COOLING OF SLOW SOLAR WIND PROTONS FROM THE HELIOS 1 EXPERIMENT

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In a recent survey of initial results of the Helios experiment, Rosenbauer et al. [1977] suggested that there could be two types of solar wind, characterized by a 'slow' and a 'fast' component. This idea is based mostly on two distinct ranges of observed flow speed and on a preliminary analysis of data showing that the protons in the slow component expand nearly isothermally.

Contrary to this result, we have found from the same data that the slow protons in the solar wind do clearly exhibit cooling, compatible with adiabatic expansion. For the analysis we used the data published by Rosenbauer et al. [1977] and treated them as we did in our previous analysis of the Mariner 2 data [Eyni and Steinitz, 1978]. The essence of our analysis is twofold: (1) the reduction of the strong dependence of temperature T on velocity u by the definition of a reduced temperature $\tau \equiv T/u^2$ and (2) the choice of samples which are as uniform as possible in velocity u and in (distance) normalized density n.

We chose several distance intervals, and in each one we selected a sample of simultaneous measurements consisting of n, T, and u. All samples were further restricted to be within a small specified range of u.

In Table 1 the mean values and the standard deviations of the mean values are given for the appropriate distance ranges. Since T depends on distance r, the scatter in the logarithm of the reduced temperature ($\log \tau$) is at least in part due to the scatter in $\log r$. The table contains data for two velocity ranges, a very slow and a slow component. We find that the cooling (Figure 1) is given roughly by $T \propto r^{-\alpha}$. We estimate for the very slow component $\alpha = 1.7\pm0.4$ and for the slow component $\alpha = 1.2\pm0.2$. This result appears to be compatible with adiabatic cooling, provided account is being taken of the anisotropic temperature distribution, aligned along a spiral magnetic field, and the fact that in the analysis only the radial temperature is used. Furthermore, the cooling exhibited by these two groups is consistent with our previous finding [Eyni and Steinitz, 1978] from Mariner 2 data, namely, that slow solar wind does indeed exhibit cooling with heliocentric distance. Thus the suggestion by Rosenbauer et al. [1977], based on a preliminary analysis of Helios data, that

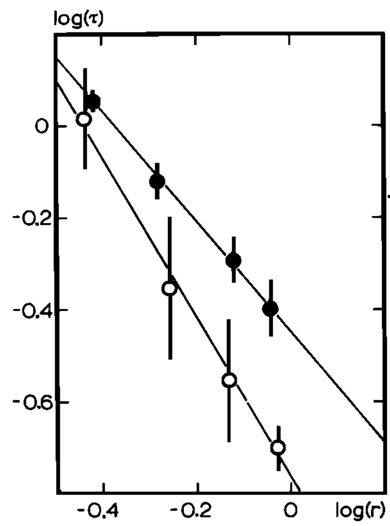

Fig. 1. Cooling lines from Table 1. Open circles are for very low speed, and closed circles for low speed.

TABLE 1. Variation of the Reduced Temperature With Distance

Range of r, AU	<log r>*	<log τ>+	<u> km/s	<n>++ cm^{-3}
0.31-0.42	-0.436 ± 0.030	+0.020 ± 0.115	331 ± 15	12.7 ± 1.9
0.42-0.71	-0.263 ± 0.052	-0.351 ± 0.160	314 ± 10	12.2 ± 3.0
0.65-0.82	-0.130 ± 0.044	-0.555 ± 0.135	333 ± 21	11.5 ± 1.8
0.94-0.95	-0.026 ± 0.001	-0.698 ± 0.050	340 ± 7	12.4 ± 1.8
0.31-0.46	-0.420 ± 0.035	+0.053 ± 0.023	378 ± 10	9.4 ± 0.6
0.47-0.55	-0.281 ± 0.013	-0.117 ± 0.038	401 ± 20	10.0 ± 1.2
0.68-0.84	-0.122 ± 0.011	-0.288 ± 0.049	386 ± 8	10.2 ± 1.0
0.84-0.96	-0.040 ± 0.009	-0.395 ± 0.063	392 ± 6	10.0 ± 1.2

*The notation <x> signifies a mean of all values of x chosen in the particular distance interval.

+The reduced temperature τ is given in K km^{-2} s^{2}.

++The density n is distance normalized to 1 AU.

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the slow solar wind expands nearly isothermally is not supported by the foregoing analysis.

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