ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **114,** 499-508 (1995)

P Cygni-spectral atlas with complete line identifications in the wavelength range from 4840 to 6760 Å*

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Received March 8; accepted June 14, 1995

Abstract. — Using the coudé spectrograph of the NAO 2m RCC telescope at the Rhodope Mountains, Bulgaria, 11 spectra in the wavelength range from 4840 to 6760 Å of P Cygni were obtained during the years 1981, 1983 and 1985. By averaging these spectra we achieved a S/N-ratio of about 50. Here we present a spectral atlas with complete line identifications. Apart from the lines listed by de Groot (1969) many pure bright lines are identified. Most of them are lines of FeIII with high multiplet numbers and NII. Further emission lines are those of SiII multiplets 2, 4 and 5. A new feature is SII spectrum in absorption and emission. In addition to the forbidden lines discovered by Stahl et al. (1991, 1993) three new lines, [FeII19] λ5159, [FeII18] λ5273 and [FeII34] λ5477 are identified. The presence of some [TiII9] lines as well as the red lines of [NII1] is considered as quite probable.

Key words: stars: P Cygni — line: identifications — atlases

1. Introduction

P Cygni is the brightest and the first discovered *LBV*. The star is classified as B1-1.5 Ia but its spectrum differs from that of normal B1 supergiant by the appearance of P Cygni-type profiles of the lines of abundant ions (de Groot 1969). In 1991, using high quality CCD spectra, Stahl et al. (1991) recognized a number of forbidden lines of [FeII] and the [NII3] λ5755 line in the spectrum of P Cygni. Later Stahl et al. (1993) published a spectral atlas of the star on which, because of the small scale, only the strongest lines could be seen. As the authors have noted, however, "there are plenty of weak lines which are not identified".

The last two studies aroused our interest in obtaining an atlas of P Cygni with complete line identifications which would represent its spectrum in our own days. The first part of the atlas covering the wavelength range $3550 \leq \lambda \leq 4800$ Å was already published (Markova 1994). Here we represent the second part, from 4840 to 6760 Å.

2. Observations and data reduction

The atlas is based on eleven spectra taken with the coudé spectrograph of the NAO 2m RCC telescope during the years of 1981, 1983 and 1985. The stellar spectrum is widened to 480μ and recorded on 103aF emulsion with a linear dispersion of 18 Åmm^{-1} and a spectral resolution of about 0.36 Å. The usable spectral range is about 1900 Å, from 4840 to 6760 Å.

All steps in the reduction procedure were described in detail in our previous work (Markova 1994) and will not be repeated here.

According to our previous plan the atlas should have been based on observations carried out during 1985 only. Unfortunately the larger half of the spectra obtained in that year are of rather bad quality. The necessity to improve our S/N - ratio forced us to extend the sample by including spectra taken in other years, namely 3 spectra of 1983 and 5 - of 1981. By averaging all spectra we achieved a S/N-ratio of about 50.

3. Atlas with line identifications

The presented atlas consists of plots each covering about 90 Å, including 10 Å of wavelength overlapping between contiguous plots. It ranges from 4840 to 6760 Å. Only the newly identified lines are marked on the plots. The lines observed by de Groot are marked with an asterisk (*). A question mark indicates an uncertain identification.

The wavelengths and identifications are listed in Table 1. The telluric lines are not included in the list but they are marked on the plots with an open circle. The successive

*Table 1 is available electronically at the CDS by anonymous ftp 130.79.128.5

columns of Table 1 give:
Column (1): The central wavelength of the measured spectral feature corrected for the Earth radial velocity. A question mark indicates an uncertain feature.
Column (2): Nature of the line: a = absorption, e = emission. If two or three contiguous features are formed by the same line or lines, the wavelength of these features are connected by round brackets just behind the letter in Col. 2.
Column (3): Laboratory wavelength of the identified line transition.
Column (4): Identification of the ions contributing to the line. The line which is believed to be the most important contributor to a blend has an asterisk (*).
Column (5): Remarks: "new", newly identified line; "1", line observed and identified by de Groot (1969); "2", line observed and identified by Stahl et al. (1993).
Column (6): Additional remarks: "I.S.", interstellar line; "bl", blend of two or more lines.
Column (7): Identification of forbidden lines. The area of overlapping of forbidden and permitted lines is marked by a series of two dashes "- -".

Most lines were identified with the Revised Multiplet Table (Moore 1972). The lists of line identifications of de Groot (1969) and Stahl et al. (1993) were also used.

In addition to the lines listed by de Groot many pure bright lines were identified. Most of them are lines of FeIII with high multiplet numbers (e.g. Nos. 113, 114, 115 and 117) and NII (multiplets Nos. 1, 28, 31, 36, 41, 46, 57 and probably 24 and 45). Multiplets 2 and 63 of NII appear in absorption. The other NII lines show P Cygni-type profiles. NII λ5180 (multiplet Nos. 66 and 70) is probably the line of highest excitation energy ($\epsilon_{\rm exc} = 27.60$ eV) observed in the spectrum as weak absorption. Multiplets 5 and 68 of FeIII show P Cygni-type profiles.

