SPECTRA AND CROSS SPECTRA OF SOLAR WIND PARAMETERS FROM MARINER 5

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ABSTRACT The spectra of the radial (V_R) and nonradial (V_T, V_N) velocity components of the solar wind, the proton density (ρ) and the proton thermal speed (W), show increasing power with increasing period up to a period of about 1 day. The powers tend to level off above 1 day except for that of V_R, which continues to increase up to a period of 10 days. At all periods, the power in V_R is greater than that in V_T V_N, and W, and the difference becomes very large at the longest periods because of the increasing power in V_R. The powers in V_T V_N, and W are similar at all periods.

The cross spectra reveal a sharp change in behavior at periods above and below approximately 1 day, suggesting that two distinct types of physical processes must dominate above and below this dividing period. In general, the coherences at the long periods are larger than at the short periods suggesting that the physical situation in the long period regime may be simpler than in the short period regime where multiple processes appear to be required to account for the low coherences. At periods less than 1 day, the cross spectra are consistent with the presence of intermediate hydromagnetic waves propagating outward in the frame of reference of the wind and with nonpropagating constant pressure fluctuations. However, one or more other processes are required to account for all the observed correlations. At periods greater than 1 day, the models of corotating structure and the spherically symmetric two-fluid model jointly appear capable of accounting for most of the correlations.

INTRODUCTION

The Mariner and Pioneer series of space probes have allowed measurements of solar wind parameters over long time intervals. These measurements occur in deep space away from the influence of the earth's magnetosphere or the lunar wake. The data are therefore well suited for long-time, statistical studies of the interplanetary environment.

From the Mariner series, spectra of the magnitude and components of the magnetic field and of the solar wind speed have been presented for the period range 74 sec to 2 hr [*Coleman*, 1967] and for the period range 74 sec to 27 days [*Coleman*, 1968]. Spectra of the field magnitude and components from Mariner 4 have been given for the period range 3 sec to 1.4 hr [*Siscoe et al.*, 1968] and for the range 100 sec to 27 days [*Coleman et al.*, 1969]. In general, the Pioneer probe tracking coverage was poorer than on the Mariner missions and long-time analysis is therefore more difficult. Spectra of the field magnitude and components from Pioneer 6 for the period range 1 min to 1 hr have been given [*Ness et al.*, 1966; *Sari and Ness*, 1969, 1971]. Power spectra of the solar wind density in the period range 10^3 to 10^4 sec have also been presented [*Intriligator and Wolfe*, 1970].

The spectra all show increasing power with increasing period up to a period of approximately 1 day. On a log power versus log period plot in the less-than-one-day range, the curves approximate straight lines with slopes

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in the range 1 to 2. The exact slope depends on which variable is considered and also to a lesser extent on the solar wind conditions at the time of observations. The magnitude of the power at a given period is much more sensitive to solar wind conditions (weather) than is the slope. Those spectra extending to periods greater than 1 day, which include the magnetic field magnitude and components and the solar wind speed, show a tendency for the power to level off with increasing periods and in some cases to decrease beyond a period of approximately 10 days.

There have been fewer presentations of cross spectra of interplanetary parameters. *Coleman* [1967] has given the coherence and phase of the cross spectra between the solar wind speed and the radial component of the magnetic field in the period range approximately 12 min to 2 hr from Mariner 2 data. This same information has been given from Mariner 4 data in the period range 10 min to 4.2 hr [*Belcher and Davis,* 1971]. The results from both spacecraft show significant coherences and nearly constant phases over most of the displayed period ranges. The cross spectrum between the radial and transverse solar wind velocity components from Pioneer 6 data in the period range 10 hr to 4 days has been presented [*Siscoe et al.,* 1969*b*]. High coherences, especially at the long period end, and constant phases also were found.

Spectral and cross spectral information are useful both for concisely displaying important statistical properties of solar wind parameters and for trying to understand the physical nature of their fluctuations. Efforts to interpret solar wind fluctuations with the help of spectral information include descriptions in terms of turbulence [*Coleman,* 1968], of hydromagnetic waves [*Coleman,* 1967; *Belcher and Davis,* 1971], of discontinuities [*Sari and Ness,* 1969, 1971], and of fast stream-slow stream interactions [*Siscoe et al.,* 1969*b*]. From the variety of interpretations it seems likely that different physical processes may dominate at different times and in different frequency regimes. We might expect the situation to be clarified by incorporating more variables and by greater use of cross spectral-analysis.

A correct physical description of solar wind fluctuations is needed for application to related fields. Assumptions about their nature have already been made to estimate the angular momentum flux of the solar wind [*Schubert and Coleman,* 1968], to interpret the interplanetary scintillation of radio sources [*Dennsion and Hewish,* 1967; *Cohen et al.,* 1967; *Hewish and Symonds,* 1969; *Jokipii and Hollweg,* 1970], and to determine cosmic ray diffusion coefficients [see recent review by *Jokipii,* 1971]. The level of geomagnetic activity as measured by the K_p index is known to be well correlated to fluctuations in the period range 1 min to 3 hr of the interplanetary magnetic field [*Ballif et al.,* 1967, 1969], and to larger scale features recognized as the solar wind sector structure [*Wilcox and Ness,* 1965]. Even prior to direct solar wind measurements, geomagnetic activity was believed due to time variations of the solar corpuscular radiation [*Bartels,* 1957; *Chapman and Bartels,* 1962; and *Chapman,* 1963].

