Remarks on paper by K. G. Ivanov

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In a recent paper (1), it has been suggested that the IMP-I observations of a lunar wake (2) in the solar wind may actually be due to the wake of the Earth. The basis for this interpretation is the well known phenomenon in MHD fluid flow (3) of an upstream disturbance forming which precedes a body under the condition of sub-Alfvénic flow. In the original discussion of the lunar lee wake (2) this possibility was considered (see pg. 528) but rejected as not being plausible in view of the available data on the plasma properties of the solar wind (4-7). Indeed in the early interpretation of the IMP-I magnetic field data in the interplanetary medium (8) it was estimated that the Alfvén Mach number of the solar wind flow at 1 A.U. was in the range 3.3 to 28. This was subsequently refined to the range of 4-20 on the basis of measured solar wind velocities of 300-400 kilometers/sec (7,9) and for densities in the range 1.5 to 35 protons/cm^3. Thus unless conditions in the interplanetary medium were extremely anomalous, the assumption was made that the solar wind flow was super Alfvénic at equivalent Mach numbers greater than 4. This letter presents direct evidence from both the IMP-I magnetic

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field and plasma measurements to substantiate these earlier interpretations of a possible lunar lee wake.

On the IMP-I satellite the interplanetary magnetic field was measured at 20.5 second intervals for a total of 12 observations in each 5.46 minute period (8). A statistical distribution of the magnitude of the interplanetary field during orbit No. 5 has been computed and is shown in Figure 1. It is seen that the median field is approximately 6 gammas with the magnitude in the range 3.5 to 8.5 gammas for 82% of the time. The Alfvén Mach number is defined as

$$M_A = \frac{V_s}{V_A} \quad \text{but} \quad V_A = \frac{B}{\sqrt{4\pi mn}}$$

so

$$M_A = V_s \frac{\sqrt{4\pi mn}}{B}$$

where V_a = Alfvén velocity

V_s = velocity of solar wind (cm/sec)

n = proton density (protons/cm^3)

B = magnetic field intensity (gauss = 10^5 gamma)

m = mass of proton (gms)

For the maximum field of 15 gammas, the plasma density would have to be less than 1.2 protons/cm^3 in order for the solar wind flow to be sub-Alfvénic. This low density was not observed on IMP-I during orbit No. 5 (10).

In order to provide a more quantitative basis for the argument of super Alfvénic flow, a direct computation of the average Alfvén Mach number has been made. By combining the direct measurements of solar wind (i.e., velocity and density) with the magnetic field (i.e., magnitude), the value M_A has been computed at 3 hour intervals during orbit No. 5 and is displayed in Figure 2. It is seen that M_A is never less than 4 and has an average value of approximately 8. The super Alfvénic flow precludes the possibility of any disturbances propagating upstream from the geomagnetosphere. Thus these results support the original interpretation of the interplanetary event as the wake of the moon in the flow of the solar wind.

Additional opportunities for observation of the lunar wake by IMP-I in January and February 1964 have been discussed previously (2). The correlation of terrestrial data with satellite data is a difficult task since the physical models are not always readily evident. Elementary computations of the propagation times between fluctuations observed on the Earth and in space require more than simply the phase velocities, as used in (1). Also the frequent occurrence of fluctuations, both on Earth and in space, leads to a number of apparent correlations which are only circumstantial. Thus the non-negative results of correlative studies as conducted in (1) can not be expected apriori to provide a consistency argument for the hypothesis of an upstream wake of the Earth.

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In this case, comprehensive measurements of the downstream portion of the geomagnetosphere have revealed the formation of an extended magnetic tail (11).

Acknowledgements

I am pleased to acknowledge the contributions of my colleague Dr. John M. Wilcox in reporting this work. I appreciate the opportunity to employ the MIT plasma data in advance of its publication.