Further pure emission lines are the forbidden lines. Most of the lines discovered by Stahl et al. (1991, 1993) are clearly seen on our average spectrum too. In addition we identified three new lines, [FeII19] λ5159, [FeII18] λ5273 and [FeII34] λ5477. The presence of the second one is, in some sense, disputable because of overlapping of three emission lines of FIII λ5269, λ5272 and λ5276. But comparing the observed intensities of the last two lines and neighboring FeIII λ5282 line of the same multiplet and taking into account the corresponding laboratory intensities one can conclude that the presence of [FeII18] λ5273 is quite probable. We consider the presence of some [TiII9] lines as probable too. There is some evidence to suppose that the red lines of [NII] also present. If one try to symmetrize the profile of H_α with respect to its observational emission peak an excess in emission appears at the expected position of these two lines. The fact that the CII λ6582 line does not show absorption component while the other line of the doublet, λ6578, shows strong absorption seems to confirm our suggestion.

The SiII spectrum is obviously intensified with respect to the epoch studied by de Groot. The lines of multiplets 2, 4 and 5 are seen only in emission.

No structures in absorption have been confidently observed in any of the lines on the average spectrum. In view of the lower resolution of the data, about 0.36 Å - the FWHM of the discrete components observed in the higher Balmer lines is about 0.44 to 0.66 Å - and the established variability of the structures in question (Markova 1986, 1993) this result seems to be quite explicable.

Another remarkable feature is the appearance of SII spectrum. This spectrum was looked for but not found by de Groot (1969). The lines with multiplet numbers 6, 11 and 14 show P Cygni-type profiles. Few lines of multiplet No. 7 are seen in emission only. The other SII lines are observed as weak absorptions.

There are a number of features that cannot be identified. All of them are weak, 2 to 3 per cent of the continuum level, with one exception - the emission at λ6717. The reality of the faint features is confirmed on the basis of CCD observations kindly placed at our disposal by Drs. Wolf & Stahl (Heidelberg, Germany). It is necessary to mention here that in the blue photographic region, at λ3649, another unidentified feature exists whose reality is beyond any doubt (Markova 1995).

Summarizing the obtained results we confirmed our previous conclusion (Markova 1994) that at our epoch the spectrum of P Cygni was rather similar to this published by Stahl et al. than to that studied by de Groot.

Acknowledgements. We are grateful to the referees Drs. Wolf and Stahl for their valuable comments and for giving us an opportunity to use thier CCD data. This work was supported by the National Fund "Scientific investigations" to Ministry of Education (F-496/1994).

