DECAMETER RADIO AND WHITE LIGHT OBSERVATIONS OF THE 21 AUGUST 1973 CORONAL TRANSIENT.

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Observations from SKYLAB have shown that coronal transients, which involve mass ejections occur quite frequently, possibly up to three times a day at solar maximum (Hildner et al., 1976). An estimated mass of $\sim 10^{15}$ - 10^{16} g (Stewart et al., 1974) and a total mechanical energy in excess of 2×10^{31}ergs (Webb et al., 1978) is expelled from the Sun during each event. The transients therefore play a major role in the dynamics of the outer corona and of the interplanetary medium. Joint radio and white light observations provide the best opportunity to derive the physical parameters, such as the electron density and magnetic field in different parts of the transients, and consequently to estimate the forces driving the ejecta.

The coronal transient which occurred on 21 August has been well observed and extensively analyzed (e.g. Poland and Munro, 1976; and references therein). Radio observations of the event were obtained with the two-dimensional, swept-frequency array (called the Teepee Tee) of the University of Maryland. White-light observations consisting of a series of photographs were taken by the High Altitude Observatory's coronagraph aboard SKYLAB. The radio emission associated with the transient was continuum in nature, and lasted for almost 5 hours. Simultaneous radio and white-light measurements show that the radio source was cospatial with one of the secondary white-light loops. To establish the association of the radio source with a particular feature of the transient, we compared the white light and the radio "pictures" of the event. The earliest available radio position corresponds to 1555 UT, while the white-light picture corresponding most closely in time was taken at 1511 UT. An overlay shows the radio source to coincide in position with the lower part of a secondary white-light loop, and with the northern edge of the primary loop system. The correspondence in time between the radio and the white-light pictures is better than 1 minute for the three other times when white-light pictures were taken. The position of the radio source corresponds closely with the densest portion of the secondary white-light loop on all of these measurements. Since the pictures cover a period of more than two hours, we conclude that the radio source was associated with the secondary white-light loop.

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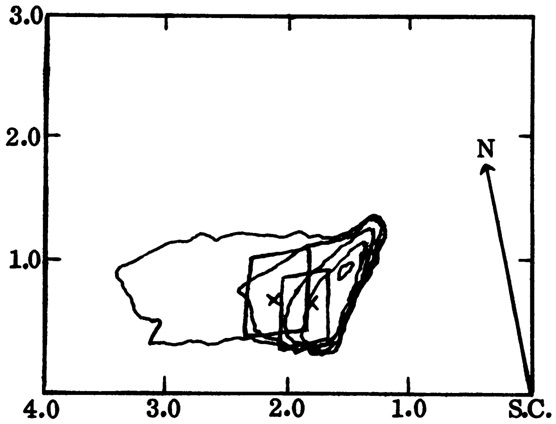
The columnar electron density at the source of the radio emission, combined with information about the frequency spectrum of the source, can be used to determine a lower limit of the thickness of the loop as follows. For radio emission to escape from the coronal plasma, the condition $f > f_p$ must be satisfied, where f is the observed frequency of emission and f_p is the local plasma frequency, given by:

$$f_p = 9 \times 10^{-3} N_e = 9 \times 10^{-3} (\sigma/L)^{\frac{1}{2}}, \qquad (1)$$

where N_e (cm^{-3}) is the local electron density, σ(cm^{-2}) is the columnar electron density, L(cm^{-1}) is the extent of the transient along the line of sight and f_p is in MHz. Since f and σ are observed quantities, a lower limit for L may be obtained from the above relationship. As a first approximation, we neglect the contribution of the background corona to the electron density. The lowest frequency at which radio emission was observed was f = 32 MHz. The radio emission originated entirely within the region enclosed by the columnar electron-density contour $\sigma > 10^{17}$ cm^{-2}. The columnar electron density at the site of the radio source ranges from 10^{17} cm^{-2} to 10×10^{17} cm^{-2}. Assuming an average value of $5 \times 10^{17} cm^{-2}$, we derive a lower limit for the depth (extension along the line of sight) of the transient $L > 4 \times 10^{10}$ cm $\sim$ 0.6 $R_\odot$ ($N_e < 1.2 \times 10^7$ cm^{-3}). It appears, therefore, that the extension of the coronal transient along the line of sight was comparable to its characteristic extension on the plane of the sky.



