3475, 4562, 8092, 4890, 14893, and Kpr 23, the residuals are very substantial and call for major revision of the orbits. In the case of the last three pairs as well as for ADS 6828 and 15281, McAlister and Fekel's observations[3] point to a similar conclusion. Excluding these eight stars from further consideration, we have analyzed the remaining 56 orbital pairs and have found that $\langle \Delta\theta \rangle = -0°.3$, $\langle \Delta\rho \rangle = -0''.006$. The rms deviations from the ephemerides are $\sqrt{\langle \Delta\rho^2 \rangle} = 0''.032$, $\sqrt{\langle (\rho\Delta\theta)^2 \rangle} = 0''.017$, values which significantly exceed the uncertainty in our results and evidently represent the mean accuracy of the orbits as derived from all visual observations combined, their errors therefore being included.

G. A. Starikova has pointed out that, as a rule, the closest pairs have negative $\Delta\rho$ values. For the 15 stars having $\rho < 0''.2$ we obtain $\langle \Delta\rho \rangle = -0''.019$, whereas $\langle \Delta\rho \rangle = -0''.002$ for the other 41 stars. To ascertain whether this systematic effect is peculiar to our observations, we have analyzed McAlister and Fekel's results,[3] which were obtained with different equipment on a 4-m telescope. From their list we selected 33 orbital pairs with $\rho < 0''.2$ that were studied prior to the development of speckle interferometry. Only 15 of these have orbits of satisfactory quality ($|\Delta\theta| < 8°$), the mean deviation from those orbits is $\langle \Delta\rho \rangle = -0''.017$, which is close to our own result. Thus experiments with two different instruments indicate that the orbits contain systematic errors in excess of the small angular separations.

Figure 1 plots the residuals $\Delta\rho$ as a function of ρ for our observations (dots) and for those by McAlister and Fekel (crosses). For stars in common to the two programs, residuals relative to the same orbit are joined. The curve drawn in the interval $0''.1 < \rho < 0''.3$ has been obtained by averaging the points in $0''.05$ intervals of ρ; the expression $\Delta\rho = -5 \cdot 10^{-5}\rho^{-3}$ arc sec (ρ in arc sec) provides a reasonable fit. For $\rho = 0''.1$ the error in the ephemerides reaches 30%.

The exaggeration of small distances causes the apparent motion of a close pair not to be described by the proper Keplerian ellipse when the orbit is calculated, and if the whole set of observations is used one will obtain a decidedly incorrect solution. For a certain number of close pairs the orbits ought to be determined anew on the basis solely of interferometric observations (as can in fact already be done for ADS 14773). From these new orbits one should evaluate the personal errors of the individual visual observers, in order that they may be taken into account when the orbits are revised.

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The effect of the neutral solar-wind component upon the interaction of the solar system with the interstellar gas stream

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The interaction between the neutral solar-wind component and the ionized component of the interstellar gas may significantly influence the gas parameters. Proper allowance for this effect may alter our ideas about processes in the solar-wind deceleration zone, and measurements of the $L\alpha$ brightness of the interstellar gas may have to be interpreted.

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The question of how the solar system interacts with the ambient interstellar medium has lately been given much attention. Interest in the problem has been stimulated by successful satellite experiments for measuring the luminosity of the hydrogen (Lyman-α) and helium resonance lines emitted by interstellar gas flowing into the solar system.[1–3]

Experiments of this kind are designed to determine the parameters of the undisturbed interstellar medium that surrounds the solar system. This can be done by adopting a model for the interaction between the interstellar gas and the solar system, and then comparing the predicted sky brightness in the hydrogen and helium resonance lines against the picture actually observed. When the observations are interpreted in this manner, the reliability of the properties inferred for the undisturbed interstellar gas will depend fundamentally on the completeness and correctness of the models employed.

Such models thus far have made no allowance for the fact that the solar wind contains a neutral component. In this letter we shall qualitatively examine the influence of the neutral solar-wind component on the interaction of the interstellar gas stream with the solar system, and we shall obtain some semiquanitative estimates which indicate

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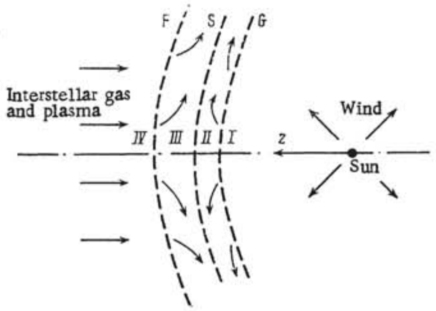

FIG. 1. A schematic diagram of the supersonic interstellar gas (plasma) stream interacting with the solar wind.

that the influence is by no means negligible.

