PRELIMINARY RESULTS FROM THE ORBITING SOLAR OBSERVATORY 8:
OBSERVATIONS OF OPTICALLY THIN LINES

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Received 1976 May 5; revised 1976 July 19

ABSTRACT

Measurements of the C iv and Si iv solar resonance lines have been analyzed to yield mean profiles, a comparison of cell and network profiles, and the behavior of the lines at the extreme solar limb.

Subject headings: line profiles — Sun: chromosphere — Sun: corona

I. INTRODUCTION

The University of Colorado spectrometer aboard the Orbiting Solar Observatory (OSO-8) satellite (Bruner et al. 1976) has within its usable spectral range the strong C iv resonance lines at X1548 and X1551 and the Si iv resonance lines at X1393 and X1402. These are high-temperature lines (approximately 60,000 K for Si iv and 100,000 K for C iv) formed in the solar chromosphere-corona transition region, and their detailed study can provide important quantitative information about this little understood region of the solar atmosphere. Early results from our analysis of these observations include average profiles, cell-network studies, and limb profiles.

II. AVERAGE PROFILES

A number of scans taken early in the mission with the 900" slit are averaged to obtain mean profiles of the C iv X1548, X1551, and Si iv X1393 lines. The spectral resolution is better than 30 mÅ, quite sufficient for these broad lines. This spatial average includes some active regions. No contributions from the extreme limb were included. The X1402 line has not been studied sufficiently to include it. To combine the scans, we first performed a least-squares fit to each with a Gaussian profile convoluted with the instrumental ghost pattern to compensate for this effect. The fit defines four parameters: the amplitude, the background level, the line width, and the position of the line center. The scans for a given line were centered on the computed line center and summed. These profiles were then also fitted to a convoluted Gaussian curve. The Gaussian (e-folding) widths obtained, together with the number of scans summed and the total count at line center, are listed in Table 1.

The resulting widths are roughly 20 percent larger than the Boland et al. (1975) photographic measurements, probably because theirs are averaged only over 40" in a quiet region. Observations with our 20" slit decker show variations in line widths of a factor of two at disk center. In X1548, for example, we have disk center plage profiles with widths of 35 km s⁻¹ and quiet regions with 18 km s⁻¹.

Determining the detailed shapes of the line profiles was the main motivation for this study. Figure 1 shows the X1548 profile and the fitted curve. The solar profile shows a small deviation from a Gaussian curve which we also see in X1551 and X1393. It is also seen in the individual scans that went into the average. They have a more triangular shape, more peaked at the top and broader at the bottom than a Gaussian curve. This shape would result if the profile is a sum of Gaussian curves with a range of widths and with about the same line centers. If the mean profile had a simple sinusoidal or sawtooth component, such as from constant-amplitude waves or shocks passing through the line formation region, then it would be more rectangular than a Gaussian curve (Shine and Oster 1973).

There are no clearly defined asymmetries in the profiles, but the centers may be shifted from the solar rest frame wavelength. We are not able to make absolute wavelength measurements of these lines (although a detailed analysis may relate them to the telluric O I lines near X1300), but accurate measure-

* National Center for Atmospheric Research, sponsored by the National Science Foundation.
merits of the wavelength differences from nearby lines in the same scan can be made. Most of these lines are formed lower in the solar atmosphere. However, we have not yet been able to make unambiguous identifications of the weak lines within the ranges covered by the scans. One possible identification indicates that the C iv lines are redshifted by about 6 km s\(^{-1}\) relative to nearby lines formed in the upper chromosphere.

III. CELL-NETWORK STUDIES

For the examples given here, a series of spectroheliograms was made, each at a particular wavelength in the line profile being studied. The raster mode yielded a 16 \(\times\) 7 element array covering about 2\(\text{'}\)7 \(\times\) 2\(\text{'}\)3 in the Sun. Twenty such rasters were performed per orbit (1 hour), stepping across the line from blue to red and building up a line profile for each element. The sum of all 20 rasters for a Si iv \(\lambda1393\) study in a quiet region near disk center is shown in Figure 2a. For separating the raster area into cell and network regions, we assumed, in rough accordance with measurements in chromospheric lines and other transition region lines, that the brighter network occupies about 20 percent of the area (Skumanich 1975). With this definition the shaded areas in Figure 2b represent the network. The average profiles for network and cell are shown in Figure 2c.

Profiles obtained in this way are often noisy for individual raster elements because of the time span involved, and this extra noise appears in the averages in Figure 2c. Also, the profile widths will be increased by about 10–20 percent and the profiles will be somewhat distorted because of thermal stresses and the orbital motion during this time. Nevertheless, we can get a good measure of the differences between the average profiles of solar features with this mode since each element is affected in almost the same way.

