HRTS EVIDENCE FOR ROTATION OF TRANSITION REGION TEMPERATURE SPICULES

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INTRODUCTION

The HRTS (High Resolution Telescope and Spectrograph) instrument is a high spectral (0.05 Å) and spatial (<1 arc sec) resolution spectrograph with a slit length of 900 arc sec on the solar disk (see Bartoe and Brueckner 1975, 1978). HRTS contains in addition a double grating, zero dispersion broadband spectroheliograph which images the spectrograph slit jaw plate (see Cook et al. 1983). The central wavelength is tunable by changing the grating geometry. Hα images are also photographed from the slit jaw plate image. HRTS has been flown four times as a rocket payload, and will fly in April 1985 as one of the solar experiments aboard Spacelab 2. The four rocket flights of the HRTS program have each been customized for a particular scientific objective. For the fourth flight, because the original hardware was utilized as the basis of the Spacelab HRTS, the opportunity was used to design and build a new rocket HRTS instrument specialized for observations at the solar limb. In this configuration the photographic speed was increased, a new curved slit was fabricated, and the spectroheliograph was modified for limb observations. The scientific observing program was a study of structure and short term temporal evolution at the limb, with a comparison of quiet and coronal hole areas.

INSTRUMENT AND OBSERVATIONS

In order to increase speed the slit was opened wider, giving 0.1 Å spectral resolution instead of 0.05 Å, and a faster mechanically ruled grating was used instead of the original holographic second grating. Because ruled gratings cannot be produced uniformly to the large size of the original grating, two ruled gratings were used covering 1200-1310 Å and 1340-1560 Å, with a region of overlap.

The most original feature was a new curved slit for use at the limb. The slit radius of curvature was greater than the solar radius: if the slit were placed tangent to the limb and displaced 5 arc sec inside the limb at the center, the two ends would rise to 15 arc sec above the limb. Thus a sample of all heights from -5 to +15 arc sec above the limb could be obtained on slit spectra.

The spectroheliograph was tuned in wavelength to obtain images in C IV (1550 Å) of fine structure above the limb (on the disk the continuum is the main flux source; see Cook et al. 1983). A new coating was used on the bottom slit jaw to give a less reflectant surface for the area reflecting the bright disk, in order to cut stray light above the limb. This coating ended, on the disk side of the slit jaw plate, below the curved slit, tending to obscure the exact location of the solar limb. On Hα images this shows only as a line across the image at the coating edge, allowing the limb location to be identified.

The new HRTS instrument was flown on 7 March 1983 at White Sands, and obtained 145 slit spectra, 157 spectroheliograms, and 32 Hα images. The curved slit was placed at the solar limb with its center at the

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western edge of the south polar coronal hole, giving both coronal hole and quiet region coverage (this position was obtained with help from J.W. Harvey at Kitt Peak). Because command control to the instrument was lost most of the time due to malfunction of a ground transmitting station, the slit pointing was not capable of fine adjustment, and the telescope focus could not be critically adjusted in flight. As a result the pointing was slightly off and drifted generally outward above the limb, and the spatial resolution of the data was approximately 3 arc sec instead of the potential sub arc sec resolution. For one brief period when commanding was possible a focus adjustment was attempted, and several of the spectroheliograms and a slit spectra have improved resolution, which should have been achieved for all the data.

RESULTS

In the slit spectra (see Figure 1) both the coronal hole and the quiet region show chromospheric and transition region line emission, but in the coronal hole hotter coronal lines are weak or essentially absent. While an expected result, the illustration with these data is striking. Si VIII 1446 Å (10^6 K) is noticeably weaker in the coronal hole, and Fe XII 1242 Å and 1349 Å (1.6×10^6 K) are suppressed. In both regions there is little apparent fine structure in the coronal lines, while C IV and Lα show fine structure at the instrumental resolution both on and above the disk.

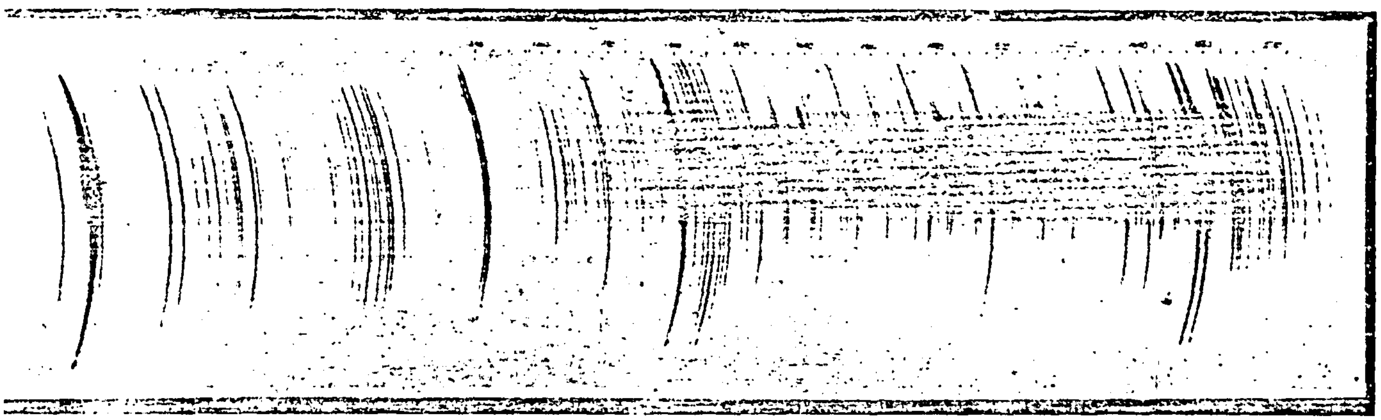

Figure 1. HRTS slit spectrum. The grating overlap can be seen around 1330 Å. Quiet region to top, coronal hole to bottom.