Supersonic solar wind is flowing into an interstellar medium characterized by a finite pressure. The stream of interstellar gas incident on the solar system at a veloctiy V_0 = 20 km/sec is partially ionized; the interstellar plasma has a density[4] $n_e = 0.04\ cm^{-3}$ and a temperature T_0 = 6000-8000°K. The interstellar plasma flow is supersonic as well. In the most fully developed theory of solar-wind braking, the double-shock model proposed by Baranov et al.,[5] the supersonic solar wind would be decelerated at a discontinuity G and the supersonic interstellar plasma stream at another discontinuity F, forming a contact surface S as depicted in Fig. 1. Solar-wind protons would exchange charge with gas atoms entering the solar system, thereby producing the neutral solar-wind component.[3,6,7] The resultant fast hydrogen atoms would have the same velocity as the solar wind itself; after traversing zones II and III (Fig. 1) they would arrive in the region IV, where they could exchange charge again with the protons in the interstellar plasma. Thus fast protons would be formed in region IV, and as they are decelerated they would transfer their momentum and energy to the plasma. In existing models the interstellar plasma in region IV is considered undisturbed, but in fact it represents a plasma stream interacting with the neutral solar wind.

In previous efforts to determine the character and amount of disturbance of the interstellar gas it has been assumed that both the neutral gas density n_0 everywhere in space and the electron density n_e in regions III and IV (the interstellar plasma flow has a Mach number of nearly unity) are constant. The solar-wind velocity is independent of the distance from the sun, having a value V_{SW} = 400 km/sec, and at the earth's orbit the density n_{SW} = 5 cm^{-3}. For the adopted solar-wind and interstellar-plasma parameters the distances along the z axis from the sun to surfaces G, S, F are[5] R_G = 220, R_S = 300, R_F = 500 AU.

In region IV the density of the neutral solar-wind stream on the z axis will be expressed by

$$j(R) = n_{SW} V_{SW} \xi_1 \xi_2 (R_E/R)^2 \exp[-n_e \sigma (R - R_F)],$$

where $\xi_1 = 1 - \exp(-n_0 \sigma R_G)$ is the probability that a solar-wind proton will exchange charge with interstellar gas atoms along the way from the sun to R_G, $\xi_2 = \exp[-n_e \sigma \cdot (R_F - R_S)]$ represents the attenuation of the neutral solar wind due to charge exchange as zone III is crossed, σ =

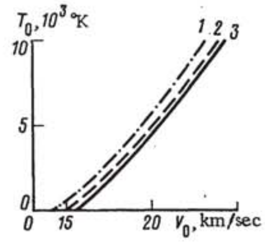

FIG. 2. Curves specifying the "state" of the undisturbed interstellar plasma such that critical flow will set in when supersonic flow is achieved at the point $z = R_F$. Each curve corresponds to a diferent value of the interstellar gas density n_0: 1) 0.10; 2) 0.07; 3) 0.04 cm^{-3}.

$2 \cdot 10^{-15}\ cm^2$ is the cross section for charge exchange between a proton and a hydrogen atom for a 400-km/sec relative velocity, and R_E is the radius of the earth's orbit.

Because of kinetic-type instability the stream of fast protons formed in the interstellar plasma through charge exchange with the atoms in the neutral solar wind will deliver energy to the plasma.[8] The survival time τ_p of the fast protons may be taken equal to the reciprocal of the instability growth rate, a function of the fast-proton density n_p in the plasma. Setting $n_p = j\sigma\tau_p n_e$, one can evaluate τ_p. The electron distribution function in plasma perturbed by the onset of instability will be Maxwellized after at most 10 electron–electron collisions, whose frequency is well established[9]; and under the conditions of the problem at hand, the energy of a proton will be converted into disordered motion of the plasma electrons within $\tau_0 \leqslant 10^7$ sec.

The physical processes chiefly involved in the interaction between neutral solar wind and interstellar plasma should operate, as will be clear presently, on time scales much longer than τ_0. One may accordingly suppose that the fast protons born through charge exchange transfer their energy and momentum to the plasma instantaneously. Then along the z axis from infinity to the contour F an interstellar proton–electron pair will acquire an energy

$$q(R_F) = \varepsilon \frac{\sigma}{V_0} \int_{R_F}^{\infty} j(R)\, dR,$$

where $\varepsilon = m_p V_{SW}^2/2$ (m_p is the mass of a proton). A similar expression may be written for the momentum $p(R_F)$. For the characteristic spatial scale L of the interaction between neutral wind and interstellar plasma it is natural to take the distance from the contour F at which one-half the energy $q(R_F)$ is released. One finds that L ≈ 200 AU, and the corresponding characteristic interaction time

