OBSERVATIONS OF THE CHROMOSPHERIC NETWORK: INITIAL RESULTS FROM THE APOLLO TELESCOPE MOUNT


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ABSTRACT

A preliminary analysis of early data taken by the HCO spectrometer on Skylab shows that the solar chromospheric network can be clearly seen with varying contrast in the extreme-ultraviolet emission characteristic of temperatures between $10^4$ °K (the Lyman continuum) and $3 \times 10^6$ °K (O vi). In the emission of Mg x, a coronal line formed at about $1.5 \times 10^6$ °K, the network is generally unrecognizable. This is interpreted as being due to a spreading of the magnetic field lines of the network boundary in the height interval corresponding to the temperature difference between $3 \times 10^5$ °K and $1.5 \times 10^6$ °K. We note that in certain anomalous cases, bright points of the network are seen to extend with high contrast and essentially unchanged in their cross-section through the full range of temperatures characteristic of the chromosphere, transition region, and low corona.

Subject headings: granules and supergranules, solar—spectra, ultraviolet

I. INTRODUCTION

The results reported in this Letter were obtained from early data taken by the Harvard spectrometer on the Apollo Telescope Mount (ATM), the solar observatory array on the Skylab Earth-orbiting laboratory. Skylab was launched on 1973 May 14, and scientific operation of the instruments began shortly after the launch of the first crew on May 25.

The purpose of the ATM is to make a concerted approach to certain solar problems by making simultaneous observations of high spatial and spectral resolution over the broadest range of wavelengths. Ground-based observatories are kept continuously aware of the ATM observing programs and many are making closely coordinated observations. The ATM instrument parameters and the approach to coordinated observations are reviewed elsewhere (Reeves, Noyes, and Withbroe 1972).

At this point in the 8-month mission, it is clear that the ATM will be a fully realizable success. Data retrieved from both telemetry and film have shown that for all instruments the original instrumental parameters have been met or exceeded. Data have been acquired against most of the objectives planned for ATM prior to launch, and the innovational abilities of the astronaut crews have led to the inception of new observing sequences which will obtain data in several new ways.

II. INSTRUMENTATION

The HCO spectrometer has been described elsewhere (Reeves et al. 1972; Huber, Reeves, and Timothy 1973), and the characteristics will be only summarized here. The instrument operates in the extreme-ultraviolet regions 280–1350 Å with a spatial resolution of 5" and a limiting spectral resolution of 1.2 Å in the wavelength scanning mode. The spectrometer is provided with seven separate channel electron multipliers arranged to cover simultaneously the lines given in table 1, which are formed over a large range of temperatures in the solar atmosphere. Table 1 lists, for the principal polychromatic setting, wavelengths, species, excitation temperatures, and spectral purities for the various detectors.

A second polychromatic position placing detectors 2, 3, 4, and 5 on La, Lß, Ly, and the Lyman continuum is available by stepping the grating 5.5 Å. Detector 2 is provided with a wide slit to accommodate La in both grating settings. Additionally a large number of random coincidences of the fixed slit positions and lines of differing excitation energy, which are useful in securing data simultaneously under differing excitation conditions, are available at other grating settings. At any one of these grating positions and detector combinations, the mirror can be commanded to scan a 5' × 5' field in approximately 5.5 minutes.

<table>
<thead>
<tr>
<th>Detector</th>
<th>λ Setting (Å)</th>
<th>Species</th>
<th>Excitation Temperature (° K)</th>
<th>Spectral Purity (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1335.7</td>
<td>C II</td>
<td>$5 \times 10^4$</td>
<td>1.6</td>
</tr>
<tr>
<td>2</td>
<td>1219.1</td>
<td>H La</td>
<td>$10^6$</td>
<td>8.3</td>
</tr>
<tr>
<td>3</td>
<td>1032.6</td>
<td>O vi</td>
<td>$3 \times 10^5$</td>
<td>4.0</td>
</tr>
<tr>
<td>4</td>
<td>977.9</td>
<td>C III</td>
<td>$10^5$</td>
<td>4.0</td>
</tr>
<tr>
<td>5</td>
<td>896.0</td>
<td>H Lyman cont.</td>
<td>$10^5$</td>
<td>8.3</td>
</tr>
<tr>
<td>6</td>
<td>625.5</td>
<td>Mg x</td>
<td>$1.5 \times 10^6$</td>
<td>4.0</td>
</tr>
<tr>
<td>7</td>
<td>554.1</td>
<td>O iv</td>
<td>$2 \times 10^5$</td>
<td>4.0</td>
</tr>
</tbody>
</table>

* Also at the Federal Institute of Technology (ETH-Z), Zurich, Switzerland.
mirror modes provide for a single spatial line scan with 5-s period for improved time resolution of dynamic events.)

