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THE SISYPHUS PARTICLE DETECTOR

I will describe the particle measurement subsystem we are planning for the MJS 77 missions.

Briefly, our scientific objectives with respect to Saturn's rings are as follows:

Measure the particulates outside of the visible rings. These include particulates orbiting in possible more distant (fainter) rings and particulates scattered out of visible rings.

Measure the meteoroid environment in the vicinity of Saturn.

From the above, develop an understanding of the dynamics of the rings with respect to their collisional interaction with the environment.

With the present project constraints, we will be passing outside the visible rings. The intent is to measure those particles that may be orbiting further out, such as the possible D′ ring particles and those particles scattered out of the visible rings. Another objective is to measure the meteoroid environment in the vicinity of the planet and try to develop from this an understanding of the dynamic history of the rings with respect to their collisional interactions.

The parameters to be measured are listed below:

Spatial distribution

Orbital distribution

Size distribution (by optical detection)

Mass distribution (by impact detection, using the telescope primary mirrors as the impact target)

Density?

Albedo?

Composition?

General Electric, Space Sciences Laboratory.

I have put question marks on the last three parameters to be measured. Our success with these depends on how closely we can combine the size and mass distributions from the two different kinds of detectors (i.e., impact and optical). If one can determine the size distribution and the total amount of light scattered, one can determine the mean albedo of the particles. Composition has to be the most difficult parameter, but from albedo, density, and scattering properties, one can hope to determine whether the particles are ice or stone.

Figure 1 gives the geometry for the optical particle detector or Sisyphus. It depends basically on a variation of the parallax principle. We use multiple telescopes. Three is the minimum needed; we have a fourth for redundancy and data improvement. If one can measure the entry and exit time through the overlapping fields of view, then one can mathematically solve for the trajectory relative to the instrument. Briefly, it requires the solution of the five vector equations with the notation shown in figure 1. Because of spacecraft constraints, the telescopes are to be extremely close together, and consequently the parallax is small. This means that the velocity measurements, particularly in the direction of the optical axis, depend to a large extent on how slowly the particle is moving with respect to the instrument.

Figure 2 shows the planned instrument sensitivity for MJS 77 as compared to the instruments now flying on Pioneers 10 and 11. The instrument is particle-range-to-radius dependent. A number of improvements allow us to improve the signal-to-noise ratio substantially over the Pioneer version (our first flight attempt). The various sensitivity curves are for different electronic bandwidths. By narrowing the bandwidth, we raise the signal-to-noise ratio but degrade the accuracy of the time resolution. At 9 to 10 A.U. in the widest bandwidth, we would obtain about

