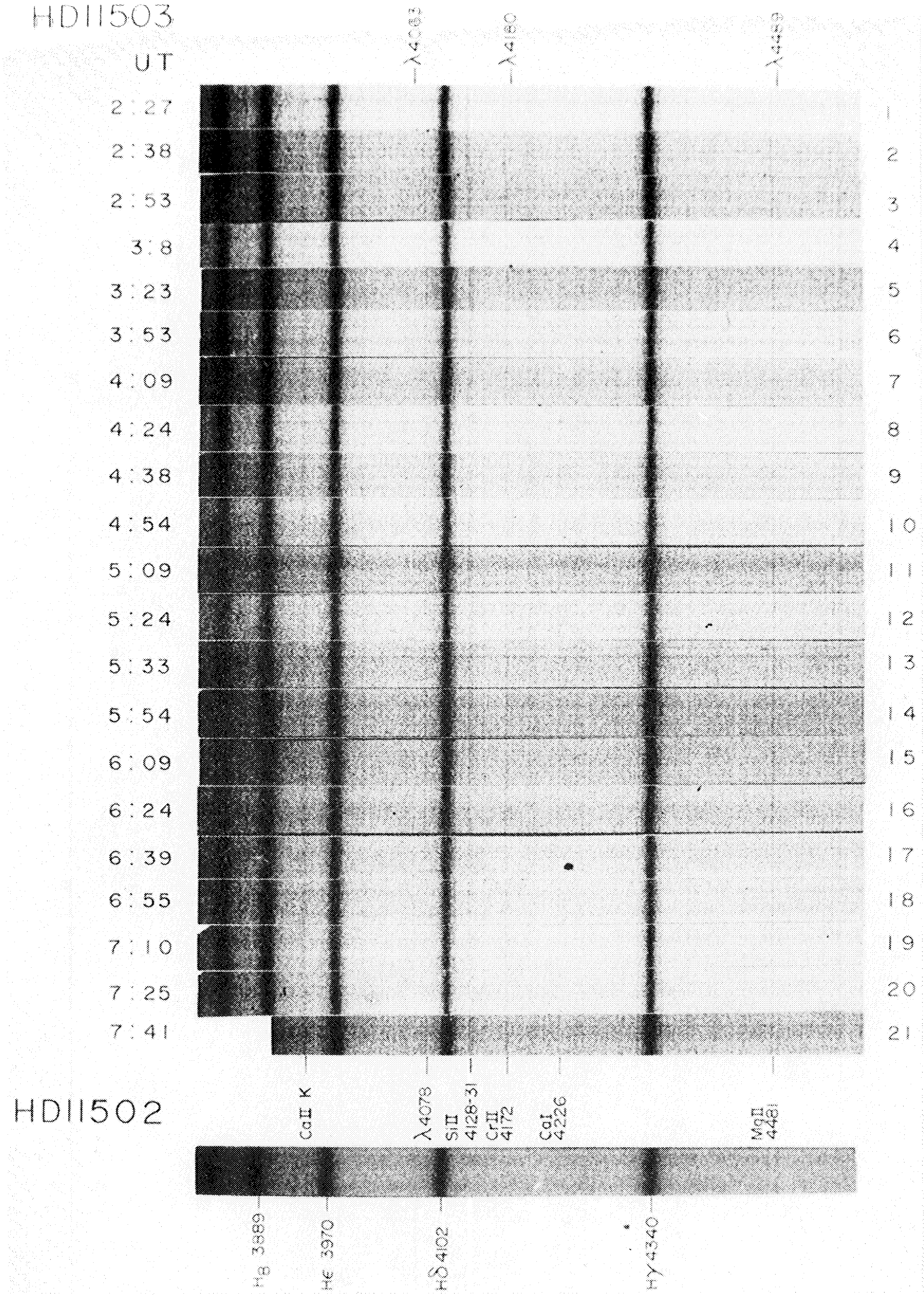

Fig. 5. Spectroscopic observations of HD 11503 on December 3, 1987 obtained with a dispersion of 67 A/mm centered at Hγ. Last spectrum is of HD 11502 which, along with HD 11503, constitute the binary system ADS 1507.

