N72-33807

TYPE III SOLAR RADIO BURSTS

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Rapid drift type III solar radio bursts are caused by streams of high-speed electrons ejected from the Sun that excite radio waves at the local plasma frequency as they move through the corona. Ground-based radio observations can provide information on these electrons only in regions very close to the Sun, within the first one-hundredth of the distance from the Sun to the Earth.

With the detailed low-frequency observations made possible by the RAE and IMP 6 satellites, these electrons can be followed to vastly greater distances, of the order of 1 AU from the Sun. A study of the radio observations, along with the knowledge of how the electrons excite radio waves as they move through the corona can provide information on the structure of the interplanetary media extending from the Sun to the Earth, such as its temperature, density, and magnetic configuration.

In the past 25 yr, since the discovery of these bursts, numerous theories have been proposed to account for this generation process. For the first time, using low-frequency satellite observations, a direct comparison of the different theories is possible, since we have available independent measurements by satellite electron detectors in the same region of the interplanetary media where the radio emission is being generated.

Our results show, on the basis of this comparison, the general inadequacies of current type III burst theories and indicate a needed emphasis on formulating a new theory that is consistent with the low-frequency observations.

Representative observations from the RAE satellite are shown in Figure 1. The brightness temperature, which is a measure of the energy flux, versus frequency is plotted. Shown are two events, a large burst and a large storm, each recorded at frequencies of 2.8 MHz and 700 KHz. Also shown are high-frequency curves obtained from ground-based observations. It can be seen that the RAE observations are consistent with the extrapolation of the ground-based observations.

Each of the different theories of Type III bursts gives a relation between the exciter electron density and the resulting brightness temperature. Since we have these observations of brightness temperature as a function of

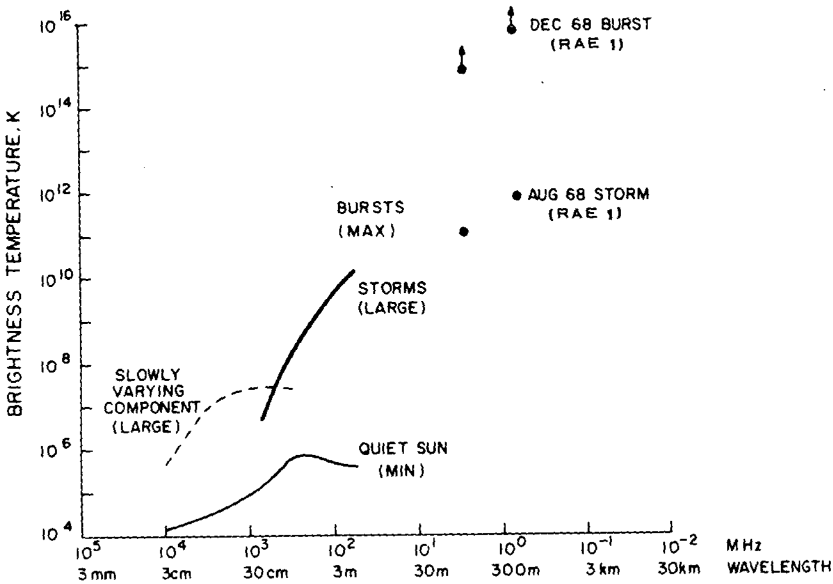

Figure 1–Comparison of RAE and ground-based observations of brightness temperature.

frequency, we can calculate the required exciter electron density as a function of frequency. With a corona model also obtained from the RAE observations, the plasma frequency scale can be converted into a distance from the Sun scale. Thus we are able to calculate, as shown in Figure 2, the required exciter electron density as a function of coronal distance (in solar radii).

Figure 2 shows some of the most popular and widely used theories of type III bursts. For each of the theories, a curve is plotted using three high-frequency observations indicated by the solid circles and the two low-frequency satellite observations, indicated by open circles. Also shown in this figure are a representative range of 6.4 fJ (400 keV) electron densities measured by satellites in the vicinity of 1 AU. This is the energy range of electrons corresponding to an exciter velocity of 10^{10} cm s^{-1}, calculated from the radio observations.

If we extrapolate the curves to 1 AU, then except for the curve labeled S_2, all the theories give an exciter electron density quite different from the measured values; and it has been argued because of other considerations that the S_2 curve may not represent a realistic physical solution.

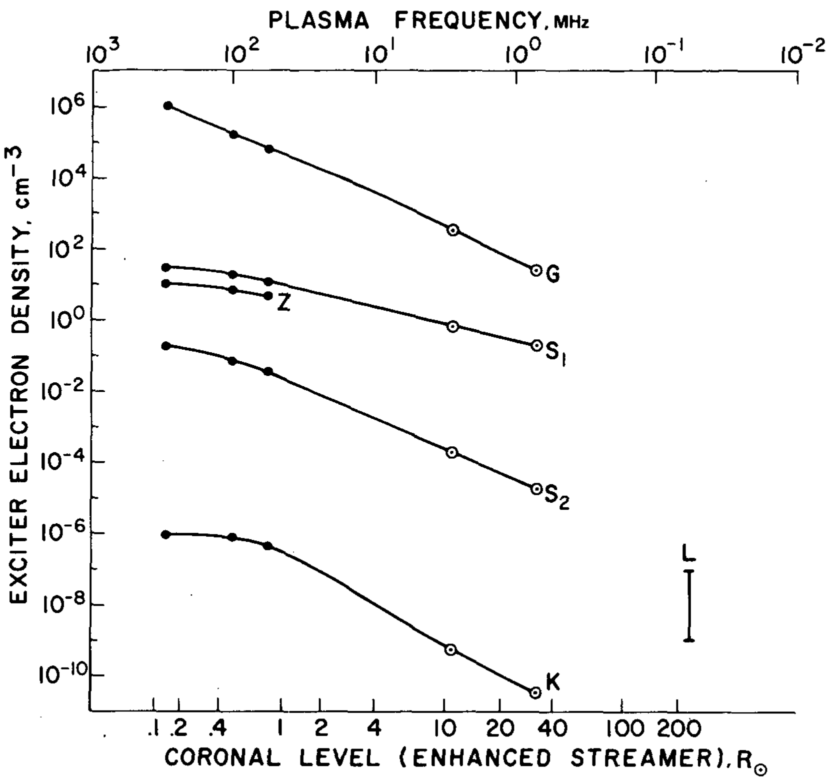

Figure 2–Exciter electron density as a function of coronal distance. The curves are identified as follows: G from Ginzburg and Zhelezynakov (Ref. 1); $S_1, \delta \neq 1$, and S_2, $\delta = 1$, from Smith (Ref. 2); K from Kaplan and Tsytovich (Ref. 3); Z from Zhelezynakov and Zaitsev (Ref. 4); and L, the measured energetic density range for a storm, from Lin (Ref. 5).

Thus, we were left with the conclusion that none of the current type III burst theories give an adequate description of the conversion process consistent with these observations. Since the conversion process must be understood before a description of the corona structure and the properties of the interplanetary media can be determined, the low-frequency satellite observations necessitate a renewed emphasis on the theoretical treatment of type III bursts.

In the near future, observations from the IMP 6 satellite at frequencies down to 30 kHz will enable these curves to be extended out to 1 AU. We do not, however, expect that these observations will markedly affect the trends shown in Figure 2 or the resulting necessity for new theoretical work.

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