AN INVESTIGATION OF IR TRIPLET He I 10830 Å PROFILES IN ACTIVE REGIONS AND THE QUIET CHROMOSPHERE

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Abstract. This paper gives a description of the technique and equipment used to make solar observations in the near IR region with a coronagraph. Examination of active-region spectra in the neighborhood of the He I 10830 Å line confirm that the the line is enhanced in sunspot umbrae. The line profiles of umbrae and faculae differ qualitatively. Flares show a decrease in the line depth in comparison to faculae, and in flare kernels the line undergoes an emission reversal. Simultaneous observations of spectra of chromospheric spicules at two heights above the solar surface reveal that the half-width of the 10830 line increases with height.

Key words: He I 10830 Å – infrared: stars – Sun: activity – Sun: flares – telescopes

1. Introduction

Since the mid-70s, at the Sayan Solar Observatory Coronagraph of the Institute of Solar-Terrestrial Physics (formerly SibIZMIR), observations of solar spectra have been carried out in the near IR region using different types of image tubes. The best results were achieved by use of image tubes with magnetic focusing, installed within the chamber of a diffraction spectrograph which enables spectra to be obtained in the He I 10830 line with 1.0 Å/mm dispersion and 0.03 Å spectral resolution.

The advantage of image tubes with magnetic focusing is that, owing to the high resolving power of the photocathode and the luminescent screen (up to 60 lp/mm), the use of a strong, homogeneous magnetic field allows geometrical aberrations to be eliminated. We used Helmholtz coils to produce a focusing magnetic field, of 3.5 kG, with 1% homogeneity. Because of the large magnetic field strength, the electron Larmor radius inside the image tube turned out to be less than image resolution, and the device was insensitive to variations in external conditions. Spectra from the flourescent screen were recorded using fast optics ($f/1.1$) imaging onto photographic film. The resulting resolution on film was about 20 μm. The use of contact photography by means of an optical-fiber disk results in substantially degraded image quality due to inhomogeneous transmission through the optical fiber section. The spectra obtained were digitized using an automated microdensitometer, with a density-measurement error of 0.02 D and a scanning step of 5 μm.

The observing program was aimed at a study of the behavior of the He I 10830 triplet in different features on both the solar limb and disk. In this case we tried to take advantage of the fact that rather stringent requirements on light scattering are satisfied for the optical elements in the coronagraph; the instrumental scattered light is less than 0.5% (Nikolsky and Sazanov, 1967). With this instrument we obtained spectra of the He I 10830 line in sunspot umbrae and in chromospheric spicules and flares.

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TABLE I
Results of Observations and Analysis of Two Sunspots

Sunspot Area	r_λ^s	$r_\lambda^{s\ a}$	r_λ^{pl}	$\Delta\lambda_{0.5}^s$ (Å)	$\Delta\lambda_{0.5}^{pl}$ (Å)	$(\frac{W_v}{W_n})^s$	$(\frac{W_v}{W_n})^{pl}$
35×10^{-6}	0.93 ± 0.02	0.95	0.78	1.0	0.68	1.3	2.1
50×10^{-6}	0.94 ± 0.02	0.94	0.83	1.4	0.62	1.2	1.5

[a] reduced value.

2. Observational Results

2.1. Sunspot Umbrae

Fay *et al.* (1972) were among the first to detect the enhancement of the absorption line He I 10830 in a sunspot umbra. As they report, the spectrum was recorded photoelectrically; in this case the spectral region around 10830 Å was recorded in a time of about 1 minute (spectral resolution 0.1 Å, time constant 0.8 second). A question arises as to whether the sunspot line profile may be contaminated by plage due to blurring of the image over long exposure time.