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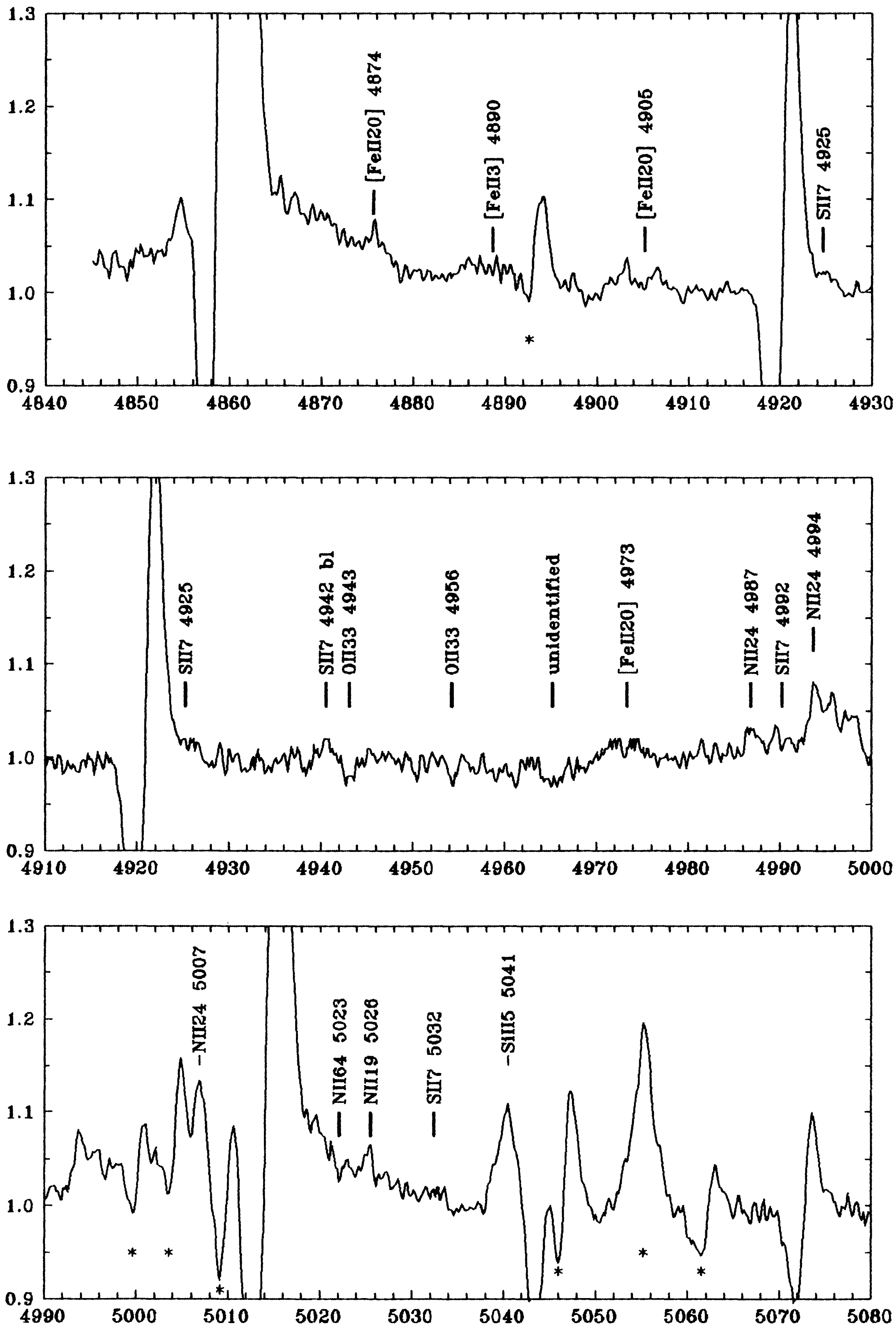
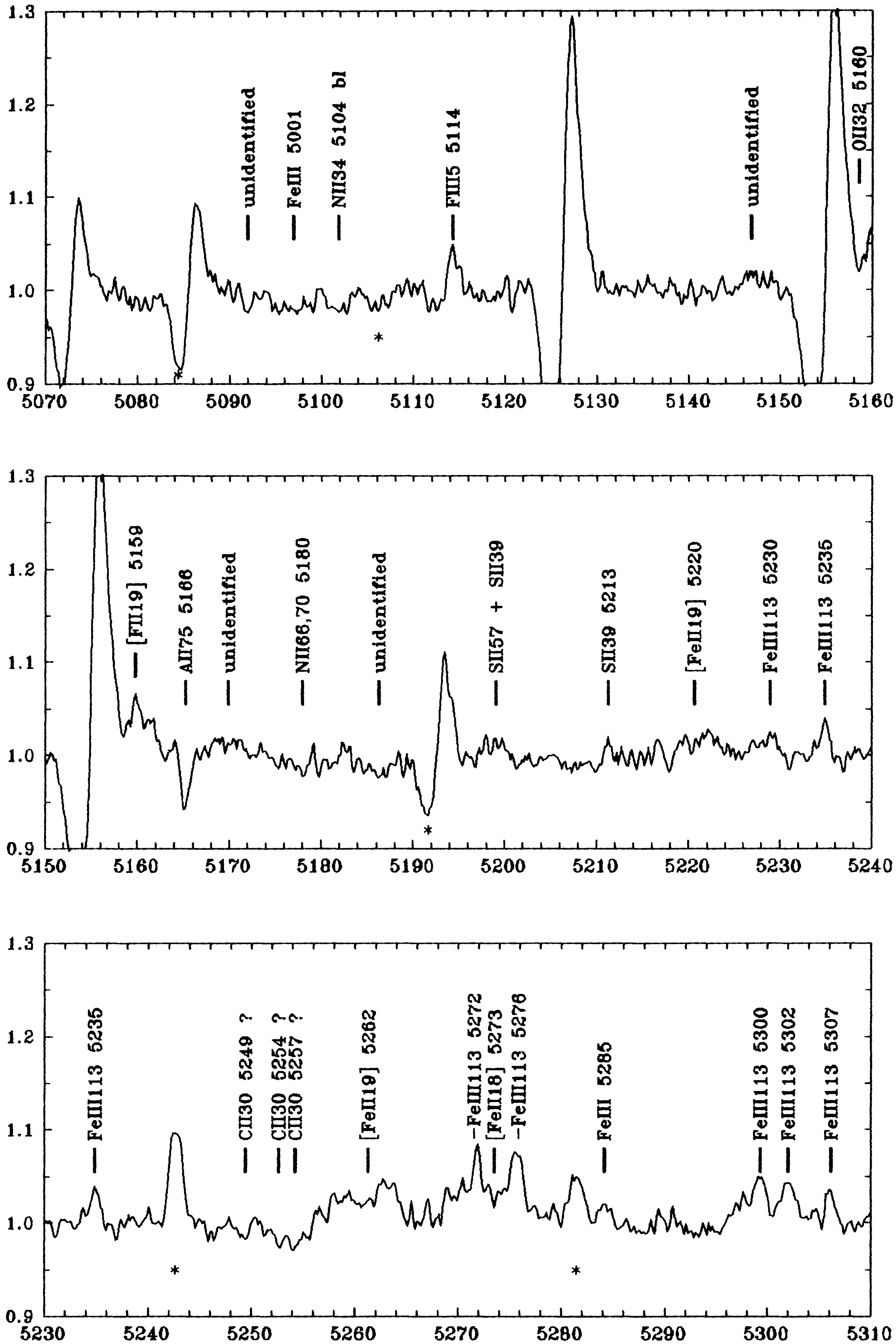


