STATISTICAL PROPERTIES OF MHD FLUCTUATIONS ASSOCIATED WITH HIGH-SPEED STREAMS FROM HELIOS-2 OBSERVATIONS

B. BAVASSANO, M. DOBROWOLNY, G. FANFONI*, F. MARIANI* and N. F. NESS**

Istituto Plasma Spazio, CNR, Frascati, Italy

Abstract. A variance analysis of Helios-2 magnetic data has been used to derive several statistical properties of MHD fluctuations associated with the trailing edge of a given stream observed in different solar rotations. Such properties are derived both as a function of distance from the Sun and as a function of the frequency range included in the sample. The most noticeable result is that the radial gradients of various parameters, such as anisotropy and normalized power of the fluctuations, depend from frequency range. In particular the variation with distance of the normalized power does not correspond, for periods \( \lesssim \) 1 hr, to what is expected from WKB propagation effects.

1. Introduction

Investigations of MHD fluctuations in the solar wind started with the early work of Coleman (1966, 1967) and Unti and Neugebauer (1968). Since then, the work of Belcher and Davis (1971), followed by numerous others (Burlaga and Turner, 1976; Denskat and Burlaga, 1977; Bavassano et al., 1978), pointed out that fluctuations of Alfvénic type are mostly found in association with the trailing edges of high-speed streams. These observations have in turn stimulated much theoretical work on the waves, their propagation in the nonhomogeneous and expanding solar wind and their possible role in heating solar wind ions (for reviews of these works see Hollweg, 1978; and Barnes, 1979).

The fluctuations exhibit a power spectrum extending over many frequency decades (Coleman, 1968) so that it is natural to describe the medium as a turbulent medium rather than trying to compare the data with the picture of single Alfvén waves. A recent critical analysis of the observations in terms of the equations of incompressible MHD turbulence (Dobrowolny et al., 1980a) has shown that the presently known statistical properties of Alfvénic fluctuations can be naturally accounted for in such a framework. It indeed appears that the trailing edges of high speed streams (because of the high degree of incompressibility of the observed fluctuations) can be ideal regions for studying fundamental properties of fully developed incompressible MHD turbulence, a subject which, because of the difficulty of laboratory experiments, is not as developed as that of hydrodynamic turbulence. Some indications drawn from present solar wind observations, as to the nonlinear state of MHD turbulence, have in fact stimulated recent theoretical developments on the subject (Dobrowolny et al., 1980b; Mangeney et al., 1982).

* Istituto di Fisica, Università di Roma, Rome, Italy.
** Laboratory for Extraterrestrial Physics, NASA Goddard Space Flight Center, Greenbelt, Md 20771, U.S.A.
It is from the above point of view that we found it important to take up again a systematic investigation of statistical properties of incompressible fluctuations (eigenvalues and eigenvectors of the variance matrix, variances of various fluctuating components) associated with the trailing edges of the high-speed streams.

What we propose to discuss, using Helios-2 observations, are variations of statistical properties of the fluctuations with frequency (at a given distance from the Sun) and with distance (in a given frequency range).

Variations with frequency are already contained in the work of Belcher and Davis (1971), who used different time intervals as their statistical basis. However, both in this work and in the others quoted previously, the statistical sample used embraces in general regions of the solar wind with different characteristics and which are therefore likely not to be homogeneous in their fluctuation content.

On the contrary, in the present work, our data refer to the trailing edge of a given stream taken at different distances from the Sun. Therefore our statistical sample is quite homogeneous, in comparison with those of other works, as we are focusing actually on the same turbulent region convected in time at different distances from the Sun. Variations of properties of Alfvénic turbulence with distance, for the range of heliocentric distances covered by the Helios spacecraft, have been considered by Denskat et al. (1981) and Denskat and Neubauer (1982). The most recent of these works concentrates on features of the wave power spectrum, pointing out some quite interesting results. These works, again, embrace large periods of observations and do not follow our idea of having a sample as homogeneous as possible.

The statistical properties we will be discussing in this paper are: ratios of eigenvalues, denoting anisotropy of the fluctuations; minimum variance direction, total power and compressibility of the fluctuations.

2. Magnetic Field Data Analysis

For our study on interplanetary magnetic field fluctuations we have used the magnetic data of Helios-2. This spacecraft, launched on 15 January, 1976, has been injected in a solar orbit having an aphelion of 0.98 AU and a perihelion of 0.29 AU, with an orbital period of about six months. A description of the instrumentation and data reduction is given by Searce et al. (1975), Bavassano (1976), Villante and Mariani (1977).

During the primary mission of Helios-2 (January to April, 1976) we have selected, by inspection of hourly averages of the solar wind data of the Max-Planck plasma experiment on Helios-2 as distributed to Helios investigators (see also Schwenn et al., 1977), a high-velocity stream which is observed by the spacecraft during three successive solar rotations at different distances from the Sun. The three periods of the stream observation begin on days 48, (17 February), 74 (14 March), and 103 (12 April) of 1976, at heliocentric distances of about 0.89, 0.68, and 0.31 AU, respectively. Figure 1 gives the ecliptic projection of the spacecraft trajectory from day 20 to day 120, 1976. The solar wind velocity profile is only slightly changing between the first two periods considered, whereas more pronounced differences are present for the third period.