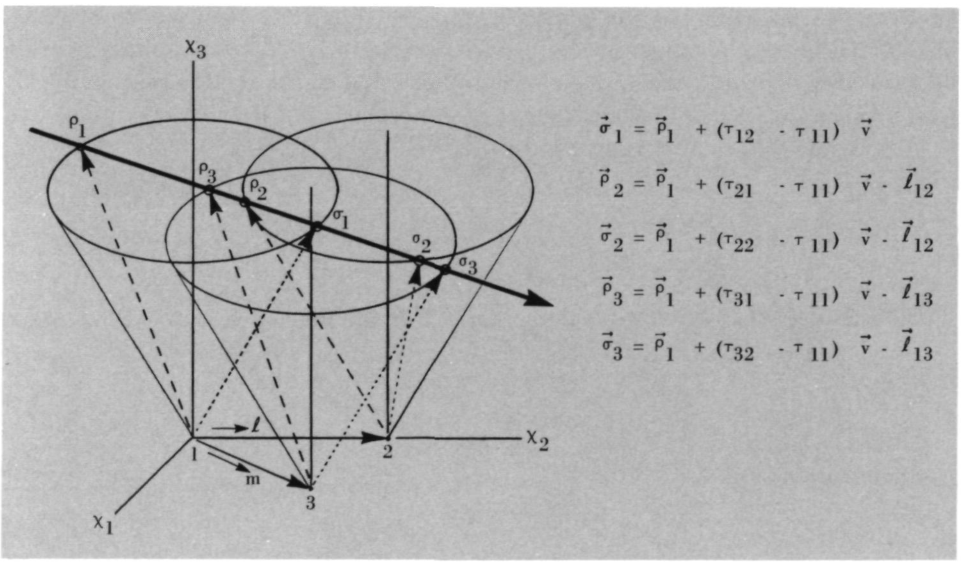

FIGURE 1.—*Sisyphus geometry.*

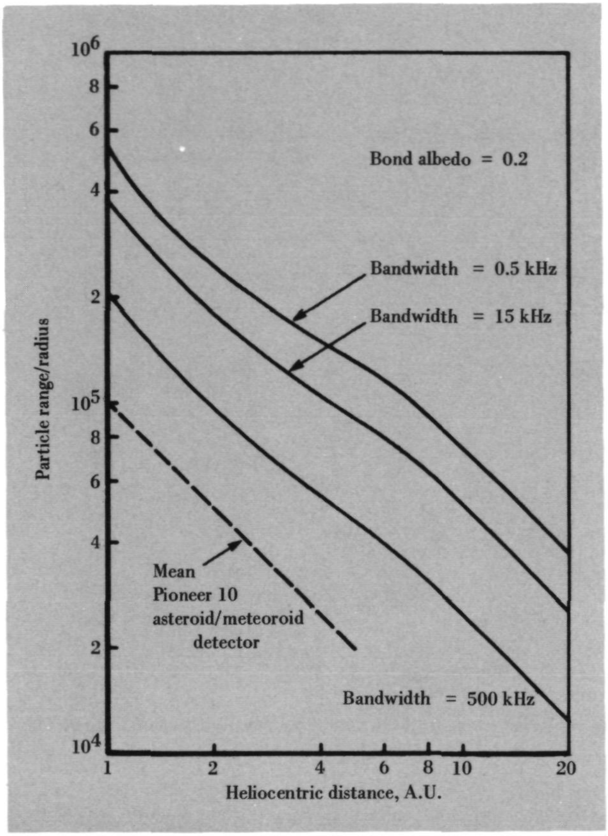

FIGURE 2.—*Sisyphus sensitivity vs heliocentric distance for MJS 77 trajectory.*

2 to 3×10^4 for the range-to-radius ratio if we assume a Bond albedo of 0.2. The sensitivity improves at the narrower bandwidths. I might also add that we plan to be looking at particles in two electronic bandwidths simultaneously (which gives us additional redundancy). The narrower or more sensitive bandwidths are particularly applicable to the large particle sizes we have heard discussed these last 2 days (i.e., on the order of meters in diameter).

I might point out that when you get to large boulders at large distances, with our parallax there is no ranging or orbit measuring capability. If one makes a reasonable assumption of the velocity of the particle passing through the fields of view, then one has a way of gauging the range from the total time in the field of view and hence the particle size.

Figure 3 is a cross section view of one of the telescopes. An acoustic detector is shown mounted on the primary mirror. This will be in coincidence with a light flash pulse detector. A particle that strikes the primary mirror would be detected by both the acoustic and the light flash detector. We have approached NASA Headquarters with the idea of adding an ionization detector. This would measure the ions that are generated at impact. The light flash detector is subject

