tion in a sucrose gradient (*3*). Figure 2 shows the $\log_2$ titers of fractions of cord serum No. 26 obtained by ultracentrifugation in a continuous sucrose gradient (10 to 40 percent). The cells used were coated with Bence-Jones protein No. 46. All hemagglutinating activity was found in the heaviest protein fraction and none in fractions Nos. 8 to 10 in which γG-globulin was concentrated.

The hemagglutinating characteristics of normal human cord blood for cells coated with Bence-Jones protein are the same as those previously described for normal adult serums (*3*). This latter activity has been categorized as being an expression of antibody. It is probable that the use of different Bence-Jones proteins as cell-coating substances will reveal hemagglutinating activity in most, if not all, healthy infants. The macroglobulin hemagglutinating substances found in normal cord blood are thought to be of fetal rather than maternal origin, as judged by the presence of such agglutinating activity in cord blood provided that it is absent or that it is present in a much smaller concentration in the mother's blood.

In the serum of adults, macroglobulin antibody to Bence-Jones protein is directed toward those L-chain sites which are relatively obstructed in intact γ-globulins by the adjacent H-polypeptide chain (*3*). In this study the agglutination system involving cord serum and cells coated with Bence-Jones protein, type L, No. 46, may be inhibited by the same Bence-Jones protein and by some but not all other type-L Bence-Jones proteins. Type-K Bence-Jones proteins and normal pooled γG-globulin fail to inhibit under the same conditions. The agglutinating substances of cord serums with specificity for some type-L Bence-Jones proteins like those found in adult serums therefore appear directed toward a restricted portion of the L-polypeptide chain and are capable of distinguishing subtypes of type-L Bence-Jones proteins.

The specificity of the agglutinating activity of any cord serum for the free L-chain protein of that particular cord-maternal serum pair has not been established, because of limitations in the amount of individual cord and maternal serum available from which free L-chain protein may be isolated.

The specificity of this macroglobulin system directed toward the polypeptide chain common to all the immune globulins and its presence in healthy infants suggest a homeostatic function. One such function might be related to the regulation of the activity of those cells responsible for L-chain synthesis as they undergo antenatal differentiation. The exact nature of the antigenic stimulus for this antibody system in healthy adults and in the healthy human fetus remains to be delineated.

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13 May 1965

Sector Structure of the Quiet Interplanetary Magnetic Field

Abstract. *Observations of the interplanetary magnetic field by the Imp-1 satellite have revealed a regular longitudinal sector structure in this field. The sectors co-rotate with the sun; as an average sector sweeps past the earth the magnitude of the interplanetary field decreases from greater than 6 gammas (1 gamma* $= 10^{-5}$ *gauss) to less than 4 gammas, and the daily sum of the geomagnetic activity index,* Kp, *decreases from 25 to less than 10.*

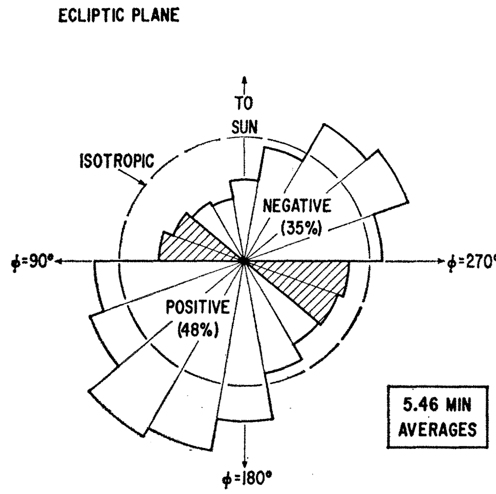
The average direction of the interplanetary magnetic field measured by the magnetometer experiment on the Imp-1 satellite (*1*) is consistent with the Archimedean spiral angle predicted by Parker (*2*). The radial motion of the solar wind stretches the solar magnetic field out away from the sun, and the solar rotation twists the field into a spiral such that at the earth the average angle between the interplanetary field direction and the earth-sun direction is about 45°. The angular distribution of the observed field directions shown in Fig. 1 is clearly peaked in approximately these directions. It is also usually possible to characterize the field direction at a given time as being predominantly either away from the sun or toward the sun.

We have shown (*1*) on this basis that the large-scale structure of the interplanetary magnetic field during three solar rotations has a recurrence period equal to the synodic rotation period of the equatorial region of the sun. This implies that the interplanetary field co-rotates with the sun (*3*).