This paper extends the statistical analyses of interplanetary parameters by giving spectra of plasma parameters and cross spectra between plasma and field parameters from Mariner 5 data over a large period interval (10 min to approximately 10 days.). We concentrate primarily on the plasma parameters since the magnetic field has been well treated. However, cross spectra with the magnetic field are also needed for a complete analysis.

RESULTS FROM MARINER 5

Mariner 5 collected solar wind data from June 14, 1967, to November 21, 1967. The data telemetry changed from a "high" to "low" rate 40 days into the mission. Solar wind plasma parameters were obtained with a modulated grid Faraday map of the type described by *Lazarus et al.* [1967]. The data are being reduced to provide the solar wind velocity vector and the proton density and temperature. At the present stage of analysis the temperature is calculated assuming an isotropic, Maxwellian distribution; thus, it is only a rough measure of the thermal condition of the protons. A complete set of plasma parameters is determined every 5.04 min at the high data rate and 20.16 min at the low rate. The vector magnetic field was measured with a helium magnetometer [*Connor,* 1968] at a high data rate of three vector measurements every 12.6 sec and every 50.4 sec at the low rate. In the following analysis the magnetic field data were averaged over the plasma sampling interval to provide commensurate data sets.

The magnetic and velocity vector components are given in coordinates (R, T, N) based on a spherical, polar coordinate system (r, θ, φ) with the solar rotation axis the polar axis such that $V_R = V_r$, $V_T = V_\varphi$, and $V_N = -V_\theta$.

The data record covers a 140-day interval, the first 40 days at the high data rate and the remainder at the low rate. Throughout the interval there was an approximately 80 percent data coverage. The missing data occurred mostly in small intervals except near the end of the mission when there were large gaps. Two methods were used for estimating the error in the power spectra. First, a white noise (random) spectrum was sampled with a data rate and gap sequence to duplicate that of

Mariner 5. A spectrum of this record should be constant over the period range 10 min to 40 min and then jump at 40 min to a constant value, four times the old one, and remain constant for all longer periods. The jump at 40 min is due to the change in sampling rate (a factor of 4 after 40 days) and is an example of the effect of aliasing. The spectrum of the random signal is given in figure 1 and shows the features just mentioned. The spectrum is reasonably flat between 10 and 40 min and between 40 min and 10 days with a jump of about a factor of 4 at 40 min. The rise above 10 days is apparently due to data gaps, since a spectrum obtained with the same sampling sequence but with no data gaps shows no rise. Thus, although the spectra and cross

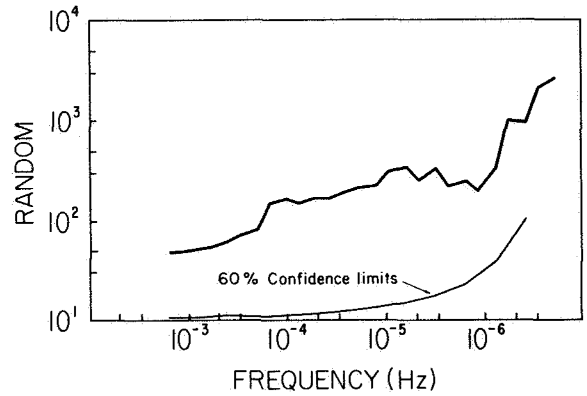

Figure 1. *The power spectrum of a white noise signal with a sampling and gap sequence duplicating that of Mariner 5. The jump at a period of 40 min corresponds to the change in data sampling rate 40 days into the mission and is an example of the effect of aliasing. The increase in power above a period of 10 days is due to data gaps. Also shown for comparison on following spectra are the 60 percent confidence limits.*

spectra go up to a period of about 80 days, accurate results are claimed only for the interval 10 min to 10 days. It should be noted that all the spectra near 40 min are sufficiently steep that the effect of aliasing, evident for a flat spectrum, is not very important.

The second method estimates the confidence limits assuming an equivalent number of degrees of freedom equal to 2N/m, where N is the number of points in the data record and m is the number of points in the period interval [*Blackman and Tukey,* 1959]. In this estimate $n = 9$, but N varies from 10^4 to 40 as the data are progressively averaged over larger nonoverlapping intervalues to obtain the spectrum over a large period interval. The use of different values of N leads to the 60 percent confidence limit, which is analogous to one standard deviation, shown as the bottom line in figure 1. It increases from 0.02 decade at 10 min to 1 decade at 28 days. It is 0.13 decade at 10 days. This curve can be viewed as the ± error limits on the subsequent spectra.

The estimate of errors in the cross spectra is more difficult, and we have relied primarily on the behavior of the phase as an indication of significance. If the phase is nonrandom from one estimate to the next over a sizable period range, it may be assumed that a real correlation is being observed. The same criterion may be applied to the coherence. It will be seen that persistent phases and coherences do exist in many of the cross spectra.