Fig. 1. Average spectrum of P Cygni with line identifications. Each plot covers 80 Å and there is a 10 Å overlap between contigous plots. Only the newly identified lines are indicated. The lines observed by de Groot (1969) are marked with an asterisk (*). The telluric lines are indicated by an open circle



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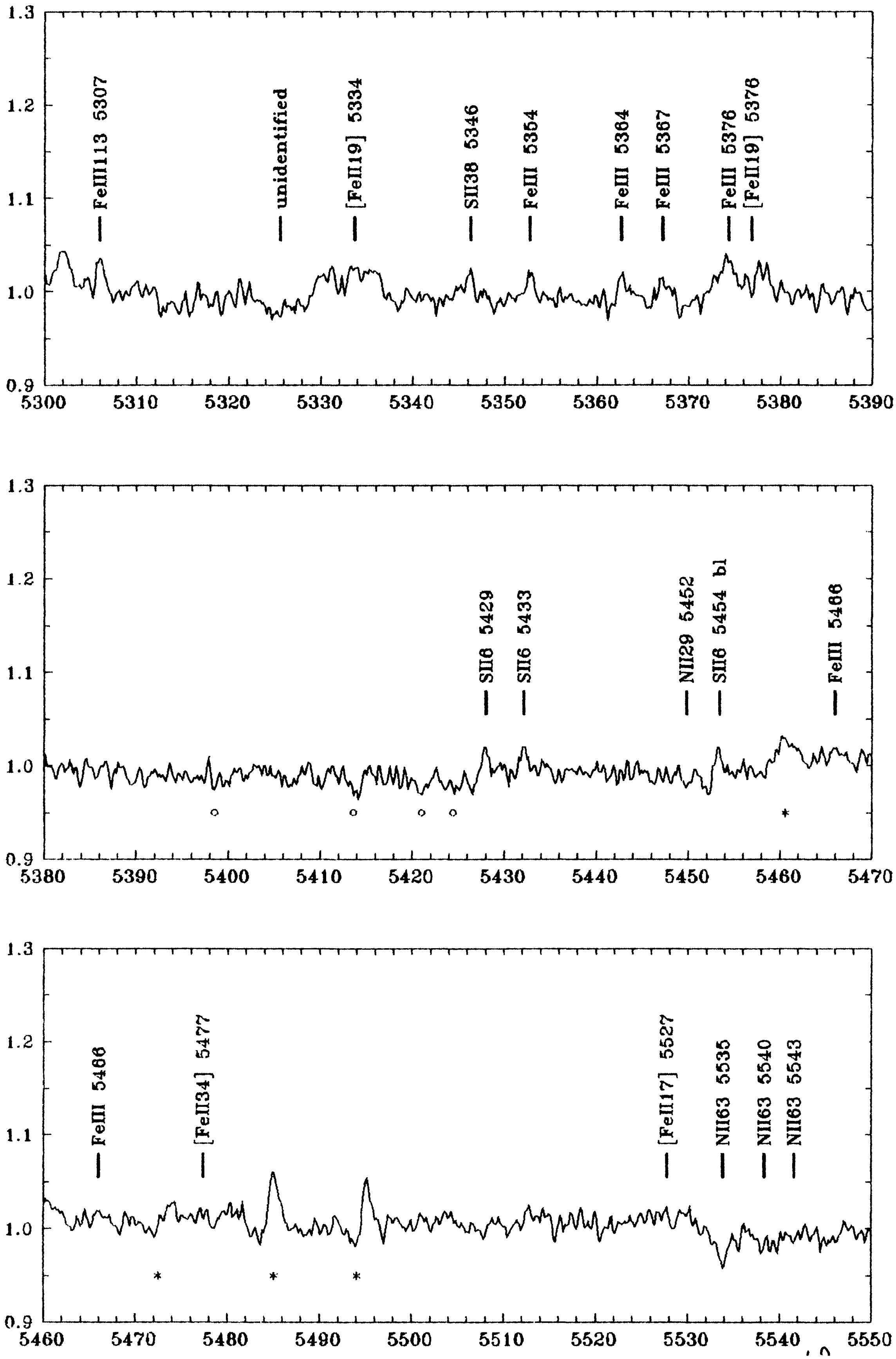