The field direction during successive 3-hour intervals during the first three solar rotations observed by Imp-1 is shown by the + (away from sun) and − (toward the sun) signs at the circumference of Fig. 2. For a period of about 1 day centered about perigee the satellite is within the region dominated by the influence of the geomagnetic field so that measurements of the relatively undisturbed interplanetary field cannot be made. The corresponding gaps in the data can be seen in Fig. 2.

The large-scale direction of the field shown in the inner portion of Fig. 2 reversed twice during each solar rotation. In two sectors each occupying about 2/7 of the total longitude the field was directed away from the sun, and in one sector of width about 2/7 and one sector of width about 1/7 of the total longitude the field was directed toward the sun. This interplanetary magnetic structure co-rotates with the sun and therefore sweeps past the earth once every 27 days. Changes associated with this structure, as observed at the earth, are therefore not to be interpreted as being caused by a predominantly radial propagation from the sun but rather as being associated with the rotational motion of the structure past the earth. At the sector boundaries the change in field direction occurs within a few minutes. Thus the magnetic neutral sheet at a sector boundary is thin, and may produce impulsive effects as it sweeps past the earth. Approximate times at which this structure was observed at the earth by Imp-1 during the first solar rotation are labeled in Fig. 2.

The first orbit contains an exception to the proposed sector structure that is not yet understood. During the second orbit the velocity of the solar wind was considerably higher than average (*4*), so that in terms of a regular longitudinal structure sweeping past the earth the change from − to + arrived "too soon." For the 2½ solar rotations beginning 13 December 1963, the average solar wind velocity for each orbit (*4*) varied by less than 10 percent, and therefore the large-scale



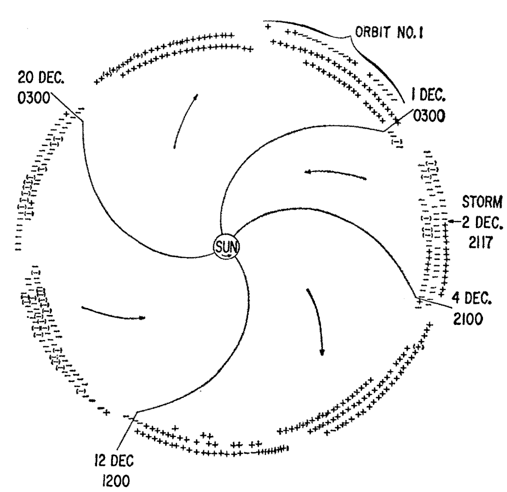
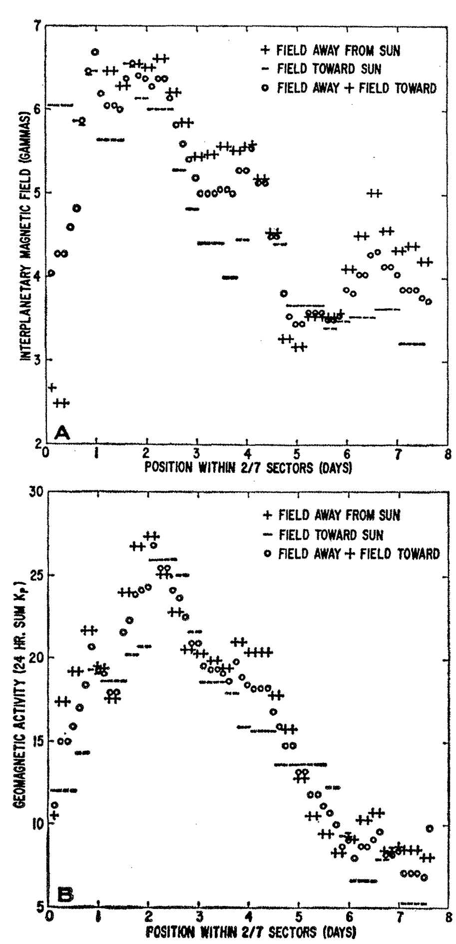


