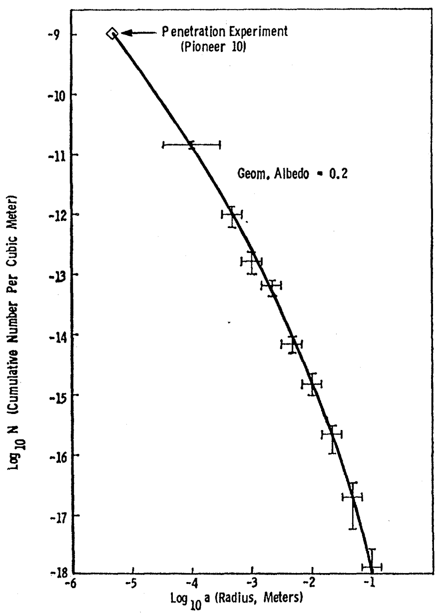


Fig. 1. Particle size distribution in the asteroid belt (2 to 3.5 A.U.).

derived by making the assumption that the uncertainty was proportional to the square root of the number of particles observed multipled by the average transit time through the field of view. The particles were assumed to be traveling in direct circular orbits with no inclination. For a distribution function of the form $N \sim a^{-\beta}$, the value of $\beta$ varies from about 1.7 for the smallest to about 3 for the largest size measured. We have also plotted in Fig. 1 the point obtained by the meteoroid detector (penetration experiment) on Pioneer 10 (*2*).

To illustrate the change in size distribution we combined the data into decades of size for solar distance increments of 1/4 A.U. This is shown in the histograms of Fig. 2. Since the changes in size distribution that were noted in the data as the region from 2 to 3.5 A.U. was transited are not appreciable on the logarithmic scale used in Fig. 1, they are shown in the histograms of Fig. 2. The particle size domains are shown with each histogram. We have shown the number of events in each bar to give an idea of the statistical uncertainty; this shows why it was necessary to combine data into larger size groupings. Note that the ordinates on these histograms are linear and are expressed in mass per unit volume, which is more meaningful for such a large range of sizes. We assumed a density of 3 g/cm$^3$ for the conversion. From Fig. 2 it can be seen

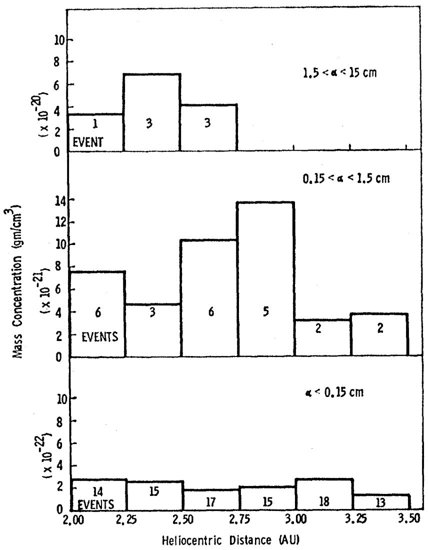


Fig. 2. Mass concentration for three ranges of particle radius.

that the largest sizes were observed in the region from 2 to 3.0 A.U., with an apparent peak at the heliocentric distance where the visible asteroids are most heavily concentrated. The intermediate sizes appear to show the greatest concentration at a somewhat larger solar distance. The change in concentration of the smallest sizes is only a factor of 2 and one can easily conclude a distribution which does not vary with solar distance. The latter is in agreement with the results of the penetration measurement on Pioneer 10 (*2*).


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**References and Notes**


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3. Supported by NASA contract NAS 2-6559. We would like to express our deep appreciation to the personnel of the Pioneer Project Office, NASA Ames Research Center, for their outstanding work with the Pioneer 10 spacecraft and their unstinting cooperation with the investigators to maximize the scientific yield from this historic mission.

21 December 1973


## Interplanetary and Near-Jupiter Meteoroid Environments: Preliminary Results from the Meteoroid Detection Experiment

The first measurements of the population of meteoroids of mass $\sim 10^{-9}$ g have been made in interplanetary space through the region of the asteroid belt, to the orbit of Jupiter, and in the near vicinity of Jupiter by the Langley Research Center's meteoroid detection experiment on Pioneer 10. Specifically, the experiment is detecting meteoroid penetrations in stainless steel targets 25 $\mu$m thick along the flight trajectory.

The Langley experiment consists of 234 individually sealed cells pressurized by gas (*1*). The dimensions of each cell are 0.84 by 29.2 cm, the cell volume is 2.5 cm$^3$, and the cell pressure is 1175 mm-Hg. The sensitive surface area aboard the spacecraft was 0.265 m$^2$ because of an electronic anomaly in one of the two data systems. This

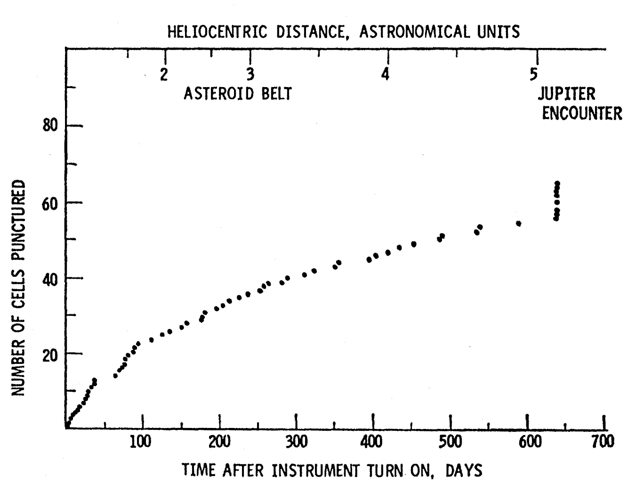


Fig. 1. Data on interplanetary dust obtained by the Pioneer 10 meteoroid detection experiment.