Figure 2 shows the spectra of the three solar wind velocity components. They exhibit the usual increase with period in the range 1 to 2 at periods less than 1 day. At greater periods the powers tend to level off,

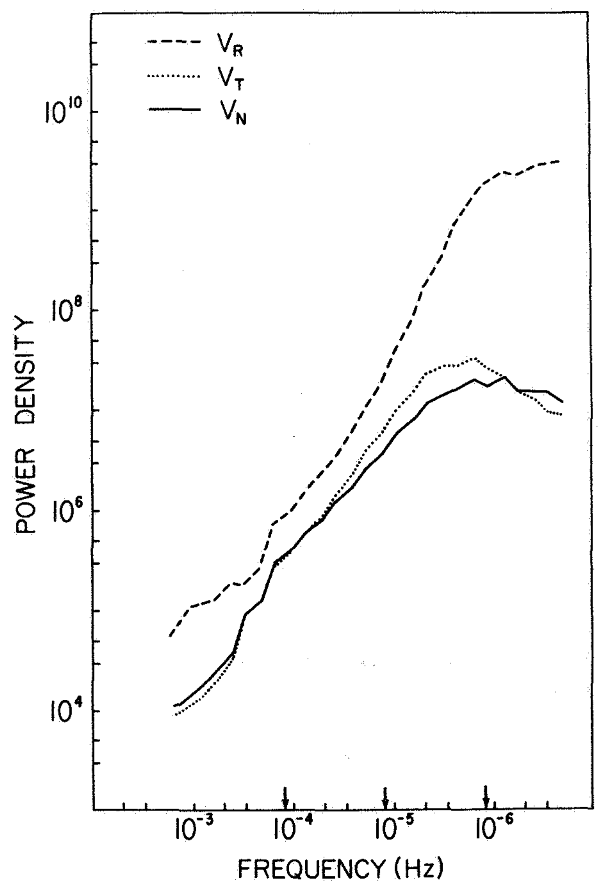

Figure 2. *Spectra of solar wind velocity components, V_R, V_T, and V_N. The arrows on the horizontal axis locate the periods of 0.1 day, 1 day, and 10 days. The units for the spectral density are (km/sec)^2/Hz.*

much sooner in the case of the nonradial components, resulting in considerably higher power in V_R at the long periods. At periods less than 1 day, the powers in the two nonradial components are seen to be approximately equal and to be less than the power in V_R by approximately a factor of 2. This is opposite to the behavior of the magnetic field components, for which all previous studies have shown the power in B_R to be less than in the two non-radial components by approximately a factor of 2 for periods less than 1 day.

As complimentary information to the spectra, it is useful also to give the averages and standard deviations over the entire data interval of each variable. These are

Variable	Average	Standard Deviation
V_R	426 km/sec	87.9 km/sec
V_T	7 km/sec	17.9 km/sec
V_N	–2.6 km/sec	14.8 km/sec

Figure 3 compares the spectra of the three solar wind parameters V_R, the proton thermal speed W, and proton density ρ. The spectrum of W is very similar in shape and amplitude to those of the nonradial velocity components given in figure 2. All three spectra have a similar shape except that the slope of the density is steeper at short periods. All the velocity spectra, including the thermal speed, have slopes near 1 at short periods and steeper slopes at longer periods up to the turnover near 1 day. The density slope at periods less than 1 day is nearly constant at approximately 1.3. The values for V_R and ρ can be compared with results from other spacecraft, referenced earlier, and are found to be consistent.

The averages and standard deviations of the density and thermal speed are:

Variable	Average	Standard Deviation
ρ	9.2 cm^{-3}	5.6 cm^{-3}
W	44.8 km/sec	13.5 km/sec

It should be noted that the difference in the absolute values of the specta of V_R and ρ is due to different units and not different levels of fluctuations. In fact, there is relatively more fluctuation in ρ than in V_R as indicated by comparing averages and standard deviations.

The tendency of the power spectra to change slope near a period of 1 day suggests that there may be interesting differences in the physical processes dominating above and below that period. This suggestion is dramatically confirmed by the cross spectral results. Figure 4 is the cross spectrum between radial speed and density, which shows a sudden change in both the coherence and phase beginning at a period near 8 hr. The change in the phase is very sudden, but the coherence increases from less than 0.1 to greater than 0.8 in the

