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Ultraviolet spectropolarimetric observations to probe the solar chromosphere and transition region

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There is a thin transition region (TR) in the solar atmosphere where the temperature rises from 10000 K in the chromosphere to millions of degrees in the corona. Little is known about the mechanisms that dominate this enigmatic region other than the magnetic field plays a key role. The magnetism of the TR can only be detected by polarimetric measurements of a few ultraviolet (UV) spectral lines, the Lyman-alpha line of neutral hydrogen at 121.57 nm (the strongest line of the solar UV spectrum) being of particular interest given its sensitivity to the Hanle effect (the magnetic-field-induced modification of the scattering linear polarization; [1,2]). We performed a NASA sounding-rocket experiment, the Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP; [3-5]), to measure the scattering polarization of the Lyman-alpha line and to explore the magnetism and geometry of the upper solar chromosphere and TR. The development of the CLASP instrument [6,7] was finished by the spring of 2015 (see also [8,9]), and it was launched from White Sands in the US on September 3, 2015. During its 5-minute ballistic flight, CLASP successfully made the first spectropolarimetric observation of the Lyman-alpha line (121.57 nm) of the solar disk radiation, which forms all through the upper chromosphere and in the TR.

CLASP discovered that the hydrogen Lyman-alpha line is indeed linearly polarized [10]. The Stokes profiles (I, Q and U) observed by CLASP with a spatial resolution of about 3 arcsec and a temporal resolution of 5 minutes show that the Q/I and U/I linear polarization signals are of order 0.1% in the line core and up to a few percent in the nearby wings and that both have conspicuous spatial variations with scales of 10-20 arcsec, in good agreement with the theoretical predictions [1,11,12]. However, the Q/I line-center signals observed by CLASP do not show a clear center-to-limb variation (CLV), in marked contrast with the results of radiative transfer calculations in 1D [1,11] and 3D [12] models of the solar atmosphere. This suggests that the plasma structures of the upper chromosphere and transition region are more complex than those present in the theoretical models.

In addition, CLASP discovered that the resonance line of Si III at 120.65 nm is also linearly polarized by scattering processes. Via the Hanle effect this Si III line is sensitive to significantly stronger magnetic fields than the Lyman-alpha line: the critical magnetic strength for the onset of the Hanle effect in the Lyman-alpha core is 53 Gauss, while it is 290 Gauss for the Si III line. By comparing the scattering polarization observed in the Lyman-alpha wing (which is insensitive to the Hanle effect), in the Lyman-alpha core and in the Si III line we have provided some indications for the operation of the Hanle effect in the chromosphere-corona TR [13].

We plan to perform another sounding rocket experiment in 2019, the Chromospheric LAyer Spectro-Polarimeter 2 (CLASP2; [14]), to measure the intensity and the linear and circular polarization profiles of the Mg II h & k lines around 280 nm. To this end, we will use most of the CLASP instrument, with some modifications so as to be able to observe the 280-nm spectral range. These resonance lines are of great potential interest to explore the magnetic fields of the upper solar chromosphere, in active and quiet regions of the solar disk, because they are sensitive to the joint action of scattering processes and the Hanle and Zeeman effects [15-17]. These sounding rocket experiments help us to open a new diagnostic window in solar physics: ultraviolet spectropolarimetry.

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