Fig. 1 (left). Distribution of the measured interplanetary magnetic field direction in the plane of the ecliptic and normal to the ecliptic. Both histograms show the angular distribution of the field per unit solid angle; the dashed circles would correspond to an isotropic distribution of the same number of vectors. The distribution is peaked in directions corresponding to the spiral streaming angle. The angular intervals in which the field is predominantly away from the sun and predominantly toward the sun are labeled positive and negative, respectively, in this figure, and represented by + and — signs in Fig. 2. The distribution normal to the ecliptic shows that the interplanetary field is predominantly parallel to the ecliptic rather than being perpendicular to it. Fig. 2 (right). The + (away from the sun) and — (toward the sun) signs at the circumference of the figure indicate the direction of the measured interplanetary magnetic field during successive 3-hour intervals. A parenthesis around a + or — indicates a time during which the field direction has moved beyond the "allowed regions" shown in Fig. 1 for a few hours in a smooth and continuous manner. The inner portion of the figure is a schematic representation of a sector structure of the interplanetary magnetic field that is suggested by these observations. The deviations about the average streaming angle that are actually present are not shown.

structure sweeping by Imp-1 would not be seriously distorted. These 2½ rotations have been selected for further analysis as representing rather quiet and uniform interplanetary conditions. Seven of the 2/7 sectors are then available for analysis, four with field directed away from the sun and three with field directed toward the sun. Thus the results will have limited statistical value and in any case will apply only to one short period of the quiet sun.

The magnitude of the interplanetary magnetic field has been analyzed in terms of the sector structure with the method of superposed epochs (*5*). In Fig. 3*A* the abscissa represents the time interval (about 7¾ days) for a 2/7 sector to sweep past the earth (and past Imp-1). The left edge of the abscissa represents the first portion of the sector that sweeps past the earth, and the right edge represents the trailing portion. The ordinate of Fig. 3*A* represents the average value of the interplanetary field magnitude as measured at the same relative position within each sector. Thus, structure that is organized with respect to the 2/7 sectors will tend to be reinforced, while other "random" effects will tend to be averaged out. Because of the limited data and an uncertainty in the position of the sector boundaries, we used 24-hour average values of the field magnitude. The results are presented with points interpolated in the computation at 3-hour intervals.

Figure 3*A* shows the results of the superposed epoch analysis applied to the four 2/7 sectors with field away from the sun, to the three 2/7 sectors with field towards the sun, and to all



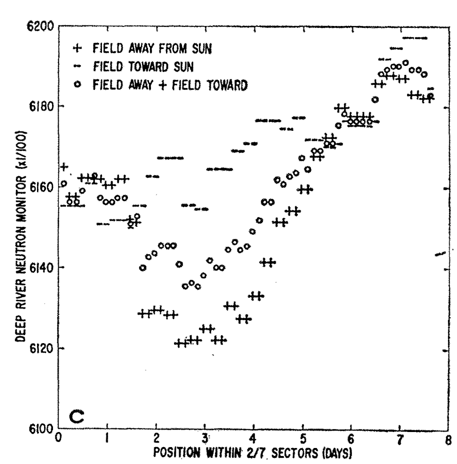


Fig. 3. (*A*) Superposed epoch analysis of the magnitude of the interplanetary magnetic field as a function of position within the 2/7 sectors shown in Fig. 2. The abscissa represents position within the sector, measured in days as the sector sweeps past the earth. The ordinate shows the average magnitude at the same relative position within the sectors. The results are shown separately for the four sectors with field away from the sun, the three sectors with field toward the sun, and for all sectors. (*B*) The same as *A*, except that the ordinate shows sum values for 24 hours for the geomagnetic activity index, *Kp*. (*C*) The same as *A*, except that the ordinate shows the results obtained with a cosmic-ray counter, the Deep River neutron monitor.

seven sectors combined. It is difficult to assess the statistical significance of such limited data.

The extent to which the structure in the "away" sectors resembles that in the "toward" sectors provides some estimate of this. It appears that in both the "away" and "toward" sectors the average field magnitude is greater than 6 gammas (1 gamma $= 10^{-5}$ gauss) near the beginning of the sector, and decreases to less than 4 gammas as the sector sweeps past the earth.

We have investigated the effect on geomagnetic activity of the interplanetary sector structure sweeping past the earth, using the 24-hour sum values of the geomagnetic index *Kp* (*6*). In Fig. 3*B*, the gross structure of *Kp* in both the "away" and "toward" sectors appears to be similar, with a change of about a factor of three from maximum to minimum; *Kp* reaches a peak greater than 25 about 2 days after the sector boundary sweeps past the earth, and then decreases to less than 10 in the trailing portion of the average sector. The interplanetary field magnitude and geomagnetic activity tend to be large (or small) at the same positions within the sector.

