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INTERPLANETARY DUST PARTICLES OF MICRON SIZE PROBABLY ASSOCIATED WITH THE LEONID METEOR STREAM

W. M. Alexander,
C. W. McCracken, and H. E. LaGow
Goddard Space Flight Center
Greenbelt, Maryland

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SUMMARY

An interplanetary dust particle event, coincident with the Leonid meteor shower and lasting approximately 70 hours, was recorded by a sensor on the Vanguard III satellite. During this interval the satellite's microphone system registered impacts of approximately 2800 dust particles with momenta exceeding 10^{-2} dyne-second. The impact rate varied by as much as two orders of magnitude within a few hours.

The microphone system was almost omnidirectional, so the radiants of the dust particles cannot be defined. Association of these dust particles with the Leonid meteor stream is suggested by the coincidence in time and by the location of the satellite. Vanguard III traversed five major meteor streams, but the impact rates significantly exceeded the background rate only during this one interval. This is the first case in which a significant increase in the directly measured impact rate of dust particles possibly can be associated with a major meteor stream.

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INTRODUCTION

The IGY Vanguard III satellite (1959 η) carried several sensors for determining the environmental conditions of its surroundings. Among these sensors was a microphone which detected individual impacts of interplanetary dust particles on selected portions of the metallic shell of the satellite. Besides adding to the knowledge of the mass and space distributions of small interplanetary dust particles gained from direct measurements made by rockets and other satellites, this sensor revealed an interval of unusual interplanetary dust particle activity. This paper reports the important details of the observed interplanetary dust particle event and some tentative conclusions reached while analyzing the data.

DATA FROM THE DUST PARTICLE EVENT

The experimental data consists of a set of sequential counter readings which can be used with a satellite ephemeris to determine the impact rates of the interplanetary dust particles. Telemetry coverage exhibiting a good signal-to-noise ratio was not sufficiently complete to allow a detailed segmentation of the satellite orbit into small sampling intervals. A good reading of the counter settings was obtained only about once per orbit on the average.

The completed read-out of the telemetered data for November 10-20, 1959, shows the existence of a most interesting interplanetary dust particle event. This event was not evident in an earlier and preliminary data read-out reported by LaGow and Alexander (Reference 1). Figure 1 shows average impact rates telemetered to ground stations, for a 70-hour interval on November 16-18. The time of this interval coincides closely