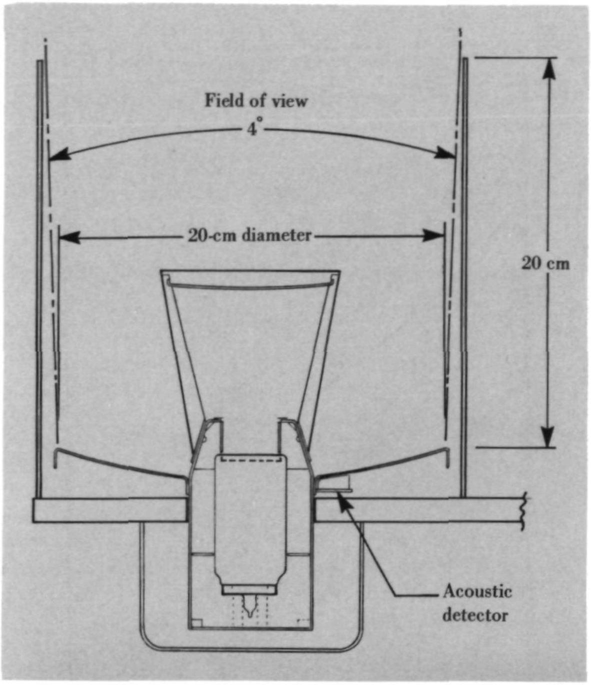

FIGURE 3.—*Sisyphus telescope equipped for impact flash-acoustic detection.*

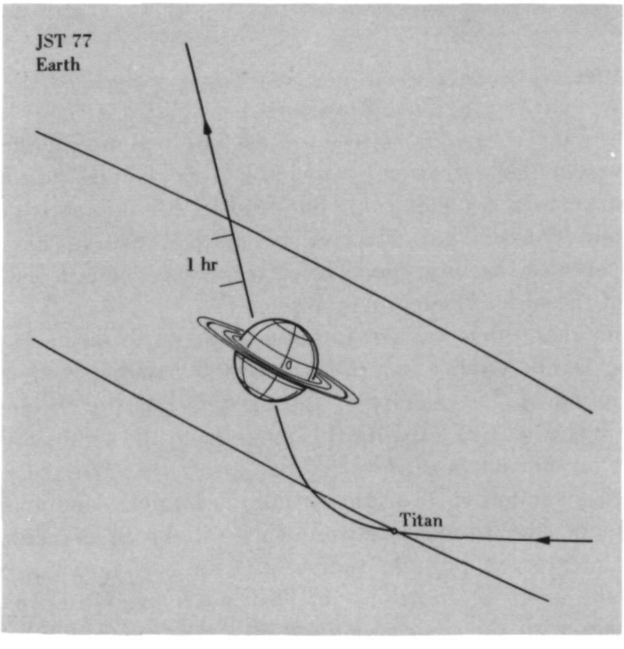

FIGURE 4.—*Saturn flyby trajectory, view from Earth.*

to noise. If we were to utilize only coincidence with the acoustic detector, we would have to raise the threshold of the light flash detector to particles no smaller than about 10^{-10} g. If we could utilize coincidence with an ionization detector, we could trust the combination down to 10^{-14} or 10^{-15} g particles.

We are still addressing a number of problem areas. The first, trajectory, was just discussed by Von Eshleman (see contribution by Eshleman). He would like to see occultation by the planet at a fairly close range. For the optical detector to work, we need to cross the ring plane while still outside the planetary shadow. This is in conflict with some of the requirements of the other experiments and is currently being examined by the MJS 77 project. We also have a problem with the acceptance angle for the particle impact detectors. These need to encompass particles that