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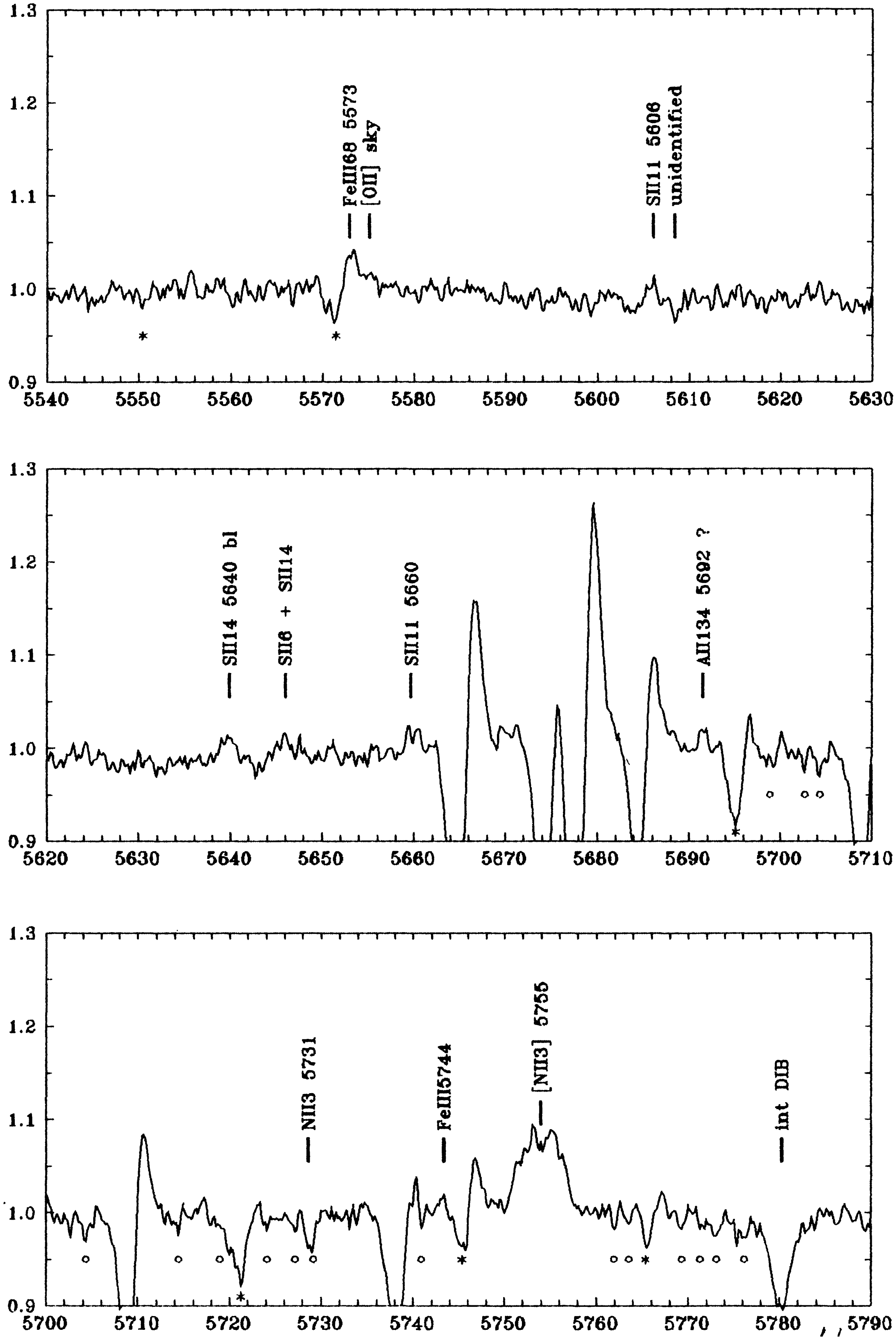