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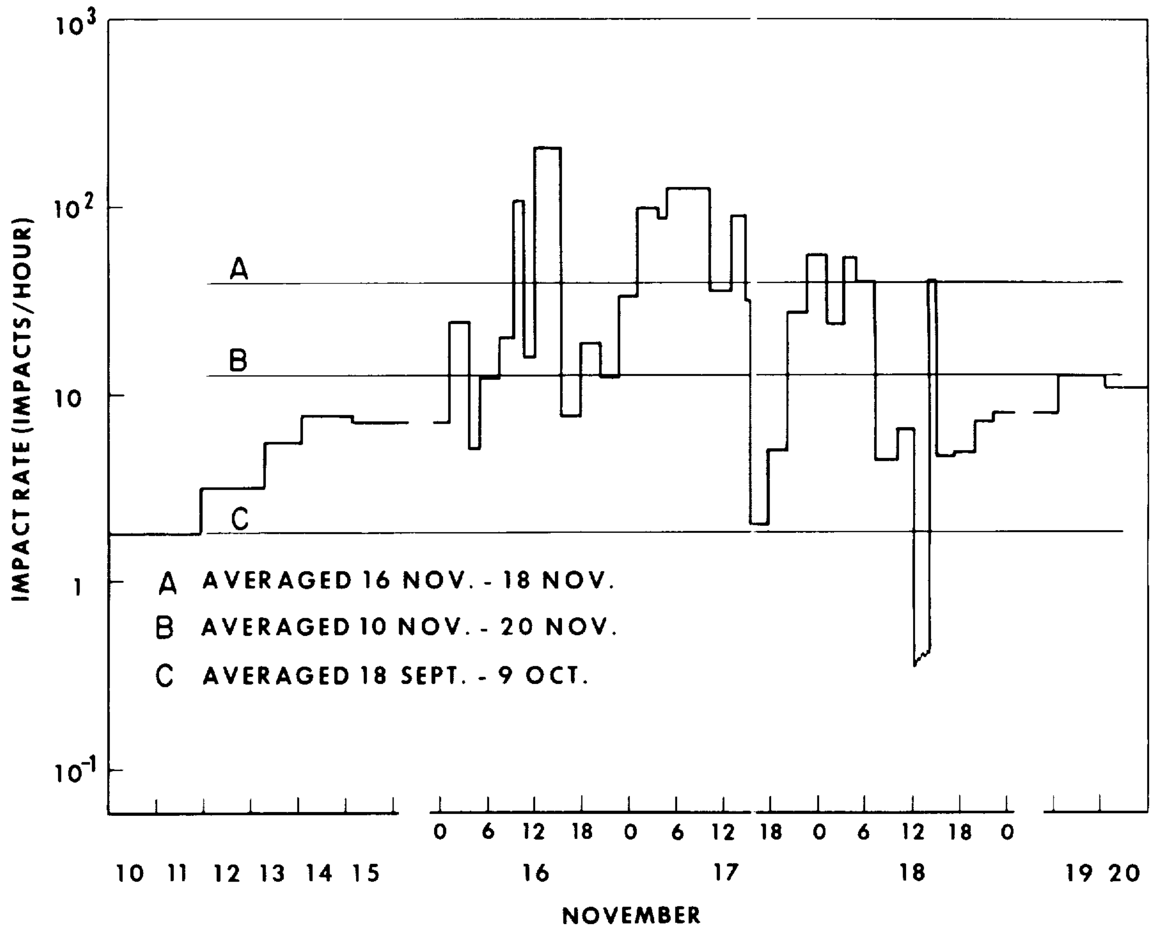

Figure 1 – Impact rates during the November 1959 interplanetary dust particle event

with the occurrence of the Leonid meteor shower. Impacts of approximately 2800 dust particles having momenta greater than 10^{-2} dyne-second were recorded during this period. This number of impacts is approximately equal to the number observed during the remainder of the life of the experiment, about 78 days. The dust particle event certainly represents a pronounced, if short-lived, increase in interplanetary dust particle activity above the average background activity. Figure 1 also shows average daily impact rates for the remainder of the November 10-20 interval (on a compressed time scale) and the rapidity with which the impact rate varied during the event.

Figure 2 is a representation of orbital segments during which extreme dust particle activity occurred between November 16 and 18. The two segments during which unusually high impact rates occurred (3 and 8 times the 70-hour average) represent high-velocity perigee passes when the satellite was moving almost directly into the Leonid radiant. In such cases, dust particles in the Leonid stream could have had velocities,

