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1)The components of all vector quantities are taken with respect to the direction of the magnetic field H.

2)When allowance is made for thermal forces, the integral of the system of MHD equations is somewhat modified, becoming $N^{\alpha}T^{\beta}$ const, where α, β are only of order unity, rather than equal to 1. This adjustment clearly will cause no significant change in Eq. (2) or in our conclusions.

3)If the condition (11) is violated, the particles may be regarded as having straight-line trajectories. The quantity $|k^{-}|$ will then determine the Landau damping ($|k| \gg k_{\parallel}$).

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Hectometer radio bursts and the transonic solar wind

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Based on the frequency drift of type II solar hectometer-wave bursts, H. V. Cane has revealed an anomaly in the time profiles of shocks propagating at heliocentric distances $r \approx 10$–$40\ R_{\odot}$. This anomaly is probably an artifact of the kink in the radial profile of the electron-density gradient in the transonic solar-wind transition zone, as indicated by the scintillation of compact radio sources. Low-frequency ($f \sim 0.5$–1.5 MHz) type III bursts triggered by energetic electron fluxes can serve as high-speed (minutes), local probes of the transonic region.

Type II and III solar radio bursts are triggered, respectively, by shock waves and by energetic (tens or hundreds of keV) electron fluxes resulting from large flares. These burst events span a broad frequency range. As the disturbances responsible for them advance through the middle corona from a heliocentric distance $r \approx 1.3\ R_{\odot}$ to $r \approx 3\ R_{\odot}$, the radio frequency f gradually drops from 200 to 20 MHz. The subsequent propagation of the shocks and electron beams through the outer corona and the interplanetary medium is accompanied by the generation of low-frequency ($f < 2$ MHz) type II and III bursts, which are detectable by satellites and space probes initially at hectometer, and ultimately even at kilometer, wavelengths.

Studies of these low-frequency type II and III bursts are invaluable, for they can improve our knowledge of the radio generation mechanisms, enable us to track the shock waves and electron flows all the way from the flare site to the earth's orbit, and contribute new information on the solar wind and the interplanetary medium.[1-5]

It is customary to interpret type II and III radio bursts in terms of a plasma mechanism that entails the excitation of Langmuir waves by electron flows originating in a flare or accelerated at a shock front, followed by conversion of these plasma waves into radio emission at the fundamental and second harmonic of the local plasma frequency. Then by adopting a suitable electron-density profile N(r) one can use the observed rate $\partial f/\partial t$ of frequency drift of the emission peak to calculate a profile for the velocity component V(r) of the disturbance along the density gradient, employing the standard expression[6]

$$V(r) \simeq 2\frac{N}{f}\frac{|\partial f/\partial t|}{|\operatorname{grad} N(r)|}.$$

This is the practice followed, in particular, by Cane[7] in analyzing the low-frequency type II bursts recorded by the ISEE 3 satellite. Assuming a smooth density curve N(r) in the outer corona and interplanetary medium, she determined the shock-velocity profile V(r), which indicated tht the shocks tend to accelerate somewhat at distances $r < 80$-$100\ R_{\odot}$ and then to decelerate beyond $100\ R_{\odot}$. One other notable property of the V(r) profile determined in this

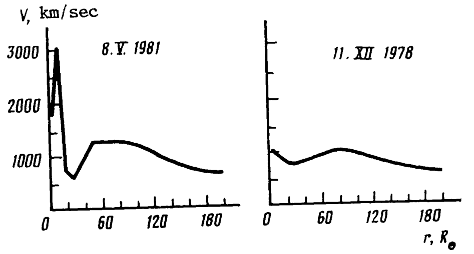

FIG. 1. Radial profiles of the shock velocity in the outer corona and interplanetary space that Cane[7] derived from the frequency drift of type II bursts, assuming a smooth electron-density distribution N(r).

manner, a behavior to which we shall return presently, is a considerable variability and irregular trend in the shock velocity at distances $r \approx 10$-40 $R_\odot$ (see Fig. 1). In this respect the velocity of the shocks responsible for the coronal (meter—decameter) type II bursts differs from that of the shocks that generate the interplanetary (hectometer—kilometer) type II bursts.