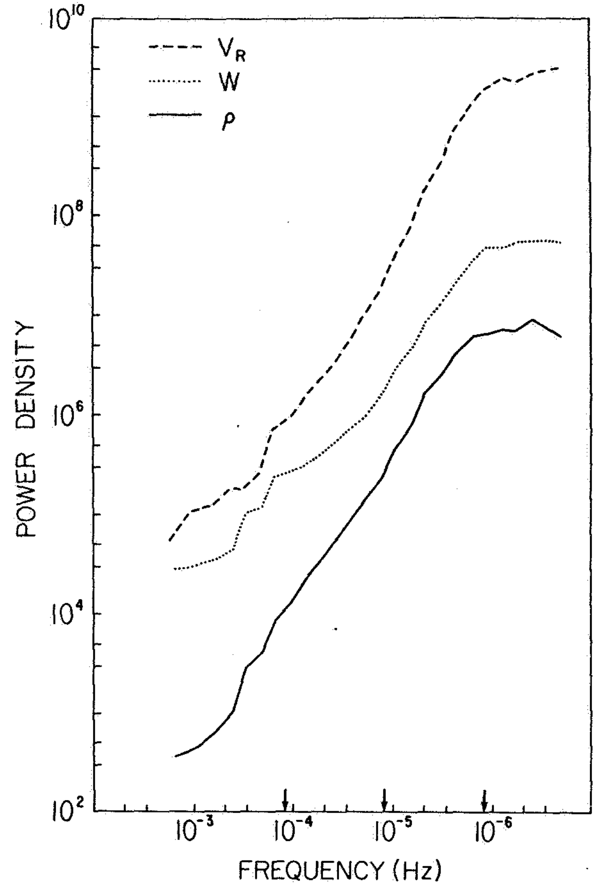

Figure 3. *Spectra of V_R, proton thermal speed W, and proton density ρ. Units for V_R and W same as in figure 1 and for ρ, $(cm^{-3})^2/Hz$.*

range 8 hr to 10 days. Although the coherence at periods less than 8 hr is very small, the tendency of the phase to cluster near 0° indicates the presence of a definite but weak mechanism correlating V_R and ρ. The change from near 0° to near –150° phase strikingly signals the presence of different mechanisms above and below the 1-day period.

Figures 5 and 6 give the cross spectra between V_R and the proton thermal speed and between V_R and V_T. The coherence of the former again exhibits a large contrast between the values above and below approximately 1 day. However, the coherence between V_R and V_T becomes large at 0.1 day. In both cases the phases do not change across most of the period range. Over the whole range, V_R is in phase with W and out of phase with V_T up to a period of about 6 days, when it suddenly becomes in phase. If there are different mechanisms correlating these parameters above and below 1 day, they do so with the same phase up to 6 days. Alternatively, it may be a single mechanism that

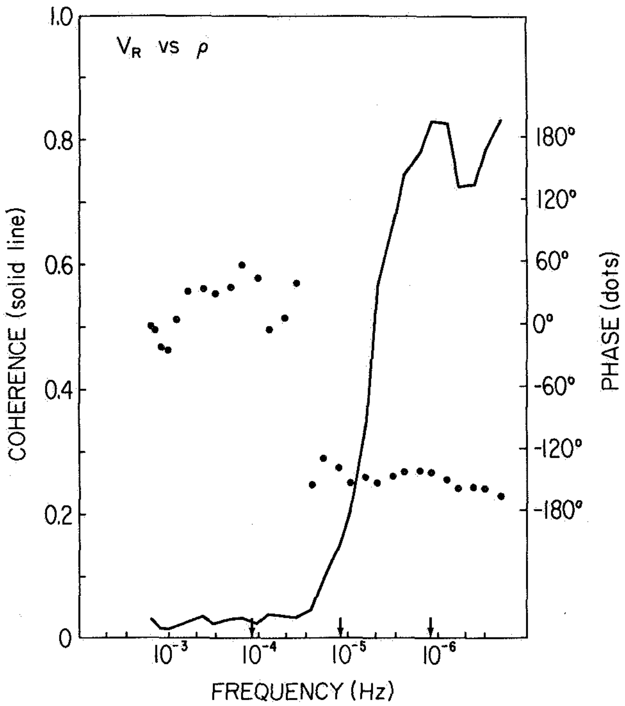

Figure 4. *Cross spectrum between V_R and ρ. A positive phase angle means the first of the two variables listed leads the second.*

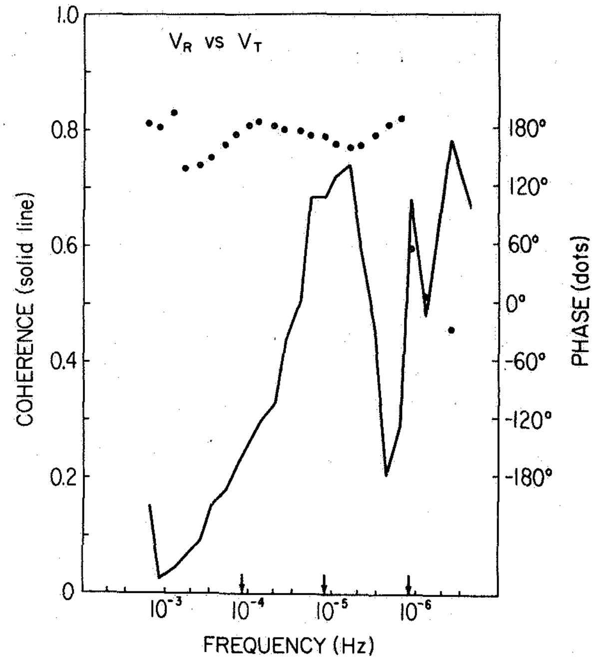

Figure 6. *Cross spectrum between V_R and V_T. A positive phase angle means the first of the two variables listed leads the second.*

