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The Role of Velocity Redistribution in Enhancing the Intensity of the He II 304 Å Line in the Quiet Sun Spectrum

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ABSTRACT

We present observational evidence of the effect of small scale ("microturbulent") velocities in enhancing the intensity of the He II λ304 line with respect to other transition region emission lines, a process we call "velocity redistribution". We first show results from the 1991 and 1993 flights of SERTS (Solar EUV Rocket Telescope and Spectrograph). The spectral resolution of the SERTS instrument was sufficient to infer that, at the spatial resolution of 5″, the line profile is nearly gaussian both in the quiet Sun and in active regions. We were then able to determine, for the quiet Sun, a lower limit for the amplitude of non-thermal motions in the region of formation of the 304 Å line of the order of 10 km/s. We estimated that, in the presence of the steep temperature gradients of the solar Transition Region (TR), velocities of this magnitude can significantly enhance the intensity of that line, thus at least helping to bridge the gap between calculated and observed values. We also estimated the functional dependence of such an enhancement on the relevant parameters (non-thermal velocities, temperature gradient, and pressure). We then present results from a coordinated campaign, using SOHO/CDS and H-α spectroheliograms from Coimbra Observatory, aimed at determining the relationship between regions of enhanced helium emission and chromospheric velocity fields and transition region emission in the quiescent atmosphere. Using these data, we examined the behavior of the He II λ304 line in the quiet Sun supergranular network and compared it with other TR lines, in particular with O III λ600. We also examined the association of 304 Å emission with the so-called "coarse dark mottle", chromospheric structures seen in H-α red wing images and associated with spicules. We found that all these observations are consistent with the velocity redistribution picture.

Subject headings: Line: formation — Line: profiles — Sun: atmospheric motions — Sun: chromosphere — Sun: corona Sun: transition region —

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However, much work needs still to be done to assess whether the conditions for this process to be effective are realistically present in the solar atmosphere.

The other suggestion offered by CJ75, CJ80, a velocity redistribution of the He^+ ions, is the subject of this paper. A preliminary study of SERTS spectra supported this suggestion (S. Jordan 1994). We now present much more extensive evidence, based on observations taken with the SERTS sounding rocket in 1991 and 1993, and supplemented by more recent SOHO and ground-based results, that a redistribution of the He^+ ions by comparatively small-scale "microturbulent" motions in the presence of a sharp TR temperature gradient makes a significant contribution to the required intensity enhancement in the quiet Sun. Further support for this hypothesis, which we have chosen to call "velocity redistribution," is provided by an analysis based on an earlier SERTS flight in 1989, that makes a strong case for collision domination of the 304 Å line, at least in the quiet Sun and possibly in active regions as well (Jordan et al. 1993), an effect that is confirmed by results from a recent SERTS flight, in 1997, reported later in this paper.

The paper is organized as follows. In Section 2 we present and analyze SERTS observations of the He II λ304 line from the 1991 and 1993 flights. In Section 2.1 we review the "velocity redistribution" mechanism, and show that substantial unresolved motions (a requisite of that mechanism) are present in the region of formation of the 304 Å line, at least in the quiet Sun. Having established the plausibility of a significant role of the "velocity redistribution" mechanism in the quiet Sun, in Section 3 we discuss the June 20 – 21, 1998 coordinated H-α and SOHO observations, investigating the relationship between the 304 Å line and quiet-Sun chromospheric and TR structures.

2. SERTS Observations

The SERTS observations used for this study include spectra and images in the He II λ304 line taken during the May 7, 1991 and the August 17, 1993 flights, denoted in this paper as SERTS-91 and SERTS-93, respectively. The science instrumentation was identical on the two flights, making the two sets of observations highly compatible. A basic description of the instrument is given in Neupert et al. (1992). The unique "dumb-bell" shape of the SERTS entrance slit permitted us to obtain spectra of both active regions and quiet Sun, over areas that were also imaged in the same wavelengths in near-real time. The spectral resolution for these flights was approximately 55 mÅ (full-width at half maximum, FWHM, see below), and the spatial resolution about 5″. Further details on the configuration of the SERTS instrument, as well as an analysis of average active-region and quiet-Sun spectra for the above two flights are given in Brosius et al. (1996).

Slit spectra were selected from two different pointing positions during each flight. For SERTS-91, the second pointing position yielded narrow-slit spectra over the edge of active region NOAA 6615 (S08, W32) and images (spectroheliograms) of the quiet Sun in the lower wide lobe that crossed the west limb, as shown in the left-hand panel of Figure 1. We will refer to this pointing position as SERTS-91 position A. At the first pointing position, the upper wide lobe imaged the same active region while the narrow slit provided spectra of the previously imaged adjacent area that was partially off the limb (SERTS-91 position Q). For SERTS-93, the slit at the first pointing position bisected active region NOAA 7563 (S01, W15), and will be referred to as SERTS-93 position A (right-hand panel of Figure 1). For the second pointing position, the narrow slit was moved over a prevalently quiescent area (SERTS-93 position Q), while the wide-slit provided imaging of the active region. We selected the best 64 spatially resolved spectra along the narrow slit in all the cases.