In order to address this question using the device described above, we obtained spectrograms with 0.5–1.0 second exposure. Because of the low level of instrumental stray light in the coronagraph, we considered it possible to address the effect of image blurring by itself upon the profiles, using the method suggested by Stepanov (1957). Results of observations and analysis of two sunspots are presented in Table I (Borodina and Papushev, 1979). Indices *s* and *pl* stand for the sunspot umbra and plage respectively, the other symbols being standard. As is evident from Table I, the He I 10830 line is indeed present in the sunspot umbra, and its depth is increased in comparison to the quiet photosphere, for which $r = 98\%$. Fay *et al.* (1972) obtained residuals, r, of 0.83 and 0.72 for sunspots with fractional hemispheric areas, S, of 70×10^{-6} and 100×10^{-6} respectively. Comparing our values of 0.95 and 0.94 for $S = 35 \times 10^{-6}$ and $S = 50 \times 10^{-6}$, one is justified in believing that the dependence of r on the sunspot umbral area found by Fay *et al.* (1972) is real. The asymmetry of the He I 10830 profile, caused by its triplet character, is less in a sunspot umbra than in plage.

2.2. Chromospheric Flares

Available data on the behavior of the helium IR triplet line in solar active regions suggest that this line is useful not only for studying the physical conditions in flare chromospheres but also for predicting the occurrence of a flare, as well as for concluding that a flare has recently occurred in a particular active region. For this purpose, we have observed and examined spectrograms of active regions in the He I 10830 line during the period of the Solar Maximum Year, 1980–1982.

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Typical flare behavior of the IR triplet He I 10830 is exemplified by the flare of importance 1B in active region 474 (see *Solar Geophysical Data*) of 1982 July 17 at 02:11:30 UT. The flare lasted about 30 minute During this time interval we recorded the He I 10830 line profiles in different spatial features in the flare. Simultaneously with the 10830 spectrograms, Hα filtergrams were taken at line center from the spectrograph slit monitor using a Hallé filter. Our 10830 line-profile observations had better time resolution (0.1 second exposures) than previous observations of the line in flares.

In flares the depth of the He I 10830 line becomes smaller, compared to the plage line depth, by 10–20%. In flare kernels the line goes into emission. The line spends about one-third of the total flare lifetime in emission. The profiles show the 10830 emission core to be significantly weaker in the flare kernel than is the core of Hα.

Following the disappearance of the emission kernel of the flare, the depth of the 10830 line where the kernel was located decreases by 10–20%. The half-width of the emission core of the line in the flare kernel varies from $\Delta\lambda_{0.5} = 0.8$ Å to $\Delta\lambda_{0.5} = 0.8$Å.

2.3. Chromospheric Spicules

Investigations by Papushev (1977) and Papushev and Salakhutdinov (1989) indicate a possible transition of spicular material evolving from a "cold" state to a "hot" state and, thus, the formation of a transition region between the chromosphere and the corona. To address this problem it seems appropriate to study spicule evolution simultaneously in several spectral lines, which is a difficult task when observations are made at the coronagraph with a single objective lens, except in the case of the spectral blend consisting of the lines H_8 and teh neighboring He line.

Extensive data from spicule observations in different spectral lines have been published in the literature to date. In particular, according to Zirker (1962) the halfwidths of the hydrogen lines Hα and Hβ decrease with height in spicules, while the halfwidth of the He I D_3 line increases. We have attempted to measure the He I 10830 line at two height levels in chromospheric spicules simultaneously, since 10830 is the most intense helium emission line. Again, we benefit from the substantially lower level of stray light due to atmospheric turbulence in the near IR region than in the visible.

Results of analysis of line profiles from 12 spicules at two height levels are listed in Table II. We find an increase in halfwidth with height, but our halfwidths are greater than those obtained by Nikolsky (1965) and Livshitz and Demkina (1965). The larger halfwidths are the subject of further investigation. We are also investigating the evolution of spicules in the He I 10830 line over time.

Our results suggest a rise in the temperature of the spicule with height, and a thermal emission mechanism of the middle and upper chromosphere in the He I 10830 line.

TABLE II
Halfwidths of 10830 Profiles of Spicules at Two Heights

Halfwidth (Å)	
Height (±1000 km)	
4000 km	7000 km
2.89	2.96
2.41	2.96
2.02	2.89
2.34	2.88
2.27	2.62
2.27	2.55
2.20	2.62
2.13	2.95
2.14	2.82
2.15	2.97
2.28	3.23
2.40	2.48

3. Conclusions

In this report we have presented some preliminary results of an investigation of the He I 10830 line profile in the Sun. We plan to publish the results after a full analysis of the observational data.

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