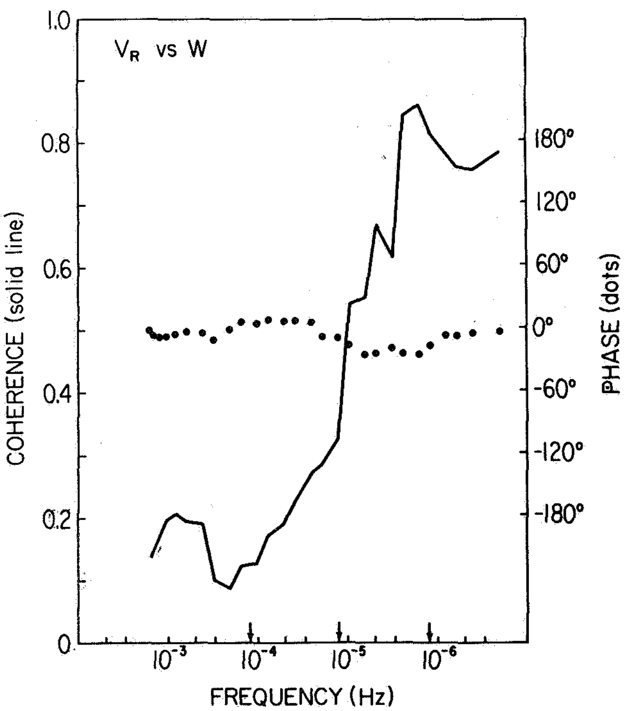

Figure 5. *Cross spectrum between V_R and W. A positive phase angle means the first of the two variables listed leads the second.*

dominates at the longer periods but is a less dominant process at the shorter periods where other processes that do not correlate these parameters may dominate. The cross spectra between V_R and V_N and between V_T and V_N, not shown here, do not reveal any large coherence in any particular period band, although a nearly constant phase over a broad period band, especially for the $V_R - V_N$ case, suggests that the low level of coherence is related to a definite process.

The last example involving purely plasma parameters (fig. 7) is a cross spectrum between V_R and the combination ρW^2, the proton thermal pressure. The distinct short and long period regimes in this case are marked by a change from low to high coherence and from nearly random phase to a fairly definite phase of -90° at the long periods. Since W is the least well-determined quantity, small changes in it may not be very significant. The power spectra show that there is relatively little variation at short periods. Hence, the lack of coherence and the random phase at short periods shown in figure 7 may not be accurate. However, we believe the results at long periods, which involve large changes in W, are accurate.

Figures 8 through 11 involve correlations between plasma and magnetic field variables. Figures 8 and 9 correlate the R and N components of the magnetic and

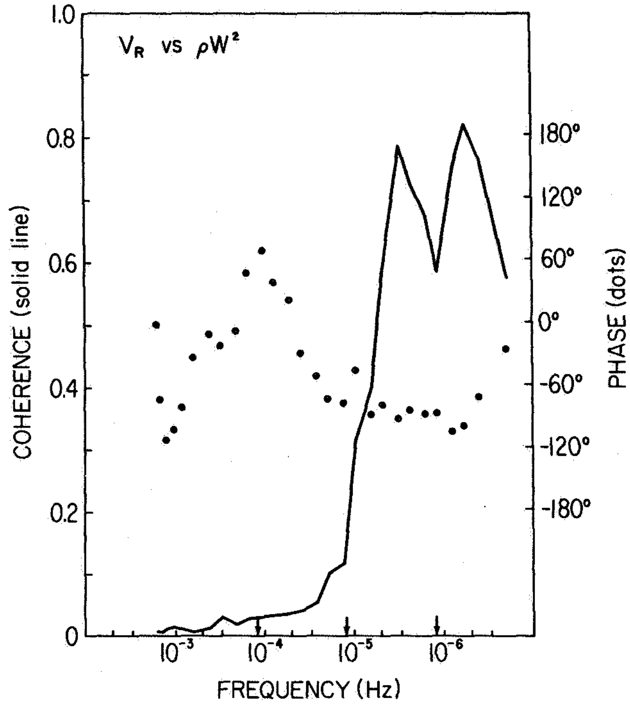

Figure 7. *Cross spectrum between V_R and ρW^2. A positive phase angle means the first of the two variables listed leads the second.*

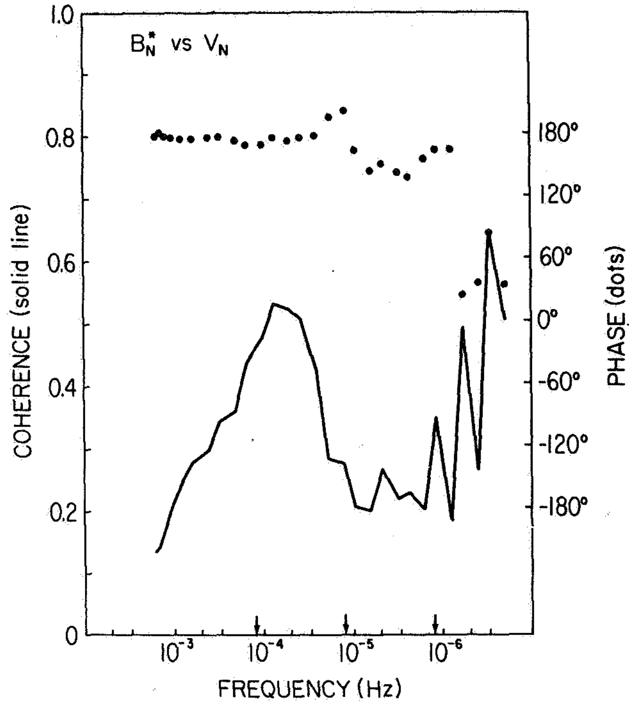

Figure 9. *Cross spectrum between B_N^* and V_N. A positive phase angle means the first of the two variables listed leads the second.*