Consequently Cane drew the very important conclusion[7,8] that coronal and interplanetary type II bursts are excited not by one but by two different shock waves: the first would be an eruptive shock triggered during the impulsive phase of the flare and initially propagating within the coronal transient, while the second would be a piston shock formed in the outer corona at the leading edge of the transient.

It seems to us that the features in the shock-velocity profile at $r \approx 10$-40 $R_\odot$ that Cane has described[7] are actually only an apparent effect, an artifact of the assumption that the electron density varies smoothly. Indeed, this heliocentric distance range corresponds to the solar-wind transition zone, identified through transillumination of the circumsolar plasma by signals from natural and artificial radio sources.[9-11] It is in this very zone that the solar-wind velocity increases sharply, and the plasma undergoes a transformation from subsonic to supersonic flow.

The transition zone exhibits anomalies in all the observable parameters characterizing the medium. In particular, the radio scintillation index strengthens here, the scattering angle increases, electron-density fluctuations are enhanced, the turbulence spectrum is modified, and the plasma velocity along the line of sight shows a larger spread.

With regard to the qustion at hand, it is especially noteworthy that the solar-wind transition zone is also the site of a peculiarity of the radial electron-density distribution: first the absolute value of the density gradient drops steeply, and then it rises, only to decrease again. A peculiarity of this kind is in fact apparent in several density profiles N(r) that have been obtained by dual- and multifrequency radio sounding,[12-14] even though the corresponding authors neglected to point it out.

Figure 2a illustrates the qualitative dependence of electron density on distance when the solar-wind transition zone is taken into account. For comparison the dashed line represents a smooth power-law N(r) profile. Clearly even if the shock propagation velocity remains constant, the rate of frequency drift of a type type II burst should experience substantial variations at the fundamental frequency $f \approx 500$-800 kHz) corresponding to the electron density in the transition-zone region (Fig. 2b). Conversely, if the oberved $\partial f/\partial t$ variations were converted to the shock-velocity profile V(r) on the basis of a smooth density distribution N(r), then at distances $r \approx 10$-40 $R_\odot$ one would obtain velocity fluctuations resembling those discussed by Cane.[7]

Evidently, then, the variations in the frequency drift rate encountered in type II bursts at $f \approx 500$-800 kHz reflect not changes in the shock velocity or a replacment of one shock wave by another, as proposed by Cane,[7,8] but attest instead to a distinctive behavior of the electron density in the transonic region of the solar wind at distances ranging from about 10 to 40 $R_\odot$.

Furthermore it is clear that the lowest-frequency radio bursts convey information on the solar-wind transition zone. In particular, by solving the inverse problem one might be able, from observed radio-frequency drift rates, to calculate the electron-density profile N(r) in the corresponding heliocentric distance range. For this purpose it would be necessary, to be sure, to establish in some manner the velocity of the agent that produces the radio emission. One could do so, for example, by considering the drift at distances (frequencies) outside the transonic region, where the density profile may indeed be considered smooth, by meausring the time delay of a radio burst relative to the impulsive phase of the parent flare, or by determining the direction toward the burst source from the radio modulation that occurs when one spacecraft, or several vehicles with differently oriented dipole antennas, undergo stabilized rotation.[15,16]

Type III bursts are best suited for sounding the solar-wind transition zone. Unlike type II bursts they usually exhibit a well-defined dynamic spectrum and rapid, easily measurable frequency drift. The significant changes in the frequency drift rate due to the special behavior of the N(r) profile in the transonic region (Fig. 2) should in the case of type III bursts manifest themselves on a time scale of a few few minutes, since the electron beams exciting these bursts have a velocity of order 10^5 km/sec, some two orders of magnitude faster than the shocks responsible for type II bursts ($\sim 10^3$ km/sec).