O. LOPEZ-CRUZ ET AL. (See page 249)

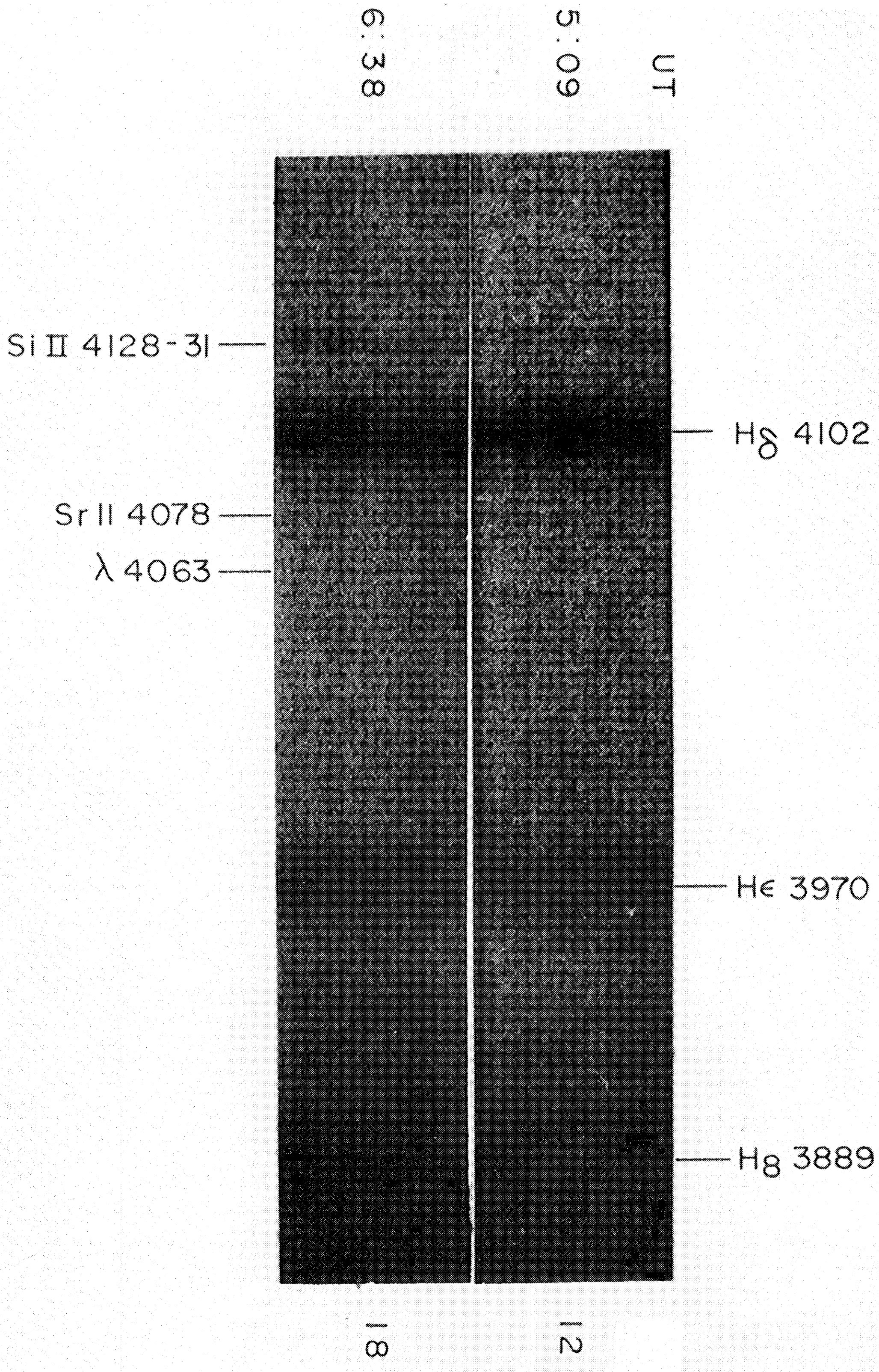

Fig. 8. Enlargment of the spectra of HD 11503 from the MG 12 plate. These spectra show fast variability in a short time span of the line λ4063.