References

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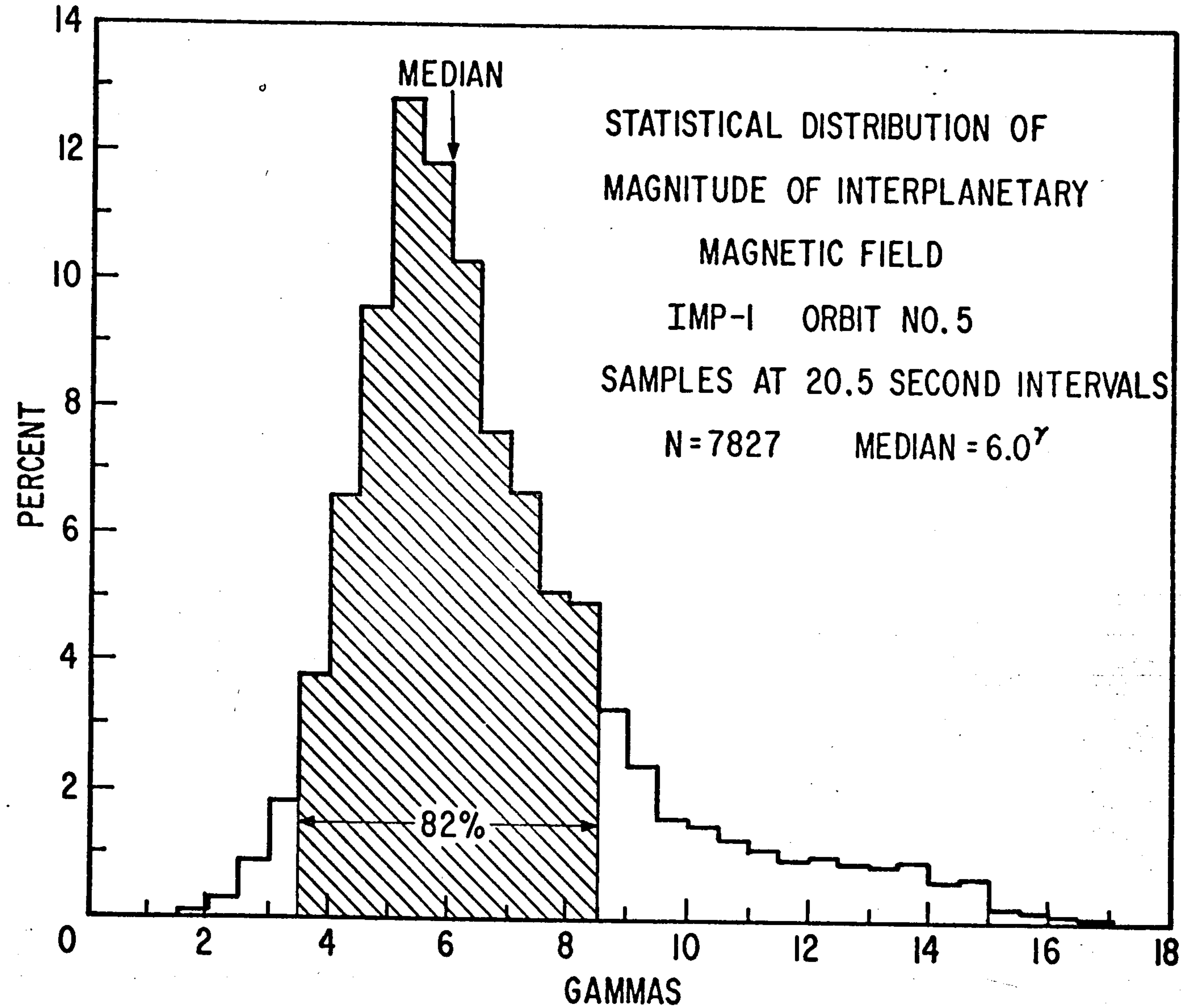
List of Figures

1. Statistical distribution of the interplanetary magnetic field magnitude measured by IMP-I on orbit No. 5 in mid-December, 1963. A total of 7289 data points obtained at 20.5 second intervals are used in this study.