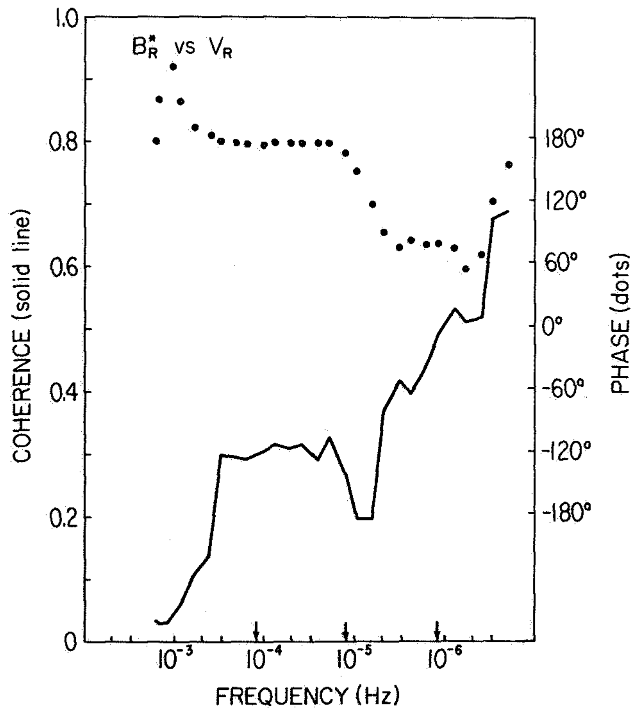

Figure 8. *Cross spectrum between B_R^* and V_R. A positive phase angle means the first of the two variables listed leads the second.*

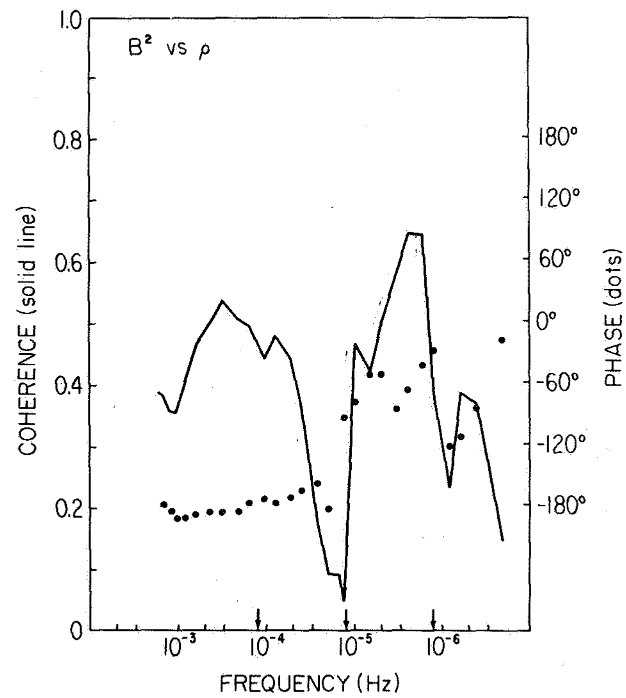

Figure 10. *Cross spectrum between B^2 and ρ. A positive phase angle means the first of the two variables listed leads the second.*

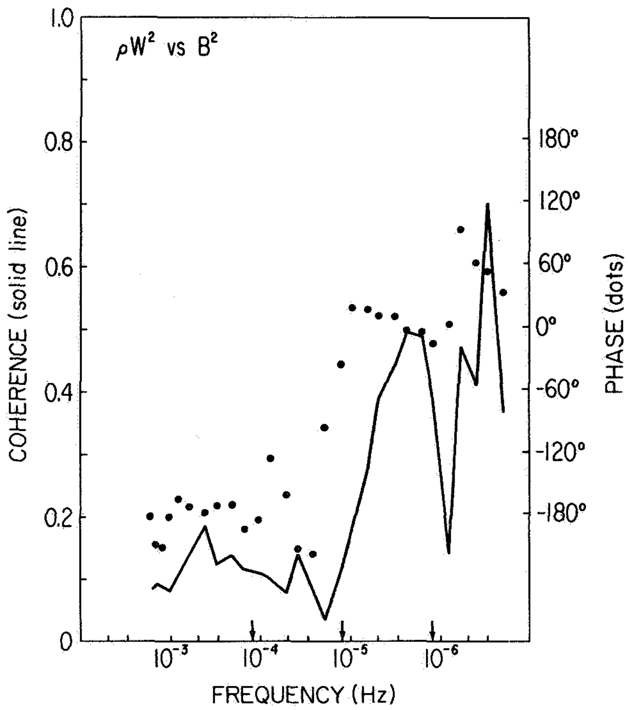

Figure 11. *Cross spectrum between ρW^2 and B^2. A positive phase angle means the first of the two variables listed leads the second.*

velocity fields. Variations due to changes in the polarity of the large scale magnetic field (sector structure) were removed by projecting each magnetic vector in the data set onto the spiral direction based on the simultaneously measured solar wind speed, and reversing the vector if the projection was negative. The result produces the effect of an always outward directed polarity. The operation is signified by an asterisk over the field components. Both figures show moderately large coherences in the short period regime and persistent phases near 180°. The long period regime is different in the two cases with high coherence and a change to near +90° in the R component and low coherence with little phase change in the N component. The changeover in the R component again occurs at a period near 1 day.

