7 December 1962, Volume 138, Number 3545 **SCIENCE**

The Venus Mission

Mariner II is already a record-breaking success. The pre-calculated flight trajectory has been followed, all interplanetary experiments have functioned, and many engineering data have been acquired. Though Mariner II is now more than 23 million miles away, data from 90,000 measurements a day are being received.

In this issue we are pleased to present scientific results obtained during the interplanetary phase of the mission. Our pleasure contrasts with corresponding sadness at five consecutive fiascos in the lunar program. The Venus shot is feasible for only a short period once every 584 days. Yet our first real lunar or interplanetary triumph has attended the more difficult mission.

The prerequisite for a successful space flight is functioning of all components. During launch phases, vibration and acceleration place unusual stresses on the vehicle. Even partial failure of one of hundreds of thousands of components can nullify the performance of all. After ascent to a circular parking orbit 115 miles from the earth, Mariner II was allowed to coast to a calculated point and was then boosted to escape velocity. During the next eight days the space craft was tracked to determine its path, and a slight corrective maneuver was made. The magnitude of the guidance problem can easily be seen. When Mariner II misses Venus by 21,000 miles on 14 December, it will be 26.3 million miles from Earth. The space craft will have traveled 182 million miles at highly variable speeds. Starting from rest with respect to Earth, the velocity rose quickly to 18,000 miles per hour. The vehicle was later accelerated to 25,503 mph, a speed in excess of escape velocity. After three days the velocity had decreased to 6874 mph. Then the space craft was moving about the sun 6874 mph slower than the earth's 66,000 mph, that is, about 59,400 mph. From that time the velocity of Mariner II increased as it moved toward the sun. The craft will attain a velocity of 84,000 mph and catch up with Venus, which moves about the sun at 78,300 mph. These figures make evident the complexity of calculating the trajectory and attaining it; this is only one facet of a successful flight.

The experimental and engineering data sensors must operate, and their information must be transmitted back to Earth. Hence the space craft must be positioned so that the solar batteries can operate and the antenna is directed toward Earth. Miraculously, all the components of Mariner II have functioned.

Prospects are excellent that worthwhile measurements will be made during planetary approach. At that time two additional instruments will be turned on, a microwave radiometer and an infrared radiometer. They should measure temperature distribution on Venus and tell whether there are discrete clouds with breaks. Previous measurements from Earth seem to indicate a surface temperature of 300°C, but this value is not universally accepted.

The magnetic field of the planet will also be measured. If it is comparable with that of Earth, the observation will be interpreted as indicating that Venus has a hot molten core. Other similarities of Venus and Earth such as a history of differentiation would also be inferred.

The striking success of Mariner II is reassuring. We now have grounds to hope that the Space Administration will ultimately shake down into an organization capable of sponsoring and carrying out solid scientific research.—P.H.A.

SCIENCE, now combined with THE SCIENTIFIC MONTHLY, is published each Friday by the American Association for the Advancement of Science at National Publishing Company, Washington, D.C. SCIENCE is indexed in the *Reader's Guide to Periodical Literature.*

Editorial correspondence should be addressed to SCIENCE, 1515 Massachusetts Ave., NW. Washington 5, D.C. Manuscripts should be typed with double spacing and submitted in triplicate. The AAAS assumes no responsibility for the safety of manuscripts. Opinions expressed by authors are their own and do not necessarily reflect the opinions of the AAAS or the institutions with which the authors are affiliated. For detailed suggestions on the preparation of manuscripts, see *Science* 138, 496 (26 Oct. 1962).

Advertising correspondence should be addressed to SCIENCE, Room 1740, 11 West 42 St., New York 36, N.Y.

Change of address notification should be sent to 1515 Massachusetts Ave., NW, Washington 5, D.C., 4 weeks in advance. Furnish an address label from a recent issue. Give both old and new addresses, including zone numbers.

Annual subscriptions: $8.50; foreign postage, $1.50; Canadian postage, 75¢. Single copies, 35¢. School year subscriptions: 9 months, $7.00; 10 months, $7.50. Cable address: Advancesci, Washington.

The Mission of Mariner II: Preliminary Observations

Profile of Events

The interplanetary spacecraft Mariner II, designed and built by the Jet Propulsion Laboratory of the California Institute of Technology, was launched from Cape Canaveral by an Atlas-Agena propulsion system at 06h 53m 14s Universal Time on 27 August 1962. In addition to two radiometers designed to make close-up measurements of the electromagnetic radiation from Venus in the microwave and infrared spectral regions, it carries seven other scientific instruments to observe various features of the interplanetary medium. Preliminary results of some of these experiments are discussed in the papers which follow.

Mariner II is, by a large margin, the most successful interplanetary space probe which has ever been sent out from the earth. It will pass closer to another planet than any of its predecessors. No other attitude-stabilized spacecraft has operated so far into space. Rocket propellants have never before been stored in space for so long and then used successfully. This is the deepest penetration into space at which a craft has been commanded and which, in response, performed maneuvers successfully. Far more data from translunar space have been recorded on earth from Mariner II than were ever received before—720,000 data bits per day for more than 75 days (as of 20 November 1962).