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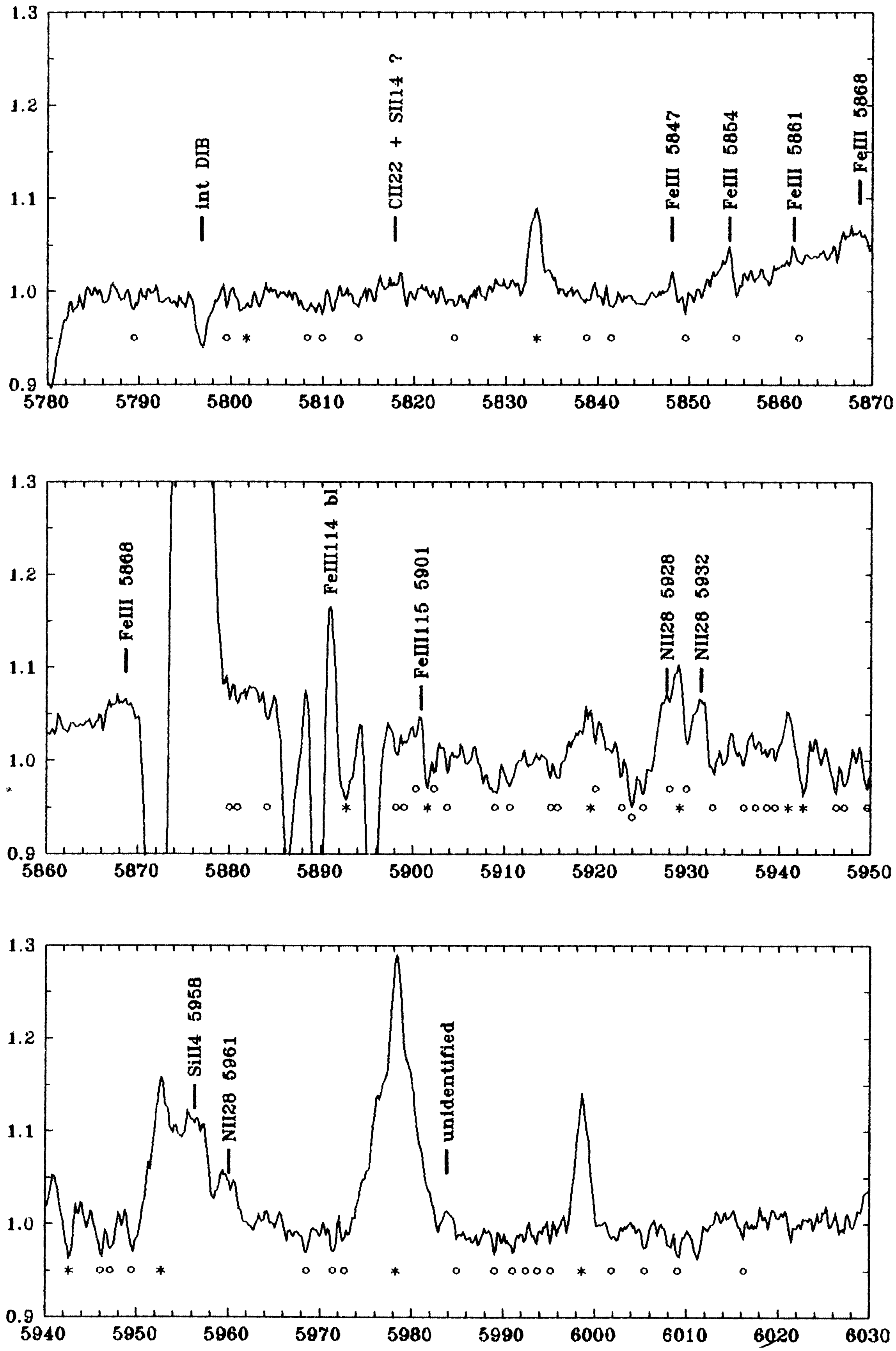