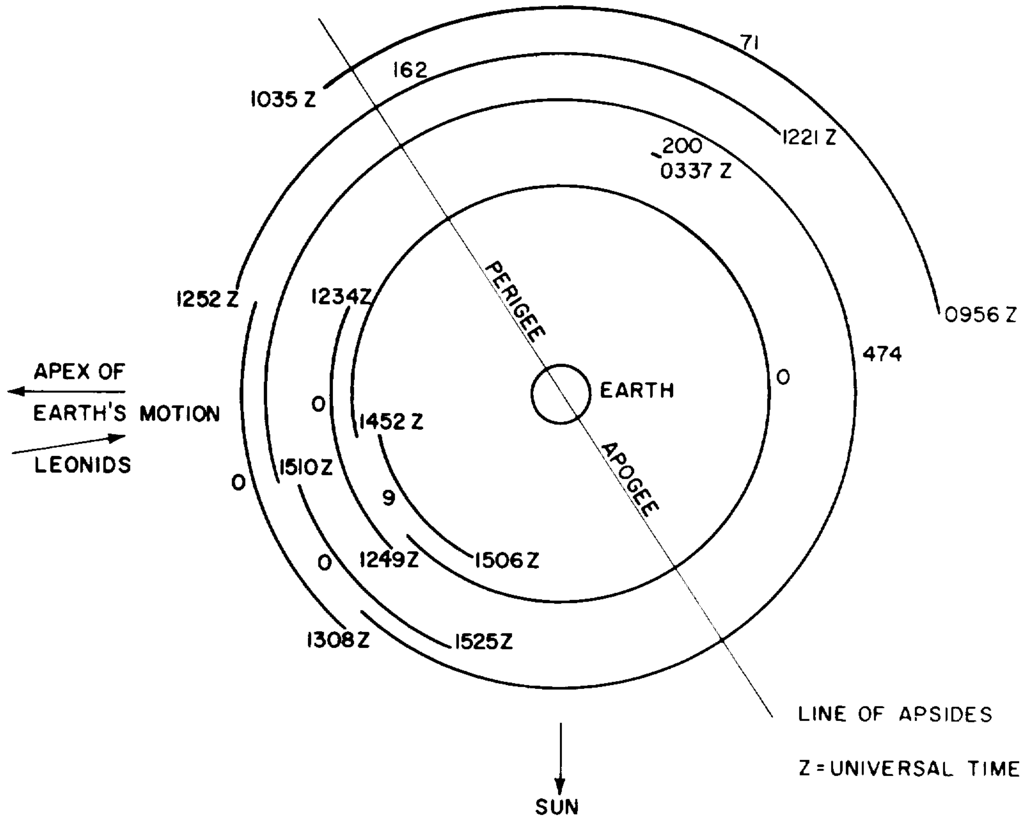

Figure 2 – Intervals of extreme activity during the November 1959 dust particle event

relative to the satellite, as high as 81 km/sec. Three orbital segments of approximately 15 minutes duration each during which no impacts occurred all lay in mid-morning, satellite local time, when the satellite was moving almost perpendicular to the direction of the Leonid radiant. At such times, dust particles in the Leonid stream had velocities of about 70 km/sec relative to the satellite. One of these three segments was the beginning of a 2.3-hour interval during which no impacts occurred. This interval was followed immediately by a 14-minute interval during which 9 impacts occurred.

The average impact rate of 41.2 impacts per hour for the 70-hour interval may be contrasted with four sampling intervals of 1.3, 2.5, 2.5 and 2.3 hours duration, during which the numbers of impacts were 7, 5, 13 and 0, respectively. These rates can be expressed in impacts per orbit as 12, 4, 11 and 0, respectively, which are considerably lower than the average of 89 impacts per orbit during the 70-hour interval.

The highest impact rate was 1900 impacts per hour, when 200 ± 10 impacts were observed in 6.3 minutes of real-time telemetry at 2237^h (satellite local time) on November 17. Although dust particles in the Leonid meteor stream would have had to pass tangentially through a portion of the earth's atmosphere to reach the satellite, the altitude and position of the satellite were such that the particles would have been negligibly decelerated by atmospheric drag before encountering it. The 200 ± 10 dust particles easily could have come from the Leonid meteor stream.

The outstanding features of this particle event may be summarized as follows:

(1) Impact rates were much higher than during the remainder of the lifetime of the experiment;
(2) There were rapid fluctuations in the impact rate;
(3) On several orbits the satellite sensor recorded no or very few impacts;
(4) There were very high impact rates during several small segments of orbits and during an interval of real-time telemetry.

ORIGIN OF THE DUST PARTICLES

The dust particle sensor was almost omnidirectional. This made it difficult to determine much about the radiants of the dust particles. Since better segmentation of the satellite orbit was not possible, the shielding effect of the earth could not be used to obtain a rough determination of the regions of the celestial sphere in which the radiants lay. Correlation in time with the Leonid meteor shower, as observed by other means, is about the only way to determine whether the dust particle event could possibly be direct evidence of the presence of small dust particles in the meteor stream.