Some of the significant events in the voyage of Mariner II are listed below; the times are given in days after launch and the distances from the spacecraft to the earth in gigameters (1 Gm = 10^9 meters = 1 million kilometers = 621,370 miles).

1) 2.39 days, 0.72 Gm: The interplanetary experiments were begun.

2) 8.73 days, 2.41 Gm: The orbit was corrected in response to radio command from earth.

3) 38.73 days. 9.96 Gm: The spacecraft stopped falling behind the earth and began to overtake it (that is, earth and spacecraft had equal angular velocities about the sun).

4) 65.40 days, 19.10 Gm: The spacecraft passed the earth (that is, heliocentric longitude of earth and spacecraft were the same).

5) 65.57 days, 19.23 Gm: The interplanetary experiments were turned off by radio command from earth because of the malfunction of one of the solar power panels.

6) 73.61 days, 23.56 Gm: Interplanetary experiments turned on again by radio command from earth after solar power returned to normal.

7) 81.0 days, 28.5 Gm: New distance record was attained for the transmission of telemetry data, and surpassed that set by Pioneer V in June 1960. The Pioneer V record for one-way transmission of a radio signal (36.15 Gm) will have been surpassed at 90.18 days if Mariner II is still operating at that time.

8) 109.33 days, 57.70 Gm: Mariner II will pass by Venus at a distance of 0.04 Gm from the center of the planet.

Solar Plasma Experiment

Abstract. A preliminary summary of the data received from the Mariner II solar plasma experiment for the period 29 August through 31 October 1962 is presented. During this period there was always a measurable flow of plasma from the direction of the sun. The velocity of this ion motion was generally in the range 400 to 700 km/sec. Time variations, plasma density, and ion temperatures are also discussed.

The Mariner II solar plasma experiment is made with a single electrostatic spectrometer which always points to within less than ½ degree of the center of the sun. Positively charged particles of kinetic energy per unit charge, E/Q, within a certain range, and of near-normal incidence are allowed to pass through the spectrometer to a Faraday cup. The current to this cup is measured for each of ten ranges of E/Q, 3.7 minutes being required to obtain a complete spectrum.

Data were received from the interplanetary experiments on Mariner II almost continuously from 29 August through 31 October 1962. In this period, approximately 23,550 spectra were received from the plasma experiment; of these, approximately 20,200 have already been made available for analysis.

One of the principal results of the Mariner plasma experiment is the finding that there was always a measurable flow of plasma from the direction of the sun. The data are summarized in Fig. 1, which contains eight plots of the logarithm of the collected current versus time—one plot for each value of E/Q between 516 and 8224 volts. Each bar represents the total spread in measured current for the time corresponding to 256 spectra, or 15.77 hours.

The lines in Fig. 1 marked 130 and 140 correspond to approximately 10^{-11} and 10^{-12} ampere, respectively; thus, the vertical distance between these lines is equivalent to one decade of collected current. The largest current observed during the 63-day period was about 4×10^{-10} ampere. Measurements were also made at values of $E/Q = 231$ and 346 volts; however, the currents in these ranges of E/Q are not plotted because they were always below 10^{-13} ampere.

From Fig. 1 it can be seen that there was almost always a plasma flux at values of $E/Q = 1664$ and 2476 volts (corresponding to proton velocities of 563 and 690 km/sec). Only occasionally during this period did E/Q become as low as 516 volts (314 km/sec) or as high as 8224 volts (1250 km/sec).

Table 1 is a summary of the percentage of time the peak of the measured spectrum fell in each of the windows of E/Q.

There were eight geomagnetic storms during the period 29 August through 31 October. The geomagnetic storm which started at 2025 hours universal time, on 7 October has been studied in some detail. A sudden increase in plasma flux and energy occurred at about 1547 on 7 October, when the spacecraft was 8.55×10^6 km closer to the sun than the earth was. If one assumes that this plasma front was advancing with spherical symmetry and constant velocity from the center of the sun (at least for the region of space containing the spacecraft and the earth), then the velocity

Table 1. Distribution of E/Q of the peak of the solar plasma spectrum.

E/Q (volt)	Time (in %) during which measured current in E/Q was the maximum	Time (in %) during which measured current in two adjacent channels of E/Q was approximately equal
516	0.0	
		0.2
751	18.3	
		2.0
1124	22.5	
		2.2
1664	30.5	
		4.0
2476	19.9	
		0.1
3688	0.3	
Total	91.5	8.5

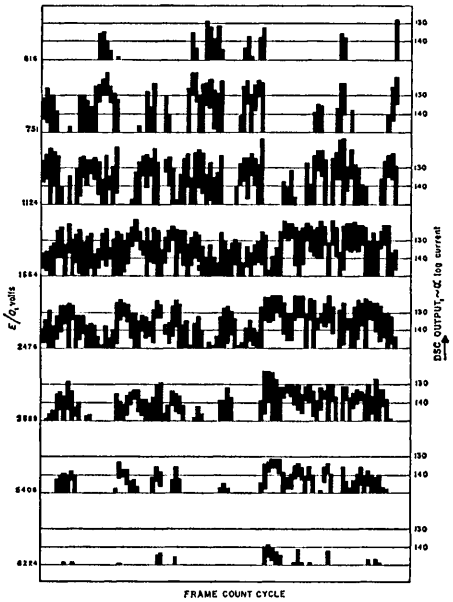

Fig. 1. Summary of plasma flux as a function of E/Q and time for the period 29 August through 31 October.