Figure 10 is a cross spectrum between B^2 and ρ. Again, these independently measured quantities show a dip in coherence and a change in phase at a period near one day. An important feature of this cross spectrum to note for later discussion is the high coherence of short periods and definite 180° phase.

Figure 11 is a cross spectrum between the proton thermal pressure and the magnetic field pressure. Again, the division near 1 day is evident, separating low coherences but a definite phase near 180° at short periods and higher coherences with a definite phase near 0° at the long periods. We note here again that the short period results may be inaccurate because of the uncertainty in W at short periods.

CONCLUSIONS

A major result of the present analysis, most clearly revealed in the cross spectra, is the demonstration of two distinctive regimes, divided approximately at a period of 1 day, within the period band studies, 10 min to 10 days. The division is indicated by dramatic changes in both the coherences and phases at the dividing period. As a general rule, the coherences at the long periods tend to be the largest. This may reflect the existence of more competing processes at the short periods. Values of 0.8 occur in many of the cross spectra in the band above 1 day, suggesting that a single, very dominant process may be operating there. That the solar wind behavior might be essentially different in different period ranges was recognized by *Burlaga and Ness* [1968] who suggested division of phenomena into microstructure ($\lesssim$1 hr), mesostructure (1 hr to 10^2 hr), and macrostructure ($>10^2$ hr), although the single division suggested by the cross spectra is somewhat different. We attempt in this section to relate the cross-spectral results to specific physical mechanisms. There has been considerable discussion in the literature of solar wind processes, so the main task is to identify which of these may be operating in which period regime.

The Short Period Regimes

Consider first periods less than 1 day. Previous waveform analysis of the Mariner 5 plasma and field data [*Belcher et al.*, 1969; *Belcher and Davis*, 1971] have confirmed the presence of intermediate hydromagnetic waves. They find that for periods of less than several hours, the intermediate waves dominate in the variations of the velocity and magnetic field at least 50 percent of the time. Since intermediate waves do not modulate the density or temperature, this is consistent with the low coherences at short periods between V_R and ρ (fig. 4), V_R and W (fig. 5), and V_R and ρW^2 (fig. 7). It is also consistent with the moderate coherences at short periods between B_R^* and V_R (fig. 8) and B_N^* and V_N (fig. 9). The phase in the last two figures, 180° in both cases, is consistent with outward propagating waves in the frame of reference moving with the solar wind [*Belcher et al.*, 1969]. This is also the situation found in the previous studies. Thus, the assumption of outward propagating intermediate waves dominating about 50 percent of the time explains the short period coherences and phases involving the velocity and magnetic field components.

It was noted by *Belcher and Davis* [1971] and emphasized by *Burlaga and Ness* [1968] that many of the fluctuations occurring at less than 1 day periods cannot be intermediate waves since they involve changes in density, temperature, or magnetic pressure. A study by *Burlaga et al.* [1969] of fluctuations involving pressure changes in the period range 1 min to 1 hr shows that they tend to conserve the total pressure, which is the sum of the thermal and magnetic pressures. Such constant pressure variations will not propagate but will be statically convected by the wind. Thus, there will be no associated modulation of the velocity. This is the hydromagnetic extension of the constant pressure, non-propagating entropy fluctuations in ordinary hydrodynamics, in which the density and temperature vary out of phase in such a way as to keep the total pressure constant. The present cross spectral results at short periods are consistent with the presence of this type of variation. The low coherence between V_R and ρ and V_R and W have already been noted. Further support is given by the short-period, high coherence, anticorrelation between B^2 and ρ shown in figure 10. The anticorrelation implies either static pressure variations or slow mode hydromagnetic waves. If the latter are responsible, then the small coherence between V_r and ρ implies essentially equal amounts of outward and inward propagating waves, in contrast to primarily outward propagating intermediate mode waves. The present analysis cannot select between the two possibilities, but the predicted strong damping of slow mode waves [*Barnes*, 1968, 1969] favors the first possibility.

In summary, for periods of less than 1 day, many of the cross spectral results can be understood in terms of two mechanisms: outward propagating, intermediate mode hydromagnetic waves and nonpropagating, constant pressure variations. Although the results do not uniquely select these mechanisms, they are the ones that are not strongly damped.

The Long Period Regimes

The generally larger coherences in the long period regimes suggest a simpler interpretation than for the short period situation. First, note, that for all the solar wind variables most of the power in fluctuations occurs at the long periods. Hence, the correlative studies of solar wind parameters previously reported should show the same general correlations as are exhibited in the long period regime of the present cross spectral results. These general correlations, summarized recently by *Hundhausen et al.* [1970], show that: V_R and ρ tend to be anticorrelated [*Neugebauer and Snyder,* 1966]; V_R tends to be anticorrelated with V_T [*Siscoe et al.*, 1969*b*]; and V_R and W tend to be positively correlated [*Neugebauer and Snyder,* 1966; *Strong et al.*, 1966; *Hundhausen et al.*, 1967; *Coon,* 1968; *Burlaga and Ogilvie,* 1970]. Each instance is seen to agree with the long period regime phases given in figures 4, 5 and 6: namely, $V_r - \rho$, -160°; $V_r - V_T$, 180°; and $V_R - W$, 0°.