The profiles in Figure 2 show a line center intensity ratio of about 3. Gaussian fits indicate a network profile width 8 percent greater than the cell and a network redshift of 1.1 km s\(^{-1}\) relative to the cell. A similar study made in C iv \(\lambda1548\) also shows a line center intensity ratio of 3 but has a network width increase of 20 percent and a redshift of 1.6 km s\(^{-1}\). These widths and shifts are averages, and there is a wider range of variations. The velocity and intensity variations are described by Lites et al. (1976).

These examples are typical of cell-network studies that we have analyzed to date. Detailed processing of many more observations in this mode will include center-to-limb cell-network studies and observations of plages, filaments, and coronal holes.

IV. LIMB PROFILES

Since the C iv and Si iv lines are optically thin, they show impressive limb brightness at the extreme solar limb where the chromosphere-corona transition region is seen edge on. We have made measurements of the profiles across this bright limb by stepping the telescope along a line perpendicular to the limb and taking a scan at each position. With the 20\(\text{'}\) slit decker, each scan covered a spatial region of 20\(\text{'}\) \(\times\) 3\(\text{'}\) parallel to the limb. Twenty positions were usually used, and the spacing varied from 2\(\text{'}\)5 to 5\(\text{'}\). An example is shown in
Figure 3 for C iv λ1548. We have fitted the profiles with Gaussian curves and plotted the parameters versus relative position. Each profile consisted of 11 points equally spaced over a 0.75 Å range. The strongest had a line center count of 700. Noise in the line profiles causes uncertainties in the fit parameters, and determining these uncertainties is nontrivial. The assignment of error bars awaits further analysis. Certainly the three leftmost positions have the most unreliable parameters.

The disk is to the right in the figure, and the bright limb is clearly seen in the intensity curve. There is also a pronounced increase in the line width at the limb. This is an expected effect of the increased optical depth along the line of sight. A puzzling result, however, is the relative blueshift that accompanies the other effects in this example. The magnitude of this velocity, about 5 km s\(^{-1}\), is not especially large. We see relative shifts of 10 km s\(^{-1}\) or more in sequences of profiles on the disk. The effect appears in about half of the λ1548 data—otherwise the curve is relative flat over the limb. The other C iv line at λ1551, for which we only have a few measurements of this type to date, also shows this effect, but it is either not present or less pronounced in Si iv λ1393. The λ1393 line does show an intensity and width increase comparable to λ1548.

Perhaps the most straightforward explanation of this shift would be that it is a result of the rapidly varying projection factor for radial motions at the edge of the disk. Downward motions would cause a relative blueshift toward the limb. The projection, μ, varies from 0 at the edge to 0.14 at 10° into the disk and 0.2 at 20°. Clearly the curve in Figure 3 does not show the monotonic behavior expected for a spherically symmetric downward flow. This could perhaps be attributed to variations in the radial velocities. One possibility is that a large region with a strong downflow was situated at the limb. The 5 km s\(^{-1}\) change in the 10° at the edge would imply a downward velocity \(\sim 35\) km s\(^{-1}\).

There are other ways to produce such a shift. Note that the width of the line increases more rapidly than the shift, indicating that the line is broadening in both directions but more to the blue. This is consistent with two more novel explanations of this phenomenon. One is that the effect results from horizontal outward flows. We would see both components of such flows except at the extreme limb where the line is optically thick enough to emphasize the component on our side of the line of sight. The other possibility is that the extra photons on the blue side result from scattering between vertically converging components in the solar atmosphere; i.e., photons generated in a falling element are scattered by a rising or stationary element below the first or vice versa.

More information is required before we can explain this shift, and the lack of a pronounced effect in λ1393 must also be explained. One critical quantity required is the wavelength of the profiles on an absolute scale or at least relative to the solar average. Further observations and analysis should determine an absolute wavelength. Our entire data set must be processed to give better statistics on the variable effects and a mean limb curve for each line. We are also currently working on models based on the mechanisms mentioned above.

V. CONCLUDING REMARKS

The examples given in this paper serve to demonstrate some of the various types of data that we have acquired, as well as presenting some early results of our analysis of the C iv and Si iv observations.

The final stage in our analysis will be to integrate the information obtained with other available data in order to model more accurately the physical properties and dynamics of the transition region. The high spectral resolution of the University of Colorado spectrometer...
SHINE ET AL.

is an important contribution. Clearly, our measurements of line shapes along with periodic and steady state flows will impose important constraints and suggest new ideas in the development of such models.

The observations reported in this paper could not have been made without the many contributions of the entire OSO-8 staff at the Laboratory for Atmospheric and Space Physics. This research was supported by the National Aeronautics and Space Administration grants NAS 5-22409 and NAS 5-11363.

REFERENCES


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