Observations and Analyses of Heliospheric 2-3 kHz Radio Emissions

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For more than ten years the Voyager 1 and 2 spacecraft have been detecting an unusual radio emission in the outer heliosphere at frequencies from about 2 to 3 kHz. Two particularly strong events have occurred, the first in 1983-84 [Kurth et al., 1984] and the second in 1992-93 [Gurnett et al., 1993]. Several other much weaker events have also been observed. The two strong events occurred about 400 days after two deep depressions (Forbush decreases) in the cosmic ray intensity. This relationship is illustrated in Fig. 1. The two strong radio emission events are labeled A′ and B′, and the two deep Forbush decreases are labeled A and B. These Forbush decreases are the two deepest depressions in the cosmic ray intensity (21% and 30%) observed in the more than thirty years that such data have been recorded. For further details, see Gurnett and Kurth [1995].

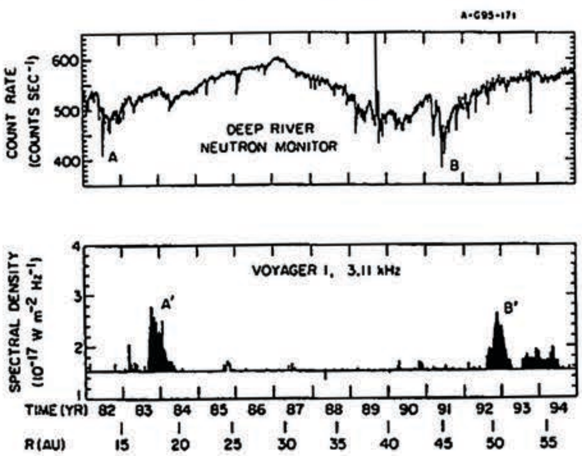

Figure 1

It is well known that Forbush decreases are caused by a strong interplanetary shock and associated disturbances propagating outward from the Sun. The observed relationship between 2-3 kHz radio bursts and Forbush decreases strongly suggests that the radio emission is produced when a strong interplanetary shock interacts with one of the outer regions of the heliosphere. Just where this interaction occurs is still a subject of discussion. There are two primary possibilities: in the solar wind between the termination shock and the heliopause, and in the interstellar medium between the heliopause and the interstellar bow shock (if such a shock exists). In the first case the onset of the radio emission would occur when the interplanetary shock reaches the termination shock; and in the second case the onset would occur when the interplanetary shock reaches the heliopause. We believe that the radio emission is most likely generated in the vicinity of the heliopause. The reason has to do with the plasma frequency, f_p. All mechanisms known to date for generating the 2-3 kHz radio emission involve generation at either the plasma frequency or its harmonic. If the radio emission is generated in the region just beyond the termination shock, the emission frequency can be estimated from the expected (1/R) variation of the plasma frequency with distance from the Sun. If the propagation speed of the interplanetary shock is 600 km/s, which is a good representative value, and for a travel time of 400 days, the distance to the termination shock works out to be 138 AU. At this great distance, the plasma frequency in the solar wind is too small (~145 Hz) to explain the observed emission frequency.

In the vicinity of the heliopause the situation is much more favorable. Since the heliopause is a contact discontinuity, the density can increase by whatever factor is required to maintain pressure balance. Present estimates are that the electron density in the local interstellar medium is in the range from 0.06 to 0.1 cm^{-3} [Lallement et al., 1993]. The corresponding plasma frequency is approximately 2.2 to 2.8 kHz. Although the exact electron density profile in the vicinity of the heliopause is subject to a great deal of uncertainty due to charge exchange and other interactions, the plasma frequency is expected to be in a suitable range for explaining the frequency of the 2-3 kHz radio emission. Thus, the region near and beyond the heliopause appears to be the favored region for generating the heliospheric radio emission.

If the 2-3 kHz heliospheric radio emission is generated at or near the heliopause, then the distance to the heliopause can be computed from the travel time and speed of the interplanetary shock. Using a relatively simple model for the shock propagation speed Gurnett and Kurth [1995] estimate that the radial distance to the heliopause is in the range from about 110 to 160 AU. Using nominal values for the ratio of the distance to the termination shock to the distance to the heliopause (~0.73), the termination shock is estimated to be in the range from about 80 to 115 AU.

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