Preliminary Results from the Orbiting Solar Observatory 8: Transition-Zone Dynamics over a Sunspot

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ABSTRACT

The University of Colorado experiment aboard OSO-8 observed the C IV 1548 Å line in the bright plume over a sunspot. Transient redshifts at 5 minute intervals were studied, but the expected phenomena associated with simple Alfvén wave effects were not observed.

Subject headings: Sun: atmospheric motions — Sun: sunspots

I. INTRODUCTION

The University of Colorado experiment on OSO-8 investigated the problem of the energy transport mechanisms responsible for heating the solar corona. Our major goal has been to apply state-of-the-art, high-resolution ultraviolet spectroscopic techniques to the direct measurement of chromospheric and transition-zone velocity distributions, persistent flows, and, in particular, the predicted wave motions thought to be responsible for this heating.

A comprehensive observing program has exploited the capabilities of the instrument to measure line profiles and their variations with time and with position on the solar disk. Some of the highlights of our work to date are the following:

1. The detection of systematic downward velocities correlated with bright points in the quiet chromosphere.
2. The detection of velocity and intensity oscillations in both chromosphere and transition zone lines.
3. The apparent detection of polar coronal holes in the H α line.

II. INSTRUMENTATION

The details of our instrumentation have yet to be published. We include a brief summary here for reference purposes. The instrument is a 1 m Ebert-Fastie grating spectrometer fed by a Cassegrain telescope of 1.8 m effective focal length and aperture ratio f/20 (Fig. 1). The useful wavelength range at launch (1975 June 21) was 1150–2200 Å. Subsequent degradation of the optical system had, by late fall of 1975, restricted the useful range to wavelengths longer than about 1350 Å. Spectral resolution is in the range 15–40 mÅ depending upon how the instrument is employed. Angular resolution is variable in the range 2.5'' X 4'' to 2.5'' X 900'' through use of a slit decker. Wavelengths are selected by rotating the grating with a precision screw mechanism driven by a stepping motor. Radiation emerging from the spectrometer is detected by a photomultiplier tube operated in the photon counting mode.

A general purpose digital computer controls the spectrometer functions and experiment sequencing. All major experiment modes are defined by programs in the computer memory and may be modified in orbit to allow for operational contingencies or to meet new observing requirements. The computer also interacts with the spacecraft to modify the pointing strategy based on the result of spectrometer measurements.

The spacecraft provides a versatile pointing system with both raster and offset pointing capability. Short-term pointing stability is of the order 1''. Measurements made with the CNRS (French) experiment show a slow drift in pointing of about 8'' in one orbit. This figure includes contributions from both the Sun sensor, which is mounted on the University of Colorado instrument, and drift due to thermal flexure in the two instruments and their supporting structure. The relative magnitude of these two effects is not clear.

III. IMPULSIVE EVENTS IN THE TRANSITION REGION ABOVE SUNSPOTS

Observations were made on 1975 September 15 in an attempt to detect wave motions in the transition zone over a sunspot. The spot selected for study was located in McMath region 832 at a μ value of about 0.7. The size of the umbra was about 12''4. Comparison of the ultraviolet and Hα spectroheliograms showed that the bright plume which we were to observe was viewed against a background of an adjacent plage, rather than directly against the sunspot umbra. Our line of sight made an angle of about 45° with the solar surface, giving us sensitivity to both horizontal and vertical components of velocity. The field of view for these observations was about 2'' X 20''.

The C IV 1548 Å line was observed using the instrument computer to locate the region of brightest plage emission (see Fig. 2). We then measured the line profile

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Fig. 1.—The layout of the optical system for the University of Colorado high-resolution ultraviolet spectrometer.
as a function of time, as shown in Figure 3 where each peak is one line profile. Time resolution in the series is 48 s per profile, and fluctuations in the intensity of the line are readily apparent.

A least squares fit of Gaussian functions was made to the individual profiles. The line parameters from these fits are shown as functions of time in Figure 4. As expected, the intensity versus time curve mimics the envelope of the individual observations in Figure 3. In the line width and line position curves, however, we see at least three impulsive events. Each event is marked by a rapid shift to the red, concurrent with an increase in line width.

The amplitude of the first pulse in position corresponds to a Doppler shift of 10 km s\(^{-1}\). The interval between pulses is about 5 minutes, leading to the speculation that the well-known photospheric oscillations may be either the trigger or the ultimate driving mechanism.

By examining the individual traces, shown in Figure 5, we can see that, as time progressed, additional emission appeared in the red wing of the line and then disappeared again. This additional feature would, of course, explain both the increase in width and the redshift revealed by the Gaussian parametrization.

Identification of these additional emissions as arising from other spectroscopic transitions appears to be unlikely since candidate ions either are not sufficiently abundant or have formation temperatures too close to that of C\textsc{iv} to vary independently. We believe that our observations represent pulses of material, guided along magnetic field lines, falling through the region covered by our field of view. Presumably, this flow corresponds to the so-called coronal rain that is observed in Ha over sunspots.

A similar observation of redshifted transition zone lines was made by Brueckner (1976), who observed line-of-sight velocities of 100 km s\(^{-1}\) in C\textsc{iv}. The line-of-sight velocity required to produce the shifts seen in

Fig. 2.—An example of the raster experiment that locates the brightest picture element in the field and stops the raster scan during the next frame.

Fig. 3.—A portion of a time series of C\textsc{iv} 1548Å line profiles
Fig. 4.—Time series of line position, line strength, and line width obtained from gaussian fits to single profiles.

Fig. 5.—Examples of individual profiles that illustrate time variations in the C iv line shape. Note the large changes in the red side of the line core.
the individual blended profiles of our data is 30 km s\(^{-1}\).

Brueckner’s data show the region of high velocity to be confined to a very narrow portion of his field of view, which indicates that the transient nature of our observations might be explained by a drift of the spacecraft pointing system. Studies of the short-term orbital pointing stability show variations of the order of 1", which is less than the effective width of our slit. The primary disturbance torque is the rotation of the spacecraft wheel which has a period of 10 s. The drift noted by CNRS is still relatively small, being about 3 slit widths per hour; therefore, it could probably produce the slow variations in the envelope, but it cannot account for changes on a 5 minute scale. There is no known mechanism on the spacecraft that could give rise to the observed five minute interval between pulses, therefore, we believe that its origin is due to solar phenomena. (See note added in proof.)

IV. CONCLUSIONS

We have observed the time history of the \(\text{C} \ \text{IV} \ 1548 \ \text{Å}\) line in the bright plume over a sunspot. The profiles are characterized by transient redshifts at 5 minute intervals which we interpret as material (coronal rain) falling through our field of view. Since these observations do not show both redshifts and blueshifts, which we would have expected for simple Alfvén waves observed at an angle to the magnetic field, and since we do not yet understand the field geometry of these observations, we are unable to comment on the heating mechanism suggested by Parker (1974) for sunspot phenomena.

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REFERENCES


Note added in proof.—Aliasing of the wheel spin frequency cannot account for the recurrence of transients at 5 minute intervals.