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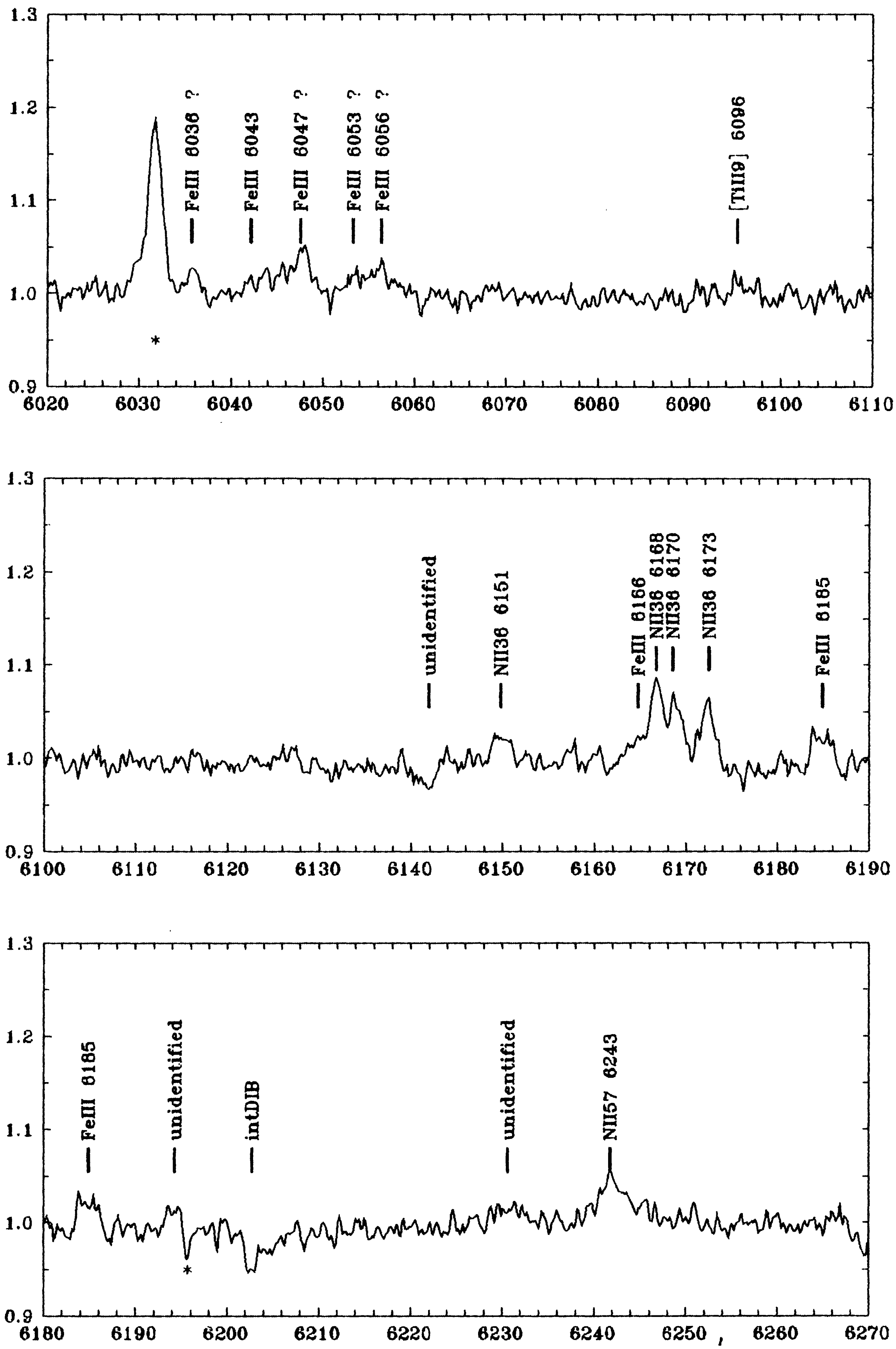

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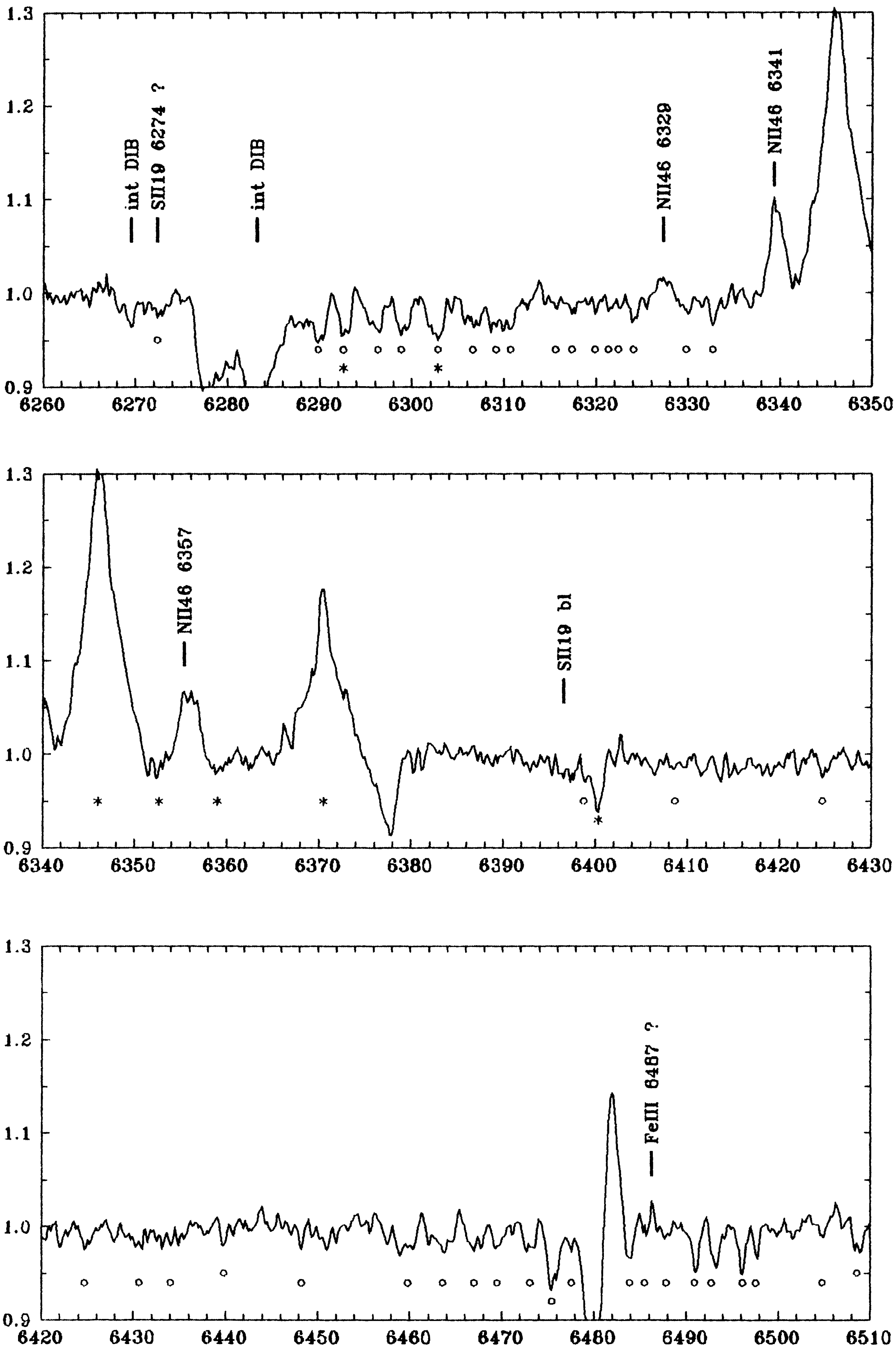