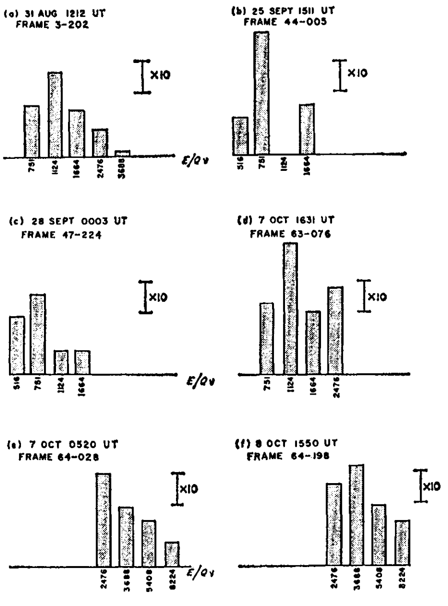

Fig. 2. Selected plasma spectra.

of the front was 504 km/sec. This velocity corresponds fairly well to the measured plasma spectrum, in which more current was measured at the value of E/Q which corresponds to a proton velocity of 464 km/sec than at 379 or 563 km/sec.

This discontinuity, or plasma front, passed the spacecraft so quickly that the instrument, with its 3.7-minute time resolution, could not resolve its structure, which must therefore be less than 112,000 km thick. The Mariner magnetometer data for this period could be interpreted as showing a front of thickness of the order of 50,000 km.

Another interesting feature of the plasma spectrum for this period is that the energy of the ions in the plasma kept increasing for approximately one day after the passage of the initial front. The plasma density, however, increased very rapidly, by a factor of about 5, and then returned to below its prestorm value about 5 hours after the storm front passed.

The plasma associated with the seven other geomagnetic storms exhibited similar behavior, although it is more difficult to identify the storm front for these other storms.

A few selected spectra are given in Fig. 2. An outstanding feature of many of the spectra is the presence of two peaks, the lower-voltage peak being the higher of the two. Due to the relatively wide spacing of values of E/Q for which the flux was measured, it is not possible to prove whether or not two peaks were always present. The most probable explanation of the presence of two peaks is that the lower-voltage maximum is due to protons while the higher-voltage maximum is due to alpha particles with approximately the same velocity away from the sun as the protons (and thus twice the value of E/Q).

Another consequence of the wide spacing of values of E/Q is the difficulty in determining the density and temperature of the plasma. Estimates have been made for only a few spectra so far. The values for spectra *a* and *f* of Fig. 2 were estimated on the basis of a model in which the plasma flows directly from the sun with a bulk velocity v_0, density n, a proton temperature T in the direction of motion, and zero proton temperature perpendicular to the direction of motion, with results as follows: For spectrum *a*—$v_0 = 460$ km/sec, $n = 2.5$ cm^{-3}, $T = 1.9 \times 10^5$ deg K; for spectrum *f*—$v_0 = 810$ km/sec, $n = 4.5$ cm^{-3}, $T = 7.4 \times 10^5$ deg K. These figures were based on the further assumption that the currents at the three lowest values of E/Q were due to protons only.

Another model which we hope soon to be able to compute has equal proton temperatures parallel and perpendicular to the direction of motion. In this respect, it should be noted, the plasma flow observed by Explorer X was consistent with ion temperatures of 4 to 8 × 10^5 deg K (*1*).

If we assume that the values of v_0, n, and T given above are approximately correct, and if we further assume an average value for the interplanetary magnetic field of $B = 5$ gamma $= 5 \times 10^{-5}$ gauss, we can compute the following important parameters for spectrum *a*, which appears to be fairly representative of quiet, non-storm conditions during the period of observation: Plasma flux $= nv_0 = 1.2 \times 10^8$ cm^{-2} sec^{-1}; plasma energy density $= n(\frac{1}{2} mv_0^2 + \frac{1}{2}kT \approx \frac{1}{2}\ nmv_0^2 = 4.4 \times 10^{-9}$ erg cm^{-3}; magnetic field energy density $= B^2/8\pi = 1.0 \times 10^{-10}$ erg cm^{-3}; Alfvén velocity $= v_A = B/\ (4\ \pi\ mn)^{\frac{1}{2}} = 69$ km sec^{-1}; $v_0/v_A = 6.7$.

From these computations, conclusions can be drawn as follows:

1) The plasma flux is in good agreement with the values found by Explorer X (*2*) and by the ion traps on the Lunik satellites (*3*).

2) However, the plasma velocity v_0 appears to be greater than that observed close to the earth by Explorer X. The measured velocity agrees fairly well with the value predicted from Parker's "solar wind" theory (*4*) but is higher than the value predicted from the observation of comet tail orientations (*5*) and much higher than the values predicted by "solar breeze" theories (*6*).

3) The plasma energy density is much greater than the energy density of the magnetic field. Thus we may conclude that the magnetic field in interplanetary space is carried along by the plasma, the field giving little or no hindrance to the plasma flow.

4) The flow of plasma about the earth and its magnetosphere is supersonic in the sense that the flow velocity is greater than the Alfvén velocity; this is probably a necessary condition for production of the predicted bow shock wave (*7*).