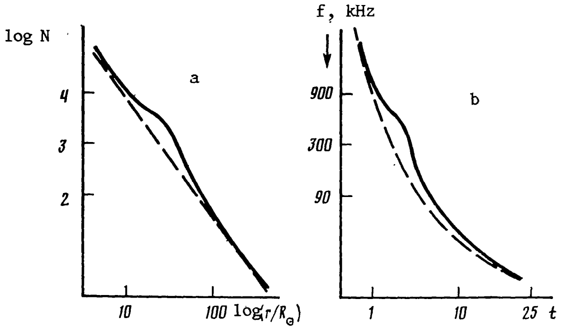

FIG. 2. a) Solid curve, a typical profile for the electron density N(r) as a function of heliocentric distance, allowing for the solar-wind transition zone; dashed line, a smooth power-law profile. b) The corresponding changes in the radio frequency f as a function of time t, expressed in hours for type II bursts and in minutes for type III bursts.

Clearly in order to probe the solar-wind transition zone one would have to record type III bursts at quite a high frequency resolution: straightforward estimates suggest that Δf should be ~20-50 kHz in the 500-1500 kHz frequency range. In most cases, published dynamic spectra of type III hectometer burts are represented by time profiles at a limited number of frequencies, spaced apart by $\Delta f \gtrsim 100$-200 kHz. It therefore is hard to tell whether the anticipated frequency-drift peculiarity corresponding to the transonic region has actually been detected. However, in the well-studied type III burst of 19 June 1971, for which a more detailed dynamic spectrum obtained with the IMP 6 satellite has been given by Fainberg and Stone [17] and elsewhere, a peculiarity of this kind does appear rather distinctly, if one compares the epochs of peak radio intensity at $f = 737$, 600, 475, 425, 375 kHz. In this part of the spectrum the changes in the frequency drift rate resemble those illustrated schematically in Fig. 2b.

Perhaps certain other properties of the transition zone, such as the enhanced level of plasma turbulence, may account for several further peculiarities observed in type III hectometer burst. For instance, in most type III bursts the frequency spectra acquired with the IMP 6 and OGO 5 satellites (Refs. 18, 19) display a well-defined flux maximum at $f \approx 300$-900 kHz, close to the Langmuir frequencies of the solar-wind transition zone at $r \approx 10$-30 $R_\odot$.

Thus the presence of the transonic region ought to be taken into account when interpreting the behavior, particularly the frequency drift, of type II and III hectometer bursts, and when analyzing how shock waves and electron flows propagate outward from flares. In turn the bursts themselves, especially those of type III, can be utilized as probes of the transition zone. Such a method for diagnosing the transonic region has several advantages over the traditional radio sounding of the circumsolar plasma. In principle, it would provide a momentary (minutes rather than days) and local (rather than integrated along the line of sight) picture of the transition zone in the solar wind above such structures as active regions and coronal rays.

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Stresses in the Venus crust and the topography of the mantle boundary

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A joint analysis of the interrelated topography and nonequilibrium gravity-field component, based on spherical harmonics $n = 3$–18, yields clues as to the character of the topography of the crust–mantle interface as well as the crustal tension–compression stresses beneath the surface of Venus. Several realistic models are considered, including some with an asthenosphere. Depending on the model, the deflection of the Mohorovičić boundary from its average level ranges from about $+80$ km (downward) to -20 km (upward), but on the whole it is fairly smooth. The stresses range from about $+600$ bar (tension) to -700 bar (compression).

1. Now that space probes have supplied information on the surface relief and exterior gravity field of Venus, attempts can be made to study the structure of the planet's crust—mantle interface. For Venus the spherical harmonics of the topography correlate with the corresponding harmonics in the nonequilibrium part of the gravitational potential [1,2] at all orders $n \geq 3$.

In fact the relief on Venus shows considerable isostatic compensation. Unlike the Earth, where mantle convection emerges in the form of midoceanic ridges