$$\tau_V = L/V_0 \approx 1.5 \cdot 10^9 \text{ sec.}$$

The time scale for the energy released by the neutral solar-wind component to be transferred by thermal conduction is given by $\tau_{th} \approx 3L^2 k n_e / 2\varkappa$, where k is the Boltzmann constant. The dependence of the thermal conductivity $\varkappa$ on the plasma parameters is well understood,[10] and in our case $\tau_{th}/\tau_V \approx 2 \cdot (10^4 °K/T)^{5/2} > 2$ for T < 10,000°K. One also can easily estimate the time scale τ_T for achieving temperature balance between the ion and electron components of the plasma[11]: $\tau_T/\tau_V \approx (T/10^4 °K)^{3/2}/2 < 1/2$ for T < 10,000°K. Since $T_0 \leqslant$ 10,000°K, these ratios between the quantities τ_V, τ_{th}, τ_T show that thermal conduction may be neglected and the heat exchange between the electron and ion components of the plasma may be regarded as occurring instantaneously, materially simplifying the problem. For the time scales mentioned above these simplifying assumptions clearly will not be strictly valid. Nevertheless, invoking them can only affect the quantitative side of the estimates to be obtained, not the character of the relationships themselves.

We would point out that the presence of even a weak (by astrophysical standards) interstellar magnetic field could almost completely suppress the thermal conductivity across the field. Plasma mechanisms might also exist which can equalize the temperatures of the ion and electron components more rapidly. It is worth noting that the energy released to a proton–electron pair in the interstellar plasma advancing from infinity to the point $R = R_F$ at an impact parameter R_F away from the z axis will be only 20% smaller than the energy delivered to a pair moving along the z axis. One may therefore regard the interstellar plasma within a region not too far from the axis as being in one-dimensional motion.

To describe the interstellar plasma flow we shall adopt the hydrodynamic approach (as justified, for example, by Baranov and Krasnobaev[10]), and on the assumptions introduced above we may employ a single-fluid model without conduction. The neutral and ionized components of the interstellar gas will interact efficiently through charge exchange, so that some of the energy and momentum acquired by the interstellar plasma as it interacts with the neutral solar wind will be transferred to the neutral interstellar gas. We shall allow for this effect by assuming that the plasma interacts with the neutral solar wind (the interaction with the interstellar gas being "turned off") only in the zone extending from R_F to $R_F + V_0\tau_{CE}$, where τ_{CE} denotes the survival time of a proton in the interstellar plasma against charge exchange with interstellar gas atoms.

By writing differential equations for a streamtube along the z axis, one can show that the interaction between the neutral solar wind and the supersonic interstellar plasma flow will serve to decelerate and heat the plasma, thereby diminishing the Mach number of the plasma flow. One can also write integral equations for the streamtube to obtain the dependence of the velocity and temperature of the plasma flow upon V_0, T_0, q(R), and p(R) at a given point on the z axis. These last two quantities are in turn functions of V_0, T_0, and the interstellar gas density n_0.

It is of interest to determine the values of the parameters T_0, V_0 of the undisturbed interstellar plasma such that for given n_0 the Mach number of the flow will become equal to unity at the point $z = R_F$, and critical flow will set in. Figure 2 shows the $T_0(V_0)$ relations computed for the values $n_0 = 0.04, 0.07, 0.10\ cm^{-3}$. If the undisturbed plasma state is represented by points to the right of the corresponding curve in Fig. 2, critical flow will not develop, and the double-shock model (including the additional heating of the plasma by the neutral solar wind) can then be employed to describe the plasma–solar wind interaction. But if the undisturbed state of the interstellar plasma is represented by points to the left of the curve (and this is the alternative that obtains for the interstellar plasma and gas parameters adopted at the present time), then critical flow will set in before the flow reaches the contour $z = R_F$, and the double-shock model will be inapplicable. Actually the supersonic plasma flow heated by interaction with the neutral solar wind may prove to be unstable, giving rise to a shock wave in the supersonic plasma stream and thereby significantly broadening zone III.

The discussion given above and the semiquantitative estimates obtained for the interaction of the neutral solar wind with the interstellar plasma stream demonstrates that the interaction may materially alter the parameters of the interstellar medium at distances well beyond the solar-wind deceleration zone. This circumstance may in turn call for revision both of our ideas concerning the processes at work in the region where the solar wind "terminates," and of interpretations of sky brightness measurements in the Lyman-α line.

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