MARCIA NEUGEBAUER
CONWAY W. SNYDER
Jet Propulsion Laboratory, California Institute of Technology, Pasadena

References

1. F. Scherb, private communication.
2. A. Bonetti, H. S. Bridge, A. J. Lazarus, E. F. Lyon, B. Rossi, F. Scherb, "Explorer X plasma measurements," paper presented at COSPAR meeting, Washington, May 1962.
3. K. I. Gringauz, V. V. Bezrukikh, V. D. Ozerov, R. E. Rybchinskii, *Soviet Phys. "Doklady" English Transl.* **5**, 361 (1960).
4. E. N. Parker, *Astrophys. J.* **132**, 175, 832 (1960).
5. J. C. Brandt, *Icarus* **1**, 1 (1962).
6. J. W. Chamberlain, *Astrophys. J.* **131**, 47 (1960); *ibid.* **133**, 675 (1961).
7. W. I. Axford, *J. Geophys. Res.* **67**, 3791 (1962); P. J. Kellogg, *ibid.* **67**, 3805 (1962).

23 November 1962

The Iowa Radiation Experiment

The primary purposes of the Iowa experiment in Mariner II are to search for charged particles magnetically trapped in the vicinity of the planet Venus and, if such particles are found, to obtain preliminary measurements of their spatial distribution and intensity. These measurements, when taken together with measurements by the magnetometer equipment on the same vehicle, should advance knowledge of the planet's internal constitution and its magnetosphere. The radiation equipment is also useful in monitoring the intensity of low-energy particles in interplanetary space during the 3½-month flight from the earth to the planet.

At present only the planets Earth and Jupiter are known to have extended belts of magnetically trapped particles. The belts of Earth have been studied by a comprehensive series of *in situ* observations with satellite and space probe equipment, those of Jupiter by radio-astronomical observations with ground-based equipment.

Current radar-astronomical evidence, obtained independently from the Millstone and Goldstone observatories, indicates that the angular rotational rate of Venus is of the same order of magnitude as the angular rate of its orbital motion around the Sun. Hence it is widely believed that Venus, by virtue of tidal friction during the evolution of the solar system, is now revolving about the Sun with its same hemisphere continuously facing the Sun. If this is indeed true, and if, despite such a low rotational rate of the planet, Mariner II finds a substantial intensity of trapped particles and a substantial magnetic field intensity (say, of the order of 100 gammas) at the expected miss distance of some 6.5 planetary radii from the center of the planet, then it would seem that profound revisions of general theories of planetary magnetism will be necessary. The implications of other combinations of conceivable outcomes of current work may be considered.

In planning the experiment it was thought most likely that the radiation belt of Venus, if any, would have a much lower intensity of particles than that of Earth and that the energy of these particles would also be lower. Other general considerations were the very limited weight, power, and telemetry allocations for this experiment and the necessity for the highest possible reliability. Our final choice of detector was an Anton type 213 Geiger-Mueller tube, which is a miniature tube having a 1.2 mg/cm² mica window about 0.3 cm in diameter. A number of such tubes have operated successfully in orbital flight for over 16 months in Injun I, throughout Explorer XII's lifetime of 4 months, and (as of the date of writing) for over 6 weeks in Explorer XIV. Some properties of the Mariner II detector are given in Table 1.

The tube also detects soft x-rays efficiently (~ 0.1 for 2-kev x-rays) and ultraviolet quite inefficiently (~ a few counts per second from a laboratory mercury arc whose ultraviolet intensity simulates that of the Sun). Although the x-ray sensitivity of this detector has valuable applications for studying x-ray bursts from the Sun and has been so used in Injun I, in the Mariner II apparatus special care was taken to shield it from both direct and reflected sunlight. The physical arrangement is shown in Fig. 1. No portions of the spacecraft lie within or near the conical aperture of the collimator. The axis of the spacecraft is stabilized to within less than 1 degree from the probe-sun line. (This angle is also measured and telemetered.) The sunshade of the tube's collimator prevents any sunlight from falling on any part of the collimator if the error in this angle is less than 10° in any plane; and the collimator itself prevents sunlight from falling on the window of the detector unless the axis of the detector is tilted toward the sun-probe line by more than 25 degrees, a situation which would correspond to a gross failure of the stabilization of the spacecraft. During flight to Venus, the spacecraft is gradually rolled around the probe-sun line in a systematic and known way in order to keep the directional telemetry antenna pointed toward the earth. The slow sweep of the axis of our detector across the celestial sphere may conceivably provide a significant search for sources of soft x-rays, but no analysis of the data from this point of view has yet been made.

Table 1. Properties of the Iowa detector.