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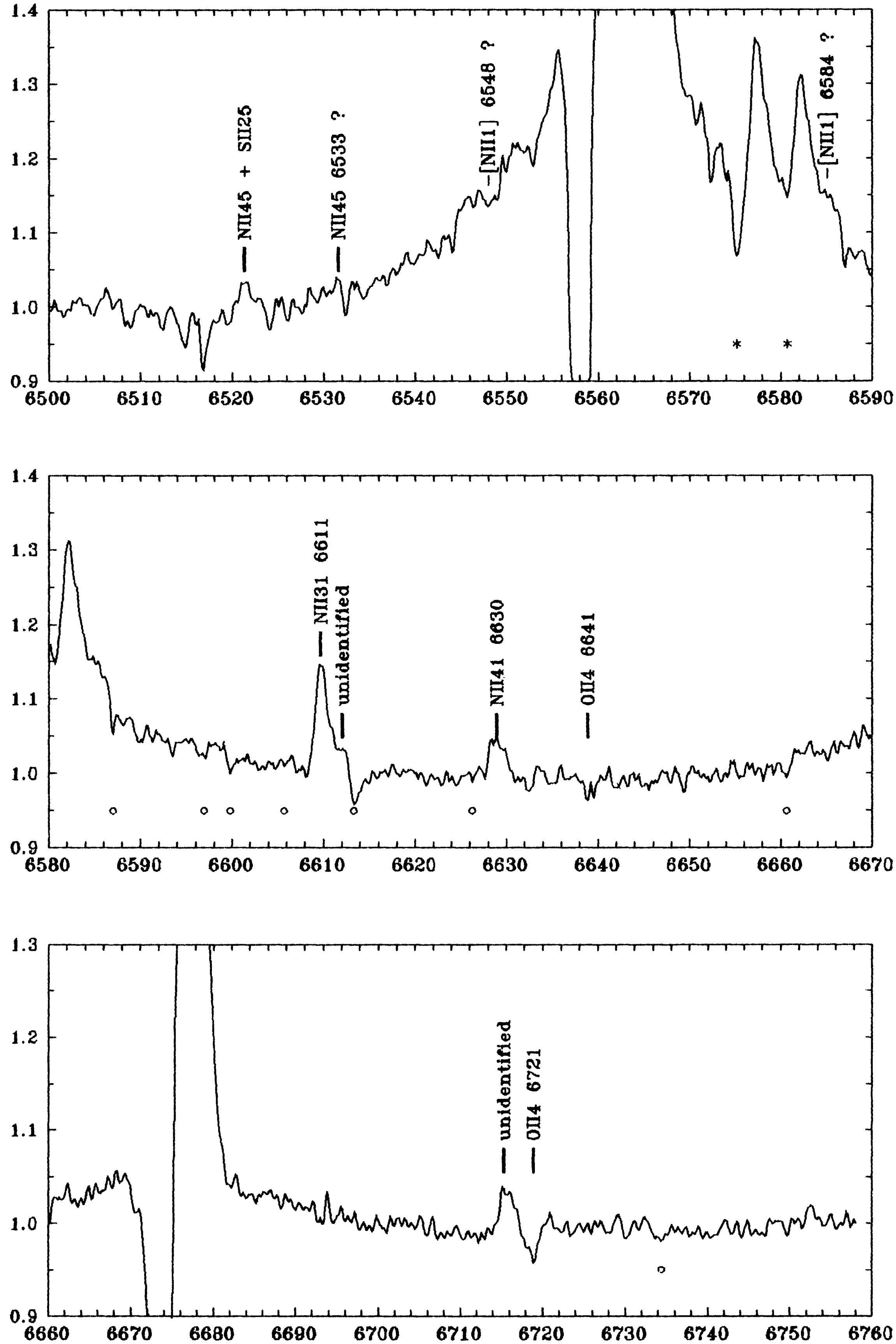

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