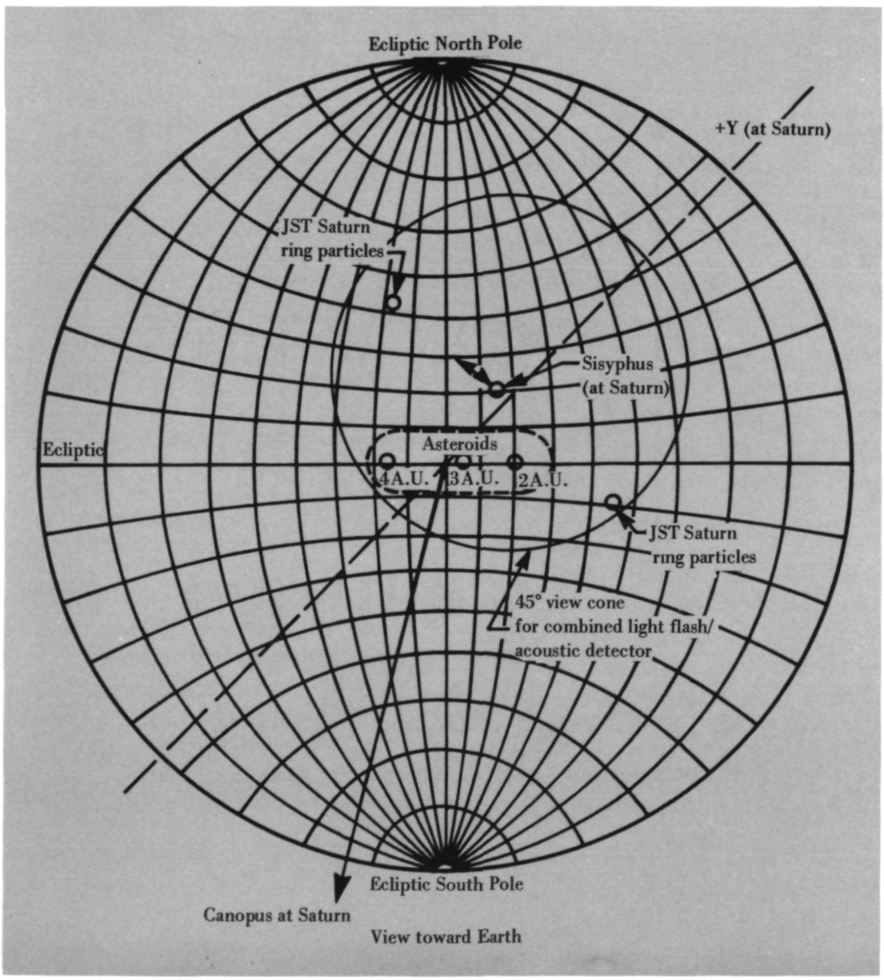

FIGURE 5.—*Direction of particle encounter relative to the instrument and spacecraft for two MJS 77 Saturn encounter trajectories.*

may have widely different encounter trajectories for the two spacecraft. Finally, we also wish to avoid illumination by the planets, since this would degrade our sensitivity.

Figure 4 shows a sample trajectory, and you can see the problem of trying to keep outside the shadow of the planet during ring plane passage.

Figure 5 addresses the particle encounter problem with the two guideline trajectories. It was possible to have a light shield around the telescopes and still allow a particle impact acceptance angle of about 90° into the primary mirrors for both the JST and JSI [1] (or currently a JSX-type) trajectory past Saturn.

Figure 6 is an example of the data that we have obtained from Pioneer 10. All that is required for this plot is to measure the time that the particles spend in the field of view of the telescopes. We believe that we have seen several of the Kirkwood gaps in the asteroidal debris and a sweeping effect due to the planet Mars.

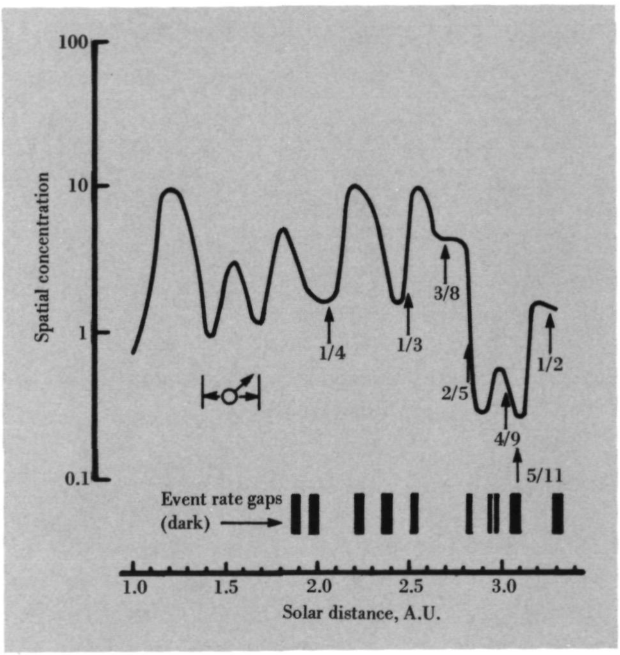

FIGURE 6.—*Relative spatial concentration of particles as a function of solar distance.*

DISCUSSION

James Pollack How big are these particles (in figure 6)?

Robert Soberman These particles are primarily less than a millimeter.

Von Eshleman How many counts do you have at a given distance? What is the error bar?

Soberman The error bars are substantial but nowhere wipe out the gaps. These are 2-week averages of particle events with a smooth curve drawn through average data.

As far as developing error bars, what we did was to assume the worst of two possible cases for our uncertainties—that is, the square root of the number of particles in each 2-week period times the mean time spent in the field of view, or the longest time spent by a single particle in the field of view. We use the larger of those as the uncertainty.

Brad Smith Bob, what do you do on Pioneer 10 since it is spin-stabilized? Aren't you getting stars flashing through all the time?

Soberman Yes. We have a star exclusion circuit. We measure in 3° segments around the rotation cycle, and, if we see an event in the same sector of the sky on the next or succeeding cycles, the instrument excludes it.

Smith Do you have a cone angle of about 90°?

Soberman Yes, our optical axis is 45° to the spin axis.

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[1] Designations for trajectories being considered for the MJS 77 missions.