The C IV spectroheliograms show general spiked emission at the limb. These C IV spicules appear to fall somewhere between Hα spicules and macrospicules in their properties but more closely resemble macrospicules in size and height. A major difference from macrospicules is that the C IV spicules are <u>not</u> confined to the coronal hole side of the limb.

POSSIBLE ROTATION OF C IV SPICULES

The most interesting result from the rocket flight is the observation in slit spectra at C IV 1550 Å (and Lα) of features tilted with respect to the constant wavelength curve of the slit, at locations where the slit is passing over the tops of several of the spicular structures seen in the spectroheliograms (see Figure 2). Observations of such tilts in spectra of Hα spicules have long been known, but their interpretation is apparently still somewhat contentious (see discussion in Bray and Loughhead 1974). Although other interpretations are possible, the axial rotation of a cylindrical body would give the observed tilted features (see Figure 3). Hα observations interpreted in this manner give rotational velocities of <30 km s^{-1} at the edges of a 1 arc sec diameter spicule.

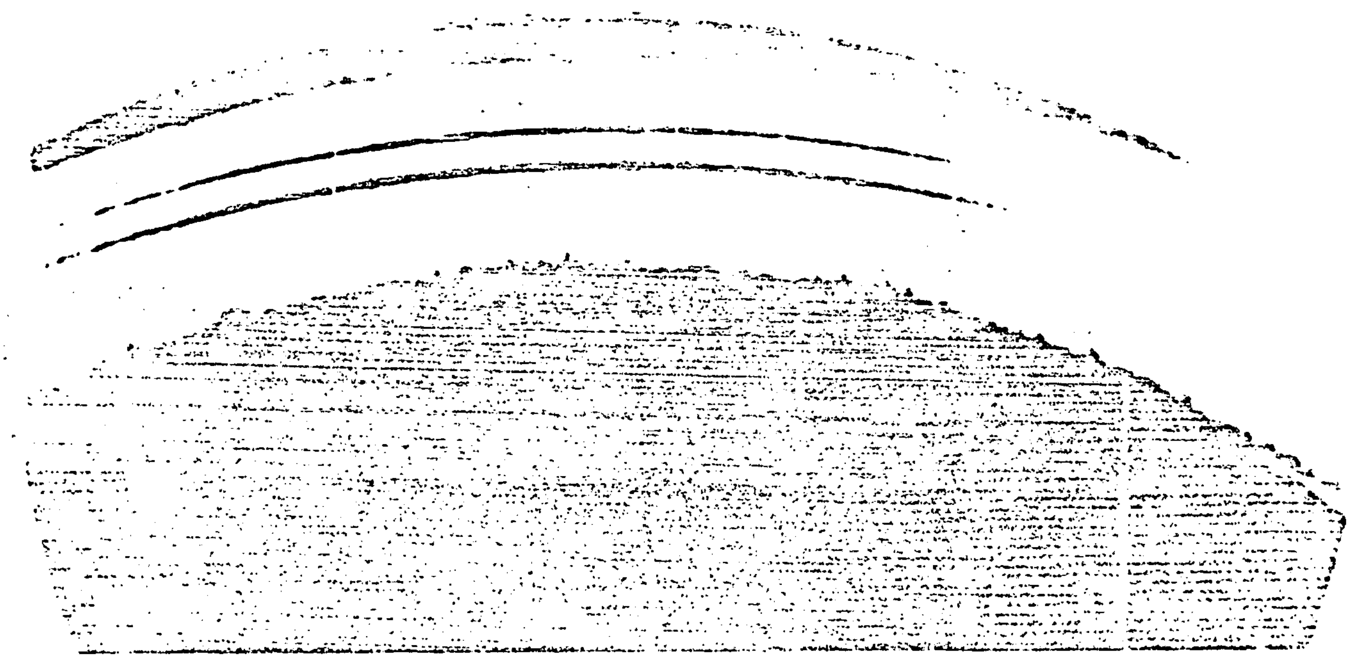

Figure 2. C IV lines 1548 Å (bottom) and 1550 Å (top) from slit spectrum are shown between two spectroheliograph (SH) images. Examples of small tilted features are seen at extreme left, where the slit is crossing the tops of several spicules seen in the lower SH image, a 0.9 s exposure. Top SH image, a 0.1 s exposure, shows some of the spectrograph slit which is overexposed in the bottom SH image.