Type: Anton 213 Geiger-Mueller tube
Weight of assembly: 60 g
Window thickness: 1.2 mg/cm² mica
Full angle of collimator: 90°
Directional geometric factor: 0.2 cm² sterad
Efficiency for electrons:
  1.0 for $E > 70$ kev
  0.35 for $E = 40$ kev
  0.1 for $E = 34$ kev
  0.01 for $E = 29$ kev
  10^{-3} for $E = 27$ kev
  10^{-6} for $E = 5$ kev (nonpenetrating)
Efficiency for protons: 1.0 for $E > 500$ kev
Side shielding: 0.35 g/cm² of stainless steel and magnesium
Omnidirectional geometric factor: 0.2 cm²
Maximum apparent counting rate: 50,000 count/sec
Maximum observable true counting rate by use of laboratory calibration curve: 10^7 count/sec

The basic telemetry frame for the Iowa detector is 887.04 seconds in length. During each such frame the counting rate of the detector is sampled twice, at intervals separated by 37 seconds, as follows:

1) The number of counts during an interval of 9.60 seconds ("long gate") is accumulated on a shift register of seven binary stages. This register "overflows" on the 256th count.

2) The number of counts during an interval of 0.827 second ("short gate") is accumulated on a shift register of 15 binary stages. This register overflows on the 65,536th count.

Since the maximum apparent counting rate of the 213 detector is 50,000 per second the "short gate" system always gives a unique reading. At counting rates less than 26.6 per second the "long gate" reading is unique and has, of course, much better statistical accuracy than the "short gate" read-

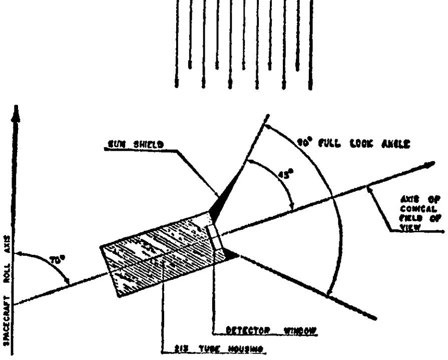

Fig. 1. Schematic diagram of the detector on Mariner II.

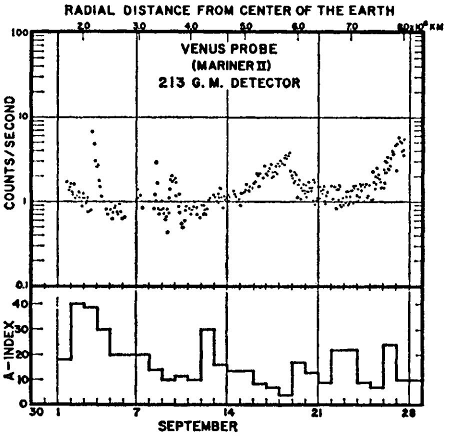

Fig. 2. Data reported in September 1962. (Top) Counting rate. (Bottom) Magnetic A indices.

ing. At rates in the range 26.6 per second to about 60 per second the "short gate" system gives the approximate rate, indicates the number of times (one, two, or three) which the "long gate" register has overflowed, and, with some reservation, makes it possible to use the "long gate" reading for obtaining a more accurate rate, if it appears that one is entitled to assume substantial constancy of counting rate over a time period of some 47 seconds.

The upper portions of Figs. 2 and 3 show data observed in interplanetary flight during September and October 1962. Each point corresponds to an average over five sampling periods. The expected minimum counting rate is about 0.6 count/sec because of galactic cosmic rays, whose interplanetary intensity in the general vicinity of Earth's orbit is about 3 particles cm^{-2} sec^{-1} during the present period of reduced solar activity. Such a minimum counting rate is indeed seen to have been approached during portions of the period covered by Figs. 2 and 3. In general, the data attest to a remarkable "cleanliness" of interplanetary space in respect to the types of radiations to which this detector is sensitive (see *1*). Marked increases of counting rate are noted on the following dates: 3, 8, 9–10, 15–19, and 25–28 (?) September, and 8–9, 12–15, and 23–24 October 1962.

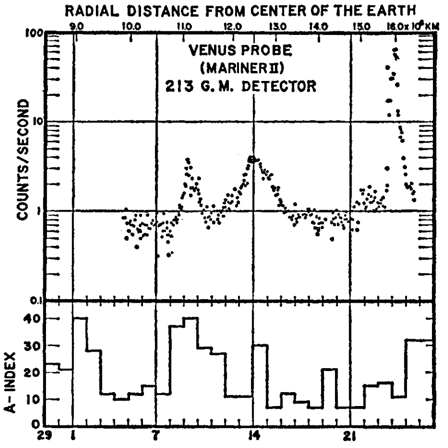

Fig. 3. Data reported in October 1962. (Top) Counting rate. (Bottom) Magnetic A indices.

No proper interpretation of these peaks has yet been made. The following general lines of interpretation are being investigated: (i) changes in directionality or intensity and/or energy spectrum of particles in the solar wind; (ii) solar cosmic rays; (iii) galactic x-rays (see above). It is expected that the following other lines of evidence will contribute to an understanding of the significance of these peaks:

1) Mariner II magnetometer measurements.

2) Mariner II plasma probe data.

3) Data from the ionization chamber and two other (thick-walled) Geiger-Mueller tubes in Mariner II.

4) Data from a set of thin-window 213 detectors in the Iowa equipment in Explorer XIV, particularly near apogee (which is at 16.4 earth radii).

5) Data from the magnetometer in Explorer XIV.

6) Terrestrial data on geomagnetic and auroral activity.

7) Data from rocket, balloon, and low-altitude satellite equipment near Earth.

8) Radio and optical observations of the Sun.