Theoretical explanations for some of the general correlations have appeared, and they should also apply to the cross spectral features in the long period regime. The explanations thus far put forth have been based on two different assumptions, corotating inhomogeneities and quasistatic changes in spherically symmetric models. In the first, variations in solar wind parameters are assumed to be associated with long-lived coronal inhomogeneities, and they will therefore be time stationary in a frame of reference corotating with the sun. The second assumes that observed variations are due to different boundary conditions to a spherically symmetric expansion. Both assumptions require that any intrinsic time changes be on a time scale long compared to a "flow time" or approximately the transit time between the sun and earth (4 to 5 days). The two approaches should give similar results in the longest period range. However, the assumption of corotating structure can be used at periods shorter than 4 to 5 days since any change in the symmetric model must be an intrinsic time change and this is not true for the corotation model. Where the spherically symmetric model is valid, it should yield better results since it is physically more sophisticated.

The existing corotation models sacrifice physical sophistication to include the complication of an extra spatial variable. They have been used primarily to describe the interaction of adjacent, long-lived fast and slow streams—so-called "stream-stream interactions." These interactions appear capable of accounting for the $V_R - V_T$ and $V_R - \rho W^2$ phases. In these models, the first arises out of nonradial deflections of the streams as they interact along their spiral interface and the second from a pressure compression at the interface in a preceding-slow-stream interaction and a pressure rarefaction at the interface of a preceding-fast-stream interaction [*Siscoe et al.*, 1969*a*, *b*; *Carovillano and Siscoe,* 1969; *Siscoe and Finley,* 1970]. The 180° phase between V_R and V_T can be restated in more familiar terms: fast streams tend to come from the west and slow streams from the east. The -90° phase between V_R and ρW^2 means that the thermal pressure tends to maximize on the rising slopes and to minimize on the falling slopes of the velocity variations.

The stream-stream interaction model does not explain the $V_R - \rho$, $V_R - W$, or $\rho - W$ phases. These reflect the coronal boundary conditions for the flow, and for these the spherically symmetric models may be more appropriate, although *Burlaga et al.* [1971] believe that the $\rho - W$ phase may also be primarily the result of the stream-stream interaction. The lastest attempt to explain the $V_R - W$ phase (0°) is by *Hartle and Barnes* [1970]. They find that with a two-fluid model, agreement with the more explicit, empirical $V_R - W$ relationship of *Burlaga and Ogilvie* [1970] can be obtained if nonthermal heating of the solar wind occurs over an extended range of 2 to 25 $R_\odot$ heliocentric distance.

In summary, it appears that most of the cross spectral phases in the long period regime can be explained as being due either to the stream-stream interaction or to changes in the amount of heat deposited in the solar wind within 25 $R_\odot$ of the sun. However, there are still some uncertainties in this assessment, especially with regard to the $\rho - W$ phase.

The question still remains as to why there are two distinctive period regimes separated at approximately a period of 1 day. One possibility can be formulated in terms of strong damping of compressional waves in a collisionless plasma [*Barnes*, 1968, 1969]. Compressional waves are believed to damp in only a few wave periods. The situation at periods less than 1 day may be due to all compressional waves in this regime having been damped in transit to earth. This idea is consistent with the small $V_R - \rho W^2$ coherence at short periods. The compressions at periods greater than 1 day, due perhaps to the stream-stream interaction, are of longer period and may not have had time to damp in the 4- to 5-day transit time to earth. If this is the explanation, future missions to Mercury and Jupiter should find that the cross-over period becomes shorter close to the sun and longer at greater distances.

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DISCUSSION

C. P. Sonett I would say that the turnover in your spectra at around 10^{-6} Hz is very comforting; it shows that the sun rotates about once every 27 days.

J. R. Jokipii Is it possible that the reason the radial power continued to go up was that you were beginning to get away from the turbulent regime and into the stream structure?

G. L. Siscoe That seems to be consistent with this break at 1 day. The V_R really represents the corotating part of the variations, and it is certainly a dominant part of the corotation picture. And when one looks at the calculations that determine V_T and V_N from variations in the V_R the theory says that V_T and V_N should be much less, so it is consistent with that.

L. Davis In connection with the two or more mechanisms that seem to be operating at periods of the order of an hour or so—that is, all the periods of less than 1 day—do these have to be operating simultaneously, or from the way the data are analyzed would you get the same result if for a period of 1 to 2 days you had what we would call good Alfvén waves, and that was the dominant mechanism for a couple of days, then the next couple of days there were practically no Alfvén waves and you had a completely different mechanism, would that produce the kind of thing that—

G. L. Siscoe Yes, yes. I think that's what we should like to do next, that is to break up this 140-day interval into subintervals that look homogeneous in some respect, and see if we can identify dominant processes in subintervals.

N. F. Ness For periods of less than 1 day it is obviously not a pure Alfvén mode, because there are other processes evident in this statistical summary.