MEASUREMENTS RELATING TO THE DUST PARTICLES

If it is assumed that the majority of the interplanetary dust particles detected during the 70-hour interval were from the Leonid meteor stream, an average particle velocity relative to the satellite may be assigned. Under this condition particles are limited to velocities between 66 and 81 km/sec. The value 70 km/sec is chosen as an appropriate value for the 70-hour interval. The corresponding limiting mass sensitivity of the system then is 1.4×10^{-9} gm, which, for a mass density of 1 gm/cm^3, gives a particle radius of 7μ. The value 1 gm/cm^3 is somewhat higher than the value 0.05 gm/cm^3 used by Whipple (Reference 2). However, the value used by Whipple was determined for photographic meteors and not for dust particles in the direct measurement range of sizes.

The effective area of the dust particle sensor was approximately 0.4 m^2 for an omnidirectional flux of particles. For particles in a meteor stream, the effective area drops to approximately 0.1 m^2 because of the characteristics of the system. The average influx rate during the 70-hour interval was 2.5×10^{-2} particles per m^2 per sec with an average particle mass of 1.4 x 10^{-9} gm. This rate is between 1 and 2 orders of magnitude higher than that predicted from the value for average distribution established by direct measurements with other satellites and rockets (Reference 3).

The manner in which the impact rate varied during the 70-hour interval indicates high variability in the spatial density distribution of dust particles during the event. Corrections for average particle velocity are very important when momentum-sensitive dust particle sensors are used; but the large fluctuations in the impact rate during the November 16-18 event cannot be attributed to variation in effective mass sensitivity of the system, such as would arise from a changing average particle velocity. Neither can the degree of fluctuation in the impact rate be explained by statistical fluctuations during a series of sampling intervals. The conclusion, then, is that the rapid fluctuations in the impact rate are manifestations of real fluctuations in the spatial density of the interplanetary dust particles encountered by Vanguard III during the event. Since concentrations of dust particles will rapidly disperse – in accordance with the Poynting-Robertson effect and because of the cumulative effects of small differences in the orbital elements of individual dust particles – it would seem that the observed concentration of dust particles must have been of rather recent origin.

METEOR STREAMS

The age of a meteor stream would seem to be of major importance in discussing the presence or absence of small dust particles in the stream. And, in line with what is now believed about cometary and meteor stream evolution, it seems plausible that younger streams are more likely to contain these small dust particles than are older streams. It also seems reasonable to believe that very young meteor streams are more likely to contain concentrations of dust particles.

Whipple and Wright (Reference 4) investigated the average deviation of photographic meteor radiants from the mean radiant of the meteor stream for various known meteor showers. If either this average deviation or the stream width can be used as a measure of the age of a given stream, the indication is that the Taurids and Perseids are from relatively old meteor streams and the Giacobinids and Leonids are from relatively young meteor streams.

On the other hand, the age of the stream possibly may be less important an index to dust particle activity than is the time elapsed since larger fragments in the stream broke up into dust particles of the sizes observed by the direct measurements technique. Direct measurements of the dust particle content of the Perseid meteor stream could do much in helping to answer this question, since the Perseid stream is generally regarded as one of the oldest.

The 1946 display of the Draconids is usually taken as evidence of a very recent formation of that meteor stream from the comet Giacobini-Zinner. High dust particle activity was not observed by Vanguard III during the 1959 Draconid meteor shower, which, of course, should have been a periodic return of the concentration of meteoroidal debris responsible for the 1946 display. However, the increase in the distance of the stream from the earth due to Jupiter's perturbation probably is sufficient to explain the absence of dust particles in the direct measurements range of sizes. And even without the effect of Jupiter's perturbation a shower would have been unlikely, according to the results of Davies and Lovell (Reference 5). These studies show a relationship between the occurrence of the Draconids and the relative times at which the comet Giacobini-Zinner and the earth reached the node of the comet's orbit.

CONCLUSION

The observations of Vanguard III have revealed interesting planetary dust particle activity at particle sizes for which ground-based observations are not possible. The impossibility of determining the radiants of the dust particles of the November 16-18, 1959, event demonstrates the need for more sophisticated dust particle sensors on oriented satellites. It probably would be most desirable to use satellites to study the dust particle content of meteor streams by the direct measurements technique so that ground-based observations of meteors could be checked out to see what, if any, correlation exists between the influx of dust particles in widely different ranges of mass.

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