INTERFEROMETRIC OBSERVATIONS OF THE EXTREME SOLAR LIMB AT 2.8 AND 6 cm DURING THE OCTOBER 1977 ECLIPSE

G.J. Hurford, K.A. Marsh, and H. Zirin
California Institute of Technology

ABSTRACT

The radial intensity profile at the extreme solar limb was measured with high angular resolution during the October, 1977 partial solar eclipse using the Owens Valley solar interferometer at 2.8 cm and the VLA at 6 cm. Substantial limb brightening was observed at 6 cm, with a peak brightness temperature corresponding to an 80% increase over the disk value. Much less limb brightening was observed at 2.8 cm. In each case an extended "tail" to the brightness distribution was detected. The results at both wavelengths are consistent with a simple model in which a rough chromosphere is overlaid by a corona in hydrostatic equilibrium with a density of 5×10^8 cm^{-3} at its base.

Spherically symmetric models of the variation of electron density and temperature with height predict a much larger degree of limb brightening than is observed at centimetric wavelengths, a discrepancy probably due to the inhomogeneous nature of the lower atmosphere (e.g. Simon and Zirin, 1969, Furst et al., 1974).

In order to obtain improved radial profiles of the extreme limb where single antenna measurements are the most difficult, we conducted interferometric observations of the quiet limb during the partial solar eclipse of 12 October 1977 at the Owens Valley Radio Observatory (OVRO) at 2.8 cm during 4th contact and the National Radio Astronomy Observatory's Very Large Array (VLA) at 6 cm at 1st contact.

The eclipse geometry is shown in Figure 1. In each case tracking was fixed on the solar limb. Representative plots of observed amplitude and phase are shown in Figure 2. The amplitude oscillations and phase variations are characteristic of a moving "knife edge" covering or uncovering the extended solar brightness distribution. Since the lunar limb signal is negligible, stable amplitudes and phases result when the moon is beyond the radio sun. Figure 2 indicates that the oscillations were present for several minutes before 1st contact and after 4th contact, thus providing direct evidence of an extended brightness distribution outside the optical limb.

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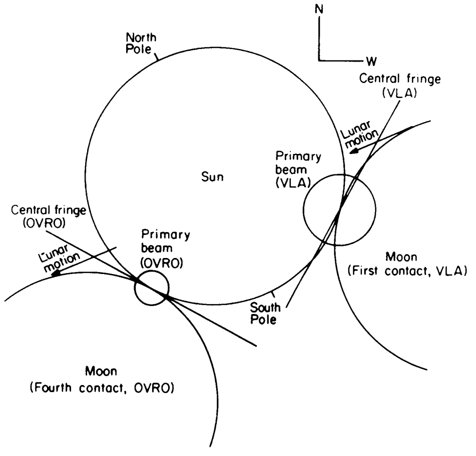

Figure 1: Eclipse geometry as seen at the VLA (1st contact) and OVRO (4th contact).

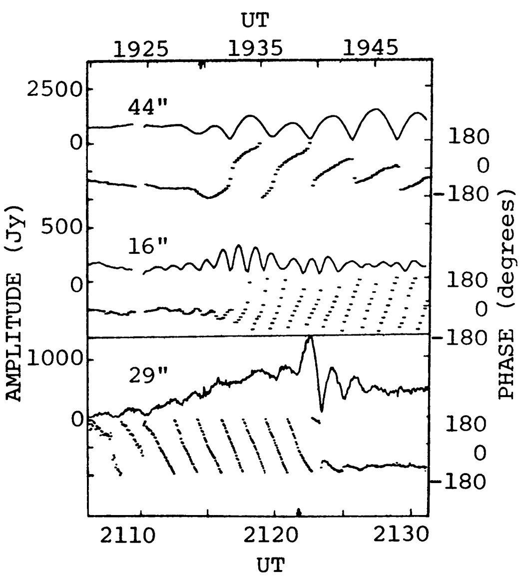

Figure 2: Amplitude and phase variations for representative baselines at the VLA (top panel) and OVRO (lower panel).
The arrows indicate the times of optical first and fourth contacts.