Contours of transient mass (electrons cm^{-2}) as a function of position in solar radii at 1835 UT, 21 August 1973. Contours are at 1×10^{16}, 2×10^{17}, 5×10^{17}, 1×10^{18} and 2×10^{18} electrons cm^{-2}. The two crosses and the quadrilaterals indicate the centroid and extension to a level of approximately 0.05 peak intensity of the low (f < 50 MHz) and high frequency (f > 50 MHz) radio source.

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The depth has remained unknown until now, since coronal transients in white light can be observed only near the limb and not in projection on the disk. The radio source showed no dispersion of height with frequency, and therefore we attribute the emission to gyrosynchrotron radiation. Another argument can be made in support of the gyrosynchrotron origin of the emission. Fundamental plasma radiation would have been heavily attenuated as the burst occurred close to, and possibly behind, the limb. Second harmonic radiation, on the other hand, would have required the depth of the source L to be greater than 1.2 $R_\odot$, and consequently greater than its extent on the plane of the sky. This seem rather unlikely. Gyrosynchrotron emission from mildly relativistic electrons occurs at fairly low harmonics ($\sim$ 4-10) of the gyrofrequency. Since the peak intensity of the emission occurred at about 50 MHz we estimate from the relation $f_{peak} \approx 4\text{-}10\ f_H = 11.2\text{-}28.0\ B$, the magnetic field strength in the secondary loop to be in the 2.0-4.5 gauss range at 2.0 $R_\odot$.

Radio measurements can clearly provide an estimate of the magnitude of the magnetic field in coronal transients when the mechanism giving rise to the emission can be established. Owing to the lack of accurate information about the field geometry, however, it is not possible to use these results to distinguish directly between the various models proposed to account for the observed dynamics of coronal transients (i.e. Mouschovias and Poland, 1978; Anzer, 1979; Dryer et al., 1979). If we assume a coronal temperature of 1.5×10^6 K, our results yield approximate equality of the gas and magnetic pressures at 2.0 $R_\odot$ (i.e. $\beta \sim 1.0$). For this transient, therefore, the gas is strongly influenced by changes in the magnetic field.

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DISCUSSION

Pneuman: Have you made a comparison between the spatial location and heights of the secondary loop you mentioned and the location of the X-ray loop system observed during the same event?

Gergely: We have not made a comparison between the location of the X-ray loop system and the secondary loop studied by us. The X-ray loop system was of course much lower in the corona than the features I described.

Uchida: What spectral type does the radio emission related to the secondary feature show? I presume that it is stationary type IV. Is there any trace of type II's related to the primary loop feature at all?

Gergely: There is no evidence of a type II burst related to the primary loop. The early part of the radio event was detected by G. Dulk with the Colorado University interferometer, and he doesn't see any type II burst. I guess you may classify the burst as a stationary type IV.

Benz: The fact that the radio positions coincide at different frequencies does not necessarily mean that you observed gyro-synchrotron emission. If the density enhancement in the transient is a factor of ten above the background, the plasma levels of your range of frequencies are very close to each other. Do you have other evidence for gyro-synchrotron emission?

Gergely: I agree with your comments. There are arguments against both fundamental and second harmonic plasma emission, details of which are given in our paper. We feel that gyro-synchrotron emission describes better the observations, but the evidence is not conclusive.

Anzer: From your data and $\beta = 1$, one would have $n \approx 10^{10}/\mathrm{cm}^3$ at $2R_\odot$, which seems extremely high.

Gergely: From our data and considering $\beta = 1$, one gets $n_e \approx 4 \times 10^8$ to $10^9\ \mathrm{cm}^{-3}$. I agree that this is still quite high, β is probably in the range 0.1-1.0. Of course the temperature may be wrong too. In any case, the transient is magnetically controlled.

Degaonkar: What is the duration of continuum; i.e., whether it was of the same duration as that of the transient? Did the continuum show high or low frequency cut-off?

Gergely: The continuum did not extend above 90 MHz on the high frequency side and approximately 30 MHz on the low frequency side. The emission lasted for about 5 hours, but the intensity varied during this time. Details are given in Gergely *et al.* (*Ap. J., 230,* 575, 1979).

Sheeley: Are you sure that the secondary feature in the August 21, 1973 coronal transient is really a loop, or could it have some other structure?

Gergely: No, I use the term "loop" in a general sense. Perhaps it would be more correct to speak of a secondary feature.

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Petelski: Concerning source heights, can one really determine the radial position or does one just obtain the projection onto a plane perpendicular to the line of sight?

Gergely: One determines the position on the plane of the sky. However, the white light polarization measurement shows the features to be at less than 10° from the plane of the sky; therefore, projection effects are negligible.

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