2. Alfvén Mach Number, measured by ratio of observed solar wind velocity to computed Alfvén velocity, for orbit No. 5 of IMP-I. Three hour averages of the density and velocity of the solar wind and magnitude of the interplanetary field have been used to compute these values.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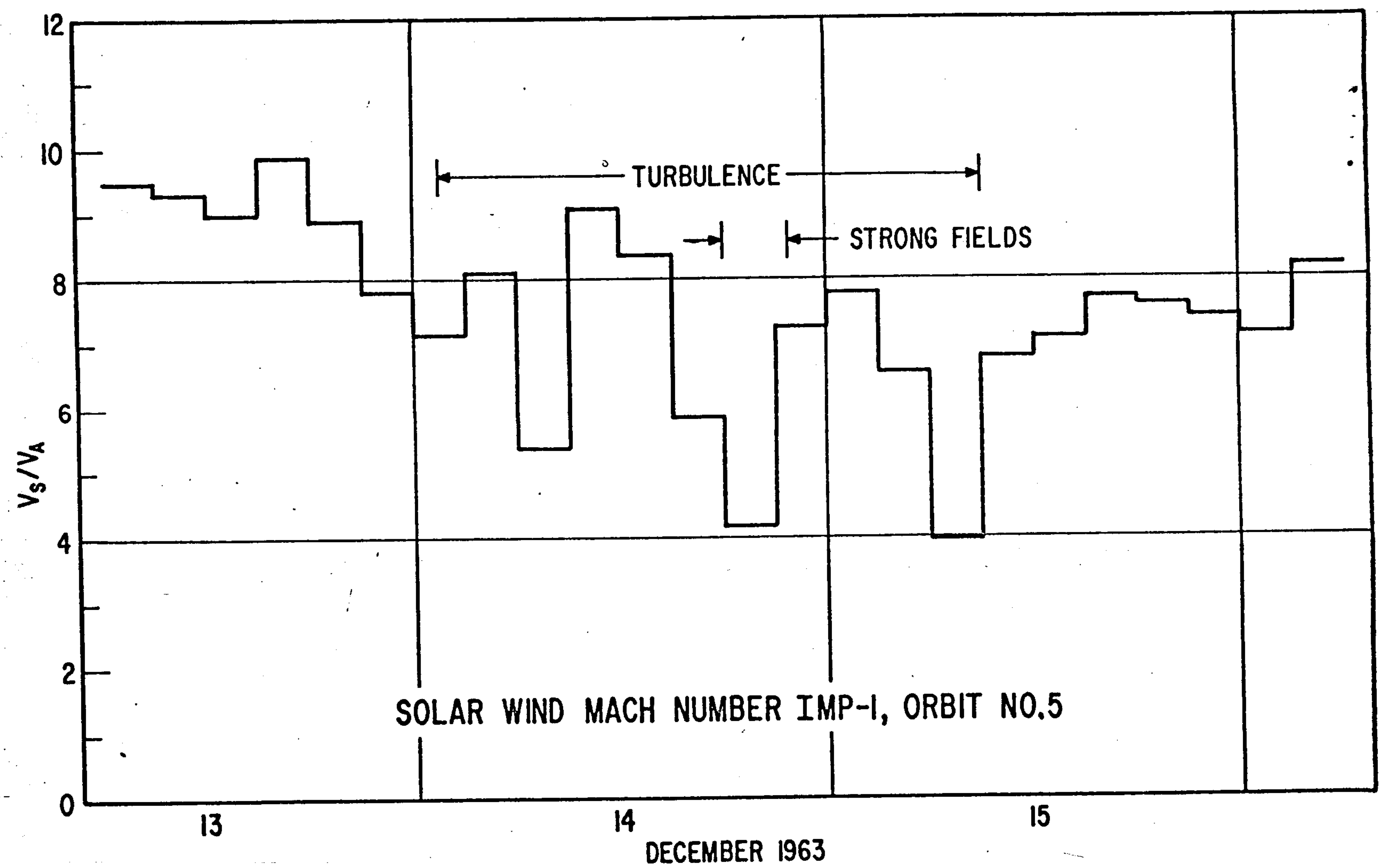
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