THE POLAR EXTENSION OF THE SOLAR CHROMOSPHERE

F. Auchère, J. P. Delaboudinière
Institut d’astrophysique spatiale, bâtiment 121, Université Paris XI, 91405 Orsay Cedex, France

S. Koutchmy, S. Boulade
Institut d’astrophysique de Paris, CNRS, 98 bis boulevard Arago, 75014 Paris, France

ABSTRACT

We present a comparative analysis of the polar extension of the chromosphere, using strictly simultaneous \(H_\alpha\) ground-based observations and \(He^{II}\) space-based observations. The typical prolateness is found to be \(dr/r = 0.01\) in \(He^{II}\) and \(0.001\) in \(H_\alpha\). The first measurements in the 30.4 nm \(He^{II}\) line over a period of two years, as well as coronal data, are discussed to infer the role of the global magnetic field.

1. INTRODUCTION

Since the earliest space observations, it has been known that the radial gradient for many TR lines, including the \(He^{II}\) lines, is lower inside coronal holes than outside (Ref. 6 and Ref. 10). From historic visual \(H_\alpha\) observations, it was evident that the polar chromosphere looks more extended than the low latitude chromosphere (Ref. 8). More recent measurements confirmed that characteristic (Ref. 1 and Ref. 5). At the same time, the theoretically expected oblate shape of the Sun was measured repeatedly by many observers, and the most recent measurements (Ref. 7 and Ref. 9) reduce this oblateness to a value of order of \(10^{-2}\) arcsec.

Although theoretically unexpected, we present here the first quantitative measurements of the prolate shape of the chromosphere as simultaneously measured in \(H_\alpha\) and in the \(He^{II}\) line at 30.4 nm. We also present statistically more significant values derived for both the high chromosphere and the very inner corona.

2. RESULTS OF THE AUGUST 1997 OBSERVING CAMPAIGN

We compared \(H_\alpha\) limb data from the NSO/Sacramento Peak 20-cm aperture emission-line coronograph, with those simultaneously recorded by the EIT onboard SoHO in the \(He^{II}\) line at 30.4 nm (Ref. 4), both types of images covering the full limb (see Fig. 1). The \(He^{II}\) images were processed with an occulting mask to simulate the form of the coronagraph images, and a cross-correlation method involving small azimuthal steps was applied to corresponding image pairs. By this method it was found that an excellent overall correlation does exist between the full limb features in the two lines. But in agreement with Ref. 3 local details can appear quite different, and the small features do not correlate.

This procedure allowed an exact comparison between these space and ground-based images, and by extension the shape of the chromosphere of the Sun as observed in \(H_\alpha\) and in \(He^{II}\) emission (see Fig. 1). We looked at the edges defined as the minimum of the radial gradient of intensity outward the disk, which in turn has allowed a comparison of the polar and equatorial diameters for both wavelengths. Taking into account distortion due to monochromatic dispersion in the Earth’s atmosphere, it was found that the solar chromosphere as observed with a 0.1nm FWHM Lyot \(H_\alpha\) filter is prolate to an extent of \(2.2 \pm 0.1\) arcsec (over a solar diameter); this value is possibly a function of the phase of the solar activity cycle. The corresponding value for the \(He^{II}\) is \(\sim 10\) arcsec prolate. We recall that by contrast, measurements of the photosphere report an oblateness of perhaps 10 milliarcsec (Ref. 7). In order to improve the accuracy of our measurements, we also processed all the full-field full-resolution EIT images with the same technique, now including the coronal lines. Figure 2 gives the mean profiles (over hundreds of images) of the solar limb in polar coordinates for the EIT channels. The mean prolateness over a solar diameter is \(10.4 \pm 0.1\) arcsec for \(He^{II}\), \(2.2 \pm 0.1\) arcsec for \(H_\alpha\), \(1.0 \pm 0.1\) arcsec for \(Fe^{XII}\), and \(2.1 \pm 0.1\) arcsec for \(Fe^{IX}/X\) and \(Fe^{XV}\).

3. DISCUSSIONS

The reason for a prolate chromosphere is not completely understood. However, since the chromosphere is a magnetically-dominated atmosphere, the distribution of the chromospheric plasma presumably relates to the predominantly radial direction of the field lines at the poles, especially around solar minimum. The different scale heights for these two lines presumably results in the \(He^{II}\) emission "magnifying" the effect, as well the effect of prolateness. For the moment, we have demonstrated that \(H_\alpha\) full-limb coronal images show a definite prolateness quite well, although coronal holes are not seen in \(H_\alpha\). We estimated the equatorial \(H_\alpha\) limb to be at an average height of order of 4.0 Mm, in agreement with the classical work of Dunn, 1960 (Ref. 5). Using the same approximations, the \(He^{II}\) limb is estimated to be at 5.0 Mm in equatorial regions. In \(He^{II}\), the
prolateness is quite large. We are now looking at lower levels to check where the prolateness starts. Coronal data show a smaller prolateness, of order of \( dr/r = 0.5 \times 10^{-3} \), two times smaller than the \( H_a \) prolateness. However, the inner corona “limb” is also deeper; the VLA model puts the top of the chromosphere at 2.1 Mm; the corona penetrates into the transition region to the 2.5 Mm heights (Ref. 2). Overall, the prolateness that we measure increases with the height above the classical chromosphere, see table 1.

To make the connexion with the high corona, we remind that the solar corona is “flattened” equatorially; indeed, the heliosphere at solar minimum is made of two components, the fast wind and the helio-sheet and/or the slow wind. We speculate that the prolate chromosphere is linked closely with the origin of this behaviour, since it should produce the fast wind with an interplay between the dynamical pressure and the magnetic structure on a global scale, although the role of small-scale jet-like phenomena is not clear.

4. REFERENCES

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Figure 2: Mean profiles of the solar limb observed in the four EIT channels.

<table>
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<tr>
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<th>HeII</th>
<th>FeXV</th>
<th>FeXII</th>
<th>FeX</th>
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<td>1.0</td>
<td>2.1</td>
<td>2.2</td>
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Table 1: Prolateness over a solar diameter and estimated altitude of the limb above \( \tau = 1 \) for different lines.