Pending completion of a thoroughgoing study, we have plotted the daily average Fort Belvoir magnetic A indices from the weekly Boulder reports (*2*) in the lower portions of Figs. 2 and 3 with the idea of testing whether or not our counting rate peaks have any correspondence to geomagnetic effects which are presumably caused by changes in the solar wind. There is some indication of correspondence, but the relationship to this crude index of geomagnetic activity does not appear to be intimate, and no conclusions are proposed at this time.

The planetary encounter, now expected on 14 December, continues to represent the observing period of greatest interest for this experiment (*3*).

JAMES A. VAN ALLEN
LOUIS A. FRANK
Department of Physics and Astronomy, University of Iowa, Iowa City

References and Notes

1. J. A. Van Allen and L. A. Frank, *Nature* **184**, 219 (1959).
2. Billings, Trotter, LaVelle, "Preliminary reports of solar activity" (High Altitude Observatory, Boulder, Colo.).
3. We are grateful to Hugh R. Anderson and Leonard A. Parker of the Jet Propulsion Laboratory, California Institute of Technology, for continuing cooperation on all aspects of payload integration and data handling. Substantial experimental and data analyses have been provided by H. K. Hills and C.-S. Wang of our laboratory. Our work has been supported in large part by a contract with the Jet Propulsion Laboratory.

21 November 1962

Cosmic Dust

The objective of the cosmic dust experiment on Mariner II is to make a determination of the flux of dust particles in interplanetary space by direct measurement techniques similar to those used in recent satellite experiments. Prior information concerning distributions of dust particles in interplanetary space has been obtained from analyses of photometric studies of the zodiacal light and the solar corona. Dubin and McCracken (*1*) have compared the measurements from the satellite experiments with these photometric observations and have demonstrated that the spatial density of cosmic dust may be greater near the earth than in interplanetary space by at least three orders of magnitude. The cosmic dust detector on the Mariner II spacecraft is at present extending the direct measurements to interplanetary space.

The experiment consists of one metallic sensor plate (3.5×10^{-2} m^2) with an acoustical transducer bonded to it (*2*). The electrical signal from the detector is proportional to the mechanical impulse received by the sensor plate from an object impacting on its surface. The electronic instrumentation is capable of differentiating two momentum ranges differing in magnitude by a factor of 10. The minimum threshold sensitivity, as determined by low-velocity calibration techniques (*3*), is $7.4 \pm 1.7 \times 10^{-4}$ dyne-sec.

At both momentum levels the system is capable of counting and storing three events until they are telemetered to earth, whereupon the system is reset for more data. An in-flight calibration signal occurs after each telemetry readout and thus repeatedly demonstrates the operation of the electronic section of the experiment. The solid viewing angle of the system is approximately π steradians.

So far, 950 hours of data have been studied, and all information indicates that the experiment is functioning properly. During the portion of the flight represented by these data, the detector plate was approximately perpendicular to the ecliptic plane and facing in the direction of flight. Thus, it was primarily sensitive to particles in retrograde heliocentric orbits, although impacts from particles in direct heliocentric orbits with low relative collision velocities were a possibility.

During this period, one definite hit was recorded on the more sensitive momentum channel. Some of the data will be re-examined in order to check several possible hits which are classified questionable at the present time.

However, an estimate of the flux can be made by computing the flux necessary for a 0.9 probability of at least one impact for the time of the measurement.

With an area-time product of 1.2×10^5 m^2 sec, a flux of 6×10^{-6} particles/m^2 sec srad is obtained. If an average collision velocity of 55 km/sec for this retrograde flux is assumed, the mass of the minimum detected particle is $1.3 \pm 0.3 \times 10^{-10}$ g.

A few brief remarks can be made concerning the direct measurements from earlier satellites and the preliminary results from the cosmic dust experiment on Mariner II. If an assumption is made that the flux of the dust particles in interplanetary space is omnidirectional, the flux of dust particles measured by satellites near the earth (see *3*, *4*) is found to be about 10^4 times greater than the preliminary measurement from the Mariner II experiment.

From a similar experiment on Pioneer I, Dubin reported a measurement of dust particle flux in cislunar space (see *5*). The flux obtained from this measurement is 10^2 times greater than the preliminary Mariner II flux value. These direct measurements are showing a concentration of small dust particles near the earth.

The spacecraft has completed its scheduled 180-degree roll around the sun-probe axis. The detector plate is now primarily sensitive to particles in direct heliocentric orbits. A more effective comparison of the dust-particle flux in interplanetary space with that near the earth will be possible with the analysis of these data.

W. M. ALEXANDER
Goddard Space Flight Center,
Greenbelt, Maryland

References

1. M. Dubin and C. W. McCracken, "Measurements of distributions of interplanetary dust," paper presented at the 110th meeting of the American Astronomical Society, Cambridge (1962).
2. R. C. Wyckoff, Ed., "Scientific Experiments for Mariner R-1 and R-2," *Calif. Inst. Technol. Jet Propulsion Lab. Publ. No. TN-32-315* (1962).
3. C. W. McCracken, W. M. Alexander, M. Dubin, *Nature* **192**, 441 (1961).
4. W. M. Alexander, C. W. McCracken, L. Secretan, O. E. Berg, in *Space Res. Proc. Intern. Space Sci. Symp. 3rd, 1962*, in press.
5. M. Dubin, in *Proc. Intern. Space Sci. Symp. 1st, Nice* (1960), p. 1042.

