TYPE I RADIO EMISSION AND THE STRUCTURE OF THE SOLAR CORONA RESULTS OF THE STEREO-I EXPERIMENT

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Abstract : High resolution spatio-temporal observations of noise storms in the meter wavelength range show the existence of many center-limb effects. We show that these effects cannot be interpreted without appealing to scattering effects which must take place close to the primary source of electromagnetic radiation. This contradicts STEREO-1 observations of very directional radiation which require that the scattering takes place far from the primary source, in order to be consistent with the observed source sizes. Using other results of the STEREO-1 Experiment, we suggest a model for the noise storm region in which the Type I bursts are emitted by gyromagnetic radiation of electron packets. The emission is very directional and oriented in the direction of the local magnetic field. The various center-limb effects and the spatio-temporal behavior can be explained using strong scattering effects in a fibrous medium.

The observations of individual Type I bursts with high space and time resolution (3.4' and 0.1s) have shown the existence of "moving bursts" whose peak intensity move during their lifetime. These bursts are found systematically on the limbs (Bougeret, 1973). It is possible to show that this is due to propagation effects that must take place very close to the primary source (Bougeret and Steinberg, 1977).

The STEREO-1 Experiment has shown that the Type I beam is narrower than about 25° (Steinberg et al., 1974). This sets an upper limit to the amount of classical isotropic angular scattering suffered by the radiation, that is $\pm$ 12° overall. This is not enough neither to explain the apparent size of the wider sources as scattered images of point sources, nor center-limb distribution of the moving bursts. We conclude that this scattering model has to be dropped.

Radioheliography has also shown the homology or persistence of a given spatio-temporal shape at the same position (Bougeret, 1973).

M.R. Kundu and T.E. Gergely (eds.), Radio Physics of the Sun, 401-404.

https://doi.org/10.1017/S0074180900037141 Published online by Cambridge University Press

This persistence allows to reduce a broad noise active center into few distinct and fixed sources where bursts of constant characteristics are emitted. This shows the existence of very well localized regions of the corona which must be connected with very fixed structures in the corona. These results are also supported by time delay measurements during the STEREO-1 Experiment (Bougeret, in preparation) : the dispersion of these delays appears to be very small.

These results point towards a very inhomogeneous medium, in agreement with X-EUV pictures. Other observations (Stewart and Vorpahl, 1977) confirm the location of the Type I sources over regions with loop structures. We suggest that there exist much more loops that what can be observed : we do not observe them because they are not hot enough.

On the other hand, the Type I beam is sometimes oriented far from the radial direction : up to 60° away. A given source region generates bursts with almost the same beam orientation. Some noise centers are resolved into distinct sources in position and beam orientation (Bougeret, in preparation).

The various orientations of the beam are more easily understood if one supposes that the beam orientation is mostly controlled by the magnetic field, and not by the electron density gradient.

In the first two paragraphs we have found that we need some scattering which has to preserve the directivity. This can be obtained by multiple reflection on bunches of overdense fibers (Bougeret and Steinberg, 1977).

It is easy to find that a primary directivity is not destroyed in a plane parallel to the fibers. For the model to work, however, we need a primary directional emission, more or less in the direction of the fibers. This is just what is expected from Mangeney' and Veltri's model (1976) which is based on a gyromagnetic mechanism. The propagation inside such a fibrous medium has been simulated on a computer (Steinberg, in preparation), and it is found that it is possible to explain the various spatio-temporal shapes and the observed center-limb effects.

Many loops consisting of a number of fibers can be present in the active region, with different densities and orientations ; thus it is possible to expect close-by sources with different beam orientation, as sometimes observed. The noise center consists of many sources that cannot be observed simultaneously from a given direction. The spatio-temporal shape is obtained by strong scattering close to the source, inside the fibrous medium, and the contribution from the ambient corona to the various effects is very small and almost negligible.

The observed center-limb variation of the degree of polarisation is tentatively interpreted in the following way :
(i) the beam is more frequently oriented in the direction of the fibers. Orientations at large angles can occur, but they are much less frequent ;
(ii) a depolarisation effect is expected for propagation transverse to the direction of the fibers due to multiple reflections ; this effect is much smaller for propagation along the fibers (the number of reflections is much smaller when the rays leave the bunch of fibers) ;
(iii) the burst sources are statistically more frequently situated in regions where the orientation of the arch (the bunch of fibers) is close to the solar radial, as deduced from (i) and from the observed center-limb distribution of the occurence of Type I sources.

To conclude with, it appears that the study of Type I bursts inside noise storm centers can bring information on the coronal structures and on the type of inhomogeneities, and we have good hopes to be able to use the Type I burst sources to probe the physical parameters in the active solar corona ; this is important if the Type I mechanism is a very sensitive radio diagnostic for non-flare evolution of coronal active regions.

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DISCUSSION

Gergely: I find your results very interesting, they coincide with what we are finding in comparing positions of decametric bursts with soft x-ray pictures. It has been shown recently by Webb that the highest loops are tilted with respect to the meridian by large amounts in some cases.

Golub: The slide you showed, in which a number of isolated loops were contributing to the observed radio events, is actually in accord with the x-ray observations. The simple soft x-ray flare profile which rises and falls smoothly over some tens of minutes is seen when no spatial resolution is available. But when one has sufficient resolution to see individual loops within the region, one often finds that the flare is more complex and consists of several isolated loop events. The simple profile is only the envelope obtained by combining the separate loop activations.

Takakura: If your loop model is correct, we expect low percentage of polarization degree for the total emission. This is inconsistent with the observations.

Pick: With the Nançay radioheliograph, sometimes mixed polarization is observed in a noise storm region of small extent, less than 2 arc minutes. Also, in the same region bursts of different diameters can be observed. A strong inhomogeneous medium is locally required to explain these observations, in agreement with the model presented by J.L. Bougeret (Kerdraon, 1979, Astron. and Astrophys.).

Kai: Many type I-storms show nearly 100% polarization consistently during their passage on the disk. I am wondering how you can explain this observed fact in terms of your model.

Kundu: In your model, the question of whether or not one should observe strong polarization in type I should depend upon the scale size of the loops. I agree with Drs. Takakura and Kai that it will be difficult to explain the strong polarization observed in noise storms even in low resolution total flux measurements.

Bougeret: If propagation takes place more or less parallel to the fibers, one may expect very few reflections to take place and if the emission is very strongly polarized, it would remain so. On the other hand, if one considers propagation perpendicular to these fibers, one expects many more reflections and therefore the polarization would be destroyed.