THE APPLICATION OF CORONAL SCATTERING MEASUREMENTS TO SOLAR RADIO BURSTS

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The interpretation of ground based observations of solar "plasma frequency" radio bursts has been hampered in the past by an insufficient knowledge of coronal scattering by density inhomogeneities close to the sun. Calculations based on measurements of the angular broadening of natural radio sources, and Woo's 1975 measurement of the angular broadening of the telemetry carrier of Helios I near occultation (Woo, 1978), indicate that plasma frequency solar bursts should undergo considerable scattering, at least near the maximum of the sunspot cycle. The calculated displacements of the apparent positions of the bursts are about equal to the observed displacements which have been attributed to the bursts occurring in dense streamers. In order to obtain more scattering data close to the sun, interferometer measurements of the angular broadening of spacecraft signals are planned, and the important contribution which could be made with large dishes is discussed.

The positions of plasma frequency solar bursts, measured with ground based radio telescopes, are farther from the sun than optically determined plasma frequency levels in the quiet corona (Stewart, 1976). Theoretically, an apparent position shift of this magnitude could be caused by strong refractive scattering of the radio waves, due to coronal density inhomogeneities. The bursts would appear to come from the top of the scattering layer, analogous to light coming from a translucent lampshade surrounding a lamp.

The height of the top of the layer is estimated by integrating the r.m.s. radio wave scattering inward from infinity until it reaches $\sim 90°$. The integration has the same form for either the scattering of a solar burst, or the coronal angular broadening of an external radio source, hence the calculated height of the top of the scattering layer h_{TOP} can be related to the observed angular broadening function $\phi_{EXT}(h,f)$:

M.R. Kundu and T.E. Gergely (eds.), Radio Physics of the Sun, 265-268.

https://doi.org/10.1017/S0074180900036949 Published online by Cambridge University Press

$$\phi_{EXT}(h_{TOP}, f) = \left(\frac{I_{EXT}}{I_{BURST}}\right)^{1/2} \left(\frac{f_{BURST}}{f}\right)^2 \phi_{TOP}, \quad (1)$$

where I_{EXT} and I_{BURST} are dimensionless ray path integrals of order unity, ϕ_{TOP} ($\sim 90°$) is the scattering angle (e^{-1} half-width) defining the top of the scattering layer, and f is the frequency of the angular broadening observations. h_{TOP} is plotted against f_{BURST} in Figure 1, together with burst position observations and quiet corona plasma frequencies for comparison.

The plotted values of h_{TOP}, should be the smallest heights at which solar radio emission is observed.

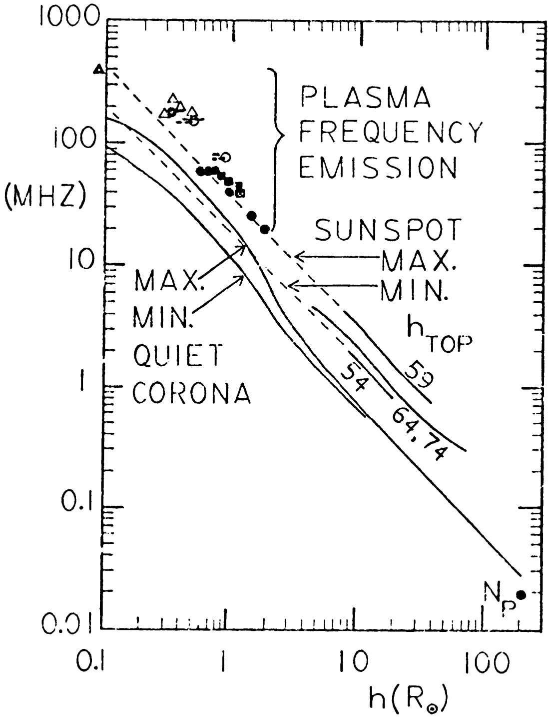

Figure 1. Calculated height of the top of the scattering layer, measured from the photosphere. The plasma frequency emission symbols are those of Stewart (1976). The solid portions of the h_{TOP} curves are based on the summary of angular broadening measurements given by Woo (1978). N_p represents the mean proton density measured by Mariner 2 (Neugebauer and Snyder, 1966).

Scattering can account for the observed burst heights at the maximum of the sunspot cycle, but not at the minimum, if the dashed extrapolations of the angular broadening observations are correct.

Strong scattering should cause bursts with short excitation times, like type III, to decay at the radio wave thermal (collisional) damping rate (Steinberg et al., 1971, and Riddle, 1974), allowing coronal temperatures to be derived from the observed decay times. Close to the sun the burst temperatures are comparable to corona model temperatures, but at lower frequencies they decrease more rapidly with distance, and resemble the temperatures in dense streamers deduced from transverse pressure equilibrium arguments (Hartz, 1969). This might be a selection effect, if the corona contains streamer-like structures ranging all the way from large densities and steep negative temperature gradients to quiet corona values. Radiation excited in lower density regions would encounter more scattering and thermal absorption, consequently radiation from denser structures with plasma frequency levels close to the top of the scattering layer should predominate.

Measurements of the angular broadening of radio sources at $h < 2\ R_\odot$ are needed to make more reliable interpretations of ground based observations of solar bursts. The superior conjunctions of satellites provide excellent opportunities for such measurements because the relatively strong narrow band carrier signals permit tracking close to the sun. D. R. Routledge (University of Alberta) and the author plan to make 2.3 GHz interferometer measurements of Voyager 2 and both Helios satellites this summer and fall at Owens Valley. Angular broadening measurements could be extended much closer to the sun by mapping the satellite brightness distributions with large dishes.

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DISCUSSION

Bhonsle: What is the size of the dish required for recording signals at 2.3 GHz from the Helios satellite when the line of sight gets close to the Sun?

Bradford: The minimum required dish diameter for single dish measurements of coronal angular broadening at 2.3 GHz is about 50 meters. A large diameter is required for a narrow main beam which can resolve the angular broadening without "seeing" the disk of the sun.

https://doi.org/10.1017/S0074180900036949 Published online by Cambridge University Press

Gorgolewski: Did you consider the use of the Arecibo 10 km interferometer?

Bradford: The next occultations of Helios 1 and 2 are in October and November 1979, and will be at too low a declination to be observed with the 1000 foot fixed reflector at Arecibo.

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