ARE SOLAR WIND MEASUREMENTS OF DIFFERENT SPACECRAFT CONSISTENT?

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1. INTRODUCTION

Results of solar wind measurements by different spacecraft are not always in full accord. Such measurements are in general not from one and the same distance r from the sun, nor are they taken at the same phase of the solar activity cycle. One would like to be able to discriminate between spacecraft calibration effects on the one hand, and solar wind variations which reflect true spatial gradients or changing boundary conditions at the sun on the other hand. Accordingly, we examine in this paper the possibility of reconciling the apparent discrepancies.

In the following, we first compare density measurements and relate their differences to the velocities with which they have been sampled. Furtheron we compare proton temperature gradients obtained from Helios 1 and Mariner 2 and suggest that the different results are due to stream-stream interactions in the solar wind. We conclude with a brief summary of the more obvious as well as the subtle effects velocity sampling has on the evaluation of some solar wind parameters and their gradients.

2. COMPARISON OF DENSITIES

Table 1 lists average proton number densities $\langle n \rangle$ from Mariner 2 (Neugebauer and Snyder, 1966), Vela 3 (Bame et al., 1971), Helios 1 (Rosenbauer et al., 1977), Heos (Formisano and Moreno, 1974) and Imp 6, 7,8 (Feldman et al., 1978). Making use of the result that $n \sim r^{-2}$ (Eyni and Steinitz, 1979), the densities given in the table are normalized to 1 AU. Also average velocities $\langle u \rangle$ and average momentum flux densities per unit mass are given. For Mariner 2, Vela 3 and Helios 1 it is immediately apparent that the differences in average densities can simply be attributed to velocity biasing: for Mariner 2 higher densities closer to the sun are accompanied by lower average velocities, an effect which is further enhanced for Vela 3. In full accord with momentum flux density invariance (Eyni and Steinitz, 1979), the last column in the table indicates the high degree of consistency between Mariner 2 and Vela 3, as

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Table 1. Proton Number Densities

	No. of points	Range (AU)	$\langle n \rangle$ (cm^{-3})	$\langle u \rangle$ ($km\ s^{-1}$)	$\langle nu^2 \rangle/10^{16}$ ($cm^{-1}\ s^{-2}$)
Mariner 2	35	0.70-0.83	6.75	461	1.18
	50	0.84-1.00	4.45	529	1.14
Vela 3	122	1.00	7.01	410	1.14
Helios 1	37	0.30-0.50	7.22	492	1.35
	61	0.50-1.00	5.88	514	1.33
Heos	2513	1.00	4.17	410	0.70
Imp 6,7,8	56	1.00	9.13	482	-

well as the internal consistency of the Mariner 2 data. Thus, the momentum flux density enables a meaningful comparison to be made between different density measurements. Similarly, the Helios 1 data show good internal consistency, but a slight difference with Mariner 2 and Vela 3 (a calibration effect?). The Heos results appear to be inconsistent with the other measurements.

The mean velocity from Imp is similar to Helios 1 in the 0.3-0.5 AU range, yet the densities are significantly higher. The data we used for the Helios 1 analysis have velocities well represented in the range 300-720 km/s, but the Imp data are restricted to the range 365-560 km/s. The lower velocity range for Imp may be the result of (a) the fact that the published Imp data are averages over complete solar rotations, and (b) high velocities not persisting over complete rotations. The variance of velocity over a whole solar rotation together with the averaging process will thus result in higher mean densities corresponding to a given mean velocity, than would be obtained without averaging over a large velocity variance. Another effect of this averaging procedure is the weakening of the anticorrelation of density and flow velocity. A least-squares fit to the Imp data (56 points) yields

$$\log n = -1.12 \log u + 3.95 ,$$

which is considerably weaker than the $n \sim u^{-2}$ dependence.

3. COMPARISON OF TEMPERATURE GRADIENTS

In a previous analysis (Eyni and Steinitz, 1978) we demonstrated the presence of proton cooling in the Mariner 2 data for velocities below 500 km/s, but for higher velocities cooling is not evident. However, the Helios 1 data show cooling in all velocity ranges.

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Representing the temperature T for a given velocity as

$$T = T_0 r^{-\alpha} ,$$

we can regard the cooling index α as a measure of the temperature gradient. For $u \sim 600$ km/s, the Mariner 2 data yield $\alpha = 0.15$, while the Helios 1 data yield $\alpha = 0.45$ in the same range (0.7-1.0 AU). We suggest that the weak temperature gradient from Mariner 2, may be due to masking of the true cooling present, by stream-stream interactions. Presumably these interactions have been more effective in Mariner 2 than in Helios 1: in Helios 1 velocities above 550 km/s persisted unintermittently for typically 5-9 days, while in Mariner 2 they persisted only for 2-4 days.

4. CONCLUDING REMARKS

The effect velocity sampling has on the interpretation of solar wind densities and proton temperatures, can be summarized as follows:
(a) simple velocity biasing (i.e. Table 1) can result in erroneous values of densities and may mask the presence of temperature gradients;
(b) averaging over samples with a large velocity variance yields excessive densities and weakens the density-velocity anticorrelation;
(c) the presence of a large velocity variance is also accompanied by real physical effects - in the form of stream-stream interactions and a possible masking of the true temperature gradients by local heating.

We propose that the momentum flux density is a useful quantity for comparison purposes, since its variance is small. The suggestion that temperature gradients are masked by local heating through stream-stream interactions in the ecliptic plane, can be tested by probing the solar wind outside the ecliptic.

REFERENCES

Bame, S.J., Asbridge, J.R., Felthauser, H.E., Gilbert, H.E., Hundhausen, A.J., Smith, D.M., Strong, I.B., and Sydoriak, S.J.: 1971, *A compilation of Vela 3 solar wind observations, 1965 to 1967*. Los Alamos Scientific Report LA-4536.

Eyni, M., and Steinitz, R.: 1978, *J. Geophys. Res.*, 83, 215-216.

Eyni, M., and Steinitz, R.: 1979, this conference.

Feldman, W.C., Asbridge, J.R., Bame, S.J., and Gosling, J.T.: 1978, *J. Geophys. Res.*, 83, 2177-2189.

Formisano, V., and Moreno, G.: 1974, *J. Geophys. Res.*, 79, 5109-5117.

Neugebauer, M., and Snyder, C.W.: 1966, *J. Geophys. Res.*, 71, 4469-4483.

Rosenbauer, H., Schwenn, R., Marsch, E., Meyer, B., Miggenrieder, H., Montgomery, M.D., Mühlhäuser, K.H., Pilipp, W., Voges, W., and Zink, S.M.: 1977, *J. Geophys.*, 42, 561-580.

DISCUSSION

Stix: Couldn't it be that the discrepancy between the Mariner and Vela results on the one side and the Helios results on the other side is due to some deviation from the r^{-2} law which you assumed for your calibration to 1 AU?

Steinitz: As shown in the previous paper (Eyni and Steinitz) the r^{-2} is not an assumption, but a result. Therefore, I doubt that the difference between Helios 1 and Mariner 2 and Vela 3 is due to the r^{-2} dependence.