28 November 1962

Interplanetary Magnetic Fields

Abstract. Preliminary analysis of Mariner II magnetometer data indicates a persistent interplanetary field varying between a least 2 and 10 gamma ($1\gamma = 10^{-5}$ gauss). The interplanetary field appears to lie mainly in the ecliptic plane, although there is a substantial, fluctuating, transverse component. The Mariner II data agree reasonably well with the prior Pioneer V observations. Typically, variations as large as 5 to 10 gamma in the field component radial from the sun are measured. Correlations with the Mariner II plasma measurements have been observed.

The orbit of Mariner II will take the spacecraft from its injection point just outside the earth on 27 August 1962 to the vicinity of Venus on 14 December 1962. The scientific instruments aboard the spacecraft are designed to provide observations in the vicinity of Venus and to measure several properties of the interplanetary environment over the range of heliocentric distances between 1.5×10^8 and 1.1×10^8 km. Among these instruments is a triaxial, fluxgate magnetometer with three orthogonal sensors. Readings of the *X*-, *Y*-, and *Z*-field components are separated by 1.9 seconds, and a complete set of triaxial readings is relayed to earth every 36.96 seconds. The accuracy of each reading is about 1 gamma (10^{-5} gauss). However, the observed field is the super-position of the interplanetary magnetic field and a nearly constant spacecraft magnetic field. Thus, only *changes* in the interplanetary field can be measured unless the spacecraft field can be independently determined. The two components of the spacecraft field perpendicular to the sun-spacecraft direction have been determined as described below, but not the radial component parallel to this direction. The results described herein were obtained in interplanetary space during late August and early September 1962, far enough from the earth to be unaffected by the earth's presence. No magnetic measurements were obtained either inside the geomagnetic field or in the region of the transition to interplanetary space.

Preliminary analysis of data from the earlier portion of the Mariner II flight has verified a number of widely accepted beliefs and confirmed the main features of prior, less complete observations. Probably the most important result is the convincing evidence that interplanetary space is rarely empty or field free. Magnetic fields of at least a few gamma are nearly always present, except perhaps for occasional, transient nulls. The fields usually vary irregularly with characteristic periods ranging from an observable lower limit of 40 seconds to several hours. The magnitude of the field component transverse to the sun-spacecraft direction (see $B\perp$, Fig. 1) agrees reasonably well with the Pioneer V observations (*1*). The magnitude is typically 5 gamma during times of small magnetic activity, rising to values of 20 gamma or more during magnetic storms, and falling to about 2 gamma during very quiet times. Occasionally, all three components of the field show almost no variations for periods of an hour or two. Such intervals appear to be of shorter duration, and to occur less frequently, than was indicated by Pioneer V data obtained in March and April 1960.

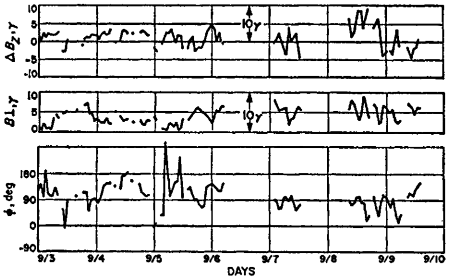

Fig. 1. Magnitude and direction of the interplanetary field. ΔB_Z is the variation in the radial field component. The absolute magnitude of this component is not known at this time because the *Z*-component of the spacecraft magnetic field is unknown. The $+Z$-direction is radially outward from the sun. $B\perp$ is the component of the interplanetary field perpendicular to the *Z*-direction. $B\perp = (b_x^2 + b_y^2)^{\frac{1}{2}}$ where b_x and b_y are derived from the *X*- and *Y*- measurements by subtracting the *X*- and *Y*- spacecraft magnetic field components. The angle $\phi = \tan^{-1}(b_y/b_x)$. During the period shown, the *X*-axis was nearly paralled to the direction of the north ecliptic pole. ϕ is a counter-clockwise angle in a view toward the sun. The values of each variable are hourly averages obtained during the 7 days after the spacecraft was stabilized.

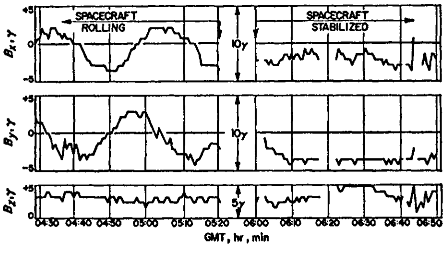

Fig. 2. Interplanetary magnetic field measurements before and after the stabilization of the spacecraft 3 September 1962. The data preceding the gaps in the curves were obtained while the spacecraft was rolling about the *Z*-axis. The ambient field was relatively undisturbed. B_Z was nearly constant, while B_X and B_Y showed sinusoidal variations produced mainly by the rolling motion. The curves that follow the break in the data were obtained after the spacecraft was stabilized. B_Z was virtually unchanged. B_X and B_Y were also nearly constant after the spacecraft stopped rolling. Note that B_X and B_Y are approximately equal on both sides of the break; the spacecraft orientation corresponding to the data taken just before the break was within 10 degrees of the stabilized orientation.