The effect of the interplanetary sector structure on cosmic rays was investigated by means of the Deep River neutron monitor in a similar manner, as shown in Fig. 3*C*. The "away" sectors show a minimum at about the 3rd day while the "toward" sectors show a rather uniform increase with time. The counting rates obtained with the Deep River neutron monitor thus tend to be large at the positions within the sector where *Kp* and the interplanetary magnetic field are small and vice versa.

The orbital period of Imp-1 is 93.5 hours, while the 1/7 sectors sweep past the earth with an average interval of about 91.5 ± 2 hours. The sector boundaries usually sweep past while Imp-1 is near perigee and therefore the boundaries cannot be observed. We have carefully checked the possibility inherent in this situation that an artifact was introduced, but have obtained negative results.

The existence of a longitudinal structure in the interplanetary magnetic field has important implications in determining the structure of the sun.

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12 April 1965

Explosion of Burning Zirconium Droplets Caused by Nitrogen

Abstract. *Single droplets of zirconium were photographed as they burned luminously in free fall. When the oxidizer was oxygen containing small amounts of nitrogen (less than 5 percent), the burning droplets exploded only when a threshold concentration of nitrogen was exceeded. Explosions also occurred when the zirconium was partially nitrided before being burned in pure oxygen. These experiments prove that the presence of nitrogen can cause the explosion of zirconium droplets burning in oxygen-rich atmospheres.*

When metal droplets burn in gaseous oxidizers, they often glow brightly for a time, then explode violently (*1, 2*). Familiar examples of such explosions are the sparks formed when certain metals are ground (*3*) and in the pyrotechnic "sparkler." These explosions have been variously attributed to boiling of the metal (*4*), possibly aided by an alteration of the metal oxide by water vapor (*5*), to boiling of the metal oxide (*6*), to dissolved gas (*7*), and to the evolution of CO from the combustion of carbon alloyed with the metal (*8*).

I now report that the presence of small amounts of nitrogen can cause the explosion of zirconium droplets burning in oxygen-rich atmospheres.

Experiments were performed as follows. Single droplets were formed from small squares, 56 μ thick, of zirconium foil dropped through a flash-heating apparatus similar, except for slight improvements, to that described previously (*2*). The squares were melted and ignited in oxygen or in the mixed-gas oxidizers by means of a helical flash lamp which was fired as the foil passed through. As they fell downward through the Pyrex combustion chamber, the droplets were photographed by their own luminosity (Polapan type 52 film at aperture f/45 from a distance of 1 meter). The camera's shutter was opened for 1 second by a solenoid about 25 msec after the scattered light from the heating flash had extinguished.

Droplets with diameters of 525 μ burned brilliantly but did not explode in oxygen flowing at 5.0 lit./min at an overall pressure of 625 torr; each droplet extinguished gradually to form a dense white sphere with a diameter of approximately 600 μ.

As small amounts of nitrogen were added to the streaming oxygen, neither the photographic images of the burning droplets nor the appearance of the products changed until the concentration of nitrogen reached 2.9 percent (measured with calibrated flowmeters). When the nitrogen concentration was increased gradually from 2.9 to 4.0 percent, a progressively greater fraction of the droplets showed fragmentations. At concentrations of 4.5 percent nitrogen, all droplets exploded. Photographs of droplets burning in pure oxygen and in 4.5 percent nitrogen and 95.5 percent oxygen are shown in Fig. 1.

In the threshold region between 2.9 and 4.0 percent nitrogen the droplets formed several types of products, each apparently caused by the release of a gas inside a partially molten sphere. Some droplets formed white spheres similar in diameter and appearance to those formed when the nitrogen concentration was below 2.9 percent, except that there were a few bulges on the outside.

Other droplets formed thin-walled semiopaque white sacs with thicker portions attached. A few formed complete thin-walled white sacs as large as 1.3 mm across. With nitrogen concentrations of 4.5 percent, each droplet formed approximately 10 to 30 thin-walled white sacs with dimensions between about 50 and 700 μ. The thin-walled white sacs appear to be identical to those obtained by Meyer (*9*)