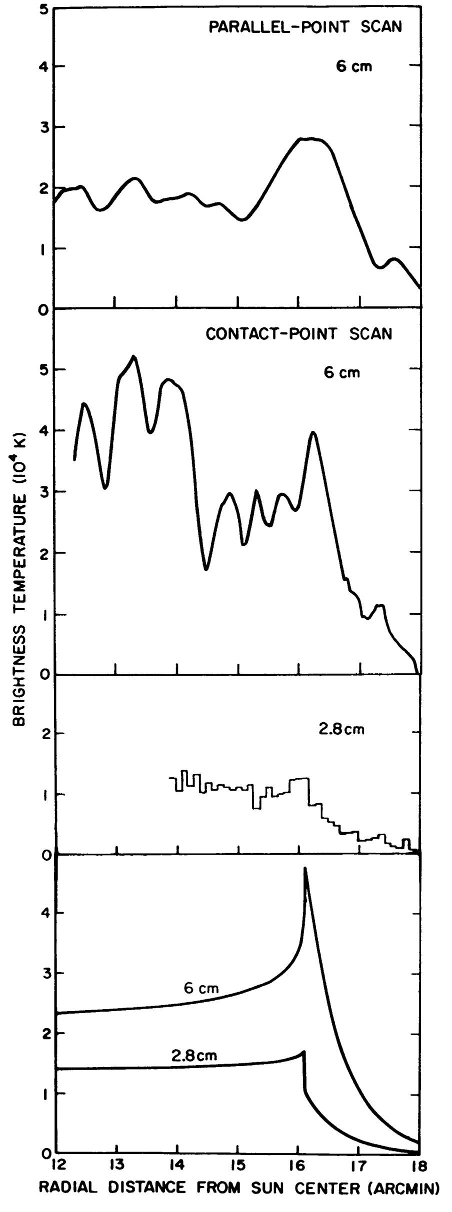

Figure 3: Radial brightness temperature profiles obtained from:
(a) 6 cm parallel-point scan;
(b) 6 cm contact-point scan;
(c) 2.8 cm observations;
(d) 2.8 and 6 cm model calculations.

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At the VLA, data from 21 baselines with resolution of 2"-145" were combined to form a series of one-dimensional synthesis maps (Marsh et al., 1979). The difference of maps formed by successive 10 second integrations is the one-dimensional brightness distribution of the narrow annulus covered by the moon during this time. Time variations of specific points on the one-dimensional synthesis map then correspond to apertures scanning the sun, along lines parallel to the lunar motion. One such scan line passes through the point where the lunar limb is parallel to the fringes (parallel-point scan) while another passes through the point of 1st contact (contact-point scan). The effective aperture for the parallel point scan is 2" x 110" with a position angle of - 27.8°. The contact-point scan has a pair of 2" x 12.5" apertures separated by 332". The resulting profiles, shown in Figure 3 after smoothing to effective spatial resolutions of 46" and 14", show a sharp intensity increase at the extreme solar limb with peak absolute brightness temperatures of 29000 K and 40000 K respectively and an extended component with a 37" scale height.

At OVRO the relevant data were acquired on a single 29" baseline using the solar interferometer (Zirin et al., 1978). The sequence of amplitudes and phases were converted into a radial brightness profile using a deconvolution algorithm whose only assumptions were that the brightness temperature was zero at large distances from the sun and was independent of solar position angle. The resulting profile with 7.4" resolution is shown in Figure 3 and features a possible small limb enhancement and an extended component with a scale height of 34".

To account for the observations a simple model was evaluated which combined a thoroughly roughened chromosphere (i.e. a flat brightness distribution) with a spherically symmetric corona in hydrostatic equilibrium. In such a model the brightness temperature of the optically thin corona outside the chromospheric limb is independent of the coronal temperature and depends only on the electron density. Figure 3 shows that the model limb profile, calculated for an electron density of 5×10^{8} cm^{-3}, provides a good match to the observations.

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DISCUSSION

Kundu: With regard to the 2.8 cm brightness distribution, is not the distinct feature near the limb indicative of some sort of limb brightening?

Hurford: I would say its a possible limb enhancement. I don't want to say it's limb brightening.

Kundu: The tail at 2.8 cm near the limb outward from the center could it be due to sidelobe effects?

Hurford: No. That showed in the raw data, well before the first contact and well after the last contact.

Alissandrakis: Did you have sufficient coverage of the u-v plane to get a synthesis of the limb outside an eclipse? How does the eclipse help you when you already have high resolution with the VLA?

Hurford: The U-V coverage was not adequate to do a good job on limb synthesis without an eclipse, particularly because of the lack of short baselines (see the synthesized beam in Marsh et al., 1979).

With an eclipse, the U-V coverage is not critical. The experiment is basically a single-dish experiment in which the lunar motion provides spatial resolution and the interferometer serves to suppress the signal from the exposed sun and so significantly reduce the problems of tracking, jitter, etc.

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