Preliminary analysis of the Mariner II magnetometer data has also produced some new information. These results, including correlations with the plasma data, do not agree in an obvious way with any simple model of the interplanetary medium (*2*). Averaged over almost any period of several hours, the transverse component of the interplanetary field appears to lie more nearly in, rather than normal to, the plane of the ecliptic (the plane of the earth's orbit). However, there is a substantial, fluctuating component perpendicular to the ecliptic plane. Further investigation should establish whether or not its average, over periods of days, is zero. During the first ten days of the flight, the transverse component was usually directed toward the east, opposite to the direction of planetary motion (see ϕ, Fig. 1). Our earlier speculation (*1*) that in very quiet periods the transverse component might be mainly perpendicular to the ecliptic plane is inconsistent with the Mariner II data for this period. During this same period the range of variations in the radial-field component, ΔB_Z (Fig. 1), was typically 5 to 10 gamma.

When the plasma density and velocity increase during magnetic-storm intervals, the interplanetary field becomes larger and more irregular. Many of the changes in the field components correlate in detail with simultaneous changes in the plasma flux. Often, however, the plasma and field variations cannot be readily correlated. A consistent pattern has not yet been identified that can be ascribed to simple structures or to waves. No correlations have been noted that correspond to the plasma-field correlations observed by Explorer X (*3*) near the earth in which regions of intense plasma flux and intense magnetic flux alternated.

The orientation of the spacecraft, and therefore of the magnetometer, is controlled so that the *Z*-axis points toward the sun. The orientations of the other two orthogonal axes, *X* and *Y*, depend upon the mode of operation of the spacecraft. From 29 August to 3 September the spacecraft was allowed to roll about the *Z*-axis, so that the *X*- and *Y*-magnetometer sensors, although remaining perpendicular to the spacecraft-sun direction, also rotated about the *Z*-axis. On 3 September the orientation of the *X*- and *Y*-axes was stabilized with the *Y*-axis lying in a plane defined by the sun, earth, and spacecraft.

The magnetometer measurements obtained immediately preceding, and immediately following, the stabilization of the spacecraft about its roll axis are shown in Fig. 2. Since the scientific instruments were inoperative during stabilization, there is a gap in the measurements. The variation in the *X*- and *Y*-components during the period preceding the stabilization is attributable principally to the rolling of the spacecraft. The contribution from the transverse interplanetary field, when averaged over many complete revolutions, is zero. The average field values represent the *X*- and *Y*-spacecraft field components. Fortunately, the interplanetary field was relatively undisturbed during this period.

The center-to-peak amplitude of the variations in the *X*- and *Y*-components is a measure of the transverse component of the interplanetary field. During the period shown in Fig. 2, the component was approximately 3 gamma. The spacecraft made almost one complete revolution (approximately 350°) about the *Z*-axis between the end of the rolling period and stabilization. Thus, components measured just before, and just after, stabilization are approximately equal. Since the orientation of the *Z*-axis was not affected by stabilization, and since conditions were magnetically quiet, the measurements of B_Z show very little change (*4*).

P. J. COLEMAN, JR.
University of California, Los Angeles
LEVERETT DAVIS, JR.
California Institute of Technology, Pasadena
E. J. SMITH
Jet Propulsion Laboratory, Pasadena
C. P. SONETT
Ames Research Center, Moffett Field, California

References and Note

1. P. J. Coleman, L. Davis, C. P. Sonett, *Phys. Rev. Letters* **5**, 43 (1960).
2. E. N. Parker, *Astrophys. J.* **133**, 1014 (1961); T. Gold, *J. Geophys. Res.* **64**, 1665 (1959); J. H. Piddington, *Planetary Space Sci.* **9**, 305 (1962).
3. J. P. Heppner, N. F. Ness, T. L. Skillman, C. S. Scearce, *J. Phys. Soc. Japan* **17**, Supplement A-II, 546 (1962); H. S. Bridge, C. Dilworth, A. J. Lazarus, E. F. Lyon, B. Rossi, F. Scherb, *ibid.* p. 553.
4. We acknowledge the assistance of B. V. Connor, magnetometer project engineer, and K. Heftman, scientific data coordinator. Supported by contracts with the National Aeronautics and Space Administration.

23 November 1962

Lysergic Acid Diethylamide: Its Effects on a Male Asiatic Elephant

Because of his remarkable intelligence, his extended life span, his capacity for highly organized group relationships, and his extraordinary psychobiology in general, the elephant is an animal of great interest to the zoologist and the comparative psychologist. It has only been in recent years that the physiology of the elephant has received the attention of scientists (*1*). There is now a growing interest in this animal on the part of psychiatrists (*2*).

One of the strangest things about elephants is the phenomenon of going "on musth." This syndrome, a form of madness which occurs almost exclusively in the males, begins with early adulthood (when the elephant is between 12 and 20 years old) and continues to occur once or twice a year until after the involutional period (around age 45 to 50). As he enters a period of musth, the bull elephant begins to show signs of restlessness and irritability, his eyes water, and the slit-like bilateral temporal gland (located midway between the eye and ear) starts to excrete a brown, sticky fluid. Within 48 to 72 hours there is a violent change in the animal's behavior. Normally cooperative and tamable, the elephant now runs berserk for a period