Data are recovered from telemetry once per revolution of Skylab (93 min), and a small fraction of these data is made available within a day for scientific evaluation. Although final data for the HCO instrument will not be available until some months beyond the end of the mission, a number of interesting observations can be drawn from this current incomplete data file. This first paper presents one example.

III. RESULTS AND DISCUSSION

Figure 1 (plate L3) shows a set of observations in the first polychromatic grating setting covering the excitation range from the Lyman series to Mg x, taken near Sun center on 1973 May 29. Each picture covers an area of 5' × 5' in 60 lines and 120 image elements per line. The photographic presentations are conversions to a 64-level gray scale from the numerical data, obtained with a FR-80 plotter at the Johnson Space Center. The chromospheric network can be easily seen extending almost unchanged, except in contrast, from the Lyman continuum at 10⁴ °K, through the resonance lines of C ii, C iii, O iv, and O vi. Between the temperature of 3 × 10⁵ °K characteristic of the O vi and the 1.5 × 10⁶ °K temperature of formation of Mg x there is a very abrupt change in the observed structure with height. In Mg x the chromospheric network is almost totally unrecognizable, although in some places remnants frequently can be seen to remain if the network is followed up in temperature from below. Nevertheless, the reverse is not true and the course of the network cannot generally be traced downward in height from the Mg x alone. The similarity in structure and contrast of the network as observed from the middle chromosphere through transition-zone lines suggests that the magnetic field pattern in the network is essentially vertical through temperatures as high as 3 × 10⁵ °K. After this temperature the magnetic field pattern must change abruptly, with a reduced vertical component by the time the temperature reaches 1.5 × 10⁶ °K.

Figure 2 shows a plot of the numerical data across line 51 of the 60-line polychromatic images of figure 1. These scans were reduced from "quick-look" data in which adjacent data elements were summed, so that the spatial resolution is degraded somewhat. These scans show the strong correlation between structure observed between 10⁴ °K (Lyman continuum) and 3 × 10⁶ °K (O vi). Examination of these and other data shows that lines formed in the transition layer (C iii, O iv and O vi) show more contrast than lines and continua formed in the chromosphere (e.g., La and Lyman continuum). The maximum contrast is observed for lines such as C iii, O iv, and O vi where enhancement between the network and central portion of the cells is usually a factor of 10 to 15 for O iv, and slightly lower for C iii and O vi at respectively lower and higher temperatures. The intensity tracing for Mg x shows a marked difference in structure from that observed in lines of lower excitation temperature in the network.

An examination of the quick-look data for a number of cell boundaries gave a measured width of about 15", of which a significant fraction is due to the degraded spatial resolution (about 15/2 or 7.5 half-widths) of the quick-look format. Within that resolution, no obvious trend of network width with height was noted. A more detailed study of the intensity profile across an "average" network cell must await the receipt of the final data tapes where consecutive intensities are not summed, and where an accurate determination of the slit function will permit a more accurate determination of the network structure.

Ground-based observations of the chromospheric network and the underlying photospheric magnetic field (Simon 1964) indicate that the network coincides with areas of moderately strong vertical magnetic fields, apparently concentrated by the large-scale supergranulation flow field. Since the gas pressure decreases much more rapidly with height than the magnetic pressure, the magnetic pressure becomes the dominant pressure at some height. At this height, occurring at some level between the chromosphere and the corona, the magnetic field assumes a force-free configuration and spreads out so as to create a coronal field distribution that is uniform and vertical to a first approximation. Consequently, one expects to observe significant differences in the appearance of the...
Fig. 1.—The chromospheric network as seen near Sun center on 1973 May 29 at 1142 GMT. Solar north is approximately 13° counterclockwise from the vertical, and east is to the left. The arrows on the O vi portion indicate the scanning position for fig. 2. In the figure progressively lighter shades of gray correspond to increasing intensities.