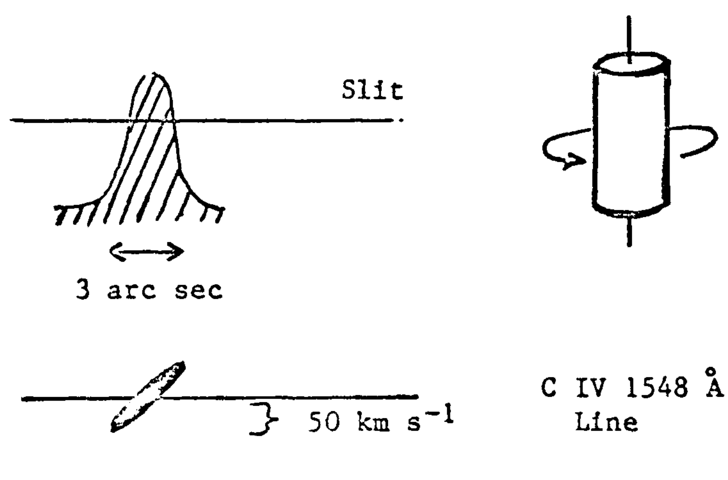

Figure 3. Rotational interpretation of tilted spectral feature.

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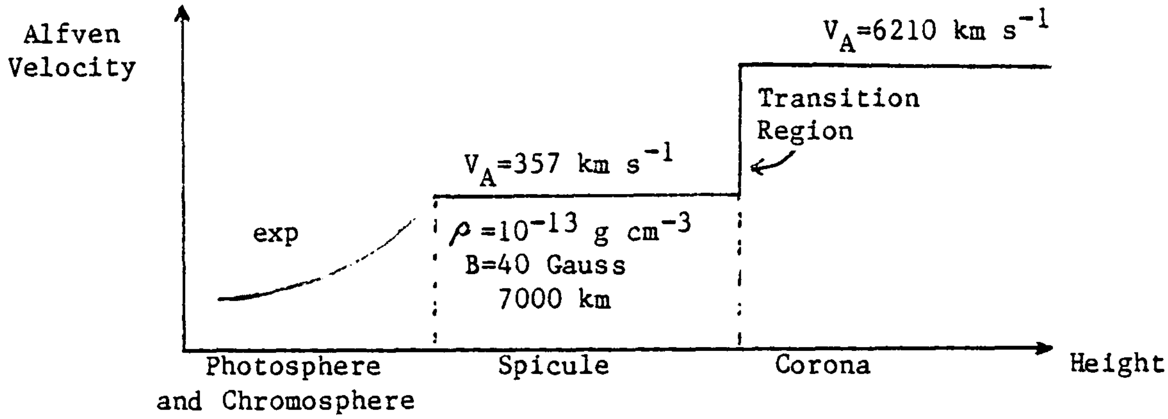

Figure 4. Model of Sterling and Hollweg (1984) for Hα spicule.

The attraction of the rotational interpretation is its possible explanation in terms of a propagating torsional wave. If the observed C IV features are interpreted as Doppler shift signatures of rotation, the HRTS observations show tilted features with a velocity at the outer edge of 50 km s^{-1}, where at least some examples do not appreciably slow or reverse tilt over the duration of the rocket observations (3 minutes). One recent model by Sterling and Hollweg (1984) for the heating of a (lower temperature Hα) spicule involves an Alfven wave in a resonant cavity. They approximate the increase of the Alfven speed $V_A=B/(4\pi\rho)^{1/2}$ (where B is the magnetic field strength and ρ the density) in the upper photosphere and chromosphere by an exponential function, assume a constant Alfven speed in the Hα spicule, and treat the transition region as a step function to a corona with much higher constant Alfven speed (see Figure 4). Alfven waves of certain frequencies are preferentially transmitted through the spicule, which acts as a resonant cavity. Sterling and Hollweg find an average rotational velocity of 20-30 km s^{-1} for Hα spicules, but at a fundamental period of around 80 s. They give the frequency of the fundamental as $4L/V_A$, where L is the spicule length and V_A the Alfven speed within the spicule. For the transition region the Alfven speed should be larger, and the spicule length perhaps somewhat greater. But the HRTS observational result on period is not as negative as first appears, because of the difficulty due to the drifting slit in following an individual spicule. The model needs to be extended to investigate what happens at transition region temperatures.

REFERENCES

Bartoe, J.-D.F., and Brueckner, G.E. 1975, J. Opt. Soc. Am., 65, 13.
Bartoe, J.-D.F., and Brueckner, G.E. 1978, in New Instrumentation for Space Astronomy, ed. K. Van der Hucht and G.S. Vaiana (Oxford: Pergamon), p. 81.
Bray, R.J., and Loughhead, R.E. 1974, The Solar Chromosphere (London: Chapman and Hall), pp. 58-60.
Cook, J.W., Brueckner, G.E., and Bartoe, J.-D.F. 1983, Ap. J. (Letters), 270, L89.
Sterling, A.C., and Hollweg, J.V. 1984, Alfvenic Resonances on Solar Spicules, Ap. J., in press.

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