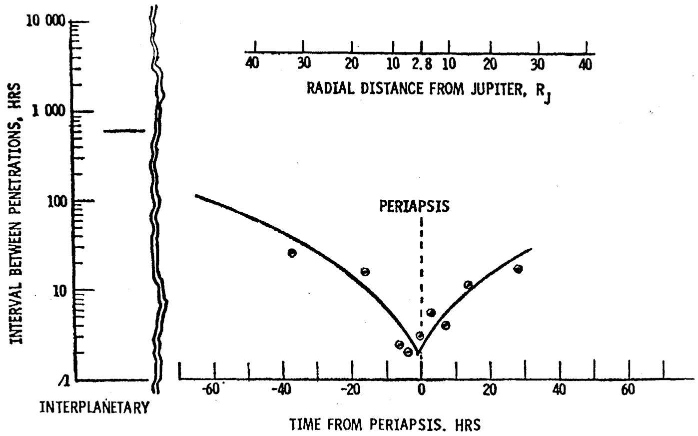


Fig. 2. Meteoroid detection experiment near-Jupiter data obtained during encounter.

anomaly caused the experiment to lose data from 126 cells, leaving 108 cells unaffected.

A micrometer-sized particle penetrating the 25-$\mu$m steel skin of the cell produces a leak which reduces the pressure inside the cell. A cold cathode device, essentially a nixie tube, mounted inside each cell conducts when the gas density drops to a predetermined value (*2*). This conduction phase is interpreted as a cell puncture.

The data obtained by the Langley experiment are presented in Fig. 1, which depicts cumulative number of cells punctured versus time on the lower scale and heliocentric distance on the upper scale. The data largely indicate a slowly decreasing flux of particles capable of puncturing the pressurized cells. Overall, this flux varies as $R^{-\beta}$, where $R$ is teliocentric distance and $\beta \simeq 3/4$.

A closer look at the data uncovers three highly interesting observations. The data gap at 50 days is significant. From the flux rates before and after it, one would expect a gap that long to occur less than once every hundred missions. The gap extends from 1.14 to 1.34 A.U. and may be caused by orbit perturbations due to the earth and Mars. Jupiter causes analogous perturbations in the asteroid belt, resulting in the Kirkwood gaps.

The asteroid belt was noted for its absence in the data. The region of the asteroid belt, from 2.0 to 3.5 A.U., exhibited the same slow decrease in penetration flux that characterized interplanetary space from the earth to Jupiter.

The most surprising data were obtained at Jupiter encounter at 5.05 A.U. ($756 \times 10^6$ km). Figure 1 shows that there were ten punctures during a very short period of time (64 hours).

Figure 2 presents the last 11 events on an expanded scale. The data are presented as time intervals between punctures (in hours) versus the time from Pioneer periapsis. The horizontal bar on the left shows that before encounter the average time between consecutive punctures was about 600 hours. The solid line represents a rough fit to the Langley data. The plot implies that Jupiter is much "dustier" than interplanetary space. Whereas the near-earth particulate flux showed very little increase over the interplanetary flux, the near-Jupiter penetration flux was over two orders of magnitude higher than the interplanetary flux. At present we do not know whether interplanetary particles attracted to Jupiter or particles in orbit about Jupiter caused this dramatic increase in the penetration flux. Both possibilities are currently being investigated.

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## Gravitational Parameters of the Jupiter System from the Doppler Tracking of Pioneer 10

Abstract. *Preliminary analyses of Doppler data from Pioneer 10 during its encounter with Jupiter indicate that the mass of Io is about 20 percent greater than previously thought and that Io's mean density is about 3.5 grams per cubic centimeter. A determination of the dynamical flattening of Jupiter* (a − b)/a (*where* a *is the semimajor axis and* b *is the semiminor axis*) *is found to lie in the neighborhood of 0.065, which agrees with the value determined from satellite perturbations.*

High-quality Doppler tracking data were obtained from Pioneer 10 during its encounter with Jupiter. Three 64-m antennas were used to track the Pioneer spacecraft in a two-way, phase-coherent mode at S-band ($\approx$ 2200 Mhz). These three antennas were operated, respectively, by stations of the Deep Space Net in Goldstone, California (station 14), Canberra, Australia (station 43), and Madrid, Spain (station 63), and nearly continuous two-way tracking coverage was achieved during the critical encounter period. As a result, much new information on the gravity field of Jupiter and on the masses of the four Galilean satellites will be obtained in the next few months from an analysis of the Doppler data.

Tracking was interrupted during the encounter when the spacecraft was occulted by Io at about 16 minutes after closest approach and again during the occultation by Jupiter. Occultation by the planet occurred about 78 minutes after closest approach and lasted for about 1 hour. However, a minimum of data was lost during the two occultations because of a careful planning and execution of station procedures.

The noise on the Pioneer 10 Doppler data, as inferred from the root-mean-square residuals from least squares fits, is about 0.005 hertz for a count time of 60 seconds. At an S-band frequency of 2200 Mhz, this amounts to a one-way range rate error of about 0.3 mm/sec.

The determination of the masses of the Galilean satellites has in the past been derived from observations of the mutual perturbations in the satellite system. The most recent determination is that of de Sitter (*1*). His estimate of the errors in the determination is about 8 percent for Io and Callisto and between 1 and 2 percent for Europa and Ganymede. The Pioneer data will make it possible to determine all four satellite masses to 1 percent or better.

Preliminary analyses of the data show