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Fig. 3.—The chromospheric network observed from the Harvard instrument on ATM at 1946 GMT near Sun center on 1973 August 18. The center picture in calcium was taken at Sacramento Peak Observatory at 1353 GMT. All pictures are to be the same approximate scale, namely, 5′ X 5′.

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quiet solar atmosphere when it is observed in spectral lines formed where the magnetic field is concentrated in the network and in lines formed higher in the atmosphere where the field has spread out. The observations in figure 1 suggest that the temperature where the network becomes more diffuse occurs between $3 \times 10^5 \, \text{K}$, where O vi is formed, and $1.5 \times 10^6 \, \text{K}$, where Mg x is formed. Through detailed analysis of extreme-ultraviolet data from ATM and comparison with magnetic observations obtained with ground-based instrumentation, we hope to substantially improve knowledge of the energy balance in the chromosphere, transition layer, and lower corona and to determine how the configuration of the magnetic field changes through these layers.

Figure 3 (plate L3) shows another example of the network obtained from the second Skylab mission on 1973 August 17, also near Sun center. The figure shows a comparison of the network observed from the HCO instrument in C ii 1335 Å and in La at 1154 GMT, with Ca ii 3933 Å obtained by Sacramento Peak Observatory only 2 hours later. The bright network can be traced on an almost perfect basis between the ground-based calcium observations and the extreme-ultraviolet observations from ATM. The brighter elements of the network can also be found as elements on the daily magnetogram from Kitt Peak National Observatory, taken at 1552 GMT.

In both figures 1 and 3 some small bright structures can be traced up through the height characteristic of Mg x at $1.5 \times 10^6 \, \text{K}$ without lateral change, whereas the majority of the network elements spread abruptly as described above. In the general chromosphere and transition-region network many similar intense points can be seen which do not show this preservation of structure with height. These small features of approximately 15" dimension, observed in Mg x in the corona, have been observed in quiet solar regions, and in all cases studied to date they can be traced downward in the solar atmosphere to connect with the bright chromospheric network. For these features the magnetic field appears to remain in the same contained configuration at least through the temperature range $1.6 \times 10^6 \, \text{K}$. The physical height represented by the Mg x temperature in these bright points might be significantly different from the height of this ion in the quiet network. More detailed analyses of height, temperature, density, and magnetic field parameters are being undertaken to study the structure of these features more quantitatively. The structures will also be compared with higher-excitation X-ray photographs to extend the study to greater heights.

IV. CONCLUSIONS

The observations reported here on the chromospheric network serve to illustrate the great improvement in sensitivity and spatial resolution, and the value of simultaneity in analytical parameters, which have been made possible by the ATM.

The chromospheric network has been observed in many wavelengths arising from a range of excitation energies characteristic of the chromosphere, transition region, and corona. The observations reported here show that the network preserves its spatial identity quite well, with significant changes in contrast, up to effective excitation temperatures of $3 \times 10^5 \, \text{K}$. Above the height characteristic of this temperature the network diffuses rapidly and can be almost unrecognizable at temperatures of $1.5 \times 10^6 \, \text{K}$ (Mg x), suggesting a substantial spreading of the magnetic field configuration at these heights.

Individual bright points in the network have been seen to persist unchanged in size up through temperatures equivalent to that of Mg x, which suggests a channeling of the magnetic field at least through coronal temperatures.

It is a pleasure to express here our thanks to all those who have participated in the ATM program. We express particular appreciation to Leo Goldberg for his continued encouragement, and to the three astronaut crews for their special efforts in making the mission a success. The continued cooperation of the personnel of NASA Headquarters, MSFC, and JSC have been greatly appreciated, especially Dixon Forsythe, Jesse Mitchell, Goetz Oertel, and William Keathley. The program was supported by contract NAS5-3949 and carried out by the staff of the Solar Satellite Project under the direction of Nathan Hazen and the Project Manager, William Harby, with the technical support of Ball Brothers Research Corporation, with John Roach and Dave Roalsted as Program Managers.

REFERENCES


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